Introduction to Climate Projections and Analysis

Presented by Thelma A. Cinco, PAGASA
24 August 2016

Source: Jack Katzfey, CSIRO Oceans and Atmosphere

www.csiro.au

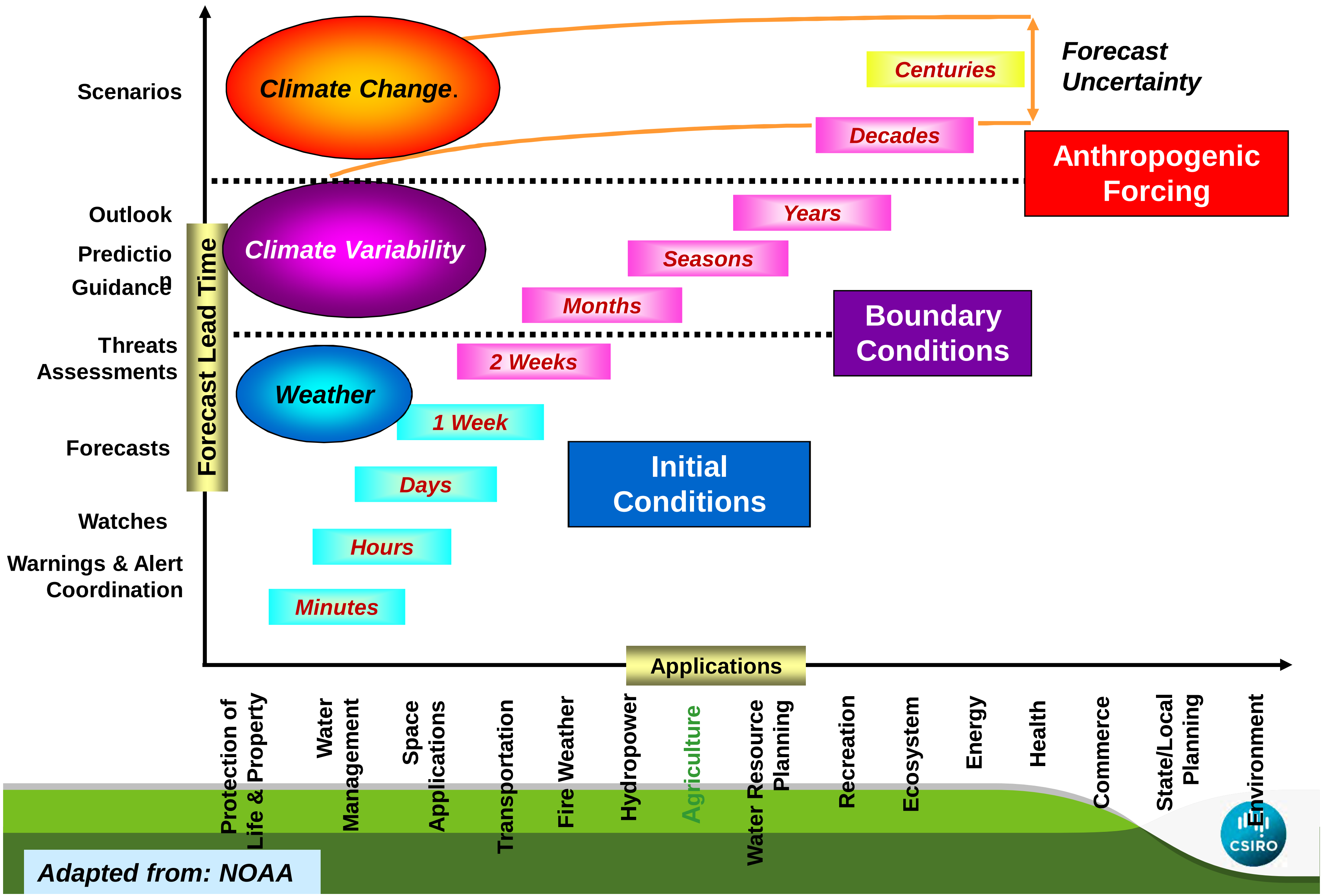
The project is being implemented by the Asian Development Bank through the technical assistance (TA 8359-REG) financed by the Japan Fund for Poverty Reduction.

ADB
From the People of Japan
Griffith UNIVERSITY
CSIRO

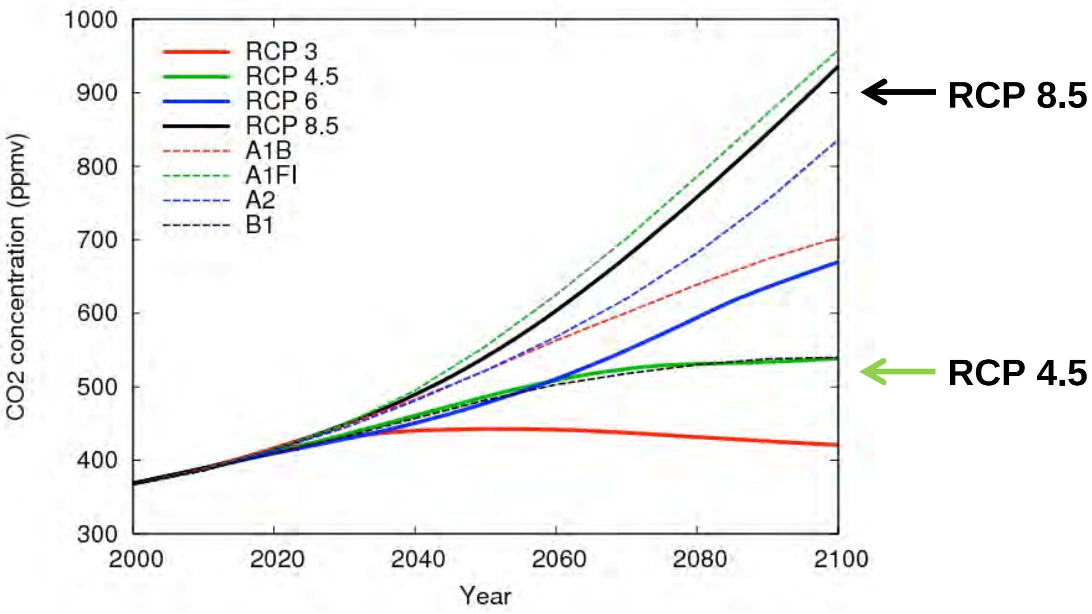
Outline

- Introduction
- Summary of IPCC AR5
- Summary of dynamical downscaling used for case study
- Example of Climate Projections for the Philippines

Climate Prediction Framework



Comparison of CO_2 concentrations from SRES (A1B, A1FI, A2, B1) and RCPs (3.0, 4.5, 6.0, 8.5) approaches

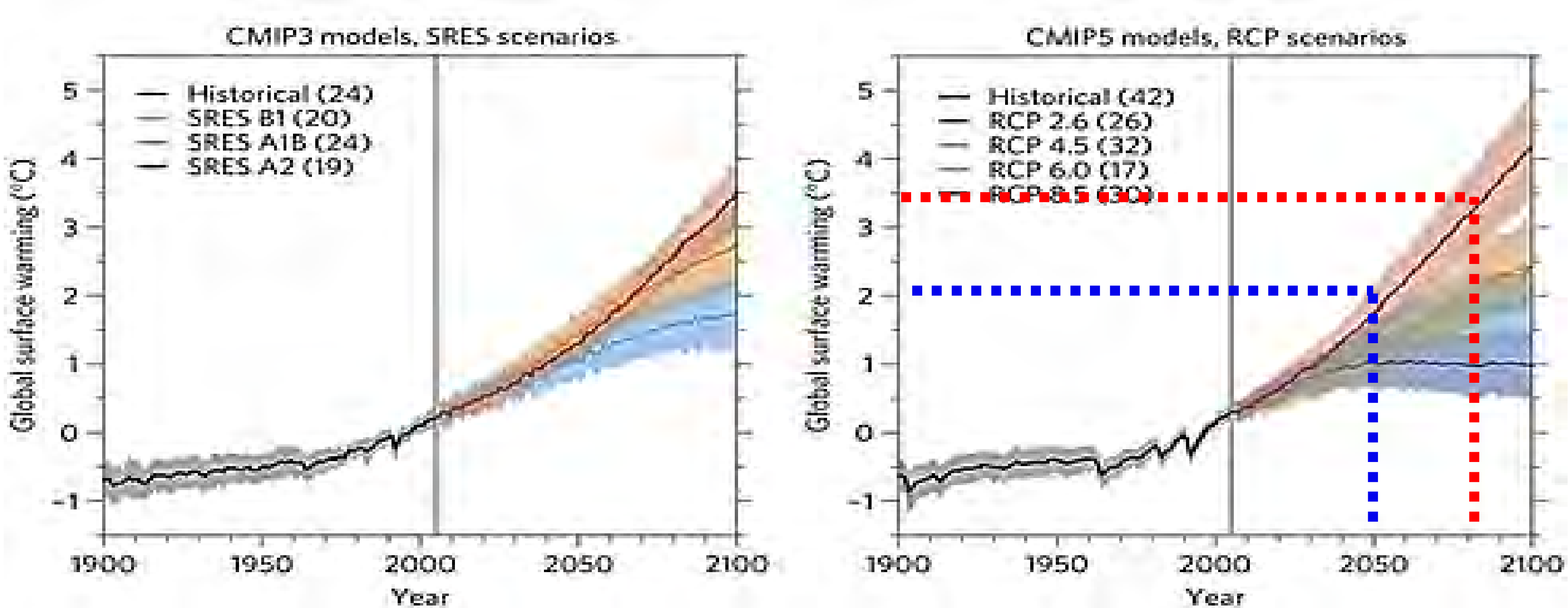


RCP 8.5	Rising radiative forcing pathway leading to 8.5 W/m² in 2100.
RCP 6	Stabilization without overshoot pathway to 6 W/m² at stabilization after 2100
RCP 4.5	Stabilization without overshoot pathway to 4.5 W/m² at stabilization after 2100
RCP 2.6	Peak in radiative forcing at ~ 3 W/m² before 2100 and decline

Representative Concentration Pathway scenarios
RCPS scenarios are new scenarios that specify concentrations and corresponding emissions, but are not directly based on socio-economic storylines like the SRES scenarios.

