

Signature of the Madden-Julian Oscillation in the Tropical Tropopause Transition Layer

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Introduction, Data, and Analysis Techniques

Motivating questions

- How do TTL temperature, water vapor, cloud, and carbon monoxide vary with the MJO?
- Is there a zonal-mean MJO signature?

Constellation Observing System for Meteorology Ionosphere & Climate (COSMIC) temperature profiles

- Derived by radio occultation of GPS signals
- 100-m vertical resolution
- ~500 profiles per day in tropics

Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Operations (CALIPSO) cloud base & top heights

- Capable of detecting clouds with optical depth 0.01 or lower
- Define TTL cirrus index as fraction of CALIPSO profiles in selected region that identify a cloud with base > 15 km
- Define height-dependent cloud index as cloud fraction in successive 200-m layers

Microwave Limb Sounder (MLS) water vapor and carbon monoxide profiles

- H₂O mixing ratio at 13 pressure levels from 316 to 32 hPa
- CO mixing ratio at 6 pressure levels from 215 to 32 hPa

Analysis technique

- Four years of data (June 2006-June 2010)
- Calculate weekly averages at each vertical level for 10° latitude × 10° longitude grid
- For zonal mean, calculate weekly averages at each vertical level for 5° latitude bands
- Apply 80-day high-pass Lanczos filter at each grid point
- Correlate with two time series components (Real-time Multivariate MJO series 1 & 2 [RMM1 & RMM2]) of Wheeler and Hendon (2004) MJO index

100-hPa Level

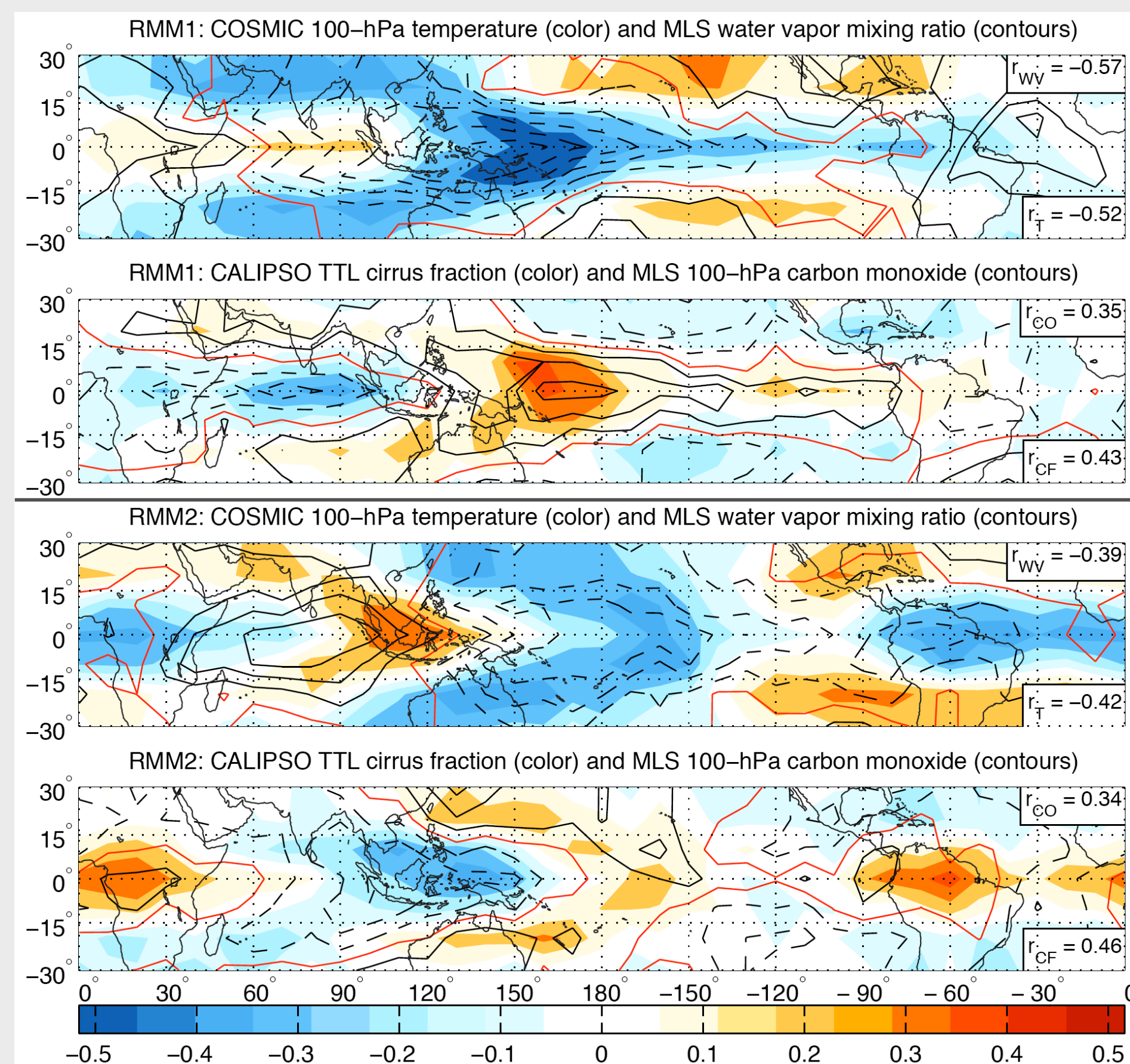


Fig. 1 First and third panels show filtered 100-hPa temperature and water vapor correlated with two components of MJO index (RMM1 and RMM2, respectively). Second and fourth panels show filtered TTL cirrus index and 100-hPa carbon monoxide correlated with RMM1 and RMM2, respectively. Strongest correlations indicated in right corners.

