Single Frequency Processing of Radio Occultation Data Including GPS/MET

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Afternoon Session 1 "Specific Occultation Methods and Processing"
Thursday April 16, 2015

Outline

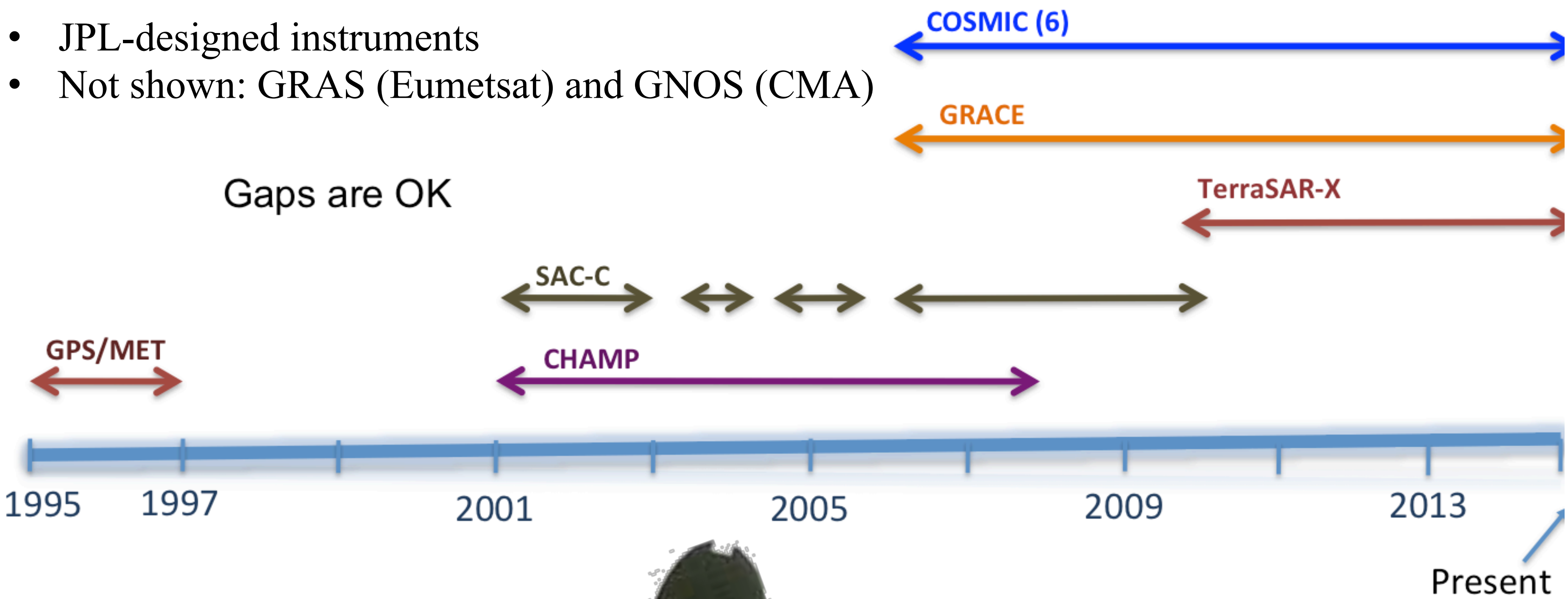
1. Motivation
2. Approach
3. Initial Results
4. Discussion – how best to use?
5. Summary

See also:

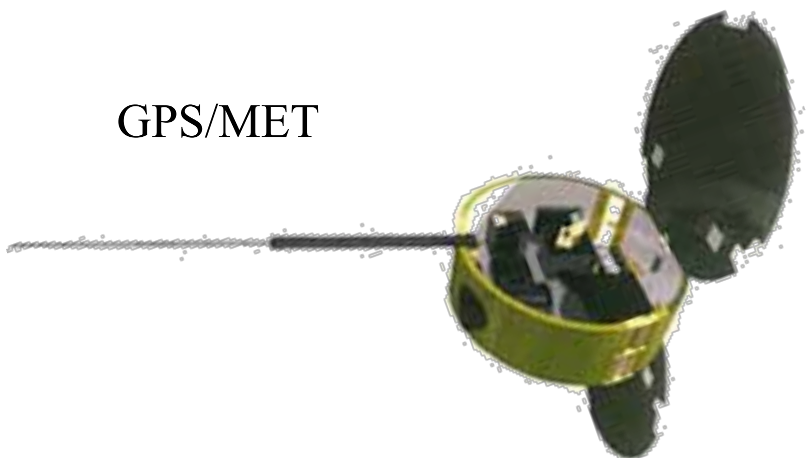
de la Torre Juárez et al., International Journal of Remote Sensing, 2004.
Larsen et al., GPS Solutions, 2005 (Ørsted)

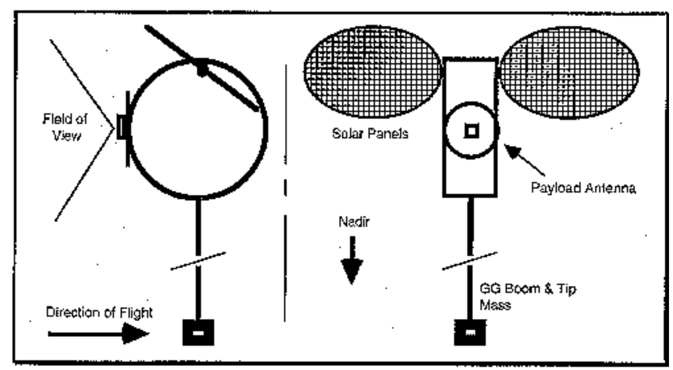
The Radio Occultation Data Set

- JPL-designed instruments
- Not shown: GRAS (Eumetsat) and GNOS (CMA)



