# NOAA Profiler Network

## *Benefits and Plans*

Briefing for Jack Kelly

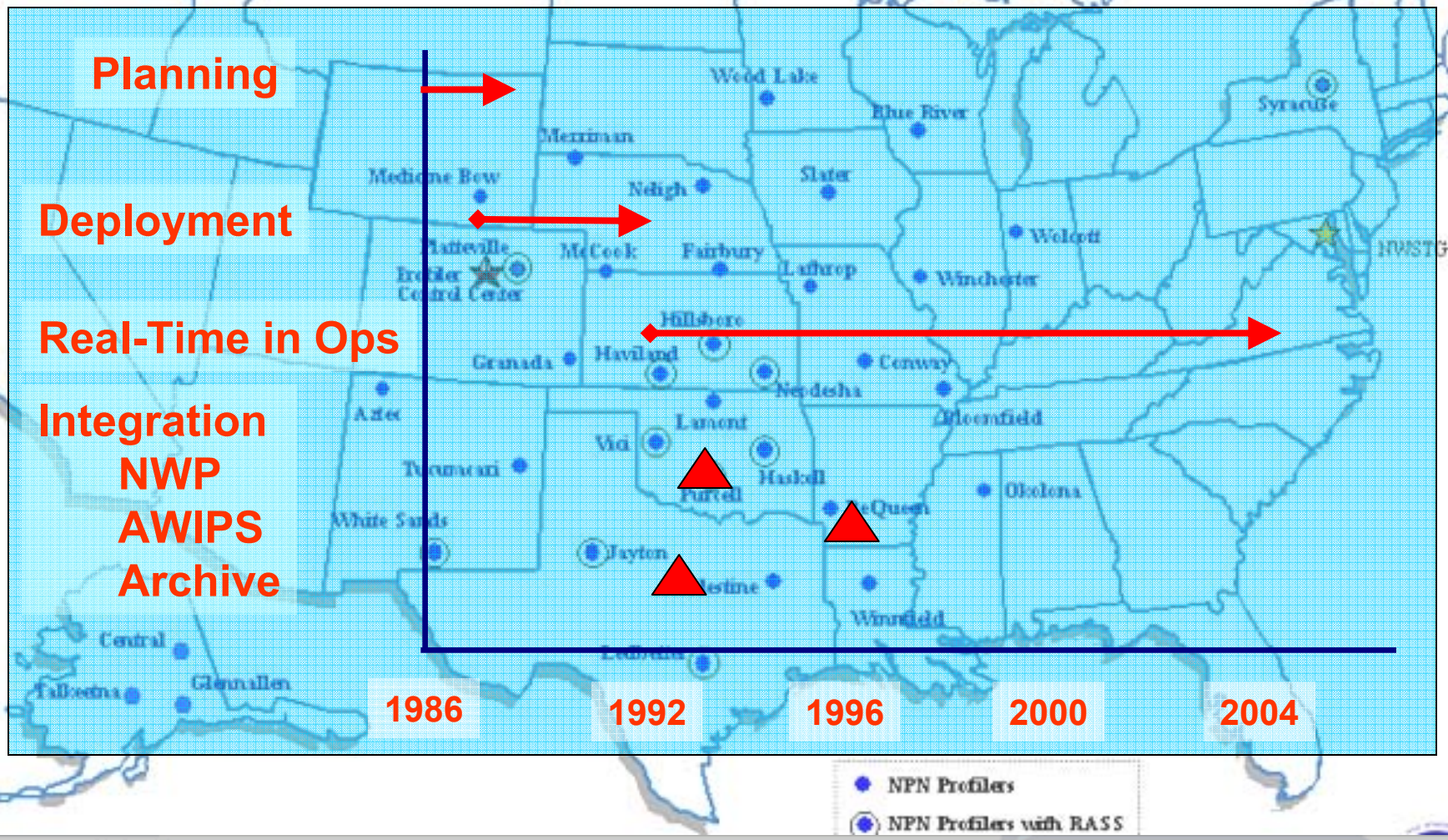
Jack Hayes
May 17, 2004

# Outline

- Background
- Benefits
- COEA
- Assessment
- National Network
- Roadmap

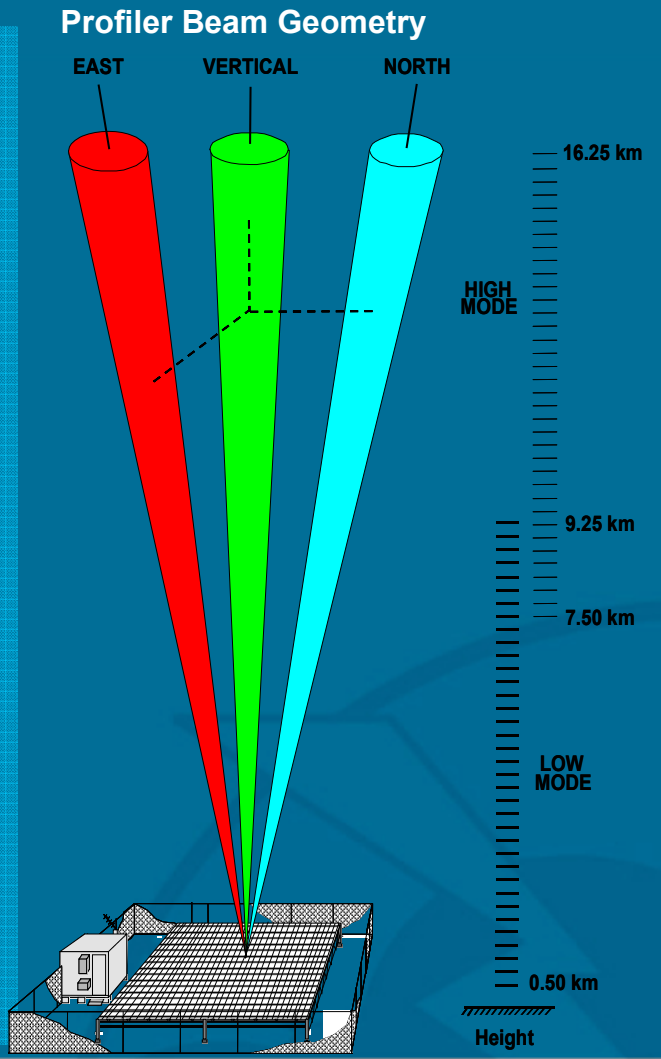
# Background
## *History*

**NPN Winds Used in Routine Operations for 10+ Years**



# Background
## *System Description*

- 35 NPN sites in central U.S., Alaska, and New York, providing:
  - *Wind profiles at 64 vertical levels through 16 km every 6 minutes*
  - *Water vapor measurements*
  - *Surface observations*
  - *Temperature soundings up to 4 km at 11 sites*
- 3,066,000 wind profiles per year



# Background
## *Funding*

## Capital Investments:

- $36 M to develop and deploy
- $13 M for additional instrumentation
  - Cooperative Agency Profilers, GPS Integrated Precipitable Water, and Radiometric Acoustic Sounding System (RASS - temperature soundings)

- $13.2 M will be needed in FY06-08 for frequency upgrade

## Annual Funding: $4.1M

| | |
|---|---|
| –NPN Ops: | $2.4M |
| –Sust. Engineering: | $0.8M |
| –CAP: | $0.3M |
| –GPS IPW: | $0.6M |

RASS Sensor

Moisture Sensor

CAP Low Altitude Winds

NPN Hub Quality Control

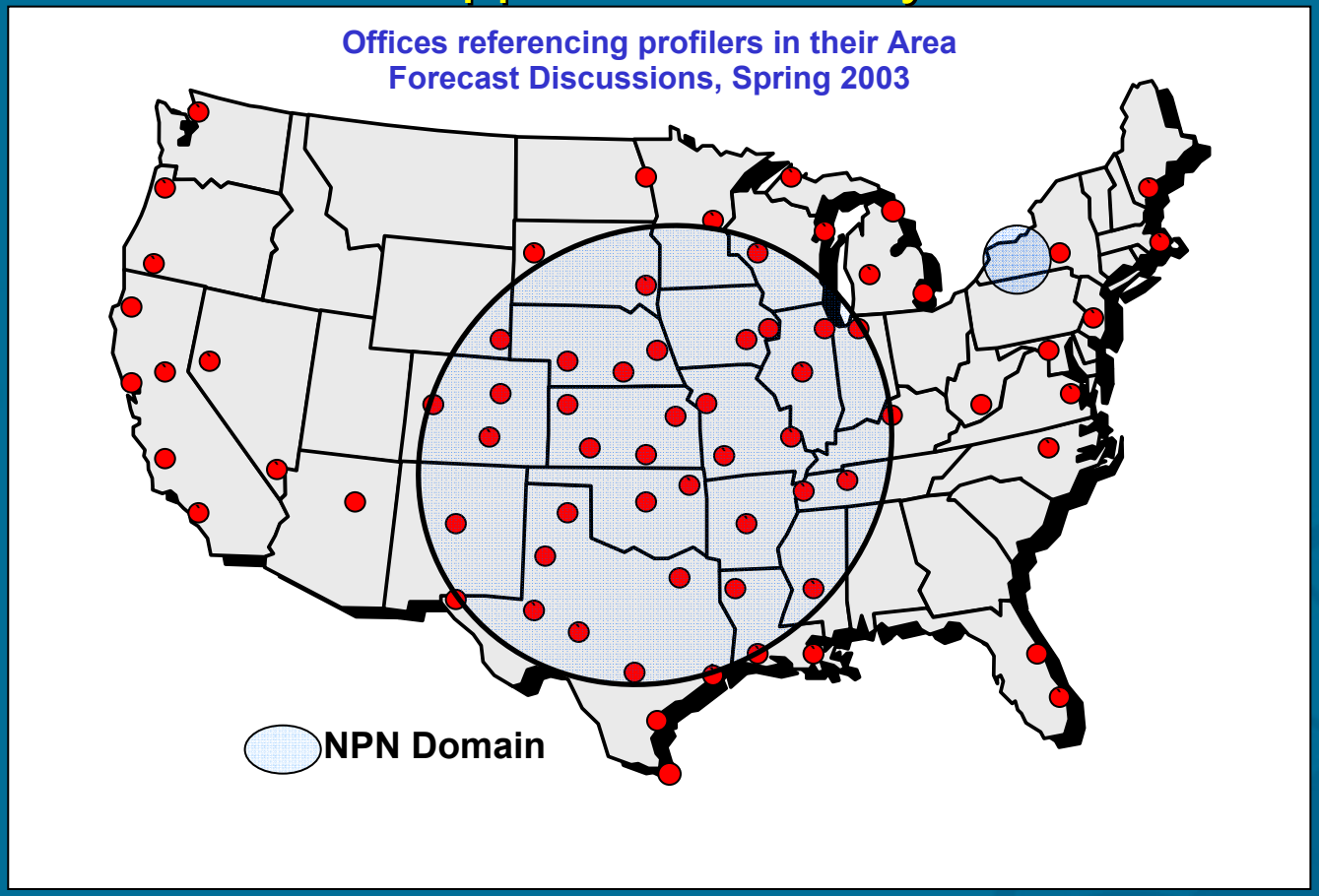
# Benefits

## *Questions Addressed*

- How are NPN winds used in operations?
- What are benefits of NPN wind observations?
- Is NPN a cost-effective solution?

# Benefits
## *Use in Operations*

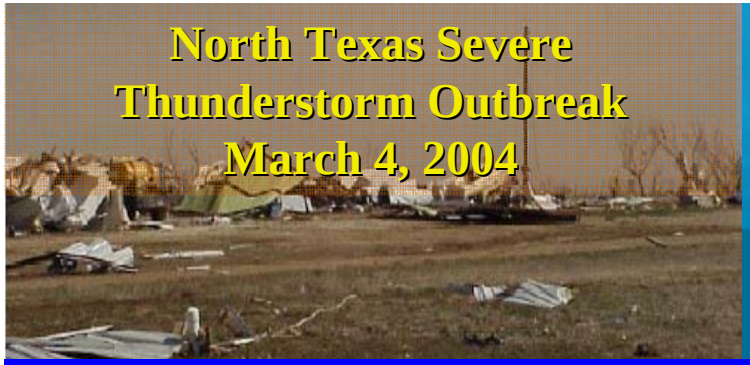
Wind Profiler observations used by at least 70 Weather Forecast Offices in support of a variety of missions



# Benefits
## *Forecasts and Warnings*

- High space- and time-resolution NPN wind measurements improve *warnings*, *watches*, and *numerical forecasts*:
  - *Warnings:* *Statistical improvements in POD, FAR, and Lead Time performance for tornadoes and flash floods*

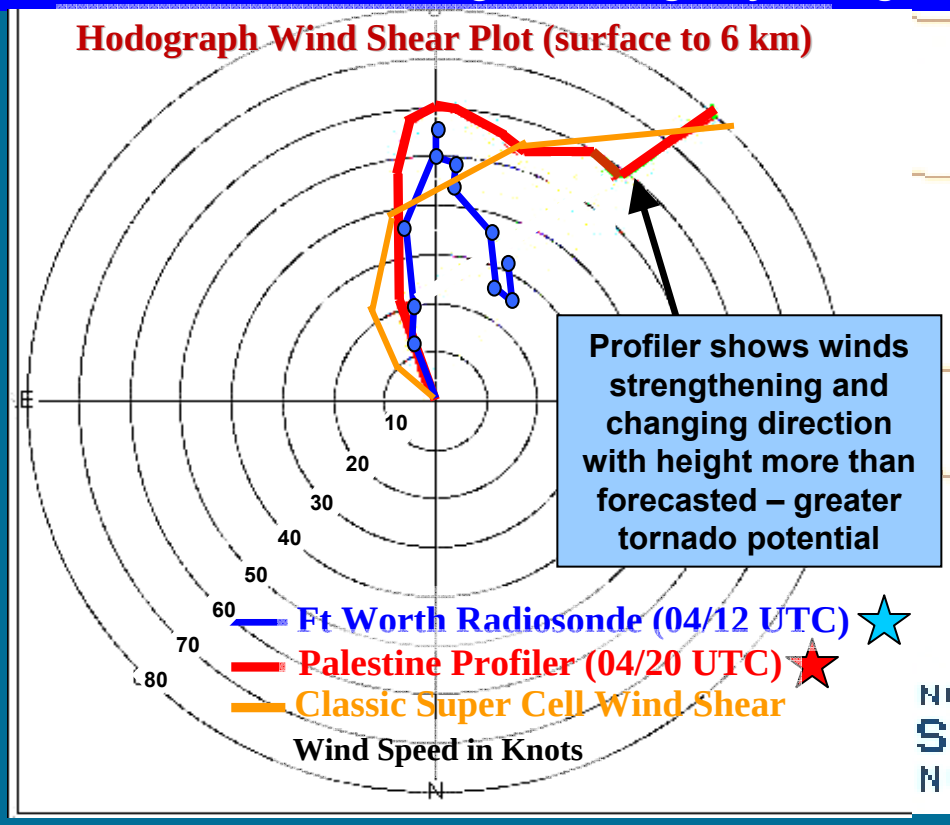
    *Lead time improvements in representative winter storm, fire weather, and turbulence warning events*
  - *Watches and Outlooks:* *Statistical improvements in severe weather watch and outlook accuracy*
  - *Numerical Weather Prediction:* *Statistical improvements in 0-12 h forecasts*



