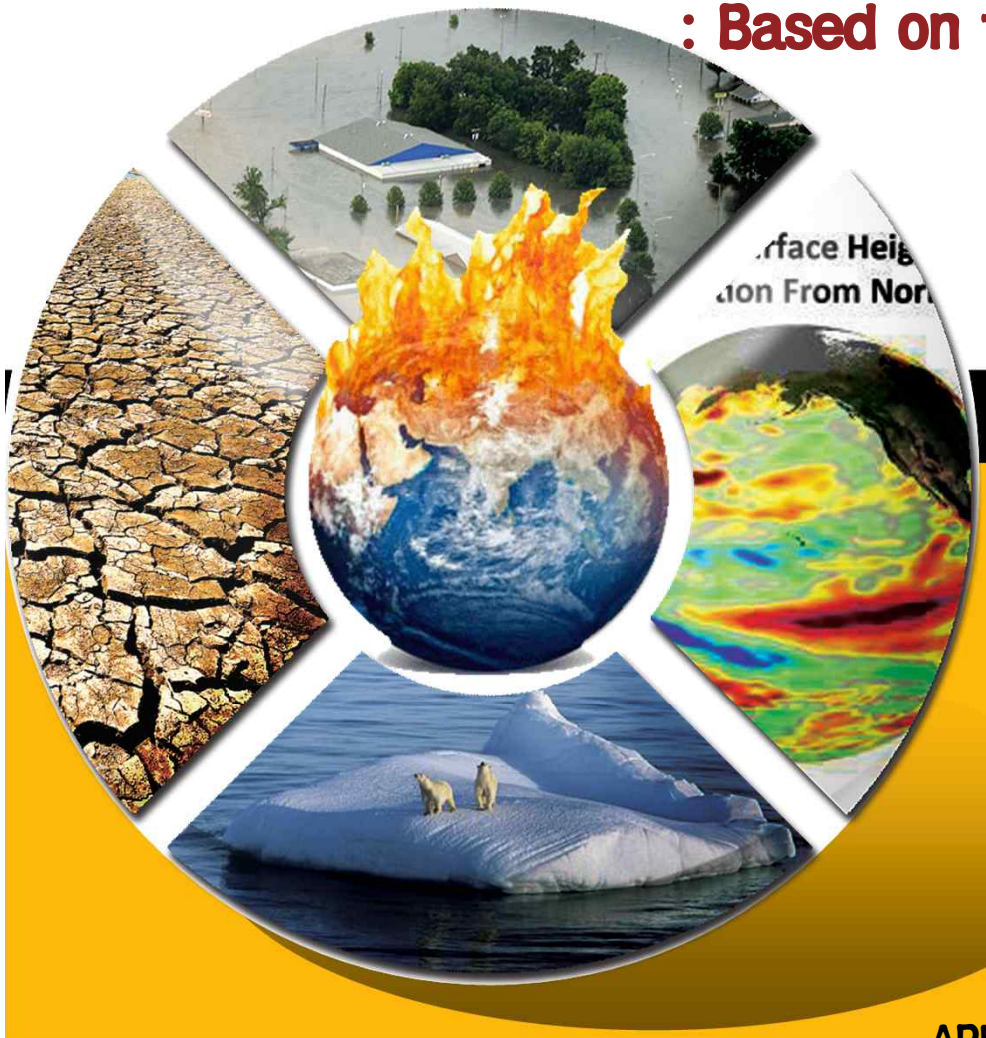
SMART
Singapore-MIT Alliance for Research and Technology

Assessment of Future Drought over Korea

: Based on the ECHAM5-RegCM3 model chain

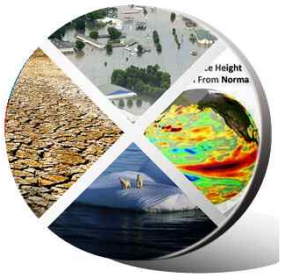


E.-S. Im[1] & J.-B. Ahn[2]

[1]Singapore-MIT Alliance for Res.&Tech.
[2]Pusan National University

eunsoon@smart.mit.edu

APEC Climate Symposium 2013 / 11-13 Nov. Jakarta



Overview of IPCC AR5

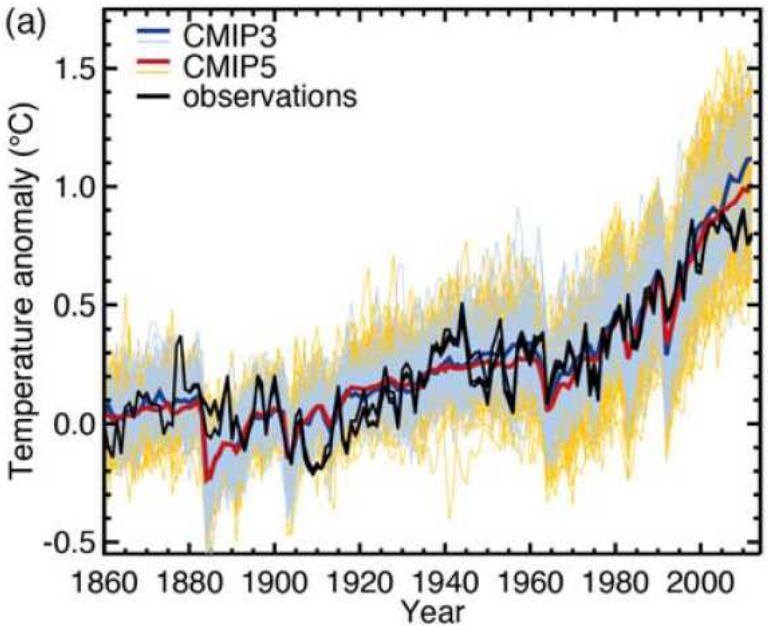
: Focusing on the comparison between CMIP3 & CMIP5

Anthropogenic Warming

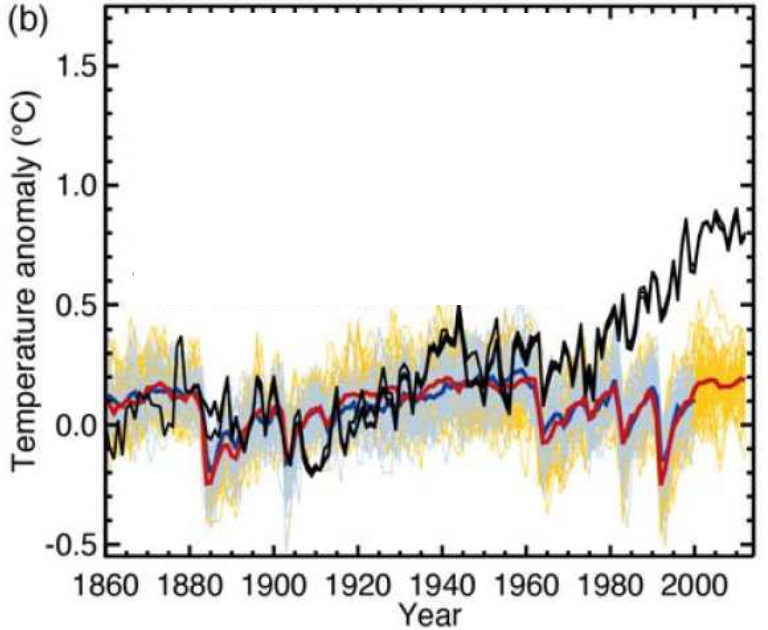
Surface Temperature Change

- It is "extremely likely" that human influence has been the dominant cause of observed warming since the mid 20th century.
- The global mean surface temperature response simulated by CMIP3 and CMIP5 models is very similar, both in mean and variability.
- The range of temperature change across all scenarios is wider in CMIP5 than in CMIP3, in response to emission scenarios.

