# An overview of the COSMIC follow-on mission (COSMIC-II) and its potential for GNSS-R

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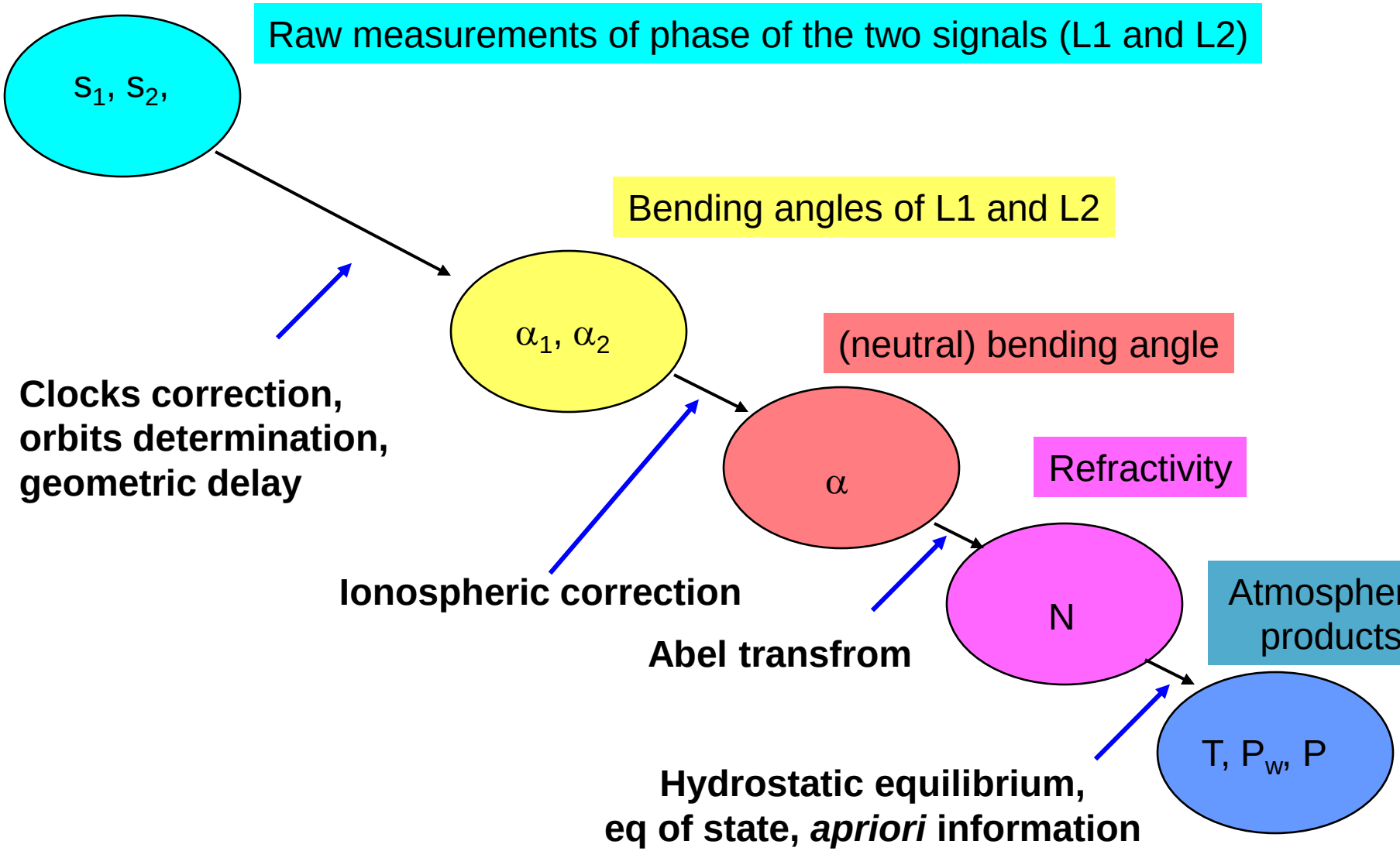
# Overview chart

