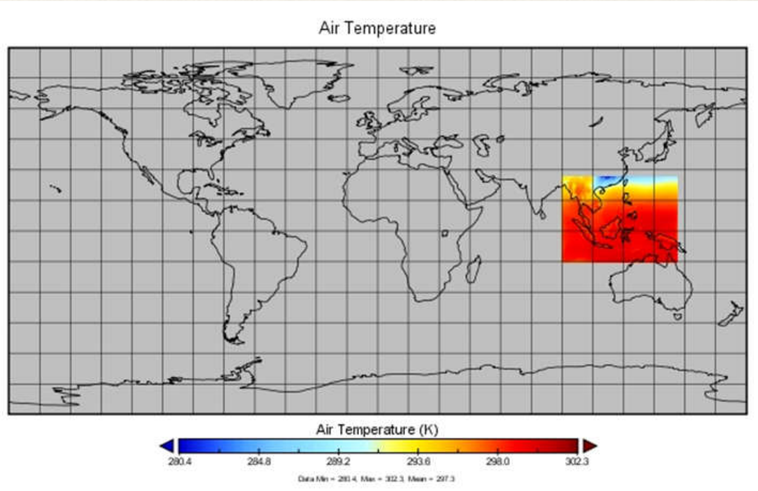
Climate Change Science from Global to Regional and Local Perspectives: Future Climate Change Impact in Southeast Asia



Asst.Prof.Dr.Jerasorn Santisirisomboon
Ramkhamhaeng University Center of Regional Climate Change and Renewable Energy

1 August 2017

Outline

Greenhouse Effect

Observation of Climate

Climate Model

Future Climate Projection

Downscaling GCMs

Previous Studies

Current and Future study

The Father of Greenhouse Effect

Published a paper in early 1900 highlighting the greenhouse effect

The first person to predict that emission of CO_2 from burning of fossil fuels would cause global warming

Predicted doubling of CO_2 would result 5-6°C increase in global mean temperature (IPCC projection was 2-4.5°C)

Predicted it would take 3000 years to double the CO_2 concentration (IPCC estimated this would be achieved within this century)

Svante Arrhenius

(1859-1927, Nobel Prize Winner for Chemistry 1903; The first Swedish Nobel Prize Winner)

Key Statement / Headline of IPCC WG1 AR5 SPM

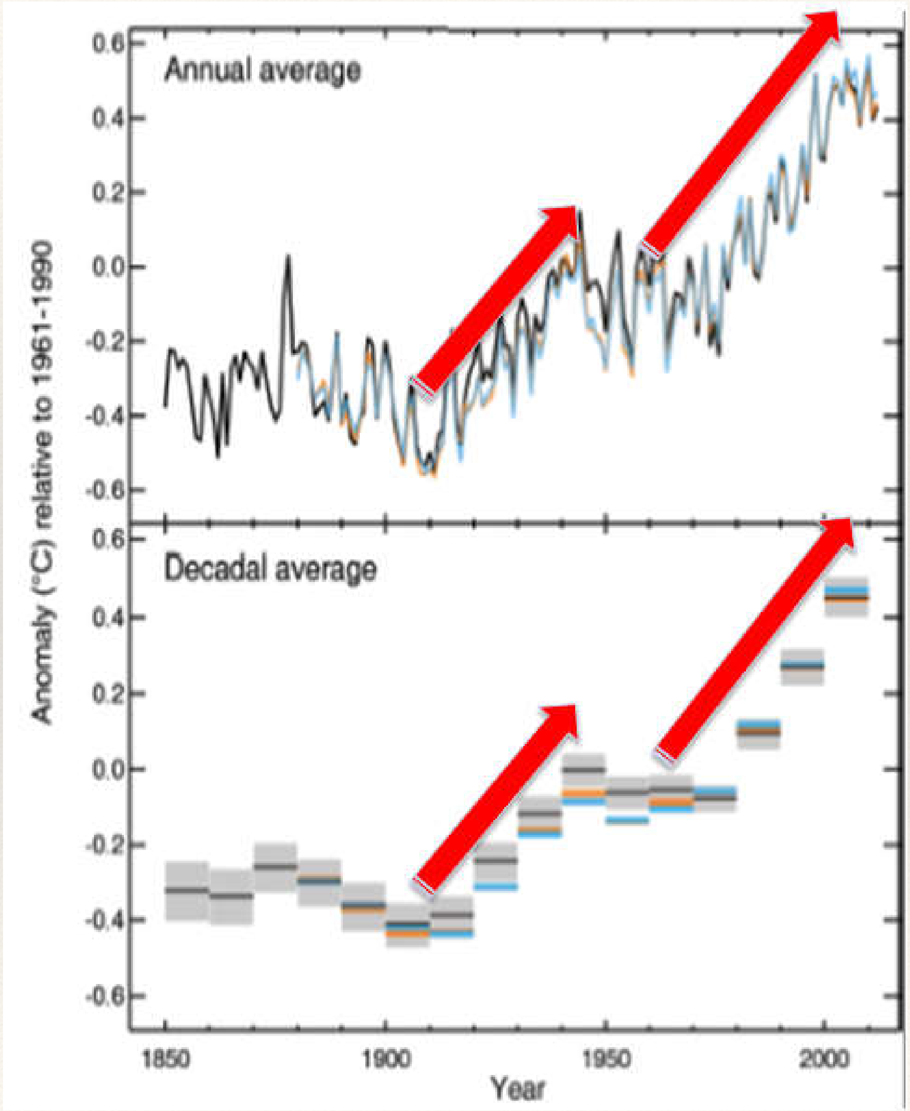
Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased

Observation of Climate

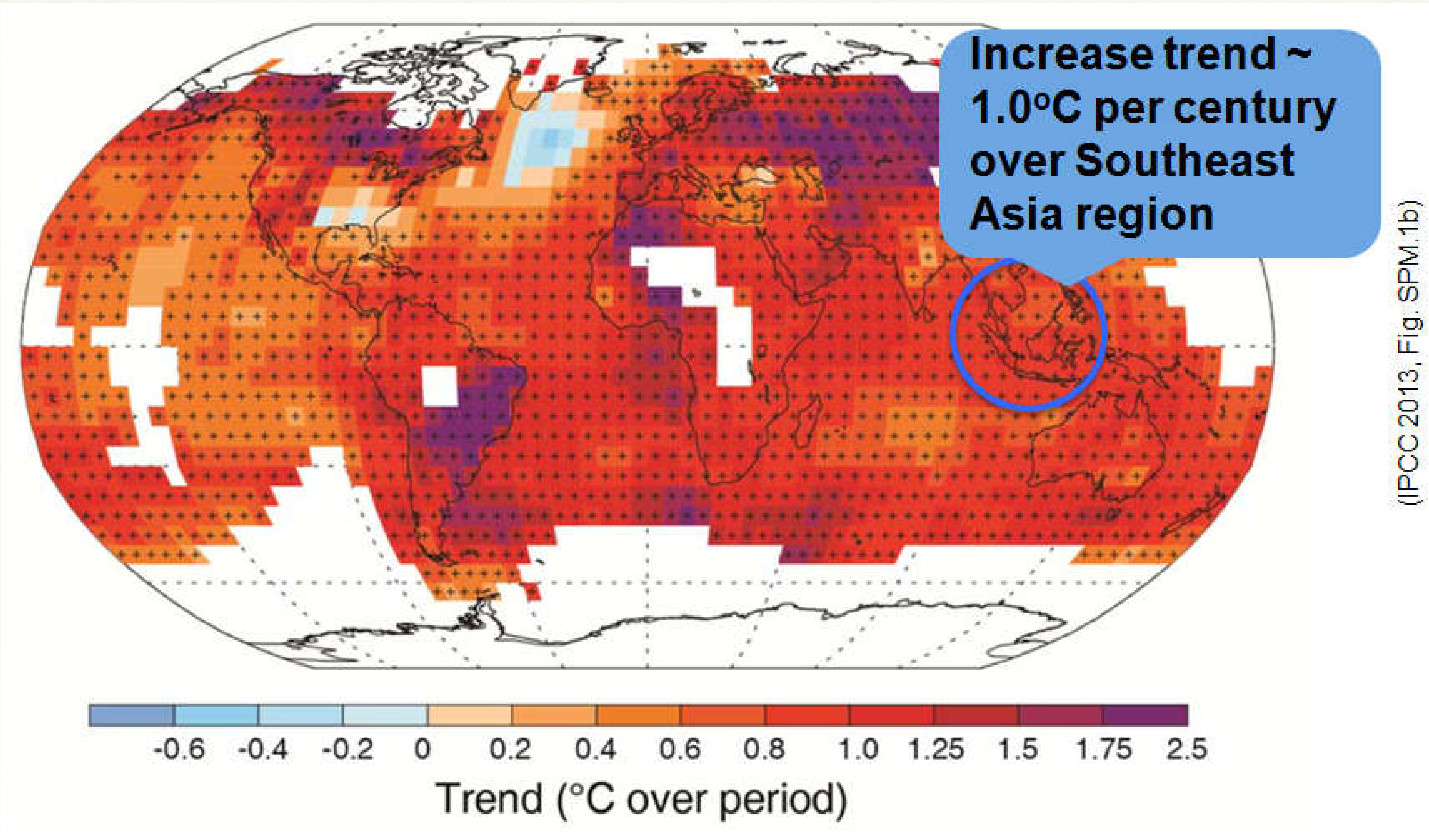
The globally averaged surface temperature data as calculated by a linear trend, show a warming of 0.85 [0.65 to 1.06] °C over 1880 - 2012

Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850.

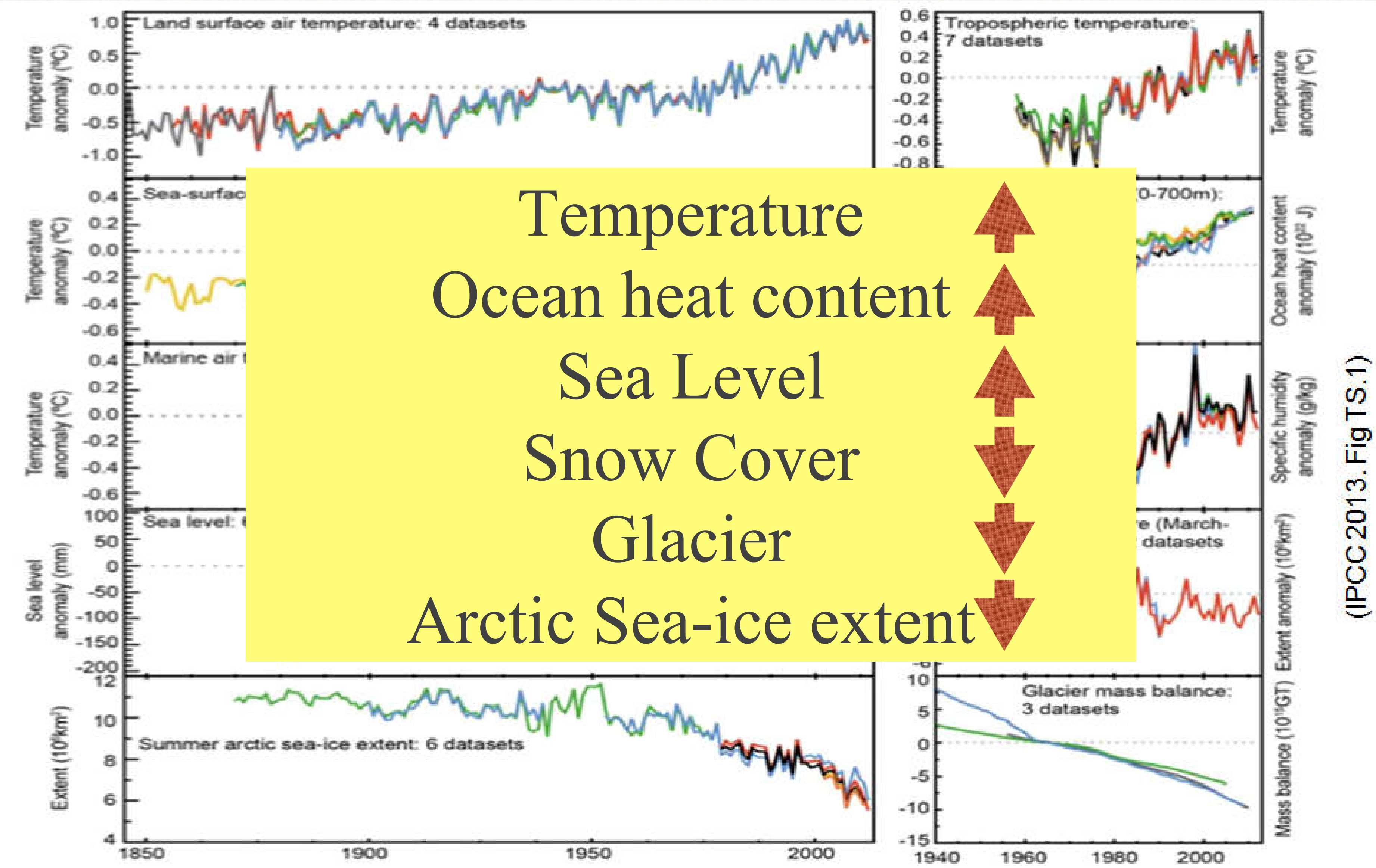
In the Northern Hemisphere, 1983–2012 was likely the warmest 30-year period of the last 1400 years (medium confidence)



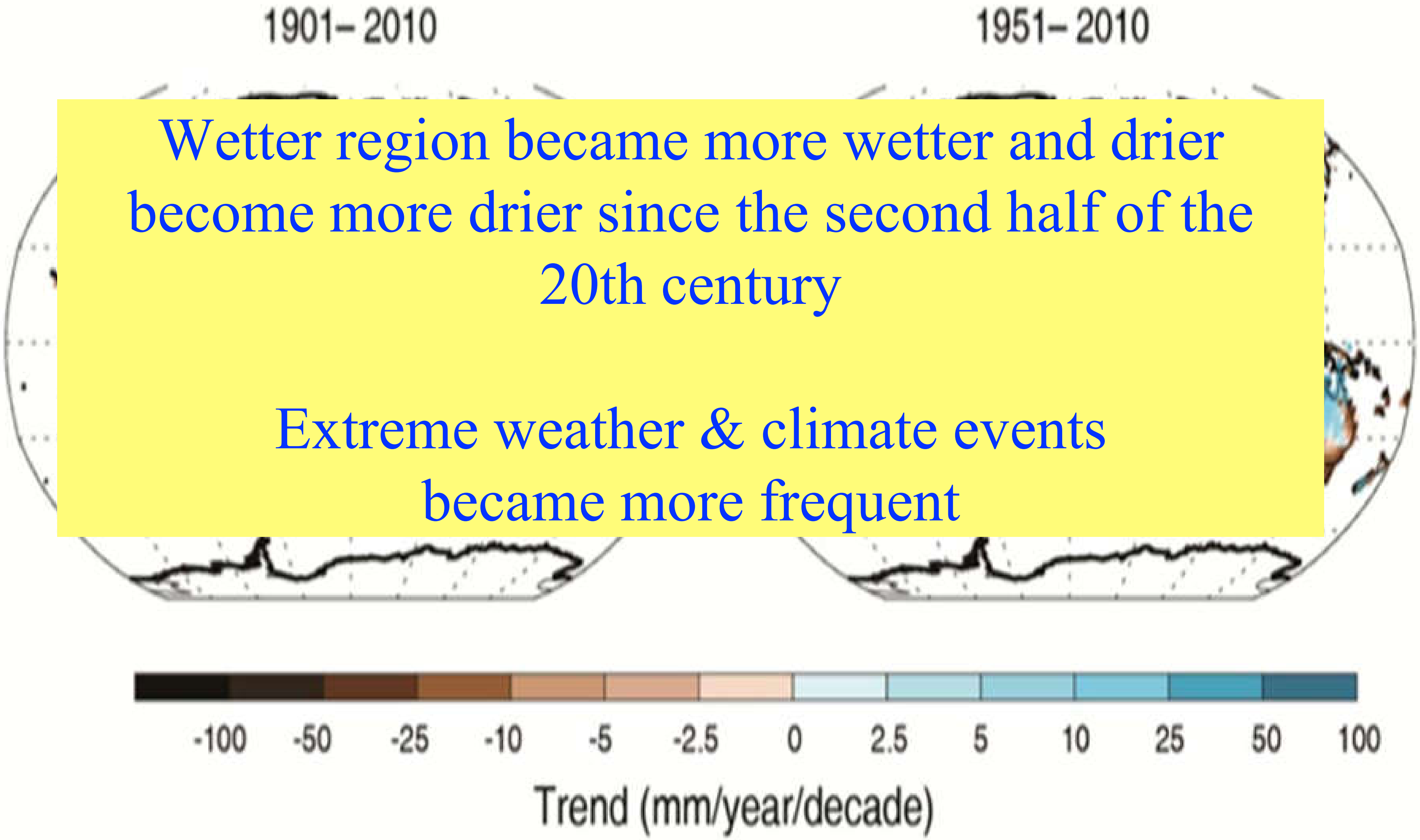
Warming in the climate system is unequivocal



Key findings based on observation



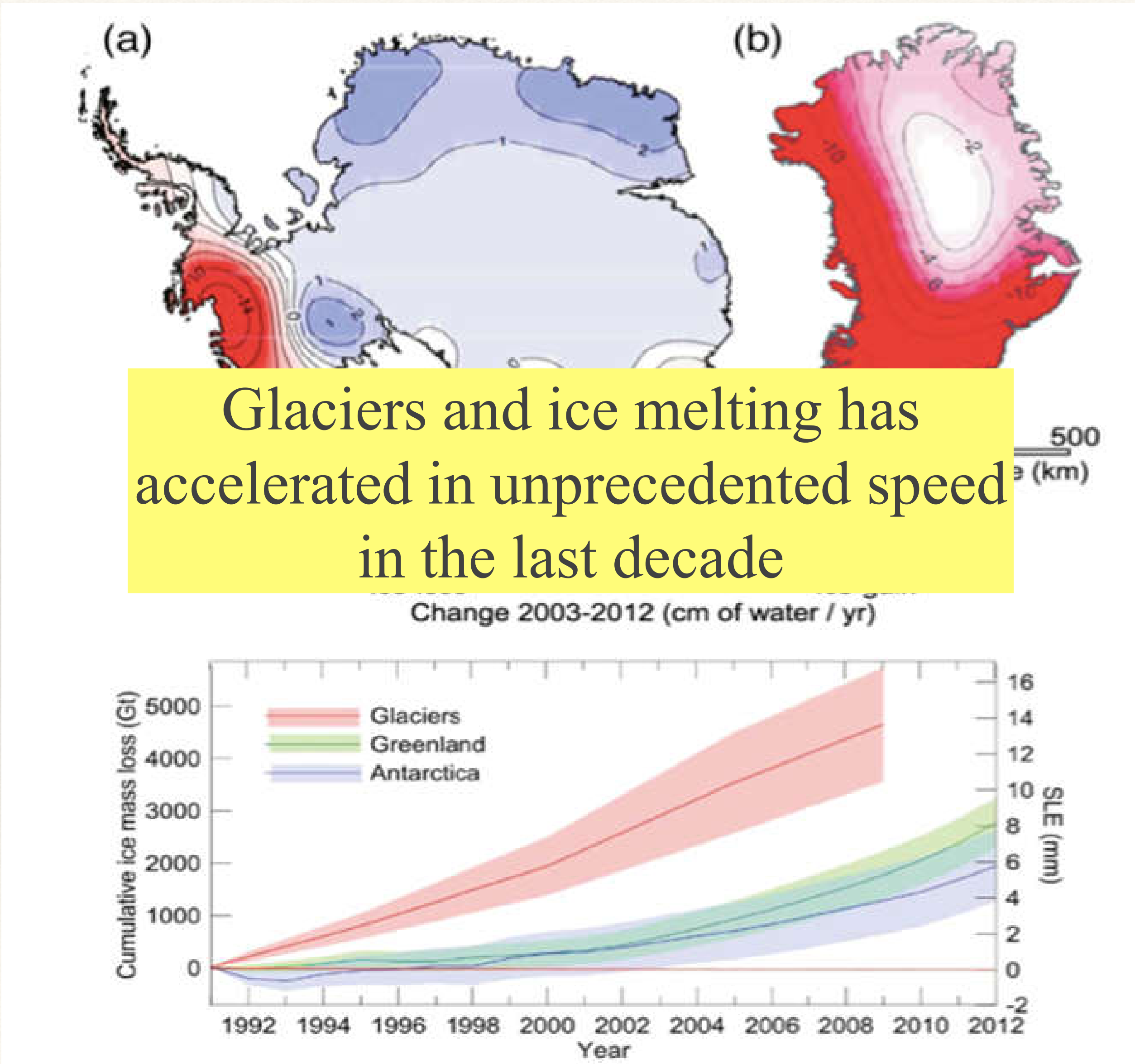
Observation change in precipitation over land



Wetter region became more wetter and drier become more drier since the second half of the 20th century

Extreme weather & climate events became more frequent

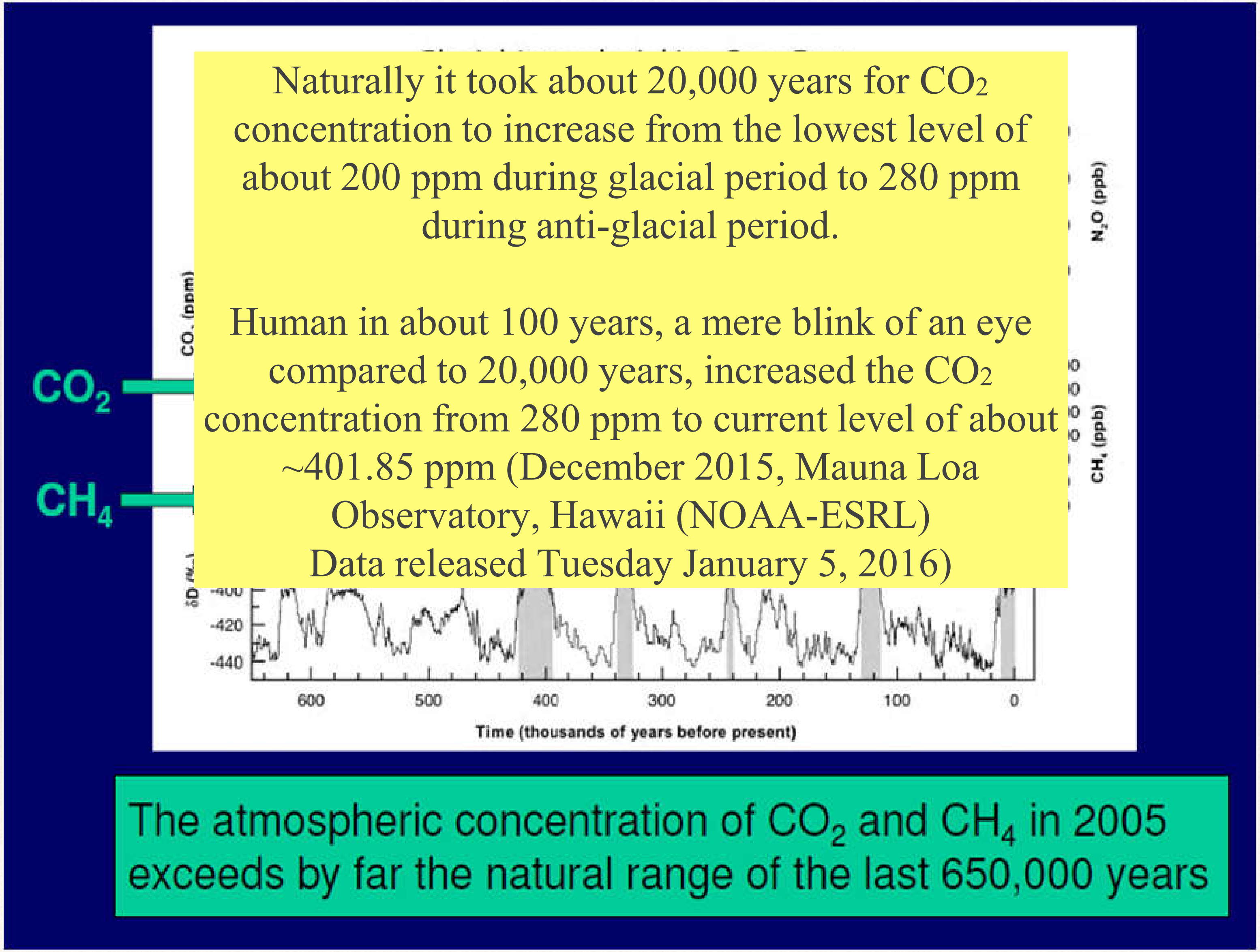
Glaciers and ice melting



Glaciers and ice melting has accelerated in unprecedented speed in the last decade

