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Marine X-band weather radar data calibration

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ABSTRACT

Application of weather radar data in urban hydrology is evolving and radar data is now applied for both modelling, analysis, and real time control purposes. In these contexts, it is all-important that the radar data is well calibrated and adjusted in order to obtain valid quantitative precipitation estimates. This paper presents some of the challenges in small marine X-band radar calibration by comparing three calibration procedures for assessing the relationship between radar and rain gauge data. Validation shows similar results for precipitation volumes but more diverse results on peak rain intensities.

1. Introduction

In the past, most quantitative precipitation estimates for hydrological modelling purposes have been measured with tipping bucket rain gauges, which operate in high temporal resolution, but unless multiple gauges are installed, within a limited area with deficient spatial resolution. Spatio-temporally distributed quantitative precipitation estimates using weather radars,have the benefit of high resolution in both space and time and thus become a rapidly expanding area of research within hydrology, e.g. Krajewski and Smith (2002), Overeem et al. (2009),Borga (2002),Borga et al. (2006),Rollenbeck and Bendix (2006) and in urban hydrology, e.g. Rasmussen et al. (2008a), Thorndahl et al. (2009, 2010), Einfalt et al. (2004), Smith et al. (2007), Borup (2008), Pedersen et al. (2006), and Pedersen et al. (2010). One of the radar types applied is the Local Area Weather Radar (LAWR) developed by DHI, Denmark (Jensen and Overgaard, 2002). This radar is produced on the basis of a marine X-band radar which makes it affordable compared to conventional weather radars.

Quantitative precipitation measurements with conventional X-, C-, or S-band weather radars are conventionally based on a theoretical relationship between radar power emission, reflectivity and rain intensity (e.g. Marshall and Palmer, 1948; Battan, 1973). The precipitation measurements with the Local Area Weather Radar, however, are based on a purely empirical relationship between radar reflectivity and rain intensity due to limitations in the marine radar design. Therefore the traditional theory cannot be applied. In order to obtain reliable rainfall measurements this type of radar has to be calibrated against rain gauges. This type of empirical calibration has previously been investigated by, e.g. Jensen (2002),Jensen and Pedersen (2005), Pedersen et al.(2008, 2010),Rollenbeck and Bendix (2006), Einfalt et al. (2005), Borup (2008), Rasmussen et al. (2008a), and Thorndahl et al. (2010).These authors present very different approaches to empirical weather radar calibration, ranging from simple static approaches based on accumulated values over a long time to more advanced dynamical (or transient) approaches in which calibration parameters are continuously adjusted. The different approaches are, however, all based on the empirical relationships between the radar reflectivity output in a given point or grid cell (pixel) and the rain volumes (or rain intensity) recorded in a rain gauge located in the same grid cell. The alterations between the

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different approaches are mostly differences in spatial and temporal resolutions or aggregation levels. Furthermore, some of the methods diverge in terms of how the distance (or scanning volume) correction is implemented (a volume correction has to be implemented as the beam width increases as a function of the distance from the radar). Some authors assume that the distance correction is done a priory,within the radar software, so that the radar output is aligned with regards to the distance from the radar. Others assume the distance correction as part of the post processing of radar data and therefore as part of the calibration.

There is a crucial need for consistency of calibration methodologies in order to apply these small weather radars for hind- or forecasting purposes in urban hydrology. Therefore, this paper will investigate three different calibration methods in order to determine which one gives the most reliable and consistent results in terms of estimating rain intensities (especially peak intensities) and volumes. The first and simplest method is based on an assumption of uniform rain depth within the range of the radar. The ratio between radar output and rain intensity is thus based on accumulated values over a long period of time. This method is referred to as the sum calibration method by Pedersen et al. (2010). The second method has its origin in event based precipitation and by applying linear regression, the ratio between the radar and rain gauges is obtained. The third method is an intensity based distribution fitting approach in which the ratio between rain gauge and radar is calculated in time steps, so that a distribution of ratios can be calculated. Basically the comparison between the three methods is a study of different aggregation levels in the calibration procedure ranging from accumulated yearly or monthly values over accumulated event based values to a level corresponding to the individual time steps. In order to compare the methods, the distance correction is carried out as part of the calibration procedure.

