Refractivity biases in O-B under precipitation conditions: new insights from polarimetric RO

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rohp-PAZ

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Polarimetric RO (PRO) in a nutshell

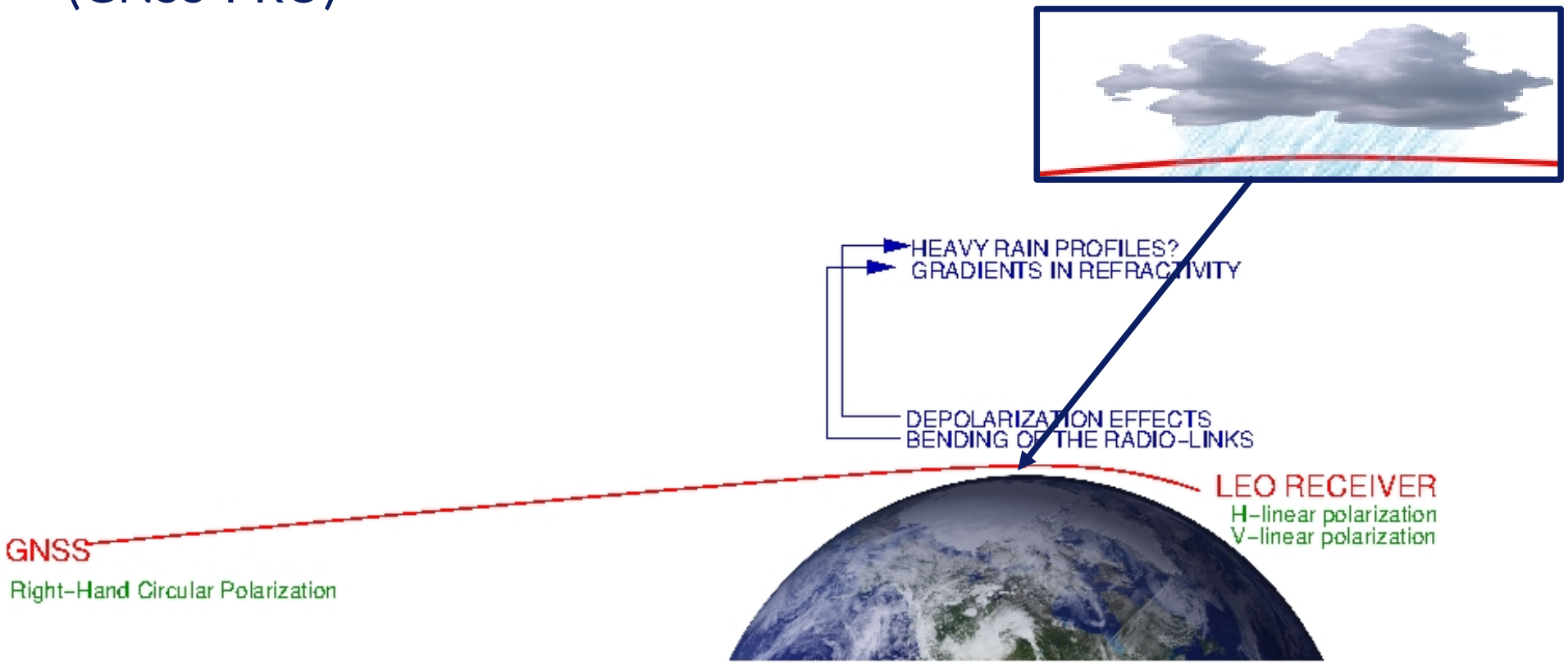
O-B biases under precipitating conditions: pre-PRO studies

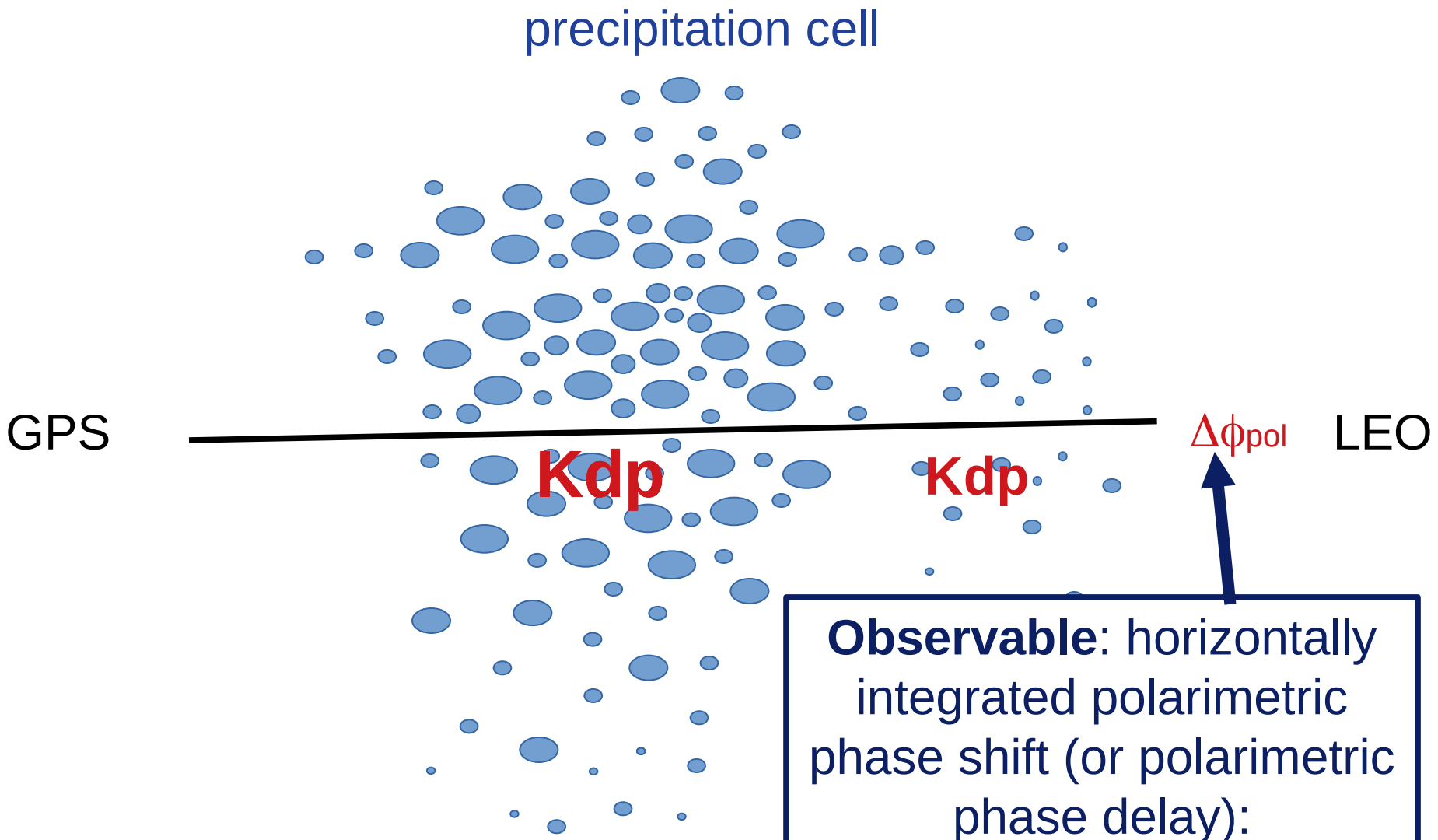
O-B biases under precipitating conditions: use of PRO data

