CHALMERS
UNIVERSITY OF TECHNOLOGY

David I. Duncan[1], Chris Kummerow[2], Brenda Dolan[2], Veljko Petković[2]
1. Chalmers University of Technology, Gothenburg, Sweden
2. Colorado State University, Fort Collins, CO
david.duncan@chalmers.se

TOWARDS VARIATIONAL RETRIEVAL OF WARM RAIN FROM PASSIVE MICROWAVE OBSERVATIONS

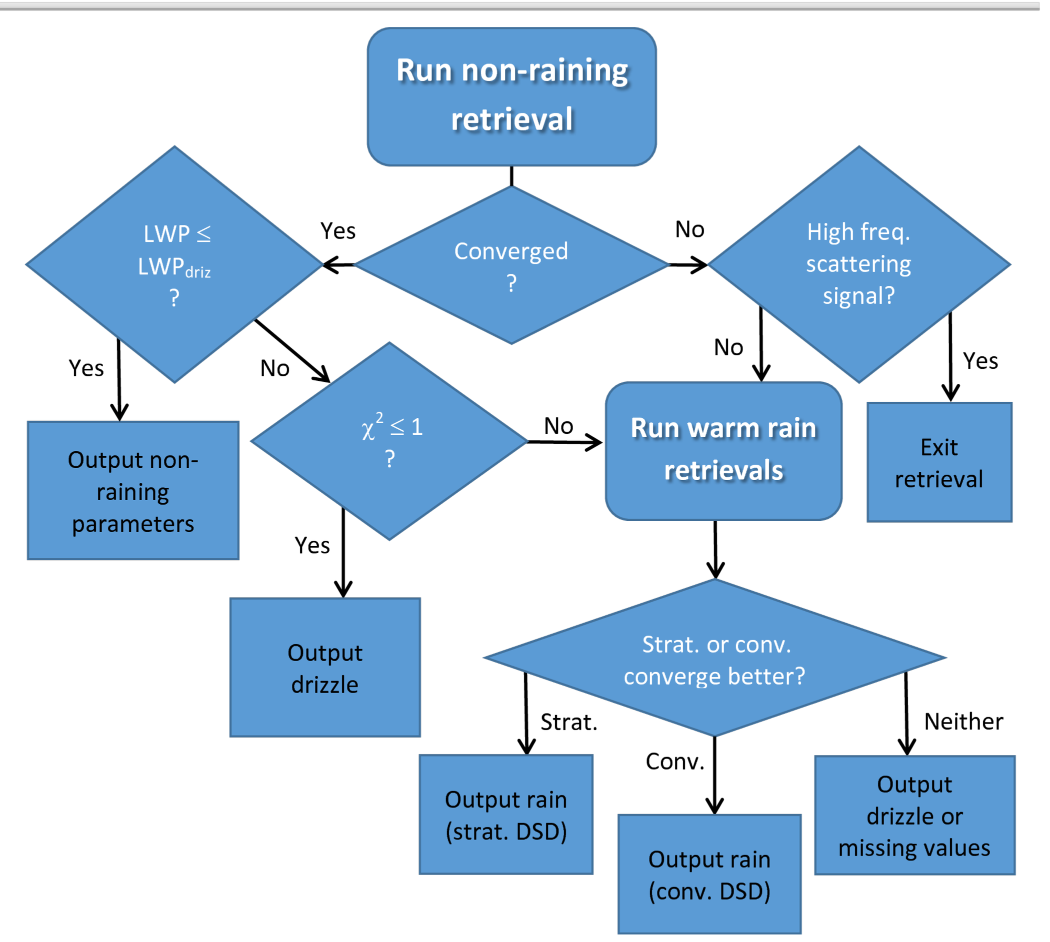
Using CloudSat and disdrometer data to increase sensitivity to light rain from the GPM Microwave Imager (GMI)

