Impact of Polarimetric CASA Radar Observations on a Distributed Hydrologic Model

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ABSTRACT

Radar can monitor the atmospheric conditions of a large area very quickly and provide advanced observations and warnings for precipitation systems at high spatial resolution. The high spatiotemporal-resolution rainfall products from the quantitative precipitation estimation (QPE) system developed by the U.S. National Science Foundation Engineering Research Center (NSF-ERC) of Collaborative Adaptive Sensing of Atmosphere (CASA) can serve as a reliable input to distributed hydrological models. The Hydrology Laboratory - Research Distributed Hydrologic Model (HL-RDHM) developed by the U.S. National Weather Service (NWS) Office of Hydrologic Development (OHD) is a promising tool for generating streamflow and other hydrological information such as soil moisture. It incorporates the Sacramento soil moisture accounting model (SAC) with heat transfer (HT) dynamics to convert rainfall to runoff and channel routing models to convert runoff to streamflow.

In this research, the SAC-HT model was forced by high resolution rainfall estimates produced by the CASA X-band dual-polarization radar network to help advance understanding of urban hydrologic response and to improve flash flood monitoring and prediction. Both hourly and 5-minute rainfall estimated from XUTA radar in CASA's Dallas-Fort Worth Metroplex (DFW) Urban Demonstration Network are used to simulate surface and subsurface flow.

CASA DFW Urban Demonstration Network

In spring of 2012, CASA, in collaboration with the North Central Texas Council of Governments (NCTCOG), the National Weather Service (NWS) and other stakeholders, started establishing the Urban Demonstration Network in the DFW metropolitan area. The issues to be addressed include urban flooding, low-level wind sensing, weather forecasting, weather and water hazard decision making and network of networks demonstration. This partnership and the test bed are expected to be a prototype of a national-scale "network-of-networks" in which different users and data providers can exchange observational data across a common infrastructure. Figure 1 shows the layout of the first 8 radars. More information about the DFW Urban Demonstration Network can be found in **Poster: NH1.8/B363.**

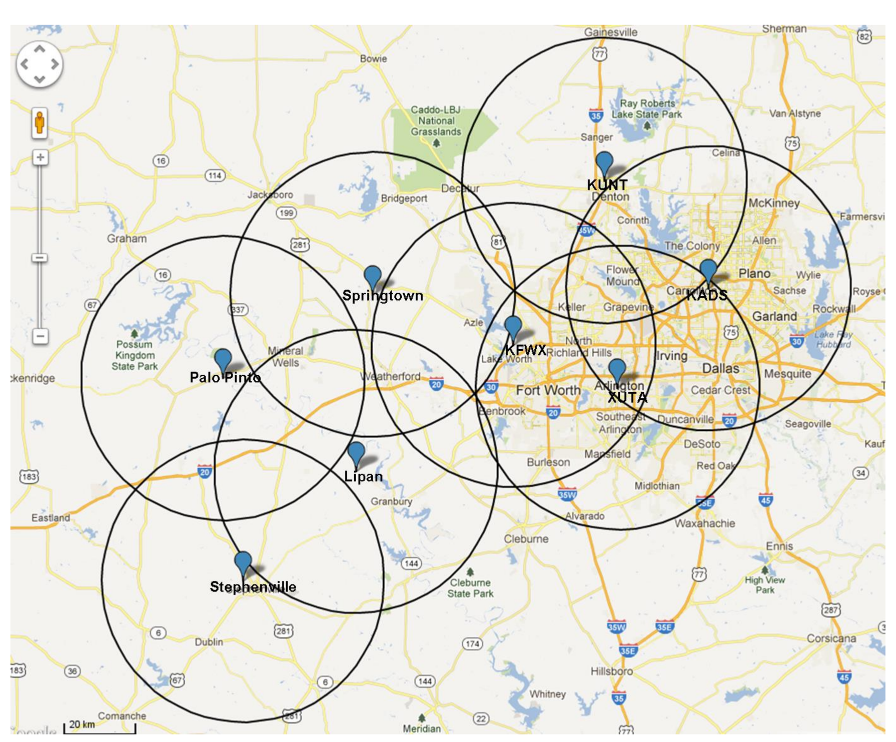

Figure 1: 8-radar layout in the DFW area.

