GNSS Radio Occultation
Applications for Weather Forecasting

GNSS: Global Navigation Satellite Systems

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# Outline

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What is GNSS Radio Occultation?

Bending of the GPS signal in the atmosphere provides information on temperature, pressure, and humidity.

**Unique:** very high vertical resolution (~ 100 m), all-weather operation, global coverage, and high accuracy (T: ~0.5 K and q: ~0.1 g/kg).

Bending of the GPS signal in the ionosphere provides information on the free electron number density.

LEO – Low Earth Orbiter (altitudes 350-1500 km)
GNSS Radio Occultation Timeline

- **Proof of concept**
  - GPS/MET

- **Operational demonstration**
  - SAC-C
  - CHAMP

- **Operational**
  - COSMIC (6)
  - GRACE
  - GRAS A-B

- **Experiment on an operational satellite**
  - GNOS

Timeline:
- 1995
- 1997
- 2001
- 2005
- 2009
- 2013
- 2015

November 15, 2017
JPL/Caltech
PV/JPL
Weather Forecasting Benefits – 2

Stratosphere, Summer Hemisphere

Started assimilating COSMIC data in 2006

From S. Healy, ECMWF
The impact of using RO observations on forecasts of Hurricane Ernesto’s genesis (2006)

Ensemble mean of 48-h forecasts of Ernesto’s central sea level pressure (hPa) initialized from the analyses at 0000 UTC 25 Aug 2006 (Liu et al., 2012; Monthly Weather Review, doi:10.1175/MWR-D-11-00024.1)
Remote sensing of hurricane intensity could greatly improve quantity of timely data

GNSS RO-based Method of Estimating Hurricane Intensity

First estimates of hurricane intensities (maximum wind speed) from GPS radio occultations (GPSRO) and the Wong and Emanuel [2007] hurricane model.

GPSRO-derived hurricane intensities show 0.9 linear correlation with respect to NHC intensities with a small bias. GPSRO shows great potential in augmenting current hurricane datasets, with possible applications to the initial vortex parameterization and intensity forecasting.

Science Applications

1. Climate monitoring

Timeseries of RO Dry Air Temperature Anomalies [K] in the Tropics (10N to 10S)

Pressure level (hPa)

01/96 01/97 01/98 01/99 01/00 01/01 01/02 01/03 01/04 01/05 01/06 01/07 01/08 01/09 01/10

Temperature (K)

Time, months

2. Characterizing the planetary boundary layer

3. Expansion of the tropical belt

Northern Hemisphere

Southern Hemisphere

4. Electron density irregularities

Auroral (64–80°)

Polar (> 80°)
COSMIC-2A launch, 6 satellites: ~March 2018
COSMIC-2 observation density

A high-inclination launch is necessary to obtain global and uniform distribution of RO profiles and to improve weather forecast skill globally.

Spatial distribution of the COSMIC-2A and COSMIC-2B observations for (a) ±3 hours assimilation time window

L. Cucurull, NOAA, 2017
Future Research Satellites: RO+Reflections?

- CHAMP and SAC-C had nadir antennas and observed some reflections from frozen areas
- GNOS (RO) has a reflections experiment onboard
- CYGNSS (NASA mission) is first GNSS-Reflections constellation
• RO observations have improved weather forecasting, have demonstrated great potential in extreme weather research, and have provided valuable information in space weather research.

• Given the success of previous RO missions, future and follow-on missions will track additional signals of opportunity (beyond the GPS signals).

• Synergistic applications between GNSS-RO and GNSS reflections appear to be a viable path forward to begin exploring new science applications.