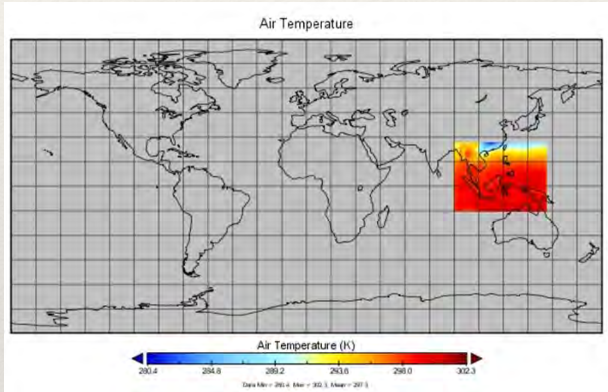
Downscaling GCMs in the Context of Thailand



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Ramkhamhaeng University (RCMRCC-RU)

1 June 2016

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^{o}C increase in global mean temperature (IPCC projection was 2-4.5^{o}C)
- Predicted it would take 3000 years to double the CO_2 concentration (IPCC estimated this would be achieved within this century)

Svante Arrhenius

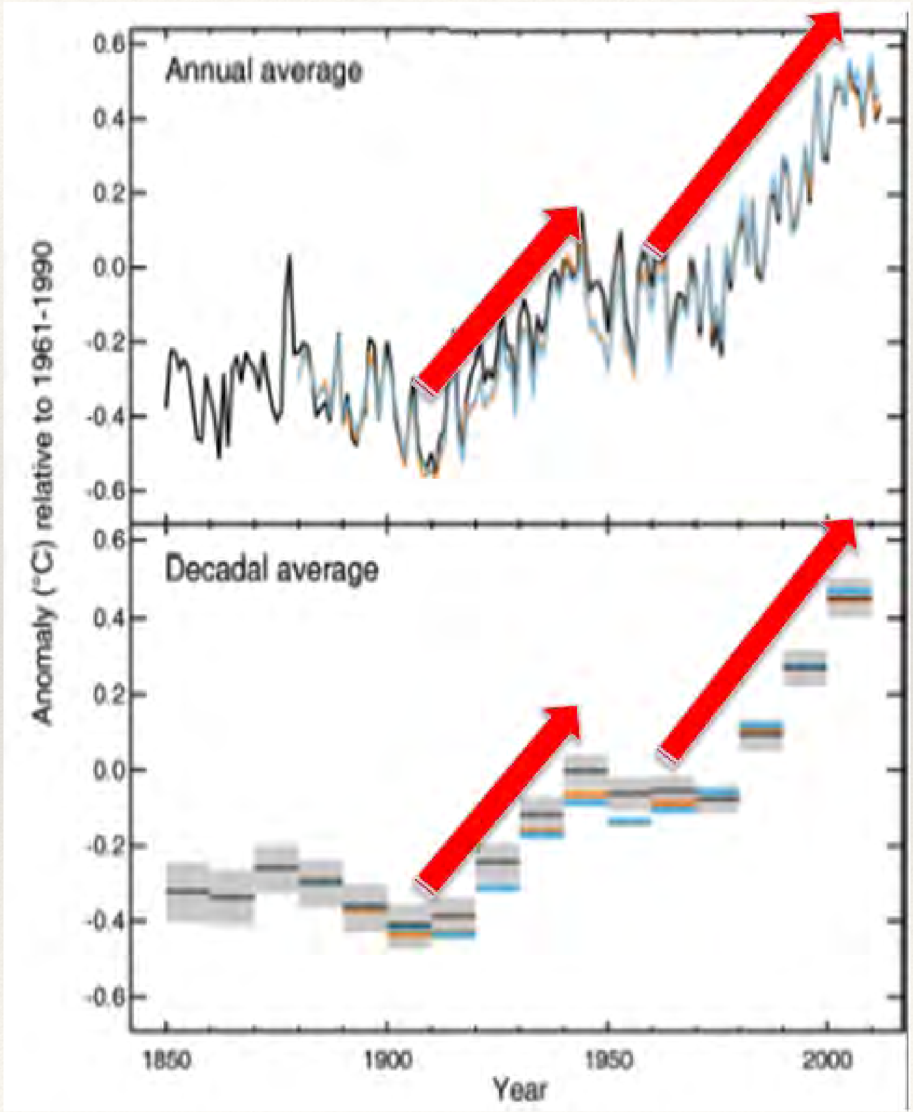
(1859-1927, Nobel Prize Winner for Chemistry 1903; The first Swedish Nobel Prize Winner)

Key Statement / Headline of IPCC WG1 AR5 SPM

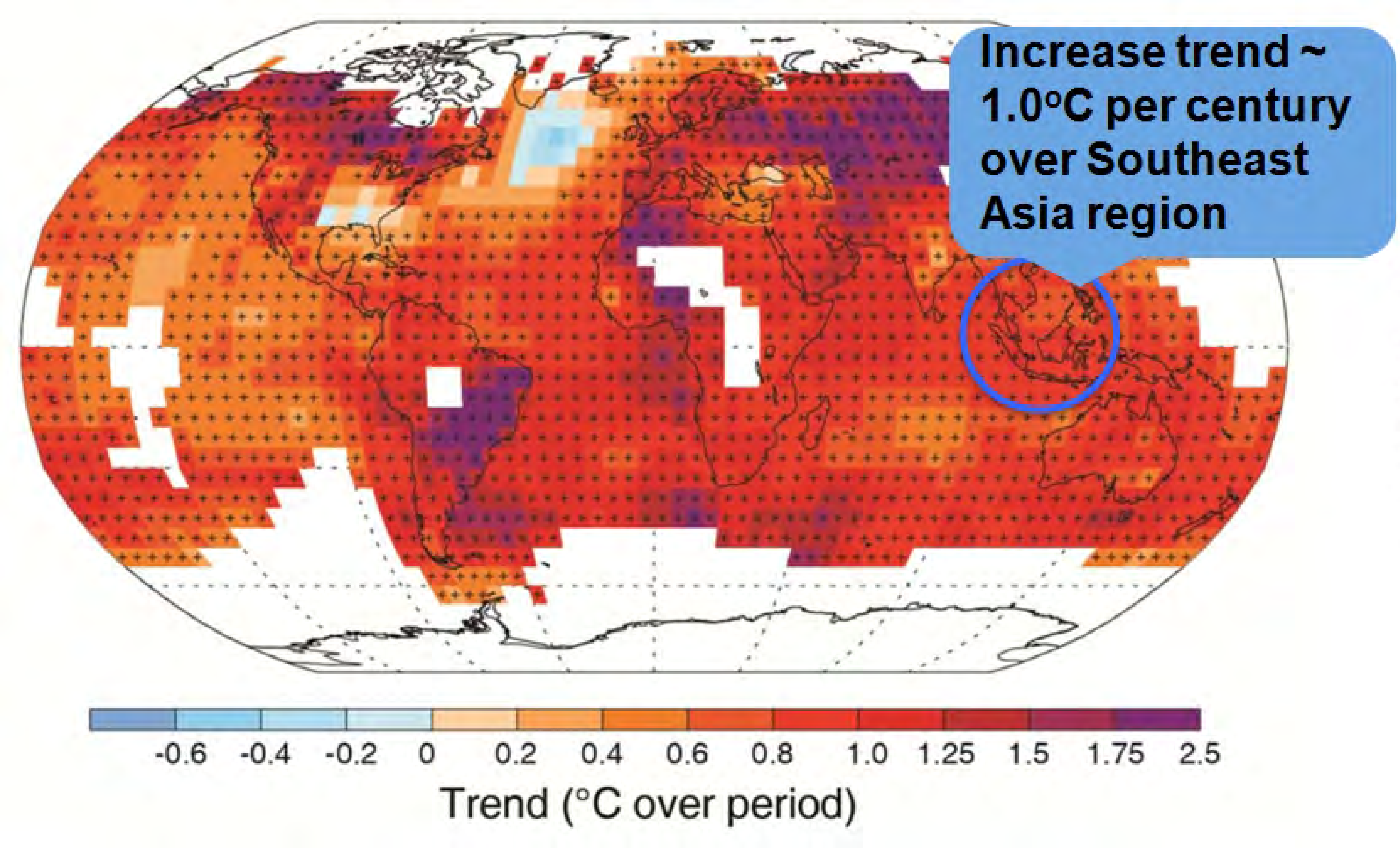
Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased

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)

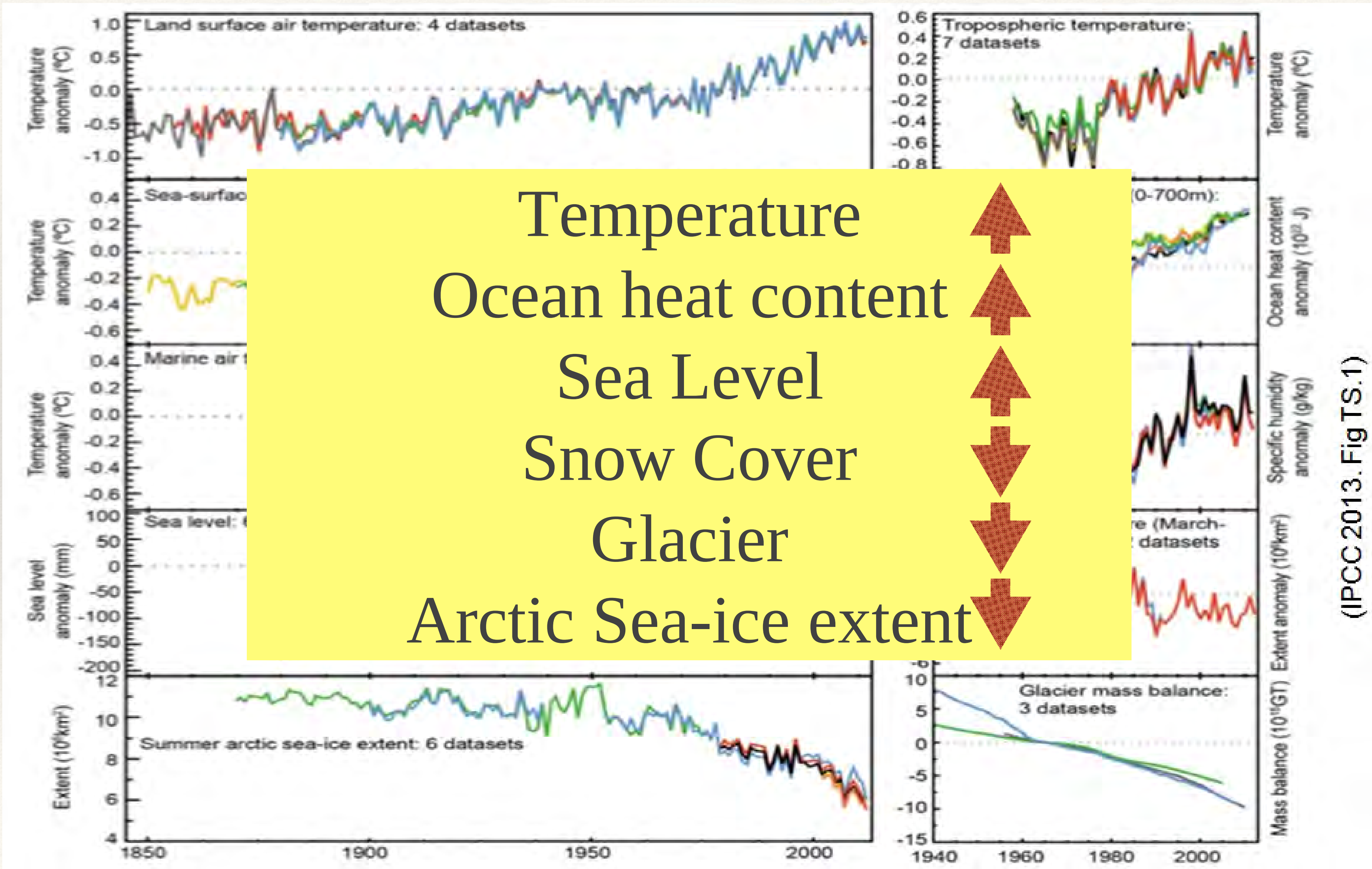


Warming in the climate system is unequivocal

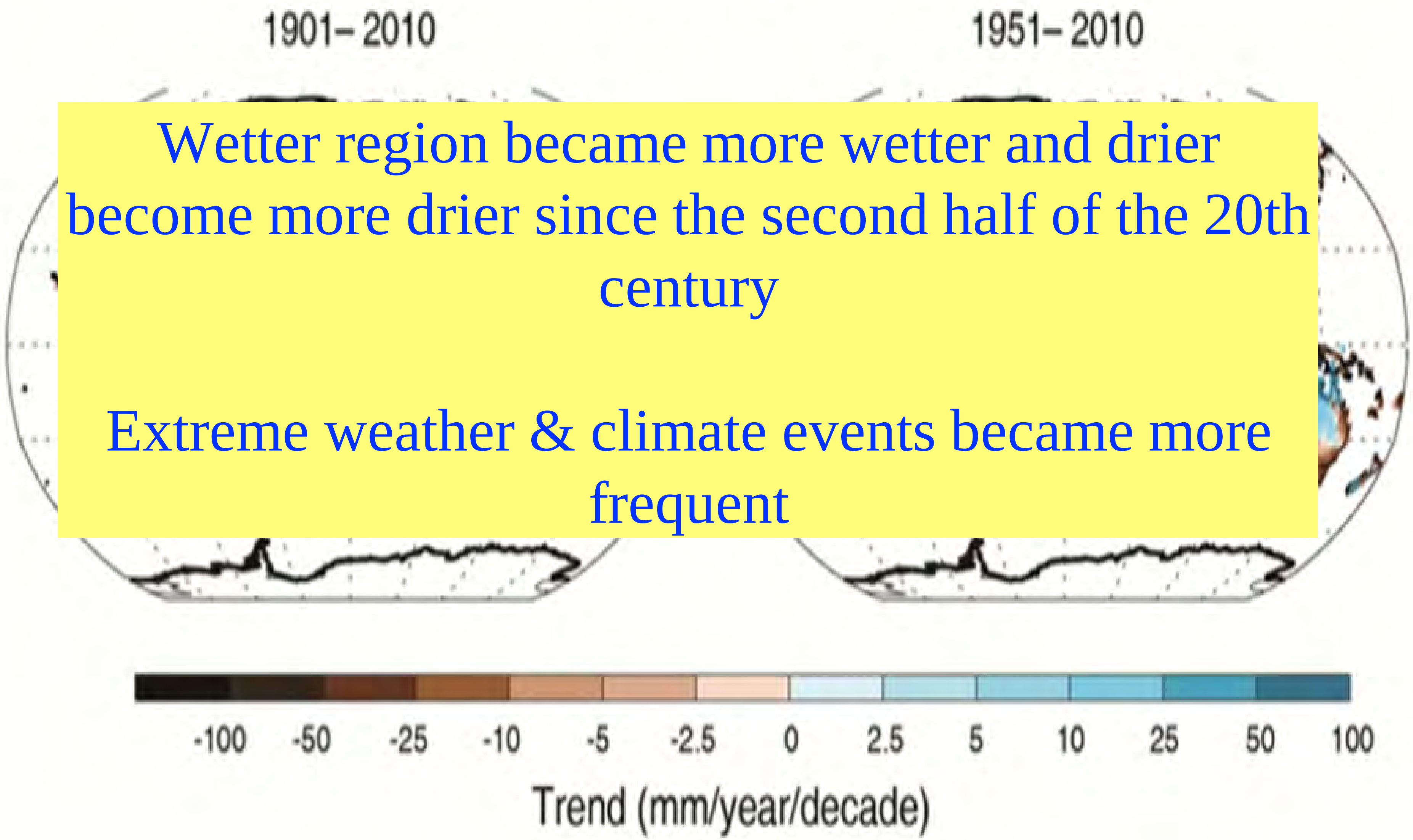


(IPCC 2013, Fig. SPM.1b)

Key findings based on observation



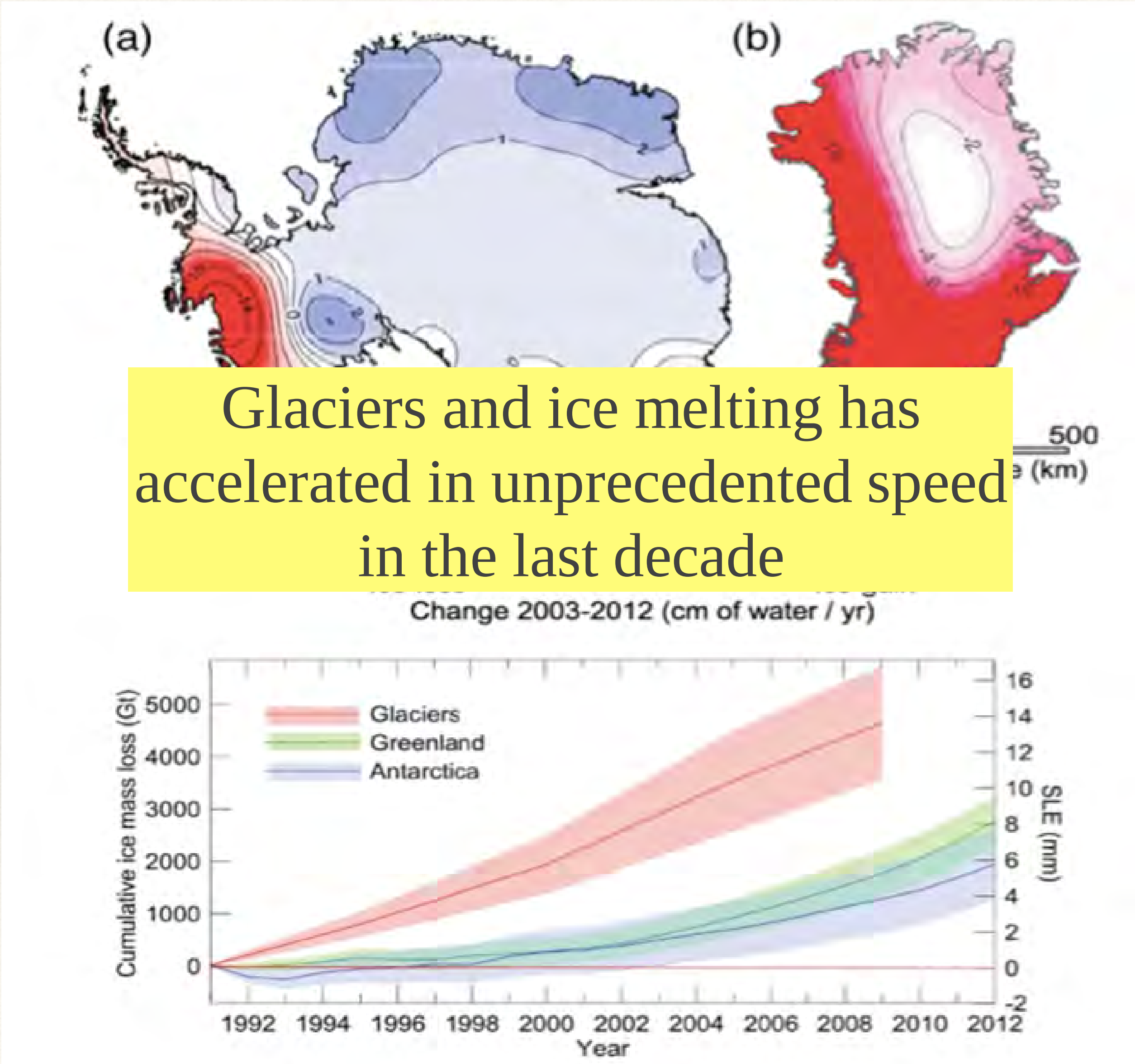
Observation change in precipitation over land



