Uncertainties in precipitation estimates from space-borne radar observations

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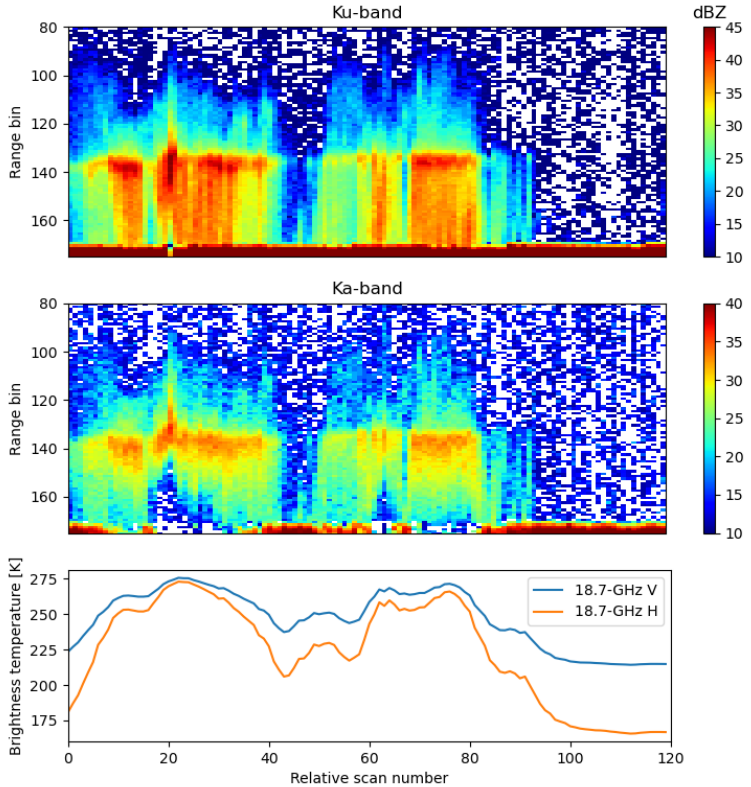
General considerations

- Space-borne precipitation radars were not intended to be global precipitation mapping instruments.
- They were intended to be calibrating/validation instruments (flying rain-gauges, physics laboratories, etc.).
- However, although space-borne radar observations are more directly related to precipitation parameters than other satellite observations, radar precipitations estimates are not uncertainty-free.
- Significant progress has been in the last 25 years in understanding and reducing uncertainties in satellite radar precipitation estimates. Yet, uncertainties still exist.

