Application of Objective Diagnostics to the Madden-Julian Oscillation

Brandon Wolding and Eric Maloney
Colorado State University

Introduction

Objective assessment of the Madden-Julian Oscillation (MJO), past or present, typically relies on an EOF/PC based method (Wheeler and Hendon 2004) or wavenumber-frequency filtered fields (Kiladis et al. 2005) such as OLR or precipitation. While these methods have proven sufficient for capturing the large-scale structure of a mature MJO, their further application is restricted by obvious limitations. Traditional EOF/PC methods do not provide precise spatial locations of MJO activity, and can be disproportionally influenced by a single field, while wavenumber-frequency filtering methods rely on heavily filtered fields that are not available in real-time and do not incorporate the full dynamical structure of the MJO. Here we derive objective diagnostics from combined EOF (CEOF) analysis and utilize previously overlooked information to examine the physics of the MJO, and its initiation, in the context of a vertically-integrated moist static energy (MSE) budget. Our central question then is: **Can yet another set of diagnostics provide unique and useful information about the MJO?**

Diagnostics

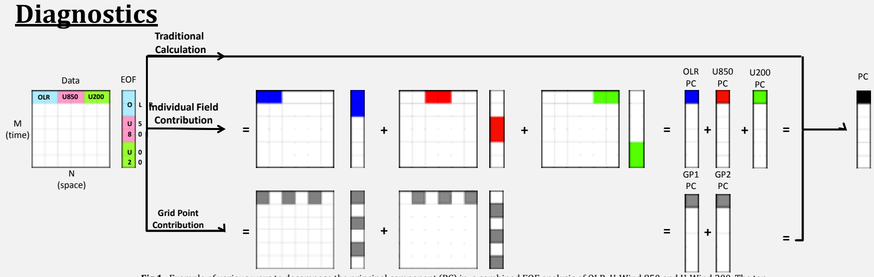


Fig 1. Example of various ways to decompose the principal component (PC) in a combined EOF analysis of OLR, U-Wind 850 and U-Wind 200. The top pathway represent the traditional calculation of the PC, the middle pathway shows the PC as the sum of the individual field PCs, and the bottom pathway shows the PC as sum of the individual grid point PCs. Further decomposition into individual field grid point contribution follows a similar method.

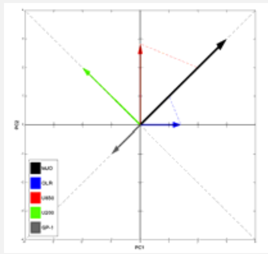
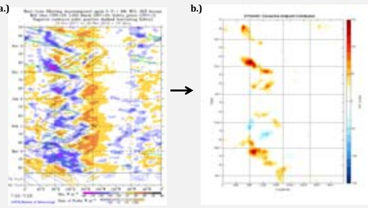


Fig 2. An example of how the projection of the component vectors onto the MJO vector in PC1/PC2 phase space can be used to quantify the contribution of any subdivision of the MJO vector to its overall magnitude.

Decomposing the MJO magnitude vector into component vectors in PC1/PC2 phase space provides a measure of the contribution of each field, at each grid-point, to the overall MJO magnitude, as well as measures of the convective and suppressed phase contributions to the overall MJO magnitude (see Fig. 1 & 2).

Grid Point Contribution (GPC)

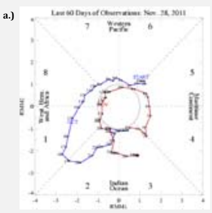
- Fig. 3 & 4 calculated from 1-D/2-D RMM-like methodology respectively, using ERA-Interim data.
- Provides insight to what the RMM(Fig. 4a.) was "seeing" and missing during the DYNAMO campaign(Fig. 3 & 4).
- Accurately identifies spatial location of convection associated with the MJO (Fig.3 & 4a), in context of large-scale winds (Fig. 4 d-g).



Courtesy of DYNAMO Field Catalog

Fig 3. a.) Hovmoller diagrams of OLR(left) averaged 7.5N-7.5S and **b)** convective GPC(right) averaged 15N-15S.

- Compares well with filtered products(Fig. 3a contours) without actually needing to be filtered(Fig. 3b).
- OLR GPC can easily be separated into convective and suppressed phase GPC(Fig. 3b & 4c)
- Caveat: dependent on EOF structure used (ex: winter vs. full year).