Applying almost 2 years of data (July 2008 to May 2010) from Aalborg Weather Radar, Denmark, this paper investigates different aspects of this calibration and the variations of the calibration parameters. Based on these different analyses, the paper proposes a standardized methodology for calibration of these marine and low-cost X-band radars for precipitation measurements in urban areas.

2. The radar

The Local Area Weather Radar applied in this study is located west of Aalborg, in the northern part of Denmark, Fig. 1. The radar has been running since 2004 as an experimental radar, and thus with changing configurations. The configuration was fixed in July 2008, and the data applied count the period from July 7, 2008 to May 5, 2010. Applications and specifications of the radar have been published by Rasmussen et al. (2008a, 2008b 2008c), Thorndahl et al. (2009) and Thorndahl et al. (2010). The radar has the specifications shown in Table 1.

In comparison with conventional meteorological radars, which mostly scan the atmosphere in different elevations with a narrow opening angle (Rinehart, 1997), the LAWR scans the atmosphere continuously with quite a large verticalopening angle of $\pm 10°$. This means that the sampling volume increases as a function of the distance from the radar. In order to handle this phenomenon, an exponential volume correction, mostly referred to as the distance correction, (γ_{VOL}) is implemented within the radar software (Pedersen et al., 2010; Jensen, 2004):

$$\gamma_{VOL}(r) = \frac{1}{a \cdot exp(b \cdot r)} \tag{1}$$

r is the radial distance from the radar
a and b are constants ($a = 1$ and $b = -0.01$)

In this study the values a and b are fixed and the distance correction is done as part of the calibration procedures instead of within the radar software.

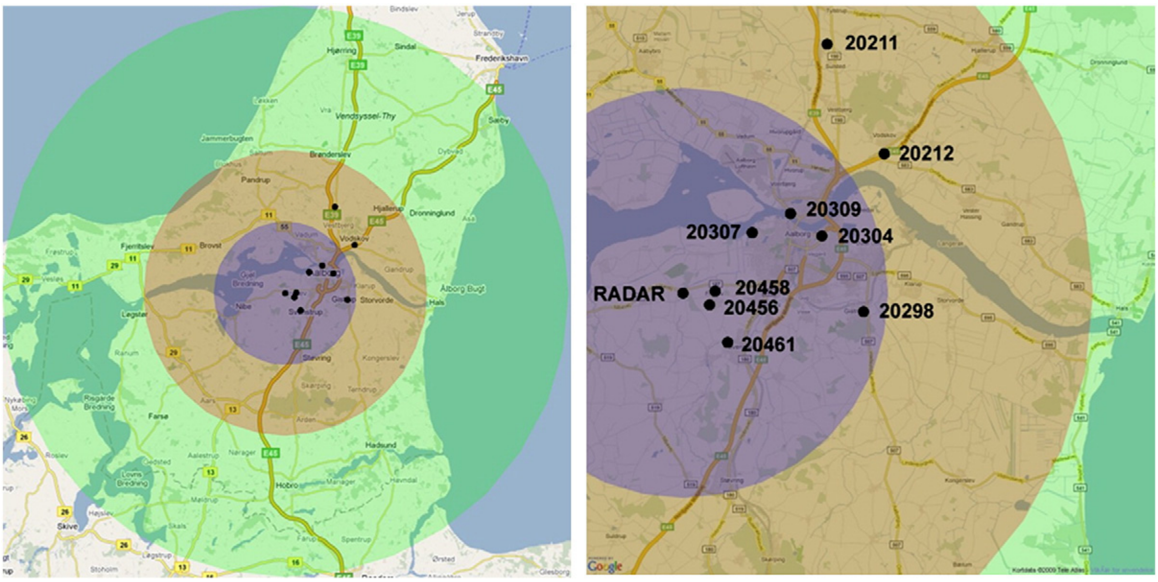

Fig. 1. Left: the three ranges of the radar, 60 km (green), 30 km (red) and 15 km (blue). Right: close up of rain gauges within the radar range. (Google Maps).