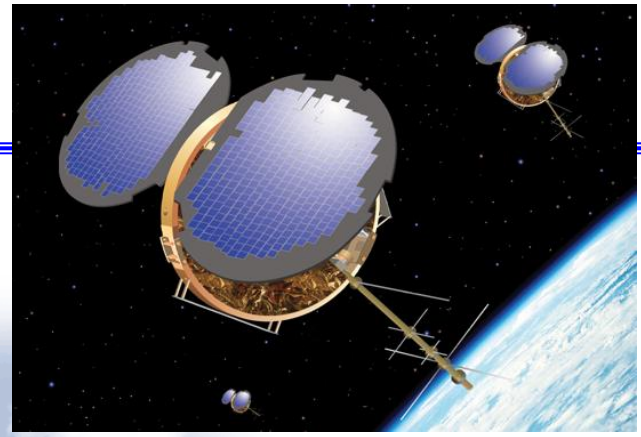

COSMIC Data Assimilation: progress report

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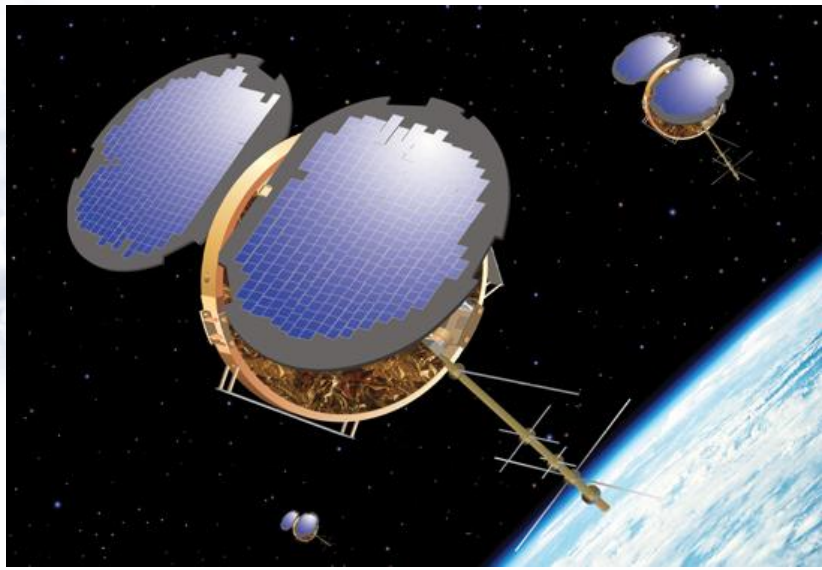
COSMIC (Constellation Observing System for Meteorology, Ionosphere and Climate)

- 6 Satellites launched in April 15 2006
- Three instruments:
  GPS receiver, TIP, Tri-band beacon
- Demonstrate quasi-operational GPS limb sounding with global coverage in near-real time
- Climate Monitoring
- web page:

