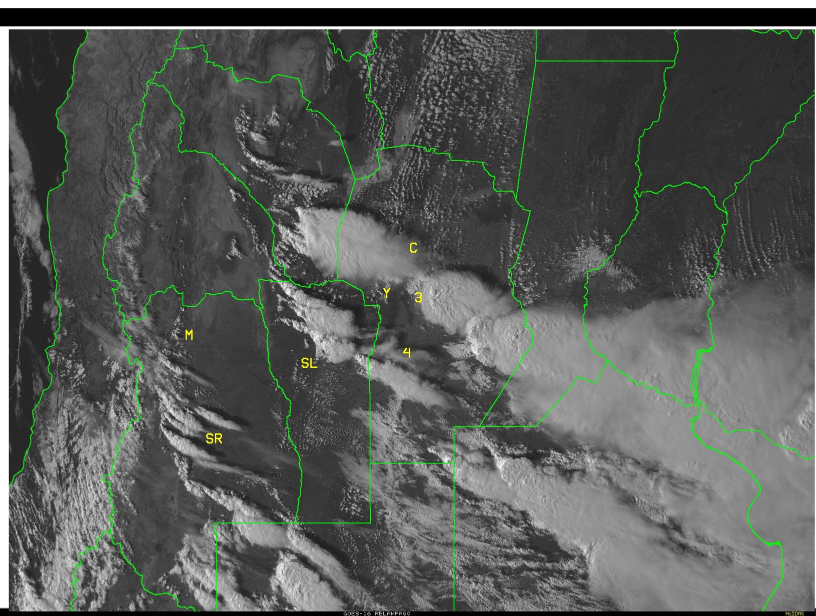
GOES-16 500m ch2 hires vis of case study

Exploring how uncertainties in NWP model microphysics are carried through to microwave radiance space

Exploring their relative importance compared with radiative transfer inconsistencies

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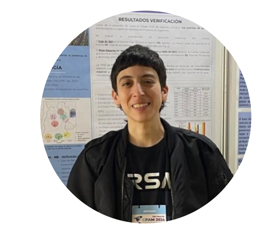

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Motivation

- Satellite data assimilation relies on efficient and accurate radiative transfer models (RTMs).
- All-sky microwave assimilation requires RTMs to perform well in complex scattering media (clouds), where frozen hydrometeors exhibit varied shapes and particle size distributions (PSD).
- Under increasing resolution in meso-scale and global NWP models, it is key to revisit fast RT assumptions to ensure microphysics-consistent forward model that improve fit to observations.
- This work builds on the discussions raised in e.g., Han et al. (2013), Geer and Baordo (2014), Galligani et al. (2017), Sieron et al. (2018), Eriksson et al. (2015), etc.

Aims

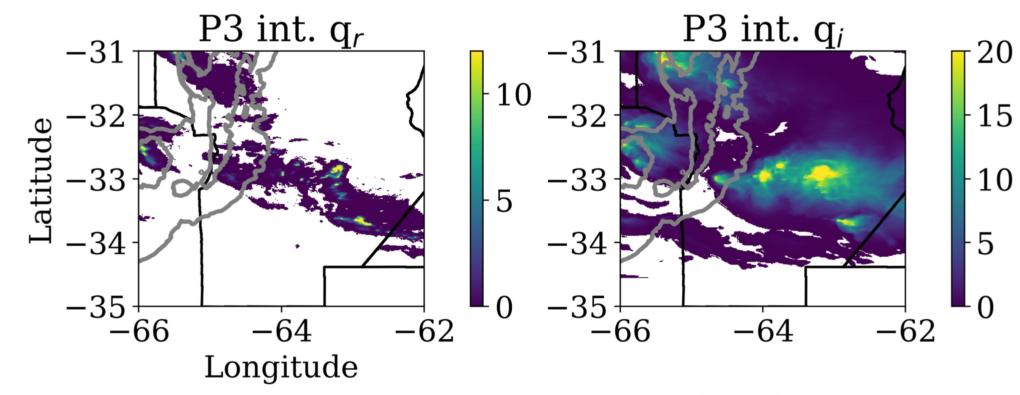
- Run WRF microphysics-consistent RTTOV v14 microwave simulations of a high—resolution (1km) midlatitude MCS case study.
- Analyze the sensitivity of simulated Tbs to *different ways of implementing consistency* between RTTOV bulk scattering properties and WRF microphysics schemes, i.e., elements of the forward operator chain to examine: single scattering properties, PSD, footprint model.
- The aim is to dive deeper into the impact of these choices, not a direct fit to observations. Important in the forward model chain of regional models with RTTOV.

