Intercomparison of Reanalysis Products as Boundary Conditions of Cloud Resolving Modeling

Hiroshi G. TAKAHASHI[1], Takao YOSHIKANE[1]
and
Tetsuzo YASUNARI[1,2]

1: Frontier Research Center for Global Change (FRCGC), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokohama, Japan
2: Hydrospheric Atmospheric Research Center (HyARC), Nagoya University, Nagoya, Japan

1. Introduction

Dynamically and statistically downscaling methods will be more important for understanding of climate changes on regional scale. In this recent decade, the global warming has been one of the most important issues, which is a worldwide problem. Although a climate change on regional scale is probably much severer than the global climate change, it would be a coming issue. Because a hydrological cycle, including rainfall, has stronger non-uniformity, compared to a parameter like temperature, it would be a coming challenging issue of the climate changes. Also, the changes in the hydrological cycle presumably has significant influences on biosphere on the earth, including human beings. Regional climate model is a practical option of the investigation of the regional climate changes. Actually, initial and boundary conditions are needed for simulations of a regional climate model, which strongly affects their simulations. Most of realistic simulations of regional climate models have been using major reanalysis products as initial and boundary conditions. However, previous studies (e.g. Trenberth et al. 2005) have been noted that the major reanalysis products have large differences. This study compares reanalysis products, in terms of initial and boundary conditions of a cloud resolving model simulations.

2. Data and Model Design

In this study, three major reanalysis products are given as initial and boundary conditions. The reanalysis products are NCEP/NCAR (hereafter NCEP1; Kalnay et al. 1996) reanalysis, ERA40 (Uppala et al. 2005) reanalysis, JRA25 (Onogi et al. 2007). Trenberth et al. (2005) noted that water vapor fields have large discrepancy. To compare total column-integrated water vapor of an observation to a reanalysis, NASA (National Aeronautics and Space Administration) Water Vapor Project (NVAP, Randel et al. 1996) are used as a observational data.

The Southeast Asian monsoon region is one of highest rainy area, which was selected as computational target region. As observation of rainfall, we select the TRMM-PR precipitation, which is included in TRMM 3G68 product. We used 8-year climatology from 1998 to 2005.

ARW-WRF(V2.1) meso-scale model was used for simulation. The model was integrated from 1 to 30 June 1998. The dual nested computational grids are depicted in Figure 1. Grid 2 (the inner grid) and 1 (the outer grid) have grid increments of 5 km and 25 km, respectively. The each grid has 31 vertical layers. The model top is located at 50 hPa. We didn't used cumulus convective parametrization on the both grids, because it artificially changes the diurnal patterns of rainfall. WRF Single-Moment 6-Class microphysics scheme (WSM6) was used for Grids 1 and 2. The Noah land surface model was employed as the surface scheme.

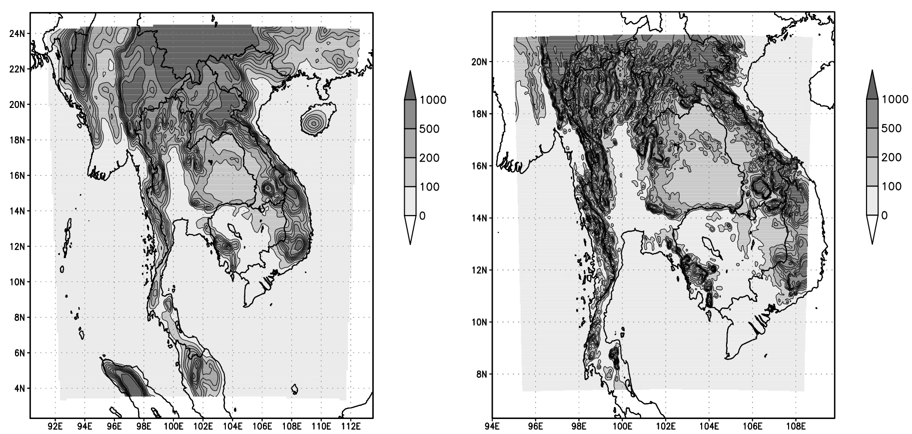

Figure 1: Domains of numerical simulations are shown. Left (Right) panel shows the outer (inner) domain.

3. Results

3a. *Climatological Rainfall Distribution and Amount*

Figure 2 shows the climatological total rainfall in June over the Indochina Peninsula, which was observed by TRMM-PR. The climatology was computed based on the 8-year average of monthly rainfall. Great rainfall regions where total rainfall exceeds 600 mm month^{-1} exist over the eastern Bay of Bengal, offshore of the northeast coast of the Gulf of Thailand and the west to the Annam mountain range. The distribution of rainfall clearly shows relationship between the monsoon westerlies and the mountain ranges.

