Precipitation and ice retrievals from PAZ Polarimetric Radio Occultations

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8th International Radio Occultation Working Group Meeting

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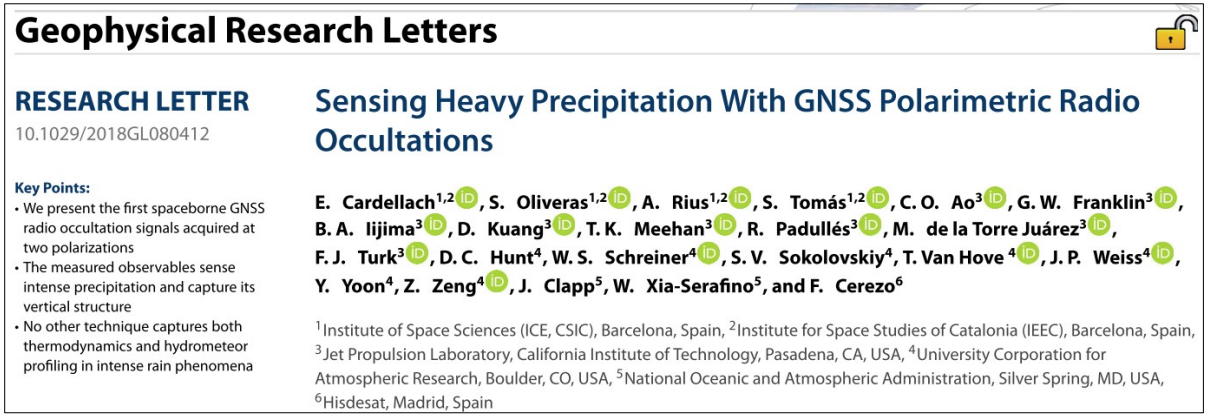
Motivation

Since its activation in May 2018 PAZ has collected 249,783 polarimetric RO

Soon after activation we demonstrated the sensitivity to heavy precipitation

Recently, we have demonstrated that PRO is also sensitive to horizontally oriented frozen particles, way above the freezing level



Geophysical Research Letters

RESEARCH LETTER
10.1029/2018GL080412

Key Points:
- We present the first spaceborne GNSS radio occultation signals acquired at two polarizations
- The measured observables sense intense precipitation and capture its vertical structure
- No other technique captures both thermodynamics and hydrometeor profiling in intense rain phenomena

Sensing Heavy Precipitation With GNSS Polarimetric Radio Occultations

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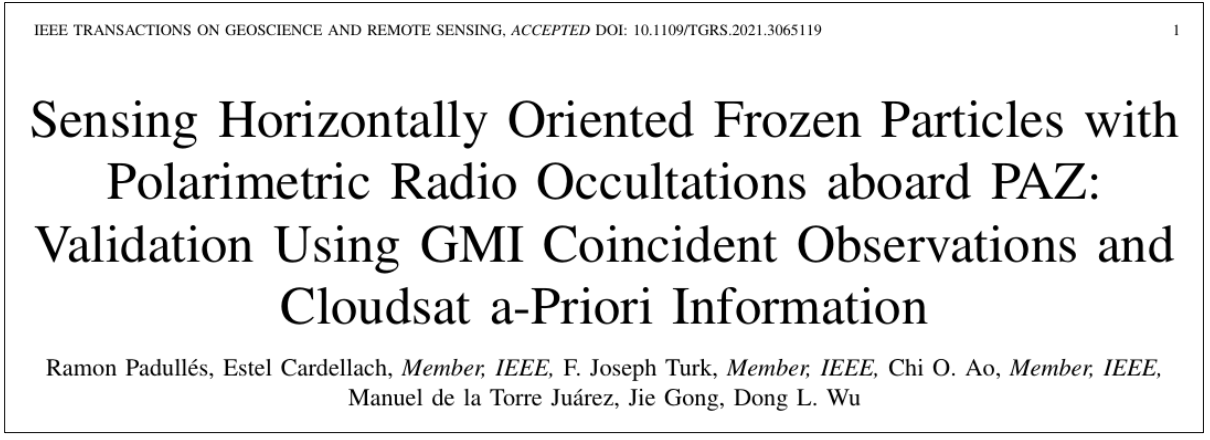


IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, *ACCEPTED* DOI: 10.1109/TGRS.2021.3065119 1

Sensing Horizontally Oriented Frozen Particles with Polarimetric Radio Occultations aboard PAZ: Validation Using GMI Coincident Observations and Cloudsat a-Priori Information

Ramon Padullés, Estel Cardellach, *Member, IEEE,* F. Joseph Turk, *Member, IEEE,* Chi O. Ao, *Member, IEEE,* Manuel de la Torre Juárez, Jie Gong, Dong L. Wu

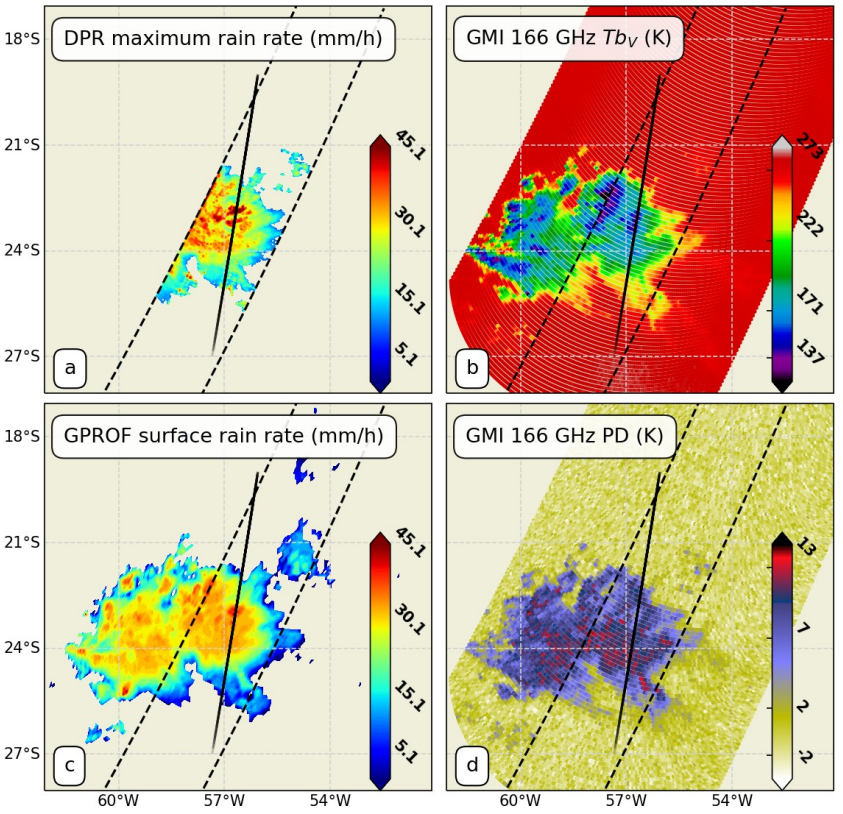
Motivation

Examples:

Coincident observation with **GPM radar** (Ka & Ku band, 15-35 GHz)