CASA QPE System

- CASA QPE system is *KDP*-based.
  - In Southern Oklahoma or Northern Texas, $R = 18.15KDP^{0.791}$.
- CASA QPE system has high spatiotemporal resolution compared to the traditional S-band-based systems.
  - Spatial resolution: about or less than 500 meters
  - Temporal resolution: about 1 minute
- CASA Rainfall Products:
  - Instantaneous rainrate maps
  - Hourly rainfall accumulation maps
  - Evaluation scores for 5-, 10-, 15-, 20-, 30-min rainfall estimation (under developing for the DFW network)
- Sample Products
  - Figures 2 and 3 show sample rainfall products in HRAP grids for the City of Fort Worth, from the CASA QPE system using polarimetric XUTA radar observations at 21:32:20UTC, 29 Jan 2013.

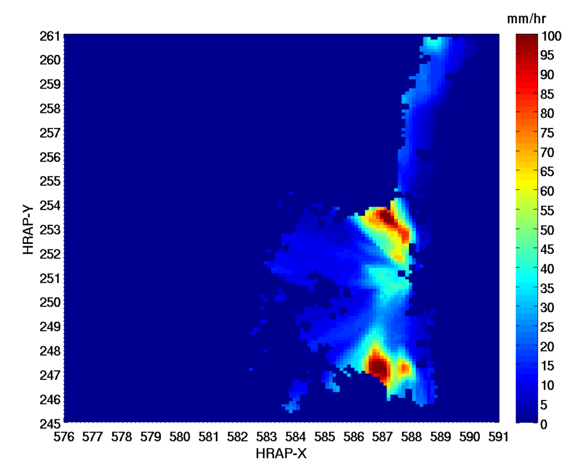

Figure 2: Instantaneous rainrate map

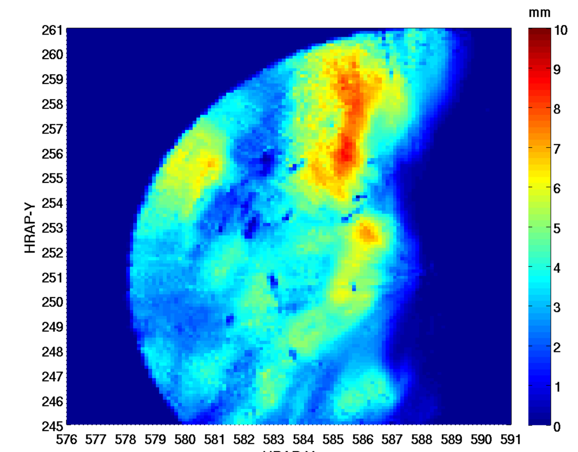

Figure 3: Hourly rainfall map

NWS Distributed Hydrologic Model, HL-RDHM

The Research Distributed Hydrologic Model (RDHM) developed by the NWS Hydrology Laboratory (HL) (Koren et al., 2004) has been used in a wide range of applications.

Key Features:

- Designed for river forecasting, flash flood forecasting, and water resources research
- Supports gridded connected or unconnected domain runs
- Flexible I/O in standard NWS formats
- Multiple modeling resolutions
- Contains models for snow, rainfall-runoff, frozen ground, hillslope and channel routing
- Simulation/calibration mode exists.

In this research, the SAC-HT model is used for hydrologic analysis. Both the QPE system and the hydrologic model are scaled to 1/8 HRAP resolution, which is about 500 meters. The hourly and 5-minutes rainfall estimates are used to force the hydrologic model.

Hydrologic Study Domain - City of Fort Worth

The study domain is a 15x16 HRAP grid (~60km x 64km) covering the entire City of Fort Worth. Figure 4 shows a high-resolution map of the impervious area in this domain. Figure 5 shows the impervious area map at the HRAP resolution generated by NWS/OHD. In this study, the high-resolution impervious area is remapped at 1/8 HRAP resolution, as shown in Figure 6.