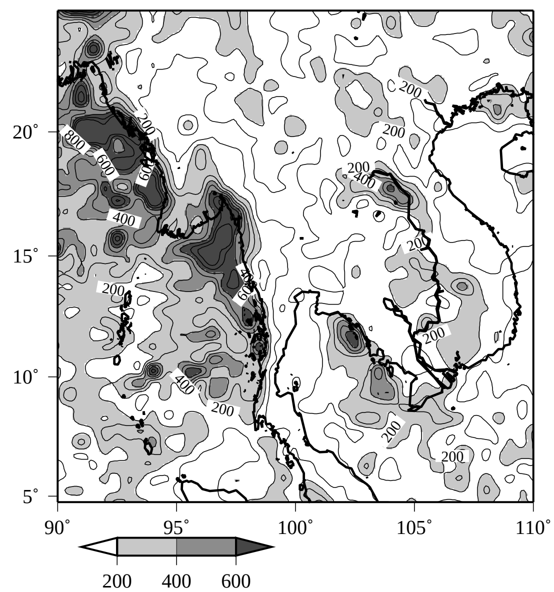

Figure 2: Climatological monthly rainfall (mm month^{-1}) from TRMM-PR.

3b. *Simulated Rainfalls and Atmospheric Circulations*

Figure 3 shows the simulated rainfall (left panel: CTL-ERA40, right panel: CTL-NCEP1) from 3 to 30 June 1998 over the Indochina Peninsula. The unit was converted to mm month^{-1}. When we use ERA40 as initial and boundary conditions, presumable rainfall were simulated over and around the Indochina Peninsula (CTL-ERA40). The rainfall peaks are located over the eastern Bay of Bengal, the offshore of the northeastern coast of the Gulf of Thailand and the west of the Annam mountain range, which were very similar to the observations. The rainfall amounts over the eastern Bay of Bengal, the northeastern coast of the Gulf of Thailand and the west of the Annam mountain range exceeded 600 mm month^{-1}, which were consistent with the observation. The CTL-ERA40 captured not only the distribution but also the quantity of rainfall. On the other hand, the performances of the CTL-JRA25 and CTL-NCEP1 was quite poor. Although the peaks of rainfall might be simulated over the eastern Bay of Bengal, the quantity was remarkably lower than the observation. The differences between these simulated rainfall suggest that NCEP1 is not available for the rainfall simulation in this region. Although the CTL-JRA was better than NCEP1, the simulated rainfall amount was much less.

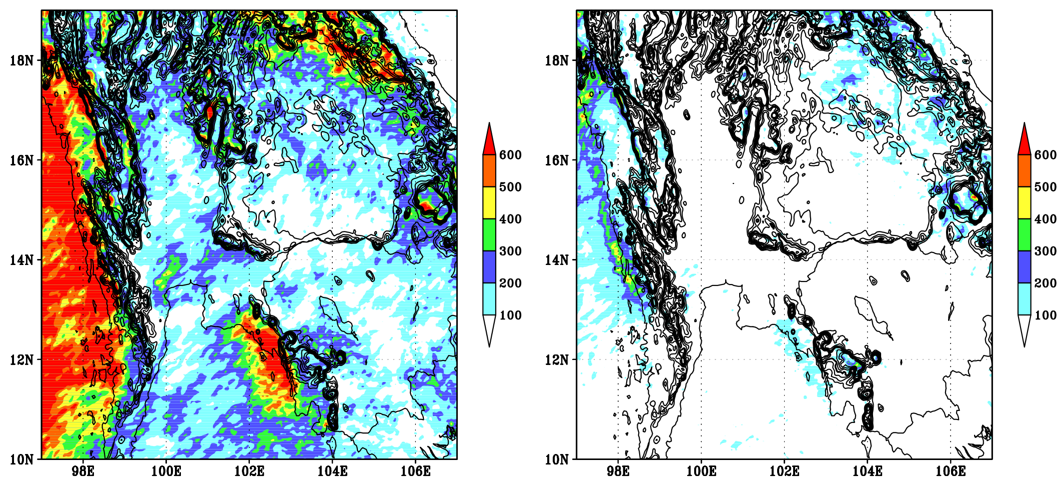

Figure 3: Simulated monthly rainfall of CTL-ERA40 (left) and CTL-NCEP1 (right) over the Indochina region. Unit is mm day^{-1}.

3c. *Differences in precipitable water*

Trenberth et al. (2005) noted that there was a large discrepancy in the water vapor field. Figure 4 shows the climatological mean PW during summer (JJA). Highest PW was observed over the Bay of Bengal, which is consistent with the rainy peak (Figure 2). Also, high PW exists over the South China Sea and west of the Philippines. Although the 3-month mean PW was averaged for 12 years, the PW over the Bay of Bengal estimated to 62 mm, which is one of the highest precipitable water regions.