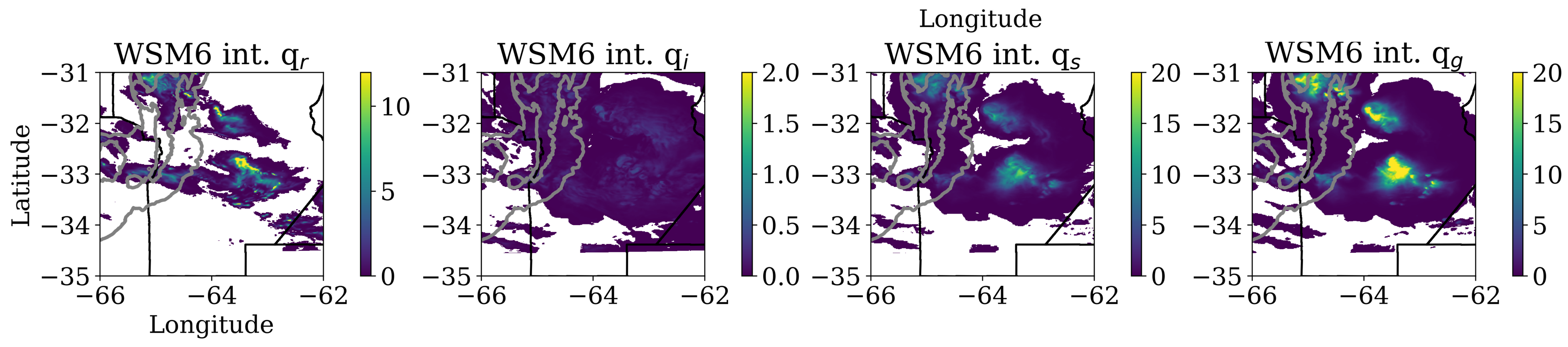
How do we enforce microphysical consistency?

1/ What do NWP models provide?

Cloud prognostic variables
- 1-mom.: q_x, parameterizations (e.g. WSM6)
- 2-mom: q_x, N_x, parameterizations (e.g. THOM)
- 3-mom: q_x, N_x, prognostic properties (e.g. P3)

WRF 10/11/2018 MCS case in Códoba Argentina





1-mom and 2-mom schemes have pre-defined particle categories. Let's take WSM6

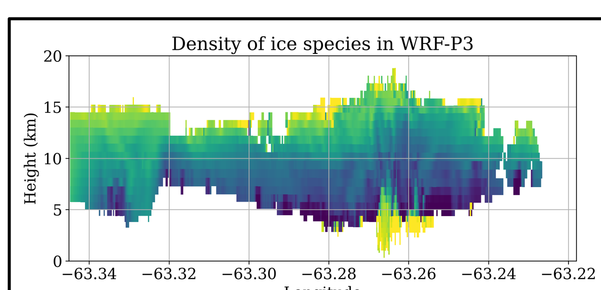
"SNOW" ρ_s=100 kg/m^3 $N(D) = n_{0s} \exp(-\lambda_s D)$

