Intersatellite Bias in GNSS RO Retrievals

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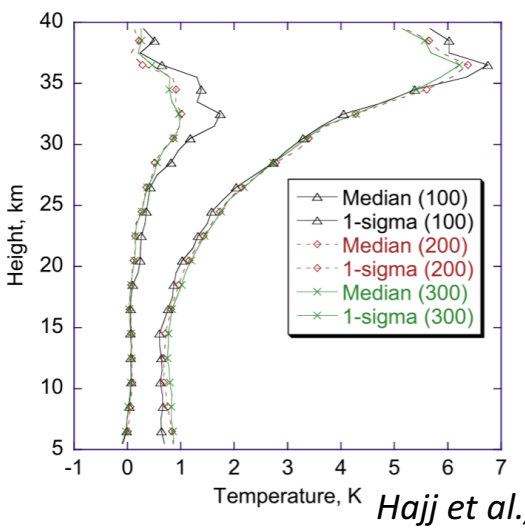
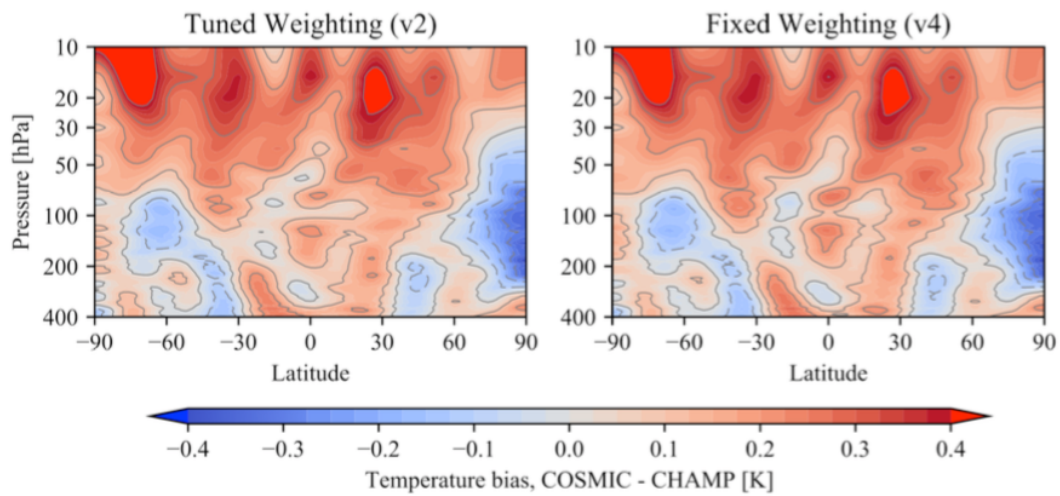
Introduction

- **Objective**: assess RO biases by comparing contemporaneous, collocated pairs of observations from different satellites/missions.
- Similar to past studies [Hajj et al. 2004; Schreiner et al. 2007] but with more in-depth look at the mean differences from bending angle to temperature.



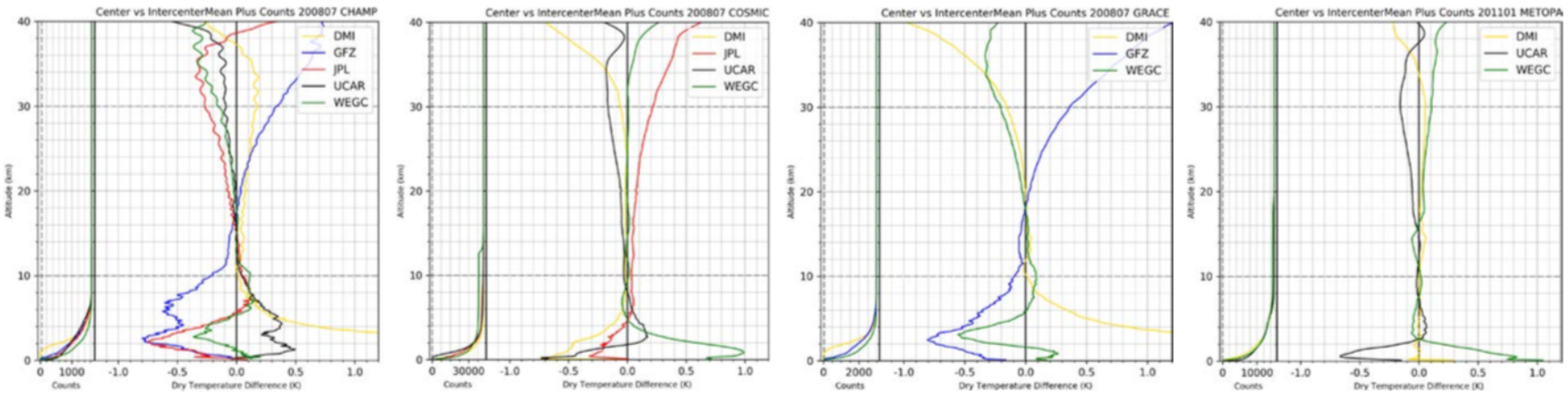
Hajj et al., JGR, 2004



RO-CLIM: Multi-center, multi-mission comparisons

Steiner et al., IROWG-6, Sept 2017

CHAMP 07/2008 **COSMIC 07/2008** **GRACE 07/2008** **METOP-A 01/2011**



Inter-center temperature differences of ~ 0.2 K vary from mission to mission

The changing landscape of GNSS-RO

Single receiver design → Diverse receivers design

GPS → Multiple GNSS sources (GPS, GLONASS, Galileo, Beidou, IRNSS, etc.)

