# Outstanding Issues Concerning GPS RO Measurements in the Lower Troposphere

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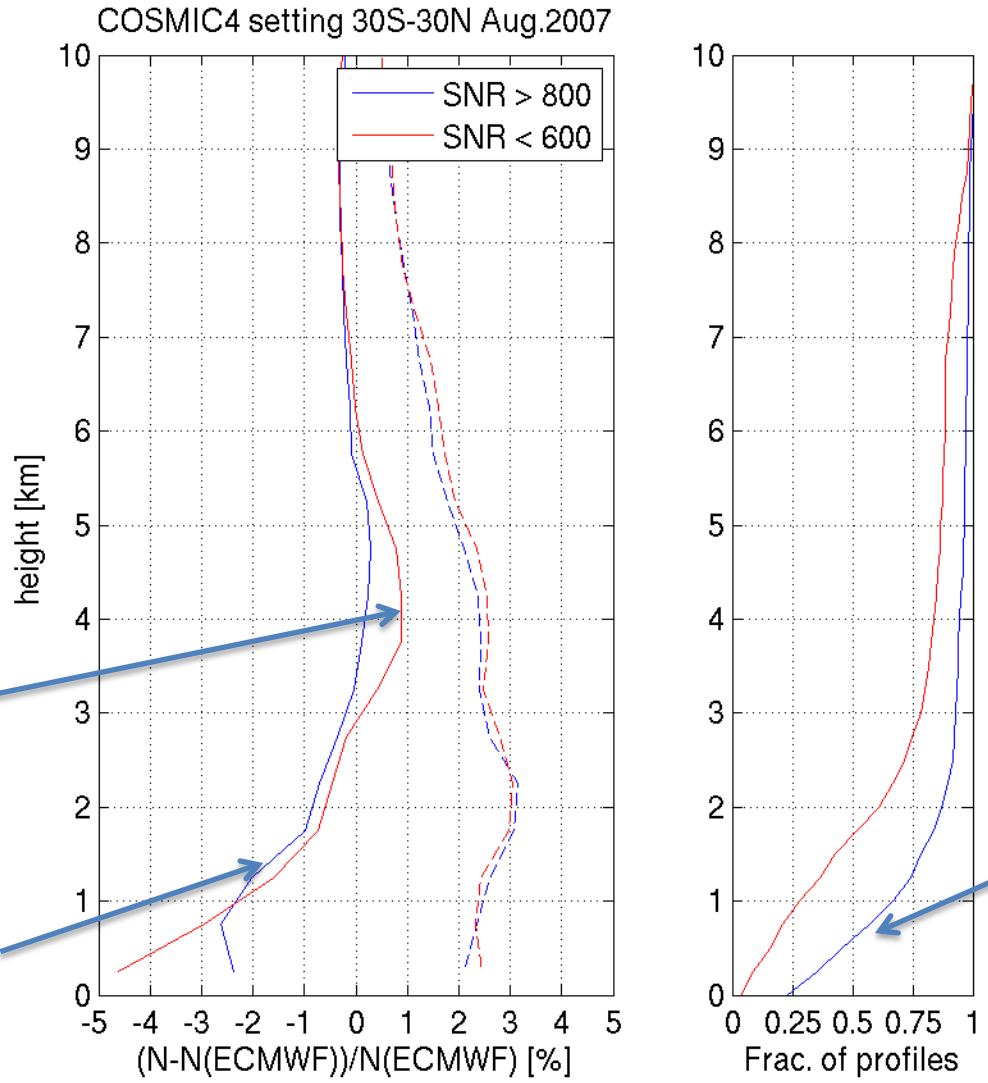
# Three issues impacting retrievals in the lower troposphere & PBL (mainly over the tropics)

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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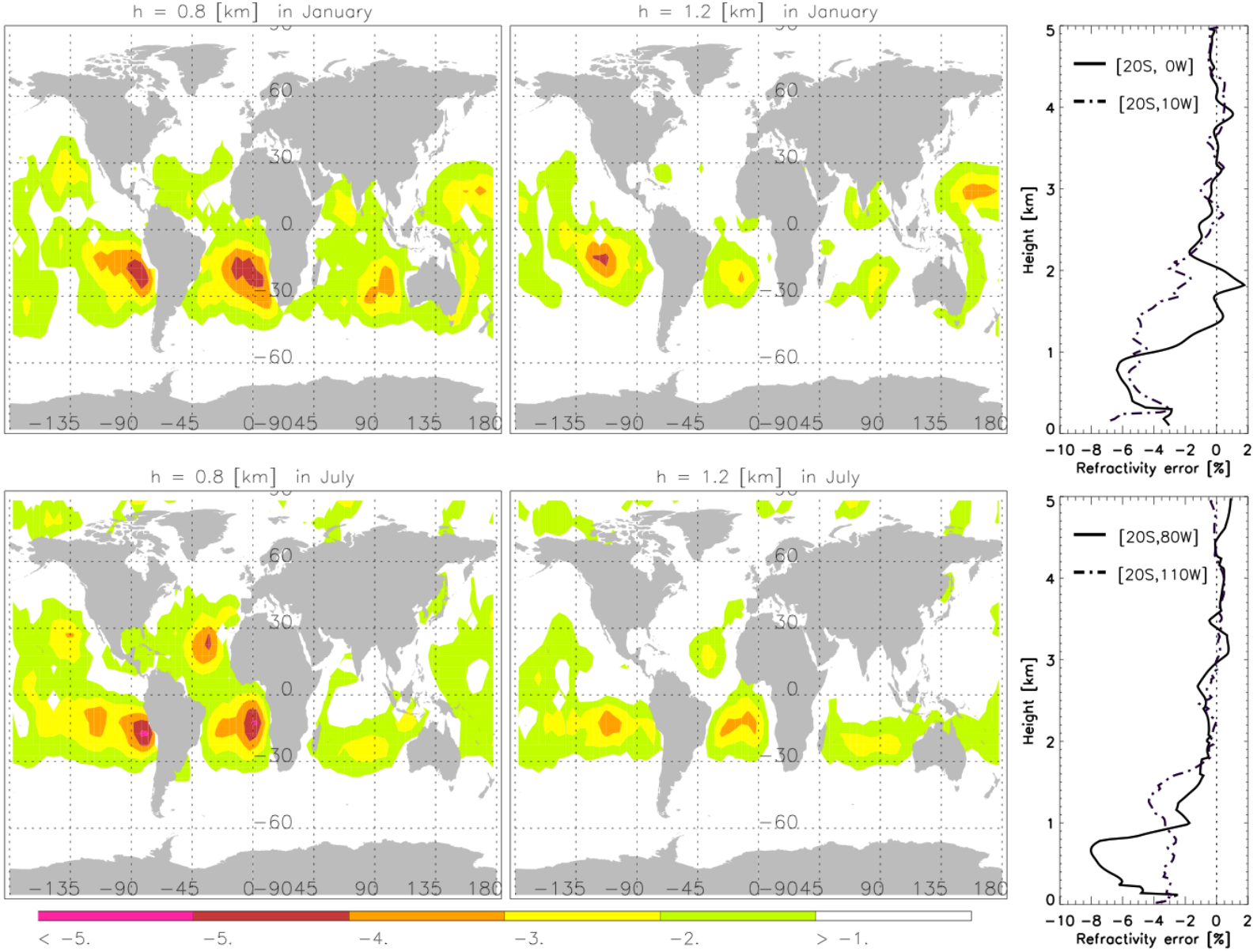
(N-N(ECMWF))/N(ECMWF) [%]

