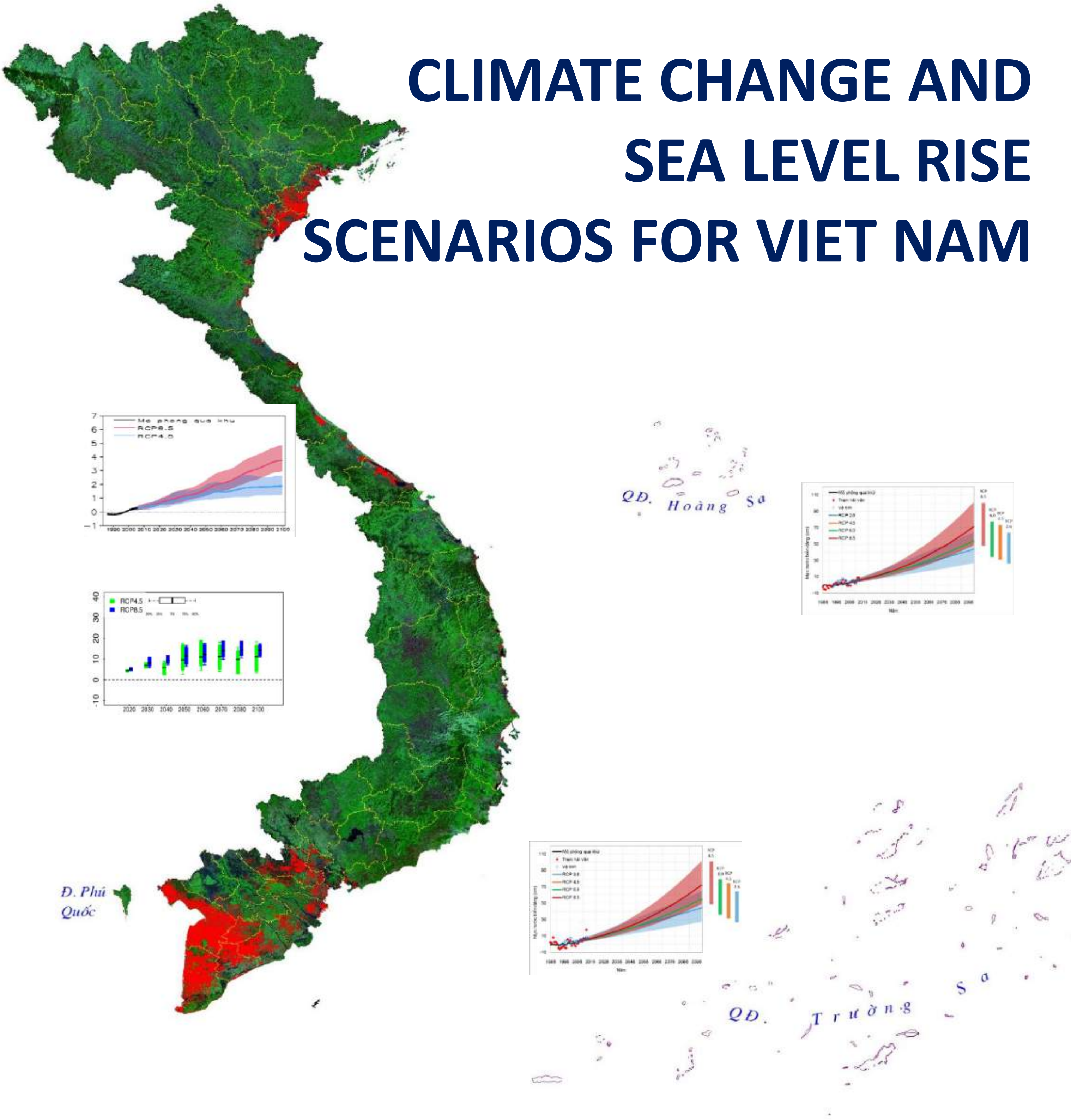
MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT

CLIMATE CHANGE AND SEA LEVEL RISE SCENARIOS FOR VIET NAM



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Forewords

Viet Nam is considered as one of countries most affected by climate change. Over the past years, under the impact of climate change, the frequency and intensity of natural disasters are increasing, caused huge loss of human life, property, infrastructure, economy, society and lead to the bad influence on environment. Climate change impacts on Viet Nam are serious and induce threats to the cause of poverty reduction, the realization of millennium goals and the country's sustainable development. Viet Nam has made a great stride in responding to climate change, reflecting through national policies and programs.

In 2009, The Ministry of Natural Resources and Environment developed and published climate change and sea level rise scenarios to promptly serve ministries, sectors and localities to implement the National Target Program to Respond to Climate Change.

In 2011, The National Strategy on Climate Change was realeased, determining the targets for each period and priority projects. The Ministry of Natural Resources and Environment has updated the climate change and sea level rise scenarios based on data sources, specific climatic conditions of Viet Nam and the results from climate models at that time. The climate change scenarios provided the basis for the ministries, sectors and provincials to assess the impact of climate change, develop action plans to respond to climate change and integrate climate change issues into socio-economic development strategies.

Implementing the directive of the government on updating the climate change and sea level rise scenarios for Viet Nam, The Viet Nam Institute of Meteorology, Hydrology and Climate Change (IMHEN) was assigned by the Ministry of Natural Resources and Environment to take lead on this task and to cooperate with domestic and international research agencies to develop and update the detailed climate change scenarios for Viet Nam. The climate change scenarios version 2016 are based on the observed hydro-meteorological data and sea level data updated to 2014, topographic data updated till March 2016; the latest methodology of the 5th assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC); global and regional climate models with high resolution; dynamical downscaling methodology combined with statistical method for bias-correction of model outputs.

Climate change and sea level rise scenarios were downscaled at provincial - level administrative units and islands and archipelago of Viet Nam. Inundation maps caused by sea level rise were downscaled at district level and at commune level where high scale topographic maps are available for areas with large topographic map. Scenarios of some climate extreme features are provided for planning purposes.

The Ministry of Natural Resources and Environment would like to introduce the climate change and sea level rise scenarios for Viet Nam. The scenarios could be used as the basis orientation for ministries, sectors and provinces to assess the potential impacts of climate change, develop and implement effective plans to respond to climate change and sea level rise.

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LIST OF ABBREVIATIONS

A1B	Medium Emission Scenario
A1FI	Highest Emission Scenario
A2	High Emission
AGCM-MRI	General Circulation Models of the Atmosphere
AOGCMs	Atmosphere-Ocean General Circulation Model
APHRODITE	Asian Precipitation Highly Resolved Observational Data
AR4	Fourth Assessment Report
AR5	Fifth Assessment Report
B1	Low emission Scenario
B2	Medium Emission Scenario
CC	Climate Change
CCAM	Conformal Cubic Atmospheric Model
CLWRF	Climate WRF model
CMIP5	Coupled Model Intercomparison Project Phase 5
CORDEX	Coordinated Regional Climate Downscaling Experiment
CRU	Climate Research Unit
CSIRO	Commonwealth Scientific and Industrial Research Organization
DEM	Digital Elevation Model
ECE_IPCC	Extreme Climate Event
ECMWF	European Centre for Medium-Range Weather Forecasts
GCM	Global Climate Model
GDP	Gross Domestic Product
GIS	Geographic Information System
IMHEN	Viet Nam Institute of Meteorology, Hydrology and Climate change
ICTP	International Centre for Theoretical Physics
IPCC	Intergovernmental Pannel on Climate Change
MAGICC/SCENGEN	Model for the Assessment of Greenhouse-gas Induced Climate Change/Regional Climate SCENario GENerator)
NCAR	National Center for Atmospheric Research
MOS	Model Output Statistics
NOAA	National Oceanic and Atmospheric Administration
MRI/AGCM	Atmosphere General Circulation Model/Meteorology Research Intitute
PCMDI	Program for Climate Model Diagnosis and Intercomparison
PP	Perfect Prognosis
PRECIS	Providing Regional Climates for Impacts Studies
R	Rainfall
RCM	Regional Climate Model
RCP	Representative Concentration Pathways
RCP2.6	RCP2.6

RCP4.5	RCP4.5
RCP6.0	RCP6.0
RCP8.5	RCP8.5
RegCM	Regional Climate Model
Rx1day	Maximum Rainfall in 1 day
Rx5day	Maximum Rainfall in 5 days
SD	Statistical Downscaling
SDSM	Statistical Downscaling Model
SLRRP	Sea Level Rise Rectification Program
SRES	Special Report on Emission Scenarios
TAR	Third Assessment Report
T2m	Average Temperature at a height of 2 metre
Tn	Temperature min
Tx	Temperature max
UNFCCC	United Nation Framework Convention on Climate change
WMO	World Meteorological Organization
WRF	Weather Research and Forecast

THE KEY TERMS

- **Intergovernmental Panel on Climate Change (IPCC)**: IPCC is the intergovernmental science organization, was set up in 1988 by the World Meteorology Organization (WMO) and United Nation Environment Program (UNEP).
- **Cryosphere:** All regions covered by snow and ice on and beneath the surface of the Earth and ocean.
- **Diurnal Temperature Range (DTR)**: The difference between the maximum and minimum temperature during a 24-hours period
- **Climate Change**: is the change of climate over a long period which is attributed of human activities and natural causes. Climate change is manifested by global warming, sea level rise and the increase of extreme hydrometeorological phenomena.
- **Radiative Forcing**: Impact radiation is defined as the change in the radiant energy balance that is absorbed by the earth and the radiation energy back to the atmosphere. Typically, the impact radiation (unit of measurement: W / m2) is defined at the top of the troposphere (About 10-12 km above the ground). A positive-effect radiation (more incoming energy) will warm the system, while negative-energy radiation (more energy goes out) will cool the system. In this report, the impact radiation is interpreted as the annual global radiative change of the mean relative to the corresponding value of 1750. The above-mentioned radiation effects with interfering clouds It concerns the influence of clouds on radiation throughput at the top of the atmosphere.
- **Surface mass balance**: Changes in surface ice mass due to: (i) change in ice accumulation (precipitation minus evaporation); (Ii) ice lost due to ice flow; (Iii) ice separates and drifts off the continent. Changes in ice mass can cause sea levels to rise or fall.
- **Climatic Normal**: The average value of a climate element over a given period of time, usually 30 years, is the basis for assessing the climate difference between one place and another, between one period and another.
- **Climatic Anomaly**: (i) the deviation of the value of a climate element relative to a climate standard or of its mean value over a period; (ii) The difference between the value of a climatic factor in one place and the average value of that factor taken along the perimeter passing through that place.
- **Carbon Cycle**: The term used to describe the flow of carbon (invarious forms, e.g., as carbon dioxide) through the atmosphere, ocean, terrestrial and marine biosphere and lithosphere. In this report, the reference unit for the global carbon cycle is GtC.
- United Nation Framework Convention on Climate Change (UNFCCC):
- **Climatic variability**: Climate variablility refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).
- **Climate Projection**: A climate projection is the stimulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and

aerosols, generally derived using climate models. The scenarios based on assumptions of future socioeconomic, population and technological developments.

- **Carbon Dioxit**: A naturally occurring gas, also a by-product of burning fossil fuels from fossil carbon deposits, such as oil, gas and coal, of burning biomass, of land use changes and of industrial processes. This is the basic gas man-made that affects to Earth's radiative balance. It is the reference gas against which other greenhouse gases.
- **Glacial isostatic adjustment**: The response of the Earth's surface to changes in ice masses around the globe. This process will change the sea level in areas, especially areas near the permanent ice mass.
- **Ice sheet dynamic**: Dynamic processes can lead to changes in ice mass: (i) ice-breaking and ice-breaking processes at glacial outlets; (Ii) the melting process below the surface of the water due to warmer seawater; (Iii) Interactions between mass balance the amount of ice and ice flow.
- **Thermal Expansion of the Oceans**: As oceans warm up, volume increases and sea level rises. Changes in salinity in small areas also alter the density and volume of seawater, but this effect is relatively small on a global scale.
- **Drought:** Severe water shortages, which are often related to dry weather and prolonged rainfall depletion, reduce the moisture content of the air and water content in the soil, depleting the flow of rivers and streams, Water levels in ponds and ponds, water levels in underground aquifers, adversely affect crop growth, environmental degradation, poverty and disease. There are four main types of drought: (i) Meteorological drought is an unusual rainfall shortfall for a particular area; (Ii) Agricultural shortage is the lack of water supply for the water needs of crops in different stages of development; (Iii) Hydrographic refers to the maintenance of low water levels in rivers, streams and reservoirs; Hydrography is often associated with meteorological drought; (Iv) Socio-economic constraints occur when demand for water exceeds supply to ensure socio-economic activities. Megadrought is a very extensive drought, in an unusually long period, usually a decade or more.
- **Climate System**: The climate system is the highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the lithosphere and the biosphere, and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcings such as volcanic eruptions, solar variations and anthropogenic forcings such as the changing composition of the atmosphere and land use change.
- **Greenhouse Effect**: The effect of infrared radiation (longwave radiation) of all components absorbing longwave radiation in the atmosphere. These components include greenhouse gases, clouds, aerosols that absorb longwave radiation from the surface of the earth and everywhere in the atmosphere and long wave radiation emitted back in all directions. However, the total radiant energy of these components emits less space than the portion they receive, leading to a portion of the long-wave radiation energy retained in the atmosphere to warm the atmosphere in the absence of causing components. greenhouse effect. In nature, this effect saves around 30 ° C higher than the absence of such gases and therefore the earth is not too cold. However, the increase in the concentration of greenhouse gases due to human activity

enhances this effect, accelerating the rate of global warming during the period of recent few decades.

- **General Circulation of the Atmosphere**: Large-scale wind systems of the earth formed by the rotation of the earth and inconsistent heating on the surface of the earth and the atmosphere by the sun.
- **Climate Feedbacks**: The reciprocal mechanism of processes in a climate system is called climate feedback, the result of an initial process that causes changes in a second process that in turn has the opposite effect. Again the original process. Positively boosts the original process, the feedback decreases ...
- **Climate:** It is a combination of weather conditions in a given area, characterized by long-term statistics of meteorological factors in the area.
- **Greenhouse Gases (GHGs)**: Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the earth's surface, the atmosphere itself, and by clouds. The primary GHGs in the earth's atmosphere are CO_2, N_2O, CH_4, O_3, H_2O... Greenhouse gases cause the greenhouse effect by reducing the radiant energy of the Earth to escape to the cosmos, warming the stratosphere beneath the atmosphere and the earth's surface.
- **Atmosphere:** The air around the earth. The dry air consists almost entirely of nitrogen (78.1% by volume) and oxygen (20.9% by mass), along with a small proportion of other gases, such as argon (0, 93%), helium and greenhouse gases such as carbon dioxide (0.035%) and ozone. In addition, the atmosphere that contains greenhouse gases is water vapor, which varies considerably but is usually about 1%. The atmosphere also has clouds and aerosols.
- **Climate Scenario**: A suitable and simplified representation of the future climate, based on a consistent set of climate relations, has been developed to study the potential consequences of climate change. Human-induced rearrangements, often used as inputs to impact models. Climate projections are often used as raw materials for the development of climate scenarios, but climate scenarios often require additional information such as current climate observations.
- **Climate Change Scenario**: Is the difference between the current climate and climate scenario. Given the climate change scenario identified from the climate scenario, it implies scientifically sound assumptions and the reliability of the future evolution of socio-economic relations, GDP , Greenhouse gas emissions, climate change and sea level rise.
- **Land water storage:** The long-term change in the storage and use of water on the continent, which involves artificial reservoirs and groundwater extraction. The change in water storage on the continent can alter sea level.
- **Methane (CH_4)**: is a chemical compound of chemical formula CH4. It is a major component of natural gas. In its natural state, methane is found both in the ground and in the sea floor. It is one of the six greenhouse gases controlled by Congress Kyoto Protocol. Major sources of methane are landfills, coal mines, rice fields, natural gas systems and livestock.
- **General Circulation Model (GCM)**: A fundamental tool for studying the effects of increased greenhouse gas concentrations on climate. GCM is basically a hydrodynamic

model of the atmosphere on a point grid or spectral resolution, whereby the mass, energy, and momentum equations for the atmosphere and oceans are integrated together over time, On an area of the globe to simulate the motion of the oceanic-atmospheric system.

- **Climatic Factors**: Certain physical conditions (other than climatic factors) regulate the climate (latitude, altitude, land distribution, sea, topography, ocean currents etc.).
- **Fossil Fuels**: Fossil fuels are fuels formed by natural processes such as anaerobic digestion of fossil-carbon organisms. These bodies are buried in sediment layers and compressed through the geologic period, gradually turning into fuel. Fossil fuels contain high percentages of carbon, including coal, oil and natural gas. Fossil fuels are constantly being formed through natural processes, but they are often considered non-renewable because it takes millions of years to form.
- **Extreme Temperatures**: The highest and lowest temperatures reached during certain times.
- **Global Warming**: Strictly speaking, global warming and cooling are the warming and colder tendencies the earth has experienced throughout its history. However, the term often refers to the escalation of the temperature of the earth due to the accumulation of greenhouse gases in the atmosphere.
- **Sea Level Rise (SLR)**: SLR is an increase in the volume of water in the world's oceans excluding tide, storm surge etc. Sea level rise at specific locations may be more or less than the global average because it is affected by ocean temperature and other factors.
- **Nitrous Oxide (N_2O)**: is a chemical compound with N_2O formula. It is one of the six greenhouse gases controlled by the Kyoto Protocol, arising from the burning of fossil fuels and the production of fertilizers.
- **Emission:** The emission of greenhouse gases and/or their precursors into the atmosphere on a particular area and time (According to the Climate Convention).
- **Biosphere**: It is part of the earth where natural conditions are suitable for life to thrive. The biosphere is a natural system consisting of material composition of living matter like animals, plants, bacteria, mushrooms ... and inferior components (environmental factors) such as weathered crust, soil cover, air in troposphere ... Biosphere is maintained By the transformation of matter and energy among its components, the consequence is that it can alter the atmospheric and climatic components of the earth.
- **Aerosols:** These are very small particles that cause blindness. They are mostly water and particles of pollutants such as sulfuric acid and sea salt. Air convection in the troposphere is often precipitated by precipitation. Aerosols carried to the stratosphere are usually there much longer. Saline stratospheric substances are mainly sulphate particles from volcanic eruptions, which can significantly reduce solar radiation.
- **Lithosphere**: The outer shell of the rocky planet. On Earth, the lithosphere consists of the crust and the topmost layer of the mantle connected to the crust. Earth's horizons are not uniform in vertical and horizontal directions. Along with warming up and cooling down unevenly under the influence of the sun, the lithosphere has a major impact on climate and climate change.

- **Weather:** Weather is the state of the atmosphere at a given location determined by a combination of temperature, pressure, humidity, wind speed, and precipitation.
- **Hydrosphere**: The earth's portion consists of water, which is ocean, sea, ice, lake, river, etc.
- **World Meteorological Organization (WMO):** WMO is an intergovernmental organization with a membership of 191 Member States and Territories. It originated from the International Meteorological Organization (IMO), which was founded in 1873. Established by the ratification of the WMO Convention in 1950, WMO became the specialised agency of the United Nations for meteorology (weather and climate), operational hydrology and related geophysical sciences.
- **Climatologycal Station**: The station performs climate observations
- **Atmosphere-Ocean Interactions**: It is the process of exchanging heat, moisture, kinetic energy, energy between ocean surface water layer and upper air layer, mainly through convection and atmospheric vortex.
- **Climatic Trend**: Climate change is characterized by an increase or decrease in monotony and smoothness of mean values during the data series. Not limited to linear change over time, but characterized by just one maxima and one minima at the ends, at the end of the series.
- **Climatic Element**: One of the properties or conditions of the atmosphere (such as air temperature) characterizes the physical state of weather or climate in one place, at a given time.

I. Introduction

Climate change and sea level rise scenarios for Viet Nam were released by the Ministry of Natural Resources and Environment for the first time in 2009 based on the synthesis of domestic and international researches in order to provide information to ministries, sectors and localities on climate change impacts, and contribute to the development of strategies and socio-economic development plans for the period 2010-2015. The boundaries of the scenarios were only for 7 climate regions and the coastal areas of Viet Nam.

In 2011, the National Strategy on Climate Change was issued, determining the priority targets for each period, the Ministry of Natural Resources and Environment has updated the climate change and sea level rise scenarios based on data sources, specific climatic conditions of Viet Nam and the results from climate models. The scenarios were for each decade of the 21st century, in which, the climate change scenarios were downscaled at provincial level, and the sea level rise scenarios were for coastal areas of Viet Nam.

Scenarios of climate change and sea level rise for Viet Nam are updated in 2016 following the roadmap defined in the National Strategy on Climate Change, providing the latest information on the trends of climate change and sea level rise in recent years, as well as climate change and sea level rise scenarios for Viet Nam in the 21st century.

The climate change and sea level rise scenarios are built upon the 5th assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC); observed hydro-meteorological and sea level data till the year 2014, and digital national topographic maps updated till 2016; recent changing trend of climate and sea level in Viet Nam; global and regional climate models with high resolution for Viet Nam, and coupled atmosphere-ocean models; the studies derived from the Institute of Meteorology, Hydrology and Climate Change (IMHEN), the Viet Nam Panel on Climate Change (VPCC), and other research institutions of Viet Nam; research results in the framework of cooperation of IMHEN with the United Nations Development Programme through CBCC and CBICS projects; Commonwealth Scientific and Industrial Research Organisation (CSIRO); Climate Research Centre of Norway (Bjerknes); Meteorological Agency of the United Kingdom (UK MetOffice); and Meteorological Research Institute of Japan (MRI).

Climate change scenarios take into account the change of climate variables in the 21st century, namely, temperature (average annual temperature, seasonal temperature and temperature extremes), rainfall (annual rainfall, seasonal rainfall and rainfall extremes), summer monsoon and some extreme events (typhoons and tropical depressions, damaging cold days, the number of hot days and occurrence of droughts). Twenty-year average changes for the early 21st century (near term, 2016 - 2035), for the mid-21st century (mid-term, 2046 - 2065) and for the late 21st century (long term, 2081 - 2100) are given, relative to a reference period of 1986 - 2005.

Sea level rise scenarios take into account the trend of average sea levels due to climate change (thermal and dynamical expansion, thaw of glaciers, surface mass balance of Antarctic and Greenland ice sheets, dynamics of Antarctic and Greenland ice sheets, changes of water reserves on continents, and isostatic adjustments of ice sheets).

The inundation maps are based on the average sea level rise due to climate change. Other dynamical factors such as tectonic uplift and subsidence, topographical changes, land subsidence due to groundwater extraction, coastline change, influence of tides, storm surges, monsoon induced sea level rise, impact of hydropower cascade, and saline intrusion have not been considered in this scenarios. Transportation works and irrigation structures such as sea dykes and river dykes, embankments, roads, and others have not been considered when mapping inundation due to sea levels rise caused by climate change.

Climate change scenario is designed to provide information in an easy-to-understand and easy-to-use format, based on the extensive consultations with ministries, sectors and localities to assess information, data needs and methods of expression. The comment contributions from ministries, sectors and localities on the exploitation and use of climate change and sea level rise scenario for Viet Nam are reviewed, absorbed and updated in the scenario version 2016.

This report is a part of product sets including data, supplemental information and user manuals. The information in the report is the basis for ministries, sectors and localities to assess the impact of climate change and develop respond measures to climate change.

The new aspects in the 2016 climate change and sea level rise scenarios in comparison with the 2012 scenarios:

1) State of the art data were used, including: (i) Observed metrological data of 150 stations on land and island from the meteorological observation network of the National Hydro-Meteorology Service up to 2014; (ii) Observed sea water level data of 17 gauging stations along the coast and islands of Viet Nam up to 2014; (iii) Sea water level data measured by satellites till 2014; (iv) Topographic maps with scales 1:2,000, 1:5,000 and 1:10,000 measured by the projects under the National Target Program to Response to Climate Change updated till 2016.

2) State of the art results of global climate models (under CMIP5 project) were used, namely: NorESM1-M, CNRM-CM5, GFDL-CM3, HadGEM2-ES, ACCESS1-0, MPI-ESM-LR, NCAR-SST, HadGEM2-SST and GFDL-SST.

3) Dynamical downscaling were applied based on 5 high-resolution regional climate models, namely: AGCM/MRI, PRECIS, CCAM, RegCM and clWRF. There are 16 computational cases in total.

4) Statistical methods were applied for bias correction of the model output based on the observed data to minimize the bias of model results.

5) Climate change scenarios and climate extremes were provided in detail for 63 provinces/cities, the Hoang Sa and Truong Sa archipelagos of Viet Nam and 150 meteorological stations (the detail is at district level).

6) Sea level rise scenarios were developed in detail for 28 coastal provinces, as well as Hoang Sa and Truong Sa archipelagos of Viet Nam.

7) Certainty levels in terms of percentile were estimated for climate change and sea level rise projections for the future.

8) Inundations due to sea level rise caused by climate change for the delta, coastal areas, islands and archipelagos of Viet Nam were estimated. For areas, where topographic maps scale 1:2000 is available, the level of detail of the inundation maps were at commune level.

9) Extreme water events were assessed, including storm surges, tides, and storm surges in combination with tides of Viet Nam. This can help users to understand twofold impact of sea level rise due to climate change and extreme sea level due to natural factors such as storm surges and high tides.

10) Remarks on some factors that influence the inundation due to sea level rise caused

by climate change are drawn, including the geological uplift and land subsidence as a result of groundwater extraction in the Mekong Delta and the Central coastal areas.

The climate change and sea level rise scenario is structured in the following format:

Chapter 1: Introduction

Chapter 2: Scientific bases of climate change. Presented about: (i) causes of climate change; (ii) GHG scenario and climate model; (iii) climate change and sea level rise with global and regional scale.

Chapter 3: **Manifestation of climate change and sea level rise in Viet Nam**. Presented about: (i) data used for trend analysys and scenario building; (ii) Changing trends of climatic factors; (iii) Changing trend of extreme climate; (iv) Changing trends of sea level rise.

Chapter 4: **Methodology for developing climate change and sea level rise scenario for Viet Nam**. Presented about: (i) methodology for developing climate change scenario; (ii) methodology for developing sea level rise; (iii) methodology for constructing inundation risk map.

Chapter 5: Climate change scenario for Viet Nam. Presented about: (i) temperature; (ii) precipitation; (iii) extreme climate.

Chapter 6: Sea level rise for Viet Nam. Presented about: (i) sea level rise and some comments on the extreme sea level; (ii) inundation risk due to sea level rise.

Annex: Presented about the detail climate change scenario for 63 provinces/cities and inundation risk map caused by sea level rise for plain and coastal provinces, islands and archipelago of Viet Nam.

The 2016 electronic version of climate change and sea level rise scenario for Viet Nam, componant reports and other related publication are posted on the website of the Viet Nam Institute of Meteorology, Hydrology and Climate Change. (**www.imh.ac.vn**).

II. Scientific basis of climate change

2.1. Causes of climate change

Climate change can be attributed to natural and human causes.

2.1.1. Natural causes of climate change

The climate system on the Earth can be changed by both external and internal forcing mechanisms. They are listed in detail below:

Change in Earth orbital variations: The Earth makes naturally a full orbit around its axis and around the sun. By the time, variation of orbital shape, axial tilt and axial precession occur with defined period. The cycle of these variation are 96.000 years, 41.000 years and from 19.000 to 23.000 years, respectively. These variations alter provided solar radiation to climate system in the Earth, so climate has been changing.

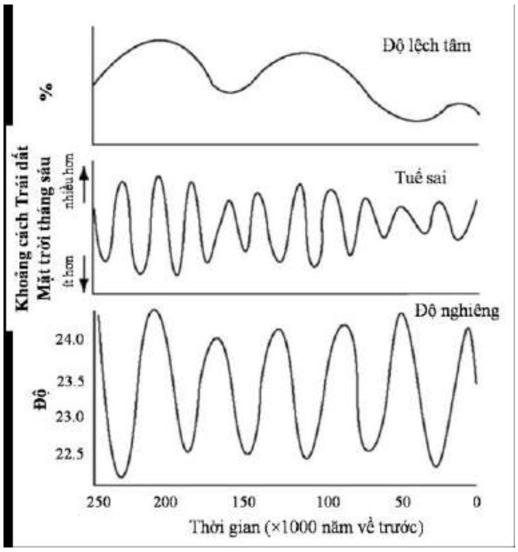


Figure 2.1. Change in the Earth orbital variation from 250.000 years ago until present

(Source: www.fs.fed.us/ccrc/primers/climate-change-primer.shtml)

Change in distribution of continents – oceans on the Earth's surface: The shape of Earth surface has been changed over geologic periods due to the continental drift, plate tectonics, volcano activities and others. These changes have contributed to the redistribution of continents and oceans, the form the Earth's surface that has caused the changes in radiation balance between atmosphere and oceans. Oceans are an important component of the climate system. The ocean currents transfer a large amount of heat over the Earth. Their changes have considerably had impacts on the climate system through the movement of CO_2 into the atmosphere.

Change in emission of solar radiation and long-wave radiation absorption of the Earth: Solar variability has had significant impacts on the climate system. The cold and greater glacier have extended over centuries once solar radiation has decreased. On the contrary, drier and hotter climate on the Earth's surface have occurred when solar radiation has been intensified. Moreover, the appearance of sunspots also alters intensity of solar radiation and energy onto the Earth's surface leading the change of temperature.

Volcanism activities: The eruptions can affect climate system in several years. The aerosols from the eruptions reflex shortwave radiation from the sun causing the decline in surface temperature.

In a word, climate system gradually changes due to natural causes. Therefore, these causes contribute trivially to current climate change.

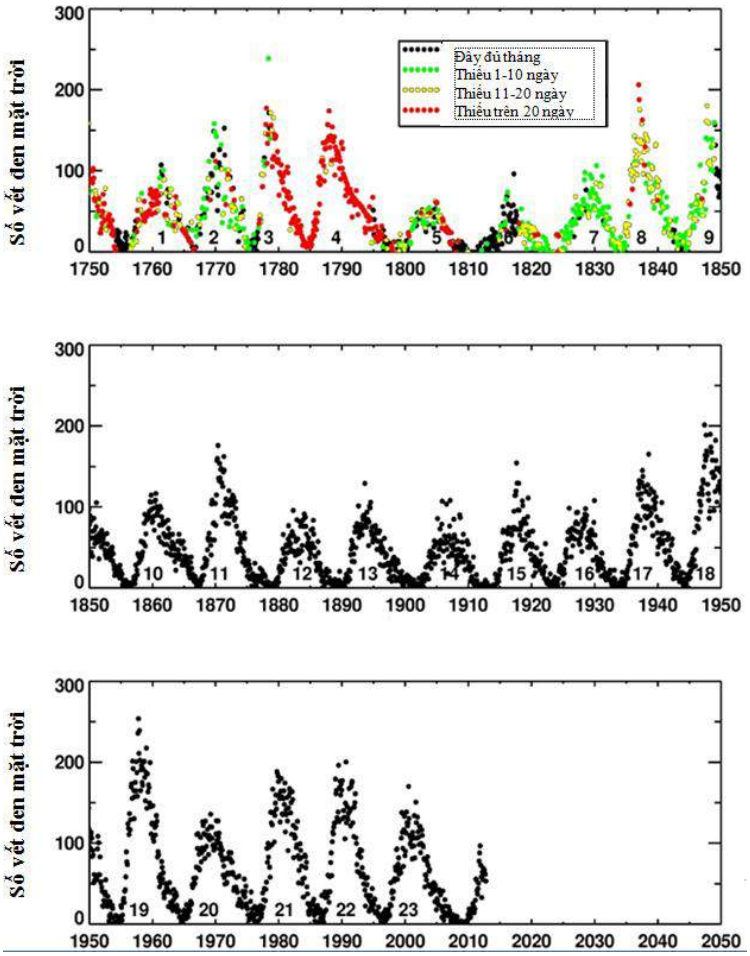


Figure 2.2. The average number of Sunspots from 1750 to 2010

(Source: NASA)

2.1.2. Human causes of climate change

1) Greenhouse effect

Greenhouse effect is the process which keeps surface-troposphere system warmer 30^oC than it would otherwise be. This process is based on the absorption and reflection of longwave radiation from Earth's surface by clouds and greenhouse gases including water vapor, CO_2, NO, CH_4 and CFC. These gases reduce the heat released into space from atmosphere and keep the atmosphere warmer.

The greenhouse gases in the atmosphere consist of natural gases and released gases from human activities. Although these gases account for a small percentage of the atmosphere, they play an important role in the climate system. To be more specific, shortwave radiation from the sun is transmitted by these greenhouse gases. However, these gases absorb most longwave radiation from surface as well as partly reflex it backward to the surface. Therefore, infrared radiation that move out to space is confined and the Earth's surface is kept warmer, especially at night when there is no solar radiation.

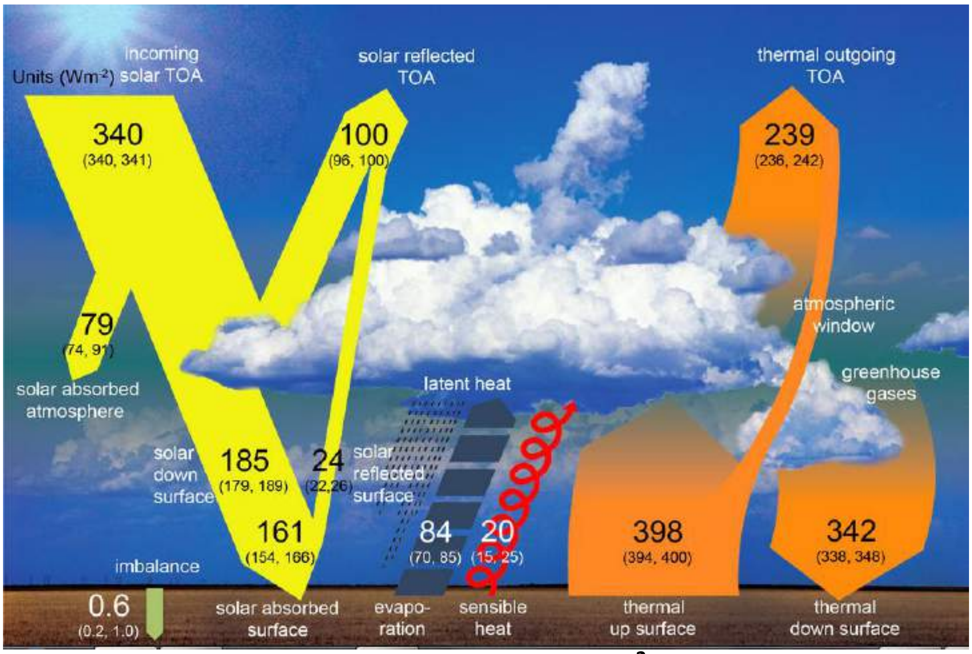


Figure 2.3. Diagram of exchange energy (W/m^2) in the climate system
(Source: IPCC, 2013)

2) Influence of human activities on global warming

Climate change can be induced by human activities which emit GHG´s excessively into the atmosphere. Consequently, the climate system has been impacted substantially, especially from pre-industrial period (from 1750). It is indicated by IPCC that the increase of greenhouse gases from 1950 is attributed to human activities. In other words, it is considered as the major reason for global warming.

Since pre-industrial period, human-activities have utilized more and more fossil fuel that emits much greenhouse gases to the atmosphere. As a result, global temperature has increases.

The increase in greenhouse gases retains most of the outgoing longwave radiation from the surface, subsequently enlarge cumulative heat on surface leading to the warming climate. This change draw other changes such as decrease in glacier and ice and snow cover, change in land cover. Therefore, the ability to absorb energy from the sun may increase because the albedo of glacier and snow is much higher than from ocean and land surface. And then, the absorbed heat by ocean and land continuously causes the decline in glacier and snow-ice cover.

The Climate Convention assigns greenhouse gases consisting of Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydro fluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulfur hexafluoride (SF_6).

According to the fifth assessment report of IPCC, greenhouse gas concentrations including CO_2, CH_4, and N_2O in the atmosphere has increased with record rates for 800,000 recent years. CO_2 concentrations increased by 40% in compared with pre-industrial levels. It was mainly generated by the use of fossil fuel and change in the surface. 30% of these emitted CO_2 was absorbed by the ocean causing ocean acidification (IPCC, 2013).

In 2011, the concentrations of CO_2, CH_4 and N_2O were 391ppm, 1803 ppb and 324 ppb, respectively. They corresponded to the increase by 40%, 150% and 20% respectively compared to the pre-industrial period (IPCC, 2013). The average increase in greenhouse gases concentration during the last century has not been observed for last 22,000 years.

From 1759 to 2011, CO_2 emission due to fossil fuel consuming and cement manufacturing constituted 375 GtC, while it due to forest destroying and other activities altering land use constituted approximately 180 GtC. In total, the emission by human activities was 555 GtC (IPCC, 2013).

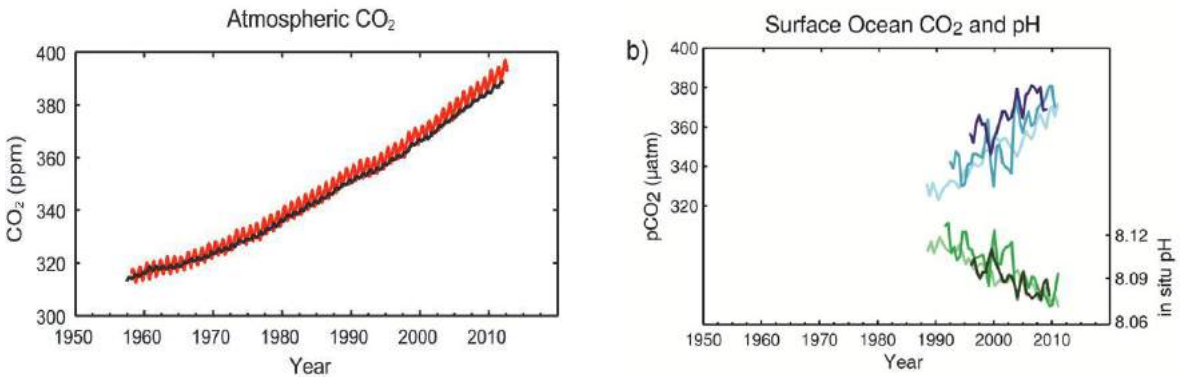


Figure 2.4. CO_2 concentration, partial pressure of CO_2 on the ocean surface and pH concentration

(Source: IPCC, 2013)

Note: (a) CO_2 concentration at Mauna Loa (19°32'N, 155°34'W - red) and The Antartic (89°59'S, 24°48'W - black) from 1958; partial pressure of CO_2 on ocean surface (blue line) and pH concentration (green line) – These results were analyzed from 3 stations in Atlantic (29°10'N, 15°30'W – dark blue/dark green; 31°40'N, 64°10'W -blue/green) and Pacific ocean (22°45'N, 158°00'W – light blue/light green)

In total of CO_2 emission by human activities mentioned above, the accumulative mass of CO_2 in the atmosphere was 240 GtC, the absorbed CO_2 by the ocean and terrestrial-natural ecosystems were 155 GtC and 160 GtC, respectively (IPCC, 2013).

The ocean acidification is quantified by the decline in pH concentration. The pH concentration of ocean surface has reduced by 0.1 since industrial period. That corresponds to 26% increase in ion hydro concentration (IPCC, 2013).

Water vapor (H_2O) play a great role in greenhouse effect in atmosphere system. However, it cannot be considered as a dangerous gas because it can change its phase into cloud and rainfall.

Ozone (O_3) in the troposphere: The anthropogenic ozone is generated mainly from car, motorbike and electricity manufactory. In the troposphere, it is difficult to determine the radiative effects of the increase in O_3 concentration from human activities because this gas exists in short time and its spatial and temporal variation is quite high. O_3 in the troposphere contributes 0.4 W/m^2 to global radiative forcing.

CFC and HCFC: These gases are completely produced by human activities. Although the concentration of these gases is not large, the fast increase of them may damage ozone layer. However, practically, the concentration of these gases tended to reduce because of the implementation of the Montreal protocol.

Other factors including aerosols, dust, organic carbon, sulphates, nitrates, ect cool the surface with -0.9W/m^2 contribution into global radiative impact.

2.2. Emissions scenarios and climate models

2.2.1. Future scenarios of greenhouse gas concentrations

Changes of greenhouse gas concentration in the atmosphere are an important variable for climate change projections (Wayne, 2013). The climate change scenarios have been building from the assumption of a change in the future and the relationship between GHG emissions and socio-economic activity, total national income, land use and etc.

In order to provide climate change projection information, in 1992 the IPCC published the first set of climate change scenarios, called IS92. In 2000 the IPCC released a second generation of projections, collectively referred to as the Special Report on Emissions Scenarios (SRES). These were used in two subsequent reports; the *Third Assessment Report* (TAR) and Assessment Report Four (AR4).

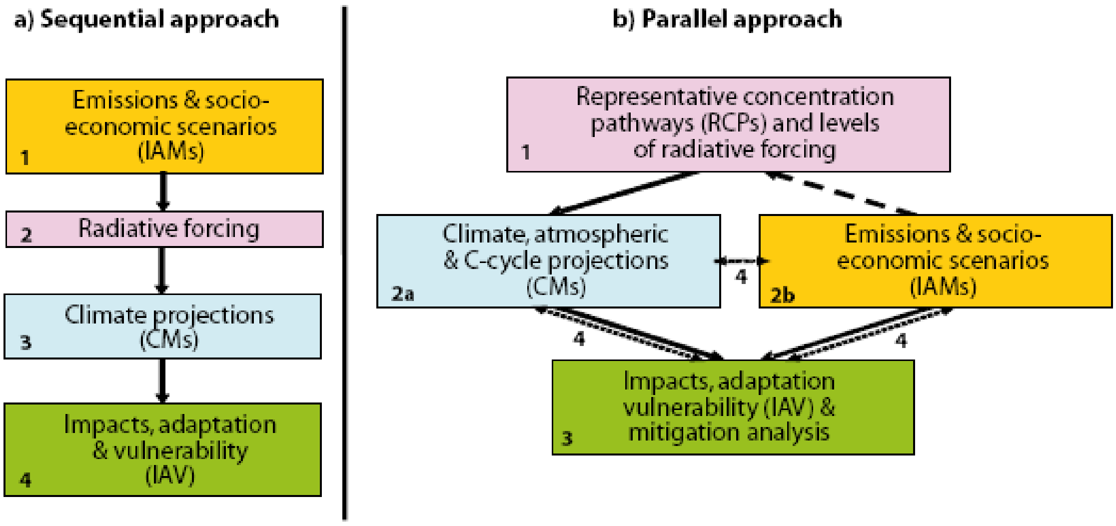


Figure 2.5. Approaches to the development of global scenarios

(a) previous sequential approach; (b) proposed parallel approach. Numbers indicate analytical steps (2a and 2b proceed concurrently). Arrows indicate transfers of information (solid), selection of RCPs (dashed), and integration of information and feedbacks (dotted). (Source: Moss et al, 2008).

Former scenarios have been used in a linear process, when climate change projections have been carried out based on socioeconomic and emission scenarios. In contrast to this sequential form, a parallel process for scenario development were decided by IPCC (Moss et al., 2008). These new generation scenarios have been started to develop in 2007. The parallel approach is initiated with the identification of the so-called RCPs (Representative Concentration Pathways), which should provide better integration, consistency, and consideration of feedbacks, and more time to assess impacts and responses. (Figure 2.5). In 2013, the IPCC has suggested Representative Concentration Pathways (RCPs) as new scenarios. The RCPs have replaced the old SRES emission scenarios (Wayne, 2013). Each of the new emission scenarios, contains a set of starting values and the estimated emissions up to 2100, based on assumptions about economic activity, energy sources, population growth and other socio-economic factors. The chosen RCPs have to represent for a group of emission scenarios and ensure that they will cover fairly reasonable about changes of GHG concentrations in the future. The RCP also ensures to keep all advantages of SRES scenarios (IPCC, 2007a, 2007b).

The criteria were agreed for the RCPs, as described in Moss et.al. 2010:

(1) The RCPs should be based on scenarios published in the existing literature, developed independently by different modeling groups and, as a set, be 'representative' of the total literature, in terms of emissions and concentrations (see further in this section); At the same time, each of the RCPs should provide a plausible and internally consistent description of the future;

(2) The RCPs should provide information on all components of radiative forcing that are needed as input for climate modeling and atmospheric chemistry modeling (emissions of greenhouse gases, air pollutants and land use). Moreover, they should make such information available in a geographically explicit way;

(3) The RCPs should have harmonized base year assumptions for emissions and land use and allow for a smooth transition between analyses of historical and future periods;

(4) The RCPs should cover the time period up to 2100, but information also needs to be made available for the centuries thereafter.

Based on those criteria, the four RCPs, RCP2.6, RCP4.5, RCP6, and RCP8.5, are named after a possible range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 W/m^2, respectively).

The radiative forcing is defined as the difference of insolation (sunlight) absorbed by the Earth and energy radiated back to space. Typically, radiative forcing is quantified at the tropopause (10-12km) in units of watts per square meter of the Earth's surface.

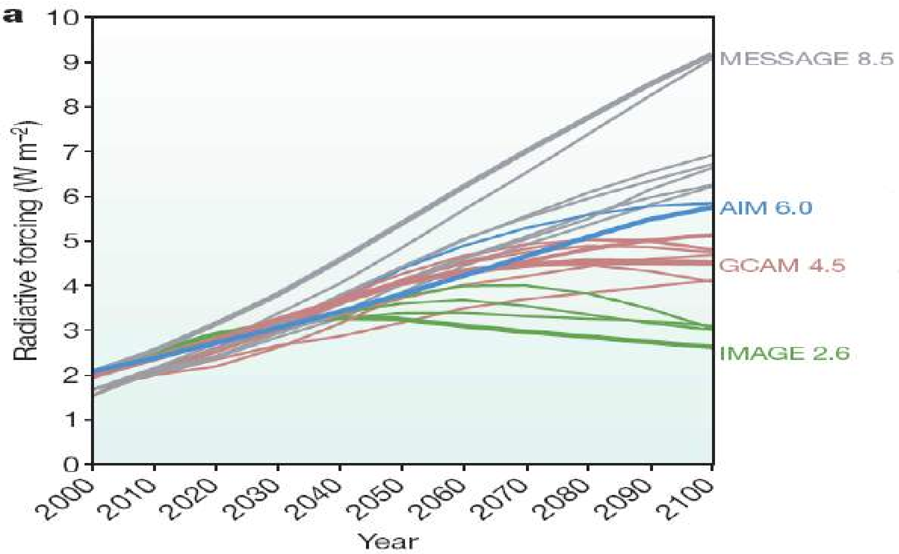


Figure 2.6. Changes in radiative forcing relative to pre-industrial conditions

Bold coloured lines show the four RCPs; thin lines show individual scenarios from approximately 30 candidate RCP scenarios that provide information on all key factors affecting radiative forcing

(Source: Moss et.al., 2010)

RCP8.5 was developed using the MESSAGE model and the IIASA Integrated Assessment Framework by the International Institute for Applied Systems Analysis (IIASA), Austria. This RCP is characterized by an increase in greenhouse gas emissions from the beginning of the century and reaching to 8.5 W/m^2 in 2100 and continuously increasing to

13W/m^2 in 2200, and then stabilizing thereafter. The RCP8.5 scenario is equivalent to the SRES A1FI. (Riahi et al. 2007).

RCP6.0 was developed by the AIM modeling team at the National Institute for Environmental Studies (NIES) in Japan. It is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshoot, by the application of a range of technologies and strategies for reducing greenhouse gas emissions (Fujino et al. 2006; Hijioka et al. 2008).

RCP4.5 was developed by the GCAM modeling team at the Pacific Northwest National Laboratory's Joint Global Change Research Institute (JGCRI) in the United States. It is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshooting the long-run radiative forcing target level (Clarke et al. 2007; Smith and Wigley 2006; Wise et al. 2009).

RCP2.6 was developed by the IMAGE modeling team of the PBL Netherlands Environmental Assessment Agency. The emission pathway is representative of scenarios in the literature that lead to very low greenhouse gas concentration levels. It is a "peak-and-decline" scenario; its radiative forcing level first reaches a value of around 3.1 W/m^2 by mid-century, and returns to 2.6 W/m^2 by 2100. In order to reach such radiative forcing levels, greenhouse gas emissions (and indirectly emissions of air pollutants) are reduced substantially, over time (Van Vuuren et al. 201107a).

The RCPs and SRES comparisons are showed in Table 2.1

Table 2.1. RCPs median temperature anomaly over pre-industrial levels and SRES comparisons based on nearest temperature anomaly

RCP	Radiative forcing in 2100	CO2 equiv. In 2100 (p.p.m.)	Global temperature anomaly over pre-industrial level in 2100 (^{o}C)	Pathway till 2100	SRES temp anomaly equiv.
RCP8.5	8.5 W/m^2	1370	4.9	Rising	A1FI
RCP6.0	6.0 W/m^2	850	3.0	Stabilization without overshoot	B2
RCP4.5	4.5 W/m^2	650	2.4	Stabilization without overshoot	B1
RCP2.6	2.6 W/m^2	490	1.5	Peak at 3.0 W/m^2 and decline	None

2.2.2. Global Climate Model

Modelling of the climate system is the simulation of all physical, chemical, biological processing in the climate system by mathematical equations (Fig. 2.7). The climate model originally was from General Circulation Model. GCMs represent the atmosphere and ocean as threedimensional grids, with a typical atmospheric resolution of around 200 km, and 20 to 50 levels in the vertical (CSIRO, 2015).

A general circulation model (GCM) is a type of climate model. It employs a mathematical model of the general circulation of a planetary atmosphere or ocean. It uses the Navier–Stokes equations on a rotating sphere with thermodynamic terms for various energy sources (radiation, latent heat). These equations are the basis for computer programs used to simulate the Earth's atmosphere or oceans. Atmospheric and oceanic GCMs (AGCM and OGCM) are key components along with sea ice and land-surface components.

GCMs and global climate models are used for weather forecasting, understanding the climate and forecasting climate change.

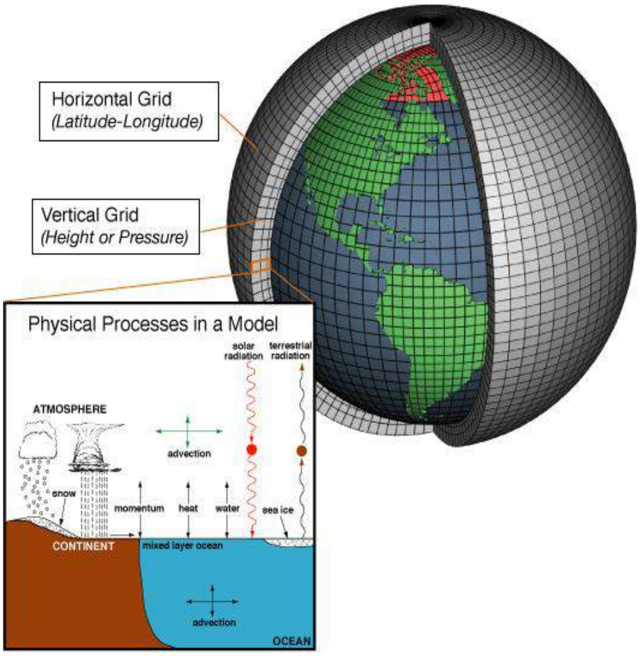


Figure 2.7. GCM's components and physical processes
(*Source: https://www.wmo.int*)

The development of climate models have a turning point in the 1980s with the establishment of the IPCC. GCM has begun to be applied for simulating the long-term accumulation of GHG in the atmosphere by industrial activities and fossil fuels burning. The ocean is also one of the important components of the climate system (Ocean General Circulation Model-Atmosphere - OGCM), it has been coupling with General Circulation models of the atmosphere - AGCM) to form an atmosphere-ocean General Circulation model - AOGCM (https://www.wmo.int).

Although the GCM has achieved remarkable results in climate simulation for the past and projected future climate, morever most of the GCM are low resolution (typically 2.5 ° to 3.7°). They could not describe well region characters as monsoon climate, topography, ecology and human impacts.

The regional climate model (RCM) is designed to study regional climate. Dynamical downscaling refers to the use of RCM to dynamically extrapolate the effects of large-scale climate processes from output of GCMs to regional or local scales. The Figure 2.8 illustrates the dynamical downscaling techniques.

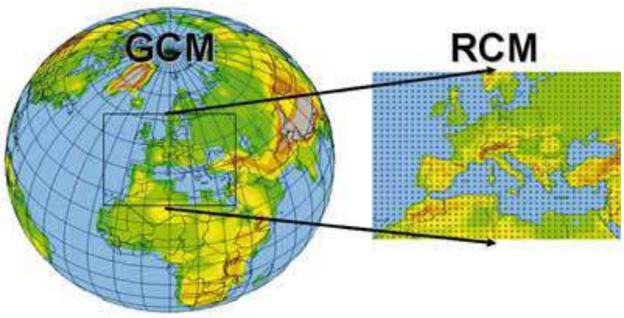


Figure 2.8. Dynamical downscaling techniques
(*Source: https://www.wmo.int*)

2.2.3. The CMIP5 ensemble

In response to a proposed activity of the World Climate Research Programme's (WCRP's) Working Group on Coupled Modelling (WGCM), the Program for Climate Model Diagnosis and Intercomparison (PCMDI) volunteered to collect model output contributed by leading modeling centers around the world. Climate model output from simulations of the past, present and future climate was collected by PCMDI and they were archived as phase 3 of the Coupled Model Intercomparison Project (CMIP3). The CMIP3 includes outputs of 24 models of 12 groups from 17 different countries and was used in assessment reports 4th (AR4) of the IPCC (Meehl et al, 2007).

The CMIP5 (*Couple Model Intercomparison Project Phase 5*) is a project built on the success of the previous phase CMIP, replace CMIP3 in the assessment report of the IPCC 5th (Meehl et al, 2000, 2005). The purpose of this stage is to answer the unresolved questions in AR4, and given the projected climate change scenario for AR5. Some recent researches show that CMIP5 simulate quite well even though have not yet collected all of GCM members from all parties. All collected models from working groups are better and better to provide useful information for other Working Groups of IPCC.

In Paris, September 2008, a meeting with the participation of over 20 groups on climate modeling from all over the world agreed to start the 5th phase of CMIP (Taylor et al, 2009). More than 20 modeling groups are performing CMIP5 simulations using more than 50 models, of which 47 models are available (Table 2.2). The CMIP5 is a project built on the success of the previous phase CMIP, replace CMIP3 in the 5th IPCC assessment report (Meehl et al, 2000, 2005). The purpose of this stage is to answer the unresolved issues in AR4, and given the projected climate change scenario for AR5. Some recent researches show that CMIP5 simulate quite well even though have not yet collected all of GCM members from all parties. All collected models from working groups are better and better to provide useful information for other working groups of IPCC. CMIP5 promotes a standard set of model simulations in order to: (i) Evaluate how realistic the models are in simulating the recent past; (ii) Provide projections of future climate change on two time scales, near term (out to about 2035) and long term (out to 2100 and beyond); and (iii) Understand some of the factors responsible for differences in model projections, including quantifying some key feedbacks such as those involving clouds and the carbon cycle (http://cmip-pcmdi.llnl.gov).*(Source: IPCC, 2013)*

Table 2.2. List models in CMIP5

No.	CMPIP5 MODEL	INSTITUTE AND COUNTRY OF ORIGIN	Ocean horizontal resolution (°lat x °lon)	Atmosphere horizontal resolution (°lat x °lon)	Atmosphere resolution (at the equator) (km)
1	ACCESS-1.0	CSIRO-BOM, Australia	1.0 x 1.0	1.9 x 1.2	210 x 130
2	ACCESS-1.3	CSIRO-BOM, Australia	1.0 x 1.0	1.9 x 1.2	210 x 130
3	BCC- CSM1-1	BCC, CMA, China	1.0 x 1.0	2.8 x 2.8	310 x 310
4	BCC-CSM1-1-M	BCC, CMA, China	1.0 x 1.0	1.1 x 1.1	120 x 120
5	BNU-ESM	BNU, China	0.9 x 1.0	2.8 x 2.8	310 x 310
6	CanCM4	CCCMA, Canada	1.4 x 0.9	2.8 x 2.8	310 x 310
7	CanESM2	CCCMA, Canada	1.4 x 0.9	2.8 x 2.8	310 x 310
8	CCSM4	NCAR, USA	1.1 x 0.6	1.2 x 0.9	130 x 100
9	CESM1-BGC	NSF-DOE-NCAR, USA	1.1 x 0.6	1.2 x 0.9	130 x 100
10	CESM1-CAMS	NSF-DOE-NCAR, USA	1.1 x 0.6	1.2 x 0.9	130 x 100
11	CESM1-FASTCHEM	NSF-DOE-NCAR, USA	1.1 x 0.6	1.2 x 0.9	130 x 100
12	CESM1-WACCM	NSF-DOE-NCAR, USA	1.1 x 0.6	2.5 x 1.9	275 x 210
13	CMCC-CESM	CMCC, Italy	2.0 x 1.9	3.7 x 3.7	410 x 410

No.	CMPIP5 MODEL	INSTITUTE AND COUNTRY OF ORIGIN	Ocean horizontal resolution (°lat x °lon)	Atmosphere horizontal resolution (°lat x °lon)	Atmosphere resolution (at the equator) (km)
14	CMCC-CM	CMCC, Italy	2.0 x 1.9	0.7 x 0.7	78 x 78
15	CMCC-CMS	CMCC, Italy	2.0 x 2.0	1.9 x 1.9	210 x 210
16	CNRM-CMS	CNRM-CERFACS, France	1.0 x 0.8	1.4 x 1.4	155 x 155
17	CNRM-CMS-2	CNRM-CERFACS, France	1.0 x 0.8	1.4 x 1.4	155 x 155
18	CSIRO-Mk3-6-0	CSIRO-QCCCE, Australia	1.9 x 0.9	1.9 x 1.9	210 x 210
19	EC-EARTH	EC-EARTH, Europe	1.0 x 0.8	1.1 x 1.1	120 x 120
20	FIO-ESM	FIO, SOA, China	1.1 x 0.6	2.8 x 2.8	310 x 310
21	GFDL-CM2p1	NOAA, GFDL, USA	1.0 x 1.0	2.5 x 2.0	275 x 220
22	GFDL-CM3	NOAA, GFDL, USA	1.0 x 1.0	2.5 x 2.0	275 x 220
23	GFDL-ESM2G	NOAA, GFDL, USA	1.0 x 1.0	2.5 x 2.0	275 x 220
24	GFDL-ESM2M	NOAA, GFDL, USA	1.0 x 1.0	2.5 x 2.0	275 x 220
25	GISS-E2-H	NASA/GISS, NY, USA	2.5 x 2.0	2.5 x 2.0	275 x 220
26	GISS-E2-H-CC	NASA/GISS, NY, USA	1.0 x 1.0	1.0 x 1.0	110 x 110
27	GISS-E2-R	NASA/GISS, NY, USA	2.5 x 2.0	2.5 x 2.0	275 x 220
28	GISS-E2-R-CC	NASA/GISS, NY, USA	1.0 x 1.0	1.0 x 1.0	110 x 110
29	HadCM3	MOHC, UK	1.2 x 1.2	3.7 x 2.5	410 x 280
30	HadGEM2-AO	NIMR-KMA, Korea	1.0 x 1.0	1.9 x 1.2	210 x 130
31	HadGEM2-CC	MOHC, UK	1.0 x 1.0	1.9 x 1.2	210 x 130
32	HadGEM2-ES	MOHC, UK	1.0 x 1.0	1.9 x 1.2	210 x 130
33	INMCM4	INM, Russia	0.8 x 0.4	2.0 x 1.5	220 x 165
34	IPSL-CMSA-LR	IPSL, France	2.0 x 1.9	3.7 x 1.9	410 x 210
35	IPSL-CMSA-MR	IPSL, France	1.6 x 1.4	2.5 x 1.3	275 x 145
36	IPSL-CMSB-LR	IPSL, France	2.0 x 1.9	3.7 x 1.9	410 x 210
37	MIROC4h	JAMSTEC, Japan	0.3 x 0.2	0.56 x 0.56	60 x 60
38	MIROCS	JAMSTEC, Japan	1.6 x 1.4	1.4 x 1.4	155 x 155
39	MIROC-ESM	JAMSTEC, Japan	1.4 x 0.9	2.8 x 2.8	310 x 310
40	MIROC-ESM-CHEM	JAMSTEC, Japan	1.4 x 0.9	2.8 x 2.8	310 x 310
41	MPI-ESM-LR	MPI-N, Germany	1.5 x 1.5	1.9 x 1.9	210 x 210
42	MPI-ESM-MR	MPI-N, Germany	0.4 x 0.4	1.9 x 1.9	210 x 210
43	MPI-ESM-P	MPI-N, Germany	1.5 x 1.5	1.9 x 1.9	210 x 210
44	MRI-CGCM3	MRI, Japan	1.0 x 0.5	1.1 x 1.1	120 x 120
45	MRI-ESM1	MRI, Japan	1.0 x 0.5	1.1 x 1.1	120 x 120
46	NorESM1-M	NCC, Norway	1.1 x 0.6	2.5 x 1.9	275 x 210
47	NorESM1-ME	NCC, Norway	1.1 x 0.6	2.5 x 1.9	275 x 210

The information about data in CMIP5 is described detail in Table 2.3 as: depending on the storage capacity each model can provide data with different time scales, including:

Monthly data: **hurs** (surface relative humidity); **pr** (precipitation); **psl** (surface pressure); **rsds** (surface downward solar radiation); **tas** (surface air temperature); tasmin and

tasmax (minimum and maximum surface air temperature; **uas** and **vas** (surface zonal and meridional winds).

Daily data: **rx1day** (annual maximum 1-day rainfall); **rx1day-RV20** (20-year return value for rx1day); **txx** (annual maximum daily maximum temperature); **txxrv20** (20-year return value for txx); **tnn** (annual minimum daily minimum temperature); **tnn-rv20** (20 year return value for tnn); **sfcwindmax** (annual maximum surface wind speed); **sfcwindmax-rv20** (20 year return value of sfcwindmax).

Table 2.3 shows that not all modelling centres made the same data fields available and there are gaps in the data archive globally. For example, while there are monthly rainfall data from 48 models, the maximum 1-day rainfall is only available from 31 models, highlighting the fact that different modelling centres have different priorities with respect to which model output they can contribute.

Overall, the average resolution has significantly improved from CMIP3 to CMIP5 and is shown for the atmospheric grid cells. The median size of an atmospheric grid cell has decreased from (300 x 300 km) to (200 x 200 km) and there are now global models in CMIP5 with sub-100 km grid cell size, which is approaching values usually seen in regional climate models (Fig. 2.9).

Table 2.3. List of available simulations from CMIP5

Monthly fields	hurs	pr	psl	rsds	tas	tasmax	tasmin	uas	vas
Historical	37	47	46	45	46	42	42	19	19
RCP4.5	31	38	38	37	38	36	36	23	23
RCP8.5	30	39	39	39	37	37	36	24	24
RCP6.0	18	21	21	21	21	20	19	13	13
RCP2.6	20	28	27	26	28	24	24	18	18
Daily fields (extremes)	rxlday	rxlday-RV20	txx	txx-RV20	tnn	tnn-RV20	sfcWind max	sfcWind max-RV20	
Historical	25	25	27	27	27	27	22	22	
RCP4.5	21	22	23	24	23	23	18	15	
RCP8.5	24	24	25	26	26	26	18	17	
RCP6.0	-	-	-	-	-	-	3	3	
RCP2.6	-	-	-	-	-	-	12	12	

Note: "-"not avaiable

Some of the new experiments of CMIP5 models include a biogeochemical component accounting for carbon cycles in the land, atmosphere, and ocean which never ever seen in CMIP3.

In summary, the CMIP5 experiments are more advantages than CMIP3 in new scenarios, more models and finer resolution. All CMIP5 model data have been accessed using the global Earth System Grid (ESG), which had been setup to facilitate the movement of large data amounts across many institutes (see https://www.earthsystemgrid.org/about/overview.htm for details about the ESG).

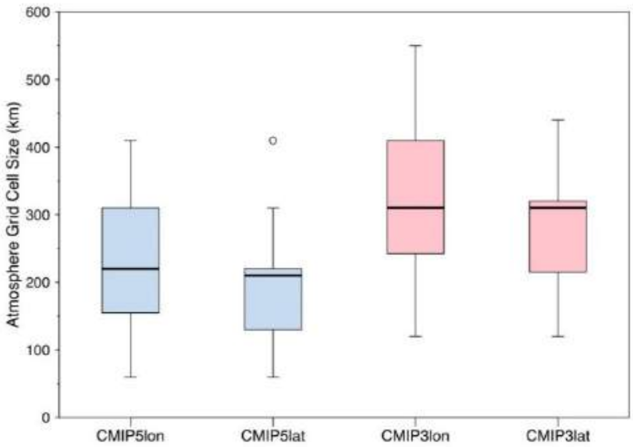


Figure 2.9. Box-whisker plot of grid cell size (in km) in global climate model's atmosphere for CMIP5 models

(Source: Climate Change in Australia, 2015)

Note: The box displays the middle 50 % of the models while the whiskers show the range. the centre line is the median grid cell size. the circle represents an outlier model (e.g. a model with much lower resolution compared to the other models)

2.3. Climate change, sea level rise global and regional scale

2.3.1. Climate change, sea level rise trend according to historic data

1) Global climate change

a) Temperature

According to AR5 report, the global average temperature has increased markedly since the 1950s, many weather and climate extremes were recorded in the past few decades. Global warming, reduced amount of snow and ice, rising sea levels, the concentration of greenhouse gases increased (IPCC, 2013).

The trend of temperature change is faster in high latitudes than low latitudes; faster in inland than the coastal regions and islands; the minimum temperature has rosen faster than maximum temperature. The AR5 report (IPCC, 2013) continues to confirm the number of days and cold nights tend to decrease; number of days and hot nights, the heat wave tends to increase on a global scale. Due to the rapid rise of temperature, the ice area also tends to decrease, most significantly reduced in recent years.

Box 1. Summary of global climate change (IPCC, 2013)

- Global average surface temperature increases by about 0.89°C (0.69-1.08°C) in the period 1901-2012.
- The global average temperature tends to increase more substantially in recent decades. The average rate is about 0.12°C/decade in the period 1951-2012.
- Precipitation has increased in the midlatitude regions of the northern hemisphere since 1901.
- The number of cold days and cold nights has decreased while the number of hot days and hot nights has increased on global scales since about 1950.

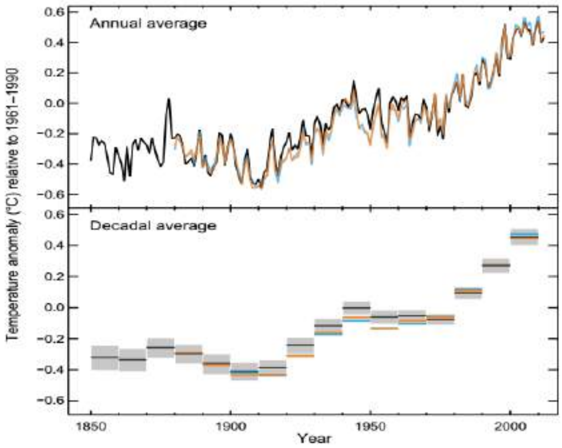


Figure 2.10. Observed globally averaged combined land and ocean surface temperature anomaly 1850–2012
(Source: IPCC, 2013)

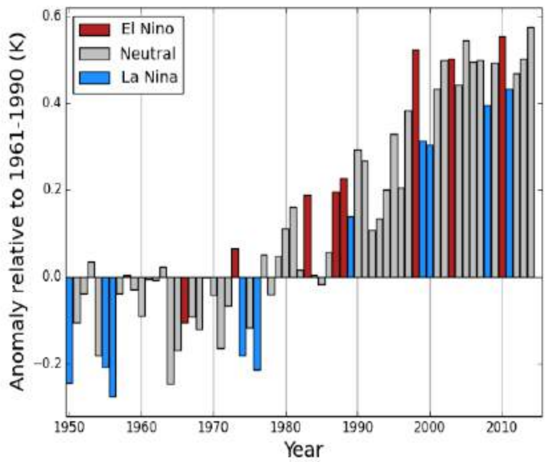


Figure 2.11. Global average temperature anomaly 1950-2015 relative to 1961-1990
(Source: WMO, 2016)

According to WMO report in 2016, hottest years occurred in the recent years, especially in early years of the 21st century. The global average surface temperature in 2015 broke all previous records by a strikingly wide margin, at 0.76 ± 0.1° C above the 1961-1990 average.

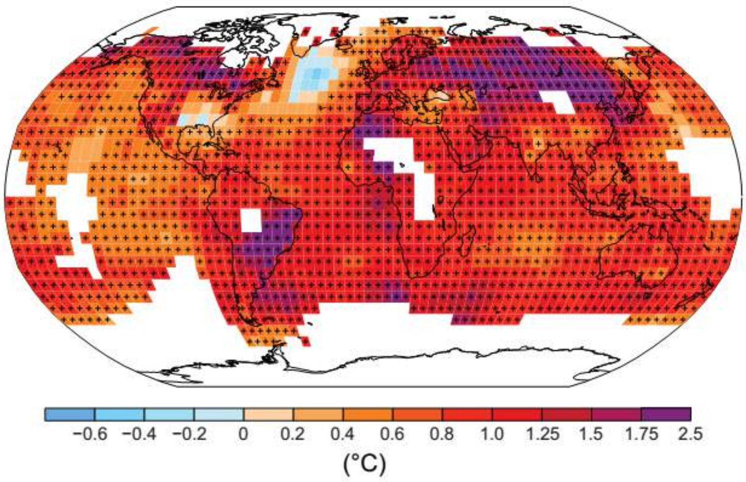


Figure 2.12. Observed change in surface temperature 1901–2012
(Source: IPCC, 2013)

Legend: Map of the observed surface temperature change from 1901 to 2012 derived from temperature trends determined by linear regression from one dataset (orange line in panel a). Trends have been calculated where data availability permits a robust estimate (i.e., only for grid boxes with greater than 70% complete records and more than 20% data availability in the frst and last 10% of the time period). Other areas are white. Grid boxes where the trend is signifcant at the 10% level are indicated by a + sign.

b) Rainfall

The rainfall has tended to increase in most areas on global scale in the period 1901-2010. In which, the most obvious upward trend in the average latitudes and high latitudes; in contrast, many tropical areas tend to decrease. The trend of increase / decrease in rainfall was more clearly in the period 1951-2010 compared to the period 1901-2010. The most obvious upward trend is in America, Western Europe, Australia; The most obvious downtrend in the African region and China.

Widespread increases in heavy precipitation events have been observed, even in places where total amounts have decreased. These changes are associated with increased water vapour in the atmosphere arising from the warming of the world's oceans, especially at lower latitudes. There are also increases in some regions in the occurrences of both droughts and floods. The trend of storm frequency is not clear, however, almost certainly number of strong storms has increased (IPCC, 2013).

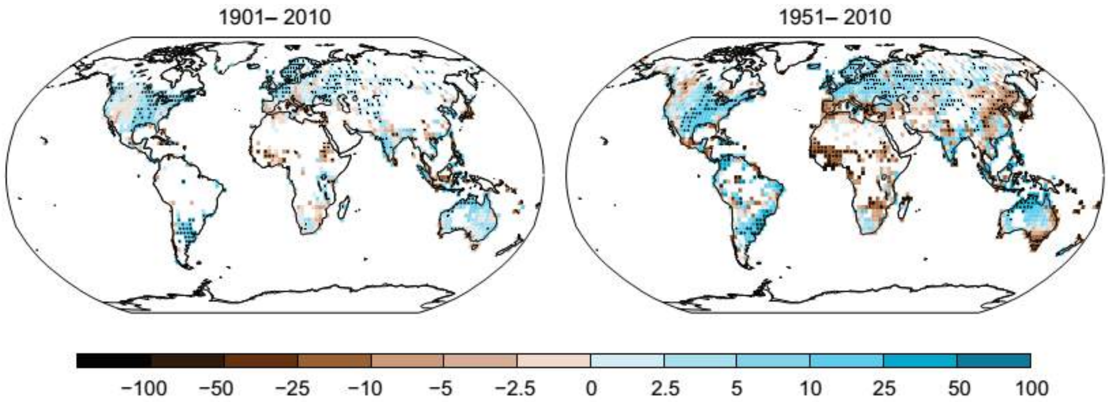


Figure 2.13. Maps of observed precipitation change from 1901 to 2010 and from 1951 to 2010

(calculated and displayed similarly to Figure 2.12)

(Source: IPCC, 2013)

2) Trends of global sea level rise

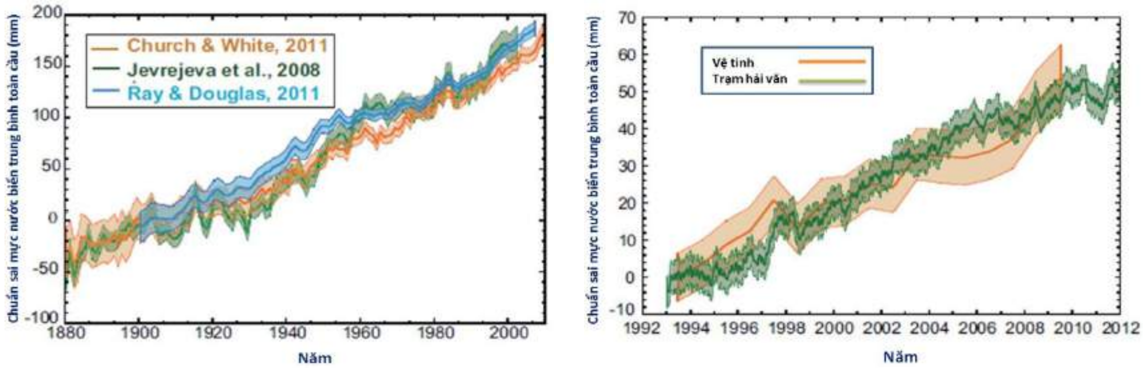
In the past, sea level in the world has changed with the time scale of several hundred to several thousand years. Sea levels have changed more than 100 meters due to fluctuations in ice on Earth during glacial periods (Foster and Rohling, 2013, Rohling et al., 2009).

Since the last glacial period, about 2000 to 6,000 years ago, sea levels have increased by more than 120m (Lambeck et al., 2002), then decayed. For the past 1000 years, global average global sea level fluctuations were no more than 0.25 m (Woodroffe et al., 2012, Masson-Delmotte et al., 2010).

Box 2. Brief description of global sea level change trends (IPCC, 2013).

- In the period 1901 - 2010, the average global sea level increased by 19cm with an average increase of 1.7mm per year.
- In the period 1993 - 2010, the average global sea level increased by 3.2mm / year.

Sea level monitoring data at coastal water level gauges (Jevrejeva et al., 2008, Woodworth, 1999) and coastal floodplains (Gehrels and Woodworth, 2013) indicate that sea level tends to change from about 0.1 to 0.25 mm/decade in the period from late 19th century to early 20th century.



(a) in the period of 1880 to 2010 *(b) in the period of 1993 to 2010*

Figure 2.14. Trends in global average sea level change

(source: IPCC, 2013)

Sea levels at global monitoring stations during the period 1900 - 2010 increased by 1.7 ± 0.2 mm / yr (Church and White, 2006, Church and White, 2011, Jevrejeva et al., 2012a, Ray and Douglas 2011), with a marked upward trend in the 1920s and 1950s and especially since 1993. The high sea level rise in 1993 has also been confirmed in assessments of sea level fluctuations from satellite data (Figures 2.14a and b).

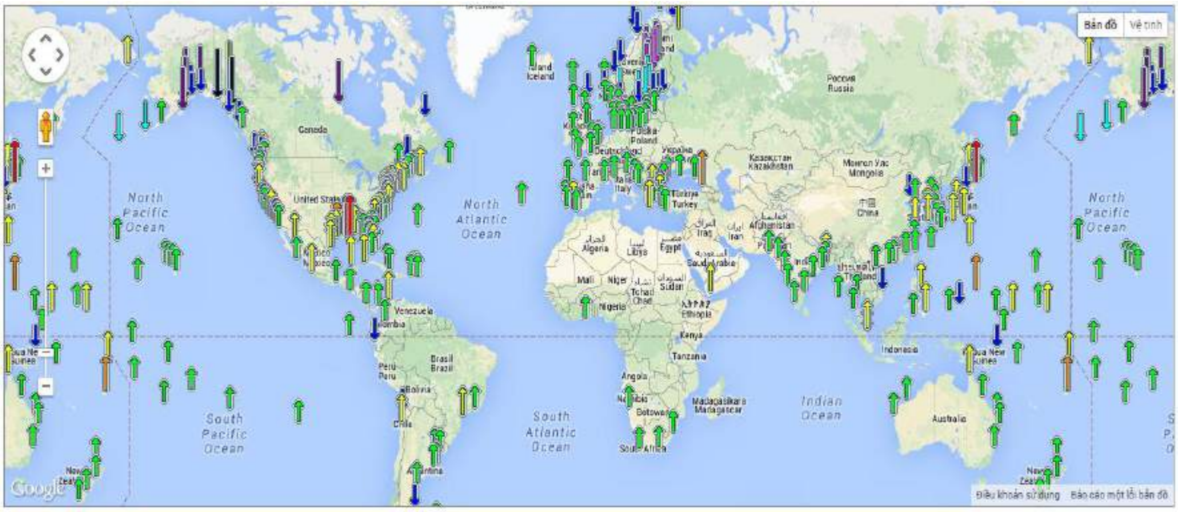


Figure 2.15. Average sea level change trend according to monitoring data

(Source: http://tidesandcurrents.noaa.gov/sltrends/sltrends.html)

Data at sea level monitoring stations show that sea level tends to increase globally. However, the sea level rise is not uniform among regions, especially in some water stations tend to decrease. This is due to the fact that the melting ice mass in the ocean changes the loading force on the Earth's crust, leading to the reaction of the Earth's crust to the ocean's liquid layer, which causes the sea level to drop sharplyin glacial melting regions like Alaska, Scandinavia, but strongly increase in other parts of the globe (Fig. 2.15).

2.3.2. Climate change and sea level rise scenarios

In September, 2013, IPCC published a report of Group 1 (Working Group 1 - WG1), whis is one of three main reports of the AR5 synthesis report. AR5-WG1 report was built upon the AR4 report, supplemented with new research results. In the AR5 report, building climate change and sea level rise projections have been approached in a new way, in which SRES emission scenarios are replaced by the RCPs. The main results in AR5 report are: manifestation of climate change and sea level rise; greenhouse gas scenarios; methods of climate change projection and sea level rise; climate change and sea level rise scenarios in the early, middle and end of 21st century; uncertainty of the scenarios; Atlas for global and regional climate change.

The methods of climate change projection and sea level rise in AR5 is by using AOGCM, GCM, regional climate model, global ocean model (25-42 models) and the statistic downscaling techniques. The future periods are selected to compare the reference period 1986-2005. The scenario is built for the future period: (1 The beginning of the 21st century (near future, 2016-2035); (2) The mid-century (medium future, 2046-2065); (3) The end of the century (far future, 2081-2100).

The main climate variables are projected: temperature, average rainfall, extremes, sea level, ice area, the atmospheric chemical composition, monsoon, ENSO, tropical cyclones, ... (the rate of change compared to the basic period 1986-2005.)

Box 3. Summary of climate projections (IPCC, 2013)

- The global average temperatures will increase in a range of 1.1-2.6°C based on the RCP4.5 scenario and 2.6-4.8°C based on the RCP8.5 scenario by the end of 21st century compared with the period 1986-2005.
- Projected precipitation will increase considerably in high latitudes and decrease in the tropics and subtropics.
- It is very likely that extreme temperatures will have an increasing trend. Based on the RCP8.5 scenario, by the end of the 21st century, the temperatures of the coldest days will likely increase by about 5- 10°C; the temperatures of the hottest days will likely increase by about 5-7°C; the number of frost days will likely decrease; the number of hot nights will increase markedly.
- Precipitation extremes will tend to increase: the largest precipitation in 1-day (average 20 years) will increase by 5.3%, corresponding to an increased surface temperature of 1°C.
- The amount of ice will have a decreasing trend. According to RCP8.5, there will be little ice left at the North Pole by 2100.
- Monsoons will likely be extended in the 21st century. The summer monsoon will tend to begin earlier and end later. Monsoon rainfall will tend to increase due to increased moisture content in the atmosphere
- The number of storms is likely to decrease or no change. The strong storm and storm induced-rainfall tend to rise.

1) Climate change scenarios

a. Average temperature scenarios

Beginning century period, 2016-2035, the global average temperature tends to increase by 0.3-0.7 °C. In Vietnam, the average temperature will rise equivalent to global scale.

The temperature in inland is likely rise faster than in the sea and temperature in polar areas tends to rise faster than tropical areas (Figure 2.16).

The end of century (2081-2100), global average temperature will increase from 0.3°C to 1.7°C with RCP2.6 scenario; from 1.1°C to 2.6°C for RCP4.5 scenario; from 1.4°C to 3.1°C for RCP6.0 scenario and from 2.6°C to 4.8°C for RCP8.5 scenario.

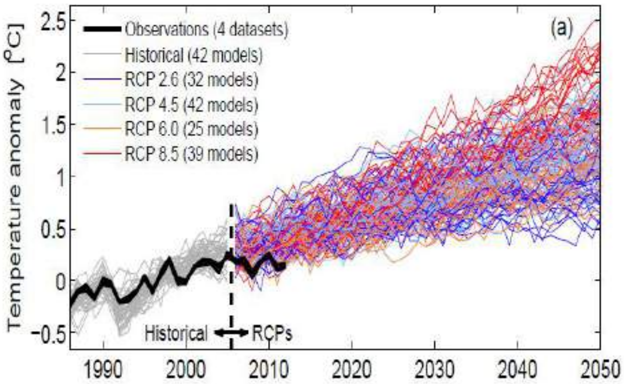


Figure 2.16. Global mean temperature near-term projections relative to 1986–2005
(Source: IPCC, 2013)

In general, temperature will not rise the same rate for all regions. The average temperature in the period 2081-2100 is expected to rise higher than the period 1986-2005 over 2°C for RCP8.5 scenario.

However, it should be noted that the rate of temperature change may be greater than description in Figure 2.16. The greenhouse gas concentration may be greater than assumed in the scenario RCP8.5. The increase may be caused by relase of CO_2 and CH_4 into the atmosphere and the ice melting in the Arctic and the Arctic peatbogs. Some regions such as Alaska, Canada and the North Russia may also occur the ice melting. However, increasing greenhouse gas emission from melting ice in the 21st century is very uncertain. Current permafrost areas are projected to become a net emitter of carbon (CO2 and CH4) with a loss of 180 to 920 GtCO2 (50 to 250 GtC) under RCP8.5 over the 21st century (low confidence) Global oceans will continue to absorb CO_2 emission in the future that leading to ocean acidification. Oceans will also continue to absorb heat from the air in the deeper layer but the process is very slow and will lead to a warming of the ocean (IPCC, 2014, Chapter 6).

Global warming is not uniform in space. It can easily been shown for the period 2081-2100 compared to the period 1986-2005 for RCP8.5 and RCP2.6 scenario (Figure 2.17a). Under both scenarios, the increase of temperature on the mainland is likely to be higher than that in the sea and the highest increase will be in the Arctic. The trend of decrease in temperature may occur in some seas.

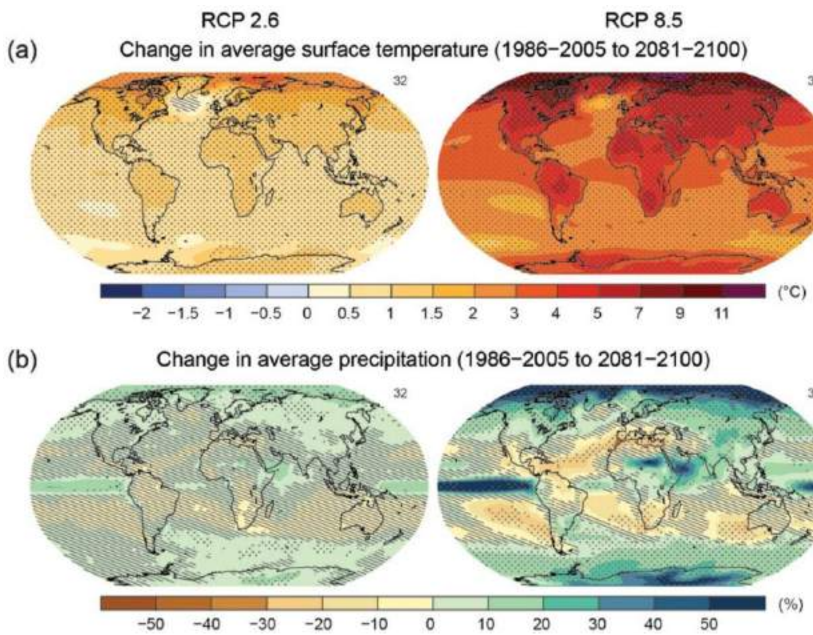


Figure 2.17. Maps of CMIP5 multi-model mean results for the scenarios RCP2.6 and RCP8.5 in 2081–2100 of (a) annual mean surface temperature change, (b) average percent change in annual mean precipitation

(Source: IPCC, 2013)

b. Precipitation scenarios

Figure 2.17b shows that changes in global rainfall are expected in both RCP2.6 and RCP8.5 scenario. Under both scenarios, rainfall will change dramatically due to the temperature increases. In some areas rainfall will increa, while some other areas rainfall will decrease. The general trend is increased rainfall in rainy season and decresed in dry season. Precipitation tends to increase at high latitudes and near the equator but decrease in southwestern Australia, South America, Africa, Atlantic Ocean and Mediterranean.

c. Other climate fields

Global warming will increase the number of hot days and reduce cold days over most land areas. Therefore, heat waves will occur more frequently and last longer as well. The cold winter also may occur shorter. Furthermore, extreme phenomena related to rain in mid-latitude and humid tropicical areas will become more severe and more frequent at the end of century due to the rise in average global temperatures (IPCC, 2013). The origin of this change is from strenthening of moisture holding capacity of the warm air (IPCC, 2013) as well as the increasing kinitic of gas (O ' Gorman and Schneider, 2009).

Global monsoon system play a very important role in the Earth's water cycle. At global scale, the impact of the regional monsoon is expected to increase with increasing precipitation and intensity of monsoon. This increase can be understood as related to increasing air humidity due to the global warming. At present, the monsoon is considered to be weakening by a slow global tropic circulation (IPCC, 2013, Chapter 12). Some results show that the monsoon onset will come earlier or as normal meanwhile the offset of monsoon will finish later (IPCC, 2013, Chapter 12).

IPCC report also indicates that ENSO will keep significant effects on global climate in the 21st century. Increasing of potential moisture and changing of rainfall related to ENSO in small areas will be strengthened. Because of big oscillation of ENSO, the confidence of any change related to ENSO is quite low. In addition, recent studies show that global warming will increase the impact of the El Niño to droughts in the western Pacific and heavy rainfall in the central and eastern Pacific (Power et al, 2013, Cai et al, 2014).

Indian Ocean Dipole phenomenon also known as the Indian Niño, is an irregular oscillation of sea-surface temperatures in which the western Indian Ocean becomes alternately warmer and then colder than the eastern part of the ocean. IOD phenomenon is closely related to the droughts in Indonesia, water shortages in Australia, stronger winds of Indian summer season, floods in East Africa, warm climate in Japan and the climate phenomenon in the tropical Southern Hemisphere (IPCC, 2013). In its postitve phase of IDO, winter and spring precipitation in the middle and southern Australia are usually lower than normal. The projected results show that the phenomenon of IOD (both hot and blow cold phase) is likely to be not changed in the future (Ihara et al, 2008, IPCC, 2013, Cai et al, 2014).

The Southern Annular Mode Phenomenon also known as The Antarctic Oscillation (AAO) is a low-frequency mode of atmospheric variability of the southern hemisphere. It is defined as a belt of westerly winds or low pressure surrounding Antarctica which moves north or south as its mode of variability. In its positive phase, the westerly wind belt contracts towards Antarctica, while its negative phase involves this belt moving towards the Equator. In few recent decades, the SAM index is uptrend in the summer and autumn because of O_3 decline in stratospheric (Thompson and et al, 2011, IPCC, 2013).

2) Global Sea Level Rise Scenarios

Box 4. Summary of global sea-level rise scnenarios (IPCC, 2013)

- Global average sea level continues to rise in the 21st century with the rate greater 2,0mm/year, mainly due to thermal expansion and glaciers.
- By the mid-21st century, sea level rise will likely in the ranges of 19 ÷ 33cm for the RCP4.5 and 22 ÷38cm RCP8.5 scenario.
- By the end of the 21st century, sea level rise will likely in the ranges of 32 ÷63cm for RCP4.5 and 45 ÷ 82cm for RCP8.5.
- By 2100, sea level would rise 36 ÷ 71cm for RCP4.5 and 52 ÷ 98cm for RCP8.5.

According to the global sea level rise scenario (IPCC, 2013), thermal expansion accounts for 30 to 55% of 21st century global mean sea level rise, and glaciers for 15 to 35%. Other components have lesser contributions, even leads to negative contribution such as surface mass balance on Antarctic. Dynamical changes in both Greenland and Antarctic contribute to 0,03 ÷ 0,2m of sea-level rise by the end of the 21st century for different RCP scenarios. Human activities on land water storage also contribute to sea level rise, mainly due to ground water extraction. **(Figure 2.18)**

- For RCP4.5 scenario, global sea level would rise 26cm (19cm ÷ 33cm) by the mid-21st century; 47cm (32cm ÷ 63cm) by the end of the 21st century; 53cm (36cm ÷ 71cm) by 2100.

- For RCP8.5 scenario, global sea level would rise 30cm (19cm ÷ 33cm) by the mid-21st century; 63cm (32cm ÷ 63cm) by the end of the 21st century; 74cm (36cm ÷ 71cm) by 2100.

Regional sea level changes may differ substantially from a global average, showing complex spatial patterns which result from ocean dynamical processes, movements of the sea floor, and changes in gravity due to water mass redistribution (land ice and other terrestrial water storage)

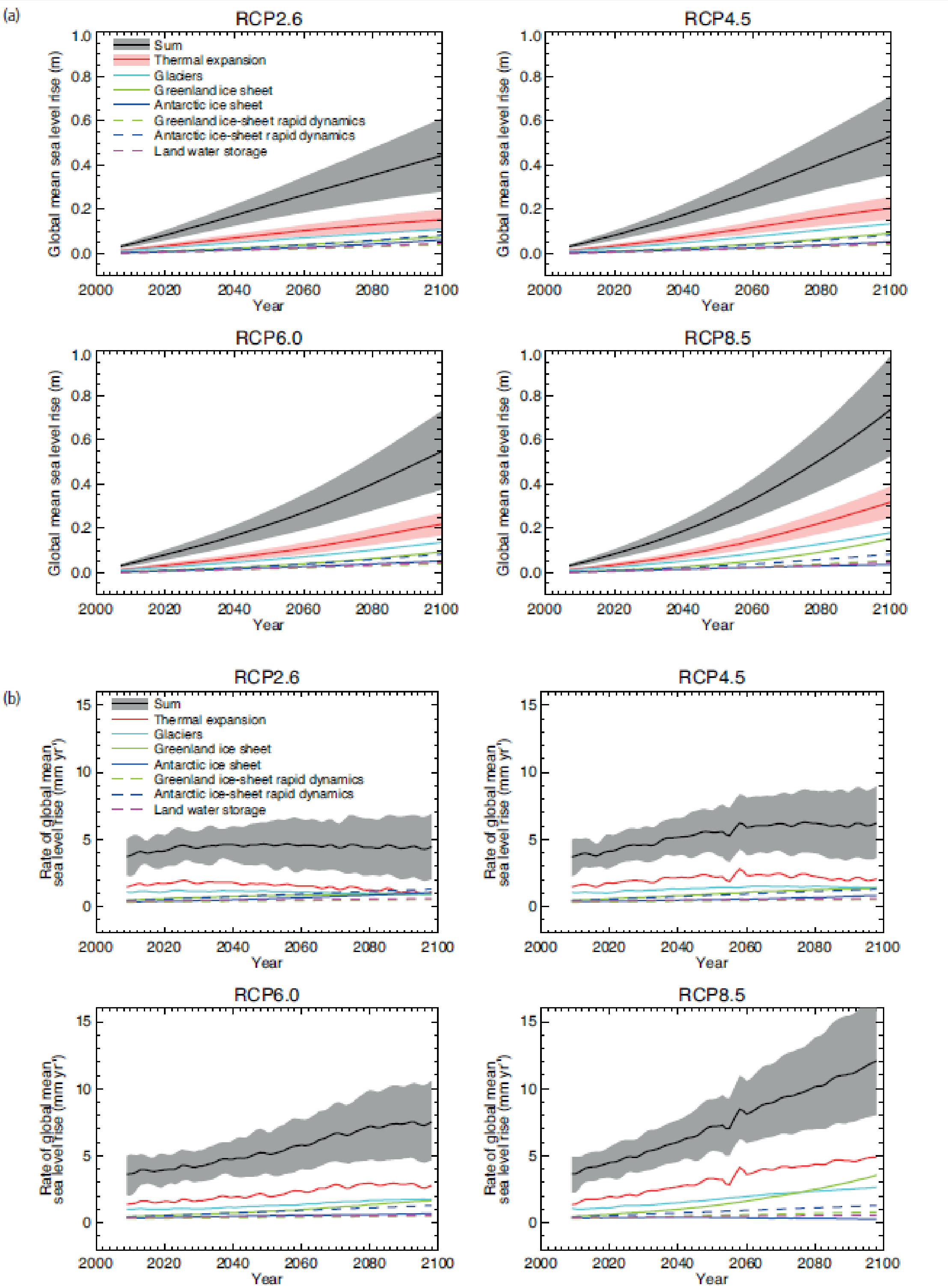


Figure 2.18. Global Sea Level Rise Scenarior

(Source: IPCC, 2013)

Hình 2.1 shows that, according to the RCP4.5 scenario, the west and middle Pacific Ocean, south Atlantic and Indian Ocean sea levels tended to rise sharply against the global average. By contrast, in the southeast Pacific and the north Atlantic and especially around the poles, sea levels tend to rise less than the global average. According to the RCP8.5

scenario, regional sea level tends to increase more strongly than the global average, except that some small areas near the poles tend to rise less.

