To: Operational Modelling Centres

From: The CAS/WCRP Working Group on Numerical Experimentation (WGNE)
and
US-CLIVAR Madden-Julian Oscillation Working Group

Date: February 2008

This letter seeks to gain the involvement of Operational Modelling Centres in an activity to monitor and compare numerical model forecasts of the Madden-Julian oscillation (MJO). The activity is a result of discussions and work of the U.S. Climate Variability and Predictability (CLIVAR) programme's MJO Working Group[1]. The group is co-sponsored by international CLIVAR, and the activity has the support of the Working Group on Numerical Experimentation (WGNE). The aim of the activity is to generate further interest, expertise, and forecast skill on the intraseasonal time scale, with the MJO being the most dominant mode of variability on this time scale. Advances in computing have led to numerical forecast models, either coupled ocean-atmosphere models or atmosphere-only models, being run out to an increasingly extended range beyond 10 days, thus allowing for the examination of this mode. This letter seeks to obtain the input of a small subset of the data from these forecasts, including ensembles, for the computation of an MJO index that measures its evolving state in real time. The activity is seen as an important step for the further realisation of intraseasonal prediction skill, especially in the tropics. The MJO Working Group has already obtained the participation of several Centres (e.g., NCEP, ECMWF, UKMO, ABOM, CMC)[2], and wishes to use this letter to formalise the process, encourage further participation, and entrain additional Centres.

An important element of this activity is the establishment and use of a common MJO index. Such an index provides for uniform and continued assessments of a given model's MJO capabilities within each Centre, a comparison of MJO forecast skill between Centres, and a means to easily construct a multi-model ensemble forecast for the MJO. The MJO index chosen for this activity followed from deliberations amongst the MJO Working Group in conjunction with input from a number of Centres. The index follows closely that developed by Wheeler and Hendon (2004;

---

[1] For the membership, terms of reference and a description of activities of the MJO Working Group, see http://www.usclivar.org/Organization/MJO_WG.html.

[2] NCEP – U.S. National Centers for Environmental Prediction; ECMWF – European Centre for Medium Range Weather Forecasts; UKMO – United Kingdom Met Office; ABOM – Australian Bureau of Meteorology; CMC – Canadian Meteorological Centre.

hereafter WH04)[3]. The data input into this index are latitudinally-averaged (15°S–15°N) fields of zonal winds at the 850 hPa and 200 hPa levels, and outgoing longwave radiation (OLR). After some pre-processing, these fields are projected onto a pair of observationally-derived global structures of the MJO, giving a pair of numbers to measure its state each day, called the Real-time Multivariate MJO (RMM) indices. The data contribution sought from each Centre is simply three latitudinally-averaged fields (OLR, zonal winds at 200 and 850 hPa) at a 2.5° resolution for each model forecast day and the initial condition, including that of individual forecast ensemble members if available. We seek the input of the field data itself, rather than the RMM indices, to allow for the standardization of the calculation across all contributing models. Details of the required data, and of the RMM index calculation, are provided in Appendices 1 and 2 respectively.

The contributed real-time forecast data is intended to be used for: (a) creation of the RMM indices only, with no further use or dissemination of the longitudinally-dependent fields; (b) display on the world-wide-web as a trajectory in the RMM phase space (e.g. see attached Figure 1); (c) creation of a multi-model ensemble of forecasted RMM values; and (d) for calculation of verification statistics by those in the MJO Working Group[4]. Initially this activity was deemed primarily of research interest, but is now seeing some application in an operational setting for NCEP's weekly MJO update and Global Tropics Benefits/Hazards Assessment (see http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/ghaz.shtml) as well as for the Bureau of Meteorology's weekly Tropical Climate Note (see http://www.bom.gov.au/climate/tropnote/tropnote.shtml). Further standardizing of the forecasts and their illustration along with systematic verification will further benefit the community and increase the activity's utility.

Further details are provided in the attached Appendices.

Questions regarding this activity may be directed to:

MJO Working Group:

Matthew Wheeler; m.wheeler@bom.gov.au
Klaus Weickmann; klaus.weickmann@noaa.gov
Duane Waliser (co-chair); duane.waliser@jpl.nasa.gov
Kenneth Sperber (co-chair); sperber1@llnl.gov

WGNE

Martin Miller; martin.miller@ecmwf.int

[3] Wheeler, M.C., and H.H. Hendon, 2004: An all-season real-time multivariate MJO index: Development of an index for monitoring and prediction. *Mon. Wea. Rev.*, **132**, 1917-1932.

[4] Suggestions for verification are provided in Appendix 3.

Could you please forward your response to this request to Matthew Wheeler (m.wheeler@bom.gov.au), and in the case that your Centre is willing to participate, please include the name and contact information for the chief point of contact for this collaboration. We look forward to hearing from you and working with you and your Centre.

