Intraseasonal Variations of the Tropical Total Ozone and Their Connection to the MJO

Baijun Tian
Jet Propulsion Laboratory, California Institute of Technology

Yuk L. Yung
Division of Geological & Planetary Sciences, California Institute of Technology

Duane E. Waliser
Jet Propulsion Laboratory, California Institute of Technology

Tomasz Tyranowski
Jagiellonian University, Krakow, Poland

Le Kuai
Division of Geological & Planetary Sciences, California Institute of Technology

JPL AIRS Team

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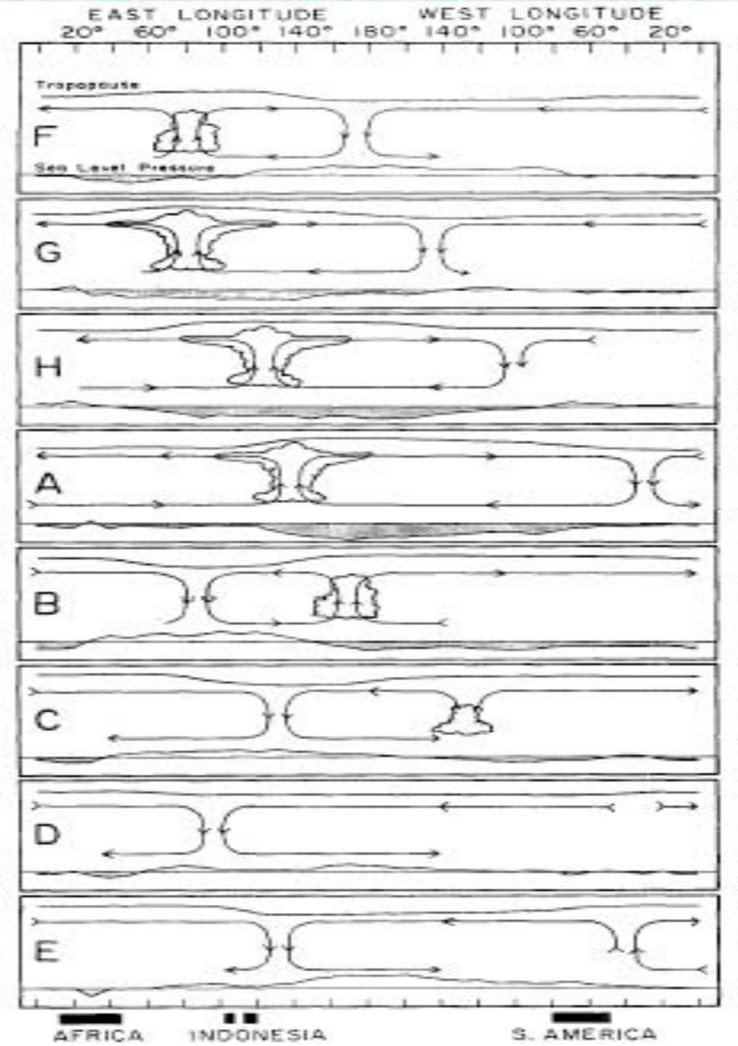
Outline

- MJO
- Motivation
- Data and Analysis Methods
- Results
- Summary

Madden-Julian Oscillation
(a.k.a. Intraseasonal Oscillation)

