Characterization of Atmospheric Aerosols and Water Vapor at SGP Using MFRSR Measurements

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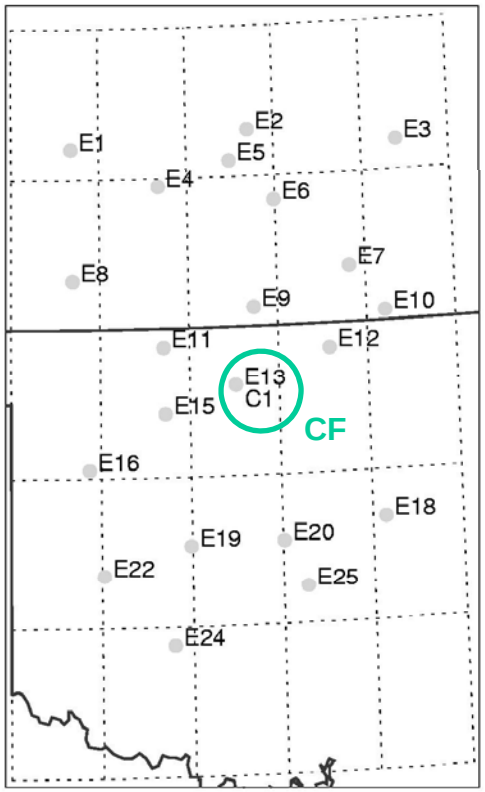
MFRSR networks

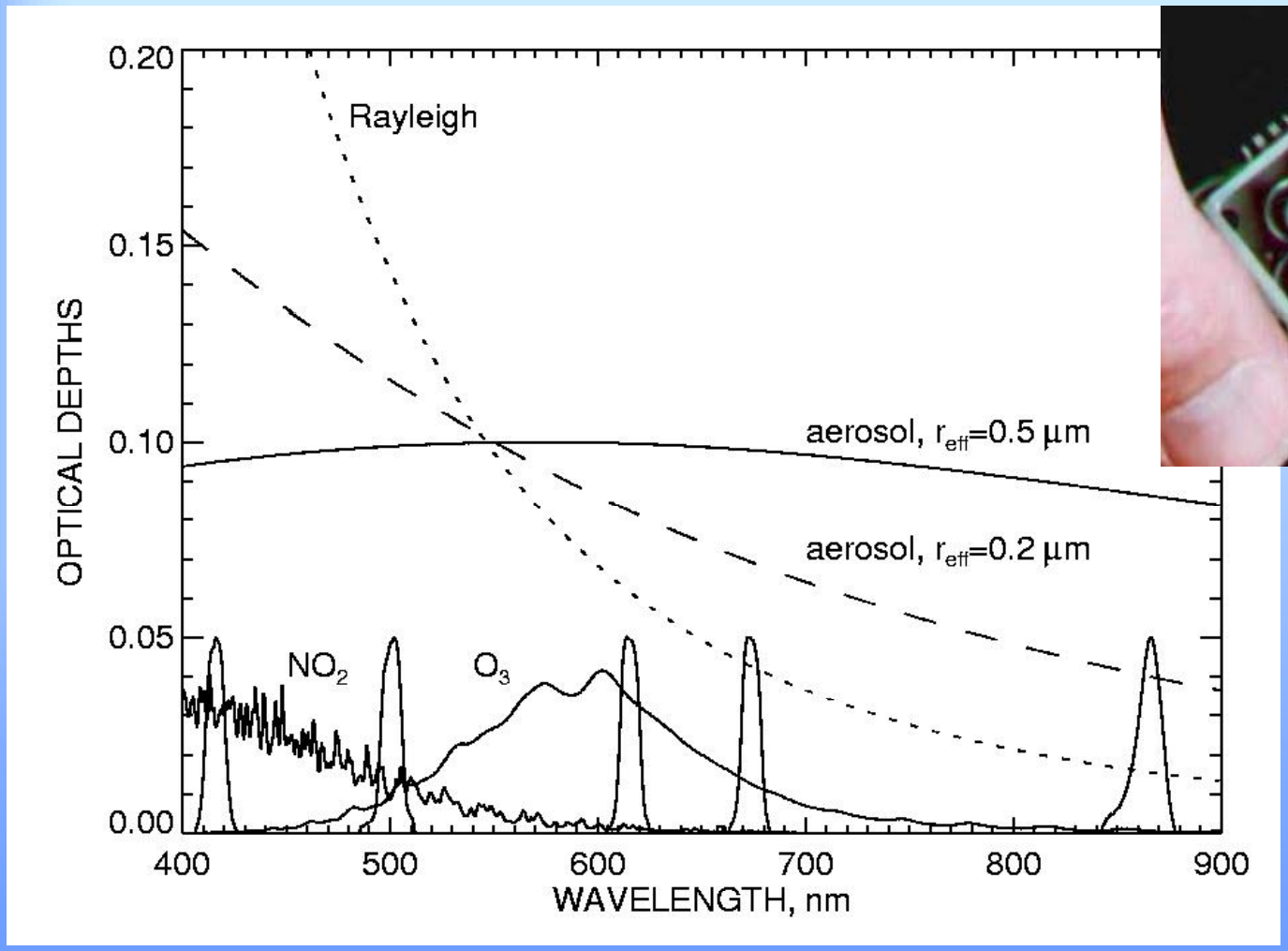


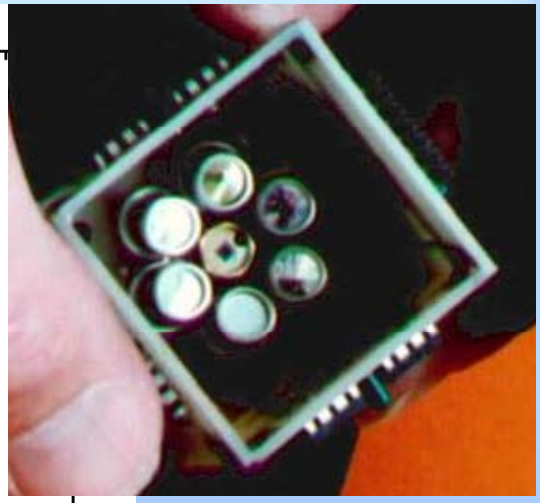
- DOE Atmospheric Radiation Measurement (ARM)
- USDA UV-B Monitoring and Research Program
- NOAA Surface Radiation (SURFRAD) Network
- NASA Solar Irradiance Research Network (SIRN)

Southern Great Plains (**SGP**) Site operated by DOE ARM Program.