GPS/MET

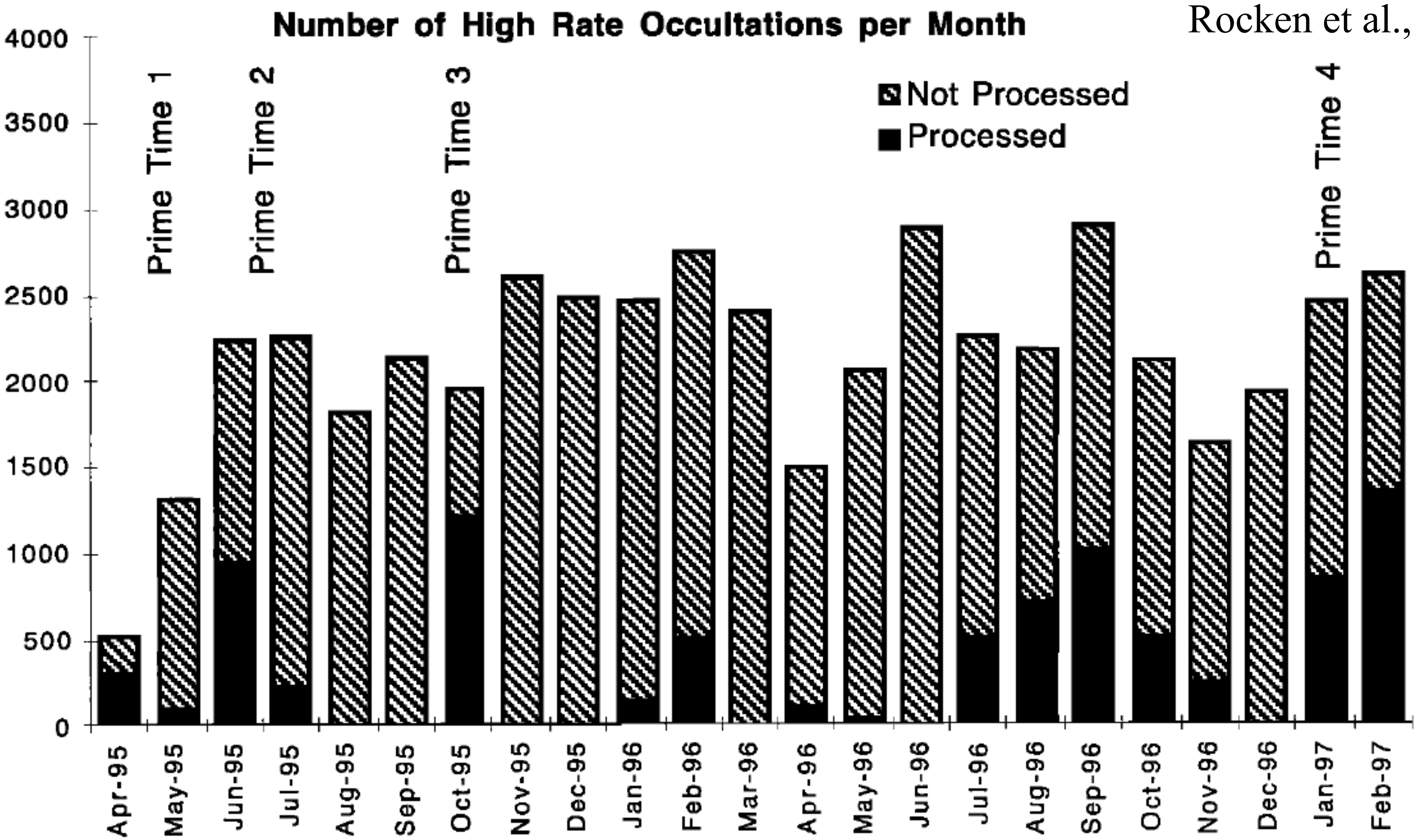




http://www.cosmic.ucar.edu/gpsmet/over/septsumm_top.html

Achieving a Climate Record to 1995

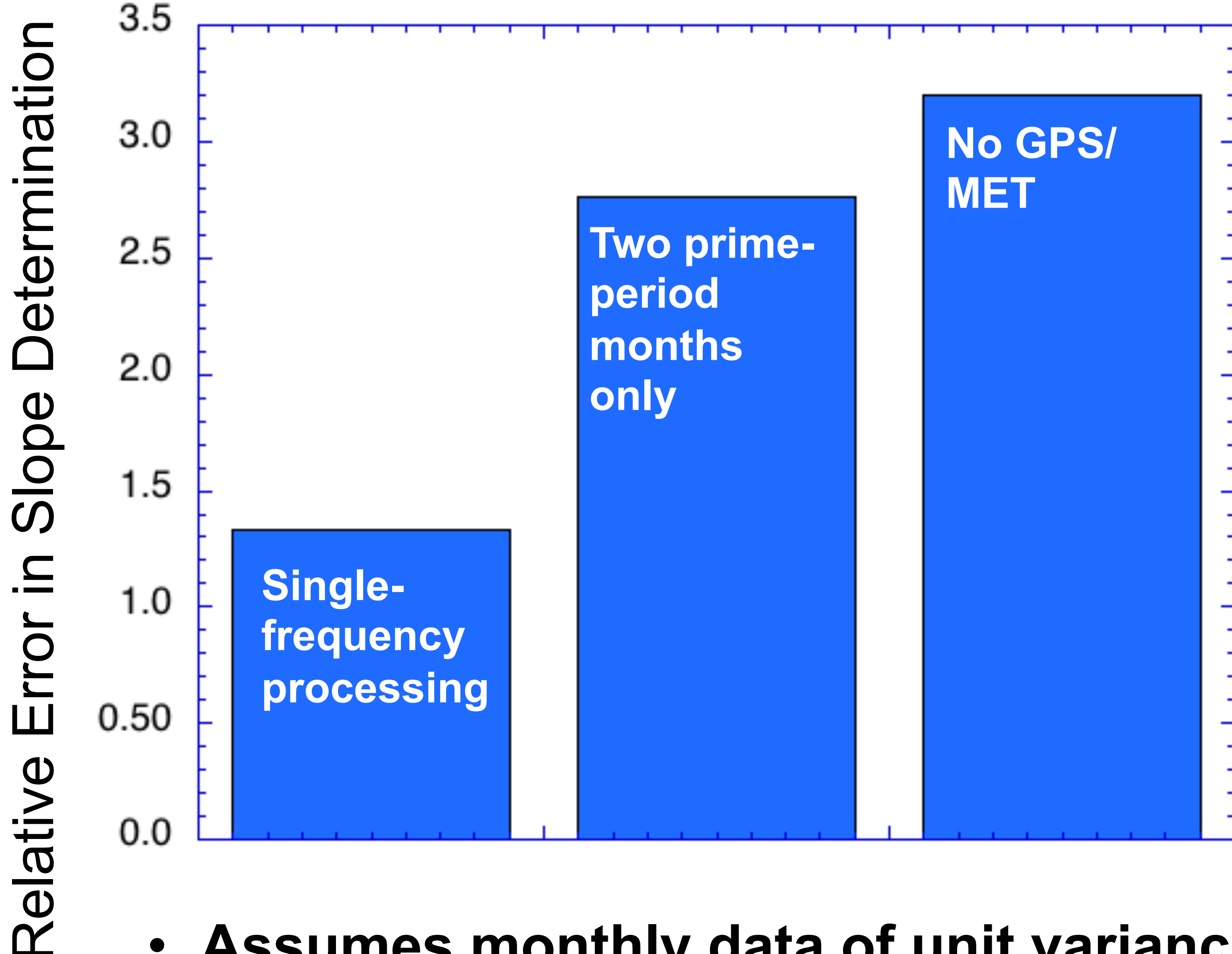
Rocken et al., 1997



Processed in Steiner et al., 2009

Different trends found for October than February

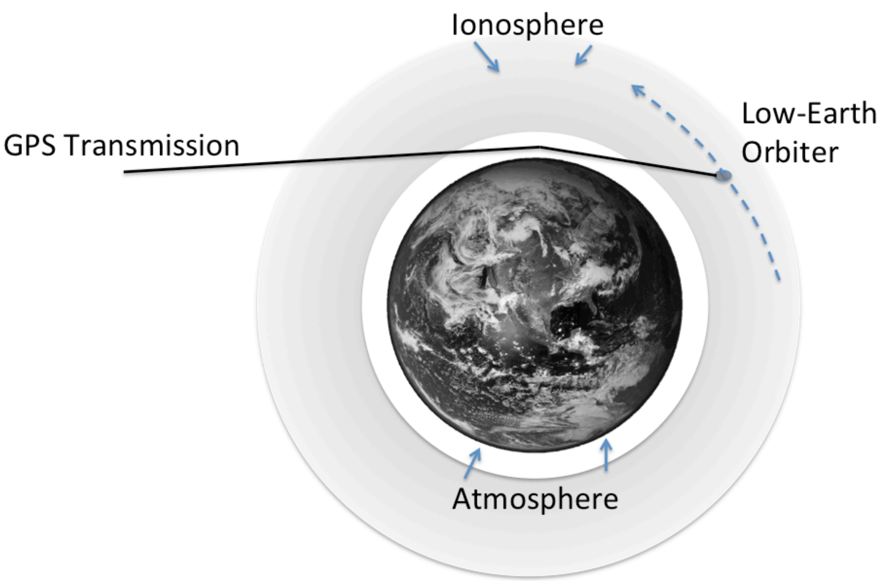
