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

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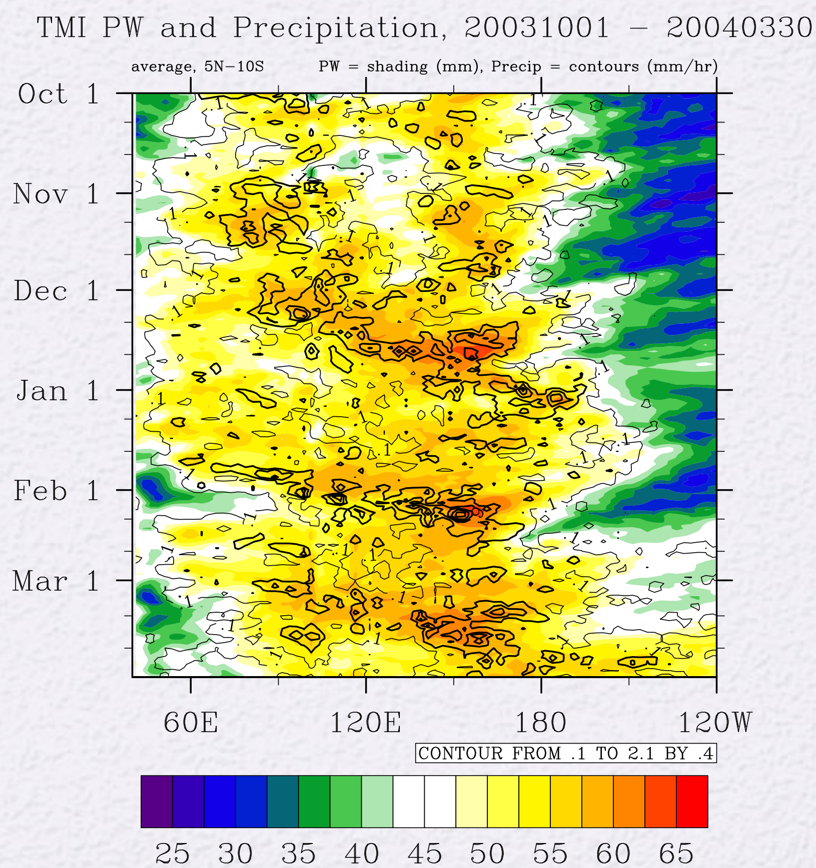
CMMAP Student Colloquium
August 2, 2011

About Me

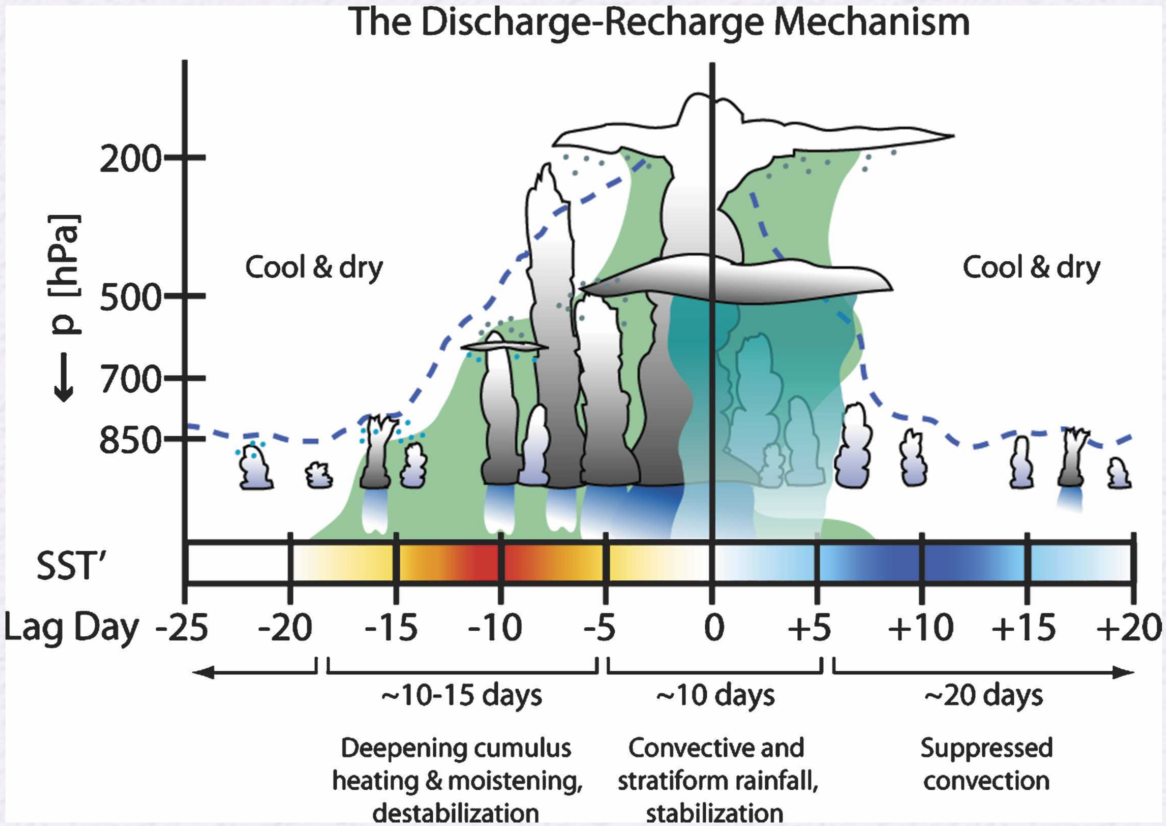
- Research Interests:
  - Tropical meteorology
  - Climate
- Education:
  - Undergraduate at the University of Miami
  - Studying Meteorology and Mathematics
- CMMAP Intern