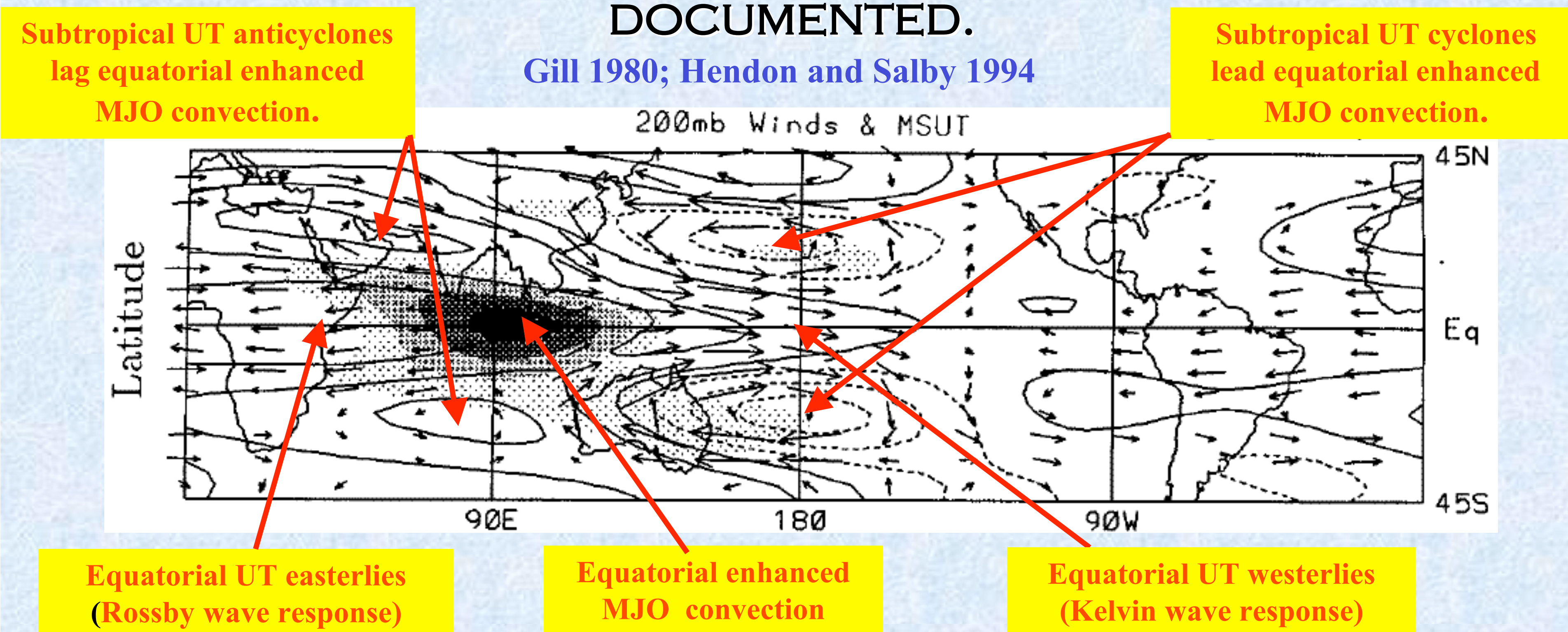


- ❖ Intraseasonal Time Scale: 30-60 days
- ❖ Slow Eastward Propagation:
  ~5 m/s Phase Speed
- ❖ Strong Coupling Between Deep Convection
  and Large-Scale Circulation
- ❖ Planetary Zonal Scale (Wavenumber One-Two)
- ❖ Vertical Baroclinic Structure
- ❖ Equatorially Trapped
- ❖ Strong Geographic Preference: The Tropical
  Indian and West Pacific Oceans ("Warm Pool")
- ❖Strong Seasonal Dependence:
  NH Winter: Strong; Eastward Propagation
  NH Summer: Weak, Northeast Propagation
- ❖ Significant Interannual Variability
- ❖ Scale Interaction with Many Other High-
  Frequency, Small-Scale Convective Systems

Madden & Julian (1971; 1972), Lau and Waliser (2005), Zhang (2005)

The large-scale MJO convection and circulation anomalies have been well understood and documented.

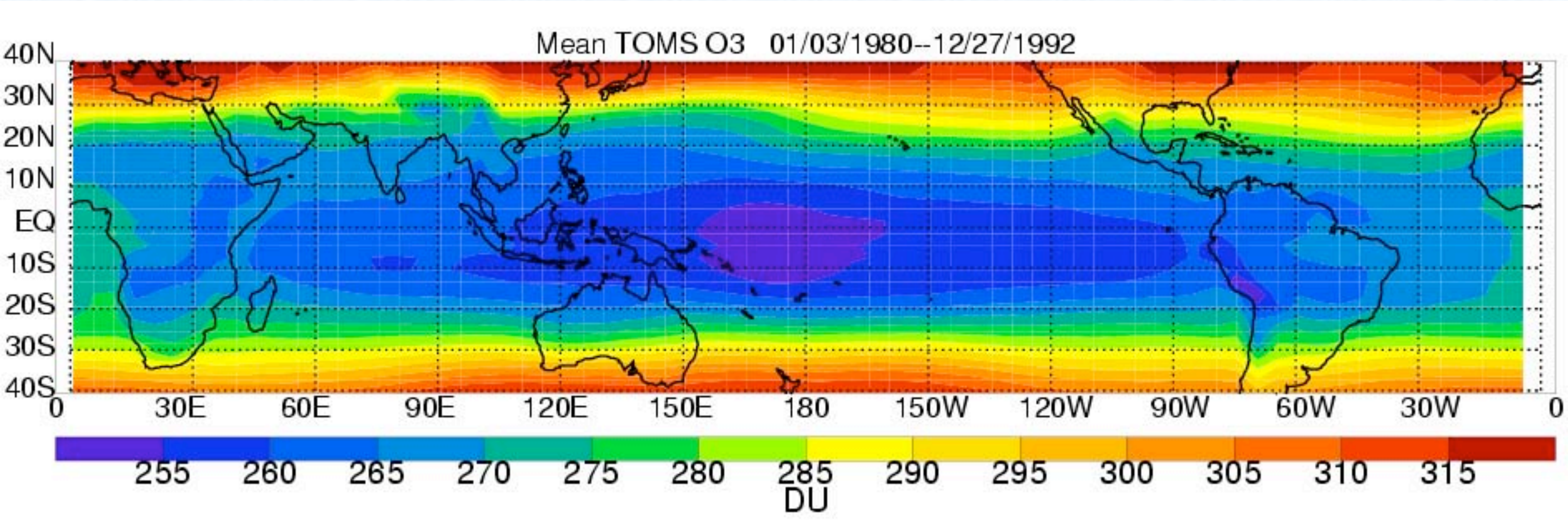
Gill 1980; Hendon and Salby 1994



However, the intraseasonal variations of atmospheric compositions, such as ozone and aerosol, have not been well documented and understood.

Tropical Ozone (O3) Variations

Time Scale	Annual Cycle	QBO	ENSO	Solar Cycle	Intraseasonal (MJO)
Magnitude	±10DU (3%)	±15DU (5%)	±10DU (3%)	±5DU (2%)	???