Anthropogenic + Natural Forcings



Natural Forcings

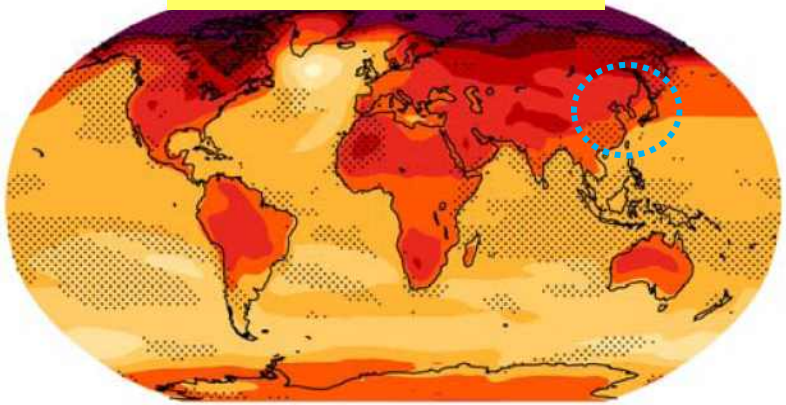


Adapted from Technical Summary of AR5 (Final Draft)

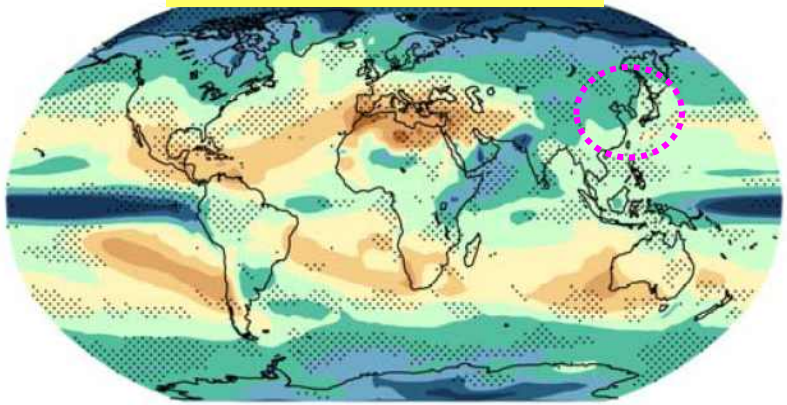
Spatial Distribution of T & P

CMIP3 vs. CMIP5 Projection (2080-2099)

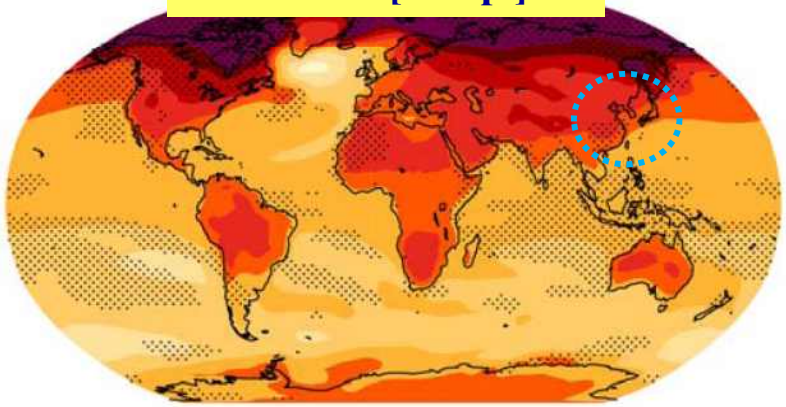
CMIP3 [Temp.]



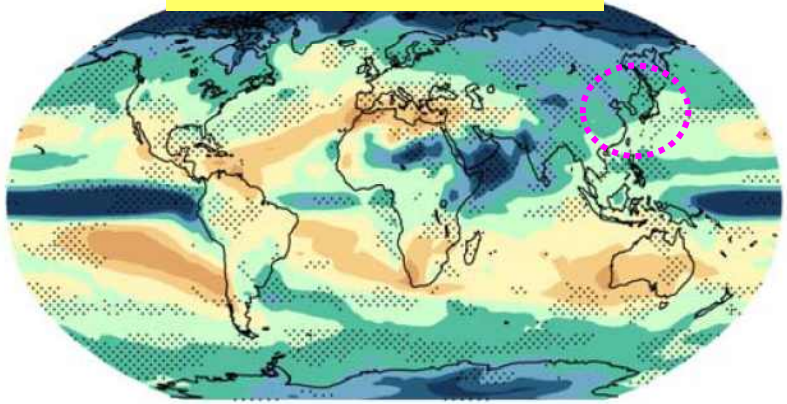
CMIP3 [Precipi.]



CMIP5 [Temp.]

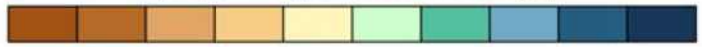


CMIP5 [Precipi.]



(°C per °C global mean change)

(% per °C global mean change)

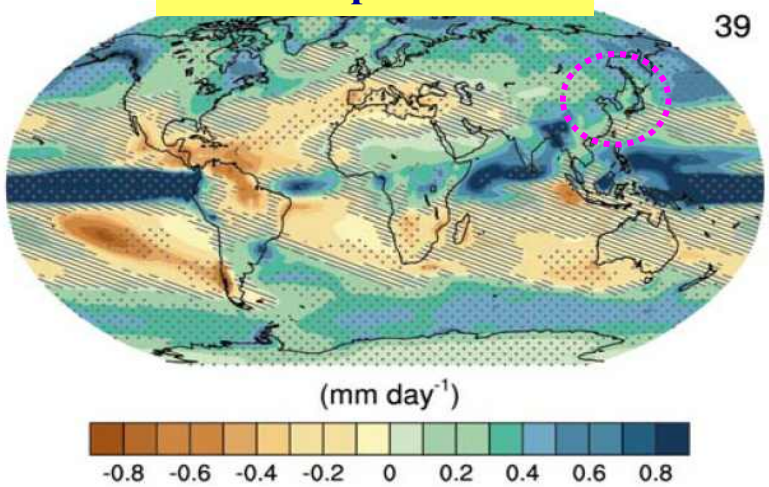


Adapted from Technical Summary of AR5 (Final Draft)

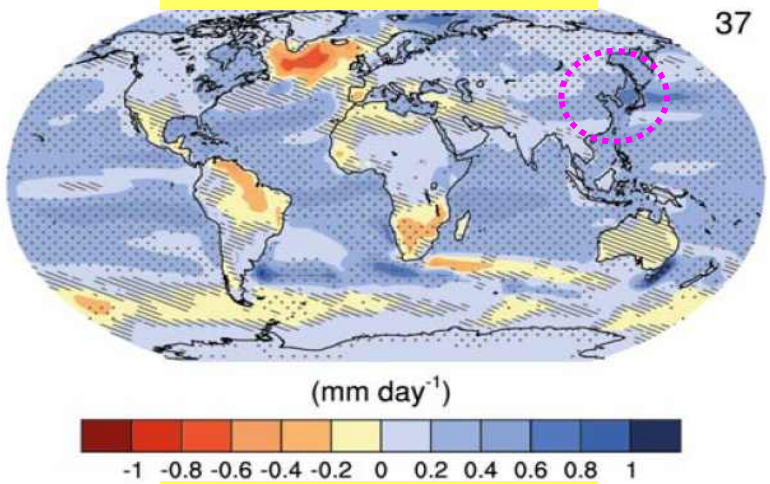
Hydrological Cycle Change

CMIP5 RCP8.5 Projection (ANN, 2081-2100)