Scientists investigate long-period fluctuations of GHG concentration through ice cores

Atmospheric Concentration of GHGs

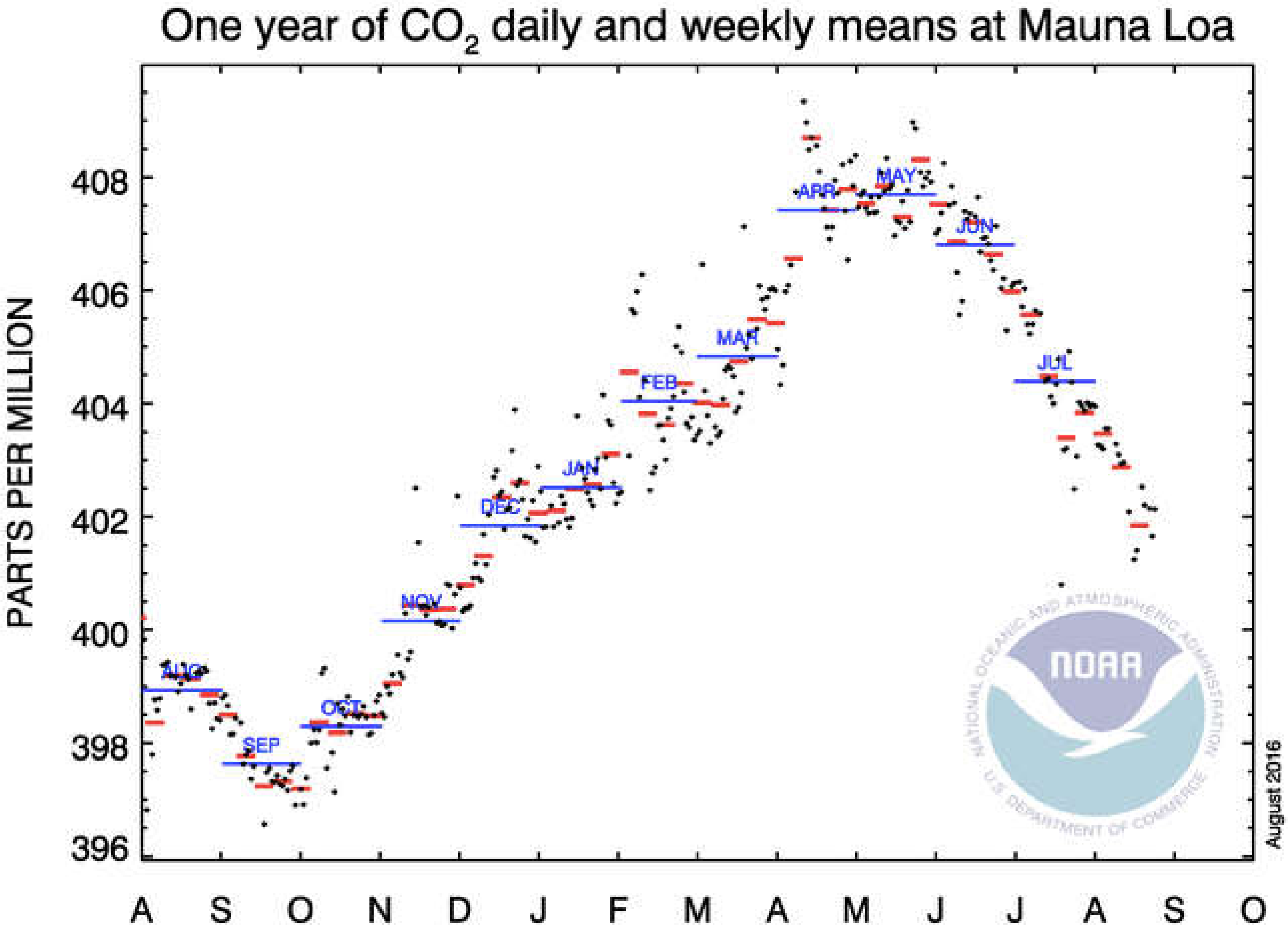


Naturally it took about 20,000 years for CO_2 concentration to increase from the lowest level of about 200 ppm during glacial period to 280 ppm during anti-glacial period.

Human in about 100 years, a mere blink of an eye compared to 20,000 years, increased the CO_2 concentration from 280 ppm to current level of about ~401.85 ppm (December 2015, Mauna Loa Observatory, Hawaii (NOAA-ESRL) Data released Tuesday January 5, 2016)

Up-to-date weekly average CO_2 at Mauna Loa

Week beginning on August 14, 2016: 401.85 ppm
Weekly value from 1 year ago: 399.10 ppm
Weekly value from 10 years ago: 380.38 ppm
Last updated: August 24, 2016



What is Climate Variability?

(Natural Driver)

What is Climate Change ?

(Anthropogenic)

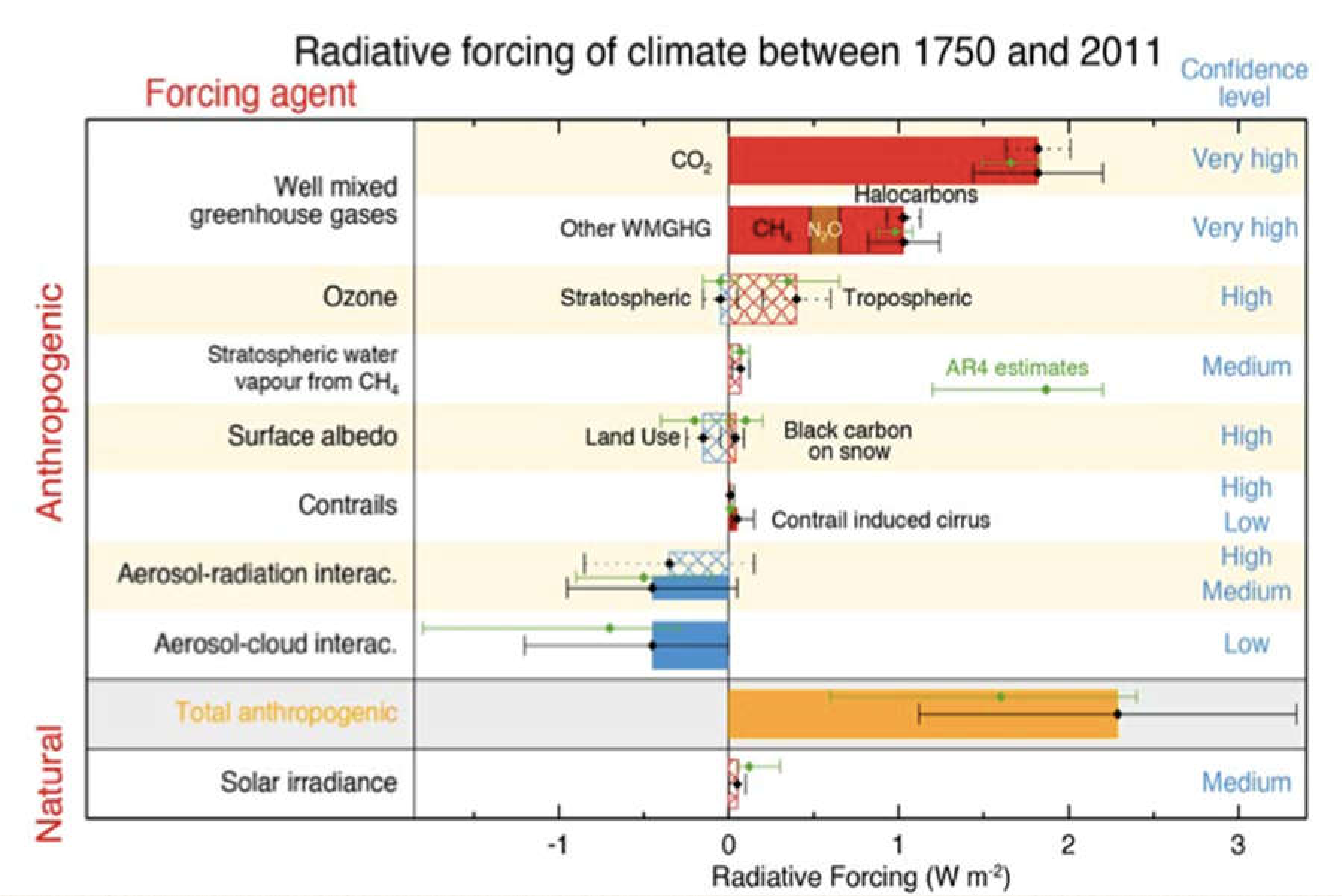
Radiative Forcing

Change in energy flux caused by natural or anthropogenic drivers of climate change (in Wm^{-2})

Positive near-surface warming; Negative cooling

Puts various drivers on common scale, indicates magnitude of impact

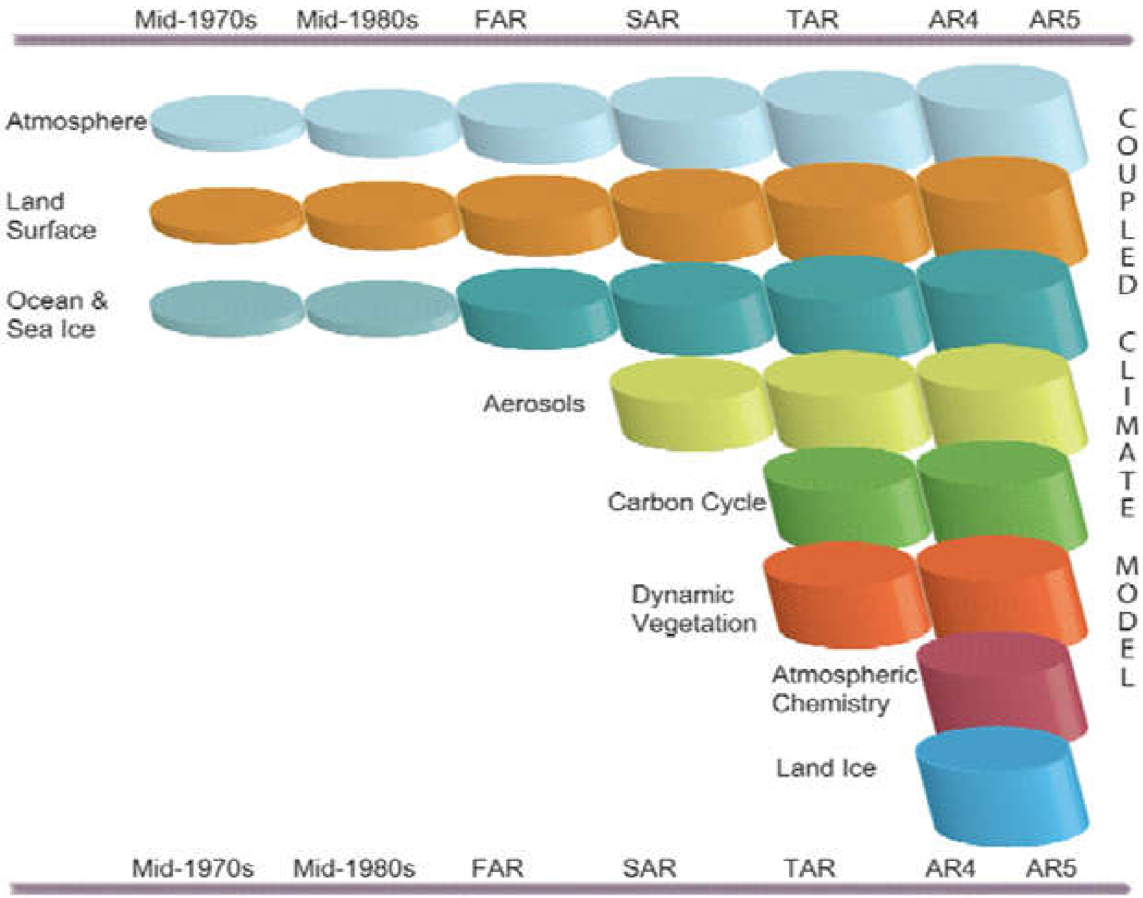
Radiative Forcing

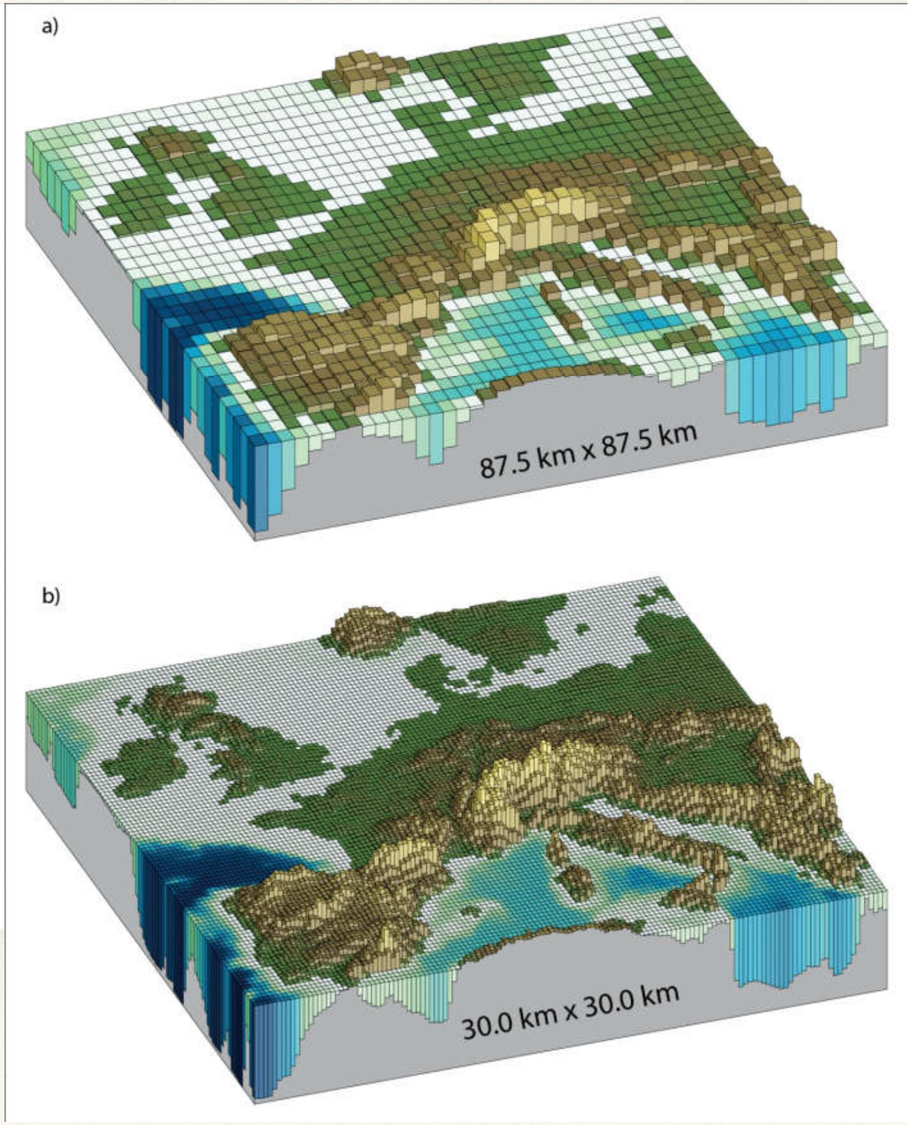


Radiative Imbalance

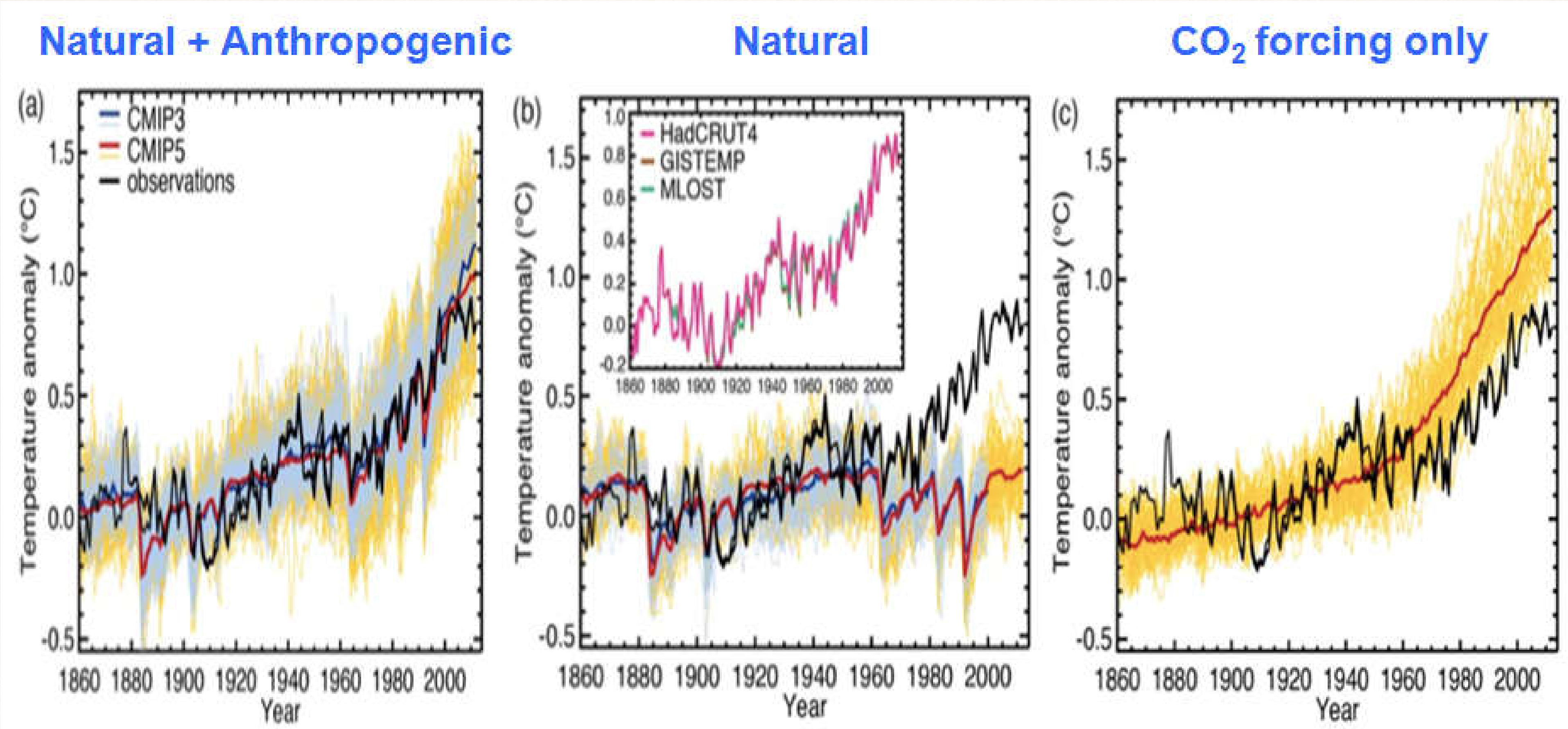
Earth has been in radiative imbalance, with more energy from the sun entering than exiting the top of the atmosphere, since at least circa 1970. It is virtually certain that Earth has gained substantial energy from 1971–2010. More than 90% of this extra heat is observed by the ocean (high confidence)

Complexity of Climate Model over Time



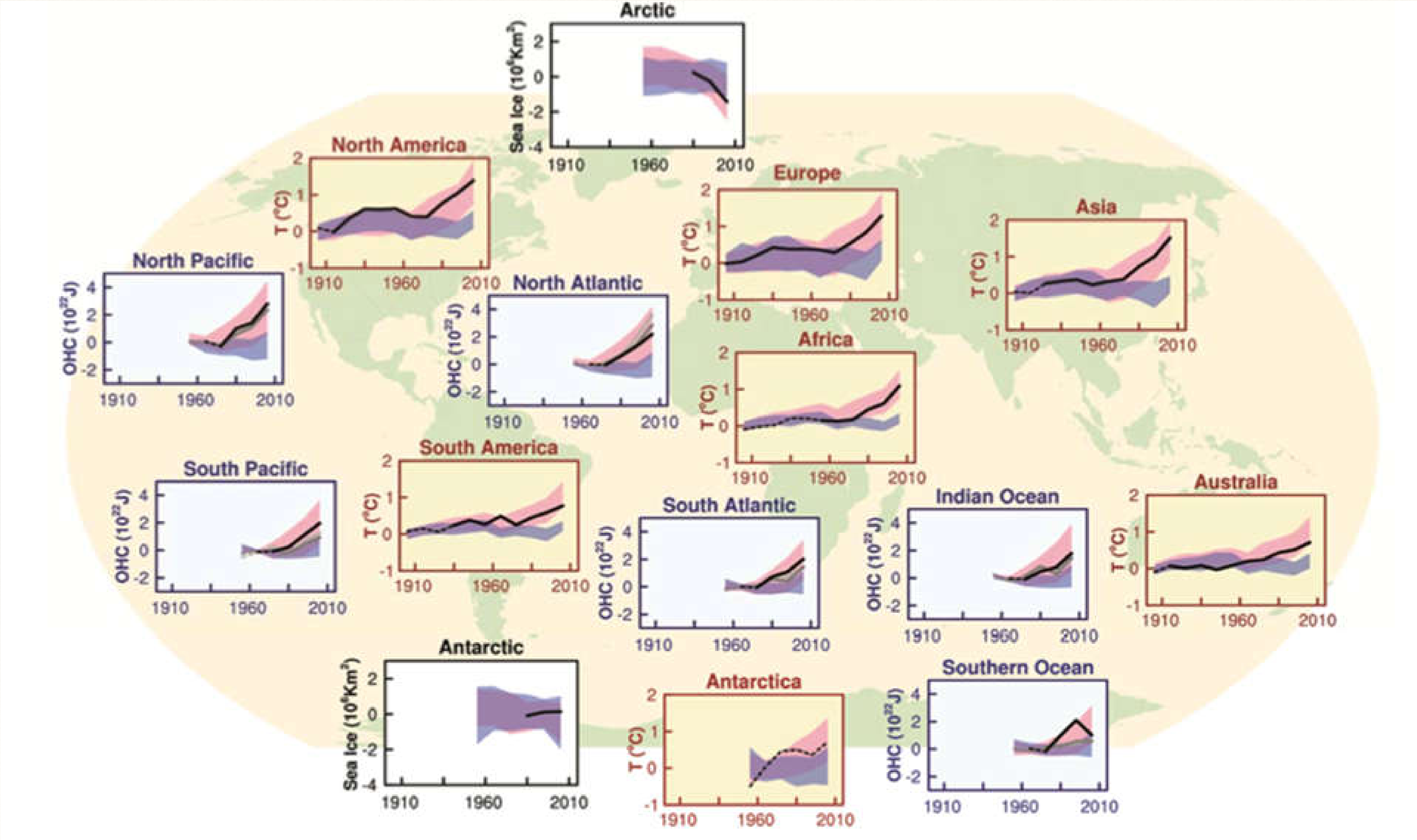


Climate Models Response to Various Forcing



(IPCC 2013. Fig TS.9)

