Prediction of the diurnal change of precipitation using a multi model superensemble and TRMM data sets

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Modelling the diurnal change of precipitation is a challenging scientific problem. The phase of the diurnal change varies even within the land and oceanic areas of the tropics. This paper explores satellite data sets and the predicted precipitation from a suite of global coupled atmosphere ocean models to examine the predictability of the phase and amplitude of the diurnal mode. The models are based on several versions of the FSU coupled global models that utilize different physical parameterization schemes. With these models we carry out a large sample of five-day forecasts. This study utilizes 3 hourly TRMM and model based data sets between 40^{o}S and 40^{o}N and highlights the advantage of constructing a superensemble for improving the forecasts of diurnal change since it reduces the large systematic errors for the phase and amplitude of the member models drastically.

The overall picture of afternoon rain over land areas and early morning rain over the oceanic area are only partially true. Strong exception to this rule exists over many land and oceanic areas. Over the eastern Tibetan Plateau, during the northern summer season, afternoon showers are prevalent, however if we proceed 300 km to the southeast over the eastern foothills of the Himalayas the rainfall maximum occurs in the early morning hours. The aforementioned asymmetries within land or within ocean domain of the tropics suggests the possible complexity involved in the modelling of these features.

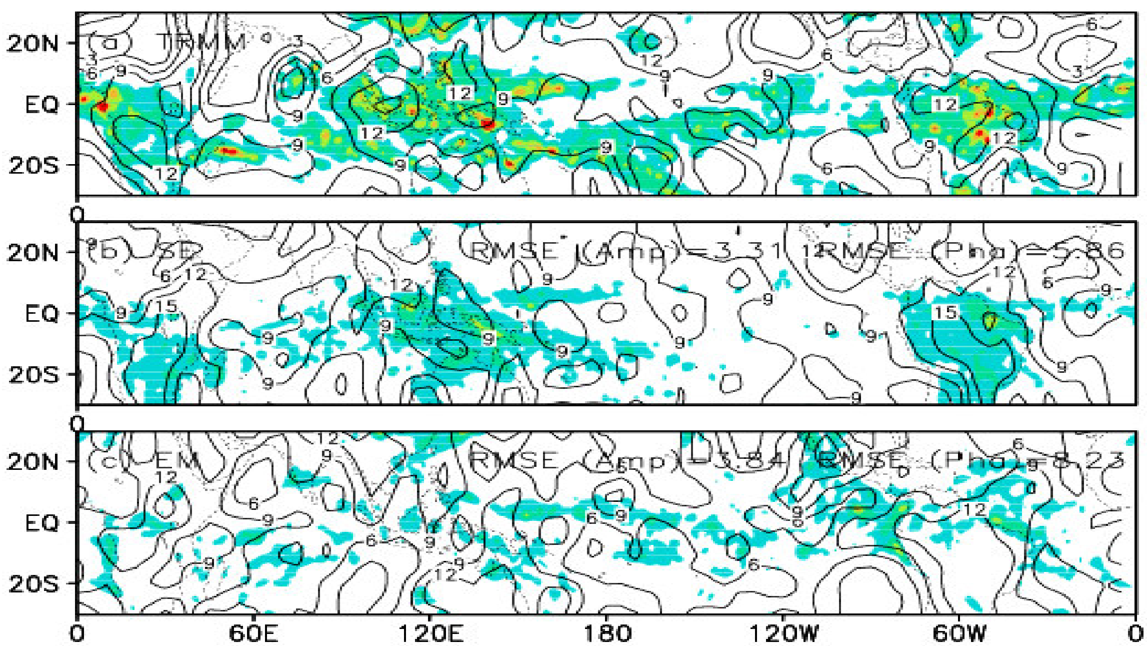

Fig. 1: Amplitude and phase (diurnal cycle) during 31 Mar–4 Apr 2000(Day 5 forecast)

(Top panel: TRMM, middle panel: Super Ensemble, bottom panel: Ensemble Mean)

Figure 1 describes the amplitudes and phases of the diurnal cycle of the observed, superensemble and ensemble mean of the member models over the global tropics. The rms errors of the amplitude and phase of the diurnal modes predicted for day 1 through 5 of forecasts show that the phase of the superensemble is considerably better than those of the other member model forecasts. The oceans generally carry a phase angle 06 and 09 hours local time (early morning). The land areas of South America and Africa carry a phase angle of around 15 to 18 hours (late afternoon). These features are well captured by the superensemble. These geographical distributions show that the superensemble carries a much better description of the phase of the diurnal mode compared to those of the ensemble mean. The latter carries very large amplitude errors as well. The ensemble mean represents the behavior of the member models that still have larger errors. The superensemble by reducing the systematic errors (locally and globally) reduces the errors very nicely.

Figure 2 illustrates the major improvements in the phase and amplitude for day-5 of forecasts for precipitation over some of the areas where modeling the diurnal cycle is most difficult, i.e., the eastern foothills of the Himalayas (EFH), the eastern Tibetan Plateau (ETP), and the Amazon valley (AMZ). Here we note that it is possible to obtain up to day-5 of forecasts for the phase and amplitudes very close to the observed counterparts for the superensemble (SE) that is trained with the TRMM precipitation data sets. The phase and amplitudes of the ensemble mean of the member models (EM) carry large errors. The superensemble algorithm corrects the bias in the individual models and is able to provide the accurate diurnal cycle.