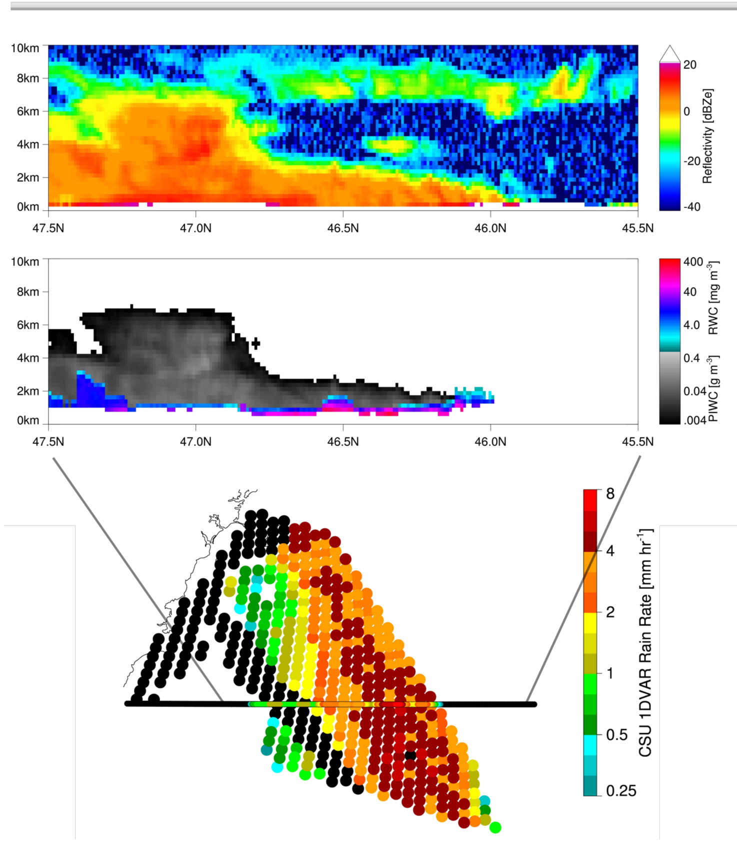
ABSTRACT

A variational retrieval (CSU 1DVAR) is extended into warm rain, underpinned by hydrometeor covariances and drizzle onset data derived from CloudSat. Radiative transfer modeling of drop size variability from disdrometer observations permits state-dependent observation error covariances, scaling with total rainwater during iteration. The state-dependent errors for raindrop distributions are novel and may be applicable for future retrievals and all-sky data assimilation. This method can effectively increase passive sensors' sensitivity to light rainfall that might otherwise be missed.

Comparisons with radar estimates demonstrate that the passive-only variational retrieval is sufficiently constrained from clear-sky through warm rain conditions. For liquid-only precipitation, it shows better sensitivity than a benchmark retrieval. Analysis against products from the Global Precipitation Measurement (GPM) satellite shows substantial differences in precipitation frequency, with this retrieval observing more frequent light rain. This approach may be complementary to other precipitation retrievals.

Fig. 1. Flowchart for the CSU 1DVAR retrieval with warm rain. The non-raining retrieval (Duncan and Kummerow, 2016) retrieves column water vapor, liquid water path (LWP), wind speed, and SST simultaneously over ocean via a 1DVAR methodology. Drizzle onset liquid water path (LWP_{driz}) is a function of SST and water vapor, determined offline from CloudSat data. The high frequency scattering signal condition is met if 166 and 183GHz observed T_B is -8K or less than simulated T_B.