Objective

- To investigate the intraseasonal variations of the tropical total O3.

- Are there any intraseasonal variations of the tropical total O3?
- If yes, how large?
- What physical and/or dynamical processes are responsible to these intraseasonal variations?

Data

- **Total O3:**

  AIRS L3, 1.0° x 1.0°, Pentad, From 09/01/2002 to 01/31/2005

  TOMS, 3° lat x 5° long, Pentad, From 01/01/1980 to 12/31/1992

- **Rainfall:**

  TRMM, 1.0° x 1.0°, Pentad, From 01/01/1998 to 07/31/2006

  GPCP, 2.5° x 2.5°, Pentad, From 01/01/1979 to 12/31/2005

- **Dynamical Fields (Winds, Geopotential Height):**

  NCEP/NCAR Reanalysis, 2.5° x 2.0°, Pentad,
  From 01/01/1980 to 12/31/1992

MJO Analysis and Compositing Procedure

(1) **Removing the annual cycle.**

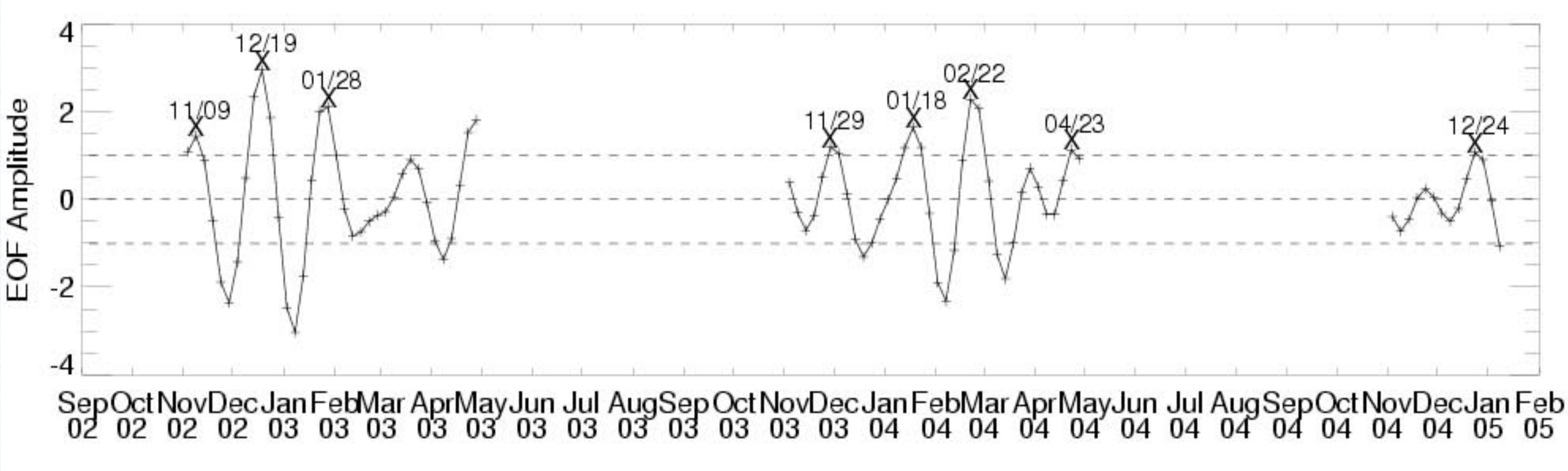
(2) **Filtering the data using a 30-90-day filter.**

