Planning and Management in a Climate Change Scenario

# Potential changes of future dryness over Korea from a regional climate projection

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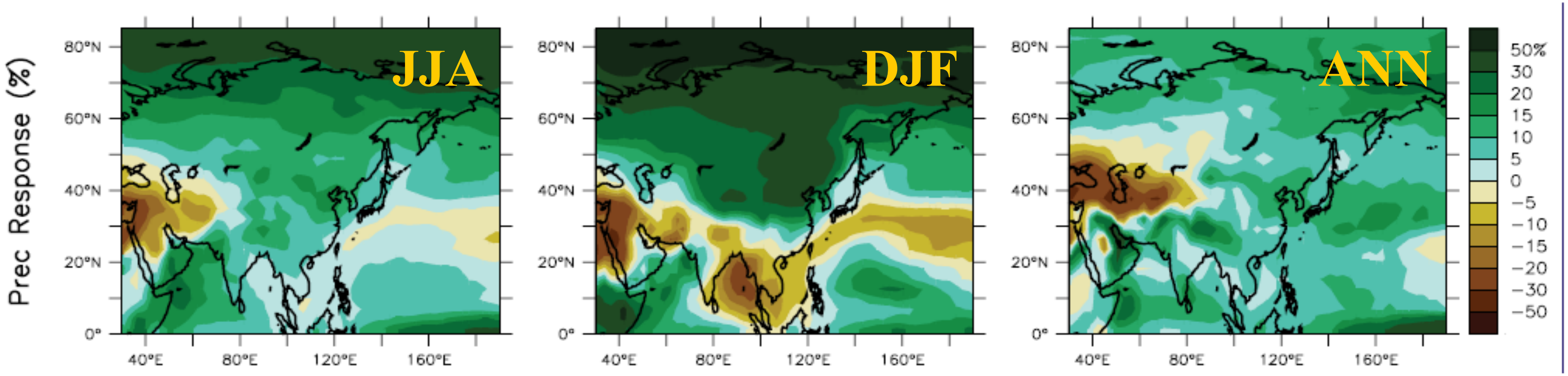
# Background I

## Precipitation Change Projection

- There is a growing agreement of the broad increase of precipitation over East Asia under global warming based on climate change projections with global climate models (GCMs) (IPCC 2007).
- Although the GCMs provide the foundation for future climate projections with improved confidence , precipitation projections could lead to different interpretations at the regional scale.
- For example, Gao et al. (2008) reported the reduction of future monsoon precipitation over China.

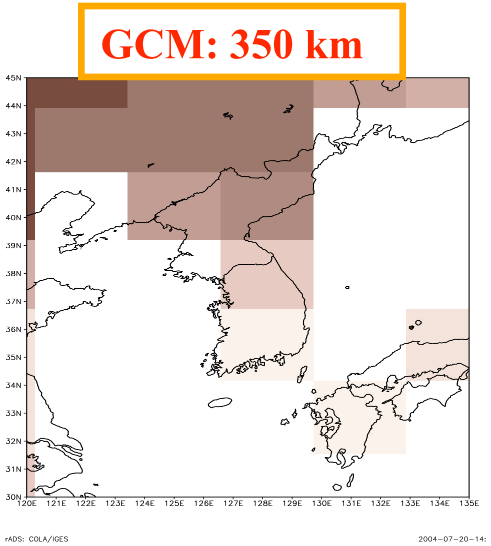


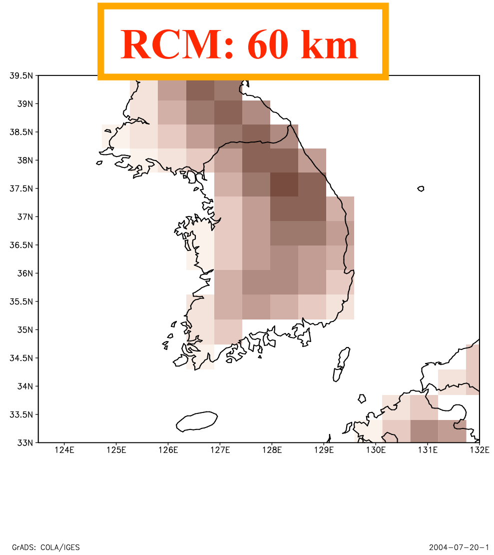

[Adopted from Chapter 11. Regional Climate Projection in IPCC AR4]

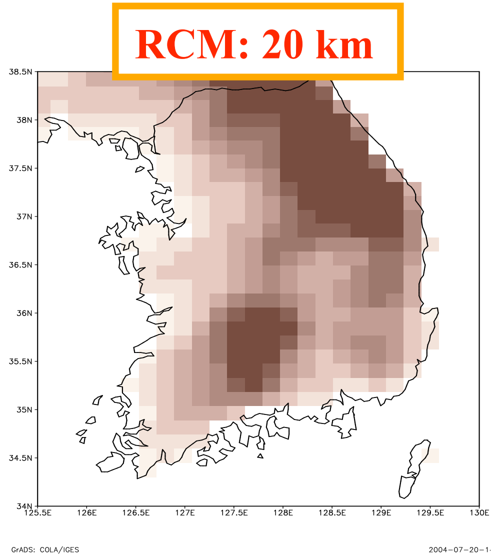
# Background II

## Necessity of High Resolution Modeling

- Because of the complex topography and the unique weather and climate system, the climate change signal over East Asia may exhibit a complex spatial structure which can be simulated only with high resolution modeling systems.
- In particular, the Korean peninsula is a representative region that can reveal the limitation of the GCM simulation since the territory is relatively small and has complicated mountainous terrain.
- Typical resolution (150-300km) of current GCMs can not represent the physiographical characteristics with sufficient accuracy.