Simulations using liquid phase precipitation cannot explain PAZ Δϕ

Radiometer GMI 166 GHz Tb indicates presence of frozen particles, and PD (TbV-TbH) indicates orientation



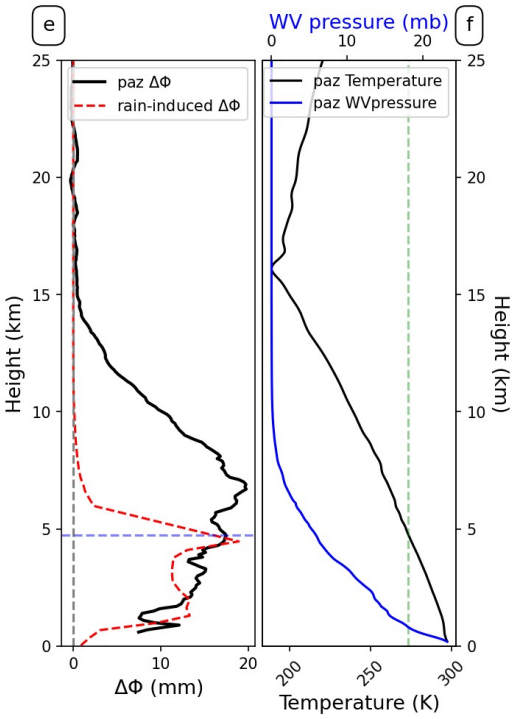
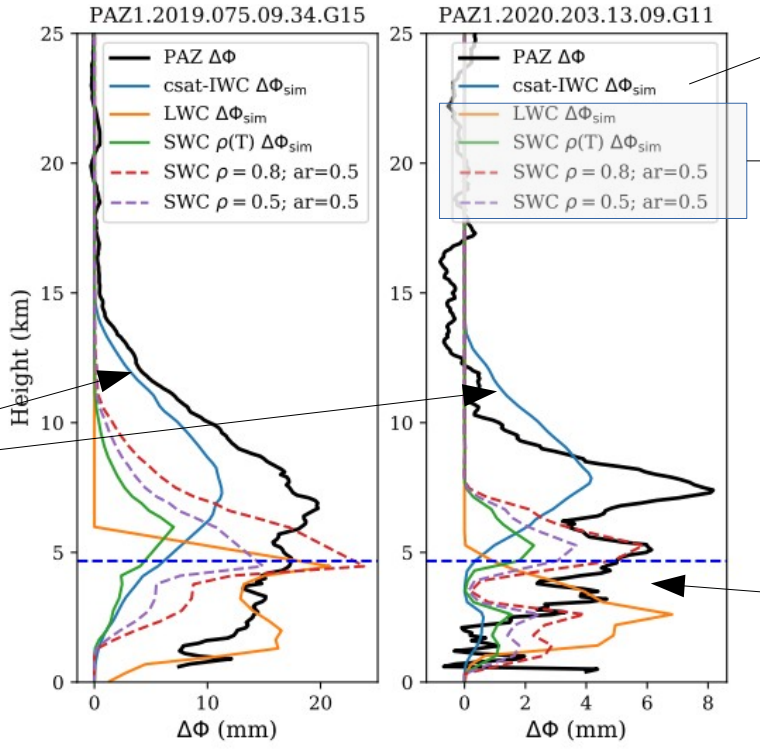


Figure from Padullés et al, 2021, IEEE TGRS (accepted) doi: 10.1109/TGRS.2021.3065119

Motivation

Examples:

We need retrievals from **Cloudsat** (radar 94 GHz) to explain PAZ Δϕ.



Cloudsat retrievals

GPM retrievals

Better match with observations using Cloudsat retrievals in the higher layers *(room for improvement changing parameters)*

GPM retrievals explain the lower layers

Figure from Padullés et al, 2021, IEEE TGRS (accepted) doi: 10.1109/TGRS.2021.3065119

Motivation

We know we are sensitive to ice, so
Can we attempt ice retrievals in the higher layers?

(where there is little contamination from the liquid, and the ray-paths within clouds are not as long as in the lower layers)

PAZ Δϕ Climatology

Climatology approach

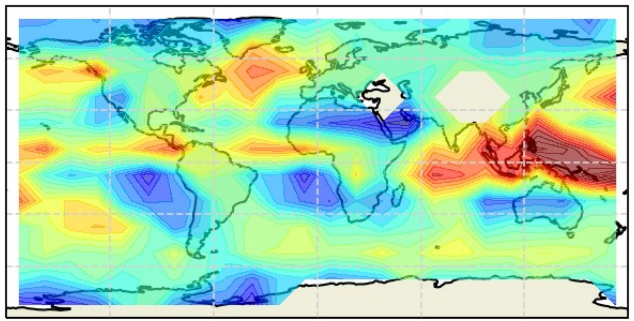
- **Objective:** To look for a relationship between PAZ Δϕ and Ice Water Content, as a function of height and region
- **Challenge:** No direct collocations with Cloudsat (or any other radar sensitive to ice particles). How to build an empirical relationship? How to validate it?
- **Approach:** Empirical relationship between PAZ Δϕ climatology and Cloudsat Ice Water Content climatology

PAZ Δϕ Climatology

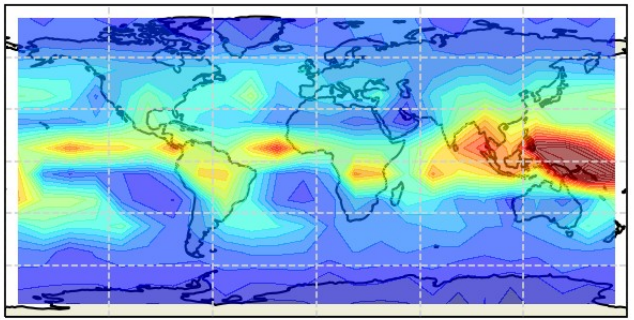
Relationship between Δϕ and water content

