Observed Intraseasonal Variability in Eastern Pacific

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Abstract. The MJO is known to be strongest during Northern-Hemisphere winter in the Indian Ocean and Western Pacific (WPac) regions, where rising/convective motions are most pronounced [*Madden & Julian*, 1972; *Zhang*, 2005]. Here we studied long records of cloud liquid water, column water vapor from SSM/I, and water vapor mixing ratio at 634 hPa measured by AIRS. We found a significant intraseasonal variations in water vapor (both column and at 634 hPa) over the eastern Pacific (EPac) that seem to be related to the MJO in the EPac, but have distinct characteristics [also see *Tian et al.*,2006]. We performed the Wheeler-Kiladis space-time spectral analysis to AIRS water vapor and found an anti-symmetric equatorial (westward propagating) Rossby wave mode with a period of 30-90 days. This mode is not present in the OLR and cloud-related variables probably due to the weaker convection in the EPac relative to the WPac. Confirmation and an explanation for this newly identified mode will provide new insights into intraseasonal variability in the tropics.

Data. In this study, we employ

(a) The 0.25°×0.25° daily data products (1987-2008) of **rain rate, cloud liquid water and column water vapor** acquired by the Special Sensor Microwave Imager (SSM/I)

(b) **The Level 3 daily AIRS H_2O profiles** from 1 September 2002 to 31 July 2009 retrieved from the spectral measurements by AIRS and Advanced Microwave Sounding Unit (AMSU).

Methods.

(a) **The MJO phase is determined by the Realtime Multivariate MJO (RMM) index [*Wheeler & Hendon*, 2004]&.** Only MJO events occur in the boreal winter are considered and weak MJO events ($RMM_1^2 + RMM_2^2 < 1$) are ignored. The MJO patterns are obtained by averaging the data in the respective phases.

(b) To study the contributions of individual atmospheric modes, **we also apply the *Wheeler-Kiladis* wavenumber-frequency spectral analysis [*Wheeler & Kiladis*, 1999] to the AIRS H_2O products**, which have been decomposed into latitudinally antisymmetric and symmetric components. At each grid point, the 7-year AIRS H_2O time series is divided into 96-day segments with 2 months (~ 60%) overlap. Each segment is detrended and deseasonalized. A 2D Complex FFTs are performed on all available segments of the 7-year record and the resultant spectral powers are averaged over, and are summed for the latitudes between 15° S and 15° N.

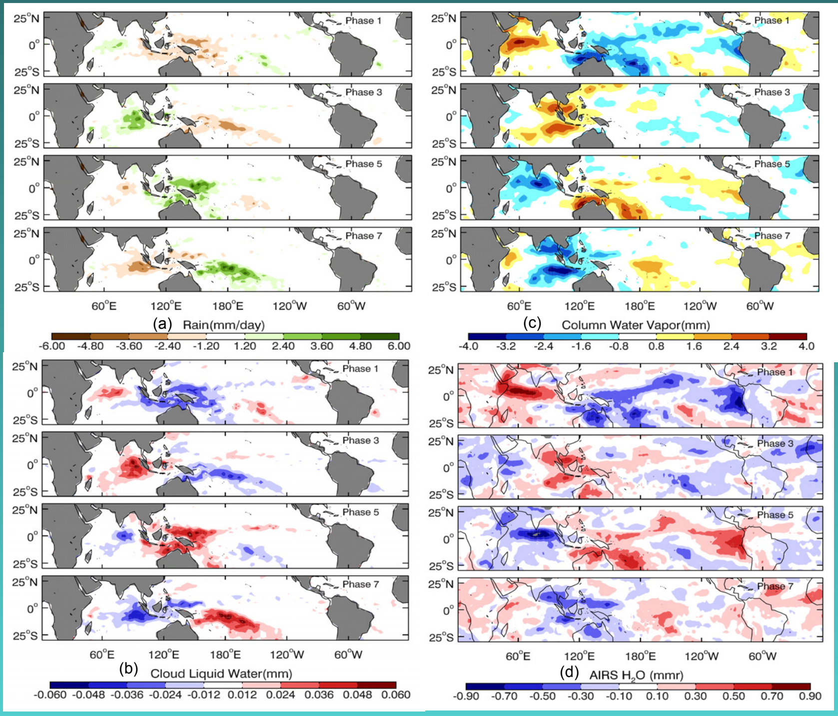

Figure 1. MJO phases of atmospheric variables: (a) rain rate, (b) cloud liquid water, (c) column water vapor, (d) water vapor (mass mixing ratio) at 634 hPa. (a)-(c) are from SSM/I; (d) is from AIRS.

