Kinematic analysis of the MJO by wind partitioning

Ángel F. Adames, Jérôme Patoux and Ralph C. Foster

1. Department of Atmospheric Sciences, University of Washington, Seattle, WA

2. Applied Physics Laboratory, University of Washington, Seattle, WA

Introduction

The Madden-Julian Oscillation is the dominant component of intraseasonal variability in the tropical atmosphere.

Its structure is potentially influenced by multiscale processes and extratropical motions.

A partitioning technique is proposed that can separate the wind field within the tropics into an irrotational component ($\mathbf{U}_\chi$), a non-divergent component ($\mathbf{U}_\psi$), and a third component associated with the extratropics ($\mathbf{U}_\theta$).

We analyze the contribution of these components to the MJO.

Free Space Green's Functions

A vorticity element, C_{kl}, centered at (λ'_{kl}, ϕ'_{kl}) contributes to the wind at any point (λ, ϕ). One reconstructs the total non-divergent wind field induced at (λ, ϕ) using the following equation:

$$u_\psi(\lambda,\phi) = \frac{1}{4\pi a}\sum_{k=1}^{M-1}\sum_{l=1}^{N-1} C_{kl}\frac{\cos\phi\sin\phi'_{kl} - \sin\phi\cos\phi'_{kl}\cos(\lambda-\lambda'_{kl})}{1-\cos\gamma_{kl}}$$

$$v_\psi(\lambda,\phi) = \frac{1}{4\pi a}\sum_{k=1}^{M-1}\sum_{l=1}^{N-1} C_{kl}\frac{\cos\phi'_{kl}\sin(\lambda-\lambda'_{kl})}{1-\cos\gamma_{kl}}$$

Where (λ, ϕ) represent longitude and latitude, and γ represents the central angle between two points on the sphere.

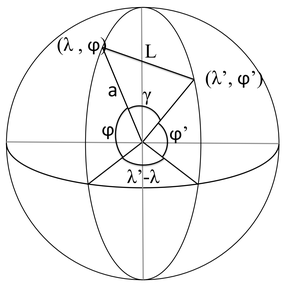


Fig. 1: Spherical coordinate system for wind partition.

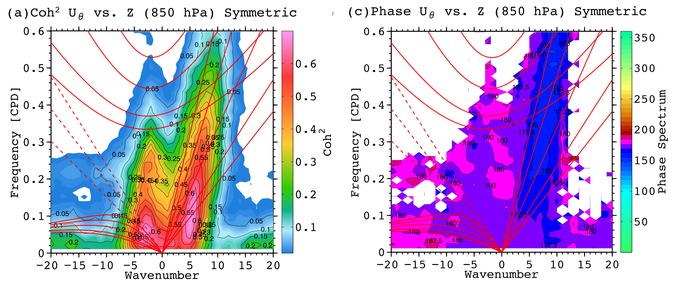
We can do similarly for divergence elements to reconstruct the irrotational wind field.

The final component ($\mathbf{U}_\theta$) can be obtained via substraction of $\mathbf{U}_\psi$ and $\mathbf{U}_\chi$ from the total wind field. We will refer to this component as the background flow.

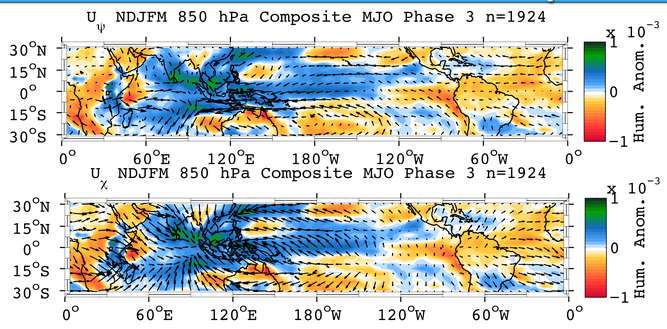
Coherence – Background Flow

- The spectral regions of highest coherence do not correspond to any equatorial wave mode.
- Fluctuations are nearly out of phase.
- Appearance looks similar to extratropical Rossby waves.

Fig. 2: Coherence (left) and phase (right) of U_θ from 15°S-15°N with geopotential height anomalies from 30°-45° (N and S).



