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Ahead of the Weather

Humidity Mapping and High-Impact Weather Prediction

Met Tech World Expo Conference

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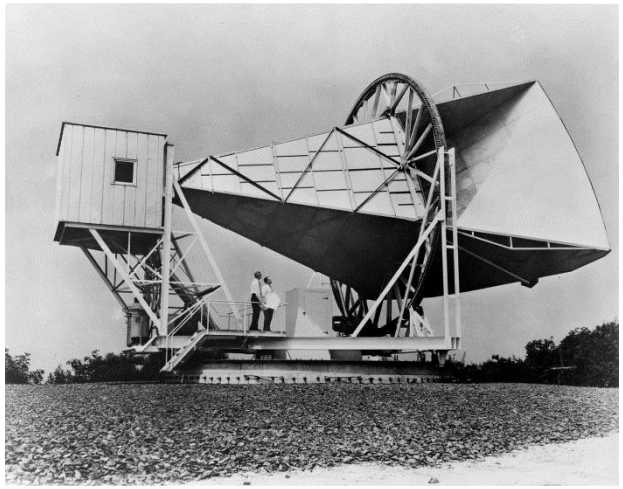
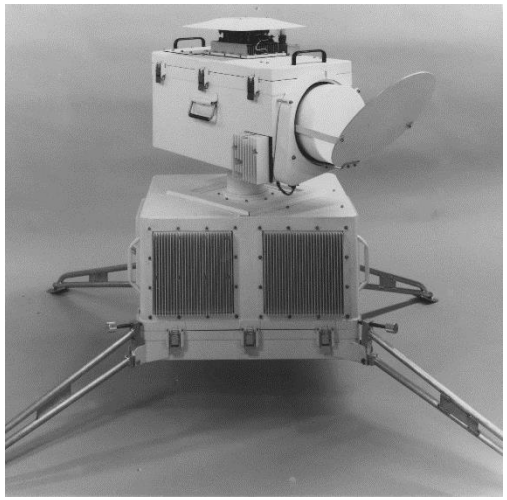


1963 Bell Labs

1978 NOAA Labs



1986 NASA JPL

1990 Radiometrics

2005 Radiometrics

2008 Radiometrics

Thermodynamic Profiler Evolution

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Basic Physics and Retrieval Method

- Multi-channel microwave observations are converted to brightness temperatures using the Planck Radiation Equation
- Air temperature, humidity and liquid are linked to brightness temperatures by Radiative Transfer Equations
- Neural Networks convert brightness temperatures to temperature, humidity and liquid profiles

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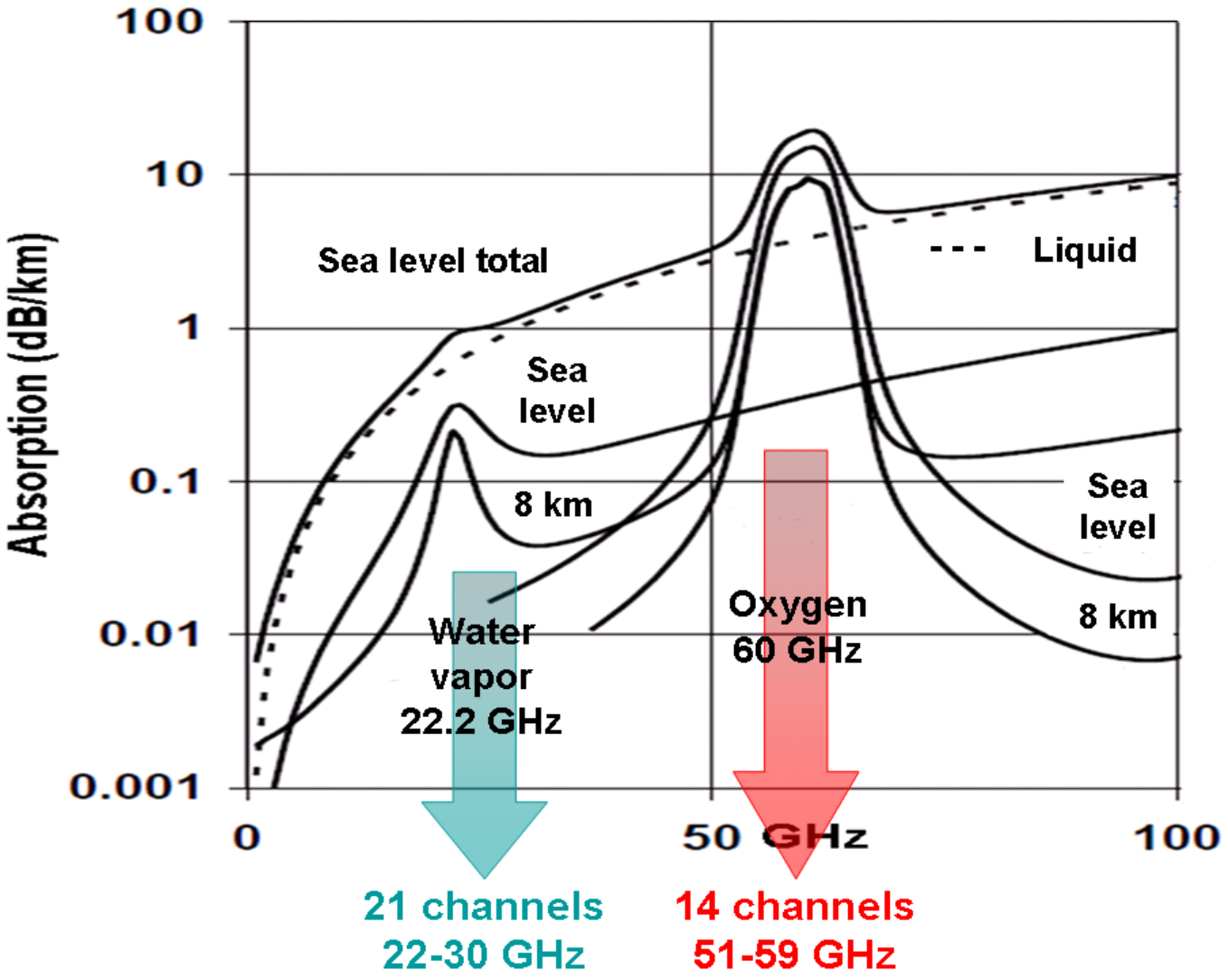

Absorption spectrum of a typical mid-latitude atmosphere
for two altitudes and two water vapor densities

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Planck Radiation Equation:

$$B_\nu(T) = \frac{2h\nu^3}{c^2} \frac{1}{(\exp(h\nu/kT) - 1)}$$

Chandrasekar Radiative Transfer Equation:

$$B_\nu(T_b) = B_\nu(T_c)\exp(-\tau_\nu) + \int_0^\infty B_\nu(T(s))\,\alpha_\nu(s)\exp(-\int_0^s \alpha_\nu(s')ds')\,ds$$

Westwater et al., Principles of Surface-based Microwave and Millimeter wave Radiometric Remote Sensing of the Troposphere, Quaderni Della Societa Italiana Elletromagnetismo, 2005 (http://radiometrics.com/wp-content/uploads/2013/02/Westwater_QSIE_2005.pdf).

