Radar Network for Urban Flood and Severe Weather Monitoring

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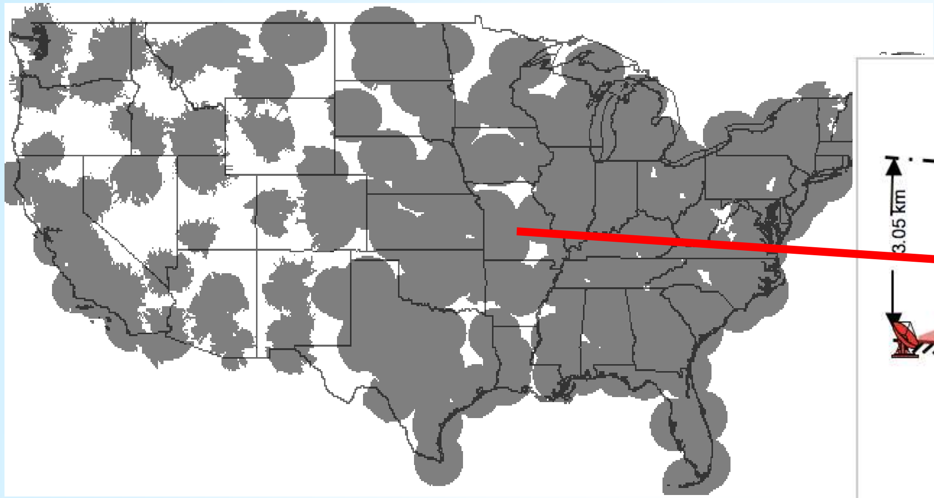
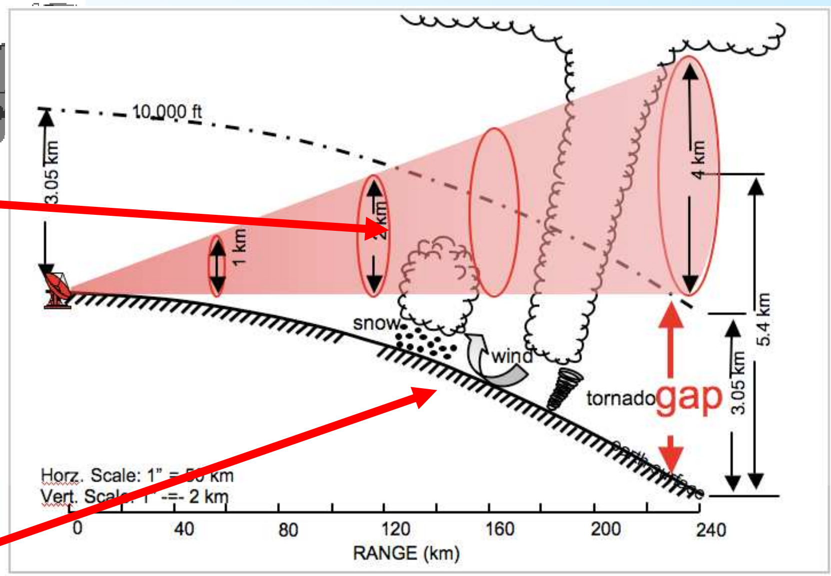
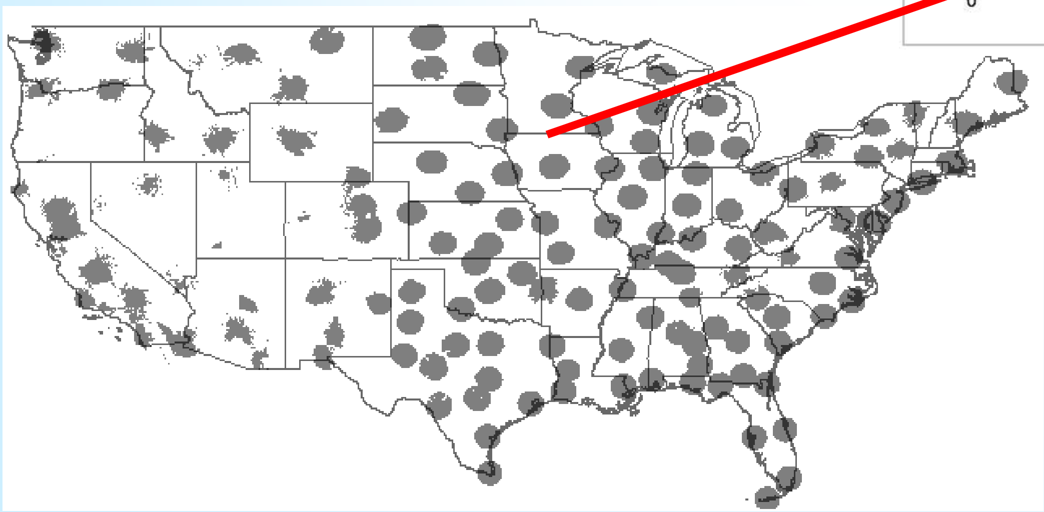
And the full DFW team

CASA Motivation



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





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

- Radar "Gap"
- Spatial Resolution
- Temporal Resolution
- Radars function autonomously

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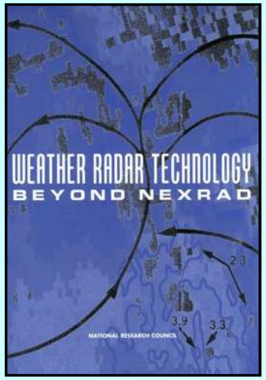
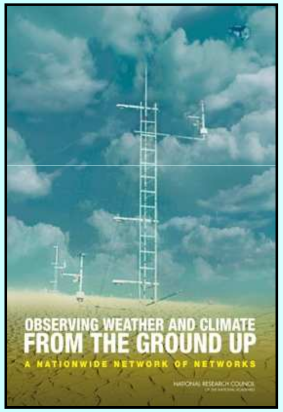
CASA's Solution

