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# Ionospheric Signatures in Radio Occultation Data

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Session 6 “Ionosphere”
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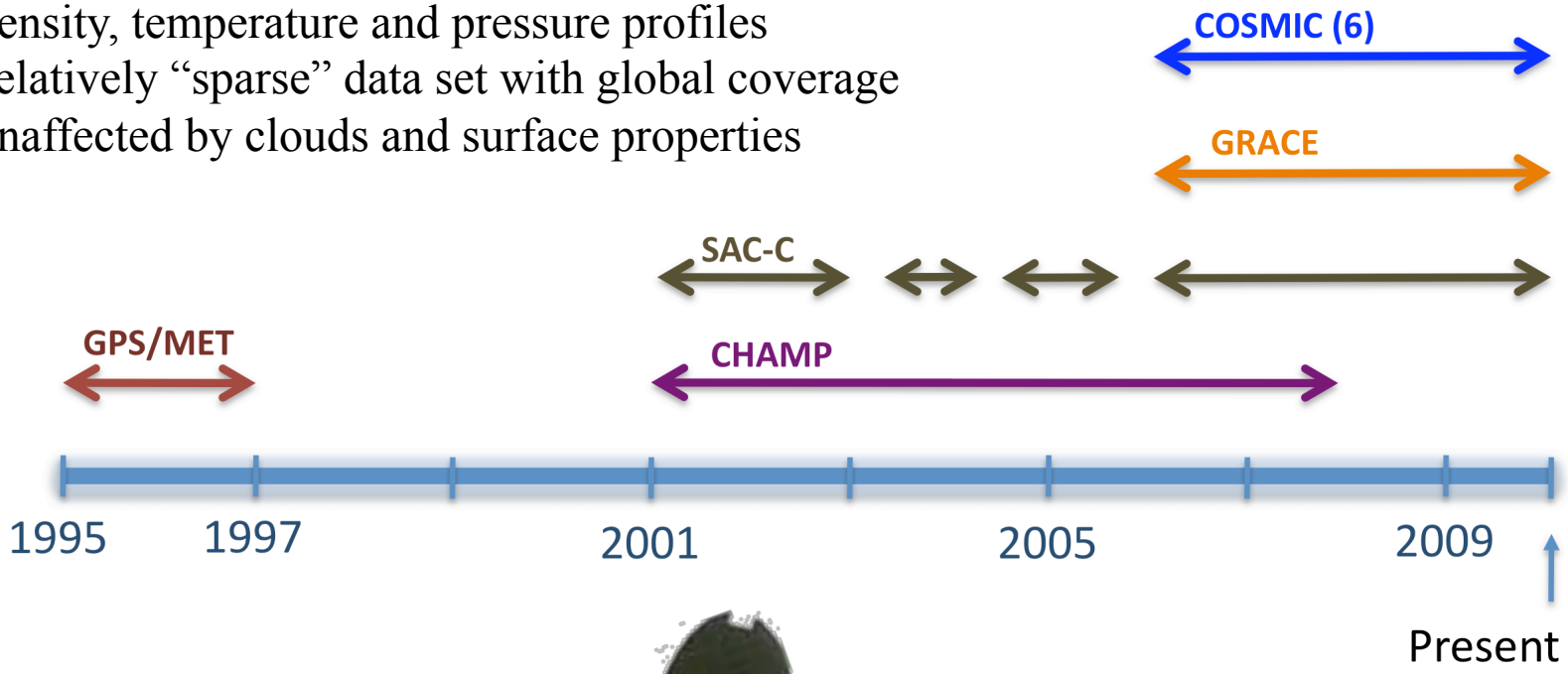
# Outline

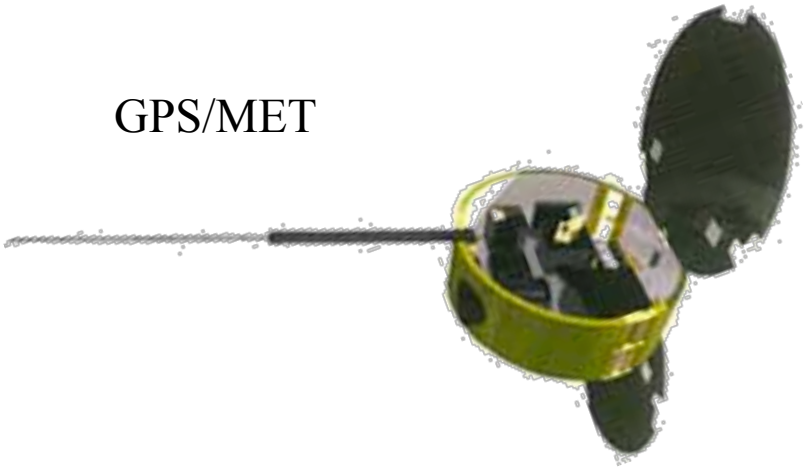
1. **Motivation**
2. **Single Frequency Method**
   - **Testing phase using COSMIC**
3. **Summary and Conclusions**

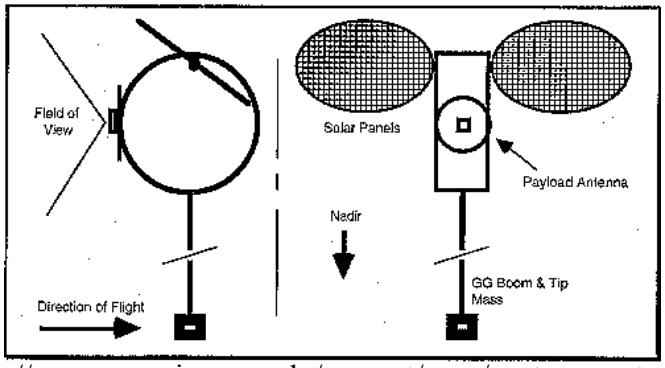
# The Radio Occultation Data Set

- Density, temperature and pressure profiles
- Relatively "sparse" data set with global coverage
- Unaffected by clouds and surface properties