Conclusions

- Polarimetric RO (PRO) is a **NEW MEASUREMENT CONCEPT**

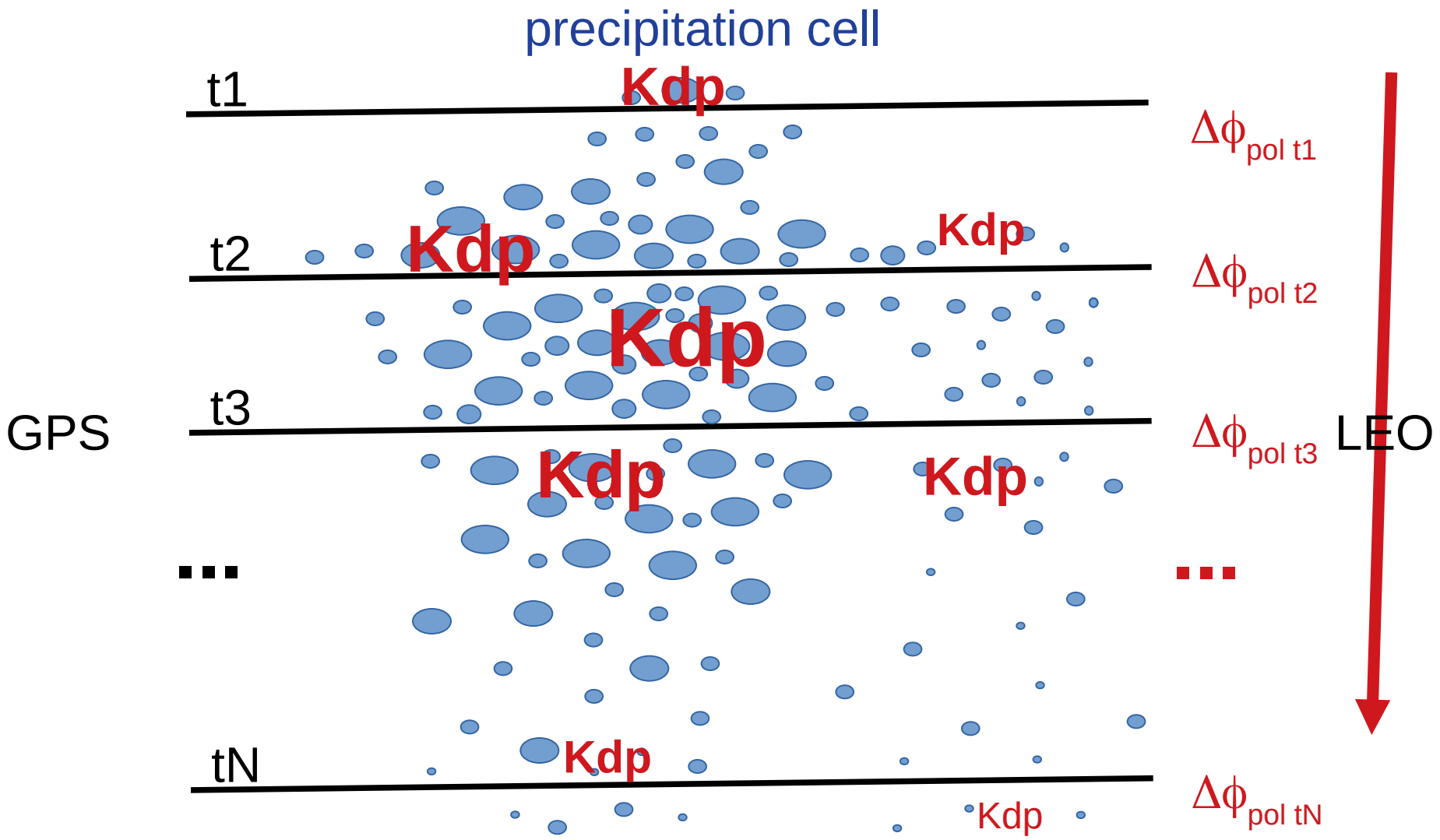
- It combines **radio occultation links** of the GNSS with the **polarimetric properties** of the forward **scattering off non-spherical hydrometeors**: GNSS polarimetric radio occultations (GNSS-PRO)





Observable: horizontally integrated polarimetric phase shift (or polarimetric phase delay):

$\Delta\phi_{pol} = \phi_H - \phi_V$



Vertical scanning, Δh ~ 200 m

This new measurement concept is being proved aboard the Spanish PAZ LEO

→ the Radio Occultation and Heavy Precipitation aboard PAZ experiment
(ROHP-PAZ)

Now we know it's also very sensitive to frozen particles
Doi:10.1109/TGRS.2021.3065119

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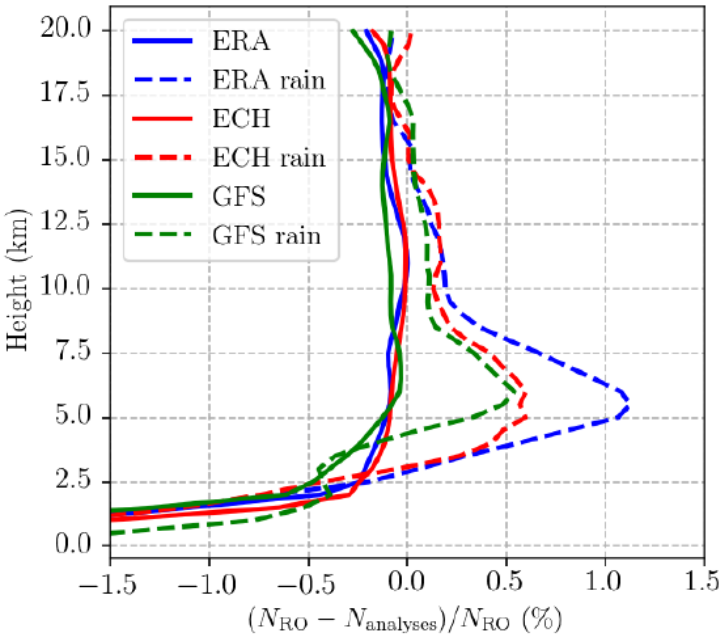
- Positive Refractivity bias under precipitation conditions reported
  (Nobs – Nmod) / Nobs > 0.5 %

