Unambiguous information retrievals from remote sensing measurements

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Space-based measurements provide a wealth of information for Earth Science studies. Deriving the maximum benefit from such measurements depends heavily on the inverse method applied for converting data to information. A tremendous progress in solid-state physics in the past few decades offers highly precise sensors and the understanding of radiative-transfer physics is mature, but the operational practice of deriving information from these data falls short of a visible progress due to the applied inverse methods. Since the commence of the satellite era, operational retrievals have been generally dominated by stochastic approaches (*e.g.* Bayesian inverse and/or Regression/Machine Learning), where many ambiguities are pervasive. The major drawbacks of these methods include a high reliance on *a priori* information, treating error as definite information and binding the satellite retrievals to in-situ measurements.

In this talk, a simulated retrieval experiment is conducted for a nadir-pointing W-band (94 GHz) radar for the CloudSat cloud profiling radar. The measured radar reflectivity is simulated by considering a) the backscatter component, and b) the two-way attenuation along the slant path of the radar beam, both of which are proportional to the rain-rate, but of opposite signs. Results from transformative approach are also compared against those from the dominant Bayesian Inverse (BI) and are shown in Figs. 1 a-b, respectively.

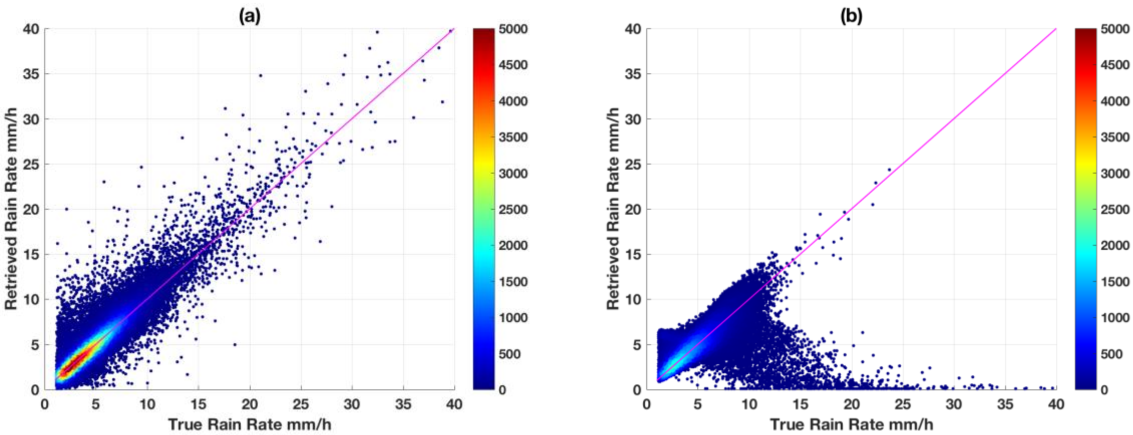

Figure 1: Bivariate density plot of retrievals *vs.* true rain rate. Retrievals are performed employing equivalent of direct CloudSat measurements. [a] Employing transformative approach. [b] Employing BI.

Fig. 1 shows that transformative approach outperforms BI for almost all cases. However, what is striking here in the case of BI results is the gross underestimation of retrievals above ~10 mm/h of true rain rate. Conventionally, it is assumed that constraining a BI implementation with *a priori* profile will force the solution to stay within a reasonable range. As was discussed in [1], many of the BI retrievals are of low value and close to 0 in Fig. 1b due to the *a priori* constraint of 5 mm/h and produce a one-sided pattern. Another interesting observation is regarding the misconception about the effect of information content on the quality of retrievals. It has often been argued that the information content of an ill-posed problem is very low, which degrades the retrieval. But in this particular case-study, as seen in the study elaborated in [1], the information content in terms of Degrees of Freedom in Retrieval (DFR) is reasonably high, *i.e.*, 12 to 15 pieces of information are available for deriving a solution for 16 grids. This implies that the information content cannot be regarded as the reliable metric for the quality of retrieval for all problems. Nevertheless, Fig. 1b clearly highlights the drawbacks of using BI to solve this problem. Even with full information content and no measurement noise, a gradient-based retrieval scheme cannot produce a unique solution for such Lagrangian functions. Thus, the information content measure cannot guarantee a high quality solution when the problem suffers in an iterative optimization process resulting from the functional complexity.

[1] P. K. Koner, A. Battaglia and C. Simmer, ‘A Rain Rate Retrieval algorithm for Attenuating Radars Measurement,’ J. Appl. Meteorol. Climatol., **49**, 2010, pp. 381–393.