CMIP Diagnostic Subproject Proposal

Synoptic to Intraseasonal Variability

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BACKGROUND

The Madden-Julian Oscillation (MJO) is a dominant mode of variability in the tropics (Madden and Julian 1971, 1972). It has long been recognized that it is manifested on a time scale of ~30-60 days through large-scale circulation anomalies, which occur in conjunction with eastward evolving convective anomalies in the tropical eastern hemisphere. Characteristics of the life cycle of intraseasonal oscillations have been described by many authors (e.g., Knutson and Weickmann 1987, Rui and Wang 1990, Matthews 1993, Hendon and Salby 1994, Sperber et al. 1997). Extensive analysis of intraseasonal variability in atmospheric GCMs performed by Slingo et al. (1996) indicates that:

1) No model was able to capture the dominance of the MJO seen in the ECMWF analyses; the simulated oscillations were usually weaker and not as spatially coherent as observed; the correct seasonality was not well reproduced.

2) Those models with weak MJO activity tend to have a weak seasonal cycle; an accurate description of the basic climate may be a prerequisite for producing a realistic MJO.

3) Models with the most realistic MJO's have precipitation distributions which were well correlated with warm sea surface temperatures.

4) Buoyancy closure of a convection scheme may be preferable to moisture convergence for the simulation of intraseasonal oscillations.

Following the basic assessment of 15 AGCMs, Sperber et al. (1997) analyzed case study periods from two of the models that produced the most realistic MJO's to investigate the initiation and propagation of the MJO and the potential mechanisms involved. The model results were compared with NCEP/NCAR reanalysis. This study indicated that:

1) The models were unable to simulate the large scale organization of convection associated with the MJO and its eastward migration from the Indian Ocean into the western Pacific. Rather, the simulated convection and latent heat flux tended to lock onto the west Pacific warmpool.

2) Evaporative wind feedback is not the principal mechanisms for maintaining eastward propagation of the MJO in either the NCEP/NCAR reanalyses or in the models.

3) Sea surface temperatures display intraseasonal variability which may interact coherently with the MJO, and thus may play a role in its initiation and propagation. This result that air-sea interaction may be necessary to adequately capture the spatio-temporal evolution of the MJO is supported by Waliser et al. (1998). They have coupled the GLA atmospheric model to a slab model of the tropics/subtropics, finding that in coupled mode the MJO is more realistic with respect to seasonality, variability, propagation rate and periodicity. These results strongly suggest that evaluation of intraseasonal phenomena in coupled ocean-atmosphere models (and control integration with prescribed SSTs) would be extremely useful.

Subsequently, Slingo et al. (1999) investigated the interannual and interdecadal variability of the MJO in NCEP/NCAR reanalysis and in 4 realizations of the Hadley Centre climate model (HADAM2a). The results indicated that:

1) For the uncoupled system there is no reproducibility of the activity of the MJO from year to year.

2) The interannual variability of the MJO is not controlled by ENSO or any other SST pattern.

3) However, the model has confirmed interdecadal variability of the MJO seen in the reanalysis that is associated with increased SST over the tropical Indian and western Pacific Oceans. This suggests that the MJO becomes more active as the SST warms. This result may have implications for the effects of global warming on the coupled ocean-atmosphere system.

4) Subsequent work indicates that the interdecadal variability is also manifested in the low-level winds, affecting the duration and intensity of the MJO related westerly anomalies over the western Pacific Ocean.

These results indicate that a realistic simulation of the MJO has yet to be achieved. The nature of the MJO, particularly its periodicity and its sporadic occurrence, has yet to be unraveled. However, Slingo et al. (1996) and Sperber et al. (1997) have demonstrated the considerable benefits and advances in understanding that can be achieved through intercomparison of models and validation against reanalyses.

The MJO is also important because of its potential to excite intraseasonal variability in the ocean which may play a key role in the evolution of El Niño. Kessler and McPhaden (1995) have suggested that intraseasonal oceanic Kelvin waves, possibly excited by the MJO (Kessler et al. 1995), played a prominent part in the prolonged warm event of the early 1990s. The relationship between the activity of the MJO and WWBs, equatorial ocean waves and El Niño is not fully understood but, as recent events suggest, may be very important (Slingo 1998). It is possible that errors in the simulation of El Niño may be related to errors in the representation of subseasonal atmospheric and oceanic variability.

OBJECTIVES

We wish to investigate synoptic to intraseasonal timescales and their interaction with the ocean. The main emphasis will be on the coherent eastward propagating MJO which occurs predominantly during northern winter. Specifically, we plan to:

1) Provide an assessment of the skill of participating models to simulate the MJO, including its seasonality and interannual variability.

2) Investigate further the processes responsible for the initiation, maintenance, and dissipation of the MJO including the potential role played by an interactive ocean.