Sources of uncertainties

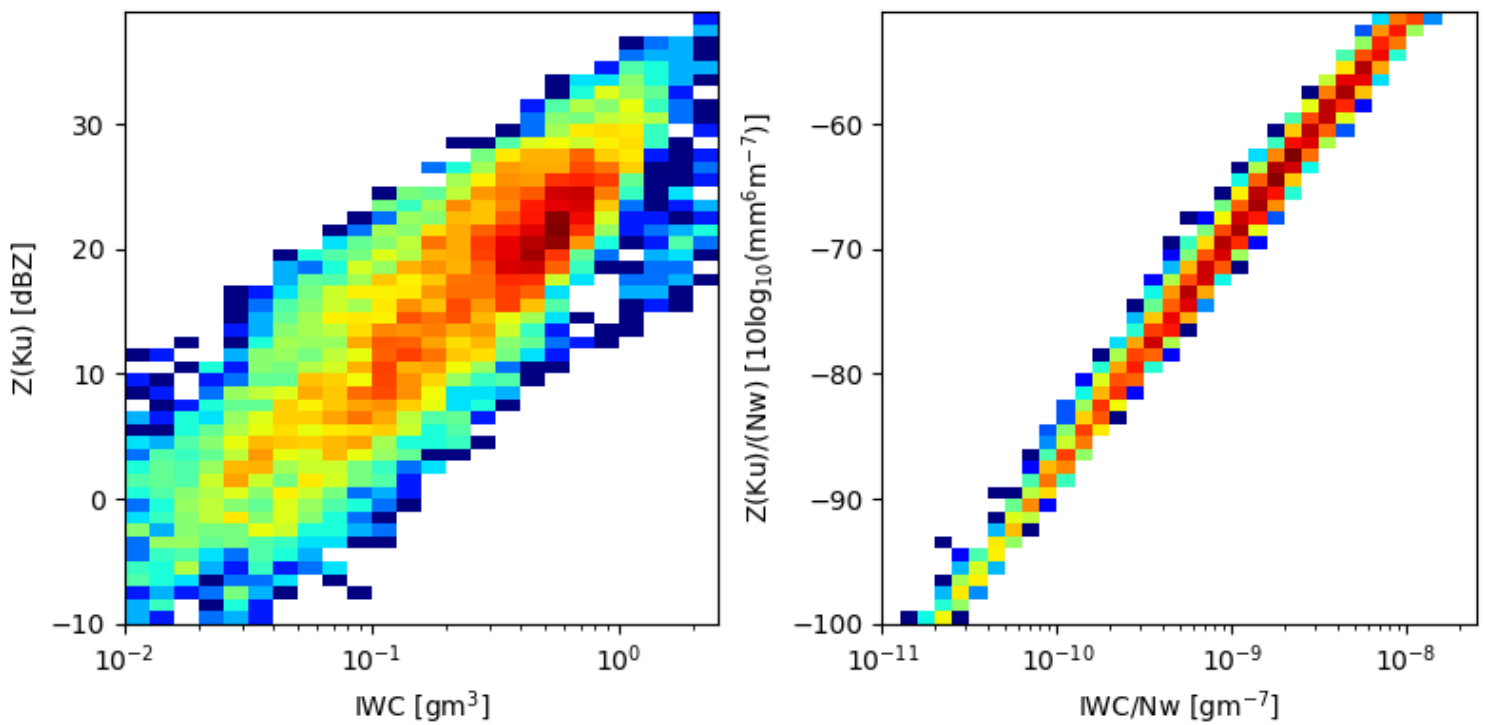
Major sources of uncertainty include:

- Variability in the Z-R relationships
- Attenuation in the observed radar reflectivity
- Ground clutter
- Light precipitation (below the detection threshold)
- Variability in the radar beam footprint



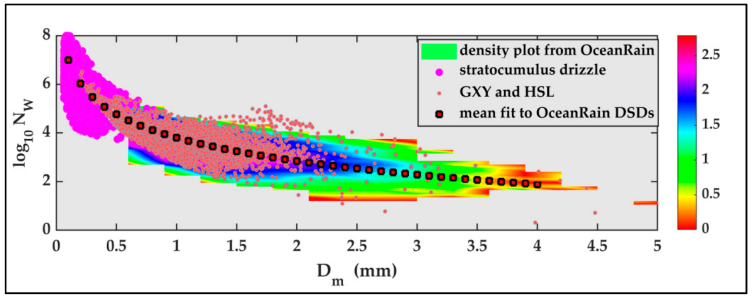
Variability in the Z-Precipitation Rate relationships

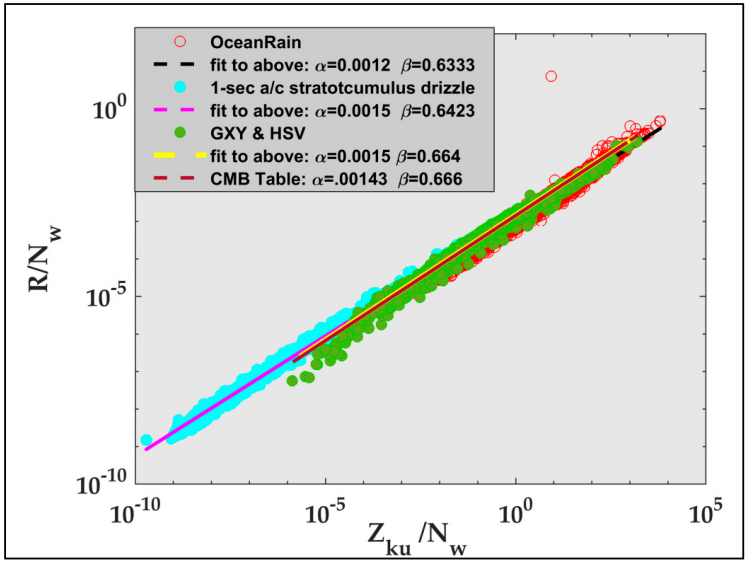
- At least 2 parameters are required to describe Particle Size Distributions (PSDs).
- Consequently, Z-Precipitation Rate relationships require at least 2 parameters. The generalized PSD intercept, $N_w = \frac{4^4}{\pi \rho_w} \frac{PWC}{D_m^4}$, greatly simplify Z-Rate relationships.