PAZ Δϕ Climatology

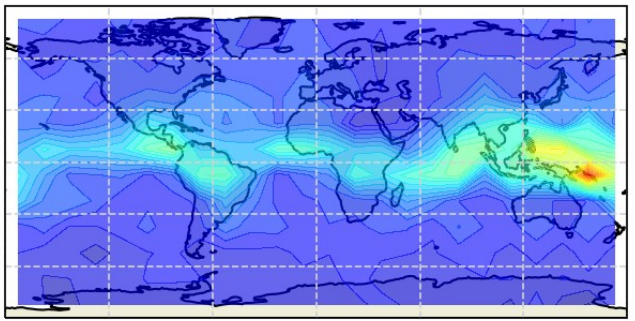
Tangent height = 2 km



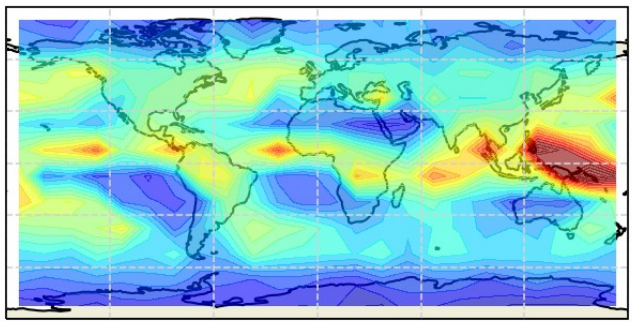
Tangent height = 6 km



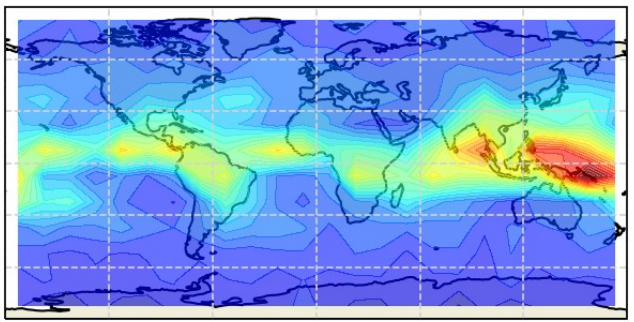
Tangent height = 10 km



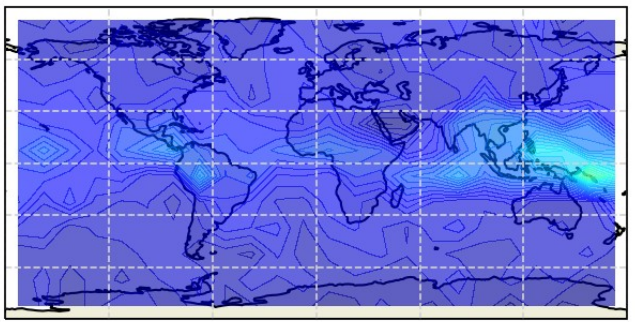
Tangent height = 4 km



Tangent height = 8 km



Tangent height = 12 km

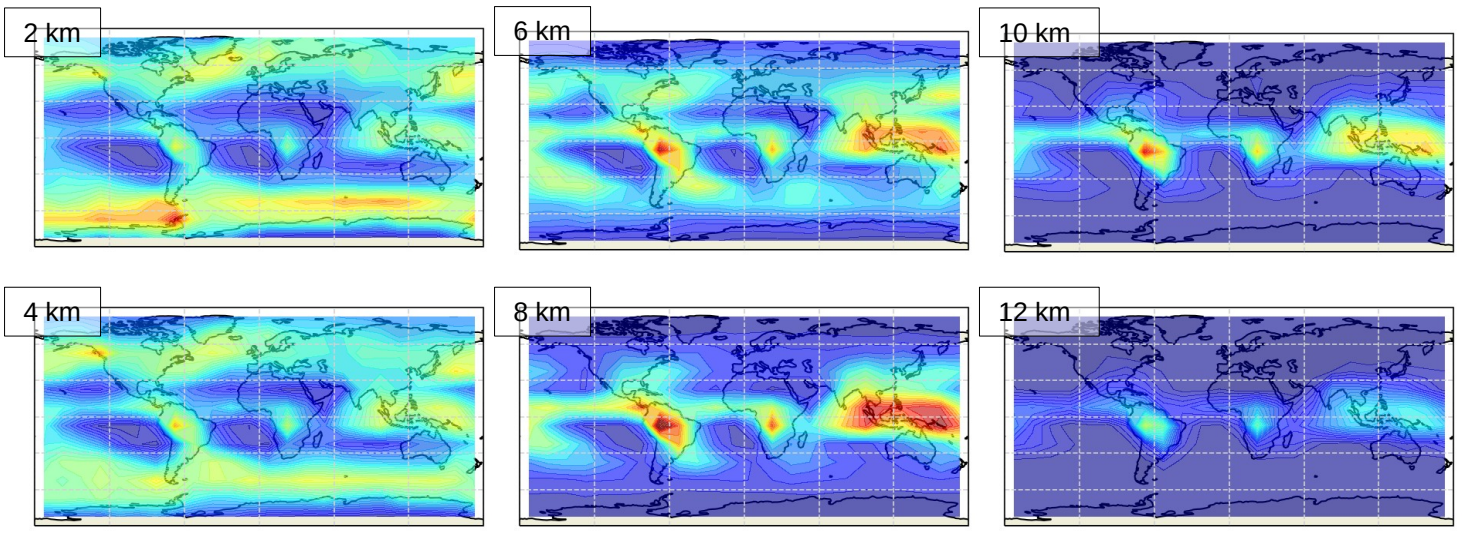


PAZ Δϕ Climatology

We compare it with Cloudsat (radar):

- Taking into account the RO geometry
- 680,000 “events” (2009 – 2016)
- Integrated water content along RO ray

Cloudsat WC Climatology

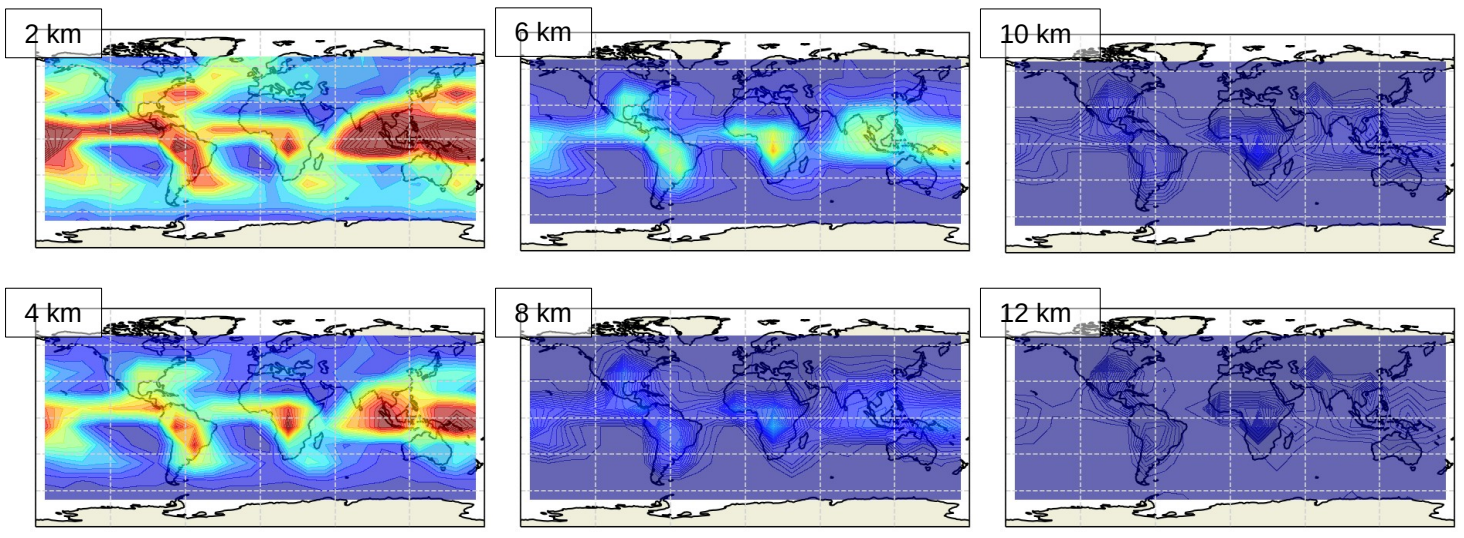


PAZ Δϕ Climatology

We compare it with GPM – DPR (radar):

