The Value That Wind Profilers Bring To Weather Forecasting

George Frederick

March 2005

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What Value Do Wind Profilers Bring to Weather Forecasting?

Wind profilers are an important source of meteorological data for numerical weather prediction at the *national level.*

Traditionally, weather models have been run at synoptic radiosonde launch times (e.g 00Z and 12Z) and could assimilate data only at synoptic times "Z" = "Zulu" (GMT)

The new, high-resolution models and powerful computers enable forecasters to run their models more frequently (hourly, or more often)

By improving your numerical models you can:

- Issue more accurate forecasts
- Issue forecasts more frequently
- Issue forecasts with greater spatial resolution (horizontal and vertical)

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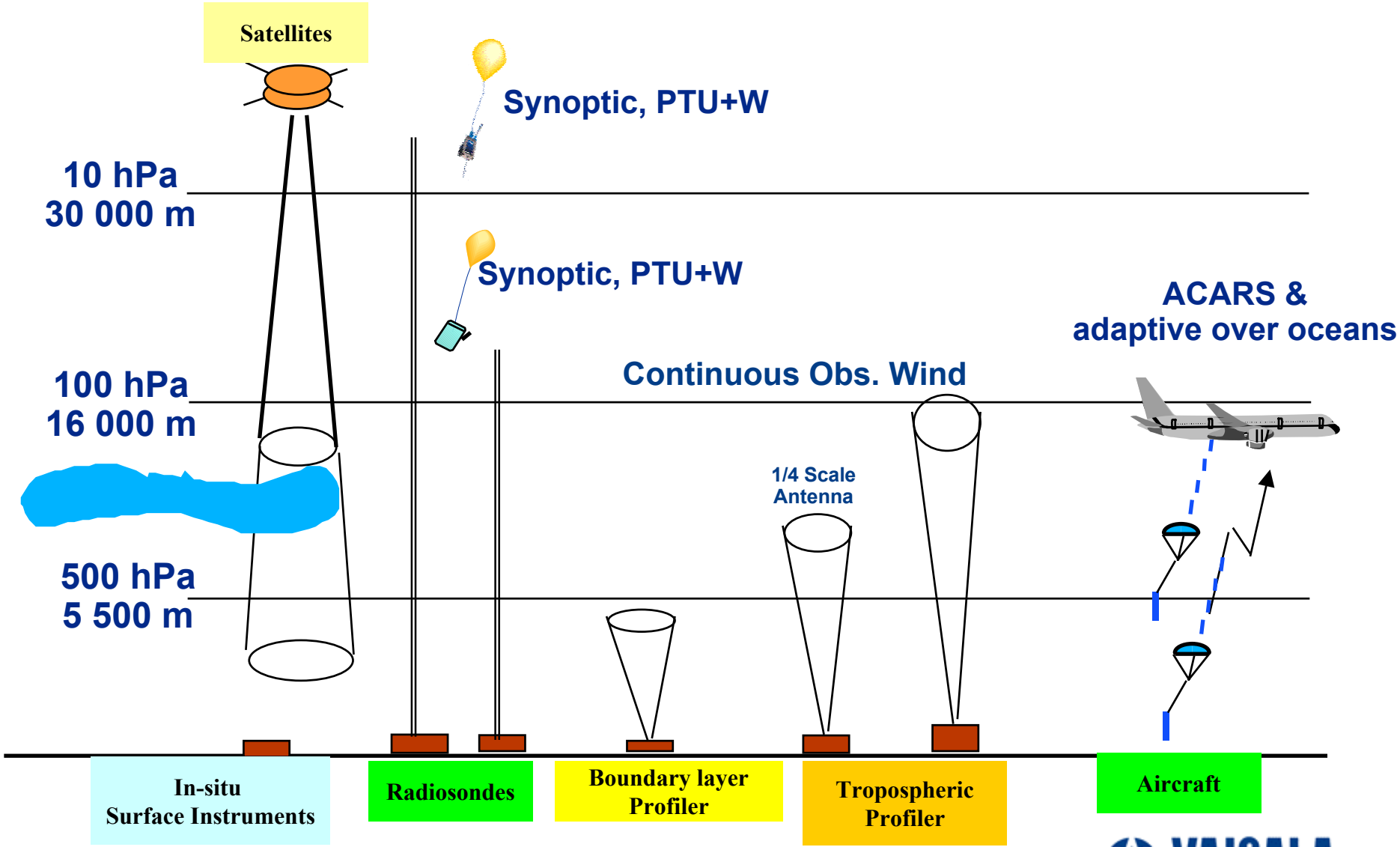
Observation Mix for Input to Numerical Models



What Value Do Wind Profilers Bring to Weather Forecasting?

With a continuous wind data input, you can run your models more often with better results.

As soon as a computer model is run it begins to degrade over time due to its inherent computational instability

Fresh observational data needs to be input continuously in order to run the model frequently

The new models can assimilate asynchronous data

Wind profilers are an important source of fresh data: their sampling period is as short as 6 minutes

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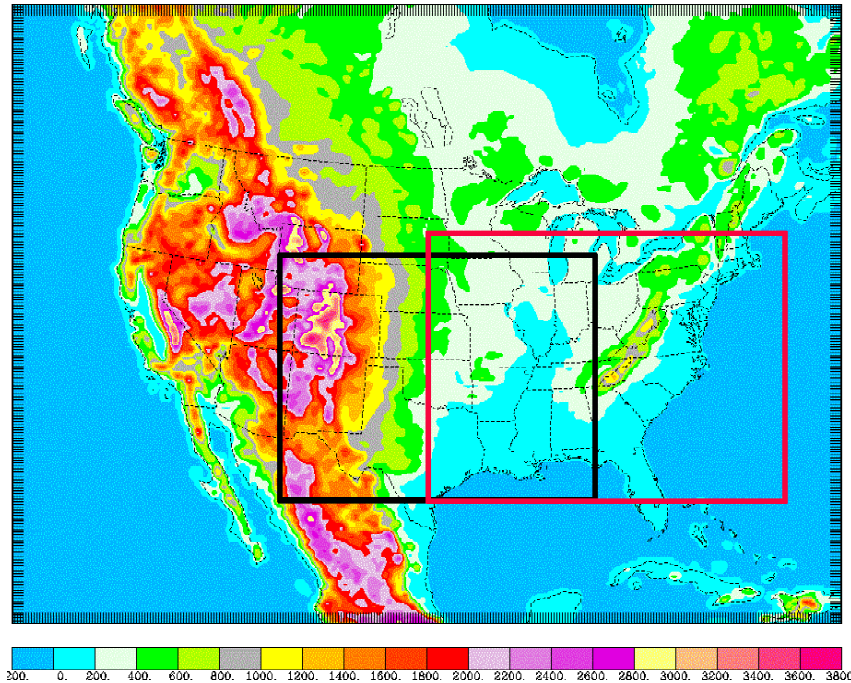
Positive Effects of Wind Profiler Data on Short-Range Numerical Weather Prediction

Profiler and ACARS denial experiments using 20km Rapid Update Cycle (RUC) 20-km model, 4 Feb - 16 Feb 2001

Effects measured over 3 sub-domains

- **Profiler domain (black)**
- **Downstream domain (red)**
- **RUC model domain (outer box)**



Three experiments performed at NOAA/FSL

- **CNTL: All data used (includes ACARS & VAD)**
- **EXP-P: All profiler data withheld**
- **EXP-A: All ascent/descent & flight-level ACARS data withheld everywhere in the RUC domain (VAD still present)**

Courtesy of NOAA/FSL Boulder CO, USA

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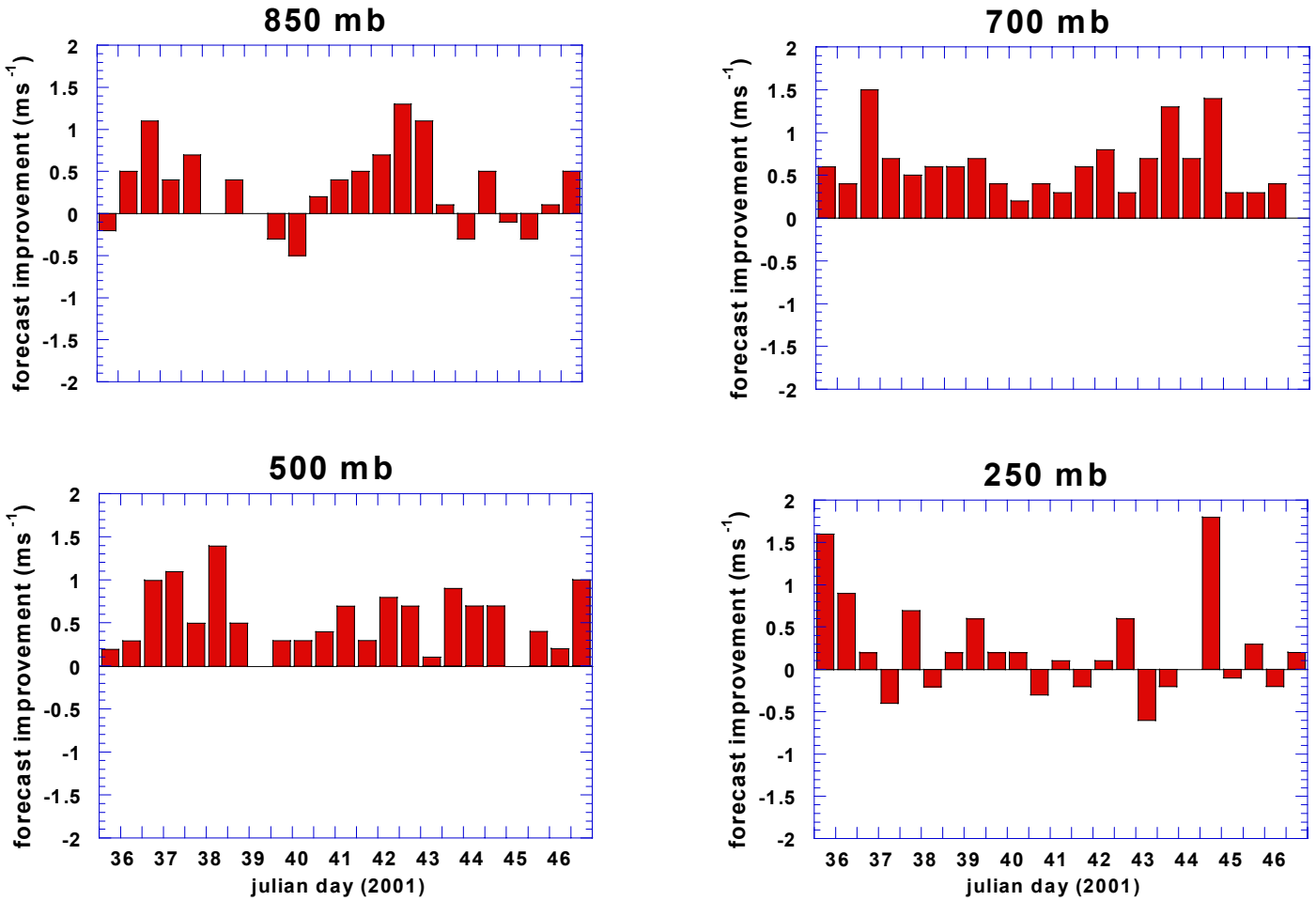
3-Hour Forecast Improvement By Isobaric (Pressure) Level



