GNSS Radio Occultation Applications for Weather Forecasting

GNSS: Global Navigation Satellite Systems

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Outline

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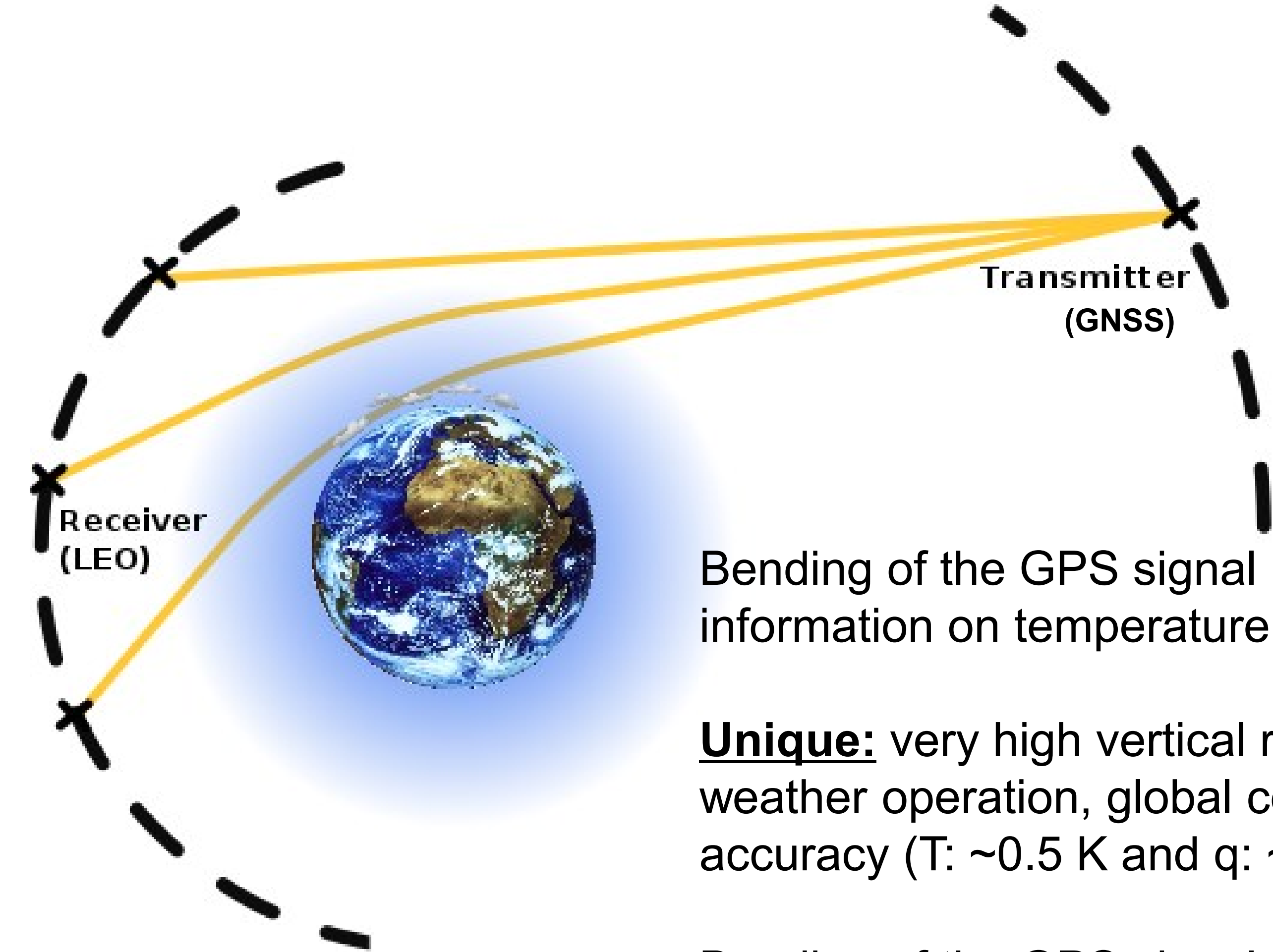
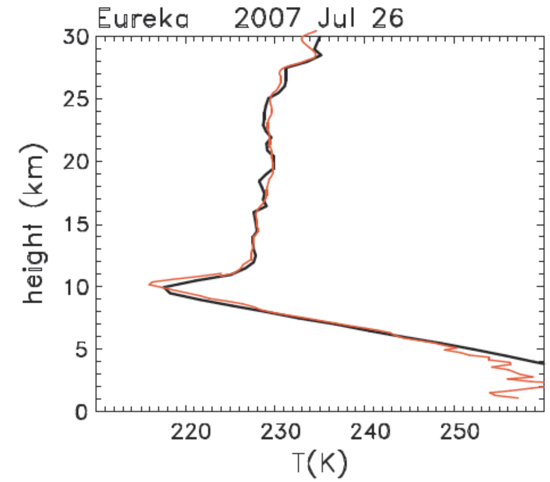
What is GNSS Radio Occultation?