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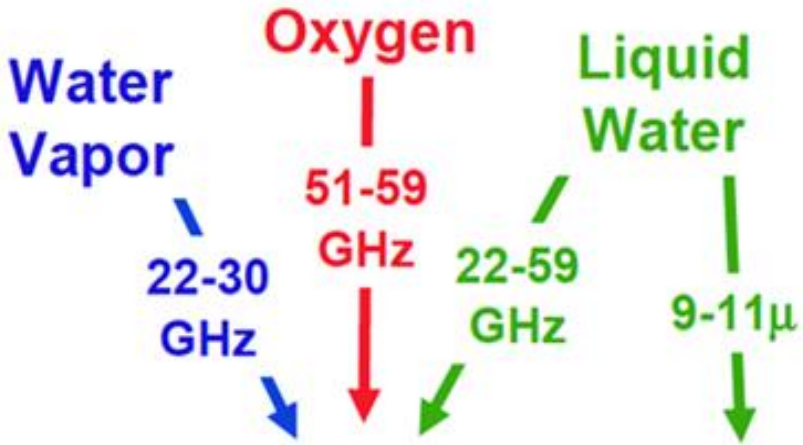
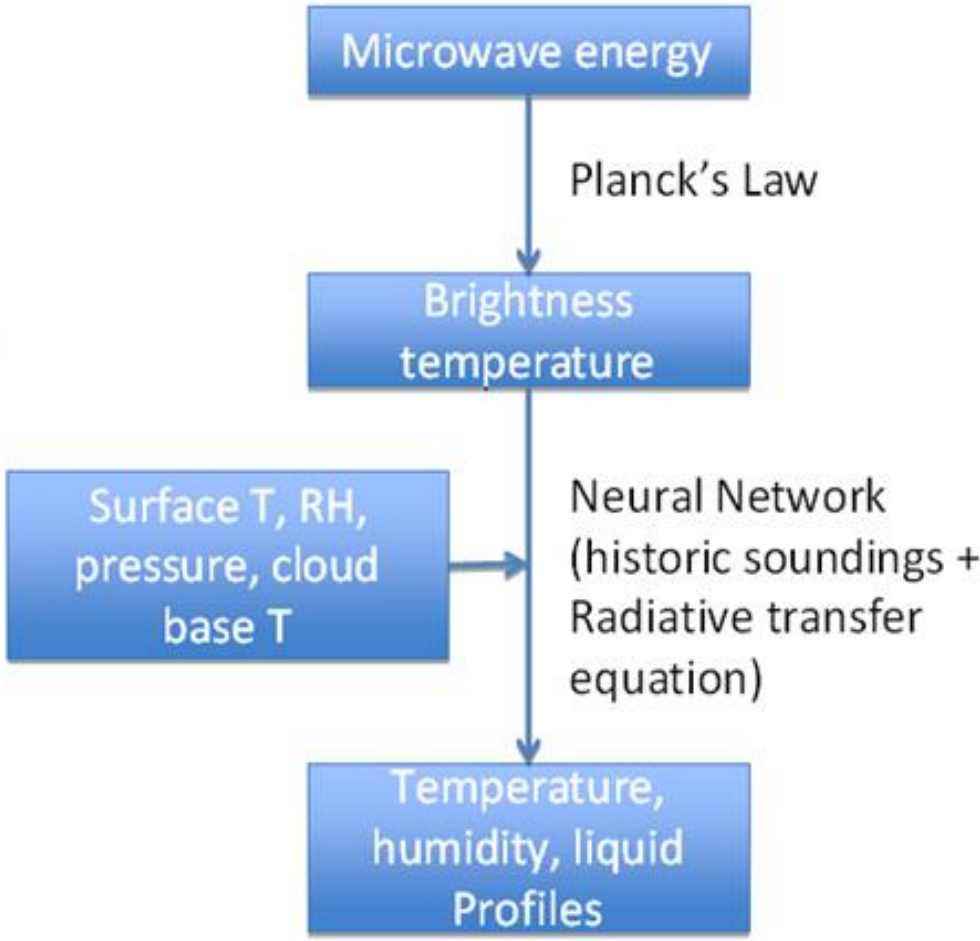


Microwave and infrared emission from air are converted into **temperature**, **humidity** and **liquid** profiles



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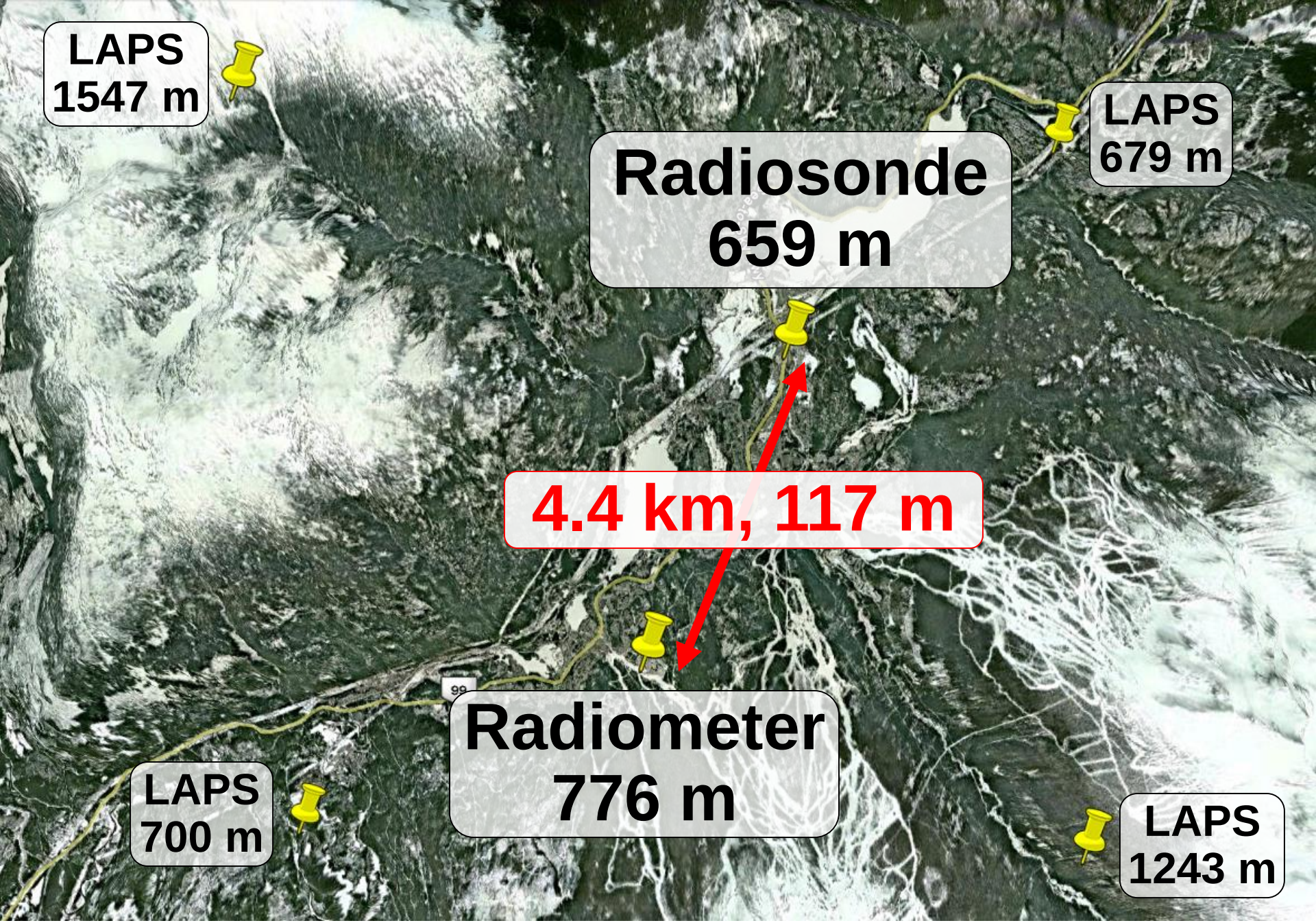
Radiometer – Radiosonde Comparison