Human influence on the climate system is clear



Future Climate Projection

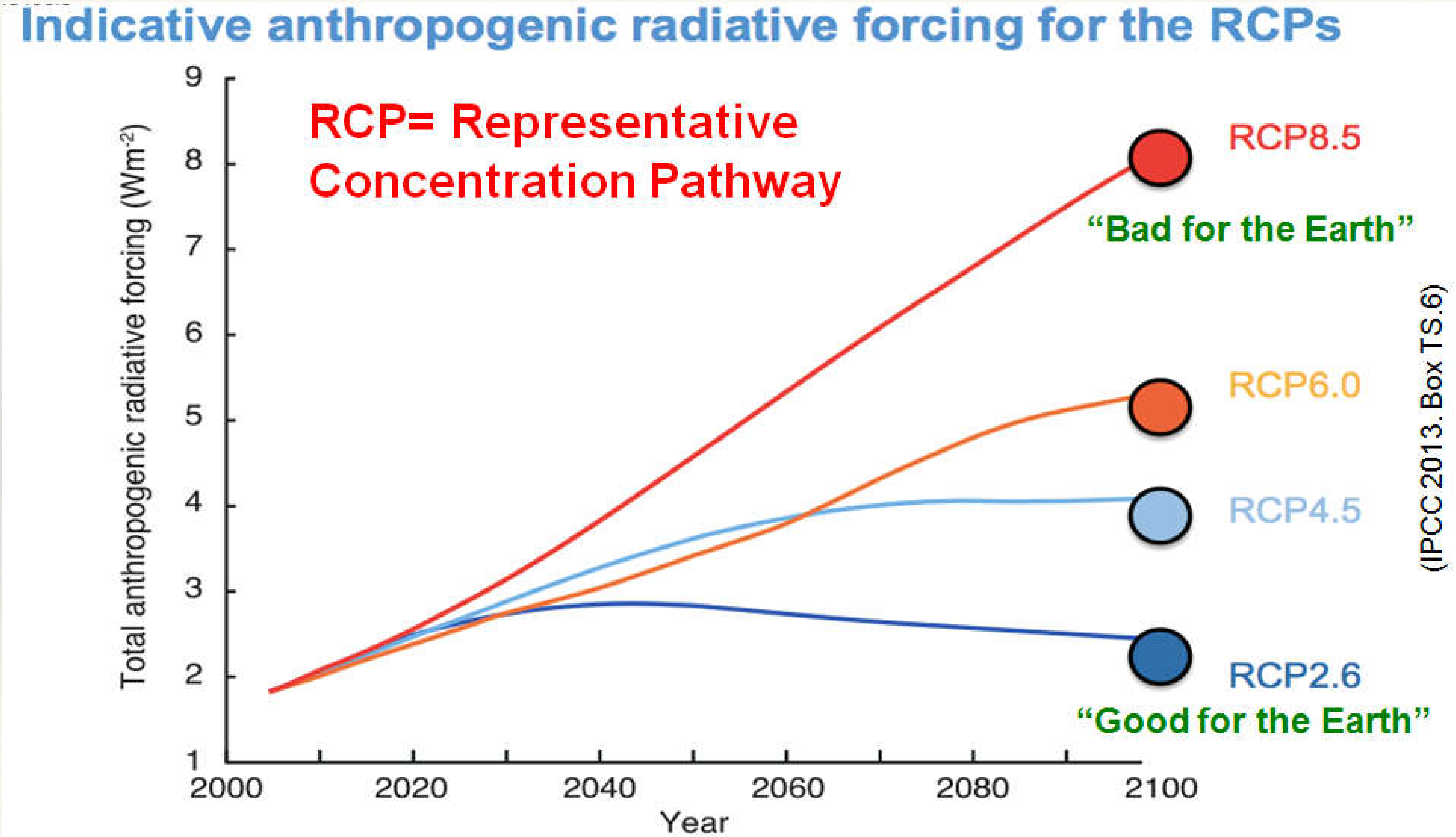
For future climate projections,
climate models require Emission Scenarios.
Models in AR5 use Representative
Concentration Pathway (RCP)

RCP Scenario

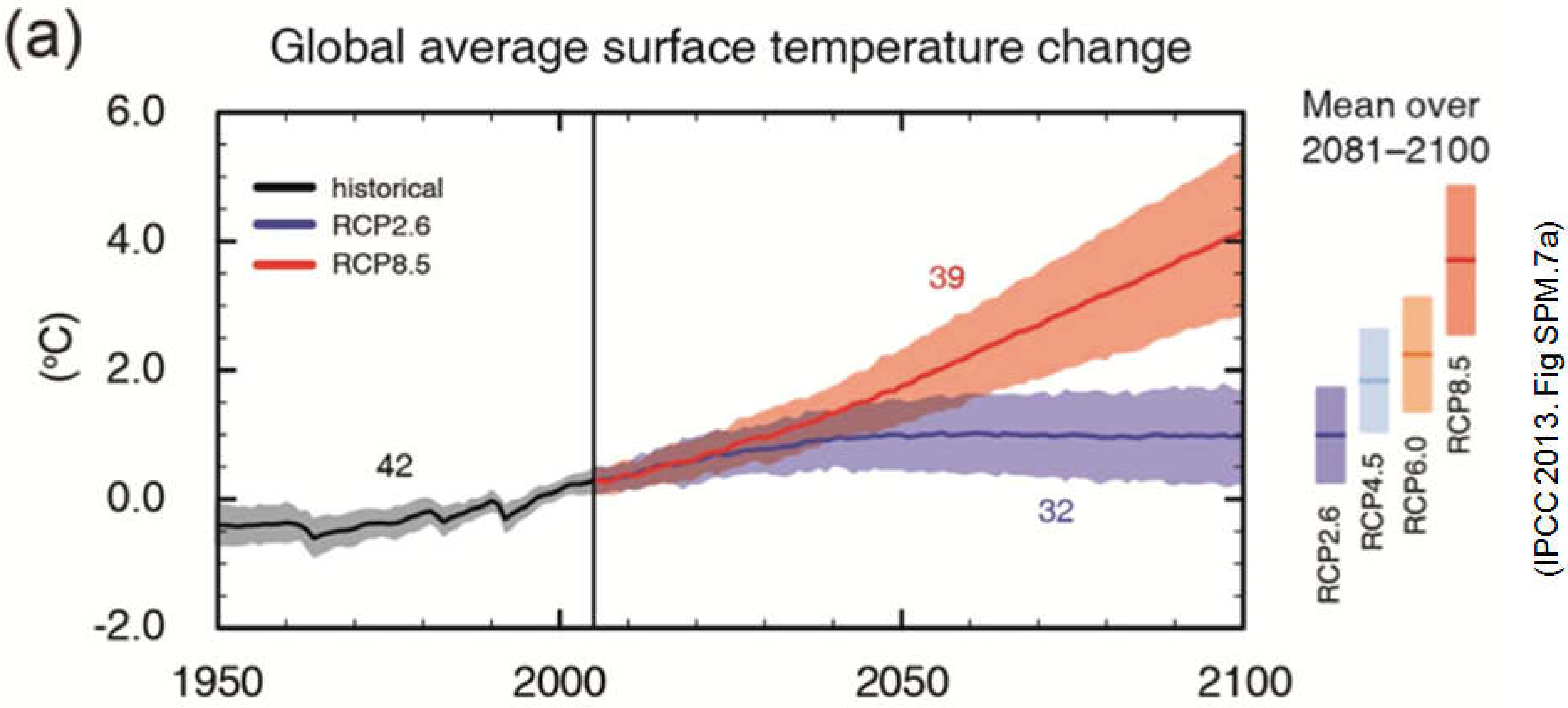
	Description[a]	Publication—IA Model
RCP8.5	Rising radiative forcing pathway leading to 8.5 W/m^2 (~1370 ppm CO_2 eq) by 2100.	(Riahi et al. 2007)—MESSAGE
RCP6	Stabilization without overshoot pathway to 6 W/m^2 (~850 ppm CO_2 eq) at stabilization after 2100	(Fujino et al. 2006; Hijioka et al. 2008)—AIM
RCP4.5	Stabilization without overshoot pathway to 4.5 W/m^2 (~650 ppm CO_2 eq) at stabilization after 2100	(Clarke et al. 2007; Smith and Wigley 2006; Wise et al. 2009)—GCAM
RCP2.6	Peak in radiative forcing at ~3 W/m^2 (~490 ppm CO_2 eq) before 2100 and then decline (the selected pathway declines to 2.6 W/m^2 by 2100).	(Van Vuuren et al., 2007a; van Vuuren et al. 2006)—IMAGE

[a] Approximate radiative forcing levels were defined as ±5% of the stated level in W/m^2 relative to pre-industrial levels. Radiative forcing values include the net effect of all anthropogenic GHGs and other forcing agents

Representative Concentration Pathways

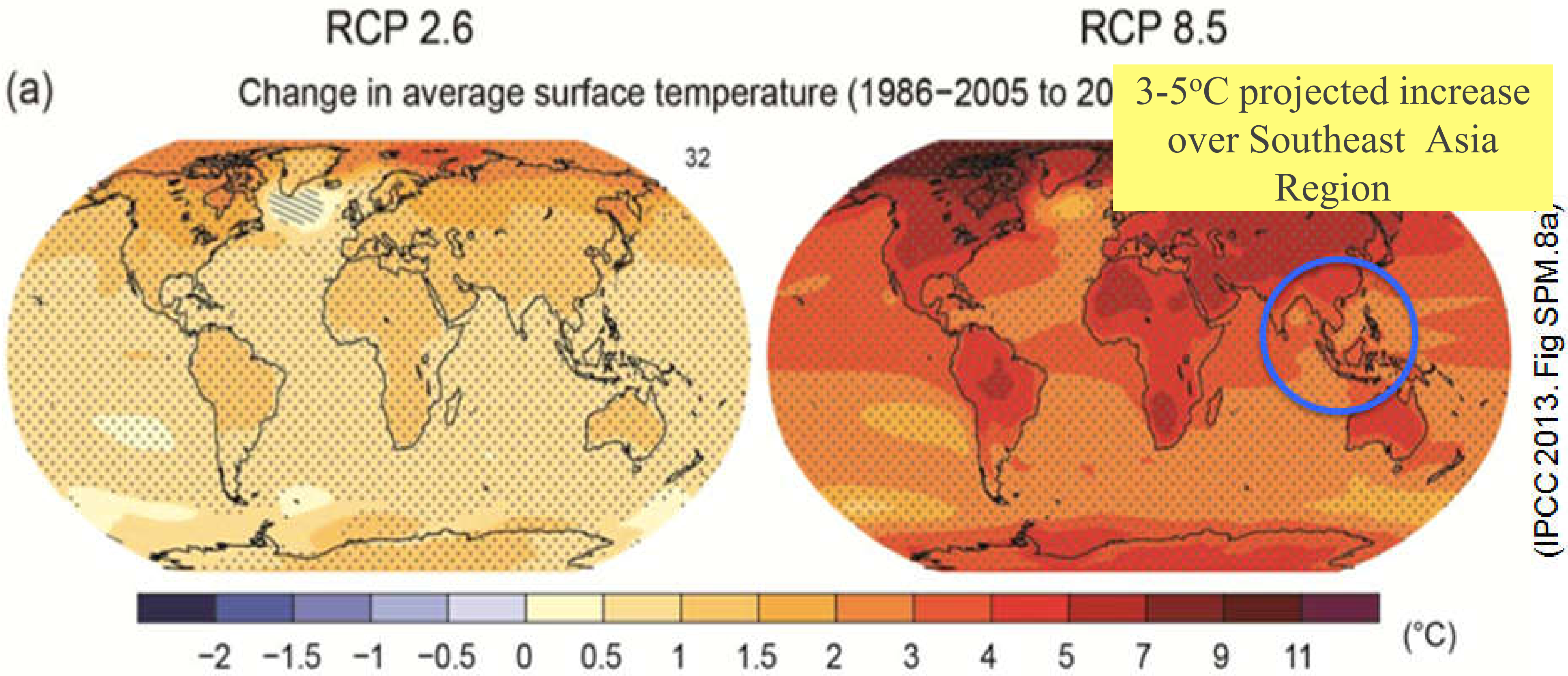


Projected Global Average Temperature Change by end of 21st Century



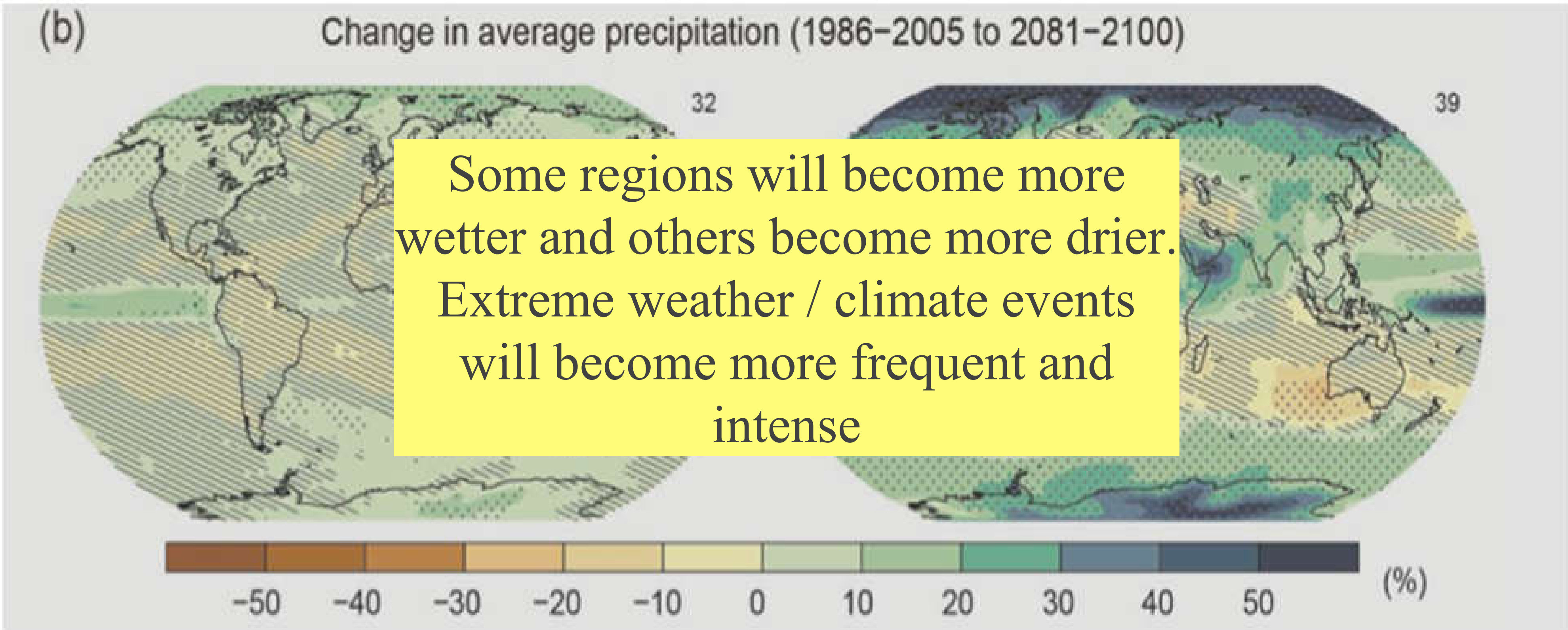
The temperature increase during the last 100 years was only about 0.8°C.

Projected Global Average Temperature Change by end of 21st Century



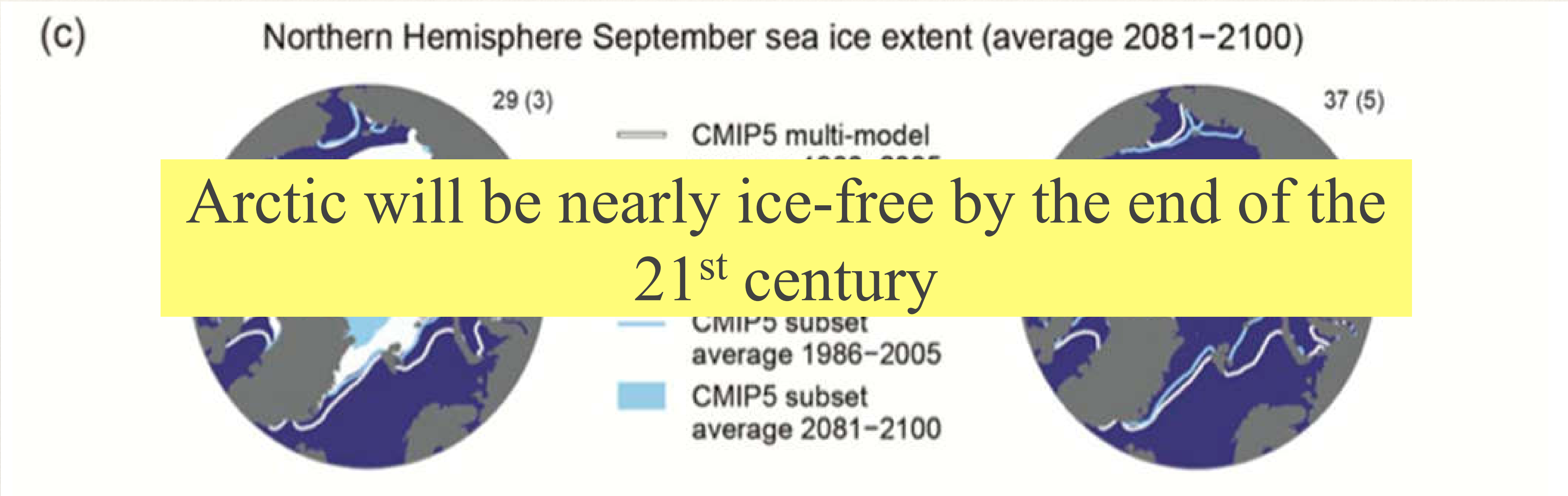
The temperature increase during the last 100 years is only about 0.8°C.

Projected Precipitation Change by end of 21st Century



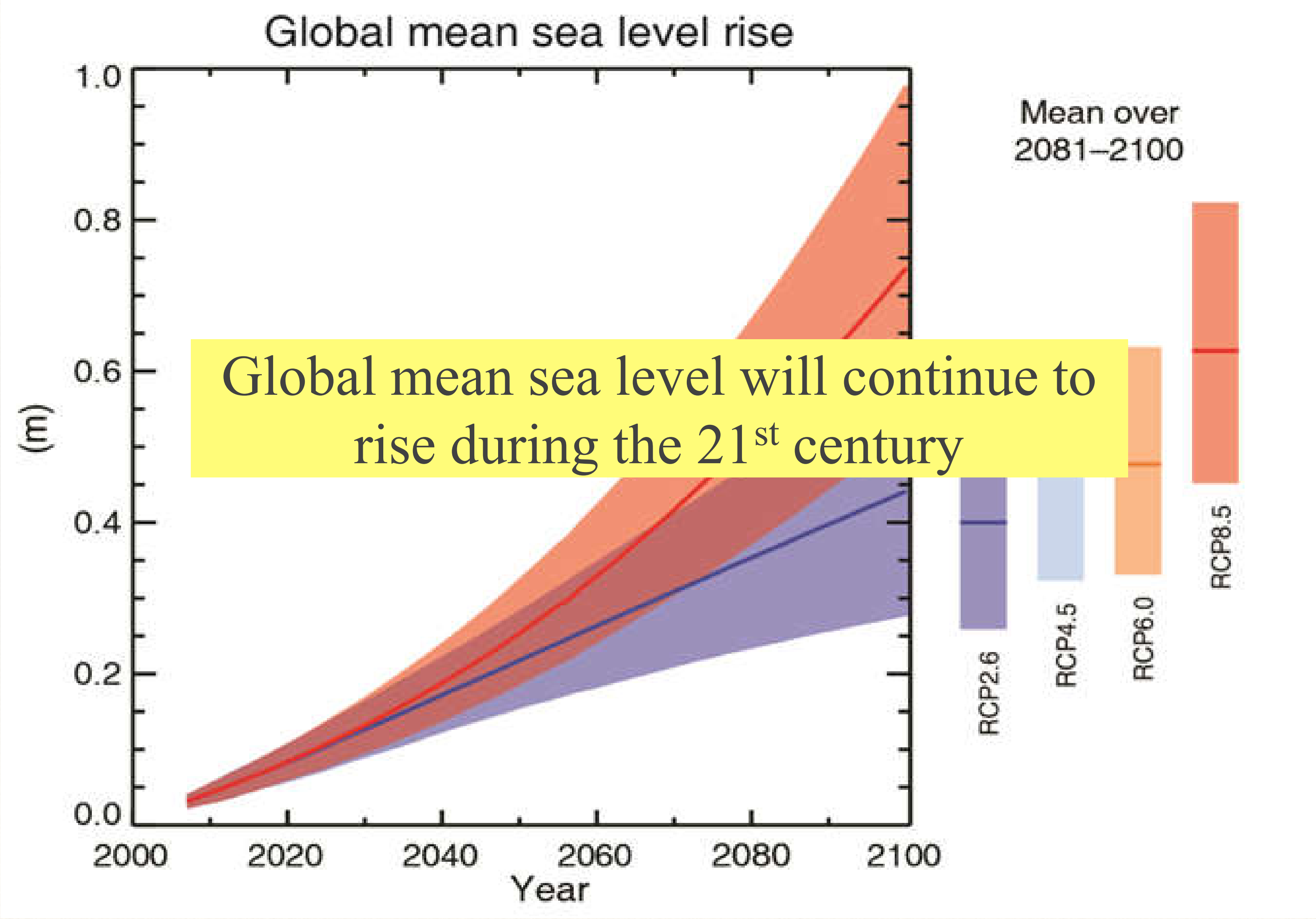
Some regions will become more wetter and others become more drier. Extreme weather / climate events will become more frequent and intense

Projected Arctic Ice Change by end of 21st Century



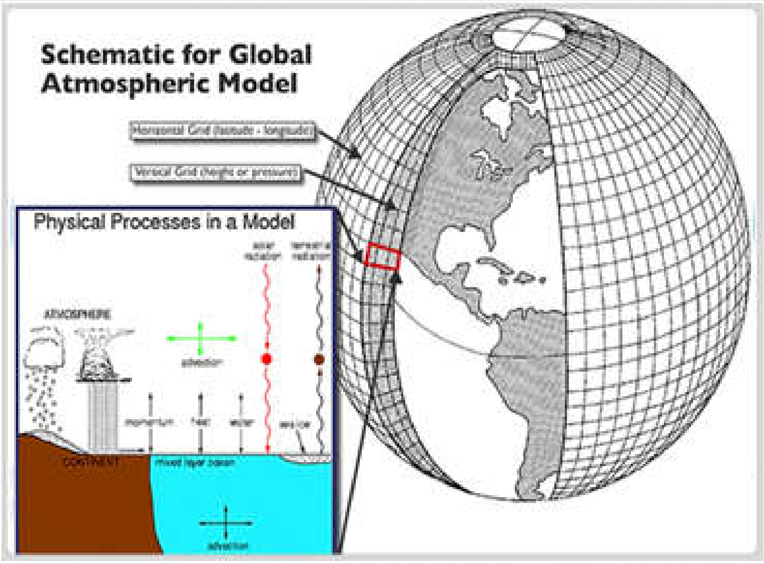
Arctic will be nearly ice-free by the end of the 21st century