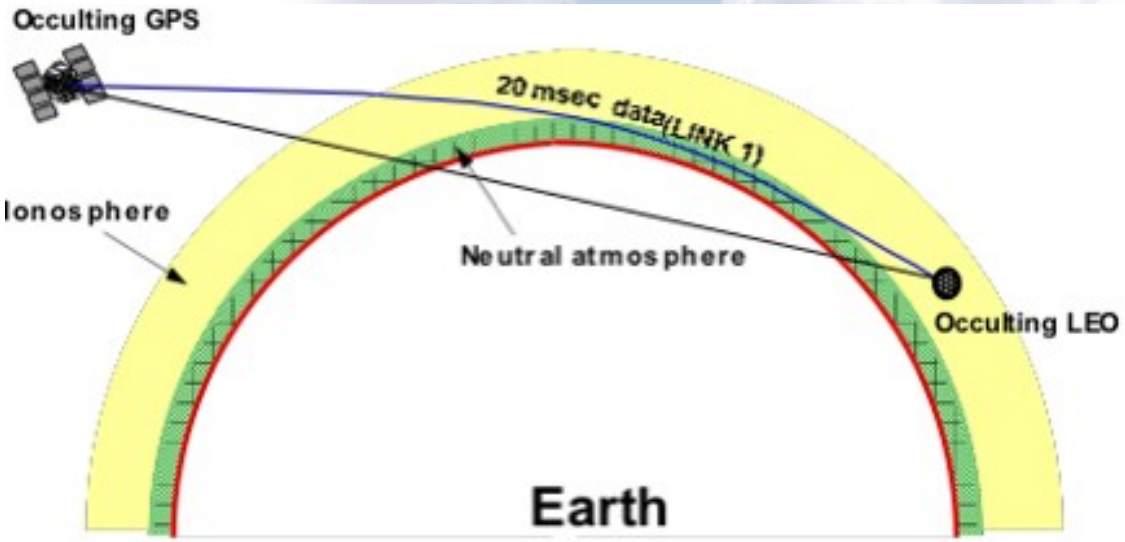
www.cosmic.ucar.edu



GPS Occultation

Basic measurement principle:

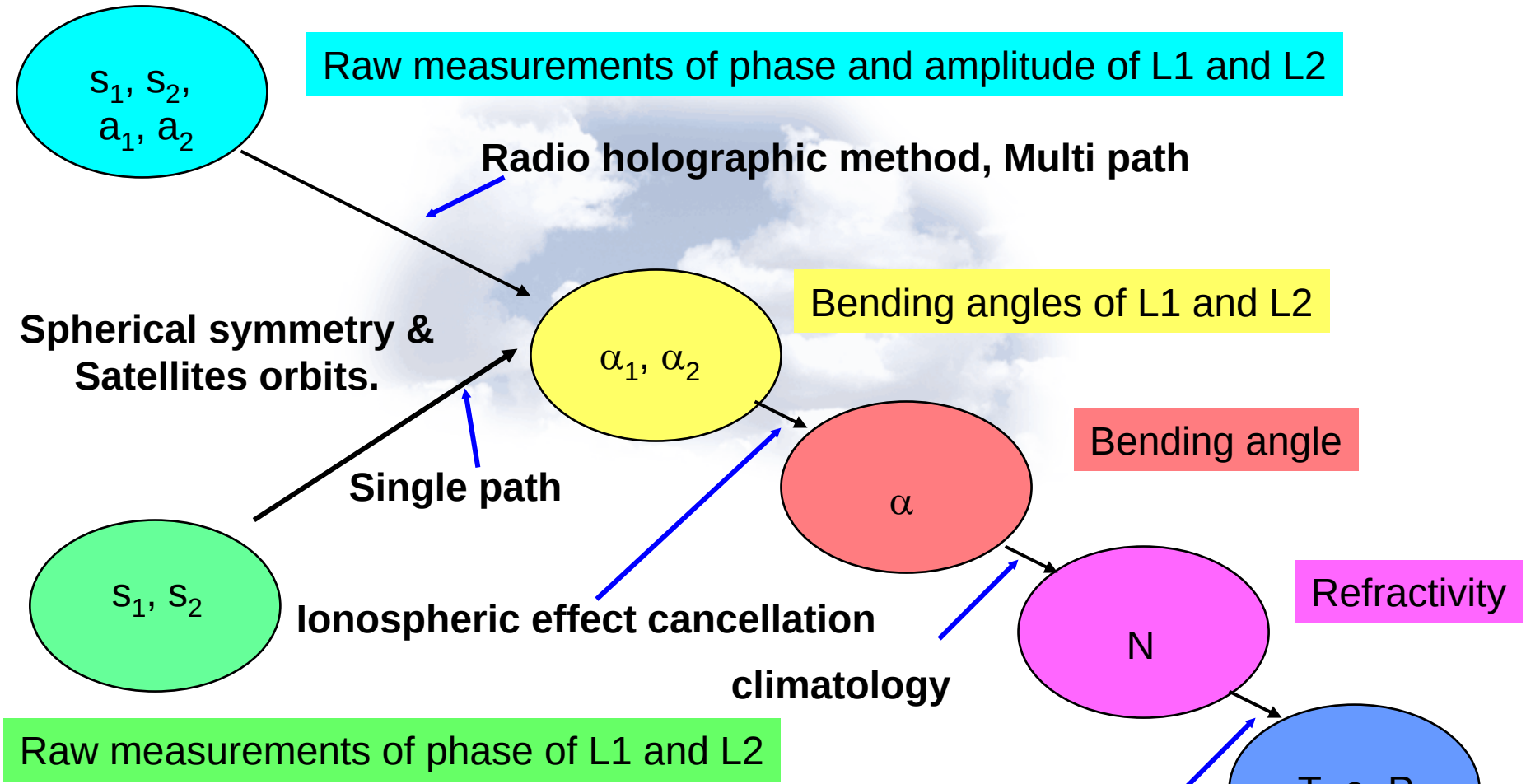
Deduce atmospheric properties based on
precise measurement of phase delay and amplitude.