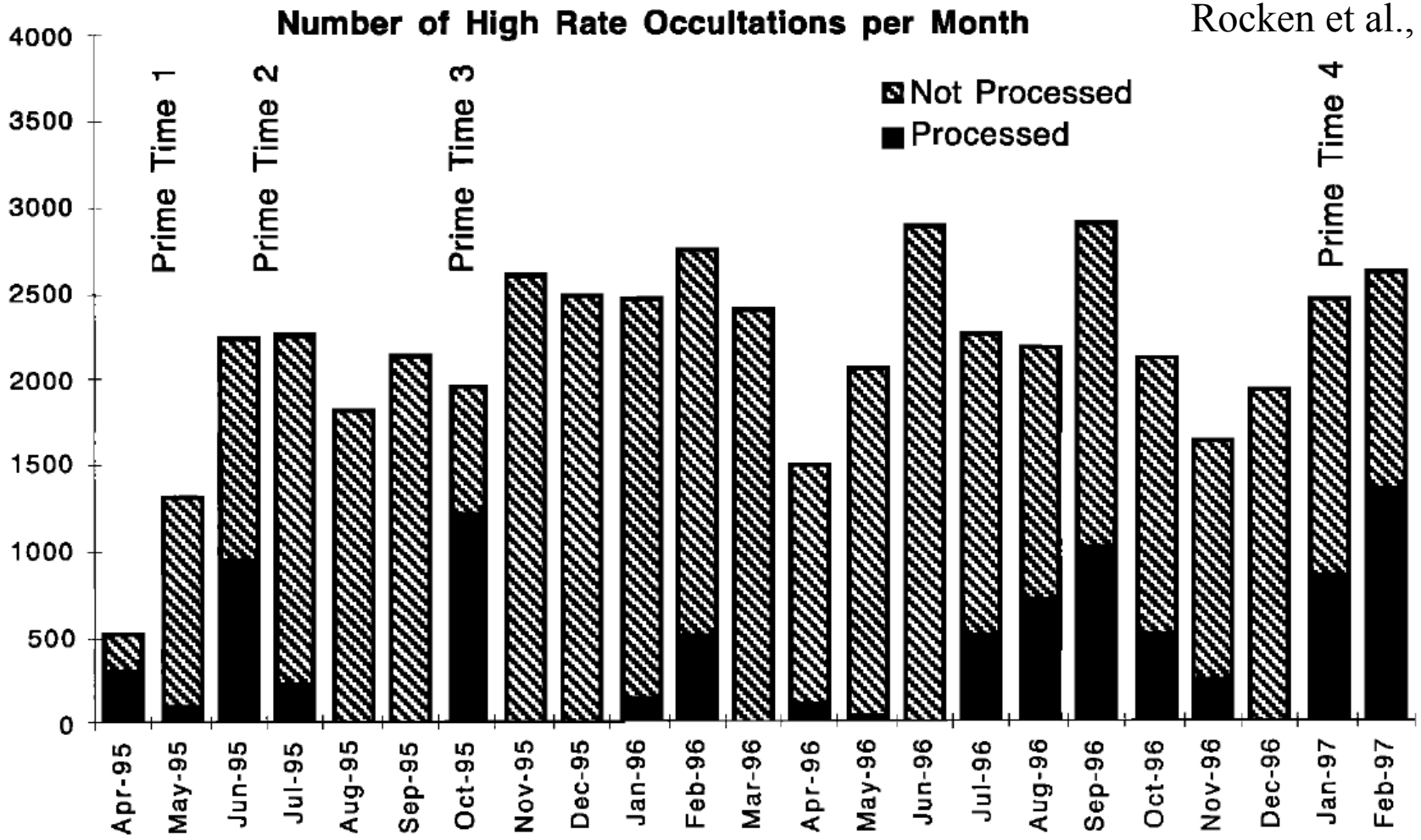

GPS/MET






http://www.cosmic.ucar.edu/gpsmet/over/septsumm_top.html

# Achieving a Climate Record to 1995




Rocken et al., 1997

Processed in Steiner et al., 2009

Different trends found for October than February

# Achieving Records From 1995-1997

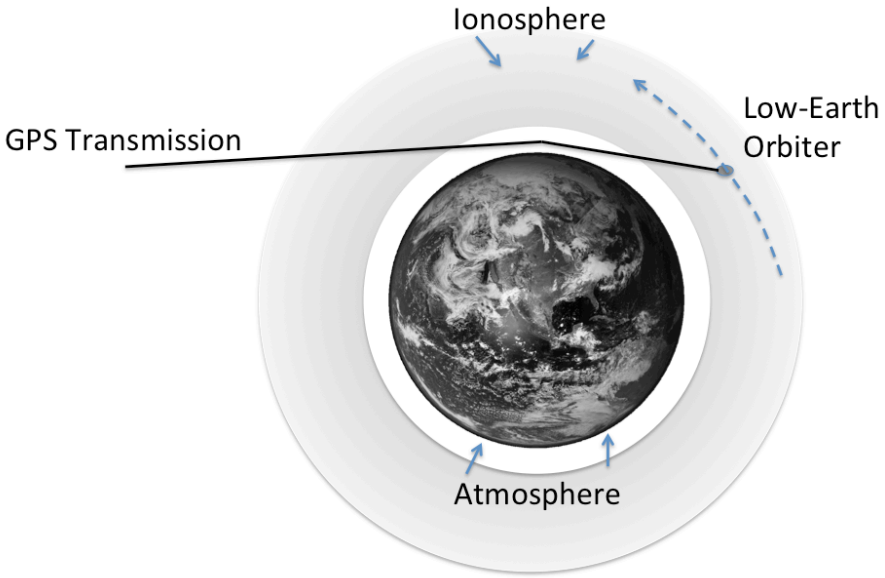
- **Overcome limitation of the data: only one GPS frequency available, non-prime periods**
- **Develop a method of calibrating ionosphere delay that uses a single-frequency**
- **Reprocess GPS/MET 1995-1997 dataset using single frequency**

- **Philosophy: monitor latitudinal and diurnal signatures**

See also:

de la Torre Juárez et al., International Journal of Remote Sensing, 2004.