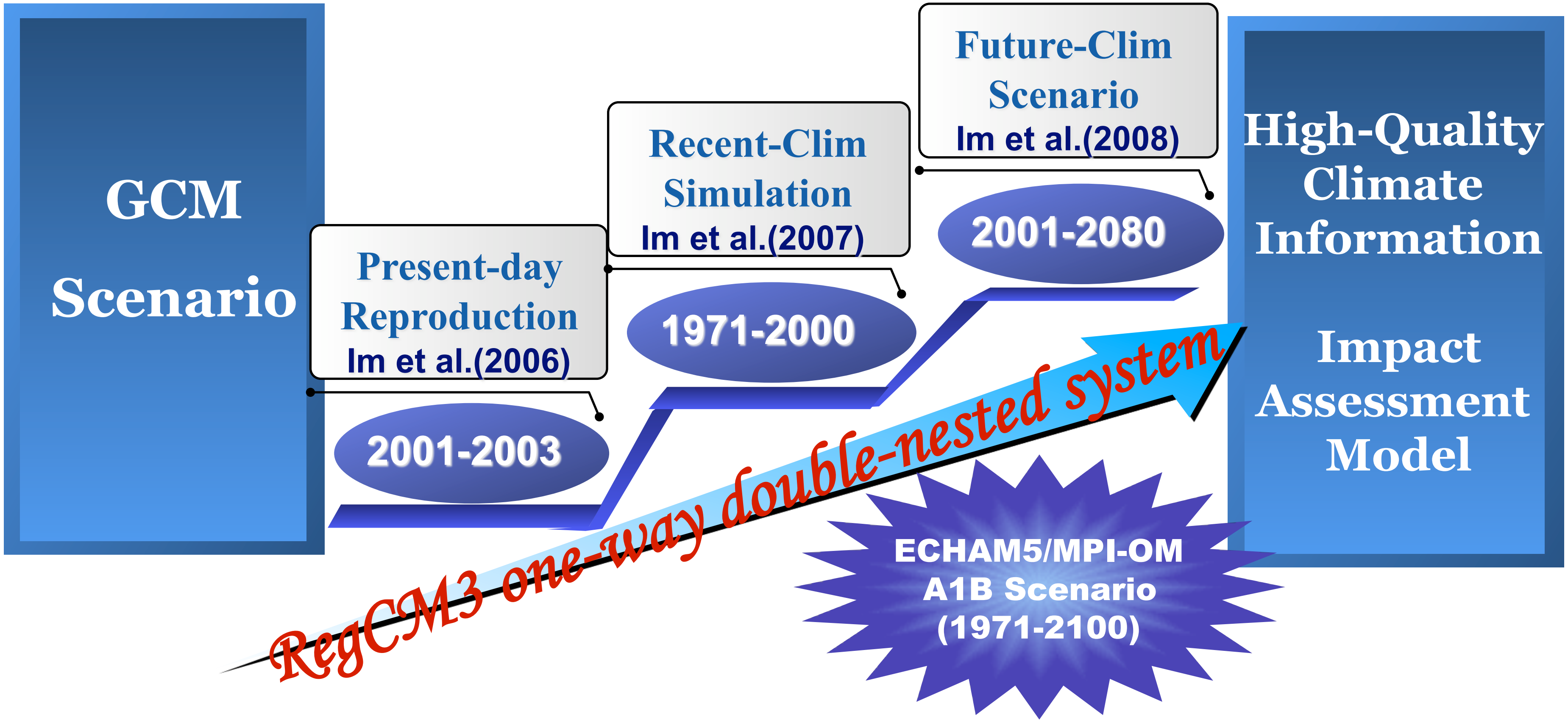



# Dynamic Downscaling

## RegCM3 double-nested modeling system

- In order to produce high-quality climate information over Korea, we developed RegCM3 double-nested modeling system.



# Main Topic

## Future Dryness

- Analysis based on monthly temperature and precipitation
- Calculation of ***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.
- To assess the influence of increasing temperature trend on PDSI

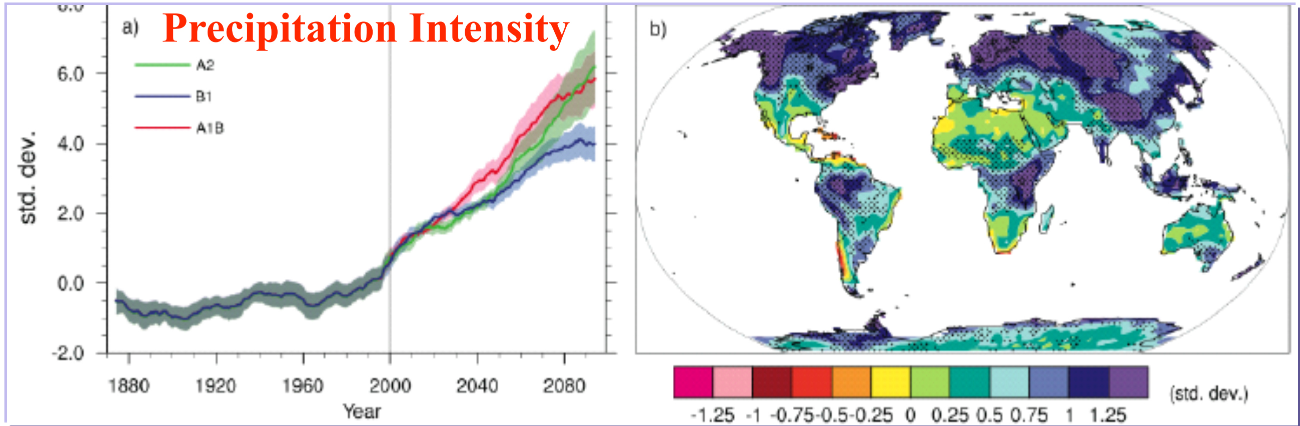
## Trend Analysis

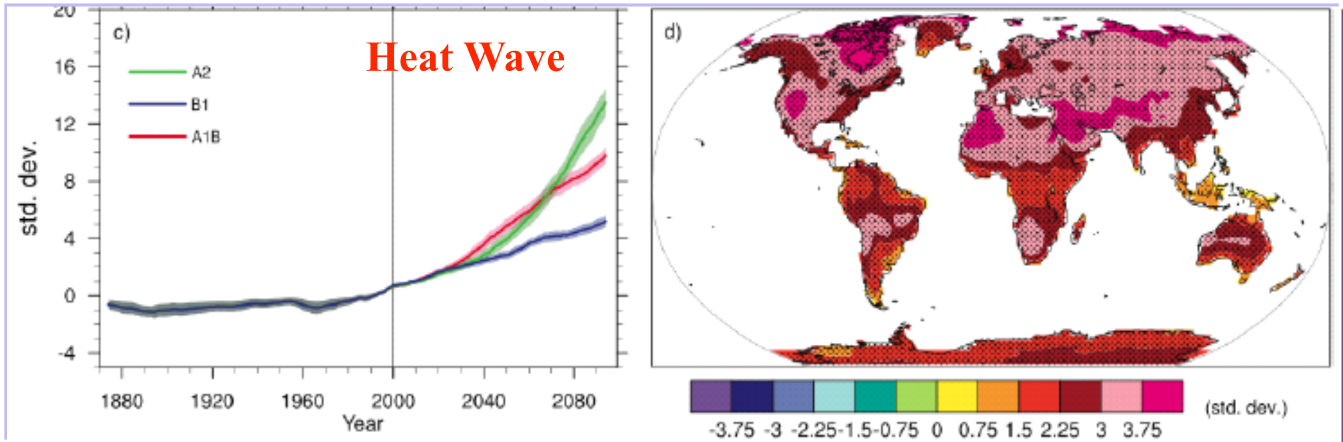
- Continuous ***130-year simulation*** allows us to derive meaningful statistical aspects of change signals.

# Expected Conclusion

## What can we expect ?

➢ Global warming gives different effects on the geographically diverse region even though future climate tends to evolve toward the same direction.



