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Toward the optimal resolution of rainfall estimates to obtain reliable urban hydrological response: X-band polarimetric radar estimates applied to Rotterdam urban drainage system

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Abstract

Weather observations are conventionally performed by single polarization C-band weather radars with a temporal and spatial resolution of 5 min and 1 Km, respectively. However, for urbanized areas, these spatial and temporal resolutions may not be sufficient to detect, monitor, and obtain accurate rainfall rate estimates of fast-evolving weather phenomena. An extended convective front over Western Europe was observed on January 03rd 2012. In this work, a S-band vertical profiler (TARA) and a X-band horizontal scanner polarimetric weather radars (IDRA) from the Dutch national meteorological observatory (CESAR) detected a fast-evolve convective storm showing typical supercell storm's features but at smaller scale. It is expected that new insights will be revealed based on the polarimetric and high-resolution capabilities from both radars. Rainfall rate estimates obtained from IDRA at elevation angle of 0.50^{o} will be used to show the rain spatial variability of rainfall input (from 100 m to upscale 1 km), in a highly impervious urban drainage system belonging to Rotterdam urban area.

Synoptic Observation

(Jan. 03rd 2012)

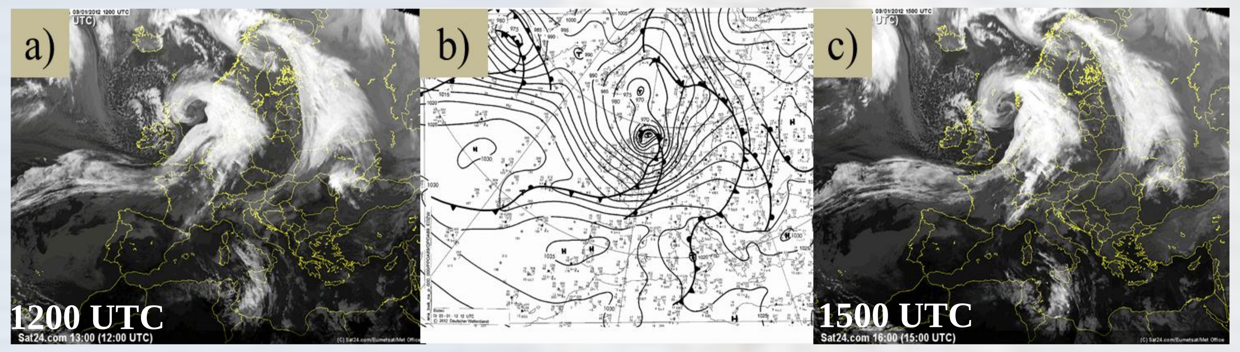

Fig.1 Panel a) shows an infrared (IR) satellite imagery from SAT24-EISQ51 over Europe on 1200 UTC, 03 January 2012 showing the strong frontal zone over the Netherlands associated with a deep low pressure system centered over the North Sea. Panel b) displays the corresponding synoptic chart at ground level, courtesy of the German Weather Service. Panel (c) is as in a) but 3 hours later at 1500 UTC, 03 January 2012.

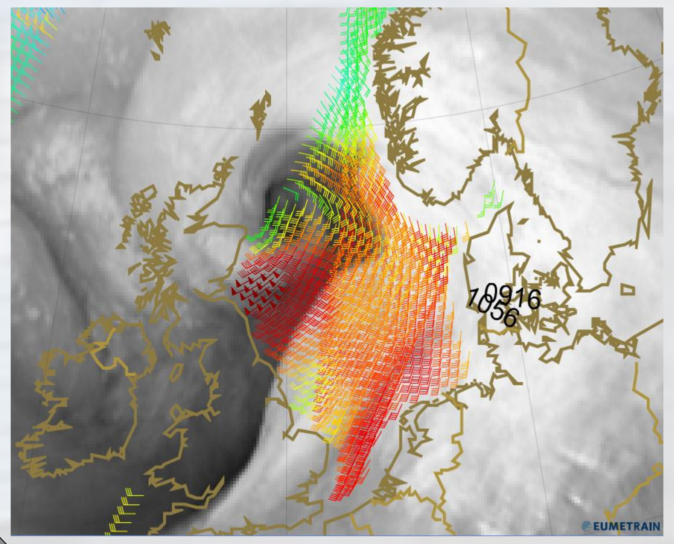

Fig.2 Wind field at 1200 UTC associated with the cyclone system located in the North Sea and moving eastwards. Courtesy of EUMETRAIN.