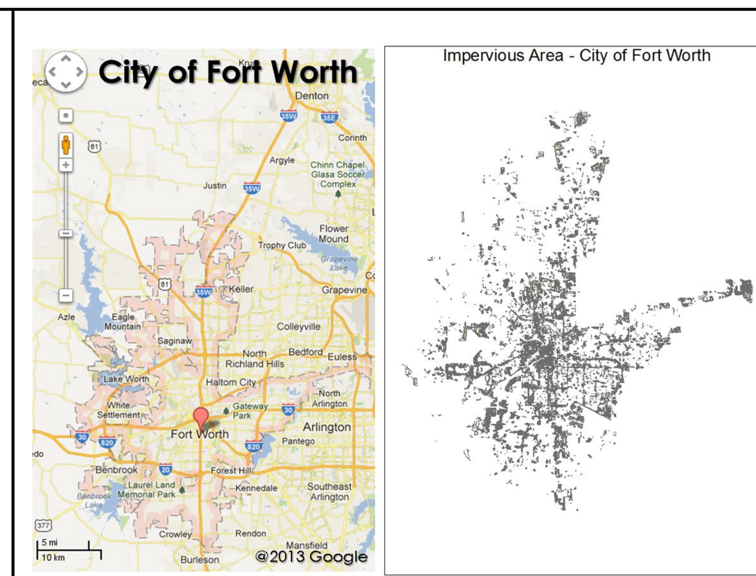

Figure 4: Impervious area in the City of Fort Worth

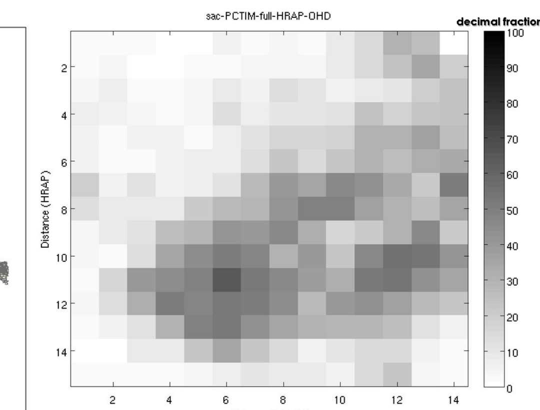

Figure 5: Impervious area (PCTIM) at 1-HRAP grid resolution

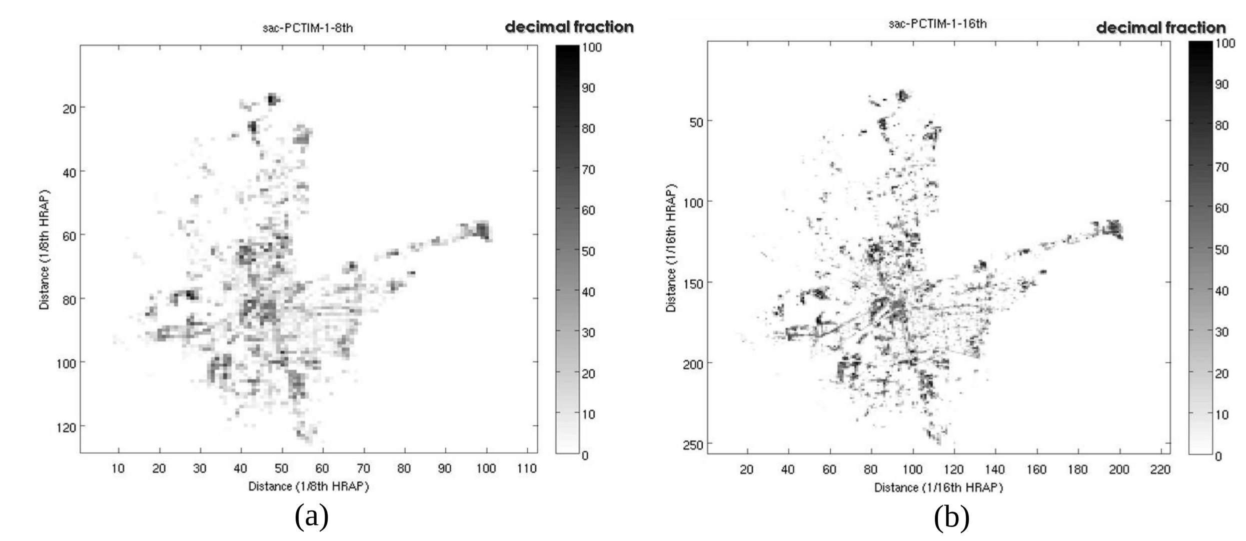

Figure 6: Impervious area (PCTIM) at (a) 1/8- and (b) 1/16-HRAP grid resolution

29 Jan, 2013, Case Study

The HL-RDHM analysis is based on the rainfall event occurred on Jan 29, 2013.

