Cloud Edges: the Spectral-Invariant Relationship Between Ratios of Zenith Radiances Near Them

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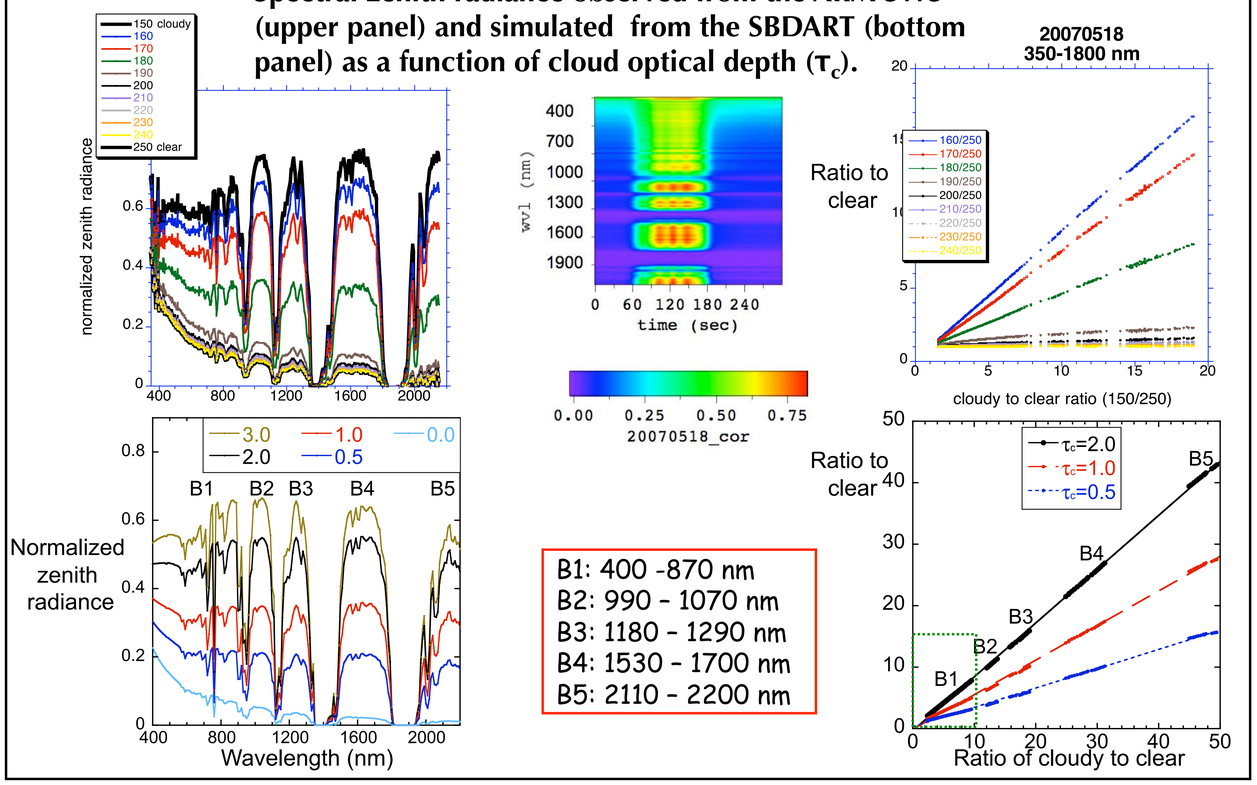
A surprising spectral-invariant relationship is found in the ARM Shortwave Spectrometer data near cloud edges

- Spectral zenith radiance observed from the ARM SWS (upper panel) and simulated from the SBDART (bottom panel) as a function of cloud optical depth (τ_c).



