Enhancing the ARSCL Product: Incorporating Doppler Spectra and Additional Instrumentation

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Abstract

The widely-used Active Remote Sensing of CLouds (ARSCL) Value-Added Product (VAP) provides cloud boundaries and best-estimates of zenith-pointing cloud radar moments. The VAP combines observations from several instruments: cloud radar, Micropulse Lidar (MPL), ceilometer, and Microwave Radiometer (MWR).

Planning for the next-generation version of ARSCL is underway. This enhanced KAZR-ARSCL product, is expected to incorporate additional input sources, including Doppler spectra, Radar Wind Profiler and Raman Lidar (where available). Here we present the motivation for the new product and consider how best to employ the added input sources.

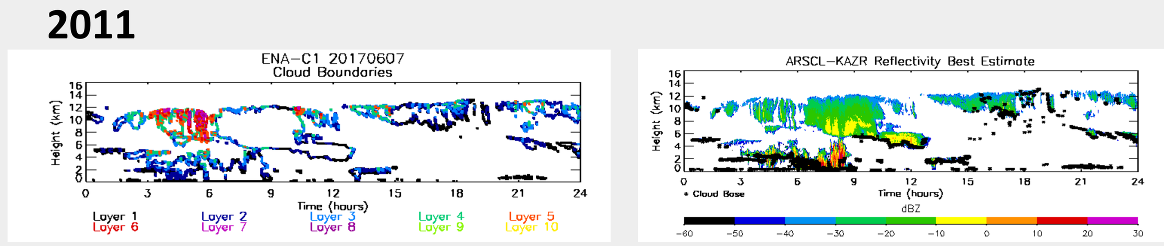
1. Background

The ARSCL product has been produced using various sources of cloud radar data as input. The full ARSCL record extends as far back as 1997 (at the SGP site).

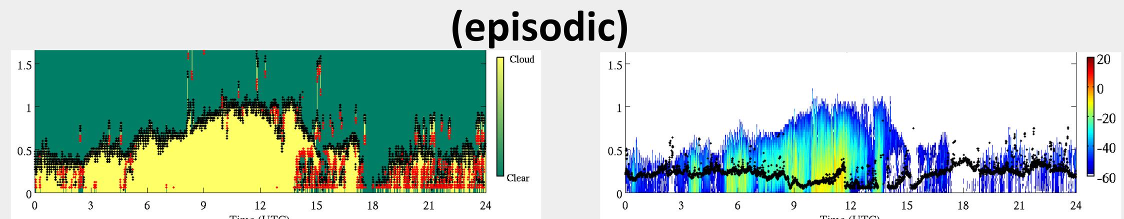
Currently we have several ARSCL 'flavors,' primarily differentiated by the cloud radar employed:

- **'Original' ARSCL: based on now-retired MMCR cloud radar**

- **KAZR-ARSCL: based on Ka-band Zenith Radar (KAZR) since 2011**



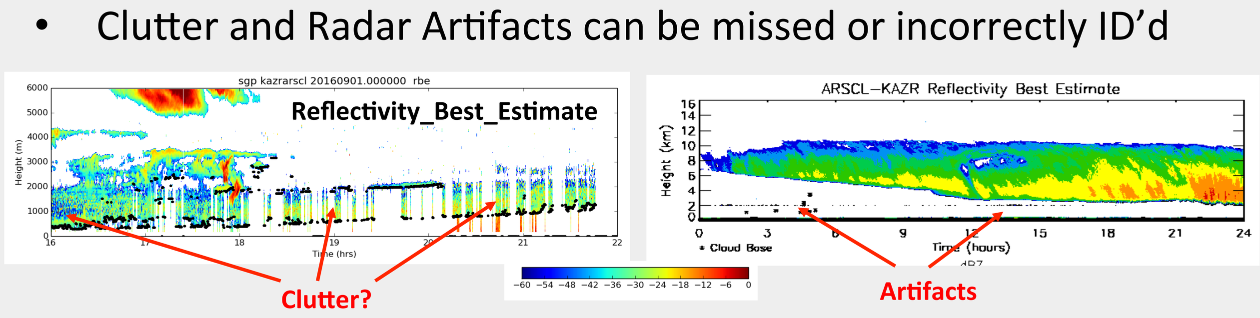
- **WACR-ARSCL: based on W-band ARM Cloud Radar (WACR) (episodic)**