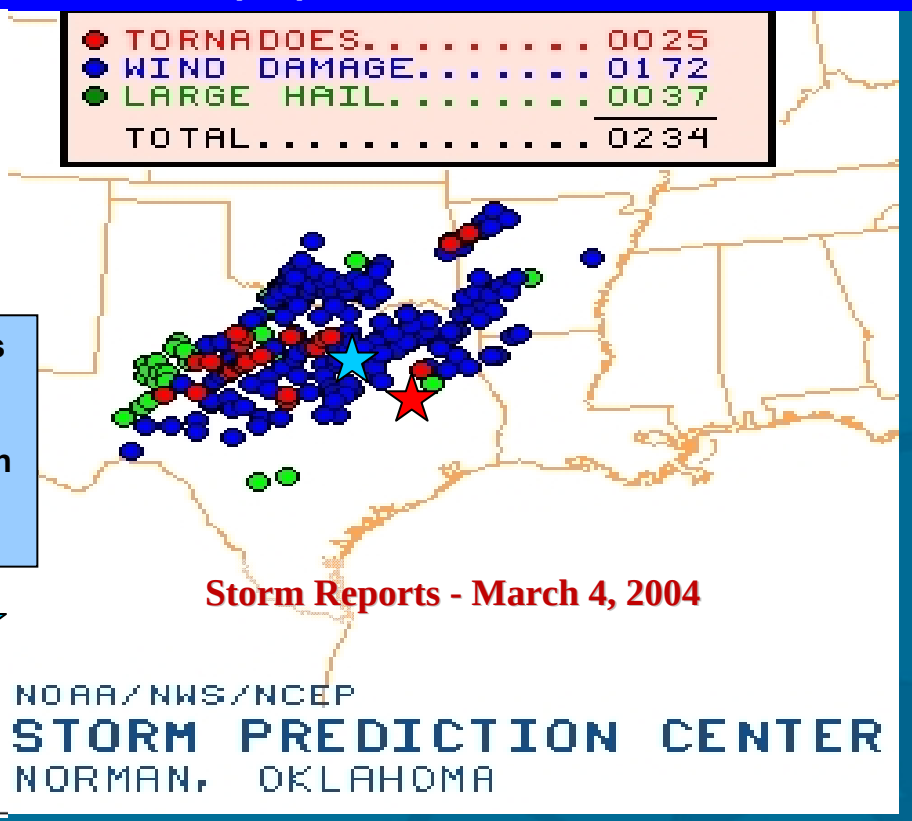

# Benefits - Warnings

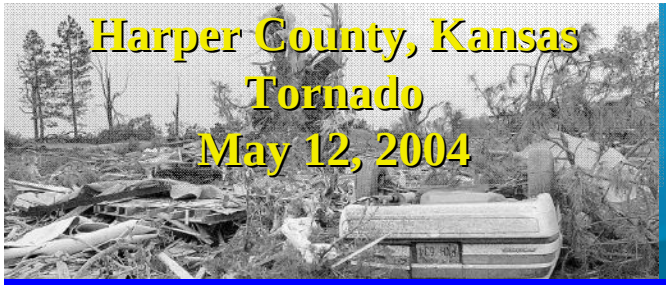
## *How WFOs use Profiler Data in Tornadic Situations*

**"…BEFORE outbreak started. Observed wind fields from NPN helped our forecasters become fully aware of severe weather potential…. Once we noticed that convection had developed and was moving east, our briefings to Emergency Managers reflected proper threat level …"**




Profiler shows winds strengthening and changing direction with height more than forecasted – greater tornado potential

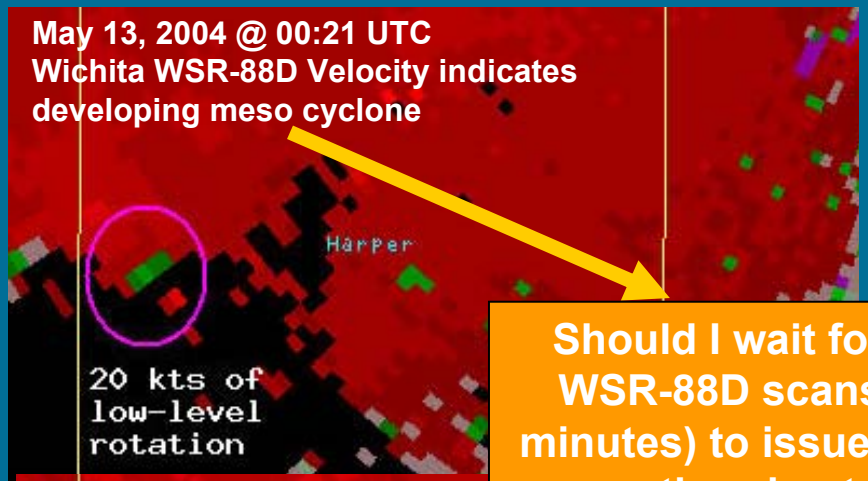




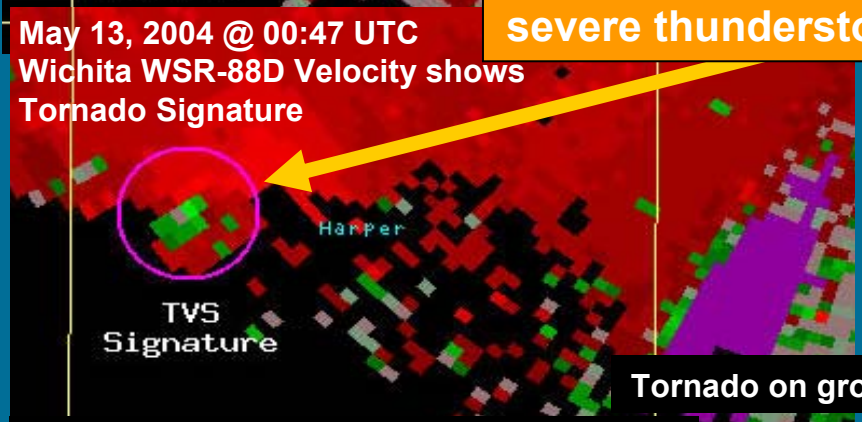

# Benefits - Warnings

## *How WFOs use Profiler Data in Tornadic Situations*

**"At least six tornadoes touched down in central and southern Kansas, including one that just missed the town of Attica in Harper County. No fatalities or injuries are reported." ---Wichita Eagle, May 13, 2004**



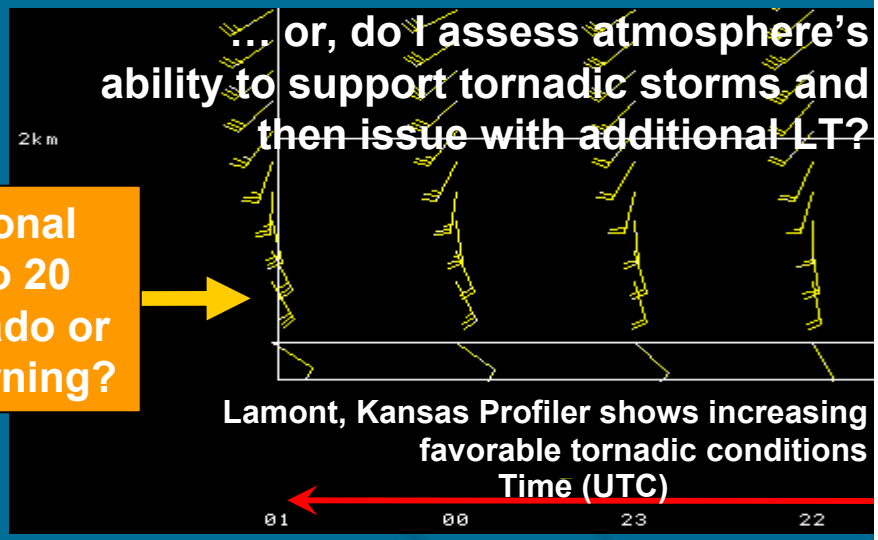

**Should I wait for additional WSR-88D scans (+10 to 20 minutes) to issue a tornado or severe thunderstorm warning?**




**Tornado on ground 00:53 UTC**

**Waiting: 5-10 Minute Lead Time**

**… or, do I assess atmosphere's ability to support tornadic storms and then issue with additional LT?**



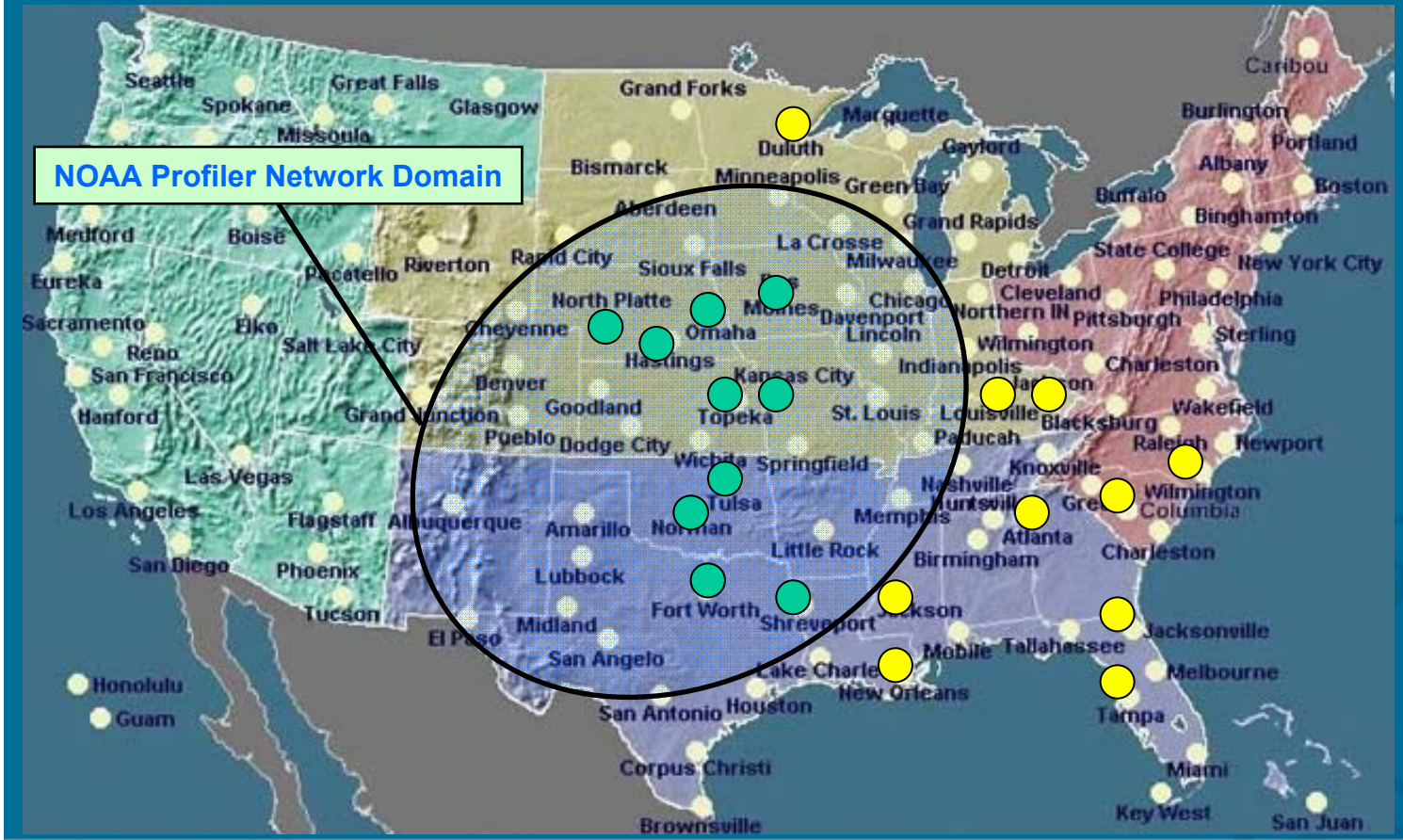

**Using profiler network to improve situational awareness enabled WFO Wichita to issue a tornado warning 16-21 minutes *before* radar indicated tornado signature**

**Use Situational Awareness: 26 Minutes Lead Time**

# Benefits - Warnings

## *Warning Performance - Tornadoes*

Quantify benefits by comparing tornado warning performance statistics for 10 WFOs within network and 10 WFOs outside network



# Benefits - Warnings

## *Performance – Tornado Warnings*

Results: Tornado warning statistics better within NPN network

**Impact of NPN Data on Warning Performance**
**Statistics: 1999-2003 Average (10 WFOs each Category)**

| | WFOs within NPN | WFOs Outside NPN | % Difference |
|---|---|---|---|
| Probability of Detection | 0.79 | 0.62 | +27 |
| False Alarm Rate | 0.68 | 0.85 | -20 |
| Critical Success Index | 0.29 | 0.14 | +107 |
| Lead Time | 12.9 | 9.5 | +14 |

Increased situational awareness from wind profiler data *improves* tornado lead time, detection, and false alarm performance measures