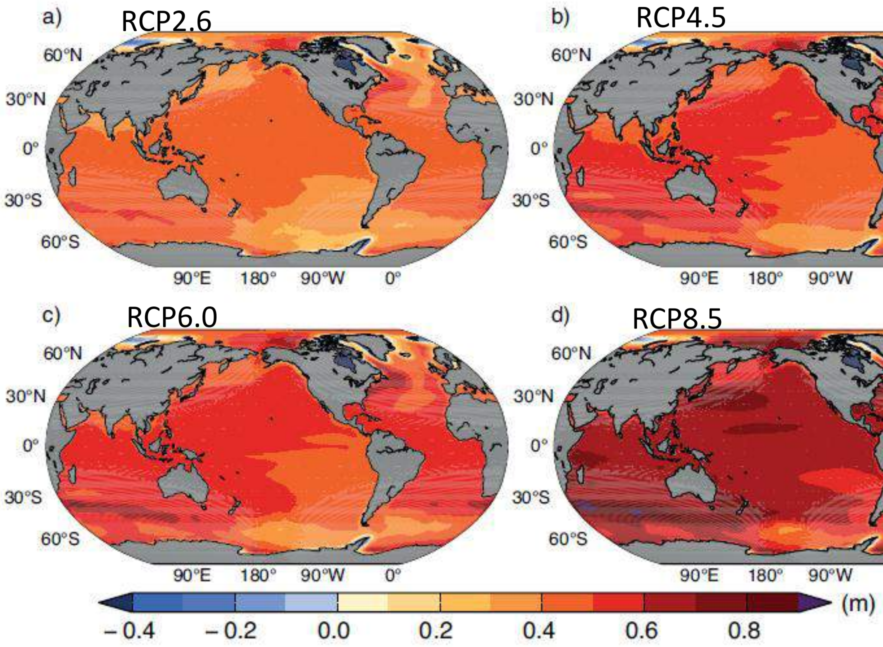


Figure 2. 19: Sea Level Rise Scenario in the period of 2081-2100 compares to base period

Table 2. 4 Sea level rise scenario 2081-2100 in comparison with base period (cm) (Average value 50%, probability range 5% ÷ 95%)

Scenario / Factor	SRES A1B	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Thermal expansion	21 (16 ÷ 26)	14 (10 ÷ 18)	19 (14 ÷ 23)	19 (15 ÷ 24)	27 (21 ÷ 33)
Ice River	14 (8 ÷ 21)	10 (4 ÷ 16)	12 (6 ÷ 19)	12 (6 ÷ 19)	16 (9 ÷ 23)
SMB at Greenland	5 (2 ÷ 12)	3 (1 ÷ 7)	4 (1 ÷ 9)	4 (1 ÷ 9)	7 (3 ÷ 16)
SMB at Antarctic	-3 (-6 ÷ -1)	-2 (-4 ÷ -0)	-2 (-5 ÷ -1)	-2 (-5 ÷ -1)	-4 (-7 ÷ -1)
Greenland Ice Dynamics	4 (1 ÷ 6)	4 (1 ÷ 6)	4 (1 ÷ 6)	4 (1 ÷ 6)	5 (2 ÷ 7)
Antarctic Ice Dynamics	7 (-1 ÷ 16)	7 (-1 ÷ 16)	7 (-1 ÷ 16)	7 (-1 ÷ 16)	7 (-1 ÷ 16)
Terrestrial water storage	4 (-1 ÷ 9)	4 (-1 ÷ 9)	4 (-1 ÷ 9)	4 (-1 ÷ 9)	4 (-1 ÷ 9)
Global average sea level rise (2081-2100)	52 (37 ÷ 15)	40 (26 ÷ 55)	47 (32 ÷ 63)	48 (33 ÷ 63)	63 (45 ÷ 82)
Global average sea level rise (2046-2065)	27 (19 ÷ 34)	24 (17 ÷ 32)	26 (19 ÷ 33)	25 (18 ÷ 32)	30 (22 ÷ 38)
Global average sea level rise to 2100	60 (42 ÷ 80)	44 (28 ÷ 61)	53 (36 ÷ 71)	55 (38 ÷ 73)	74 (52 ÷ 98)

III. Manifestation of climate change and sea level rise for Viet Nam

3.1. Data

3.1.1. Climate data

1) Results acquired from regional climate models

Global climate and regional climate models are main tools to assess the trend of change and future climate variability, especially climate extremes. The following models have been used in updating climate change scenarios for Vietnam: The AGCM / MRI (Meteorological Research Institute of Japan); PRECIS (Hadley Centre – UK); CCAM (The Commonwealth Scientific and Industrial Research Organisation – Australia; RegCM (Italy) and the clWRF model (US.).

2) Observed data

Until September 2015, there are 180 surface meteorological stations, 889 rainfall stations (including 485 automatic rainfall stations, 404 manual rainfall stations), 14 automatic radiation measurement stations, 27 agro-meteorological stations; 23 hydrometeorological stations in whole Vietnam. Not all stations have been fully data, most of the stations in the south since 1975.

After checking and evaluating the quality, the reliability of the data string, we have chosen 150 stations to carry out research on precipitation and temperature projections

Table 3.1 described in detail data and information have used for building CC projection for Vietnam. The locations of station network are shown in Figure 3.1.

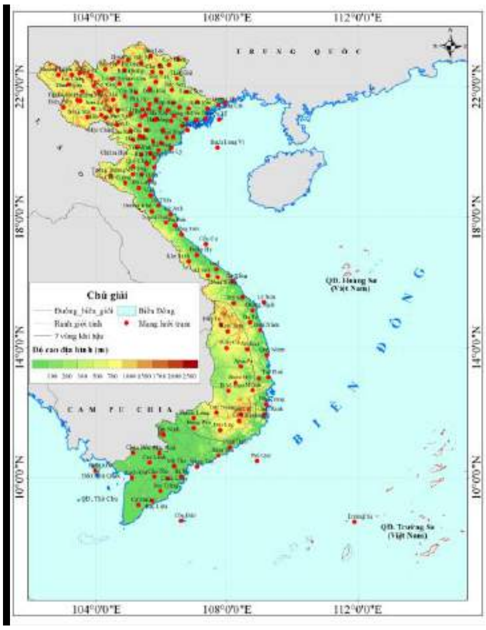


Figure 3.1. The locations of station network

Table 3. 1 . List of observation stations

TT	Name of station	Long (°E)	Lat (°N)	Altitude (m)	Since
			Northwest		
1	Tam Duong	103°29’	22°25’	964.8	1973
2	Muong Te	102°48’	22°23’	336.7	1961
3	Sin Ho	103°14’	22°22’	1533.7	1961
4	Muong Lay (aka Lai Chau)	103°09’	22°04’	243.2	1956
5	Tuan Giao	103°25’	21°35’	571.8	1961
6	Pha Din	103°31’	21°34’	1377.7	1964
7	Dien Bien	103°00’	21°22’	475.1	1958
8	Phieng Lang (Quynh Nhai)	103°38’	21°40’	155.3	1961
9	Son La	103°54’	21°20’	675.3	1960

TT	Name of station	Long (°E)	Lat (°N)	Altitude (m)	Since
10	Bac Yen	104°25′	21°15′	643	1973
11	Co Noi	104°09′	21°08′	670.8	1963
12	Song Ma	103°44′	21°04′	359.5	1962
13	Yen Chau	104°17′	21°03′	314	1961
14	Than Uyen	103°54′	21°01′	601.2	1961
15	Phu Yen	104°38′	21°16′	169	1961
16	Moc Chau	104°41′	20°50′	972	1961
17	Hoa Binh	105°20′	20°49′	22.7	1955
18	Kim Boi	105°32′	20°40′	61.1	1962
19	Mai Chau	105°03′	20°39′	165.5	1961
20	Chi Ne	105°47′	20°29′	11.3	1973
21	Lac Son	105°27′	20°27′	41.2	1961
		VietBac			
22	Sa Pa	103°49′	22°21′	1584.3	1957
23	Ha Giang	104°58′	22°49′	117	1956
24	Hoang Su Phi	104°41′	22°45′	539.4	1961
25	Bac Me	105°19′	22°44′	150	1964
26	Bac Quang	104°52′	22°30′	73	1961
27	Bac Ha	104°17′	22°32′	928.7	1961
28	Luc Yen	104°43′	22°06′	105.5	1960
29	Mu Cang Chai	104°05′	21°51′	955	1962
30	Yen Bai	104°52′	21°42′	55.6	1955
31	Nghia Lo (Van Chan)	104°31'	21°35'	274.6	1961
32	Chiem Hoa	105°16′	22°09′	60.3	1961
33	Ham Yen	105°02′	22°04′	46.2	1961
34	Tuyen Quang	105°13′	21°49′	40.8	1960
35	Cho Ra	105°43′	22°27′	182.6	1961
36	Ngan Son	105°59′	22°26′	517.3	1961
37	Bac Can	105°50′	22°09′	174	1956
38	Dinh Hoa	105°38′	21°55′	106.9	1961
39	Tam Dao	105°39′	21°28′	933.8	1961
40	Phu Ho	105°14′	21°27′	54.1	1960
41	Viet Tri	105°24′	21°19′	30.5	1960
42	Minh Dai	105°03′	21°10′	91.6	1972
43	Thai Nguyen	105°50′	21°36′	35.3	1958
44	Vinh Yen	105°35′	21°17′	10.1	1960
		Northeast			
45	Bao Lac	105°40′	22°57′	209.7	1961
46	Trung Khanh	106°31′	22°50′	531.5	1961
47	Cao Bang	106°15′	22°40′	244.1	1956
48	Nguyen Binh	105°57′	22°39′	491.4	1961
49	That Khe	106°28′	22°15′	162.5	1959
50	Bac Son	106°19′	21°54′	392.6	1962
51	Lang Son	106°46′	21°52′	257.9	1955
52	Dinh Lap	107°06′	21°32′	190.6	1963
53	Huu Lung	106°21′	21°30′	41.5	1961
54	Quang Ha	107°45″	21°27	6.284	1979
55	Tien Yen	107°24′	21°20′	13.6	1956
56	Uong Bi	106°45′	21°02′	2.4	1965
57	Cua Ong	107°21′	21°01′	57.2	1960

TT	Name of station	Long (°E)	Lat (°N)	Altitude (m)	Since
58	Co To	107°46′	20°59′	70	1958
59	Bai Chay	107°04′	20°57′	52.4	1960
60	Luc Ngan	106°33′	21°23′	14.6	1961
61	Son Dong	106°50′	21°20′	58.5	1961
62	Hiep Hoa	105°58′	21°21′	20.565	1970
63	Bac Giang	106°12′	21°17′	7.5	1960
64	Phu Lien	106°38′	20°48′	113.4	1957
65	Hoan Dau	106°48′	20°40′	37.2	1955
66	Bach Long Vi	107°43′	20°08′	55.6	1958
	Northern Delta				
67	Son Tay	105°30′	21°08′	16.8	1958
68	Ba Vi	105°25′	21°09′	30.3	1969
69	Ha Dong	105°46′	20°58′	5.6	1973
70	Lang	105°48′	21°01′	6.0	1956
71	Hung Yen	106°03′	20°39′	3	1960
72	Chi Linh	106°23′	21°07′	33.6	1960
73	Hai Duong	106°18′	20°57′	2.2	1960
74	Thai Binh	106°23′	20°25′	1.9	1960
75	Ha Nam	105°55′	20°31′	2.8	1960
76	Nam Dinh	106°09′	20°26′	1.9	1956
77	Van Ly	106°18′	20°07′	1.8	1959
78	Nho Quan	105°45′	20°19′	3.6	1960
79	Ninh Binh	105°59′	20°15′	3.0	1960
	North Central				
80	Hoi Xuan	105°06′	20°22′	102.3	1955
81	Yen Dinh	105°39′	19°58′	9.2	1962
82	Bai Thuong	105°23′	19°54′	20.7	1961
83	Thanh Hoa	105°47′	19°45′	4.4	1957
84	Nhu Xuan	105°34′	19°38′	12.6	1962
85	Tinh Gia	105°47′	19°27′	4.4	1962
86	Quy Chau	105°07′	19°34′	85.1	1962
87	Quy Hop	105°09′	19°19′	89.2	1968
88	Tay Hieu	105°24′	19°19′	47.9	1960
89	Quynh Luu	105°38′	19°10′	1.6	1962
90	Tuong Duong	104°26′	19°17′	96.1	1961
91	Con Cuong	104°53′	19°03′	33	1961
92	Do Luong	105°18′	18°54′	11.3	1961
92	Vinh	105°40′	18°40′	5.1	1955
94	Ha Tinh	105°54′	18°21′	2.8	1958
95	Huong Khe	105°43'	18°11'	17.0	1961
96	Ky Anh	106°17′	18°05′	2.8	1961
	Mid - Central				
97	Tuyen Hoa	106°01′	17°53′	27.1	196
98	Ba Don	106°25′	17°45′	2.7	1960
99	Dong Hoi	106°36′	17°29′	5.7	1955
100	Con Co	107°20′	17°10′	3.4	1974
101	Dong Ha	107°05′	16°51′	8	1973
102	Khe Sanh	106°44′	16°38′	394.6	1975
103	Hue	107°35′	16°26′	10.4	1976
104	Nam Dong	107°43′	16°10′	59.7	1973

TT	Name of station	Long (°E)	Lat (°N)	Altitude (m)	Since
105	A Luoi	107°17'	16°13'	572.2	1976
106	Da Nang	108°12'	16°02'	4.7	1975
107	Tam Ky	108°28'	15°34'	23	1979
108	Ly Son	109°09'	15°23'	4	1984
109	Tra My	108°14'	15°21'	123.1	1973
110	Quang Ngai	108°48'	15°07'	8.1	1976
111	Ba To	108°44'	14°46'	50.7	1979
			South Central		
112	Hoai Nhon	109°02'	14°31'	17.5	1977
113	Quy Nhon	109°13'	13°46'	7.8	1975
114	Tuy Hoa	109°17'	13°05'	11.6	1976
115	Son Hoa	108°59'	13°03'	38.6	1976
116	Nha Trang	109°12'	12°13'	3.2	1976
117	Cam Ranh	109°09'	11°55'	15.9	1977
118	Truong Sa	111°55'	8°39'	2	1977
119	Phan Thiet	108°06'	10°56'	10	1978
120	Ham Tan	107°46'	10°41'	12	1977
121	Phu Quy	108°56'	10°31'	5.2	1979
			Highland Central		
122	An Khe	108°39'	13°57'	422.2	1978
123	Aunpa	108°27'	13°23'	159.7	1977
124	MDrac	108°46'	12°44'	419	1977
125	Dac To	107°50'	14°39'	620.4	1981
126	Kon Tum	108°00'	14°30'	537.6	1976
127	Playcu	108°01'	13°58'	778.9	1976
128	Buon Ho	108°16'	12°55'	707.2	1982
129	Buon Ma Thuot	108°03'	12°40'	470.3	1976
130	Dac Nong	107°41'	12°00'	631	1978
131	Da Lat	108°27'	11°56'	1508.6	1977
132	Lien Khuong	108°23'	11°45'	957.2	1975
133	Bao Loc	107°49'	11°32'	840.4	1979
			Southern		
134	Phuoc Long	106°59'	11°50'	198.5	1977
135	Dong Xoai	106°54'	11°32'	88.6	1979
136	Tay Ninh	106°07'	11°20'	9.4	1977
137	Vung Tau	107°05'	10°22'	4	1978
138	Con Dao	106°36'	8°41'	6.3	1978
139	Moc Hoa	105°56'	10°47'	1.9	1977
140	My Tho	106°24'	10°21'	1.1	1976
141	Ba Tri	106°36'	10°03'	0.9	1977
142	Cang Long	106°12'	9°59'	1.6	1978
143	Soc Trang	105°58'	9°36'	2.3	1978
144	Can Tho	105°46'	10°02'	1	1976
145	Cao Lanh	105°38'	10°28'	1.8	1978
156	Chau Doc	105°08'	10°42'	4.2	1979
147	Phu Quoc	103°58'	10°13	3.3	1957
148	Rach Gia	105°04'	10°00'	1.4	1979
149	Bac Lieu	105°43'	9°17'	1.2	1980
150	Ca Mau	105°09'	9°11'	1.2	1978

3.1.2. Sea level data

The sea level observation in Vietnam was started at Hon Due station from the beginning of 1938 and was interrupted by the war. By January 1956, the station was back in operation and began measuring four times a day from 1957. For many reasons, data from the station between 1945 and March 1960 were lacking. In addition, before 1956, observation data were measured by other equipment, so systematic differences could occur. From June 1965, the elevation of the station was changed.

In the North, there are also other boat stations such as Co To, Bach Long Vy (1958), Cua Ong, Bai Chay (1960), Hon Ngu (1961), Con Co (1974) and Sam Son (1998). Among them, Bach Long Vy and Hon Ngu stations were temporarily suspended from war. Hon Ngu Station has been continuously measuring since 1990 and Bach Long Vy since 1998. At most stations, the water level is measured in hydrostatic and four times a day.

In the south, the Quy Nhon navigational station was established in 1958 and began monitoring in 1959. Due to the war, Quy Nhon station stopped its observation from 1965 and its observation has been stable since 1986. Since April In 1986, the water level was measured in hours. The water level was measured by hydrostatic, Lapante dynasty (since 1959), Sum machine, Stevens-A35 machine (since 1992). Data before 1986 was severely interrupted and observation locations moved. Data from April 1986 to now is continuous.

Table 3.2. Oceanographic stations used in the analysis and calculations

No	Name of station	Data series	Equipment	Note
1	Cua Ong	1962 - 2014	Gauge	Coastal Station
2	Co To	1960 - 2014	Gauge	Island
3	Bai Chay	1962-2014	Gauge	Coastal Station
4	Bach Long Vi	1998-2014	Gauge	Island
5	Hon Dau	1960-2014	CYM Machine	Island
6	Sam Son	1998-2014	Gauge	Coastal Station
7	Hon Ngu	1961-2014	Gauge. CYM Machine	Island
8	Con Co	1981-2014	Gauge	Island
9	Son Tra	1978-2014	Gauge	Coastal Station
10	Quy Nhon	1986-2014	Gauge, Steven Machine	Coastal Station
11	Phu Quy	1986-2014	Gauge	Island
12	Truong Sa	2002-2014	Gauge	Island
13	Vung Tau	1978-2014	Gauge, Water Level Gauge	Coastal Station
14	Con Dao	1986-2014	Gauge	Island
15	DK I-7	1992-2014	Steven A-71 Machine	Floating rigs
16	Tho Chu	1995-2014	Gauge	Island
17	Phu Quoc	1986-2014	Steven A-71 Machine	Island

After 1975, in the South, many marine stations were built such as Vung Tau, Son Tra (1978), Phu Quy (1979), Con Dao (1986), Phu Quoc (1986), DK I-7 (1992), Tho Chu (1993), Truong Sa (2002). The sea level is mainly monitored by hydrostatic and 4 times a day, with a few stations installed with tides. Most stations have relatively stable measurement data. Particularly, the DK I-7 station is located on floating platform, with sea level data with hourly measurement using the Steven A-71 water level meter since 1992. The station's water column after more than one year of establishment was damaged, the aqueduct of the station is currently attached to the floating platform DK I-7, so the water level measured in recent years tends to fluctuate very strong. Sea level monitoring stations are shown in Table 3.2.

Thus, by 2014, in Vietnam there are 17 marine observation stations along the coast and islands. Among them, Truong Sa station has relatively short data series (13 years), DK I-7 station has unstable data due to hydrostatic attached to floating platform.

Since 1993, measured water level data from satellites have been a reliable source of data for assessing sea level changes in Vietnam. AVISO's oceanographic data set (ERS-1/2), Topex / Poseidon (T / P), ENVISAT and Jason-1/2 . The time resolution data is 7 days and the space is 1/4 theta. Measurement errors have been corrected, such as signal congestion in the troposphere, ionosphere, ocean tide, inertial pressure, and equipment errors.

3.1.3. Terrain Digital Map Data

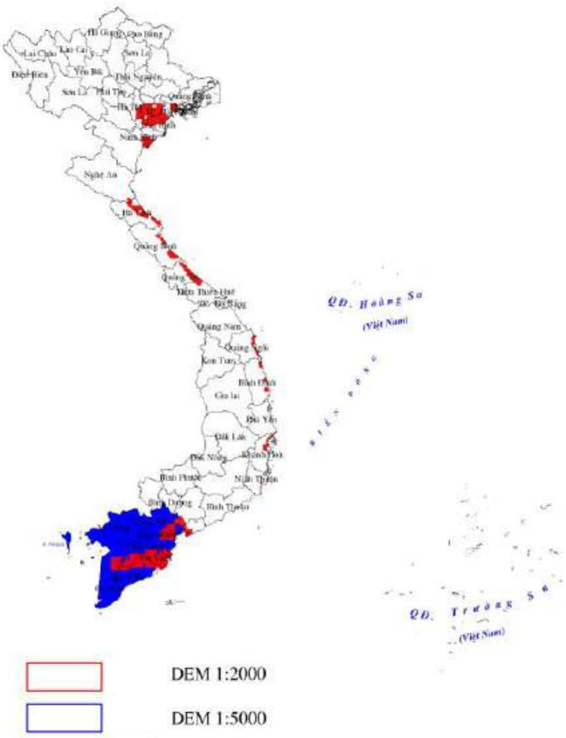


Figure 3.2. Map data of topographical maps of scale 1:2.000 and 1:5.000 of coastal province

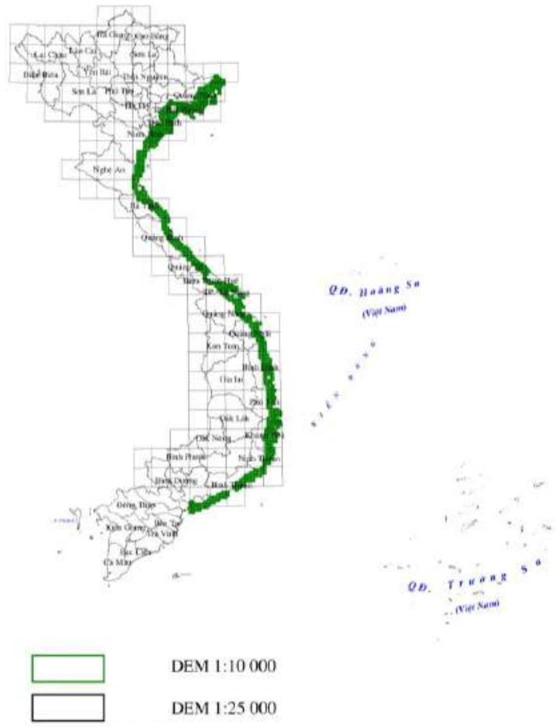


Figure 3.3. Map data of topographical maps of scale 1: 10,000 and 1: 25,000 of coastal province

Terrain data are aggregated and selected from topographic maps of the largest scale and best quality. The map data includes:

+ 1: 10,000 scale terrain map, 5mx5m grid size, 2.5m - 5m accuracy of 19 coastal provinces from Quang Ninh to Binh Thuan (terrain model, administration, hydro model) By the mapping Vietnam in 2012.

+ The grid model of grid size is 2mx2m in 13 Mekong Delta provinces, conducted by the National Remote Sensing Bureau in 2008.

+ The topographic map of the scale of 1: 2.000 by the project of Lidar taken by the Department of Mapping Vietnam in 2016. Size of grid 1mx1m, accuracy 0.2m-0.4m, area of flight The shooting area is 26,765 km2 for 21,535 pieces of DEM maps, of which the North is 8.500 km2 (6904), the Central is 4.765 km2 (4,179) and the South is 13,500 km2 (10,452 pieces).

+ 1: 2,000 terrain model with grid size of 2mx2m in Ho Chi Minh City by the Department of Surveying and Mapping in Vietnam in 2010.

+ 1: 25,000 topographical maps are used for flood-prone areas in the Red River and Central Coast provinces.

Map data of topographical maps at scales are shown in Figure 3.2 and Figure 3.3.

3.2. Observational analysis of climate variables

Box 5. Manifestation of climate change in Viet Nam

- Average annual temperatures increased by 0.62°C in the period 1958-2014, aproximately 0.1°C/decade. The temperatures increased by 0.42°C in the last 20 years when compared with the period 1981-1990.
- Annual rainfall decreased in the North, while it increased in the South.
- Extreme temperatures increased in most of climatic regions, but maximum temperatures decreased in some stations of the South.
- Droughts in the dry season occurred more frequently.
- Extreme rainfall decreased in the Northern Delta, increased considerably in South Central and Central Highlands.
- The number of strong typhoons had an increasing trend.
- The number of extremely cold days decreased, but there were some abnormally cold spells.
- The influence of El Nino and La Nina showed increasing trends.

3.2.1. Temperature

Average temperature tended to increase in most observational stations over Viet Nam, especially in recent decades. In average for the whole country, temperatures increased by 0.62°C in the period 1958-2014. In particular, it increased 0.42°C in period 1985-2014 (**Figure 3.4**). The average trend slope was 0.1°C/decade that was little lower than global slope of temperature (0,12°C/decade, IPCC 2013)

The temperature at coastal and island stations tended to increase a little lower than mainland stations (**Figure 3.5**). In seasonal distribution, the increase among different seasons were also not the same. The highest increase orccured in the winter and the lowest was observed in the spring. In spatial distribution, temperature shows the highest-increasing trend in the Central Highland and the lowest in the South Central of Viet Nam (**Figure 3.6**).

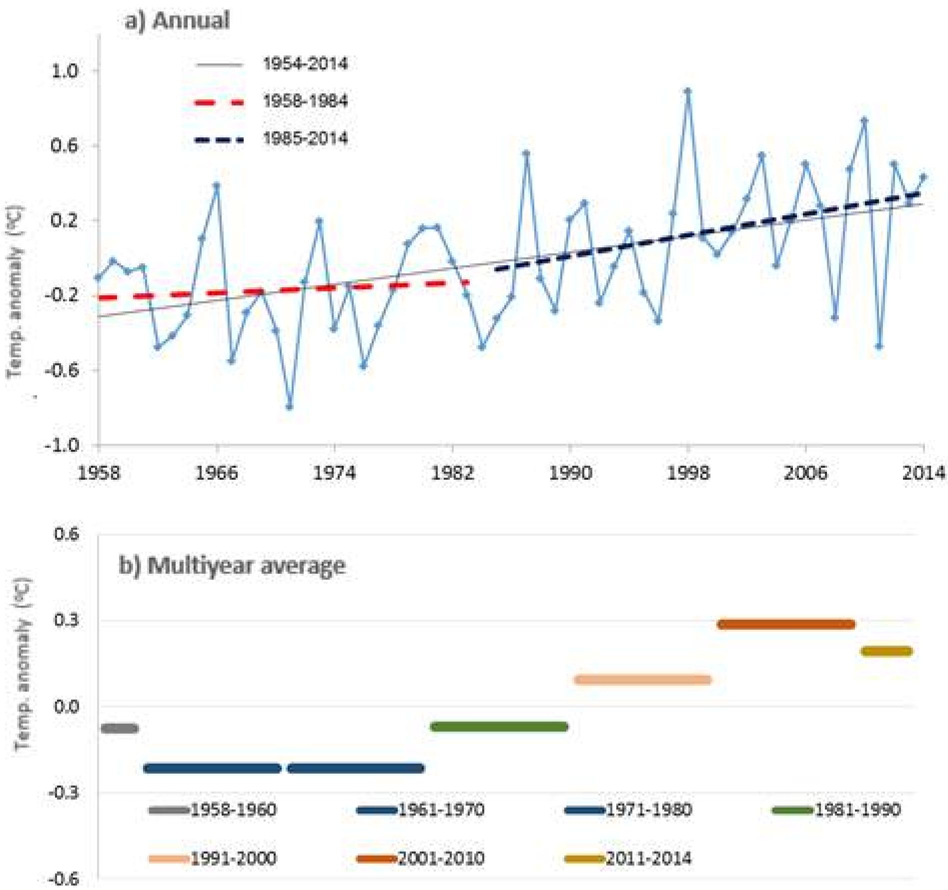


Figure 3.4. Annual and Inter-Annual anomalies of temperature (^{o}C) for the whole country

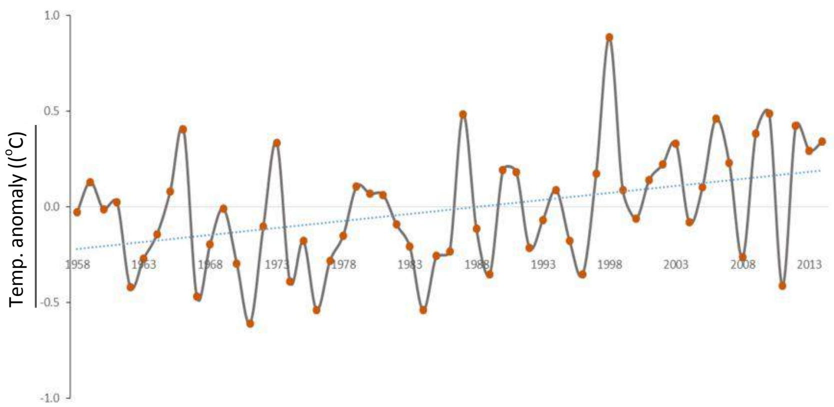


Figure 3.5. Annual anomaly of temperature (^{o}C) at coastal and island stations

3.2.2. Rainfall

In the period of 1958 – 2014, annual rainfall tended to increase slightly over Viet Nam. In seasonal scale, rainfall tended to increase in the winter and spring, however, it reduced in the autumn. It is indicated in **Table 3.3** that the decline in annual rainfall in the Northern part of Viet Nam ranged from 5.8%/57-years to 12.5%/57-years.

But in the southern part of Viet Nam, annual rainfall tended to increase from 6.9%/57-years to 19.8%/57-years. To be more specific, the largest increase in annual rainfall occurred in the South Central of Viet Nam (19.8%/57-years). Meanwhile annual rainfall in the North Delta decreased the largest, by 12.5%/57-years. Specifically, in the Northern part of Viet Nam, rainfall reduced significantly in the autumn and increased slightly in the spring.

In the Southern part, winter and spring rainfall tended to increase that ranged from 35.3 to 80.5%/57-years and 9.2 to 37.6%/57-years, respectively (**Figure 3.7**).

Table 3.3. Change of rainfall (%) during last 57 years (1958-2014) over 7 climatic regions

Climatic Regions	MAM	JJA	SON	DJF	Annual
The NorthWest	19.5	-9.1	-40.1	-4.4	-5.8
The NorthEast	3.6	-7.8	-41.6	10.7	-7.3
The North Delta	1.0	-14.1	-37.7	-2.9	-12.5
The North Central	26.8	1.0	-20.7	12.4	0.1
The South Central	37.6	0.6	11.7	65.8	19.8
The Central Highland	11.5	4.3	10.9	35.3	8.6
The South	9.2	14.4	4.7	80.5	6.9

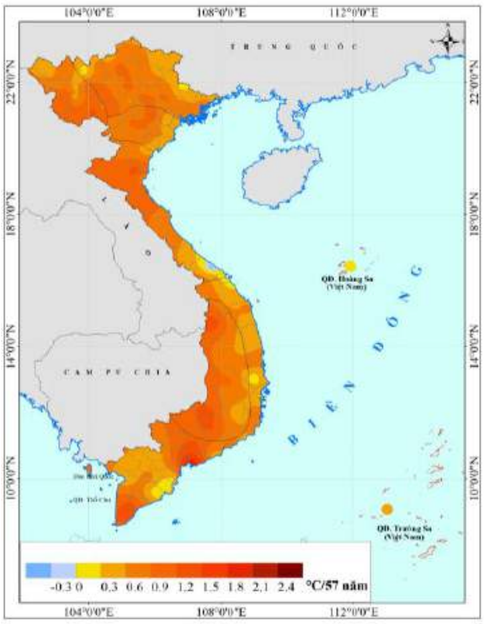


Figure 3.6. Change of annual average temperature (°C) in 1985-2014

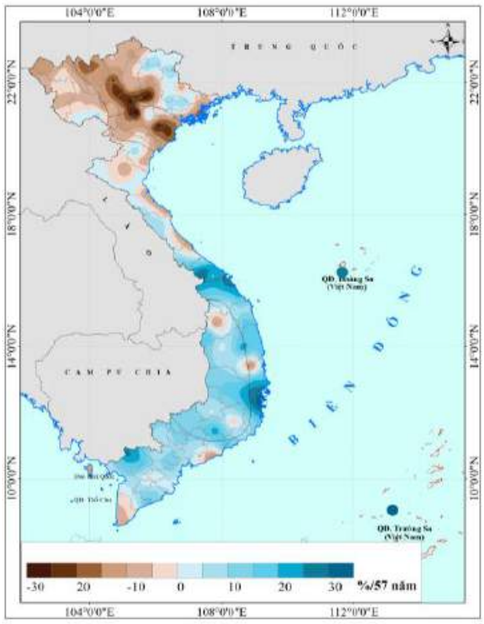


Figure 3.7. Change of annual total precipitation (%) in 1958-2014

3.2.3. Extreme temperature events

According to observation data of 1961 – 2014, maximum (Tx) and minimum (Tm) temperature over Viet Nam tended to increase considerably. The highest rate was up to 1°C/decade. The number of hot days, whose maximum temperature is greater than 35°C, increased virtually in all over Viet Nam, especially in The North East region, The North Delta and The Central Highland. The popular increase was observed by 2÷3 days/decade. However, at some stations in the North West region, and the Southern part of Viet Nam, it tended to decline. Record of maximum temperature was greater year by year. For example, at Con Cuong station, Nghe An, absolute maximum temperature in 1980 was 42°C. In 2010, it was 42.2°C and worse still, it was 42.7°C in 2015.

The number of droughts, especially extreme drought events, increased significantly in Viet Nam. Record events was continuously observed in recent years. Since 2000, droughts has occurred more frequently. Specifically, in 2010, the insufficient level of river flow over Viet Nam was 60÷90%. The water level in several regions was extremely low that was equivalent to insufficient level of 40 to 100-years return period. In 2015, rainy season lasted shorter that drew to inadequate rainfall compared to climatology over Viet Nam, especially in the Southern part of Viet Nam.

The number of cold and extremely cold days, in general, tended to decrease, especially in recent 2 decades. However, several extremely cold events, lasting significantly, occurred frequently with exceptionally low minimum temperature. To be more specific, in 2008, extremely cold weather event lasted 38 days (from January 13th to February 20th) causing snowfall in Mau Son mountain (Lang Son) and Hoang Lien Son mountain (Lao Cai). The average of minimum temperature in these days was from -3^{o}C to -2^{o}C. In the winter of 2015-2016, extremely cold weather dominated over the Northern part of Viet Nam. Although it did not last in many days, the lowest minimum temperature ranged from -5^{o}C to -4^{o}C which was the lowest temperature in recent 40 years. As a result, heavy snow occurred in a large scale, especially in Ba Vi (Ha Noi) and Ky Son (Nghe An) where snowfall has been observed for the first time.

3.2.4. Extreme rainfall events

Extreme rainfall changed differently among distinguish regions. It tended to decrease in most stations of The North West, North East and North Delta region. However, increasing trend was observed in other regions. It is indicated from observation that abnormal rainfall occurred more frequently in recent years. Extreme rainfall was difficult to anticipate in terms of place, time, frequency and intensity. As an example, the amount of rainfall in Ha Noi was by 408 mm from 19h October 30th to 01h November 1st in 2008. The total amount of rainfall in 10-days event in the October ranged from 700 to 1600 mm over NgheAn – Quang Binh region, which account for 50% annual rainfall. In Quang Ninh province, during heavy rainfall event lasting from July 23rd to August 4th, total amount of rainfall was 1000 to 1300 mm, especially at Cua Ong station, gauged rainfall was approximately 1600mm. Heavy rainfall not only occurred in rainy season, but also in dry season. Specifically, from March 24th to 27th at Hue – Quang Ngai region, the total amount of rainfall ranged from 200 to 500mm.

3.2.5. Tropical depressions and typhoons

According to the data from 1959-2015, there are 12 tropical depressions and typhoons in Viet Nam East sea every year. In which, 45% of them were formed in East sea and the remaining were formed in the Pacific Ocean and moved to East sea. Every year, there are 7 tropical depressions and typhoons having impacts on Viet Nam, in which, 5 of them made landfall or directly influence to the mainland of Viet Nam. The highest frequency of tropical depressions and typhoons activity was observed in the center of the north of East sea. Across the coastal line of Viet Nam, the highest frequency of their activities was observed from 16^{o}C to 18^{o}N and from 20^{o}N to the north.

According to the data from 1959-2015, the change in the number of tropical depressions and typhoons in East Sea, influencing and making landfall to Viet Nam was slight. However, the inter-annual variation of number of tropical depressions and typhoons was substantial, sometimes up to 18÷19 storms (in 1964, 1989, 1995 and 2013), sometimes 4÷6 storms (1963, 1969, 1976, 2014, 2015) (**Figure 3.8**). The number of super typhoon (maximum wind speed >= 12 category in Beaufort scale) tended to increase slightly (**Figure 3.9)**. Typhoon season tened to last longer and typhoon tracks had a southward trend.

The activity and impacts of tropical depressions and typhoons on Viet Nam have been abnormal in recent years. In March 2012, Pakhar storm made landfall in the South of Viet

Nam with a record maximum wind speed. The SonTinh (10/2012) and HaiYan (10/2013) made landfall to the North of Viet Nam in the end of storm season that was extraordinary. In 2013, the highest number of storms making landfall to Viet Nam was observed (8 storms and 1 tropical depression).

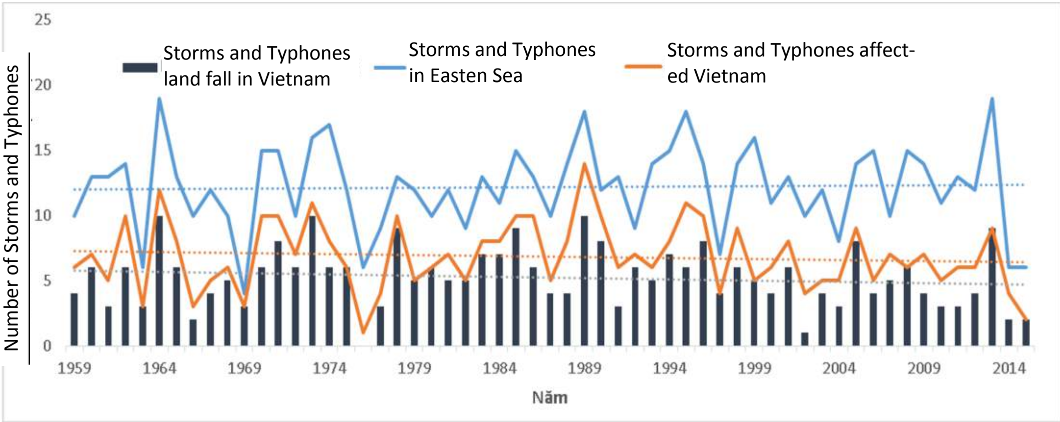


Figure 3.8.The development of tropical depressions and typhoons in period 1959-2014

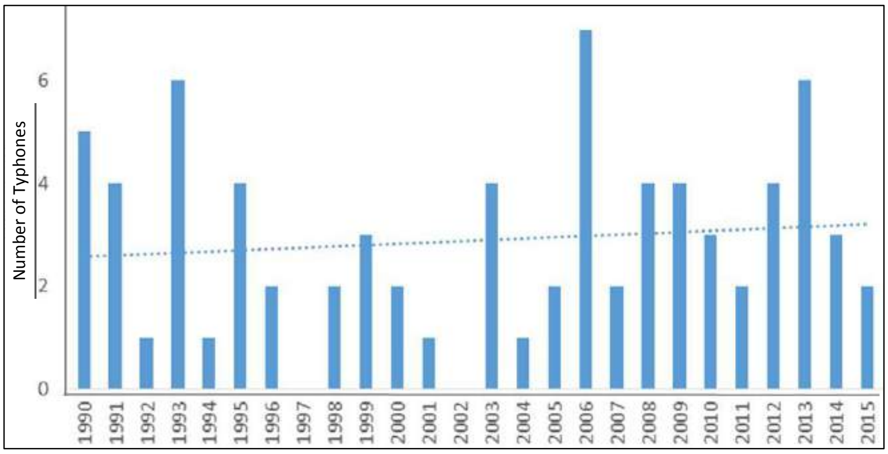


Figure 3. 9. The development of typhoons with maximum wind speed exceeding 12 category in Beafort scale in Viet Nam East Sea (1990-2015)

3.3. Sea level changes

Box 6. Summary of sea level changes in Viet Nam

- From observed data:
  - Sea levels at most of tide gauges show an increase trend.
  - The highest rate is at Phu Quy tide gauge (5,6mm/year).
  - Sea level decreases at Hon Ngu and Co To tide gauges (- 5,77 mm/year and - 1,45mm/year).
  - No clear trend of sea level rise at Con Co and Quy Nhon tide gauges.
  - Mean sea level at all tide gauges increases 2,45mm/year.
  - For the period of 1993-2014, sea level at all tide gauges increases 3,34mm/year.
- From satellite data (1993-2014):
  - Mean sea level over the Viet Nam East Sea increases 4,05±0,6mm/year.
  - Mean sea level at Viet Nam's coastal area increases 3,50±0,7mm/year.

- Sea level rise at South Central Viet Nam is highest with the rate of 5,6mm/year.
- Sea level rise at the Gulf of Tonkin inceares least (2,5mm/year).

3.3.1. Sea level changes from sea-level records from tide gauges

The results show that all the rates of sea level at most of tide gaues are significant (by t-test) exept Con Co and Quy Nhon tide gauges. At most tide gauges, sea level increases with the highest rate at Phu Quy and Tho Chu tide gauges (5,58mm/year and 5,28mm/year, respectively). In contrast, sea level decreases at Co To and Hon Ngu (-1,45mm/year and -5,77mm/year). On average, sea level at all tide gauges show a clear increase 2,45mm/year. **(Table 3.4, Figure 3.10.)** For 1993-2014 period, mean sea level at tide gaues increases with the rate of 3,34mm/year.

Table 3.4. Estimation and significant test of sea level changes

No	Tide gauges	Observation period	Trend	Coefficient test	Conclusion
1	Cua Ong	1962 - 2014	5.23	0.78	Increase
2	Co To	1960 - 2014	-1.39	0.60	Decrease
3	Bai Chay	1962 - 2014	1.54	0.50	Increase
4	Bach Long Vy	1998 - 2014	1.33	0.58	Increase
5	Hon Dau	1960 - 2014	2.02	0.62	Increase
6	Sam Son	1998 - 2014	3.65	0.80	Increase
7	Hon Ngu	1961 - 2014	-5.77	0.71	Decrease
8	Con Co	1981 - 2014	0.61	0.11	No trend
9	Son Tra	1978 - 2014	2.89	0.70	Increase
10	Quy Nhon	1986 - 2014	-0.01	0.09	No trend
11	Phu Quy	1986 - 2014	5.58	0.90	Increase
12	Vung Tau	1978 - 2014	3.19	0.60	Increase
13	Con Dao	1986 - 2014	4.79	0.86	Increase
14	Tho Chu	1995-2014	5.28	0.79	Increase
15	Phu Quoc	1986-2014	3.40	0.76	Increase
	Average		**2.45**		

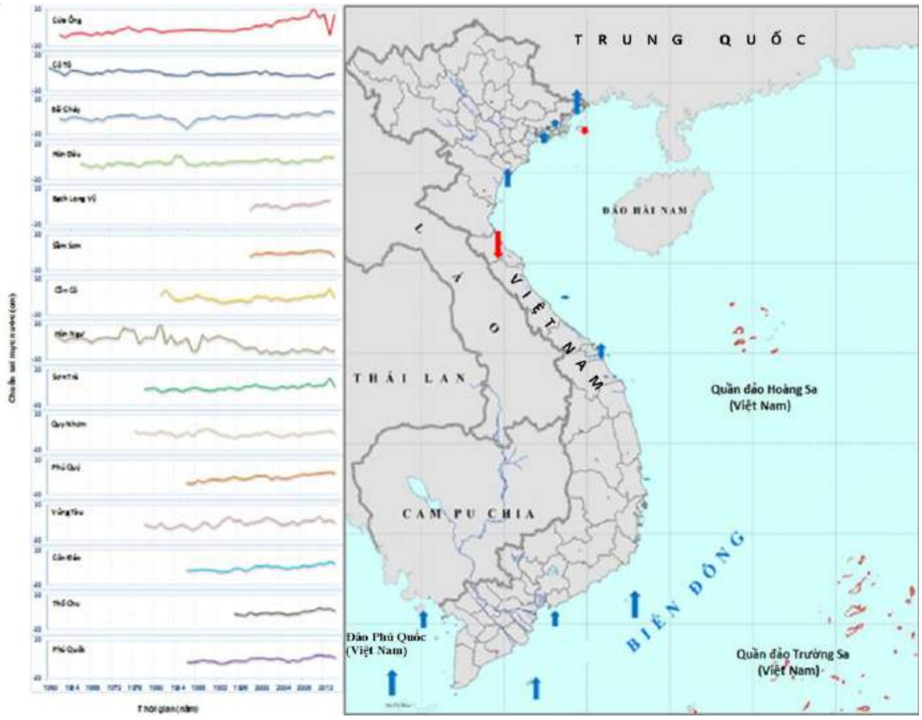


Figure 3. 10. Annual sea level trend at tide gauges

3.3.2. Sea-level changes from satellite data

The method for estimating sea level changes from satellite data is similar as that of obversed data. The results show that, sea level over the Viet Nam East Sea increases with the rate of 4,05±0,6mm/year, higher than global average for the same period (3,25 ± 0,08 mm/year) **(Figure 3.11)**

Spatial distribution of sea level trends is shown in **Figure 3.11**. Sea level rise off-shore Central Viet Nam (from Viet Nam's coastline to Phillippine) is highest (5,0÷5,5mm/year) whereas nothern East Sea shows smallers rate (1,0÷2,0mm/year).

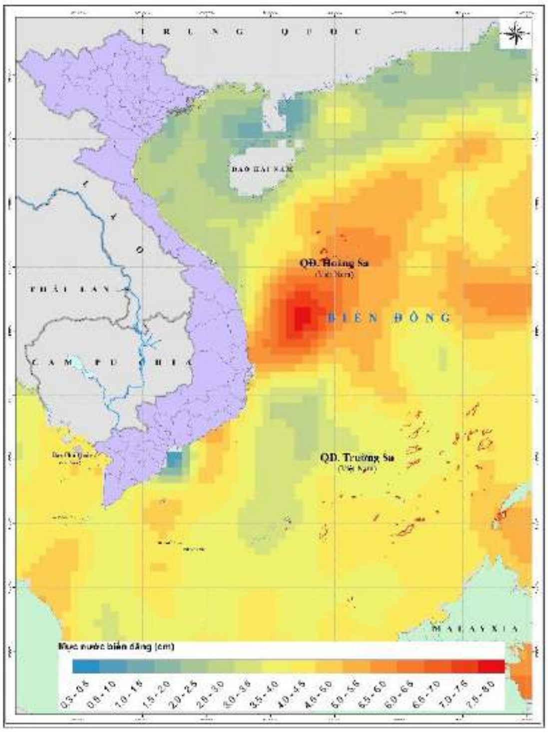


Figure 3. 11. Sea level trends over Viet Nam East Sea from satellite data

On average, sea level along Viet Nam's coastline increases with the rate of 3,50±0,7mm/year. The south central area shows the highest rate (> 4mm/year) whereas the coastal area of Gulf of Tonkin has smallest rate (2,5mm/year) **(Figure 3.11)**

IV. Methodologies for constructing climate change and sea level rise scenarios

4.1. Methodologies of construction of climate change scenarios

4.1.1. Observation trend analysis

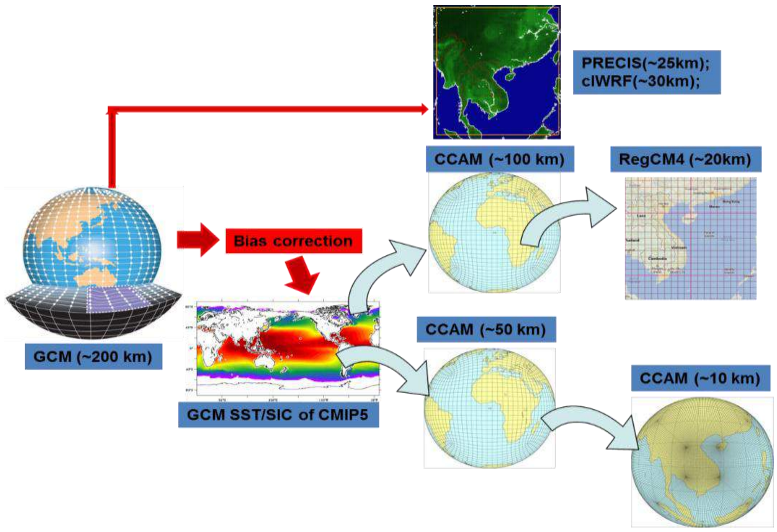
In this project, the linear regression will be employed for analysising the trend climate variables in the past.

4.1.2. Future climate change projection methodologies

1) Dynamical downscaling

Dynamical downscaling method was applied to conduct climate change projection in high resolution for Viet Nam. The advantage of climate dynamic models is that they can consider a lot of physical and chemical processes in the atmosphere as well as provide diverse variables. However, it still has disadvantages which are the high requirement in boundary condition and limited skill in local simulation due to the resolution.

There are 5 Global and Reginal climate models used for calculation: (i) AGCM/MRI from Japanese Meteorology Research Institute, (ii) PRECIS from Hadley Center, United Kingdom, (iii) CCAM from CSIRO, Australia, (iv) RegCM from ICTP, Italy and (v) clWRF from NCAR, USA. Each RCM is driven by GCMs from IPCC AR5 (Figure 4.1). In total, there are 12 used members to update climate change scenario for Viet Nam (Table 4.1)



Firgure 4.1. High-Resolution dynamical downscaling scheme for Viet Nam

- ***CCAM model***

CCAM (Conformal Cubic Atmospheric Model) is a global atmospheric model that has been developed by CSIRO. CCAM is be able to simulate climate in various scales, from global to regional. The model is hydrostatic. It employs semi-Lagrangian horizontal advection with bi-cubic horizontal interpolation. The updated GFDL parameterizations for long-wave and short-wave radiation, Rotstayn cloud scheme, boundary-layer scheme based on Monin–Obukhov similarity theory, CABLE biosphere-atmosphere exchange model having six layers for soil temperatures, six layers for soil moisture and three layers for snow and the cumulus convection scheme using mass-flux closure are employed in CCAM. Particularly, CCAM also includes a simple parameterization to enhance role of SSTs under conditions of low wind speed and large downward solar radiation, affecting the calculation of surface fluxes. CCAM uses three-dimensional Cartesian, higher resolution in the domain center and lower resolution in other regions (McGregor 1993, 1996, 2003, 2005a,b; McGregor và Dix 2001, 2008).

- ***PRECIS model***

PRECIS (Providing Regional Climates for Impacts Studies) has been developed by Hadley center, UK. This model can be uses on a personal computer for climate change scenarios for a limited area. PRECIS can be set up for using with the 2 resolutions including 50x50 km and 25x25 km. PRECIS version 2.0 used in Viet Nam is HadRM3P. This is an updated version of HadAM3P which is a part of global couple model HadCM3.

Table 4.1. Information on RCMs used for updating climate change scenario

No	RCM	Organization	Driving GCMs	Resolution, Domain	Vertical level
1	clWRF	NCAR, NCEP, FSL, AFWA, …	1. NorESM1-M	30 km, 3.5-27^{o}N and 97.5-116^{o}E	27
2	PRECIS	Hadley, UK	1. CNRM-CM5 2. GFDL-CM3 3. HadGEM2-ES	25 km, 6.5-25^{o}N and 99.5-115^{o}E	19
3	CCAM	CSIRO, Australia	1. ACCESS1-0 2. CCSM4 3. CNRM-CM5 4. GFDL-CM3 5. MPI-ESM-LR 6. NorESM1-M	10 km, 5-30^{o}N and 98-115^{o}E	27
4	RegCM	NCAR, USA	1. ACCESS1-0 2. NorESM1-M	20 km, 6.5-30^{o}N and 99.5-119.5^{o}E	18
5	AGCM/MRI	Meterology Research Institute (MRI)	1. NCAR-SST 2. HadGEM2-SST 3. GFDL- SST 4. Ensemble SSTs	20 km	19

- ***RegCM model***

Regional Climate Model was primarily developed by NCAR, USA based on Community Climate Model (CCM) and Mesoscale Model version 4 (Marshall và Henson, 1997). This model uses compressive atmospheric assumptions, satistics on hydrostatic balance and uses σ vertical coordinate. This model can be utilized for climate predictions and simulation after several times of improvement in physical parameterization schemes, radiation schemes and land surface schemes. A RegCM system consists of 4 principal components which are terrain, initial and boundary condition, RegCM and post processing. RegCM can be driven by global climate models, global reanalysis data such as ERA40, NNRP1, NNRP2, JRA25, ect. RegCM version 4, which are employed in this project, has been improved significantly compared to previous versions by ICTP, Italy.

- ***clWRF model***

Weather Research and Forecast is a flexible model which can be used for many purposes of weather and typhoon forecast or climate projection (clWRF). clWRF is basically similar to weather forecast version. However, it is enhanced by integrating several GHG modules from SRES as well as RCP (Peter et al., 2009; Chakrit et al., 2012; Fita et al., 2009).

ClWRF model employs CAM radiation scheme with mixing ratio of CO_2 from SRES-A2. It is not difficult to adjust the mixing ration of 5 gases including CO_2, N_2O, CH_4, CFC-11 and CFC-12 (Fita, 2010). The output of the model consits of mean and extreme variable such as temperature at 2m, rainfall, windspeed, relative humidity.

- ***AGCM/MRI model***

AGCM/MRI is the combination between weather forecast and climate prediction model. It can be use for simulation of long climatology with the resolution 20km and 60 km. The historical simulation by AGCM/MRI prolongs 25 years (1979-2003) and the projection under RCP8.5 lasts also 25 years (2075-2099).

2) Selection of future climate projections

Climate change scenarios for Viet Nam are constructed using 5 regional climate models (AGCM/MRI, PRECIS, CCAM, RegCM, clWRF). In total, 16 members are employed in calculation, 5 RCMs driven by different GCMs. AGCM/MRI: 4 members (NCAR, SSTHadGEM2, SSTGFDL-SST, Ensemble SSTs); PRECIS: 3 members (CNRM-CM5, GFDL-CM3, HadGEM2-ES); CCAM: 6 members (ACCESS1-0, CCSM4, CNRM-CM5, GFDL-CM3, MPI-ESM-LR, NorESM1-M); RegCM: 2 members (ACCESS1-0, NorESM1-M); clWRF: 1 member (NorESM1-M).

By applying different models, the obtained information would be more objective. It also produces the result more reability and higher certainty (Weigel và nnk, 2008). Therefore, IPCC recommends to use the ensemble of multi model results to accquire better calculation results (IPCC 2007).

It is indicated from evaluation of those RCMs skill in simulating climate for Viet Nam that most models produced temperature well over Viet Nam, except clWRF with large system bias. For rainfall, the difference in simulation among RCMs is clearly. In which, PRECIS shows the best skill (Nguyen Van Hiep, 2015). Therefore, temperature change scenarios are constructed by ensemble of all members, while rainfall change scenarios are built by ensemble of 3 PRECIS members.

The change of several climatic variables in future periods is calculated in comparison with baseline period of 1986 - 2005.

For mean, maximum and minimum temperature:

$$\Delta \boldsymbol{T}_{future} = \boldsymbol{T}^{*}{}_{future} - \overline{\boldsymbol{T}^{*}_{1986-2005}} \qquad \textbf{(4.1)}$$

For precipitation:

$$\Delta \boldsymbol{R}_{future} = \frac{(\boldsymbol{R}^{*}{}_{future} - \overline{\boldsymbol{R}^{*}_{1986-2005}})}{\overline{\boldsymbol{R}^{*}_{1986-2005}}} * \mathbf{100} \qquad \textbf{(4.2)}$$

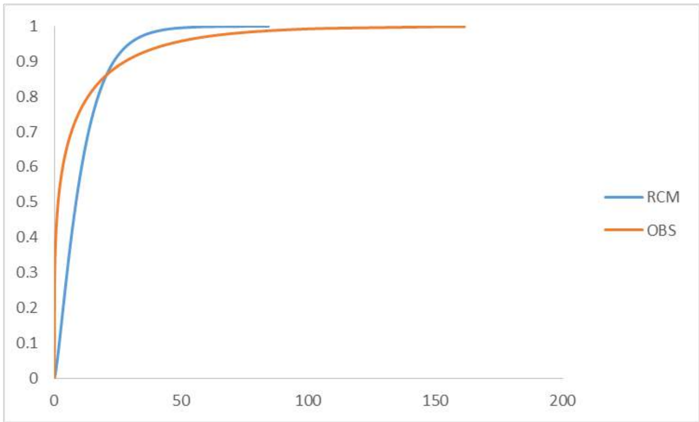
Where: ΔT_{future} and ΔR_{future} are the change of temperature and rainfall respectively in the future compared to baseline period (^{0}C). T^*_{future} and R^*_{future} are also temperature and rainfall in the future respectively. $T^*_{1986-2005}$ and $R^*_{1986-2005}$ are climatology of temperature and rainfall in the period of 1986 - 2005, respectively.

4.1.3. Statistical bias-correction method

As presented above, dynamical model can stimulate well physical and chemical processes in the atmosphere as well as provide many climatic variables. However, because of the limited resolution, this type of model cannot capture accurately climate at a small local region, specifically in a complicated topographic region. Moreover, systematic errors always exist inside the model. Therefore, it is very necessary to apply bias correction method using observation data at local station to minimize the bias from model simulation. The bias correction procedures for daily temperature and rainfall are showed below.

1) Bias correction for rainfall

Quantile Mapping is employed to adjust daily rainfall from model by observation data. At each quantile of model result, a transfer function is used to eliminate partly bias to gain a new value approximating with observation (Ines, V. M. et al., 2006; Kumar Mishra, B et al., 2014).



Firgure 4.2. Cumulative distribution function (CDF) of rainfall
(Red: OBS, Blue: RM)

2) Bias correction for temperature

This method is proposed by Amengual et al. in 2012. The main idea is to remove the bias at each corresponding quantile and this method can be applied for average, maximum and minimum temperature. It consists of 2 main steps:

Construction of empirical cumulative distribution of model and observation dataset. At each quantile, adjusting model temperature base on transfer function which is expressed below:

$$P_i = O_i + g\bar{\Delta} + f\Delta'_i$$

Where i is ith quantile, O and P are observation and adjusted temperature at ith quantile, respectively. $\bar{\Delta} = \bar{S_f} - \bar{S_c}$ of which $\bar{S_f}$ and $\bar{S_c}$ are average raw temperature in future and baseline period. $\Delta'_i = S_{fi} - S_{ci} - \bar{\Delta}$ whereas, S_{fi} and S_{ci} are raw temperature at ith quantile in future and baseline period, respectively. *g* is set to 1 and *f* is showed.

$$f = \frac{\sigma_o}{\sigma_{S_c}}$$

Where σ_{S_c} and σ_o are respectively standard deviation of baseline from observation and model

4.1.4. Assessment of confident levels of climate change projections

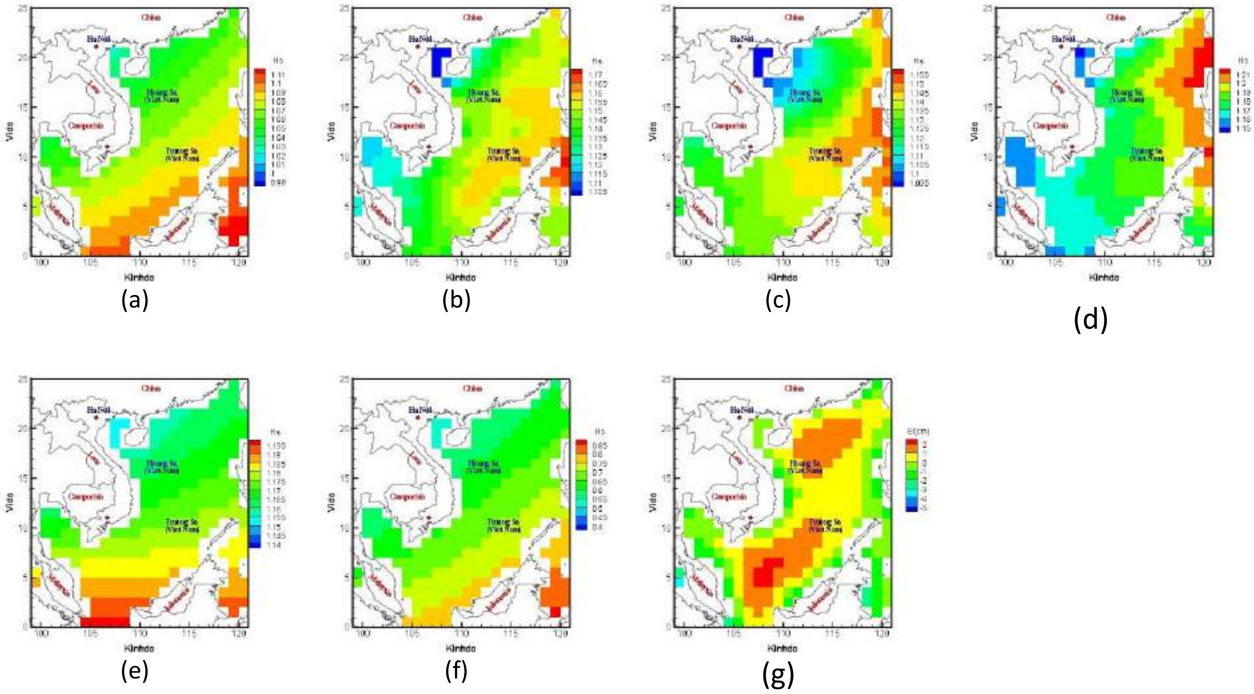
In climate change scenarios, the state of climate in the future is addressed basde on greenhouse gas (GHG) scenarios. Different GHG input for climate model generates different climate change scenarios. In addition, there are many uncertainty sources inside the model as well as from the outside. It is indicated that the uncertainty in climate change scenario is very clear for any region in the world. Therefore, it is indispensable to consider several situations and state of climate in the future under some GHG scenarios.

In this report, not only ensemble mean scenario but also range of change in scenario is provided. It makes the scenario more confident for users.

4.2. Methods for constructing sea-level rise scenarior due to climate change

4.2.1. Methods for sea-level rise scenarios

The method to determine sea level rise for Vietnam was developed based on IPCC's AR4, Church (2013), and Slangen (2014), other sea level rise scenarios from Australia, the Netherlands, and Singapore.



Firgure 4.3. Spatial distributions of sea-level rise contributing components

Legend: (a) Glacier melting; (b) surface mass balance of the Greenland Ice Sheet; (c) Antarctic Ice Sheet surface mass balance; (d) Ice sheet dynamics in Greenland; (e) ice sheet dynamics in Antarctica; (f) land water storage changes, (g) GIA

The total sea-level rise is considered as a sum of (i) thermosteric processes, (ii) melting of glaciers, (iii) surface mass balance of the Greenland Ice Sheet (GSMB), (iv) Abtarctic Ice Sheet surface mass balance (ASMB), (v) ice sheet dynamics in Greenland (GDIS), (vi) ice sheet dynamics in Antarctica (ADIS), (vii) land water storage, and (viii) glacial isostatic adjustment (GIA). **Error! Reference source not found.** presented the spatial distributions of contributing components for East Sea from global data (Slagen, 2014).

Table 4.2 presented contributing components of global sea-level rise and calculating methods for sea-level rise for Viet Nam East Sea.

Sea-level rise scenarios are built for 28 coastal provinces, Hoang Sa and Truong Sa archipalegos, the mean sea-level rise for seven coastal regions and for entire East Sea.

Table 4. 2 Components contributing to sea level rise

No.	Component	Method	Data
1	Thermal expansion	Calculated by the contribution of change in sea level rise due to global thermal expansion (zosto-ga) in AOGCM. The component is adjusted before interpolating for the Viet Nam Sea region under	Coupled at-mosphere-ocean model - global climate model

No.	Component	Method	Data
		the guidance of the IPCC.	AOGCM.
2	Glaciers and ice caps	Interpolation for Viet Nam Sea regions using Slangen's method (2014), based on average global data.	From "*glaciers*" in the IPCC data.
3	Greenland ice sheet	Interpolation for Viet Nam Sea regions using Slangen's method (2014), based on average global data.	From "*greensmb*" in the IPCC data.
4	Antarctic ice sheet	Interpolation for Viet Nam Sea regions using Slangen's method (2014), based on average global data.	From "*antsmb*" in the IPCC data.
5	Greenland ice sheet dynamics	Interpolation for Viet Nam Sea regions using Slangen's method (2014), based on average global data.	From "*greendyn*" in the IPCC data.
6	Antarctic ice sheet dynamics	Interpolation for Viet Nam Sea regions using Slangen's method (2014), based on average global data.	From "*antdyn*" in the IPCC data.
7	Land water storage	Interpolation for Viet Nam Sea regions using Slangen's method (2014), based on average global data.	From "*landwater*" in the IPCC data.
8	Glacial isostatic adjustment	Using the results of ICE5G model, including components of rate changes in geoid, vertical shifting speed.	From the results of ICE5G model.

Firgure 4.4. Zoning map and grid cells for coastal regions

4.2.2. Estimation of uncertainty of sea-level rise

1) Uncertainty of total sea-level rise estimations

The level of uncertainty of the total sea level rise was determined based on the sum of the uncertainties of each individual component. For the dynamic and thermosteric components, uncertainty was determined based on the models utilized. For the changes in surface mass balance, it is assumed that the component is seriously influenced by the magnitude of climate change. For the glaciers, uncertainty was determined based on IPCC (2013).

The level of uncertainty of each component (except for the glacial isostatic adjustment) has a central estimate (median), an upper and lower estimate which are indicative of the 5th and 95th percentiles of the distribution and/or the likely range assessed in the IPCC AR5 (2013). A sum of the estimates of the uncertainty of each component was determined so that a total value of the possible variation of the sea level rise for Vietnam could be calculated.

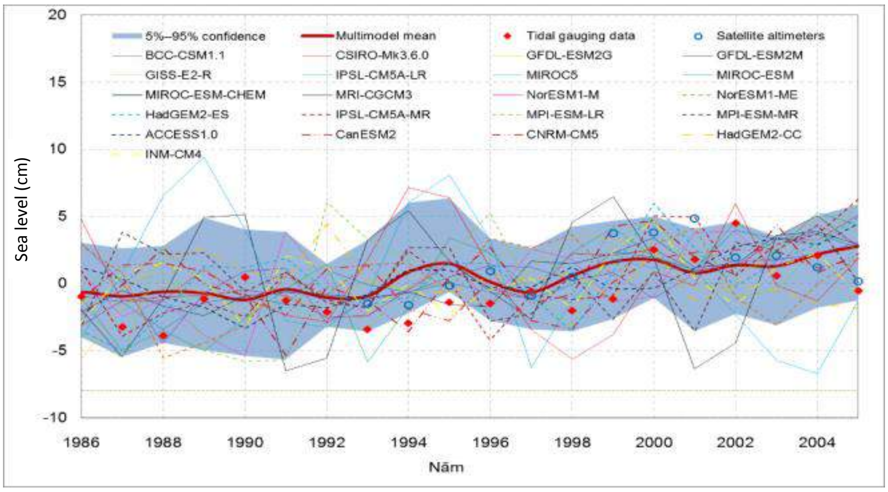
The level of uncertainty in the calculation of the total sea level rise was determined assuming that all contributions have a strong correlation with global air temperature and are correlated uncertainties; therefore can be added linearly as follows (Church, 2013):

$$\sigma^2_{tot} = (\sigma_{steric/dynamic} + \sigma_{smb\_a} + \sigma_{smb\_g})^2 + \sigma^2_{glac} + \sigma^2_{LW} + \sigma^2_{GIA} + \sigma^2_{dyn\_a} + \sigma^2_{dyn\_g} \quad (4.5)$$

In which: σ_{tot} is the total uncertainty of sea level; $\sigma_{steric/dynamic}$, σ_{smb_a}, σ_{smb_g}, σ_{glac}, σ_{LW}, σ_{dyn_a}, σ_{dyn_g} are the uncertainties of the thermosteric, dynamic sea level, surface mass balance in Antarctica, surface mass balance in Greenland, glaciers, land water storage, dynamic ice sheet in Antarctica; and dynamic ice sheet in Greenland respectively.

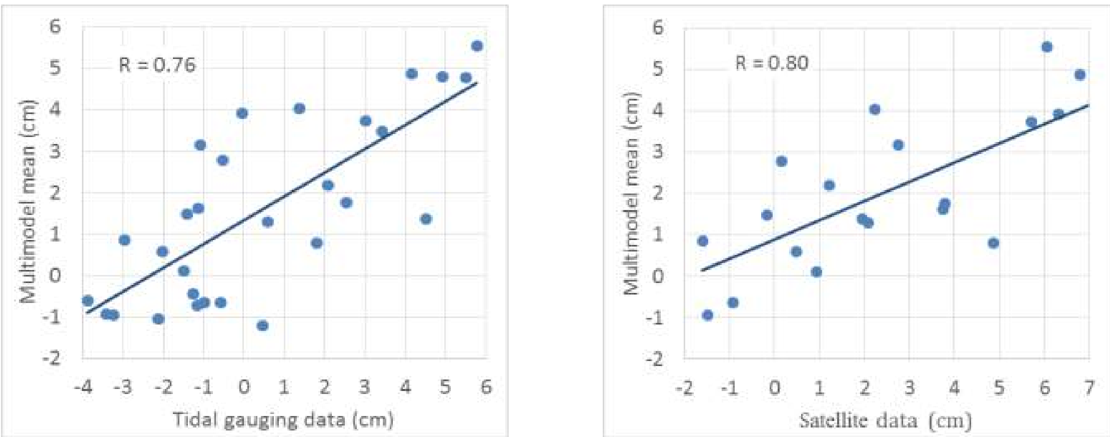
2) Results

Figure 4.5 compares the standard deviations of: (1) observed sea-level data from tide gauges, (2) satellite data and (3) from AOGCMs. Comparing the results of the calculation of the water level standard deviation with the data of the coastal areas and islands of Vietnam including: (1) data from marine stations, (2) observation data from satellites , And (3) calculation results from AOGCMs models. It can be seen that for the period 1986-2013, calculated trend of changing sea level in the Vietnam East Sea is in line with both observed data and satellite data. The rate of sea level change estimated from tide gauges is approximately 2.8mm/year, slightly higher than results from AOGCMs (approximately 2.4mm/year). In general, for most of the analyzed period, average sea water level at tide gauges as well as satellite data are within the 5-95% confidence interval of the modelled results.



Firgure 4.5. Standard deviations of sea level from tide gauges (red diamond shaped), satellite data (blue circle), AOGCMs (dotted lines), multimodel mean (red bold line), The grey shaded area indicates confident interval.

Correlation coefficient of standard deviations between models and tide gauges during period of 1986-2014 is 0.76 whereas correlation coefficient between models and satellite data is 0.8 for the period of 1993-2014.



Firgure 4.6. Correlation between ensemble mean sea level of models and observed data from a) tidal gauging stations in the Vietnam East Sea for the period of 1986-2014 and b) satellite data for the period 1993-2006 (b).

4.3. Method for mapping inundation risk from sea-level rise

Inundation risk map from sea level rise is established on the basis of the data presented in section 3.1.3.

Inundation risk maps for 34 provinces/cities of coastal and delta regions are constructed in correspondence to sea-level rise from 50cm to 100cm with the interval of 10cm. For 10 island groups, the flood risk maps are constructed at level of 100cm.

Inundation risk maps express inundation topography by basic contours with 10 cm intervals, if the basic contours could not describe the shape of inundation areas, a half of the basic contour. In case there is a need for expressing inundation areas in detail, subsidiary contours with suitable height would be used.

V. Climate change scenarios for Vietnam

Some noteworthy points in the climate change scenario for Vietnam: (i) Meteorological data acquired from land and island stations till 2014 have been used for calibration; (Ii) The future change of climate variables has been compared to the mean value of the baseline period (1986-2005); (iii) Calculated results of climte variables from models have been extracted by daily average values from 1986 to 2100; Climate change in the future has been analyzed and presented for the first century (2016-2035), mid-century (2046-2065) and the end of the century (2080-2099). Comparison between the baseline period 1986-2005 and the period 1980-1999, the average temperature increased by 0.1^{o}C in the North and the South, 0.07^{o}C in the Central; Precipitation will likely decrease by 6÷13% in the Northwest, Northeast, North Delta and North Central Coast, while there will likely be unchanged in other areas.

Box 7. Summary of climate change scenarios by the end of 21st century

- ***Temperature****:* For the RCP4.5 scenarios, surface temperatures would increase by 1.9÷2.4^{o}C in the North and 1.7÷1.9^{o}C in the South. For the RCP8.5 scenarios, temperature would increase by 3.3÷4.0^{o}C in the North and 3.0÷3.5^{o}C in the South. Extreme temperatures would have an upward trend.
- ***Rainfall****:* For the RCP4.5 scenarios, annual rainfall would generally increase in a range of 5÷15%. For the RCP8.5 scenarios, the greatest increase would be over 20% in most of the North, Central Coast, a part of the South and Central Highlands. Average maximum 1-day rainfall would increase all over Viet Nam (10÷70%) compared to the baseline period.
- ***Monsoon and climate extremes****:* The number of strong and very strong typhoons has an upward trend. The summer monsoon would start earlier and end later. Monsoon rainfall would have an increased trend. The number of extreme cold and damage cold days would reduce in the provinces of the North, the Red River Delta, the North Central. The number of hot days (Tx ≥ 35°C) would increase, the largest increase would be in the North Central Coast, South Central Coast and Southern Viet Nam. Droughts would become more severe due to rising temperatures and rainfall deficit in the dry season.

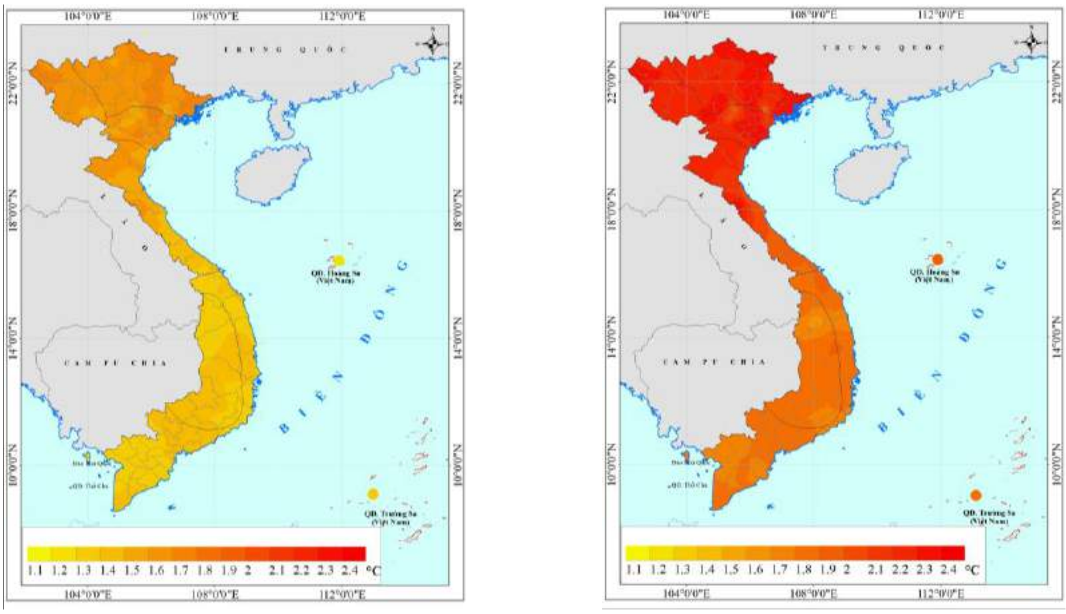
5.1. Climate change scenarios for temperature

5.1.1. Average temperature

1) Average annual temperature

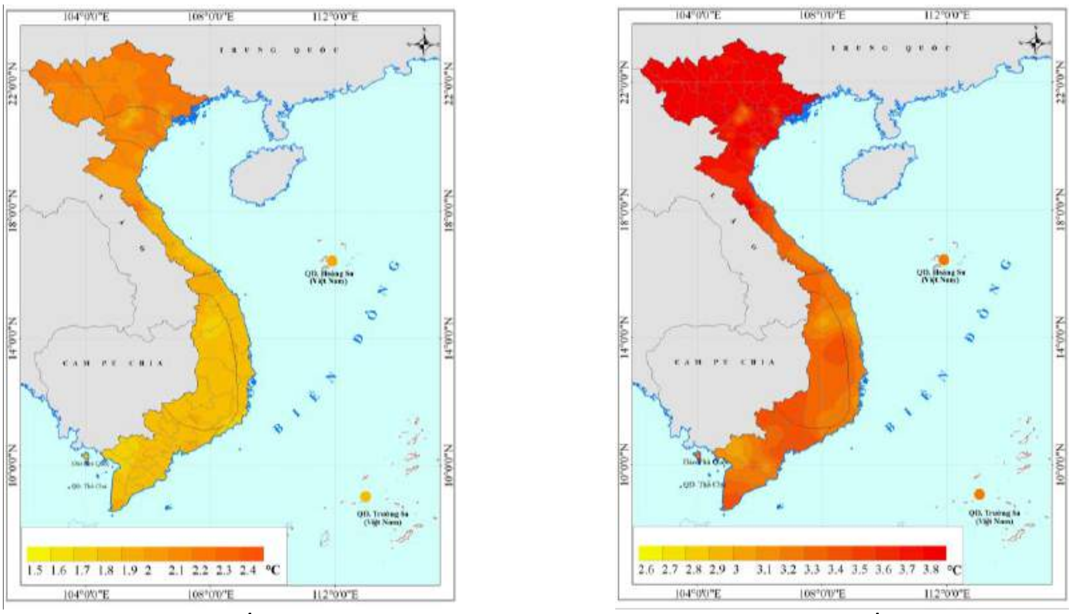
According to the RCP4.5 scenario, the average temperatures at the beginning of the century will likely increase by 0.6-0.8^{o}C throughout the country. At the middle century, the temperatures are expected to increase by 1.3-1.7^{o}C, in which increase by 1.6-1.7^{o}C in the North (the Northwest, the Northeast and the Red River Delta), 1.5-1.6^{o}C in the North Central Coast, 1.3-1.4^{o}C in the South (the South Central Coast, the Central Highlands and the Mekong River Delta). At the end of the 21st century, temperatures in the North will likely increase by 1.9-2.4^{o}C, while the temperature will likely increase by 1.7-1.9^{o}C in the South (**Error! Reference source not found.**).

According to the RCP8.5 scenario, at the beginning of the century, average annual temperature will likely increase by 0.8-1.1^{o}C for the country. At the mid-21st century, the temperature will likely increase by 1.8-2.3^{o}C, in which the temperature of the North will likely increase by 2.0-2.3°C and 1.8-1.9°C in the South. At the end of the century, temperature will likely increase by 3.3-4.0°C in the North and increase by 3.0-3.5°C in the South **(Figure 5.2)**.



(a) mid-21st century *(b) end of 21st century*

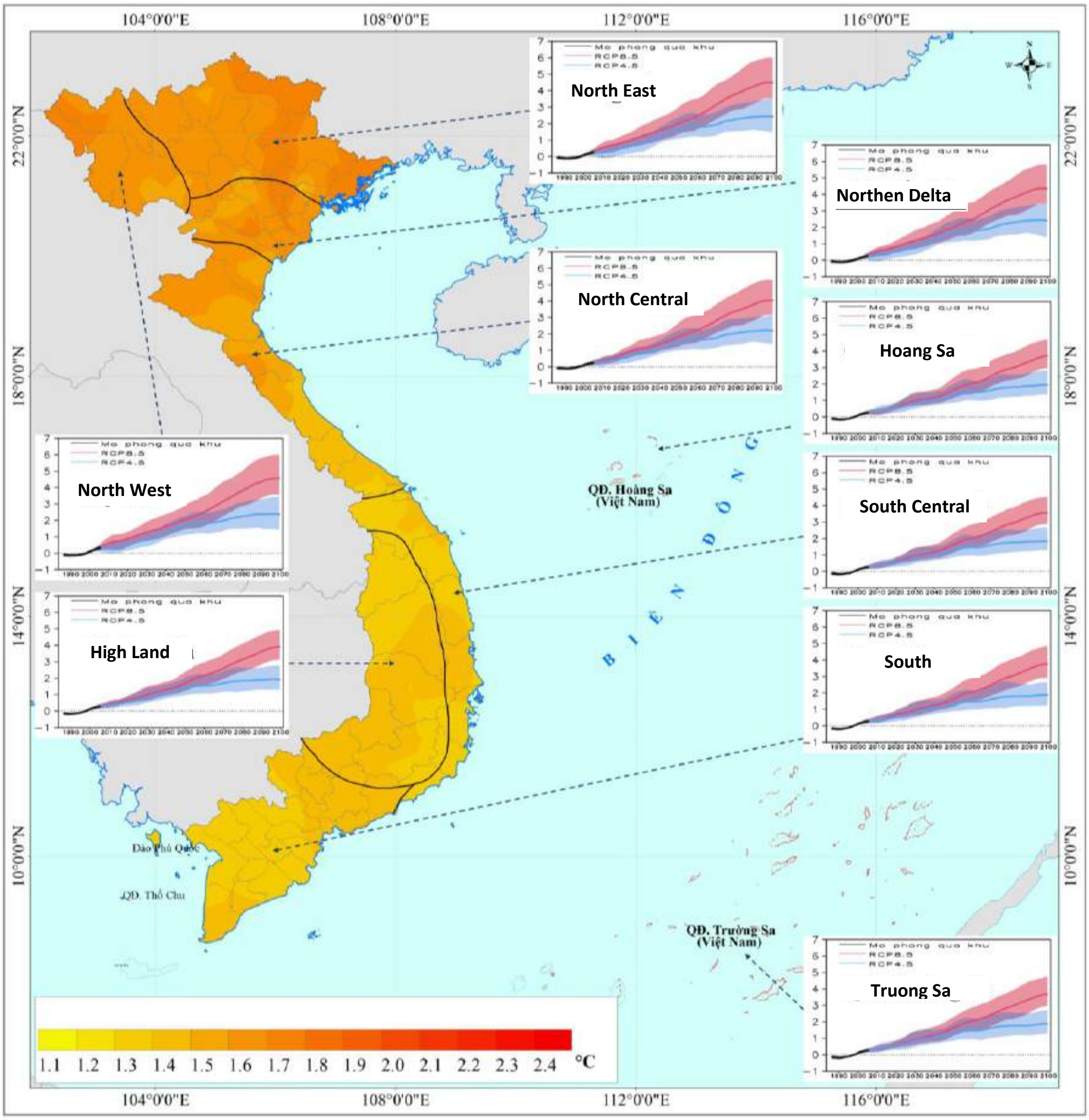
Firgure 5.1. Changes in average annual temperature (°C) based on RCP4.5 scenario



(a) mid-21st century *(b) end of 21st century*

Firgure 5.2. Changes in average annual temperature (°C) based on RCP8.5 scenario

The increases in mean annual temperature for 63 provinces/cities at the beginning, the middle and the end of the century, compared to the baseline period, are shown in Table 5.1. Trends and changes in average annual temperature for 7 regions and islands of Viet Nam are shown in Figure 5.3. Values in parentheses are the range of temperatures changes from the climate model results with the lower boundary of 10% and the upper boundary of 90% (for example, by the mid-21st century, in Lai Chau, the increases in average temperature based on climate models can be in a range of 1.2-2.3°C, and 1.7°C in average). Trends and the average changes for each province of seven climatic zones in Viet Nam are presented in Appendix A.