- 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

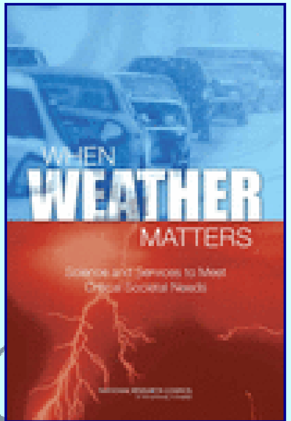
National Research Council



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

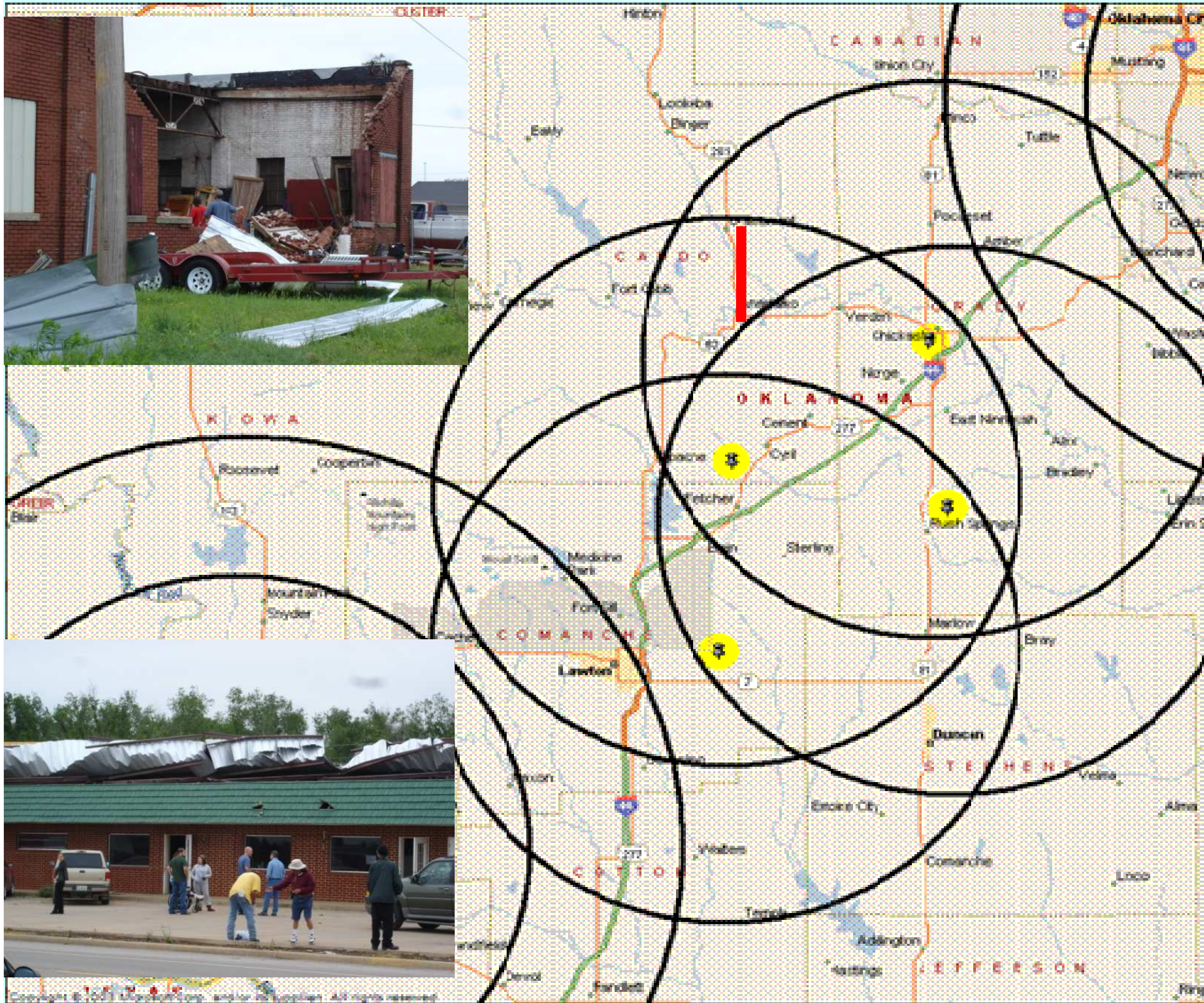


Recommendation: "Emerging technologies for distributed-collaborative-adaptive sensing should be employed by observing networks, especially scanning remote sensors such as radars and lidars." NRC, 2008