Source: Meinshausen, M. and Coauthors, 2011

Comparison of CMIP3 and CMIP5



Global climate model experiments indicate a global warming of

0.3-1.7 ℃ (RCP2.6),

1.1-2.6 ℃ (RCP4.5),

1.4-3.1 ℃ (RCP6.0)

and 2.6-4.8 ℃ (RCP8.5)

for 1981-2100 relative to 1986-2005 (IPCC,2013).

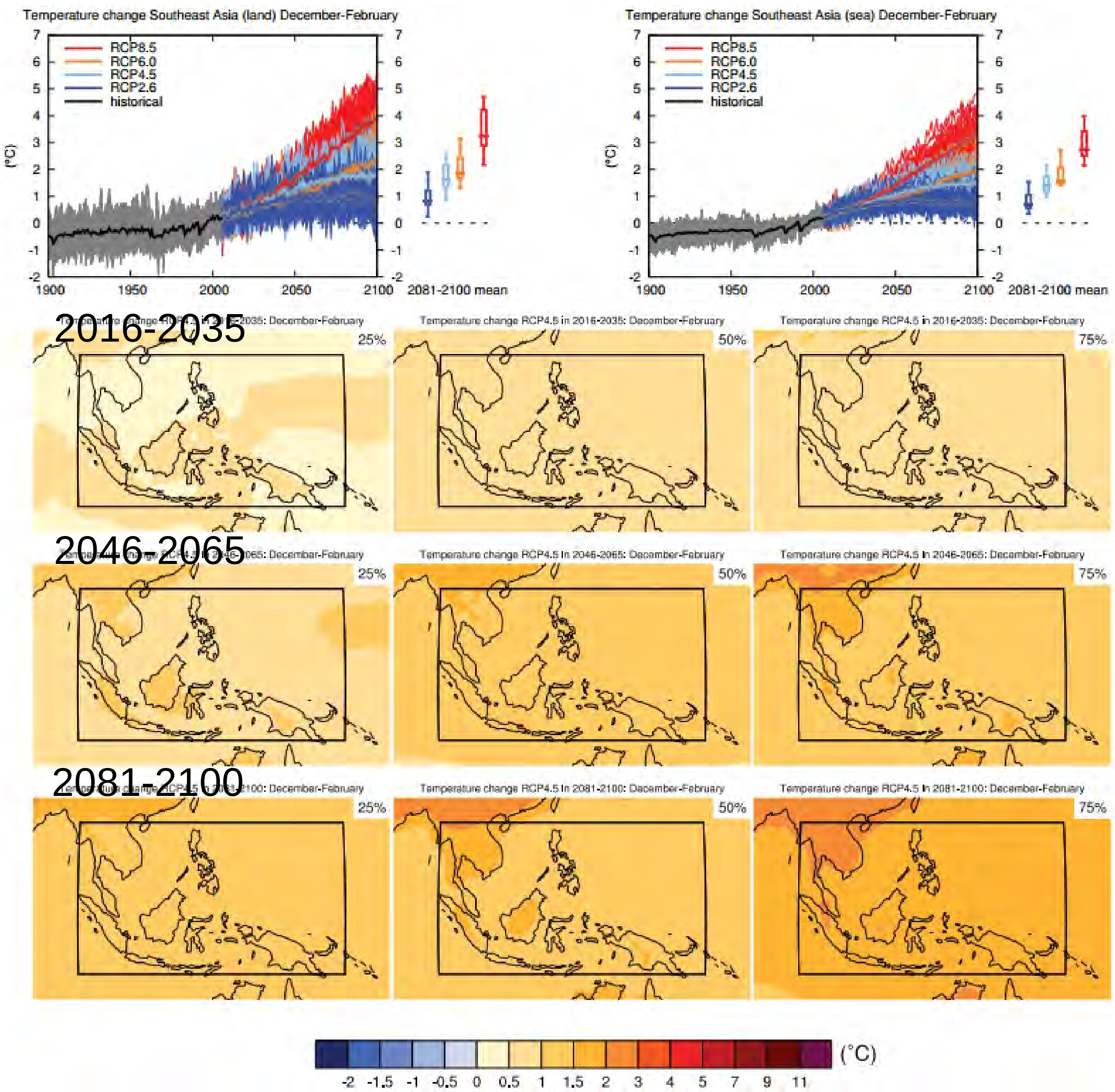
Knutti & Sedlacek, 2013

The goal of working with scenarios is not to predict the future but to better understand uncertainties and alternative futures, in order to consider how robust different decisions or options may be under a wide range of possible futures”.

Source: IPCC Scenario Process for AR5

Dec-Jan-Feb
Mean Temperature

- Note large spread between scenarios
- Note different probabilities of change signals