Govt funded science based missions → Commercial CubeSats with less capability but more coverage designed for weather forecasting

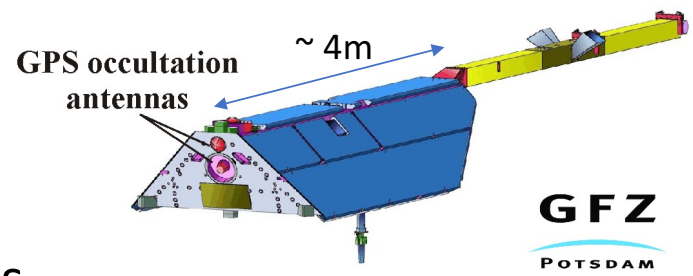
- In the future, we will likely have to utilize an increasingly diverse portfolio of data for constructing a RO climate record.
- Collocated RO measurements from different spacecraft/missions provide one of the best ways to validate the accuracy and precision of less mature hardware/dataset.

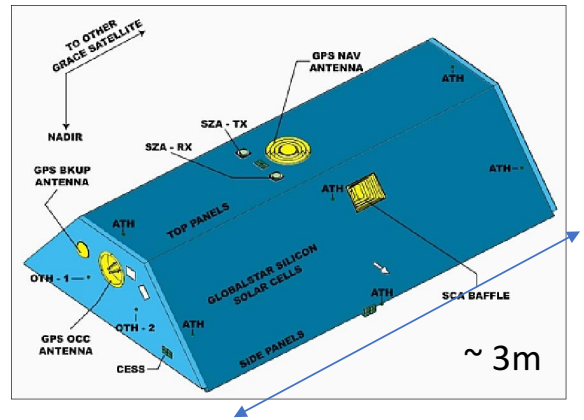
Datasets

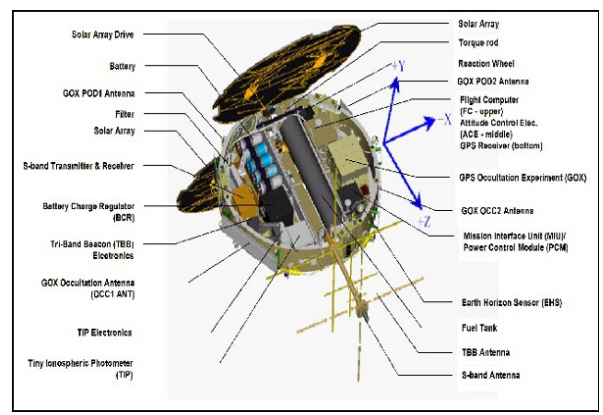
In 2007, there are three separate missions collecting GPS-RO data and processed by JPL:

- CHAMP (BlackJack Rcr, Setting only)
- GRACE (BlackJack Rcr, Setting only)
- COSMIC/FORMOSAT-3 (IGOR Rcr, Setting & Rising)

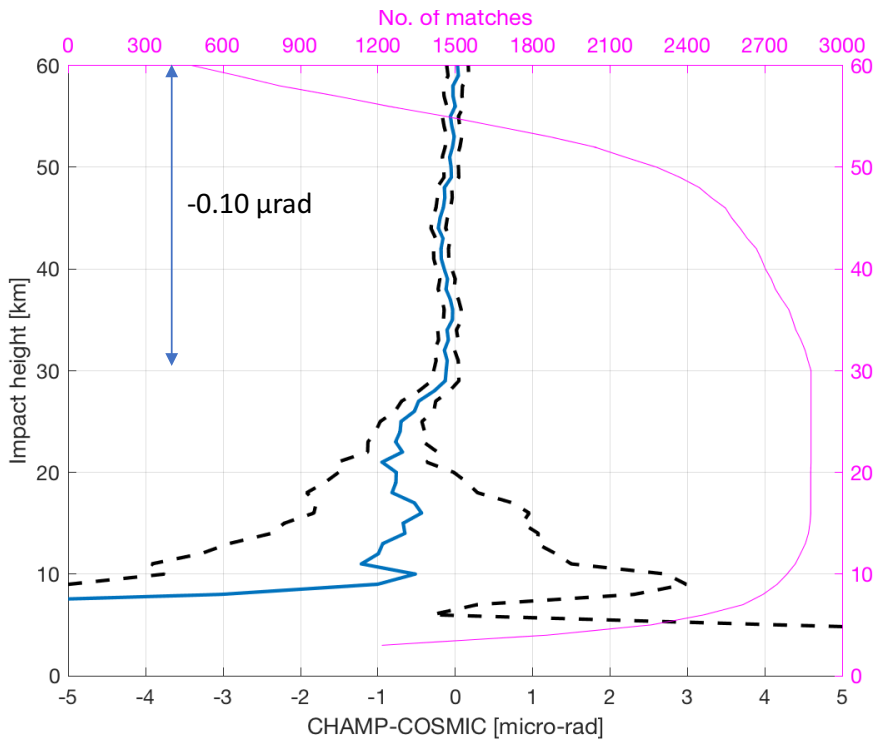
Collocation criteria: < 3 hr, < 300 km @ 15 km height

