Intraseasonal Variations of Water Vapor and Cirrus Clouds in the Tropical Upper Troposphere

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This paper just appeared in JGR, 109, D12106, 10.1029/2003JD004314, 2004
• The intraseasonal oscillation (ISO), also known as the Madden and Julian oscillation (MJO) with a time scale of 30-60 days, is one of the most dominant phenomena in the tropical troposphere.

• ISO around the tropopause – Madden & Julian (1972); Parker (1973)

• ISO in upper tropospheric water vapor using MLS data – Clark et al. (1998); Mote et al., (2000); Sassie et al., (2002)

• In this talk, space-time variations of water vapor and the cirrus clouds associated with the IOS will be examined, and the impact on dehydration around the tropical tropopause layer (TTL) will be shown.
Data

- UARS/MLS water vapor data (ver. 4.9)
  - 215, 146, 100 hPa; Sep. 1991- Apr. 1993
- UARS/CLAES aerosol (780 cm\(^{-1}\)) data
  - 146, 100 hPa; Oct 1991- May 1993
- ECMWF operational analysis data
- NOAA OLR data

We applied a 20- 80 day bandpass filter, and made composite analyses.
ISO in OLR

- Maximum variability at 165E, 10S
- Five ISO events are selected during boreal winter seasons. (Note that 1991/1992 is the ENSO year.)
- In the composite map, we see the active convective region moves eastward with an average speed of 5.4 ms⁻¹.
Zonal wind and temperature

Zonal wind:
A divergent area is located at the slightly east side of the convective center.
- almost coherent in the vertical direction

Temperature:
- [215hPa] Warm at 20° east of the convective center
- [146hPa] Cold over the convective center
- [100hPa] Cold at 30° east of the convective center
- tilting eastward with increasing altitude

(Contour: temperature, Shading: zonal wind)
[215hPa] Wet anomalies move eastward with the convective system.

[146hPa] Similar to 215hPa, but seems to be affected from above in the western hemisphere?

[100hPa] The eastward moving system is not clear. Two dry regions: over the Indian Ocean around Day -15; over the eastern Pacific Ocean around Day +5

(Contour: temperature, Shading: water vapor)
Cirrus cloud frequency

[146hPa] Eastward moving positive anomalies of the cloud frequency coexist with the cold anomalies where the convective system is active.

[100hPa] Positive anomalies still coexist with the cold anomalies at the east side of the convective system. Two peaks: around 120E on Day -18 and around 180E on Day +2 when the convective system is active.

- Clear relationship between the cirrus cloud occurrence and the cold temperature

(215hPa - degraded by overlying clouds over the convective region)

(Contour: temperature, Shading: cloud frequency)
Vertical structure

At 146 hPa cold anomalies appear over the convective center, and at 100 hPa they appear in the east side of the convective center with an eastward tilt. This feature is essentially similar to that due to the Kelvin wave response to the convective heating.
Horizontal structure

(saturation mixing ratio and horizontal wind) (water vapor and cloud frequency)
Time evolution
Water vapor in the subtropics

- Subtropical dry air moves eastward around the globe
- It is less clear over the central Indian Ocean (Day - 15) and the eastern Pacific (Day 0).
- Around these days in the equatorial region the dry anomalies appear and extend westward.
- The dry air created over the equatorial cold region is transported to the subtropics by the northern gyre.
Schematic view
(two responses to the convective heating)

The Kelvin wave response:
The temperature field is almost symmetric with respect the equator and tilts eastward with increasing height in the tropics.

The Rossby wave response:
There are two anticyclonic gyres and the eaterly wind blows through the equatorial cold region between the two gyres.
Dehydration in the northward flow?

Randel et al. (2001)
Dehydration in the northward flow? 

(Gettelman et al., 2002)
UARS/ MLS version 7.2

(The data are provided by courtesy of Dr. Read)
ISO events in other years
Summary

- Space-time variations of tropical upper tropospheric water vapor and cirrus clouds associated with the ISO have been investigated using data from the MLS and the CLAES on board the UARS.
- At 215 and 146 hPa, wet anomalies exist over the convective system, suggesting a direct effect of convective activity up to this level. At 100 hPa, however, the moisture field seems to be indirectly affected by the dynamical response to the convective heating.
- Dynamical structures around the tropopause level are characterized by the equatorial temperature anomalies (Kelvin wave response) and by the subtropical anticyclonic gyres (Rossby wave response), respectively.
- Between the two gyres the easterly wind blowing through the equatorial cold region may cause dehydration with cirrus formation.
- As the northern gyre intensifies, tropical dry air is transported to the subtropical Pacific and eventually to the equatorial Pacific.
- It is suggested that the temperature and flow variations due to the coupled Kelvin-Rossby wave structure play an important role in dehydrating air in the tropical and subtropical tropopause region.