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

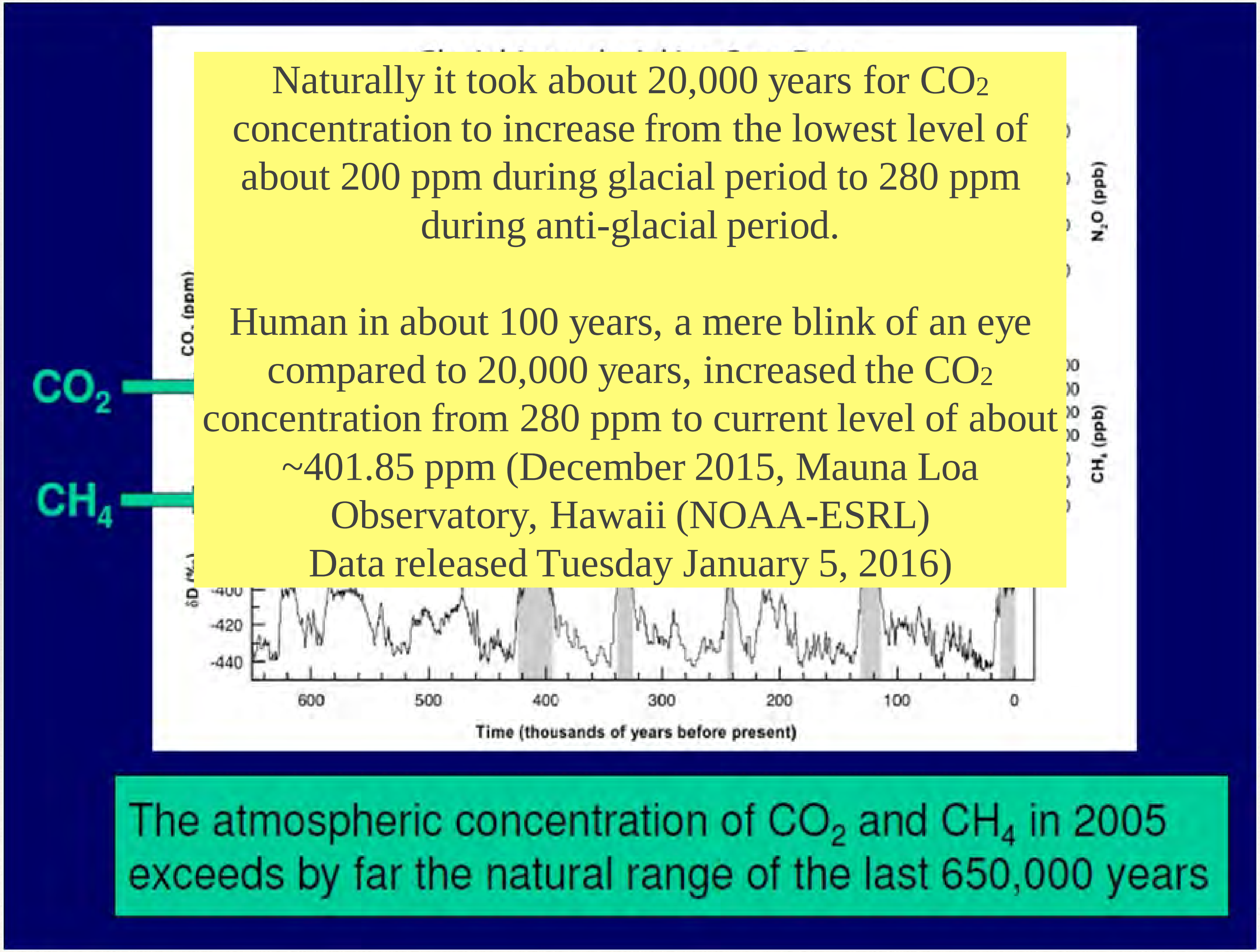
Glaciers and ice melting



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

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

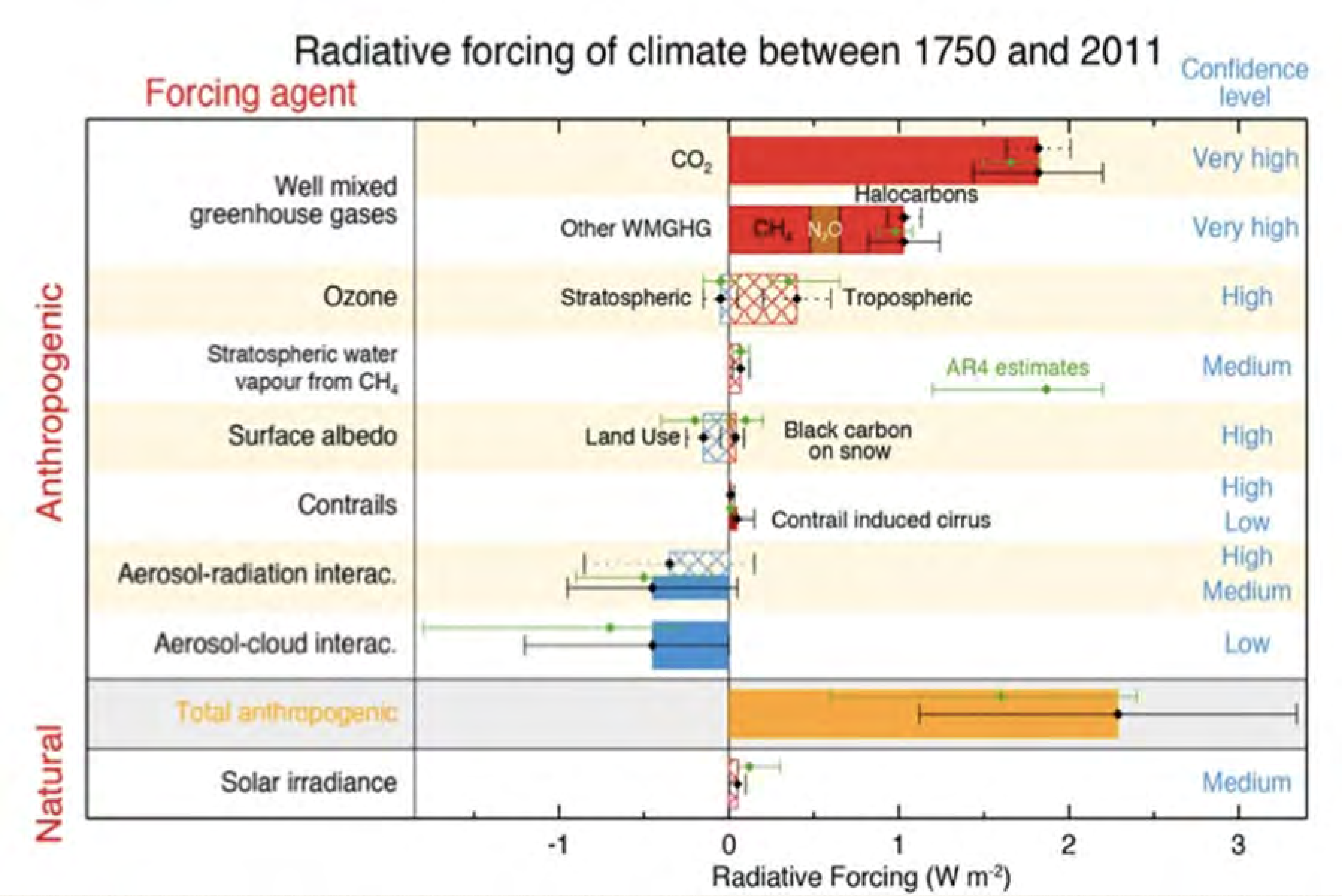
Atmospheric Concentration of GHGs



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

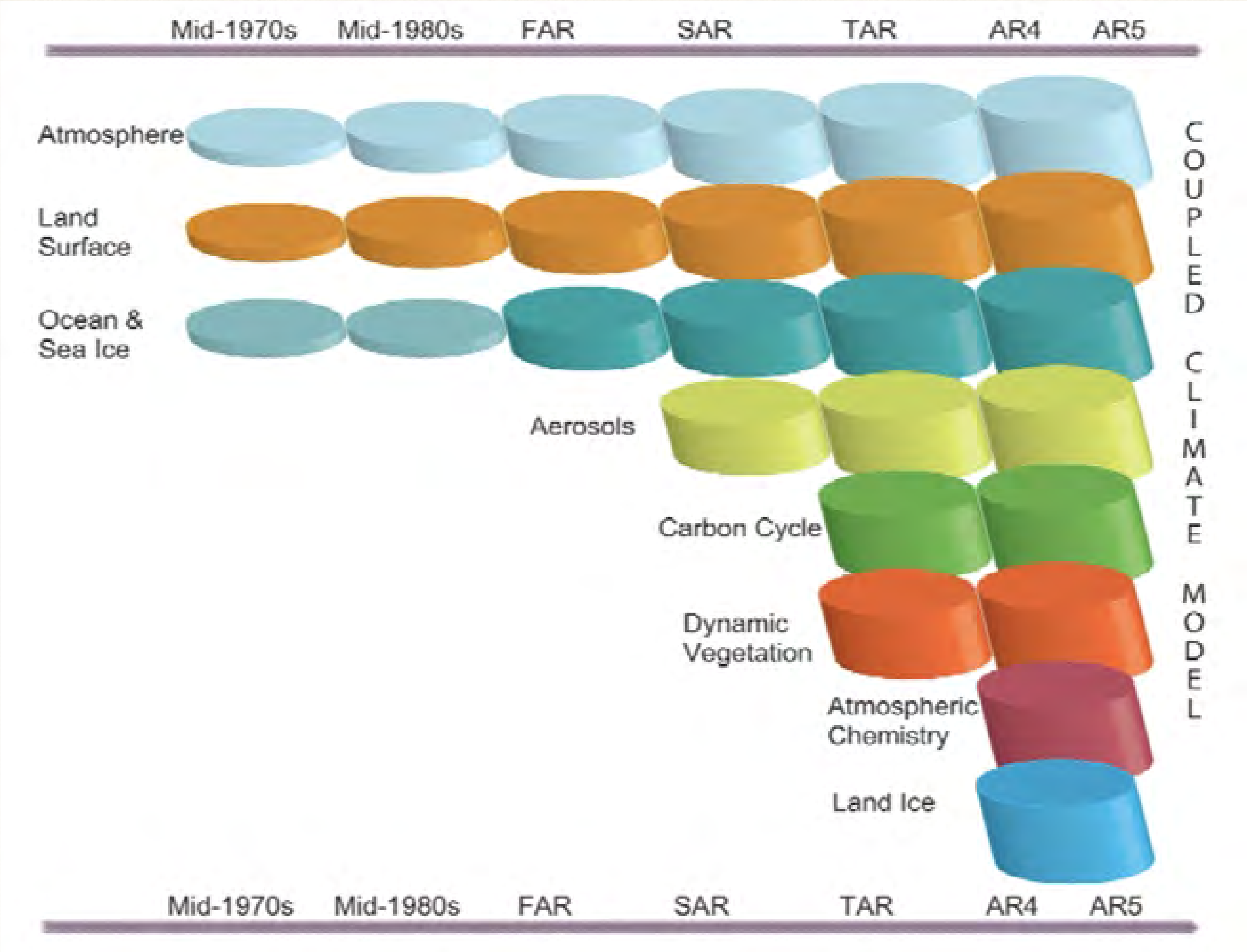
Radiative Forcing



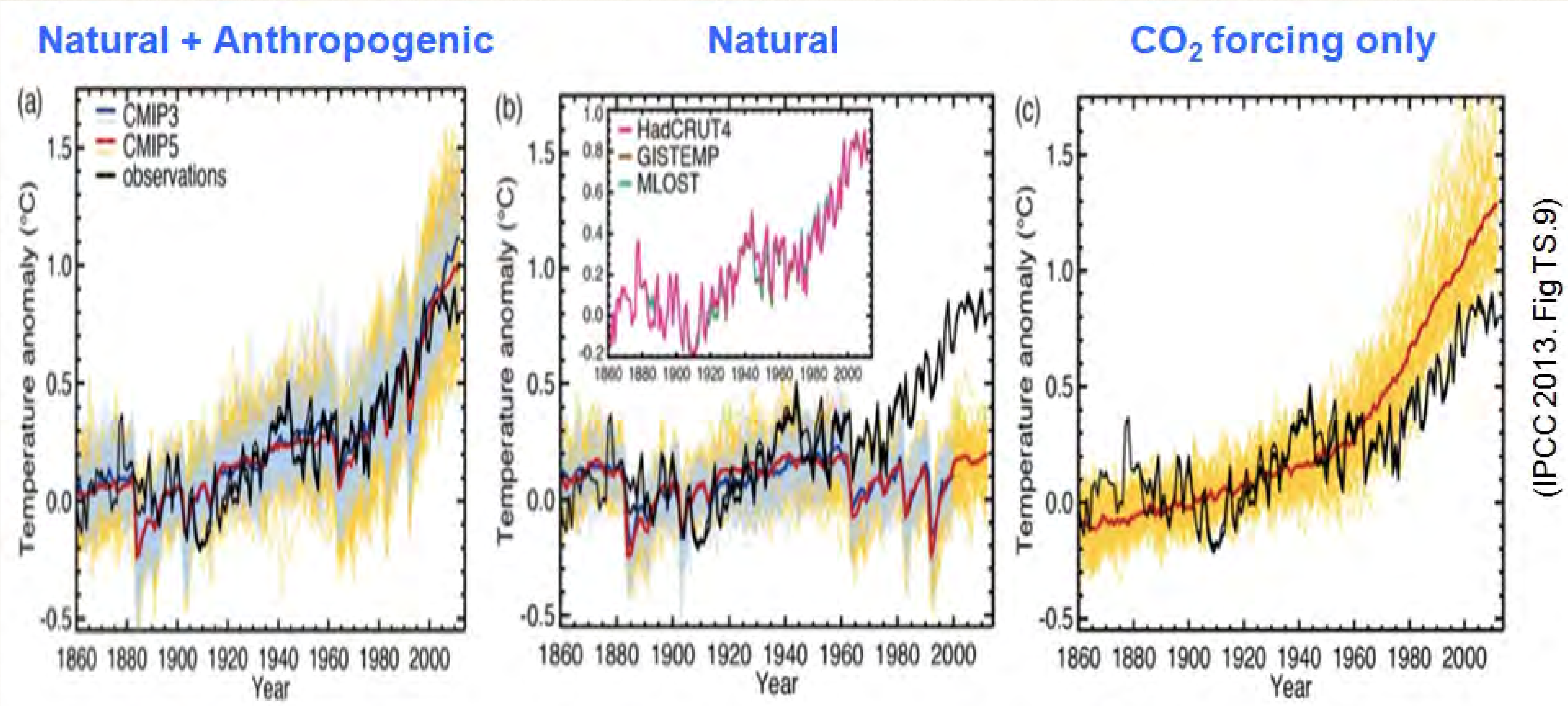
Radiative Imbalance

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)

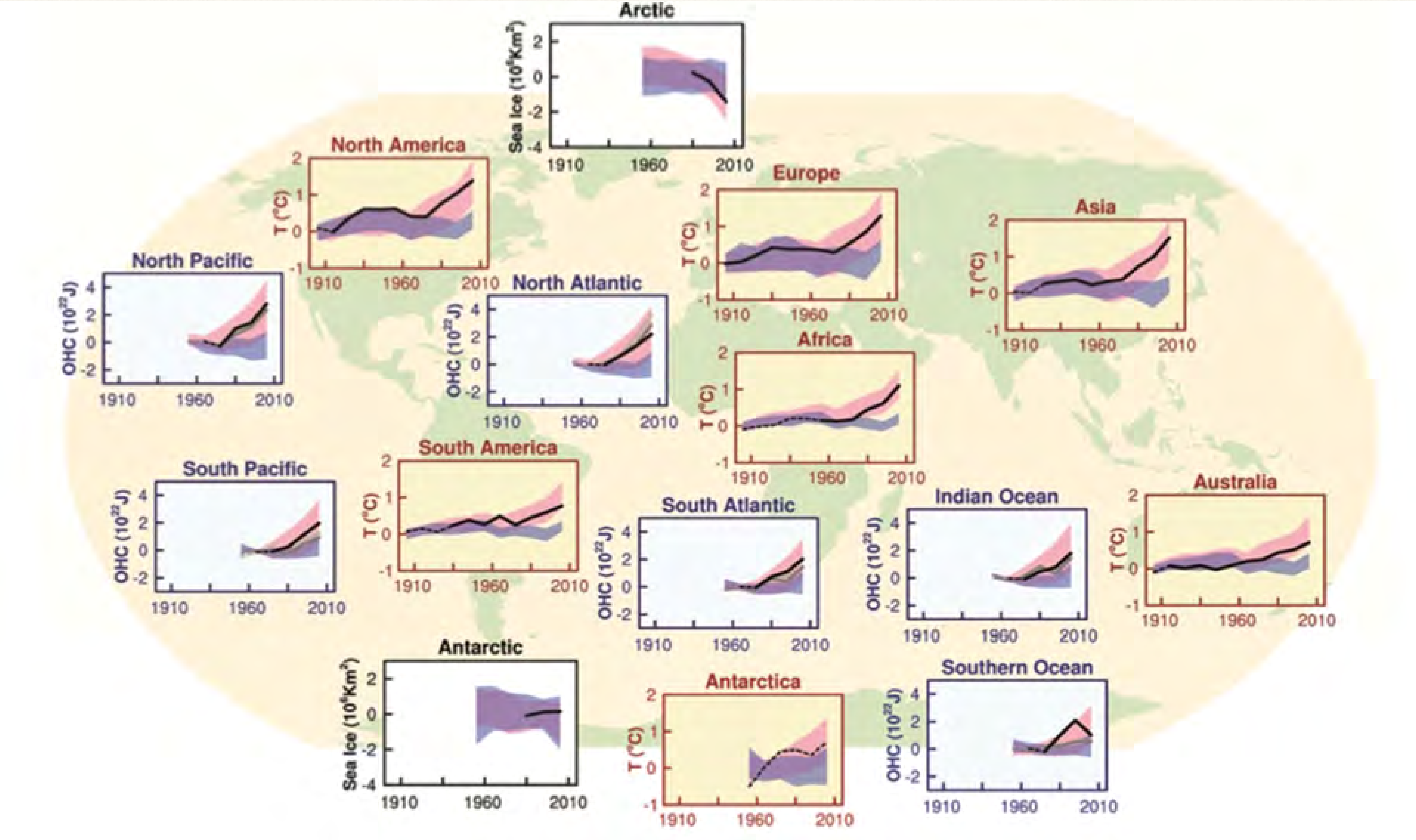
Complexity of Climate Model over Time



Climate Models Response to Various Forcing



Human influence on the climate system is clear



Future Climate Projection

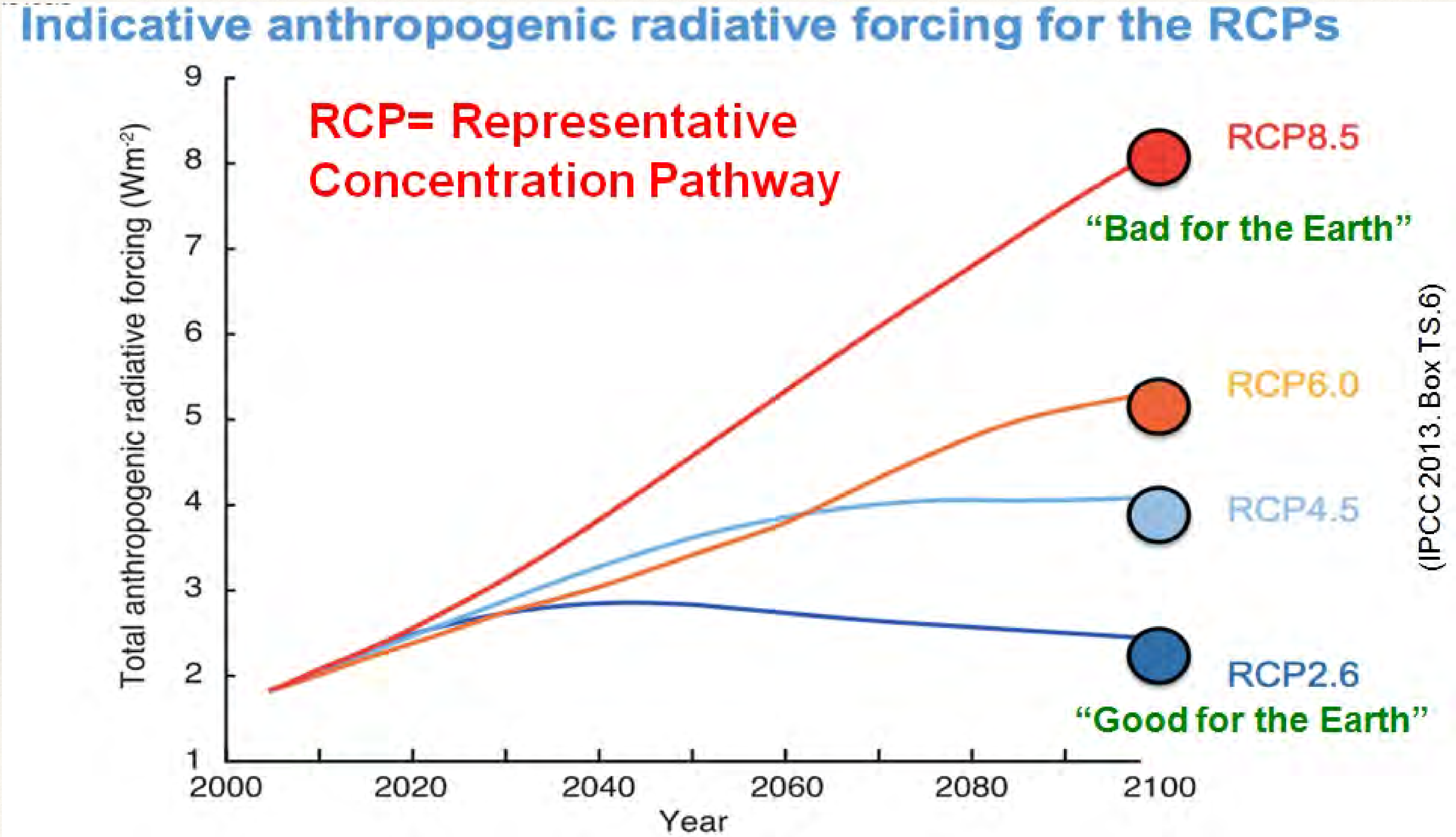
For future climate projections, climate models require Emission Scenarios. Models in AR5 use Representative Concentration Pathway (RCP)

RCP Scenario

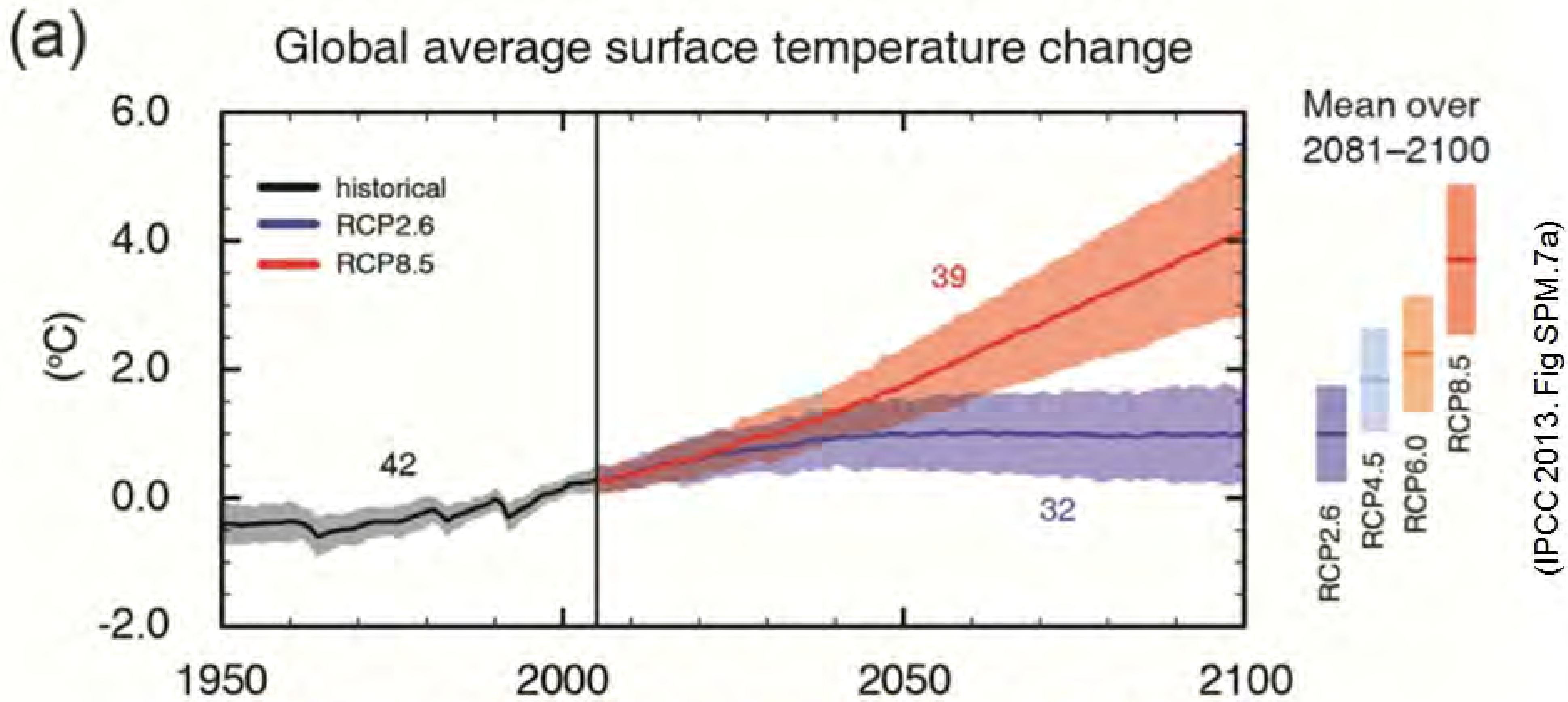
	Description[a]	Publication—IA Model
RCP8.5	Rising radiative forcing pathway leading to 8.5 W/m^2 (~1370 ppm CO_2 eq) by 2100.	(Riahi et al. 2007)—MESSAGE
RCP6	Stabilization without overshoot pathway to 6 W/m^2 (~850 ppm CO_2 eq) at stabilization after 2100	(Fujino et al. 2006; Hijioka et al. 2008)—AIM
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