(3) **Identifying MJO events using Extended EOF analysis.**

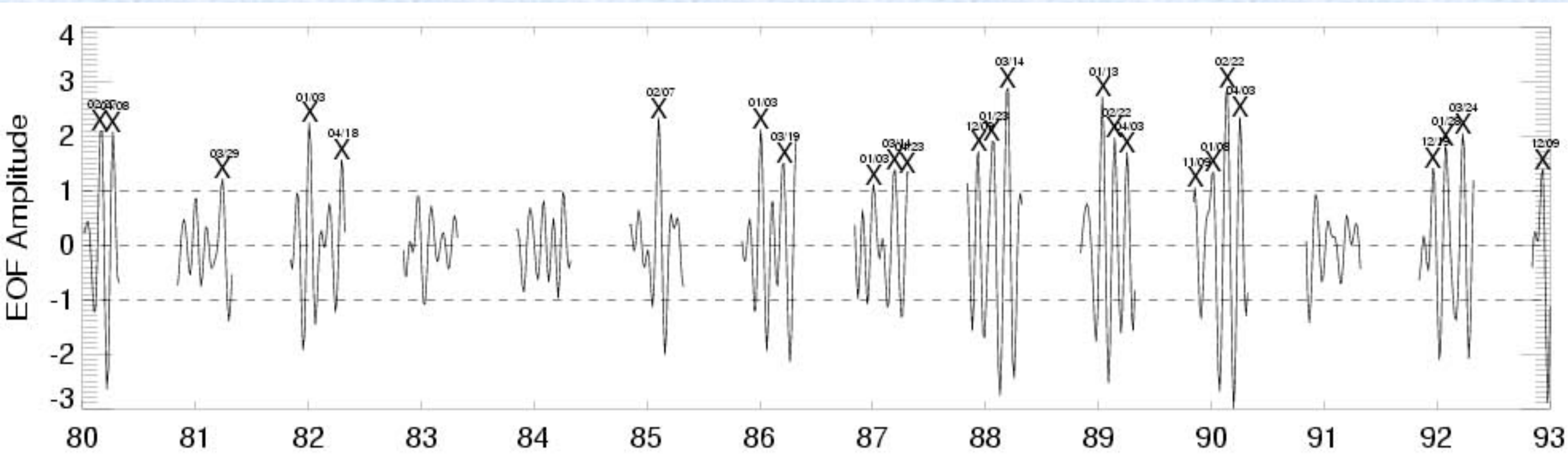
(4) **Averaging all the MJO events.**

Reference: Tian, B. J., D. E. Waliser, E. J. Fetzer, B. H. Lambrigtsen, Y. Yung, and B. Wang, 2006: Vertical moist thermodynamic structure and spatial-temporal evolution of the MJO in AIRS observations. *J. Amos. Sci.*, 63, 2462-2485.

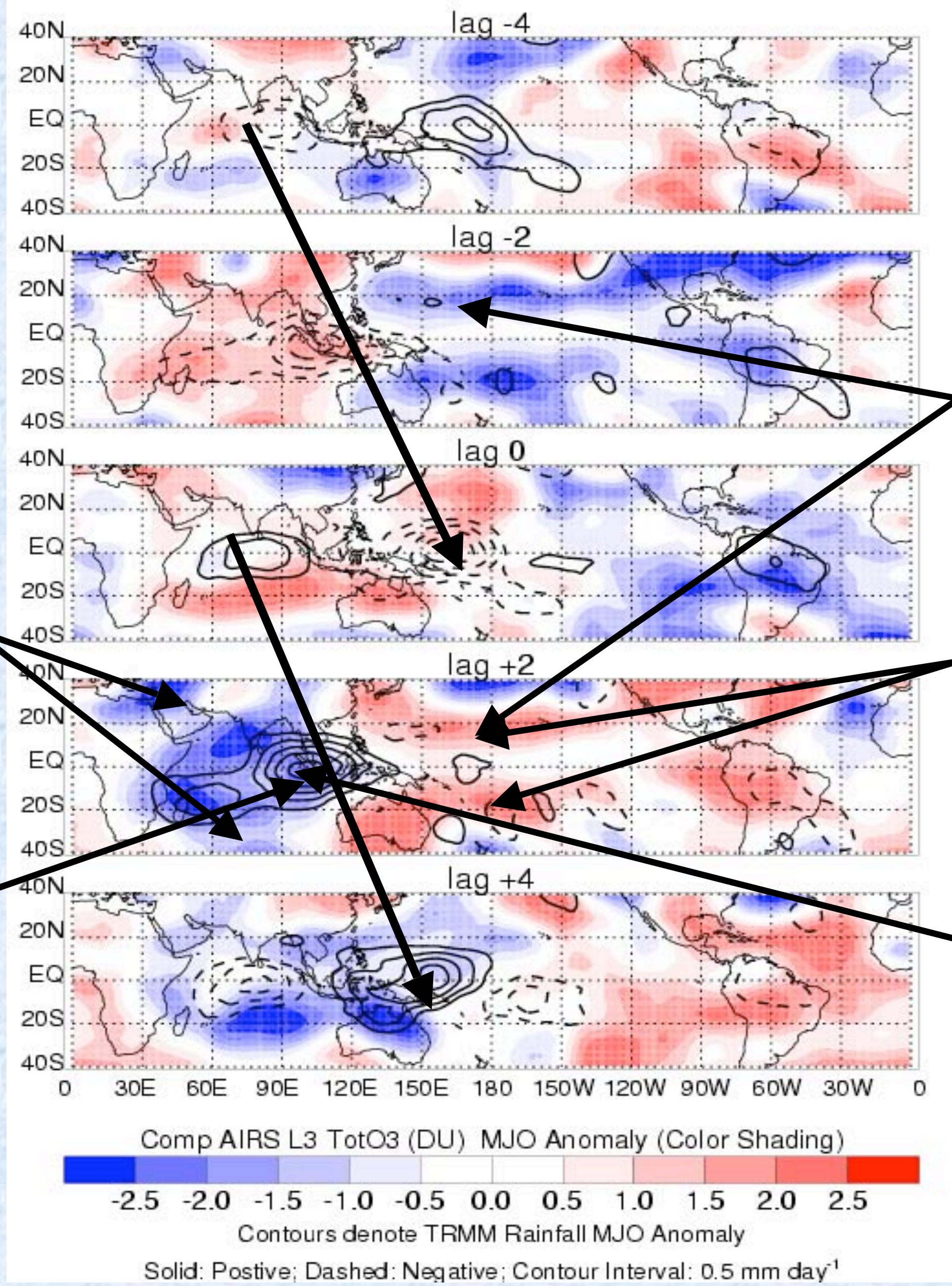
Selected 8 MJO events for AIRS data



Selected 24 MJO events for TOMS data



AIRS Total O3 MJO Anomaly



Lags -2 and +2 have the same pattern but opposite signs.

Subtropical negative total O3 anomalies lag equatorial enhanced MJO convection.

