Linked Environments for Atmospheric Discovery:
Web Services for Meteorological Research and Education

What Would **<u>YOU</u>** Do if These Were About to Occur?
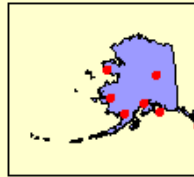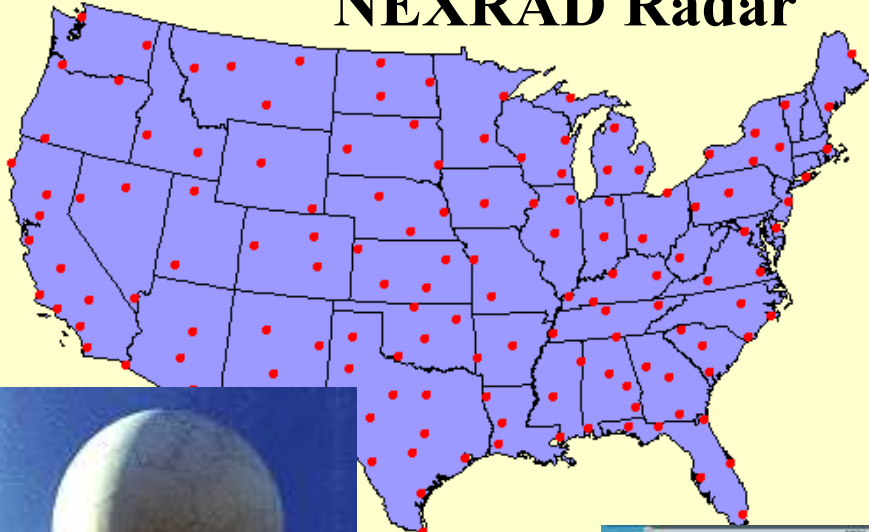

Warren Faidley/Weatherstock®

What **THEY** Do to Us!!!

- Each year in the US, **mesoscale weather** – local floods, tornadoes, hail, strong winds, lightning, and winter storms – causes hundreds of deaths, routinely disrupts transportation and commerce, and results in annual economic losses > $13B.
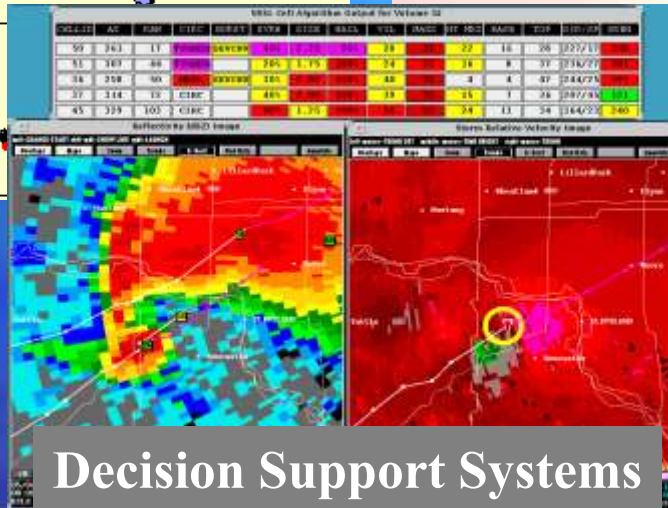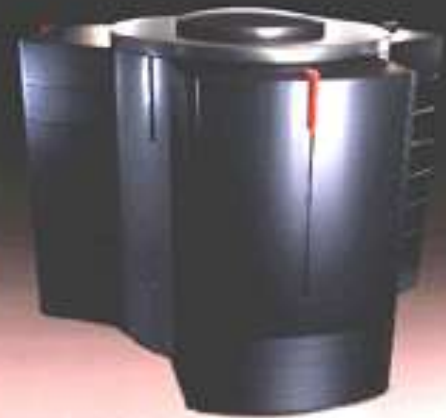
What **Weather Technologies** Do…

NEXRAD Radar

Forecast Models
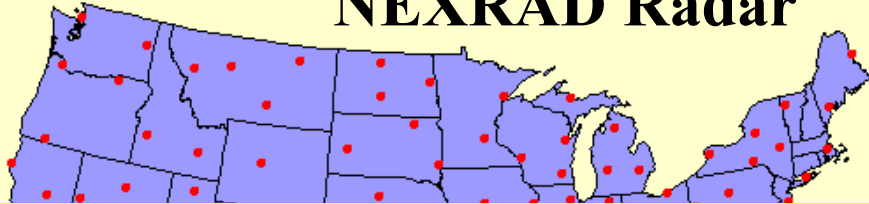
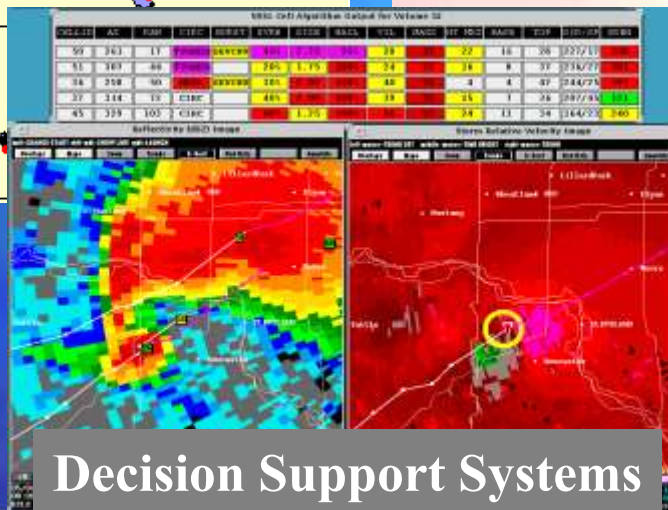Decision Support Systems
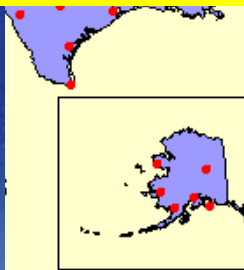
What **Weather Technologies** Do...
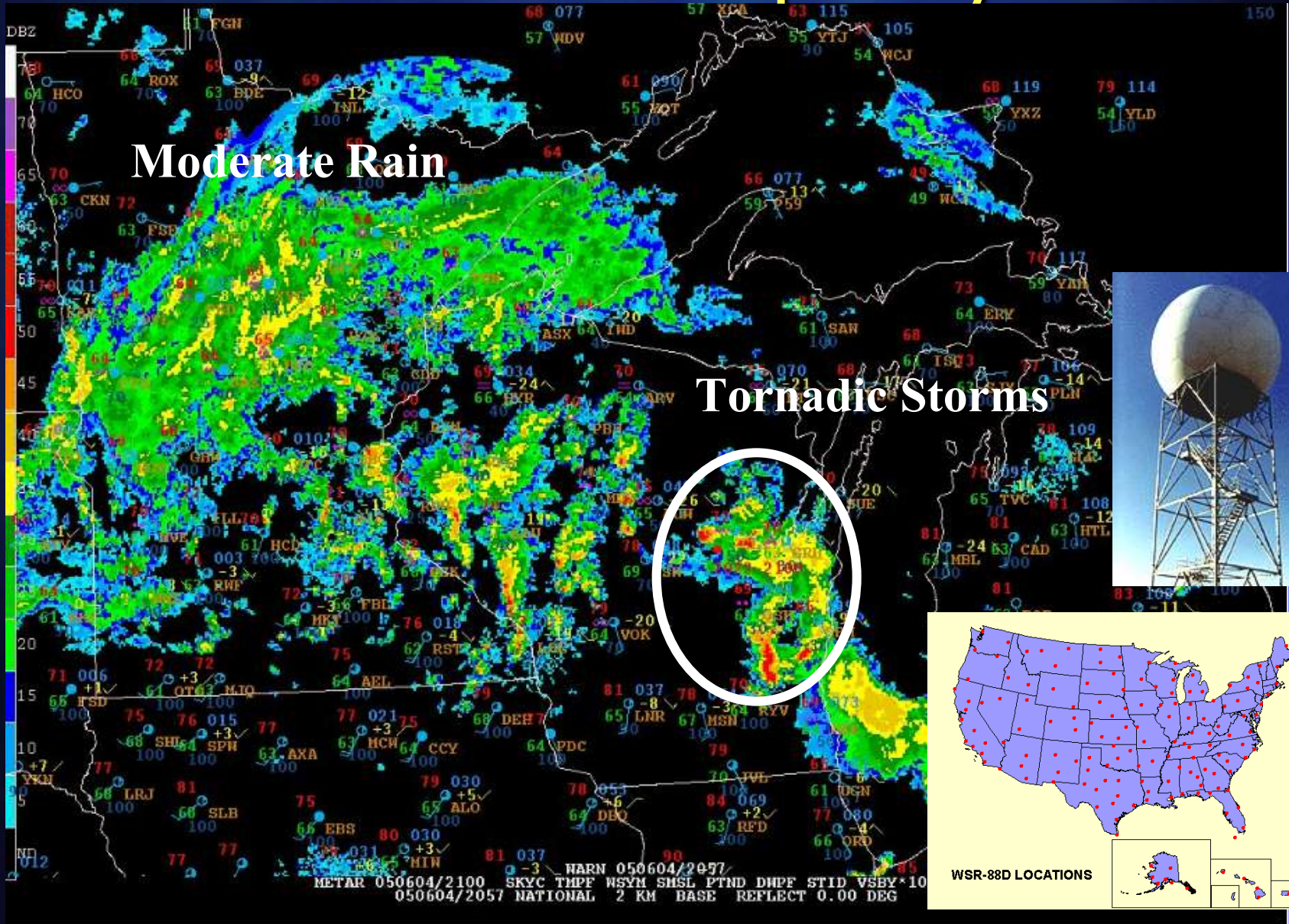
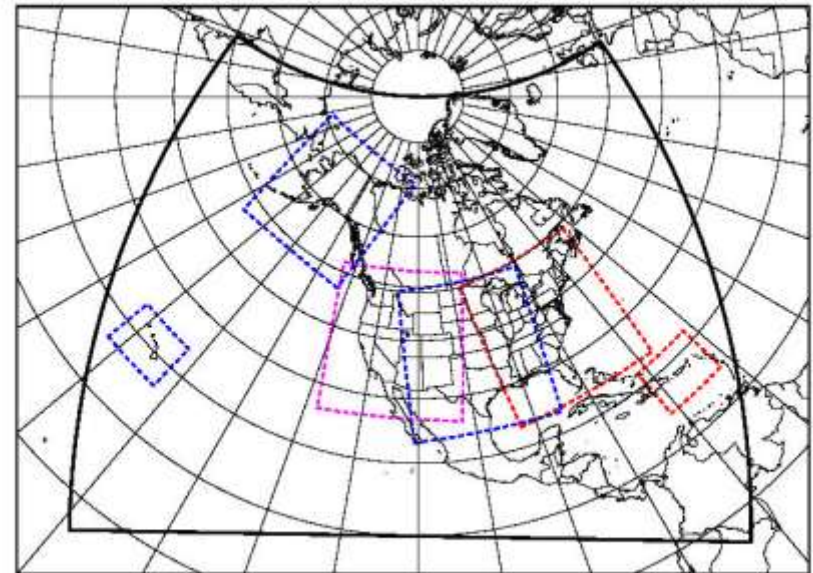**NEXRAD Radar**

Forecast Models

Virtually Nothing!!!