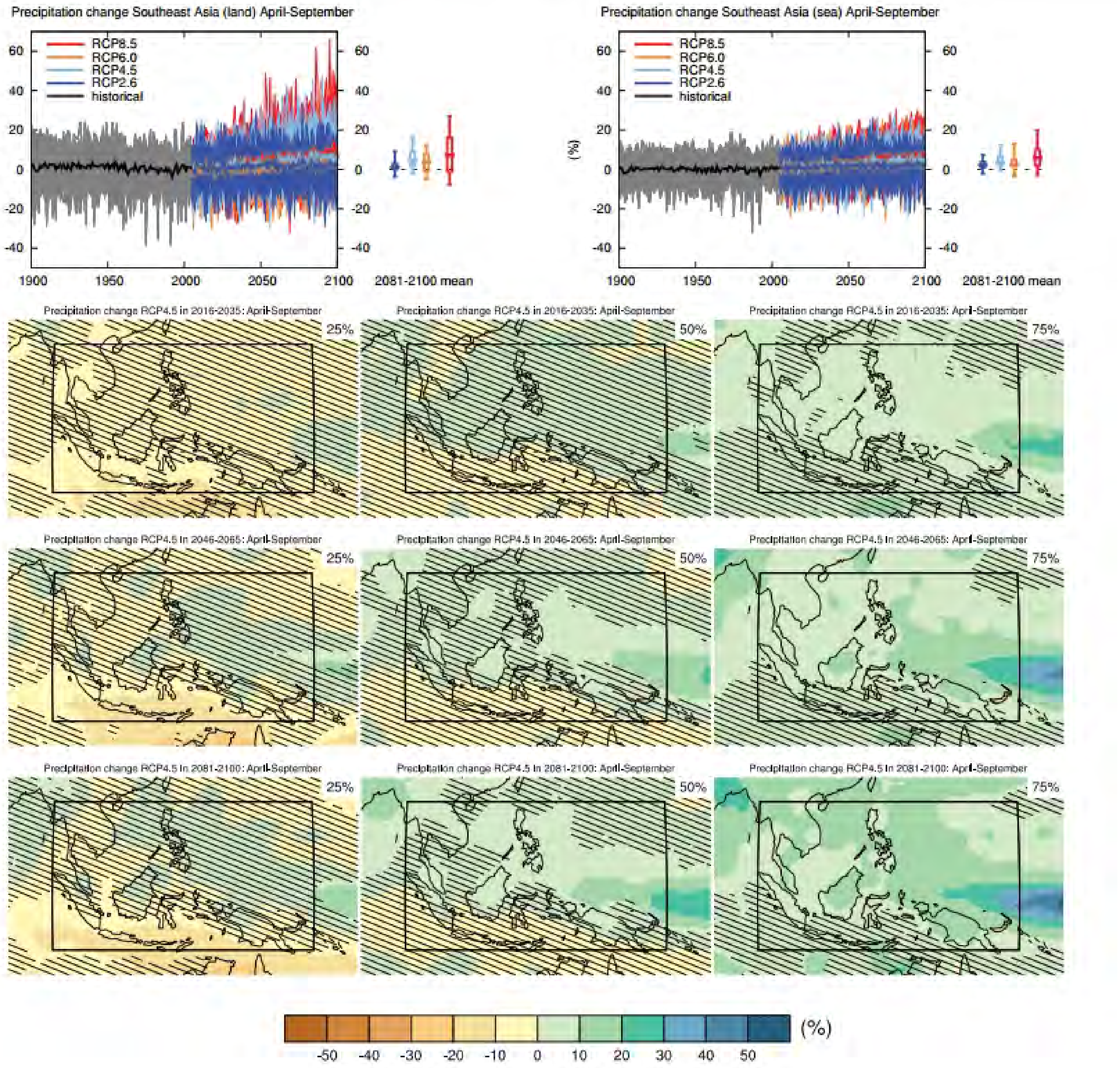
CSIRO

Apr-Sept Projected Rainfall 1986-2005

2016-2035

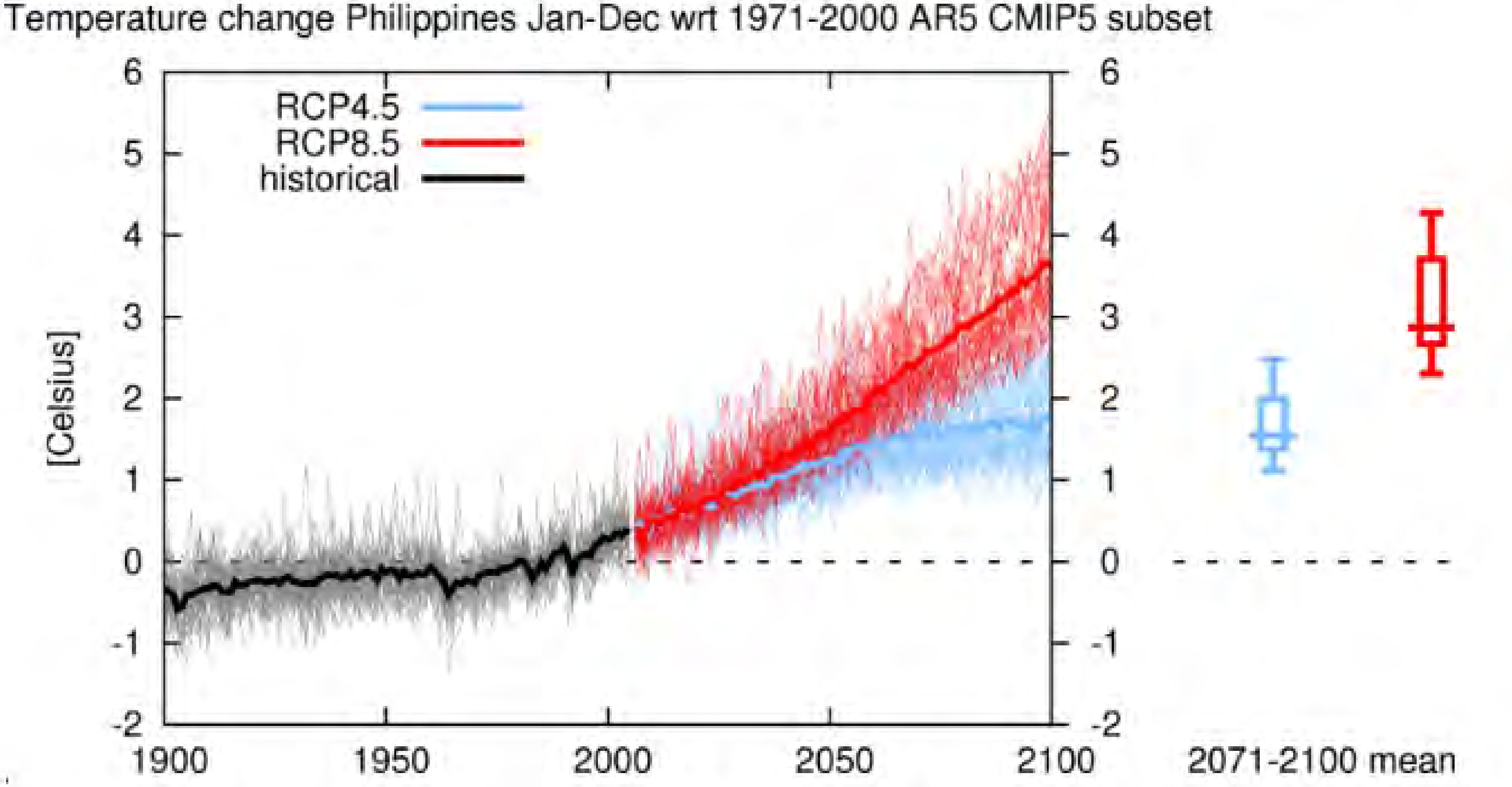
2046-2065

2081-2100



CMIP5 GCM model ensemble for Philippines Tave

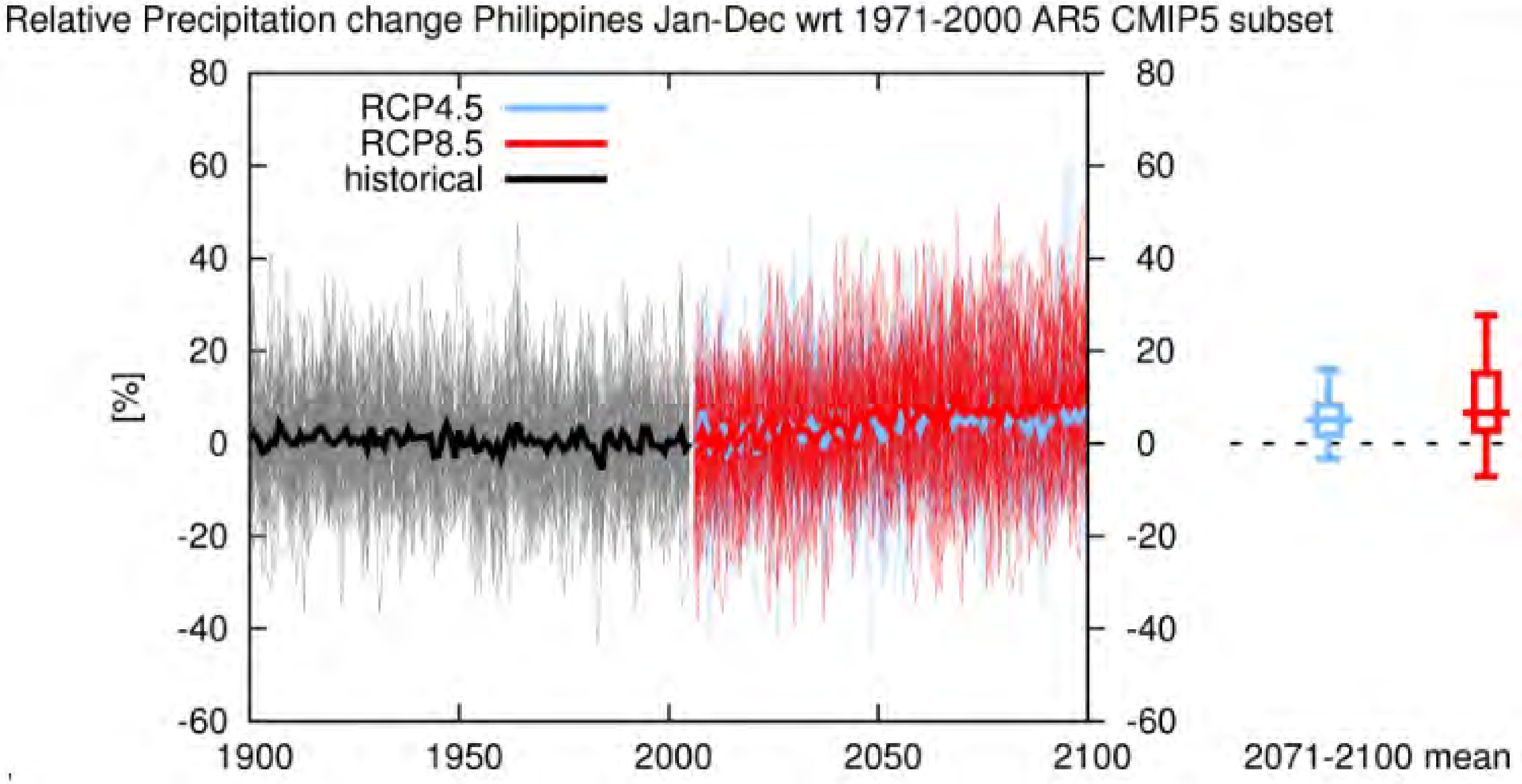
Temperature change Philippines Jan-Dec wrt 1971-2000 AR5 CMIP5 subset. On the left, for each scenario one line per model is shown plus the multi-model mean, on the right percentiles of the whole dataset: the box extends from 25% to 75%, the whiskers from 5% to 95% and the horizontal line denotes the median (50%).(png, eps, pdf, plotscript, all data, means, masks)



https://climexp.knmi.nl/selectfield_cmip5.cgi?id=someone@somewhere

CMIP5 GCM model ensemble for Philippines Rainfall

Relative Precipitation change Philippines Jan-Dec wrt 1971-2000 AR5 CMIP5 subset. On the left, for each scenario one line per model is shown plus the multi-model mean, on the right percentiles of the whole dataset: the box extends from 25% to 75%, the whiskers from 5% to 95% and the horizontal line denotes the median (50%).(png, eps, pdf, plotscript, all data, means, masks)



https://climexp.knmi.nl/selectfield_cmip5.cgi?id=someone@somewhere

Regional extreme changes

Table 2.13 | Regional observed changes in a range of climate indices since the middle of the 20th century. Assessments are based on a range of 'global' studies and assessments (Groisman et al., 2005; Alexander et al., 2006; Caesar et al., 2006; Sheffield and Wood, 2008; Dai, 2011a, 2011b, 2013; Seneviratne et al., 2012; Sheffield et al., 2012; Donat et al., 2013a, 2013c; van der Schrier et al., 2013) and selected regional studies as indicated. Bold text indicates where the assessment is somewhat different to SREX Table 3-2. In each such case a footnote explains why the assessment is different. See also Figures 2.32 and 2.33.

