Implications of a Decadal Climate Shift over East Asia in Winter: A Modeling Study

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J of Climate, in press

Introduction

✓ The East Asian winter monsoon (EAWM) is one of the most active components of the global climate system. Climatological aspects of the EAWM have been investigated using reanalysis or observation data (e.g., Zhang et al. 1997). However, research on Asian winter monsoon is still limited compared with summer monsoon.

✓ The features of EAWM are subject to dramatic change under the influence of global warming (Hu et al. 2000; Hori and Ueda 2006). It is evident that the EAWM and associated meridional heat transport both undergo substantial modulations on an interannual time scale (Zhang et al. 1997). It is now becoming apparent that the winter monsoon is also modulated on decadal time scales (Nakamura et al. 2002), with its weakening since the late 1980s along with a decreased intensity of the Siberian high (Panagiotopoulos et al. 2005).

Introduction

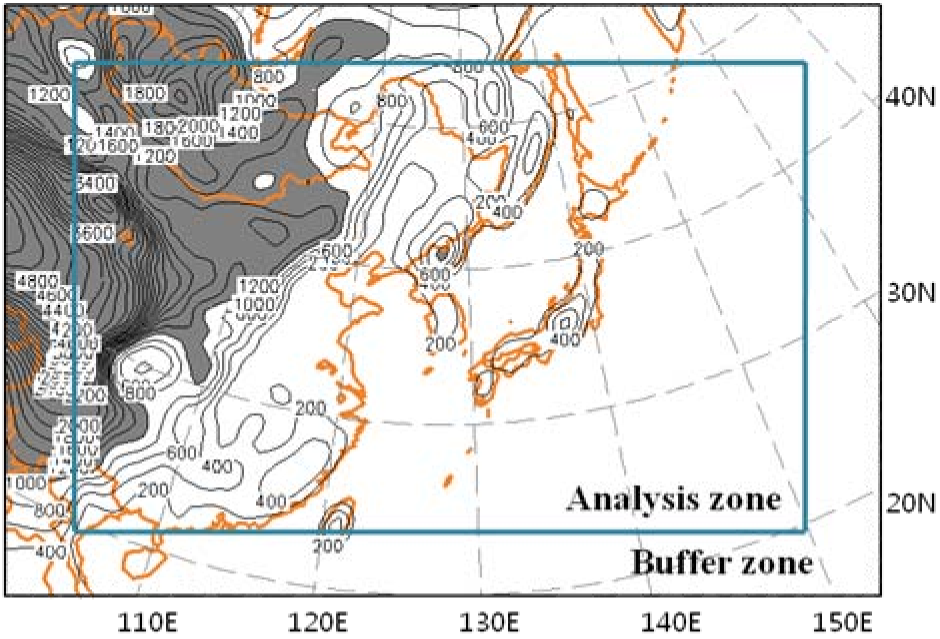
✓ Anomalies of the EAWM do not only bring anomalous weather and climate (cold or warm winter) in Asia, they also link to the variations of large-scale general circulation and convective activity over the tropical maritime continents and the western Pacific (Hu and Nitta 1997).

✓ Anomalies in the monsoon circulation may accompany significant changes in the hydrological cycle over the North Pacific through anomalous evaporation from warm ocean surfaces and precipitation. Therefore, interannual and decadal modulations in the winter monsoon could have significant climatic implications.

✓ This study investigates a decadal climate shift over East Asia in winter, focusing on the changes in hydrological cycle as well as large-scale circulation.

