History of Weather RADAR

Daryl Herzmann
Meteorology 590d
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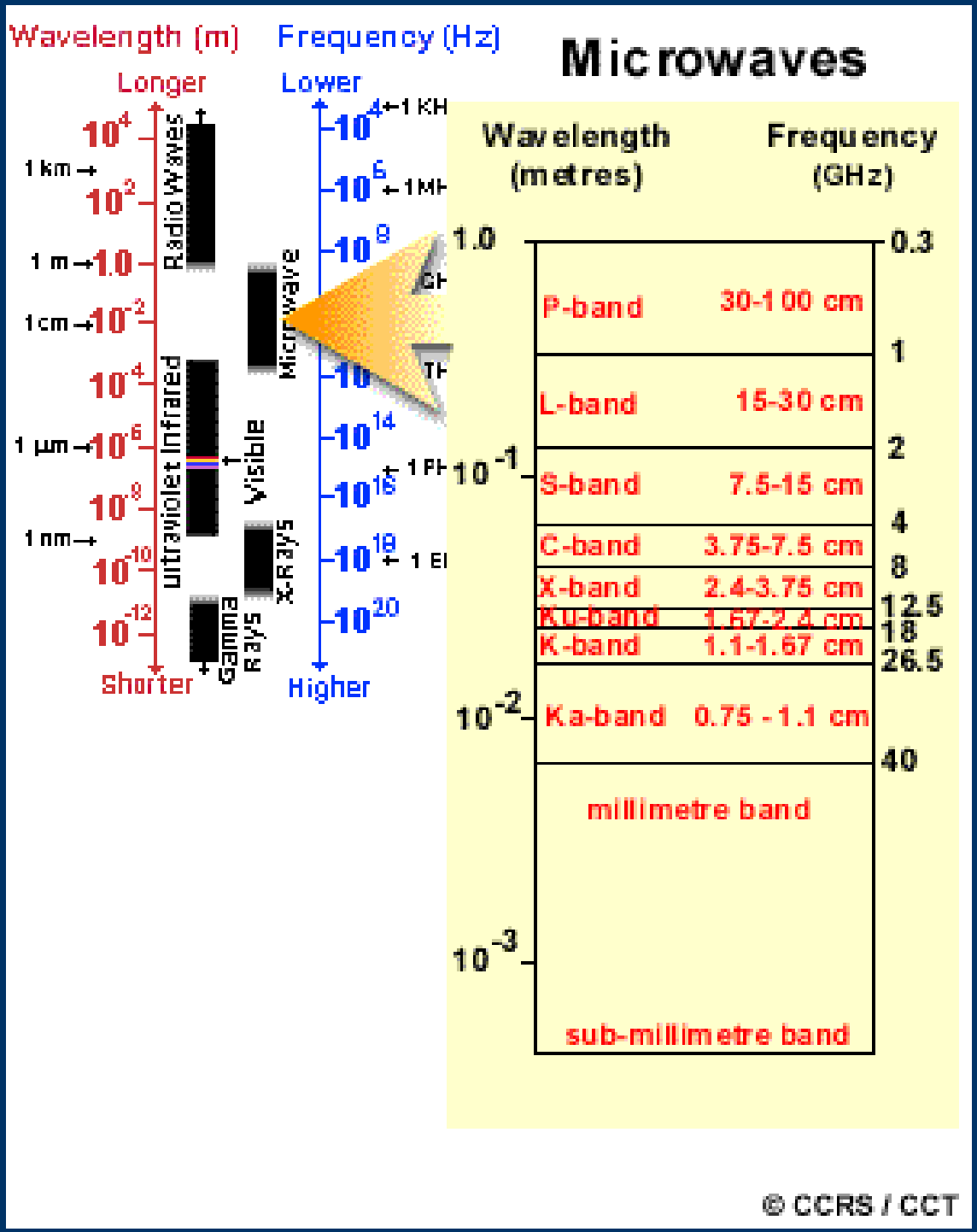
Outline

- What I am not going to talk about.
- Development of the RADAR
- Application to Meteorology
- Pre-Doppler Activities
- Doppler Activities
- ~~The Future~~

Wait a second, this is history class

EM Spectrum


Wavelength (m)
Frequency (Hz)
Longer
Shorter
Lower
Higher
1 km
1 m
1 cm
1 µm
1 nm
Radio Waves
Microwave
Infrared
Visible
Ultraviolet
X-Rays
Gamma Rays
Microwaves
Wavelength (metres)
Frequency (GHz)
P-band 30-100 cm
L-band 15-30 cm
S-band 7.5-15 cm
C-band 3.75-7.5 cm
X-band 2.4-3.75 cm
Ku-band 1.67-2.4 cm
K-band 1.1-1.67 cm
Ka-band 0.75 - 1.1 cm
millimetre band
sub-millimetre band
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German Air Attacks during WWI

- 24 Dec 1914: German seaplane bombed England without warning. This was not a good thing.
- 13 June, 7 July 1917: Raids on London were devastating. Germans were well outnumbered, but the unorganized Brits did nothing.
- Lt Gen Jan Christian Smuts wrote two critical reports of this event. They lead to the formation of the LADA (London Air Defence Area)
- The LADA was more effective, but night vision was not possible.

There is no hope....

- 'Our aeroplanes afford no means of defense at night as they find it impossible to see the enemy machines even at a couple of hundred yards. They might as well remain on the ground.'

  - *Jan Christian Smuts*

Remotely Sensing Air Planes

- Use large 'sound mirrors' to listen for the German planes
- < 10km range
- Any environmental noise decreased sensitivity
- Wind wasn't good either.

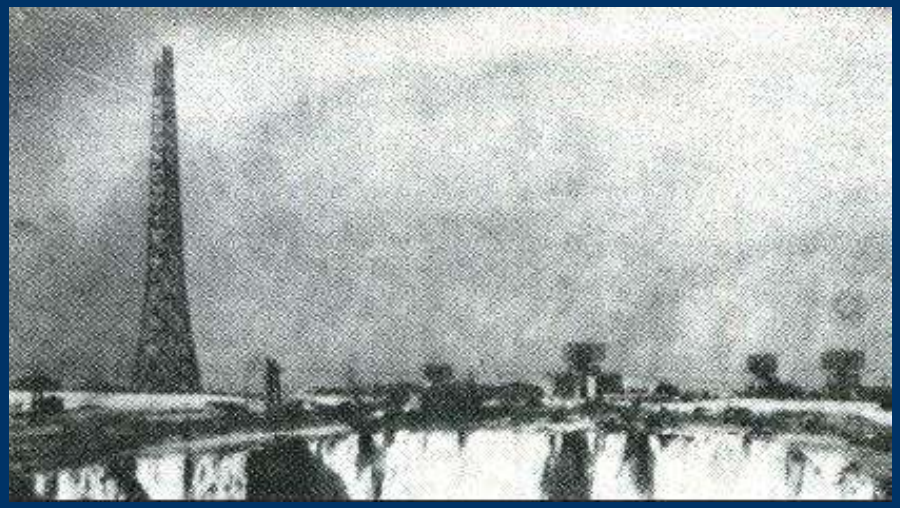
Mega Sound Mirror

- ~65m wide
- Said to detect aircraft 40km away under prefect conditions
- Large dish was needed to focus large wavelengths (rumbles of distant planes)
- Semi-effective, but they had problems buying land to place the mirrors on.

Discovery of RADAR (Death Ray)

- 1887 Heinrich Hertz(man) proved Maxwell's theory of EM at frequencies lower than light
- The boom of RADIO focused research and energy at large wavelengths
- Shorter wavelength research lead to the discovery of the ionosphere. It was also discovered that the shorter wavelengths needed line of sight in order to work.

In the beginning, there was RAF's RDF (Radio Detection Finding)

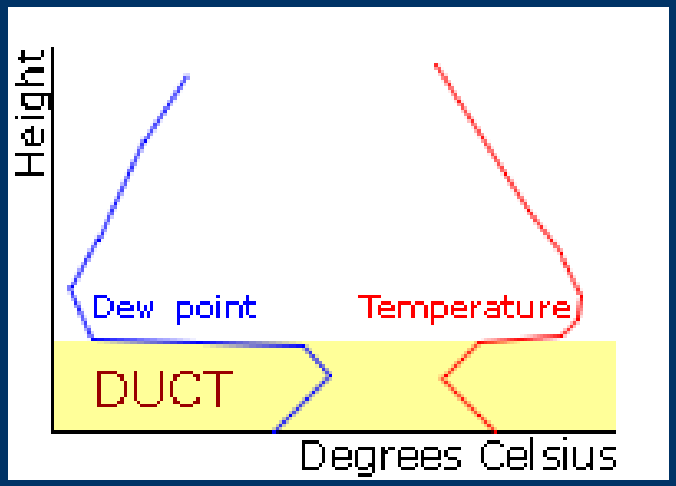


- Death-Ray contest. Kill a sheep at 100m! Lots of entries...
- Finally, 1935 Robert Watson-Watt is credited with the first successful RADAR, but it was extremely crude.
- Failures on both sides kept the system secret before WWII
- Many believe that RADAR won the war for the Allies and not the nuclear bomb

Joseph O. Fletcher

- While on U-boat patrols off the American coast, he noticed the sensitivity of microwave radar to rainstorms.
- Proved that deriving winds was possible using reflective targets on balloons.

