Continental-scale simulation of diurnal variations in South Asian summer monsoon: Insights from the explicit and parameterized convection experiments

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1. *Introduction*

In South Asian Summer Monsoon (SASM), Indian summer monsoon (ISM) is a most crucial season in the annual cycle over the south Asian region, with 80% of the annual precipitation received during ISM (Jain and Kumar, 2012). Gadgil *et al.* (2003) stated that the simulation and prediction of ISM on all scales could be improved. It is requisite to understand the significance of deep convection in the tropics. The representation of such convection in the climate models is a chief source of miscalculation (Sherwood *et al.* 2014). Palmer *et al.* (2007) Showed that the errors in the convection simulation in climate models are due to miss-representation of small-scale processes in convection like diurnal cycle etc. by a physical process. In connection with Indian summer monsoon, the diurnal cycle of convection is the fundamental mode of variability controlled by the solar insolation. Therefore, it is essential for proper simulation of diurnal scale processes in either regional climate models or global climate models (Prein *et al.* 2015; Takahashi *et al.* 2016). In this study, a sensitivity of the diurnal cycle of precipitation to with and without convection parameterized simulations and with variable model resolutions is evaluated.

2. *Numerical setup and analysis*

A suite of three ensemble experiments conducted at different spatial resolutions (25km, 12.5km, and 6.25km), with (convection on, CON) and without cumulus parameterization scheme (convection off, COFF). These continental scale simulations forced by Era-interim six hourly datasets for a period April 1 to October 31. The evaluation performed on peak south Asian summer monsoon season (July-August) and, compared with Tropical Rainfall Measuring Mission (TRMM) three hourly datasets. Harmonic analysis is implemented to assess model simulated diurnal cycle with TRMM precipitation dataset. COFF simulations were performed to know the sensitivity of convection off on diurnal cycle as compared to the utilization of convection parameterization scheme.

3. *Results and discussion*

Simulated precipitation shows that COFF simulations added value in the representation of precipitation diurnal maxima and diurnal phase. Over core monsoon region, the diurnal peak of precipitation is realized around afternoon or later afternoon in COFF simulations especially at 6.25km (fig 1). However, in CON experiments diurnal peak is seen 3-6 hours earlier around noon/afternoon. It is also clear that the fine model resolution does not show any notable improvements in the diurnal cycle