Firgure 5.3. Changes in average annual temperature (°C) over 7 regions and Islands of Vietnam

Table 5.1. Changes in average annual temperature (°C) compared with the period 1986 - 2005

(Values in parentheses are the range of temperatures changes from the climate model results with the lower boundary of 10% and upper boundary of 90%)

No.	Province, city	RCP4.5 scenario			RCP8.5 scenario		
		2016-2035	2046-2065	2080-2099	2016-2035	2046-2065	2080-2099
1	Lai Chau	0.7 (0.4-1.1)	1.7 (1.2-2.3)	2.3 (1.5-3.3)	1.1 (0.6-1.7)	2.2 (1.4-3.1)	3.9 (3.1-5.5)
2	Dien Bien	0.7 (0.4-1.1)	1.7 (1.2-2.3)	2.3 (1.5-3.3)	1.1 (0.6-1.7)	2.2 (1.4-3.2)	3.9 (3.0-5.6)
3	Son La	0.7 (0.3-1.1)	1.6 (1.2-2.3)	2.3 (1.6-3.2)	1.1 (0.6-1.6)	2.2 (1.5-3.2)	3.9 (3.0-5.6)
4	Hoa Binh	0.7 (0.3-1.1)	1.6 (1.2-2.3)	2.3 (1.6-3.3)	1.0 (0.6-1.5)	2.2 (1.4-3.3)	3.8 (2.9-5.5)
5	Lao Cai	0.7 (0.3-1.1)	1.7 (1.2-2.3)	2.3 (1.5-3.3)	1.1 (0.6-1.6)	2.2 (1.5-3.2)	3.9 (3.1-5.6)
6	Ha Giang	0.6 (0.1-1.1)	1.7 (1.1-2.5)	2.3 (1.5-3.5)	1.1 (0.6-1.6)	2.2 (1.5-3.3)	3.9 (3.1-5.8)
7	Yen Bai	0.6 (0.2-1.1)	1.7 (1.2-2.3)	2.3 (1.6-3.3)	1.1 (0.6-1.6)	2.2 (1.5-3.2)	3.9 (3.1-5.6)
8	Cao Bang	0.6 (0.2-1.1)	1.7 (1.2-2.6)	2.3 (1.6-3.4)	1.1 (0.6-1.6)	2.2 (1.5-3.5)	4.0 (3.1-5.7)
9	Tuyen Quang	0.6 (0.1-1.1)	1.7 (1.2-2.5)	2.4 (1.7-3.5)	1.1 (0.5-1.7)	2.3 (1.5-3.4)	4.0 (3.0-5.8)
10	Bac Kan	0.6 (0.2-1.1)	1.7 (1.2-2.6)	2.3 (1.6-3.5)	1.1 (0.6-1.6)	2.2 (1.5-3.4)	4.0 (3.1-5.7)
11	Lang Son	0.6 (0.2-1.0)	1.7 (1.2-2.6)	2.3 (1.6-3.3)	1.0 (0.5-1.6)	2.2 (1.4-3.4)	4.0 (3.0-5.6)
12	Thai Nguyen	0.6 (0.2-1.1)	1.7 (1.2-2.6)	2.4 (1.7-3.4)	1.1 (0.6-1.7)	2.3 (1.5-3.4)	4.0 (3.0-5.7)
13	Phu Tho	0.7 (0.2-1.1)	1.8 (1.2-2.5)	2.4 (1.7-3.5)	1.1 (0.6-1.7)	2.3 (1.4-3.4)	4.0 (3.0-5.8)
14	Vinh Phuc	0.7 (0.3-1.1)	1.7 (1.2-2.5)	2.4 (1.7-3.5)	1.1 (0.6-1.7)	2.3 (1.4-3.4)	3.9 (2.9-5.8)
15	Bac Giang	0.7 (0.3-1.0)	1.7 (1.2-2.5)	2.3 (1.6-3.3)	1.0 (0.5-1.6)	2.2 (1.4-3.4)	3.9 (3.0-5.5)
16	Bac Ninh	0.7 (0.3-1.1)	1.7 (1.2-2.5)	2.3 (1.6-3.3)	1.0 (0.5-1.5)	2.2 (1.4-3.3)	3.9 (2.8-5.6)
17	Quang Ninh	0.7 (0.4-1.1)	1.6 (1.1-2.3)	2.1 (1.5-3.0)	0.9 (0.6-1.4)	2.0 (1.5-3.0)	3.6 (2.9-4.8)
18	Hai Phong	0.7 (0.4-1.1)	1.5 (1.0-2.2)	2.0 (1.5-2.9)	0.9 (0.6-1.4)	2.0 (1.4-2.8)	3.5 (2.8-4.6)
19	Hai Duong	0.7 (0.3-1.1)	1.7 (1.2-2.5)	2.3 (1.6-3.3)	1.0 (0.6-1.6)	2.2 (1.4-3.3)	3.8 (2.9-5.5)
20	Hung Yen	0.7 (0.3-1.1)	1.7 (1.2-2.5)	2.3 (1.6-3.4)	1.0 (0.6-1.6)	2.2 (1.4-3.3)	3.8 (2.9-5.6)
21	Ha Noi	0.6 (0.2-1.1)	1.7 (1.2-2.5)	2.4 (1.6-3.4)	1.1 (0.6-1.6)	2.2 (1.4-3.4)	3.9 (3.0-5.7)
22	Ha Nam	0.7 (0.2-1.1)	1.7 (1.2-2.5)	2.4 (1.6-3.4)	1.1 (0.6-1.6)	2.2 (1.4-3.4)	3.9 (2.9-5.6)
23	Thai Binh	0.7 (0.3-1.1)	1.6 (1.2-2.4)	2.3 (1.6-3.2)	1.0 (0.6-1.5)	2.1 (1.5-3.2)	3.7 (2.9-5.2)
24	Nam Dinh	0.7 (0.4-1.1)	1.6 (1.2-2.2)	2.2 (1.5-3.1)	0.9 (0.6-1.4)	2.0 (1.4-3.0)	3.6 (2.8-4.9)
25	Ninh Binh	0.7 (0.2-1.1)	1.6 (1.2-2.3)	2.3 (1.6-3.3)	1.0 (0.6-1.5)	2.2 (1.4-3.2)	3.8 (2.9-5.4)
26	Thanh Hoa	0.7 (0.3-1.1)	1.6 (1.1-2.3)	2.2 (1.6-3.2)	1.0 (0.6-1.5)	2.1 (1.4-3.2)	3.7 (2.9-5.2)
27	Nghe An	0.7 (0.3-1.1)	1.6 (1.1-2.2)	2.2 (1.5-3.1)	1.0 (0.6-1.5)	2.0 (1.4-3.1)	3.7 (2.9-5.2)
28	Ha Tinh	0.6 (0.3-1.0)	1.5 (1.0-2.1)	2.0 (1.4-2.9)	0.9 (0.6-1.3)	1.9 (1.3-2.8)	3.5 (2.8-4.8)
29	Quang Binh	0.6 (0.3-1.1)	1.5 (1.0-2.1)	2.0 (1.5-2.8)	0.9 (0.6-1.2)	1.9 (1.3-2.8)	3.3 (2.7-4.7)
30	Quang Tri	0.6 (0.4-1.2)	1.4 (1.0-2.0)	1.9 (1.3-2.8)	0.9 (0.6-1.2)	1.9 (1.3-2.7)	3.3 (2.6-4.6)
31	Thua Thien - Hue	0.7 (0.4-1.1)	1.4 (0.9-2.0)	1.9 (1.3-2.7)	0.8 (0.6-1.2)	1.9 (1.3-2.6)	3.3 (2.6-4.5)
32	Da Nang	0.7 (0.4-1.2)	1.4 (1.0-2.1)	1.9 (1.3-2.7)	0.8 (0.6-1.2)	1.9 (1.3-2.6)	3.2 (2.6-4.3)
33	Quang Nam	0.7 (0.4-1.2)	1.4 (0.9-2.0)	1.8 (1.3-2.6)	0.8 (0.6-1.2)	1.9 (1.3-2.6)	3.2 (2.5-4.2)
34	Quang Ngai	0.7 (0.4-1.2)	1.4 (1.0-2.1)	1.9 (1.3-2.7)	0.8 (0.6-1.2)	1.9 (1.3-2.6)	3.2 (2.6-4.3)
35	Binh Dinh	0.7 (0.4-1.2)	1.4 (0.9-2.0)	1.8 (1.3-2.5)	0.8 (0.5-1.2)	1.8 (1.3-2.5)	3.2 (2.5-4.1)
36	Phu Yen	0.7 (0.4-1.2)	1.3 (0.9-2.0)	1.8 (1.3-2.5)	0.8 (0.6-1.2)	1.8 (1.3-2.5)	3.1 (2.5-4.1)
37	Khanh Hoa	0.7 (0.4-1.2)	1.4 (0.9-2.0)	1.8 (1.2-2.5)	0.8 (0.5-1.2)	1.8 (1.2-2.5)	3.2 (2.5-4.1)
38	Ninh Thuan	0.7 (0.4-1.1)	1.4 (1.0-2.0)	1.8 (1.3-2.5)	0.8 (0.5-1.1)	1.8 (1.3-2.5)	3.3 (2.6-4.2)
39	Binh Thuan	0.7 (0.4-1.2)	1.3 (0.9-2.0)	1.7 (1.2-2.4)	0.8 (0.5-1.2)	1.8 (1.3-2.5)	3.2 (2.6-4.0)
40	Kon Tum	0.8 (0.4-1.2)	1.5 (1.1-2.2)	1.9 (1.4-2.7)	0.9 (0.6-1.3)	1.9 (1.5-2.7)	3.5 (2.9-4.6)
41	Gia Lai	0.7 (0.4-1.1)	1.4 (0.9-2.0)	1.8 (1.3-2.6)	0.8 (0.6-1.2)	1.8 (1.3-2.6)	3.3 (2.7-4.5)
42	Dak Lak	0.7 (0.4-1.2)	1.4 (0.9-2.0)	1.8 (1.2-2.6)	0.9 (0.6-1.2)	1.9 (1.3-2.6)	3.3 (2.7-4.4)
43	Dak Nong	0.7 (0.4-1.2)	1.4 (1.0-2.1)	1.9 (1.3-2.6)	0.9 (0.6-1.3)	1.9 (1.4-2.7)	3.4 (2.8-4.5)
44	Lam Dong	0.7 (0.4-1.2)	1.5 (1.0-2.1)	1.9 (1.4-2.7)	0.9 (0.6-1.3)	1.9 (1.4-2.7)	3.5 (2.8-4.5)
45	Binh Phuoc	0.7 (0.4-1.2)	1.5 (1.0-2.1)	1.9 (1.3-2.7)	0.9 (0.6-1.3)	1.9 (1.4-2.7)	3.5 (2.8-4.6)
46	Tay Ninh	0.7 (0.4-1.2)	1.4 (0.9-2.1)	1.9 (1.3-2.7)	0.8 (0.6-1.2)	1.9 (1.4-2.7)	3.5 (2.7-4.7)
47	Binh Duong	0.7 (0.4-1.2)	1.5 (0.9-2.2)	1.9 (1.2-2.7)	0.9 (0.5-1.3)	2.0 (1.4-2.8)	3.6 (2.7-4.8)
48	Dong Nai	0.7 (0.4-1.2)	1.5 (0.9-2.1)	1.9 (1.2-2.7)	0.9 (0.5-1.3)	2.0 (1.4-2.8)	3.5 (2.7-4.7)
49	Ho Chi Minh	0.7 (0.4-1.2)	1.5 (1.0-2.1)	1.9 (1.2-2.7)	0.9 (0.5-1.3)	2.0 (1.4-2.8)	3.5 (2.8-4.7)
50	Ba Ria - Vung Tau	0.7 (0.4-1.2)	1.3 (0.9-2.0)	1.7 (1.2-2.3)	0.8 (0.5-1.2)	1.8 (1.3-2.5)	3.0 (2.5-3.9)

No.	Province, city	RCP4.5 scenario			RCP8.5 scenario		
51	Long An	0.7 (0.4-1.2)	1.4 (0.9-2.0)	1.9 (1.2-2.7)	0.8 (0.5-1.2)	1.9 (1.4-2.7)	3.4 (2.7-4.6)
52	Vinh Long	0.7 (0.4-1.1)	1.4 (0.9-2.1)	1.8 (1.2-2.6)	0.8 (0.5-1.2)	1.9 (1.4-2.7)	3.5 (2.7-4.6)
53	Hau Giang	0.7 (0.4-1.2)	1.4 (0.9-2.1)	1.8 (1.2-2.6)	0.8 (0.6-1.2)	1.9 (1.4-2.7)	3.4 (2.6-4.5)
54	Tien Giang	0.7 (0.4-1.2)	1.4 (1.0-2.1)	1.9 (1.3-2.7)	0.9 (0.6-1.3)	1.9 (1.4-2.7)	3.4 (2.7-4.6)
55	Dong Thap	0.7 (0.4-1.2)	1.4 (0.9-2.0)	1.8 (1.2-2.6)	0.9 (0.6-1.2)	1.8 (1.4-2.6)	3.3 (2.7-4.4)
56	Ben Tre	0.7 (0.4-1.2)	1.4 (0.9-2.0)	1.8 (1.2-2.5)	0.8 (0.5-1.2)	1.8 (1.4-2.5)	3.3 (2.7-4.2)
57	Tra Vinh	0.7 (0.4-1.2)	1.4 (1.0-2.0)	1.8 (1.2-2.6)	0.8 (0.6-1.2)	1.9 (1.4-2.6)	3.4 (2.7-4.5)
58	An Giang	0.7 (0.4-1.2)	1.4 (1.0-2.0)	1.9 (1.3-2.7)	0.9 (0.6-1.3)	1.9 (1.3-2.7)	3.5 (2.6-4.6)
59	Can Tho	0.7 (0.4-1.2)	1.4 (0.9-2.0)	1.8 (1.2-2.6)	0.9 (0.6-1.3)	1.9 (1.4-2.6)	3.4 (2.7-4.5)
60	Soc Trang	0.7 (0.4-1.2)	1.4 (1.0-2.0)	1.8 (1.2-2.5)	0.8 (0.6-1.2)	1.8 (1.4-2.6)	3.3 (2.7-4.3)
61	Kien Giang	0.7 (0.4-1.2)	1.3 (0.9-2.0)	1.8 (1.2-2.5)	0.8 (0.5-1.2)	1.8 (1.3-2.5)	3.2 (2.6-4.2)
62	Bac Lieu	0.7 (0.4-1.3)	1.4 (1.0-2.0)	1.8 (1.2-2.5)	0.8 (0.6-1.2)	1.8 (1.4-2.5)	3.3 (2.7-4.2)
63	Ca Mau	0.7 (0.4-1.2)	1.4 (1.0-2.0)	1.8 (1.2-2.5)	0.9 (0.6-1.3)	1.8 (1.3-2.5)	3.3 (2.7-4.3)

2) Average winter temperature (December – February)

According to the RCP4.5 scenario, average winter temperatures will likely increase by 0.6-0.8^{o}C for the country at the beginning of the century. At the mid-century, the temperatures will likely increase by 1.2-1.6^{o}C, in which the highest increase will likely occur in the North, subsequently in the South and the Central Highlands; the lowest increase will likely be in the Central region. By the end of the century, the increase will likely be 1.5-2.2^{o}C, in which the highest increase in the North and the lowest increase in the Central region (more detail in Appendix A).

According to the RCP8.5 scenario, average winter temperatures will likely increase by 0.8-1.2^{o}C for the country at the beginning of the century. At the mid-century, the temperatures will likely increase by 1.8-2.2^{o}C; the highest increase will likely be in the Central region. By the end of the century, the increase will likely be in a range of 2.8-3.8^{o}C, the lowest increase will likely be in a range of 2.8-3.2^{o}C in the Central region (more detail in Appendix A).

3) Average spring temperature (March - May)

According to the RCP4.5 scenario, average spring temperatures will likely increase by 0.6-0.8^{o}C for the country at the beginning of the century. At the mid-century, the temperatures will likely increase by 1.3-1.6^{o}C, in which the highest increase will likely occur in the North, subsequently in the South and the Central Highlands; the lowest increase will likely be in the Central region. By the end of the century, the increase will likely be 1.7-2.3^{o}C, in which the lowest increase in the South Central Coast and the South (more detail in Appendix A).

According to the RCP8.5 scenario, average spring temperatures will likely increase by 0.8-1.1^{o}C for the country at the beginning of the century. At the mid-century, the temperatures will likely increase by 1.8-2.2^{o}C; in which the highest increasing temperature will likely be in the Northwest and the Northeast (2.0-2.2^{o}C); afterward in the Red River Delta, the Central Highlands and the South; the lowest increase will likely be 1.7-1.9^{o}C occur in the Central region. By the end of the century, the increase will likely be in a range of 3.0-3.9^{o}C, the highest increase will likely be in the Northwest and the Northeast (more detail in Appendix A).

4) Average summer temperature (June - August)

According to the RCP4.5 scenario, at the beginning of the century, average summer temperature for the country will likely increase by 0.6-0.8^{o}C. At the mid-century, the temperature will likely increase by 1.6-2.0^{o}C in the North, 1.3-1.7^{o}C in the South. At the end of the century, the temperature will likely increase by 1.8-2.8^{o}C, in which the increasing trend will likely be greater than the South (more detail in Appendix A).

According to the RCP8.5 scenario, at the beginning of the century, average summer temperature for the country will likely increase by 0.8-1.0^{o}C. At the mid-century, the temperature will likely increase by 2.1-2.5^{o}C in the North, 1.8-2.1^{o}C in the South. At the end of the century, the temperature will likely increase by 3.7-4.3^{o}C in the North and 3.2-3.7^{o}C in the South (more detail in Appendix A).

5) Average autumn temperature (September - November)

According to the RCP4.5 scenario, at the beginning of the century, average autumn temperatures for the country will likely increase by 0.6-0.7^{o}C. At the mid-century, the temperatures will likely increase by 1.3-1.9^{o}C, the highest increase will likely be in the North (1.6-1.9^{o}C); afterward in the North Central Coast (1.3-1.7^{o}C), the Central Highlands, the South Central Coast and the South (1.3-1.5^{o}C). At the end of the century, the temperatures will likely be 1.7-2.5^{o}C, in which above 2^{o}C in the North and below 2^{o}C in the South (more detail in Appendix A).

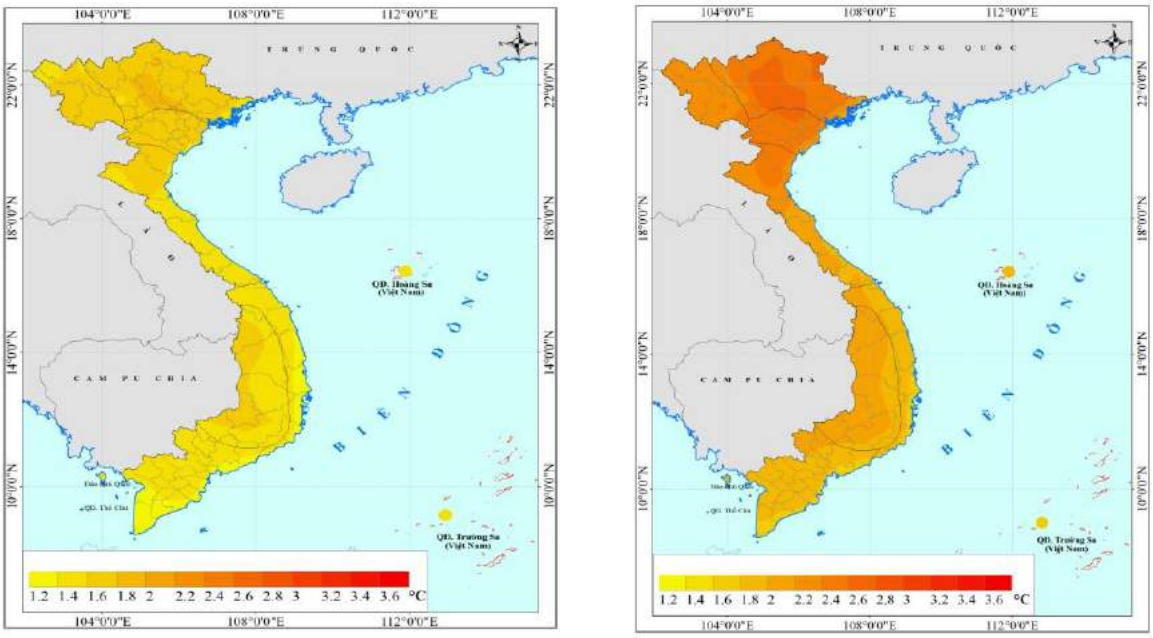
According to the RCP8.5 scenario, at the beginning of the century, average autumn temperatures for the country will likely increase by 0.8-1.2^{o}C. At the mid-century, the temperatures will likely increase by 2.0-1.5^{o}C in the North and Thanh Hoa - Nghe An, in which the increased temperatures in the Northwest will be lower than the ones in the Northeast and the Red River Delta. The temperatures will likely increase by 1.8-2^{o}C in the South (from Ha Tinh), lower than the Central Highlands and the Central region. The increasing trend of the average autumn temperature at the end of the century will likely be the same as the temperatures at the mid-century, but higher in value, 3.5-4.3^{o}C in the North and 3.2-3.5^{o}C in the South (more detail in Appendix A).

5.1.2. Extreme temperature

1) Average annual maximum temperature

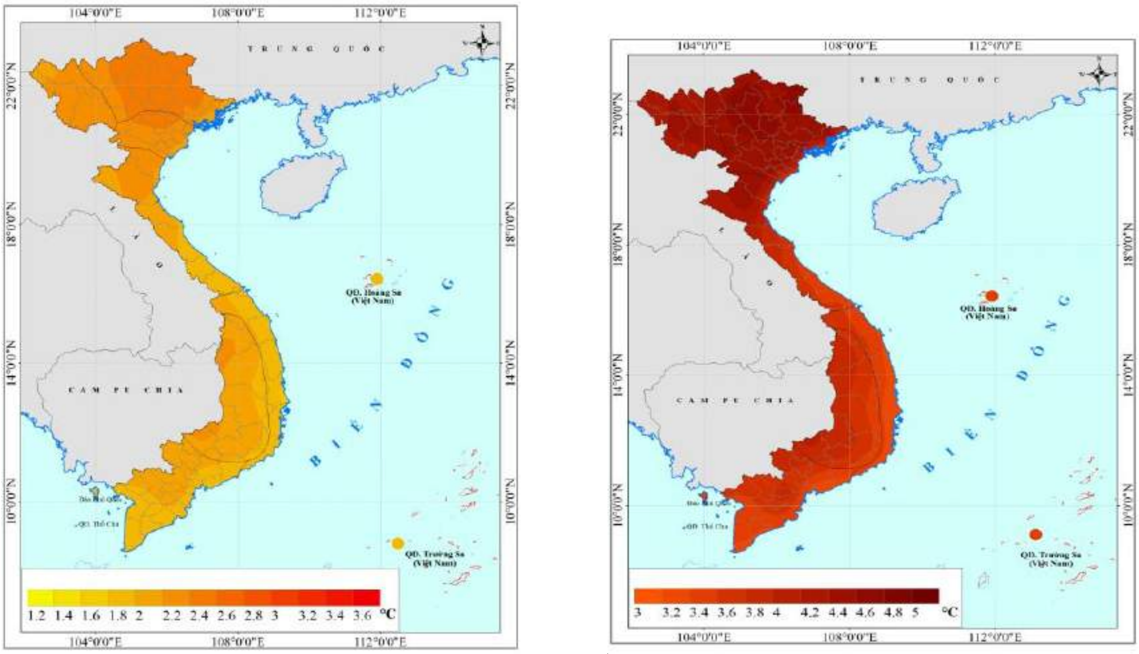
According to the RCP4.5 scenario, by the mid-century, the average annual maximum temperature for the country will likely increase by 1.4-1.8^{o}C. By the end of the century, there will likely be an increase of 1.7-2.7^{o}C. In particular, the highest increase will likely be in the Northeast, the Red River Delta; the lowest increase will likely be in the South Central Coast and the South (Figure 5.4).

According to the RCP8.5 scenario, by the mid-century, the average maximum temperature for the country will likely increase by 1.6-2.4^{o}C, the highest increase will likely be in the North with an increase of about 2.6^{o}C. By the end of the century, the trend of the average maximum temperature will likely continue with increasing trend (3.0-4.8^{o}C), the highest increase may be up to 5.0^{o}C for some provinces of the mountainous north (Figure 5.5).



(a) mid-21st century *(b) end of the 21st century*

Firgure 5.4. Changes in average annual maximum temperatures (°C) based on RCP4.5 scenario



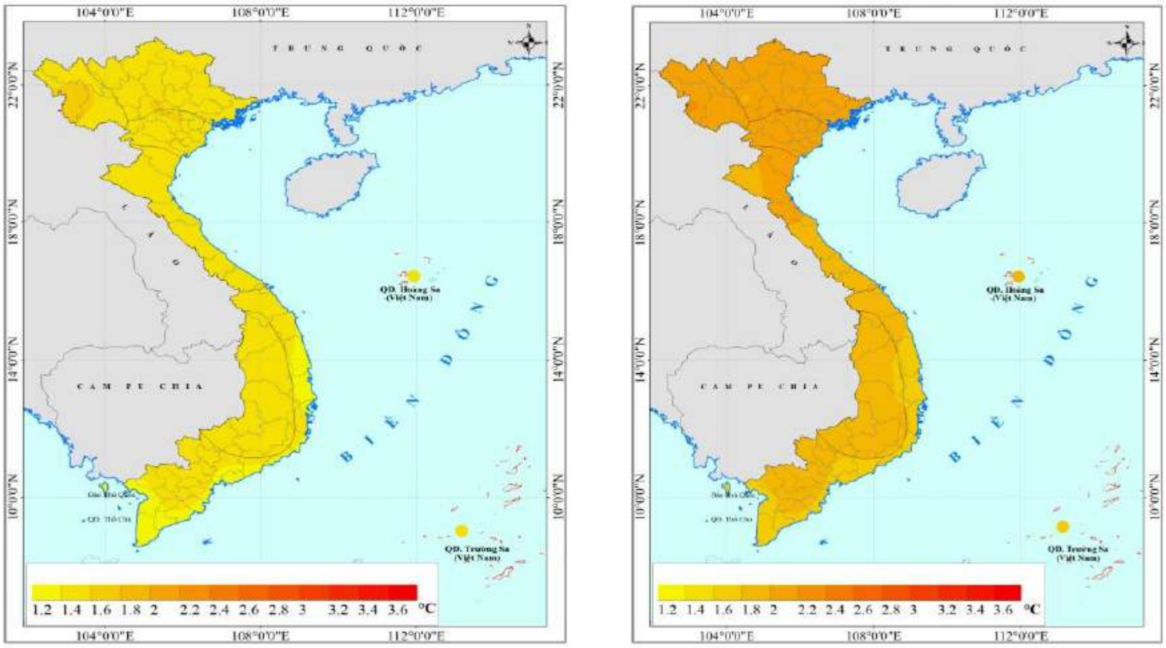
(a) mid-21st century *(b) end of the 21st century*

Firgure 5.5. Changes in average annual maximum temperatures (°C) based on RCP8.5 scenario

3) Average annual minimum temperature

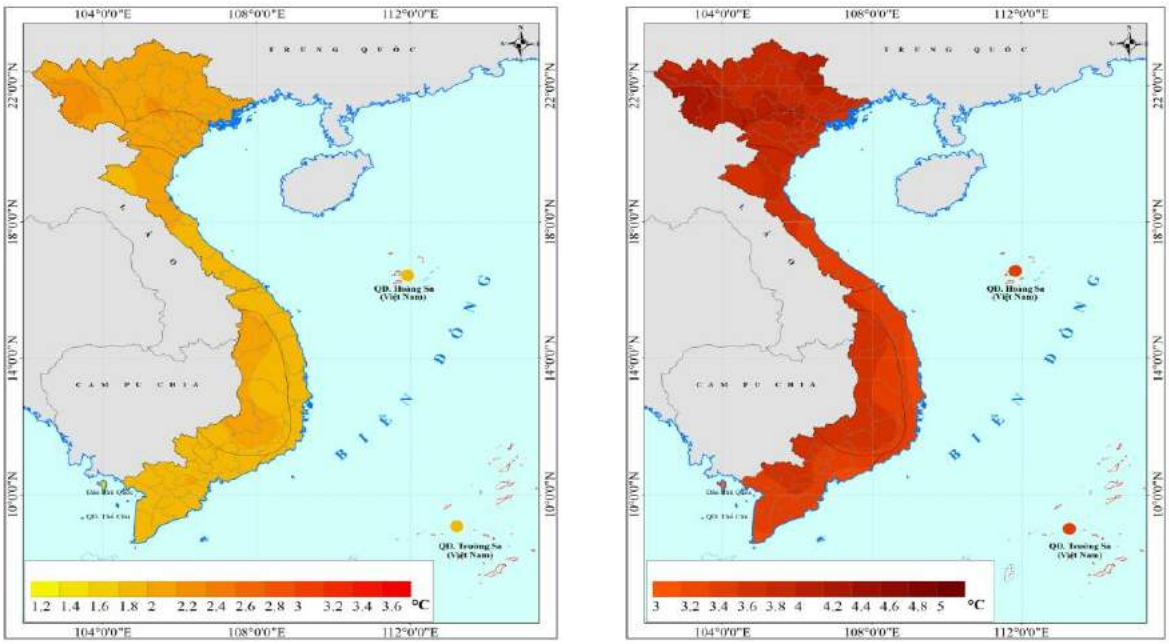
According to the RCP4.5 scenario, average minimum temperatures for the country will likely increase by 1.4-1.6°C at the mid-century, the temperatures will likely be 1.8-2.2°C at the end of the century. Along the coastline of the South Central Coast and the South, the lowest increase will likely be 1.3-1.4°C at the mid-century, and 1.6-1.8°C at the end of the century (Figure 5.6).

According to the RCP8.5 scenario, by mid-century, the average minimum temperature will likely increase by 1.6-2.6°C, the highest increase will likely be in the North and the Central Highlands (2.2-2.6^oC). Other regions will have a lower increase (1.6-1.8^oC). By the end of the century, the increase will likely be 3.0-4.0^oC in general, some northern provinces will likely have higher increase (Figure 5.7).



(a) mid-21st century *(b) end of the 21st century*

Firgure 5.6. Changes in average annual minimum temperatures (^oC) based on the RCP4.5 scenario



(a) mid-21st century *(b) end of the 21st century*

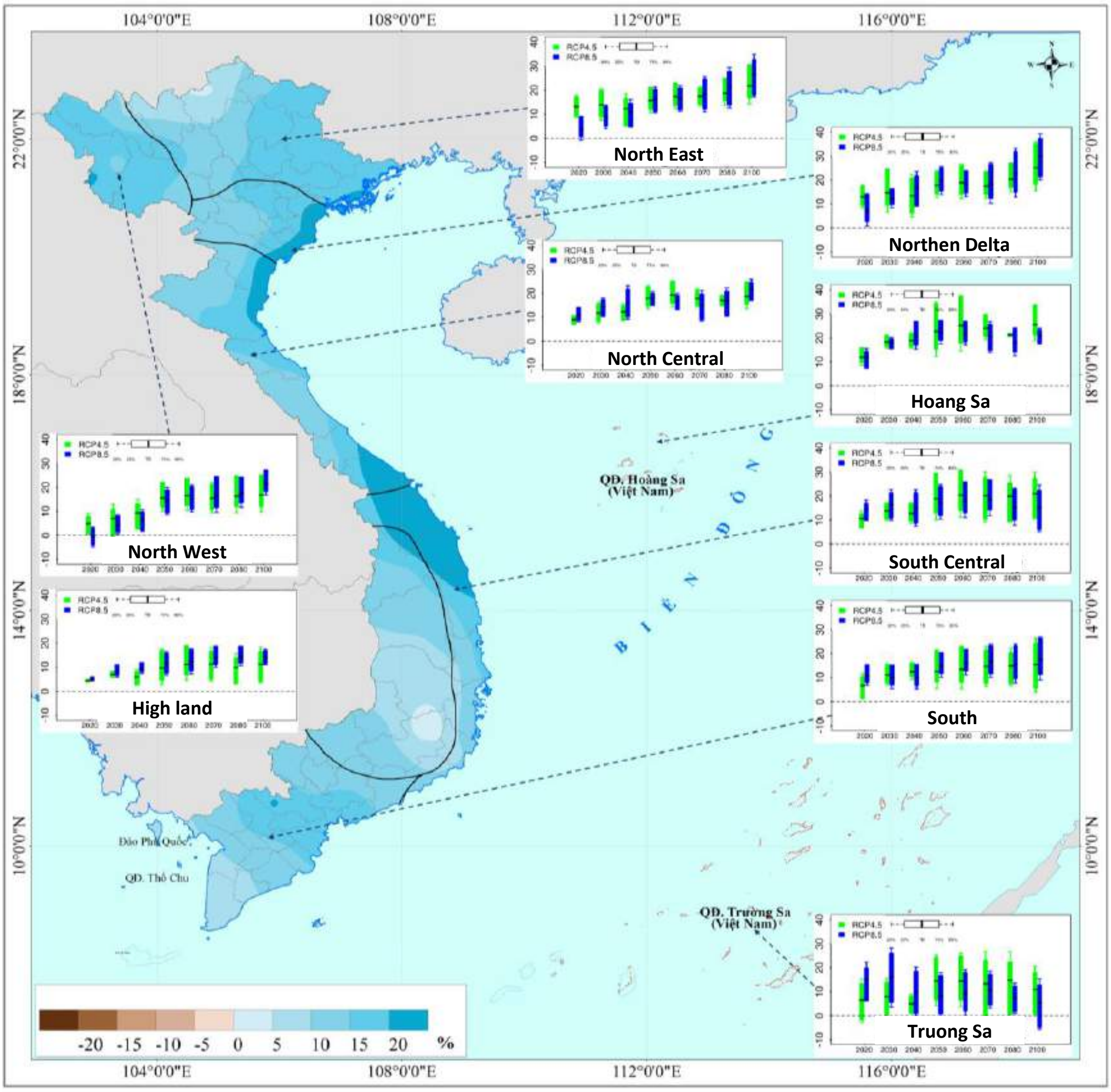
Firgure 5.7. Changes in average annual minimum temperatures (^oC) based on the RCP8.5 scenario

5.2. Climate change scenarios for rainfall

5.2.1. Rainfall

1) Annual rainfall

According to the RCP4.5 scenario, at the beginning of the century, annual rainfall will tend to increase by 5-10% in most of the country. By the mid-century, the rainall will likely increase by 5-15% in general. Some coastal provinces in the Red River Delta, the North Central Coast and Central Central Coast may rise above 20%. By the end of the century, the rainfall patterns are similar with the pattern in the mid-century; however, it is likely that the areas where rainfall increase by more than 20% will be extended (Figure 5.9).



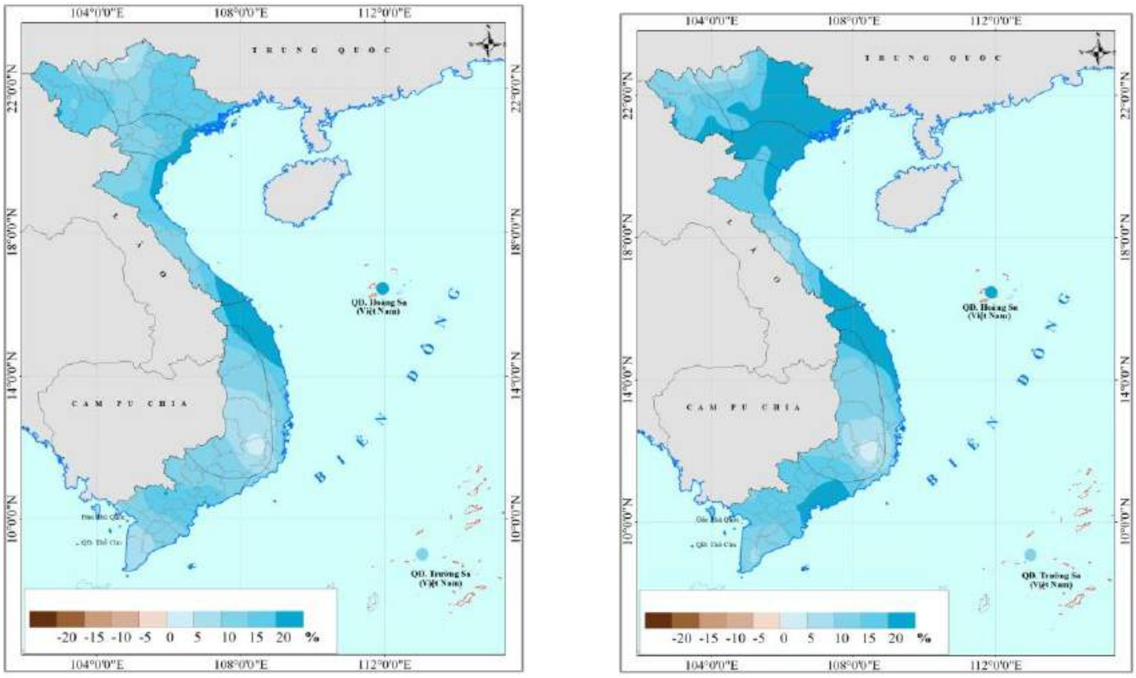
Firgure 5.8. Changes in annual rainfall (%) over 7 regions and Islands of Vietnam

According to the RCP8.5 scenario, at the beginning of the century, annual rainfall will likely increase in most of the country, 3-10% in general. By the mid-century, the increased trend of annual rainfall will likely be the similar as the increased trend RCP4.5 scenario.

It is noteworthy that the highest rainfall amount will likely increase by over 20% at the end of the century in most of the North, the Central Central Coast and a part of the South and the Central Highlands (Figure 5.10).

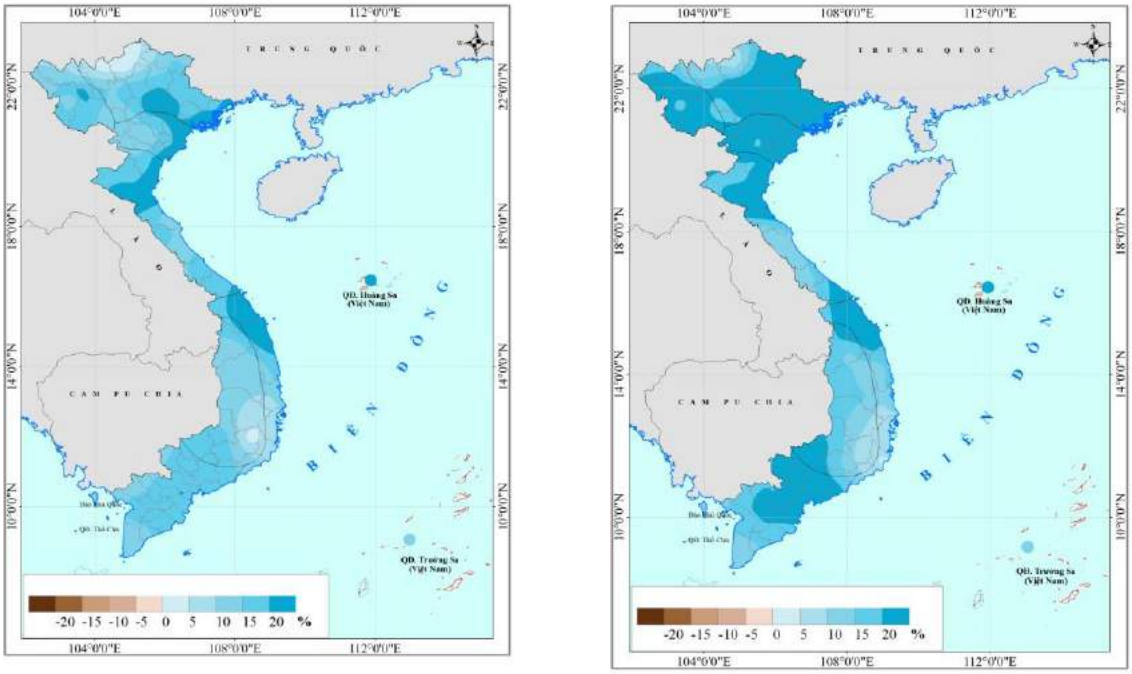
Table 5.2 shows the change of annual rainfall (%) in the beginning, the middle and the end of the century compared to the period 1986-2005 for the 63 provinces and cities. The trend and the level of the averaged changes in 7 climate zones and islands of Viet Nam are shown in Figure 5.8. Similar to the temperature, at the middle and the end of the century, rainfall is identified by the variation around the mean of model results. For example, by the mid-century, in Lai Chau, the variability of annual rainfall with RCP4.5 scenarios under different models will likely increase by 9.4-17.9%, 13.5% in average for all model results.

The trend and the level of the average change in each province of 7 climatic zones in Viet Nam are presented in Appendix A.



(a) mid-21st century *(b) end of 21st century*

Firgure 5.9. Changes in annual rainfall (%) based on RCP4.5 scenario



(a) mid-21st century *(b) end of 21st century*

Firgure 5.10. Changes in annual rainfall (%) based on RCP8.5 scenario

Table 5.2. Changes in annual rainfall (%) when compared with the period 1986-2005

(Values in parentheses are the range of rainfall changes from climate model results with the lower boundary of 20% and upper boundary of 80%)

No.	Province, city	RCP4.5 scenario			RCP8.5 scenario		
		2016-2035	2046-2065	2080-2099	2016-2035	2046-2065	2080-2099
1	Lai Chau	3.3 (-3.3-9.7)	13.5 (9.4-17.9)	11.2 (4.6-18.3)	-1.0 (-4.0-2.1)	10.6 (4.4-16.0)	18.4 (12.0-25.3)
2	Dien Bien	5.9 (-2.2-13.2)	16.5 (8.9-24.3)	15.1 (6.6-24.4)	2.7 (-1.7-7.3)	15.2 (8.0-21.7)	21.2 (14.8-28.2)
3	Son La	7.0 (-0.5-14.2)	15.5 (8.4-23.4)	19.9 (10.3-30.4)	5.1 (-1.3-11.2)	15.3 (9.3-21.3)	22.3 (15.7-28.9)
4	Hoa Binh	7.5 (0.0-15.4)	12.9 (8.1-18.1)	20.2 (12.2-29.1)	7.0 (1.4-12.9)	12.8 (7.4-18.2)	20.9 (12.4-29.0)
5	Lao Cai	1.8 (-4.0-7.1)	8.2 (3.0-13.8)	9.3 (2.2-17.0)	-2.9 (-8.0-2.5)	5.9 (0.4-10.9)	12.6 (5.2-20.0)
6	Ha Giang	5.8 (2.7-8.9)	7.8 (3.1-12.6)	11.8 (5.0-19.0)	-3.3 (-9.6-3.3)	4.0 (-0.2-8.1)	12.7 (6.6-18.8)
7	Yen Bai	7.5 (0.2-14.3)	14.8 (7.5-23.0)	19.4 (7.8-32.7)	5.9 (-0.7-12.7)	15.6 (7.9-23.3)	23.3 (9.4-35.7)
8	Cao Bang	14.2 (8.2-19.9)	16.0 (9.8-21.8)	22.1 (13.1-31.4)	3.8 (-4.2-11.8)	12.8 (9.4-16.1)	25.7 (17.0-34.4)
9	Tuyen Quang	11.5 (6.2-16.4)	12.5 (7.5-17.7)	18.4 (10.2-27.1)	5.8 (-0.1-11.6)	16.7 (9.7-23.5)	27.4 (15.0-38.7)
10	Bac Kan	17.4 (11.3-23.1)	18.3 (13.5-22.7)	23.7 (16.9-30.8)	6.6 (0.2-13.1)	15.4 (10.4-20.3)	28.0 (19.4-36.1)
11	Lang Son	18.7 (7.0-29.8)	18.7 (11.5-25.5)	25.1 (16.5-34.2)	10.5 (4.6-17.0)	17.9 (12.4-23.3)	27.8 (20.1-35.1)
12	Thai Nguyen	15.9 (8.2-23.3)	17.8 (11.1-24.2)	22.5 (14.9-31.0)	9.9 (4.9-15.0)	22.0 (13.8-30.2)	31.1 (21.8-40.1)
13	Phu Tho	10.0 (0.3-19.7)	15.0 (8.2-22.6)	21.3 (10.7-33.4)	8.5 (1.6-15.6)	17.1 (7.5-26.1)	25.4 (11.8-37.4)
14	Vinh Phuc	14.8 (5.4-24.6)	18.2 (10.6-26.6)	22.4 (12.5-34.1)	10.7 (4.7-17.0)	22.2 (12.4-32.1)	30.8 (18.5-42.1)
15	Bac Giang	17.7 (5.4-29.3)	18.8 (11.0-26.9)	25.7 (16.6-35.6)	10.9 (5.8-16.7)	21.1 (15.4-27.2)	32.7 (25.5-39.5)
16	Bac Ninh	13.0 (4.1-21.9)	13.9 (6.6-22.2)	22.9 (14.2-32.8)	4.8 (-0.9-11.1)	15.4 (9.2-22.0)	25.2 (15.4-34.9)
17	Quang Ninh	20.4 (6.5-33.4)	19.1 (11.7-26.9)	29.8 (19.8-40.9)	14.8 (6.4-23.4)	24.0 (14.7-33.0)	36.8 (25.9-46.5)
18	Hai Phong	24.4 (10.1-38.2)	26.4 (18.0-35.5)	34.3 (19.3-50.3)	17.9 (10.1-26.0)	30.2 (21.4-39.0)	44.1 (33.4-54.5)
19	Hai Duong	17.4 (4.9-30.0)	18.7 (9.6-28.4)	27.8 (17.0-39.6)	11.4 (4.0-19.0)	23.0 (16.5-30.2)	32.8 (24.0-42.2)
20	Hung Yen	13.8 (4.3-23.7)	16.3 (10.4-22.9)	25.3 (15.4-36.2)	8.2 (1.5-15.3)	17.1 (11.1-23.3)	28.5 (17.4-39.8)
21	Ha Noi	12.6 (3.1-22.9)	17.0 (10.8-23.8)	24.0 (14.3-35.3)	9.9 (2.7-17.0)	17.8 (9.8-25.9)	29.8 (18.0-40.9)
22	Ha Nam	14.0 (3.8-24.8)	17.6 (11.5-24.4)	24.7 (14.8-36.1)	10.5 (3.1-17.9)	19.0 (10.8-27.3)	30.1 (18.3-41.3)
23	Thai Binh	19.8 (6.5-32.5)	20.1 (14.2-26.5)	27.6 (17.0-39.1)	13.0 (4.9-21.1)	23.9 (15.0-33.0)	31.3 (19.4-42.8)
24	Nam Dinh	16.0 (6.0-26.0)	21.1 (14.8-27.8)	27.5 (17.5-38.1)	15.2 (8.6-22.0)	21.9 (13.2-30.5)	34.7 (24.8-44.6)
25	Ninh Binh	11.2 (2.8-19.5)	16.5 (10.6-22.5)	22.0 (13.5-30.7)	9.6 (4.8-14.8)	17.7 (11.4-24.2)	25.3 (18.4-32.0)
26	Thanh Hoa	10.1 (3.7-16.8)	17.6 (11.5-23.6)	21.3 (14.2-29.0)	13.8 (8.5-19.0)	18.6 (13.0-24.5)	25.5 (19.9-31.2)
27	Nghe An	10.2 (2.4-17.7)	16.8 (10.6-23.1)	18.1 (10.3-26.3)	16.6 (7.7-24.5)	21.6 (14.1-28.5)	26.4 (18.8-33.6)
28	Ha Tinh	11.3 (6.0-16.6)	16.3 (8.5-24.4)	13.0 (3.4-22.6)	12.9 (6.8-18.9)	14.1 (8.9-19.0)	17.4 (10.6-24.4)
29	Quang Binh	10.1 (3.5-16.5)	12.6 (3.8-22.0)	10.9 (0.0-21.4)	10.8 (4.0-17.4)	14.1 (8.2-19.6)	12.1 (5.5-19.0)
30	Quang Tri	11.4 (2.9-20.0)	16.6 (7.5-26.2)	20.1 (9.8-31.3)	16.5 (9.9-22.8)	16.8 (10.7-22.6)	16.4 (8.2-24.2)
31	Thua Thien - Hue	17.0 (10.4-23.6)	22.5 (10.7-34.3)	26.2 (15.4-38.1)	16.5 (9.0-23.3)	18.6 (12.9-23.9)	21.2 (13.8-28.2)
32	Da Nang	16.2 (11.7-21.1)	22.7 (10.0-36.1)	25.5 (14.4-37.8)	16.4 (11.3-21.3)	22.0 (15.9-28.3)	20.8 (15.0-26.8)
33	Quang Nam	18.2 (13.0-23.7)	24.9 (14.3-36.8)	29.9 (17.5-42.9)	17.5 (12.2-22.6)	25.9 (18.6-33.5)	25.9 (13.0-38.2)
34	Quang Ngai	18.0 (12.9-23.2)	25.2 (14.0-38.3)	29.5 (15.3-42.9)	18.0 (12.2-23.5)	25.1 (17.0-33.5)	22.2 (7.2-35.9)
35	Binh Dinh	14.9 (8.8-21.2)	20.4 (10.9-30.8)	23.0 (11.2-34.3)	17.0 (10.1-23.4)	19.0 (11.9-26.2)	16.5 (5.8-26.5)
36	Phu Yen	10.0 (3.2-17.0)	13.4 (5.2-22.8)	14.4 (0.9-26.9)	12.4 (3.2-21.9)	10.4 (2.7-18.5)	10.1 (-1.0-20.4)
37	Khanh Hoa	9.1 (-1.3-19.2)	14.4 (3.9-25.5)	11.0 (-0.2-21.1)	16.1 (4.9-27.2)	8.1 (-1.5-18.0)	5.4 (-6.1-15.6)
38	Ninh Thuan	5.0 (-0.9-11.5)	6.2 (-0.8-14.4)	8.1 (-2.9-17.7)	14.0 (7.3-20.2)	5.6 (-1.5-12.5)	1.6 (-8.5-11.6)
39	Binh Thuan	14.1 (5.9-22.0)	13.6 (3.9-24.2)	17.7 (9.4-25.3)	12.5 (5.9-19.8)	15.0 (7.8-22.0)	14.9 (8.1-21.6)
40	Kon Tum	7.2 (4.5-9.9)	12.0 (2.4-22.0)	14.1 (5.2-23.3)	8.1 (5.0-11.4)	12.5 (6.6-18.4)	16.2 (12.0-20.6)
41	Gia Lai	8.3 (3.4-12.5)	11.0 (3.2-19.5)	12.1 (4.2-19.9)	10.0 (5.2-15.1)	11.8 (4.7-19.1)	14.6 (10.6-18.5)
42	Dak Lak	6.5 (2.2-10.9)	7.6 (0.8-15.7)	10.1 (-1.0-20.3)	5.3 (-1.0-11.6)	8.7 (1.8-16.2)	11.4 (2.4-19.5)
43	Dak Nong	6.5 (3.7-9.3)	11.3 (3.3-20.7)	11.5 (4.0-19.4)	5.0 (1.4-8.6)	17.2 (13.6-21.1)	18.6 (14.7-22.7)
44	Lam Dong	3.9 (1.0-6.8)	6.5 (0.3-12.9)	7.8 (-0.6-15.6)	4.7 (0.6-8.9)	9.0 (4.8-13.5)	10.1 (6.6-13.6)
45	Binh Phuoc	8.7 (5.3-12.4)	12.1 (4.3-21.2)	15.1 (5.3-24.1)	9.0 (2.8-15.4)	16.0 (10.2-21.6)	23.3 (17.8-28.6)
46	Tay Ninh	9.4 (4.5-14.3)	14.1 (5.2-23.3)	16.0 (4.9-26.1)	10.3 (4.2-16.3)	15.0 (8.7-21.9)	20.7 (13.6-28.2)
47	Binh Duong	7.2 (1.8-12.6)	10.4 (3.3-18.4)	13.8 (2.6-24.1)	7.5 (3.1-12.1)	12.8 (6.9-19.4)	16.8 (8.4-25.9)
48	Dong Nai	8.3 (3.1-13.0)	11.1 (3.8-19.8)	15.0 (1.2-28.0)	7.8 (3.7-12.1)	13.3 (6.8-20.4)	16.1 (5.9-26.8)
49	Ho Chi Minh	9.7 (4.2-14.9)	12.7 (5.1-21.7)	16.9 (1.7-31.1)	9.3 (4.6-14.1)	13.5 (7.3-20.2)	16.8 (6.4-27.8)
50	Ba Ria - Vung Tau	17.5 (9.6-25.0)	14.5 (4.6-25.2)	17.5 (8.1-27.0)	13.5 (7.3-20.0)	16.4 (9.4-23.6)	15.6 (7.7-24.1)
51	Long An	11.7 (4.0-18.5)	20.6 (7.8-33.8)	16.7 (2.9-29.0)	12.8 (5.9-19.1)	16.1 (9.2-23.4)	19.9 (11.6-28.2)
52	Vinh Long	6.2 (2.5-10.1)	9.1 (1.2-17.9)	11.1 (0.6-21.8)	7.6 (2.7-13.2)	11.8 (7.0-17.0)	13.4 (4.5-23.7)
53	Hau Giang	4.9 (2.1-7.8)	4.5 (-2.3-11.7)	7.4 (-1.8-17.0)	3.8 (0.2-7.9)	8.6 (4.4-13.4)	9.8 (0.5-21.0)
54	Tien Giang	13.7 (8.6-18.9)	17.1 (7.3-28.3)	16.1 (2.7-28.8)	12.7 (6.3-18.9)	18.0 (10.6-25.8)	20.9 (10.5-32.3)
55	Dong Thap	10.0 (4.8-15.1)	17.9 (8.9-28.0)	17.2 (5.3-28.4)	11.0 (4.4-17.4)	16.2 (10.7-22.2)	23.7 (15.6-32.0)
56	Ben Tre	17.0 (10.1-23.2)	18.2 (7.6-30.4)	21.2 (7.7-33.6)	14.7 (9.7-19.8)	18.1 (11.3-25.6)	21.8 (11.3-33.0)
57	Tra Vinh	10.9 (4.9-16.3)	15.7 (5.7-26.8)	17.7 (4.1-30.0)	11.4 (5.6-17.5)	14.6 (8.4-21.5)	18.2 (9.0-28.2)
58	An Giang	4.7 (-0.3-9.4)	13.1 (3.8-23.3)	14.1 (0.5-26.4)	8.2 (1.5-15.1)	11.1 (5.4-17.3)	14.7 (6.7-23.4)
59	Can Tho	10.5 (6.6-14.4)	13.7 (4.5-23.6)	15.1 (2.8-26.6)	10.7 (4.0-18.0)	18.3 (13.5-23.6)	21.2 (12.3-30.7)
60	Soc Trang	11.1 (7.2-15.0)	10.6 (2.2-19.5)	14.0 (4.0-23.7)	10.6 (5.1-16.7)	15.4 (10.4-20.6)	18.4 (9.8-28.3)
61	Kien Giang	4.9 (0.0-10.3)	9.2 (0.8-18.4)	17.0 (2.3-31.8)	6.5 (-1.2-14.6)	14.4 (7.3-21.9)	15.4 (4.4-28.0)
62	Bac Lieu	9.6 (5.0-13.9)	11.0 (2.3-20.5)	13.6 (4.3-22.8)	11.8 (6.4-18.0)	16.5 (10.1-23.3)	18.0 (8.5-29.0)
63	Ca Mau	8.4 (2.1-14.0)	5.8 (-2.4-14.7)	9.6 (-0.3-19.5)	6.7 (2.2-11.7)	10.8 (6.0-16.2)	12.6 (3.7-22.9)

2) Winter rainfall

According to the RCP4.5 scenario, at the beginning of the century, winter rainfall will likely increase by 5-12% in most of the country. By the mid-century, it is likely that the decreased trends will be in the Northwest, in most of the North with the largest decrease of 10%. The winter rainfall of the other regions will likely increase by 5-20% with the largest increase in the South, the southern of Central Highlands, the western Central Coast. By the end of the century, it is likely that the decreased trend of winter rainfall will be in most of the Northeast, the Red River Delta and a part of northern border of the Northwest and the Northeast with the largest decrease of 15%. Most of provinces from Quang Binh to the South will likely increase by 20-25% in general (detail in Appendix A).

According to the RCP8.5 scenario, at the beginning of the century, it is likely that the trend of winter rainfall will decrease slightly in the North and Central Highlands and increase in the South. By the mid-century, it is likely that the decreased trend of rainfall will be in most of the Northwest and the western Northeast, the largest decrease of about 10%. Rainfall of the other regions will likely increase with the greatest increase of about 20%. By the end of the century, the decreased trend of winter rainfall will likely be in most of the Northeast, Northwest, the southern Central Highlands and the southern Central Coast. In the other regions, winter rainfall will likely decrease by 5-15% with largest decrease in the further southern Central Coast. The other regions will likely increase by 10-40%, especially in most of the South, rainfall will likely increase by 50-80% (detail in Appendix A).

3) Spring rainfall

According to the RCP4.5 scenario, at the beginning of the century, it is likely that the spring rainfall will decrease slightly in the North and increase by 5-10% in the South. By the mid-century, the increased trend of spring rainfall will likely be in the North (from Quang Tri to the North), about 5-10% and the decrease trend will likely be in many provinces of South (from Thua Thien - Hue to the South). A part of the Northwest and Northeast will likely have the greatest increase of about 15%. Spring rainfall will likely decrease in most of coastal provinces of the South Central Coast and the South (from Thua Thien - Hue to Ca Mau) with a decrease of under 10%. By the end of the century, the rainfall will likely increase by 3-10% over the country, in some parts of the North (detail in Appendix A).

According to the RCP8.5 scenario, at the beginning of the century, the spring rainfall will likely decrease in most of the country, under 8% in general. By the mid-century, the trend of the spring rainfall will likely be quite similar to the trend of the rainfall in the RCP4.5 scenario, except for a considerable decrease in south Central Coast. By the end of the century, the spring rainfall will likely increase by 3-15% over most of the country, except for decrease of spring rainfall in a small part of the northern Northeast, the southern Northwest, the further southern Central Coast and the further southern South North (detail in Appendix A).

4) Summer rainfall

According to the RCP4.5 scenario, at the beginning of the century, summer rainfall will likely increase in most of the country, 3-12% in general. By the mid-century, the rainfall will likely increase by 5-15% in most of the country, except for the South Central Coast, the eastern Central Highlands and a part of the western South with the decrease of 3-15%. The greatest increase will likely be in the Northeast and the Northwest; the smallest increase will likely in the North Central Coast, Central Highlands and the South. By the end of the century, the changes in summer rainfall will likely be similar to the changes in the mid-century.

However, the areas which have decreased trend of rainfall will likely extend to the North. It is likely that the greatest increase of rainfall will be in the Northeast and the Northwest, 15-25%. The Central Highlands and the western South will likely increase by under 5% (detail in Appendix A).

According to the RCP8.5 scenario, the changes in summer rainfall will likely be similar to the changes in the RCP4.5 scenario. At the beginning of the century, it is likely that the rainfall will increase by 5-15% in general. By the mid-century, the summer rainfall will likely increase in most of the country, except for a small percentage of decrease in the South Central Coast and the Central Highlands (under 5%). The greatest increase of rainfall will likely be in the Northwest, Northeast, North Central Coast, southern Central Highlands and the eastern South, 15-25% in general; the smallest increase will likely be in the Central Highlands, the South Central Coast and the western South, under 5%. By the end of the century, summer rainfall will likely decrease by 15% (detail in Appendix A).

5) Autumn rainfall

According to the RCP4.5 scenario, at the beginning of the century, autumn rainfall will likely increase by 10-25%. By the mid-century, it is likely that the rainfall will increase by 15-35%. The greatest increase in rainfall will be expected in most of the Northeast, from Thanh Hoa to Nghe An and from Thua Thien - Hue to Binh Dinh (30% to above 40%). By the end of the century, the changes of the autumn rainfall will likely be similar to the changes in the mid-century, but greater in amount: the greatest increase will be expected in the Red River Delta and the Northeast (30-50%), the lowest increase will be expected in the southern Central Highlands and the northern Northwest (under 10%) (detail in Appendix A).

According to the RCP8.5 scenario, at the beginning of the century, autumn rainfall will likely increase in most of the country, 10-20% in general. By the mid-century, the rainfall will have an increased trend in most regions with 15-30% in general, in which the greatest increase will likely be in the Northeast, the coast areas of the Red River Delta and in most of the Central Coast. The rainfall will likely decrease in a small part of the southern Central Highlands, the southernmost part of the Central Coast and some provinces in the Northwest and Northeast. By the end of the century, the increased trend of the rainfall will likely be in the whole country (10-70%), in which the North and Central Coast will increased by 30-70%; the South will increased by 10-30%, a southernmost part of the southern Central Coast and the southern Central Highlands (below 10%) (detail in Appendix A).

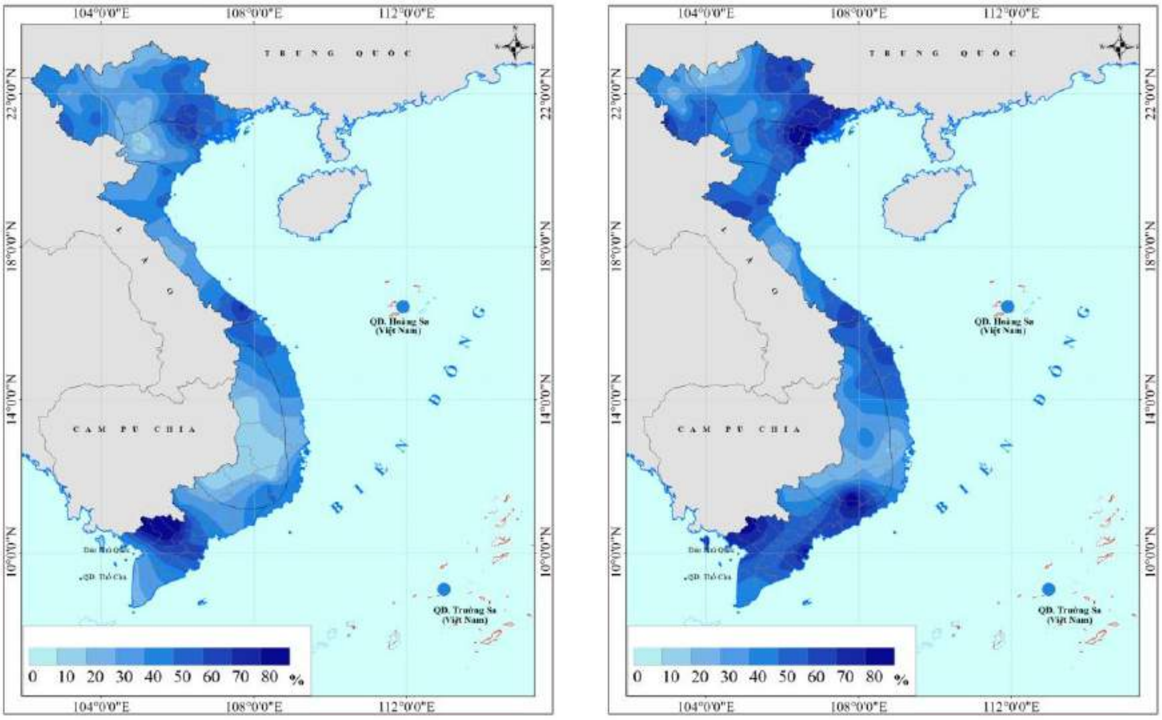
5.2.2. Extreme rainfall

1) Average maximum 1-day rainfall (Rx1day)

According to the RCP4.5 scenario, by the mid-century, the average maximum 1-day rainfall will likely increase over the country, 10-70% in general. It is likely that the greatest increase of the rainfall will be in the Northeast, from Thua Thien - Hue to Quang Nam and the eastern South. By the end of the country, the trend of the rainfall will likely be the same as the trend at the mid-century, but greater in amount and larger in spatial scales (Figure 5.11).

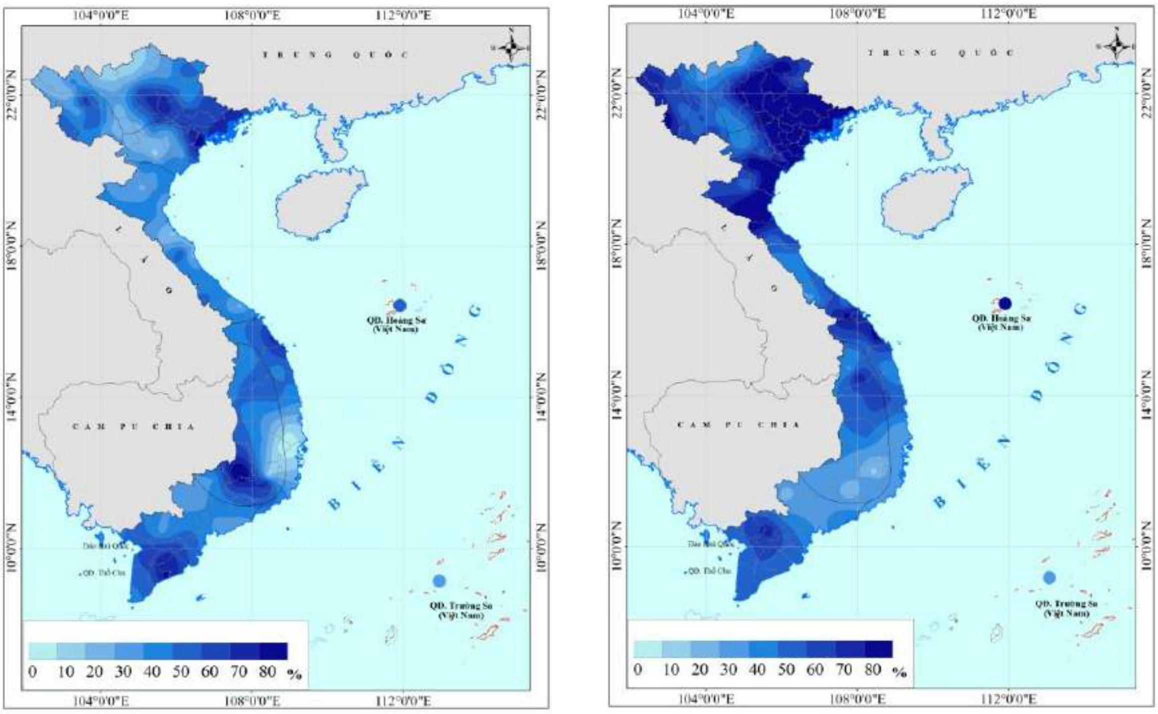
According to the RCP8.5 scenario, by the mid-century, the average maximum 1-day rainfall will likely increase over the country with the increases of 10-70%, in which the rainfall will likely increase considerably in the Northeast, the southern Central Highlands, southernmost South Central Coast and the South. By the end of the century, the trend of the rainfall will likely similar to the trend in the mid-century, but greater in amount and larger in spatial scale. The greatest increase of the rainfall will likely be in the Northeast, the western

Northwest, the southern Red River Delta, the North Central Coast, the northern Central Highlands and the South (Figure 5.12).



(a) mid-21st century *(b) end of the 21st century*

Firgure 5.11. Changes in average maximum 1-day rainfall based on RCP4.5 scenario



(a) mid-21st century *(b) end of the 21st century*

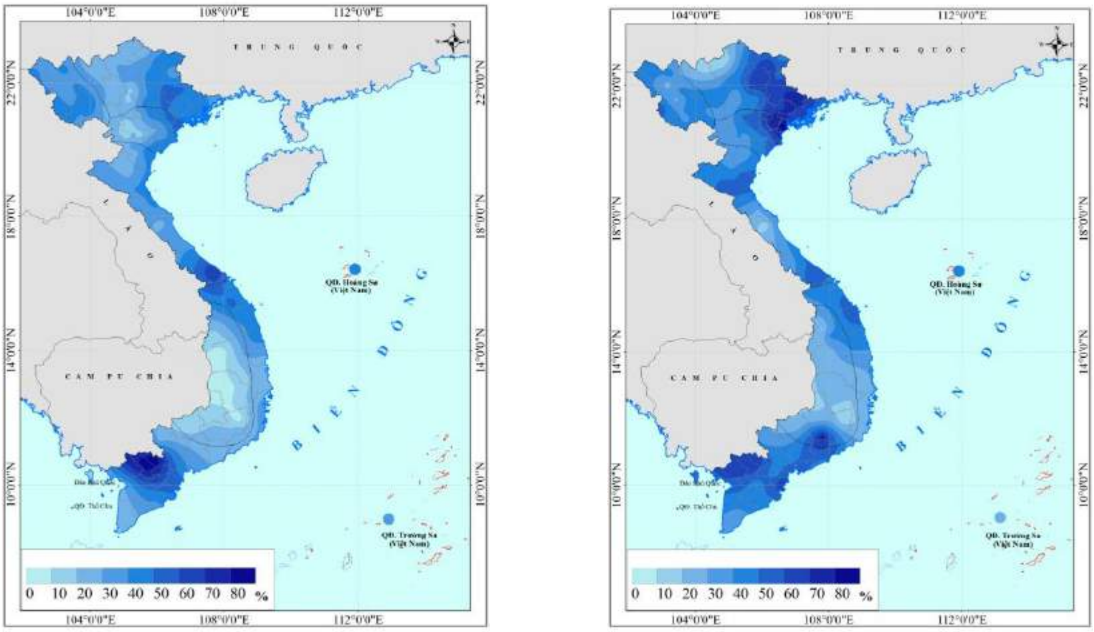
Firgure 5.12. Changes in average maximum 1-day rainfall based on RCP8.5 scenario

2) Average maximum 5-day rainfall (Rx5day)

According to the RCP4.5 scenario, by the mid-century, the average maximum 5-day rainfall will likely increase by 10-50% in general. It is likely that the greatest increase of about

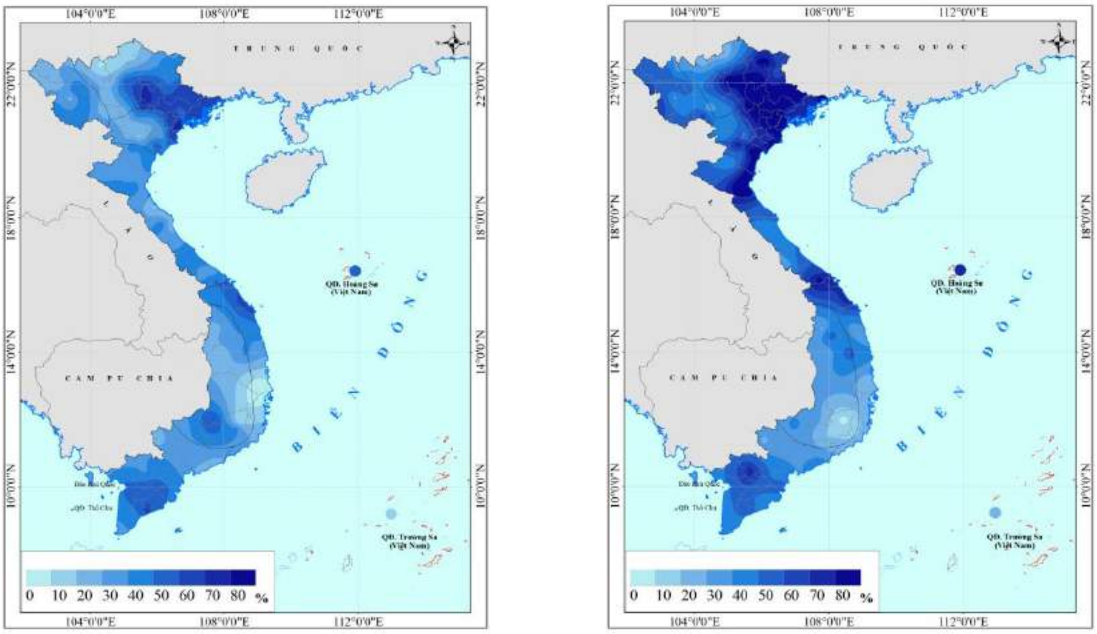
80% will be in the Southeast. By the end of the century, the trend will be similar to the trend at the mid-century, but greater in amount and larger in spatial scale, especially in the Northeast (Figure 5.13).

According to the RCP8.5 scenario, by the mid-century, the average maximum 5-day rainfall will likely have a similar trend as the maximum 1-day rainfall with the increases of 10-60% in general. The greatest increase of the rainfall will likely be in the Northeast. By the end of the century, the highest increased trend will likely be in the Northeast and North Central Coast (Figure 5.14).



(a) mid-21st century *(b) end of the 21st century*

Firgure 5.13. Changes in average maximum 5-day rainfall based on RCP4.5 scenario



(a) mid-21st century *(b) end of the 21st century*

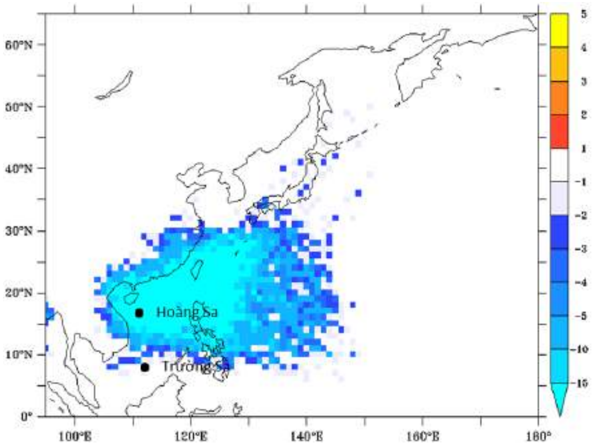
Firgure 5.14. Changes in average maximum 5-day rainfall based on RCP8.5 scenario

5.3. Climate change scenarios for climate extremes

5.3.1. Tropical depression and typhoon

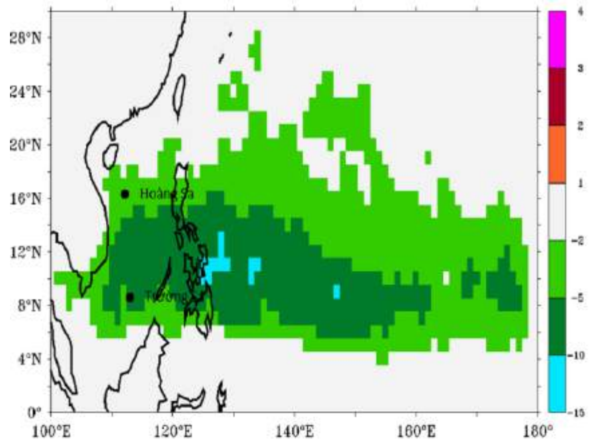
IPCC has suggested that the changed trend of storms in the 21st century could not be definitely identified the increase/decrease of global storm frequency (including the Northwest Pacific Ocean). The IPCC suggests that storm intensity will likely increase by 2-11%, storm rainfall within a radius of 100 km from the storm eye will likely increase by about 20% in the 21st century (IPCC, 2013).

The calculation results for tropical depressions and typhoons derived from the high-resolution models (MRI model, CCAM and PRECIS) for the East Sea are consistent with the IPCC report. According to the RCP8.5 scenario, by the end of the century, the tropical depressions and typhoons affecting to Viet Nam will likely reduce in frequency (Figure 5.15, 5.16 and 5.17). According to the RCP4.5 scenario, the projected number of tropical depressions and typhoons based on the PRECIS model will not be significant change (Figure 5.17).



Firgure 5.15. Changes in tropical depressions and typhoons at the end of 21st century compared with the baseline period

(based on MRI model with the RCP8.5 scenario)



Firgure 5.16. Changes in tropical depressions and typhoons at the end of 21st century compared with the baseline period

(based on CCAM model with the RCP8.5 scenario)

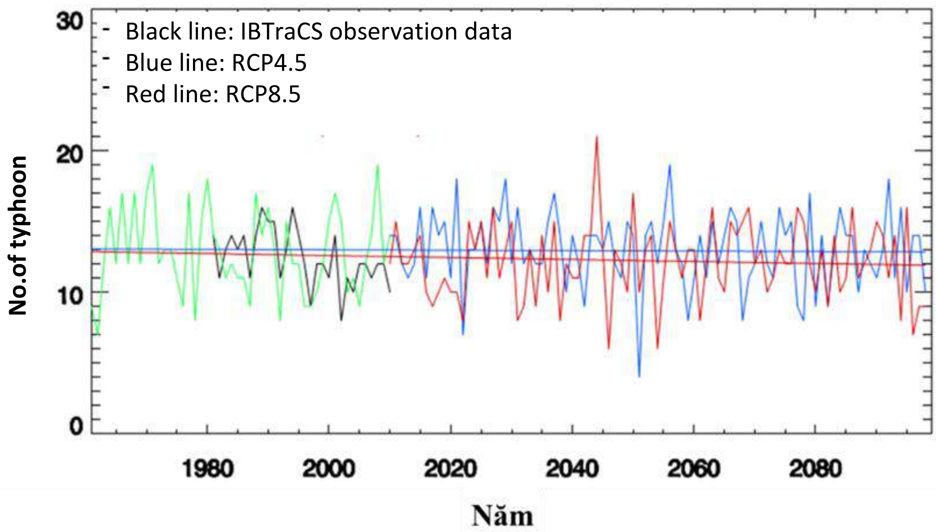
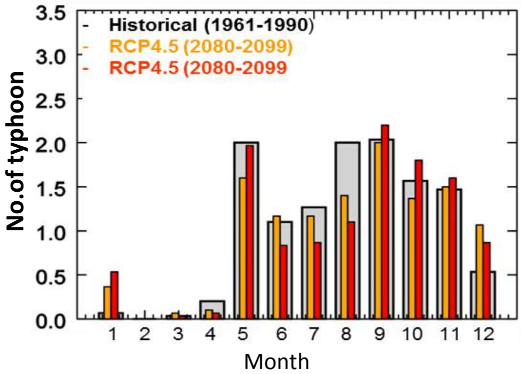


Figure 5.17. Changes in tropical depressions and typhoons at the end of 21st century compared with the baseline period

(based on PRECIS model with RCP4.5 and RCP8.5 scenario)

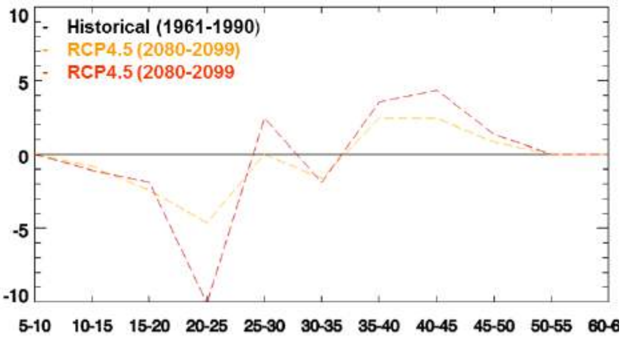
Based on the PRECIS model, the projected number of tropical depressions and typhoons in the East Sea will decrease at the beginning of the typhoon seasons (June - Agust) for both scenarios, RCP4.5 and RCP8.5 (Figure 5.18). Thus, the tropical depressions and typhoons will likely occur at the end of the typhoon season which is a period of typhoon activity occuring mainly in the South.

Figure 5.19 shows that the number of weak and moderate typhoon will likely decrease, while the number of strong typhoons will likely increase when compared with the baseline period.



Firgure 5.18. Projection number of typhoons and tropical depressions at the end of the century

(based on PRECIS model with RCP4.5 and RCP8.5 scenario)



Firgure 5.19. Changes in the number of typhoons and tropical depressions at the end of the century compared with the baseline period

(based on PRECIS model with RCP4.5 and RCP8.5 scenario)

5.3.2. Moonsoon

The most important characteristic of the monsoon is the period (starting date, duration and ending date). The characteristic has a special meaning because of the relation between the period with rainfall season and rainfall variation in the year.

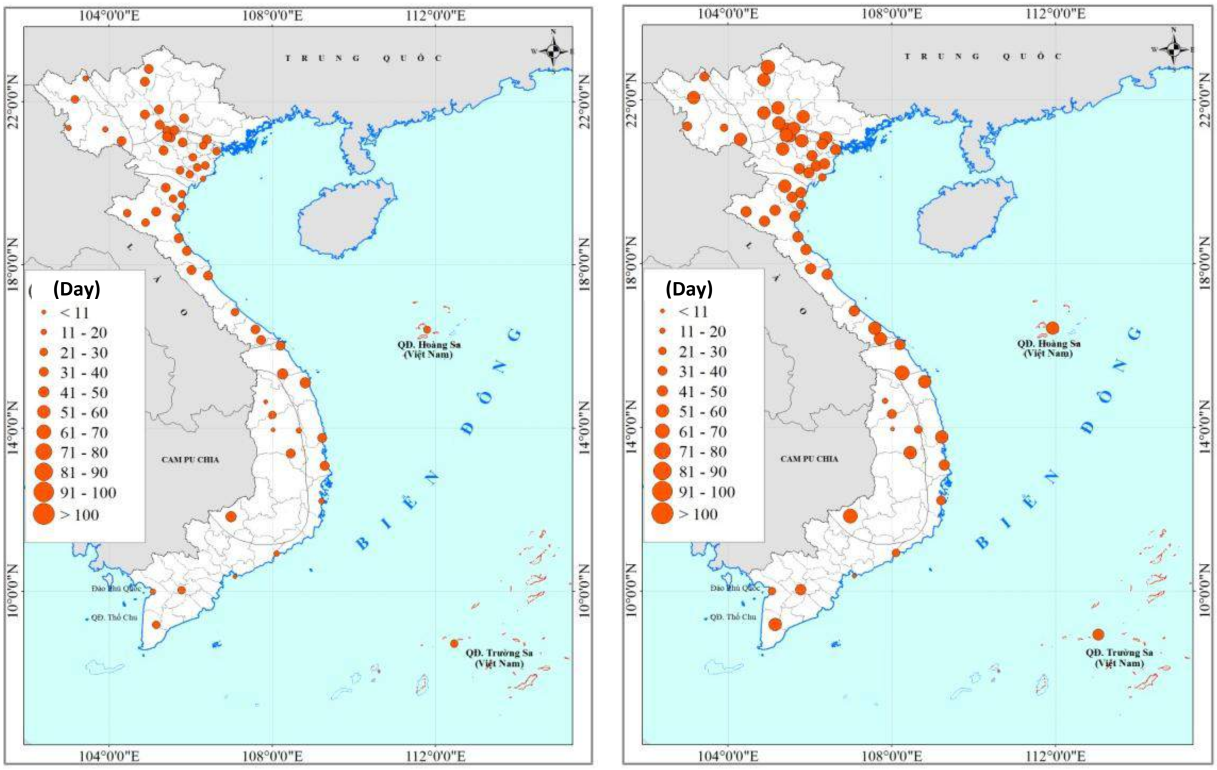
According to the results based on the CMIP5 models, areas affected by the monsoon system will likely increase in the 21st century. The date of Asian summer monsoon will likely start sooner and end later, resulting in a longer monsoon period. Results derived from most of CMIP5 models indicates a greater amount of rainfall and extreme rainfall in summer monsoon due to an increase of atmospheric moisture content (Hsu et al, 2013; Kitoh et al, 2013).

5.3.3. Extreme and damaging cold, heat wave and drought

Extreme and damaging cold

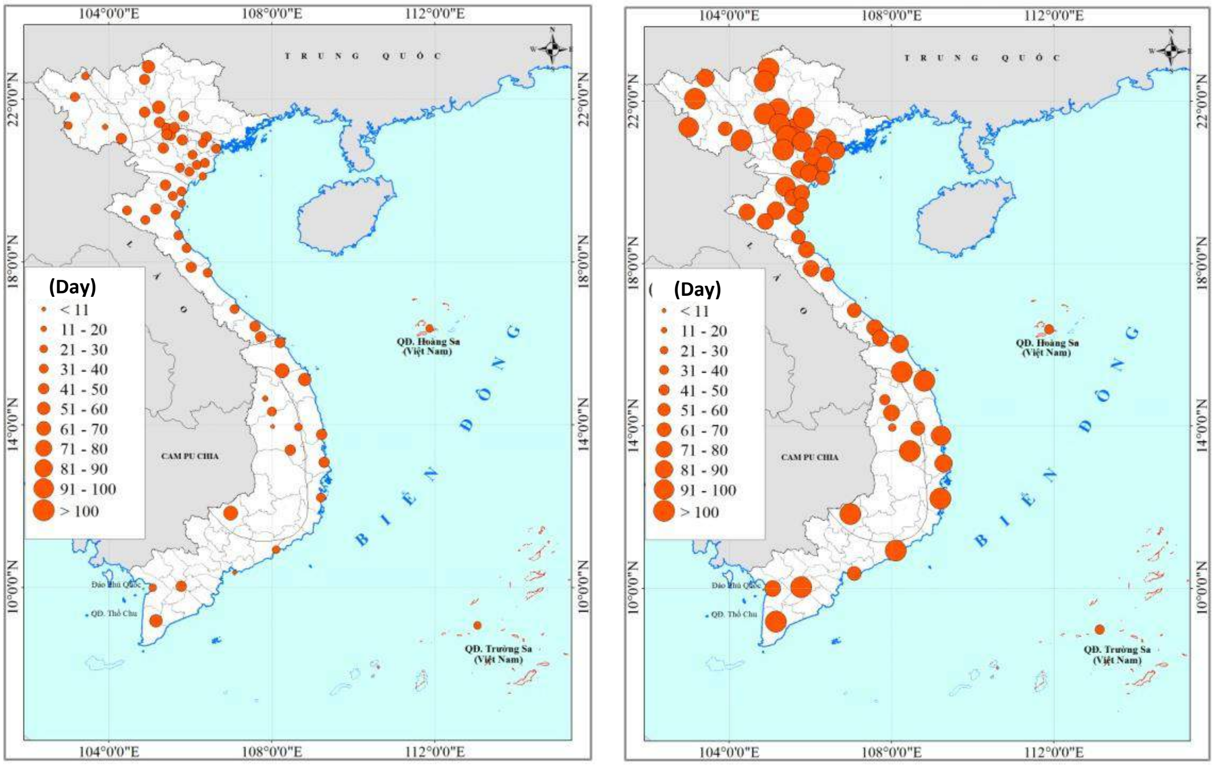
According to the RCP4.5 scenario, by the mid-century, the number of extreme cold days (the number of days with a minimum temperature Tn ≤ 15°C), the number of damaging cold days (the number of days with a minimum temperature Tn ≤ 13°C) will likely decrease by 5-10 days in most of provinces of the North compared to the baseline period. It is likely that the largest number of decreasing cold day will be 15 days in the Northwest and Northeast, the smallest number of decreasing cold day will be 5 days in the North Central Coast. By the end of the century, the number of extreme and damaging cold days will likely decrease by 10-20 days, the largest number of decreasing extreme and damaging cold day will likely be in some stations of the Northwest and the Northeast (over 20 days), the smallest number of decreasing extreme and damaging cold day (under 10 days) will likely be in some stations of the North Central Coast.

Heat wave: According to the RCP4.5 scenario, at the mid-century, the number of hot days (the number of days with a maximum temperature Tx ≥ 35^{o}C) will likely increase in most of the country when compared with the baseline period, 25-35 days in general. The greatest increase of the number of hot days will likely be in the South Central Coast (over 40 days), the smallest increase of the number of hot days will likely be in the Central Highlands and the South (Figure 5.20, left). By the end of the century, the number of hot days will likely increase considerably, over 50 days in the North Central Coast, the South Central Coast. The smallest increase in the number of hot days will likely in most of the Central Highlands and the South (Figure 5.20, right).



Firgure 5.20. Changes in the number of hot days (day/year) at the middle and the end of the century compared with baseline period, based on multi-models ensemble with RCP4.5 scenario

According to RCP8.5 scenario, by the mid-century, the number of hot days for the country will likely increase by 35-45 days compared to the baseline period, the largest increase will likely be in the South Central Coast, followed by the North Central Coast, the Northeast, the smallest increase will likely be in the Central Highlands and the South (Figure 5.21, left). By the end of the century, the number of hot days will likely be higher than the number of hot days in the middle of the century, the largest increase (over 100 days) will likely be in the Northeast, the South Central Coast and the South compared to the baseline period (Figure 5.21 , right).



Firgure 5.21. Changes in number of hot days (day/year) in the middle of (2046-2065) and the end of century(2080-2099) compared to the baseline period

Drought: According to the IPCC Fourth Assessment Report (AR4), drought tends to increase on a global scale, particularly in the tropics and subtropics since about 1970. However, the IPCC Fifth Assessment Report (AR5) has identified that droughts will likely increase in some seasons and some areas due to decrease in precipitation and/or increase in evaporation**.**

For Vietnam, it is likely that drought in some areas will be more severe due to the decrease in rainfall in dry season (e.g. drough in the spring and summer of the South Central Coast, the spring of the South and the winter of the North).

Climate change scenarios for the 63 provinces/cities are presented in detail in the **Annex A.**

VI. Sea- level rise scenarios for Viet Nam

6.1. Sea-level rise scenarios due to the climate change

Sea-level rise scenarios for Viet Nam were developed based on IPCC's AR5; the latest studies and national sea-level rise scenarios of Australia, Netherland and Singapore.

The increase in sea level was considered as a sum of the components including: (i) thermosteric processes, (ii) melting of glaciers, (iii) surface mass balance of the Greenland Ice Sheet (GSMB), (iv) Antarctic Ice Sheet surface mass balance (ASMB), (v) ice sheet dynamics in Greenland (GDIS), (vi) ice sheet dynamics in Antarctica (ADIS), (vii) land water storage, and (viii) glacial isostatic adjustment (GIA). Sea level rise due to dynamic and thermosteric components were determined using outputs from 21 Atmosphere-Ocean General Circulation Model (AOGCMs) published by IPCC. Both of these data were downloaded at monthly resolution and on the native model grids. Other components such as glaciers, surface mass balance in Greenland and Antarctica; dynamic ice sheet in Greenland and Antarctica; land water storage; and glacial isostatic adjustment were determined based on the global mean time series published in IPCC's AR5 (IPCC, 2013)

There are some updates reagarding the sea-level rise scenarios in this report compared to the 2012 report including: (i) applied the method from IPCC's AR5 report; (ii) based on the results from Atmosphere-Ocean General Circulation Models; (iii) used observed sea-level data and satellite data (updated to 2014) to valildate the model's results; (iv) identified sea-level rise for locations along the coastline, Spralty and Paracel Islands and for entire Viet Nam East Sea.

Sea level rise scenarios only consider changes in average sea water level caused by climate change. The scenarios do not take in to account the effects of other factors on sea water level, such as storm surge, monsoon induced water level rise, tide, tectonic uplift and subsidence, etc.

6.1.1. Contribution of components to sea-level rise

The total sea-level rise is considered as a sum of (i) thermosteric processes, (ii) melting of glaciers, (iii) surface mass balance of the Greenland Ice Sheet (GSMB), (iv) Abtarctic Ice Sheet surface mass balance (ASMB), (v) ice sheet dynamics in Greenland (GDIS), (vi) ice sheet dynamics in Antarctica (ADIS), (vii) land water storage, and (viii) glacial isostatic adjustment (GIA).

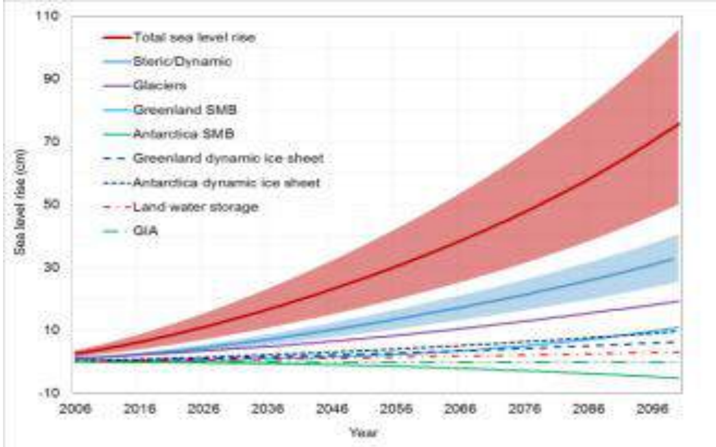
Table 6.1. Contribution of components to total sea-level rise in the Viet Nam East Sea by the end of the 21st century compared to the refenrence period

Unit: cm

Components	RCP4.5 scenario		RCP8.5 scenario	
	Global *(IPCC, 2013)*	Viet Nam East Sea	Global *(IPCC, 2013)*	Viet Nam East Sea
Dynamic/thermosteric processes	19 (14 ÷ 23)	21 (15 ÷ 34)	27 [21 ÷ 33]	33 (25 ÷ 40)
melting of glaciers	12 (6 ÷ 19)	14 (8 ÷ 20)	16 [9 ÷ 23]	19 (8 ÷ 25)
Ice sheet dynamics in Greenland	4 (1 ÷ 9)	5 (2 ÷ 10)	7 [3 ÷ 16]	11 (7 ÷ 20)
surface mass balance of the Greenland Ice Sheet	4 [1 ÷ 6]	5 (2 ÷ 7)	5 [2 ÷ 7]	7 (4 ÷ 10)
Antarctic Ice Sheet surface mass balance	-2 [-5 ÷ -1]	-3 (-4 ÷ 0)	-4 [-7 ÷ -1]	-5 (-8 ÷ -2)

Components	RCP4.5 scenario		RCP8.5 scenario	
	Global *(IPCC, 2013)*	Viet Nam East Sea	Global *(IPCC, 2013)*	Viet Nam East Sea
ice sheet dynamics in Antarctica	7 [-1 ÷ 16]	10 (3 ÷ 18)	7 [-1 ÷ 16]	10 (3 ÷ 19)
land water storage	4 [-1 ÷9]	3 (0 ÷ 8)	4 [-1 ÷ 9]	3 (0 ÷ 8)
glacial isostatic adjustment		-0,1	N/A	-0,2
Total sea-level rise	**53 (36 ÷ 71)**	**55 (33 ÷ 75)**	**74 (52 ÷ 98)**	**77 (52 ÷ 106)**

The method for each component was presented in the Chapter 4, section 4.2.1. The results for the Viet Nam East Sea are shown in table 6.1 and figure 6.1. The results show that the contribution of dynamic/thermosteric component is larger than any other component followed by glaciers, ice sheet melting in Greenland, ice melting in Antartica and land water storage.



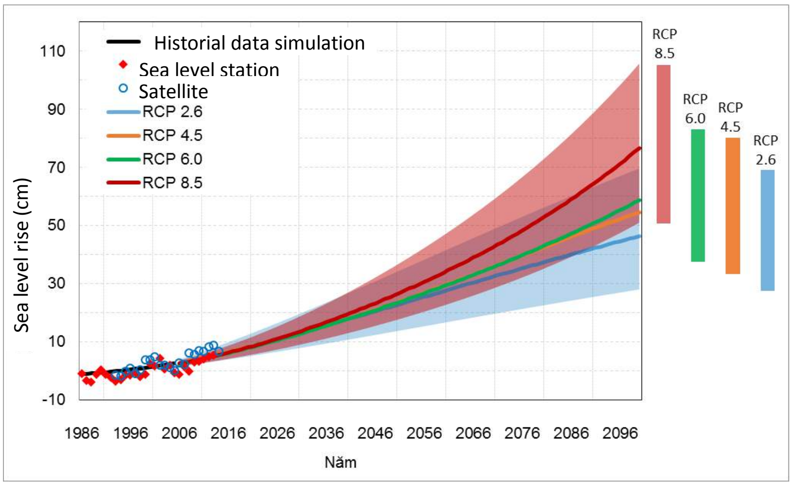
Firgure 6.1. Contribution of component to the total sea-level rise in the Viet Nam East Sea following RCP8.5 scenario

6.1.2. Sea-level rise scenarios for Viet Nam East Sea

- By mid-21st century:
  - For RCP2.6 scenario, sea level would rise 22 cm (from 14 cm ÷ 34 cm);
  - For RCP4.5 scenario, sea level would rise 23 cm (from14 cm ÷ 34 cm);
  - For RCP6.0 scenario, sea level would rise 23 cm (from 15 cm ÷ 34 cm);
  - For RCP8.5 scenario, sea level would rise 24 cm (from 17 cm ÷ 36 cm).
- By late 21st century:
  - For RCP2.6 scenario, sea level would rise 46 cm (from 28 cm ÷ 70 cm);
  - For RCP4.5 scenario, sea level would rise 55 cm (from 33 cm ÷ 75 cm);
  - For RCP6.0 scenario, sea level would rise 59 cm (from 38 cm ÷ 84 cm);
  - For RCP8.5 scenario, sea level would rise 77 cm (from 51 cm ÷ 106 cm).

Figure 6.2 presents sea-level rise scenario for the Viet Nam East Sea. The results show a agreement with the observed data and satellite data in regard of magnitudes and trends. The estimated trend from observed data and the models are about 2.8 mm/year and 2,4 mm/year, respectively.

In the first decades of the 21st century, the rate of sea level rise for the RCP 4.5 and RCP 8.5 scenarios are similar. However, this similarity no longer holds after 2040 with sea level for the two scenarios differing greatly. The trend of sea-level rise is largest in RCP8.5 scenario and smallest in RCP4.5 scenario.



Firgure 6.2. Sea-level rise scenario for Viet Nam East Sea

The shaded areas show the confident intervals of RCP2.6 and RCP8.5 scenarios; the columns on the right indicate the 5% - 95% confident intervals by 2100.

Table 6.2 hows the results of sea-level estimations in the 21st century timelines. The highest sea-level rise would be up to 106 cm (RCP8.5 scenario).

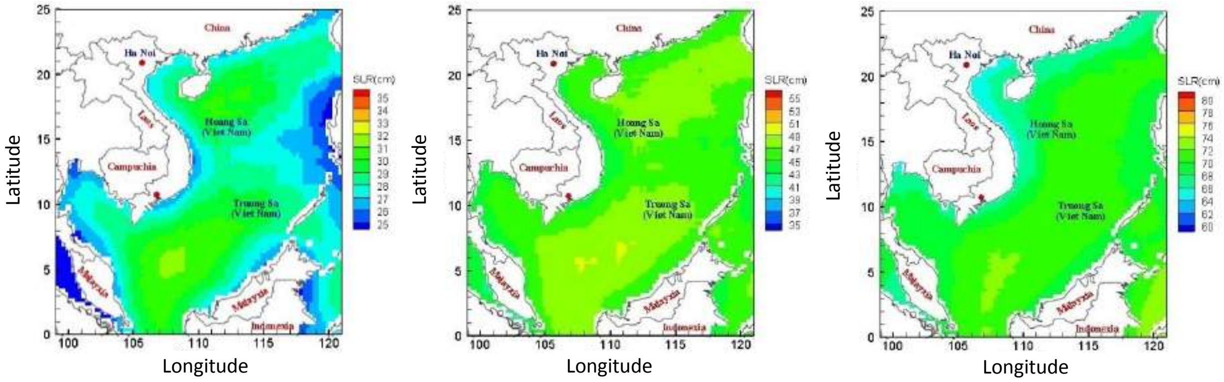
Table 6. 2 Sea-level rise scenarios for Viet Nam East Sea in the 21st century timelines

Unit: cm

Scenarios	The timeline of the 21st century							
	2030	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
RCP2.6	13 (8 ÷ 19)	18 (11 ÷ 26)	22 (14 ÷ 34)	27 (17 ÷ 41)	32 (20 ÷ 49)	37 (22 ÷ 56)	42 (25 ÷ 63)	46 (28 ÷ 60)
RCP4.5	13 (8 ÷ 19)	18 (11 ÷ 26)	23 (14 ÷ 34)	29 (18 ÷ 43)	36 (22 ÷ 53)	42 (26 ÷ 62)	49 (30 ÷ 72)	55 (34 ÷ 81)
RCP6.0	13 (8 ÷ 19)	18 (11 ÷ 26)	23 (15 ÷ 34)	29 (19 ÷ 42)	36 (23 ÷ 51)	43 (28 ÷ 61)	50 (33 ÷ 72)	59 (38 ÷ 84)
RCP8.5	13 (9 ÷ 19)	19 (13 ÷ 27)	26 (17 ÷ 36)	34 (23 ÷ 47)	43 (28 ÷ 59)	52 (35 ÷ 72)	64 (42 ÷ 88)	77 (51 ÷ 106)

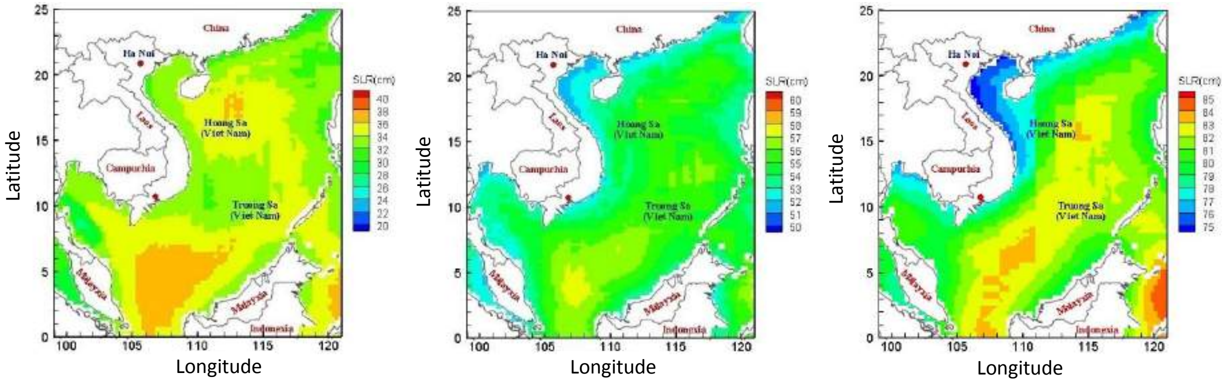
Spatial distributions of sea-level rise by the end of 21st century compared to 1986-2005 period are shown in Figs. 6.3 – 6.6. Sea-level rise in the central East Sea, the regions of Hoang Sa and Truong Sa archipelagos and the south of East Sea is considerbly higher than other regions. Sea-level rise is lowest in the northern part of East Sea and Gulf of Tonkin.