Decision Support Systems
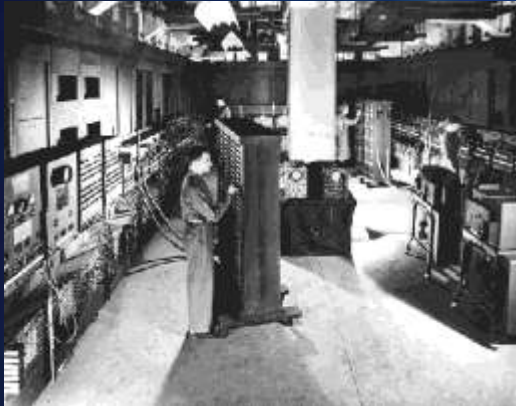
Radars Do Not Adaptively Scan

Moderate Rain

Tornadic Storms

WSR-88D LOCATIONS

Operational Models Run Largely on Fixed Schedules in Fixed Domains
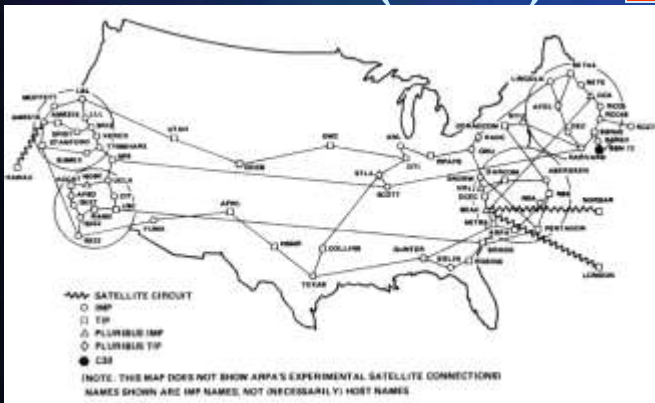

WRF-NMM 8-km HIRESW Domains
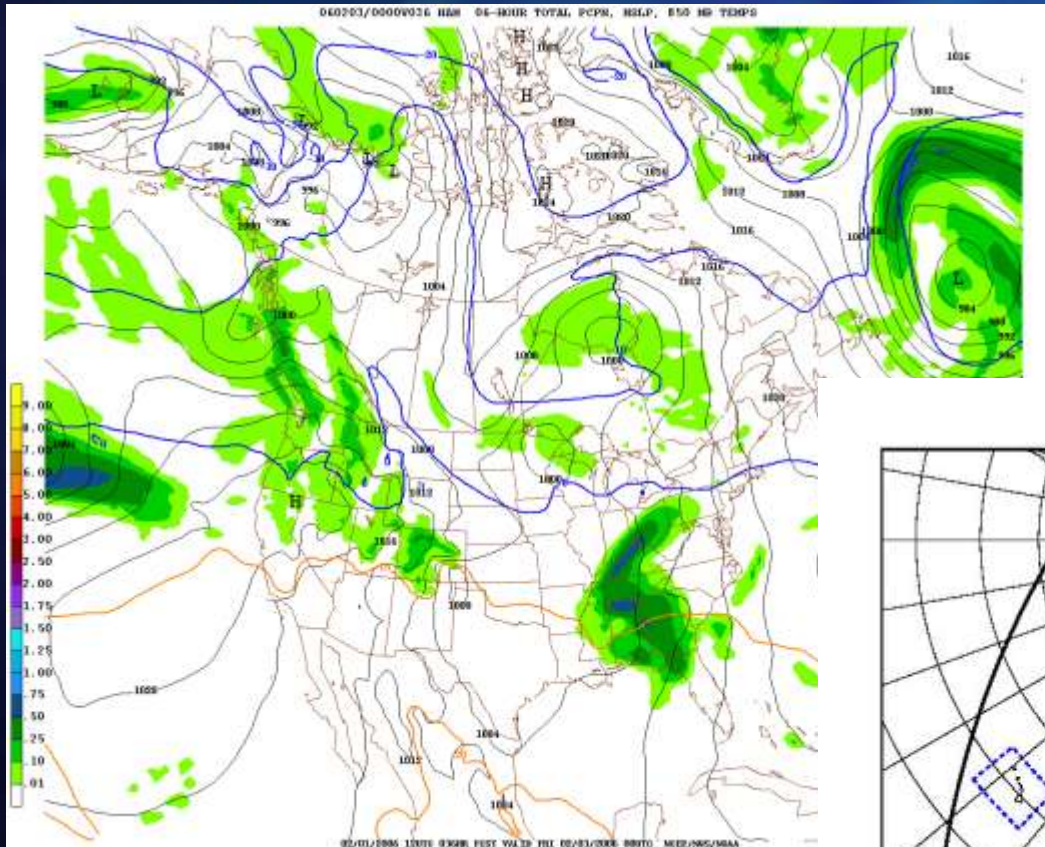
Cyberinfrastructure is Virtually Static

ENIAC (1948)

Earth Simulator (2005)
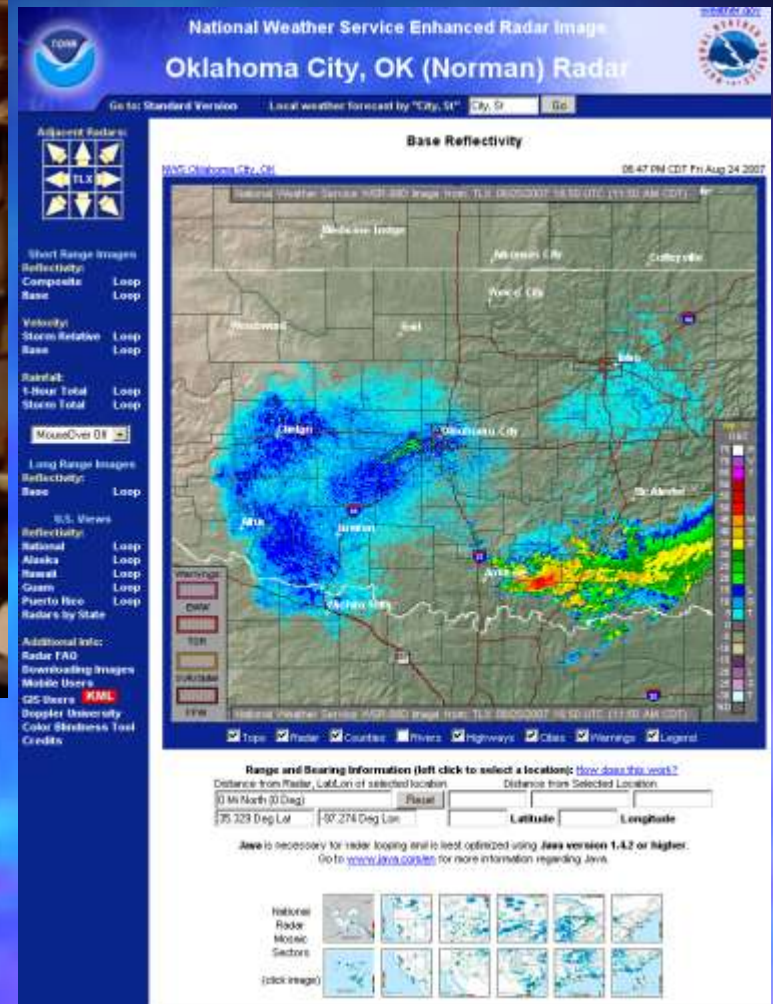

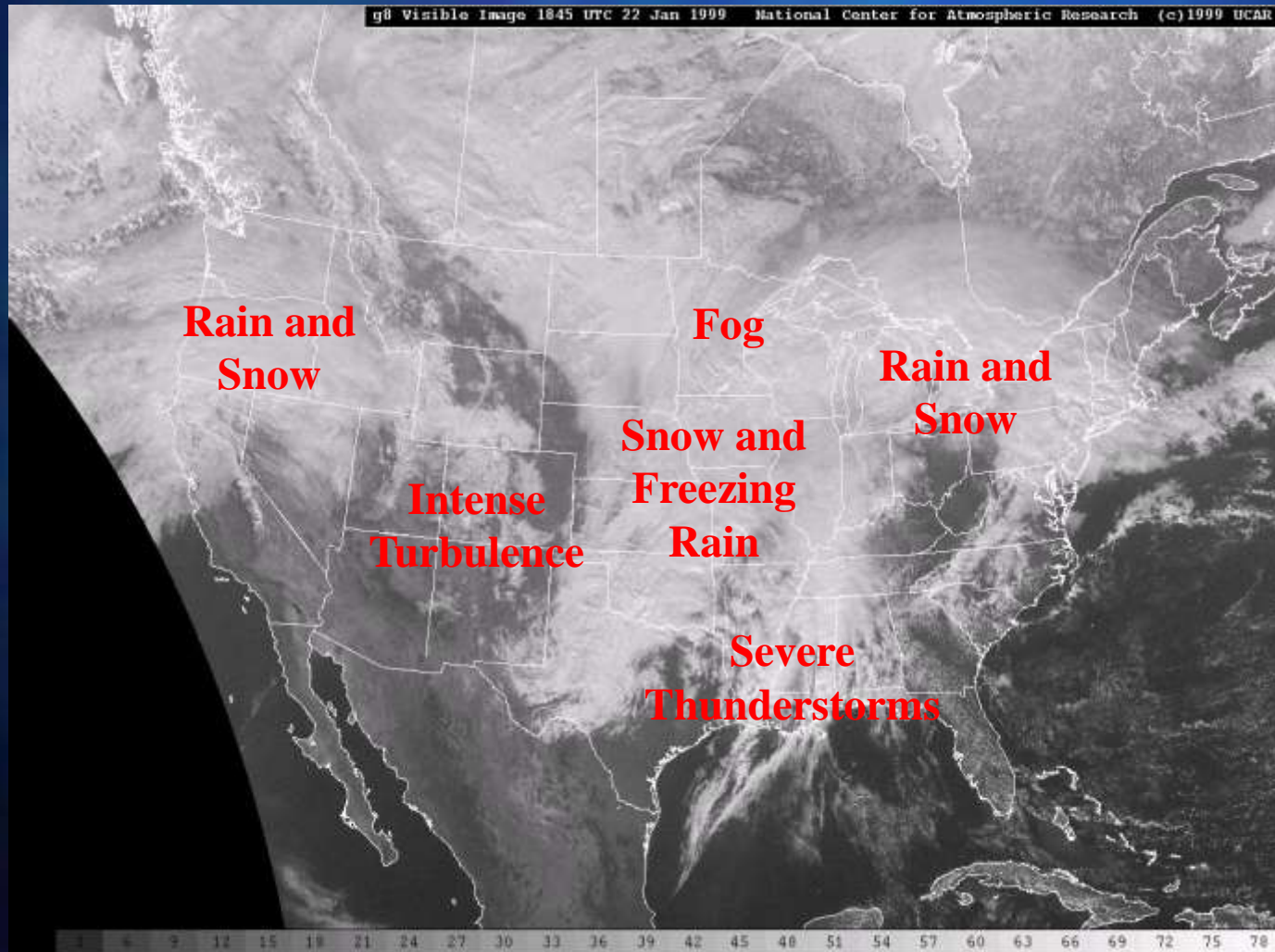**ARPANET (1980)**

National Lambda Rail (2005)

Abilene Backbone (2005)

We Teach Using Current Weather Data But Students Don't <u>Interact</u> With It
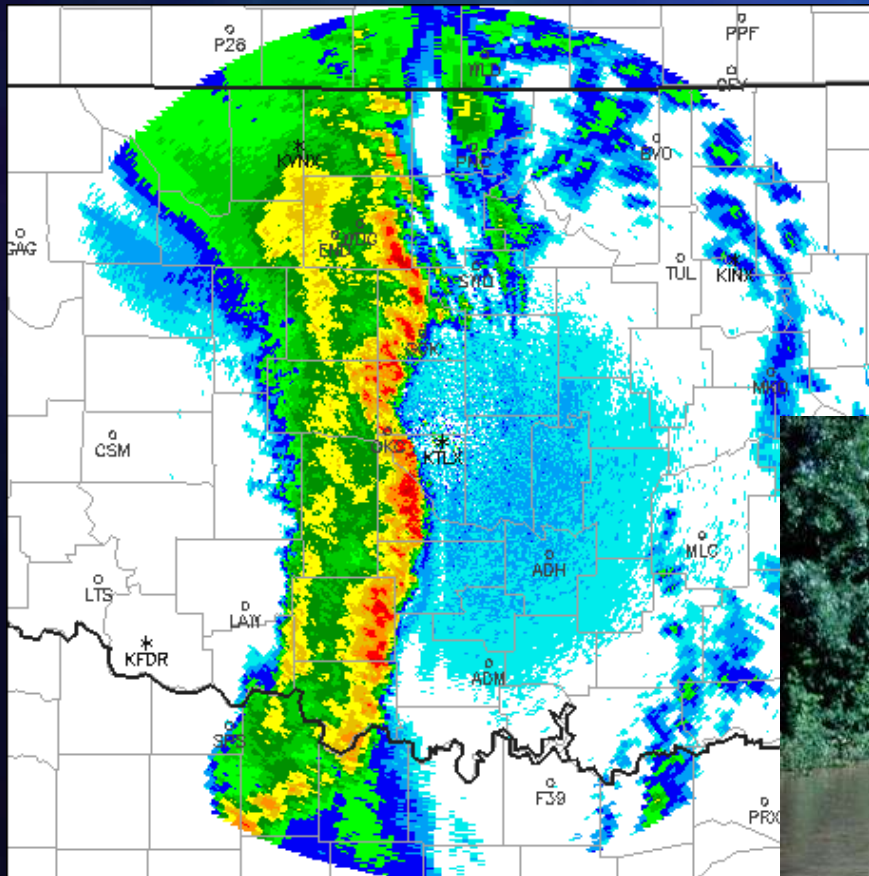
So What??? Weather is Local, High-Impact, Heterogeneous and Rapidly Evolving…Yet Our Technologies and Thinking are **Static**

The Reality for Society: Dynamic, Local and High Impact

A Fundamental Research Question

- Can we better understand the atmosphere, educate more effectively about it, and forecast more accurately if we adapt our technologies and approaches to the weather as it occurs?