The N_w problem. General considerations

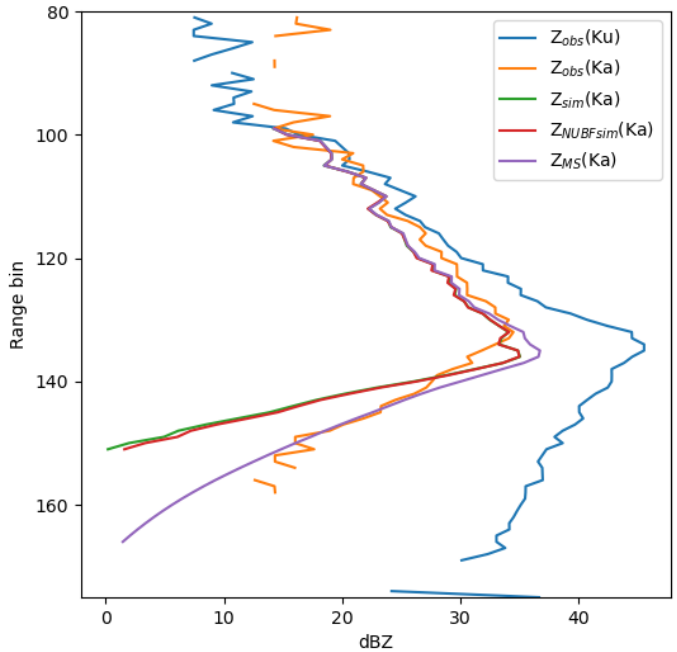
- The N_w parameter greatly simplifies the formulation, but not the problem.
- N_w still needs to estimated independently of the radar observations.
- Ground observations may be used to impose constraints on N_w.
- However, such constraints are not very effective for PSD characterized by large mean particle sizes D_m.