"**…**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

Tornado Tracking



Anadarko Tornado
May 14, 2009

EF2 Tornado
~9:22 – 9:40PM

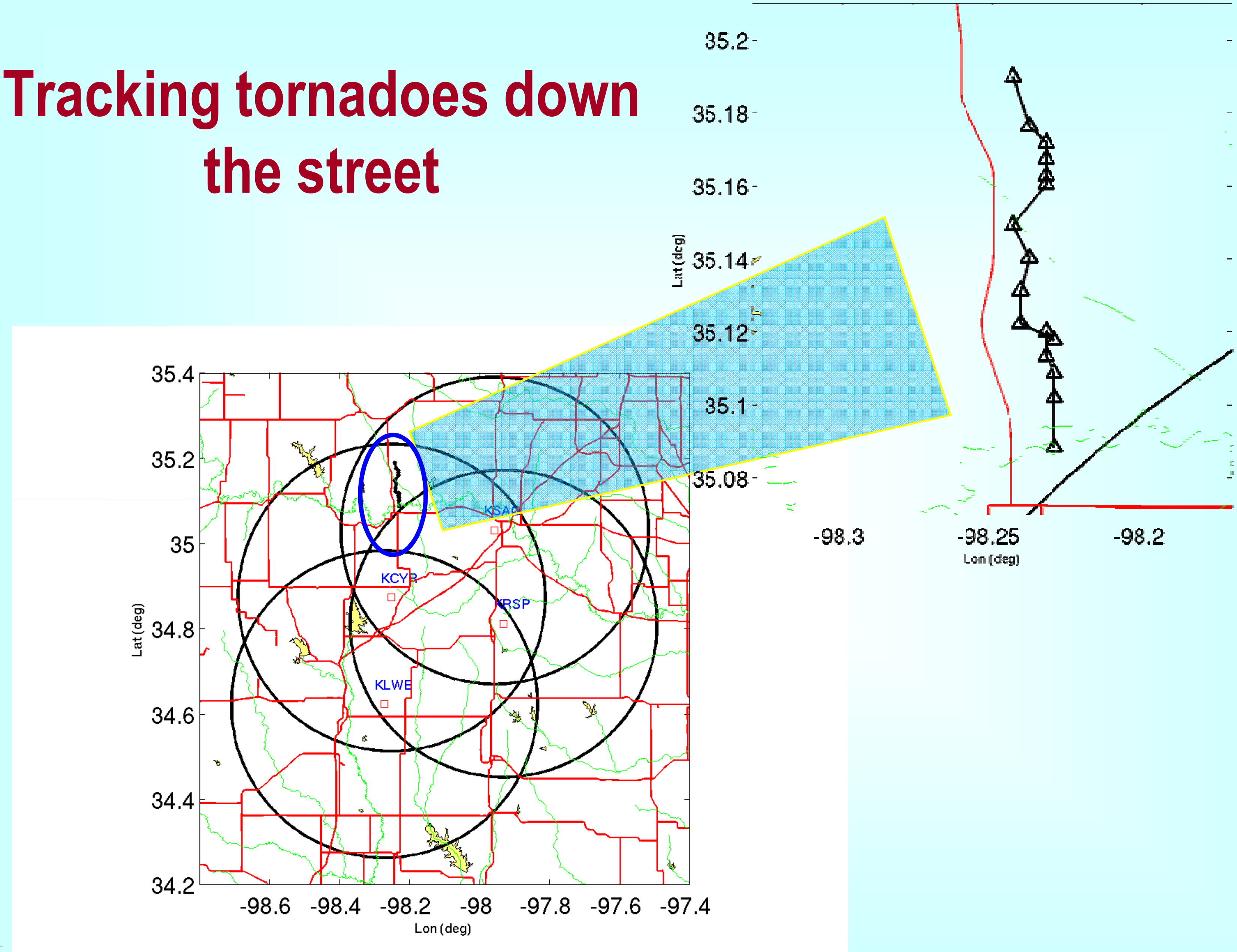
Prolonged Damaging Winds 100mph+

3 injuries
$43 million+ in property damage

CASA Tornado Warning 9:21

NWS Tornado Warning 9:24

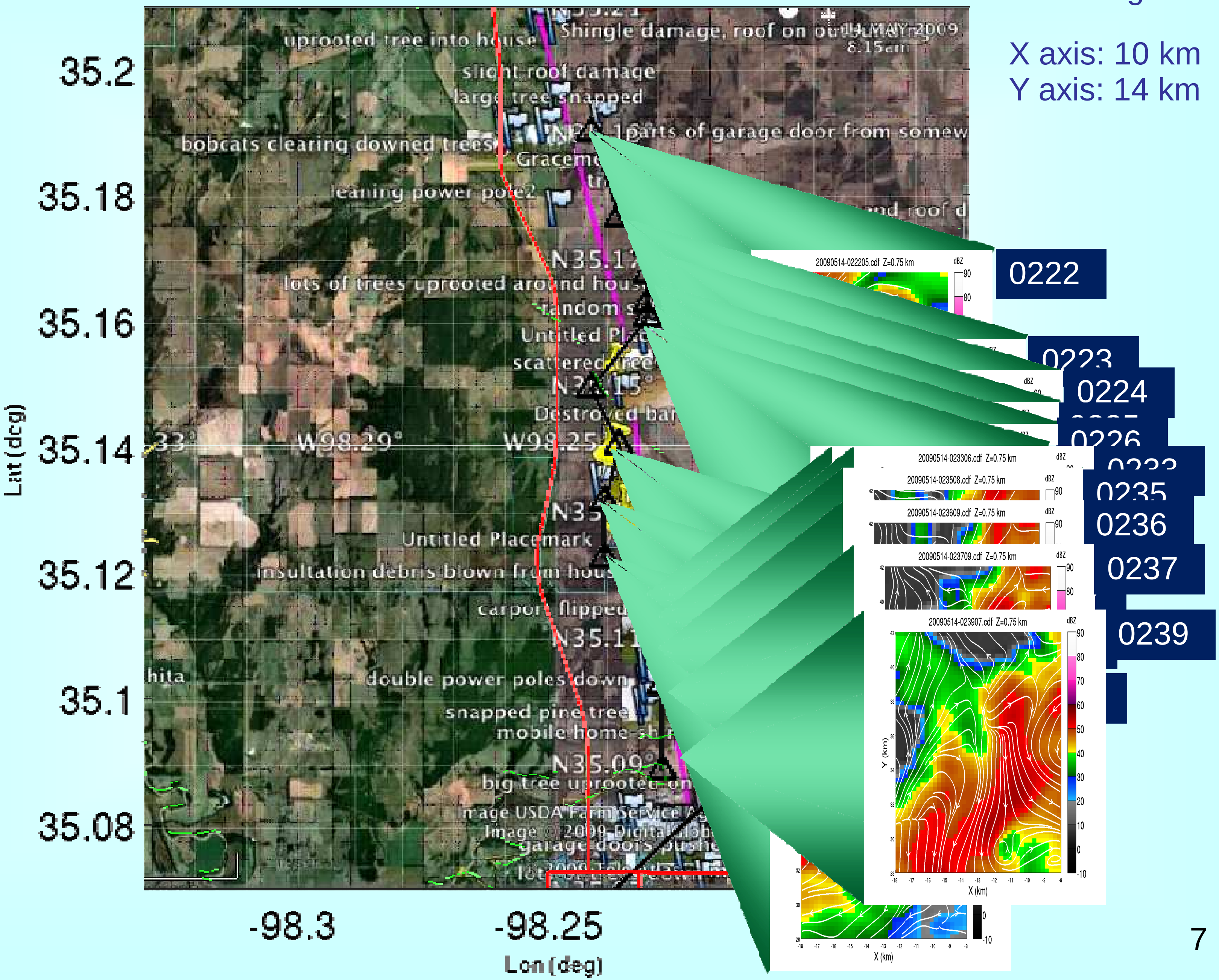
Tracking tornadoes down the street



Tornado Path as Observed by IP1 Radars

350 m above ground

X axis: 10 km
Y axis: 14 km



QPE Challenge

- Measurements are not low enough in altitude.
- Nonlinear transformation to get rainfall that does not fit well with all practical issues.

Urban QPE Challenge

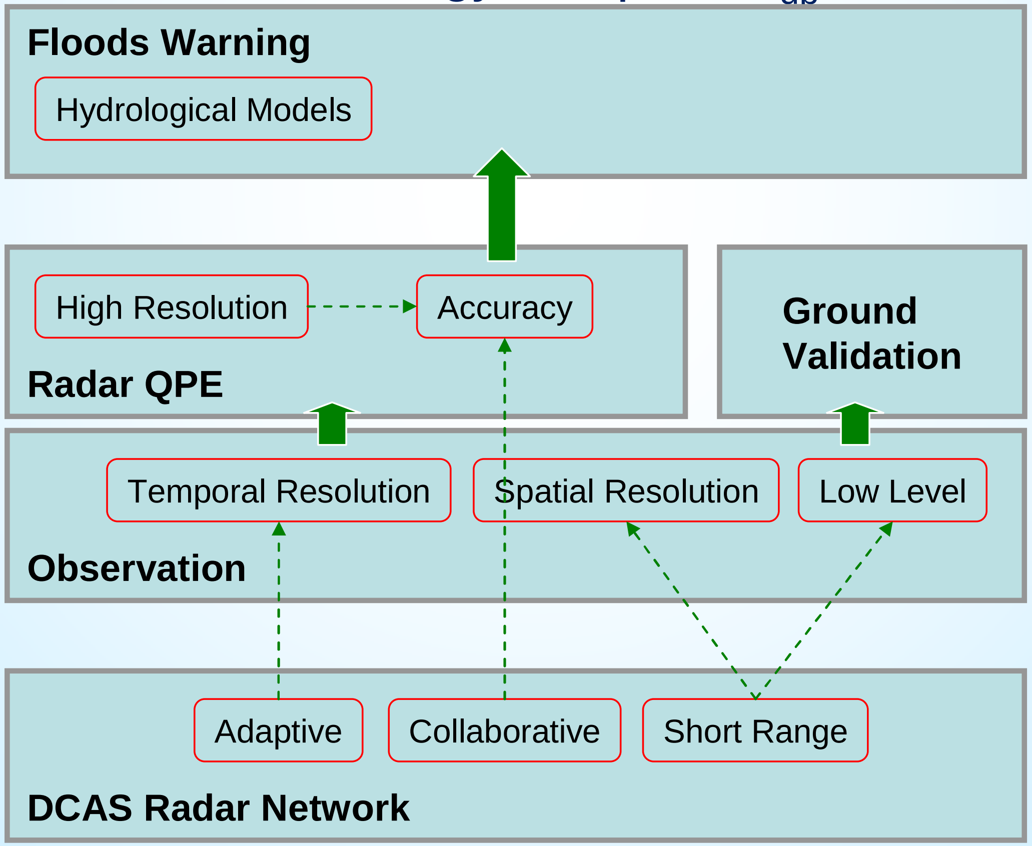
- High spatiotemporal observations are required in order to capture and monitor the highly localized, rapidly evolving rainfall events.

- 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.