- People, even animals adapt/respond: Why don't our resources???

University Corporation for Atmospheric Research

Colorado State University

HOWARD UNIVERSITY

INDIANA UNIVERSITY
Quality Education. Lifetime Opportunities.®

LINKED ENVIRONMENTS FOR ATMOSPHERIC DISCOVERY

O the university of KLAHOMA

UNC CHAPEL HILL

UAH The University of Alabama in Huntsville

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

MILLERSVILLE UNIVERSITY Ville

The LEAD Vision

Revolutionize the ability of scientists, students, and operational practitioners to observe, analyze, predict, understand, and respond to intense local weather by interacting with it dynamically and adaptively in real time

What Does Adaptation Really Mean? What Does it Buy?
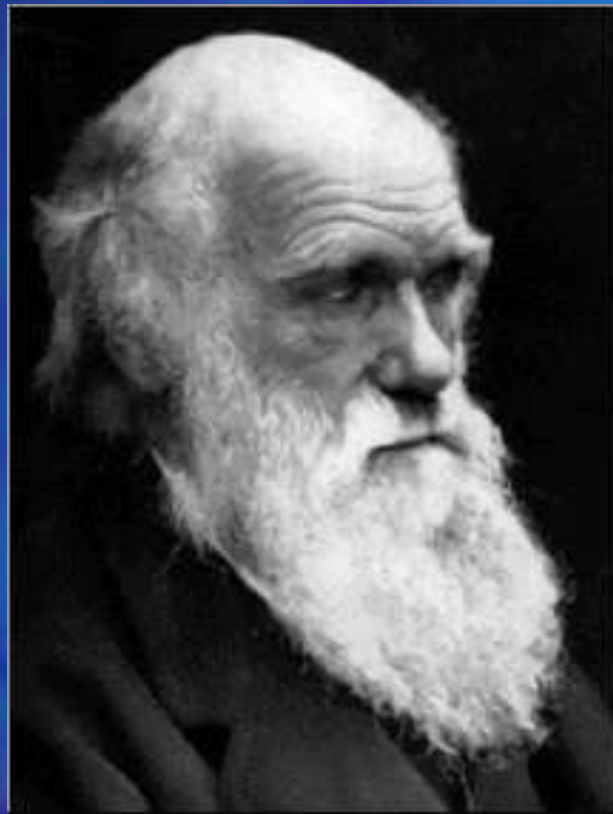
Charles Darwin

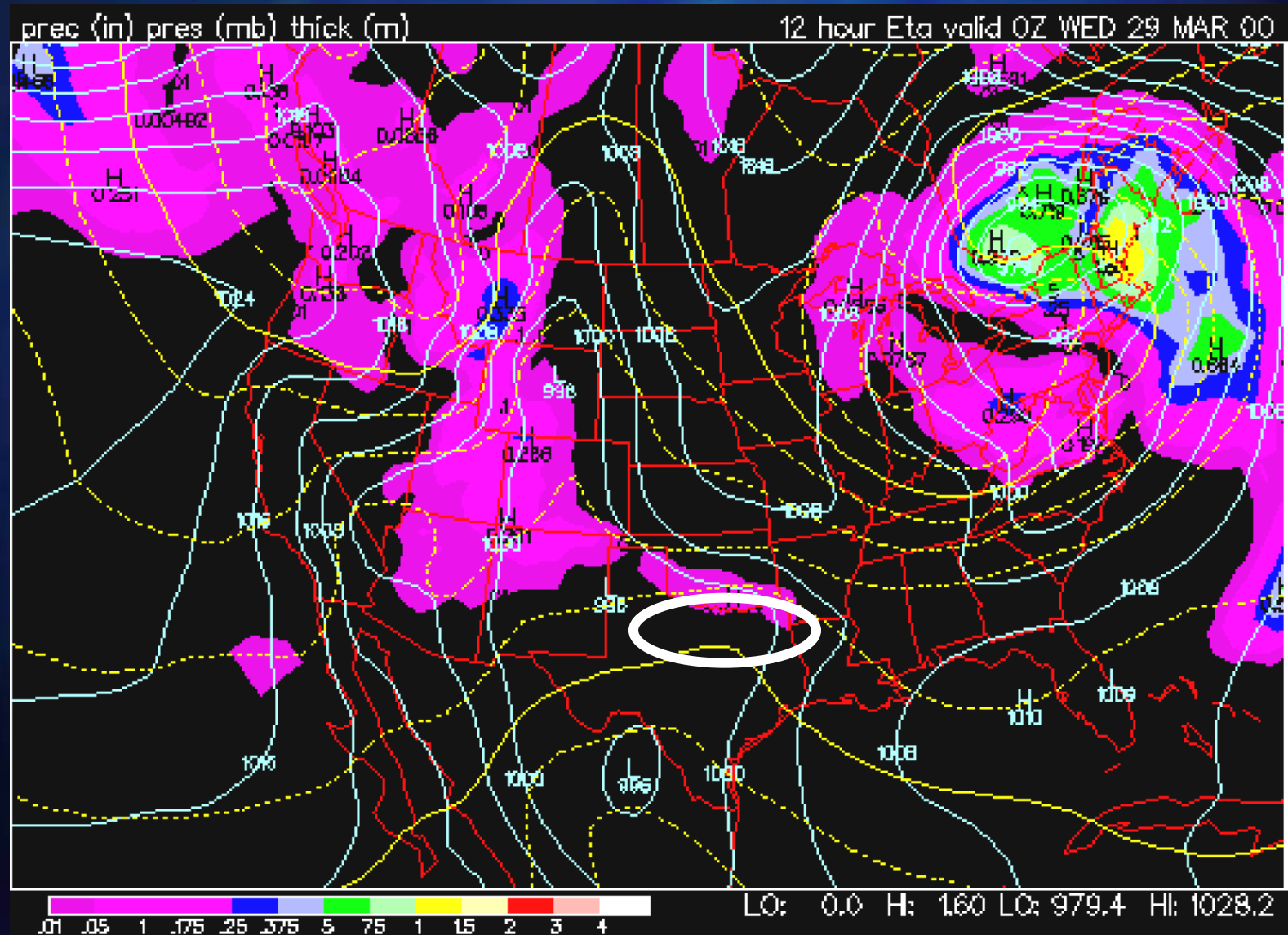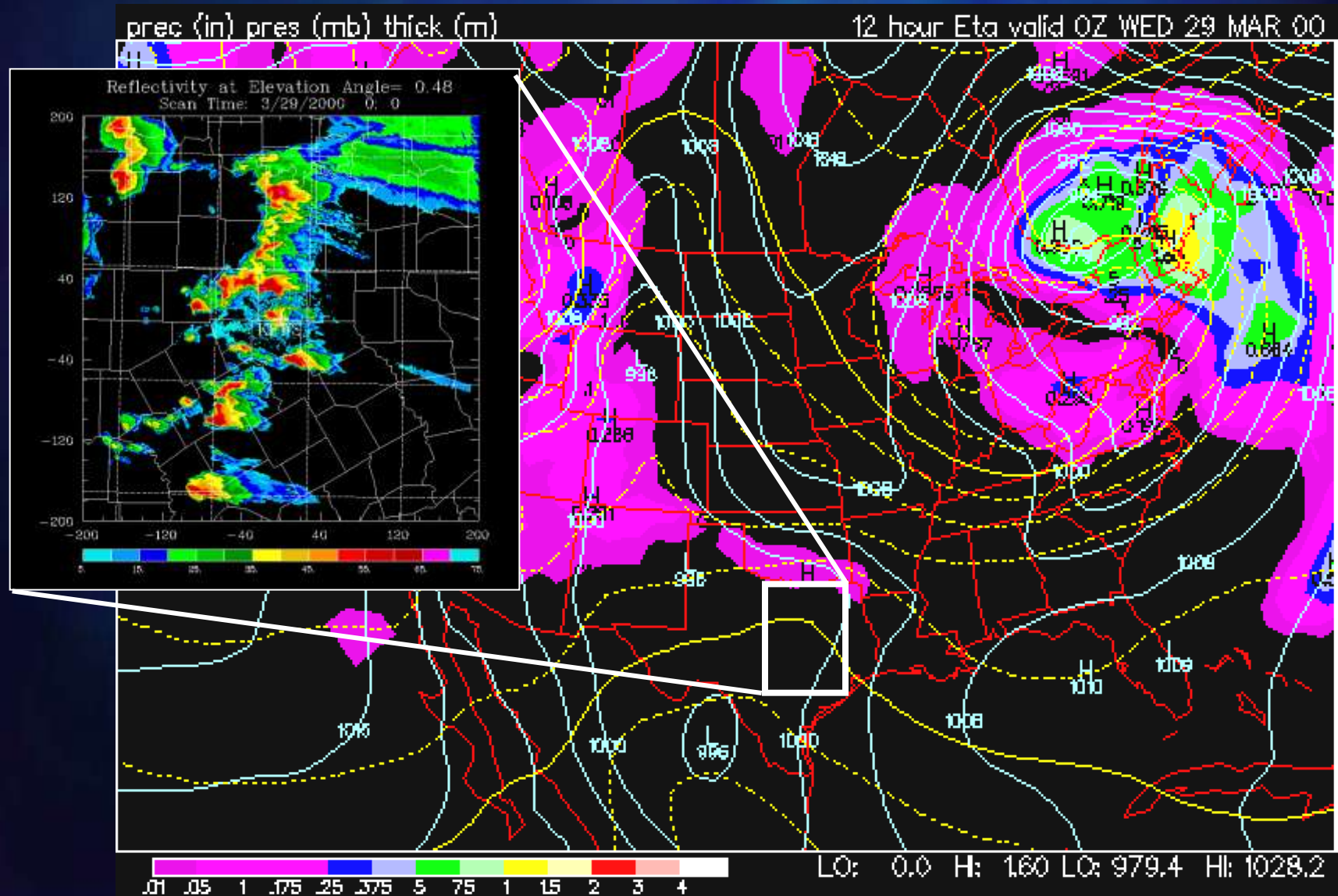# Sample Problem: March 2000 Fort Worth Tornadic Storm

Copyright 2000 Star-Telegram

Local TV Station Radar

NWS **12-hr** Computer Forecast Valid at 6 pm CDT (near tornado time)
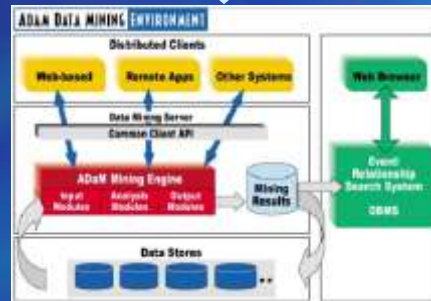# No Explicit Evidence of Precipitation in North Texas

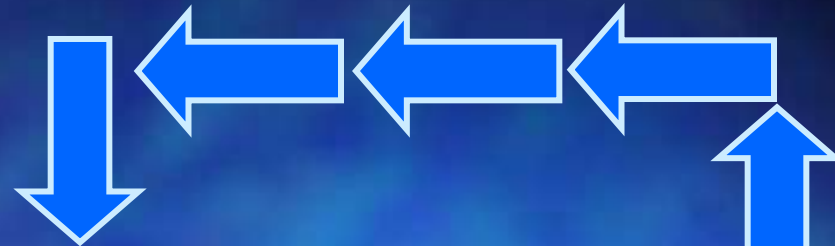prec (in) pres (mb) thick (m)   12 hour Eta valid 0Z WED 29 MAR 00

LO: 0.0   HI: 1.60   LO: 979.4   HI: 1028.2

.01 .05 .1 .175 .25 .375 .5 .75 1 1.5 2 3 4

Reality Was Quite Different!

