Smoke plumes observation with surveillance weather radars

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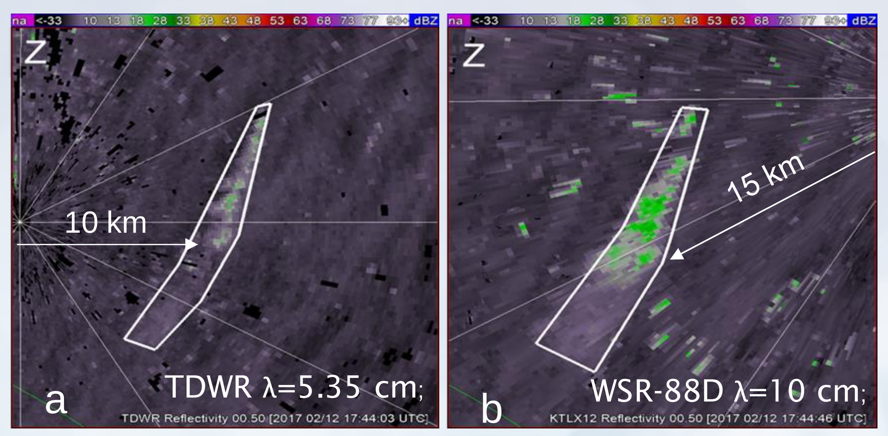
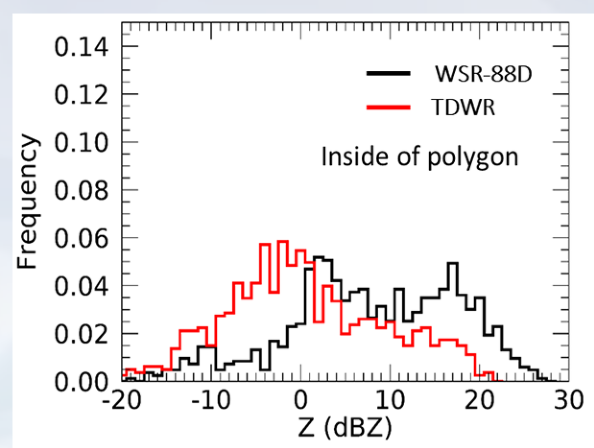
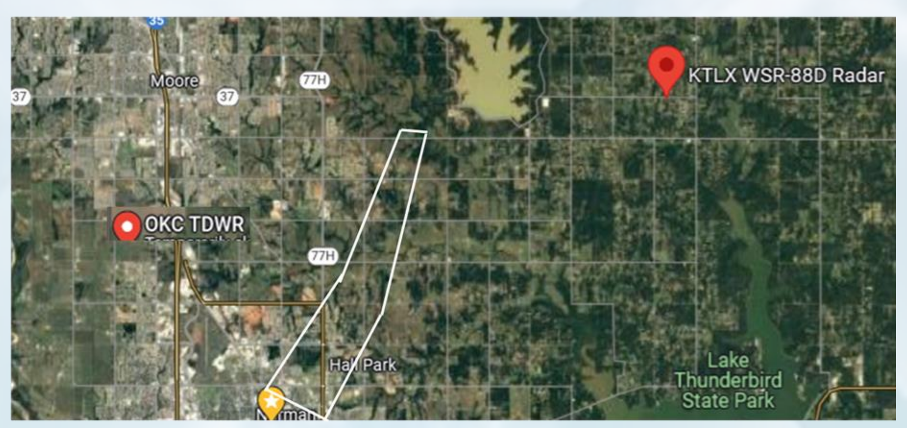
NOAA's Role in Fire Hazards Information

- Identifies new fires and describes spatial evolution (growth and decay) in time
- Forecasts where the smoke from the fire will travel and how it will impact weather and air quality
- Principal observing tools are satellites geostationary like Goes and polar orbiting
- Studies use of new capabilities like dual polarization radar and UAS