The forecast improvements achieved with wind profiler data are consistent over time

Courtesy of NOAA/FSL Boulder CO, USA

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Positive Effects of Wind Profiler Data

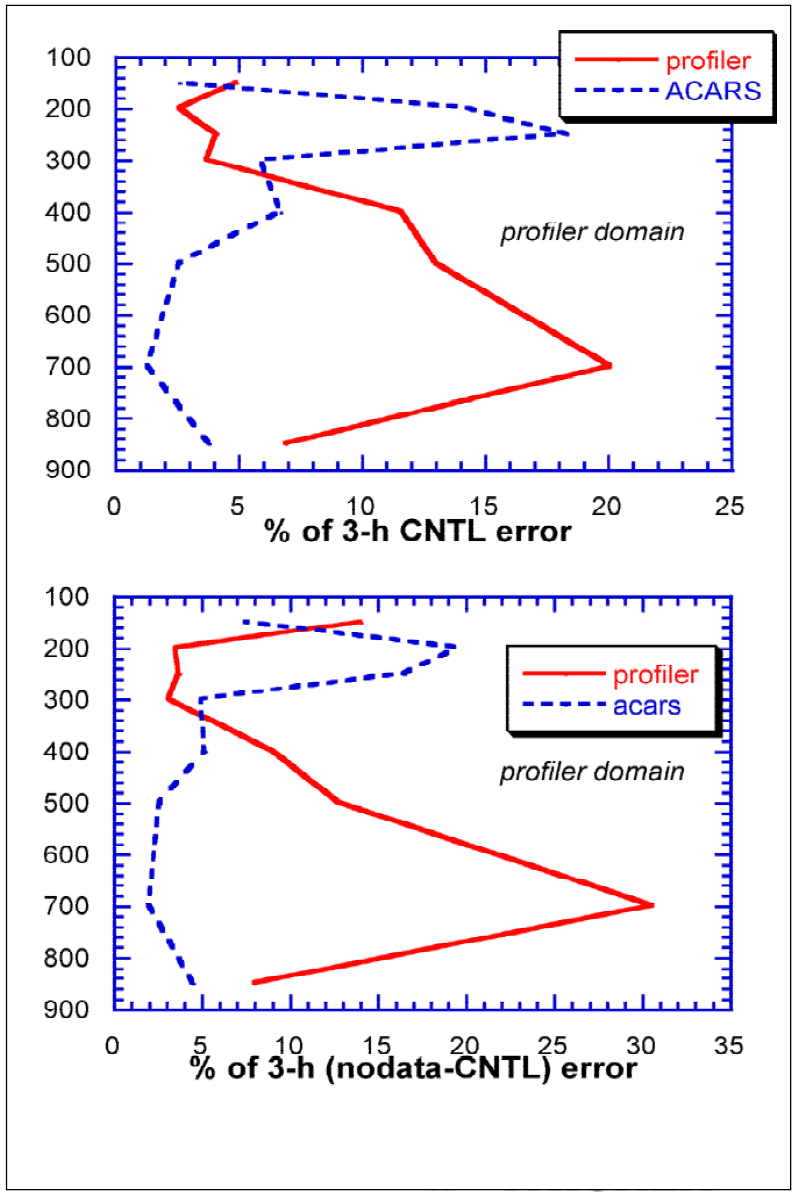
Profiler impact calibrated by the difference between 13-day experiments with all data and the CNTL experiment over the profiler domain: (EXP - CNTL) / (CNTL)

Profiler data accounts for as much as 20 – 30% of the improvement in 3-h wind forecasts in the low-mid troposphere.

ACARS data account for as much as 15 – 20% of the forecast improvement in a thin layer at jet levels where there are many ACARS reports.

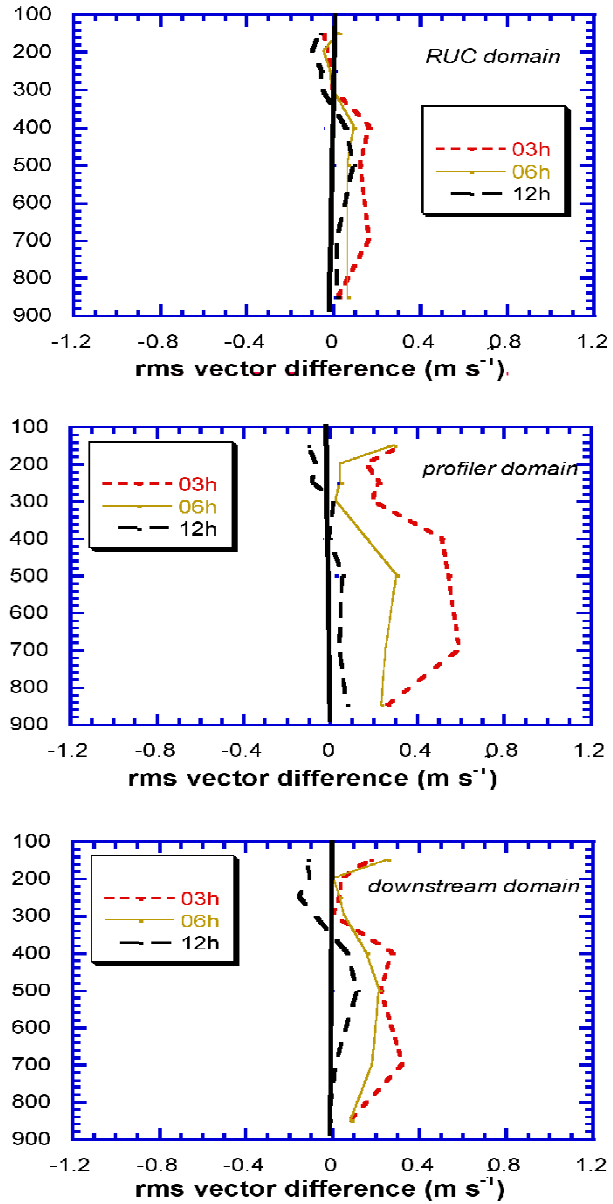
Profiler and ACARS are complementary data. They cannot substitute for one another.

Profiler impact calibrated by difference between 13-day experiments with all data and no observations over the profiler domain: (EXP - CNTL) / (NODATA - CNTL)



Courtesy of NOAA/FSL Boulder CO, USA

Positive Effects of Wind Profiler Data on Short-Range Numerical Weather Prediction



The positive differences show that the CNTL experiment using wind profiler data had fewer errors than the EXP-P "no-profiler" experiment.

<u>Note</u> that the positive effect diminishes with time as the wind profiler data are swept out of the Profiler Domain. For the same reason, wind profiler data have the greatest positive effect at the 12h-point over the Downstream Domain.

Courtesy of NOAA/FSL Boulder CO, USA

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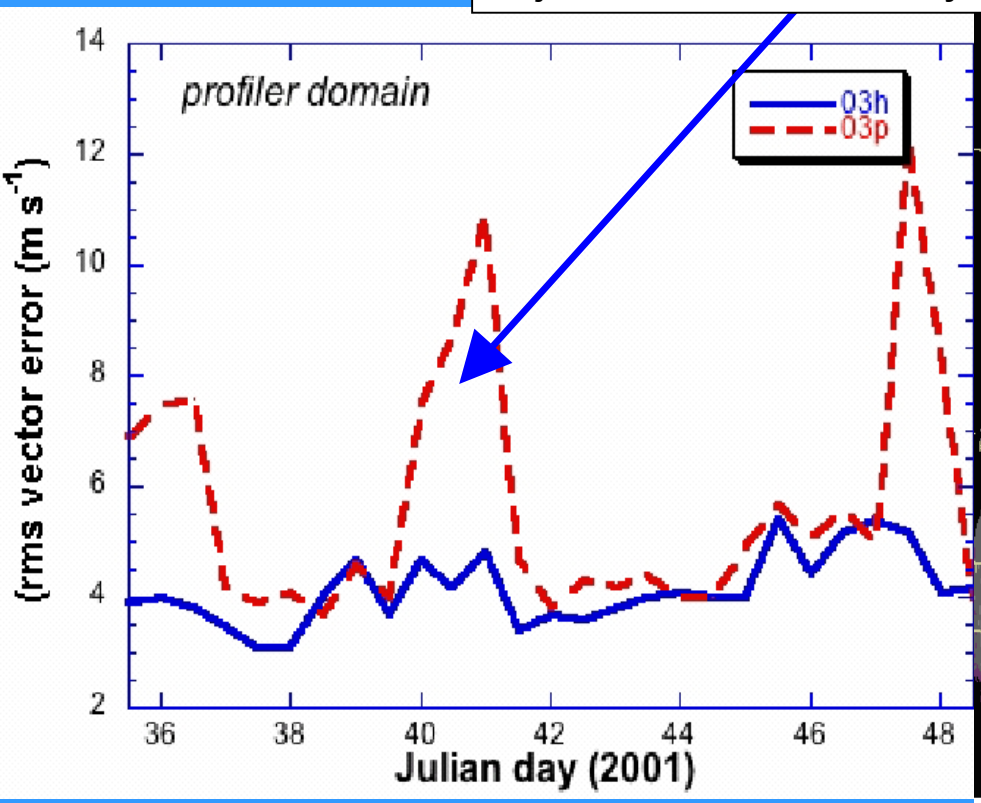
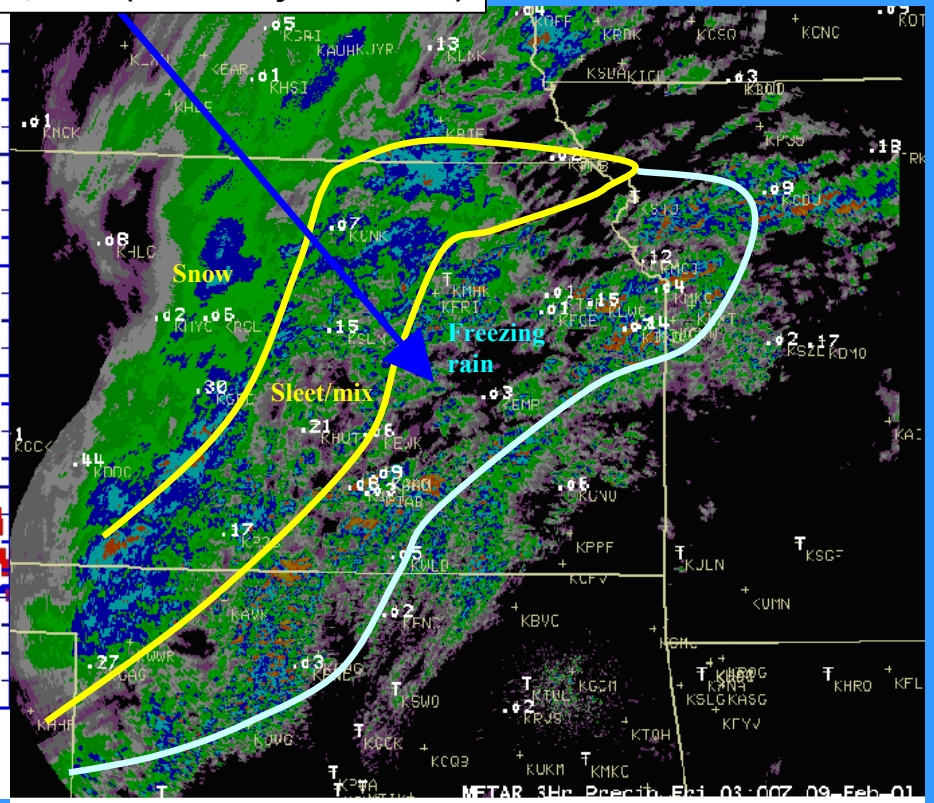
Value Brief