LEAD Approach
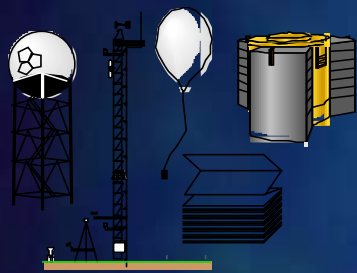
Streaming Observations

Data Mining

Storms Forming or Conditions Favorable

Forecast Model

On-Demand Grid Computing

What Does it Take to Make This Possible?

- Adaptive weather tools
- Adaptive sensors
- Adaptive cyberinfrastructure

In a User-Centered Framework Where Everything Can Mutually Interact

LINKED ENVIRONMENTS FOR ATMOSPHERIC DISCOVERY

How Does LEAD Do It?
The Notion of a Web Service
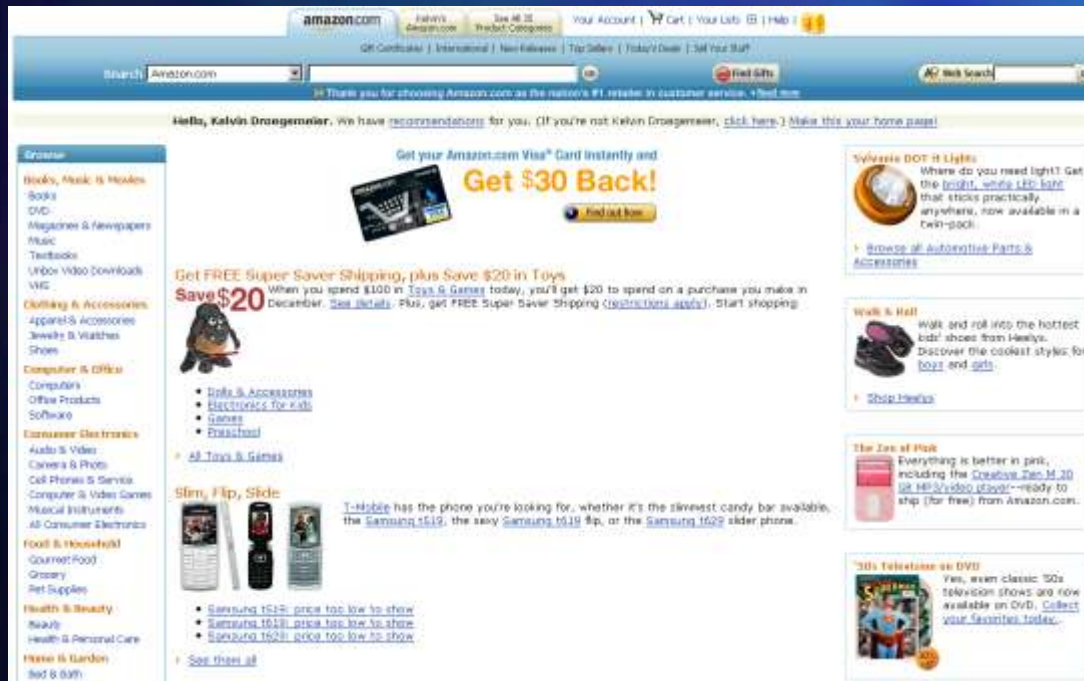
- Web Service: A program that carries out a specific set of operations based upon requests from clients

- The LEAD architecture is a "Service Oriented Architecture" (SOA), which means that all of the key functions are represented as a set of services.

Service-Oriented Architecture

Service A (Analysis)	**Service B** (Model)	**Service C** (Radar Stream)
Service D (Work Space)	**Service E** (VO Catalog)	**Service F** (Viz Engine)
Service G (Monitoring)	**Service H** (Scheduling)	**Service I** (Decoder)
Service J (Repository)	**Service K** (Mining)	**Service L** (Decoder)
	Many others…	

Can Solve Broad Classes of Problems by Linking Services Together in <u>Workflows</u>

Service D
(Work Space)

Service C
(Radar Stream)

Service L
(Decoder)

Service A
(Analysis)

Service B
(Model)

Service K
(Mining)

Service J
(Repository)
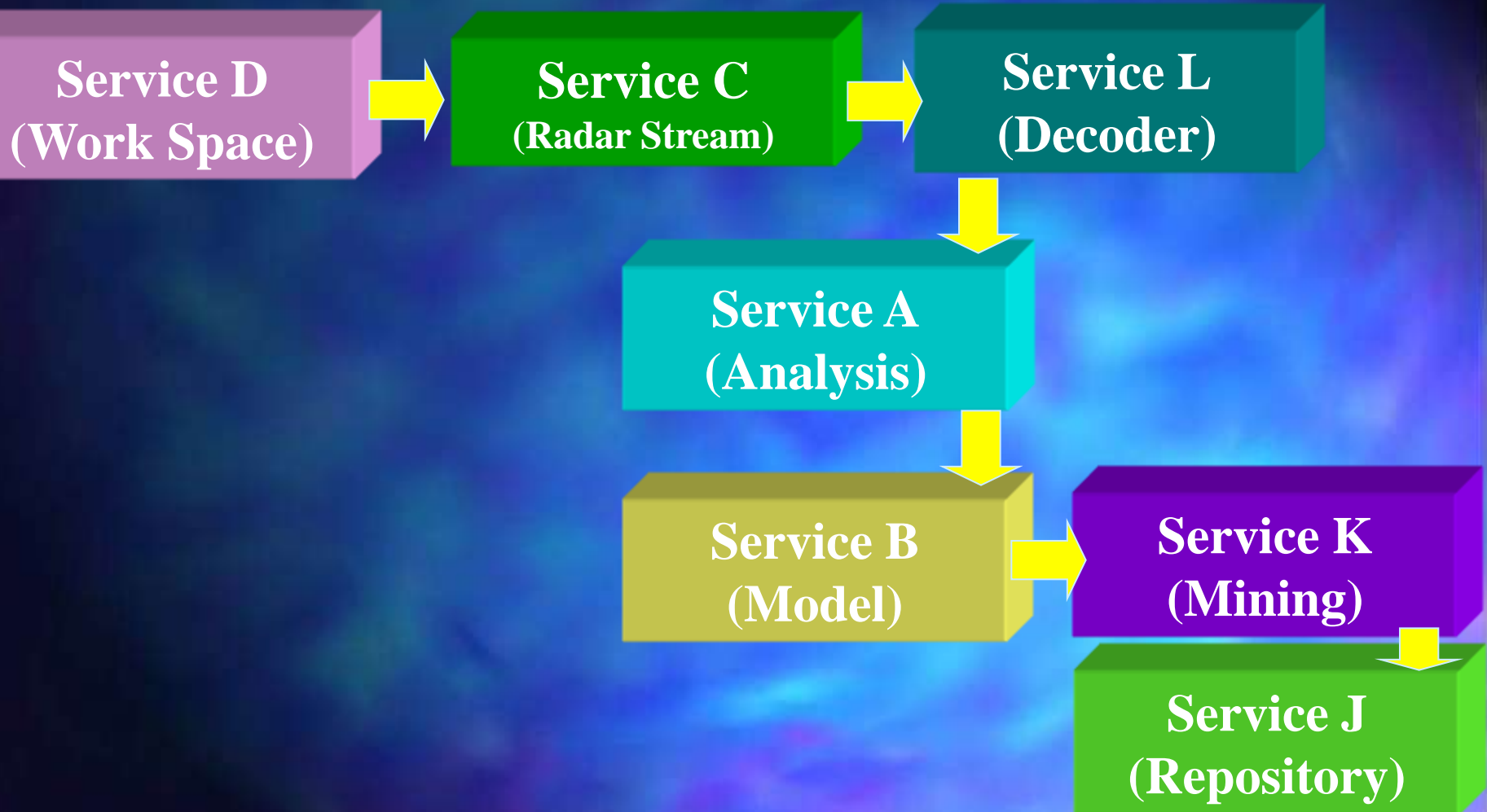
A LEAD Weather Prediction Workflow

Back to the Earlier Example...