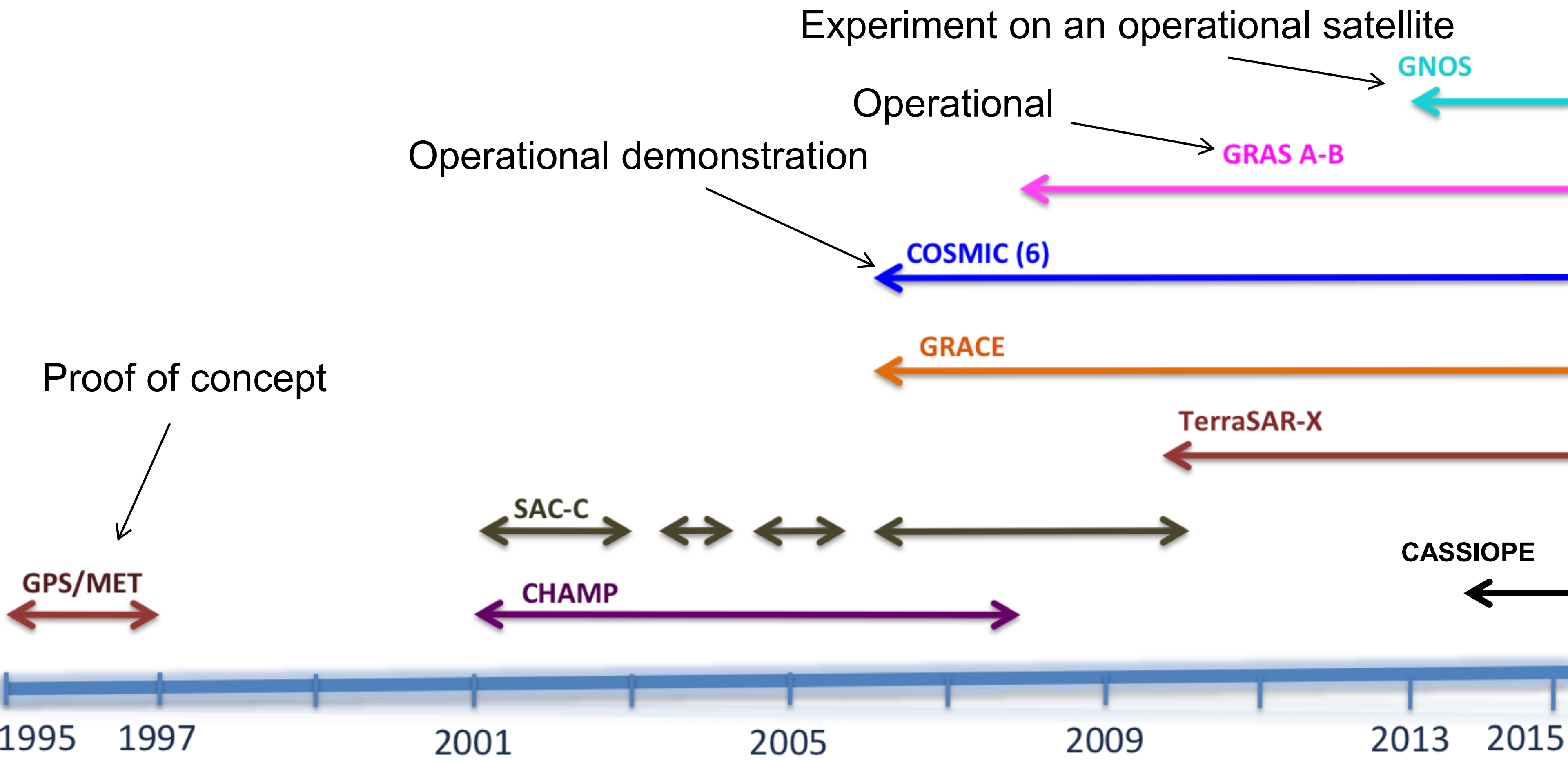
Bending of the GPS signal in the atmosphere provides information on temperature, pressure, and humidity.

