SOW: S-Band On Wheels
BARN: Bistatic Array of Radars and Mesonets

What we want:

Targetable, Affordable, Long-Wavelength, Fine-Scale, Fast, Dual-Polarization, Vector-Winds

Having it all
Adaptable, Fine-Scale, Fast, Vector Winds.

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What we also want:

Even more targetable, Even more affordable, Long-Wavelength, Even finer scale, Fast, Dual-Polarization, Vector-Winds

What we have:

1995 Research S-Band Paradigm
One big super-high capability radar

Extremely valuable tool for ~25 years

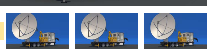
~~Targetable, Affordable,~~
Long-Wavelength,
Fine-Scale, ~~Fast,~~
Dual-Polarization,
~~Vector-Winds~~

- **Expensive** to deploy: < $1M
- **Expensive** to maintain: $$$$ / year
- Single-point of failure
- **Long** set up time (so not so targetable)

S-Band On Wheels Network SOW

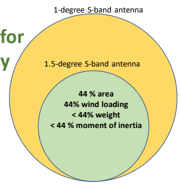
S-Band 2x 1 MW Transmitters
1.5⁰ degree beam 5.5 m antenna

x4



4 dual-pol, dual-frequency, radars in a S-band multiple-Doppler network

Size Matters for Adaptability and Cost



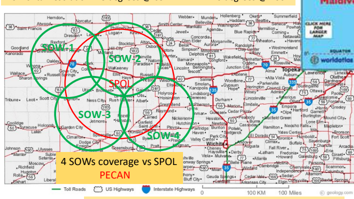
Size Doesn't Matter for Science

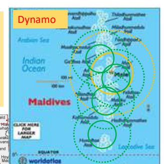
Resolution at Targets Matters

SOWs *closer* to targets than 1-degree radar.
Resolution is comparable … or better … throughout domain

Volumetric resolution 1.5 degrees @ 44 km ~ 1.0 degrees @ 100

Horizontal resolution 1.5 degrees @ 65 km ~ 1.0 degrees @ 100





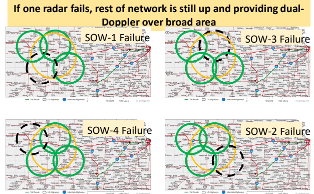
Examples of how 4x SOW could replace 1x big S-Band

Network of 1.5⁰ S-Band SOW

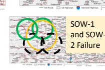
- More flexible coverage configurations:
  (triangle, linear, overlapping or spread out)
  (Single S-band radar coverage is rigidly a circle)
- 1, 2, 3, … N could be requested for **small**, medium, and large projects
- **Multiple-Doppler vectors from coordinated scanning network**
- ~< ½ **cost to deploy whole network** compared to big S-band
  - No big pedestal, dish, trailers, power to maintain … **quicker**
- 1-Day set up and tear down time, each.
- **Same or better scientific capability in nearly all deployments**
  - equal or better spatial resolution
  - 2x scan rates with dual-frequency
  - better sensitivity with 2x 1MW transmitters
  - *but only 2/3 resolution far out to sea*

More Failure-Tolerant Network

If one radar fails, rest of network is still up and providing dual-Doppler over broad area



even if 2 fail, there's still coverage



Size Matters

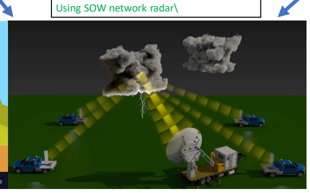
Set up similar to COW

1 Day Each

Of course, combine these two technologies

Bistatic **A**daptable **R**adar **N**etwork (BARN)

Using SOW network radar\

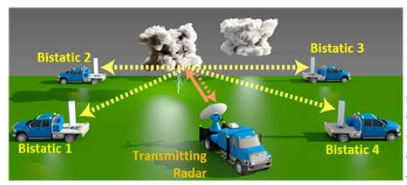


Bistatic Adaptable Radar Network (BARN)

Using DOW / COW / SOW network

Most of what used to be "hard" about bistatics is now easy

- Faster computers
- Full time series recording
- 10-20 receiver networks feasible, extremely overdetermined solutions to vector wind field