Region	Warm Days (e.g., TX90p[a])	Cold Days (e.g., TX10p[a])	Warm Nights (e.g., TN90p[a], TR[a])	Cold Nights/Frosts (e.g., TN10p[a], FD[a])	Heat Waves / Warm Spells[g]	Extreme Precipitation (e.g., RX1day[a], R95p[a], R99p[a])	Dryness (e.g,. CDD[a]) / Drought[h]
Asia (excluding South-east Asia)	***High confidence*[b,e]: *Likely* overall increase[27,28,29,30,31,32]**	***High confidence*[b,e]: *Likely* overall decrease[27,28,29,30,31,32]**	***High confidence*[b,e]: *Likely* overall increase[27,28,29,30,31,32]**	***High confidence*[b,e]: *Likely* overall increase[27,28,29,30,31,32]**	***Medium confidence*[b,e]: Spatially varying trends and insufficient data in some regions** ***High confidence*[b,c]: *Likely* more areas of increases than decreases[3,28,33]**	***Low to medium confidence*[b,e]:** ***Low confidence* due to insufficient evidence or spatially varying trends.** ***Medium confidence*: increases in more regions than decreases[5,34,35,36]**	***Low to medium confidence*[b,e]** ***Medium confidence*: Increase in eastern Asia[36,37]**
South-east Asia and Oceania	***High confidence*[b,f]: *Likely* overall increase[27,38,39,40]**	***High confidence*[b,f]: *Likely* overall decrease[27,38,39]**	***High confidence*[b,f]: *Likely* overall increase[27,38,39,40]**	***High confidence*[b,f]: *Likely* overall decrease[27,38,39]**	***Low confidence* (due lack of literature) to *high confidence*[b,f] depending on region** ***High confidence*[2]: *Likely* overall increase in Australia[3,14,41]**	***Low confidence* (lack of literature) to *high confidence*[b,f]** *High confidence*: *Likely* decrease in southern Australia[42,43] but index and season dependent	***Low to medium confidence*[b,f]: inconsistent trends between studies in SE Asia. Overall increase in dryness in southern and eastern Australia** ***High confidence*[b]: *Likely* decrease northwest Australia[25,26,44]**

Summary

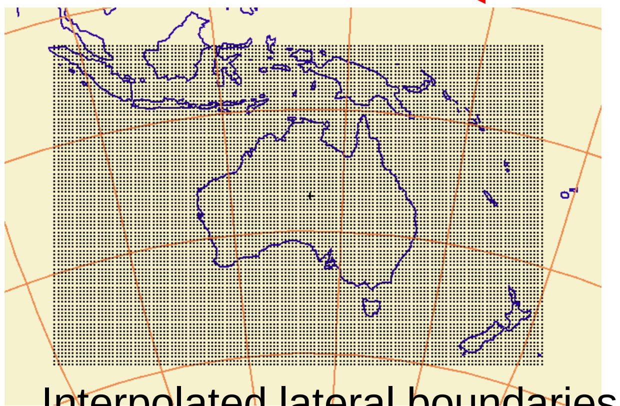
- Some improvement in representation of current climate
- Greater confidence on human impact on observed trends
- New Representational Concentration Pathways
- Some GCMs are more complex (‘earth system models’)

Regional Climate Modelling Approaches

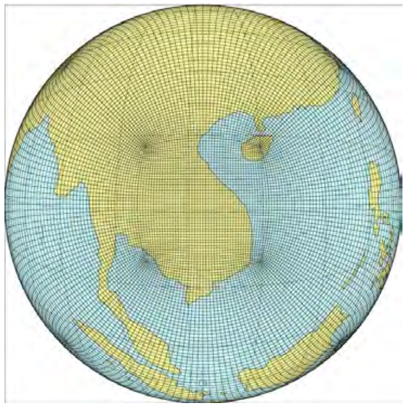
High — Lateral boundary influence → None

Limited area | Variable resolution | Global high-resolution

Low ← Computational expense — High



Interpolated lateral boundaries, one-way information



Scale-selective information passed, some 2-way interaction

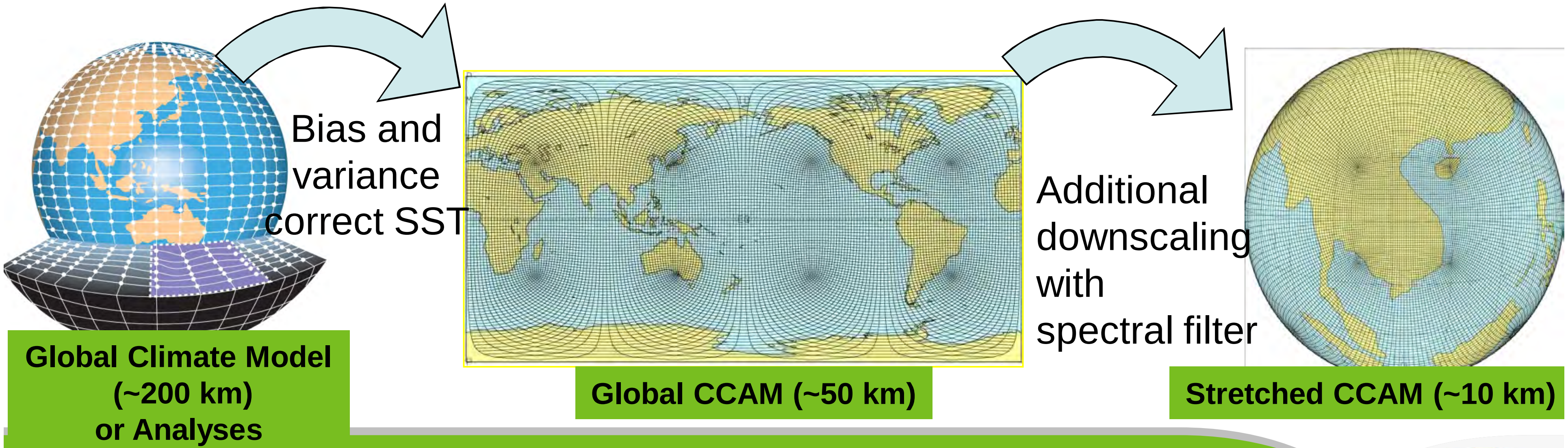
- Also need to consider:
  - Domain size/location
  - Resolution
  - Internal variability

Conformal Cubic Atmospheric Model

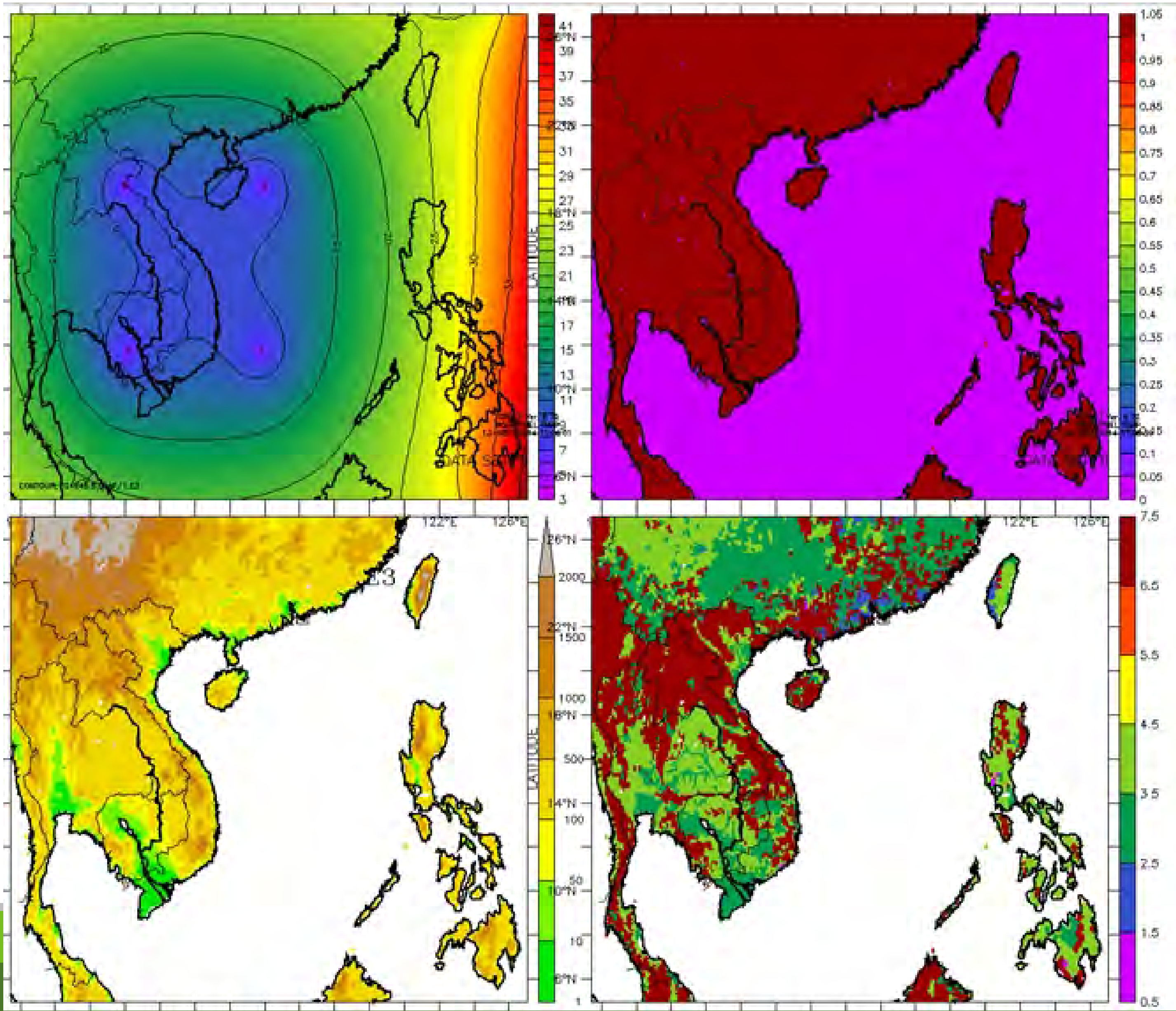
- Developed at CSIRO for over 20 years
- First 3D cubic atmospheric model in the world
- CCAM is highly computationally efficient for comparable accuracy. CCAM can run on 25,000+ core supercomputers, or as a ‘distributed’ system on laptops.