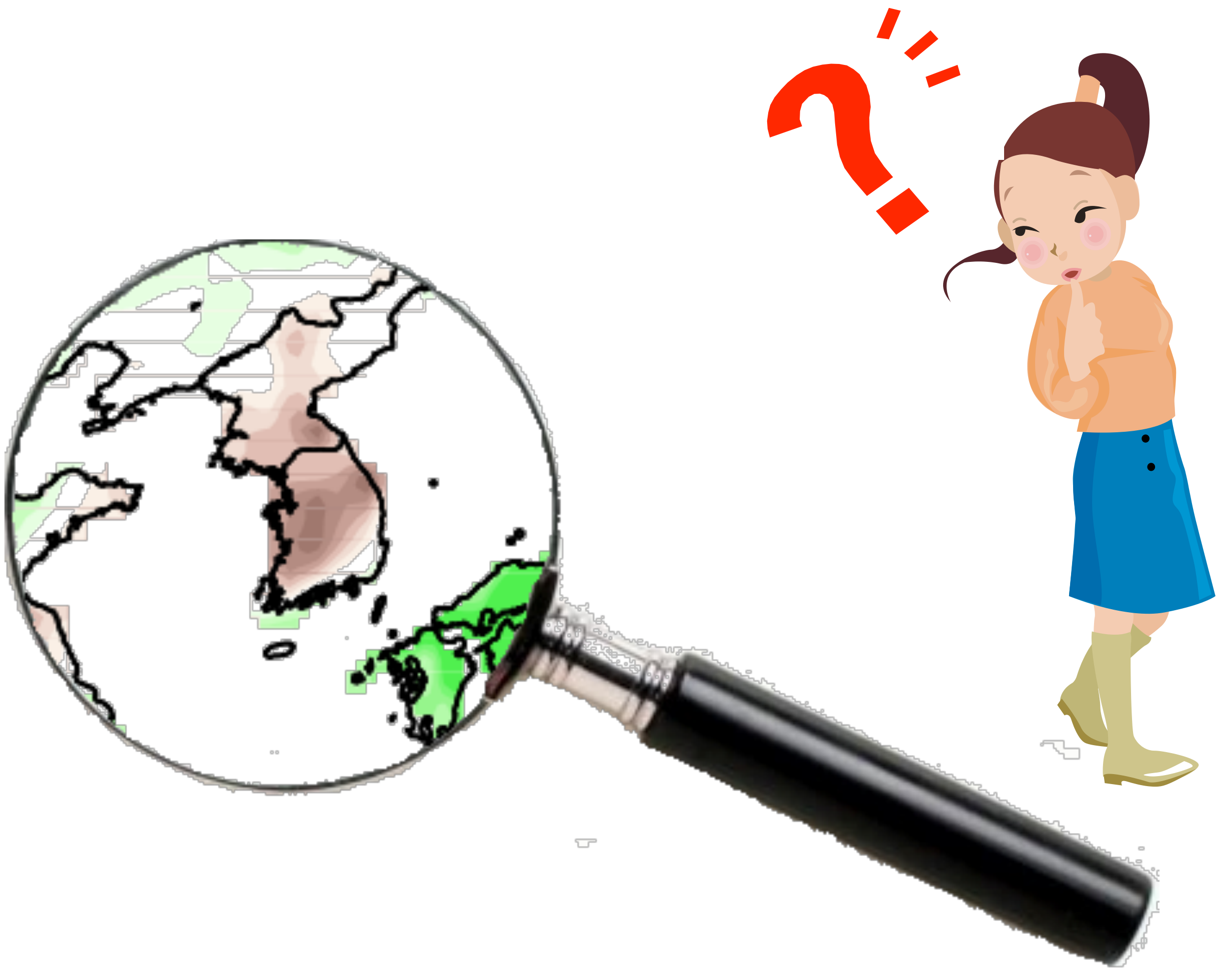



# Expected Conclusion

Global W arming

- Significant increase of temperature
- Enhancement of high intensity precip.
- Increase of potential evapotranspiration
- More favorable dryness condition
- Pronounced water stress

# Expected Conclusion

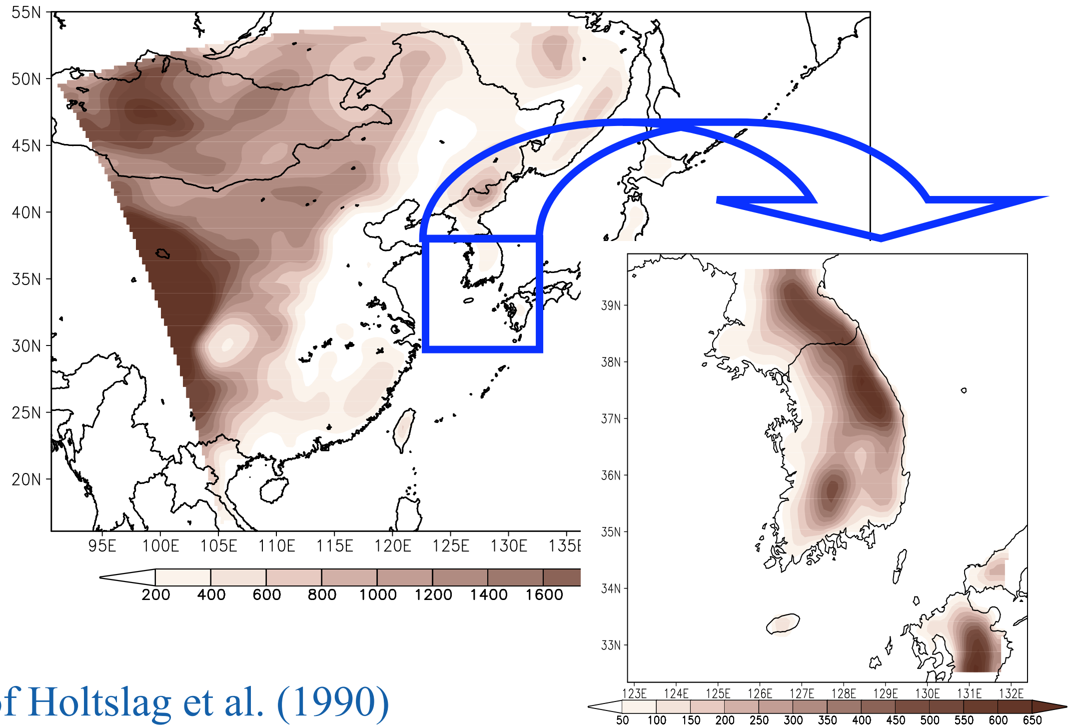


# RegCM3 double-nested system

## Model Configuration

### ❑ RegCM3 one-way double-nested system

- **RegCM3 (Regional Climate Model Ver.3)**
- **Resolution**
  : Mother domain – 60 km
  : Nested domain – 20 km
- **Integration Period**
  : [Reference Scenario] 1971 - 2000 (30yr)
  : [Future Scenario] 2000 – 2100 (100yr)
- **Initial & Boundary Condition**
  : ECHAM5/MPI-OM  A1B (1.875)
- **Physics parameterization**
  : Cumulus – MIT Emanuel (1991)
  : Radiation – CCM3 (Kiehl et al. 1996)
  : PBL – Nonlocal vertical diffusion scheme of Holtslag et al. (1990)



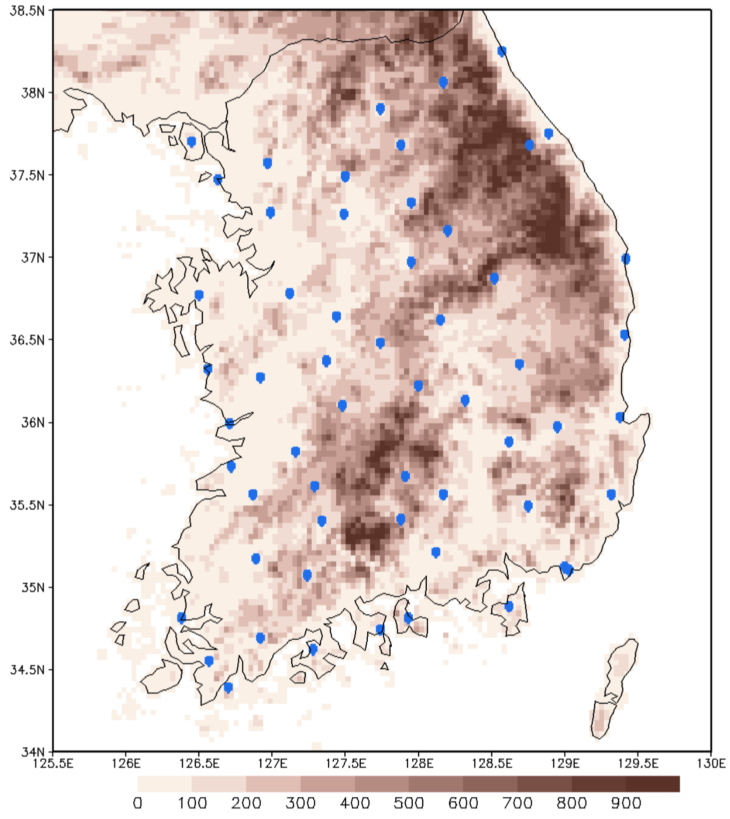
# Verification Strategy

## Mother Domain

- NCEP/NCAR Reanalysis : 1979-2003, 25yr
- CRU Temperature & Precipitation : 1971-2000, 30yr

