PBL Profiling with Active Microwave Crosslink Occultations

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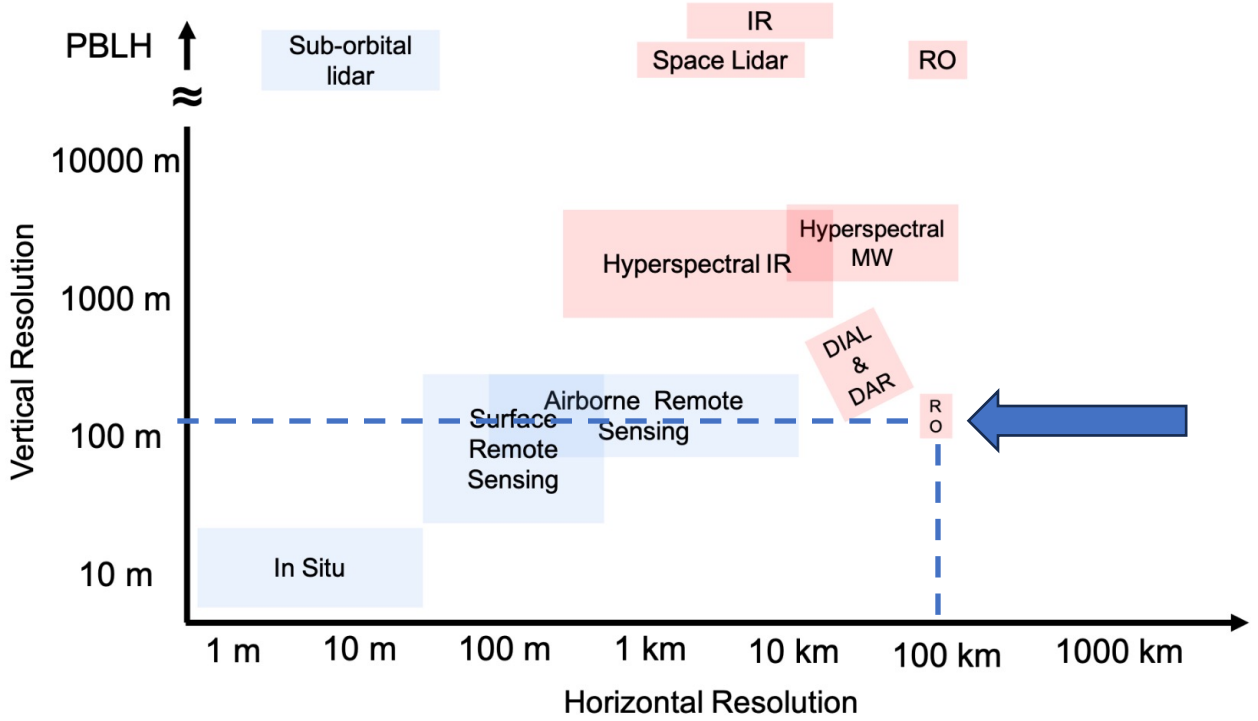
Motivation