"GRAU" ρ_g=500 kg/m^3 $N(D) = n_{0g} \exp(-\lambda_g D)$

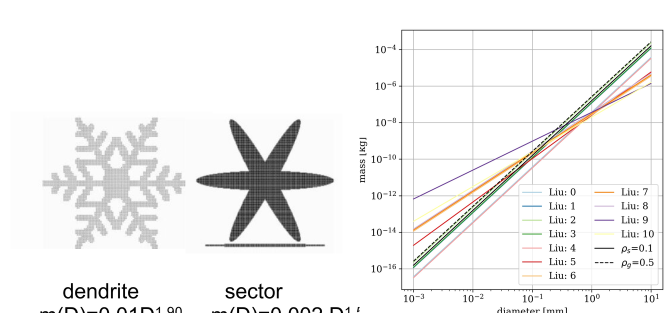
Implicitly: spherical particles, $m(D) = \pi\rho/6\ D^3$

* Note pre-defined particle categories in NWP are abrupt, and lead to unphysical conversions

** aD^b, b=3 is also unrealistic. DDA databases like Liu (2008) that represent the growth of ice particle habits in a more natural way with b < 3



3-mom shemes like WRF-P3 offer an opportunity to constrain the problem with prognostic variables: ρ, Dmax, PSD parameters λ and μ



mass-size relationships are diverse and complex One-shape fits is a computationally efficient approach (unrealistic)

2/ Bulk scattering properties in RTTOV

- The RTTOV hydro-table generator (Geer et al. 2021): RTTOV pre-calculates the bulk optical properties for each hydrometeor type as a function of temperature, frequency and water content, allowing for certain freedom to define these species: i.e., PSD parameters, m(D), and single scattering properties including the Liu (2008) database.
- Enforcing m(D) consistency between WSM6 microphysics and RTTOV

1/ WRF m(D) = RTTOV soft-spheroids. Shown to be deficient (e.g., Geer & Baordo, 2014) although there are certain tunning approaches like the frequency-dependent bulk ρ approach (Liu 2004).

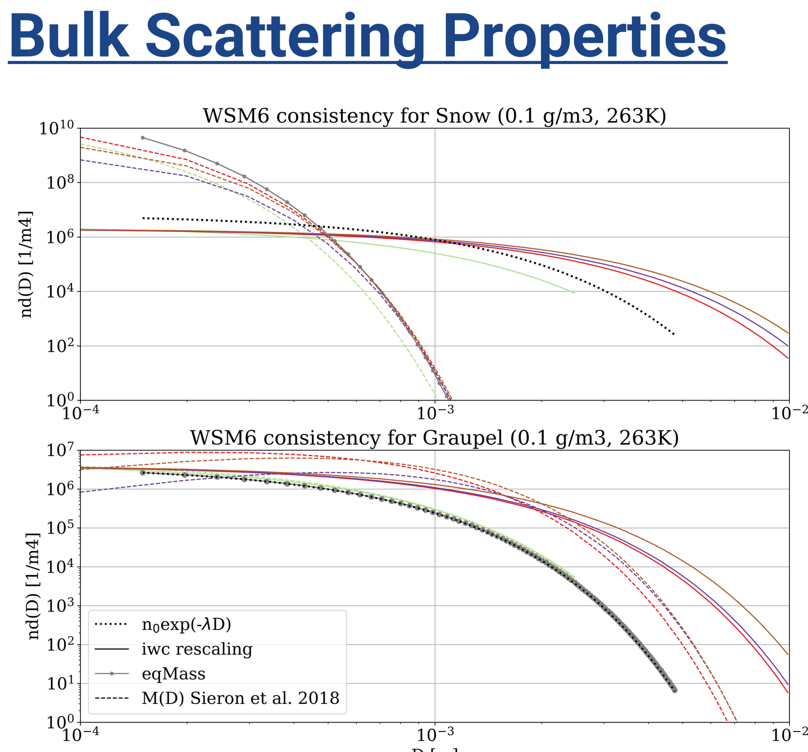
2/ Equivalent-mass approach (e.g., Galligani et al. 2017): use particles of the same mass. No consistency in the N(D) specially for less dense particles. There is however consistency in the mass distribution.

