The CFS126: a dynamical system for subseasonal forecast -- challenges in predicting the MJO

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Abstract

We explore the ability of a fully coupled general circulation model to forecast tropical intraseasonal oscillations. We use the CFS126 model which is an enhancement of the Climate Forecast System (CFS) with respect to the horizontal truncation of the atmospheric model which rises from T62 to T126. We performed a series of 65-day-long retrospective forecast initialized four times daily in May, June, July and November, December, January from 2000 to 2004. We use a simple measure of the MJO i.e., the projection of forecast anomalies of the zonal wind at 200 hPa averaged from 20S to 20N to the intraseasonal EOFs of the observed field. Using this measure, forecast of patterns during summer can be skillful for periods of up to 25 days. However, in the current system we note a predictability barrier associated to the eastward propagation of enhanced convective activity over the eastern Indian Ocean and the Maritime Continent. We analyze reasons for this predictability barrier and provide some evidence for the possibility of further improvements of forecasts of tropical intraseasonal oscillations with this dynamical system.

The observed 2000-2004 period

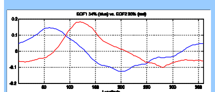
Figure 1a

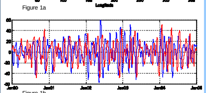
Figure 1b

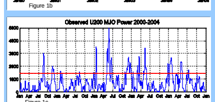

Figure 1c

In order to establish a simple measure of MJO activity we use the 6 hourly zonal wind at 200 hPa from the reanalysis 2 project (R2). This field is averaged between 20ºS and 20ºN, then band pass filtered (20 to 90 days) and finally analyzed by the EOF method. The two first EOFs and their corresponding PCs are shown in Figure 1a and 1b respectively. These PCs present a maximum lagged correlation of 0.75 at 10 days corresponding to an oscillation of 40 days. The spatial patterns describe an eastward propagation with typical MJO characteristics.

Figure 1c shows the sum of the squares of the two first PCs. From 2000 to 2004 there are 12 strong events (exceeding 2 standard deviations shown as the red dashed line). The strongest event occurred in May – June 2002.

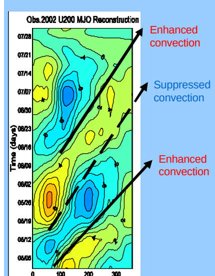

Figure 1d

Figure 1d shows the reconstruction of the zonal wind anomalies at 200 hPa based on the two first EOFs for the period from May to July 2002 (the strongest event). Units are in m/sec. According to this reconstruction, there is a very clear eastward propagation of enhanced convective activity (indicated by upper level divergence). Then, from mid-May to the end of June, a period of suppressed convection propagating eastwards is followed by a period of enhanced convection from the beginning of June to mid-July.

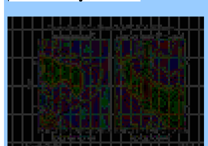
Figure 1e

Figure 1e (left panel) shows 10-meter zonal wind anomalies as observed by the TAO array in May and June 2002 (note that the time axis is reversed). As seen in Figure 1d, during the end of May over the western Pacific there is a strong negative anomaly of zonal wind at 200 hPa. Figure 1e demonstrates that this upper level flow anomaly goes along with positive surface winds anomalies which have significant impacts on the ocean (right panel).

Tropical Intraseasonal Oscillation in CFS62 and CFS126

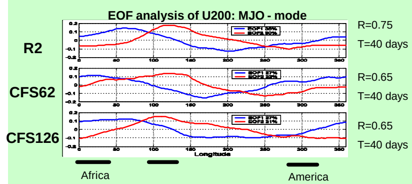

Figure 2

Figure 2 compares the MJO modes of R2 and 5-year segments from free coupled runs with CFS62 and CFS126. Increasing the horizontal resolution of the atmospheric model improves somewhat the MJO mode especially over the Indian ocean. However, the lagged correlation between the PCs in both models has a maximum of only 0.65 indicating less well defined eastward propagation.

Tropical Intraseasonal Oscillation forecast skill

Global measure of skill: anomalous pattern correlation

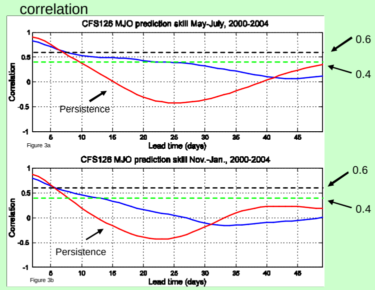

Figure 3a
Figure 3b

Pattern correlation of forecast anomalies projected on the mode of Figure 1a and the observed mode (Fig. 1d) as a function of lead time is presented in Figures 3. The red curve presents pattern correlation for a persistence forecast. Levels of 0.6 and 0.4 of correlation are shown respectively by the black and green dashed lines. The summer cases (Fig. 3a) present some useful skill up to lead times of 25 days while for winter cases (Fig. 3b) this skill decreases to 12 days. Forecasts with the CFS126 are better than persistence for all realistic lead times with the exception of the first 7 days due to the use of a 7-day lagged ensemble averaging.