Considering the coastal areas of Viet Nam, sea-level rise in the region from Da Nang to Kien Giang is higher than the northern part. This result is in line with the results from observed data at tide gauges (Tran Thuc et al., 2015). By the end of 21st century, the trend of sea-level rise is largest in RCP8.5 scenario and lowest in RCP2.6 scenario.



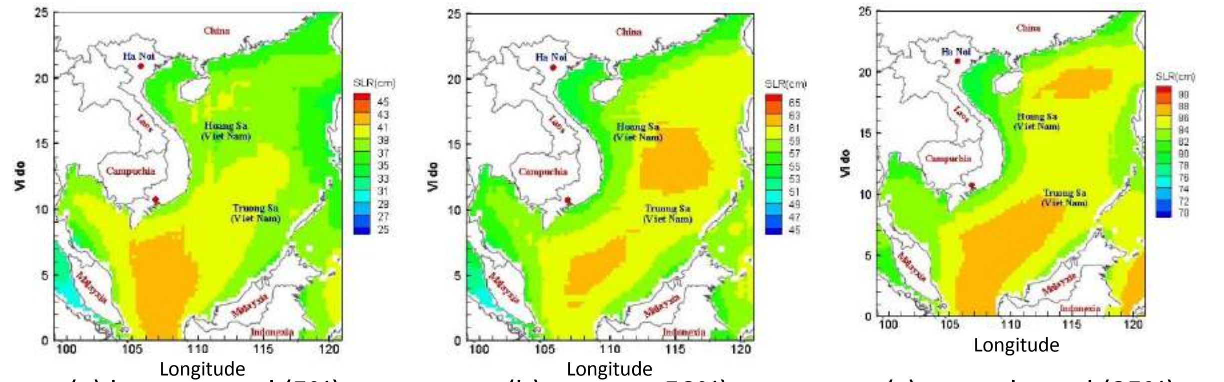
(a) lower bound (5%) (b) median (50%) (c) upper bound (95%)

Firgure 6.3. Sea-level rise by the end of 21st century from RCP2.6 scenario



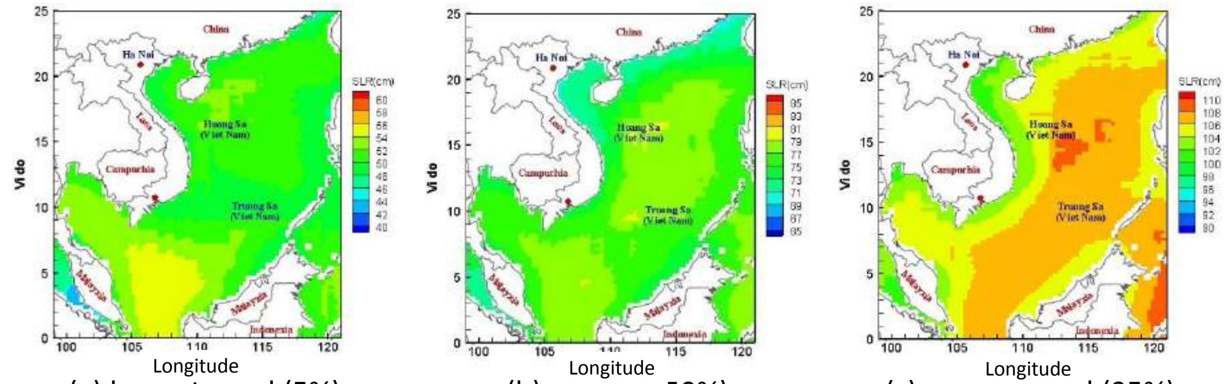
(a) lower bound (5%) (b) median (50%) (c) upper bound (95%)

Firgure 6.4. Sea-level rise by the end of 21st century from RCP4.5 scenario



(a) lower bound (5%) (b) median (50%) (c) upper bound (95%)

Firgure 6.5. Sea-level rise by the end of 21st century from RCP6.0 scenario



(a) lower bound (5%) (b) median (50%) (c) upper bound (95%)

Firgure 6.6. Sea-level rise by the end of 21st century from RCP8.5 scenario

6.1.3. Sea-level rise scenarios for coastal areas and island in Viet Nam

Table 6.3 presents the results of sea-level rise estimations for Viet Nam's coastline by the end of 21st century.

By early 21st century, there is no significant difference in sea level rise for all RCP scenarios. By 2030, the average sea level rise for Viet Nam coast would be about 13 cm (8÷18 cm) for the RCP2.6, RCP4.5 and RCP6.0 scenarios, and 13 cm (9÷18 cm) for the RCP8.5 scenarios.

By mid-21st century, there is a difference in trend of sea level rise. By 2050, average sea level rise for the coastal areas of Viet Nam are about 21 cm (13÷32 cm) for the RCP2.6 scenarios, about 22 cm (14÷32 cm) for the RCP4.5 scenarios, about 22 cm (14÷32 cm) for the RCP6.0 scenarios, and about 25 cm (17÷35 cm) for the RCP8.5 scenarios.

By late 21st century, differences in trend of sea level rise for different RCP scenarios are clear. By 2100, average sea level rise for the coastal areas of Viet Nam would be about 44 cm (27÷66 cm) for the RCP2.6 scenarios, about 53 cm (32÷76 cm) for the RCP4.5 scenarios, about 56 cm (37÷81 cm) for the RCP6.0 scenarios, and about 73 cm (49÷103 cm) for the RCP8.5 scenarios.

Table 6.3. Sea-level scenarios for Viet Nam's coastline

Unit: cm

Scenarios	The timeline of the 21st century							
	2030	2040	2050	2060	2070	2080	2090	2100
RCP2.6	13 (8 ÷ 19)	17 (10 ÷ 25)	21 (13 ÷ 32)	26 (16 ÷ 39)	30 (18 ÷ 45)	35 (21 ÷ 52)	40 (24 ÷ 59)	44 (27 ÷ 66)
RCP4.5	13 (8 ÷ 18)	17 (10 ÷ 25)	22 (14 ÷ 32)	28 (17 ÷ 40)	34 (20 ÷ 48)	40 (24 ÷ 57)	46 (28 ÷ 66)	53 (32 ÷ 76)
RCP6.0	13 (8 ÷ 17)	17 (11 ÷ 24)	22 (14 ÷ 32)	27 (18 ÷ 39)	34 (22 ÷ 48)	41 (27 ÷ 58)	48 (32 ÷ 69)	56 (37 ÷ 81)
RCP8.5	13 (9 ÷ 18)	18 (12 ÷ 26)	25 (17 ÷ 35)	32 (22 ÷ 46)	41 (28 ÷ 58)	51 (34 ÷ 72)	61 (42 ÷ 87)	73 (49 ÷ 103)

The sea level rise scenarios are built for coastal provinces and 9 regions, namely: (I) from Mong Cai to Hon Dau; (II) from Hon Dau to Deo Ngang; (III) from Deo Ngang to Deo Hai Van; (IV) from Deo Hai Van to Mui Dai Lanh; (V) from Mui Dai Lanh to Mui Ke Ga; (VI) from Mui Ke Ga to Mui Ca Mau; (VII) from Mui Ca Mau to Kien Giang; (VIII) Hoang Sa archipelago; and (IX) Truong Sa archipelago.

The results of sea-level rise for each region and each scenario are shown in **Table 6.4 – 6.7**, synthesized in **Figure 6.7**, downscaled to each coastal province in **Figure 6.8**. In generall, the rate of sea-level rise increases from the north to the south.

For RCP2.6 scenario: by late 21st century, the highest sea level rise would be in the regions of Hoang Sa and Truong Sa archipelagos with the sea level rise of about 48 cm (29 cm ÷ 70 cm) and 49 cm (30 cm ÷ 71 cm), respectively; Sea-level rise is lowest in the regions of Mong Cai - Hon Dau and Hon Dau - Deo Ngang 44 cm (27 cm ÷ 65 cm) **(Table 6.4).**

For RCP4.5 scenario: By late 21st century, the highest sea level rise would be in the regions of Hoang Sa and Truong Sa archipelagos with the sea level rise of about 58 cm (36÷80 cm) and 57 cm (33÷83 cm), respectively; Sea level rise would be about 55 cm (33÷78 cm) from Ca Mau to Kien Giang; the lowest sea level rise would be about 53 cm (32÷75 cm) in the regions of Mong Cai - Hon Dau and Hon Dau - Deo Ngang **(Table 6.5)**

Table 6.4. Sea level rise scenarios based on the RCP2.6 scenario

Unit: cm

Regions	The timeline of the 21st century							
	2030	2040	2050	2060	2070	2080	2090	2100
Mong Cai-Hon Dau	13 (8 ÷ 19)	17 (10 ÷ 25)	21 (13 ÷ 31)	25 (16 ÷ 38)	30 (18 ÷ 44)	34 (21 ÷ 51)	39 (24 ÷ 58)	44 (27 ÷ 65)
Hon Dau-Đeo Ngang	13 (8 ÷ 19)	17 (10 ÷ 25)	21 (13 ÷ 31)	25 (16 ÷ 38)	30 (18 ÷ 44)	34 (21 ÷ 51)	39 (24 ÷ 58)	44 (27 ÷ 65)
Đeo Ngang-Đeo Hai Van	13 (8 ÷ 19)	17 (11 ÷ 25)	21 (13 ÷ 31)	26 (16 ÷ 38)	30 (19 ÷ 44)	35 (22 ÷ 51)	40 (25 ÷ 58)	44 (28 ÷ 65)
Đeo Hai Van-Mai Đai Lanh	13 (8 ÷ 19)	17 (10 ÷ 25)	22 (13 ÷ 32)	26 (15 ÷ 39)	31 (18 ÷ 45)	35 (21 ÷ 52)	40 (24 ÷ 59)	45 (26 ÷ 66)
Mui Đai Lanh-Mui Ke Ga	13 (7 ÷ 19)	17 (10 ÷ 26)	22 (13 ÷ 32)	26 (16 ÷ 39)	31 (18 ÷ 46)	35 (21 ÷ 53)	40 (24 ÷ 60)	45 (27 ÷ 67)
Mui Ke Ga-Mui Ca Mau	12 (7 ÷ 19)	17 (10 ÷ 25)	21 (12 ÷ 32)	26 (15 ÷ 39)	30 (18 ÷ 46)	35 (20 ÷ 52)	39 (23 ÷ 59)	44 (26 ÷ 66)
Mui Ca Mau-Kien Giang	13 (8 ÷ 19)	17 (10 ÷ 26)	22 (13 ÷ 33)	27 (16 ÷ 40)	31 (19 ÷ 47)	36 (22 ÷ 54)	41 (25 ÷ 61)	45 (27 ÷ 68)
Hoang Sa archipelago	13 (8 ÷ 20)	18 (11 ÷ 27)	23 (14 ÷ 34)	28 (17 ÷ 41)	33 (20 ÷ 49)	38 (23 ÷ 56)	43 (26 ÷ 63)	48 (29 ÷ 70)
Truong Sa archipelago	13 (8 ÷ 19)	18 (11 ÷ 26)	23 (14 ÷ 34)	28 (17 ÷ 41)	33 (20 ÷ 48)	38 (24 ÷ 56)	44 (27 ÷ 63)	49 (30 ÷ 71)

Table 6.5. Sea level rise scenarios based on the RCP4.5 scenario

Unit: cm

Regions	The timeline of the 21st century							
	2030	2040	2050	2060	2070	2080	2090	2100
Mong Cai-Hon Dau	13 (8 ÷ 18)	17 (10 ÷ 24)	22 (13 ÷ 31)	27 (17 ÷ 39)	33 (20 ÷ 47)	39 (24 ÷ 56)	46 (28 ÷ 65)	53 (32 ÷ 75)
Hon Dau-Đeo Ngang	13 (8 ÷ 18)	17 (10 ÷ 24)	22 (13 ÷ 31)	27 (16 ÷ 39)	33 (20 ÷ 47)	39 (24 ÷ 56)	46 (28 ÷ 65)	53 (32 ÷ 75)
Đeo Ngang-Đeo Hai Van	13 (8 ÷ 18)	17 (11 ÷ 24)	22 (14 ÷ 32)	28 (17 ÷ 39)	34 (20 ÷ 47)	40 (24 ÷ 56)	46 (28 ÷ 65)	53 (32 ÷ 75)
Đeo Hai Van-Mai Đai Lanh	13 (8 ÷ 18)	17 (11 ÷ 25)	23 (14 ÷ 32)	28 (17 ÷ 40)	34 (21 ÷ 48)	40 (25 ÷ 57)	47 (29 ÷ 66)	54 (33 ÷ 76)
Mui Đai Lanh-Mui Ke Ga	12 (8 ÷ 18)	17 (11 ÷ 25)	23 (14 ÷ 33)	28 (17 ÷ 41)	34 (21 ÷ 50)	40 (24 ÷ 59)	47 (28 ÷ 68)	54 (33 ÷ 78)
Mui Ke Ga-Mui Ca Mau	12 (7 ÷ 18)	17 (10 ÷ 25)	22 (13 ÷ 32)	28 (17 ÷ 40)	33 (20 ÷ 49)	40 (24 ÷ 58)	46 (28 ÷ 67)	53 (32 ÷ 77)
Mui Ca Mau-Kien Giang	12 (7 ÷ 18)	17 (10 ÷ 25)	23 (14 ÷ 32)	28 (17 ÷ 40)	34 (21 ÷ 49)	41 (25 ÷ 58)	48 (29 ÷ 68)	55 (33 ÷ 78)
Hoang Sa archipelago	13 (8 ÷ 18)	18 (12 ÷ 26)	24 (15 ÷ 34)	30 (19 ÷ 42)	37 (23 ÷ 51)	43 (27 ÷ 61)	50 (31 ÷ 70)	58 (36 ÷ 80)
Truong Sa archipelago	14 (8 ÷ 20)	19 (11 ÷ 27)	24 (14 ÷ 35)	30 (17 ÷ 44)	36 (21 ÷ 53)	43 (25 ÷ 62)	50 (29 ÷ 72)	57 (33 ÷ 83)

For RCP6.0 scenario: By late 21st century, the highest sea level rise would be in the regions of Hoang Sa and Truong Sa archipelagos with the sea level rise of about 60 cm (37÷85 cm) and 60 cm (39÷86 cm), respectively; the lowest sea level rise would be about 54 cm (35÷79 cm) and 54 cm (35÷78 cm) in the regions of Mong Cai - Hon Dau and Hon Dau - Deo Ngang. **(Table 6.6)**

For RCP8.5 scenario: By late 21st century, the highest sea level rise would be in the regions of Hoang Sa and Truong Sa archipelagos with the sea level rise of about 78 cm (52÷107 cm) and 77 cm (50÷107 cm), respectively; the lowest sea level rise would be about

72 cm (49÷101 cm) in the regions of Mong Cai - Hon Dau and Hon Dau - Deo Ngang. **(Table 6.7)**

Table 6.6. Sea level rise scenarios based on the RCP6.0 scenario

Unit: cm

Regions	The timeline of the 21st century							
	2030	2040	2050	2060	2070	2080	2090	2100
Mong Cai-Hon Dau	12 (8 ÷ 17)	16 (11 ÷ 24)	21 (14 ÷ 31)	27 (17 ÷ 39)	33 (21 ÷ 48)	40 (26 ÷ 57)	47 (30 ÷ 68)	54 (35 ÷ 79)
Hon Dau-Đeo Ngang	12 (8 ÷ 17)	16 (11 ÷ 24)	21 (14 ÷ 31)	27 (17 ÷ 39)	33 (21 ÷ 48)	39 (25 ÷ 57)	46 (30 ÷ 67)	54 (35 ÷ 78)
Đeo Ngang-Đeo Hai Van	12 (8 ÷ 17)	17 (11 ÷ 24)	22 (14 ÷ 31)	27 (18 ÷ 39)	34 (22 ÷ 48)	40 (27 ÷ 58)	47 (31 ÷ 68)	55 (37 ÷ 80)
Đeo Hai Van-Mai Đai Lanh	12 (8 ÷ 17)	17 (11 ÷ 24)	22 (15 ÷ 31)	28 (19 ÷ 40)	34 (23 ÷ 49)	41 (28 ÷ 59)	49 (33 ÷ 70)	57 (38 ÷ 82)
Mui Đai Lanh-Mui Ke Ga	11 (8 ÷ 16)	16 (11 ÷ 23)	22 (14 ÷ 31)	28 (18 ÷ 40)	34 (23 ÷ 49)	41 (28 ÷ 59)	49 (33 ÷ 70)	57 (38 ÷ 82)
Mui Ke Ga-Mui Ca Mau	11 (7 ÷ 16)	16 (10 ÷ 23)	21 (14 ÷ 31)	27 (18 ÷ 39)	34 (22 ÷ 48)	41 (27 ÷ 58)	48 (32 ÷ 69)	56 (37 ÷ 81)
Mui Ca Mau-Kien Giang	11 (8 ÷ 16)	16 (11 ÷ 23)	22 (15 ÷ 31)	28 (19 ÷ 40)	35 (23 ÷ 49)	42 (28 ÷ 59)	50 (33 ÷ 70)	58 (39 ÷ 82)
Hoang Sa archipelago	13 (8 ÷ 18)	18 (11 ÷ 25)	24 (15 ÷ 33)	30 (19 ÷ 42)	37 (23 ÷ 52)	44 (27 ÷ 62)	52 (32 ÷ 73)	60 (37 ÷ 85)
Truong Sa archipelago	13 (8 ÷ 18)	18 (12 ÷ 26)	24 (16 ÷ 34)	30 (20 ÷ 43)	37 (24 ÷ 52)	44 (29 ÷ 63)	52 (34 ÷ 74)	60 (39 ÷ 86)

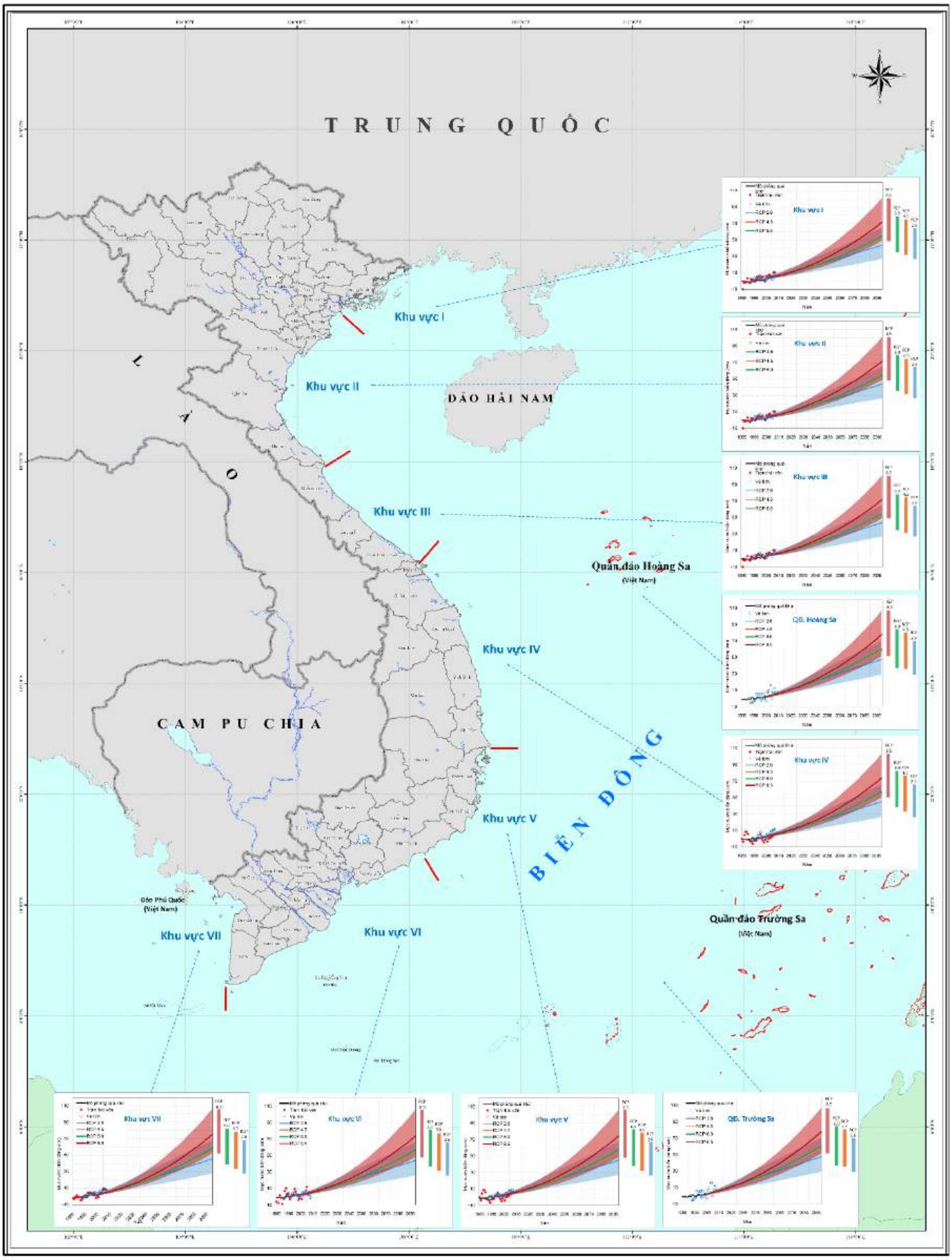
Table 6.7. Sea level rise scenarios based on the RCP8.5 scenario

Unit: cm

Regions	The timeline of the 21st century							
	2030	2040	2050	2060	2070	2080	2090	2100
Mong Cai-Hon Dau	13 (9 ÷ 18)	18 (13 ÷ 26)	25 (17 ÷ 35)	32 (22 ÷ 45)	41 (28 ÷ 57)	50 (34 ÷ 70)	60 (41 ÷ 85)	72 (49 ÷ 101)
Hon Dau-Đeo Ngang	13 (9 ÷ 18)	18 (12 ÷ 26)	25 (17 ÷ 35)	32 (22 ÷ 45)	40 (28 ÷ 57)	50 (34 ÷ 71)	60 (41 ÷ 85)	72 (49 ÷ 101)
Đeo Ngang-Đeo Hai Van	13 (9 ÷ 18)	19 (13 ÷ 26)	25 (17 ÷ 35)	33 (22 ÷ 46)	41 (28 ÷ 58)	50 (34 ÷ 71)	61 (42 ÷ 86)	72 (49 ÷ 102)
Đeo Hai Van-Mai Đai Lanh	13 (9 ÷ 18)	18 (13 ÷ 26)	25 (17 ÷ 35)	33 (22 ÷ 46)	41 (28 ÷ 58)	51 (35 ÷ 71)	62 (42 ÷ 86)	73 (50 ÷ 103)
Mui Đai Lanh-Mui Ke Ga	12 (8 ÷ 18)	18 (12 ÷ 26)	25 (16 ÷ 35)	33 (21 ÷ 46)	41 (27 ÷ 59)	51 (34 ÷ 73)	62 (41 ÷ 89)	74 (49 ÷ 105)
Mui Ke Ga-Mui Ca Mau	12 (8 ÷ 17)	18 (12 ÷ 26)	25 (16 ÷ 35)	32 (21 ÷ 46)	41 (27 ÷ 59)	51 (33 ÷ 73)	61 (41 ÷ 88)	73 (48 ÷ 105)
Mui Ca Mau-Kien Giang	12 (9 ÷ 17)	18 (13 ÷ 26)	25 (17 ÷ 35)	33 (23 ÷ 47)	42 (29 ÷ 59)	52 (36 ÷ 73)	63 (44 ÷ 89)	75 (52 ÷ 106)
Hoang Sa archipelago	13 (9 ÷ 18)	19 (13 ÷ 26)	26 (17 ÷ 36)	34 (23 ÷ 47)	44 (29 ÷ 60)	54 (36 ÷ 74)	65 (43 ÷ 90)	78 (52 ÷ 107)
Truong Sa archipelago	14 (9 ÷ 19)	20 (13 ÷ 28)	27 (18 ÷ 37)	35 (23 ÷ 49)	44 (29 ÷ 61)	54 (36 ÷ 75)	65 (42 ÷ 90)	77 (50 ÷ 107)

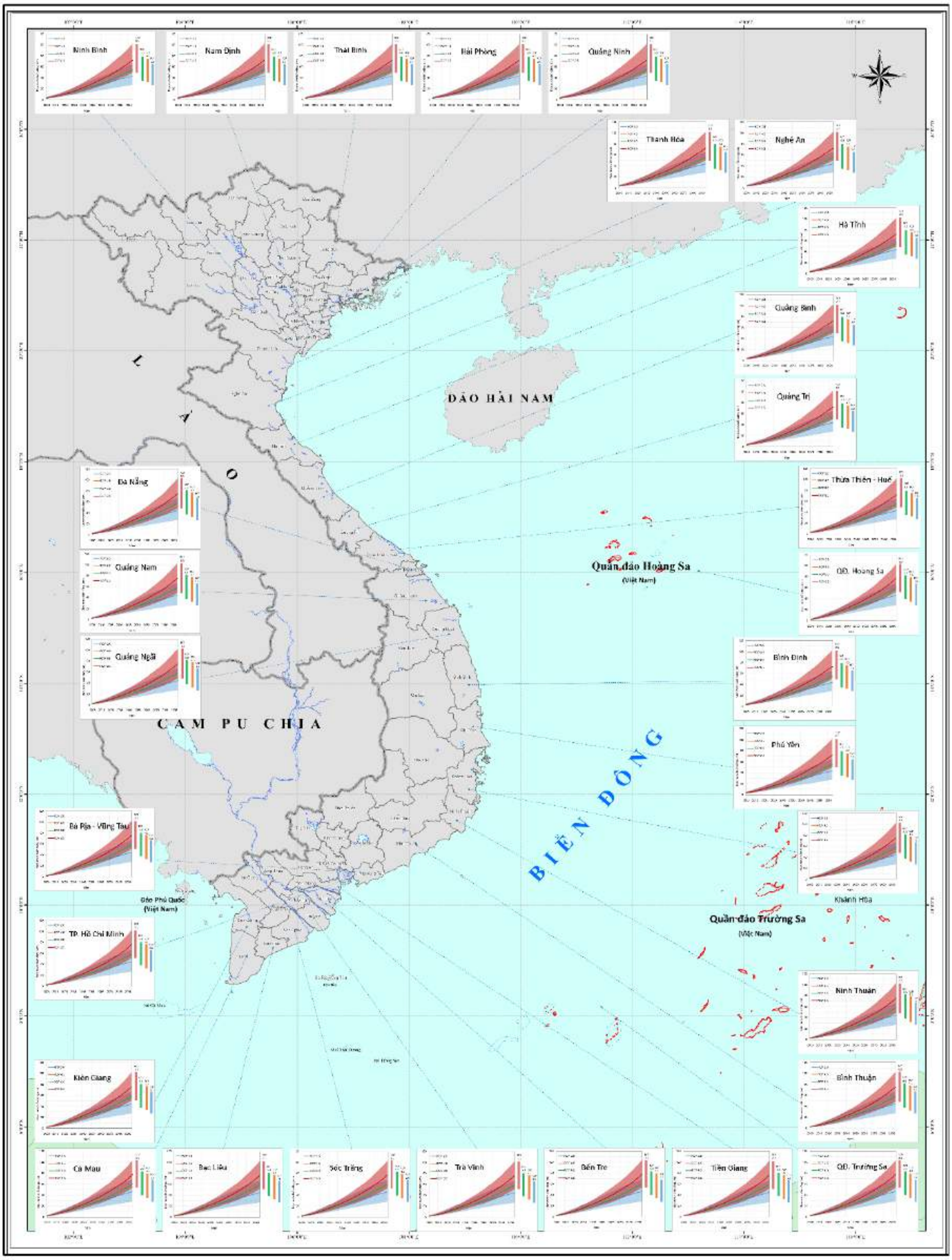
Box 8. Summary of sea-level rise scenarios for Viet Nam

- Sea-level rise scenarios only considered climate change-induced mean sea-level changes; other factors were not included into the scenarios such as: storm surges, monsoon-related surges or vertical land movements.
- Sea-level rise scenarios were developed for coastal provinces, seven coastal regions, Hoang Sa and Truong Sa archipelagos.
- Dynamic/thermosteric and glaciers melting components contirbuted most to the total sea-level rise in Viet Nam.
- By the year of 2050, the mean sea-level rise along Viet Nam's coastline for RCP2.6, RCP4.5, RCP6.0 and RCP8.5 scenarios are 21 (13 cm ÷ 32 cm), 22 cm (14 cm ÷ 32 cm), 22 cm (14 cm ÷ 32 cm) and 21 cm (17 cm ÷ 35 cm), respectively.
- By the year of 2100, the mean sea-level rise along Viet Nam's coastline for RCP2.6, RCP4.5, RCP6.0 and RCP8.5 scenarios are 44 cm (27 cm ÷ 66 cm), 53 cm (32 cm ÷ 76 cm), 56 cm (37 cm ÷ 81 cm) and 73 cm (49 cm ÷ 103 cm), respectively.
- Mean sea-level rise in Viet Nam is likely higher than global mean sea-level rise. Sea level rise in the Southern coastline would be higher than in the Northern coastline. By late 21st century, sea-level rises at Mong Cai-Hon Dau and Hon Dau-Deo Ngang regions would be lowest: 55 cm (33 cm ÷ 78 cm) for RCP4.5, 72 cm (49 cm ÷ 101 cm) for RCP8.5 whereas Ca Mau – Kien Giang regions would have the largest sea-level rise: 53 cm (32 cm ÷ 75 cm) for RCP4.5 and 75 cm (52 cm ÷ 106 cm) for RCP8.5;
- Sea-level rise at the central part of East Sea would be higher than other regions. By late 21st century, sea-level rise at Hoang Sa archipelago would be 58 cm (36 cm ÷ 80 cm) for RCP4.5 and 78 cm (52 cm ÷ 107 cm) for RCP8. Sea-level rise at Truong Sa archipelago would 57 cm (33 cm ÷ 83 cm) for RCP4.5 and 77 cm (50 cm ÷ 107 cm) for RCP8.5.



Firgure 6.7. Sea-level rise scenarios for coastal areas and islands of Viet Nam

<u>Legend</u>: Obervered sea-level data at tide gauges (lozenges), satellite data (circle); Water levels computed from models for the reference period (black line); Sea level rise scenarios of the RCP2.6 scenarios compared to the reference period (blue), RCP4.5 (orange), RCP6.0 (green), and RCP8.5 (red), levels of confidence of 5% - 95% (shading) of the two scenarios RCP2.6 and RCP8.5. The values of the right column indicate the levels of confidence of 5% - 95% by 2100.



Firgure 6.8. Sea-level scenarios for coastal provinces and islands of Viet Nam

Legend: Sea level rise scenarios compared to the reference period, for RCP2.6 (blue), RCP4.5 (orange), RCP6.0 (green), and RCP8.5 (red), levels of confidence of 5% - 95% (shading) of the two scenarios RCP2.6 and RCP8.5. The values of the right column indicate the levels of confidence of 5% - 95% by 2100.

6.2. Some results of extreme sea levels

As mentioned in **section 6.1,** climate change-based sea-level scenarios only considered the mean sea level and did not included other factors causing surges. This part syntheses previous works in order to provide information of extreme sea levels at Viet Nam's coastal areas.

6.2.1. Storm surges

The highest storm surge recored in Viet Nam occurred in 1989 during Typhoon Dan (3,6 m). Historical records also documented lots of damages cuaused by storm surges. Typhoon Kelly 1918 made landfall in Nghe An rising high surge up to 2,8-3,2 . Typhoon Andy 1985 caused 1,7 m – surge at Quang Binh; Typhoon Cecil produced 2,5 m – surge at Thua Thien Hue in the same year; Typhoon Wayne 1986 created 2,3 m – surge at Thai Binh. There are many more examples of high storm surges at Hai Phong (Typhoon Dot 1989, 2,2 m); Thanh Hoa (Typhoon Irving 1989, 2,9 m); Thai Binh (Typhoon Frankie 1996, 3,14 m) (Dinh Van Manh et al., 2011; Pham Van Ninh et al., 1991; Do Ngoc Quynh, 1999).

In 2014, MONRE released a report on storm zoning, storm risk and storm surge identifying for Viet Nam coastal areas (updated in 2016). According to this report, Viet Nam's coastal areas are divided into different sub-regions based on storm-surge charateristics: (i) Quang Ninh – Thanh Hoa with highest surge reached 350 cm and might be up to above 490 cm; (ii) Nghe An – Ha Tinh with highest surge reached 440 cm and might be up to above 500 cm; (iii) Quang Binh – Thua Thien Hue with highest surge reached 390 cm and might be up to above 420 cm; (iv) Da Nang – Binh Dinh with highest surge reached 180 cm and might be up to above 230 cm; (v) Phu Yen – Ninh Thuan with highest surge reached 170 cm and might be up to above 220 cm; (vi) Binh Thuan – Ba Ria Vung Tau with highest surge reached 120 cm and might be up to above 200 cm; (vii) Ho Chi Minh city – Ca Mau with highest surge reached 200 cm and might be up to above 270 cm; (viii) Ca Mau – Kien Giang with highest surge reached 120 cm and might be up to above 210 cm **(Table 6.8)**.

Table 6.8. Storm surges at Viet Nam's coastal areas

Coastal areas	The highest observed storm surge in history (cm)	The highest storm surge that might occur (cm)
Quang Ninh - Thanh Hoa	350	490
Nghe An -Ha Tinh	440	500
Quang Binh - Thua Thien – Hue	390	420
Da Nang - Binh Dinh	180	230
Phu Yen - Ninh Thuan	170	220
Binh Thuan – Ba Ria - Vung Tau	120	200
TP. Hồ Chí Minh - Ca Mau	200	270
Ca Mau – Kien Giang	120	210

Source: MONRE, 2016

Storm surges are more dangerous when occuring during spring tide and combining with big waves that could be overtop of dikes. Typhoon Washi and Typhoon Damrey (2005) were concided with spring tide causing massive damage for Hai Phong city and Nam Dinh province (Nguyen The Tuong et al., 2007; Nguyen Manh Hung and Duong Cong Dien, 2006).

6.2.2. Tidal regimes along Viet Nam's coastline

Data of extreme tides (amplitude and phase) are very important for coastal engineering as well as inundation maps. There are 4 main types of tidal regimes along the coastline of Viet Nam, namely, diurnal, semidiurnal, irregular diurnal, and irregular semidiurnal tide. Diurnal tides are observed along the coastline of Quang Ninh to a half of the northern Thanh Hoa and part of the southern Ca Mau. Irregular diurnal tides are found from the southern Thanh Hoa to Nghe An, Da Nang to Quang Nam, the northern Binh Thuan, Soc Trang, Bac Lieu, and from Kien Giang to Phu Quoc. The irregular semidiurnal tides occure along the coastline of Quang Binh, Thua Thien - Hue and southern Binh Thuan, and from Vung Tau to Tra Vinh. Semidiurnal tide is only found along the coastline of Quang Tri (Pham Van Ninh et al., 2005). The tidal amplitudes vary from region to region in Viet Nam, the highest tidal amplitude is observed along the coastline of Quang Ninh and Soc Trang (180÷220 cm). The lowest amplitude is found along the coastline of Thua Thien - Hue (40÷50 cm). Highest tide usually occurs from October to January of the following year. Tidal regimes are presented in **table 6.9**.

Table 6.9. Tidal regimes and characteristics along Viet Nam's coastline

No	Tide gauge	Lon	Lat	Tide regime	The highest amplitude (cm)
1	Cua Ong	107,37	21,05	Diurnal	219
2	Hong Gai	107,07	20,95	Diurnal	206
3	Cat Ba	107,05	20,72	Diurnal	189
4	Hon Dau	106,82	20,67	Diurnal	186
5	Ba Lat	106,52	20,32	Diurnal	185
6	Lach Truong	105,93	19,88	Mixed, more diurnal	184
7	Cua Hoi	105,75	18,77	Mixed, more diurnal	171
8	Cua Gianh	106,47	17,70	Mixed, more semi-diurnal	107
9	Cua Tung	107,10	17,02	Mixed, more semi-diurnal	80
10	Thuan An	107,63	16,57	Mixed, more semi-diurnal	50
11	Chan May	107,97	16,32	Mixed, more semi-diurnal	80
12	Da Nang	108,22	16,12	Mixed, more diurnal	90
13	Cu Lao Cham	108,48	15,95	Mixed, more diurnal	110
14	Tam Quan	109,05	14,58	Mixed, more diurnal	120
15	Quy Nhon	109,22	13,75	Mixed, more diurnal	119
16	Vung Ro	109,40	12,87	Mixed, more diurnal	130
17	Cam Ranh	109,02	11,88	Mixed, more diurnal	124
18	Phu Quy	108,95	10,50	Mixed, more diurnal	160
19	Vung Tau	107,07	10,33	Mixed, more semi-diurnal	192
20	Ca Mau	104,75	8,65	Mixed, more semi-diurnal	76

Source: Hoang Trung Thanh, 2011

6.2.3. Storm surge in combination with tides

Storm surges along with large waves are the main cause of serious damage to the dykes and coastal structures, and are particularly dangerous if occurring during high tides. The storm surge levels taken from the total water level in models that accounted for tide are often lower than the storm surge levels simulated under average water level conditions. Storm surges will be higher if storms hit the tide during low tide and lower when storms hit the tide (Nguyen Xuan Hien, 2013).

At areas where tidal amplitudes are large such as Quang Ninh – Hai Phong and Vung Tau – Ca Mau, if storm makes landfall in time of spring tide the coastal areas would be submerged even with small surges (e.g., Typhoon Washi and Xangsen) but if in time of low tide, the risk of inundation is low (e.g., Typhoon No.10 in November 2013).

In case of storm surge in combination with tides, the 200-year return level would reach to 450-500 cm at Quang Ninh – Nghe An region and only 150-200 cm at Quang Binh – Quang Nam (Dinh Van Manh et al., 2011). At Hai Phong, the 100-year return level would be more than 500 cm if accounting for wave and more than 600 cm if accounting for climate change (Dinh Van Uu, 2010; Nguyen Xuan Hien, 2013).

6.3. Inundation risk due to sea-level rise caused by climate change

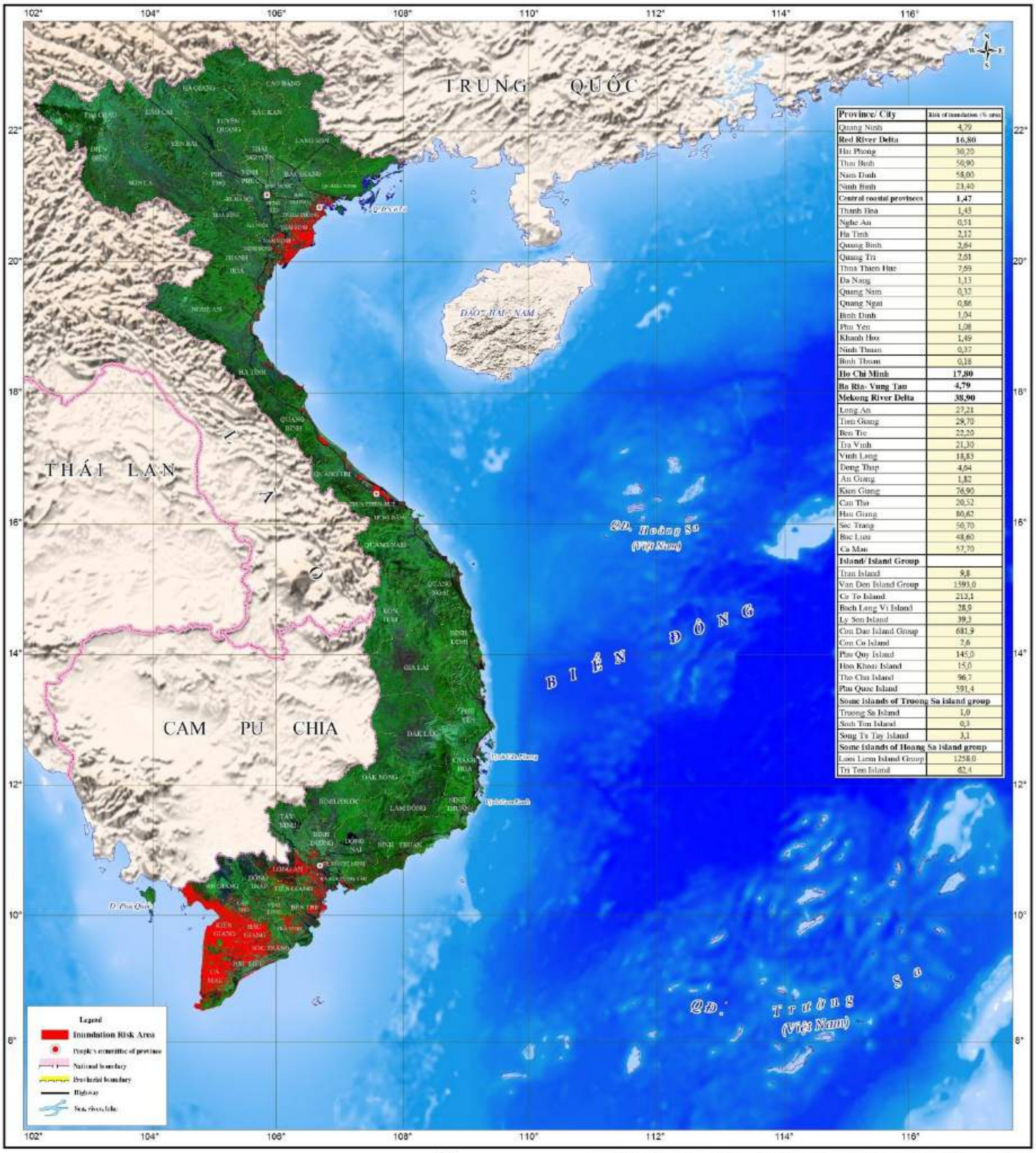
The risk of inundation due to rising sea levels under climate change is based on sea-level rise scenarios. Other dynamical factors (except climate change factors) as tectonic uplift and subsidence, topographical changes, land subsidence due to groundwater extraction, coastline change, influences of tides, storm surge, monsoon surge, impacts of hydro-power plants etc have not been considered in this estimation. The constructions of transportation and irrigation such as sea dykes, river dykes, embankments, roads and etc have also not been taken into account when establishing inundation risk maps.

Box 9. Inundation risk corresponding to the sea-level rise of 100cm

- Approximately 16.8% of the area of the Red River delta, 4.79% of the area of Quang Ninh province are at risk of inundation;
- Approximately 1.47% of the land of the central coastal provinces from Thanh Hoa to Binh Thuan are at risk of inundation. Among them, Thua Thien - Hue has the highest risk (7.69% area);
- Approximately 17.8% of Ho Chi Minh city about 4.79% of Ba Ria - Vung Tau are at risk of inundation;
- Mekong Delta is an area having high inundation risk (38.9% of the area);
- Islands having highest risk of inundation are Van Don group island, Con Dao group island and Phu Quoc Island. The risk of inundation of Truong Sa archipelago is not so high. Hoang Sa archipelago has higher inundation risk, especially Luoi Liem island group and Tri Ton island.

6.3.1. The risk of inundation for delta and coastal provinces

The inundation risk due to rising sea levels caused by climate change are estimated for provinces having inundation risk, including 34 provinces/cities in the delta and coastal areas and islands, Hoang Sa and Truong Sa archipelago of Viet Nam. Inundation risk maps are built in correspondence to sea-level rise from 50cm to 100cm with the interval of 10cm. Results estimating inundation risk corresponding to rising sea levels are summarized in **Table 6.9** and **Figure 6.10**.



Province/ City	Risk of inundation (% area)
Quang Ninh	4,79
Red River Delta	**16,80**
Hai Phong	30,20
Thai Binh	50,90
Nam Dinh	58,00
Ninh Binh	23,40
Central coastal provinces	**1,47**
Thanh Hoa	1,43
Nghe An	0,51
Ha Tinh	2,12
Quang Binh	2,64
Quang Tri	2,61
Thua Thien Hue	7,69
Da Nang	1,13
Quang Nam	0,32
Quang Ngai	0,86
Binh Dinh	1,04
Phu Yen	1,08
Khanh Hoa	1,49
Ninh Thuan	0,37
Binh Thuan	0,18
Ho Chi Minh	**17,80**
Ba Ria- Vung Tau	**4,79**
Mekong River Delta	**38,90**
Long An	27,21
Tien Giang	29,70
Ben Tre	22,20
Tra Vinh	21,30
Vinh Long	18,83
Dong Thap	4,64
An Giang	1,82
Kien Giang	76,90
Can Tho	20,52
Hau Giang	80,62
Soc Trang	50,70
Bac Lieu	48,60
Ca Mau	57,70
Island/ Island Group	
Tran Island	9,8
Van Don Island Group	1593,0
Co To Island	213,1
Bach Long Vi Island	28,9
Ly Son Island	39,3
Con Dao Island Group	681,9
Con Co Island	2,6
Phu Quy Island	145,0
Hon Khoai Island	15,0
Tho Chu Island	96,7
Phu Quoc Island	591,4
Some islands of Truong Sa island group	
Truong Sa Island	1,0
Sinh Ton Island	0,3
Song Tu Tay Island	3,1
Some islands of Hoang Sa island group	
Luoi Liem Island Group	1258,0
Tri Ton Island	62,4

Scale
0 100 200 Km

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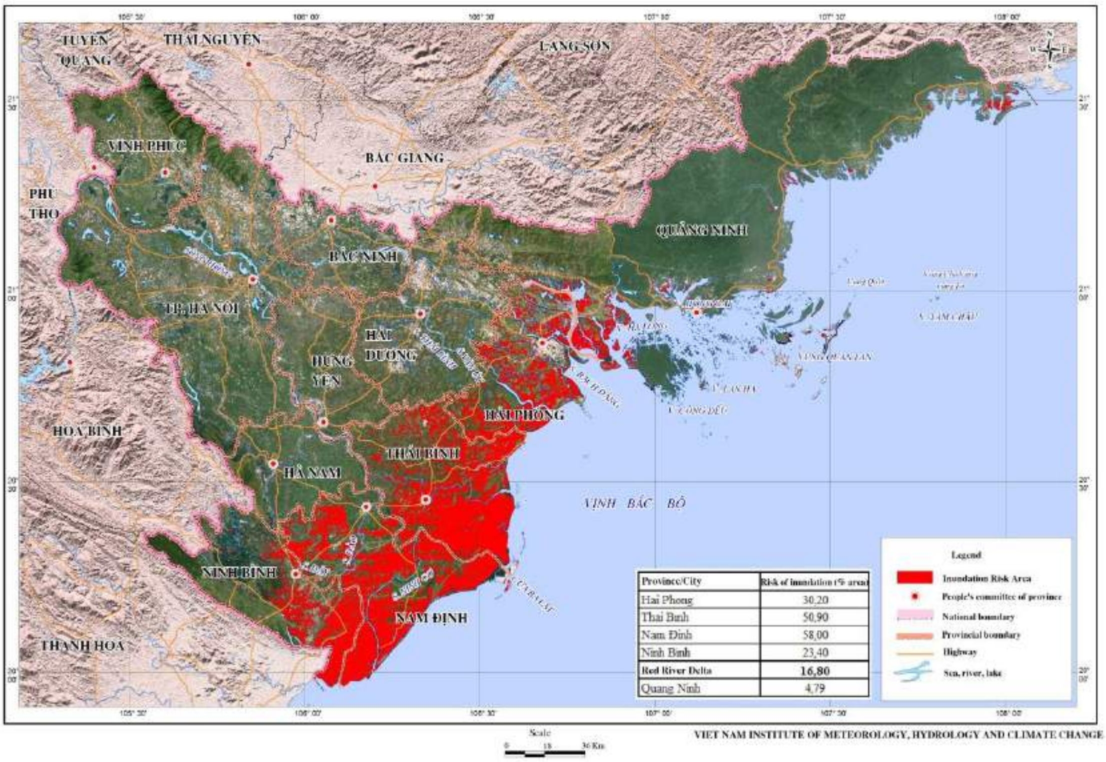
Firgure 6.9. The inundation risk map with sea-level rise of 100cm

Table 6.10. The inundation risk due to rising sea levels caused by climate change for delta and coastal provinces

City/Provinces	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level					
		50cm	60cm	70cm	80cm	90cm	100cm
Quang Ninh	967655	3.33	3.62	3.88	4.10	4.40	4.79
The Red River Delta							
Hai Phong	154052	5.14	7.61	11.7	17.4	24.0	30.2
Thai Binh	158131	27.0	31.2	35.4	39.9	45.1	50.9
Nam Đinh	159394	26.0	32.5	39.1	45.8	52.3	58.0
Ninh Binh	134700	8.29	11.0	14.0	17.1	20.5	23.4
Total	***1492739***	***6.93***	***8.55***	***10.4***	***12.5***	***14.7***	***16.8***
From Thanh Hoa to Binh Thuan							
Thanh Hoa	1111000	0.51	0.65	0.8	0.98	1.2	1.43
Nghe An	1656000	0.13	0.17	0.22	0.27	0.32	0.51
Ha Tinh	599304	0.86	1.00	1.2	1.39	1.81	2.12
Quang Binh	801200	1.73	1.87	2.01	2.24	2.27	2.64
Quang Tri	463500	0.71	0.97	1.22	1.49	1.91	2.61
Thua Thien - Hue	503923	0.93	1.67	2.59	3.46	4.31	7.69
Đa Nang	97778	0.70	0.78	0.87	0.96	1.04	1.13
Quang Nam	1043220	0.18	0.20	0.23	0.26	0.28	0.32
Quang Ngai	514080	0.43	0.51	0.59	0.66	0.75	0.86
Binh Đinh	609340	0.55	0.64	0.74	0.84	0.93	1.04
Phu Yen	503690	0.55	0.63	0.74	0.86	0.97	1.08
Khanh Hoa	519320	0.72	0.89	1.04	1.19	1.38	1.49
Ninh Thuan	335630	0.20	0.24	0.28	0.30	0.33	0.37
Binh Thuan	796833	0.10	0.12	0.13	0.15	0.17	0.17
Total	***9554819***	***0.53***	***0.66***	***0.80***	***0.95***	***1.11***	***1.47***
Ho Chi Minh City	209962	11.4	12.6	13.9	15.2	16.5	17.8
Ba Ria - Vung Tau	190223	2.13	2.53	3.01	3.52	4.16	4.79
Mekong Delta							
Long An	449100	0.61	1.36	2.85	7.12	12.89	27.21
Tien Giang	239470	1.56	2.92	4.54	7.08	12.0	29.7
Ben Tre	235950	6.21	7.58	9.87	12.8	17.0	22.2
Tra Vinh	234120	0.80	1.02	1.33	2.38	4.93	21.3
Vinh Long	152020	6.55	7.49	8.23	8.97	11.27	18.83
Đong Thap	337860	0.36	0.69	0.96	1.28	1.94	4.64
An Giang	342400	0.08	0.16	0.29	0.49	0.90	1.82
Kien Giang	573690	7.77	19.8	36.3	50.8	65.9	76.9
Can Tho	140900	1.44	1.59	1.90	2.77	6.54	20.52
Hau Giang	160240	3.41	10.27	20.55	32.05	42.66	80.62
Soc Trang	322330	2.46	5.88	10.8	16.7	25.8	50.7
Bac Lieu	252600	3.65	7.65	14.5	23.4	33.8	48.6
Ca Mau	528870	8.47	13.7	21.9	30.3	40.9	57.7
Total	***3969550***	***4.48***	***8.58***	***14.7***	***21.0***	***28.2***	***38.9***

1) Quang Ninh province and coastal provinces of the Red River

If sea-level will rise 100 cm, approximately 4.79% of Quang Ninh province and 16.8% of the Red River Delta are at risk of inundation. Among them, Thai Binh province (50.9%) and Nam Dinh province (58.0%) are 2 provinces having the highest risk of inundation (**Figure 6.10**).



Firgure 6.10. The inundation risk map with sea-level rise of 100cm, Quang Ninh and The Red River Delta area

2) The central provinces from Thanh Hoa to Binh Thuan

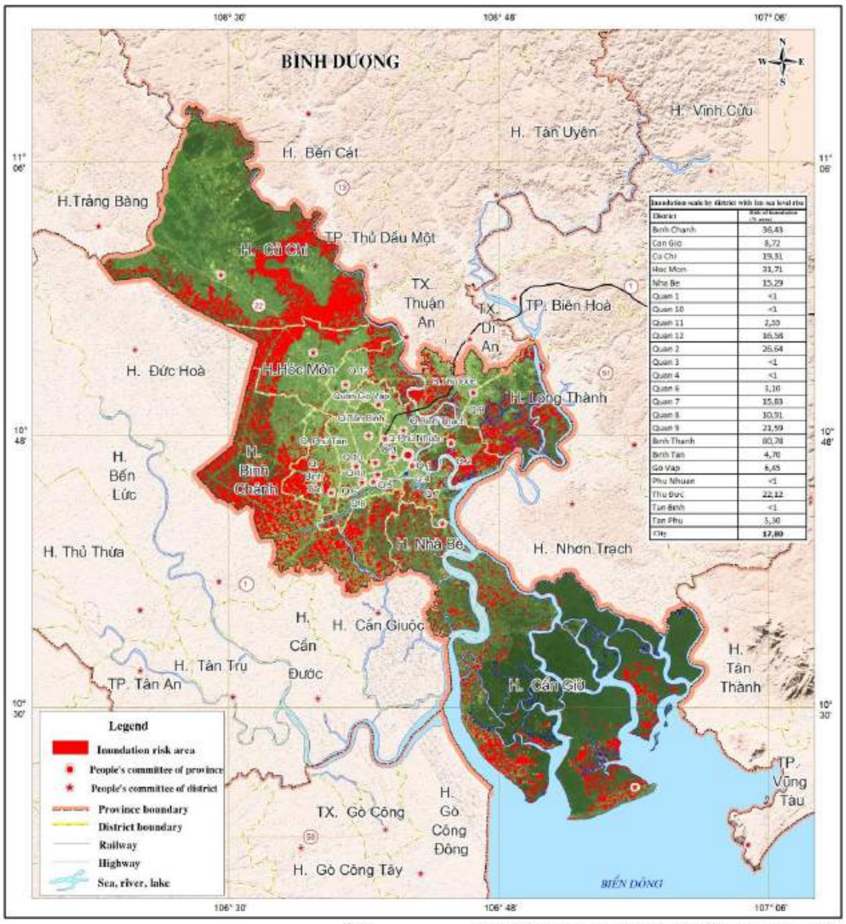
If sea-level rises 100 cm, approximately 1.47% of the central coastal provinces from Thanh Hoa to Binh Thuan are at risk of inundation. Among them, Thua Thien Hue has the highest risk (7.69%).

3) Ho Chi Minh City

If sea-level rises 100 cm, approximately 17.84% of Ho Chi Minh City at risk of inundation. Among them, Binh Thanh district (80.78%) and Binh Chanh district (36.43%) are the two areas with highest risk of inundation (**Figure 6.11**).

4) Mekong River Delta

The Mekong Delta is a region having very high risk of inundation. If sea-level rises 100 cm, approximately 38.9% of Mekong River Delta would be at risk of flooding. Among them, the provinces having the highest risk of inundation are Hau Giang (80.62%), Kien Giang (76.86%) and Ca Mau (57.69%) (**Figure 6.12**).



Scale

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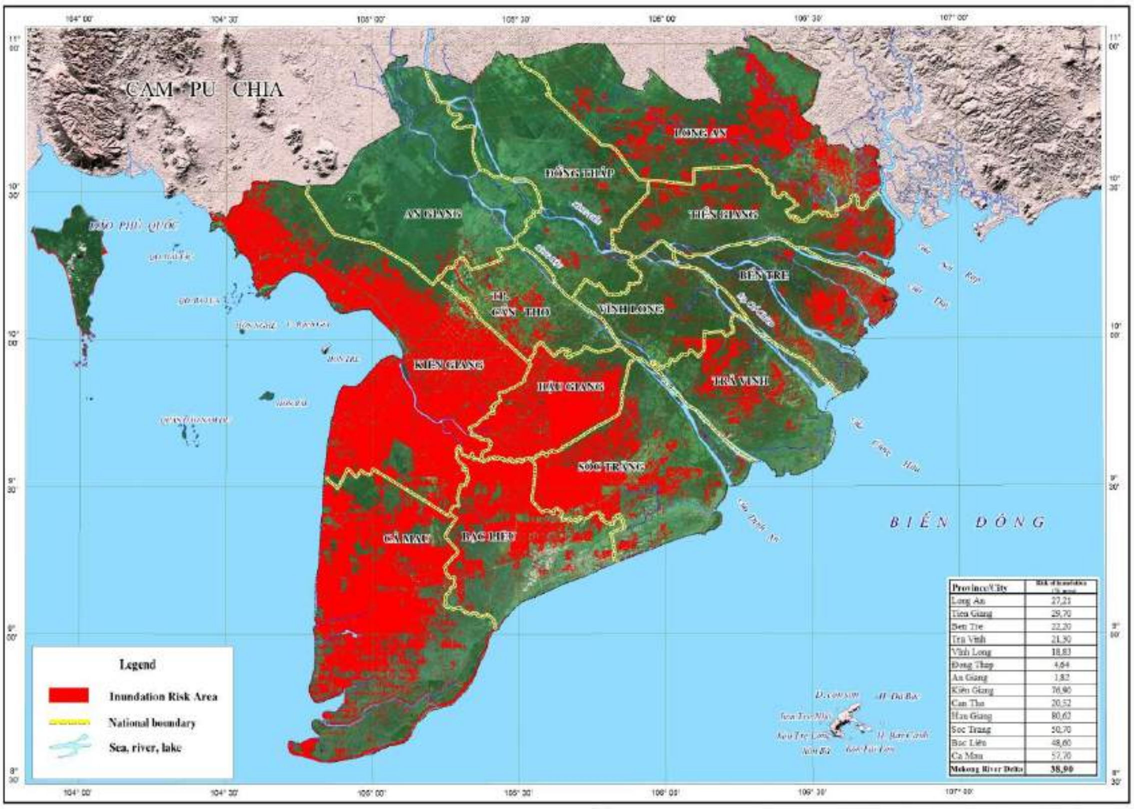
Firgure 6.11. The inundation risk map with sea-level rise of 100cm, Ho Chi Minh City



Scale

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Firgure 6.12. The inundation risk map with sea-level rise of 100cm, Mekong Delta

6.3.2. Inundation risk for islands and archipelagos of Viet Nam

If sea-level rises 100 cm, the most affected islands will be islands having potential social-economic development, such as Van Don group island with 1593 hectares at risk of inundation, Con Dao group island (681.9 ha) and Phu Quoc island (591.37 ha). Some islands belong to Truong Sa will be flooded insignificant, central Truong Sa (Big Truong Sa) will have inundation area of 1 ha, Sinh Ton (0.3 ha), Song Tu Tay (3.1 ha). Hoang Sa archipelago will have larger inundation area, especially Luoi Liem island (1258 ha) and Tri Ton (62.4 ha) (Table 6.11).

Table 6. 11 The inundation risk for islands and archipelagos of Viet Nam

Island/Island group	Inundation risk area (ha)
Tran Island	9.8
Van Don Island group	1593.0
Co To Island	213.1
Bach Long Vi Island	28.9
Ly Son Island	39.3
Con Đao Island group	681.9
Con Co Island	2.6
Phu Quy Island	145.0
Hon Khoai Island	15.0
Tho Chu Island	96.7
Phu Quoc Island	591.4
Some islands belong to Truong Sa archipelago	
Big Truong Sa Island	1.0
Sinh Ton Island	0.3
Song Tu Tay Island	3.1
Some islands belong to Hoang Sa archipelago	
Some island belong to Luoi Liem group	1258.0
Tri Ton Island	62.4

Statistical tables and inundation risk maps with sea-level rise of 100cm for each province, the islands and archipelagos of Viet Nam's Hoang Sa and Truong Sa are presented in Appendix B.

6.4. Evaluation of factors that affecting inundation risk

As presented in **section 6.3**, inundation risk due to sea-level rise under climate change is defined based on sea-level rise scenarios. Other dynamical factors related to tectonic uplift and subsidence, topographical changes, land subsidence due to groundwater extraction, coastline changes, the influence of tides, storm surges, sea level surges during monsoon, the impact of hydro-power plants, salt water intrusion have not been considered in this estimation.

This session provides some information about researches and assessments related to tectonic uplift and subsidence and subsidence due to groundwater exploitation.

6.4.1. Tectonic uplift and subsidence

Tectonic uplift and subsidence may decrease or increase the levels of flood prone regions under rising sea levels corresponding to climate change scenarios, as indicated in the following three groups:

a) Tectonic subsidence would lower surface topography; therefore, the level of inundation due to sea-level rise under climate change would be exacerbated;

b) The level of flooding in the regions with stable tectonics will likely be the same as the level of flooding due to sea-level rise under climate change in the scenarios;

c) Tectonic uplift would raise the tectonic terrain surface and thereby reducing the level of flooding due to sea-level rise under climate change.

Currently, several studies have been done for the region such as the Mekong Delta and the central coastal area. However there is no official evaluation for tectonic uplift and subsidence speed in national scale.

Some initial findings on tectonic uplift and subsidence can be summarized as follows:

Mekong Delta Area: Causes leading to tectonic uplift and subsidence may come from: (i) slow tectonic movements in pre-Holocen bed rock exposing regions; (ii) new compressive sediment (*sediment autocompaction)*; (iii) groundwater extraction; (iv) human activities (construction, urbanization), and (v) magnetic-variability of rock. Depending on the structure of geodynamics characteristics, those causes may affect different areas. The detailed assessment about the trend of tectonic uplift and subsidence Mekong delta can be summarized as follows (General Department of Vietnam Minerals and Geology, 2015):

- The trend of tectonic uplift and subsidence had a difference in the block structure and geodynamics with the minimum average absolute subsiding speed of 2.3÷2.7mm ±1mm/year, the maximum of 19.9±3mm/year, on the average of 6mm±3mm/year, accounting for about 67% of the study area, which developed on the terrain formed by Holocene sediments of the blocks in Ca Mau - Phung Hiep and in Vinh Long – Tan An.

- The minimum rate of uplift was 0.8mm/year, the maximum was 20.6±3mm/year, the minimum average rate of uplift was 2.7mm/year and the maximum average rate of uplift was 7.1±3mm/year, the geodynamics blocks had average uplift trend of 5.9±3mm/year, accounting for about 33% of study area, which developed on exposing Kainozoi sediments of the blocks in Dat Mui – Chau Doc and Dong Nai – Vung Tau.

- Vertical shifting at 5 stable and reliable geodynamic landmarks (A001, A007, A011, A013, A016) in the Mekong Delta showed that subsiding speed was 19.9mm/year (A014 milestone in Can Gio), the largest speed of uplift 20.6mm/year (A005 milestone in Hon Dat).

- The shift of tectonic uplift and subsidence between geodynamic blocks in international reference system IGb08: geodynamic building blocks of Ha Tien - Kien Hai had the signals of absolute subsidence of 8.9 millimeters/year, Dat Mui - Ca Mau block has an absolute uplift of 11.3 mm/year, Ca Mau - Phung Hiep block had an absolute subsidence of 7.4 mm/year and Vinh Long - Tan An block had an absolute subsidence of 11.8 mm/year.

- Results acquired from geodynamic model: the amplitude of lifting and subsiding due to the cohesion by Holocene sediments was 0÷4mm/year; Groundwater extraction led to subside about 0÷3.5mm/year, the amplitude due to tectonic activities was 0÷1.5mm/a shifting time. The total amplitude of the subsidence in the structural unit geodynamic changes was 0÷4.3mm/year in developing regions of Holocene sediments. Total magnitude of uplift was 0÷6,7mm/year in the area revealed sediments before Cenozoic. According to the GPS data, the greatest magnitue of uplift was nearly 5 times larger than the greatest magnitude of subsidence and nearly 6 times larger than the largest magnitude identified from dynamical models. However, on average, the rate of subsidence from 5 stable and reliable landmarkers was just about 2.7mm/year, almost equal to the amplitude identified from geodynamic models.

Central coastal area: Results of modern tectonic uplift and subsidence fluctuation identifying for several areas along the coast of Central area can be summarized as follows (Tran Thanh Hai, 2015):

As a result of the national project BDKH-42, the amplitude of modern tectonic lifting for some areas along the cetral coastal strip can be summarized as follows: Some areas have obviously expressed the tectonic subsiding due to the tectonic collapse as the tub pulled apart with a rate of 0.13cm/year at Ho Hao Son of Phu Yen, a rate of 1cm/year at Quy Nhon and over 2cm/year at Cua Dai of Quang Nam. Many areas in the region have the speed of tectonic uplift from under 1 to several mm/year and their magnitude of tectonic lifting differentiate among regions, ranging from a few mm/year to under 1cm/year. Phu Yen area is generally located in the tectonic uplift, but the speed of uplift is uneven, from 0.16cm/year in Ganh Ba, 0.27cm/year at Hon Yen, 0.48cm/year in Phong Nien, and 0.07cm/year in Ban Thach. Similarly, Ninh Thuan region also has a tectonic uplift regime with varying uplifting speed, which is the highest speeds are in the north 0.40cm/year in Nui Chua, 0.214cm/year in Ca Na, and 0.16cm/year in Nha Ho. Cam Ranh area (Khanh Hoa) has a high-speed uplift, reach to 0.50cm/year. Areas with the large shifting amplitudes have high a risk of flood in the near future, especially in terms of climate change-induced sea-level rise.

On 05 June 2014, the Government assigned the Ministry of Natural Resources and Environment to construct the project of inspection in stability of the national landmarks for the provinces as Tien Giang, Dong Thap, Vinh Long, Tra Vinh, Hau Giang, Soc Trang, Ben Tre, An Giang, Kien Giang, Bac Lieu, Ca Mau, Ho Chi Minh city and Can Tho city.

Currently, the results related to the subsidence of specific areas have been gathered and reported to the Prime Minister by Department of Surveying and Mapping of Vietnam, after evaluation it will be announced by the Government. Therefore, there is no eligibility to include this kind of information to this scenario.

6.4.2. Subsidence due to groundwater exploitation

Geological subsidence is the lowering of the land surface. Geological subsidence may come from natural causes due to geological factors or it may come from human such as overexploitation of groundwater. Geological subsidence may occur quickly or takes place in a long time.

Changing land surface elevation due to geological factors is a continuous process that occurs in deltas. Some processes may rise or subside the land surface elevation like sedimentation, sediment compaction, dehydration, erosion and organic deposition. The change in elevation of the land surface can occur due to the lifting of the tectonic activities or the deposition of silt in delta regions. In fact, many deltas was subsided instead of rising up by silt. The reason is that the source of sediment in the delta region is deficient because of upstream dams and hydropower reservoirs, the constructions of flood control. Natural subsidence due to the compaction of sediment can reach to 10mm/year.

Excessive groundwater extraction is also a cause of geological subsidence. There has been no formal evaluation of geological subsidence rate due to groundwater extraction in the country.

According to preliminary results of the research cooperation between Viet Nam and the Geotechnical Institute of Norway for Ca Mau province, the pace of geological subsidence due to groundwater extraction in Ca Mau is in a range of 1.9 to 2.8cm/year . However, this estimation is only based on the level of groundwater extraction in the province, no actual measurements, thereby reference only.

The Prime Minister has approved a project "Investigation and assessment of the exploitation and use of underground water affecting the land surface subsidence for Hanoi city, Ho Chi Minh City and Mekong Delta, orienting the management, exploitation and sustainable use of groundwater resources." The project will be implemented from 2016 to 2020. One of the key objective of the project is "... to assess the current status and changes in land surface subsidence in the areas of groundwater extraction and low groundwater level; and determine the impact of the exploitation of underground water induced the land surface subsidence ... ". The results of the project will be updated in the next versions of climate change and sea level rise scenarios.

CONCLUSIONS AND RECOMMENDATIONS

I. Conclusions

The 2016 version of the climate change and sea level rise scenarios were developed based on the knowledge gained from the previous scenarios. The meteorological, sea water level and terrain data of Viet Nam were updated. The latest methods used in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, the global and regional climate models, as well as statistical methods have been applied for regionally detailed computation for Viet Nam.

Comments and suggestions from line ministries, sectors and provinces on the use and application of the climate change and sea level rise scenarios for Viet Nam were taken in to account in the developing process of the scenarios.

Climate change, sea level rise scenarios can be summarized as follows:

- ***Temperatures*** show an increasing trend in all regions of Viet Nam compared to the reference period, with highest increase in the North. ***For the RCP4.5 scenarios***, by early 21st century, average annual temperatures would increase by 0.6÷0.8^{o}C across the country. By mid-21st century temperatures would increase 1.3÷1.7^{o}C in general, in which increase 1.6÷1.7^{o}C in the northern regions (Northwest, Northeast, North Delta), 1.5÷1.6^{o}C in the North Central Coast, 1.3÷1.4^{o}C in the South Central Coast, Central Highlands and South. By late 21st century, temperature would increase 1.9÷2.4^{o}C in the North, and 1.7÷1.9^{o}C in the South. ***For the RCP8.5 scenarios***, by early 21st century, average annual temperatures would increase 0.8÷1.1^{o}C. By mid-21st century, temperatures would increase 1.8÷2.3^{o}C, in which increase 2.0÷2.3^{o}C in the North, and 1.8÷1.9^{o}C in the South. By late 21st century, temperatures would increase 3.3÷4.0^{o}C in the North, and 3.0÷3.5^{o}C in the South. The average maximum and minimum temperature changes are expected to be "considerably higher" than mean temperature for both scenarios.

- ***Rainfall*** tend to increase over the whole country. ***For the RCP4.5 scenarios***, by early 21st century annual rainfall would increase in most regions of the country with general values of 5÷10%. By mid-21st century, rainfall would increase 5÷15% in general, while some coastal provinces in the North Delta, the North Central and the Mid-Central the increase would be up to 20%. By late 21st century, the rainfall patterns are similar to that of mid-21st century, however, the areas with an increase of over 20% would expand. ***For the RCP8.5 scenarios***, annual rainfall would increase in the same trend of the RCP4.5 scenarios. However, the highest increase would be over 20% in most of the North, the Central Coast, part of the Central Highlands and the South by late 21st century. Changes in short term rainfall events will be higher than annual changes. The average 1-day and 5-day maximum rainfalls would increase by 10÷70% compared to the reference period in the western parts of the Northwest, the Northeast, the Red River Delta, the North Central Coast, Thua Thien - Hue to Quang Nam, the eastern South, the southern Central Highlands, and 10÷30% for other regions.

- ***Monsoon and other climate extremes: The number of typhoons and tropical depressions*** may decrease, occurrence would be more concentrated to the end of the typhoon season which is the main period of typhoon activity in the South. Strong to very strong typhoons would increase. ***The summer monsoon*** would start earlier and end later. Rainfall during monsoon activity would increase. ***The number of extreme cold and damaging cold days*** would decrease in the northern mountainous provinces, the Red River Delta and the North Central. ***The number of hot days*** (Tx ≥ 35^{o}C) has increasing trends in most parts of the country, the largest number wold be in the North Central, the South Central and the South. ***Droughts*** would become more serious in some regions because of increased temperatures and rainfall deficits in the dry season (e.g. spring and summer in the South Central, spring in the South and winter in the North).

- Sea level rise scenarios: Sea level rise in the coastal areas of Viet Nam would be higher than the average global sea level rise. The sea level rise at the central and south of the East Sea would considerably be higher than in other regions. Sea level rise along the southern coast would be higher than along the northern coast. For the ***RCP4.5 scenarios***, the average sea level rises for coastal areas throughout Viet Nam would be about 22 cm by 2050 (14÷32 cm), and about 53 cm (32÷76 cm) by 2100, in which the lowest sea level rise would be about 53 cm (32÷75 cm) in the regions of Mong Cai - Hon Dau and Hon Dau - Deo Ngang. Sea level rise would be about 55 cm (33÷78 cm) from Ca Mau to Kien Giang. Highest sea level rise would be in the regions of Hoang Sa and Truong Sa archipelagos, with values of 58 cm (36÷80 cm) and 57 cm (33÷83 cm), respectively. For the ***RCP8.5 scenarios***, the average sea level rises for coastal areas throughout Viet Nam would be 25 cm by 2050 (17÷35 cm), and 73 cm (49÷103 cm) by 2100, in which the lowest sea level rise would be 72 cm (49÷101 cm) in the regions of Mong Cai - Hon Dau and Hon Dau - Deo Ngang. Sea level rise would be 75 cm (52÷106 cm) from Ca Mau to Kien Giang. Highest sea level rise would be in the regions of Hoang Sa and Truong Sa archipelagos, with values of 78 cm (52÷107 cm) and 77 cm (50÷107 cm), respectively.

- *Inundation due to sea level rise caused by climate change*: If sea level would rise up to 100cm and without any adaptation measures, an area of about 16.8% of the Red River Delta, 1.5% of the Central Coast from Thanh Hoa to Binh Thuan, 17.8% of Ho Chi Minh City and 38.9% of the Mekong Delta would be under high risk of inundation. Van Don Island group, Con Dao Island and Phu Quoc Island have high inundation risks. There is a low inundation risk for Truong Sa archipelago. Hoang Sa archipelago has a higher inundation risk, especially in Luoi Liem and Tri Ton island group.

The new aspects in the 2016 climate change and sea level rise scenarios in comparison with the 2012 scenarios:

1) State of the art data were used, including: (i) Observed metrological data of 150 stations on land and island from the meteorological observation network of the National Hydro-Meteorology Service up to 2014; (ii) Observed sea water level data of 17 gauging stations along the coast and islands of Viet Nam up to 2014; (iii) Sea water level data measured by satellites till 2014; (iv) Topographic maps with scales 1:2,000, 1:5,000 and 1:10,000 measured by the projects under the National Target Program to Response to Climate Change updated till 2016.

2) State of the art results of global climate models (under CMIP5 project) were used, namely: NorESM1-M, CNRM-CM5, GFDL-CM3, HadGEM2-ES, ACCESS1-0, MPI-ESM-LR, NCAR-SST, HadGEM2-SST and GFDL-SST.

3) Dynamical downscaling were applied basing on 5 high-resolution regional climate models, namely: AGCM/MRI, PRECIS, CCAM, RegCM and clWRF. There are 16 computational cases in total.

4) Statistical methods were applied for bias correction of the model output based on the observed data to minimize the bias of model results.

5) Climate change scenarios and climate extremes were provided in detail for 63 provinces/cities, the Hoang Sa and Truong Sa archipelagos of Viet Nam and 150 meteorolog-

ical stations (the detail is at district level).

6) Sea level rise scenarios were developed in detail for 28 coastal provinces, as well as Hoang Sa and Truong Sa archipelagos of Viet Nam.

7) Certainty levels in terms of percentile were estimated for climate change and sea level rise projections for the future.

8) Inundations due to sea level rise caused by climate change for the delta, coastal areas, islands and archipelagos of Viet Nam were estimated. For areas, where topographic maps scale 1:2000 is available, the level of detail of the inundation maps were at commune level.

9) Extreme water levels were assessed, including due to storm surges, tides, and storm surges in combination with tides of Viet Nam. This can help the users to understand the double impact of sea level rise due to climate change and extreme sea level due to natural factors such as storm surges and high tides.

10) Remarks on some factors that influence the inundation due to sea level rise caused by climate change are drawn, including the geological uplift and land subsidence as a result of groundwater extraction in the Mekong Delta and the Central coastal areas.

II. Recommendations

1) In using climate change and sea level rise scenarios for assessing impacts and developing response measures as well as the integration into the strategy, planning and socio-economic development plans, it is necessary to select scenarios suitable for specific sector and locality considering the following criteria: (i) characteristics (of sectors, local circumstance, etc); (ii) multi-purpose; (iii) efficiency in many aspects (socio-economics, and environmental); (iv) sustainability; (v) feasibility, ability to integrate into strategies, policies and development plans.

2) When applying climate change and sea level rise scenarios for impacts and vulnerability assessments, and development of sectoral or provincial action plans, the following steps are recommended: (i) identification of critical climate parameters for the sectors or research objects; (ii) selection of climate change and sea level rise scenarios from the national scenarios; (iii) application of computational analysis tools to determine important information such as changes in flow regimes, floods, saltwater intrusion, typhoon surges, changes in shoreline, etc.

3) The development and implementation of response measures for climate change are not necessarily carried out on large and century scale. It should be with specific phases. Priorities need to be identified based on practical needs and available resources in each phase in order to select the most appropriate scenario.

4) Under the Paris Agreement on climate change, all countries must take action to keep the global temperature rise well below 2°C by the end of the century compared to the pre-industrial era. This means the RCP4.5 scenarios is more likely to happen than the other RCP scenarios.

5) The RCP4.5 scenarios can be applied to design standards for non-long-term projects and short-terms plans.

6) The RCP8.5 scenarios should be applied to the permanent projects and long-term plans.

7) Climate change and sea level rise scenarios always have uncertainties, which de-

pend on the identification of GHG scenarios (socio-economic development in global scales, population growth and the level of world consumption, standards of life and lifestyle, energy consumption and global energy resources, technology transfer from developed to developing countries, land use change, etc.), the limited understanding of the global climate system and regions, ice melting dynamics, methods and mathematical models for developing scenarios and more. Therefore, when applying climate change and sea level rise scenarios for impact assessments, it is necessary to consider and analyse carefully all the possible occurrences of a future climate. Users should consult appropriate experts in determining these values as well as the most relevant changes for the planning process.

8) Climate models are being further developed to enhance the reliability of climate change and sea level rise scenarios. Climate change and sea level rise scenarios will be continuously updated according to the schedule of the IPCC. Thus the impact and vulnerability assessments should be reviewed and updated when new scenarios are published. The Global Conference on Climate Change in 2015 requested the IPCC to publish in 2018 a special report on scenarios of greenhouse gas concentrations and its effects when the global temperature increases by 1.5°C compared to pre-industrial era. Based on that, up-to-date information will be supplemented to the climate change and sea level rise scenarios for Viet Nam.

9) It is noted that the inundation maps are based on the average sea level rise due to climate change. Other dynamical factors such as tectonic uplift and subsidence, topographical changes, land subsidence due to groundwater extraction, coastline change, influence of tides, storm surges, monsoon induced sea level rise, impact of hydropower cascade, and saline intrusion have not been considered in this scenarios. Transportation works and irrigation structures such as sea dykes and river dykes, embankments, roads, and others have not been considered when mapping inundation due to sea levels rise caused by climate change.

Therefore, when using the climate change and sea level rise scenarios for assessing impacts of climate change in more detail, the dynamical factors, and relevant infrastructures mentioned above, should be considered in the calculation, along with climate change induced sea level rise.