Fletcher's trapping inversion



- While calibrating RADARs along the coast, he noticed no signal above 25m
- Nearly crashed the plane while investigating this phenomena just meters above the ocean
- An inversion was probably to blame for RADAR missing a bombing raid on Bari, Italy during WWII

Fletcher's weather radar program

- Used a converted Night Club, 'Sea Girt Inn' to experiment and train folks in the use of RADAR for observing weather
- Tricked field commanders to get more time on the RADARs to sample winds
  - Need to calibrate the RADARs
  - Need to train the RADAR operators
  - Test out the balloons
- Worldwide use was very effective in WWII

Doing research while they trained

- 1944-1946
- Worked on the theory of storm and cloud detection
- Make slide shows of storm evolution with picture cameras
- Worked to classify and identify different forms of AP
- Tried to explain the “angels” that were seen on RADAR during optically clear days

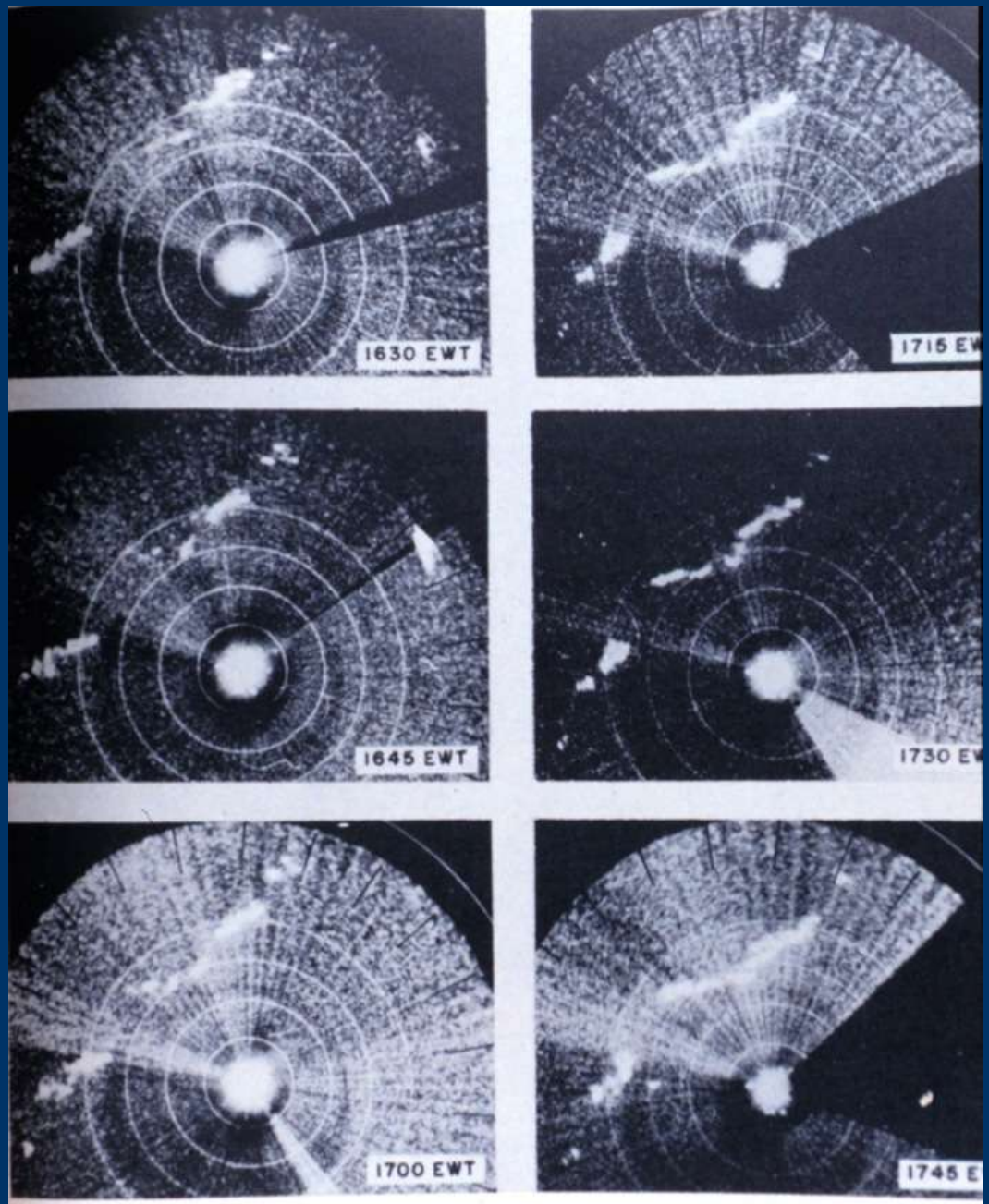


Figure 74. Approach of Cold Front Detected by X-Band Set, 22 July 1943, Boston, Mass. Range markers are at 20-mile intervals. Storms associated with front show considerable motion during the interval between 1630 and 1645 EWT, but very little motion thereafter.

And the allies win WWII....

Army Air Corps funded three RADAR projects 1945

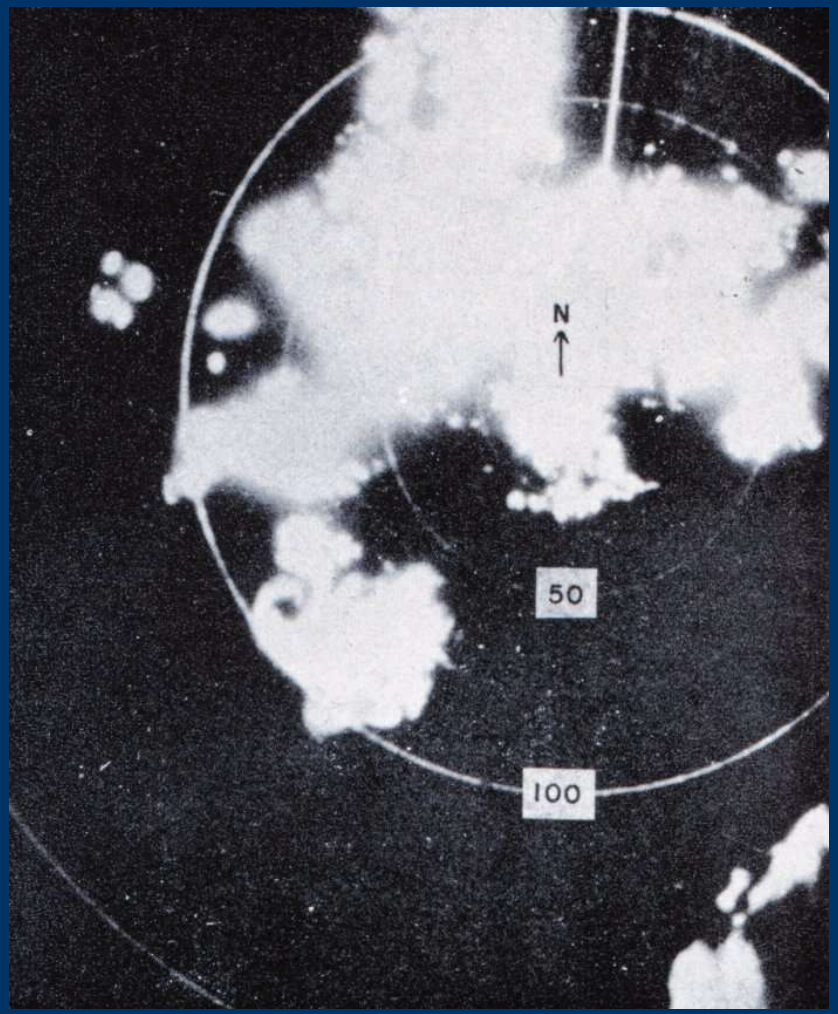
- Wind Finding RADAR
  - To be air transportable
- Storm Detection RADAR
  - To be air transportable
- Cloud Base and Top Detector
  - Must be physically small, so large antenna needed to be transportable

APQ-13A

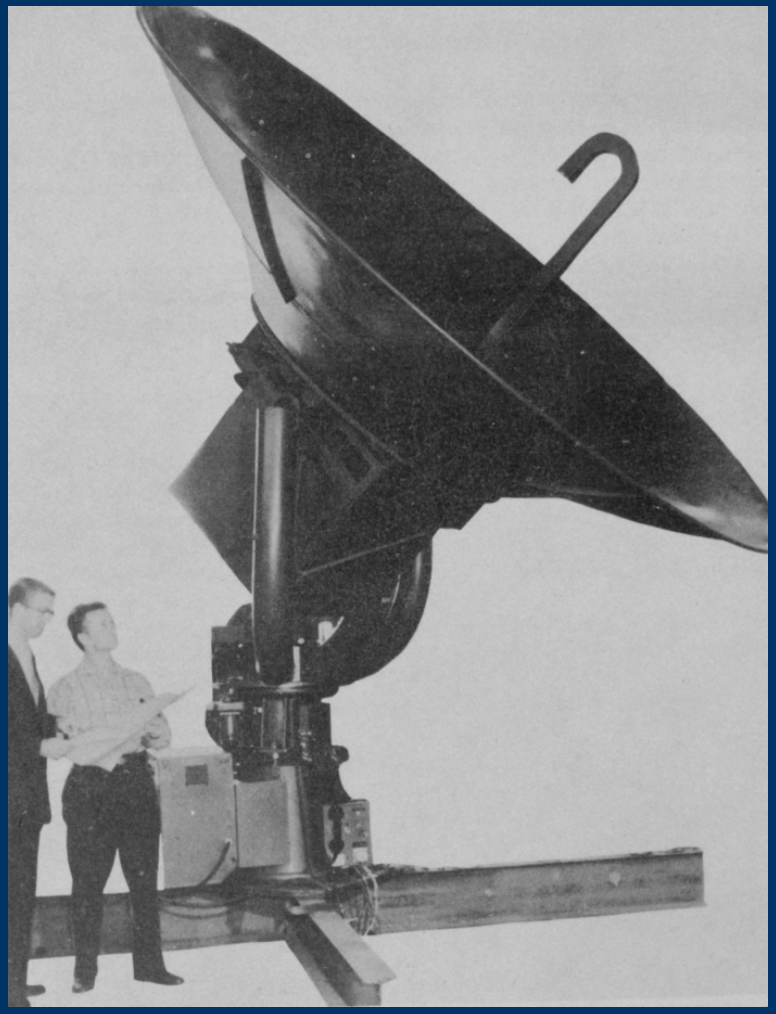
- First RADAR for general weather use
- Was adopted from military RADAR with only slight modifications for weather surveillance
- Deployed at 3 Air Force Bases in the Southern US

CPS-9

- Raytheon Cooperation
- Design accepted by the Air Force in 1953
- First RADAR specifically designed for weather detection
- Picture of severe convection on 1 July 1959 in Alabama



WSR-57



- Nationwide deployment at Airports and other locations
- Last one decommissioned 2 Dec 1996 in North Carolina.
- Greatly advanced the science, but had limitations.