# Single-Frequency Processing Method



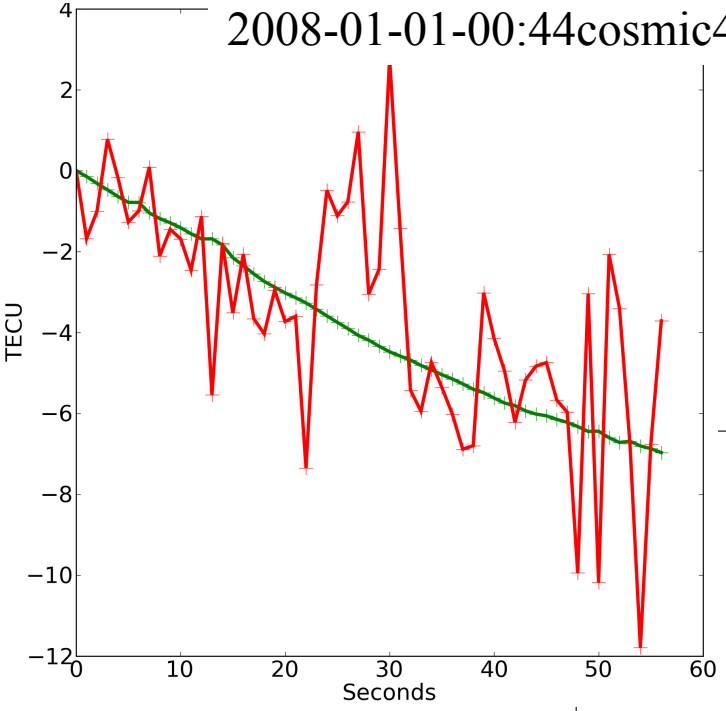

Ionospheric refractive index for phase and range signal types

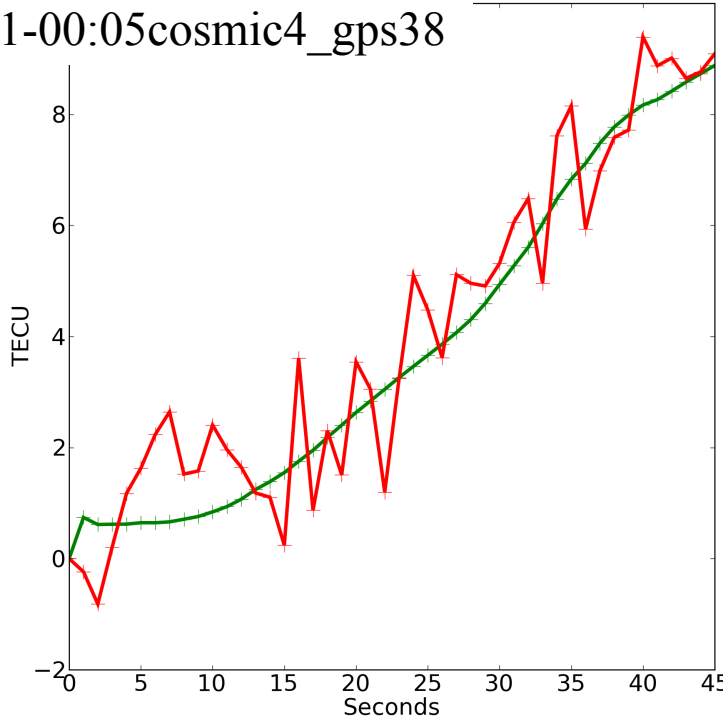
$$N_{Phase} = 1 - \frac{40.3 n_e}{f^2}$$

$$N_{Range} = 1 + \frac{40.3 n_e}{f^2}$$

Subtract and divide by two. Perform low-order fit.

