The impact of convective parameterization schemes on the tropical precipitation diurnal cycle simulated by MRI-AGCM3

[1,2]Osamu Arakawa, [2]Hideaki Kawai and [2]Hiromasa Yoshimura
[1]University of Tsukuba, [2]Meteorological Research Institute, Japan Meteorological Agency
E-mail: oarakawa@mri-jma.go.jp

Nakamura (2009) showed that the precipitation diurnal cycle simulated by the Japan Meteorological Agency (JMA) short range forecast model over the Japanese islands in the boreal summer has its maximum in the evening, and this is in good agreement with the observations. Here, we compare the diurnal cycle of tropical precipitation simulated by the Meteorological Research Institute (MRI) global atmospheric model (MRI-AGCM3.2; Mizuta et al. 2012) with that in the observations from the viewpoint of the phase of the diurnal cycle; i.e., the timing of the daily precipitation maximum (and minimum). The model has three cumulus convective parameterization schemes: the Yoshimura scheme (Yoshimura et al. 2015, YMM); the prognostic Arakawa–Schubert scheme (Randall and Pan 1993, AS); and the Kain–Fritsch scheme (Kain and Fritsch 1990, KF). MRI-AGCM3.2 that uses the AS scheme is similar to the JMA short range forecast model. We conducted three experiments using MRI-AGCM3.2: (1) YMM (3.2YMM), (2) AS (3.2AS), and (3) KF (3.2KF). In these experiments the horizontal resolution of the model was a linear triangular truncation at wave number 319 (TL319), corresponding to the grid size of 60 km at the equator. The sea surface temperature (SST) and sea ice distribution given to the model were obtained from HadISST1.1. The period of numerical integration was 1979–2003. We compared the simulated 25-year average hourly precipitation with the observed 10-year climatology derived from the Tropical Rainfall Measuring Mission (TRMM) 3G68V7/PR gridded precipitation radar product, which only covered the period 1998–2007 because of restricted data availability.

Figure 1 shows the annual mean precipitation diurnal cycle for the tropics (30°S–30°N) over land and ocean. Over land, the observed precipitation has its maximum at 1600 local time (LT). However, the simulated precipitation in the 3.2YMM and 3.2KF runs has its maximum at 1400 LT, two hours earlier than that in the observations, that is a problem shared among global atmospheric models. In 3.2AS, precipitation has its maximum at 1700–1800 LT, 1–2 hours later than the observations. Minimum precipitation over land in all experiments is a few hours earlier than the observations (0900–1000 LT). Over ocean, observed precipitation reached its maximum (minimum) at 0500–0600 LT (1900–2000 LT). The diurnal cycle in all experiments of MRI-AGCM3.2 is close to that in the observations. In addition, oceanic precipitation in 3.2AS had a secondary maximum at 1400–1500 LT, and the observations showed a similar secondary maximum in the afternoon (1300 LT).

Over land, the precipitation maximum in run 3.2AS was a few hours later than in 3.2YMM and 3.2KF. The diurnal cycle in 3.2AS was similar to that in 3.2YMM and 3.2KF between midnight and 1000 LT. However, after 1000 LT the increase rate of hourly precipitation in 3.2AS was lower than that in 3.2YMM and 3.2KF. The reduced convective activity during the daytime in 3.2AS would be associated with the DCAPE scheme (Nakagawa 2008, Xie et al. 2000) introduced in 3.2AS.

To examine the impact of the DCAPE scheme on the precipitation diurnal cycle, we compared our results with the hourly precipitation simulated by MRI-AGCM3.1 (3.1AS; Kitoh et al. 2009), which uses AS as its convective parameterization but does not include the DCAPE scheme, under the same boundary conditions. Over land, the precipitation diurnal cycle in 3.1AS has its maximum (minimum) at 1400–1500 LT (0700 LT), which is similar to that in 3.2YMM and 3.2KF. Over ocean, on the other hand, the cycle in 3.1AS is similar to that in 3.2AS. The DCAPE scheme would delay the timing of precipitation diurnal cycle over land, although the fact that some of the physical processes used in MRI-AGCM3.1 differ to those in MRI-AGCM3.2 (e.g., the radiation scheme) may also change the timing of precipitation diurnal cycle. The mechanism that causes these differences remains unclear and should be the focus of future research.