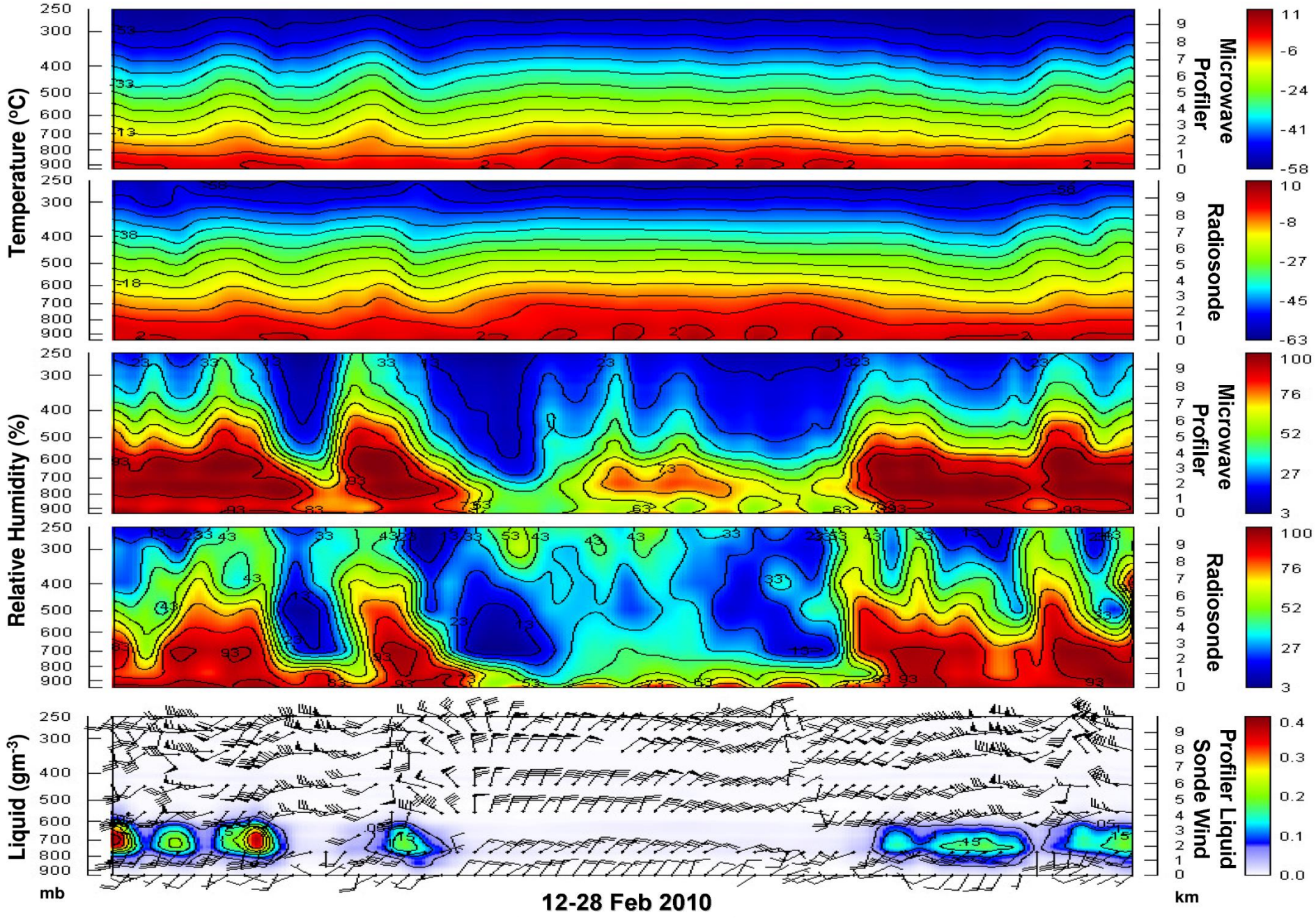
- An MP-3000A radiometer was operated during the 2010 Winter Olympics by Environment Canada
- Radiosondes were launched every six hours at 4 km distance from the radiometer
- Radiometer and radiosonde temperature and humidity profiles show good agreement during rain, sleet and snow up to 20 mm/hr



Radiometer, radiosonde and gridded analysis locations

Radiometer and other sensors (776 m elevation)

Radiosonde launch site (659 m elevation)



16-day radiometer and radiosonde comparison (Ware et al, Atmos. Res., 2013)

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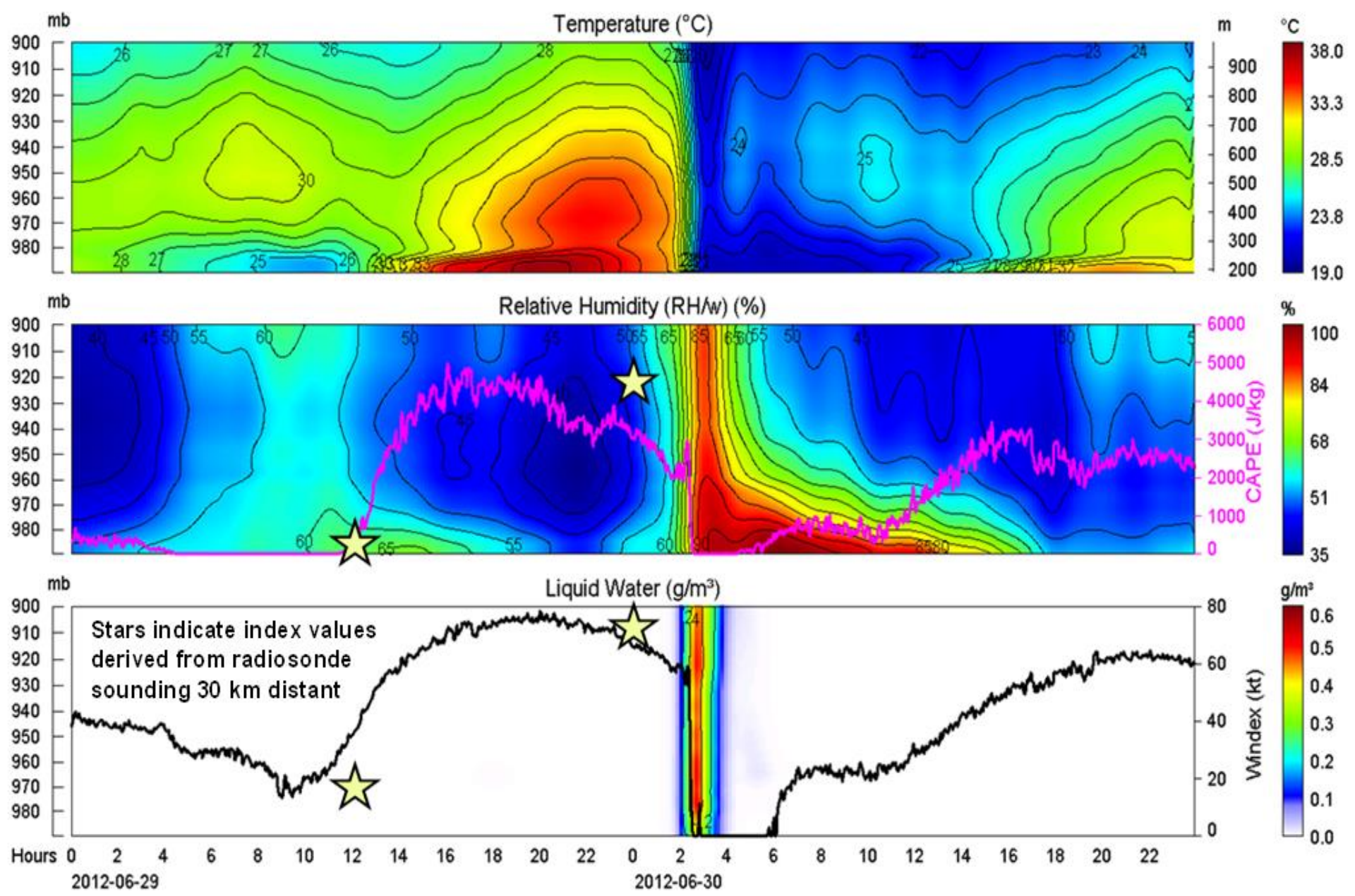
Severe Storm Warning

- Severe thunderstorms including lightning, torrential rain and 100 mph wind gusts resulted in 22 deaths and widespread damage, leaving millions without power for five days in Washington, DC.
- Forecast index time series derived from local thermodynamic profiles showed extremely unstable conditions and risk of 100 mph winds more than seven hours in advance.



Thermodynamic evolution of severe thunderstorm that caused 22 deaths and 5-day power outage in Washington, D.C. (Novakovskaia et al, 2013)