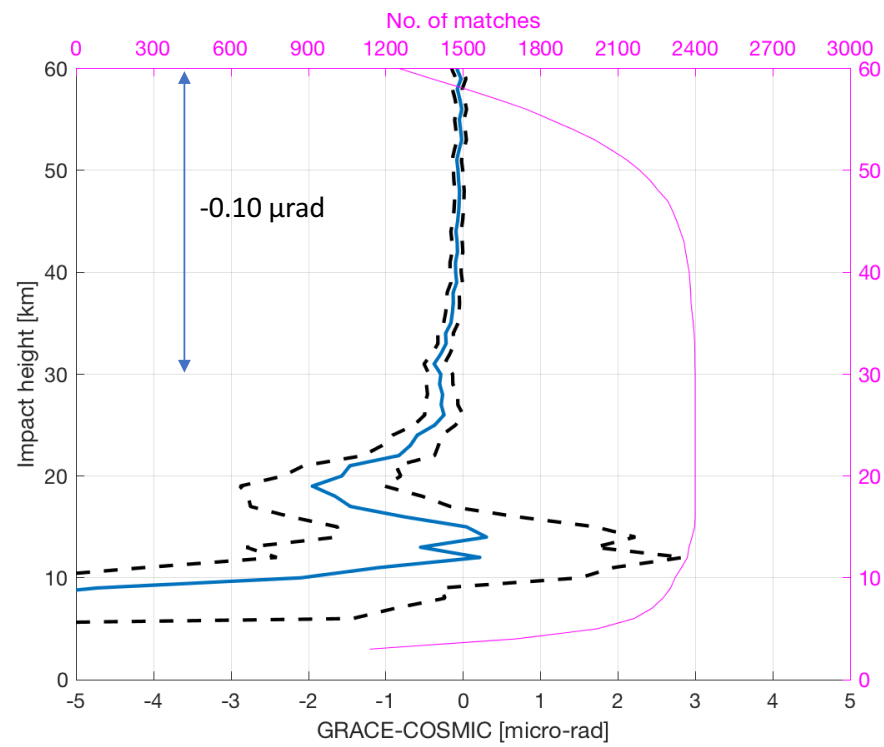






Bending angle comparison



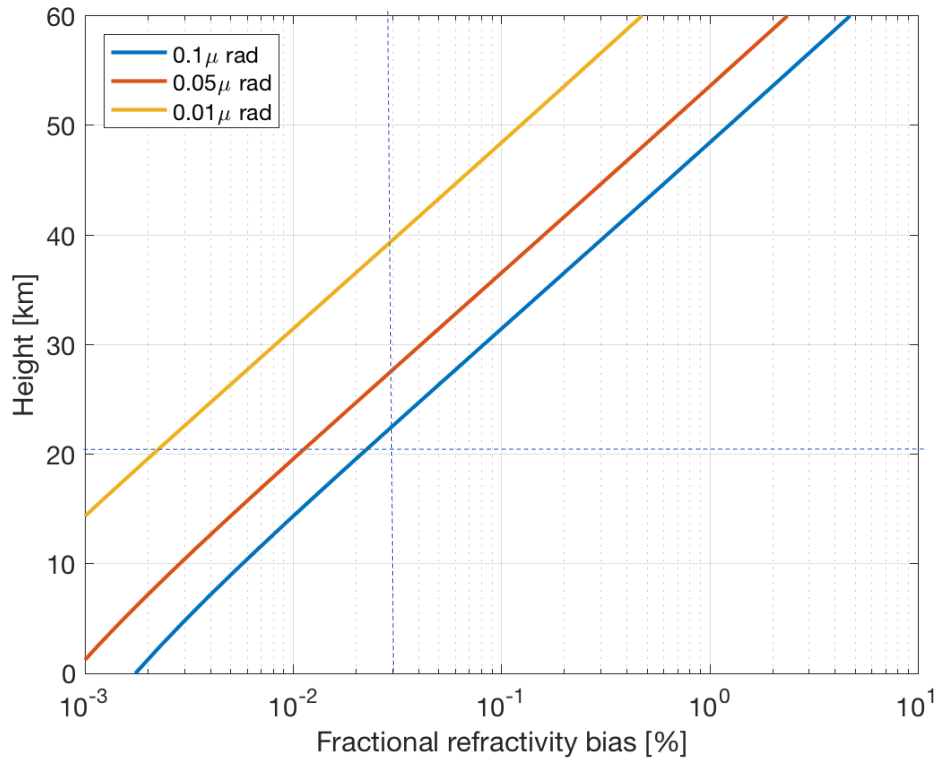


1 micro-rad ~ 0.2”