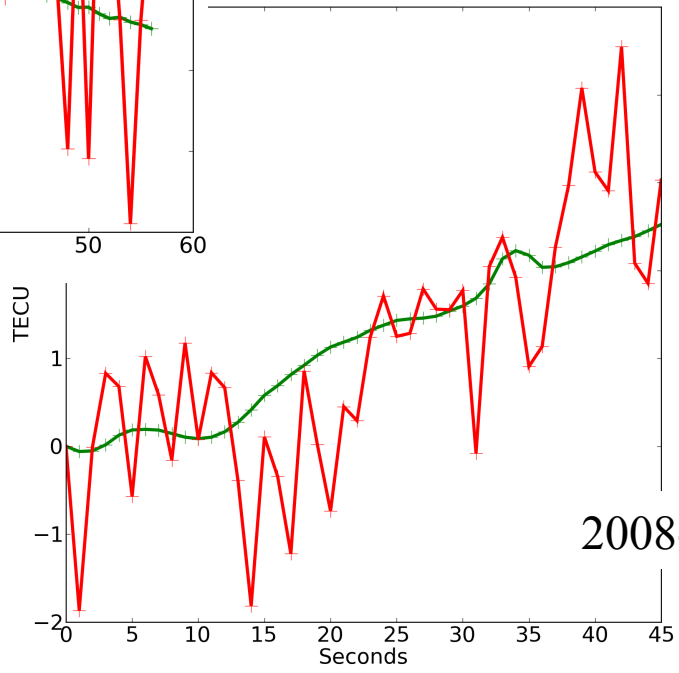
# Ionospheric Estimates of Delay




**L1-L2 phase**

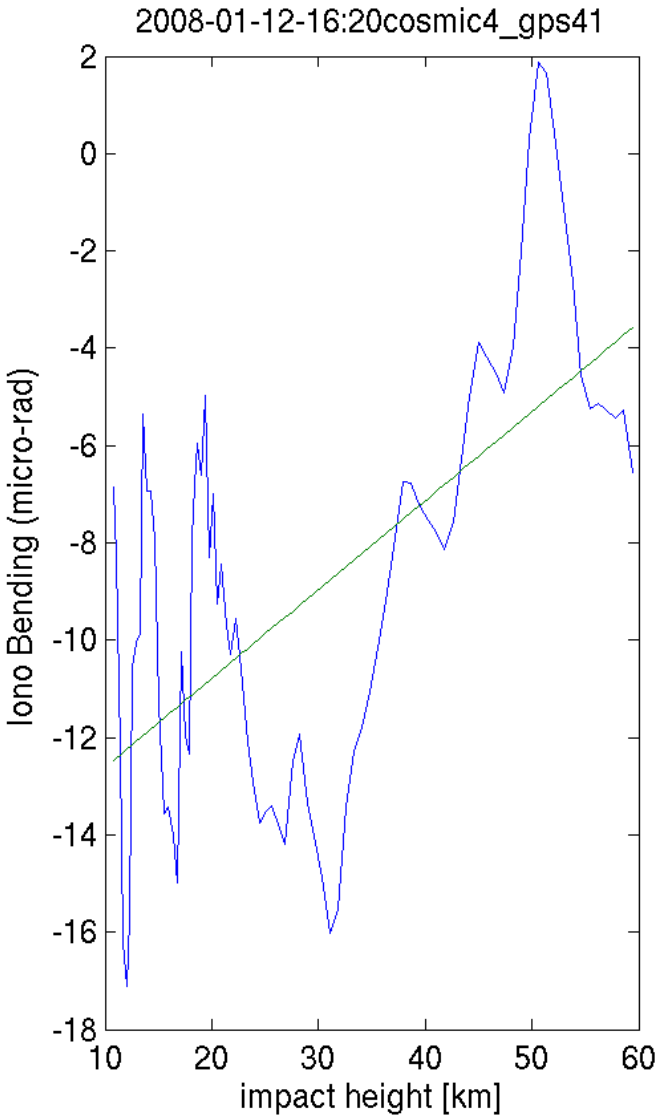
**CA-L1 phase-range**

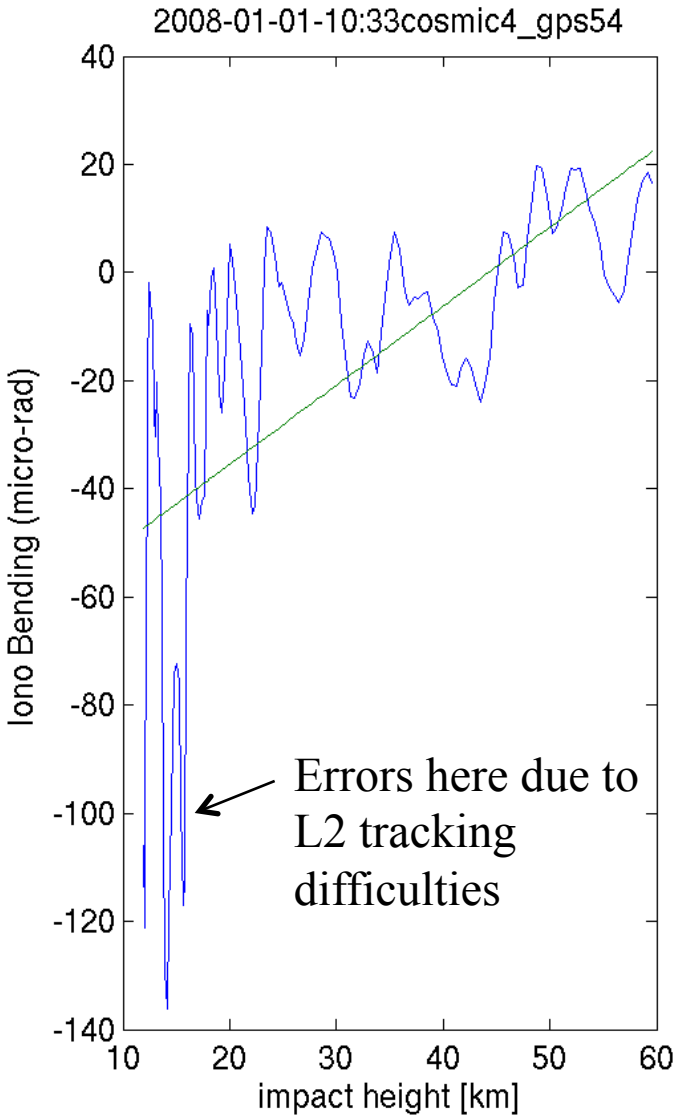


# Processing Strategy

- Calculate CA-L1 (range – phase observable)
- Fit linear or low-order polynomial – smoothing
- Correct L1 phase with polynomial
  - Not bending angle
- Perform retrieval
- Partition results according to diurnal signature and other factors