- Simulation duration: 170000Z-230000Z, Jan 29, 2013
- Simulation time step: hourly and 5-minutes

• Hydrologic Analysis Using Hourly Rainfall Estimates

- Rainfall Products from XUTA Radar

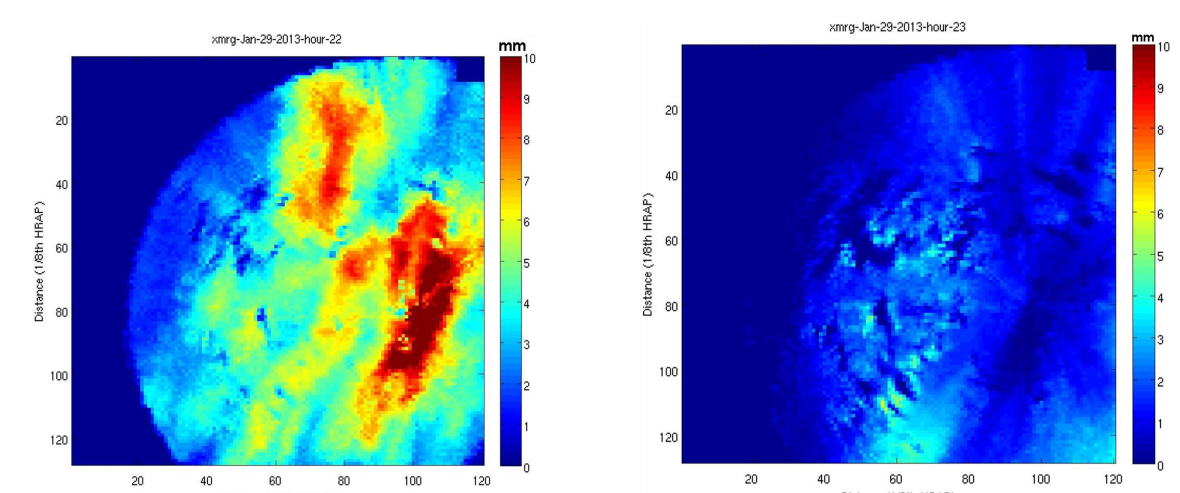

Figure 7: Hourly rainfall estimates at 2200UTC, 2300UTC, for the 29 Jan 2013 Case

