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INNOVATIVE ADVANCEMENTS IN RADAR TECHNOLOGY FOR WEATHER OBSERVATIONS

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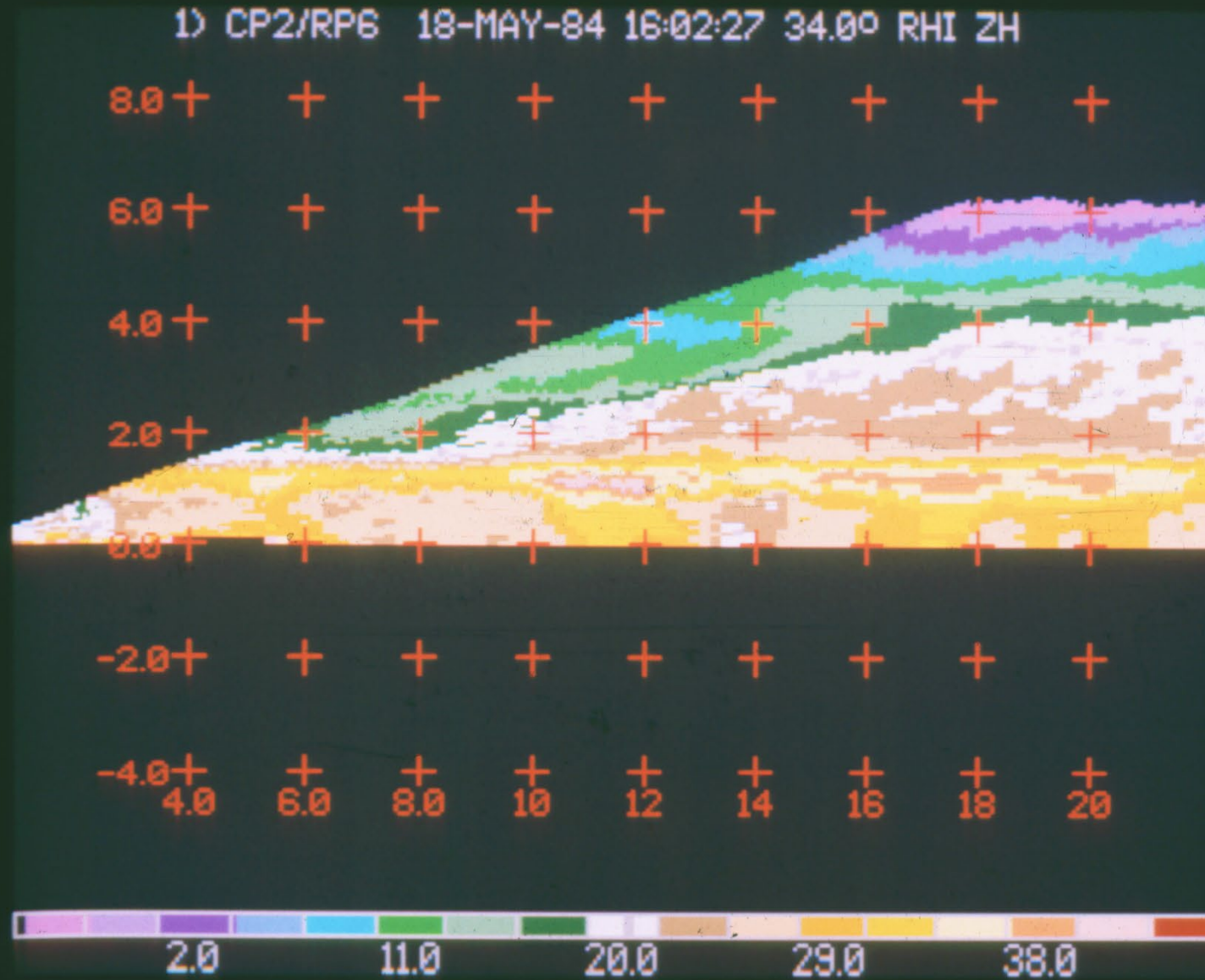
Introduction, some window into the past

How and when Innovative advancement in radar
technology
was applied for weather observations

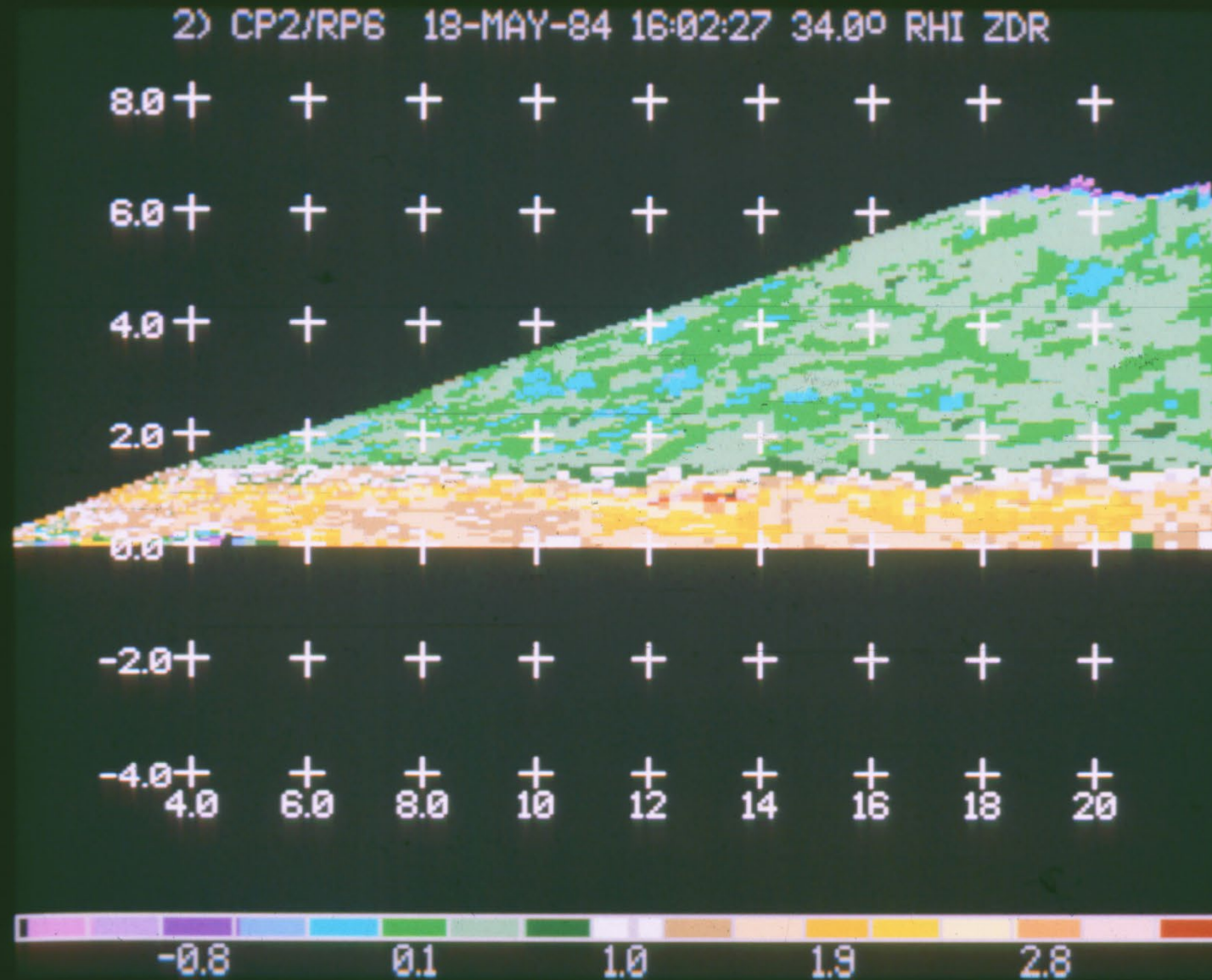
Dual Polarization Radar and precipitation microphysics: Basic Science to Systems