Scientific Applications

Hurricane Tracking, Sept 1944

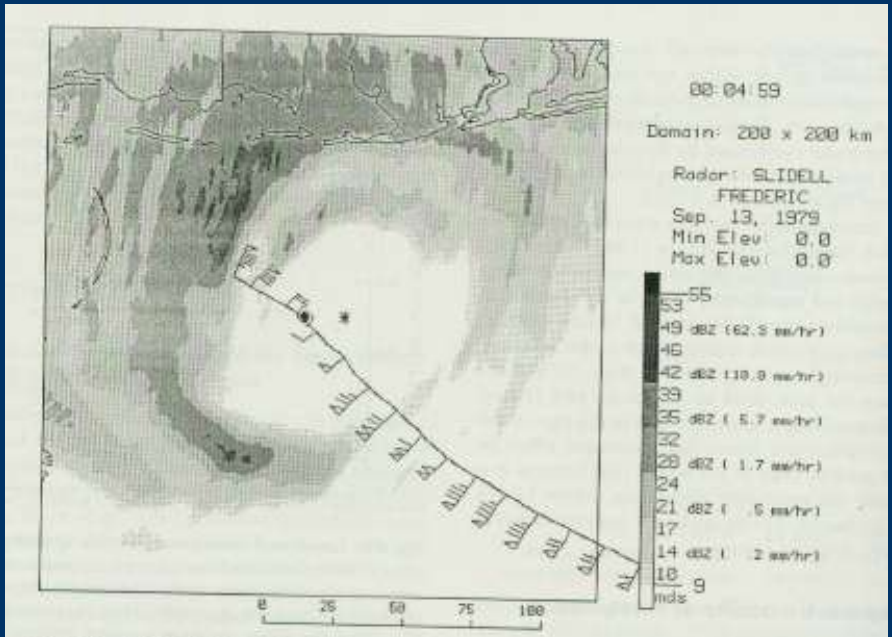


Fig. 3.10 Reflectivity data during Hurricane Frederic from the WSR-57 radar in Slidell, Louisiana at 0005 UTC 13 September 1979. The wind data are from one of the WP-3D aircraft. The flight-level observations were collected from 2355 to 0017 UTC as the aircraft headed northwest. The hurricane symbol represents the wind center, and the asterisk shows the approximate location of the radar center. The wind-plotting convention is as in Fig. 3.4. (From Burpee and Marks, 1984.)

- Large hurricane traveled up the East Coast past MIT
- The azimuth drive was broke on the RADAR, so D.E. Kerr pushed the RADAR along inside of the radome!
- National Hurricane Center would eventually do lots of great things with ground based and airborne RADAR.

1945-1946: Thunderstorm Project

FIG. 6. SCR 584 radar wind unit.

- Byers and Braham carried out field projects in Florida and Ohio
- Most important discovery was that RADAR could be used to guide aviation away from turbulence

Lightning Detection 1953

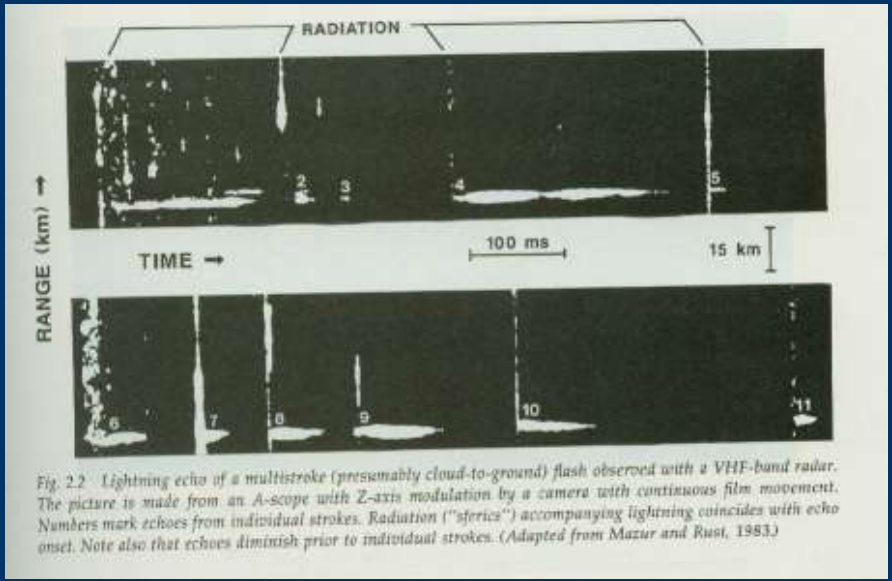


Fig. 2.2 Lightning echo of a multistroke (presumably cloud-to-ground) flash observed with a VHF-band radar. The picture is made from an A-scope with Z-axis modulation by a camera with continuous film movement. Numbers mark echoes from individual strokes. Radiation ("sferics") accompanying lightning coincides with echo onset. Note also that echoes diminish prior to individual strokes. (Adapted from Mazur and Rust, 1983.)

- Minor modification to the radar and display to detect lightning. Wanted to identify the electrically active storms.
- Much was and still is not known about lightning today.

Nuclear Cloud Detection 1958

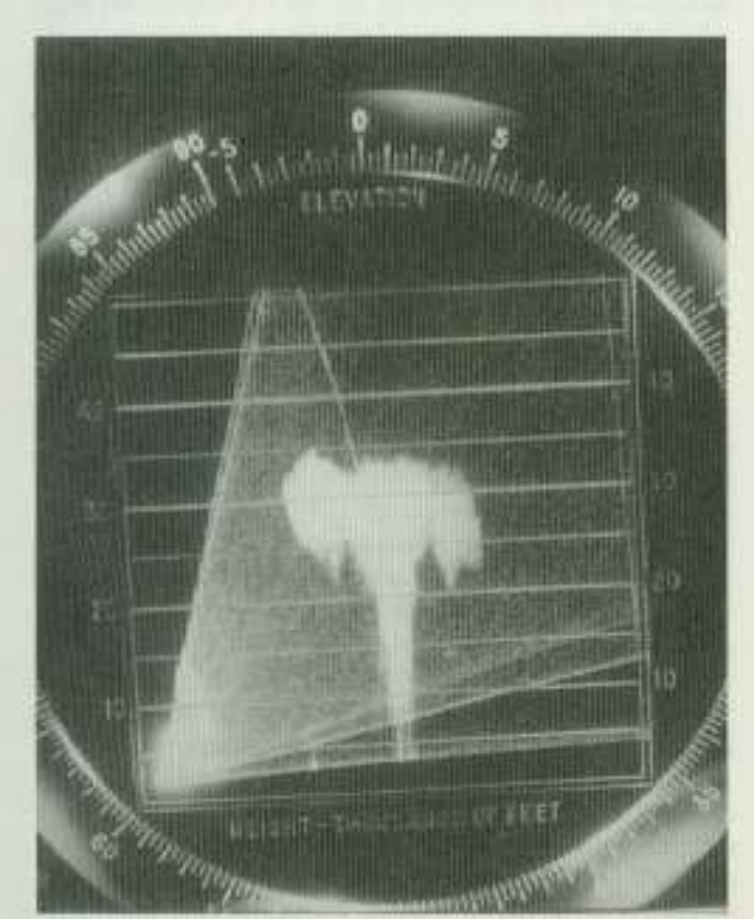


Fig. 2.1 *Mature nuclear cloud on AN/CPS-9 RHI scope.*

- Needed to detect and predict the movement of nuclear fallout for the Army.
- Had to take great care to remove the evidence of the mushroom clouds from the data logs.
- A lot of the research was classified and thus not available to the research community

Ingesting data for modeling

- Halstead and Clayton (Texas A&M) got a contract to ingest the RADAR data into a computer that solved an Eulerian set of equations for a baroclinic atmosphere.
- Found that they could make accurate boundary layer predictions with more skill than a persistence model.
- Major military benefits for ordinance delivery.

