Improving NWP forecasts through the direct 4D-Var assimilation of space-borne cloud radar and lidar observations

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As the fidelity of global numerical weather prediction (NWP) models to resolve convective scale features increases with advances in computing power, high-resolution observations of clouds and precipitation are becoming increasingly important for both evaluating model performance and initialising forecasts. This talk focusses on the latter by presenting developments made to the ECMWF integrated forecast system (IFS) to allow the direct 4D-Var assimilation of spaceborne cloud radar and lidar observations. Due to the radar and lidar signal's ability to penetrate clouds, these observations provide a unique insight to the vertical and horizontal structure of clouds. The additional information provides a fantastic opportunity to improve the model analysis of cloud and precipitation and the subsequent forecast, however extracting useful information from these observations, which are often only partially resolved by the model, pushes current data assimilation systems to their limit.

In this talk we will provide an overview of the developments to the IFS to allow the assimilation of cloud radar and lidar, including a triple-column technique to represent unresolved condensate variability in the simulated observations and the characterisation of observation error, both of which are vital to optimise the observations' use. We will then give a thorough assessment of the impact of assimilating cloud radar and lidar on NWP forecast skill by assimilating CloudSat radar reflectivity and CALIPSO lidar backscatter on top of routinely assimilated observations. As well as showing improvements by evaluating forecasts against analyses, we will show the observations provide increases in forecast skill when verifying against independent observations, such as top-of-atmosphere radiative fluxes. Looking to the future, the upcoming ESA EarthCARE satellite mission will provide the opportunity to assimilate cloud radar and lidar observations operationally. Differences between CloudSat and CALIPSO with EarthCARE observations will be briefly discussed along with the potential for synergistic uses of other EarthCARE observations, such as Doppler velocity, cloud extinction and shortwave radiances.