Urban rainfall Monitoring Network

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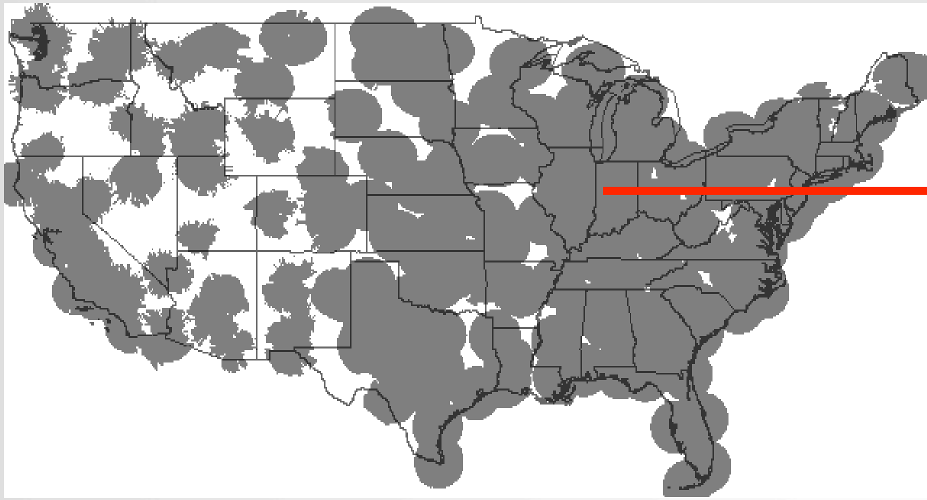
CASA


"CASA RADAR"
ABC News
"World News with
Charles Gibson"
July 25, 2008

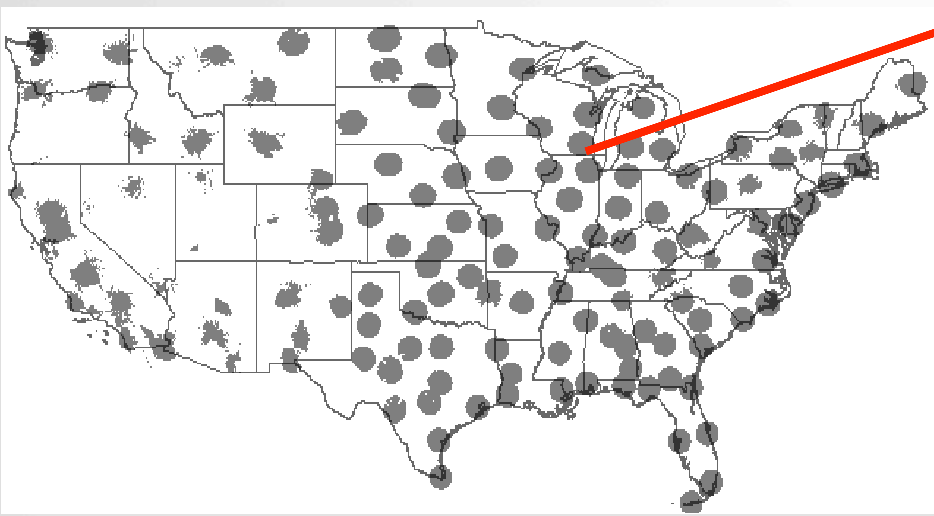
Background

- CASA: Collaborative Adaptive Sensing of the Atmosphere, a NSF (US National Science Foundation) ERC (Engineering Research Center) commissioned to ***improve warnings and save lives***
- DCAS: Distributed Collaborative Adaptive Sensing, a ***network centric sensing paradigm*** founded and engineered by CASA ERC
  - Distributed – dense network
  - Collaborative – networked operation
  - Adaptive – intelligent dynamic sensing, closed-loop system
- Unique Added-Value Impacts:
  - Achieved very high resolution operationally using low-cost radars
  - Created the capability of detecting urban scale severe storms
  - Engaged end-users in sensing and improved responding to threats and disasters

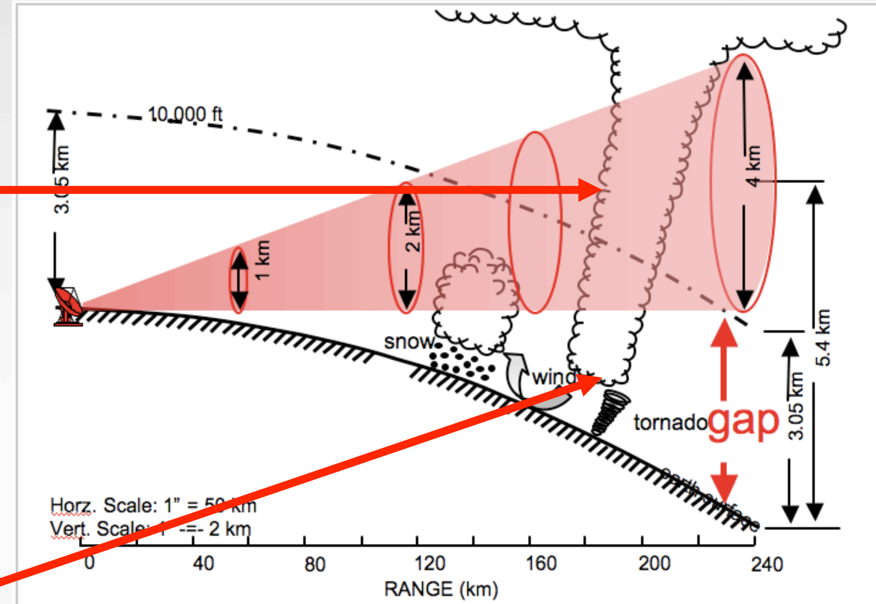
CASA Motivation



NEXRAD coverage at 3 km (10,000 ft) AGL.

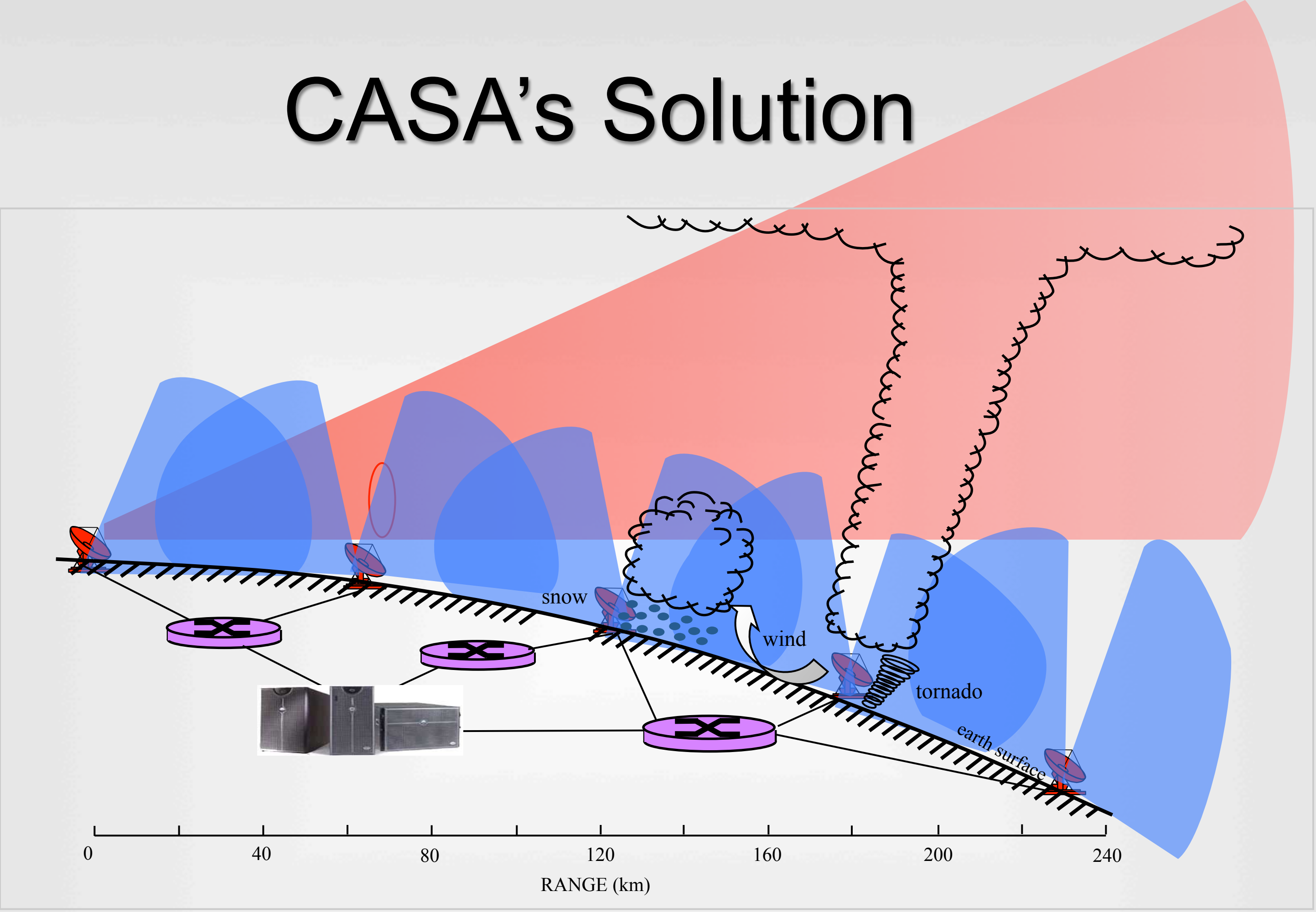


NEXRAD coverage at 1 km (~3200 ft) AGL.