Projected Sea Level by end of 21st Century

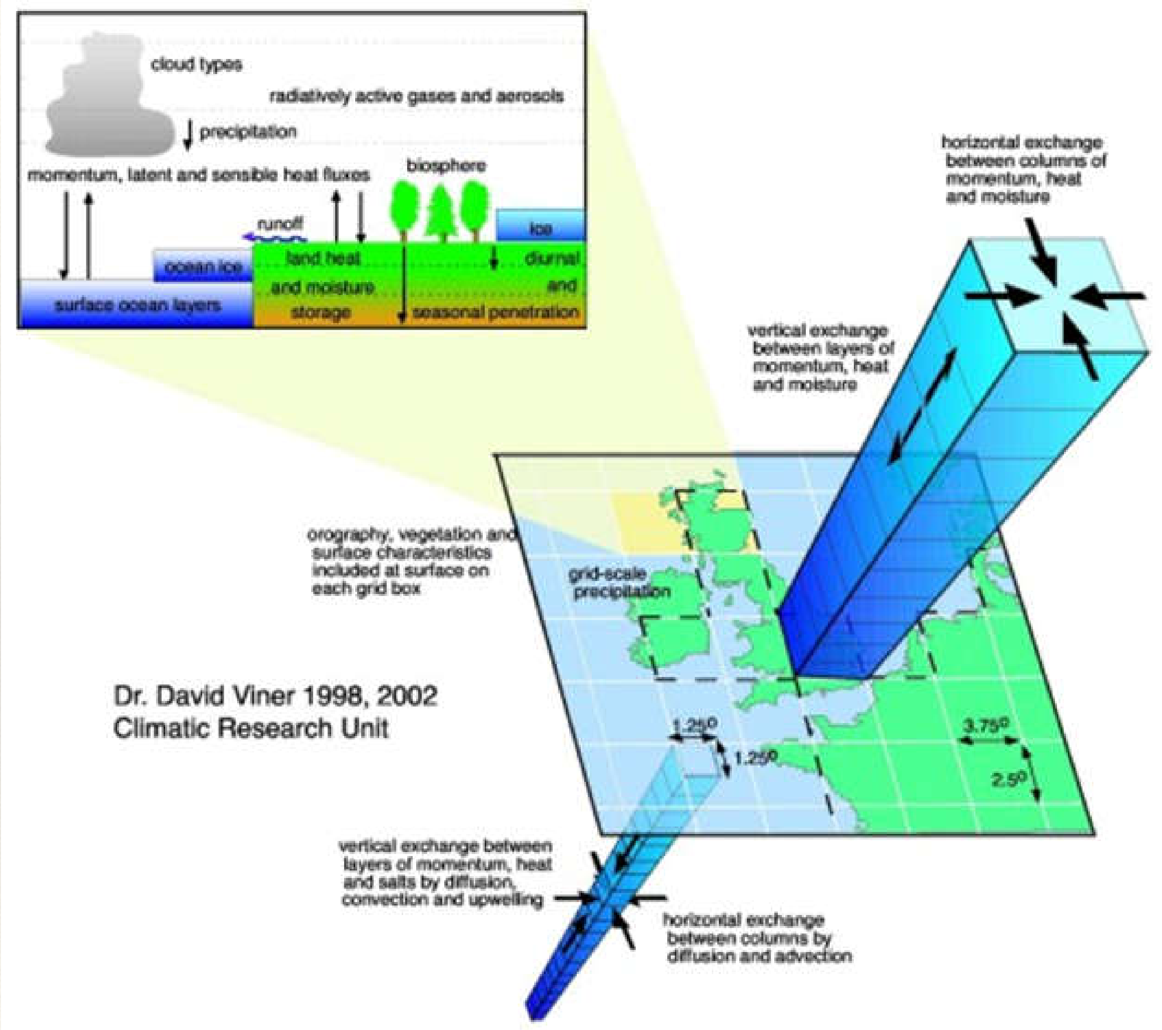


Global mean sea level will continue to rise during the 21st century

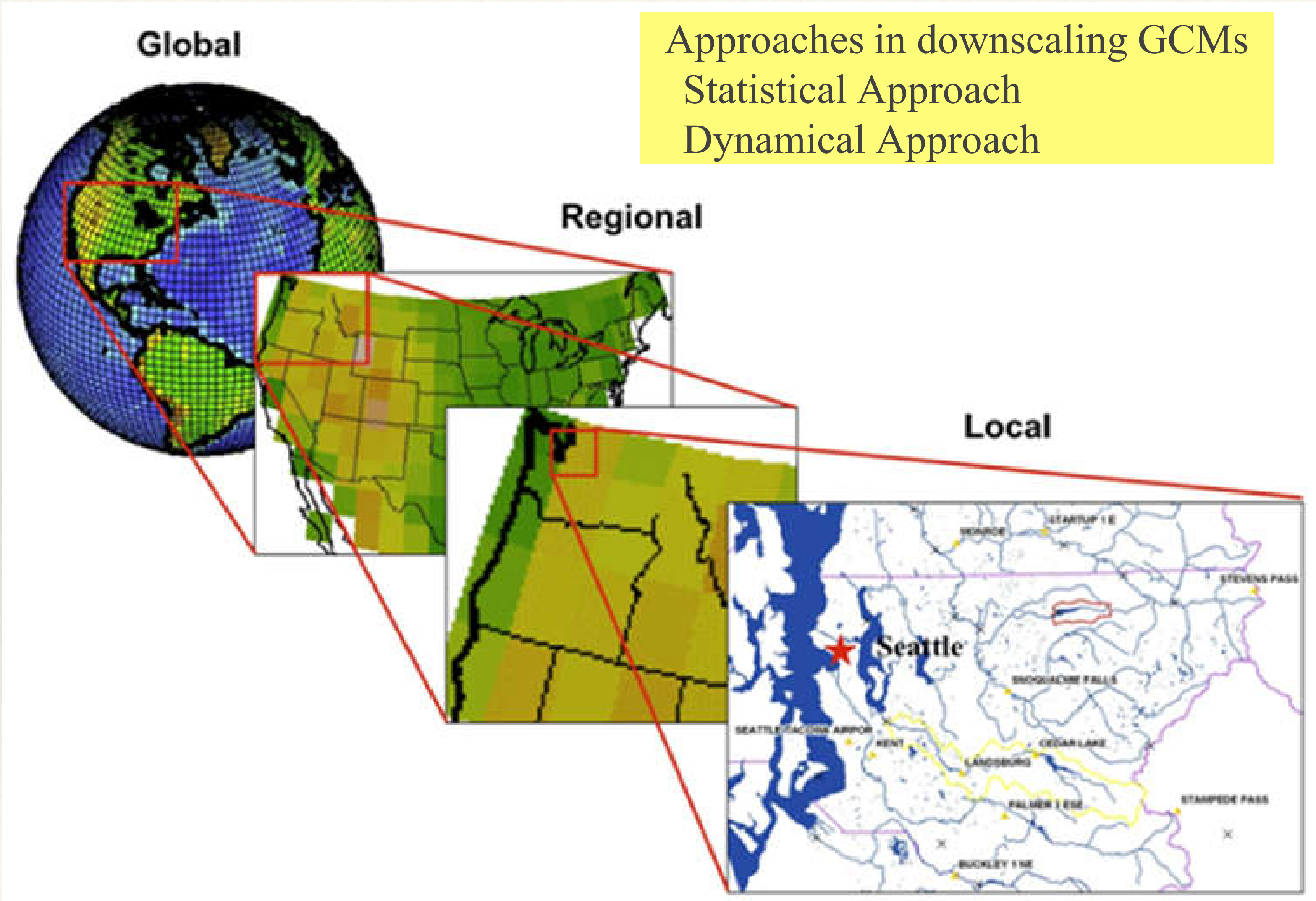
General Circulation Model (GCM)



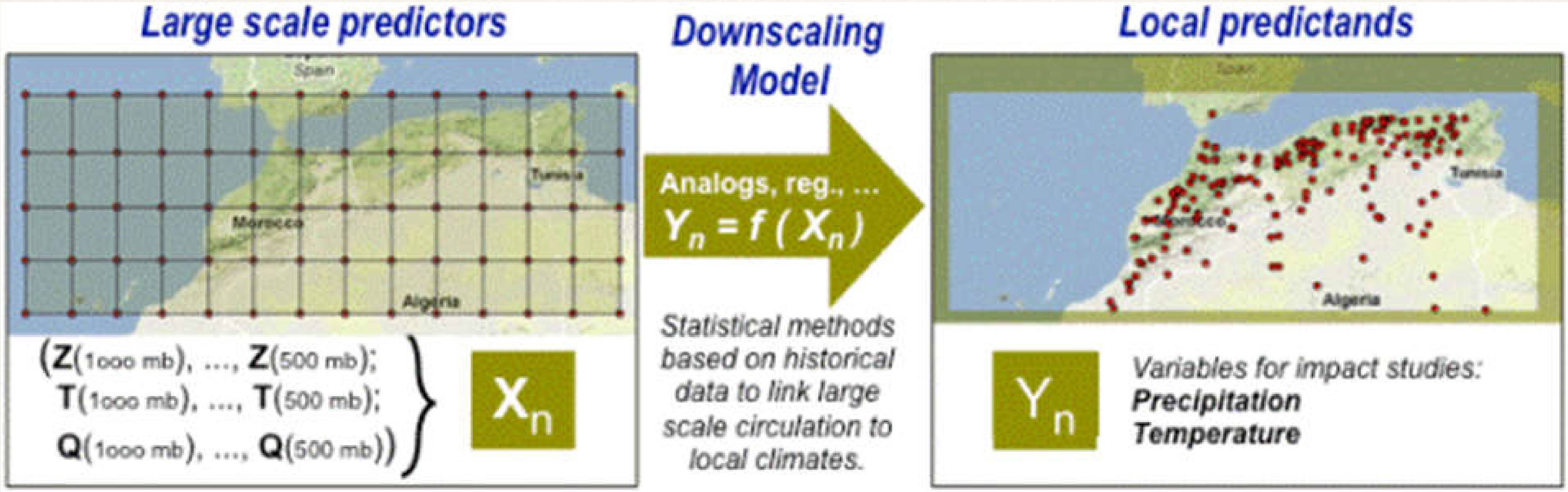
CMIP3, 5 ; Resolution 100 - 300 km



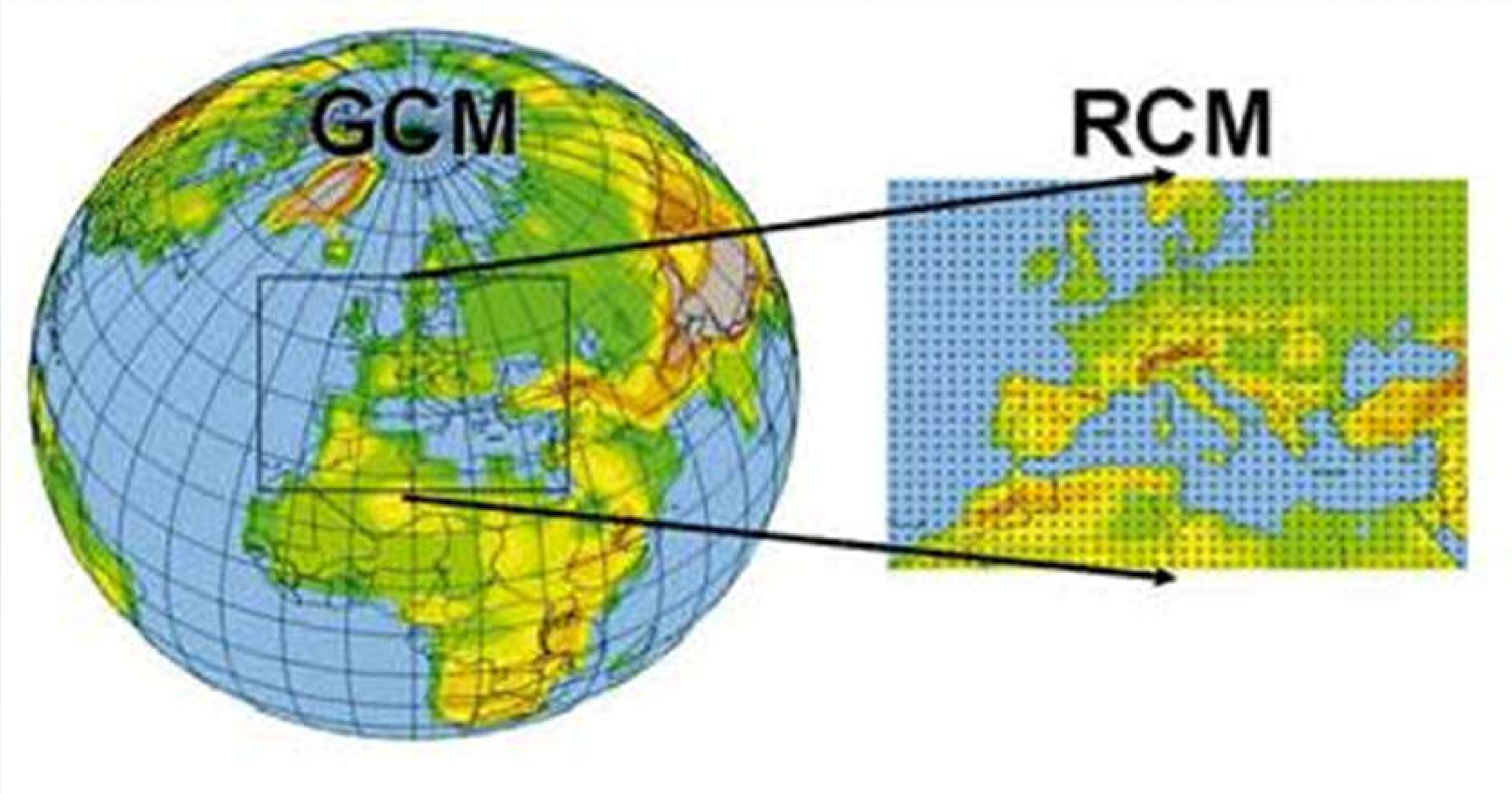
Downscaling GCMs



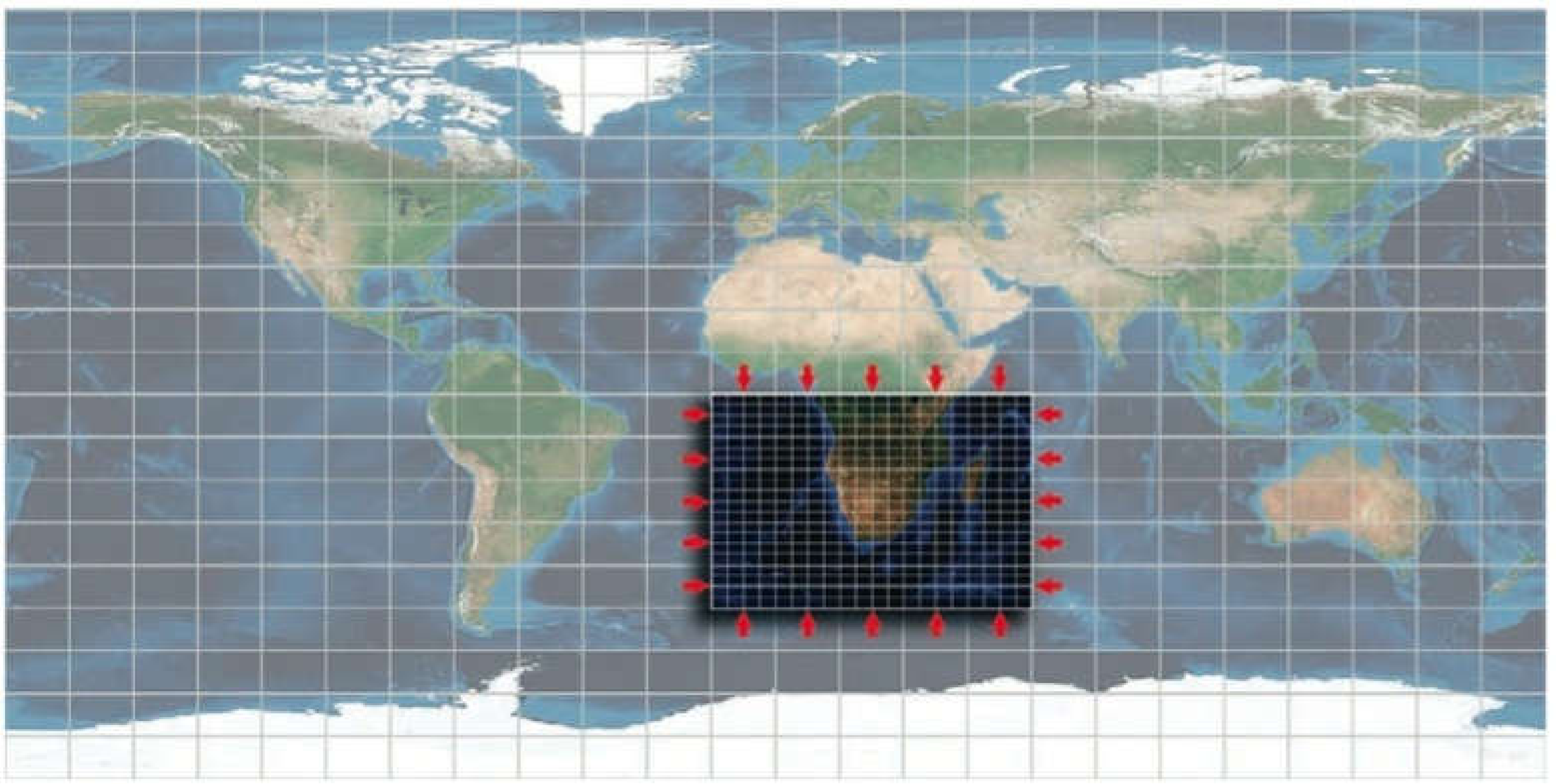
Statistical Approach



Dynamical Approach



Regional Climate Model



Downscaling Activities in Thailand

1999 : Kansri Boonpragob and Jerasorn Santisirisomboon

2005 : Chinvanno and Snidvongs

2009 : Chinvanno

2010 : Jiamjai Kreasuwun

2010 : Sirinthornthep Taoprayoon

2010 : Kansri Boonpragob and Jerasorn Santisirisomboon

2012 – 2014 : Jerasorn Santisirisomboon

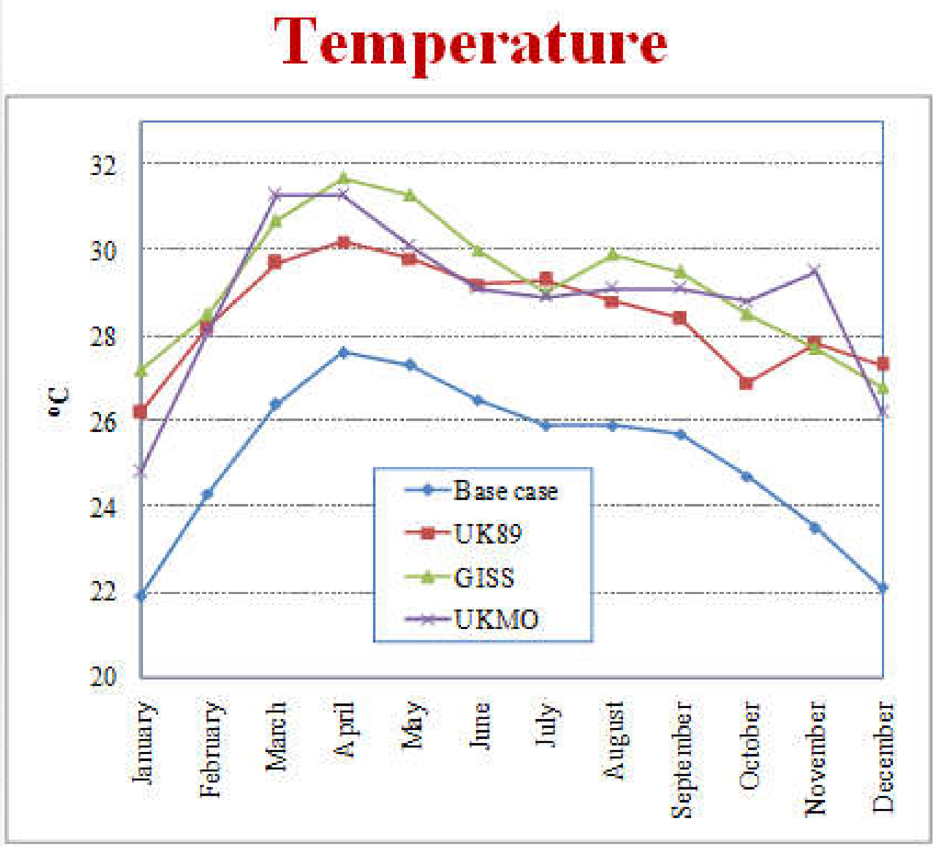
2013 – 2016 : Jerasorn Santisirisomboon

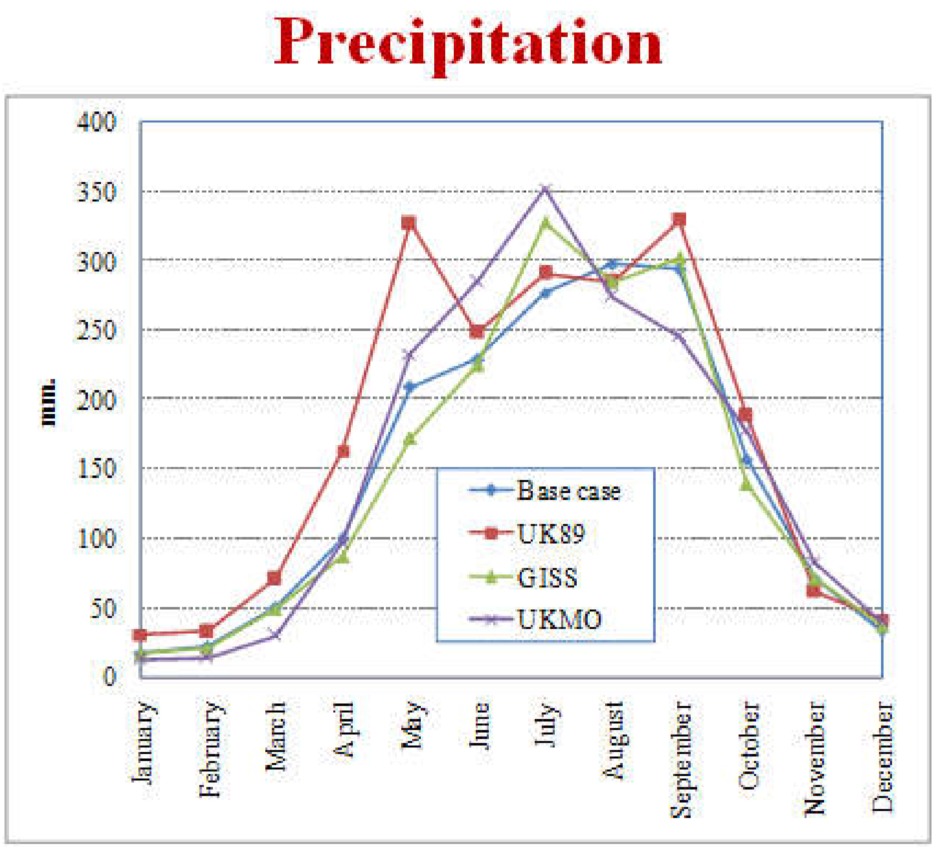
2016 – 2019 : Jerasorn Santisirisomboon

Previous Study 1 (1999)

Year	: 1999
Project leader	: Kansri Boonpragob
Organization	: Thailand Environment Institute and Ramkhamhaeng University
Funding agency	: US Country Studies Program
GCM	: GISS, UKMO, HADCM
Scenario	: Double CO2 from base year (1990)
Resolution	: 0.5 degree

Previous Study 1 (1999)