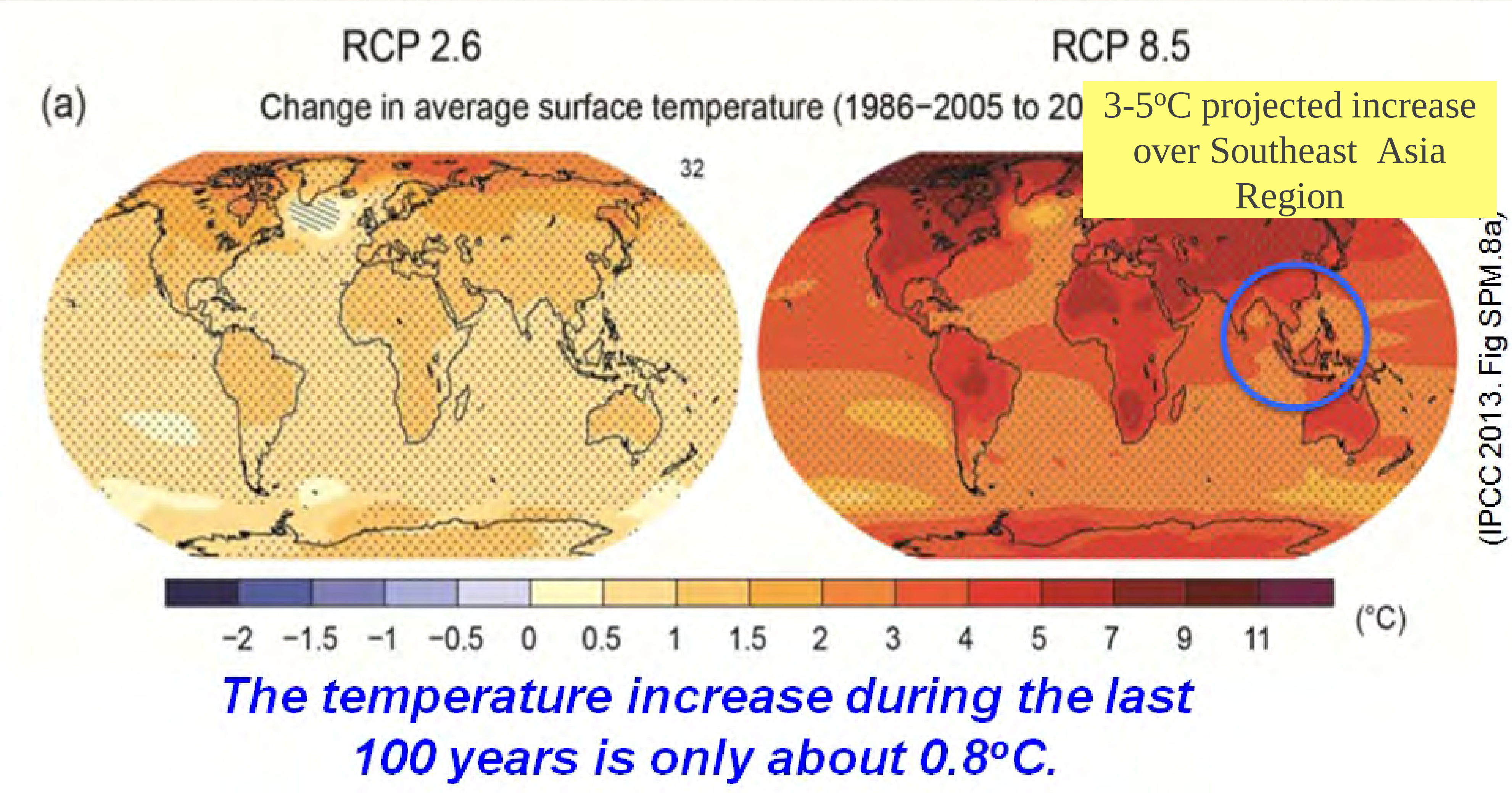


Projected Global Average Temperature Change by end of 21st Century

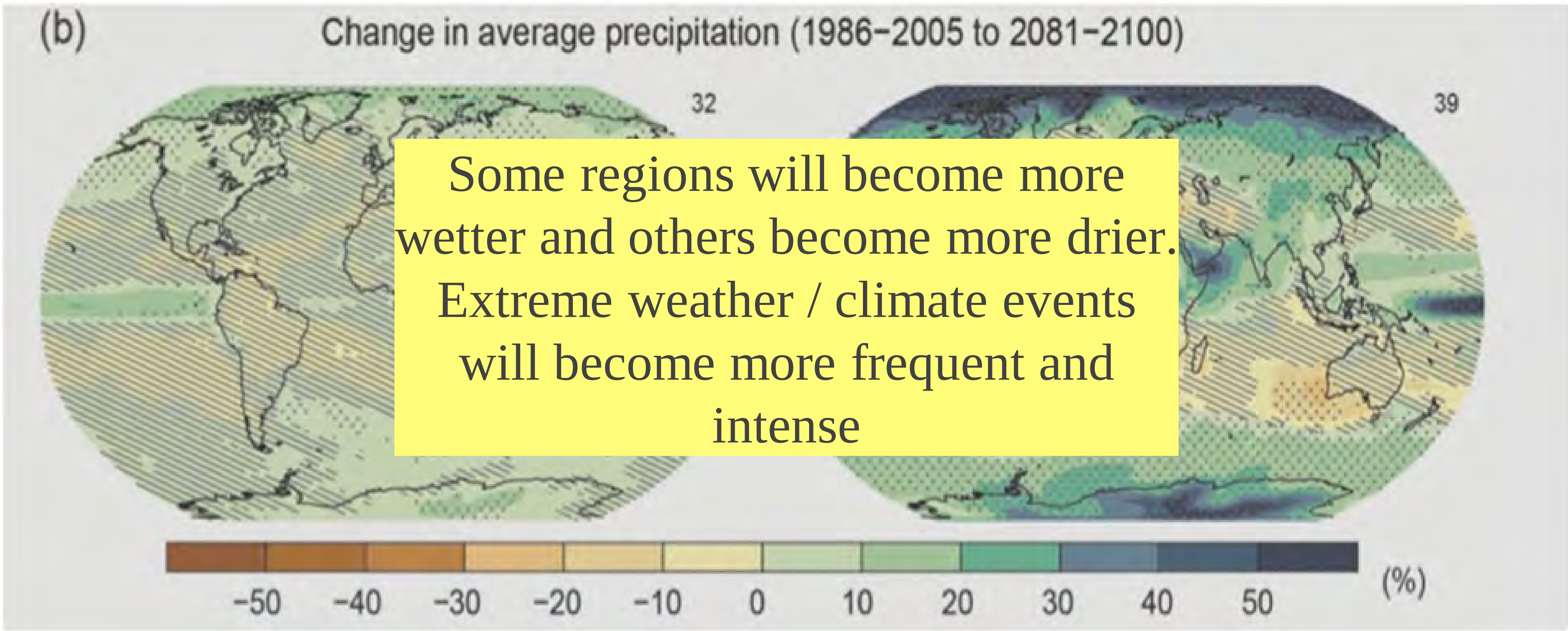


The temperature increase during the last 100 years was only about 0.8°C.

Projected Global Average Temperature Change by end of 21st Century

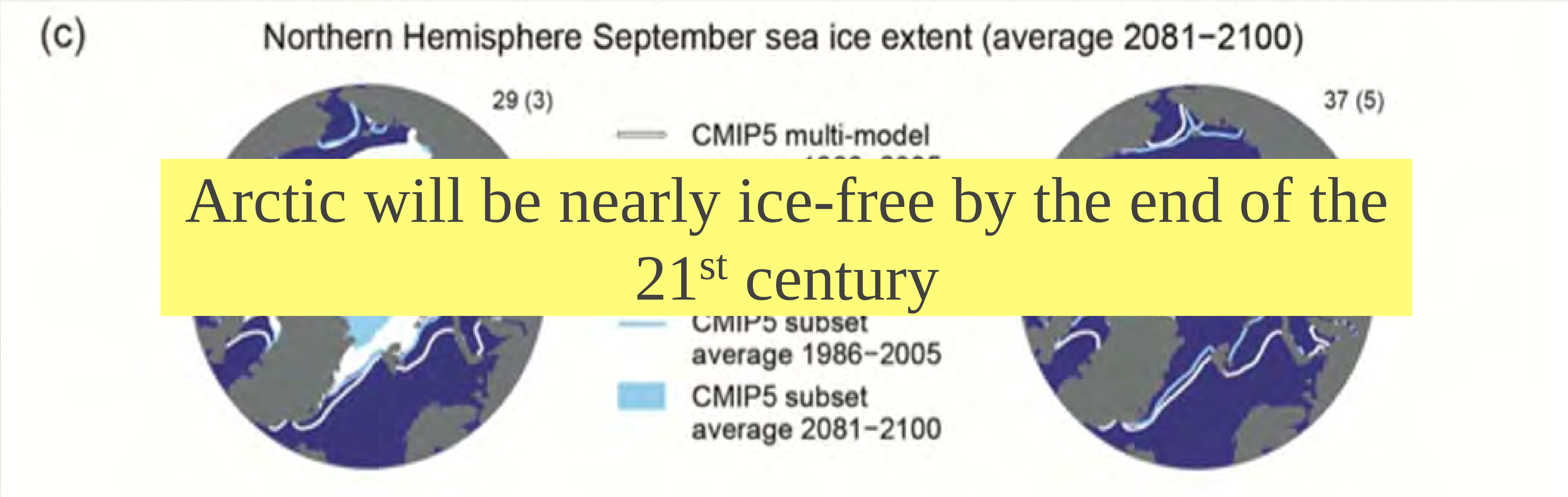


Projected Precipitation Change by end of 21st Century



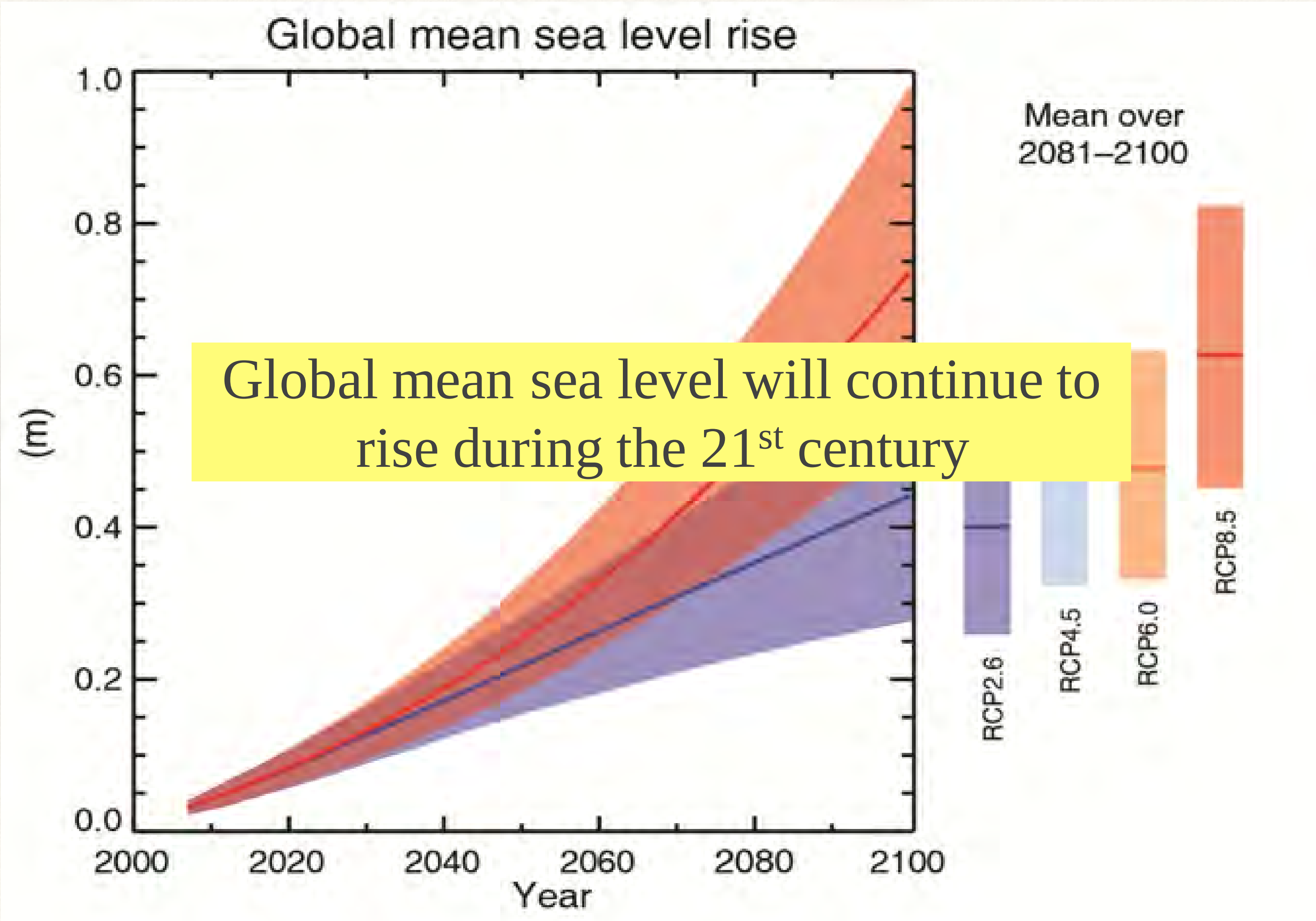
Some regions will become more wetter and others become more drier. Extreme weather / climate events will become more frequent and intense

Projected Arctic Ice Change by end of 21st Century



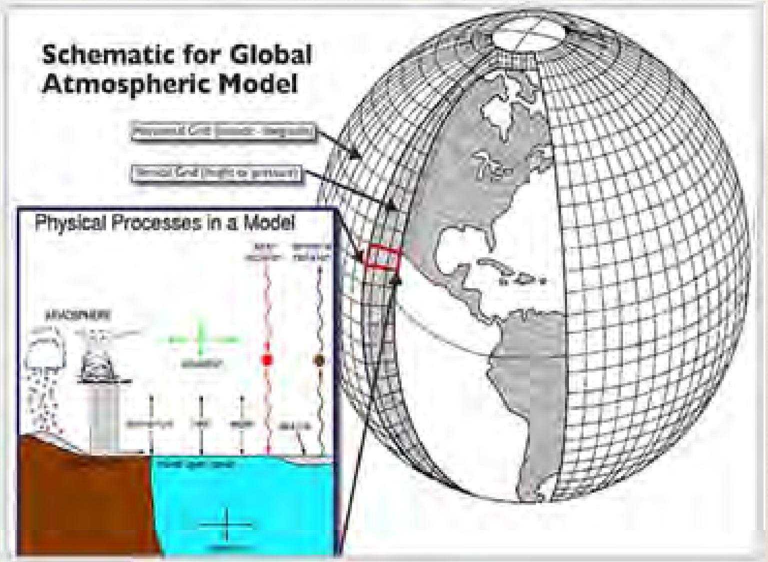
Arctic will be nearly ice-free by the end of the 21st century

Projected Sea Level by end of 21st Century

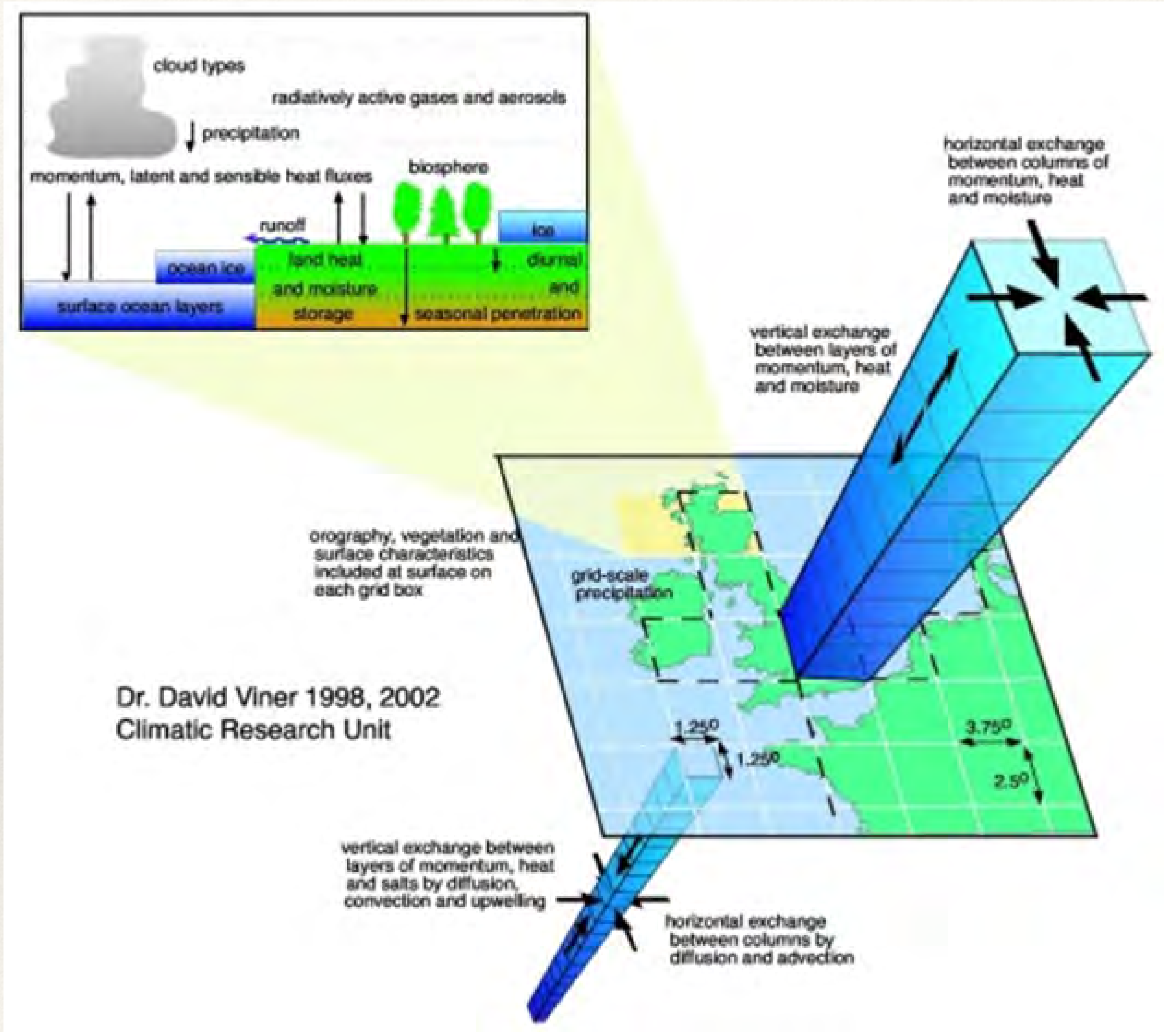


Global mean sea level will continue to rise during the 21st century

General Circulation Model (GCM)