# Examples of Fitted Ionospheric Bending Angle

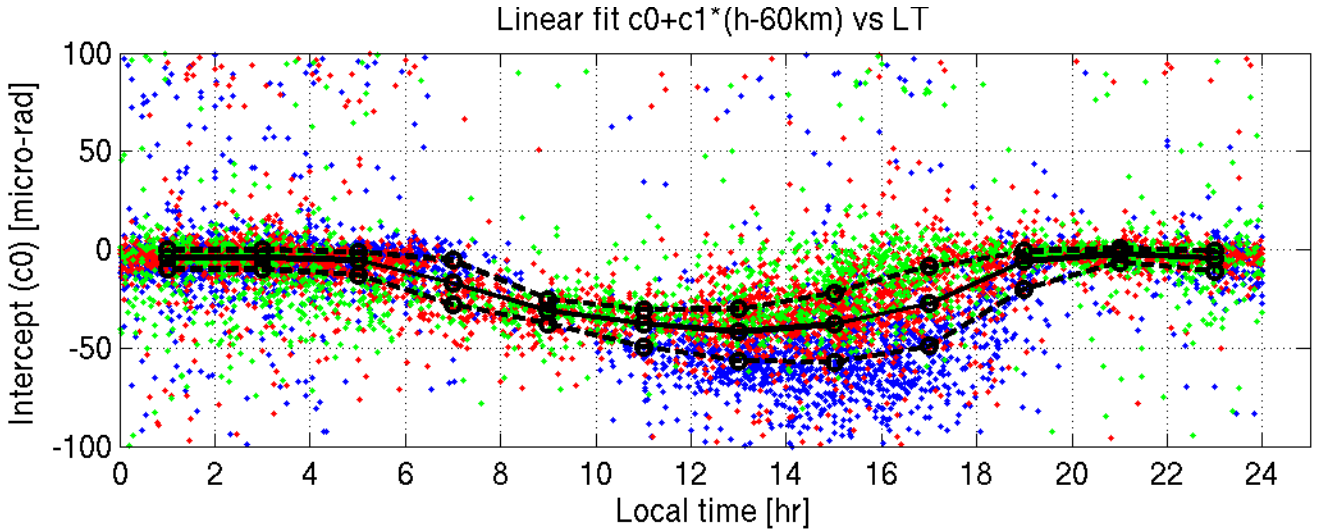


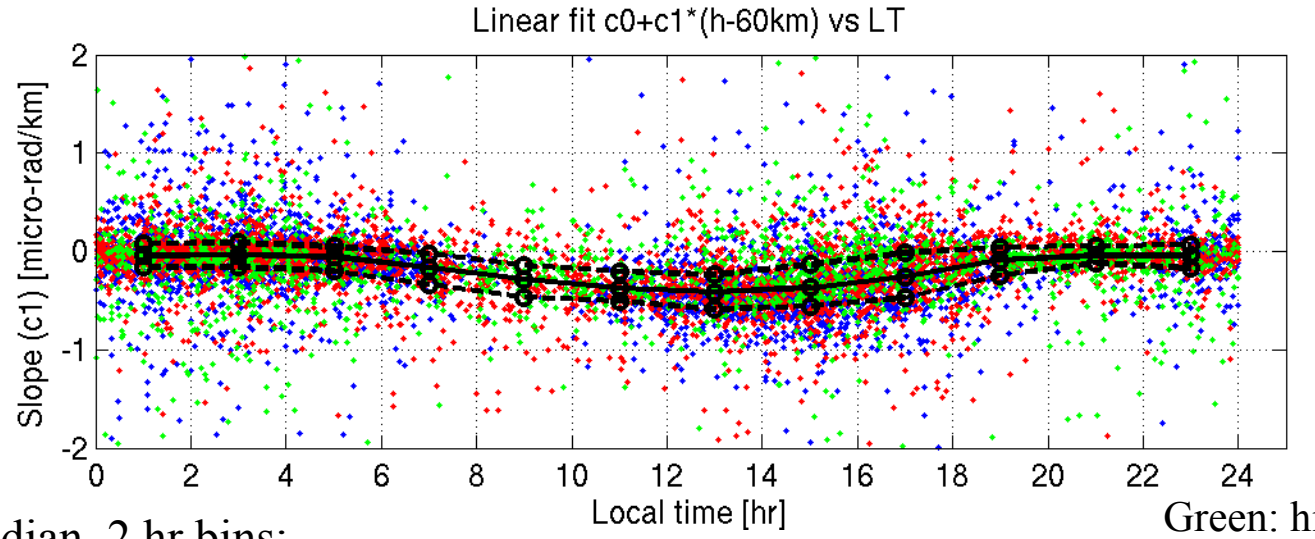




"Optimistic" – No C/A noise

"Pessimistic" – Bending angle instead of delay