## Nested Domain

- Station data (57 points)
  : 1973-2004, 30yr

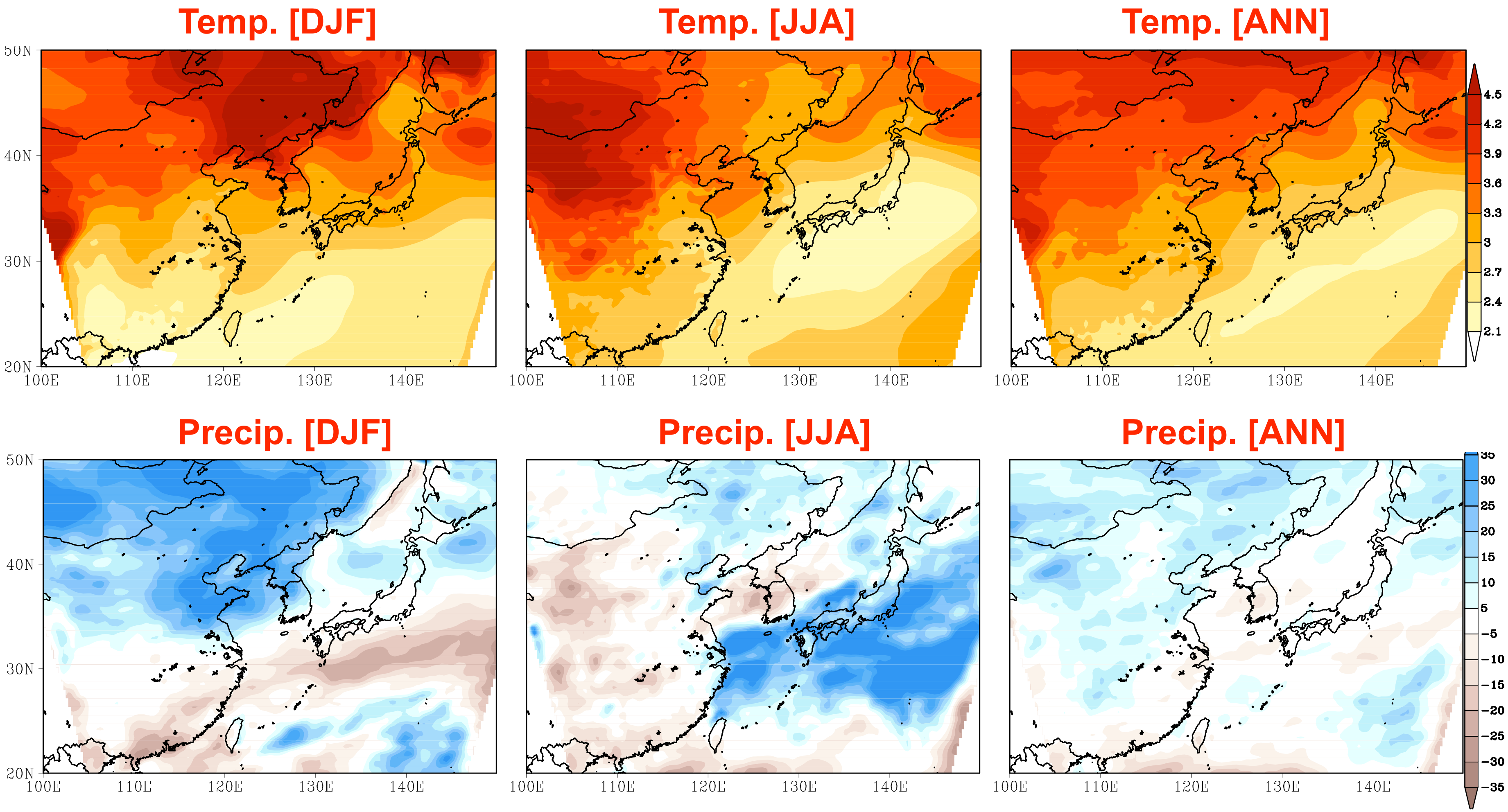


# Mother domain simulation

- **By comparison of the global observations with the mother domain simulation during the reference period (1971-2000), the model reasonably reproduces the mean climatology of the temperature and precipitation as well as large scale circulation, in terms of seasonal variation and spatial distribution.**

# Temp. & Precip. Change

## Future change=Fut.(2071-2100)-Ref.(1971-2000)



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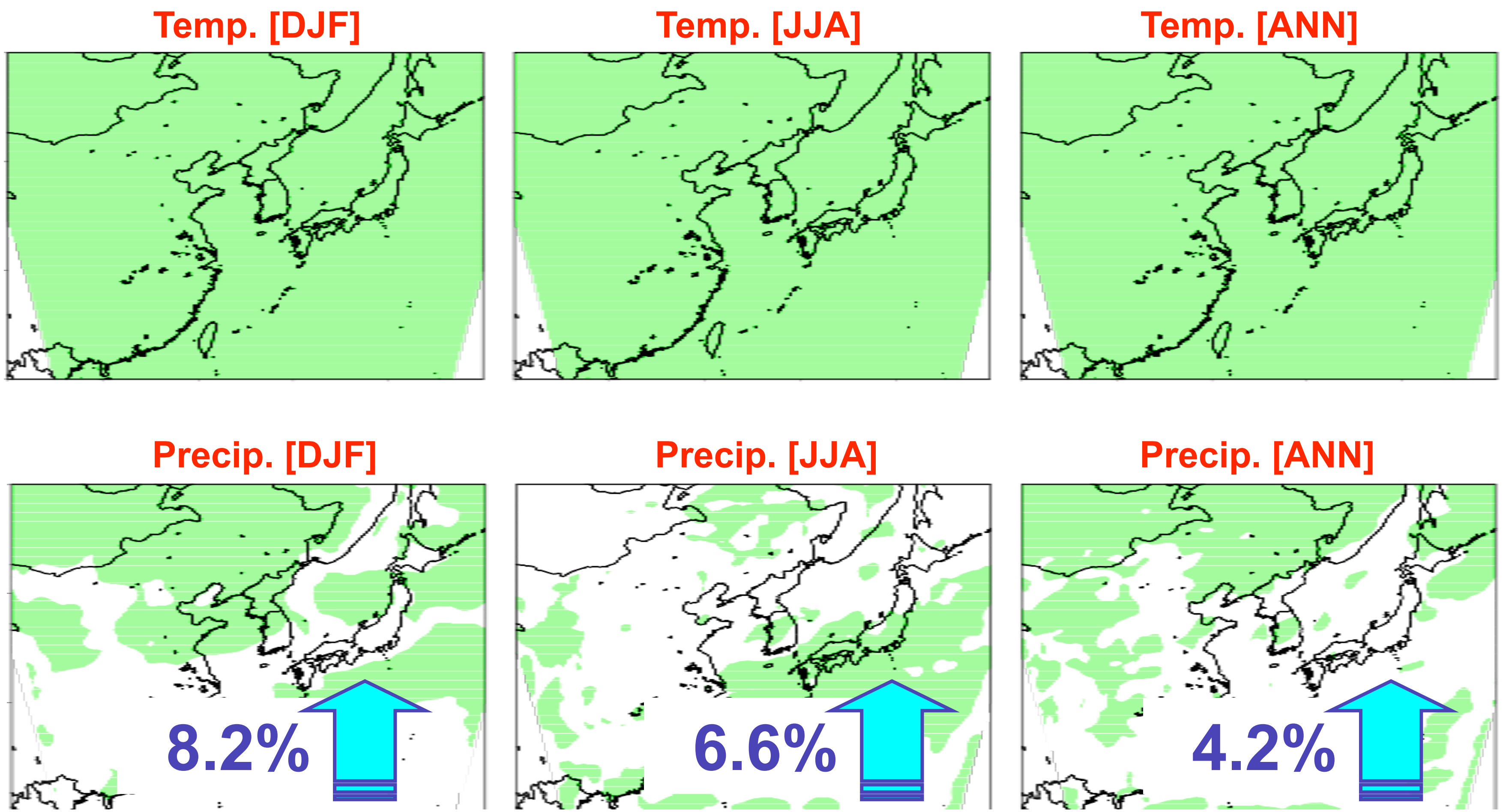
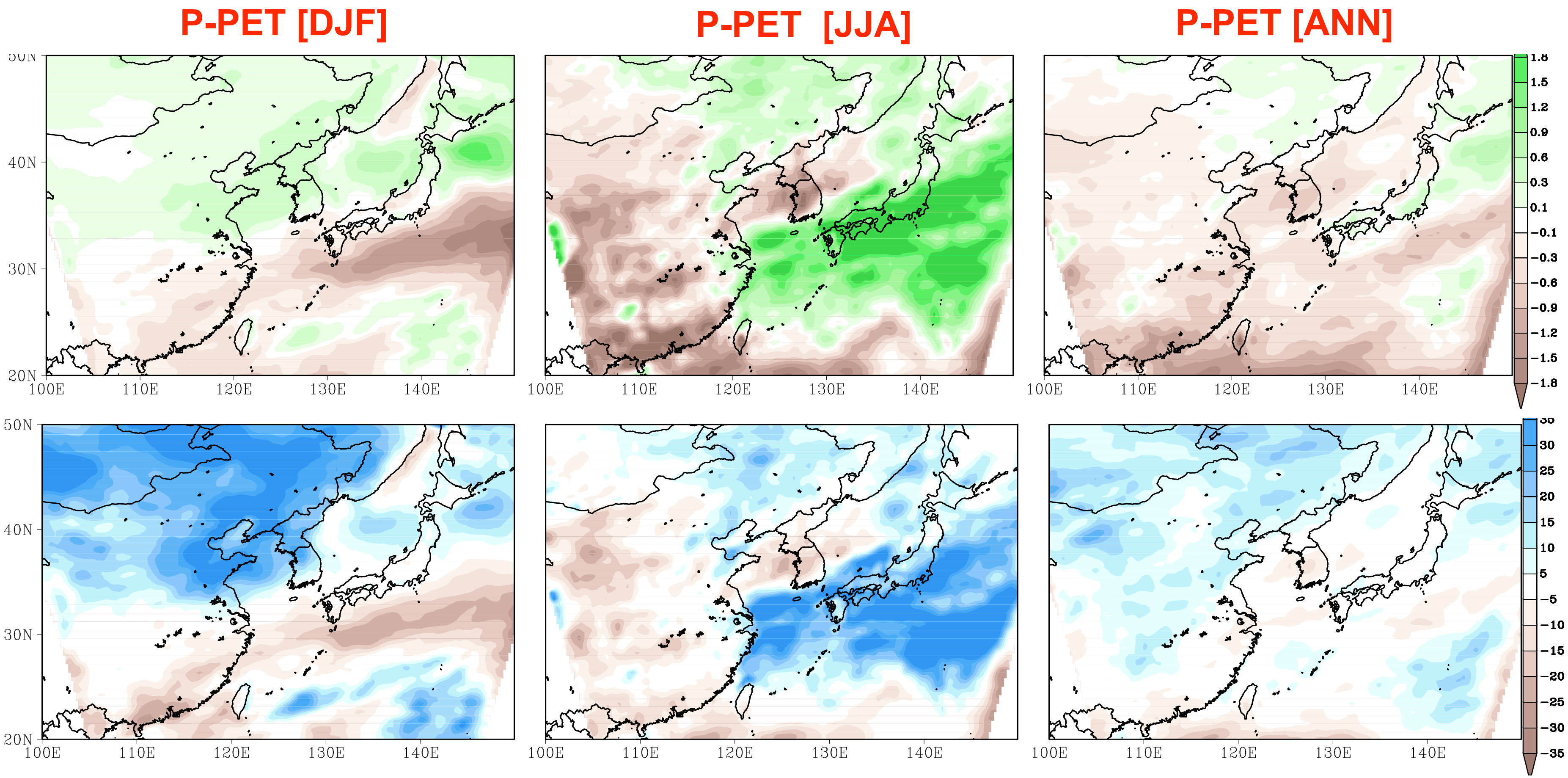


