The Hydrological Cycle of the Madden-Julian Oscillation

An Estimate from Satellite Observations

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Motivation

- The MJO is the dominant form of intraseasonal variability in the Tropics, with impacts a wide range of phenomena.

- Our weather & climate models have a relatively poor representation.

- Most studies have focused on dynamics or components of the energy and water cycle.

- Space-based observations now make it possible to document and examine the complete hydrological cycle of the MJO.

QUESTION?

Using space-based observations only, what can be said about the hydrological cycle of the MJO?
**Data**

- **CMAP Rainfall:**
  - Global, 2.5° x 2.5° lat-long, pentad, 01/01/1979-02/22/2007. Xie and Arkin (1997)

- **TRMM 3B42 Rainfall:**
  - 40S-40N, 0.25° x 0.25°, 3-hourly, 01/01/1998-06/30/2007. Huffman et al. (2007)

- **AIRS H2OVapMMR & TotH2OVap**
  - V4, L3, global, 1.0° x 1.0°, 2X daily, 09/01/2002-04/30/2007. Chahine et al. (2006)

- **QuikSCAT & TMI Moisture Transport**

- **OAFlux Evaporation**
  - 65S-65N, 1.0° x 1.0°, daily, 01/01/1981-12/31/2002. Yu and Weller (2007)

- **SSMI Total Column H2O Vapor & Total Cloud Liquid H2O**
  - V6, DMSP F13, global, 0.25° x 0.25°, 2X daily, 01/01/1996-06/30/2007. Wentz (1997), Wentz and Spencer (1998)

- **MLS Ice Water Content**
HYDROLOGIC BALANCE

\[
\frac{\partial W}{\partial t} + \nabla \cdot \Theta = E - P
\]

\[
\Theta = \frac{1}{g} \int_0^{p_0} q Ud\rho
\]

\[
W = \frac{1}{g} \int_0^{p_0} q d\rho
\]

\[
\Theta = U_e W
\]

\(U_e = f(U_s)\) \hspace{1cm} \text{Liu (1993)-polynomial}

\(U_e = U_{850mb}\) \hspace{1cm} \text{Heta & Mitsuta (1993)}

\(U_e = U_{850mb}\) \hspace{1cm} \text{Liu & Tang (2005) - Neural Network}

\(U_e = U_{850mb}\) \hspace{1cm} \text{Both Us & U_{850mb}}

\(U_e = U_{850mb}\) \hspace{1cm} \text{Xie et al. (2007) - SVR}
Spatial-temporal Pattern of the 1st EEOF Mode of Rainfall Anomaly

Methods
MJO Event Selection

Spatial-temporal Pattern of the 1st EEOF Mode of Rainfall Anomaly
MJO Events in Hydrological Time Series

Principal Component Time Series of 1st EEOF Mode of Rainfall Anomaly

EOF Amplitude

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Rainfall Pattern & Data Sensitivity
Rainfall and Total Column Moisture Convergence tend to be Correlated throughout Tropics - except maybe over S. America
Rainfall & Surface Evaporation

Largest Evap anomalies in the subtropics in association with Rossby grye modulations of tradewind regimes

Near-equatorial Evap anomalies tend to lag precipitation anomalies

Comp QLH MJO Anom (mm day⁻¹)

Contours: CMAP Rainfall MJO Anom; Solid Pos; Dashed Neg
Contours start at +/-0.5 with interval of 1 mm day⁻¹
Composite Hydrological Cycle

Vertical Structure

Water Vapor

Cloud Ice

EQ Mean AIRS H2OVap MMR MJO Anom (gm kg⁻¹)
-0.3 -0.2 -0.1 0.0 0.1 0.2 0.3
Black: CMAP Rainfall; Green: QuikSCAT QConv;
Purple: OAFlux QLH (Solid: 0S-0N; Dotted 10-25N)

EQ Mean MLS /WC MJO Anom (mg m⁻³)
-0.4 -0.3 -0.2 -0.1 0.0 0.1 0.2 0.3 0.4
Black: CMAP Rainfall;
Green: SSMI TotCldLiqH2O; Purple: SSMI TotH2OVap
MJO Hydrological Cycle - Troposphere

Upper Troposphere - See Other Diagram

Column Integrated Values

- 0.5 mg/m³
- 0.1 gm/kg
- 0.3 gm/kg
- 0.2 mm/day
- 0.03 mm
- 2 mm
- 3 mm/day
+ 0.5 mg/m³
+ 0.1 gm/kg
+ 0.3 gm/kg
+ 0.2 mm/day
+ 0.03 mm
+ 2 mm
+ 3 mm/day

Surface

300 hPa

600 hPa

900 hPa

~ 45 days
MJO Hydrological Cycle - UTLS

~100 hPa

~150 hPa

~250 hPa

~150 hPa

Surface

-3 mm/day

+3 mm/day

~ 45 days

Lower-Middle Troposphere - See Other Diagram

Total-column Moisture Budget

\[ \frac{\partial W}{\partial t} = -P + MC + E \]

- **Total column Moisture change**
  - Moistening (>0)
  - Drying (<0)
- **Surface Rainfall**
- **Moisture Convergence due to large-scale moisture transport**
- **Surface Evaporation**
\[ \frac{\partial W}{\partial t} + P - MC - E = \text{residual} \]
Summary

• Satellite Observations are now able to provide an estimate of the chief components of the Hydrological Cycle Associated with the MJO, in some cases with vertical structure information.

• However, calculations of the Residual Term of the column-integrated values indicates closing the budget with current generation of satellite retrievals is difficult.

• It is all but certain that robust moisture convergence estimates will necessarily be derived from a numerical analysis system but having co-located wind and moisture sounding information from the same platform would be ideal for making such estimates via assimilation.

• Within the levels of uncertainty, Future plans involve applying the observed Hydrological Cycle of the MJO as a means to diagnose, evaluate and validate GCM simulations of the MJO or Evaluate Theoretical considerations.