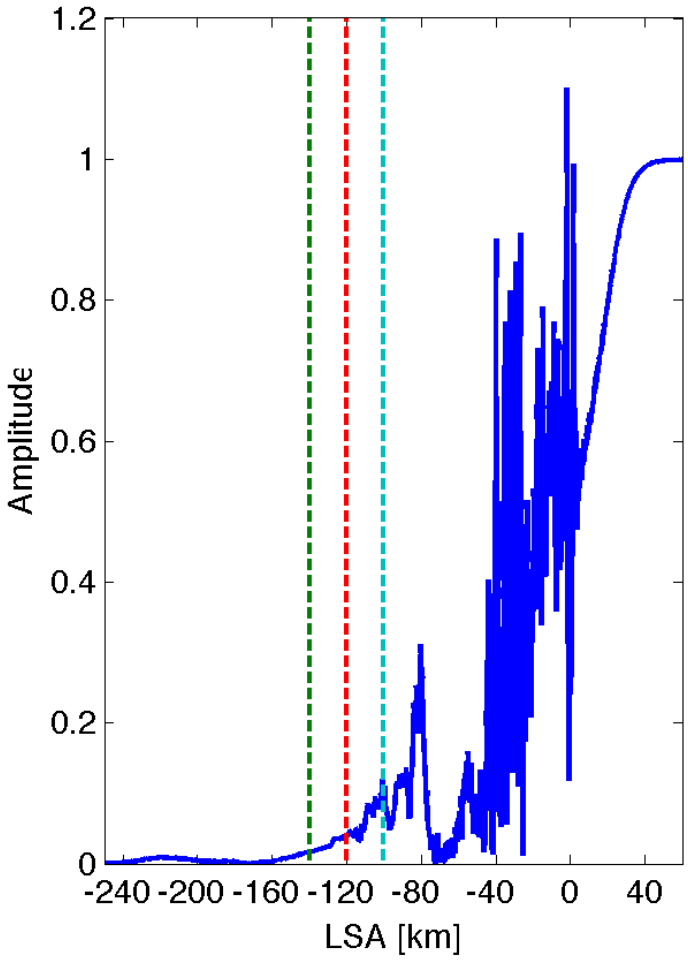


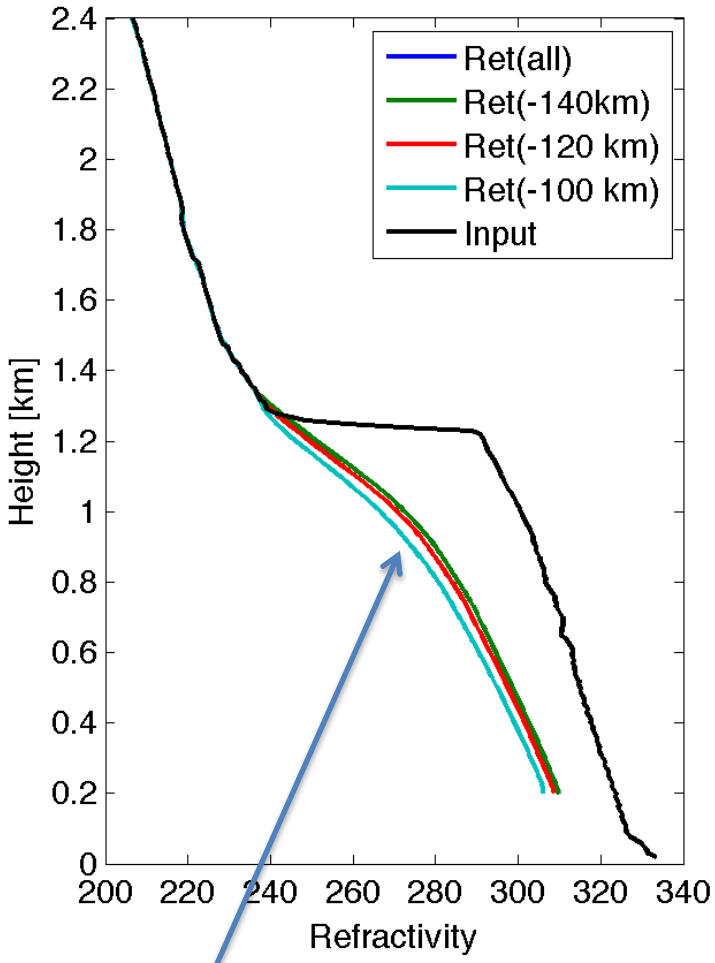

Xie et al., GRL, 2010

# Causes of Negative N-Bias

1. Critical-refraction (CR) (aka super-refraction or ducting)
   - When dN/dz < - 10^6/R ~ -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.

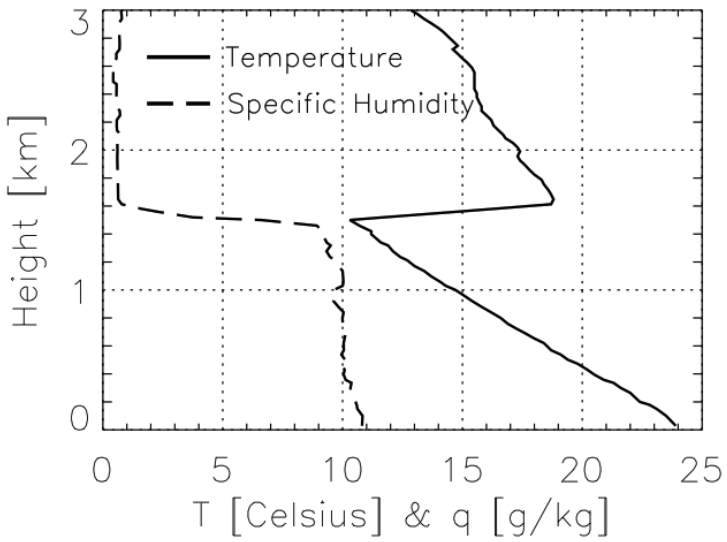
# Critical Refraction vs. Insufficient Tracking Depth