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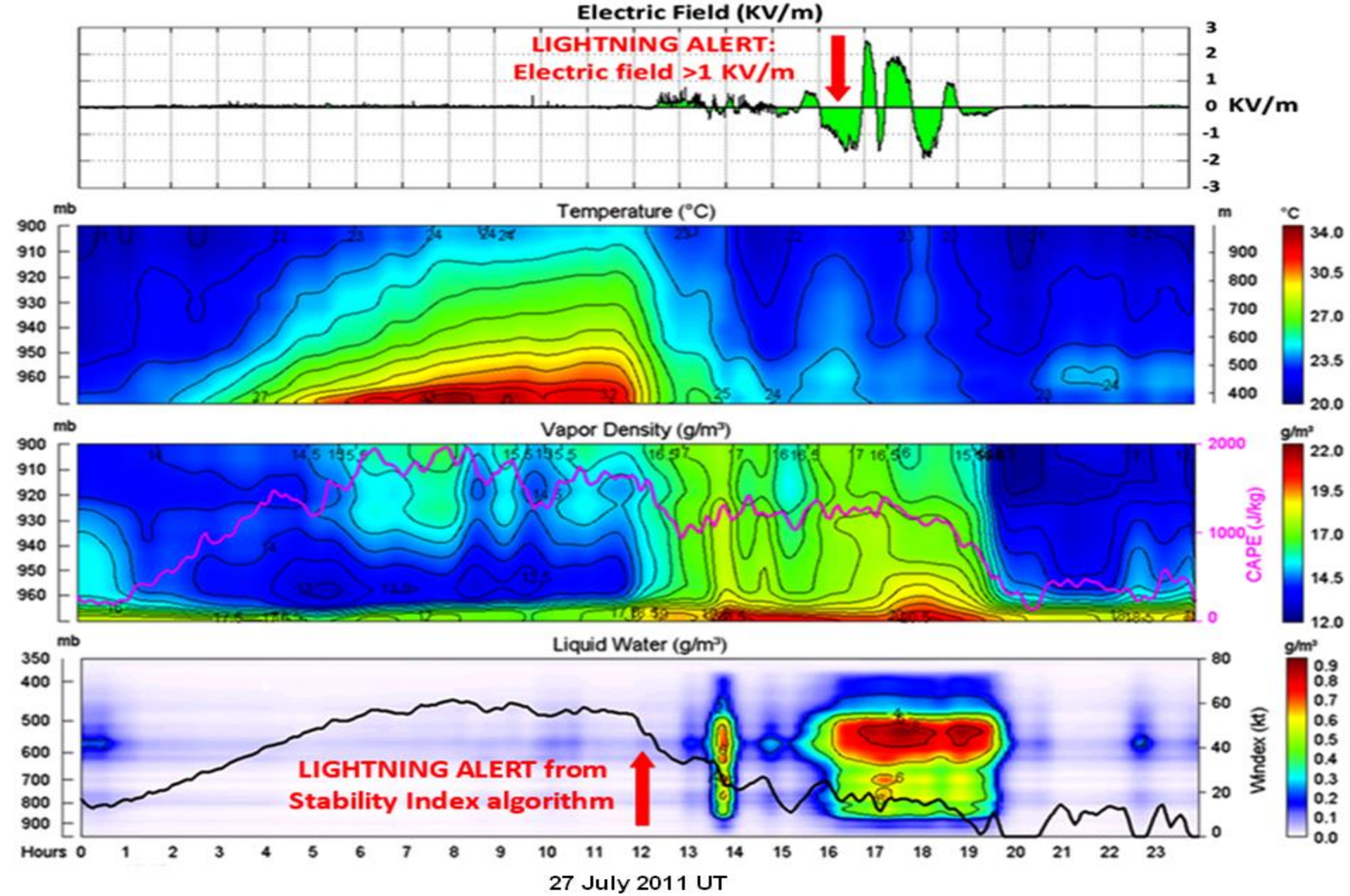
High Impact Local Weather Warnings >2-hr in Advance

- *"…ground-based MWR observations can be used effectively to predict the occurrence of thunderstorms at least 2 h in advance."* (Madhulatha et al, 2013)
- High Impact Local Weather includes: Fog, Lightning, Hail, Rain, Gust Fronts, Turbulence, Wind Shear, Icing