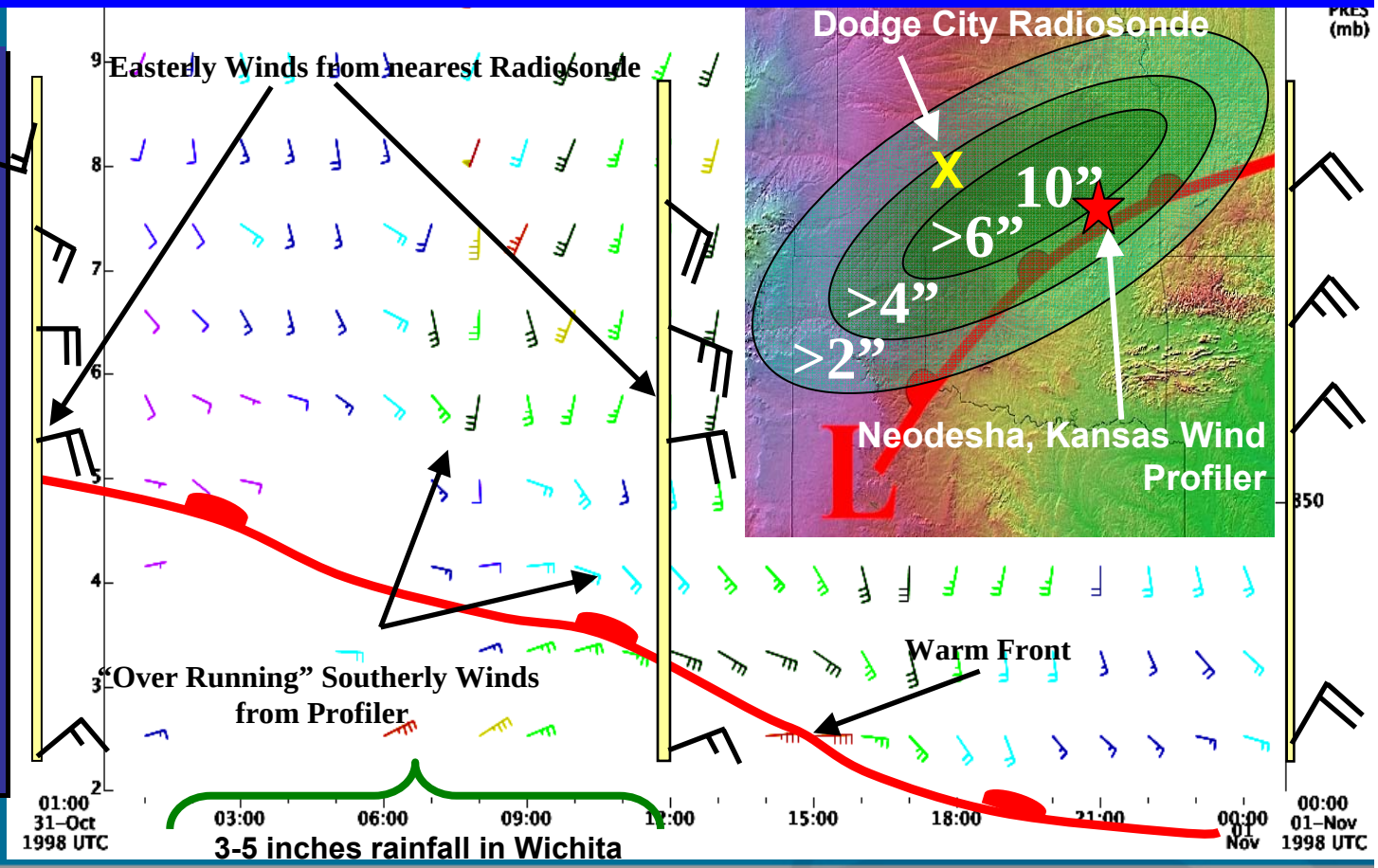
Warning Event Simulation Experiment

# Benefits - Warnings

## *How WFOs use Profiler Data in Flash Flood Situations*

**As a result of accurate forecasts of rainfall and a record flood, law enforcement and emergency preparedness officials had ample lead time to commence evacuation procedures**

- **Profiler shows southerly winds conducive for heavy rainfall over 24-hour period**
- **Nearest radiosonde winds remain easterly – not as conducive**

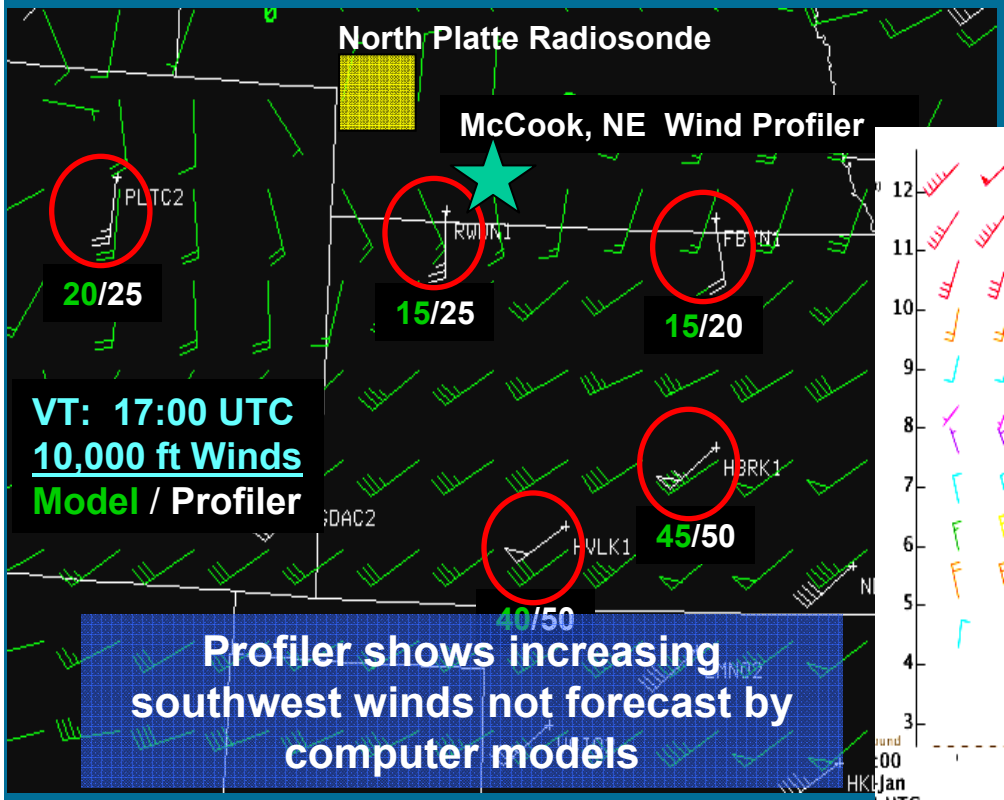


**WFO Hastings, Nebraska Heavy Snow Warning, January 3-4, 2004**

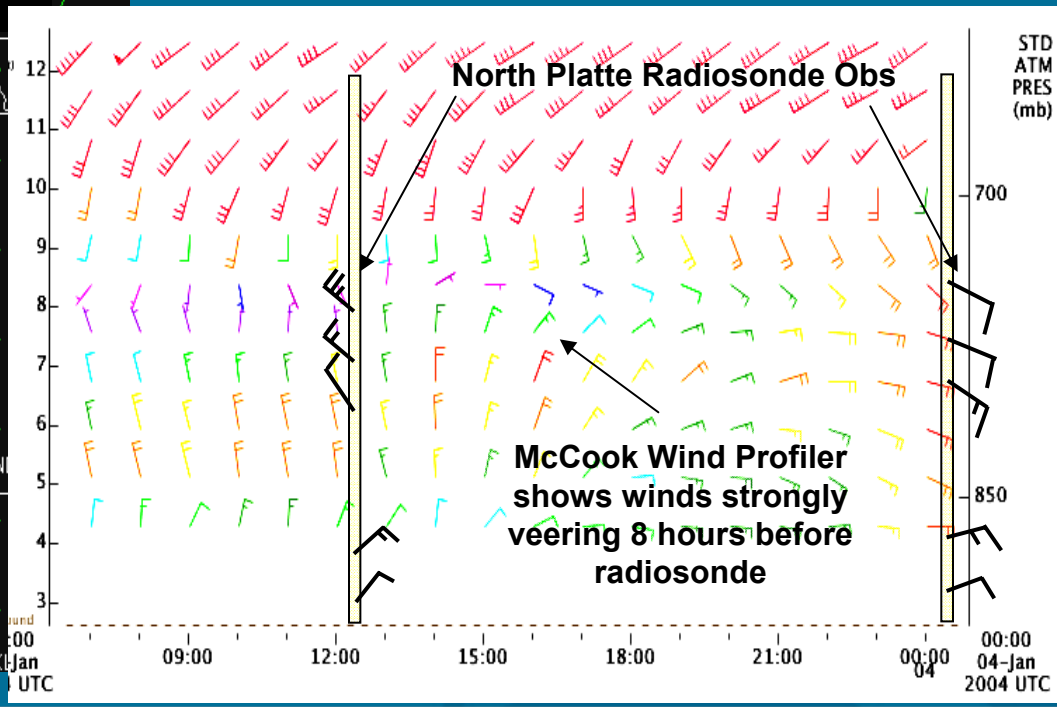
# Benefits - Warnings

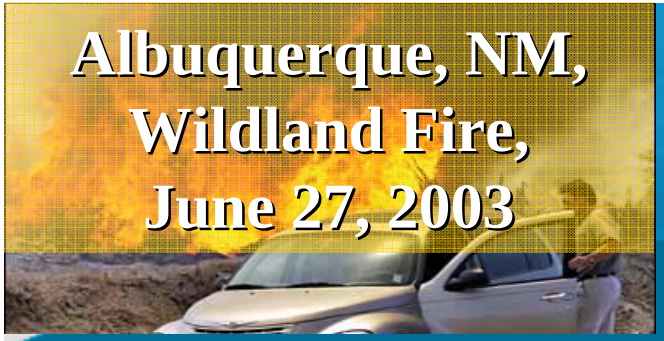
## *How WFOs use Profiler Data in Winter Storm Situations*

**"Winter weather advisory upgraded… to a winter storm warning based, on part, on signatures seen on the wind profiler"**




**Height-Time Cross Section at McCook**






# Benefits - Warnings

## *How WFOs use Profiler Data in Fire Weather Situations*

**"Firefighters were ready when wind shifted -- no homes burned in the nearby neighborhoods"**

**Height-time cross section at Tucumari**

**Surface Analysis**
**June 28, 2003 at 12 UTC**

1020
HIGH

**Tucumcari Profiler picks up intensifying winds not seen in nearby ABQ Radiosonde Observation**

**Albuquerque (ABQ) Radiosonde**

10
9
8
7
6
5

12:00
27–Jun
003 UTC

12:00
15:00
18:00
21:00
00:00
28
03:00

**"Forecasters at NWS office in Albuquerque used Tucumcari wind profiler data to inform fire management crew that abrupt increase in low-level wind would occur shortly before midnight."**

# Projected Benefits - Warnings
## *of a National Network*

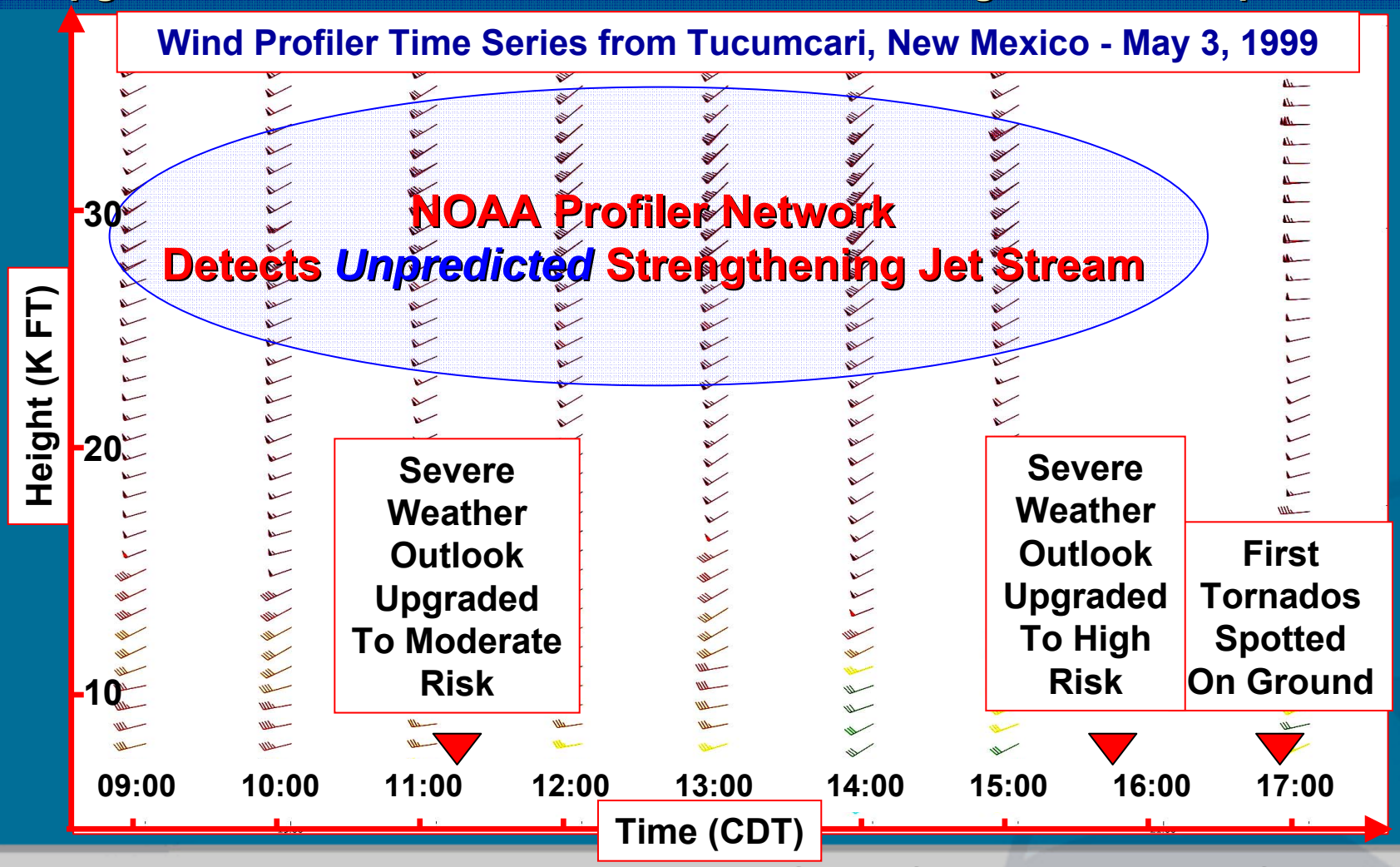
*Warning Lead Time Improvements:*

| | Improvement | Baseline LT | With National Network |
|---|---|---|---|
| Tornado | +1.2 mins | 11.5 mins | 12.7 mins |
| Flash Flood | +3.1 mins | 46.4 mins | 49.5 mins |
| Winter Storms | +0.3 hours | 13.0 hours | 13.3 hours |
| Red Flag Warnings | +2.3 hours | 8.7 hours | 11.0 hours |

