Moisture Cycle of the Madden-Julian Oscillation: An Analysis of TRMM and SP-CAM Data

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1. Introduction

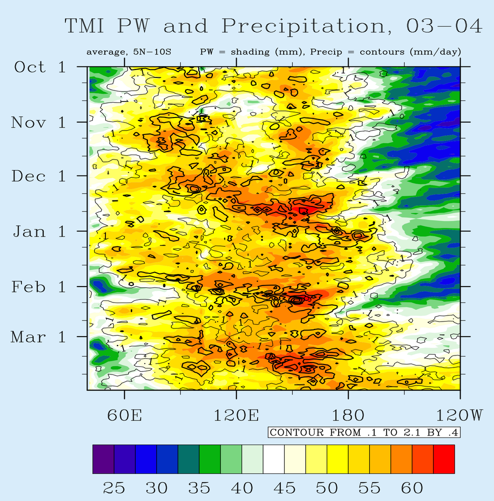

Figure 1

The Madden-Julian Oscillation is an eastward moving oscillation of deep convection that occurs in the equatorial Indian and western/central Pacific Oceans with a timescale of about 30-90 days.

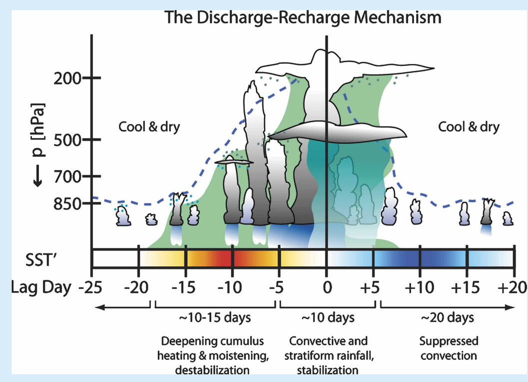

Figure 2: Benedict and Randall 2007, JAS

The Discharge-Recharge Cycle theory explains the time cycle of the MJO: moisture builds up until it reaches a tipping point, causing large-scale convection that allows the air to dry through horizontal and vertical advection (Bladé and Hartmann 1993).

2. Objectives

To analyze the moisture cycle of the MJO using data analysis of precipitable water, precipitation, specific humidity, and zonal wind.

To evaluate how the MJO moisture cycle in the superparameterized Community Atmosphere Model version 3.0 (SP-CAM) compares with observations.

3. Data

Model:

(2.8 degree horizontal resolution)

SP-CAM
- PW, PR, U, Q, OLR
- Daily data, 1985-2004
- Version of the CAM 3.0 using two-dimensional Cloud Resolving Models
- Unlike many models, SP-CAM has a fairly realistic MJO (Benedict and Randall 2009)

Observations:

(2.5 degree horizontal resolution)

TMI
- PW, PR
- Daily data, 1998-2010

NCEP2
- U, Q
- 8 vertical levels between 1000-300 hPa
- Daily data, 1979-2010

OLR
- Daily data, 1979-2010

4. Identification of MJO Events

Observed MJO events identified using OLR data
- •OLR filtered to MJO space and time scales
- •Events cross-checked with PW/PR data (Figure 1)

SP-CAM MJO events identified by Benedict and Randall (2009)
- •Events cross-checked with SP-CAM filtered OLR (Figure 3) and PW/PR data

For both TRMM and SP-CAM events:
- •Events found only for October-March, as the MJO is stronger during the boreal winter
- •Data averaged from 5N-10S, the region with the strongest MJO signals during the boreal winter
- •Plots averaged over 20 degrees longitude

Three years of active MJOs analyzed in each dataset

Events analyzed at three different locations: Indian Ocean, western Pacific, central Pacific

All plots centered on the date of the maximum PW

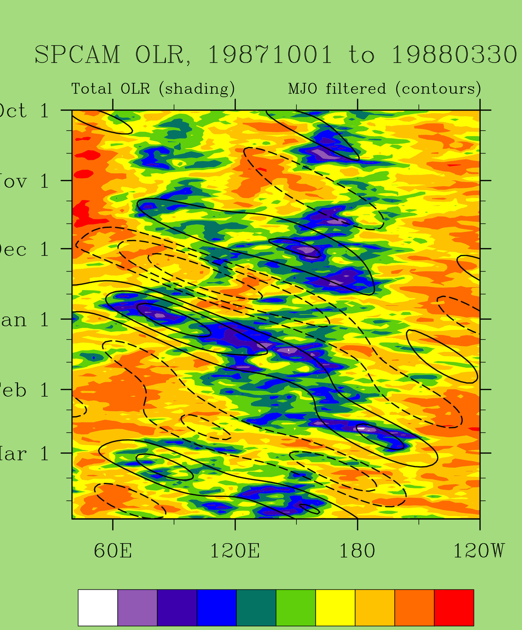

Figure 3: SP-CAM OLR (shading) with MJO filtered OLR (contours), used to help identify MJO events