QPE Sensing Aspects in a network

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

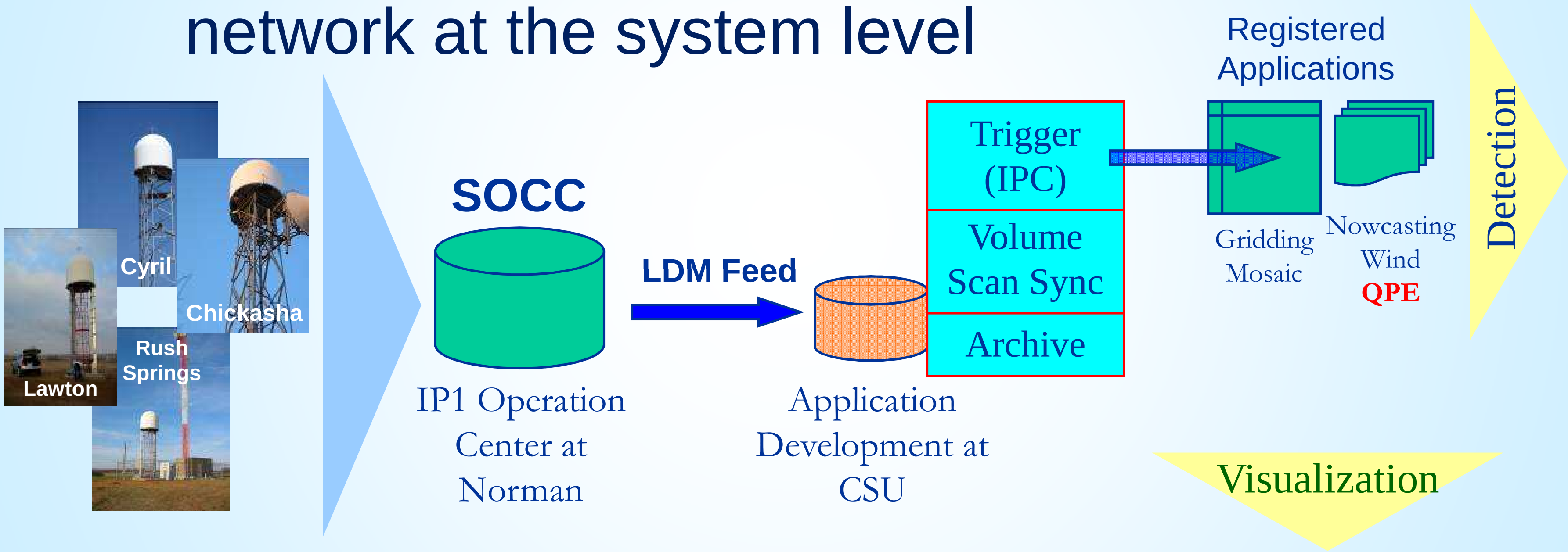


QPE Algorithm: Adaptive K_{dp}

- K_{dp}, as the derivative of Φ_{dp} , can be very noisy.
- Adaptive estimation:
  - Estimate over longer spatial scales in light rain region
  - Estimate over shorter spatial scale in heavy rain region
- Network Advantage: The data volume from radar differs on different propagation path, mainly depending on the cross-beam gradients.
- Network Composition: “Favorable” K_{dp} is chosen according to the quality metric of K_{dp} estimation.

Real-time QPE Product

- Real-time QPE is operated in IP1 radar network at the system level



Rainfall Conversion

- K_{dp} based rainfall estimation was implemented in CASA's IP1 test bed.

$$R = 0.6\pi \times 10^{-3} \int v(D) D^3 N(D) dD$$

$$K_{dp} = \frac{\pi^2}{6\lambda} C \int (1-r) D^3 N(D) dD$$

A scaled version of KOUN's rainfall estimation is tested

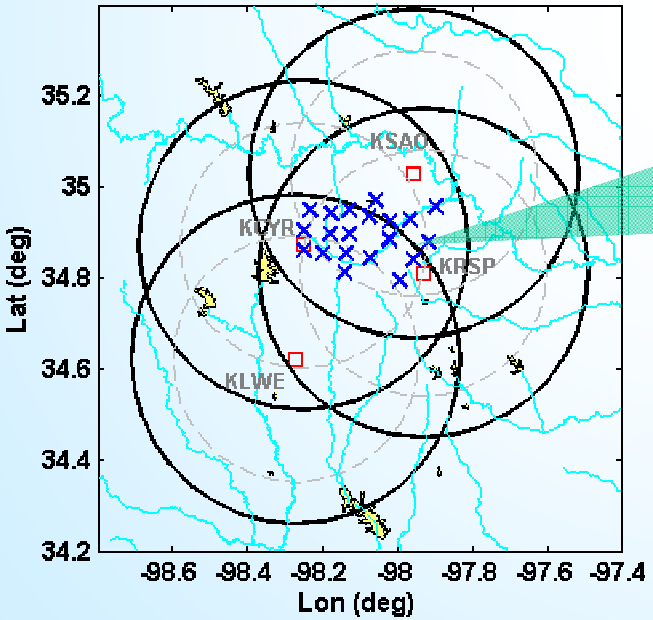
$$R = 47.3 K_{dp}^{0.791} \text{ mm/hr}$$

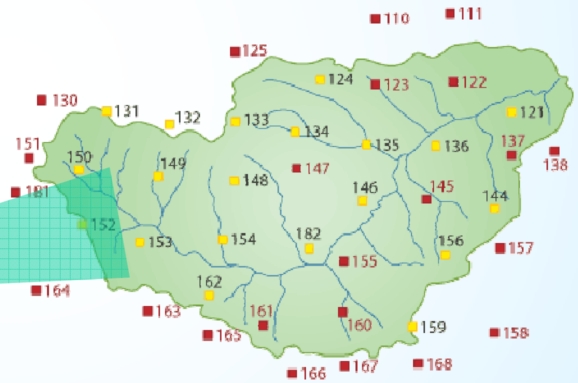
⇓

$$R = 18.15 K_{dp}^{0.791} \text{ mm/hr}$$

Validation Study

- Gauge comparison was investigated to evaluate the QPE system
- USDA ARS Micronet – A rain gauge network located at the center of the IP1 test bed





Source: http://ars.mesonet.org

Little Washita

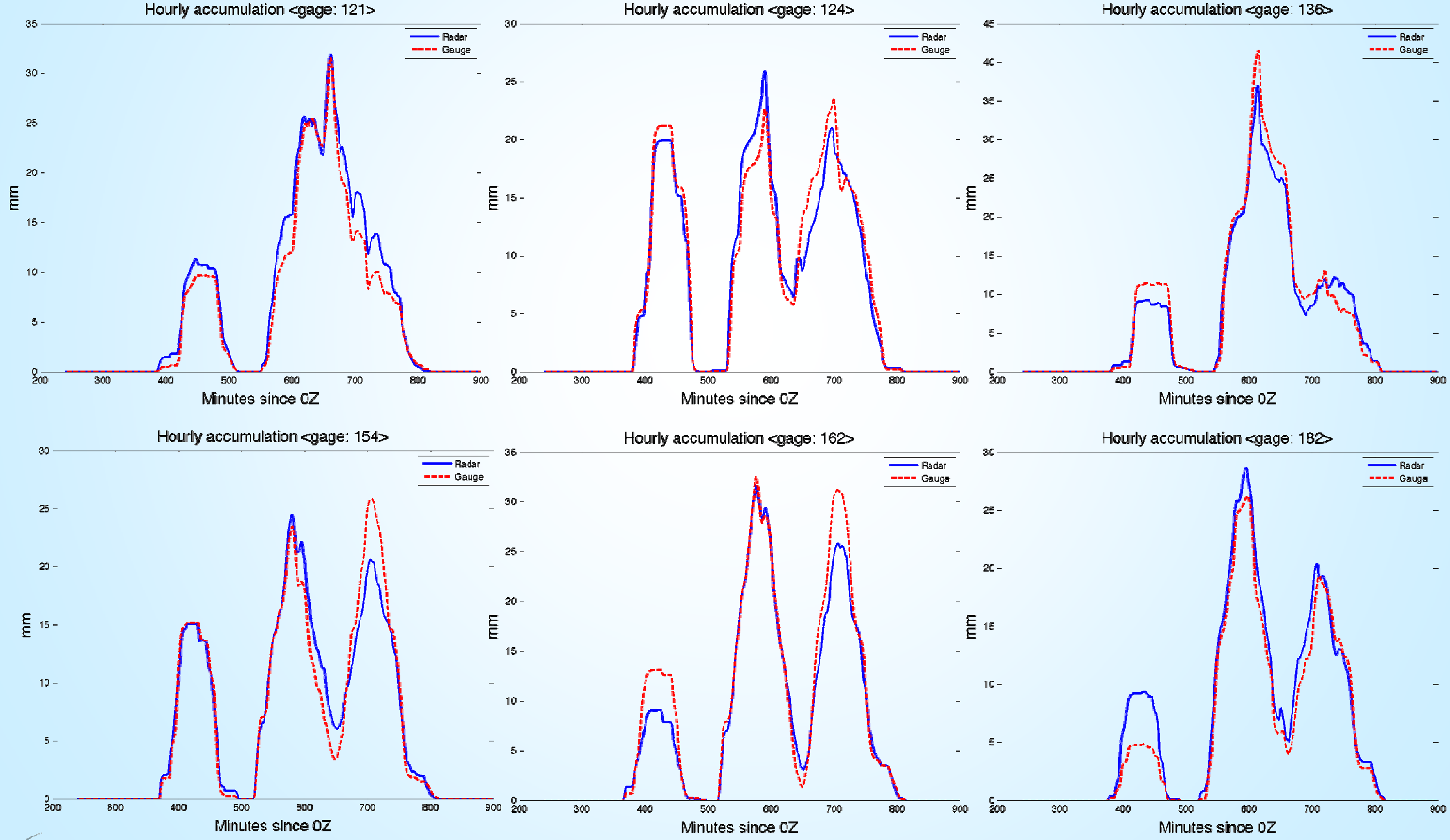
Watershed size: 611 km^2
Mean annual precipitation: 760 mm
Gauge network: 20 tip-bucket stations