Dual Polarization Measurements



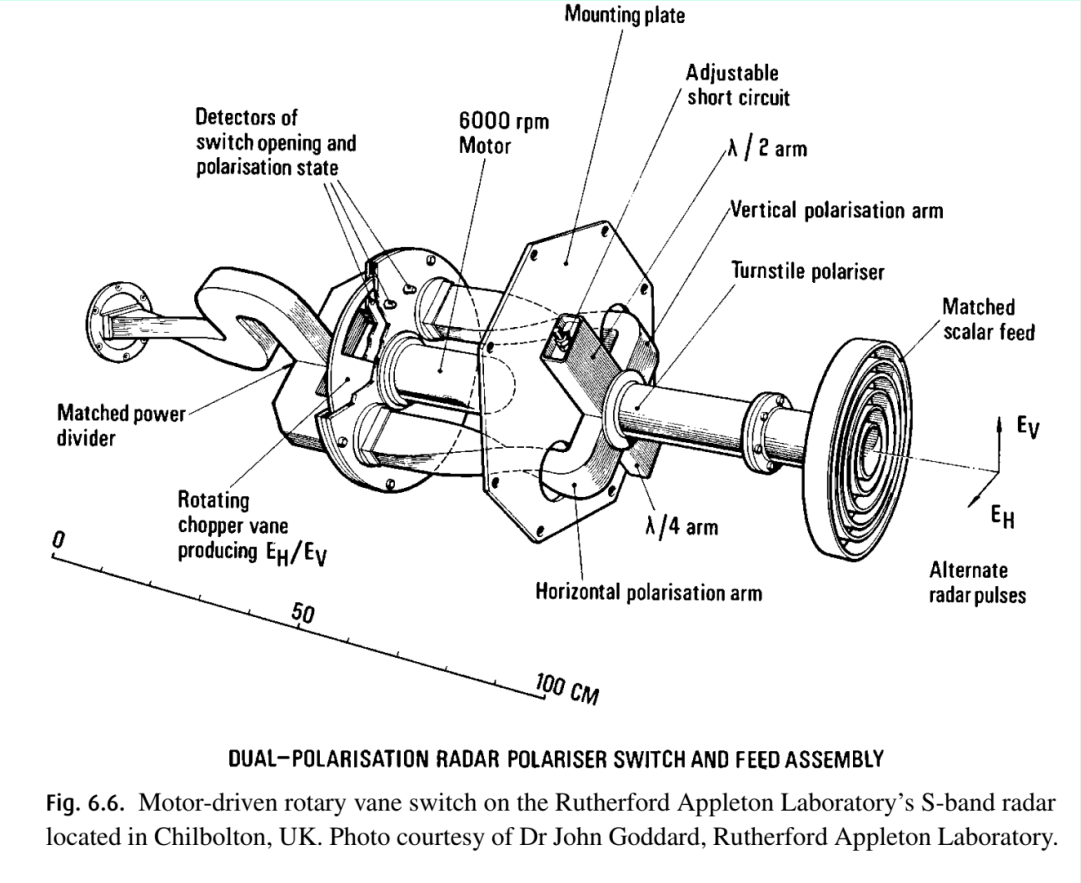
Dual Polarization Measurements



How was it accomplished (in the tone of how I built it)

1. Knew we had to make dual-pol measurements
2. Simple measurements with one radar at H pol and the other at V pol did not cut it.
3. Needed fast measurements (near simultaneous transmit and receive)
4. In early eighties if you asked for two transmitters and two receivers , you will be thrown out of the room.
5. Had to settle for a fast switch to change polarization between H and V .
That was accomplished with a High-speed switch that can handle MW of peak power and switch between two ports.
6. Two technologies enabled that a) Waveguide switch built in UK and Ferrite Switch built in the US (CP-2 and CHILL radars).
7. Later at CHILL Gene Mueller, got a spare klystron transmitter and we built the two transmitter two receive system, which was the first architecture suggested by Seliga and Bringi in 1976.