Experimental Design

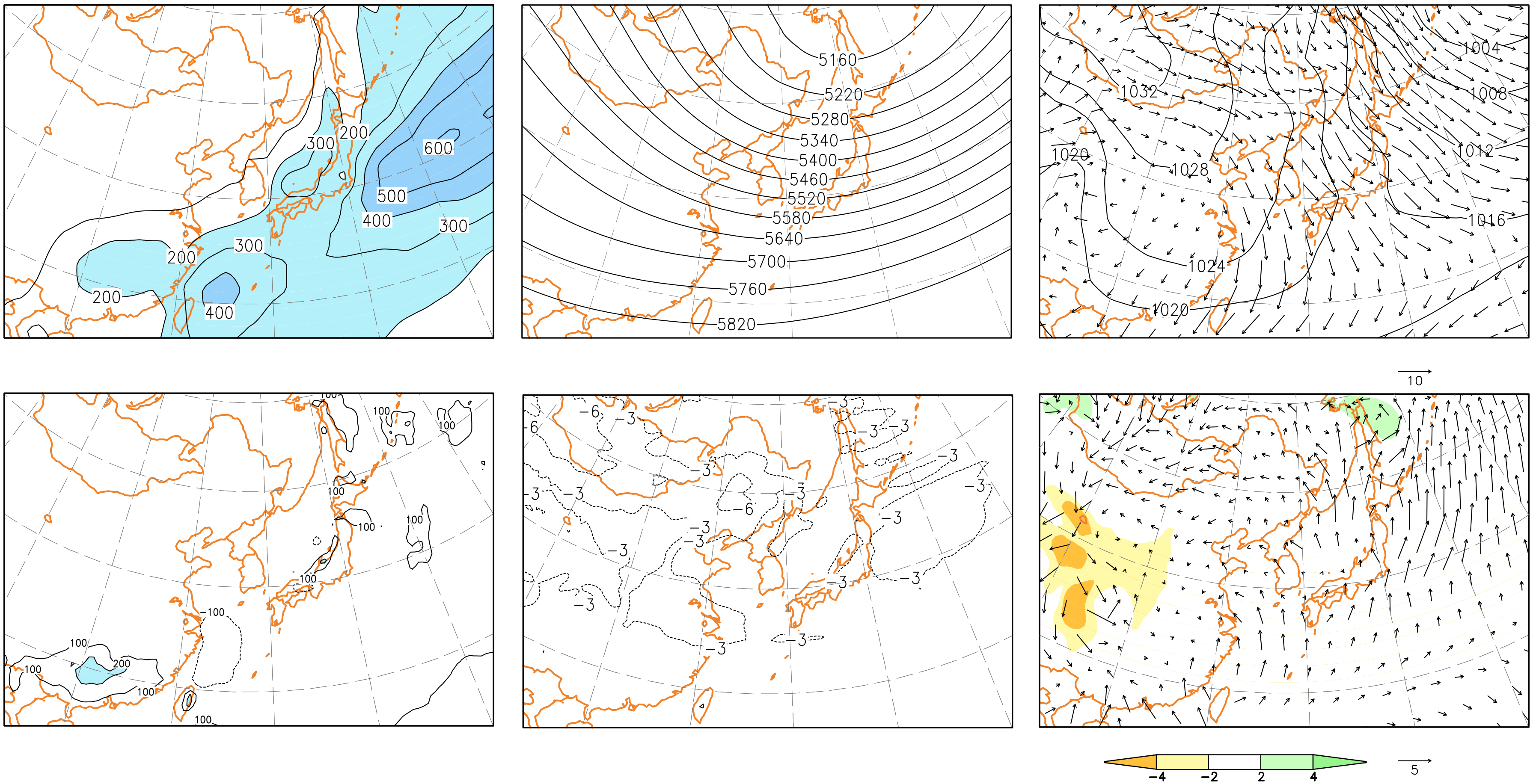
- Model : NCEP RSM (Juang et al. 1997)
- Grid : 129×86
  (horizontal resolution : 50km)
- Period : 1979-2007 DJF
- BDY : NCEP/DOE Reanalysis II data (R2)



- Physics: OSULSM2
  YSUPBL (Hong et al. 2006)
  SAS
  SSBC (Kanamaru and Kanamitsu 2005)

29-year mean of CMAP/R2& difference with the RSM

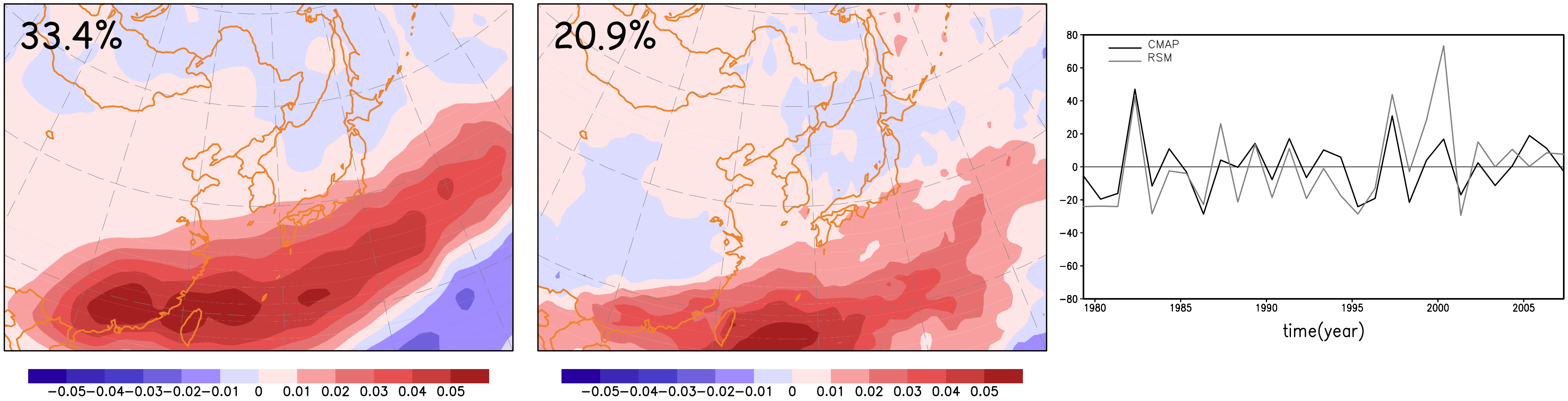
Precipitation | 500-hPa G.H. | 10-m wind & sfc P.