Subtropical positive total O3 anomalies lead equatorial enhanced MJO convection.

Equatorial enhanced MJO convection

Equatorial negative total O3 anomalies are coincident with equatorial enhanced MJO convection.

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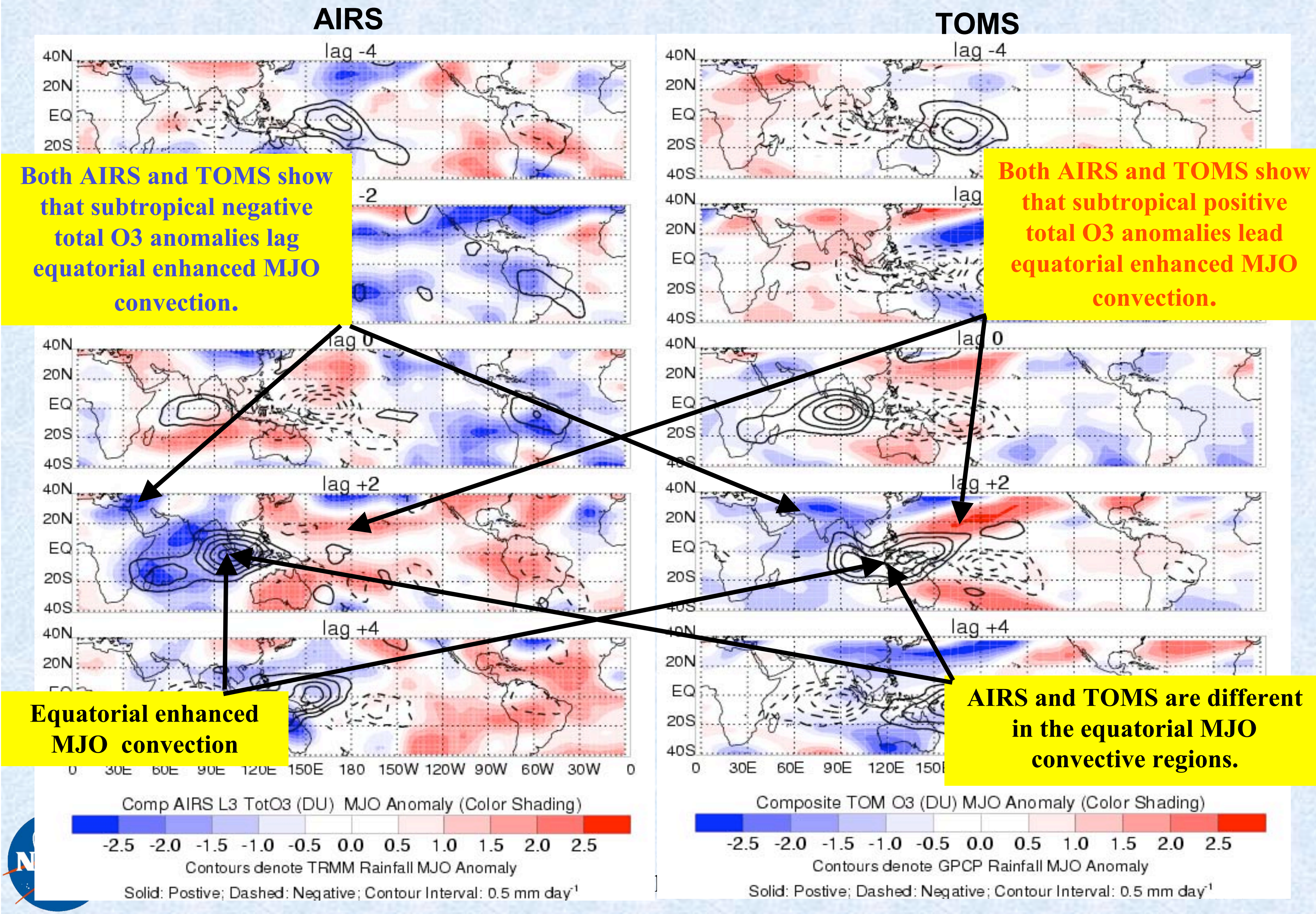
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Total O3 MJO Anomaly



Objective

1. **Is any intraseasonal variation of the tropical total O3?**

   Answer: Yes.

2. **If yes, how large?**

   Answer: 5 DU

3. **What physical and/or dynamical processes are responsible to these variations?**