Propagation of systematic BA error to N

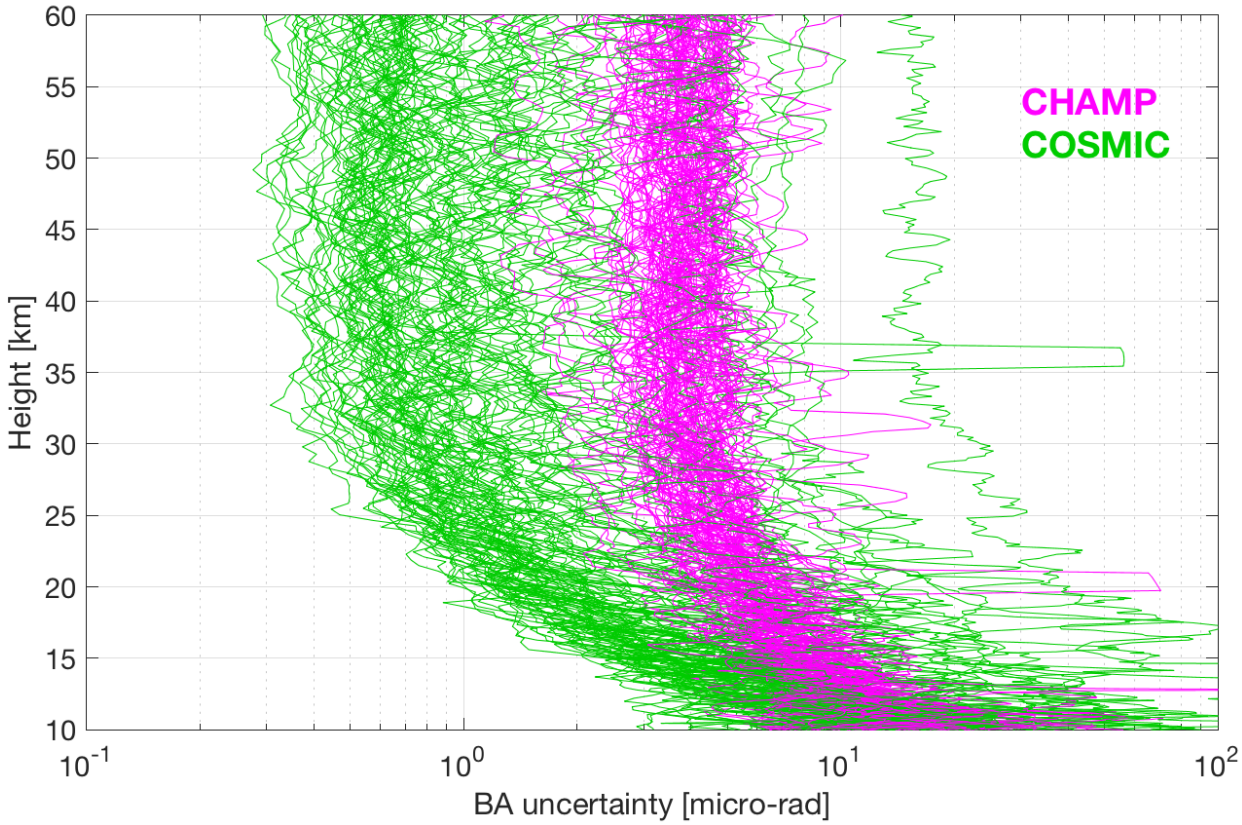
$$\langle \Delta N_j \rangle = \sum_{i=j+1}^{M} F_{ji} \langle \Delta \alpha_i \rangle$$