# Benefits – Watches & Outlooks

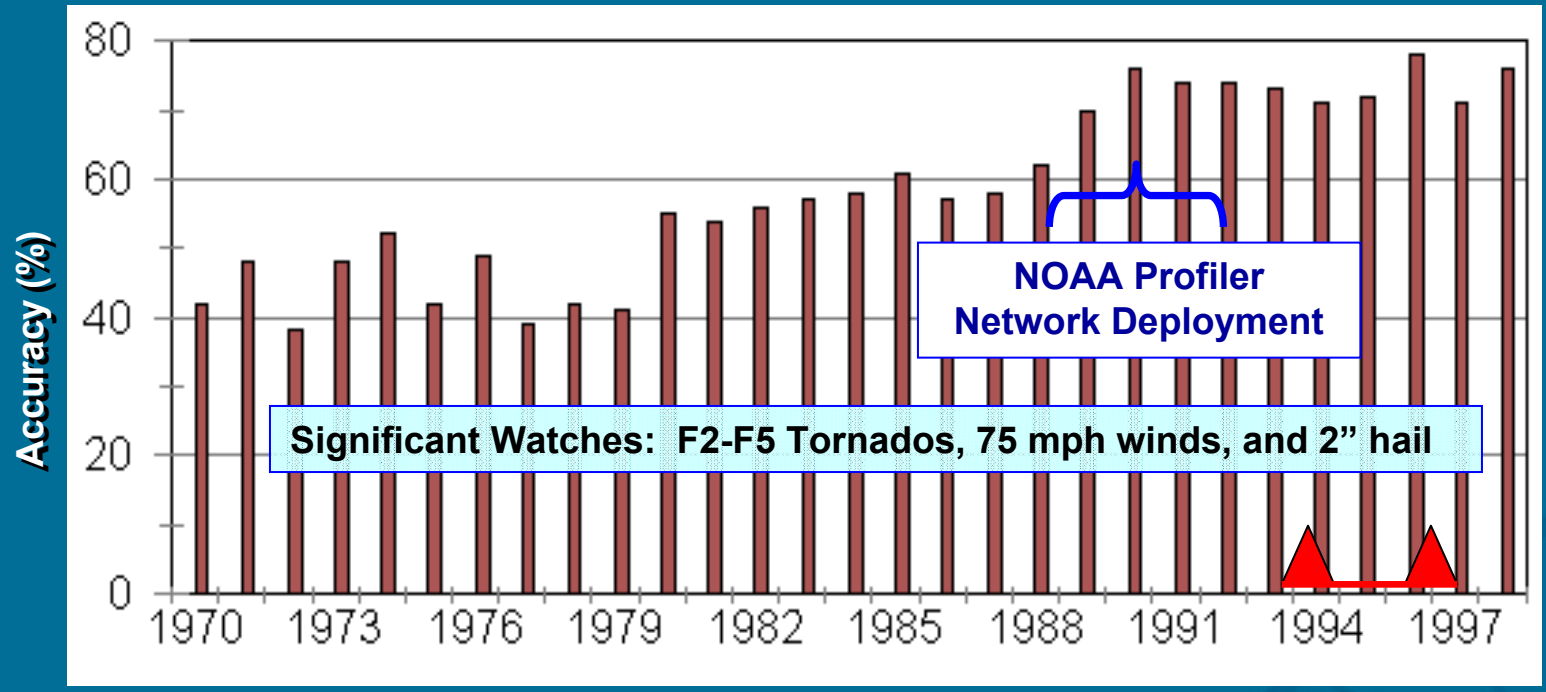
## *How SPC uses Profiler Data in Convective Situations*

**SPC upgrades severe weather risk in Oklahoma to "high" based on profiler winds**



# Benefits – Watches & Outlooks
## *Performance*

**Results: SPC National Watch Accuracy for F2-F5 Tornadoes Improved *15%* with NPN Deployment**




**NPN vertical wind shear data used to monitor rapidly changing conditions to assess *risk and type* of severe thunderstorms.**

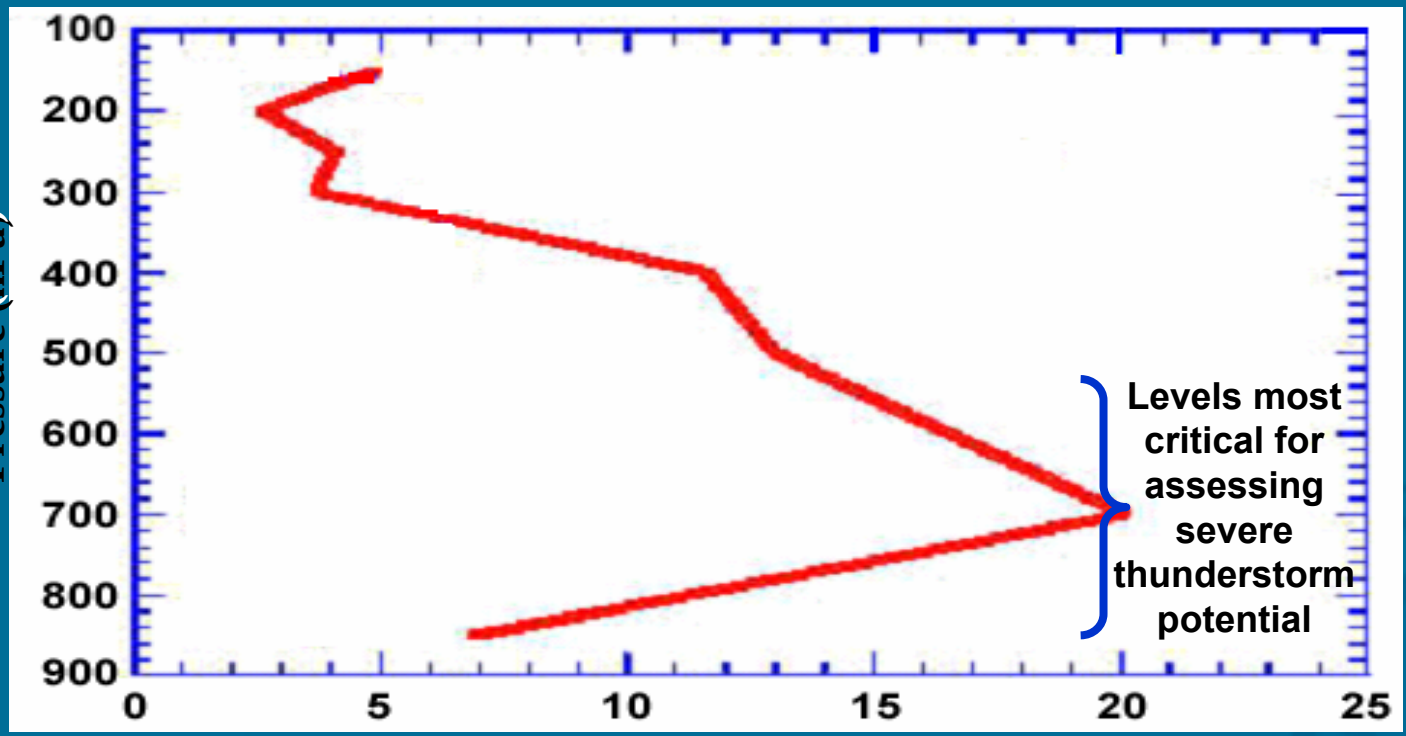
# Projected Benefits – Watches & Outlooks

*of a National Network*

*Watches and Outlooks:* Improve (F2+) tornado watch accuracy *by 13%* East of the Rocky Mountains from 62% to 75% POD

# Benefits – NWP
## *Performance*

**Results: Adding NPN wind data improves short-term (<12 hr) model forecast accuracy by *as much as 20%.***




**Avg. Percent Error Reduction for the 3 Hour Wind Forecast over 2-week period**

**Improvements**

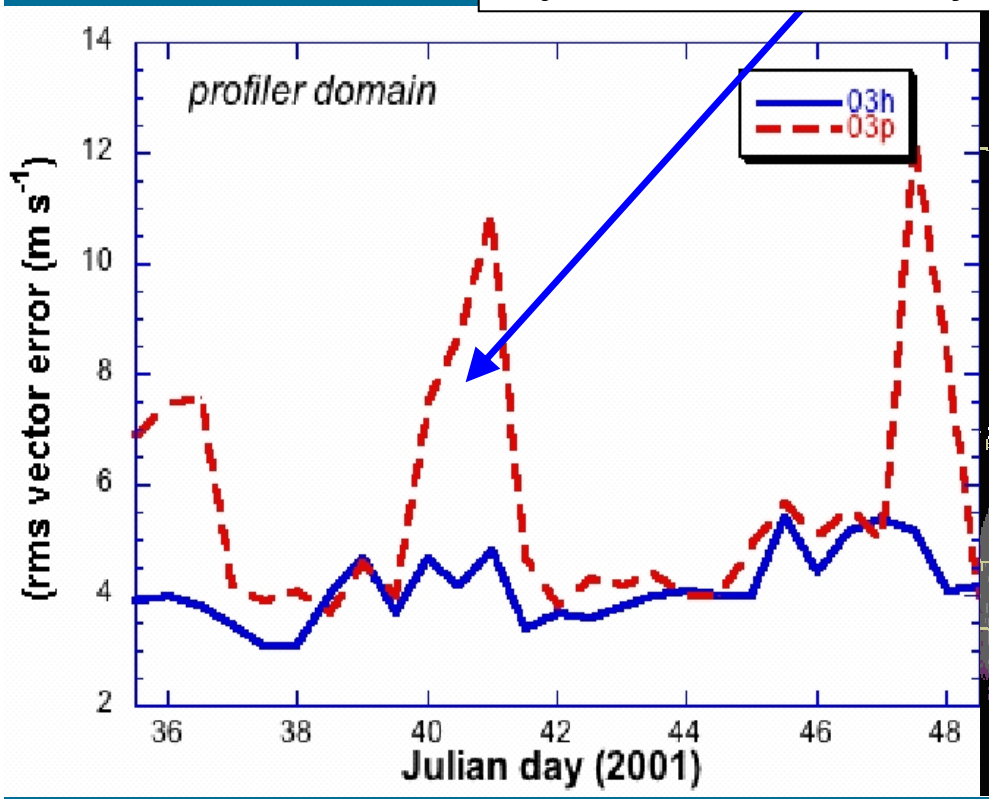
- **Avg = +0.5 to 1.0 m/s**
- **Max = +13 m/s**

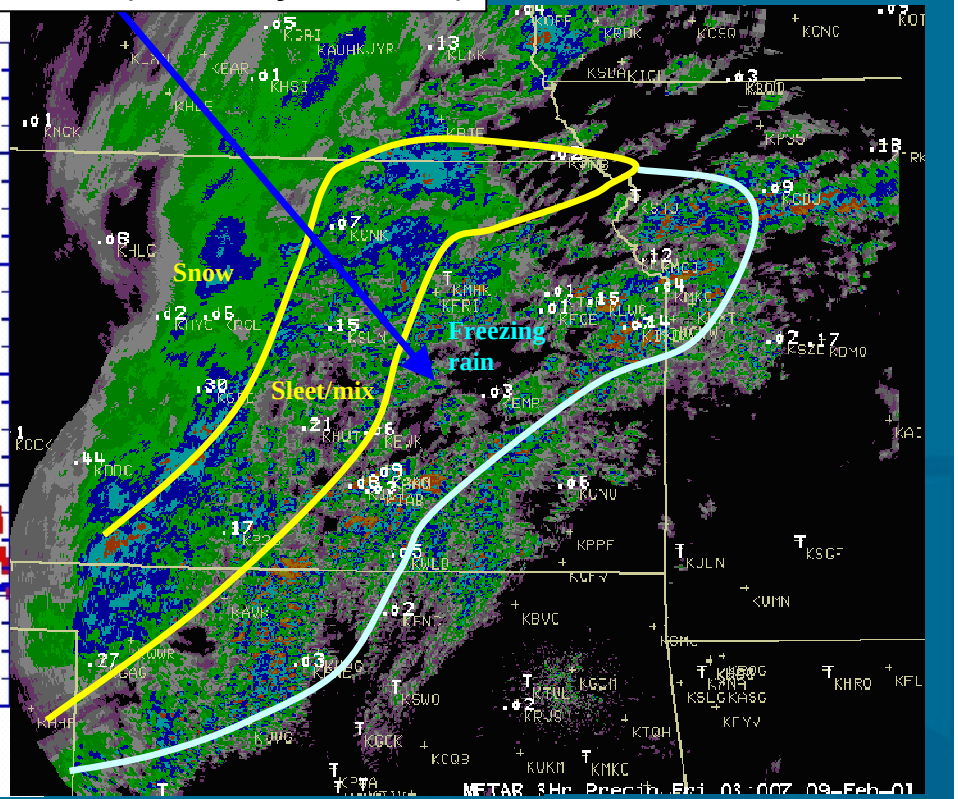
# Benefits – NWP

## *Performance*

### Eta Data Denial Experiment: Model Error at 500 hPa 4-17 February 2001

**Major Winter Storm - February 9, 2001 (Julian Day of Year 40)**




**Profiler data improve 3 hour prediction by *more than 10 m/s* during changing weather**

# Cost and Operational Effectiveness Analysis

*Purpose*

## Congressionally-directed …

COEA is provided in response to a request by the Senate Appropriations Committee to "…compare the $10,000,000 cost to upgrade the NOAA Profiler Network (NPN) over the next decade versus the short, medium, and long-term costs of ending the NPN program."

**2004 Senate Appropriations Bill**

# Cost and Operational Effectiveness Analysis

*Methodology*

**Wind attributes selected to characterize performance of wind profile systems**

- **Frequency of observations**
- **Geographic coverage**
- **Vertical reach**
- **Horizontal spacing**
- **Vertical spacing**
- **Accuracy**

**Weighting established by panel of internal and external meteorologists**

# Cost and Operational Effectiveness Analysis

*Methodology*

**Attributes weighted by their importance to NWS missions**

| NWS Mission | Most Important Attribute |
|---|---|
| Short-range Forecasts | Update Frequency |
| Warnings | Update Frequency |
| Watches | Geographic Coverage |
| Short-range Numerical Weather Prediction | Geographic Coverage |

**Need wind observing system with balanced capabilities**

# Cost and Operational Effectiveness Analysis

*Systems Considered*

**Wind observing systems evaluated in COEA**

- **12 Hour Rawinsonde**
- **1 Hour Rawinsonde**
- **ACARS/MDCRS**
- **WSR-88D VAD Winds**
- **GOES Drift Winds**
- **NOAA Profiler Winds**

# Cost and Operational Effectiveness Analysis

*Results – Top Three Systems*

## Radiosonde (hourly):

**Performance**: Ranked #1 system in coverage, vertical reach, and accuracy
**Cost**: Most expensive (by order of magnitude) system evaluated
**Assessment**: Extreme cost limits attractiveness

## MDCRS:

**Performance**: Ranked 4th and 5th of 5 systems in geographic coverage and resolution
**Cost**: Least cost per observation of all sensors
**Assessment**: Cost of MDCRS relative to other sensors indicates these data should be leveraged whenever possible