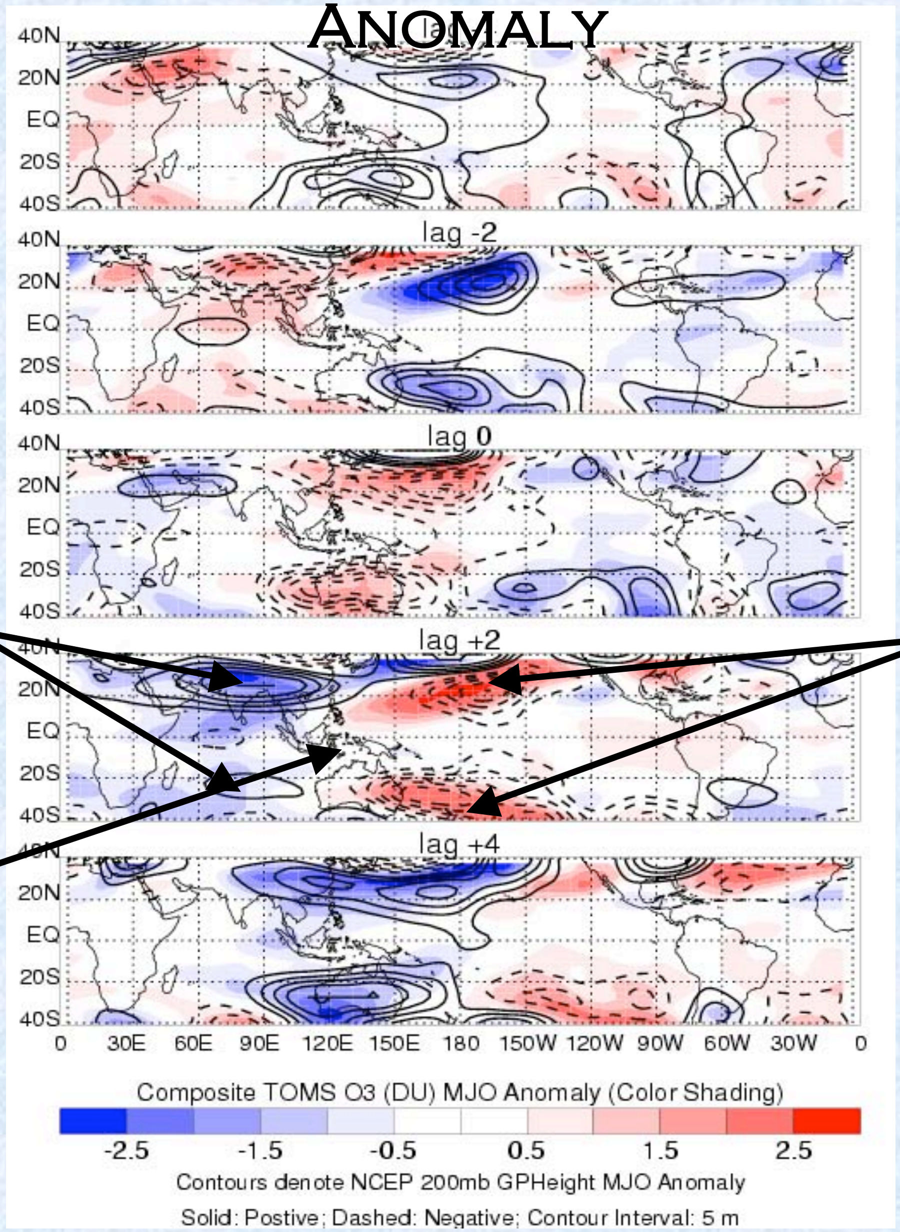
Connection between TOMS Total O3 MJO Anomaly and NCEP UT GPHeight MJO Anomaly

UT air moves up ↑

Total O3 decreases ↓

Subtropical negative total O3 anomalies are coincident with the subtropical positive UT geopotential height anomalies.

Equatorial enhanced MJO convection



UT air moves down ↓

Total O3 increases ↑

Subtropical positive total O3 anomalies are coincident with the subtropical negative UT geopotential height anomalies.

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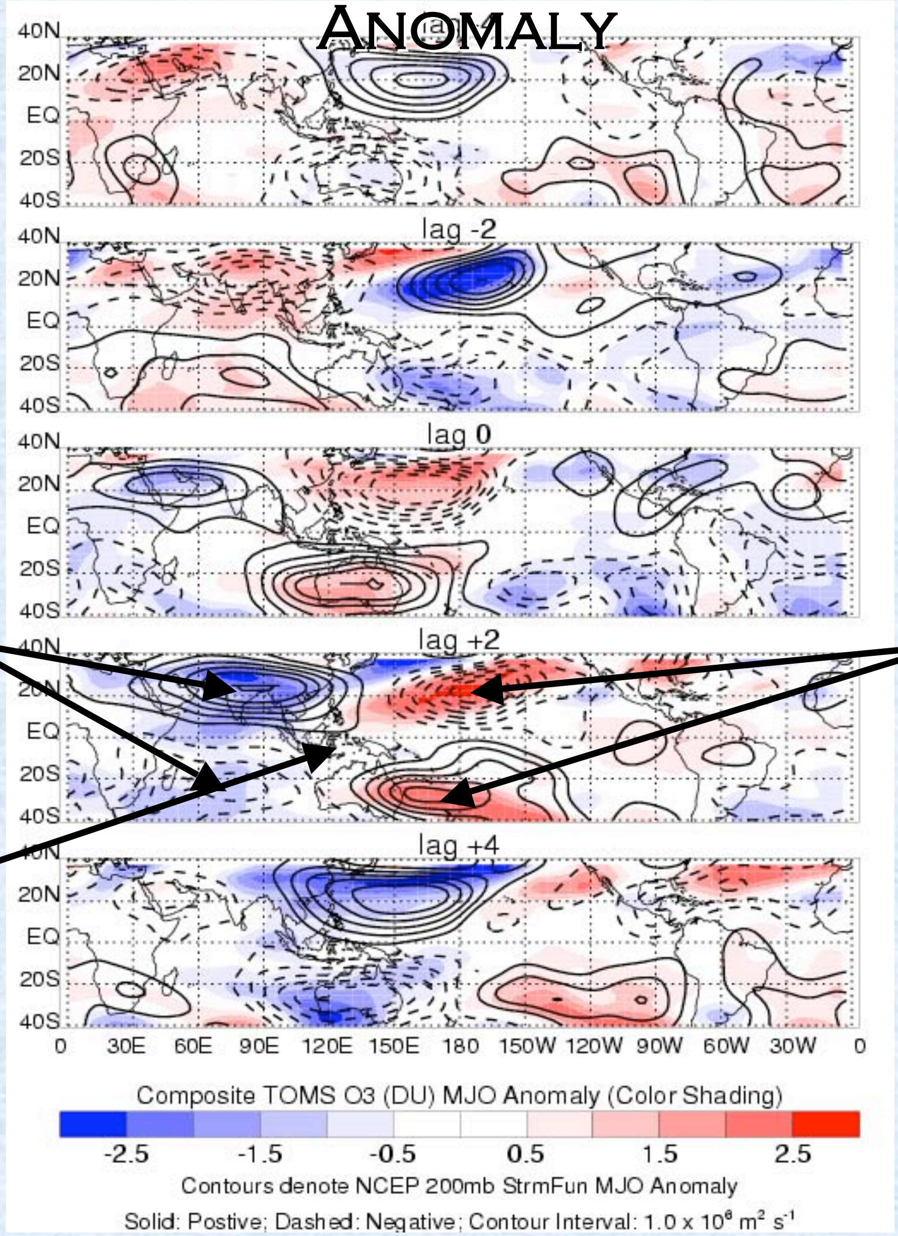
Connection between TOMS Total O3 MJO Anomaly and NCEP UT Stream Function MJO Anomaly