Tropopause Detection

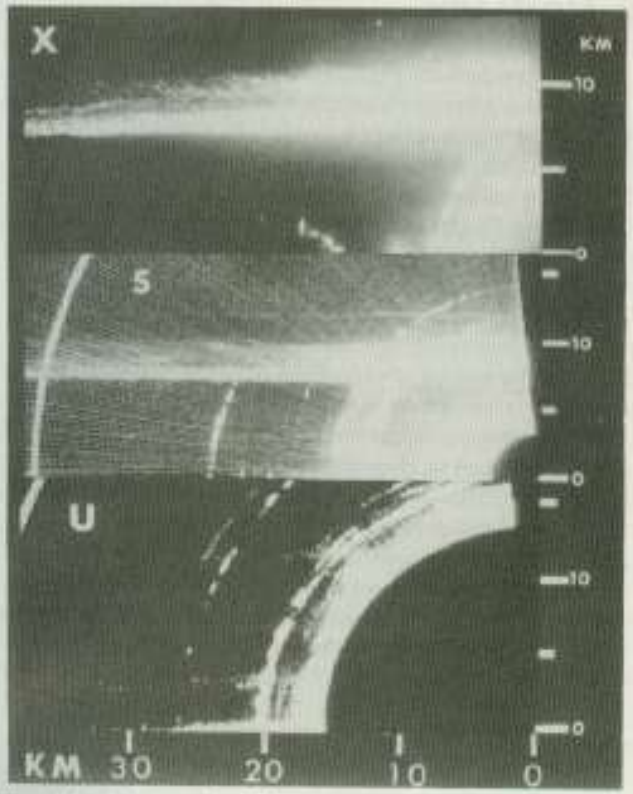
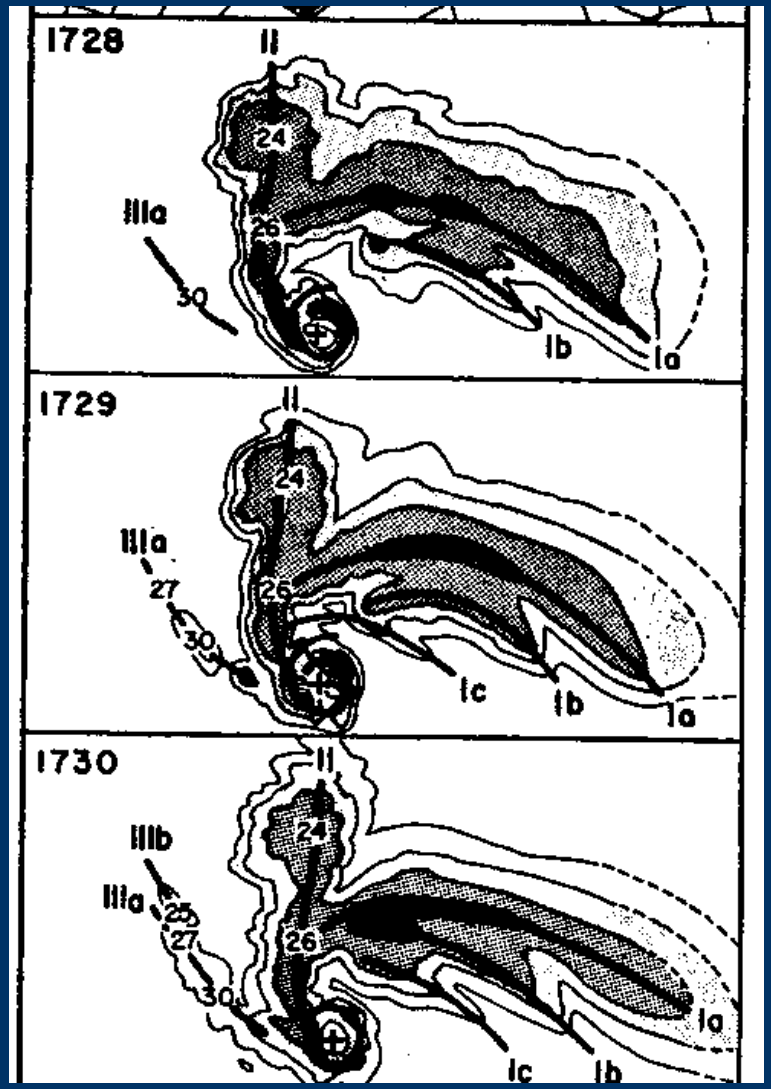
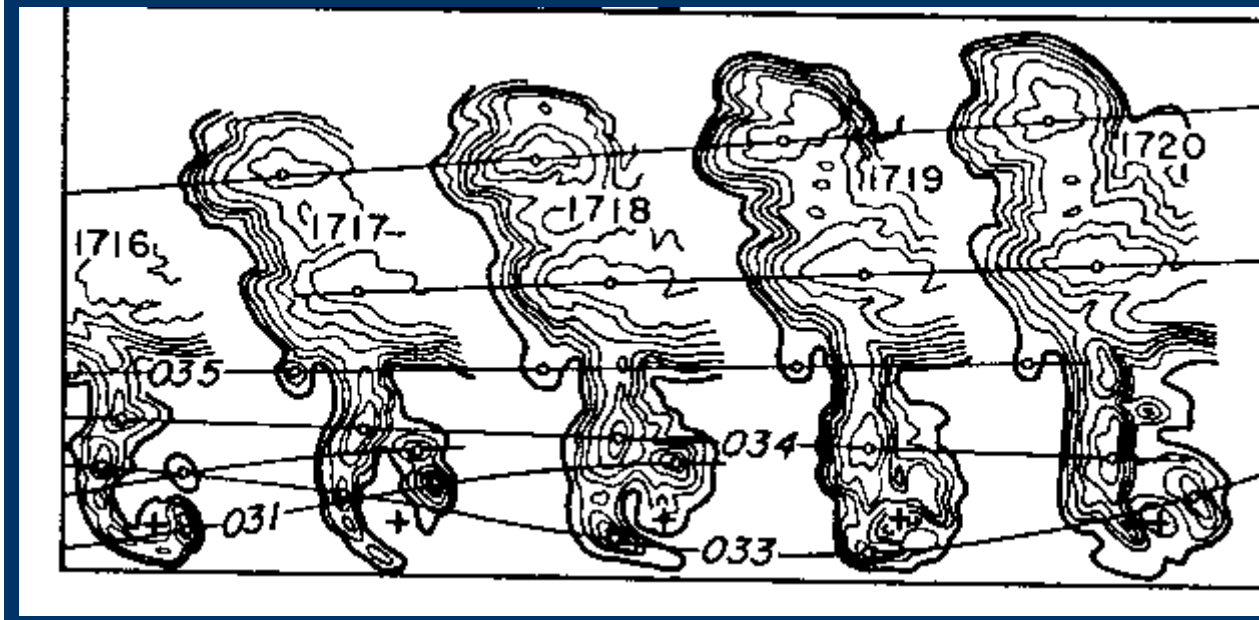


Fig. 9 First observation of the tropopause by radar, from Wallops Island, Virgina , in February 1966. Observations (top to bottom) were made with radars of 3 cm (X-band), 11 cm (S-band), and 72 cm (UHF) wavelengths. Tropopause is near 11 km height, above a cloud layer which is strongly reflective at the shorter wavelengths but undetectable at 72 cm (after Atlas et al. 1966b). (© 1966 by the AAAS.)

- The vertical refractive index is effectively a function of stability.
- Tropopause can be easily found by a vertically pointing RADAR.
- The importance of the tropopause was just being understood for hail prediction.

Fujita's Work





NCAR Projects

- MAYPOLE “May Polarization Experiments” 1983
- CLAWS “Classify, Locate, and Avoid Wind Shear” 1984
- MIST “Microburst and Severe Thunderstorm” 1986
- CINDE “Convective Initiation and Downburst Experiment” 1987

NSSL 1960s

- Increasing air traffic was encountering severe local convection. Weather Bureau responded by forming SELS (Severe Local Storms Forecast Unit).
- NSSP (NSSL) grew out of SELS as a research project with their own WSR-57
- The rise of Doppler RADAR had high priority at NSSL. Being able to sense velocity and water at the same time had many applications.

1965: Project Rough Rider

- A host of aircraft to penetrate storms and take various readings
- 5 RADARs staffed with highly trained personal
- During the 1960s, ~1000 flights were made
- Major findings
  - How storms modify their environment
  - in-situ data for effects on aviation
- Even with a massive increase in air travel during the 1970s, convection related accidents went down.

1970s: RADAR and aviation

- While mid-tropospheric accidents went way down, low attitude problems persisted.
- NSSL & FAA worked closely to diagnose the gust front and its threat to aviation
- It was decided that an automated network of anemometers would be needed at each of the airports to augment the RADARs
- Low Level Windshear Alert System (LLWAS)

24 May 1973: Tornadic circulation

- Massive tornado struck Union City and was visible from the NSSL facility
- Very strong gate-to-gate sheer was clearly visible.
- First capture of the complete life-cycle
- TVS – Tornadic Vortex Signature was noted on the RADAR. Later formalized by Leslie Lemon et al

JDOP: The precursor to NEXRAD

- WSR-57 was aging fast and doppler technology was proving to be the logical successor
- Joint Doppler Operational Project (JDOP) 1976 to test NSSL Doppler RADAR operationally
- Final Report in 1979 proved that Doppler RADAR can be used to issue more timely and accurate warnings
- Governments response was NEXRAD

SESAME: The Big One!

- Severe Environmental Storms and Mesoscale Experiment was operated by NSSL 1979
- 18 government agencies, 17 universities studied all sorts of things with 6 Dopplers
- They caught the famous 10 April 1979 Wichita Falls, Texas tornado.
- Lots of data and new understanding came from this research

Research groups around the world

Stormy Group: (Canadians)

