Advanced datasets to diagnose higher-order features embedded in expected GPM measurements and their impact on retrieval algorithms

Simone Tanelli[1],
Co-I: S.L.Durden[1], A. Heymsfield[2], K.-S. Kuo[3],
Coll: W. Olson[3], L. Liao[3], A. Battaglia[4],
Contributions: G. Heymsfield[3]
1 Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA;
2 National Center for Atmospheric Research, Boulder, CO, USA;
3 NASA/Goddard Space Flight Center, Greenbelt, MD, USA;
4 Univ. of Leicester, Leicester, UK

Outline

① Higher order effects

- Complex particle shape and scattering

  (A. Heymsfield, G. Liu, M. Kulie, G. Skofronick Jackson, L. Bliven, B. Johnson, etc… made the point quite clearly already)

- NUBF (some in Poster 215, Tanelli et al. SPIE 2012)
- Multiple Scattering
- Surface Clutter & scattering

② Tools

Multiple Scattering (MS):
postulations and conjectures?

We now have sufficient experimental evidence and modeling capabilities to prove that Multiple Scattering WILL impact DPR measurements.

Please hold the fire until the next slide.

How often will it happen?
Ka: frequently in deep mature and aging convection, rarely elsewhere;
Ku: rarely (only in large-hail-bearing convection)

What impact can it have on retrievals?
From minor biases to catastrophic

Can we detect it?
Most definitely yes when it is strong, less and less so as it weakens

Can we mitigate it? Possibly.

Can we actually use to our advantage? Sometimes.

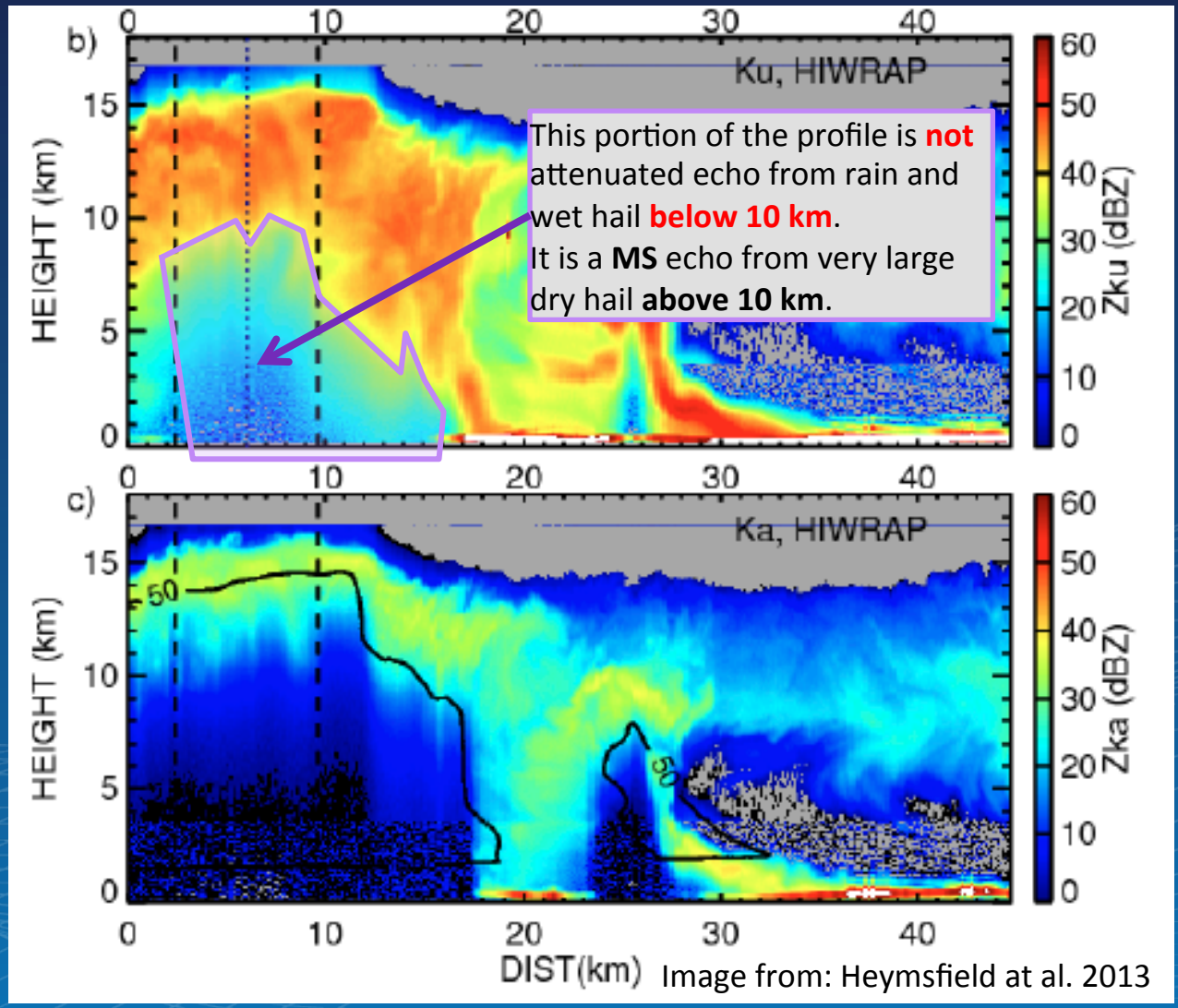


Image from: Heymsfield at al. 2013

Multiple Scattering:
1) What is it? 2) How can we tell?

1) When the pulse emitted by the radar encounters a region with significant attenuation (e.g., > 1 dB/Km) AND large albedo (e.g., > 0.5) most of its energy is scattered in all directions and further interacts with surrounding particles. The path length resulting from the multiple events can be erroneously interpreted under the single scattering assumption as the echo of a target further away from the radar. Note to self: remember to click now.

2) Where is the surface return? How can there be an attenuated echo from rain at 0 m above the surface…but no surface? At Ku and Ka band the surface echo persists longer than the near surface rain because it is stronger to start with. Note to self: remember to click now.