Evaluation

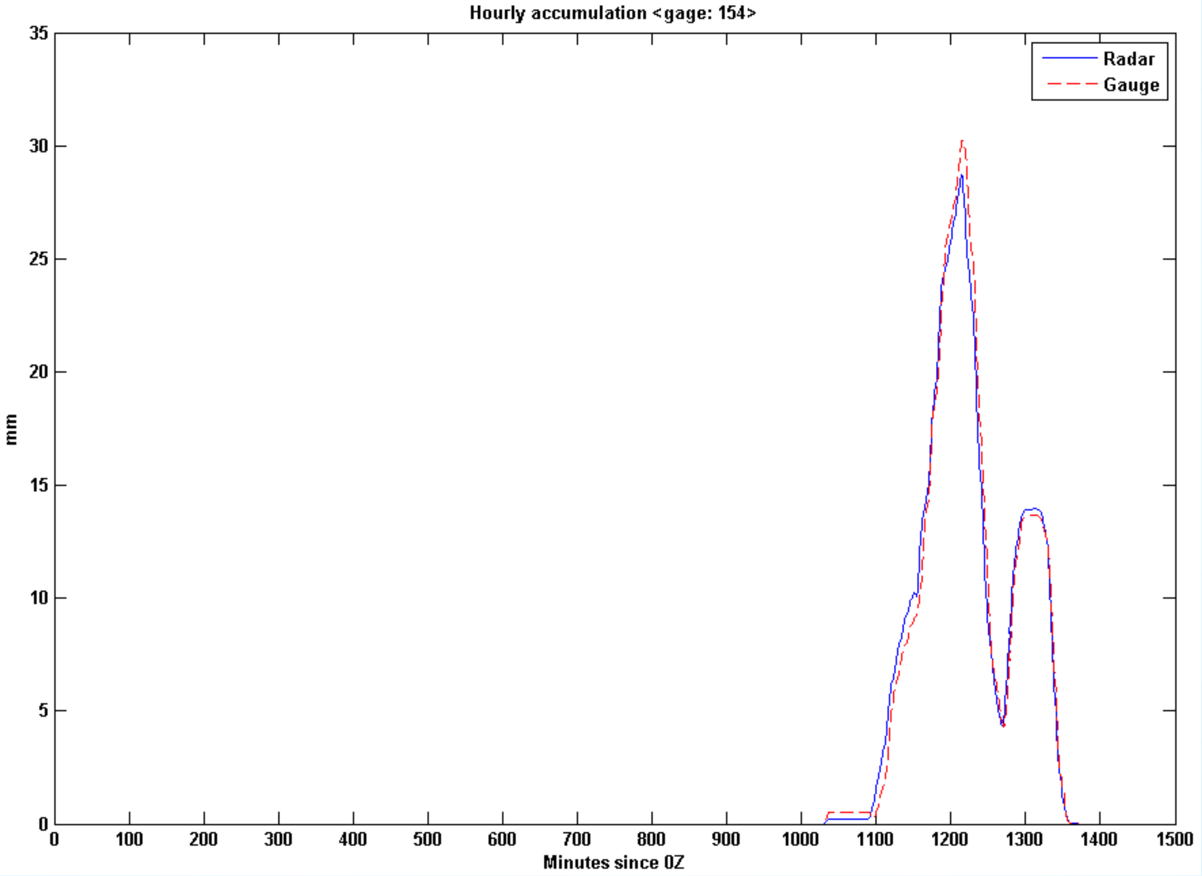
- In total, 42 precipitation events were observed passing over the Little Washita gauge network during the **five years** of experiments (2007-2011), including: severe, multi cellular thunderstorms; scattered, ordinary thunderstorms; squall lines, and wide spread stratiform rain.
- The cross-comparison pairs are constructed out of each rain gauge station for each storm event, rather than the collection of areal totals or storm totals.
- The QPE composition was acquired from the estimates with the best K_{dp} quality.
- Both hourly rainfall and instantaneous rainfall rate are evaluated for each storm event.

Hourly Rainfall Accumulation

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



Sample Automatic Products



Detailed comparison between radar and gauge at gauge number 154 location (Lat: 34.8553, Lon: -98.1369)