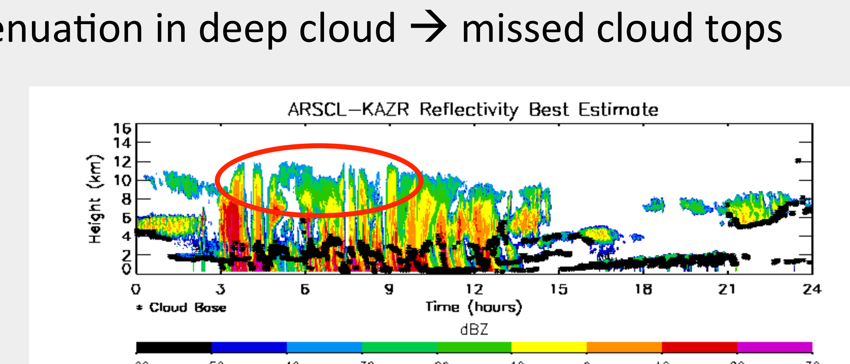
2. Why an Enhanced ARSCL?

In the enhanced VAP, we intend to address the following issues in the current ARSCL product:

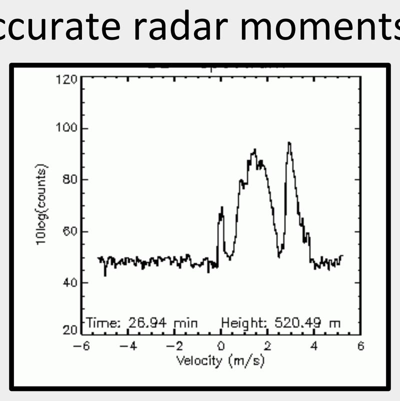
- Clutter and Radar Artifacts can be missed or incorrectly ID'd



- Attenuation in deep cloud → missed cloud tops



- Thin clouds missed (at any level)
- Inaccurate radar moments in mixed phase conditions



Moments should be calculated for Individual spectral peaks, not simply for the entire spectrum, when multiple peaks exist.

3. Spectra-Based Clutter ID, Moments

An enhanced ARSCL may address two types of non-hydrometeor returns:

- **Airborne clutter** (insects, organic matter, etc.)
- **Radar-related artifacts**

Also **inaccurate moments can be corrected** by identifying multiple peaks in spectra and computing individual moments for each.

Two spectra-based efforts can help:

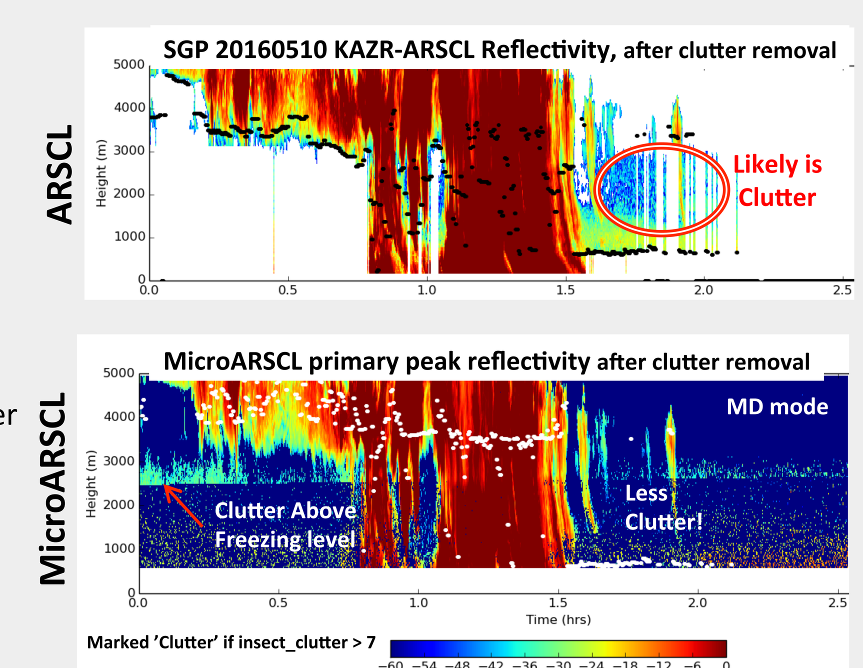
- **MicroARSCL** (Luke et al., see References)
  VAP based on a neural network algorithm which generates an insect mask, improved moments estimates and higher order moments.
- **C. Williams, et al. spectral processing** (Williams et al., see References)
  Here we focus on the clutter mitigation portion of this work.