# Line Fit Parameters Vs Local Time



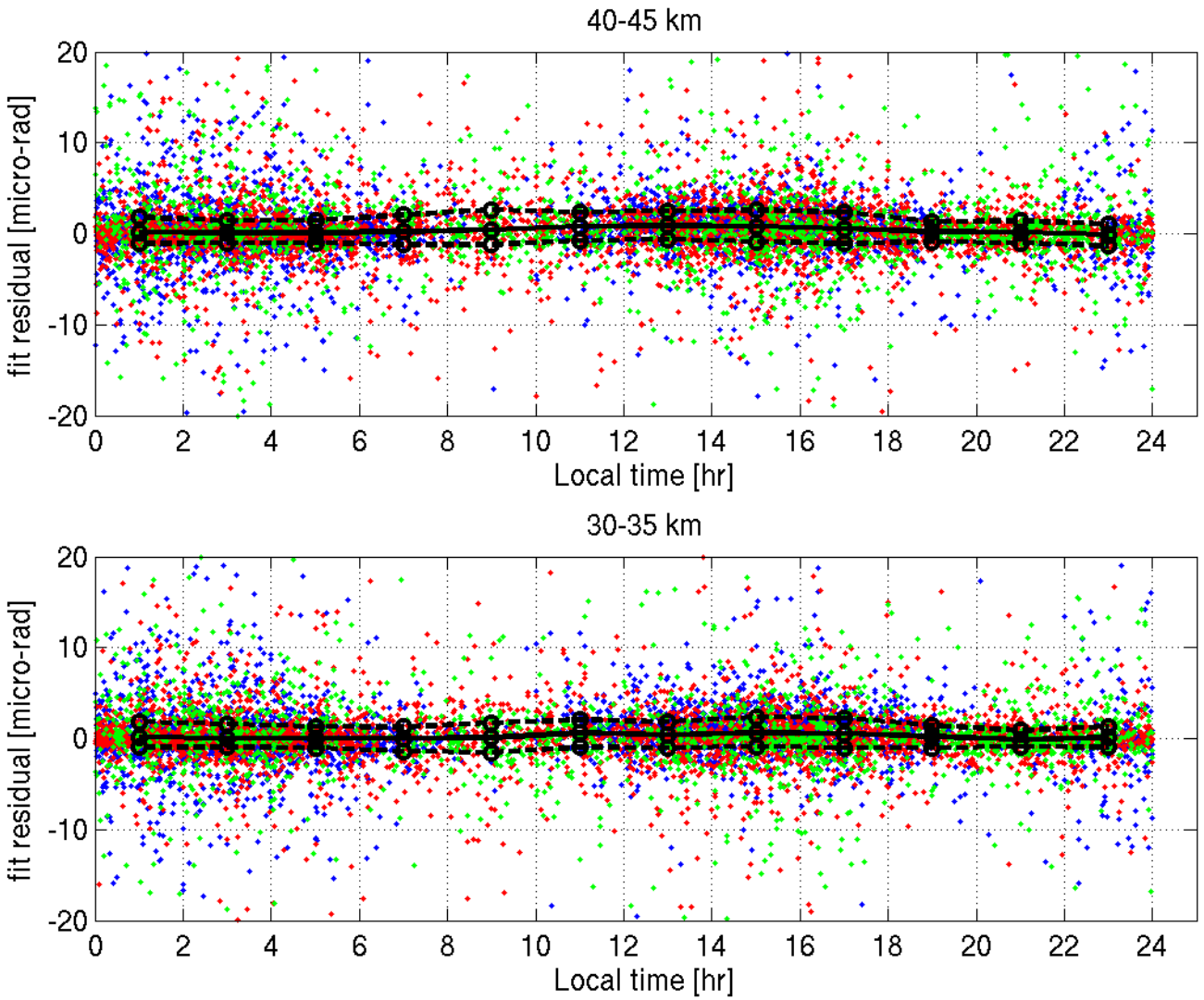

COSMIC
Jan 2008

Solid line: median, 2 hr bins;
Dashed line: 25, 75 percentiles

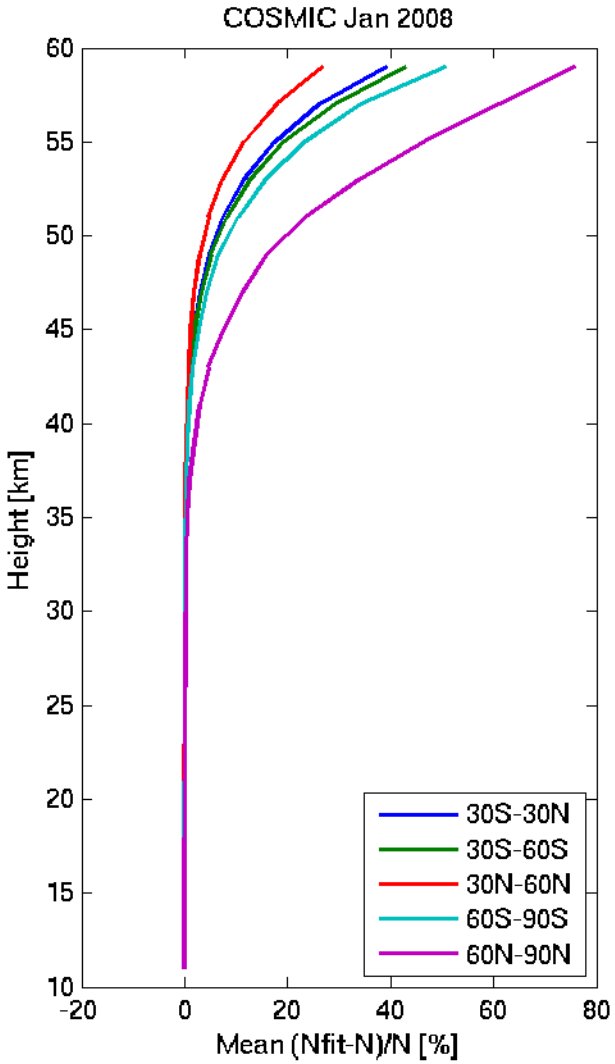
Green: high-lat (> 60)
Red: mid-lat (30-60)
Blue: tropics (< 30)

