Integrated Cloud Optical Properties from Zenith Radiance Measurements Collected During the ARM COPS Experiment

Christine Chiu[1], Alexander Marshak[2], Yuri Knyazikhin[3], Warren Wiscombe[2,4]

[1]Joint Center for Earth Systems Technology/UMBC [2]NASA/Goddard Space Flight Center [3]Boston University [4]Brookhaven national Laboratory

Zenith radiance measurements

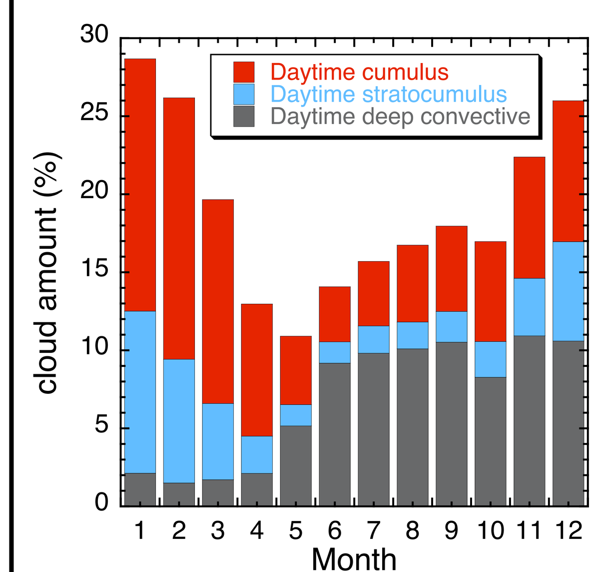
- Zenith radiance measurements are taken primary from two instruments at the Black Forest during the ARM Convective and Orographically Induced Precipitation Study (COPS) field campaign : 1) the AMF Cimel sunphotometer, and 2) the ARM two-channel narrow-field-of-view radiometer (2NFOV).

Cimel Normal aerosol mode (sun-seeking)

Cimel Cloud mode (zenith-pointing)

2NFOV in the Black Forest (1-sec resolution)

- ISCCP cloud fractions and total sky images over the COPS area show a high degree of fractional cloudiness.



Summary

- Even though clouds in COPS were far from the idealized homogeneous 1D clouds assumed by most retrieval methods, our methods using zenith radiance performed quite well in retrieving cloud optical depth and liquid water path.
- By "performed quite well", we mean that intercomparisons between our methods, the microwave radiometer, the MFRSR flux method, and MODIS retrievals are reasonably satisfactory.

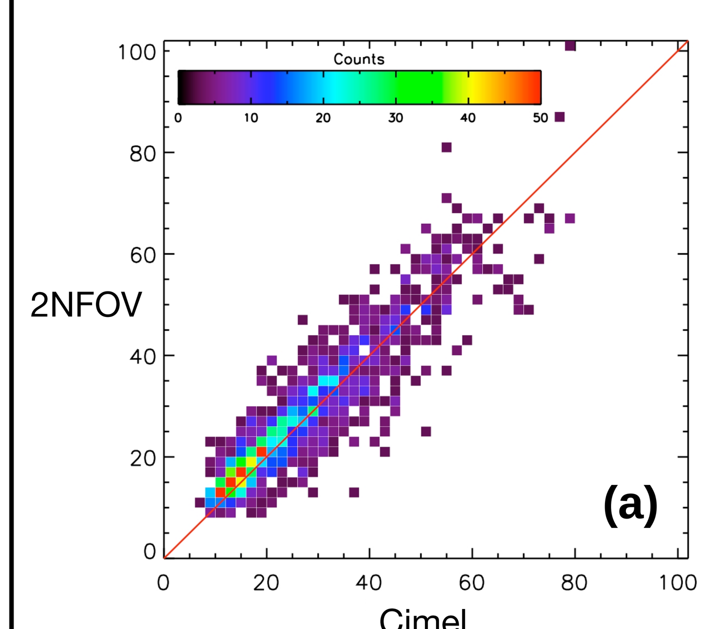
Theoretical basis

- Our retrieval method uses zenith radiance measurements at 673, 870, and 1640 nm wavelengths and requires the presence of green vegetation in the surrounding area.
- This method works because:
  1. At 673 and 870nm, clouds have nearly identical optical properties, but vegetated surfaces reflect quite differently;
  2. 1640 nm is a water-absorbing wavelength that contains information about the strength of forwarding scattering and absorption due to various cloud drop sizes.
- Using a 1D radiative transfer model and surface reflectance from MODIS, we calculate zenith radiance I_{673} , I_{870} and , I_{1640} as a function of cloud optical depth τ, effective cloud fraction A_c, and cloud effective radius R_{eff} to build our lookup tables (LUT) :

