The ARM Volume-Imaging Array (AVA): A Path Forward for the Development of Three-dimensional ARM Cloud Observations

A concept developed by **Pavlos Kollias** of Brookhaven National Laboratory in collaboration with members of the ARM science team during Spring/Summer 2006

Motivation

The current ARM “soda-straw” view of clouds, at least in regards to the ARM active remote sensors, is limiting ARM progress on understanding of clouds and radiation and their treatments within models. Can an observational capability be developed by ARM that enables remote sensing of three-dimensional distributions of clouds with sufficient sensitivity, spatial resolution and temporal resolution both to advance our understanding of cloud-radiation interactions and to improve the treatment of clouds and precipitation in numerical models?

Proposed Path Forward

Deployment of three radars all with

Scanning
Doppler
Polarization

capabilities.

Two radars operating in the

X-band (9.4 GHz frequency/3.2 cm wavelength)

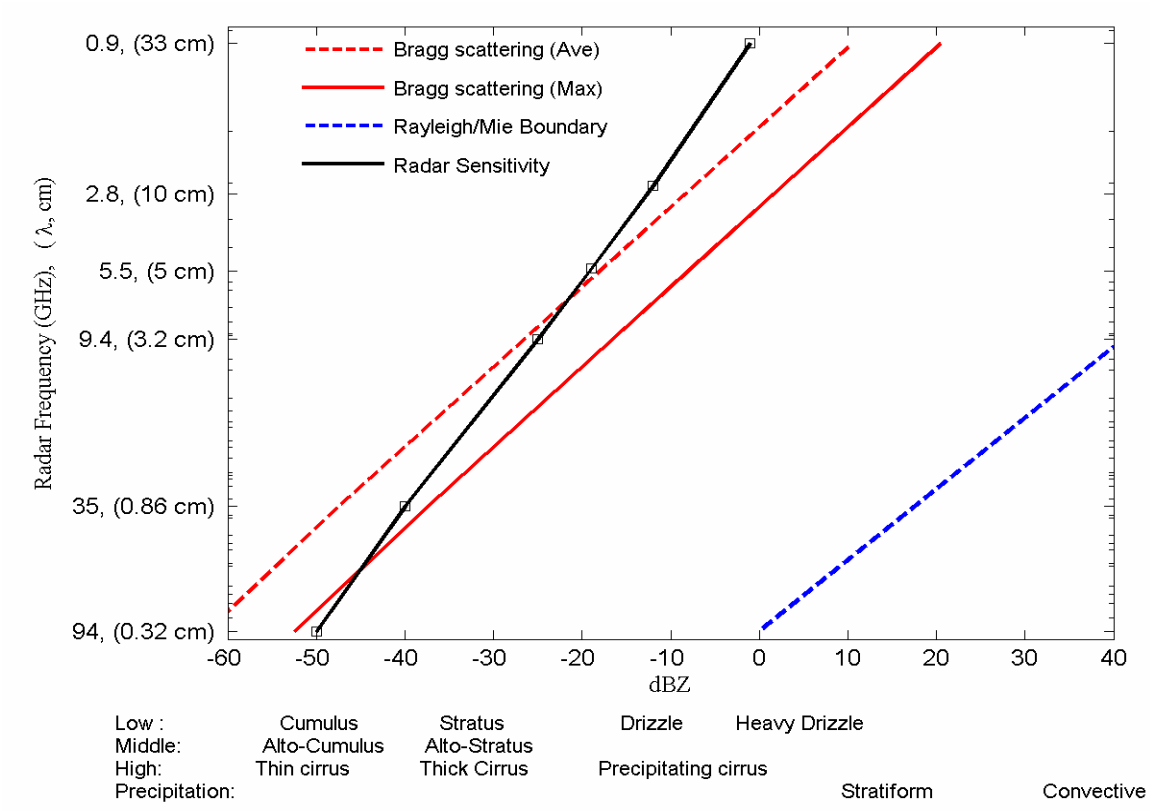
and **one** operating in the

Ka-band (35 GHz frequency/0.86 cm wavelength)

The Ka-band radar is necessary for unambiguous detection of clouds versus scattering from moist turbulent pockets of air.

