Retrievals of liquid cloud properties from the Research Scanning Polarimeter measurements made during SEAC4RS field experiment

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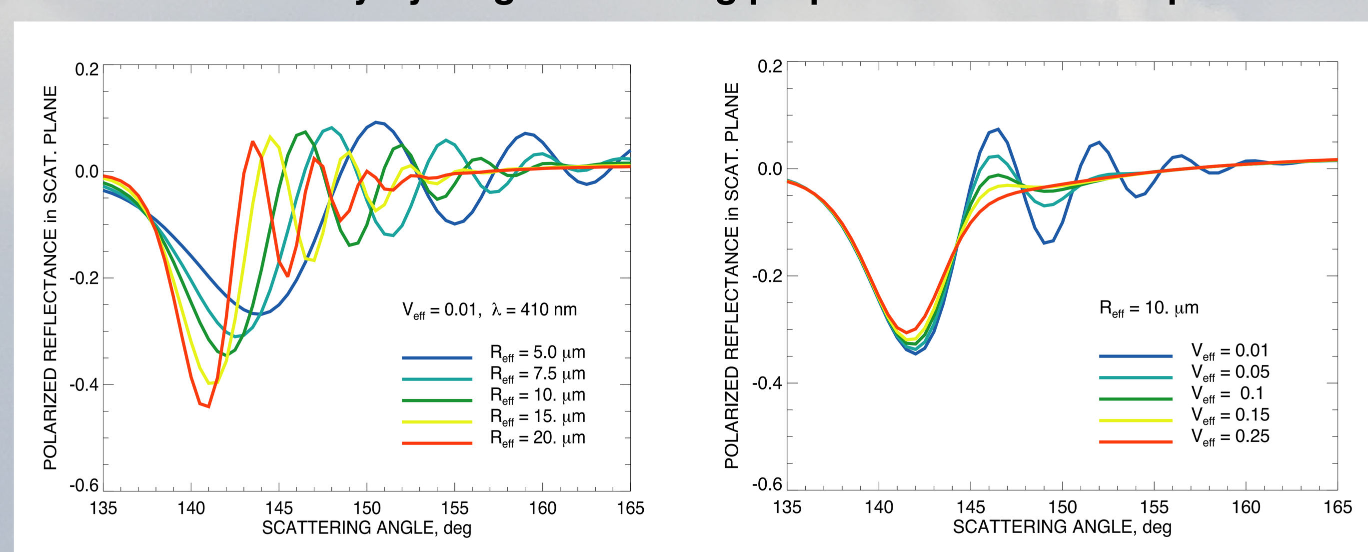
Cloud droplet size retrieval algorithm

We utilize the scattering angle dependences of the polarized reflectances with the focus on the sharply defined rainbow structure within the scattering angle range between 137 and 165 degrees. The shape of the rainbow is determined mainly by single scattering properties of the cloud particles.



Sensitivity of polarized reflectance to the effective radius (left) and variance (right) of cloud droplet size distribution.

Total reflectance: $R(\theta) = \dfrac{\pi I(\theta)}{\mu_s I_0}$ Polarized reflectance: $R_p(\theta) = -\dfrac{\pi Q(\theta)}{\mu_s I_0}$

I_0 - TOA irradiance, μ_s - cosine of SZA, θ - scattering angle

We fit measured polarized reflectance as

$$R_p(\theta) = a\, R_p^{(Mie)}(\theta, r_{eff}, v_{eff}) + b\,\theta + c$$

where $R_p^{(Mie)}$ are computed using Mie theory (single scattering) for a grid of r_{eff} and v_{eff} assuming Gamma size distribution. Parameters *a*, *b*, and *c* account for the effects of multiple scattering.

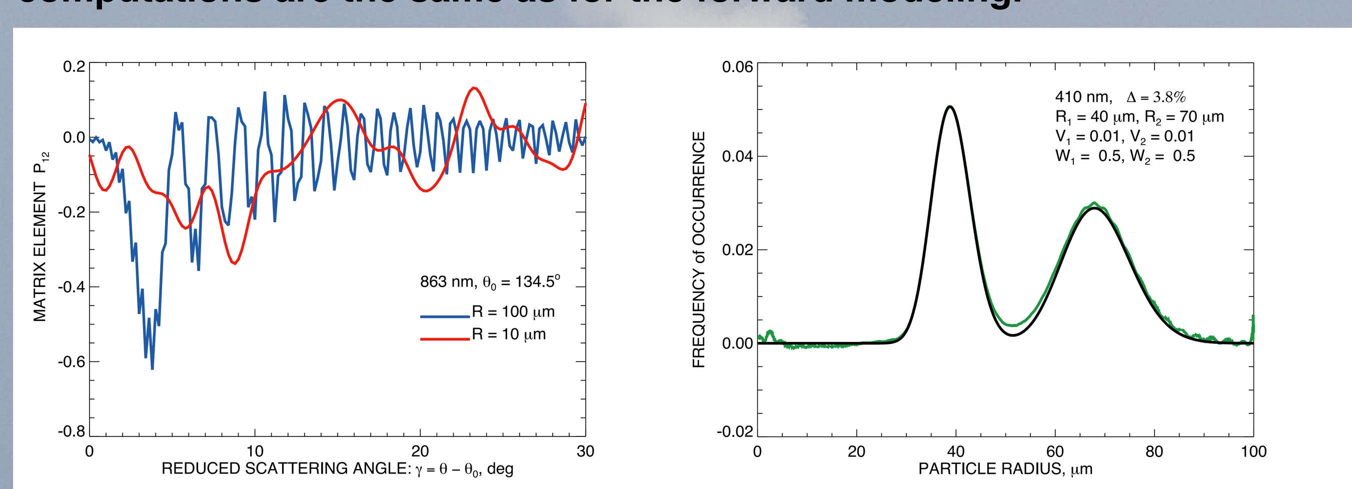
Rainbow Fourier Transform (RFT)