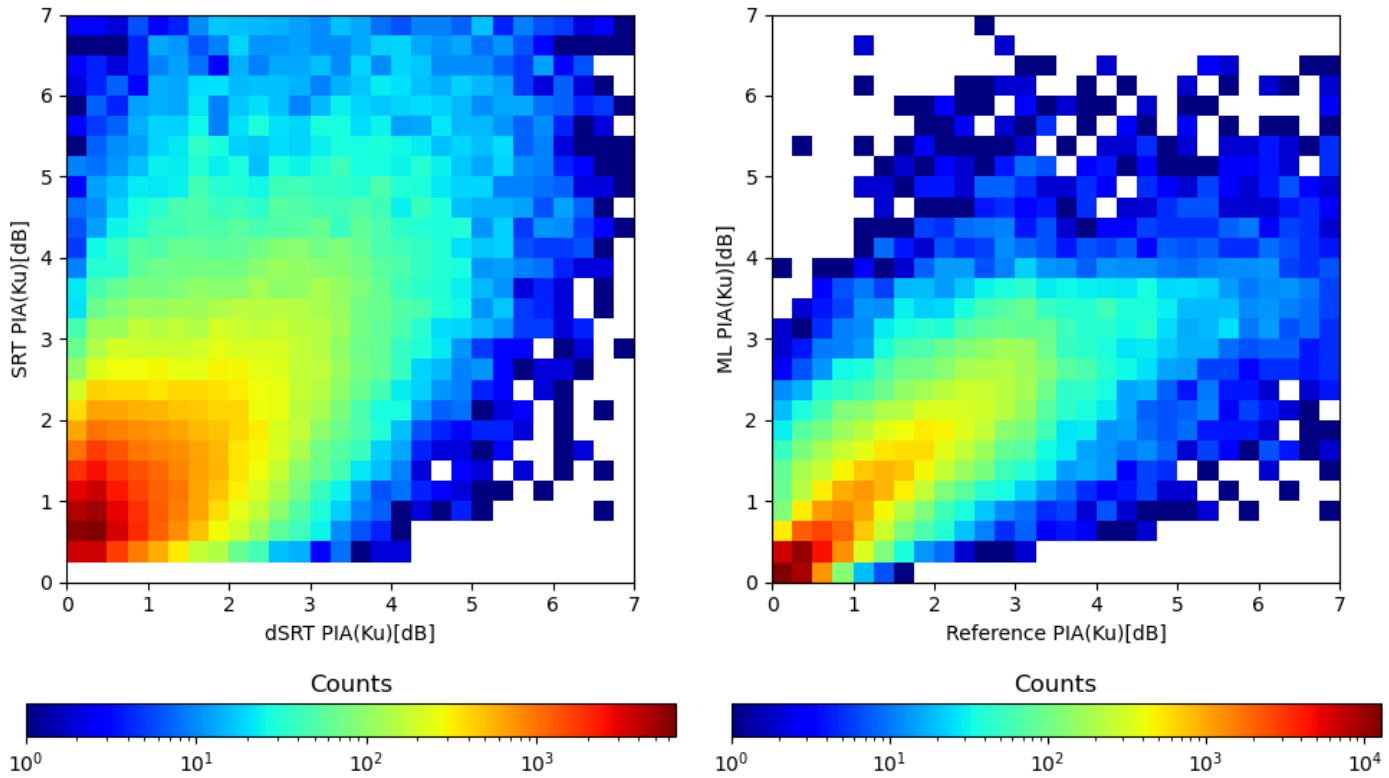
The N_w problem. Radar profiling considerations

- Additional constraints can be imposed by considering N_w in the radar profiling context.
- That is, the attenuation correction process needs to be consistent with the N_w parameter. $Z(r) = Z_m(r)/PIA$ $PIA = (1 - \epsilon(N_w) q \int_0^r Z_m^\beta(s) ds)^{1/\beta}$
- The analytical PIA needs to be consistent with the SRT PIA estimate and Ka-band reflectivity observations when available.