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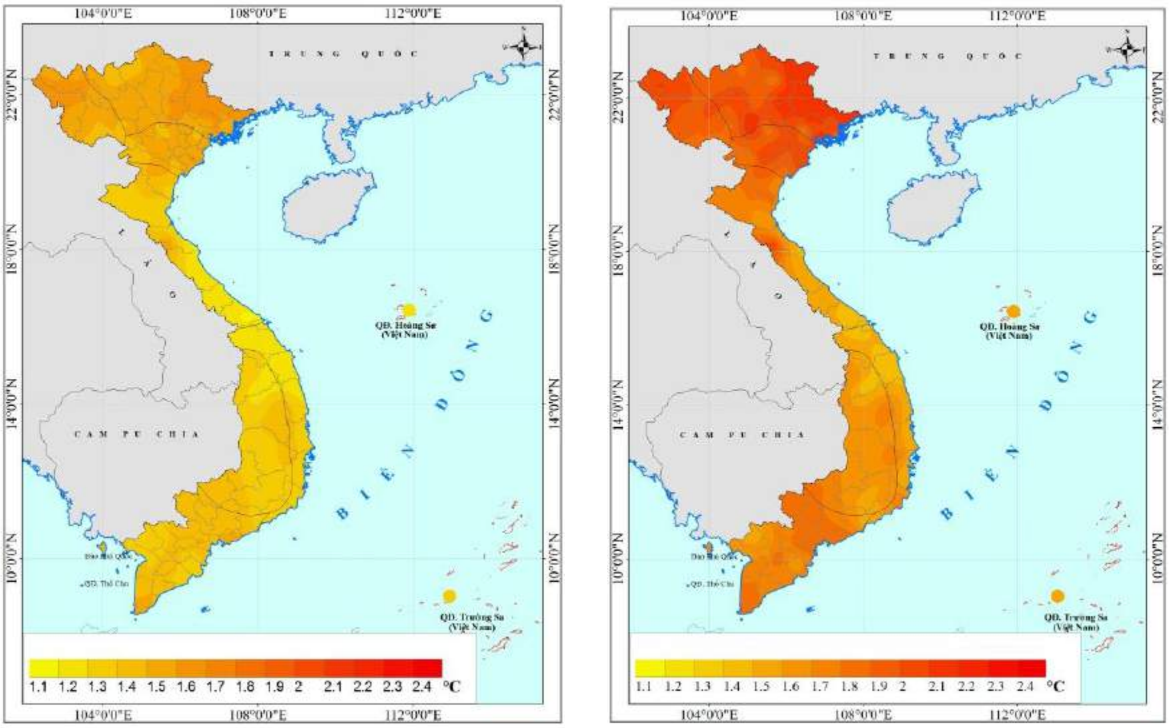
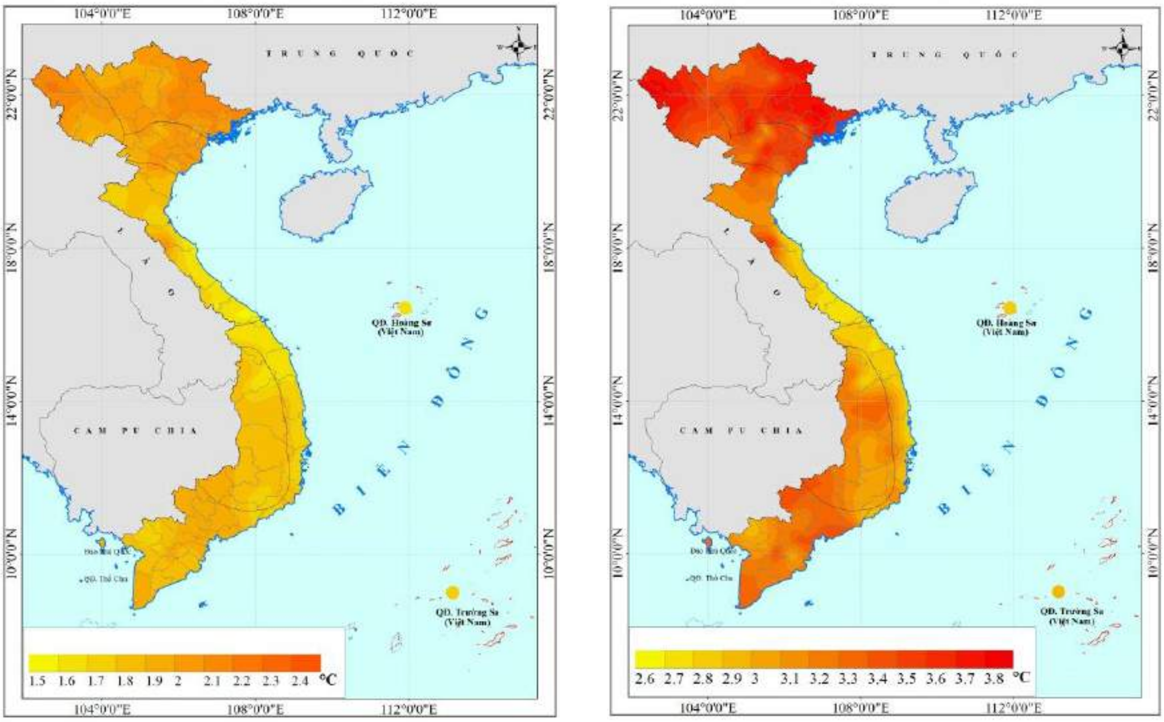
APPENDIX A:

Seasonal climate change scenarios for 63 provinces/ cities under RCP4.5 and RCP8.5 scenarios compared to the baseline period (1986-2005)



(a) mid-21st century *(b) end of 21st century*

Figure A1. Changes in average winter temperature (°C) based on RCP4.5 scenarios



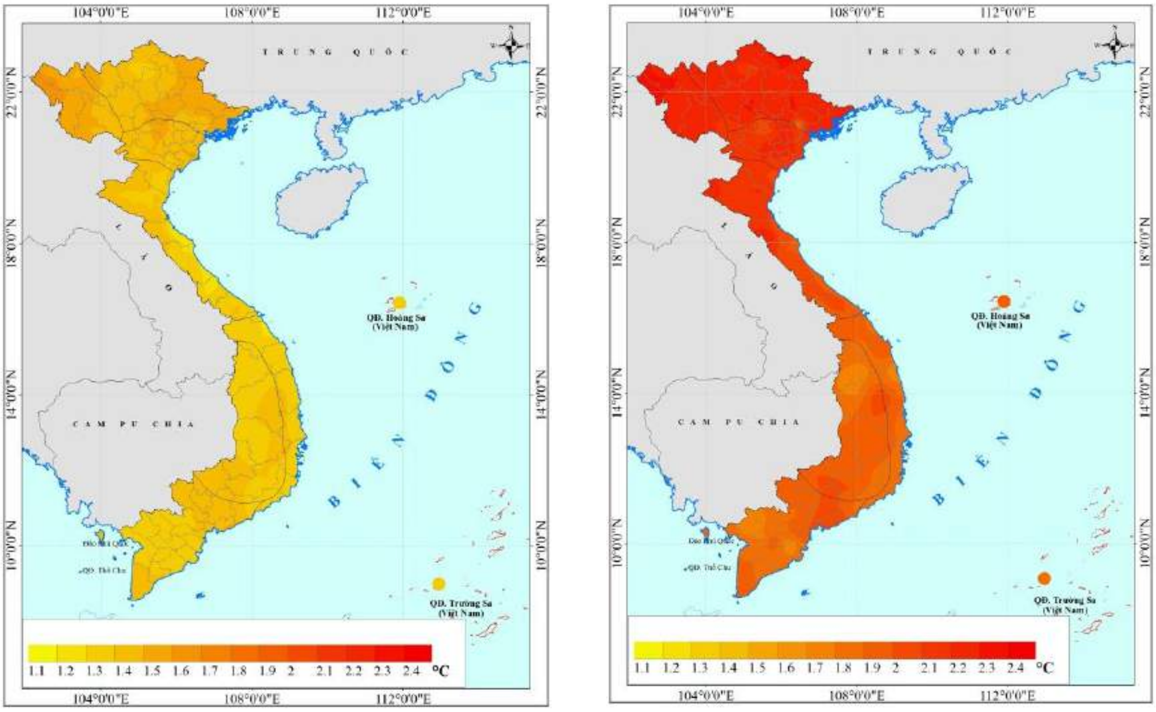
(a) mid-21st century *(b) end of 21st century*

Figure A2. Changes in average winter temperature (°C) based on RCP8.5 scenarios

Table A1. Changes in average winter temperature (°C) compared with the baseline period

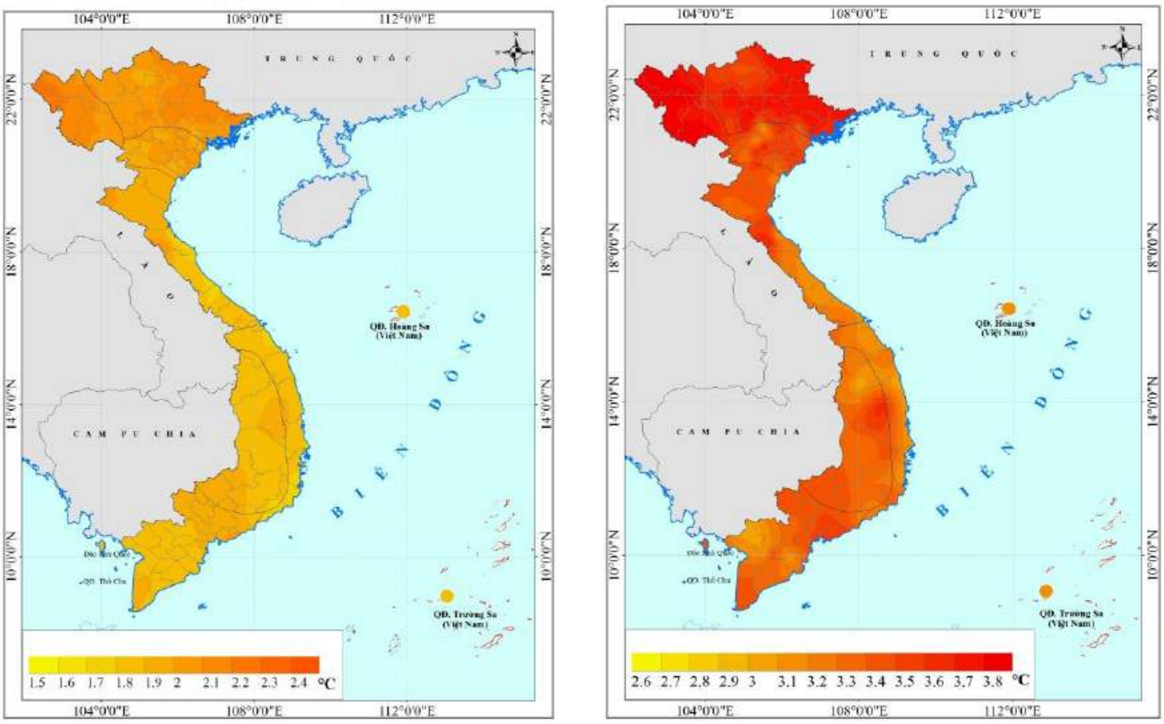
(Values in parentheses are the range of temperatures changes from the climate model results with the lower boundary of 10% and upper boundary of 90%)

No.	Province, City	RCP4.5 scenario			RCP8.5 scenario		
		2016-2035	2046-2065	2080-2099	2016-2035	2046-2065	2080-2099
1	Lai Chau	0.8 (0.3÷1.4)	1.6 (1.1÷2.2)	2.0 (1.4÷2.9)	1.2 (0.6÷1.8)	2.1 (1.5÷2.8)	3.7 (2.9÷5.0)
2	Dien Bien	0.7 (0.2÷1.3)	1.6 (1.1÷2.3)	2.0 (1.3÷3.0)	1.2 (0.6÷1.8)	2.1 (1.5÷2.9)	3.7 (2.9÷5.0)
3	Son La	0.7 (0.2÷1.2)	1.5 (0.9÷2.1)	1.9 (1.1÷2.8)	1.1 (0.7÷1.6)	2.0 (1.3÷2.8)	3.5 (2.7÷4.8)
4	Hoa Binh	0.7 (0.3÷1.1)	1.5 (1.0÷2.1)	1.9 (1.1÷2.7)	1.1 (0.7÷1.5)	2.0 (1.3÷2.8)	3.4 (2.4÷4.6)
5	Lao Cai	0.7 (0.3÷1.2)	1.6 (1.0÷2.1)	2.0 (1.2÷2.9)	1.1 (0.6÷1.7)	2.0 (1.4÷2.8)	3.5 (2.7÷5.0)
6	Ha Giang	0.6 (0.2÷1.2)	1.6 (1.1÷2.3)	2.1 (1.3÷3.1)	1.2 (0.6÷1.7)	2.1 (1.5÷3.0)	3.7 (2.8÷5.2)
7	Yen Bai	0.7 (0.2÷1.1)	1.5 (1.0÷2.1)	2.0 (1.2÷2.9)	1.1 (0.7÷1.7)	2.0 (1.4÷2.8)	3.5 (2.7÷4.9)
8	Cao Bang	0.6 (0.2÷1.1)	1.6 (1.0÷2.4)	2.1 (1.2÷3.2)	1.1 (0.6÷1.7)	2.1 (1.5÷3.1)	3.7 (2.8÷5.2)
9	Tuyen Quang	0.6 (0.2÷1.1)	1.6 (1.1÷2.3)	2.1 (1.2÷3.1)	1.2 (0.6÷1.8)	2.1 (1.5÷3.0)	3.7 (2.7÷5.2)
10	Bac Kan	0.6 (0.2÷1.2)	1.6 (1.1÷2.4)	2.1 (1.3÷3.1)	1.2 (0.6÷1.7)	2.1 (1.5÷3.1)	3.7 (2.8÷5.2)
11	Lang Son	0.7 (0.2÷1.2)	1.6 (1.0÷2.4)	2.1 (1.2÷3.1)	1.1 (0.6÷1.7)	2.1 (1.4÷3.1)	3.8 (2.8÷5.2)
12	Thai Nguyen	0.6 (0.2÷1.2)	1.6 (1.0÷2.5)	2.2 (1.2÷3.1)	1.2 (0.6÷1.8)	2.2 (1.5÷3.1)	3.7 (2.8÷5.2)
13	Phu Tho	0.6 (0.1÷1.0)	1.6 (1.0÷2.2)	2.0 (1.1÷2.9)	1.1 (0.7÷1.6)	2.1 (1.4÷2.9)	3.6 (2.6÷4.9)
14	Vinh Phuc	0.6 (0.2÷1.1)	1.6 (1.0÷2.4)	2.1 (1.2÷3.0)	1.2 (0.7÷1.6)	2.1 (1.4÷3.1)	3.6 (2.6÷5.0)
15	Bac Giang	0.7 (0.3÷1.2)	1.6 (1.0÷2.4)	2.1 (1.2÷3.0)	1.1 (0.6÷1.6)	2.1 (1.4÷3.0)	3.7 (2.7÷5.0)
16	Bac Ninh	0.7 (0.4÷1.2)	1.5 (1.0÷2.4)	2.0 (1.2÷3.0)	1.1 (0.6÷1.6)	2.1 (1.4÷3.1)	3.5 (2.6÷5.0)
17	Quang Ninh	0.7 (0.3÷1.2)	1.5 (1.0÷2.2)	2.0 (1.2÷2.8)	1.0 (0.6÷1.5)	2.0 (1.4÷2.8)	3.4 (2.6÷4.5)
18	Hai Phong	0.7 (0.4÷1.2)	1.5 (0.9÷2.1)	1.9 (1.2÷2.6)	1.0 (0.6÷1.4)	1.9 (1.3÷2.7)	3.2 (2.4÷4.2)
19	Hai Duong	0.7 (0.3÷1.2)	1.5 (1.0÷2.3)	2.0 (1.2÷3.0)	1.1 (0.6÷1.6)	2.0 (1.4÷3.0)	3.5 (2.5÷4.9)
20	Hung Yen	0.7 (0.3÷1.2)	1.5 (1.0÷2.3)	2.0 (1.2÷2.9)	1.1 (0.7÷1.6)	2.0 (1.4÷3.0)	3.5 (2.5÷4.8)
21	Ha Noi	0.6 (0.2÷1.0)	1.6 (1.0÷2.3)	2.0 (1.1÷3.0)	1.1 (0.7÷1.6)	2.1 (1.4÷3.0)	3.6 (2.5÷4.9)
22	Ha Nam	0.6 (0.2÷1.1)	1.6 (1.0÷2.3)	2.0 (1.1÷2.9)	1.1 (0.7÷1.6)	2.1 (1.4÷3.0)	3.6 (2.5÷4.8)
23	Thai Binh	0.7 (0.3÷1.2)	1.5 (1.0÷2.2)	1.9 (1.2÷2.8)	1.1 (0.7÷1.5)	2.0 (1.3÷2.9)	3.4 (2.3÷4.5)
24	Nam Dinh	0.7 (0.2÷1.2)	1.5 (0.9÷2.1)	1.9 (1.2÷2.7)	1.0 (0.6÷1.5)	2.0 (1.2÷2.8)	3.3 (2.3÷4.3)
25	Ninh Binh	0.7 (0.3÷1.2)	1.5 (0.9÷2.1)	1.9 (1.1÷2.8)	1.1 (0.6÷1.5)	2.0 (1.3÷2.9)	3.4 (2.3÷4.6)
26	Thanh Hoa	0.6 (0.3÷1.1)	1.4 (0.9÷2.0)	1.8 (1.1÷2.6)	1.0 (0.6÷1.4)	1.9 (1.3÷2.7)	3.2 (2.3÷4.3)
27	Nghe An	0.7 (0.3÷1.1)	1.4 (0.9÷1.9)	1.7 (1.1÷2.4)	1.0 (0.6÷1.4)	1.8 (1.2÷2.6)	3.1 (2.2÷4.2)
28	Ha Tinh	0.6 (0.3÷1.0)	1.3 (0.7÷1.8)	1.6 (1.0÷2.1)	0.9 (0.6÷1.2)	1.7 (1.2÷2.4)	2.8 (2.0÷3.7)
29	Quang Binh	0.6 (0.2÷1.0)	1.2 (0.8÷1.7)	1.5 (0.9÷2.0)	0.9 (0.6÷1.2)	1.7 (1.2÷2.3)	2.8 (2.0÷3.6)
30	Quang Tri	0.7 (0.3÷1.1)	1.2 (0.8÷1.6)	1.5 (1.0÷2.0)	0.8 (0.5÷1.1)	1.7 (1.2÷2.2)	2.8 (2.2÷3.5)
31	Thua Thien - Hue	0.7 (0.3÷1.1)	1.2 (0.7÷1.6)	1.4 (0.9÷2.0)	0.8 (0.5÷1.1)	1.6 (1.2÷2.1)	2.8 (2.2÷3.4)
32	Da Nang	0.7 (0.4÷1.2)	1.2 (0.8÷1.7)	1.5 (1.0÷2.0)	0.8 (0.5÷1.1)	1.7 (1.3÷2.1)	2.8 (2.3÷3.3)
33	Quang Nam	0.7 (0.4÷1.2)	1.2 (0.8÷1.7)	1.5 (1.0÷1.9)	0.8 (0.5÷1.1)	1.7 (1.3÷2.1)	2.8 (2.3÷3.4)
34	Quang Ngai	0.7 (0.4÷1.2)	1.3 (0.9÷1.7)	1.5 (1.0÷2.0)	0.8 (0.5÷1.1)	1.7 (1.3÷2.1)	2.8 (2.3÷3.4)
35	Binh Dinh	0.7 (0.4÷1.2)	1.3 (0.9÷1.8)	1.5 (1.0÷2.0)	0.8 (0.5÷1.2)	1.7 (1.3÷2.2)	2.8 (2.3÷3.4)
36	Phu Yen	0.7 (0.4÷1.2)	1.3 (0.9÷1.8)	1.5 (1.1÷2.0)	0.8 (0.5÷1.2)	1.7 (1.3÷2.2)	2.9 (2.3÷3.4)
37	Khanh Hoa	0.7 (0.4÷1.2)	1.3 (0.9÷1.8)	1.5 (1.1÷2.1)	0.8 (0.5÷1.1)	1.7 (1.3÷2.2)	2.9 (2.3÷3.5)
38	Ninh Thuan	0.7 (0.4÷1.2)	1.3 (1.0÷1.9)	1.6 (1.2÷2.2)	0.8 (0.5÷1.1)	1.7 (1.3÷2.3)	3.0 (2.4÷3.8)
39	Binh Thuan	0.8 (0.4÷1.3)	1.3 (0.9÷1.9)	1.6 (1.1÷2.2)	0.8 (0.5÷1.3)	1.8 (1.3÷2.4)	3.1 (2.5÷3.7)
40	Kon Tum	0.8 (0.5÷1.3)	1.5 (1.1÷2.2)	1.8 (1.2÷2.3)	0.9 (0.6÷1.3)	1.9 (1.5÷2.5)	3.3 (2.7÷4.2)
41	Gia Lai	0.8 (0.4÷1.3)	1.4 (1.0÷2.0)	1.7 (1.2÷2.2)	0.9 (0.6÷1.2)	1.8 (1.4÷2.3)	3.1 (2.6÷3.9)
42	Dak Lak	0.8 (0.4÷1.2)	1.3 (1.0÷1.8)	1.6 (1.2÷2.2)	0.9 (0.6÷1.2)	1.8 (1.3÷2.2)	3.0 (2.5÷3.7)
43	Dak Nong	0.8 (0.4÷1.3)	1.4 (1.1÷2.1)	1.7 (1.2÷2.4)	0.9 (0.6÷1.2)	1.9 (1.5÷2.5)	3.3 (2.8÷4.1)
44	Lam Dong	0.8 (0.4÷1.3)	1.5 (1.2÷2.2)	1.8 (1.3÷2.6)	0.9 (0.6÷1.3)	2.0 (1.6÷2.6)	3.4 (3.0÷4.4)
45	Binh Phuoc	0.8 (0.4÷1.3)	1.5 (1.1÷2.2)	1.9 (1.3÷2.6)	0.9 (0.6÷1.3)	2.0 (1.6÷2.7)	3.5 (3.0÷4.6)
46	Tay Ninh	0.8 (0.4÷1.3)	1.5 (1.1÷2.1)	1.9 (1.2÷2.6)	0.9 (0.6÷1.3)	2.0 (1.5÷2.6)	3.5 (2.8÷4.7)
47	Binh Duong	0.8 (0.4÷1.3)	1.6 (1.0÷2.2)	1.9 (1.2÷2.7)	0.9 (0.6÷1.3)	2.1 (1.5÷2.8)	3.7 (2.9÷4.7)
48	Dong Nai	0.8 (0.4÷1.3)	1.5 (1.1÷2.1)	1.9 (1.2÷2.6)	0.9 (0.6÷1.3)	2.1 (1.5÷2.7)	3.5 (2.8÷4.5)
49	Ho Chi Minh	0.8 (0.4÷1.3)	1.5 (1.1÷2.1)	1.9 (1.2÷2.6)	0.9 (0.6÷1.3)	2.0 (1.6÷2.7)	3.5 (2.8÷4.4)
50	Ba Ria - Vung Tau	0.7 (0.4÷1.2)	1.3 (0.9÷1.8)	1.5 (1.2÷2.2)	0.8 (0.5÷1.2)	1.8 (1.2÷2.3)	3.0 (2.4÷3.6)
51	Long An	0.8 (0.4÷1.3)	1.5 (1.0÷2.1)	1.9 (1.3÷2.6)	0.9 (0.6÷1.2)	2.0 (1.5÷2.6)	3.5 (2.7÷4.5)
52	Vinh Long	0.8 (0.4÷1.2)	1.5 (1.1÷2.1)	1.9 (1.2÷2.6)	0.9 (0.6÷1.2)	2.0 (1.6÷2.7)	3.5 (2.8÷4.4)
53	Hau Giang	0.8 (0.4÷1.2)	1.5 (1.1÷2.1)	1.9 (1.3÷2.5)	0.9 (0.6÷1.2)	2.0 (1.5÷2.6)	3.4 (2.7÷4.4)
54	Tien Giang	0.8 (0.4÷1.3)	1.5 (1.1÷2.1)	1.8 (1.3÷2.5)	0.9 (0.6÷1.3)	2.0 (1.5÷2.6)	3.4 (2.8÷4.3)
55	Dong Thap	0.8 (0.4÷1.2)	1.5 (1.1÷2.0)	1.8 (1.2÷2.4)	0.9 (0.6÷1.2)	1.9 (1.5÷2.5)	3.3 (2.8÷4.1)
56	Ben Tre	0.7 (0.4÷1.2)	1.4 (1.1÷2.0)	1.7 (1.2÷2.3)	0.8 (0.6÷1.2)	1.8 (1.5÷2.5)	3.2 (2.7÷3.9)
57	Tra Vinh	0.8 (0.4÷1.2)	1.5 (1.1÷2.1)	1.8 (1.3÷2.5)	0.9 (0.6÷1.2)	1.9 (1.5÷2.5)	3.3 (2.8÷4.3)
58	An Giang	0.8 (0.4÷1.3)	1.5 (1.1÷2.1)	1.9 (1.3÷2.6)	0.9 (0.6÷1.3)	2.0 (1.5÷2.6)	3.5 (2.7÷4.6)
59	Can Tho	0.8 (0.4÷1.3)	1.5 (1.1÷2.1)	1.8 (1.3÷2.5)	0.9 (0.6÷1.2)	2.0 (1.5÷2.6)	3.3 (2.8÷4.3)
60	Soc Trang	0.8 (0.4÷1.2)	1.4 (1.1÷2.0)	1.8 (1.2÷2.4)	0.9 (0.6÷1.2)	1.9 (1.5÷2.5)	3.2 (2.7÷4.1)
61	Kien Giang	0.7 (0.4÷1.2)	1.4 (1.0÷2.0)	1.8 (1.2÷2.3)	0.8 (0.6÷1.2)	1.8 (1.5÷2.5)	3.2 (2.7÷4.0)
62	Bac Lieu	0.8 (0.4÷1.2)	1.4 (1.1÷2.0)	1.7 (1.2÷2.4)	0.9 (0.6÷1.2)	1.9 (1.5÷2.4)	3.2 (2.7÷4.0)
63	Ca Mau	0.8 (0.4÷1.2)	1.4 (1.1÷2.0)	1.8 (1.2÷2.4)	0.9 (0.6÷1.2)	1.9 (1.5÷2.5)	3.2 (2.7÷4.1)



(a) mid-21st century *(b) end of 21st century*

Figure A3. Changes in average spring temperature (^{o}C) based on RCP4.5 scenarios



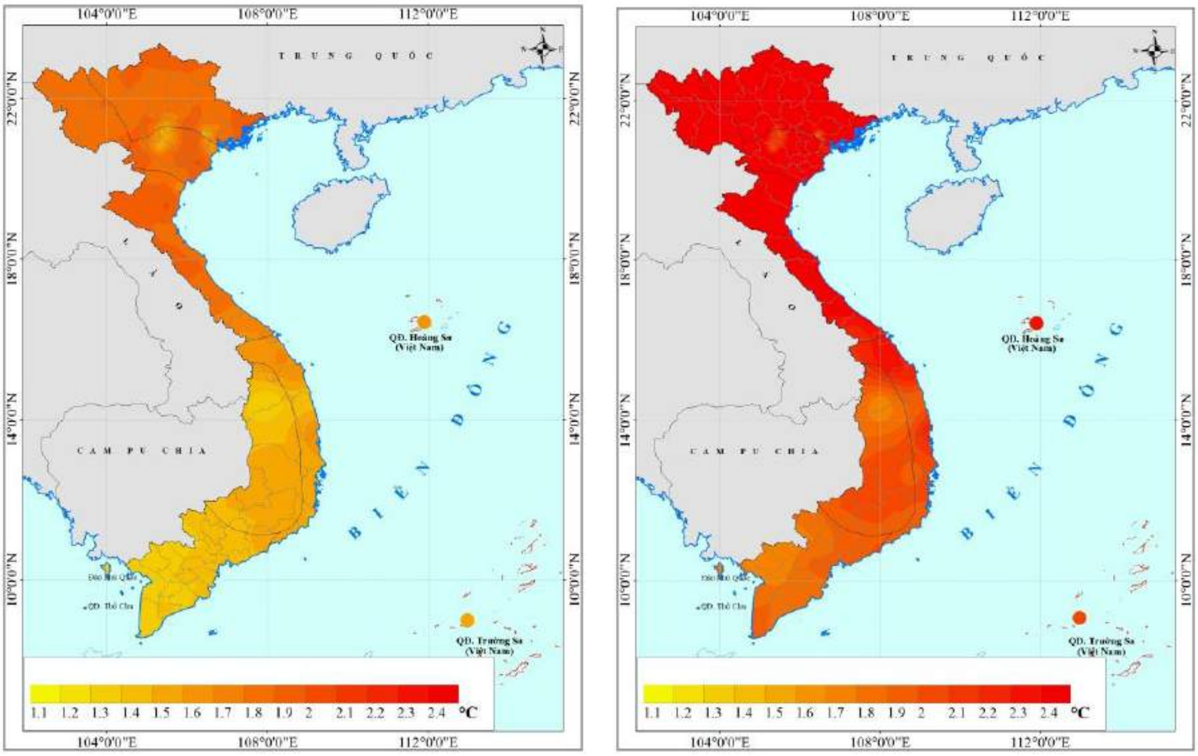
(a) mid-21st century *(b) end of 21st century*

Figure A4. Changes in average spring temperature (^{o}C) based on RCP8.5 scenarios

Table A2. Changes in average spring temperature (°C) compared with the baseline period

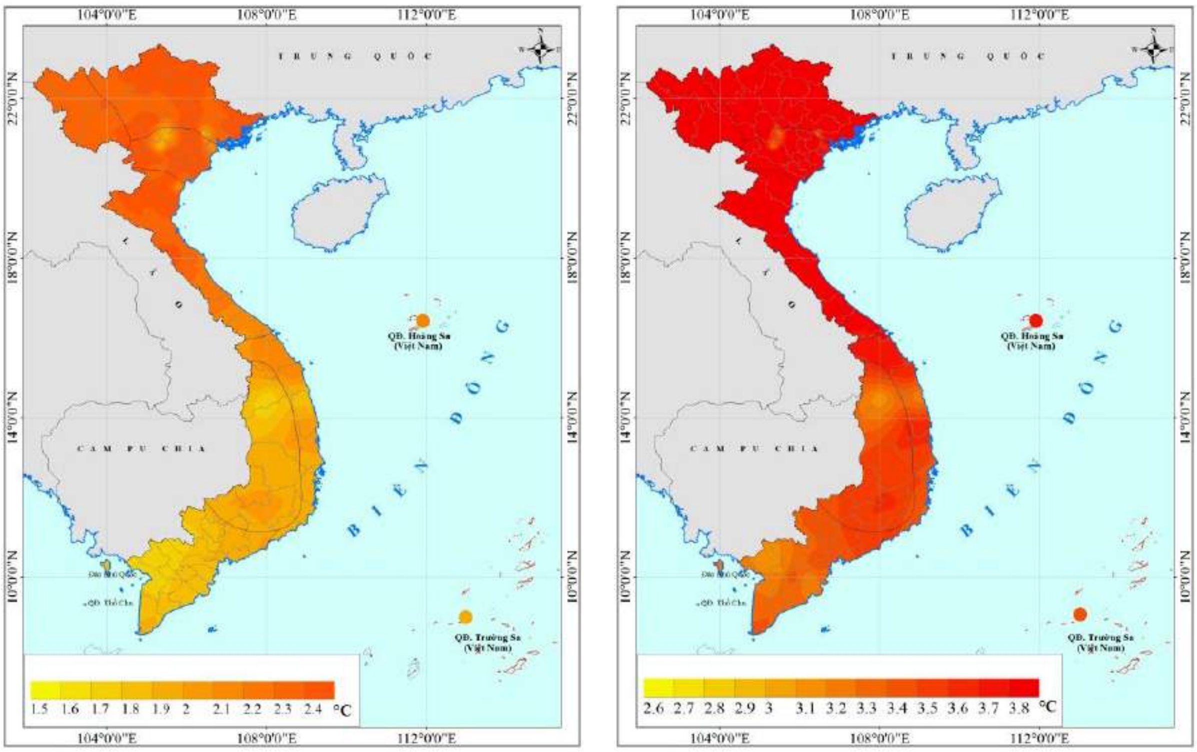
(Values in parentheses are the range of temperatures changes from the climate model results with the lower boundary of 10% and upper boundary of 90%)

No.	Province, City	RCP4.5 scenario			RCP8.5 scenario		
		2016-2035	2046-2065	2080-2099	2016-2035	2046-2065	2080-2099
1	Lai Chau	0.7 (0.1÷1.3)	1.5 (1.0÷2.0)	2.3 (1.4÷3.5)	1.2 (0.6÷1.8)	2.1 (1.1÷3.2)	3.8 (2.9÷5.6)
2	Dien Bien	0.7 (0.2÷1.3)	1.6 (1.0÷2.1)	2.3 (1.4÷3.4)	1.2 (0.6÷1.7)	2.2 (1.1÷3.2)	3.9 (2.9÷5.7)
3	Son La	0.7 (0.1÷1.3)	1.5 (0.9÷2.0)	2.2 (1.4÷3.4)	1.1 (0.6÷1.6)	2.1 (1.0÷3.2)	3.8 (2.8÷5.6)
4	Hoa Binh	0.6 (0.0÷1.2)	1.4 (0.9÷2.0)	2.2 (1.3÷3.3)	1.0 (0.5÷1.4)	2.0 (1.0÷3.2)	3.5 (2.4÷5.2)
5	Lao Cai	0.7 (0.2÷1.2)	1.5 (1.0÷2.1)	2.2 (1.4÷3.4)	1.1 (0.6÷1.6)	2.1 (1.1÷3.2)	3.7 (2.7÷5.5)
6	Ha Giang	0.6 (-0.1÷1.2)	1.5 (0.9÷2.2)	2.3 (1.3÷3.5)	1.0 (0.5÷1.5)	2.1 (1.1÷3.3)	3.7 (2.7÷5.6)
7	Yen Bai	0.7 (0.0÷1.2)	1.5 (0.9÷2.1)	2.3 (1.4÷3.4)	1.1 (0.6÷1.6)	2.1 (1.1÷3.2)	3.7 (2.7÷5.6)
8	Cao Bang	0.6 (-0.1÷1.1)	1.5 (0.9÷2.2)	2.2 (1.3÷3.4)	1.0 (0.5÷1.5)	2.1 (1.1÷3.3)	3.7 (2.8÷5.6)
9	Tuyen Quang	0.6 (-0.1÷1.2)	1.5 (0.9÷2.2)	2.3 (1.4÷3.6)	1.1 (0.5÷1.6)	2.1 (1.2÷3.4)	3.8 (2.8÷5.7)
10	Bac Kan	0.6 (-0.1÷1.2)	1.5 (0.9÷2.2)	2.3 (1.4÷3.4)	1.1 (0.5÷1.5)	2.1 (1.2÷3.4)	3.7 (2.8÷5.6)
11	Lang Son	0.6 (-0.1÷1.1)	1.5 (1.0÷2.2)	2.2 (1.4÷3.3)	1.0 (0.5÷1.4)	2.1 (1.2÷3.2)	3.7 (2.9÷5.4)
12	Thai Nguyen	0.6 (-0.1÷1.2)	1.5 (0.9÷2.2)	2.3 (1.4÷3.5)	1.1 (0.5÷1.5)	2.1 (1.2÷3.3)	3.7 (2.8÷5.6)
13	Phu Tho	0.6 (0.0÷1.3)	1.5 (0.9÷2.2)	2.3 (1.4÷3.5)	1.1 (0.6÷1.6)	2.1 (1.2÷3.4)	3.7 (2.6÷5.5)
14	Vinh Phuc	0.6 (0.0÷1.2)	1.5 (0.9÷2.2)	2.3 (1.3÷3.5)	1.0 (0.6÷1.6)	2.1 (1.1÷3.4)	3.7 (2.6÷5.5)
15	Bac Giang	0.6 (0.0÷1.1)	1.5 (1.0÷2.0)	2.2 (1.4÷3.2)	0.9 (0.5÷1.4)	2.0 (1.2÷3.2)	3.6 (2.7÷5.2)
16	Bac Ninh	0.6 (0.1÷1.1)	1.5 (0.9÷2.1)	2.2 (1.4÷3.3)	0.9 (0.5÷1.4)	2.0 (1.2÷3.2)	3.7 (2.6÷5.2)
17	Quang Ninh	0.7 (0.3÷1.1)	1.5 (1.0÷2.0)	2.1 (1.5÷3.0)	0.9 (0.5÷1.2)	2.0 (1.3÷2.8)	3.4 (2.7÷4.5)
18	Hai Phong	0.8 (0.3÷1.2)	1.5 (0.9÷2.0)	2.0 (1.4÷2.9)	0.9 (0.5÷1.2)	2.0 (1.2÷2.8)	3.2 (2.5÷4.3)
19	Hai Duong	0.6 (0.1÷1.1)	1.5 (0.9÷2.1)	2.2 (1.3÷3.3)	0.9 (0.5÷1.4)	2.0 (1.1÷3.1)	3.5 (2.5÷5.1)
20	Hung Yen	0.6 (-0.1÷1.2)	1.4 (0.9÷2.0)	2.2 (1.3÷3.3)	0.9 (0.4÷1.4)	2.0 (1.0÷3.2)	3.5 (2.5÷5.1)
21	Ha Noi	0.6 (-0.1÷1.2)	1.5 (0.9÷2.2)	2.2 (1.3÷3.4)	1.0 (0.5÷1.5)	2.0 (1.1÷3.3)	3.6 (2.5÷5.4)
22	Ha Nam	0.6 (-0.1÷1.2)	1.5 (0.9÷2.1)	2.2 (1.4÷3.3)	1.0 (0.5÷1.5)	2.0 (1.1÷3.3)	3.6 (2.5÷5.2)
23	Thai Binh	0.6 (0.0÷1.1)	1.4 (0.9÷1.9)	2.2 (1.4÷3.1)	0.9 (0.5÷1.3)	1.9 (1.1÷3.0)	3.4 (2.5÷4.8)
24	Nam Dinh	0.7 (0.2÷1.2)	1.4 (0.9÷2.0)	2.2 (1.3÷3.1)	0.9 (0.5÷1.3)	2.0 (1.1÷2.9)	3.3 (2.5÷4.6)
25	Ninh Binh	0.6 (-0.1÷1.2)	1.4 (0.8÷2.0)	2.2 (1.3÷3.2)	0.9 (0.4÷1.3)	2.0 (1.0÷3.2)	3.5 (2.4÷5.0)
26	Thanh Hoa	0.6 (0.0÷1.2)	1.4 (0.8÷2.0)	2.1 (1.3÷3.2)	0.9 (0.5÷1.4)	1.9 (1.0÷3.1)	3.4 (2.3÷4.9)
27	Nghe An	0.7 (0.1÷1.3)	1.4 (0.8÷2.0)	2.1 (1.3÷3.1)	1.0 (0.5÷1.5)	1.9 (1.0÷3.1)	3.4 (2.2÷5.0)
28	Ha Tinh	0.6 (0.1÷1.2)	1.3 (0.7÷1.9)	2.0 (1.2÷2.9)	0.9 (0.5÷1.3)	1.8 (0.9÷2.8)	3.2 (2.0÷4.5)
29	Quang Binh	0.6 (0.2÷1.2)	1.3 (0.8÷1.8)	2.0 (1.2÷2.8)	0.9 (0.4÷1.2)	1.8 (0.9÷2.8)	3.2 (2.1÷4.5)
30	Quang Tri	0.7 (0.2÷1.2)	1.3 (0.8÷1.8)	2.0 (1.3÷2.8)	0.9 (0.5÷1.2)	1.8 (1.0÷2.7)	3.2 (2.2÷4.6)
31	Thua Thien - Hue	0.7 (0.2÷1.2)	1.4 (0.7÷1.9)	2.0 (1.2÷2.8)	0.9 (0.5÷1.2)	1.9 (1.0÷2.7)	3.2 (2.2÷4.5)
32	Da Nang	0.7 (0.3÷1.2)	1.3 (0.8÷1.9)	1.9 (1.2÷2.7)	0.8 (0.5÷1.1)	1.8 (1.1÷2.6)	3.1 (2.4÷4.1)
33	Quảng Nam	0.7 (0.3÷1.2)	1.3 (0.8÷1.9)	1.9 (1.2÷2.7)	0.8 (0.5÷1.2)	1.8 (1.1÷2.6)	3.2 (2.3÷4.1)
34	Quang Ngai	0.7 (0.3÷1.2)	1.3 (0.8÷1.8)	1.9 (1.2÷2.7)	0.8 (0.5÷1.1)	1.8 (1.1÷2.6)	3.1 (2.3÷4.1)
35	Binh Dinh	0.7 (0.3÷1.1)	1.3 (0.8÷1.9)	1.8 (1.2÷2.6)	0.8 (0.5÷1.0)	1.8 (1.1÷2.5)	3.1 (2.3÷3.9)
36	Phu Yen	0.7 (0.4÷1.1)	1.3 (0.9÷1.9)	1.8 (1.2÷2.6)	0.8 (0.6÷1.0)	1.7 (1.1÷2.6)	3.1 (2.3÷3.9)
37	Khanh Hoa	0.7 (0.4÷1.2)	1.3 (0.8÷2.0)	1.8 (1.2÷2.6)	0.8 (0.6÷1.0)	1.8 (1.2÷2.7)	3.2 (2.4÷4.1)
38	Ninh Thuan	0.7 (0.4÷1.1)	1.3 (0.9÷2.0)	1.8 (1.2÷2.6)	0.8 (0.6÷1.0)	1.8 (1.2÷2.6)	3.3 (2.5÷4.1)
39	Binh Thuan	0.7 (0.4÷1.3)	1.3 (0.8÷2.0)	1.8 (1.2÷2.6)	0.8 (0.5÷1.1)	1.8 (1.2÷2.6)	3.2 (2.5÷4.0)
40	Kon Tum	0.8 (0.5÷1.2)	1.5 (1.0÷2.1)	2.0 (1.5÷2.8)	0.9 (0.6÷1.3)	2.0 (1.4÷2.8)	3.7 (2.7÷4.8)
41	Gia Lai	0.7 (0.3÷1.2)	1.4 (0.9÷1.9)	1.9 (1.3÷2.7)	0.9 (0.5÷1.2)	1.8 (1.2÷2.7)	3.4 (2.4÷4.5)
42	Dak Lak	0.7 (0.3÷1.2)	1.4 (0.9÷2.0)	2.0 (1.3÷2.8)	0.9 (0.6÷1.2)	1.9 (1.2÷2.7)	3.3 (2.4÷4.5)
43	Dak Nong	0.7 (0.4÷1.2)	1.5 (0.9÷2.0)	2.0 (1.4÷2.8)	0.9 (0.6÷1.2)	2.0 (1.3÷2.7)	3.4 (2.6÷4.5)
44	Lam Dong	0.7 (0.4÷1.1)	1.5 (1.0÷2.0)	2.0 (1.4÷2.8)	0.9 (0.6÷1.3)	2.0 (1.4÷2.7)	3.5 (2.8÷4.5)
45	Binh Phuoc	0.7 (0.4÷1.2)	1.5 (0.9÷2.2)	2.1 (1.4÷2.8)	0.9 (0.5÷1.4)	2.0 (1.4÷2.9)	3.6 (2.7÷4.7)
46	Tay Ninh	0.7 (0.3÷1.3)	1.4 (0.9÷2.1)	2.0 (1.3÷2.9)	0.9 (0.5÷1.4)	1.9 (1.3÷2.8)	3.5 (2.6÷4.7)
47	Binh Duong	0.7 (0.3÷1.3)	1.5 (0.9÷2.3)	2.0 (1.3÷3.0)	0.9 (0.6÷1.5)	2.0 (1.3÷3.0)	3.6 (2.6÷4.9)
48	Dong Nai	0.8 (0.4÷1.3)	1.4 (0.8÷2.2)	2.0 (1.3÷2.9)	0.9 (0.5÷1.4)	2.0 (1.3÷3.0)	3.5 (2.6÷4.8)
49	Ho Chi Minh	0.8 (0.4÷1.3)	1.5 (0.9÷2.2)	2.0 (1.3÷2.9)	0.9 (0.6÷1.4)	2.0 (1.4÷2.9)	3.6 (2.7÷4.7)
50	Ba Ria - Vung Tau	0.8 (0.4÷1.2)	1.3 (0.8÷2.0)	1.7 (1.2÷2.5)	0.8 (0.6÷1.1)	1.8 (1.2÷2.6)	3.0 (2.5÷3.8)
51	Long An	0.7 (0.3÷1.2)	1.4 (0.8÷2.1)	2.0 (1.3÷2.8)	0.8 (0.5÷1.4)	1.9 (1.3÷2.8)	3.5 (2.5÷4.7)
52	Vinh Long	0.7 (0.3÷1.2)	1.4 (0.8÷2.2)	1.9 (1.3÷2.8)	0.8 (0.5÷1.3)	2.0 (1.3÷2.9)	3.5 (2.6÷4.8)
53	Hau Giang	0.7 (0.3÷1.2)	1.4 (0.8÷2.1)	1.9 (1.2÷2.8)	0.8 (0.5÷1.3)	1.9 (1.3÷2.8)	3.5 (2.5÷4.7)
54	Tien Giang	0.8 (0.4÷1.3)	1.5 (0.9÷2.1)	2.0 (1.3÷2.9)	0.9 (0.6÷1.4)	1.9 (1.4÷2.9)	3.5 (2.7÷4.6)
55	Dong Thap	0.8 (0.4÷1.2)	1.5 (0.9÷2.0)	1.9 (1.2÷2.8)	0.9 (0.6÷1.3)	1.8 (1.3÷2.8)	3.4 (2.7÷4.4)
56	Ben Tre	0.7 (0.4÷1.2)	1.4 (0.9÷2.0)	1.8 (1.2÷2.6)	0.8 (0.5÷1.2)	1.8 (1.3÷2.6)	3.3 (2.6÷4.2)
57	Tra Vinh	0.7 (0.4÷1.2)	1.4 (0.9÷2.0)	1.9 (1.3÷2.8)	0.9 (0.6÷1.3)	1.9 (1.3÷2.8)	3.4 (2.7÷4.5)
58	An Giang	0.7 (0.3÷1.2)	1.4 (0.9÷2.0)	2.0 (1.3÷2.8)	0.9 (0.5÷1.3)	1.9 (1.3÷2.8)	3.5 (2.5÷4.7)
59	Can Tho	0.7 (0.3÷1.2)	1.4 (0.9÷2.1)	1.9 (1.3÷2.8)	0.9 (0.6÷1.4)	1.9 (1.3÷2.8)	3.4 (2.6÷4.6)
60	Soc Trang	0.7 (0.4÷1.2)	1.4 (0.9÷2.0)	1.9 (1.3÷2.6)	0.8 (0.6÷1.3)	1.9 (1.3÷2.7)	3.4 (2.6÷4.4)
61	Kien Giang	0.7 (0.4÷1.2)	1.3 (0.9÷2.0)	1.8 (1.3÷2.6)	0.8 (0.6÷1.2)	1.8 (1.3÷2.6)	3.2 (2.6÷4.1)
62	Bac Lieu	0.8 (0.4÷1.3)	1.4 (0.9÷1.9)	1.8 (1.3÷2.6)	0.8 (0.6÷1.2)	1.8 (1.3÷2.6)	3.3 (2.6÷4.2)
63	Ca Mau	0.7 (0.4÷1.3)	1.4 (0.9÷1.9)	1.9 (1.3÷2.6)	0.8 (0.6÷1.3)	1.8 (1.2÷2.7)	3.4 (2.5÷4.4)



(a) mid-21st century *(b) end of 21st century*

Figure A5. Changes in average summer temperature (oC) based on RCP4.5 scenarios



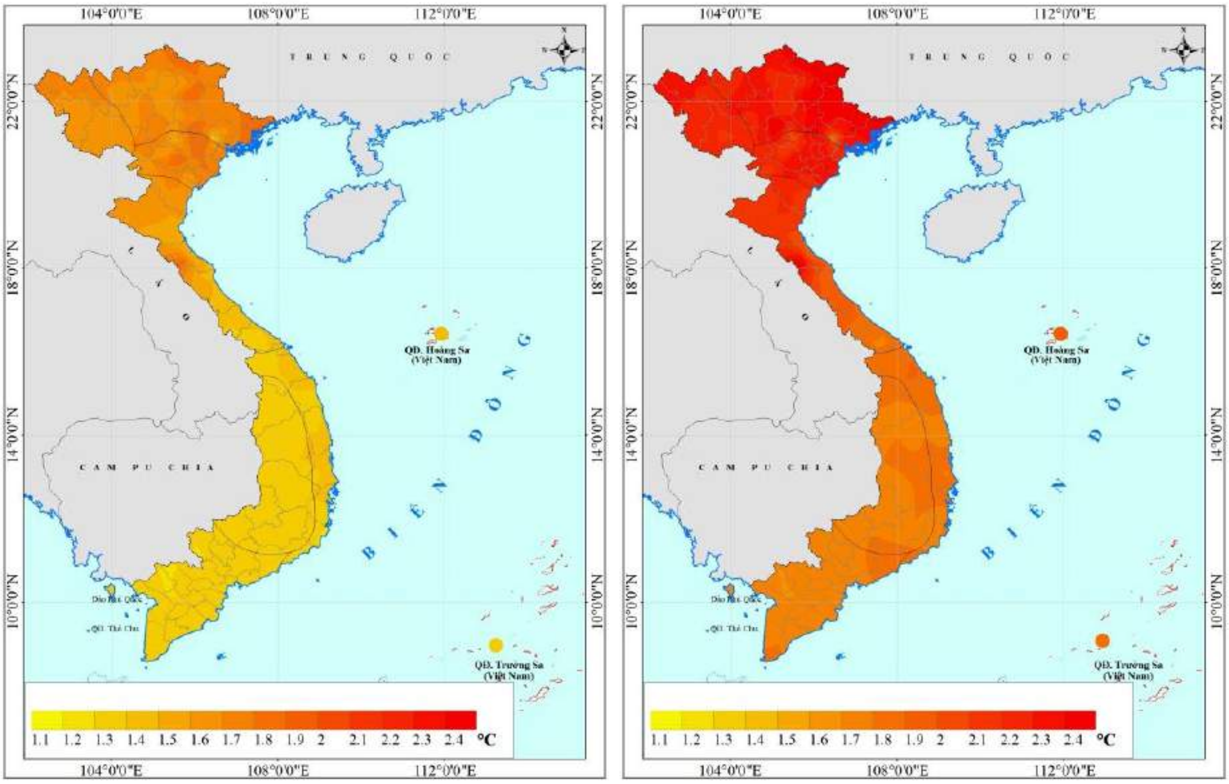
(a) mid-21st century *(b) end of 21st century*

Figure A6. Changes in average summer temperature (oC) based on RCP8.5 scenarios

Table A3. Changes in average summer temperature (^oC) compared with the baseline period

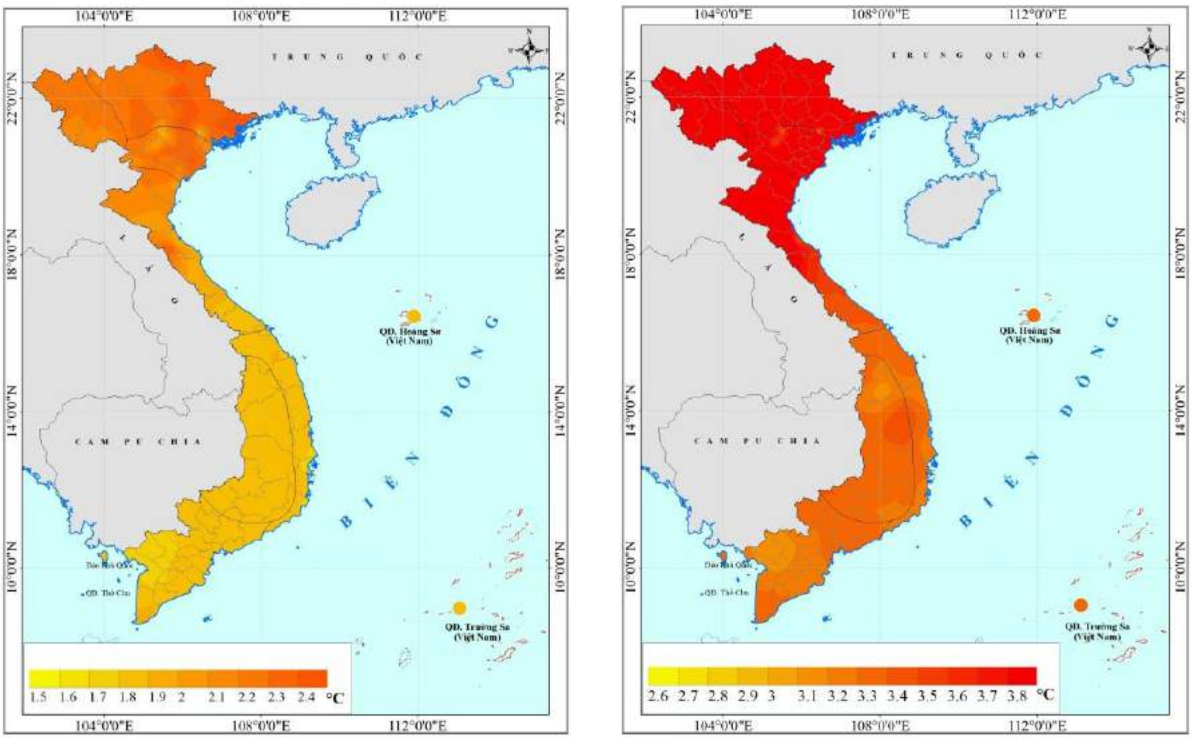
(Values in parentheses are the range of temperatures changes from the climate model results with the lower boundary of 10% and upper boundary of 90%)

No.	Province, City	RCP4.5 scenario			RCP8.5 scenario		
		2016-2035	2046-2065	2080-2099	2016-2035	2046-2065	2080-2099
1	Lai Chau	0.6 (0.3÷1.1)	1.8 (1.2÷2.7)	2.4 (1.6÷3.5)	1.0 (0.5÷1.5)	2.3 (1.4÷3.3)	3.9 (2.9÷5.6)
2	Dien Bien	0.7 (0.3÷1.1)	1.8 (1.3÷2.6)	2.5 (1.7÷3.6)	1.0 (0.5÷1.4)	2.3 (1.5÷3.3)	4.0 (2.9÷5.7)
3	Son La	0.7 (0.3÷1.1)	1.9 (1.3÷2.8)	2.7 (1.9÷3.7)	1.0 (0.5÷1.5)	2.4 (1.5÷3.5)	4.2 (3.0÷5.9)
4	Hoa Binh	0.8 (0.3÷1.2)	1.9 (1.3÷2.9)	2.7 (1.9÷3.8)	1.0 (0.5÷1.5)	2.5 (1.4÷3.7)	4.2 (3.0÷6.1)
5	Lao Cai	0.7 (0.3÷1.1)	1.8 (1.2÷2.8)	2.5 (1.8÷3.6)	1.0 (0.5÷1.5)	2.3 (1.5÷3.4)	4.0 (3.0÷5.7)
6	Ha Giang	0.6 (0.2÷1.1)	1.9 (1.2÷2.9)	2.6 (1.9÷3.8)	1.0 (0.5÷1.4)	2.4 (1.5÷3.6)	4.1 (3.0÷5.9)
7	Yen Bai	0.7 (0.2÷1.1)	1.8 (1.3÷2.8)	2.6 (1.9÷3.8)	1.0 (0.5÷1.5)	2.4 (1.5÷3.6)	4.2 (3.0÷5.9)
8	Cao Bang	0.7 (0.2÷1.1)	1.9 (1.2÷2.9)	2.6 (1.8÷3.7)	1.0 (0.5÷1.5)	2.4 (1.5÷3.7)	4.2 (3.0÷5.9)
9	Tuyen Quang	0.7 (0.2÷1.1)	1.9 (1.3÷2.9)	2.8 (2.0÷3.9)	1.1 (0.5÷1.5)	2.5 (1.5÷3.8)	4.2 (3.0÷6.0)
10	Bac Kan	0.7 (0.3÷1.1)	1.9 (1.3÷2.9)	2.6 (1.9÷3.8)	1.0 (0.5÷1.5)	2.4 (1.5÷3.6)	4.1 (3.0÷6.0)
11	Lang Son	0.7 (0.3÷1.1)	1.8 (1.2÷2.9)	2.6 (1.9÷3.7)	1.0 (0.5÷1.5)	2.4 (1.4÷3.6)	4.1 (3.0÷5.9)
12	Thai Nguyen	0.8 (0.3÷1.2)	1.9 (1.2÷2.9)	2.7 (1.9÷3.8)	1.1 (0.5÷1.6)	2.4 (1.4÷3.6)	4.2 (3.0÷6.0)
13	Phu Tho	0.8 (0.3÷1.3)	2.0 (1.3÷3.0)	2.8 (1.9÷4.0)	1.1 (0.5÷1.6)	2.6 (1.4÷3.8)	4.3 (3.0÷6.2)
14	Vinh Phuc	0.8 (0.4÷1.3)	2.0 (1.3÷3.0)	2.8 (1.9÷4.0)	1.1 (0.5÷1.6)	2.5 (1.4÷3.7)	4.3 (3.0÷6.2)
15	Bac Giang	0.7 (0.3÷1.1)	1.8 (1.2÷2.9)	2.6 (1.8÷3.7)	1.0 (0.5÷1.5)	2.4 (1.4÷3.6)	4.1 (3.0÷5.9)
16	Bac Ninh	0.7 (0.4÷1.2)	1.9 (1.2÷3.0)	2.7 (1.9÷3.7)	1.0 (0.4÷1.5)	2.4 (1.4÷3.6)	4.3 (3.0÷6.2)
17	Quang Ninh	0.7 (0.4÷1.1)	1.6 (1.1÷2.5)	2.2 (1.6÷3.1)	0.9 (0.4÷1.3)	2.1 (1.4÷3.0)	3.7 (2.9÷5.0)
18	Hai Phong	0.7 (0.4÷1.2)	1.6 (1.0÷2.5)	2.2 (1.6÷3.2)	0.9 (0.4÷1.4)	2.1 (1.4÷3.1)	3.7 (2.9÷4.9)
19	Hai Duong	0.7 (0.4÷1.2)	1.9 (1.2÷3.0)	2.7 (1.9÷3.8)	1.0 (0.4÷1.5)	2.4 (1.5÷3.7)	4.1 (3.0÷6.1)
20	Hung Yen	0.8 (0.4÷1.2)	1.9 (1.3÷3.0)	2.8 (1.9÷3.9)	1.1 (0.5÷1.6)	2.5 (1.5÷3.7)	4.2 (3.0÷6.2)
21	Ha Noi	0.8 (0.4÷1.2)	2.0 (1.3÷3.0)	2.8 (1.9÷4.0)	1.1 (0.5÷1.6)	2.5 (1.4÷3.8)	4.3 (3.0÷6.2)
22	Ha Nam	0.8 (0.4÷1.2)	2.0 (1.3÷3.0)	2.8 (1.9÷3.9)	1.1 (0.5÷1.6)	2.5 (1.4÷3.7)	4.2 (3.0÷6.1)
23	Thai Binh	0.8 (0.4÷1.2)	1.9 (1.2÷2.9)	2.7 (1.8÷3.7)	1.0 (0.5÷1.5)	2.4 (1.5÷3.6)	4.1 (3.1÷5.8)
24	Nam Dinh	0.8 (0.4÷1.2)	1.8 (1.2÷2.7)	2.5 (1.8÷3.5)	1.0 (0.4÷1.5)	2.2 (1.5÷3.3)	3.9 (3.0÷5.4)
25	Ninh Binh	0.8 (0.4÷1.2)	1.9 (1.3÷2.9)	2.8 (1.9÷3.8)	1.0 (0.5÷1.5)	2.5 (1.5÷3.8)	4.2 (3.0÷6.1)
26	Thanh Hoa	0.8 (0.4÷1.2)	1.9 (1.3÷2.9)	2.7 (1.9÷3.7)	1.0 (0.5÷1.5)	2.4 (1.5÷3.6)	4.1 (3.1÷5.9)
27	Nghe An	0.8 (0.3÷1.3)	1.9 (1.3÷3.0)	2.7 (1.9÷3.7)	1.0 (0.5÷1.6)	2.4 (1.4÷3.7)	4.2 (3.2÷6.0)
28	Ha Tinh	0.8 (0.4÷1.3)	1.9 (1.2÷3.0)	2.6 (1.8÷3.6)	1.0 (0.5÷1.5)	2.3 (1.4÷3.6)	4.1 (3.2÷5.7)
29	Quang Binh	0.8 (0.4÷1.3)	1.8 (1.2÷2.9)	2.5 (1.7÷3.5)	0.9 (0.5÷1.5)	2.2 (1.4÷3.4)	4.1 (3.0÷5.8)
30	Quang Tri	0.8 (0.3÷1.3)	1.8 (1.2÷2.7)	2.3 (1.7÷3.3)	0.9 (0.5÷1.5)	2.2 (1.4÷3.2)	3.8 (3.0÷5.5)
31	Thua Thien - Hue	0.7 (0.3÷1.3)	1.7 (1.2÷2.7)	2.4 (1.7÷3.3)	0.9 (0.6÷1.4)	2.2 (1.4÷3.2)	3.8 (3.0÷5.4)
32	Da Nang	0.8 (0.4÷1.3)	1.7 (1.1÷2.6)	2.3 (1.7÷3.2)	0.9 (0.6÷1.4)	2.1 (1.4÷3.0)	3.7 (3.0÷5.2)
33	Quảng Nam	0.7 (0.4÷1.3)	1.6 (1.0÷2.5)	2.2 (1.5÷3.1)	0.8 (0.5÷1.3)	2.1 (1.4÷3.0)	3.6 (2.9÷5.0)
34	Quang Ngai	0.8 (0.4÷1.3)	1.7 (1.1÷2.6)	2.3 (1.7÷3.3)	0.9 (0.6÷1.4)	2.1 (1.4÷3.1)	3.7 (3.0÷5.3)
35	Binh Dinh	0.7 (0.3÷1.2)	1.6 (1.0÷2.5)	2.1 (1.5÷3.0)	0.8 (0.5÷1.2)	2.0 (1.3÷2.8)	3.5 (2.9÷4.8)
36	Phu Yen	0.7 (0.4÷1.2)	1.5 (0.9÷2.4)	2.0 (1.4÷2.8)	0.8 (0.5÷1.2)	1.9 (1.3÷2.7)	3.4 (2.9÷4.7)
37	Khanh Hoa	0.7 (0.3÷1.2)	1.5 (0.9÷2.3)	2.0 (1.3÷2.8)	0.8 (0.5÷1.3)	2.0 (1.3÷2.9)	3.5 (2.7÷4.6)
38	Ninh Thuan	0.7 (0.3÷1.1)	1.5 (0.9÷2.2)	2.0 (1.3÷2.8)	0.8 (0.5÷1.2)	1.9 (1.3÷2.7)	3.4 (2.8÷4.6)
39	Binh Thuan	0.7 (0.4÷1.2)	1.4 (0.9÷2.1)	1.8 (1.2÷2.5)	0.8 (0.5÷1.3)	1.8 (1.3÷2.6)	3.2 (2.7÷4.2)
40	Kon Tum	0.7 (0.3÷1.2)	1.5 (1.0÷2.2)	2.0 (1.4÷2.8)	0.9 (0.6÷1.4)	2.0 (1.4÷2.8)	3.6 (2.8÷4.9)
41	Gia Lai	0.7 (0.3÷1.2)	1.5 (1.0÷2.2)	2.0 (1.4÷2.9)	0.9 (0.5÷1.4)	2.0 (1.4÷2.9)	3.6 (2.7÷5.0)
42	Dak Lak	0.7 (0.4÷1.2)	1.5 (1.0÷2.2)	2.0 (1.4÷3.0)	0.9 (0.6÷1.4)	2.0 (1.3÷3.0)	3.6 (2.8÷5.0)
43	Dak Nong	0.7 (0.4÷1.2)	1.5 (1.0÷2.2)	2.0 (1.3÷2.8)	0.9 (0.6÷1.4)	2.0 (1.4÷2.8)	3.5 (2.8÷4.8)
44	Lam Dong	0.7 (0.4÷1.1)	1.5 (1.0÷2.2)	1.9 (1.3÷2.7)	0.9 (0.6÷1.3)	1.9 (1.4÷2.7)	3.5 (2.7÷4.7)
45	Binh Phuoc	0.6 (0.3÷1.1)	1.4 (0.9÷2.1)	1.9 (1.3÷2.6)	0.8 (0.5÷1.3)	1.9 (1.3÷2.7)	3.4 (2.7÷4.7)
46	Tay Ninh	0.7 (0.3÷1.1)	1.4 (0.9÷2.2)	1.9 (1.3÷2.7)	0.8 (0.4÷1.3)	1.9 (1.3÷2.7)	3.4 (2.7÷4.7)
47	Binh Duong	0.6 (0.3÷1.1)	1.5 (0.9÷2.2)	1.9 (1.2÷2.7)	0.8 (0.4÷1.3)	2.0 (1.3÷2.8)	3.6 (2.8÷4.8)
48	Dong Nai	0.7 (0.3÷1.2)	1.5 (0.9÷2.2)	1.9 (1.2÷2.7)	0.9 (0.5÷1.4)	2.0 (1.3÷2.8)	3.6 (2.7÷4.8)
49	Ho Chi Minh	0.7 (0.3÷1.2)	1.5 (0.9÷2.2)	1.9 (1.3÷2.7)	0.9 (0.4÷1.4)	2.0 (1.3÷2.8)	3.6 (2.8÷4.8)
50	Ba Ria - Vung Tau	0.7 (0.4÷1.3)	1.3 (0.9÷2.1)	1.8 (1.2÷2.4)	0.8 (0.4÷1.3)	1.8 (1.2÷2.5)	3.2 (2.6÷4.1)
51	Long An	0.7 (0.3÷1.2)	1.4 (0.9÷2.1)	1.9 (1.3÷2.7)	0.8 (0.4÷1.3)	1.9 (1.3÷2.7)	3.5 (2.7÷4.7)
52	Vinh Long	0.7 (0.3÷1.1)	1.4 (0.9÷2.2)	1.9 (1.2÷2.7)	0.9 (0.5÷1.3)	1.9 (1.3÷2.7)	3.6 (2.7÷4.7)
53	Hau Giang	0.7 (0.4÷1.2)	1.4 (0.9÷2.2)	1.8 (1.2÷2.7)	0.9 (0.5÷1.4)	1.9 (1.3÷2.7)	3.5 (2.7÷4.6)
54	Tien Giang	0.7 (0.3÷1.2)	1.4 (0.9÷2.1)	1.9 (1.3÷2.7)	0.9 (0.5÷1.4)	1.9 (1.3÷2.8)	3.4 (2.7÷4.8)
55	Dong Thap	0.7 (0.3÷1.2)	1.4 (0.9÷2.1)	1.8 (1.2÷2.6)	0.9 (0.4÷1.4)	1.8 (1.3÷2.7)	3.3 (2.7÷4.7)
56	Ben Tre	0.7 (0.3÷1.2)	1.4 (0.9÷2.1)	1.8 (1.2÷2.5)	0.9 (0.4÷1.4)	1.8 (1.3÷2.6)	3.3 (2.7÷4.5)
57	Tra Vinh	0.7 (0.3÷1.2)	1.4 (0.9÷2.1)	1.9 (1.3÷2.6)	0.9 (0.5÷1.4)	1.9 (1.3÷2.7)	3.4 (2.7÷4.6)
58	An Giang	0.7 (0.4÷1.2)	1.5 (0.9÷2.2)	2.0 (1.3÷2.8)	0.9 (0.5÷1.4)	1.9 (1.3÷2.7)	3.5 (2.7÷4.8)
59	Can Tho	0.7 (0.3÷1.2)	1.4 (0.9÷2.1)	1.9 (1.2÷2.6)	0.9 (0.5÷1.4)	1.9 (1.3÷2.7)	3.4 (2.7÷4.6)
60	Soc Trang	0.7 (0.3÷1.2)	1.4 (0.9÷2.1)	1.8 (1.2÷2.6)	0.9 (0.5÷1.4)	1.8 (1.3÷2.6)	3.4 (2.7÷4.6)
61	Kien Giang	0.7 (0.4÷1.2)	1.4 (0.9÷2.1)	1.8 (1.2÷2.5)	0.9 (0.5÷1.3)	1.8 (1.2÷2.5)	3.2 (2.6÷4.3)
62	Bac Lieu	0.8 (0.4÷1.3)	1.4 (0.9÷2.1)	1.8 (1.2÷2.5)	0.9 (0.5÷1.4)	1.8 (1.3÷2.6)	3.3 (2.7÷4.4)
63	Ca Mau	0.8 (0.4÷1.3)	1.5 (0.9÷2.1)	1.9 (1.2÷2.6)	1.0 (0.5÷1.5)	1.9 (1.2÷2.7)	3.4 (2.7÷4.5)



(a) mid-21st century *(b) end of 21st century*

Figure A7. Changes in average autumn temperature (°C) based on RCP4.5 scenarios



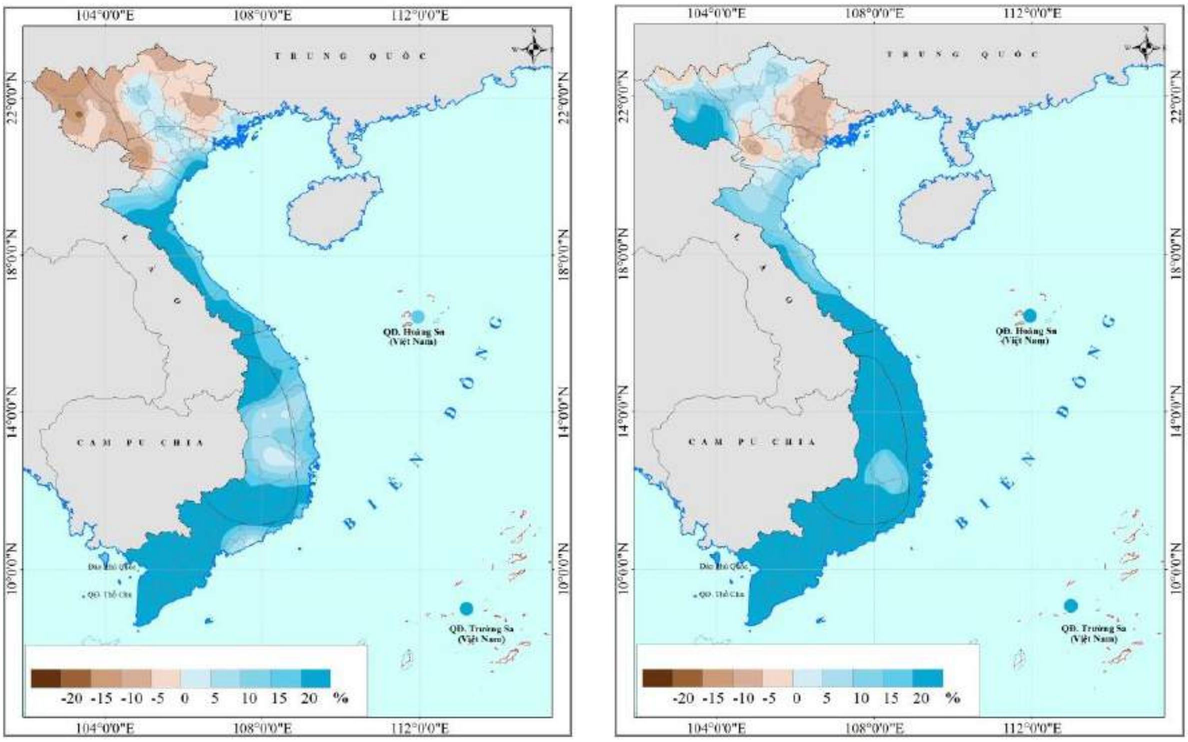
(a) mid-21st century *(b) end of 21st century*

Figure A8. Changes in average autumn temperature (°C) based on RCP8.5 scenarios

Table A4. Changes in average autumn temperature (^oC) compared with the baseline period

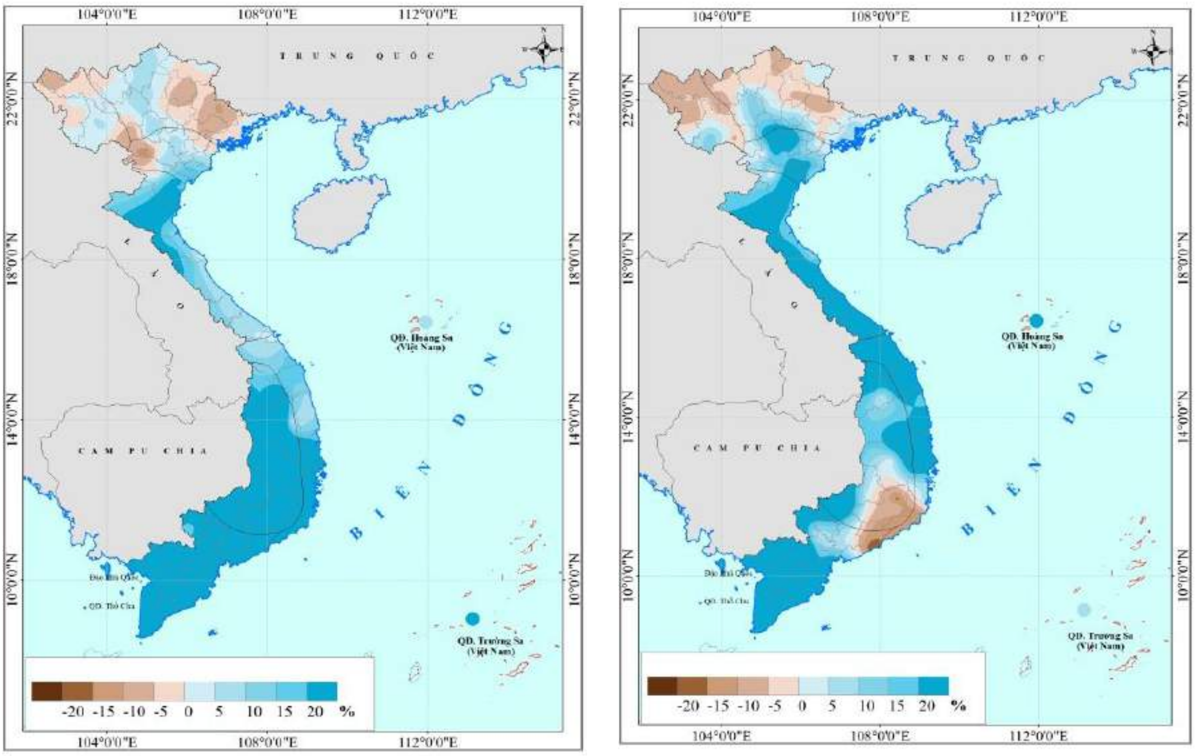
(Values in parentheses are the range of temperatures changes from the climate model results with the lower boundary of 10% and upper boundary of 90%)

No.	Province, City	RCP4.5 scenario			RCP8.5 scenario		
		2016-2035	2046-2065	2080-2099	2016-2035	2046-2065	2080-2099
1	Lai Chau	0.7 (0.3÷1.2)	1.7 (1.2÷2.5)	2.3 (1.6÷3.4)	1.2 (0.4÷2.0)	2.2 (1.4÷3.4)	4.1 (3.1÷5.8)
2	Dien Bien	0.7 (0.4÷1.2)	1.7 (1.1÷2.5)	2.3 (1.6÷3.4)	1.2 (0.4÷2.0)	2.2 (1.4÷3.3)	4.2 (3.1÷5.8)
3	Son La	0.7 (0.3÷1.1)	1.7 (1.2÷2.5)	2.2 (1.5÷3.2)	1.1 (0.5÷1.9)	2.2 (1.4÷3.5)	4.2 (3.0÷5.8)
4	Hoa Binh	0.7 (0.2÷1.1)	1.7 (1.2÷2.6)	2.3 (1.6÷3.3)	1.1 (0.5÷1.8)	2.3 (1.5÷3.6)	4.1 (2.9÷5.7)
5	Lao Cai	0.7 (0.3÷1.1)	1.7 (1.2÷2.6)	2.3 (1.5÷3.4)	1.1 (0.4÷1.9)	2.2 (1.4÷3.6)	4.1 (3.1÷5.9)
6	Ha Giang	0.7 (0.2÷1.2)	1.7 (1.2÷2.7)	2.4 (1.5÷3.5)	1.1 (0.4÷1.9)	2.3 (1.5÷3.7)	4.2 (3.1÷6.0)
7	Yen Bai	0.7 (0.2÷1.2)	1.7 (1.2÷2.6)	2.3 (1.6÷3.4)	1.2 (0.5÷2.0)	2.3 (1.5÷3.7)	4.2 (3.1÷5.9)
8	Cao Bang	0.7 (0.1÷1.2)	1.7 (1.2÷2.7)	2.4 (1.5÷3.4)	1.1 (0.4÷1.9)	2.3 (1.5÷3.9)	4.2 (3.1÷5.9)
9	Tuyen Quang	0.7 (0.1÷1.2)	1.8 (1.3÷2.8)	2.5 (1.7÷3.6)	1.2 (0.5÷2.0)	2.4 (1.5÷3.9)	4.3 (3.1÷6.1)
10	Bac Kan	0.7 (0.2÷1.2)	1.7 (1.2÷2.7)	2.4 (1.6÷3.5)	1.1 (0.4÷1.9)	2.4 (1.5÷3.8)	4.2 (3.2÷5.9)
11	Lang Son	0.7 (0.3÷1.2)	1.8 (1.2÷2.7)	2.4 (1.6÷3.3)	1.1 (0.4÷1.8)	2.3 (1.5÷3.7)	4.2 (3.1÷5.8)
12	Thai Nguyen	0.8 (0.2÷1.2)	1.8 (1.2÷2.8)	2.5 (1.7÷3.5)	1.2 (0.4÷2.0)	2.4 (1.5÷3.8)	4.2 (3.1÷5.9)
13	Phu Tho	0.7 (0.3÷1.2)	1.9 (1.3÷2.8)	2.5 (1.7÷3.4)	1.2 (0.6÷2.0)	2.5 (1.5÷3.8)	4.3 (3.0÷5.9)
14	Vinh Phuc	0.8 (0.3÷1.2)	1.9 (1.4÷2.8)	2.5 (1.7÷3.5)	1.2 (0.6÷2.1)	2.4 (1.5÷3.9)	4.3 (3.0÷6.0)
15	Bac Giang	0.7 (0.3÷1.2)	1.8 (1.3÷2.7)	2.3 (1.7÷3.3)	1.1 (0.5÷1.9)	2.3 (1.5÷3.7)	4.2 (3.0÷5.7)
16	Bac Ninh	0.7 (0.3÷1.2)	1.8 (1.3÷2.8)	2.3 (1.6÷3.3)	1.1 (0.5÷1.8)	2.3 (1.5÷3.7)	4.2 (2.8÷5.8)
17	Quang Ninh	0.7 (0.3÷1.1)	1.7 (1.1÷2.5)	2.2 (1.4÷3.1)	0.9 (0.4÷1.5)	2.1 (1.4÷3.3)	3.8 (3.0÷5.2)
18	Hai Phong	0.7 (0.4÷1.2)	1.6 (1.0÷2.4)	2.2 (1.4÷3.1)	0.9 (0.4÷1.5)	2.0 (1.3÷3.2)	3.7 (2.8÷4.9)
19	Hai Duong	0.7 (0.2÷1.2)	1.8 (1.2÷2.8)	2.3 (1.5÷3.3)	1.1 (0.5÷1.8)	2.3 (1.5÷3.7)	4.1 (2.9÷5.7)
20	Hung Yen	0.7 (0.2÷1.2)	1.8 (1.3÷2.7)	2.3 (1.6÷3.4)	1.1 (0.5÷1.8)	2.3 (1.4÷3.7)	4.2 (2.9÷5.8)
21	Ha Noi	0.7 (0.3÷1.2)	1.8 (1.3÷2.8)	2.4 (1.7÷3.4)	1.2 (0.5÷1.9)	2.4 (1.5÷3.8)	4.2 (3.0÷5.9)
22	Ha Nam	0.7 (0.3÷1.2)	1.8 (1.3÷2.7)	2.4 (1.7÷3.4)	1.2 (0.5÷1.9)	2.4 (1.5÷3.7)	4.2 (3.0÷5.8)
23	Thai Binh	0.7 (0.2÷1.2)	1.7 (1.2÷2.6)	2.3 (1.5÷3.2)	1.1 (0.4÷1.7)	2.2 (1.5÷3.5)	4.0 (2.9÷5.4)
24	Nam Dinh	0.7 (0.2÷1.2)	1.7 (1.2÷2.4)	2.2 (1.5÷3.1)	1.0 (0.4÷1.6)	2.1 (1.4÷3.3)	3.9 (2.8÷5.2)
25	Ninh Binh	0.6 (0.2÷1.1)	1.7 (1.2÷2.6)	2.2 (1.5÷3.2)	1.0 (0.5÷1.7)	2.2 (1.5÷3.5)	4.1 (2.9÷5.6)
26	Thanh Hoa	0.6 (0.2÷1.1)	1.7 (1.1÷2.5)	2.2 (1.4÷3.2)	1.0 (0.5÷1.6)	2.2 (1.4÷3.3)	3.9 (2.9÷5.4)
27	Nghe An	0.6 (0.2÷1.1)	1.6 (1.1÷2.4)	2.1 (1.3÷3.2)	1.0 (0.4÷1.6)	2.1 (1.4÷3.3)	3.9 (2.8÷5.5)
28	Ha Tinh	0.6 (0.3÷1.1)	1.5 (1.0÷2.2)	2.0 (1.2÷2.9)	0.8 (0.4÷1.4)	2.0 (1.3÷3.0)	3.6 (2.7÷5.0)
29	Quang Binh	0.6 (0.2÷1.2)	1.5 (0.9÷2.1)	1.9 (1.2÷2.8)	0.8 (0.4÷1.3)	1.9 (1.3÷2.9)	3.5 (2.7÷4.8)
30	Quang Tri	0.6 (0.3÷1.2)	1.3 (0.9÷2.1)	1.8 (1.2÷2.8)	0.8 (0.4÷1.3)	1.8 (1.3÷2.8)	3.4 (2.7÷4.6)
31	Thua Thien - Hue	0.6 (0.3÷1.1)	1.4 (0.9÷2.1)	1.8 (1.2÷2.7)	0.8 (0.4÷1.3)	1.9 (1.2÷2.8)	3.4 (2.6÷4.6)
32	Da Nang	0.7 (0.4÷1.2)	1.5 (0.9÷2.1)	1.9 (1.2÷2.7)	0.8 (0.5÷1.2)	1.9 (1.2÷2.8)	3.4 (2.6÷4.4)
33	Quảng Nam	0.7 (0.4÷1.2)	1.4 (0.9÷2.1)	1.9 (1.2÷2.7)	0.8 (0.5÷1.2)	1.9 (1.2÷2.8)	3.3 (2.6÷4.4)
34	Quang Ngai	0.7 (0.3÷1.2)	1.4 (0.9÷2.1)	1.8 (1.1÷2.7)	0.8 (0.5÷1.2)	1.9 (1.2÷2.7)	3.3 (2.6÷4.5)
35	Binh Dinh	0.7 (0.4÷1.2)	1.4 (0.9÷2.0)	1.8 (1.2÷2.6)	0.8 (0.5÷1.2)	1.8 (1.2÷2.7)	3.2 (2.6÷4.3)
36	Phu Yen	0.7 (0.4÷1.2)	1.3 (0.9÷2.0)	1.8 (1.1÷2.6)	0.8 (0.5÷1.2)	1.8 (1.2÷2.7)	3.2 (2.6÷4.2)
37	Khanh Hoa	0.7 (0.4÷1.2)	1.3 (0.9÷2.0)	1.8 (1.1÷2.7)	0.8 (0.4÷1.2)	1.8 (1.2÷2.7)	3.2 (2.5÷4.4)
38	Ninh Thuan	0.7 (0.3÷1.1)	1.4 (0.9÷2.0)	1.8 (1.2÷2.5)	0.7 (0.5÷1.1)	1.9 (1.3÷2.6)	3.3 (2.6÷4.3)
39	Binh Thuan	0.7 (0.4÷1.3)	1.3 (0.9÷1.9)	1.8 (1.1÷2.4)	0.8 (0.5÷1.2)	1.8 (1.3÷2.6)	3.2 (2.7÷4.1)
40	Kon Tum	0.7 (0.4÷1.1)	1.4 (1.0÷2.2)	1.8 (1.2÷2.7)	0.8 (0.5÷1.3)	1.9 (1.3÷2.8)	3.5 (2.8÷4.5)
41	Gia Lai	0.7 (0.3÷1.1)	1.3 (0.9÷2.1)	1.8 (1.2÷2.7)	0.8 (0.5÷1.2)	1.8 (1.2÷2.7)	3.3 (2.6÷4.5)
42	Dak Lak	0.6 (0.4÷1.2)	1.3 (0.9÷2.1)	1.8 (1.1÷2.7)	0.8 (0.5÷1.2)	1.8 (1.2÷2.8)	3.3 (2.5÷4.5)
43	Dak Nong	0.7 (0.4÷1.1)	1.4 (0.9÷2.1)	1.8 (1.2÷2.7)	0.8 (0.5÷1.2)	1.9 (1.3÷2.7)	3.4 (2.6÷4.5)
44	Lam Dong	0.7 (0.4÷1.1)	1.4 (1.0÷2.1)	1.8 (1.2÷2.6)	0.8 (0.5÷1.2)	1.9 (1.3÷2.7)	3.4 (2.7÷4.5)
45	Binh Phuoc	0.7 (0.4÷1.1)	1.4 (0.9÷2.1)	1.7 (1.2÷2.6)	0.8 (0.5÷1.2)	1.9 (1.3÷2.7)	3.4 (2.6÷4.5)
46	Tay Ninh	0.6 (0.3÷1.1)	1.3 (0.9÷2.0)	1.8 (1.1÷2.5)	0.7 (0.4÷1.2)	1.9 (1.3÷2.6)	3.3 (2.6÷4.6)
47	Binh Duong	0.7 (0.3÷1.1)	1.4 (0.9÷2.1)	1.8 (1.1÷2.6)	0.8 (0.5÷1.2)	2.0 (1.3÷2.7)	3.5 (2.6÷4.7)
48	Dong Nai	0.7 (0.3÷1.1)	1.4 (0.9÷2.1)	1.8 (1.1÷2.6)	0.8 (0.5÷1.2)	2.0 (1.3÷2.8)	3.5 (2.6÷4.8)
49	Ho Chi Minh	0.7 (0.3÷1.1)	1.4 (0.9÷2.1)	1.8 (1.1÷2.6)	0.8 (0.5÷1.3)	2.0 (1.3÷2.8)	3.5 (2.6÷4.8)
50	Ba Ria - Vung Tau	0.7 (0.4÷1.2)	1.3 (0.9÷1.9)	1.7 (1.1÷2.3)	0.8 (0.5÷1.2)	1.8 (1.2÷2.5)	3.2 (2.6÷4.0)
51	Long An	0.7 (0.3÷1.2)	1.4 (0.9÷2.0)	1.8 (1.1÷2.5)	0.8 (0.4÷1.2)	1.9 (1.3÷2.6)	3.3 (2.6÷4.5)
52	Vinh Long	0.6 (0.3÷1.1)	1.3 (0.8÷2.0)	1.8 (1.1÷2.6)	0.7 (0.5÷1.2)	1.9 (1.3÷2.7)	3.4 (2.6÷4.7)
53	Hau Giang	0.7 (0.4÷1.1)	1.3 (0.8÷2.0)	1.7 (1.1÷2.5)	0.8 (0.5÷1.2)	1.8 (1.3÷2.6)	3.4 (2.6÷4.4)
54	Tien Giang	0.7 (0.3÷1.1)	1.4 (0.9÷2.0)	1.8 (1.2÷2.6)	0.8 (0.5÷1.3)	1.9 (1.3÷2.7)	3.4 (2.5÷4.6)
55	Dong Thap	0.7 (0.3÷1.1)	1.3 (0.9÷2.0)	1.8 (1.2÷2.5)	0.8 (0.4÷1.2)	1.8 (1.3÷2.7)	3.3 (2.6÷4.4)
56	Ben Tre	0.7 (0.3÷1.1)	1.3 (0.9÷2.0)	1.7 (1.1÷2.5)	0.8 (0.4÷1.2)	1.8 (1.3÷2.6)	3.3 (2.7÷4.2)
57	Tra Vinh	0.7 (0.3÷1.1)	1.4 (0.9÷2.0)	1.8 (1.1÷2.5)	0.8 (0.5÷1.2)	1.9 (1.3÷2.6)	3.3 (2.6÷4.5)
58	An Giang	0.7 (0.3÷1.2)	1.3 (0.8÷2.0)	1.8 (1.1÷2.5)	0.7 (0.4÷1.2)	1.9 (1.2÷2.6)	3.3 (2.5÷4.6)
59	Can Tho	0.6 (0.3÷1.1)	1.4 (0.9÷2.0)	1.8 (1.1÷2.5)	0.8 (0.5÷1.2)	1.9 (1.3÷2.6)	3.3 (2.6÷4.5)
60	Soc Trang	0.7 (0.4÷1.1)	1.3 (0.9÷1.9)	1.7 (1.1÷2.5)	0.8 (0.5÷1.2)	1.8 (1.3÷2.6)	3.3 (2.6÷4.3)
61	Kien Giang	0.7 (0.4÷1.2)	1.3 (0.8÷1.9)	1.7 (1.1÷2.4)	0.8 (0.4÷1.2)	1.8 (1.3÷2.5)	3.2 (2.5÷4.1)
62	Bac Lieu	0.7 (0.4÷1.2)	1.3 (0.9÷2.0)	1.7 (1.1÷2.4)	0.8 (0.5÷1.3)	1.8 (1.3÷2.5)	3.3 (2.6÷4.2)
63	Ca Mau	0.7 (0.4÷1.2)	1.3 (0.8÷1.9)	1.8 (1.1÷2.4)	0.8 (0.5÷1.3)	1.8 (1.3÷2.5)	3.3 (2.6÷4.2)



(a) mid-21st century *(b) end of 21st century*

Figure A9. Changes in winter rainfall (%) based on RCP4.5 scenarios



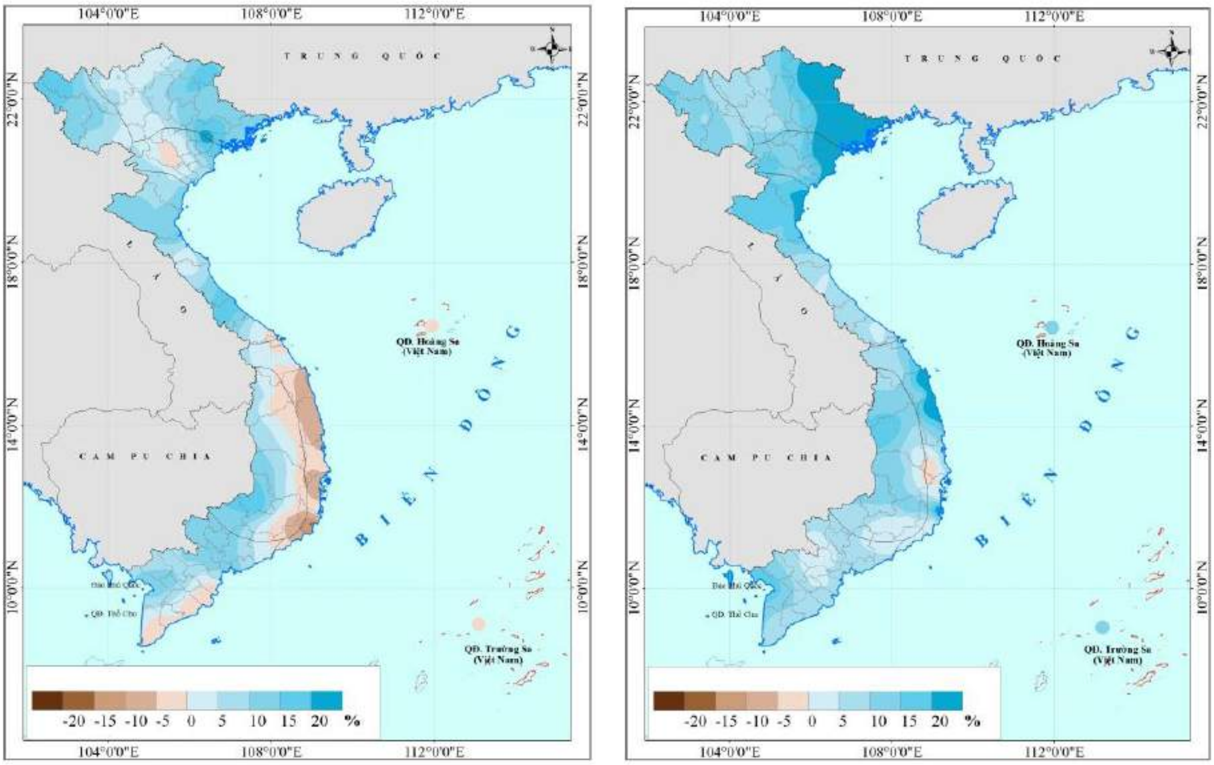
(a) mid-21st century *(b) end of 21st century*

Figure A10. Changes in winter rainfall (%) based on RCP8.5 scenarios

Table A5. Changes in winter rainfall (%) compared with the baseline period

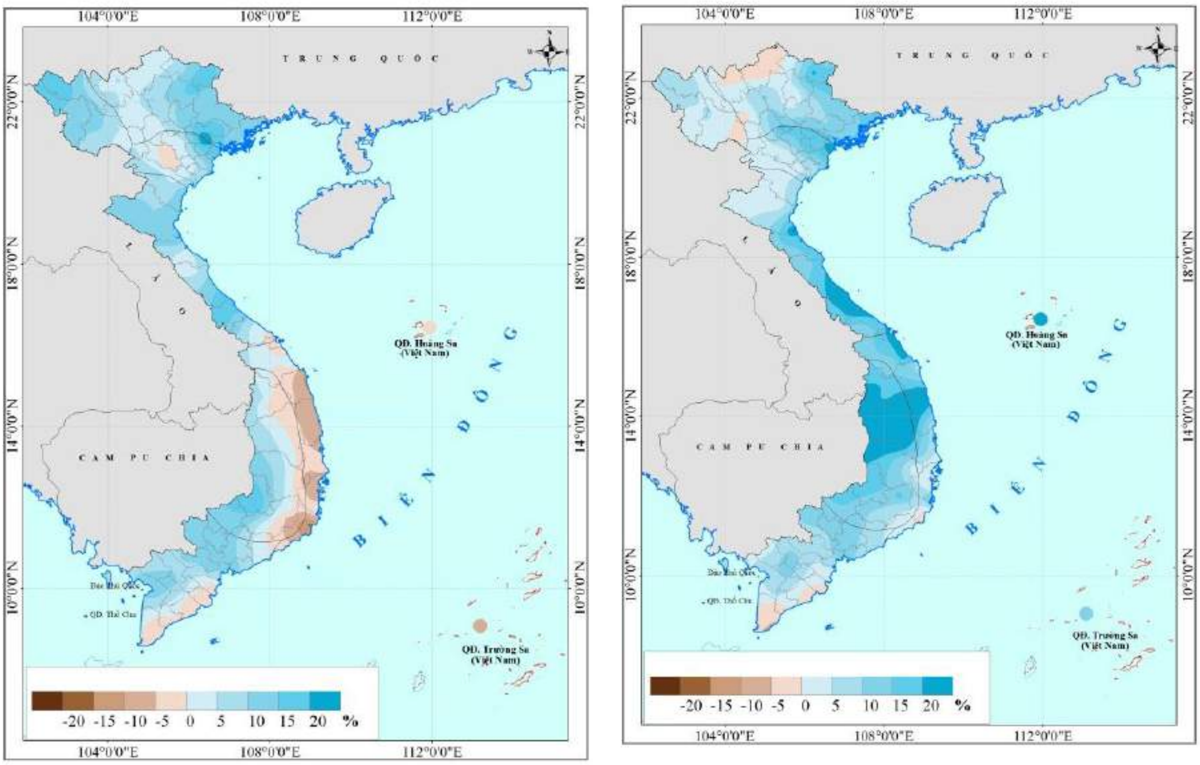
(Values in parentheses are the range of temperatures changes from the climate model results with the lower boundary of 20% and upper boundary of 80%)

No.	Province, City	RCP4.5 scenario			RCP8.5 scenario		
		2016-2035	2046-2065	2080-2099	2016-2035	2046-2065	2080-2099
1	Lai Chau	5.0 (-7.3÷18.2)	-12.6 (-22.6÷-3.2)	0.3 (-14.9÷14.9)	-9.4 (-19.7÷1.0)	-4.9 (-16.3÷5.8)	-6.7 (-30.8÷15.7)
2	Dien Bien	17.0 (-2.7÷37.2)	-9.7 (-23.2÷2.8)	15.3 (-12.4÷40.5)	-8.5 (-20.4÷3.4)	0.9 (-15.4÷16.8)	-4.8 (-29.9÷17.7)
3	Son La	11.2 (-7.3÷30.1)	-6.1 (-24.7÷10.6)	15.7 (-9.7÷39.9)	-5.5 (-19.7÷8.9)	-2.4 (-18.4÷13.9)	1.0 (-23.8÷24.7)
4	Hoa Binh	4.7 (-9.0÷19.4)	-1.8 (-15.1÷10.9)	-2.4 (-11.2÷6.4)	-2.4 (-14.4÷10.4)	1.3 (-11.8÷15.0)	16.8 (3.7÷29.8)
5	Lao Cai	7.2 (-2.1÷17.3)	-7.5 (-15.2÷0.4)	-0.2 (-9.9÷10.7)	-5.4 (-13.8÷2.8)	0.0 (-10.1÷10.6)	-4.4 (-23.3÷12.9)
6	Ha Giang	15.0 (4.4÷25.6)	-1.3 (-8.7÷6.0)	3.0 (-11.0÷17.8)	-0.8 (-12.4÷10.0)	5.8 (-4.6÷16.4)	-3.6 (-18.2÷11.5)
7	Yen Bai	11.1 (-0.6÷23.3)	-0.5 (-9.4÷7.7)	7.2 (-6.1÷20.9)	-0.9 (-11.1÷9.3)	4.0 (-7.8÷16.5)	5.2 (-8.1÷18.0)
8	Cao Bang	8.1 (-0.5÷16.4)	-4.3 (-14.3÷4.9)	1.6 (-13.6÷18.5)	-4.1 (-14.7÷6.4)	-0.4 (-13.9÷13.2)	-0.2 (-16.6÷17.2)
9	Tuyen Quang	17.8 (5.6÷29.6)	3.6 (-4.8÷12.2)	3.9 (-10.9÷19.4)	0.1 (-10.9÷11.5)	2.6 (-8.9÷15.0)	3.7 (-14.9÷23.2)
10	Bac Kan	12.8 (0.1÷25.0)	-3.9 (-15.1÷7.3)	1.9 (-16.0÷21.2)	-1.2 (-16.2÷14.0)	-6.5 (-20.9÷8.4)	-2.8 (-22.8÷19.3)
11	Lang Son	-2.2 (-14.9÷10.8)	-3.5 (-13.1÷5.7)	-5.4 (-20.0÷8.3)	-4.8 (-20.4÷11.3)	-6.5 (-20.1÷7.7)	-3.2 (-18.6÷13.5)
12	Thai Nguyen	10.1 (-3.2÷24.3)	-0.4 (-10.6÷9.4)	-3.5 (-18.4÷12.5)	0.6 (-15.1÷17.5)	-3.8 (-20.6÷13.6)	4.3 (-13.6÷23.6)
13	Phu Tho	11.9 (0.9÷22.5)	4.5 (-4.0÷12.6)	3.7 (-5.2÷13.1)	3.1 (-6.6÷13.7)	6.6 (-4.4÷18.8)	22.3 (9.8÷34.8)
14	Vinh Phuc	12.5 (0.4÷25.8)	5.8 (-4.1÷15.1)	-3.2 (-13.6÷8.2)	4.7 (-8.0÷18.7)	2.7 (-11.9÷18.5)	20.0 (5.9÷35.1)
15	Bac Giang	0.5 (-16.0÷17.4)	-2.7 (-12.9÷7.4)	-9.1 (-24.0÷4.8)	-0.6 (-21.9÷22.2)	-6.8 (-23.5÷10.5)	4.2 (-11.7÷21.3)
16	Bac Ninh	0.1 (-13.4÷14.4)	-3.8 (-14.2÷ 6.4)	-9.4 (-19.6÷ 0.7)	0.6 (-14.3÷15.1)	-6.8 (-23.2÷9.8)	-5.5 (-21.7÷12.2)
17	Quang Ninh	4.3 (-16.6÷25.6)	5.3 (-10.3÷20.2)	-2.3 (-17.5÷12.4)	3.2 (-19.6÷26.5)	-0.5 (-14.8÷14.4)	6.3 (-12.6÷27.2)
18	Hai Phong	12.1 (-8.8÷33.4)	9.1 (-7.6÷24.6)	-2.9 (-16.8÷10.8)	2.8 (-15.3÷21.4)	-1.8 (-17.6÷14.0)	-1.9 (-19.6÷17.1)
19	Hai Duong	1.2 (-14.4÷18.1)	-1.6 (-12.6÷9.1)	-10.4 (-24.0÷3.0)	-4.0 (-22.9÷15.1)	-3.8 (-19.6÷12.8)	7.6 (-7.8÷24.4)
20	Hung Yen	5.2 (-8.7÷19.9)	5.3 (-8.6÷17.9)	-3.2 (-13.2÷6.9)	-4.1 (-17.1÷9.7)	2.9 (-15.5÷21.9)	11.4 (-6.1÷28.7)
21	Ha Noi	8.9 (-3.9÷21.9)	5.4 (-4.2÷14.1)	1.9 (-7.7÷11.5)	4.3 (-7.1÷16.4)	4.9 (-8.2÷19.5)	24.6 (11.9÷37.2)
22	Ha Nam	8.2 (-6.2÷23.1)	8.3 (-5.3÷20.5)	1.7 (-8.9÷12.4)	4.5 (-8.6÷18.5)	6.1 (-9.0÷22.2)	23.3 (6.9÷39.7)
23	Thai Binh	5.5 (-15.5÷27.7)	19.7 (-9.5÷46.2)	0.7 (-13.9÷15.9)	5.3 (-14.4÷26.8)	10.6 (-12.2÷33.1)	18.2 (-13.1÷49.8)
24	Nam Dinh	7.8 (-12.2÷28.8)	23.6 (-4.9÷49.2)	8.4 (-10.8÷26.3)	5.7 (-13.0÷24.9)	13.3 (-9.2÷34.7)	16.1 (-12.9÷43.1)
25	Ninh Binh	12.4 (-5.4÷31.1)	9.8 (-7.2÷26.0)	6.9 (-3.4÷17.3)	4.4 (-11.1÷20.0)	14.0 (-6.9÷33.5)	26.8 (-5.8÷54.7)
26	Thanh Hoa	9.8 (-6.2÷26.9)	4.6 (-10.7÷19.5)	7.3 (-5.6÷19.6)	5.6 (-11.8÷23.2)	14.6 (-3.2÷32.5)	22.1 (-1.1÷43.4)
27	Nghe An	12.8 (0.1÷25.8)	19.8 (3.9÷34.7)	10.1 (-0.9÷20.6)	5.2 (-7.9÷18.6)	23.1 (6.3÷39.8)	22.7 (2.7÷41.0)
28	Ha Tinh	12.0 (4.1÷19.5)	21.0 (11.4÷30.4)	12.8 (5.4÷20.0)	3.5 (-2.1÷9.2)	13.0 (1.6÷24.4)	19.8 (6.5÷33.2)
29	Quang Binh	12.8 (3.9÷20.6)	21.5 (11.7÷31.3)	12.2 (5.0÷19.8)	4.2 (-1.8÷10.6)	12.1 (-0.5÷25.1)	25.9 (11.0÷41.6)
30	Quang Tri	7.8 (-2.6÷17.8)	16.8 (5.8÷27.9)	19.7 (6.1÷33.9)	2.7 (-3.8÷9.4)	7.6 (-10.4÷26.9)	24.4 (6.4÷43.2)
31	Thua Thien - Hue	9.1 (1.5÷17.2)	21.8 (6.2÷37.0)	26.7 (10.3÷41.9)	9.8 (0.8÷18.6)	7.4 (-9.3÷25.6)	26.6 (-2.3÷55.8)
32	Da Nang	0.5 (-8.7÷11.0)	14.1 (-2.1÷30.7)	26.0 (6.9÷45.0)	0.6 (-7.1÷8.4)	4.1 (-13.1÷22.6)	19.9 (-11.8÷52.2)
33	Quảng Nam	5.9 (-1.8÷13.4)	14.4 (-0.9÷30.0)	53.0 (21.3÷83.3)	6.1 (-4.7÷16.3)	15.7 (-4.9÷37.9)	31.0 (-7.9÷70.4)
34	Quang Ngai	3.2 (-5.6÷11.9)	17.9 (0.2÷35.0)	65.8 (18.8÷108.8)	5.8 (-2.6÷14.1)	16.0 (-4.2÷38.7)	38.3 (-7.9÷85.6)
35	Binh Dinh	5.3 (-6.2÷16.4)	12.6 (-4.4÷28.0)	54.5 (9.6÷94.7)	1.2 (-9.2÷11.4)	11.8 (-9.1÷33.7)	23.9 (-7.5÷59.2)
36	Phu Yen	10.9 (-1.6÷23.1)	16.0 (-4.8÷35.0)	41.3 (3.5÷75.9)	-8.0 (-14.5÷-1.5)	30.5 (5.1÷58.8)	37.4 (-0.2÷77.4)
37	Khanh Hoa	7.1 (-6.2÷19.8)	23.2 (-8.0÷52.0)	26.4 (5.0÷47.3)	-11.2 (-18.1÷-4.4)	43.1 (5.8÷83.4)	7.7 (-19.8÷38.0)
38	Ninh Thuan	5.9 (-15.1÷27.3)	16.5 (-23.5÷54.8)	17.8 (-21.1÷51.4)	-10.3 (-27.5÷ 4.9)	40.8 (-9.4÷92.6)	-17.5 (-41.9÷ 9.6)
39	Binh Thuan	42.0 (4.5÷77.2)	2.7 (-19.5÷23.8)	36.8 (-1.9÷74.2)	-5.0 (-27.5÷15.9)	44.6 (1.9÷87.7)	-8.6 (-36.9÷19.1)
40	Kon Tum	3.4 (-32.7÷38.0)	31.1 (-9.2÷70.9)	91.8 (-29.1÷197.2)	3.2 (-28.6÷32.5)	30.7 (-0.1÷60.2)	13.7 (-20.8÷47.7)
41	Gia Lai	-8.1 (-33.6÷17.5)	7.3 (-29.9÷40.7)	47.2 (-29.3÷115.3)	-23.2 (-39.4÷-8.2)	38.1 (-8.9÷81.2)	22.8 (-26.9÷71.8)
42	Dak Lak	3.2 (-19.4÷23.7)	2.0 (-15.9÷19.2)	18.0 (-23.2÷55.3)	-26.1 (-34.0÷18.7)	28.8 (-1.8÷59.2)	13.4 (-24.6÷52.8)
43	Dak Nong	13.4 (-10.2÷36.3)	20.9 (-3.5÷42.6)	22.2 (-13.1÷54.8)	25.0 (-14.8÷58.2)	46.1 (8.1÷81.7)	2.6 (-20.6÷28.2)
44	Lam Dong	32.5 (-4.6÷69.7)	35.1 (-0.7÷67.3)	54.4 (-9.1÷112.3)	19.9 (-29.2÷63.3)	85.8 (29.1÷137.9)	-9.8 (-25.8÷6.0)
45	Binh Phuoc	49.8 (-2.6÷98.3)	39.2 (-11.3÷86.4)	65.6 (5.6÷122.3)	19.8 (-7.4÷47.0)	43.4 (-4.4÷87.7)	48.7 (-5.5÷96.6)
46	Tay Ninh	18.7 (-10.1÷46.1)	34.6 (6.8÷64.1)	61.1 (19.7÷99.5)	12.4 (-4.4÷28.5)	18.2 (-4.5÷42.2)	24.9 (-2.6÷50.0)
47	Binh Duong	19.4 (-8.4÷44.2)	32.0 (-2.5÷65.0)	60.6 (-4.1÷118.3)	23.7 (6.2÷40.6)	25.4 (-0.3÷52.5)	5.5 (-15.5÷26.7)
48	Dong Nai	45.2 (8.6÷78.6)	36.4 (12.6÷57.8)	114.8 (-12.5÷222.1)	17.7 (0.8÷35.6)	34.7 (3.2÷62.9)	16.4 (-9.8÷46.0)
49	Ho Chi Minh	49.7 (11.7÷ 83.9)	45.5 (16.1÷71.1)	179.6 (-16.3÷-341.2)	27.4 (9.9÷45.2)	46.0 (13.1÷79.9)	24.5 (-5.9÷59.3)
50	Ba Ria - Vung Tau	50.8 (26.2÷75.1)	34.8 (2.2÷67.7)	81.1 (12.1÷142.1)	42.8 (10.9÷74.8)	61.9 (15.9÷104.3)	43.3 (1.2÷86.3)
51	Long An	43.2 (6.0÷77.1)	52.3 (19.8÷86.0)	80.5 (17.3÷135.1)	37.5 (14.5÷57.6)	22.8 (-6.8÷54.5)	55.6 (15.5÷96.8)
52	Vinh Long	67.9 (24.7÷108.8)	62.0 (3.7÷110.6)	136.1 (-0.6÷252.8)	51.3 (3.6÷92.6)	75.4 (38.9÷108.7)	49.4 (-12.2÷106.6)
53	Hau Giang	125.4 (32.8÷205.0)	54.7 (-9.7÷110.6)	43.4 (2.3÷83.1)	33.7 (4.4÷62.1)	87.8 (51.8÷124.6)	59.7 (-7.0÷117.5)
54	Tien Giang	37.8 (23.4÷52.4)	25.1 (-0.7÷49.3)	68.9 (1.3÷125.4)	17.9 (-0.3÷36.2)	37.5 (-5.3÷79.7)	46.8 (3.6÷87.8)
55	Dong Thap	48.6 (3.3÷88.4)	50.7 (22.2÷79.2)	90.0 (17.1÷151.0)	30.5 (5.4÷55.3)	35.3 (5.0÷66.2)	53.8 (9.6÷99.2)
56	Ben Tre	73.8 (41.7÷103.5)	63.5 (8.2÷111.4)	116.6 (-5.4÷221.3)	61.1 (38.8÷83.4)	69.2 (23.8÷116.4)	73.4 (16.1÷132)
57	Tra Vinh	55.5 (22.5÷84.9)	53.7 (11.9÷92.4)	120.3 (4.8÷218.9)	47.8 (26.0÷69.2)	58.1 (14.7÷101.5)	64.5 (15.8÷116)
58	An Giang	37.2 (3.3÷66.4)	43.9 (15.6÷73.4)	124.1 (14.9÷216.4)	34.4 (13.1÷55.0)	47.0 (5.6÷86.6)	55.6 (15.4÷98.7)
59	Can Tho	75.3 (32.5÷114.9)	43.8 (11.4÷72.7)	92.8 (10.2÷167.9)	53.6 (29.1÷80.0)	77.3 (33.3÷122.7)	64.5 (26.8÷106)
60	Soc Trang	88.1 (48.0÷126.4)	51.4 (17.1÷82.5)	79.1 (12.9÷141.0)	77.9 (34.0÷118.3)	110 (61.8÷159.9)	81.5 (13.3÷143)
61	Kien Giang	47.0 (19.4÷73.2)	24.5 (-6.9÷52.5)	99.4 (7.8÷182.0)	25.9 (-5.3÷54.5)	54.7 (14.1÷94.7)	55.0 (2.2÷107.0)
62	Bac Lieu	71.3 (39.3÷103.1)	48.8 (3.3÷89.6)	102.1 (42.1÷165.5)	103.6 (33.9÷168.1)	158 (93.1÷221.4)	85.6 (11.6÷157.0)
63	Ca Mau	53.5 (25.4÷79.6)	31.7 (-7.0÷64.8)	45.4 (3.5÷90.7)	31.8 (2.2÷59.6)	71.7 (32.9÷108.2)	52.3 (-4.6÷111.1)