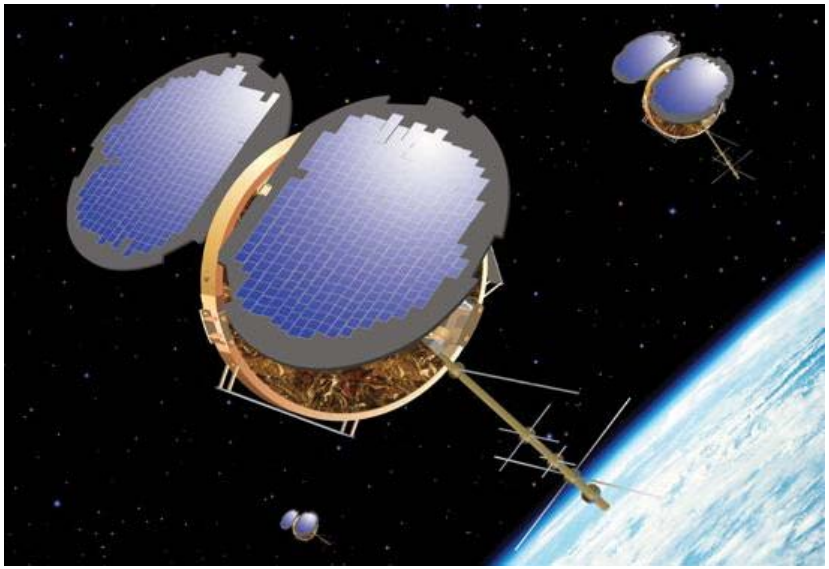


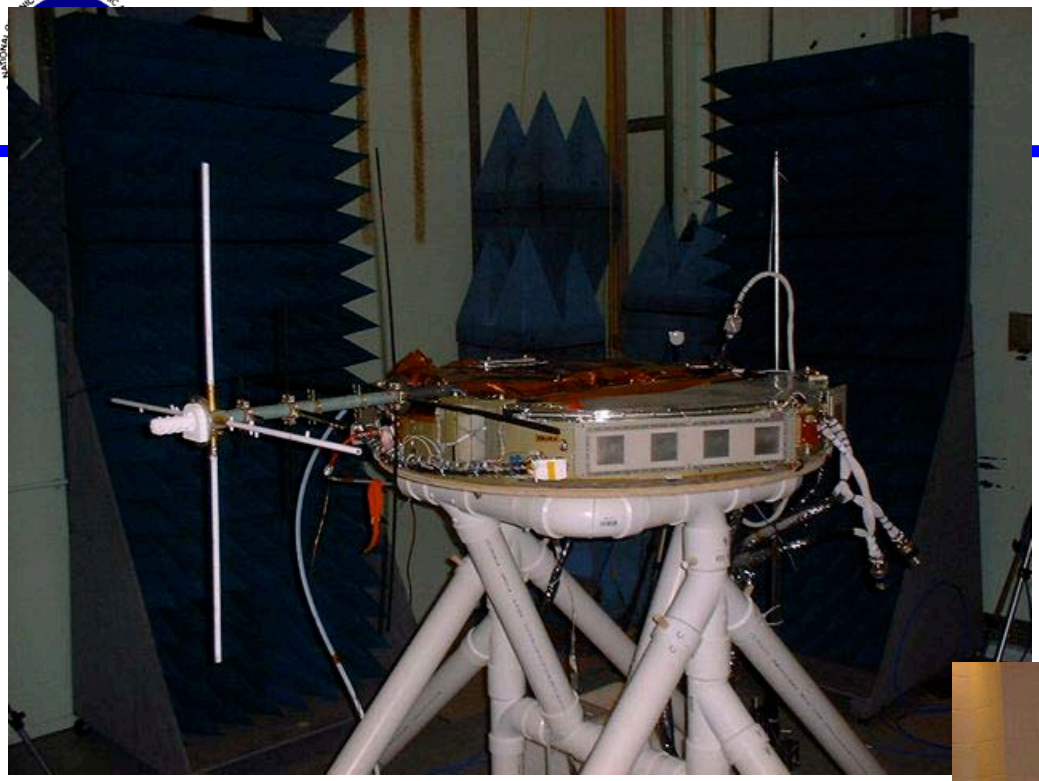
# Radio Occultation features

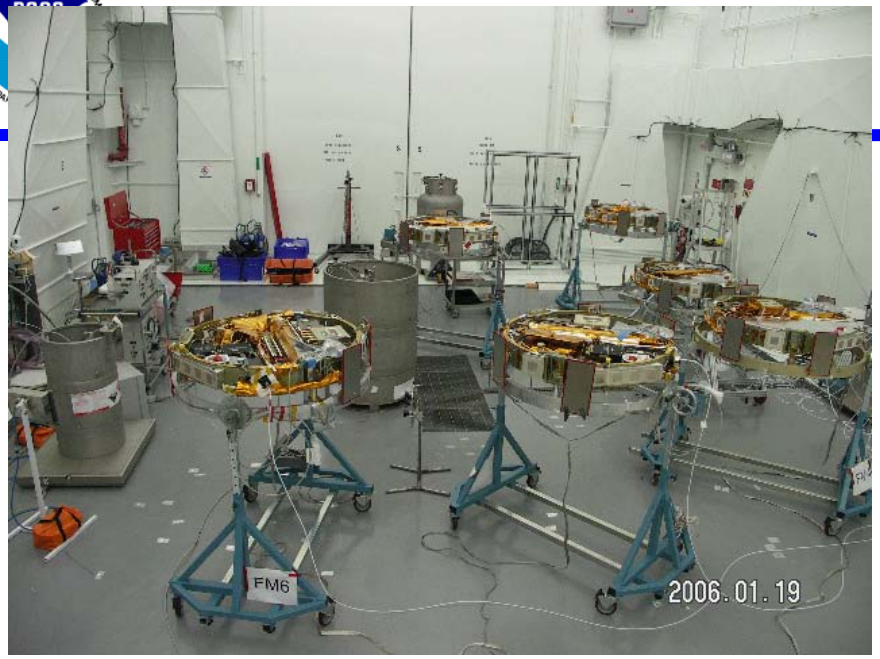
- Limb sounding geometry complementary to ground and space nadir viewing instruments
  - High vertical resolution (~100 m)
  - Lower ‘along-track’ resolution (~200 km)
- All weather-minimally affected by aerosols, clouds or precipitation
- High accuracy (equivalent to ~ 0.5 Kelvin from ~7-25 km)
- Equivalent accuracy over ocean than over land
- No instrument drift, no need for calibration
- Global coverage
- No satellite-to-satellite measurement bias
- Inexpensive compared to other sensors

# COSMIC (Constellation Observing System for Meteorology, Ionosphere and Climate)

- 6 Satellites was launched:
  **01:40 UTC 15 April 2006**
- Three instruments:
  **GPS receiver, TIP, Tri-band beacon**
- Weather + Space Weather data
- Global observations of:
  Pressure, Temperature, Humidity
  Refractivity
  Ionospheric Electron Density
  Ionospheric Scintillation
- Demonstrate quasi-operational GPS limb sounding with global coverage in near-real time
- Climate Monitoring