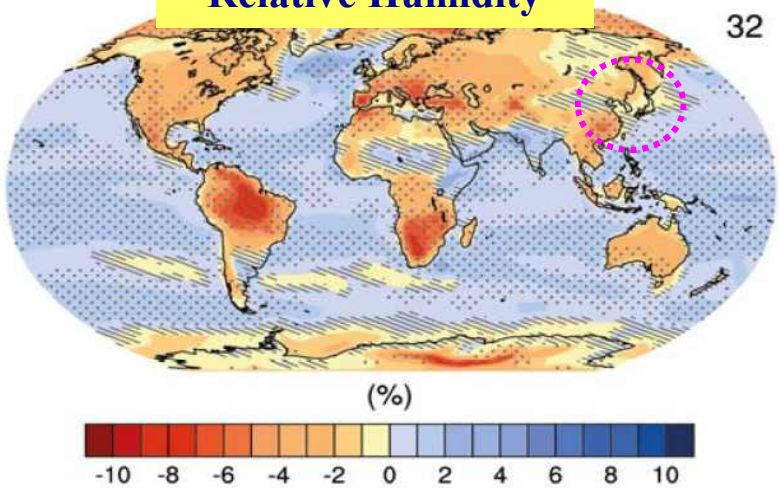
Precipitation



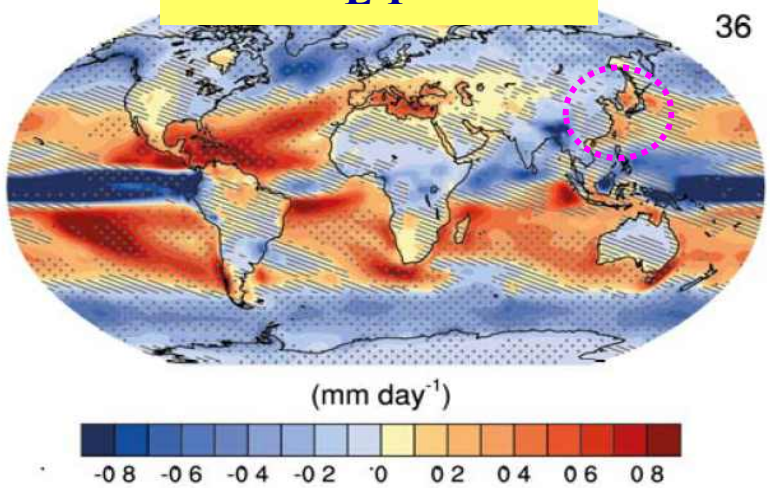
Evaporation



Relative Humidity



E-P



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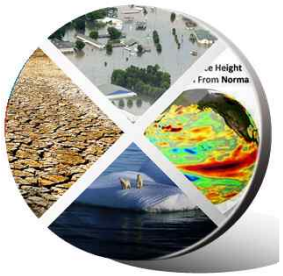


Climate Change Simulation over Korea based on the ECHAM5-RegCM3 Model Chain

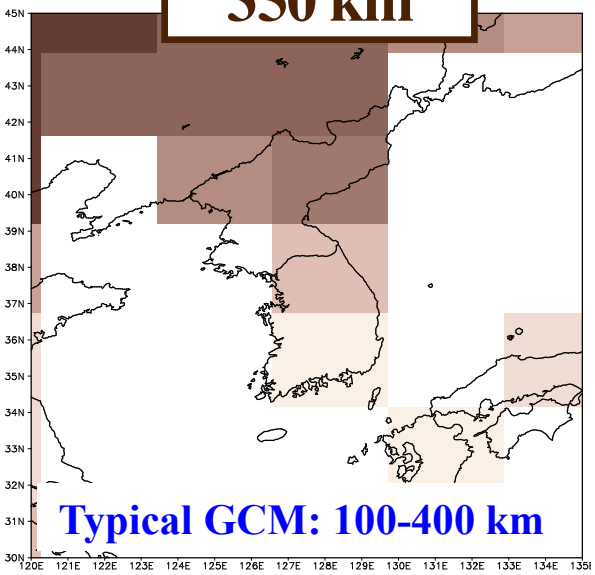
Necessity of Downscaling

Global Climate Model: 100-400 km

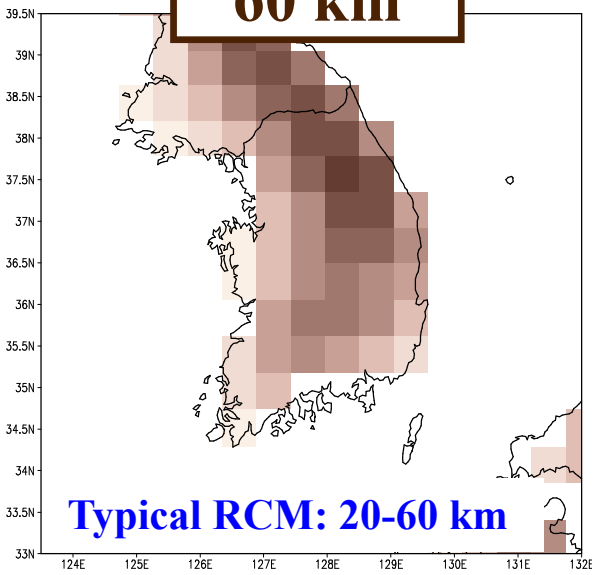
Dynamical Downscaling

Regional Climate Model: 20-60km

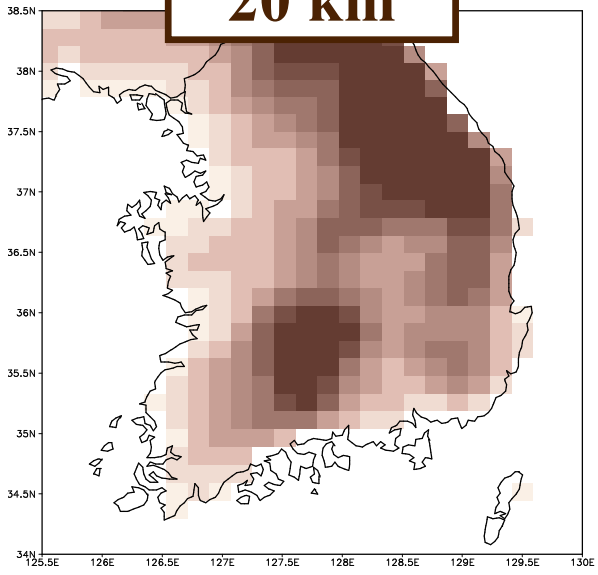
350 km



60 km



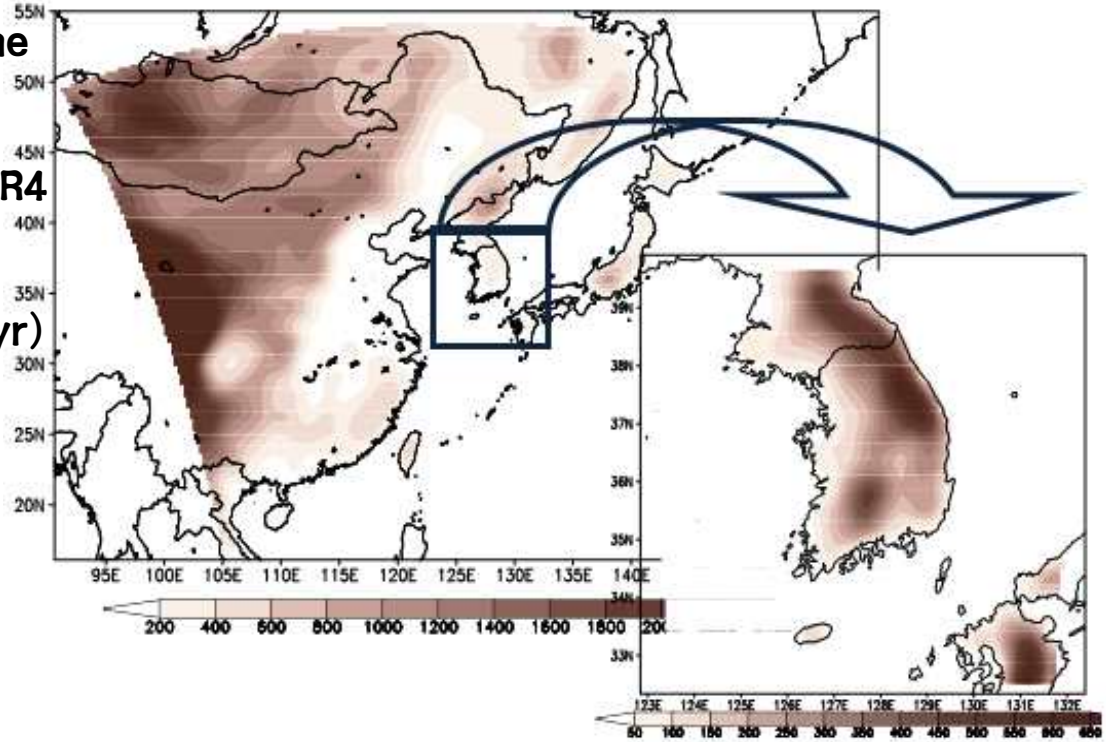
20 km



RegCM3 One-Way Double-Nested System

Model Configuration

- ICTP Regional Climate Model Ver. 3
- Resolution: Mother domain – 60km / Nested domain – 20km
- Physical parameterization
  - MIT Emanuel Convection Scheme
  - BATS Land Surface Scheme
- Initial & Boundary :
  - ECHAM5 A1B(1.875)-IPCC AR4
- Integration Period :
  - [Reference] 1971-2000 (30yr)
  - [Future] 2000-2100 (100yr)