Mesoscale Observation

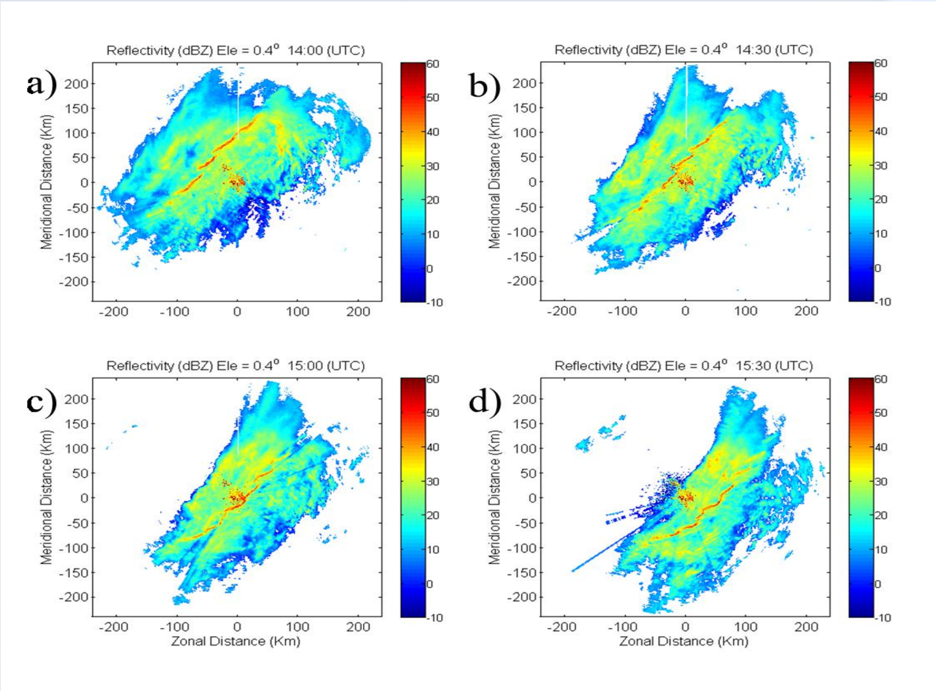

Fig.3 Reflectivity field results from elevation angle of 0.40^{o} observed by DeBilt radar. The evolution of the squall line from 1400 to 1530 UTC sampled at 30 min is shown in panels a) ... d). The squall line moves southeastward passing over DeBilt. Note the multiple bow echoes segments along the front.

Conceptual Supercell Model

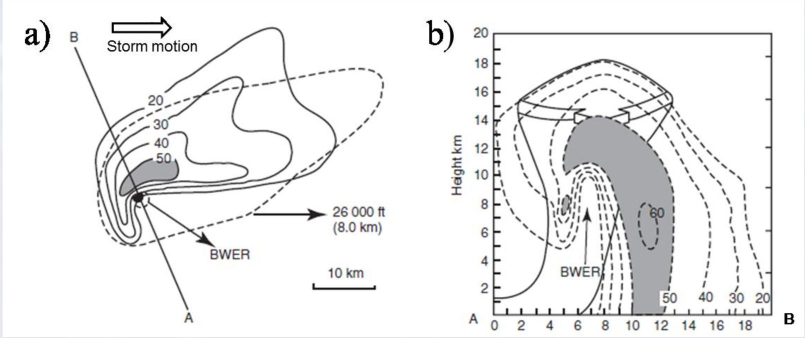

Fig.4 Schematic representation of a mature phased supercell storm. a) Top view: Hooklike appendage and the bounded weak echo region (BWER) located at the southwest flank of the cell. b) Vertical cross-section view: Solid lines indicate the updraft and the outflow aloft. The strong downdraft is shown by the gray area. The BWER is located within the updraft region and indicated by the vertical arrow.