Equivalent to the role played by magnetron in the invention of radars



The most modern architecture that will be in all modern solid-state dual pol radars –
Will revisit with signal processing technology

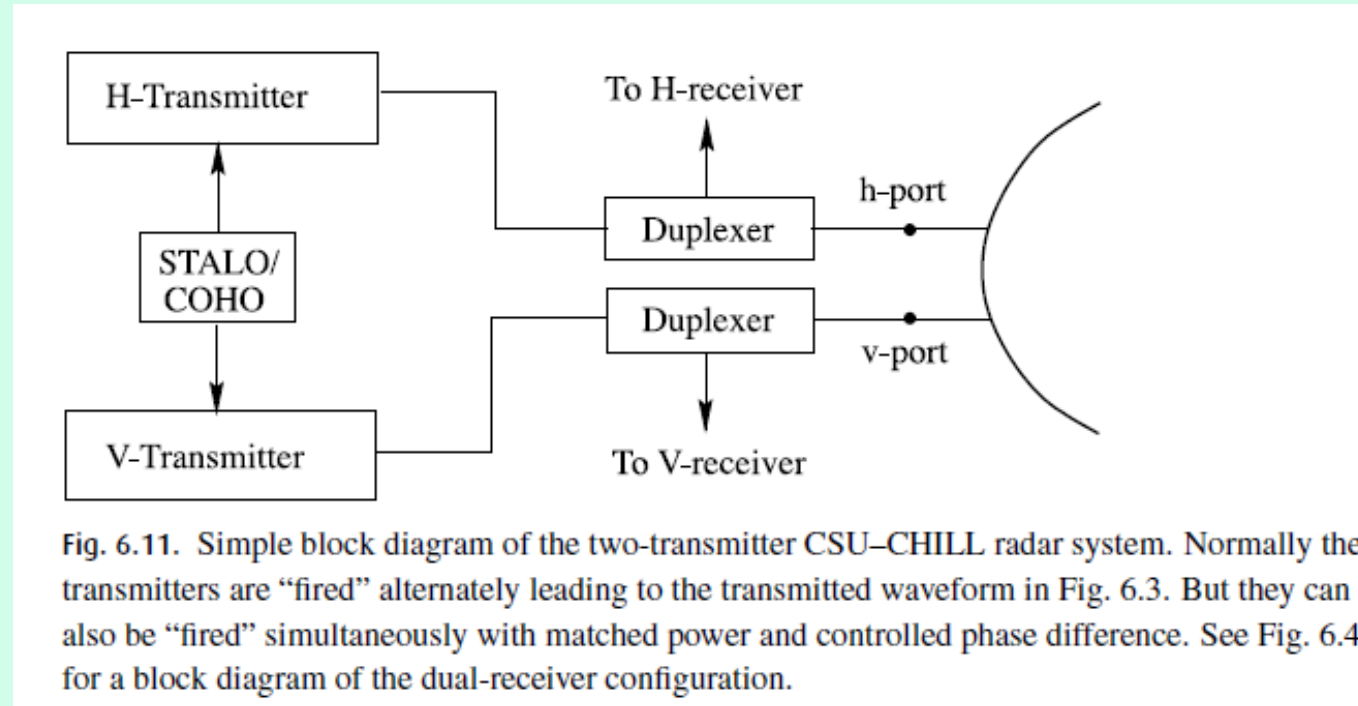
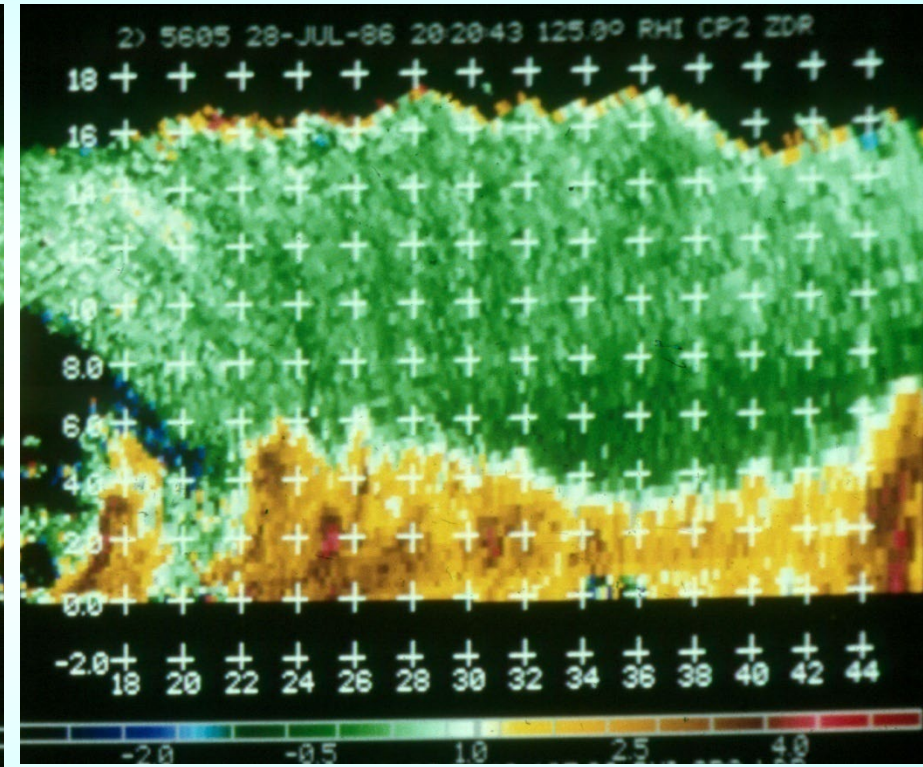
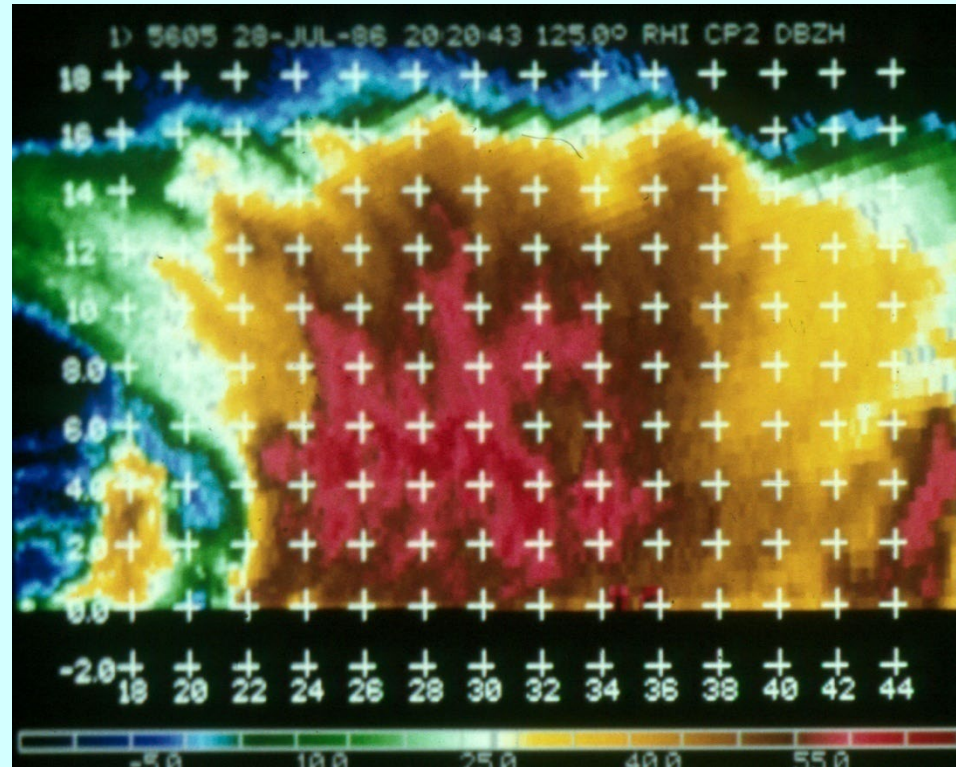