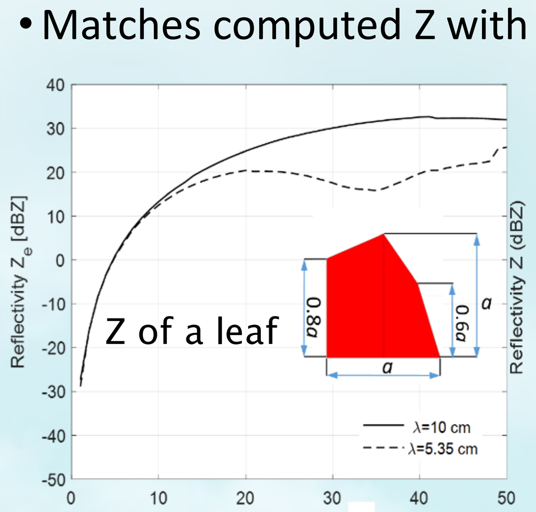


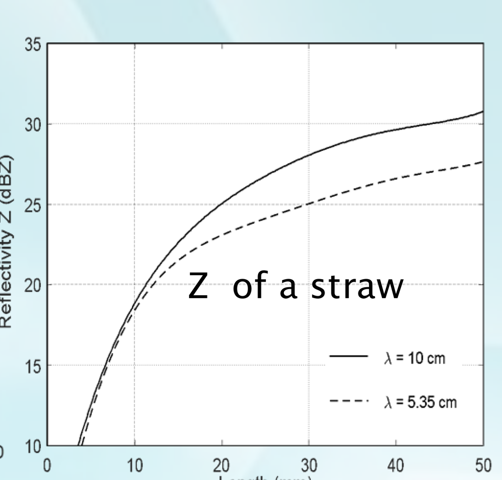
Histograms of reflectivities

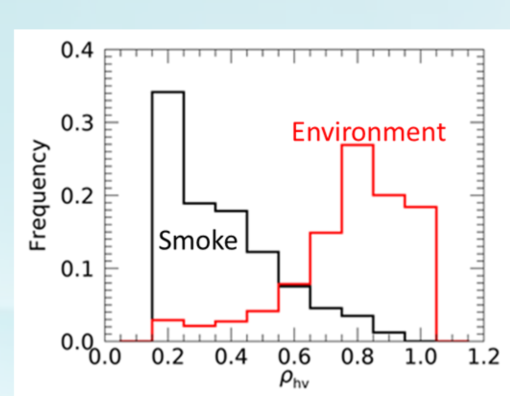
-The offset of peak reflectivities is due to the resonant effect at the 5 cm wavelength (TDWR); WSR-88D operates at 10 cm wavelength

Models of burned leaf and straw

- Pentagon representing a burned leaf
- Hollow cylinder representing burned straw
- Specified are
  - Random orientation in pitch (±30°), roll (±30°) and yaw (360°)
  - Dielectric constant of carbon black (0.1 volume fraction) 7 +j2
  - EM solver WIPL-D was used to compute reflectivities at 5 and 10 cm wavelengths
- Matches computed Z with the one at 10 cm wavelength for the size of 20 mm.