- Taking into account the RO geometry
- 350,000 “events” (2015 – 2017)
- Integrated water content along RO ray

GPM WC Climatology

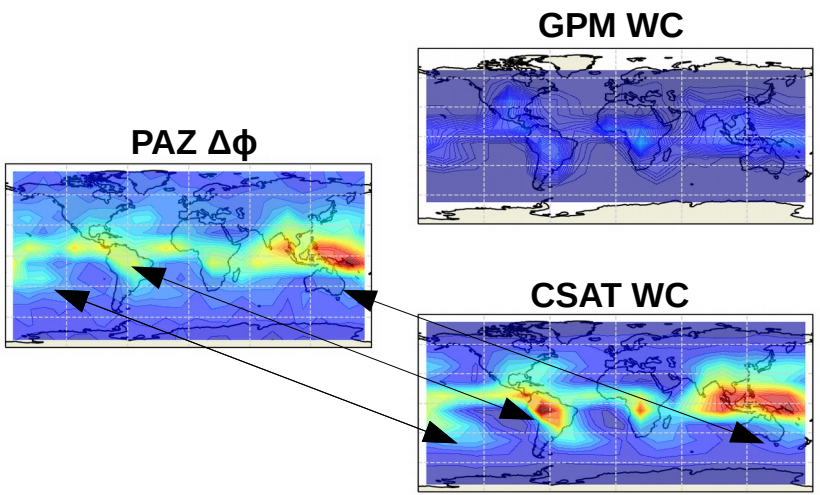


PAZ Δϕ Climatology

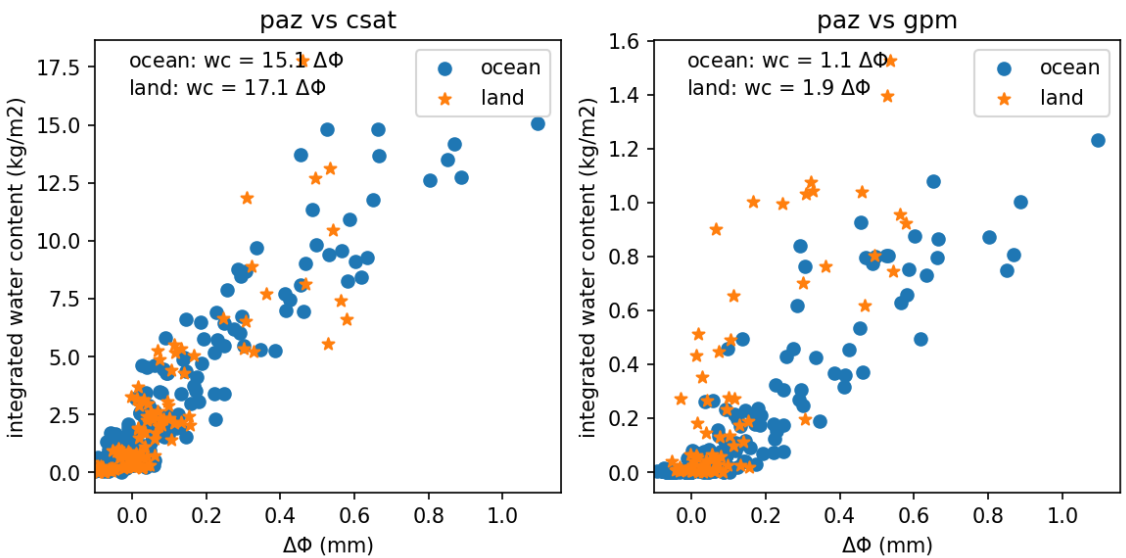
Relationship between Δϕ and water content

Spatial correlation between Δϕ and WC for the different satellites

Using the same binning, we compare the climatologies (at 8 km)



Height = 8km



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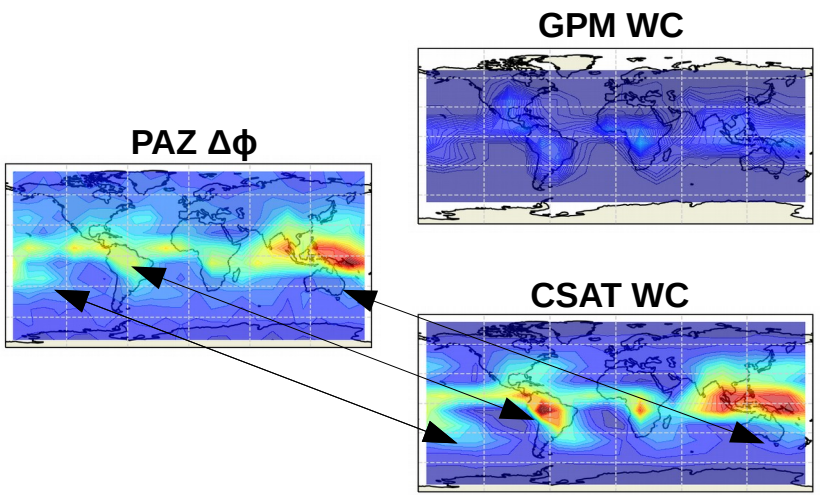
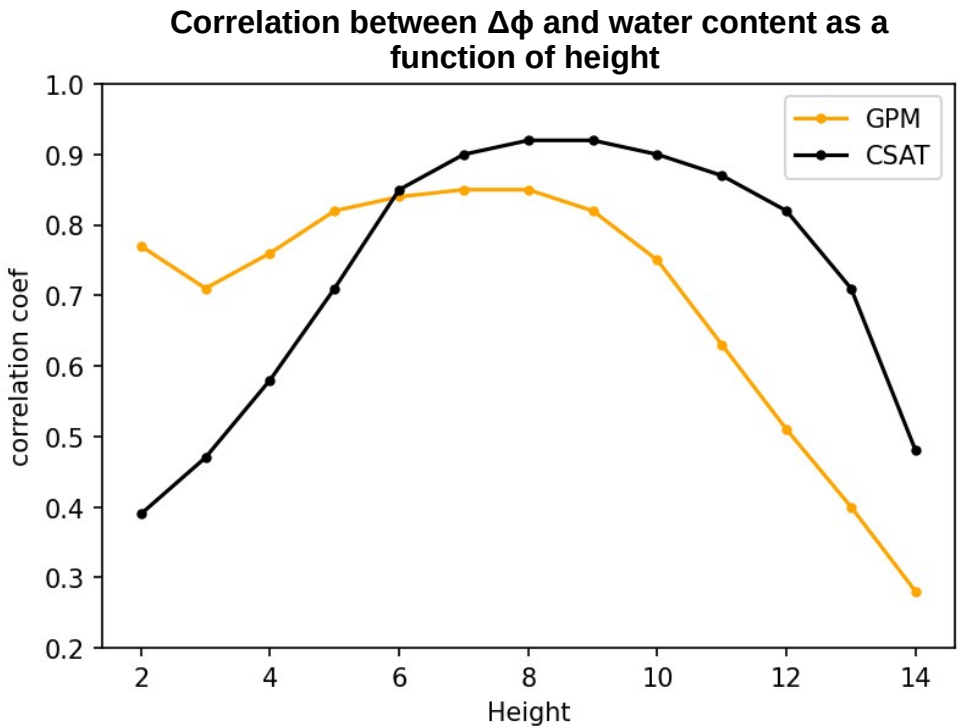
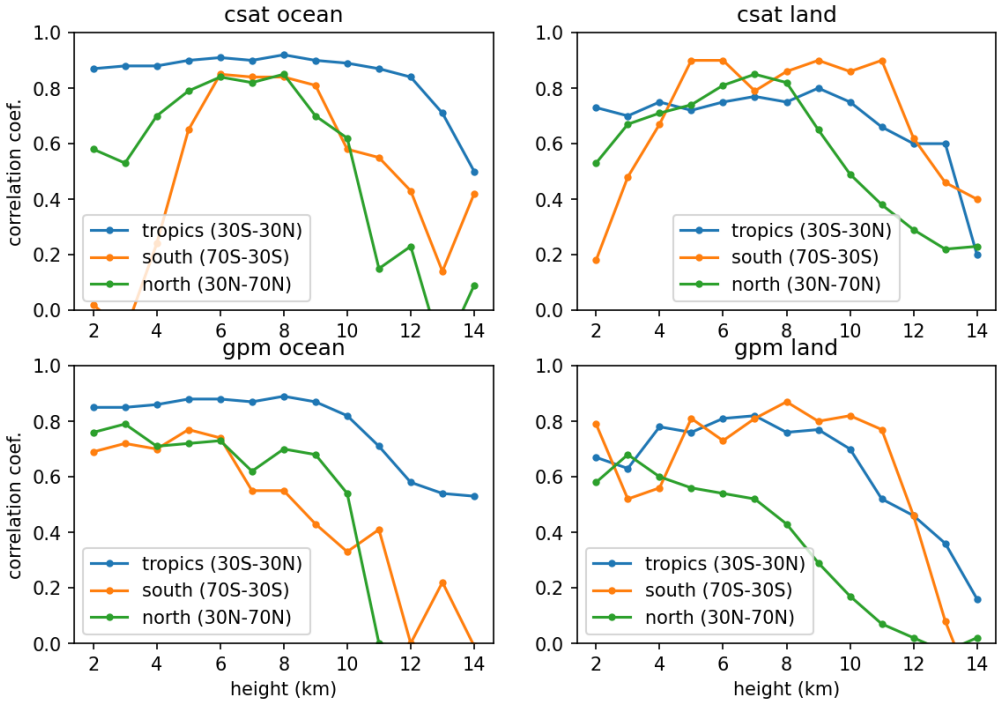