# Moisture Budget Change

## Change of (Precip. – Potential Evapotranspiration)

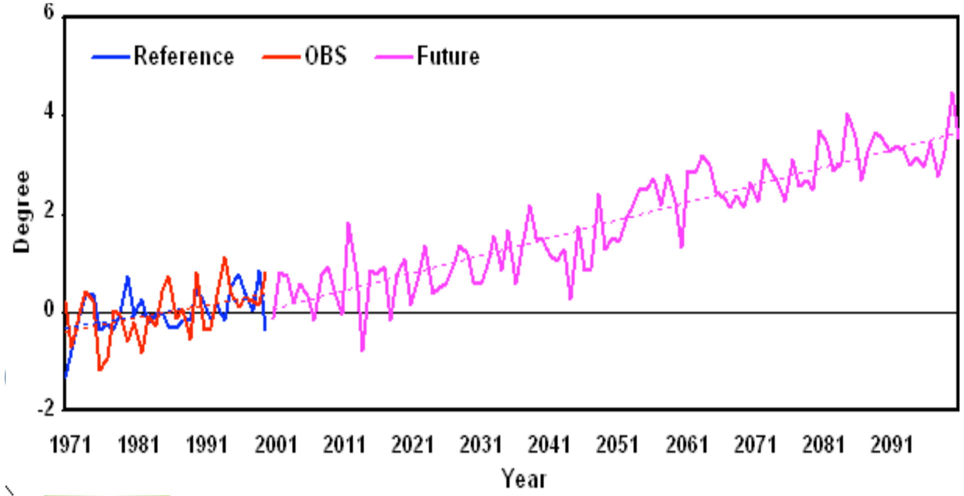
- Moisture deficit = Potential Evap. > Precip. (Negative sign)