CF = Central Facility

MFRSR spectral sensitivity





Spectral channels:

415 nm
500 nm
615 nm
673 nm
870 nm
940 nm

Retrieval algorithm

Aerosol size model: *bimodal Gamma*

V_{eff}=0.2 both modes

Aerosol retrievals:

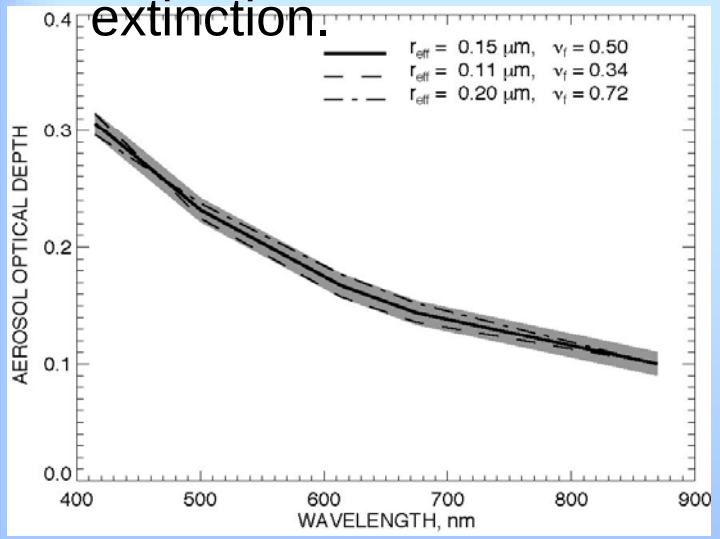
- Fine mode AOT and R_{eff}
- Coarse mode AOT (fixed R_{eff}=1.5 μm)
- Single Scattering Albedo (preliminary)

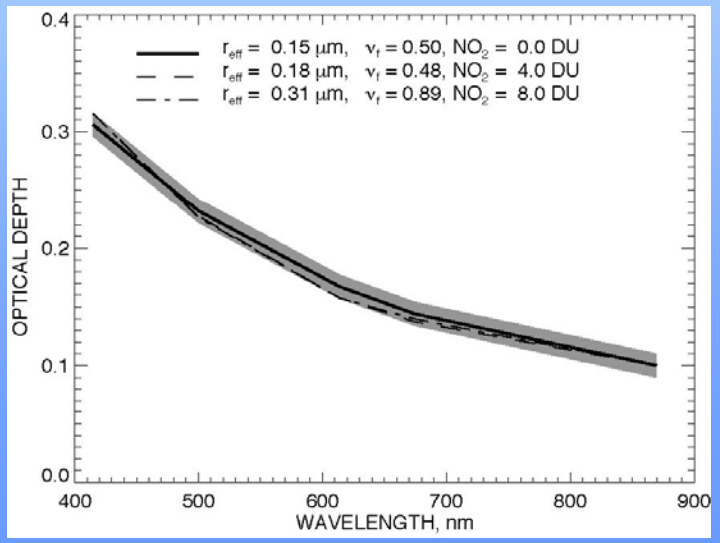
NO_2 column from SCIAMACHY (clim.)

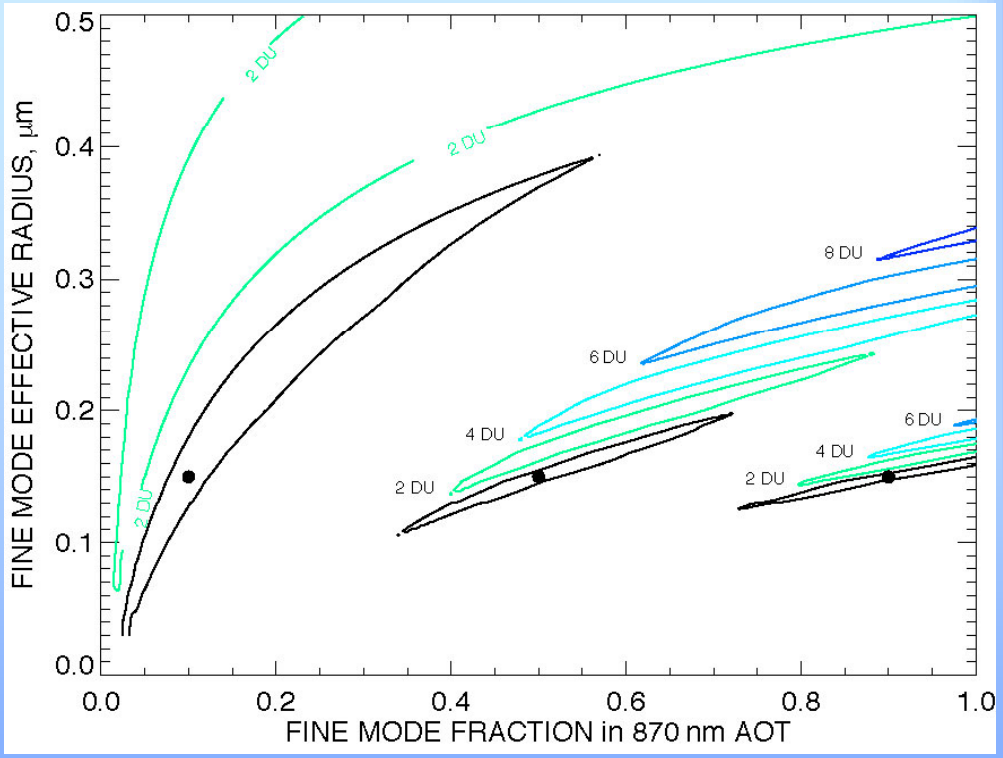
O_3 column from TOMS

Can we retrieve NO_2?

NO, because of trade-offs between NO_2 absorption of and aerosol extinction.







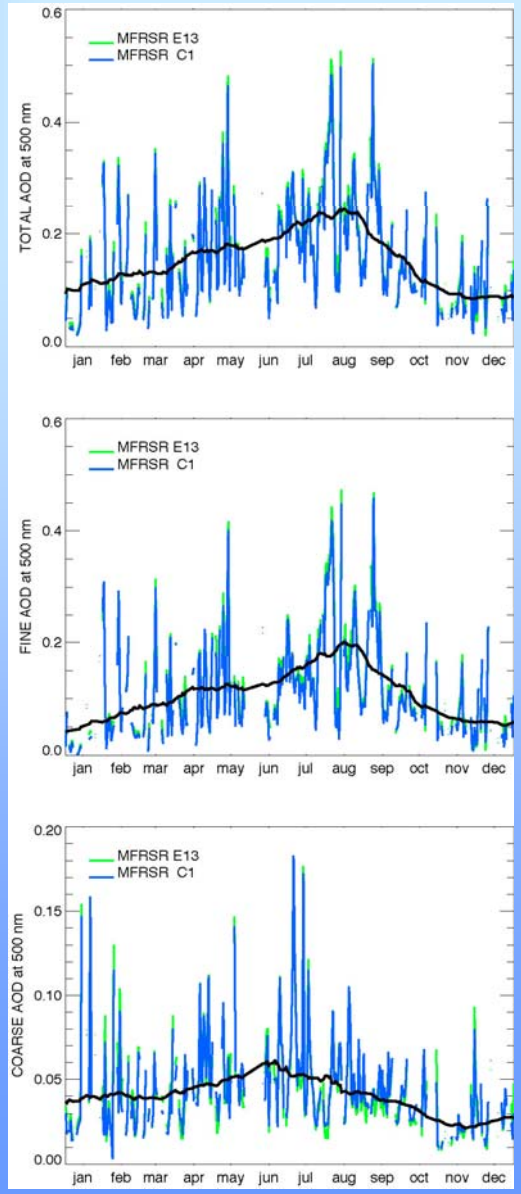
Left: Spectral AOD for fine mode r_{eff} = 0.15 μm, 0.5 fine mode fraction in 870 nm AOD and 0 DU NO_2 together with two competitive models fitting within 0.01 error margin.
Right: Sensitivity of retrievals of r_{eff}, fine mode fraction and NO_2. AOD at 870 nm is 0.1. Three test aerosol models with fine mode fraction of 0.05, 0.5, and 0.95 are depicted by bullets.