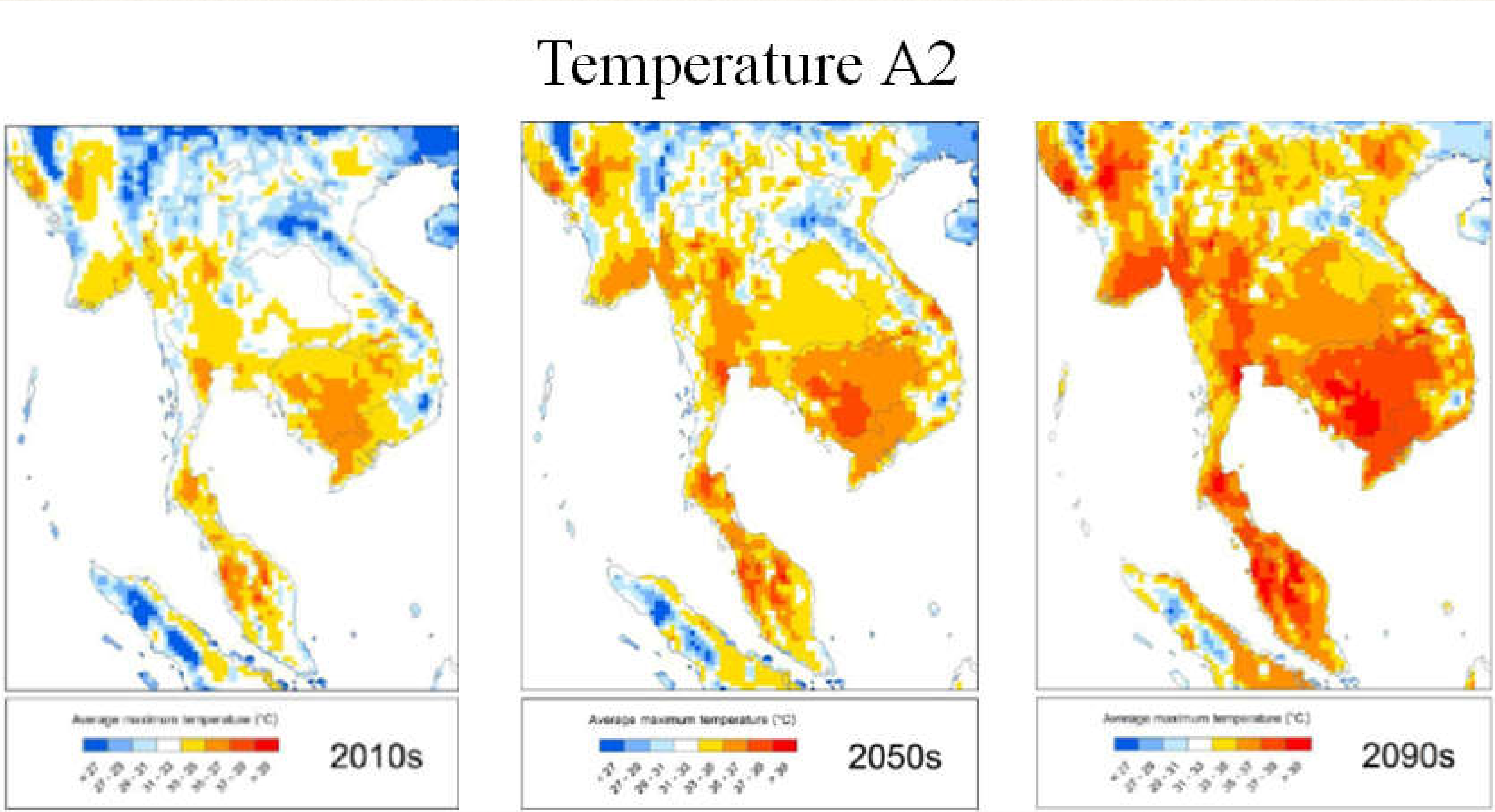
Previous Study 2 (2005)

Year	: 2005
Project leader	: Supakorn Chinvanno
Organization	: Southeast Asia System for Analyses, Research and Training (SEA Start)
Funding agency	: Global Environmental Facility (GEF)
Technique	: Dynamical
RCM	: CCCM
Scenario	: CO_2 concentration 360 540 720 ppm
Resolution	: 10 km

Previous Study 3 (2009)

Year	: 2009
Project leader	: Supakorn Chinvanno
Organization	: Southeast Asia System for Analyses, Research and Training (SEA Start)
Funding agency	: Thailand Research Fund (TRF)
Technique	: Dynamical
RCM	: PRECIS
GCM	: ECHAM4
Scenario	: SRES A2 and B2
Future year	: 2010 – 2099
Resolution	: 25 km

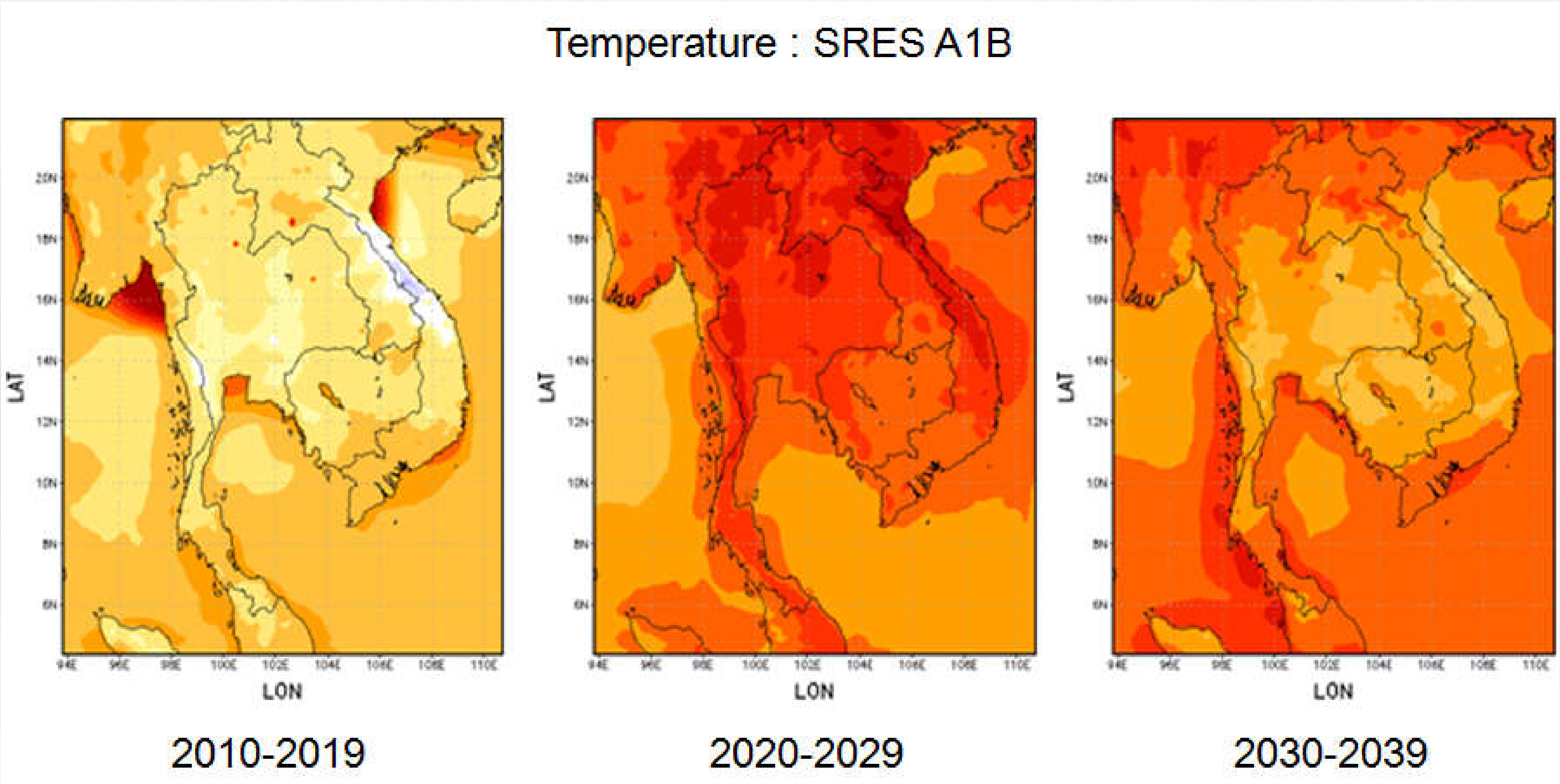
Previous Study 3 (2009)



Previous Study 4 (2010)

Year	: 2010
Project leader	: Jiamjai Kreasuwun
Organization	: Chiang Mai University
Funding agency	: Thailand Research Fund (TRF)
Technique	: Dynamical
RCM	: MM5
GCM	: CCSM3
Scenario	: SRES A1B and A2
Future year	: 2010 – 2039
Resolution	: 45 and 15 km

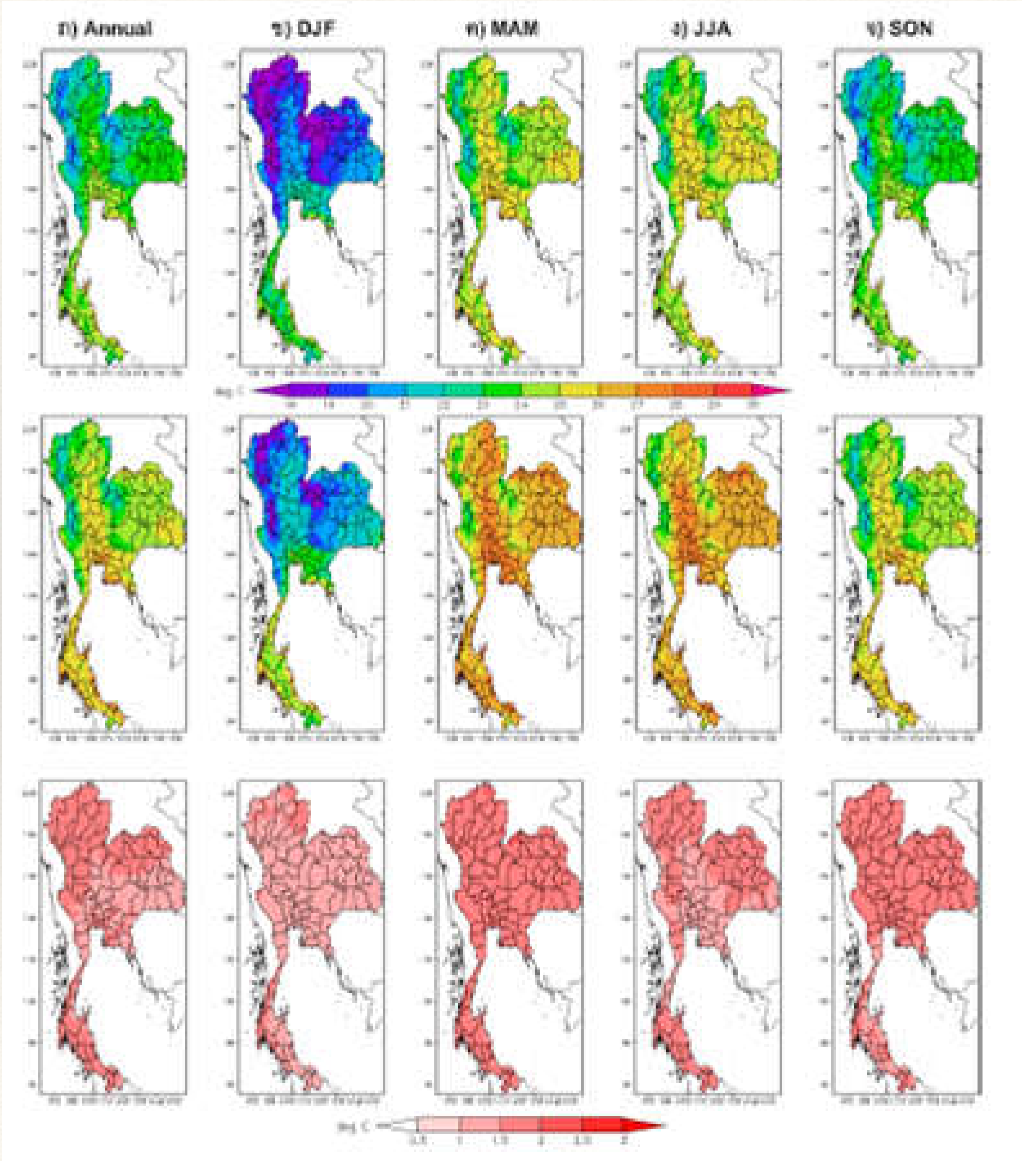
Previous Study 4 (2010)



Previous Study 5 (2010)

Year	: 2010
Project leader	: Sirinthornthep Taoprayoon
Organization	: King Mongkut's University of Technology Thonburi
Funding agency	: Thailand Research Fund (TRF)
Technique	: Dynamical
RCM	: RegCM3
GCM	: ECHAM5
Scenario	: SRES A1B and A2
Future year	: 2031 – 2070
Resolution	: 20 km

Previous Study 5 (2010)



Previous Study 6 (2010)

Year : 2010

Project leader : Kansri Boonpragob

Organization : Ramkhamhaeng University

Funding agency : Thailand Research Fund (TRF)

Technique : Statistical

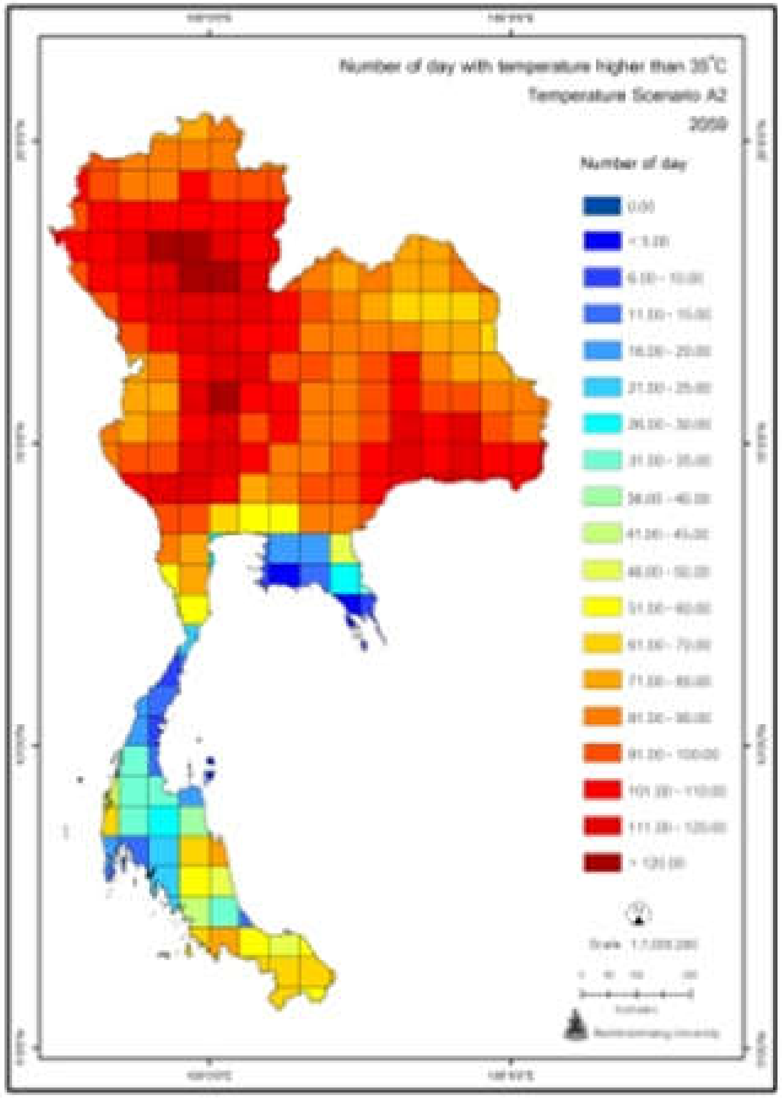
GCM : GFDL-R30

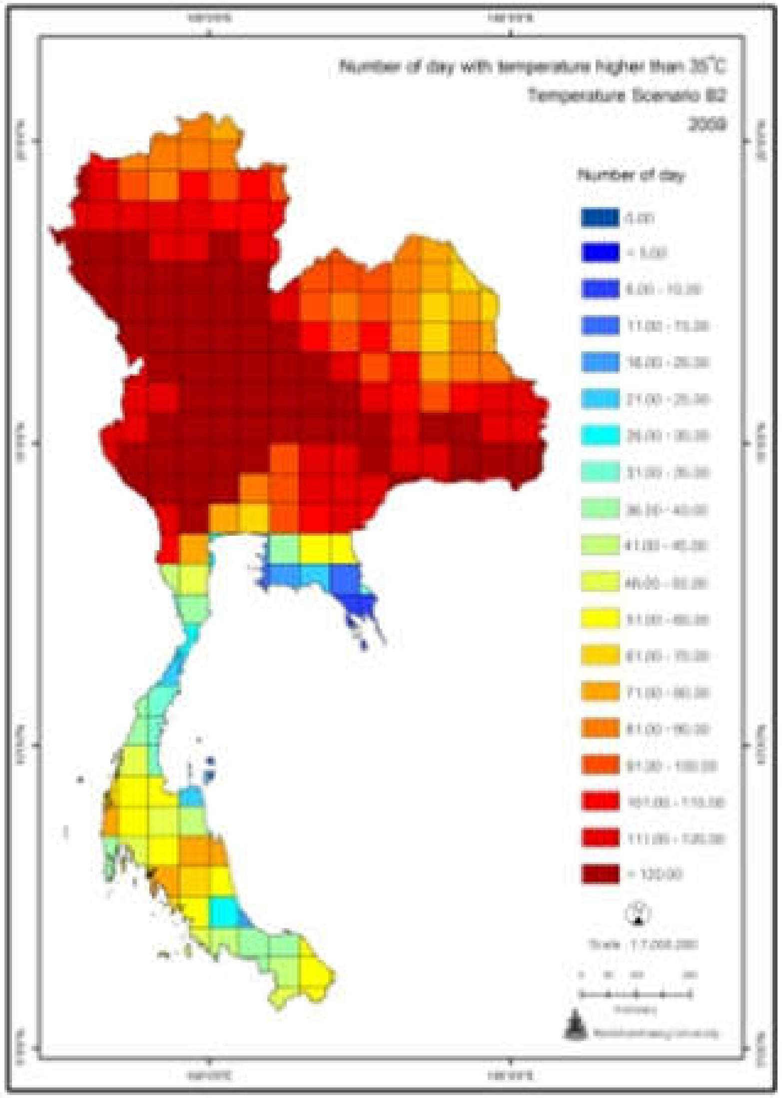
Scenario : SRES A1B and A2

Future year : 2010 – 2029, 2040 – 2059

Resolution : 0.5 degree

Previous Study 6 (2010)

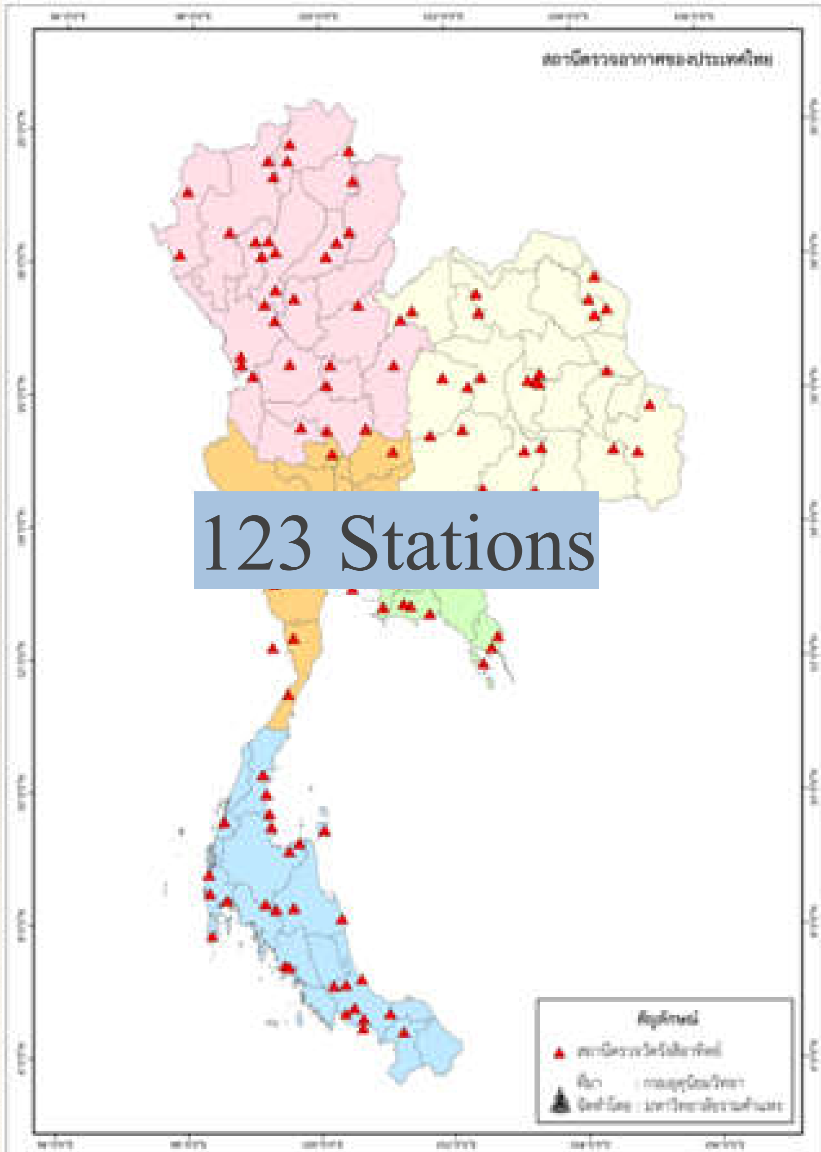


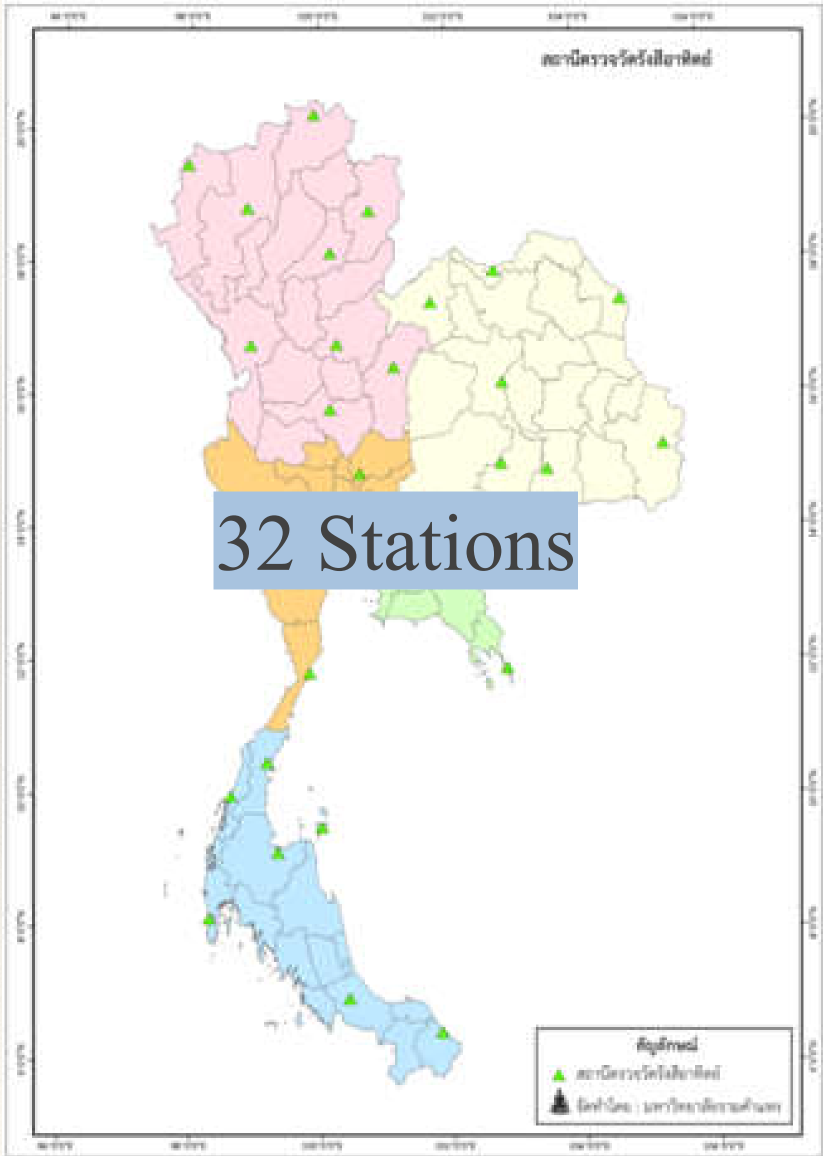


Recent Study

Year	: 2012 – 2014
Project leader	: Jerasorn Santisirisomboon
Organization	: Ramkhamhaeng University
Funding agency	: Thailand Research Fund (TRF)
Technique	: Statistical
GCMs	: GFDL-ESM2M, MPI-ESM-LR, HadGEM2-ES
Scenario	: RCPs 4.5, 6.0, 8.5
Future year	: 2006 - 2100
Resolution	: 10 km

Meteorological Stations and Data





Selected GCMs

	GFDL-ESM2M	MPI-ESM-LR	HadGEM2-ES
Organization	Geophysical Fluid Dynamic Laboratory	Max Planck Institute for Meteorology	Met Office Hadley Centre
Base year	1961 – 2005		
Future climate projection	2006 – 2100		
Scenario	RCP4.5 RCP6.0 RCP8.5	RCP4.5 - RCP8.5	RCP4.5 RCP6.0 RCP8.5
Grid resolution Latitude Longitude	 2.02247° 2.50000°	 1.86500° 1.87500°	 1.25500° 1.87500°
No. of Predictor	7	7	7