Characteristics of GPS RO Data

- Limb sounding geometry complementary to ground and space nadir viewing instruments
  - High vertical resolution (0.1 km surface - 1km tropopause)
  - Lower horizontal resolution (~300 km)
- High accuracy (equivalent to < 1 deg K from 5-25 km)
- All weather-minimally affected by aerosols, clouds or precipitation
- Independent of radiosonde calibration
- No instrument drift
- No satellite-to-satellite observational bias

GPS radio occultation measurements & processing



Forward Models:

Refractivity:

$$N = 77.6\frac{P}{T} + 3.73\times 10^{-5}\frac{P_w}{T^2}$$

Bending angle:

$$\alpha(a) = -2a\int_a^{\infty} \frac{d\ln n / dx}{(x^2 - a^2)^{1/2}}\,dx$$

$$(x = nr)$$

Milestones accomplished

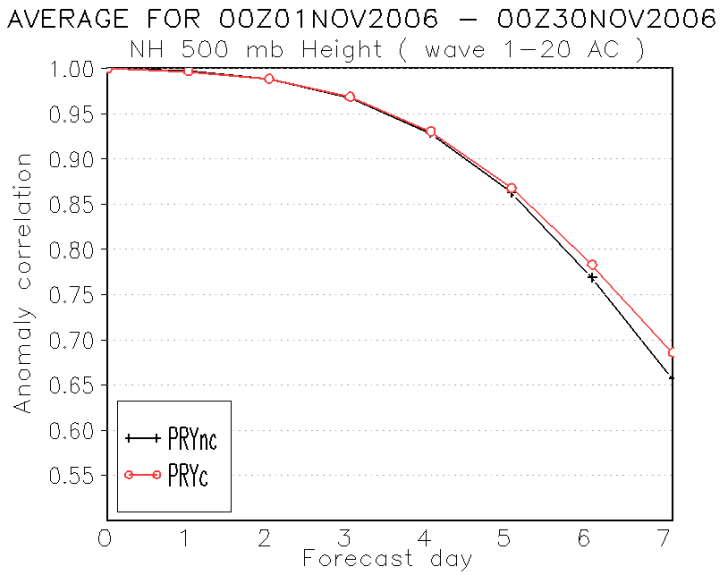
- The JCSDA has developed, tested and incorporated into the next generation of NCEP's Global Data Assimilation System (GSI/GFS) the necessary components to assimilate two different type of GPS RO observations (**refractivity** and **bending angle**). These components include:
  - complex forward models to simulate the observations (refractivity and bending angles) from analysis variables and associated tangent linear and adjoint models
  - Quality control algorithms
  - Error characterization models
  - Data handling and decoding procedures
  - Verification and impact evaluation procedures