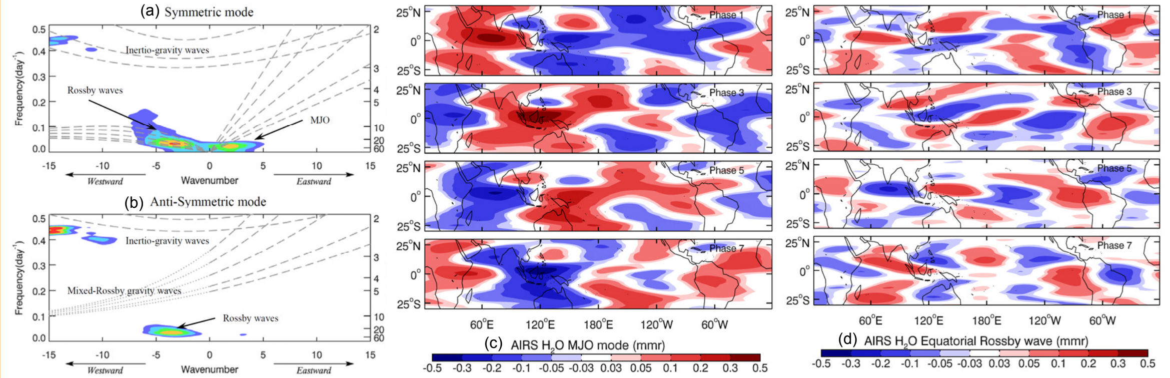

Figure 2. (a & b) The Wheeler-Kiladis space-time spectra, applied to AIRS H_2O at 634 hPa. (b) Filtered MJO phases using the symmetric MJO mode. (d) Filtered MJO phases using both symmetric and anti-symmetric equatorial Rossby wave modes.

Results. For simplicity, only the 1st, 3rd, 5th and 7th phases of the MJO are shown in Figure 1. All figures are of the same region (-30 to 30 latitude). The rainfall anomalies indicate the eastward propagation of the convective anomaly associated with the MJO. Besides the typical MJO variations over the Indo-Pacific region, **both SSM/I column water vapor and AIRS water vapor mixing ratio at 634 hPa show a robust nonzero anomalies in EPac, which are as large as those over WPac. AIRS data also reveal the tropograhic effects near the coast of Peru.**

Figure 2(a,b) show the space-time spectra of H_2O at 634 hPa. Compared to the one in Figure 3 of *Wheeler and Kiladis* [1999], the absence of the symmetric Kelvin waves and antisymmetric mixed Rossby gravity waves are readily seen. **There exists an antisymmetric equatorial Rossby wave, which is absent in the OLR data.** There are some signals of periods ~ 2 – 3 days and zonal wavenumbers ~ 10 – 15 in both symmetric and antisymmetric components, which are likely to be related to inertio-gravity waves. The MJO mode is mostly symmetric.

To study the contribution of individual modes to the MJO patterns shown in Figure 1(d), we filter out the MJO modes and the symmetric and antisymmetric Rossby wave modes [*Wheeler & Weickmann*, 2001]. The MJO patterns are then calculated using the RMM index again. Figure 2(c,d) show that the MJO patterns of the MJO mode and equatorial Rossby wave (sum of symmetric and antisymmetric components) respectively. In the Indo-Pacific region, the MJO mode dominates. It has an amplitude ± 0.5 mmr whereas the Rossby wave mode has an amplitude ± 0.2 mmr. Over EPac, the MJO mode and the Rossby wave mode have the same amplitude ± 0.2 mmr. Thus, **the equatorial Rossby wave mode contribute a significant portion of the anomalies over EPac.**

Summary

1. SSM/I and AIRS have been used to study MJO in cloud water vapor, column water vapor, and vertically resolved water vapor at 634 hPa.
2. A significant anomaly is seen over the eastern Pacific in water vapor data.
3. The Wheeler-Kiladis spectral analysis has been applied to AIRS H_2O data at 634 hPa. We found an antisymmetric equatorial Rossby wave mode with a period of 30-90 days, which is absent in OLR.
4. The MJO mode and equatorial Rossby wave modes have been filtered out and the MJO patterns have been calculated for individual modes.
5. In the Indo-Pacific region, the MJO mode dominates the anomalies.
6. In the eastern Pacific, the MJO and equatorial Rossby wave modes show about the same MJO anomalies, suggesting that the latter a significant amount of anomalies in the observed variations over the region.

References Madden & Julian (1972), *J. Atmos. Sci.* **29**, 1109; Tian *et al.* (2006), *J. Atmos. Sci.* **63**, 2462; Waliser *et al.* (2009), *J. Clim.* **22**, 3006; Wheeler & Kiladis (1999), *J. Atmos. Sci.* **56**, 374; Wheeler & Hendon (2004), *Mon. Wea. Rev.* **132**, 1917; Wheeler & Weickmann (2001), *Mon. Wea. Rev.* **129**, 2677; Zhang (2005), *Rev. Geophys.* **43**, RG2003.

& RMM index downloadable from http://cawcr.gov.au/bmrc/clfor/cfstaff/matw/ maproom/RMM/RMM1RMM2.74toRealtime.txt