EOF analysis of precipitation (1st mode)

To characterize the interannual variability of physical fields, empirical orthogonal function (EOF) analysis is applied to,,

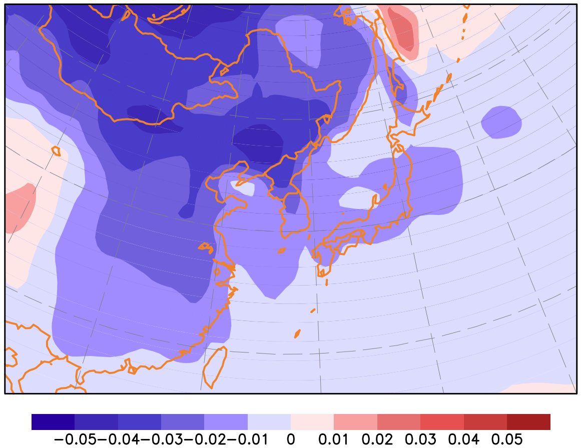
CMAP RSM



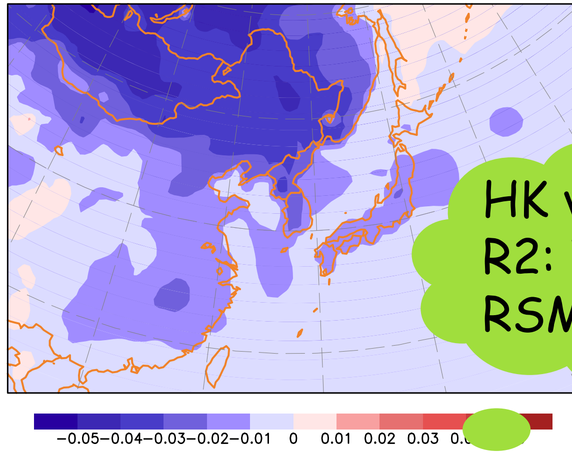
Both the CMAP and simulated precipitation are characterized by a positive-negative pattern in the north-south direction. However, the positive area simulated by the RSM is biased southward compared to the CMAP.

EOF analysis of surface temp. (1st mode)

R2

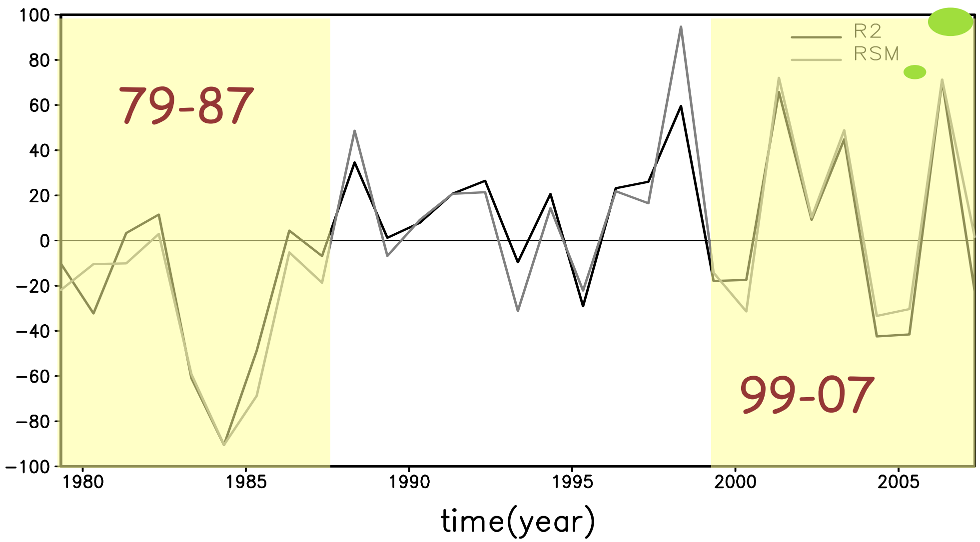


RSM



HK values
R2: 7.7
RSM: 13.4

The first dominant mode is characterized by negative ... ver the whole domain. ... n abrupt change in ... node of the PC time ... n the late 1980s.



To investigate the statistical significance in decadal change,

Lepage test (Lepage 1971)

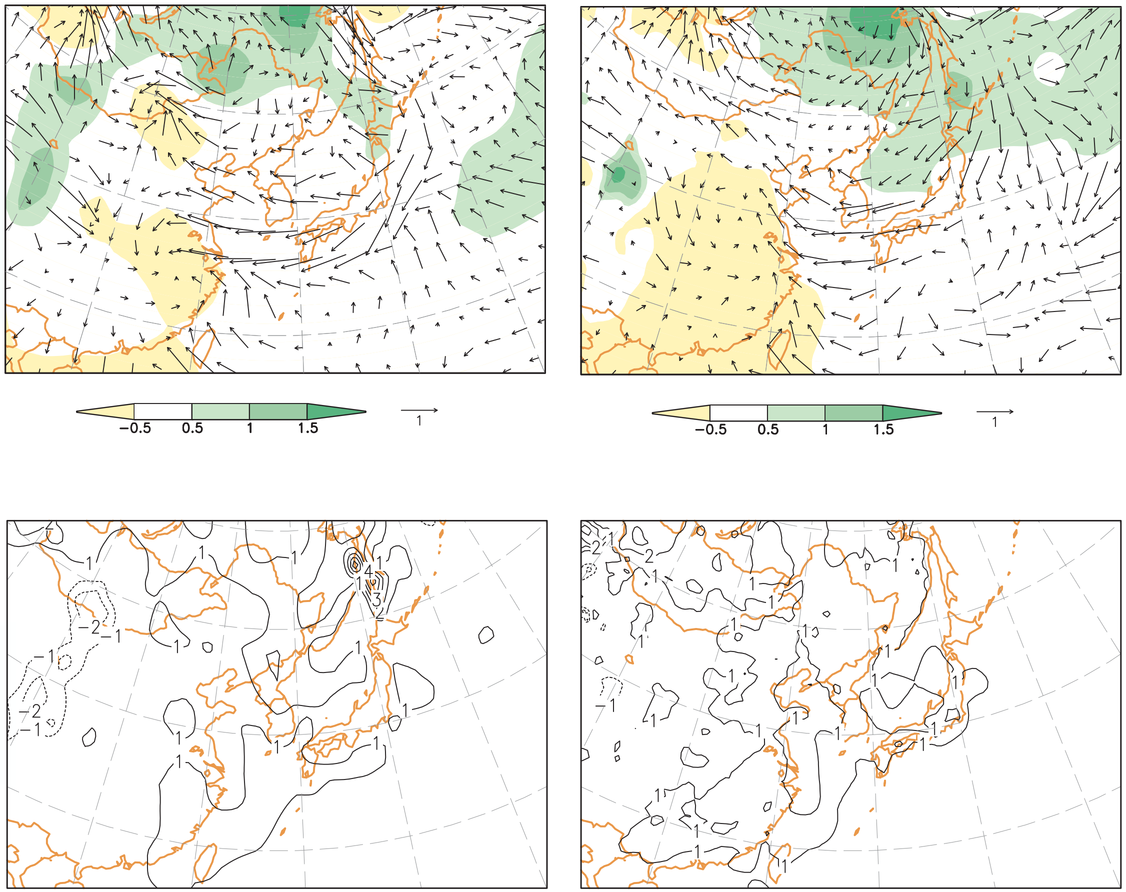
Lepage statistic (HK)
If HK > 5.99 or 9.21,
the mean change is significant at 95% or 99% confidence levels.