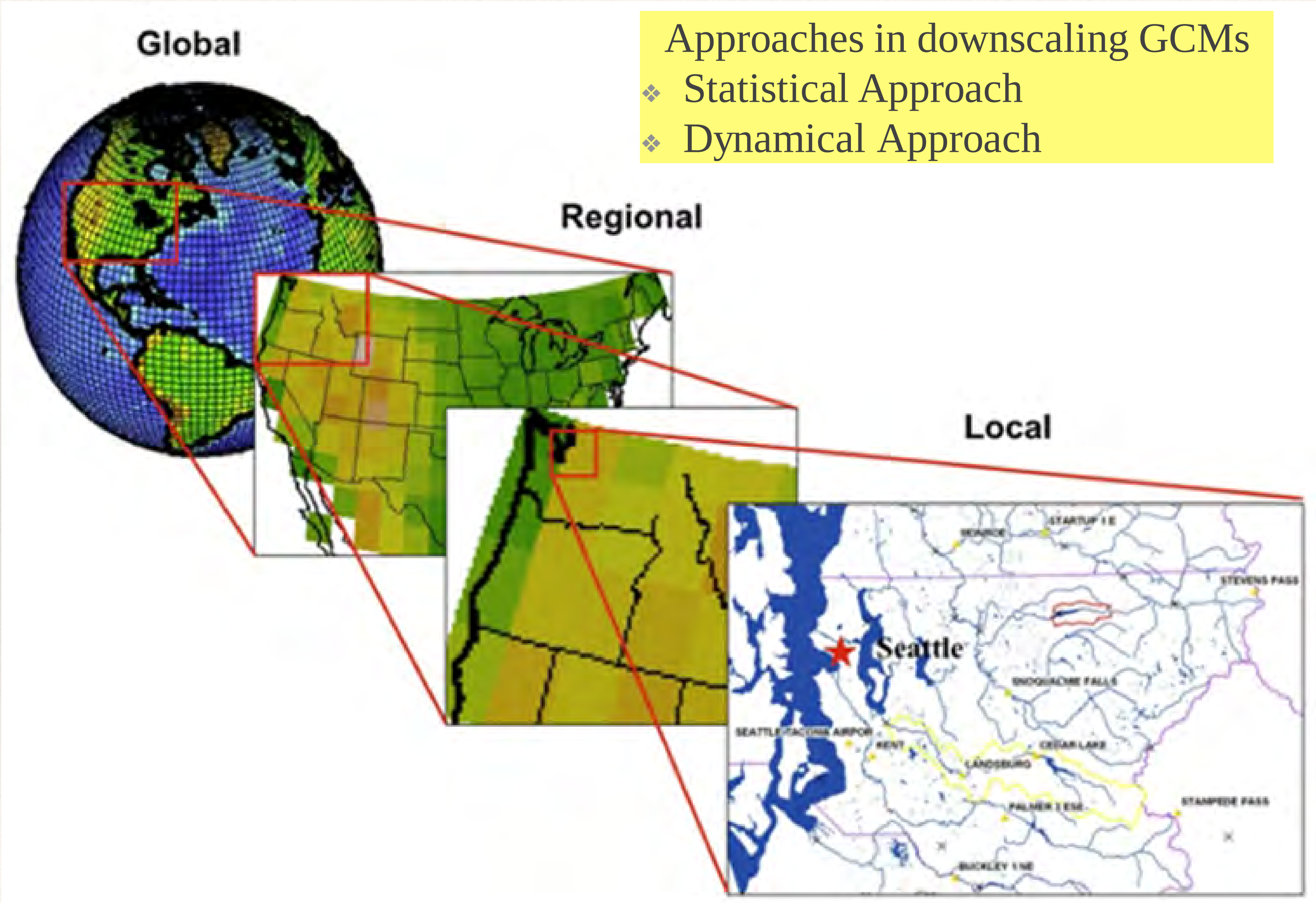


CMIP3, 5 ; Resolution 100 - 300 km

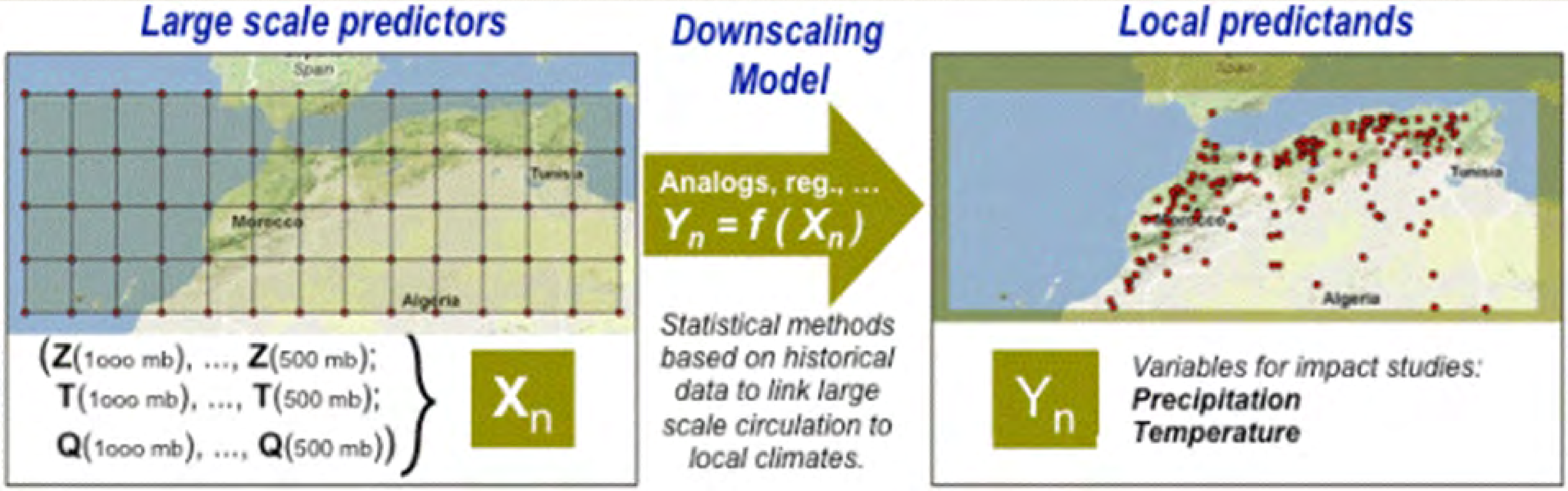


Downscaling GCMs

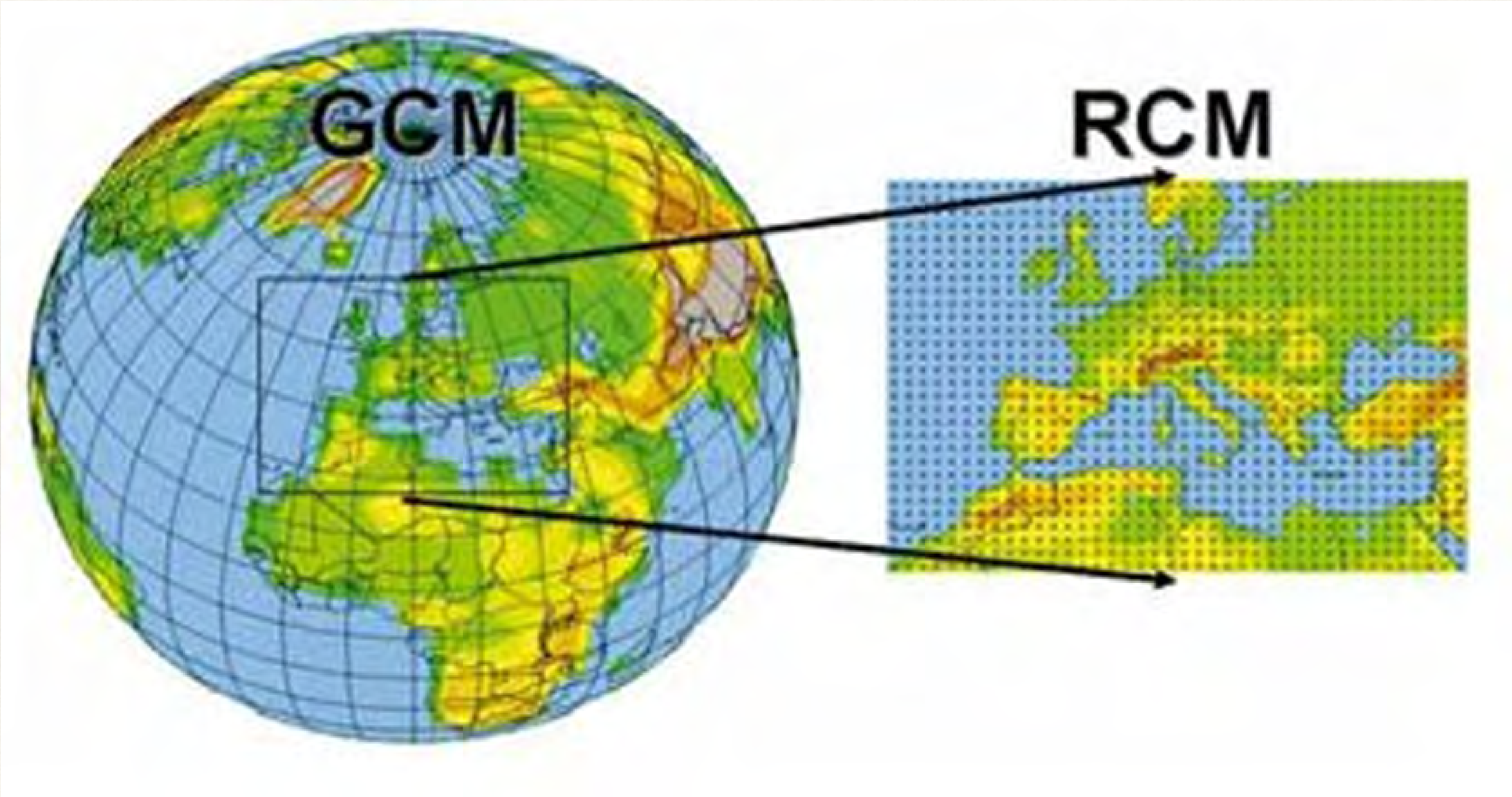
Approaches in downscaling GCMs
- Statistical Approach
- Dynamical Approach



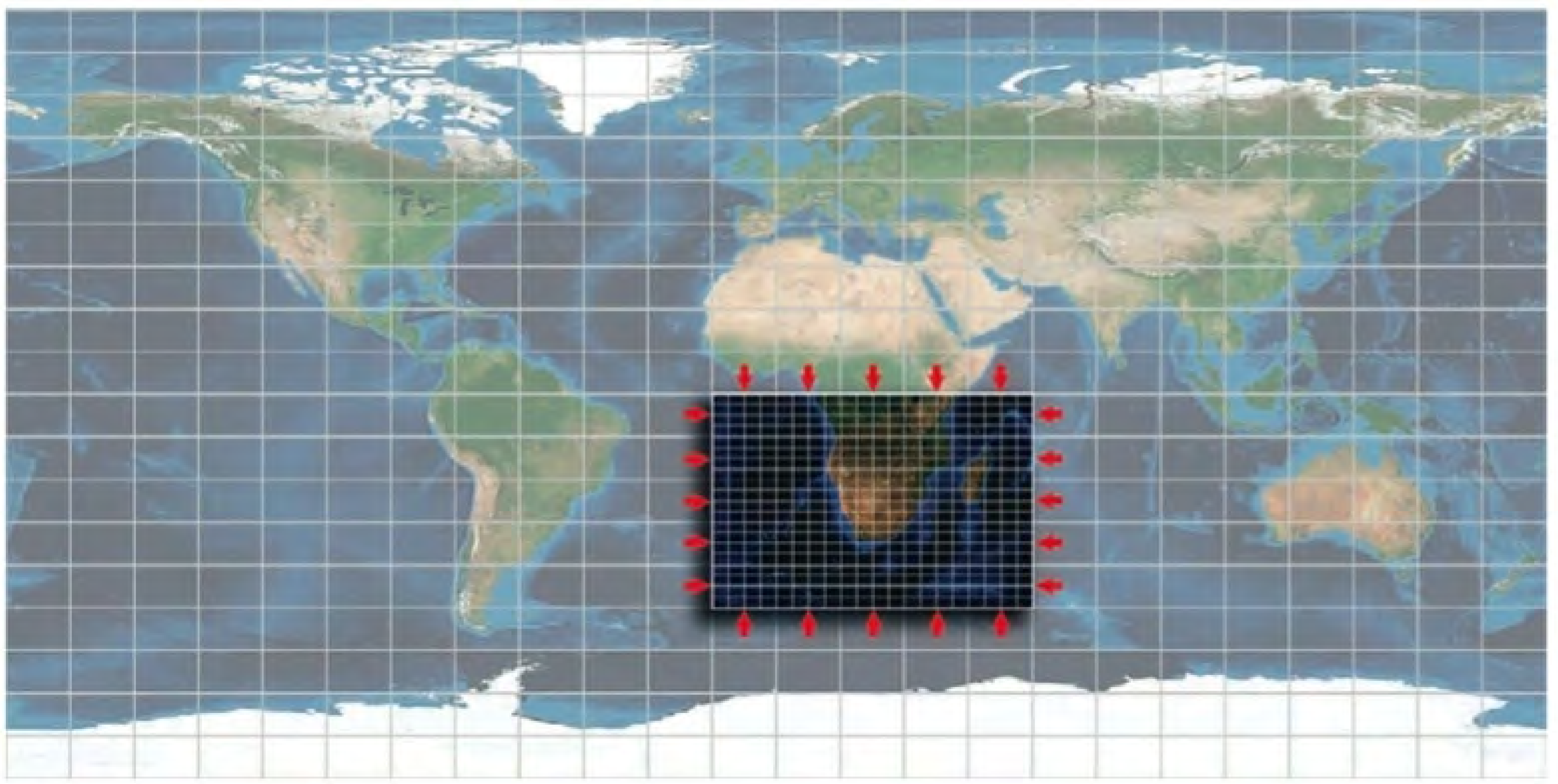
Statistical Approach



Dynamical Approach



Regional Climate Model



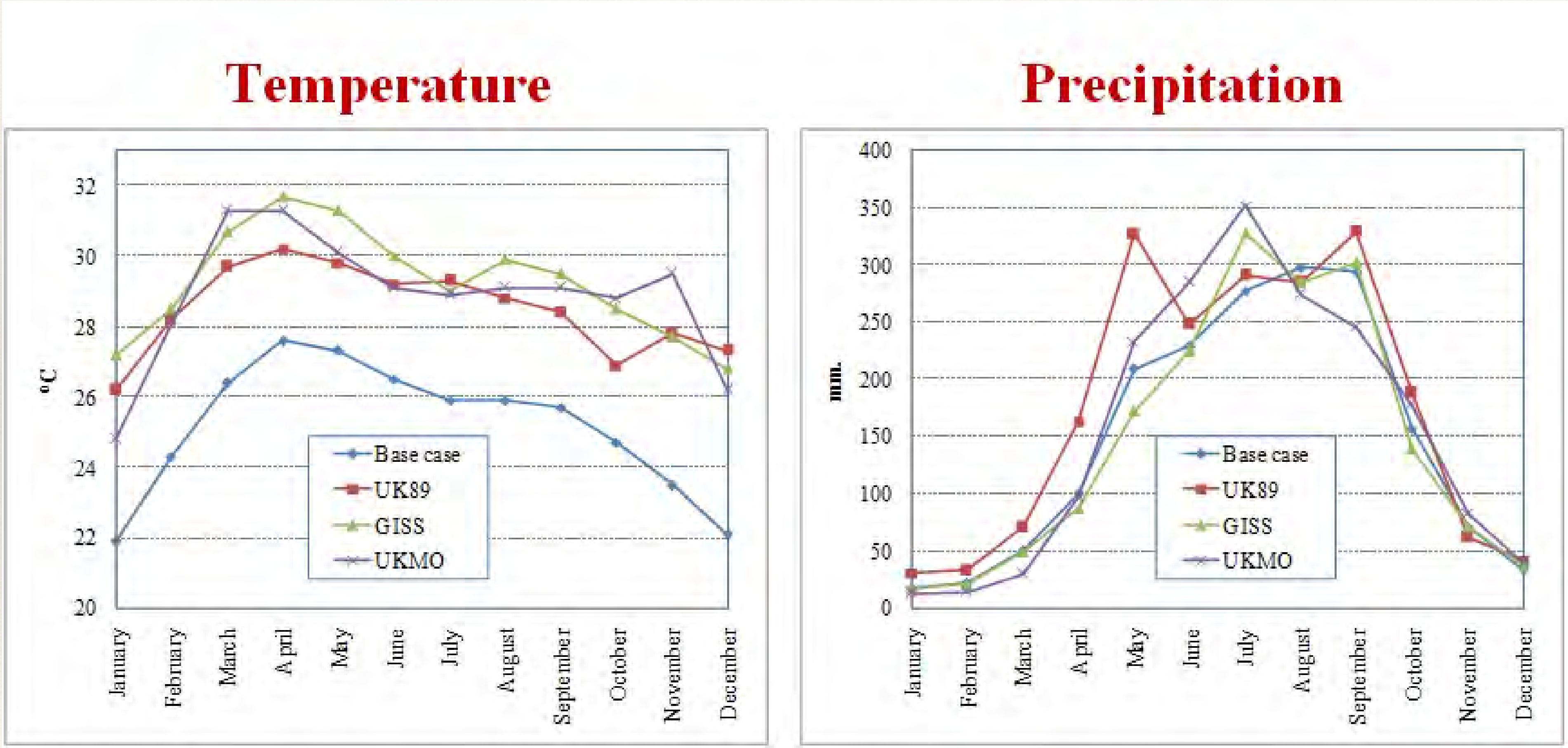
Downscaling Activities in Thailand

- 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

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)



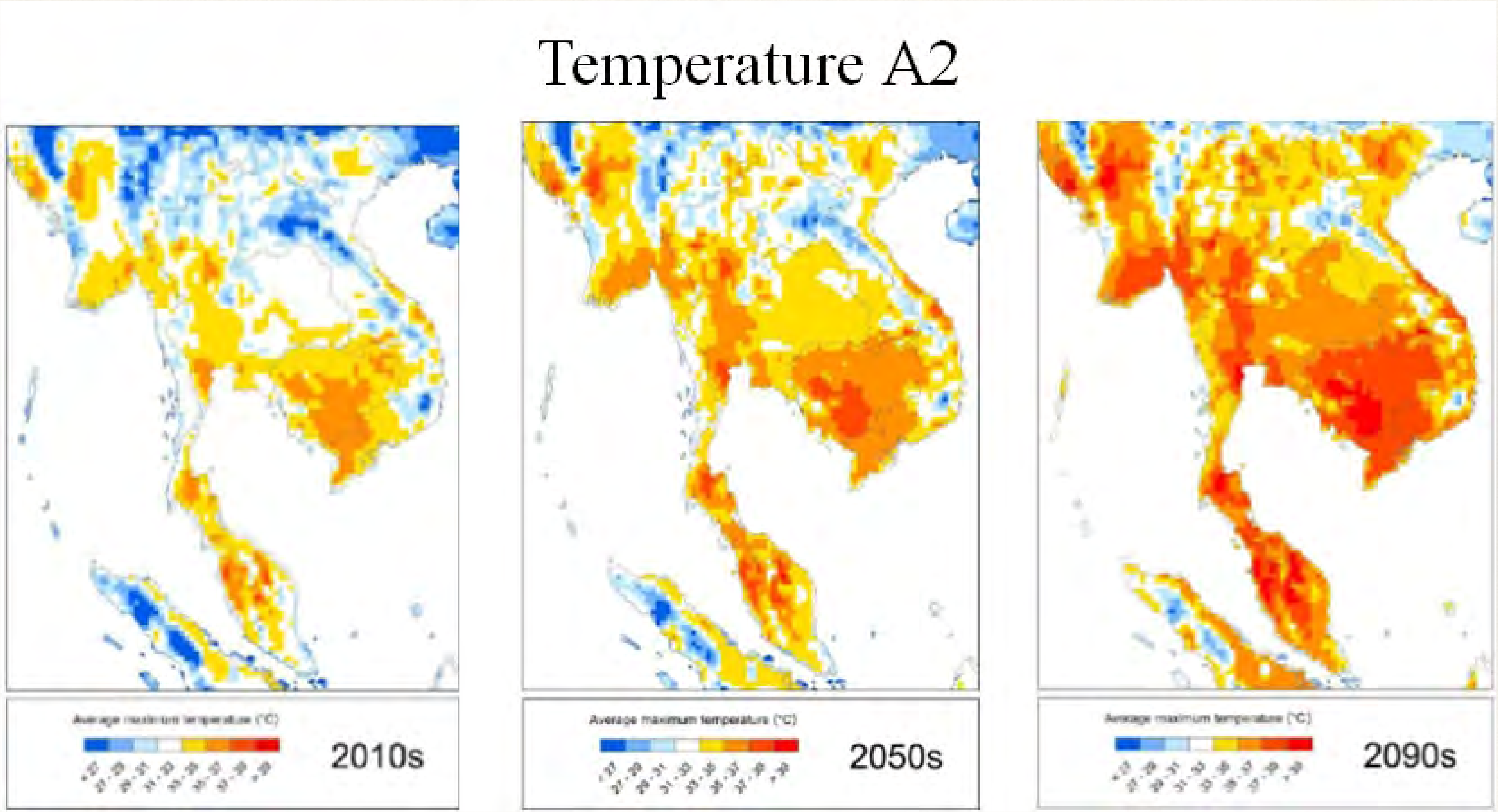
Previous Study 2 (2005)

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

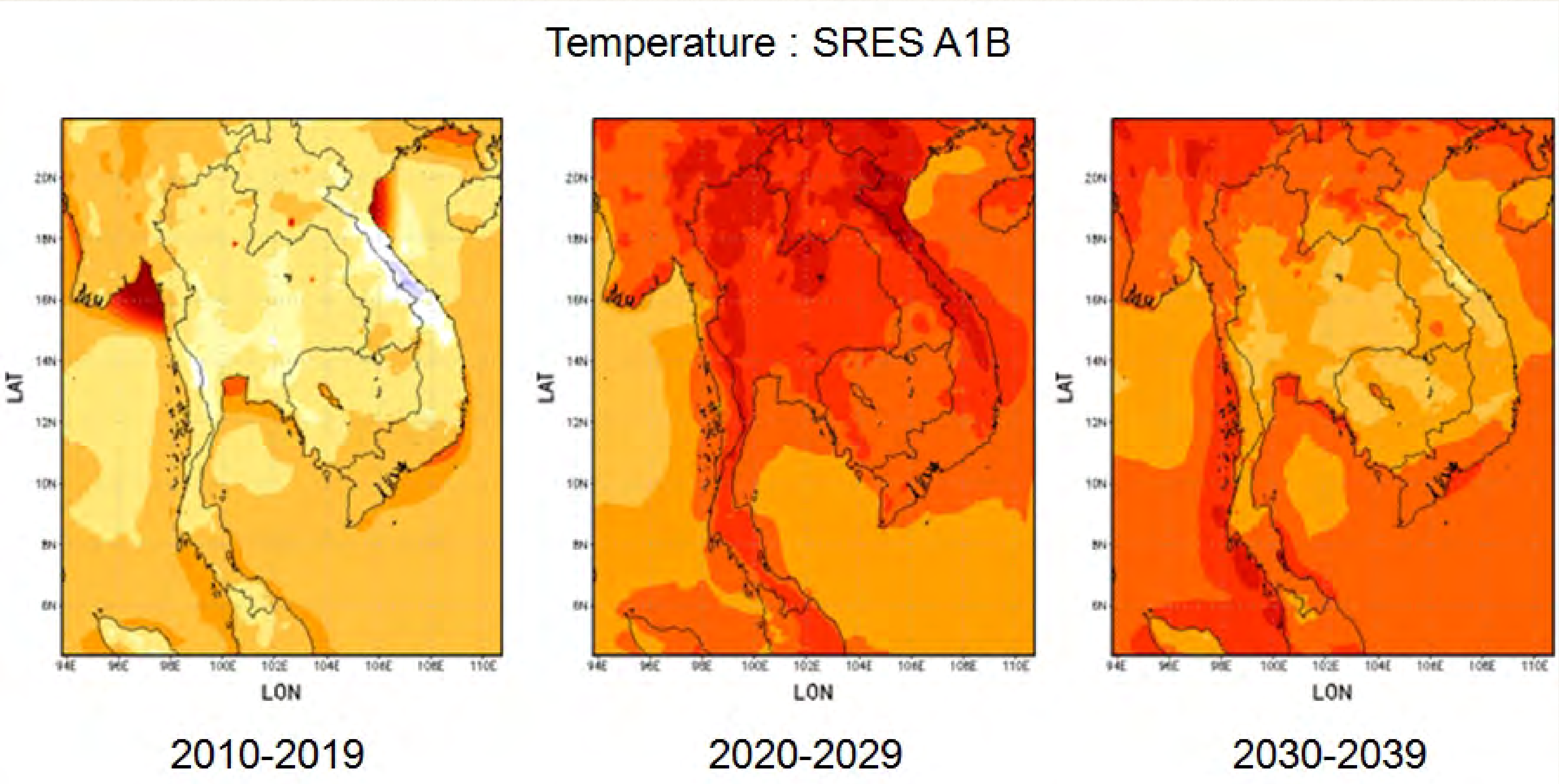
Previous Study 3 (2009)