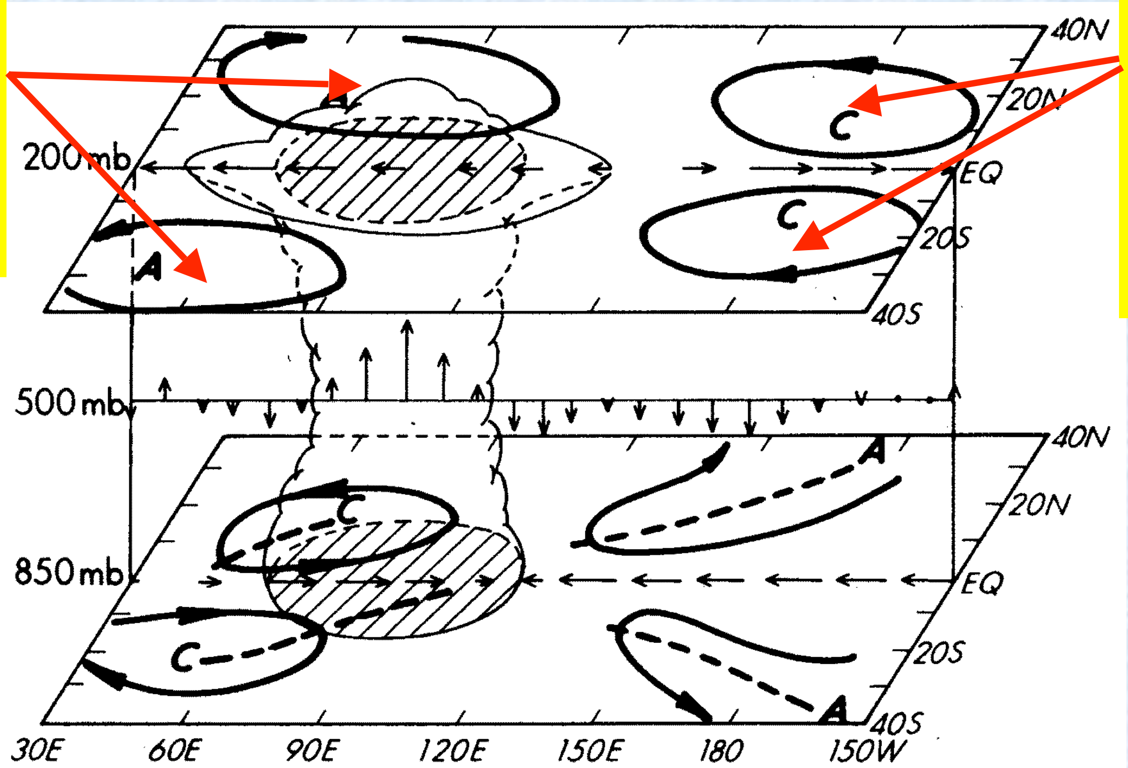
Subtropical negative total O3 anomalies are coincident with subtropical anticyclones.

Equatorial enhanced MJO convection

Subtropical positive total O3 anomalies are coincident with subtropical cyclones.

MJO Impact on Tropical Total O3

Subtropical UT anticyclones bring up O3-poor tropospheric air (increase geopotential height) to decrease the subtropical total O3.



Subtropical UT cyclones bring down O3-rich stratospheric air (decrease geopotential and tropopause height) to increase the subtropical total O3.