Climate change (99-07 minus 79-87)

R2 | RSM

10-m wind & sfc press.

sfc temp.



Weakened northwesterlies are significant, which is attributed to a smaller east-west surface pressure gradient and weaker northerly flow over the eastern coast of the Asian continent.

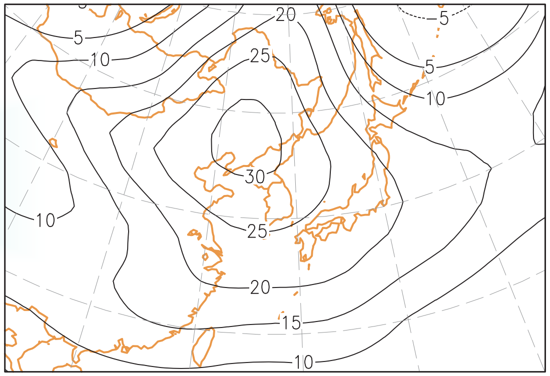
Strengthening of the southerlies brings in more warm air, which results in higher temperature.

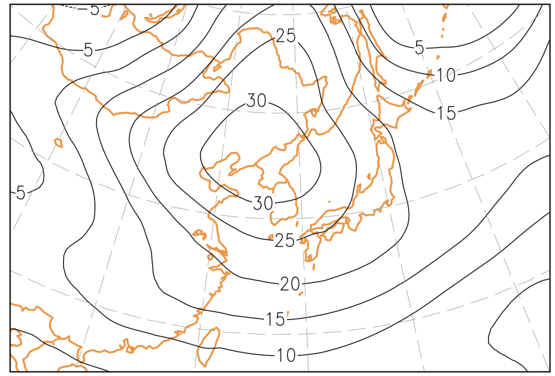
Climate change (99-07 minus 79-87)

R2

RSM

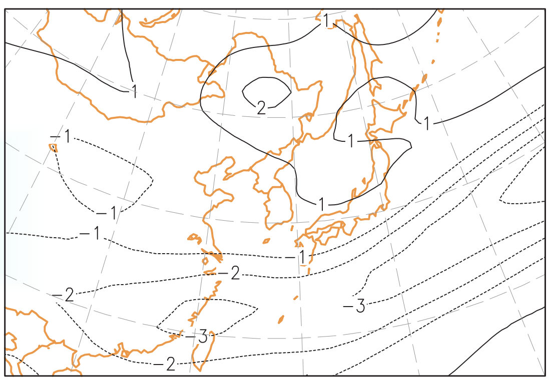
500-hPa height

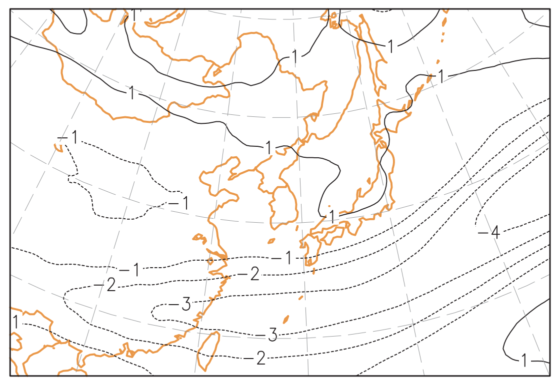




Differences show positive values, indicating weakened coastal trough.