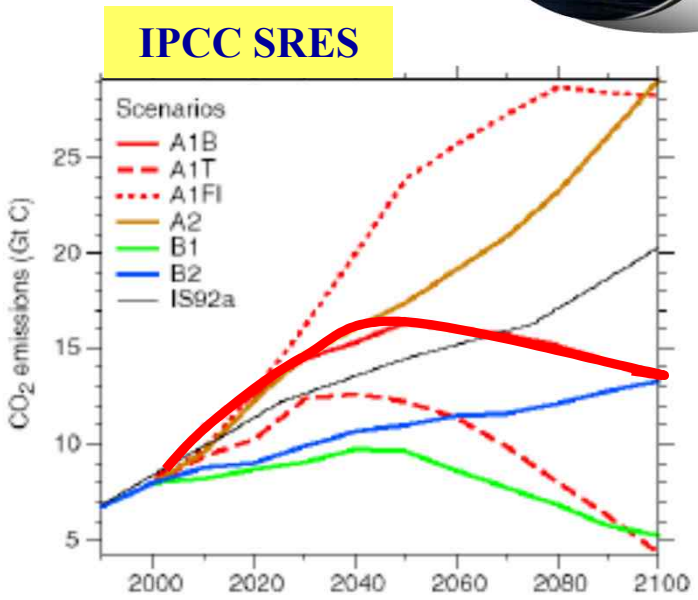


Experimental Design

Initial & Boundary Condition

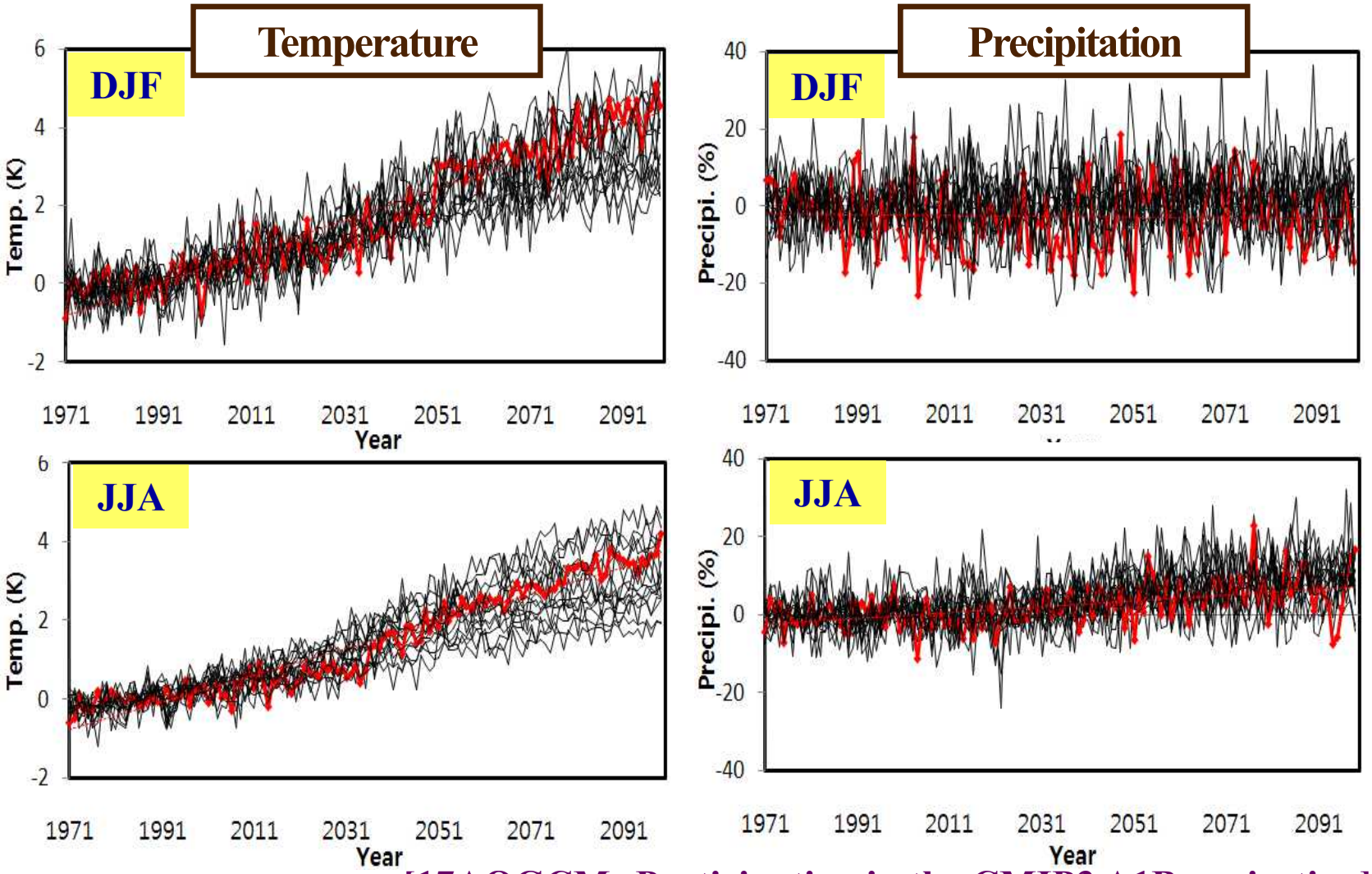
- **ECHAM5/MPI-OM A1B (1.875)**

  : State-of-the art coupled GCM, which was used to conduct ensemble simulations for the forth assessment report of the IPCC (AR4)