Data Set	Years	Beginning Center Longitude	Date of Peak PW	Middle Center Longitude	Date of Peak PW	End Center Longitude	Date of Peak PW
TMI	03-04	90 E	2003-12-03	150 E	2003-12-20	180	2004-01-03
TMI	03-04	70 E	2004-01-14	130 E	2004-01-31	160 E	2004-02-08
TMI	03-04	80 E	2004-02-29	130 E	2004-03-10	170 E	2004-03-10
TMI	06-07	70 E	2006-12-23	130 E	2006-12-30	160 E	2006-12-31
TMI	07-08	70 E	2007-12-07	120 E	2007-12-23	160 E	2008-01-21
TMI	07-08	60 E	2008-01-23	110 E	2008-01-31	150 E	2008-02-06
SP-CAM	86-87	35 E	1986-12-11	95 E	1986-12-20	160 E	1987-01-02
SP-CAM	87-88	110 E	1987-12-01	160 E	1987-11-30	200 E	1987-12-01
SP-CAM	87-88	60 E	1987-12-25	130 E	1988-01-08	180	1988-01-20
SP-CAM	87-88	100 E	1988-03-07	125 E	1988-03-20	150 E	1988-03-17
SP-CAM	93-94	90 E	1993-11-16	160 E	1993-12-26	205 E	1994-01-03

Table 1: Identified events analyzed at three different locations

5. Results

PW vs. PR Plots:

Hysteresis plots show correlation between PW and PR during the recharge and discharge phases of the MJO.

TMI shows clockwise trend, implying higher PW during the recharge phase

TMI hysteresis plots smoother and more clear than SP-CAM

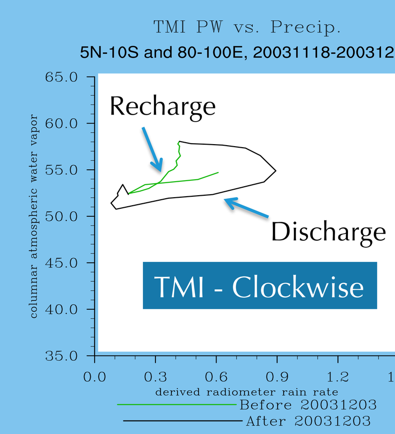

Figure 4

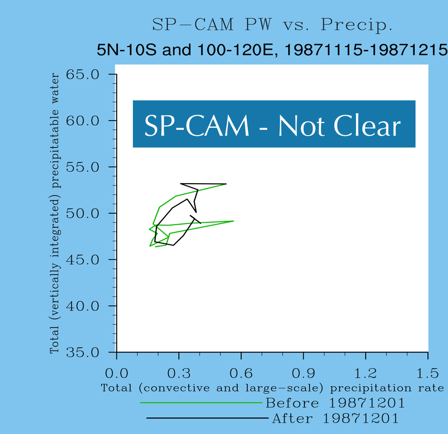

Figure 5

Data	Total	Clockwise	Counter-Clockwise	Direction changes/ not clear
TMI	18	9	2	7
SP-CAM	15	3	1	11

Table 2

SP-CAM is in blue

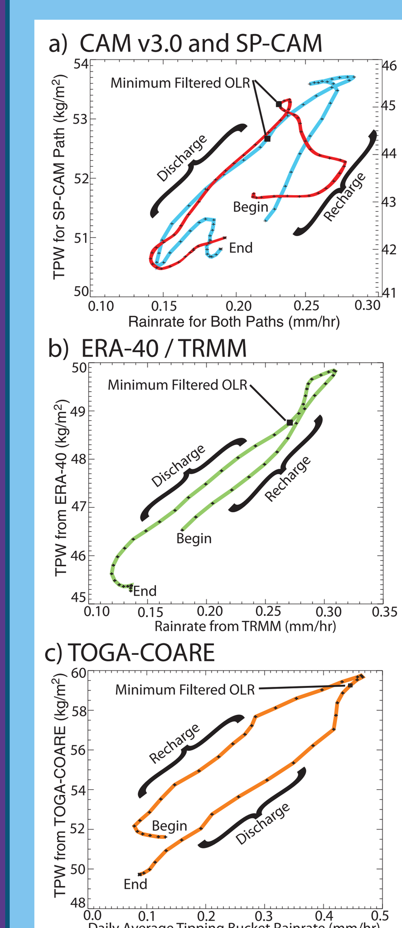

Figure 6: Thayer-Calder and Randall 2009, JAS

Clockwise direction inconsistent with results in Thayer-Calder and Randall (2009); ERA-40/TRMM and SP-CAM are counter-clockwise, though TOGA-COARE is clockwise