200-hPa wind



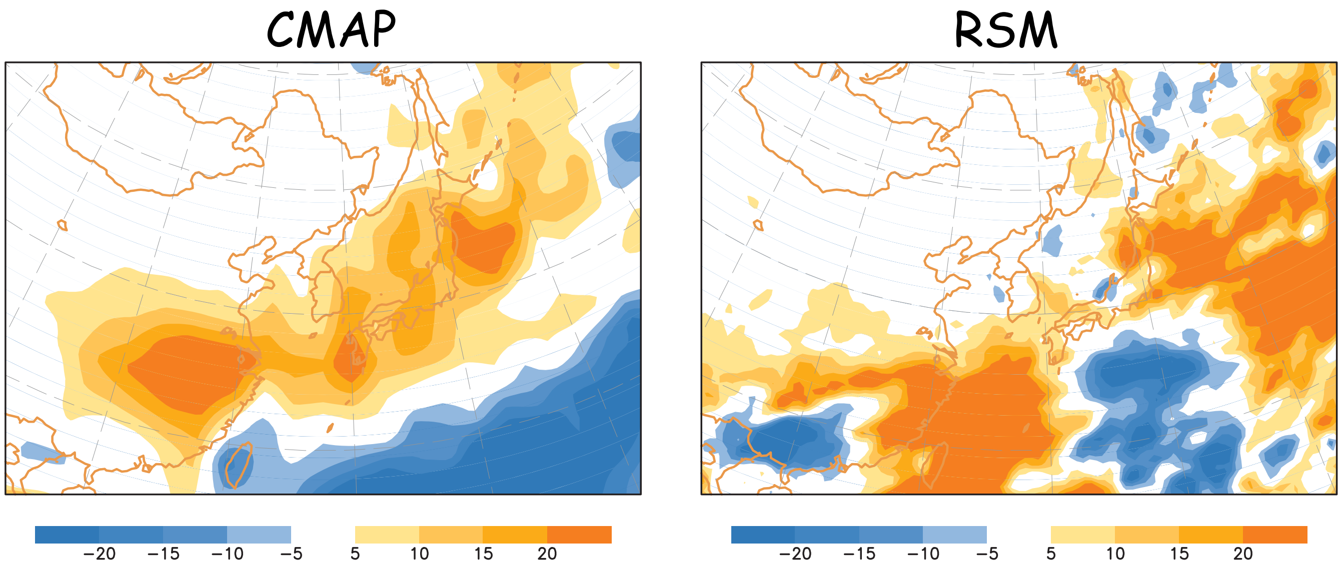


The average of the last 9 winters is weaker East Asian jet, and not extended to the east. Also, zonal wind to the northern side of the jet is intensified.

The horizontal wind shear at the upper troposphere is weaker during the last 9 years. This anticyclonic shear may weaken the East Asian coastal trough of the midtroposphere.

Precipitation change (99-07 minus 79-87)

To examine whether recent decadal variation in monsoon activities over East Asia are accompanied by significant changes in precipitation,,



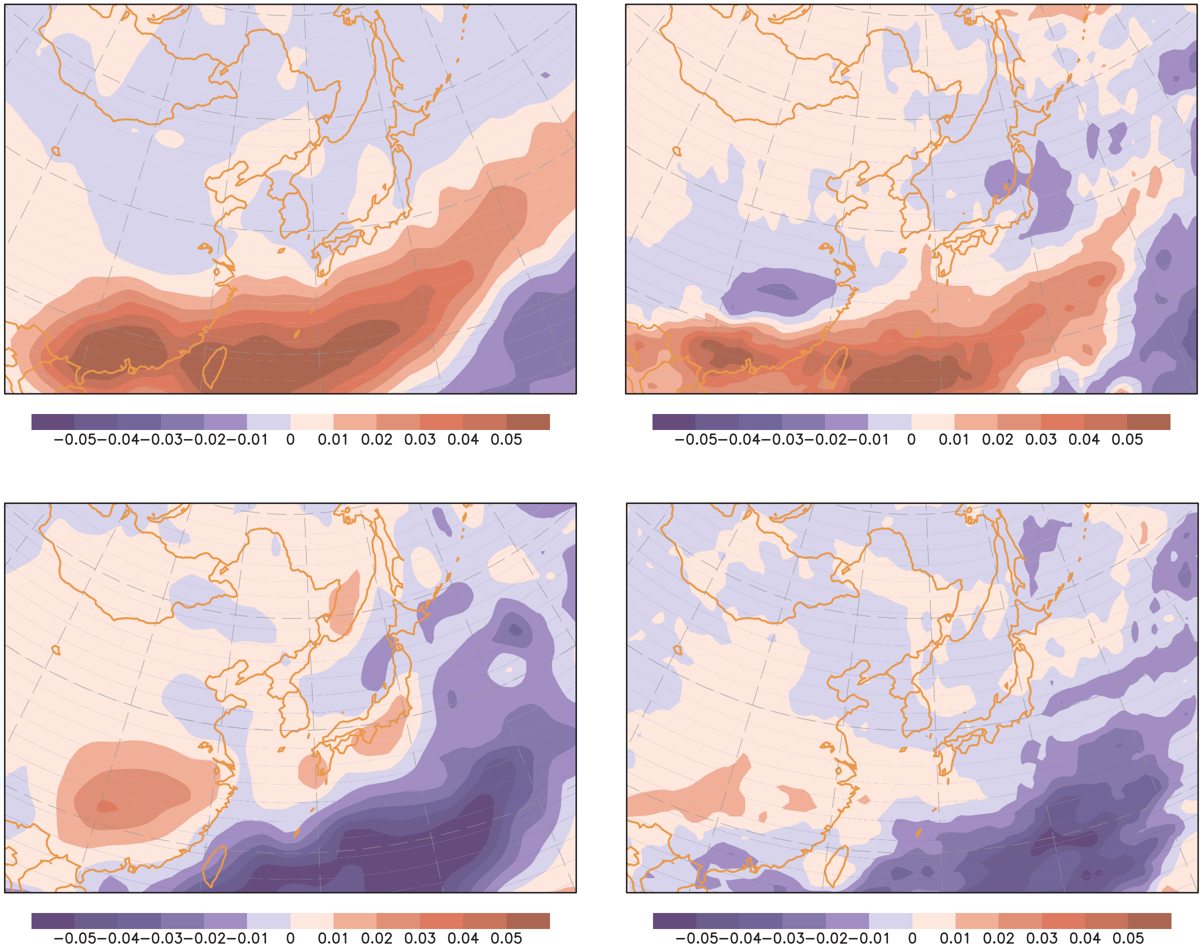
The increasing trend is extended from southern China to Japan, and the decreasing trend is seen in the oceans. The model captures the trend of precipitation changes, however, it simulates the areas of increasing trend southward and underestimates decreasing trend over the oceans.