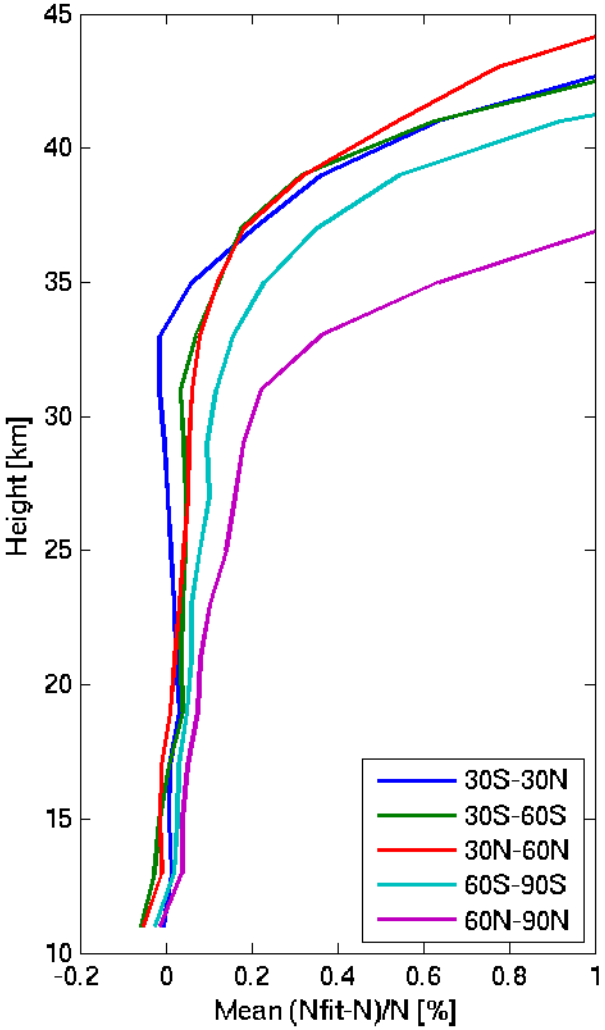
# Residuals to the Linear Fit

COSMIC
Jan 2008



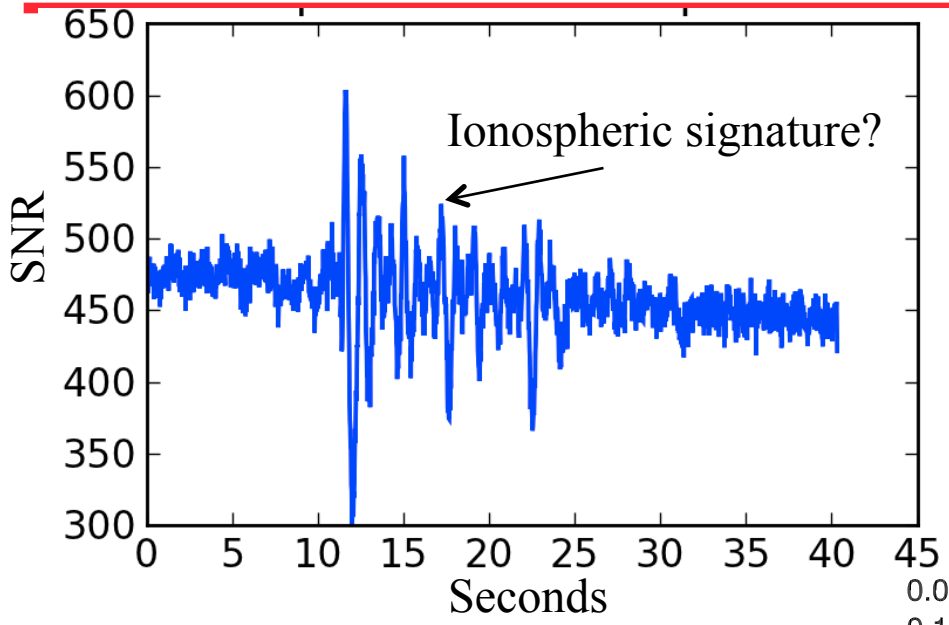
# Refractivity Retrieval Error
# Linear Fit Vs Dual-Frequency Correction



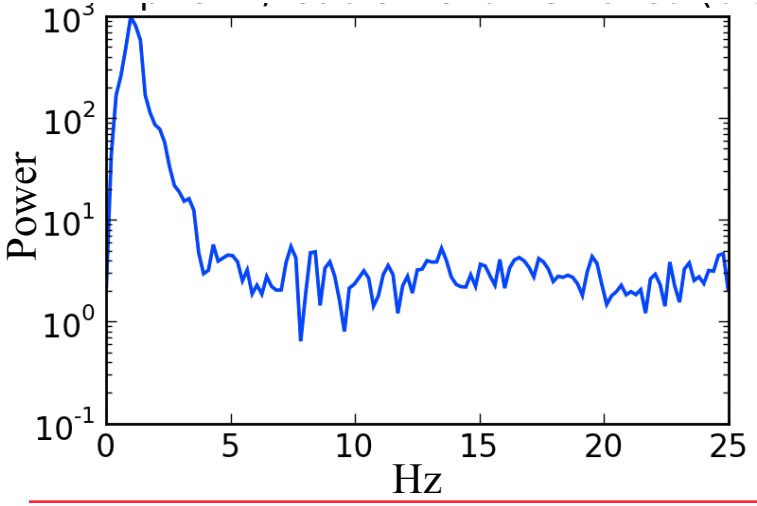



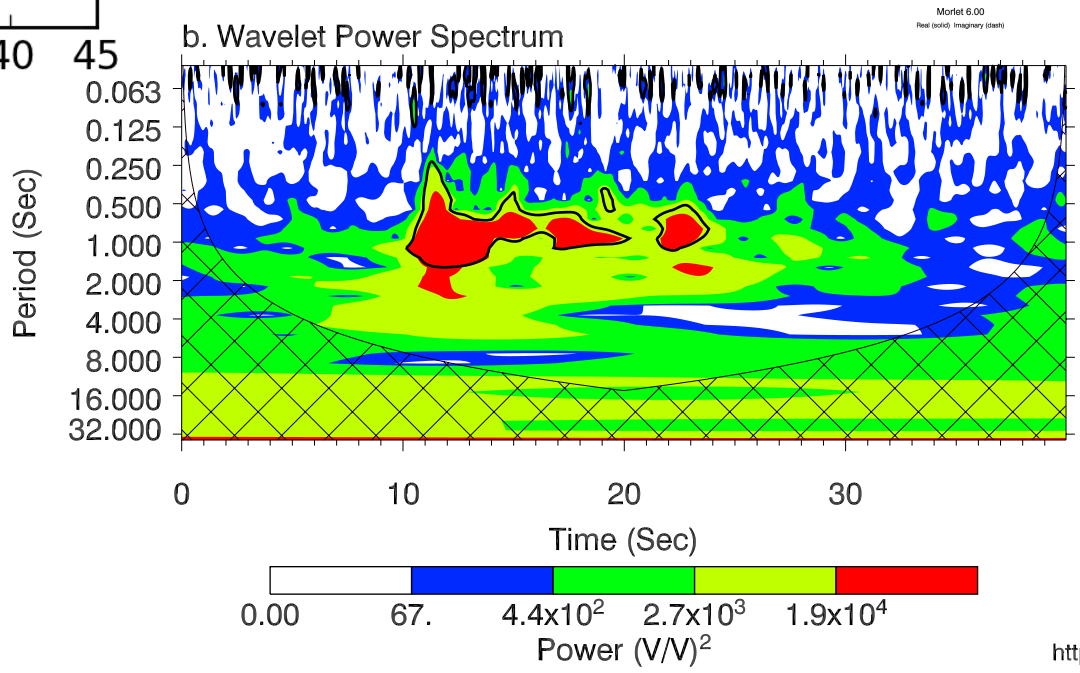

Goal: 0.03%

# Small Scale Structure & Data Characterization

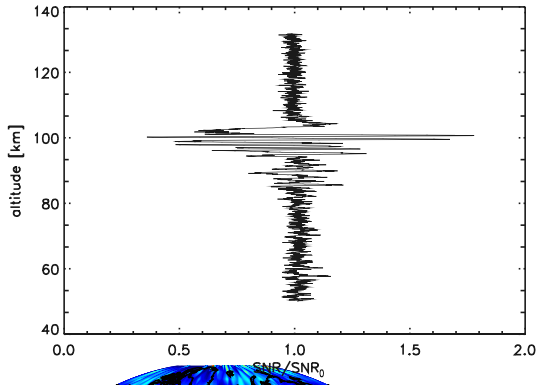



- Data from 50-120 km altitude contains signatures of ionospheric structure – atmospheric structure is nearly absent