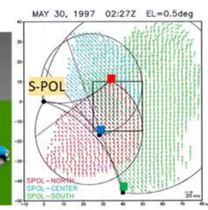


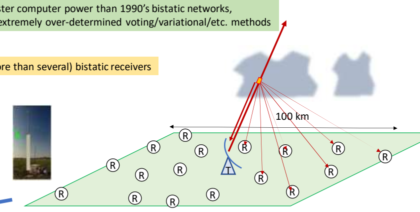
Figure 17. (left) Schematic mobile bistatic network with four receiving antennas and one transmitting radar. The transmitting radar is, in this example, a DOW or SOW, but can be a stationary radar (e.g., S-POL). The four receiving antennas are on the back of pickup trucks, but can be deployed similarly to Pods. The transmitting and receiving radars can be moved like MMs to optimize coverage and vector wind retrievals as phenomena move/evolve. As the DOW/SOW transmits and scans, the pulses in its narrow radar beam (orange arrow) are scattered from hydrometeors, dust, etc. Some of that scattered energy (dashed yellow arrows) is received by the passive antennas, as well as the by the DOW/SOW antenna (dashed orange arrow). Three-dimensional vector wind fields are calculated from these various Doppler measurements. (right) An example of vector wind retrievals from a bistatic network. In this example, there was one transmitting radar (S-POL) and three bistatic receivers (solid squares). The colored vectors depict the retrievals using data from the north (red), central (blue), and southern (green) bistatic receivers. Arcs depict the bistatic dual-Doppler lobes with the transmitting radar. The square outline encloses an overdetermined analysis domain. (Image adapted from Satoh and Wurman 2003).

The key features of BARN are:

- **BARN enables multiple-Doppler vector wind measurements over targeted regions.**
- While SOWNET is providing moderate-resolution multiple-Doppler measurements, BARN provides finer-scale and/or customized measurements over smaller domains.
- BARN units will be configured with different SOWS, COW, or DOWs. Only the receiver front ends and antennas are frequency-specific.
- BARN units will be stationary, deployed for the duration of a project, or mobile.
- **Stationary BARN units will be unattended, low power, and logistically similar to deployable weather stations.**
- Highly redundant BARN units provide extreme reliability of multiple-Doppler operations.
- **BARN units are < 1/10 the cost of scanning transmitting radars.**
- BARN receiving antennas will be designed with different characteristics. These will include previously-used low-gain systems optimized to sample broad areas of precipitation, but unable to observe clear-air non-precipitating regions., Medium-gain systems, perhaps slowly scanning or switching, which can obtain vector wind measurement in the non-precipitating boundary layer will be designed. Different configurations will be optimized for different observational needs.

With >> faster computer power than 1990's bistatic networks, can use extremely over-determined voting/variational/etc. methods

Lots (more than several) bistatic receivers



Schematic of a single transmitter, highly multiple remote bistatic receiver network. Radiation is backscattered towards the transmitting radar (T), and obliquely scattered towards several or more bistatic receivers (R). The remote receivers each may have multiple antennas focusing with moderate gain at higher and lower elevations, or at different dual-Doppler lobes.

Highly overdetermined bistatic multiple-Doppler solutions reduce error in vector windfields, increase coverage in low-reflectivity clear-air regions, and through variational or "voting" methods, produce solutions with minimized contamination from side lobes.

Bistatic receivers can be optimally located and/or pointed to enhance coverage of high-value areas (e.g. airports, focusing topography, land/sea or land use boundaries, even, if receivers are mobile, convergence lines, fronts, and other atmospheric boundaries).

$$\begin{bmatrix} U \\ V \\ W_p \end{bmatrix} = \frac{1}{\delta} \begin{bmatrix} \alpha_1 & \beta_1 & \gamma_1 \\ \alpha_2 & \beta_2 & \gamma_2 \\ \alpha_3 & \alpha_3 & \alpha_3 \\ \vdots & \vdots & \vdots \\ \alpha_n & \beta_n & \gamma_n \\ \alpha_r & \beta_r & \gamma_r \end{bmatrix} \begin{bmatrix} VR_1 \\ VR_2 \\ \vdots \\ VR_n \\ VR_r \end{bmatrix}$$

Eq 1. Calculation of vector winds from overdetermined bistatic network. *α β γ δ terms are functions of observing geometry. VR_1 to VR_n are the Doppler velocities measured by 1 through n receivers and VR_r is the Doppler velocity measured by the transmitting radar. U, V, and W_p are the vector winds in the horizontal (U, V) and vertical (W_p) directions, solved for by minimizing errors. The number of unique bistatic Doppler measurements can be >20.*

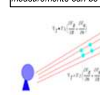


Fig. 8. *Schematic of horizontal divergence and vorticity calculations calculated on a gate-by-gate, non-interpolated basis, using the native bistatic coordinate system.*