MJO forecast skill for May – June 2002

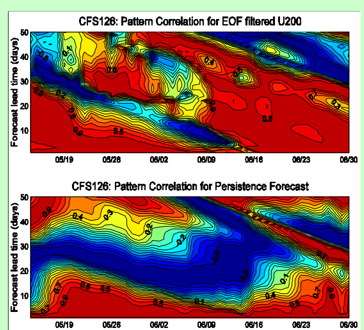

Figure 4

Figures 4 present pattern correlation as a function of initialization time from May to June 2002 (x-axis) and forecast lead time. The upper and lower panels show the CFS126 and persistence forecasts respectively. Among reasons for the drop in forecast skill for summer cases seen in Fig. 3a (a similar behavior is also found for winter cases) is the presence of a predictability barriers one of which manifests around June 7, 2002. This barrier occurs during the crossing of the active convective phase through the Indian ocean and the Maritime Continent (Figure 1d).

We next investigate two possible reasons for this barrier i.e., surface forcing and initial conditions.

Effects of SST on the predictability barrier

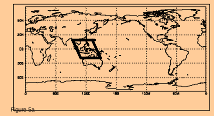
Figure 5a

One of the reasons for the predictability barrier may be the fact that over many areas of the Maritime Continent we use climatological SST (the ocean model is not computing SST at these areas). Unrealistic SST gradients can be adverse to the realistic propagation of convection.

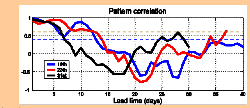

Figure 5b

In order to investigate this possibility we performed a series of forecasts initialized on the 19th, 23d, and 31st of May from 1995 to 2002 using the atmospheric component of CFS126 and observed SST. The pattern correlations shown in Figure 5b clearly indicate the presence of a barrier around June 7, 2002.

Effect of initial conditions on the predictability barrier

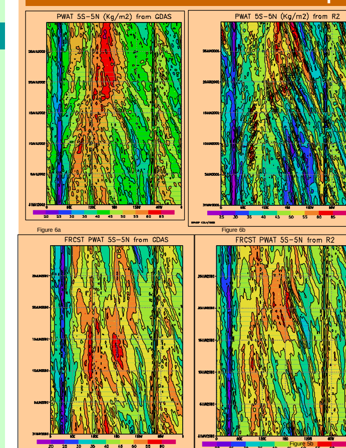

Figure 6a
Figure 6b
Figure 6e
Figure 6f

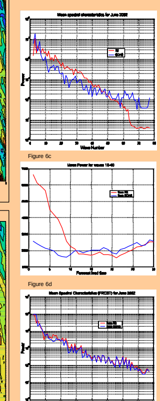
Figure 6c
Figure 6d
Figure 6g

Another possible source for the predictability barrier could be incorrect initialization. In fact, CFS126 is initialized by R2 which is based on an older version of the atmospheric model. Figures 6a and 6b compare precipitable water (a critical field for convection) for respectively the GDAS and R2 analysis for June 2002. Clearly, R2 has more power in the higher frequency easterly waves than GDAS (as also seen in the spatial spectra shown in Fig 6c). In the western Pacific, this high frequency activity results to periods of dryer conditions that in forecast mode could affect adversely the eastward propagating 'wet' MJO phase.

Figure 6d shows that effects from R2 initialization can persist for up to 10 days when compared to the forecast initialized by GDAS. However there is no obvious improvement in the forecast as seen in Figures 6e and 6f. In fact, the spatial spectra in the forecast are indistinguishable from the spectral characteristics of GDAS (Fig. 6c and 6g). Model formulations and the reason for the drying of the western Pacific will be our next investigation.

Discussion and Conclusions

- Both high and low resolution CFS runs exhibit realistic MJO signals with the high resolution being slightly better.
- Depending on the phase of the phenomenon there is high skill in forecasting MJO events with the CFS126 system. However, for May-June initializations, there is a predictability barrier associated with the crossing of the upper level divergent phase of the MJO through the Indian Ocean and the Maritime Continent. Nevertheless, this behavior can provide *a priori* information to forecasters.
- This barrier does not appear to be related to some inherent predictability limit but rather to model deficiencies. Therefore, there is room for much improvement of the forecast skill.
- The skill of this model could have been optimized by (a) better definition of the ensemble forecast and (b) projection of the forecast onto model modes instead of observed ones and then 'rescaling' of these modes towards the observed ones.

Acknowledgments

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