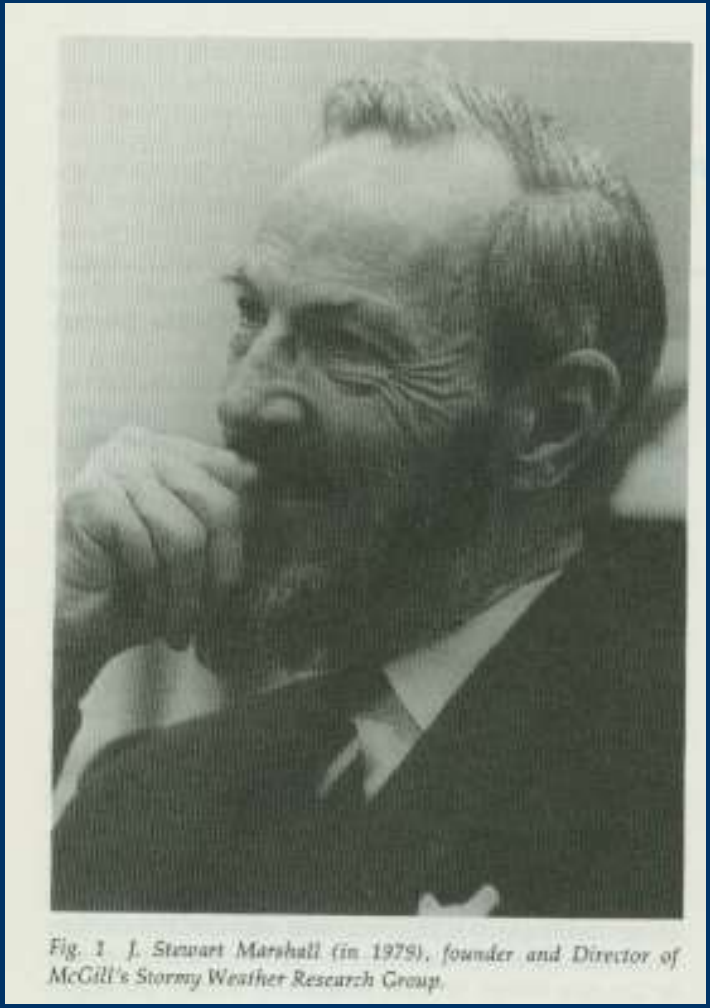
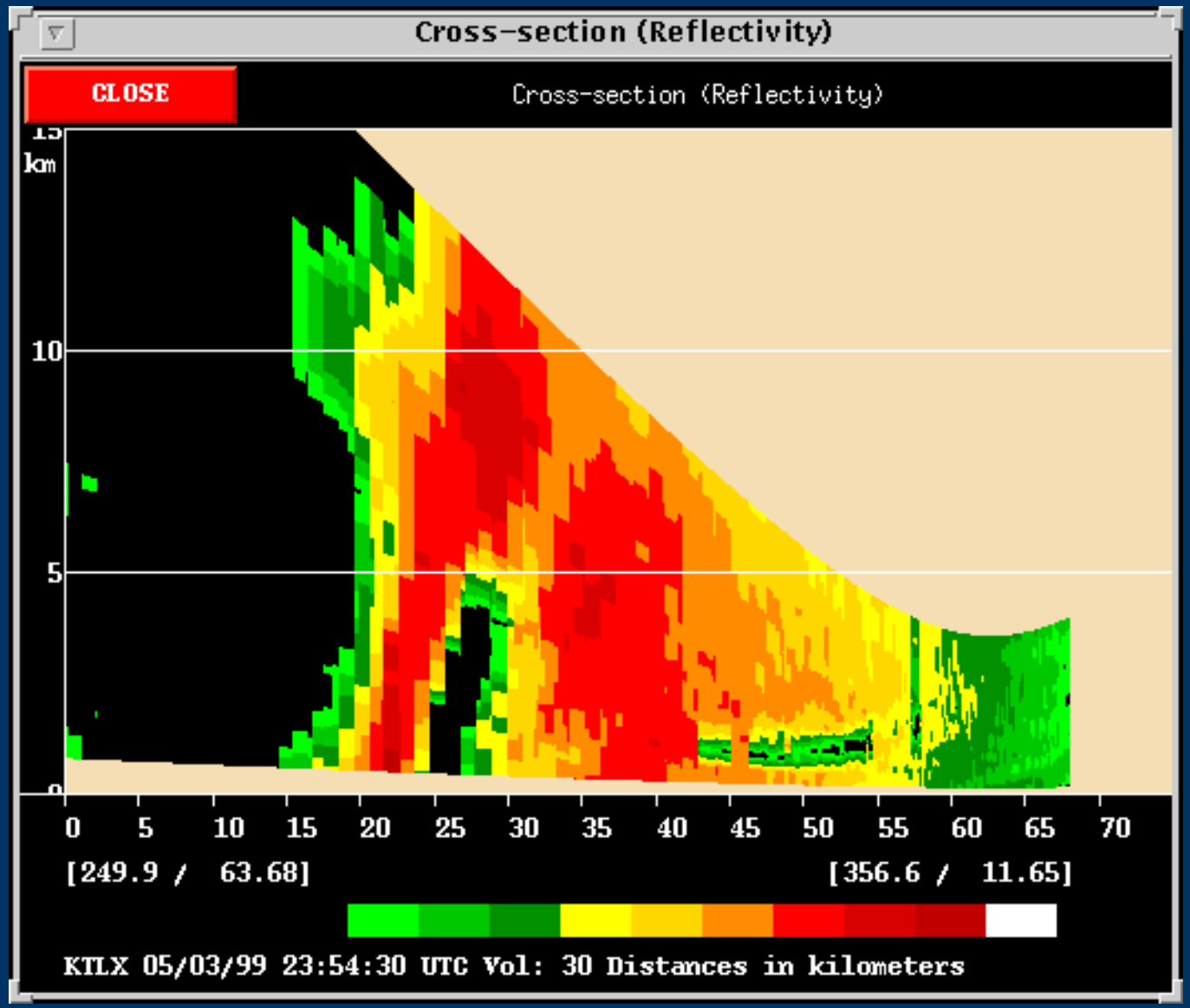


Fig. 1 J. Stewart Marshall (in 1979), founder and Director of McGill's Stormy Weather Research Group.

- Founded 1943 under Stewart Marshall
- Invented CAPPI (Constant Altitude Plan Position Indicator) -> Volume scanning
- Late 1950s, worked on hail detection
- 1967: Chisholm described BWER and UWER
- 1968: McCormick used polarized RADAR to determine hydrometers

BWER


Cross-section (Reflectivity)
CLOSE
Cross-section (Reflectivity)
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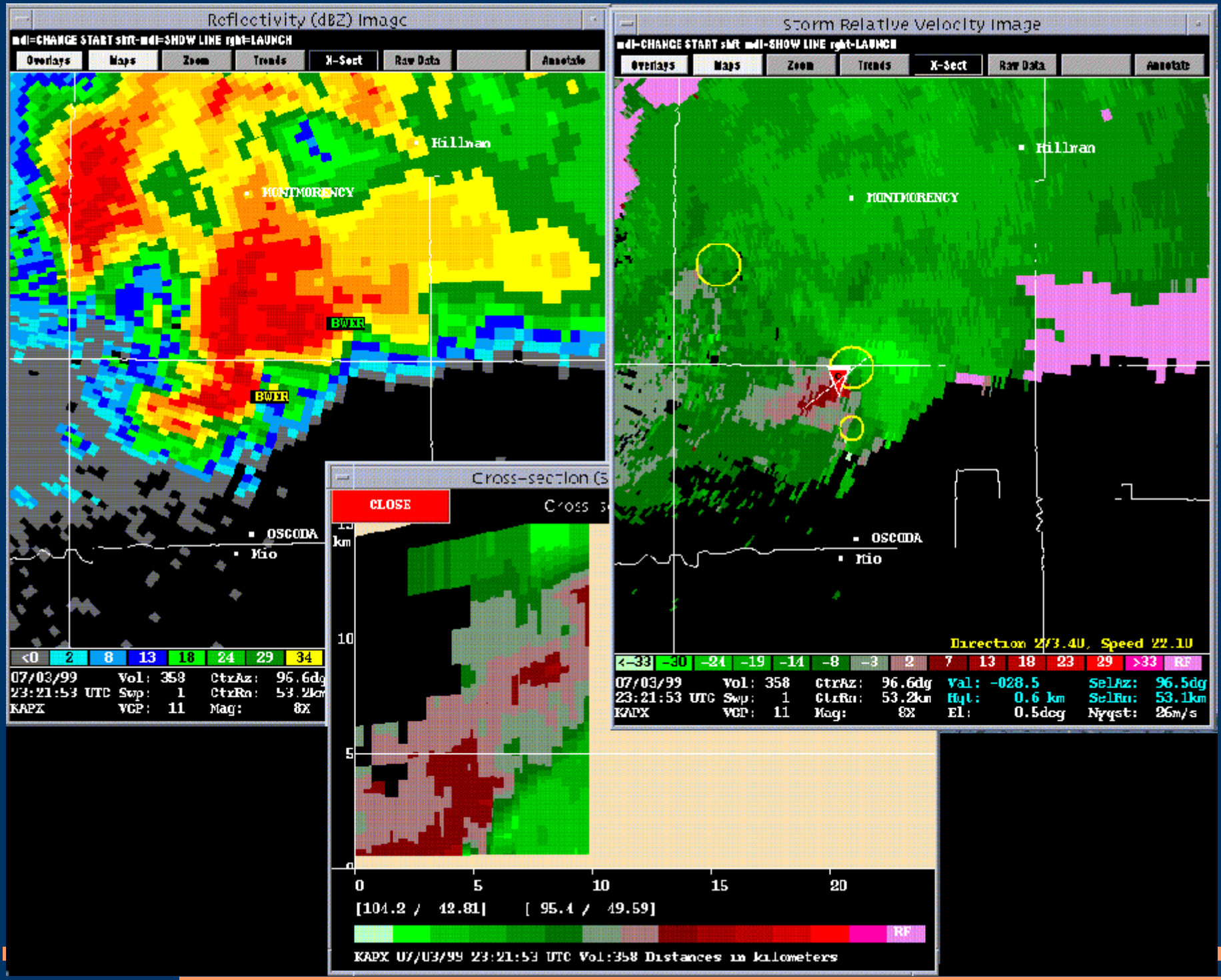
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
[249.9 / 63.68]
[356.6 / 11.65]
KTLX 05/03/99 23:54:30 UTC Vol: 30 Distances in kilometers


Reflectivity (dBZ) Image
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Storm Relative Velocity Image
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23:21:53 UTC Swp: 1 CtrRn: 53.2km Hgt: 0.6 km SelRn: 53.1km
KAPX VCP: 11 Mag: 8X El: 0.5deg Nyqst: 26m/s

Japan: Typhon Research Lab

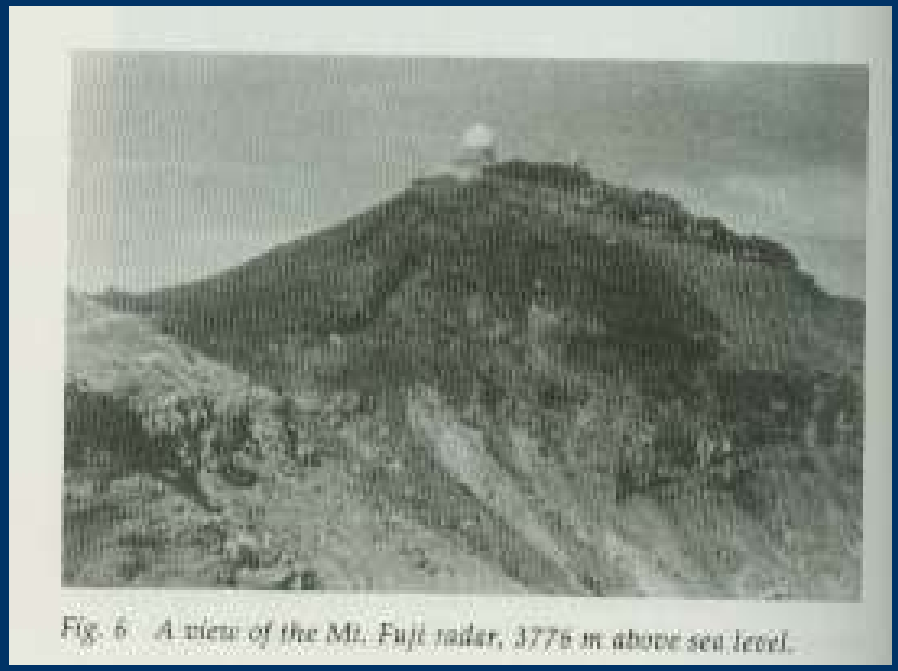


Fig. 6 A view of the Mt. Fuji radar, 377m in above sea level.