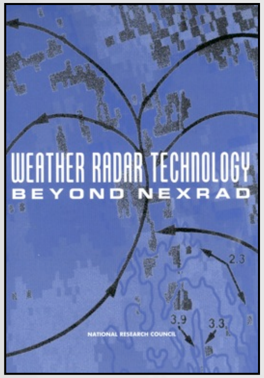
- Radar coverage “Gap”
- Spatial Resolution
- Temporal Resolution
- Terrain impact
- Pre-fixed radar operation

CASA's Solution



- Dense networks of low power, dual pol, multi-Doppler, X-band radars
- High spatial and temporal resolution (250m and 1 minute)
- Smart scans based on weather, user needs and radar capabilities

National Research Council

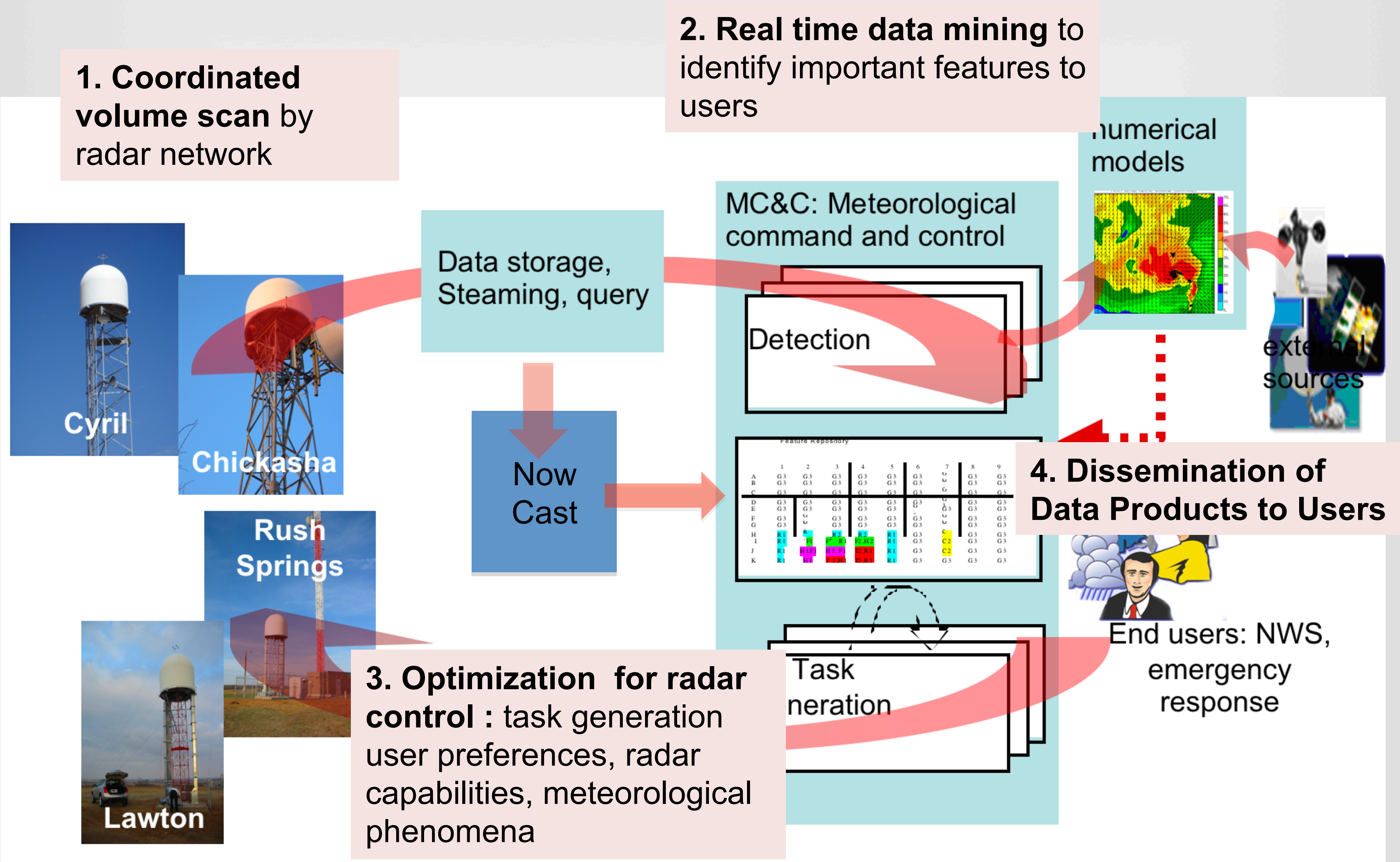


Recommendation: "The potential for a network of short-range radar systems to provide enhanced near-surface coverage and supplement (or perhaps replace) a NEXRAD-like network of primary radar installations should be evaluated thoroughly." NRC, 2002

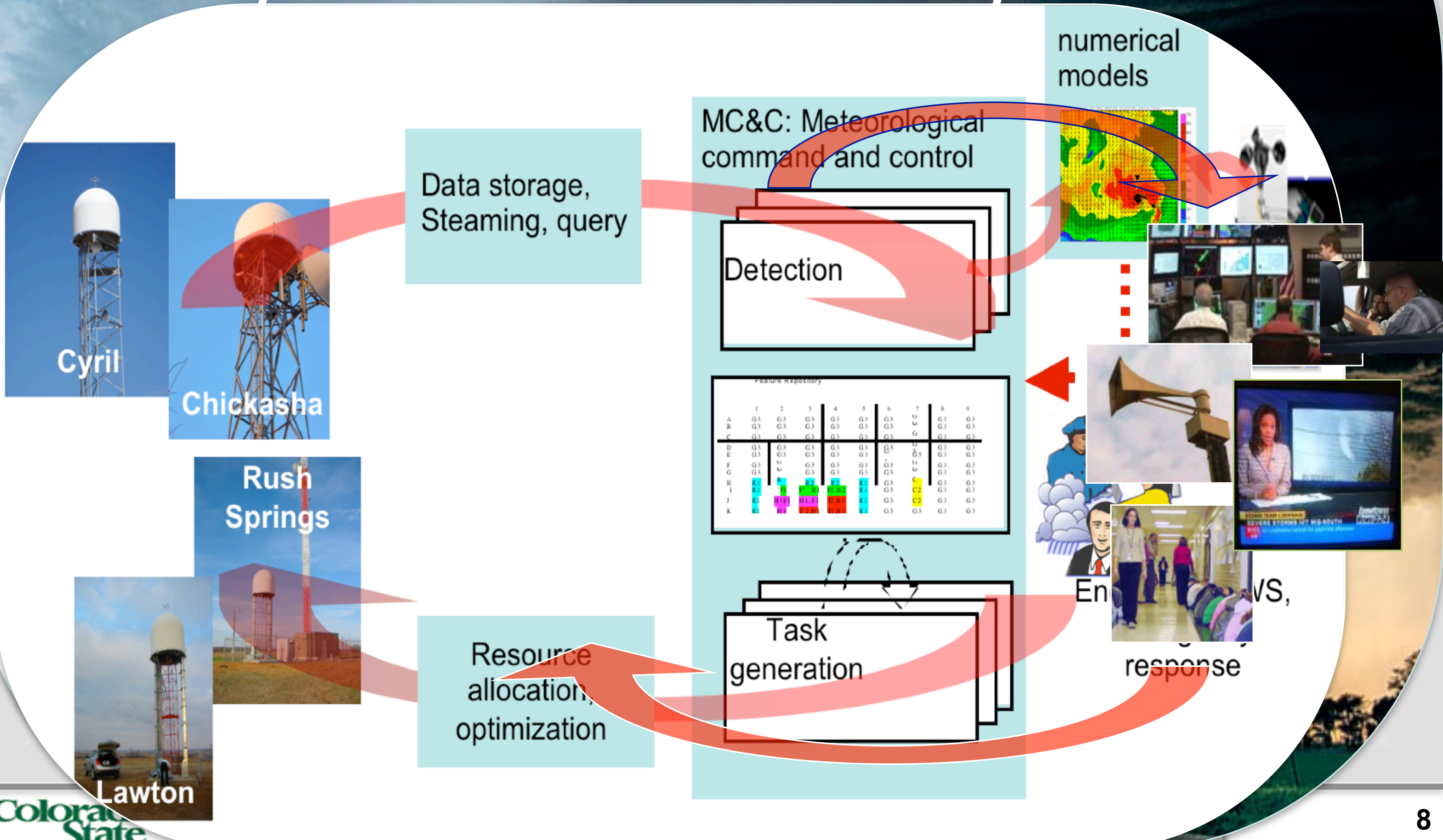
Recommendation: "Emerging technologies for distributed-collaborative-adaptive sensing should be employed by observing networks, especially scanning remote sensors such as radars and lidars." NRC, 2008

"…collaborative and adaptive sensing and related technologies can efficiently enhance the detection and monitoring of adverse weather for hazard mitigation and other applications." NRC, 2010

Where and when user needs are greatest



How can we optimize system operation for the best response?