Relative Benefit of Dual-Frequency Processing



- **Assumes monthly data of unit variance**

Single-Frequency Processing Method

How we estimate the ionospheric delay/bending using only one frequency



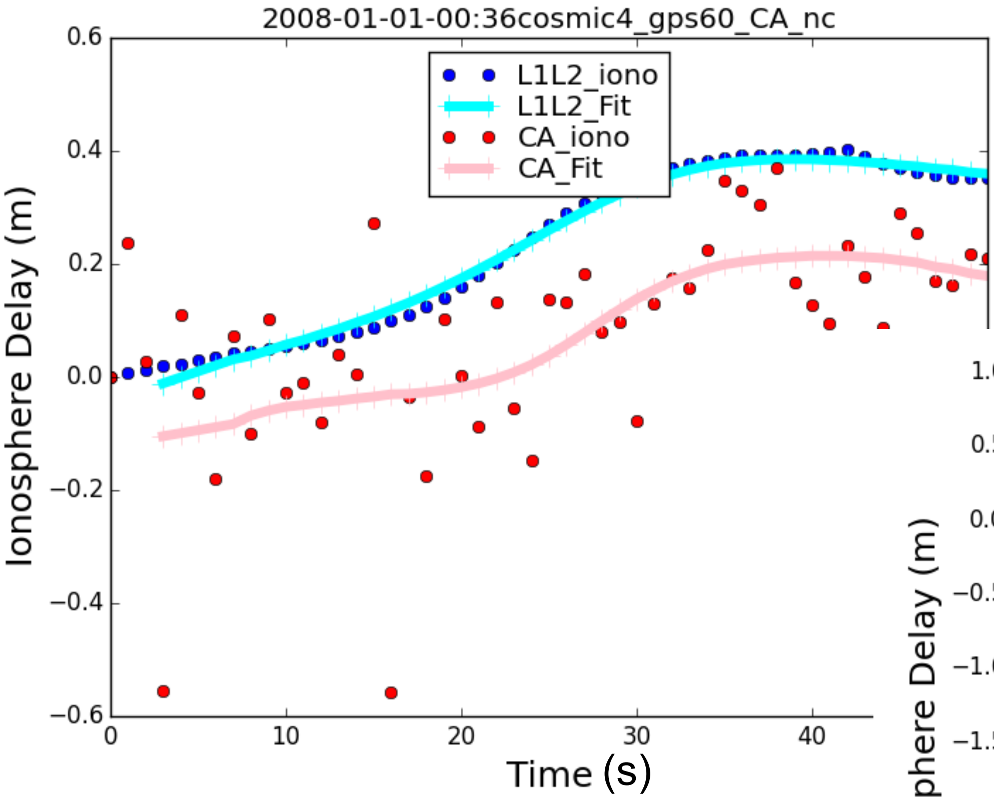
Ionospheric refractive index for phase and range signal types