$$F_{ji} = \frac{10^6}{\pi} \frac{\delta a_i}{\sqrt{a_i^2 - a_j^2}}$$

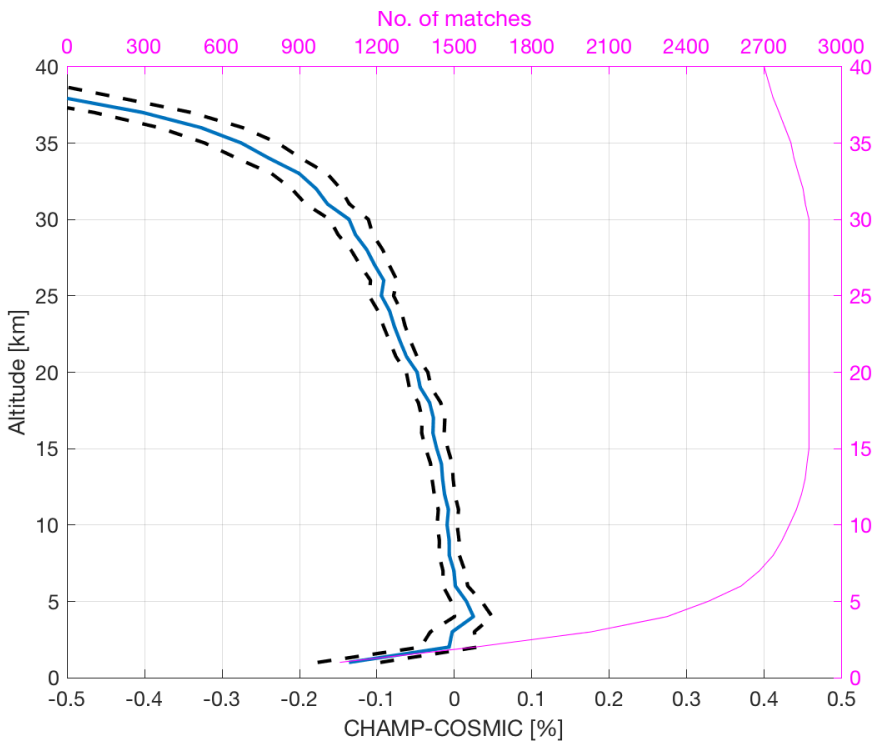


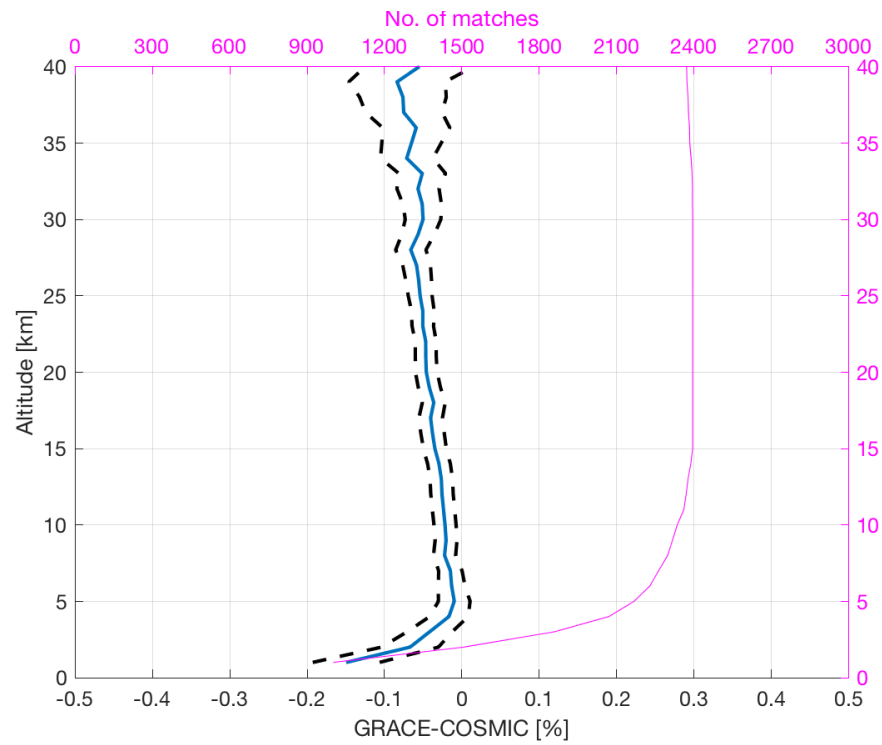
Bending angle noise: CHAMP vs COSMIC

The large measurement noise from CHAMP (poor oscillator) results in significant loss of BA data above 50 km

