FINAL REPORT PROGRAM LEFE

Program LEFE / MANU	Project Title CORRBEAU3D	Years 2020-2023
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Context : In the context of high resolution varational data assimilation, accounting for spatially correlated observation errors is one of the big challenges in meteorology. Correctly modeling these correlations enables the assimilation of observations with a much denser spatial distribution, while reducing the amount of thinning applied before minimisation. Tackling this challenge becomes more and more necessary as the native resolution of the teledetection instruments used in meteorology increases.

Objectives / scientific questions : In this project, we decided to investigate how 3D observation error correlations can be accounted for using cost-efficient algorithms in variational data assimilation. While the 2D part is usually a reference to the horizontal, the third dimension does not always refer to the vertical axis. For instance, 3D correlations in the SEVIRI measurements can be split into a 2D horizontal component and a 1D interchannel component. In this case, interpreting the interchannel correlations as « vertical » correlations is not straightforward. The question was : what is the best mathematical model to represent these correlations ?

Main results : To answer this question, we decided to take on a very pragmatic approach. Therefore, several secondary questions had to be answered first, each of which led to its own study and was very beneficial to our overall understanding of observations and how to deal with their correlated errors. To begin with, we thought about which observations actually contain errors both correlated on the horizontal plane and on the vertical. Performing Desroziers diagnostics allowed us to target three types of observations : RADAR data, SCAT data and SEVIRI data. To deal with the RADAR and SEVIRI data, we had to alleviate the thinning process to allow for assimilating observations at a higher resolution. Doing so, we drew a direct link between the way thinning is performed on the RADAR and SEVIRI observations, and the resulting condition number of the observation correlation matrix. Results were presented during the ISDA conference. Then, we sought a way to model the 3D correlation operator for RADAR observations errors using the finite element approach described in Guillet et al. 2019. However, generating the mesh led to a bad representation of the observation error gradient field and was detrimental to the finite element method. We concluded that splitting the 3D correlation operator into three 1D operators acting on each direction (radial, azimutal, elevation) was the best option. After that, we took interest in the SCAT problem. Scatterometer observations, as assimilated in our systems, are represented by horizontal vector fields. This means that each point is associated with two values (u,v) instead of one scalar value. Therefore, we had to deal with spatial u-u correlations, spatial v-v correlations, and cross-correlations between u and v. To that end, we developped a new operator based on the Hodge-Helmholtz decomposition to apply a diffusion-based correlation operator in the vorticity-and-divergence space. Results were also presented in the ISDA conference. Finally, we delt with the SEVIRI data using a 2D+1D approach, thus treating the horizontal and the interchannel error correlations separately. This last study led us to develop a full C++ maquette for modelling observation error correlations, interfaced with the OOPS (Object Oriented Prediction System) framework used at Meteo France and ECMWF. We aim to make this development operational in the next few years.

Illustration 1

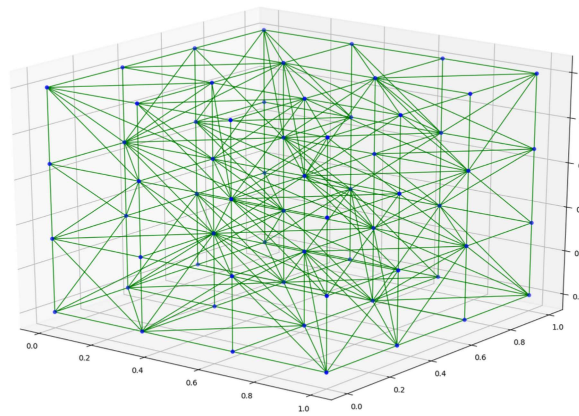

Illustration 2

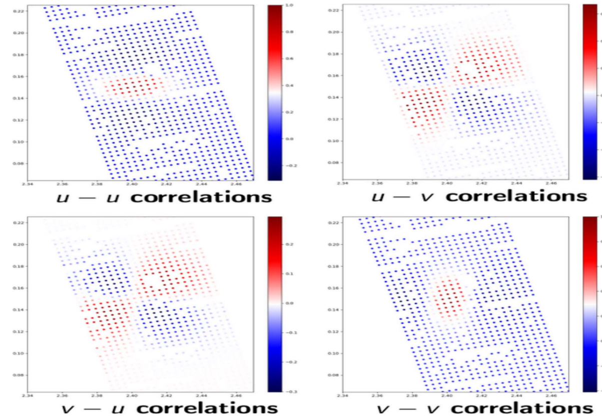

Illustration 1 : This is an example of a 3D mesh build from 7x7x7 points. In practice, we have many more observations locations and each location is a node in the mesh, but the figure was too difficult to read in we took the whole dataset. Explanation : The 3D mesh is made of 3D simplices (tetrahedra) and is generated with a modified Delaunay algorithm that proceeds in two steps. The first step is to mesh the outward surface of the observations and the second step is the extends that 2D surface to a volumetric mesh. In this example, the computations were not parallelized. In an operational framework, it is necessary to use an optimized 3D mesh generator, such as the Atlas software provided by the ECMWF.

Illustration 2 : Visualization of the horizontal correlation operator response for SCAT measurements. As seen of the figure, the operator produces cross correlations between the two components u and v of the horizontal wind. This is particularly useful for generating observations perturbations in the ensemble data assimilation system. Generating the perturbations is done by applying the square-root of the correlation operator (or matrix) to a random white noise signal.

Future of the project : In the future, we want to strengthen the international collaboration between Meteo France, Cerfacs, the ECMWF and the MetOffice on the topic of accounting for correlated observation errors in data assimilation. Also, there is an ongoing Phd work at Météo France aiming to develop a diffusion (and finite elements) -based correlation operator in the operational model Arome.

Number of publications, communications and theses :

4 communication in international symposiums and conferences

1 poster in international symposiums and conferences

2 internships

2 visits to the ECMWF and the University of Reading

Data availablility :
ISDA website
WMO website
contact : oliver.guillet@meteo.fr pour all ressources and samples codes