Histograms of correlation

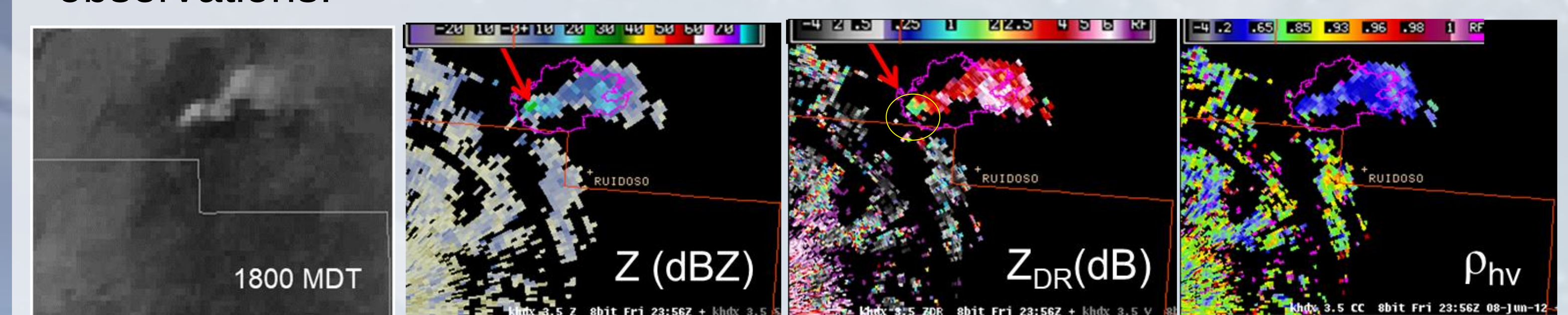
Conclusion from Model and Observations

- The significant contributors to reflectivity are burned leaves with sizes 20 to 30 mm. These are in the resonant regime at 5 cm wavelength but still in the Rayleigh regime at 10 cm wavelength
- The average concentration is about 0.032 m^{-3}.
- The number of these in the KTLX resolution volume is about 361000 and in the TDWR resolution volume it is about 28000.

Polarimetric and Satellite Observations

1. Little Bear wildfire (New Mexico, June 4, 2012)

-The fire generated a pyro-updraft, consumed over 44000 acres, 242 houses, and 12 structures. WSR-88D from Holloman (KHDX) made observations.



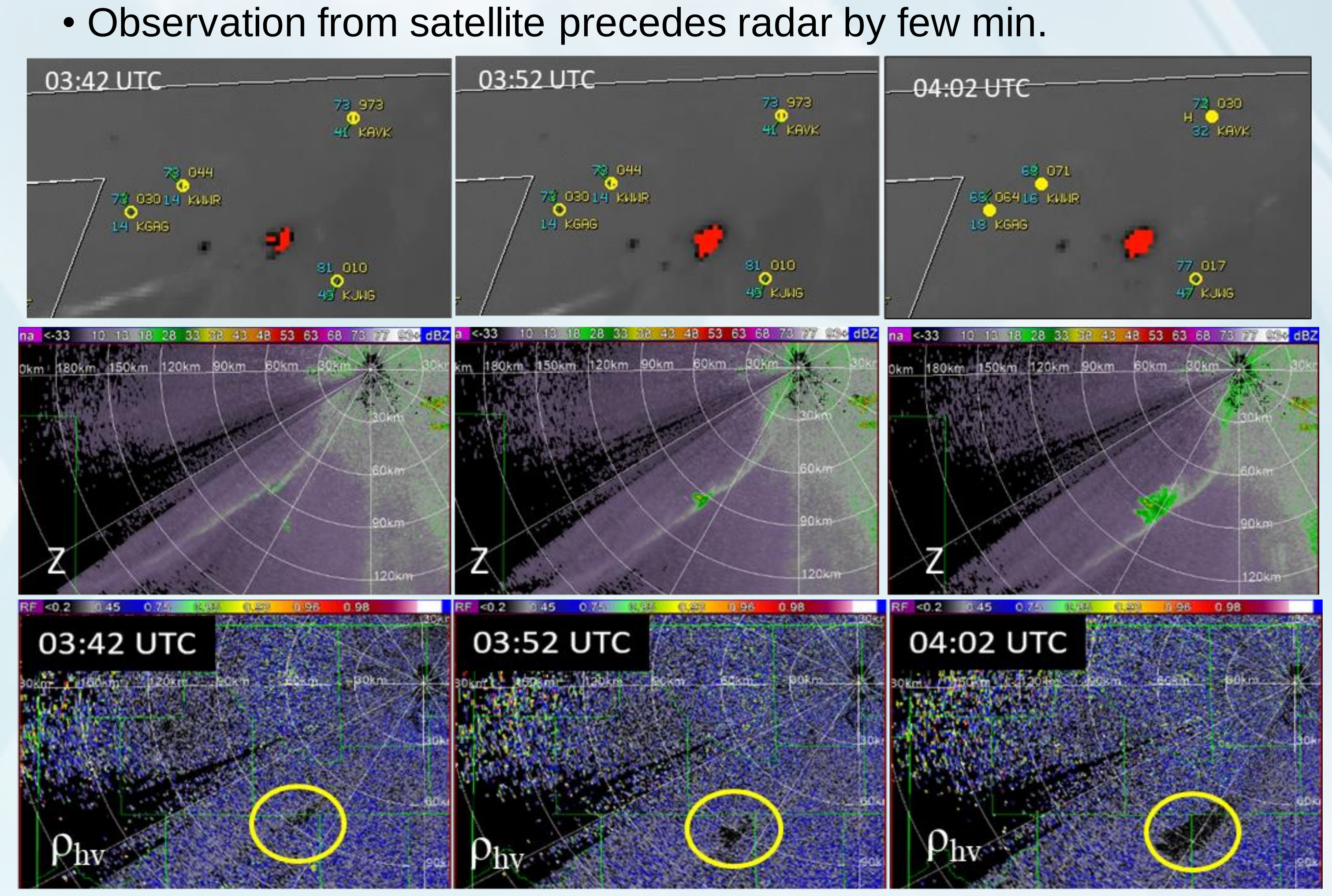
Satellite image Fields of Z, Z_{DR} and ρ_{hv} at 1800 MDT