(a) mid-21st century *(b) end of 21st century*

Figure A11. Changes in spring rainfall (%) based on RCP4.5 scenarios



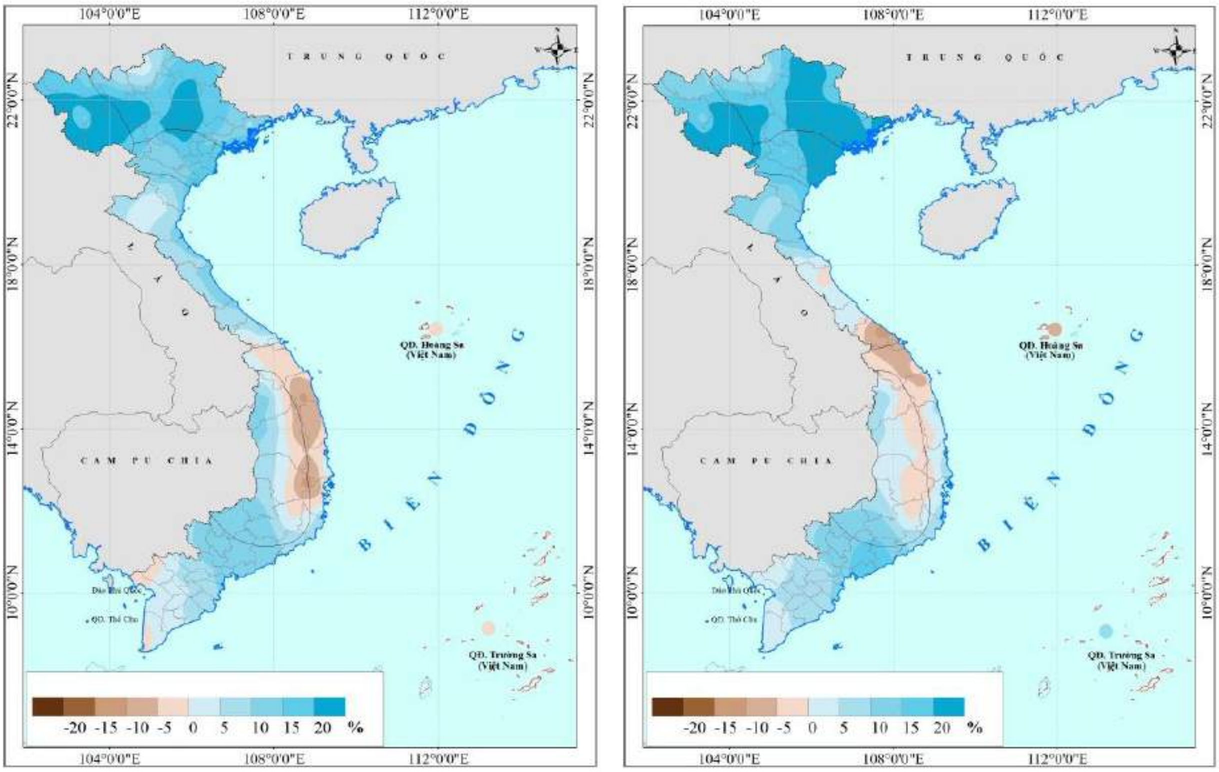
(a) mid-21st century *(b) end of 21st century*

Figure A12. Changes in spring rainfall (%) based on RCP8.5 scenarios

Table A6. Changes in spring rainfall (%) compared with the baseline period

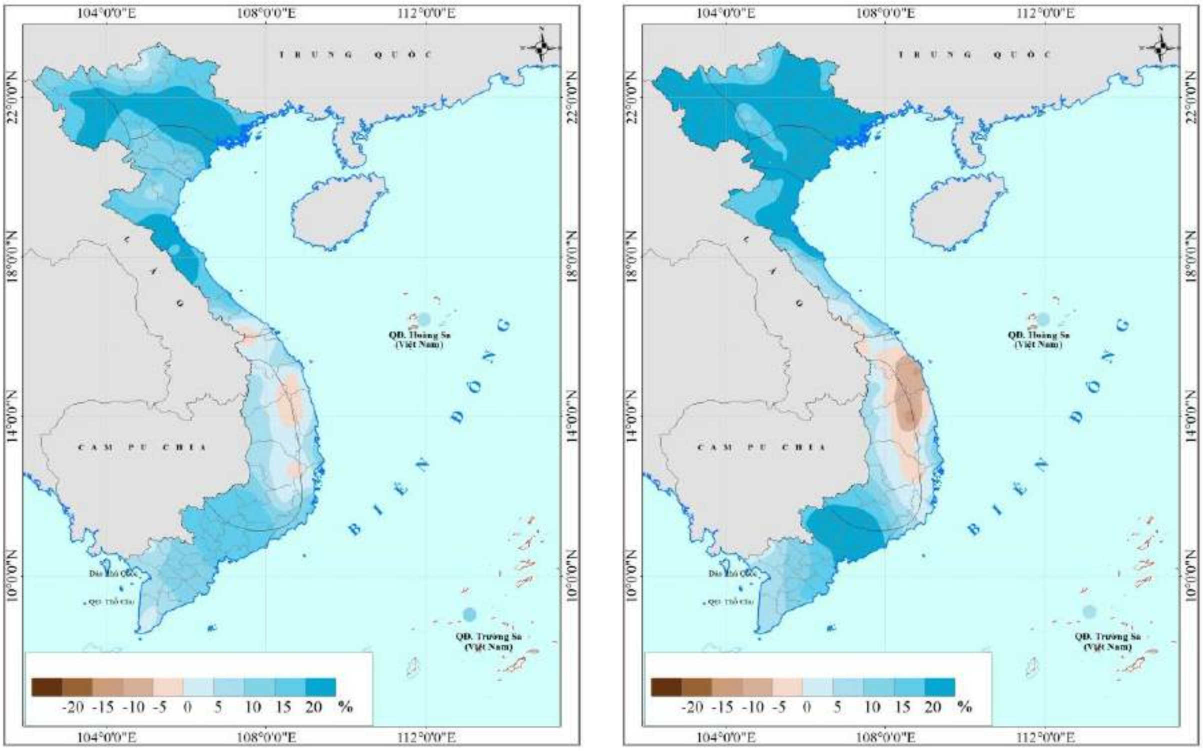
(Values in parentheses are the range of temperatures changes from the climate model results with the lower boundary of 20% and upper boundary of 80%)

No.	Province, City	RCP4.5 scenario			RCP8.5 scenario		
		2016-2035	2046-2065	2080-2099	2016-2035	2046-2065	2080-2099
1	Lai Chau	3.1 (-5.1÷11.0)	16.8 (1.9÷30.2)	11.6 (5.4÷17.7)	-5.7 (-10.9÷-0.5)	13.3 (2.9÷23.8)	5.6 (-6.6÷16.3)
2	Dien Bien	3.0 (-7.1÷12.0)	17.6 (-0.1÷33.2)	12.0 (4.1÷19.6)	-6.7 (-11.5÷-1.7)	12.3 (1.0÷23.7)	4.9 (-9.0÷16.6)
3	Son La	-0.5 (-6.2÷5.1)	9.0 (-1.8÷19.0)	10.6 (2.1÷18.7)	-9.6 (-15.0÷-4.3)	6.2 (-0.5÷13.0)	1.1 (-7.0÷8.2)
4	Hoa Binh	-7.2 (-10.5÷-3.8)	4.6 (-3.8÷12.8)	13.7 (5.7÷21.6)	-10.4 (-16.2÷-4.8)	-0.6 (-6.3÷5.7)	3.6 (-4.1÷10.5)
5	Lao Cai	-3.5 (-8.6÷1.5)	11.3 (1.2÷20.3)	6.9 (0.6÷12.9)	-8.5 (-14.0÷-2.9)	4.6 (-2.0÷11.5)	-1.2 (-9.6÷7.1)
6	Ha Giang	-3.6 (-10.0÷3.0)	12.0 (3.0÷20.7)	11.7 (3.3÷20.5)	-8.2 (-15.2÷-1.4)	3.6 (-3.6÷11.6)	-1.8 (-9.0÷5.8)
7	Yen Bai	-4.2 (-8.9÷0.3)	4.8 (-4.2÷13.1)	7.1 (-0.6÷14.6)	-6.4 (-12.5÷-0.1)	3.7 (-3.5÷11.2)	4.5 (-7.4÷15.6)
8	Cao Bang	8.3 (0.9÷15.9)	19.8 (10.3÷29.0)	23.0 (12.8÷32.9)	-2.4 (-7.1÷2.4)	12.4 (5.8÷18.9)	12.2 (4.2÷20.2)
9	Tuyen Quang	-3.4 (-9.5÷2.7)	6.9 (-0.7÷14.2)	10.7 (3.3÷17.9)	-5.6 (-14.6÷2.9)	9.8 (1.7÷18.2)	7.6 (-3.7÷18.7)
10	Bac Kan	7.5 (-0.4÷15.8)	17.3 (9.9÷24.9)	21.9 (10.7÷32.5)	-2.3 (-9.6÷5.2)	14.0 (3.7÷24.6)	7.8 (1.6÷14.0)
11	Lang Son	6.1 (0.2÷11.8)	21.4 (10.1÷32.2)	26.9 (16.1÷37.9)	-2.8 (-10.2÷4.5)	13.5 (4.7÷21.9)	12.1 (3.7÷20.5)
12	Thai Nguyen	-0.8 (-7.6÷5.8)	11.9 (3.2÷19.9)	15.8 (6.8÷24.5)	-6.4 (-14.9÷1.6)	11.3 (4.3÷18.3)	4.9 (-4.6÷14.1)
13	Phu Tho	-8.1 (-12.6÷-3.9)	5.6 (-2.6÷13.3)	10.4 (2.8÷18.2)	-10.2 (-17.5÷-3.1)	2.2 (-3.4÷8.0)	11.9 (-2.3÷24.9)
14	Vinh Phuc	-6.8 (-11.9÷-1.9)	9.9 (-0.1÷19.6)	11.4 (6.7÷16.3)	-8.2 (-15.7÷-1.0)	6.8 (0.5÷13.3)	13.5 (-0.3÷26.9)
15	Bac Giang	-0.5 (-6.3÷5.3)	18.3 (4.9÷30.7)	22.0 (11.0÷32.9)	-5.8 (-13.2÷1.8)	18.0 (9.9÷26.3)	12.1 (0.9÷23.3)
16	Bac Ninh	0.7 (-3.8÷5.2)	18.7 (5.0÷31.6)	26.3 (16.6÷35.9)	-3.1 (-9.4÷3.2)	21.8 (15.3÷28.7)	15.6 (3.3÷28.4)
17	Quang Ninh	1.6 (-3.2÷6.7)	19.0 (7.9÷29.4)	34.4 (19.4÷49.2)	-1.0 (-9.5÷7.5)	11.1 (2.1÷20.0)	15.8 (3.5÷27.7)
18	Hai Phong	-0.1 (-5.4÷5.3)	17.0 (2.4÷30.6)	31.6 (11.1÷50.2)	-2.7 (-10.5÷5.1)	15.7 (6.6÷24.8)	20.2 (3.2÷37.6)
19	Hai Duong	-0.6 (-6.4÷5.4)	18.2 (4.8÷31.3)	26.8 (15.4÷37.9)	-2.0 (-10.4÷6.4)	22.1 (14.5÷30.4)	17.5 (3.2÷32.4)
20	Hung Yen	-6.9 (-10.9÷-2.4)	8.8 (-3.5÷20.4)	19.9 (9.2÷30.7)	-7.2 (-13.5÷-1.1)	5.7 (0.8÷10.5)	15.2 (-4.1÷33.0)
21	Ha Noi	-10.3 (-13.6÷-7.1)	6.5 (-2.7÷15.2)	13.2 (6.0÷20.8)	-9.6 (-15.8÷-3.2)	2.3 (-2.8÷7.5)	15.4 (-1.4÷30.9)
22	Ha Nam	-9.3 (-12.8÷-5.9)	7.6 (-2.9÷17.4)	15.3 (6.4÷24.5)	-9.2 (-15.5÷-2.9)	3.5 (-1.8÷9.0)	15.1 (-1.7÷30.8)
23	Thai Binh	-5.5 (-9.6÷-1.4)	11.9 (-3.7÷26.2)	23.8 (7.7÷39.2)	-7.8 (-14.2÷-1.7)	8.5 (2.2÷15.2)	13.6 (-3.2÷30.4)
24	Nam Dinh	-7.6 (-12.7÷-2.6)	8.8 (-5.6÷22.0)	19.4 (5.7÷33.9)	-8.8 (-16.9÷-0.8)	7.2 (0.4÷13.7)	8.9 (-4.6÷21.6)
25	Ninh Binh	-7.8 (-11.2÷-4.3)	4.2 (-6.4÷14.5)	13.6 (4.3÷23.0)	-10.7 (-18.5÷-3.2)	2.3 (-4.2÷8.7)	3.6 (-6.2÷12.3)
26	Thanh Hoa	-1.1 (-6.3÷4.4)	7.3 (-3.7÷17.8)	19.0 (9.2÷28.4)	-4.9 (-14.2÷3.8)	7.0 (0.3÷14.2)	4.8 (-2.1÷11.6)
27	Nghe An	2.9 (-2.9÷8.4)	11.0 (-2.0÷23.5)	17.6 (9.1÷26.0)	0.3 (-7.7÷8.2)	10.9 (4.1÷17.9)	5.6 (-1.5÷12.8)
28	Ha Tinh	2.8 (-3.7÷9.2)	14.5 (4.3÷23.9)	9.4 (-1.8÷20.5)	-4.2 (-14.4÷5.8)	5.0 (-3.5÷13.0)	16.1 (2.1÷30.5)
29	Quang Binh	0.6 (-5.4÷6.4)	11.1 (-0.8÷22.0)	5.4 (-5.4÷16.0)	-6.3 (-18.2÷5.1)	6.3 (-4.7÷17.0)	16.0 (0.4÷31.2)
30	Quang Tri	4.6 (-7.1÷15.6)	9.4 (-7.7÷25.4)	7.4 (-10.0÷23.9)	12.0 (-8.1÷30.4)	19.1 (2.4÷34.0)	25.9 (4.3÷44.7)
31	Thua Thien - Hue	-0.3 (-6.4÷5.7)	-0.5 (-12.0÷10.0)	4.6 (-5.8÷15.1)	3.1 (-10.4÷15.8)	2.6 (-7.9÷12.7)	15.0 (-2.0÷30.1)
32	Da Nang	0.1 (-21.2÷19.9)	-1.6 (-21.0÷16.9)	11.0 (-19.0÷39.6)	-2.9 (-14.8÷8.2)	-1.7 (-20.0÷14.6)	21.8 (-12.7÷52.1)
33	Quảng Nam	0.2 (-10.4÷10.4)	-1.9 (-17.7÷12.6)	13.5 (-8.9÷35.1)	-7.6 (-15.3÷-0.1)	-6.0 (-18.7÷5.7)	11.2 (-11.4÷31.3)
34	Quang Ngai	4.9 (-5.9÷16.0)	-4.7 (-17.9÷8.7)	19.4 (-3.8÷42.2)	-5.4 (-13.6÷3.0)	-7.4 (-18.6÷2.7)	14.4 (-3.5÷32.5)
35	Binh Dinh	10.4 (-8.8÷28.4)	-2.9 (-18.7÷13.6)	22.5 (-5.3÷50.6)	2.9 (-12.3÷17.6)	-8.9 (-18.0÷-0.3)	17.7 (-9.6÷45.5)
36	Phu Yen	8.1 (-13.5÷27.9)	3.8 (-18.8÷25.3)	2.1 (-22.0÷25.2)	-0.8 (-15.0÷13.4)	-3.3 (-14.5÷7.4)	8.4 (-8.2÷25.5)
37	Khanh Hoa	22.3 (-18.5÷58.6)	4.3 (-16.0÷22.2)	13.3 (-2.5÷29.0)	24.5 (-9.3÷55.0)	-3.5 (-22.4÷14.0)	6.6 (-17.5÷28.2)
38	Ninh Thuan	7.4 (-16.0÷28.6)	-5.1 (-16.6÷ 5.5)	1.9 (-19.2÷22.7)	19.0 (-15.3÷52.3)	-15.4 (-24.5÷-6.0)	2.7 (-20.2÷22.2)
39	Binh Thuan	14.2 (-0.8÷28.4)	1.2 (-18.2÷19.6)	9.8 (-13.6÷30.5)	2.6 (-13.6÷17.9)	3.8 (-5.1÷12.4)	1.2 (-12.9÷14.9)
40	Kon Tum	5.8 (-1.1÷12.0)	4.1 (-8.9÷15.5)	11.9 (-2.7÷24.9)	-1.4 (-9.4÷5.9)	1.0 (-6.2÷7.9)	20.0 (9.6÷29.7)
41	Gia Lai	10.3 (2.7÷17.6)	7.4 (-5.2÷18.5)	11.3 (-4.4÷25.4)	6.3 (-4.0÷16.2)	1.2 (-5.1÷7.4)	28.6 (11.8÷45.1)
42	Dak Lak	4.5 (-3.6÷12.8)	1.1 (-6.8÷8.4)	5.5 (-5.0÷15.8)	-1.2 (-9.8÷6.9)	1.0 (-3.8÷5.8)	8.4 (1.4÷15.7)
43	Dak Nong	13.5 (6.7÷18.8)	4.6 (-6.8÷15.7)	9.6 (1.4÷17.7)	-5.3 (-11.8÷1.3)	19.3 (-3.5÷39.7)	14.8 (10.1÷19.6)
44	Lam Dong	3.1 (-1.6÷8.2)	-1.1 (-12.8÷10.3)	6.1 (-4.2÷15.4)	-8.7 (-18.8÷1.9)	-0.5 (-7.3÷6.4)	10.6 (4.4÷16.7)
45	Binh Phuoc	6.9 (-1.5÷15.5)	0.9 (-8.4÷9.2)	9.0 (4.5÷14.3)	-9.3 (-15.5÷-3.0)	14.0 (4.7÷23.7)	15.5 (7.5÷23.6)
46	Tay Ninh	8.8 (0.4÷17.8)	3.0 (-10.1÷16.7)	4.3 (-1.5÷9.6)	0.5 (-7.2÷8.4)	10.8 (0.9÷19.6)	10.2 (3.7÷17.1)
47	Binh Duong	9.6 (0.9÷18.1)	0.4 (-12.0÷12.7)	4.7 (-0.7÷ 9.7)	0.8 (-6.9÷ 8.3)	13.5 (4.6÷21.7)	8.8 (2.1÷15.7)
48	Dong Nai	9.8 (-1.9÷21.2)	-2.3 (-17.7÷10.9)	4.3 (-3.2÷11.1)	1.3 (-6.2÷8.6)	11.8 (5.1÷18.7)	9.0 (-0.2÷18.3)
49	Ho Chi Minh	10.6 (-1.3÷22.3)	1.7 (-12.7÷15.4)	7.3 (-1.8÷15.8)	5.6 (-1.5÷12.0)	9.4 (2.7÷16.2)	10.9 (1.9÷19.9)
50	Ba Ria - Vung Tau	16.5 (-0.9÷32.2)	5.2 (-14.7÷24.9)	9.6 (-15.7÷32.2)	8.7 (-4.4÷21.2)	7.3 (-5.3÷19.5)	1.1 (-16.7÷17.7)
51	Long An	9.6 (-0.2÷19.0)	4.0 (-7.6÷15.8)	3.7 (-3.3÷10.4)	3.2 (-6.0÷12.4)	10.5 (1.2÷19.4)	8.6 (-1.2÷18.6)
52	Vinh Long	12.5 (3.8÷20.8)	6.6 (-4.8÷17.5)	10.1 (-0.1÷19.7)	2.7 (-3.8÷ 9.0)	11.1 (4.1÷18.0)	13.3 (3.9÷23.0)
53	Hau Giang	10.8 (1.1÷21.1)	-3.8 (-14.2÷ 5.6)	10.7 (-1.6÷21.8)	-1.1 (-6.8÷ 4.7)	4.6 (-2.3÷11.3)	5.6 (-6.5÷18.3)
54	Tien Giang	11.5 (-3.2÷25.8)	-2.4 (-18.0÷12.1)	3.8 (-9.3÷15.6)	6.6 (-2.5÷15.9)	3.5 (-3.8÷10.6)	3.9 (-6.6÷14.7)
55	Dong Thap	9.2 (-1.2÷19.2)	7.5 (-7.5÷22.5)	6.1 (-3.8÷15.8)	1.6 (-7.0÷10.2)	9.7 (0.6÷18.3)	11.8 (-1.9÷25.8)
56	Ben Tre	11.1 (-5.6÷26.3)	-1.5 (-19.5÷15.3)	5.7 (-13.0÷22.0)	5.6 (-4.3÷15.7)	-2.6 (-9.6÷4.5)	1.4 (-12.3÷15.6)
57	Tra Vinh	10.9 (-0.5÷21.8)	0.9 (-14.4÷15.5)	7.9 (-5.0÷19.5)	4.9 (-5.2÷14.7)	1.6 (-6.7÷9.9)	2.0 (-9.2÷13.7)
58	An Giang	10.7 (4.5÷17.3)	3.2 (-9.3÷15.6)	10.1 (3.0÷16.9)	4.2 (-6.0÷13.7)	5.8 (-3.8÷15.3)	2.7 (-6.1÷11.8)
59	Can Tho	16.0 (2.4÷29.4)	7.6 (-4.7÷20.1)	6.2 (-5.9÷17.5)	2.5 (-5.0÷10.3)	8.6 (1.5÷15.2)	9.1 (-3.5÷21.8)
60	Soc Trang	8.0 (-2.0÷17.9)	-5.0 (-15.1÷4.7)	7.9 (-9.4÷22.6)	2.4 (-6.6÷10.9)	-3.1 (-8.7÷2.7)	-0.5 (-13.1÷12.0)
61	Kien Giang	11.6 (0.1÷22.6)	2.7 (-10.4÷14.4)	20.0 (-4.1÷40.7)	0.8 (-9.1÷10.5)	10.9 (2.2÷19.8)	6.2 (-10.6÷22.8)
62	Bac Lieu	8.4 (-3.3÷19.9)	-5.8 (-16.8÷4.7)	9.9 (-7.9÷25.7)	-0.5 (-10.2÷8.6)	-0.1 (-6.8÷6.4)	2.0 (-10.8÷15.5)
63	Ca Mau	5.9 (-4.5÷16.7)	-9.4 (-17.0÷-2.3)	5.1 (-6.4÷15.2)	-6.0 (-12.5÷1.4)	-3.6 (-10.2÷3.0)	-4.1 (-14.9÷7.2)



(a) mid-21st century *(b) end of 21st century*

Figure A13. Changes in summer rainfall (%) based on RCP4.5 scenarios



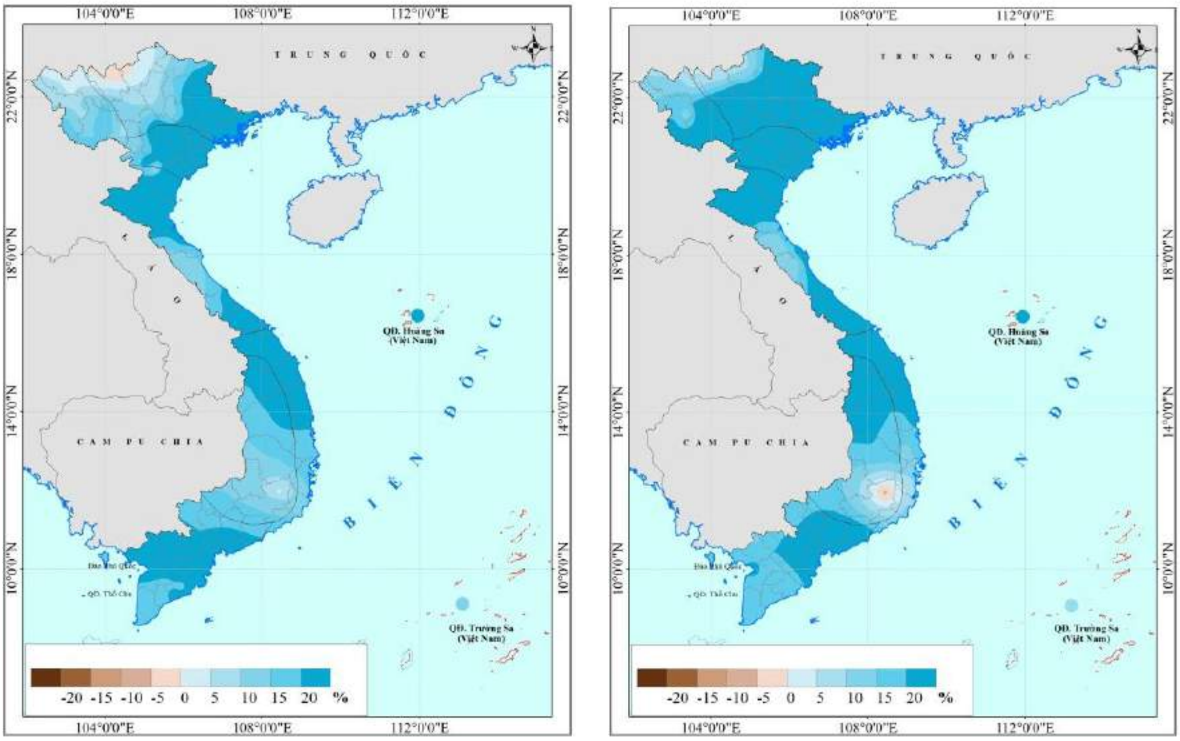
(a) mid-21st century *(b) end of 21st century*

Figure A14. Changes in summer rainfall (%) based on RCP8.5 scenarios

Table A7. Changes in summer rainfall (%) compared with the baseline period

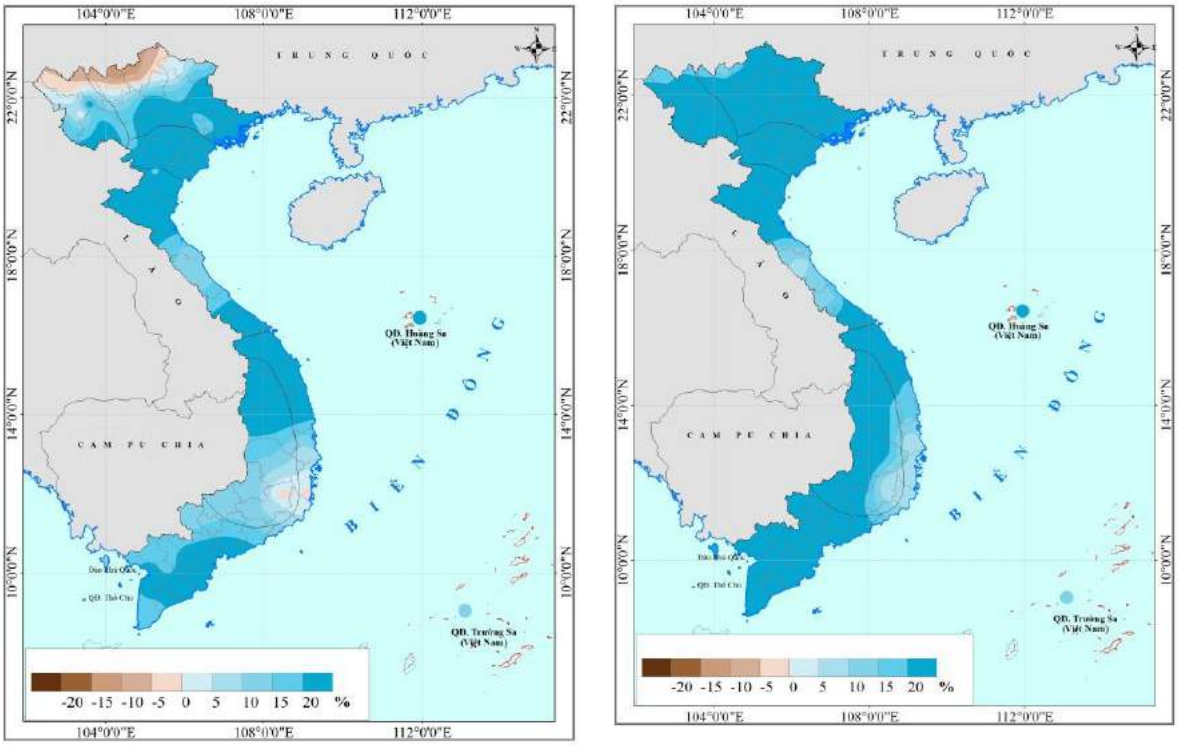
(Values in parentheses are the range of temperatures changes from the climate model results with the lower boundary of 20% and upper boundary of 80%)

No.	Province, City	RCP4.5 scenario			RCP8.5 scenario		
		2016-2035	2046-2065	2080-2099	2016-2035	2046-2065	2080-2099
1	Lai Chau	7.0 (1.0÷13.2)	16.6 (11.0÷22.0)	12.3 (4.8÷20.5)	4.5 (1.8÷7.3)	14.7 (7.1÷22.5)	24.1 (15.4÷32.8)
2	Dien Bien	9.2 (0.6÷17.4)	19.4 (10.9÷28.6)	16.9 (6.0÷29.1)	8.8 (3.4÷14.4)	19.3 (10.1÷29.1)	26.5 (17.3÷34.7)
3	Son La	10.1 (-1.7÷21.7)	21.0 (7.9÷33.7)	22.6 (8.2÷38.4)	12.8 (5.7÷19.8)	19.5 (9.9÷29.8)	26.0 (15.4÷35.6)
4	Hoa Binh	5.5 (-3.9÷14.7)	12.8 (6.4÷19.0)	16.1 (8.5÷24.3)	13.5 (7.4÷19.3)	12.4 (7.2÷17.4)	20.6 (13.7÷27.4)
5	Lao Cai	9.4 (3.0÷15.2)	12.3 (3.4÷20.7)	12.0 (3.1÷21.8)	4.7 (-1.4÷10.4)	13.5 (5.6÷22.0)	19.5 (12.1÷26.6)
6	Ha Giang	9.9 (5.6÷14.0)	8.1 (0.5÷15.1)	12.0 (2.5÷21.6)	-1.1 (-9.8÷7.2)	7.3 (1.5÷13.6)	14.4 (8.4÷20.7)
7	Yen Bai	12.8 (3.9÷21.3)	22.1 (12.5÷31.4)	20.7 (7.9÷35.3)	13.6 (8.0÷19.2)	21.8 (13.9÷30.4)	21.6 (17.0÷26.1)
8	Cao Bang	10.9 (6.2÷15.6)	17.0 (7.5÷26.1)	21.0 (8.6÷33.9)	5.7 (-3.9÷14.7)	16.3 (11.0÷21.5)	21.7 (15.2÷27.9)
9	Tuyen Quang	17.3 (12.7÷22.1)	17.6 (9.4÷25.3)	18.6 (9.0÷29.0)	11.4 (5.1÷17.1)	20.6 (14.2÷27.6)	29.4 (24.4÷34.4)
10	Bac Kan	14.6 (8.9÷19.9)	21.1 (10.9÷30.9)	23.8 (12.4÷35.4)	11.1 (3.4÷18.8)	19.2 (13.6÷24.7)	28.7 (22.2÷35.3)
11	Lang Son	11.8 (2.4÷20.8)	16.6 (9.7÷23.4)	20.9 (12.5÷30.2)	13.6 (6.6÷20.7)	21.3 (16.1÷26.8)	29.6 (23.6÷35.5)
12	Thai Nguyen	18.9 (11.1÷26.5)	22.5 (11.6÷32.7)	24.0 (13.2÷35.6)	17.0 (11.0÷23.5)	29.0 (19.6÷39.0)	35.8 (30.6÷41.0)
13	Phu Tho	12.9 (2.0÷23.5)	18.6 (11.4÷25.2)	18.2 (7.2÷30.5)	15.9 (9.4÷21.5)	19.7 (13.0÷26.4)	22.5 (17.7÷27.4)
14	Vinh Phuc	17.9 (8.7÷26.7)	22.5 (14.2÷30.0)	20.4 (9.9÷32.3)	16.8 (9.2÷23.9)	27.8 (20.2÷36.4)	29.3 (24.5÷34.3)
15	Bac Giang	14.1 (4.7÷23.0)	18.0 (10.6÷25.2)	23.8 (15.0÷33.3)	15.6 (9.6÷22.0)	26.2 (20.5÷32.2)	37.9 (30.0÷45.8)
16	Bac Ninh	14.8 (4.8 ÷24.1)	14.8 (8.4÷21.2)	22.8 (14.3÷32.1)	12.6 (7.0÷18.5)	21.3 (16.4÷26.4)	35.7 (29.3÷41.4)
17	Quang Ninh	15.7 (3.7÷26.5)	15.1 (9.7÷20.7)	25.2 (14.3÷36.1)	15.5 (5.4÷25.4)	24.2 (14.4÷33.4)	40.6 (28.8÷52.8)
18	Hai Phong	23.1 (7.9÷37.5)	22.4 (16.4÷27.9)	31.0 (12.4÷49.5)	23.0 (11.2÷34.7)	29.4 (19.5÷38.8)	53.2 (39.8÷65.8)
19	Hai Duong	14.4 (4.4÷24.0)	15.2 (9.0÷21.5)	23.0 (13.2÷33.6)	16.0 (7.8÷24.2)	23.5 (17.9÷29.1)	36.0 (27.6÷43.7)
20	Hung Yen	13.0 (3.5÷22.2)	17.5 (12.4÷22.3)	23.3 (13.0÷34.0)	17.2 (7.5÷26.5)	16.9 (11.6÷22.1)	32.7 (26.8÷38.3)
21	Ha Noi	14.1 (2.3÷25.3)	19.5 (14.0÷24.8)	19.7 (9.3÷30.8)	16.3 (7.9÷24.1)	20.9 (15.0÷26.8)	27.8 (20.9÷34.8)
22	Ha Nam	13.7 (2.1÷24.8)	18.6 (13.2÷23.8)	20.7 (10.0÷32.0)	16.7 (8.1÷24.8)	20.2 (14.1÷26.2)	28.7 (22.0÷35.4)
23	Thai Binh	11.9 (1.0÷22.9)	15.0 (10.0÷19.8)	24.8 (12.9÷36.8)	18.4 (8.9÷27.6)	17.4 (10.3÷23.8)	32.4 (26.7÷37.8)
24	Nam Dinh	11.7 (1.9÷21.8)	17.6 (8.8÷25.9)	24.5 (10.1÷39.0)	24.6 (13.6÷35.1)	14.8 (6.9÷22.1)	39.0 (28.5÷49.2)
25	Ninh Binh	7.1 (-1.3÷15.8)	14.3 (7.2÷21.0)	19.5 (10.2÷28.9)	19.5 (11.9÷26.3)	12.7 (8.2÷17.3)	27.0 (19.5÷34.6)
26	Thanh Hoa	6.5 (-3.8÷16.7)	11.1 (3.7÷18.4)	16.0 (6.8÷25.5)	24.1 (12.6÷34.6)	11.6 (3.4÷19.1)	25.0 (16.1÷33.8)
27	Nghe An	13.3 (-2.9÷28.6)	5.2 (-1.1÷11.8)	10.9 (0.5÷20.5)	31.4 (11.6÷50.5)	15.9 (-2.3÷33.2)	23.9 (12.7÷34.9)
28	Ha Tinh	21.1 (-3.7÷44.7)	9.1 (-2.1÷20.3)	4.8 (-5.7÷16.1)	40.6 (5.0÷70.7)	18.6 (-6.5÷43.4)	22.2 (3.0÷41.8)
29	Quang Binh	18.5 (-13.4÷48.1)	10.5 (1.5÷18.7)	-0.6 (-14.6÷12.9)	33.2 (-3.1÷64.0)	23.2 (-11.5÷57.7)	11.9 (-7.9÷31.8)
30	Quang Tri	7.4 (-15.4÷28.2)	11.0 (-1.7÷23.4)	4.2 (-14.2÷21.8)	30.6 (7.7÷51.1)	16.4 (-14.7÷48.0)	10.6 (-12.2÷34.5)
31	Thua Thien - Hue	2.0 (-11.4÷15.3)	3.7 (-7.8÷15.5)	-9.6 (-22.4÷2.9)	13.7 (1.2÷25.2)	0.5 (-16.6÷18.0)	5.9 (-17.0÷28.6)
32	Da Nang	-2.1 (-16.7÷10.7)	-1.1 (-10.1÷8.3)	-8.0 (-18.9÷2.5)	4.6 (-5.7÷14.1)	2.5 (-20.3÷23.2)	4.9 (-14.4÷25.1)
33	Quảng Nam	-1.9 (-11.8÷7.5)	0.2 (-12.0÷12.1)	-4.2 (-14.8÷5.8)	24.4 (3.2÷43.0)	15.2 (-5.9÷33.5)	-5.2 (-18.2÷7.4)
34	Quang Ngai	-2.0 (-9.9÷5.7)	-9.3 (-17.7÷-1.6)	-4.5 (-10.9÷2.4)	18.4 (-0.6÷34.4)	-0.9 (-8.5÷6.5)	-9.1 (-17.8÷-0.5)
35	Binh Dinh	1.5 (-10.5÷13.2)	-4.3 (-16.4÷7.3)	4.3 (-7.2÷15.5)	26.1 (2.2÷47.4)	5.2 (-4.9÷15.0)	3.2 (-9.9÷15.4)
36	Phu Yen	4.5 (-6.8÷16.2)	-1.4 (-13.0÷9.8)	4.5 (-6.9÷15.4)	14.1 (6.8÷21.7)	9.6 (0.8÷18.2)	9.5 (-4.4÷23.0)
37	Khanh Hoa	11.9 (-0.4÷23.5)	1.9 (-8.5÷12.8)	6.3 (-5.3÷17.8)	19.8 (8.1÷31.1)	9.8 (-0.7÷19.8)	4.7 (-8.2÷16.7)
38	Ninh Thuan	12.2 (0.2÷23.5)	9.6 (-2.8÷21.9)	10.9 (-6.0÷27.1)	21.8 (10.3÷32.4)	17.4 (-0.8÷34.5)	6.9 (-11.0÷23.9)
39	Binh Thuan	9.5 (-1.8÷19.7)	10.1 (0.0÷21.3)	12.4 (4.0÷20.5)	12.3 (3.9÷20.9)	12.4 (6.1÷18.9)	12.1 (3.0÷20.6)
40	Kon Tum	0.3 (-4.3÷5.2)	8.6 (-1.8÷19.3)	4.3 (-2.8÷11.4)	4.4 (-0.6÷9.2)	4.5 (0.4÷8.6)	1.9 (-1.9÷5.9)
41	Gia Lai	0.7 (-4.6÷6.1)	-0.7 (-10.1÷8.8)	0.2 (-6.7÷7.2)	4.4 (-1.7÷10.4)	2.1 (-3.5÷7.8)	-4.0 (-12.9÷5.7)
42	Dak Lak	1.3 (-6.4÷9.1)	-5.1 (-11.9÷2.2)	-2.2 (-8.7÷4.7)	2.8 (-4.6÷9.9)	0.4 (-4.8÷5.7)	-1.6 (-10.2÷7.7)
43	Dak Nong	4.9 (-0.3÷10.1)	12.1 (2.0÷23.5)	9.6 (2.3÷17.2)	7.8 (1.3÷14.9)	16.2 (10.6÷21.8)	15.5 (12.6÷18.6)
44	Lam Dong	3.8 (-0.2÷7.7)	4.6 (-1.3÷10.7)	4.1 (-2.0÷10.5)	7.2 (2.2÷12.5)	10.1 (4.5÷15.7)	9.7 (3.5÷16.5)
45	Binh Phuoc	9.8 (4.5÷15.2)	11.6 (2.6÷21.6)	10.7 (5.4÷16.2)	13.4 (6.7÷20.7)	16.9 (13.4÷20.1)	19.5 (15.6÷23.2)
46	Tay Ninh	8.9 (5.1÷12.9)	10.4 (2.2÷19.5)	10.2 (4.3÷16.3)	13.3 (8.3÷18.3)	16.7 (13.0÷20.7)	20.9 (10.7÷30.1)
47	Binh Duong	9.6 (5.5÷13.9)	12.9 (4.9÷21.0)	12.2 (2.9÷21.2)	14.1 (9.8÷18.6)	18.0 (14.3÷21.7)	22.9 (13.9÷30.9)
48	Dong Nai	9.4 (5.1÷13.9)	9.7 (2.5÷16.9)	9.8 (1.7÷18.0)	10.6 (6.0÷15.3)	15.1 (11.7÷18.5)	17.7 (11.0÷24.7)
49	Ho Chi Minh	11.8 (5.8÷17.8)	9.0 (0.9÷17.2)	9.3 (1.5÷16.9)	10.2 (5.5÷14.8)	15.2 (11.6÷18.9)	17.9 (11.1÷25.5)
50	Ba Ria - Vung Tau	11.7 (3.5÷19.2)	9.1 (-0.3÷18.9)	9.9 (1.5÷17.9)	12.6 (4.7÷20.5)	11.6 (2.5÷19.8)	12.9 (2.8÷22.3)
51	Long An	4.0 (0.4÷7.9)	6.5 (-1.6÷14.0)	7.3 (0.4÷13.0)	11.6 (7.4÷16.2)	11.8 (7.6÷15.9)	13.1 (5.8÷20.3)
52	Vinh Long	2.5 (0.1÷5.1)	4.2 (-3.7÷12.0)	6.4 (-0.3÷12.5)	4.5 (0.4÷ 8.3)	11.4 (7.6÷14.9)	10.7 (4.8÷17.1)
53	Hau Giang	1.1 (-3.0÷5.5)	1.6 (-5.2÷ 8.7)	3.4 (-2.8÷9.4)	1.6 (-2.6÷6.2)	5.9 (1.6÷10.3)	7.2 (-1.9÷16.0)
54	Tien Giang	9.2 (4.4÷13.9)	7.7 (-0.3÷16.1)	7.9 (-0.1÷15.8)	9.8 (4.7÷14.9)	14.3 (10.1÷18.5)	16.4 (8.7÷24.9)
55	Dong Thap	4.3 (0.7÷8.1)	5.2 (-2.9÷13.5)	7.7 (1.8÷13.1)	8.6 (4.1÷13.2)	11.8 (7.3÷15.9)	12.6 (5.4÷19.9)
56	Ben Tre	10.8 (6.0÷15.8)	9.7 (0.2÷19.0)	11.0 (4.6÷17.1)	11.7 (7.7÷16.0)	13.9 (7.7÷19.6)	19.5 (12.2÷26.4)
57	Tra Vinh	4.2 (0.4÷8.2)	3.6 (-4.5÷11.6)	5.2 (-0.2÷10.6)	6.8 (2.5÷11.4)	8.5 (2.8÷13.9)	11.2 (3.5÷18.8)
58	An Giang	-2.4 (-5.2÷0.6)	-2.4 (-9.1÷4.3)	-0.6 (-5.1÷4.2)	1.8 (-2.7÷6.8)	3.1 (-2.2÷8.1)	3.0 (-5.1÷11.2)
59	Can Tho	3.9 (0.4÷7.2)	3.8 (-4.0÷11.4)	6.2 (-1.0÷12.6)	5.3 (0.3÷10.5)	13.3 (8.6÷17.7)	12.1 (5.4÷19.0)
60	Soc Trang	6.2 (2.1÷10.4)	6.4 (-1.1÷14.5)	9.9 (3.0÷16.4)	6.4 (2.5÷10.8)	11.3 (6.4÷16.0)	16.5 (8.2÷25.0)
61	Kien Giang	-2.0 (-6.8÷2.8)	0.2 (-8.3÷9.1)	5.2 (-4.8÷14.8)	1.8 (-6.1÷10.5)	9.6 (2.6÷16.4)	6.7 (-3.5÷16.7)
62	Bac Lieu	2.2 (-2.8÷6.7)	3.8 (-4.2÷12.4)	7.8 (-0.1÷15.1)	5.7 (1.3÷10.7)	9.6 (2.2÷16.8)	12.7 (2.6÷22.5)
63	Ca Mau	0.5 (-4.9÷5.4)	0.5 (-6.7÷7.9)	2.3 (-3.2÷7.6)	2.9 (-0.7÷6.8)	4.8 (-0.1÷9.8)	8.4 (0.5÷16.4)



(a) mid-21st century *(b) end of 21st century*

Figure A15. Changes in autumn rainfall (%) based on RCP4.5 scenarios



(a) mid-21st century *(b) end of 21st century*

Figure A16. Changes in autumn rainfall (%) based on RCP8.5 scenarios

Table A8. Changes in autumn rainfall (%) compared with the baseline period

(Values in parentheses are the range of temperatures changes from the climate model results with the lower boundary of 20% and upper boundary of 80%)

No.	Province, City	RCP4.5 scenario			RCP8.5 scenario		
		2016-2035	2046-2065	2080-2099	2016-2035	2046-2065	2080-2099
1	Lai Chau	-11.5 (-26.9÷3.8)	4.1 (-7.4÷15.6)	10.1 (-11.1÷31.1)	-12.7 (-21.3÷-4.2)	-3.7 (-16.2÷8.6)	22.6 (1.2÷43.2)
2	Dien Bien	-6.4 (-18.5÷5.5)	9.7 (-2.3÷21.7)	16.9 (-3.9÷37.5)	-3.4 (-15.5÷8.6)	7.3 (-5.1÷19.8)	36.3 (9.3÷62.1)
3	Son La	8.1 (-2.7÷19.0)	13.2 (1.0÷25.9)	28.8 (5.7÷53.5)	6.3 (-13.1÷24.6)	20.5 (4.8÷36.2)	52.4 (18.7÷82.7)
4	Hoa Binh	23.4 (5.2÷42.0)	21.6 (8.8÷35.3)	36.4 (11.2÷63.9)	9.5 (-12.0÷31.7)	26.0 (10.1÷43.5)	37.0 (3.3÷68.8)
5	Lao Cai	-10.6 (-27.5÷5.0)	-0.6 (-12.9÷11.2)	9.0 (-10.5÷30.0)	-11.8 (-22.1÷-1.2)	-7.6 (-18.8÷3.7)	20.1 (-9.9÷47.3)
6	Ha Giang	3.6 (-14.5÷21.0)	4.5 (-8.4÷16.9)	15.4 (0.9÷30.9)	-3.6 (-14.4÷7.2)	-5.5 (-19.2÷8.4)	32.0 (-4.4÷64.5)
7	Yen Bai	6.4 (-8.6÷21.3)	11.4 (-6.3÷29.3)	33.0 (1.1÷67.6)	1.7 (-16.7÷19.8)	14.9 (-4.6÷33.6)	53.8 (-1.2÷101.1)
8	Cao Bang	36.7 (-4.2÷72.8)	15.7 (0.2÷30.5)	34.8 (9.5÷61.4)	9.8 (-7.6÷27.3)	8.6 (-5.8÷23.9)	69.5 (14.7÷118.1)
9	Tuyen Quang	15.3 (-4.7÷34.9)	8.7 (-7.0÷24.4)	34.6 (8.9÷61.7)	8.7 (-9.6÷25.3)	21.4 (-8.3÷49.5)	58.0 (0.5÷108.0)
10	Bac Kan	44.6 (2.4÷81.4)	16.5 (0.5÷32.4)	34.7 (13.8÷57.1)	6.9 (-7.6÷21.8)	11.9 (-5.5÷30.5)	65.8 (10.1÷114.6)
11	Lang Son	65.0 (-1.0÷124.1)	30.1 (0.3÷58.1)	49.3 (8.5÷90.5)	24.5 (-3.4÷52.9)	24.6 (1.7÷46.4)	59.2 (12.9÷103.4)
12	Thai Nguyen	29.4 (-0.5÷57.0)	14.2 (-2.3÷31.1)	35.6 (13.9÷59.7)	10.6 (-0.4÷21.2)	21.1 (-3.2÷44.6)	61.6 (10.1÷107.5)
13	Phu Tho	23.3 (3.7÷44.9)	20.8 (0.8÷42.4)	46.4 (13.2÷83.3)	14.7 (-9.7÷39.0)	31.6 (1.6÷60.1)	50.4 (-5.3÷99.8)
14	Vinh Phuc	28.8 (5.4÷54.4)	18.9 (-0.9÷40.8)	45.1 (16.9÷76.3)	15.1 (-3.3÷33.6)	28.7 (0.7÷55.4)	56.5 (2.1÷105.6)
15	Bac Giang	56.5 (-4.8÷111.0)	28.1 (-1.2÷56.4)	47.1 (6.9÷86.8)	21.5 (-1.4÷45.0)	20.1 (-0.2÷39.3)	56.2 (15.4÷96.4)
16	Bac Ninh	37.2 (-7.1÷75.6)	20.7 (-4.3÷44.6)	37.7 (3.9÷70.1)	8.1 (-14.2÷29.6)	14.1 (-0.5-28.2)	35.9 (5.7÷67.2)
17	Quang Ninh	52.1 (-5.0÷102.2)	32.4 (7.2÷57.3)	44.8 (6.9÷82.6)	28.1 (0.7÷56.4)	38.7 (10.8÷67.2)	50.9 (6.6÷93.7)
18	Hai Phong	45.1 (2.6÷81.5)	42.9 (17.8÷67.5)	48.2 (12.6÷83.4)	24.9 (3.5÷46.2)	46.3 (21.0÷70.9)	53.0 (12.9÷92.9)
19	Hai Duong	43.9 (-6.1÷87.6)	30.6 (3.3÷58.0)	46.7 (9.2÷84.7)	16.2 (-6.2÷39.6)	28.7 (8.9÷48.4)	47.8 (9.9÷86.5)
20	Hung Yen	33.3 (0.7÷62.0)	22.7 (5.1÷40.9)	38.4 (11.5÷66.7)	8.8 (-11.9÷30.3)	29.4 (13.5÷46.4)	37.4 (8.1÷67.7)
21	Ha Noi	35.0 (6.7÷64.3)	25.4 (4.3÷48.8)	52.3 (19.2÷89.1)	16.1 (-8.2÷40.9)	30.6 (5.8÷55.2)	54.2 (4.5÷101.7)
22	Ha Nam	37.2 (6.8÷67.1)	26.6 (6.4÷48.7)	49.3 (17.7÷83.9)	16.8 (-7.1÷41.0)	33.0 (8.8÷57.0)	52.2 (6.5÷95.9)
23	Thai Binh	45.6 (7.1÷78.4)	31.5 (14.9÷48.0)	37.1 (11.5÷62.8)	19.3 (-2.9÷41.4)	42.7 (21.2÷64.1)	44.1 (14.3÷72.9)
24	Nam Dinh	34.5 (6.7÷58.8)	31.3 (18.2÷44.3)	37.8 (15.0÷60.7)	17.8 (-4.0÷39.9)	39.2 (21.5÷57.4)	46.8 (18.0÷75.4)
25	Ninh Binh	27.6 (4.4÷48.1)	27.3 (15.5÷39.0)	32.1 (10.1÷54.4)	8.5 (-11.4÷29.0)	34.0 (19.5÷49.7)	37.1 (14.5÷59.2)
26	Thanh Hoa	22.7 (5.9÷38.1)	34.0 (19.4÷47.9)	32.2 (12.2÷53.0)	13.8 (-6.9÷34.8)	36.3 (21.5÷52.1)	42.3 (22.2÷61.4)
27	Nghe An	10.9 (3.0÷18.7)	30.6 (20.5÷41.0)	26.5 (9.1÷45.4)	12.4 (-3.8÷28.9)	32.8 (23.2÷42.9)	40.5 (26.5÷54.2)
28	Ha Tinh	9.9 (3.8÷16.1)	19.0 (5.2÷31.6)	17.6 (3.8÷30.3)	8.2 (-0.1÷15.8)	15.1 (6.6÷23.4)	17.6 (8.2÷27.0)
29	Quang Binh	8.5 (0.8÷15.8)	12.5 (-3.6÷28.2)	16.1 (1.5÷29.3)	6.8 (-1.4÷13.8)	12.3 (3.2÷21.0)	10.2 (1.1÷19.1)
30	Quang Tri	15.6 (3.0÷28.0)	21.0 (8.1÷34.1)	30.6 (17.1÷46.1)	15.0 (7.1÷22.6)	19.8 (9.5÷29.1)	18.3 (12.4÷24.2)
31	Thua Thien - Hue	24.7 (12.8÷36.1)	30.7 (13.0÷47.7)	39.9 (23.6÷57.9)	20.2 (10.4÷29.1)	27.2 (17.6÷35.9)	26.9 (15.5÷37.5)
32	Da Nang	25.4 (18.4÷31.9)	32.4 (16.8÷47.8)	36.9 (22.8÷52.4)	23.8 (18.1÷29.0)	31.5 (23.3÷39.1)	25.3 (13.4÷36.6)
33	Quảng Nam	28.9 (21.1÷36.7)	37.4 (24.0÷51.6)	36.6 (24.6÷49.6)	22.7 (16.2÷29.3)	35.0 (26.1÷43.6)	35.0 (20.1÷49.7)
34	Quang Ngai	28.9 (20.6÷37.3)	39.1 (24.2÷55.3)	33.2 (20.0÷46.6)	23.5 (15.2÷32.0)	35.9 (25.8÷45.7)	26.9 (11.5÷42.5)
35	Binh Dinh	19.0 (13.2÷24.8)	27.9 (14.9÷40.7)	22.0 (10.1÷33.2)	18.2 (10.1÷26.5)	24.5 (15.4÷32.8)	16.9 (2.8÷31.3)
36	Phu Yen	11.0 (4.2÷17.7)	16.8 (6.9÷26.8)	15.5 (0.8÷29.0)	13.0 (2.6÷24.7)	8.8 (0.2÷17.0)	7.9 (-8.9÷23.8)
37	Khanh Hoa	5.9 (-3.2÷13.9)	15.8 (4.8÷26.0)	8.5 (-3.2÷19.4)	17.2 (4.6÷30.2)	0.1 (-10.9÷10.9)	6.7 (-7.6÷19.5)
38	Ninh Thuan	4.5 (-1.5÷ 9.9)	4.7 (2.6÷26.3)	12.7 (-5.6÷28.9)	19.3 (5.7÷33.2)	4.3 (-7.5÷15.0)	9.5 (-5.2÷23.3)
39	Binh Thuan	18.4 (8.3÷28.0)	21.5 (13.5÷30.1)	23.2 (13.4÷33.2)	16.0 (6.6÷25.8)	17.8 (6.2÷28.9)	21.5 (11.8÷31.2)
40	Kon Tum	20.1 (10.8÷29.8)	22.5 (10.2÷35.5)	29.9 (14.4÷47.0)	22.0 (13.1÷30.6)	34.3 (15.4÷52.1)	39.5 (26.8÷51.2)
41	Gia Lai	15.2 (7.2÷22.8)	20.5 (10.2÷30.3)	20.8 (7.4÷33.9)	17.3 (9.5÷25.4)	22.4 (9.4÷35.3)	24.3 (12.2÷37.3)
42	Dak Lak	10.2 (3.3÷16.7)	16.3 (4.6÷28.5)	17.4 (0.6÷32.9)	9.3 (0.4÷18.1)	11.5 (-0.6÷23.8)	21.1 (1.8÷39.2)
43	Dak Nong	2.9 (-1.9÷7.7)	12.5 (0.8÷25.5)	11.9 (-2.6÷26.3)	5.9 (-0.9÷13.3)	14.2 (0.3÷29.2)	29.7 (15.7÷42.7)
44	Lam Dong	0.0 (-6.2÷6.3)	10.4 (1.8÷20.0)	3.0 (-7.7÷12.8)	5.2 (-2.7÷13.5)	5.0 (-5.2÷16.3)	11.5 (-1.3÷23.1)
45	Binh Phuoc	4.6 (0.5÷9.0)	15.6 (7.7÷24.4)	17.7 (3.6÷30.9)	11.5 (1.6÷22.3)	11.2 (2.2÷20.3)	30.6 (19.2÷40.9)
46	Tay Ninh	6.6 (-2.2÷15.6)	17.6 (4.1÷30.3)	18.4 (3.7÷31.4)	9.8 (-2.2÷21.7)	12.2 (1.0÷24.2)	23.5 (11.6÷34.4)
47	Binh Duong	8.5 (-0.1÷17.4)	18.7 (6.6÷31.3)	21.4 (6.2÷34.7)	11.2 (1.9÷20.3)	16.2 (6.3÷26.7)	24.5 (12.7÷35.5)
48	Dong Nai	19.5 (10.1÷27.9)	29.4 (14.8÷44.5)	27.6 (11.7÷42.0)	20.6 (11.4÷29.3)	24.1 (12.7÷35.5)	30.4 (15.8÷43.4)
49	Ho Chi Minh	22.0 (11.6÷31.9)	35.6 (18.8÷53.6)	30.8 (14.1÷46.8)	23.2 (12.2÷34.6)	29.8 (18.8÷40.5)	34.4 (18.3÷49.5)
50	Ba Ria - Vung Tau	21.8 (10.0÷33.0)	21.4 (10.5÷33.0)	23.7 (13.2÷34.6)	13.9 (3.3÷23.8)	20.6 (10.2÷31.6)	20.6 (10.2÷30.9)
51	Long An	14.8 (1.7÷27.1)	33.3 (9.5÷55.0)	20.9 (2.2÷37.5)	14.7 (0.4÷28.5)	19.1 (6.4÷31.7)	27.0 (14.1÷38.5)
52	Vinh Long	8.0 (1.9÷14.7)	21.2 (8.6÷35.3)	17.5 (4.9÷30.0)	15.1 (3.1÷27.7)	17.8 (10.6÷25.3)	28.4 (14.4÷42.0)
53	Hau Giang	8.1 (1.9÷13.6)	17.3 (8.3÷26.8)	16.1 (3.8÷27.9)	15.2 (6.7÷23.6)	22.2 (17.7÷26.8)	25.0 (11.6÷38.3)
54	Tien Giang	16.7 (6.1÷26.2)	31.5 (13.6÷50.0)	23.7 (7.9÷38.5)	17.4 (5.4÷28.7)	24.8 (12.2÷37.0)	29.5 (12.5÷45.4)
55	Dong Thap	11.2 (4.2÷18.8)	28.5 (12.1÷44.7)	20.2 (7.0÷32.9)	14.1 (2.1÷26.1)	19.3 (9.4÷29.3)	35.5 (24.5÷45.2)
56	Ben Tre	22.0 (7.2÷34.8)	30.0 (14.0÷46.5)	27.4 (12.6÷41.2)	18.6 (6.4÷29.6)	25.4 (12.6÷39.0)	27.8 (10.3÷44.1)
57	Tra Vinh	13.1 (1.7÷23.8)	28.6 (11.4÷45.8)	20.8 (5.5÷35.0)	15.7 (3.2÷27.7)	20.6 (8.7÷33.2)	27.1 (12.0÷40.9)
58	An Giang	4.3 (-3.8÷12.7)	27.3 (8.7÷45.2)	14.1 (-1.6÷28.8)	12.8 (0.1÷25.8)	15.9 (4.8÷27.5)	26.5 (13.7÷37.8)
59	Can Tho	10.6 (3.2÷18.0)	22.5 (9.6÷36.4)	19.0 (6.8÷31.1)	15.4 (2.9÷28.1)	21.0 (13.8÷28.3)	30.1 (17.3÷41.9)
60	Soc Trang	12.6 (5.4÷19.4)	19.4 (9.8÷29.6)	14.7 (5.9÷23.6)	15.1 (5.0÷24.8)	22.1 (15.4÷29.2)	25.9 (14.1÷37.3)
61	Kien Giang	7.9 (0.0÷16.7)	21.9 (11.9÷32.7)	19.5 (6.6÷33.4)	13.4 (2.2÷24.6)	18.5 (9.6÷27.8)	28.0 (14.4÷42.7)
62	Bac Lieu	14.7 (6.5÷22.2)	21.4 (12.2÷31.3)	17.4 (7.3÷27.3)	18.9 (9.2÷28.1)	22.7 (16.2÷29.7)	27.0 (13.2÷39.9)
63	Ca Mau	14.0 (2.9÷24.4)	16.2 (4.2÷29.0)	16.0 (3.5÷28.3)	14.3 (3.7÷24.9)	18.3 (11.3÷25.7)	23.6 (10.7÷36.3)

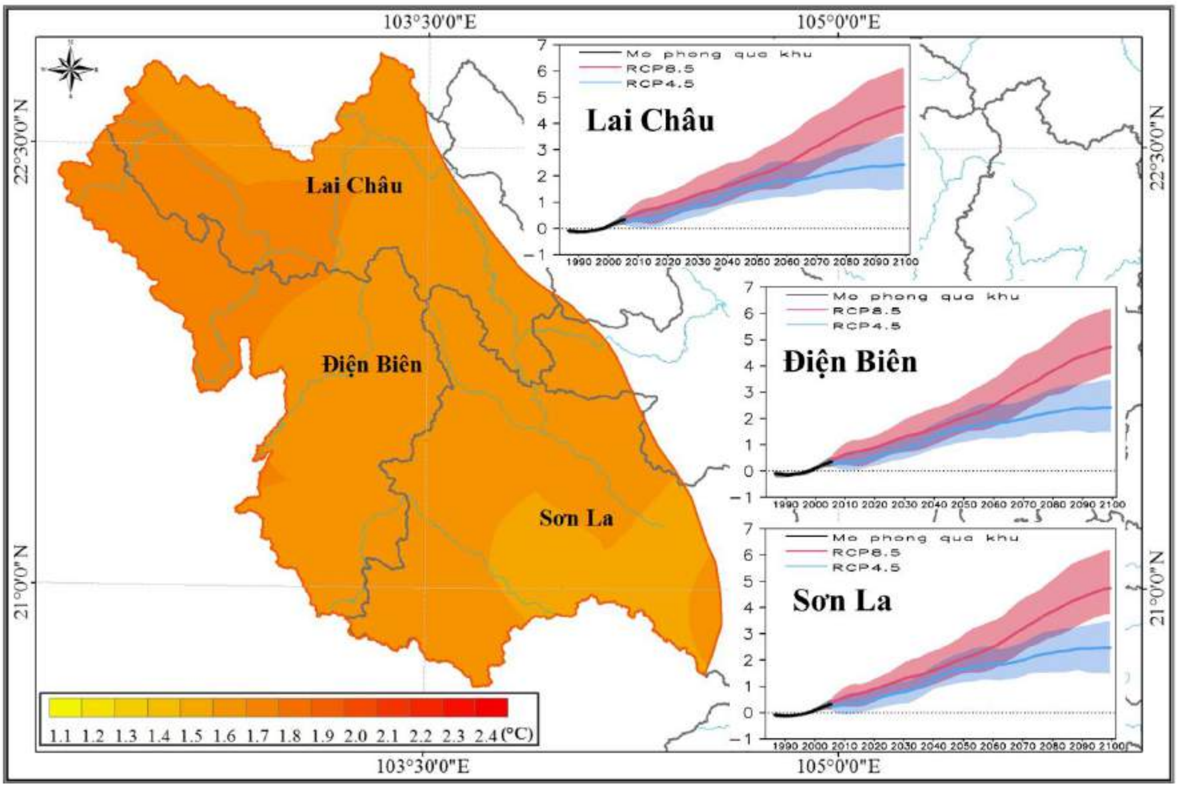


Figure A17. Change in average annual temperature (°C) for the Northwest

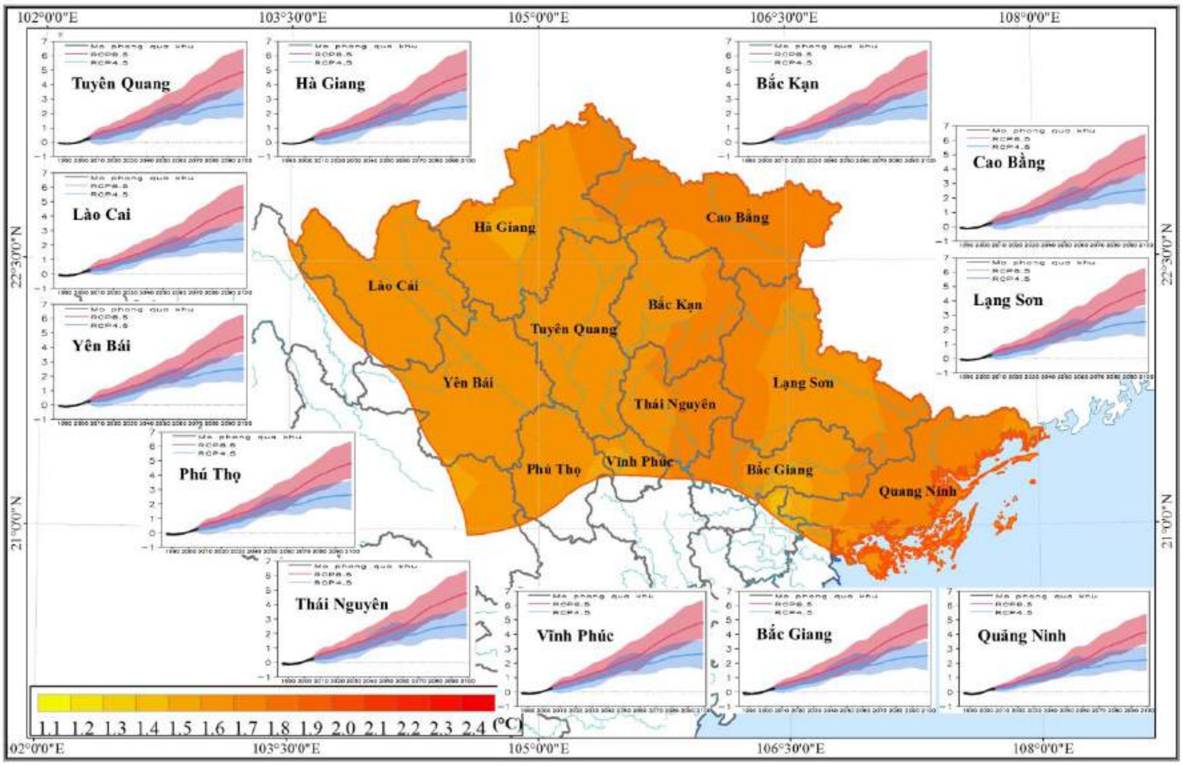


Figure A18. Change in average annual temperature (°C) for the Northeast

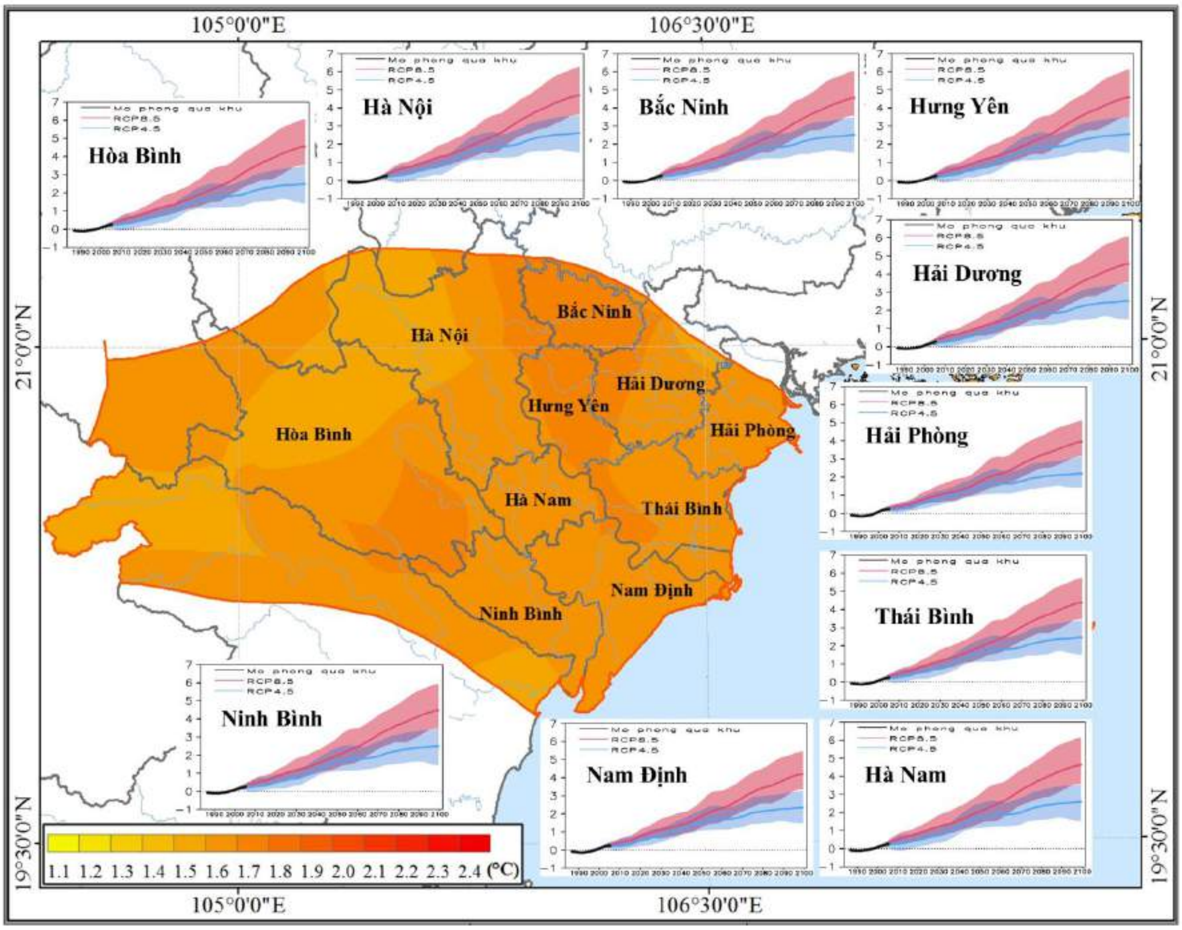


Figure A19. Change in average annual temperature (°C) for the Red River Delta

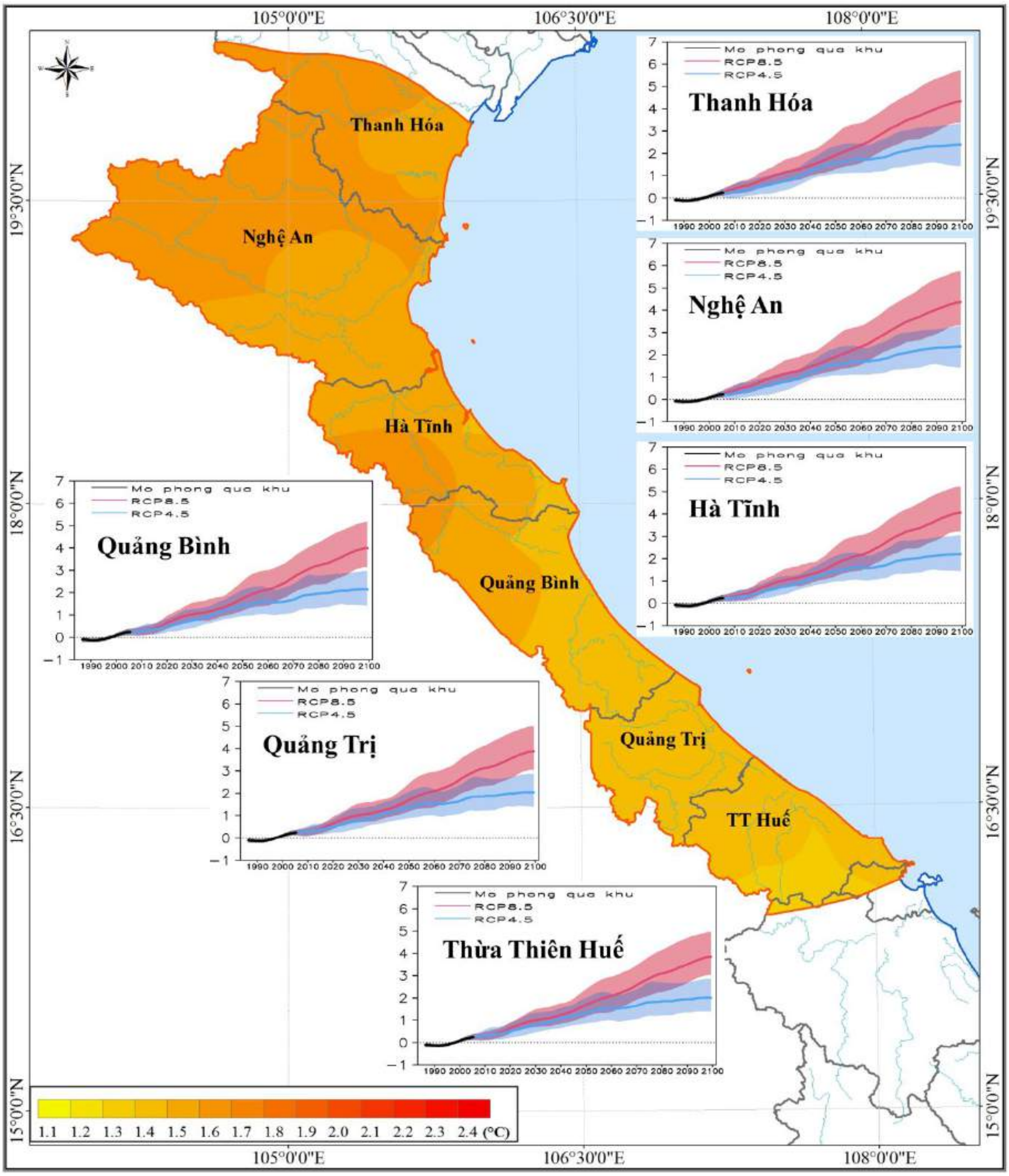


Figure A20. Change in average annual temperature (^oC) for the North Central Coast

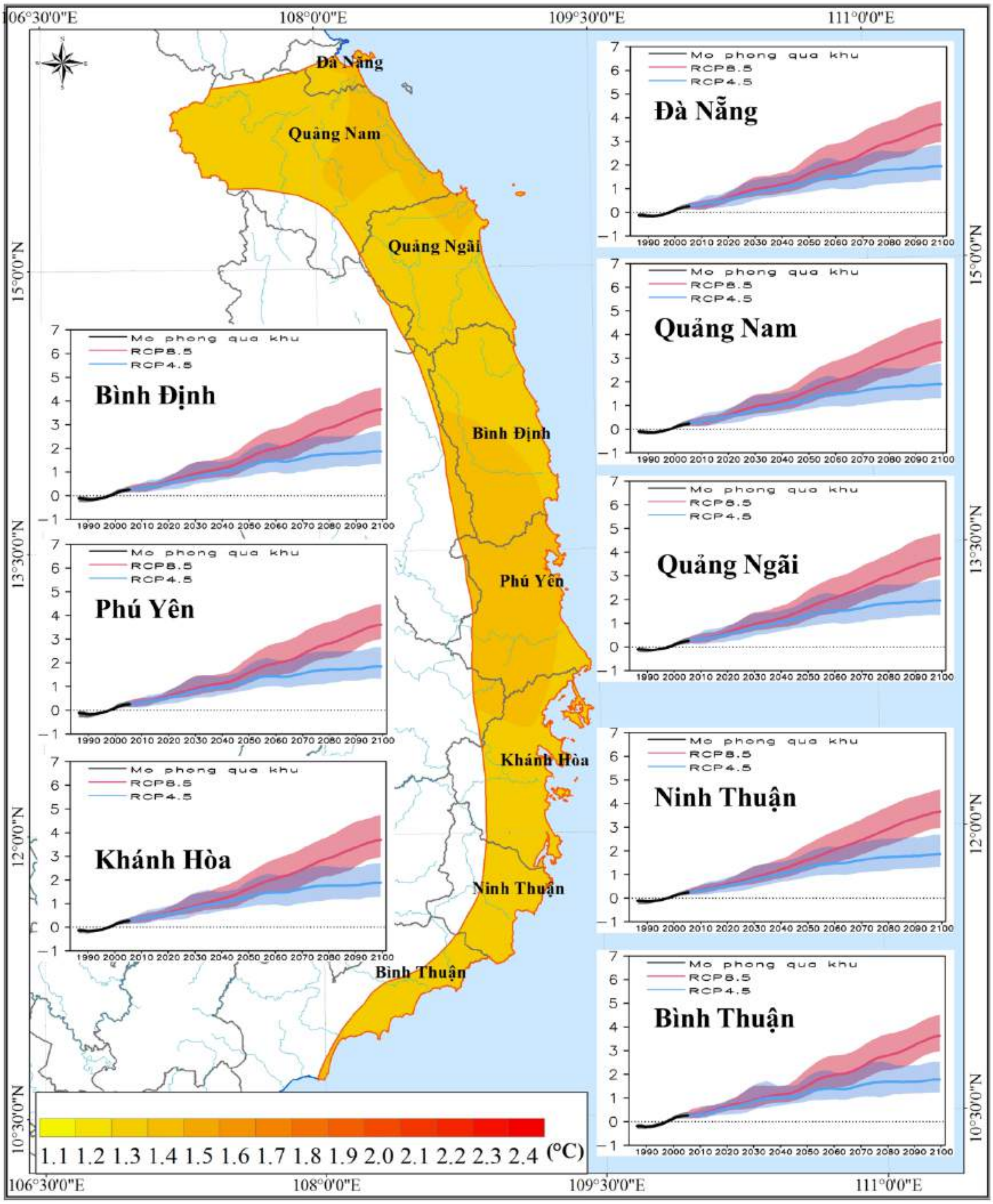


Figure A21. Change in average annual temperature (°C) for the South Central Coast