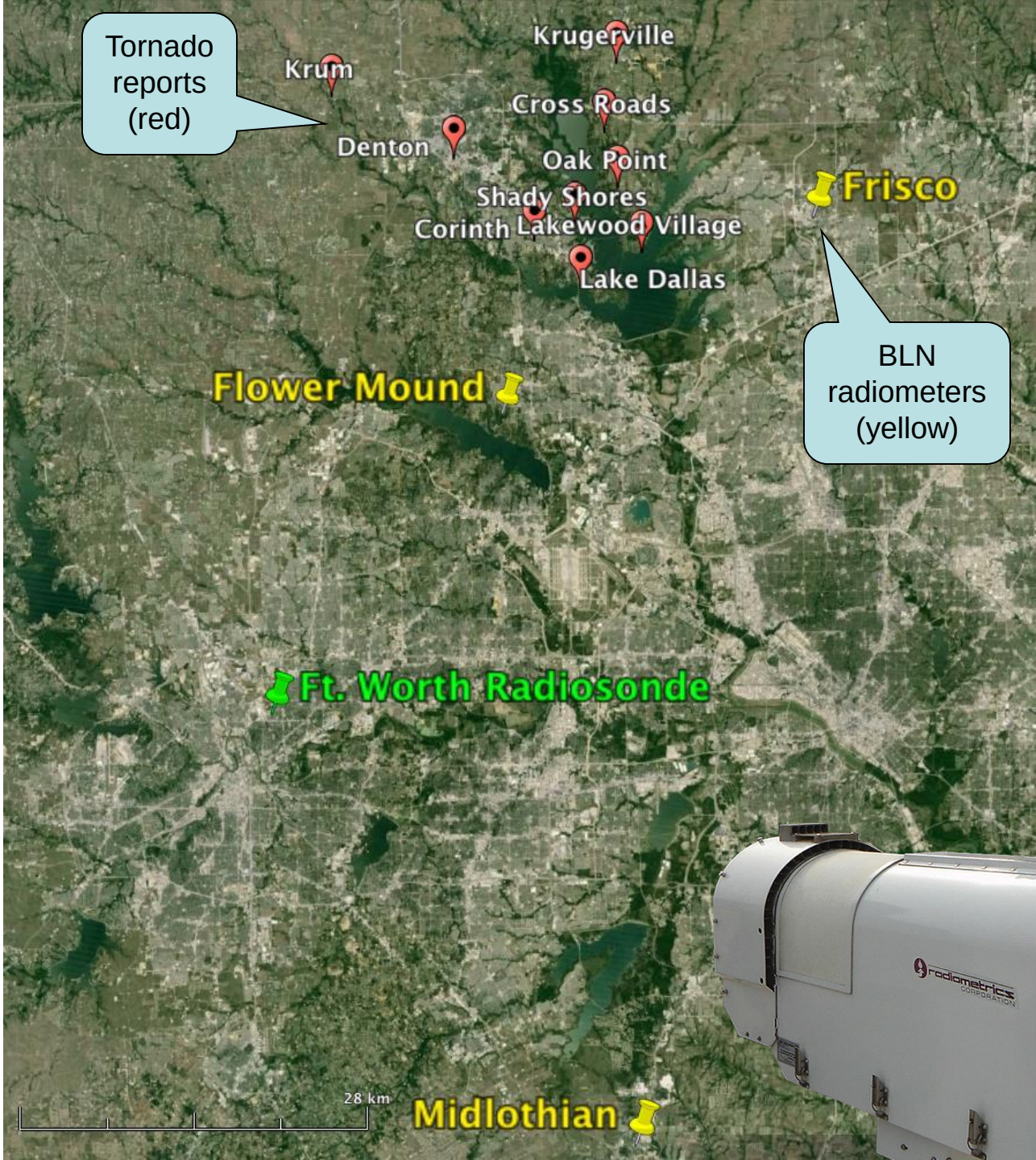


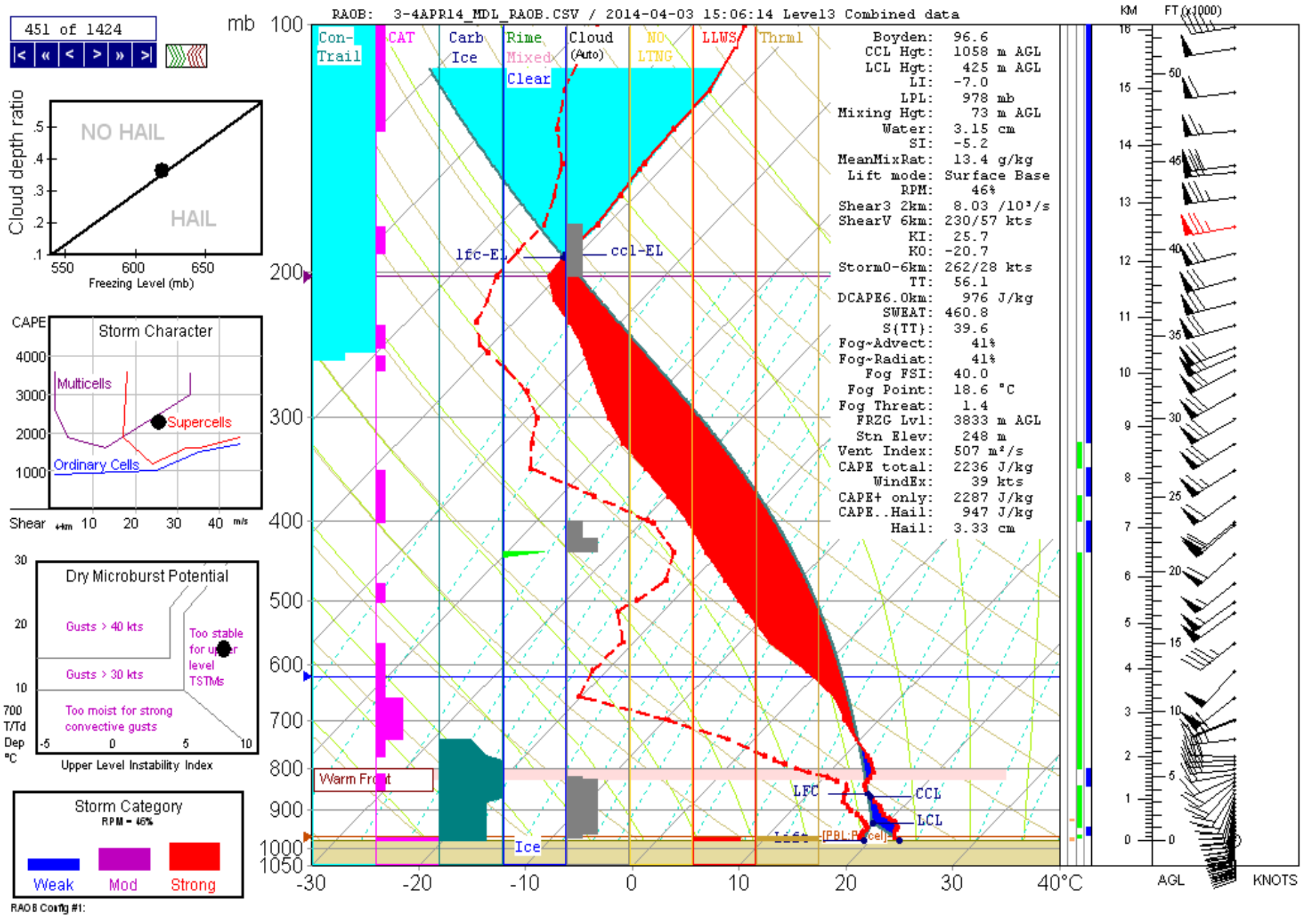
Lightning prediction more than 2 hours in advance derived from radiometer measurements (after Madhulatha et al, 2013)

THE NATIONAL WEATHER SERVICE IN FORT WORTH HAS ISSUED A

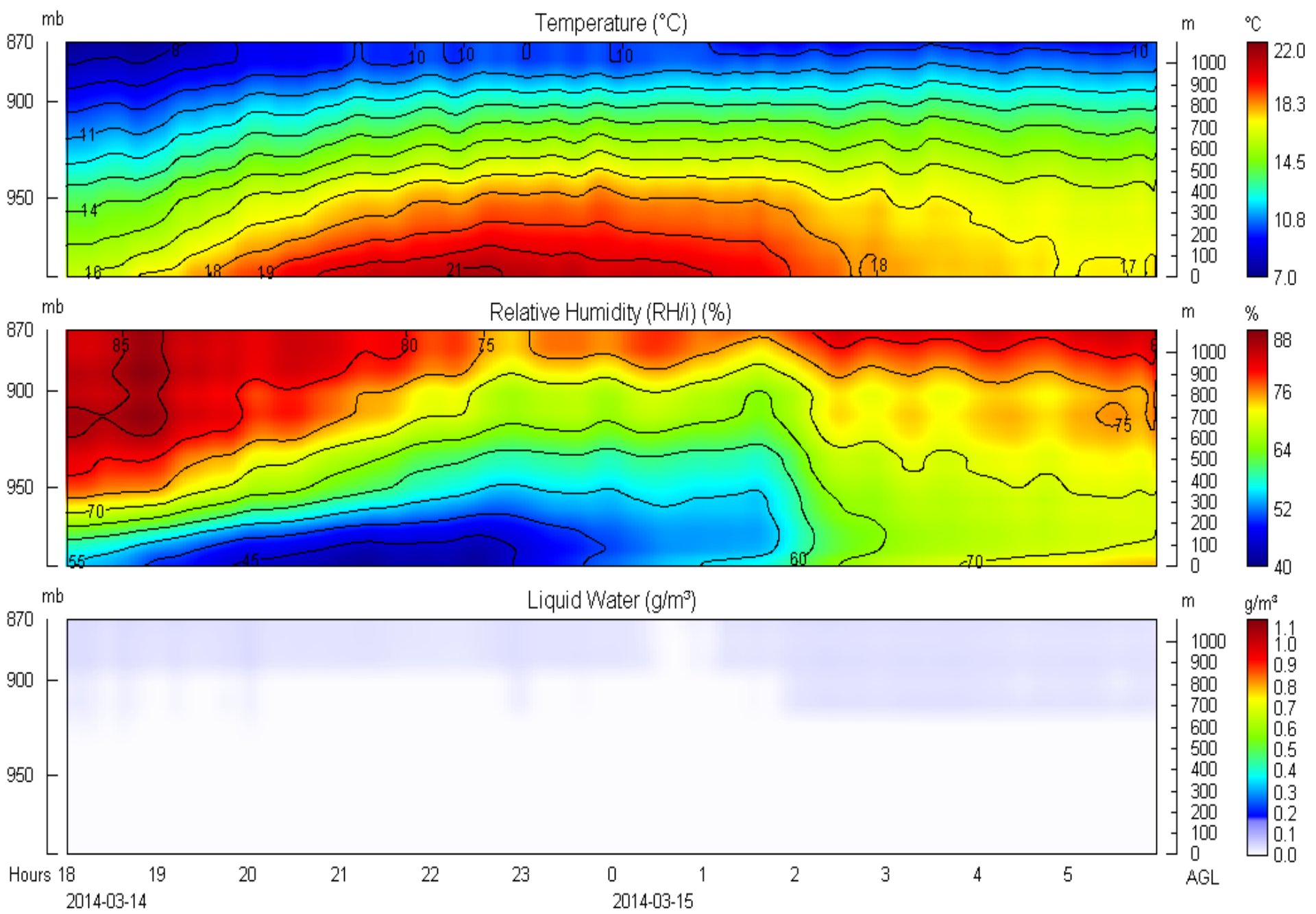
* **TORNADO WARNING** FOR… CENTRAL DENTON COUNTY IN NORTH CENTRAL TEXAS…
* UNTIL 630 PM CDT 3 April 2014
* AT 547 PM CDT… STORM SPOTTERS AND DOPPLER RADAR OBSERVED A DEVELOPING TORNADO 3 MILES SOUTHWEST OF KRUM… MOVING EAST AT 20 MPH.
* THE TORNADO WILL BE NEAR… **DENTON** AROUND 605 PM CDT… CORINTH AROUND 615 PM CDT… SHADY SHORES AND **LAKE DALLAS** AROUND 620 PM CDT… OAK POINT AROUND 625 PM CDT… KRUGERVILLE… CROSS ROADS AND LAKEWOOD VILLAGE AROUND 630 PM CDT…

- Hazardous Weather Testbed
- NOAA purchases Boundary Layer Network (BLN) radiometer data
- WMO radiosonde site at Ft. Worth
- Tornadoes reported at red markers 3 April 2014 afternoon