New features

- Urban model
- Parallel IO and improved scaling
- New model: flux form on gnomic grid



Terrain/land sea mask



GCM Selection

Requirements

- Good performance in present climate
  - Simulation of rainfall, air temperature etc.
  - Reproduce observed trends
- Good SSTs
  - ENSO pattern/frequency
  - SST distribution
- Good spread of climate change signals

- 24 CMIP5 models
- > 20 evaluation studies
- 6 publications with rankings + evaluation

  used within the project
- Peer-reviewed or submitted

GCM Selection

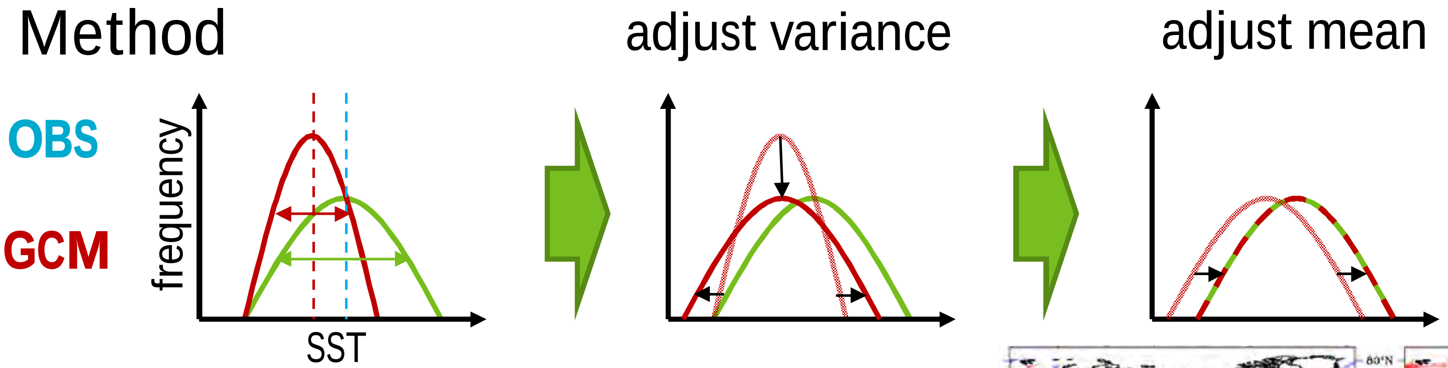
Final ranking

The rankings of the 6 individual studies are averaged to yield a final ranking of the models.

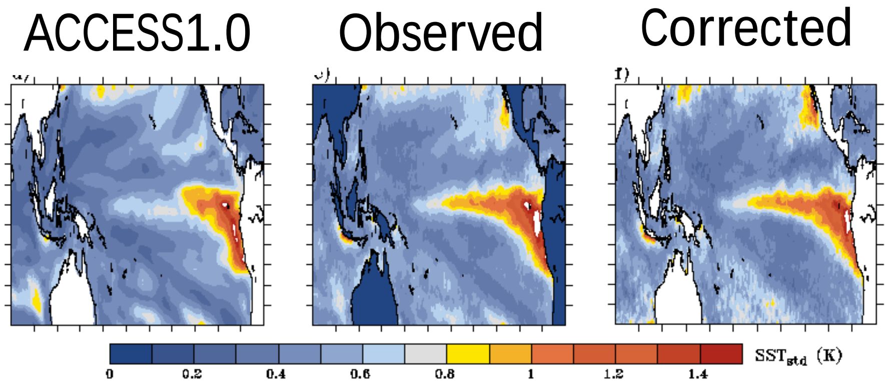
Rank	GCM	Average Score
1	**CNRM-CM5**	**0.31**
2	**CCSM4**	**0.34**
3	ACCESS1.3	0.35
4	**NorESM1-M**	**0.35**
5	**ACCESS1.0**	**0.39**
6	**MPI-ESM-LR**	**0.41**
7	**GFDL-CM3**	**0.42**
8	HadGEM2-CC	0.44
9	MIROC4h	0.46
10	MIROC5	0.47
11	GFDL-ESM2M	0.48
12	MRI-CGCM3	0.51
13	HadCM3	0.53
14	IPSL-CM5A-MR	0.53
15	HadGEM2-ES	0.54
16	FGOALS-g2	0.57
17	CSIRO-Mk3.6.0	0.57
18	inmcm4	0.61
19	CanESM2	0.61
20	MIROC-ESM-CHEM	0.69
21	GISS-ES-H	0.70
22	IPSL-CM5A-LR	0.71
23	FGOALS-s2	0.80
24	MIROC-ESM	0.84

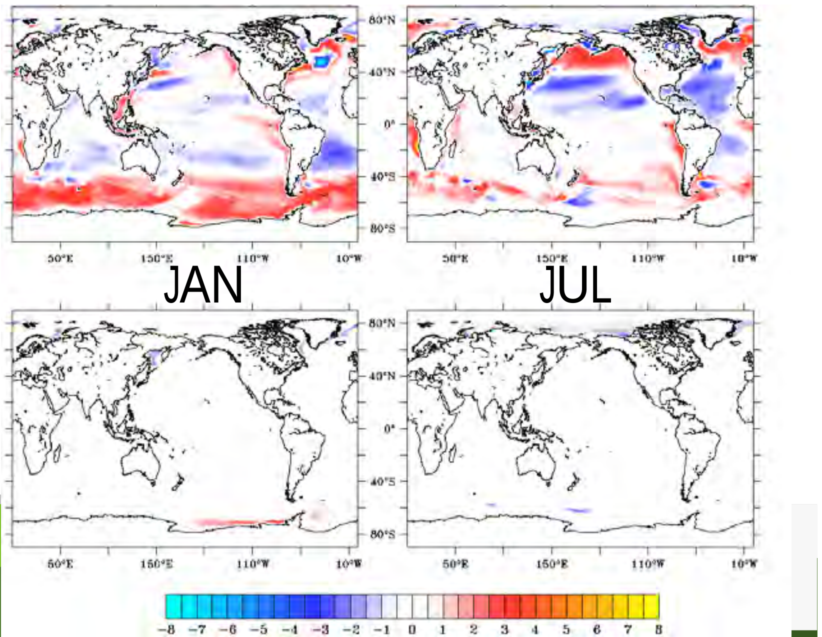
SST Correction Method

- Observations
  - daily optimum interpolation SST & SIC (Reynolds et al., 2007)
  - 1/4° resolution for 1982-2011
- Method



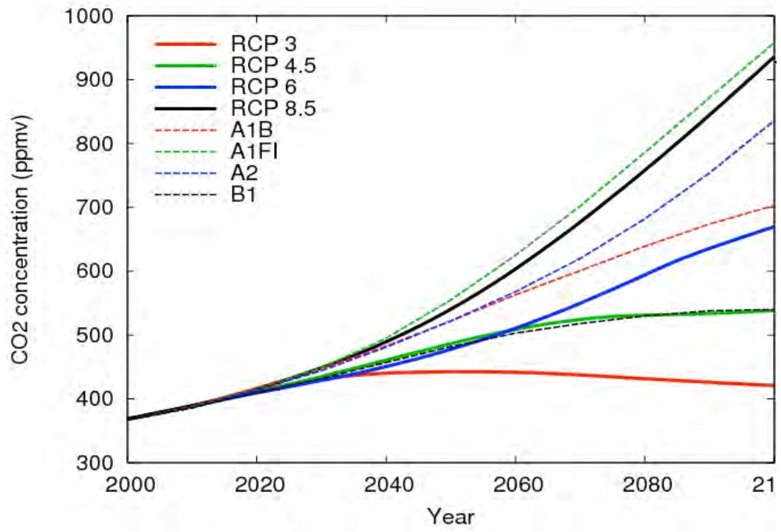
SST variance ACCESS1.0 (January)

