17b.1 ANALYSIS OF OBSERVED GROUP PROPAGATION AND QUASI-STANDING OSCILLATIONS OF THE MADDEN AND JULIAN OSCILLATION

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1. INTRODUCTION

The 30-60 day Madden and Julian Oscillation (MJO, Madden and Julian 1994) dominates the time-variance of convection and wind in the tropics, especially in the eastern hemisphere and during austral summers. The origin and maintenance of the oscillation is the subject of much debate. The author observes that a westward group velocity and quasi-standing oscillations are associated with the MJO and that these observations are related to the development of new eastward propagating disturbances. Zhang and Hendon (1997) refuted the possibility of pure standing waves associated with the oscillation, but they did not rule out all quasi-standing behavior. This work presents an analysis of outgoing longwave radiation (OLR) and precipitable water (PW) data to confirm the reality of these observations, revealing that they are generated by cooperation of the eastward propagating portion of the MJO with westward propagating equatorial Rossby modes.

2. DATA AND METHODOLOGY

Analysis methods used included filtering in the wavenumber-frequency domain as in Wheeler and Kiladis (1999). Three filter products were applied, labeled MJOe, MJOw, and MJObal, where MJOe contains the spectral region generally accepted to describe the MJO, including eastward propagation, wavenumbers 0-6 and periods of 25 to 104 days; MJOw contains the region dominated by the Rossby modes, including westward propagation, wavenumbers 1-6 and periods of 15 to 104 days; the MJObal filter contains the region formed by combining the MJOe and MJOw filters.

Daily OLR data was retrieved from the NOAA/NESDIS satellite data information service (Liebmann and Smith 1996). PW data was obtained from the NASA water vapor project (NVAP, Randel et al. 1996). Both the OLR and the PW data covered the period January 1, 1988 to December 31, 1997.

All three filters were applied to the OLR and PW data, and results were plotted in longitude-time diagrams. Longitude-time plots of MJOe filtered PW and OLR data were used to measure group velocities and compute their distribution. Most anomalies in these diagrams were organized into localized groups. The slope of the line that most nearly connects the absolute extrema of the highest amplitude PW anomalies in a group approximates the group velocity. The distribution of group velocity values was made with statistics that were measured from the PW data at 10 degrees south latitude. The greatest variance of convection that is associated with the MJO occurs near this latitude. Some measurements were eliminated from the distribution, including groups with a PW signal that was inconsistent with the OLR signal.

3. DISCUSSION AND CONCLUSIONS

The results of the observational analyses reveal that the eastward propagating part of the MJO exhibits a westward group velocity, and that MJObal filtered data exhibits quasi-standing behavior. Eastward group propagation is rare in the MJOe filtered data. Figure 1a represents one event in the filtered OLR and PW data. Figure 1b represents the same event in data that are smoothed in time only. Figure 2 represents the distribution of westward group velocities according to the analysis of our ten-year dataset.

Figure 3 is an example longitude-time diagram of MJObal filtered PW data at 15 degrees south. Quasi-standing oscillations are visible globally. Nodal points often occur near barriers such as the Andes Mountains. Patterns in the MJObal filtered observations reveal interesting interaction between the eastward and the westward propagating disturbances. The quasi-standing wave patterns are visible in spite of the structural differences between the eastward and the westward propagating parts. Simple theoretical model waves roughly approximate the behavior of these wave types, and theory based on these waves describe how they interact. Matsuno (1966) found solutions to a linearized shallow water model in the equatorial beta plane. These solutions include Rossby, gravity, and Kelvin modes. The Kelvin mode is most similar to the MJO, but significant differences between the two modes occur in phase speeds and meridional winds. Nevertheless, the Kelvin wave is the simplest approximation for horizontal MJO structure available. The model of Matsuno predicts that the westward propagating portion of the frequency range of the MJO is dominated by equatorial Rossby modes. MJOw filtered data (not shown) does reveal that the westward propagating portion of the standing oscillations often has the structure of low order Rossby modes. Some of the Rossby and Kelvin-like waves that occur in the atmosphere are interrelated because of interactions with land and because of feedbacks from moist convection. If one of these waves impinges on a barrier, the other may be produced as a reflection (McPhadden and Gill 1987, Park and Schubert 1993, and Kleeman 1989). As these waves interact with their reflections, quasi-standing behavior results. A similar theory has been developed to describe sea-surface temperature variations in the El-niño or Southern Oscillation (ENSO, Battisti 1988). Waves in the atmosphere could behave in the same way, but on different timescales.