Problem 1. Airborne Clutter

KAZR-ARSCL, right, does not attempt to remove clutter above cloud base (see red circle at right). Below cloud base, a set of heuristics handles the majority of, but not all, clutter.

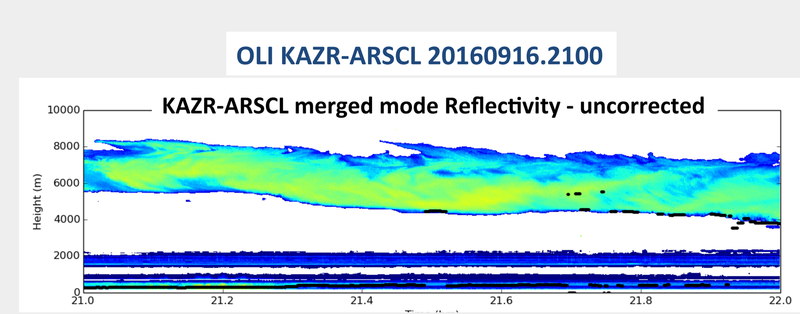
MicroARSCL provides an 'insect_clutter' flag, indicating likelihood of clutter (regardless of whether cloud is also present). Flag values range from 1…10, where higher values mean clutter is more likely present. At right, insect-containing returns were removed, and as expected, some cloud loss also occurred.

Neither the ARSCL nor MicroARSCL solution alone is ideal in all cases, but combining them looks promising.

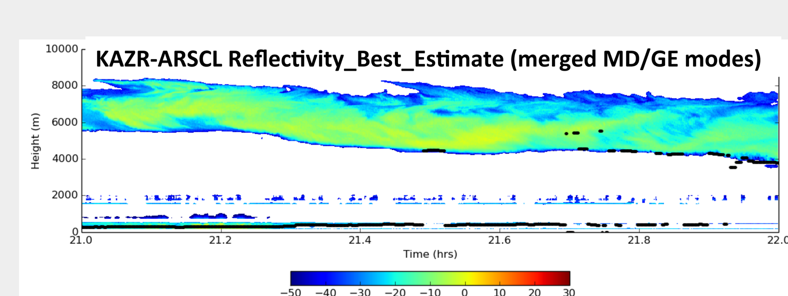


Preliminary Conclusion: **MicroARSCL can contribute valuable input to the clutter problem. A synthesis between the current-ARSCL heuristic approach and the MicroARSCL insect information should improve clutter identification.**

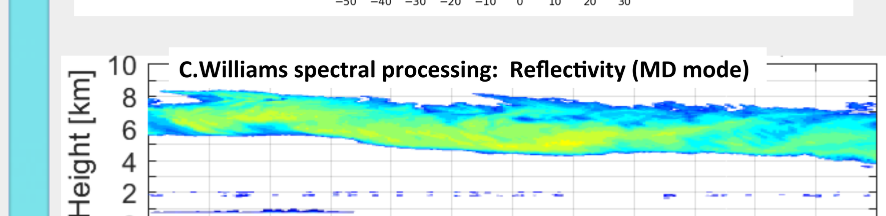
Problem 2. Ground Target Artifacts



At ENA and OLI sites, the KAZR2 radar exhibits significant artifacts at many ranges. See artifact example in reflectivity field, at left. This is likely caused by returns from ground targets interacting with antenna sidelobes.