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).

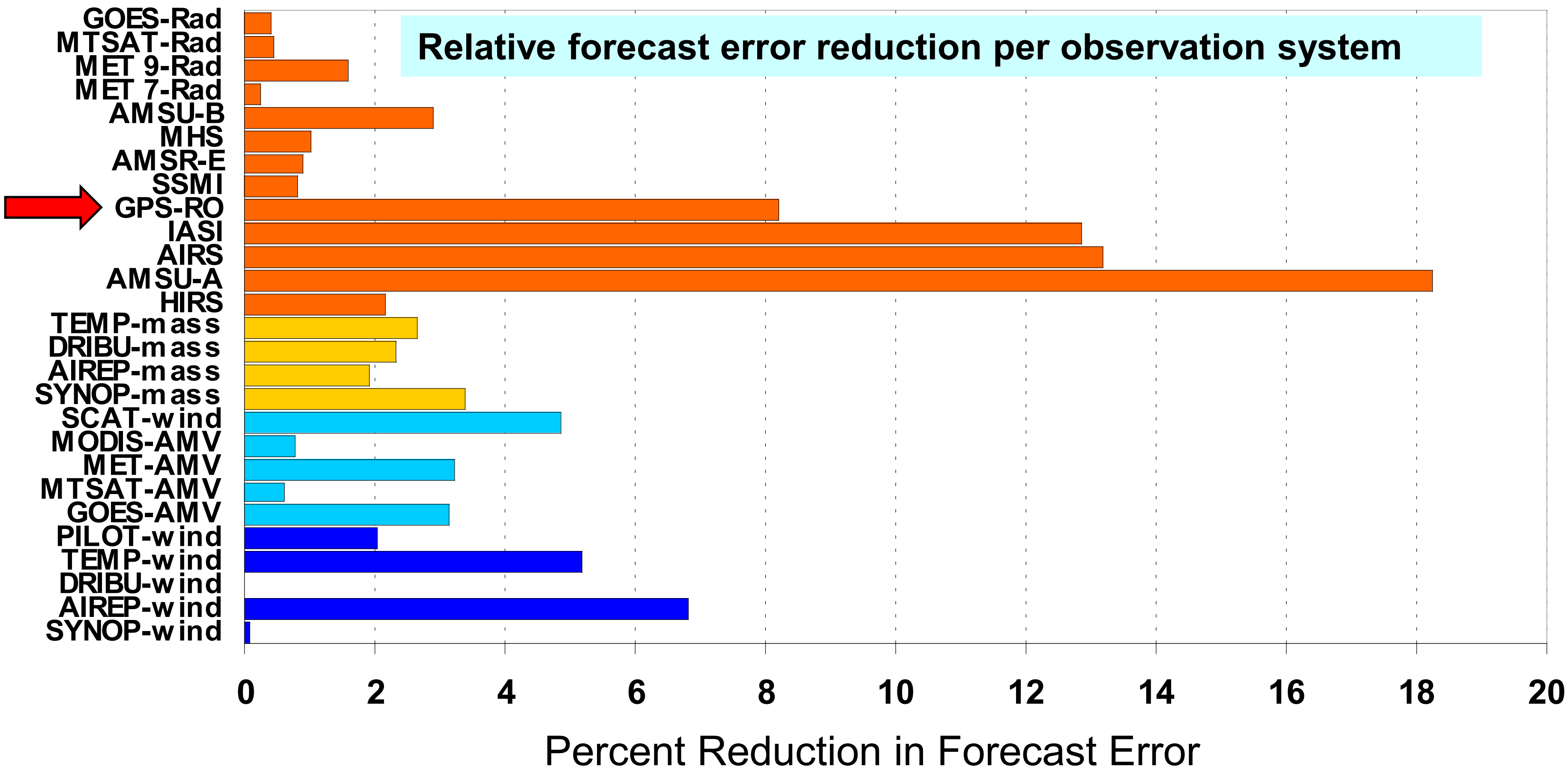
Bending of the GPS signal in the ionosphere provides information on the free electron number density.