Composites



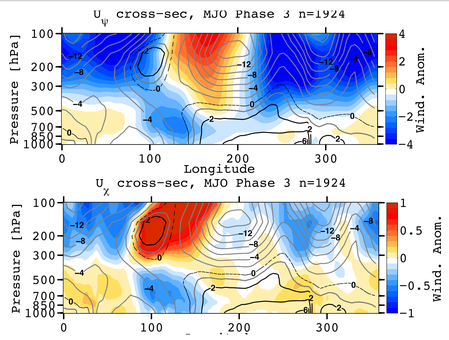


Fig 3.: Left: Non-divergent (top) and irrotational (bottom) components of the flow for MJO phase 3. Shading denotes humidity anomalies.

Right: Cross section of the zonal components of U_ψ (top) and U_χ (bottom) with local (10°S-10N) height anomalies (black-positive, grey-negative).

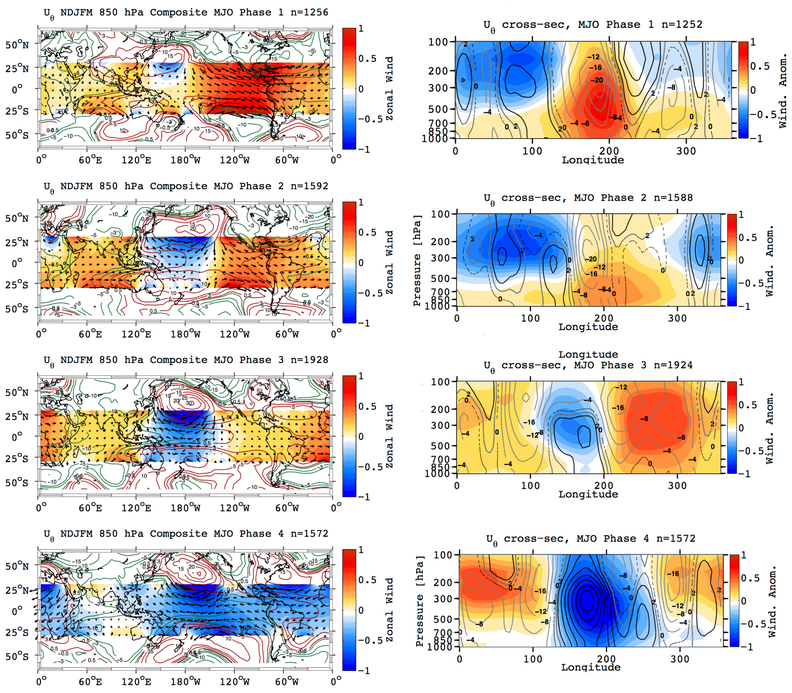


Fig 4.: Left: Background flow for MJO phases 1-4. Contours denote geopotential height anomalies (red-positive, green-negative). Shading denotes zonal wind component.

Right: Same as Fig. 3 but the geopotential height anomalies are averaged from 35°-45° N and S.

Zonal Means

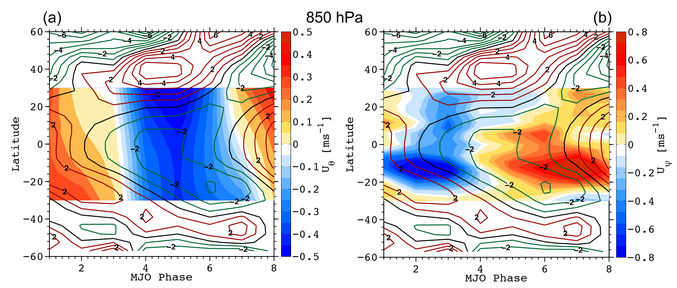


Fig. 5: Phase-latitude diagram of U_θ and U_ψ at 850 hPa averaged over NDJFM. Red contours denote positive height anomalies and green contours denoting negative anomalies. The zero height anomaly is marked as a black line. Contour interval is 2 m.

Conclusions

- The local components ($\mathbf{U}_\psi$ and $\mathbf{U}_\chi$) show a classical MJO pattern, with wind reversal with height.
- $\mathbf{U}_\theta$ is weaker, but of larger horizontal scale, than the other wind components.
- The background flow shows an oscillation in the central Pacific associated with extratropical height anomalies. The anomaly has an equivalent barotropic structure.
- An oscillation in the zonally averaged background flow is seen, associated with the zonally averaged extratropical height anomalies.
- The phase locking and sign of the background winds with respect to the local convective envelope of the MJO suggest that they might have some importance in determining the structure and propagation of the MJO.
- Future work includes further studies of how some aspects of the background flow can potentially modulate the streghth and structure of the MJO, and its initiation.

Acknowledgments

We acknowledge NASA OVWST grant support under NASA grant NNX10AO87G. Ángel F. Adames acknowledges support by the National Science Foundation Graduate Research Fellowship under Grant No. DGE-0718124.