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Flood Monitoring using X-band Dual-polarization Radar Network

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A dense weather radar network is an emerging concept advanced by the Center for Collaborative Adaptive Sensing of the Atmosphere (CASA). Using multiple radars observing over a common will create different data outcomes depending on the characteristics of the radar units employed and the network topology. To define this a general framework is developed to describe the radar network space, and formulations are obtained that can be used for weather radar network characterization. Current weather radar surveillance networks are based upon conventional sensing paradigm of widely-separated, standalone sensing systems using long range radars that operate at wavelengths in 5-10 cm range. Such configuration has limited capability to observe close to the surface of the earth because of the earth's curvature but also has poorer resolution at far ranges. The dense network radar system, observes and measures weather phenomenon such as rainfall and severe weather close to the ground at higher spatial and temporal resolution compared to the current paradigm. In addition the dense network paradigm also is easily adaptable to complex terrain.

Flooding is one of the most common natural hazards in the world. Especially, excessive development decreases the response time of urban watersheds and complex terrain to rainfall and increases the chance of localized flooding events over a small spatial domain. Successful monitoring of urban floods requires high spatiotemporal resolution, accurate precipitation estimation because of the rapid flood response as well as the complex hydrologic and hydraulic characteristics in an urban environment. This paper reviews various aspects in radar rainfall mapping in urban coverage using dense X-band dual-polarization radar networks. By reducing the maximum range and operating at X-band, one can ensure good azimuthal resolution with a small-size antenna and keep the radar beam closer to the ground. The networked topology helps to achieve satisfactory sensitivity and fast temporal update across the coverage. Strong clutter is expected from buildings in the neighborhood which act as perfect reflectors. The reduction in radar size enables flexible deployment, such as rooftop installation, with small infrastructure requirement, which is critical in a metropolitan region. Dual-polarization based technologies can be implemented for real-time mitigation of rain attenuations and accurate estimation of rainfall. The NSF Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) is developing the technologies and the systems for network centric weather observation.

The Differential propagation phase (K_{dp}) has higher sensitivity at X-band compared to S and C band. It is attractive to use K_{dp} to derive Quantitative Precipitation Estimation (QPE) because it is immune to rain attenuation, calibration biases, partial beam blockage, and hail contamination. Despite the advantage of K_{dp} for radar QPE, the estimation of K_{dp} itself is a challenge as the range derivative of the differential propagation phase profiles. An adaptive K_{dp} algorithm was implemented in the CASA IP1 testbed that substantially reduces the fluctuation in light rain and the bias at heavy rain. The K_{dp} estimation also benefits from the higher resolution in the IP1 radar network. The performance of the IP1 QPE product was evaluated for all major rain events against the USDA Agriculture Research Service's gauge network (MicroNet) in the Little Washita watershed, which comprises 20 weather stations in the center of the test bed. The cross-comparison with gauge measurements shows excellent agreement for the storm events during the Spring Experiments of 2007 and 2008. The hourly rainfall estimates compared to the gauge measurements have a very small bias of few percent and a normalized standard error of 21%.

The IP1 testbed was designed with overlapping coverage among its radar nodes. The study area is covered by multiple radars and the aspect of network composition is also evaluated. The independence of K_{dp} on the radar calibration enables flexibility in combining the collocated K_{dp} estimates from all the radar nodes. Radar QPE can be improved from the composite K_{dp} field from the radar with lowest beam height and nearest slant range, or from

the radar with the best K_{dp} estimates. More importantly, the data availability is greatly enhanced by the overlapped topology in cases of heavy rainfall, demonstrating the operational strength of the network centric radar system.

The National Research Institute for Earth Science and Disaster Prevention (NIED), Japan, is in the process of establishing an X-band radar network (X-Net) in Metropolitan Tokyo area. Colorado State University and NIED have formed a partnership to initiate a joint program for urban flood monitoring using X-band dual-polarization radar network. This paper will also present some preliminary plans for this program.