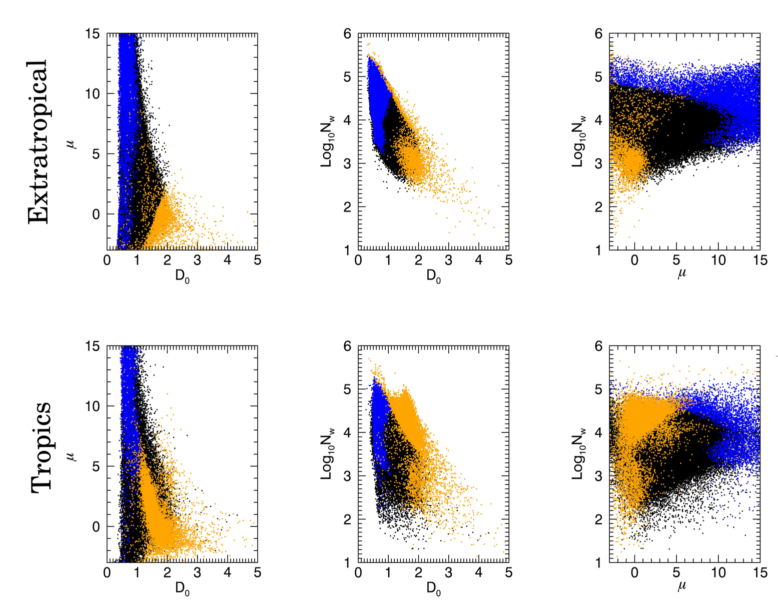


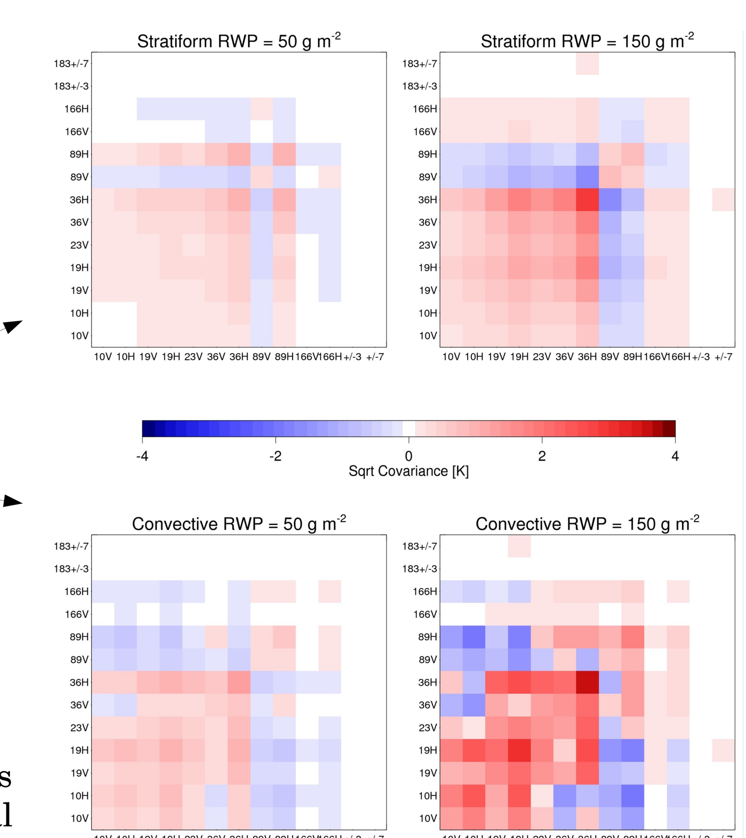
CASE STUDY NEAR FRANCE

Comparing CloudSat with the CSU 1DVAR for a case including warm rain and more convective rain driven by mixed phase processes. CloudSat and GMI estimates match fairly well where the clouds don't exhibit high ice water content (IWC), but estimates diverge as frozen hydrometeors are more prolific and affect the radiances. This showcases the retrieval's limitations, since the forward model is limited to liquid drops from warm rain, so precipitation processes driven by melting ice will cause non-convergence or bad retrievals.

METHOD

Disdrometer data (Fig. 2) are divided up into two regimes that resemble classic stratiform and convective drop size modes. Characteristic centroids are chosen to be representative of these regimes for both tropical and high latitude observations. Observation errors caused by assuming a drop size distribution (DSD) in the VAR retrieval are defined as T_B deviations caused by this assumption versus the true DSD. This is accomplished via radiative transfer simulations. These errors can be scaled as a function of rain water path (RWP). This source of observation error (Fig. 3) is added in quadrature to the errors assumed in the non-raining retrieval, populating a full error covariance to characterize raining VAR retrievals.

