PSD Parameterization to support ice retrievals from multiple instrument observations

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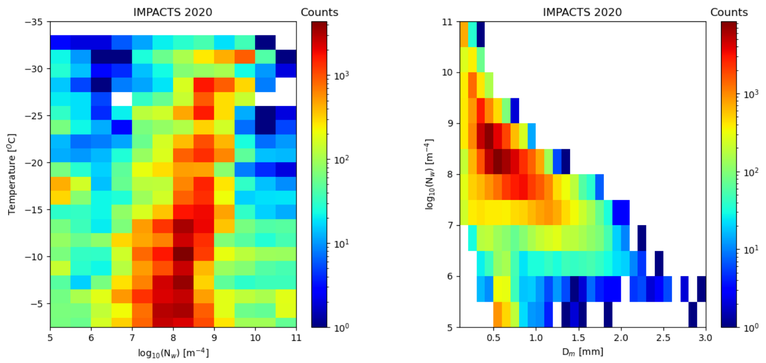
Motivation

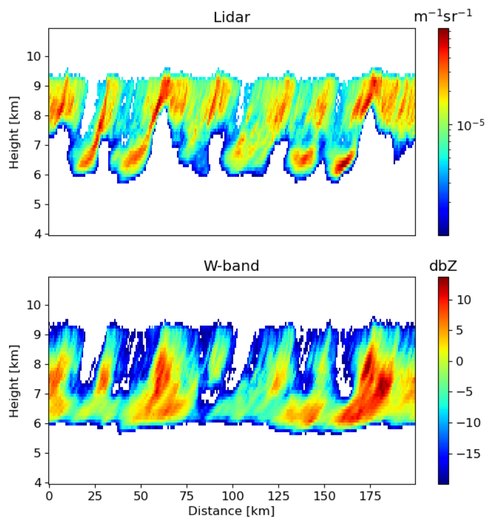
- Current and future air- and space-borne observing systems feature instruments with different sensitivities and subject to attenuation at different ranges.
- From the scientific perspective, physically consistent ice property estimates are desirable irrespective of the instruments used in their derivation.
- Such estimates may be derived through the development of consistent "a priori" probability distributions.

Approach

- Use "in-situ" Particle Size Distributions (PSDs) to simulate lidar and radar observations at X-, Ku-,Ka- and W- band.
- Develop kNN methodology to estimate ice properties from combination of observations.
- Test methodology using cross-validation.
- Evaluate using independent estimates.



The N_w distribution as a function of temperature and the $N_w - D_m$ joint distribution

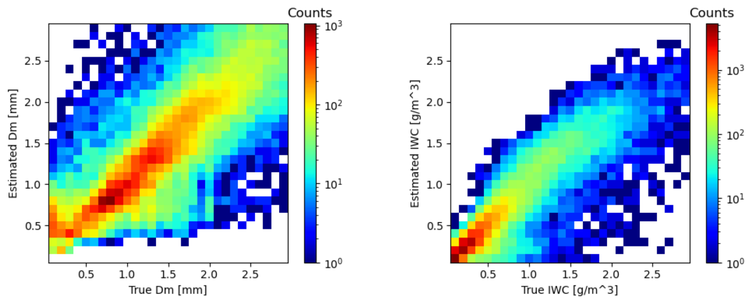


Simulated lidar backscatter and radar reflectivitiy.

- In the combined radar lidar region, the lidar backscatter and the integrated backscatter can be used as constraints for the kNN methodology.
- In the region of single frequency radar observations, temperature can be directly used as a parameter, over via N_w in "normalized relationships" e.g. $IWC = N_w^{1-b} a Z_w^b$.