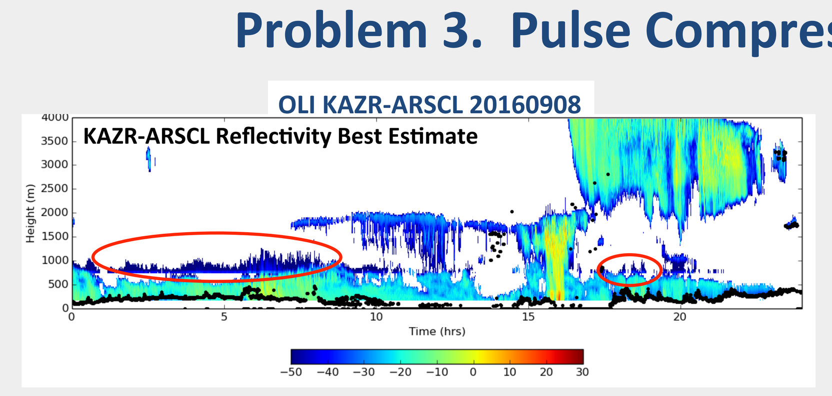


KAZR-ARSCL does a reasonable job of removing the artifacts but, at left, some remain near 1800 m range.



Single-spectral-peak reflectivity is shown at left, after Williams spectral processing. A bit more of the artifact signal has been removed vs. ARSCL.

Problem 3. Pulse Compression Artifacts



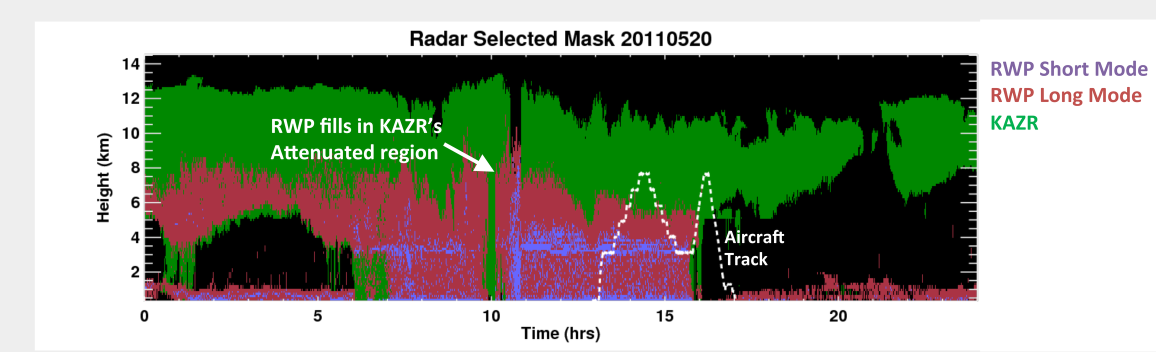
Pulse compression (MD mode only) causes strong signals to be aliased into adjacent ranges. At left, red circles indicate areas with range aliasing that does not correspond to hydrometeors. It is not clear that current spectra products help.

During this next ARSCL development stage, algorithms will be explored to handle this range aliasing issue.

Preliminary Conclusion: **Spectral processing can help somewhat with some radar artifacts.**

4. Detection of Deep Cloud Tops

The enhanced ARSCL will incorporate Radar Wind Profiler (RWP) observations to provide more accurate cloud tops in deep cloud conditions where the KAZR beam is extinguished.



5. Thin Cloud Detections

Two products have potential to assist with thin cloud detection.