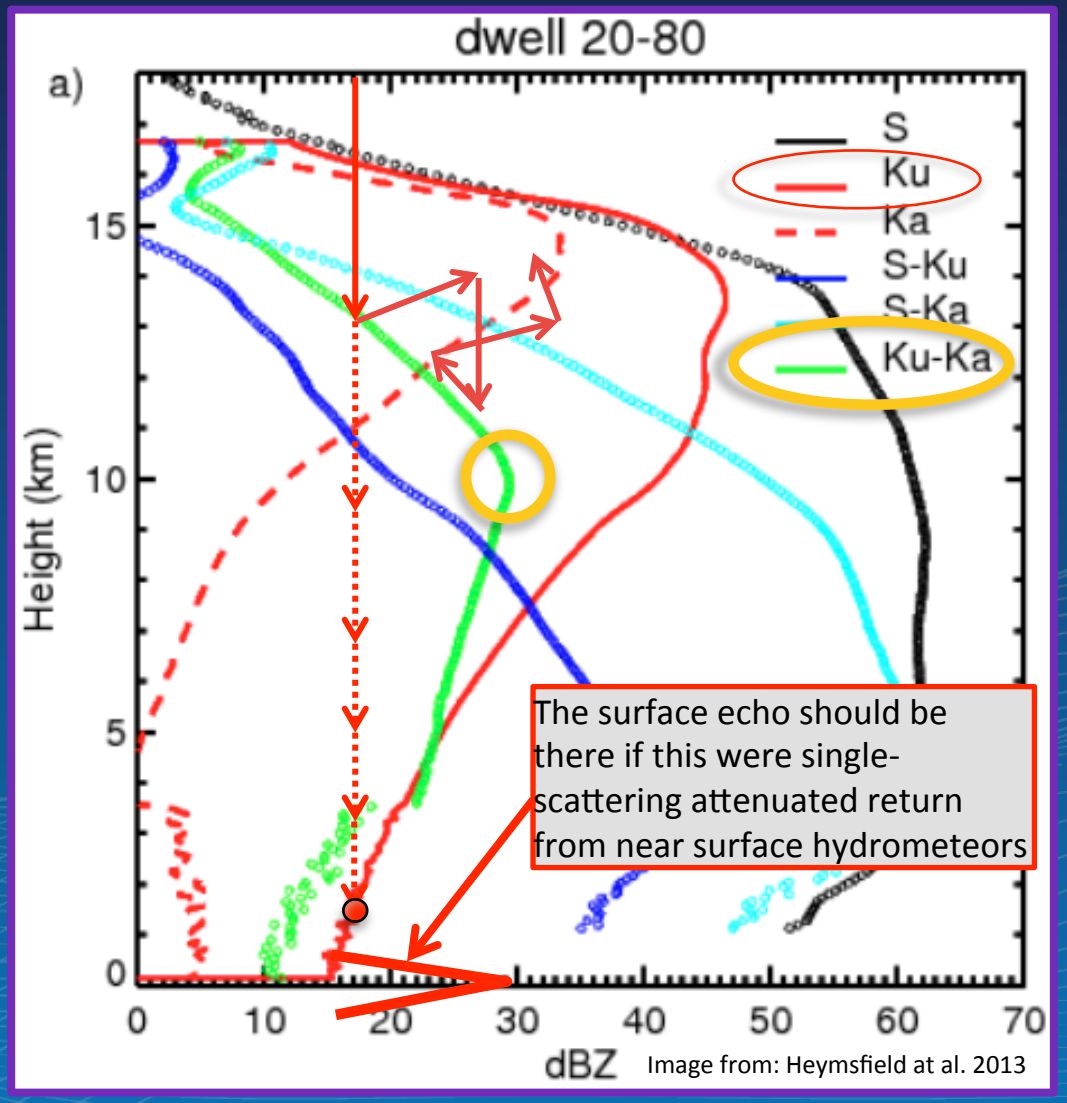
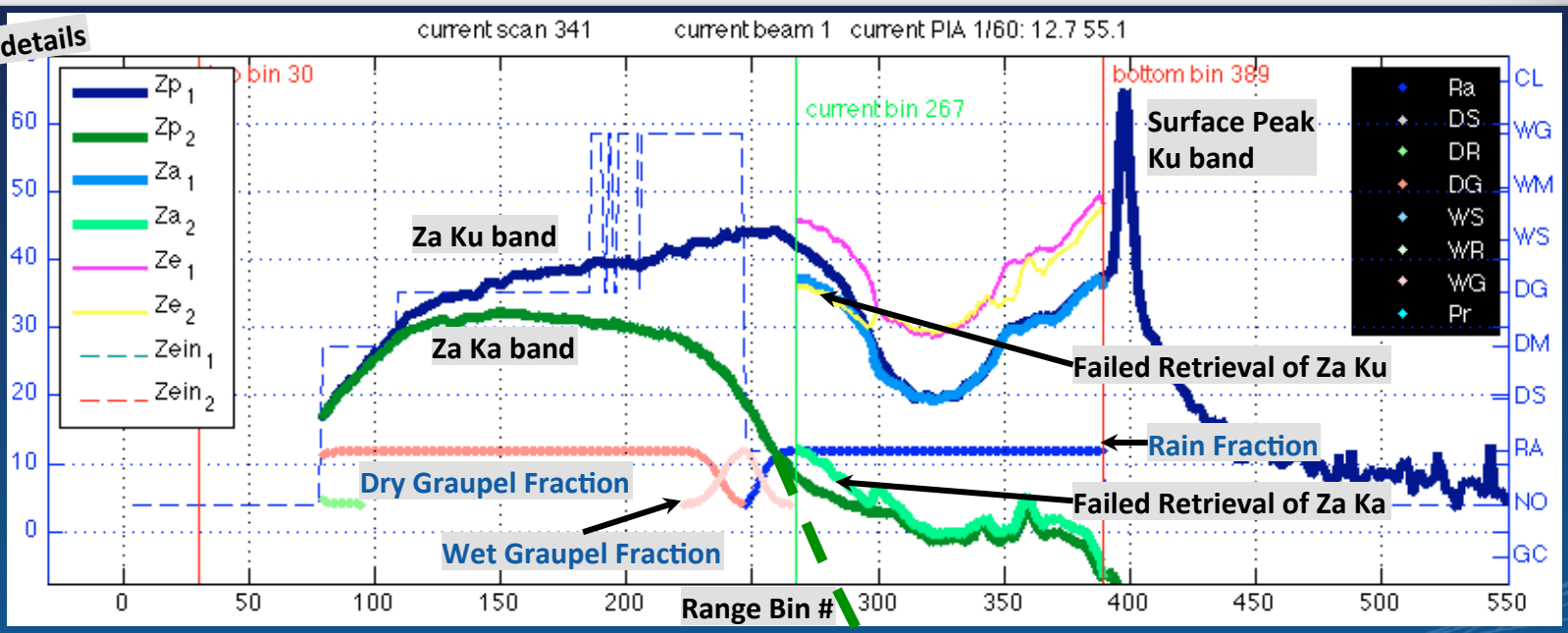


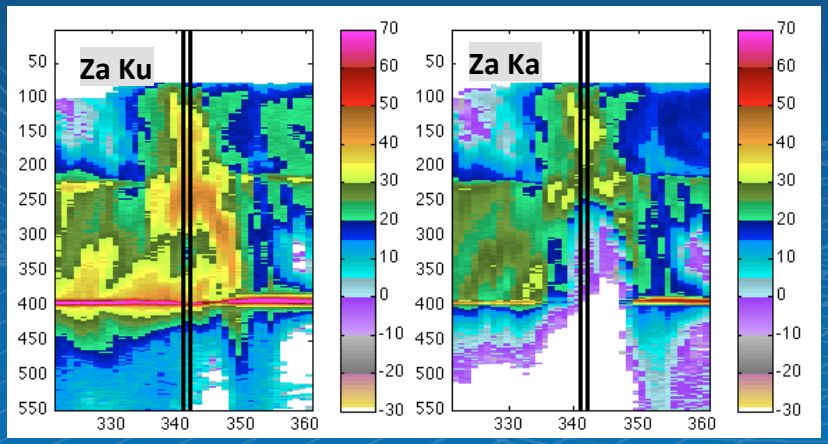
Image from: Heymsfield at al. 2013

Multiple Scattering:

Large hail is not necessary to generate MS at Ka, graupel can do

Poster 215 for details

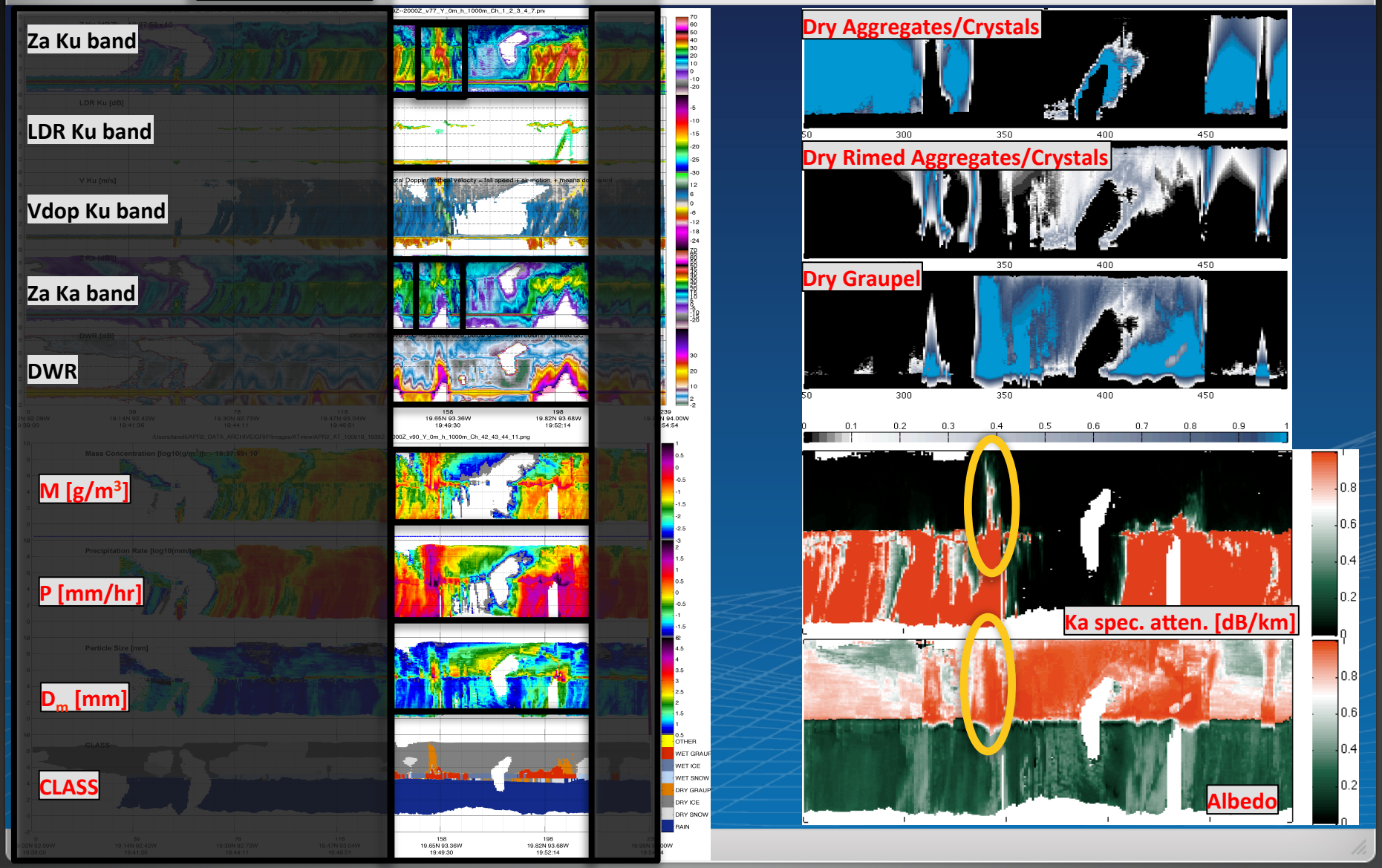




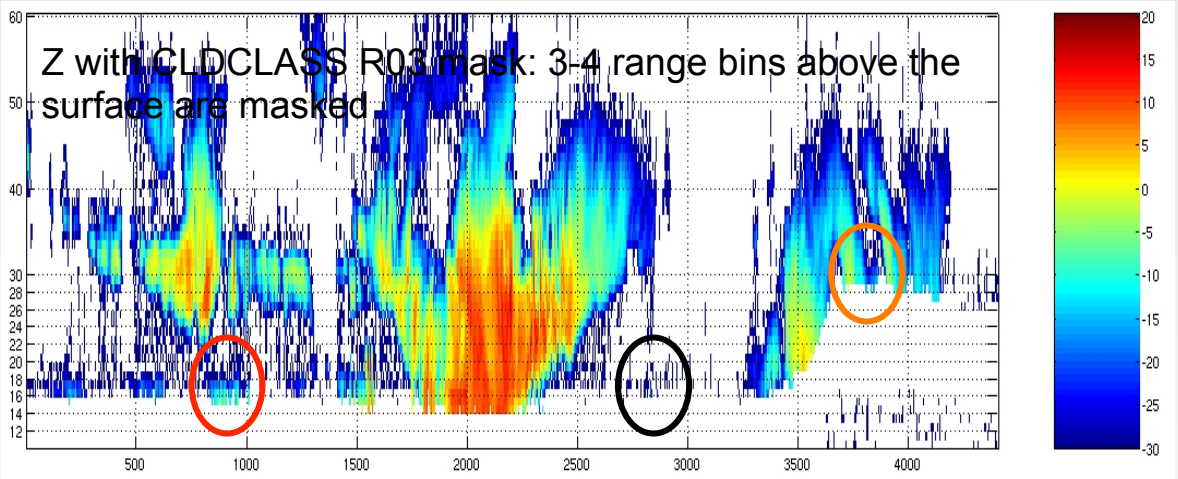
Where the Ka-band Surface Peak, and the single scattering precipitation echo could possibly be (just a guess)

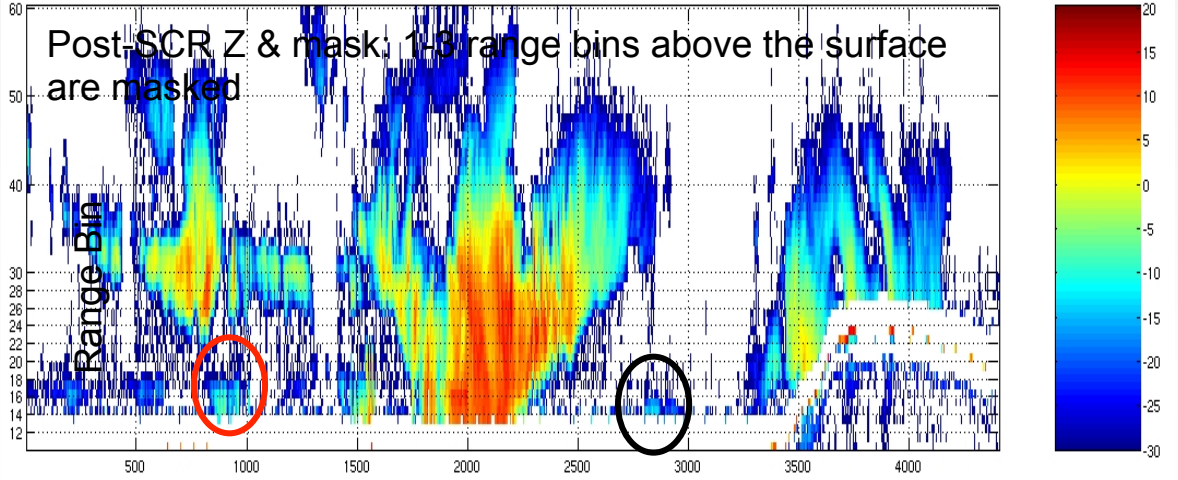
Multiple Scattering:

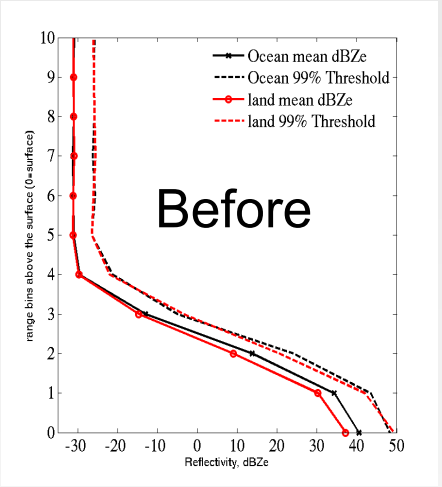
HB-style retrievals in the ice phase can tell us when to expect it

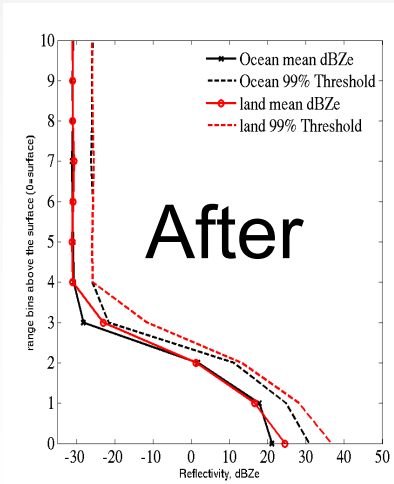


Surface Clutter:
Limited rejection of ground clutter





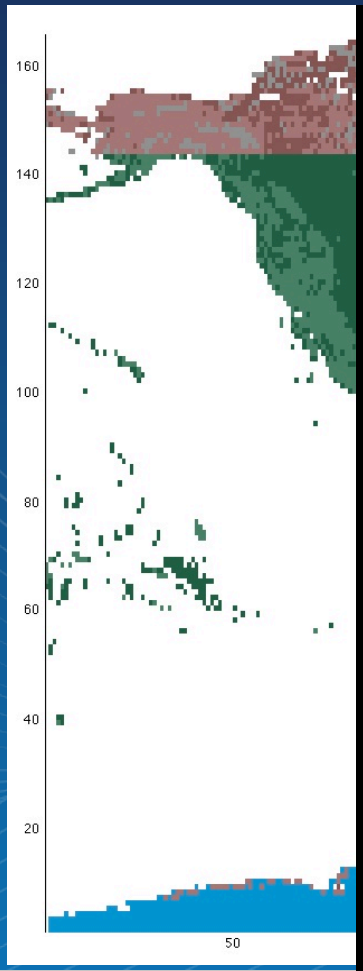


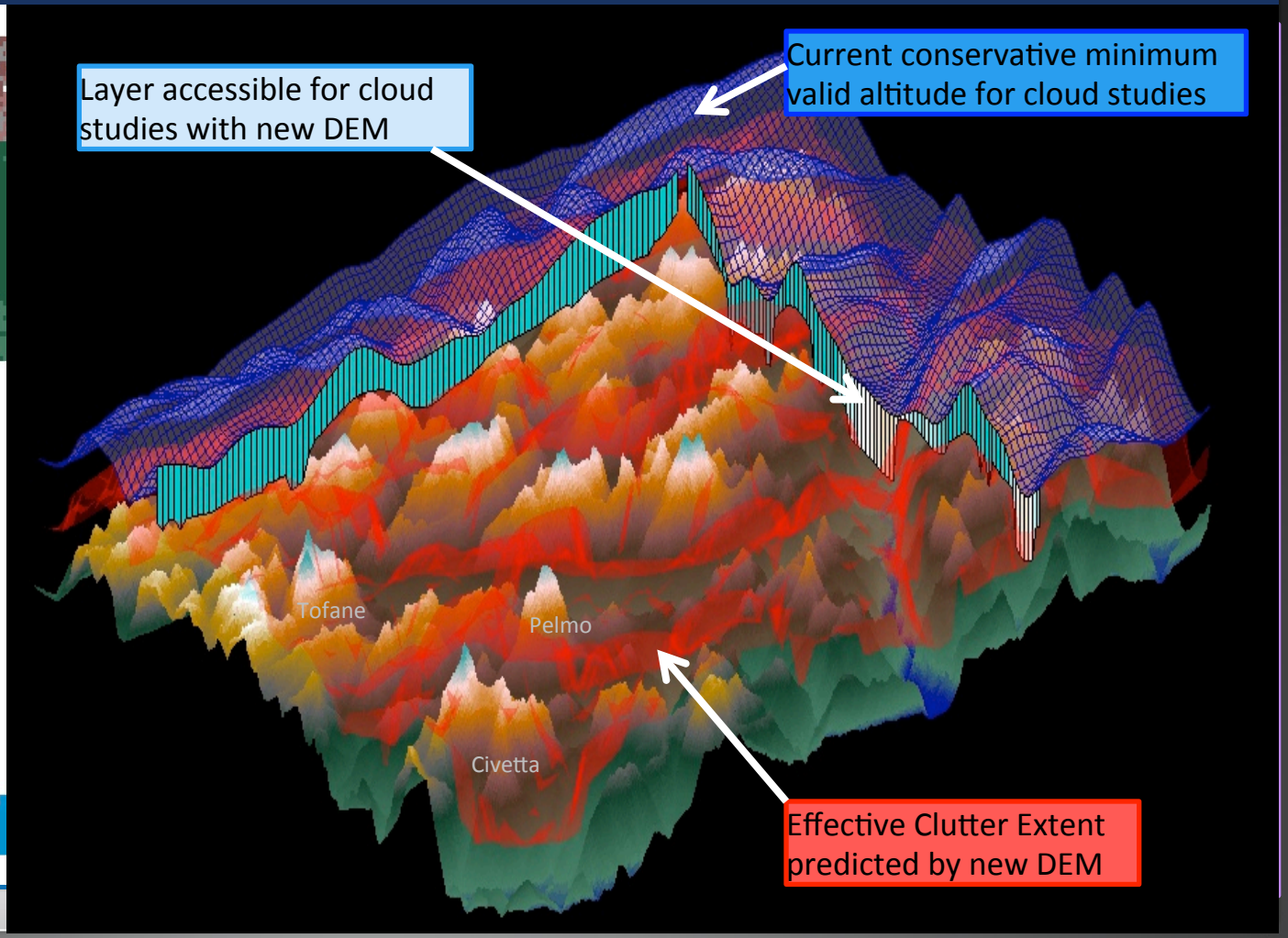


Surface Clutter

Over orography

In order to minimize the # of range bins close to the surface, and to have a chance at simulating appropriate surface scattering and emission, a good quality DEM & 3-D simulation is necessary.