LEO – Low Earth Orbiter (altitudes 350-1500 km)

GNSS Radio Occultation Timeline



Weather Forecasting Benefits – 1

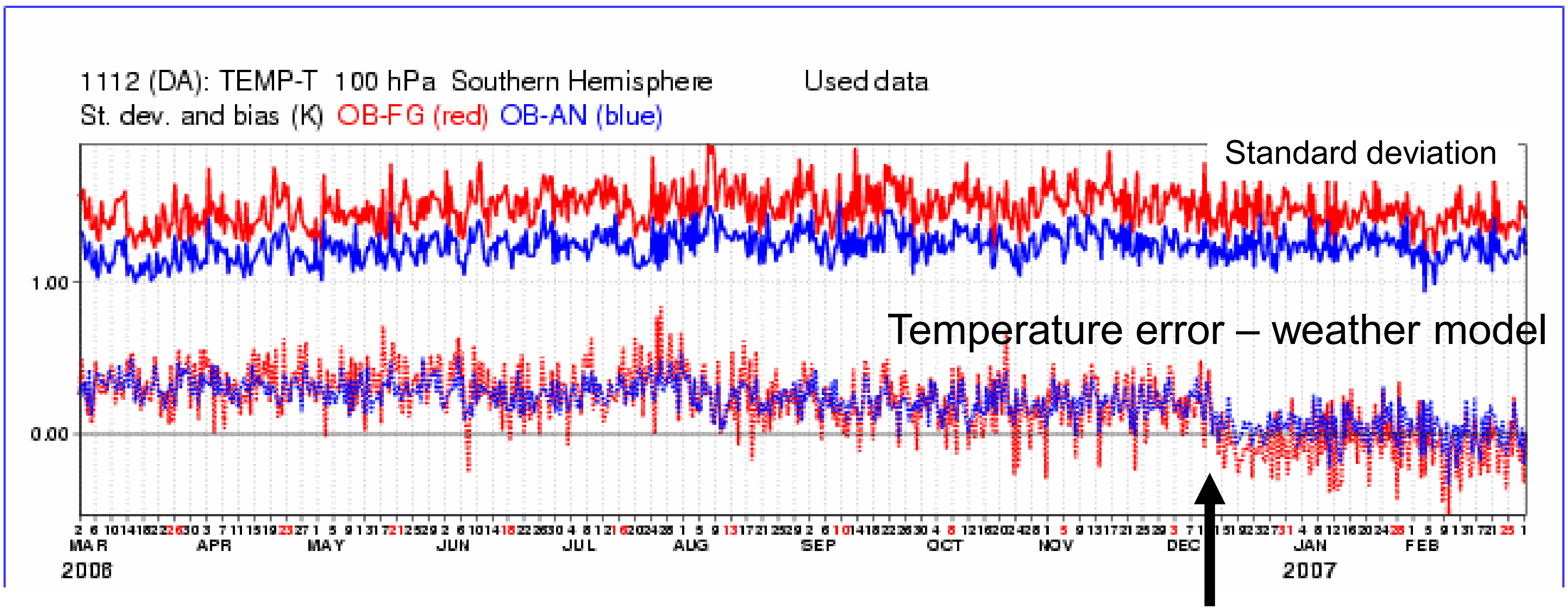


24-hour forecast

Cardinali, C., and S. Healy (2014), Impact of GPS radio occultation measurements in the ECMWF system using adjoint-based diagnostics, *Q.J.R. Meteorol. Soc.*, *140*(684), 2315–2320, doi:10.1002/qj.2300.