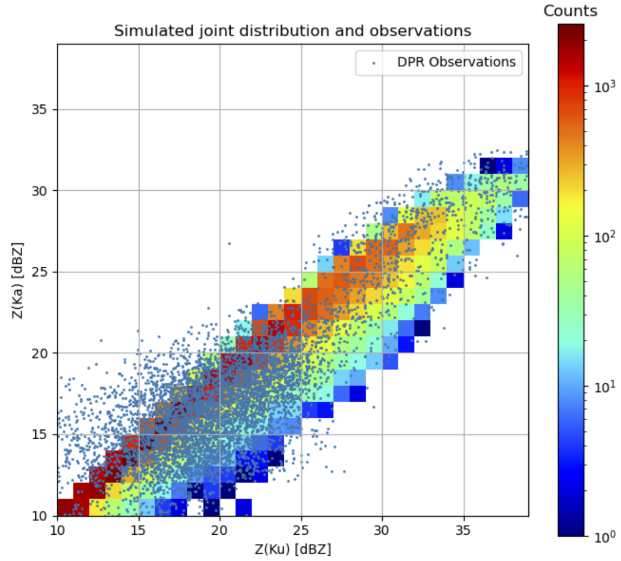
The N_w problem. Further considerations

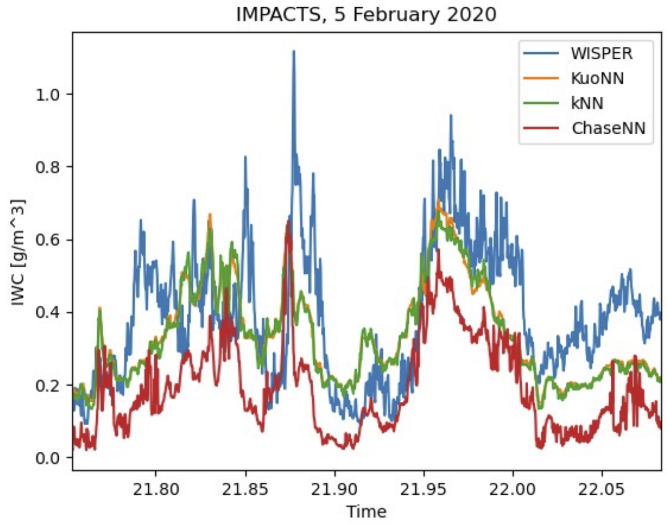
- Surface Reference Technique (SRT) PIA is a useful piece of information when reliable.
- Dual SRT PIA is more reliable than single SRT PIA, except for heavy convection.
- Over oceans SRT PIA estimates are significantly more reliable than over land.
- For snow and light rain, SRT PIA estimates are not reliable.



Snow estimation issues

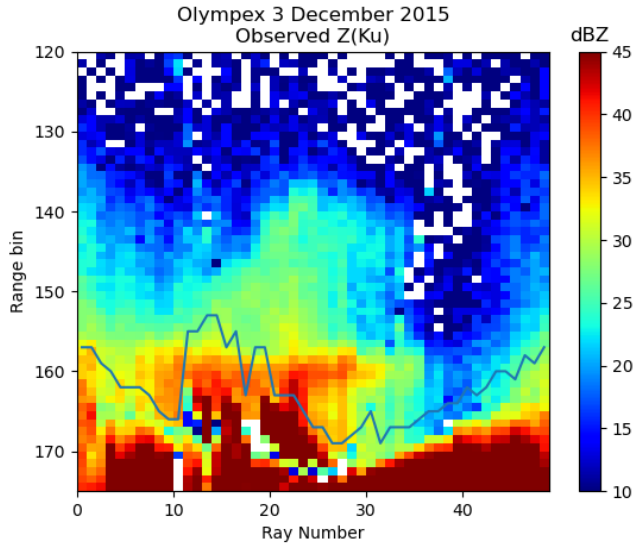
- The variability of N_w is still a problem, but there is very little attenuation in snow to use the PIA as a constraint.
- When dual frequency observations are available, mass weighted mean diameter D_m and hence N_w may be estimated from the dual frequency reflectivity ratio (DFR).
- However, the DFR may be very noisy.
- More robust methods, i.e. Machine-Learning based, may be used to derive to incorporate "in-situ" information and provide more accurate estimates.