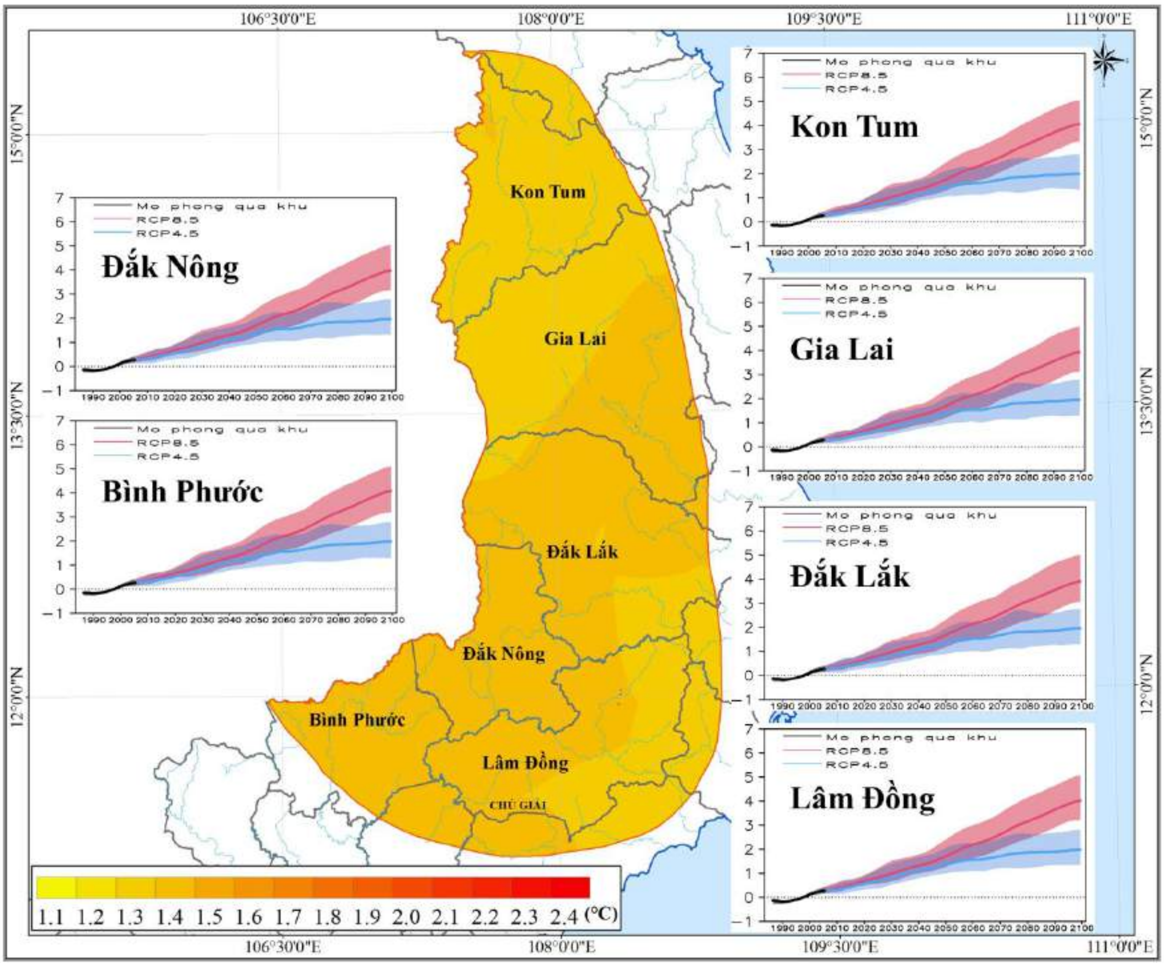


Figure A22. Change in average annual temperature (^oC) for the Central Highlands

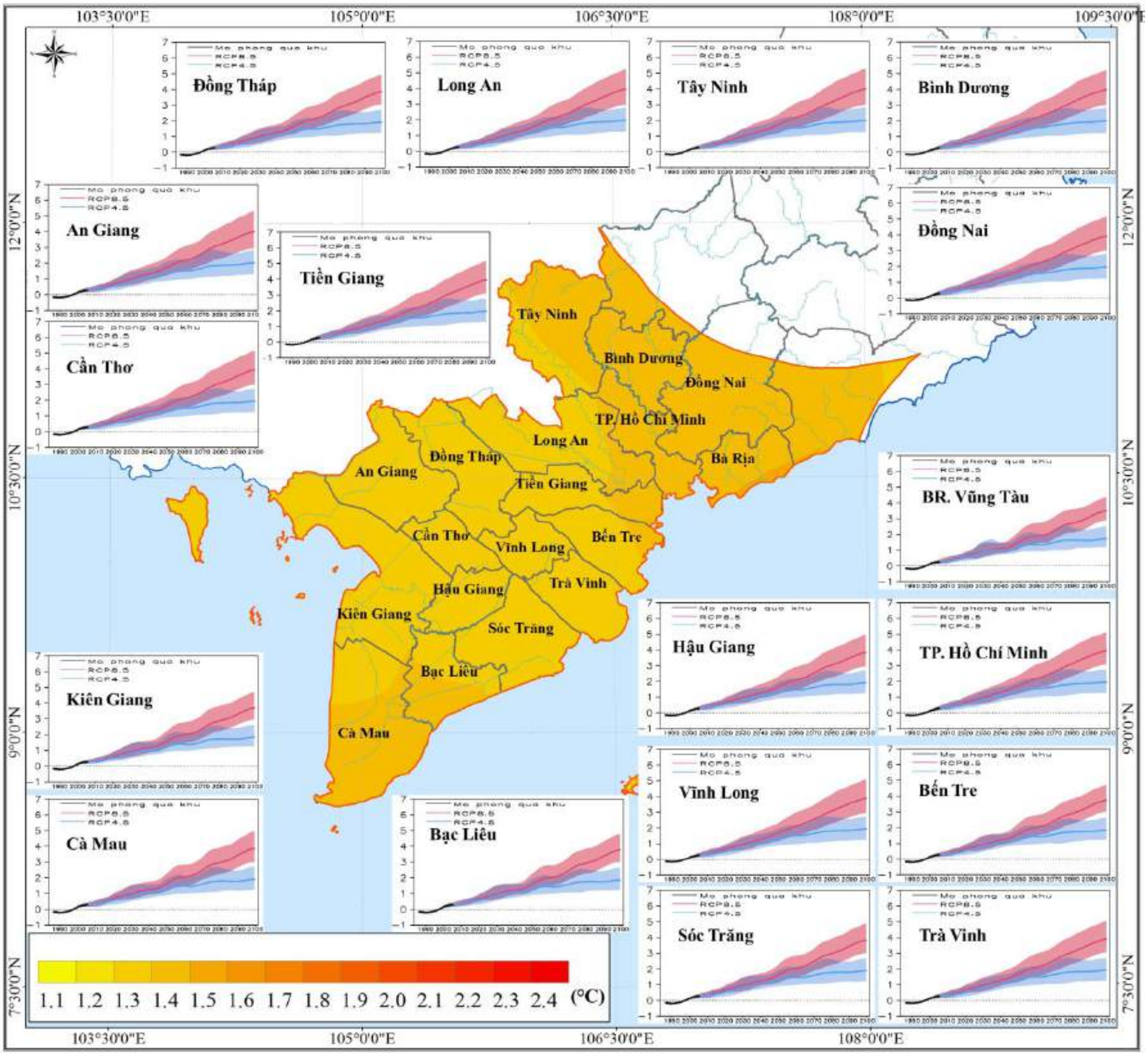


Figure A23. Change in average annual temperature (°C) for the Southern Vietnam

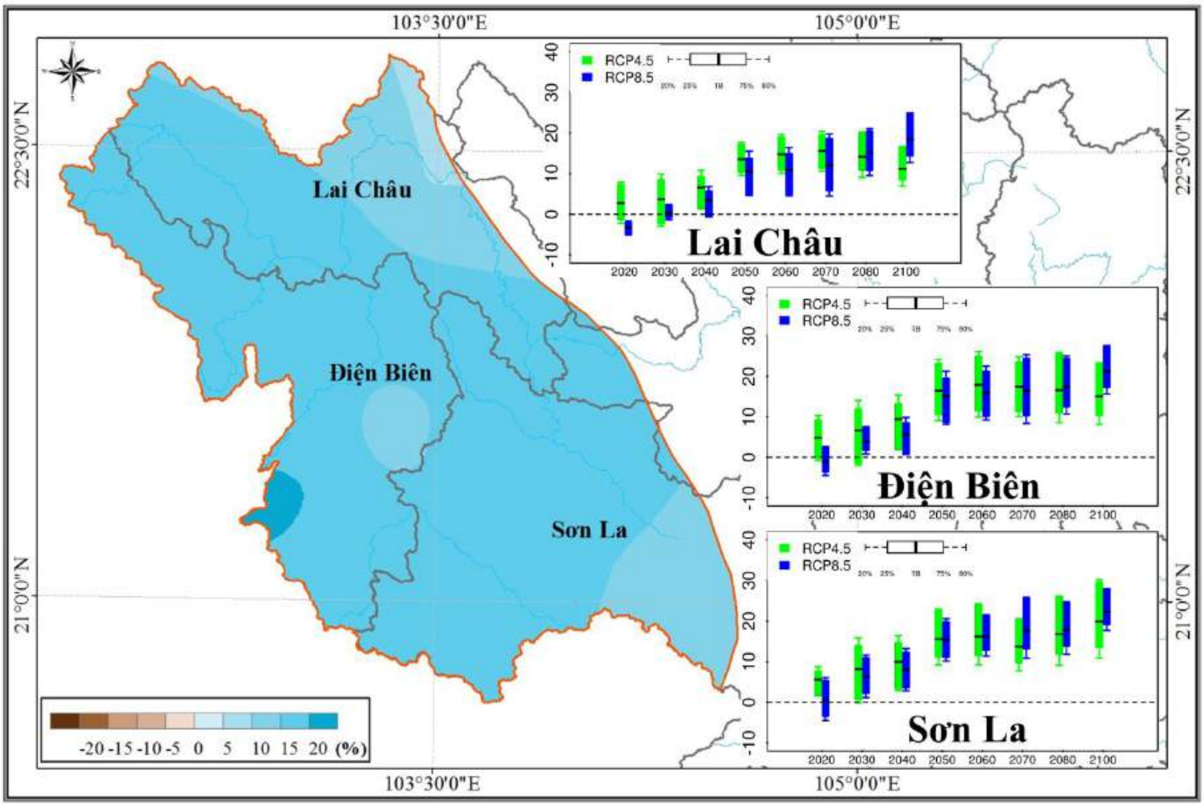


Figure A24. Change in annual rainfall (%) for the Northwest

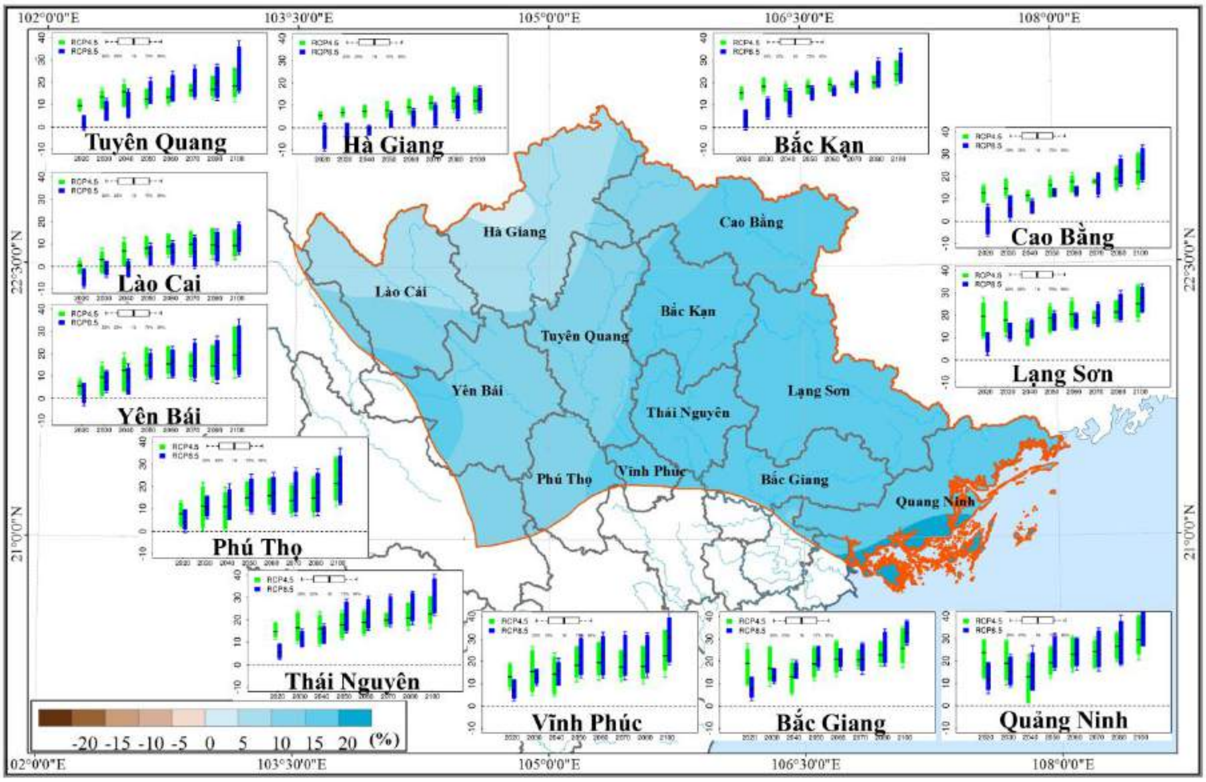


Figure A25. Change in annual rainfall (%) for the Northeast

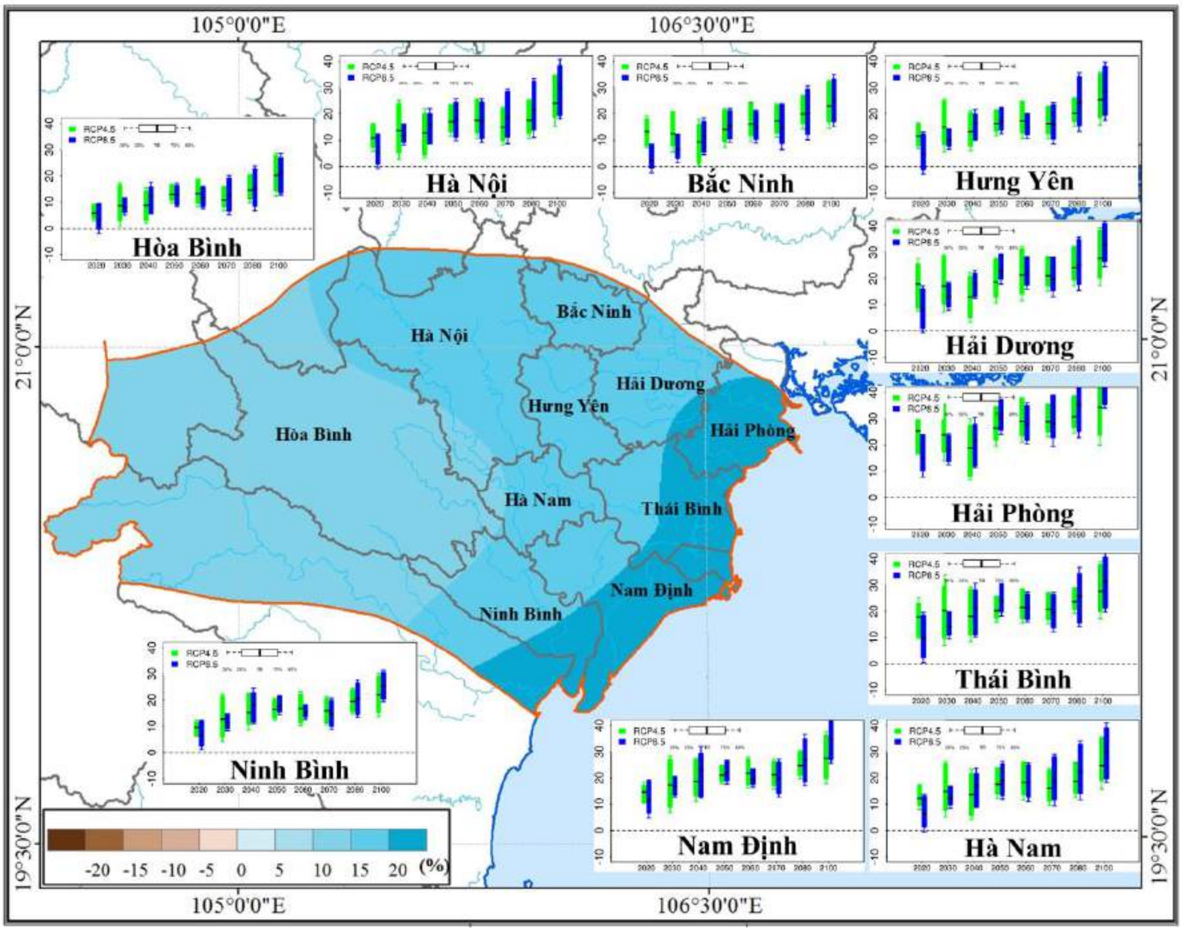


Figure A26. Change in annual rainfall (%) for the Red River Delta

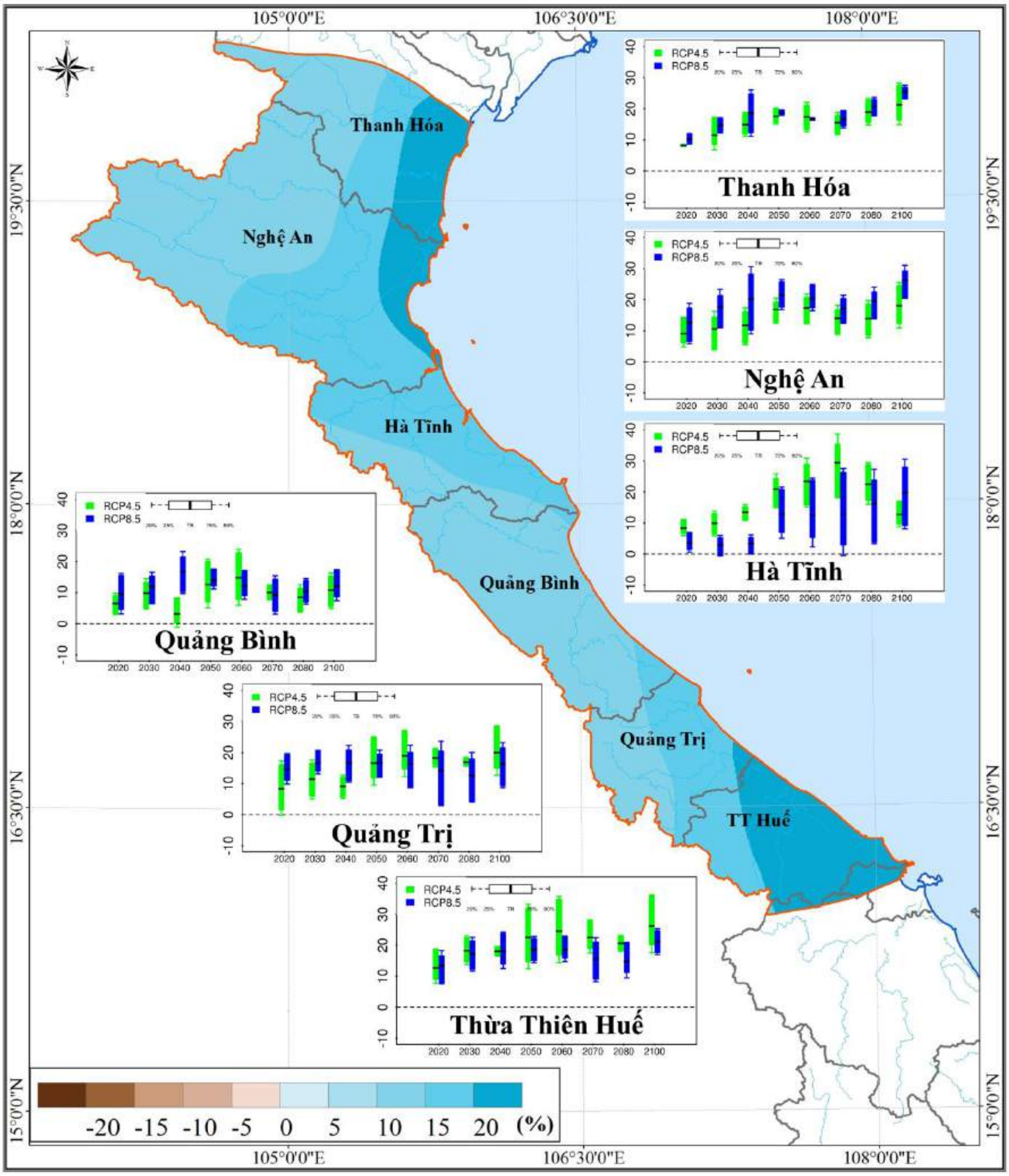


Figure A27. Change in annual rainfall (%) for the North Central Coast

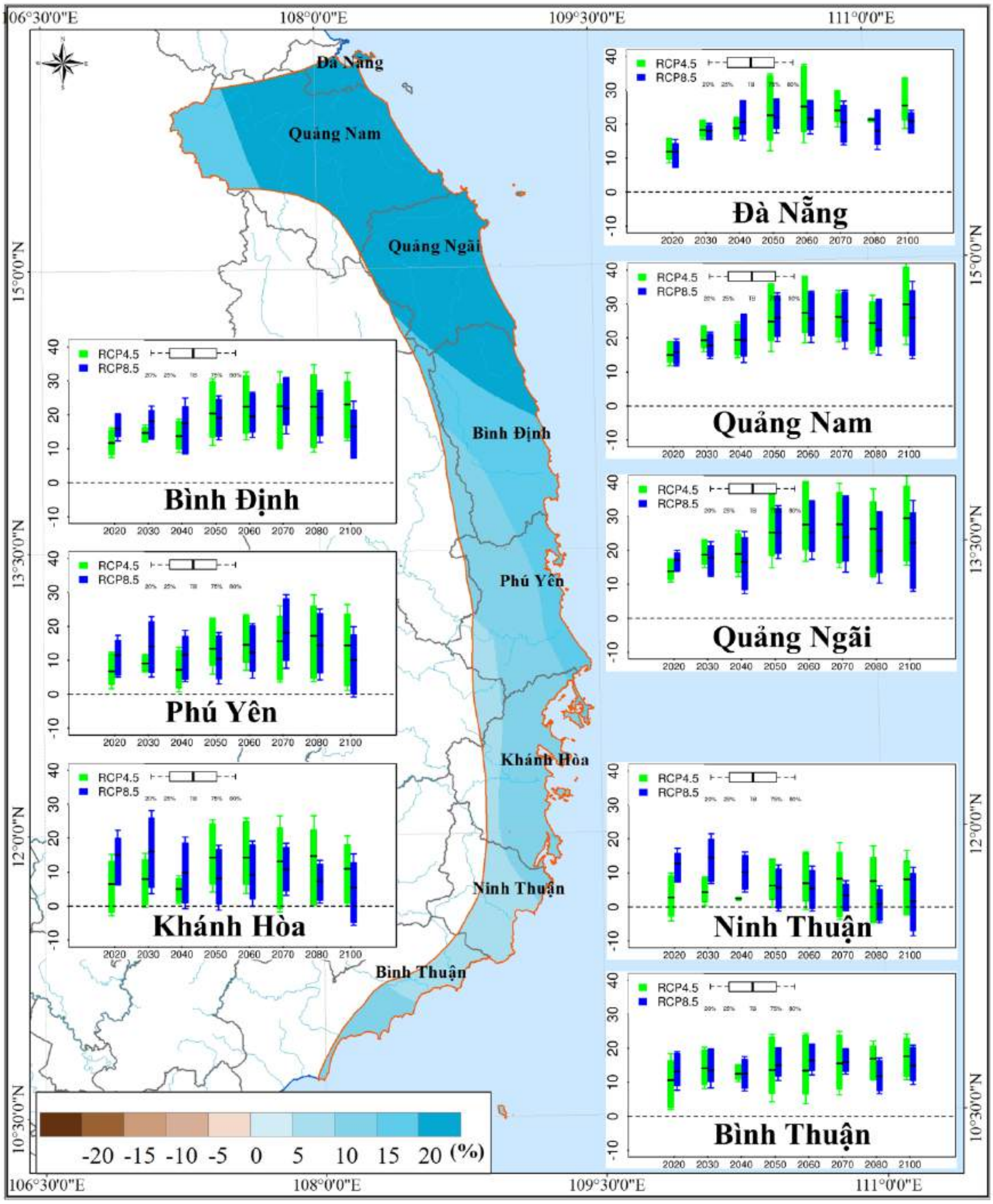


Figure A28. Change in annual rainfall (%) for the South Central Coast

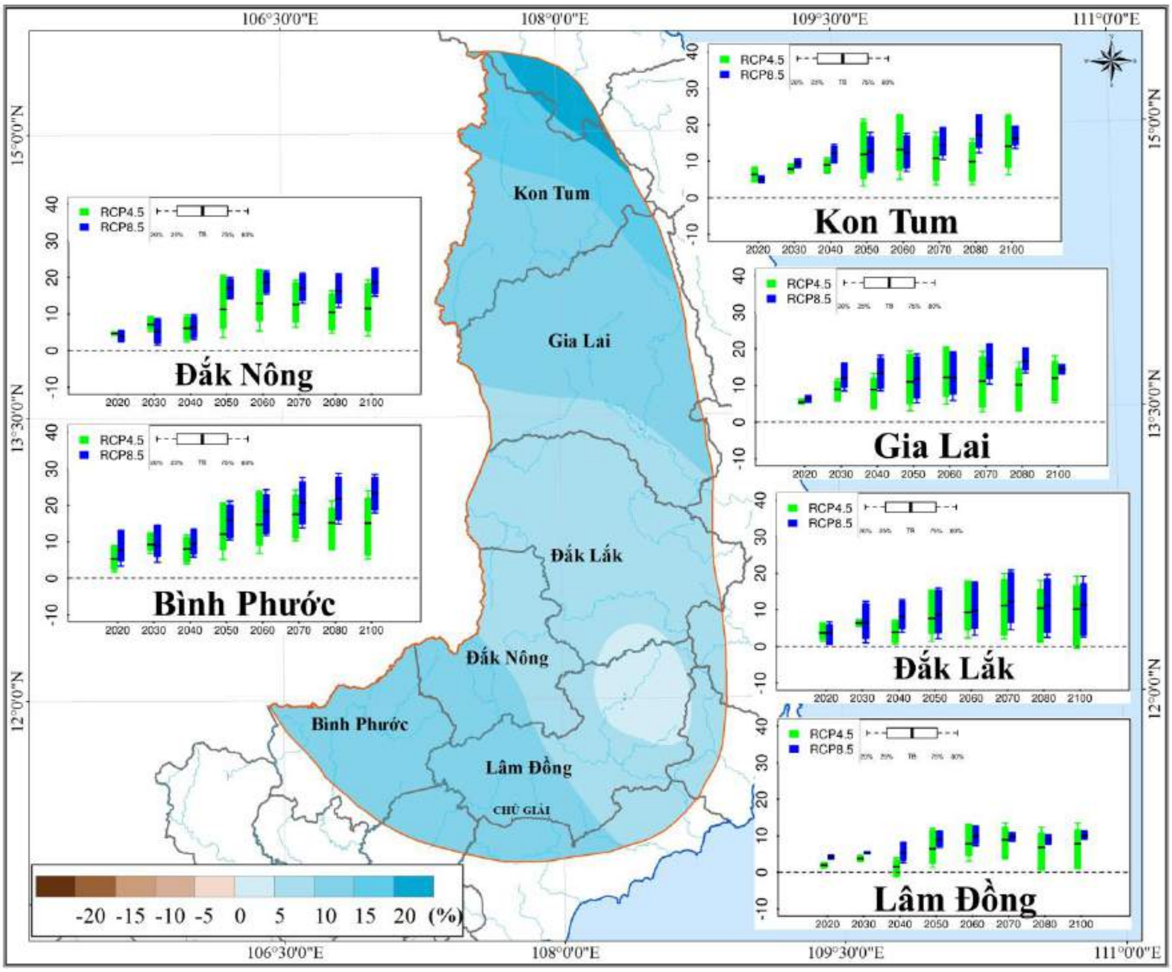


Figure A29. Change in annual rainfall (%) for Central Highlands

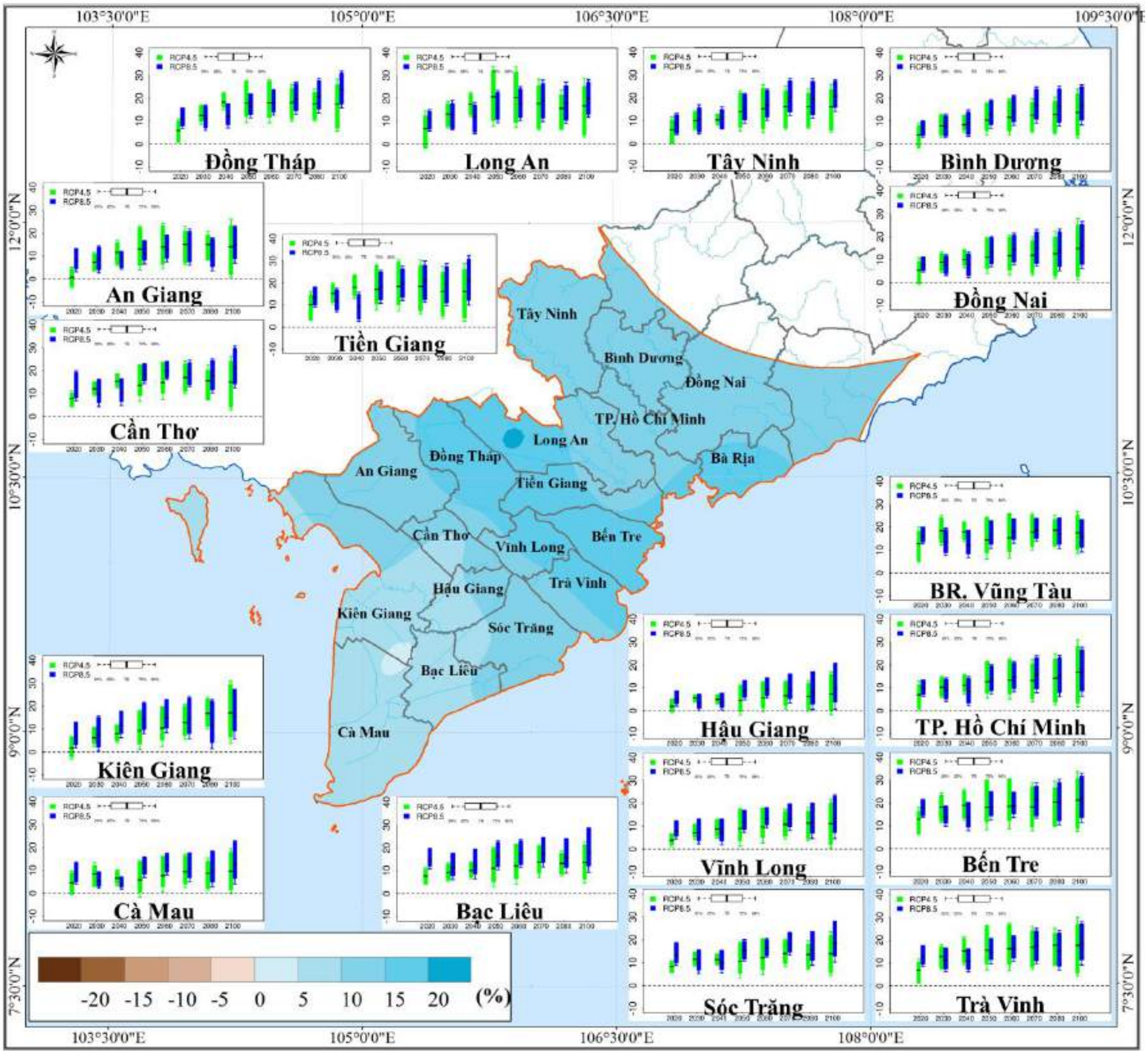


Figure A30. Change in annual rainfall (%) for the Southern Vietnam

Appendix B:

Inundation risk from sea-level rise

1. For Quang Ninh province

If sea-level rise 100 cm, approximately 4.79% area of Quang Ninh province is at risk of inundation, mainly in costal districts. Among them, Yen Hung district is the highest risk of inundation (37.7%) (**Figure B1,**

Table *B1*).

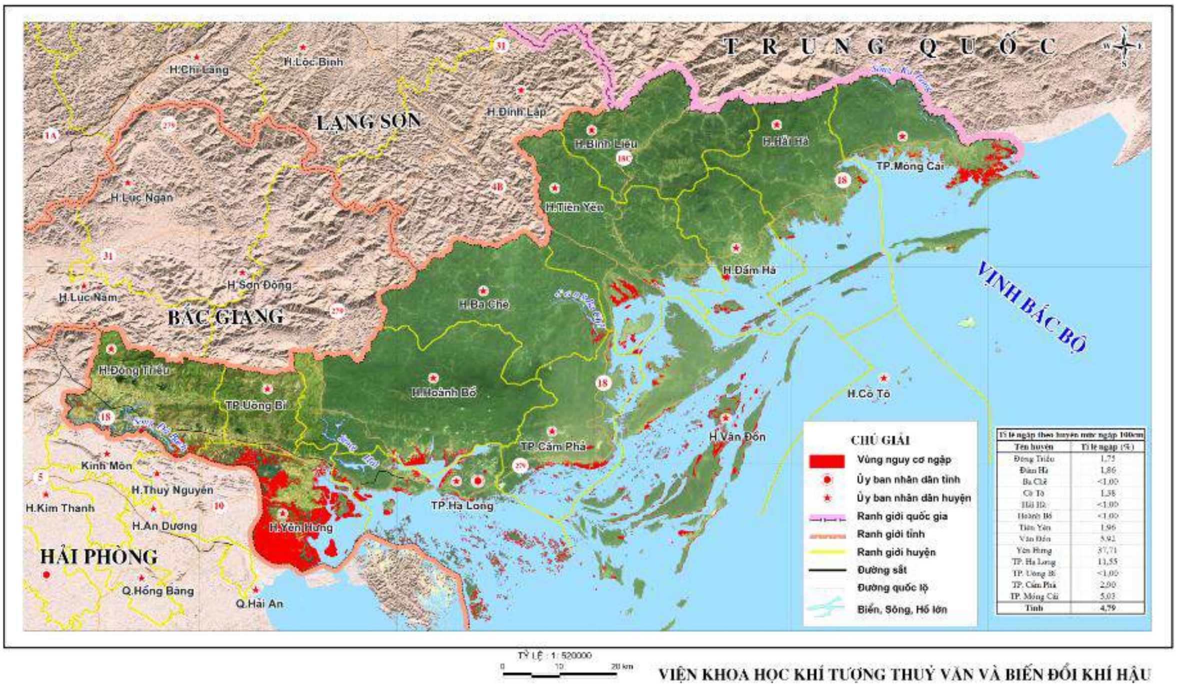


Figure B1. The inundation risk map with sea-level rise of 100cm, Quang Ninh province

Table B1. The inundation risk for Quang Ninh province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Dong Trieu	39817	0.59	0.72	0.90	1.17	1.44	1.75	6.96
Dam Ha	41060	1.50	1.57	1.64	1.66	1.76	1.86	2.89
Ba Che	60483	0.31	0.32	0.33	0.33	0.34	0.37	0.46
Co To	77133	1.09	1.13	1.18	1.18	1.26	1.38	3.29
Hai Ha	78436	0.65	0.69	0.77	0.80	0.87	0.94	1.98
Hoanh Bo	84925	0.78	0.81	0.84	0.87	0.91	0.97	1.59
Tien Yen	66673	1.41	1.51	1.60	1.68	1.79	1.96	4.37
Van Don	133137	4.83	5.13	5.23	5.26	5.41	5.92	8.11
Yen Hung	39082	25.10	27.81	30.36	32.96	35.60	37.71	50.61
Ha Long City	750667	9.76	10.04	10.29	10.32	10.77	11.55	16.95
Uong Bi City	19767	0.16	0.17	0.18	0.19	0.20	0.23	0.47
Cam Pha City	49501	2.41	2.49	2.56	2.56	2.68	2.90	3.77
Mong Cai City	155818	2.92	3.34	3.72	4.06	4.47	5.03	9.19
Province	**967655**	**3.33**	**3.62**	**3.88**	**4.10**	**4.40**	**4.79**	**7.25**

2. For Hai Phong City

If sea-level rise 100 cm, approximately 24.8 % area of Hai Phong city is at risk of inundation, mainly in costal districts. Among them, Kien Thuy district is the highest risk of inundation (50.4%) (**Figure B2,**

Table *B2*).

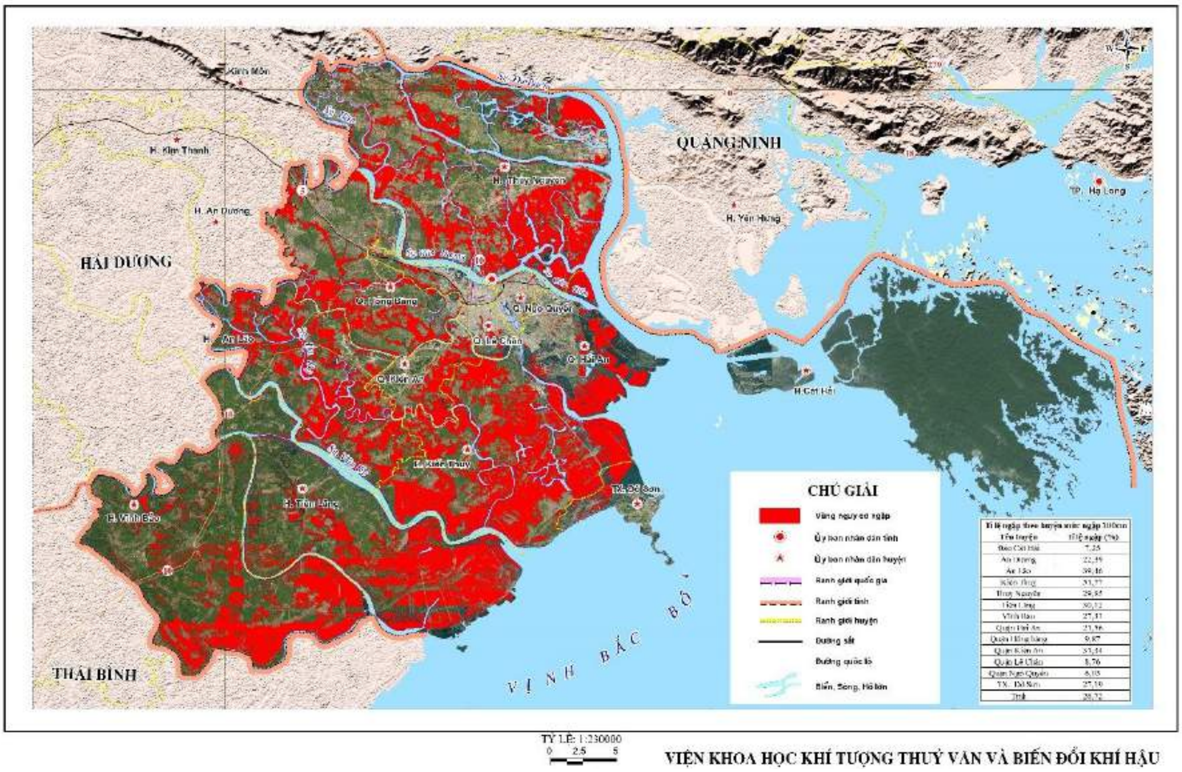


Figure B2. The inundation risk map with sea-level rise of 100cm, Hai Phong city

Table B2. The inundation risk for Hai Phong city

District	**Area (ha)**	**Inundation Percentage (% area) corresponding to rising sea level**						
		50cm	**60cm**	**70cm**	**80cm**	**90cm**	**100cm**	**200cm**
Cat Hai	336730	2.01	2.27	2.46	2.55	2.68	3.00	4.11
An Duong	10257	2.86	4.65	8.90	10.13	19.23	23.65	70.83
An Lao	11613	3.05	6.03	12.38	13.94	28.94	38.02	83.87
Kien Thuy	174501	3.60	7.78	20.64	21.55	38.02	50.44	83.09
Thuy Nguyen	26051	6.44	8.51	15.52	16.95	25.70	30.73	67.44
Tiên Lãng	18233	0.90	1.85	7.91	8.29	19.07	30.32	88.25
Vinh Bao	18685	1.28	3.55	9.39	9.71	17.21	26.90	90.82
Hai An	8268	0.60	0.75	2.54	2.83	8.36	10.96	50.26
Hong Bang	1631	1.50	2.12	3.62	4.47	8.76	11.94	36.76
Kien An	2932	2.63	5.45	11.44	12.53	26.59	31.91	67.22
Le Chan	1190	1.14	1.90	2.78	4.12	10.07	12.35	59.16
Ngo Quyen	1141	0.94	0.97	1.37	2.63	3.28	3.98	46.60
Do Son Town	2928	2.10	4.25	13.68	14.37	20.30	27.19	51.35
Province	**154052**	**2.77**	**4.51**	**9.80**	**10.48**	**18.58**	**24.82**	**60.36**

3. For Thai Binh province

If sea-level rise 100 cm, approximately 57.1% area of Thai Binh province is at risk of inundation. Among them, Kien Xuong district (83.6%) and Tien Hai district (82.3%) are 2 districts having highest risk of inundation (**Figure B3,**

Table *B3*).

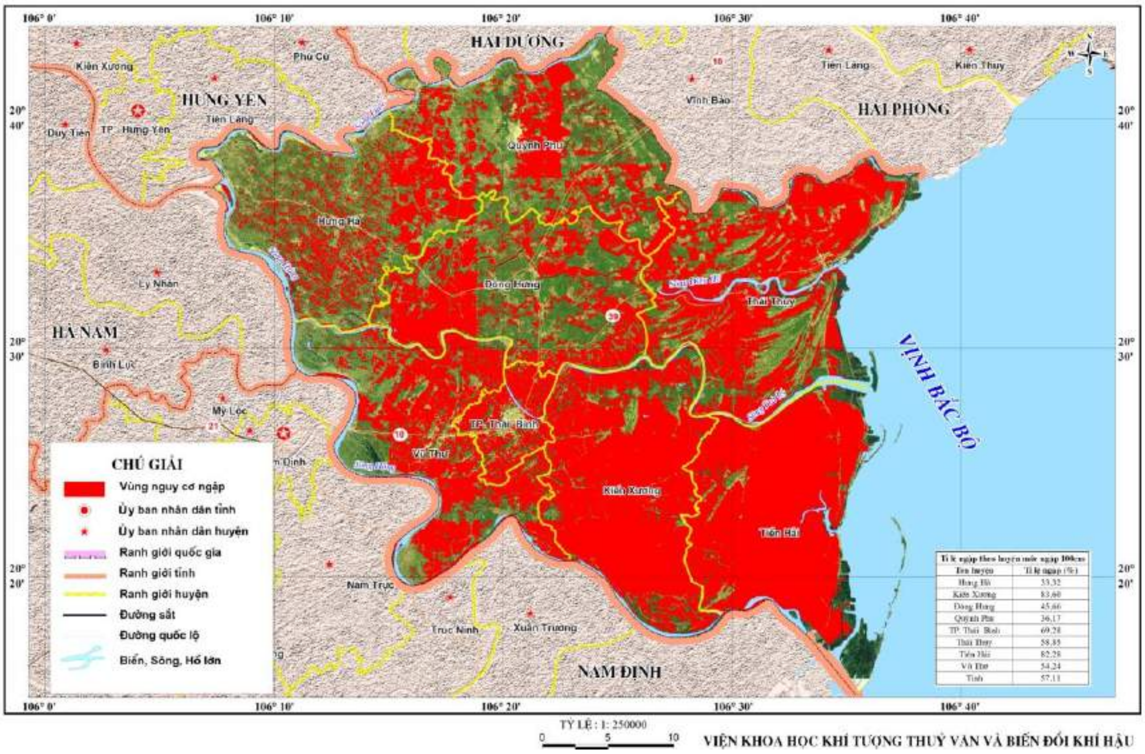


Figure B3. The inundation risk map with sea-level rise of 100cm, Thai Binh province

Table B3. The inundation risk map for Thai Binh province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Dong Hung	20652	6.91	9.00	11.72	15.56	21.10	45.66	94.16
Hung Ha	21088	16.20	18.63	21.09	21.07	21.91	33.32	56.32
Kien Xuong	21750	58.61	64.92	70.49	75.53	79.82	83.60	98.52
Quynh Phu	21061	5.04	7.46	10.78	13.68	17.30	36.17	88.44
Thai Thuy	26756	20.83	27.73	36.14	42.45	49.88	58.85	86.62
Tien Hai	22313	66.35	71.15	75.01	77.91	80.78	82.28	90.03
Thai Binh City	4351	59.39	61.51	63.56	65.51	67.40	69.28	85.70
Vu Thu	20162	28.49	33.11	38.60	44.32	48.29	54.24	82.77
Province	**158131**	**29.95**	**34.23**	**38.84**	**42.68**	**46.81**	**57.11**	**85.41**

4. For Nam Dinh province

If sea-level rise 100 cm, approximately 55.87 % area of Nam Dinh province is at risk of inundation. Nam Dinh city has low risk of inundation (1.96%). Hai Hau, Nghia Hung, Giao Thuy, Truc Ninh, Nam Truc, Xuan Truong and Vu Ban district having high risk of inundation are more than 50% area of the province (**Figure B4,**

Table ***B4***).

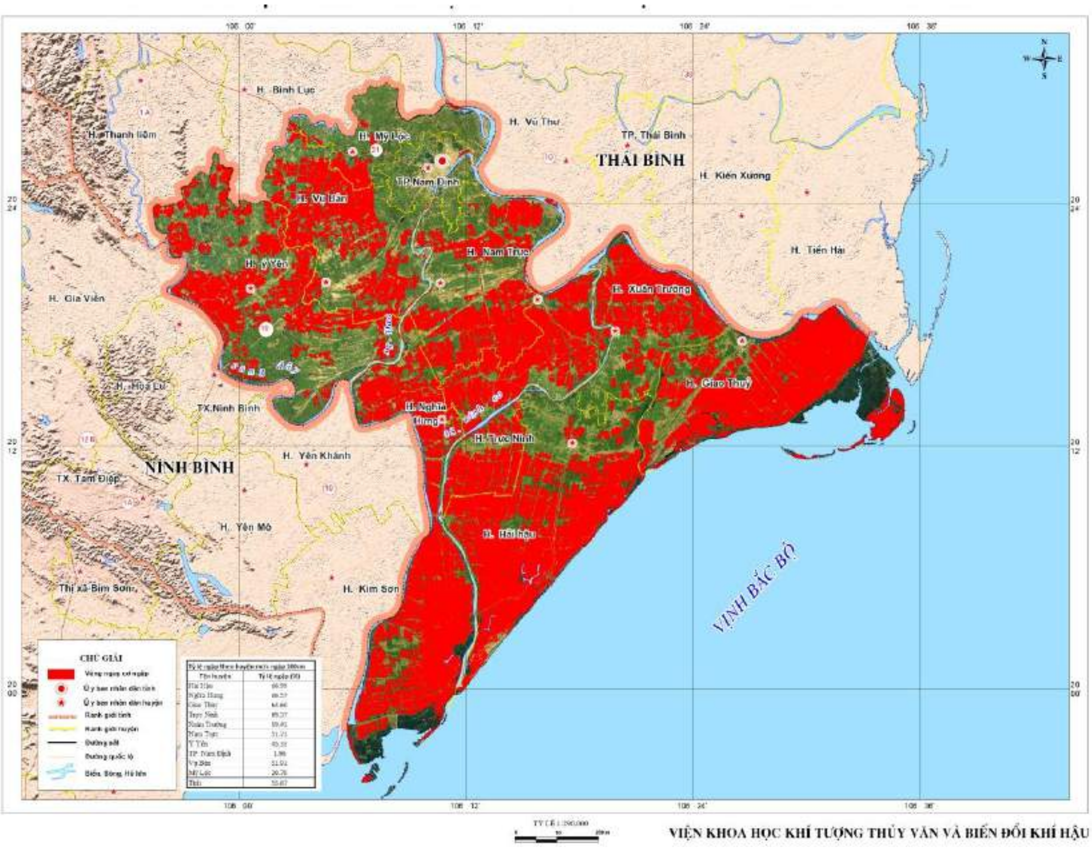


Figure B4. The inundation risk map with sea-level rise of 100cm, Nam Dinh province

Table B4. The inundation risk map for Nam Dinh province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Hai Hau	229428	27.21	35.65	44.40	52.73	60.22	66.99	96.90
Nghia Hung	220295	28.17	35.79	43.61	51.92	59.71	66.57	91.61
Giao Thuy	197474	33.62	40.93	47.64	53.79	59.56	64.60	91.91
Truc Ninh	144588	23.11	32.37	42.06	51.60	60.80	69.37	95.00
Xuan Truong	116382	22.41	28.33	35.07	42.69	51.15	59.41	92.92
Nam Truc	165015	16.44	23.36	30.51	37.72	44.83	51.71	86.42
Y Yen	245962	11.78	16.38	22.32	29.54	37.36	45.33	90.52
Nam Dinh City	463153	0.11	0.14	0.17	0.36	1.34	1.96	41.45
Vu Ban	153998	17.45	24.82	32.32	39.22	45.74	51.91	90.38
My Loc	744774	4.61	6.99	10.02	13.40	17.12	20.70	74.41
Province	**15939347**	**21.13**	**27.83**	**34.90**	**42.12**	**49.21**	**55.87**	**89.73**

5. For Ninh Binh province

If sea-level rise of 100 cm, approximately 16.35% area of Ninh Binh province is at risk of inundation. Among them, Kim Son district (44.1%) và Yen Khanh district (35.24%) are 2 districts having the highest risk of inundation (**Figure B5,**

Table ***B5***).

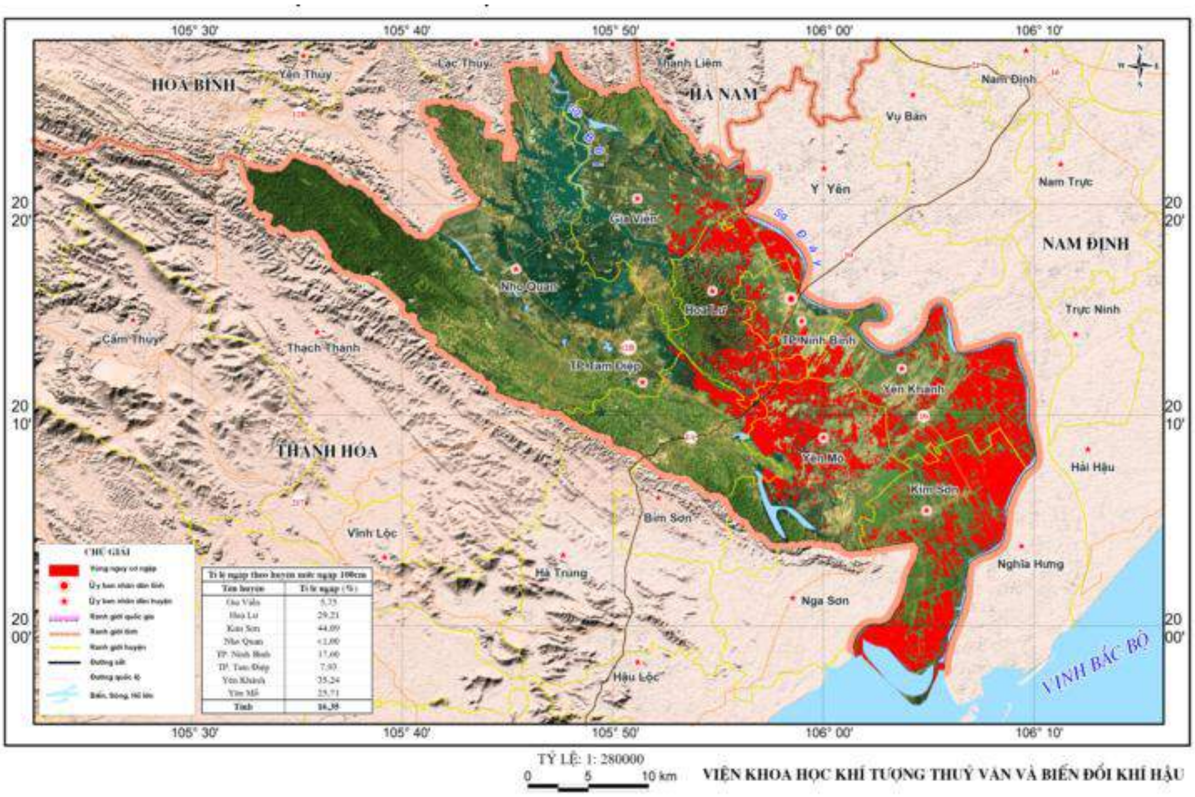


Figure B5. The inundation risk map with sea-level rise of 100cm, Ninh Binh province

Table B5. The inundation risk map for Ninh Binh province

District	**Area (ha)**	**Inundation Percentage (% area) corresponding to rising sea level**						
		50cm	**60cm**	**70cm**	**80cm**	**90cm**	**100cm**	**200cm**
Gia Vien	17870	0.68	0.94	1.93	2.53	3.79	5.75	21.77
Hoa Lu	10153	5.87	7.76	12.51	15.27	20.82	29.21	54.66
Kim Son	16834	8.65	11.77	17.71	22.76	30.18	44.09	87.56
Nho Quan	45282	0.00	0.00	0.01	0.03	0.05	0.09	2.55
Ninh Binh City	4711	1.04	1.37	3.50	5.20	9.42	17.6	49.63
Tam Diep City	10509	1.56	2.54	3.91	4.68	6.19	7.93	14.56
Yen Khanh	14308	3.66	5.95	11.86	17.27	25.26	35.24	84.92
Yen Mo	15015	4.23	6.63	11.88	14.82	19.40	25.71	70.88
Province	**134700**	**2.63**	**3.80**	**6.43**	**8.37**	**11.52**	**16.35**	**38.61**

6. For Thanh Hoa province

If sea-level rise of 100 cm, approximately 1.43% area of Thanh Hoa province is at risk of inundation. Among them, Nga Sơn district (13.51%), Hau Loc district (15.8%) and Hoang Hoa district (17.29%) are 3 districts having the highest risk of inundation (**Figure B6,**

Table *B6*).

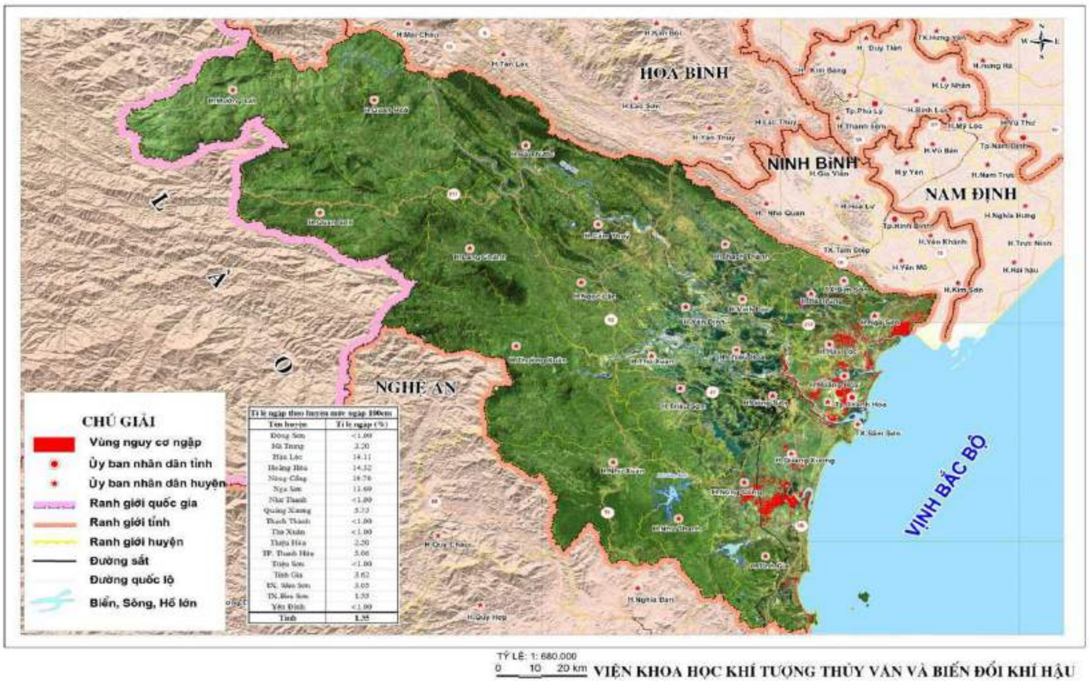


Figure B6. The inundation risk map with sea-level rise of 100cm, Thanh Hoa province

Table B6. The inundation risk map for Thanh Hoa province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Dong Son	10735	0.15	0.15	0.18	0.24	0.38	0.43	3.06
Ha Trung	24552	0.43	0.68	1.06	1.63	2.40	2.95	21.18
Hau Loc	13873	2.39	3.72	5.57	8.14	11.25	15.80	57.92
Hoanng Hoa	22449	7.06	8.53	10.42	12.30	14.59	17.29	47.79
Nong Cong	28686	2.84	4.04	5.36	6.70	8.13	9.14	24.31
Nga Son	14841	4.93	5.99	7.05	8.65	10.99	13.51	54.68
Nhu Thanh	59811	kđk	kđk	kđk	kđk	kđk	kđk	0.05
Quang Xuong	22923	2.22	3.00	3.84	4.87	5.86	7.79	33.27
Thach Thanh	56100	kđk	kđk	kđk	kđk	kđk	kđk	0.01
Thieu Haa	17556	1.04	1.21	1.37	1.42	1.50	1.91	3.86
Thanh Hoa City	5744	1.08	1.10	1.60	1.63	1.68	2.43	7.29
Trieu Son	29023	kđk	kđk	kđk	kđk	kđk	kđk	0.10
Tinh Gia	45066	2.48	3.03	3.38	3.68	4.05	4.22	7.46
Sam Son Town	1708	8.44	8.72	8.99	9.16	9.57	13.04	13.52
Bim Son Town	6371	0.78	0.89	1.00	1.13	1.26	1.30	4.17
Vinh Loc	15820	kđk	kđk	kđk	kđk	kđk	kđk	0.12
Yen Dinh	21700	kđk	kđk	kđk	kđk	kđk	kđk	0.23
Province	**1111000**	0.51	0.65	0.80	0.98	1.20	1.43	4.69

Note: kđk = neglect

7. For Nghe An province

If sea-level rise of 100 cm, approximately 0.51% area of Nghe An province is at risk of inundation. Among them, Dien Chau district (10.49%) and Quynh Luu district (5.55%) are 2 districts having the highest risk of inundation (**Figure B7,**

Table ***B7***).

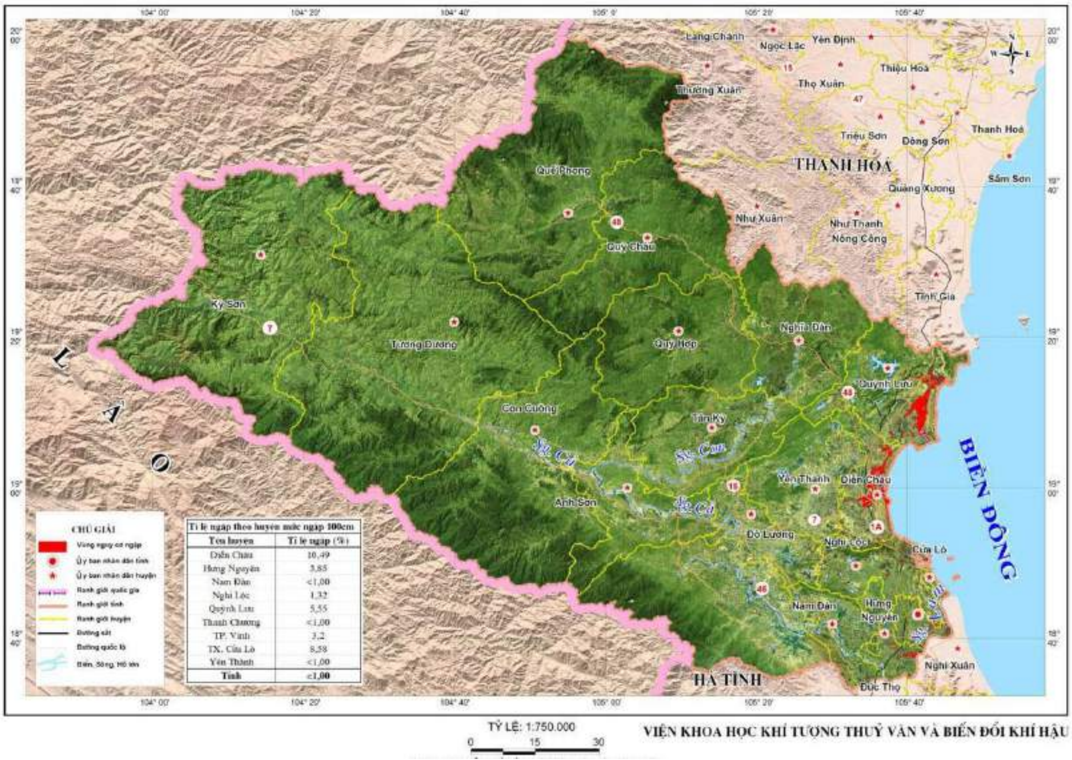


Figure B7. The inundation risk map with sea-level rise of 100cm, Nghe An province

Table B7. The inundation risk map for Nghe An province

District	**Area (ha)**	**Inundation Percentage (% area) corresponding to rising sea level**						
		50cm	**60cm**	**70cm**	**80cm**	**90cm**	**100cm**	**200cm**
Dien Chau	30700	2.38	3.33	4.26	5.14	5.97	10.49	16.03
Hung Nguyen	16200	0.15	0.30	0.51	0.72	1.39	3.85	23.43
Nam Dan	29400	kđk	kđk	kđk	0.01	0.01	0.08	3.88
Nghi Loc	36900	0.46	0.48	0.54	0.60	0.67	1.32	2.47
Quynh Luu	60900	1.73	2.35	3.02	3.77	4.41	5.55	11.85
Vinh City	10400	0.47	0.52	0.57	0.67	0.77	3.02	3.20
Cua Lo Town	2800	2.60	2.67	2.75	2.81	2.85	3.58	3.67
Yen Thanh	54500	0.01	0.01	0.01	0.03	0.07	0.11	1.94
Province	**1649000**	**0.13**	**0.17**	**0.22**	**0.27**	**0.32**	**0.51**	**1.18**

Note: kđk = neglect

8. For Ha Tinh province

If sea-level rise of 100 cm, approximately 2.12% area of Ha Tinh province is at risk of inundation. Among them, Loc Ha district (15.59%), Nghi Xuan (6.03%) and Thanh Ha district (4.80%) are 3 districts having the highest risk of inundation (**Figure B8,**

Table *B8*).

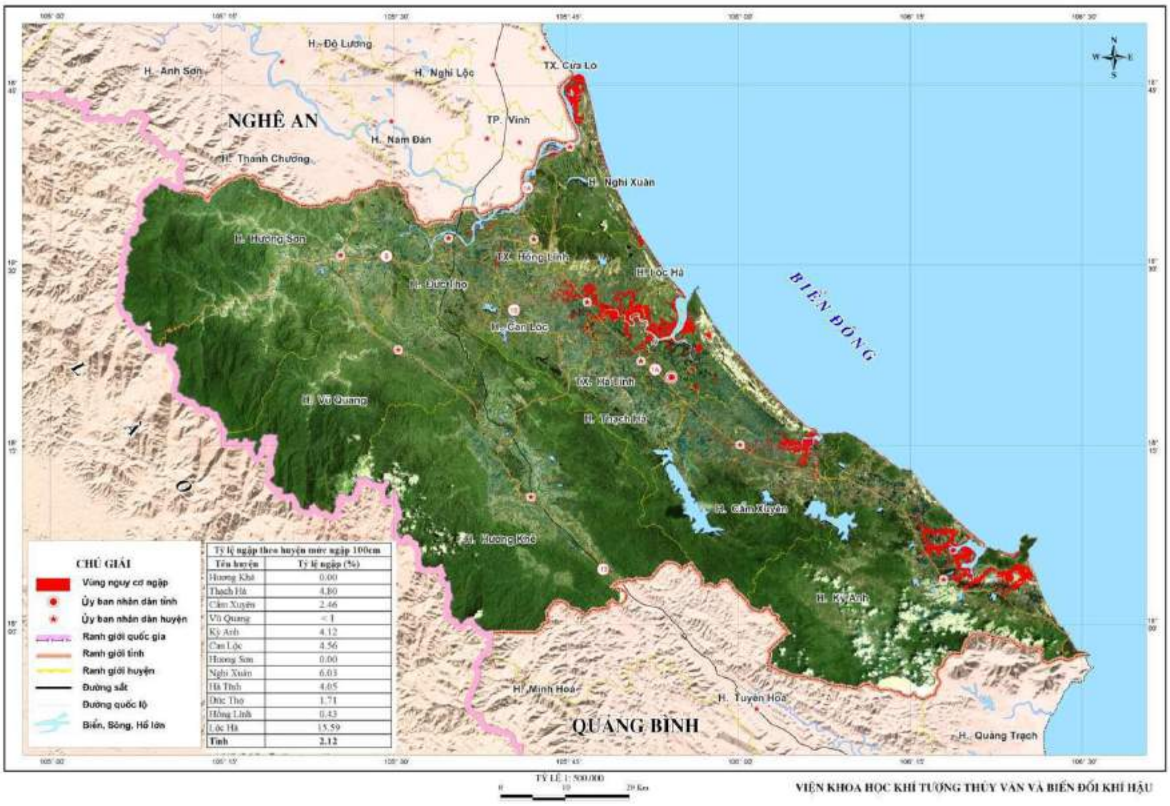


Figure B8. The inundation risk map with sea-level rise of 100cm, Ha Tinh province

Table B8. The inundation risk map for Ha Tinh province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Duc Tho	20389	0.23	0.48	0.72	0.97	1.44	1.71	10.98
Cam Xuyen	63967	1.10	1.28	1.58	1.63	2.17	2.46	6.20
Can Loc	29736	0.65	0.98	1.46	2.06	3.27	4.56	22.99
Huong Son	109944	kđk	kđk	kđk	kđk	kđk	kđk	0.10
Ky Anh	104082	2.38	2.46	2.69	2.99	3.56	4.12	7.45
Loc Ha	11605	3.36	5.04	7.16	9.75	13.18	15.59	39.06
Nghi Xuan	22097	3.11	3.29	3.60	4.12	5.75	6.03	13.49
Thach Ha	35701	1.50	2.01	2.68	3.19	4.04	4.80	20.59
Ha Tinh City	5645	2.30	2.77	3.18	3.40	3.72	4.05	10.72
Hong Linh Town	6047	0.15	0.18	0.20	0.23	0.29	0.43	4.98
Vu Quang	63808	kđk	kđk	kđk	kđk	0.01	0.01	0.02
Province	**599304**	**0.86**	**1.00**	**1.20**	**1.39**	**1.81**	**2.12**	**6.12**

Note: kđk = neglect

9. For Quang Binh province

If sea-level rise of 100 cm, approximately 2.64% area of Quang Binh province is at risk of inundation. Among them, Le Thuy district (6.79%) and Quang Trach district (5.93%) are 2 districts having the highest risk of inundation **(Figure B9,**

Table *B9*).

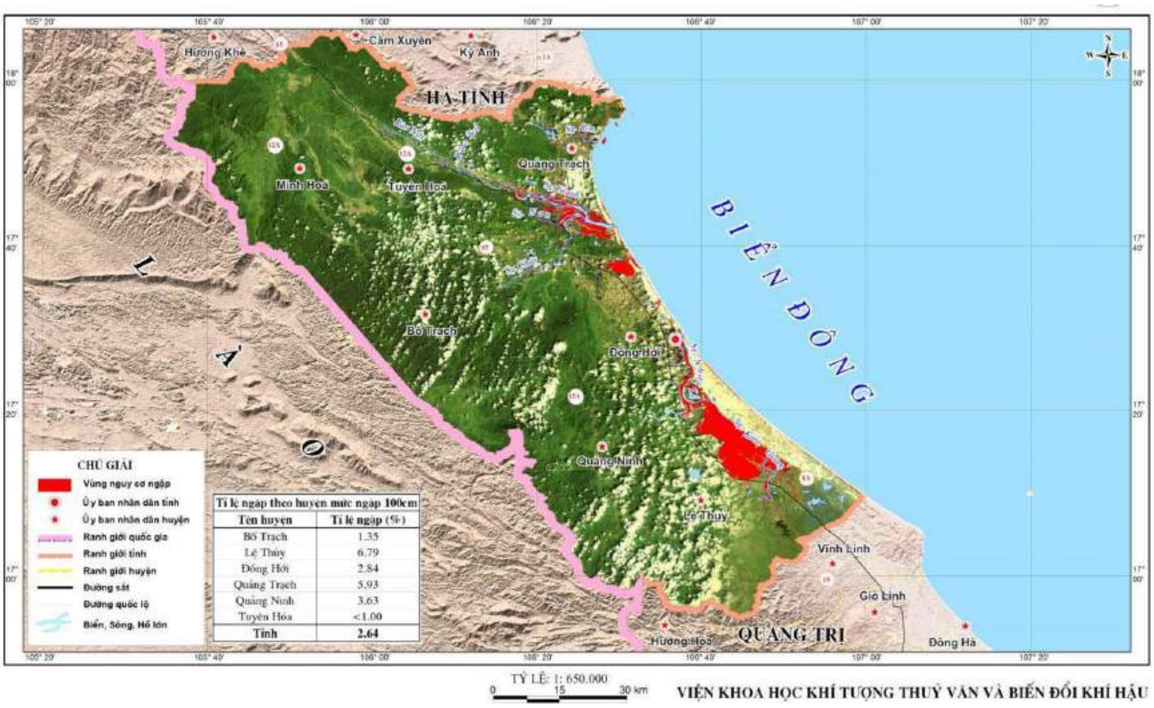


Figure B9. The inundation risk map with sea-level rise of 100cm, Quang Binh province

Table B9. The inundation risk map for Quang Binh province

District	**Area (ha)**	**Inundation Percentage (% area) corresponding to rising sea level**						
		50cm	**60cm**	**70cm**	**80cm**	**90cm**	**100cm**	**200cm**
Bo Trach	211638	0.58	0.72	0.87	1.10	1.12	1.35	2.17
Le Thuy	140374	5.76	5.99	6.21	6.58	6.61	6.79	8.44
Dong Hoi	15604	2.38	2.46	2.54	2.73	2.75	2.84	4.92
Quang Trach	60859	1.61	1.87	2.20	2.93	3.01	5.93	9.16
Quang Ninh	119852	2.67	2.92	3.11	3.44	3.47	3.63	5.15
Tuyen Hoa	113239	0.02	0.04	0.05	0.07	0.09	0.24	0.20
Province	**801200**	**1.73**	**1.87**	**2.01**	**2.24**	**2.27**	**2.64**	**3.64**

10. For Quang Tri province

If sea-level rise of 100 cm, approximately 2.62% area of Quang Tri province is at risk of inundation. Among them, Hai Lang district (9.03%) and Trieu Phong district (7.26%) are 2 districts having the highest risk of inundation (**Figure B10,**

Table *B10*).

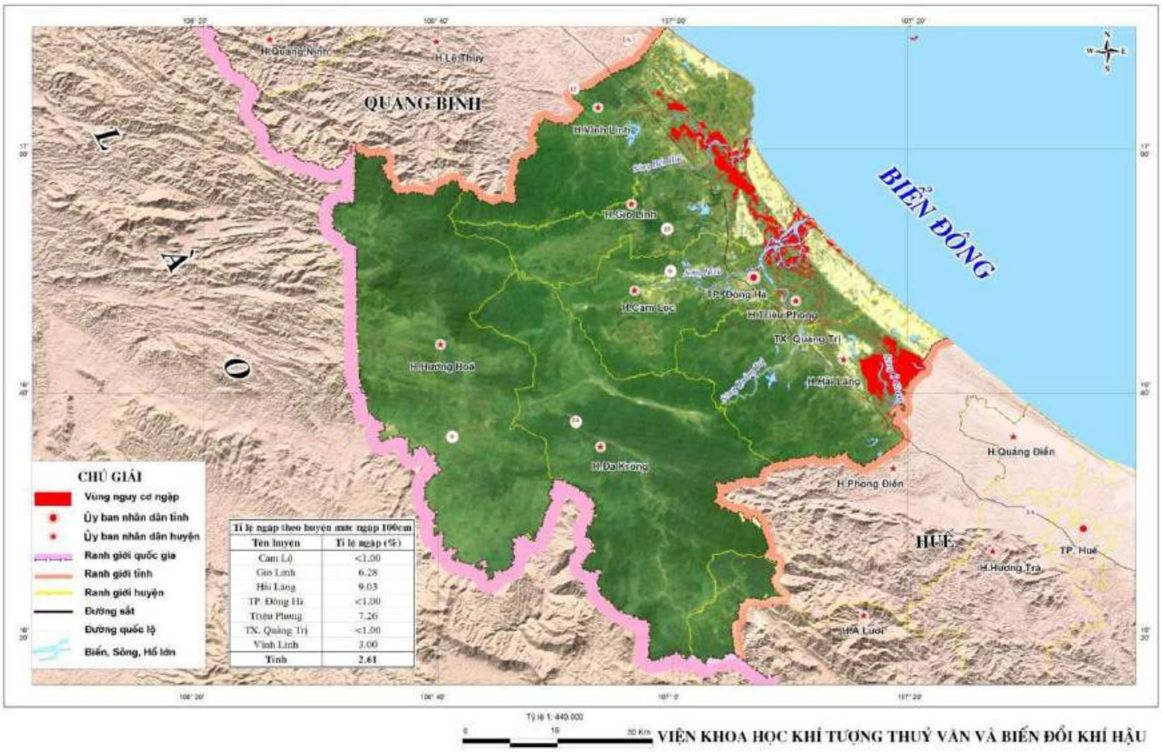


Figure B10. The inundation risk map with sea-level rise of 100cm, Quang Tri province

Table B10. The inundation risk map for Quang Tri province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Cam Lo	34503	kđk	kđk	kđk	kđk	0.01	0.01	0.06
Gio Linh	47524	0.62	1.26	2.11	3.10	4.31	6.28	13.84
Hai Lang	48970	4.31	5.47	6.36	7.11	8.17	9.03	16.02
Dong Ha City	7303	0.03	0.03	0.04	0.04	0.23	0.98	1.66
Trieu Phong	35652	1.36	1.77	2.21	2.71	4.07	7.26	16.70
Quang Tri Town	605	kđk	kđk	kđk	kđk	kđk	0.42	0.93
Vinh Linh	61949	0.67	0.97	1.19	1.61	2.18	3.00	7.78
Province	**463500**	**0.71**	**0.97**	**1.22**	**1.49**	**1.91**	**2.62**	**5.47**

Note: kđk = neglect

11. For Thua Thien – Hue province

If sea-level rise of 100 cm, approximately 7.69% area of Thua Thien-Hue province is at risk of inundation, which is the highest risk of inundation province of the Central costal province, mainly in Tam Giang- Cau Hai lagoon, Phu Vang district (42.58%), Quang Dien district (31.62%) and Hue city (26.50%) **(Figure B11, Table B11).**

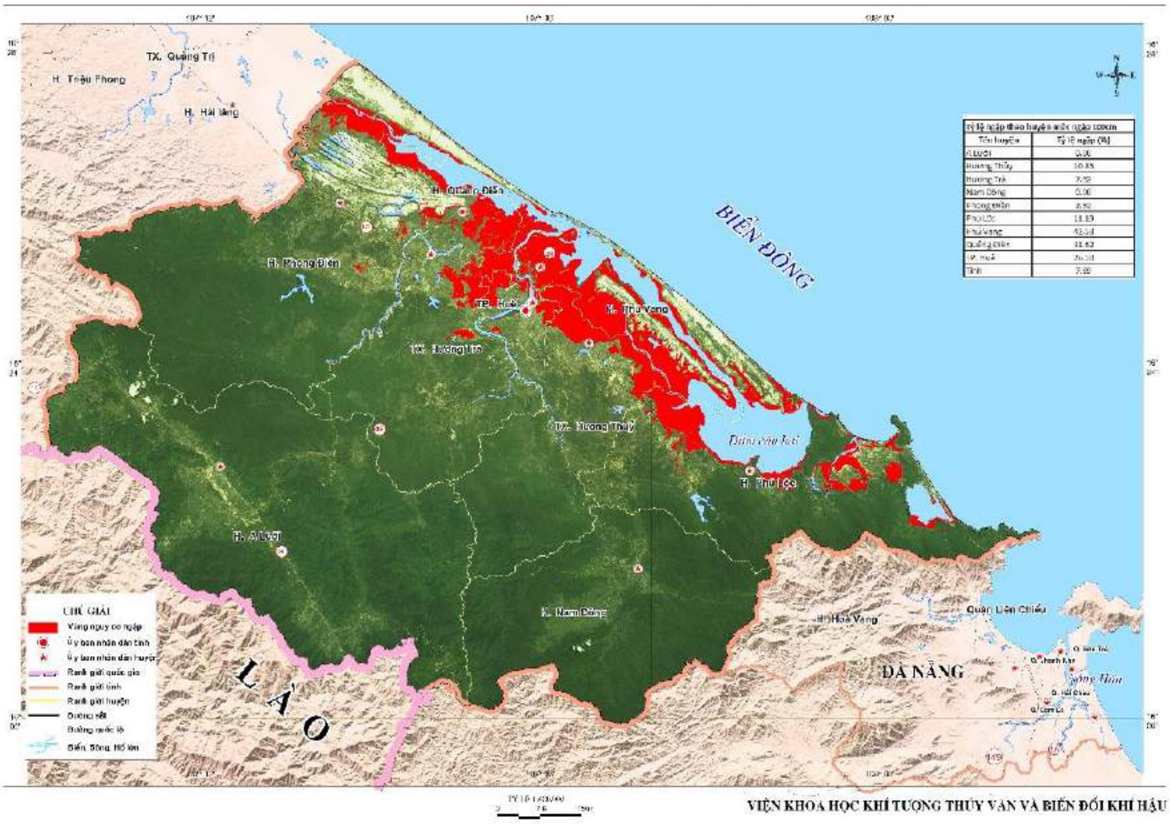


Figure B11. The inundation risk map with sea-level rise of 100cm, Thua Thien– Hue province

Table B11. The inundation risk map for Thua Thien– Hue province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Huong Thuy Town	457	1.71	3.59	5.61	6.99	7.94	10.85	13.06
Huong Tra Town	519	0.91	1.63	2.51	3.31	4.31	7.92	13.30
Phong Dien	950	0.62	0.98	1.48	1.97	2.44	2.92	11.30
Phu Loc	716	1.03	1.45	1.83	2.14	2.44	11.19	14.44
Phu Vang	278	4.43	8.46	14.17	20.22	25.61	42.58	48.93
Quang Dien	164	4.88	8.91	13.75	18.39	24.15	31.62	57.80
Hue City	71	0.94	1.79	3.82	6.54	9.97	26.50	52.86
Province	**5039**	**0.93**	**1.67**	**2.59**	**3.46**	**4.31**	**7.69**	**12.07**

12. For Da Nang city

If sea-level rise of 100 cm, approximately 1.13% area of Da Nang city is at risk of inundation. Among them, Lien Chieu district (4.92%) is the district having the highest risk of inundation (**Figure B10,**

Table ***B10***).

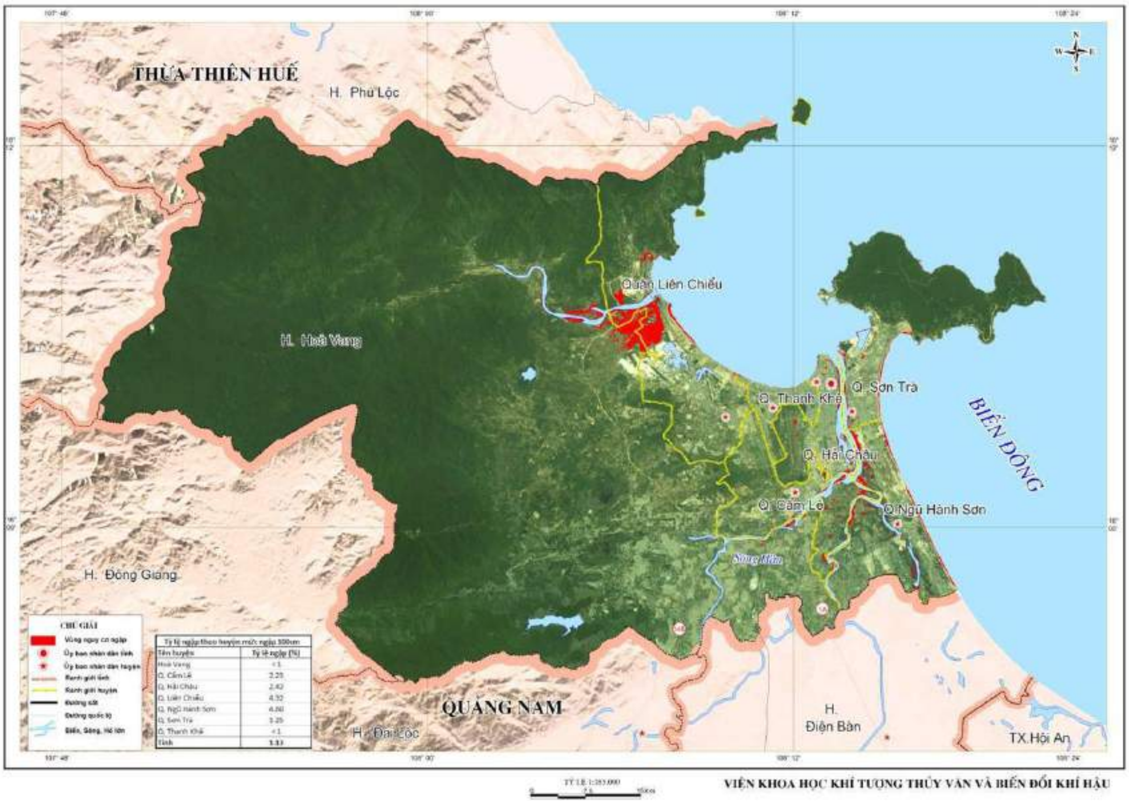


Figure B12. The inundation risk map with sea-level rise of 100cm, Da Nang city

Table B12. The inundation risk map for Da Nang city

District	**Area (ha)**	**Inundation Percentage (% area) corresponding to rising sea level**						
		50cm	**60cm**	**70cm**	**80cm**	**90cm**	**100cm**	**200cm**
Hoa Vang	736	0.19	0.23	0.29	0.34	0.39	0.44	1.14
Cam Le	35	1.61	1.72	1.83	1.96	2.09	2.23	2.74
Hai Chau	21	1.76	1.89	2.00	2.14	2.27	2.42	5.38
Lien Chieu	80	3.27	3.71	4.08	4.39	4.67	4.92	6.87
Ngu Hanh Son	39	3.53	3.71	3.92	4.14	4.35	4.60	4.82
Son Tra	58	0.82	0.83	0.89	1.06	1.15	1.25	1.59
Thanh Khe	9	0.51	0.57	0.63	0.70	0.79	0.86	2.94
Province	**978**	**0.70**	**0.78**	**0.87**	**0.96**	**1.04**	**1.13**	**1.95**

13. For Quang Nam province

If sea-level rise of 100 cm, approximately 0.32% area of Quang Nam province is at risk of inundation, mainly in Hoi An and Tam Ky city. Among them, Hoi An city (4.92%) is the area having the highest risk of inundation (**Figure B13,**

Table *B13*).

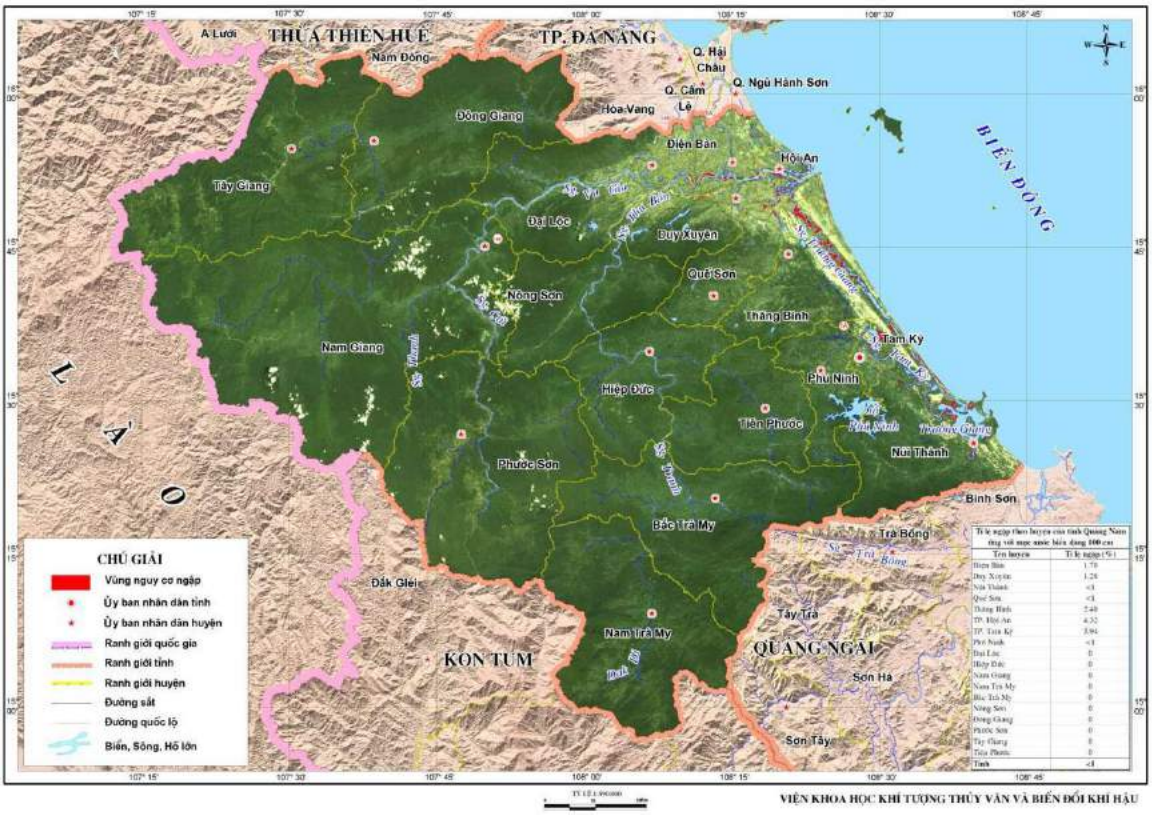


Figure B13. The inundation risk map with sea-level rise of 100cm, Quang Nam province

Table B13. The inundation risk map for Quang Nam province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Dien Ban	21470	0.36	0.77	0.89	0.97	1.06	1.70	3.73
Duy Xuyen	29910	0.63	0.78	0.87	0.96	1.04	1.28	4.70
Nui Thanh	53400	1.33	1.42	1.50	1.60	1.69	1.75	3.17
Que Son	25080	0.20	0.23	0.34	0.39	0.43	0.48	1.99
Thang Binh	38560	0.73	0.95	1.29	1.65	2.05	2.40	6.89
Hoi An City	6150	3.75	3.85	3.94	4.04	4.13	4.32	5.25
Tam Ky City	9260	3.24	3.36	3.47	3.59	3.72	3.94	6.82
Phu Ninh	25150	0.01	0.01	0.02	0.03	0.04	0.04	0.19
Dai Loc	58710	kđk	kđk	kđk	kđk	kđk	kđk	0.05
Total	**1043220**	**0.18**	**0.20**	**0.23**	**0.26**	**0.28**	**0.32**	**0.77**

Note: kđk = neglect

14. For Quang Ngai

If sea-level rise of 100 cm, approximately 0.86% area of Quang Ngai province is at risk of inundation, mainly in costal districts such as Duc Pho district (3.62%), Son Tinh district (3.24%) and Tu Nghia district (3.49 %) (**Figure B14, Table B14**).

Figure B14. The inundation risk map with sea-level rise of 100cm, Quang Ngai province

Table B14. The inundation risk map for Quang Ngai province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Duc Pho	37170	1.48	1.84	2.29	2.71	3.18	3.62	8.06
Binh Son	46390	1.06	1.12	1.18	1.25	1.33	1.41	2.07
Mo Duc	21220	0.85	0.95	1.09	1.25	1.49	1.90	8.60
Son Tịnh	34360	1.50	1.98	2.30	2.59	2.89	3.24	5.79
Tu Nghia	22730	1.91	2.18	2.46	2.77	3.09	3.49	8.02
Quang Ngai City	3710	0.52	0.56	0.60	0.66	0.71	2.78	4.85
Province	**514080**	**0.43**	**0.51**	**0.59**	**0.66**	**0.75**	**0.86**	**1.90**

15. For Binh Dinh province

If sea-level rise of 100 cm, approximately 1.04% area of Binh Dinh province is at risk of inundation, mainly in costal districts, costal lagoons and bay. Among them, Tuy Phuoc district (6.56%), Phu My district (2.71 %) and Hoai Nhon district (2.47%) are 3 districts having the highest risk of inundation (**Figure B15, Table B15**).

Figure B15. The inundation risk map with sea-level rise of 100cm, Binh Dinh province

Table B15. The inundation risk map for Binh Dinh province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Hoai Nhon	42215	1.38	1.56	1.73	1.91	2.12	2.47	5.90
Phu Cat	68291	1.08	1.36	1.71	1.94	2.16	2.40	4.53
Phu My	55820	1.68	1.86	2.02	2.31	2.50	2.71	4.61
Quy Nhon City	28587	1.61	1.77	1.90	2.04	2.19	2.35	4.31
Tuy Phuoc	22059	2.88	3.62	4.28	5.00	5.67	6.56	14.17
Province	**609340**	**0.55**	**0.64**	**0.74**	**0.84**	**0.93**	**1.04**	**2.06**

Note: kđk = neglect

16. For Phu Yen province

If sea-level rise of 100 cm, approximately 1.08% area of Phu Yen province is at risk of inundation. Among them, Dong Hoa district (7.28%) and Tuy An district (4.46%) are 2 districts having the highest risk of inundation (**Figure B16. Table B16**).

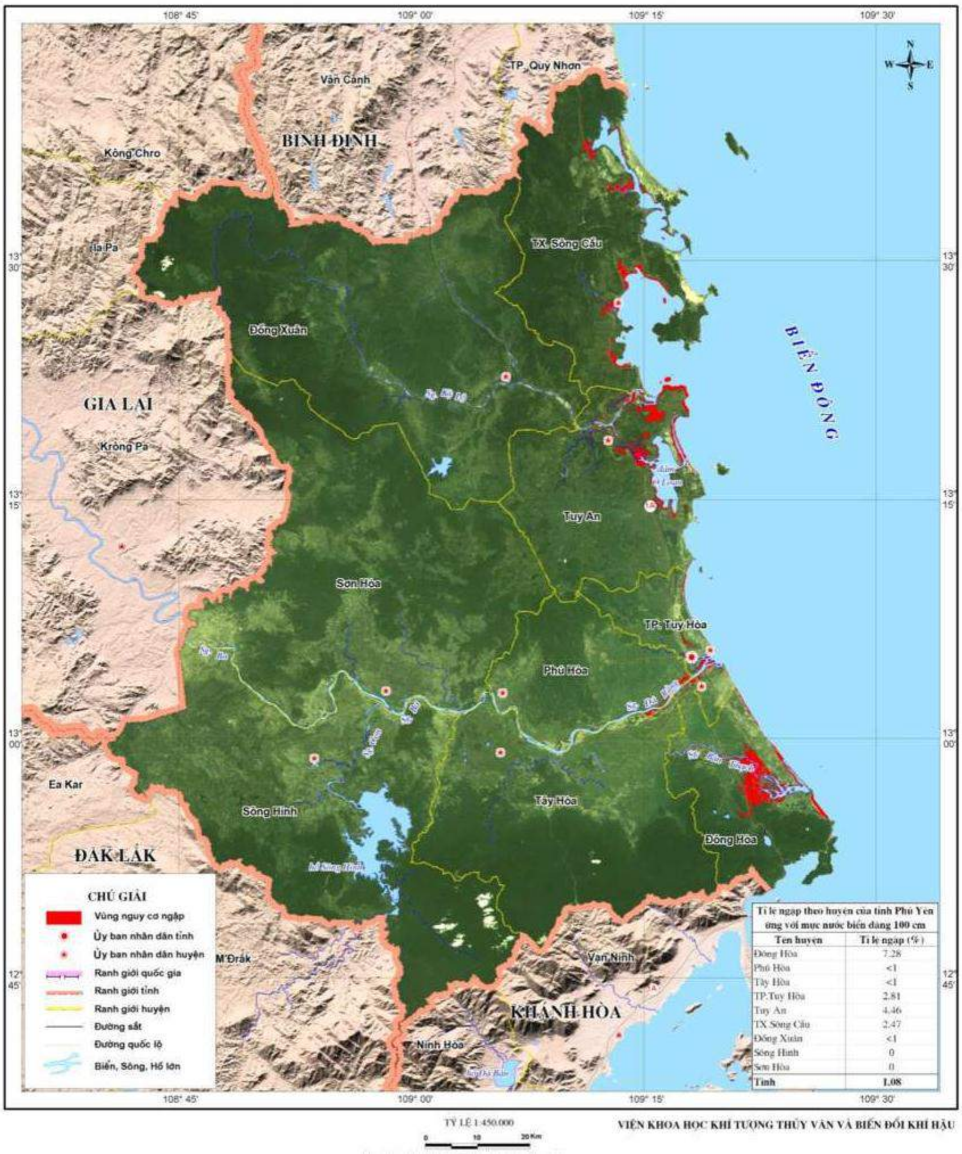


Figure B16. The inundation risk map with sea-level rise of 100cm, Phu Yen province

Table B16. The inundation risk map for Phu Yen province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Dong Hoa	26960	2.94	3.74	4.75	5.65	6.52	7.28	12.65
Phu Hoa	26320	0.49	0.50	0.51	0.52	0.53	0.66	0.86
Tay Hoa	61040	0.02	0.03	0.03	0.03	0.03	0.05	0.08
Tuy Hoa City	10680	2.23	2.33	2.43	2.55	2.66	2.81	4.68
Tuy An	39930	2.38	2.63	2.93	3.52	3.95	4.46	8.00
Song Cau Town	48930	1.28	1.51	1.74	1.99	2.22	2.47	4.86
Province	**503690**	**0.55**	**0.63**	**0.74**	**0.86**	**0.97**	**1.08**	**1.94**

Note: kđk = neglect

17. For Khanh Hoa province

If sea-level rise of 100 cm, approximately 1.49% area of Khanh Hoa province is at risk of inundation. Among them, Cam Ranh district (4.27%) and Van Ninh district (3.59%) are 2 districts having the highest risk of inundation (**Figure B17, Table B17**).

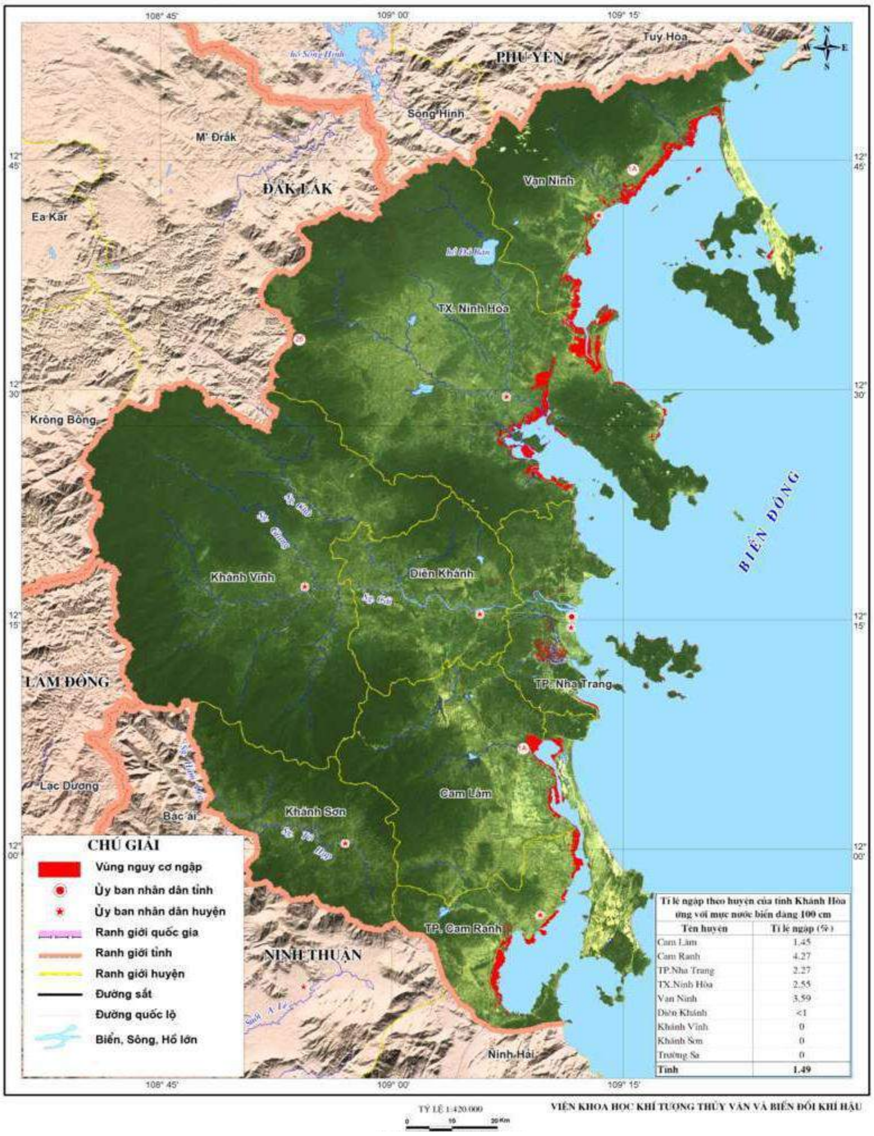


Figure B17. The inundation risk map with sea-level rise of 100cm, Khanh Hoa province

Table B17. The inundation risk map for Khanh Hoa province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Cam Lam	54380	0.24	0.60	0.95	1.22	1.36	1.45	2.24
Cam Ranh	31640	2.65	2.87	3.37	3.78	4.07	4.27	6.53
Nha Trang City	25070	1.56	1.71	1.85	1.99	2.13	2.27	4.32
Ninh Hoa Town	119780	0.93	1.24	1.47	1.75	2.29	2.55	4.54
Van Ninh	55010	2.32	2.65	2.93	3.15	3.38	3.59	6.13
Dien Khanh	33620	kđk	kđk	0.01	0.02	0.03	0.06	0.61
Province	**519320**	**0.72**	**0.89**	**1.04**	**1.19**	**1.38**	**1.49**	**2.58**

Note: kđk = neglect

18. For Ninh Thuan province

If sea-level rise of 100 cm, approximately 0.37% area of Ninh Thuan province is at risk of inundation. Among them, Ninh Hai district (3.15%) is the district having the highest risk of inundation (**Figure B18, Table B18**).