Weather Forecasting Benefits – 2

Stratosphere, Summer Hemisphere

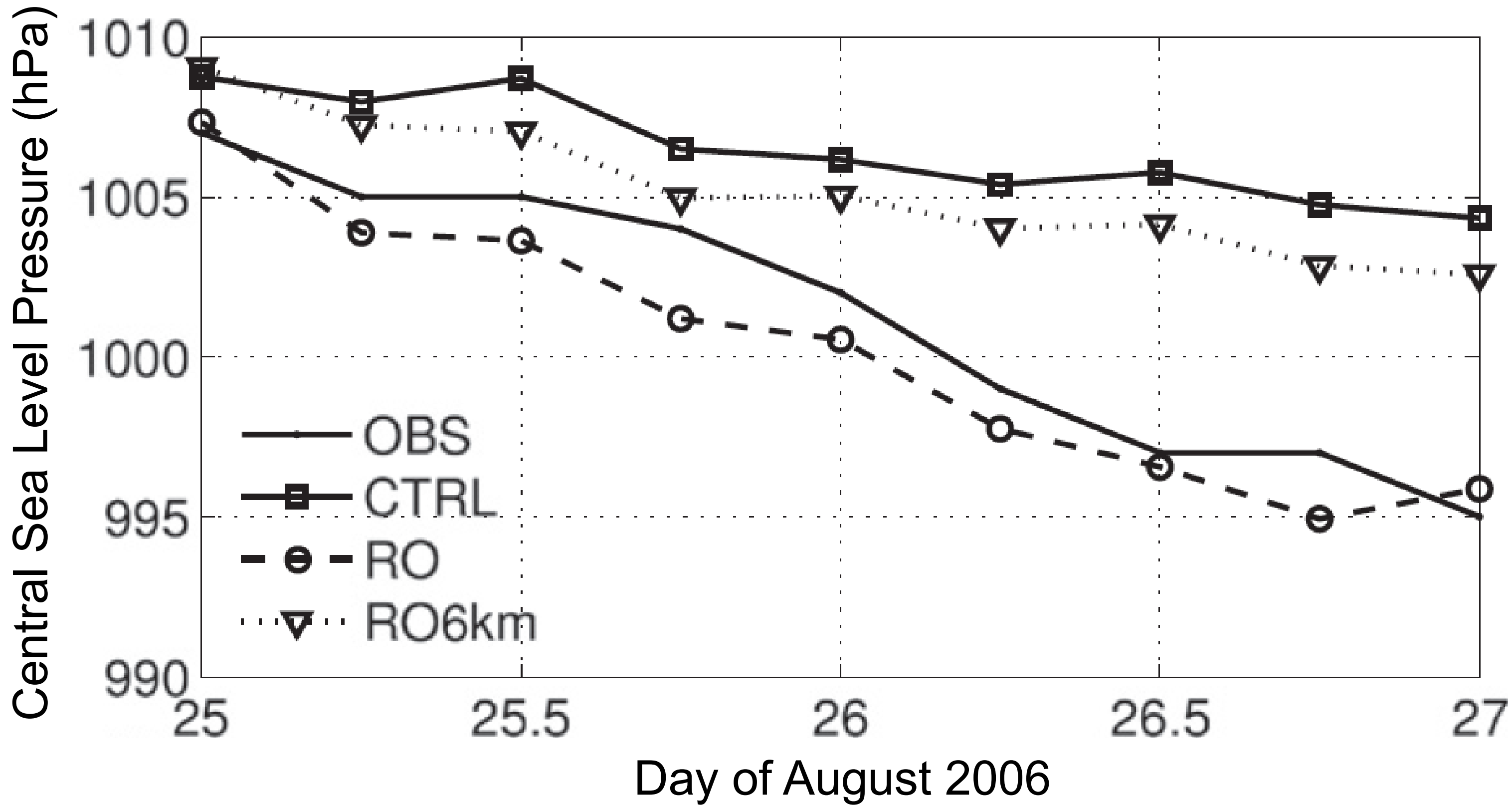


Started assimilating COSMIC data in 2006

From S. Healy, ECMWF

Weather Forecasting Benefits – 3

The impact of using RO observations on forecasts of Hurricane Ernesto's genesis (2006)



<u>Ensemble mean of 48-h forecasts</u> 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)