Z and Z_{DR} at 1830 MDT; Z and Z_{DR} at 1900 MDT

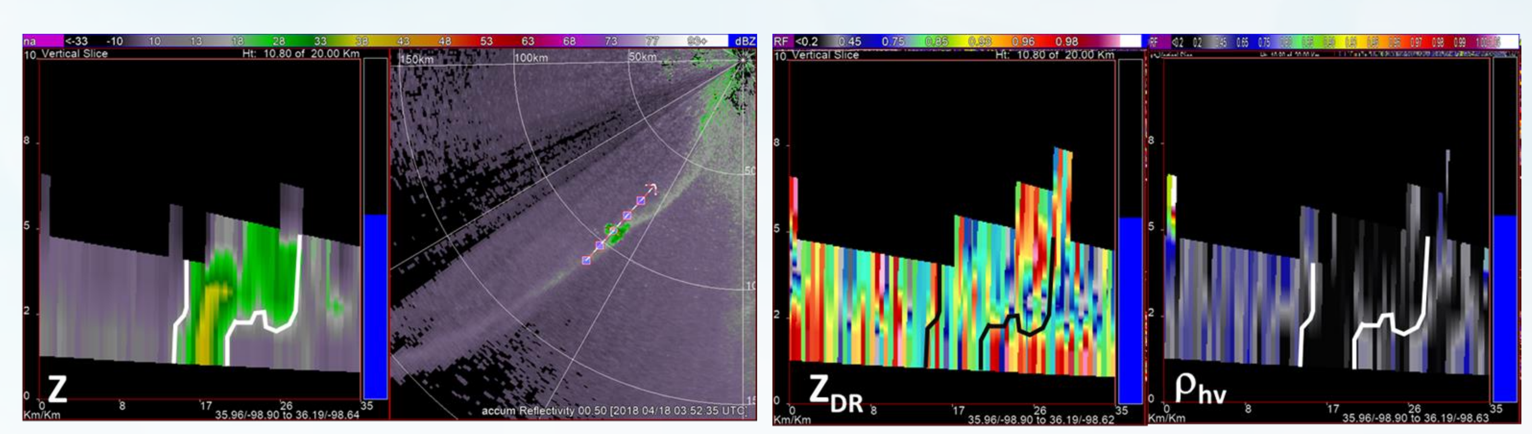
-The pyro-updraft is recognized as a column of depressed Z_{DR}. The updraft reached about 8 km; the lifting condensation level was at 5.3 km. Therefore the updraft likely created a cloud wherein ice crystals and smoke coexisted.

3. Prairie fire in Western OK (April 18, 2018)

- Observation from satellite precedes radar by few min.



