MJO Metrics

This document represents the progress on ongoing deliberations of this topic by the US CLIVAR MJO Working Group

Based on the sensitivity calculations by Duane, Eric, and Klaus, the procedures for calculating the so-called level 1 metrics were more or less finalized during the telecon of 18 July 2006 – although we expect a "final" discussion at the upcoming Working Group meeting. Level 1 metrics are meant to provide a basic indication of the spatial and temporal intraseasonal variability that can be easily understood and/or calculated by the non-MJO expert (e.g., graduate student, modeler). Ease of use at this stage dictated that the analytic procedures be as similar as possible for summer and winter, with separate calculations performed for each season. Duane agreed to generate the metrics for the two precipitation datasets, Klaus the OLR, and Eric the 850hPa and 200hPa winds. Items that require clarification are listed in red. Selection/calculation of level 2 and higher metrics is under discussion, and the final determination of the level to which a particular diagnostic belongs will be determined after all suggested candidate metrics have been analyzed.

Period of Analysis:
January 1979-December 2005 (except TRMM: January 1998-December 2005)

Season Definition (exceptions below):
Boreal summer: May-October
Boreal winter: November-April

Domain of interest:
30^{o}N-30^{o}S, all longitudes
It was necessary to truncate the 850hPs winds between 20^{o}N-20^{o}S due to extratropical influences that precluded the identification of the MJO.

Daily Datasets:
AVHRR OLR from Liebmann and Smith
NCEP/NCAR Reanalysis-1, Reanalysis-2, ERA-40, and JRA-25 for 850hPa and 200hPa winds; the importance of using of multiple data sources to provide information regarding observational uncertainty (especially fluxes) is currently being explored.
TRMM (OLR-calibrated) Rainfall

Pentad Data:
CMAP rainfall

20-100 day filter applied as necessary

Level 1 metrics:

1) VARIANCE MAPS (seasonally stratified and whole year)
   (a) Unfiltered variance (remove climatological annual cycle by subtracting the climatological daily means calculated using all years of data)

(b) 20-100 day filtered variance maps
(c) 20-100 day filtered variance maps expressed as percent of unfiltered variance

2) SPECTRA: analysis is performed on 180 day segments for each season. The results from (1) were used to isolate variance maxima, and then raw data from the surrounding region is area averaged. The regions below give the gridbox bounds over which the average is calculated. Depending on your model grid you may have to fractionally weight the data in longitude to match the bounds of the specified region, and data should be cosine weighted in latitude. As in (1) remove the climatological annual cycle by subtracting the climatological daily means calculated using all years of data. In all cases include the null, 5% and 10% red noise significance levels. For rainfall and OLR assess if consistency between regions is possible. Plot spectra according to Klaus's methodology (frequency or period (log scaling) vs. power x frequency). Calculate spectra over Indian Ocean for full year.

Compute a lag correlations on bandpass filtered data using the Indian Ocean regional time series (see item 2) and near equatorial averaged data at all longitudes to produce a lag-longitude plot. For summer also correlate the time series with anomalies averaged over Bay of Bengal longitudes to produce a latitude-lag plot. Need to decide upon regression with correlation coefficient to assess significance.

	OLR	Precipitation	u_{850}	u_{200}
Boreal Winter	7.5°N-7.5°S, 70.0°E-95.0°E	0.0°N-15.0°S, 75.0°E-100.0°E	1.25°S-16.25°S, 68.75°E-96.25°E	21.25°N-3.75°N, 53.75°E-81.25°E
	2.5°S-17.5°S, 110.0°E-140.0°E	5.0°S-20.0°S, 160.0°E-175.0W°	1.25°N-13.75°S, 163.75°E-191.25°E	1.25°N-16.25°S, 106.25°W-78.75°W
				W. Pac
Boreal Summer	7.5°N-7.5°S, 70.0°E-95.0°E	0.0°N-15.0°S, 75.0°E-100.0°E	21.25°N-3.75°N, 68.75°E-96.25°E	1.25°N-16.25°S, 43.75°E-71.25°E
	10.0°N-20.0°S, 120.0°E-140.0°E	10.0°N-25.0°N, 110.0°E-135.0°E	3.75°N-21.25°N, 118.75°E-146.25°E	1.25°N-16.25°S, 121.25°W-93.75°W
	Bay of Bengal box needed	10.0°N-20.0°N, 80.0°E-100.0°E	E. Pac box needed	W. Pac

3) EOF's of individual fields
(a) EOF analysis of 20-100 day filtered OLR
(b) EOF analysis of 20-100 day filtered CMAP rainfall
(c) EOF analysis of 20-100 day filtered TRMM rainfall
(d) EOF analysis of 20-100 day filtered 850hPa zonal wind
(e) EOF analysis of 20-100 day filtered 200hPa zonal wind
-standard information to be included is percent of variability explained by each mode. Also calculate North criterion.

The EOF patterns will be scaled by one standard deviation of the respective PC to give units consistent with the input data.
As needed, the EOF's/PC's that we present (on the web and/or in a publication) will be multiplied by -1 if necessary so that the results depict a consistent picture of eastward propagation of enhanced convection and rainfall anomalies. The winds will also be sign adjusted so that the patterns are consistent with the convection/rainfall, including their baroclinic structure. We are not requiring that users who employ these metrics do the same, but we will include a cautionary note regarding the arbitrary signs that can arise in EOF analysis.
To assess statistical significance of the EOF's projected the unfiltered anomalies back onto the EOF's, then calculate spectra as above and determine if intraseasonal power is significant to determine if the EOF is retained in this metric.