Mie-theory-derived polarized reflectance $F(r, \gamma)$ as a function of reduced scattering angle (in the rainbow angular range) and the (monodisperse) particle radius appears to be a proxy to a kernel of an integral transform (similar to the sine Fourier transform on the positive semi-axis):

$$\hat{n}_a(\gamma) = \int_0^\infty n_a(r)\, F(r,\gamma)\, dr. \qquad n'_a(r) = \int_0^{\gamma_{max}} \hat{n}_a(\gamma)\, F(r,\gamma)\, \gamma^2\, d\gamma.$$

This allows to retrieve the shape of the (area) droplet size distribution $n_a(r)$ by the application of the corresponding inverse transform to the observed polarized rainbow.

This non-parametric approach does not require any *a priori* knowledge of the droplet size distribution functional shape, no look-up tables, no fitting, computations are the same as for the forward modeling.



RFT's basis functions $F(r, \gamma)$ (above left) are not exactly orthogonal, so this procedure is complemented by a simple regression technique removing the artifacts. Right pannel shows a model area size distribution (black) and the corresponding RFT retrieval (green).

Acknowledgments

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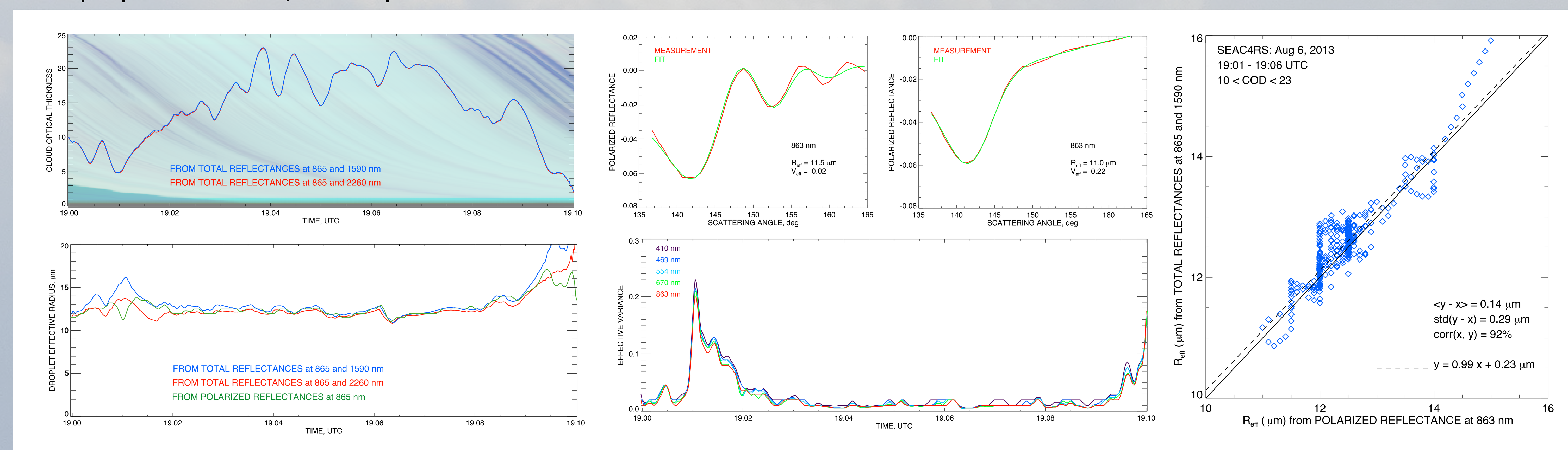
Stratocumulus cloud deck off California coast (Aug. 6, 2013, 19:00 - 19:10 UTC)

RSP allows to simultaniously use polarimetric (rainbow) and radiometric (Nakajima-King) retrievals of droplet size. The latter technique useses measurements in both water absorbing (1590 or 2260 nm) and non-absorbing (865 nm) bands. It also provides COT, and is similar to current sattelite algorithms (e.g., MODIS). The comparison between the two methods presented below demonstrates good agreement for homogeneous cloud with COT larger than 10. Note that the droplet size distribution is wider in thiner, less developed parts of the cloud, as it is expected from adiabatic cloud model.



Supercooled liquid water As cloud off Louisiana coast (Sep. 22, 2013, 17:52 - 18:05 UTC)

The supercooled liquid water (SLW) clouds (with liquid droplets at T < 0°C) contribute to the radiative budget and in the development of precipitation. They may be also an aviation hazard due to their role in aircraft icing, especially when droplet radius exceeds 25 μm. Droplet size distribution for SLW clouds appears to be wider than that of convective clouds. This may push the effective variance in the parametric algorithm to the limit, while RFT indicates that the size distribution is often multimodal. This is in agreement with Cloud Profiling Lidar measurements indicating several cloud layers in this scene.