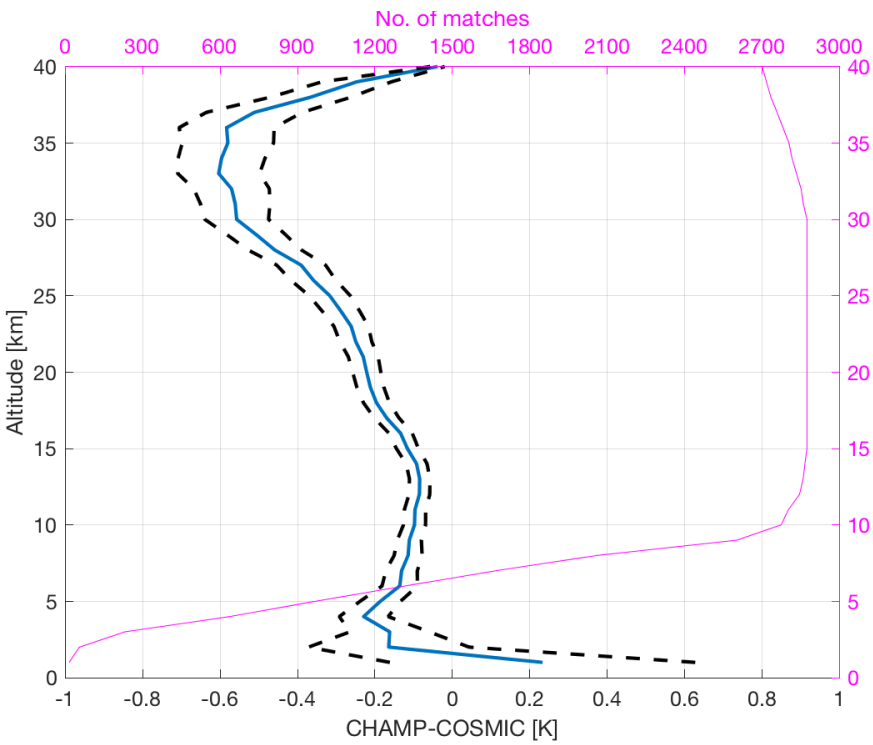


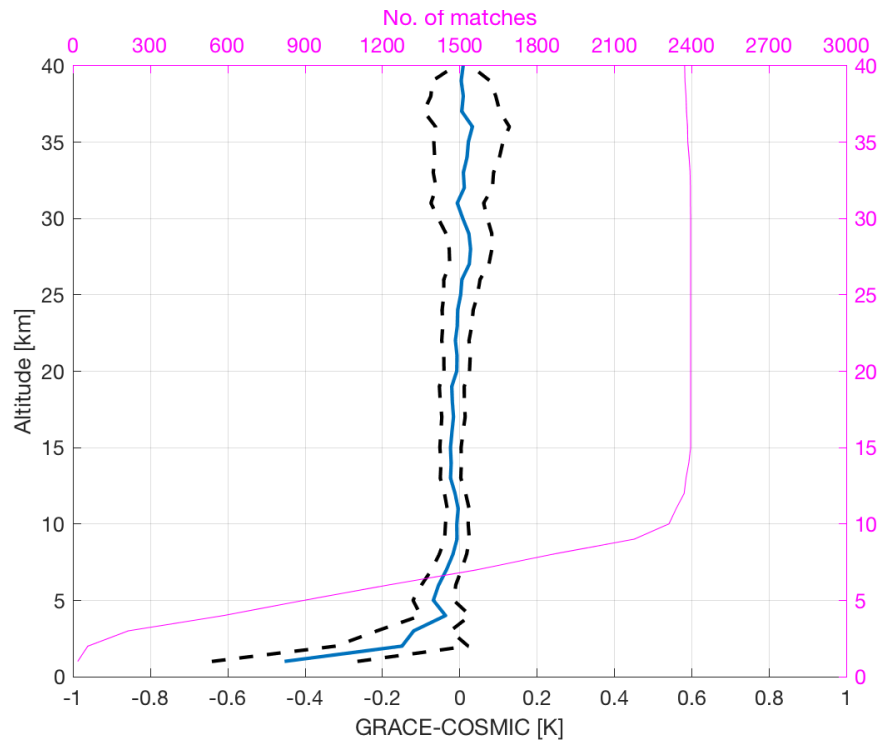
Refractivity comparison



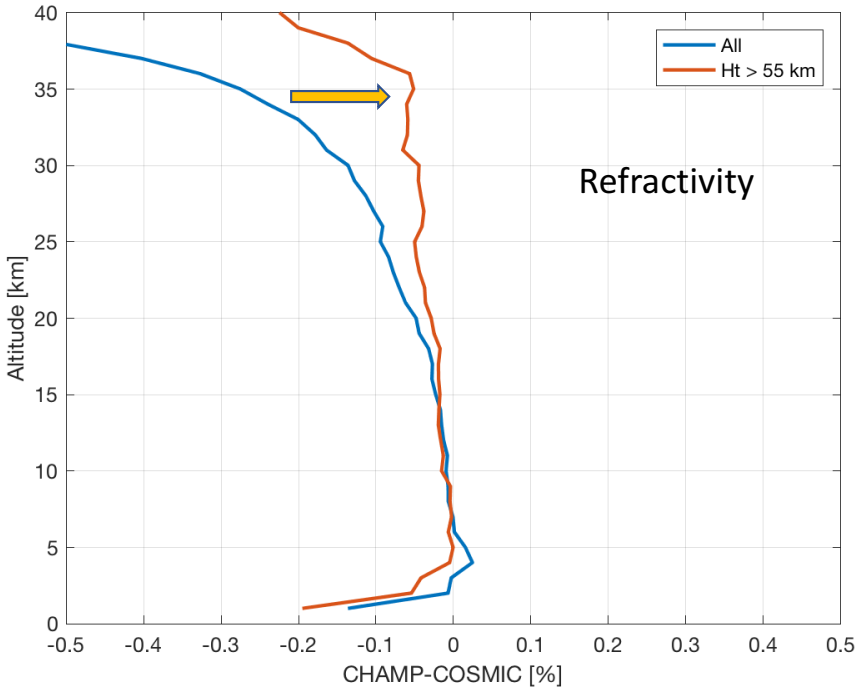


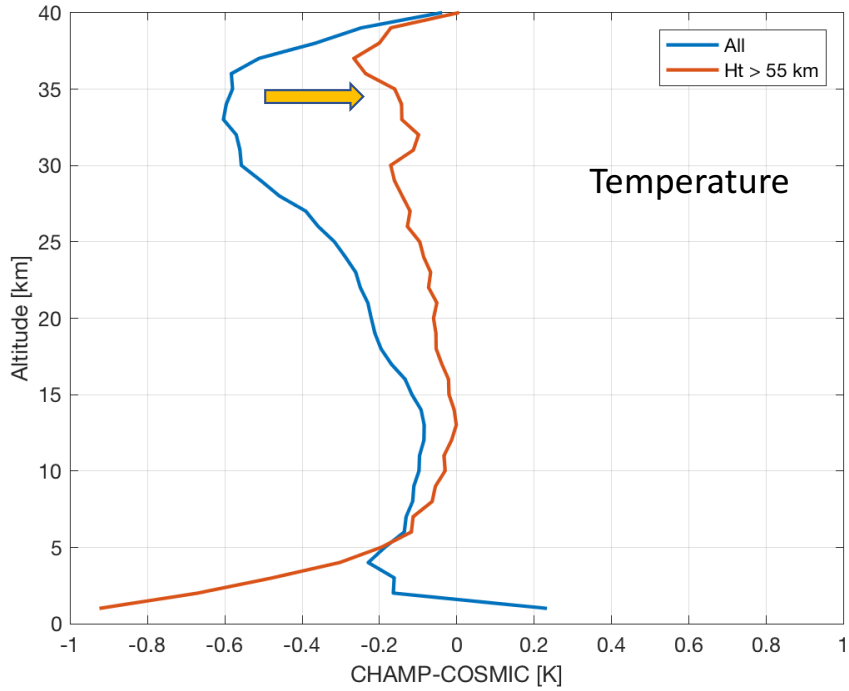
Temperature comparison



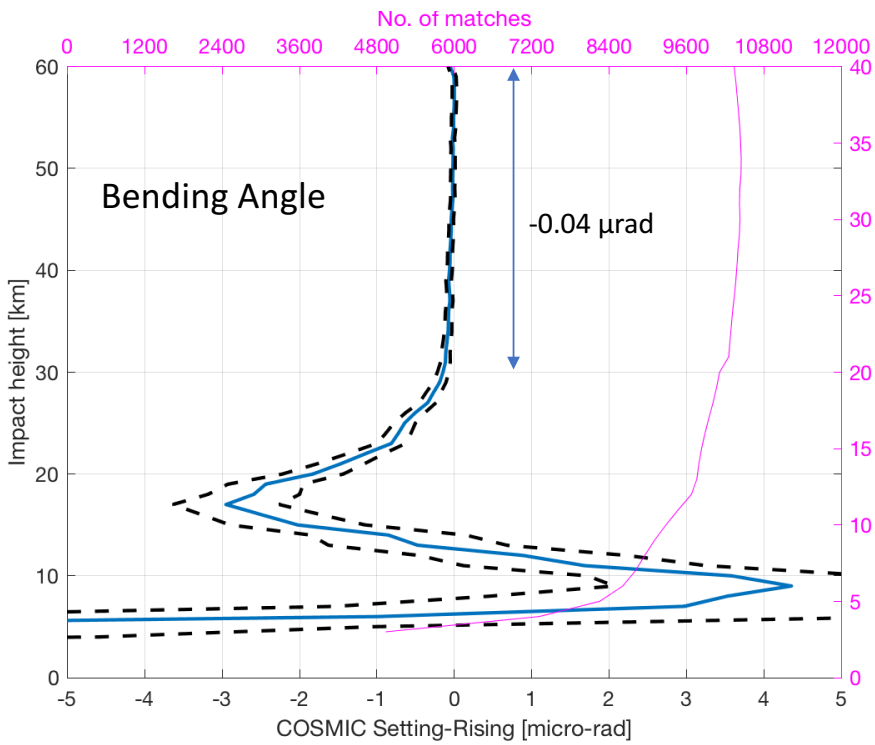


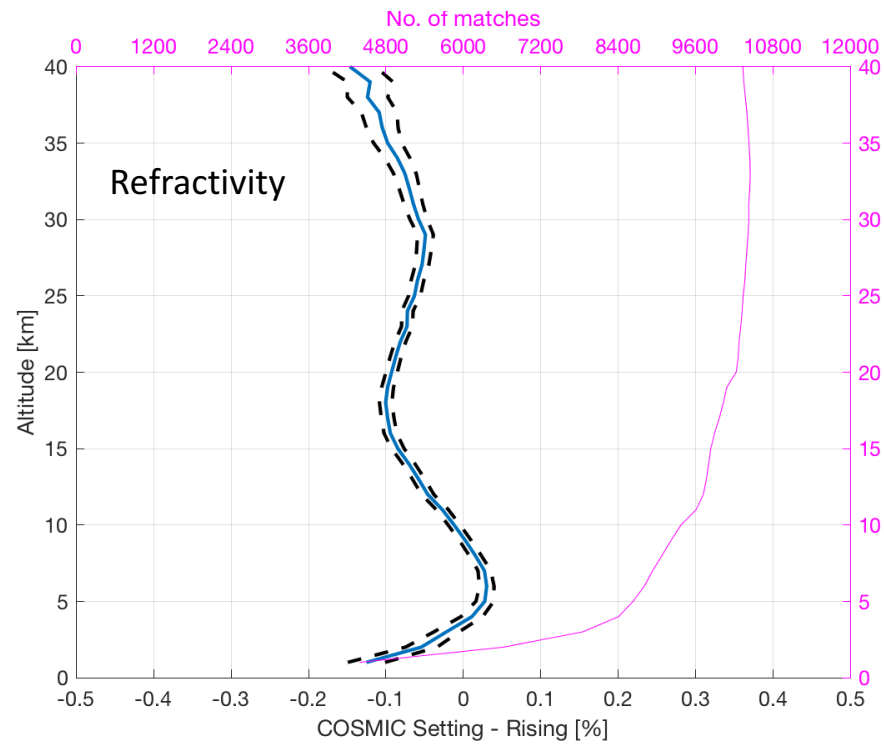
Removing poor-quality CHAMP profiles…



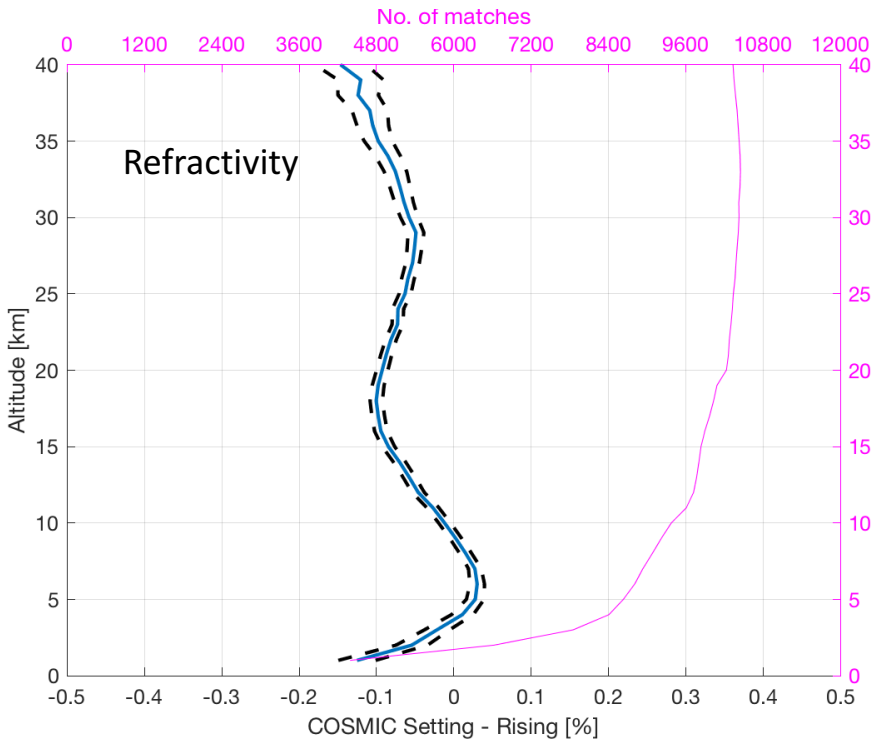


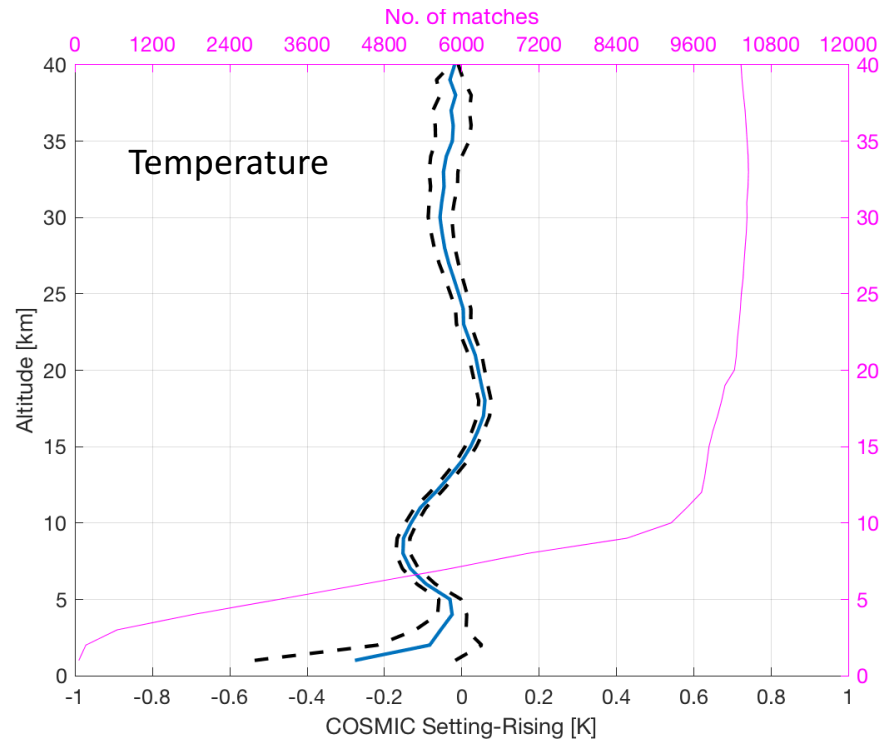
COSMIC setting vs rising (BA, N)





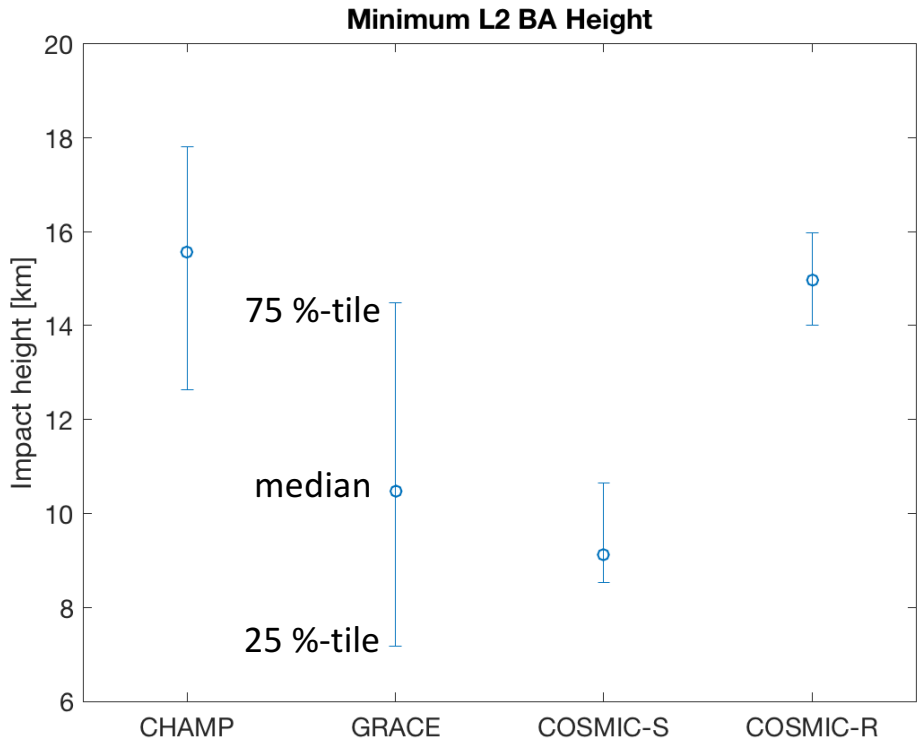
COSMIC setting vs rising (N, T)





What accounts for the BA differences below 15 km?

Quality of the L2 data varies



Factors Contributing to Intersatellite Bias

- An incorrect **antenna phase center offset** from the center of gravity of the spacecraft will produce a velocity error, leading to a ~ constant bending angle bias. 2 cm offset -> 0.01 µrad
- **Local multipath**: highly dependent on spacecraft configurations, may not average out. 1 m offset -> 0.01 µrad
- **Measurement noise**: retrieval nonlinearity can turn random noise into a bias.
- **Receiver tracking**
  - open-loop (COSMIC) vs. closed-loop (CHAMP, GRACE)
  - rising vs. setting
  - L2P codeless tracking

Summary

- Renewed efforts to characterize and understand intersatellite biases from existing RO missions.
  - BA biases among CHAMP, GRACE, and COSMIC are small above 10 km.
  - Substantial refractivity and temperature biases in CHAMP due to large measurement noise of CHAMP. Better high altitude Abel initialization will improve this.
  - Refractivity between GRACE and COSMIC agrees to < 0.05% between 5–25 km.
  - Biases between COSMIC setting and rising pairs are large. Why?
- *How do the intersatellite biases change over time?*