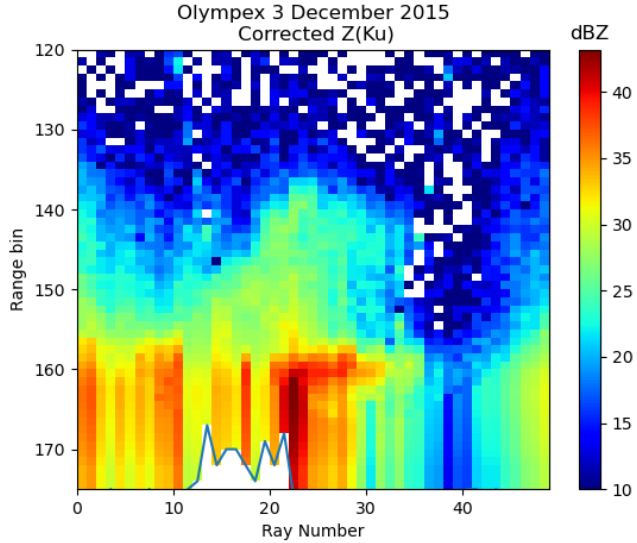




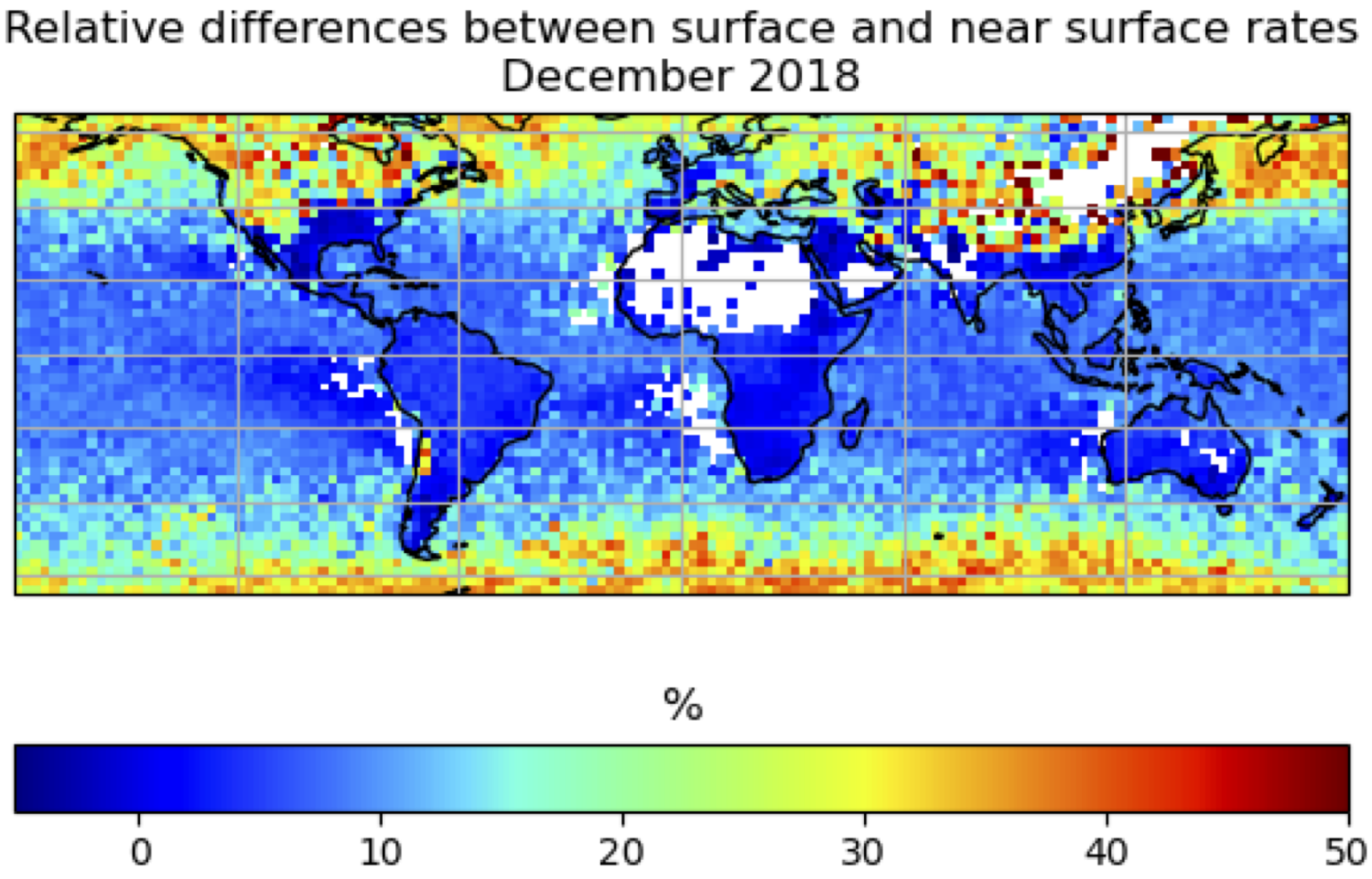
Ground Clutter

- Ground clutter is strong echo in the radar observation caused by the ground.
- It can extend up to 2.0 km above the surface and completely obscure the precipitation echo.
- Nadir observations are minimally affected and can be used in the development of statistical clutter mitigation methodologies, e.g. $pRate(z < z_{cf}) = pRate(z_{cf}) \times pRate_{mean}(z)/pRate_{mean}(z_{cf})$



