Outstanding Issues Concerning GPS RO Measurements in the Lower Troposphere

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Three issues impacting retrievals in the lower troposphere & PBL (mainly over the tropics)

1. Negative Refractivity (N) bias
2. Depth penetration
3. Retrieval nonlinearity (effect of random noise)
Positive bias when SNR is low? [Sokolovskiy et al. 2010]

Negative bias below ~ 2 km

Not all profiles reach surface due to ret/qc (worse for low SNR)
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Causes of Negative N-Bias

1. Critical-refraction (CR) (aka super-refraction or ducting)
   - When $\frac{dN}{dz} < -10^6/R \sim -157$ per km, there is no unique refractivity solution given the bending angle profile.

2. Negative bending angle bias
   - Insufficient tracking depth: The largest bending angle measurements (corresponding to lowest LSA) were not recorded.
   - Noise affecting low LSA data.
Critical Refraction vs. Insufficient Tracking Depth

Insufficient tracking depth results only in a small bias compared to the CR bias.
CR Example from COSMIC-RAOB Collocation

Xie et al., GRL, 2010
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Minimum Altitude Based on CT Amplitude

Cutoff heights with current algorithm

Ideal response for SS atm
Profile depth penetration appears anti-correlated with water vapor abundance
Zmin gets better with higher SNR, up to a point

30 S-30 N
JJA 2007
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Key Questions

• Can the results from Sokolovsky et al. 2010 be reproduced using JPL retrieval system? (Algorithm dependence)

• How does the bias vary geographically?

• Given an accuracy requirement for N, what is the desired SNR?

• Can we simulate this effect with end-to-end simulations?

• What filtering/smoothing method (if any) works best in reducing the bias?
Additive Noise

No positive bias from low SNR
RO Simulations with LES Atmosphere (From George Matheou, JPL)

Cumulus

Stratocumulus
Additive Noise: 2D Simulations

Averaged over 10 realizations

No positive bias from low SNR

Line-of-sight altitude [km]

Amplitude

Height [km]

\frac{N(\text{SNR400})-N(\text{SNR900})}{N(\text{SNR900})} [%]
Zonal N vs SNR

COSMIC 2007 Zonal Mean [-10 0] latitude

SNR [V/V]
• ECMWF (interpolated to COSMIC loc) shows similar SNR dependence to COSMIC!
• This can only be due to sampling differences between high and low SNR occultations.
• Could sampling bias account for the observed low SNR bias in COSMIC?
Distribution of COSMIC OCC

SNR > 700 (COSMIC 2007)

SNR < 700 (COSMIC 2007)

Np(<700)-Np(>700)

Np(<700)+Np(>700)
Summary

• Most of the negative N-bias below 2 km is due to critical refraction that occurs mainly over the stratocumulus region. External information is needed to constrain the solution.

• Profile penetration in the lower 2 km over the tropics is still an issue. Higher SNRs and larger bandwidth should help.

• We did not find strong evidence of a positive bias at 3-4 km due to low SNR.