Cloud Condensate Control Variable Transform and Background Errors

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We will present progress on work to add cloud condensate control variable to a 4D-VAR analysis system at ECMWF. First, in 4D-VAR the linear physics scheme needs prognostic cloud variables to be able to use additional cloud information from observations, and in the current phase of our development the additional prognostic variable is cloud condensate (cloud liquid water and ice). Second, it is necessary to describe the relationship of cloud condensate background errors to the errors in other variables, and we have found a physical-statistical balance relationship between cloud condensate, humidity (and temperature) errors which are included as a change of variable from total to "unbalanced" cloud condensate. Third, the normalization of cloud condensate by its background error standard deviation requires particular attention because of the spatial inhomogeneity of the cloud field and the non-Gaussian errors. In this presentation we will focus on the formulation of cloud condensate background errors.

The relationship between cloud condensate and humidity/temperature background errors was investigated using forecast difference samples from ECMWF ensemble data assimilation (EDA), as was the gaussianity of different versions of the cloud condensate control variable. A global wavelet covariance matrix was derived from the EDA for the resulting cloud condensate control variable. On of the main challenges in deriving cloud condensate covariance matrices (and variances) is that clouds are not present everywhere all of the time. For variances, we have addressed this by imposing minimum climatological values of the cloud condensate errors, and similarly for the covariances nonzero values are imposed above the tropopause. The wavelet covariances are determined from a large sample of EDA forecast differences spanning different seasons, which gives a series of climatological covariances, one every few hundred kilometers. This results in different covariance matrices in different regions, with broad vertical correlations in convective regions and narrow vertical correlations in subsidence regions. Single observation experiments will be used to illustrate the different aspects of the control variable transform in clear and cloudy regions.