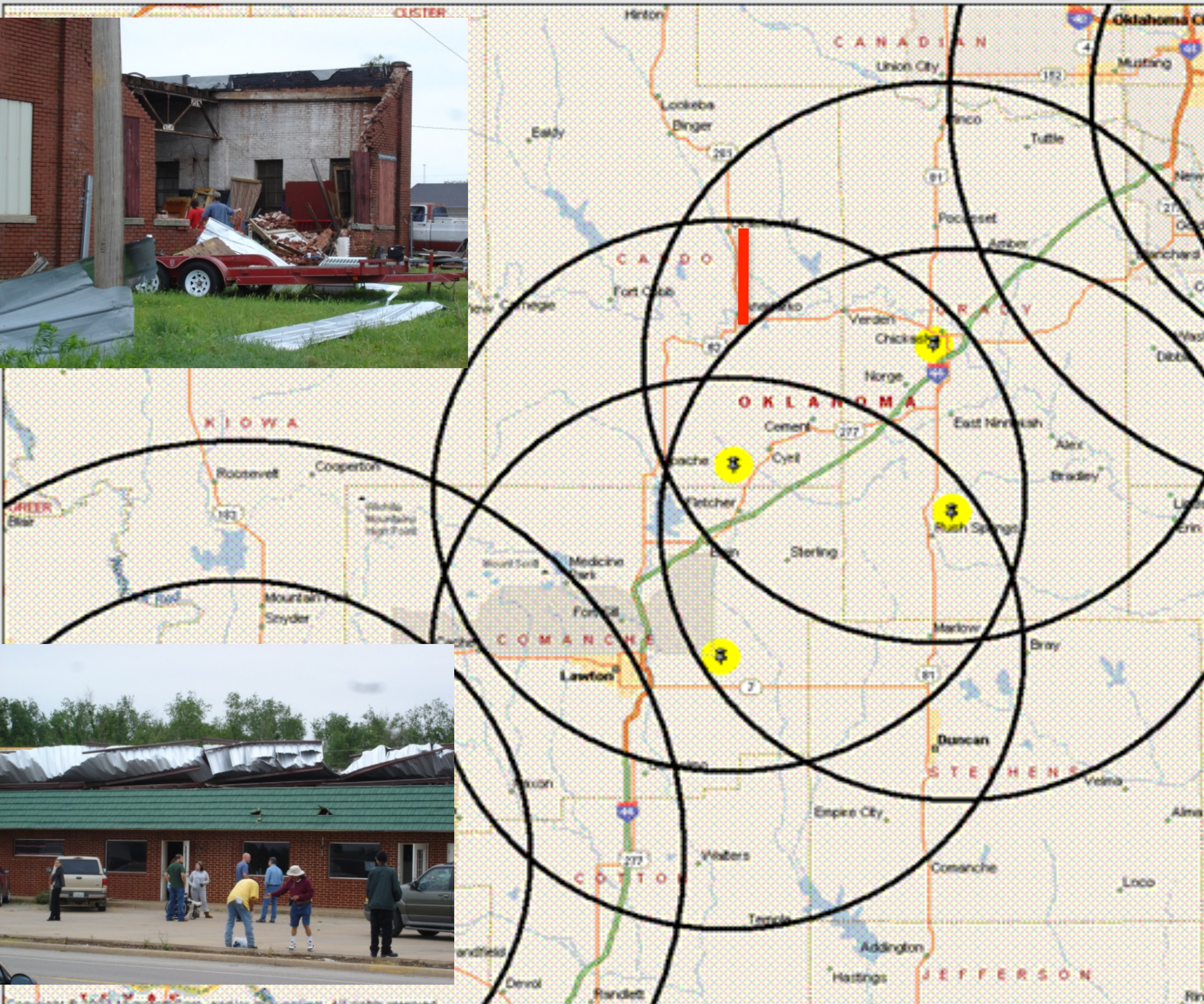
Challenges

- The network demands small-size radar to be cost-effective, driving the design to X-band;
  - Range-Doppler ambiguity
  - Attenuation
  - Very advanced software and signal processing
- Observing low requires advanced clutter mitigation for the small-scale feature of tornadoes;
- Real-time processing and reconfiguration.

Vector Wind Observations

Tornado Tracking Down Streets a real case example

Tornado Tracking



Anadarko Tornado
May 14, 2009

EF2 Tornado
~9:22 – 9:40PM

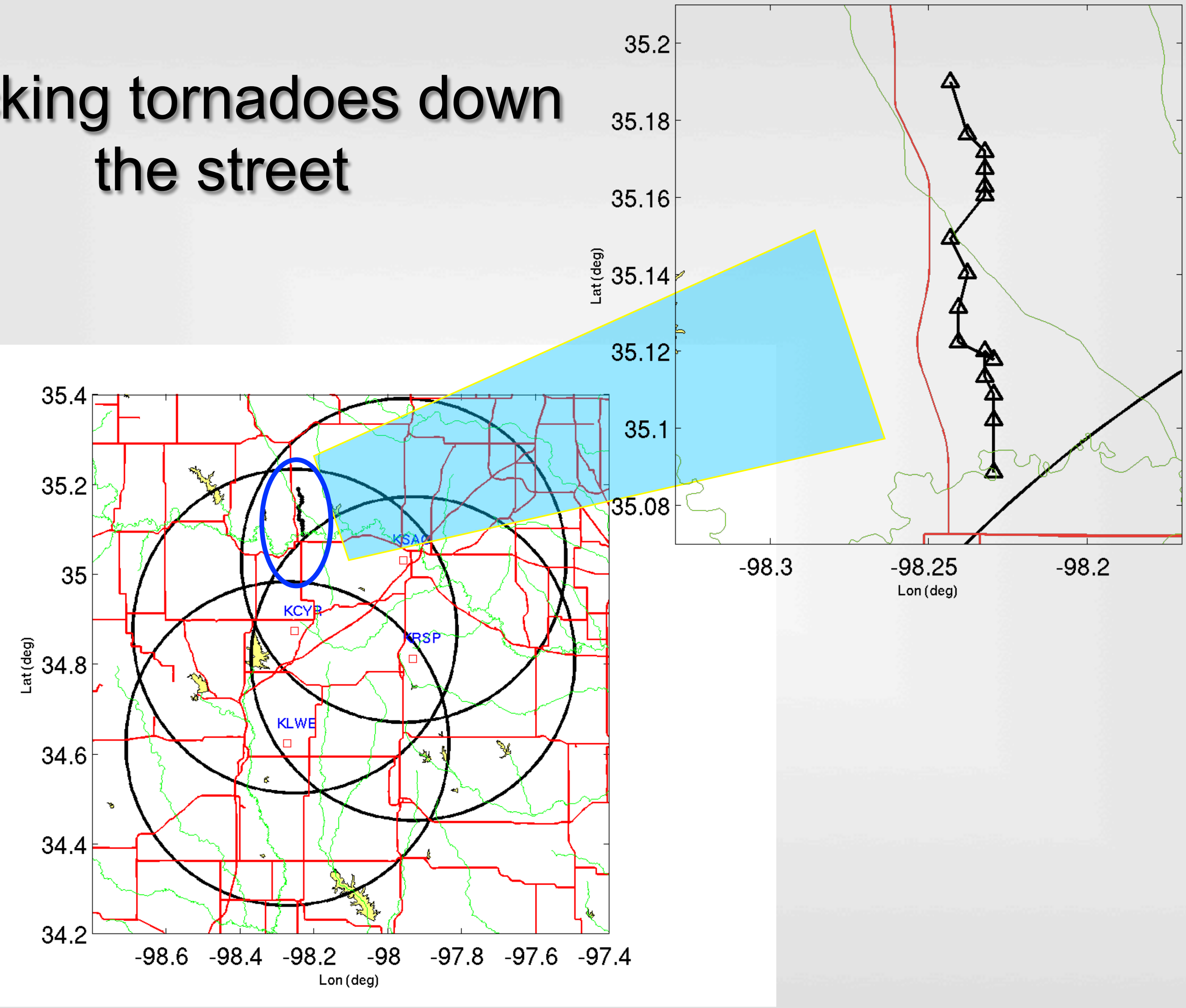
Prolonged Damaging Winds 100mph+

3 injuries
$43 million+ in property damage

CASA Tornado Warning 9:21

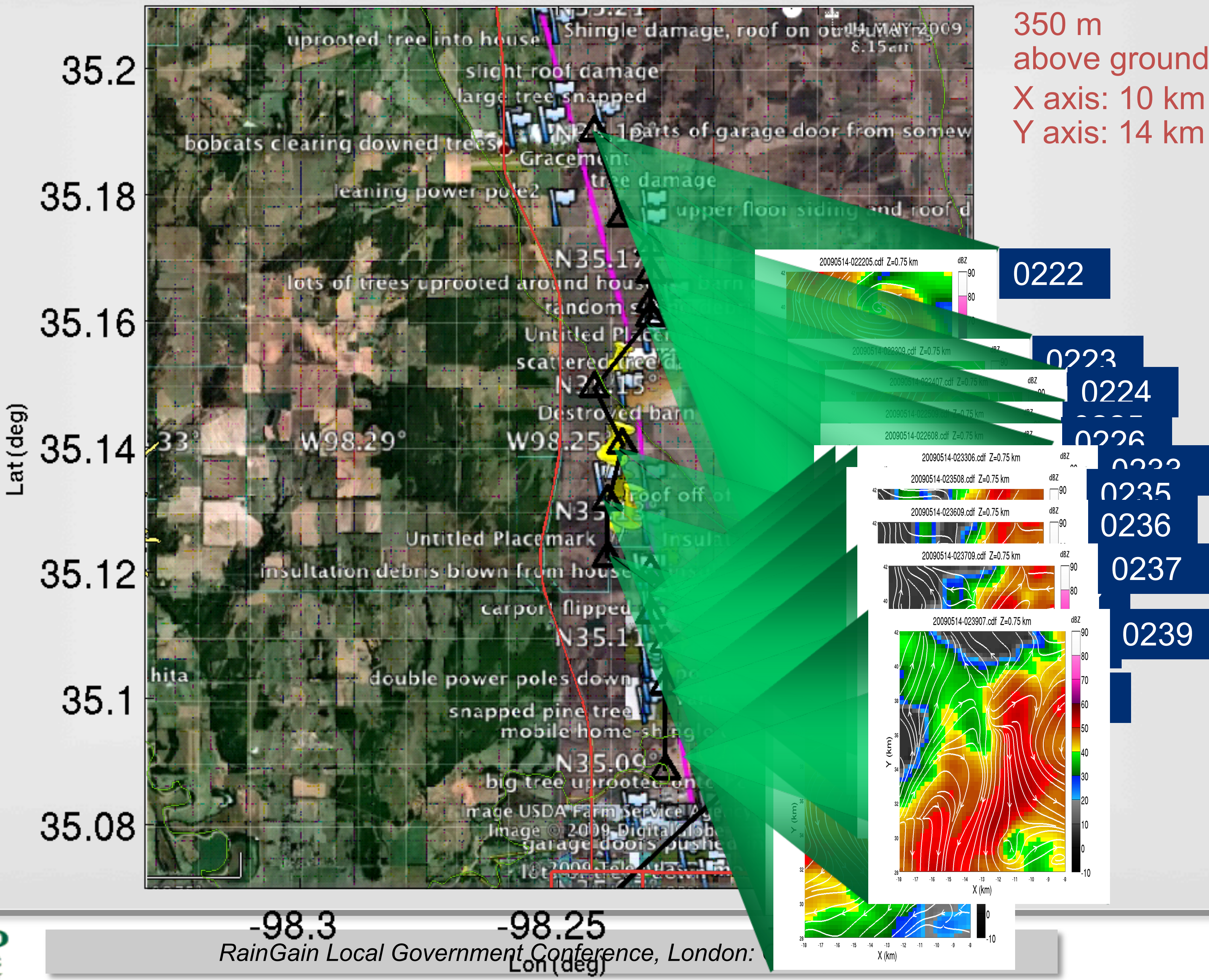
NWS Tornado Warning 9:24

Tracking tornadoes down the street



Tornado Path as Observed by CASA Radar Network

350 m
above ground
X axis: 10 km
Y axis: 14 km



Quantitative Precipitation Estimation

Every year, floods are responsible for significant causalities, of these, most are due to flash floods.