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 h
***more than 10 m/s* during changing weather**

Courtesy of NOAA/FSL Boulder CO, USA

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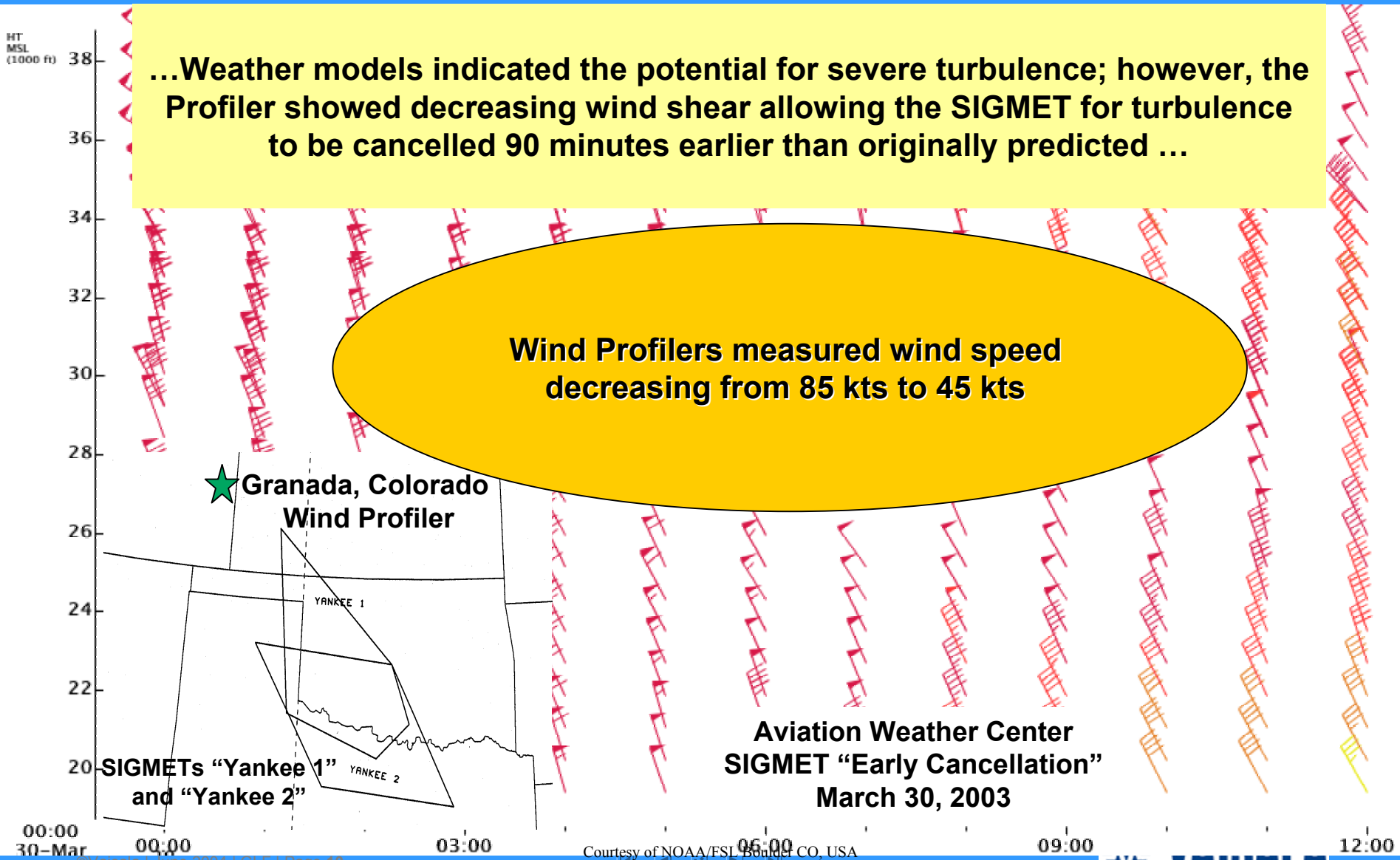
Additional Benefits – Aviation Forecasts

…Weather models indicated the potential for severe turbulence; however, the Profiler showed decreasing wind shear allowing the SIGMET for turbulence to be cancelled 90 minutes earlier than originally predicted …



Wind Profilers measured wind speed decreasing from 85 kts to 45 kts

Granada, Colorado Wind Profiler

SIGMETs "Yankee 1" and "Yankee 2"

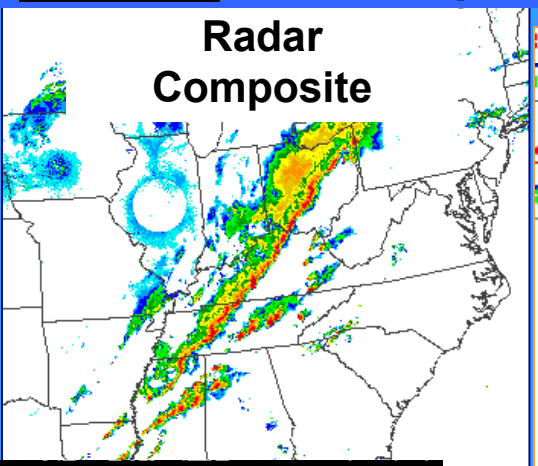
Aviation Weather Center SIGMET "Early Cancellation" March 30, 2003

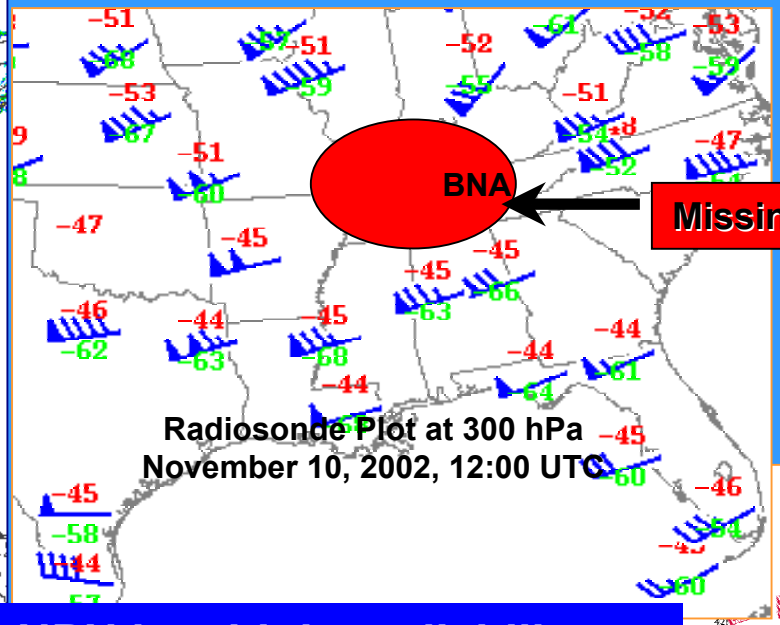
Courtesy of NOAA/FSL Boulder CO, USA

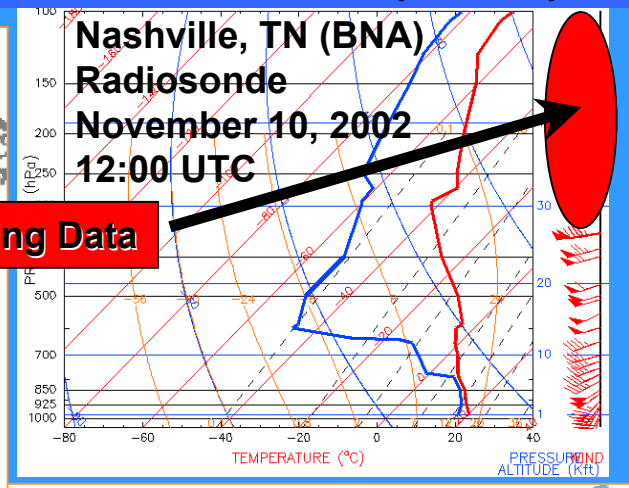
National Network

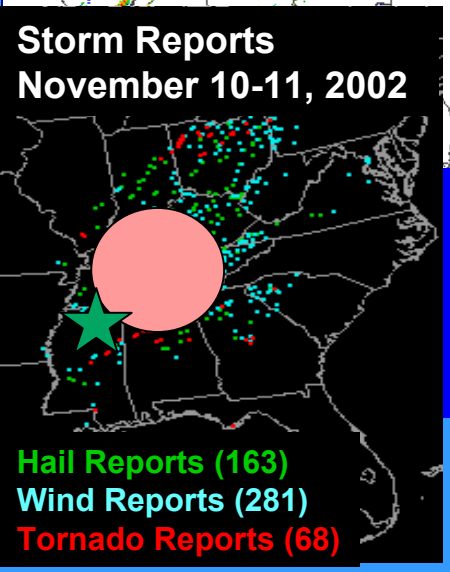
Additional Benefits - Enhanced Data Availability

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

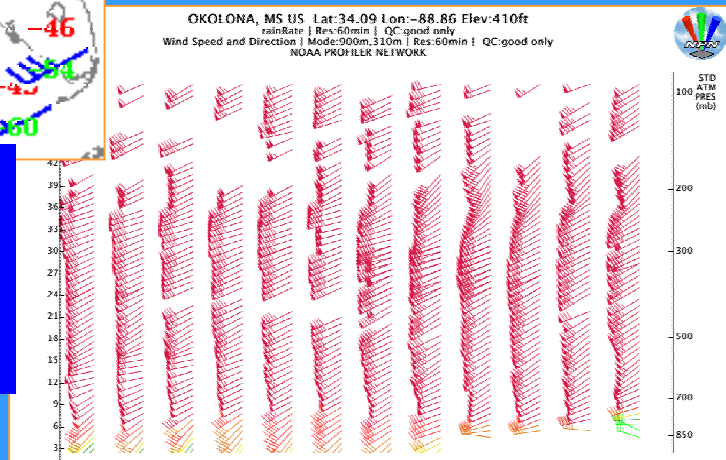








NPN has high availability during strong jet streams complimenting the radiosonde network



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

Courtesy of NOAA/FSL Boulder CO, USA

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.