What is the MJO?

- The Madden-Julian Oscillation (MJO) is an eastward moving oscillation of deep convection
- Occurs in the equatorial Indian and western/central Pacific Oceans
- Cycle has timescale of about 30-90 days



The Discharge-Recharge Cycle



Benedict and Randall 2007, JAS

Objectives

- To analyze the moisture cycle of the MJO using data analysis of:
  - Precipitable water (PW): Column integrated water vapor
  - Precipitation (PR/precip): Rainfall
  - Specific Humidity (Q): ratio of mass of water vapor to mass of system
  - Zonal Wind (U): East-west wind
- To evaluate how the MJO moisture cycle in the SP-CAM (Superparameterized Community Atmosphere Model version 3.0) compares with observations

Data

Observations:

- 2.5 degree horizontal resolution

- Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI)
  - Precipitable Water, Precipitation
  - Daily data, 1998-2010
- NCEP-DOE Reanalysis 2
  - Specific Humidity, Zonal Wind
  - 8 vertical levels between 1000 and 300 hPa
  - Daily data, 1979-2010
- NOAA Outgoing Longwave Radiation (OLR)
  - Proxy for deep clouds
  - Daily data, 1979-2010

Model:

- 2.8 degree horizontal resolution

- Superparameterized Community Atmosphere Model version 3.0 (SP-CAM)
  - Precipitable Water, Precipitation
  - Specific Humidity, Zonal Wind
  - OLR
  - Daily data, 1985-2004
  - SP-CAM is a version of the CAM 3.0 which replaces traditional cloud parameterizations with two-dimensional Cloud Resolving Models
  - Unlike many models, SP-CAM has a fairly realistic MJO (Benedict and Randall 2009)