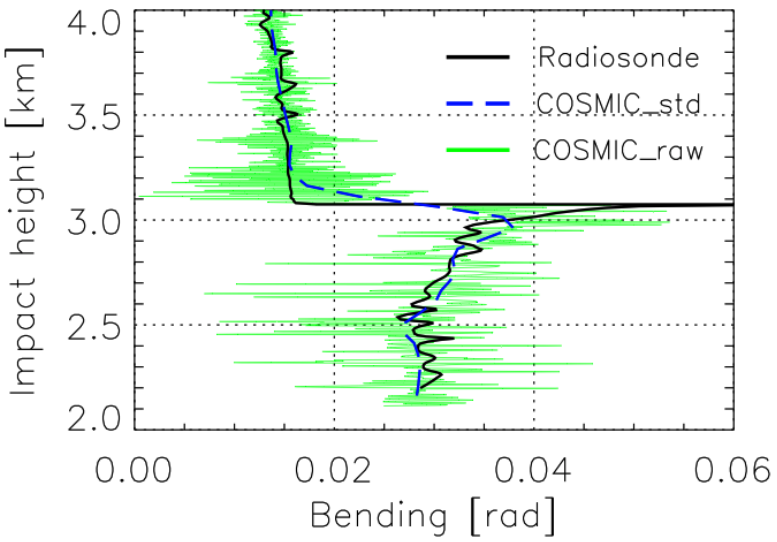


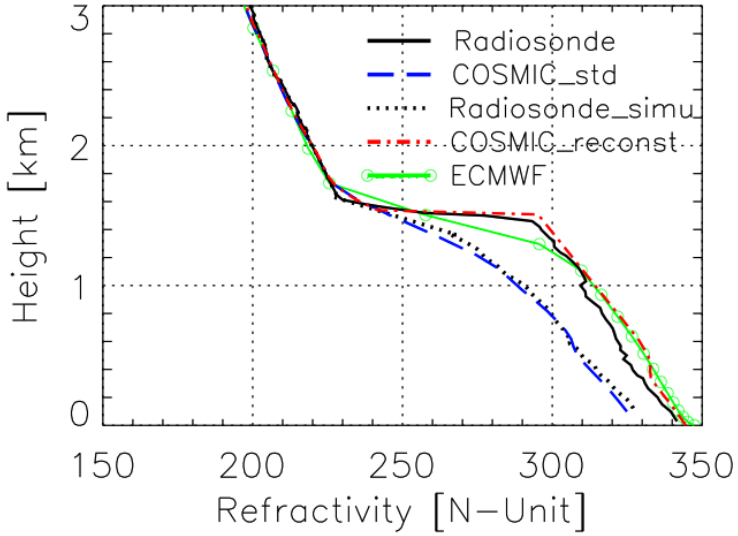



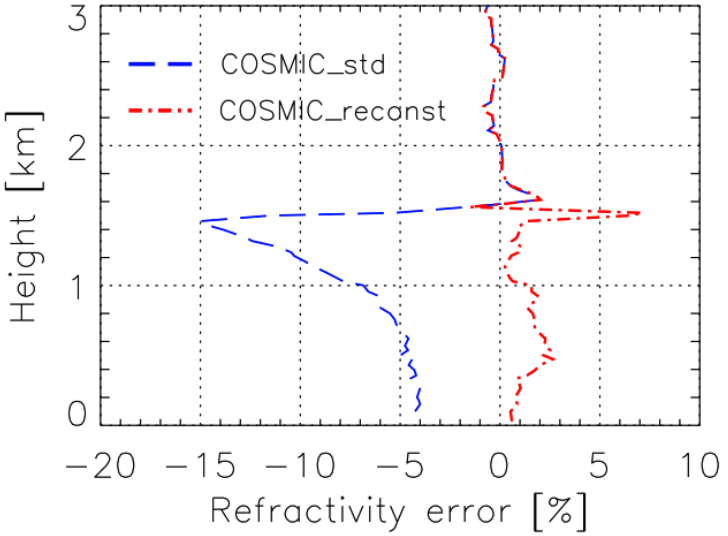

Insufficient tracking depth results only in a small bias compared to the CR bias

# CR Example from COSMIC-RAOB Collocation




Xie et al., GRL, 2010