PBL Observation Goals

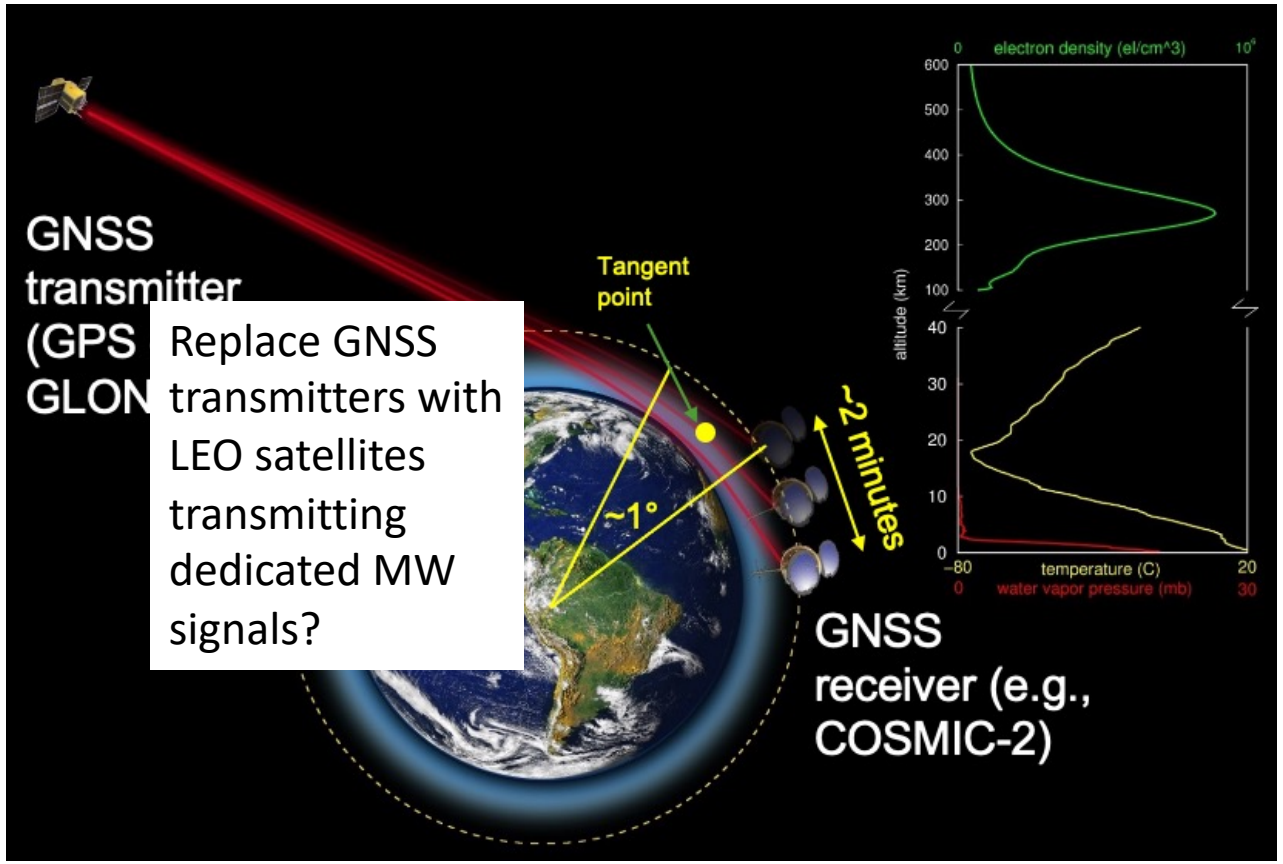
NASA PBL Incubation Study Team Report

Variable	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy
Water Vapor	0.1–100 km	0.1–1km	Minutes-Monthly	10%
Temperature				1 K
PBL Height		N/A		100 m



- Radio Occultation (RO) provides the best option for achieving the desirable high vertical resolution from space.
- GNSS-RO (which is an established technology) has been proven to provide vertical resolution of ~ 100 m.
- **GNSS-RO alone does not yield both temperature *and* water vapor in the PBL.**

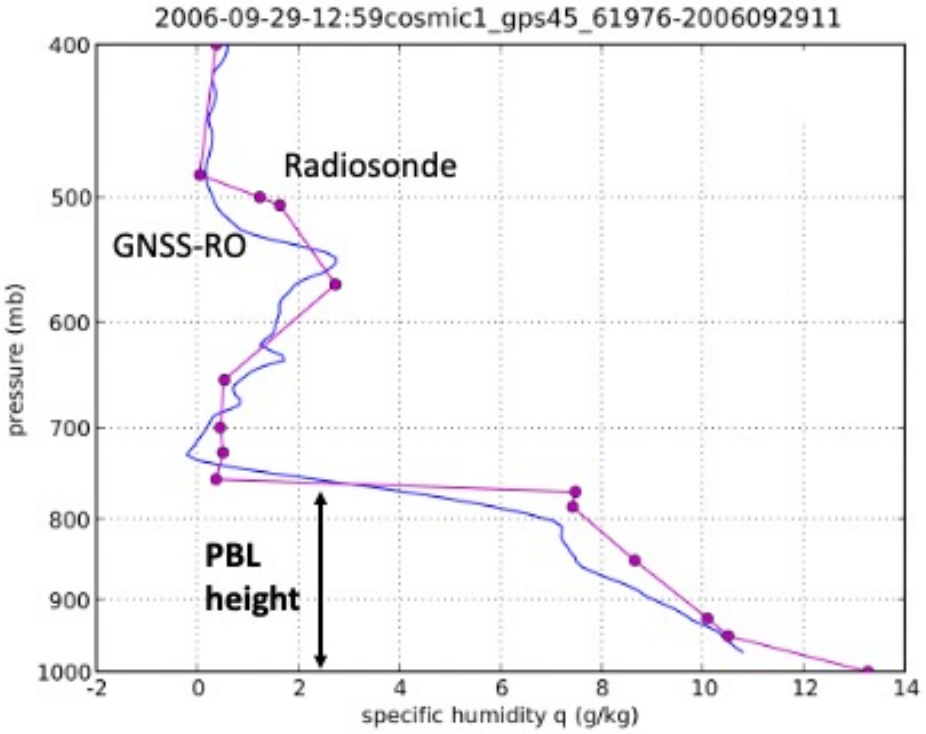
GNSS-RO



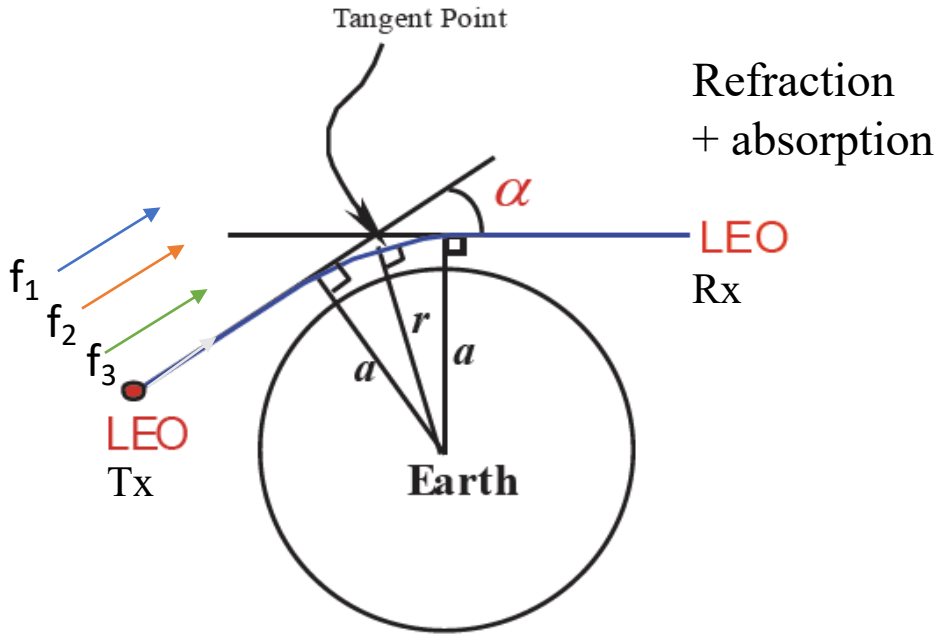
Replace GNSS transmitters with LEO satellites transmitting dedicated MW signals?