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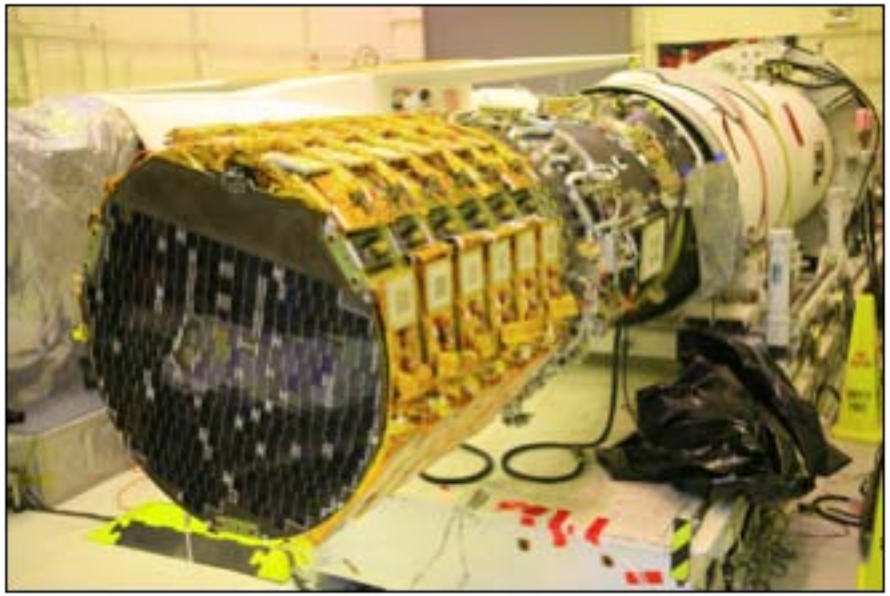
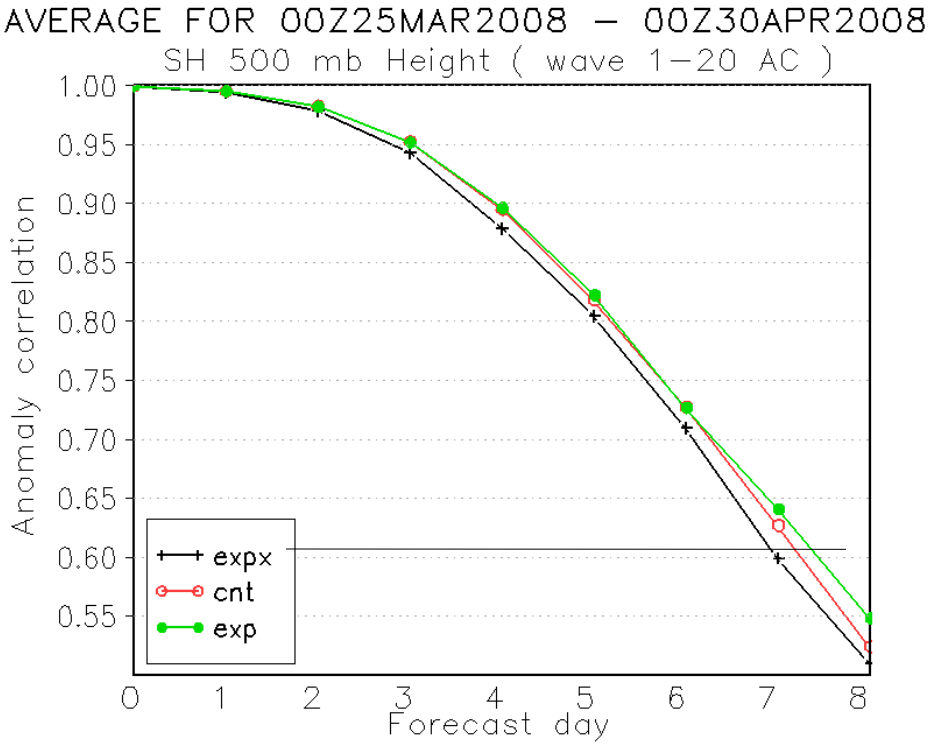


# Recent impact with COSMIC

- AC scores (the higher the better) as a function of the forecast day for the 500 mb gph in Southern Hemisphere
- 40-day experiments:
  - **expx (NO COSMIC)**
  - **cnt (old RO assimilation code - with COSMIC)**
  - **exp (ops - with COSMIC)**




**COSMIC provides 8 hours of gain in model forecast skill starting at day 4 !!!**

*Cucurull 2010 (WAF)*

# Assimilation of GPS RO @ NCEP

- **COSMIC became operationally assimilated at NCEP on 1 May 2007** (GFS, Global Forecast System)
- Observations from **Metop/GRAS and GRACE-A** were added to the operational observing system in **February 2010**
- The assimilation of COSMIC (and other GPS RO sensors) into the regional system (NAM) is under pre-operational testing
- Data from SAC-C is expected to be assimilated operationally very soon
- Results show that **RO is a very significant component of the observing system and that we have not reached saturation in model skill with the current RO constellation**