Schematic of the large-scale wind structure of the MJO. The cloud symbol indicates the convective center. Arrows represent anomalous winds at 850 and 200 hPa and the vertical motions at 500 hPa. ‘‘A’’ and ‘‘C’’ mark the anticyclonic and cyclonic circulation centers, respectively. Dashed lines mark troughs and ridges. From Rui and Wang [1990].

Summary

- There are intraseasonal variations of tropical total O3 in both AIRS and TOMS.

- The intraseasonal variations of tropical total O3 are large (around 5DU) and comparable to those associated with other time scales.

- The intraseasonal variations of total O3 are mainly in the subtropics. These anomalies are mainly dynamically driven as a result of the subtropical upper-tropospheric (anti-)cyclones generated by the equatorial MJO convection.

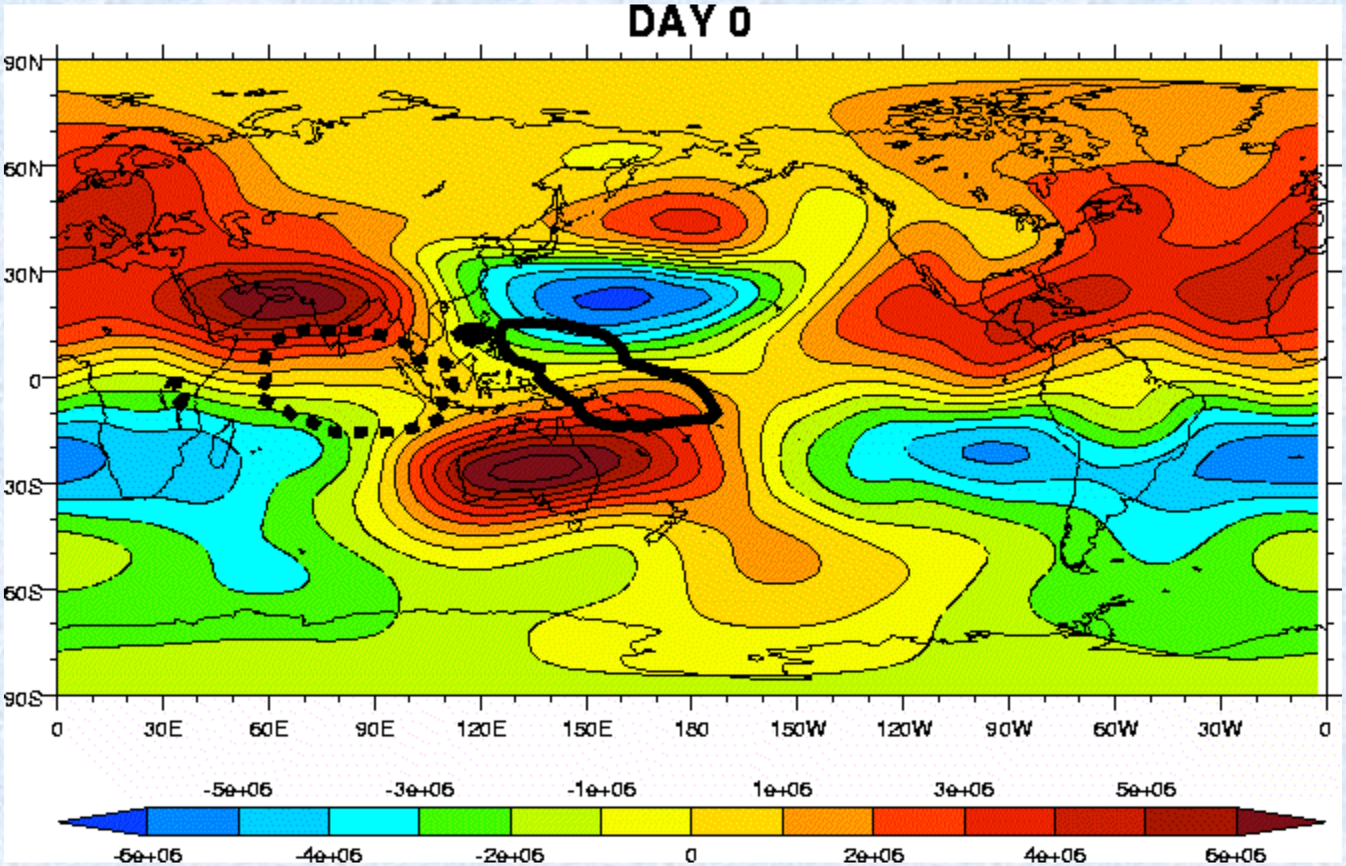
- AIRS data together with other satellite data (e.g., TRMM, CloudSat, MLS, ISCCP, and TOMS) are very useful to study tropical convection and climate.

Reference

Tian, B. J., Y. L. Yung, D. E. Waliser, T. Tyranowski, and L. Kuai, 2006: Intraseasonal variations of the tropical total ozone and their connection to the Madden-Julian Oscillation. *J. Geophys. Res.*, in preparation.

Thank You

A Typical MJO in N.H. Winter



The 200mb stream function is shown by the color shading. The OLR anomalies are contoured at 10 W m-2 (dashed line), indicating enhanced convection, and at +10 W m-2 (solid line), indicating reduced convection. The images are spaced approximately 3 days apart and one whole cycle lasts approximately 48 days. From Matthews et al. (2004).