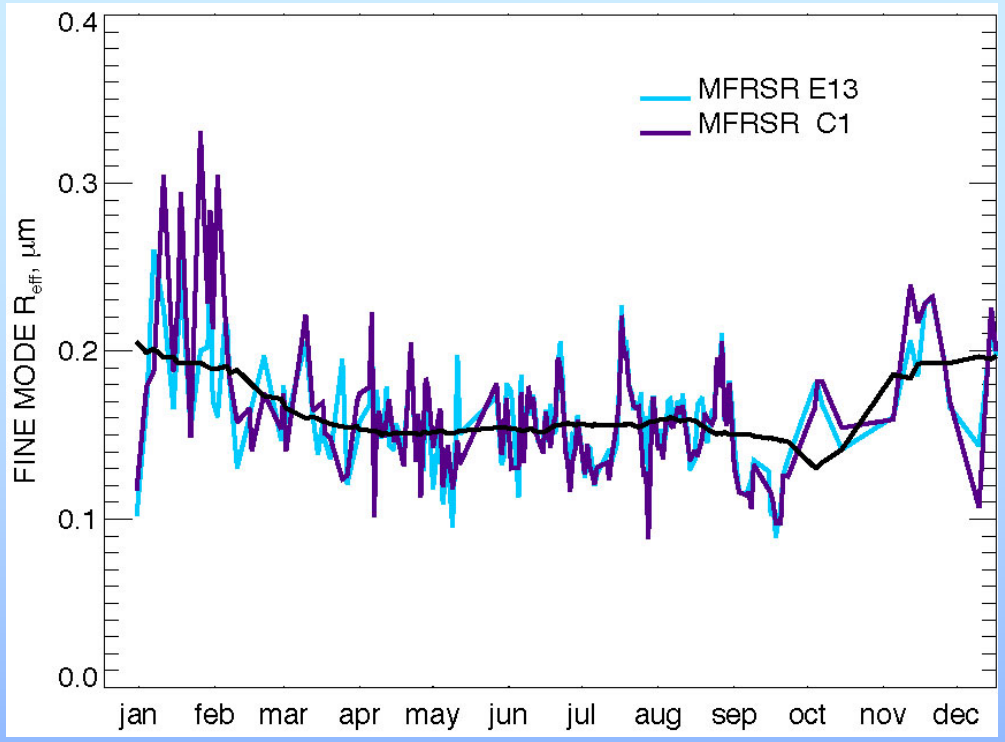
Retrievals from SGP CF

Total

Fine

Coarse

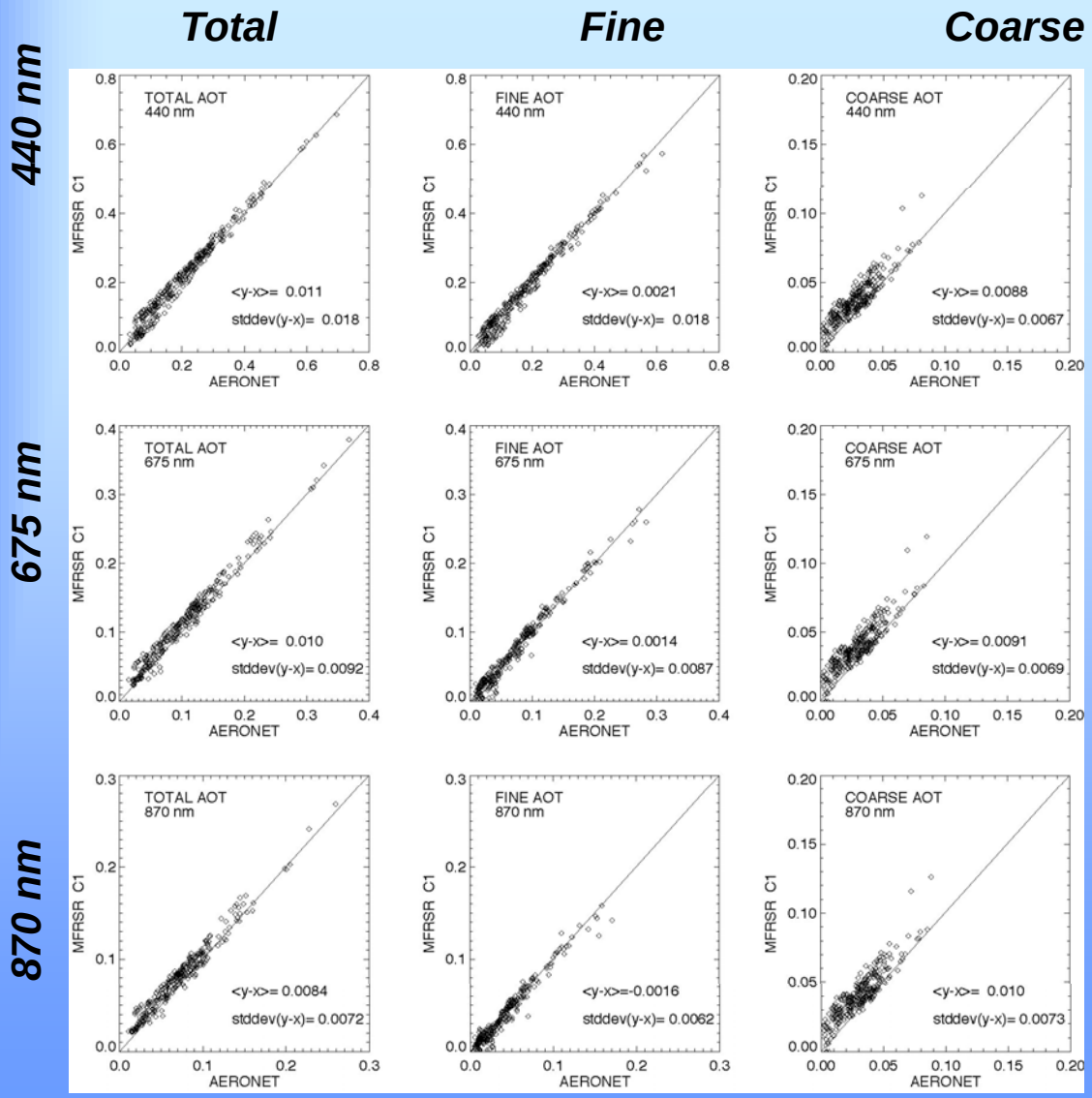




Daily mean **fine mode effective radius** from C1 and E13 MFRSRs for the days in 2000 with AOD(870 nm) > 0.006.

Daily mean **total**, **fine**, and **coarse AOD** in 500 nm channel from C1 and E13 MFRSRs data for 2000.