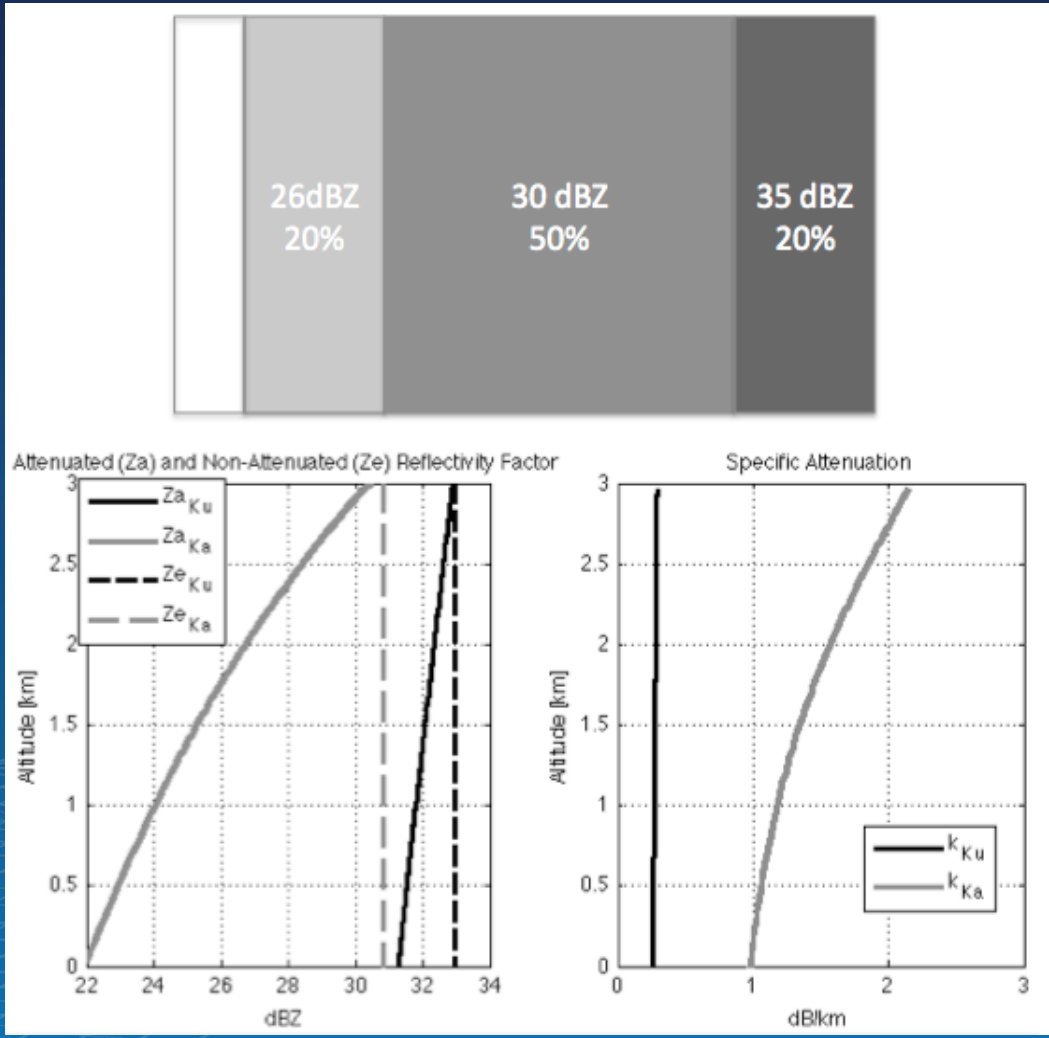




Non-Uniform Beam Filling Impact

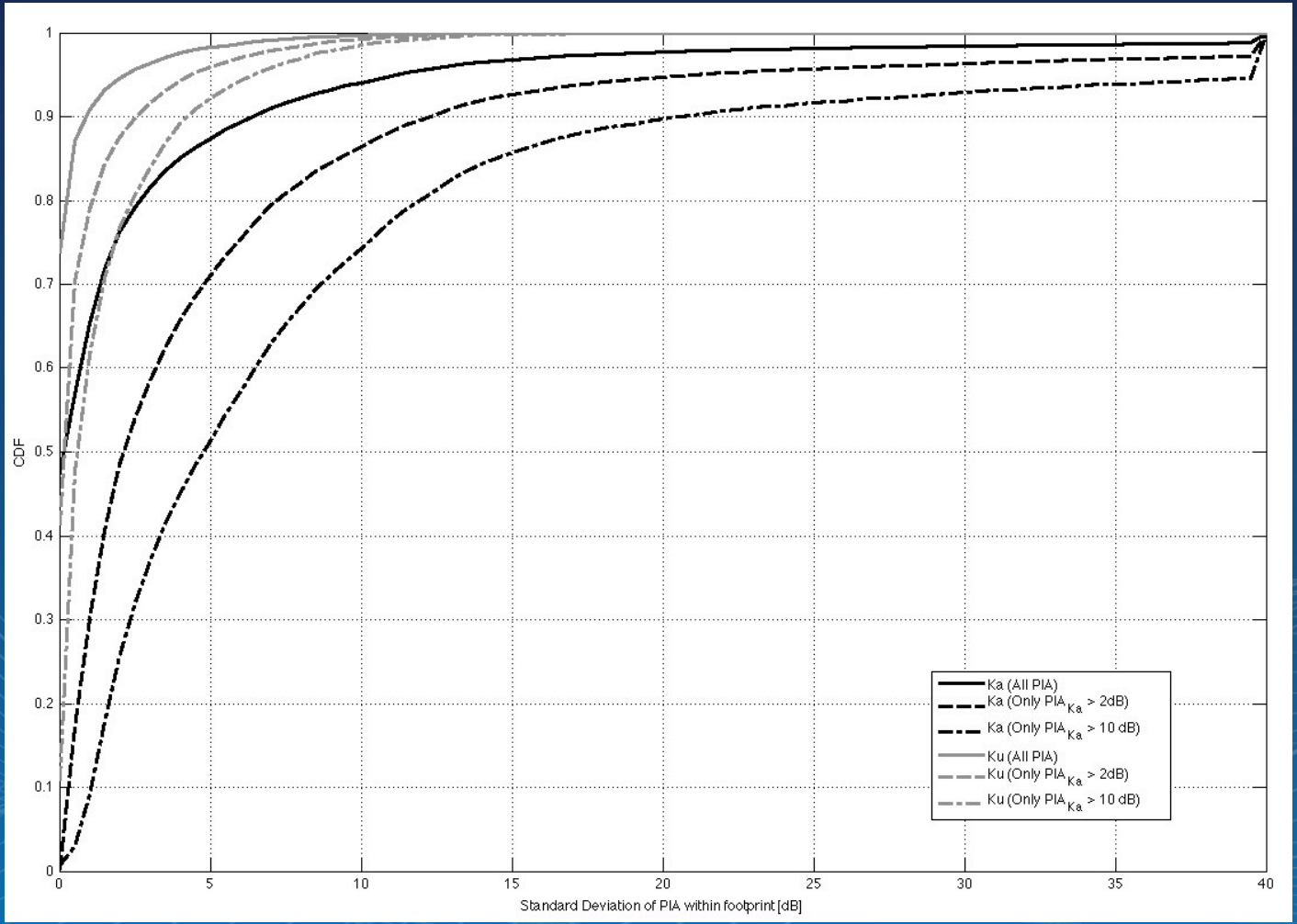
The ‘column model’

- Non-Uniform Beam Filling = inhomogeneity in the field of reflectivity across the radar beam
- Column Model = the pattern of NUBF is completely correlated along range
- This model was adopted since the first studies (e.g., Nakamura et al. 1991) and is well suited to explain the nature of the problem.
- The higher the specific attenuation the stringer the impact of NUBF➔ higher frequencies are more affected.