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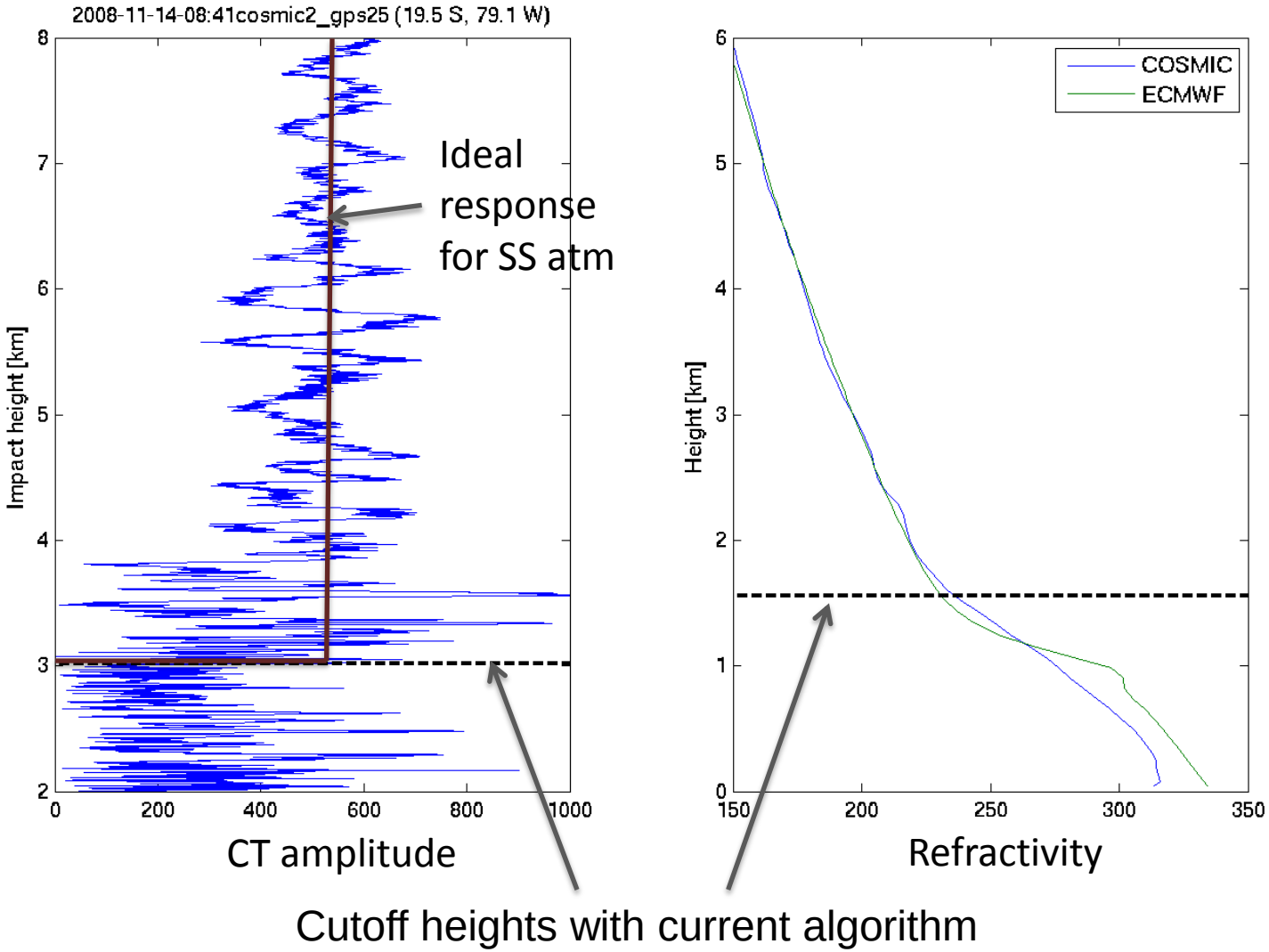
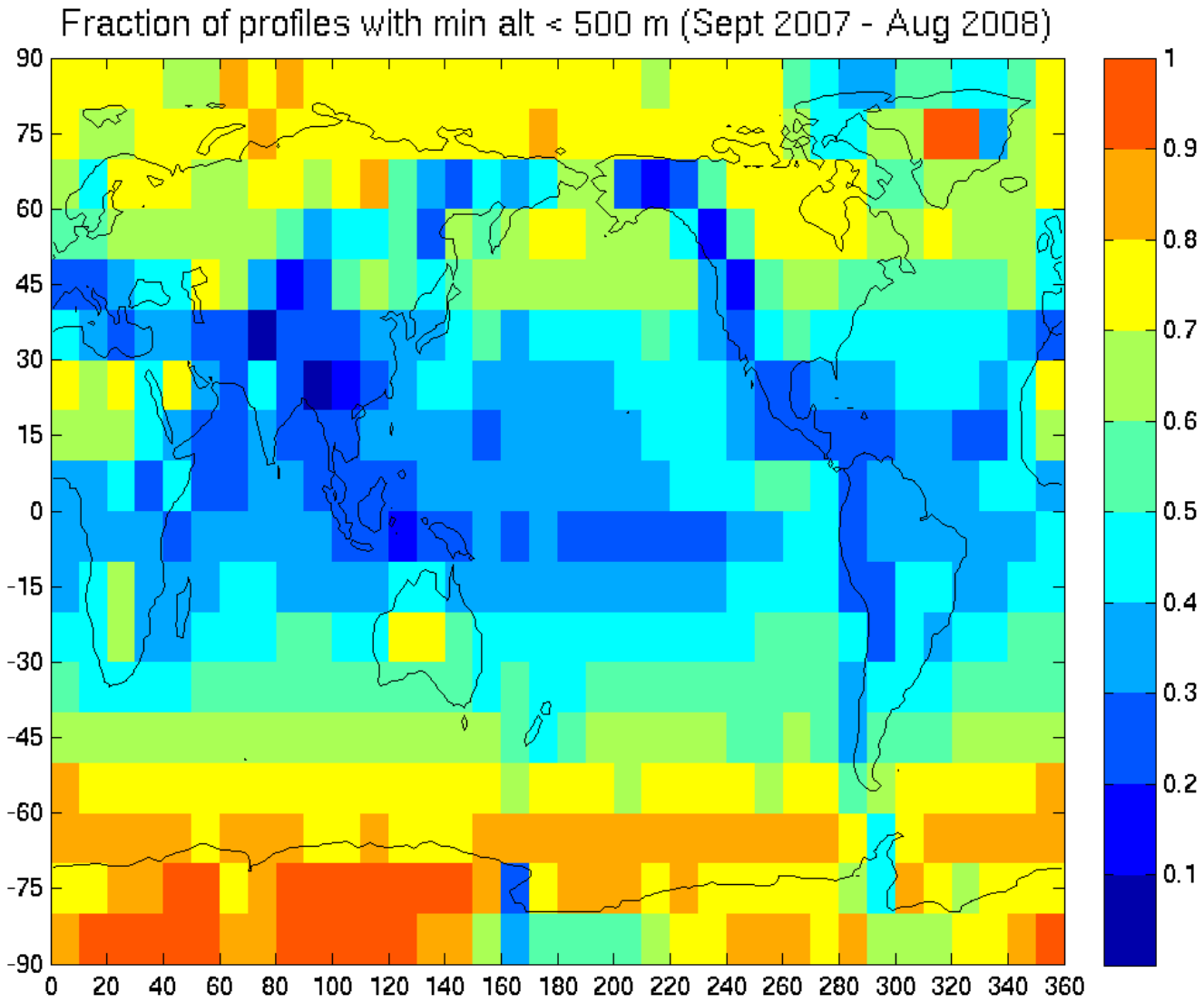
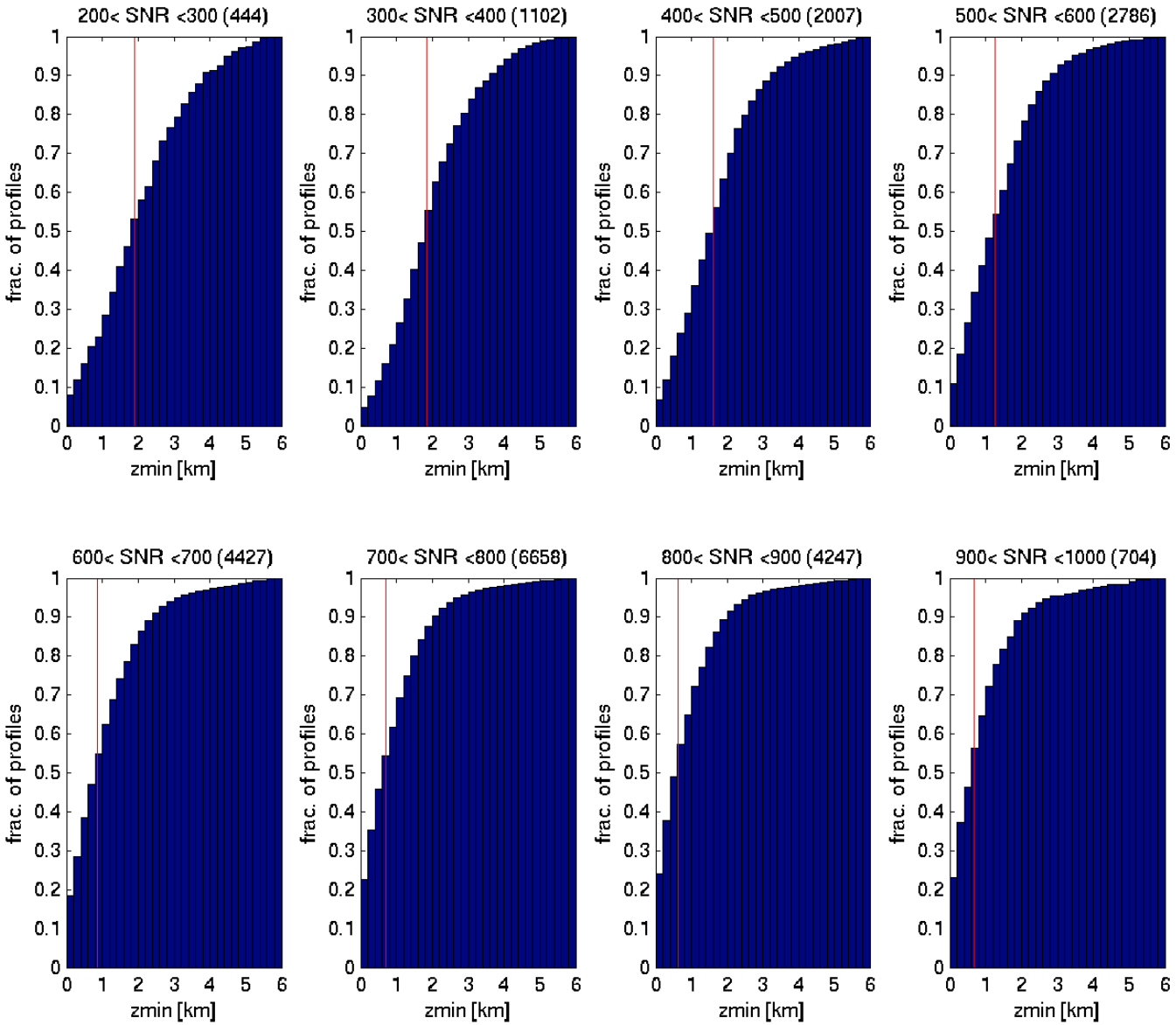
# Minimum Altitude Based on CT Amplitude