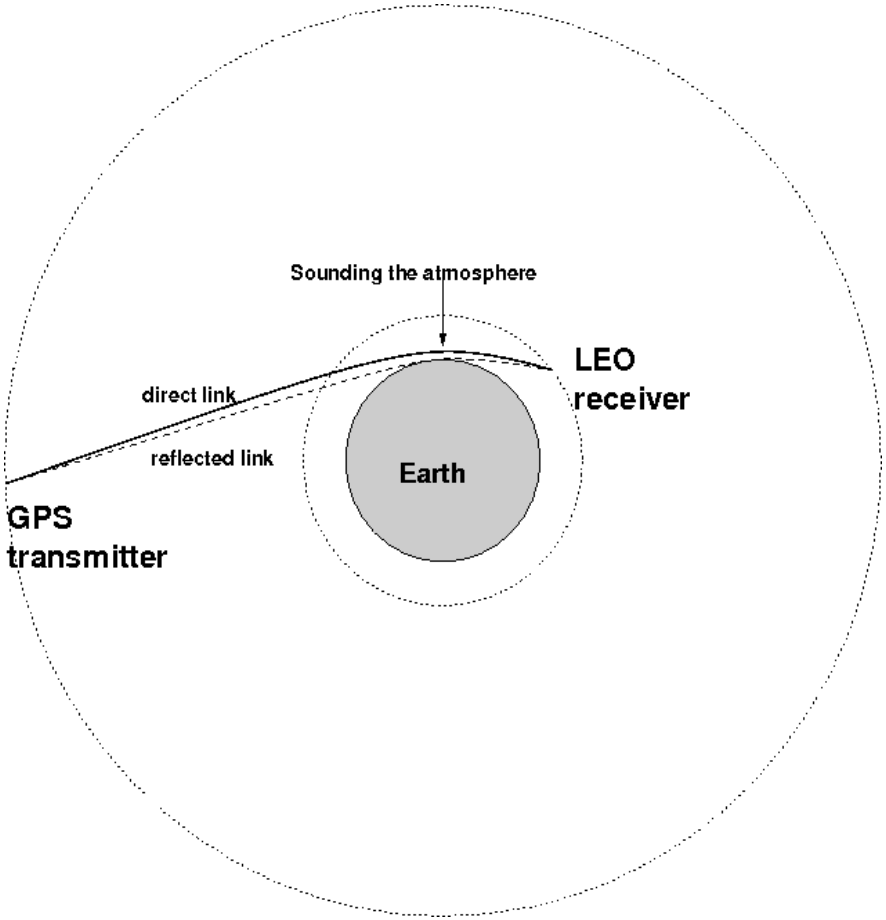
# COSMIC follow-on

- COSMIC expected end-of-life: 2011-2012
- NOAA is working on a follow-on capability beyond COSMIC (partnership with Taiwan). This involves NESDIS, NWS and other NOAA line offices.
- NOAA is moving forward on a replacement to COSMIC
- “COSMIC 2” (conceptual)
  - 12 satellites
  - Homogeneous global coverage
  - GPS and Galileo signals (minimum)
  - Higher gain antennas for higher SNR
  - 8000+ soundings per day
  - ~30 minutes data latency - from sounding to data delivery to the weather/ionospheric centers

# Potential use of COSMIC-2 for GNSS-R?

# Reflections in GNSS RO

- Very slant geometry
- RHCP data (mostly co-polar at low elevation angles of observation)
- Coherent scattering



# Brief history of GNSS-R in RO (I)

- [Beyerle et al., 2001] proves that some features in the frequency domain correspond to signals reflected off of the Earth surface:

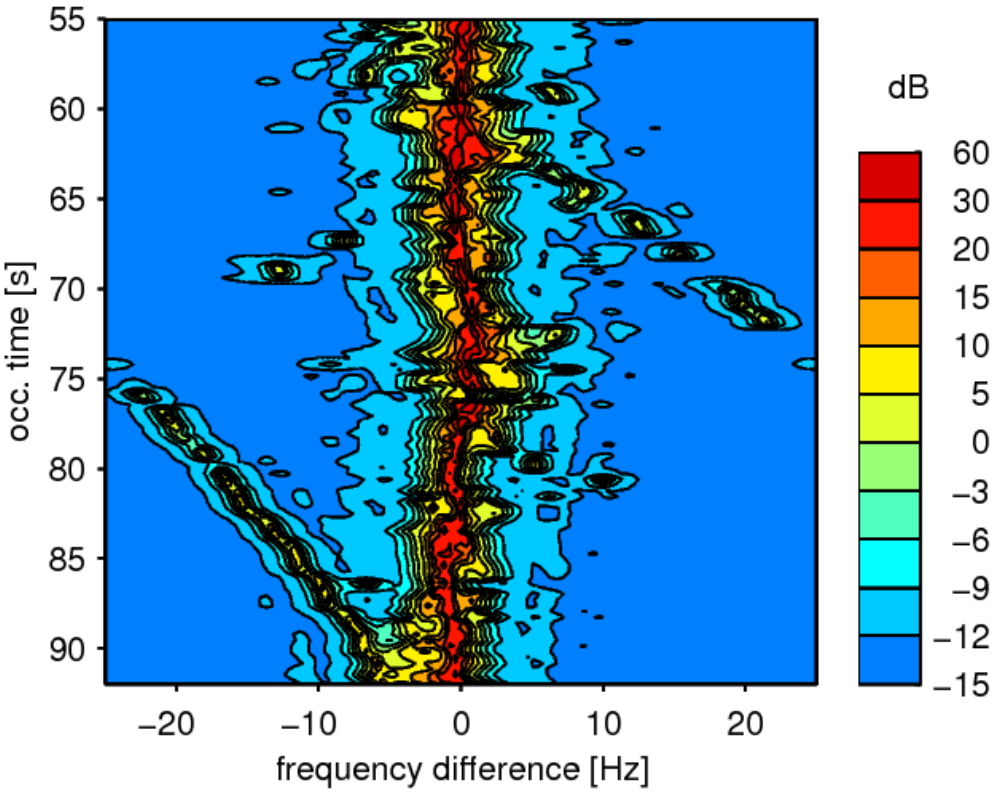
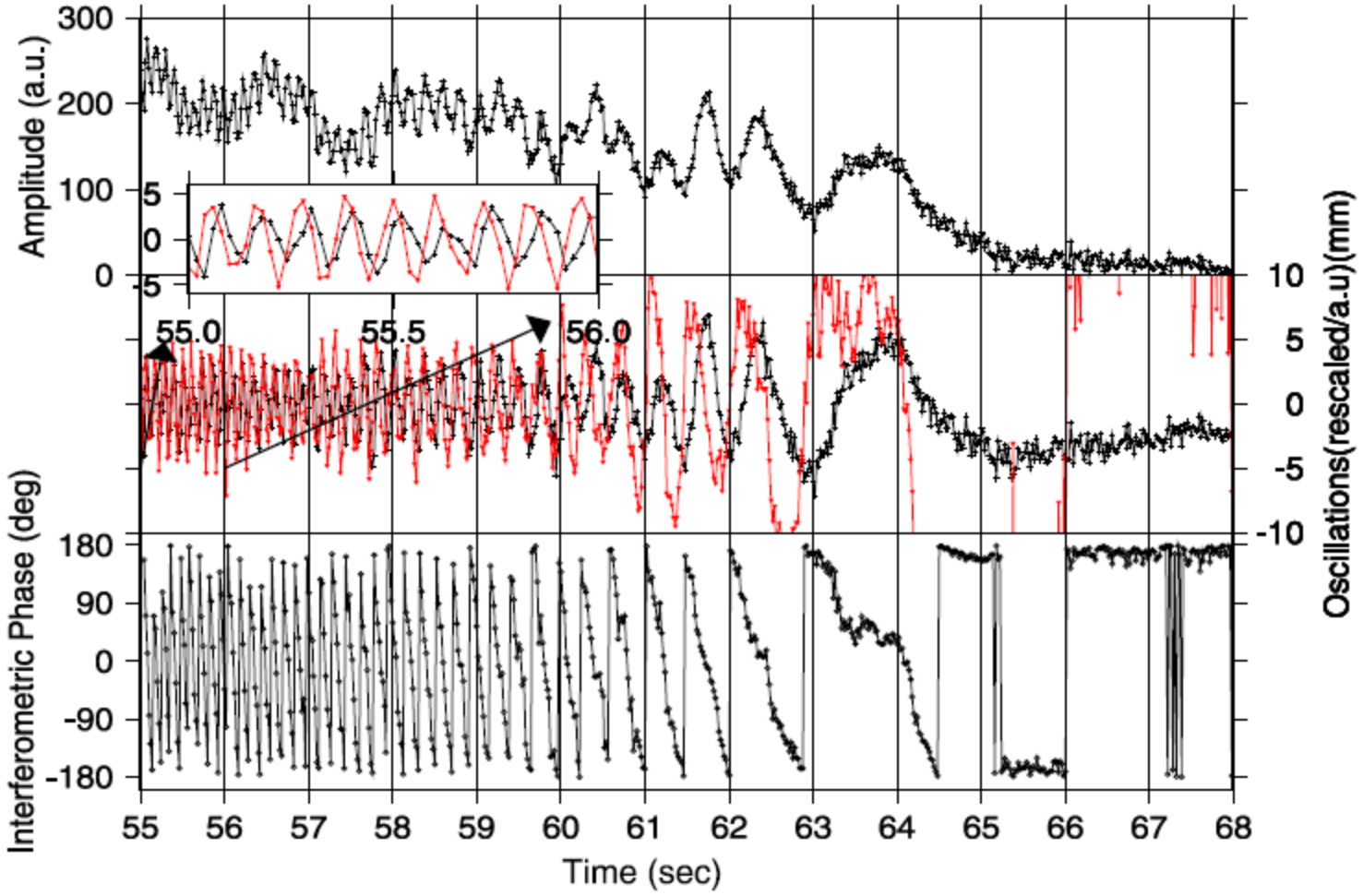