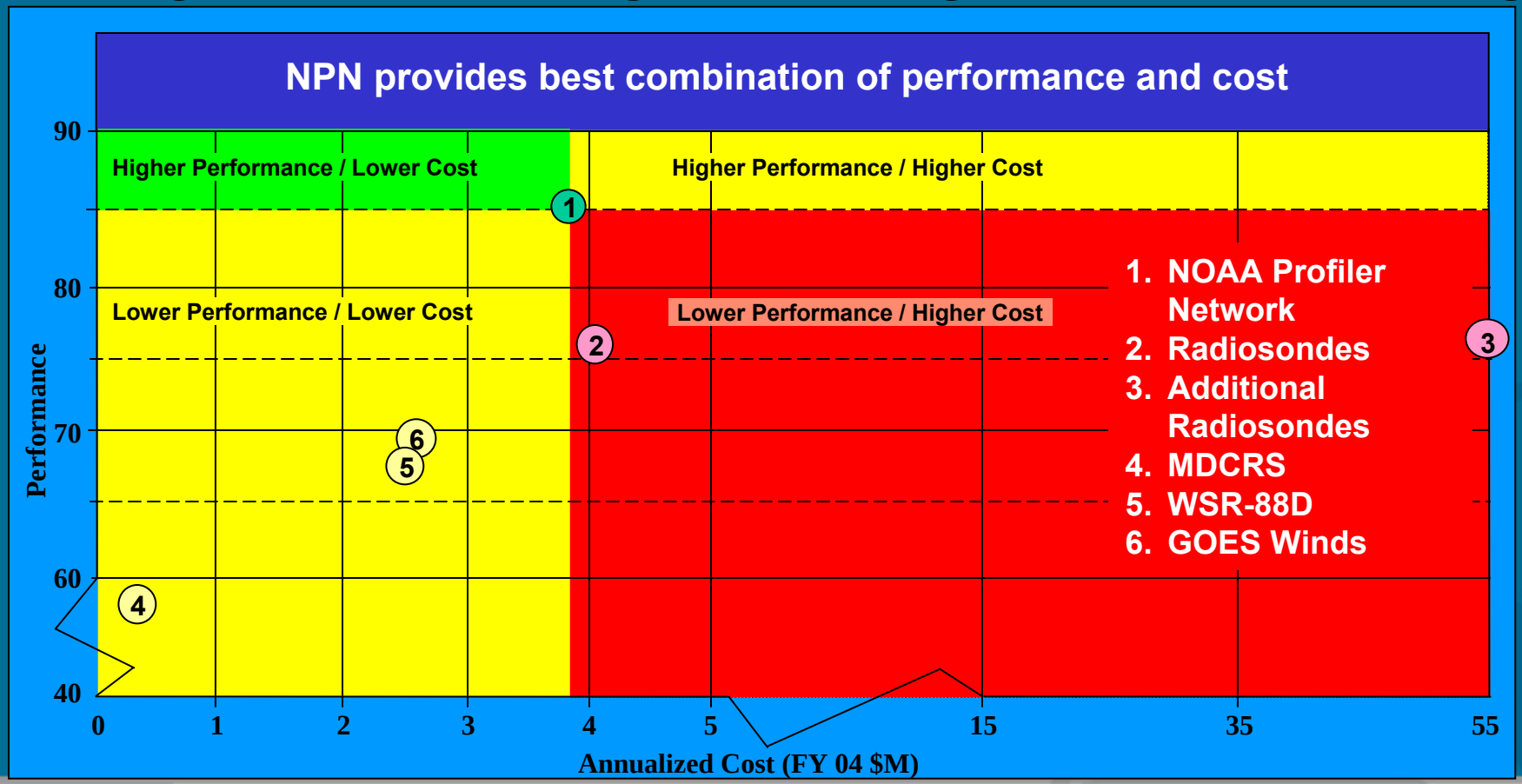
## NPN:

**Performance**: Ranked top 1st or 2nd system in 5 of 6 attributes assessed
**Cost**: About the same as 12 hour radiosondes, WSR-88D, and GOES systems
**Assessment**: Best overall cost/benefit; capable of meeting *both* watch and warning mission needs

# Cost and Operational Effectiveness Analysis

## *Results – All Systems*

**NPN *superior* to other wind detection systems in meeting NWS mission goals for short-range forecasting, watches, and warnings**



# Assessment

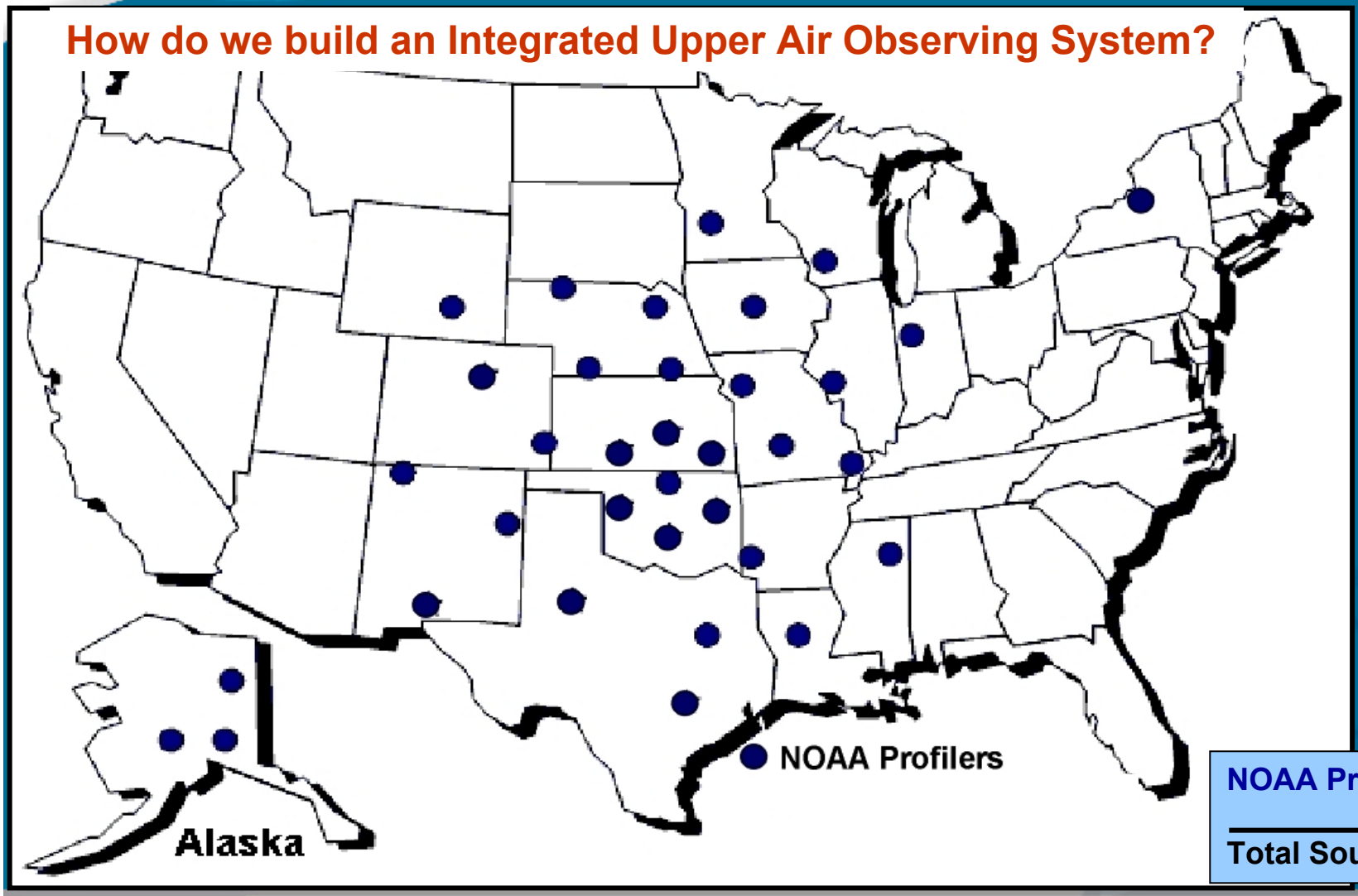
**Based upon demonstrated benefits and COEA findings:**

- **Assessment shows fund NPN beyond FY04; change frequency**
  - ***O&M: $3.5M/yr***
  - ***Frequency Change: $13.2M by end of FY08***
- **Develop plan for Integrated Upper-air Observing System with NPN as component**

# National Network

## *Current NOAA Profilers*

**How do we build an Integrated Upper Air Observing System?**

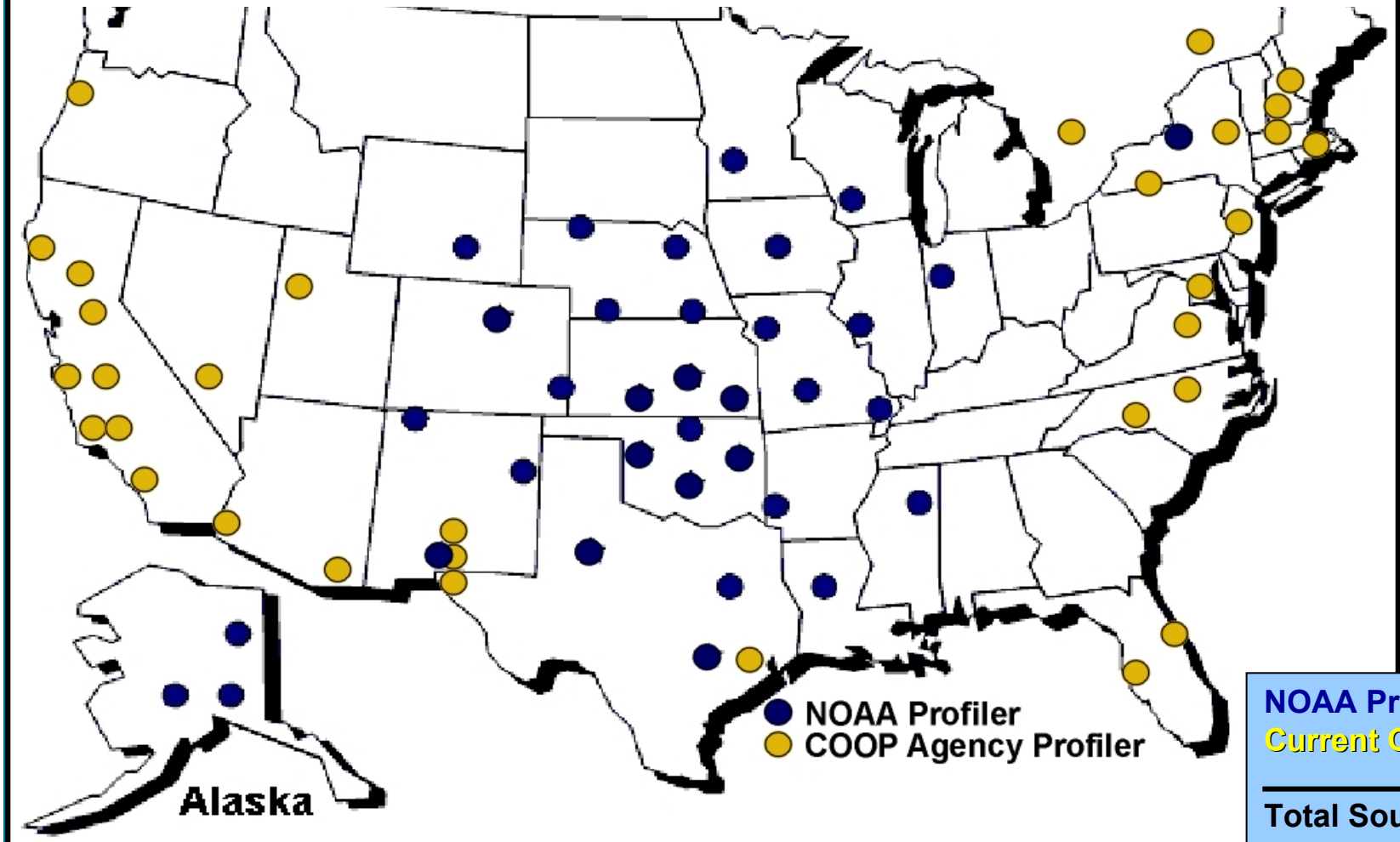



| | |
|---|---|
| **NOAA Profilers…….** | **35** |
| **Total Soundings……** | **35** |

# National Network

## *Current NOAA Profilers and CAPs*

**Maximize leveraged observations… Cooperative Agency Profilers**

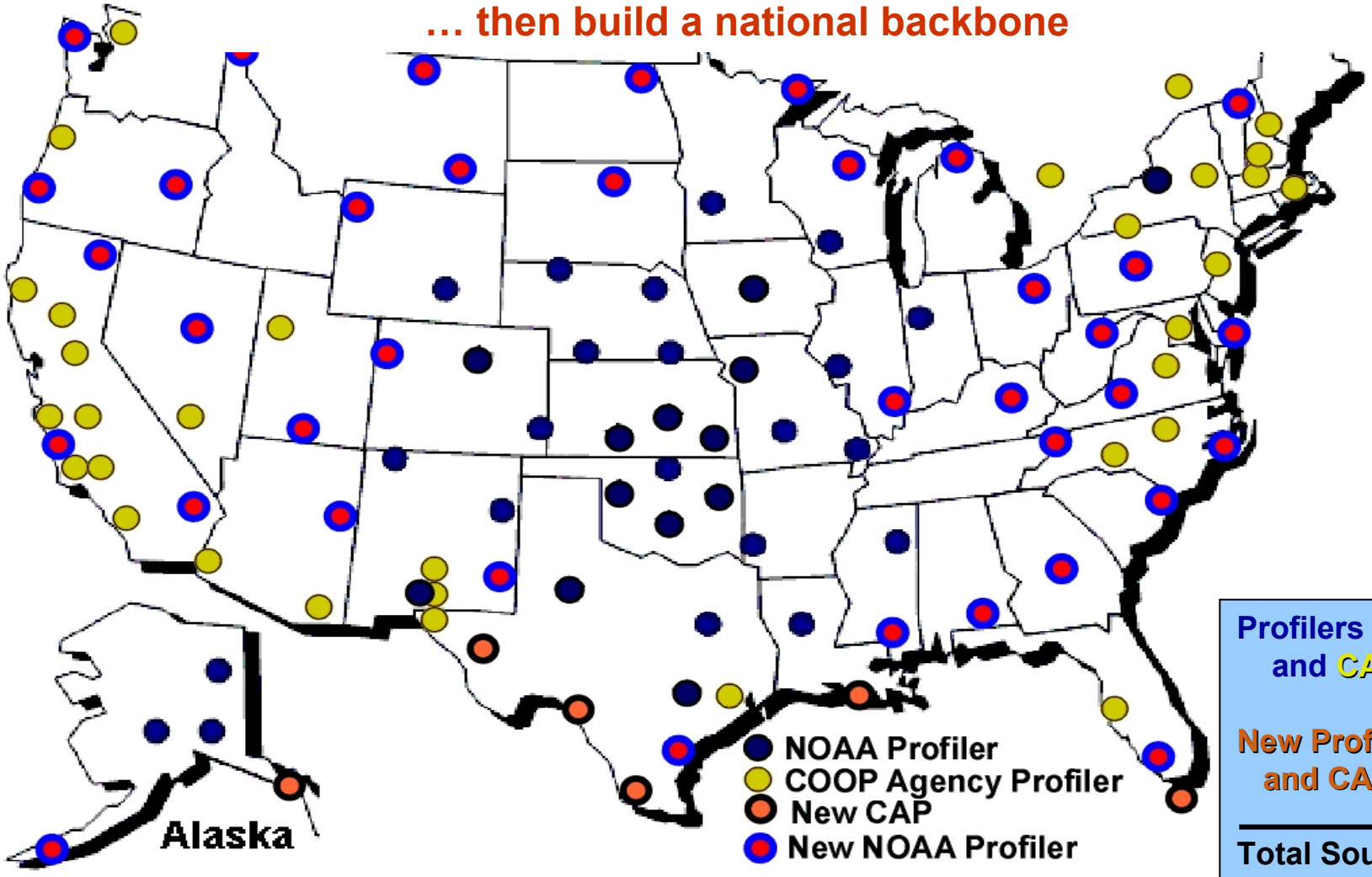



| | |
|---|---|
| NOAA Profilers……. | 35 |
| Current CAPs…….. | 80 |
| Total Soundings…… | 115 |