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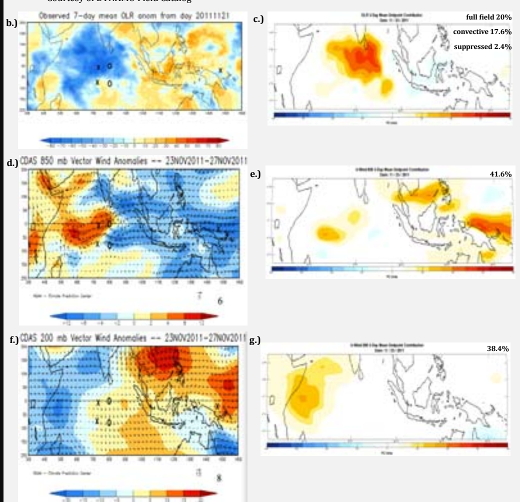

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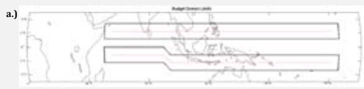
Fig 4. a.) RMM diagram from the DYNAMO field catalog website for dates that include the time period November 23 to November 27. **b,d,f.)** Corresponding 5-day mean anomalies of OLR, 850 hPa and 200 hPa zonal wind respectively, for the late November time period, as obtained from the DYNAMO field catalog courtesy of NOAA CPC. **c,e,g.)** Corresponding 5-day mean GPC anomalies for the same time period, with their total contribution to the full RMM magnitude indicated in bold in the upper right corner.

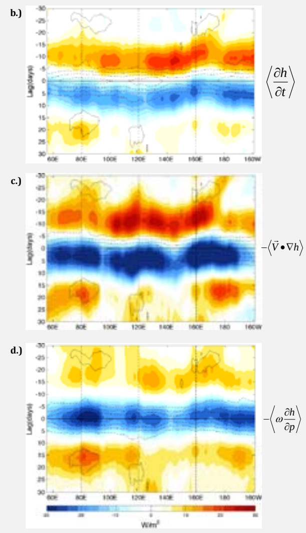
Benefits

- Available in real-time
- Does not rely on filtered products
- Applicable to any EOF/CEOF, not only the RMM
- Improves signal to noise ratio for algorithm development
- Allows case separation. For example, strong projections of winds but little OLR projection vs. strong OLR projection with little wind projection
- Potential application for model forecast skill assessment

Application to MSE Budget

- ERA-Interim, 1.5 x 1.5 , 4-times daily, 1979 – 2012
- 2-D CEOF following Wheeler and Hendon 2004 methodology. Composite index based on 5-day mean convective GPC averaged over sliding 10.5°x10.5° domain(Fig. 7a). Budget terms band-pass filtered 20-100 days.
- Horizontal advection more important than vertical advection in driving wintertime MSE tendency at all locations (Fig 6 & 7 b-d)
- The relative roles of zonal and meridional MSE advection(Fig 6.) vary substantially with time, and are dependent on location(not shown).
- Non-negligible residual provides caveat for results (Fig. 6).





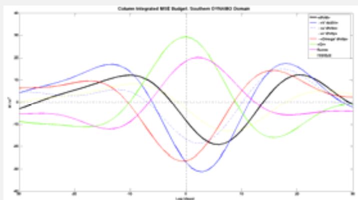


Fig 6. a.) Composite column integrated MSE budget for the southern DYNAMO domain (0° – 7.5°S, 73.5°E - 81°E)

Fig 7. a.) Column integrated MSE budget domain limits for May-October(top) and November-April(bottom). Each domain was 10°x10° and centered on the red dotted line. **b-d.)** Shading is November-April column integrated MSE tendency, horizontal advection and vertical advection respectively. OLR is contoured at 10 W/m^2 intervals (negative is dashed, positive is solid, zero contour omitted).

Summary

- GPC is a diagnostic which can be easily calculated and provides an objective measure of MJO activity(Fig. 1 & 2)
- When applied to both 1-D and 2-D RMM CEOFs(Fig. 3 & 4), GPC corresponds well with observations while reducing noise and providing insight as to what is projecting onto the RMM
- An initial application to test GPC fidelity (Fig. 6 & 7) showed that it was able to produce results similar to previous studies(Kiranmayi and Maloney 2011; Maloney 2009), as well as extend the results to provide insight into the zonal variation of MSE processes.
- Further application of this method will look at how horizontal advection of MSE affects propagation direction of the MJO

We conclude that GPC is a diagnostic that can provide unique and valuable information to various aspects of MJO research, from observation and forecasting to case studies and long-term analysis. Current methods have difficulty isolating processes that are spatially and/or temporally sensitive, such as initiation. We believe that GPC is a tool that may prove useful in advancing our understanding of such processes.

