1. Introduction

The Madden-Julian Oscillation (MJO) is the leading mode of intra-seasonal variability in the tropics. It is a quasi-regular, eastward-propagating oscillation between enhanced and suppressed convective conditions, with a period of 30-60 days. This relatively long period makes the MJO an important source of predictability for extended-range forecasts. Recent studies have found teleconnections between MJO activity and extra-tropical variability, including the North Atlantic Oscillation (Cassou, 2008).

Many current general circulation models (GCMs) display weak sub-seasonal variance in tropical convection, relative to observations (Lin et al., 2008). Even GCMs with adequate variance often fail to simulate the propagation of the MJO.

In its default configuration, the Hadley Centre HadGEM3 atmosphere-only GCM produces approximately half of the observed MJO activity (Figure 1). Particularly large deficiencies in MJO activity exist near the Maritime Continent (phases 3 and 4). The “death rate” for strong MJO activity is roughly four times greater in the model than for observations.

2. Case-study approach with YoTC/Cascade MJO events

To target improvements for the HadGEM3 MJO, initialized, climate-resolution GCM produces approximately half of the observed MJO activity (Figure 1). Particularly large deficiencies in MJO activity exist near the Maritime Continent (phases 3 and 4). The “death rate” for strong MJO activity is roughly four times greater in the model than for observations.

3. MJO phase 2 hindcasts: Experiment design and results

A further 14 hindcast sets were conducted to confirm improvements from 1.5ε and NoCMT, with 30-day integrations for each MJO in 2000-2009 satisfying:

- Amplitude = 1 in phase 2 and day n and phase 6 on day n+30
- Amplitude = 1 on all days n through n+30

1.5ε results in a stronger, propagating MJO (Fig. 4). NoCMT gives a small mean improvement for 1.0ε and 1.5ε, but also compensating errors among the cases: only three of 14 showed lower RMSE in both RMMs for 1.5ε+NoCMT over 1.5ε. RMSE in RMM phase and amplitude are halved for 1.5ε, with or without CMT (Fig. 5). 1.5ε improves skill in OLR and U850, particularly for RMM2; NoCMT increases variance in U850 and U200, but has little impact on skill.

4. Impact of increased entrainment in a climate integration

As 1.5ε produced a much more substantial impact in the hindcast cases than NoCMT, the 1.5ε change alone was tested in a 20-year HadGEM3 integration with repeating climatological SSTs from the AMIP (1982-2008) period. MJO activity nearly doubles from the 1.0ε HadGEM3 integration (Fig. 1), bringing the model much closer to observations (Fig. 7). MJO propagation is also improved in 1.5ε, although HadGEM3 is still too strongly attracted to the origin in RMM phase space (Fig. 8).

References


Conclusions

- The default HadGEM3 produces roughly one-half the observed MJO activity.
- Inexpensive, initialized, climate-resolution hindcasts of well-observed MJO events allowed many changes to physics parameterizations to be tested to target improvements in the MJO.
- Increasing convective entrainment and turning off convective momentum transport improved hindcasts of two YoTC MJO events. The former (latter) improved OLR and U850 (U200).
- Only the increased entrainment consistently improved skill in a wider range of hindcasts.
- In a 20-year climate run, increased entrainment produces near-observed MJO activity.

Figure 1. Budgets of MJO activity for observations (1980-2008) and a 20-year HadGEM3 atmosphere-only simulation with repeating climatological SSTs. The budget terms (e.g., “previous phase”, “next phase”) are the mean daily probability distributions for strong MJO activity in each Wheeler- Hendon phase. The probability of the day-plus-one persistence of no MJO activity are given inside the unit circle.