- Two hypothesis have been proposed:

1) RO Data (Nobs) includes a hydrometeor scattering term, not accounted in Nmod:

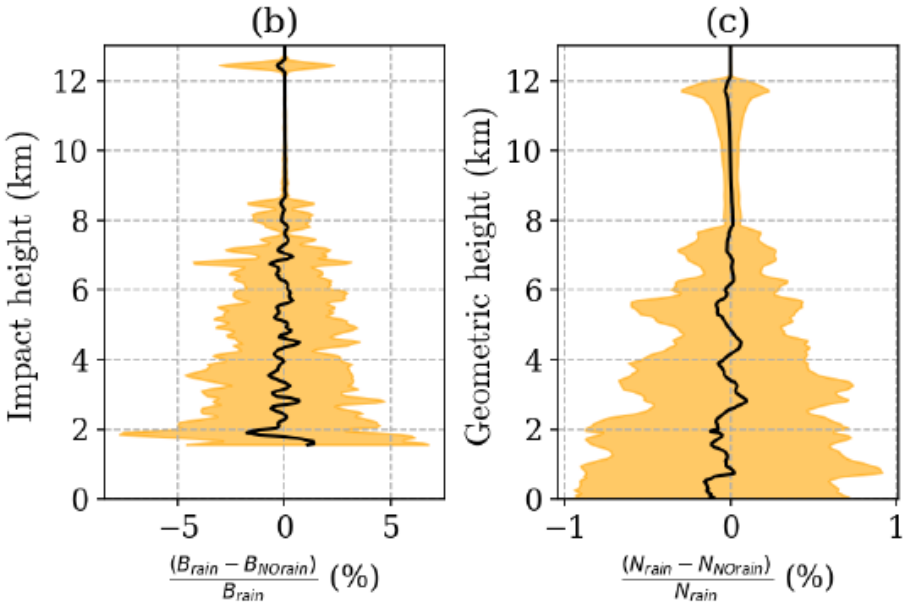
$$N = 77.6\ P/T + 3.37 \times 10^5\ e/T^2 + \mathbf{Wscat}$$

2) The bias appears because the models fail to reproduce thermodynamics in the precipitation area (low resolution, convection parameterization...)



10.5194/acp-18-11697-2018

- Padullés et al., 2018 (10.5194/acp-18-11697-2018)
  - Co-located COSMIC RO profiles with TRMM and GPM precipitation missions (65 intense cases)
  - The ancillary phase delay induced by scattering off rain droplets along the RO ray trajectories were simulated
  - The rain-induced ancillary phase delays were subtracted from the COSMIC RO excess phase
  - The modified excess phase profiles were inverted to refractivity
  - The difference between rain / rain-corrected refractivity profiles was statistically negligible
- Conclusion was that rain induced scattering term could not explain the reported biases



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- Now, a new dataset is available: PAZ polarimetric Δϕ.
- Δϕ is proportional to the presence of hydrometeors, including both rain and frozen particles (see next talks by Turk and Padullés).
- Δϕ and Nobs obtained within the same measurement: same geometry, same rays… naturally co-located.

- PAZ RO profiles analyzed 05/2018-12/2020 (~120,000 profiles)
- O-B statistics grouped by rain (IMERG), IR Tb (top cloud) and PRO Δϕ:

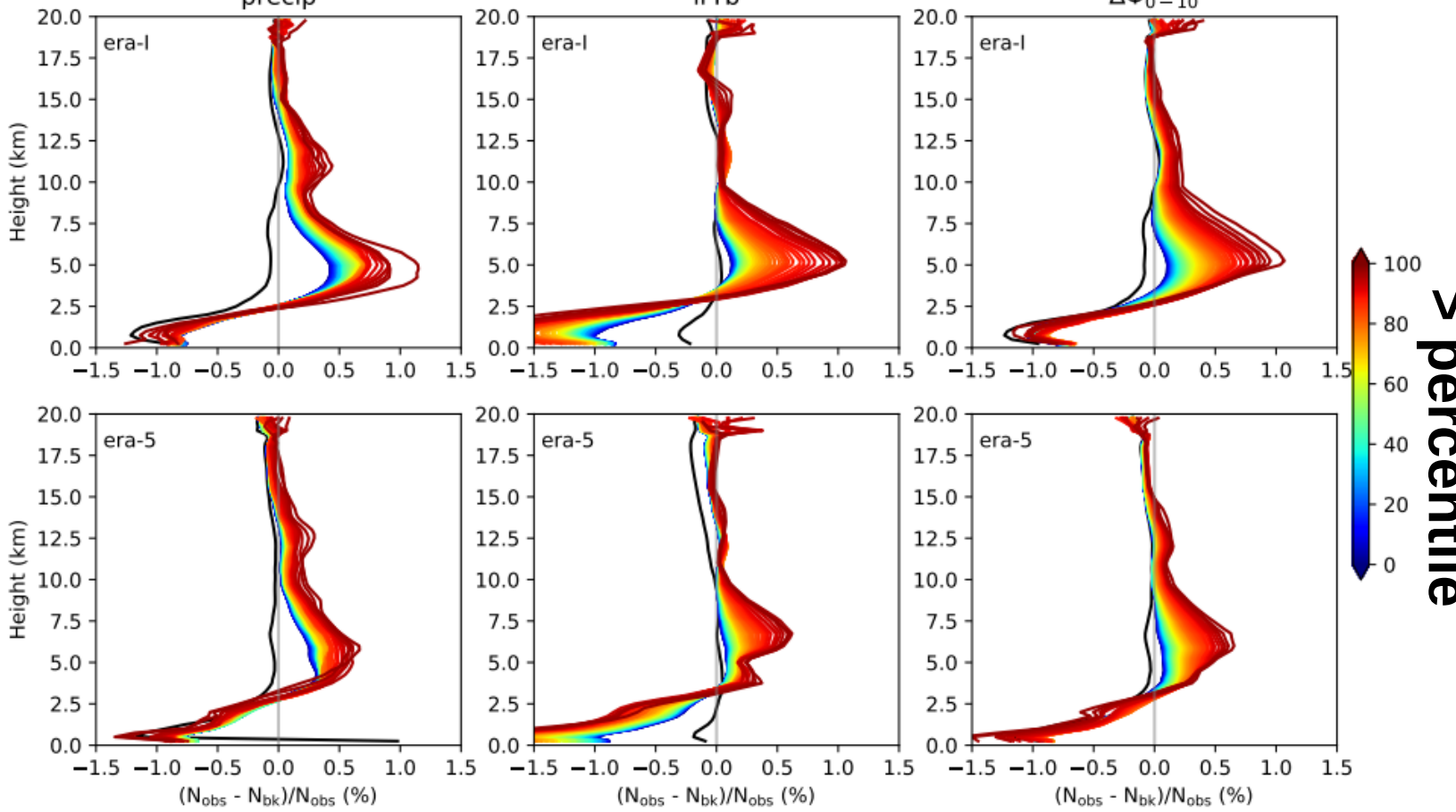
Precipitation dataset IMERG (global surface precip)

