RSP Data Status, Updates and Plans from the Team

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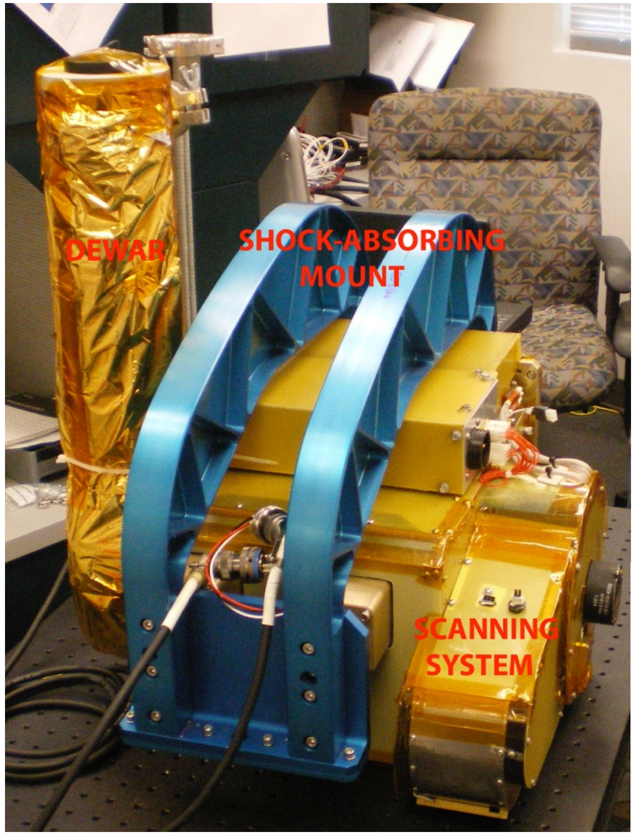
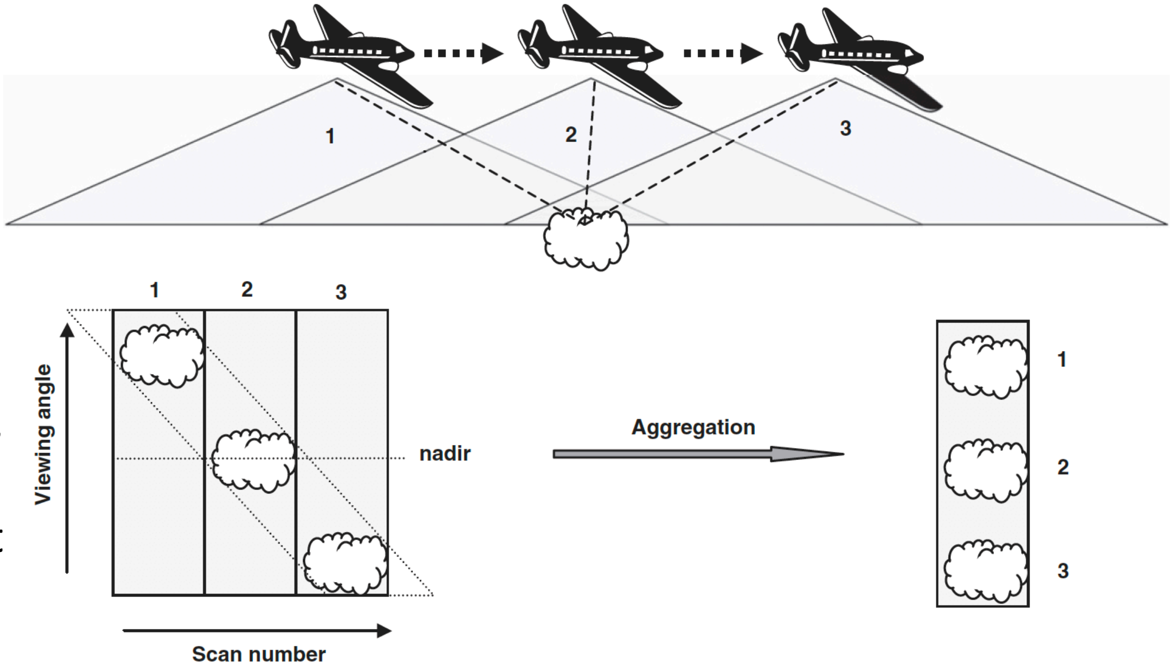
- All radiance (L1C) and and cloud (L2) products are in the archive
- Revised calibration performed at GSFC in July 2021 applied to reprocessing.
- Waiting on flight hardware testing to get access for one last calibration and reprocessing.

RSP Radiance Data – ACTIVATE-RSP-L1C_UC12_YYYYMMDD_RX

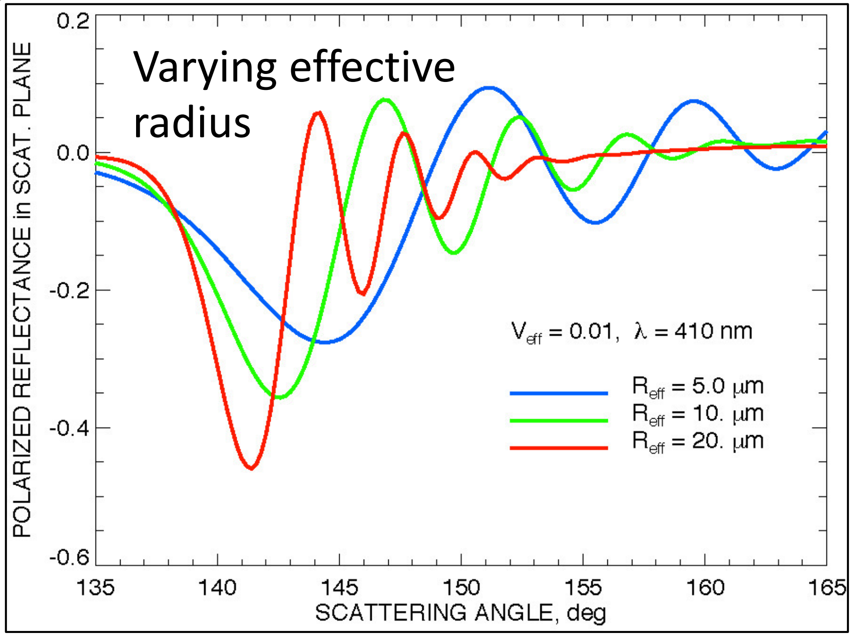


- The Research Scanning Polarimeter (RSP) is a passive, downward-looking polarimeter, with nine spectral bands between 410 and 2260 nm that scans its field of view along the aircraft ground track.

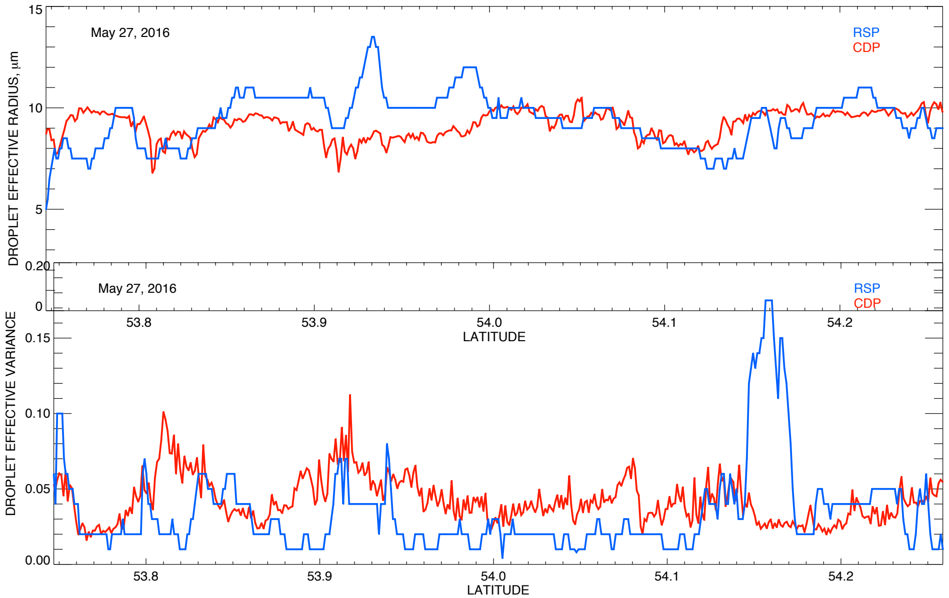
- The RSP scanner rotates continuously so any given scan consists of views of lots of different scenes both in front of, and behind, the aircraft. So, as the aircraft flies over a given point on the surface (or cloud) it will be viewed from multiple angles as shown in the figure below. These multiple views of the same scene are what is contained in the L1C files.
- Radiance and linear polarization measurements over an angular range of ±55° from nadir every 0.8° are provided for each scene.