High Resolution Observations

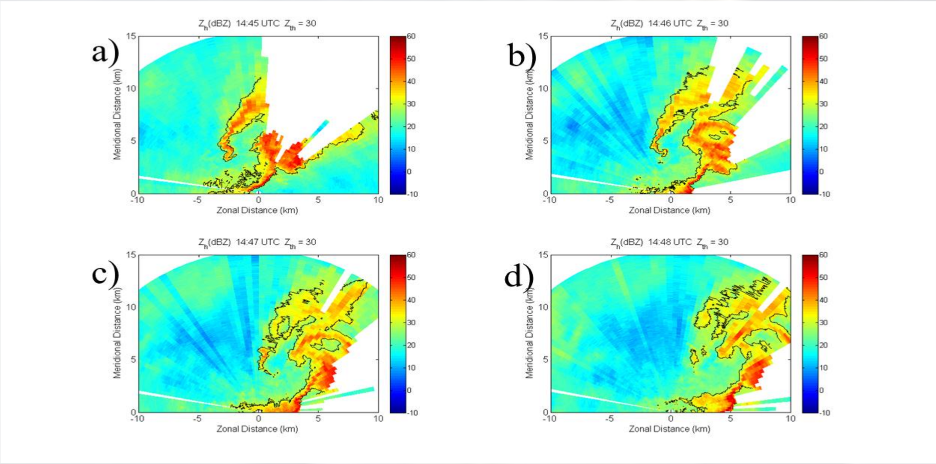

Fig.5 Reflectivity field observed by IDRA at elevation angle of 0.50^{o}. The fast-evolve storm cell is shown by panels a) ... d) from 1445 to 1448 UTC. Panel a) shows the hooklike appendage on the southeast flank of the storm cell. Panel b) shows a storm cell with similar features to the schematic representation of a mature phased supercell storm. The fast dissipation stage of the storm cell is shown by panels c) and d).

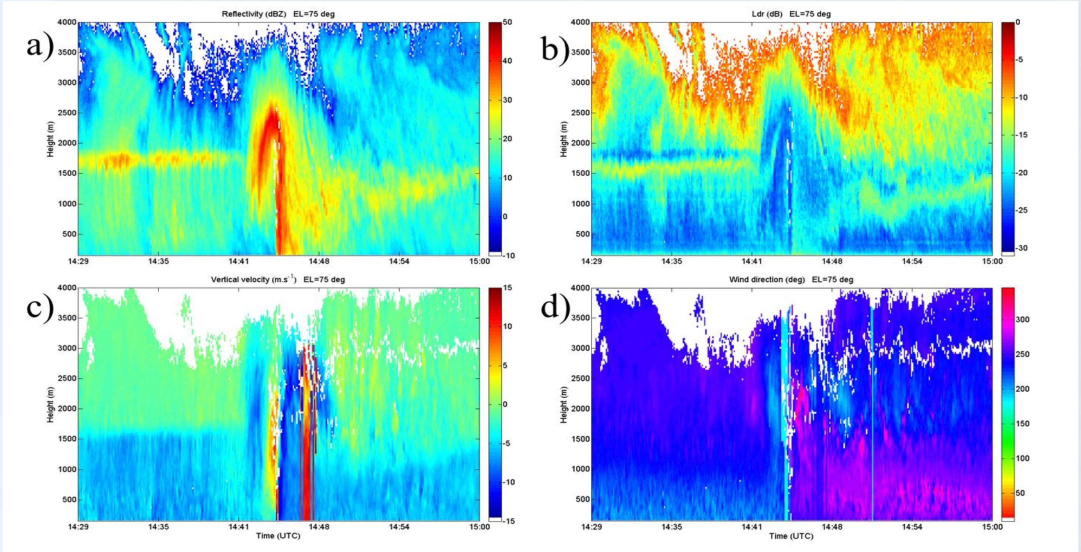

Fig.6 Height-time profile observations by TARA at elevation angle of 75^{o}. The variables of reflectivity, linear depolarization ratio, vertical velocity, and wind direction are shown in panels a), b), c), and d), respectively, from 1429 to 1500 UTC.