Fig. 6.11. Simple block diagram of the two-transmitter CSU-CHILL radar system. Normally the transmitters are “fired” alternately leading to the transmitted waveform in Fig. 6.3. But they can also be “fired” simultaneously with matched power and controlled phase difference. See Fig. 6.4 for a block diagram of the dual-receiver configuration.

Dual Polarization Measurements

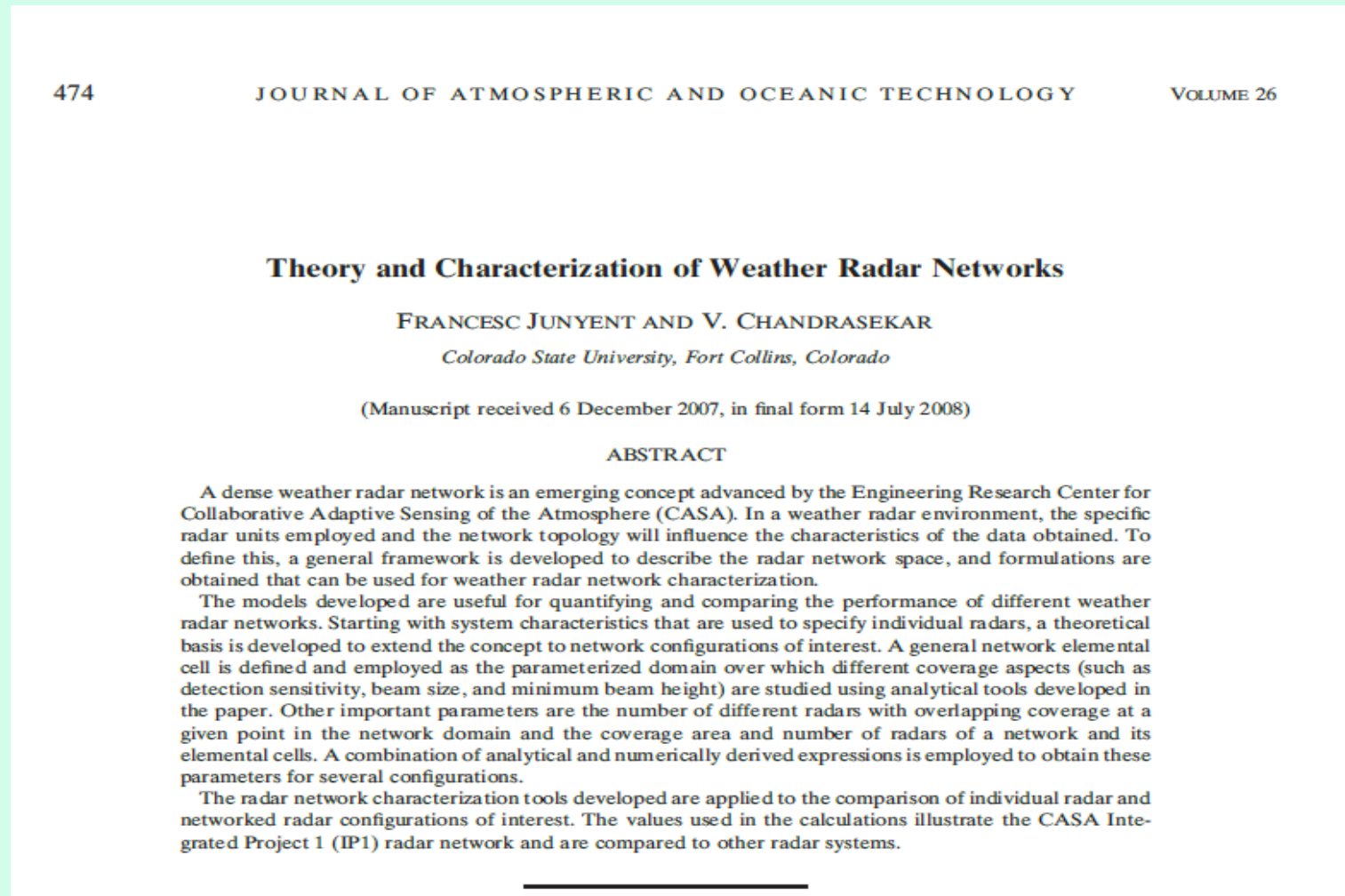


What was the alternative at that time...