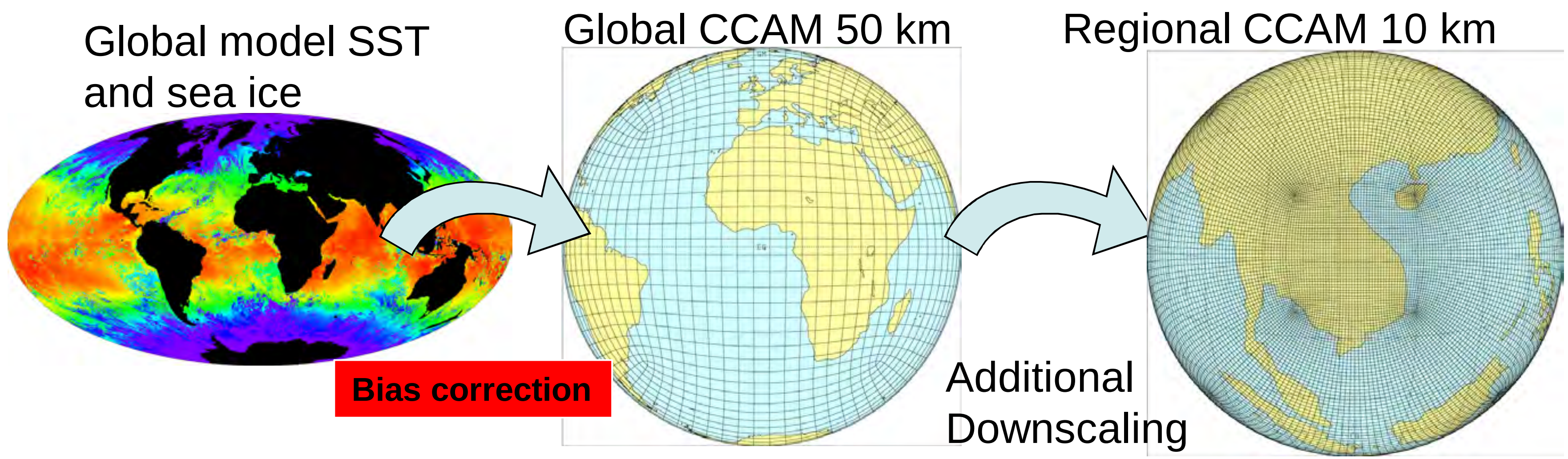




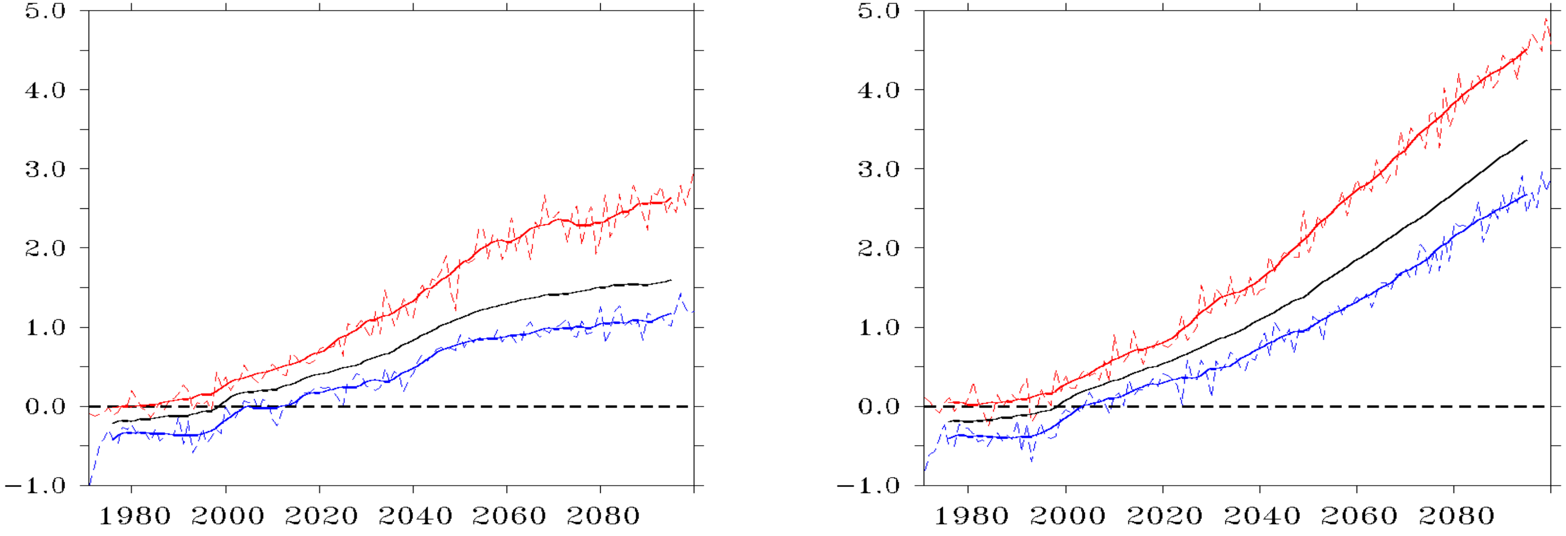
Dynamical Downscaling

- Start with Global Climate Models
- Select 6 global models and 2 scenarios
  - lower: RCP4.5 and higher: RCP8.5
- Simulations from 1970-2099
- Drive regional models with bias-corrected sea surface temperatures (SST) and sea ice





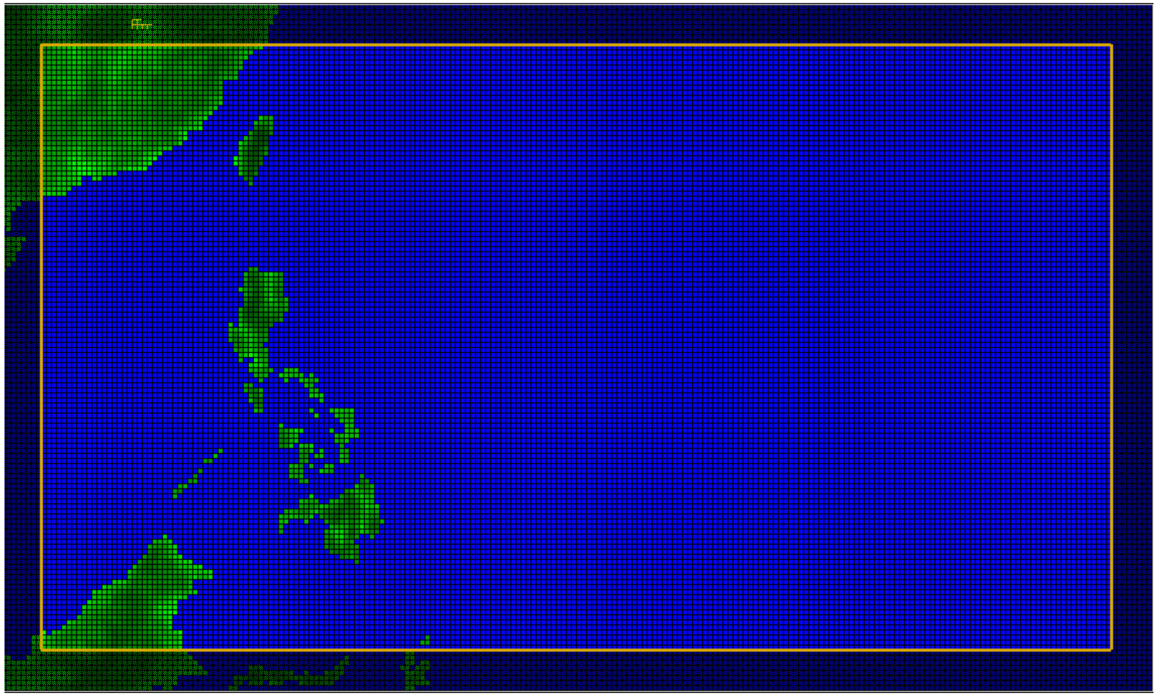
ANNUAL AVERAGE TEMPERATURE (°C)



Time series plots of change in the annual average air temperatures (°C) for the Philippines for the lower emission scenario, RCP4.5 (left column) and the higher emission scenario, RCP8.5 (right column). Black line is mean, red line is 90th percentile, and blue line is 10th percentile, based on the six downscaled projections completed in this study for both RCPs. Solid lines show the 10-year running mean while dashed lines show annual values. Dashed black line is zero change.

SUMMARY OF CHANGES		
	Mid-21st century	End of the 21st century
RCP4.5	+0.8 to +2.0°C	+1.1 to +2.6°C
RCP8.5	+1.0 to +2.5°C	+2.7 to +4.5°C

New experiments using different RCMs



Domain: 110°-160° East 0°-22° North

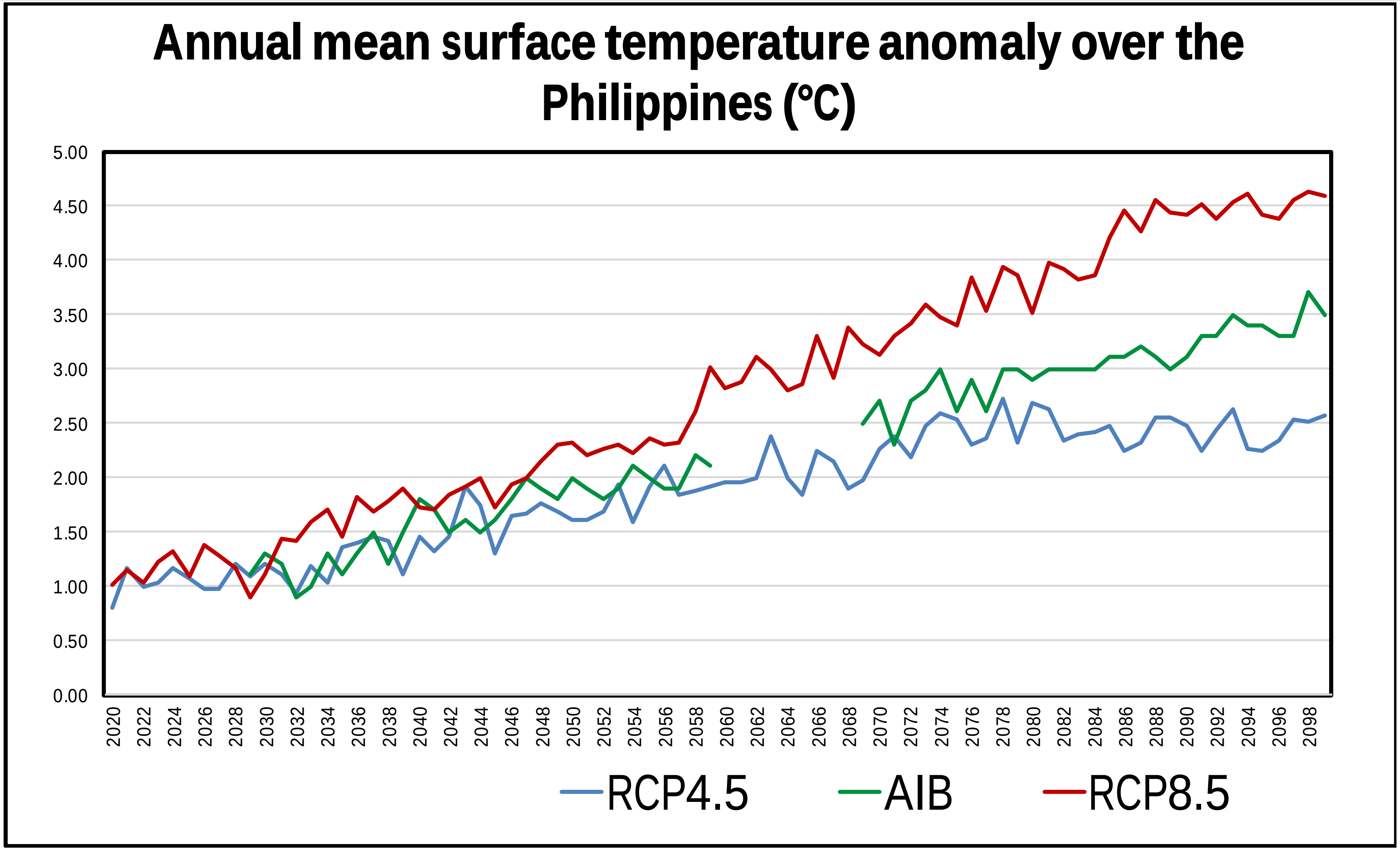
Resolution: 25km and 12Km

Baseline: 1971-2000

Time slice: 2036-2065(Mid Century)
2070-2099(Late Century)