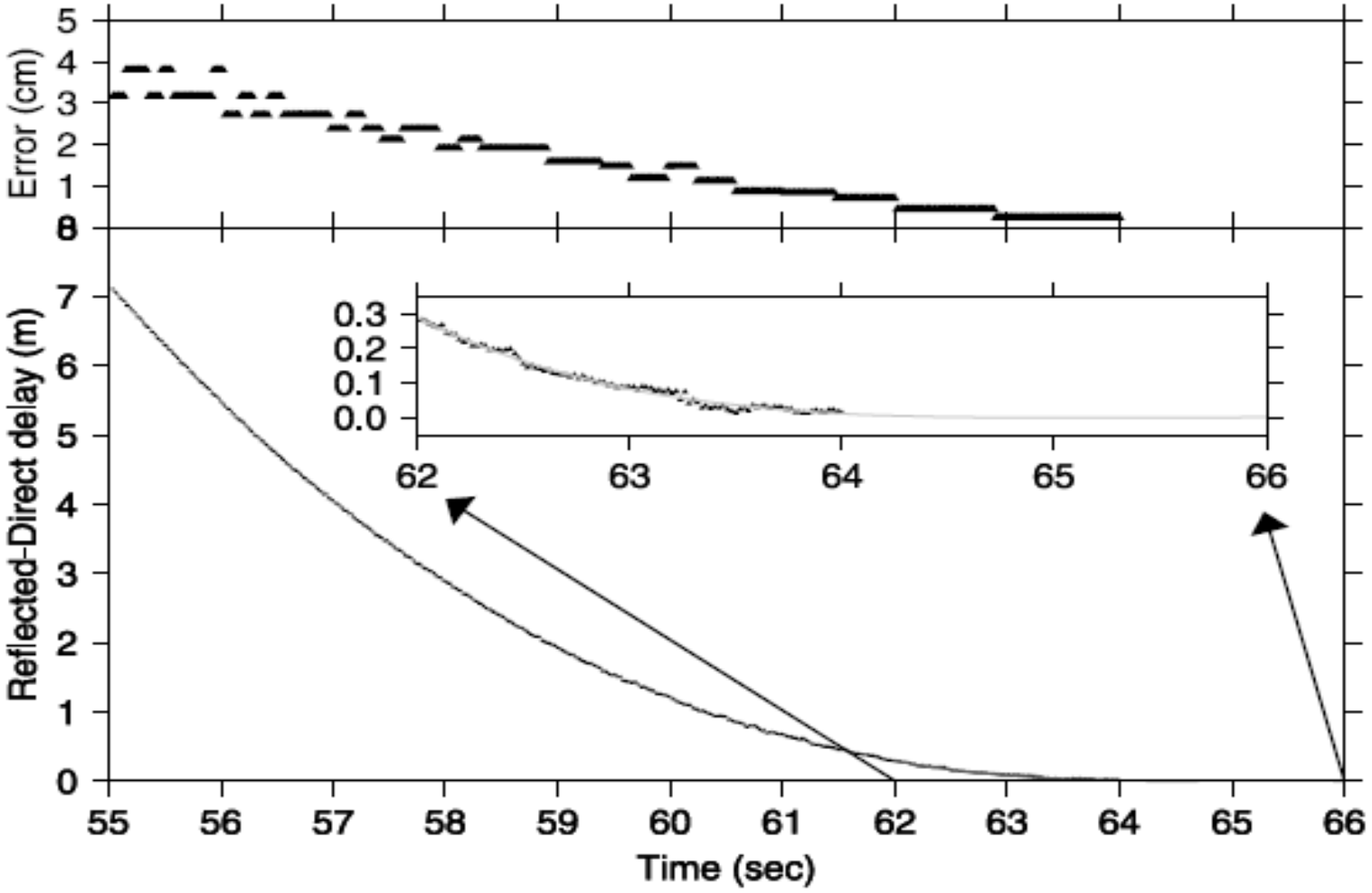

**Figure 3.** Temporal evolution of radio hologram power spectra derived from GPS/MET occultation number 10 on 3 February 1997. Blue colors denote low power levels, colors ranging from yellow to red indicate increased power levels.