Sample Products

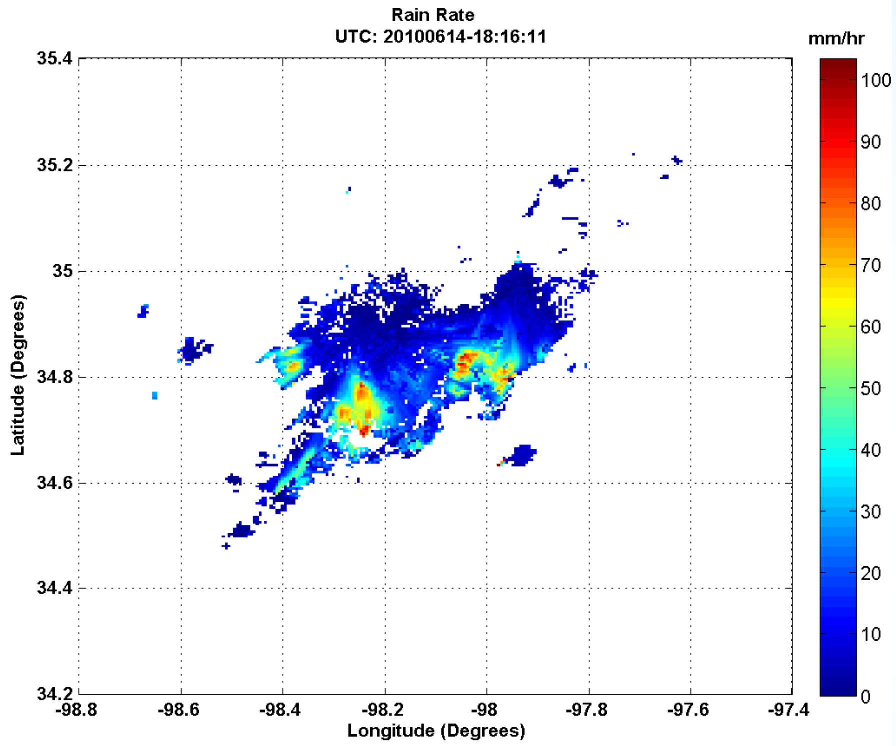


Fig. 8: sample of instantaneous rainfall maps over a storm event

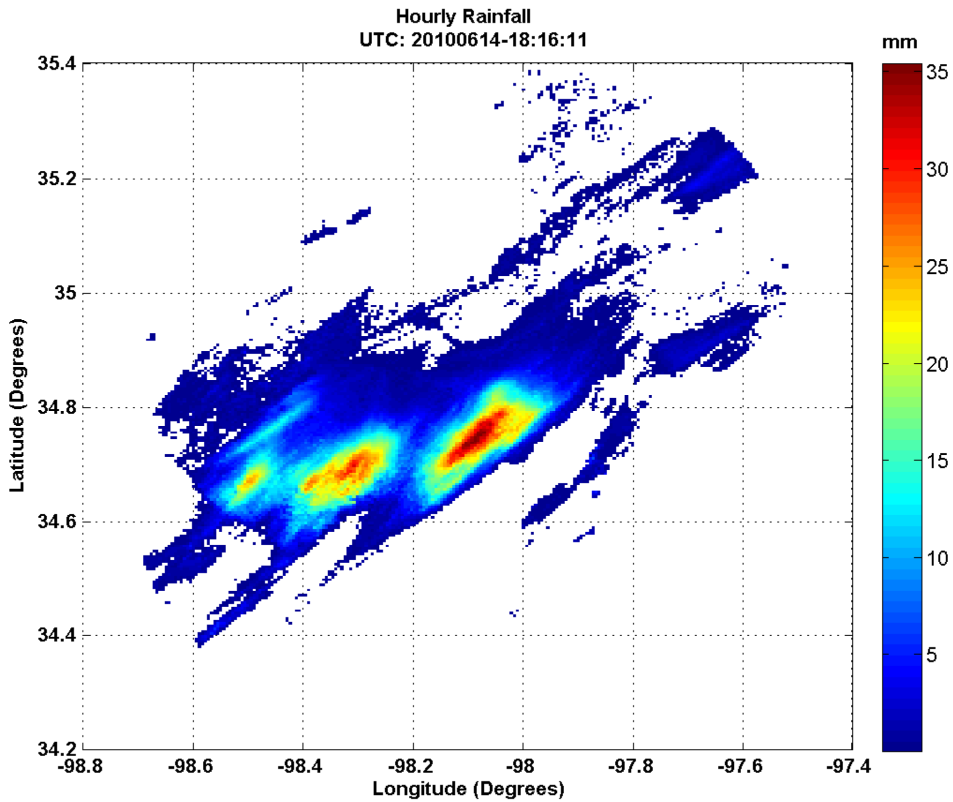


Fig. 9: A sample of the hourly accumulation maps

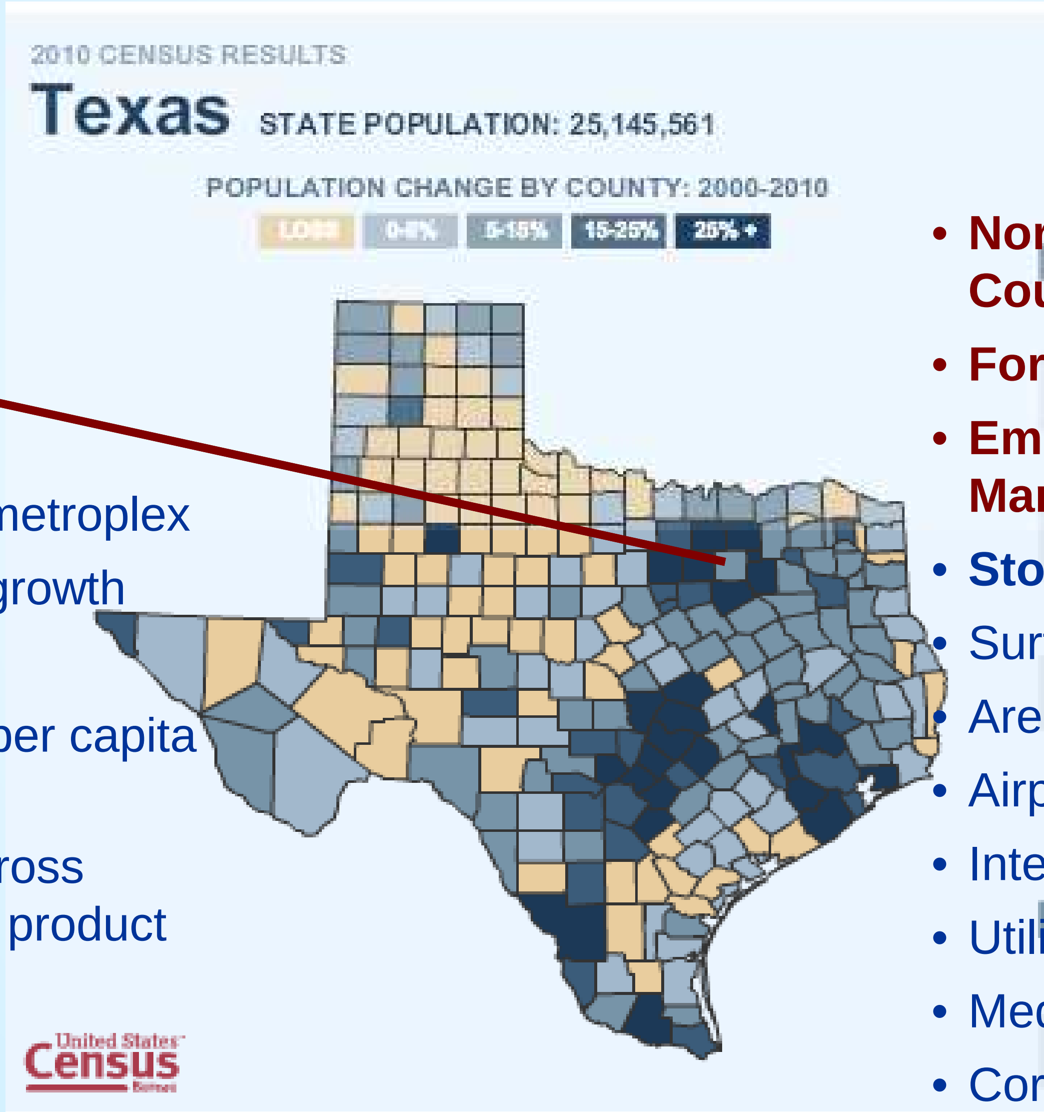
Overall Performance Comparison – Hourly Rainfall