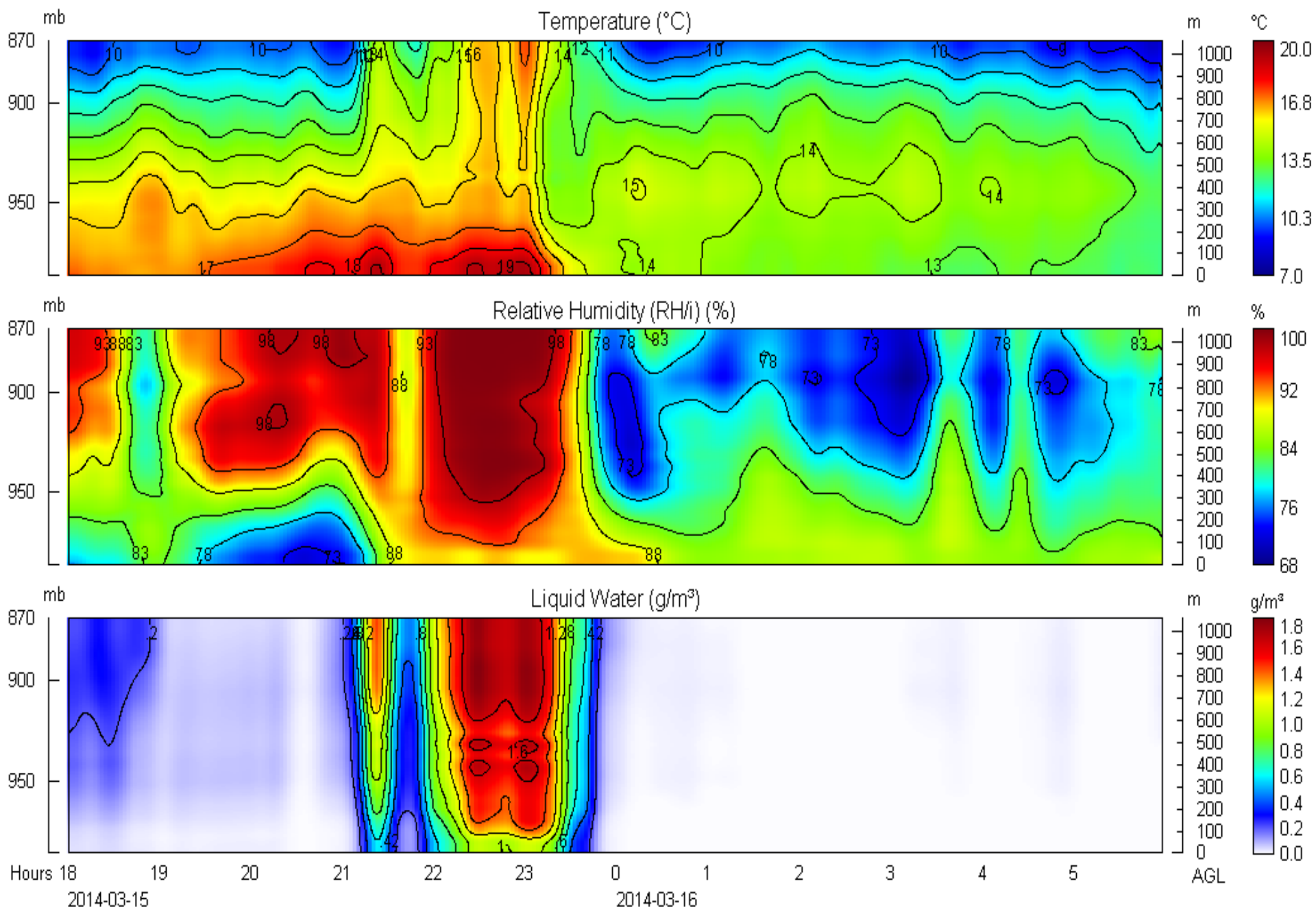




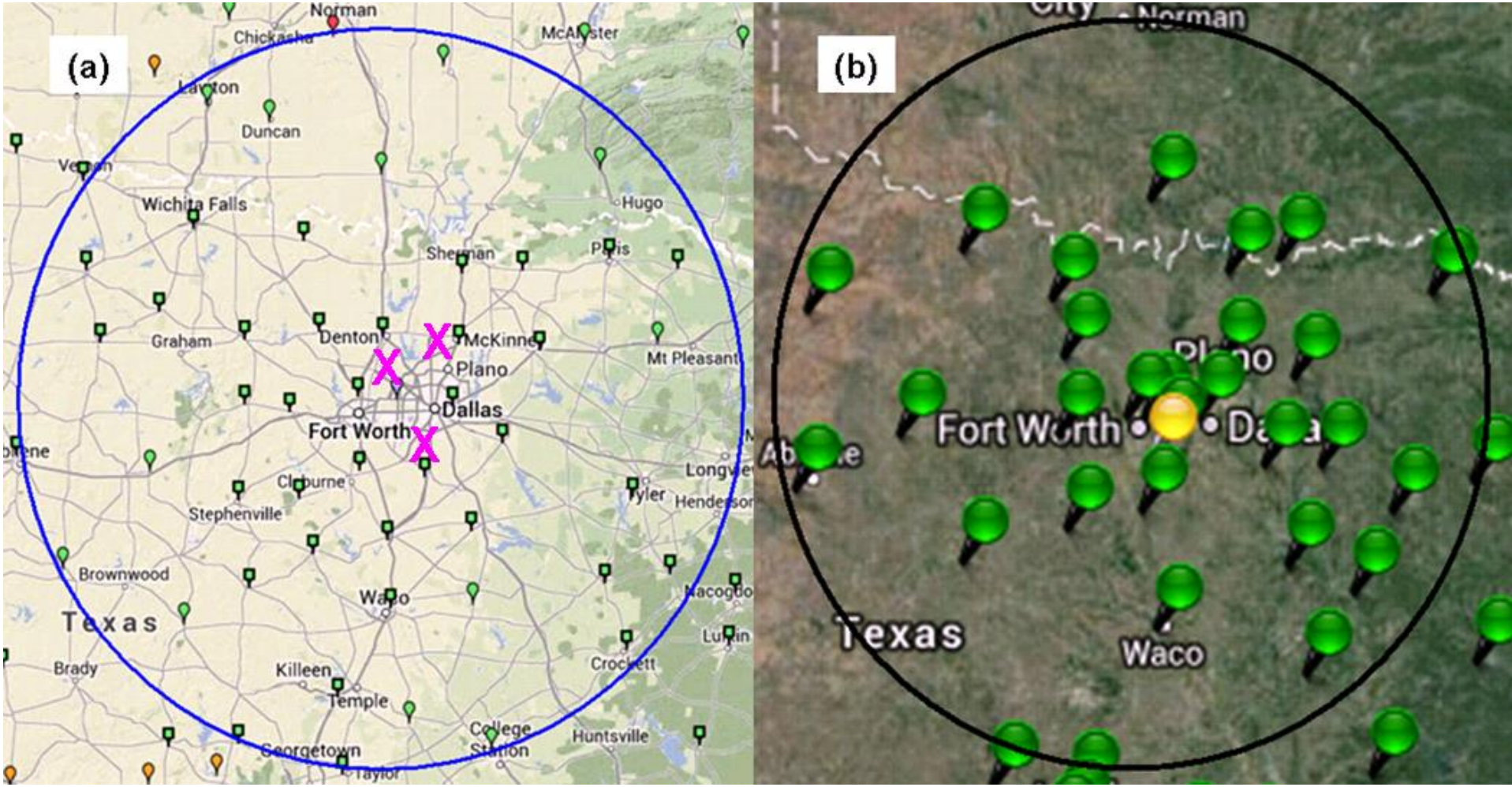
1DVAR (gridded analysis + radiometer) 3 hours prior to Denton Tornado



