On the Initiation of the Madden-Julian Oscillation (MJO)

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1. Introduction

Several hypotheses have been proposed to explain the initiation mechanism of the Madden-Julian oscillation (MJO): (i) Local discharge-recharge processes, (ii) Extratropical influences, (iii) Upstream effects of circumnavigating waves, and (iv) Stochastic forcing. The objective of this study is to further investigate the initiation mechanism of the MJO. Our approach is considerably different from other studies in many respects: (i) We utilize a tropical channel model (based on MM5), without the usual zonal boundaries. In this model, any feedbacks with the rest of the globe are controlled through the meridional/lateral boundary conditions, which allow their influences on the MJO initiation to be tested. Another advantage of using this model is its capability of two-way nested domains with high resolution and sophisticated physics. (ii) Start with full physics, and then test one factor at a time. (iii) Make the problem more tractable by doing sensitivity tests on various parameters (e.g., SST, lateral boundary conditions), instead of testing a hypothesis (e.g., extratropical influences) directly. (iv) Our approach is to simulate individual MJO events, rather than MJO statistics to help identify MJO initiation mechanisms.

2. Model and Simulation Design

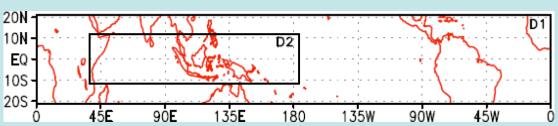

Fig. 1. Primary model domain for the TMM5 (D1, 0-360˚, 21˚S 21˚N) and the nested domain (D2, 37-183˚E, 11˚S-11˚N). Domains D1 and D2 have resolutions of 111 km and 37 km respectively. Control simulations include only D1.

Experiment	Integration Time	Remarks
1DOM	1Mar-30Jun	Single domain simulation for testing the performance of the model. Varying SST.
2DOM	1Mar-30Jun	Nested domain (111 km / 37km). Varying SST.
CS1	10Apr-10Jun	Control simulation. Constant SST. Varying lateral boundaries at 21S and 21N.
SST1A	10Apr-10Jun	Same as CS1, but with varying SST.
SST1B	1Mar-11May	Same as 1DOM, but with constant SST.
IN_VSST1_n, n = 1 – 7	24, 26, 28 Feb, 1, 2, 4, 6 Mar – 18 May	Same as 1DOM, but with different initial times and shorter simulation. Varying SST.
IN_FSST1_n, n = 1 - 5	5, 7, 10, 13, 15 Apr -10 Jun	Same as CS1 but with different initial times. Constant SST. IN_FSST1_3 (10Apr-10Jun) is the control simulation (CS1).
NO_LH1	10Apr-10Jun	Same as CS1, but with no latent heating
NO_MOIST1	10Apr-10Jun	Same as CS1, but with no moisture
FBC1A	10Apr-10Jun	Same as CS1, but with constant lateral boundary conditions.
FBC1B	1Mar-30Jun	Same as 2DOM, but with constant lateral boundary conditions.
MBV1A	10Apr-10Jun	Same as CS1, but with lateral boundaries at 28SN.
MBV1B	10Apr-10Jun	Same as CS1, but with lateral boundaries at 38SN.
PBC1A	10Apr-10Jun	Same as CS1, but with perturbation in lateral boundaries.
PBC1B	10Apr-10Jun	Same as CS1, but with boundary conditions from 30 days back.

Table 1. The descriptions of the simulations for the Case 1 (2002 event). DOM: Domain; CS: Control Simulation; VSST: Varying SST, FSST: Fixed SST; FBC: Fixed Boundary Conditions; MBV: Moved Boundary Values; PBC: Perturbed Boundary Conditions;

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3. Sensitivity Tests

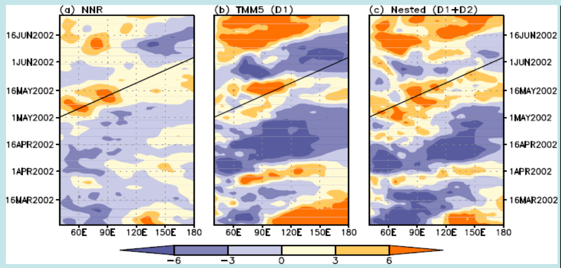

Fig. 2. Longitude-Time diagrams of daily U850 anomalies (m/s) averaged over 10˚S - 10˚N for Case 1 from (a) NNR, (b) TMM5 single domain (D1) simulation, and (c) TMM5 nested domain (D1+D2) simulation.