Predictors

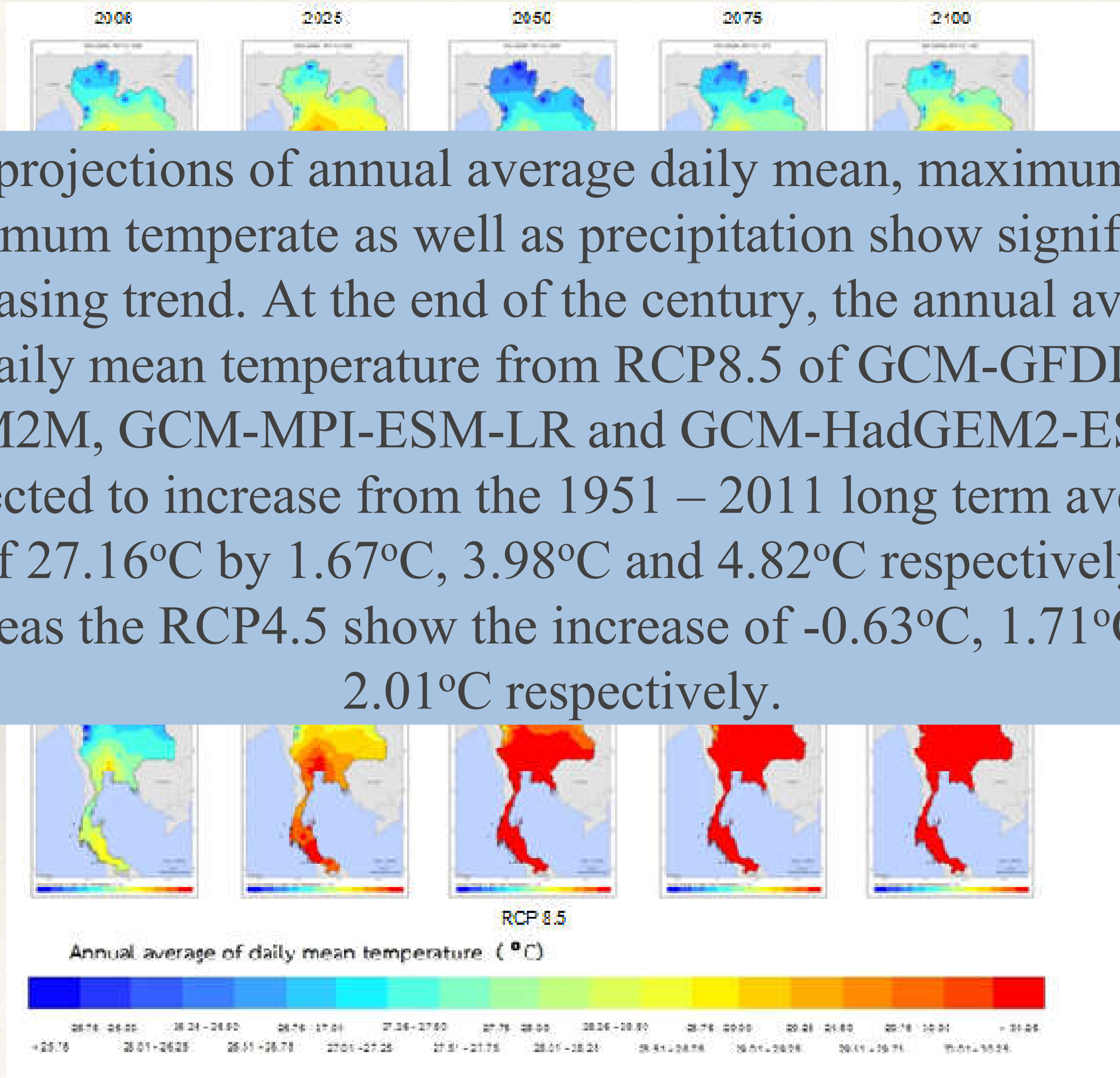
Predictors for GCMs	Unit
Daily-Mean Near Surface Wind Speed	m/s
Sea Level Pressure	Pa
Precipitation	$kg/m^2/s$
Near-Surface Specific Humidity	
Near-Surface Air Temperature	K
Daily Maximum Near-Surface Air Temperature	K
Daily Minimum Near-Surface Air Temperature	K

Downscaling Output

Base year	1961 - 2005
Future year	2006 - 2100
Spatial scale	latitude × longitude 0.1 × 0.1
Temporal scale	Daily
Area	latitude 5 – 22°N longitude 95 – 105°E
Output (Predictands)	Mean, Max., Min. Temperature Precipitation Relative humidity Sunshine duration Solar radiation Atmospheric pressure Wind speed

Temperature Change

The projections of annual average daily mean, maximum and minimum temperate as well as precipitation show significant increasing trend. At the end of the century, the annual average daily mean temperature from RCP8.5 of GCM-GFDL-ESM2M, GCM-MPI-ESM-LR and GCM-HadGEM2-ES are projected to increase from the 1951 – 2011 long term average of 27.16°C by 1.67°C, 3.98°C and 4.82°C respectively, whereas the RCP4.5 show the increase of -0.63°C, 1.71°C and 2.01°C respectively.



Southeast Asia Region

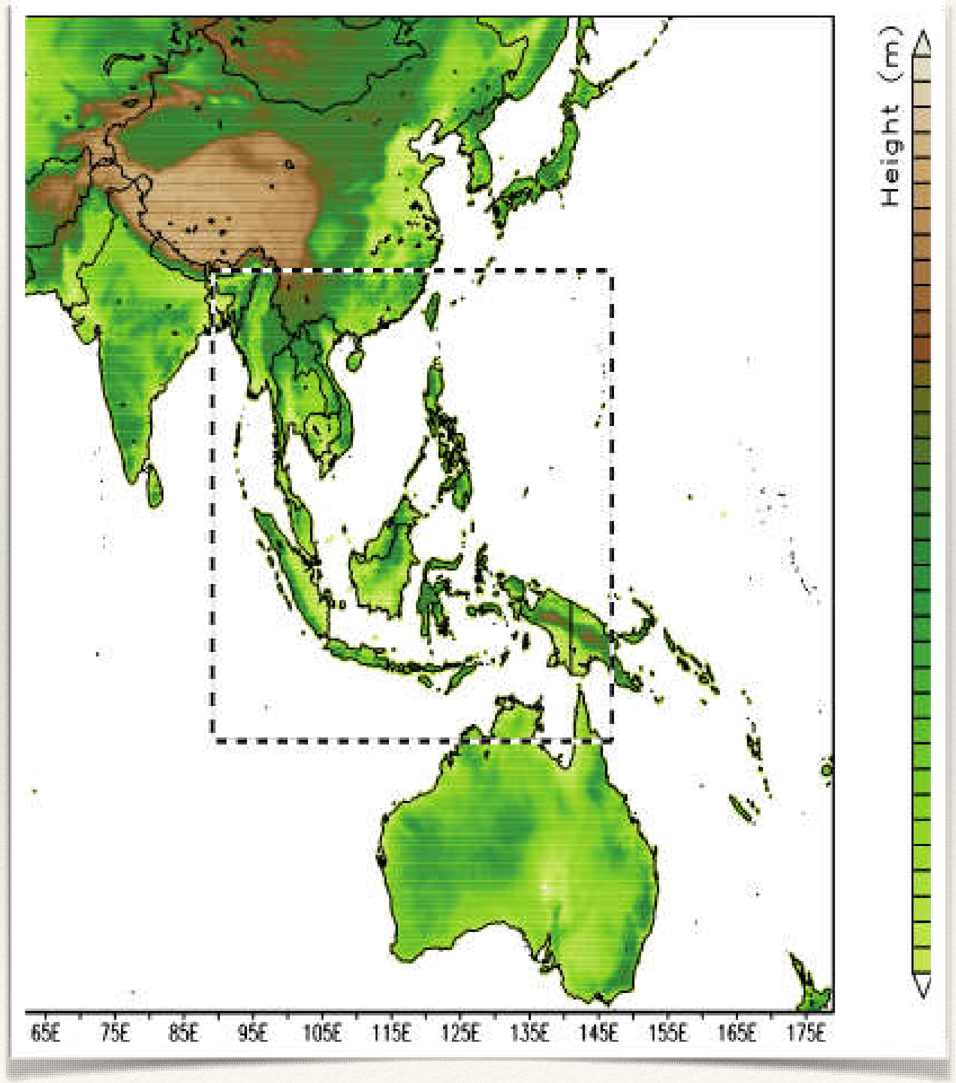
> ½ billion people

High exposure, higher vulnerability

No coordinated regional climate downscaling

No freely available downscaled regional climate change scenarios

Could be a contributing factor to lack of IAV studies in the region



Sector	Topics/issues	North Asia		East Asia		Southeast Asia		South Asia		Central Asia		West Asia	
	O = Observed impacts, P = Projected Impacts	O	P	O	P	O	P	O	P	O	P	O	P
Freshwater resources	Major river runoff	/	x	/	/	/	/	/					x
	Water supply	x	x	x	x	x	x	x					x
Terrestrial and inland water systems	Phenology and growth rates	/	/	/	/	x	x	x					x
	Distributions of species and biomes	/	/	/	/	x	x	x					x
	Permafrost	/	/	/	/	/	x	/					x
	Inland waters	x	x	/	x	x	x	x					x
Coastal systems and low-lying areas	Coral reefs	NR	NR	/	/	/	/	/					/
	Other coastal ecosystems	x	x	/	/	x	x	x					x
	Arctic coast erosion	/	/	NR	NR	NR	NR	NR					NR
Food production systems and food security	Rice yield	x	x	/	/	x	/	x					/
	Wheat yield	x	x	x	x	x	x	x					/
	Corn yield	x	x	x	/	x	x	x					x
	Other crops (e.g., barley, potato)	x	x	/	/	x	x	x					/
	Vegetables	x	x	/	x	x	x	x					x
	Fruits	x	x	/	x	x	x	x					x
	Livestock	x	x	/	x	x	x	x					x
	Fisheries and aquaculture production	x	/	x	/	x	/	x					x
	Farming area	x	/	x	/	x	x	x					x
	Water demand for irrigation	x	/	x	/	x	x	x					x
	Pest and disease occurrence	x	x	x	x	x	x	x					x
Human settlements, industry, and infrastructure	Floodplains	x	x	/	/	/	/	/					x
	Coastal areas	x	x	/	/	/	/	/					x
	Population and assets	x	x	/	/	/	/	/					x
	Industry and infrastructure	x	x	/	/	/	/	/					x
Human health, security, livelihoods, and poverty	Health effects of floods	x	x	x	x	x	x	/					x
	Health effects of heat	x	x	/	x	x	x	x					x
	Health effects of drought	x	x	x	x	x	x	x					x
	Water-borne diseases	x	x	x	x	/	x	/					x
	Vector-borne diseases	x	x	x	x	/	x	/					x
	Livelihoods and poverty	x	x	/	x	x	x	/					x
	Economic valuation	x	x	x	x	/	/	/					x

Critically lack of studies on impacts of climate change in Southeast Asia region

Table 24.2 IPCC AR5 WGII

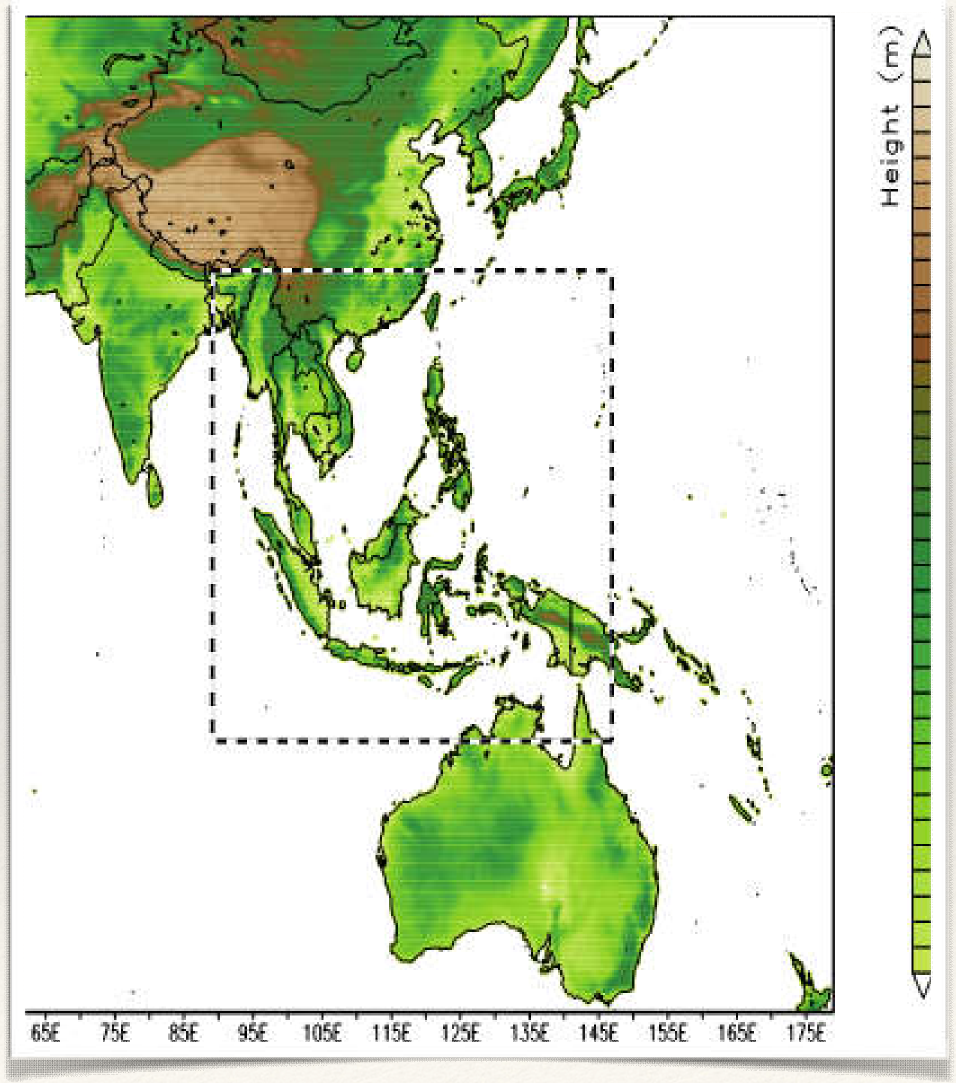
Southeast Asia Region

With multiple GCMs, RCMs, and emission scenarios, regional climate downscaling requires large computing resources

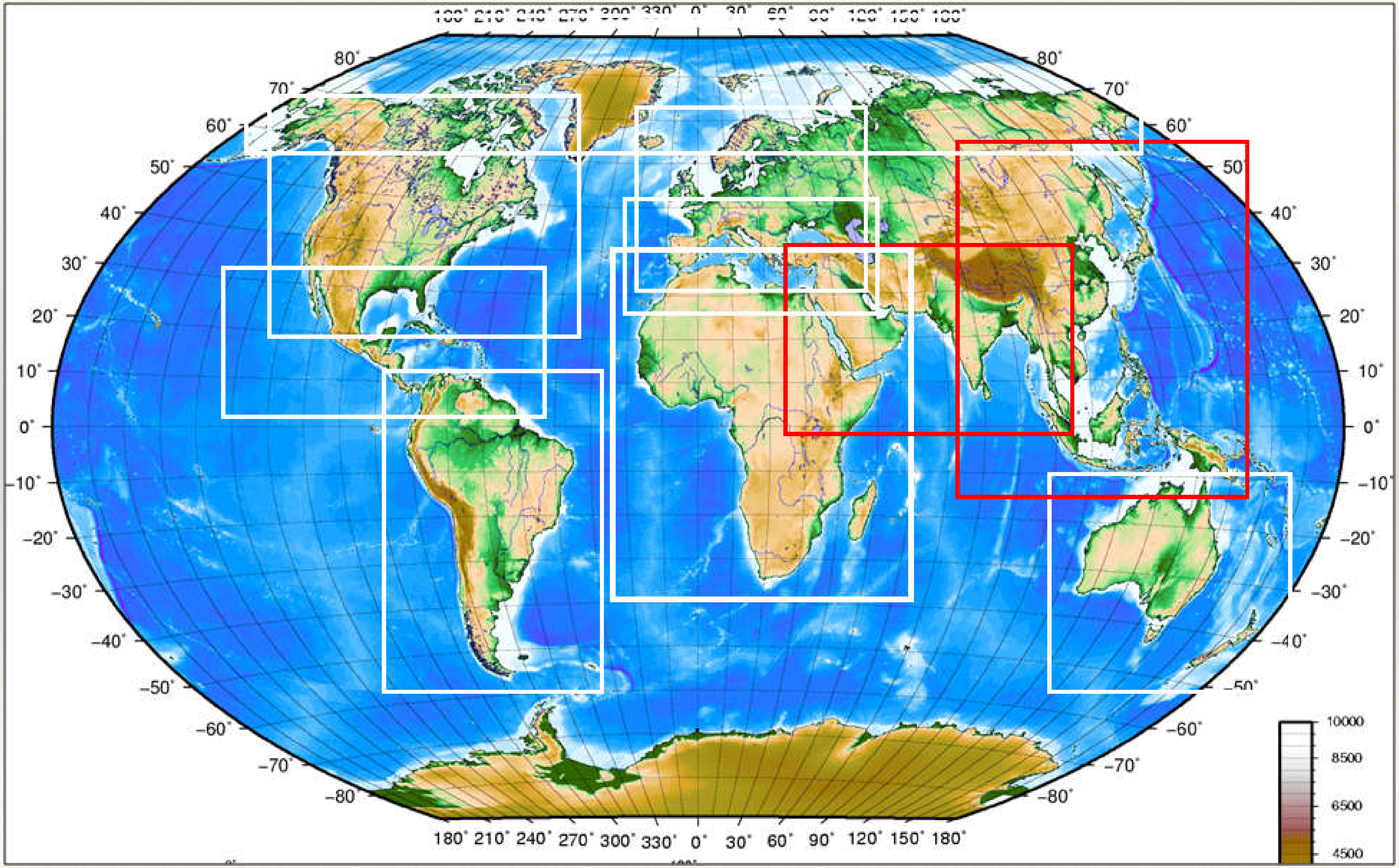
We have a number of institutions with regional climate modeling expertise but limited resources

Collaboration and sharing resources are the way to move forward

CORDEX provides a good platform for regional collaboration



CORDEX Domain



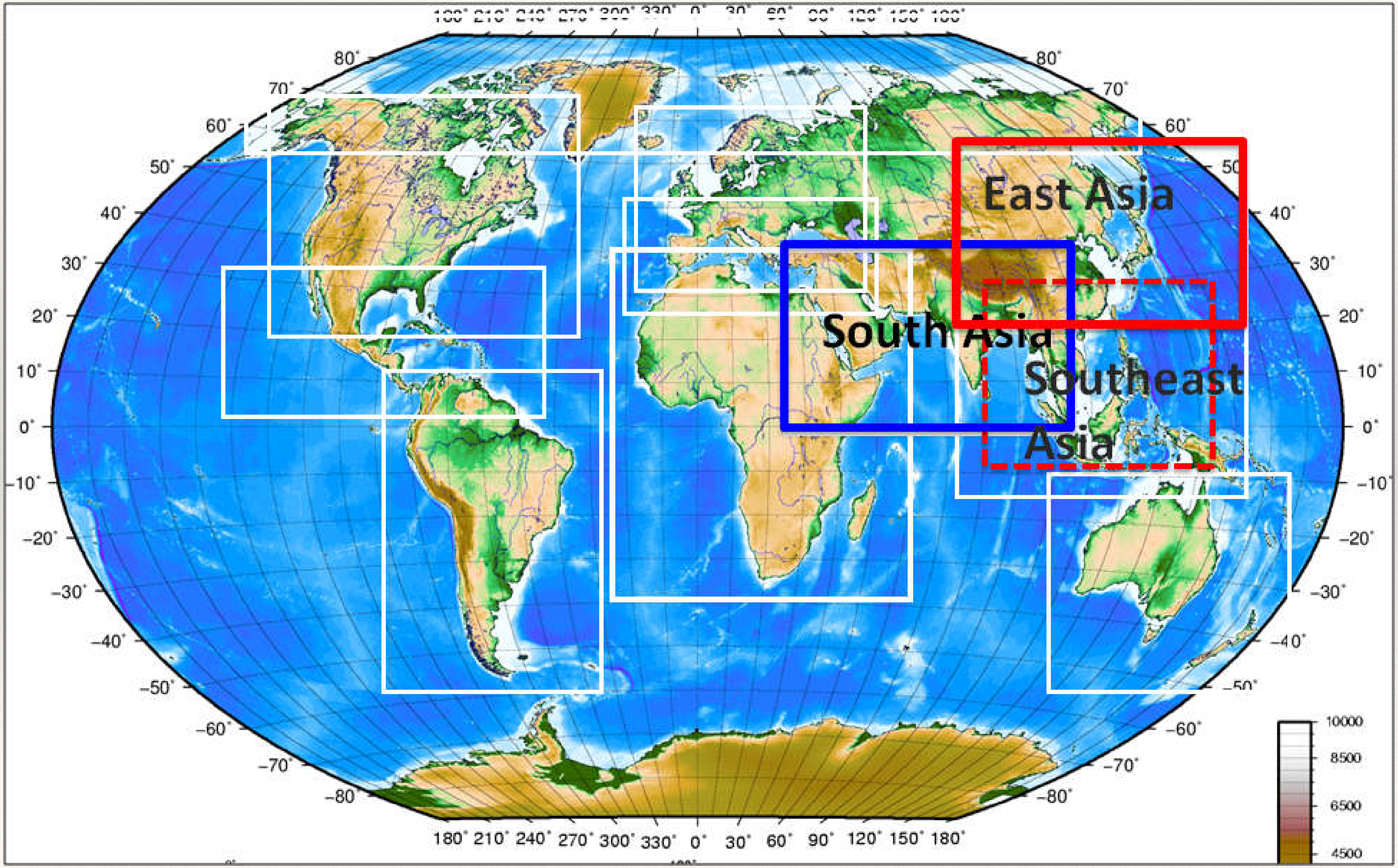
APN
ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

20 YEARS
Bridging Science & Policy for a Sustainable Asia-Pacific

Southeast Asia Regional Climate Downscaling (SEACLID)

Initial Member Countries: Malaysia, Indonesia, Vietnam, Philippines, Thailand
First Workshop hosted by VNU Hanoi University of Science, Vietnam, 2-3 Aug 2012

CORDEX domains



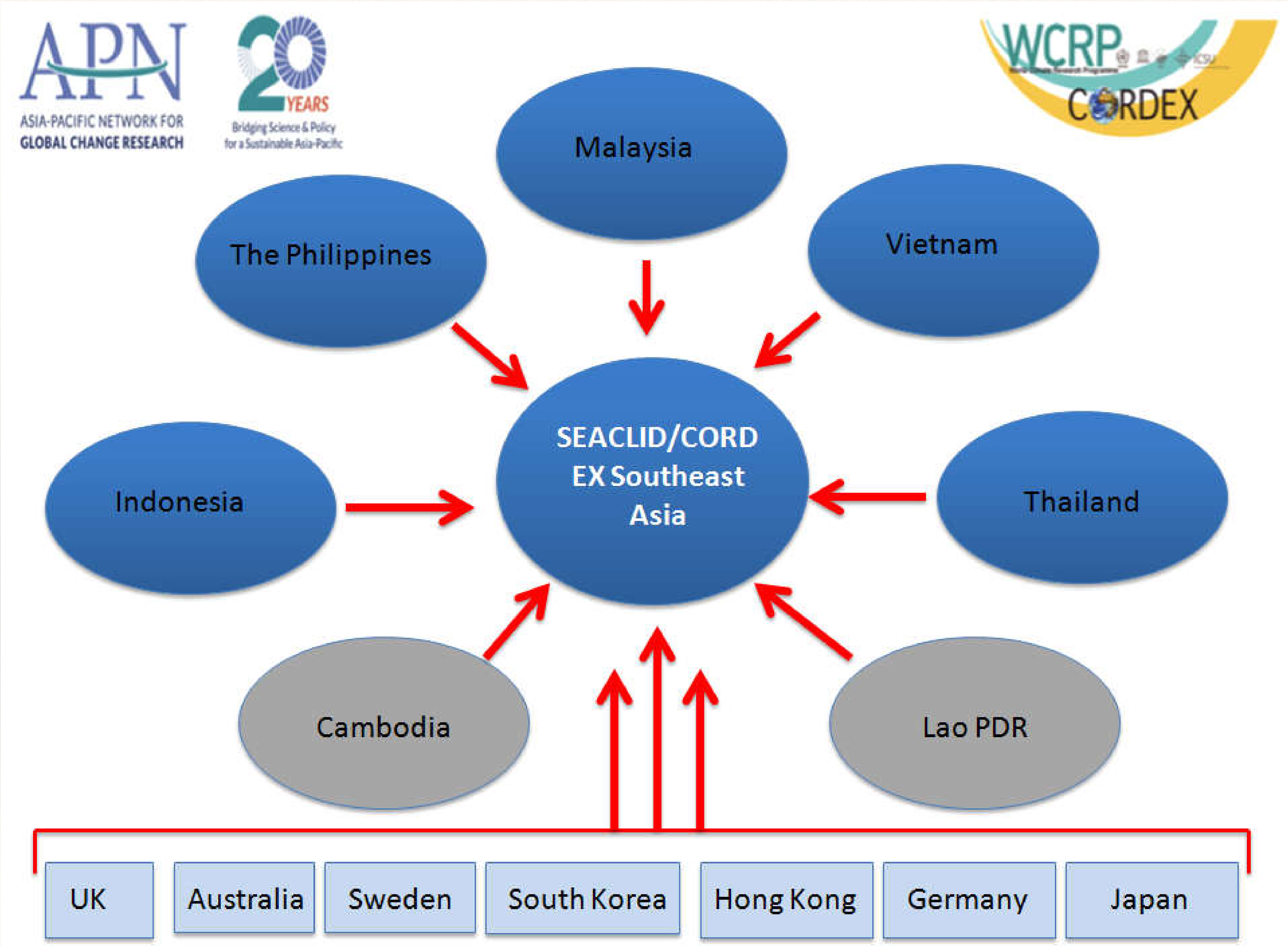
SEACLID/CORDEX SEA objectives

Create a platform for scientists (especially young scientists) within and outside the SEA region to collaborate on issues related to regional climate downscaling;

On a task-sharing basis, carry out a joint regional climate downscaling activity over a common SEA domain with RegCM4 (and other RCMs) using a number of CMIP5 GCMs and RCP scenarios;

Collectively analyze model performances, create an ensemble of regional climate projection scenarios for the SEA region, and establish a web portal and data center for efficient data dissemination (ESGF);

Narrow knowledge gaps related to regional climate change in SEA by increasing peer-review scientific and policy-relevant publications and strengthen research capacity and capability, particularly in numerical regional climate modeling.