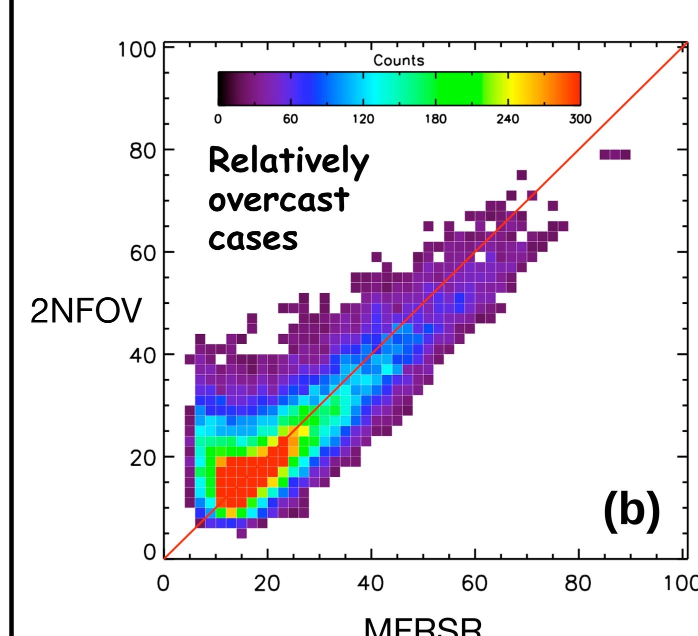
$$I_{673} = I_{673}(\tau, A_c, R_{eff})$$
$$I_{870} = I_{870}(\tau, A_c, R_{eff})$$
$$I_{1640} = I_{1640}(\tau, A_c, R_{eff}).$$

- Using LUTs, we select possible solutions in which the difference between calculated and observed zenith radiances at these wavelengths is within a threshold.

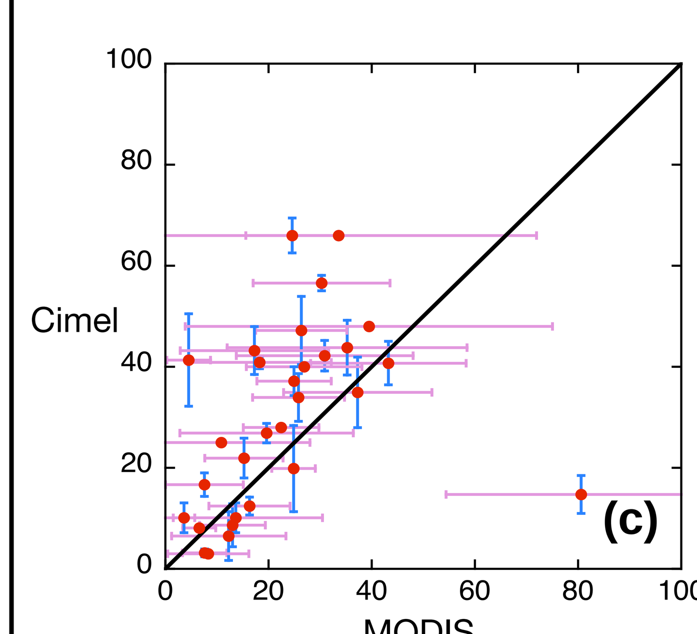
Cloud optical depth



- We have found that the majority of cloud optical depths retrieved from Cimel and 2NFOV agree within 5 (Fig. a). Note that the Cimel takes 10 measurements with 9-s time resolution every 15 minutes.



