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Retrieving consistent profiles of clouds and rain from active instruments using a unified approach

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The standard approach for retrieving cloud and precipitation properties from satellite instrument combinations such as the A-Train and EarthCARE is to use separate algorithms for ice clouds, liquid clouds and rain, with a-priori constraints on some of the retrieved variables. It is often not clear how to incorporate more complex physical constraints, such as the fact that the retrieved liquid water content profile in stratocumulus should not be super-adiabatic. Moreover, when different hydrometeor types are retrieved separately, it is not possible to add constraints between different types.

In this presentation we focus on the ability of our new "unified" variational scheme to retrieve ice and rain properties simultaneously in nimbostratus, enabling extra constraints to be incorporated. In ice clouds we use the Delanoe and Hogan (2008) approach, retrieving extinction coefficient and normalized number concentration exploiting in particular the different size dependence of radar and lidar. In rain we retrieve rain rate and normalized number concentration. Since rain drops fall rapidly, the properties of rain tend to vary slowly in the vertical. Thus, we add additional terms in the cost function penalizing vertical variations in rain rate and number concentration.

Physically we expect the ice mass flux just above the melting layer to be very similar to the rain rate just below it. This constraint is implemented by adding an extra term to the cost function penalizing the difference between the two. The radar forward model incorporates multiple scattering using the fast yet accurate method of Hogan and Battaglia (2008), melting layer attenuation using the relationship of Matrosov (2008), and the ability to use the radar path-integrated attenuation over the sea.

The performance of the method has been assessed using A-Train data. It is also being applied to NASA ER-2 aircraft data, which carries a 94-GHz radar to use in the retrieval and an X-band radar which is much less affected by attenuation and so the ability of the retrieved profile to "forward model" X-band reflectivity off-line provides one means of validation. We will also discuss the possibility of exploiting EarthCARE's Doppler signal for retrieving both raindrop size distribution information and ice density in the presence of riming.