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MERGING RADAR - RAINGAUGE RAINFALL ESTIMATES: AN IMPROVED GEOSTATISTICAL APPROACH BASED IN NON PARAMETRIC KRIGING

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1. INTRODUCTION

Raingauges networks measure rainfall directly, but usually have a low spatial density, unable to fulfill the requirements of hydrological modeling. On the other hand, weather radar measures precipitation fields in an indirect way, but with a high spatial and temporal resolution. Therefore, the development of improved methodologies to estimate rainfall merging radar and raingauges data has been an objective from the initial studies of hydrological applications of meteorological radar. In this sense, previous works spawn a varied of approaches from the simplest formulation, finding a constant multiplicative calibration factor to statistical approaches based in multivariate analysis or geostatistical estimators. The aim of this work is to provide an improved geostatistical approach able to be applied operationally in real time.

2. CLASICAL GEOSTATISTICAL APPROACH

Geostatistics is the set of statistical tools that offers a way to take advantage of the spatial continuity of many natural phenomena and provides best linear unbiased estimations. These techniques have been applied to the mapping of precipitation fields, and to the merging of radar–rain gauges data. Some authors have showed that rainfall fields estimated by radar–raingauges cokriging improve flood estimates (Sun et al. 2000). Geostatistical approaches have to know spatial continuity model that both characterize the natural phenomena and guarantee to find a unique and valid solution. Normally, a theoretical covariance or semivariogram model is fitted to real data, considering only positive linear combination of basic models known to be positive definite. Then it is used as spatial continuity model in estimation process to interpolate sample covariance values. The positive definiteness property ensures existence and uniqueness of solutions of the geostatistical systems. Different fitted-models and diverse methodologies to define them have been reported in previous works. However, the restriction to linear combinations is sometimes limitative and the modeling processes can be high time demanding and is somewhat subjective.

In the context of real time estimation, the main problem of this application is to fit, quickly, a positive definite model for the cross-correlation between rain and radar data. In radar–raingauges merging process, usually, raingauges network data is scarce to define with adequate accuracy any spatial continuity model. On the other hand, radar rainfall fields normally have enough spatial information to fit some valid model, but its high temporal variability implies, in some cases, that fitted spatial models are only useful for one time step. These problems are crucial in real time hydrological applications that uses both radar and raingauges data, because it is necessary to estimate in each time step its input rainfall field merging both information.

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3. AUTOMATIC RADAR – RAINGAUGE MERGING ALGORITHM

We propose a methodology that uses an "automatic" non-parametric spatial covariance model that avoids the traditional a priori selection of covariance models. More details about the algorithm could be found in Yao and Journel (1998), or in Cassiraga et al. (2002). The main idea is to transform the experimental (cross) covariance tables into density spectrum tables using FFT. These density spectrum tables are then smoothed under the constraints of positivity and unit sum. A back transform through inverse FFT yields permissible (jointly) positive definite (cross) covariance tables. Through this method, permissible (cross) covariance tables are obtained automatically without calling neither any analytical model nor any linear coregionalization model. Notice that the difficult to verify positive definite condition in real space is overpass in the frequency domain, where the only requirements are that the density function obtained by FFT must be positive and its integral must be unitary.

4. RESULTS

The case study corresponds to the rain event occurred the 10-June-2000 in Catalonia (Spain) area. The database make use of a set of 128 reflectivity (dBZ) radar images from the Barcelona Spanish Instituto Nacional de Meteorología (INM-CMTC) radar that cover 140 km x 140 km area in intervals of ten minutes, and 77 pluviographs measurements, providing intensity of precipitation in mm/h.

Rainfall fields in 10-min time intervals were estimated using four different geostatistical techniques: Ordinary Kriging (OK), Kriging with External Drift (KED), Cokriging (COK), and Collocated Cokriging (ColCOK). A complete description of these kriging techniques can be found for instance in Isaaks and Srivastava (1989)

For each time step, the estimation process need, first, to calculate a valid correlogram using the non-parametric technique described above, second, to build the kriging equations system corresponding to any kriging technique used and finally to solve them. Each estimation process was evaluated in terms of time computing; looking for the faster alternative. We found that OK, KED and ColCOK are solved 10 times faster that COK systems with same hardware and software conditions. On the other hand, each estimated rainfall field is compared with radar reflectivity field and with the raingauges data in both statistical and qualitative sense. In statistical sense, it is interesting notice that known point measurements and mean value are preserved in estimated fields because all kriging estimators employ raingauges values as primary data. Therefore it is necessary to analyze which estimation procedure preserves better observed radar spatial structure. In a qualitative sense, the objective is to observe estimated rainfall fields with spatial shapes similar to those of the observed radar fields. The Fig. 1 shows correlation between estimated rainfall and observed radar fields, to all time steps. All kriging techniques were evaluated. The ColCOK and COK fields have higher linear correlation coefficients compared as other techniques. For one time step, the Fig. 2 illustrates the observed radar field, the observed raingauges data spline-interpolated field, and estimated rainfall fields using radar and raingauges data by kriging techniques mentioned before. In this figure, it can be seen a dual high precipitation band in observed radar field (Fig.2 a.) that raingauges measurements didn't show (Fig 2. b.). COK, KED and ColCOK rainfall fields (Fig 2., e.,d.,f.) reproduce adequately the shape of this dual band with an accurate adjustment by raingauges values.