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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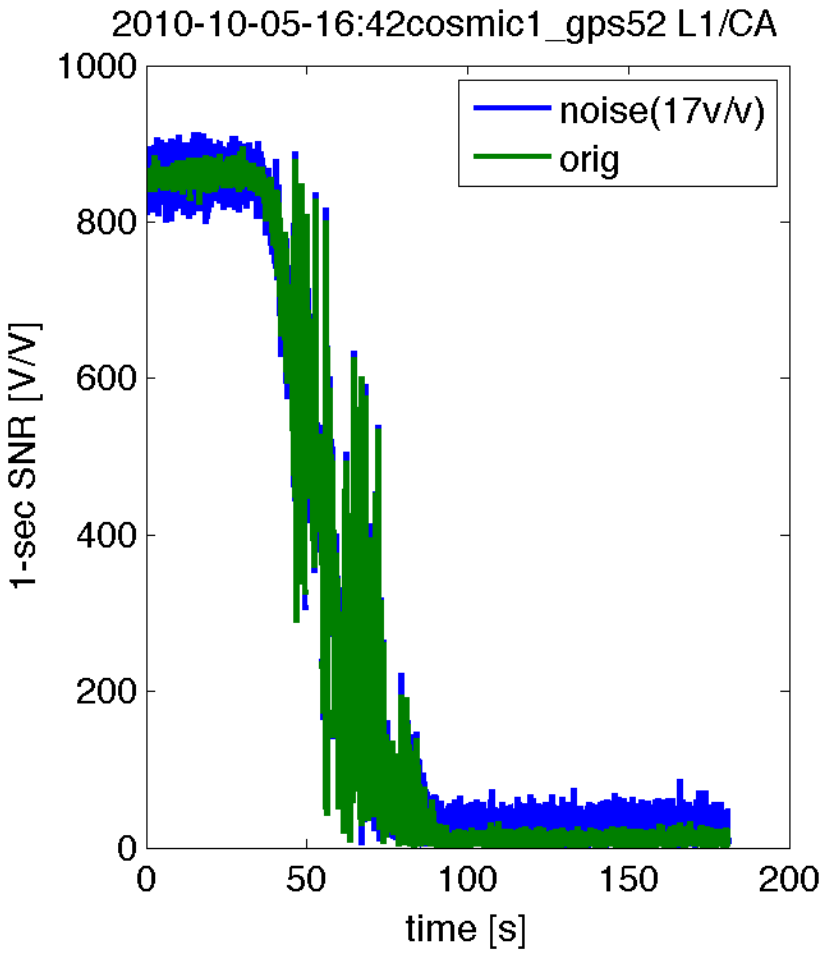
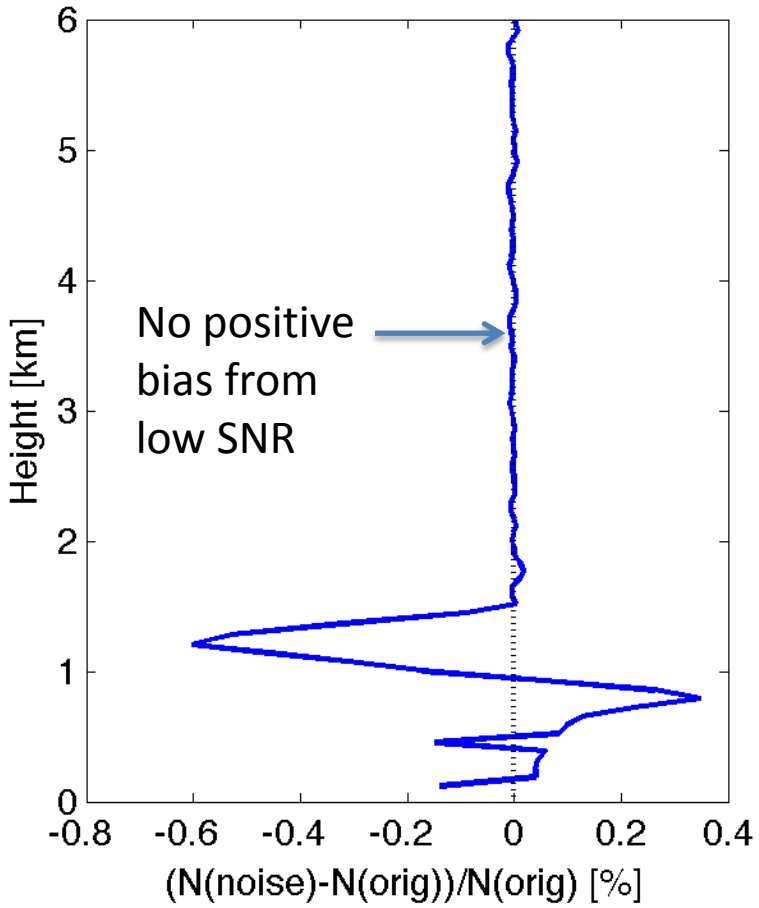
# Key Questions