Kelvin-Rossby wave signature above eastern Indian Ocean, Maritime Continent, and western Pacific

- Correlations extend along equator to the east and flank equator to the west
- Waves at 100-hPa centered ~20-30° of longitude to the east of the MJO-related convective maximum (see tropospheric cloud field in Fig. 2)

MJO signature in Western Hemisphere

- Maritime Continent out of phase with Africa and South America
- Off-equatorial Rossby lobes over eastern Pacific and Americas

Contrast between features with tropospheric and stratospheric characteristics

- Low temperature associated high carbon monoxide and increased cloud fraction, and vice versa

Equatorial Cross-Section

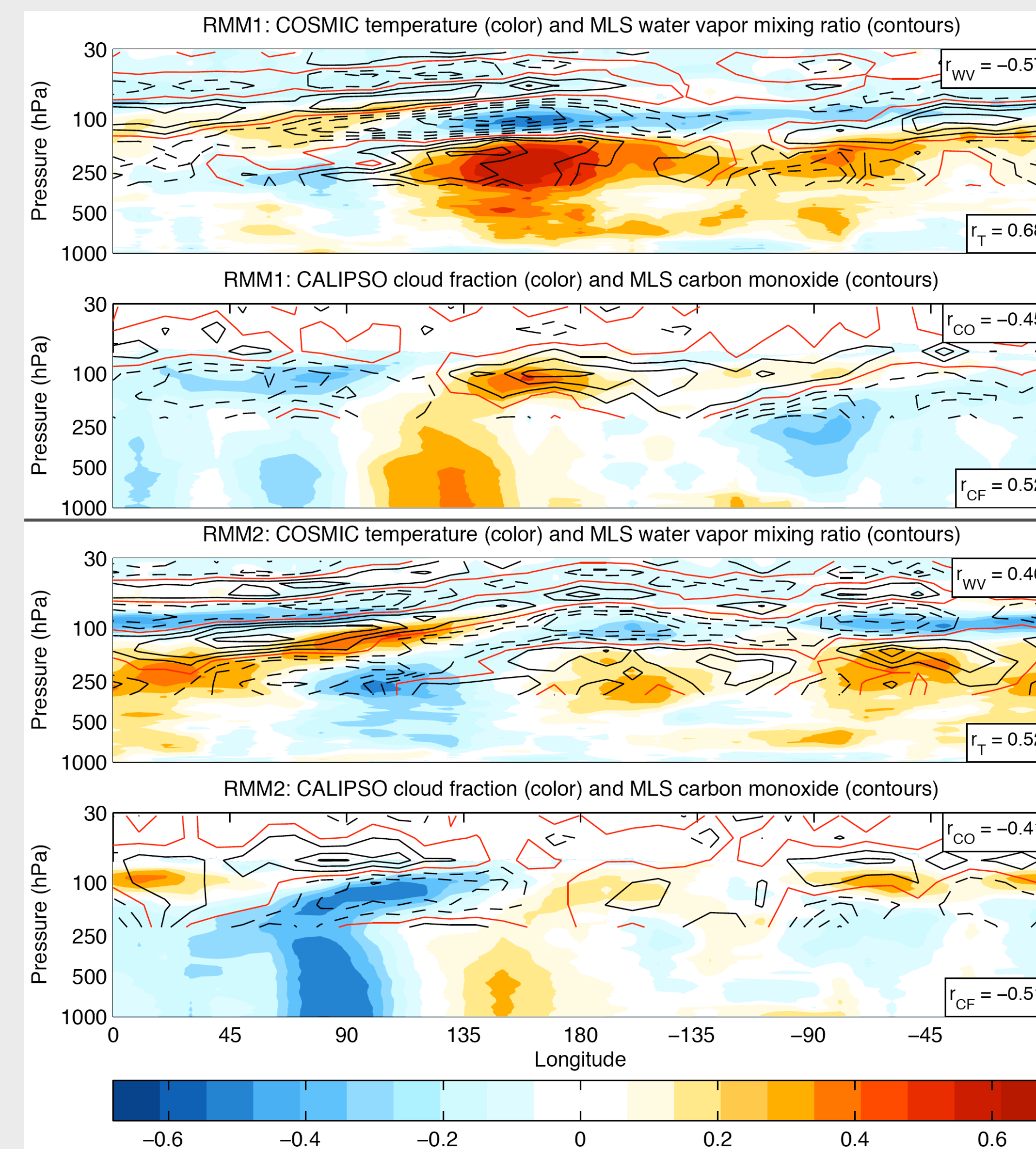


Fig. 2 As in Fig. 1, but for a cross-section from 5°S to 5°N.