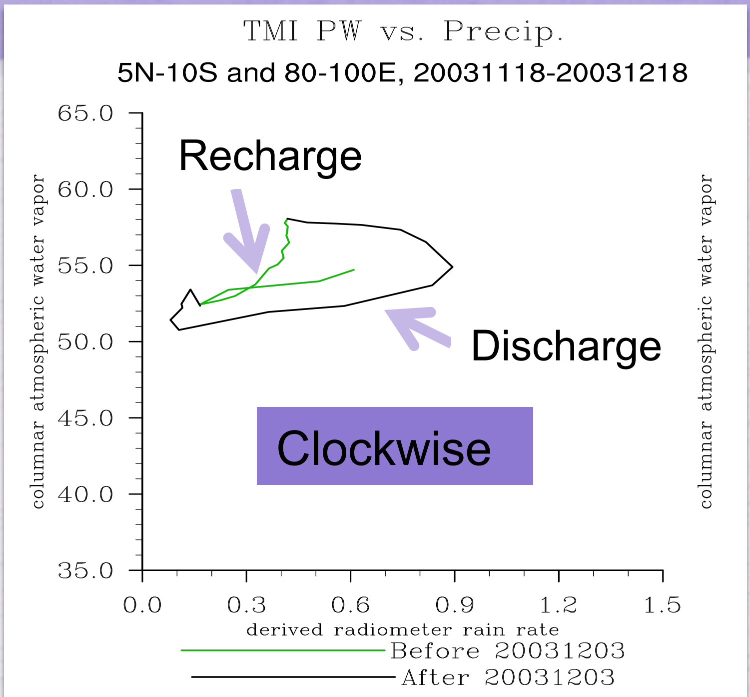
Identification of MJO Events

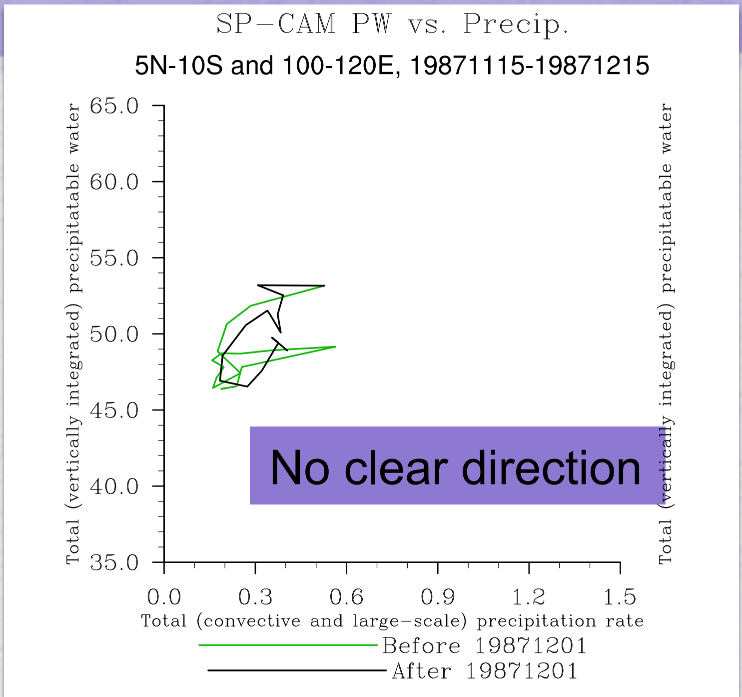
- Observed MJO events are identified using OLR data
  - OLR is filtered to MJO space and time scales
  - Events are cross-checked with precipitable water and precipitation data
- SP-CAM MJO events are identified by Benedict and Randall (2009)
  - Events are cross-checked with SP-CAM filtered OLR as well as precipitable water and precipitation data
- For both TRMM and SP-CAM events:
  - Data are averaged from 5N-10S
  - October-March only
  - For each plot data is averaged over 20 degrees longitude
- Three years of active MJOs are analyzed in each dataset, giving:
  - 6 TRMM events
  - 5 SP-CAM events
- Each event is analyzed at three different locations: Indian Ocean, western Pacific, and central Pacific
- All plots are centered on the date of the maximum precipitable water