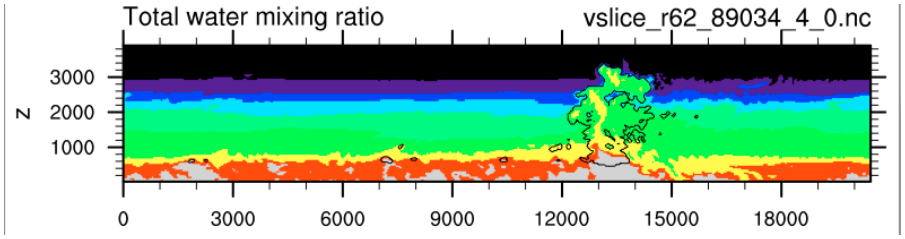
- Can the results from Sokolovsky et al. 2010 be reproduced using JPL retrieval system? (Algorithm dependence)
- How does the bias vary geographically?
- Given an accuracy requirement for N, what is the desired SNR?
- Can we simulate this effect with end-to-end simulations?
- What filtering/smoothing method (if any) works best in reducing the bias?

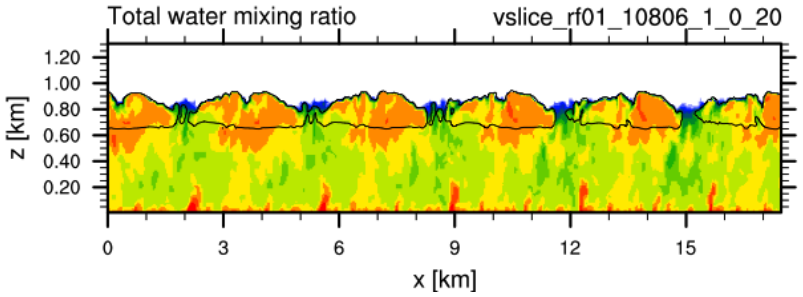