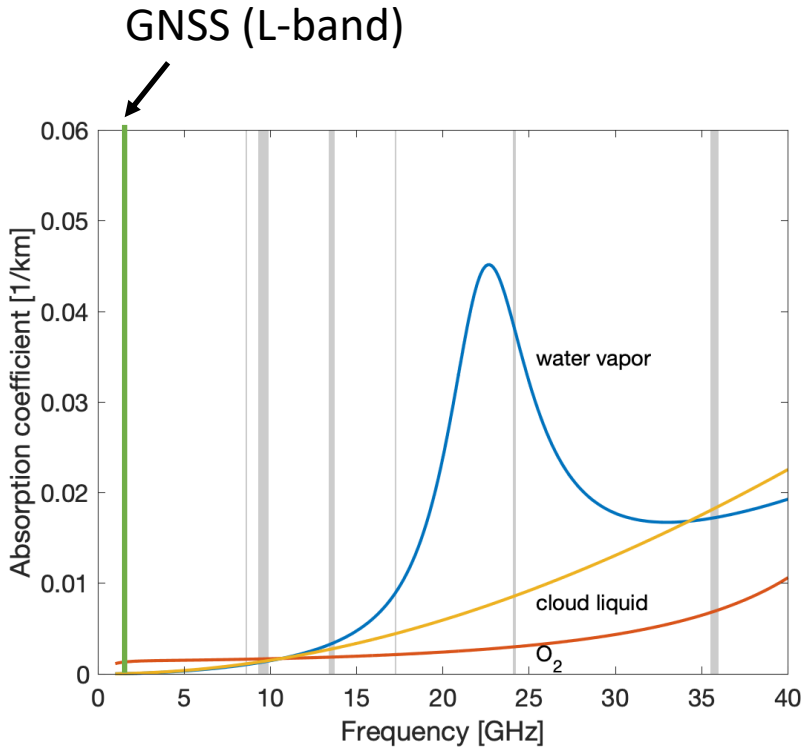
$$N = a_1 \frac{P}{T} + a_2 \frac{P_w}{T^2}$$

GNSS-RO water vapor retrievals from refractivity requires *a priori* temperature information



HiPPO (High vertical resolution PBL Profiling with LEO-LEO Occultation) Instrument Concept





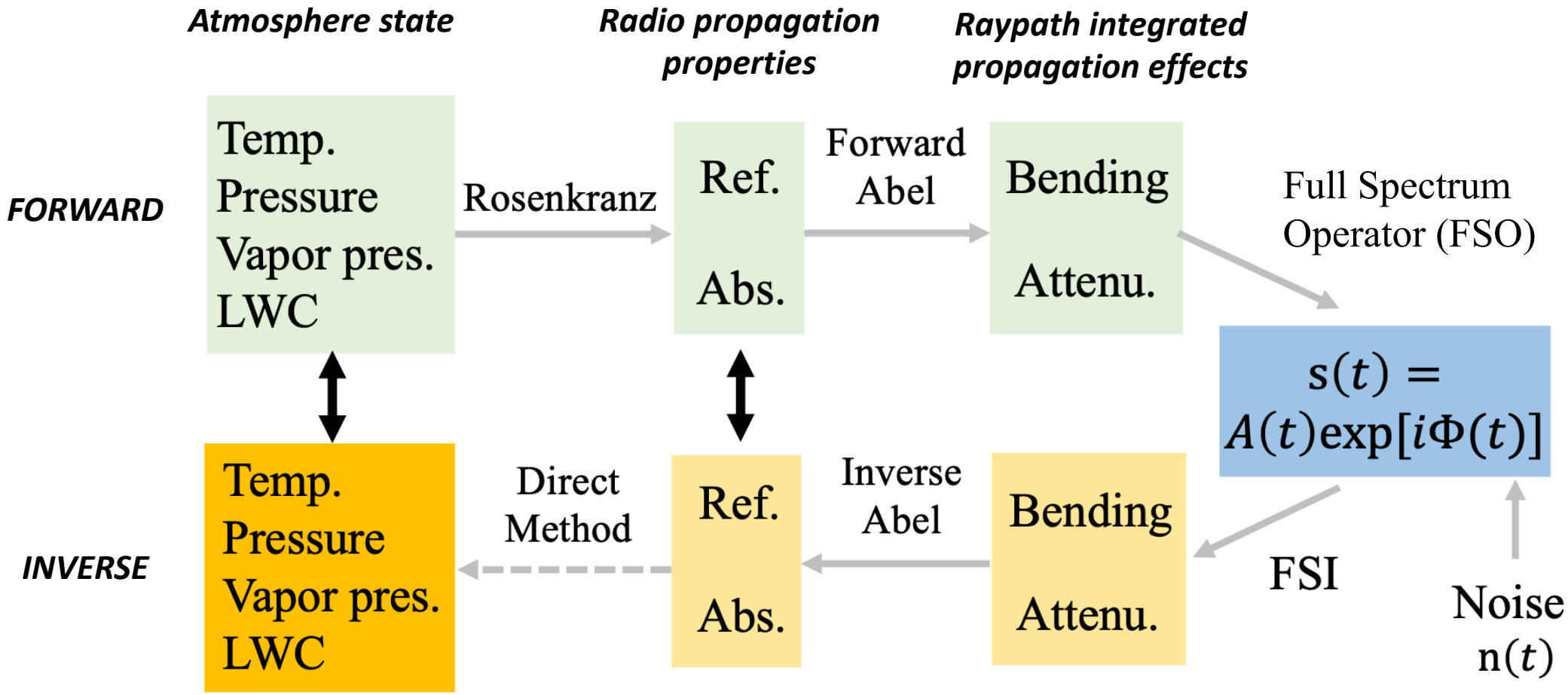
Accurately measuring the amplitude and phase at several frequencies (with different sensitivity to wv absorption) should allow retrievals of wv and T at high vertical resolution.