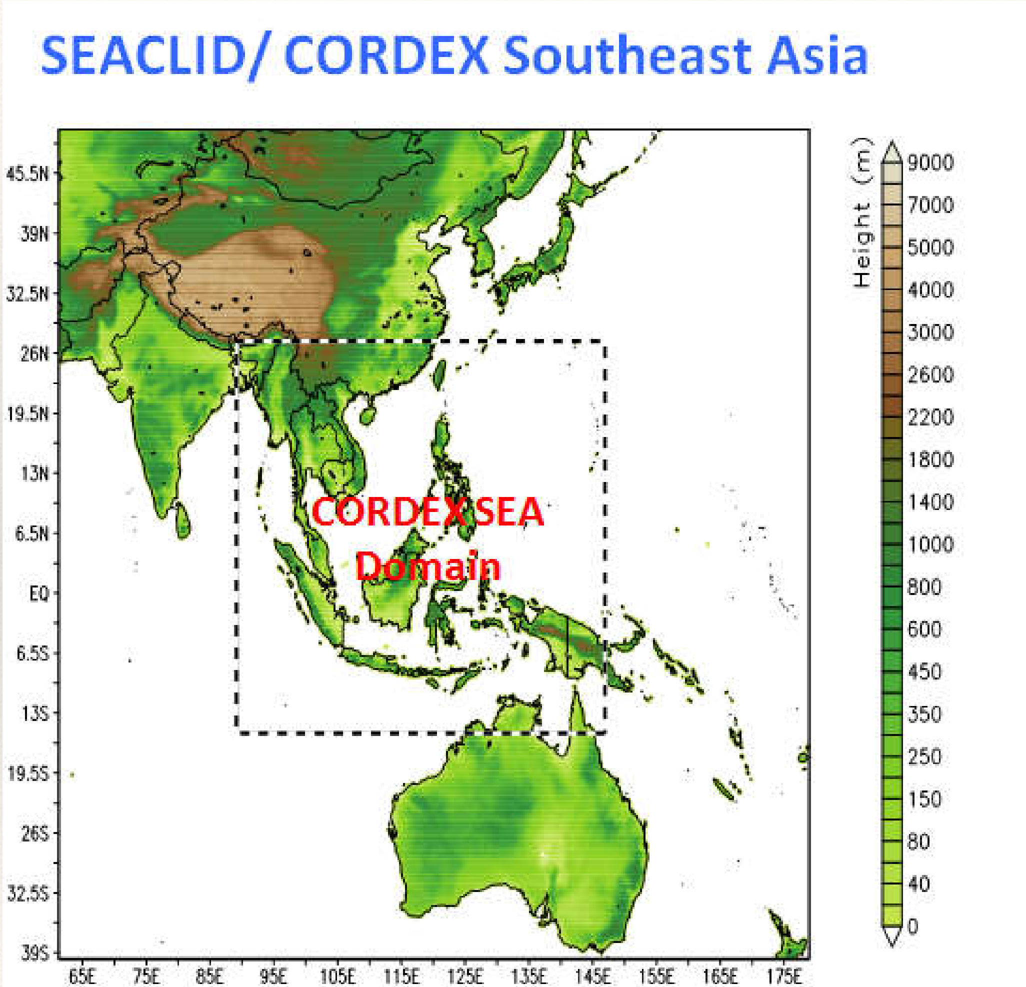

APN
ASIA-PACIFIC NETWORK FOR
GLOBAL CHANGE RESEARCH
20 YEARS
Bridging Science & Policy
for a Sustainable Asia-Pacific
WCRP
CORDEX
Malaysia
The Philippines
Vietnam
SEACLID/CORD
EX Southeast
Asia
Indonesia
Thailand
Cambodia
Lao PDR
UK
Australia
Sweden
South Korea
Hong Kong
Germany
Japan

CORDEX SEA Domain

Domain: ~15.14°S – 27.26°N, ~89.26°E – 146.96°E (approved by CORDEX)

Resolution: 25 km × 25 km

3 Years [Nov 2013 – Oct 2016]



GCMs, RCMs, RCPs and Country Assignments

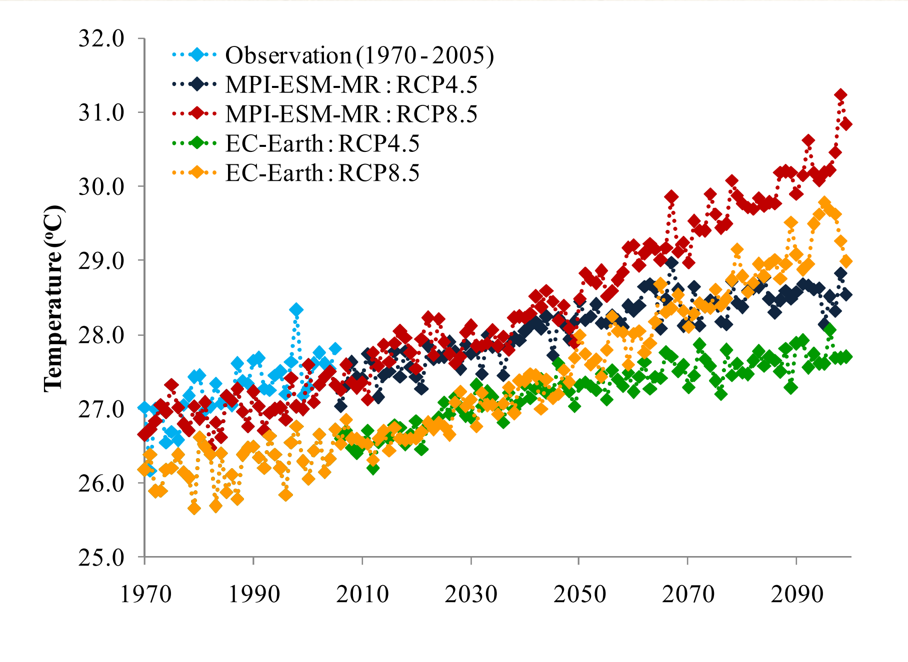
Country	GCM	Institution & Country developed the GCM	RCP	RCM
Vietnam	CNRM-CM5	Centre national de Recherches Meteorologiques, France	RCP8.5, 4.5	RegCM4
Philippines	HadGEM2	Hadley Centre, UK	RCP8.5, 4.5	RegCM4
Thailand	MPI-ESM-MR	Max Planck Institute for Meteorology, Germany	RCP8.5, 4.5	RegCM4
Thailand	EC-Earth	EC-Earth consortium	RCP8.5, 4.5	RegCM4
Indonesia	CSIRO MK3.6	CSIRO, Australia	RCP8.5, 4.5	RegCM4
Malaysia	CanESM2	Canadian Centre for Climate Modeling and Analysis, Canada	RCP8.5, 4.5	RegCM4
Malaysia	IPSL-CM5A-LR	Institute Pierre-Simon Laplace, France	RCP8.5, 4.5	RegCM4
Malaysia	GFDL-ESM2M	GFDL, USA	RCP8.5, 4.5	RegCM4
South Korea	HadGEM2-AO	Hadley Centre, UKMO	RCP8.5, 4.5	WRF
Sweden	CNRM-CM5	Centre national de Recherches Meteorologiques, France	RCP8.5, 4.5	RCA3
Sweden	HadGEM2-ES	Hadley Centre, UKMO, UK	RCP8.5,4.5	RCA3
Australia	CNRM-CM5	Centre national de Recherches Meteorologiques, France	RCP8.5	CCAM
Australia	CCSM4	NCAR, USA	RCP8.5	CCAM
Australia	ACCESS1.3	CSIRO, Australia	RCP8.5	CCAM
Hong Kong SAR	CCSM4 or CESM	NCAR, USA	RCP8.5, 4.5	WRF
United Kingdom	HadGEM2-ES	Hadley Centre, UKMO	RCP8.5, 4.5	PRECIS
Germany	MPI-ESM-LR	Max Planck Institute for Meteorology, Germany	RCP8.5, 4.5	ROM
Japan	MRI-AGCM3.2	Meteorological Research Institute, JMA, Japan	RCP8.5,4.5	NHRCM

Impacts of a 4°C global warming

The explored consequences of an increase of the global earth temperature of 4°C are indeed devastating. Among the foreseen consequences are:

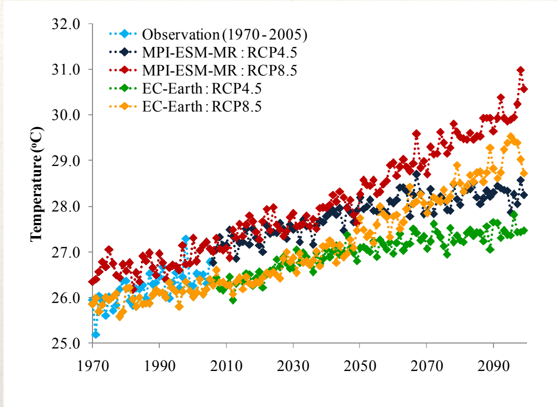
- the inundation of coastal cities;
- increasing risks for food production potentially leading to higher malnutrition rates; many dry regions becoming dryer and wet regions wetter;
- unprecedented heat waves in many regions, especially in the tropics;
- substantially exacerbated water scarcity in many regions;
- increased frequency of high-intensity tropical cyclones;
- irreversible loss of biodiversity, including coral reef systems.

Future Temperature Projection

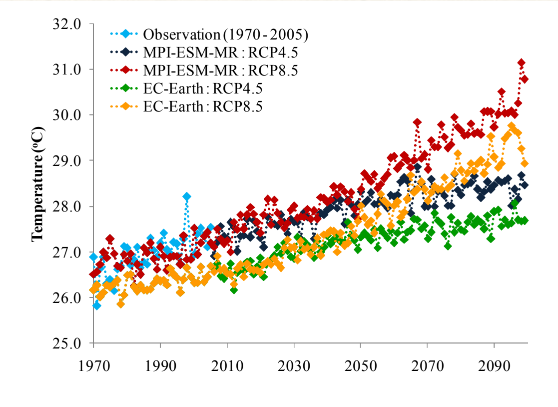


Whole Kingdom

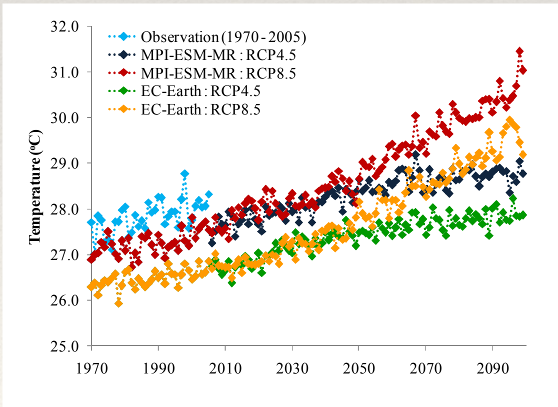
2099, Linear Trend
RCP4.5 : +1.6 – 1.8ºC
RCP8.5 : 2.8 – 3.2ºC



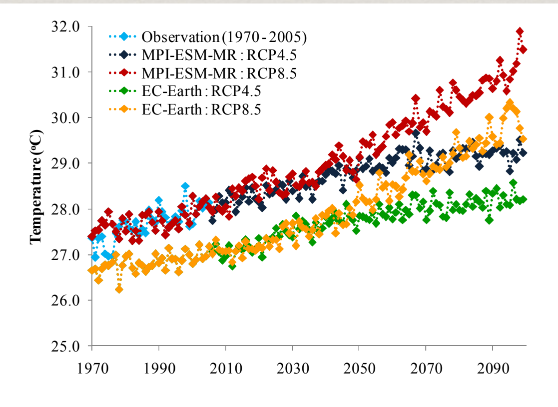
North



Northeast



Central



South

Future Temperature Projection

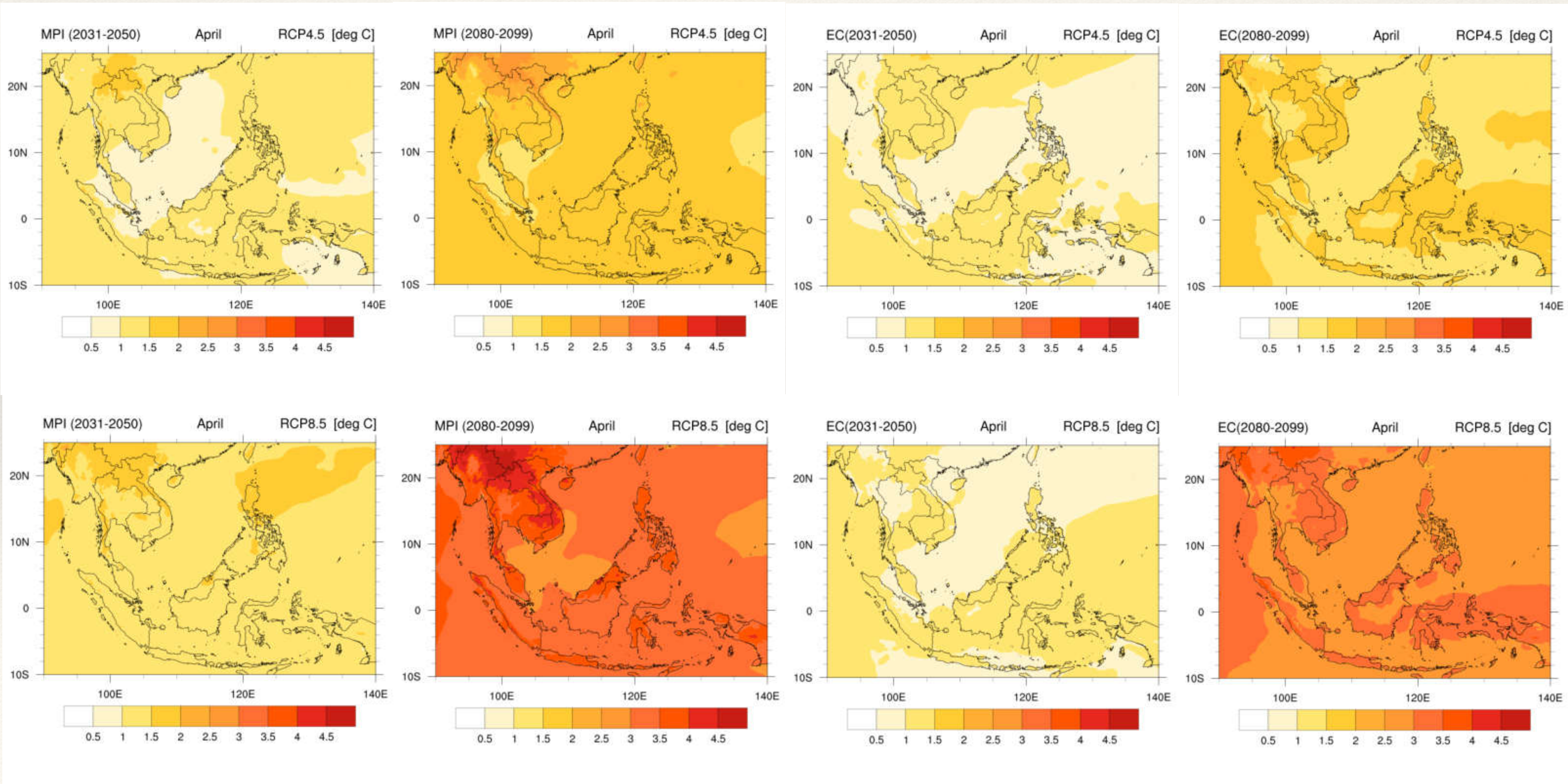
Temperature anomali in 2099 calculated base on linear trend compared to 1970 - 2005

MPI & EC-Earth	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Whole Kingdom	+1.79	+3.19	+1.65	+2.86
North	+1.82	+3.23	+1.62	+2.83
Northeast	+1.78	+3.17	+1.57	+2.78
Central	+1.78	+3.17	+1.58	+2.80
South	+1.76	+3.14	+1.57	+2.78

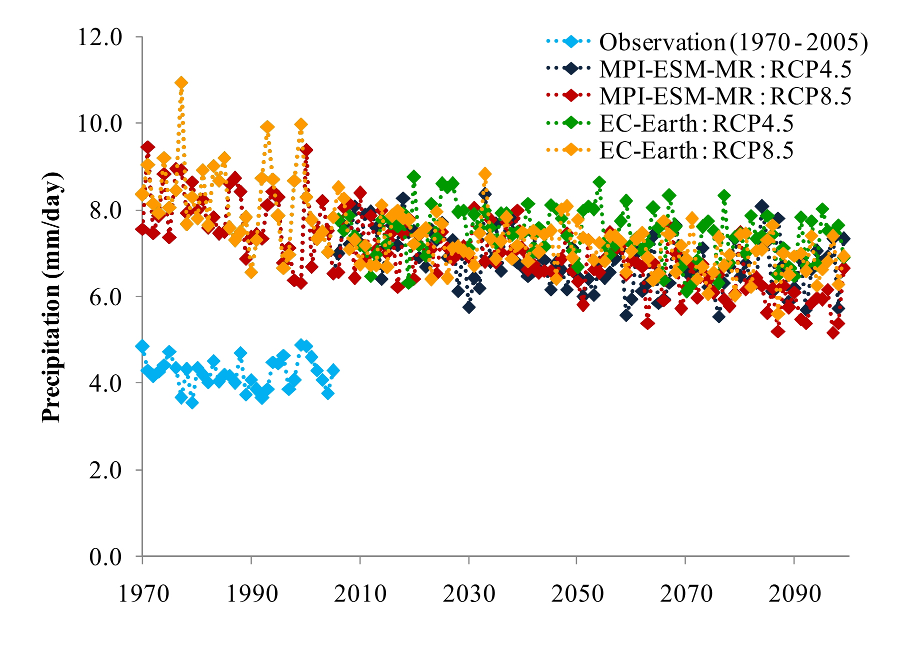
Temperature Change : April

MPI-ESM-MR | EC-Earth

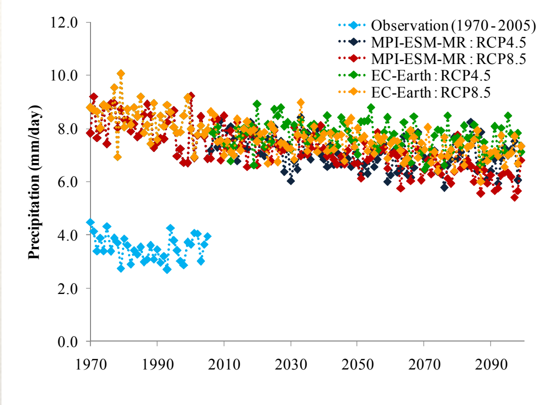
2031 – 2050 | 2080 - 2099 | 2031 – 2050 | 2080 - 2099



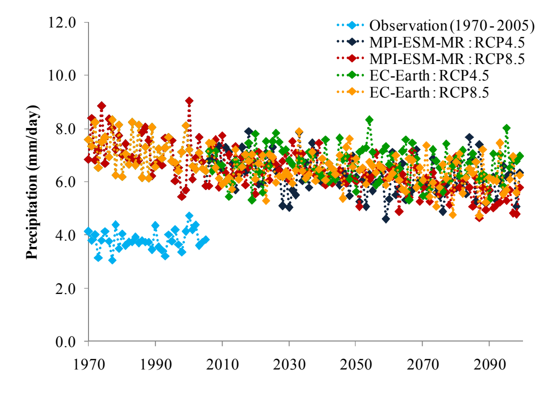
Future Rainfall Projection



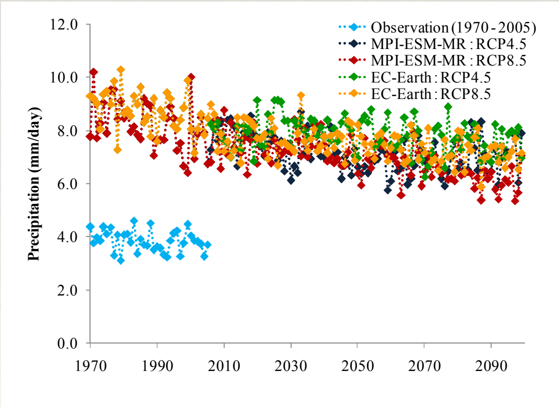
Whole Kingdom



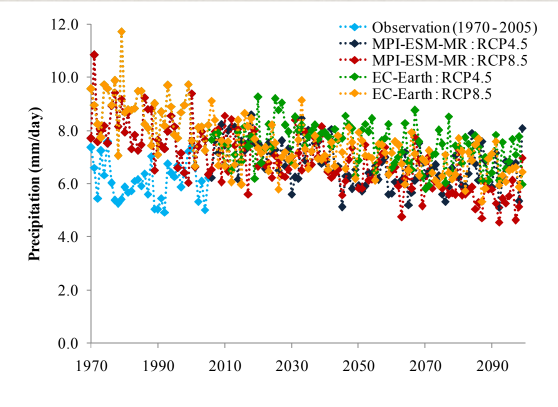
North



Northeast



Central



South

Future Rainfall Projection

Rainfall anomali in 2099 calculated base on linear trend compared to 1970 - 2005

MPI & EC-Earth	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Whole Kingdom	-1.58	-1.97	-1.11	-1.62
North	-1.49	-1.86	-0.94	-1.44
Northeast	-1.44	-1.70	-0.68	-1.15
Central	-1.70	-2.16	-1.35	-1.89
South	-1.94	-2.50	-1.81	-2.43