Courtesy of NOAA/FSL Boulder CO, USA

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NPN Integration within NOAA

How NPN Fits in NOAA: *Integrated End-to-End*

- *Maintenance:* NPN Hub, NRC, NDBC, Regional HQs; MOAs in place
- *Training:* Part of Integrated Sensor Training, WDSS, Weather Event Simulator (WES), Visit View, Regional Electronic Technicians;
- *Operations:* Data integrated into NOAAPORT, Global Telecommunication System, NCEP NWP, and AWIPS;
- *Policy:* Integral component of *Central Region Best Practice* policy for enhancing "Situational Awareness"

Courtesy of NOAA/FSL Boulder CO, USA

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What Value Do Wind Profilers Bring to Weather Forecasting?

Wind profilers are an important source of meteorological data for numerical weather prediction at the *regional level*.

Wind profiler data can be used in order to calibrate regional weather forecasts against national weather models, in order to determine how well a national model forecast is performing

This “calibration” allows the regional forecaster to adjust weather forecasts accordingly

The continuous flow of wind profiler data can be used by regional forecasters to continuously “nudge” their models towards the “correct” forecast

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Local and Regional Weather Forecasters Can Use Wind Profilers To...

- "Calibrate" their numerical models and adjust forecasts accordingly
- Predict local maximum winds for the day
- Predict the movement of toxic/hazardous particles as well as smoke caused by wildfires and prescribed burns
- Predict severe weather such as thunderstorms and tornadoes
- Predict the dissipation of fog
- Improve the monitoring and prediction of mesoscale and local weather events
  - US National Weather Service conclusions for wind profiler usage:
    - Tornado Warning Lead Times improved by 3 minutes (38%)
    - Flash Flood Warning Lead Times improved by 8 minutes (18%)
- Predict the type, nature, and intensity of precipitation in mountainous regions

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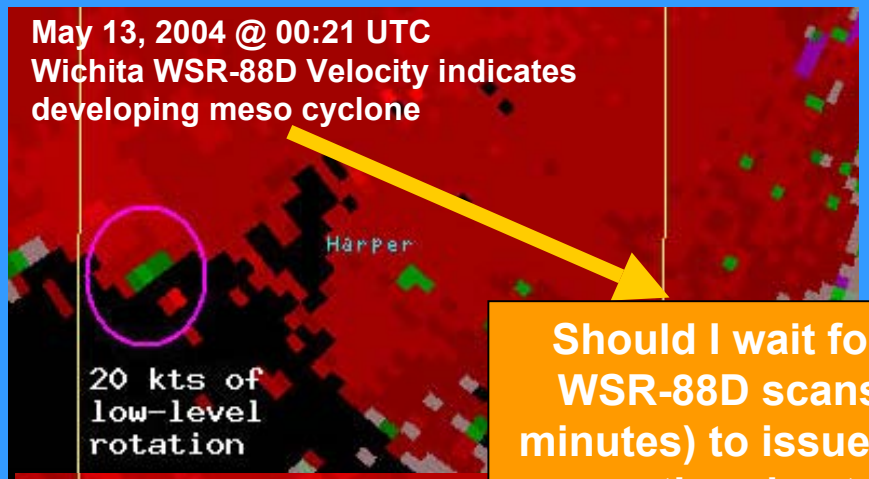
Harper County, Kansas Tornado May 12, 2004

Value Brief

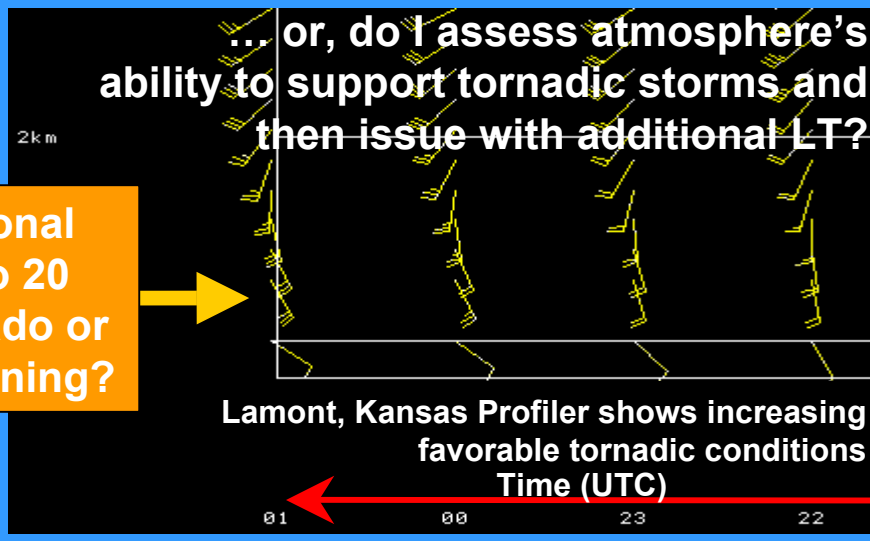
How WFOs use Profiler Data in Tornadic Situations

"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



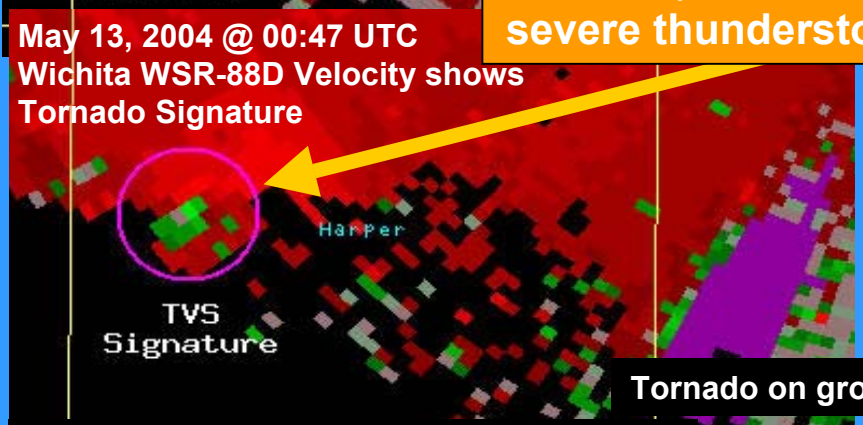
May 13, 2004 @ 00:21 UTC
Wichita WSR-88D Velocity indicates developing meso cyclone

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



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

Lamont, Kansas Profiler shows increasing favorable tornadic conditions
Time (UTC)



May 13, 2004 @ 00:47 UTC
Wichita WSR-88D Velocity shows Tornado Signature

Tornado on ground 00:53 UTC

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

Waiting: 5-10 Minute Lead Time

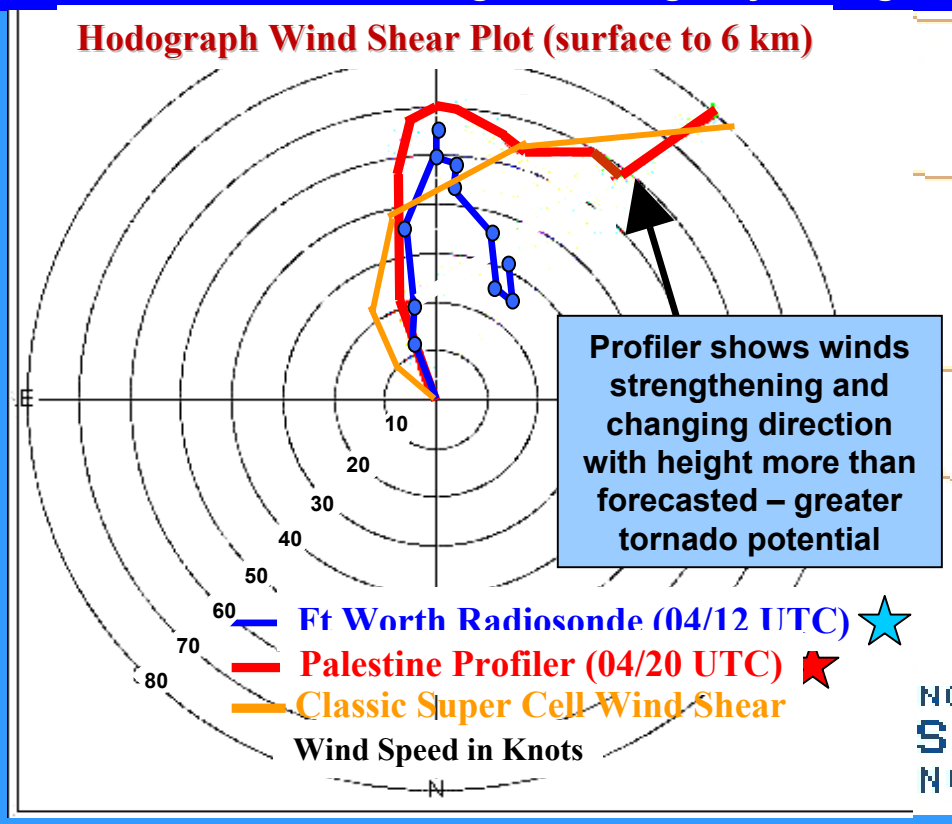
Use Situational Awareness: 26 Minutes Lead Time