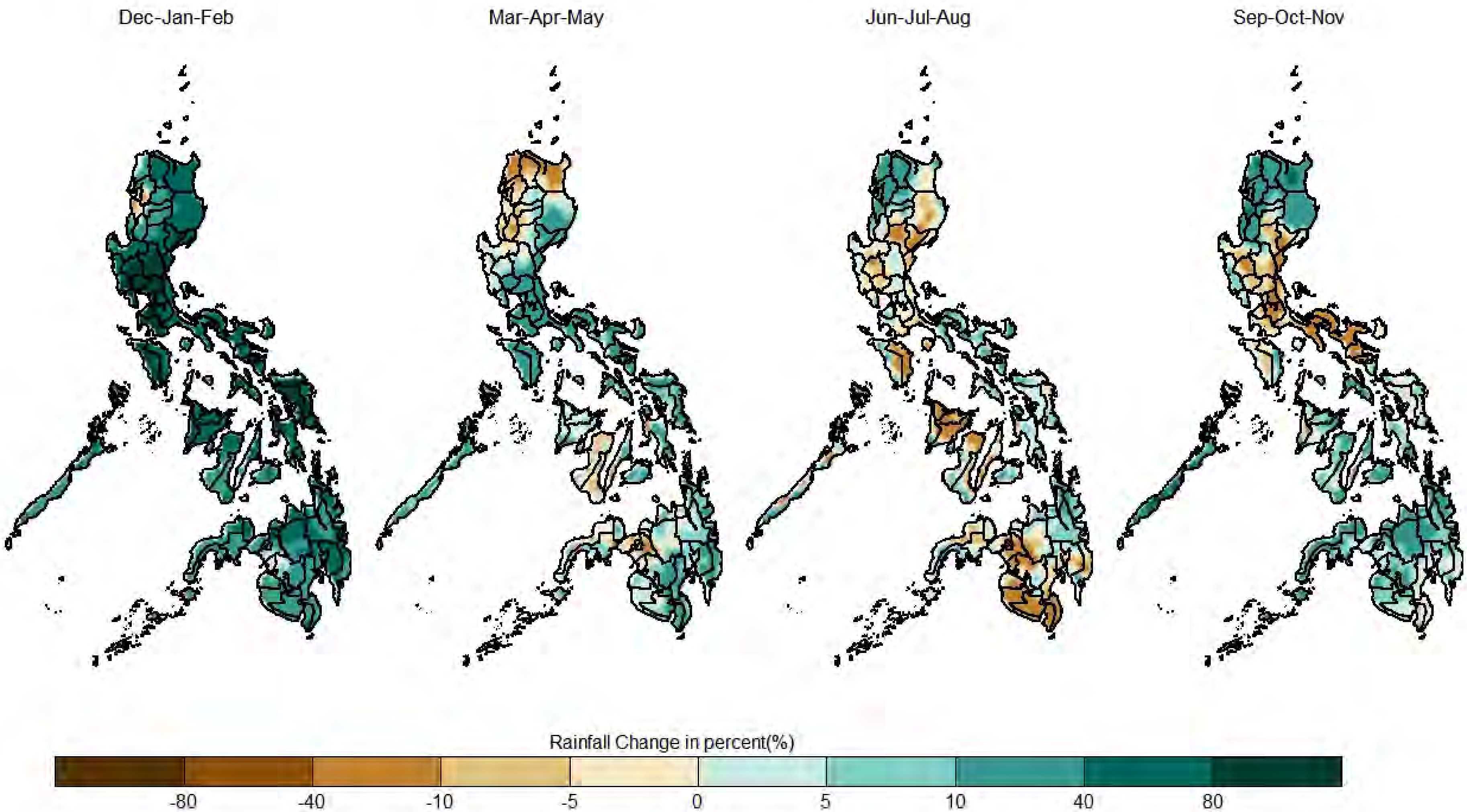
CSIRO

Comparisons between the CMIP3 A1B and CMIP5 RCP45 & RCP85



Mid 21st century (2030-2059)	**1.5**	**1.6**	**2.3**
Late 21st century (2070-2099)	**2.4**	**3.0**	**4.0**

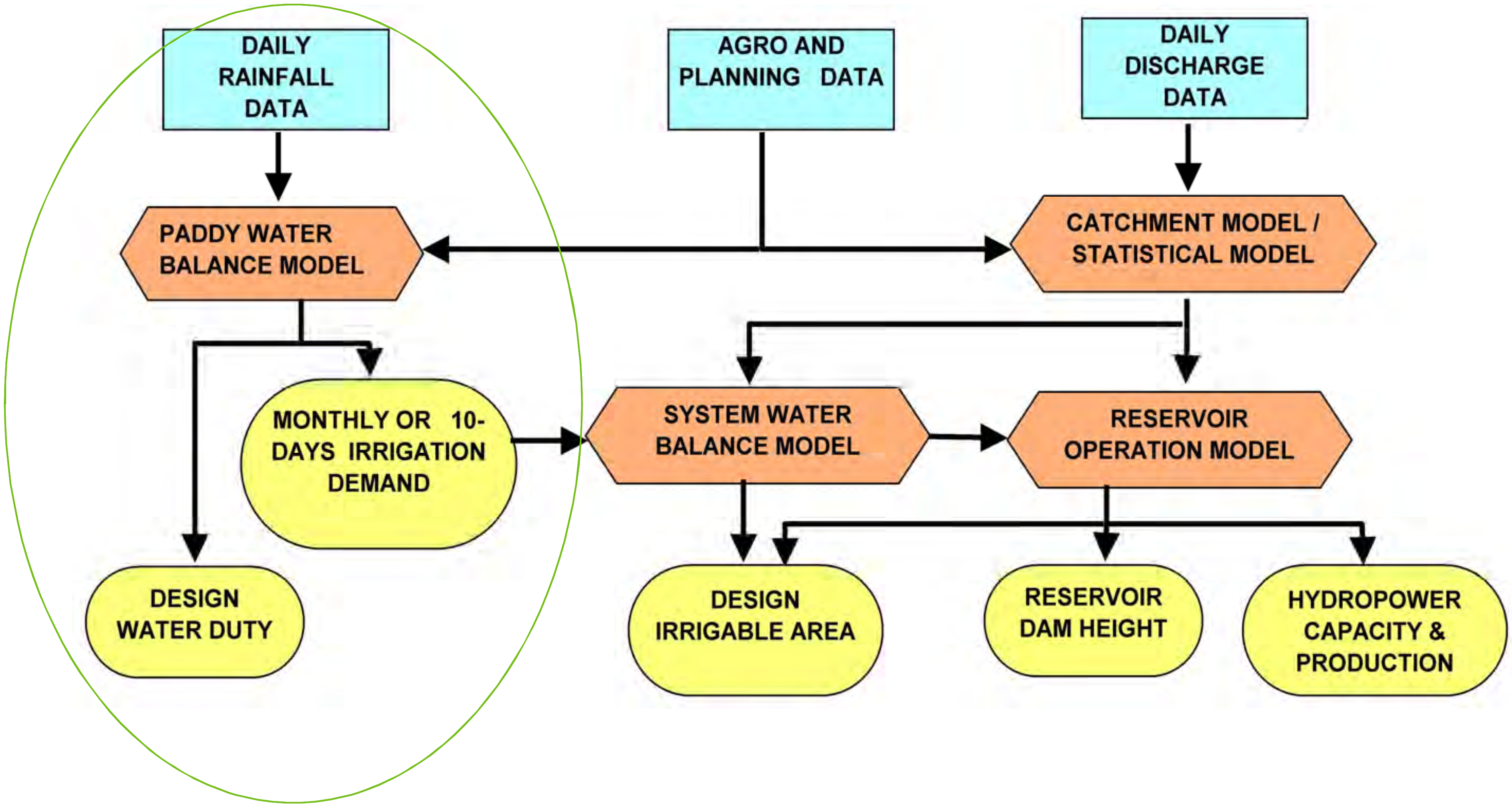
Projected Changes in Seasonal Rainfall in the Mid 21st Century(2036-2065) w.r.t. 1971-2000
Under RCP4.5 Scenario (RCM: PRECIS)
PHILIPPINES



New Climate Change information for the Philippines

SCENARIO	Regional Models(RCMs)	Number of Model	Resolution	Time slice	
AIB (Medium)	PRECIS From MDGF and results from SEACAM	6 Models 1. HadCM3Q0 2. HadCM3Q3 3. HadCM3Q10 4. HadCM3Q11 5. HadCM3Q13 6. ECHAM5	25KM	2031-2059 (2050)	2070- 2099 (2100)
RCP 4.5 Low	PRECIS	1. Hadgem2-ES	25KM	2036-2065 (2050)	2070- 2099 (2100)
	CCAM from the Vietnm study	6 Models 1. CNRM-CM5 2. NorESM1-M 3. ACCESS1.0 4. MPI-ESM-LR 5. NorESM1-M 6. GFDL-CM3	25KM	2036-2065 (2050)	2070- 2099 (2100)
RCP 8.5 High	PRECIS	1 . Hadgem2-ES	25 km	2036-2065 (2050)]	2070- 2099 (2100)
	RegCM4	1. Hadgem2-ES	25km	2036-2065 (2050)	2070- 2099 (2100)
	HadGEM3-RA	3-Models 1. Hadgem2-ES 2. MRI-CGCM3 3. CNRM-CM5	12KM	2036-2065 (2050)	
	CCAM	6 Models 1. CNRM-CM5 2. NorESM1-M 3. ACCESS1.0 4. MPI-ESM-LR 5. NorESM1-M 6. GFDL-CM3	25KM	2036-2065 (2050)	2036-2065 (2050)