Half-day 20 deg north observations during stable conditions at Flower Mound

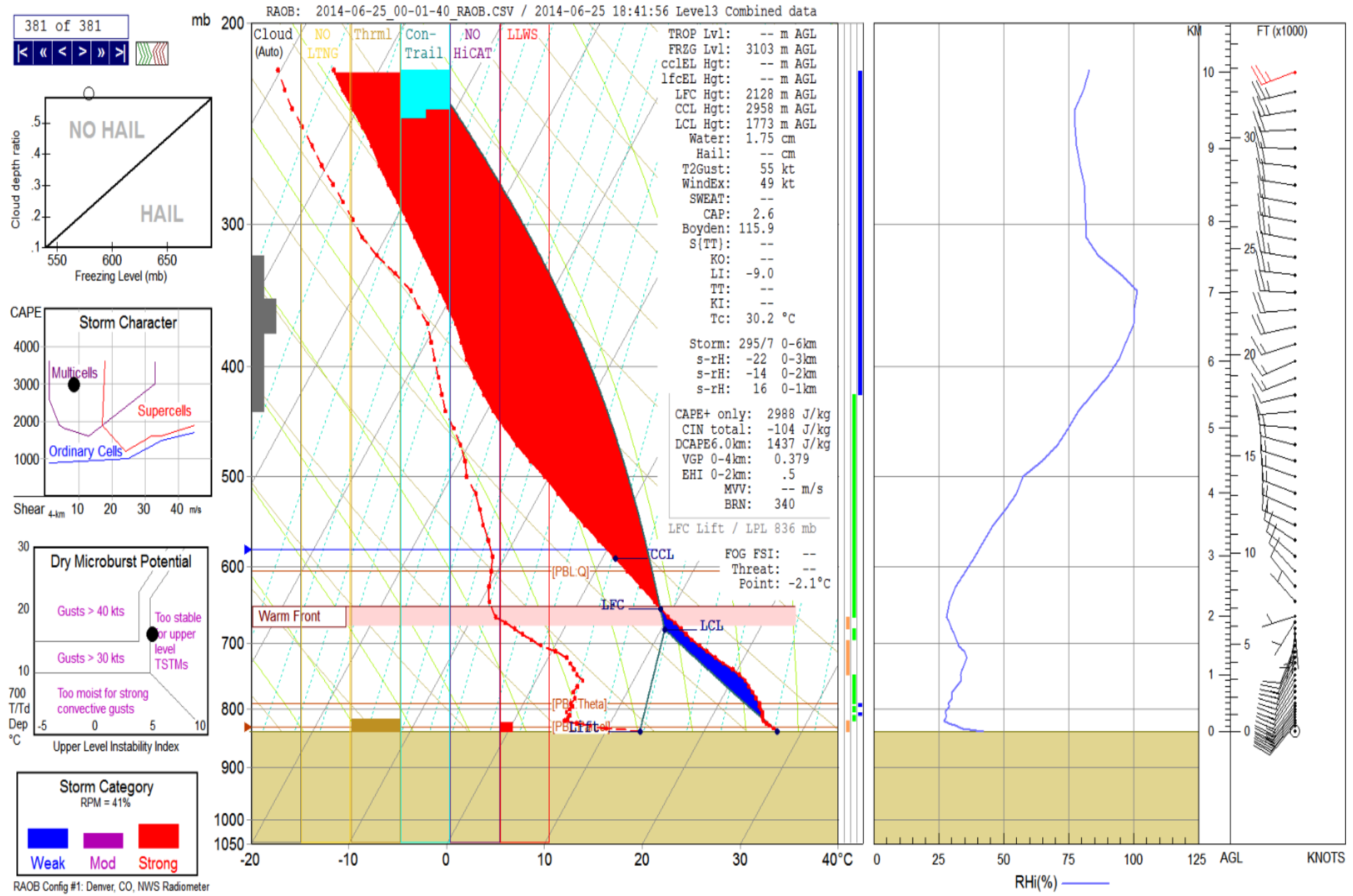


Half-day 20 deg north observations including convection at Flower Mound

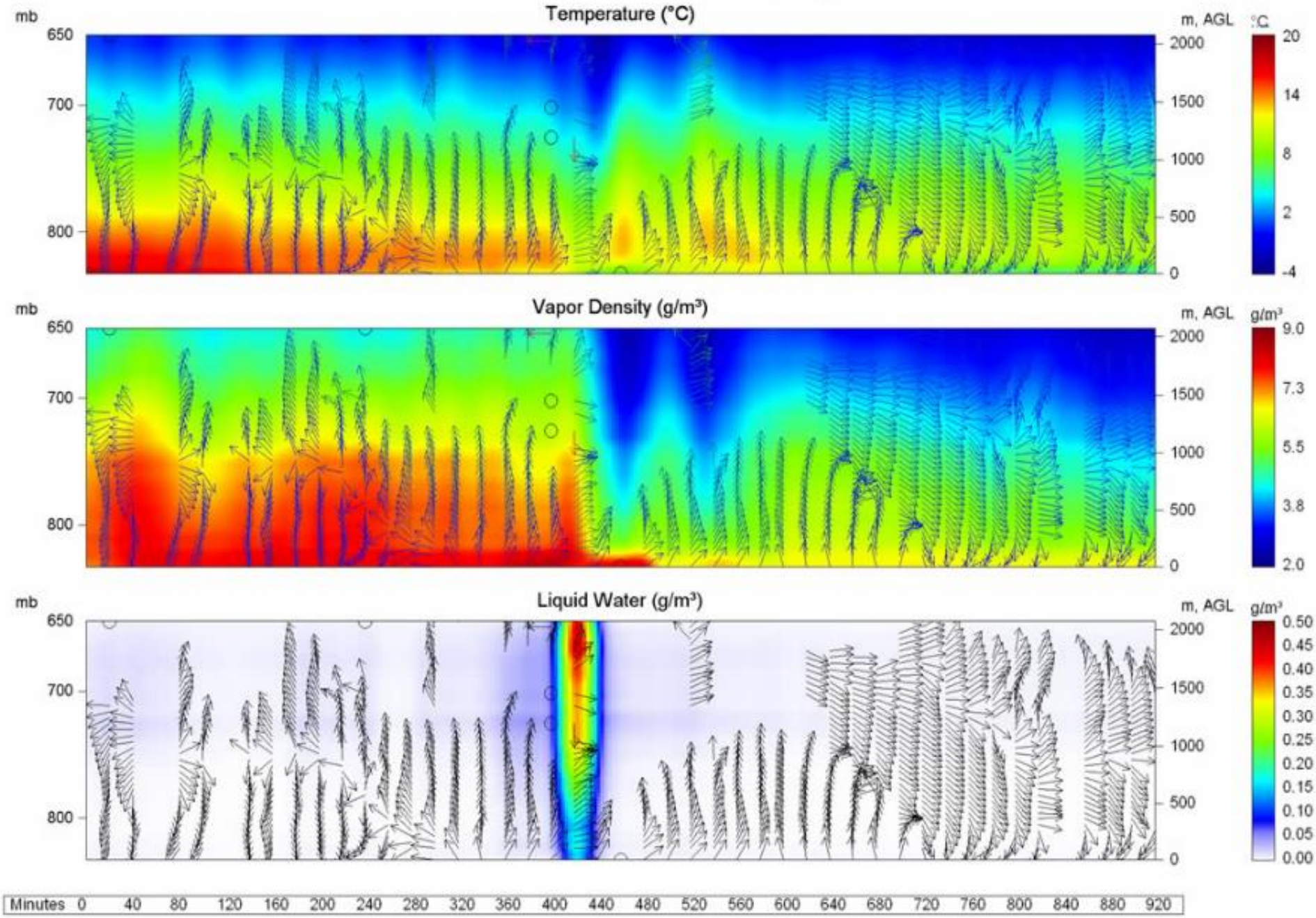


Public (a) and private (b) GNSS stations
and private radiometer stations (X)
within 250 km of Dallas-Ft. Worth.