EOF analysis of precipitation (1st mode)

CMAP | RSM

79-87

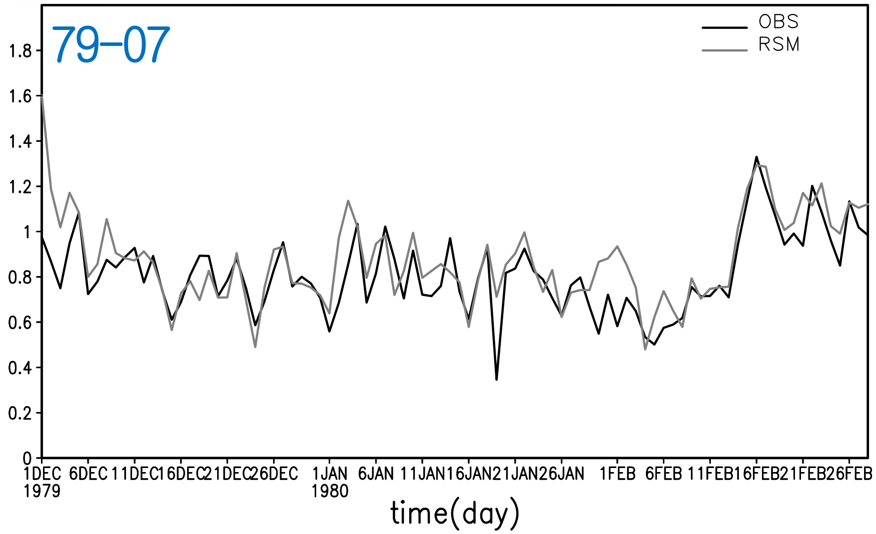
99-07



Both observation and simulation shows a positive-negative pattern in the north-south direction

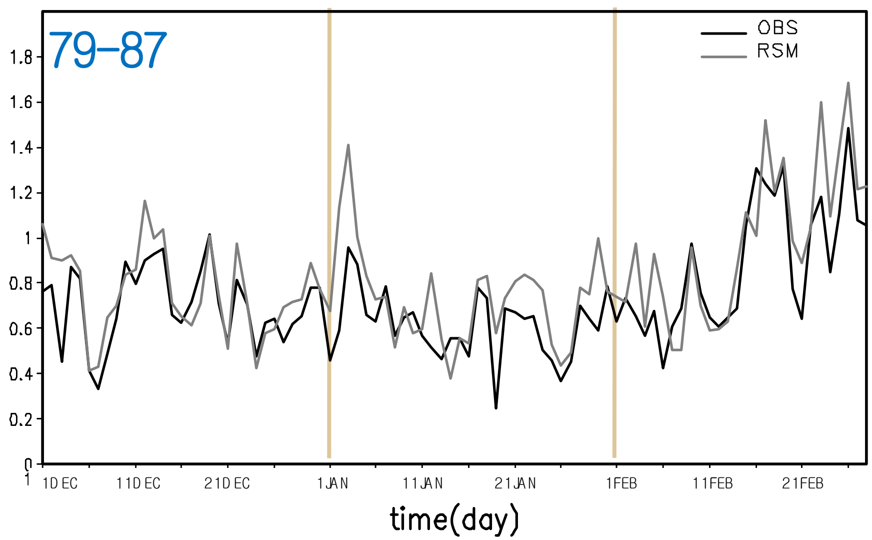
Large negative values over the oceans and a positive mode over southern China are reproduced.