Experimental Evidence

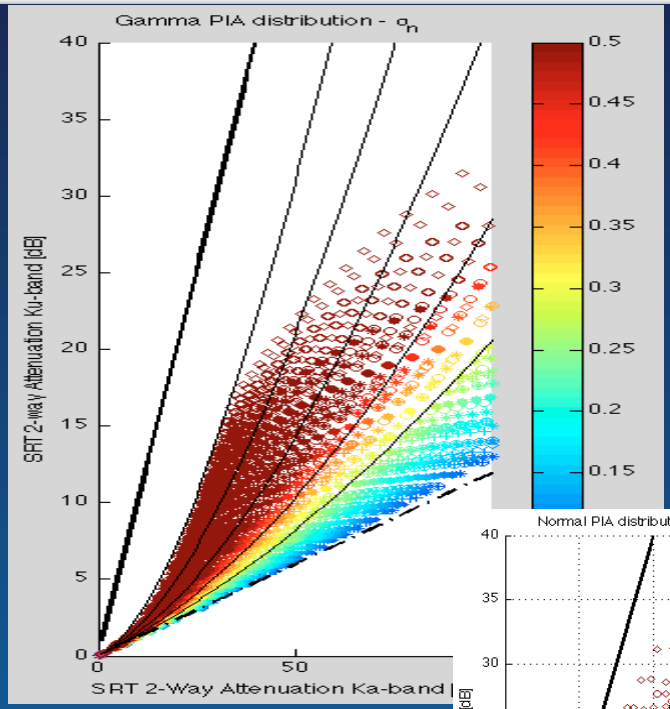
Probability of occurrence from the GRIP APR-2 dataset

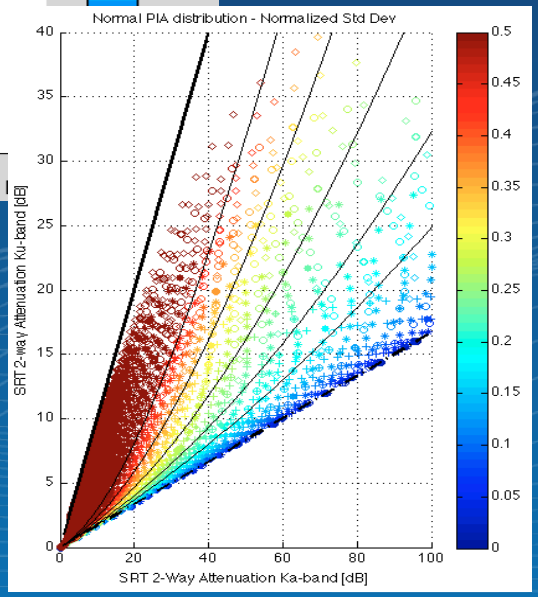


Theoretical Framework

Coefficient of variation vs. multi-frequency PIA

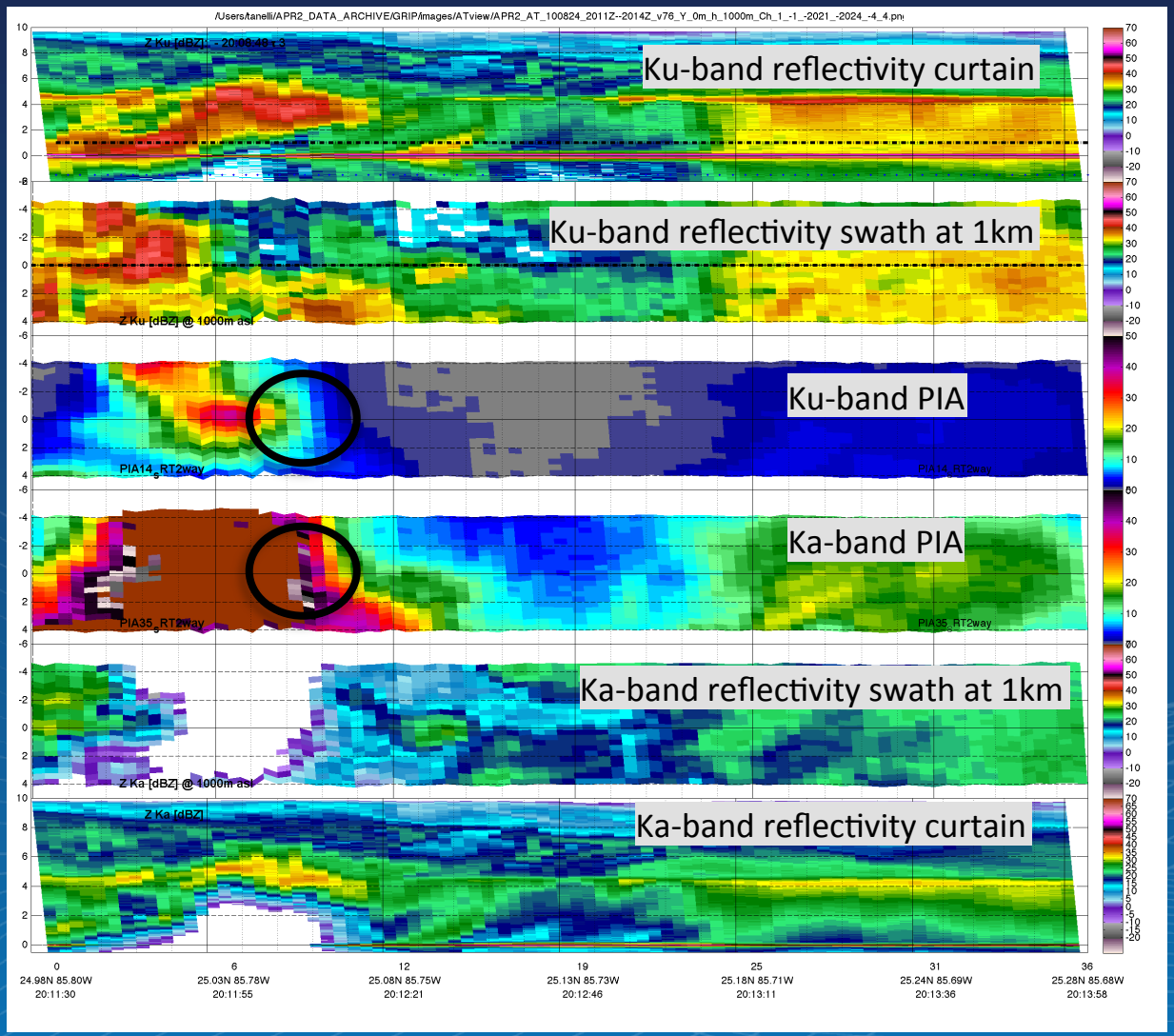
- In the TRMM operational algorithm two shapes have been considered (Iguchi et al. '00, '09):
  - Gamma
  - Log Normal
- The corresponding correction terms have been shown to be comparable.
- They enable elegant analytical solutions.
- How well do these classical monomodal distributions capture the actual distribution of PIA within a 5 km FOV?
- A 'Delta-clear + Gaussian-Rain' simple model is also explored in this paper.

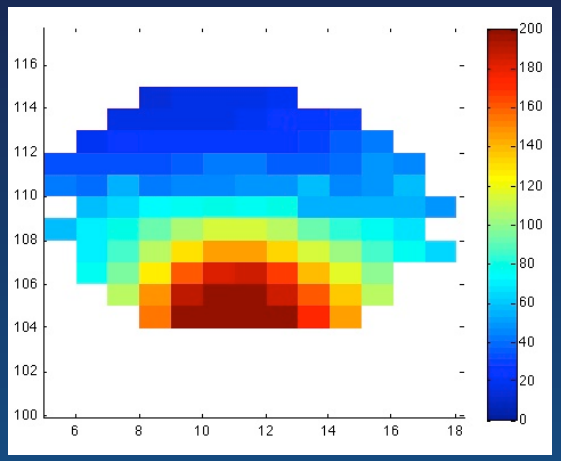




Experimental Evidence

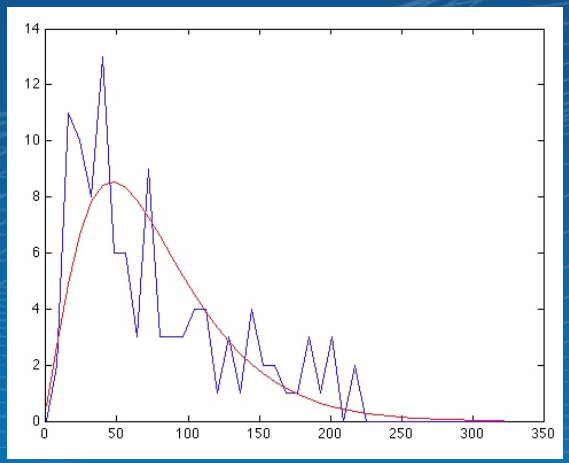
Example of Non Uniform FOV (Embedded Convection)





