Atmospheric diurnal cycle observed with COSMIC radio occultation soundings

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Motivation for Diurnal Variation Study

- Diurnal variation is one of the fundamental mode of atmospheric variations and must be taken into account in weather and climate research.
- Monitoring climate change can be biased without adequate diurnal sampling.
- The diurnal cycle of hydrological processes (e.g., precipitation, cloudiness and energy fluxes) remains a big challenge for climate models.
- Complex transition of diurnal variations near the tropopause and their impacts on cirrus formation.
- High vertical resolution needed to understand variability near tropopause.
- GPSRO observations with global coverage/high vertical resolution are desired for diurnal study.
COSMIC Daily Soundings

Occultation Locations for COSMIC, 6 S/C, 6 Planes, 24 Hrs

~ 2,000 soundings / day
Or ~10 soundings / 2.5 x 2.5 pixel / month
Full diurnal sampled in a month globally everywhere!

Chris Rocken @ UCAR
Close co-incident (GPS/rds/NCEP)

Radiosonde:
2006-1210-12Z (Lihue)

GPS/NCEP:
2006-1210-11:50Z (cosmic-4)

Apart: 10-min / 146.766 km
(Courtesy of Chi Ao at JPL)
N/T/RH Relation

\[ N = 10^6(n - 1) = 77.6 \frac{P}{T} + 3.73 \times 10^5 \frac{P_w}{T^2} - 40.3 \times 10^6 \frac{n_e}{f^2} \]

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Data Description (COSMIC 2007~2008)

- **JPL V2.5 quick version**
  - Refractivity up to 50 km / Temperature up to 40 km
  - RO Sample #:
    - Total of 896,872 (or 1228 per day)
  - Quality control (ECMWF analysis)

- **JPL V2.5 final version**
  - Refractivity up to 60 km / Temperature up to 30 km
  - RO Sample #:
    - Total of 645,278 (or ~ 900 per day)
  - Quality control (NCEP analysis)
Vertical Sampling (COSMIC-2007)

75% reach 2 km
40% reach 0.5 km
Local Time Sampling (JPL v2.5-final)
(Per 5deg per month per 2-hr)

- 5 N/S (+)
- 25 N/S
- 45 N/S
- 75 N/S

Local Time
Linear Harmonic Analysis

- Decompose a time series $y_i$, $i = 1, 2, \ldots, M$

  $$y_i(t_i) = \bar{y} + \sum_n S_n + \zeta$$

- The harmonics with different time scales

  $$S_n(t_i) = A_n \cos(nt' - \phi) = a_n \cos(nt') + b_n \sin(nt')$$

  where, $t' = 2\pi t_i / 24$  $n=1, 2, 3, 4, \ldots$ denotes harmonics with periods of 24, 12, 8, 6, \ldots hours, $\phi$ is the phase (time of the maximum $y_i$ in LST)
Diurnal fitting at 18 km Local Solar Time \[\text{[hours]}\]

**Temperature**

20S ~ 20 N @ 18 km

**Refraction**
Diurnal Tides (monthly mean)

Temperature

Refractivity

Phase

Xie et al., submitted to ACPD, 2009
Tides at 30 km

COSMIC 2007-2008

CHAMP 2001-2005

CMAM

Refractivity (%)

Temperature (K)

Latitude (deg)

Zeng et al, 2008
JPL and UCAR retrievals differences

☐ COSMIC RO throughput difference
  - Calibration: double (JPL) vs. single-differencing (UCAR)
  - Quality Control

☐ Upper stratosphere small-scale variation difference
  - Upper boundary condition (Abel inversion)
    - Extrapolation of bending above certain level (e.g., 50km) with fixed scale height (without climatology)
    - Dynamic optimization method that combines climatology (a Priori) and observed bending angles
JPL-UCAR retrieval difference (COSMIC-2007-January)

Zonal mean refractivity variance (%)
Summary

- The monthly COSMIC RO observations capture the weak migrating tidal wave in the tropics, which propagating upwards from around 140 hPa (~14 km) to the upper stratosphere.
- Distinct seasonal variation of diurnal amplitude at different altitudes are observed from RO measurements.
- Maximum amplitude of diurnal tides at 30km is out of the phase of the solar heating.
- High latitudes show large diurnal and semi-diurnal amplitude in the stratosphere with strong seasonal variations.
Future Works

- Investigate diurnal and semi-diurnal variations in the lower troposphere.
  - Separating land and ocean
  - PBL height/structure
- Evaluate the useful range of RO refractivity/temperature measurements in various scale (mean/small-scale variations).
- Understand the strong diurnal variation observed in polar region.
- Analyze diurnal variation in ECMWF reanalysis (e.g., ERA-interim).
- Access the benefit of future RO missions (e.g., the 12-satellite COSMIC-II) on global and regional diurnal variation study.
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