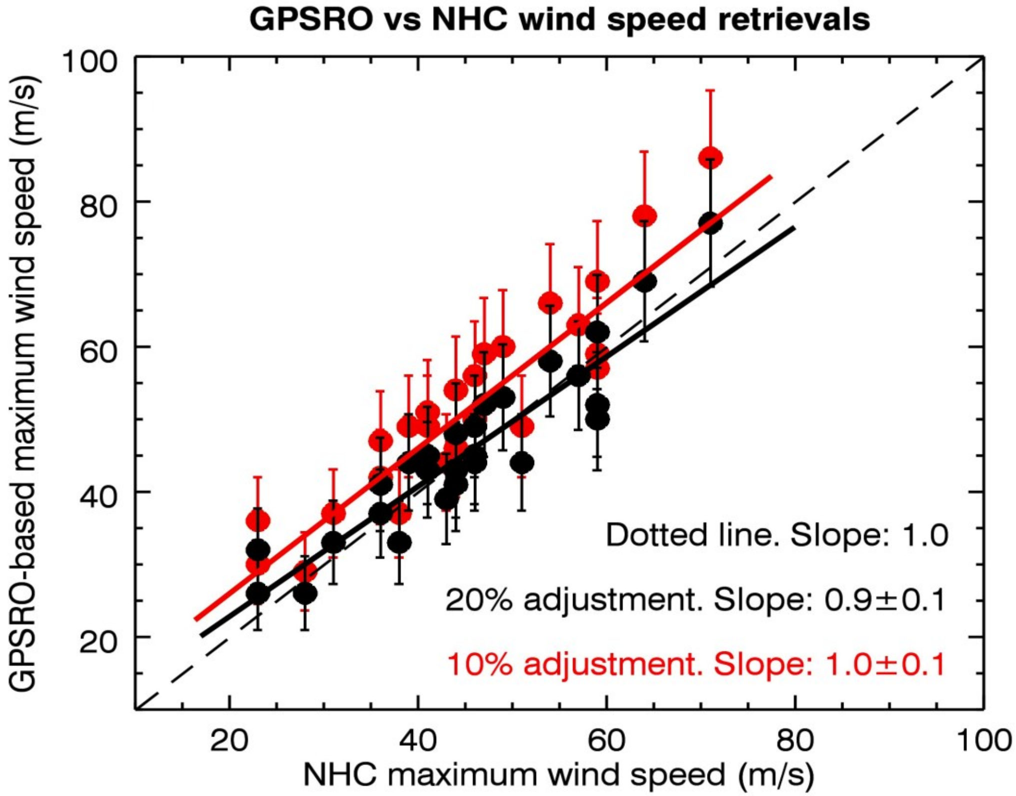
Hurricane Intensity Estimation

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.

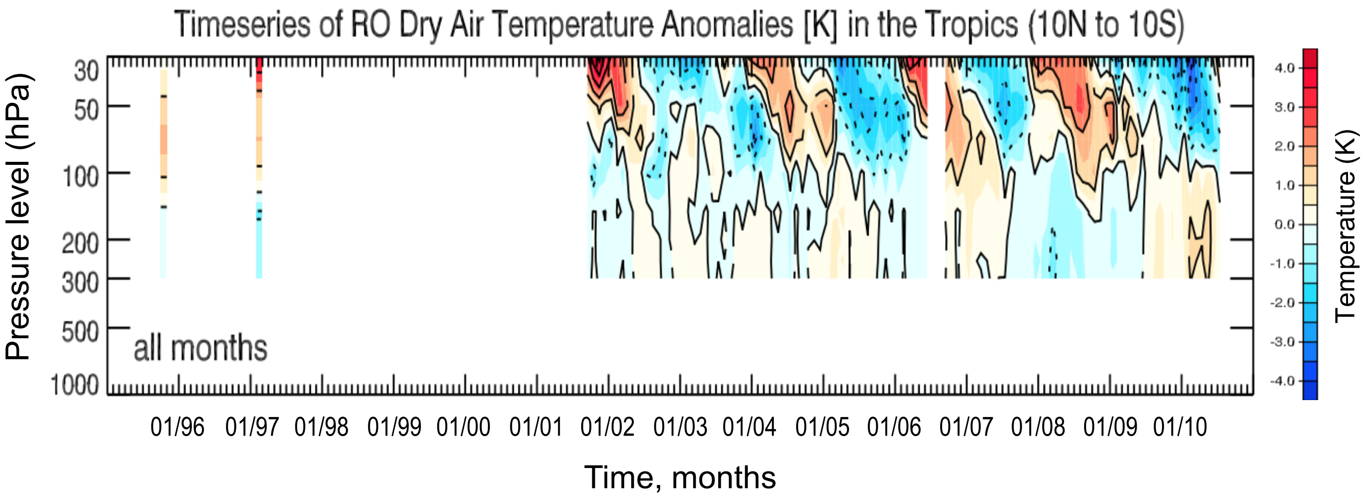
GPSRO-derived hurricane intensities show 0.9 linear correlation with respect to NHC intensities with a small bias. GPSRO shows great potential in augmenting current hurricane datasets, with possible applications to the initial vortex parameterization and intensity forecasting.



