The use of X-band polarimetric radar to assess the impact of severe convection in urban drainage system

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Abstract

Weather observations are conventionally performed by single-polarimetric scanning C-band weather radars with a temporal and spatial resolution of approximately 5 min and 1 km, respectively. However, for urbanized areas, these resolutions may not be sufficient to obtain accurate quantity precipitation estimation (QPE) of fast-evolving weather phenomena. Therefore, to model fast rainfall-runoff processes and related short response times, urban hydrological modelling requires high resolution rainfall input data. In this work, a dual-polarimetric X-band weather radar (IDRA) located in the Cabauw Experimental Site for Atmospheric Research (CESAR) observatory of the Netherlands (NL) is used to observe and derive physical processes and obtain accurate QPE of severe rainfall events at high temporal and spatial resolutions. A large convective front moving over Western Europe on January 03 2012 was observed using the two C-bands operational radar from The Royal Netherlands Meteorological Institute (KNMI in Dutch initials) and IDRA. The rainfall amount forecasted for the same event by the weather model HARMONIE (HIRLAM ALADIN Research on Mesoscale Operational NWP In Euromed) is used to study its implications at urban scales. The accuracy on estimated rainfall from HARMONIE and KNMI radars is compared against IDRA radar to analyze the spatial variability of QPE and its impact on the drainage system of Rotterdam urban area.

1. Introduction

Spatial and temporal resolutions from conventional radars may not be sufficient to detect extreme rainfall events at urban scales (Schellart et al., 2012). However, small X-band radars are suited to obtain localized weather observations at high resolution. For example, the research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) consists of a network of dual-polarimetric X-band radars that obtain accurate QPE over regions with rapidly-evolving weather (Wang and Chandrasekar, 2010). In Western Europe, the RainGain project includes a network of X-band radars to obtain high resolution QPE in urbanized areas to cope with urban flooding (http://www.raingain.edu).

In this work, a long-lived convective front (squall line) moving over Western Europe is observed and analysed at distinct spatial and temporal resolutions to assess the variability of extreme rainfall at urban scales. In section 2, observations of the convective front by the KNMI radars are discussed. Forecasted QPE by the HARMONIE weather model is presented in section 3. In section 4, the accumulated QPE (AQPE) obtained from KNMI radars and HARMONIE model are analysed and compared against AQPE from IDRA. Finally, a summary and conclusions are given in section 5.

2. KNMI radar observations

In the Netherlands, weather radar QPE is obtained by combining reflectivity (Z) in mm^3 m^{-6} from the C-band radars located at DeBilt and DenHelder cities providing QPE at the altitude of 1.5 km with a gridded horizontal resolution of 2.4 km every 5 min (Overeem et.al., 2009). The relationship used to estimate QPE or rainfall rate (R) in mm hr^{-1} from reflectivity is given by the Marshall-Palmer relationship: $Z = 200 \times R^{1.6}$.

The estimated QPE field at 1420 UTC depicts a squall line as shown in Figure 1a). Typically, a squall line is a line of convective cells that forms along the cold front with a predominately trailing stratiform precipitation. However, the estimated QPE field showed stratiform regions behind and in front of the convective line; i.e., the convective line is surrounded by a trailing and a leading edge stratiform region. In the convective front, narrow segments approaching the NL show R values between 10 and 30 mm hr^{-1}; while in stratiform regions small R values between 0.2 and 5 mm hr^{-1} are observed. The existence of both stratiform regions is due to the occluded front detected by the IR satellite SAT24-EISQ51 at 1200 UTC. The HARMONIE prediction model is introduced next.

3. The HARMONIE weather prediction model

HARMONIE is a research prediction model with the capability to model and forecast convective weather scenarios (Krikken, 2012). In our setup, its domain area extends up to 750 km with a 2.5 km grid resolution and 60 vertical layers. HARMONIE gives QPE for a period of six hours starting at 1200 UTC every 10 min. QPE forecasted field at 10 m high and 1420 UTC is shown in Figure 1b). It can be seen that the forecasted convective line is situated behind the convective line observed by the KNMI radars. Note that, the trailing stratiform precipitation is not formed by the HARMONIE QPE field, although such stratiform region was observed by the KNMI radars, as shown in Figure 1a). Because we want to know the impact of the spatial and temporal variability of QPE on urban drainage systems, comparisons of the accumulated QPE at different scales are introduced next.