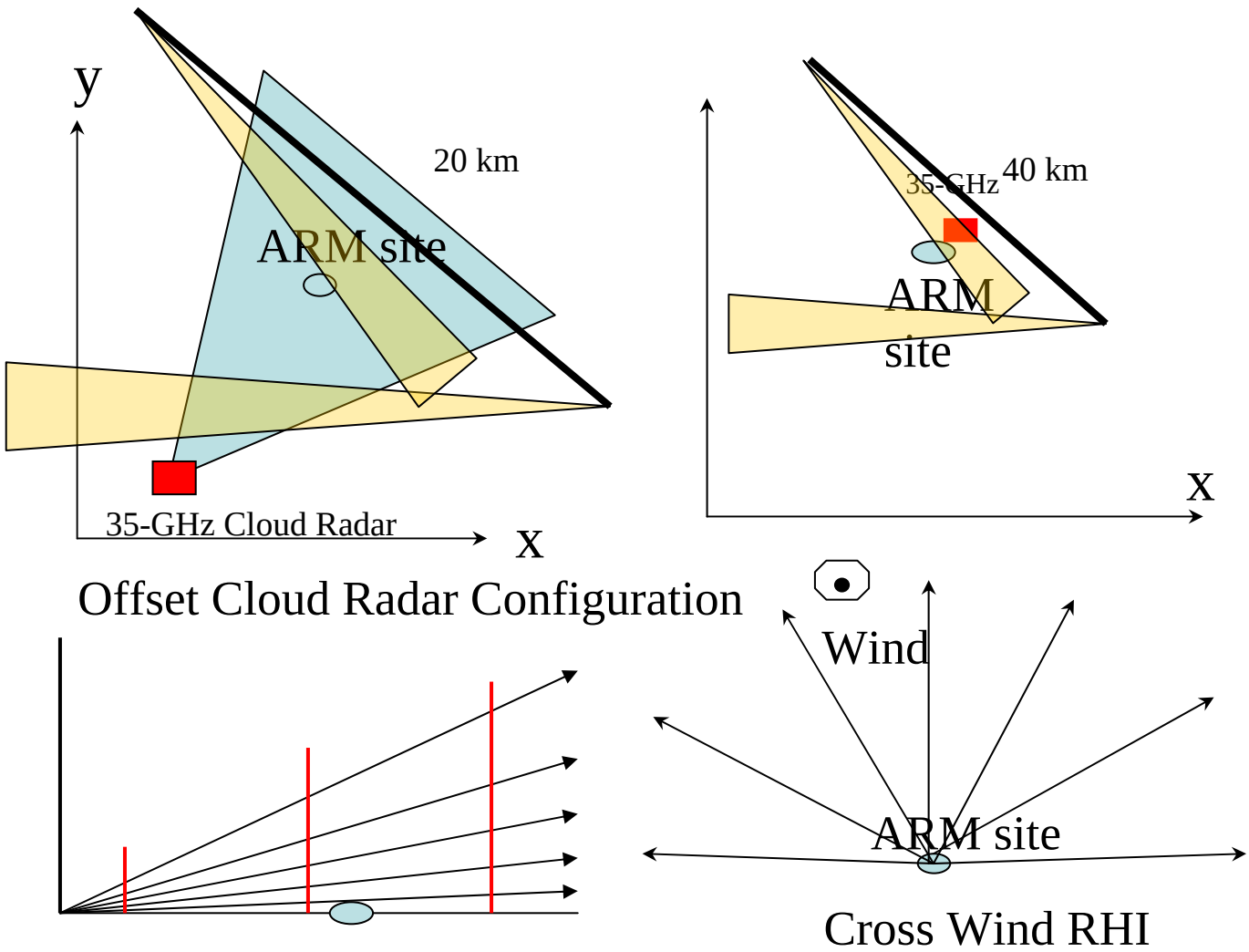
The X-band radars are necessary for characterizing the volume of air in which the Ka-band measurements are made -- provide for the spatial distributions of the larger particles and wider area measurements of the spatial patterns of precipitation. Dual-Doppler measurements enable retrieval of hydrometeor motions across the volume of air sampled.