3/ Equivalent-size approach with PSD iwc rescaling (e.g., Geer & Baordo, 2014): use same-size particles and rescale the PSD to conserve total mass (λ parameter free in PSD).

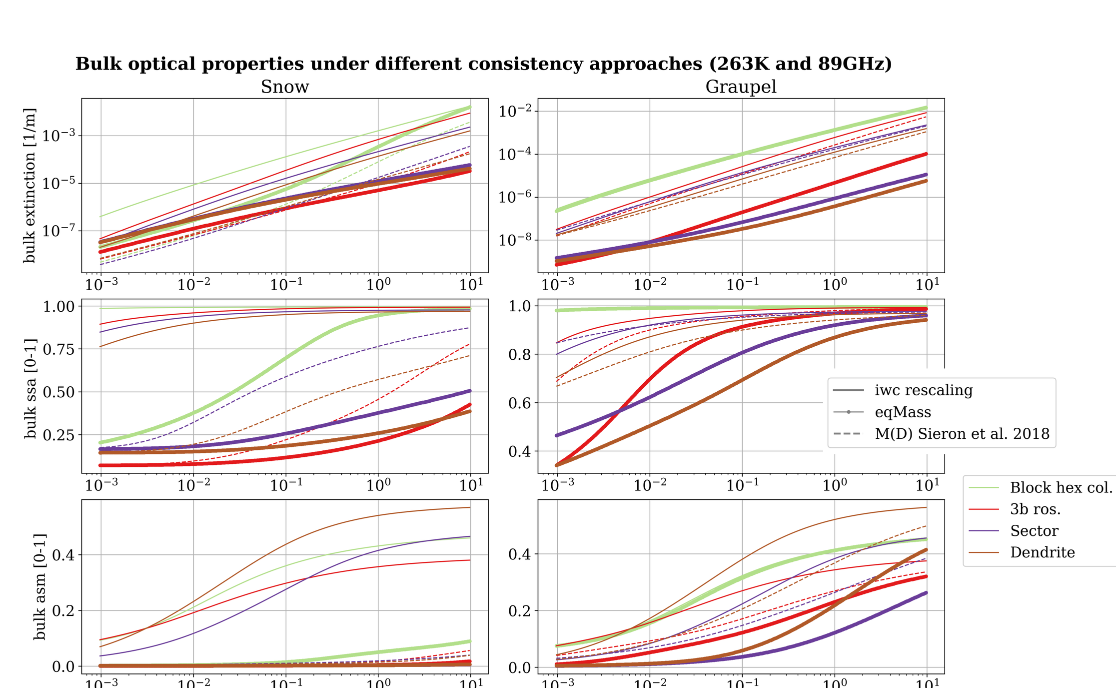
4/ Preserve M(D) (Sieron et al. 2018): use same-size particles, while rescaling their number by the mass ratio of original to new Liu particles (intercept and shape parameters free in PSD).

* Note that following Eriksson et al., (2015), particles of equal mass generally show greater similarity in microwave scattering and absorption than those with equal maximum dimension

Bulk Scattering Properties



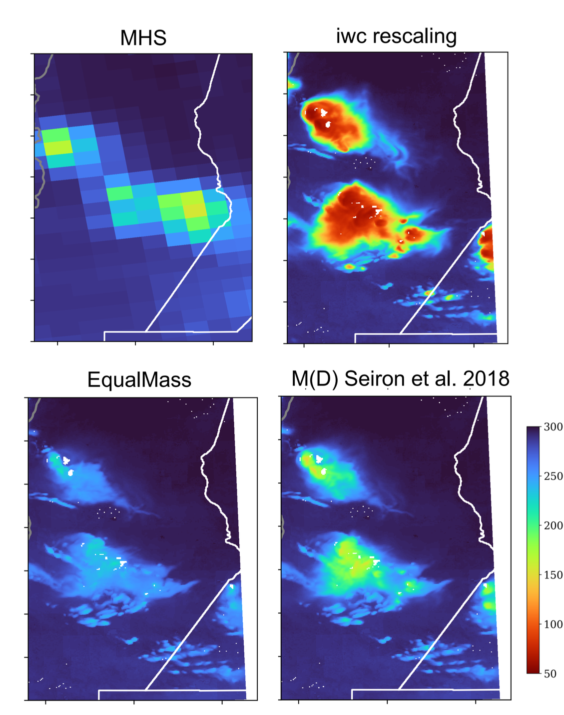
PSD impact assuming different WSM6 consistency approaches for snow (ρ_s=100) and graupel (ρ_s=500) for different Liu species. Note renormalization is done in all approaches to ensure fix numerical integration issues.



