Long Term Tidal variability in the MLT region

A ground based and Satellite based perspective and their Consistency

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Outline

• Introduction (Atmospheric Tides)
• Data and Methodology
• Discussion on Consistency between ground based and satellite based observation (in context of tidal signatures)
• Signature of lower atmospheric process in MLT region
Tidal Structure in Longitude and time

\[ T_{n,s} = A_{n,s} \cos(n\Omega t - S\lambda - \phi) \]

Phase velocity = \( \frac{n\Omega}{S} \)

Nomenclature

- \( \lambda \) - Direction
- \( t_{LT} = t + \frac{\lambda}{\Omega} \) - Time Period
- \( DE3 \) - Wavenumber

DE3 appear as wavenumber 4

Migrating components: \( n=-S \)
- DW1 \((n=1, s=-1)\) [Diurnal]
- SW2 \((n=2, s=-2)\) [Semidiurnal]
- TW3 \((n=3, s=-3)\) [Terdiurnal]

\[ T_{n,s} = A_{n,s} \cos(n\Omega t_{LT} - (S + n)\lambda - \phi) \]

Eastward: \( S > 0 \) and Westward: \( S < 0 \)
Data Sources

- MF Radar, Tirunelveli (wind, 1993-2011)
- SABER (Temperature, 2002-2013)
- TIDI (Neutral Winds, 2004-2013)
- SOI (Pressure differences)
- Stratospheric Winds for QBO
- OLR(Cloud Temperature) as proxy to deep convection (not presented here)

\[ SOI = \frac{(\text{Standardized Tahiti} - \text{Standardized Darwin})}{\text{Monthly Standard Deviation}} \]
Methods and Data (SIGNATURE IN MLT)

Wave\ns in\nMLT

\[ S_t = A \cos\left(\frac{2\pi t}{T}\right) + B \sin\left(\frac{2\pi t}{T}\right) \]
\[ T = 24\text{Hrs}, 12\text{Hrs}, 8\text{Hrs} \]

- MF Radar Winds
- SABER Temperature
- TIDI Winds
- Consistency
  - DIFFERENT PARAMETERS
  - SAME DOMAIN
- 1D LEAST SQUARE FITTING
- 2D LEAST SQUARE FITTING

**GROUND BASED**
**SATELLITE BASED**

Travelling Planetary Waves

\[
\Theta(t, \lambda) = \Theta_0 + \Theta_t t + \sum_{j=1}^{4} \sum_{s=-3}^{3} A_{j,s} \cos\left[\frac{2\pi}{24T_j} t - \frac{2\pi}{360} s\lambda - \frac{2\pi}{360} \phi_{j,s}\right]
\]

\[
+ \sum_{s=1}^{3} B_s \cos\left[\frac{2\pi}{360} s\lambda - \frac{2\pi}{360} \psi_s\right]
\]

Stationary Planetary Waves

\[
+ \sum_{k=1}^{2} \sum_{s=-4}^{4} C_{k,s} \cos\left[\frac{k}{24} t - \frac{2\pi}{360} s\lambda - \frac{2\pi}{360} \gamma_{k,s}\right] + R(t, \lambda)
\]

* Pancheva et al 2008
Methodology for extracting wave parameters from SABER data

Travelling Planetary Waves

\[ \Theta(t, \lambda) = \Theta_0 + \Theta_r t + \sum_{j=1}^{4} \sum_{s=-3}^{3} A_{j,s} \cos \left( \frac{2\pi}{24T_j} t - \frac{2\pi}{360} s \lambda - \frac{2\pi}{360} \phi_{j,s} \right) \]

Stationary Planetary Waves

\[ + \sum_{s=1}^{3} B_s \cos \left( \frac{2\pi}{360} s \lambda - \frac{2\pi}{360} \psi_s \right) \]

Thermal Tides

\[ + \sum_{k=1}^{2} \sum_{s=-4}^{4} C_{k,s} \cos \left[ k \frac{2\pi}{24} t - \frac{2\pi}{360} s \lambda - \frac{2\pi}{360} \gamma_{k,s} \right] + R(t, \lambda) \]

\[ T_j = 24, 17, 11, 5.5 \text{ day} \]

- 100 coefficients to solve for
- 10 deg Latitude bin (50N to 50S)
- 5 km Altitude bin (15-110 km)
- This equation is solved for each bin.
- Window size: 60 days, moved by one day.
- Data period: 2002-2013

Altitude bin for MF Radar = 2 km
Altitude bin for TIDI = 2.5 km

Tides are reconstructed at Lat-Long of ground station

- Altitude bin for MF Radar = 2 km
- Altitude bin for TIDI = 2.5 km
Methods and Data (SOURCE)

- SOI
- OLR
- ENSO
- Lower/Middle Atmosphere
- Stratospheric Winds
- QBO

CORRELATION

Waves in MLT
Diurnal Wave Spectrum at Equator from SABER T (95-105 km)

**Main Features**

- DW1 and DE3 are dominant diurnal tides in MLT region.
- Intra-annual (seasonal) and Inter-annual variabilities.
- Consistent QBO upto 2008.
- Missing QBO in 2010 (Delayed)
Temporal Domain: No Difference || Spatial Domain: Different wave numbers

**DW1 Tide**
- Seasonal Behavior is same for Temperature and Meridional wind
- Dominant in Meridional component

**DE3 Tide**
- Seasonal Behavior is same for Temperature and Zonal wind
- Dominant in Zonal component
SABER Diurnal Wave Spectrum

**RADAR PROBED REGION HIGH ALTITUDE WINDS?**

- **DW1 is dominant in 80-90 km**
- **DW1 is dominant in Meridional**
- **DE3 is suppressed in Meridional**

- **Radar Meridional Diurnal is dominated by DW1**
- **Zonal component will relatively more contribution from DE3**
• Good Correlation for Radar Meridional Diurnal
• Poor Correlation for Radar Zonal Diurnal
• Correlation Decrease for higher altitudes.
• Consistency in QBO phases.

Expected DE3 signatures in zonal component
• Signatures of Lower atmospheric process in zonal component.
EASTWARD QBO

WESTWARD QBO

DW1 QBO phase matches with Stratospheric QBO.

DW1 Amplitudes are suppressed during westward phase of QBO.

La Nina during Eastward phase of QBO seems to have enhanced DW1 amplitudes (2 events only)

DW1 appears to be suppressed during El Nino.

ENSO and QBO Signatures in DW1
Effect of ENSO on DW1 tide
(SABER T DW1 Anomalies vs SOI index)

- DW1 seems to be excited less efficiently during El nino
- Higher than normal amplitudes during La nina
19 years of Radar data (ENSO and QBO Signatures)

- DW1 enhanced when La Nina and Westward phase of QBO.
- Overall enhancement of DW1 during La Nina.
Inter-annual variability of DE3 at Equator

Tide13 Averaged over 95 km at Equator; QBO at 50 hpa

- La Nina
- El Nino
- QBO at 50 hpa
- SSN
- Ref line for ONI
- Ref line for QBO

DE3 at 95 km

SSN

EASTWARD QBO

WESTWARD QBO

EL NINO

ONI Index

LA NINA
Summary

• Consistency between ground based and satellite based observation in context of tidal signatures. However the correlation depends upon the altitude and wind component.

• It is important to look at data from longitudinally separated ground stations especially zonal component.

• Possible Effect of ENSO phases on DW1 and DE3 tidal amplitudes.

• Long term variability of DE3 tide.
Thank you for your Attention