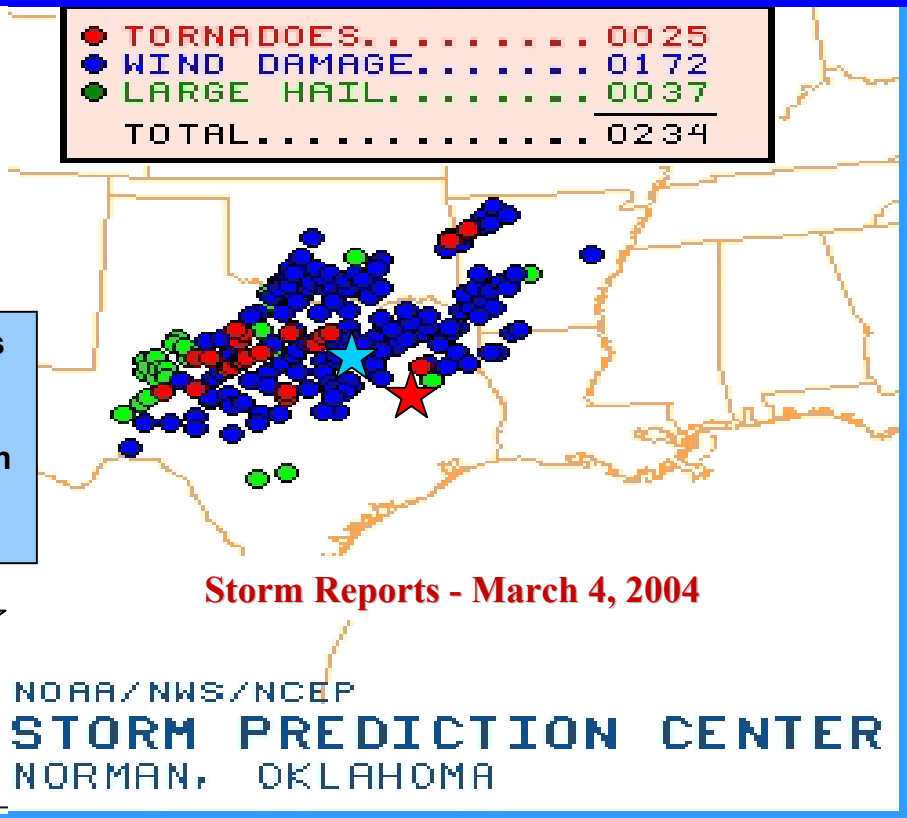
Courtesy of NOAA/FSL Boulder CO, USA

How WFOs use Profiler Data in Tornadic Situations

North Texas Severe Thunderstorm Outbreak March 4, 2004

"…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 …"