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

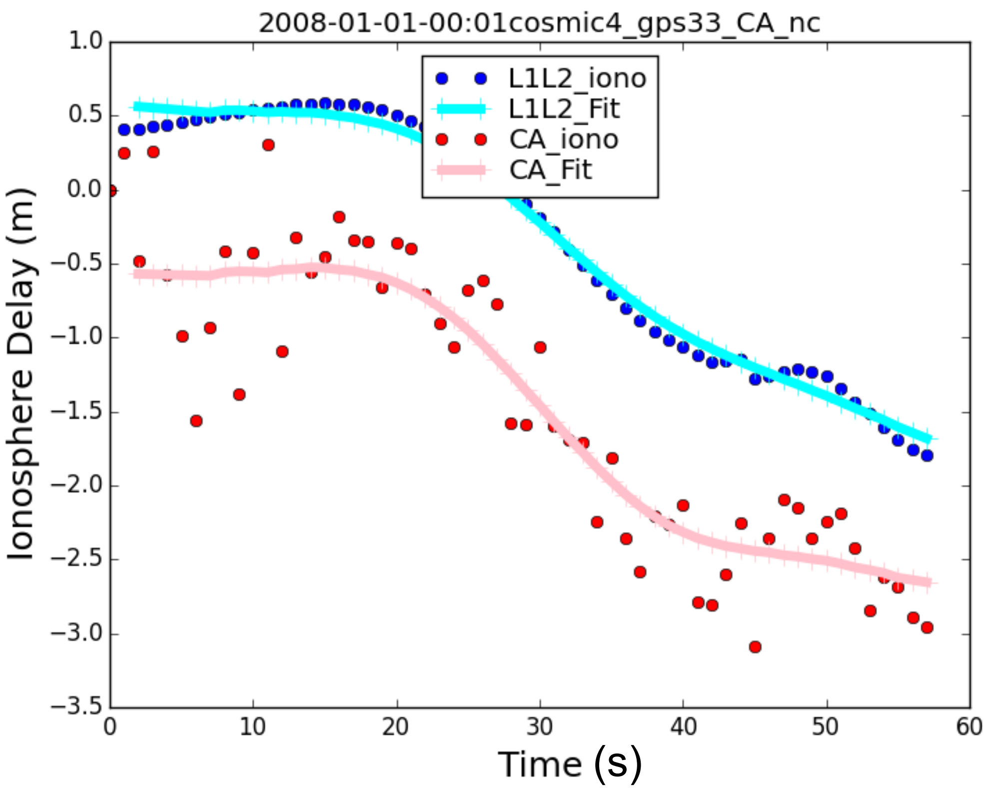
$$N_{Range} = 1 + \frac{40.3 n_e}{f^2}$$