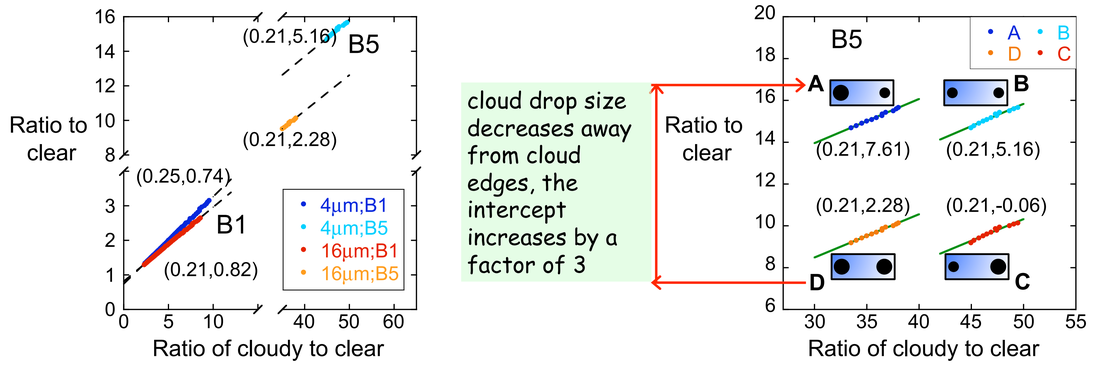
B1: 400 -870 nm
B2: 990 - 1070 nm
B3: 1180 - 1290 nm
B4: 1530 - 1700 nm
B5: 2110 - 2200 nm

Summary

- The spectral-invariant relationship (SIR) between ratios of zenith radiances near cloud edges found in SWS data has been confirmed by SBDARD simulations.
- At visible wavelengths, SIR is determined by cloud optical depth regardless of cloud thermodynamic phase. At water-absorbing wavelengths, SIR is determined by cloud drop effective size, which could provide evidence of mixing process near cloud edges.
- SIR is not sensitive to aerosol properties, the surface, and the finite FOV of the instrument. Thus, SIR can be used to infer cloud properties even without accurate aerosol or surface information.

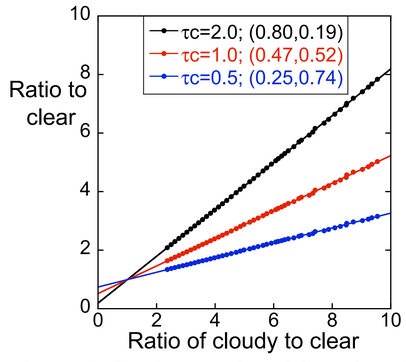
The intercept at 2.1 μm is sensitive to cloud drop size

- The spectral-invariant relationship varies with cloud drop size. With an increasing drop size, points at B5 shift toward smaller ratios in both axes.
- The intercept at 2.1–2.2 μm contains information on the growth/ evaporation tendency of cloud droplets.

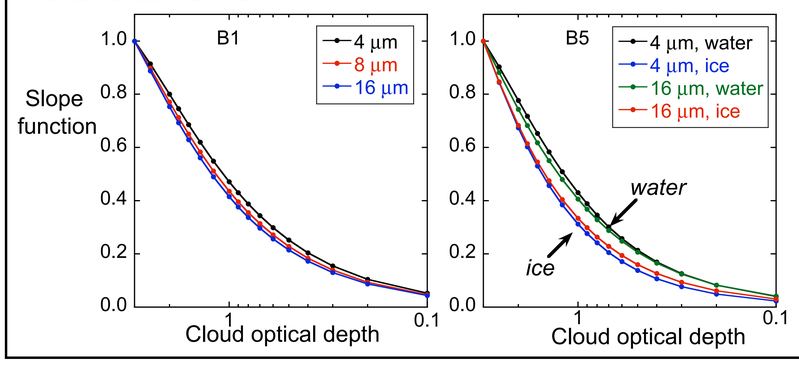


The slope of the spectral-invariant relationship is more sensitive to cloud properties than to aerosol properties, the underlying surface, and the finite instrument's FOV