Radar

6 pm

7 pm

8 pm
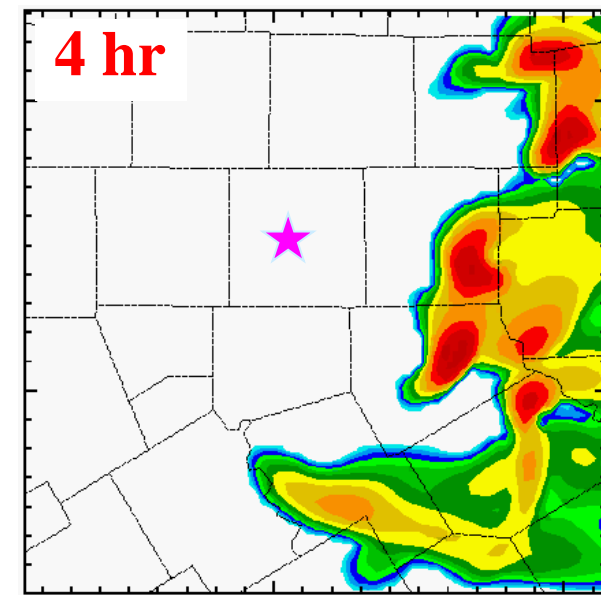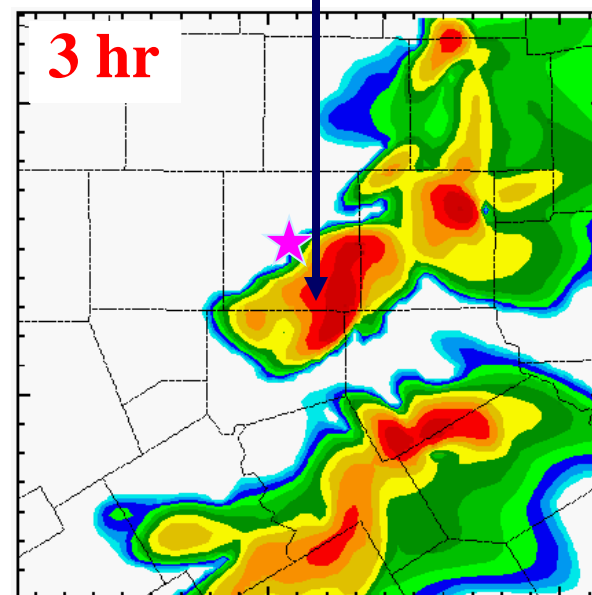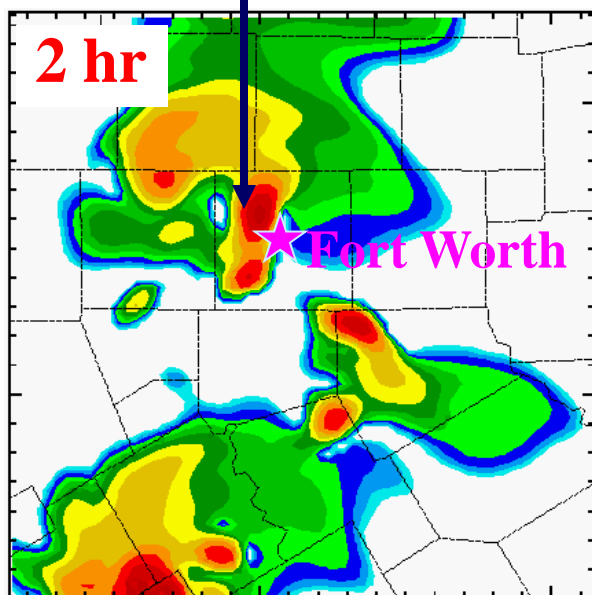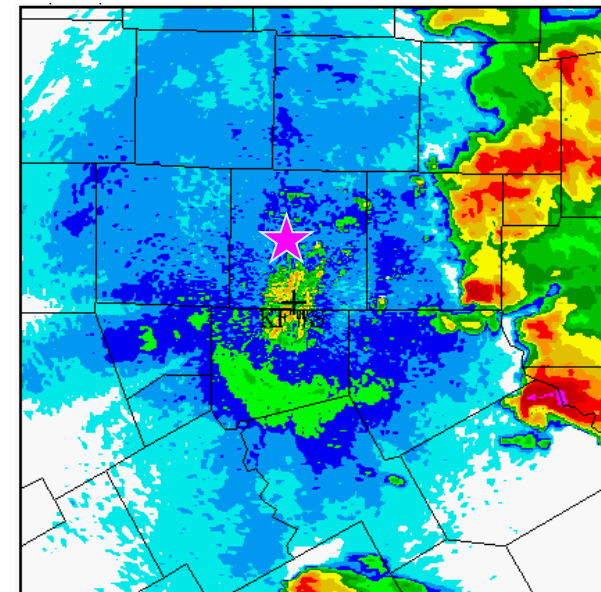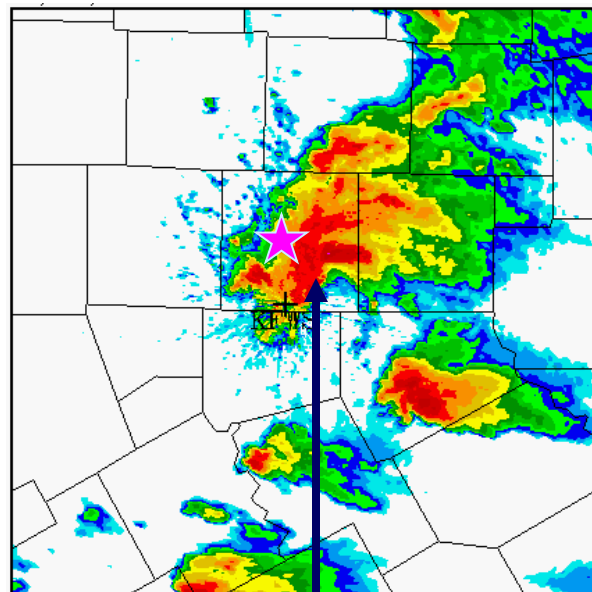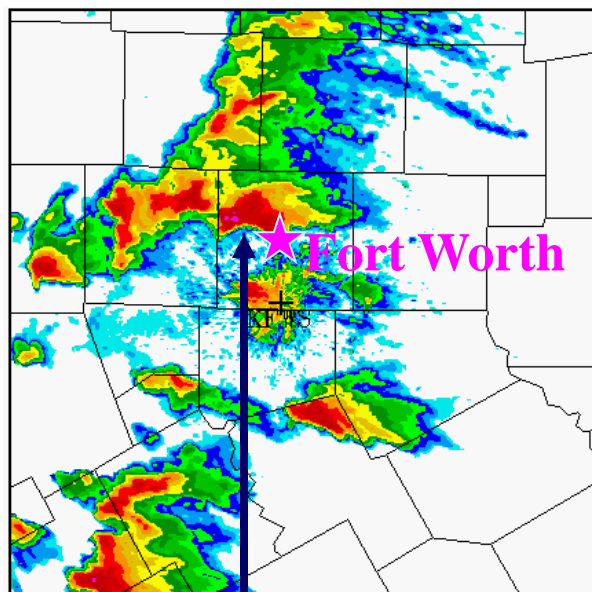
Fort Worth

Xue et al. (2003)

6 pm **7 pm** **8 pm**

Radar

Fort Worth

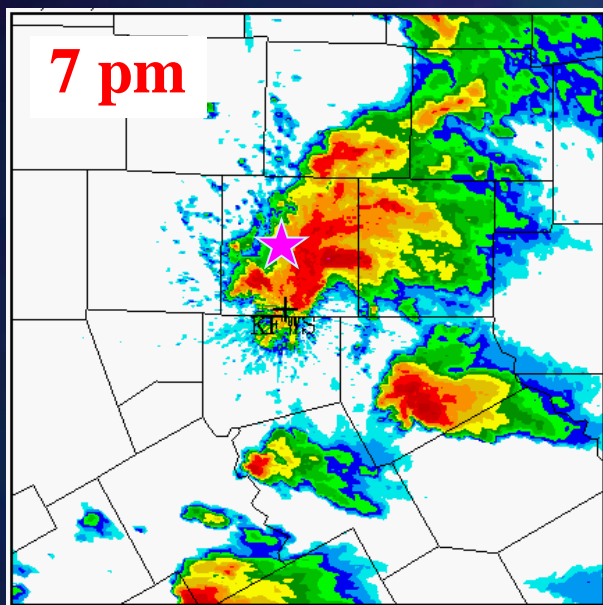**Fcst With Radar Data**

2 hr Fort Worth

3 hr

4 hr
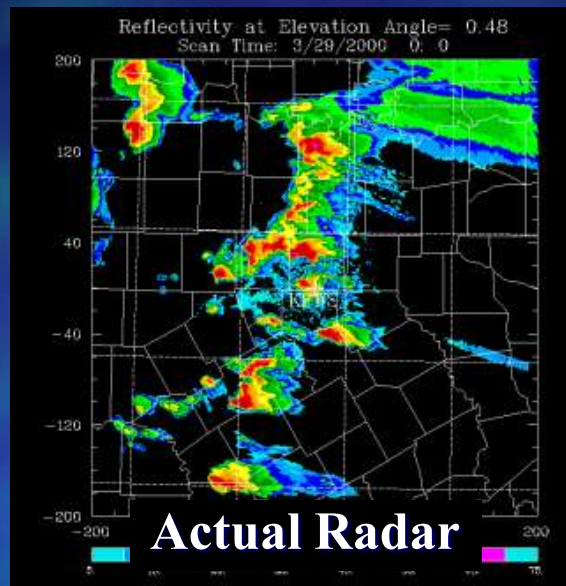
Xue et al. (2003)

7 pm

As a Forecaster Worried About This Reality...

7 pm

3 hr
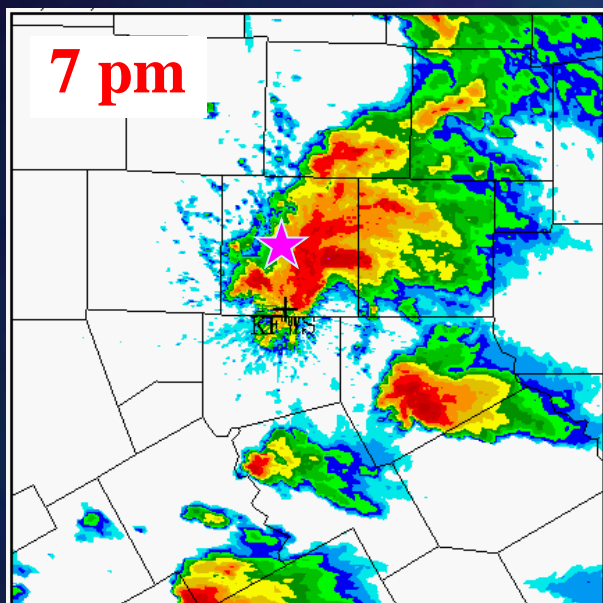
As a Forecaster Worried About This Reality...
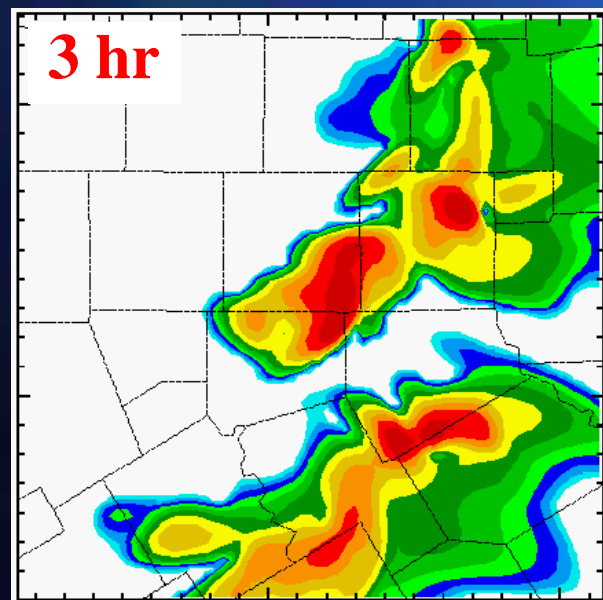
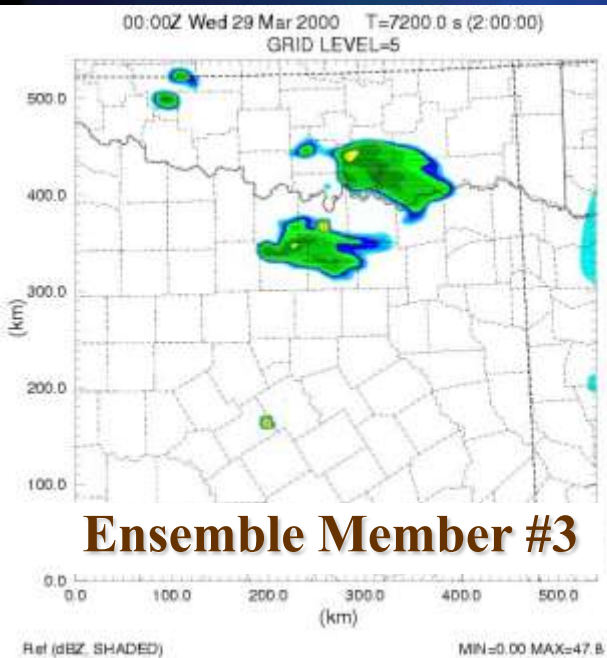How Much Trust Would You Place in This Model Forecast?