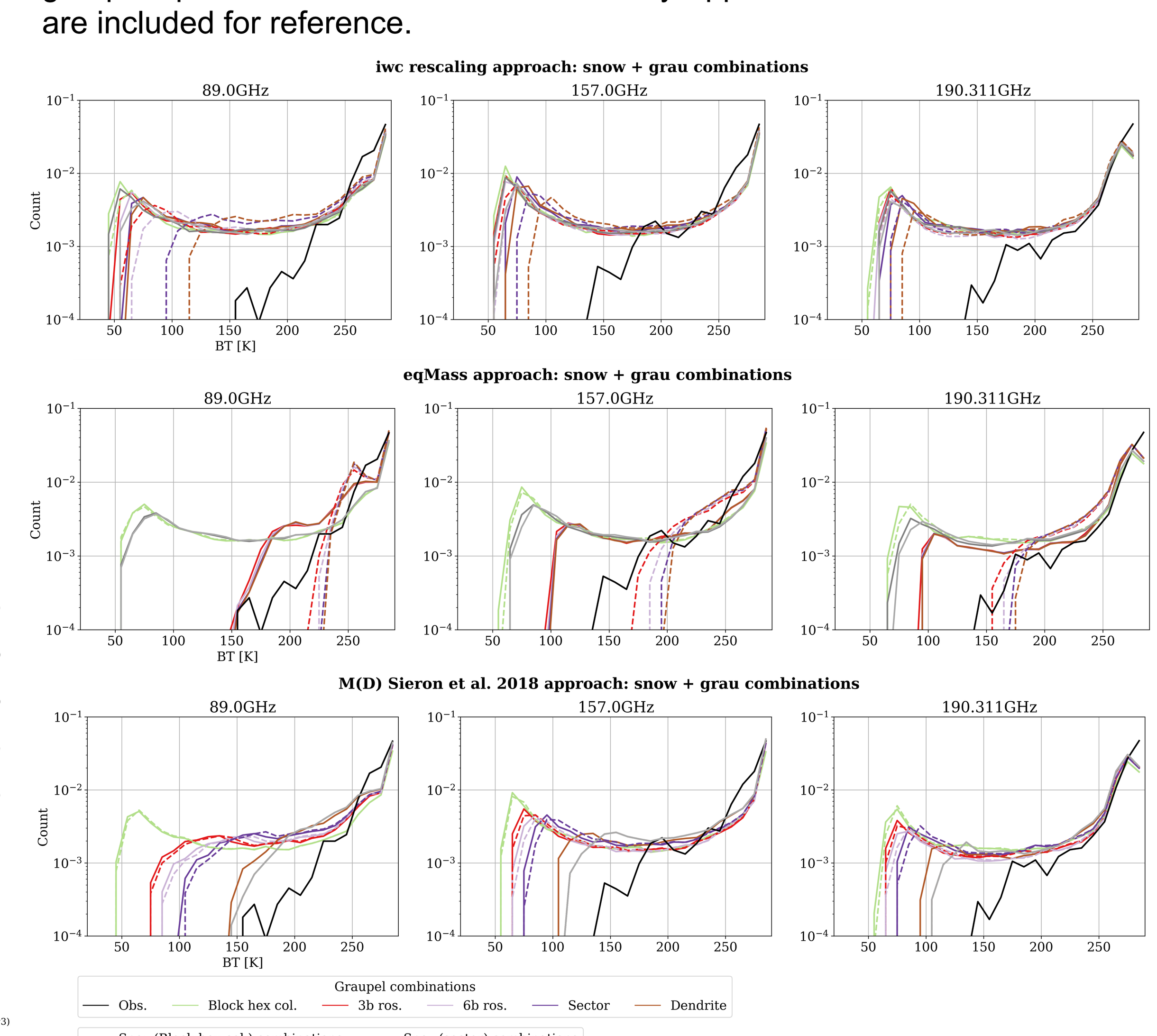
The bulk scattering properties under the different WSM6 consistency approaches for snow and graupel for four different Liu species. Different collections of particles interact with radiation differently.