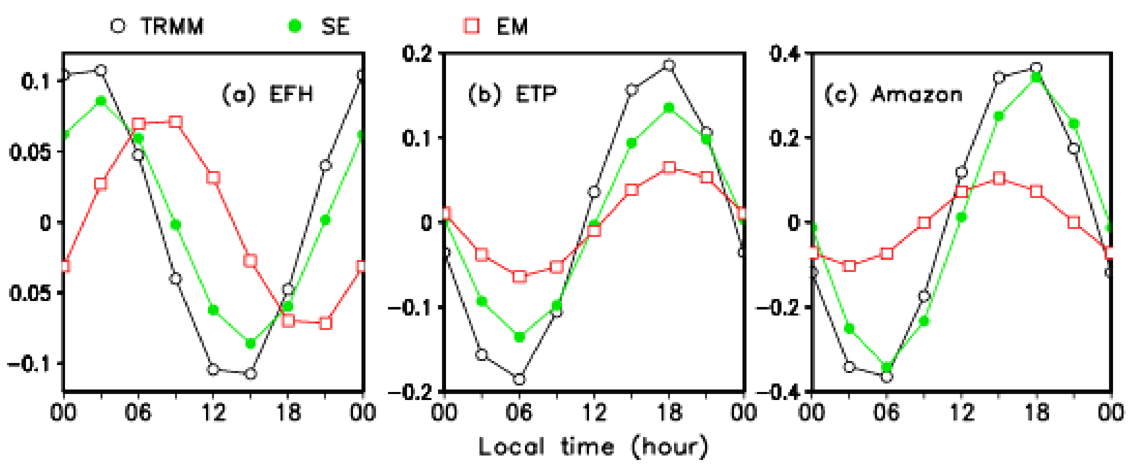

Fig. 2: Diurnal cycle of precipitation over (a) Eastern Foothills of Himalayas (b) Eastern Tibetan Plateau (c) Amazon valley for day-5 of forecasts valid during 31 March to 4 April 2000

In figure 3 we show the equitable threat score for the diurnal mode for day 3 and day 5 of forecasts. The results are similar for other days of forecasts. We include here the skills from the ensemble mean of the member models, those from a best model (that carries the lowest rms error for rainfall forecasts), those from a unified model (a single model that carries weights based on superensemble for all the physical parameterizations. This approach was previously used in Krishnamurti and Sanjay (2003)) and those from the superensemble. The bar charts show the bias scores (close to 1.0 being a good score) along ordinate and the precipitation thresholds along the abscissa (i.e. Bias scores for rainfall totals greater than 2.5, 5, 10, 15, 20, 30, 40 and 50 mm/day). The right panels show the equitable threat score along ordinate plotted against the thresholds for rainfall totals. These illustrations show that the superensemble skills are the highest for all thresholds for precipitation forecasts for total rain up to 50 mm/day. The skill of the unified model, seen in the light of these probability skill measures, shows it to be superior to the best model for both the equitable threat score and the bias scores for most of the events. The multi model superensemble has the best bias scores.

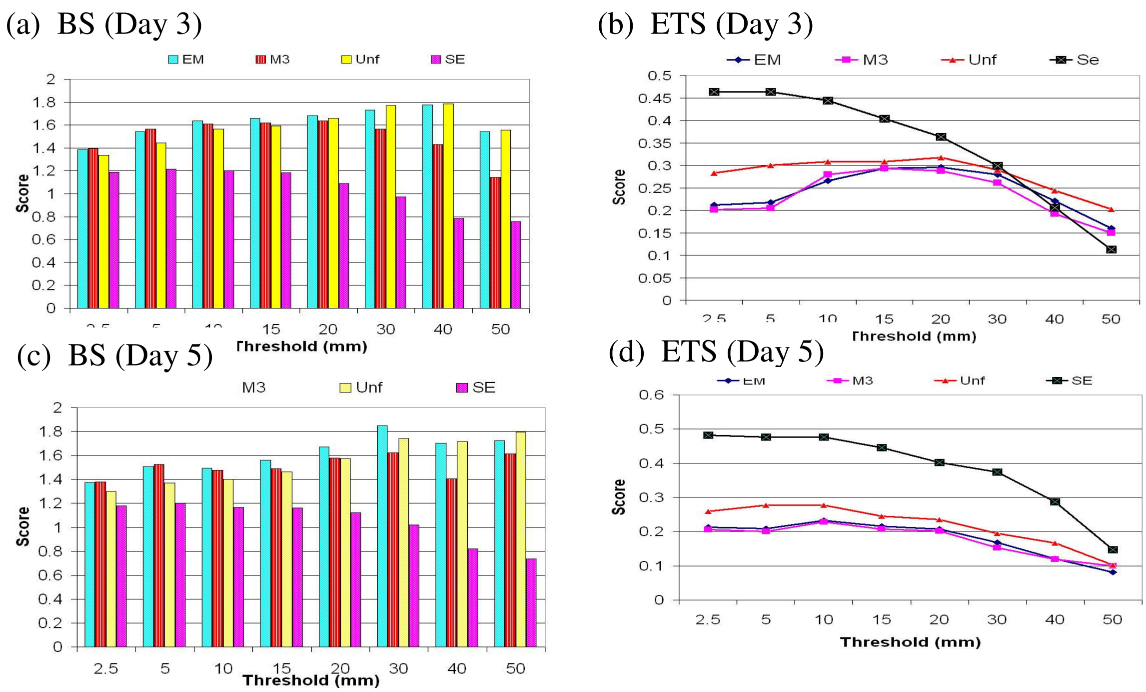

Fig. 3: The Bias Score (BS) [left panels] and Equitable Threat Score (ETS) [right panels] averaged over tropics, 0 to 360E, 30S to 30N during 29 Mar-02 Apr 2000 (Day 3 forecasts, top panels) and 31 Mar-04 Apr 2000 (Day 5 forecasts, bottom panels)