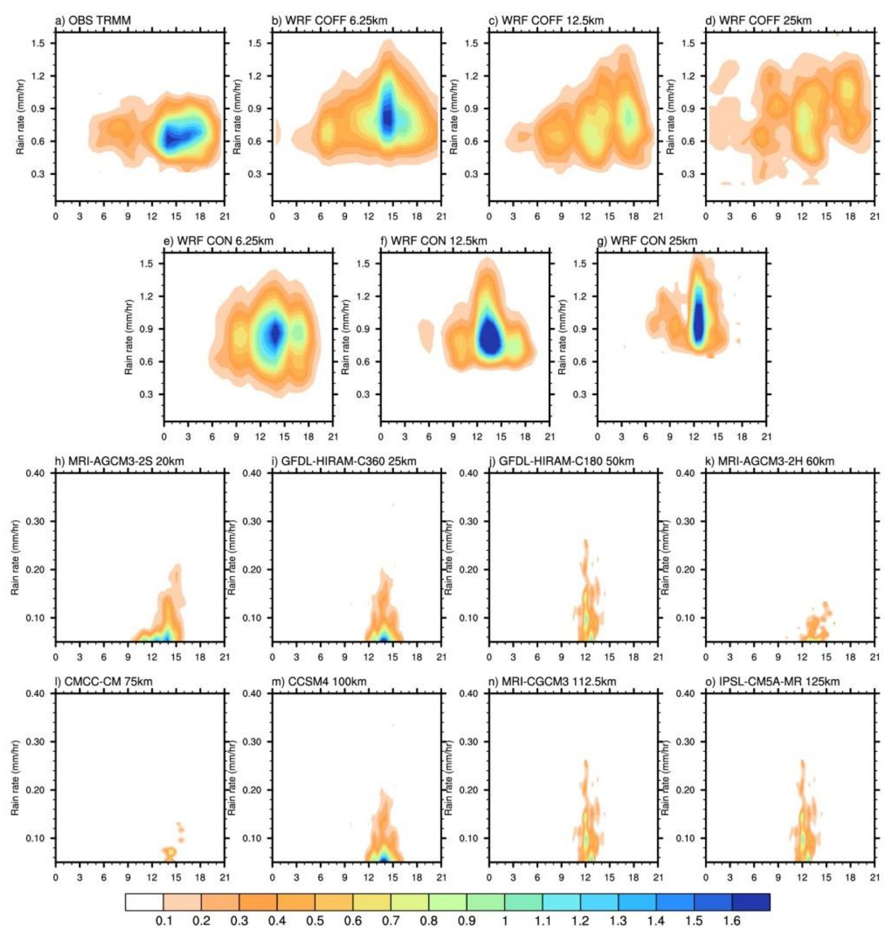

Figure 1:- Joint Probability distribution calculated for diurnal cycle of precipitation with TRMM, WRF simulations and for AMIP models.

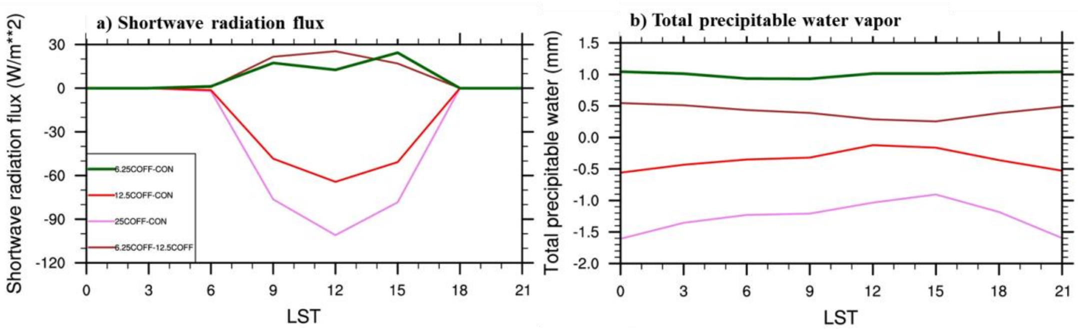

Figure 2:- It shows COFF minus CON diurnal cycle at 6.25km (green), 12.5km (red), and 25km (magenta) respectively. Brown color line shows difference between 6.25km COFF and 12.5km COFF.

phase and magnitude of precipitation. The diurnal cycle of precipitation in eight CMIP AGCM models as well failed to simulate the afternoon/late afternoon precipitation over Indian land region during ISM, except MRI-AGCM3-2S 20km model with afternoon diurnal precipitation peak.