NRC Report: Flash Flood Forecasting Over Complex Terrain: With an Assessment of the Sulphur Mountain NEXRAD in Southern California

Quantitative Precipitation Estimation in the CASA X-band Dual-Polarization Radar Network

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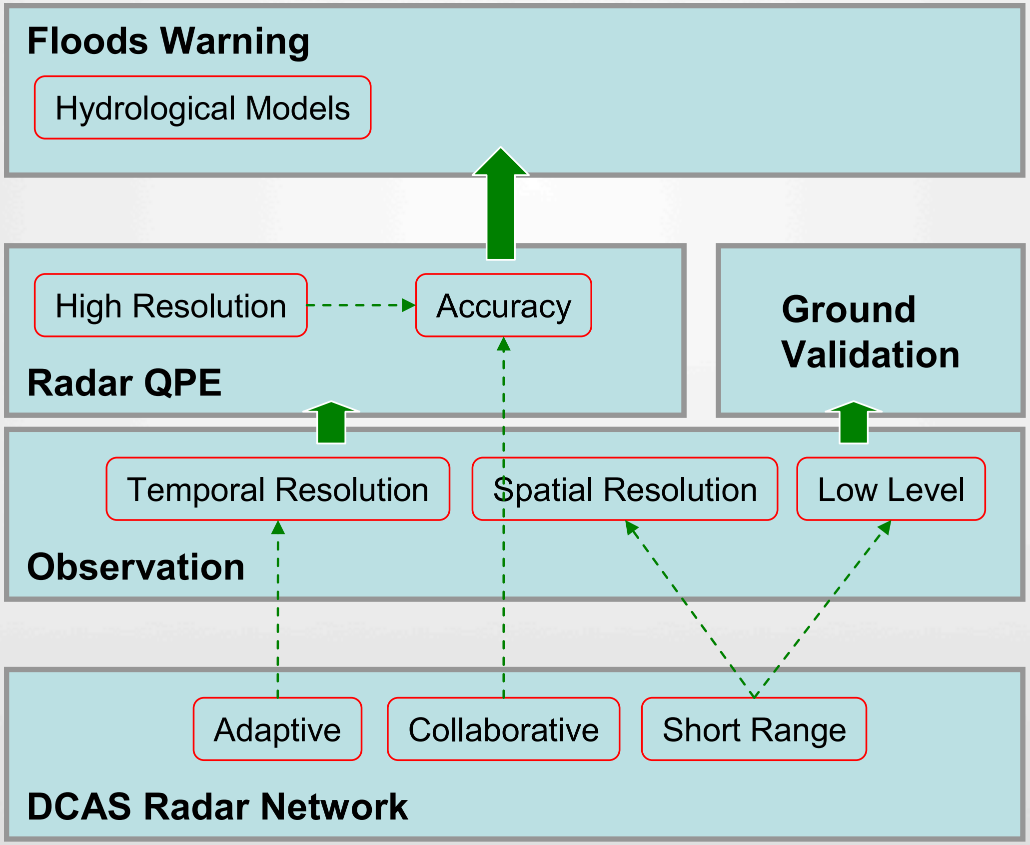
(Manuscript received 13 November 2009, in final form 14 May 2010)

ABSTRACT

This paper presents the sensing aspects and performance evaluation of the quantitative precipitation estimation (QPE) system in an X-band dual-polarization radar network developed by the Collaborative Adaptive Sensing of the Atmosphere (CASA) Engineering Research Center. CASA's technology enables precipitation observation close to the ground and QPE is one of the important applications. With expanding urbanization all over the world, vulnerability to floods has increased from intense rainfall such as urban flash floods. The QPE products that are derived at high spatiotemporal resolution, which is enabled by the deployment of a dense radar network, have the potential to improve the prediction of flash-flooding threats when coupled with hydrological models. Derivation of QPE from radar observations is a challenging process, in which the use of dual-polarization radar variables is advantageous. At X band, the specific differential propagation phase (K_{dp}) between the orthogonal linear polarization states is particularly appealing. The K_{dp} field is robustly acquired using an adaptive estimation method, and a simple $R(K_{dp})$ relation is used to perform precipitation estimation in this X-band radar network. Radar observations and QPE from multiyear field experiments are used to demonstrate the performance of rainfall estimation from the single-parameter K_{dp}-based rainfall product. The operational feasibility of radar QPE using an X-band radar network is critically assessed.

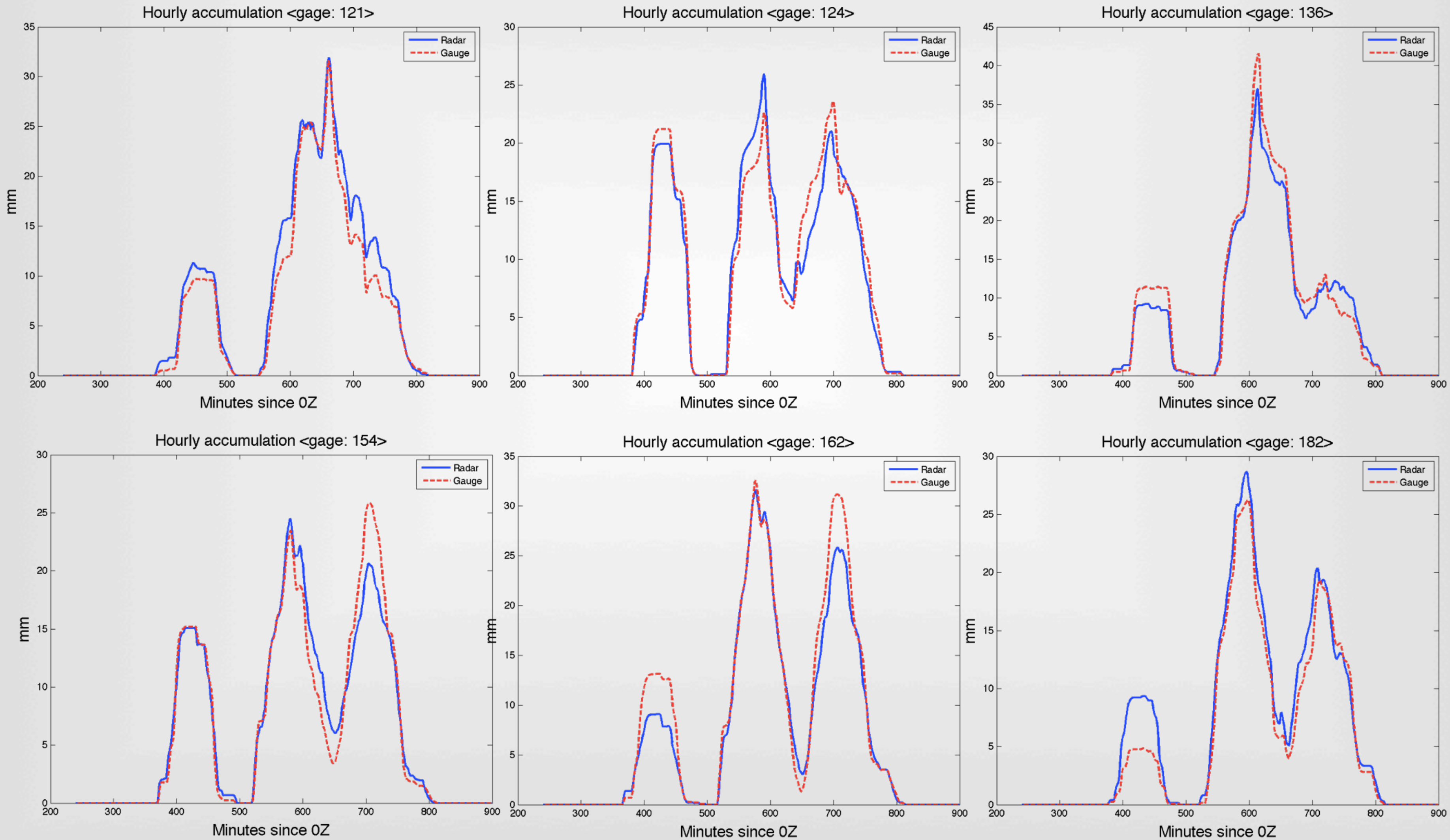
Precipitation monitoring Aspects

- Spatial resolution: mean cross-range resolution ~ 500 m
- Temporal resolution: DCAS closed-loop scan @ 60 sec update
- Beam height: < 1 km; advanced clutter suppression filter
- Dual-polarization technology: adaptive K_{dp} estimation