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

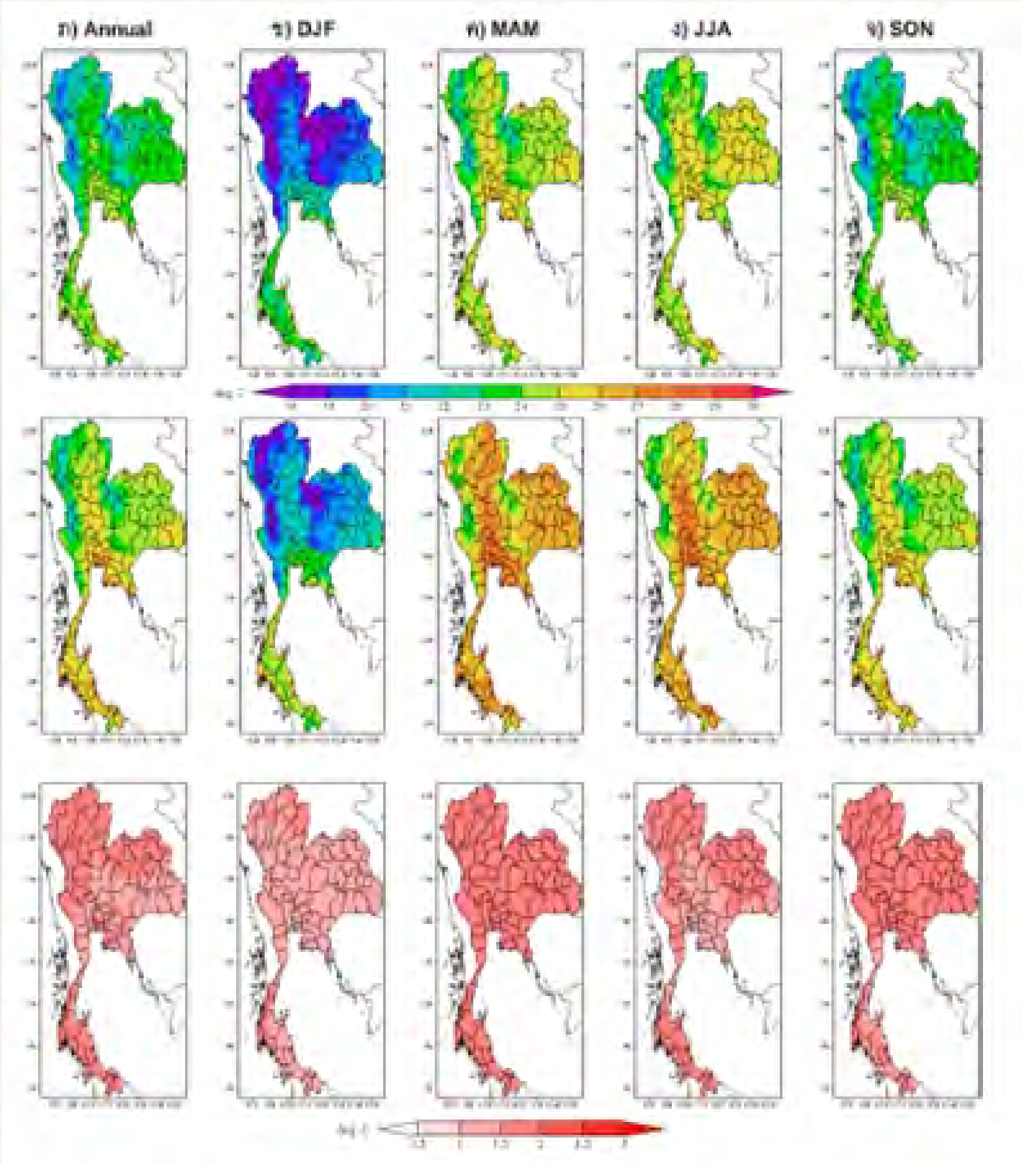
GCM : ECHAM5

Scenario : SRES A1B and A2

Future year : 2031 – 2070

Resolution : 20 km

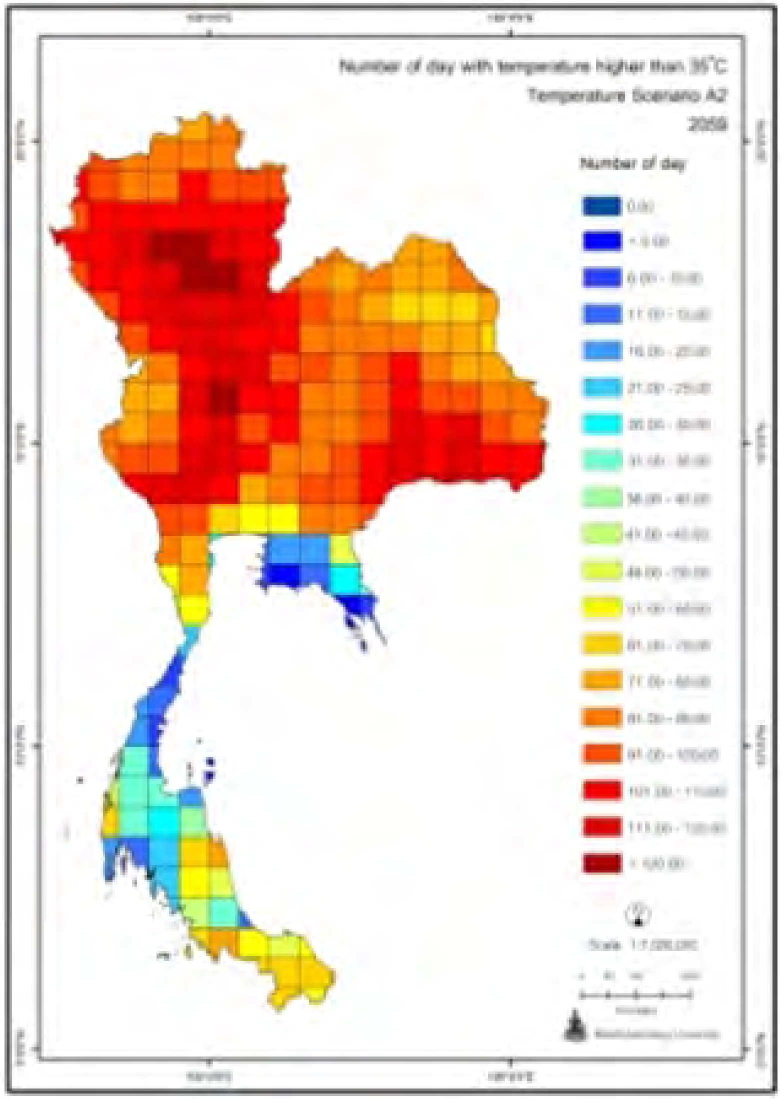
Previous Study 5 (2010)

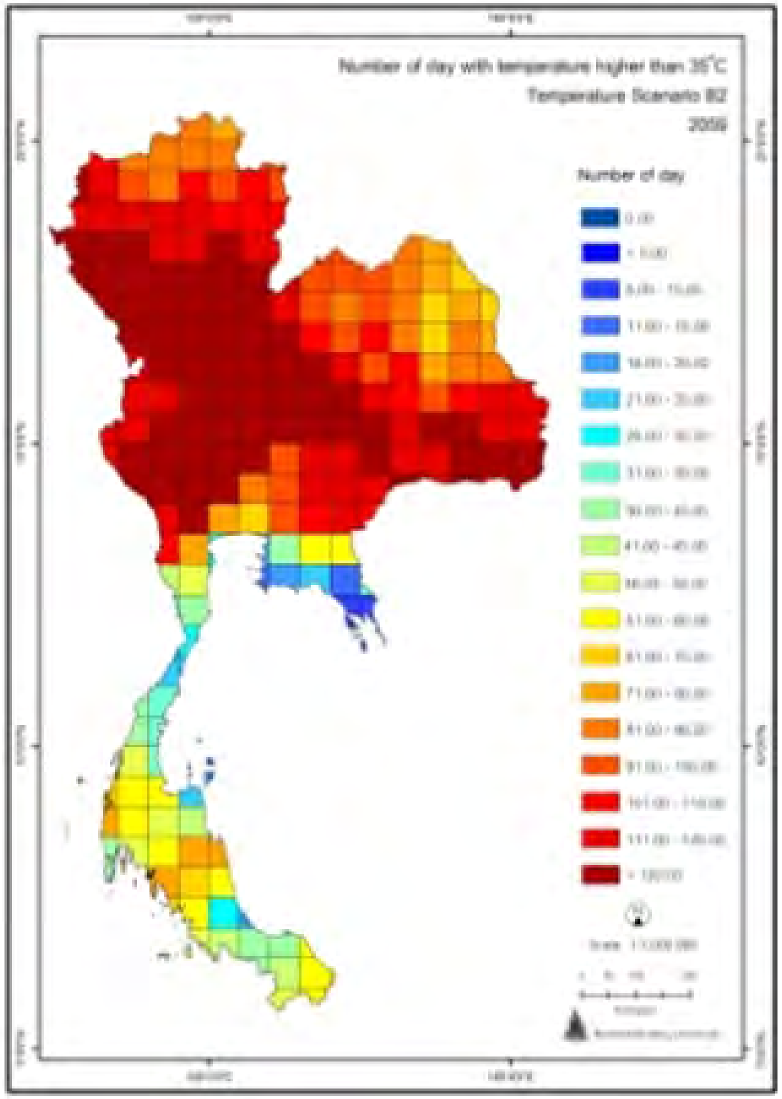


Previous Study 6 (2010)

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)

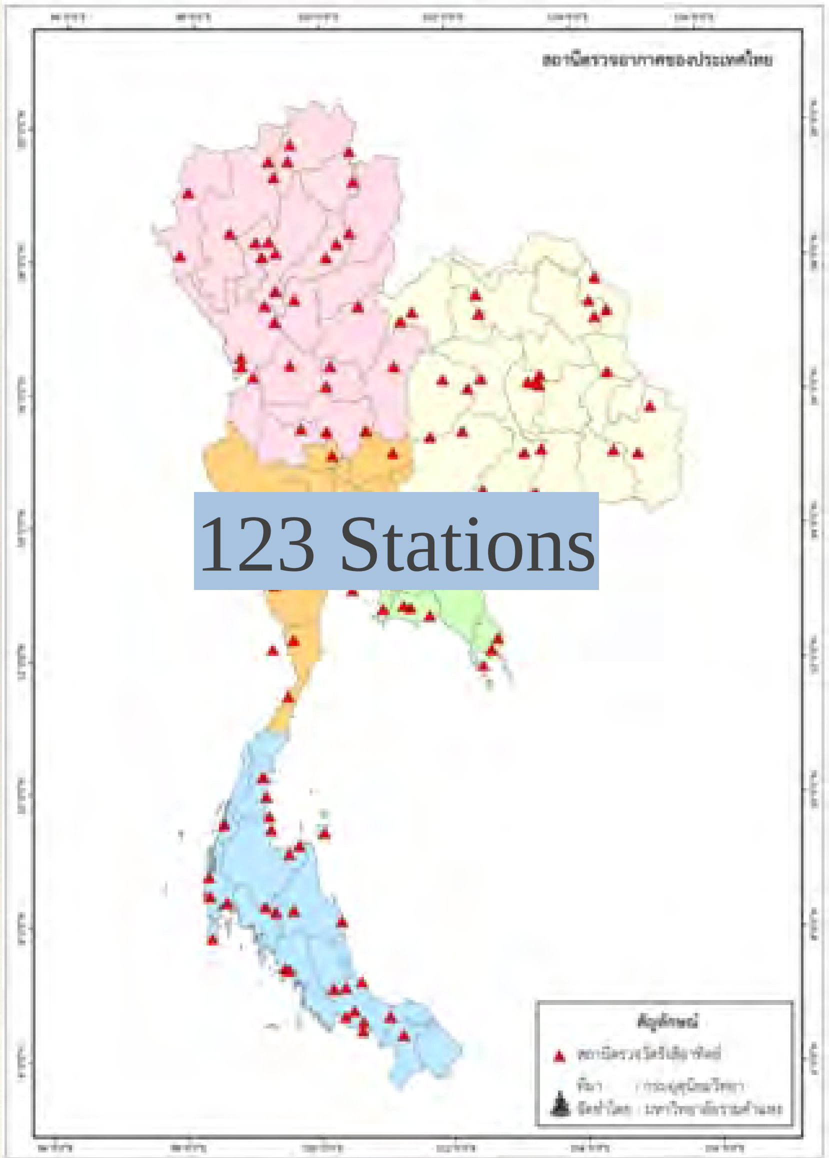


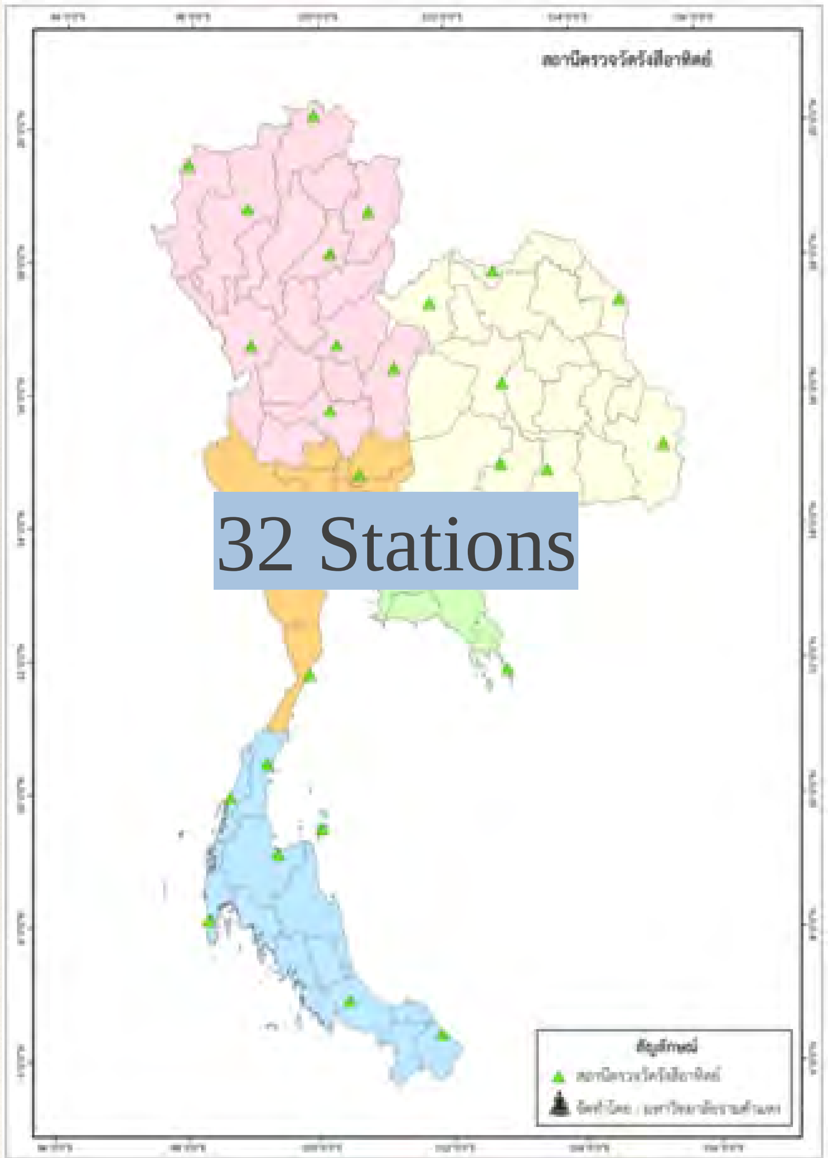


Recent Study

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

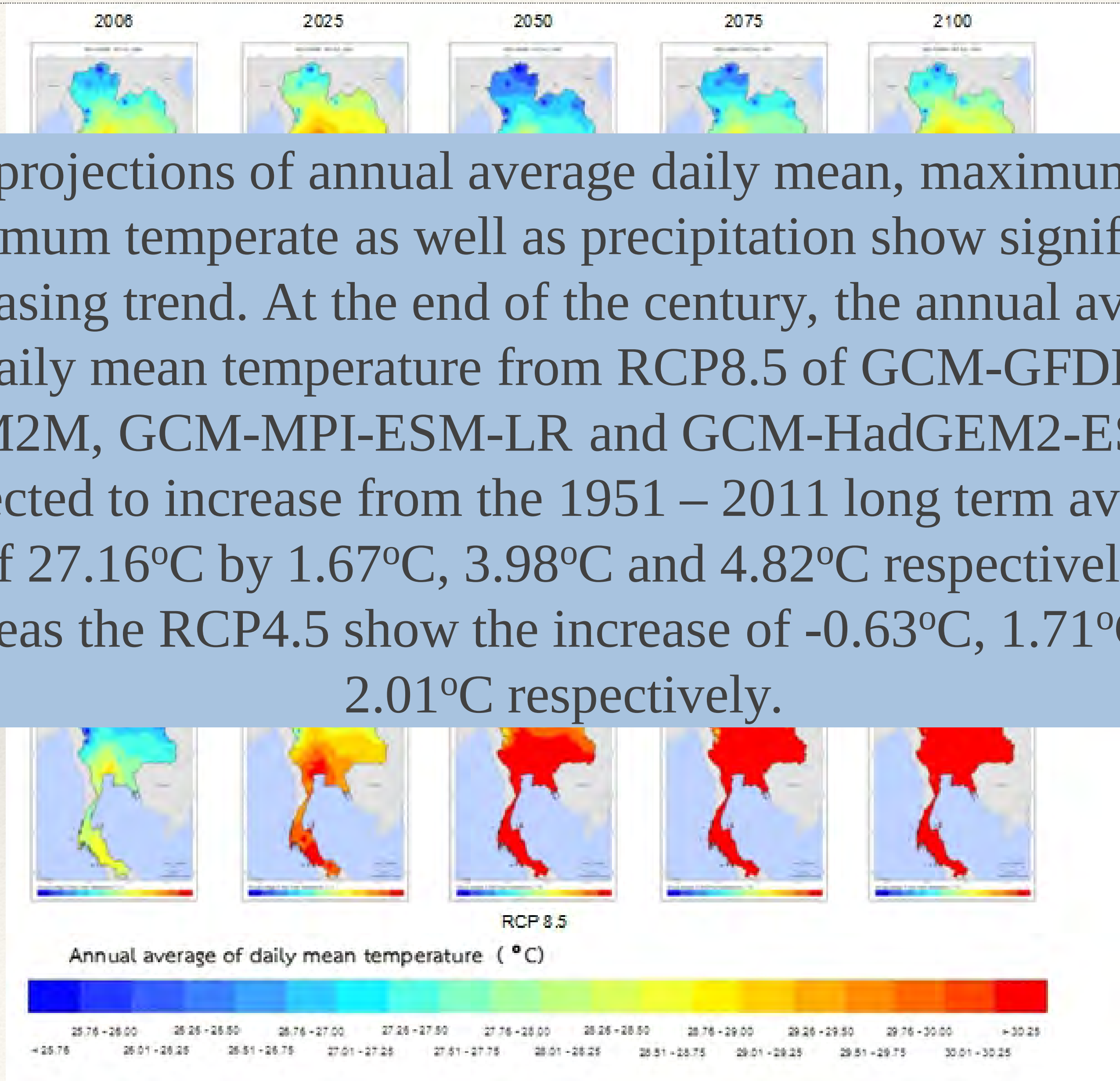
Predictors

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

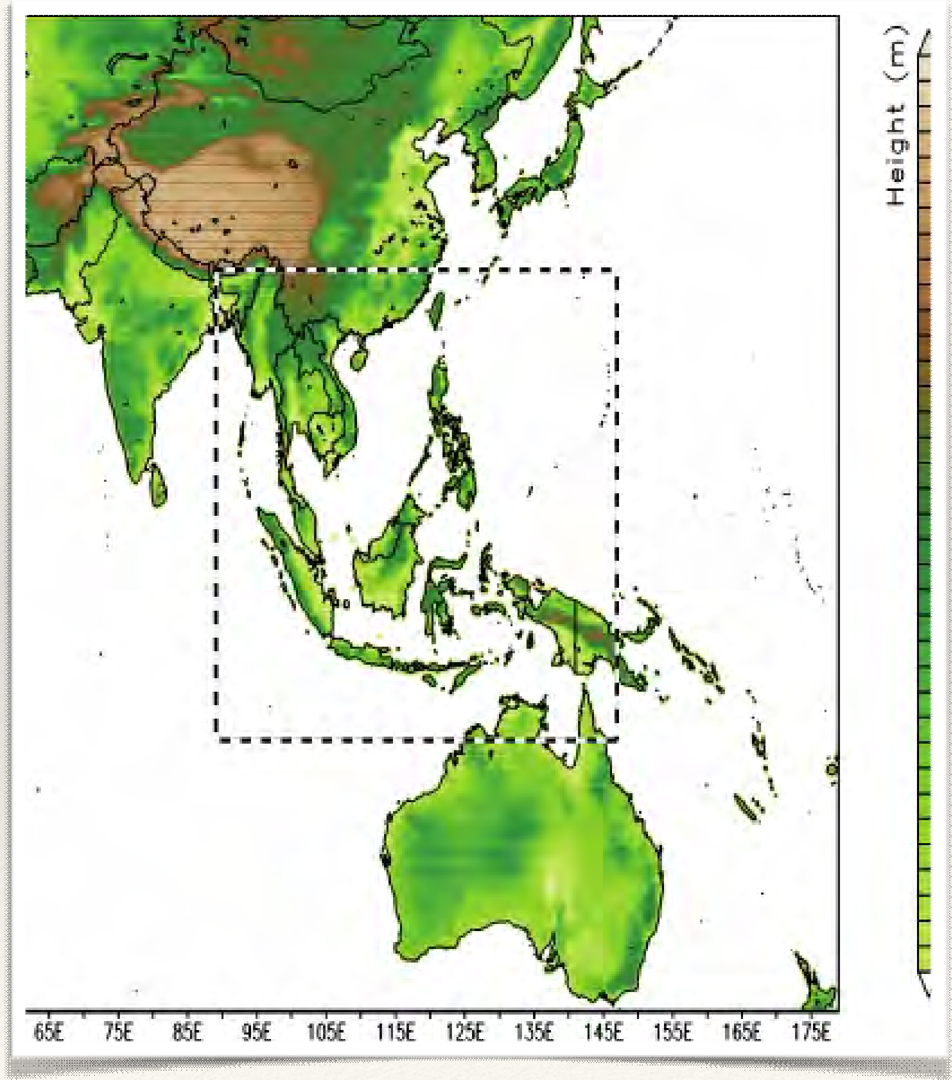
Temperature Change



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^{o}C by 1.67^{o}C, 3.98^{o}C and 4.82^{o}C respectively, whereas the RCP4.5 show the increase of -0.63^{o}C, 1.71^{o}C and 2.01^{o}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