- 1954: Installed X-band RADAR near Tokoyo
- Tracked thunderstorms and typhoons
- Notable Finds
  - Relationship between echo tops and thunderstorms
  - 1966: Yanagisava noticed a certain echo type was favored in certain synoptic conditions
  - 1968: Banded structure of Typhoons

Indian Meteorological Department

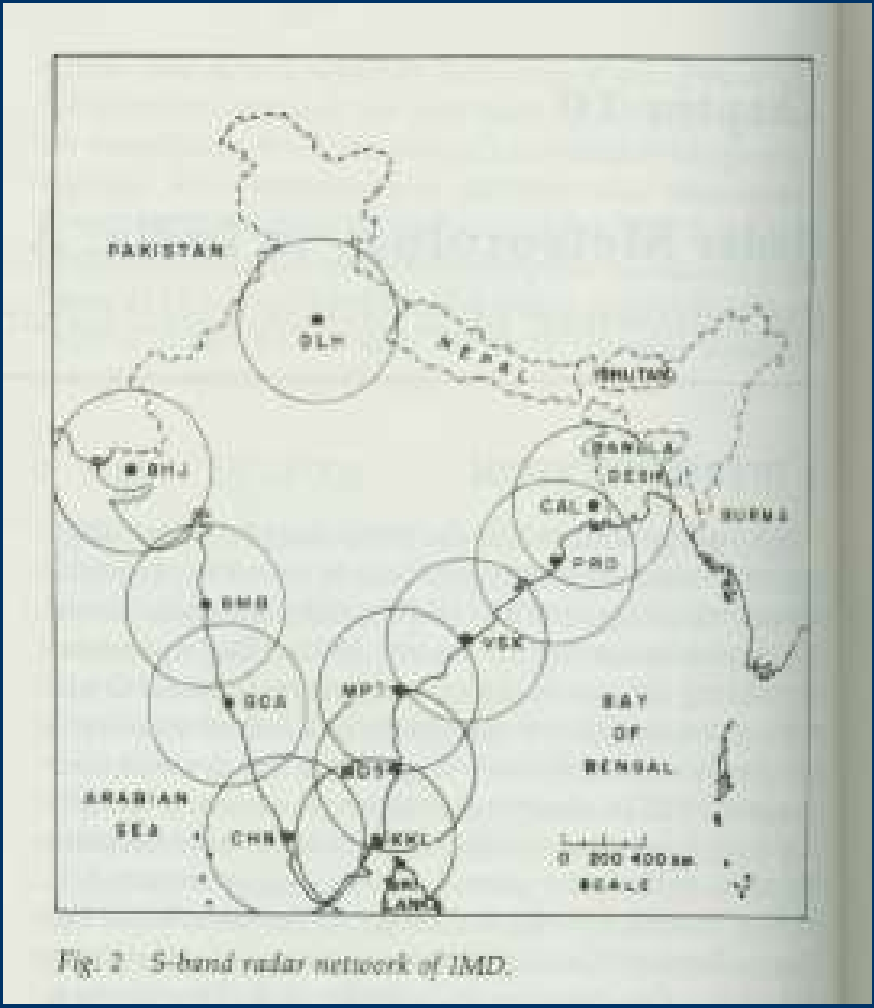


Fig. 2 S-band radar network of IMD.

- Surplus RADARs after WWI got them started
- Early 1950s, deployed a network of C & X band RADARs
- Mostly imported technology, first homegrown system was 1970.

China

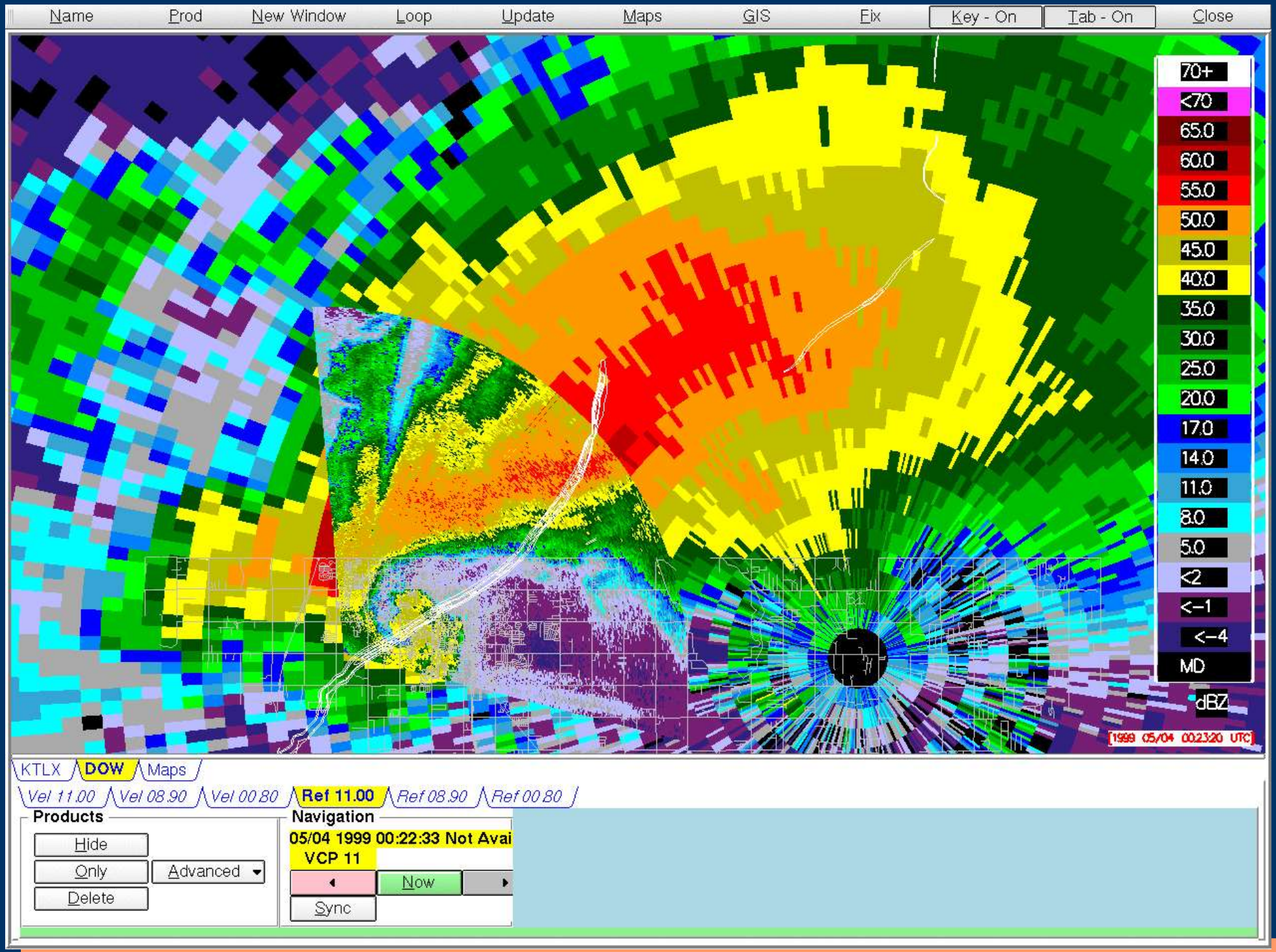
- First imported two RADARs in 1958. They were installed in Shanghai & Beijing
- Most research focused on Typhon detection and prediction
- Du-Cheng Zhou (1981) adopted the Archimedes Spiral to locate the center of “Hollow Typhoon” using RADAR

Project VORTEX

- Verification of the Origins of Rotation in Tornadoes Experiment

DOW: Doppler on Wheels

- Joshua Wurman OU
- 4 days after being deployed for VORTEX, it caught a tornado on the ground for 45 minutes near Hanston, KS. 16 May 1995
- May 3rd 1999
  - Josh Wurman's Doppler on Wheels scanned a tornado in Oklahoma and recorded a wind speed of 318 mph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Look how far we have come