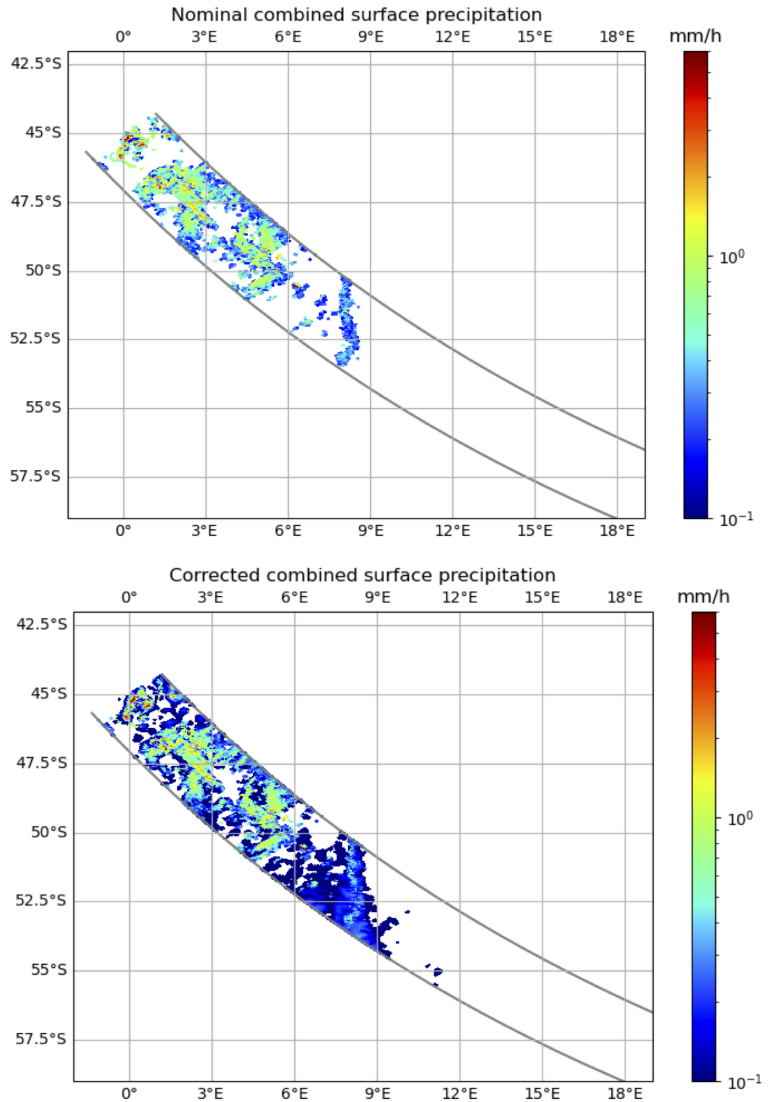


Impact of Ground Clutter Correction



Light Precipitation

- The DPR does not miss all the light precipitation associated with a given point in the Tb-space.
- An empirical algorithm may be derived from collocated Tbs and DPR retrievals.
- The empirical algorithm is to be applied only when the DPR does not detect precipitation. When estimates are greater than 0, a decision is required.



Summary and Conclusions

- Although the most accurate at the instantaneous level, space-borne radar precipitation estimates are affected by multiple types of uncertainties.
- Even when dual frequency observations are available, the estimation problem is still posed.
- Parameterizations and "a priori" information derived from ground observations may be used to mitigate the uncertainties.
- However, the process is not trivial and requires a sustained long-term effort.