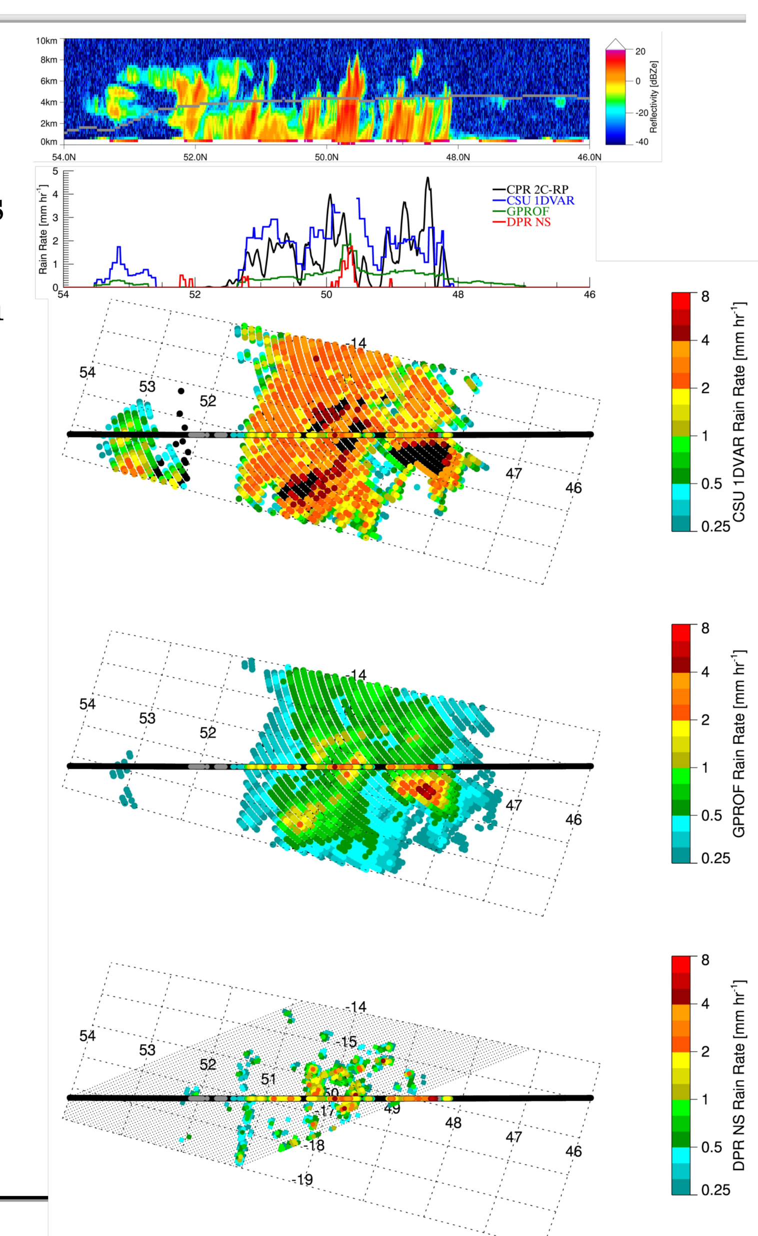




Figs. 2 & 3: Disdrometer data (above) in stratiform and convective regimes determined via EOF analysis. These data were put into a RT model to derive the error covariances (right), evaluated at GMI frequencies. Errors are a function of RWP, shown for example at two nominal values for both regimes.