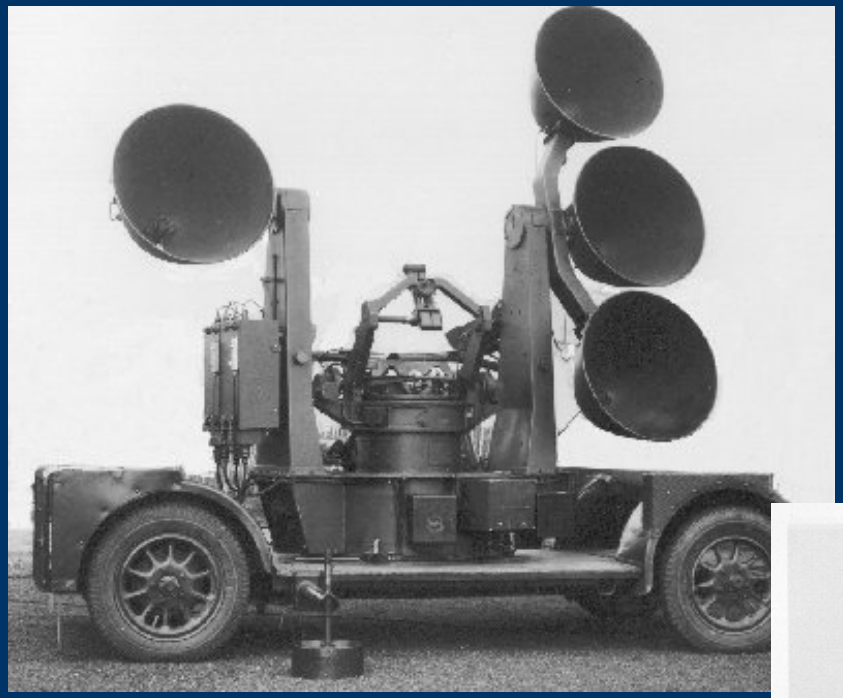
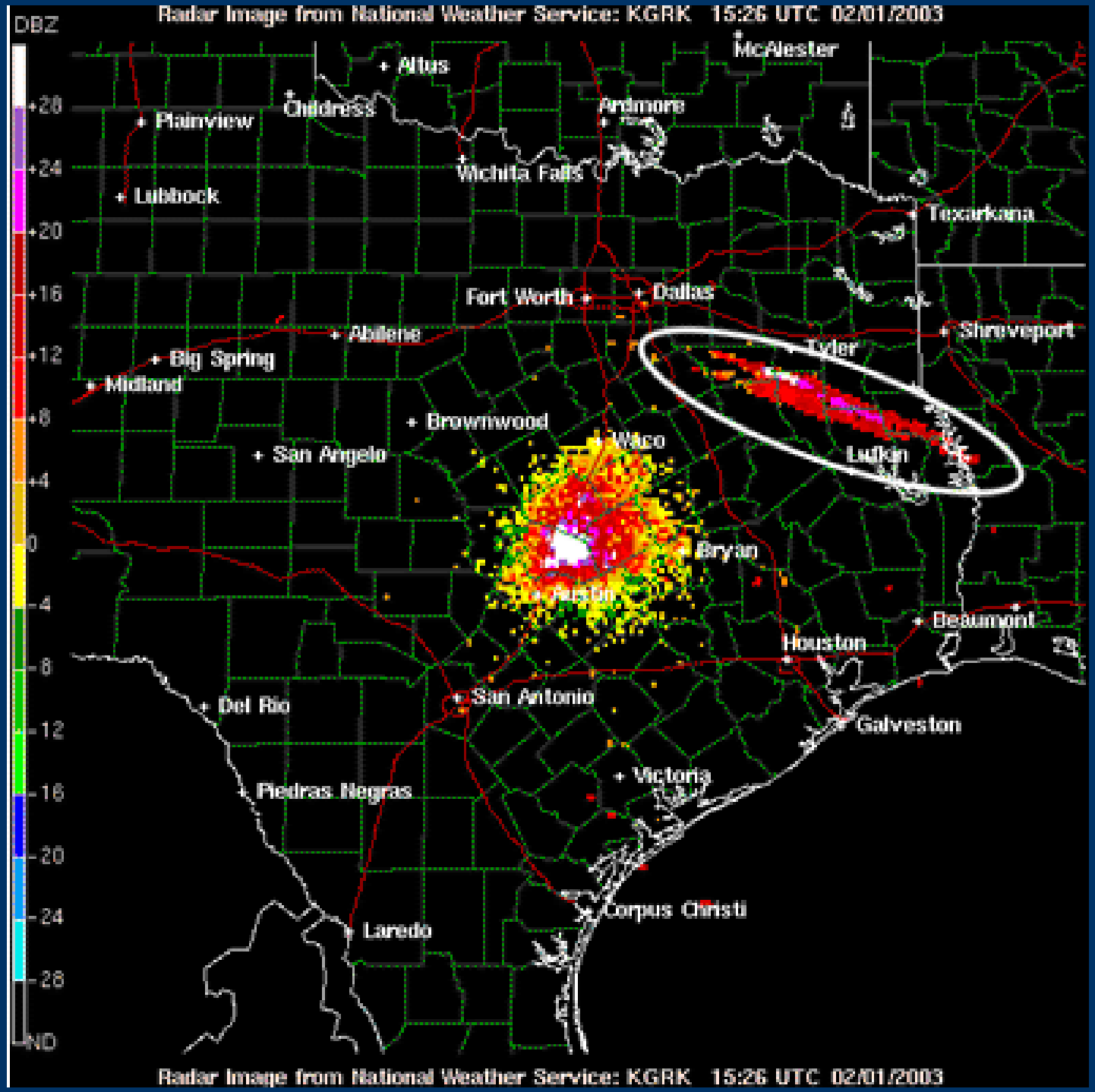


FIG. 6. SCR 584 radar wind unit.