PAZ Δϕ Climatology

- Very high correlation over tropical ocean
- Correlation with Cloudsat water content products is high up to **12 km**
- With GPM the correlation starts to decrease **h > 9km**

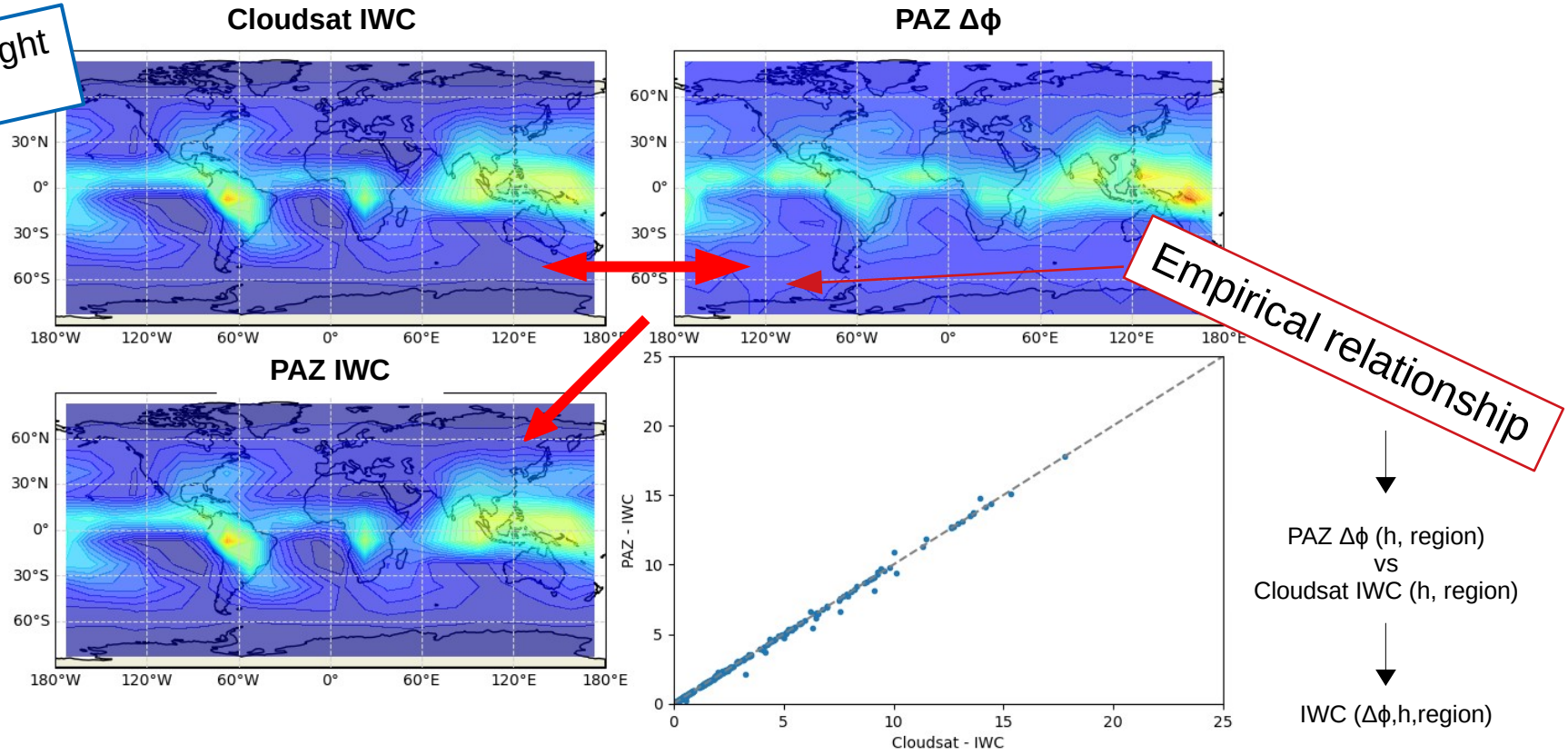
Since the correlation is very high, it makes sense to **attempt a retrieval of IWC (at least, in the upper layers)**