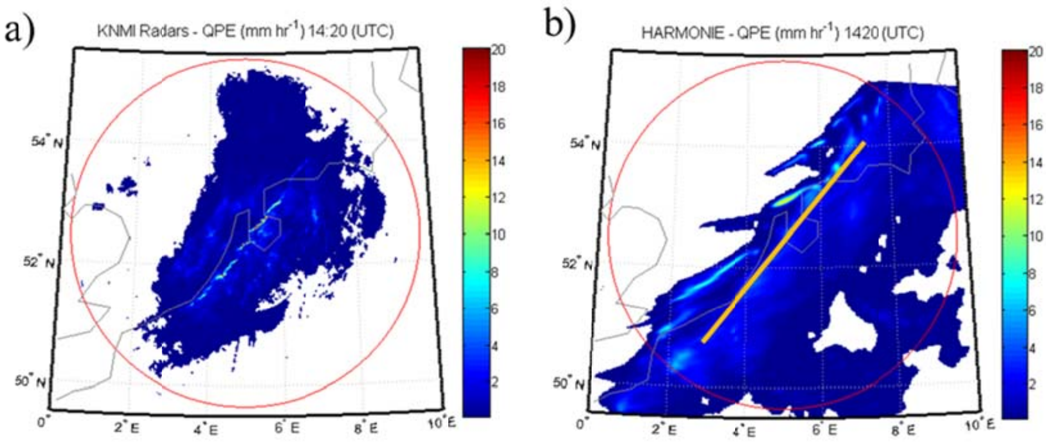

Figure 1. Panel a) QPE field obtained from KNMI radars showing a squall line moving east over the Netherlands at 1420 UTC. Panel b) 2 hr and 20 min forecasted QPE field.

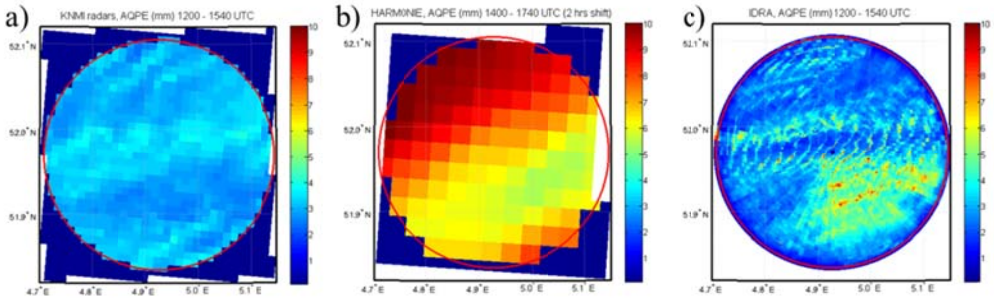

Figure 2. Accumulated QPE in mm obtained from a) KNMI radars, b) HARMONIE model, and c) IDRA radar.

4. IDRA and the accumulated QPE (AQPE)

The research radar IDRA provides QPE at the altitude of 150 m approximately, with 30 m range resolution. It uses backscatter differential phase and reflectivity to estimate QPE as described by Otto and Russchenberg, (2012). To calculate AQPE, QPE is assumed to be constant during temporal resolutions of 10, 5, and 1 min for HARMONIE, KNMI radars, and IDRA, respectively. Then, QPE is converted from mm hr^{-1} to mm and accumulated over time. AQPE from 1200 – 1540 UTC is shown in Figure 2. AQPE fields from KNMI radars, a), and HARMONIE, b), were clipped to meet the coverage area of IDRA, c). The mean of AQPE for KNMI radars, HARMONIE, and IDRA are 3.09, 7.50, and 3.16 mm, respectively. Although, the mean of AQPE from KNMI and IDRA radars are comparable, their spatial distributions of AQPE are different.

5. Conclusions

For an improvement of model initialization and QPE forecast of extreme rainfall events, weather radar observations should be assimilated by the HARMONIE model.

Due to the high resolution of IDRA, the spatial variability of AQPE was captured better than the KNMI radars and HARMONIE model.

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