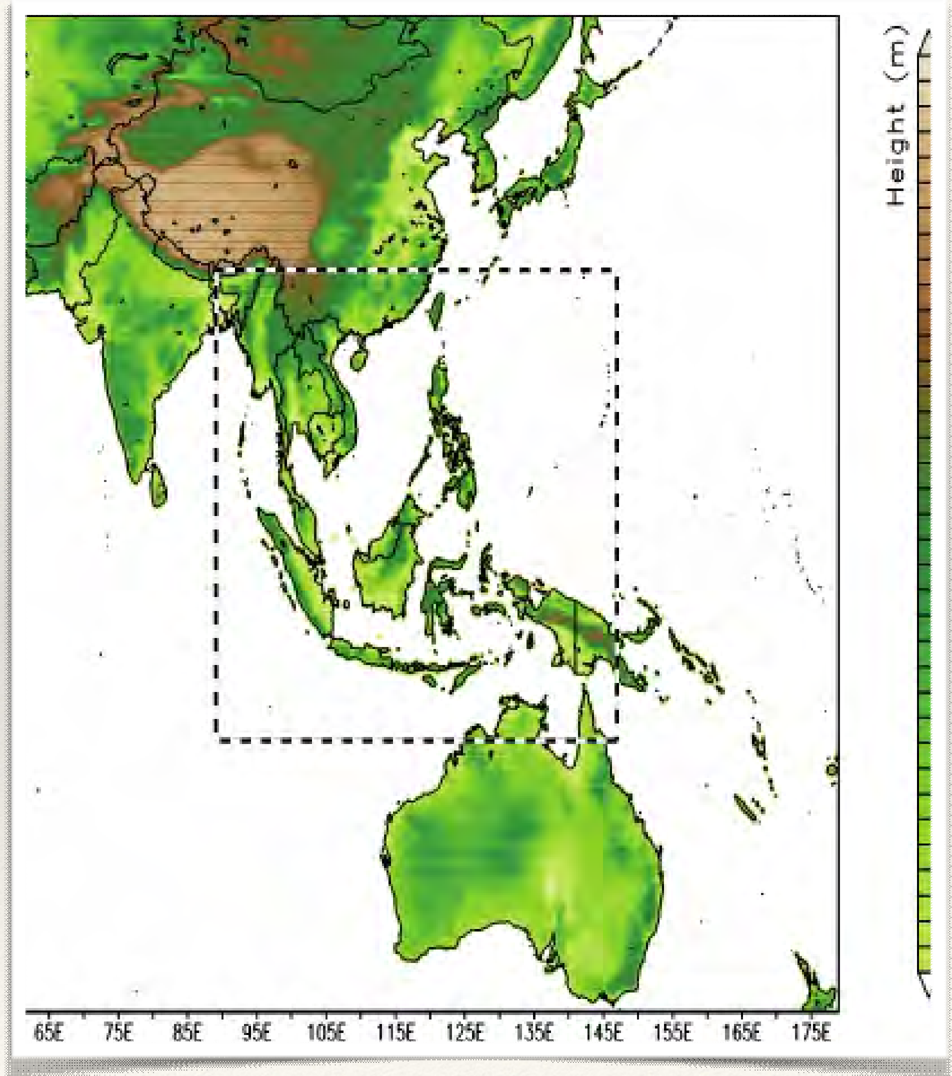
Sector	Topics/issues	North Asia		East Asia		Southeast Asia		South Asia		Central Asia		West Asia	
	O = Observed impacts, P = Projected impacts	O	P	O	P	O	P	O	P	O	P	O	P
Freshwater resources	Major river runoff	/	x	/	/	/	/	/	[illegible]	[illegible]	[illegible]	[illegible]	x
	Water supply	x	x	x	x	x	x	x	[illegible]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

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

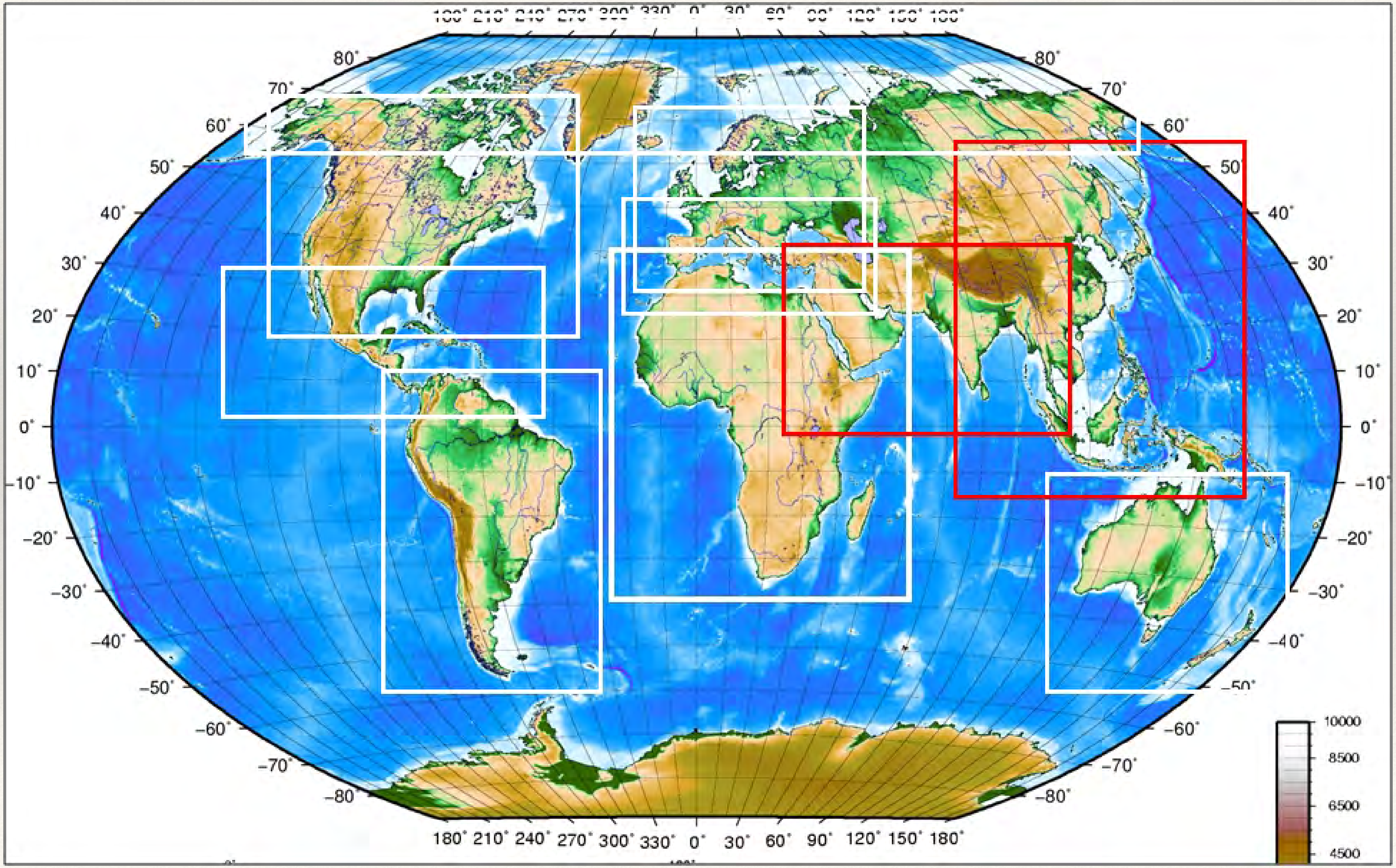
Table 24.2 IPCC AR5 WGII

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



CORDEX-SEA domains

Region 14: South-East Asia (SEA)

Ref: Description of the CORDEX domains
(23/06/2015 version)

A) For rotated polar RCMs (in rotated coordinates):
RotPole (180.0; 90.0)
TLC (89.26; 27.28)
Nx=264
Ny=194

B) For non-rotated polar RCMs (in actual coordinates):
TLC (27.26; 89.26)
CNB (27.26; 118.04)
TRC (27.26; 146.96)
CWB (6.5N; 89.26)
CPD (6.5N; 118.04)
CEB (6.5N; 146.96)
BLC (-15.14; 89.26)
CSB (-15.14; 118.04)
BRC (-14.81; 146.96)

Website:
http://www.ukm.my/seaclid-cordex/

Flyer:
CORDEX-SEA Flyer - June 2015

Points of contact:
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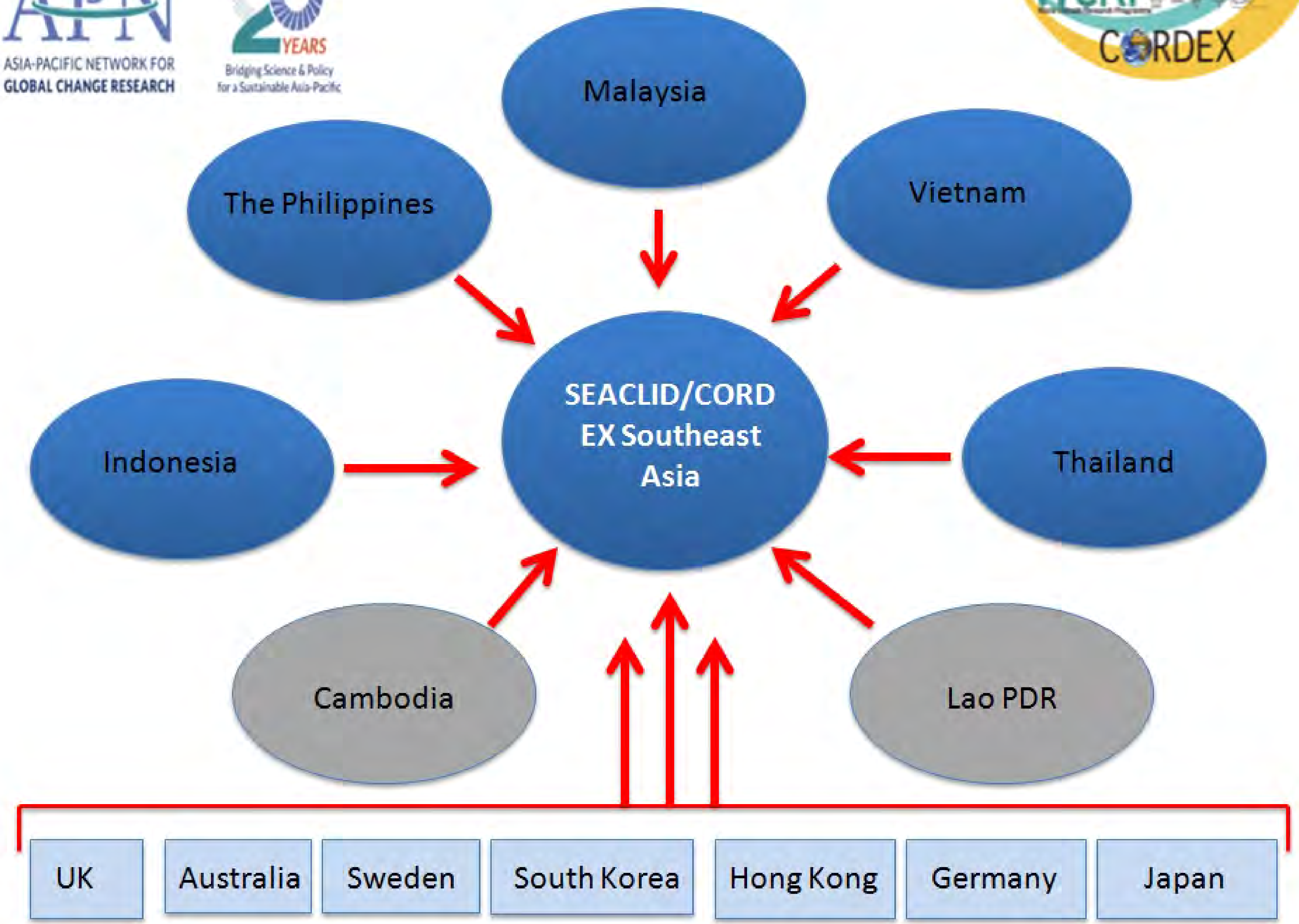
ftangang (at) gmail.com
- Gemma Narisma - Ateneo de Manila University, Philippines
gnarisma (at) ateneo.edu

CORDEX Domains

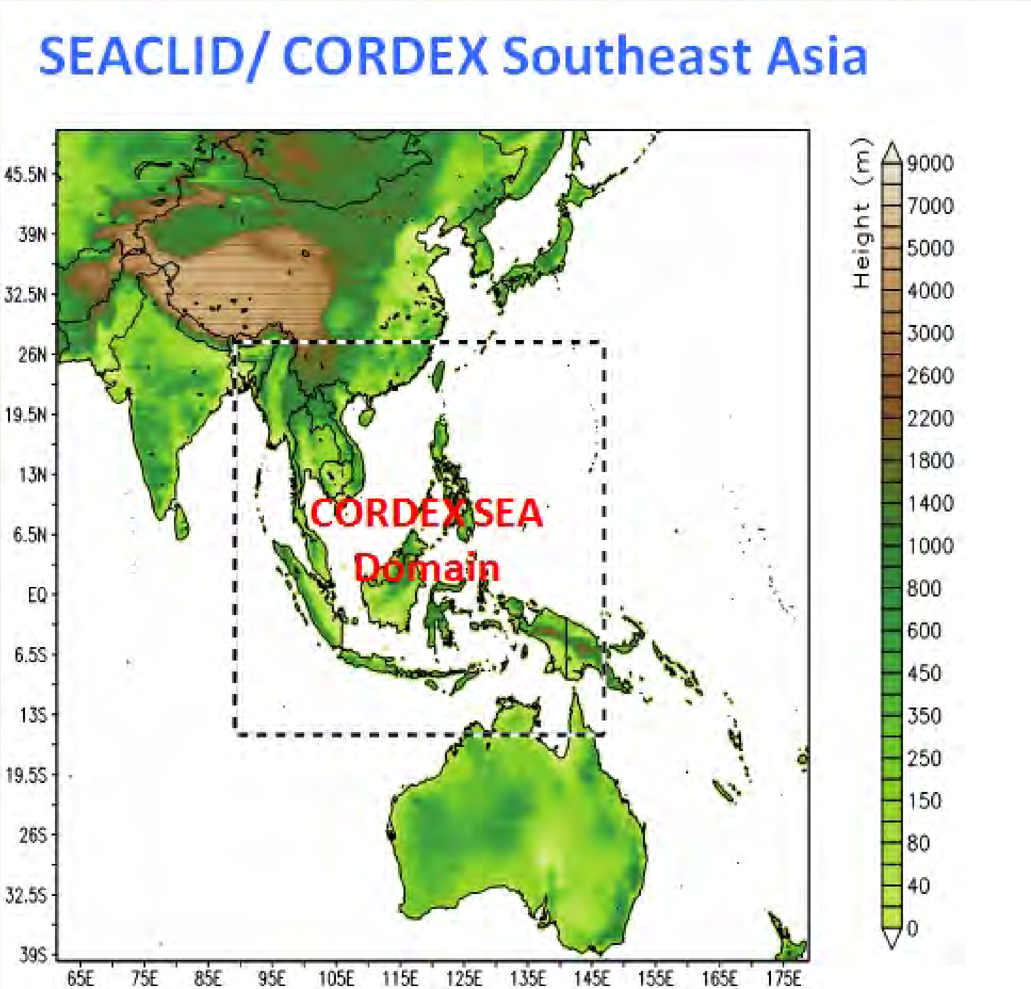
SEACLID/CORDEX SEA objectives

- 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.


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]

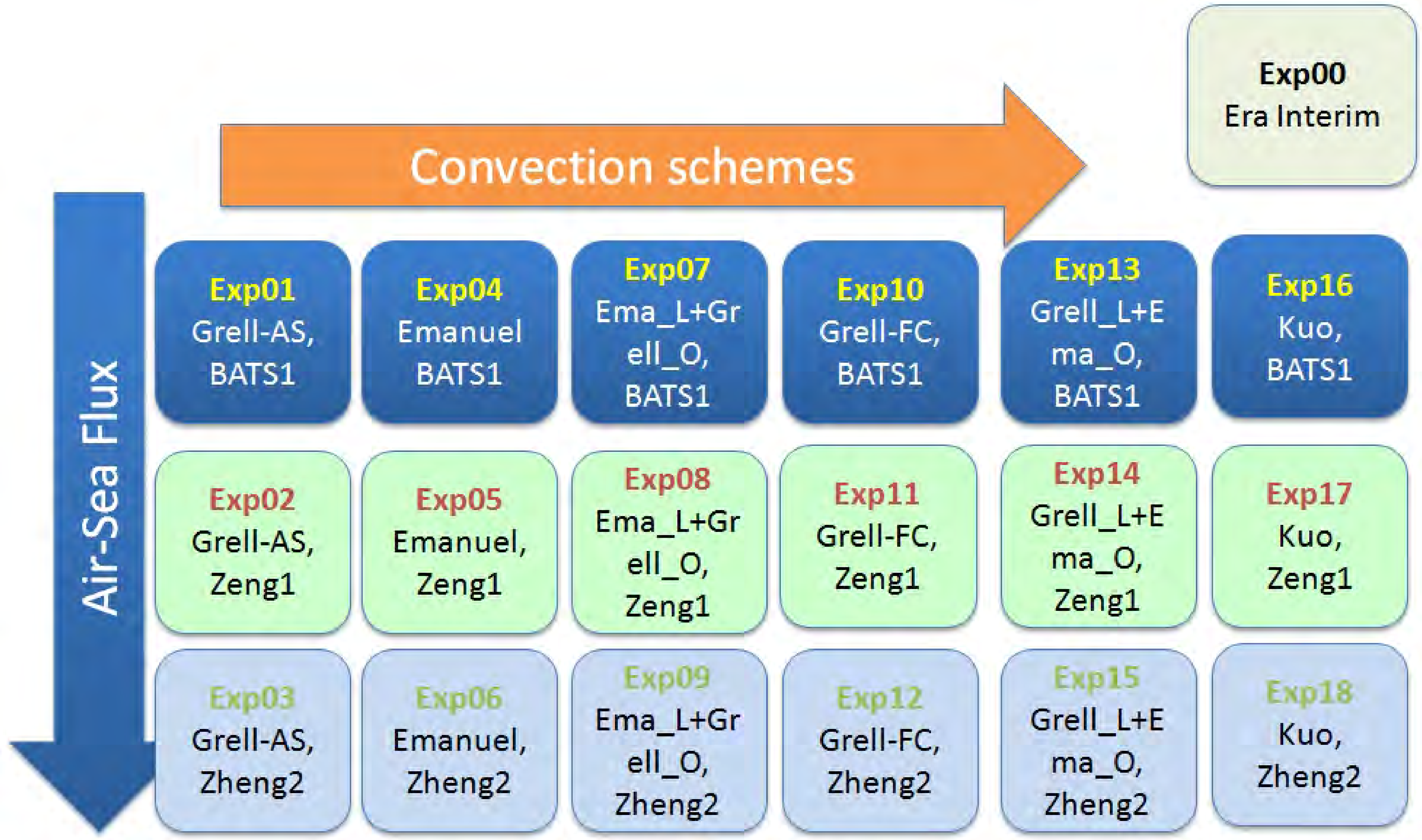


RegCM4 (ver 4.3.5.6) Sensitivity Experiments Conducted by participating institutions from Southeast Asia region

- PBL: Holtslag (1990)
- Radiation: CCSM
- Large scale moisture: SUBEX (Pal et al. 20)
- Land-surface scheme: BATSe
- Cumulus parameterization:
  - Grell / Arakawa-Schubert (closure)
  - MIT Emanual
  - MIT (O) / Grell (L)
  - Grell (O) / MIT (L)
  - Grell / Fritch-Chappell (closure)
  - Kuo
- Air-Sea flux parameterization:
  - BATSe
  - Zeng (iocnrough=1)
  - Zeng (iocnrough=2)

18 Simulations

- Lateral boundary conditions: ERA Interim
- Run length: 1989 – 2008 (20 years; 1989 is model spin-up) (To enable interananual responses to be evaluated)