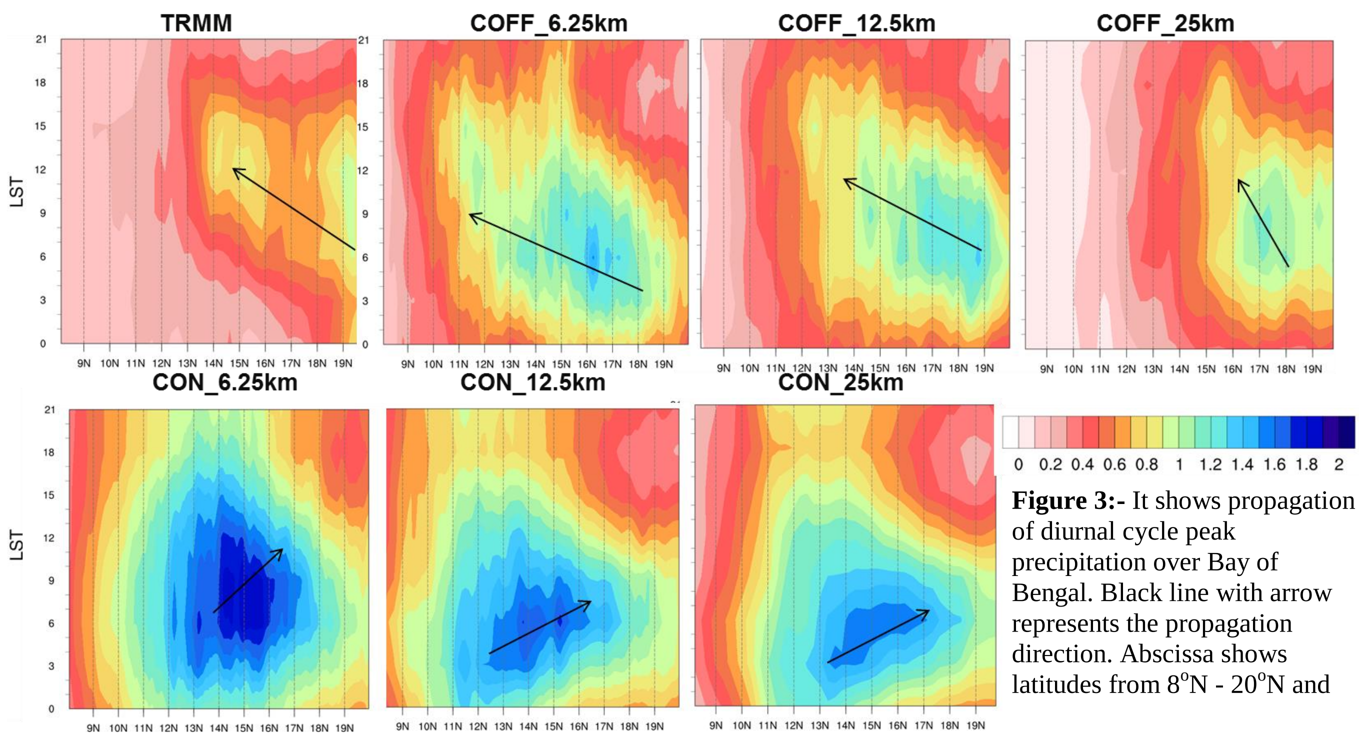

Figure 3:- It shows propagation of diurnal cycle peak precipitation over Bay of Bengal. Black line with arrow represents the propagation direction. Abscissa shows latitudes from 8°N - 20°N and

Over Indian land region, in explicit simulations (fig 2), higher solar insolation increased the surface air temperature, which deepened the monsoon trough. As a result, moisture transport to the land from ocean amplified the amount of available water vapor, and availability of sufficiently higher convective available potential energy triggered convection in the late afternoon. Nevertheless, this late afternoon convection is absent in convection parameterized simulations. On the other hand, over ocean regions like the Bay of Bengal, exhibits two diurnal peaks in the observations during early morning and afternoons, this is evident only in the COFF experiments. Besides, the southward propagation of the diurnal peak precipitation is convincingly captured over the Bay of Bengal in the explicit simulations (fig 3). However, in the convection-parameterized experiments, northward propagation of the diurnal peak precipitation simulated over the Bay of Bengal, which is not realistic. This southward propagation of diurnal peak of precipitation in COFF is associated with the mesoscale convective systems that form over North Bay of Bengal in the early morning time and propagate by afternoon to the south of Bay of Bengal. This improvement in the explicit simulations regarding southward propagation of the diurnal peak over the ocean was due to the presence of a southward component of wind at the 600 hPa; this component is no simulated in the CON experiments. These results outline the prominence of the explicit or modified convection schemes in the models to represent a realistic diurnal cycle of precipitation in Indian summer monsoon, which could simulate monsoon-related precipitation variability accurately

4. *References*

Sugimoto, S. *et al*., 2016: Effect of spatial resolution and cumulus parameterization on simulated precipitation over south Asia. *SOLA*, **12A**, 7-12.

Prein et al., 2015: A review on regional convection-permitting climate modeling demonstration, prospects and challenges. *Rev. Geophys*., **53,** 323-361.