Differences could be caused by:
- ERA-40/TRMM is reanalysis
- These events are composite
- Different method of identification of events
- SP-CAM and ERA-40/TRMM averaged over 15N-15S

Results here similarly show that observations are smoother than SP-CAM

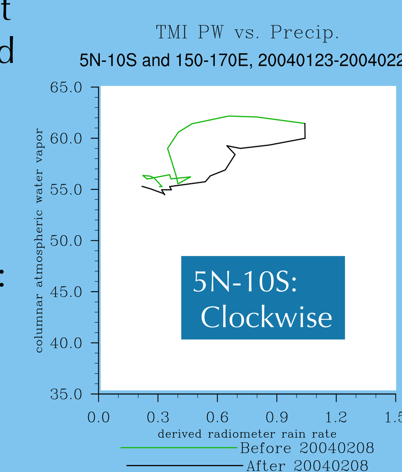

Figure 7

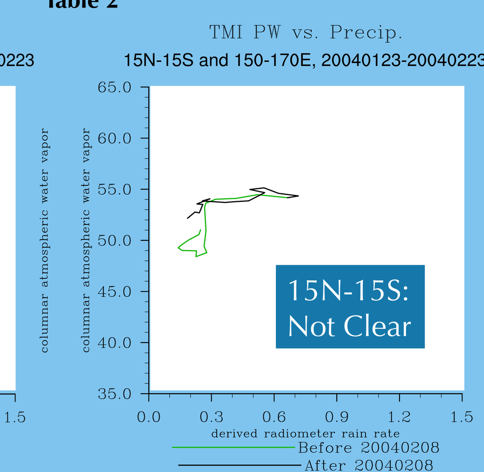

Figure 8

For 15N-15S average, observations are less clear and have less of a clockwise trend than for 5N-10S.

Latitude	Total	Clockwise	Counter-Clockwise	Direction changes/ not clear
5N-10S	18	9	2	7
15N-15S	18	2	2	14

Table 3

Time Series Plots:

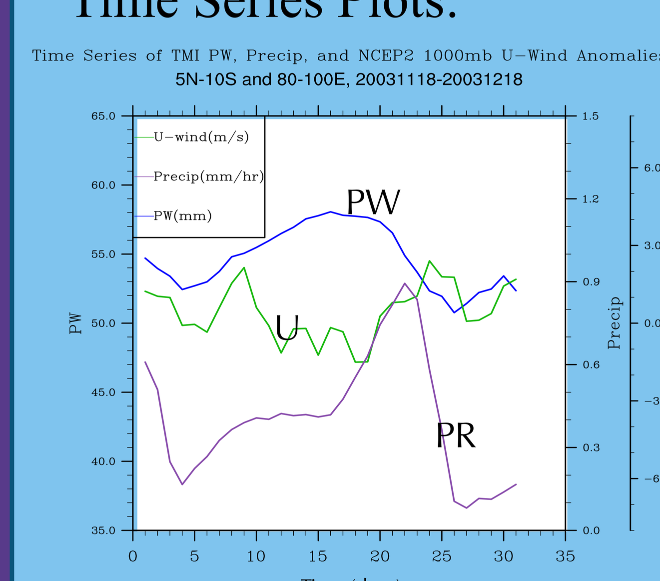

Figure 9

TMI (Figure 9)
- Smoother PW curve
- In general, order is PW peak, then PR peak, then U peak
- Recharge slower than discharge

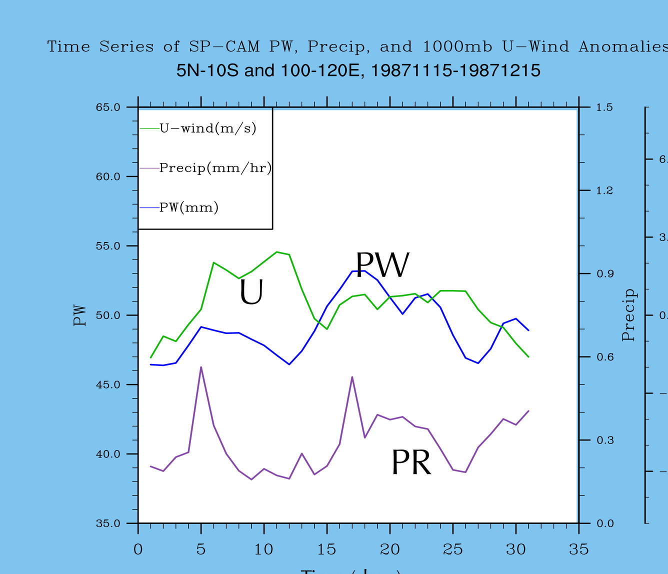

Figure 10

SP-CAM (Figure 10)
- Multiple PW peaks
- PW and PR peaks simultaneous
- Sharper increase in PW