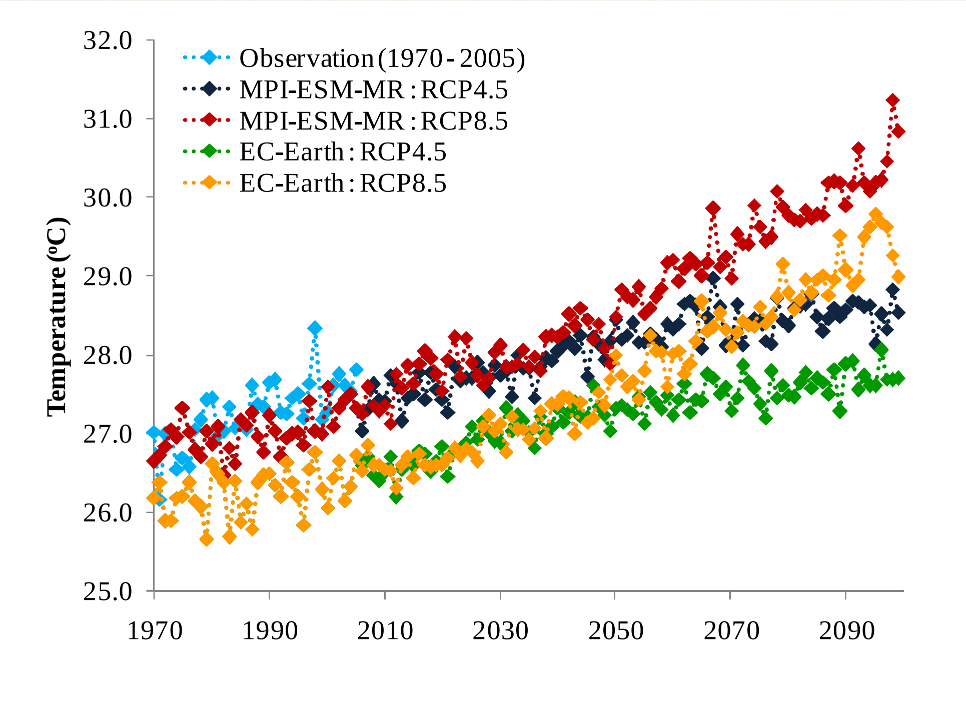

Exp00
Era Interim
Convection schemes
Air-Sea Flux
Exp01
Grell-AS,
BATS1
Exp04
Emanuel
BATS1
Exp07
Ema_L+Gr
ell_O,
BATS1
Exp10
Grell-FC,
BATS1
Exp13
Grell_L+E
ma_O,
BATS1
Exp16
Kuo,
BATS1
Exp02
Grell-AS,
Zeng1
Exp05
Emanuel,
Zeng1
Exp08
Ema_L+Gr
ell_O,
Zeng1
Exp11
Grell-FC,
Zeng1
Exp14
Grell_L+E
ma_O,
Zeng1
Exp17
Kuo,
Zeng1
Exp03
Grell-AS,
Zheng2
Exp06
Emanuel,
Zheng2
Exp09
Ema_L+Gr
ell_O,
Zheng2
Exp12
Grell-FC,
Zheng2
Exp15
Grell_L+E
ma_O,
Zheng2
Exp18
Kuo,
Zheng2

GCMs, RCMs, RCPs and Country Assignments

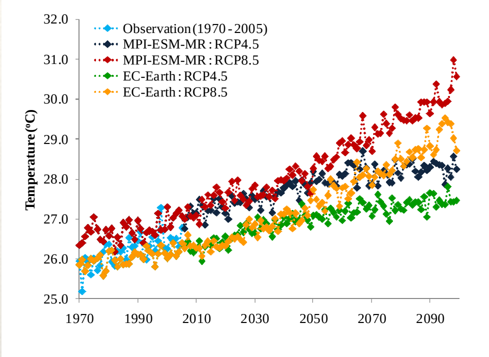
Country	GCM	Institution & Country developed the GCM	RCP	RCM
Vietnam	CNRM-CM5	Centre national de Recherches Meteorologiques, France	RCP8.5, 4.5	RegCM4
Philippines	HadGEM2	Hadley Centre, UK	RCP8.5, 4.5	RegCM4
Thailand	MPI-ESM-MR	Max Planck Institute for Meteorology, Germany	RCP8.5, 4.5	RegCM4
Thailand	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

Results from SEACLID/CORDEX SEA

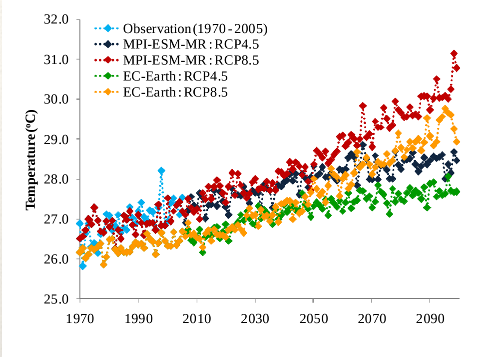
Yearly average daily mean temperature



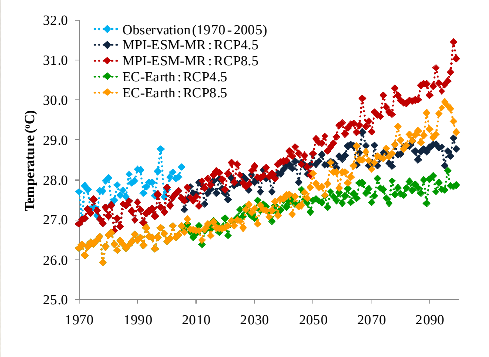
Whole Country Area



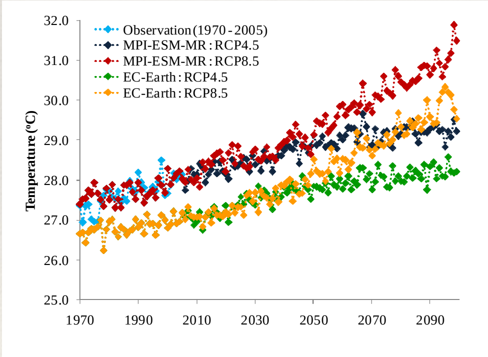
Northern Region



North Eastern Region



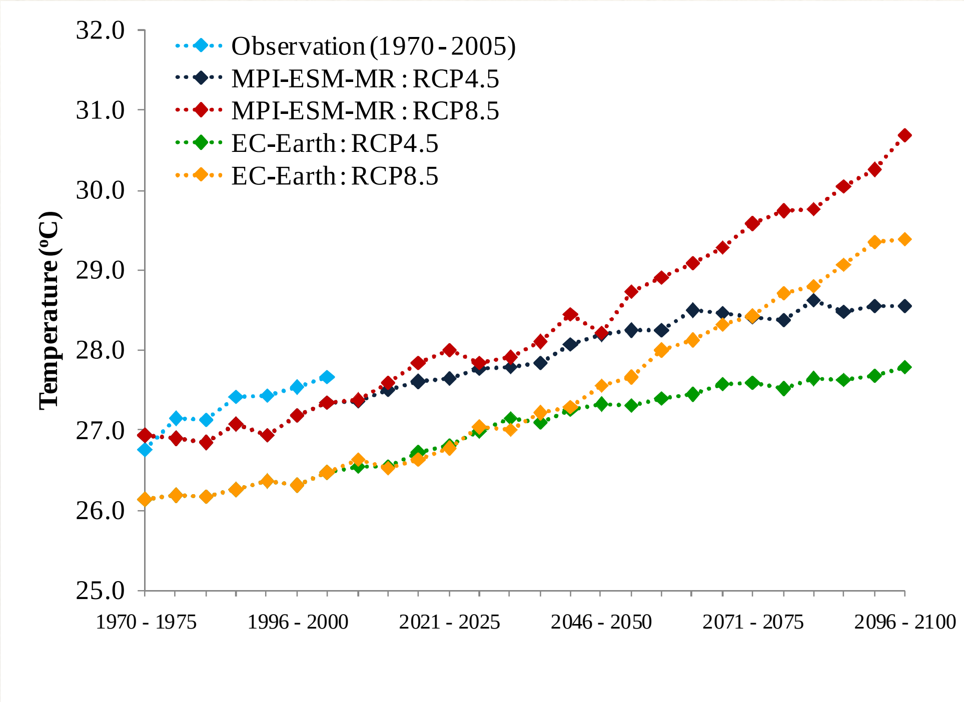
Central Region



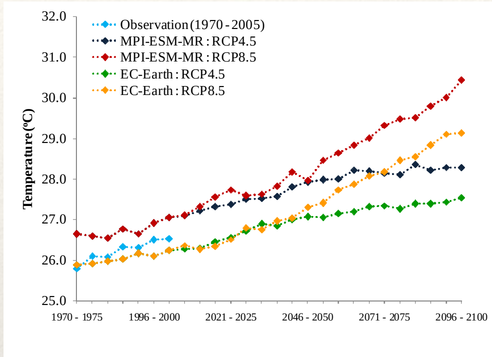
Southern Region

Results from SEACLID/CORDEX SEA

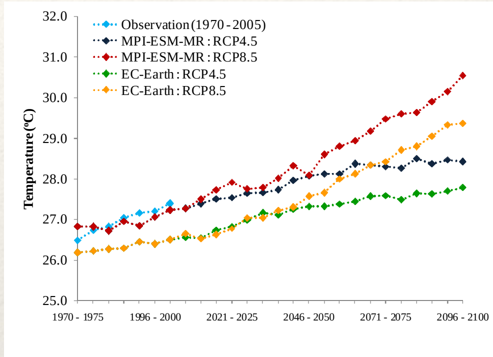
5 yearly average daily mean temperature



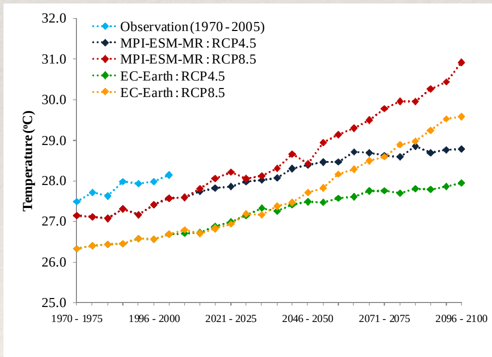
Whole Country Area



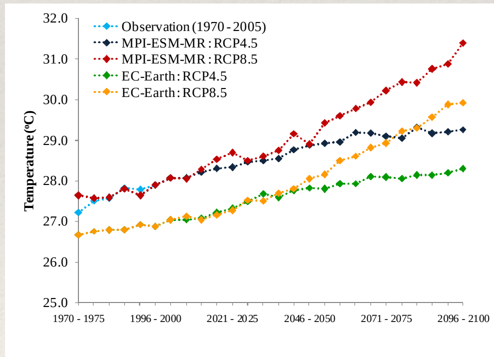
Northern Region



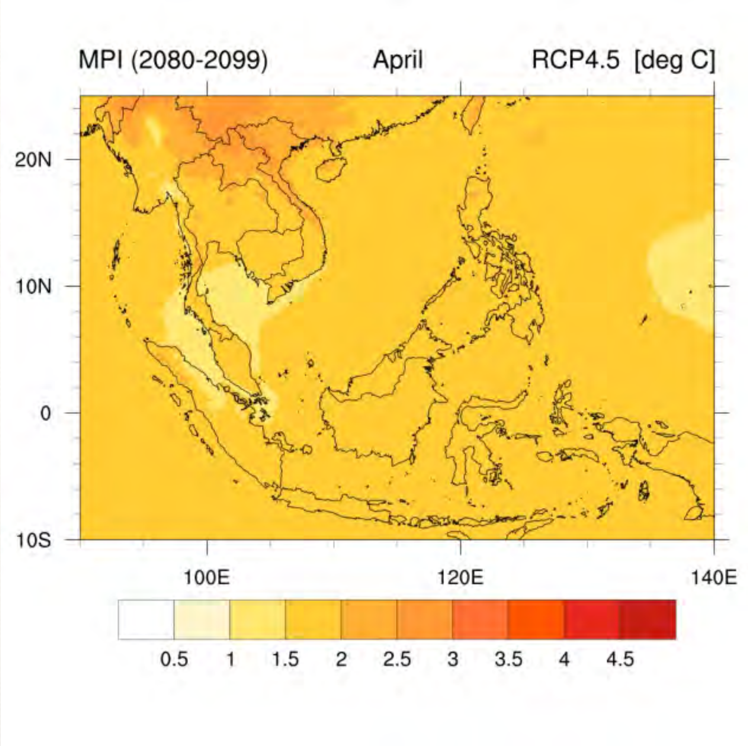
North Eastern Region

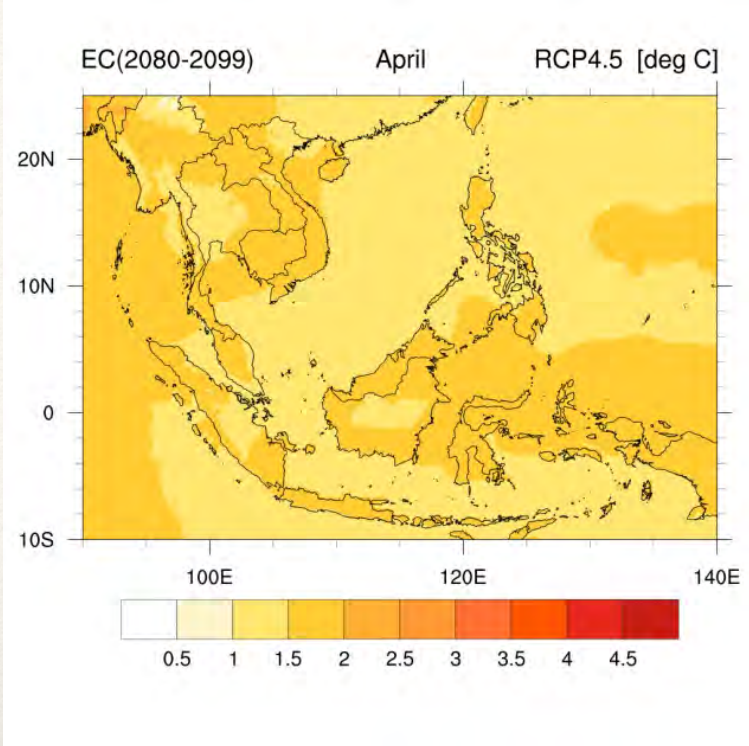


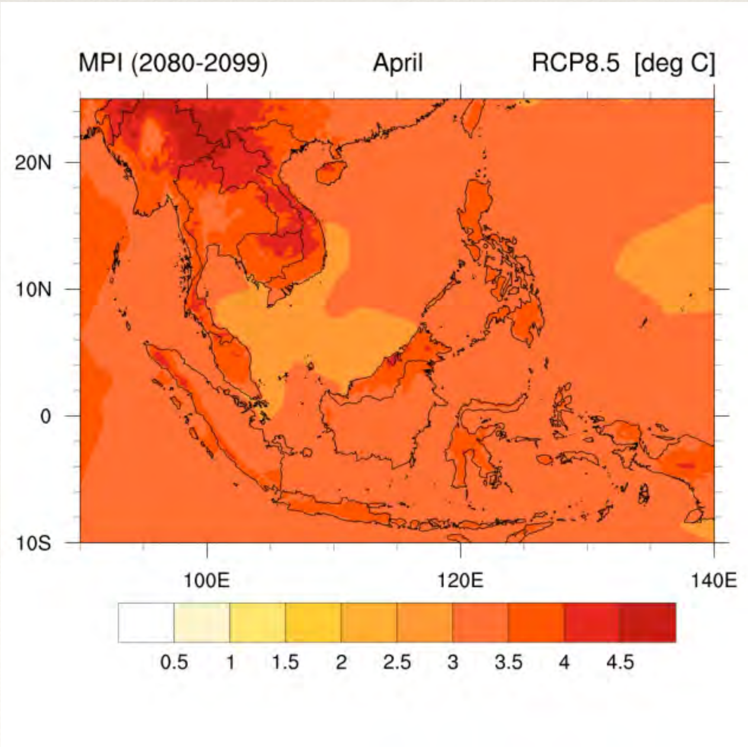
Central Region

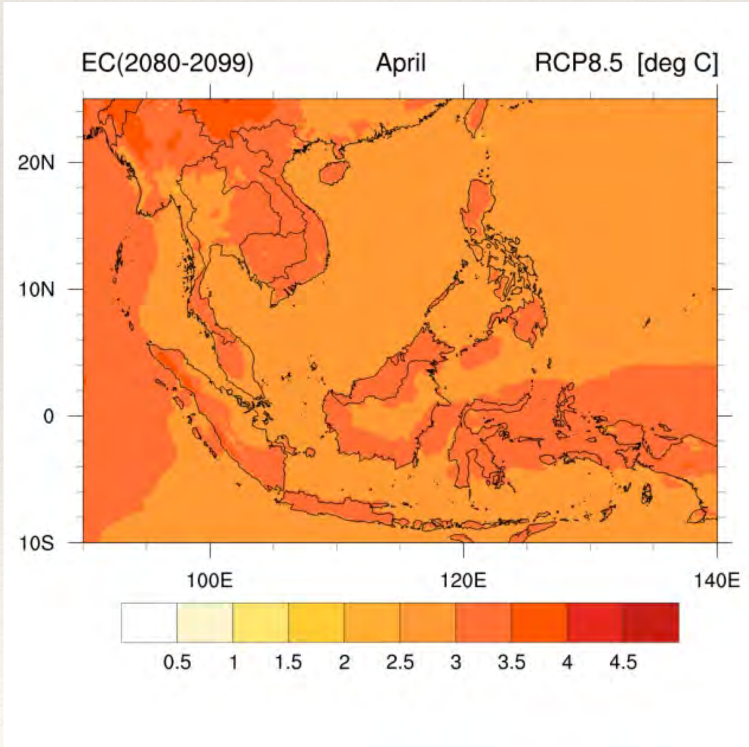


Southern Region


MPI (2080-2099)
April
RCP4.5 [deg C]
20N
10N
0
10S
100E
120E
140E
0.5
1
1.5
2
2.5
3
3.5
4
4.5

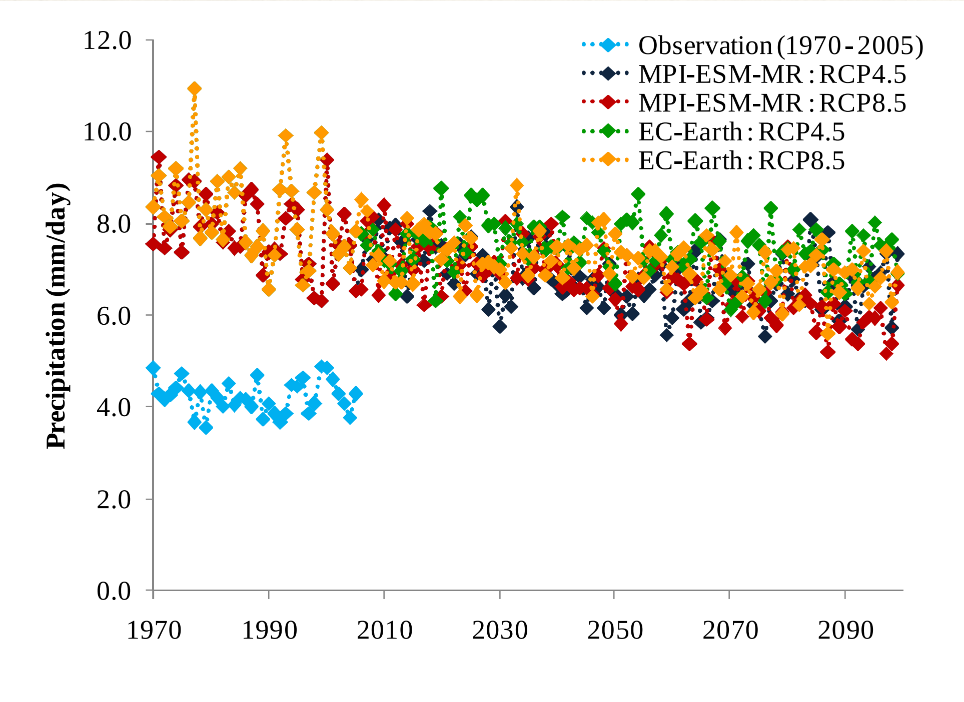

EC(2080-2099)
April
RCP4.5 [deg C]
20N
10N
0
10S
100E
120E
140E
0.5
1
1.5
2
2.5
3
3.5
4
4.5


MPI (2080-2099)
April
RCP8.5 [deg C]
20N
10N
0
10S
100E
120E
140E
0.5
1
1.5
2
2.5
3
3.5
4
4.5

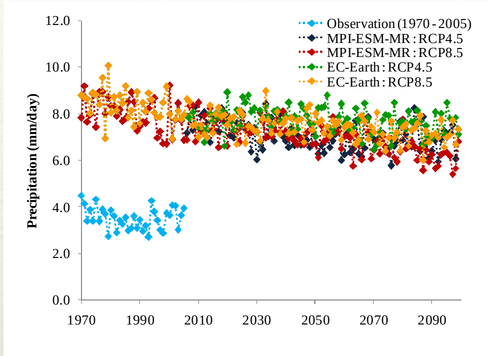

EC(2080-2099)
April
RCP8.5 [deg C]
20N
10N
0
10S
100E
120E
140E
0.5
1
1.5
2
2.5
3
3.5
4
4.5