The Rossby modes do not have the same dispersion statistics as the MJO, nevertheless the eastward and the westward propagating disturbances

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cooperate to organize convection into standing patterns. This cooperation involves interaction with land and convection. Further analysis (not shown) reveals that the apparent westward group velocity in MJOe is forced by interaction with Rossby gyres that are discernable in MJOw filtered data. These results imply that MJOe and MJOw disturbances cooperate in such a way that neither should be used independently.

ACKNOWLEDGMENTS

This work was supported by National Science Foundation grant ATM0003351 and by a supplemental NASA Spacegrant Fellowship. Mr. Roundy is and advisee of Dr. W.M. Frank.

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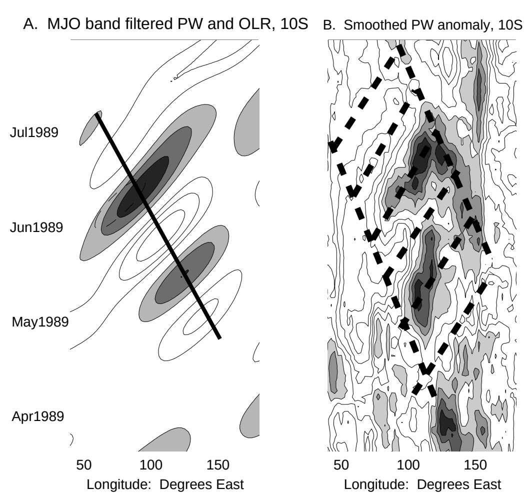

Figure 1 A, Group velocity analysis of MJOe filtered PW. Heavy line approximates group velocity. B: PW anomaly smoothed with 17-day moving average. Dashed lines represent phase speeds of both eastward and westward propagating anomalies.

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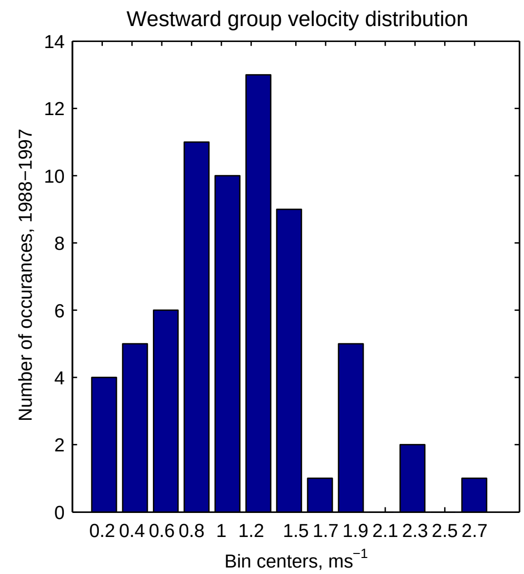

Figure 2 Distribution of westward group velocities for 10 degrees south measured from the 1988-1997 precipitable water climatology.

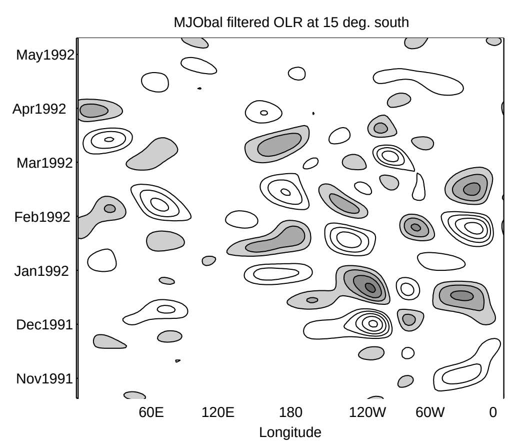

Figure 3 Example of MJObal filtered OLR at 15 degrees south. Contours are at integer local standard deviations.