This work was supported by the Center for Multi-scale Modeling of Atmospheric Processes (CMMAP) and by the Climate and Large-Scale Dynamics Program of the National Science Foundation under Grants AGS-1062161 and AGS-1025584. The statements, findings, conclusions, and recommendations do not necessarily reflect the views of NSF.

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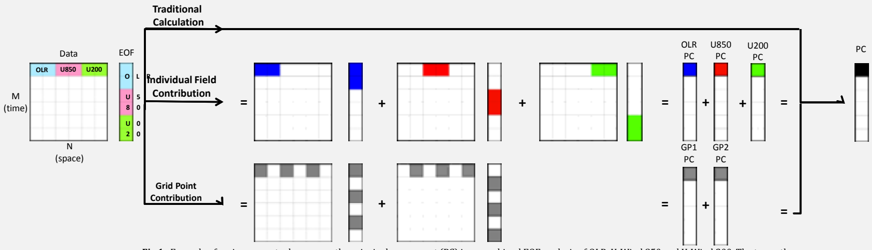
Diagnostics

Decomposing the MJO magnitude vector into component vectors in PC1/PC2 phase space provides a measure of the contribution of each field, at each grid-point, to the overall MJO magnitude, as well as measures of the convective and suppressed phase contributions to the overall MJO magnitude (see Fig. 1 & 2).



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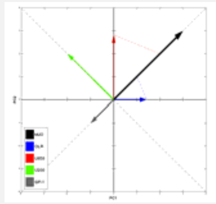

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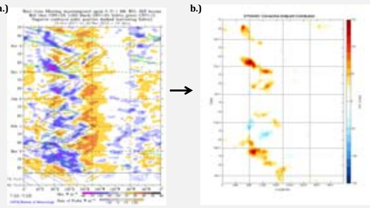

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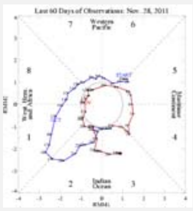

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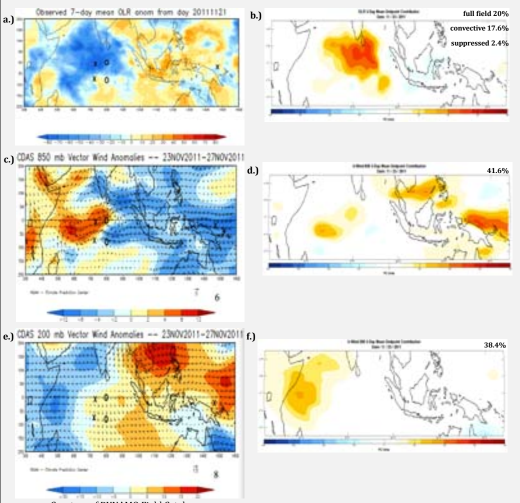

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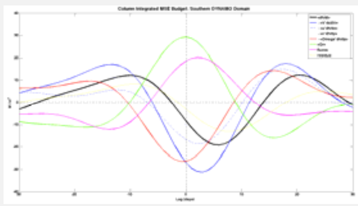

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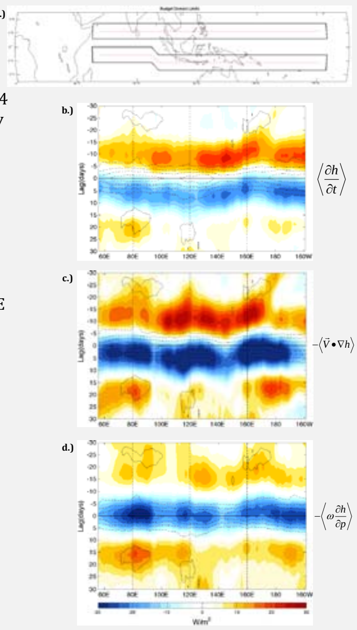

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