In-Situ Observations

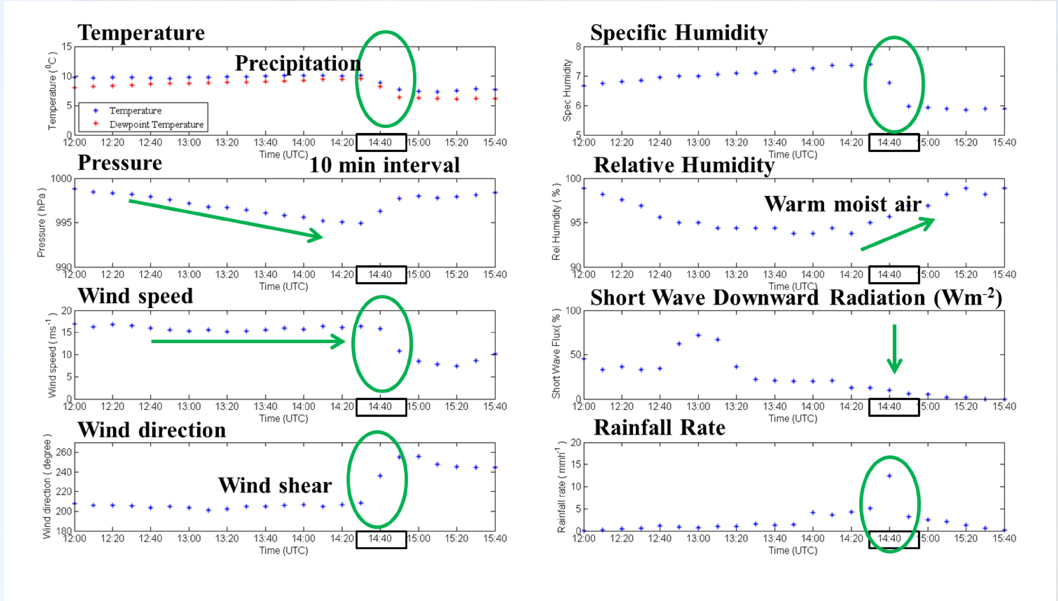

Fig.7 Surface measurements from 1200 to 1540 UTC. Large changes can be seen around 1440 UTC, which is when the front passes through CESAR.