Grey areas represent frequencies allocated by FCC for active microwave measurements

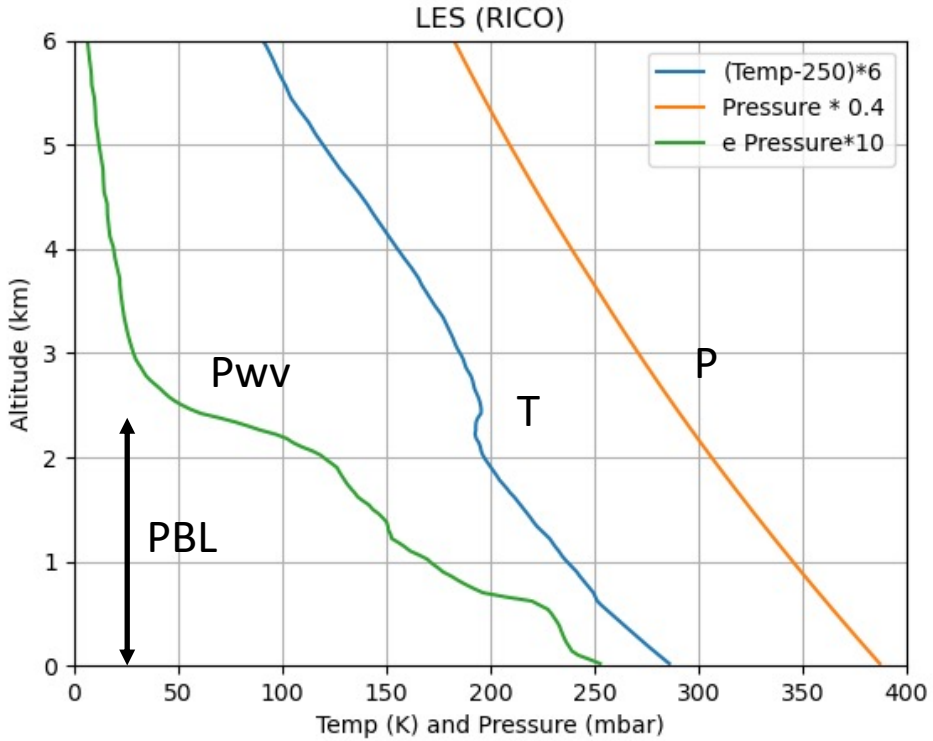
GNSS-RO vs. HiPPO

GNSS-RO	HiPPO
Tracks L-band (~1.5 GHz) signals transmitted by GNSS satellites in MEO orbits	Tracks microwave signals in multiple higher frequency bands (~ 8-30 GHz) that are sensitive to water vapor absorption
Large number of transmitters (GPS, GLONASS, Galileo, etc.) -> Large number of soundings per receiver	Need to provide our own transmitters as well as receivers on separate platforms
Sounding locations are quasi-random, depending on GNSS orbits	Allows better control of measurement locations
Phase measurements give refractivity profile which is a combination of T and q.	Phase and amplitude measurements could provide retrievals of T and q without a priori.
Mature and proven	Low TRL (1-2)