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

Ionospheric Estimates of Delay – COSMIC

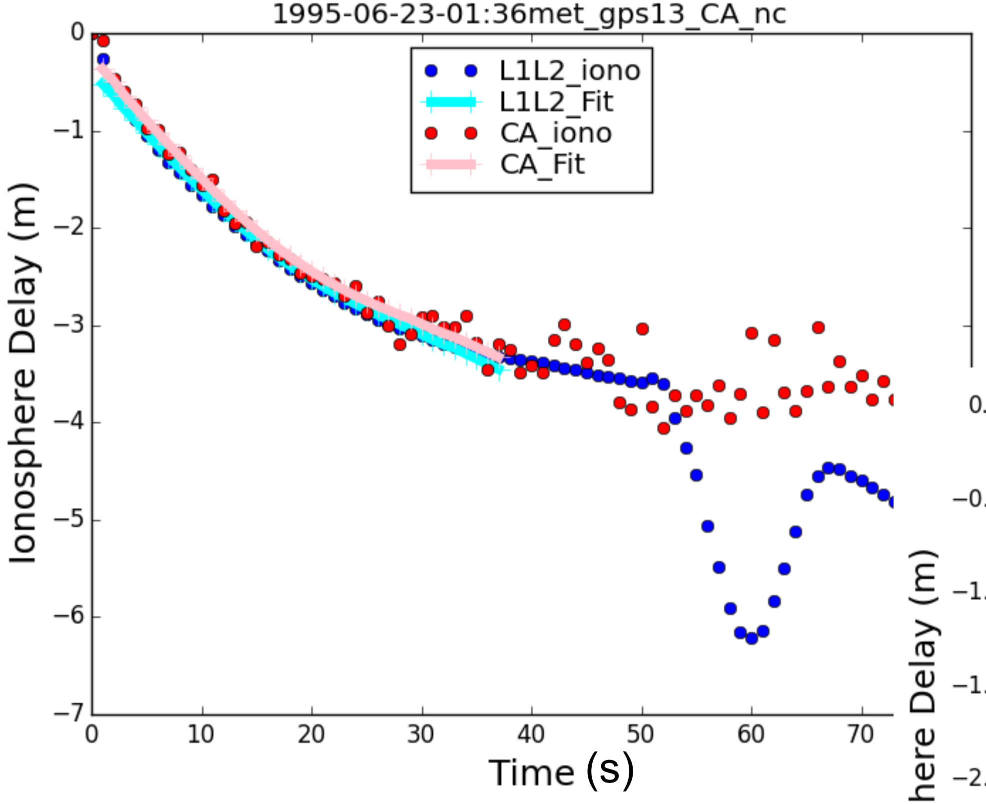


- Two examples from 2008
- CA is pseudorange
- Multiple linear fits

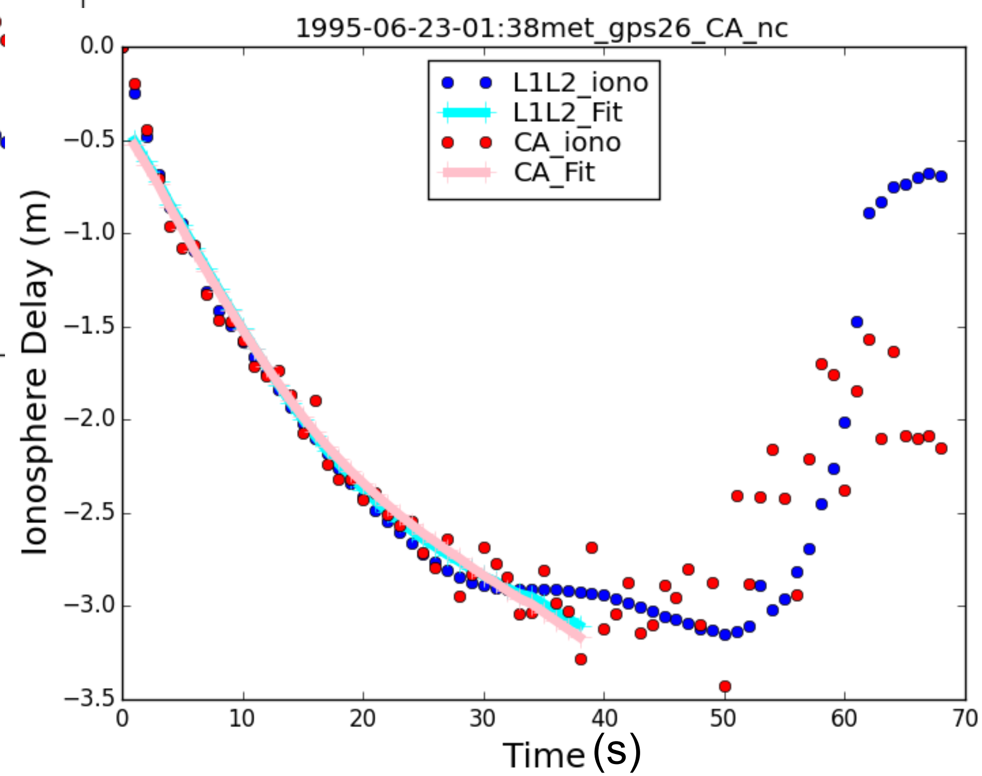


- These examples obtained when two frequencies are available
- Testing and algorithm refinement

Estimates of Ionospheric Delay – GPS/MET



- Two examples from 1995
- Setting occultations
- Multiple linear fits
- Lower pseudorange noise



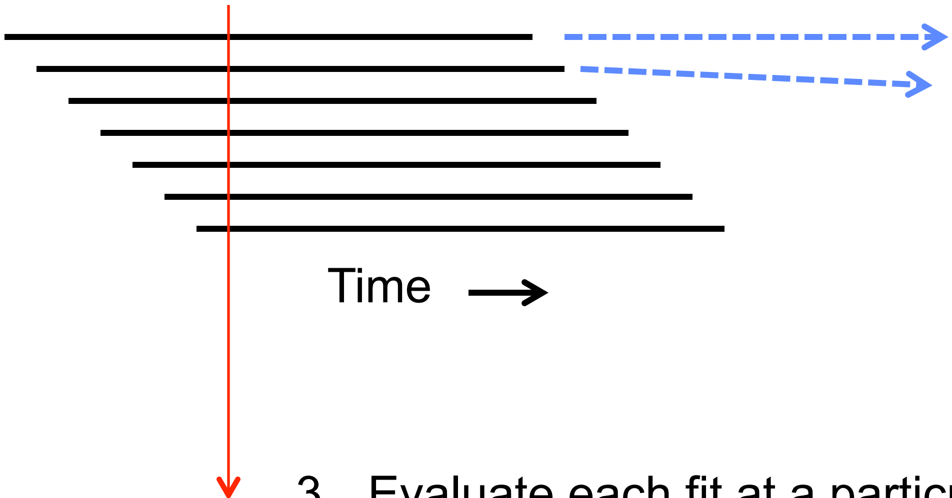
- These examples obtained when two frequencies are available
- Testing and algorithm refinement