Courtesy of NOAA/FSL Boulder CO, USA

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

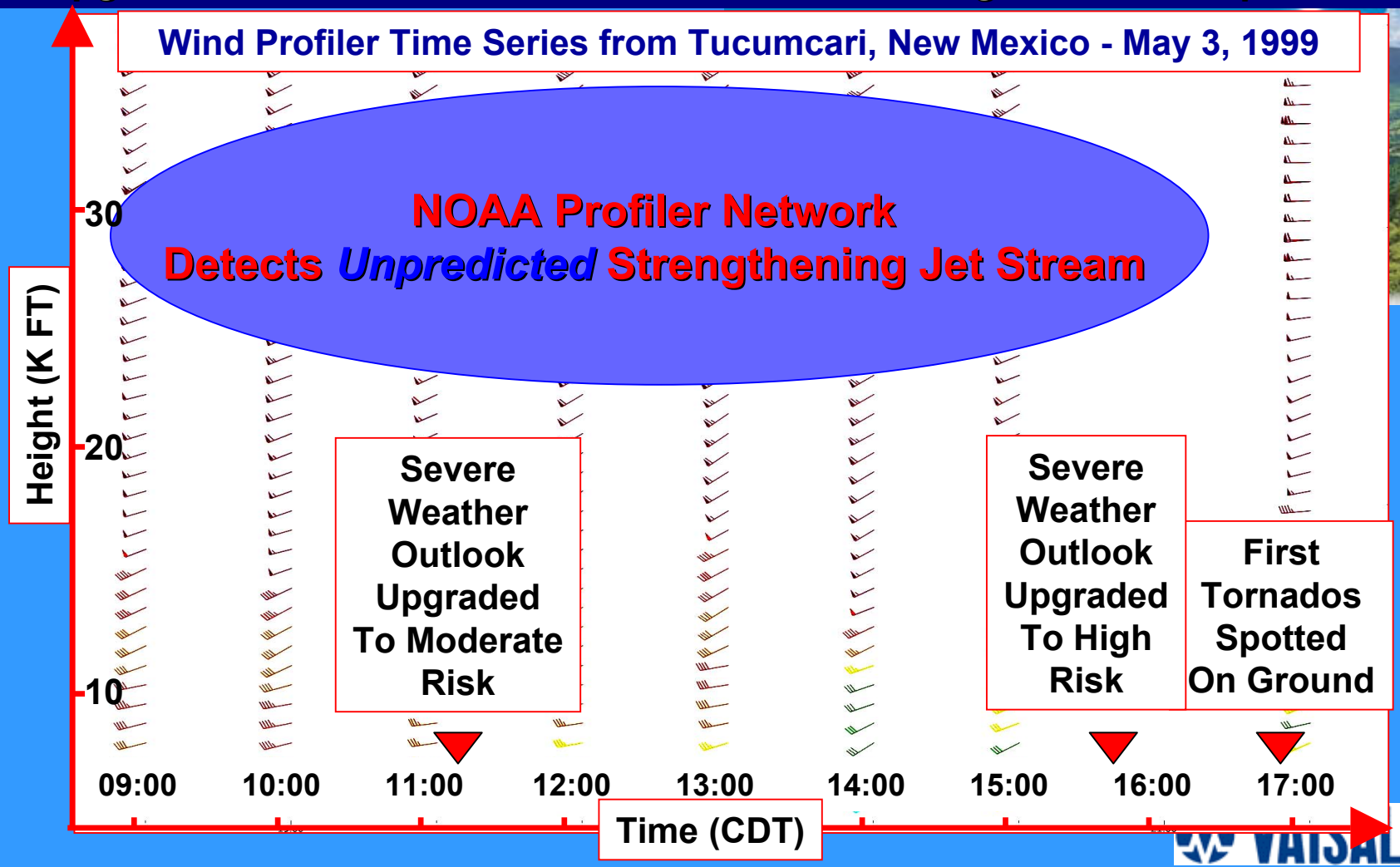
Warning Event Simulation Experiment

Courtesy of NOAA/FSL Boulder CO, USA

Value Brief

How SPC uses Profiler Data in Convective Situations

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

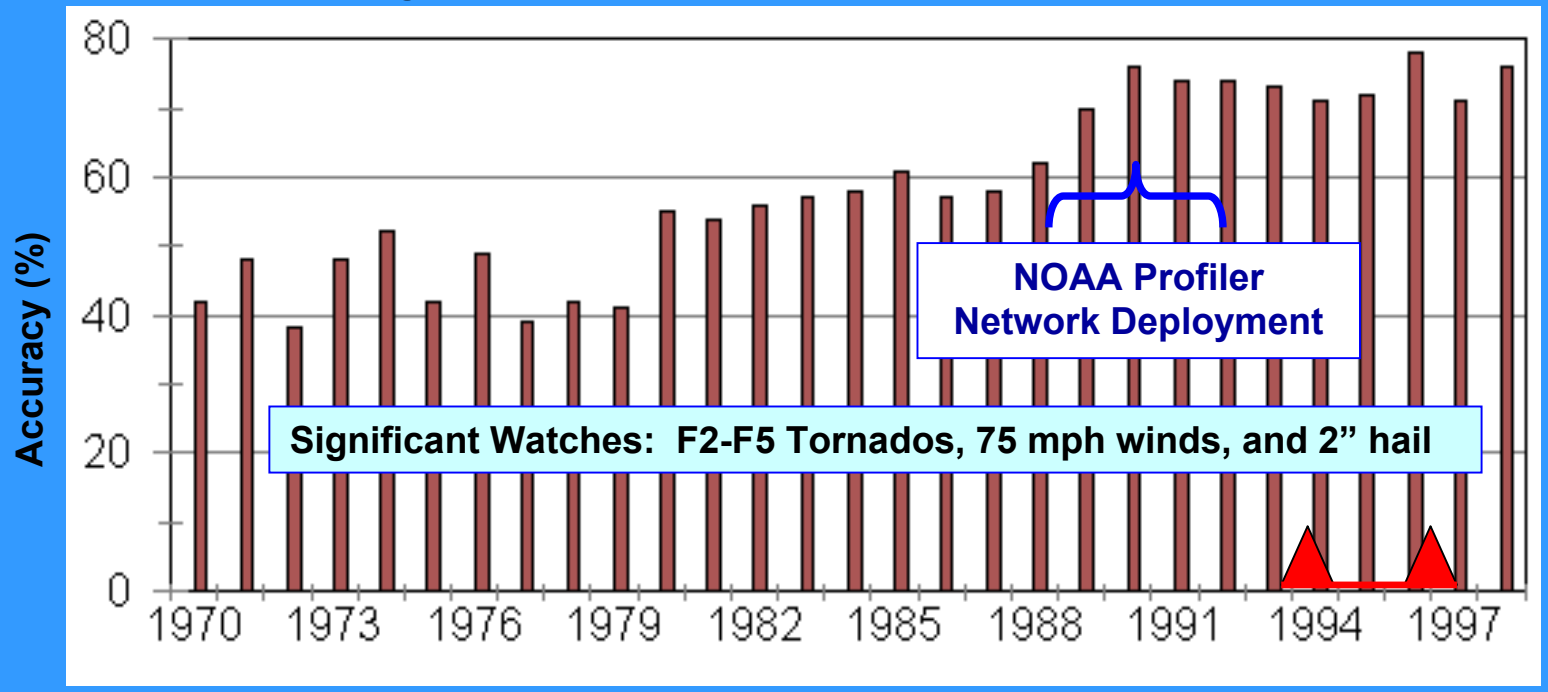


Courtesy of NOAA/FSL Boulder CO, USA

Value Brief

Performance

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



Deployment and Commissioning of WSR-88D system

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

Courtesy of NOAA/FSL Boulder CO, USA

Projected Benefits of a National Network

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

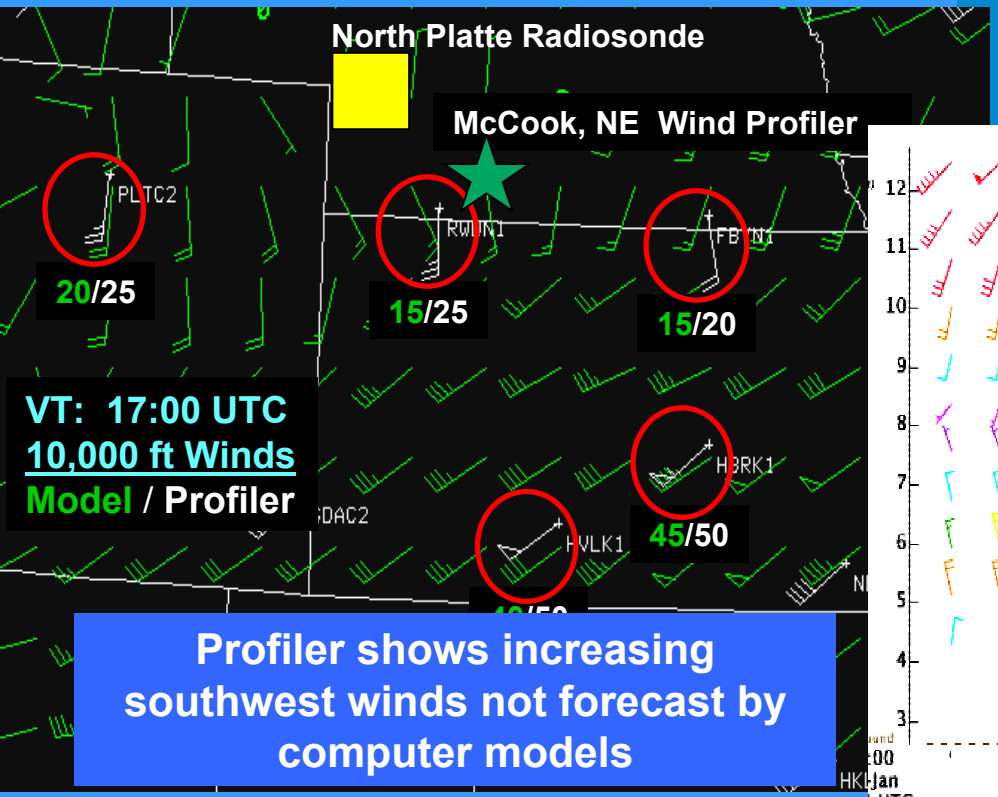
Courtesy of NOAA/FSL Boulder CO, USA

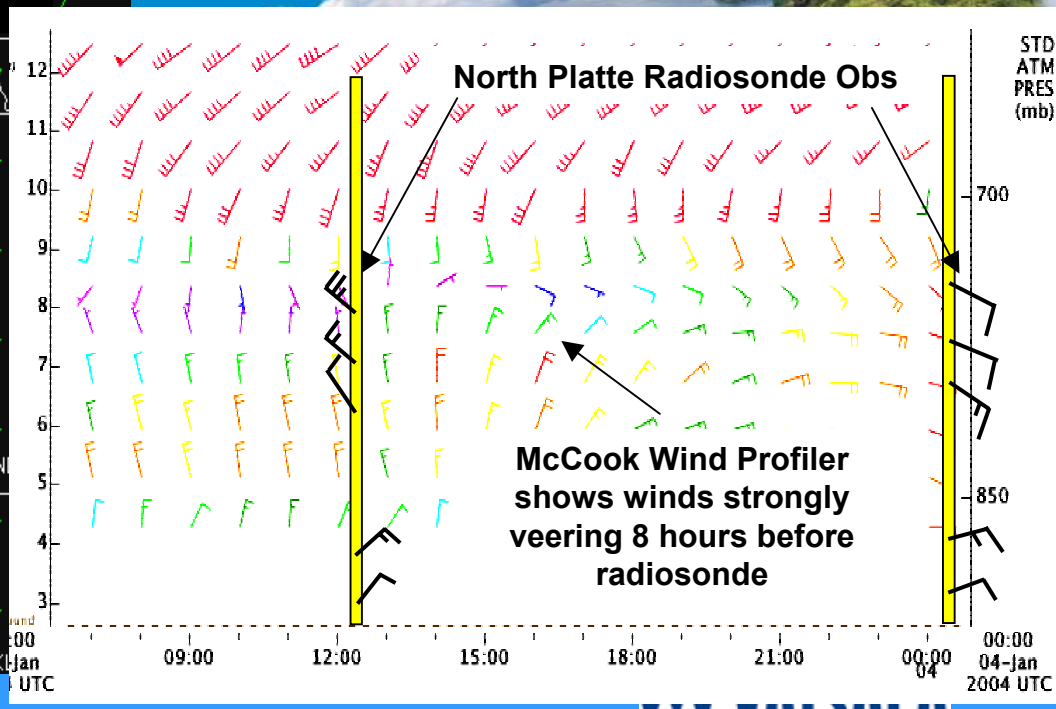
WFO Hastings, Nebraska Heavy Snow Warning, January 3-4, 2004

Value Brief

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"



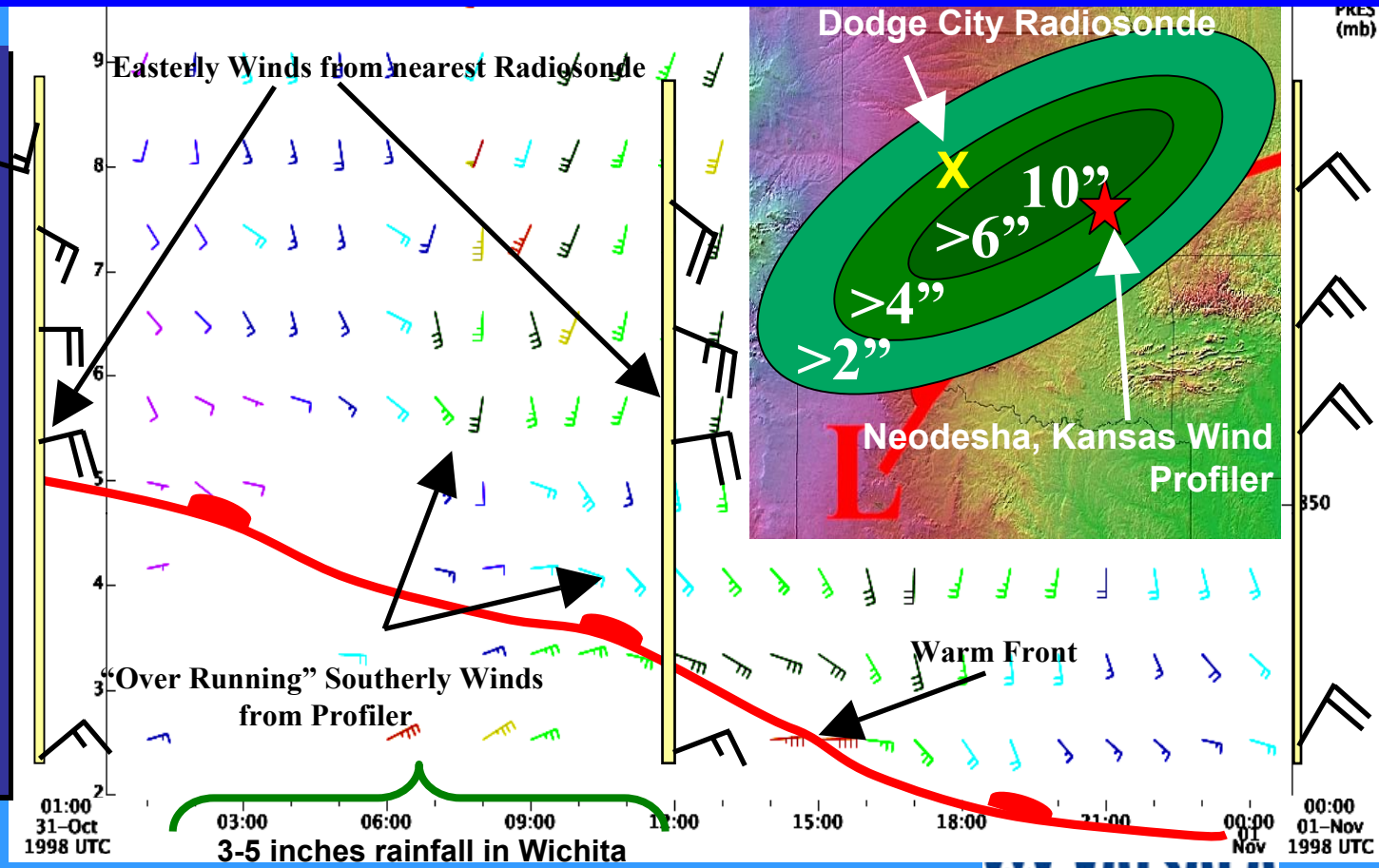


Courtesy of NOAA/FSL Boulder CO, USA

Wichita, Kansas Flood Halloween, 1998

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**



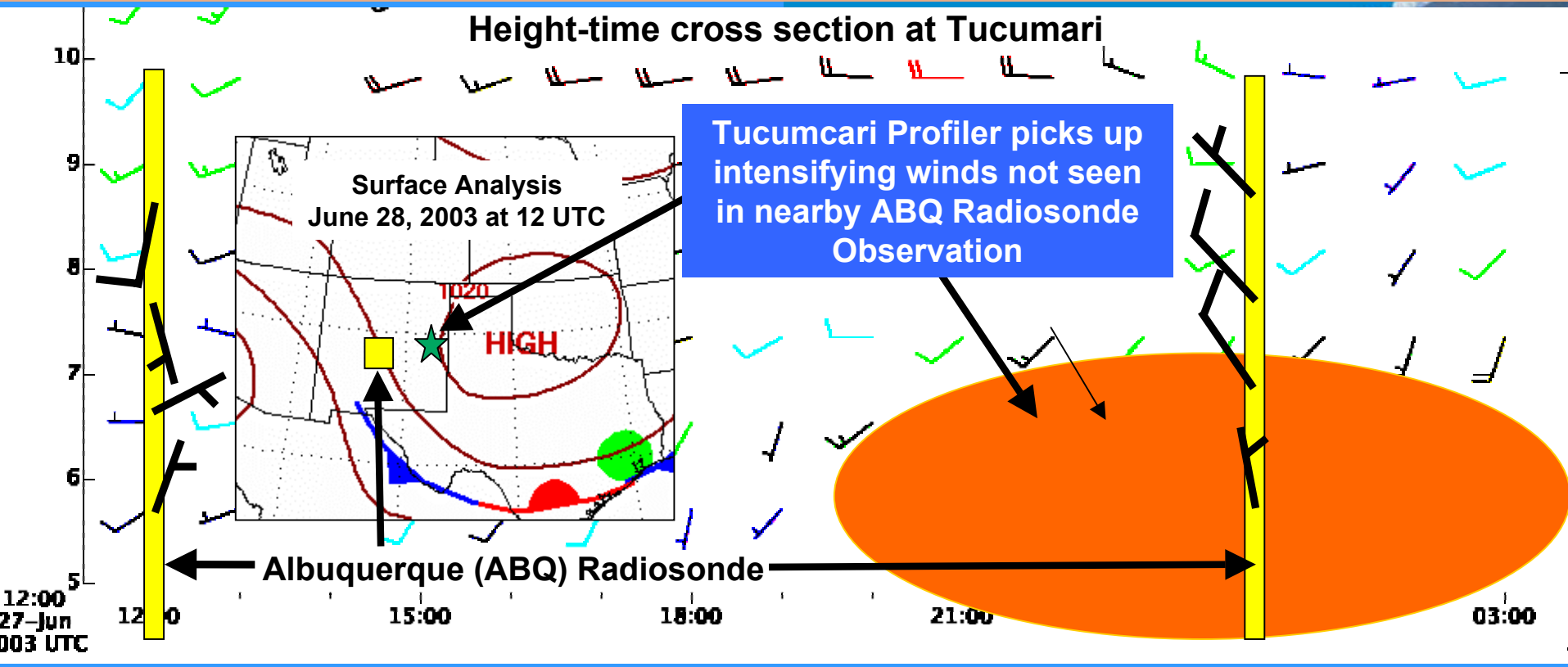
Courtesy of NOAA/FSL Boulder CO, USA

Albuquerque, NM, Wildland Fire, June 27, 2003

Value Brief

How WFOs use Profiler Data in Fire Weather Situations

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



"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."