MJO signature above eastern Indian Ocean to western Pacific

- Correlations tilt eastward with height, like fields associated with an equatorially trapped Kelvin wave
- TTL features are distinct from convection and propagate eastward more rapidly

Cirrus feature above equatorial South America and Africa when Indian Ocean convection is suppressed

- Cirrus signal confined almost entirely above 15 km
- Enhanced cirrus associated with anomalously low temperatures

Fine vertical structure in lower stratospheric temperature and water vapor

Zonal Mean Cross-Section

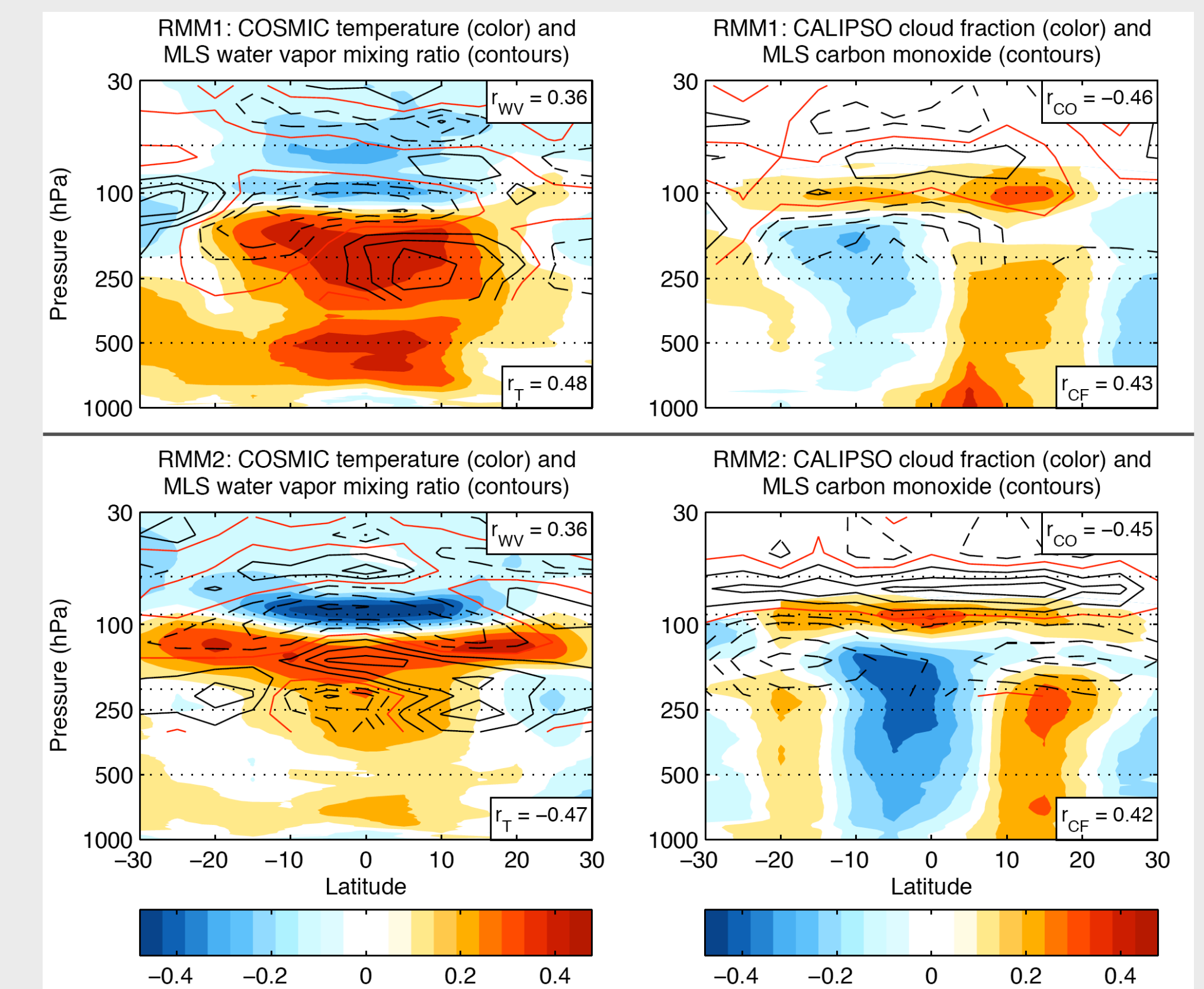


Fig. 3 As in Fig. 1, but MJO index is correlated with zonally-averaged variables.

Equatorially symmetric MJO features in TTL and stratosphere are distinct from asymmetric features in troposphere

- Tropospheric cloud and water vapor reflect distribution of convection
- TTL cirrus and temperatures have same sign equatorward of ~15°-20° latitude

TTL variables related to tropospheric convection

- Anomalously low temperatures and enhanced TTL cirrus near 100 hPa when convection is suppressed over equator, and vice versa

MJO signature in temperature, water vapor, and carbon monoxide in TTL and lower stratosphere

Reasons for these zonally symmetric MJO features have yet to be explained