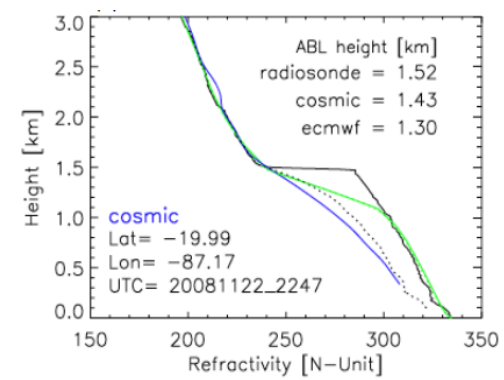
Vergados P., Z. Luo, K. Emanuel, and A. J. Mannucci (2014), Observation tests of hurricane intensity estimations using GPS radio occultations, *J. Geophys. Res. – Atmospheres.*, 13 p., doi:10.1002/2013JD020934

Science Applications

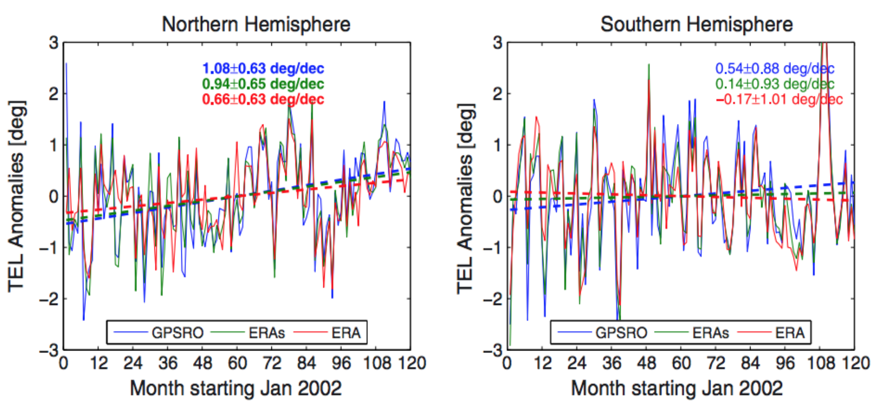
1. Climate monitoring



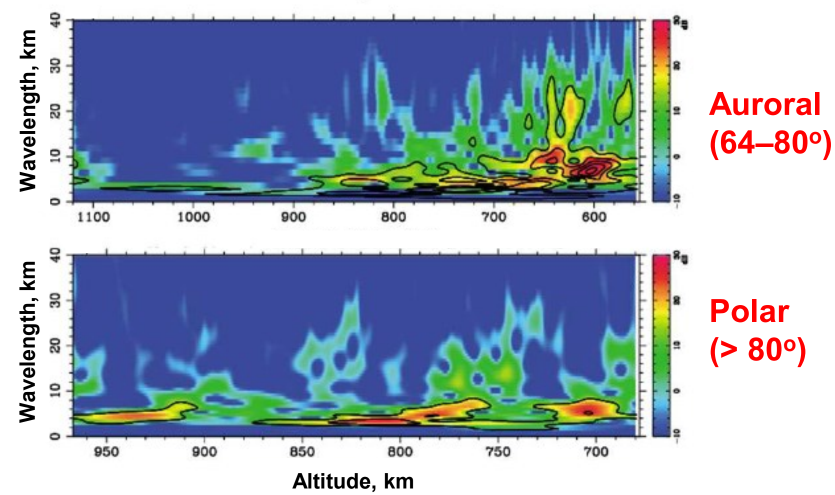
2. Characterizing the planetary boundary layer