In comparison to the PW$_{NVAP}$, the PW of ERA40 was little overestimated. The 3-month mean PW$_{ERA40}$ was 64 mm over the Bay of Bengal, a few percent of PW was overestimated. Peaks in PW$_{ERA40}$ over the Bay of Bengal, Tonkin Gulf and west of the Philippines corresponds with the observation (PW$_{NVAP}$). On the other hand, the 3-month mean PW$_{NCEP1}$ over the Bay of Bengal was calculated to about 54 mm. The underestimation of the PW is roughly 10 % of the total PW in the 12-year climatological mean. This result shows that PW$_{NCEP1}$ is much drier than PW$_{ERA40}$ and PW$_{NVAP}$ over Southeast Asian, implying that the much less rainfall was affected by much drier reanalysis data. JRA25 shows intermediate between the two (not shown).

4. Summary

This study compared reanalysis products in terms of the initial and boundary conditions of a cloud resolving model. Three simulations were conducted over the tropical Southeast Asian monsoon region. Atmospheric conditions were given from the three reanalysis products (ERA40, JRA25 and NCEP1), surface and soil conditions were given same conditions (NCEP1). Over the tropics, cumulus convective parametrization may change the diurnal patterns of rainfall and amount of rainfall. Thus, the dual-nested simulations without cumulus convective parametrization were conducted.

Basic atmospheric circulations, such as large-scale monsoon westerly flows and disturbances, could be simulated on all of the three control simulations. The simulation derived by the NCEP/NCAR reanalysis (CTL-NCEP1) could not show presumable monsoon rainfall quantitatively, although the spatial distribution of rainfall is not largely different. The rainfall amount of the CTL-NCEP1 was much less. The CTL-ERA40 could simulate monsoon rainfall over and around the Indochina Peninsula. The peak rainfall area of the observations over the eastern Bay of Bengal, northeastern Gulf of Thailand and the west of Annam mountain range has more than 600 mm month^{-1}, which was simulated in the CTL-ERA40. CTL-JRA25 was intermediate between the two (not shown). The rainfall amount of CTL-JRA25 was less than observation. Thus, the CTL-ERA40 was closest to the observation.

The differences of PW among the three products over the the Bay of Bengal and South China Sea were quite large. The difference between PW$_{ERA40}$ and PW$_{NCEP1}$ was estimated to approximate 10% of PW fields in total field over the Bay of Bengal.

We concluded that the quantity of PW has large impact on the simulation over the Southeast Asian monsoon region. Because the NCEP1 is relatively dry over the whole tropics, the difference is one of the most essential issues on dynamical downscaling.

References

Kalnay, E. et al., 1996: The NCEP/NCAR 40-Year Reanalysis Project. *Bulletin of the American Meteorological Society*, **77**, 437–471.

ONOGI, K. et al., 2007: The JRA-25 Reanalysis. *Journal of Meteorological Society of Japan*, **85**, 369–432.

Randel, D.L. et al., 1996: A New Global Water Vapor Dataset. *Bulletin of the American Meteorological Society*, **77**, 1233–1246.

Trenberth, K., J. Fasullo, and L. Smith, 2005: Trends and variability in column-integrated atmospheric water vapor. *Climate Dynamics*, **24**, 741–758.

Uppala, S.M. et al., 2005: The era-40 re-analysis. *Quart. J. Roy. Meteor. Soc.*, **131**, 2961–3012.

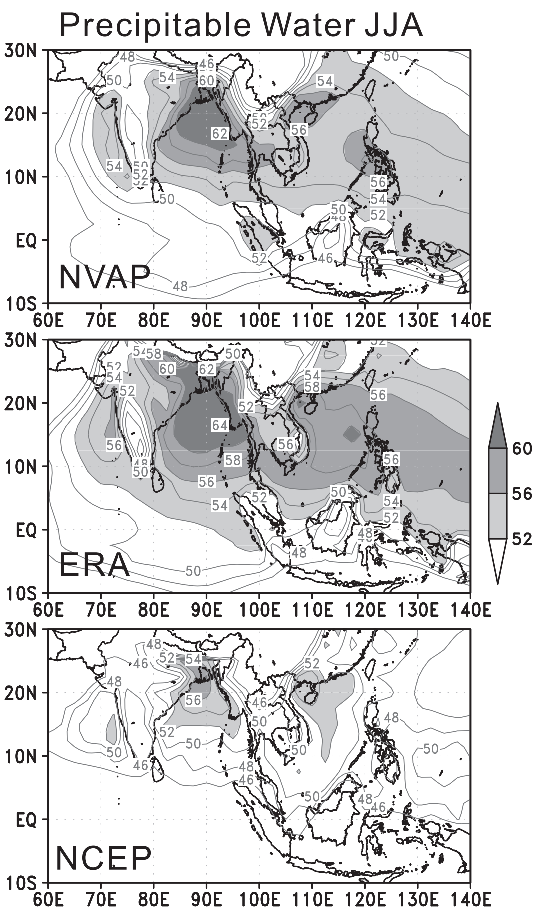

Figure 4: Precipitable water of NVAP, ERA40 and NCEP over the Southeast Asian monsoon region.