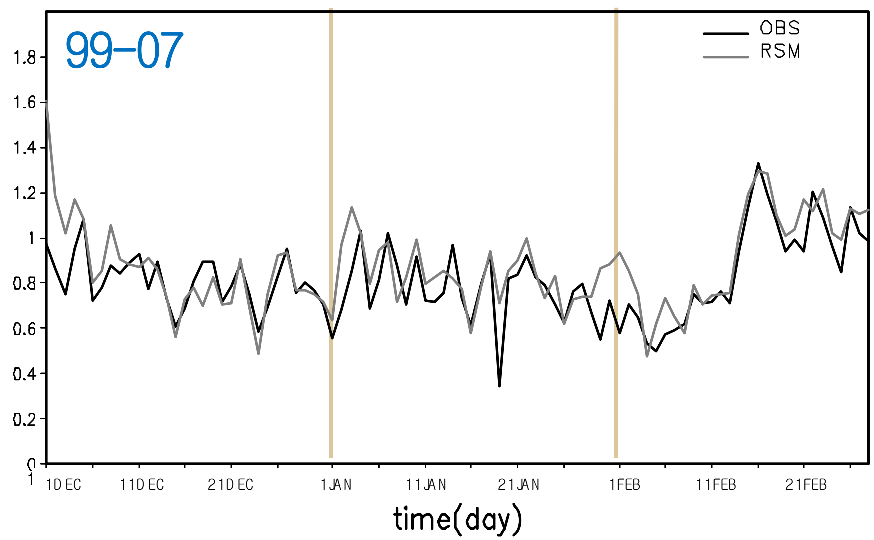
Daily Precipitation (mm/day) over East Asia (land only)



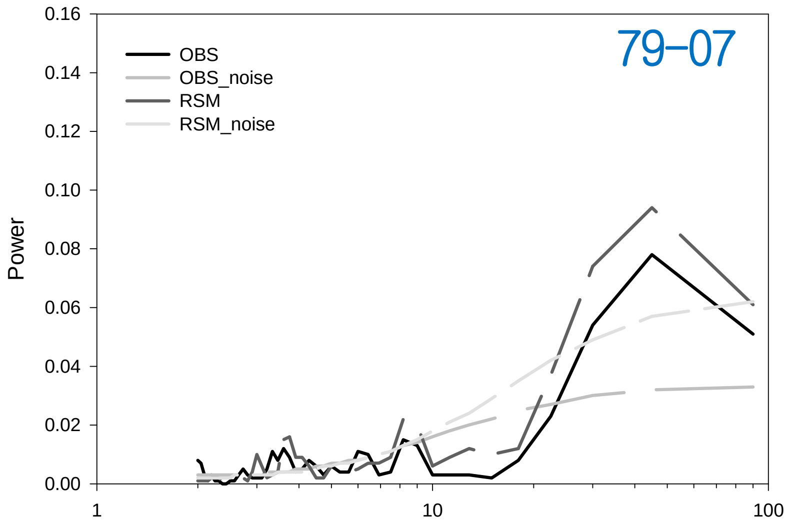
Despite increased amounts compared to the observation, the daily evolution of precipitation is captured by the RSM with a correlation of 0.77.

In the first 9 winters, it is found that the simulated and observed precipitation amounts during February are larger than December or January. Meanwhile, no months has particularly more precipitation than any other month during the last 9 years.



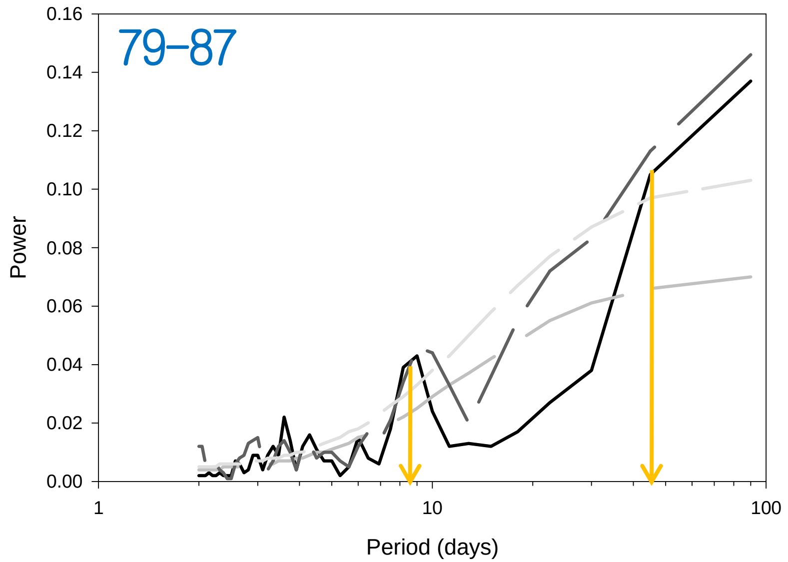


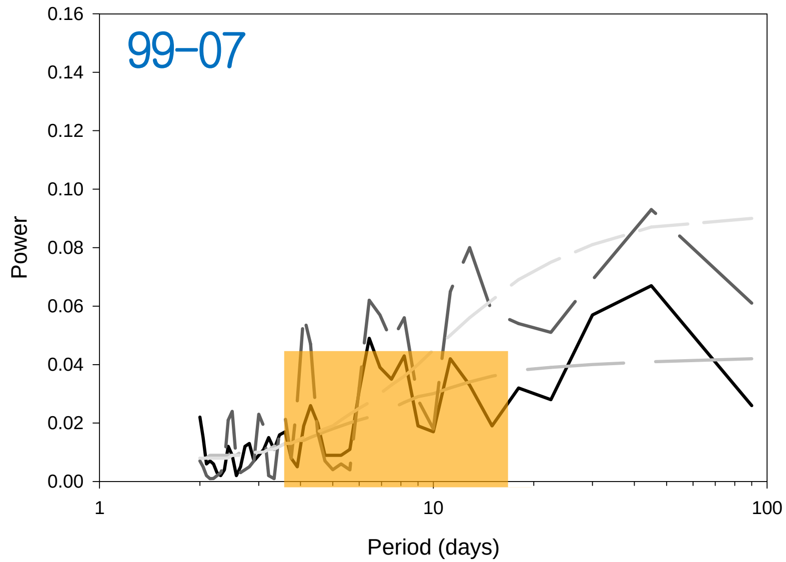
Power spectrum of precipitation (land only)



