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Optimizing weather radar observations using an adaptive multiquadric surface fitting algorithm

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Abstract

Real time forecasting of river flow is an essential tool in operational water management. Such real time modelling systems require well calibrated models which can make use of spatially distributed rainfall observations. Weather radars provide spatial data, however, since radar measurements are sensitive to a large range of error sources, often a discrepancy between radar observations and ground-based measurements, which are mostly considered as ground truth, can be observed. Through merging ground observations with the radar product, often referred to as data merging, one may force the radar observations to better correspond to the ground-based measurements, without losing the spatial information.

In this paper, radar images and ground-based measurements of rainfall are merged based on interpolated gauge-adjustment factors (Moore *et al.*, 1998; Cole and Moore, 2008) or scaling factors. Using the following equation, scaling factors ($C(\mathbf{x}_\alpha)$) are calculated at each position $\mathbf{x}_\alpha$ where a gauge measurement ($I_g(\mathbf{x}_\alpha)$) is available:

$$C(\mathbf{x}_\alpha) = \frac{I_g(\mathbf{x}_\alpha) + \epsilon}{I_r(\mathbf{x}_\alpha) + \epsilon} \tag{1}$$

where $I_r(\mathbf{x}_\alpha)$ is the radar-based observation in the pixel overlapping the rain gauge and ϵ is a constant making sure the scaling factor can be calculated when $I_r(\mathbf{x}_\alpha)$ is zero. These scaling factors are interpolated on the radar grid, resulting in a unique scaling factor for each pixel. Multiquadric surface fitting is used as an interpolation algorithm (Hardy, 1971):

$$C^*(\mathbf{x}_0) = \mathbf{a}^T\mathbf{v} + a_0 \tag{2}$$

where $C^*(\mathbf{x}_0)$ is the prediction at location $\mathbf{x}_0$, the vector $\mathbf{a}$ (Nx1, with N the number of ground-based measurements used) and the constant a_0 parameters describing the surface and $\mathbf{v}$ an Nx1 vector containing the (Euclidian) distance between each point $\mathbf{x}_\alpha$ used in the interpolation and the point $\mathbf{x}_0$. The parameters describing the surface are derived by forcing the surface to be an exact interpolator and impose that the sum of the parameters in $\mathbf{a}$ should be zero. However, often, the surface is allowed to pass near the observations (i.e. the observed scaling factors $C(\mathbf{x}_\alpha)$) on a distance $a_\alpha K$ by introducing an offset parameter K, which results in slightly different equations to calculate $\mathbf{a}$ and a_0.

The described technique is currently being used by the Flemish Environmental Agency in an online forecasting system of river discharges within Flanders (Belgium). However, rescaling the radar data using the described algorithm is not always giving rise to an improved weather radar product. Probably one of the main reasons is the parameters K and ϵ which are implemented as constants. It can be expected that, among others, depending on the characteristics of the rainfall, different values for the parameters should be used. Adaptation of the parameter values is achieved by an online calibration of K and ϵ at each time step (every 15 minutes), using validated rain gauge measurements as ground truth. Results demonstrate that rescaling radar images using optimized values for K and ϵ at each time step lead to a significant improvement of the rainfall estimation, which in turn will result in higher quality discharge predictions. Moreover, it is shown that calibrated values for K and ϵ can be obtained in near-real time.

References

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