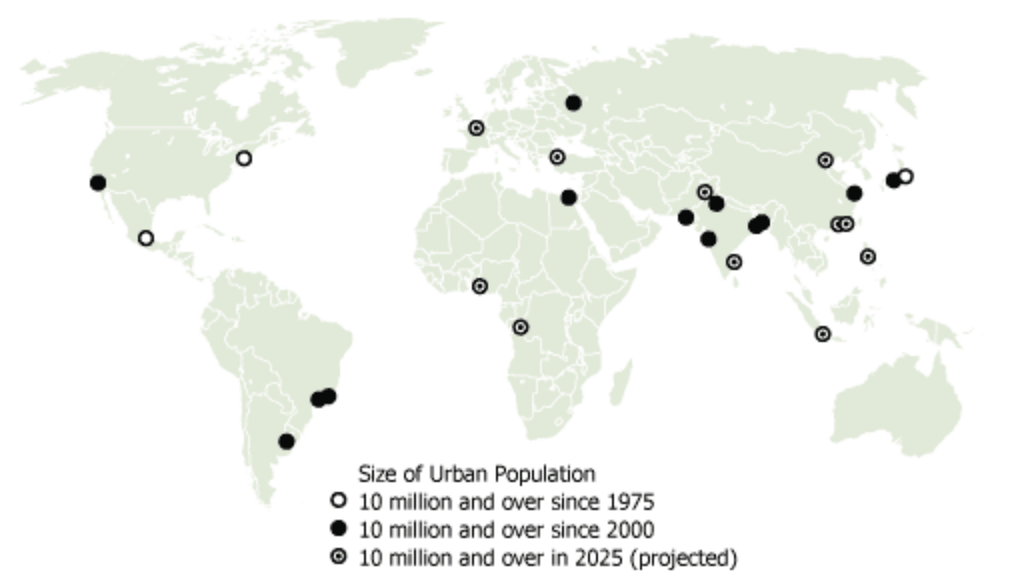
Hourly Rainfall Accumulation

May 07, 2007: Flood warning issued over the Micronet area



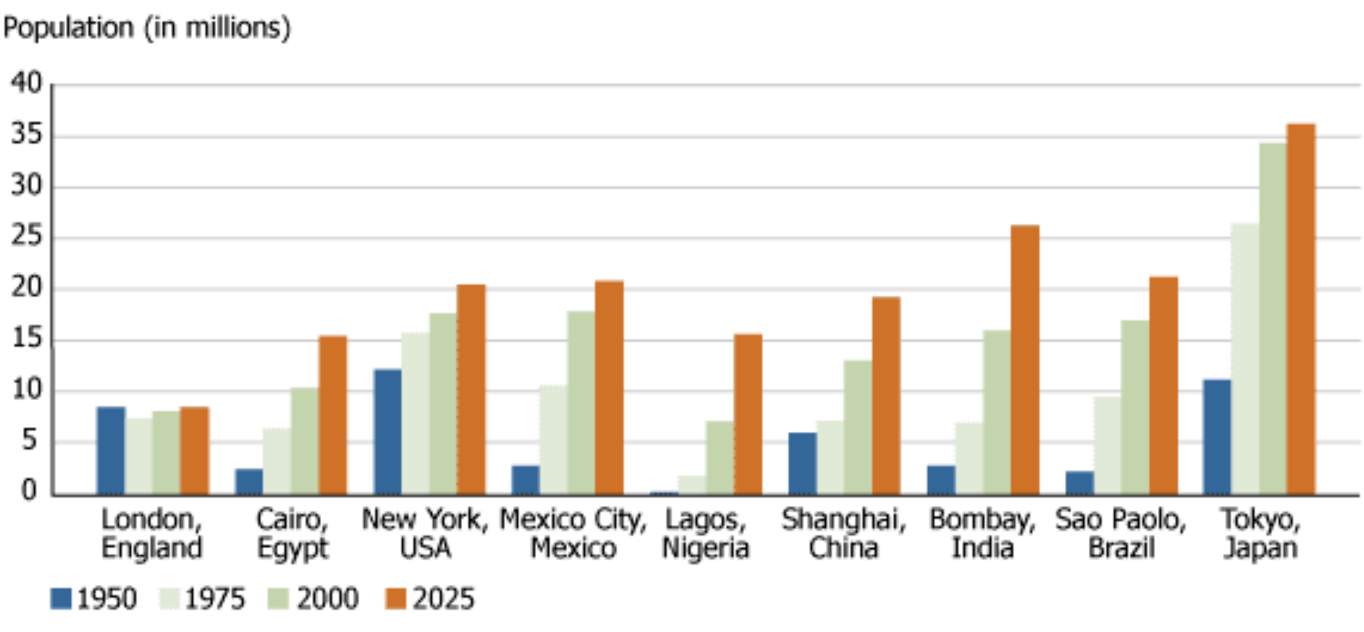
URBAN Radar Networks

- Since 2008, more than 50% of the world's population is living in cities.
- By 2030 this number will swell to almost 5 billion, with urban growth concentrated in Africa and Asia.



Source: United Nations, *World Urbanization Prospects: The 2007 Revision*.

- Many people will live in the growing number of cities with over 10 million inhabitants, known as megacities.
- As the map "Largest Urban Agglomerations" shows, just three cities had populations of 10 million or more in 1975, one of them in a less developed country. Megacities numbered 16 in 2000.
- By 2025, 27 megacities will exist, 21 in less developed countries.



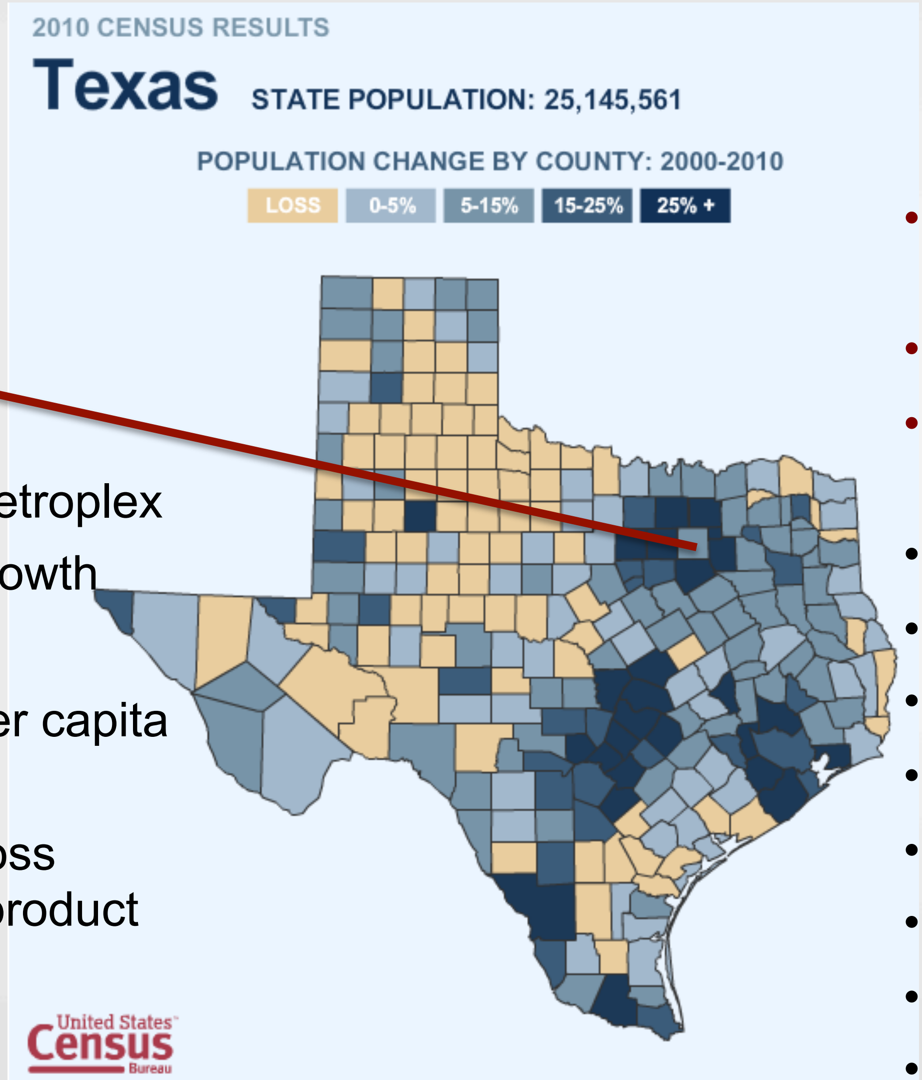
Source: United Nations, *World Urbanization Prospects: The 2007 Revision*.

The DALLAS – FORT WORTH URBAN NETWORK

Dallas-Fort Worth: A Vibrant, Growing Metroplex

6.3 million people

- 4th largest metroplex
- Population growth 25%+
- 2nd highest per capita lane miles
- 6th largest gross metropolitan product



- **North Central Texas Council of Governments**
- **Fort Worth WFO**
- **Emergency Management**
- **Storm water managers**
- Surface transportation
- Arena Events
- Airports
- Interior Port (Ft. Worth
- Utilities
- Media
- Corporate HQ's