Smoothing Algorithm

Fits are to CA range – L1 phase

1. Define overlapping time intervals

2. Perform polynomial fit over each interval



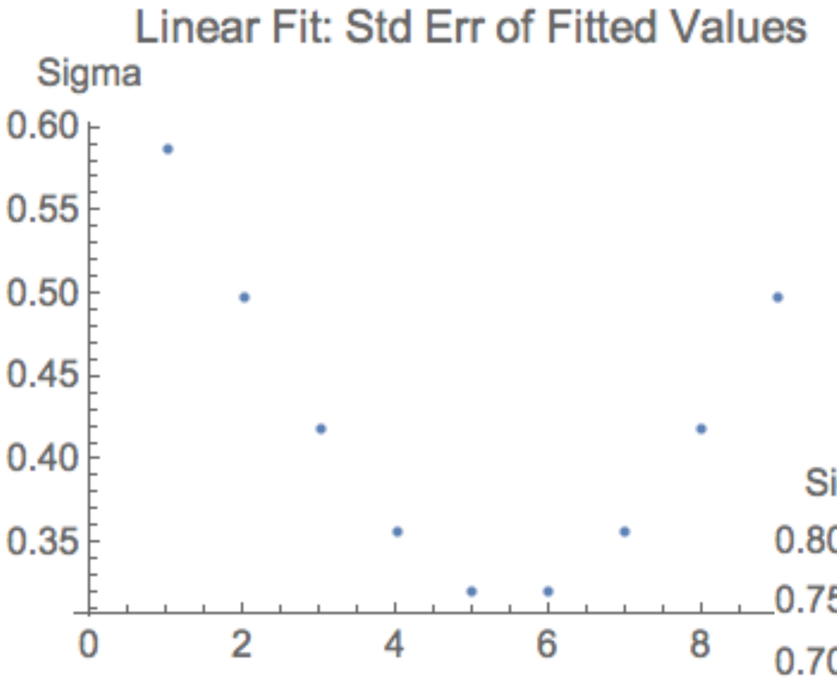
$\{a_1, b_1\}$
$\{a_2, b_2\}$
etc.

$$f(t) = a_i + b_i\, t$$

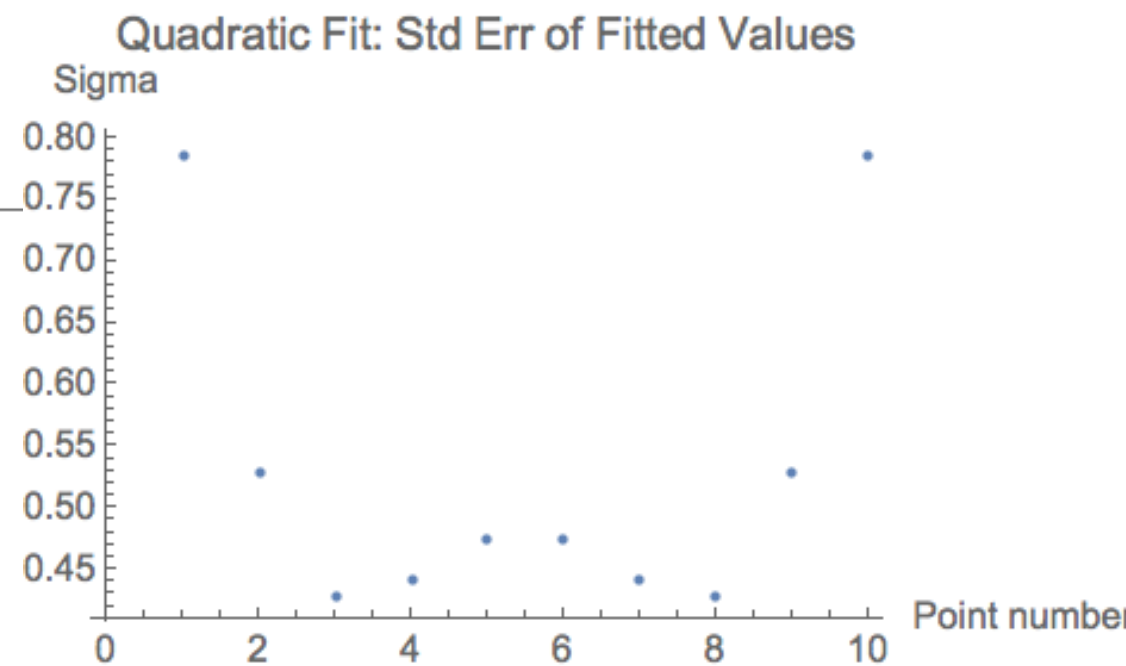
Linear case

3. Evaluate each fit at a particular time. The final result is a weighted sum of all the applicable fits.
   - The weighting function depends on distance from center of each fit
   - Each fit contains some unique information