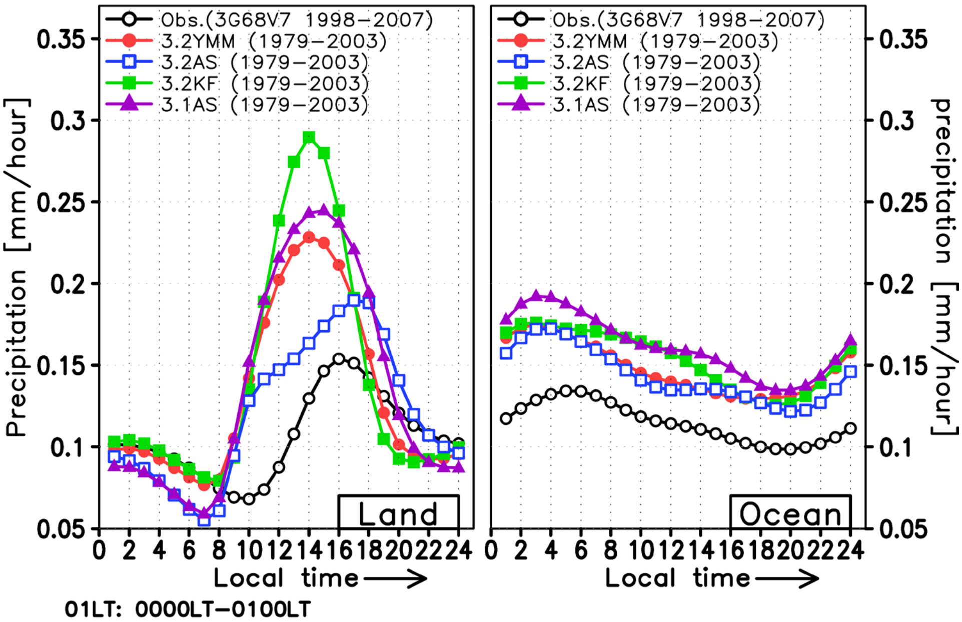

Figure 1: Annual mean precipitation diurnal cycle for the tropics (30°S–30°N) simulated by MRI-AGCM3 over land (left) and ocean (right). Units: mm/hour. Black line shows the observations (TRMM 3G68V7/PR). The red, blue, and green lines are MRI-AGCM3.2 with the Yoshimura (3.2YMM), Arakawa–Schubert (3.2AS), and Kain–Fritsch (3.2KF) schemes, respectively; the purple line is MRI-AGCM3.1 with the Arakawa–Schubert scheme (3.1AS).

Acknowledgements

This work was supported by the Program for Risk Information and Climate Change (SOUSEI program) funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan. We are grateful to Mr. E. Shindo, MRI, who introduced the KF scheme to MRI-AGCM3.2, and we would also like to express our gratitude to Dr. H. Murakami, GFDL/NOAA, for importing the DCAPE scheme into MRI-AGCM3.2.

References

Kain, J. S., and J. M. Fritsch, 1990: A one-dimensional entraining/detraining plume model and its application in convective parameterization. *J. Atmos. Sci.*, **47**, 2784–2802.

Kitoh, A., and co-authors, 2009: Projection of changes in future weather extremes using super-high-resolution global and regional atmospheric models in the KAKUSHIN Program: Results of preliminary experiments. *Hydrological Research Letters*, **3**, 49–53, doi:10.3178/hrl.3.49.

Mizuta, R., and co-authors, 2012: Climate simulations using MRI-AGCM3.2 with 20-km grid. *J. Meteor. Soc. Japan*, **90A**, 233–258.

Nakagawa, M., 2008: Improvement of the Cumulus Parameterization Scheme of the Operational Global NWP Model at JMA. *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modelling*, **38**, 4.09–4.10.

Nakamura, T., 2009: Verification of quantitative precipitation forecasts over Japan from operational numerical weather prediction models. *CAS/JSC WGNE Research Activities in Atmosphere and Oceanic Modelling*, **39**, 6.13–6.14.

Randall, D., and D.-M. Pan, 1993: Implementation of the Arakawa Schubert cumulus parameterization with a prognostic closure. *Meteorological Monograph/The Representation of Cumulus Convection in Numerical Models*, **46**, 137–144.

Xie, S., C., and M. H. Zhang, 2000: Impact of the convective triggering function on single-column model simulations. *J. Geophys. Res.*, **105**, 14983–14996.

Yoshimura, H., R. Mizuta, and H. Murakami, 2015: A spectral cumulus parameterization scheme interpolating between two convective updrafts with Semi-Lagrangian calculation of transport by compensatory subsidence. *Mon. Wea. Rev.*, **143**, 597–621, doi:MWR-D-14-00068.1.