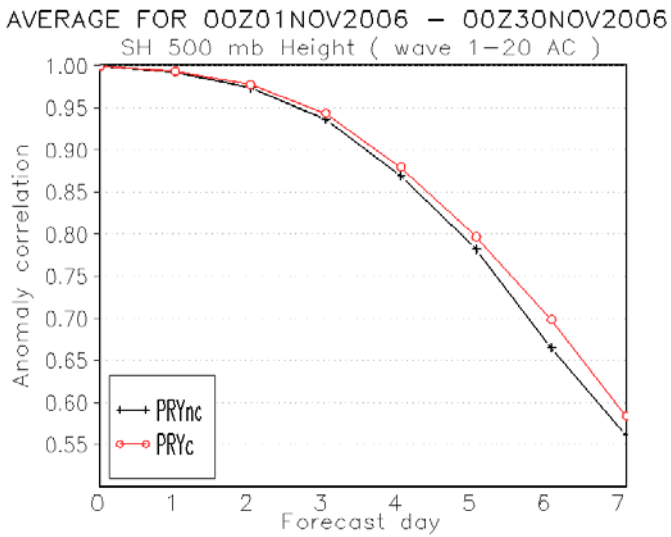
Recent achievements

- Update the forward operators for GPS RO refractivity and bending angle in the GSI code to use (1) a generalized sigma-p hybrid vertical coordinate and (2) surface pressure instead of log(surface pressure) as analysis variable. Corresponding tangent linear and adjoint codes have been implemented and tested.
- Update the quality control checks and error characterization for the GPS RO data in the GSI code with the COSMIC data.
- Conduct early impact studies with COSMIC data. Results are very encouraging.
- Preparation for transition to operations:
    - Data handling (testing the end-to-end system)
    - Parallel runs to analyze the impact of COSMIC in the latest version of GSI/GFS (to be implemented in operations).
- Refractivity has been selected for implementation in operations. Parallel runs with GSI/GFS being tested against operations include refractivity data. COSMIC observations will go into operations along with the implementation of the GSI/GFS.
- Access to CHAMP data in real time at NOAA.