RSP Cloud Data – ACTIVATE-RSP-CLD_UC12_YYYYMMDD_RX

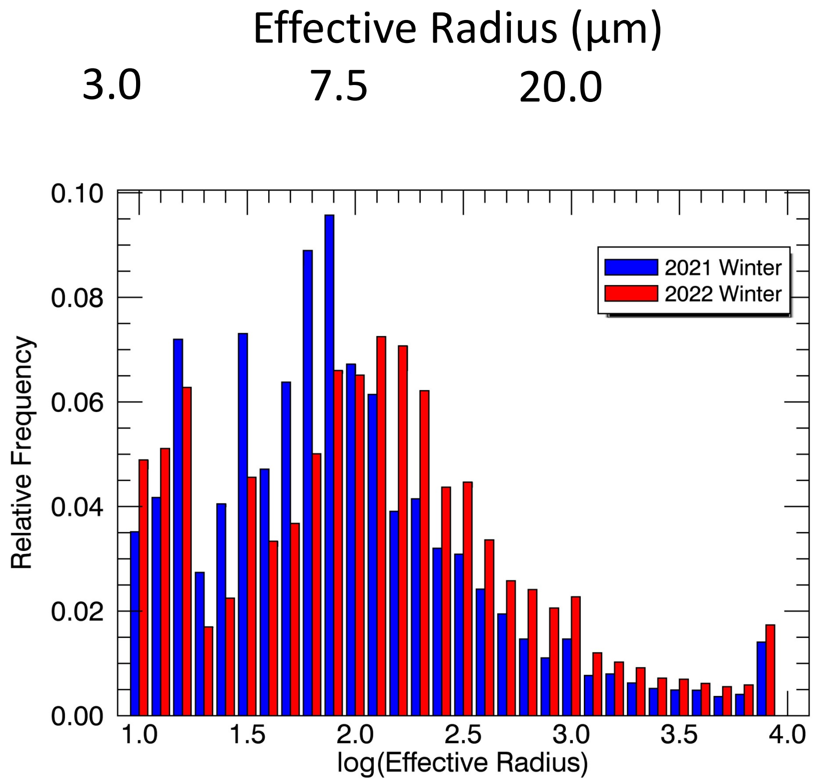


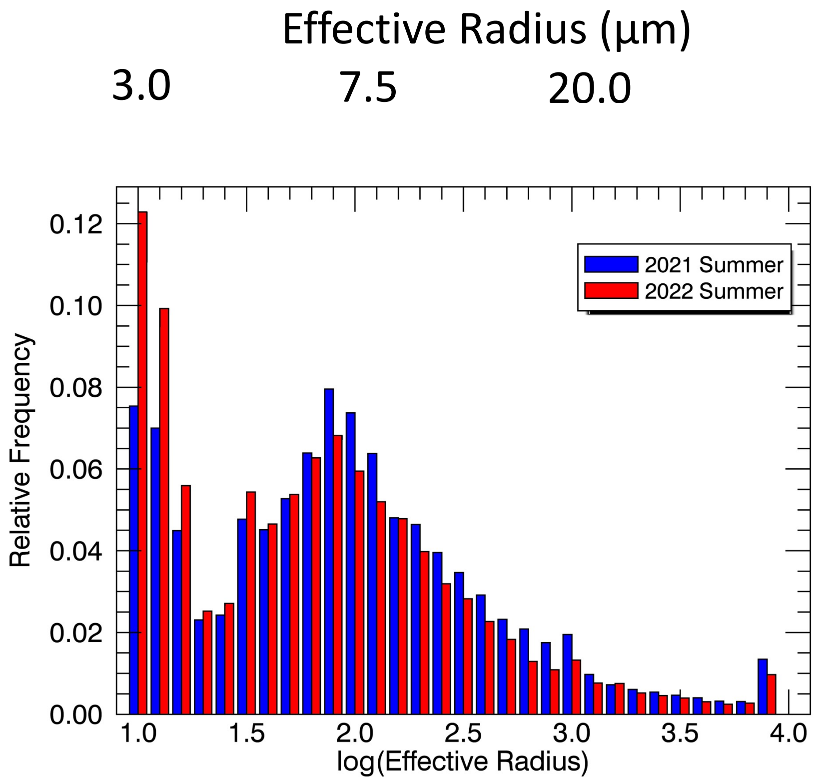
- A feature of the RSP data is that it contains high angular density observations for every scene.
- When a water cloud is present polarized observations of the cloud bow can be used to estimate the Droplet Size Distribution.
- The RSP also has spectral bands in regions where liquid and ice water absorb (1.59 and 2.26 μm) and allow for bispectral retrievals of droplet sizes similar to MODIS and VIIRS.
- The optical depth of the cloud is also estimated using a non/weakly absorbing band at 865 nm



- The remote sensing estimates of droplet size distributions have been validated against in situ observations with an agreement for effective radius ~ 0.5 μm and for effective variance of 0.02. Multimodal size distributions are available when viewing geometry is good.

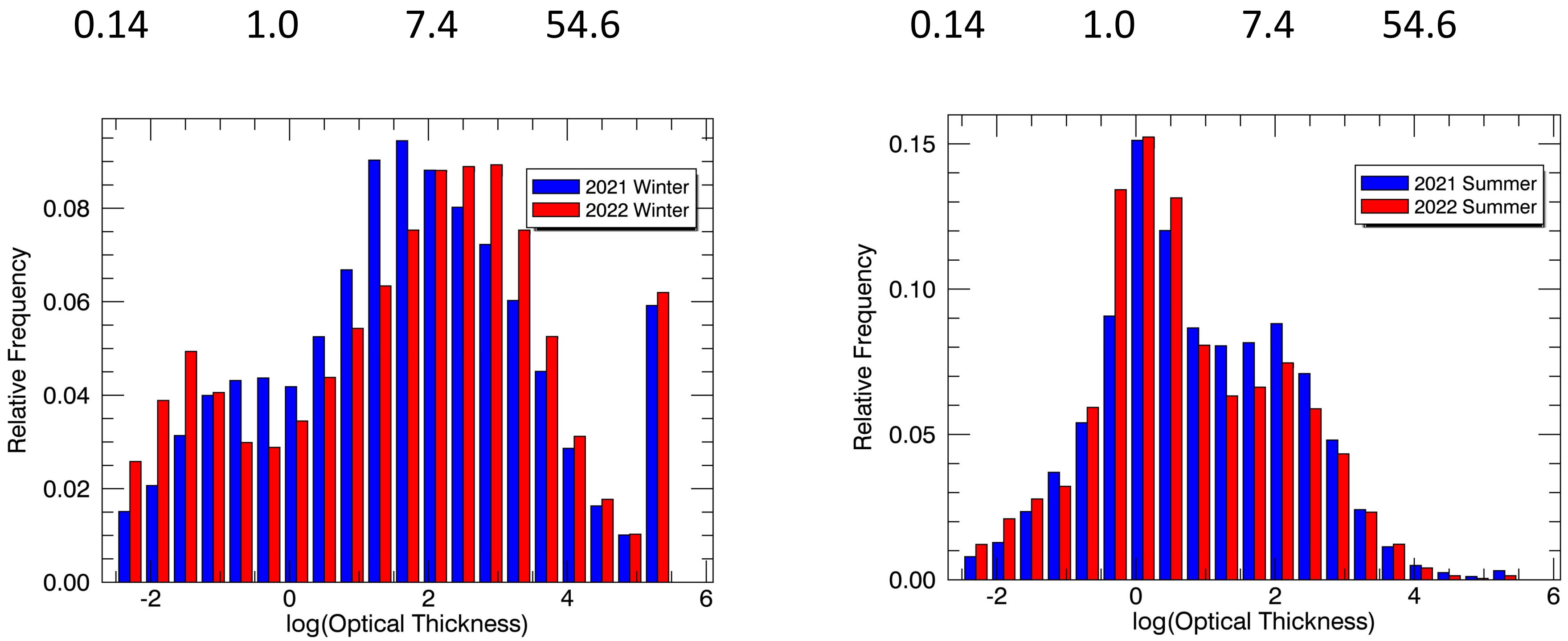
RSP Cloud Data – ACTIVATE-RSP-CLD_UC12_YYYYMMDD_RX





- Less of a difference between summer and winter in 2021/2022 than 2020/2021.
- Both the differences in optical depth and the differences in droplet size are factors in the larger droplet number observed in winter compared to summer using remote sensing.

RSP Cloud Data – ACTIVATE-RSP1-L2CLD_KingAir_YYYYMMDD_RX

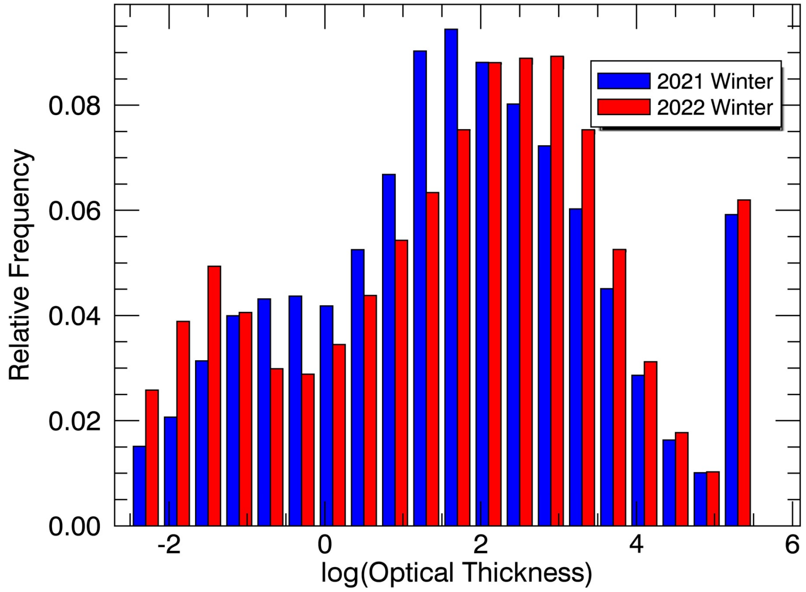


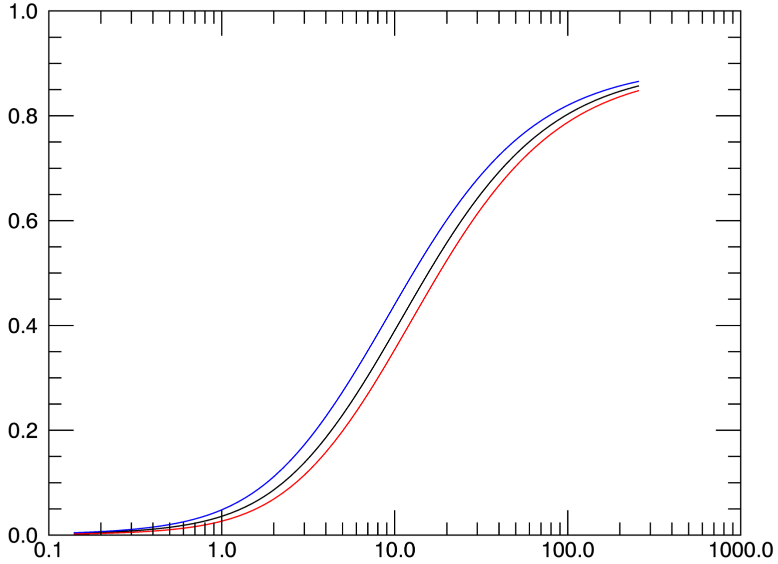
- Last two summer and winter seasons are very similar with lower optical depth "mode" in summer
- NB: in winter there is an outlier with an optical depth greater than 256 that contains ~ 5% of observations. This is likely the result of cloud shading/brightening when the sun is low in the sky. Such artifacts are almost never seen in summer (~ 0.1%).
- Next cloud data version will include LWP calculated as:

LWP=5/9*effective_radius*cloud_optical_depth

RSP Cloud Data – ACTIVATE-RSP1-L2CLD_KingAir_YYYYMMDD_RX

0.14 1.0 7.4 54.6





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- We will be adding two versions of droplet number to the next release of the cloud data.
- The "adiabatic" method popularized by JL Brenguier and co-workers.

Retrieved by RSP

$$N_d = \frac{\sqrt{5}}{2\pi k}\left(\frac{f_{ad}\, c_w\, \tau_c}{Q_{ext}\, \rho_w\, r_e^5}\right)^{1/2}.$$

$$k = (r_v/r_e)^3 = (1 - v_e)(1 - 2v_e).$$

f_{ad} – fraction of adiabaticity
c_w – condensation rate
Q_{ext} – extinction efficiency factor
k – ratio of volume mean radius to effective radius
τ_c – cloud optical thickness

- The direct method

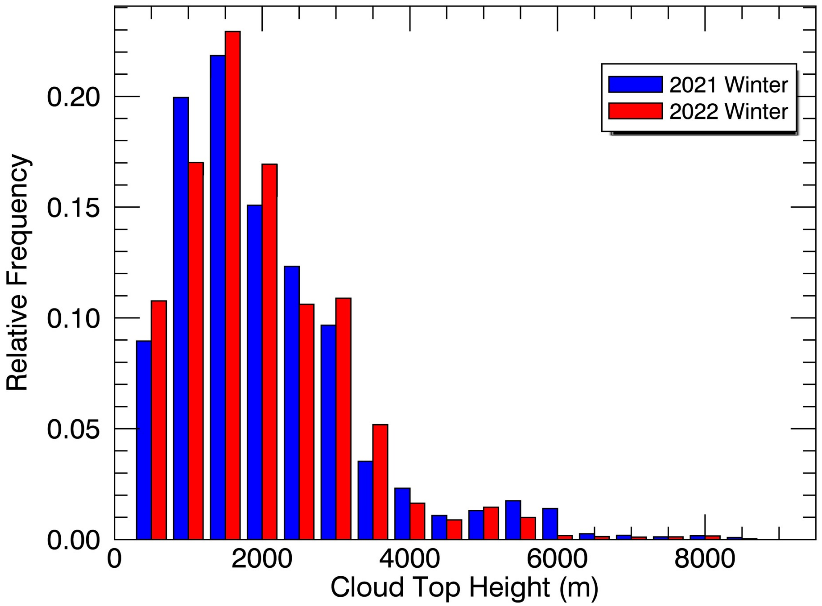
Retrieved by HSRL2

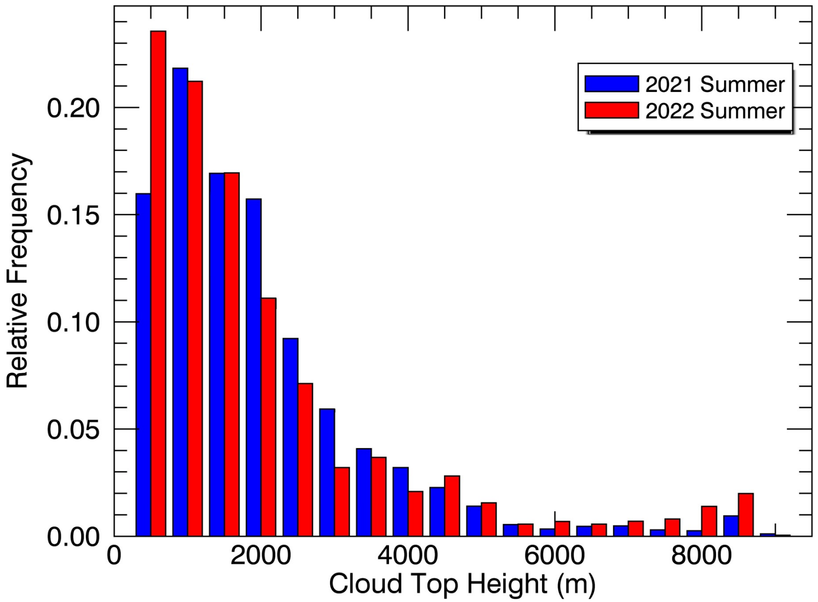
Retrieved by RSP

$$N_d = \frac{\beta_e}{\overline{\sigma_e}}$$

- N_d – droplet concentration
- β_e – in-cloud extinction (HSRL-2)
- $\overline{\sigma_e}$ – mean extinction cross-section (RSP)

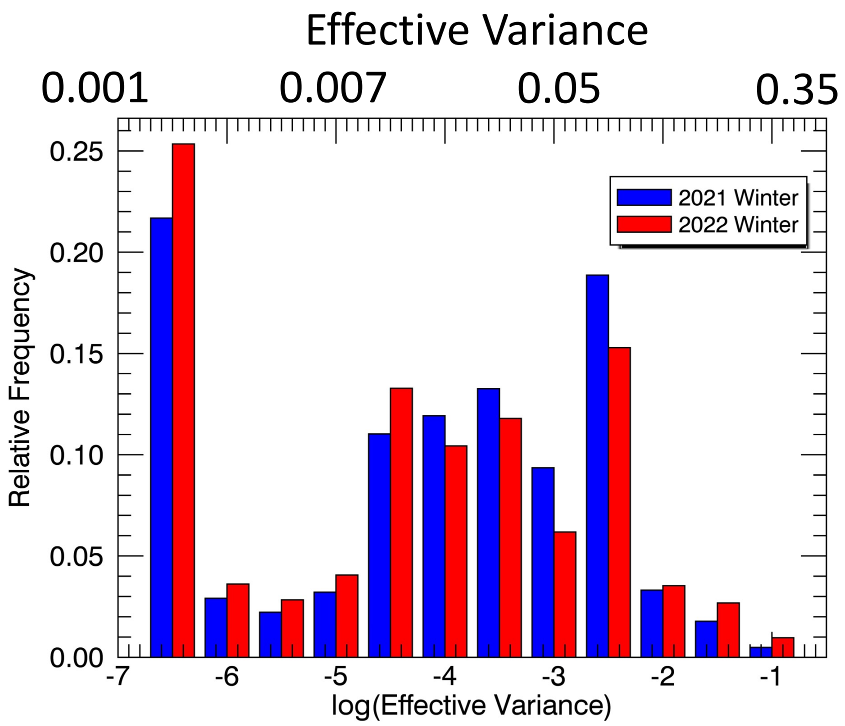
RSP Cloud Data – ACTIVATE-RSP-CLD_UC12_YYYYMMDD_RX

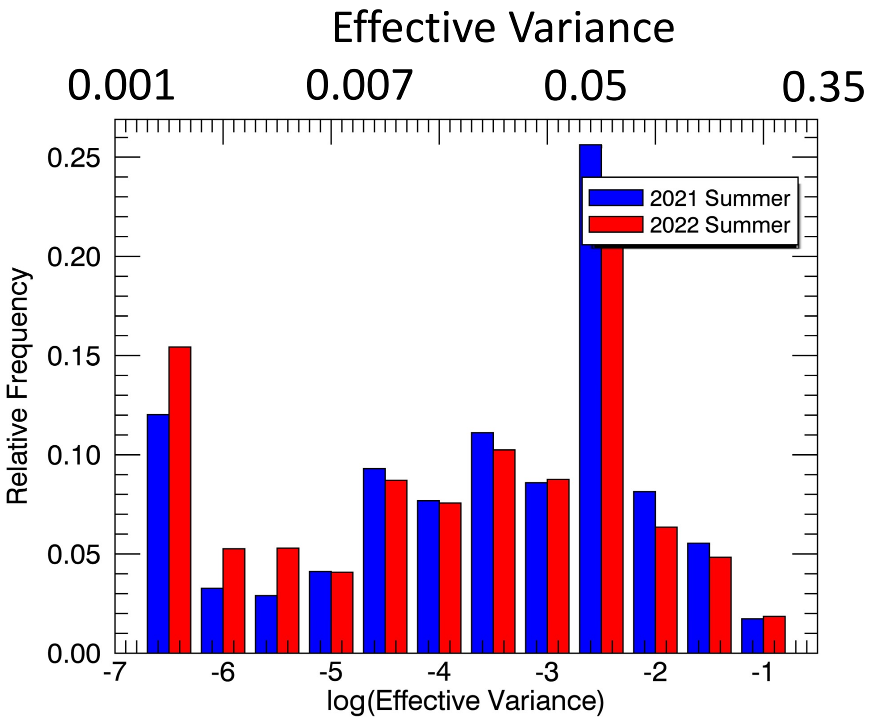




- No obvious difference in cloud top heights between summer/winter 2021 and 2022. Maybe slightly more thin, low clouds around Bermuda.