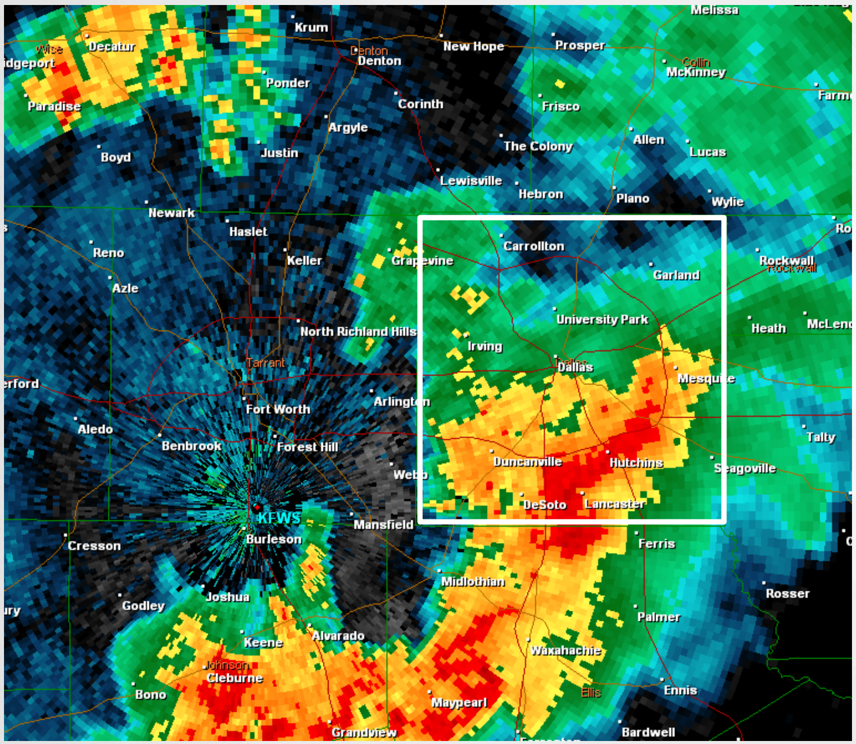
DFW Urban Test Bed

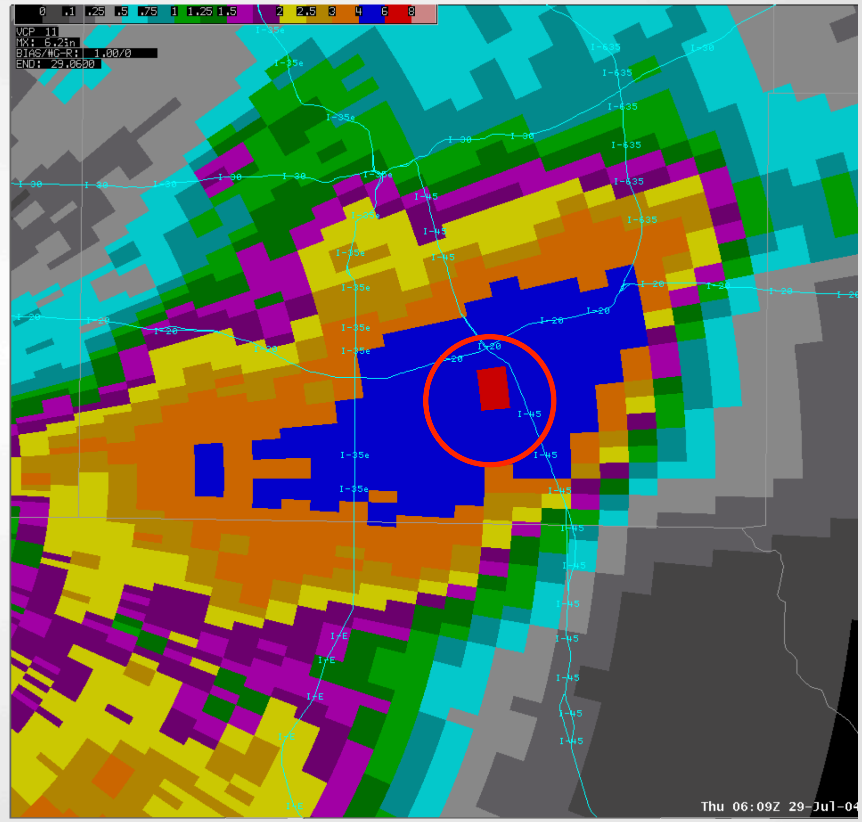
- Benefits in a densely populated urban environment
- Hazards: urban flash floods, hail, ice, high winds, tornadoes.
- Platform for collaboration/ development among researchers , government and industry partners.

Urban Precipitation Challenge

- High spatiotemporal observations are required in order to capture and monitor the highly localized, rapidly evolving rainfall events.
- High resolution hydrologic models have been developed for urban environments, which demand to be driven with high resolution QPE products.
- Urbanization significantly magnifies the scale and impact of floods. Both the spatial resolution and temporal resolution are critically important in monitoring urban floods and flash floods.

Flash Flood Challenges

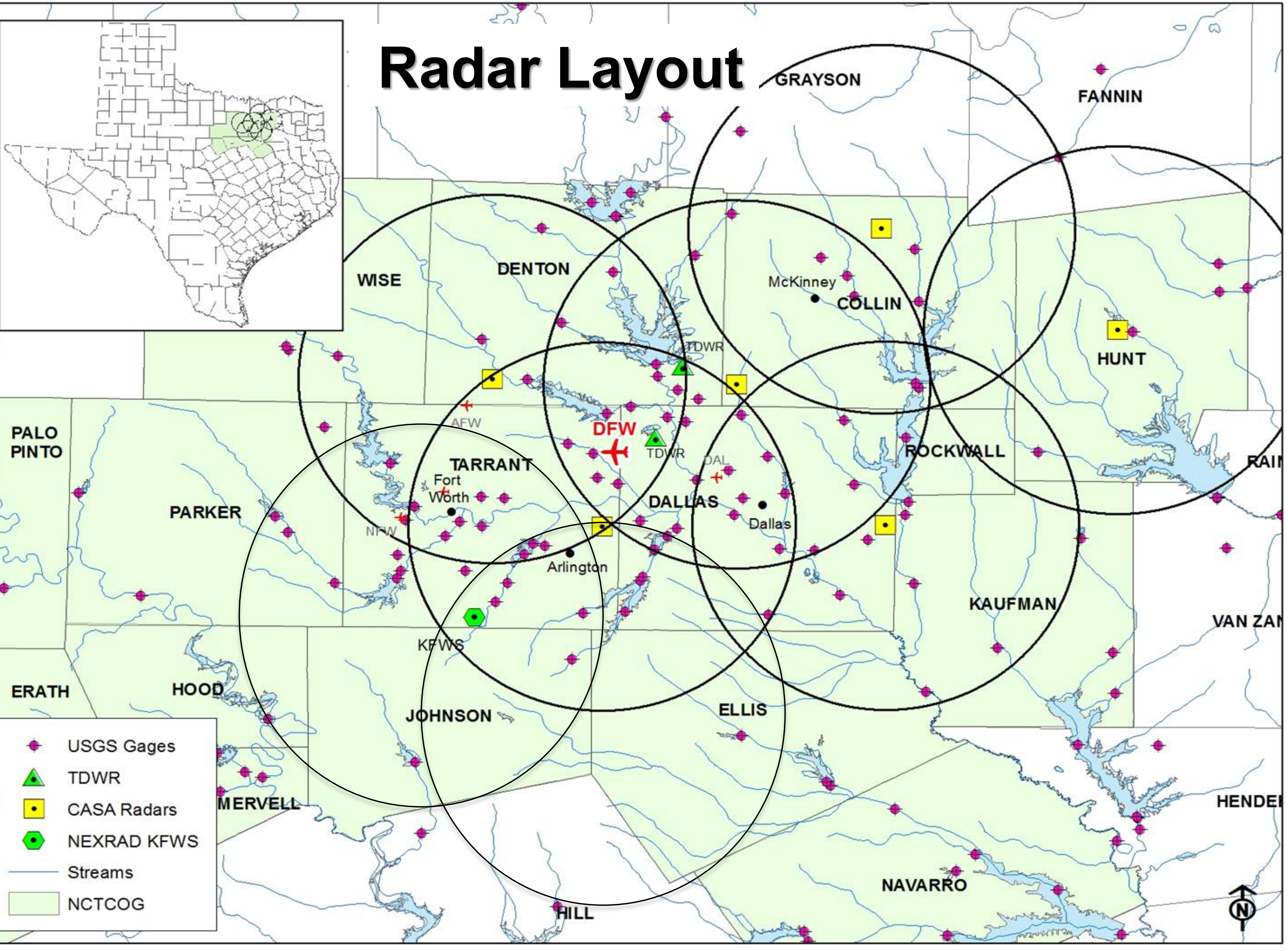




July 28, 2004: Radar estimated 6” rain; actual amounts 12”. $26 million in damages