Results from SEACLID/CORDEX SEA

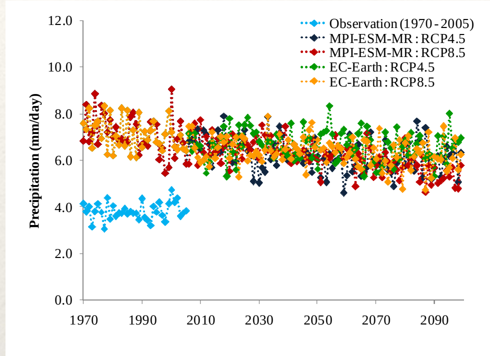
Yearly average daily mean rain fall



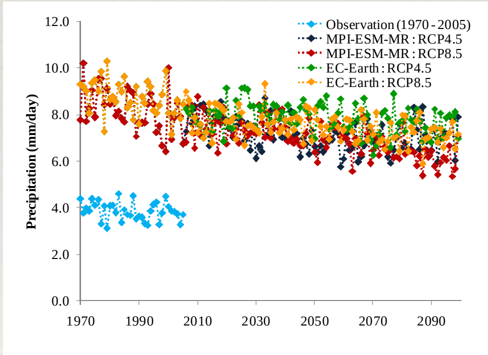
Whole Country Area



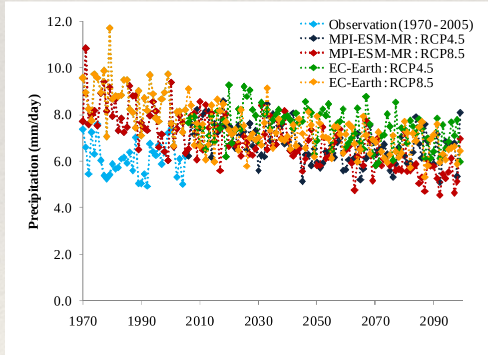
Northern Region



North Eastern Region



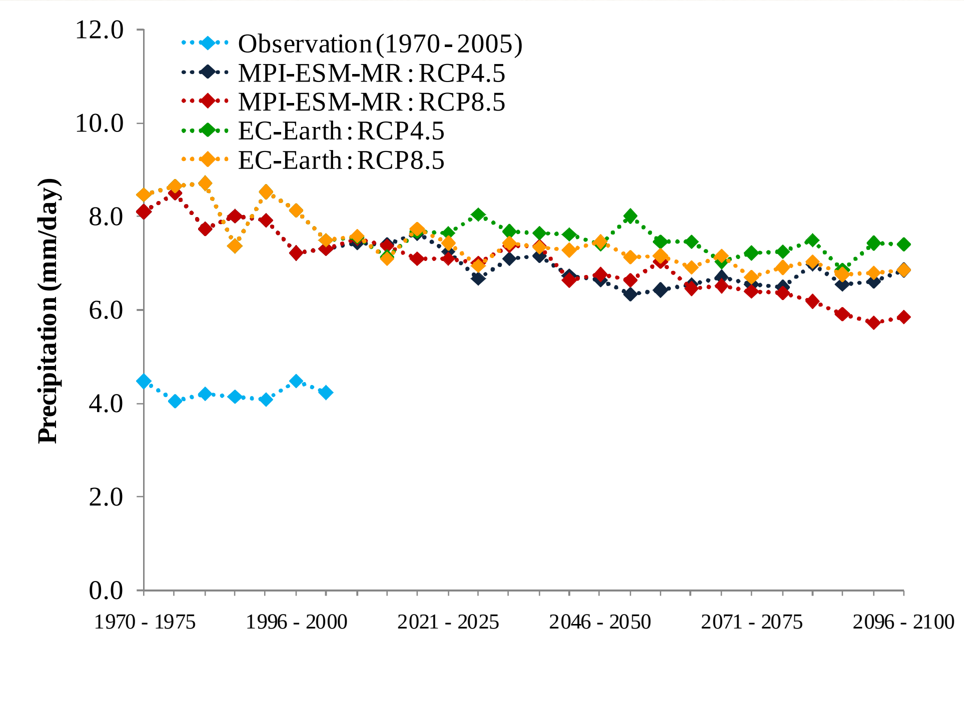
Central Region



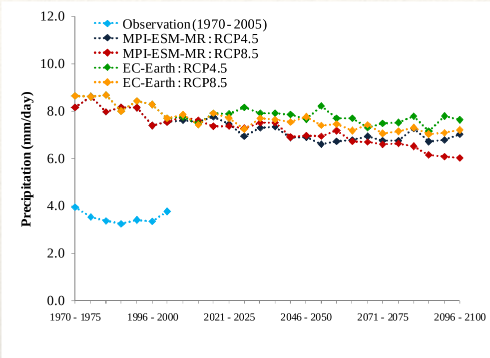
Southern Region

Results from SEACLID/CORDEX SEA

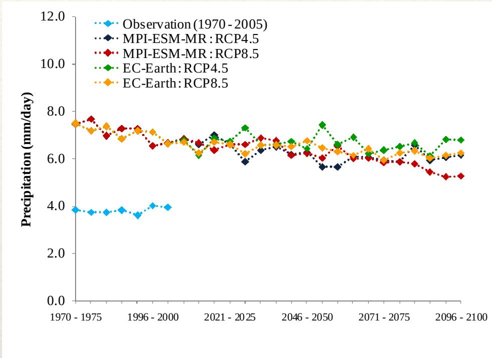
5 yearly average daily mean rainfall



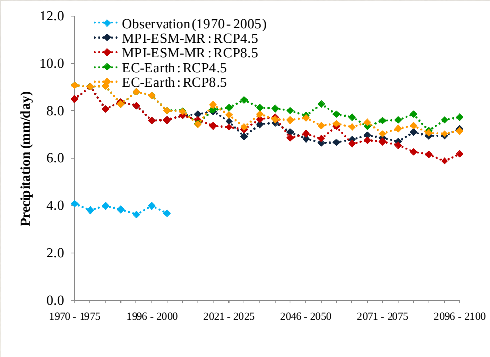
Whole Country Area



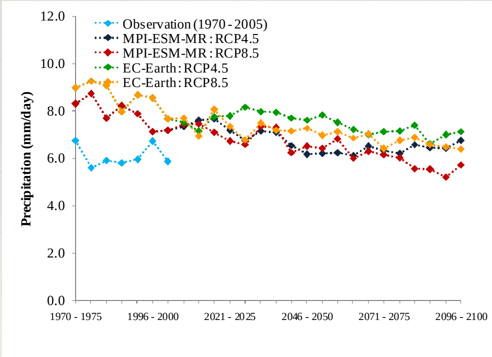
Northern Region



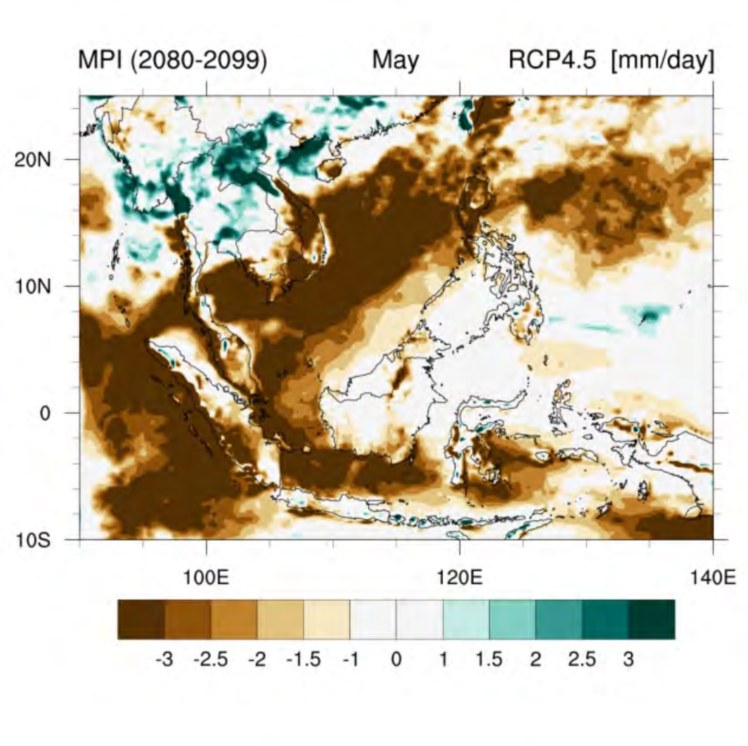
North Eastern Region

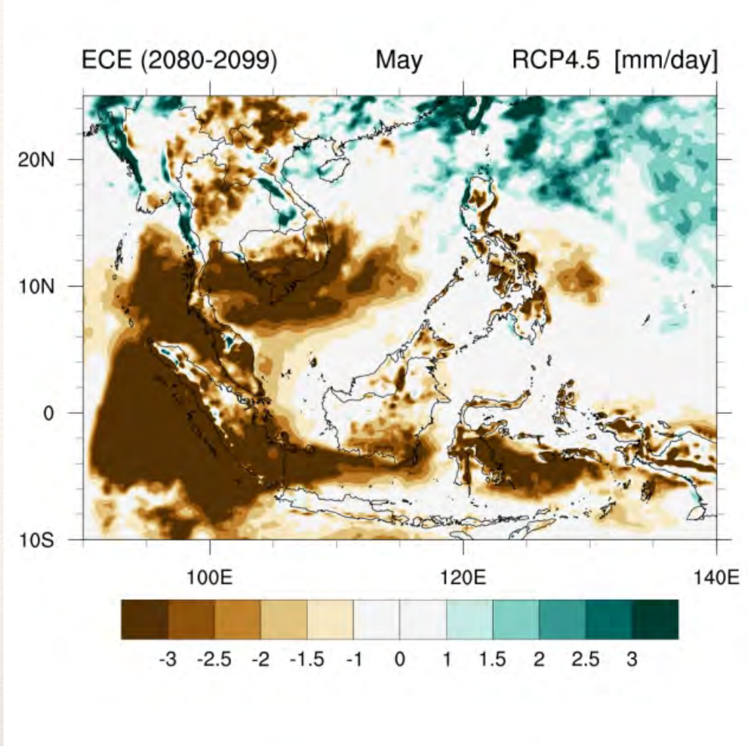


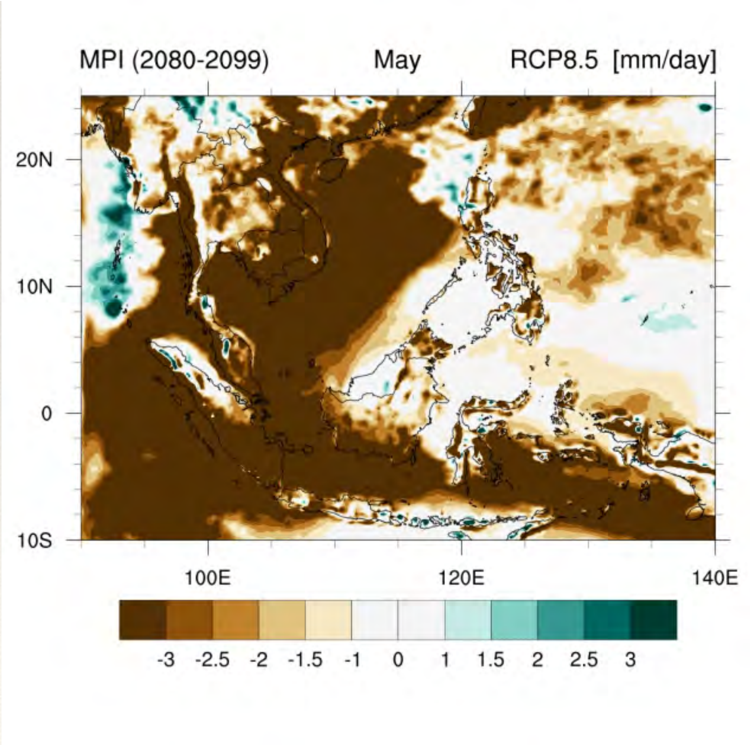
Central Region

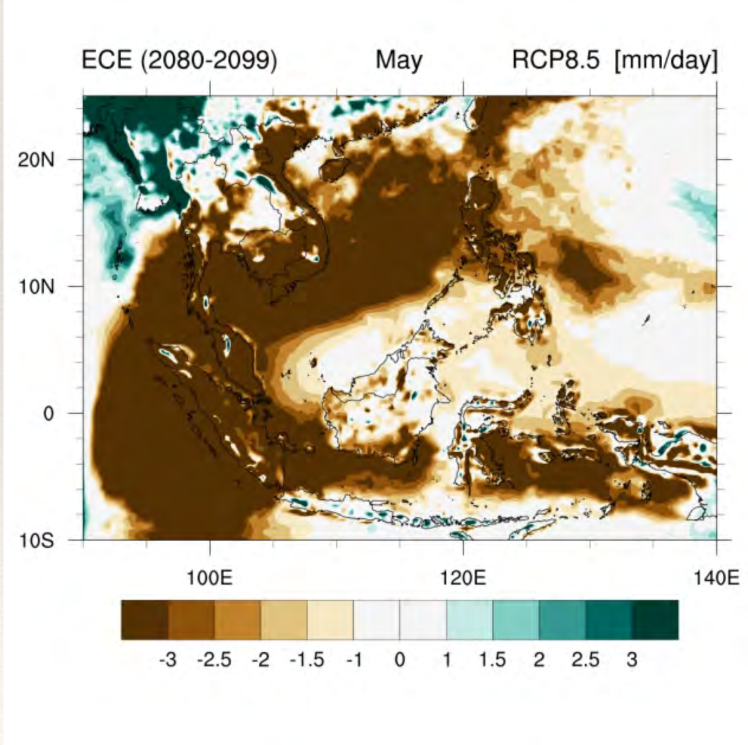


Southern Region

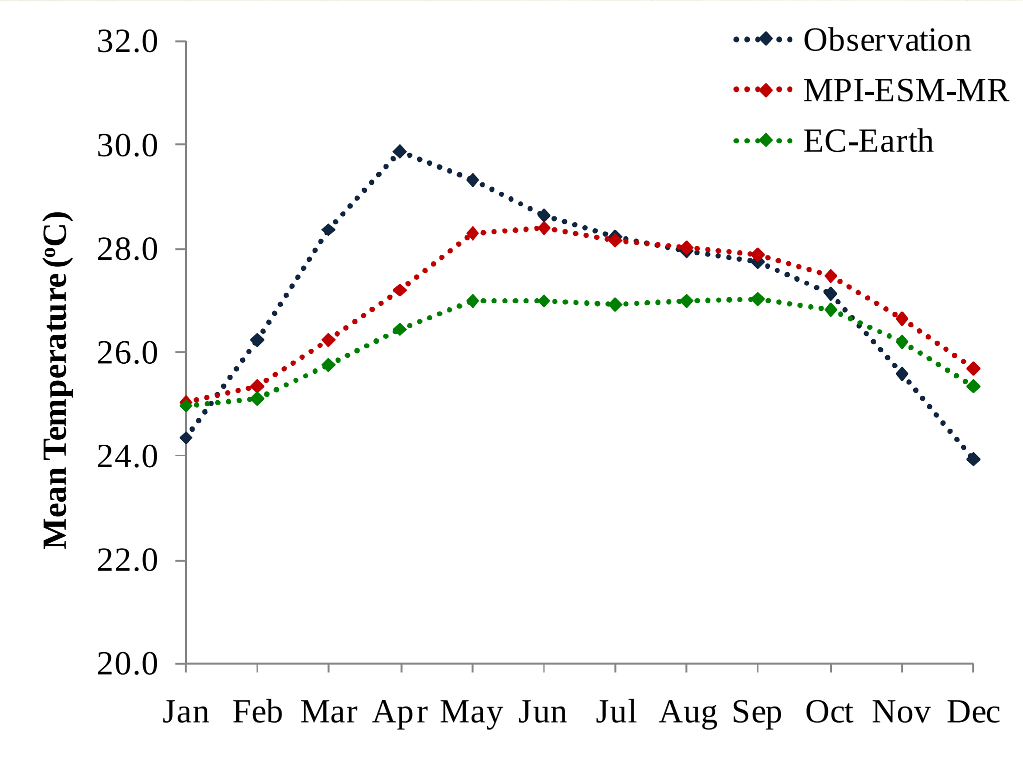

MPI (2080-2099)
May
RCP4.5 [mm/day]
20N
10N
0
10S
100E
120E
140E
-3 -2.5 -2 -1.5 -1 0 1 1.5 2 2.5 3

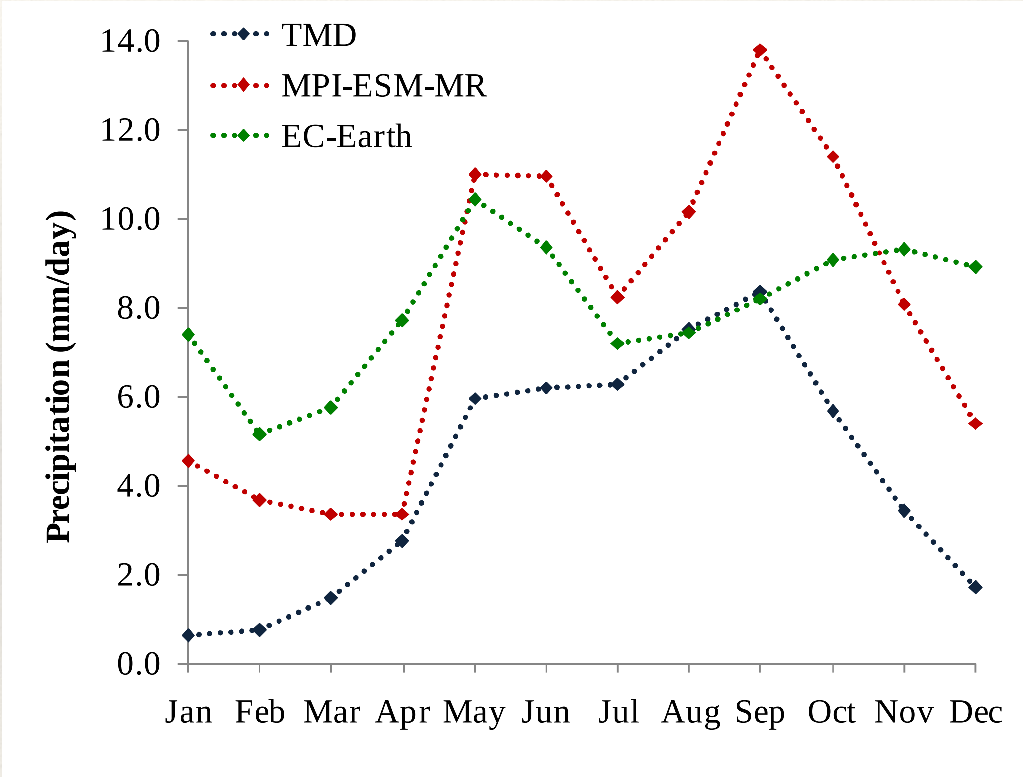

ECE (2080-2099)
May
RCP4.5 [mm/day]
20N
10N
0
10S
100E
120E
140E
-3 -2.5 -2 -1.5 -1 0 1 1.5 2 2.5 3


MPI (2080-2099)
May
RCP8.5 [mm/day]
20N
10N
0
10S
100E
120E
140E
-3 -2.5 -2 -1.5 -1 0 1 1.5 2 2.5 3

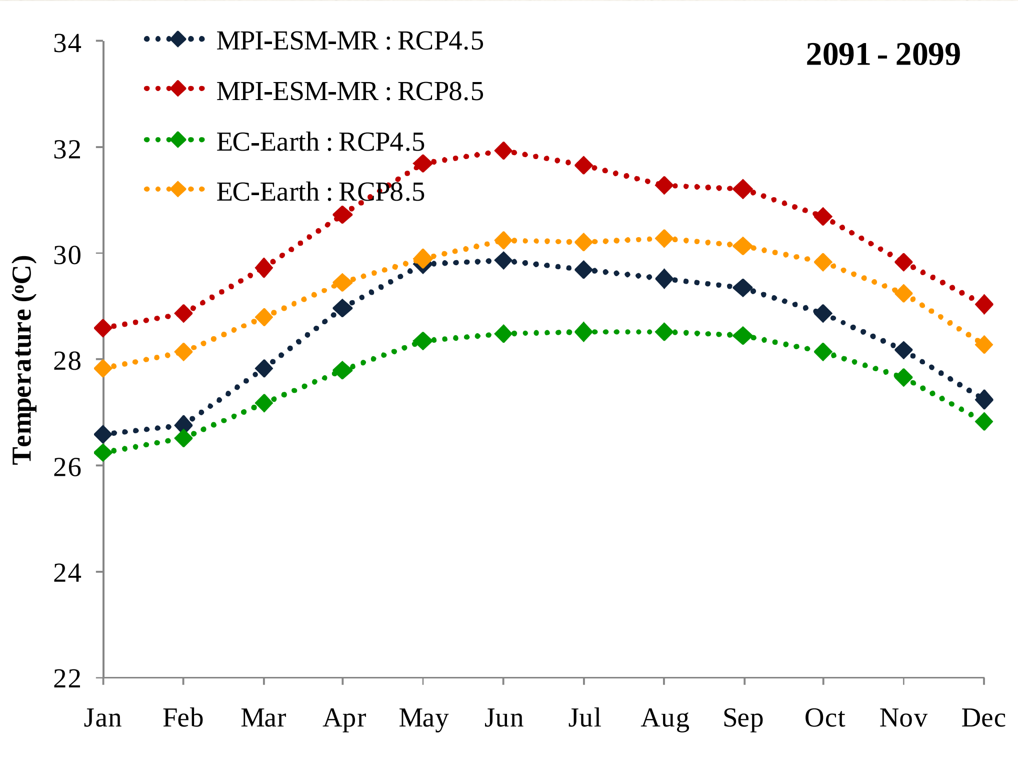

ECE (2080-2099)
May
RCP8.5 [mm/day]
20N
10N
0
10S
100E
120E
140E
-3 -2.5 -2 -1.5 -1 0 1 1.5 2 2.5 3

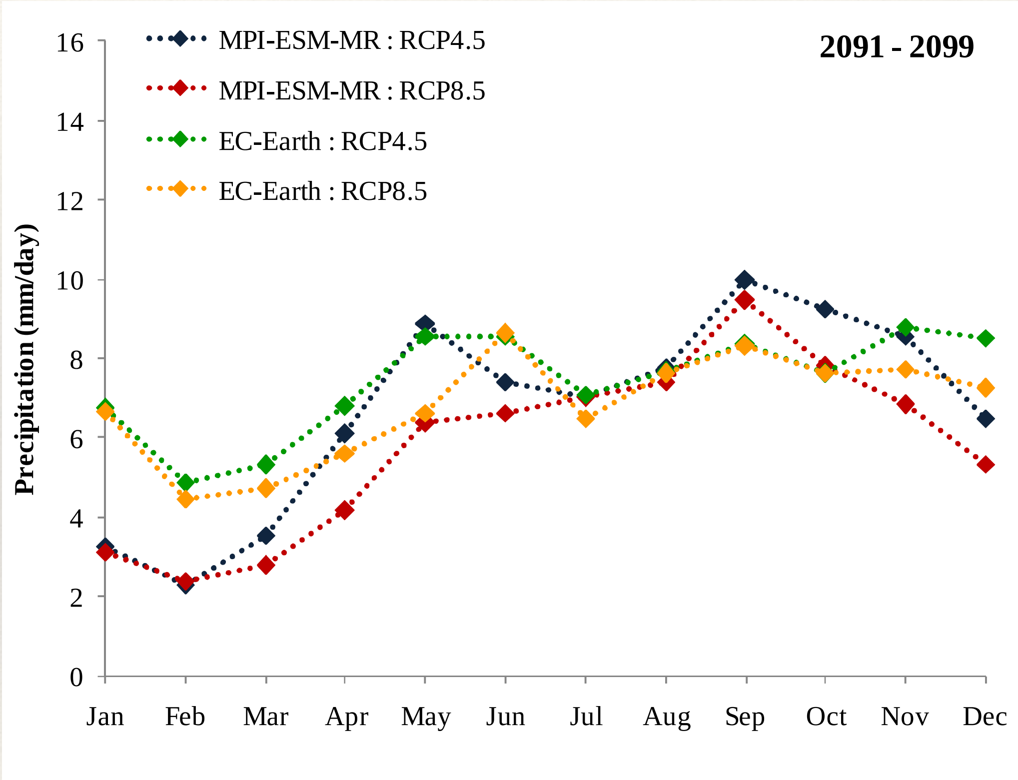
Seasonal Cycle: Base line (1970 – 2005)





Seasonal Cycle: Base line (2091 – 2099)





Why do we need bias correction for Regional Climate Model Output ?

To be continue…..

Thank you