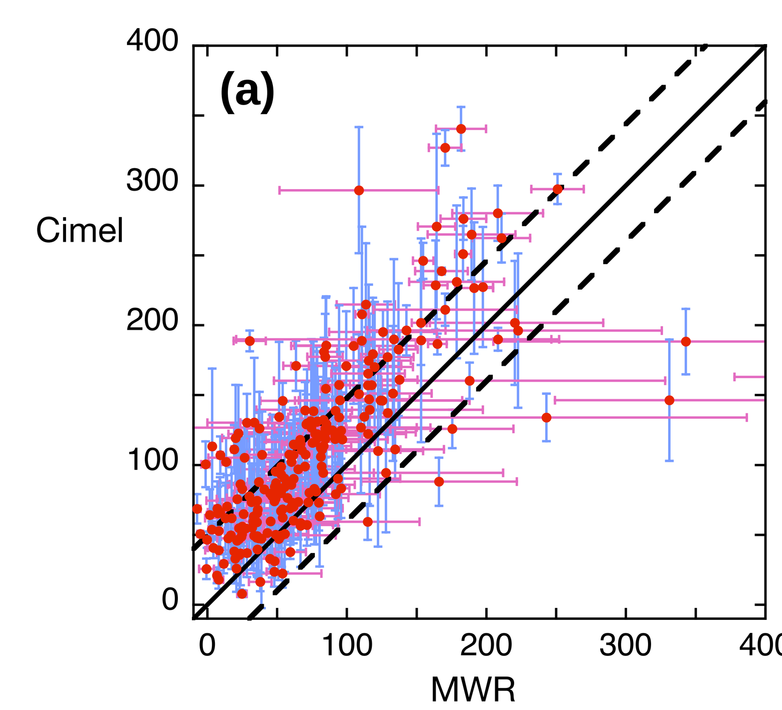
- The majority of retrievals from 2NFOV and MFRSR agree well (Fig. b), but 2NFOV retrievals are higher than MFRSR retrievals when MFRSR-retrieved cloud optical depth is in the range of 5-15.



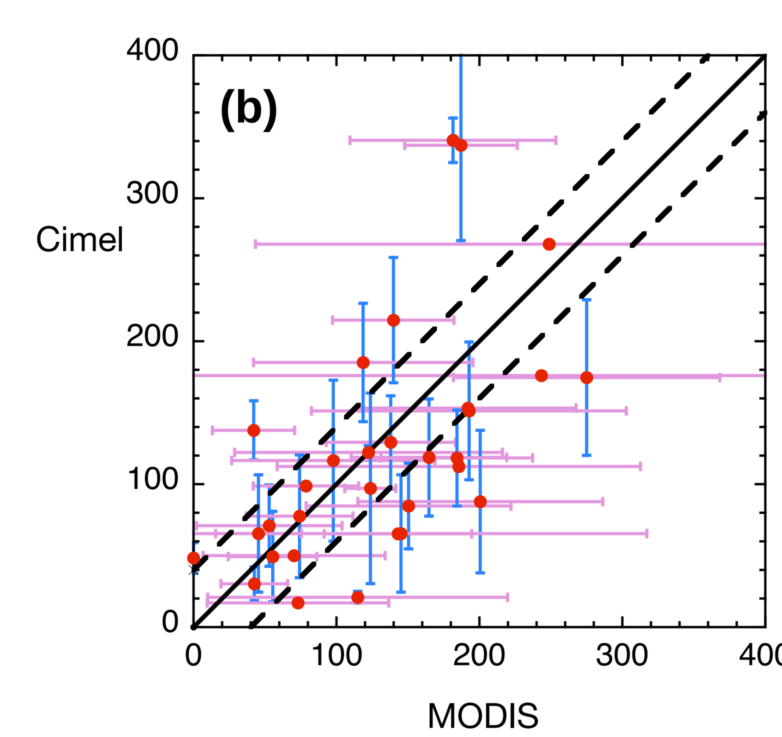
- Cimel and MODIS retrievals have a correlation of 0.7 (Fig. c). Variations of Cimel retrievals are calculated in a 10-minute time period. while those of MODIS retrievals are calculated in a 7x7km area.

Liquid water path

- We compare Cimel-retrieved liquid water paths (LWP, g/m²) to those retrieved from the ARM 2-channel microwave radiometer (MWR) and MODIS.



- The majority of Cimel and MWR retrieved LWPs agree within 40 g/m² (boundaries shown by dashed lines in Fig. a).



- Cimel and MODIS retrieved LWPs also generally agree within 40 g/m² (Fig. b), with a correlation of 0.6.