Geostationary Infrared brightness temperature (global, indication of cloud top temperature)

PAZ Δϕ averaged between 0 and 10 km

ERA Interim

ERA 5



Biases under precipitation: PRO

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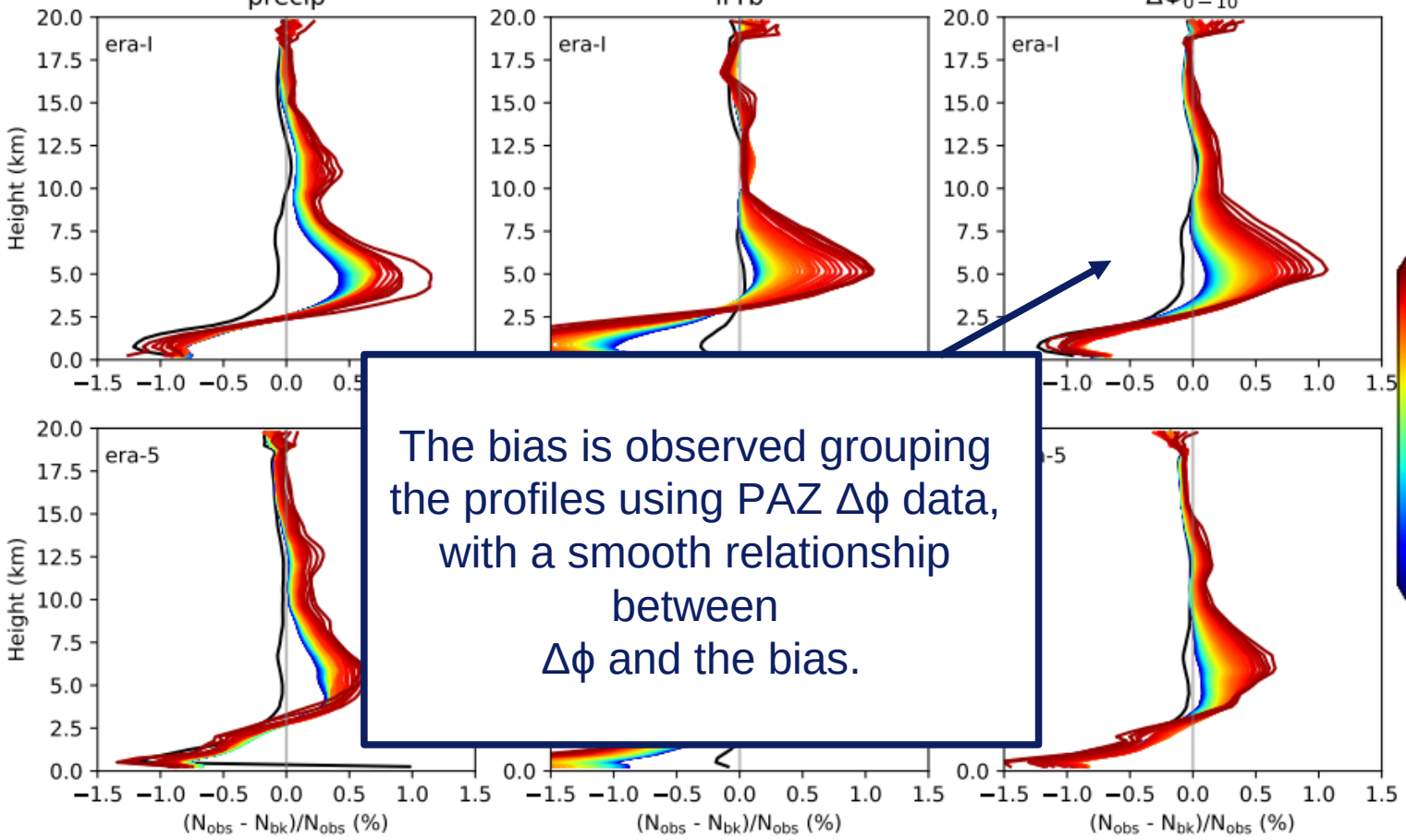

The bias is observed grouping the profiles using PAZ Δϕ data, with a smooth relationship between Δϕ and the bias.

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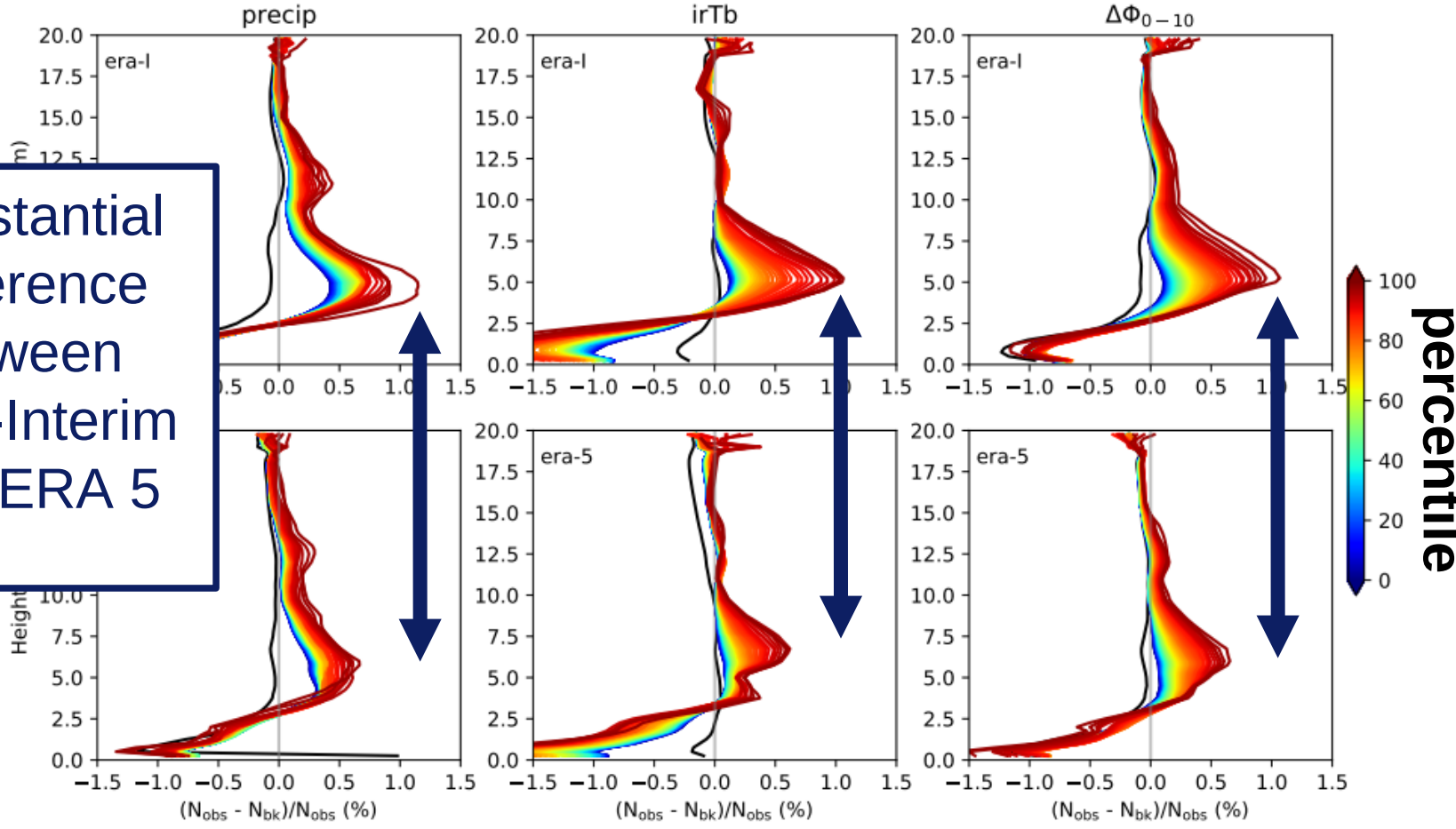