Rainfall Estimation

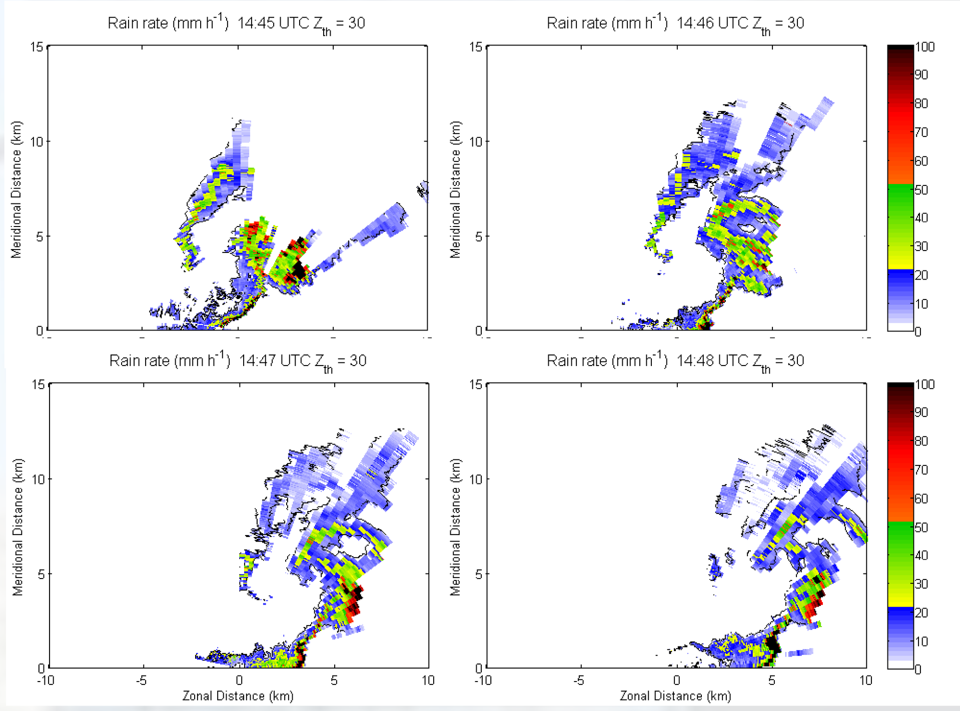

Fig.8 Rainfall rate (R) field. The estimation of R was based on the specific differential phase using a power law relation (*Otto and Russchenberg*, 2012). The dashed rectangular represents an urban catchment of 3.7 Km^2 located in Rotterdam.

Rainfall Spatial Variability

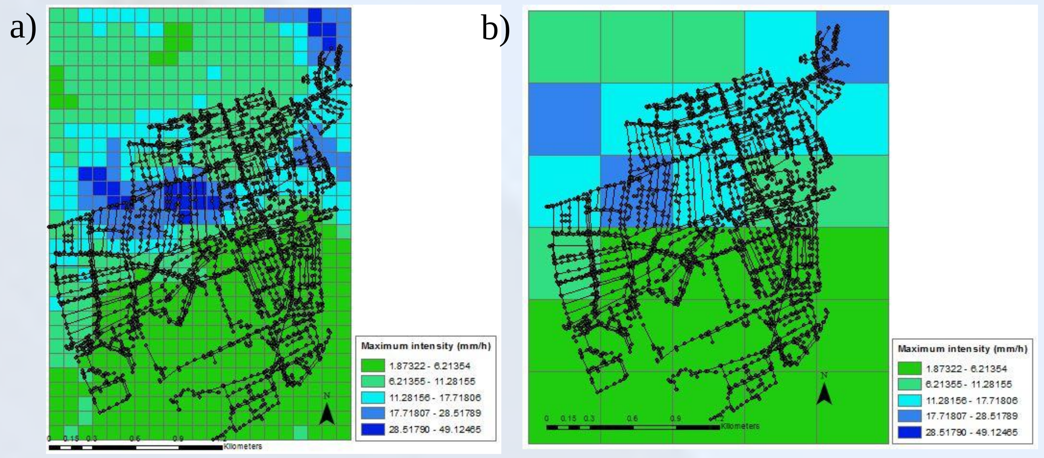

Fig.9 Maximum intensity distribution over Rotterdam urban sewer system. a) 100x100 m and b) 500x500 m grid size.

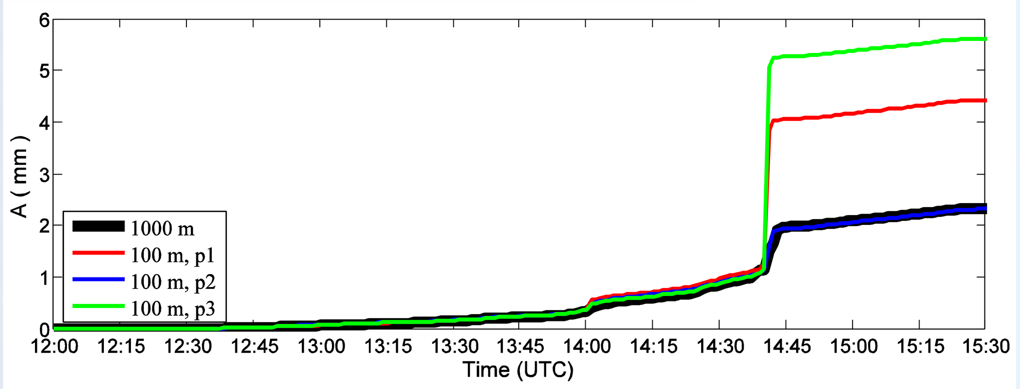

Fig.10: Accumulated rainfall depth of 3 grids (p1, p2, and p3) of 100x100 and 1 grid of 1000x1000 m..