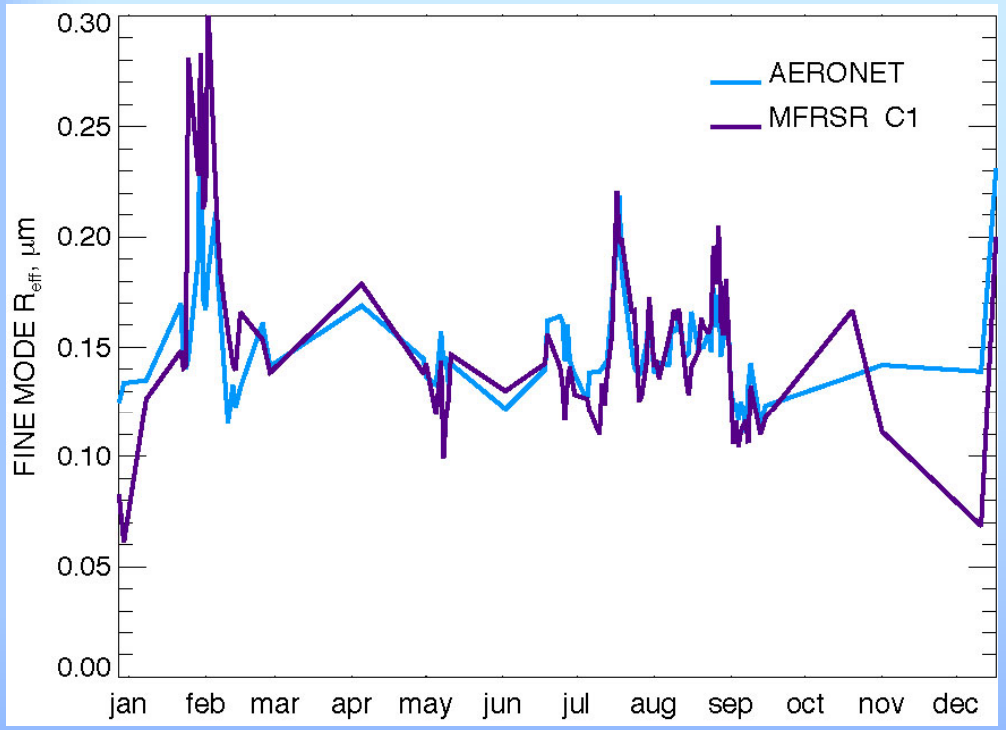
MFRSR v.s. AERONET: AOD

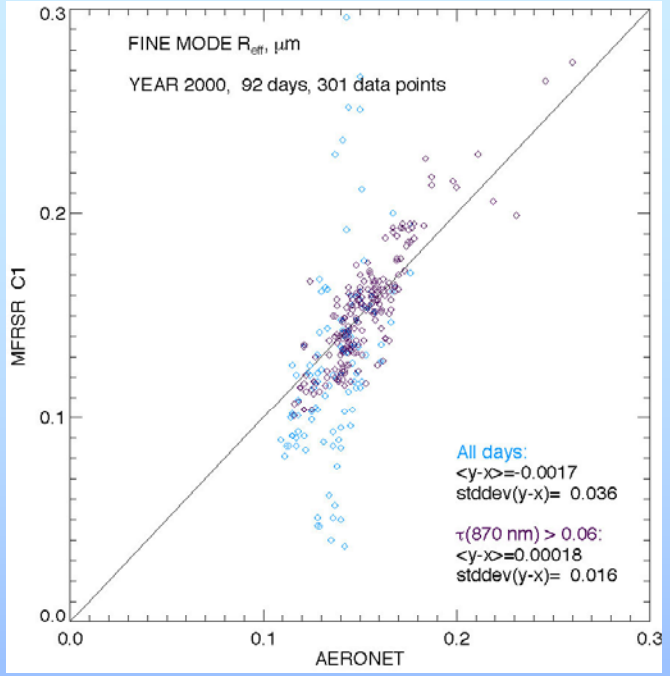


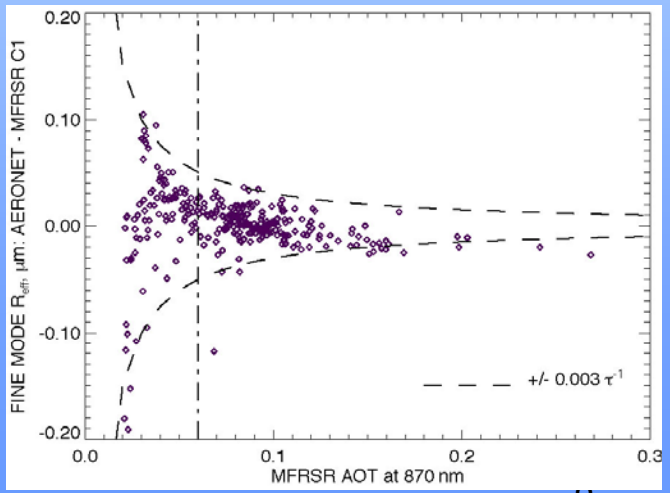
Point-by-point intercomparison between total, fine, and coarse AODs from C1 MFRSR and AERONET almucantar retrievals for the year 2000 (SGP Central Facility).

Differences are within calibration accuracy of 0.01

MFRSR v.s. AERONET: R_{eff}





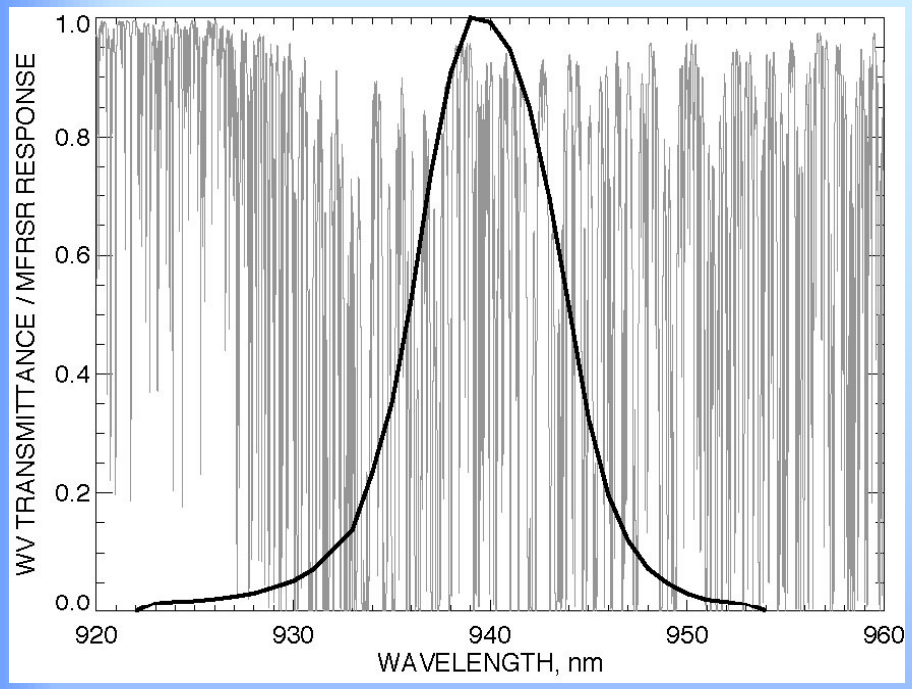


Daily mean **fine mode effective radius** from C1 MFRSR and AERONET almucantar scan retrievals for 2000.