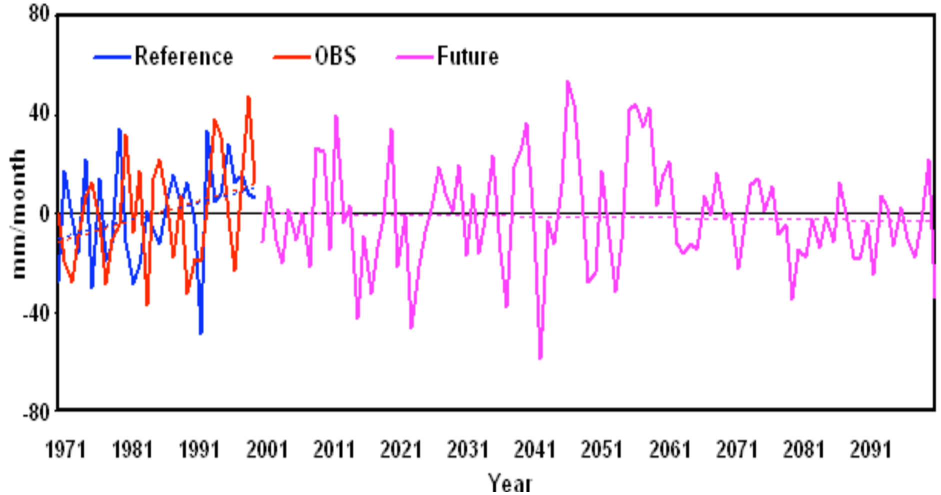
# Nested domain simulation

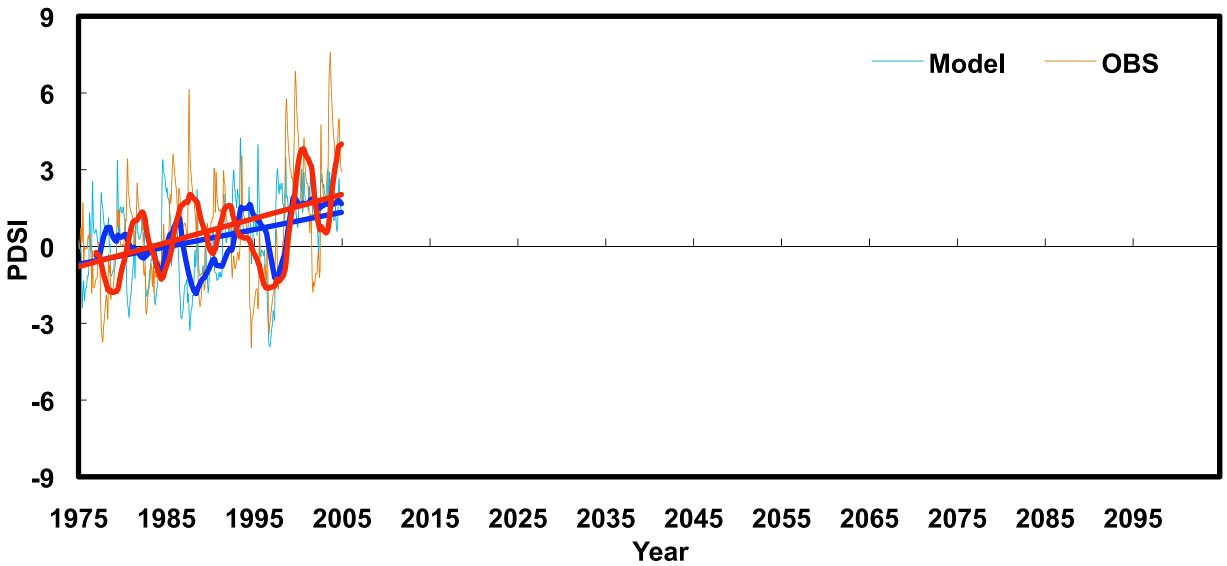
# Trend of Temp. & Preci. & PDSI

## Temperature




## Precipitation

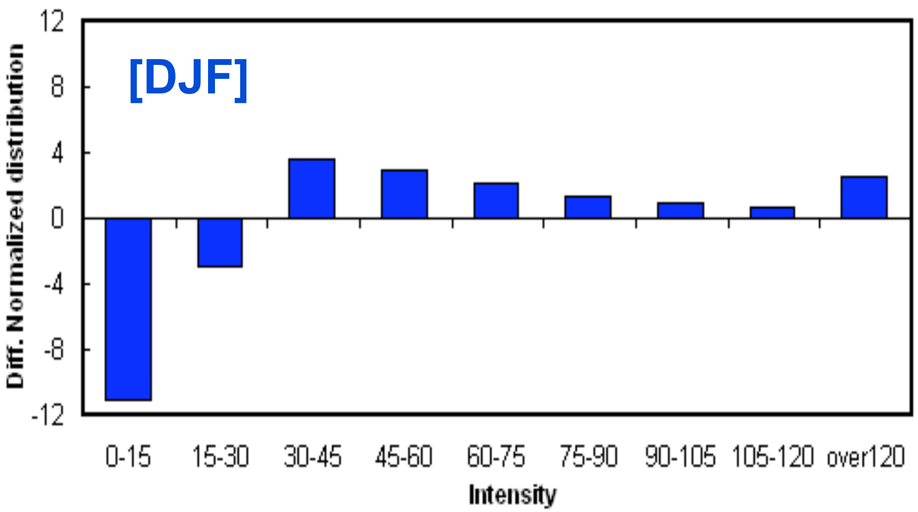


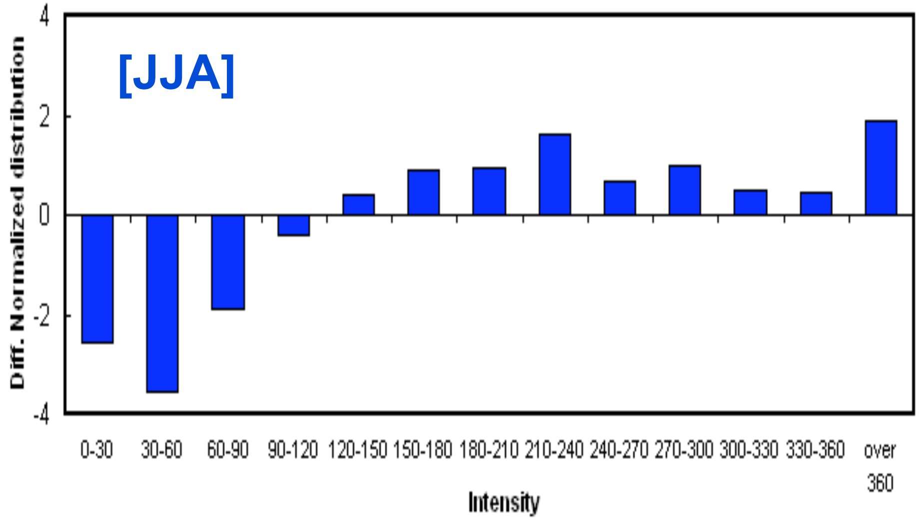



# Precip. Distribution Change

## Daily Precipitation Intensity vs. Amount

- The change distribution have transitions between decreasing and increasing contributions to the total precipitation at about the 50th percentile.
- An enhancement of relatively high intensity precipitation and a reduction of weak precipitation are discernible.
- This feature can support the increase of extreme precipitation as a consequence of climate change due to global warming, even without significant increase of total precipitation.



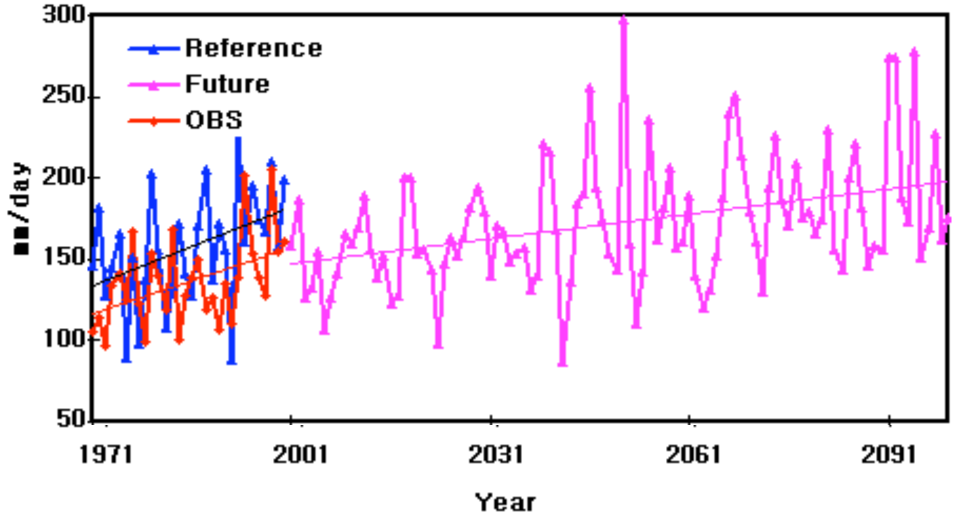



# Precipitation-based Extreme

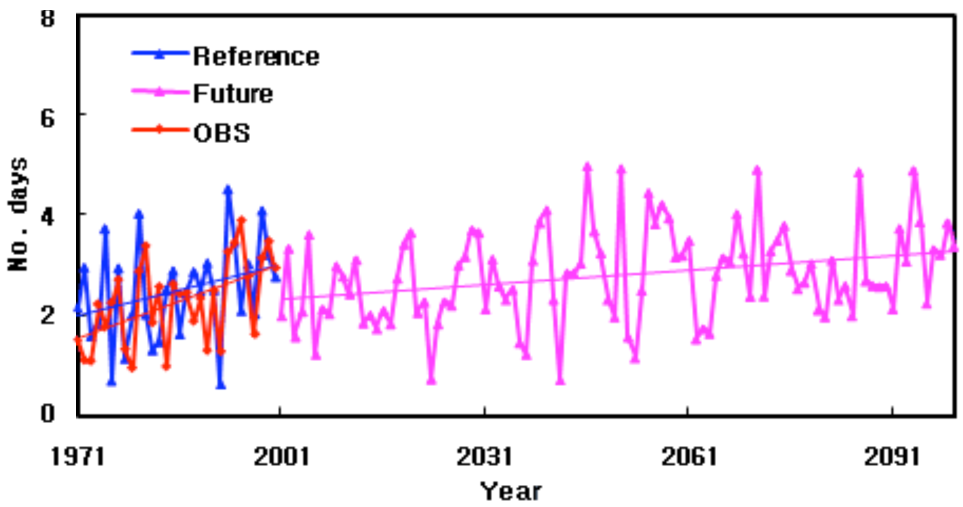
## Intensity & Frequency of Heavy Precip.

- As a precipitation index to measure the intensity and frequency of heavy precipitation, PX1D is defined as the greatest one day total precipitation amount and PN80 is defined as the number of days in which the daily precipitation is greater than 80 mm.
- Precipitation-based indices show a consistently increasing trend in spite of the large interannual variability. The future tendency continuously follows the characteristics of the reference climate.