On going analysis

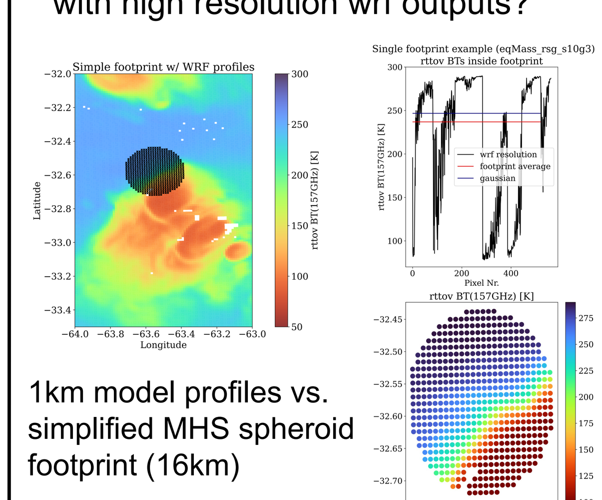
Maps of obs. and sim. BTs at 89GHz for simulations with snow(sector) and graupel(dendrite) under the different approaches



Histograms of obs. and sim. BTs for different combinations of snow and graupel species for the different consistency approaches. MHS observations are included for reference.

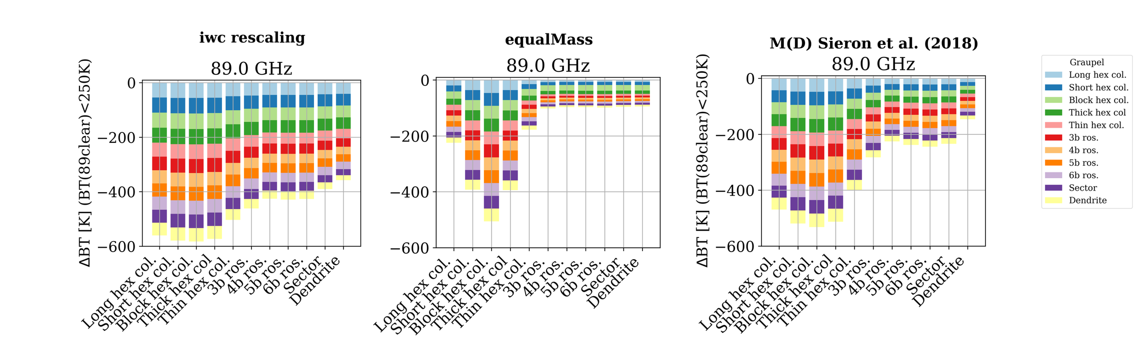


What about the footprint model with high resolution wrf outputs?