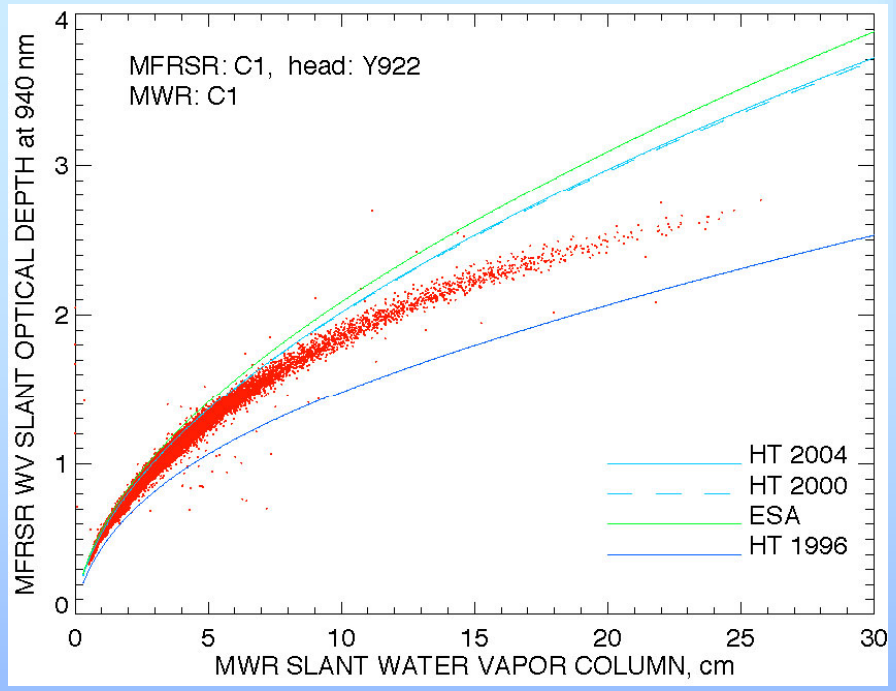
Right top: point-by-point intercomparison;

Right bottom: difference between r_{eff} values v.s. 870 nm AOD. Vertical line: threshold AOD of 0.006.

Precipitable Water Vapor



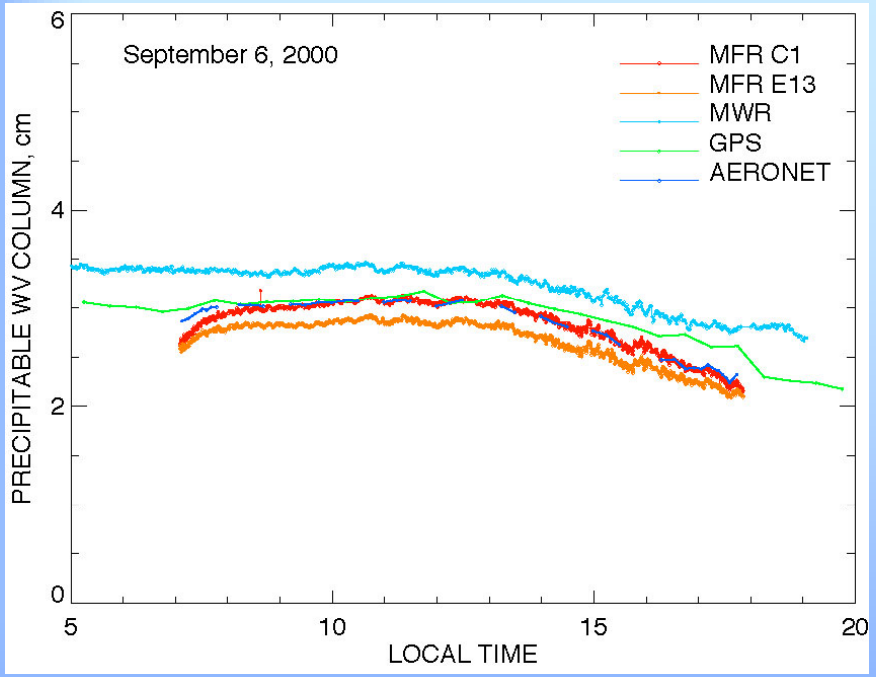
Spectral transmittance of Water Vapor (1 cm column) computed using HITRAN 2004 database (grey), and the MFRSR (head 922) 940 nm channel spectral response function normalized to unity at the maximum (black).

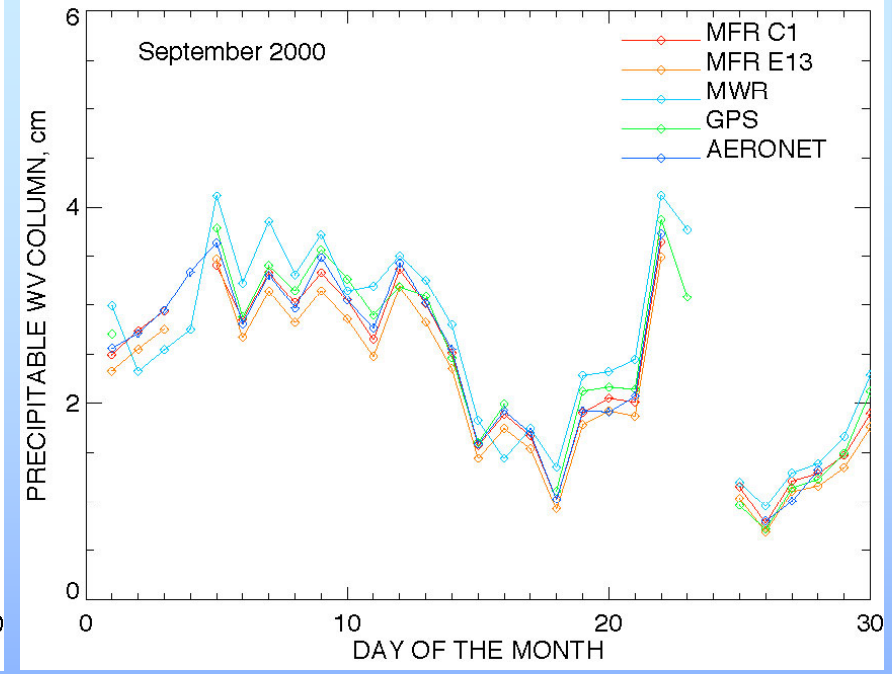


Experimental growth curve (MFRSR-derived slant optical thickness (with AOT subtracted) v.s. MWR-derived slant WV column, SGP CF, 2000). Theoretical growth curves computed using various spectral databases are shown by solid lines.