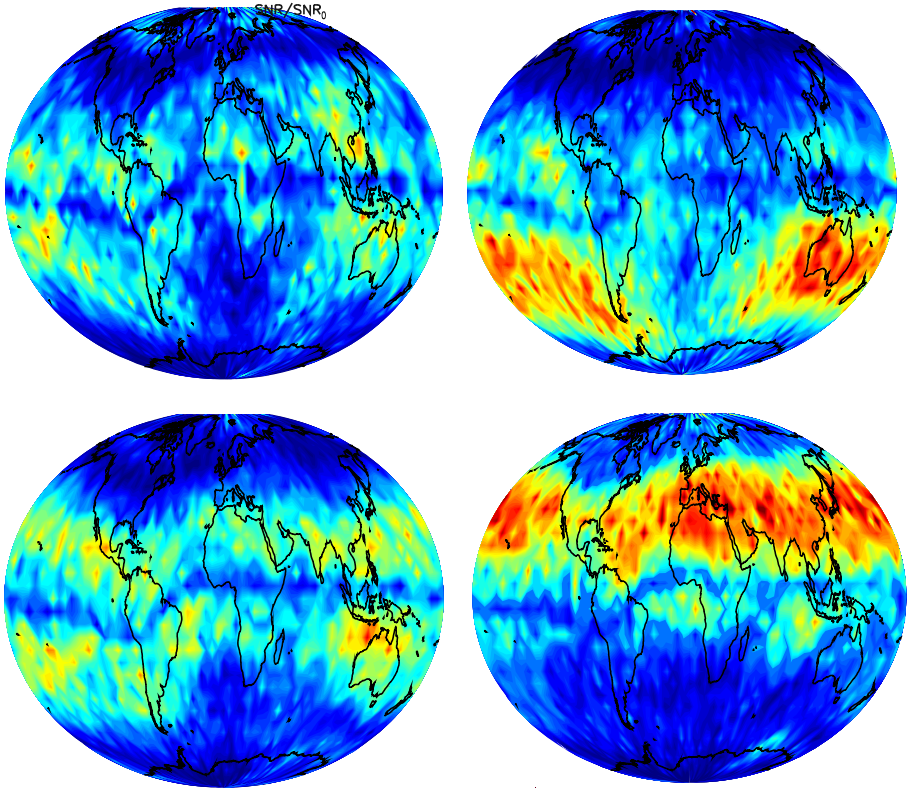


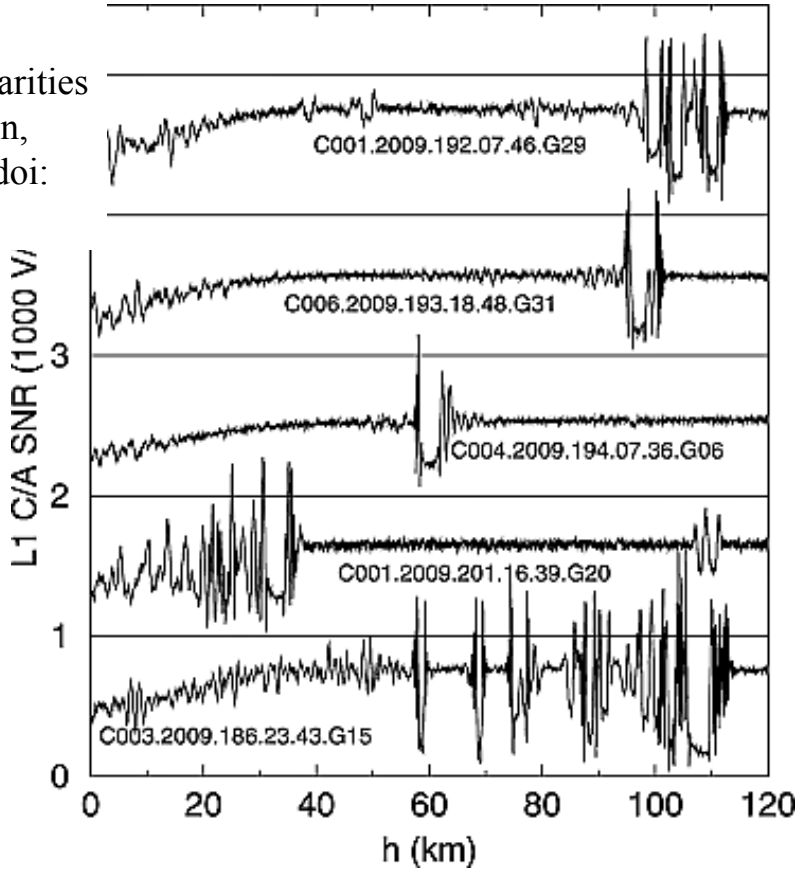



# Small Scale Structure *E*-Region




Arras, C., et al. (2008), A global climatology of ionospheric irregularities derived from GPS radio occultation, Geophys. Res. Lett., 35, L14809, doi: 10.1029/2008GL034158.




Zeng, Z., and S. Sokolovskiy (2010), Effect of sporadic E clouds on GPS radio occultation signals, Geophys. Res. Lett., 37, L18817, doi: 10.1029/2010GL044561.

# Small Scale Structure – Bias Upper Bound

- Monitor phase and amplitude fluctuations on a per-profile basis
- Aggregate according to fluctuation intensity and other factors
- Compare retrieved bending angles between affected and unaffected profiles
- Determine upper bound of bias as a function of fluctuation intensity
  - Use profile altitude to reduce bias

# Summary and Conclusions

- **We can extend robustly the radio occultation data record by 6 years (+60%) by developing a single-frequency processing method for GPS/MET data**
- **We will produce a calibrated data set with *profile-by-profile* data characterization to determine robust upper bounds on ionospheric bias**
- **Part of an effort to produce a calibrated RO data set addressing other key error sources such as upper boundary initialization**
- **Planned: AIRS-GPS water vapor cross validation (water vapor climatology and trends)**