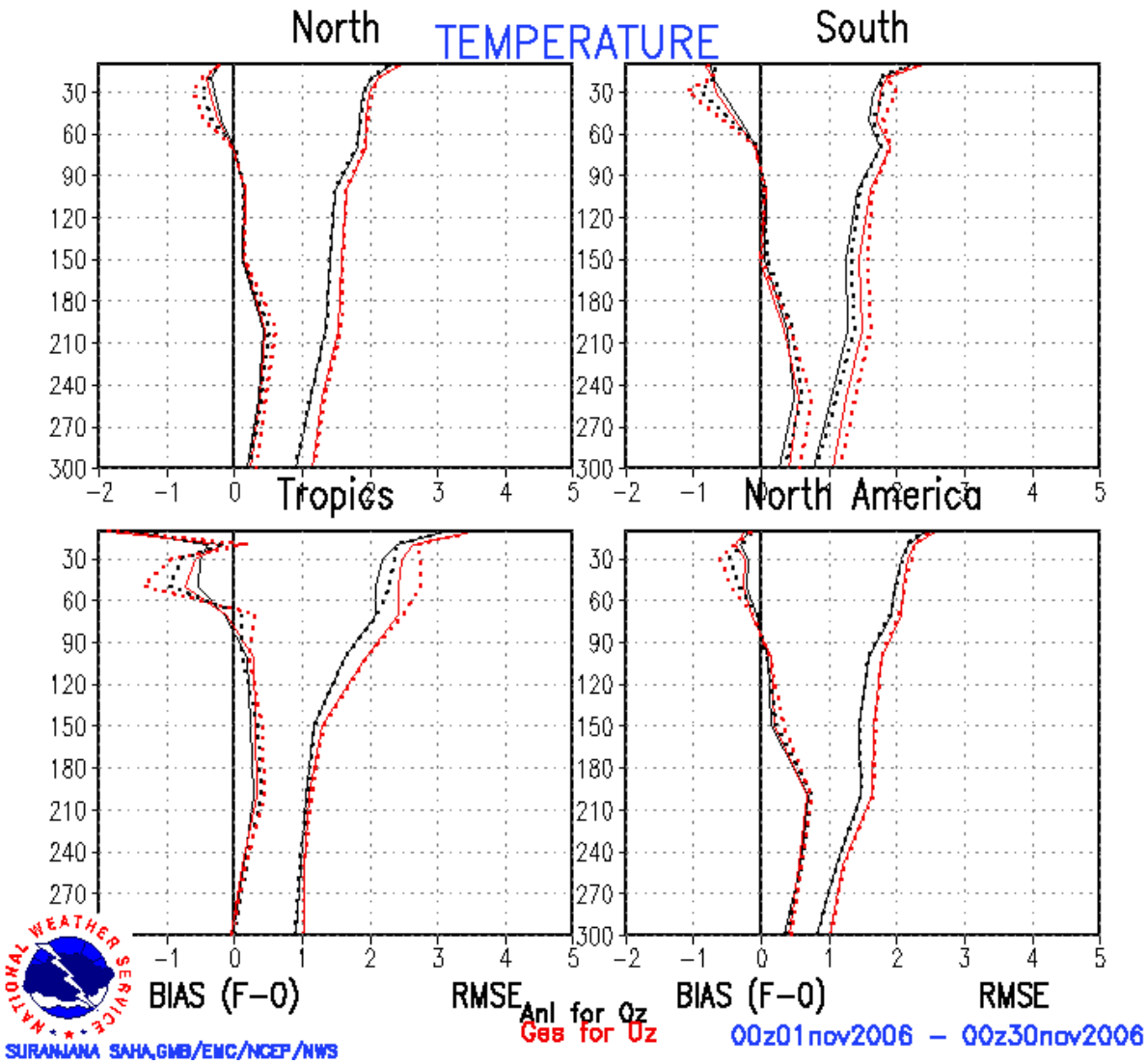
GSI/GFS Impact study with COSMIC

- Anomaly correlation as a function of forecast day for two different experiments:
  - PRYnc (assimilation of operational obs),
  - PRYc (PRYnc + COSMIC refractivity)
- We assimilated around 1,000 COSMIC profiles per day
- In general, the impact of the COSMIC data will depend on the meteorological situation, model performance, location of the observations, etc.





Fit to rawinsonde (November 2006)



- Dashed lines: CTL
- Solid lines: CTL + refractivity

Summary and future work (I)

- JCSDA has implemented and tested the capability of assimilating profiles of refractivity and soundings of bending angle in the NCEP's Global Data Assimilation System (GSI/GFS).
- *A priori*, profiles of bending angle are preferred over refractivity for assimilation because it eliminates several steps of preliminary processing (which includes a step which incorporates a strong climatological component). However, to evaluate the forward operator for bending angle profiles, it is necessary to solve a complex integral equation.
- The assimilation of COSMIC bending angle with the final version of the GSI/GFS is still under final tuning. In the meantime, profiles of COSMIC refractivity will be operationally assimilated along with the implementation of the GSI/GFS system in operations.
- The impact of COSMIC data on top of the current observations assimilated in operations shows very encouraging results.

Summary and future work (II)

- Finalize the analysis of the impact of COSMIC for selected periods.
- Update the GSI/GFS GPS RO code to a generalized vertical coordinate.
- Improve the diagnostic files for the GPS RO observations.
- Analysis and tuning of the code in order to assimilate CHAMP data.
- Further tuning of the bending angle.
- Assimilation of bending angle instead of refractivity in operations.
- Evaluation (and future implementation) of non-local forward operators.