Reliability of ECHAM5 Projection

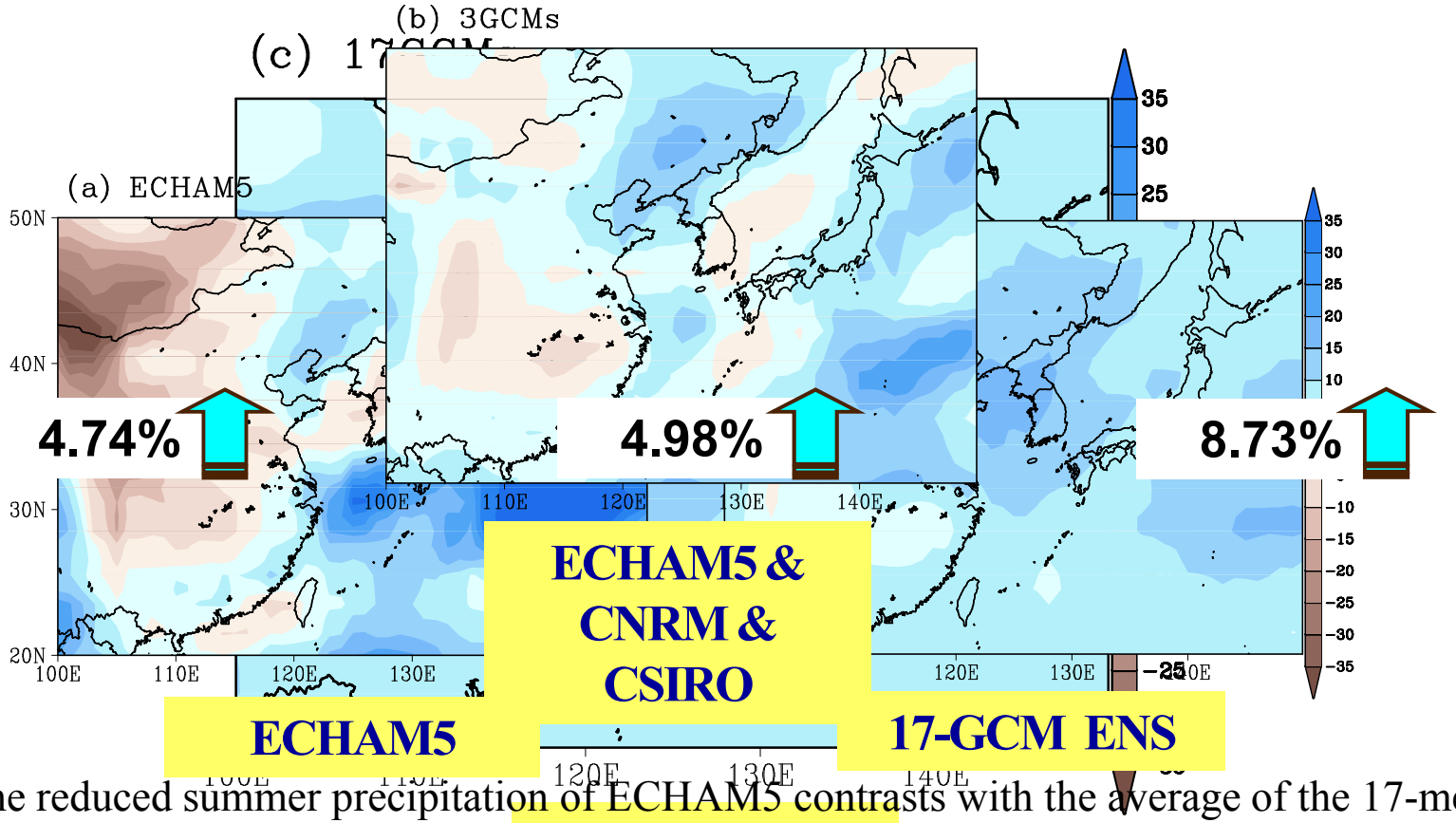
Inter-Model Variability



[17AOGCMs Participating in the CMIP3 A1B projection]

Uncertainty in GCM Projections

JJA Precipitation Change (2071-2100 minus 1971-2000)

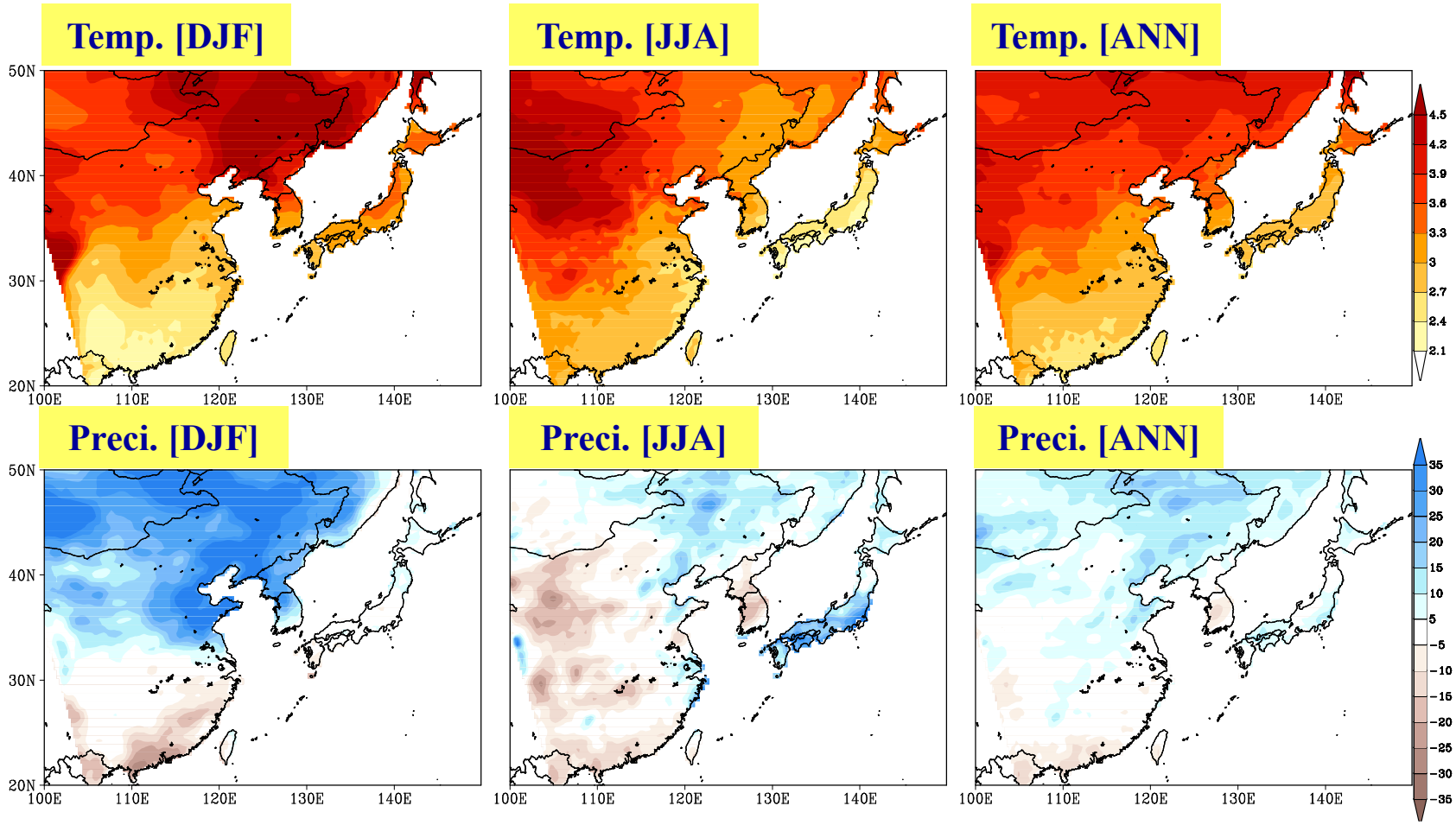


- The reduced summer precipitation of ECHAM5 contrasts with the average of the 17-member ensemble. However, when only the three GCMs (including ECHAM5) with relatively high resolution (1.875°) are used, the average of this 3-member ensemble is often negative.
- There is a large possibility of misinterpretation of precipitation change at the regional scale from the coarse-grid GCM projections.