Assessing HiPPO Concept via End-to-End Simulations



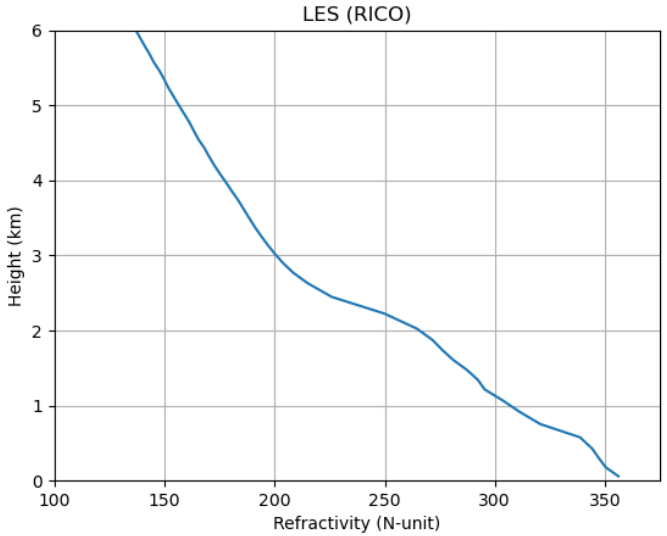
An Illustrative Example

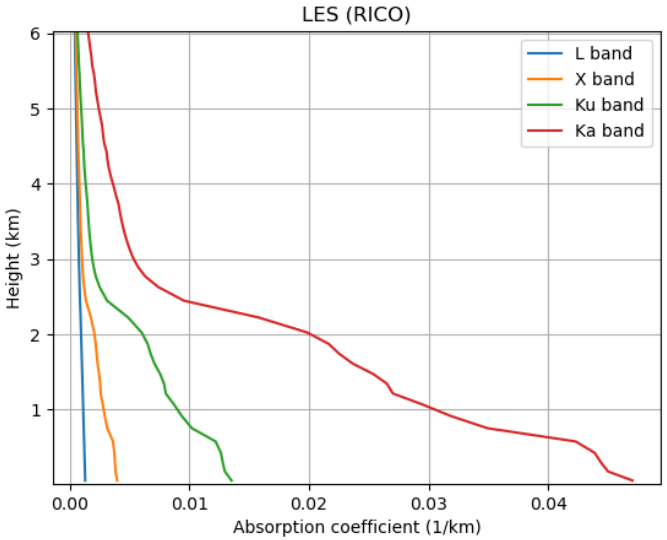


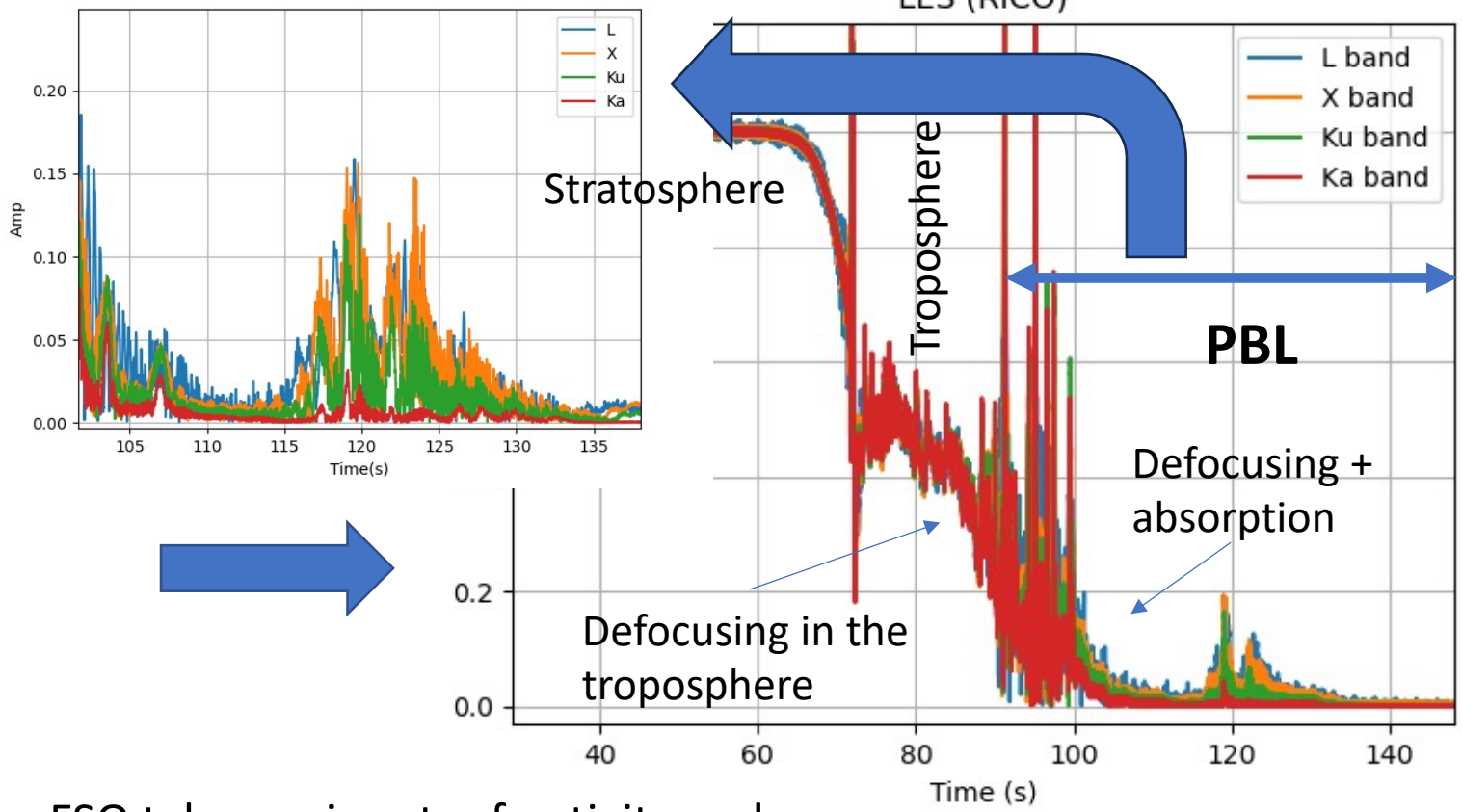
Profiles from Large Eddy Simulations of Marine Shallow Cumulus PBL
[Marcin Kurowski, JPL]

RICO (Rain in Cumulus over the Ocean) Campaign [Rauber et al. BAMS, 2007]

Forward Simulation (Signal Propagation)