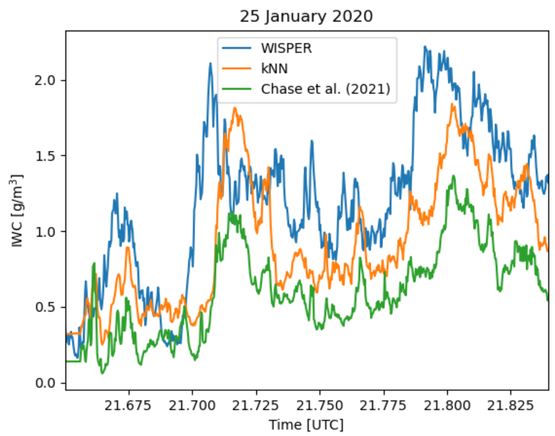
Cross-Validation Results

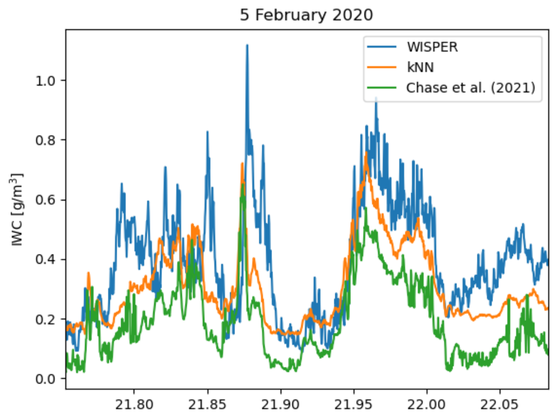
- For evaluation in the simulation space, the database of observed PSDs and calculated reflectivities is randomly split in two.
- Half of the database is used for training, while the other is used for evaluation.
- Results are shown below. Errors are likely to be caused by ambiguities in the database, rather than methodology.



Direct Validation Results

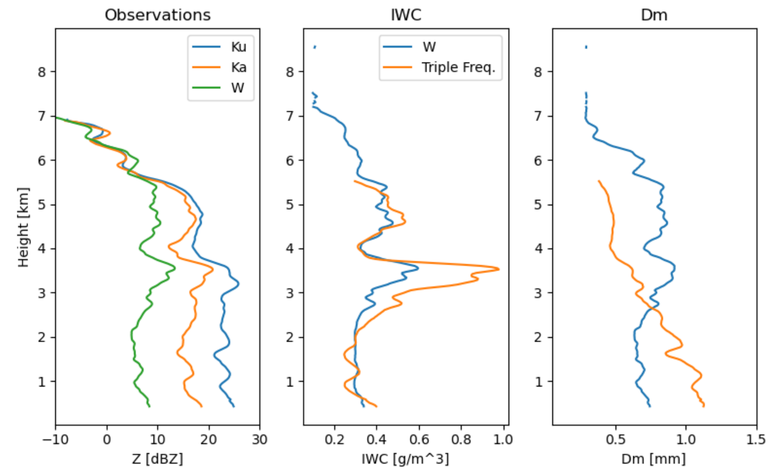
- "In-situ" and retrieved IWCs for two cases from the 2020 campaign are shown below.



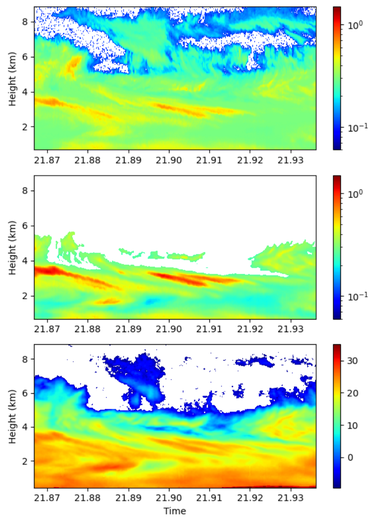


Comparisons between retrievals

Single frequency (W-band) and multiple but low sensitivity (Z_{Ku} and Z_{Ka} >10 dBZ) retrievals are compared.



- Discrepancies appear to be larger in terms of D_m than in terms of IWC.
- At the top of the echo, multiple frequency IWC tends to be larger than the W-band estimate because the DFR(Ku,Ka) is close 0.
- Near the surface single frequency IWC tends to be larger than the multiple frequency estimate. Attenuation at W-band may exacerbate differences.
- A parameterization of D_m as a function of temperature, e.g $D_m = 2.68 \cdot 10^{-4} \cdot T_c^2 + 2.67 \cdot 10^{-2} \cdot T_c + 8.62 \cdot 10^{-1}$ seems to better mitigate uncertainties than a Nw parameterization.
- The $D_m = f(T_c)$ parameterization may be combined with a $D_m = f(DFR)$ parameterization to further mitigate uncertainties. $D_m = 0.00228 \cdot DFR^3 - 0.0336 \cdot DFR^2 + 0.3486 \cdot DFR + 0.2668$



Concluding remarks

- The cross-validation and the direct comparisons suggest good retrieval performance.
- In the cross-validation evaluation, triple frequency retrievals are more accurate than dual and single frequency retrievals.
- However, in practice, triple frequency retrievals (or at least the most complex formulations) may not be as robust as simpler formulation.
- A D_m driven approach is likely to be the best option in transitioning from single to multiple frequency retrievals.