$\sigma_n > 0.15$

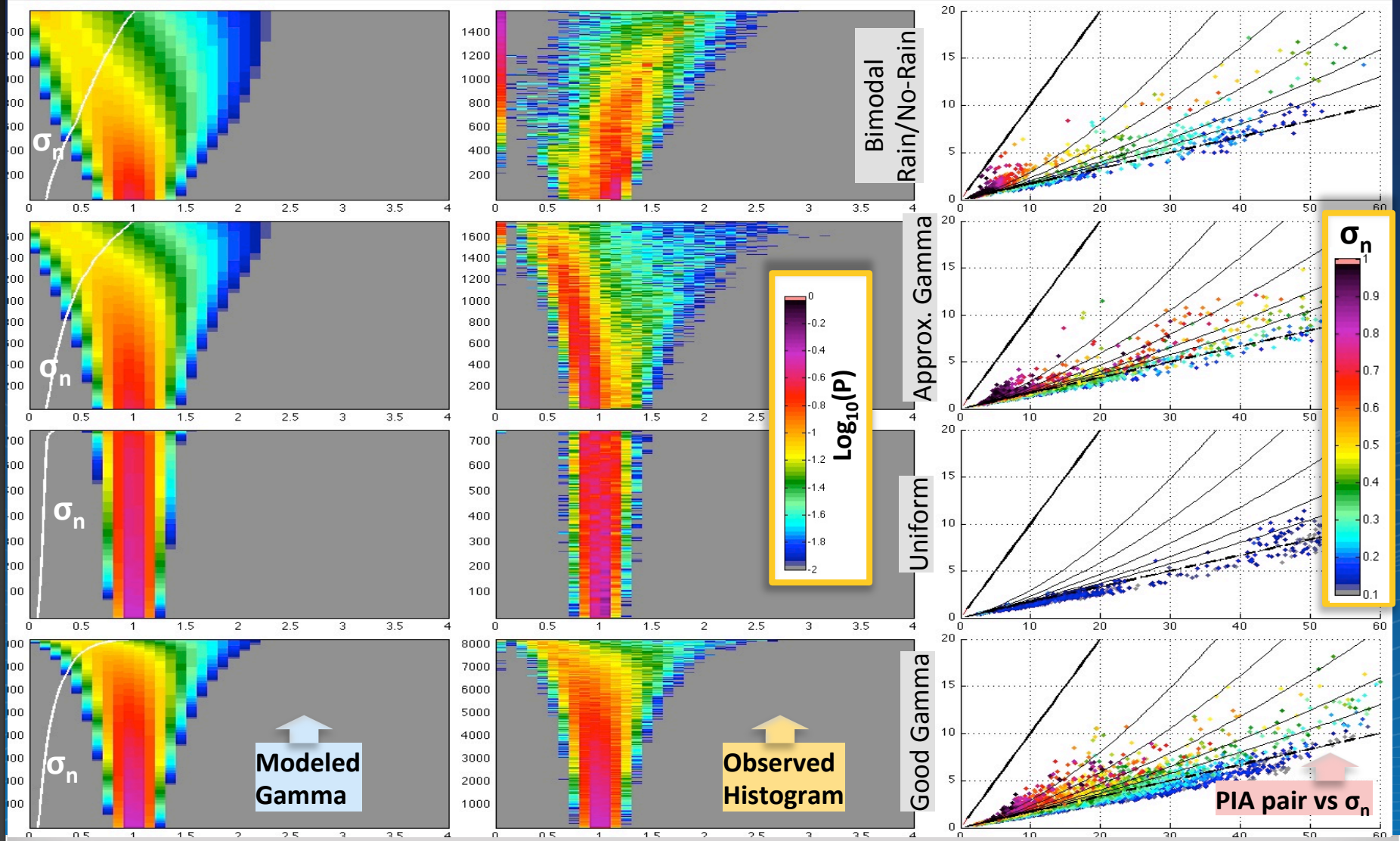
Good fit with Gamma



Experimental Evidence

PDF of nomalized PIA within one 5km (GPM) FOV (2)

There is almost never a trimodal distribution, but the no-rain/rain bimodal represents a large fraction of NUBF

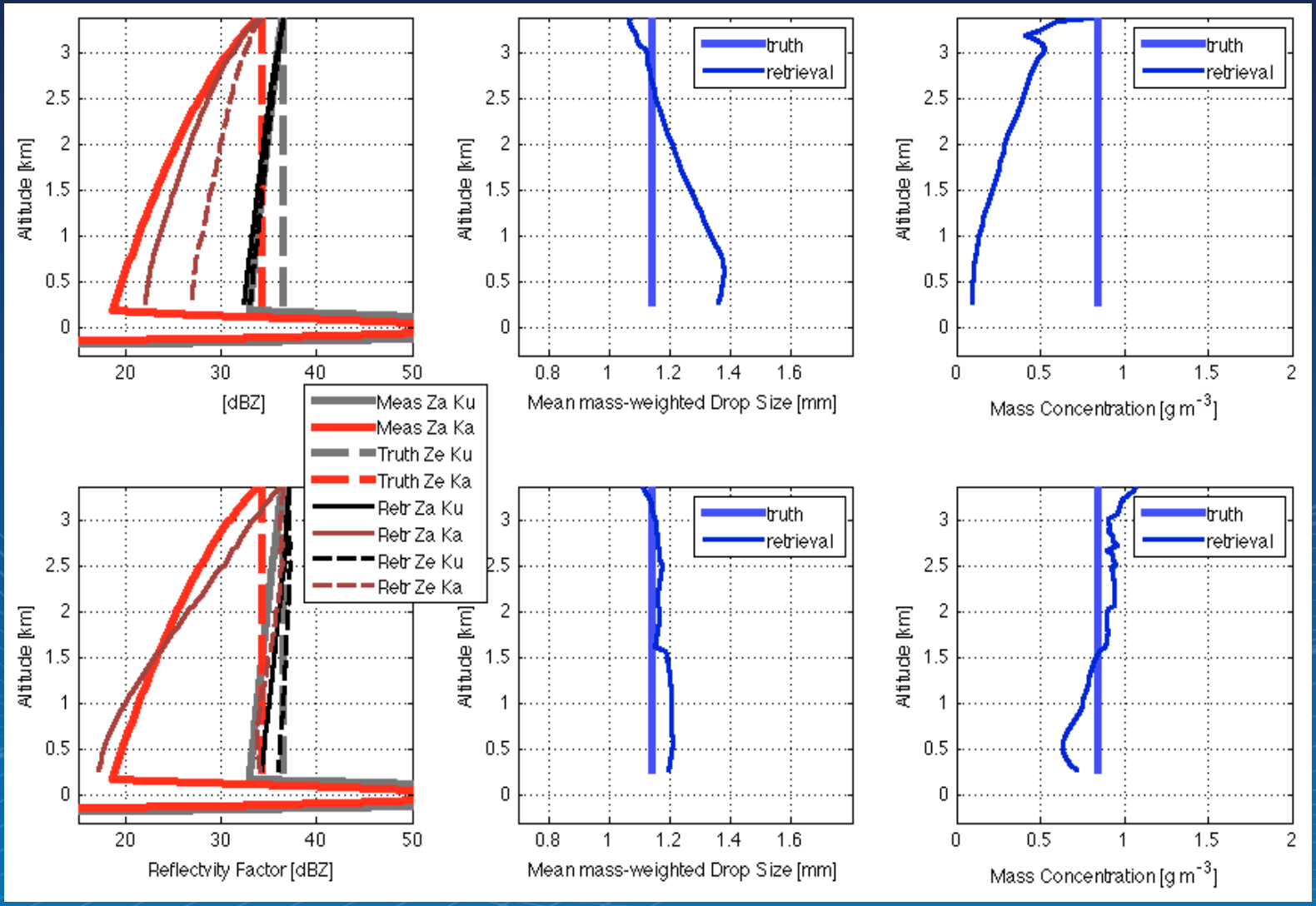


Correction and Retrievals

Simulated Column-NUBF profiles & Full Bayesian Retrievals: with and without NUBF correction