Reflectivity at Elevation Angle= 0.48
Scan Time: 3/29/2000 0: 0

Actual Radar

Ensemble Member #1

Actual Radar

Ensemble Member #2

Ensemble Member #3

Control Forecast

Ensemble Member #4
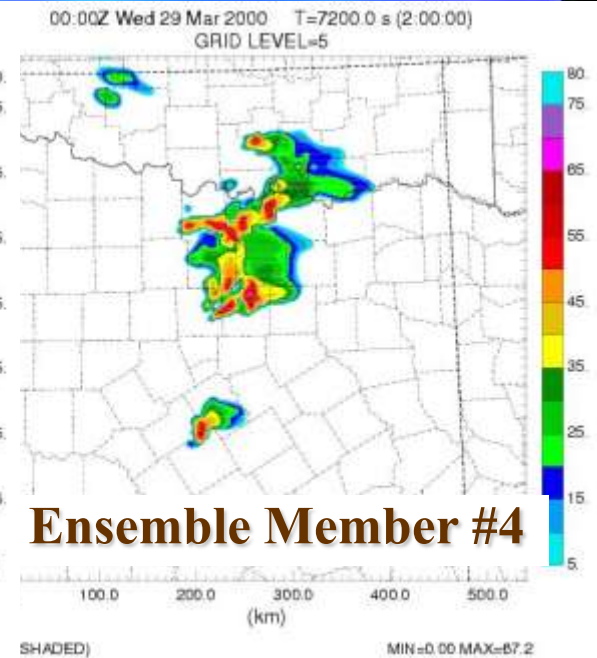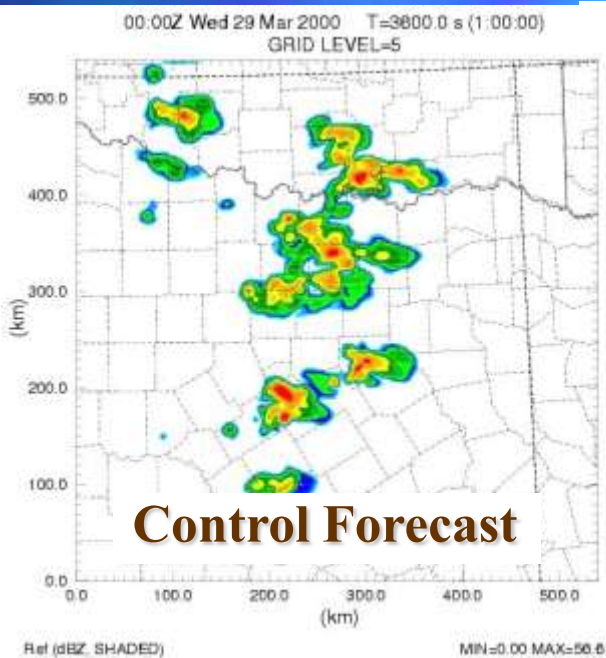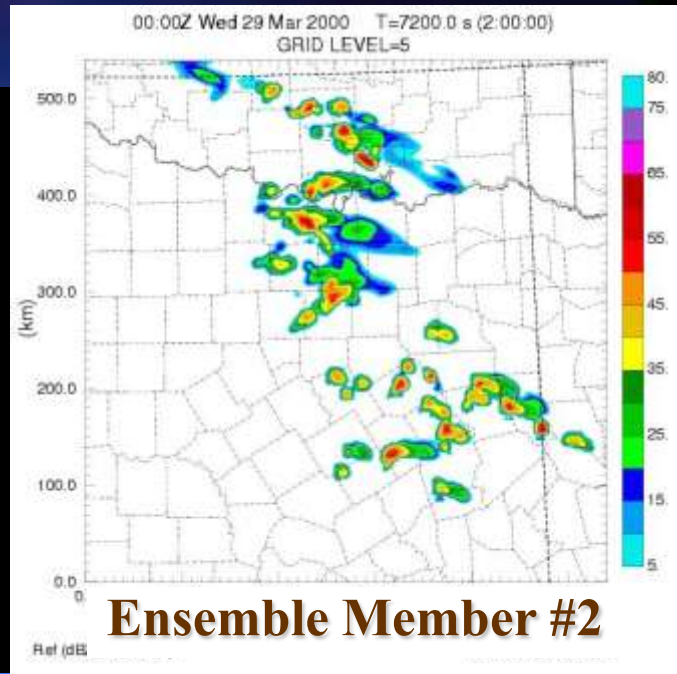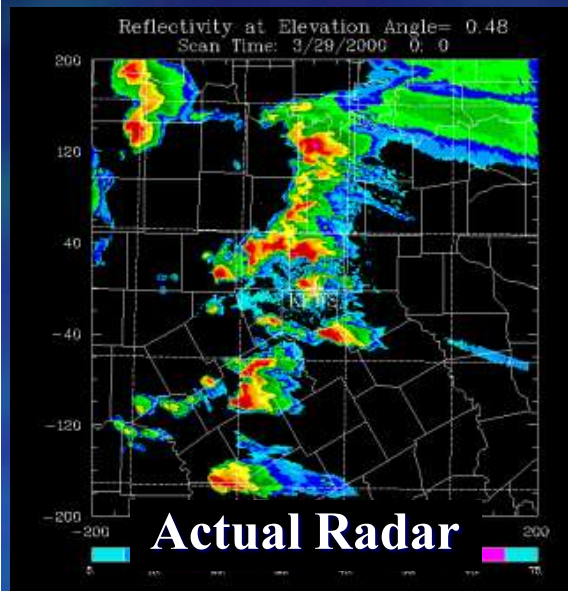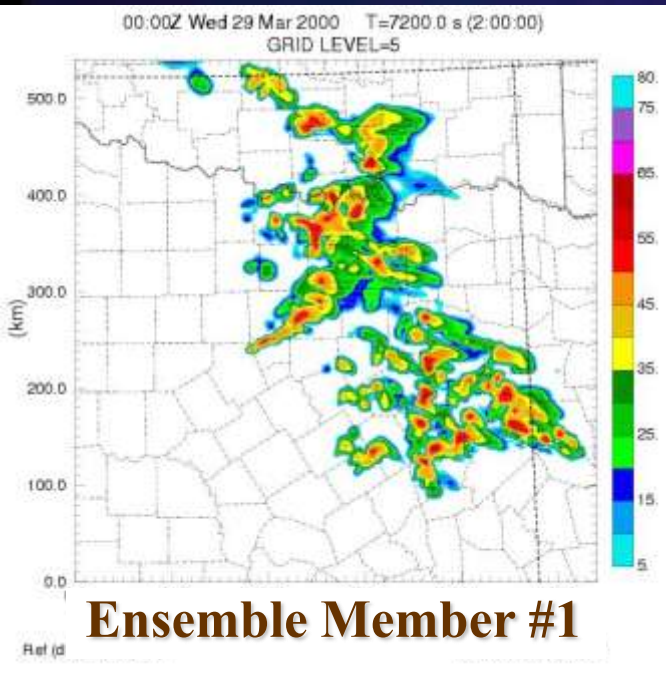
Probability of Intense Precipitation
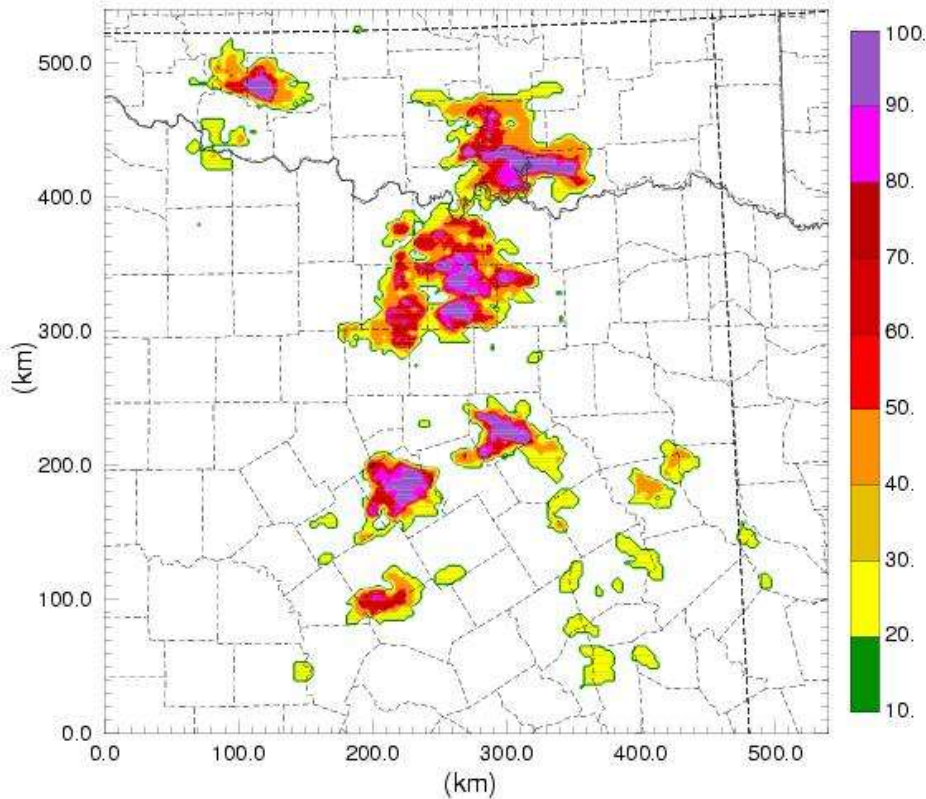
Model Forecast
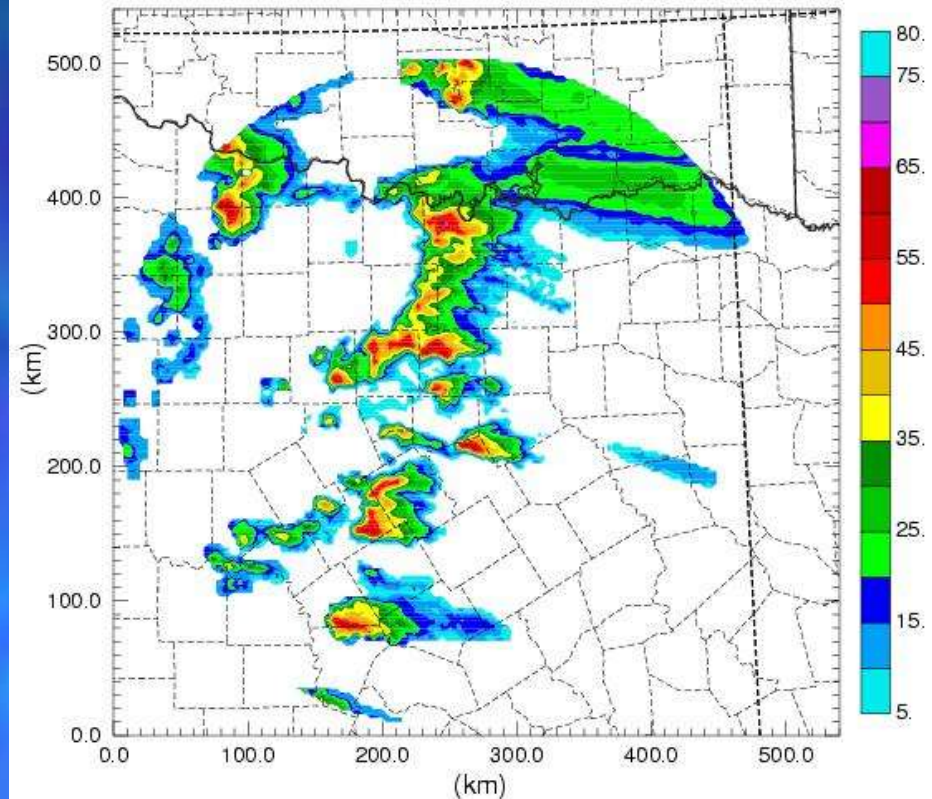
Radar Observations