	Normalized Bias Error (%)	NSE (%)
CASA Network:	3.14	22.76

DFW: 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

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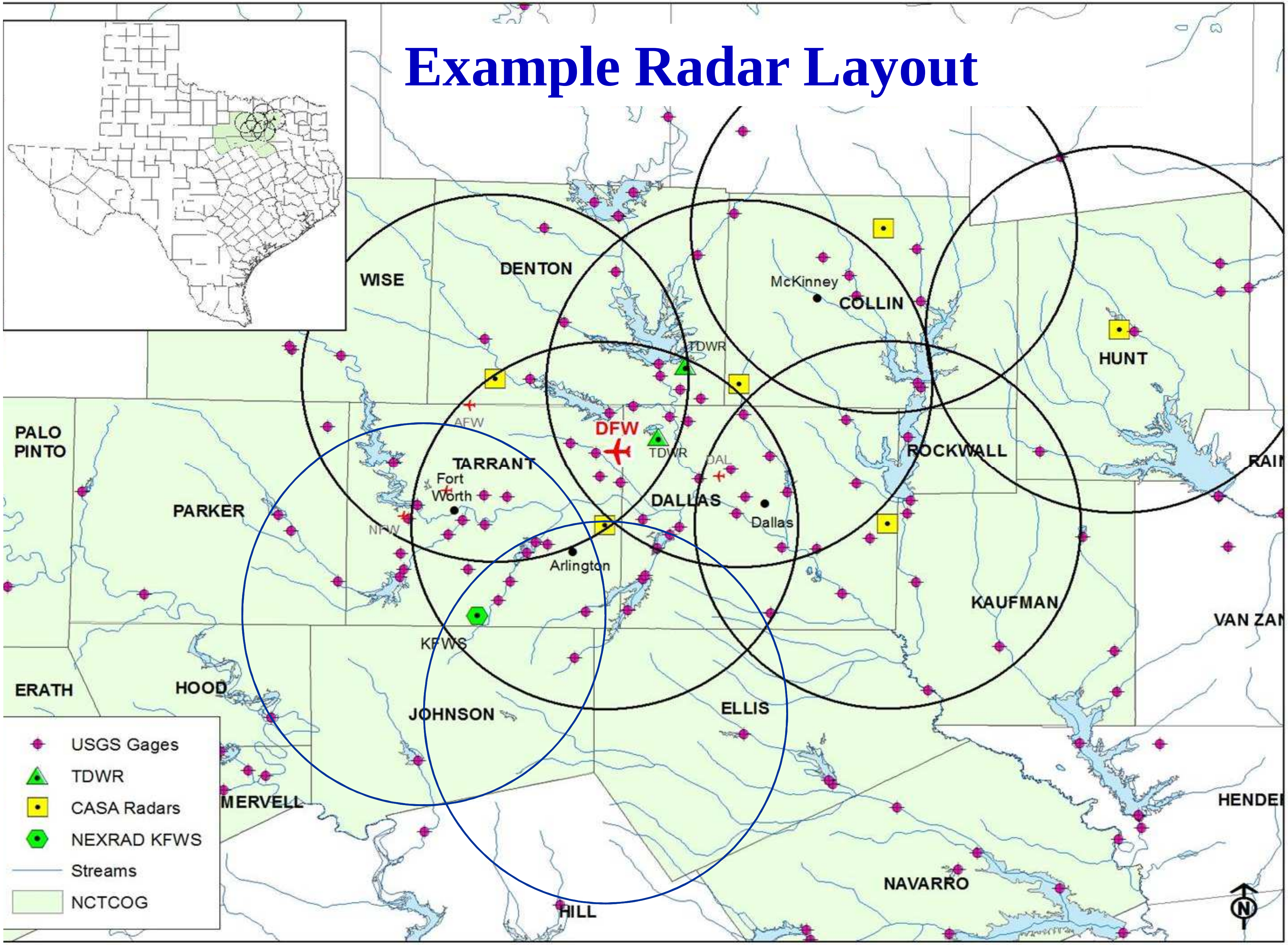
Urban Test Beds

- CASA end-to-end benefits in a densely populated urban environment
- Hazards: urban flash floods, hail, ice, high winds, tornadoes.
- Networks-of-Networks: CASA radars in heterogeneous sensor networks: architecture, products, forecaster decision making
- Model for local, private, federal participation and ownership of urban radar networks.
- Platform for collaboration among CASA researchers and industry partners.

Example Radar Layout



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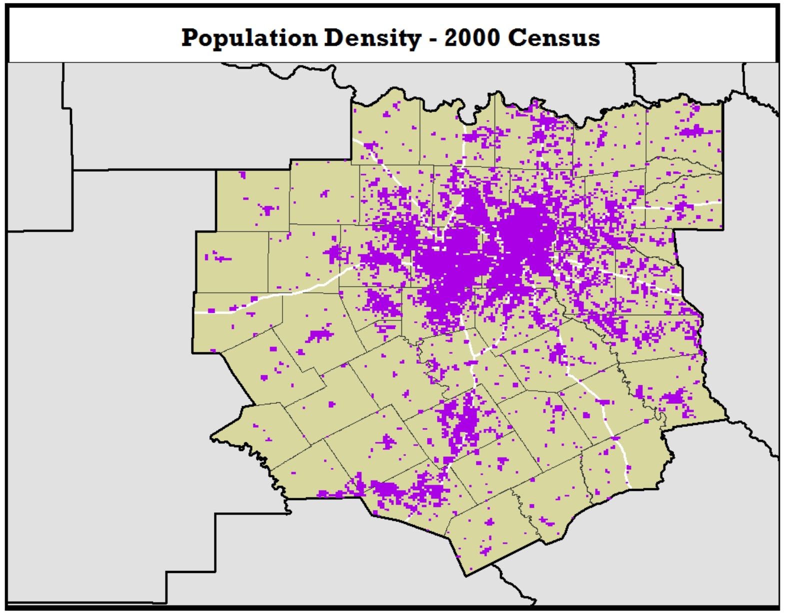
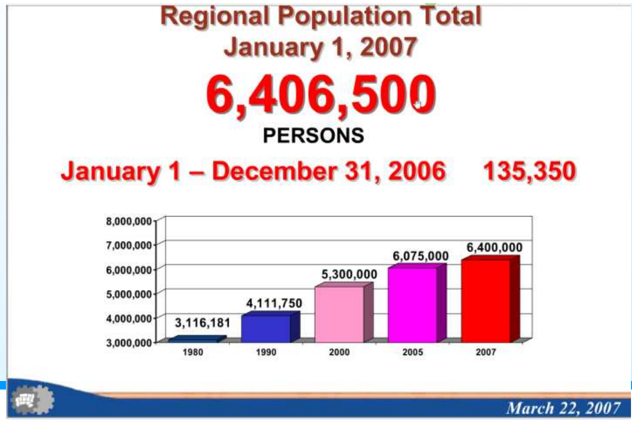
Integrated Warning System

- Local Emergency Management/Public Safety
  - Local notification systems and spotter networks
- Broadcast and Print Media
  - TV, radio, Internet
- National Weather Service
  - Weather radio, Internet, input to other systems
- Social Media
  - Nixle, Facebook, Twitter, among MANY others

Geographical/Population Challenges

- Rapid population growth
- Urbanization
- New residents unfamiliar with our severe weather threats