Precision of Polynomial Fits

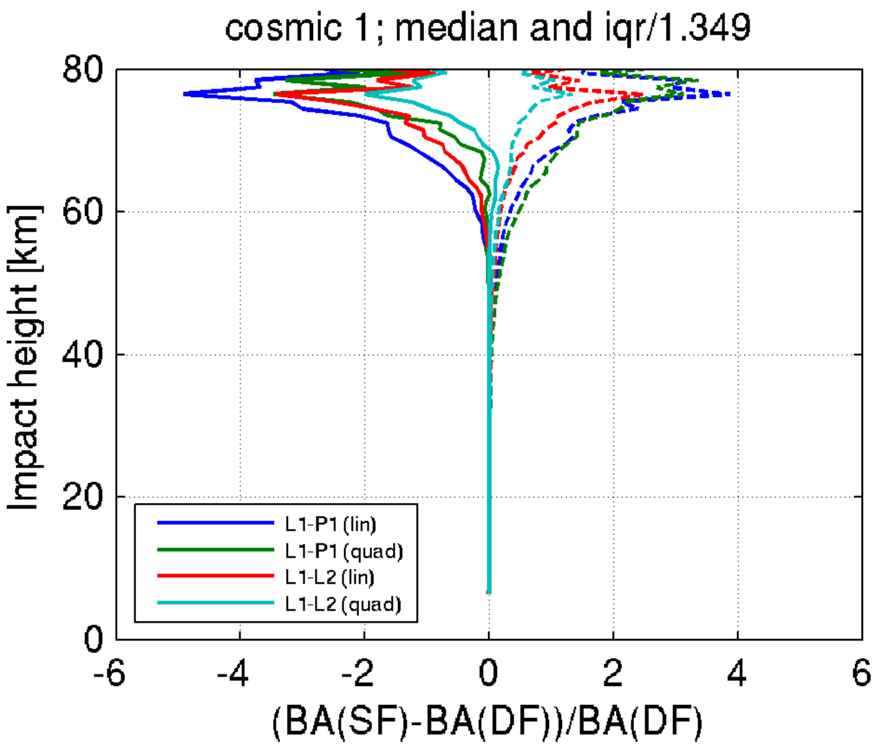


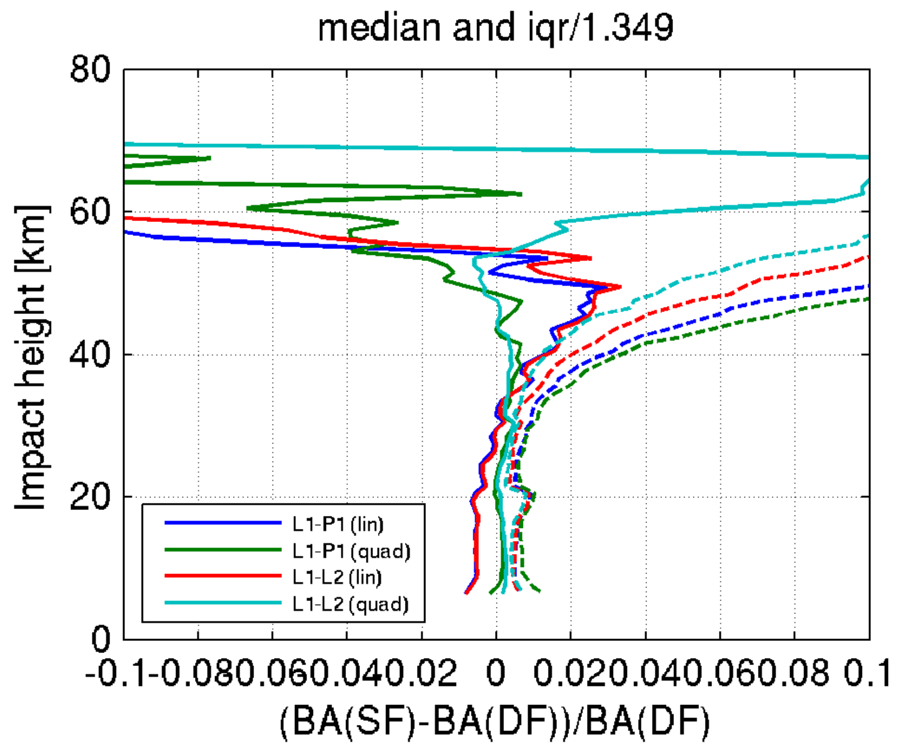
- N = 10
- Each data point has unit variance