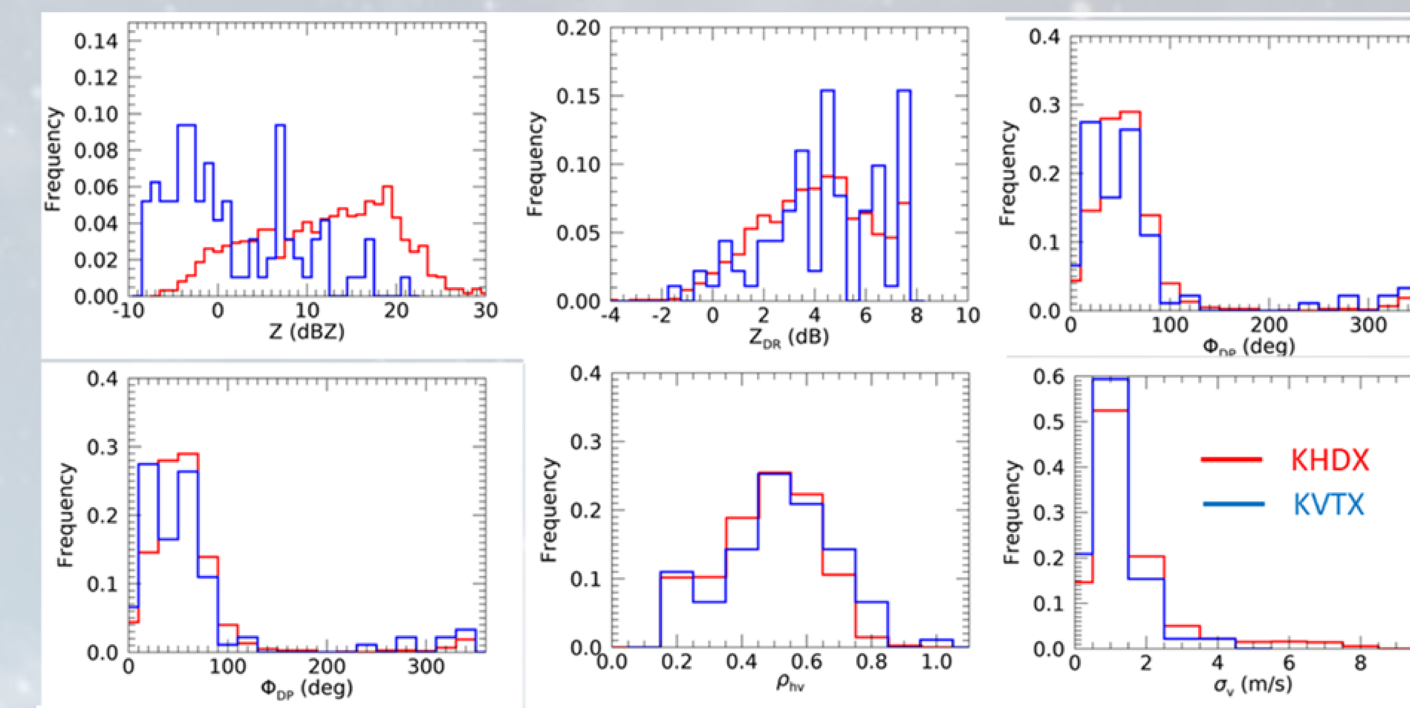
- Increasing area of low ρ_h indicates spread of the plume