# Additive Noise

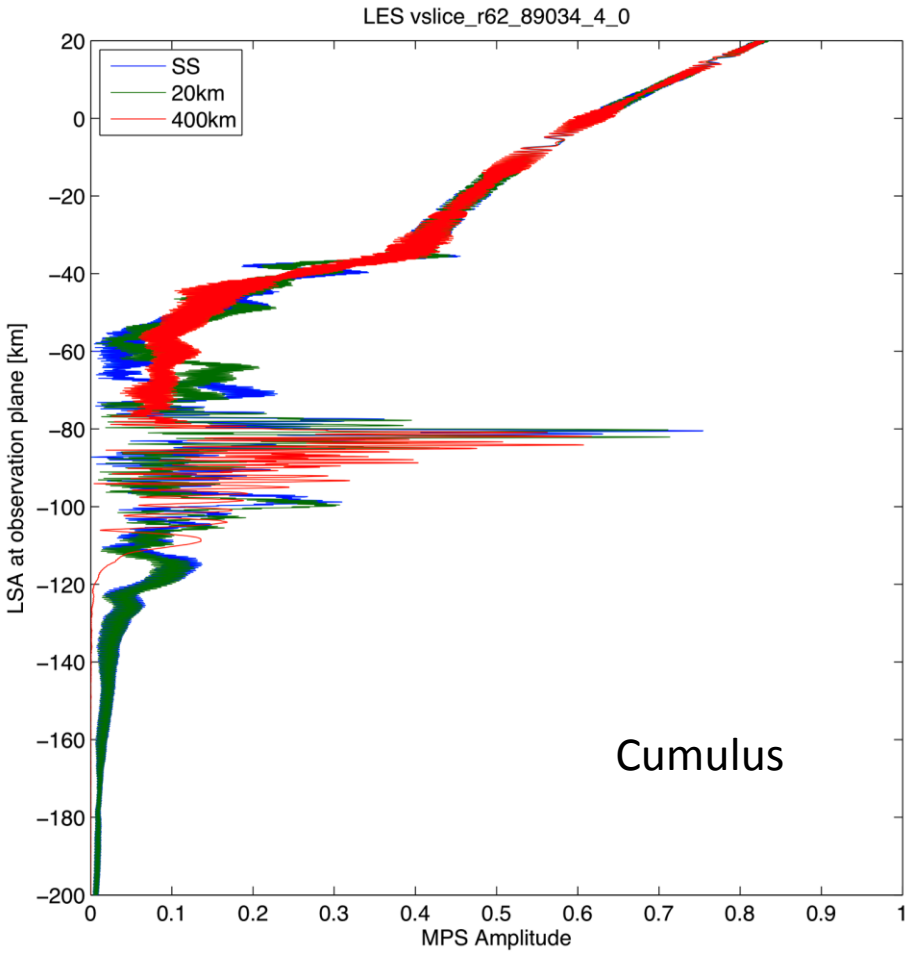


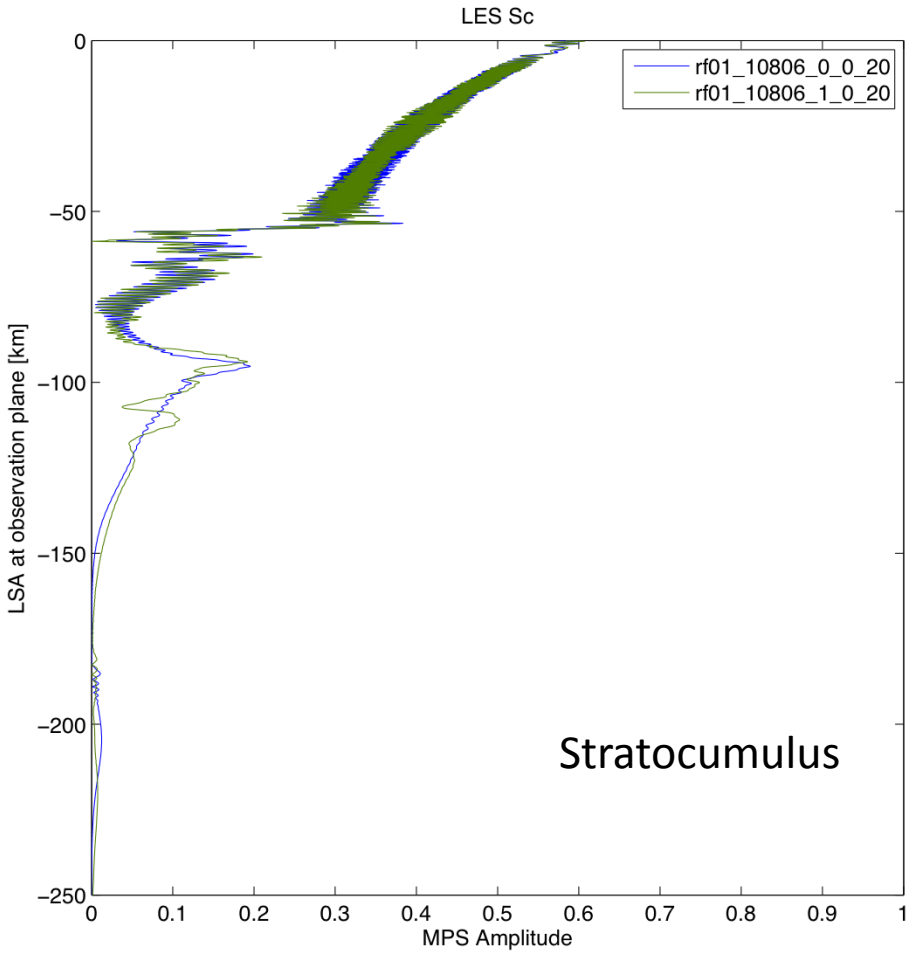



# RO Simulations with LES Atmosphere (From George Matheou, JPL)

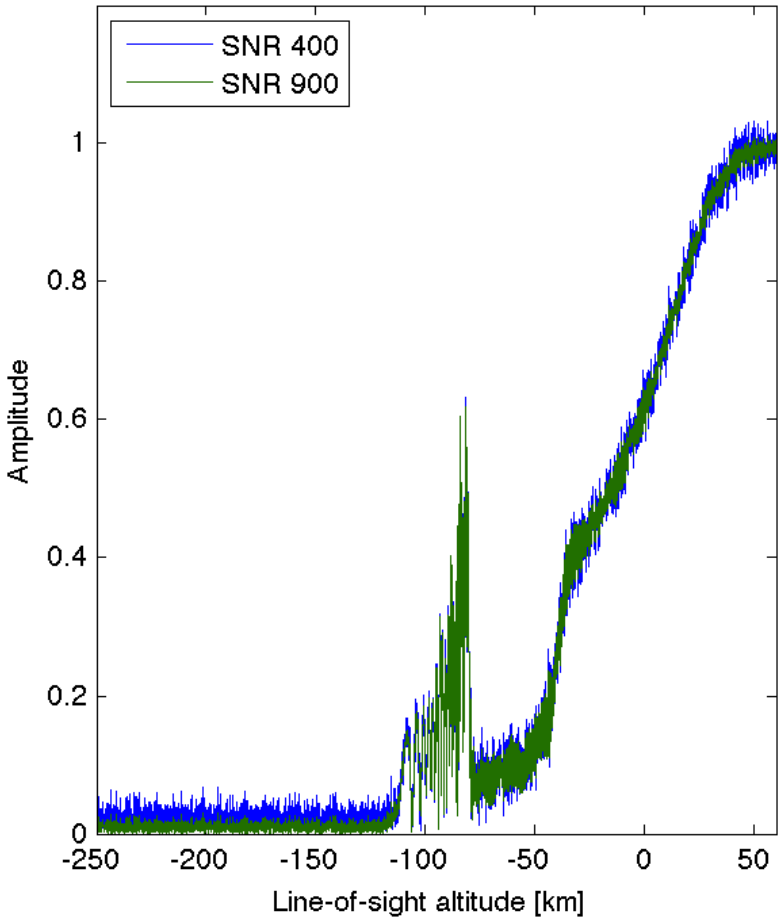


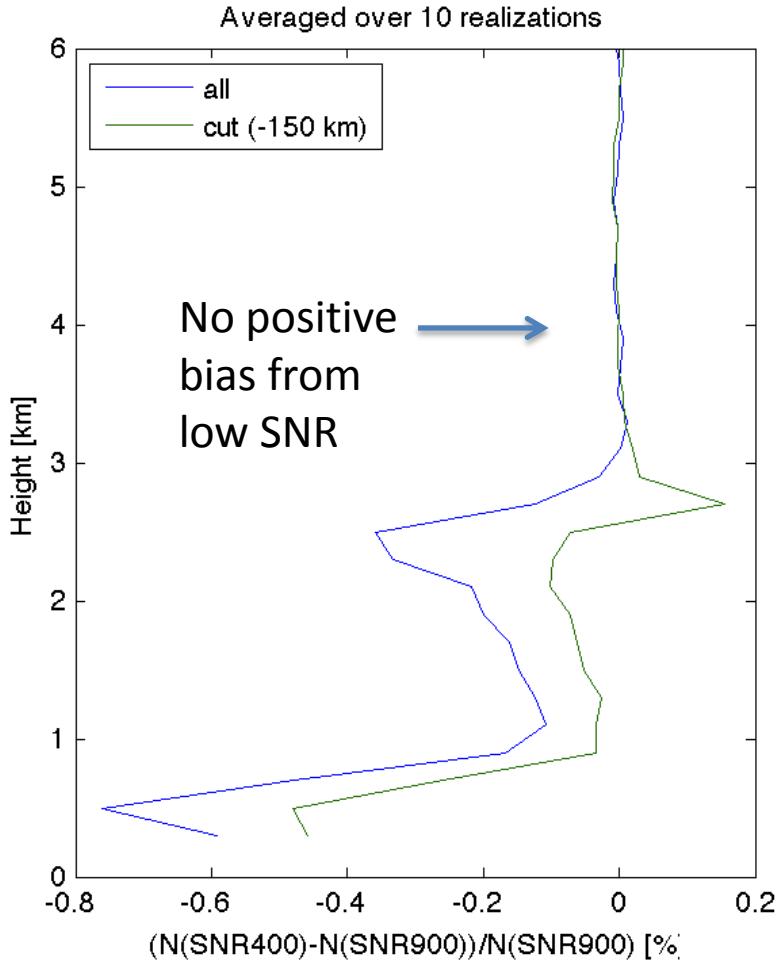



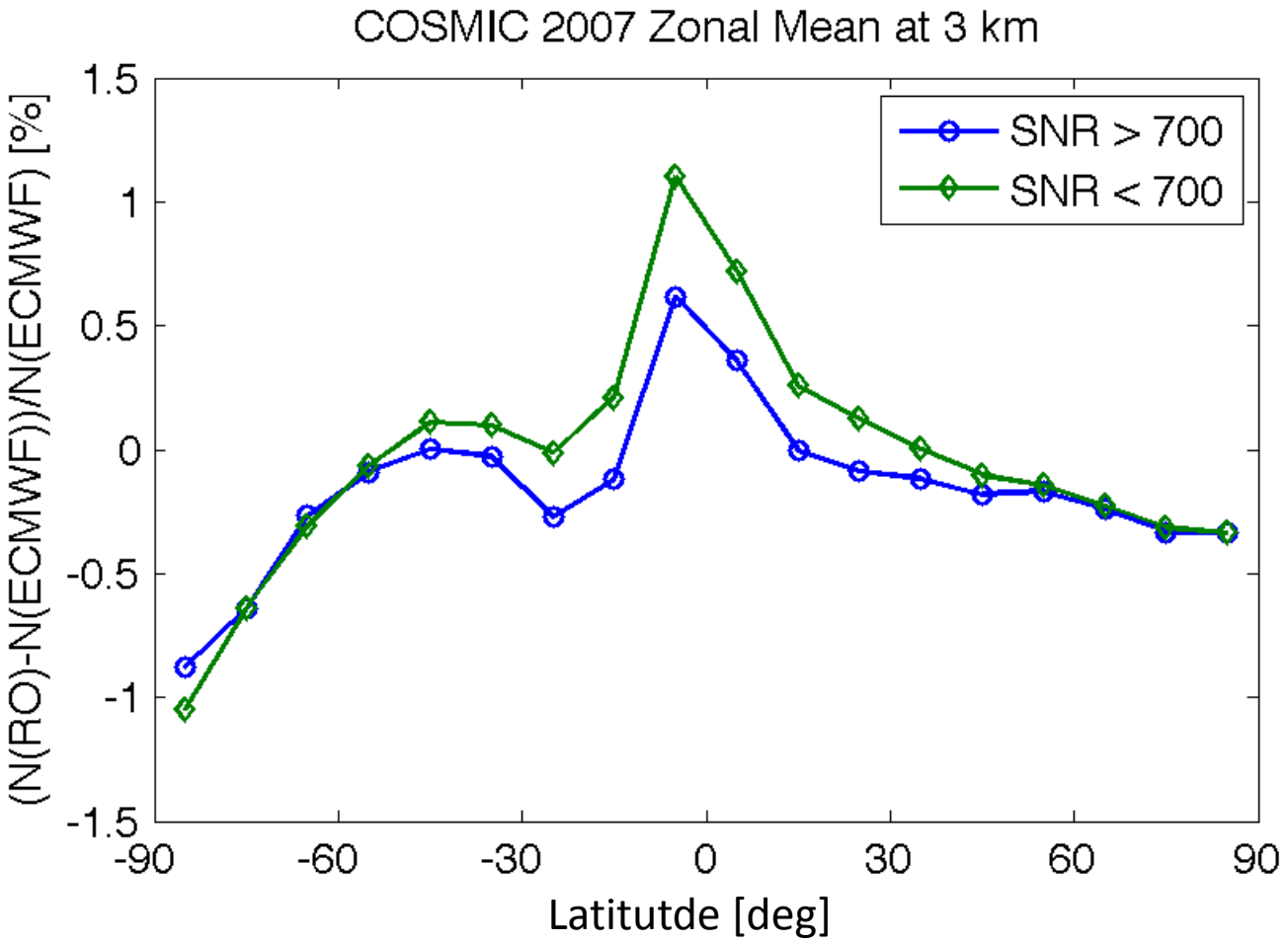



# Additive Noise: 2D Simulations

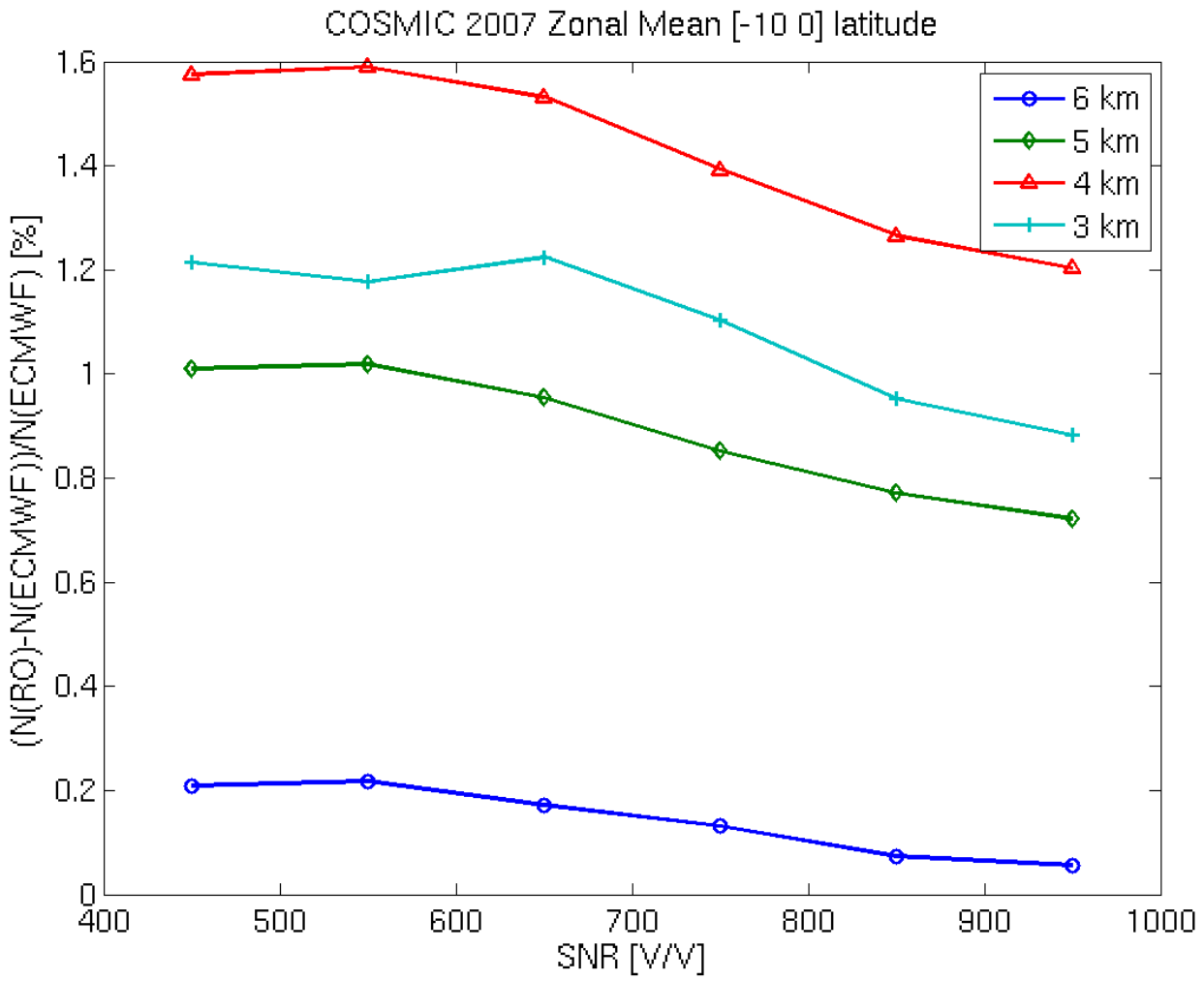


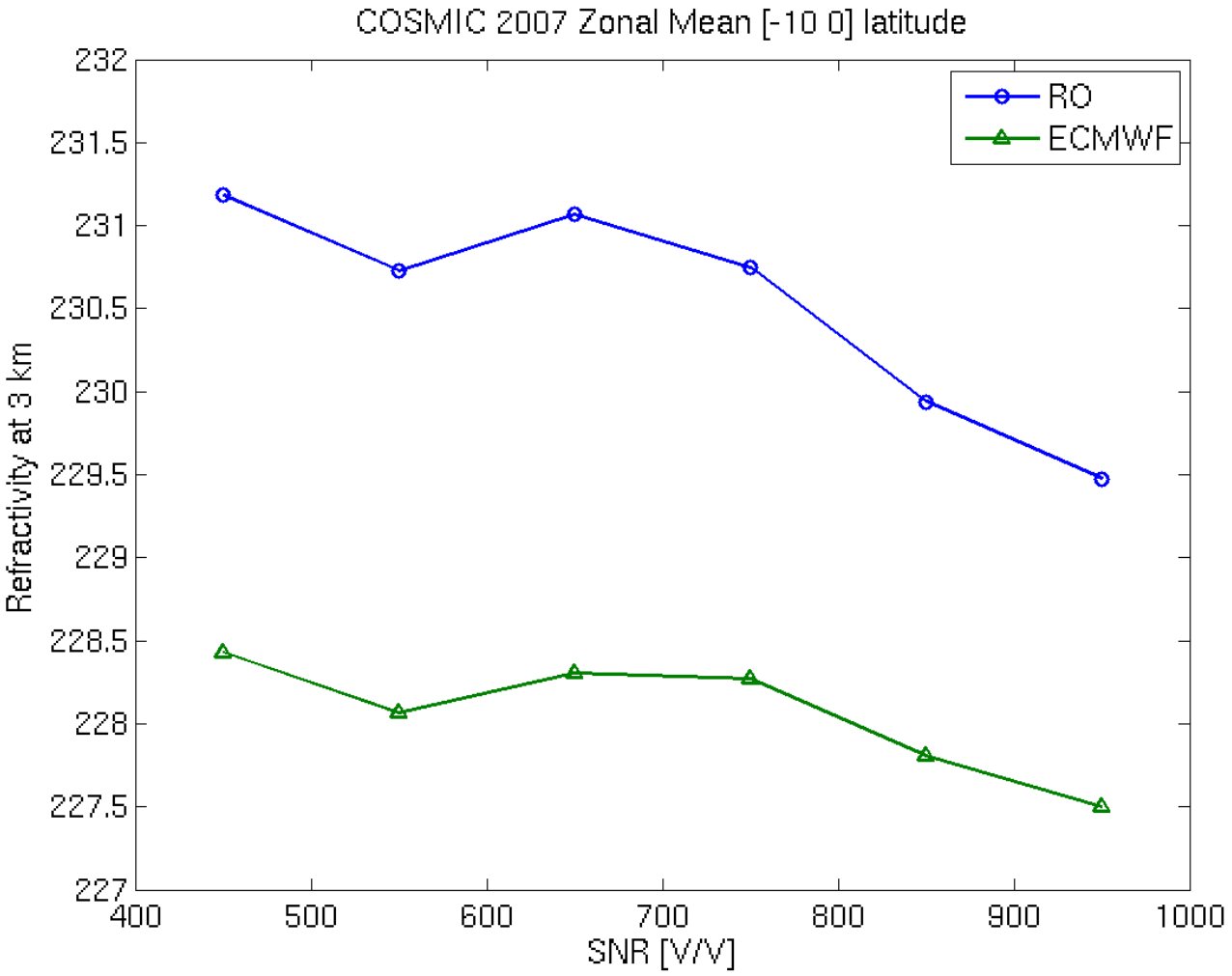



# Zonal N vs Lat



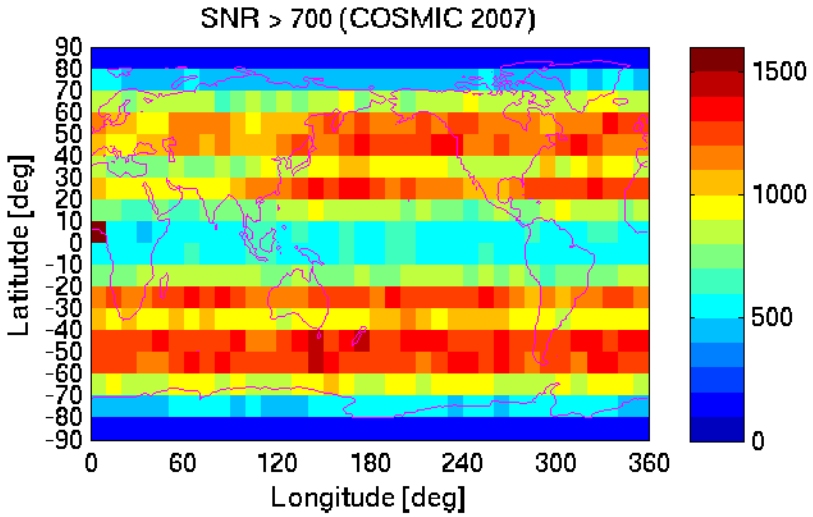