Events Analyzed

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

PW vs. Precip Plots



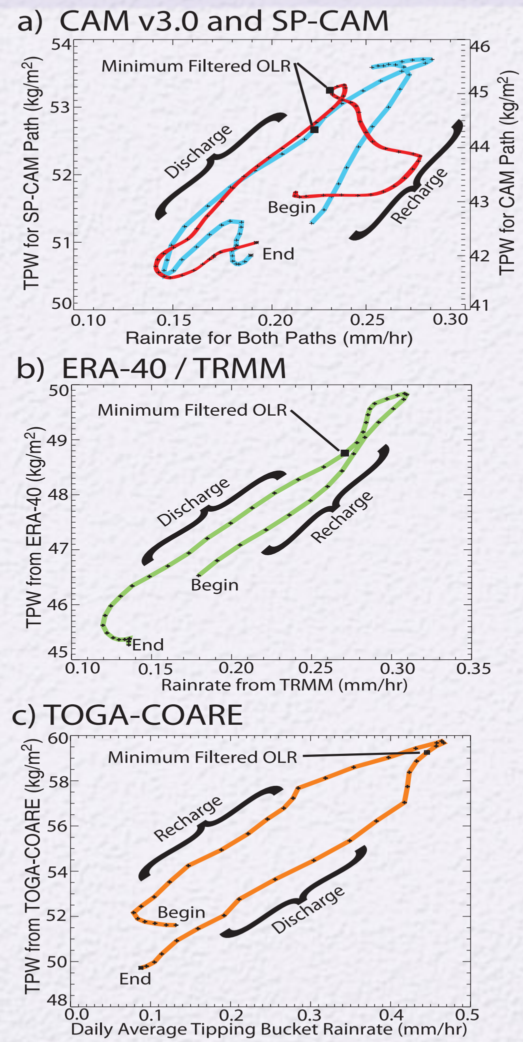


In general, TMI PW vs. Precip plots are smoother than SP-CAM

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

Clockwise vs. Counterclockwise

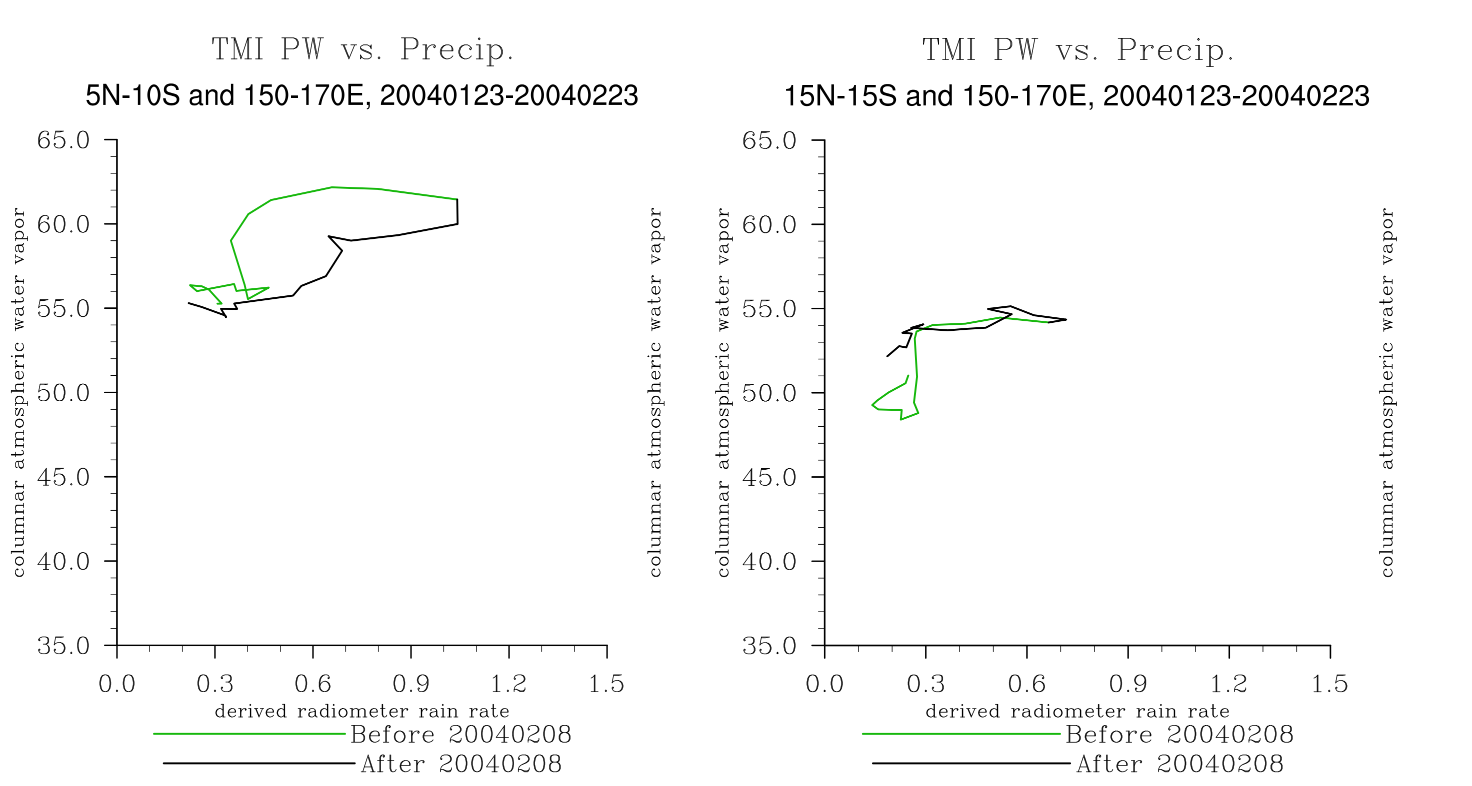
- Clockwise direction inconsistent with some results in Thayer-Calder and Randall (2009)
- SP-CAM and ERA-40/TRMM PW vs. Precip plots are counter-clockwise; only TOGA-COARE is clockwise
- Differences
  - ERA-40/TRMM is reanalysis
  - Composite of events
  - SP-CAM and ERA-40/TRMM averaged over 15N-15S