Adaptive Observing Systems: Current Operational Radar System in US
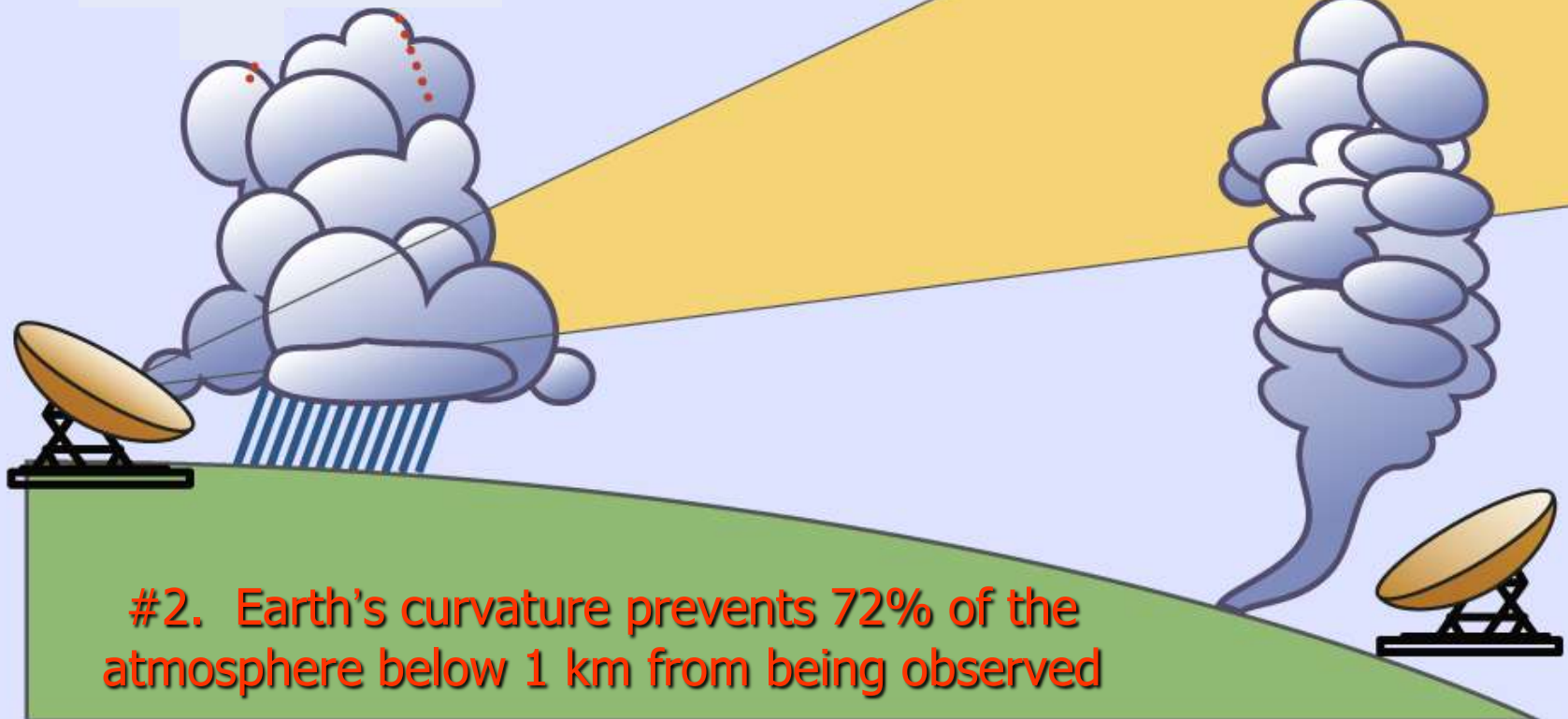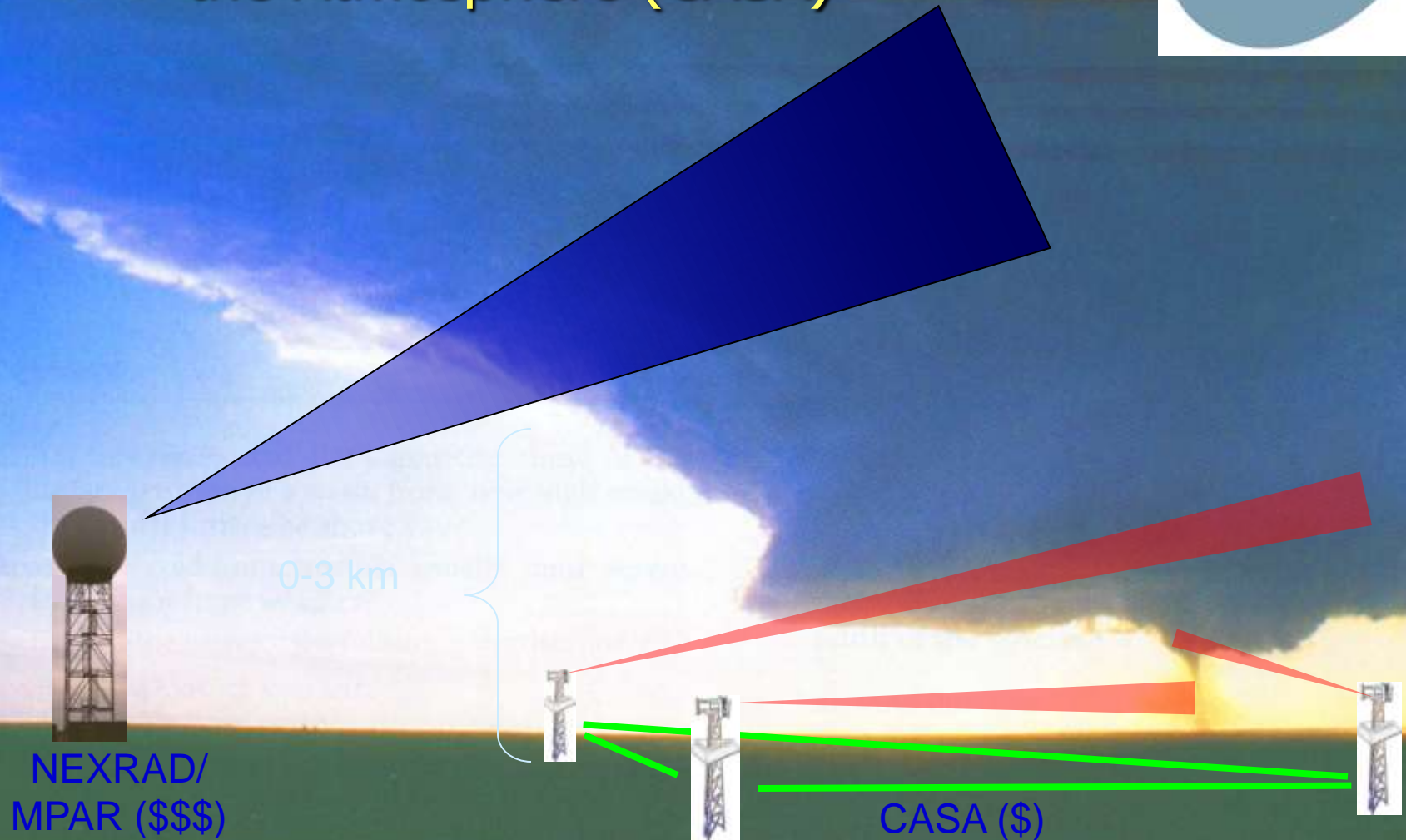

NEXRAD Doppler Radar Network
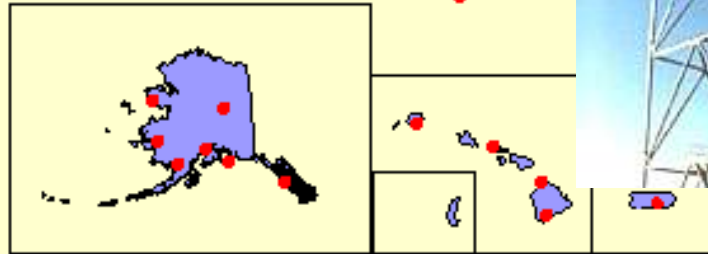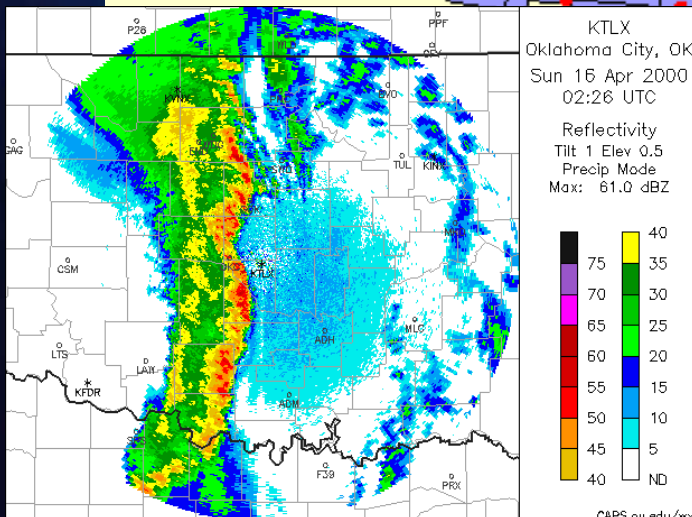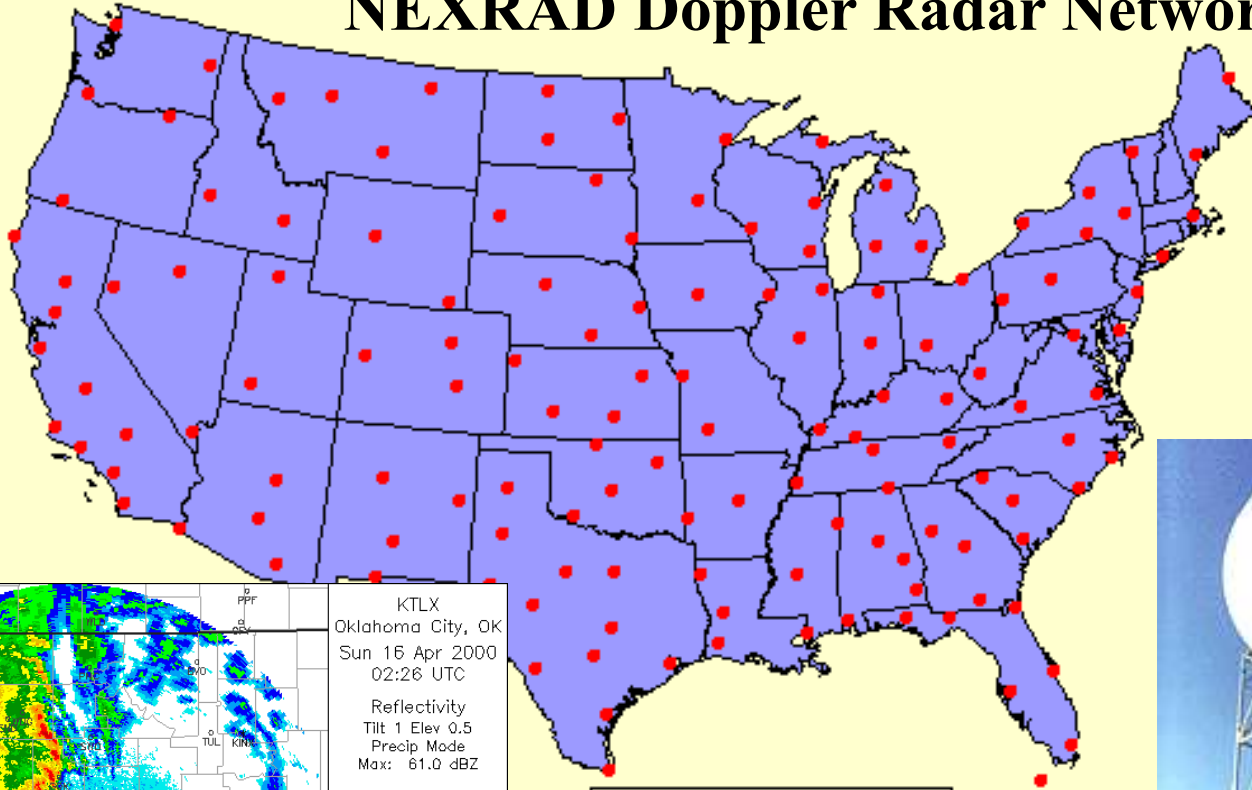
The Limitations of NEXRAD