# Zonal N vs SNR

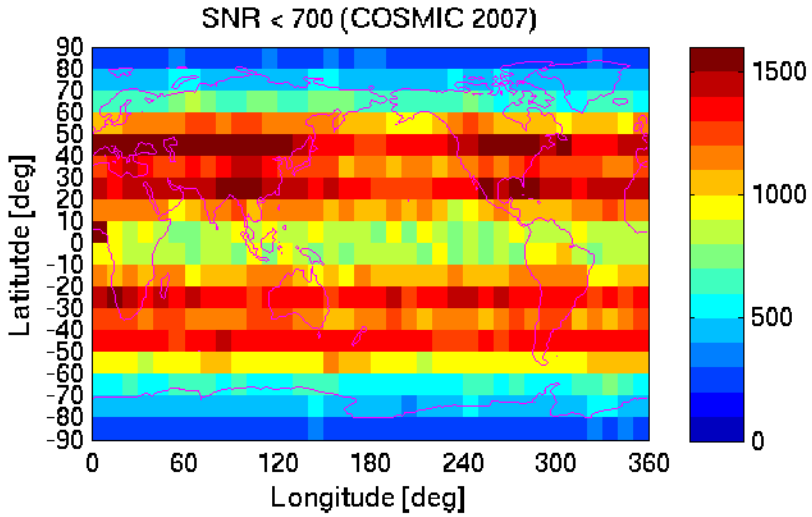


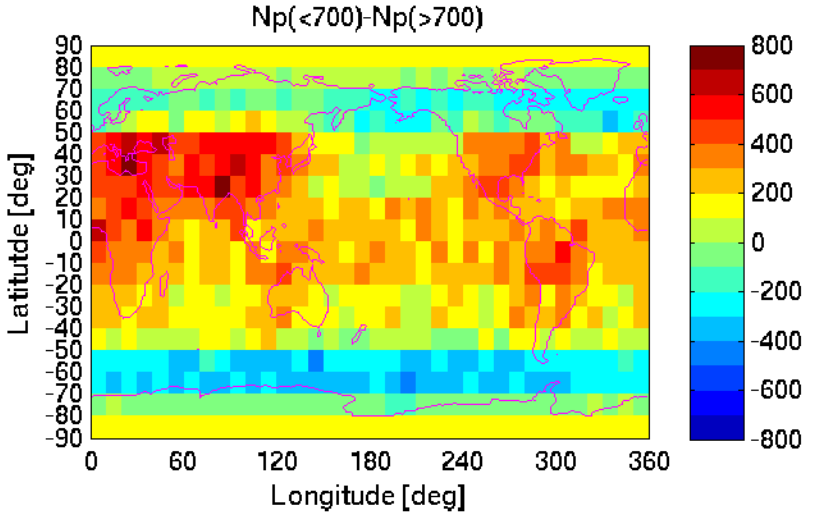


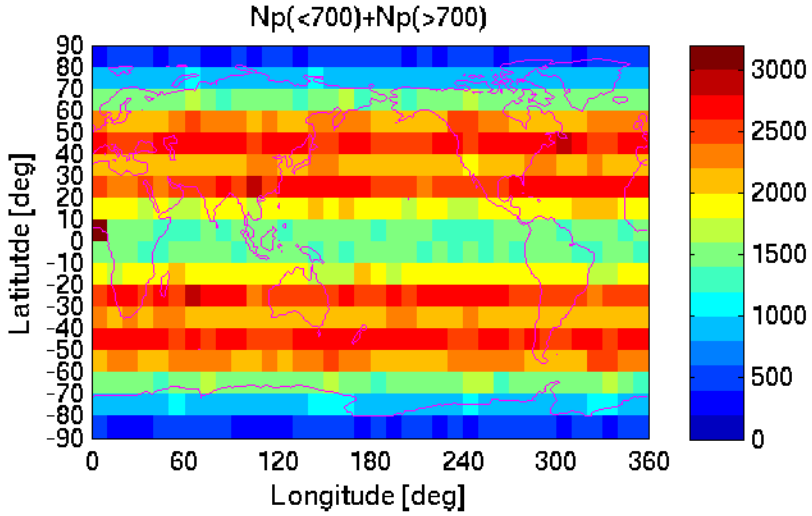

- ECMWF (interpolated to COSMIC loc) shows similar SNR dependence to COSMIC!
- This can only be due to sampling differences between high and low SNR occultations.
- Could sampling bias account for the observed low SNR bias in COSMIC?

# Distribution of COSMIC OCC



# 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.