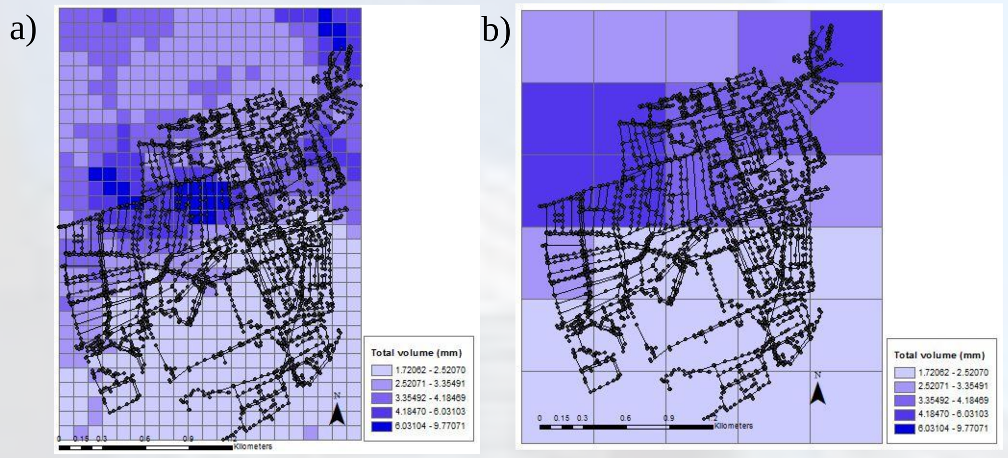

Fig.11 Total volume of the storm a) 100x100 m and b) 500x500 m grid size.

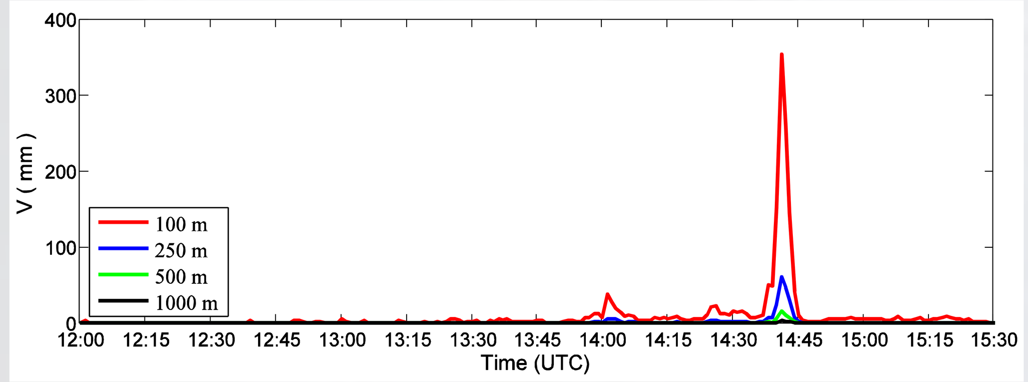

Fig.12: Total rainfall depth over the catchment for distinct simulated spatial resolutions.

Conclusions

- A squall line was observed and analysed at different time and spatial resolutions. Observations by weather radars IDRA and TARA showed reflectivity fields with similar features of a supercell storm but at smaller scale.
- Rainfall rate values were obtained and used to analyse the impact of high temporal and spatial resolutions. It has been shown that heavy precipitation from a fast-developed storm can be captured if 1 min temporal resolution is used. The surface variability of rain was demonstrated by comparing the accumulated and total rain depth for several grid sizes.

Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B.
INTERREG IVB

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