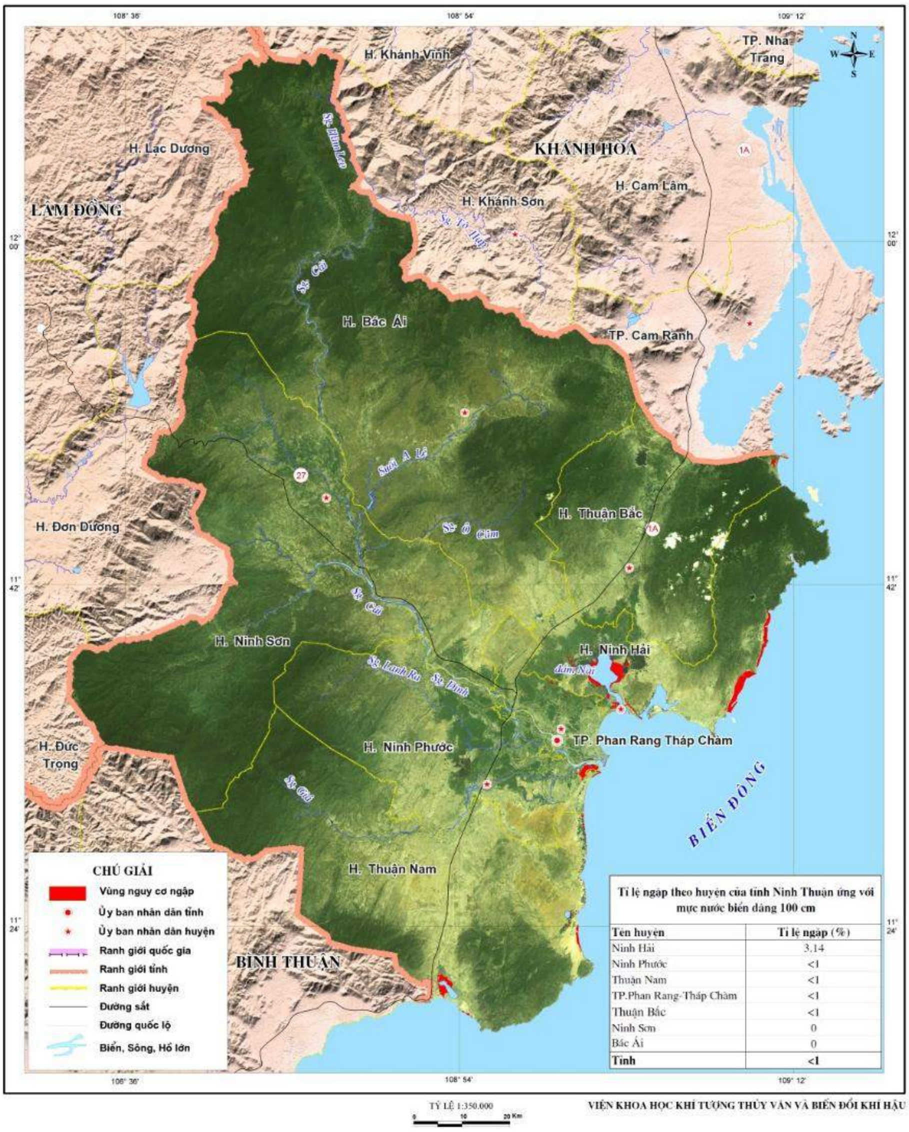


Figure B18. The inundation risk map with sea-level rise of 100cm, Ninh Thuan province

Table B18. The inundation risk map for Ninh Thuan province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Ninh Hai	25390	1.88	2.12	2.51	2.72	2.90	3.14	5.98
Ninh Phuoc	34100	0.27	0.28	0.30	0.32	0.34	0.35	0.67
Thuan Nam	56450	0.13	0.23	0.25	0.27	0.31	0.43	0.84
Phan Rang-Thap Cham City	7890	0.29	0.39	0.45	0.51	0.58	0.71	3.90
Thuan Bac	31920	kđk	0.02	0.04	0.06	0.08	0.10	0.18
Province	**335630**	**0.20**	**0.24**	**0.28**	**0.30**	**0.33**	**0.37**	**0.77**

Note: kđk = neglect

19. For Binh Thuan province

If sea-level rise of 100 cm, approximately 0.18% area of Binh Thuan province is at risk of inundation, which is the lowest risk of inundation province of the Central costal area (**Figure B19, Table B19**).

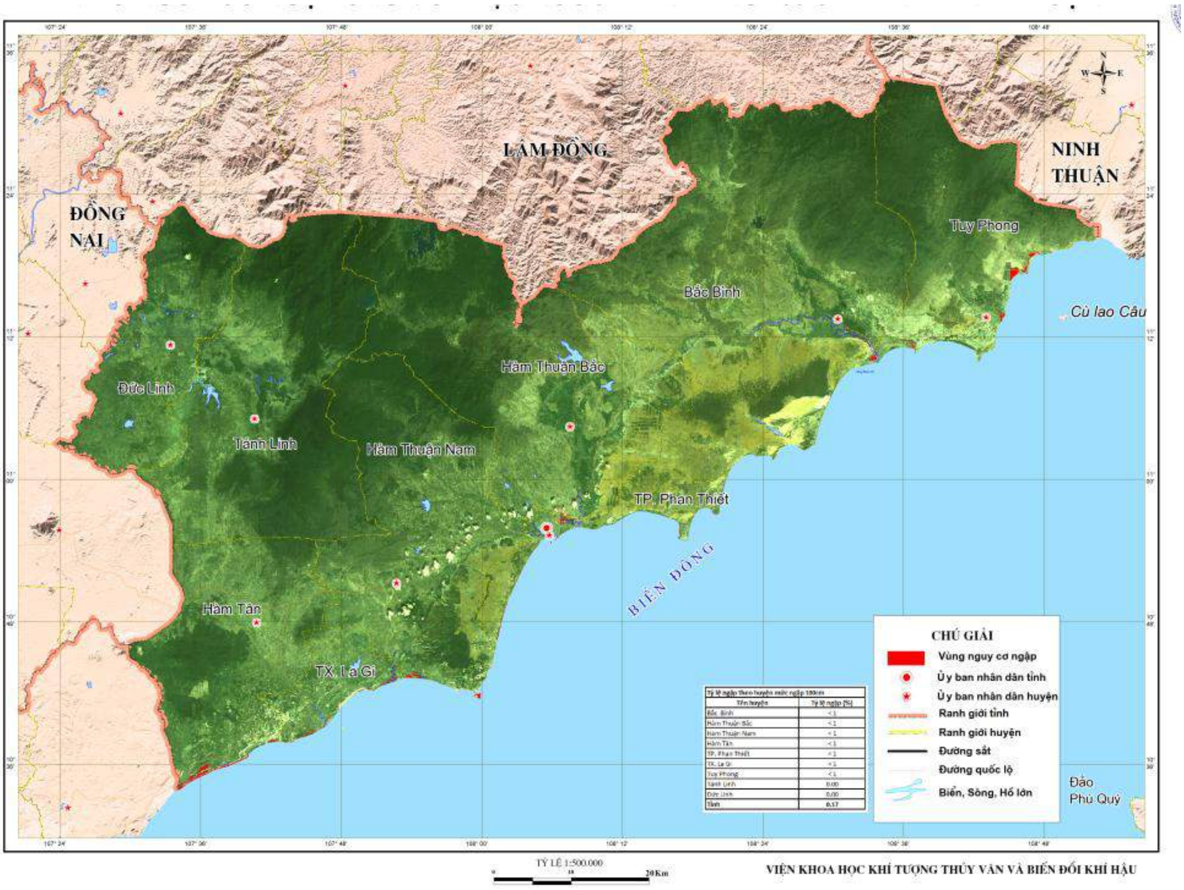


Figure B19. The inundation risk map with sea-level rise of 100cm, Binh Thuan province

Table B19. The inundation risk map for Binh Thuan province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Bac Binh	187705	0.01	0.02	0.02	0.03	0.03	0.04	0.10
Ham Thuan Bac	135044	0.01	0.01	0.01	0.01	0.01	0.02	0.06
Ham Thuan Nam	106279	0.07	0.07	0.08	0.09	0.10	0.13	0.48
Ham Tan	75309	0.30	0.34	0.40	0.46	0.51	0.54	1.07
Phan Thiet City	21168	0.73	0.79	0.83	0.88	0.93	0.97	1.66
Lagi Town	18541	0.20	0.28	0.34	0.55	0.74	0.81	3.20
Tuy Phong	77643	0.37	0.41	0.45	0.49	0.53	0.58	1.17
Province	**796832**	**0.10**	**0.12**	**0.13**	**0.15**	**0.17**	**0.18**	**0.43**

Note: kđk = neglect

20. For Ba Ria-Vung Tau province

If sea-level rise of 100 cm, approximately 4.79% area of Ba Ria- Vung Tau province is at risk of inundation. Among them, Vung Tau city (22.78%) and Tan Thanh district (13.05%) are 2 areas having the highest risk of inundation (**Figure B20, Table B20**).

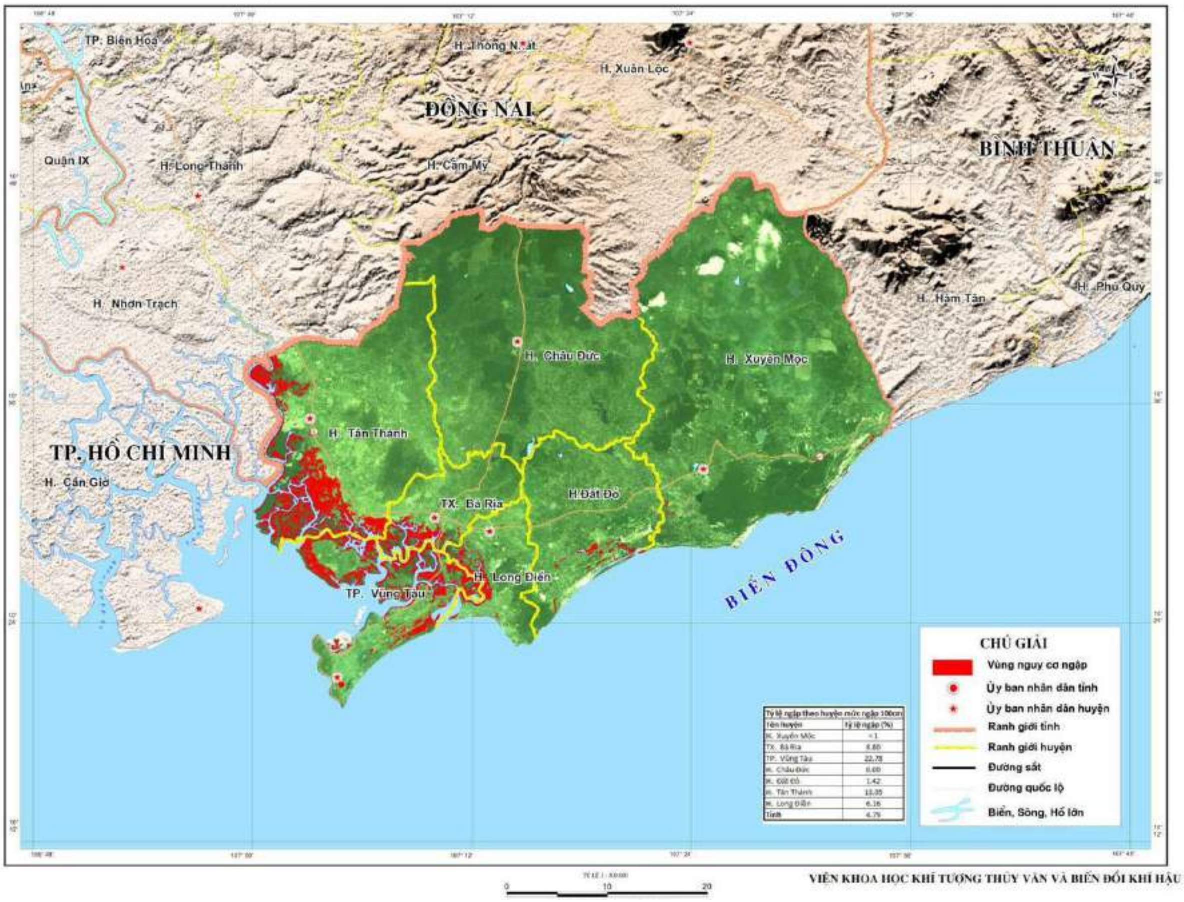


Figure B20. The inundation risk map with sea-level rise of 100cm, Ba Ria – Vung Tau province

Table B20. The inundation risk map for Ba Ria – Vung Tau province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Xuyen Moc	65395	0.06	0.07	0.08	0.10	0.14	0.17	1.40
Ba Ria Town	9058	3.59	4.87	5.80	6.69	7.72	8.80	18.45
Vung Tau City	13482	9.78	11.45	13.65	15.96	19.42	22.78	45.18
Dat Do	17951	0.36	0.49	0.65	0.81	1.20	1.42	8.49
Tan Thanh	33357	5.89	7.00	8.29	9.77	11.27	13.05	21.60
Long Dien	8371	3.92	4.34	4.99	5.50	6.25	6.16	18.22
Province	**190223**	**2.13**	**2.53**	**3.01**	**3.52**	**4.16**	**4.79**	**9.95**

21. For Long An province

If sea-level rise of 100 cm, approximately 27.21% area of Long An province is at risk of inundation. Among them, Ben Luc district (80.11%) and Thu Thua district (65.57%) are 2 districts having the highest risk of inundation (**Figure B21,**

Table B21).

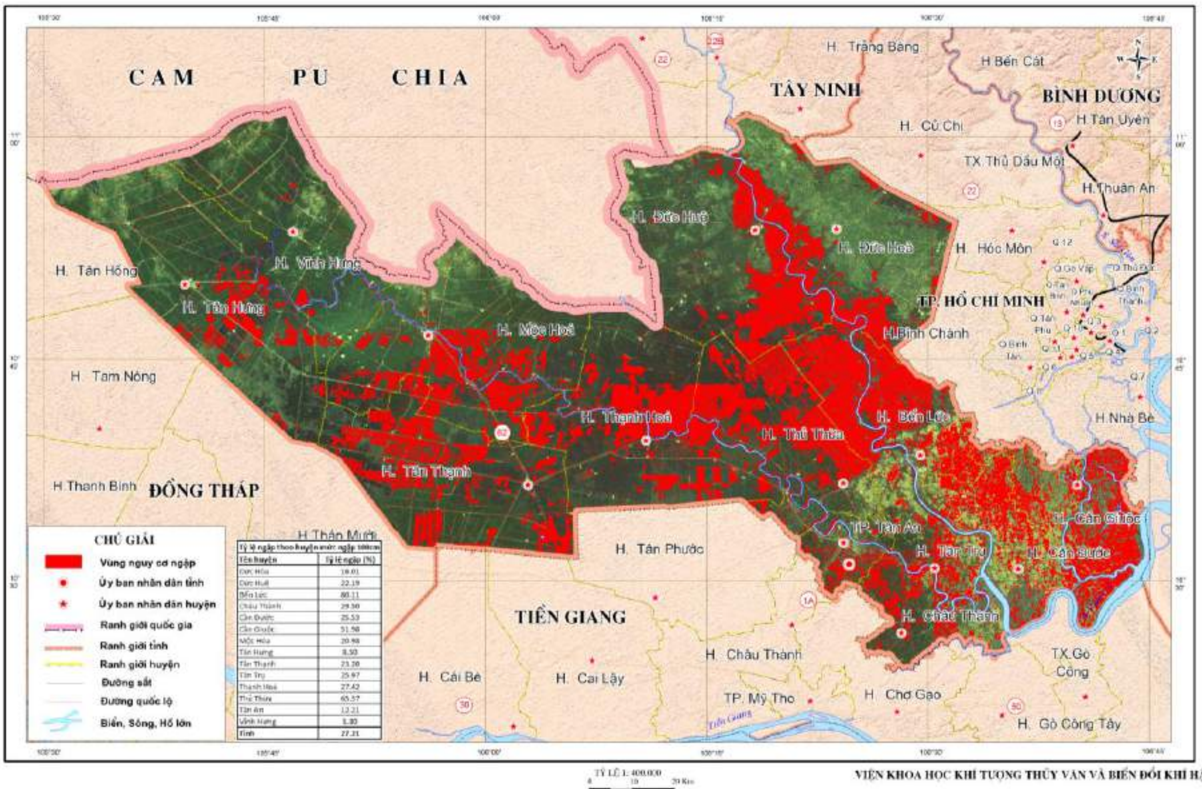


Figure B21. The inundation risk map with sea-level rise of 100cm, Long An province

Table B21. The inundation risk map for Long An province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Duc Hoa	42536	1.79	2.74	5.04	12.59	14.58	16.01	51.05
Duc Hue	42946	1.38	2.63	5.41	13.52	14.14	22.19	87.20
Ben Luc	28752	1.04	4.28	10.50	26.26	45.56	80.11	93.82
Chau Thanh	15411	1.57	2.45	3.29	8.23	10.54	29.50	94.21
Can Duoc	21964	0.10	0.73	1.27	3.17	17.91	25.53	88.26
Can Giuoc	21571	0.01	0.27	0.63	1.56	22.61	51.98	89.61
Moc Hoa	50321	0.06	0.25	0.91	2.26	6.40	20.98	82.28
Tan Hung	49892	0.02	0.05	0.20	0.50	2.58	8.50	77.25
Tan Thanh	42202	0.09	0.16	0.41	1.02	4.63	23.20	95.60
Tan Tru	10529	1.53	2.48	3.29	8.23	14.48	25.97	94.53
Thanh Hoa	46868	0.39	1.14	2.64	6.59	12.57	27.42	96.29
Thu Thua	29837	0.88	2.31	5.21	13.04	22.16	65.57	96.39
Tan An City	8048	1.92	2.84	4.85	9.70	11.17	12.21	89.01
Vinh Hung	38223	0.00	0.09	0.31	0.77	1.76	1.80	68.23
Province	**449100**	**0.61**	**1.36**	**2.85**	**7.12**	**12.89**	**27.21**	**83.90**

22. For Tien Giang province

If sea-level rise of 100 cm, approximately 31.23% area of Tien Giang province is at risk of inundation. Among them, Go Cong district (63.46%), Go Cong Dong district (59.68%) and Go Cong Tay district (58.08%) are 3 districts having the highest risk of inundation (**Figure B22, Table B22**).

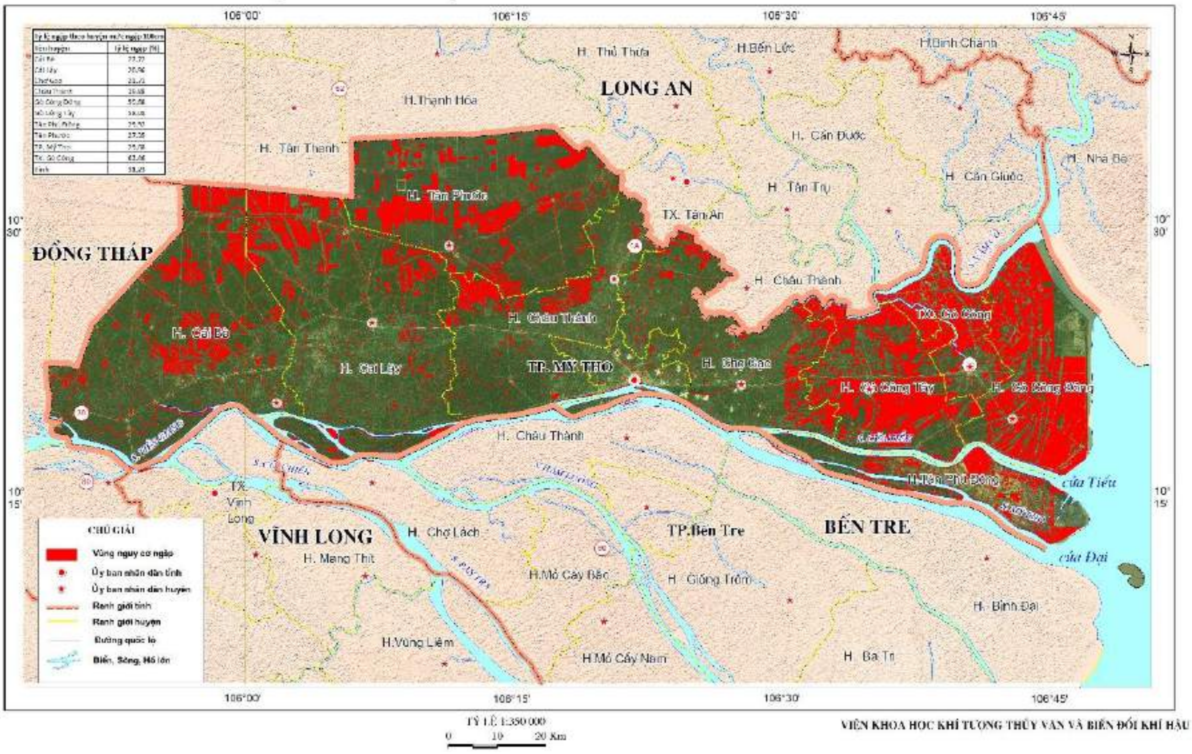


Figure B22. The inundation risk map with sea-level rise of 100cm, Tien Giang province

Table B22. The inundation risk map for Tien Giang province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Cai Be	41601	2.55	6.75	8.67	10.13	12.79	22.72	91.02
Cai Lay	43484	4.85	6.38	7.70	9.57	11.36	20.96	89.53
Cho Gao	23876	2.13	2.96	4.44	7.34	10.83	21.71	93.87
Chau Thanh	23873	4.27	5.25	6.48	7.87	9.56	19.88	91.51
Go Cong Dong	22362	10.78	13.46	20.19	29.02	42.81	59.68	98.75
Go Cong Tay	19075	11.93	13.27	19.90	30.50	45.00	58.08	95.92
Tan Phu Dong	15243	9.83	11.07	14.67	14.75	21.64	29.92	73.30
Tan Phuoc	33303	1.22	3.22	4.83	7.56	11.16	27.35	97.17
My Tho City	7033	9.61	9.70	10.56	14.41	14.32	29.68	67.25
Go Cong Town	9625	17.21	18.19	25.82	28.12	41.48	63.46	94.92
Province	**239470**	**5.83**	**7.51**	**11.27**	**12.82**	**17.95**	**31.23**	**91.38**

23. For Ben Tre province

If sea-level rise of 100 cm, approximately 22.20% area of Ben Tre province is at risk of inundation. Among them, Ba Tri district (45.91%) and Binh Dai district (34.16%) are 2 districts having the highest risk of inundation (**Figure B23, Table B23**).

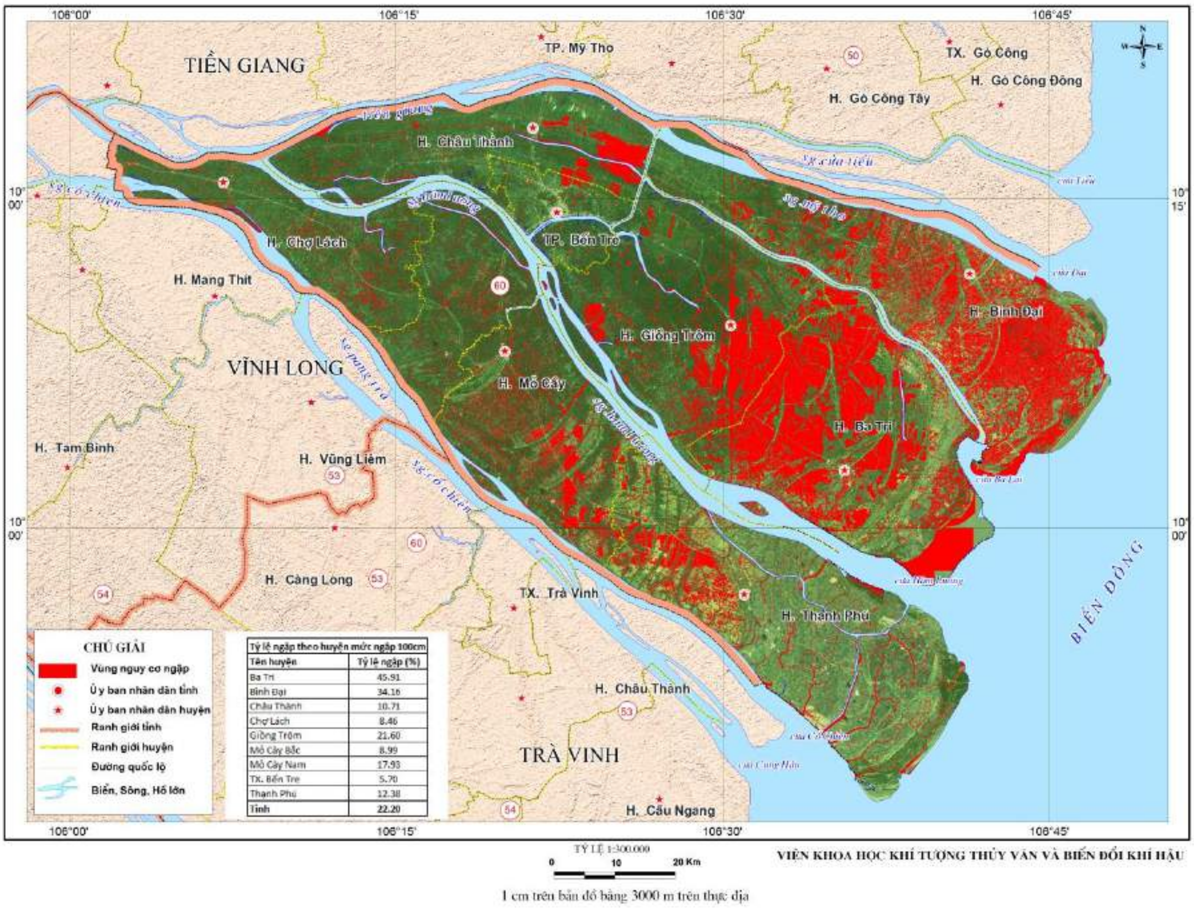


Figure B23. The inundation risk map with sea-level rise of 100cm, Ben Tre province

Table B23. The inundation risk map for Ben Tre province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Ba Tri	36014	10.01	12.18	17.63	22.86	34.53	45.91	86.39
Binh Dai	40953	6.81	9.72	12.53	19.77	26.13	34.16	77.42
Chau Thanh	22906	4.22	5.08	6.60	7.24	8.97	10.71	80.83
Cho Lach	19054	4.79	5.18	6.20	6.37	7.32	8.46	71.50
Giong Trom	31441	5.17	7.06	10.18	13.61	16.48	21.60	87.54
Mo Cay Bac	14603	4.88	5.25	5.77	6.59	7.70	8.99	83.73
Mo Cay Nam	22981	6.29	7.23	8.30	10.56	13.67	17.93	84.33
Ben Tre City	6671	2.20	2.78	3.61	4.33	5.39	5.70	80.59
Thanh Phu	41999	0.38	6.18	7.10	7.45	9.34	12.38	74.97
Province	**235950**	**6.21**	**7.58**	**9.87**	**12.80**	**17.04**	**22.20**	**80.70**

24. For Tra Vinh province

If sea-level rise of 100 cm, approximately 23.30% area of Tra Vinh province is at risk of inundation. Among them, Cang Long district (50.02%) and Tieu Can district (59.3%) are 2 districts having the highest risk of inundation (**Figure B24, Table B24**).

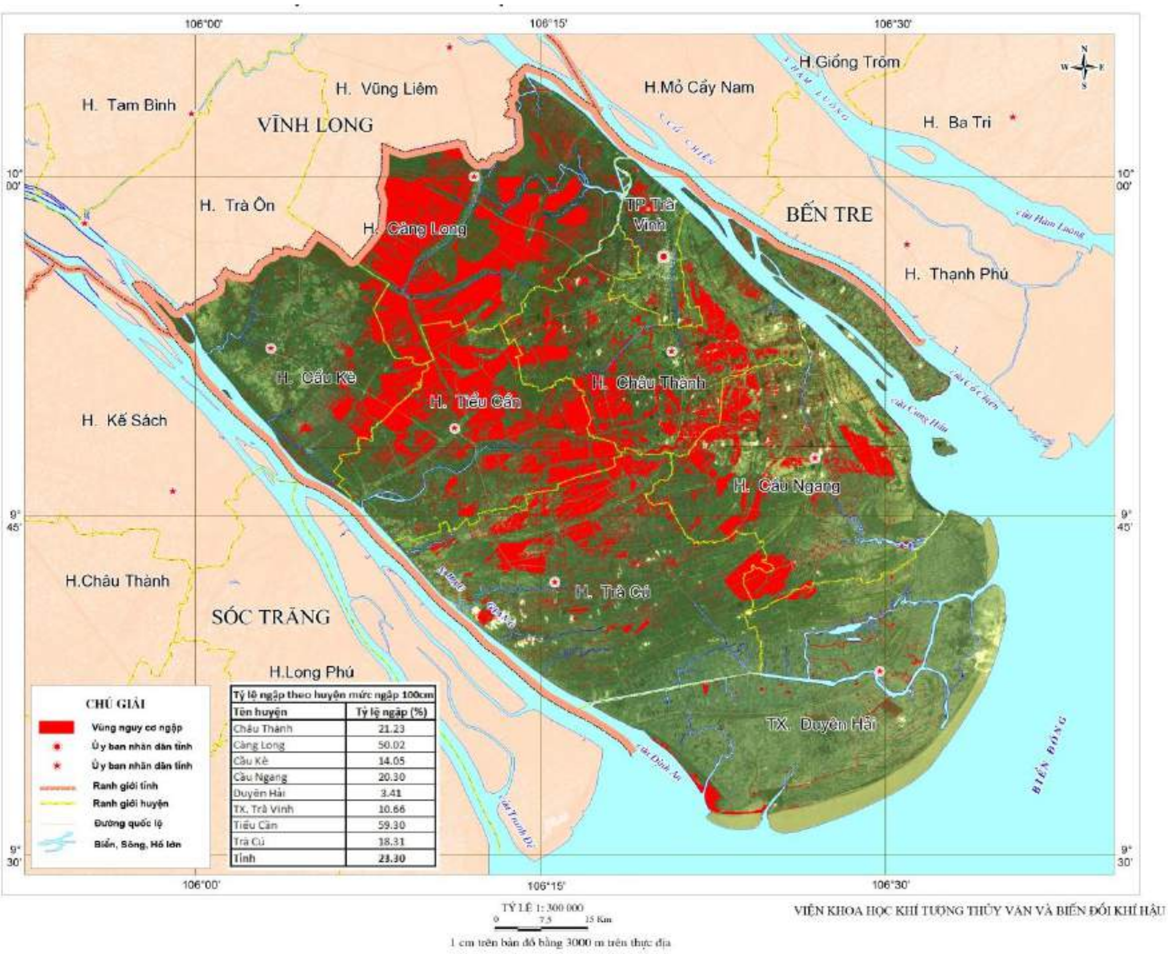


Figure B24. The inundation risk map with sea-level rise of 100cm, Tra Vinh province

Table B24. The inundation risk map for Tra Vinh province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Chau Thanh	34552	11.99	12.09	12.29	12.36	16.04	21.23	94.15
Cang Long	29438	9.12	10.87	13.66	18.69	32.95	50.02	90.29
Cau Ke	24635	0.55	1.04	2.13	4.46	8.98	14.05	96.29
Cau Ngang	32494	11.36	12.63	13.42	15.07	19.07	20.30	93.07
Duyen Hai Town	51268	5.39	5.48	5.56	5.64	5.69	3.41	78.96
Tra Vinh City	6755	7.61	7.82	7.91	8.08	8.87	10.66	72.48
Tieu Can	22776	0.53	1.47	4.71	9.73	25.40	59.30	91.34
Tra Cu	37667	1.64	2.67	4.56	7.09	11.60	18.31	98.35
Province	**234120**	**6.20**	**6.97**	**8.16**	**10.34**	**16.20**	**23.30**	**94.03**

25. For Vinh Long province

If sea-level rise of 100 cm, approximately 18.83% area of Vinh Long province is at risk of inundation. Among them, Vung Liem district (22.88%) and Long Ho district (19.98%) are 2 districts having the highest risk of inundation (**Figure B25, Table B25**).

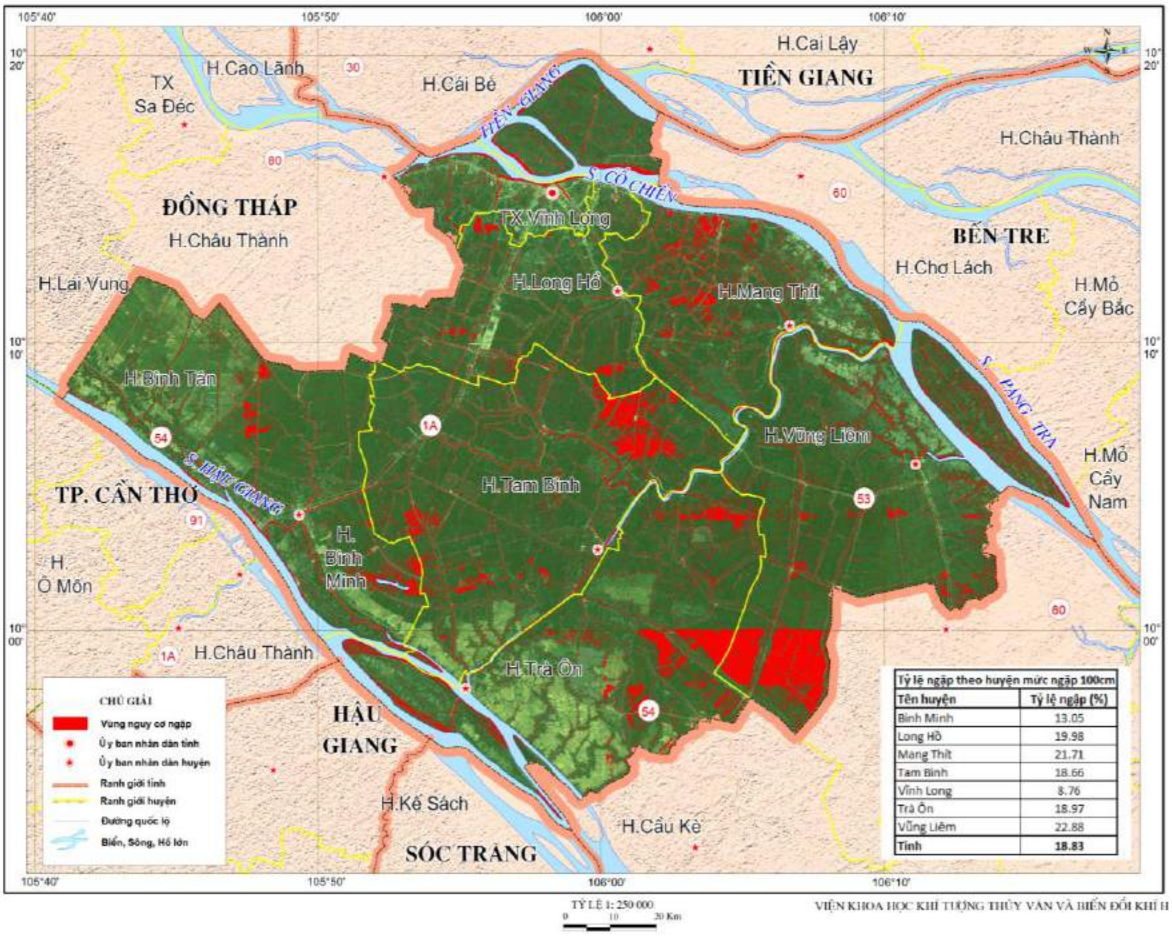


Figure B25. The inundation risk map with sea-level rise of 100cm, Vinh Long province

Table B25. The inundation risk map for Vinh Long province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Binh Minh	25191	5.63	6.39	6.86	7.07	8.06	13.05	92.75
Long Ho	19475	6.41	7.73	8.46	8.72	9.30	19.98	92.92
Mang Thit	16159	8.81	9.87	10.63	11.29	13.19	21.71	97.31
Tam Binh	28855	6.70	7.65	8.31	8.76	10.72	18.66	96.04
Vinh Long	4576	4.93	6.05	6.50	6.58	7.10	8.76	94.81
Tra On	26600	4.62	5.33	6.18	7.74	10.86	18.97	96.55
Vung Liem	31164	7.98	8.92	9.89	11.09	15.58	22.88	98.27
Province	**152020**	**6.55**	**7.49**	**8.23**	**8.97**	**11.27**	**18.83**	**96.75**

26. For Dong Thap province

If sea-level rise of 100 cm, approximately 4.64% area of Dong Thap province is at risk of inundation. Among them, Lai Vung district (11.72%) is the district having the highest risk of inundation (**Figure B26, Table B26**).

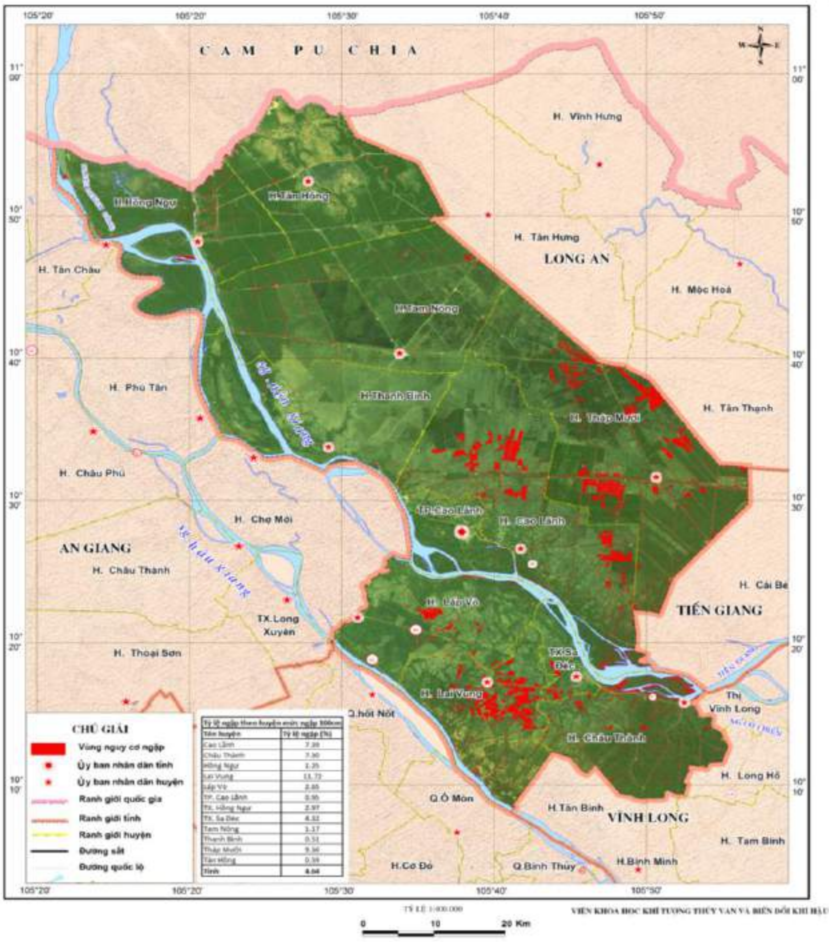


Figure B26. The inundation risk map with sea-level rise of 100cm, Dong Thap province

Table B26. The inundation risk map for Dong Thap

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Cao Lanh	49126	0.42	0.77	1.30	1.80	2.53	7.39	81.82
Chau Thanh	24585	1.73	3.07	3.61	4.27	5.11	7.30	84.31
Hong Ngu	21711	0.18	0.50	0.60	0.90	1.06	1.25	14.94
Lap Vo	24546	0.00	0.01	0.05	0.23	0.66	2.65	30.64
Lai Vung	23914	0.89	0.98	1.12	1.58	4.25	11.72	98.54
Tam Nong	47412	0.04	0.12	0.25	0.39	0.65	1.17	15.72
Thanh Binh	34230	0.02	0.04	0.11	0.21	0.39	0.51	7.33
Thap Muoi	53368	0.46	1.19	1.68	2.13	2.94	9.36	90.26
Tan Hong	31113	0.03	0.06	0.09	0.14	0.30	0.59	8.12
Cao Lanh City	10830	0.17	0.32	0.52	0.67	0.71	0.95	9.25
Hong Ngu Town	11462	0.29	0.67	1.32	2.11	2.68	2.97	28.24
Sa Dec Town	5919	0.01	0.06	0.14	0.28	0.83	4.32	50.78
Province	**337860**	**0.36**	**0.69**	**0.96**	**1.28**	**1.94**	**4.64**	**73.82**

27. For An Giang province

If sea-level rise of 100 cm, approximately 1.82% area of An Giang province is at risk of inundation. Among them, Thoai Son district (8.75%) is the district having the highest risk of inundation (**Figure B27,**

Table B27).

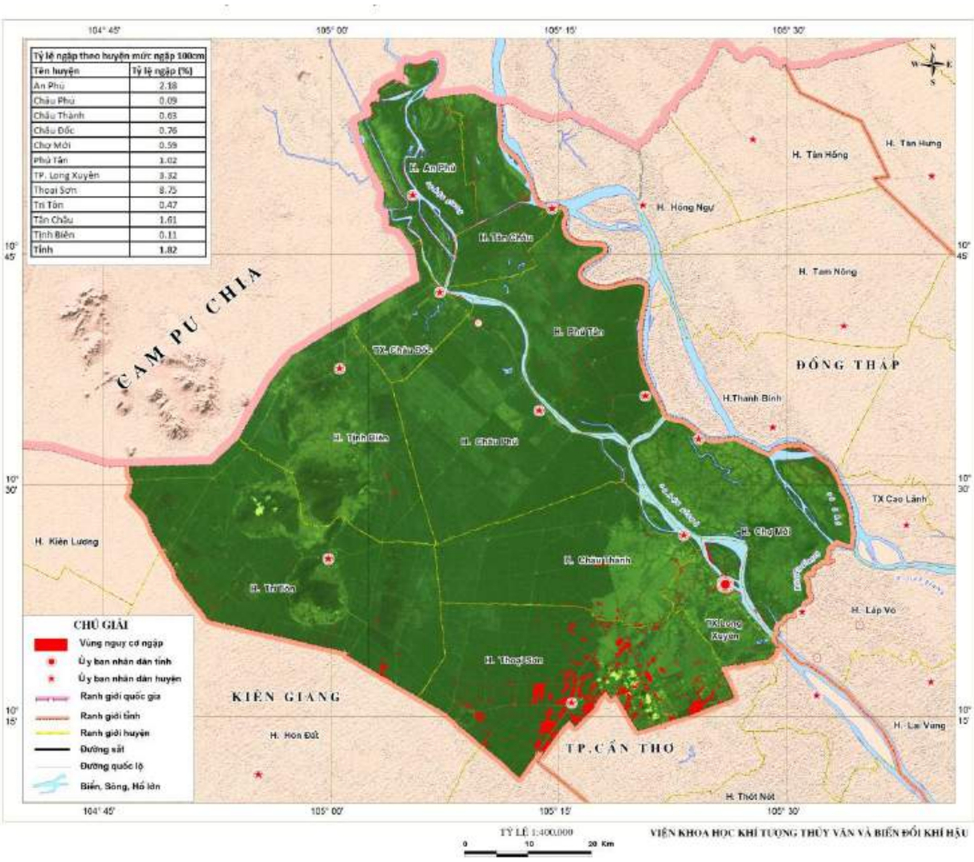


Figure B27. The inundation risk map with sea-level rise of 100cm, An Giang province

Table B27. The inundation risk map for An Giang province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
An Phu	21770	0.25	0.64	1.17	2.12	3.05	4.78	80.38
Cho Moi	36924	0.10	0.13	0.23	0.41	0.50	0.59	79.66
Chau Doc	10456	0.00	0.00	0.03	0.16	0.39	0.76	17.05
Chau Phu	45035	0.00	0.00	0.01	0.02	0.06	0.09	15.16
Chau Thanh	35489	0.01	0.02	0.05	0.11	0.23	0.63	67.95
Phu Tan	32748	0.05	0.18	0.35	0.52	0.86	1.02	65.31
Tinh Bien	35504	0.00	0.00	0.00	0.00	0.02	0.11	21.13
Thoai Son	46806	0.01	0.04	0.16	0.63	2.45	8.75	65.32
Long Xuyen City	11488	0.30	0.88	1.87	2.42	3.11	3.32	94.43
Tri Ton	59978	0.06	0.09	0.12	0.18	0.27	0.47	18.53
Tan Chau	17020	0.43	0.75	0.97	1.21	1.44	1.61	90.13
Province	**342400**	**0.08**	**0.16**	**0.29**	**0.49**	**0.90**	**1.82**	**65.31**

28. For Kien Giang province

If sea-level rise of 100 cm, approximately 76.86% area of Kien Giang province is at risk of inundation. Among them, An Bien district (95.46%) and Giang Thanh district (98.93%) are 2 districts having the highest risk of inundation (**Figure B27,**

Table B27).

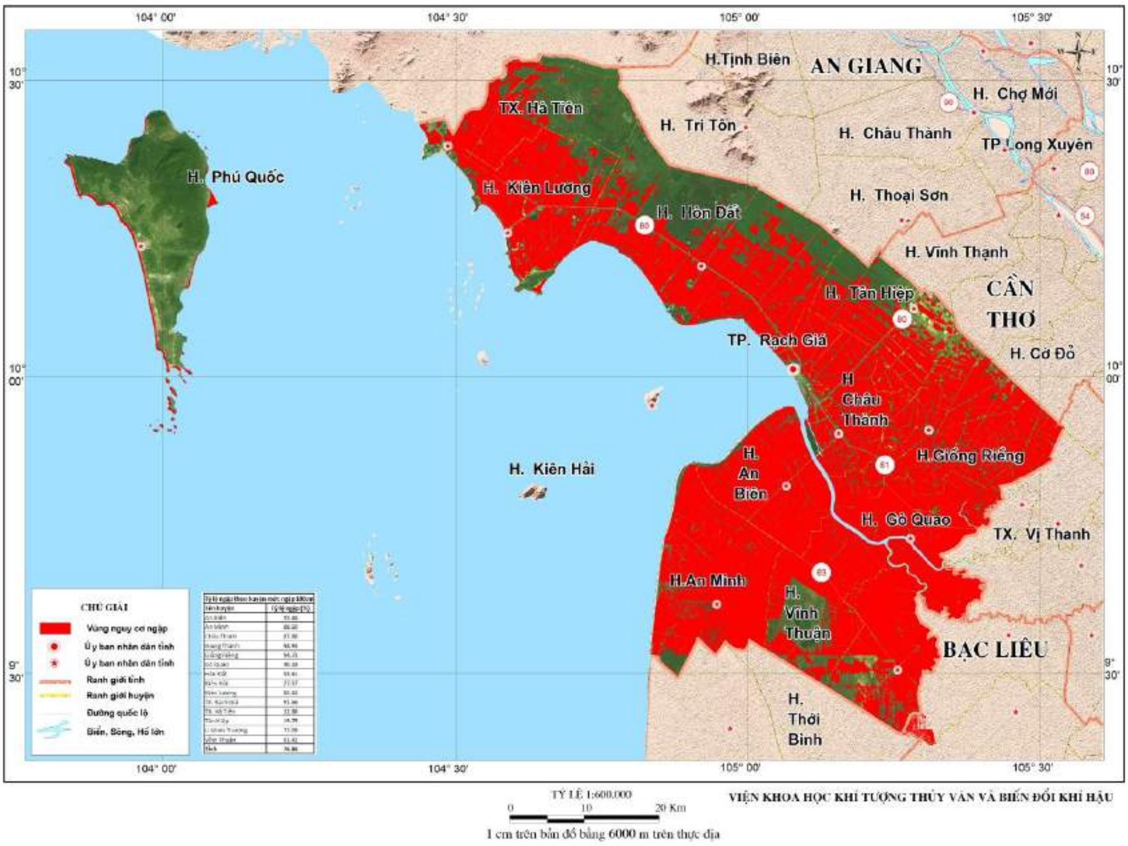


Figure B28. The inundation risk map with sea-level rise of 100cm, Kien Giang province

Table B28. The inundation risk map for Kien Giang

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
An Bien	40001	18.23	44.20	61.90	73.75	93.56	95.46	97.02
An Minh	59009	4.85	17.63	42.73	63.42	85.91	88.69	96.77
Chau Thanh	28524	4.74	18.81	45.21	65.41	82.78	87.86	97.75
Giang Thanh	42358	17.70	54.21	76.81	86.21	98.23	98.93	99.93
Giong Rieng	63886	1.04	3.22	7.86	13.37	20.70	94.73	64.67
Go Quao	43917	3.14	16.88	50.42	84.32	88.09	90.18	99.37
Hon Dat	104597	4.50	9.01	20.13	32.13	47.69	55.61	98.81
Kien Hai	2545	2.27	2.27	2.27	2.27	2.50	27.57	30.32
Kien Luong	47039	18.11	32.31	47.63	61.09	79.33	85.16	96.34
Rach Gia City	10347	0.55	1.98	14.83	58.94	90.19	91.66	99.30
Ha Tien Town	8244	10.18	31.02	58.31	76.24	93.89	32.88	98.98
Tan Hiep	42525	8.61	10.94	13.37	15.06	17.66	19.79	20.46
U Minh Thuong	43218	7.51	17.76	32.81	47.07	62.32	77.05	98.71

Vinh Thuan	37489	6.55	20.58	41.73	59.37	77.46	81.42	98.81
Province	**573690**	**7.77**	**19.76**	**36.25**	**50.80**	**65.86**	**76.86**	**87.94**

29. For Can Tho city

If sea-level rise of 100 cm, approximately 20.52% area of Can Tho city is at risk of inundation. Among them, Thoi Lai district (39.82%) is the province having the highest risk of inundation (**Figure B29, Table B29**).

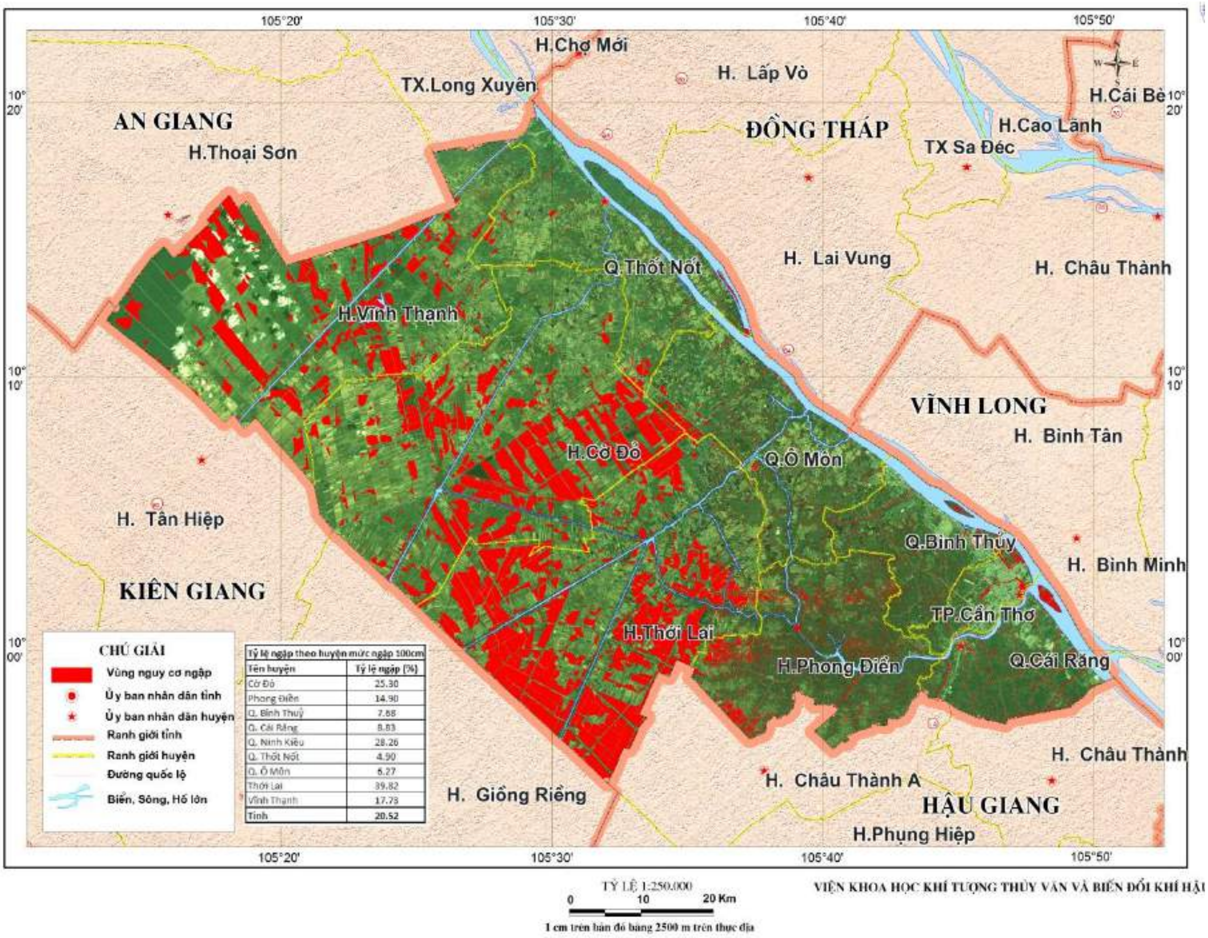


Figure B29. The inundation risk map with sea-level rise of 100cm, Can Tho city

Table B29. The inundation risk map for Can Tho city

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Co Do	32623	kđk	0.04	0.30	1.43	6.87	25.30	93.70
Phong Dien	13133	4.01	4.49	5.15	6.25	8.66	14.90	95.25
Binh Thuy	6754	3.40	4.92	5.02	5.56	6.06	7.68	96.84
Cai Rang	7059	3.62	3.92	4.27	4.71	5.31	8.83	61.82
Ninh Kieu	2771	17.15	17.99	18.96	20.06	21.40	28.26	98.19
Thot Not	13486	1.59	1.68	1.77	1.88	2.00	4.90	9.49
O Mon	12659	0.67	0.80	1.12	1.73	2.63	6.27	70.02
Thoi Lai	27717	0.53	0.63	1.00	2.74	12.28	39.82	92.77
Vinh Thanh	27870	0.02	0.06	0.11	0.28	1.66	17.73	91.17
City	**140900**	**1.44**	**1.59**	**1.90**	**2.77**	**6.54**	**20.52**	**85.57**

30. For Hau Giang province

If sea-level rise of 100 cm, approximately 82.46% area of Hau Giang province is at risk of inundation. Among them, Long My district (97.97%) and Phung Hiep district (92.94%) are 2 districts having the highest risk of inundation (**Figure B30, Table B30**).

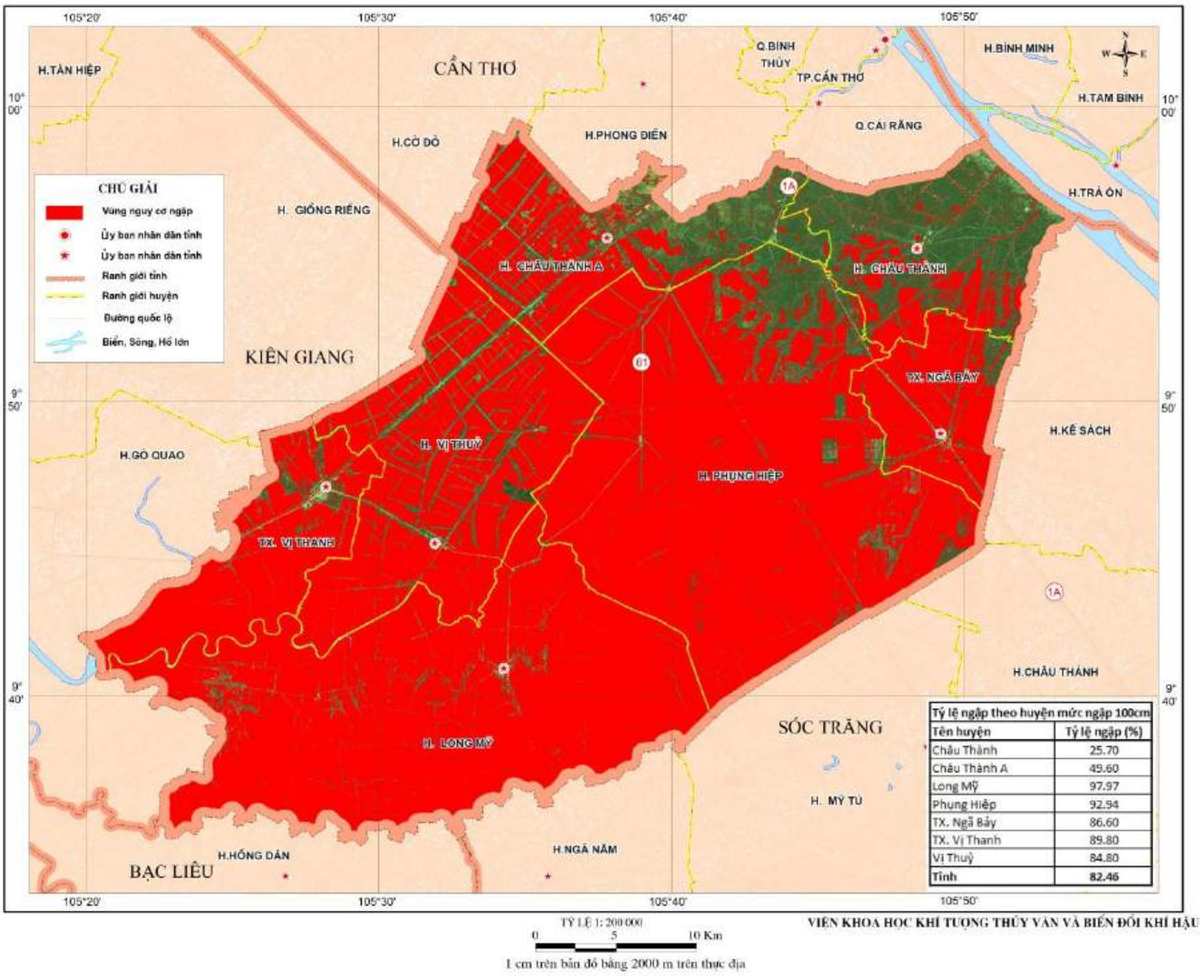


Figure B30. The inundation risk map with sea-level rise of 100cm, Hau Giang province

Table B30. The inundation risk map for Hau Giang province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Chau Thanh	14001	5.27	6.34	7.53	10.66	16.61	25.70	94.18
Chau Thanh A	15898	1.16	2.29	5.51	17.13	37.21	49.60	98.48
Long My	40950	17.76	39.78	65.10	79.25	89.05	97.97	99.12
Phung Hiep	48468	7.46	21.12	43.42	63.58	77.21	92.94	98.61
Nga Bay Town	7821	9.12	21.53	37.93	57.62	74.67	86.60	99.02
Vi Thanh Town	11863	14.04	31.70	49.96	68.11	81.67	89.80	99.96
Vi Thuy	22956	3.76	18.73	49.17	69.83	79.56	84.80	99.79
Province	**160240**	**9.29**	**23.17**	**43.11**	**59.34**	**71.58**	**82.46**	**99.33**

31. For Soc Trang province

If sea-level rise of 100 cm, approximately 53.61% area of Soc Trang province is at risk of inundation. Among them, My Tu district (97.75%) and Nga Nam district (96.54%) are 2 districts having the highest risk of inundation (**Figure B31, Table B31**).

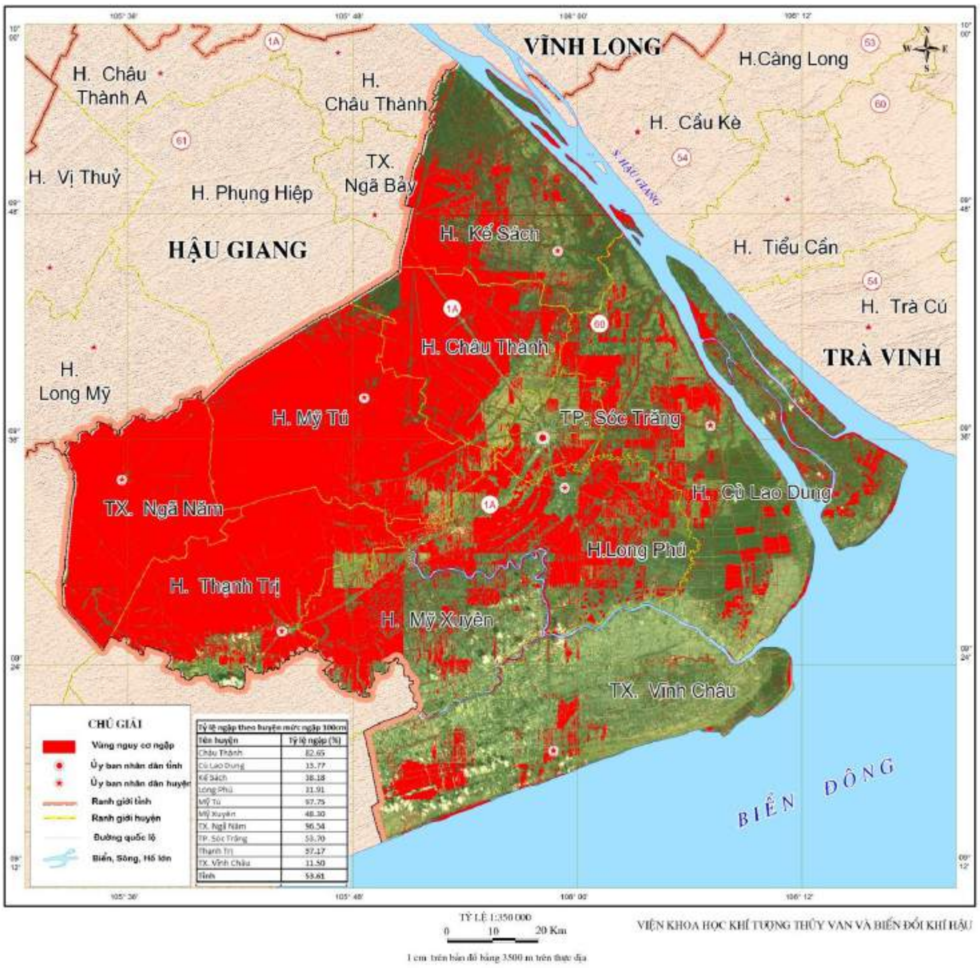


Figure B31. The inundation risk map with sea-level rise of 100cm, Soc Trang province

Table B31. The inundation risk map for Soc Trang province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Chau Thanh	23729	2.83	6.64	27.29	50.83	68.09	82.65	99.79
Cu Lao Dung	33423	1.08	1.29	11.23	12.07	12.69	13.77	78.85
Ke Sach	35298	3.15	4.53	14.88	23.02	24.68	38.18	88.14
Long Phu	45904	0.45	1.35	5.61	10.52	13.23	31.91	86.57
My Tu	36935	10.96	30.96	51.24	72.22	93.33	97.75	99.96
My Xuyen	56409	2.01	3.09	5.43	11.53	28.58	48.30	97.57
Nga Nam Town	24259	28.43	60.04	83.68	96.05	97.30	96.54	99.89
Soc Trang City	7304	1.02	2.29	4.71	8.21	19.39	53.70	98.27
Thanh Tri	28935	7.94	23.48	40.64	61.14	87.61	97.17	99.95
Vinh Chau Town	56262	0.79	0.83	2.45	4.86	5.95	11.50	86.62
Province	**322330**	**4.96**	**11.30**	**21.19**	**31.16**	**39.36**	**53.61**	**92.38**

32. For Bac Lieu province

If sea-level rise of 100 cm, approximately 48.6% area of Bac Lieu province is at risk of inundation. Among them, Hong Dan district (90.78%) and Phuoc Long district (73.45%) are 2 districts having the highest risk of inundation (**Figure B32, Table B32**).

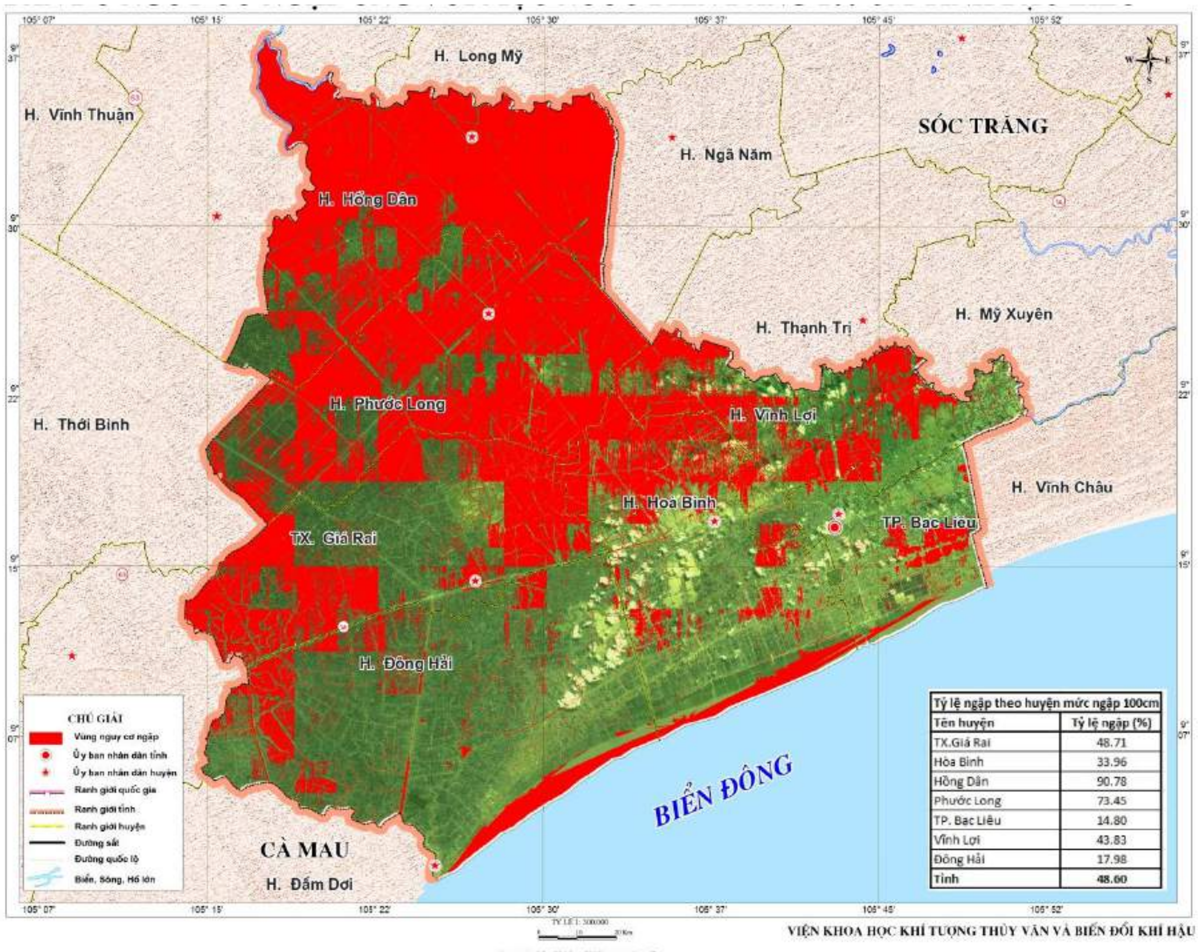


Figure B32. The inundation risk map with sea-level rise of 100cm, Bac Lieu province

Table B32. The inundation risk map for Bạc Liêu

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Gia Rai Town	35506	1.43	3.01	7.54	15.48	31.27	48.71	98.88
Hoa Binh	36735	2.28	4.78	6.97	11.74	18.87	33.96	96.15
Hong Dan	44050	10.70	22.48	41.24	59.51	72.66	90.78	95.79
Phuoc Long	42346	4.32	9.07	20.95	37.25	54.56	73.45	99.40
Bac Lieu City	15920	0.67	1.40	2.64	4.99	8.81	14.80	84.63
Vinh Loi	25267	1.54	3.23	6.58	12.71	23.88	43.83	97.87
Dong Hai	56111	1.68	3.54	5.09	7.12	10.45	17.98	90.81
Province	**252600**	**3.65**	**7.65**	**14.54**	**23.37**	**33.78**	**48.60**	**95.29**

33. For Ca Mau province

Ca Mau has 3 sides of the sea. If sea-level rise of 100 cm, approximately 57.69% area of Ca Mau province is at risk of inundation. Among them, Tran Van Thoi district (90.02%) and Cai Nuoc district (87.62%) are 2 districts having the highest risk of inundation (**Figure B33, Table B33).**

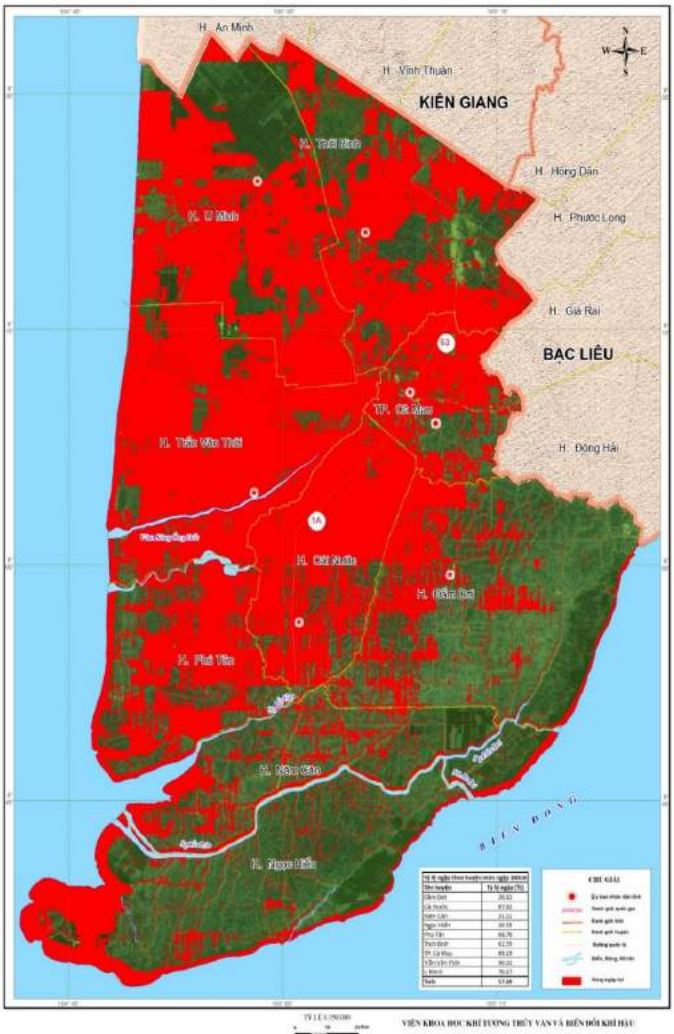


Figure B33. The inundation risk map with sea-level rise of 100cm, Ca Mau province

Table B33. The inundation risk map for Ca Mau province

District	Area (ha)	Inundation Percentage (% area) corresponding to rising sea level						
		50cm	60cm	70cm	80cm	90cm	100cm	200cm
Dam Doi	82354	4.12	6.22	9.95	13.93	18.51	28.82	87.03
Cai Nuoc	41693	21.16	38.90	62.24	77.13	84.23	87.62	99.99
Nam Can	48642	7.69	8.95	14.31	15.74	16.72	31.51	90.50
Ngoc Hien	73957	5.51	6.71	10.73	13.02	15.26	30.59	85.34
Phu Tan	44984	13.01	19.92	31.87	44.62	49.77	68.70	96.23
Thoi Binh	63750	3.78	7.70	12.32	17.24	42.52	62.59	99.82
Ca Mau City	24886	7.06	12.03	19.25	26.95	50.48	69.19	99.89
Tran Van Thoi	71507	16.05	25.87	41.40	57.96	73.86	90.02	96.96
U Minh	77098	4.25	8.27	13.24	18.53	48.15	70.67	99.88
Provine	**528870**	**8.47**	**13.69**	**21.90**	**30.66**	**40.87**	**57.69**	**94.30**

34. The inundation risk due to rising sea level of 100cm for Island and Island group of Viet Nam

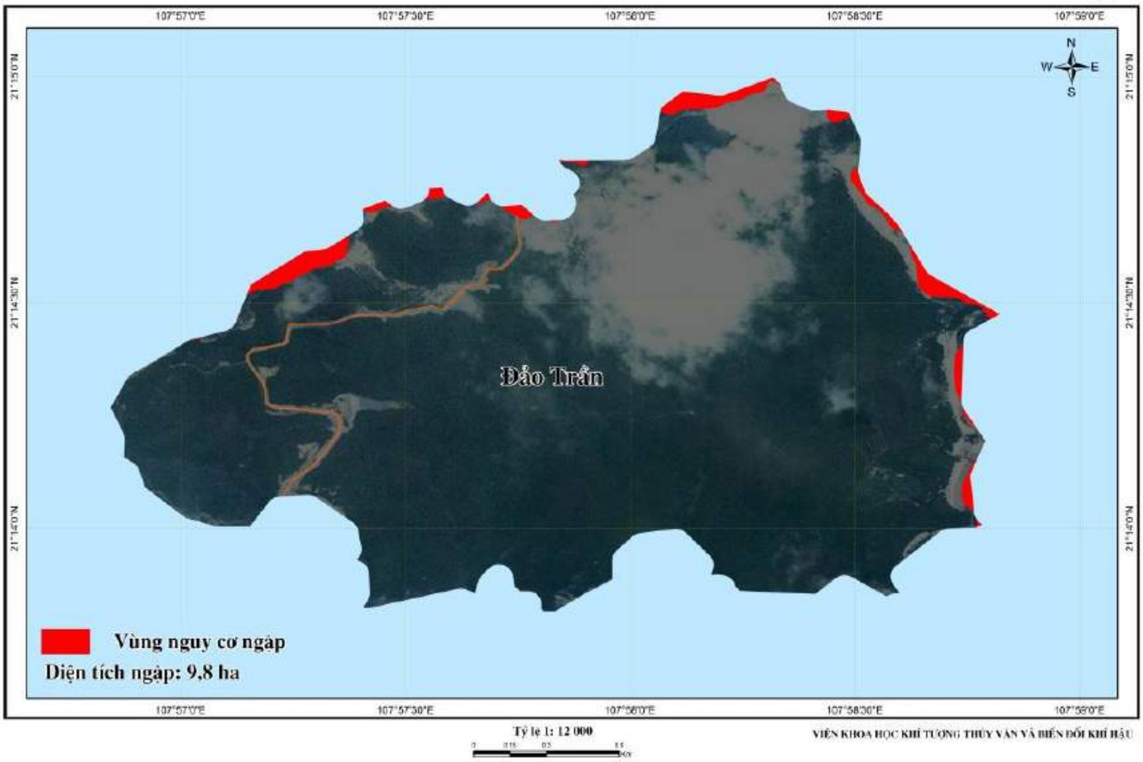


Figure B34. The inundation risk map with sea-level rise of 100cm, Tran island, Quang Ninh province

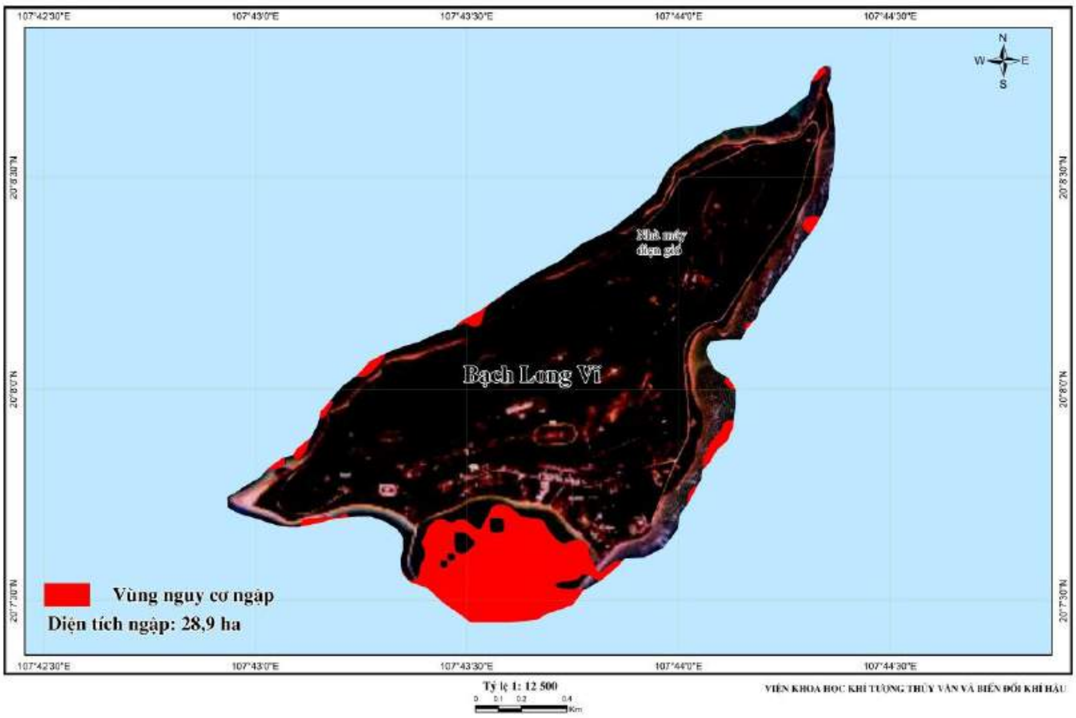


Figure B35. The inundation risk map with sea-level rise of 100cm, Bach Long Vi island, Hai Phong city

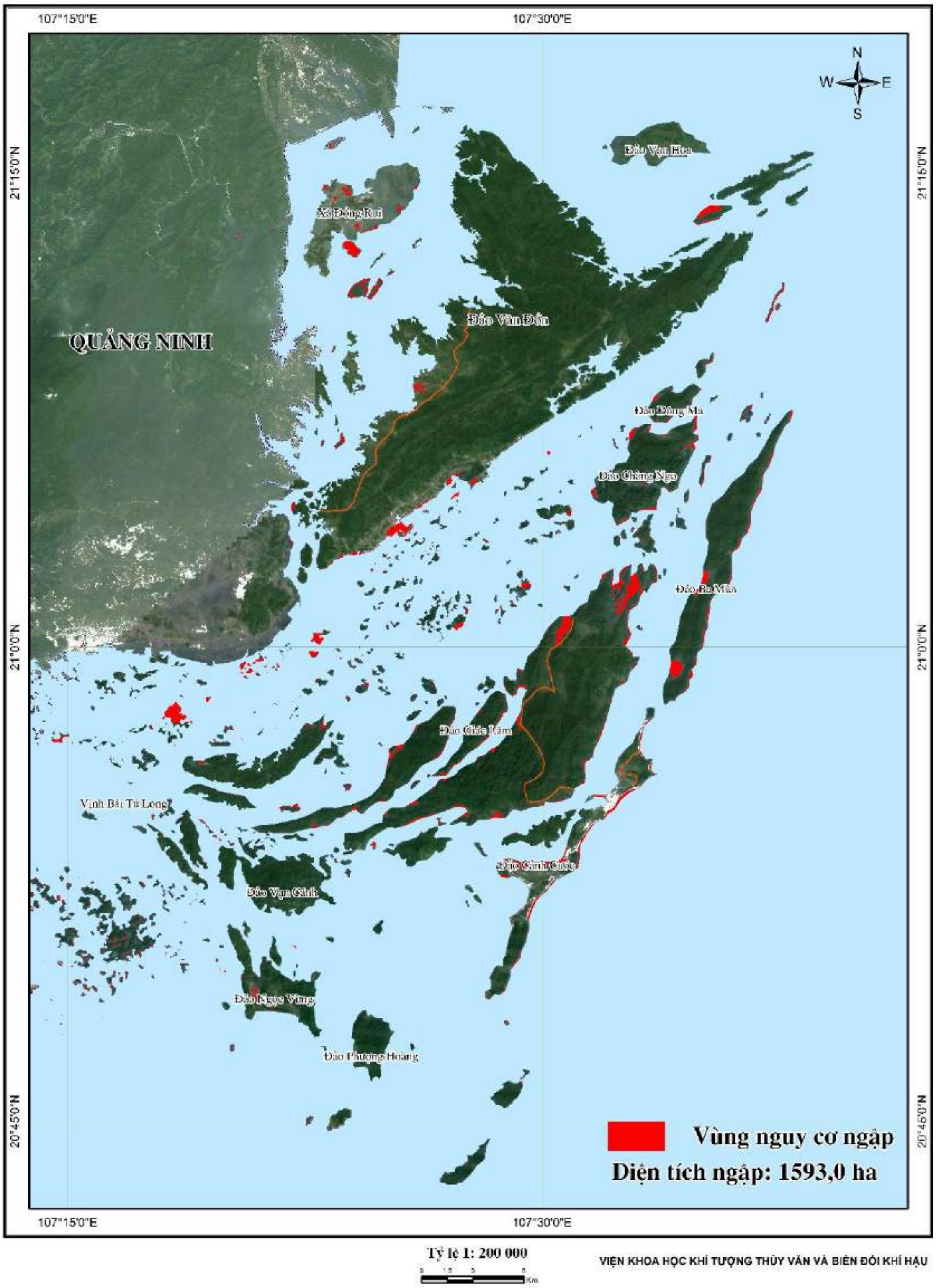


Figure B36. The inundation risk map with sea-level rise of 100cm, Van Don island group, Quang Ninh province

Figure B37. The inundation risk map with sea-level rise of 100cm, Co To island, Quang Ninh province

Figure B38. The inundation risk map with sea-level rise of 100cm, Ly Son island, Quang Ngai province

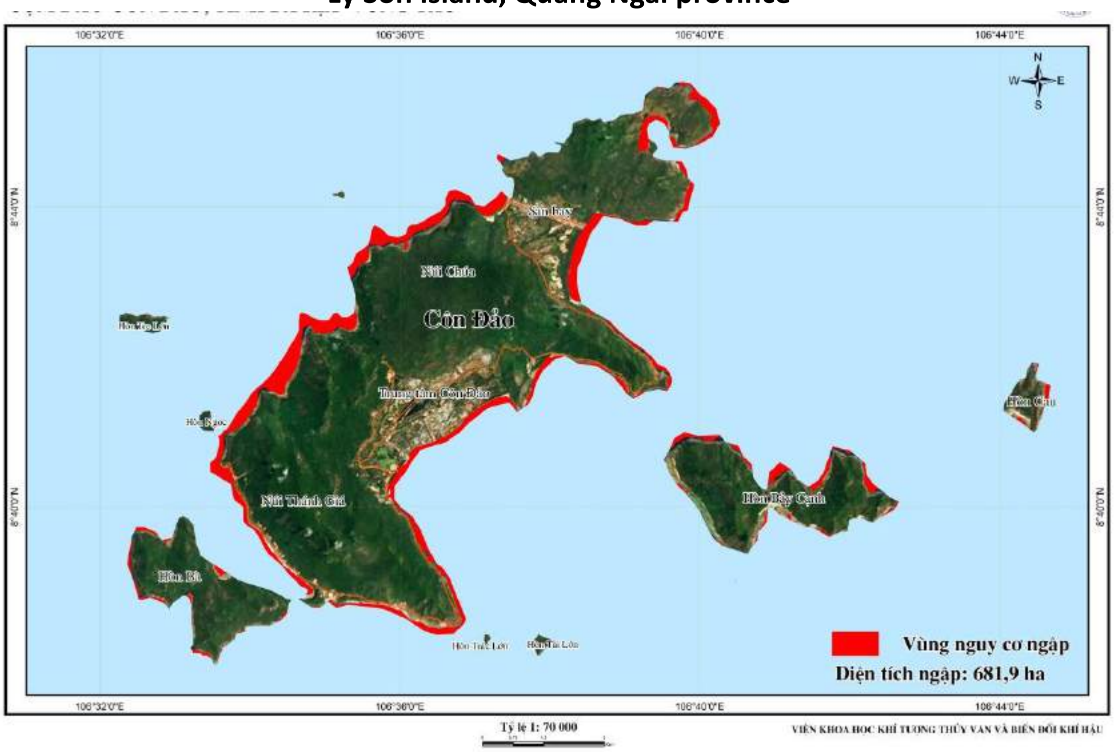


Figure B39. The inundation risk map with sea-level rise of 100cm, Con Dao island group, Ba Ria- Vung Tau province

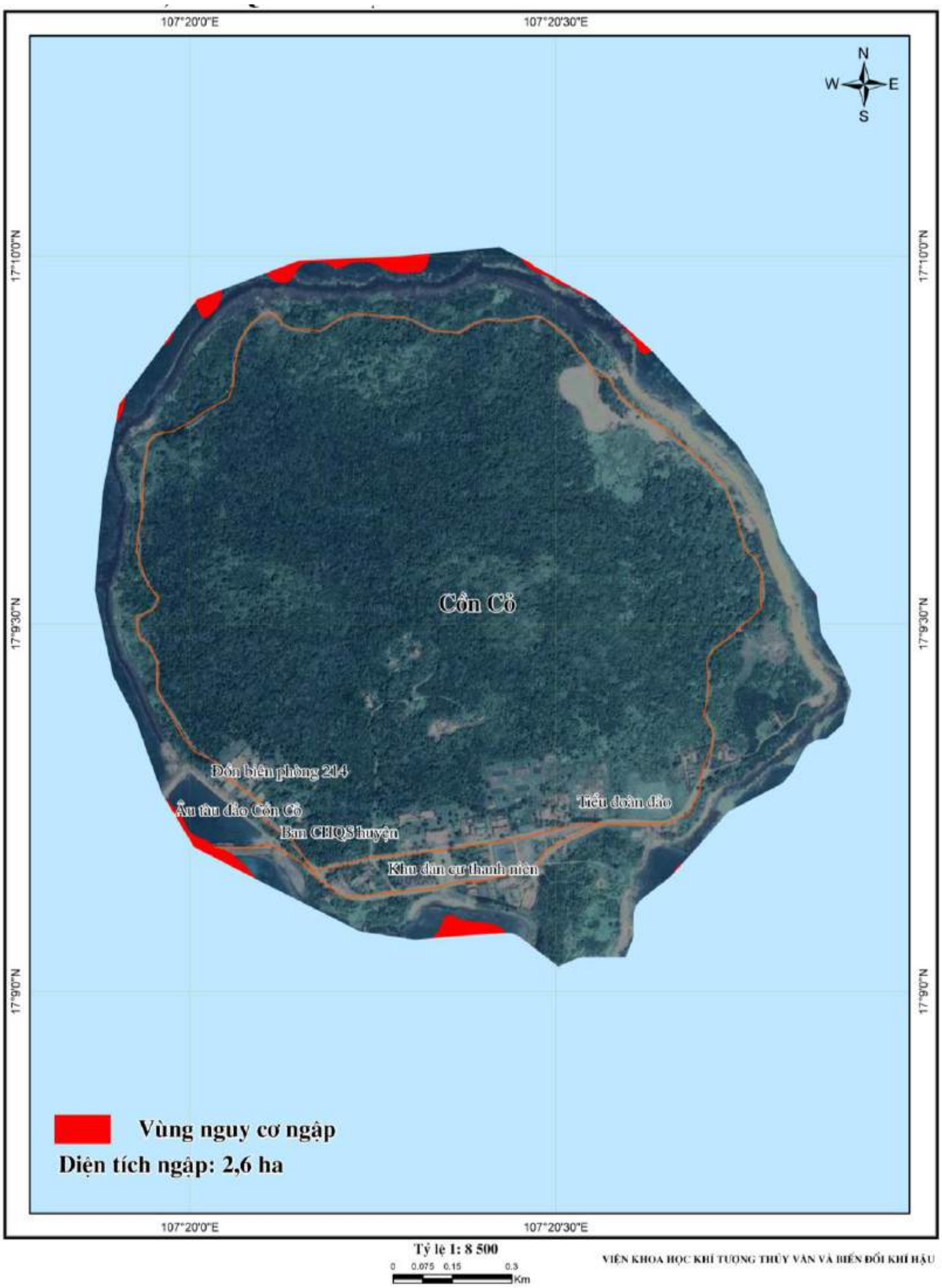


Figure B40. The inundation risk map with sea-level rise of 100cm, Con Co island, Quang Tri province

Figure B41. The inundation risk map with sea-level rise of 100cm, Phu Quy island, Binh Thuan province

Figure B42. The inundation risk map with sea-level rise of 100cm, Hon Khoai island, Ca Mau province

Figure B43. The inundation risk map with sea-level rise of 100cm, Phu Quoc island, Kien Giang province

Figure B44. The inundation risk map with sea-level rise of 100cm, Big Truong Sa island, Truong Sa island group, Khanh Hoa province

Figure B45. The inundation risk map with sea-level rise of 100cm, Song Tu Tay island, Truong Sa island group, Khanh Hoa province

Figure B46. The inundation risk map with sea-level rise of 100cm, Sinh Ton island, Truong Sa island group, Khanh Hoa province

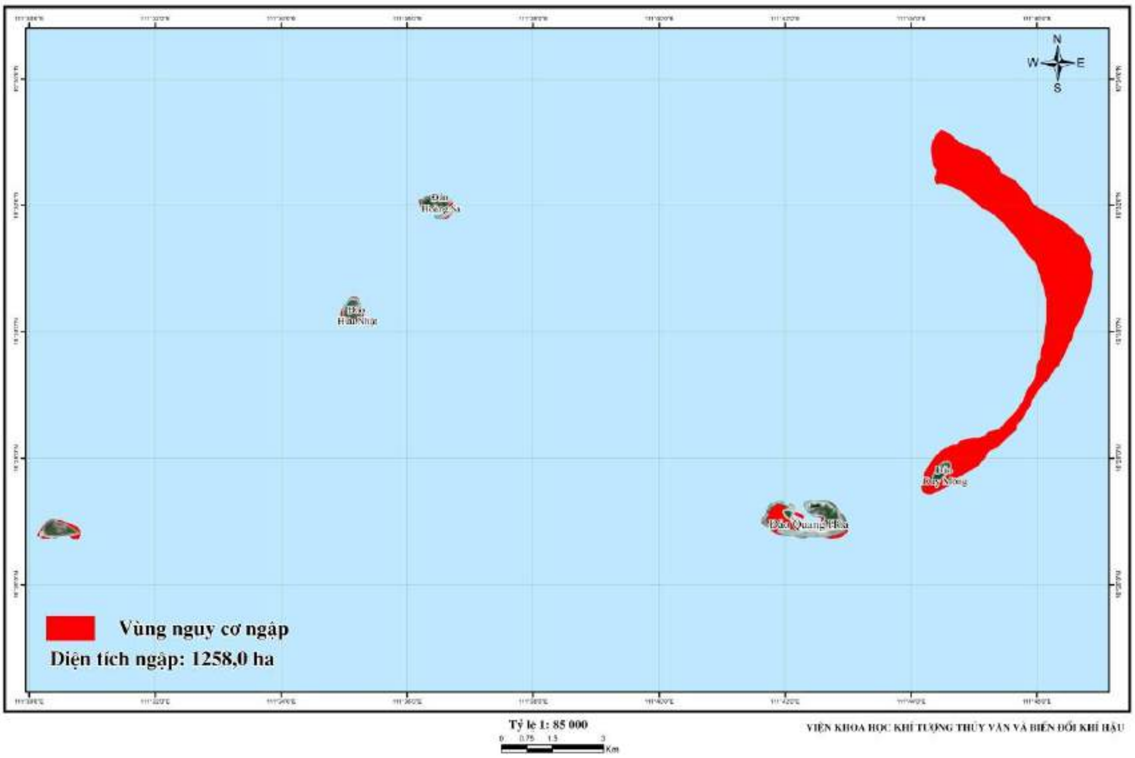


Figure B47. The inundation risk map with sea-level rise of 100cm, Luoi Liem group, Hoang Sa island group, Da Nang city

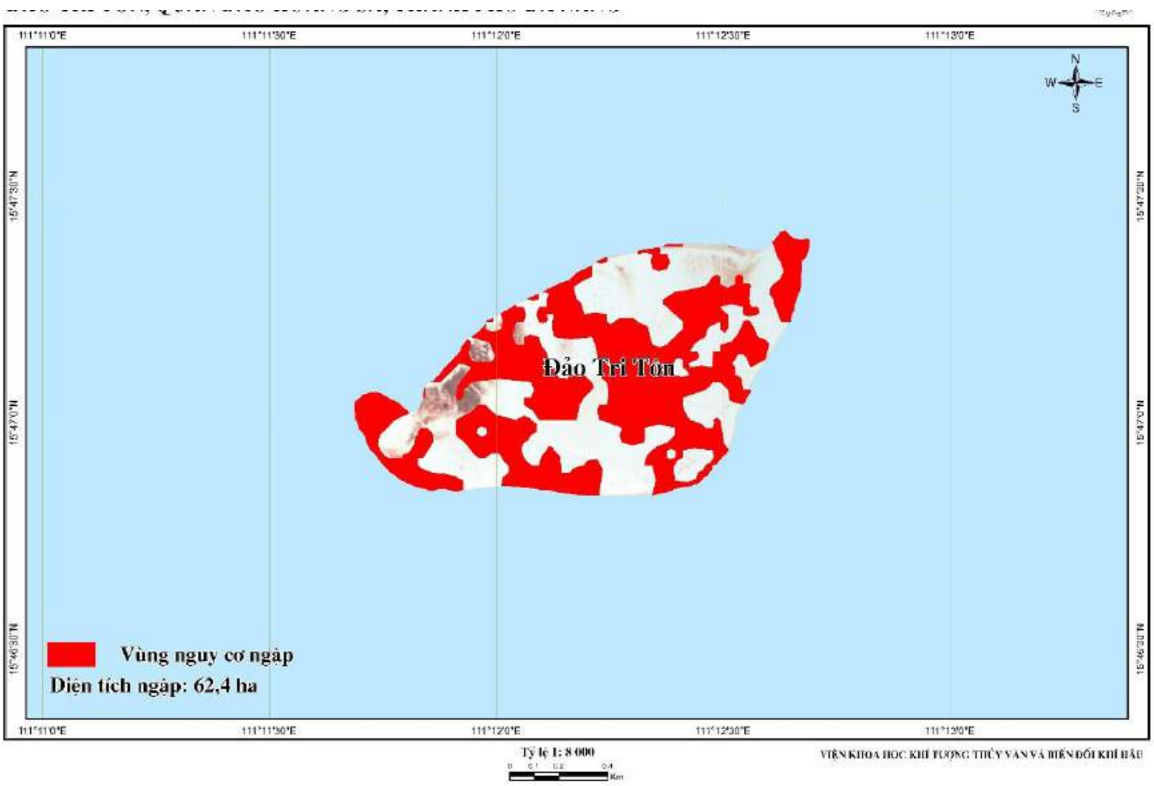


Figure B48. The inundation risk map with sea-level rise of 100cm, Tri Ton island, Hoang Sa island group, Da Nang city

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