Temp. & Preci. Change

Mother domain simulation (2071-2100)

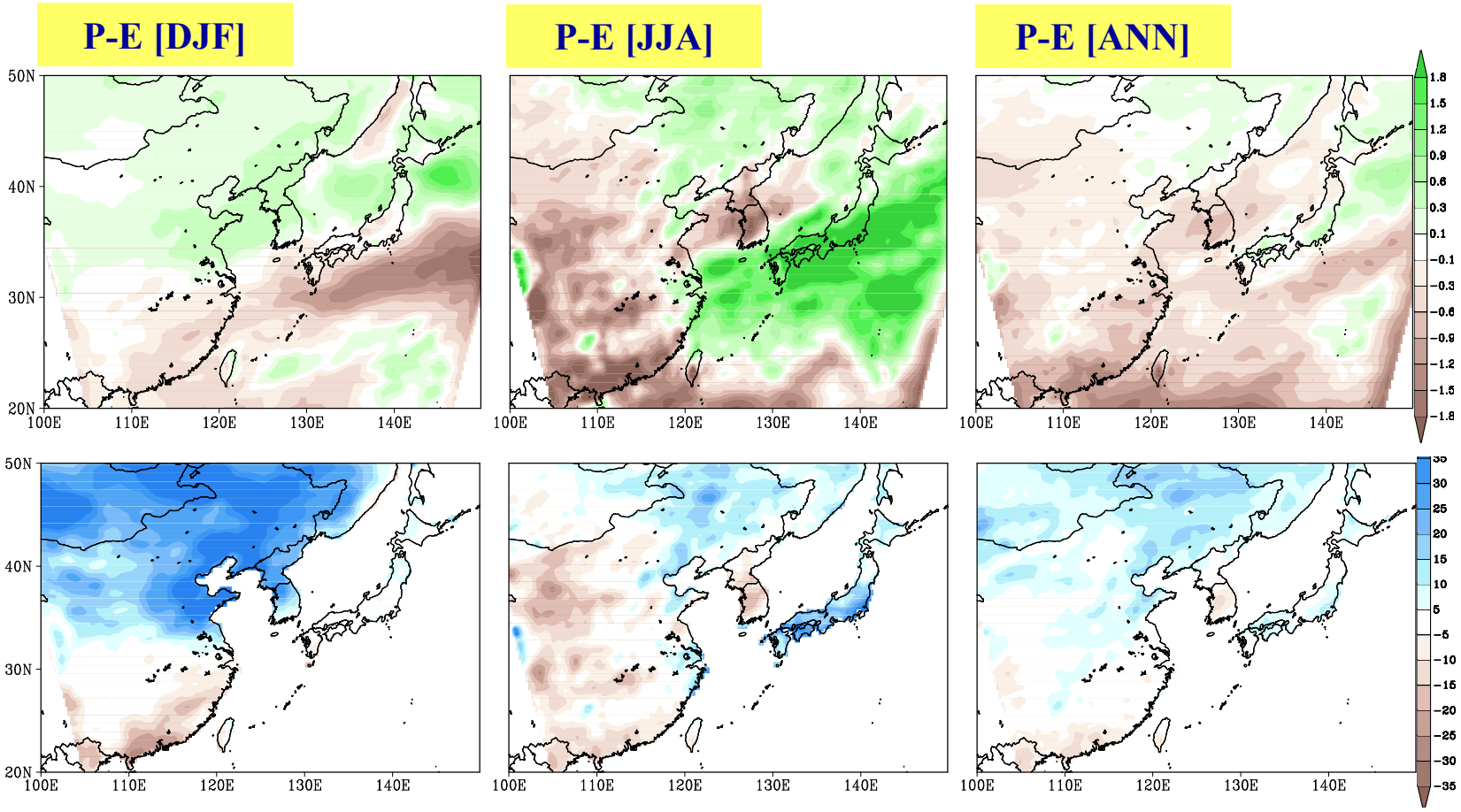
- The downscaled results generally follow the behavior of ECHAM5, but substantial fine-scale details are found in the spatial pattern, and the change signal becomes more enhanced at the local scale.



Future Dryness

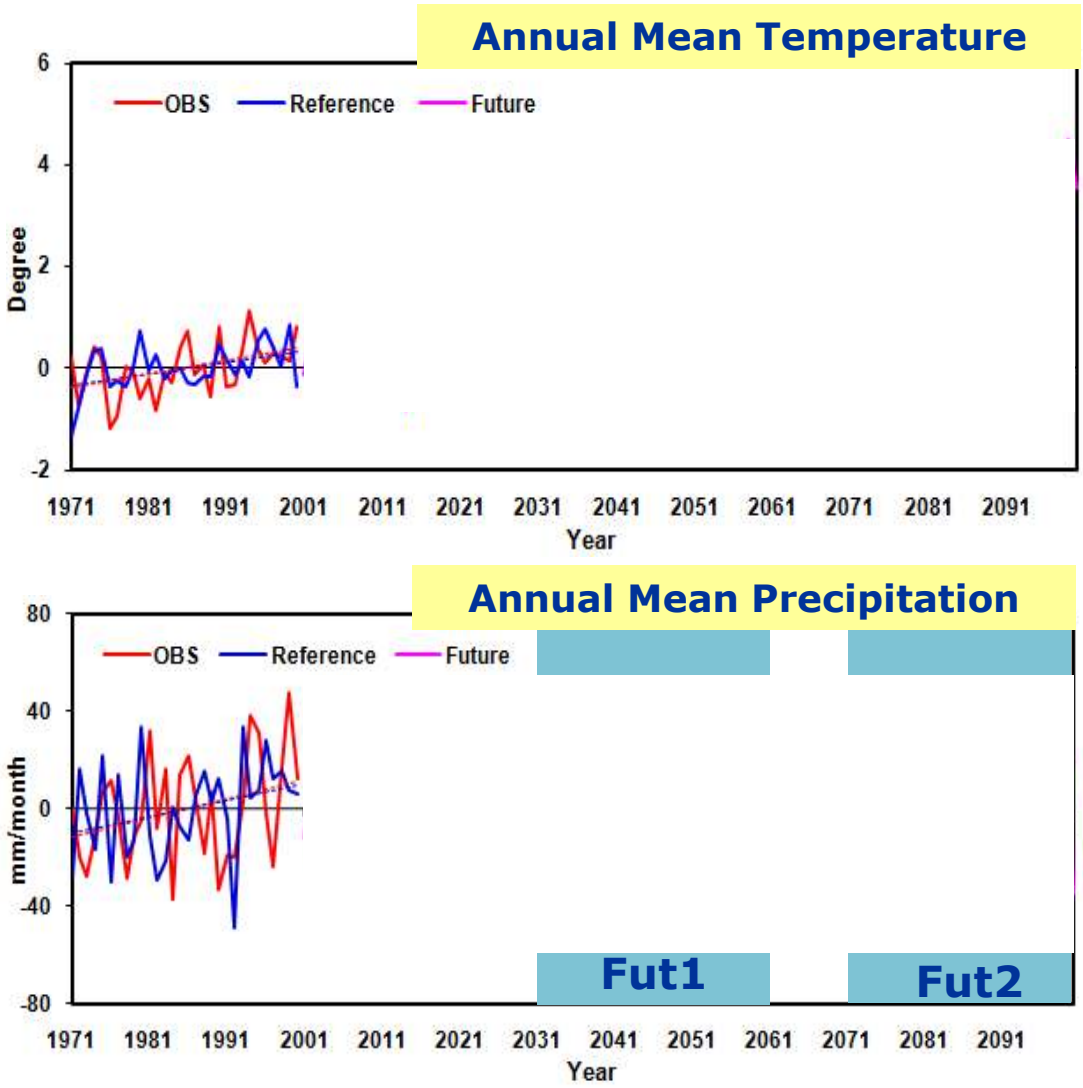
Precipitation - Evapotranspiration

- Moisture deficit = Evapotranspiration > Precipitation. (Negative sign)
- Water stress becomes more pronounced in the warmer climate due to enhanced evaportranspiration.