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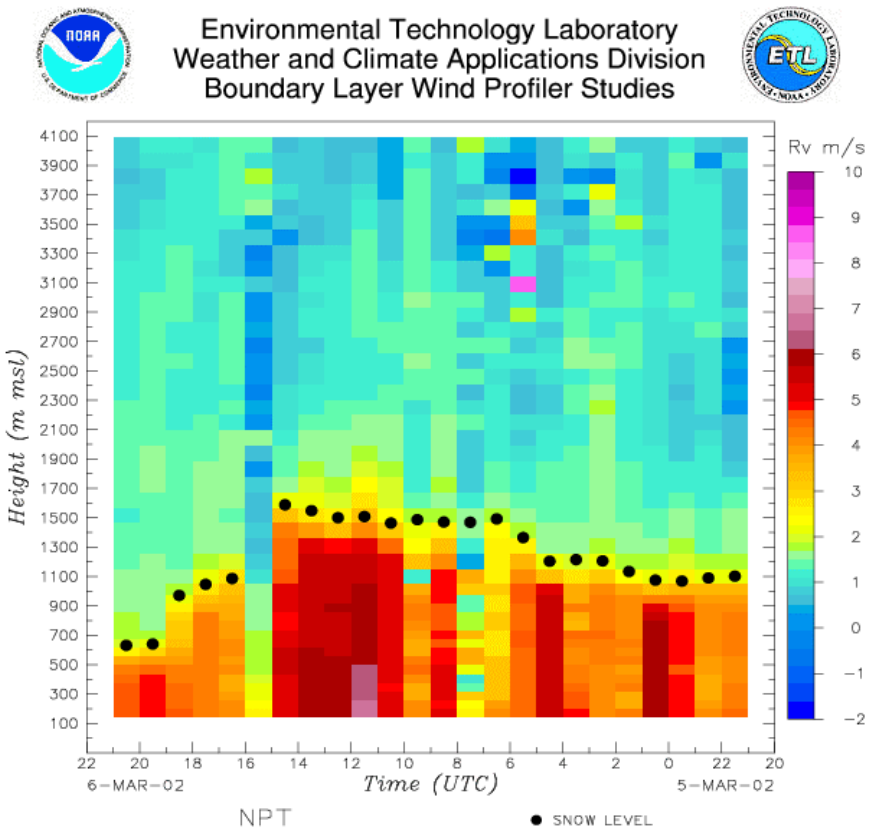
Courtesy of NOAA/FSL Boulder CO, USA

Precipitation Intensity Can Be Determined by Wind Profiler-Based, Snow-Level Determination Algorithms



Time (UTC)	2030	1930	1830	1730	1630	1530	1430	1330	1230	1130	1030	0930
Snow Level (m)	631	640	971	1046	1086	none	1588	1548	1500	1508	1464	1487
Snow Level (ft)	2069	2099	3184	3430	3562	none	5208	5077	4919	4946	4801	4877
Sfc Temp (C)	6.02	6.18	6.24	5.97	6.31	6.87	7.23	7.43	9.44	9.92	10.04	10.14

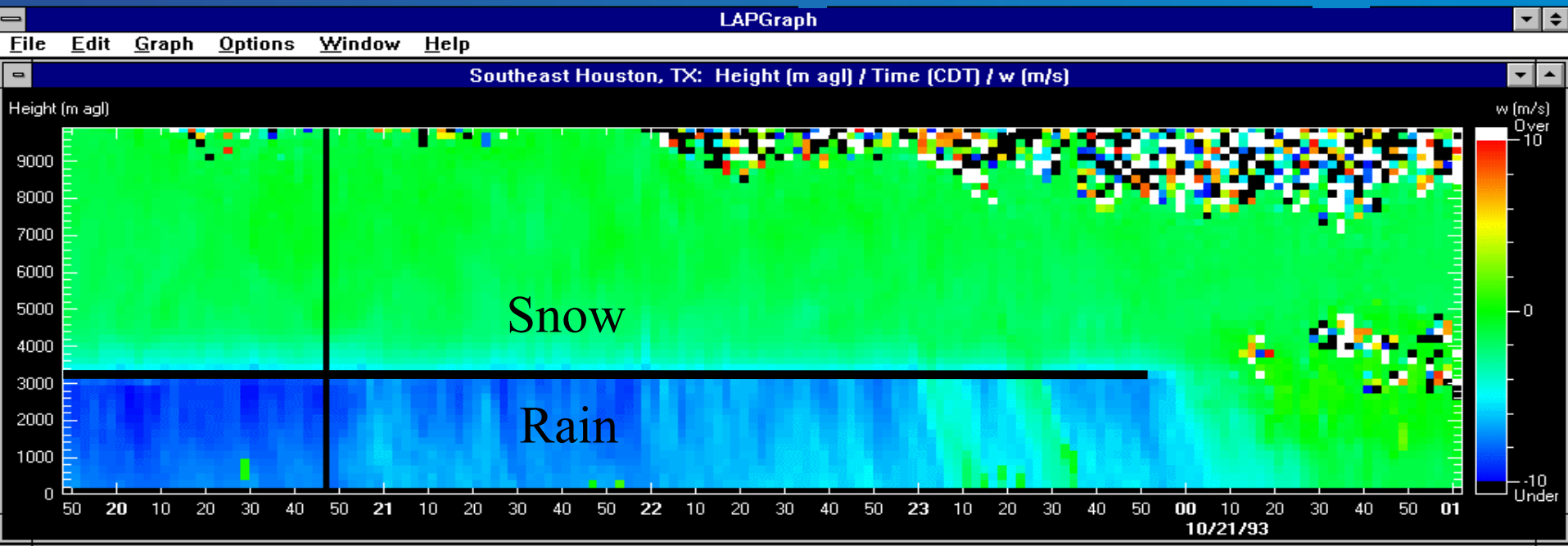
Time (UTC)	0830	0730	0630	0530	0430	0330	0230	0130	0030	2330	2230	2130
Snow Level (m)	1471	1469	1492	1365	1204	1215	1206	1134	1075	1069	1090	1102
Snow Level (ft)	4824	4818	4893	4477	3949	3985	3955	3719	3525	3506	3575	3614
Sfc Temp (C)	10.02	7.28	7.25	7.36	7.31	7.30	7.80	8.41	8.55	8.13	8.72	9.06

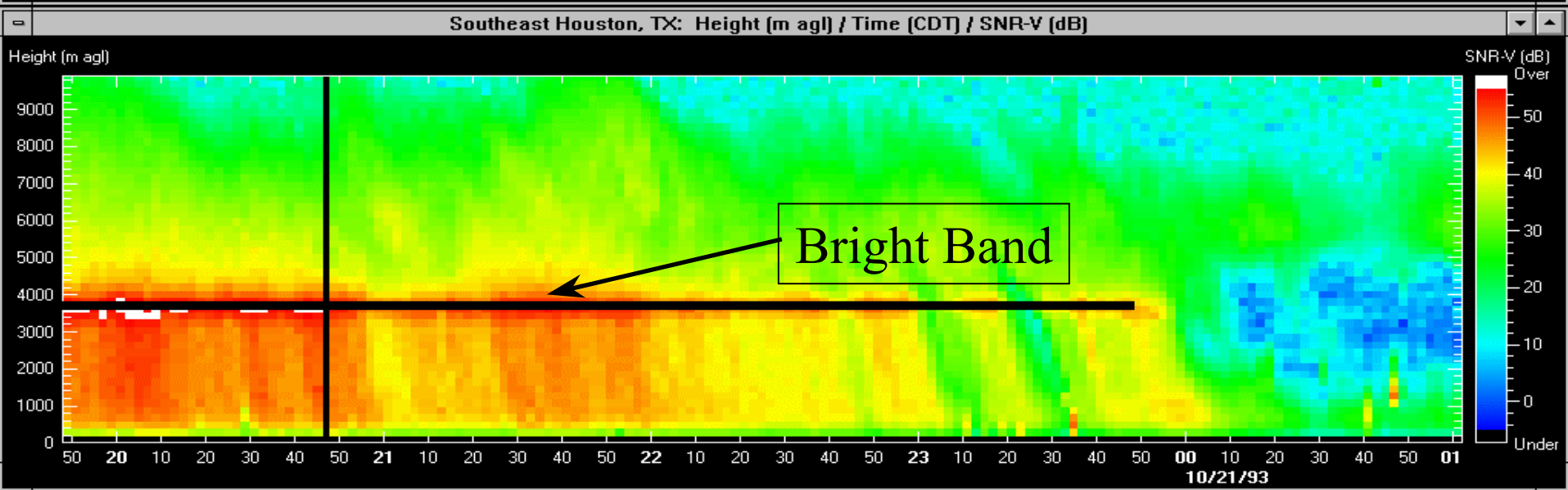
Background field of consensus Doppler vertical velocity (Rv, positive downward) showing the transition from snow to rain.

The snow-level estimates from the algorithm are indicated by the black dots. The table, which was added at the request of NWS weather forecasters, lists the snow level along with the surface temperature measured by a met station collocated with the wind profiler.

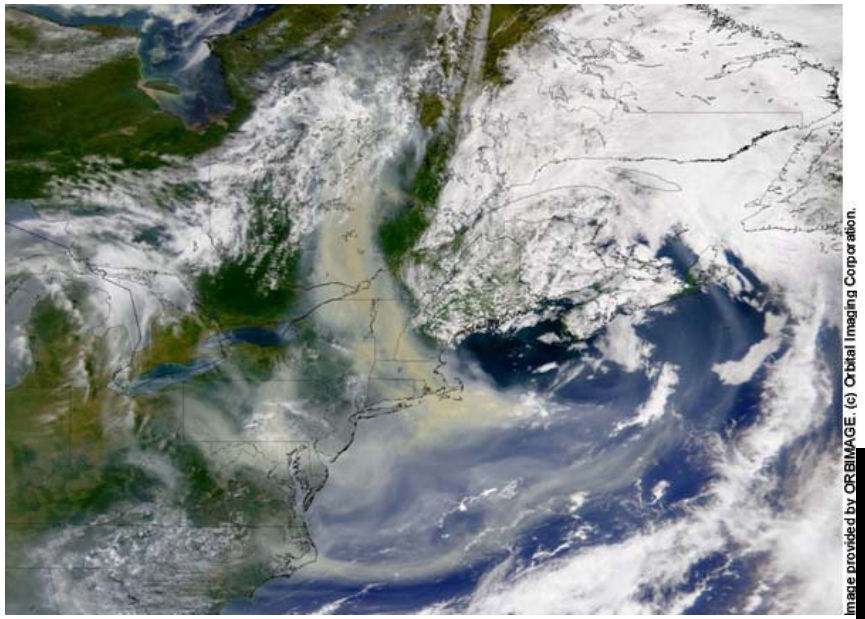
Courtesy of NOAA/ETL Boulder CO, USA

Freezing Level Can Be Determined Using Vertical Velocity and Reflectivity Data Gathered With Wind Profilers