3) Investigate the intraseasonal variability in the equatorial Pacific Ocean, its relationship with atmospheric intraseasonal variability (specifically the MJO and westerly wind bursts) and with ENSO.

METHODOLOGY and VALIDATION

Preliminary identification of the MJO will be made from analyzing hovmoller diagrams of 200hPa velocity potential. The velocity potential is the field in which the MJO is most readily identified. The forced Rossby wave response and the vertical structure of the MJO will investigated using eddy streamfunction at 200hPa, 850hPa and the surface. Bandpass filtering, Fourier analysis, space-time decomposition and empirical orthogonal function analysis will be used to identify the characteristics of the MJO. Additionally, the hierarchy of equatorially trapped wave modes (based upon shallow water theory) will be analyzed as in Wheeler and Kiladis (1998). Use of wavelet analysis may facilitate diagnosis of the interdependence of the multiple time and space scales of convection. Evaluation of the basic state may be crucial, particularly since climate drift may have a substantial impact on the MJO simulation.

The life-cycle of the MJO will be studied from a statistical point of view via lagged correlation analysis with OLR, precipitation (indicative of diabatic heating), SST and surface latent, shortwave, longwave and sensible heat fluxes. Specific case studies will be analyzed in detail to understand the surface energy budget for comparison against TOGA/COARE observations (Zhang 1996, Lau and Sui 1996, and Flatau et al. 1997) and reanalysis. In this way we will be able to investigate the mechanisms by which the models initiate and maintain the eastward propagation of the MJO.

The relationship between intraseasonal variability in the atmosphere and in the ocean, and its influence on El Niño, will be studied by analysing the phase relationship between the MJO (and WWBs), oceanic Kelvin waves (through the depth of the $20^{o}C$ isotherm) and El Niño. This aspect of the project will require longer, multidecadal time series to obtain a statistically significant result. TAO array data will be used to validate the oceanic intraseasonal response.

Extensive use of the NCEP and ECMWF reanalysis data sets will be made in order to assess the ability of the models to simulate MJO variability. The level of agreement among these reanalysis products will provide a measure of observational uncertainty against which the models can be interpreted.

DATA REQUIREMENTS

For Objectives 1) and 2) we will require approximately 10 years of **daily** mean data (with the exception of the monthly mean data in Set 4) to provide a long enough time series to assess the robustness of the simulation of synoptic to intraseasonal variability. Four sets of data are requested. Depending upon the ability of a modelling group to make available one or more of these data sets, increasingly sophisticated diagnostics can be performed. Set 1 will only enable a preliminary identification of intraseasonal variability. Set 2 will enable a more detailed analysis of the spatio-temporal evolution of MJO variations and other synoptic modes of variation, Set 3 will enable an investigation of the surface energy balance, the potential role of air-sea coupling, and investigation of tropical/extratropical interactions, and Set 4 will be used to evaluate the basic state:

Set 1:

u- and v-wind component at 200hPa (from which divergence, relative vorticity, streamfunction and velocity potential can be calculated): At T42 this corresponds to:
128 x 64 x 3653 x 4bytes/word x 2 variables = 240mbytes.

Set 2:

u- and v-wind component at 850hPa and the surface: At T42 this corresponds to 480mbytes.

Tropical domain (30^{o}N-30^{o}S) outgoing longwave radiation (OLR) and surface latent heat flux: At T42 this corresponds to 80mbytes.

Set 3:

Sea surface temperature and total precipitation rate: At T42 this corresponds to 240mbytes.

Tropical domain (30^{o}N-30^{o}S) surface wind stress (zonal and meridional), net surface longwave radiation, net surface shortwave radiation, surface sensible heat flux: At T42 this corresponds to 200mbytes.

Set 4 (required for those variables not provided above):

Evaluation of the basic state of a model is important to establish the context within which the MJO variations are embedded. Therefore, monthly mean output for these variables will be required. At T42, for all 15 variables, this corresponds to 60mbytes.

Objective 3), to investigate interannual/interdecadal variability in the intraseasonal behaviour of the tropical atmosphere-ocean system and its relationship with ENSO, will require ~50 years of **daily** data. Here the amount of data has been reduced by requesting only time-longitude datasets (with the exception of the monthly mean data):

OLR, u-wind component and velocity potential at 200hPa averaged between 10^oN and 10^oS, used to identify MJO activity.

u-wind at 850hPa averaged between 5^oN and 5^oS for WWB activity

Depth of 20^oC isotherm at the equator (or average of closest gridpoints straddling the equator if no equatorial gridpoint) to identify ocean Kelvin wave activity

SST averaged between 5^oN and 5^oS to evaluate MJO variability at the air-sea interface

Additionally, monthly means of these fields for the tropical domain (30^oN - 30^oS) are required to evaluate the basic state. At T42 this corresponds to 40mbytes.

Data should be submitted in netCDF on exabyte tape (high or low density) or 4mm DAT tape. Data should be sent to:

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