5. CONCLUSIONS

We propose a new geostatistical methodology to merge radar and raingauges data in real time to estimate rainfall fields using an automatic non-parametric covariance model. Analyzing all database images, we found that, normally, KED and ColCOK estimations produce fields that conserve better the spatial variability of original radar field, and it could be found faster that using full Cokriging estimator. As future work it would verify the effect of the KED and ColCOK estimations used in this paper, in the hydrological response of a basin modeled using a real time hydrological model.

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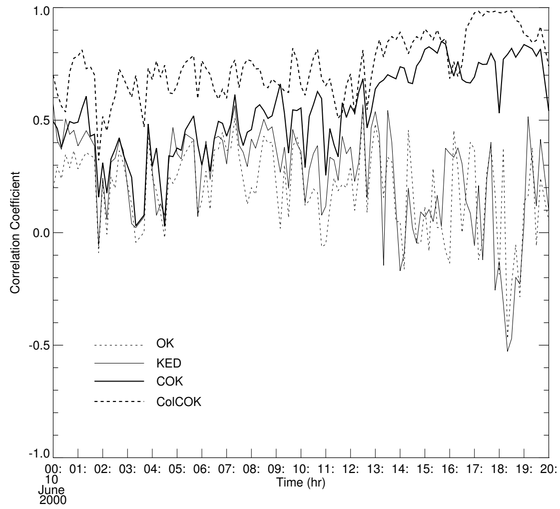

Figure 1: Temporal evolution of Kriging estimated fields and original rainfall radar field linear adjustment.

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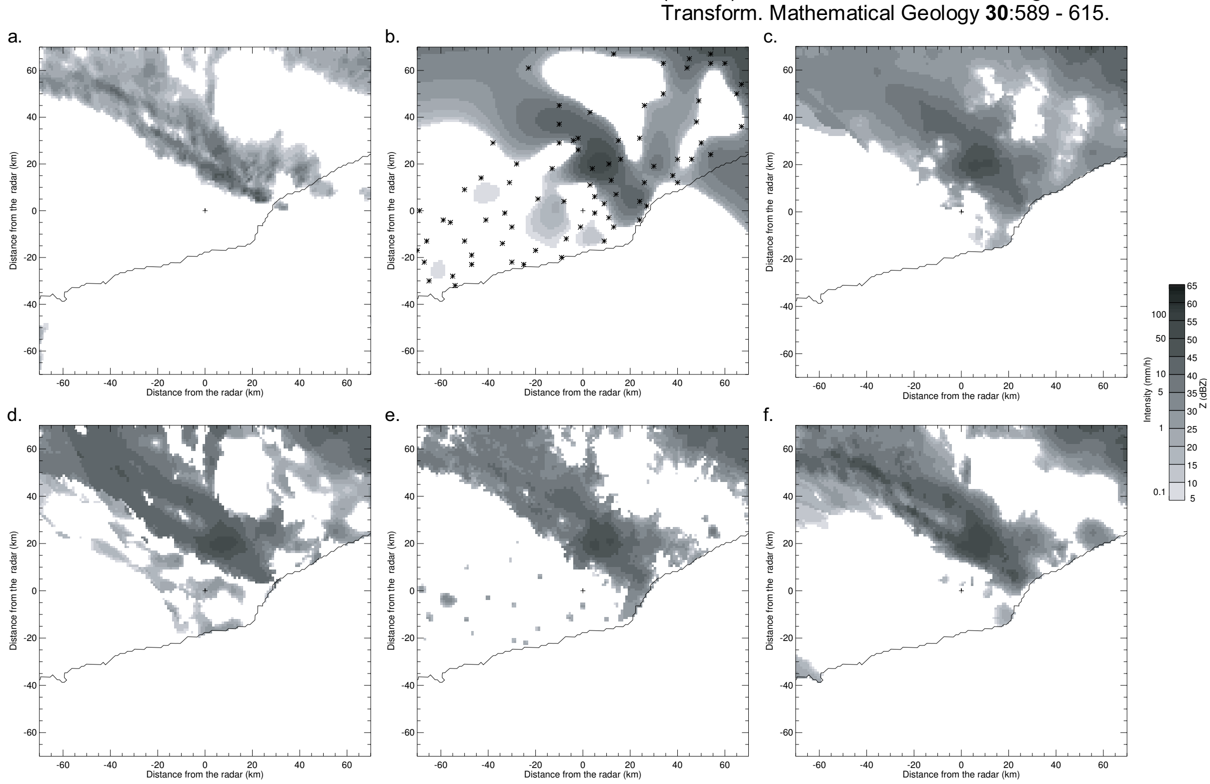

Figure 2: Rainfall field estimations. a) Observed radar field; b) Raingauges data spline-interpolated field; c) OK estimated field; d) KED estimated field; e) COK estimated field; f) ColCOK estimated field