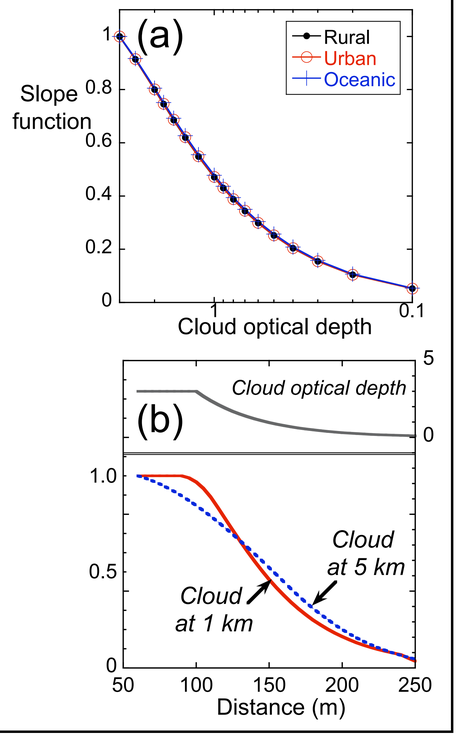
- A zoom-in plot at right shows the spectral-invariance at band B1; the corresponding slope and intercept of the line are listed in '()'.

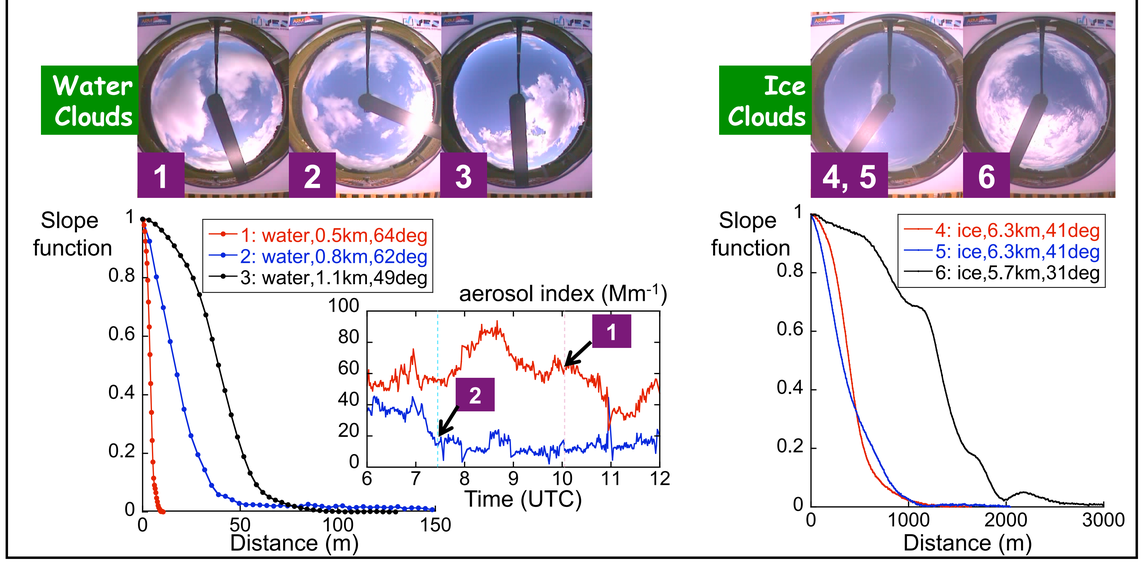


- The slope derived from B1 is mainly determined by cloud optical depth, not by cloud drop effective size
- The slope derived from B5 is more sensitive to cloud phase than that from B1.



- The slope function is not sensitive to (a) aerosol and (b) FOV.



Examples from the COPS field campaign

- The left panel shows slope functions of 3 water clouds, along with aerosol index, observed in the COPS. The right panel is same as the left one, but for ice clouds.
- Overall, ice clouds have much broader transition zones than water clouds.