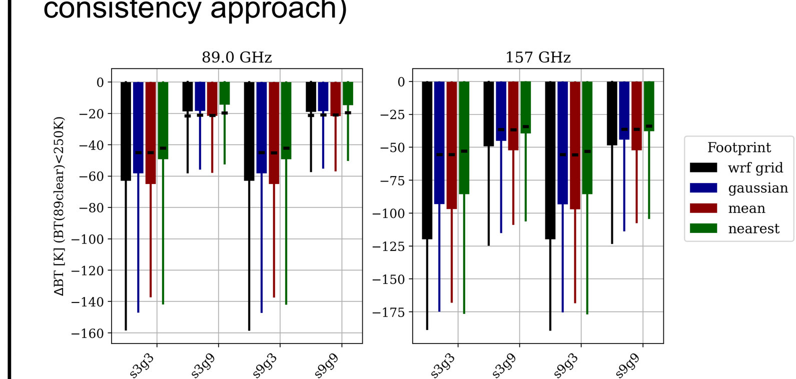


1km model profiles vs. simplified MHS spheroid footprint (16km)

Sensitivity to snow-graupel combination of the consistency approach chosen. Expressed with the mean ΔBT(cloudy-clear) at 89GHz

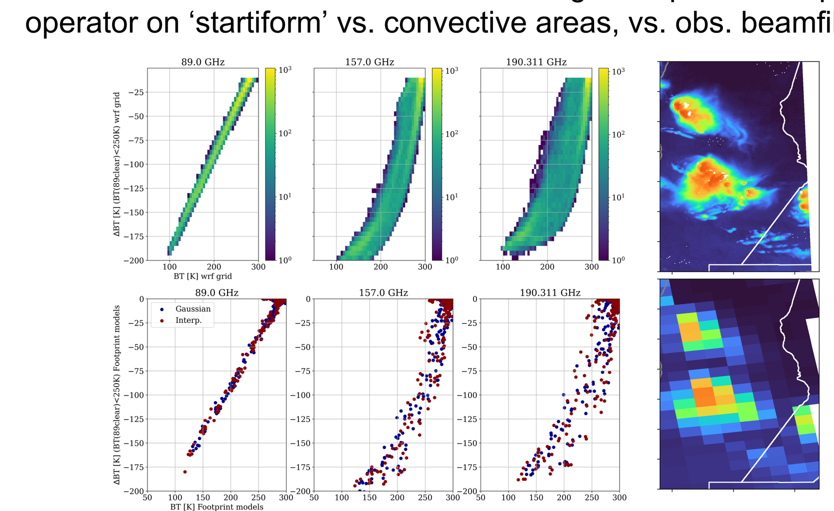


Overall the mean (horizontal lines) are simar, yet moderate BT values and the lowest BTs show considerable K difference (disregarding the consistency approach)



Impact of footprint operator on the ΔBT(cloudy-clear) at 89GHz and 157 GHz. The horizontal lines show the mean values, while the vertical lines show the 15th and 25th lowest percentiles, for 4 differente combinations of Liu species.

A collection of cases is needed to investigate impact of footprint operator on 'startiform' vs. convective areas, vs. obs. beamfilling



The simulations in this figure were run under the M(D) Sieron et al. (2018) approach for snow(sector) and graupel (sector). Top row: 2d histogram for BT and ΔBT(cloudy-clear) using the high resolutin wrf-grid (1 km), Bottom row: scatter plot of the resultant values after applying two diferent footpritn models. The maps on the right show the corresponding simulations.

Outlook

- **Extend statistical analysis** to more cases of deep convection (and ATMs channels) to explore if a single 'one-shape' fits all habit satisfies all approaches, and quantify the different approaches histogram fit to observations.
- Run WRF-P3 microphysics-consistent RTTOV v14: can 3-mom schemes help?
- How does this repercuss over e.g. ensembles with different microphysics schemes

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Dismantling of Argentine Science

- Did you know president Javier Milei's government spending on research has declined by 31% during his 1 year in office? 40% job cuts in the public sector, 35% less PhD thesis. Employees of the public sector and university teaching staff have lost 35% purchasing power in salaries due to inflation/devaluation.
- In 2024, ~$70 million USD in international loans for science from the Inter-American Development Bank were left unused
- In 2025 the gov. wants to merge the National Meteorological Service and the National Geographic Institute, a move both agencies and the scientific community reject.