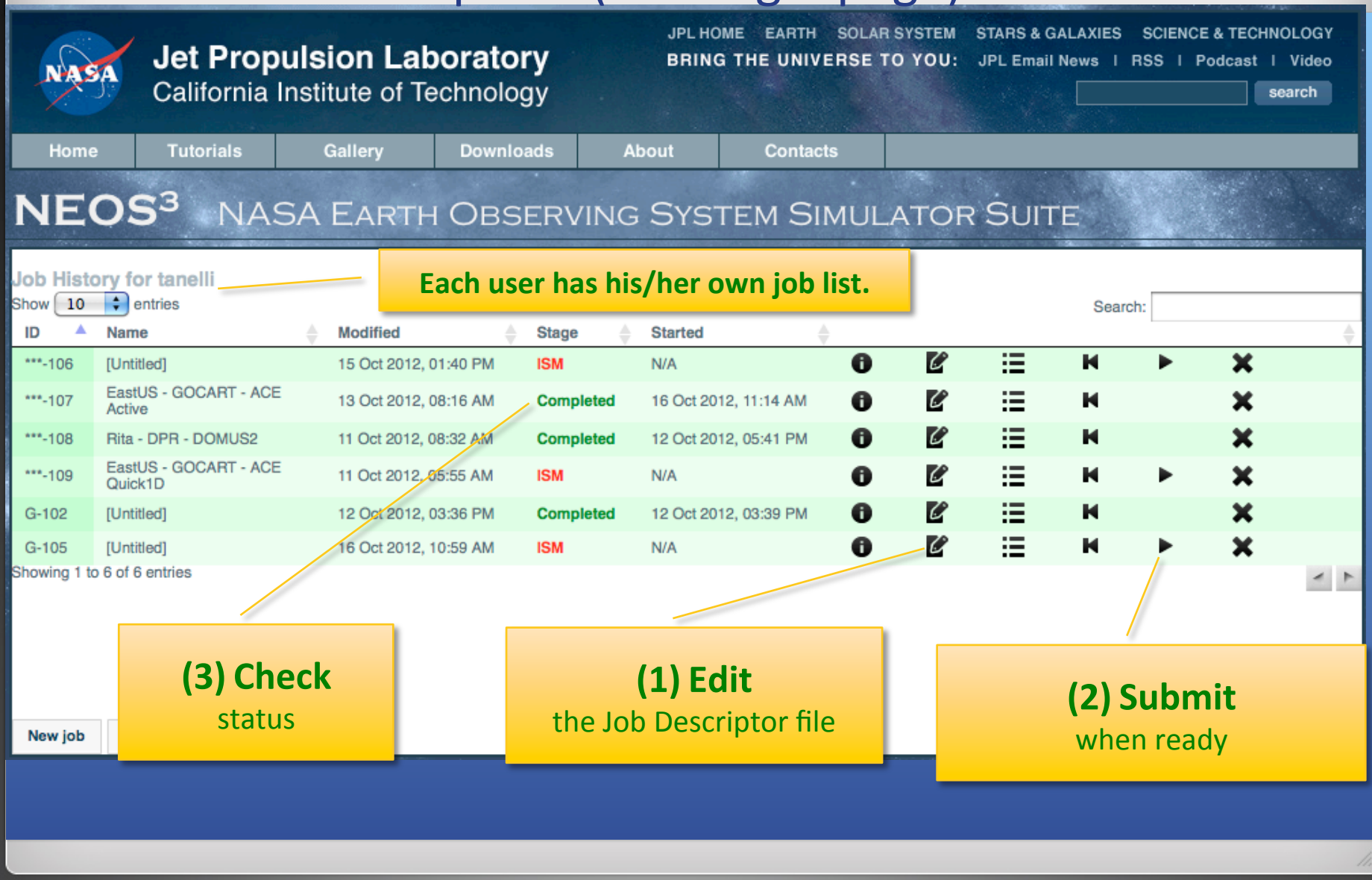
Without NUBF correction

With NUBF correction



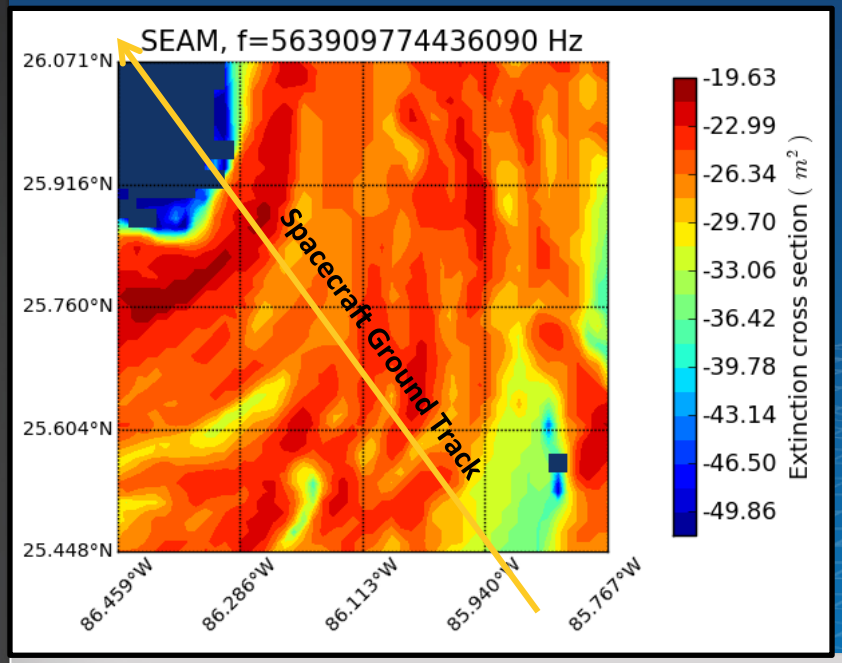
NEOS³ User Interface

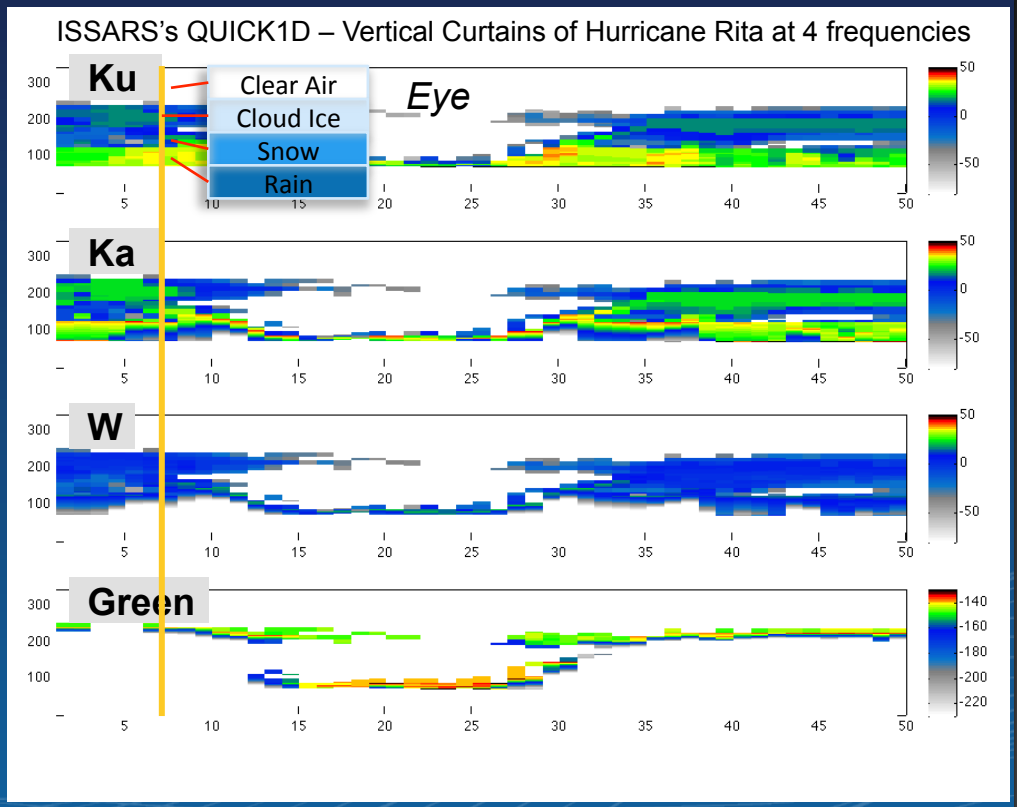
Main user control panel (aka: login page)



Advanced Active Instrument Simulators from the ‘standard’ radar/lidar equation…

Single scattering fileds are generated by the SEAM stage

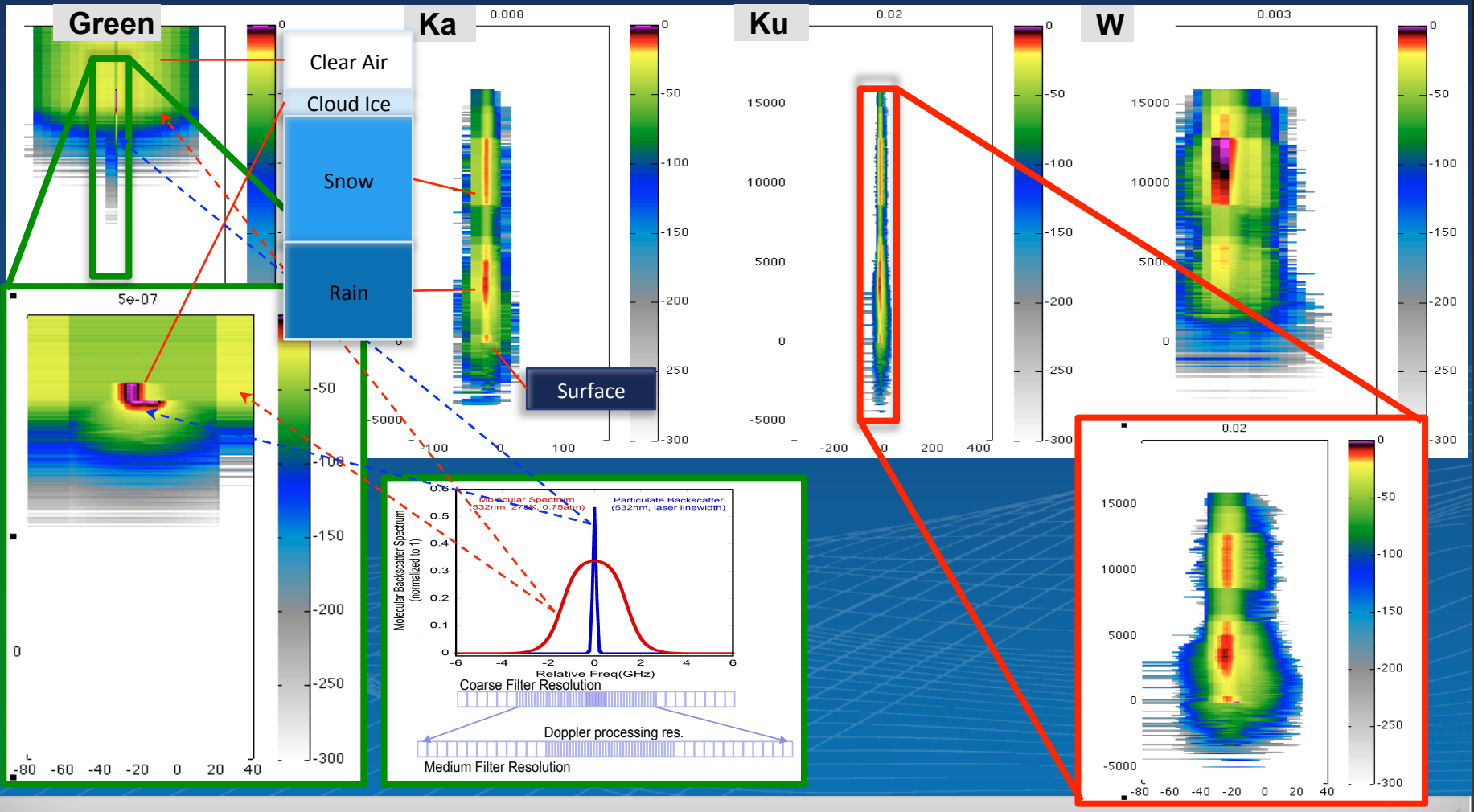




The fastest and simplest Time-Dependent RTM can produce simulated profiles of attenuated backscattering which are sufficient for cartain types of research, but for other.