RSP Cloud Data – ACTIVATE-RSP-CLD_UC12_YYYYMMDD_RX





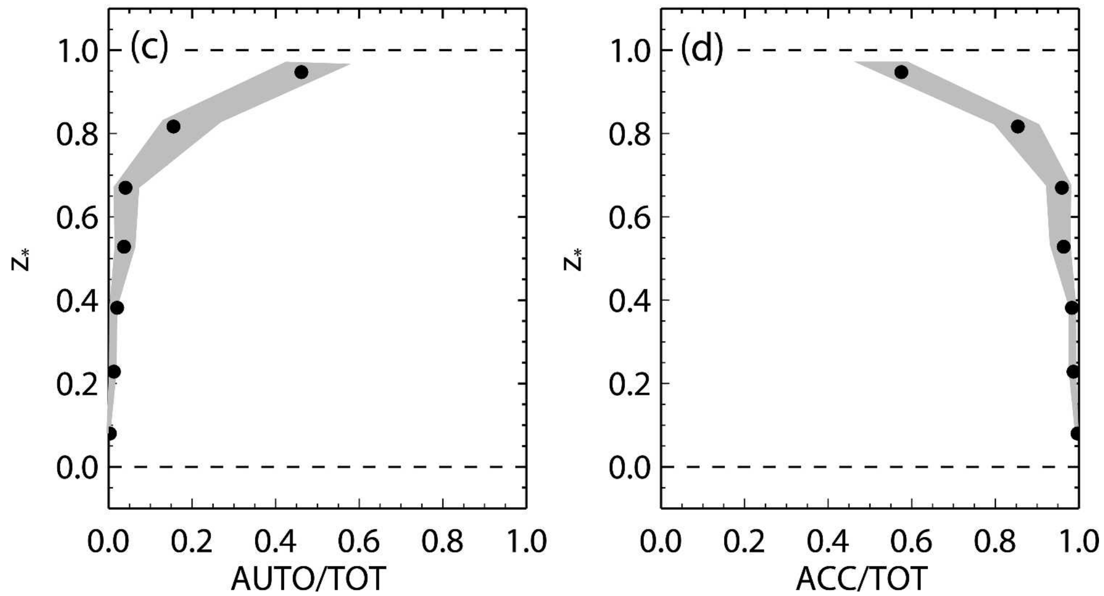
- Effective variance distributions are similar across seasons and years. Summer months do have more effective variances larger than 0.1 which are likely to be bimodal size distributions that are may form drizzle.
- Peak in v_{eff} at lower boundary of look up table and at ~0.07. This corresponds to a value for k in the equation for droplet number concentration of 0.8, which is a commonly assumed value.

- Aside from drizzle that is detected at cloud top, retrievals of droplet number concentration and size distribution allow us to directly evaluate the auto-conversion rate (the rate at which liquid water content of sizes larger than a threshold, in this case 20 μm, is increasing) at cloud top

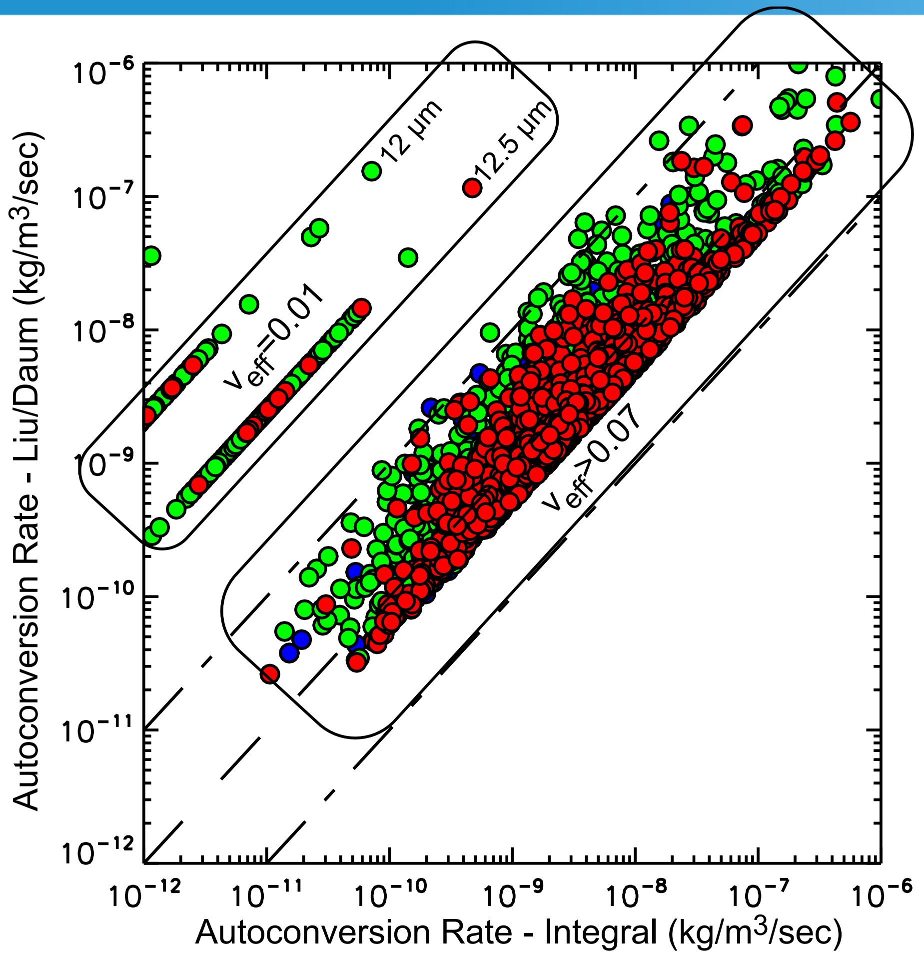
$$A = \int_0^{x_0} \left[\int_{x_0 - x}^{x_0} K(x, x') x' n(x') dx' \right] n(x) dx$$

where x and x' are the masses of two coalescing droplets, *n(x)* is the number of droplets in the mass range *x* to *x* + *dx*, *K(x,x')* is the collection kernel for coalescing droplets (Hall 1980, JAS) and x_0 is the mass of a 20 μm drop (Wood 2005, JAS; Beheng and Doms 1986).

While auto-conversion is not important overall in drizzle rates it is important for the initial formation of drizzle near cloud top (e.g. Figs 9c) and 9d) from Wood 2005, JAS).



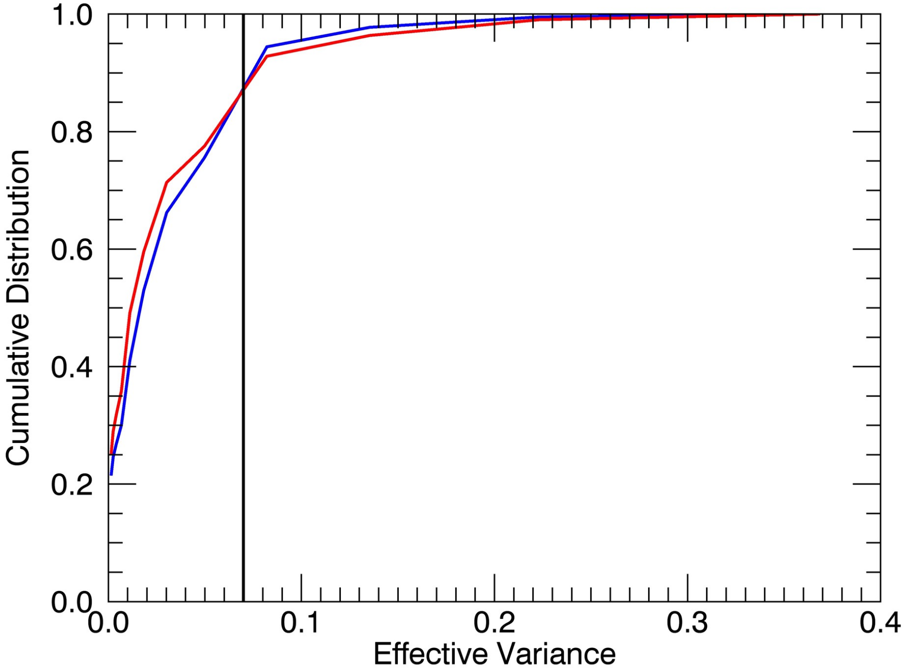
RSP Cloud Data – ACTIVATE-RSP-CLD_UC12_YYYYMMDD_RX



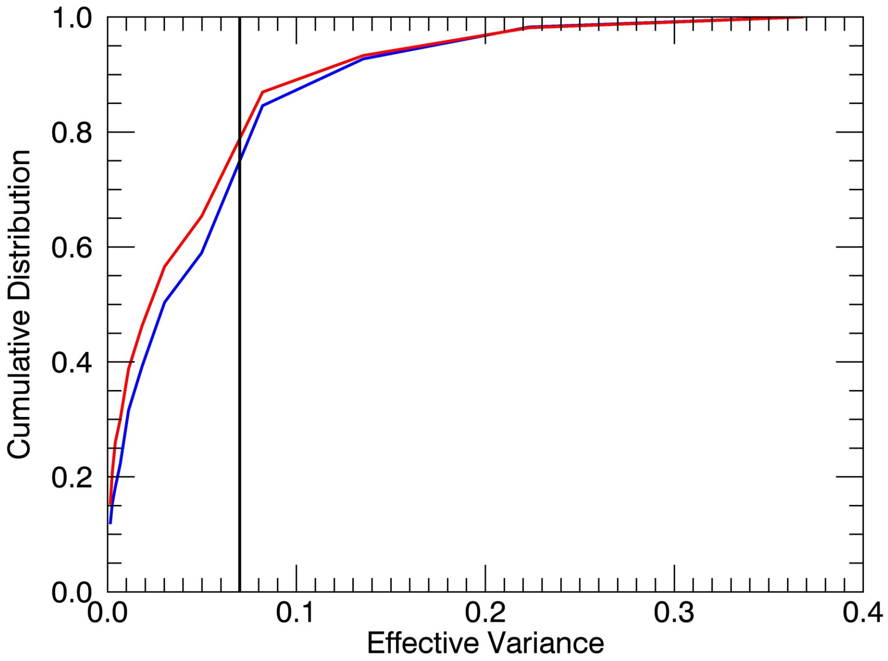
- Comparing auto-conversion rates calculated using actual size distributions with those from the Liu-Daum bulk parameterization shows there can be large discrepancies once veff < 0.07.