COSMIC Results – Comparing Single to Dual Frequency Bending Angle

One week of COSMIC 1 data in January 2008

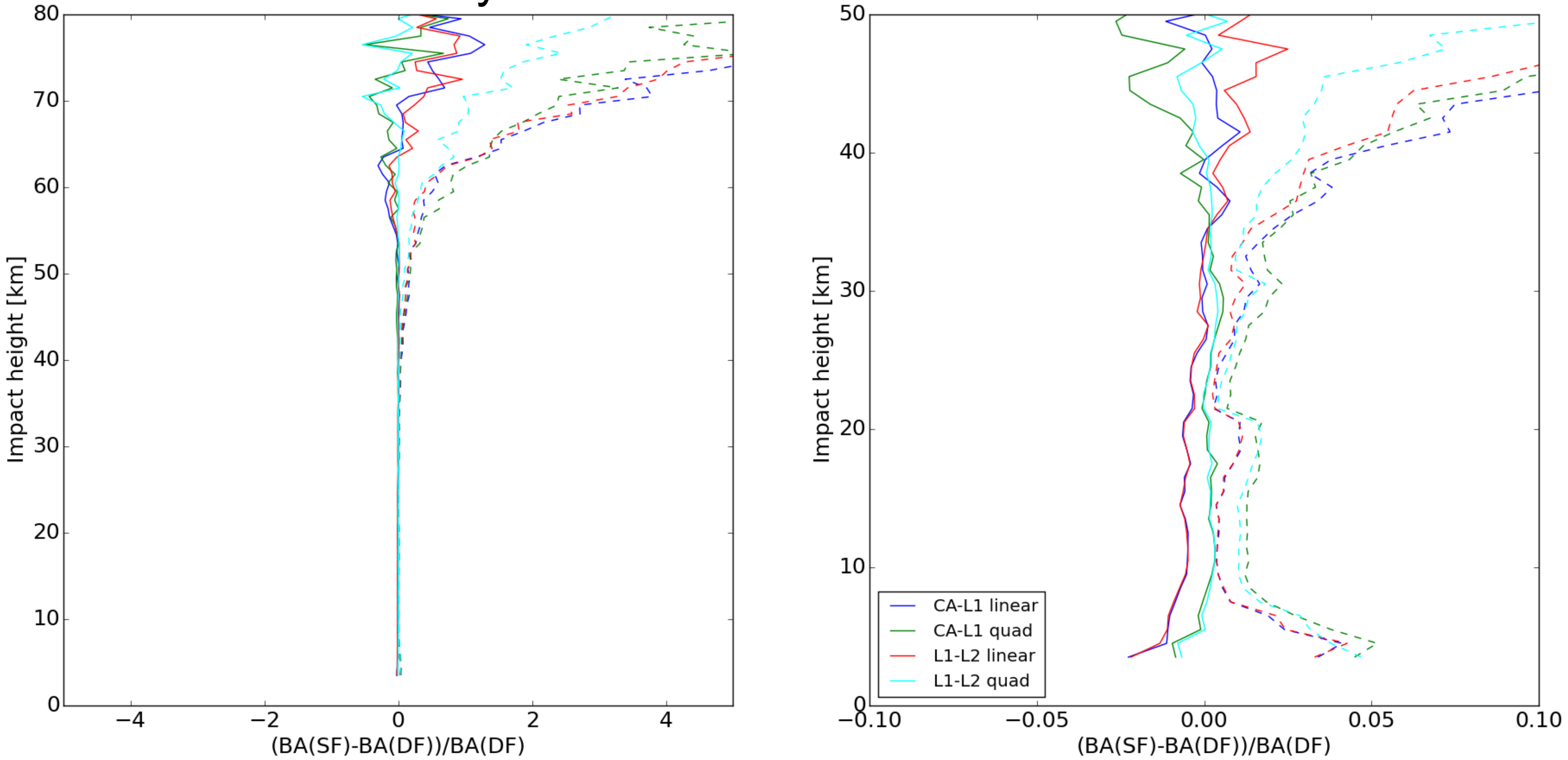




- Quadratic fits have the least bias
- Difference between fits to phase and range are very similar, suggesting a minimal impact of multipath error on the range

GPS/MET Results– Comparing Single to Dual Frequency Bending Angle

One day of GPS/MET data in June 1995

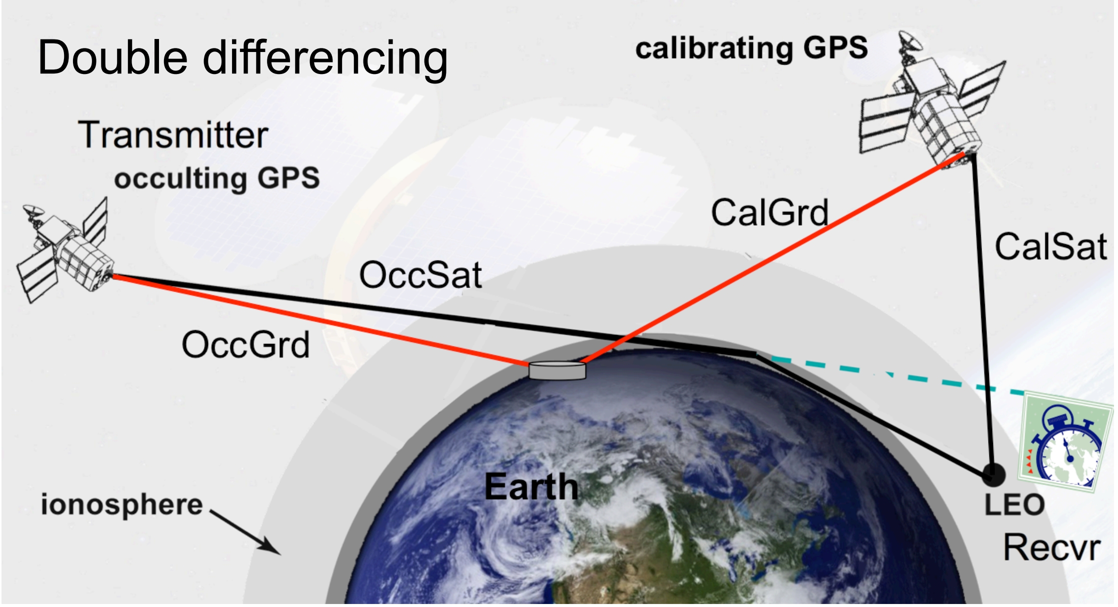


- Quadratic fits have the least bias
- Difference between fits to phase and range are very similar, suggesting a minimal impact of multipath error on the range

Towards Full Processing of GPS/MET

- **Single-frequency orbits**
- **Double differencing returns (selective availability)**

Case	H(cm)	C(cm)	L(cm)	vh(mm/s)	vc(mm/s)	vl(mm/s)
Deweight_L1	17.72	12.16	50.92	0.439	0.107	0.177
95_IF_bias	24.63	18.5	66.55	0.547	0.196	0.217
use_IONEX	21.32	12.04	51.65	0.383	0.118	0.222
phase_map	32.3	23.83	86.66	0.684	0.25	0.297
once/rev	40.45	12.28	117.09	0.958	0.156	0.371
Solarscal	45.72	13.83	142.23	1.2	0.188	0.463



These two methods use an ionospheric estimate (Bent model or IONEX)

These are solar minimum conditions

How to Best Use the GPS/MET Data

- **As the Wegener Center group [GRL, 2009] can tell you, detecting trends with even 20 years of data is a major challenge (reason: El Niño)**
- **Alternative approach: compare to trend data being generated by the microwave sounder community, who have ~40 years of data**
  - **See publications by Ben Ho, UCAR**

Summary and Conclusions

- Using the full quantity of GPS/MET data (AS on) will significantly improve trend estimates using GPS radio occultation data
- A technique for processing atmospheric radio occultation data using a single frequency has been developed and is undergoing testing and refinement
- We will produce a GPS/MET data set that covers “non-prime” periods and make these data available
- Comparison with microwave upper troposphere and lower stratosphere measurements is recommended