Precipitation Change : April

MPI-ESM-MR

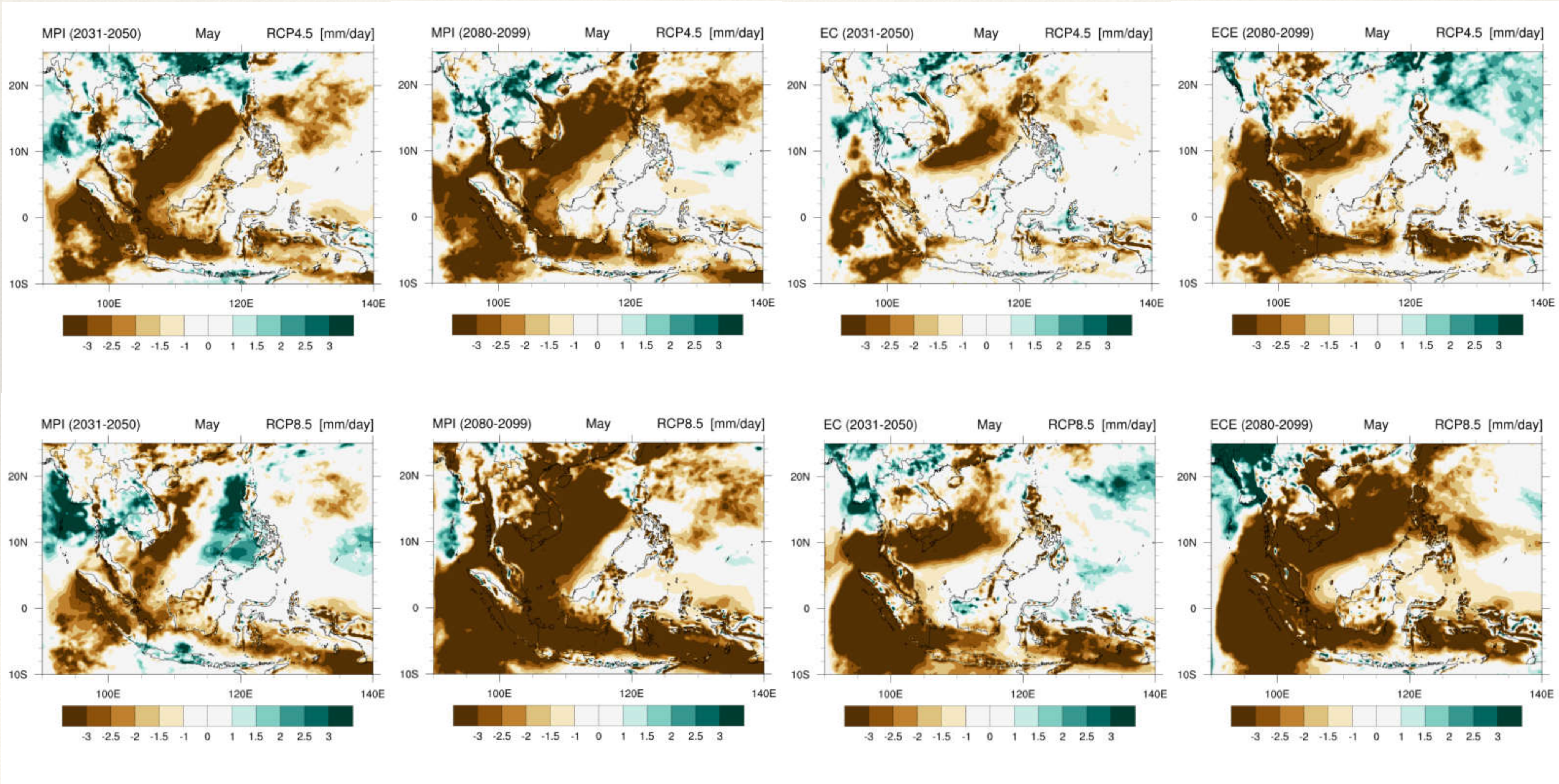
EC-Earth

2031 – 2050

2080 - 2099

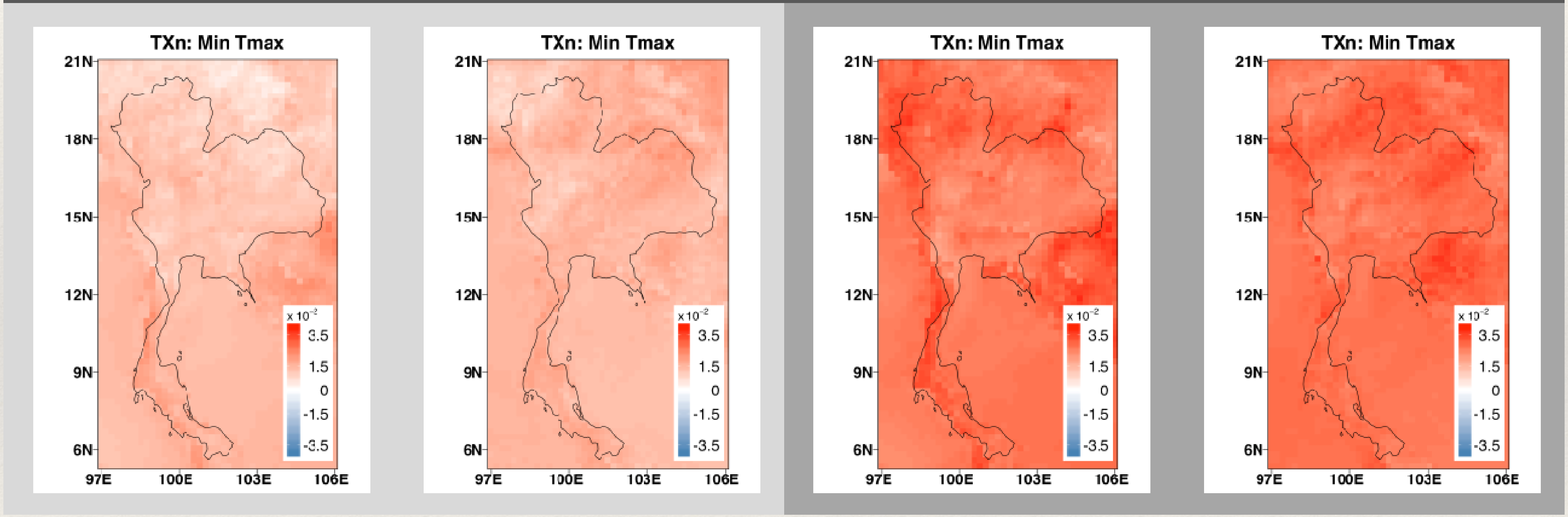
2031 – 2050

2080 - 2099



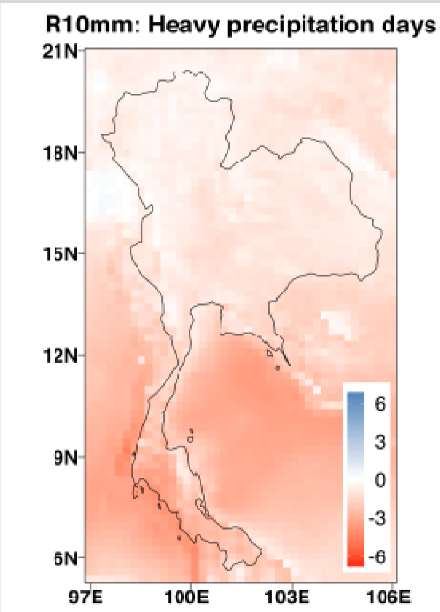
Trend of Min Tmax

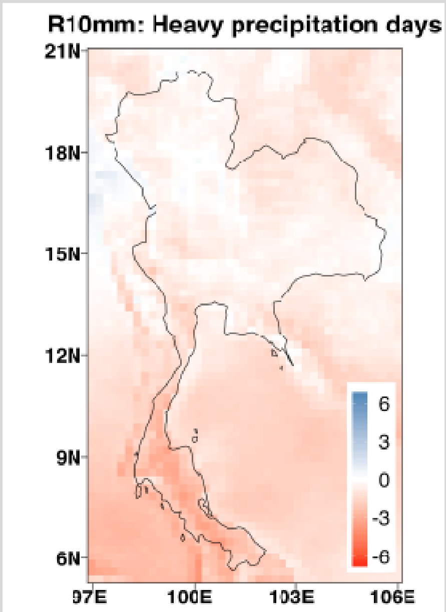
RCP4.5		RCP8.5	
MPI-ESM-MR	EC-Earth	MPI-ESM-MR	EC-Earth

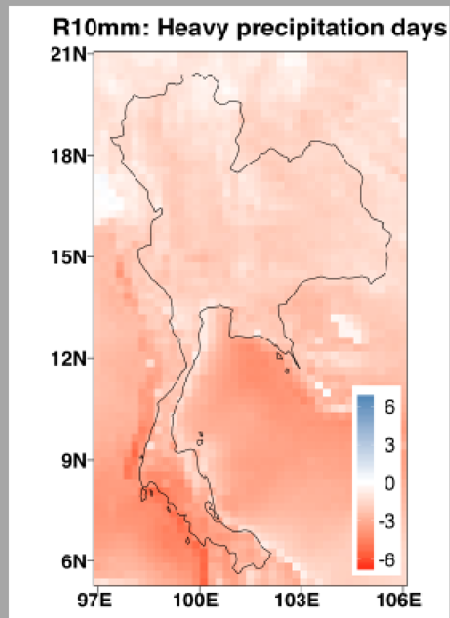


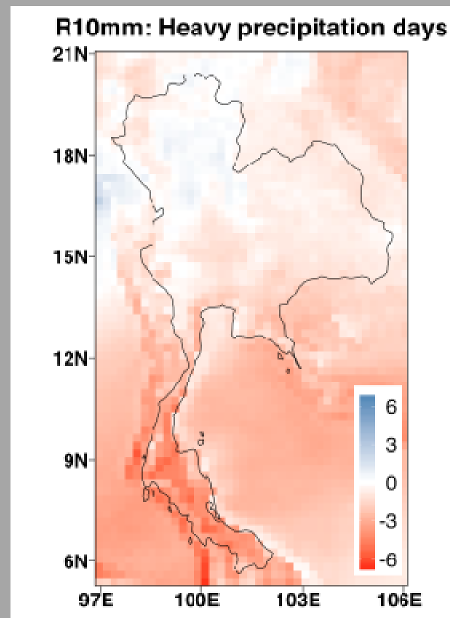
Trend of Heavy Precipitation Days

RCP4.5		RCP8.5	
MPI-ESM-MR	EC-Earth	MPI-ESM-MR	EC-Earth









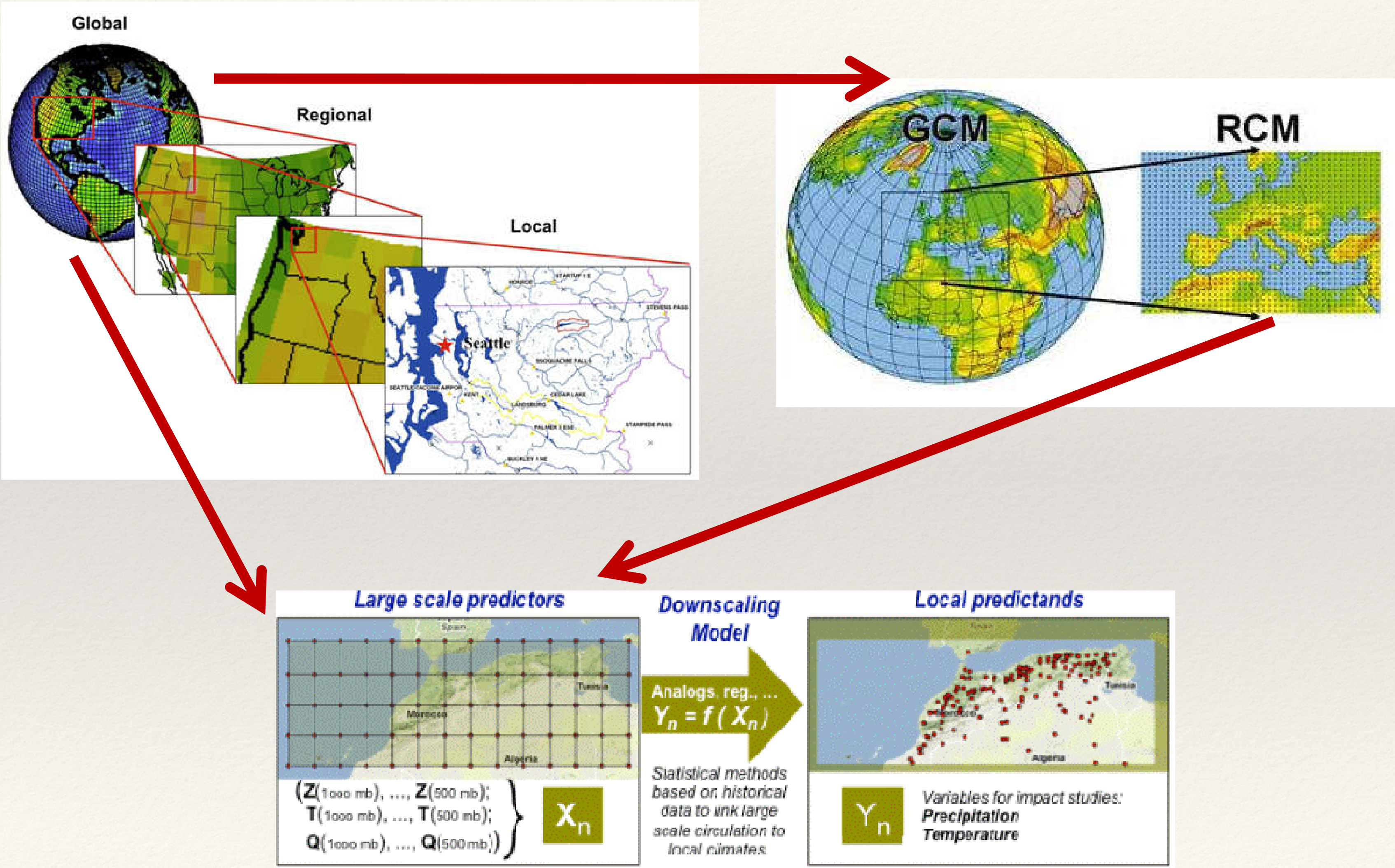
ESGF node @ RU-CORE

Needed for Higher Resolution Climate Data Set

Regional Climate Model	RegCM4 v RegCM 4.3.5.7
Domain	Latiture 15.14^{o}S – 27.26^{o}N Longitude 89.26^{o}E – 146.96^{o}E
Resollution	25 km × 25 km
Domain cartographic projection	Normal Mercator
Cumulus convection Scheme	MIT Emanual
Ocean Flux scheme	Zeng Ocean model roughness formula 1
Boundary layer scheme	Holslag PBL
Moisture scheme	Explicit moisture

Not high resolution enough!?

How to achieve higher Resolution Climate Data Set?



SEACLID/CORDEX Southeast Asia Phase 2: High-resolution analysis of climate extreme over key areas in Southeast Asia

Funding Agency: APN

Date of notification of acceptation : 1 June 2016
Contract signed by RU : 1 December 2016
Contract signed by APN : 9 December 2016

Project has started in December 2016

Co-funding : Ramkhamhaeng University
: National University of Malaysia

Objectives of SEACLID/CORDEX SEA Phase 2

To provide high resolution (3 km x 3 km) multi-model, multi-scenarios climate change and climate extremes projection for selected key vulnerable areas in Southeast Asia region

To establish stronger collaboration with stakeholders through user needs assessment and providing guidance on usage of climate information created from the project

Major Collaborators

Name	Country	Institution
Prof. Dr. Fredolin Tangang	Malaysia	National University of Malaysia (NUM)
Prof. Dr. Phan Van Tan	Vietnam	VNU Hanoi University of Science (VNU HUS)
Prof. Dr. Edvin Aldrian	Indonesia	Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG)
Assoc. Prof. Dr. Gemma Narisma	Philippines	Ateneo de Manila University
Assoc. Prof. Dr. Thanh Ngo-Duc	Vietnam	VNU HUS
Dr Liew Juneng	Malaysia	NUM
Dr Patama Singhruck	Thailand	Chulalongkorn University
Dr Faye Cruz	Philippines	Manila Observatory
Dr Dodo Gunawan	Indonesia	BMKG
Dr Ardhasena Sopaheluwakan	Indonesia	BMKG

Major Collaborators



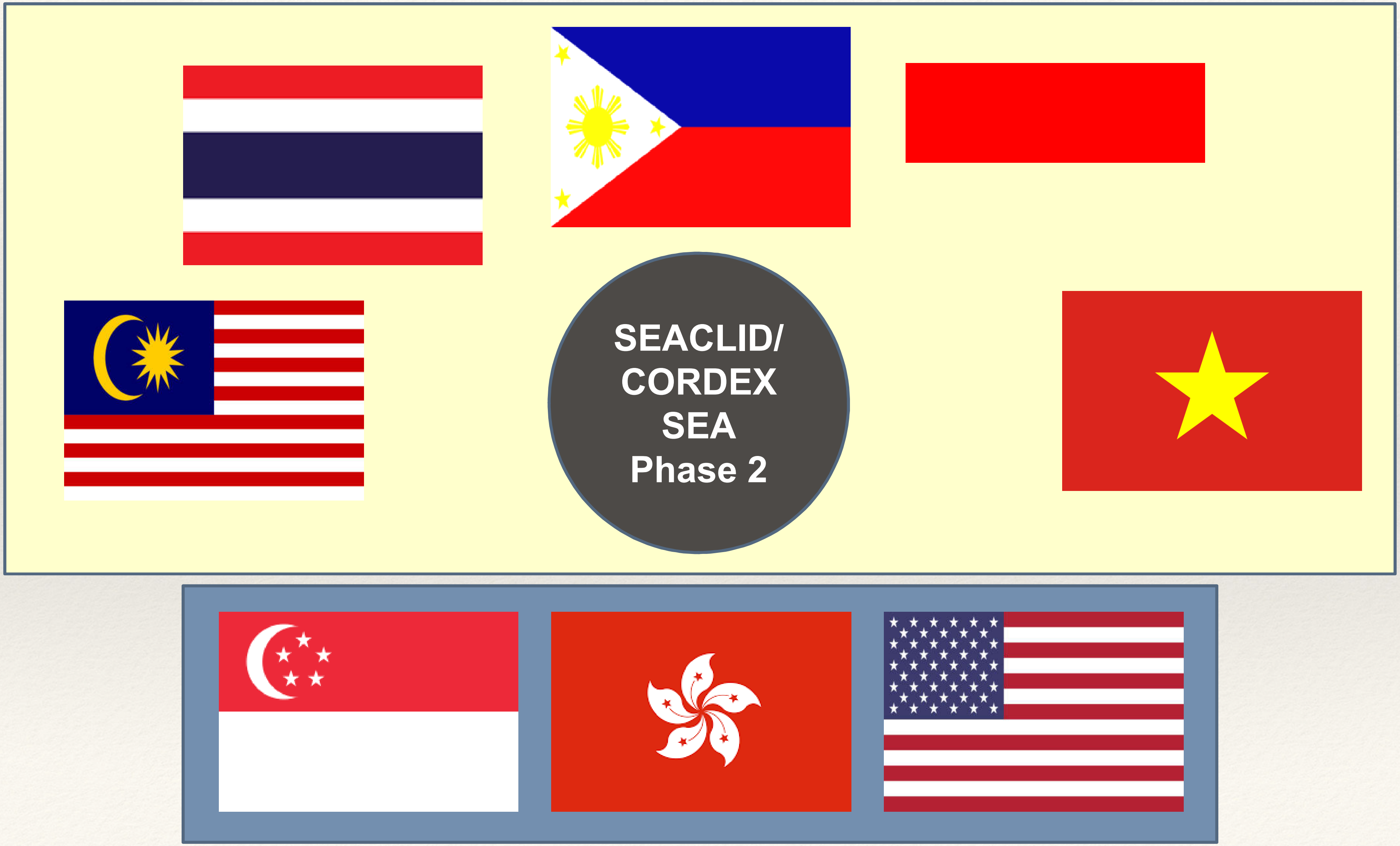








Proposed Future Collaborators



Proposed Future Collaborators

To identify key vulnerable areas for high resolution (3 km x 3 km) climate change and climate extremes projection through user engagement(0th -6th months)

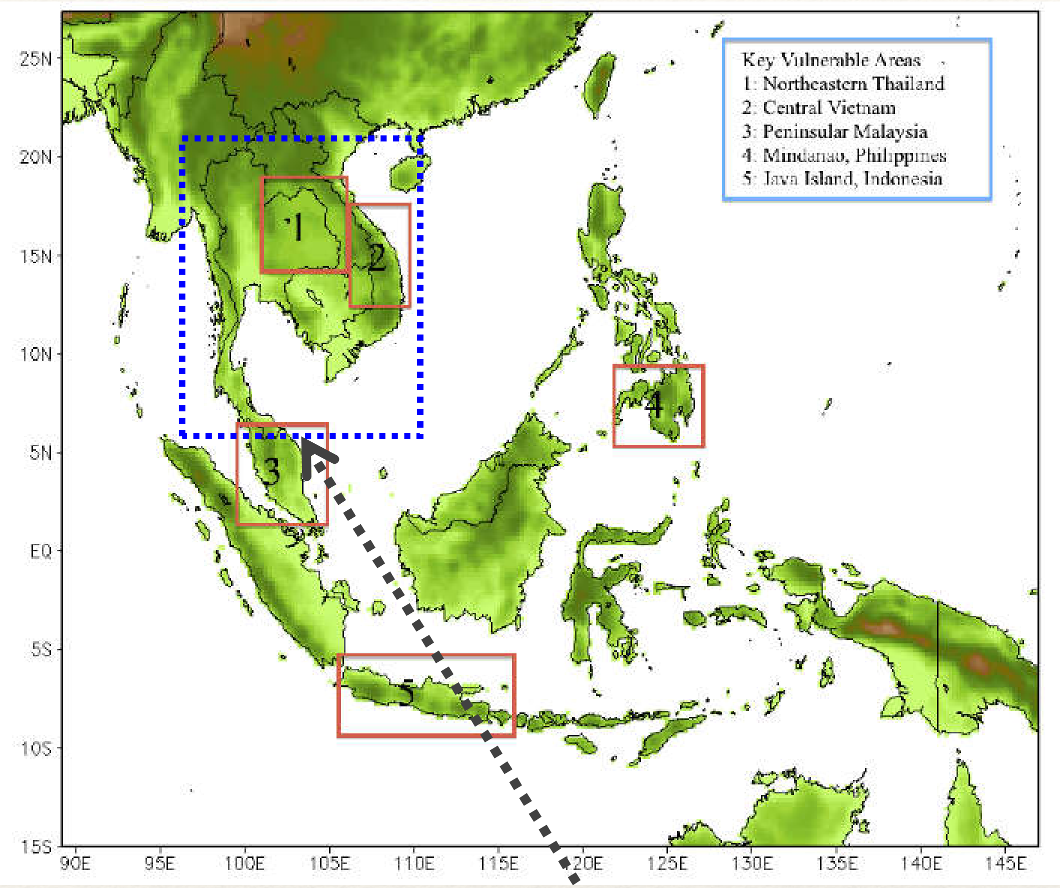
To prepare the high resolution model runs, specifically the forcing data and the gridded observation data for analysis and validation

To simulate historical and projected climatology of key vulnerable areas with high resolution model runs

To analyse modelled climatology and climate information and archiving of model outputs

To communicate output/findings through users engagement

Selection of Key Vulnerable Areas, GCMS and RCMs



Vulnerable Areas
Area1 : North-eastern region Thailand
Area 2: Central Vietnam
Area 3: Peninsula Malaysia
Area 4: Mindanao The Phiippines
Area 5: Java Island Indonesia

GCMs 3 (output from 1st phase)
RCMs 2 (RecCM, WRF, etc)

Baseline : 1970 – 2000
Projection: 2031 – 2060, 2070 – 2100

Proposed commond domain for Vietnam and Thailand that covers the “FOOD BASKET”

Thank you