SP-CAM is in blue

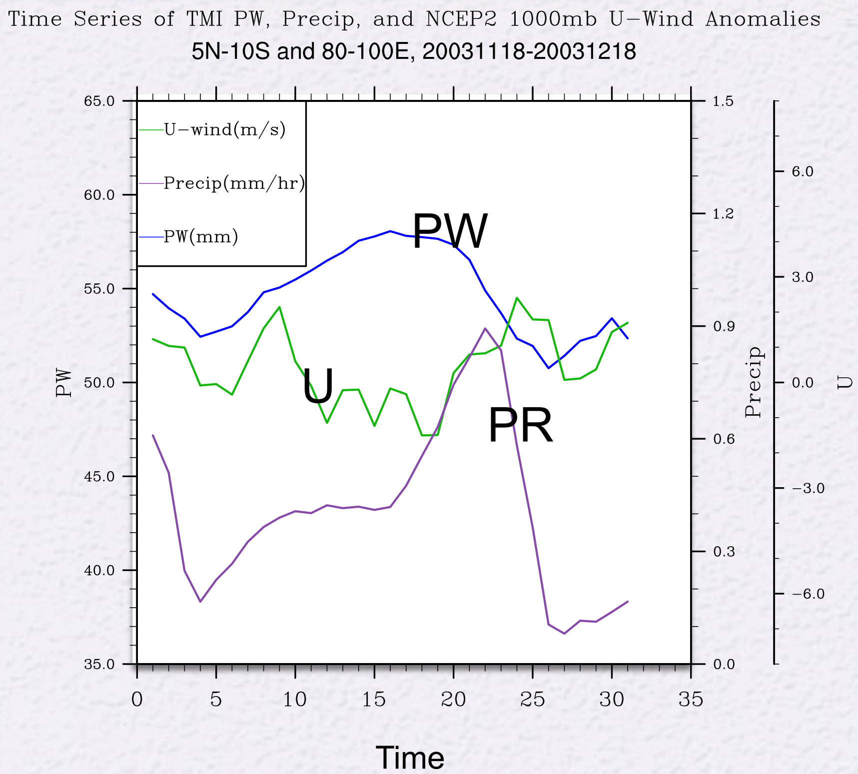
Thayer-Calder and Randall 2009, JAS

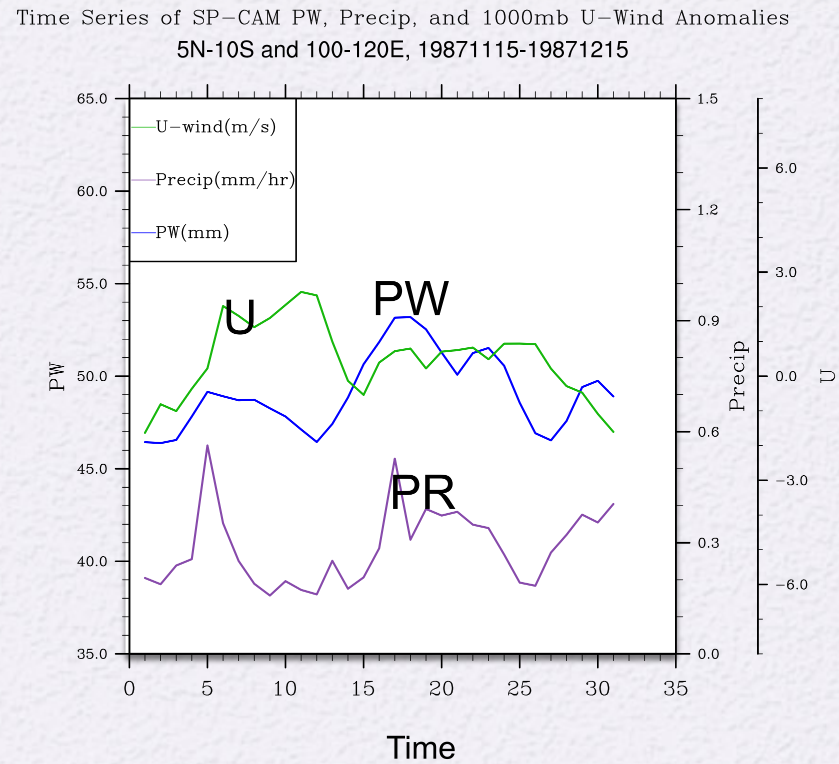
5N-10S vs. 15N-15S



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

Time Series Plots: TMI vs. SP-CAM

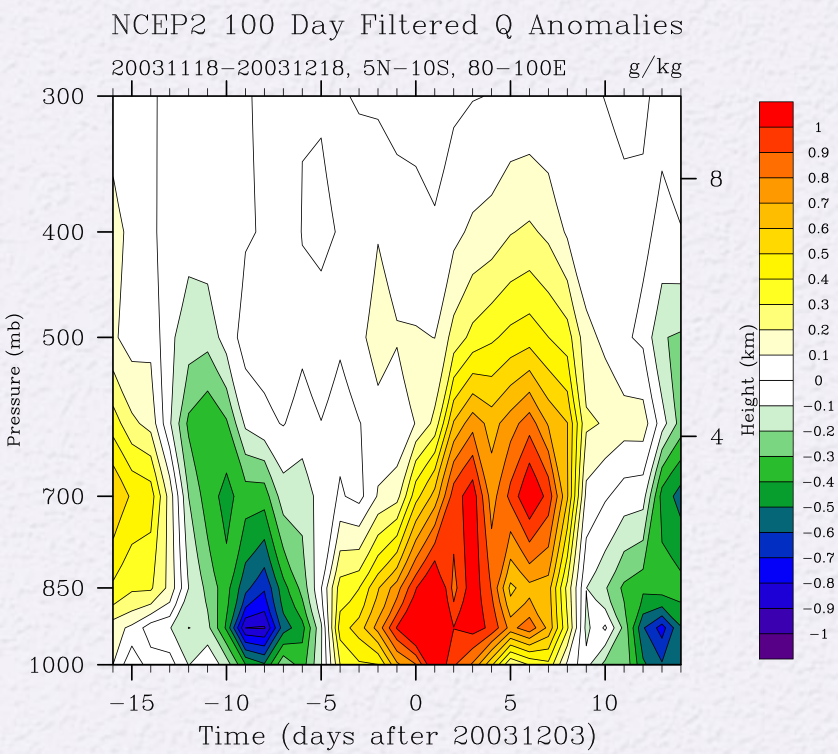


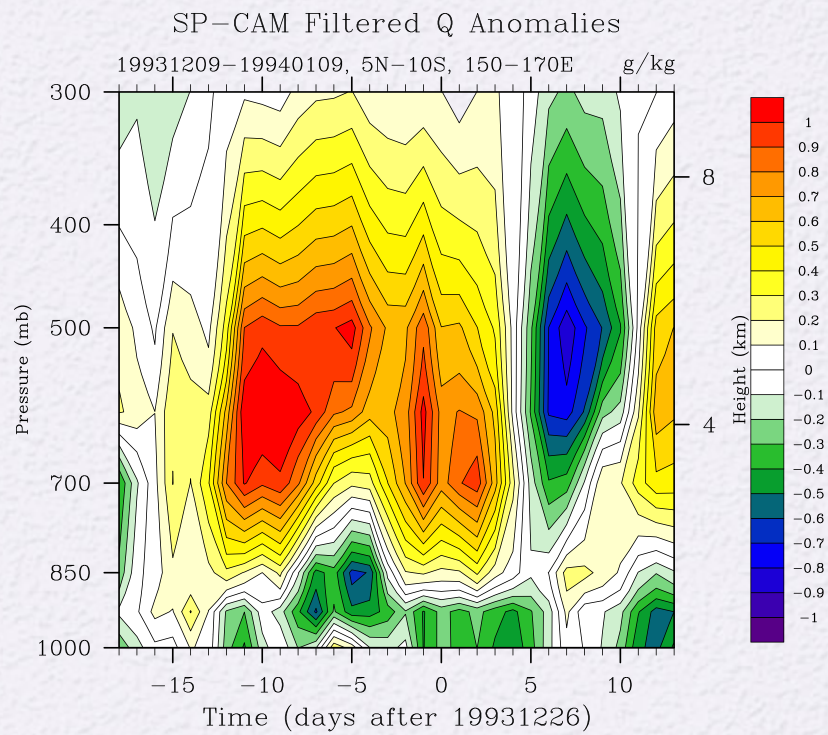


- Smoother PW curve
- Order is PW peak, then Precipitation peak, then Zonal Wind peak
- Recharge slower than discharge

- Multiple PW peaks
- PW and Precipitation peaks simultaneous
- Sharper increase in PW

Specific Humidity Cross-Section Plots





- Moisture accumulates gradually from bottom up

- Negative Q anomalies at lower levels
- Accumulation of moisture at all levels at the same time
- Multiple spikes in Q

Conclusions

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

- 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

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