Model radar rainfall uncertainty using ensembles

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Abstract

Weather radars are powerful instruments to estimate precipitation because they offer wide aerial coverage at high spatio-temporal resolution. Nonetheless, they are subject to different sources of errors, and the model through a complex physical description of the atmosphere can cause the uncertainty. One of the most used approaches is instead to model the overall uncertainty in the data and to express it through an ensemble of equiprobable realizations of the same rainfall field. This approach allows for an easy evaluation of uncertainty propagation in hydrologic, hydraulic and water quality models. It is possible to assess the propagation of uncertainty in models feeding them with all the ensemble members and observing the output spread. [1, 2] This work compares the most used approach presented by Germann et al. in 2009 (named REAL) [1] and a new approach developed by the authors. The idea is to sacrifice the directionality in the description of error spatial correlation, with the aim of improving flexibility and speed of the REAL method.

Radar Errors

Radar estimates of precipitation are a useful instrument in hydrology, but are subject to a variety of error sources [3, 4]. Some of the error sources are: attenuation (a), shielding (b), and partial beam blocking (c).

The objective of this work is to find the best method to model the radar rainfall errors and to generate ensembles for different model applications. Most of the existing methods in literature are based on the REAL ensemble generation method proposed by Germann et al. in 2009. The REAL method estimates the radar error using quality checked rain gauge data as an approximation of true rainfall. The error are modelled as closely as a rain gauge and the radar, in logarithmic domain. The error characteristics are described through the covariance matrix of the errors. The ensemble error component are then generated combining the decomposition of the covariance matrix, obtained by LU or SVD, and a random normal generated error. This approach forces the ensemble members to maintain the covariance structure of the measured errors. The REAL approach works well with a medium number of point measurements, but is not very robust for large enough when the number of rain gauges is large. The critical passages are the calculation of the covariance matrix, which is computationally demanding because it needs to be calculated on at least one year of hourly data for each gauge location in order to be representative; and the covariance matrix decomposition, which requires the calculation of the error covariance to be positive definite.

New method: model radar rainfall error spatial correlation with a lowpass filter

To deal with some of the problems reported in Figure 2, the authors are developing an alternative approach to generate radar ensemble. The main difference with the real method is that, instead of describing the error covariances between each gauge point, the spatial correlation characteristics are described through one semivariogram, with an assumption of isotropy. The error components of the ensembles are generated filtering random gaussian fields with a lowpass filter, designed to obtain a field with the same semivariogram. The error components thus generated are then scaled to get the magnitude and the correlated field and combined with the original radar acquisitions to obtain the ensemble members, like in the REAL method. This approach sacrifices directionality of spatial correlation structure to improve speed, efficiency and flexibility of the algorithm.

Discussion and future work

The REAL method is one of the best and most used ensemble generators in literature. The purpose of this work is not to question the validity of the approach, but to propose a different method for a part of the ensemble generation algorithm. Although still under development, this new approach seems promising for its speed and flexibility. If the REAL method needs to process at least one year of data in order to assess the covariance, the new method can be applied acquisition by acquisition, once the characteristics of the errors are known. This opens the possibility to calculate real-time, for example in semivariogram of the errors routed, in order for different reasons, different types of precipitation, or in case of radar failure or the raw data processing algorithms are updated. Furthermore, the method is more robust to errors in the rain gauges, because they are averaged out in the statistics calculations. Instead, they can represent a problem in the covariance matrix positive definitiveness for the REAL method. Finally, the errors are directly generated on the radar grid, with no need of interpolation.

The method is almost complete, but refinements need to be applied to the variance calculation process, in order to achieve the comparison of punctual and aerial measurements [5]. Once the method is ready, a test will be done to assess the performance in hydrologic model applications and to compare it with the REAL method performance.

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Figure 1 schematic representation of some error sources processes

Figure 2 the process scheme represents the key passages of the REAL radar ensemble generation. The scheme also highlights the online points that the work addresses.

Figure 3 the illustration shows an original radar acquisition (a) on a 256km x 256km area over England on 04/02/2009. (b) and two corresponding ensemble members (c) out of the 100 generated, obtained with the REAL approach (b,c).

Error sources: difference rain gauge – radar measurements (big domain)

N. Random error fields:

Only in gauge workflow

Ensembles: Combine N. random error fields with the original radar

Figure 4 (top): Example of 10 (a) and 309 (b) filtered outputs of the rainfall and the correlated field applying the filter to a random Gaussian field (c).

Figure 5 (below): the process scheme represents the key passages of the new radar ensemble generator.

Figure 6 (right below): the original radar rainfall and the ensemble (c), in the same area and at the same time. Figure 3 is compared with two ensemble members obtained with the developed method (c) out of the 100 generated.