ERA

ERA

Substantial difference between ERA-Interim and ERA 5

Biases under precipitation: PRO

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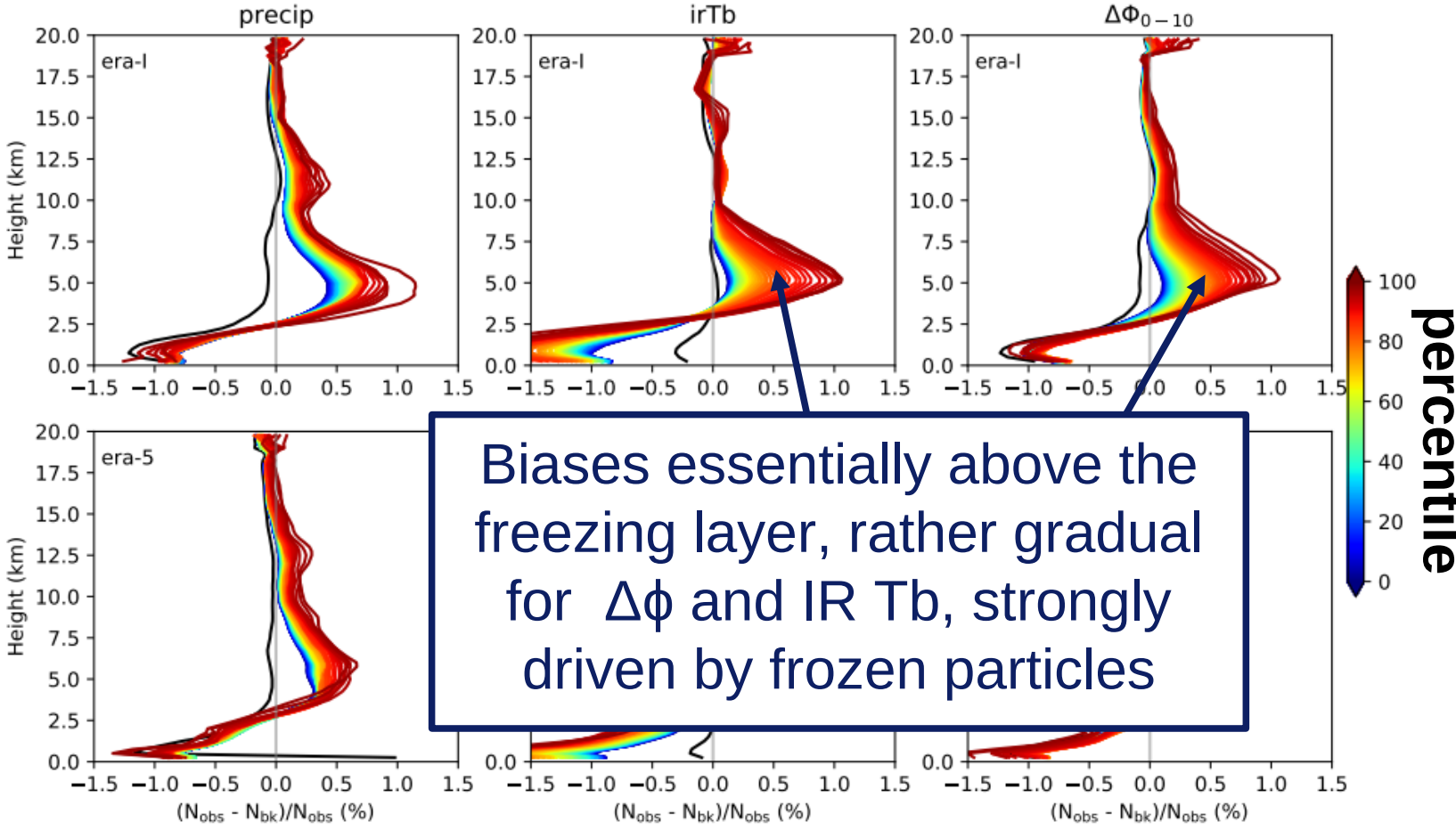
ERA Interim

ERA 5



Biases essentially above the freezing layer, rather gradual for Δϕ and IR Tb, strongly driven by frozen particles

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- In 2018 studies, the rain-induced scattering was proven to be statistically negligible.
- The higher altitude frozen particles were not accounted for.
- More recent analysis models (e.g. ERA-5 vs ERA-I) reduce the bias.

Is the remaining bias due to scattering off frozen particles?

Or still an issue of the model?