1. We all knew we have to measure more than reflectivity
2. There was lot of research into dual-frequency systems.
3. But the technology was “ complicated “.
4. More papers were written showing the artifacts than the advancements brought by dual frequency measurements
5. CP-2 radar built the dual-frequency system to also measure LDR (Spent time characterizing the X antennas at National Bureau of Standards (now NIST)

Radar networks— This is the present past and future

- There was a highly conceptual paper (similar to Seliga and Bringi paper of 1976), called theory of weather radar networks



We are going through the transformation of this as we went through for dual-pol as new innovative technologies are becoming more accessible developed by comm and space industry.



The CASA concept is growing across the world like wildfire -

SHORT-WAVELENGTH TECHNOLOGY AND THE POTENTIAL FOR DISTRIBUTED NETWORKS OF SMALL RADAR SYSTEMS

Technology concepts from
CASA and actual progress

Critical technology came from dual-pol spinoff Invented by British mathematician (just like the Cooly Tucky paper that spun off Digital Signal processing ..

Other critical technology –
Waveform design for solid-state
sources

sands of phased-array radars will be to achieve a design that can be volume manufactured for ~\$50,000 per phased-array panel (assuming four panels per site and assuming each panel is self-contained with the antenna elements and radar transceivers as well as computers for beam steering, data acquisition, and signal processing, communication interfaces, and power conditioning electronics). Establishing the specifications for these arrays is currently a work in progress (e.g., McLaughlin et al. 2007); however, several key parameters can be stated, as listed in Table 5.

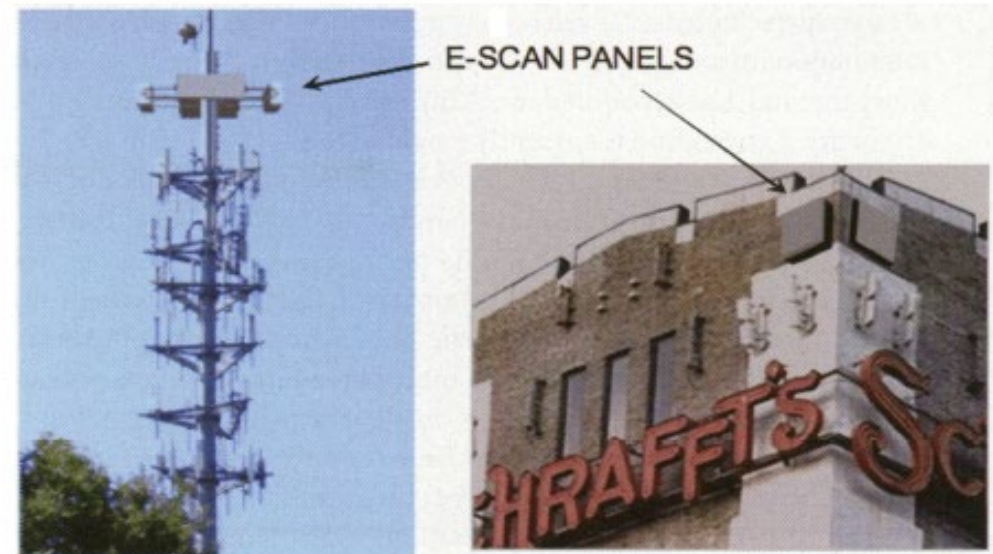
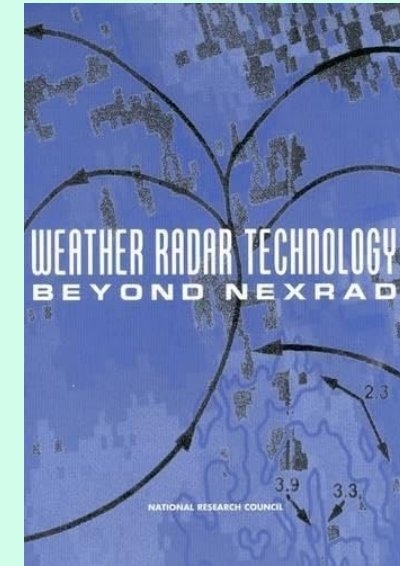
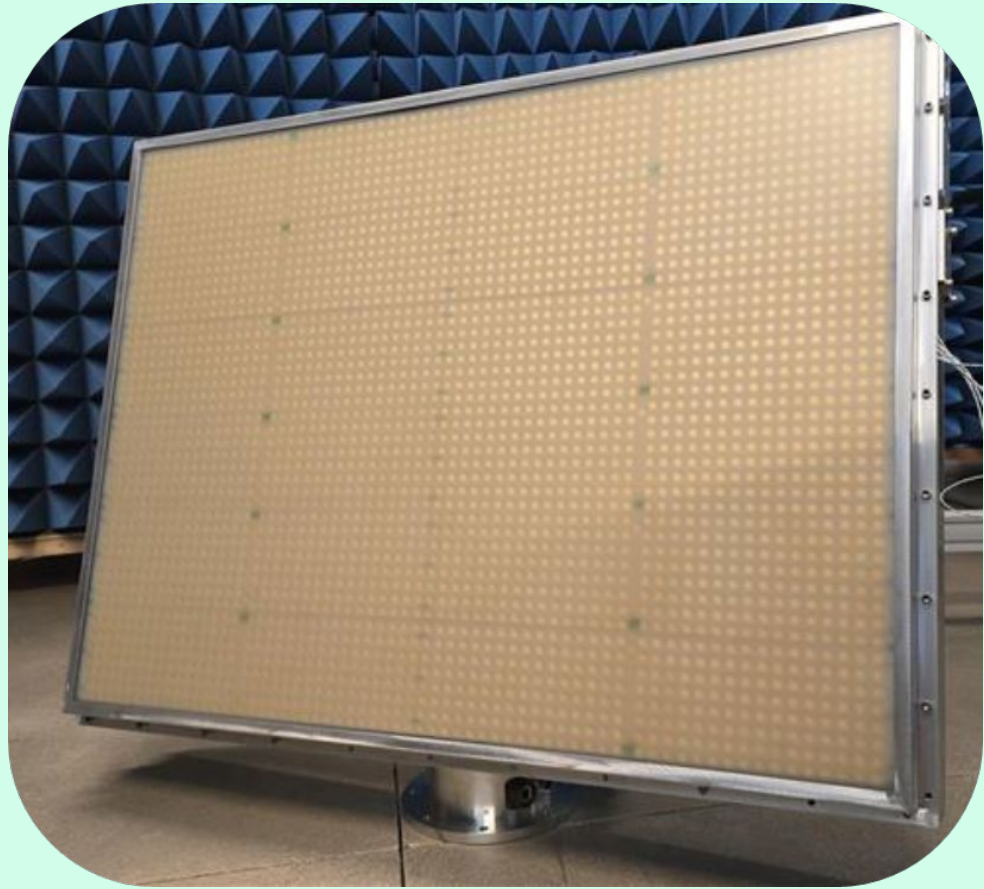
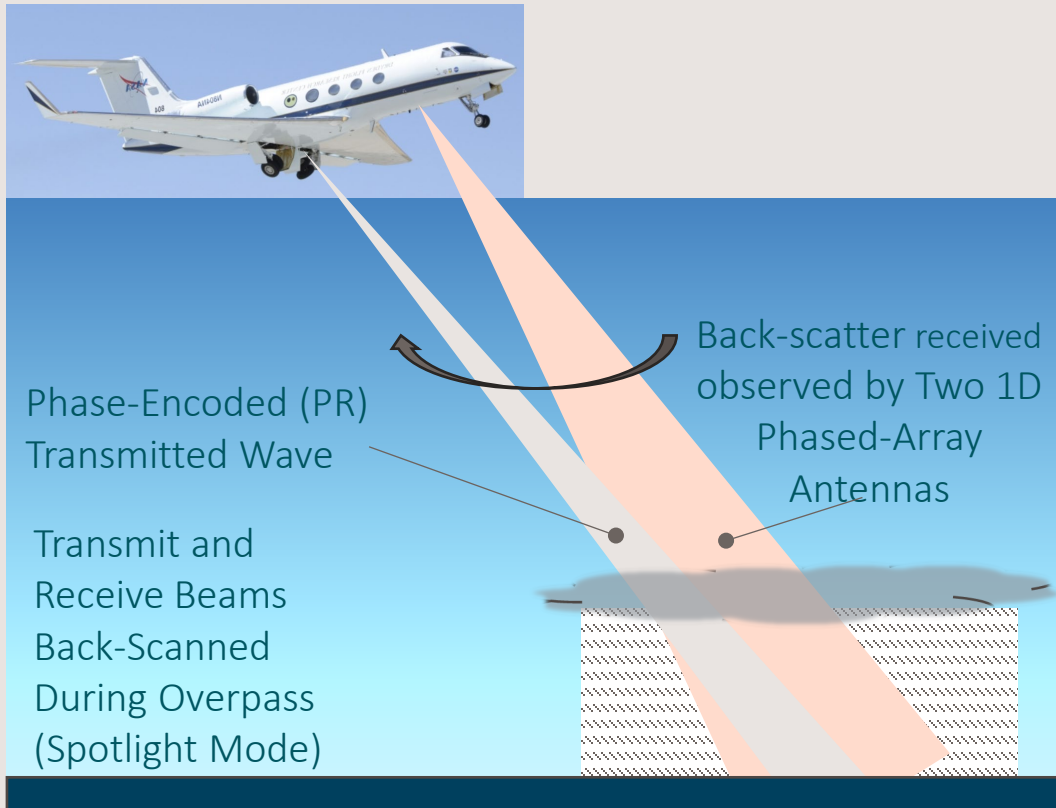