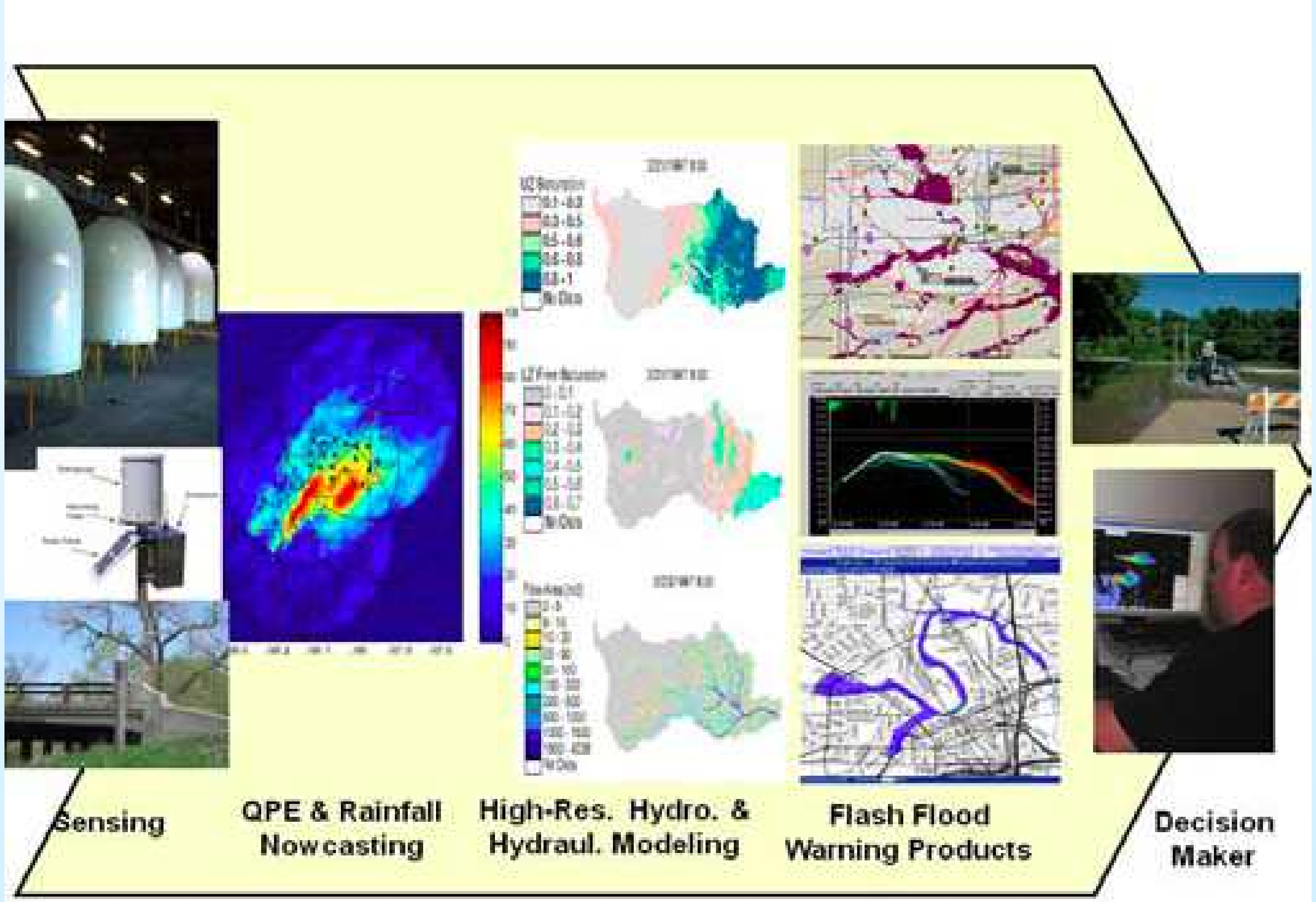




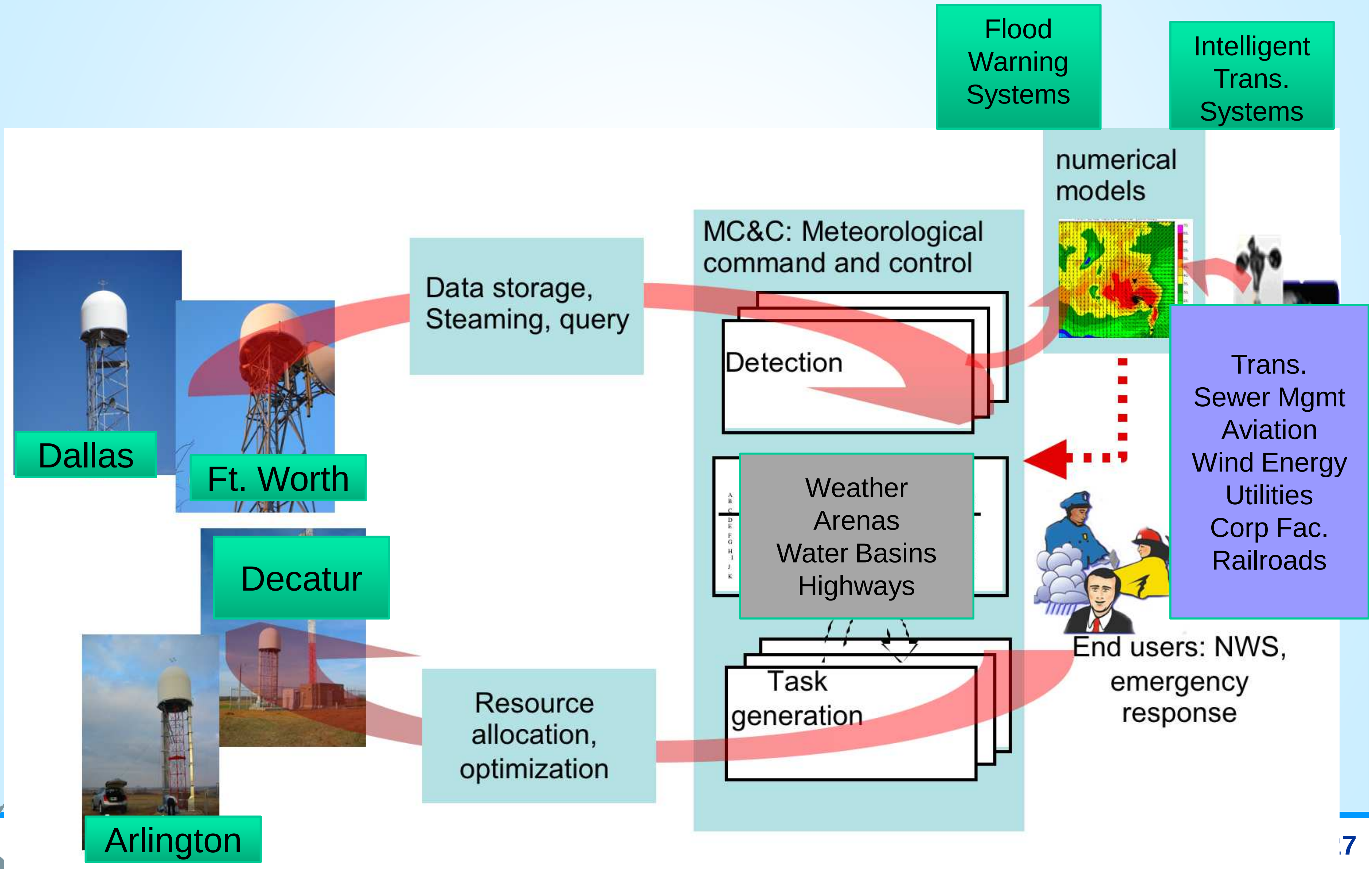
Impacts of Urbanization/Population

- Greater runoff during heavy rainfall
  - Flash floods occur more frequently
  - Events occur in more and new places
- Public Education on preparedness never ends
- Better detection of heavy rainfall leads to more timely public warnings

High Resolution Flood Warning systems



DFW Test Bed
End-to-End Systems View



Summary

- DFW network is operational demonstration implementation of the CASA system. Emphasis is deployment in a major metropolitan region
- Networked Dual-polarization radar observations, especially the specific differential propagation phase, is used to produce QPE product at X-band.
- On going work is planed to integrate QPE from radar network with hydrological and hydraulic model for real-time monitoring of urban floods.

K_{dp} and Composition

- K_{dp} based rainfall conversion is attractive at X-band
  - Responds well to low rainfall rate
  - Avoids the uncertainty in attenuation correction
  - Immune to calibration factors across the network