WV retrievals from MFRSR

Results for September 2000 and comparison with MWR, GPS and AERONET retrievals

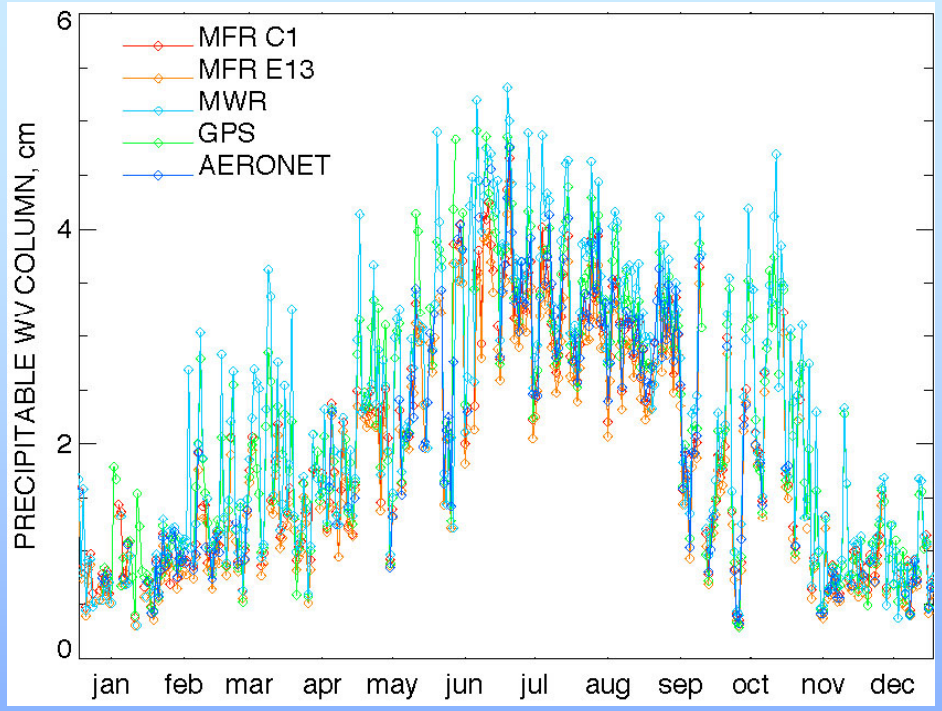




Retrievals of column WV for September 2000 using data from two MFRSRs at SGP's Central Facility (C1 and E13). HITRAN 2004 spectral database has been used. The systematic difference between C1 and E13 values is likely due to uncertainties in 940 nm channel spectral responses. C1 data appears to be almost indistinguishable from AERONET retrievals and in better agreement with GPS than with MWR, which yields systematically higher values.

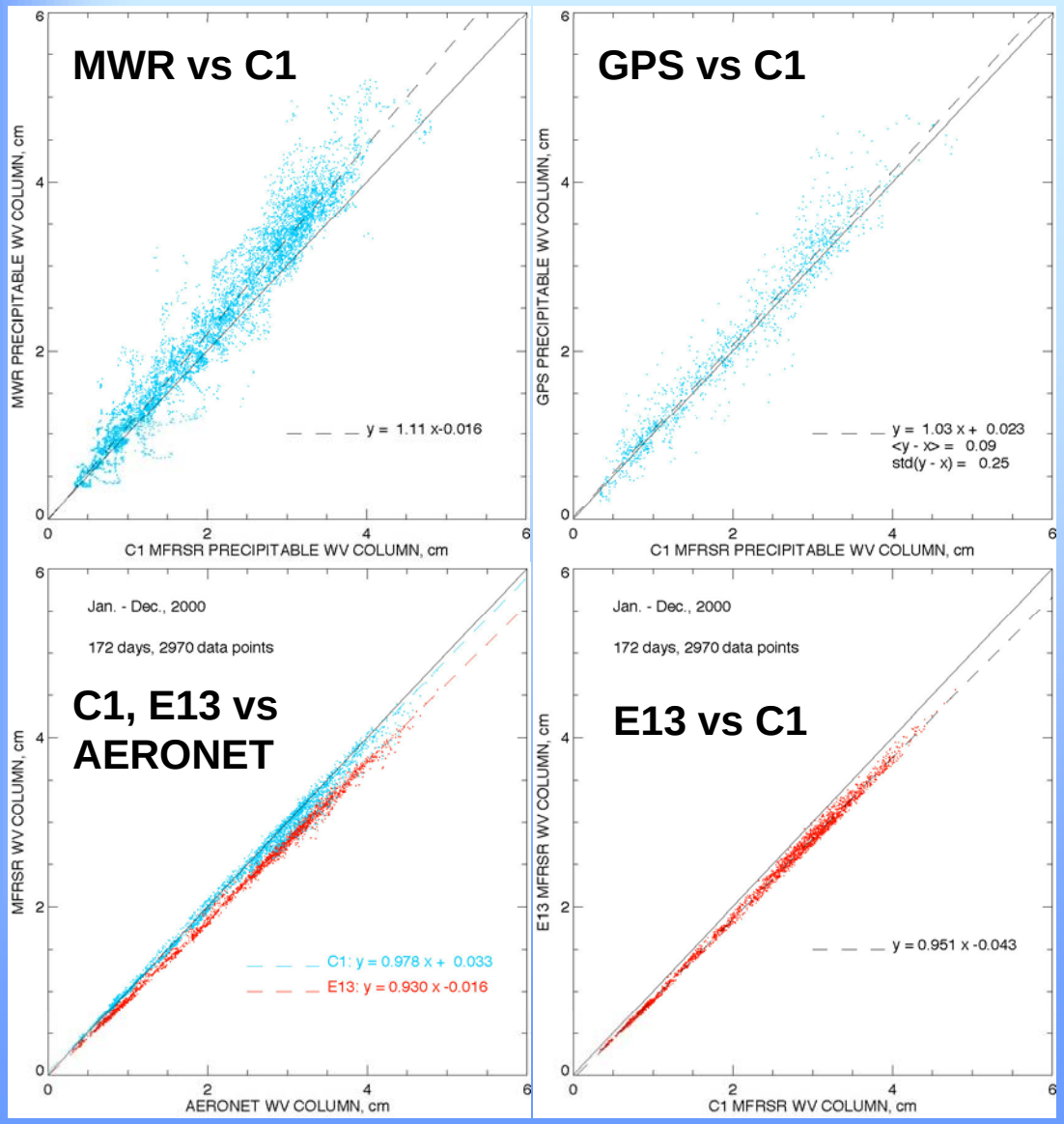
WV retrievals from MFRSR

Results for the year 2000 and comparison with MWR, GPS and AERONET retrievals



Time series of daily mean MFRSR-derived WV column values from SGP Central Facility (C1 and E13) compared with MWR, GPS and AERONET retrievals for the whole year 2000.