We want to assess the effect of the scattering into the **refractivity retrieval**, taking **advantage of the PAZ polarimetric Δϕ** measurements and accounting for **frozen particles.**

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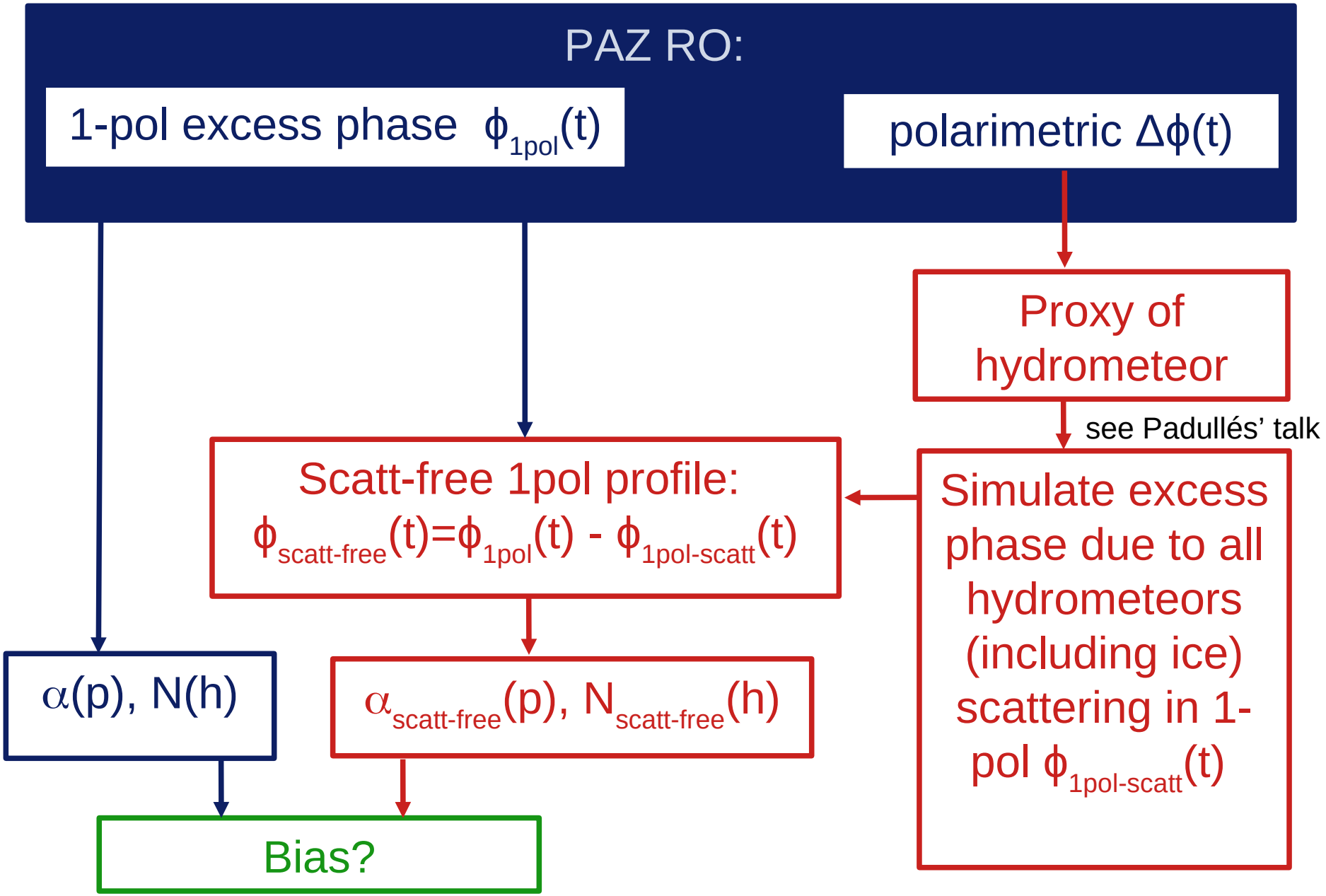
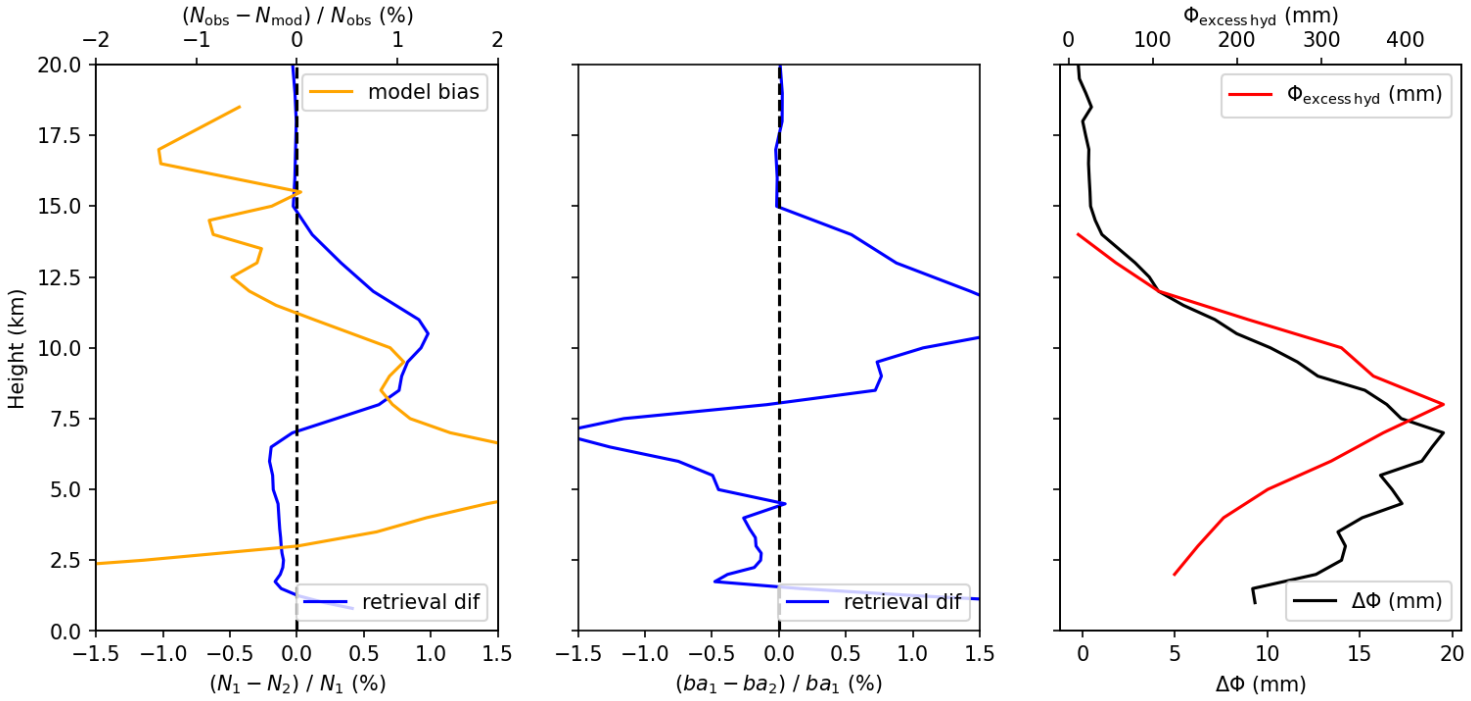


- A particular case, example:

$\Delta\phi(t)$ and $\phi_{1pol\text{-}scatt}(t)$

$\alpha(p)$ - $\alpha_{scatt\text{-}free}(p)$

N(h) - $N_{scatt\text{-}free}(h)$



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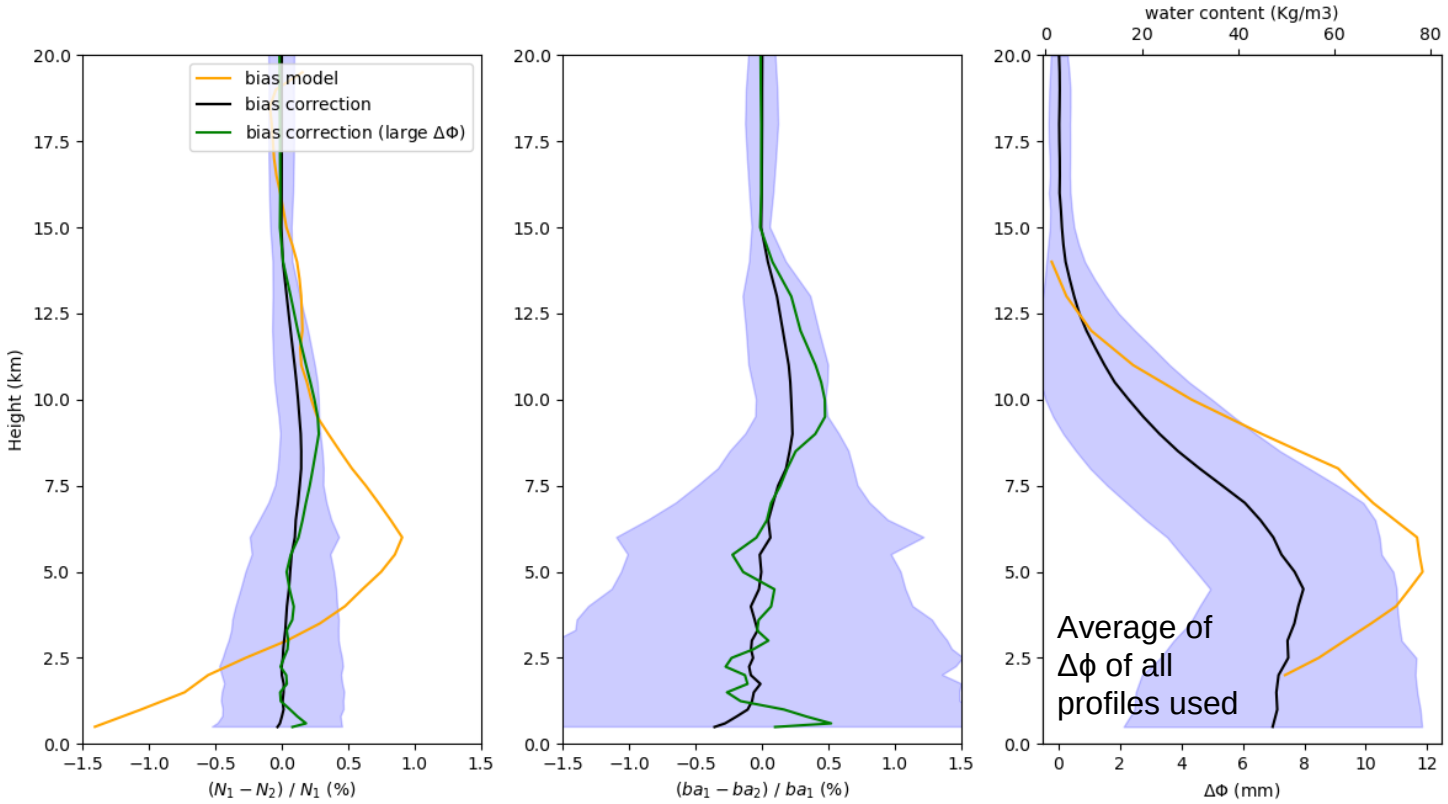
Statistically, bias found? (using 500 cases of strongest Δϕ)



Statistically, the biases cancel out.

The full hydrometeor scattering term, including ice/frozen particles, does not seem to explain the biases

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- Despite particular cases do present scattering effects, the ensemble cancels out → the scattering term cannot explain the biases (hypothesis-1 discarded)

- It seems that hypothesis-2, systematic effects in NWP models, would explain the biases.

- How can GNSS polarimetric RO help?
  - Data available to further study these phenomena.
  - To help diagnosis in NWP: cases where NWP is prone to errors.
  - To help NWP by assimilating polarimetric $\Delta\phi$ as 'flags' (nudging), or as potential indicators of different regimes/parameterization schemes.

Conclusions

- Biases reported in RO under precipitating conditions (< 2018).
- Two hypothesis
  - (1) RO data affected by hydrometeor scattering terms, not accounted in Nmod;
  - (2) issue with the NWP models.
- 2018: study found rain-induced scattering does not explain the biases (hypothesis-1 discarded).
- > 2018: polarimetric RO, PAZ data, sensitive to hydrometeors, strong sensitivity to frozen particles.
- Hypothesis-1 be revisited, effect of frozen / ice particles?
- Polarimetric RO data (PAZ) used for the study.
- Scattering term has effects on individual profiles, but it does not explain the biases → biases likely to be due to the NWP model performance under rainy / convective / cold high clouds.
- Polarimetric RO data can help further studying these aspects, as diagnosis tool for NWP or potential nudging/flag approach.