WSR-88D: NEXRAD

- D is for Doppler
- Advantages over WSR-57
  - Improved Sensitivity
  - Volume Scanning
  - Algorithms
  - Resolution
- Nationwide deployment a part of the modernization effort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Altus
Childress
Ardmore
Plainview
Wichita Falls
Lubbock
Texarkana
Fort Worth
Dallas
Abilene
Shreveport
Tyler
Big Spring
Midland
Brownwood
Waco
San Angelo
Lufkin
Bryan
Austin
Beaumont
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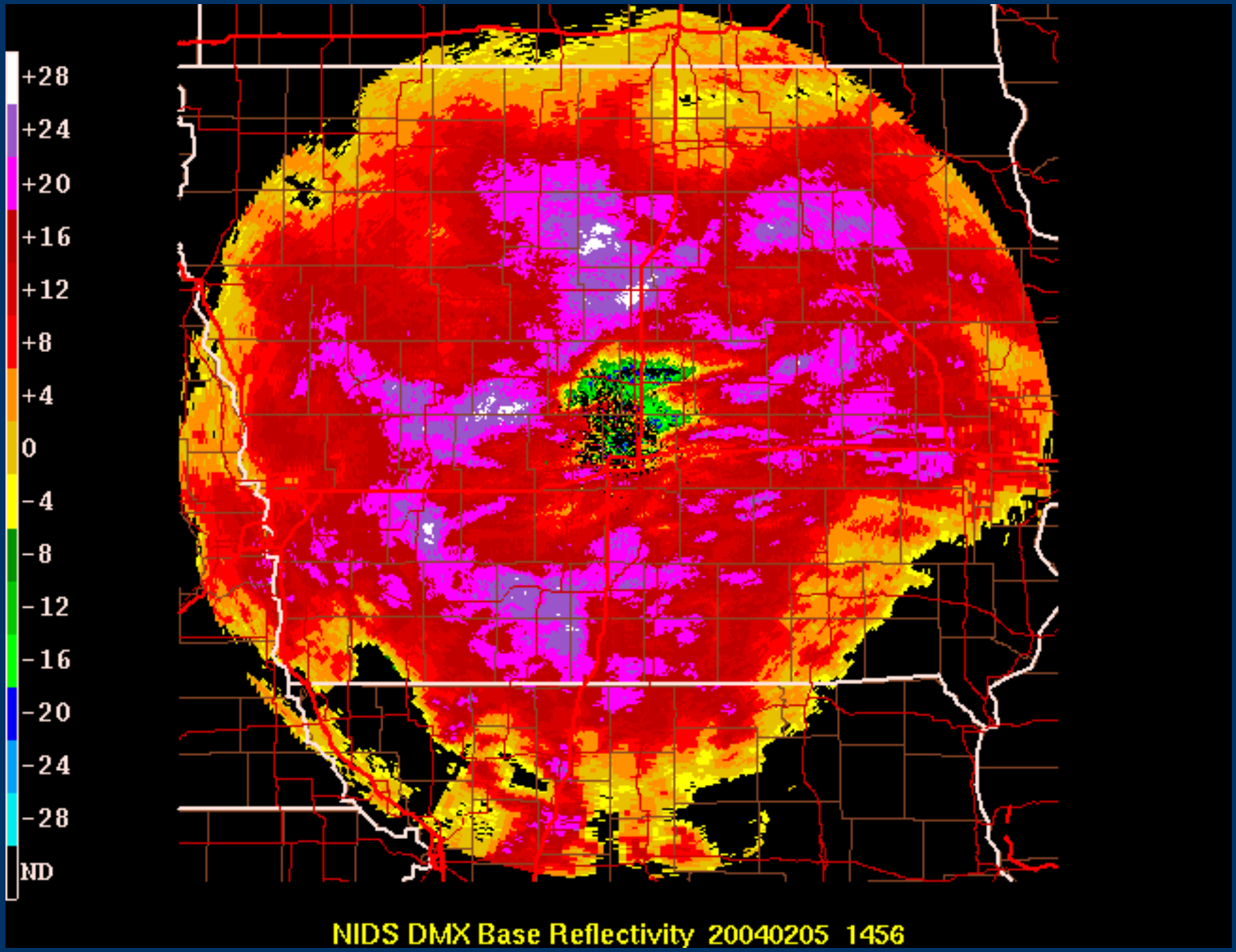
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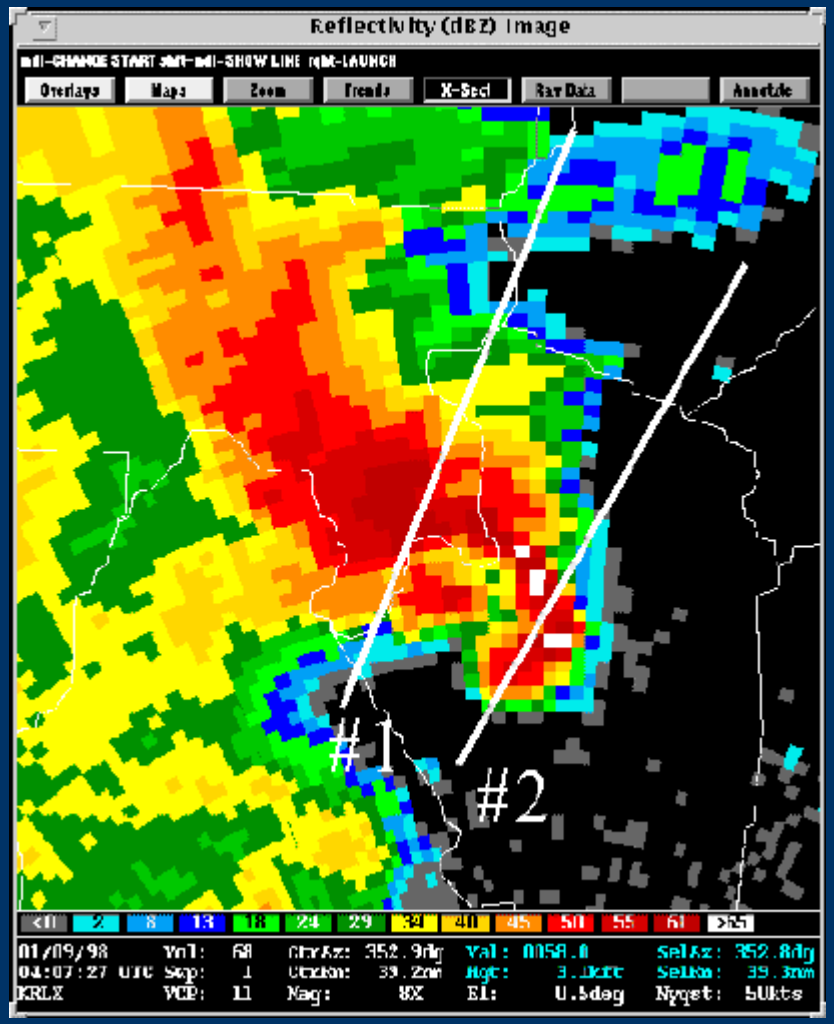
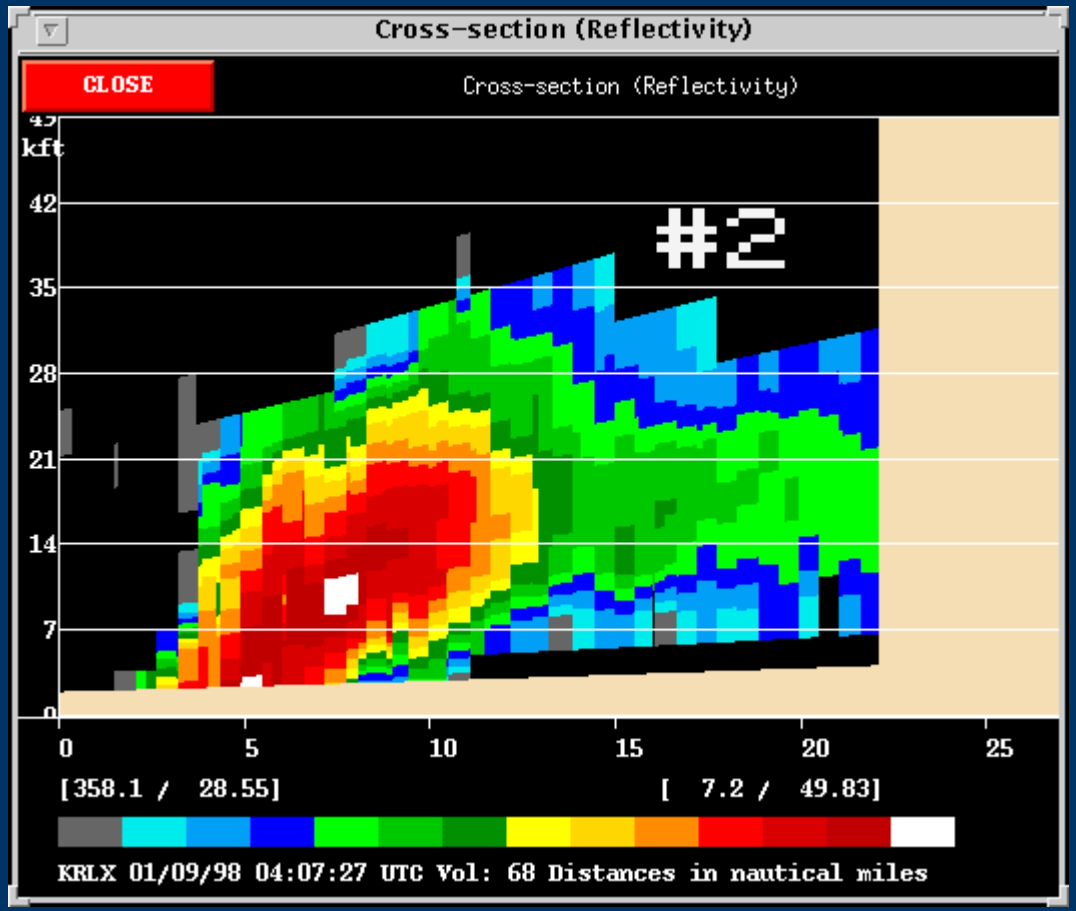
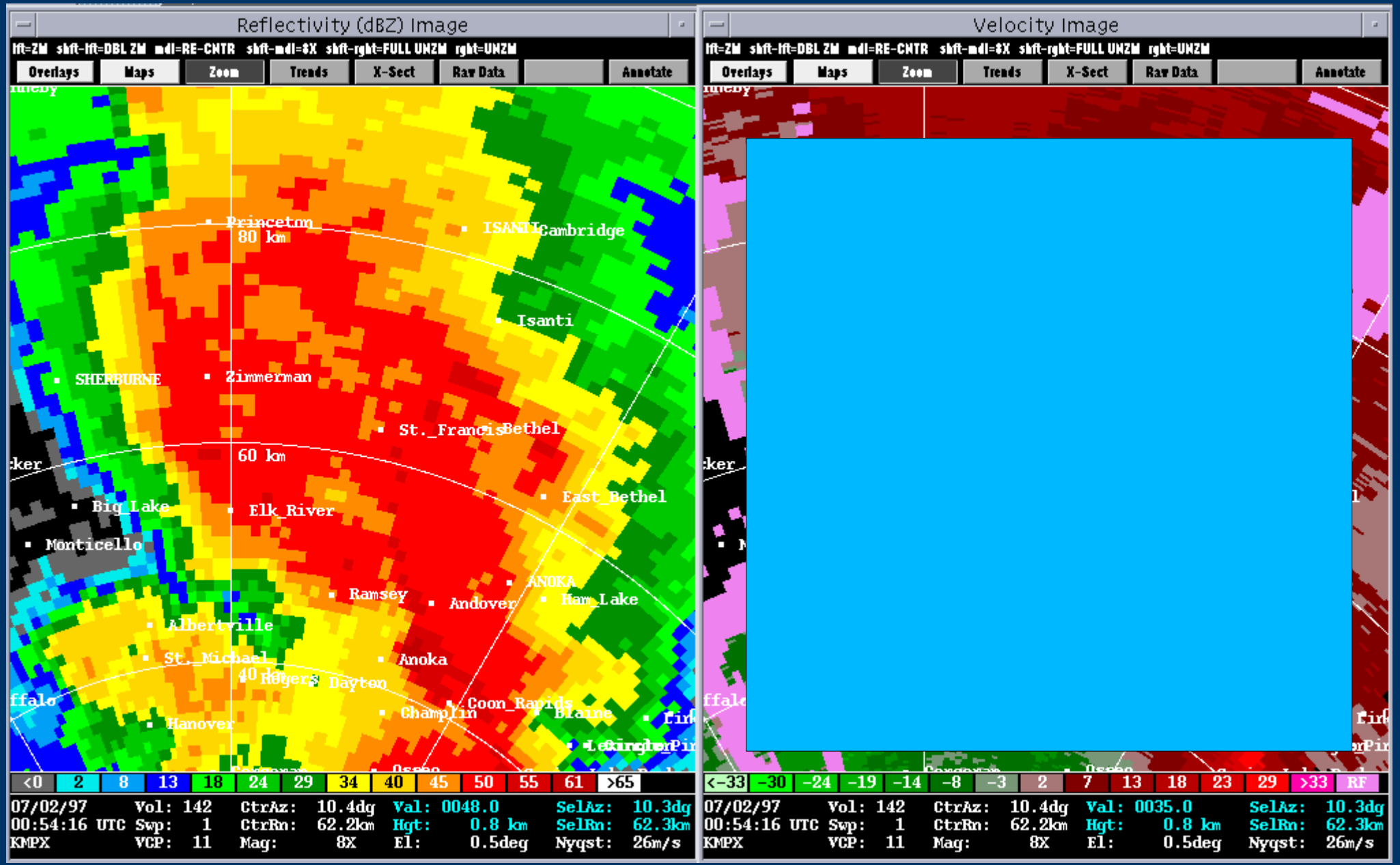
Low Top Super Cell






Reflectivity (dBZ) Image
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SHERBURNE
Zimmerman
St._Francis
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Big_Lake
Elk_River
Monticello
ANOKA
Ramsey
Andover
Ham_Lake
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00:54:16 UTC Swp: 1 CtrRn: 62.2km Hgt: 0.8 km SelRn: 62.3km
KMPX VCP: 11 Mag: 8X El: 0.5deg Nyqst: 26m/s
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KMPX VCP: 11 Mag: 8X El: 0.5deg Nyqst: 26m/s

I'm done...

Internet References

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- http://www.firstworldwar.com/bio/smuts.htm
- http://users.whsmithnet.co.uk/colin.martin/radio/ducting.html
- http://snrs.unl.edu/amet451/garner/rac.html
- http://www.skywarn.ampr.org/radar3b.htm
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