4) LAG CORRELATION
a) Calculate the lag correlation between PC-1 and PC-2 for each season separately for +/-30 days; then average the correlations at each time lag and plot correlation vs. time lag. By adjusting the sign of the EOF's/PC's we should get a consistent S-shape among in the lag correlation plots. Phase speed calculation

5) DISCUSSION ITEMS AND CAVEATS FOR THE ABOVE ITEMS
a) In observations the boreal winter extratropical jets precluded the identification of MJO EOF's using the 850hPa winds. It was necessary to truncate the latitude domain between 20^{o}N-20^{o}S.
b) Models have been known to overestimate the intraseasonal variability in the eastern tropical Pacific, which may preclude the extraction of a coherent MJO signal over the eastern hemisphere. Truncation to a regional domain may be necessary (e.g., 0^{o}-120^{o}W).
c) The sign of the individual EOF's/PC's are arbitrary and as such it may be necessary for the user to change the sign of both the EOF and PC of a given mode to determine if there is a pattern match and simulated lag correlations that are consistent with the observed metrics presented.
d) project model data onto the observed EOF's to assess how well the model captures the observed MJO

6) FUTURE ITEMS FOR CONSIDERATION
- We may consider supplying metrics for a good and a bad model to illustrate possible expectations/problems in model analysis (e.g., longitude selection may come into play for extracting model MJO [see 5b above]).

Level 2 metrics:

7) Frequency-wave number plots based on 10^{o}N-10^{o}S averaged data (OLR, u850, u200, surface zonal wind (10m), precipitation), and ratio of eastward to westward power (spectral plot as 2 above; freq x power log scale test)

(I) Use raw data (including annual cycle) for the full record to determine if the MJO signal is distinct from the lower frequency variability chop plot before nyquist freq.

(II) Seasonally stratified analysis (performed on each season separately)

(a) remove annual cycle (time mean and first 3 harmonics of climatological seasonal cycle??? ; Should this step be consistent with that for items 2 and 8? test)
(b) average data 10^{o}N-10^{o}S
(c) remove time mean for each segment
(d) taper first and last 45 days with a cosine window; test
(e) transform each segment, form power and average over all years (no other spectral smoothing). Effective bandwidth is 1/180 days; with estimates at 180 days, 90 days, 60 days, 45 days, 36 days, etc.
(f) plot period on the x-axis for the eastward and westward propagating components vs. wavenumber on the y-axis

8) Combined EOF's using 20-100 day filtered OLR, u850, and u200 averaged between 15^{o}N-15^{o}S-Harry to perform sensitivity tests for latitude extent (5^{o}N-15^{o}S, 15^{o}N-5^{o}S, seasonally dependent, map of reconstructed variance???). This is performed on seasonally stratified data, with each field normalized by the zonal mean of the temporal variance at each longitude

(a) report variance explained by each of the input fields for each mode
(b) Calculate the lag correlation between PC-1 and PC-2 for each season separately for +/-30 days; then average the correlations at each time lag and plot correlation vs. time lag. By adjusting the sign of the EOF's/PC's we should get a consistent S-shape among in the lag correlation plots.
(c) To assess statistical significance of the EOF's projected the unfiltered anomalies back onto the EOF's, then calculate spectra as above and determine if intraseasonal power is significant to determine if the EOF is retained in this metric.
(d) Mean coherence^2 and phase of PC-1 and PC-2

9) Life-cycle from Composites (20-100 day filtered)

(a) identify MJO event through plots of PC-1 vs. PC-2 exceeding 1 std. deviation
(b) generate spatial composites based on 8 different phases in PC-1 vs. PC-2 plot
(c) compare with composites from single field EOF's to assess value added

Basic
(a) OLR
(b) Pr
(c) $u_{200,}$ v_{200}
(a) $u_{850,}$ v_{850}
(d) u_{sfc}, v_{sfc}
(e) SLP

(f) 200hPa streamfunction

3-D (input from B. Mapes and G. Kiladis on vertical structure metrics)
(a) u
(b) q
(c) temperature
(d) omega

Fluxes (multiple sources to determine if developmental)
(a) SST
(b) taux, tauy
(c) LW
(d) SW
(e) SH
(f) LH

Developmental (input from B. Mapes and G. Kiladis on vertical structure metrics)
(a) all diabatic heating terms
(b) divergence

Higher Level Metrics

10) Mean state issues (seasonally stratified)

(a) SST
(b) pr
(c) Specific humidity (3-D, 10^oN-10^oS)
(d) Temperature (3-D, 10^oN-10^oS)
(e) u_{850}, u_{sfc}
(f) vertical shear of zonal wind

11) Interannual variability of the MJO

(a) using composite EOF results: $PC\text{-}1^2 + PC\text{-}2^2$
(b) wavelets
(c) stratify composites for ENSO phase
(d) 20-100 day activity; hovmoller of running variance (10^oN-10^oS averaged)

Future issue to consider

Multi-scale interaction particularly for high resolution models
a) Wheeler-Kiladis or Harry's variation thereof

MJO impact on other components of weather/climate

Providing codes for metric calculations