- Surface Runoff

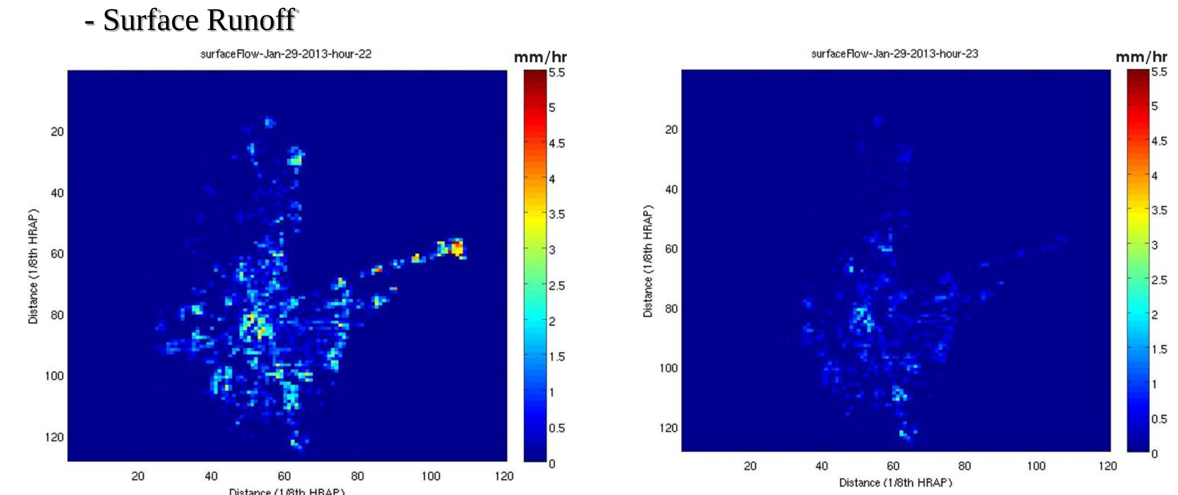

Figure 8: Surface runoff at 2200UTC, 2300UTC, for the 29 Jan 2013 case

- Subsurface Runoff

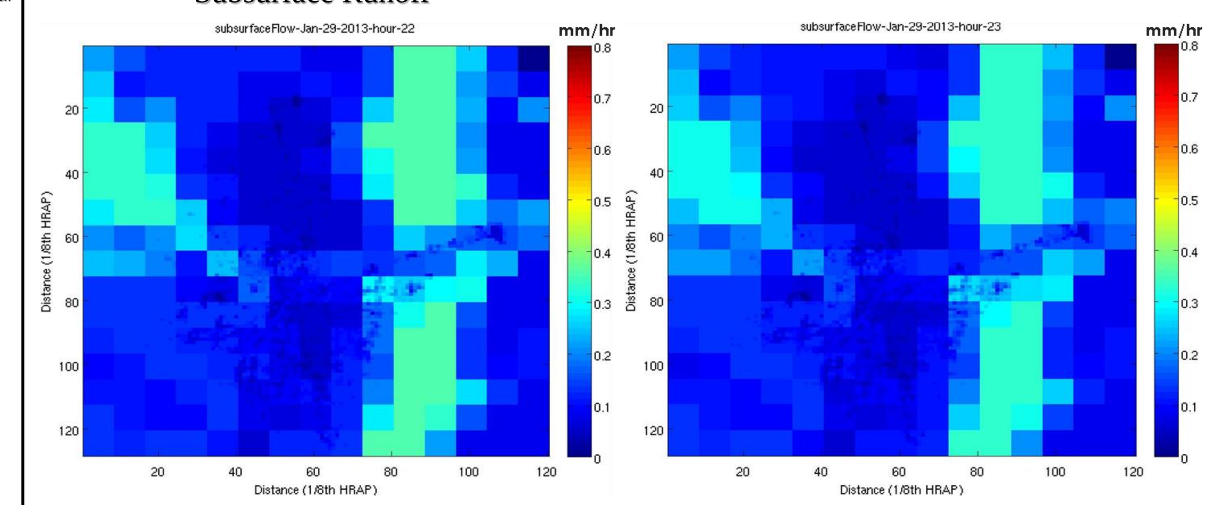

Figure 9: Subsurface runoff at 2200UTC, 2300UTC, for the 29 Jan 2013 case

Surface runoff is controlled largely by impervious fraction; the higher the impervious fraction, the larger the surface runoff. Subsurface runoff is controlled by other SAC parameters which are prepared by NWS at 1-HRAP resolution; this explains the blocky patterns in Figure 9. Also, subsurface flow change gradually over time which is observed in the figure as well.

• Hydrologic Analysis Using 5-minute Rainfall Estimates

- Figures 10 and 11 show sample plots of rainfall and surface runoff for 5-minute rainfall estimates. They too show that surface runoff is highly dependent on impervious areas; although there are large rainfall amounts in some grid boxes, surface runoff is only small to moderate due to low impervious fraction.