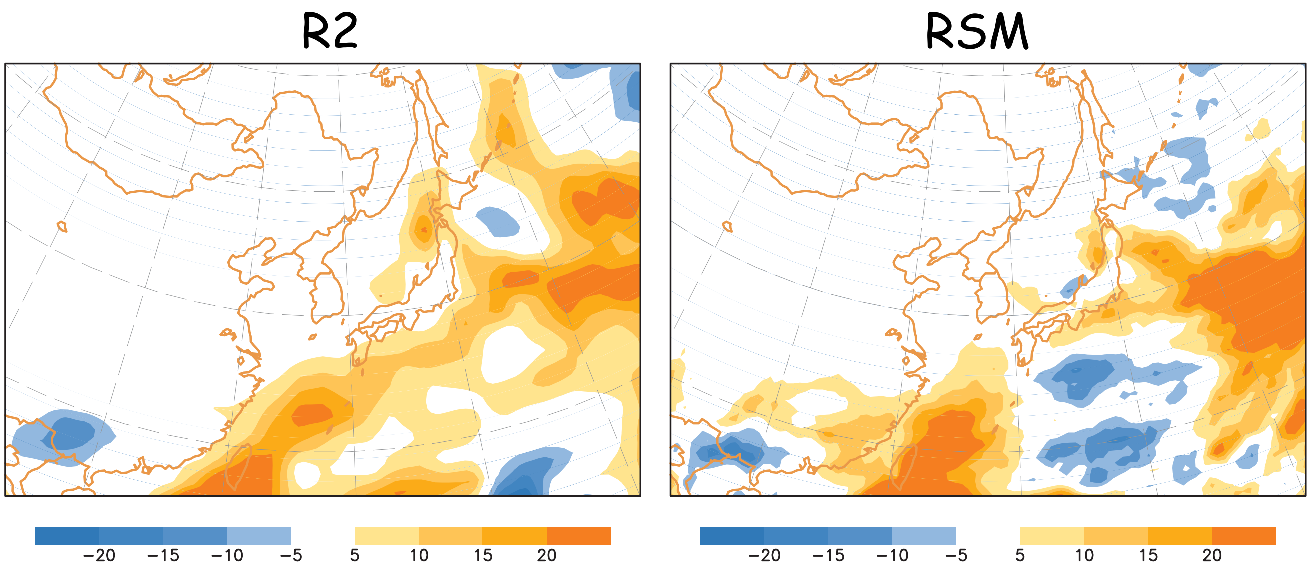
In observed precipitation, the first 9 yr have two significant peaks in power near 8.5 days and 45 days, whereas the last 9 yr show less power and have more widely spread peaks between 3 and 10.5 days compared to the first 9 yr.

The change in precipitation occurs in daily evolution, although the change in the dominant pattern is not significant. The model simulation does not capture these changes in precipitation frequency.





Convective precipitation change (99-07 minus 79-87)



Failure to accurately simulate precipitation changes for the last 9 winters is rooted in increased convective precipitation. Convective precipitation from reanalysis data is significantly increased along a belt lying over the oceans, in spite of the area where total precipitation is decreased. Enhanced convective rainfall indicates that parameterized convection is crucial to the successful simulation of mesoscale features.

The simulated convective rainfall is also increased. The pattern of convective precipitation change is similar to the total precipitation change, which implies that grid-resolvable precipitation due to baroclinic instability is decreased. It is found that the failure to simulate rainfall change is mainly caused by the uncertainty in the convective parameterizations.

Concluding remarks

- This study investigated a decadal climate shift over East Asia in winter, focusing on the changes in the hydrological cycle as well as large-scale circulation using the NCEP RSM.

- Although the RSM is capable of capturing the large-scale circulation change between the first 9 and last 9 winters, precipitation changes are not well reproduced.

- Degradation of the model performance in later years is significant. Analyses of the spectral power reveal that compared to the first 9 winters, observed monthly variation decreased during the last 9 years. However, the model is not able to capture the weakened monthly variation

Concluding remarks

- The fact that the ratio in both R2 and the RSM simulation is mostly due to the cumulus parameterization algorithm. Realizing that the activation of subgrid precipitation processes due to the cumulus parameterization scheme is responsible for the removal of the convectively available potential energy (CAPE), the characteristics of the precipitation mechanism in recent years could be due to buoyancy-driven local instability rather than the large-scale-driven baroclinicity.

- The model's relatively poor ability to simulate precipitation in recent years indicates that additional factors need to be considered for climate change study under global warming conditions using regional climate models, and this suggests that further efforts should be directed toward the development of proper precipitation physics package reflecting trends of climate change.

THANK YOU