RSP Cloud Data – ACTIVATE-RSP-CLD_UC12_YYYYMMDD_RX

Winter

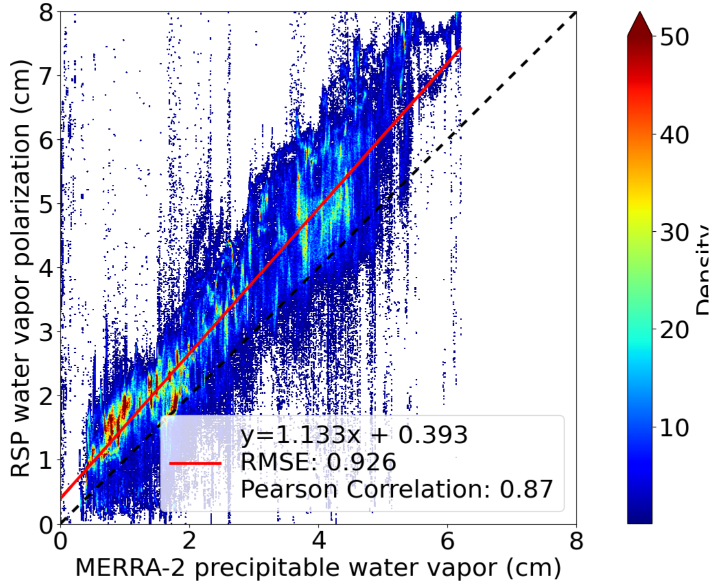


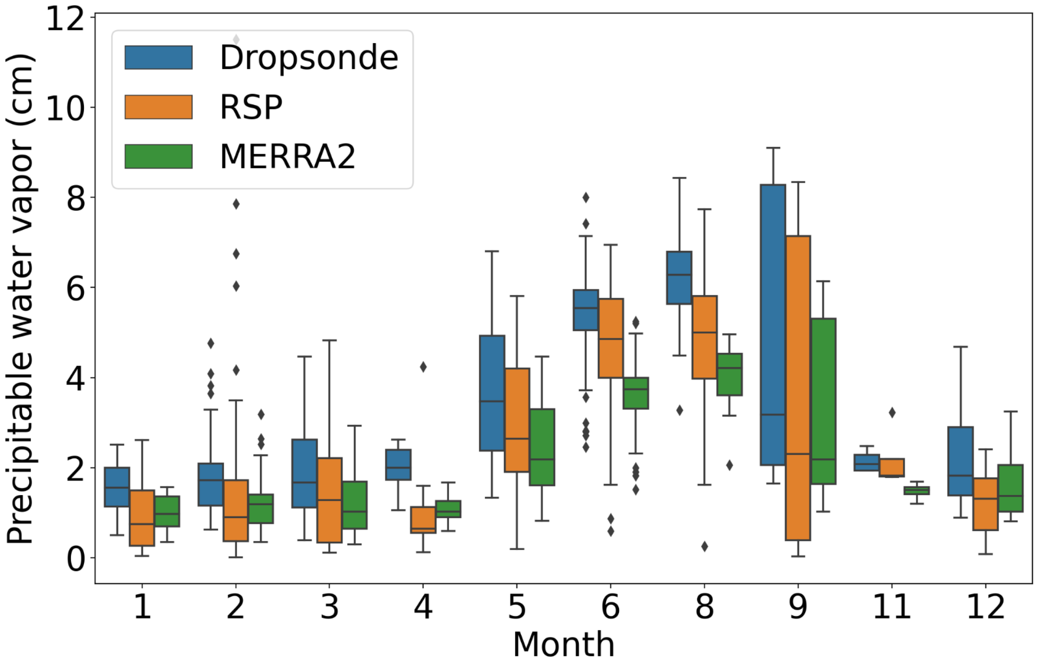
Summer



- In the last two years of ACTIVATE ~80% of clouds still have veff<0.07. If bulk parameterizations do not allow for how narrow cloud top size distributions this may lead to overestimates of auto-conversion.

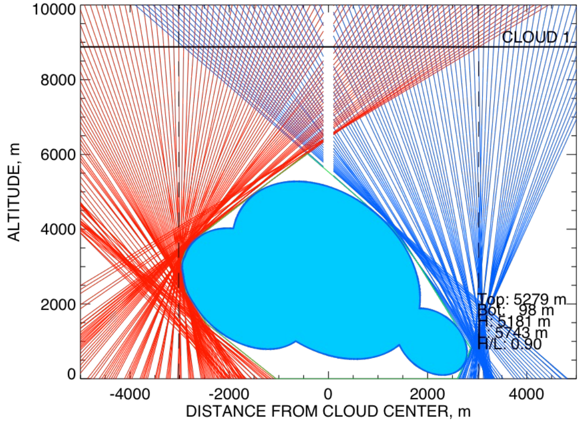
RSP Cloud Data – ACTIVATE-RSP-CLD_UC12_YYYYMMDD_RX



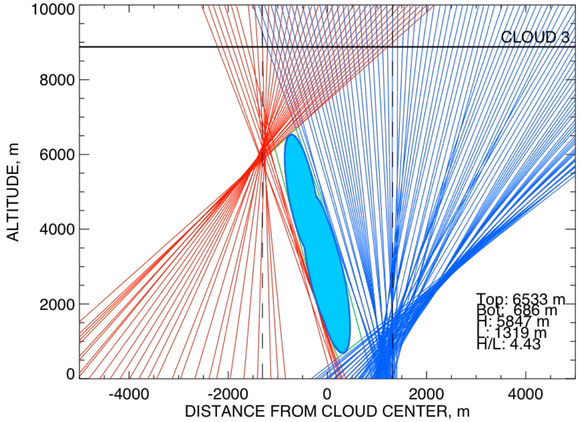


- RSP also does a water vapor retrieval. The primary reason for doing this originally was to provide a corrections for water vapor continuum absorption in the SWIR bands.
- But since it works quite well it also serves as a good test for how to make such retrievals work well from satellite.