Specific Humidity Cross-section plots:

NCEP2 (Figure 11)
- Moisture accumulates gradually from bottom up
- Similar to results found in Kiladis et al. (2005)

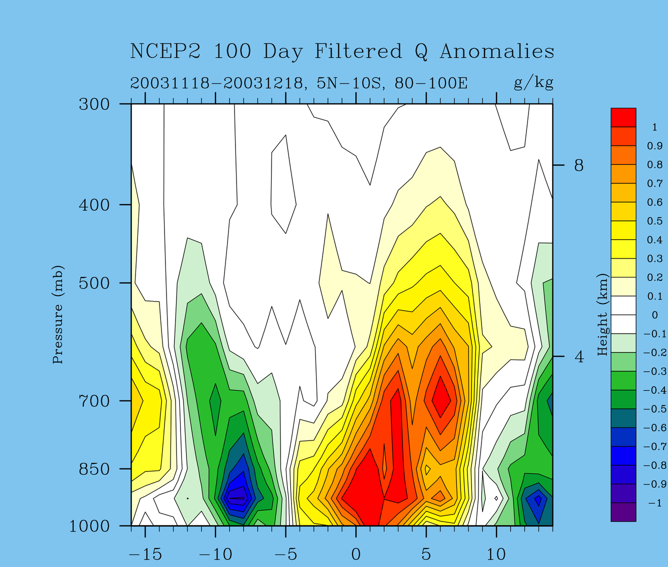

Figure 11

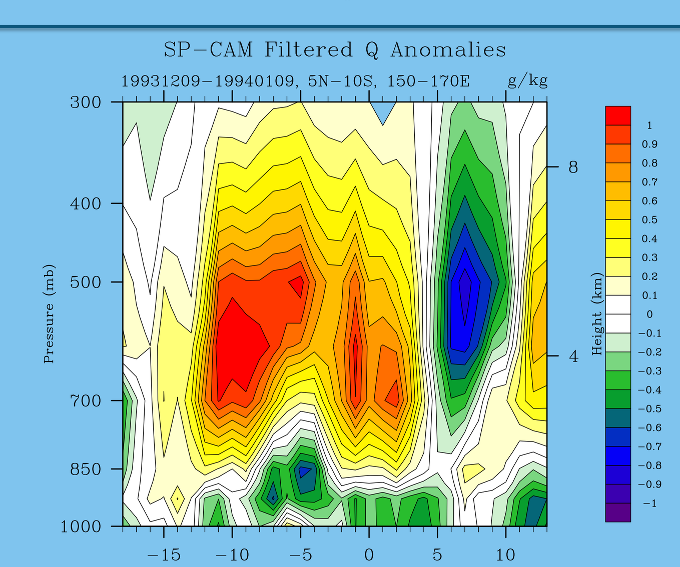

Figure 12

SP-CAM (Figure 12)
- Accumulation of moisture at all levels at the same time
- Multiple spikes in Q
- Negative Q anomalies at lower levels (extreme case shown); possible explanation could be updrafts
- Earlier date for beginning of positive Q anomalies relative to date of maximum PW
- In general, positive Q anomalies span a longer period of time

6. Conclusions

Clockwise direction of TMI Hysteresis (Preciptable Water vs. Precipitation) plots: less clear for 15N-15S and not as evident in SP-CAM

SP-CAM hysteresis plots more variable than TMI

The SP-CAM MJO moisture cycle is not as smooth as the moisture cycle in observations: SP-CAM has more peaks in precipitable water and a quicker recharge phase

In the NCEP2 data, positive Q anomalies accumulate gradually from the bottom up, whereas in the SP-CAM accumulation of moisture at all levels happens at the same time

SP-CAM has longer ranges of dates with positive Q anomalies and an earlier date comparative to maximum PW for the beginning of positive Q anomalies

In some instances, SP-CAM has negative Q anomalies at lower levels during MJO, which is inconsistent with observations

Abbreviations and Definitions:

MJO: Madden-Julian Oscillation
PW (Precipitable Water): Column integrated water vapor
PR (Precipitation): Rainfall
Q (Specific Humidity): Ratio of mass of water vapor to mass of system
U (Zonal Wind): East-west wind
TRMM: Tropical Rainfall Measuring Mission
TMI: TRMM Microwave Imager
NCEP2: NCEP-DOE Reanalysis 2
OLR: NOAA Outgoing Longwave Radiation, proxy for deep clouds
SP-CAM: Superparameterized Community Atmosphere Model Version 3.0

7. Acknowledgements

This work has been supported by the National Science Foundation Science and Technology Center for Multi-Scale Modeling of Atmospheric Processes, managed by Colorado State University under cooperative agreement No. ATM-0425247.

8. References

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