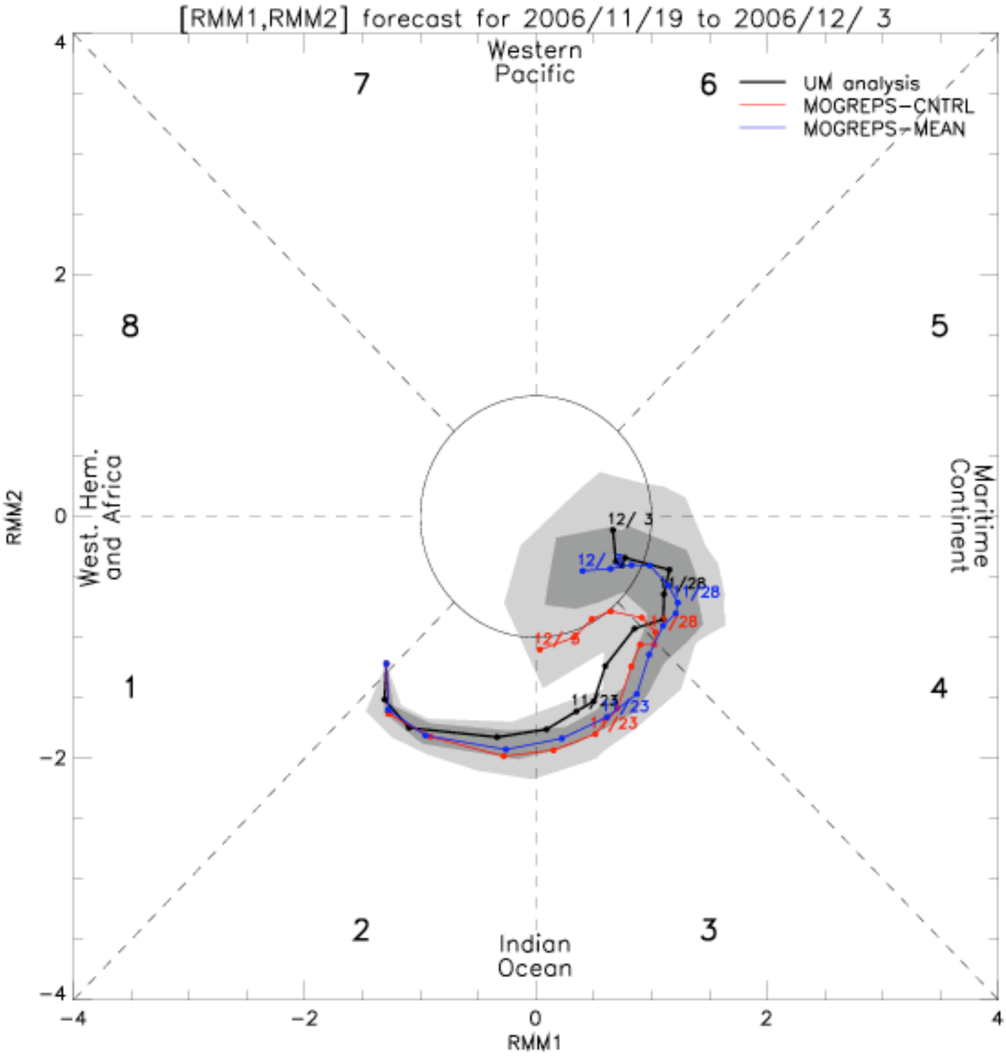

Fig.1: Example 15-day forecasts of the RMM indices from the UK Met Office Global and Regional Ensemble Prediction System (MOGREPS) initialized on the 18 November 2006. The two axes are respectively the first and second projection coefficients of the model output onto the observed empirical orthogonal function structures of the MJO, called RMM1 and RMM2. Anti-clockwise rotation in this phase space represents eastward propagation of the MJO. MOGREPS is an ensemble forecast system with 24 ensemble members. The blue line is the ensemble mean MJO forecast, the red is the forecast from the control run (unperturbed ensemble member) and the black is the MJO index of the verifying analysis. The light grey shading indicates the spread of the forecasts from all ensemble members, and the dark grey indicates the middle 50% of members. Each dot represents a day, extending from the analysis on 18 November to the last day of the forecast on 3 December (figure courtesy of Nicholas Savage).

Appendix 1: Data requirements

We intend to attract forecasts from global forecasting systems that are run out to at least 10 days. Usually, these systems are run daily, but longer integrations from systems run at a reduced frequency (e.g., monthly or seasonal forecasting systems run weekly), are also sought.

For the computation of the RMM index values we require the model fields of OLR, 850 hPa zonal wind, and 200 hPa zonal wind, averaged between the latitudes of 15°S to 15°N, for both the model forecasts and initial conditions. Initially, we will also require the most recent 120 days of model analysis data to be used for the removal of low frequency components (see Appendix 2 below). If an ensemble prediction system is run, it would be of value to get the data from all individual ensemble members as well as from their initial conditions. We ask that all Centres provide these as total fields from which anomalies will be created with respect to the NCEP/NCAR Reanalysis for the winds, and satellite observations for the OLR. Additionally, some Centres may wish to provide anomalies computed with respect to their own lag-dependent hindcast climatologies, which helps to remove model drift and systematic biases from their forecasts.