Ice water content retrieval based on Climatology comparisons

Δϕ vs integrated water content relationship, per region, per height

Example at a height of 9 km



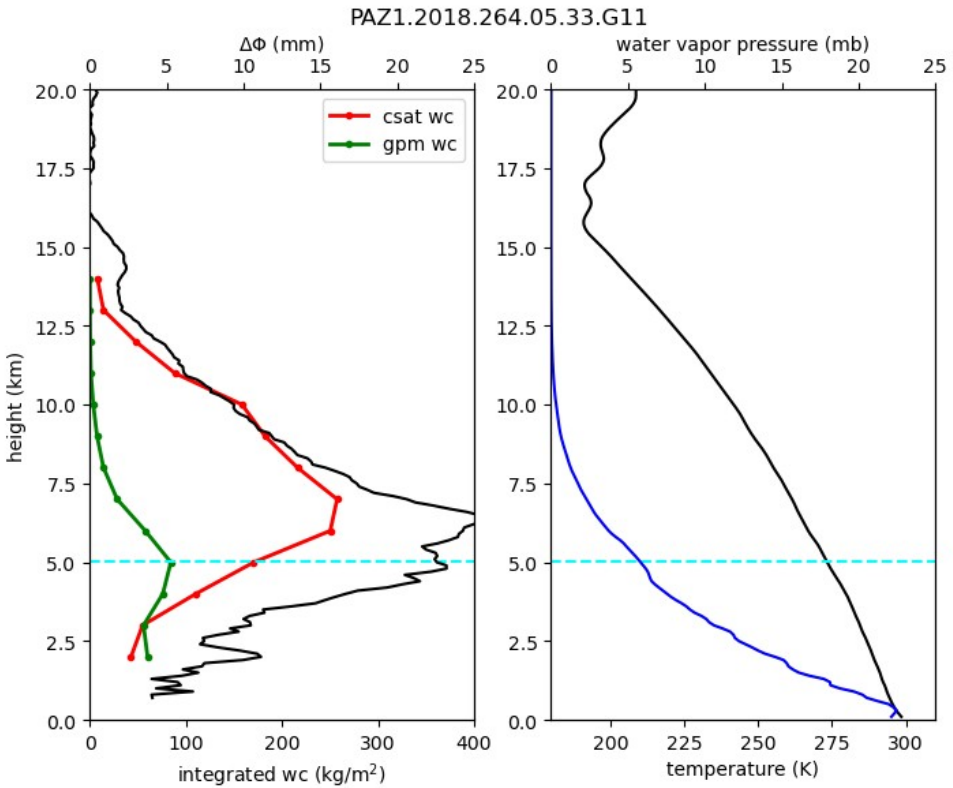
Empirical relationship

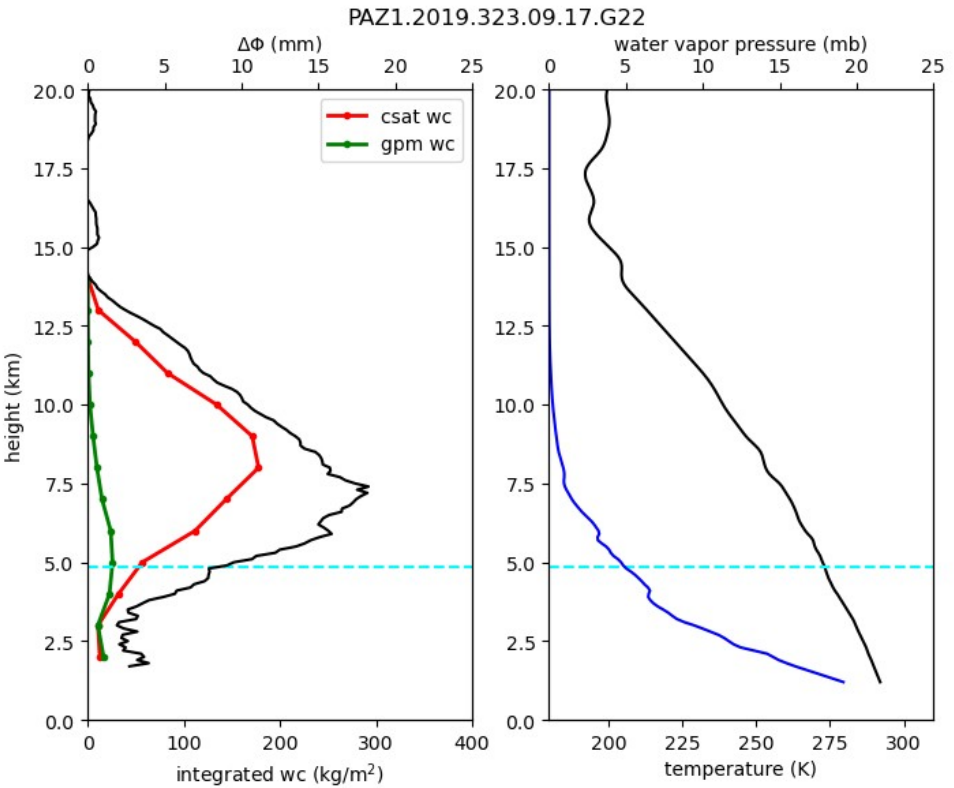
PAZ Δϕ (h, region)
vs
Cloudsat IWC (h, region)

IWC (Δϕ,h,region)