# National Network

## *An Integrated Upper Air Observing System*

**… then build a national backbone**

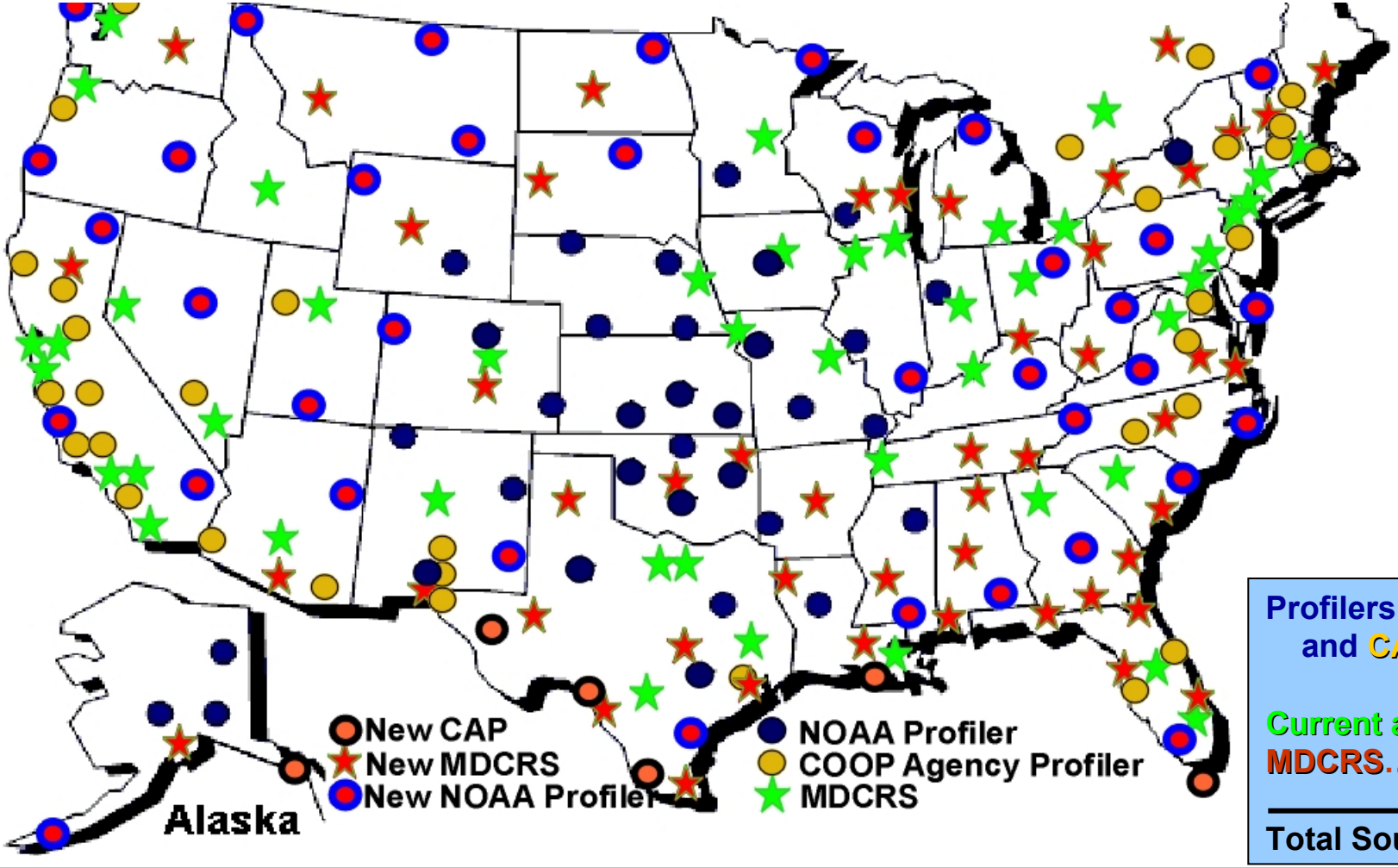



| | |
|---|---|
| Profilers and CAPs | 115 |
| New Profilers and CAPs | 60 |
| Total Soundings | 175 |

# National Network

## *An Integrated Upper Air Observing System*

**… finally, extend the backbone's impact with using aircraft soundings.**




**Profilers and CAPs…….. 185**

**Current and future MDCRS……100**

**Total Soundings…… 285**

# Funding Strategy

- **Find savings (deferrals and/or reprogramming)* in existing programs to fund FY 05 & 06 NPN O&M and portion of frequency change costs; Looking at:**
  - **Restructuring RRS**
  - **Delaying NEXRAD PPI including Dual Pol**
  - **Delaying ASOS PIP**

  ***Will need to recoup $ in out-year budgets**

- **Program NPN O&M and frequency change completion costs in FY 07-11 PPBES as part of an outyear National Integrated Upper-air Observing System**

# Roadmap

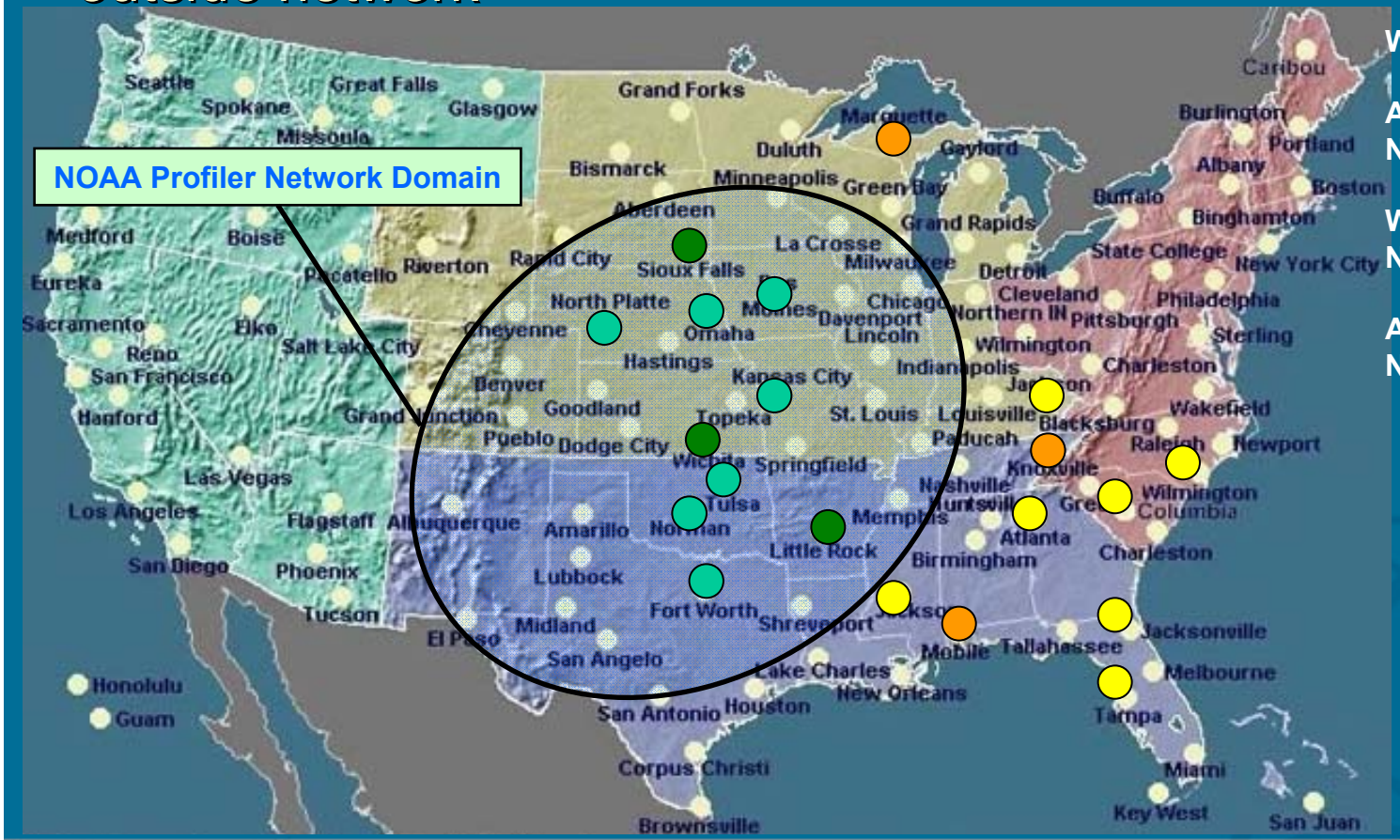
- Deliver COEA to Congress before the 2 Aug 04 suspense date. (Submit to NOAA:  June 04)
- Work FY05&06 funding (Oct. 04)
- Include NPN O&M and frequency upgrade in FY 07-11 Program Plan (OST/MG3, Fall 04)
- Develop national plan for integrated upper air observing system, including radiosondes, aircraft, profilers, satellites--all within NOAA enterprise architecture (OST/MG3, ready for FY 07-11 Program Plan)

# Backup Slides

# Benefits

## *Warning Performance - Tornadoes*

Quantify benefits by comparing tornado warning performance statistics for 10 alternative WFOs within network and 10 WFOs outside network




All experience high tornado frequencies

Data: 1999-2003

# Benefits

## *Warning Performance - Tornadoes*

Results: Tornado warning statistics better within NPN network

**Impact of NPN Data on Warning Performance**
**Statistics: 1999-2003 Average (10 WFOs each Category)**

| | WFOs within NPN | WFOs Outside NPN | % Difference |
|---|---|---|---|
| Probability of Detection | 0.79 | 0.62 | +27 |
| False Alarm Rate | 0.67 | 0.82 | -18 |
| Critical Success Index | 0.31 | 0.17 | +82 |
| Lead Time | 12.1 | 10.8 | +12 |

Alternative station sampling using 30% different stations inside and outside the NPN.

# Benefits

## *Warning Performance – Flash Floods*

Results: Flash Flood warning statistics generally better within NPN network

**Impact of NPN Data on Warning Performance**

**Statistics: 1999-2003 Average (10 WFOs each Category)**

| | WFOs within NPN | WFOs Outside NPN | % Difference |
|---|---|---|---|
| **Probability of Detection** | **0.81** | **0.89** | **-9** |
| **False Alarm Rate** | **0.38** | **0.42** | **-10** |
| **Critical Success Index** | **0.54** | **0.54** | **0** |
| **Lead Time** | **49.5** | **45.2** | **+10** |

Increased situational awareness from wind profiler data *improves* flash flood lead time

# National Network

## *Additional Benefits –Winter Storm Warnings*

Projected Winter Storm Warning Improvements with National Network

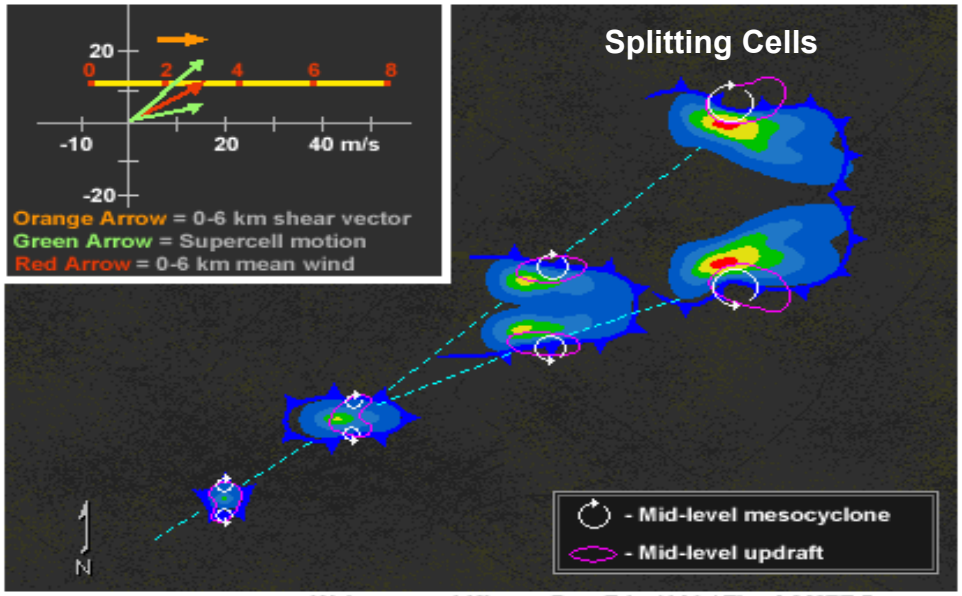
- Facts from FY 02
  - 5000 warning events
  - Avg. National Lead Time = 13 hours
  - 10% (500) events were unwarned (0 Lead Time)
- Assume 25% (130) of unwarned events will have 6 hours Lead Time with National Network
- Projected 20 min. improvement in avg. national LT (13.3 hours)

# National Network

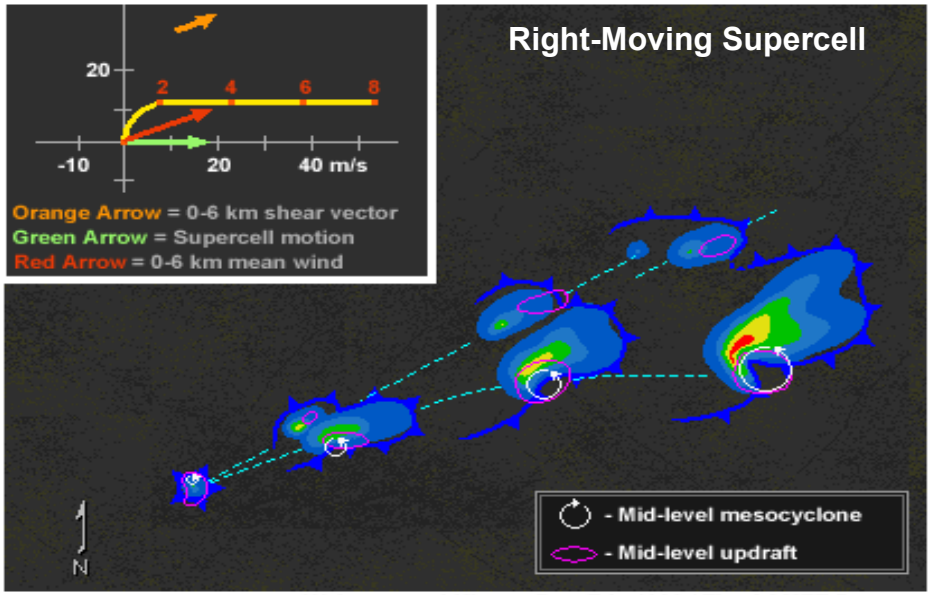
## *Additional Benefits –Use of Conceptual Models*

Vertical wind shear has a controlling influence on the form and evolution of individual convective storms -

Knowing the vertical wind shear allows meteorologists to *anticipate* thunderstorm behavior




Weisman and Klemp, Ray, Ed., 1986 / The COMET Program




Weisman and Klemp, Ray, Ed., 1986 / The COMET Program

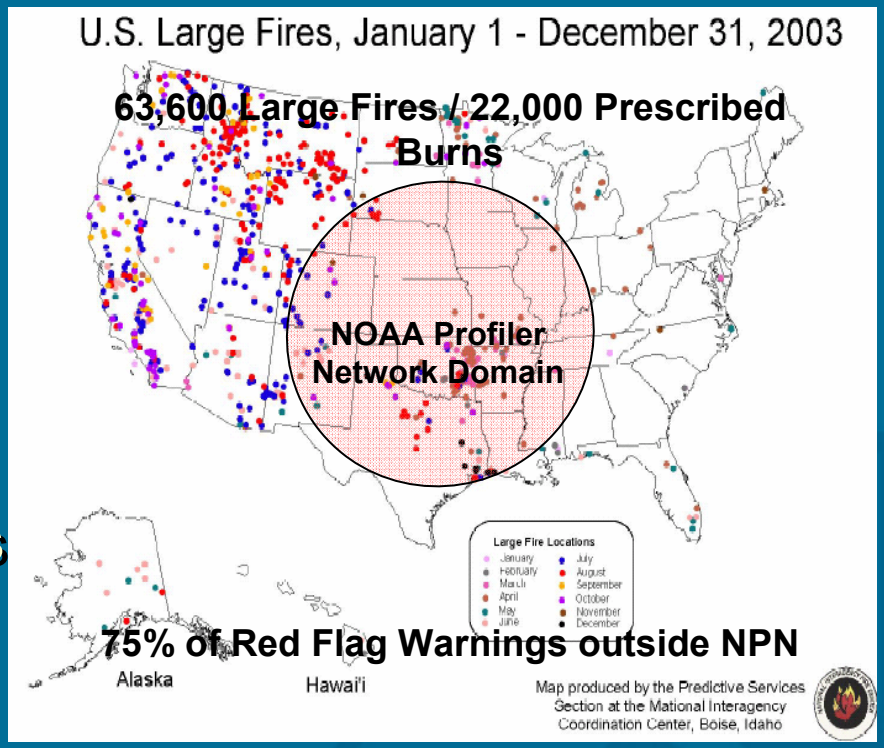
# National Network

## *Additional Benefits – Red Flag Warnings*

Projected Fire Weather Forecast Improvements with National Network

- Facts from FY 02:
  - *8400 Red Flag Warning Events*
  - *75% (6300) outside NPN*
  - *Avg. National Lead Time (L.T.) = 8.7 hours*

- Assume:
  - 50% (3150) are wind-driven events
  - 6 hours additional L.T. with National Network.