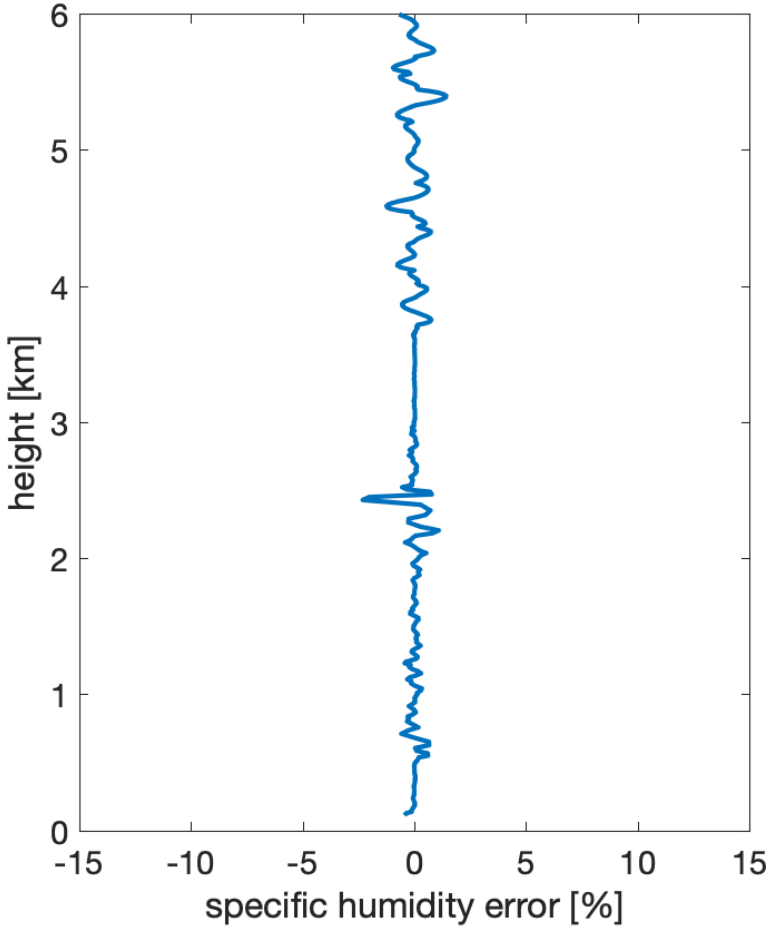


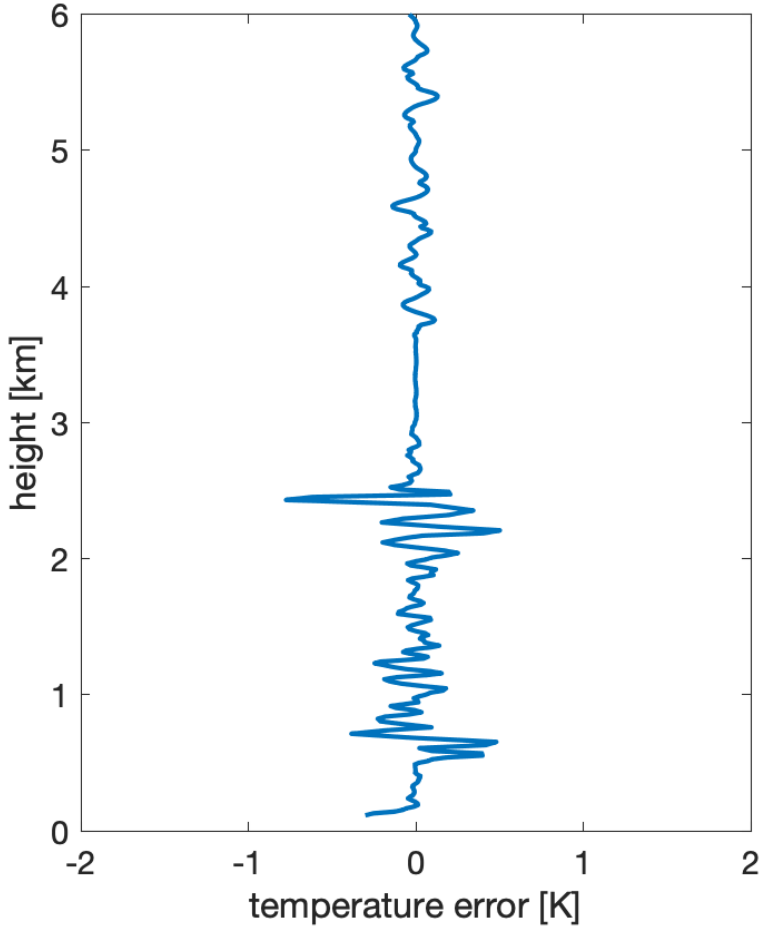


FSO takes an input refractivity and absorptivity profiles and produces signal amplitude and phase (not shown) along a circular orbit during an occultation event.

Atmospheric Retrievals (No Noise)

Ka-band results shown (similar for other frequencies)