All supplied data should be placed on a 2.5 degree grid (centred on the longitudes of 0°, 2.5°, 5°, etc..), as ASCII data. Where possible, the contributed data should be daily averages for each Greenwich day (i.e., for 00-24Z). The new data sent each day/week/month (depending on the frequency at which the forecasts are run) should include both the daily forecast data as well as each new analysis/initial condition. An ftp area at NCEP has been created to receive the data, and it is there that the processing of all models is planned to take place. To set-up the ftp transfer and obtain an example data format file, please contact Jon Gottschalck (Jon.Gottschalck@noaa.gov).

Data Summary Table	
Fields	OLR, u850, and u200 totals (anomaly fields optional). Initial conditions and forecasts of all ensemble members, out to no more than 40 days.
Resolution	2.5° in longitude (0° to 2.5°W). 15°S-15°N averaged. Daily averaged (00-24Z).
Update frequency	Daily, or less for those systems run at a reduced frequency.
Additional data	At beginning of transfer, send analysis data for past 120 days.
Format	ASCII (text).

Appendix 2: Intended recipe for calculation of the model forecast RMM indices

While the details of the index calculation are not important for a Centre to be able to contribute to this activity, we provide them here to enable those Centres who wish, to also compute it themselves. However, small modifications may be made to this recipe if unforseen issues arise, thus our request for the forecast data rather than the RMM indices.

The recipe for calculation follows closely that described in WH04, except there will be no prior removal of variability linearly related to an SST index in the tropical Pacific (as was used to remove aspects of ENSO). Note that this should result in little difference with the WH04 RMM values as the removal of ENSO variability is mostly taken care of by the subsequent removal of the mean of the previous 120 days, which effectively acts as a high-pass filter.

More precisely, the recipe for calculation is:

1. If input data are not already anomalies, subtract the mean and climatological seasonal cycle (first 3 harmonics), as computed from the daily NCEP/NCAR Reanalyses and NOAA satellite OLR for the period 1979 to 2001 (as in WH04). This seasonal cycle is a smoothly varying function of the time of year, that is, it will be slightly different for day 1 of a forecast compared to day 15.
2. Subtract the mean of the most recent 120 days of anomaly analysis/forecast data. For the 'day 1' forecasts this will be the mean of the last 119 days of analysis, plus the 1st day of the forecast (which already have had the climatological seasonal cycle removed). For the 'day 15' forecasts this will be the mean of the last 105 days of analysis, plus the 15 days of forecast data.
3. Divide each field by its longitudinally-averaged normalization factor (as computed in WH04 to be 15.1 Wm^{-2} for OLR, 1.81 ms^{-1} for 850 hPa zonal wind, and 4.81 ms^{-1} for 200 hPa zonal wind).
4. Project this data onto the WH04 EOFs (as computed using NCEP Reanalyses and satellite OLR for the period 1979-2001).
5. Divide the projection coefficients by their respective observed standard deviations (again, using 1979 to 2001 values).

Example code that does this calculation may be obtained from Matthew Wheeler (m.wheeler@bom.gov.au).

<u>Appendix 3</u>: Verification

An individual Centre may wish to verify their own forecasts against RMM values computed from their own analyses. However, for the overall comparison of the forecasts from the different Centres, it is suggested that verification be made against a "multi-model analysis", that is, an analysis computed as an average of the analyses of all contributing Centres. The OLR used in the multi-model verification should be the satellite-observed product.

If a Centre wishes to run hindcasts to test their forecast skill, we suggest they run them over the most recent years. This will enable direct comparison of skill with those Centres who cannot afford to run hindcasts but have been running their operational forecast system for some time. For example, if a Centre can afford to run hindcasts starting once per week over a 5 year period, then we suggest they do this over the most recent 5 years. However, the number of years of forecasts/hindcasts required to accurately test the MJO forecast skill is currently unknown.

Statistical benchmark model predictions for comparison may be obtained from the papers of Maharaj and Wheeler (2005)[5], which uses a first order vector autoregressive model, and Jiang et al. (2008)[6], which uses lagged linear regression with RMM1 and RMM2 at the initial condition as predictors.

---

[5] Maharaj, E.A., and M.C. Wheeler, 2005: Forecasting an index of the Madden-oscillation. *Int. J. Climatol.*, **25**, 1611-1618.

[6] Jiang, X., D.E. Waliser, M.C. Wheeler, C. Jones, M.-I. Lee, and S.D. Schubert, 2008: Assessing the skill of an all-season statistical forecast model for the Madden-Julian oscillation. *Mon. Wea. Rev.*, in press.