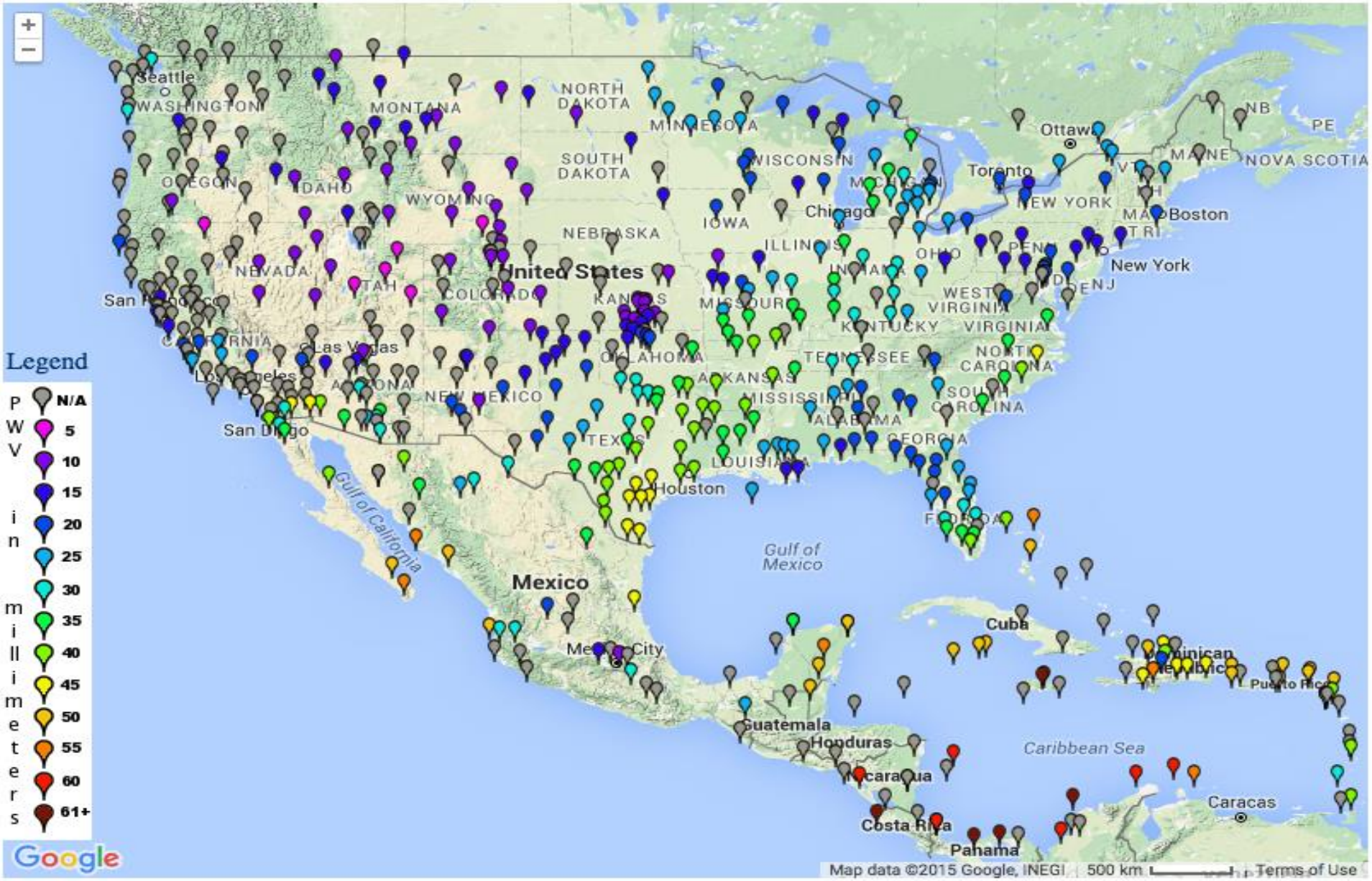
Mobile thermodynamic and wind profiler



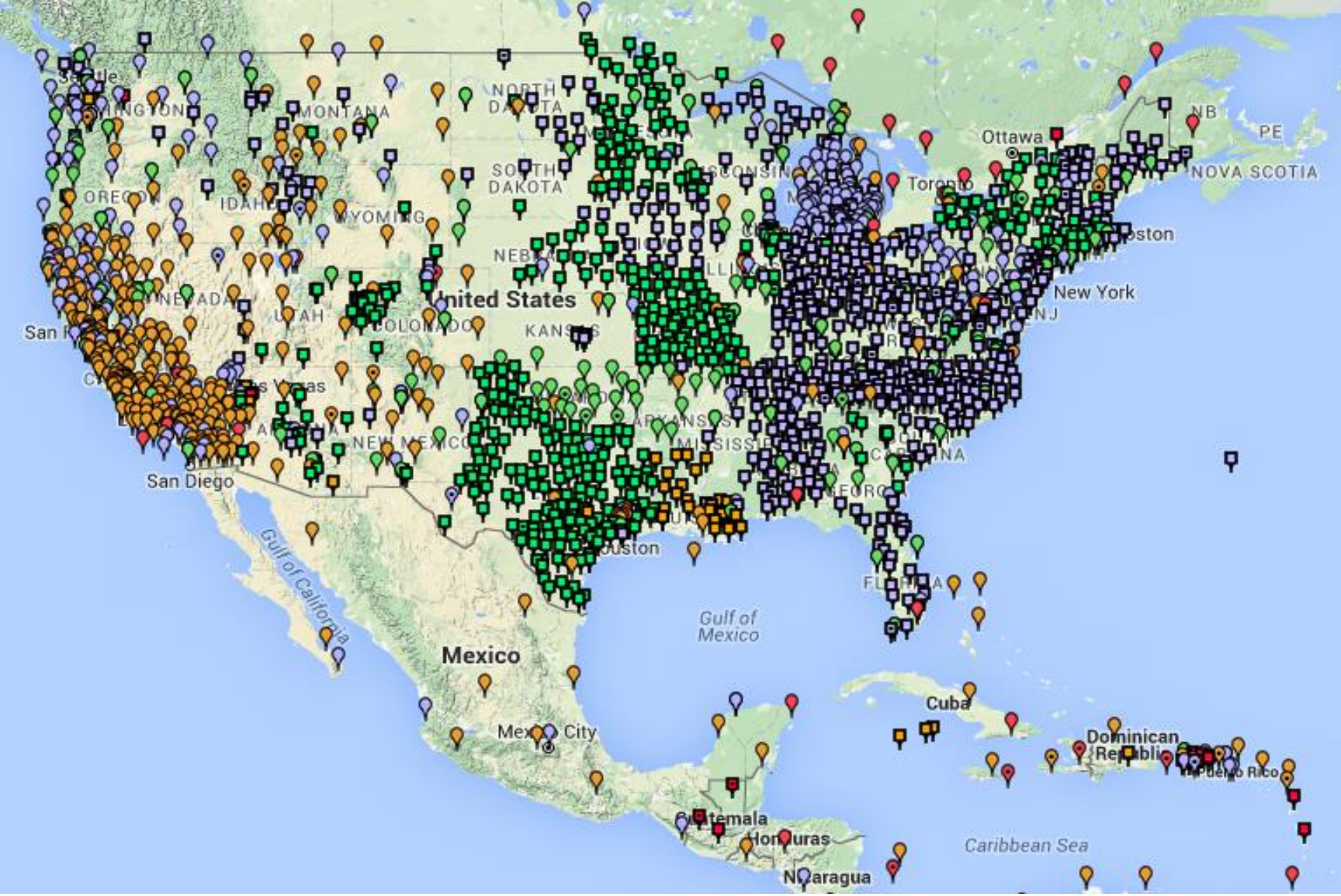
Combined radiometer, wind radar and gridded analysis at Denver, hours before multiple tornadoes were reported nearby.



Combined thermodynamic (microwave profiler) and wind (Doppler lidar) profiles



Real time vertical integrated humidity is provided by this GNSS network. Integrated humidity along the line of sight to each satellite provides additional horizontal humidity distribution information.



Continuously Operating Reference System (CORS) GNSS Network.
The number of network sites and satellites is steadily growing.

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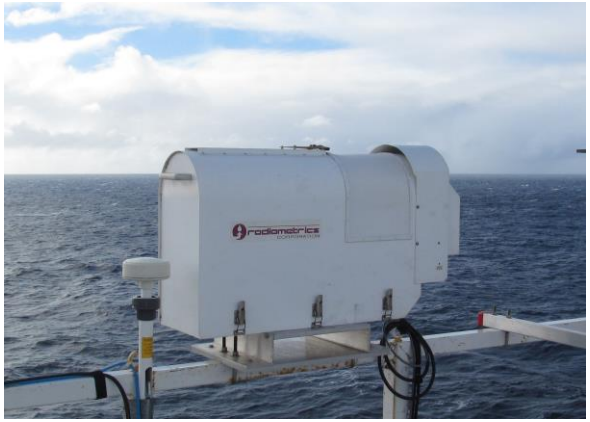
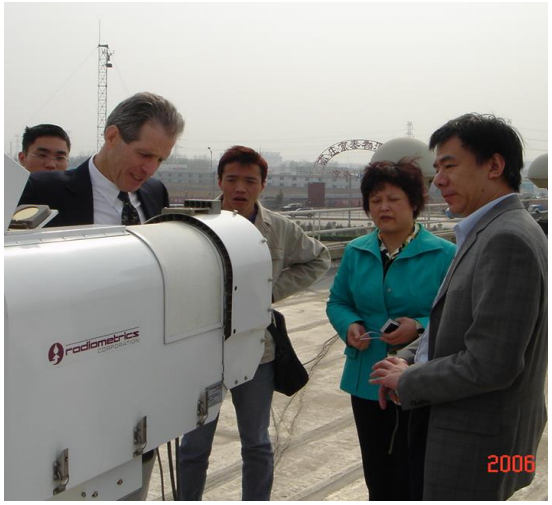
Pearson (Toronto)
International Airport



Chevron Oil Platform
Gulf of Mexico

Dubai
International Airport



Chinese Meteorological
Administration

Los Angeles
International Airport

US National
Profiler Network