The Philippine Case Study



Data preparation for the case study

Design of Irrigational Canal for Cabanatuan

Irrigation Water Requirement (Water Duty)

Design level of risk : 1 in 5 year drought

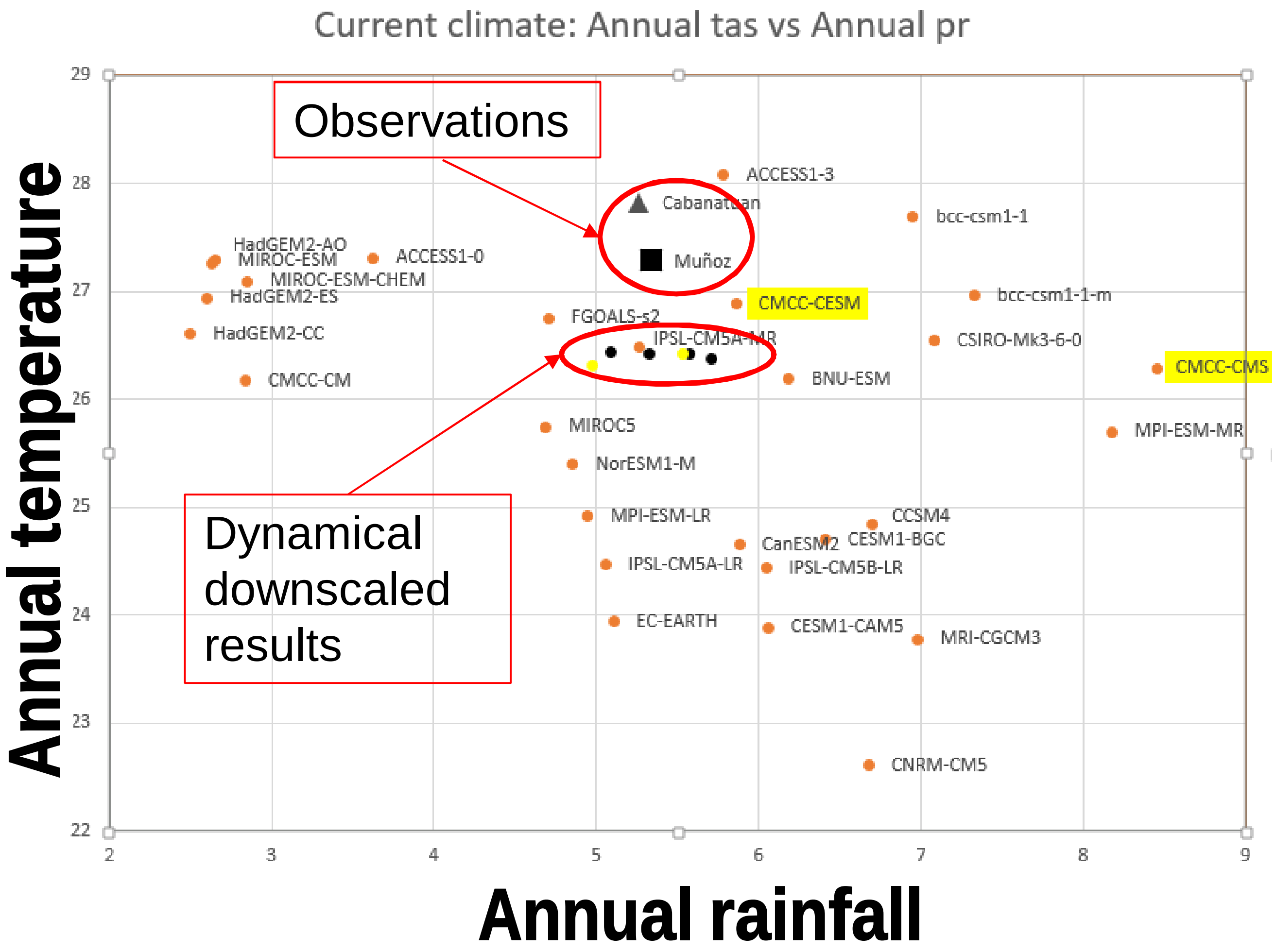
Assumption farm level computation and uses point rainfall.

The main variable needed in this case study are the rainfall The cropping calendar uses 10 day rainfall amounts.

Observed and Climate Change Data needed

- Daily Rainfall Data
  - Observations – 1971 to 2000
  - Baseline Data – 1971 to 2000
  - Long-Term Projected Data – 2036 to 2065

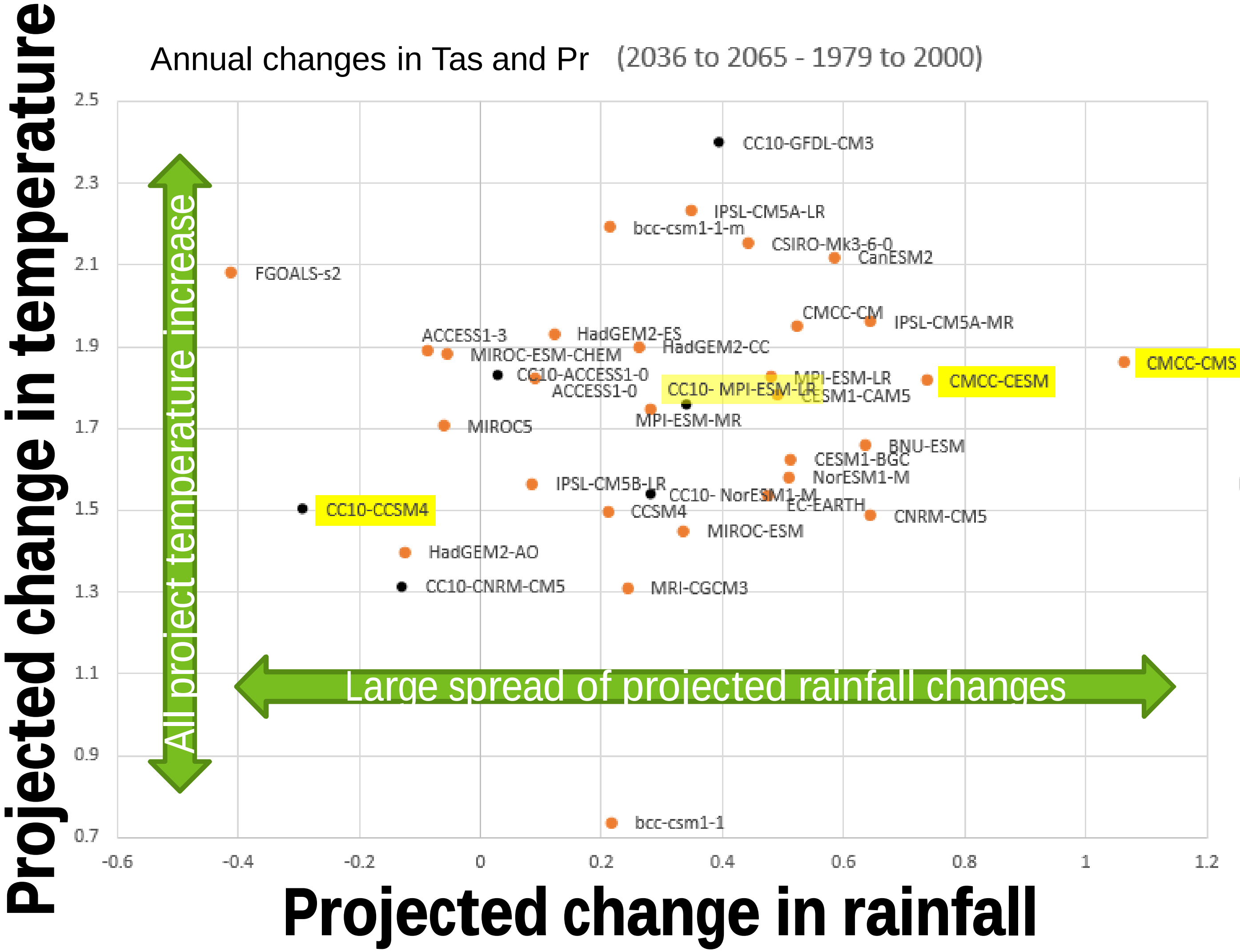
Case Study Example



Plot of mean annual temperature (°C) and rainfall (mm/day) for the baseline period for global climate models (orange markers), regional climate model output (black and yellow dots) and observational data (black square and triangle). The models selected for the case study are indicated in yellow highlight for GCMs and yellow dot for RCMs.
Location: Cabanatuan City

CSIRO

Case Study Example



Plot of changes in annual rainfall (mm/day) and annual surface air temperature (°C) for the period 2036-2065 minus the period 1971-2000 for global climate models (orange markers), regional climate model output (black dots). The models selected for the case study are indicated in yellow highlight. Location: Cabanatuan City

Conclusions

- Detailed risk assessments need projections from individual climate models to ensure **internal consistency** across multiple climate variables
- Using all climate models is very resource intensive
- Need to consider **range of scenarios**
- **No "one size fits all",** so climate projections need to be purpose-built
- For region-specific projections, select of a small number of can be models for use in risk assessment: **median case, 'worst' case and 'best' case** (not just downscaled results)

Thank you

- CC10-CCSMA (RCM)– Driest – Worst case
- CC10-MPI –ESM-LR (RCM)– Median (Likely)
- CMCC-CESM(GCM) - Wettest

Types of projection data

Application-ready data

- Some impact assessments require future weather and climate data that have a format similar to historical data, including natural variability.

- Sensitivity analysis
- Delta change or perturbation method
- Climate analogues
- Weather generation
- Statistical downscaling
- Dynamical downscaling