1. The soon-to-be-released **RLPROF-FEX VAP** will provide a Raman Lidar feature mask, which includes cloud detections. This is expected to become an input source for the Enhanced ARSCL where the lidar is available.
2. Enhanced detection of low cloud could be provided by a **new MicroPulse Lidar (MPL) product**, currently in development (Donna Flynn, personal communication). Below is a comparison of the new MPL mask (middle panel) with the mask from the MPLCMASK VAP currently used by ARSCL (bottom panel)

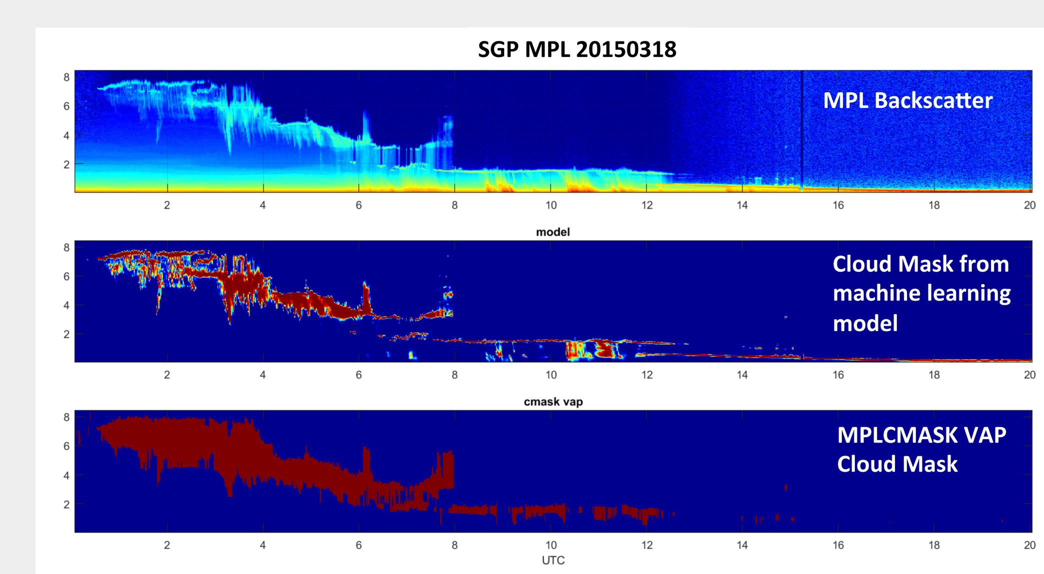


Figure provided by Donna Flynn

6. Summary (and Development Timeline)

Development of an Enhanced KAZR-ARSCL is beginning. The goals are to improve clutter removal, supply more accurate moments (e.g. for separate spectral peaks), provide better cloud tops in attenuating deep clouds, and improve thin cloud detection. We hope to incorporate spectra-based input(s), RWP input, a new Raman Lidar product, and perhaps a new MPL product.

The first stage of the project is incorporating one or both spectra products, with availability in Fall 2018. This is, of course, partly dependent upon availability of the spectra products themselves.

7. References

Luke, E., Kollias, P., Johnson, K. L., & Clothiaux, E. E. (2008). A technique for the automatic detection of insect clutter in cloud radar returns. Journal of Atmospheric and Oceanic Technology, 25, 1498–1513. https://doi.org/10.1175/2007JTECHA953.1

Williams, C., Mahn, M., Hardin, J., de Boer, G. (submitted to Atmos Meas Tech). Clutter mitigation, multiple peaks, and high-order spectral moments in 35-GHz vertically pointing radar velocity spectra.

Current KAZR-ARSCL Processing Strategy and Availability

KAZR-ARSCL data is available at the ARM Archive for all fixed and mobile KAZR and KAZR2 sites (NSA, SGP, OLI, ENA, AWR) up through late 2017. The current processing paradigm has two stages:

- Initial (.c0 data level): Created within 1-2 months of input data availability, using uncalibrated KAZR reflectivity.
- Final (.c1 data level): Created once KAZR reflectivities are calibrated.