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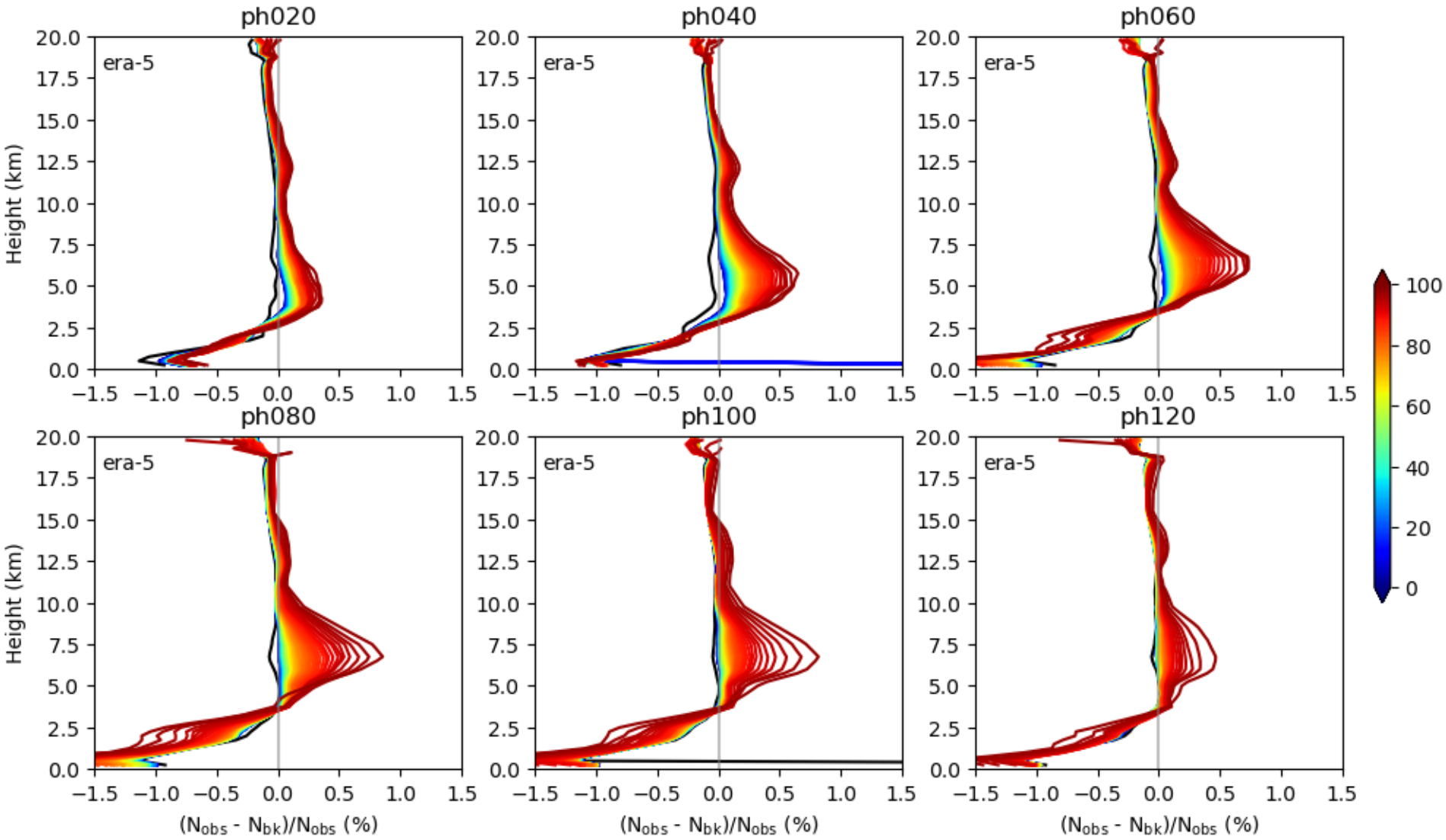
More info and data access:
https://paz.ice.csic.es

Biases grouped by $\Delta\phi$ at a given altitude (ERA5)



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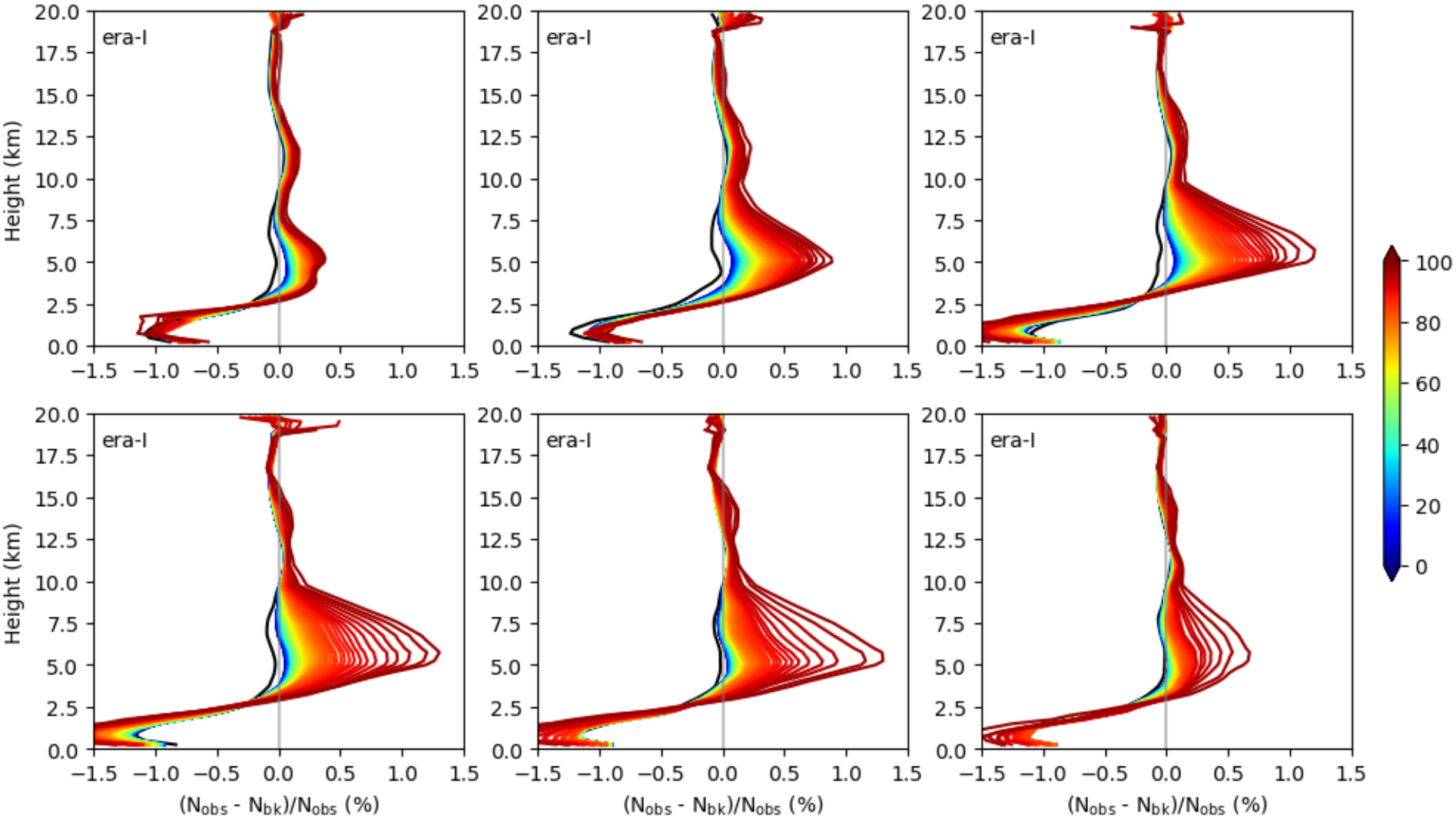
Biases grouped by $\Delta\phi$ at a given altitude (ERA-I)



Using collocations between PAZ and Microwave Radiometers, we can use the observed water content (not derived by PAZ, but from MW). Mostly sensitive to liquid water content and snow above it. Details in next talk (F.J Turk)