MFRSR v.s. other instruments

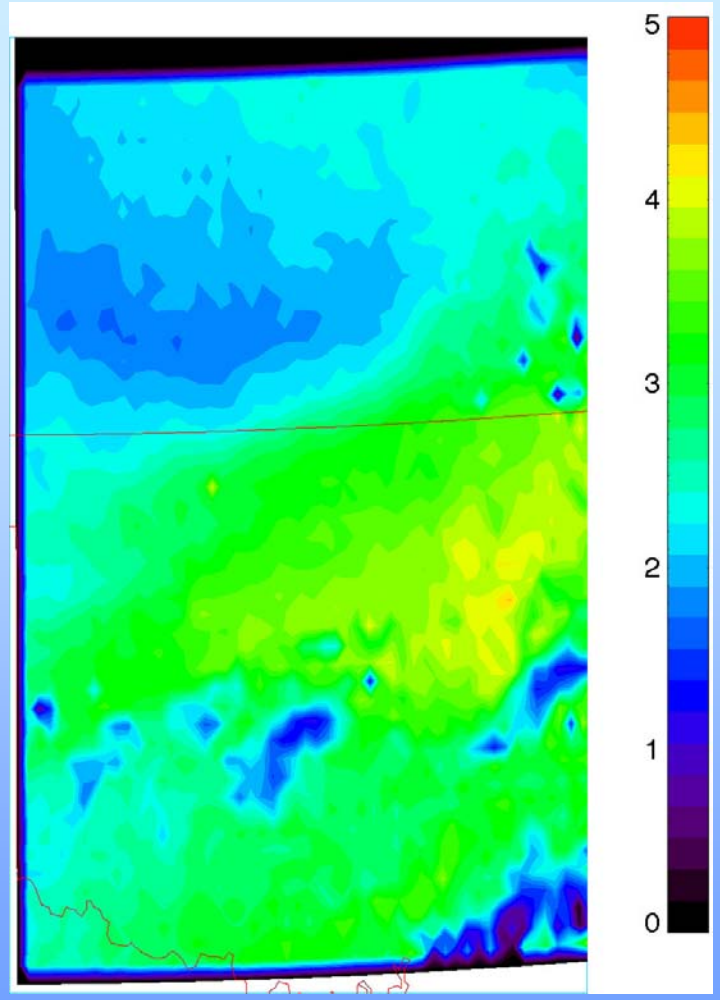


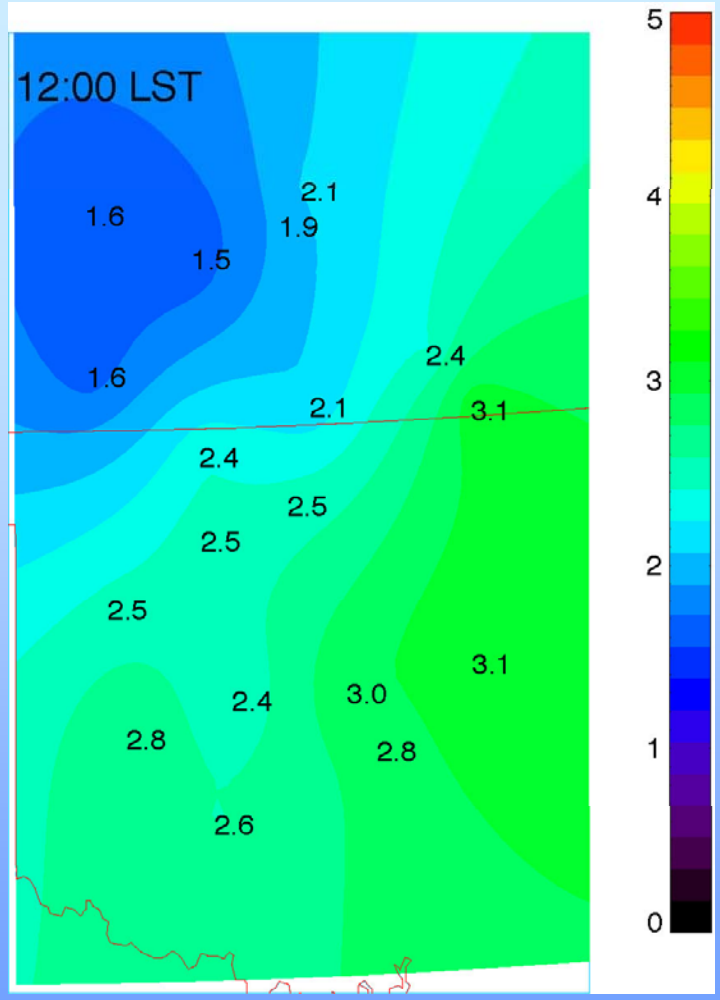
Comparisons between column WV retrievals from MFRSRs (C1 and E13) and from co-located
MWR (11% bias),
WPDN GPS station (3% bias),
AERONET (2 & 7% bias).

E13 was 5% lower than C1. This may be improved by updating spectral response of MFRSR's 940 nm channel.

C1 MWR values for the year 2000 are 6 - 9 % higher than GPS.