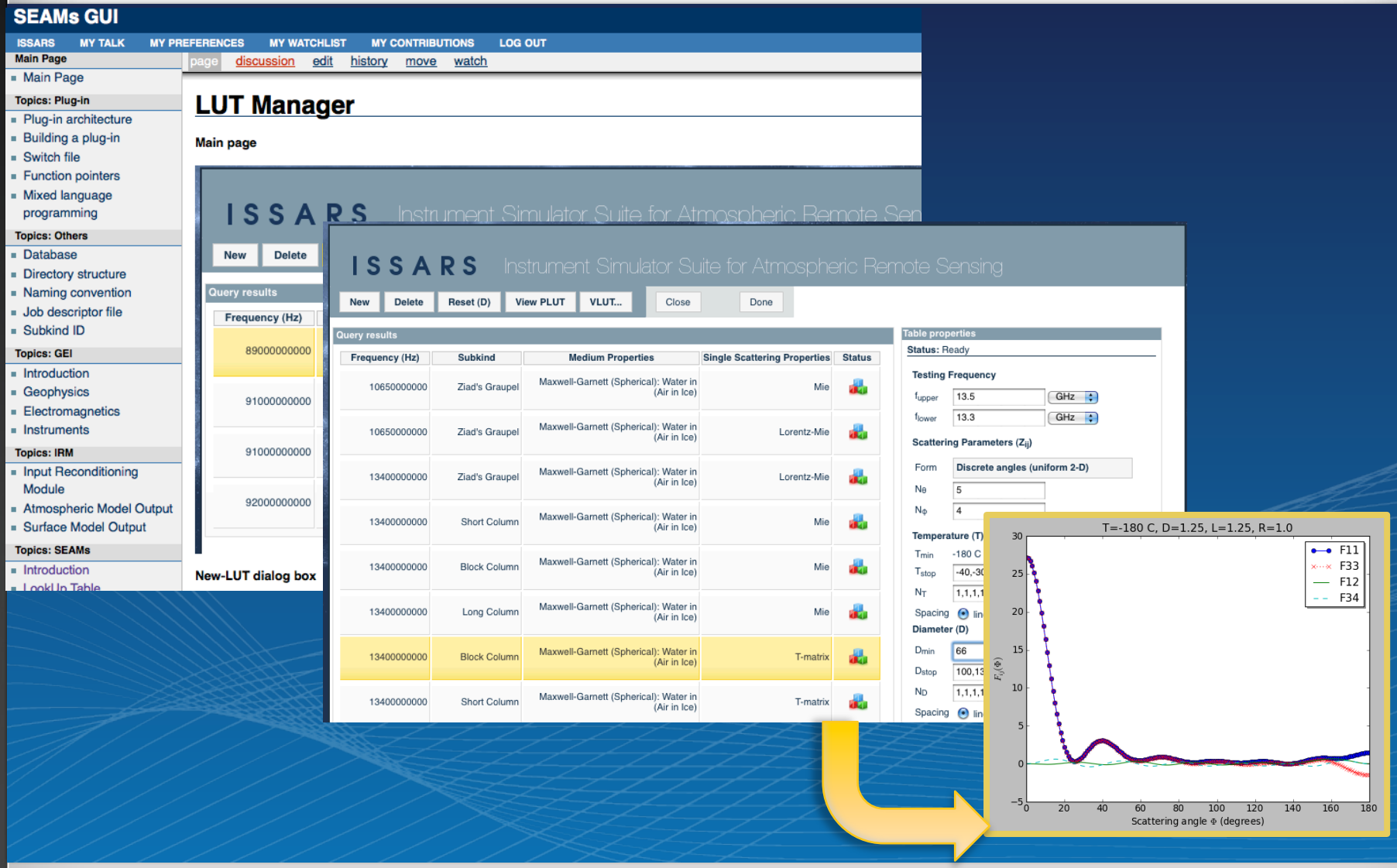
… to the Doppler Multiple Scattering Radar/HSRL simulator

Developed to capture the spectral signatures of all orders of trajectories. It reproduces the Doppler signatures necessary to test the effectiveness of the HSRL conceptand of Doppler radar measurements

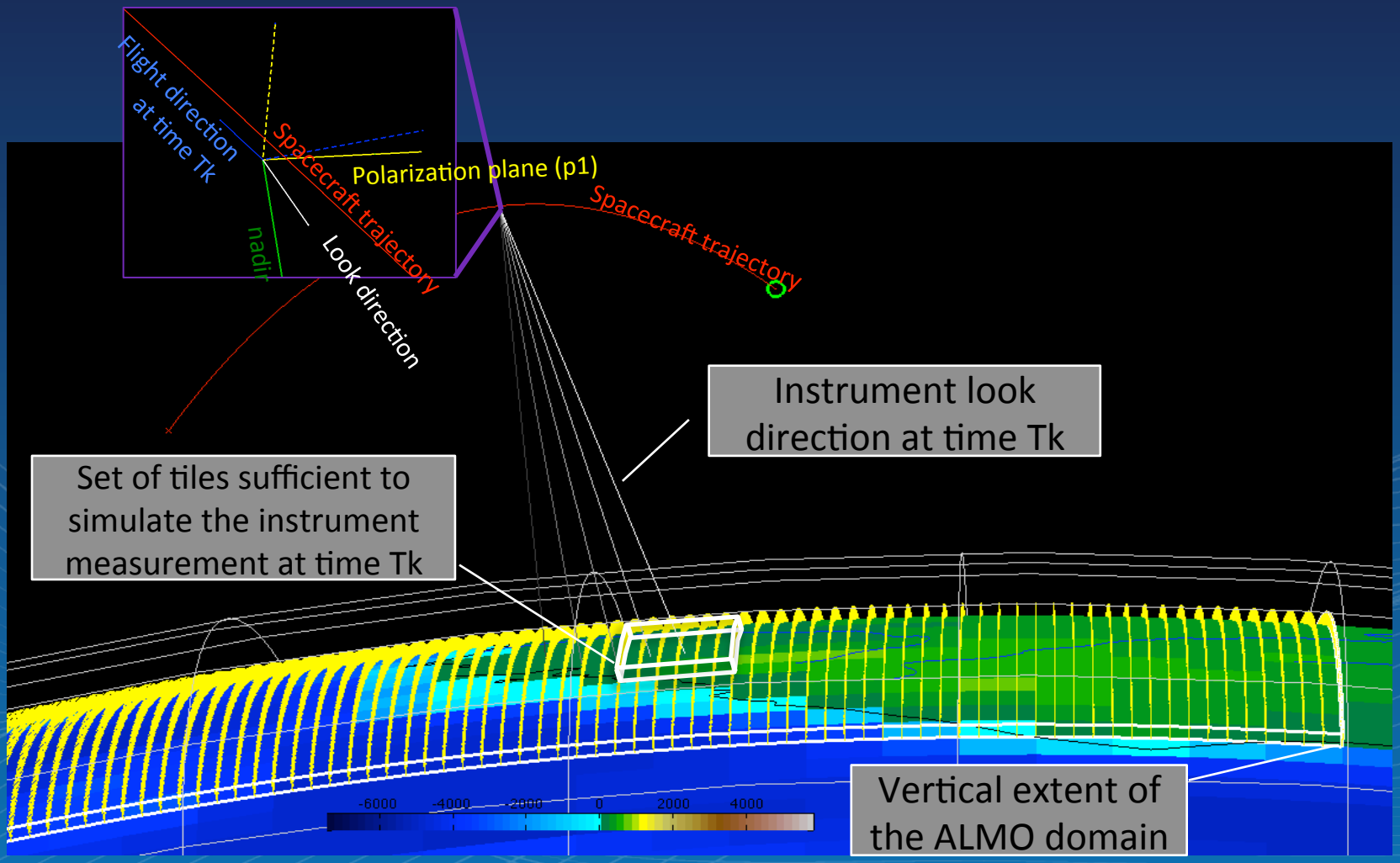


Processing Stage 2: SEAM

Scattering, Emission and Absorption Modules



The key: the decoupling of the stages determines the geometry



Simulated Radar and Radiometer