Courtesy Fort Worth WFO

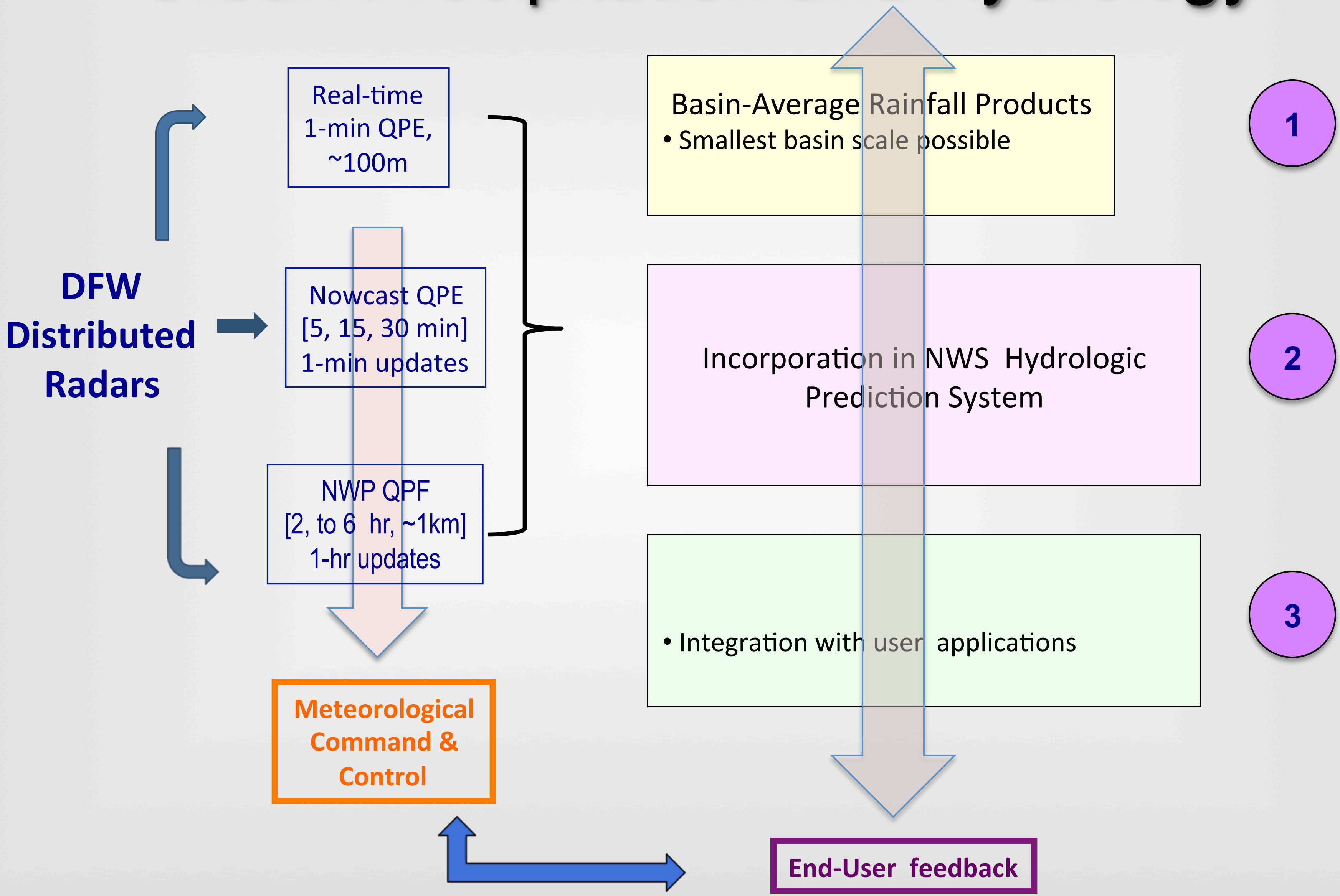
Radar Layout



Products

- Flash Floods
- Hydrometeor Reporting
- Low Level Winds

Urban Precipitation and Hydrology

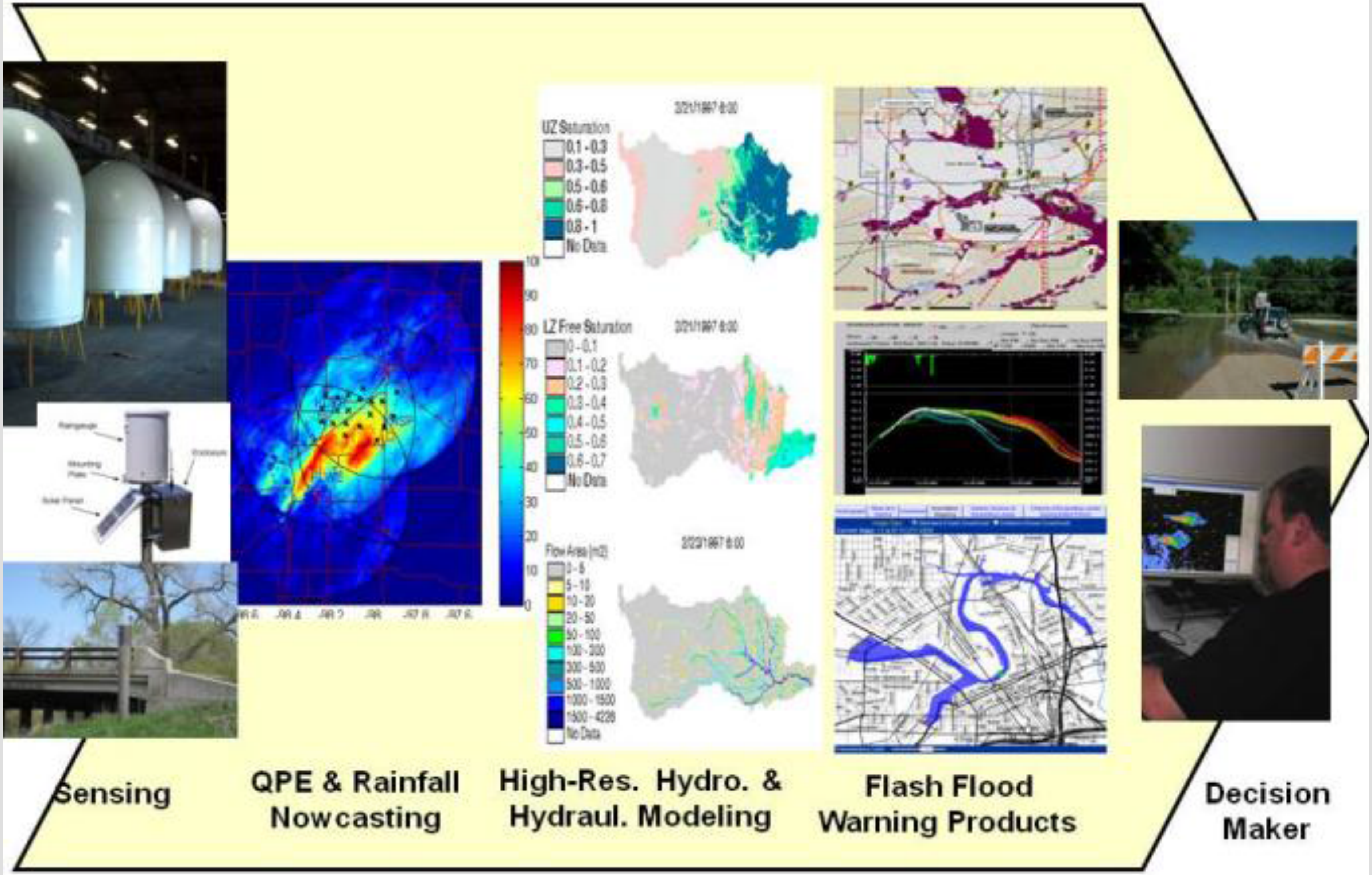


High-Resolution Flash Flood Forecasting for the City of Fort Worth

Objective

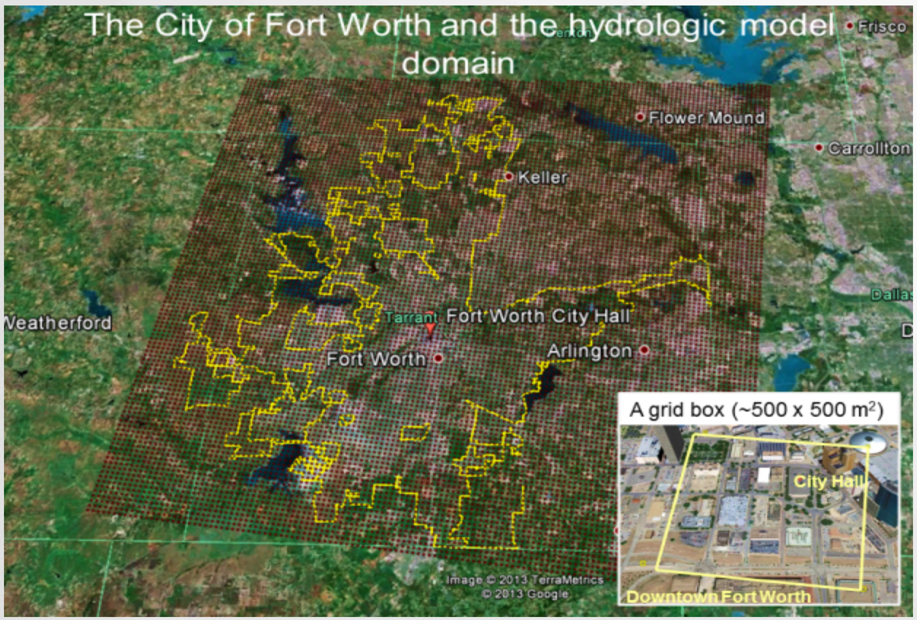
- Implement a prototype high-resolution flash flood warning system.
- Timely and seamless generation of QPE, nowcasting, hydrologic products, and inundation maps.
- Includes four principal components: QPE, nowcasting, hydrologic models and hydraulic models.

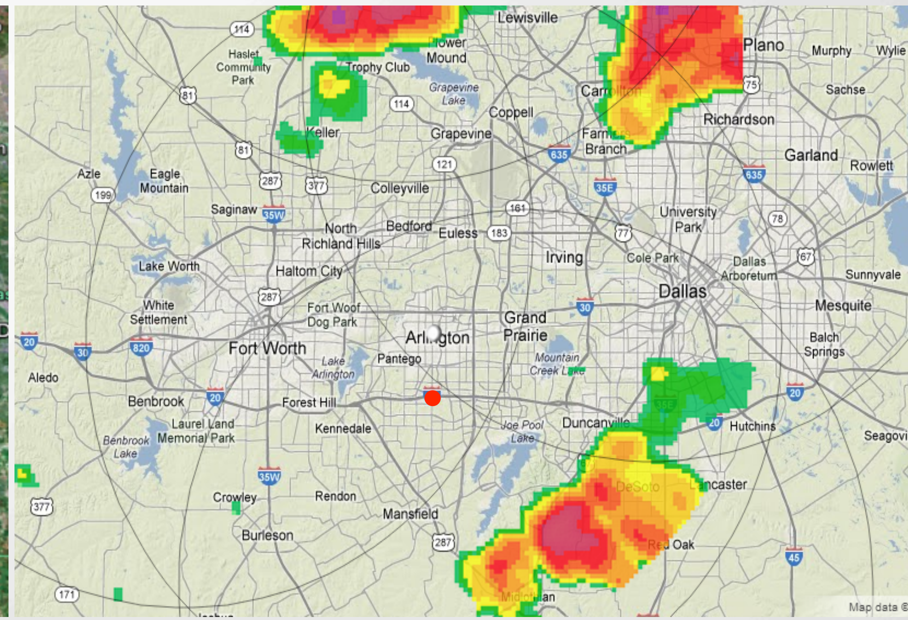
The hydrologic models ingest the QPE and nowcasting and produce high-resolution runoff and stream flow maps. Inundation maps are also produced for selected locations by the hydraulic models.


UZ Saturation
LZ Free Saturation
Flow Area (m2)
Sensing
QPE & Rainfall Nowcasting
High-Res. Hydro. & Hydraul. Modeling
Flash Flood Warning Products
Decision Maker

Study Area

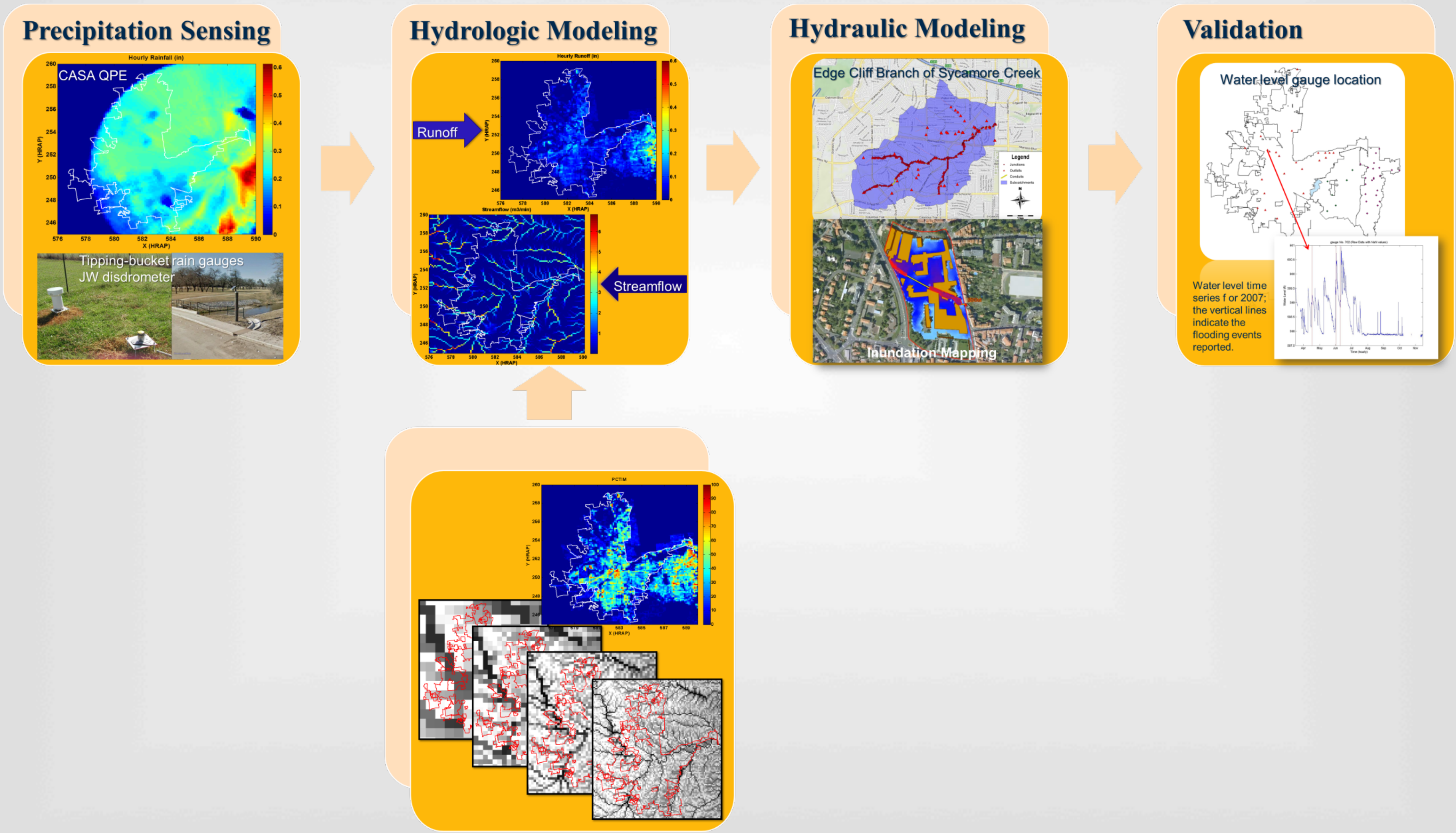
The study area is a rectangular domain that encompasses the City of Fort Worth in the Dallas-Fort Worth Metroplex (DFW) in Texas. The Cities of Arlington and Grand Prairie are being added to the domain.