- Projected 2.3 hour improvement in Avg. National L.T. (11.0 hours)

# National Network

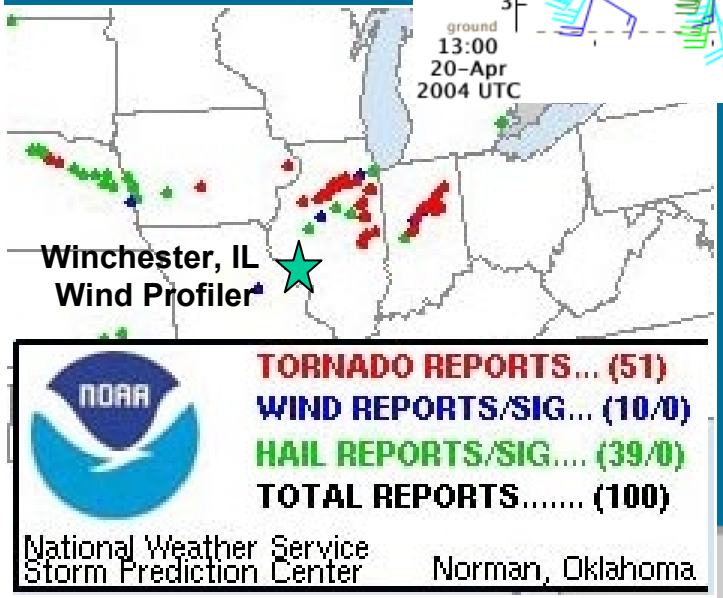
## *Additional Benefits – Watches (F2-F5)*

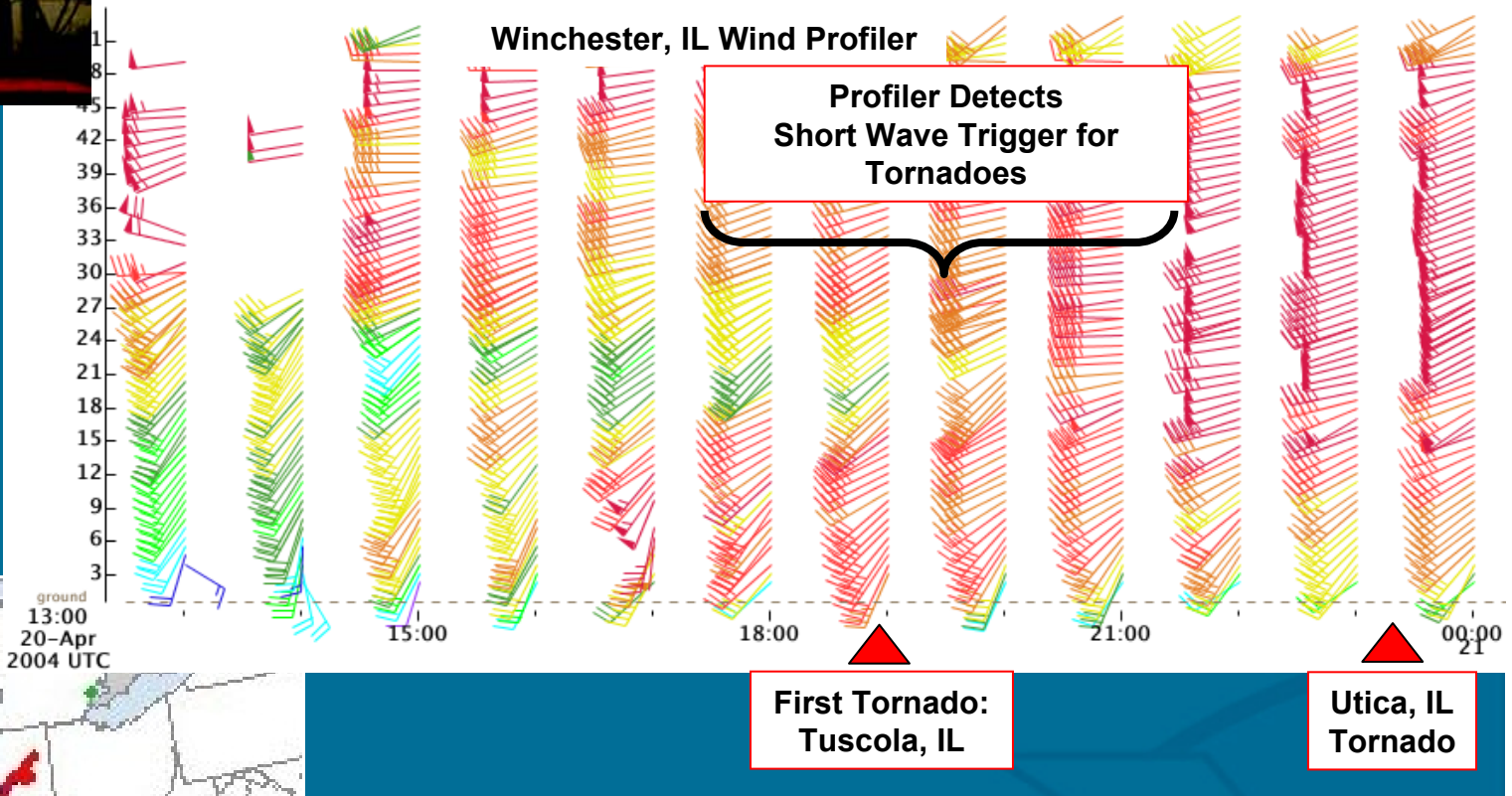
**If** the 15% *national* improvement in F2-F5 tornado watch accuracy between 1988 and 1992 may be attributed to the deployment of the NPN,

**then** one can infer that the improvement *inside* the NPN was 29%, and the further improvement in *national* scores will be 13% if the profiler network is expanded nationally.

# National Network

## *Additional Benefits – Tornado Warnings*

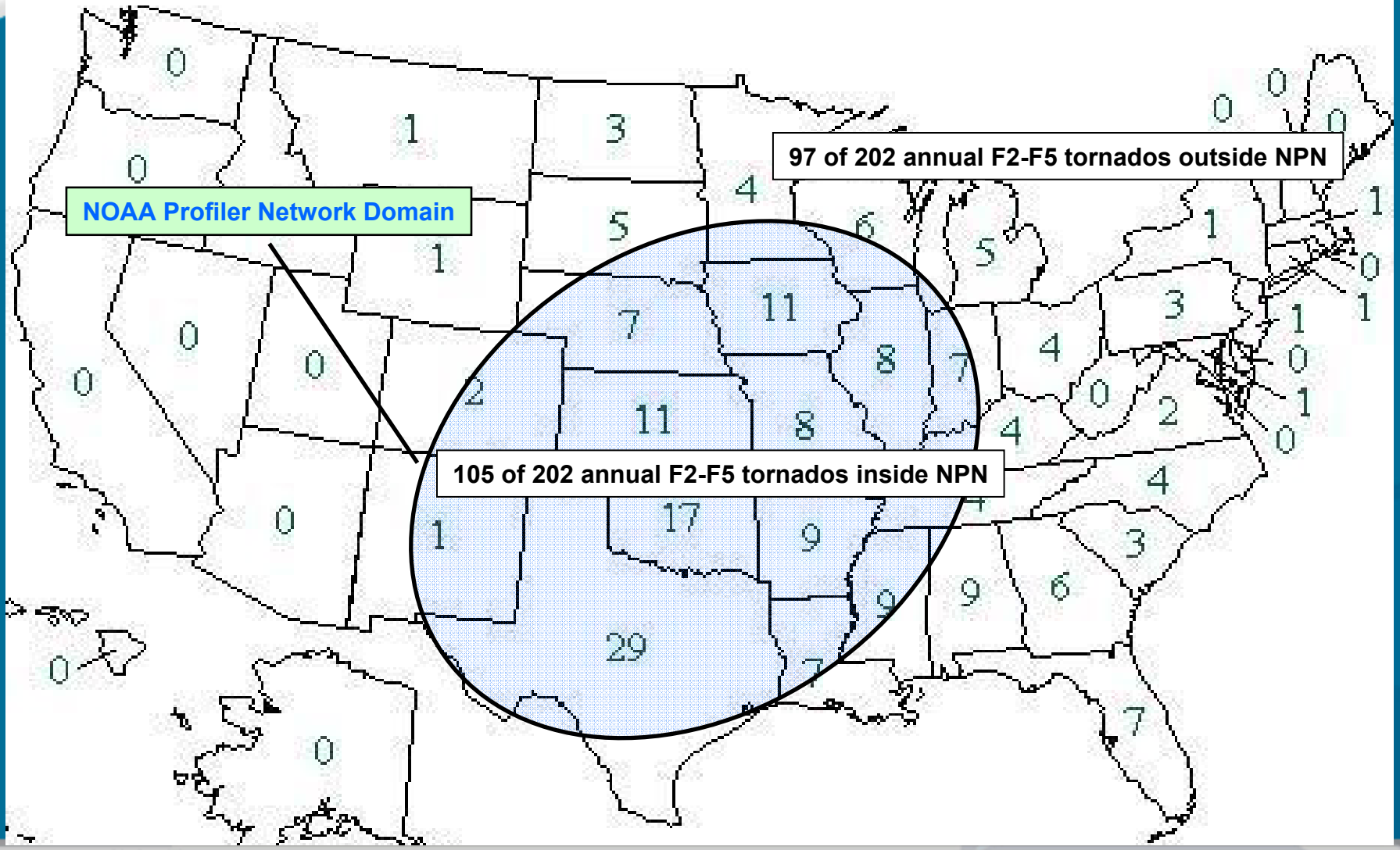

**"The environment went from one unsupportive of severe storms to one favoring large tornadoes in 2 hours. It can happen that fast!!!"**

**Pete Wolf, SOO @ WFO Wichita**

# National Network

## *Additional Benefits – Tornado Warnings*

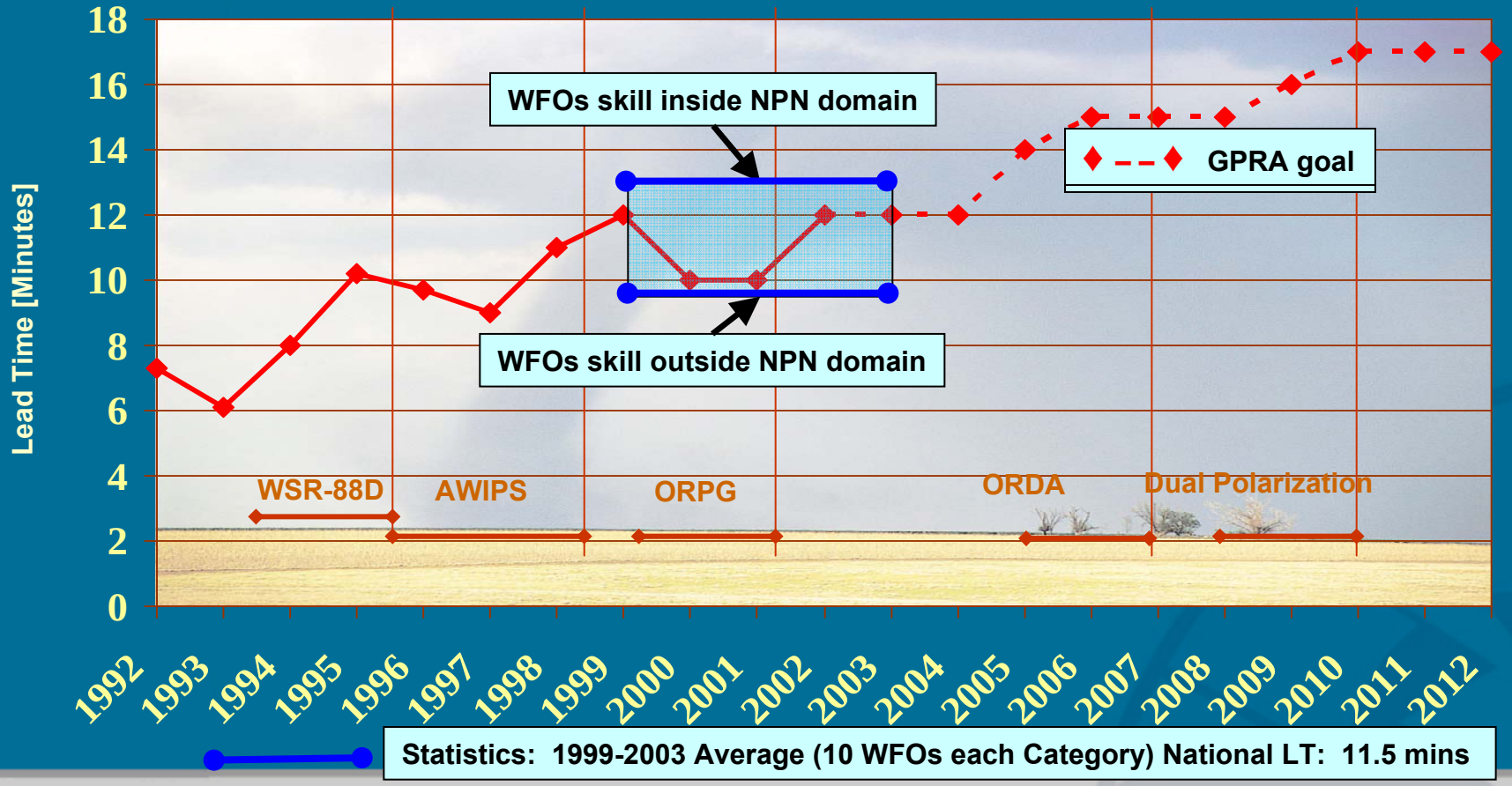
Annual Average Number of Strong-Violent (F2-F5) Tornados, 1950-1995