FIG. 14. Artist's renditions of two potential electronically scanned (e-scan) radar designs as they might appear when mounted on existing infrastructure, such as a (left) cellular communications

An example of technology progress –X band phased array radar – Same architecture – forecast in 2002- that is economically sustainable (source Agile RF Systems). Have additional bells and whistles beyond a traditional radar.



Airborne Phased Array Demonstration (collaborative project with CSU and industry)



Airborne Precipitation Observation

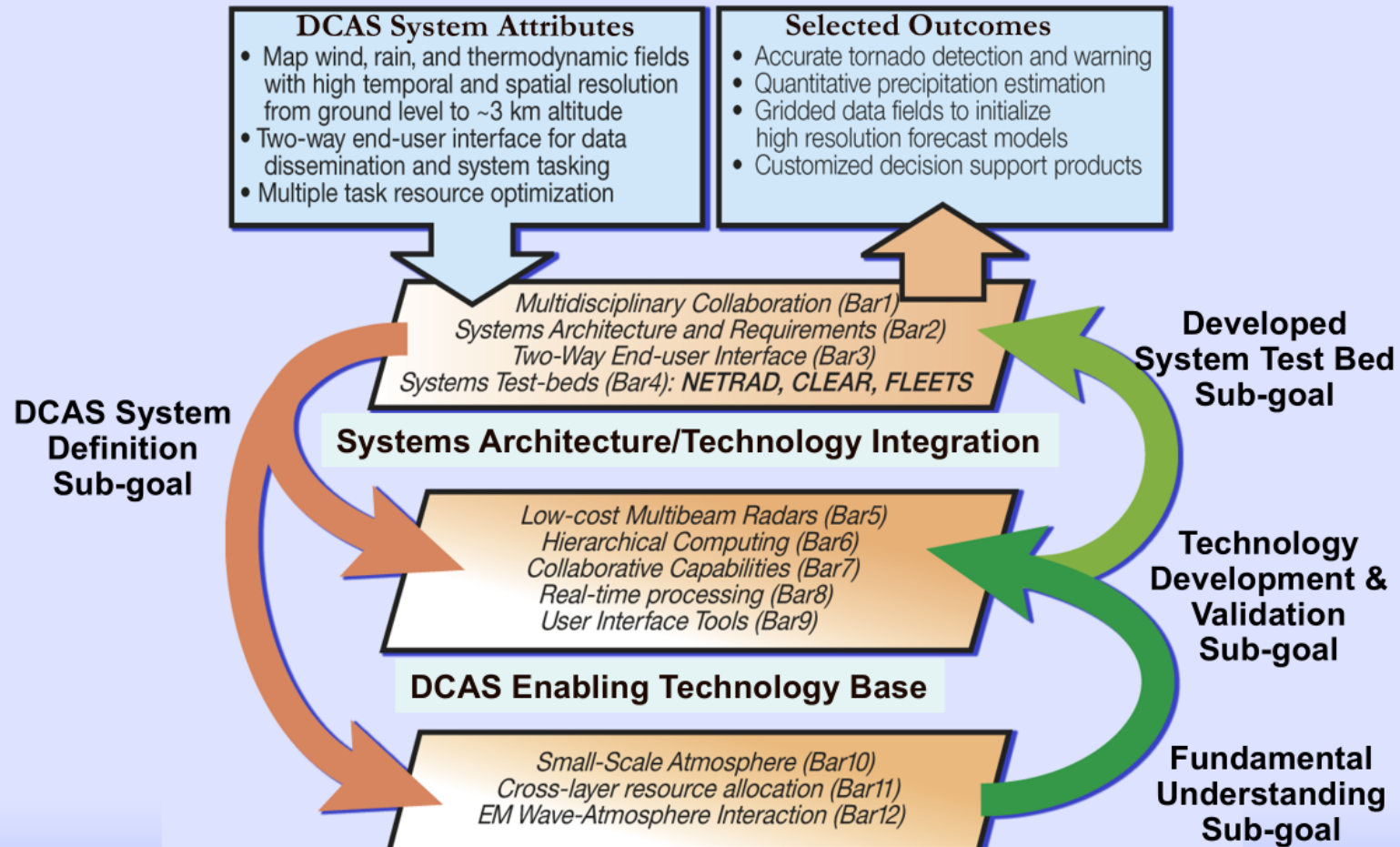
- Cross-track Observations, Recovered from Multi-Angle Range/Doppler Views (Tomographic Reconstruction)
- Sensitive to Spatial Contrast Finer than Beam Size

Phased-Array Receivers Allow:

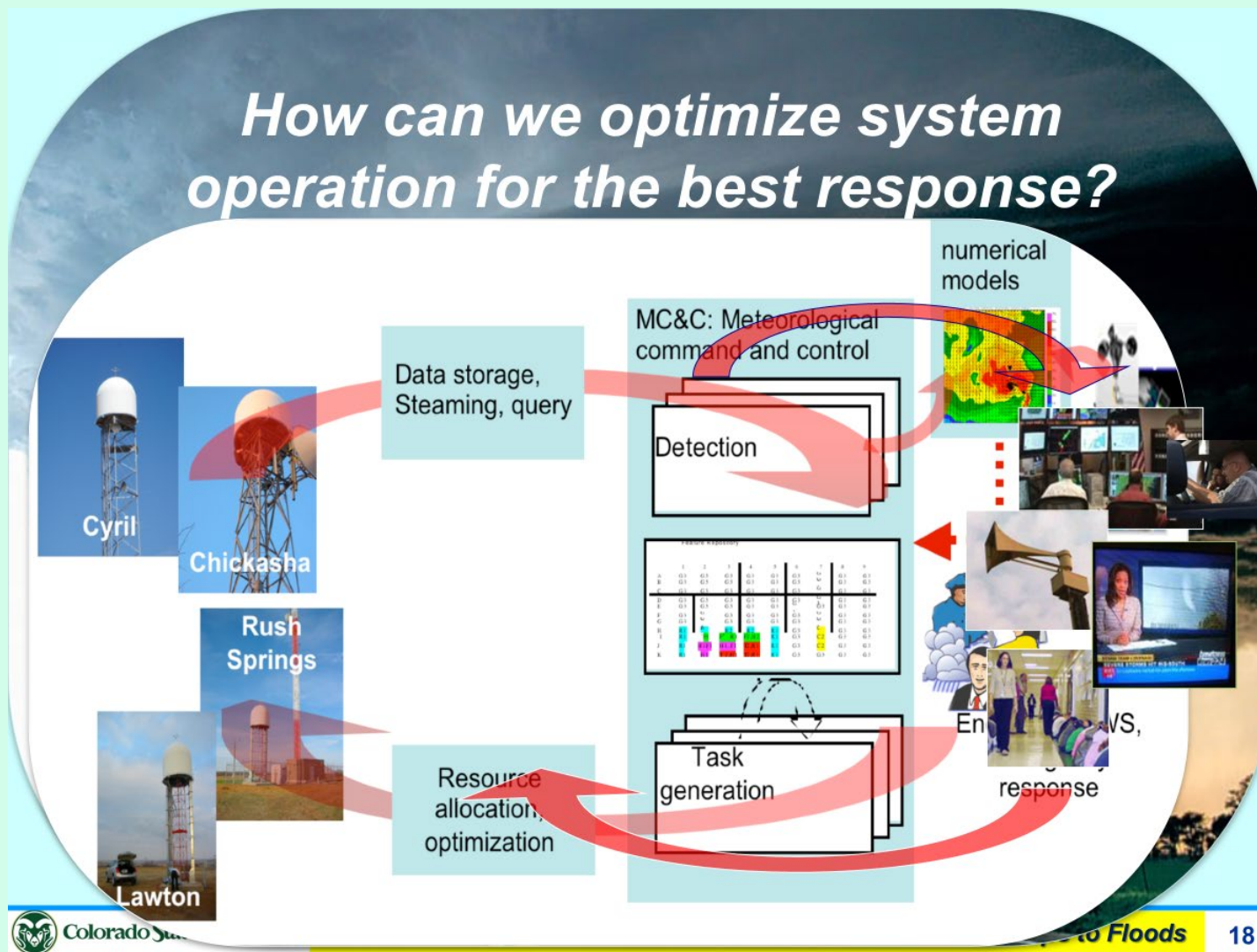
- Beam Steering for Spotlight Mode Observations
 - Long Dwell over Selected Region
- Beam Steering Cross-Track for Off-Track Storm Observations
- Simultaneous Beam Forming
 - Simultaneous Observation at Multiple Cross-Track Positions

Is it just technology ? Or Systems / it is the systems that will make the difference

Grand Challenge to action and implementation Systems Designed from the Fundamentals.