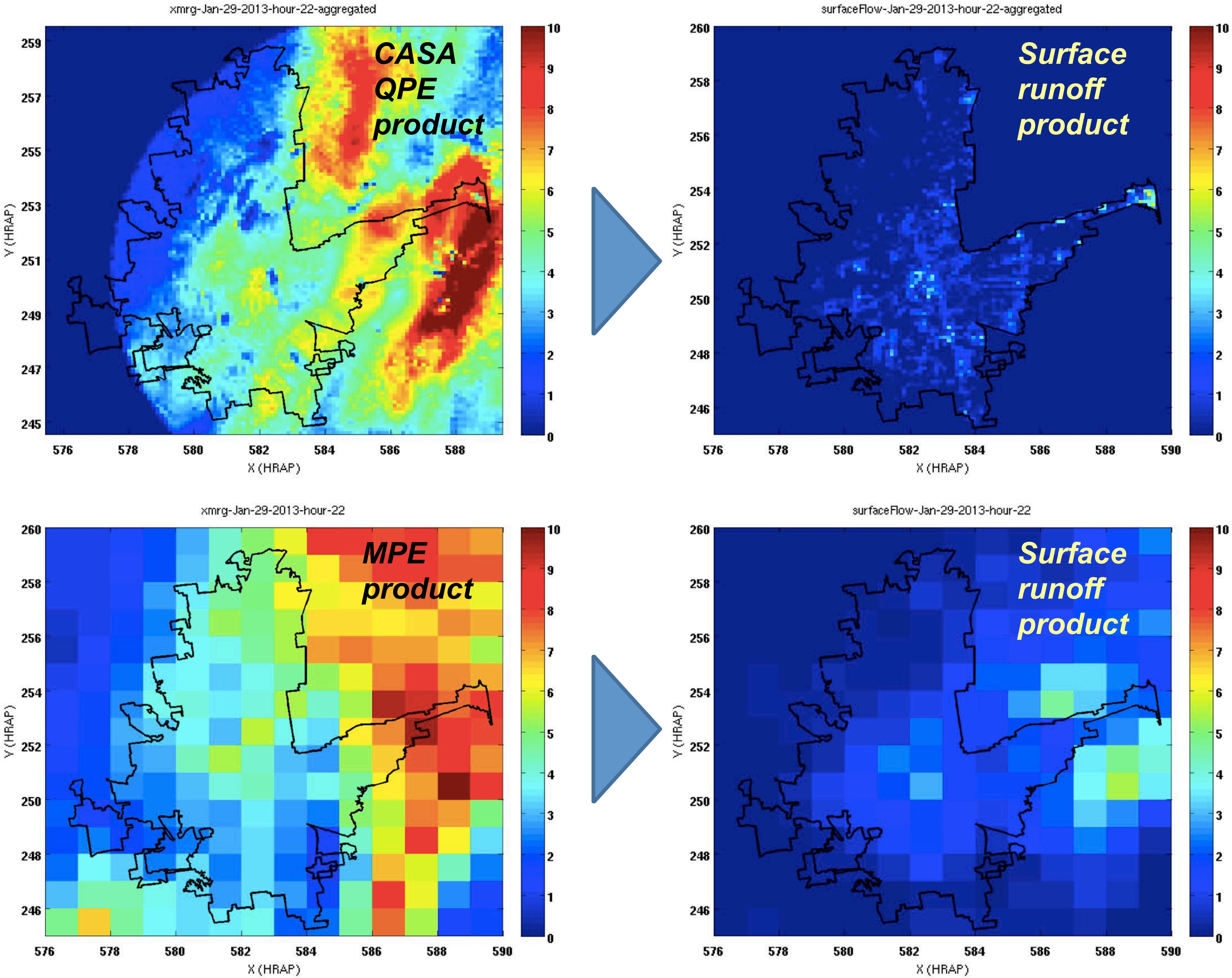




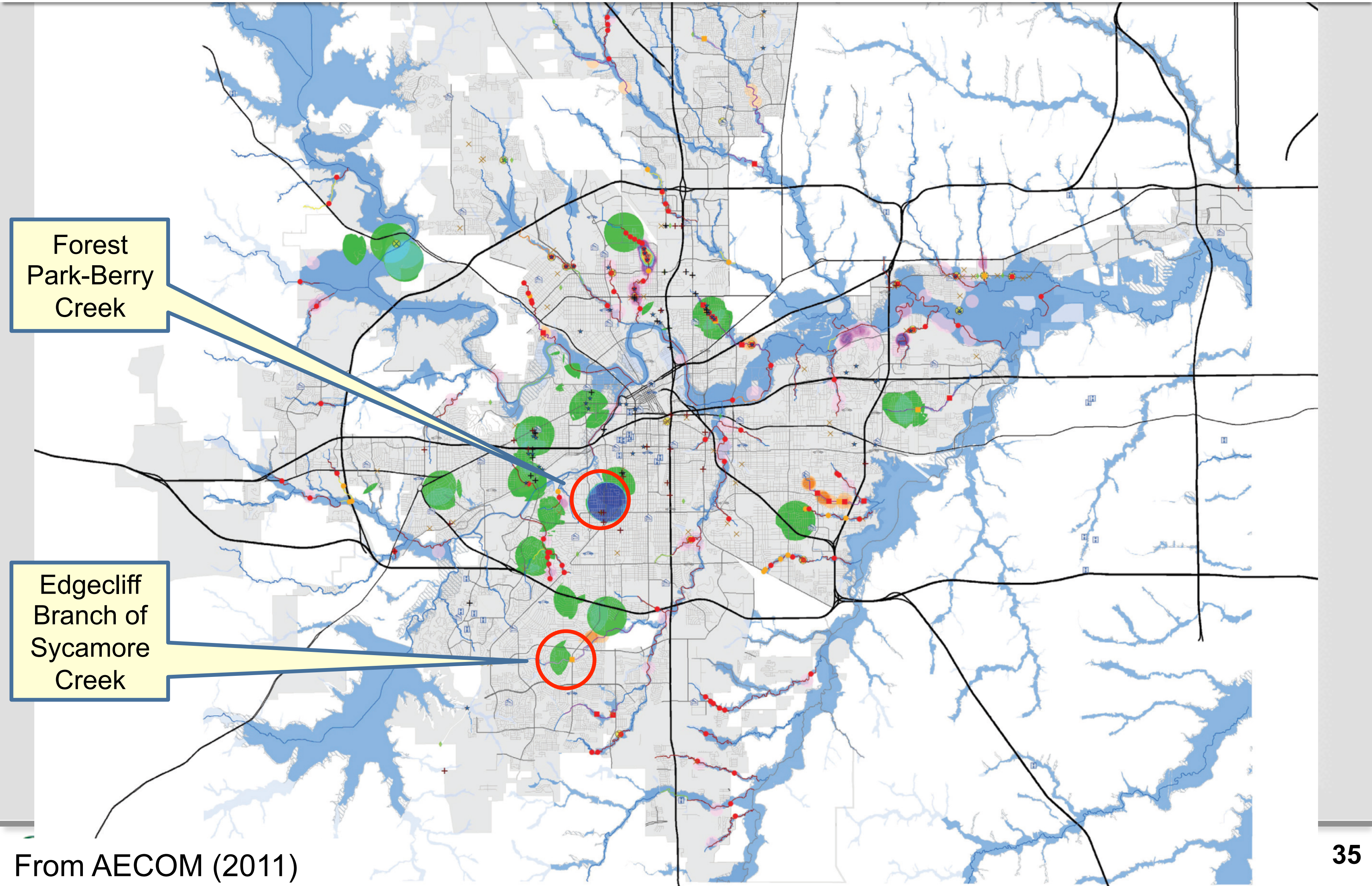
Left) The study area compassing the City of Fort Worth. Right) The DFW Demonstration Network

High-resolution flash flood forecasting




xmrg-Jan-29-2013-hour-22-aggregated
CASA QPE product
surfaceFlow-Jan-29-2013-hour-22-aggregated
Surface runoff product
xmrg-Jan-29-2013-hour-22
MPE product
surfaceFlow-Jan-29-2013-hour-22
Surface runoff product
X (HRAP)
Y (HRAP)

"Hot spots" for hydraulic modeling



From AECOM (2011)

Summary

- The flash flood forecasting system for the City of Fort Worth under development also prototypes the next-generation URBAN flash flood forecasting capability for NWS
  - A suite of new products.
  - High-resolution runoff, flow, soil moisture over large urban areas.
  - High-resolution inundation maps for hot spots

Summary

- Smart Urban Radar Network concept is important from an economic sustainability and societal impact point of view

- Monitor precipitation at fine urban scales for emergency management

- Significant impact on transportation

Thank You