Temp. & Preci. Change

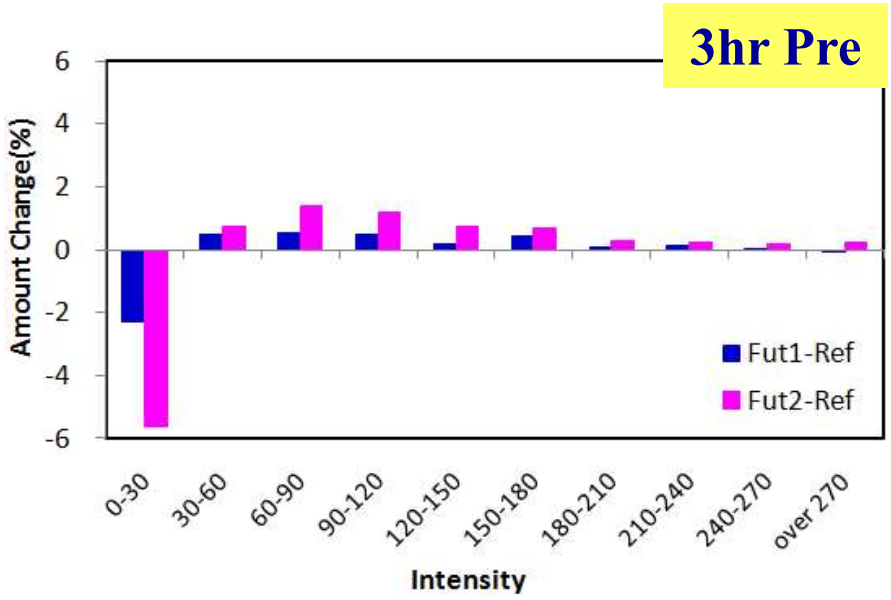
Long-term Trend & Variability

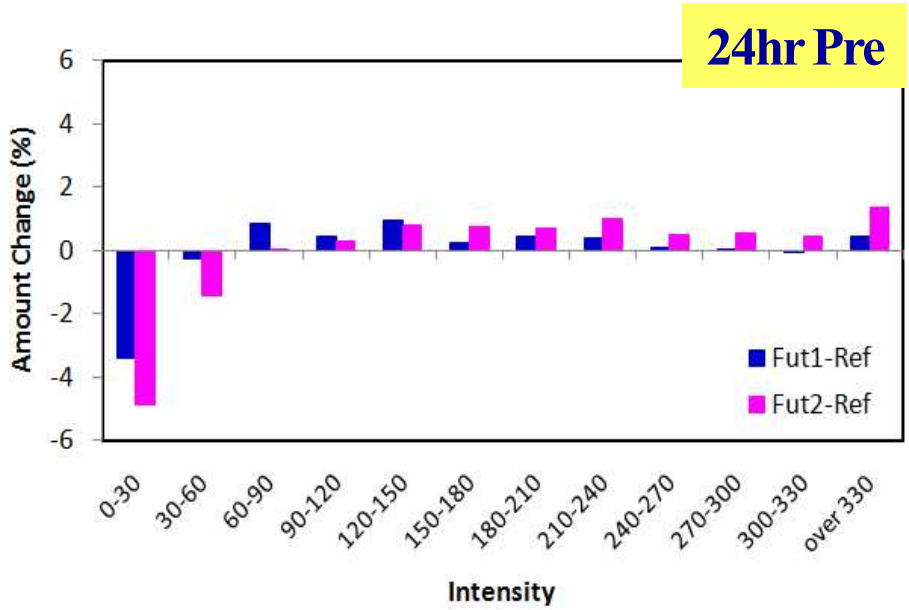


- ✓ Remarkable similarity between observation and simulation
- ✓ The degree of warming is sharply accelerated with well-defined increasing trend
- ✓ Projection derived for a short certain period could produce misinterpretation skewed by interdecadal variability.
- ✓ Despite no relevant trend during whole period, there is a visibly increasing and decreasing trend for a certain period.

Characteristics of Preci. Change

Intensity dependency of Preci. Change





- ✓ Despite the fairly large differences in 30-year temporal evolution of annual mean precipitation, change behaviors across various intensities in both Fut1 and Fut2 periods show a similar pattern and sign.
- ✓ An enhancement of relatively high intensity precipitation and a reduction of weak intensity precipitation are discernible.
- ✓ Global warming enhances the hydroclimatic intensity, through increased high intensity precipitation and reduced weak intensity precipitation.

Assessment of Drought

self-calibrated Palmer Drought Severity Index (PDSI)

- PDSI is the most prominent index of meteorological drought, which is measured by cumulative effect of atmospheric moisture supply and demand.
- PDSI incorporates both precipitation and temperature as inputs.
- Drought is shown in terms of a negative number. For example, PDSI < -3 is severe drought.

Relative Departure of Moisture

$$D = P - P^* = P - (PE^* + PR^* + PRO^* - PL^*)$$

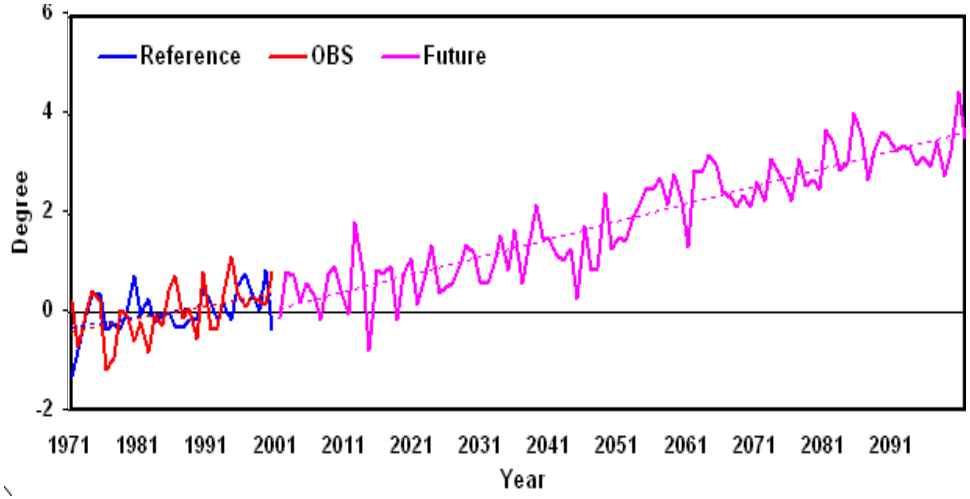
[PE: Potential Evapotranspiration / PR: Potential Recharge / PRO: Potential Runoff / PL: Potential Loss]

- The moisture departure, d, is the excess or shortage of precipitation compared to the CAFEC (climatically appropriate for existing conditions).