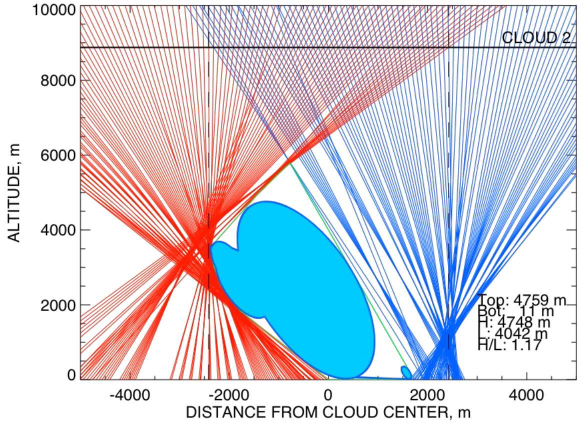
RSP Cloud Tomography



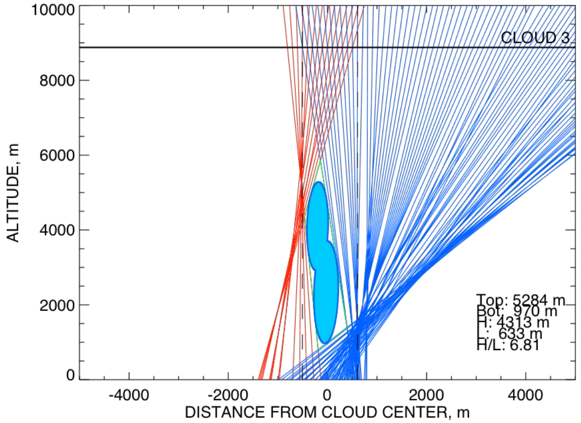
R = 0.2



R = 0.5



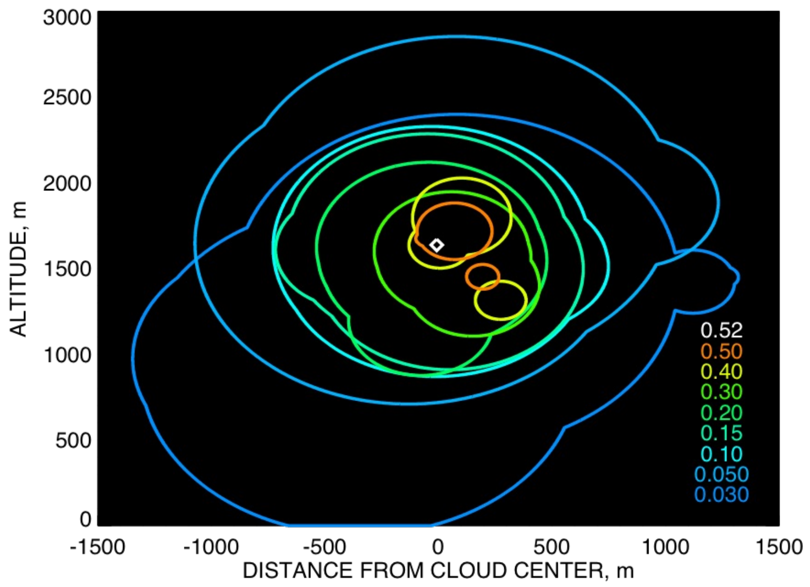
R = 0.4

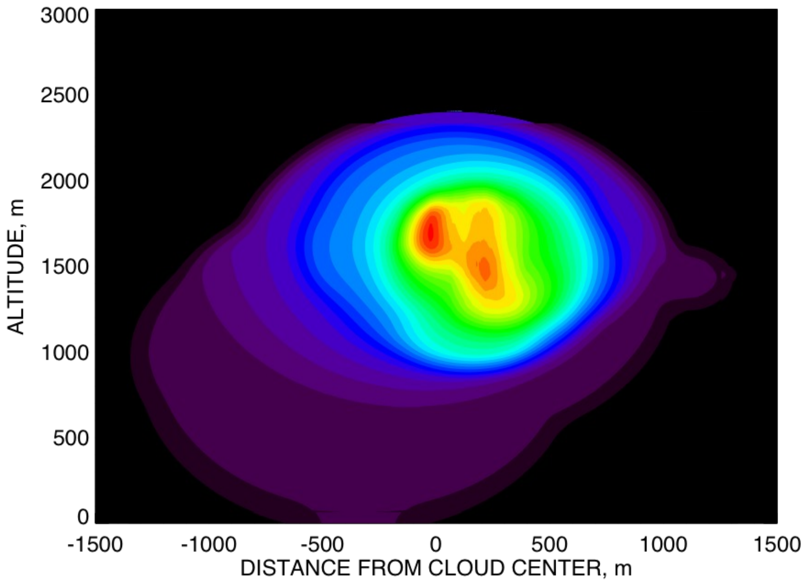


R = 0.6

- The RSP can detect edges of Cu clouds using tangent view-rays and constrain cloud shape, which depends on threshold in total reflectance

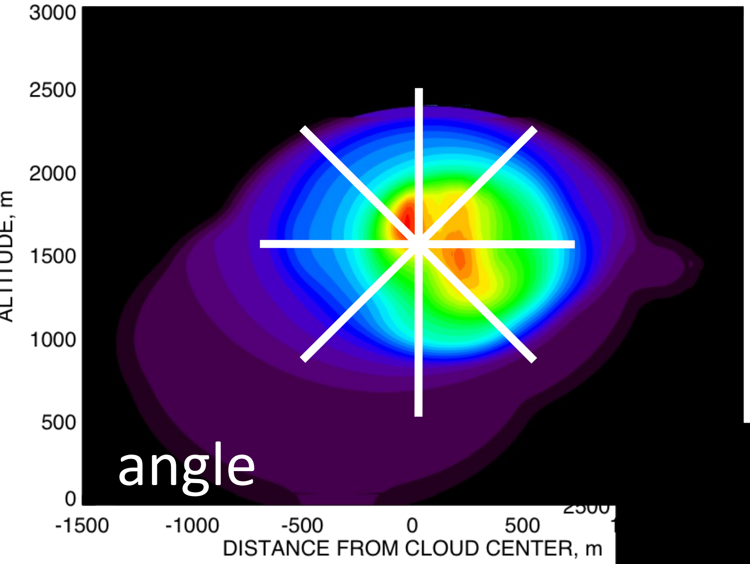
RSP Cloud Tomography



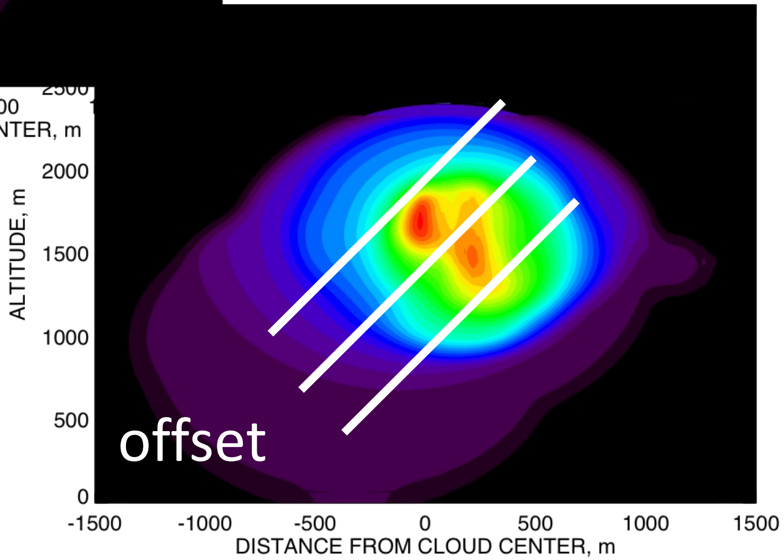


Create **nested family** of cloud shapes for a range of reflectance thresholds. Assign the threshold value to all points in the curve.

Interpret these shapes as level curves of an abstract 2D **“reflectance density” (RD)**, which is computed using interpolation.

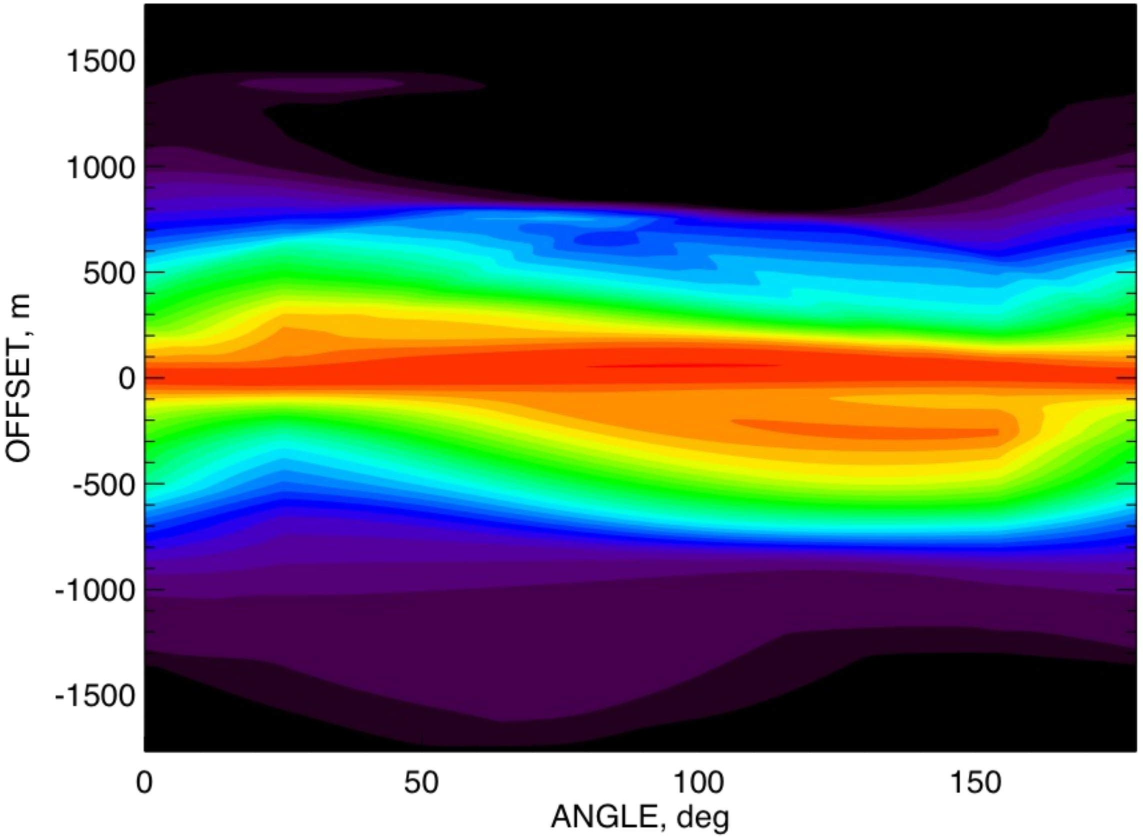


The value of view line (**chord**) is the maximum of the RD along it.



This value is achieved where chord is tangent to a level curve of RD.

Reflectance tomogram

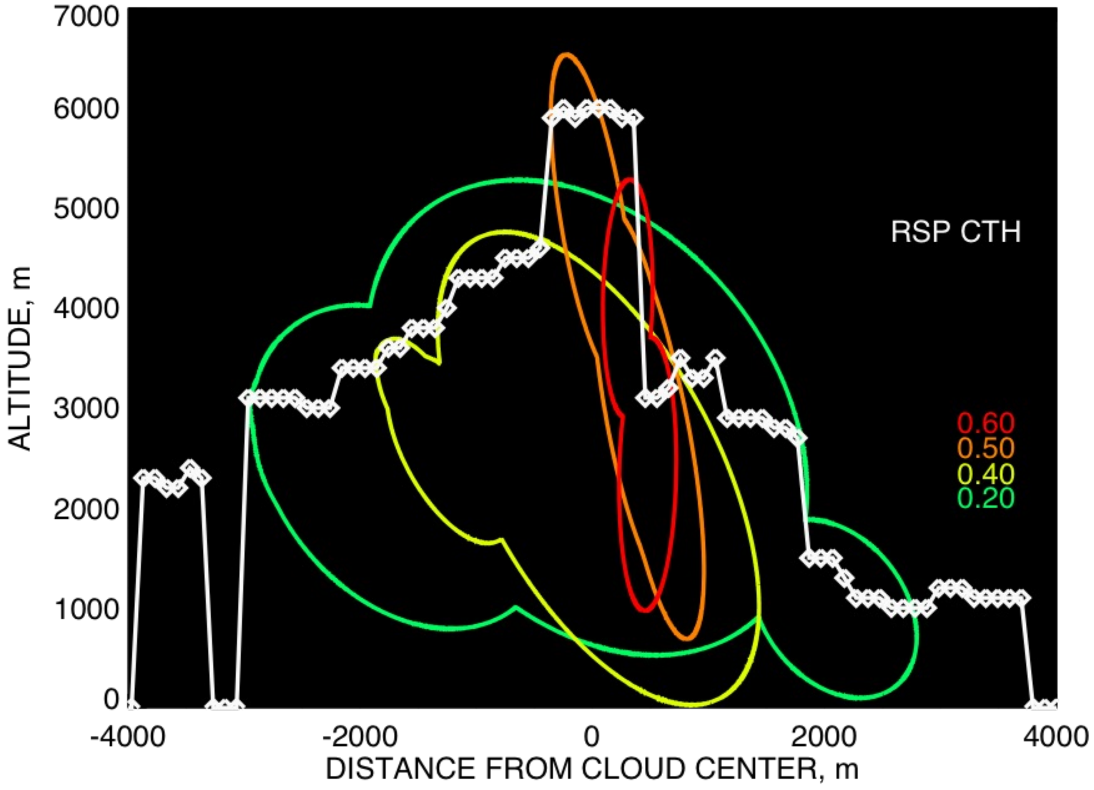


Use RD for assigning values to virtual view lines parameterized by **angle** and **offset**.