3. Expansion of the tropical belt



4. Electron density irregularities



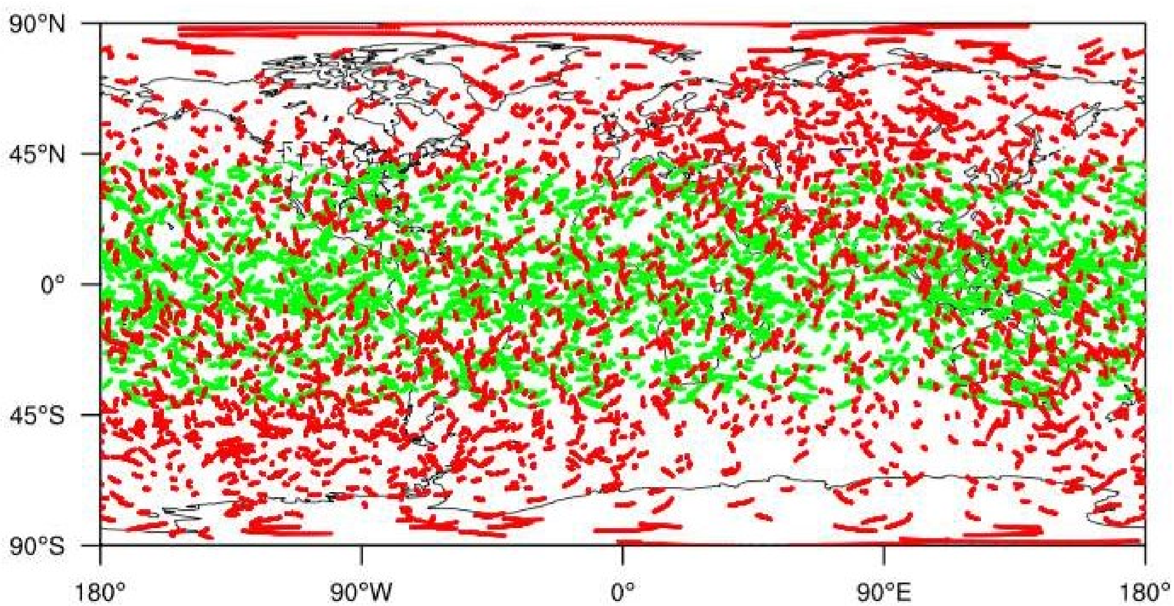
COSMIC-2/FORMOSAT-7 Mission

COSMIC-2A launch, 6 satellites: ~March 2018

COSMIC-2/FORMOSAT-7 Mission

COSMIC-2 observation density

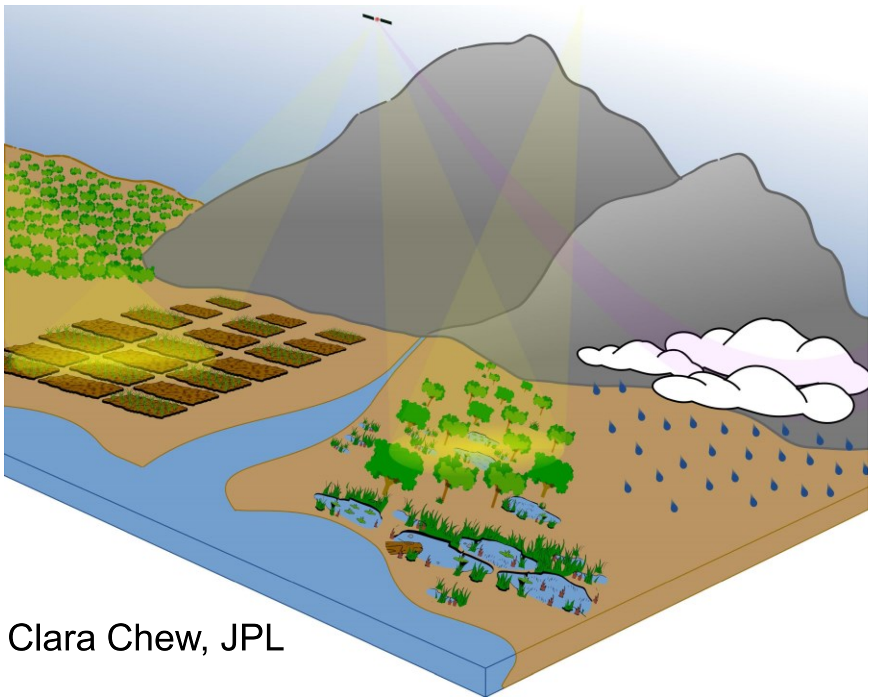
A high-inclination launch is necessary to obtain global and uniform distribution of RO profiles and to improve weather forecast skill globally



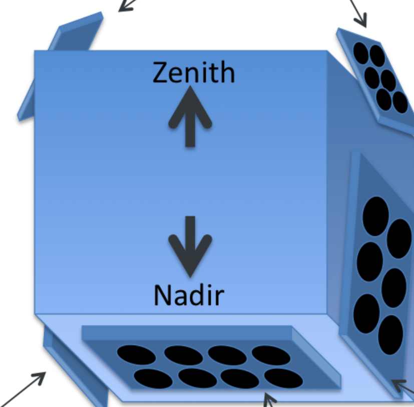
Spatial distribution of the COSMIC-2A and COSMIC-2B observations for (a) ±3 hours assimilation time window

L. Cucurull, NOAA, 2017

Future Research Satellites: RO+Reflections?



Clara Chew, JPL



- **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**

Summary

- 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.

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