Vertical cross sections (RHI) of Z reminisce of an overhanging vault

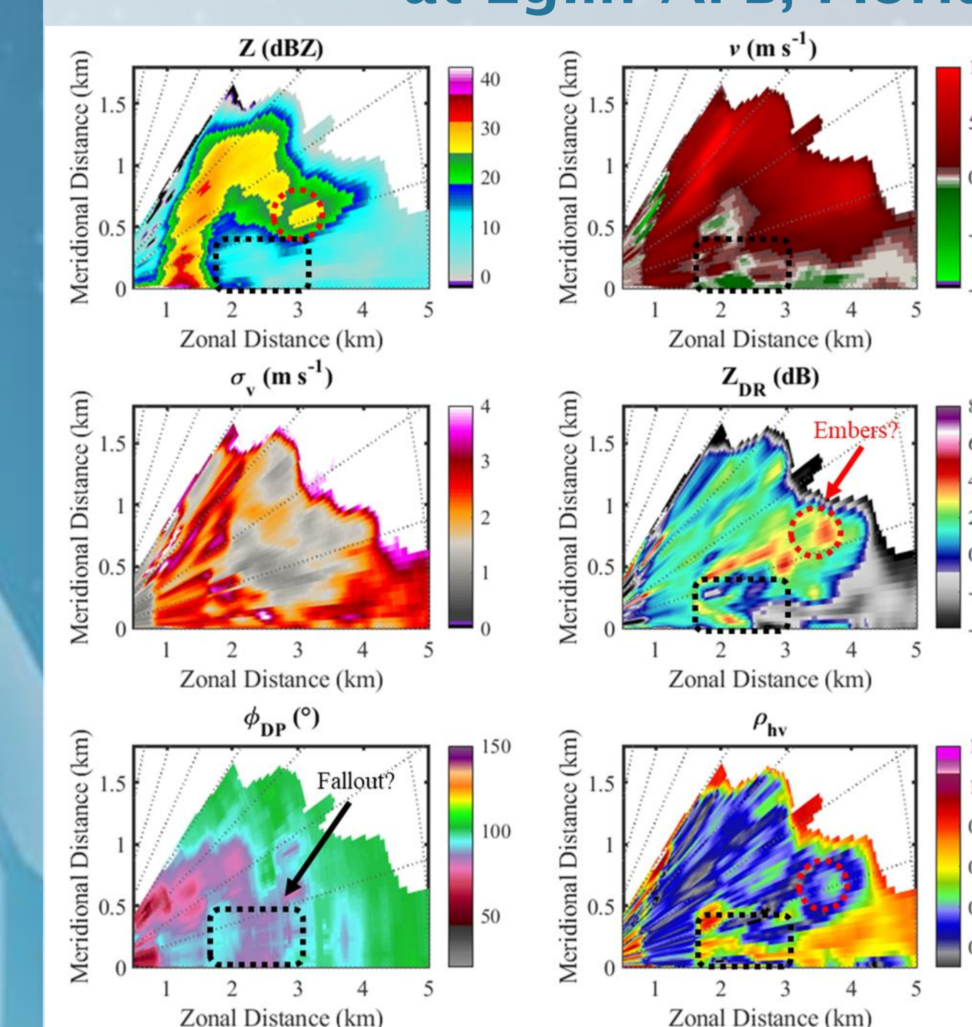
Histograms of Polarimetric Variables

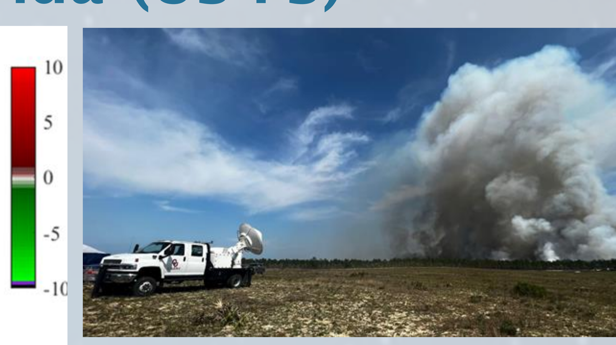
Wild Fire in NM and LA



KHDX is in New Mexico and KVTX is in Los Angeles. Both were fueled with similar vegetation (pine trees etc.) hence histograms of pol variables are very similar. This may carry to other types of vegetation?

Observation of a Prescribed Fire at Eglin AFB, Florida (US FS)





3-cm wavelength radar

-The plume is confined to the PBL

-High resolution delineates inflow, updraft, size sorting and orientation

-Reflectivity and Doppler velocity indicate a horizontal roll vortex

-Pyro updraft and its inflow exhibit positive Z_{DR}

Epilogue

- Radar detects smoke plumes as soon as these reach the beam height
- The return signals are from mm to cm size ash
- The correlation coefficient ρ_{hv} of smoke plumes is low and similar to returns from other non-meteorological particles
- Detection and identification of smoke in radar returns is relatively easy
- Radar can track the plumes' evolution (expansion, propagation and advection)
- Instantaneous measurements of the plume motion at several conical scans is feasible via several proven techniques applied to Doppler velocity and reflectivity fields. These are tracking by correlation, optical flow, linear wind assumption, etc.
- Radar analysis of smoke plumes is well suited for input to dispersion models of pollutants.

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