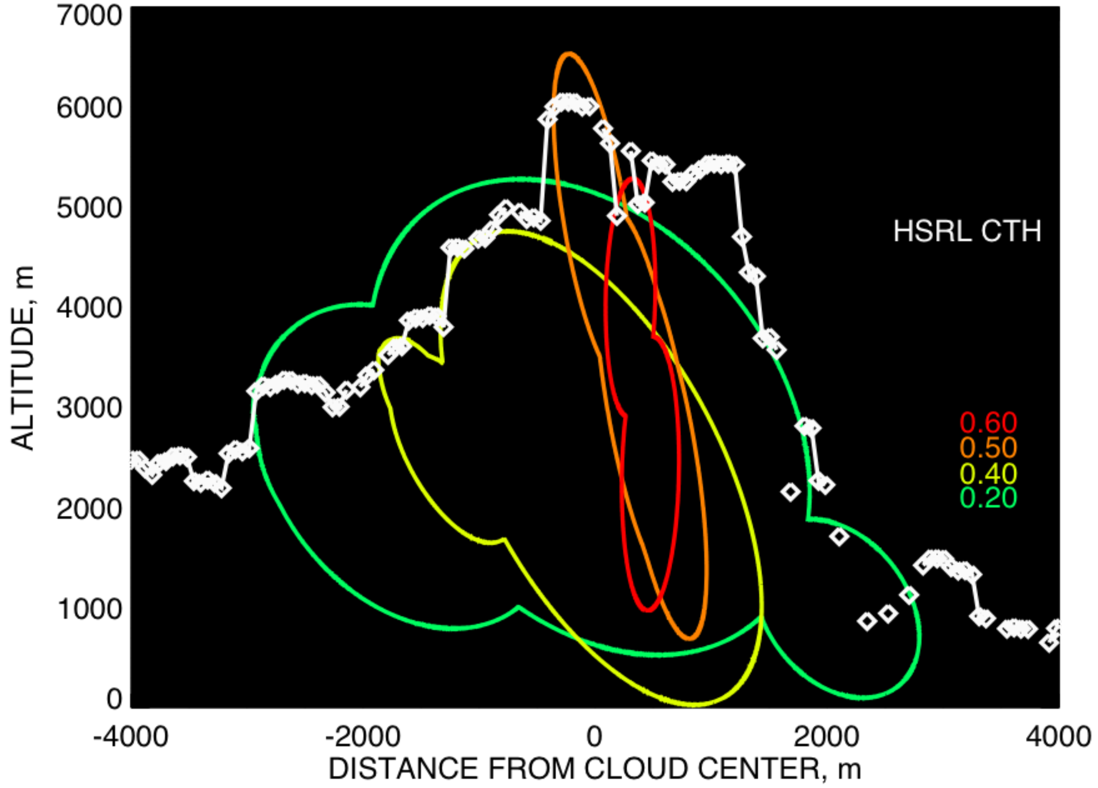
The values of all chords at the **tomogram** are converted to directional COT using a proxy.

RSP Cloud Tomography

RSP

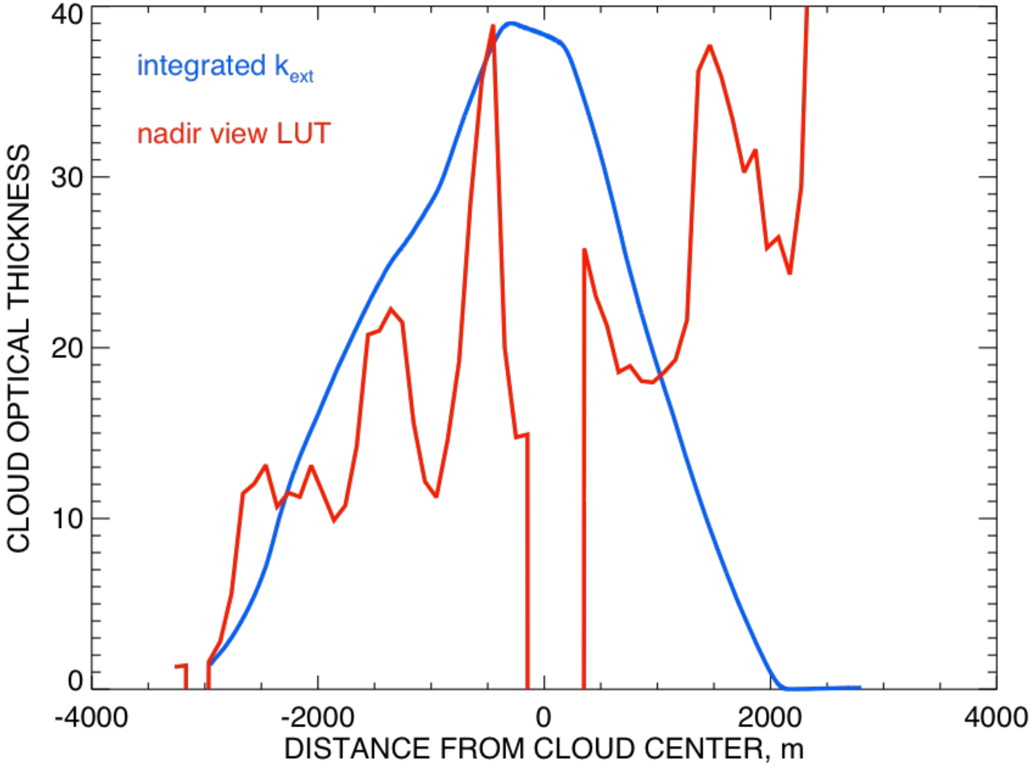


HSRL

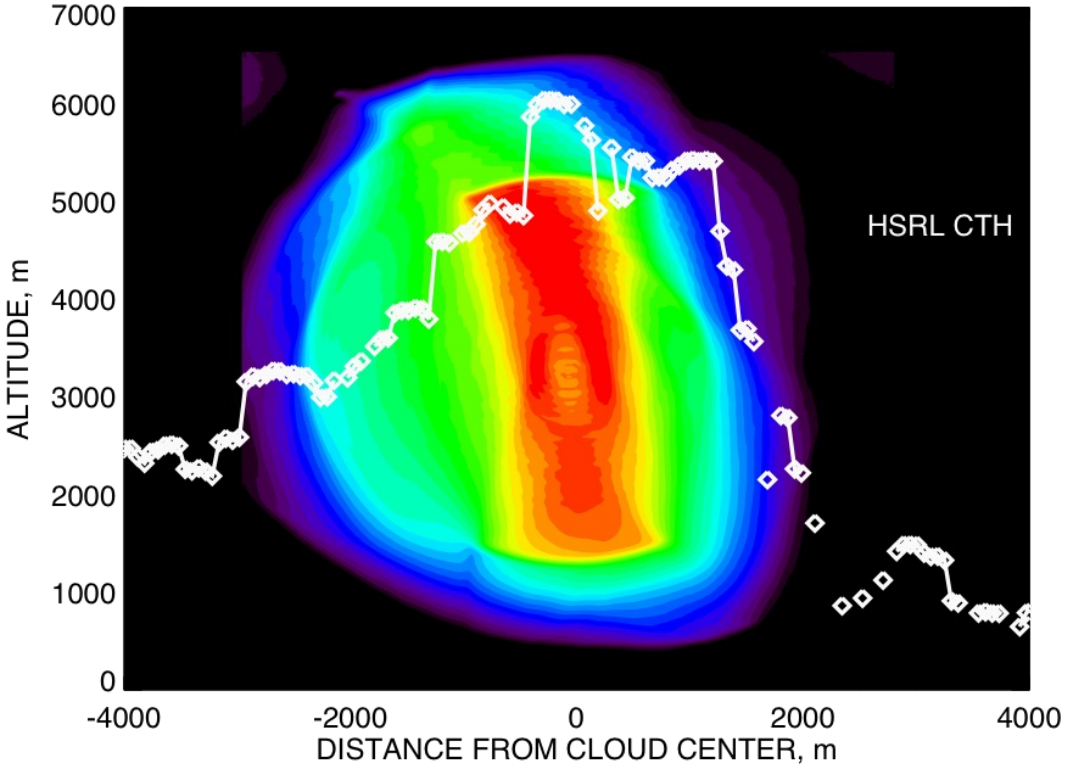


The retrieved extinction field may be shifted toward the bright cloud side by ~350 m.

