GNSS RO Retrieval Science and Science Applications with FORMOSAT-7/COSMIC-2


UCAR COSMIC Program

ICGPSRO-2016, Taipei, Taiwan
FORMOSAT-7/COSMIC-2 Summary

- 12 geodetically stable satellites
  - 6 launched to equatorial orbit Q1 2017
  - 6 launched into polar orbit ~2018 (TBD)
- JPL TriG GNSS RO receiver
  - GNSS capability (GPS + GLONASS)
  - Full OL tracking for L1CA/L2C/L2P
  - Improved oscillator over C1/IGOR
  - High-rate (50Hz) data in ionosphere
- Beam-steered high gain RO antennas
- ~10,000 global soundings/day
GNSS RO Retrievals – Active Areas of Research

- **GNSS Processing**
  - GPS and GLONASS clock estimation
  - Precise Orbit Determination
  - Atmospheric excess phase processing

- **Neutral Atmospheric Retrievals**
  - Investigation of the physical mechanisms responsible for RO biases in the moist lower troposphere
  - Optimal processing of RO data in the lower troposphere
  - Development of an advanced BA optimization scheme
  - Investigate algorithms to reduce small/large scale ionospheric residuals in neutral atmospheric retrievals
  - Observational error characterization
  - 1D VAR retrievals to estimate temperature/moisture

- **Ionospheric Retrievals**
  - Improve estimation of absolute TEC for GPS and GLONASS
  - Development of advanced electron density profile inversion techniques
  - Geo-location of regions with ionospheric irregularities that cause scintillation along observed lines of sight
Optimal processing of RO data in the lower troposphere

- Detection of tropospheric ducts (reliable detection requires 1-Hz SNR~2000 V/V)
- Determine optimal truncation of RO signals where they fall below the noise level
- Discrimination of interfering signals
- Detection/evaluation of other propagation effects

COSMIC Tropical Occultations

wave-optics modeling of RO signals

Inversion layers with different max|dN/dz|
Deep RO signals appear:
when max|dN/dz| exceeds the critical value 157/km
(sup--refraction, ducting)
134/km
141/km
148/km
157/km (critical)
167/km (duct)
180/km (duct)
196/km (duct)
Dynamic BA error characterization (individual for each occ.)

Available in UCAR atmPrf and bfrPrf files

**In the stratosphere:** based on RMS fluctuation of the LC Doppler in 1 s sliding window.

**In the troposphere:** based on local spectra of WO-transformed RO signal (Gorbunov et al., JGR, 2006) but with different definition of the local spectral width.
Atmospheric Boundary Layer from RO (Diurnal variations of the ABL depth over the Ocean)

(Sokolovskiy et al., 2009, AMS)
Specific errors of the ionospheric correction in the troposphere induced by the horizontal gradients of electron density in the ionosphere

Standard ionospheric correction (IC) of bending angle (BA) is based on the assumption: $BA(h) = BA_{atmo}(h) + BA_{iono}(h)$ where $h$ is impact height. True for a spherically symmetric N. Horizontal gradients of electron density in the ionosphere result in the errors of the IC which depend on the vertical N structure in the troposphere. The largest errors are around the inversion layers (ABL top). Confirmed by observations and modeling.

The errors result in apparent vertical shifts of the heights of inversion layers (ABL top). Possible implication (ongoing research): ionospheric correction of the ABL height. Where may be important: for monitoring of diurnal cycle of the ABL depth in the regions with large ionospheric gradients, e.g. over the sub-tropical ocean.

(Zeng et al., Atmos. Meas. Tech., 2015)
The temperature impact of COSMIC-2 Polar:

**EPS-SG + COSMIC-2 EQ + COSMIC-2 Polar**

**NH extra-tropics**

- ~18000 occs
- No RO

**SH extra-tropics**

- No RO

Courtesy: András Horányi, Sean Healy (ECMWF) and Axel von Engeln, Yago Andres (EUMETSAT)
COSMIC-2 OSSE Experiment (from Yue et al., 2013)
Summary

• Challenges still exist for GNSS RO retrievals, particularly in the upper stratosphere and lower troposphere

• High quality GNSS RO data from FORMOSAT-7/COSMIC-2 will lead to improved retrievals over FORMOSAT-3/COSMIC and enable development of new algorithms

• The large amount of data from FORMOSAT-7/COSMIC-2 will have significant positive impact on global NWP forecasts and tropical cyclone prediction

• FORMOSAT-7/COSMIC-2 data will also significantly improve ionospheric specification (and potentially forecasts)
UCAR/COSMIC POSTDOCTORAL FELLOWSHIPS

Support early career scientists with an interest in GNSS remote sensing

**Appointment Term:** Up to two years

**Areas of Research**
- Numerical Weather Prediction
- Climate
- Space Weather
- Weather and Water
- GNSS and RO retrieval development
- Emerging GNSS research opportunities, including GNSS reflectometry

Location: Boulder, Colorado

Apply by 15 April 2016 for maximum consideration

Please see: [www.cosmic.ucar.edu](http://www.cosmic.ucar.edu)

For questions, please contact Dr. John Braun at braunj@ucar.edu
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