Relationship Between Radar Reflectivity, Bragg scattering, Radar Wavelength and Cloud Type (from Pavlos Kollias)



The blue line shows the transition boundary from the Rayleigh approximation to non-Rayleigh scattering as a function of the radar frequency (wavelength) and equivalent radar reflectivity. The red lines show the point where the backscattered radar signal from clouds equals the expected backscattered radar signal from Bragg for average (dashed red line) and extreme (solid red line) refractive index variations. For a given radar frequency, observed echoes on the right of the Bragg lines have mostly contribution from hydrometeors, while observed echoes on the left of the Bragg lines have mostly contribution from Bragg scattering. Thus, the dashed red lines show on average the limit of hydrometeor detection for various radar wavelengths. For instance, at X-band (9.4-GHz) low level returns from non-precipitating fair weather cumuli will be difficult to discriminate from Bragg echoes. Note at 9.4-GHz (the X-band frequency), Bragg scattering is present in the lowest 1.5 km of the atmosphere. In addition, the black line shows examples of operational radar sensitivity of well known radar systems: the NOAA wind profiler network at 0.915 GHz (range 5 km), the WSR-88D at 2.7-GHz (range 20 km), the Bureau of Meteorology C-Pol (5.5-GHz) scanning radar (range 20 km), the NOAA Physical Science Division 9.4-GHz radar (2 km range), the 35-GHz ARM MMCR (2 km range) and the ARM 94-GHz Mobile Facility radar (5 km).

Possible AVA Radar Locations and Scanning Configurations (from Pavlos Kollias)



Two suggested AVA spacing and scanning configurations: (a) offset the 35-GHz radar from the ARM SGP site and scan a 3D sector centered at the vertically pointing radars (left); the two 9.4-GHz radars are spaced 20-30 km apart and provide 3D surveillance coverage and supplementary coverage for areas where the offset 35-GHz radar will have difficulty providing coverage (at very short and very long range from the radar location); (b) place the 35-GHz at the Central Facility, make simple cross-wind 180° scans, and use the wind to map the 3D structure of clouds (right); for this mode, the two 9.4-GHz radars would conduct autonomous volume scans independently from the 35-GHz radar.

Feedback to Date (Unanimous)

To date **no one has contested AVA's composition** of two X-band radars and one Ka-band radar. This is pretty much state-of-the-art in terms of options available to the ARM science community for three-dimensional sampling of clouds.

However, there has been much discussion and concern on whether or not the state-of-the-art AVA system is capable of making observations with sufficient sensitivity, spatial resolution and temporal resolution that ARM needs to advance studies of cloud-radiation interactions and treatment of clouds in numerical models.

There is a consensus in the feedback that I have received that **simulator** results are necessary to address the concerns of the adequacy of AVA measurements. Pavlos Kollias, with support from the Cloud Properties Working Group, is committed to producing such results for volume scanning radars and his collaboration with the ARM modeling community in their analyses of TWP-ICE IOP observations and future SGP-CLASIC IOP observations is one possible avenue forward that may lead to a consensus on the adequacy of AVA measurements. The initial work on this **small-scale** (i.e., limited to volume-scanning radar) **simulator** would take place **fall 2006** and **winter 2006/2007**.

The SGP-CLASIC IOP also has the possibility of providing **ARM its first phased-array scanning X-band radar measurements** (with the Naval Postgraduate School CIRPAS radar system) at little to no cost for ARM. Beyond this IOP, where does ARM want to take this potential collaboration with CIRPAS?

Costs (AVA)

See associated spreadsheet.