These small boxes are "Agentic AI"



Electronic Scan Strategy for Phased Array Weather Radar Using a Space–Time Characterization Model

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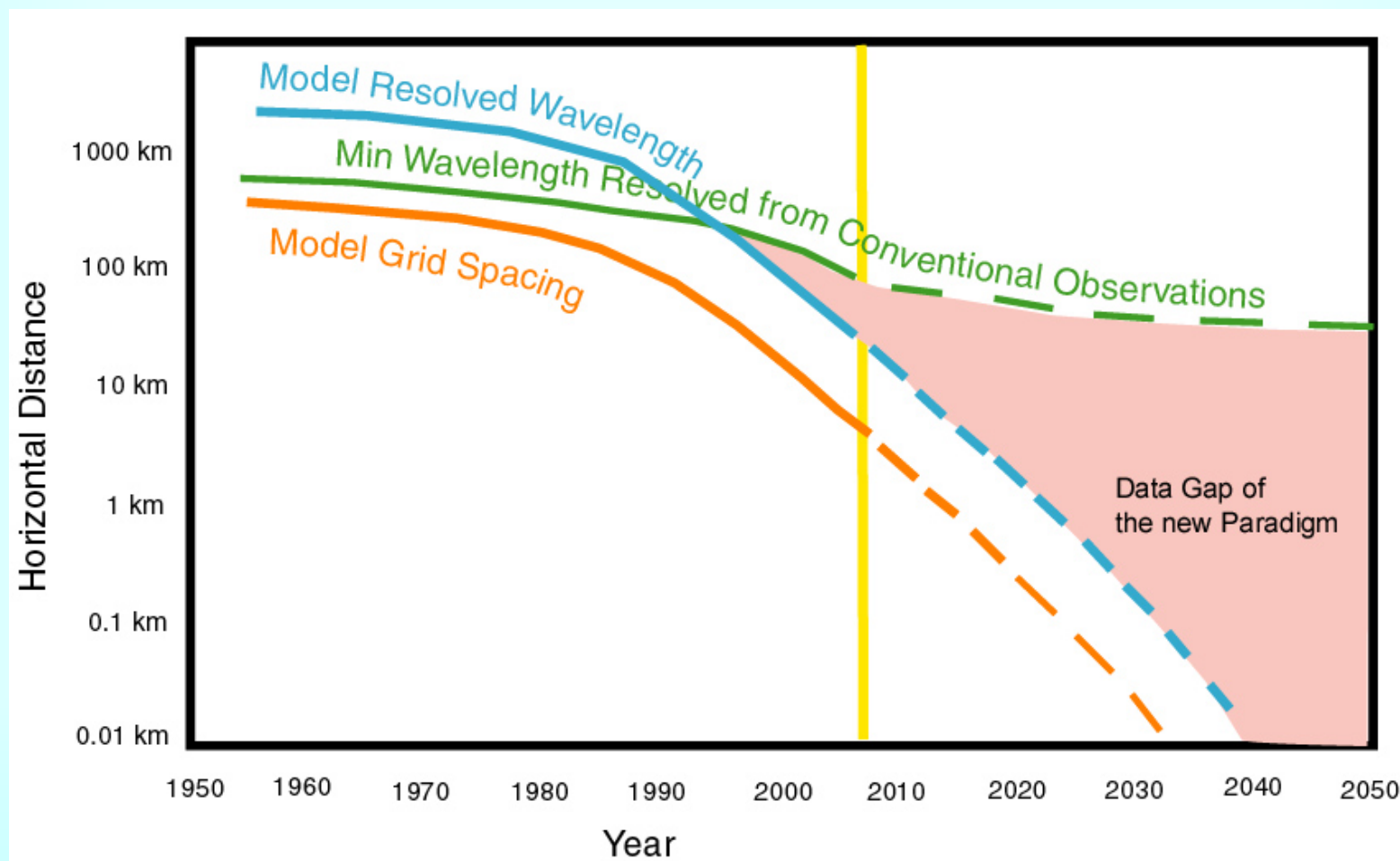
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ABSTRACT

This paper presents an adaptive scan strategy concept for phased array weather radars (PAWR) with the objective of increasing the scan speed and capturing features of the storm system while maintaining the measurement accuracy. The adaptive scan strategy is developed based on the space–time variability of the storm under observation. Quickly evolving regions are scanned more often and the spatial sampling resolution is matched to the spatial scale. A model that includes the interaction between space and time is used to extract spatial and temporal scales of the medium and to define scanning regions. The temporal scale constrains the radar revisit time, while the measurement accuracy controls the radar’s dwell time. These conditions are employed in a task scheduler that works on a ray-by-ray basis and is designed to balance task priority and radar resources. The scheduler algorithm also includes an optimization procedure for minimizing radar scan time. The model and the scan strategy are demonstrated using simulation data. The results show that the proposed scan strategy can reduce the scan time significantly without compromising data quality.

Extreme shortage of data Industry is not building compute engines but data centers . Data will rule



Closing Thoughts – Very exciting Future

- 1. Note on Phased array
- 2. System concepts critical to define standards (notoriously missing in weather radar – need to learn from IEEE- Standards group- Industry needs this)
- 3. Agentic AI will drive systems, which in turn will drive technology
- 4. Technology development will come from other commercial industries, ex; comm industry like Signal processors, transmitters and automobile sector we can benefit from, as well as DARPA (NGI project – CSU demo)
- 5. Fight for spectrum will drive additional technology innovation
- 6. Space based sensing (LEO) will catch up to fill the data gap.



THE END

Thank You!