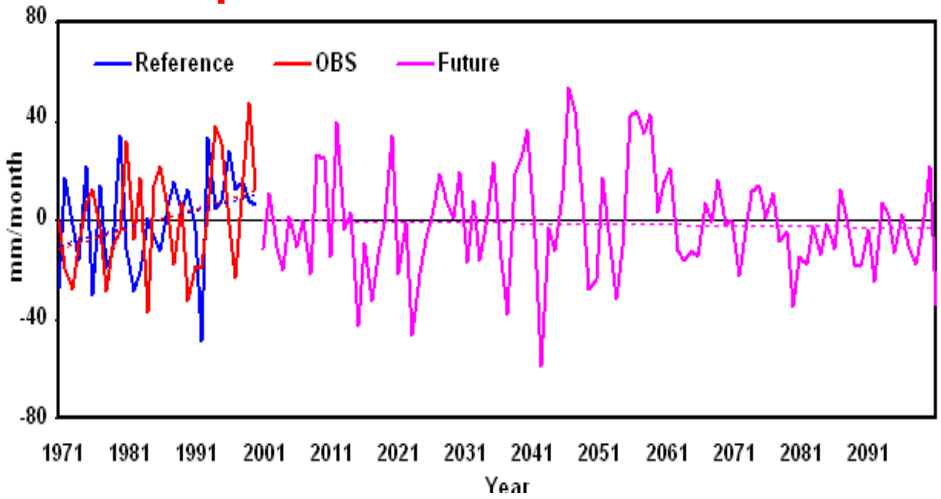
Future Drought

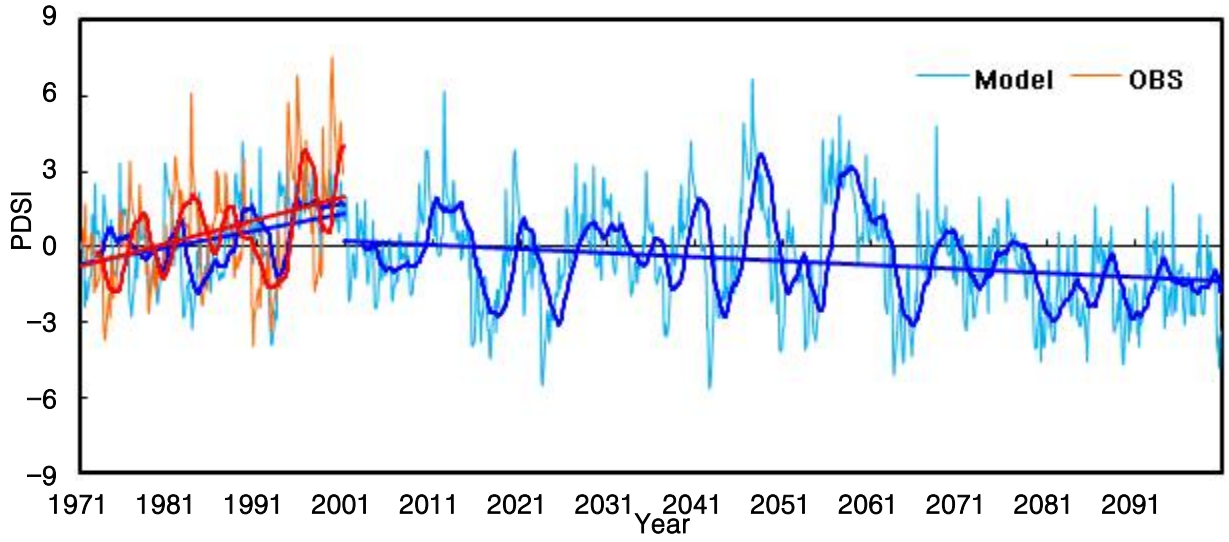
Long-term Trend on PDSI

Temperature



Precipitation

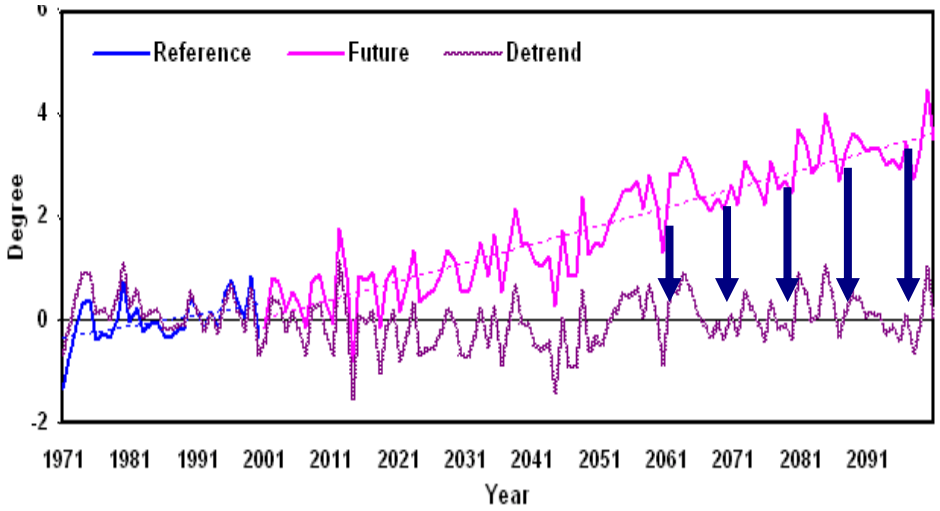




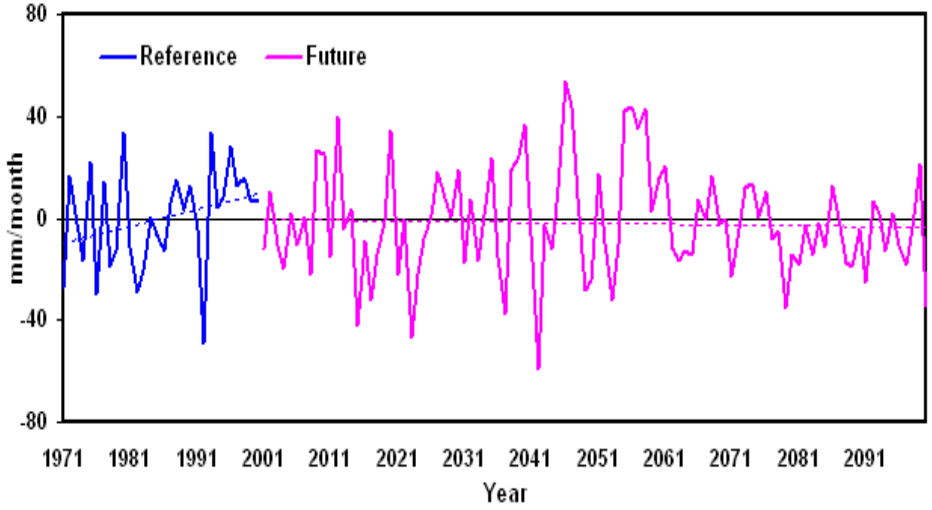
Future Drought

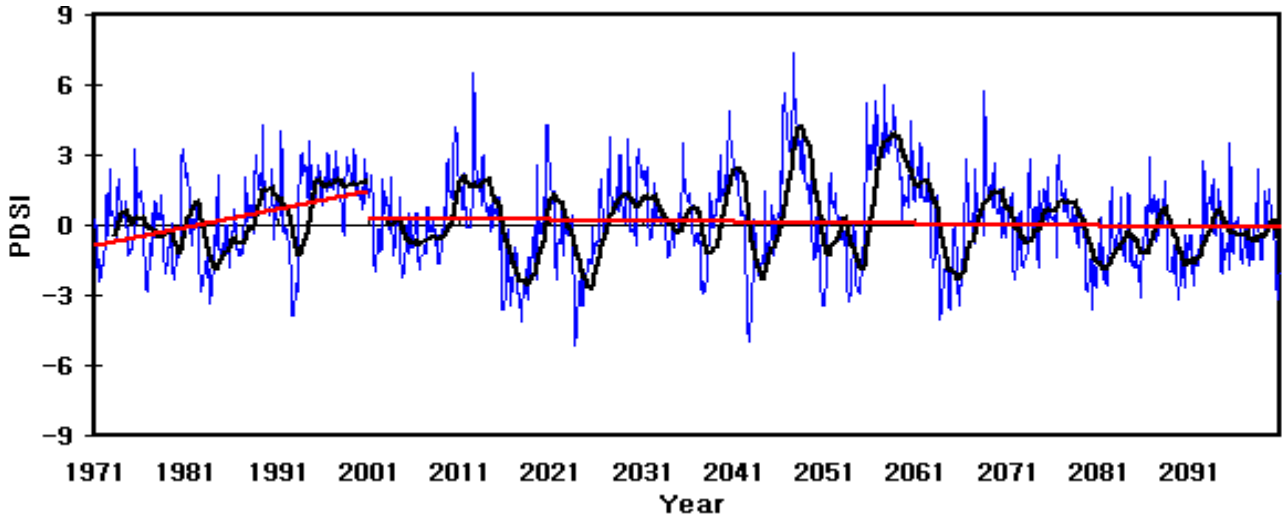
The Effect of Detrended Temp. on PDSI Trend

Temperature (Detrended)



Precipitation





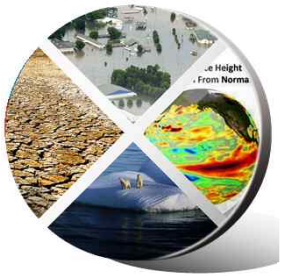
Take Home Message

Change of precipitation characteristics

- Global warming enhances the hydroclimatic intensity, through increased heavy precipitation and reduced light precipitation.
- Change in the total mean precipitation does not necessarily mean that drought will become more or less common.

Enhanced water stress due to temperature increase

- The increase of temperature enhances the evapotranspiration, and hence the water stress becomes more pronounced in the warmer climate.
- Decreasing PDSI trend is primarily due to the increasing temperature trend.
- However, the variation of drought is mainly determined by the variation of precipitation.



Thank you for your attention!!