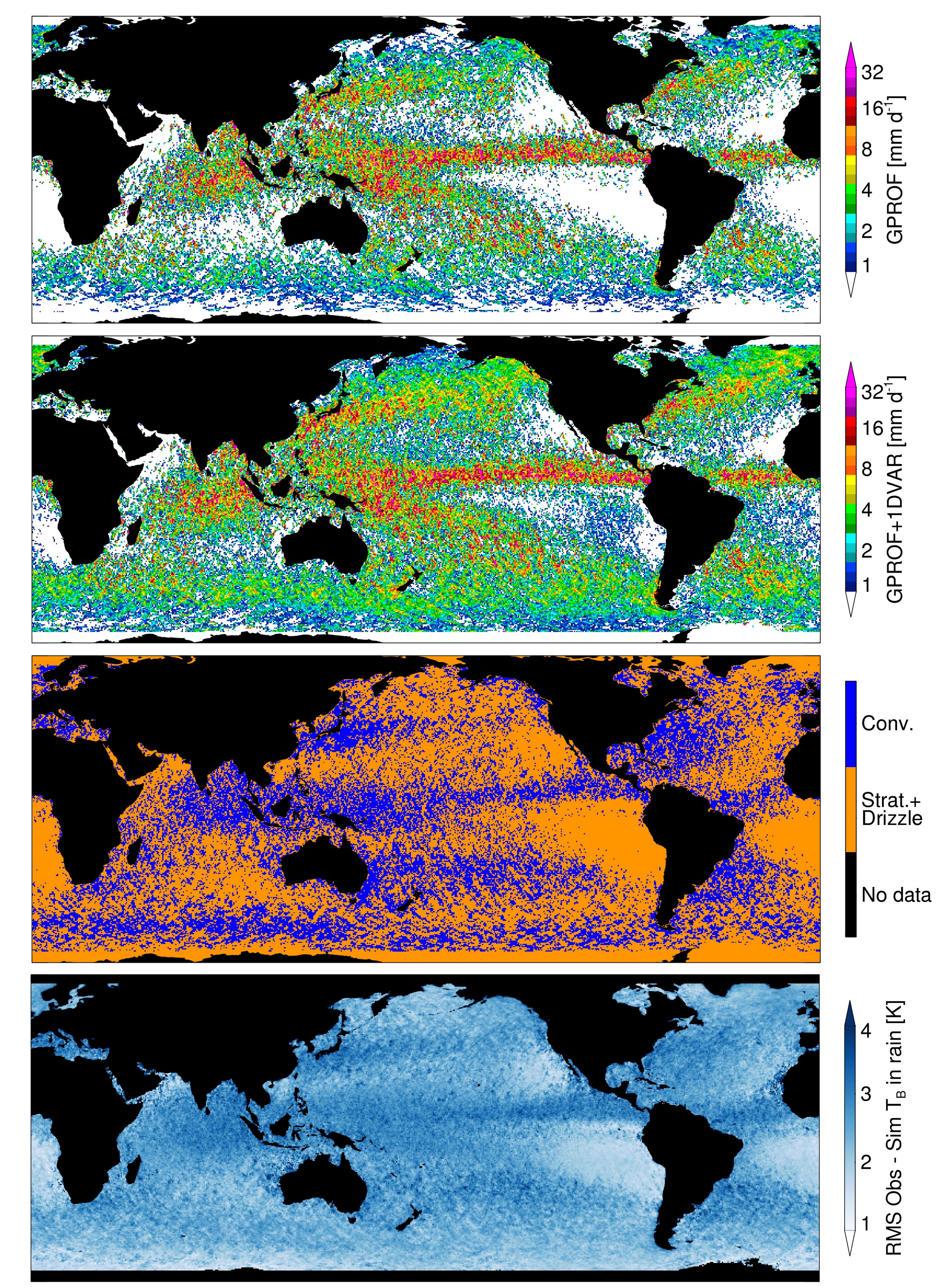
CASE STUDY IN NORTH ATLANTIC

At right is a co-located CloudSat overpass through a GPM swath. The CloudSat reflectivities are on top, with rain rates from 2C-Rain-Profile included in the bottom panels. These are contrasted with estimates from the CSU 1DVAR, the standard GMI algorithm (GPROF), and GPM's Dual-frequency Precipitation Radar (DPR). The 1DVAR estimates match CloudSat best in cases with limited reflectivity visible above the freezing level (grey), indicative of predominantly warm rain. Failed 1DVAR retrievals (black) indicate significant mixed phase or frozen hydrometeors, outside the scope of the forward model. The 1DVAR exhibits a slight overestimate relative to CloudSat, perhaps due to lack of an evaporation model in the algorithm.



GLOBAL RESULTS

One year of GMI data were run through the retrieval and compared to the operational passive GPM retrieval, GPROF (below). Results were gridded at 0.25°. In the GPROF+1DVAR panel, only 1DVAR retrievals with a match to radiances within assumed errors (χ^2<1) supplant the GPROF estimate. Merging the two retrievals' estimates is significantly increases precipitation rate and frequency at higher latitudes, with increases also visible in stratocumulus areas of the tropics and subtropics. The third panel shows the predominant DSD assumption for converged warm rain retrievals. The last panel gives the mean fit to observed radiances in rain.



CONCLUSIONS

A properly constrained variational retrieval can outperform a benchmark passive microwave rain retrieval for warm rain over ocean. This was accomplished by leveraging CloudSat and characterizing the state-dependent errors caused by assuming a DSD, as more rain in the column causes larger radiative transfer errors. This is potentially a method to bring GPM and CloudSat precipitation estimates closer together, increasing GMI's sensitivity to rainfall below the limits visible by the GPM radar.