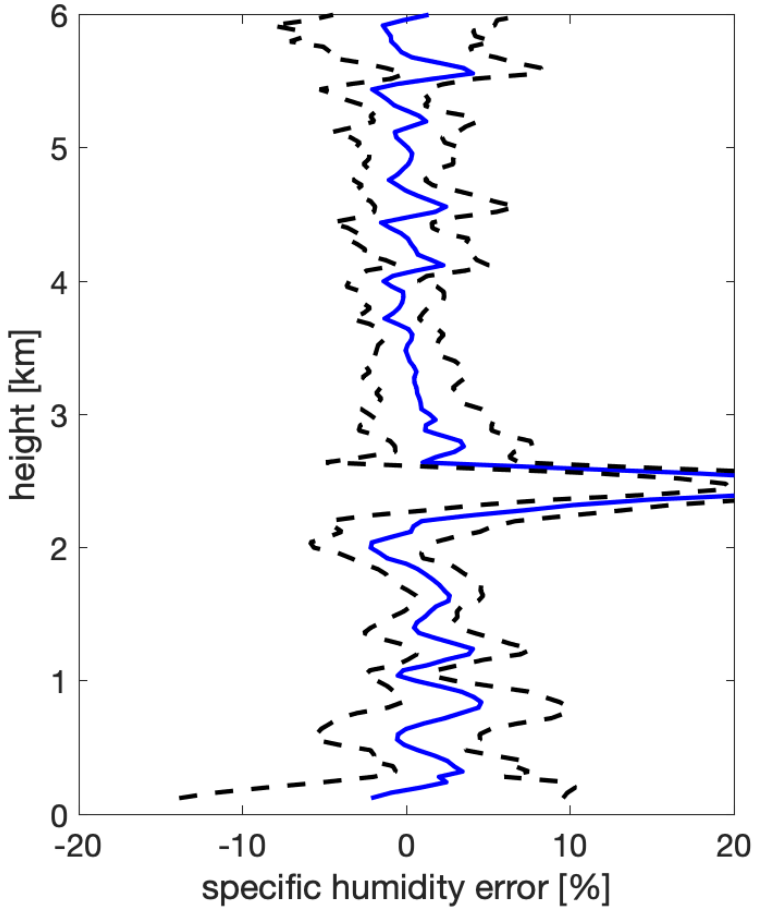


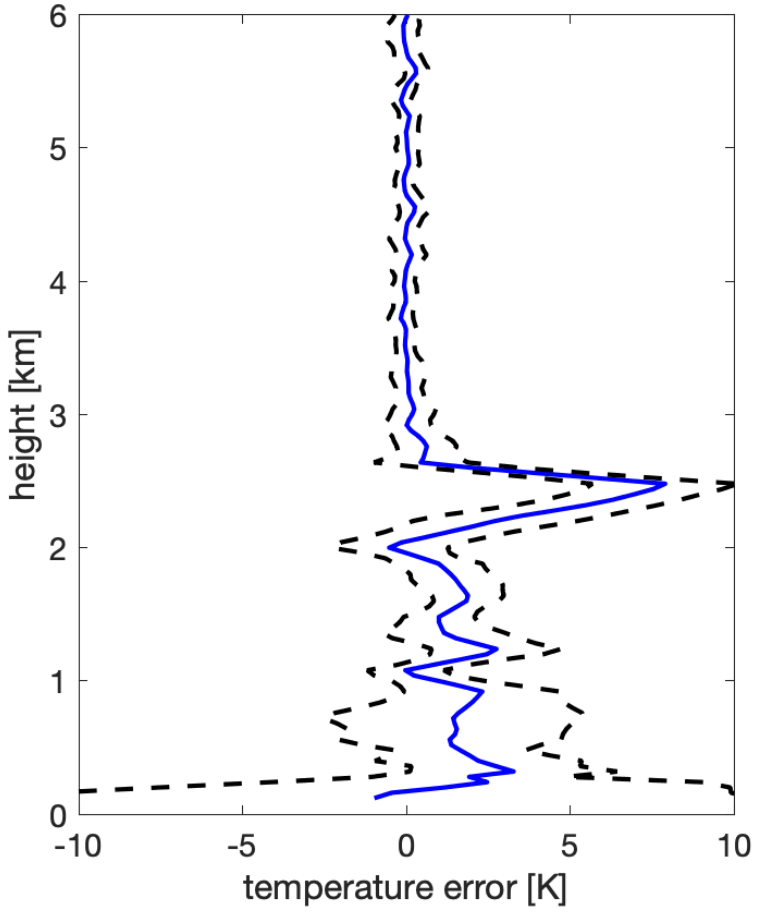
These results validate the end-to-end simulation system.

Some residual errors exist due to numerical error and representativeness error (especially near 2.5 km where the input profile is more sharply defined)

Atmospheric Retrievals (with Noise added, SNRv = 6000 V/V for all frequencies)

Ku-band (averaged over 40 realizations)



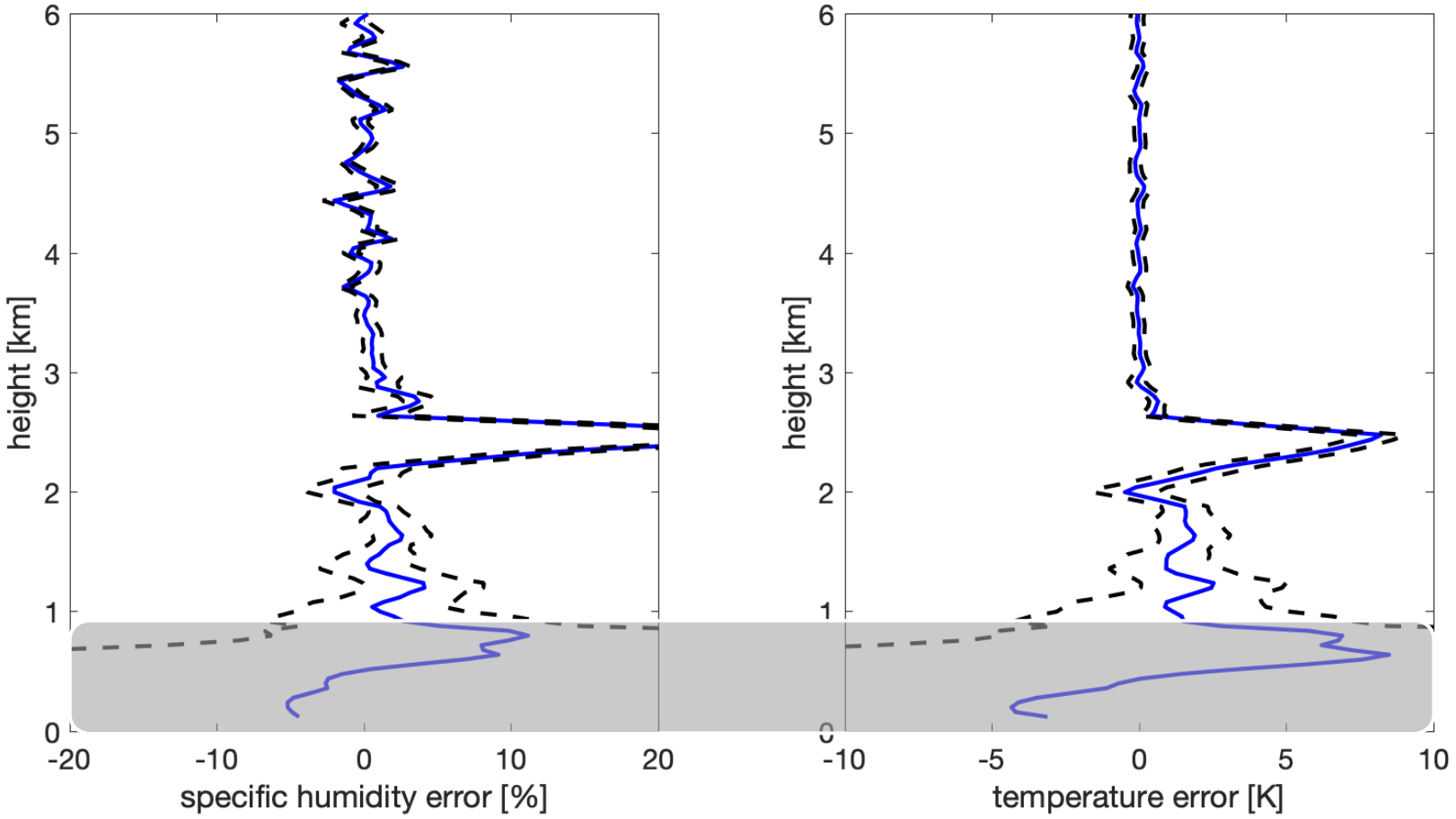


Ku-band measurements provide good wv retrieval within 10% except near 2.5 km.

Temp retrieval shows a slight bias near the surface (to be investigated).