Ice water content retrieval: application to individual cases

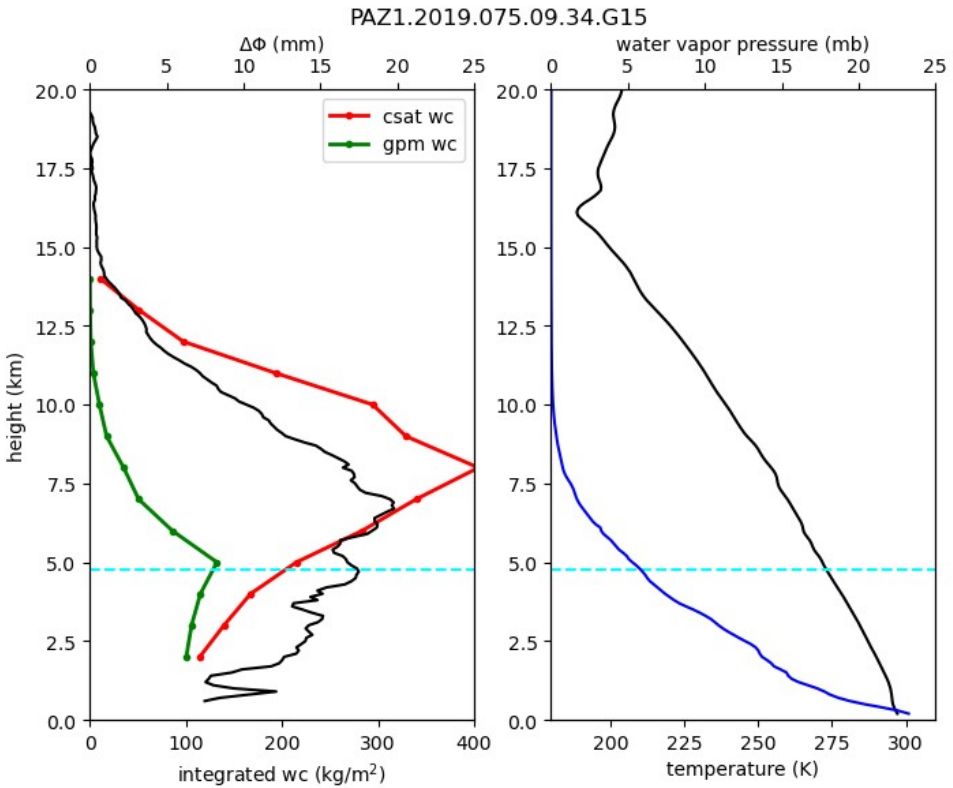
Case examples

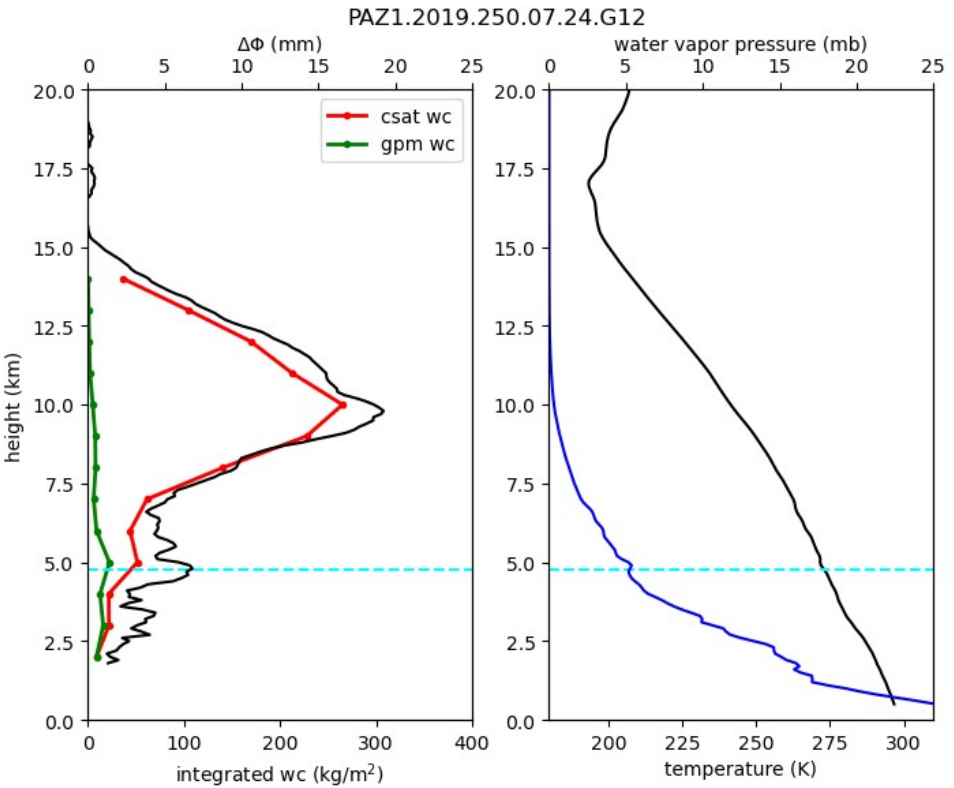




Ice water content retrieval: application to individual cases

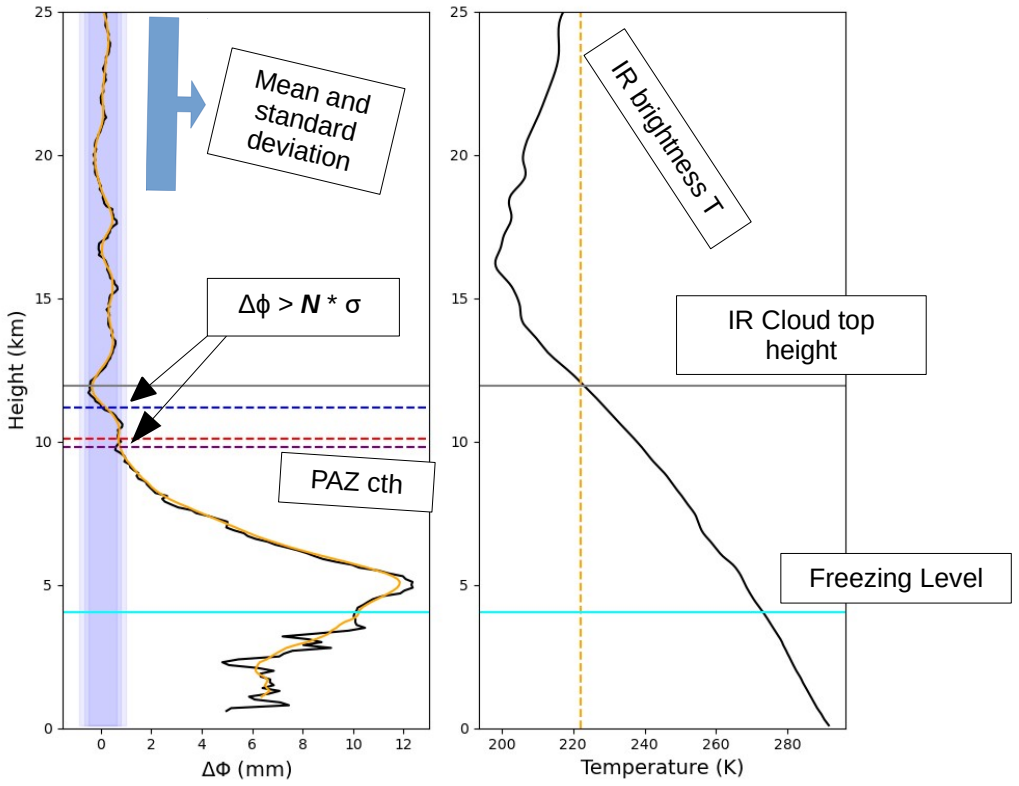
Case examples





Top of Δϕ signal: Cloud Top Height

Algorithm to detect the Δϕ top of the signal: cloud top height



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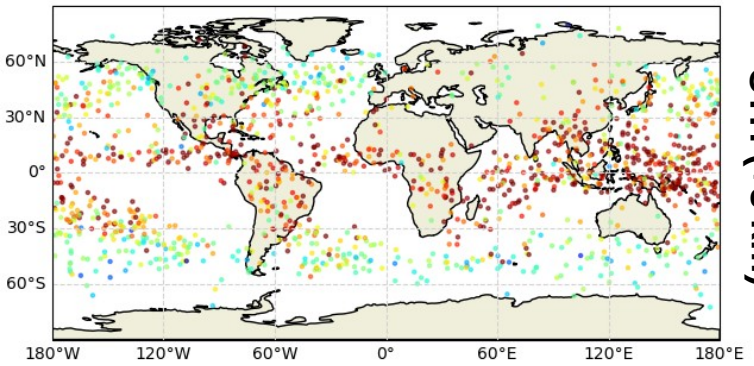
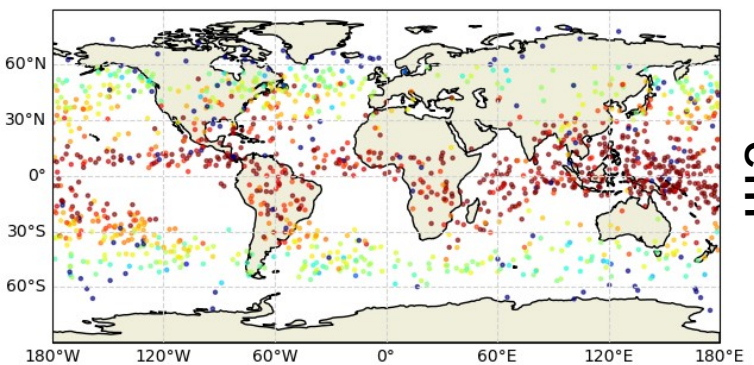
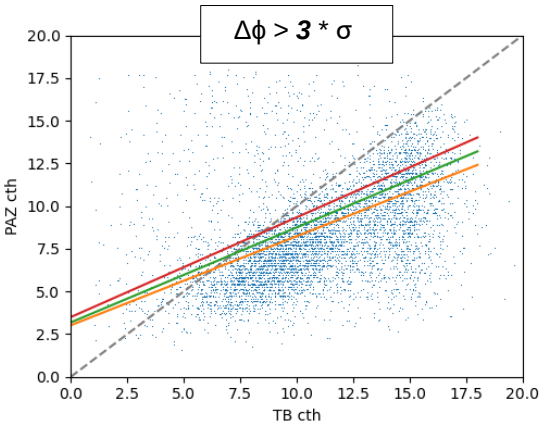
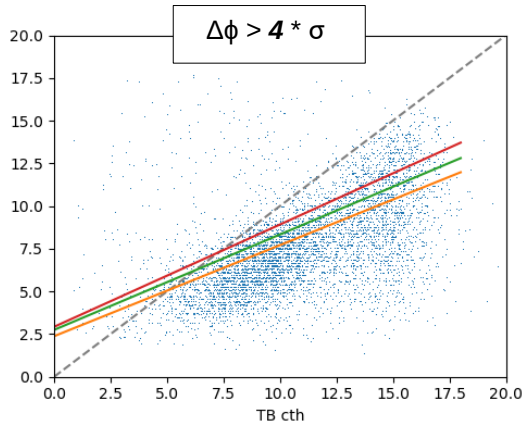