# Brief history of GNSS-R in RO (II)

- [Cardellach et al., 2004] used the interferometric phase between the direct and reflected radio-links to perform phase-delay altimetry:

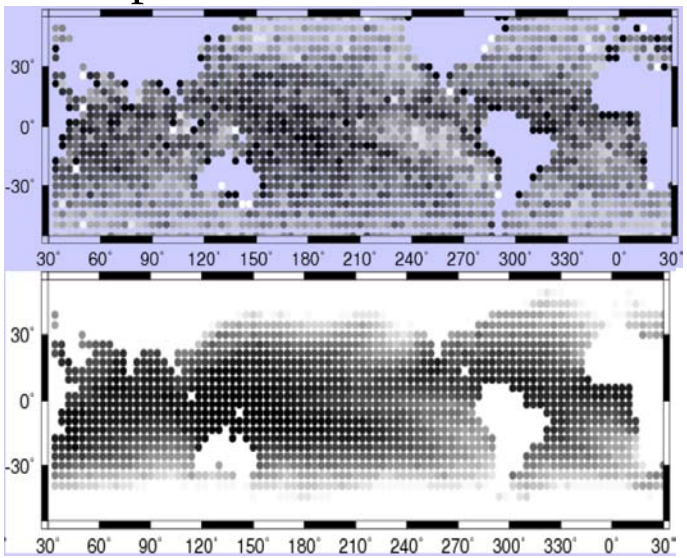


# Brief history of GNSS-R in RO (III)



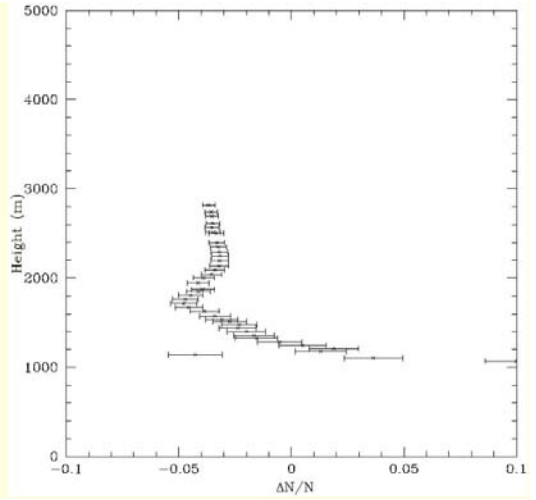
# Brief history of GNSS-R in RO (IV)

- Starting in 2008: EUMETSAT's GRAS SAF studies on potential use of GPS reflected signals in RO
  - Automatic detection of such reflection events
  - Seasonal/geographical patterns
  - Use of reflection flag as RO “quality flag”
  - Potential inversion of reflected signals
  - …




(see Poster Session: Cardellach et al.)

- Starting in 2009: Environment Canada project (see Poster Session: Boniface et al.)




- Pavelyev et al.: see talk tomorrow at 14:10

# SUMMARY

- GNSS Radio Occultation (RO) data provide limb sounding of the atmosphere: temperature, pressure, wet component
- COSMIC RO constellation will be replaced by COSMIC-2 starting in ~2014: 12 satellites equipped with GNSS limb-oriented antennas, capturing ~8000 RO events every day, globally distributed.
- RO data has been proven to contain GNSS signals reflected off of the Earth surface, especially over the Oceans/Poles (e.g. in up to ~70% of Ocean RO).
- Because of the signal coherence, the reflected-to-direct delay can be estimated using phase-delay interferometry, a few-cm delay precision.
- Several applications can be envisaged
  - Surface altimetry
  - Atmospheric enhanced estimates
- **COSMIC-2** will provide a **DAILY SET OF THOUSANDS OF GNSS-R** events in slant geometry **GLOBALLY DISTRIBUTED**, at high sampling rate.