# National Network

## *Additional Benefits –Tornado Warnings*

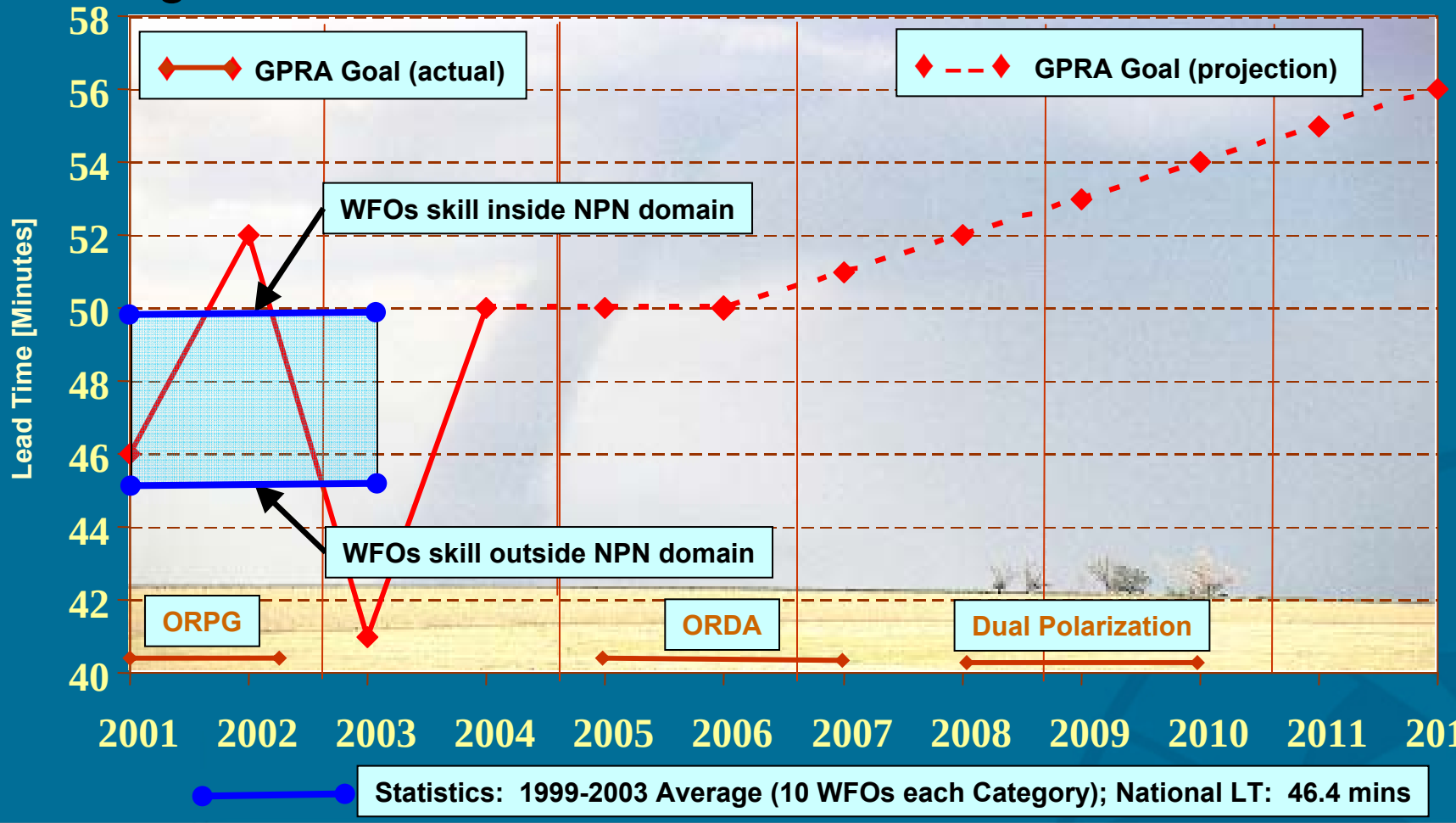
Results: WFOs within NPN domain have about 3.4 minutes longer lead time than those outside



# National Network

## *Additional Benefits – Flash Flood Warnings*

Results: WFOs within NPN domain have about 4.3 minutes longer lead time than those outside



# National Network

## *Additional Benefits – Ceiling/Visibility Forecasts*

Results: Terminal Aerodrome Forecast ceilings below 1,000 ft statistics at 3 and 6 hours

**Impact of NPN Data on TAF Ceiling Performance**

**Statistics: 1999-2003 Average (10 WFOs each Category)**

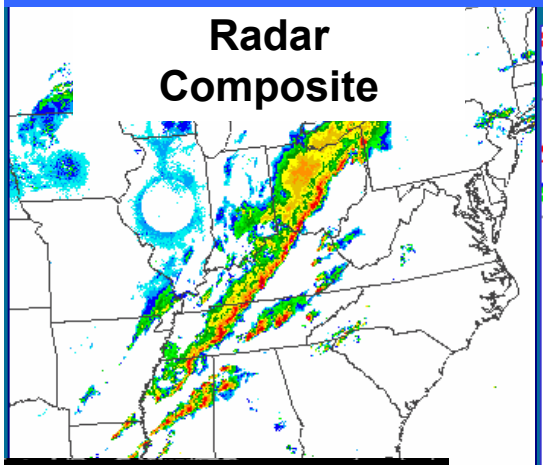
| | WFOs within NPN | WFOs Outside NPN | % Difference |
|---|---|---|---|
| **Probability of Detection** | **0.46** | **0.41** | **+12** |
| **False Alarm Rate** | **0.40** | **0.37** | **+8** |
| **Critical Success Index** | **0.35** | **0.33** | **+6** |

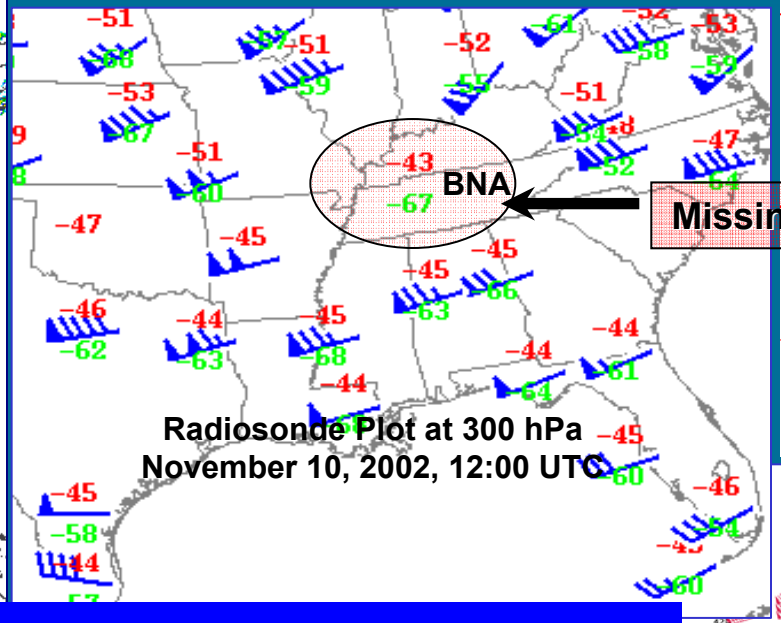
Increased situational awareness from wind profiler data *improves* stratus ceiling forecasts

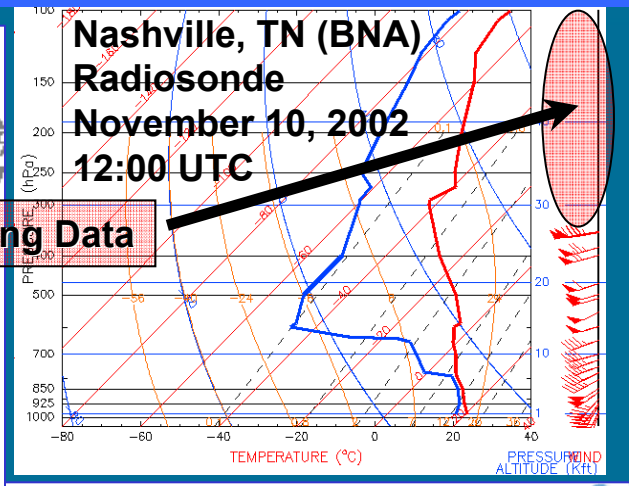
# National Network

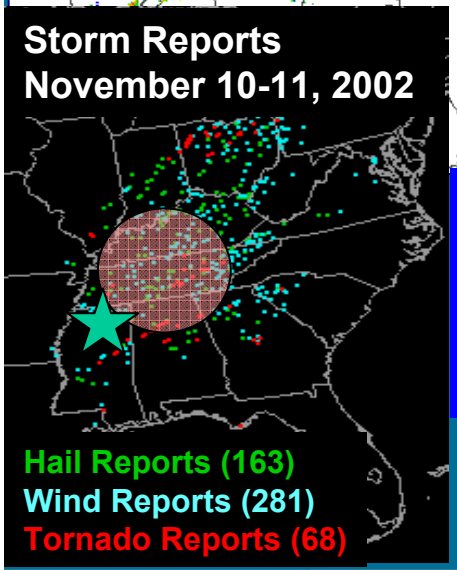
## *Additional Benefits - Enhanced Data Availability*

**Results:** **2-4% improvement in wind data availability above 400 hPa (25 Kft)**

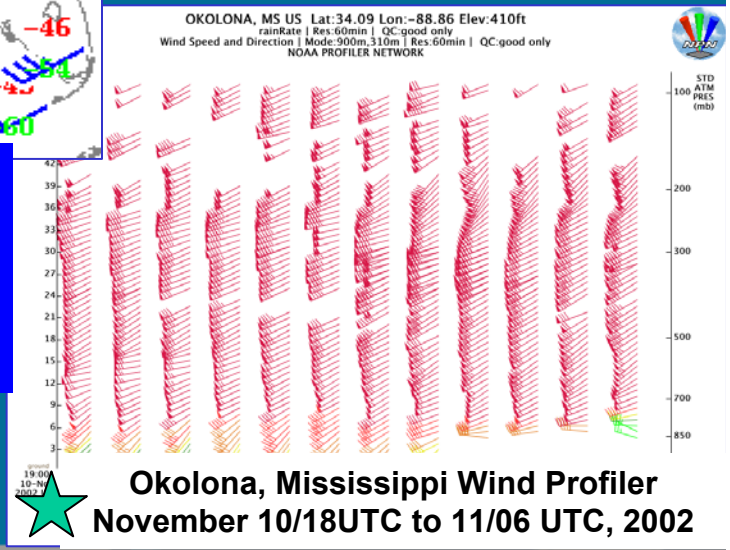



**NPN has high availability during strong jet streams complimenting the radiosonde network**




**Okolona, Mississippi Wind Profiler**
**November 10/18UTC to 11/06 UTC, 2002**

# National Network

*Additional Benefits - Enhanced Data Availability*

**If** a national wind profiler network is deployed,

**then** we can expect a 2-4% improvement in data availability above 400 hPa (25 Kft) as compared with radiosonde data alone thereby improving all services depending upon these data.

# Measures of Value

## Key Program Applications

Mission Applications: Used to support a wide range of NOAA missions, including:

- *Tornado/Severe Thunderstorms/ Flash Floods* – resolve changes to shear, jets, and moisture convergence allowing prediction of convective system development
- *Aviation* – resolve triggers for mesoscale convection; improved 2 to 6 hours SIGMET forecasts
- *Fire Weather/Air Quality* – resolve boundary layer winds, mixing potential; improved understanding of fire weather

# Measures of Value

## NOAA Program/Product and Weather Process Matrix

NOAA Profiler Network (NPN) Impact: Mission and Phenomena Detected

| | Aviation | | | | Severe | | | | Marine | | Public | | Fire | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TAF | TWEB | SIGMET/ AIRMET | Convective SIGMET | Hail | High Wind | Tornado | Flash Flood | Special Marine Warning | Small Craft Advisory | Precip | Temp-erature | Wind/ Mixing Outlooks | Red Flag Warnings |
| 1. Boundary Layer Wind Monitoring | | | | | | | | | | | | | | |
| a. Prediction of Gradient Forced High Wind Events | x | x | | | | x | | | x | x | | x | x | x |
| b. Stratus and Fog development/advection | x | x | x | | | | | | | | | x | | |
| c. Airmass mixing | | | | x | | | | | | | | x | | |
| d. Nocturnal Jet | x | x | x | x | x | | x | x | | | x | | x | x |
| e. Low Low Jet | x | x | x | x | x | | x | x | | | x | | x | x |
| 2. Short Wave Trough and Ridge Identification | | | | | | | | | | | | | | |
| a. Thunderstorm triggers | x | x | | x | x | | x | x | x | x | x | | x | x |
| b. Precip timing (start/stop) | | | | x | | | | x | | | x | | | |
| c. Vertical Motion Fields | | | | x | x | | x | x | x | | x | | | |
| 3. Airmass Identification | | | | | | | | | | | | | | |
| a. Snow Event | x | x | x | | | | | | | | x | | | |
| b. Precipitation | x | x | | x | | | | x | | | x | | | |
| c. Stratus/Fog | x | x | x | | | | | | | | | x | | |
| d. Fronts | x | x | x | | x | x | x | x | x | x | x | x | | |
| 4. Thunderstorm Behavior | | | | | | | | | | | | | | |
| a. Use of Conceptual Models, Helicity/shear, and BRN | | | | x | x | x | x | x | x | | | | | |
| b. Flash Flood – "Training Event" | x | | | | | | | x | | | x | | | |
| c. Short Term Movement | | | | x | x | | x | x | x | | x | | | |
| d. Mesoscale Convective Systems | x | | | x | x | | x | x | x | | x | | | |
| 5. Orographic Interaction | | | | | | | | | | | | | | |
| a. Precipitation | x | | | x | | | | x | | | x | | | |
| b. Stratus/Fog | x | x | x | | | | | | | | | x | | |
| c. Tubulence | | | x | | | | | | | | | | | |
| 6. Turbulence | | | | | | | | | | | | | | |
| a. Rapid change in speed and direction (shear) | | | x | | | | | | | | | | | |
| b. Jet Maxima and LLWS identification | | | x | x | x | | x | x | x | | x | | x | x |
| 7. Icing | | | x | | | | | | | | | | | |