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Background errors and control variables for clouds and precipitation

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Thanks to their explicit microphysical parameterization, non-hydrostatic Cloud Resolving Models (CRM) allow realistic representations of non linear diabatic processes. Forecast errors of thermodynamical variables and hydrometeors can be computed specifically in cloudy and precipitating conditions by applying e.g geographical masks to ensemble of forecasts obtained with such CRMs and by performing statistics on forecast differences. The resulting covariances generally strongly differ from climatological statistics that are used in operations, which demonstrate that observations performed in those conditions, as those from e.g Doppler Radar and microwave radiometers, are clearly under-exploited. Such covariances are indeed clearly flow-dependent and are characterized by strong inhomogeneities and by non-Gaussianities. Change of variables may be considered at that point to work with more Gaussian pdfs. Illustrations will be given for different meteorological phenomena such as strong convective cases or fog. Studies have shown that specific background error covariances can be modeled in those conditions (and thus used in purely variationnal DA techniques), but frequent updates are required. When considering hydrometeors in the Control Variable (CV), modeled covariances are however hardly usable, as their spatial inhomogeneities are enhanced and furthermore vertically stratified.

To account for these flow dependencies in a deterministic DA process, a direct approach consists in sampling background error covariances from an ensemble of forecasts run in parallel and to use them in sequential (e.g. EnKF) or in variationnal (e.g. EnVar) DA systems. In those methods, an important step consists in reducing the sampling noise by applying localization functions, which aim to damp sampling noise of the covariances with distance. Localization length-scales can be directly diagnosed in the model space from the ensemble and geographical masks can also be used to compute specific values for hydrometeors. Here again, great variability between variables occurs, especially for the latter variables. Illustrations will be given by using background error perturbations from the operational EDA based on AROME-France, which is run at Météo-France with at 3.2 km horizontal resolution. Such localization length-scales can then be exploited in an EnVar context.

Even without direct observations of cloud and precipitation related variables, increments of hydrometeors can be obtained from those DA algorithms thanks to the background error cross-covariances between control-variables. Such cross-covariances allow indeed to project increments of thermodynamical variables implied by the assimilation of e.g. Doppler wind and pseudo-profiles of relative humidity deduced from the Radar reflectivities onto those of hydrometeors. Improvements in the forecast of cloud coverage and accumulated precipitation have been obtained considering such covariances within an EnVar applied to AROME, but for very short ranges. Many challenges remain to reduce the spin down effect and to get more lasting impacts. Favorable analyzed thermodynamical conditions may be key aspect, as hydrometeors are transient by nature. Moreover, the assumptions made in classical DA, especially the linearity of the prominent processes and the Gaussianity of uncertainties's pdf, are likely to be violated to some degree. Some options that may help will be finally discussed.

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