#1. Operates largely independent
of the prevailing weather conditions

#3. Operates entirely independent from
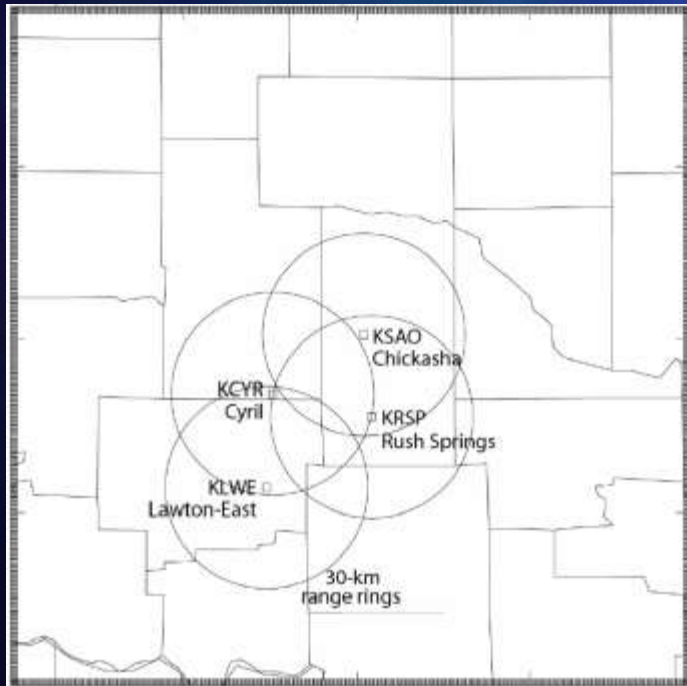the models and algorithms that use its data

#2. Earth's curvature prevents 72% of the
atmosphere below 1 km from being observed

NSF Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA)

0-3 km

NEXRAD/
MPAR ($$$)

CASA ($)

Oklahoma Test Bed

Example of Adaptive Sampling

sim415 Reflectivity 10.00 [2006 04/15 09:11:15 UTC]
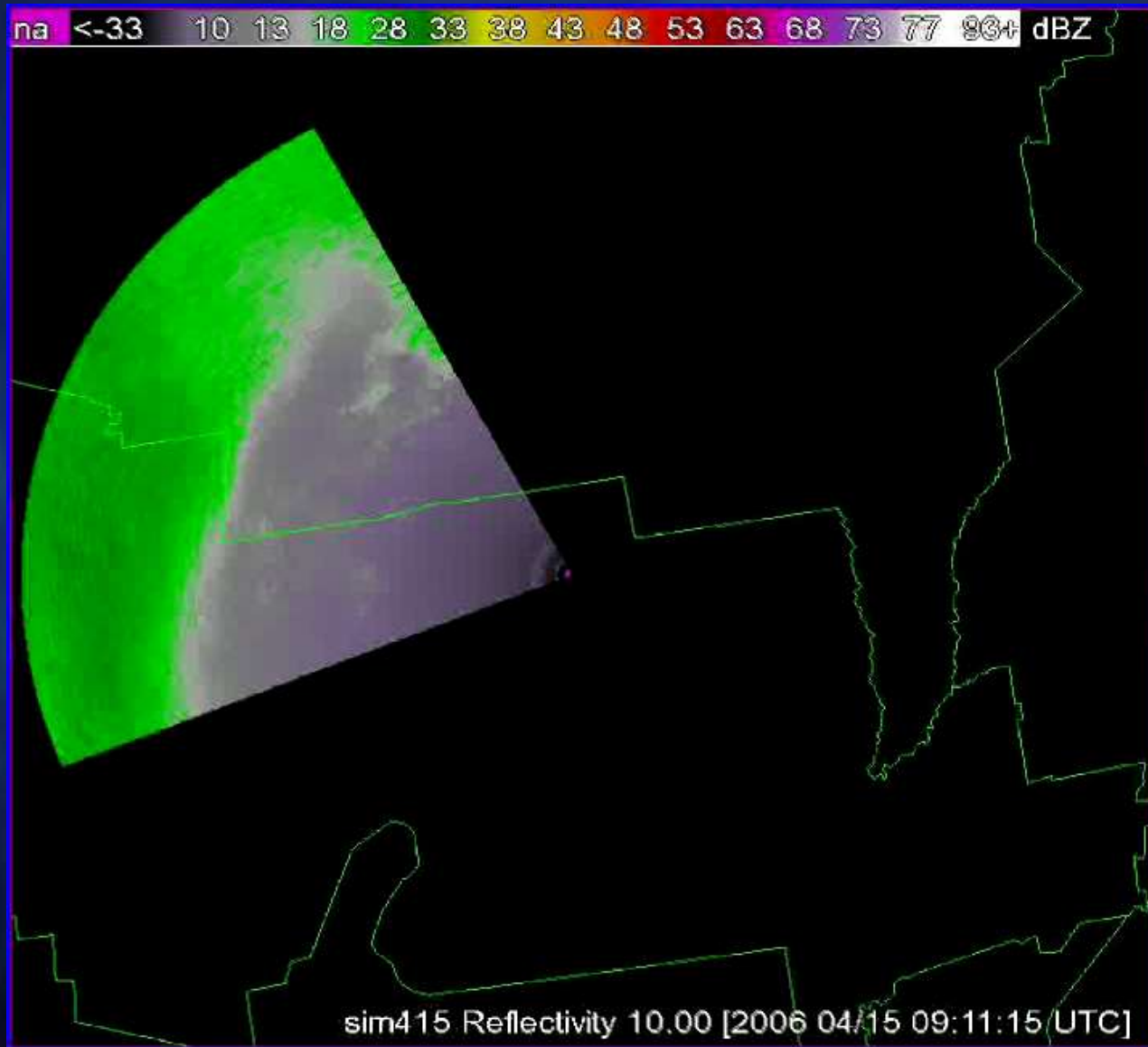
Experimental (CASA) — NWS Operational (NEXRAD)

CASA MergedReflectivityComposite 00.00 [2007 04/10 23:20:46 UTC]

KFDR Reflectivity 00.50 [2007 04/10 23:19:46 UTC]
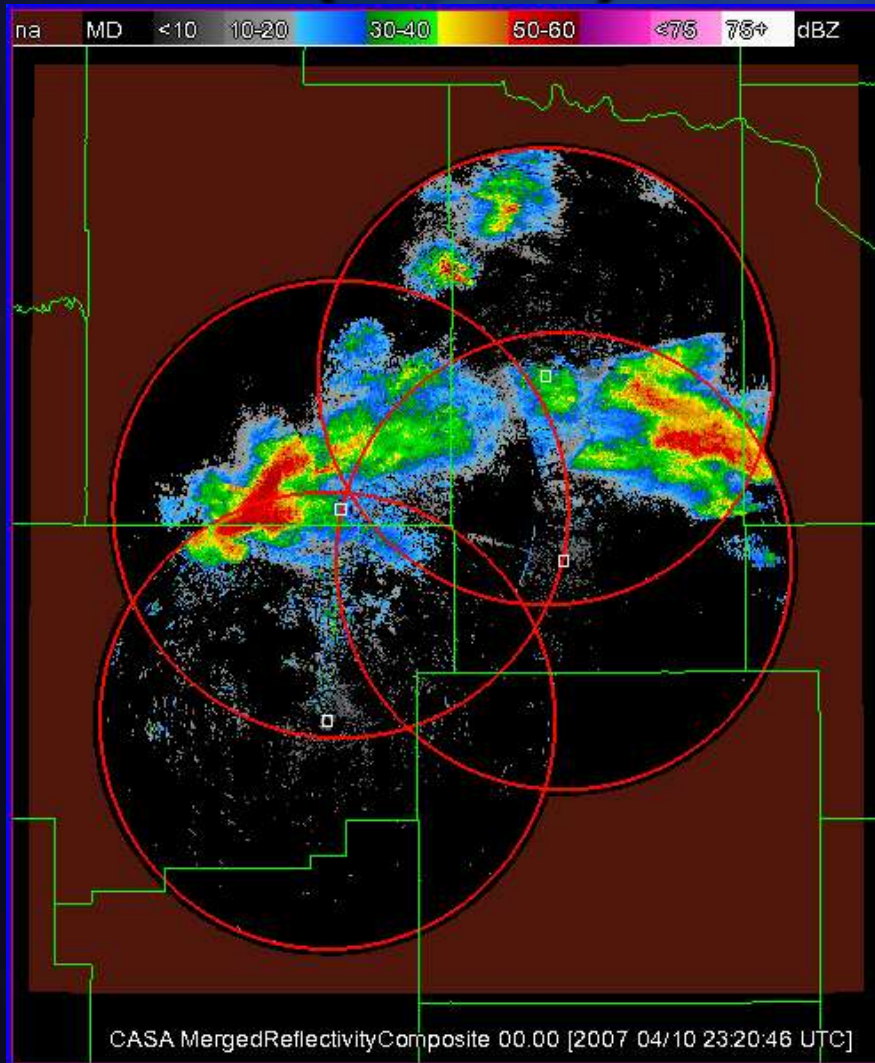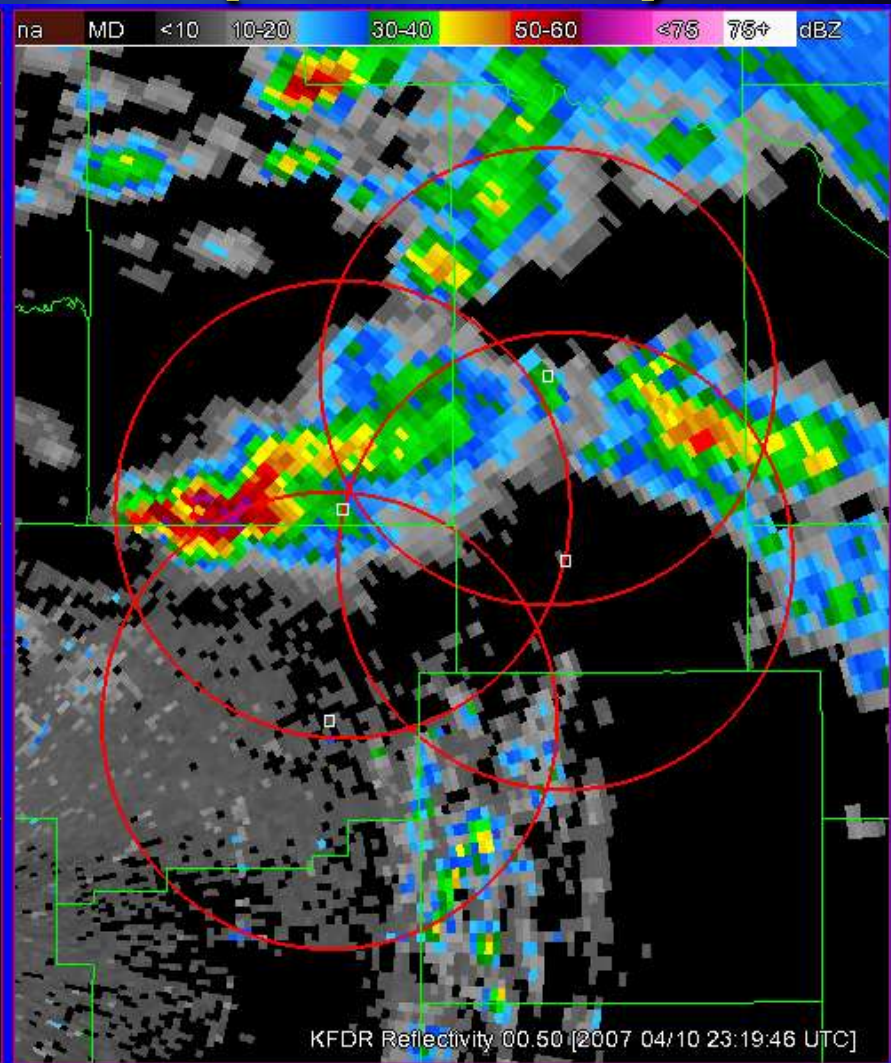
LEAD: Potential to Transform Meteorological Research And Education