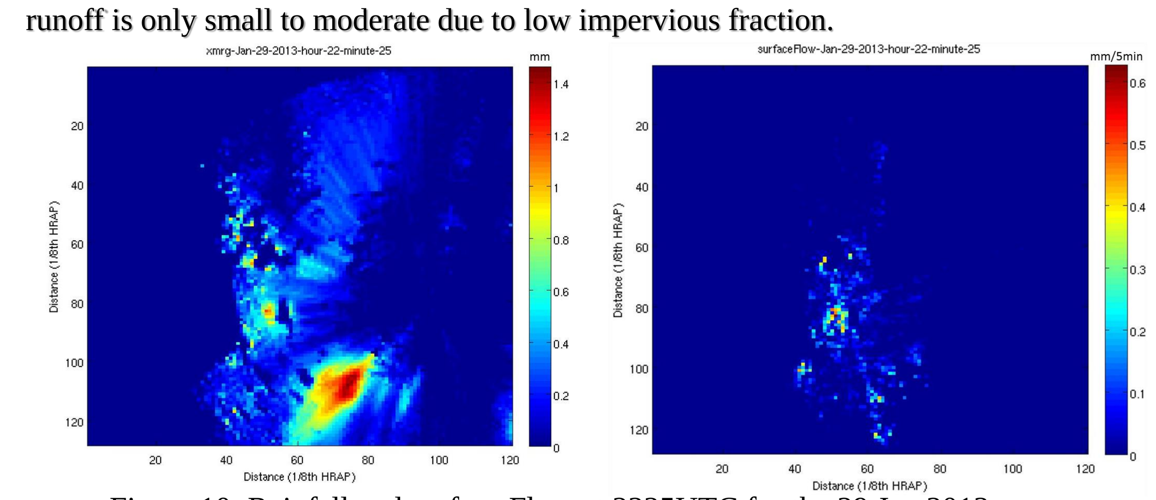

Figure 10: Rainfall and surface Flow at 2225UTC for the 29 Jan 2013 case

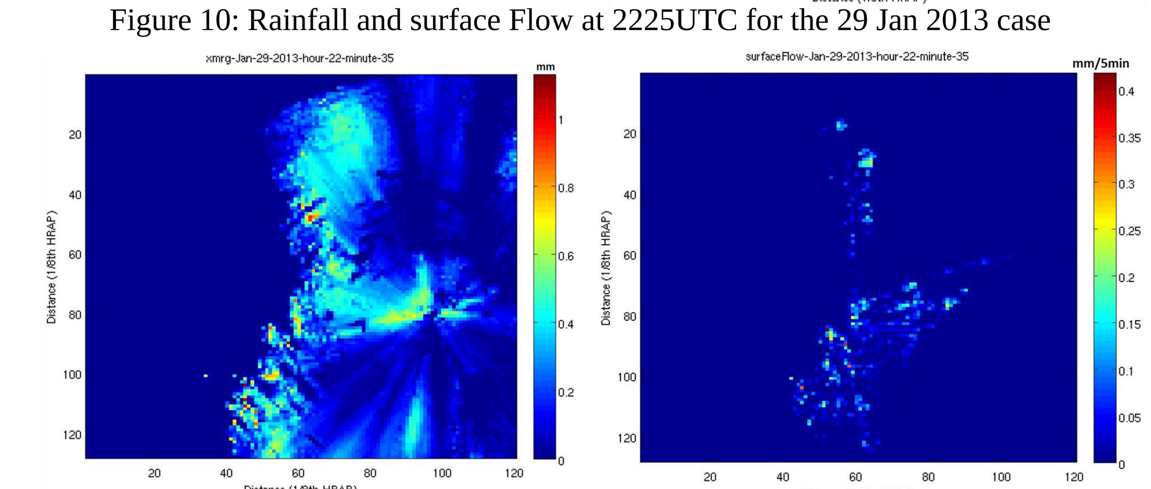

Figure 11: Rainfall and surface runoff at 2235UTC for the 29 Jan 2013 case.

• Comparison:

- Figure 12 (a) shows the surface runoff from hourly rainfall while Figure 12 (b) shows the aggregated surface runoff from twelve 5-min rainfall for the same hour. These figures show that HL-RDHM results from sub-hourly rainfall input are very reasonable.

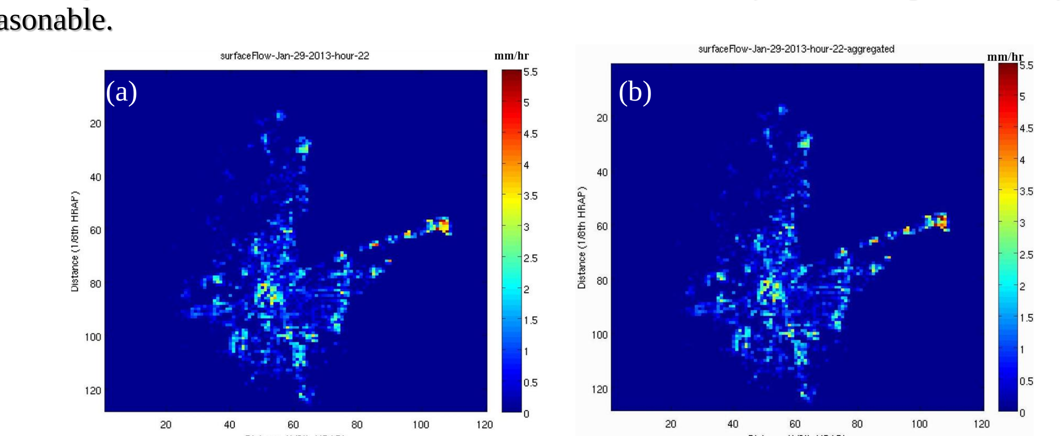

Figure 12: Surface runoff from (a) hourly rainfall (for 22Z) (b) twelve 5-min rainfall.

Acknowledgement

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