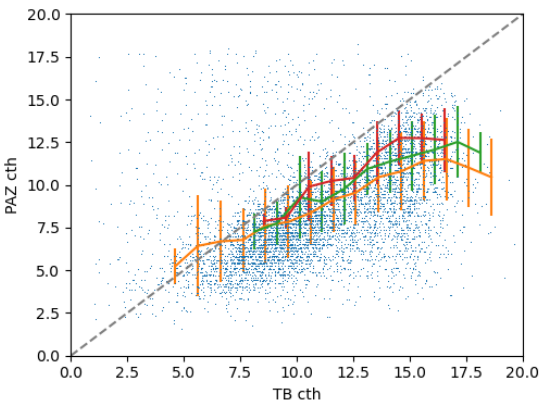
PAZ derived CTH (+3 km)

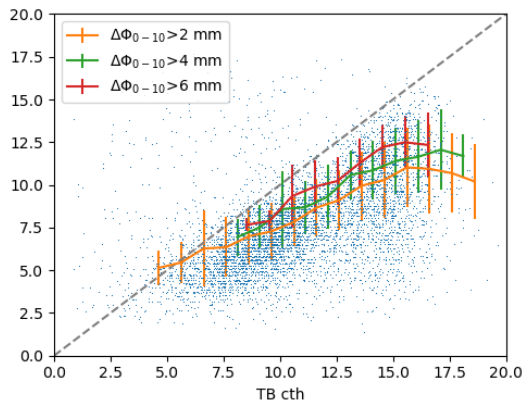


IR derived CTH









Conclusions

- PAZ Δϕ measurements are sensitive to frozen particles, in addition to heavy precipitation

- In the higher layers, it seems feasible to attempt an ice product retrieval
  - High correlation with Cloudsat climatology (specially over ocean and > 8 km)
  - Validation remains a challenge
  - **Potential level 2 or 3 product**

- PAZ Δϕ provides an indication of the Cloud Top Height (**potential product as well**)

- **work in progress** **Towards a precipitation retrieval:** Propagate Δϕ induced by frozen particles down and correct the Δϕ: the remaining part is linked to liquid precipitation

rohp-PAZ

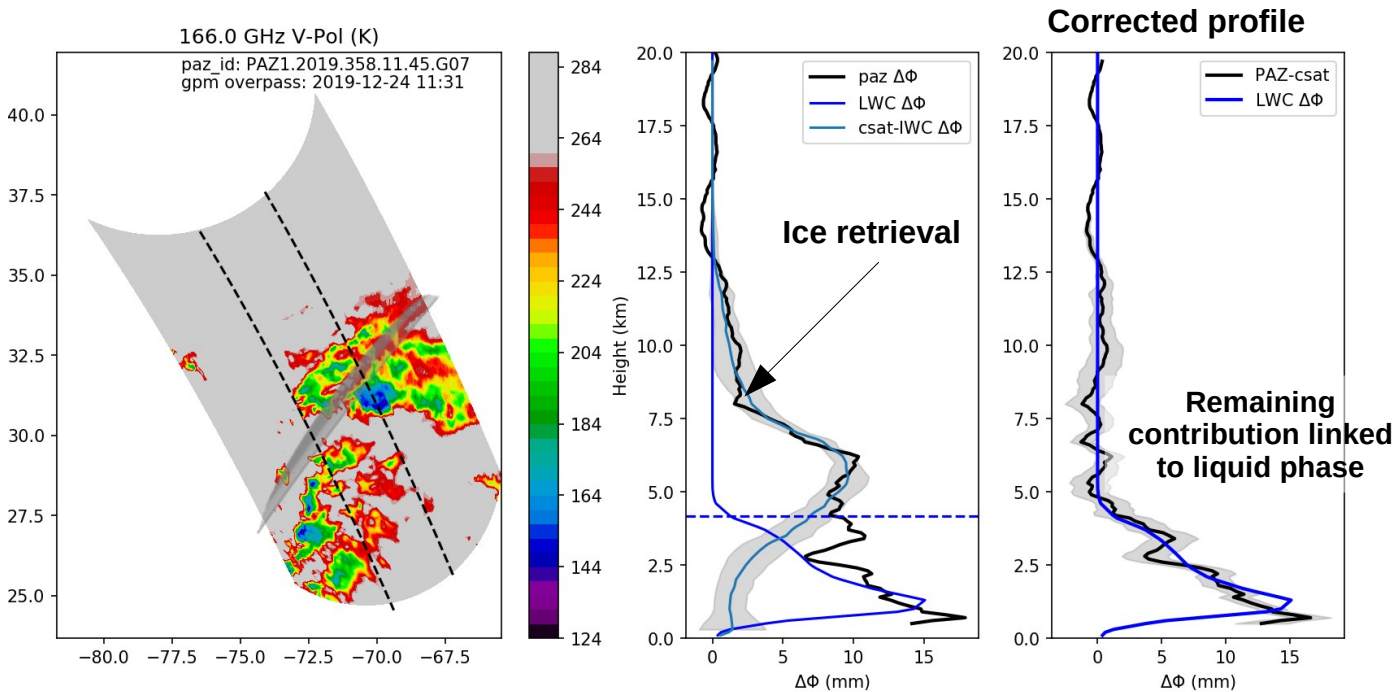
Data and more info available at: **paz.ice.csic.es**

Precipitation retrieval

Propagate down and correct the Δϕ induced by frozen particles

Work in progress

- Single example to show the concept



Inversion could be attempted using Look Up Tables built in *Cardellach et al. 2018*, doi: 10.1002/qj.3161

Thank you!

Data and more info available at:

paz.ice.csic.es