COT-based calibration



Extinction field



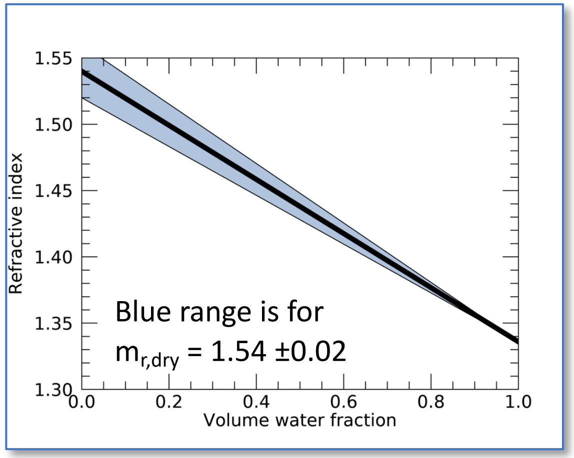
The retrieved extinction field may be shifted toward the bright cloud side by ~350 m.

Retrieval of aerosol water uptake

Aerosol water fraction f_w can be retrieved from refractive index:

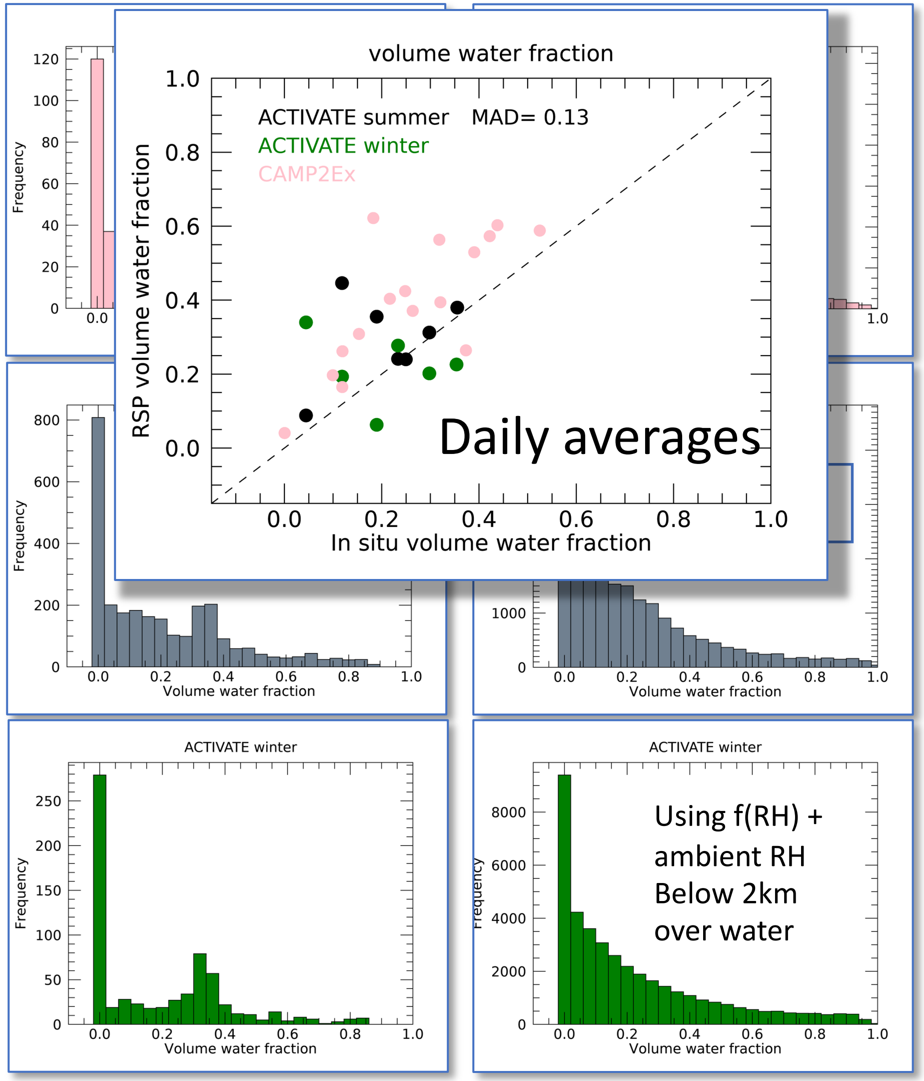
$$f_w = \frac{m_{r,retrieved} - m_{r,dry}}{m_{r,water} - m_{r,dry}}$$

$m_{r,dry}$ = ~1.54
$m_{r,water}$ = 1.33594

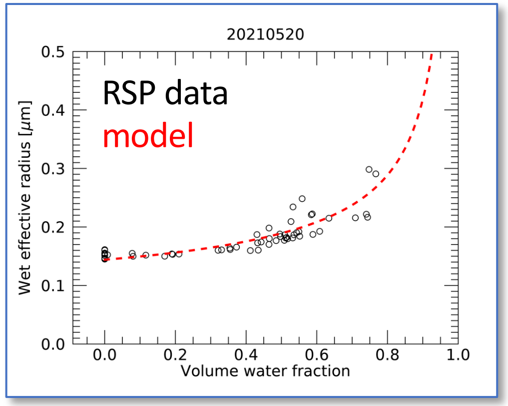


Application to ACTIVATE and CAMP2Ex RSP data

- Water uptake has widest range during CAMP2Ex, narrowest range during ACTIVATE winter 2020
- RSP sees many values of m_r ~1.54, indicating near zero water fraction
- This is consistent with the many f(RH)~1 measured in situ

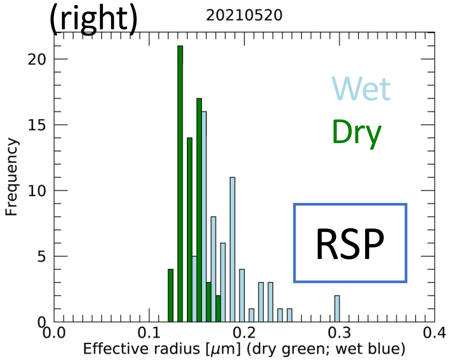


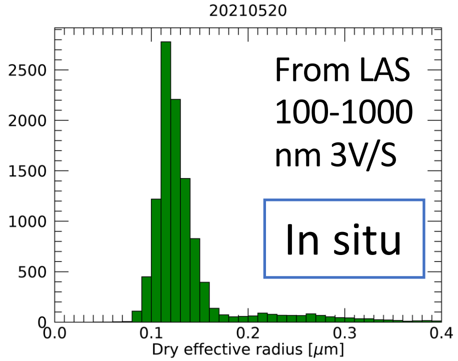
Retrieval of dry fine mode effective radius



Retrieved fine mode effective radius (dots) increases with water fraction as expected (red line)

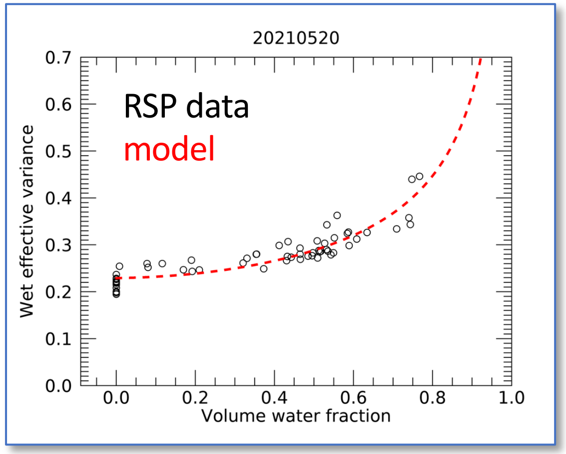
Retrieved fine mode *wet* effective radius (left, blue) can be adjusted to infer *dry* effective radius (left, green). Comparing reasonably well to in situ effective radius (right)



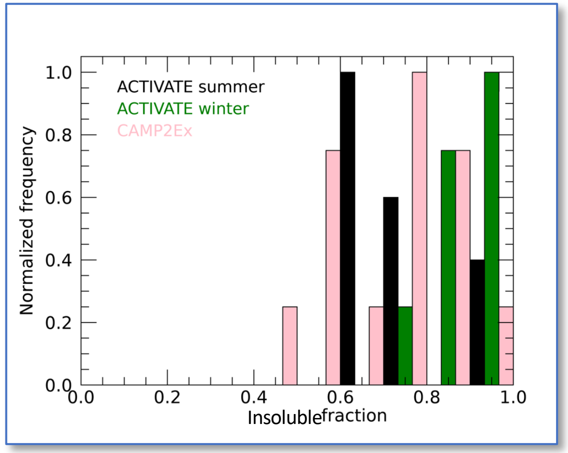


Retrieval of insoluble fraction

- Retrieved fine mode effective variance (dots) also increases with water fraction.
- A model assuming a fraction of aerosol is insoluble (with growth factor ~1) can explain this increase well.



- Using slope of wet variance vs wet effective radius for a day/region, the insoluble fraction can be estimated
- High insoluble fraction may explain prevalance of f(RH) near or below 1



RSP Summary

- As described in Dadashazar et al. 2021, clouds have smaller drops and higher optical depths (larger droplet number concentrations) in winter than in summer.
- Cloud top droplet size distributions tend to be narrow with roughly 80% having an effective variance of less than 0.07. This is relevant to how well bulk auto-conversion parameterizations are likely to work at cloud top (order of magnitude effects) and also to assumptions used in the remote sensing of droplet number (~ 10% effect).
- Real refractive index and effective radius retrievals are consistent with hygroscopic growth of aerosols
- Real refractive index and effective variance retrievals imply the presence of an insoluble fraction of aerosols
- Future work on clouds will look at differences in cloud top drizzle formation and auto-conversion rates between the different campaigns and at how well mixed phase clouds can be detected (if at all) from sensors such as VIIRS and PACE OCI.