# The Madden-Julian Oscillation in GCMs

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Using AVHRR OLR and model simulated OLR we analyze intraseasonal convection in the AMIP models and coupled ocean-atmosphere models to determine the extent to which the Madden-Julian Oscillation (MJO; Madden and Julian 1971, 1972) is simulated, and the influence that air-sea interaction has on the representation of the MJO. All data are bandpassed with a 20-100 day Lanczos filter.

Sperber and Slingo (2003) identified seven years when the boreal winter MJO was notably active as a well-defined eastward propagating mode. Using these periods, the eastward propagation of convection was isolated via EOF analysis of filtered AVHRR OLR. For EOF-1 (EOF-2) enhanced convection covers 105$^{o}$E-180$^{o}$E, 20$^{o}$N-20$^{o}$S (60$^{o}$E-140$^{o}$E, 15$^{o}$N-20$^{o}$S). In the present study, filtered AVHRR OLR and the model OLR is projected onto the afore-mentioned EOF's. Thus, all models are evaluated relative to a common metric. The analysis is confined to the months November-March, for 1979/80-1994/95 for the observations and the AMIP II models, and for 9-19 winters from the coupled models.

The amplitude of the OLR perturbations are directly proportional to the standard deviations of the PC's (Table 1). For the AVHRR OLR data, a one standard deviation perturbation of PC-1 and PC-2 gives rise to convective anomalies of about +/-25Wm$^{-2}$. The vast majority of models have much weaker MJO convective signals. Also given in Table 1 is the maximum positive correlation, R, between PC-2 and PC-1, and the time lag at which it occurred. For the AVHRR OLR, on average, PC-2 leads PC-1 by 12 days with a maximum positive correlation of 0.67. For all models, R is smaller than observed indicating that eastward propagation is not as coherent as observed. The characteristic timescale of propagation exhibits a wide-range of variability, with some models incorrectly exhibiting weak westward propagation. Comparing AMIP II and AMIP I we find that HADAM3 has a weaker MJO amplitude and less coherent eastward propagation compared to HADAM2. Importantly, air-sea interaction has a beneficial influence. Three of the coupled models have an AMIP II atmospheric component. In each case the coupled models have a larger R, indicating that the MJO convection has a more realistic propagating structure. That coupling to an ocean yields improvement to the representation of the MJO is consistent with Waliser et al. (1999), Inness and Slingo (2003) and Inness et al. (2003).

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Table 1: Observed and simulated MJO characteristics. The columns give the observation/ model designation (the last 4 entries are from the coupled models), the standard deviations of PC-1 and PC2, the maximum positive correlation, R, between PC1 and PC-2, and the time lag at which it occurred. Positive time lags correspond to eastward propagation. Shaded entries highlight models for which an AMIP II integration and a coupled ocean-atmosphere simulation using the same atmospheric model are available.

| Model | PC-1 | PC-2 | R | Lag (days) PC-2 leads PC-1 (positive) |
|---|---|---|---|---|
| AVHRR | 211.3 | 205.6 | 0.67 | 12 |
| CCCMA-99a | 100.3 | 107.0 | 0.26 | 11 |
| CCSR-98a | 106.4 | 91.7 | 0.30 | 13 |
| CNRM-00a | 155.1 | 143.3 | 0.42 | 14 |
| COLA-00a | 100.5 | 85.7 | 0.16 | 26 |
| DNM-98a | 63.0 | 67.1 | 0.16 | 25 |
| ECMWF-98a | 102.5 | 97.5 | 0.20 | -11 |
| ECMWF-98b | 121.8 | 105.7 | 0.29 | -13 |
| GFDL/DERF-98a | 159.0 | 182.1 | 0.36 | 12 |
| GISS-98a | 64.0 | 54.6 | 0.23 | -7 |
| GISS-02a | 37.1 | 37.1 | 0.17 | -15 |
| HADAM2 (AMIP I; 1979/ 80-1987/88) | 166.5 | 130.9 | 0.40 | 18 |
| HADAM3 (L58) (UGAMP-98a) | 117.1 | 102.8 | 0.28 | 14 |
| JMA-98a | 165.3 | 155.3 | 0.29 | 10 |
| MPI-98a (ECHAM4) | 222.2 | 215.8 | 0.35 | 12 |
| MRI-98a | 174.2 | 164.1 | 0.31 | 9 |
| NCAR-98a (CCM3) | 91.9 | 100.2 | 0.18 | 10 |
| NCAR-02a (CAM2) | 95.3 | 95.8 | 0.19 | -24 |
| NCEP-99a | 108.9 | 108.6 | 0.24 | 12 |
| NCEP-99b | 104.1 | 98.4 | 0.22 | 24 |
| | | | | |
| HADCM3 (L30) | 104.4 | 96.0 | 0.45 | 8 |
| IAP/LASG GOALS | 123.8 | 129.2 | 0.42 | 9 |
| NCAR CCSM2 | 91.5 | 115.9 | 0.28 | 20 |
| SINTEX (ECHAM4/OPA8.1) | 231.2 | 201.5 | 0.44 | 12 |