Atmospheric Retrievals (with Noise added, SNRv = 6000 V/V for all frequencies)

Ka-band (averaged over 40 realizations)

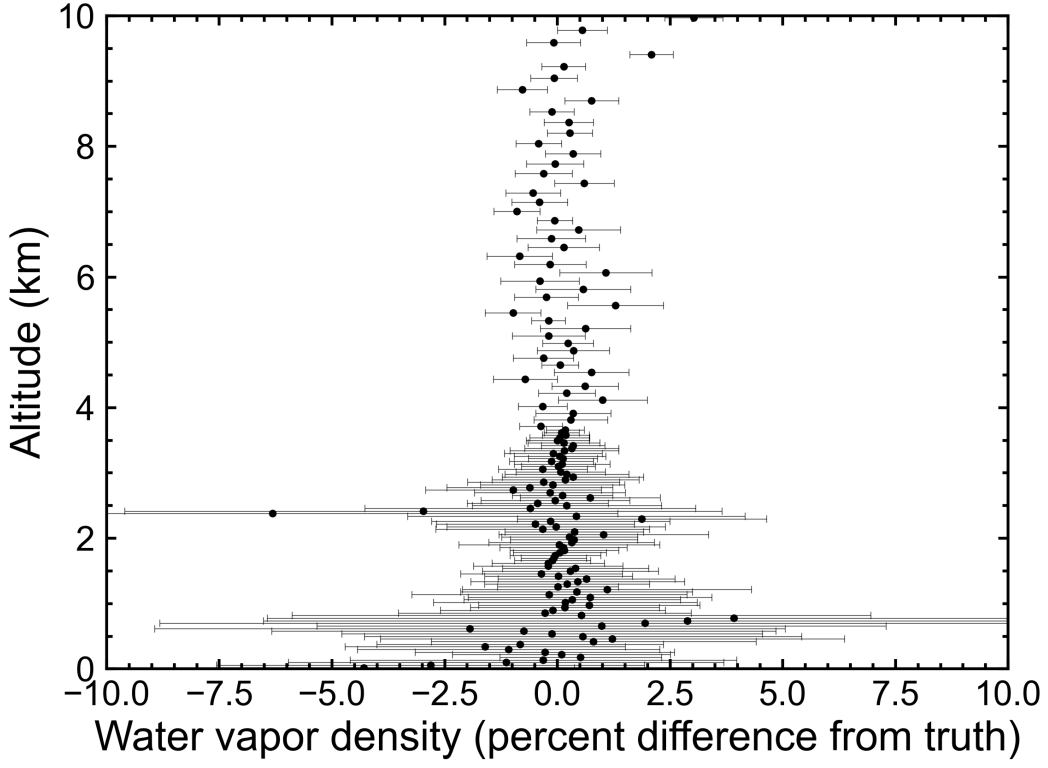


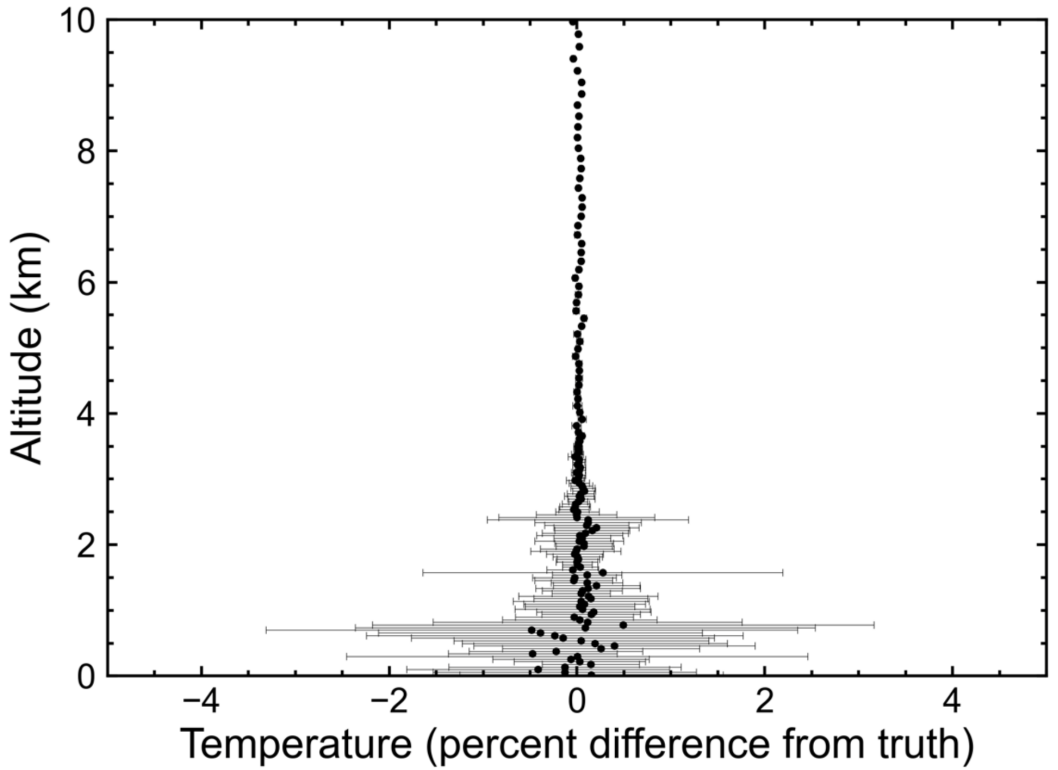
Ka-band measurements provide good wv and temp retrievals above 1 km.

Below ~ 1 km, there is too much attenuation due to wv absorption.

Multiple-Frequency Retrievals

We have also implemented a multi-frequency optimal estimation retrieval approach that solves WV and T using refractivity and absorptivity from all frequencies together. Results are promising.





Summary

- HiPPO is a new active limb-sounding technique being studied for profiling the PBL water vapor and temperature at high vertical resolution.
- HiPPO builds upon the success of GNSS-RO, but using higher frequencies that are sensitive to water vapor absorption.
- To assess the accuracy of this technique, a sophisticated end-to-end simulation system has been developed.
- We are in the process of fine tuning/validating the simulation results, which will allow us to derive key instrument requirements (SNR, optimal frequencies) under different PBL conditions.