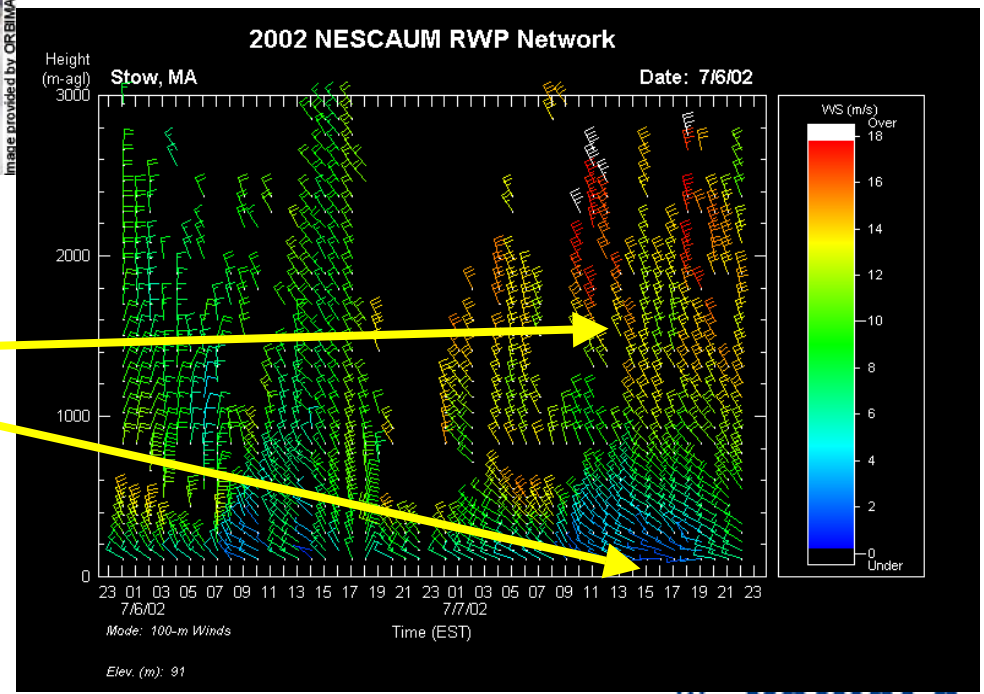


Movement of Smoke/Toxics Can Be Determined With Wind Profiler Data

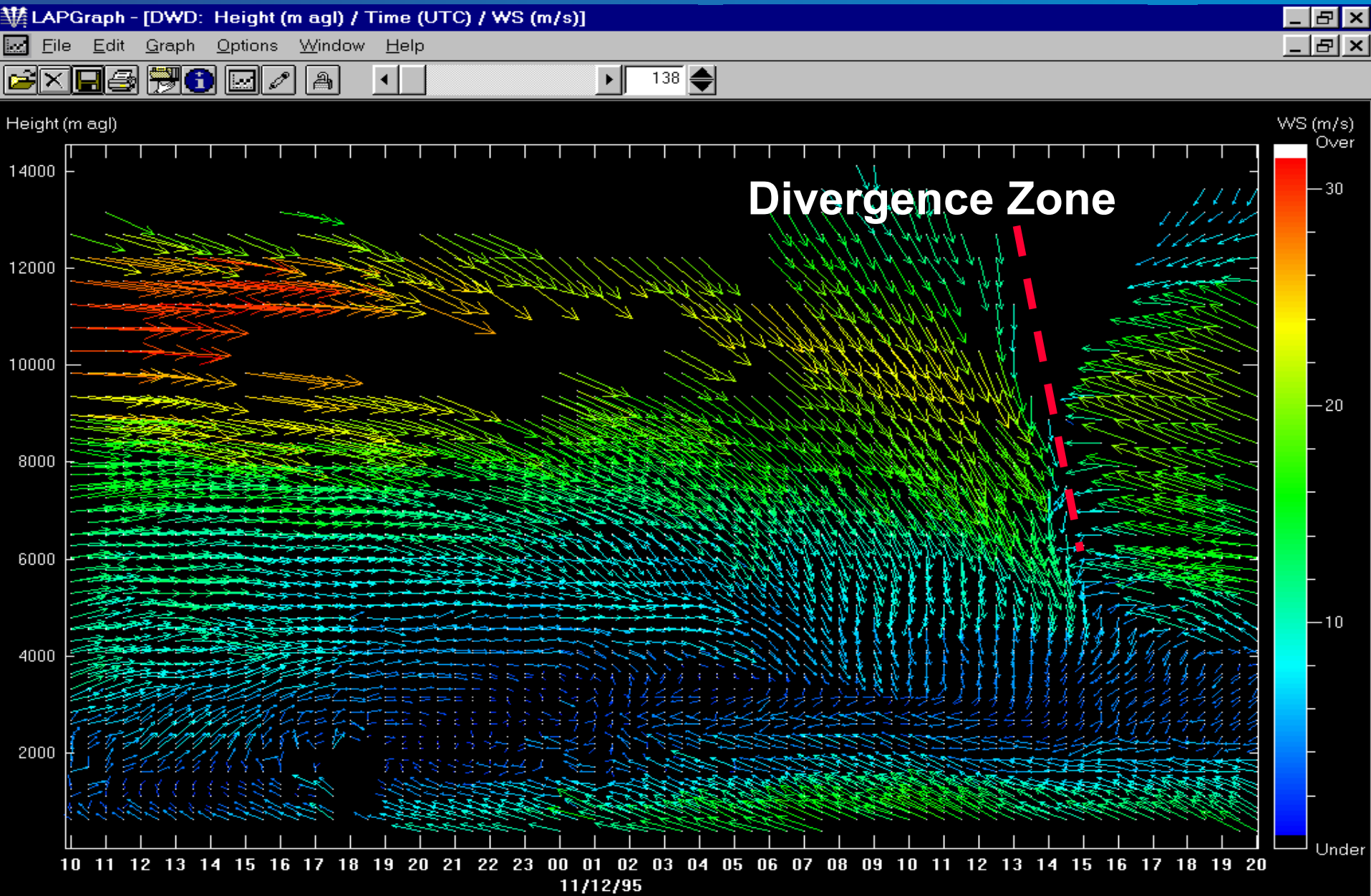


Quebec (Canada) forest fires of July 7, 2002. Wind profiler data was the key to making accurate forecasts.

NW flow within the ABL
& stronger NW flow aloft



Wind Profiler Detection of Divergence Zone Aloft



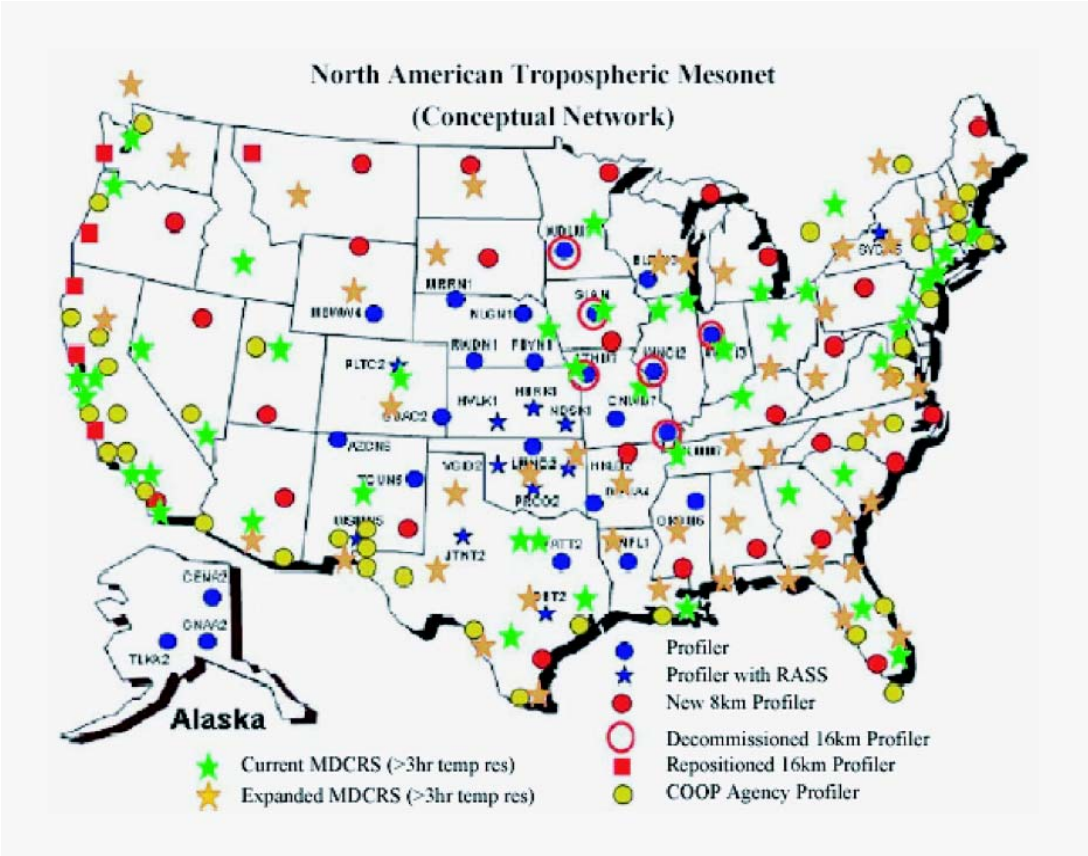
Mesonets Allow High-Resolution Weather Models To Be Updated Frequently

... As in the Japanese boundary layer wind profiler network:

Courtesy of NOAA/FSL Boulder CO, USA

Mesonets Provide Significant Network Capability in Limited Regions

...As in the North American wind profiler network, which is composed of a number of different wind profilers with different performance characteristics



The future US National Wind Profiler Network will comprise a three-tiered wind profiling system:

1) Current tropospheric profilers modified to operate at 449 MHz with some relocations

2) LAP®-3000 wind profilers as part of the expanded cooperative wind profiler program (CAPS)

3) Newly acquired mid-tropospheric 449 MHz wind profilers

Courtesy of NOAA/FSL Boulder CO, USA

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Mesonets Provide Significant Network Capability in Limited Regions

...As with the European CWINDE wind profiler network, also equipped with various wind profilers having different performance characteristics:

Courtesy of The Met Office, UK

Conclusions

Wind profilers support a broad range of weather forecasting activities:

- They increase the data input to numerical models
- They allow numerical models to be updated much more often
- They are used to “calibrate” numerical forecast model output in real-time
- They boost the value of local forecast products such as maximum winds, fog dissipation, precipitation in heavy terrain, etc.
- They allow more accurate forecasts to be made to support the transportation of toxic/hazardous materials in particular regions (homeland defense)

Wind profilers provide a continuous flow of vital weather data with very little need for human intervention.

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