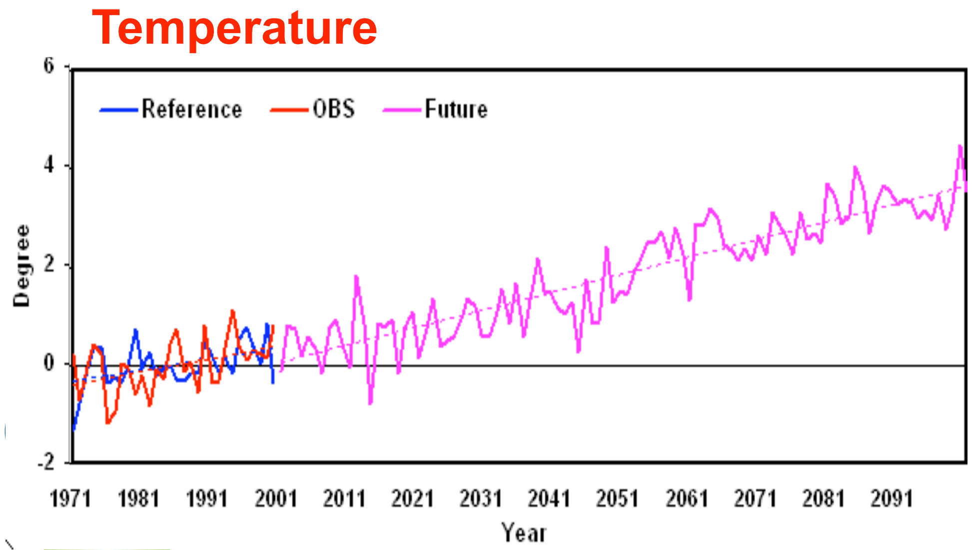
**Greatest 1-day total precip. [PX1D]**

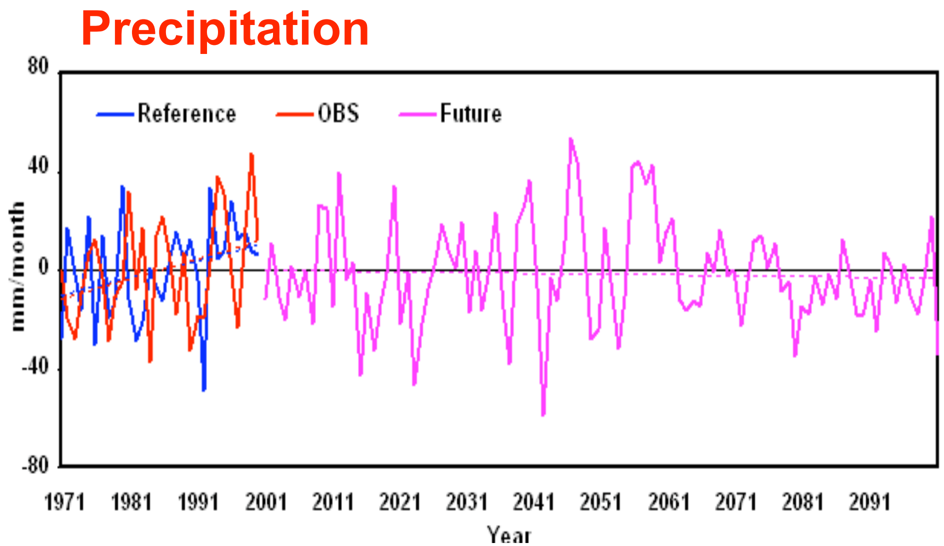


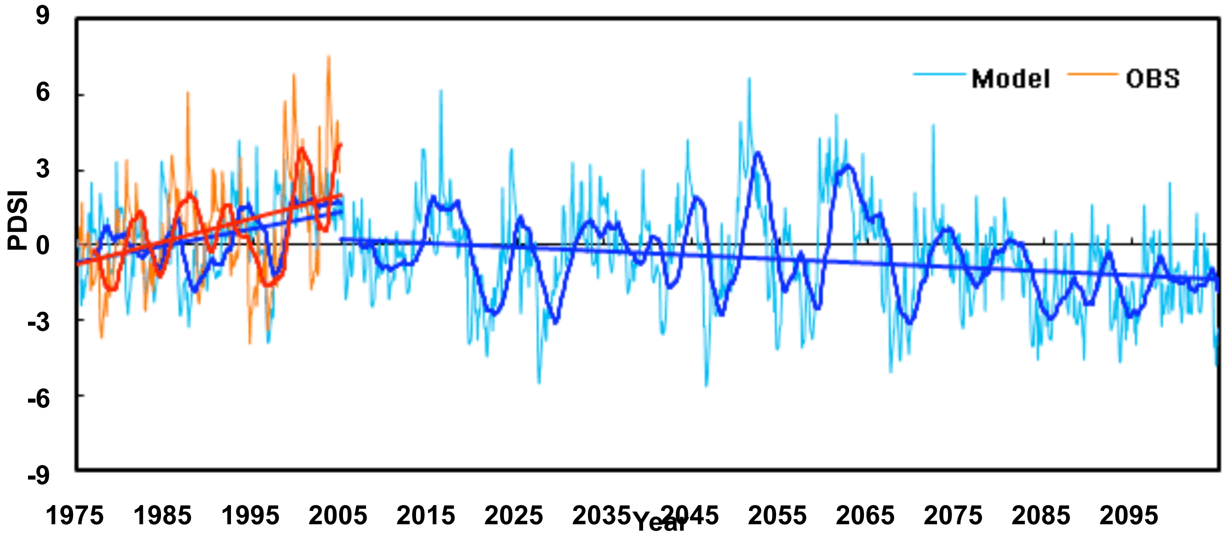

**No. of precip.days above 80 mm [PN80]**



# Trend of Temp. & Preci. & PDSI



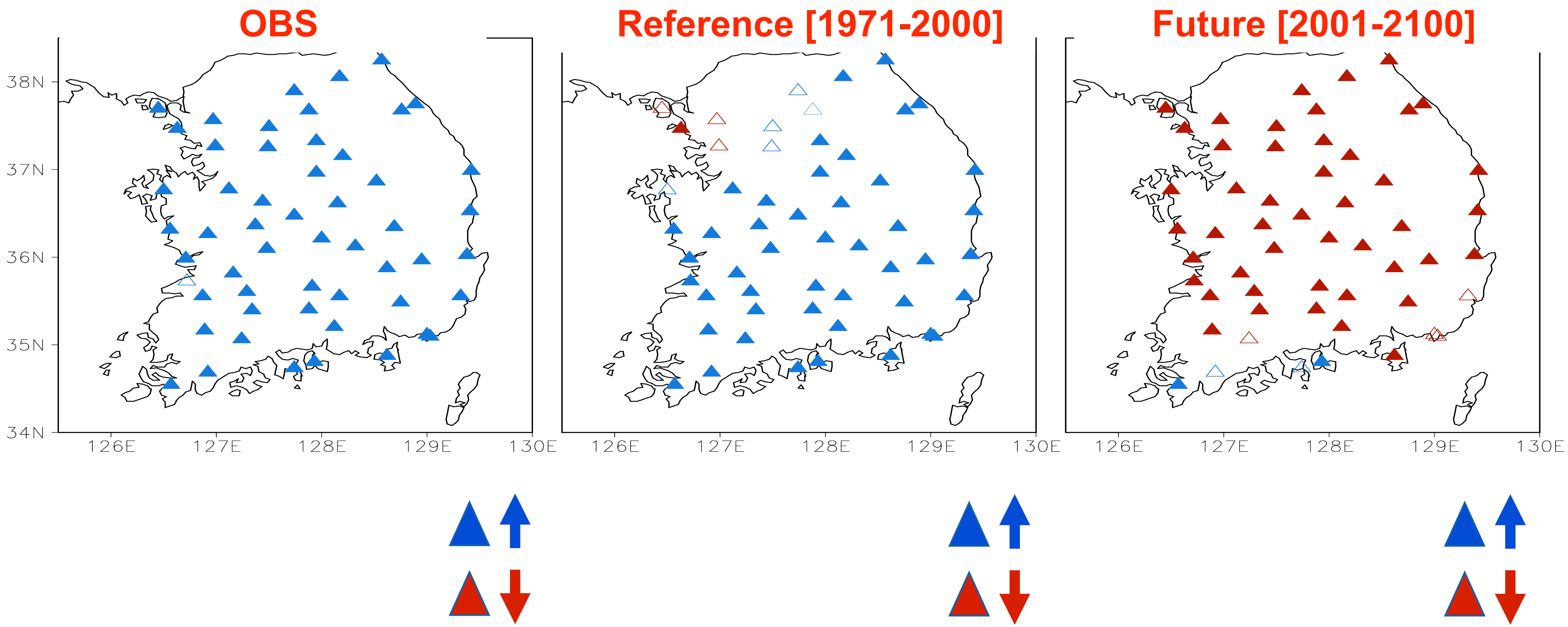



# Spatial Pattern of PDSI Trend

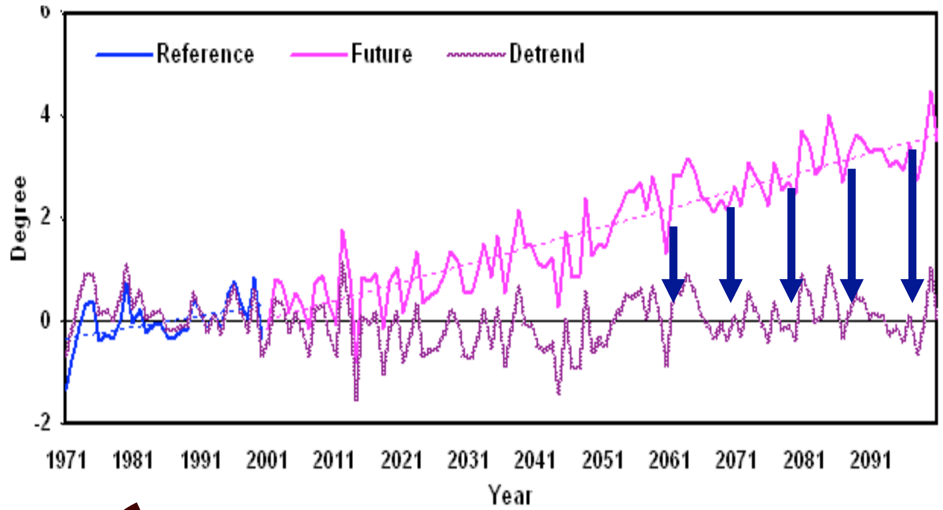
## Statistical Significance

- The model follows well observed estimates, but opposite sign and less significance are found over the northwest part of the South Korea.
- The directions of trend are altered to the future projection. The majority of stations show the decreasing trends with high statistical significance.

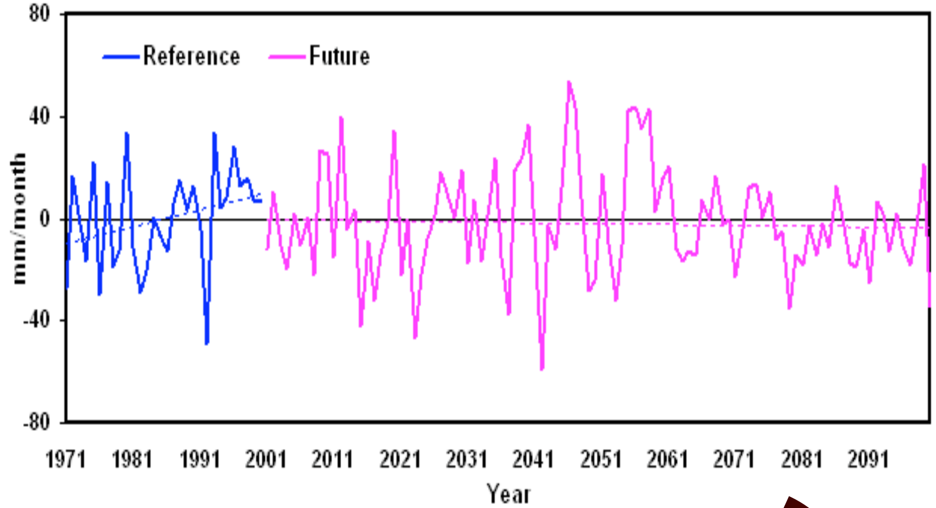


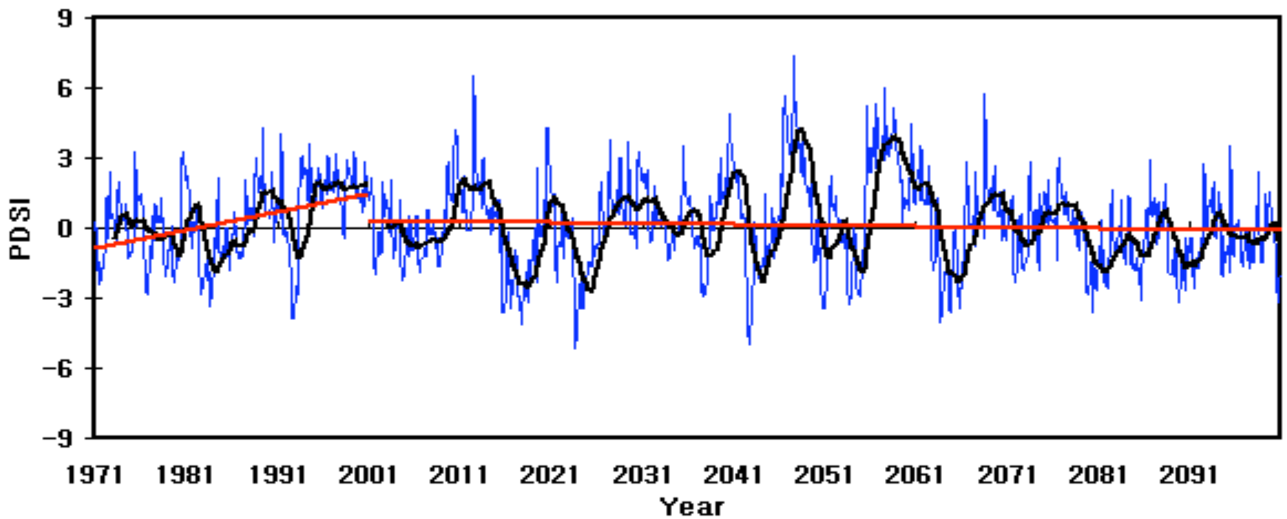
# Effect of Temperature on Drought

## Temperature (Detrended)




## Precipitation



# Summary

## Changes in Temp. & Precip.

- The significant warming in the range of 2-4 degree is found over East Asia, and degree of warming tends to be accelerated in correspondence of the emission forcing.
- The change of precipitation shows a distinct seasonal variations and a complicated spatial pattern.
- While changes in total precipitation do not show any relevant trend, the change pattern from the normalized distribution of daily precipitation clearly shows an enhancement of relatively high intensity precipitation and a reduction of weak intensity precipitation

## Changes in Future Dryness

- Actual water stress, defined as a measure of the difference between precipitation and potential evapotranspiration becomes more pronounced in the future climate.
- Although PDSI is overall associated with the precipitation variation, its long-term trend tends to be modulated by the temperature trend.
- Relevant decline of the PDSI is visible in future projection. However, the downward trend of the PDSI is mostly disappeared when the detrended temperature is used for calculation of the PDSI.

# Thank you for your attention!!!

# PDSI Calculation

## Relative departure of moisture

$$D = P - P^* = P - (ET^* + R^* + RO^* - L^*)$$

[ P: precipitation, P*: climatological precipitation appropriate for existing conditions, ET*: evapotranspiration, R*: soil water recharge, RO*: runoff L*: water loss from the soil ]

- Main effective component of P* is ET*, while others have little effect. Global warming increases the atmospheric demand of water that results in a deficit in soil moisture .
- If future increases the magnitude of R* which is absorbed by the soil, and leads to decrease the runoff RO* and soil water loss L*. The magnitude of R* plus RO* minus L* seems to hold constant during the analysis periods in contrast to the prominent increasing trend of ET*. As a result, an increase of temperature is evident from ET* variation by future increase of P*.