The MJO initiation does not critically depend on (i) detailed characteristics of sea surface temperature (varying vs.. constant in time, mean distribution from boreal spring vs. winter), (ii) initial conditions (within a 10 day period and beyond), (iii) the latitudinal location of the lateral boundaries (21-38 N and S), or even (iv) latent heating and moist processes. The only factor found critical to the reproduction of the MJO initiation is time-varying lateral boundary conditions from the reanalysis.

4. Mechanics of Extratropical Influences

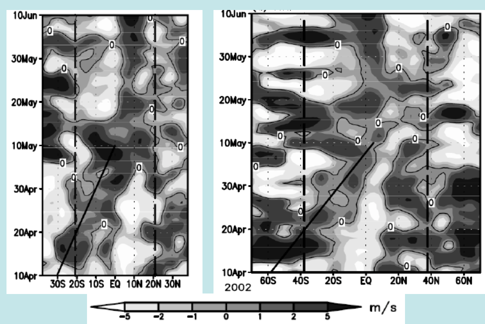

Fig. 3. (left) Latitude-Time diagrams of U850 and V850 anomalies at 850 hPa from the NNR. All are averaged over 40˚E - 50˚E, 3-day running mean. The solid line indicates meridional propagation.

The origin of the lower tropospheric anomalous westerlies in the tropics associated with this MJO initiation is found to be in the extratropics, and brought to the tropics by meridional transport of anomalous westerly momentum. An analysis of zonal momentum budget reveals that the meridional advection may be important in controlling the local tendency of the anomalous zonal winds prior to the MJO onset. The time evolution of wave activity relevant to the MJO initiation clearly identifies its source over the extratropical southern Indian Ocean where it grows by extracting kinetic energy from the mean flow.

$$\frac{\partial u'}{\partial t} = -\frac{\partial \phi'}{\partial x} + fv' - (u\frac{\partial u'}{\partial x} + u'\frac{\partial \bar{u}}{\partial x}) - (v\frac{\partial u'}{\partial y} + v'\frac{\partial \bar{u}}{\partial y}) - (w\frac{\partial u'}{\partial p} + w'\frac{\partial \bar{u}}{\partial p}) + R'$$

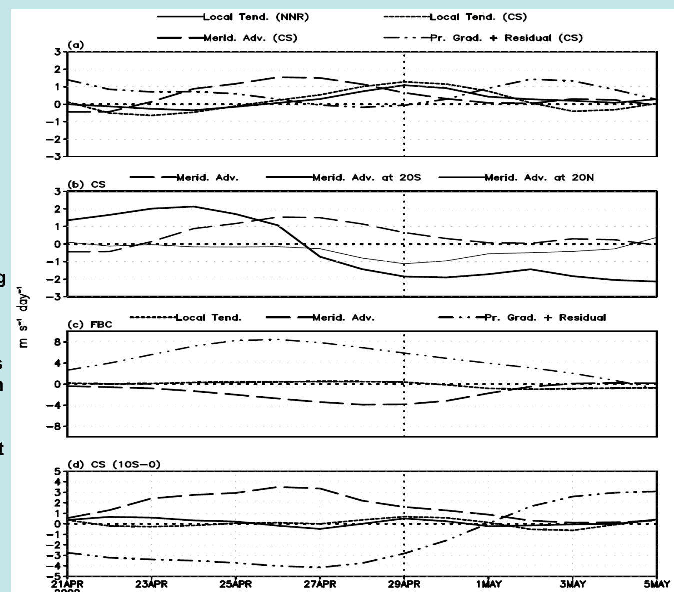

Fig. 4. (a) The local tendency of U850 anomalies from the NNR (solid) and control simulation CS (short dashed). All are in m s[-1] day[-1], averaged over 10˚S-10˚N, 40˚E -50˚E, and 3-day running mean. (b) Meridional advection from CS, and the north and south boundaries. (c) Same as (a) but from the test run with constant lateral boundary conditions FBC. (d) Same as (a) but averaged over 10˚S to 0˚.

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