Spatial structure of WV field

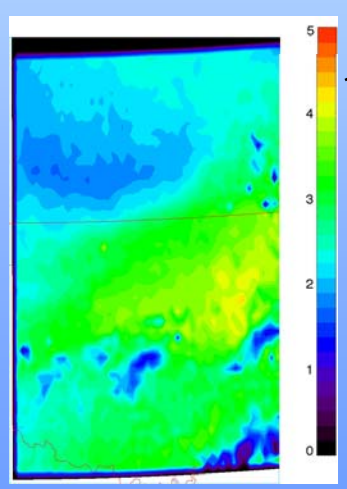




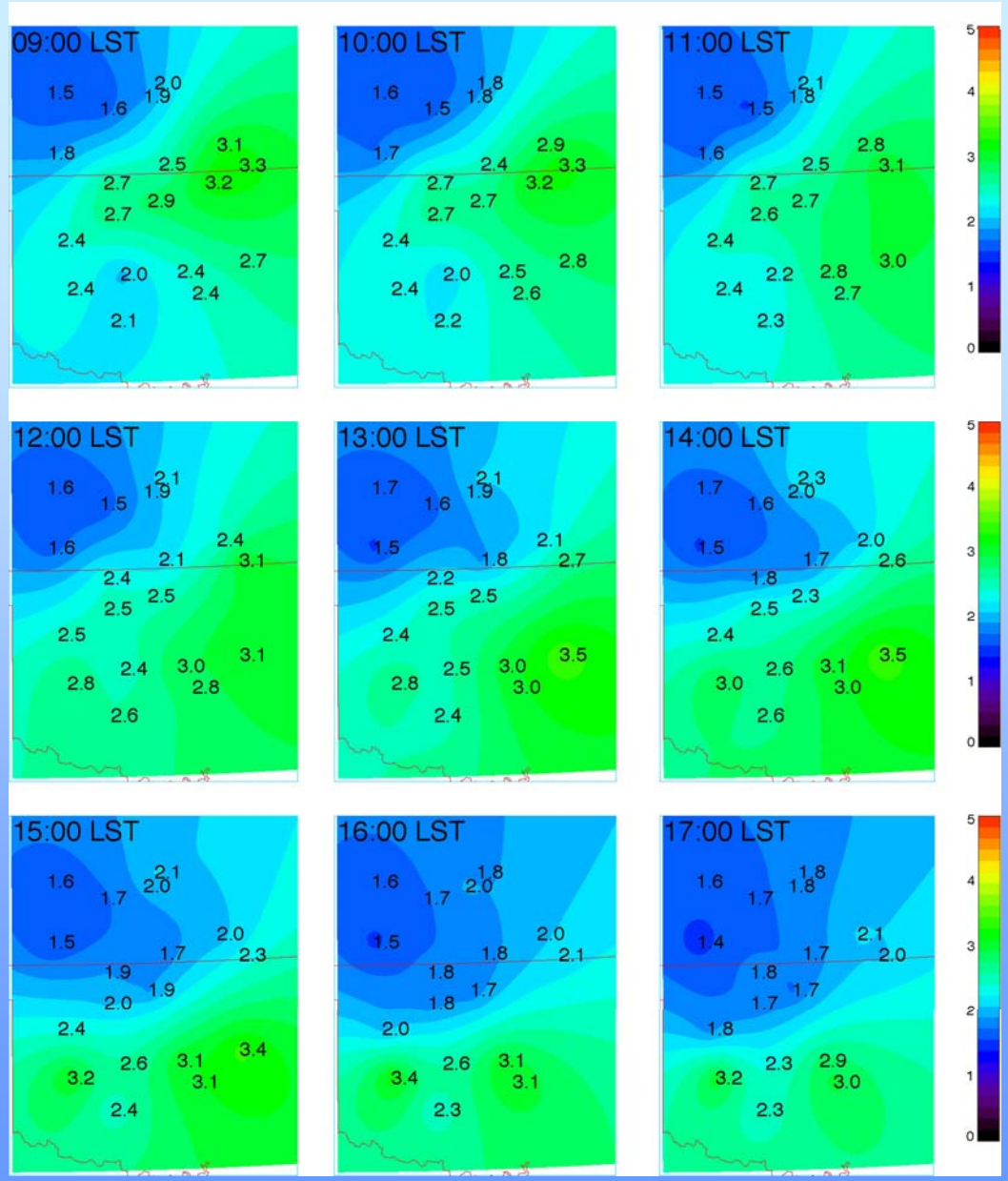
MODIS Level 2 WV product over SGP site (left) and spatial structure obtained by interpolation of MFRSR network data (left) from September 14, 2000.

Evolution of WV field

Variation of WV spatial structure during the day of September 14, 2000. The images are obtained by interpolation of MFRSR network data.

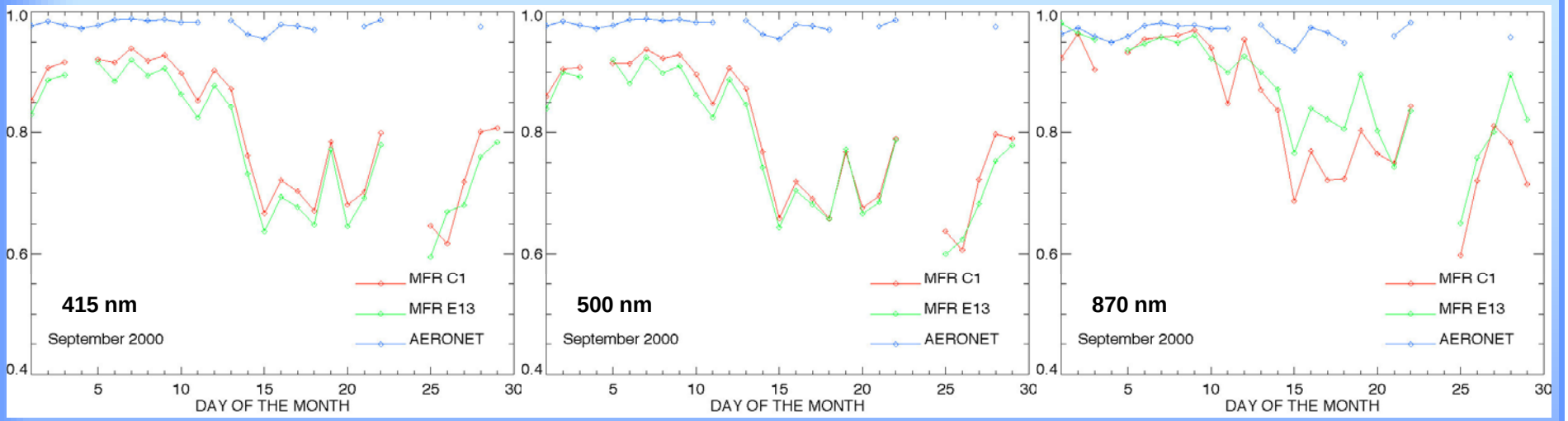


MODIS overpass



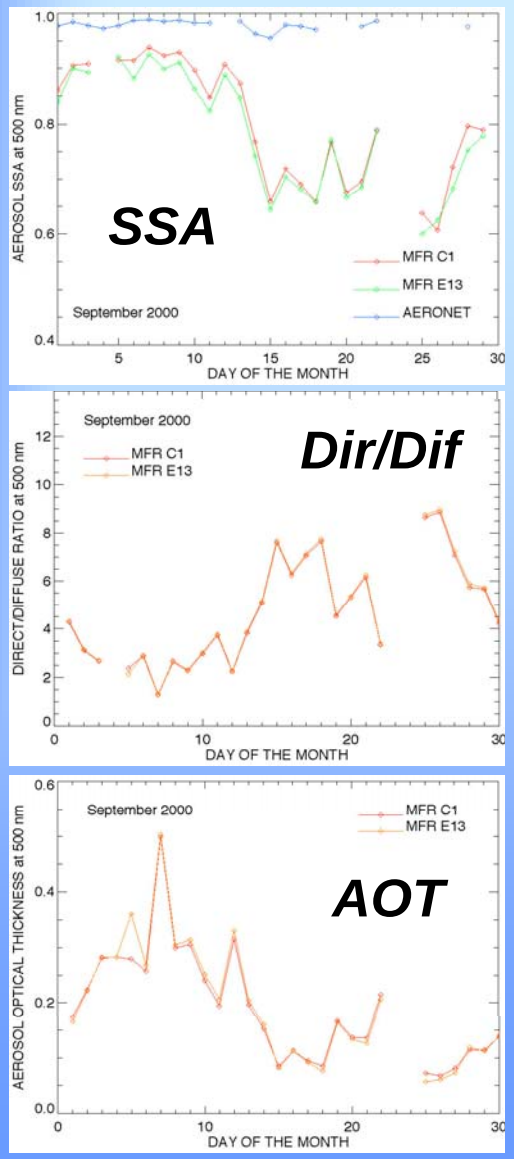
Aerosol Single Scattering Albedo

The retrieved aerosol parameters are used together with direct/diffuse ratios to derive aerosol absorption properties: imaginary part of the refractive index and aerosol single scattering albedo (SSA).



Time series of daily mean values of aerosol SSA retrieved from measurements by SGP Central Facility MFRSRs (C1, E13) made in September 2000 (preliminary results). AERONET's values (almucantar scan analysis) are shown for comparison. Constrained (zero NO2) MFRSR analysis algorithm had been used for these plots.

Problems in SSA retrievals



- MFRSR SSA values are substantially smaller than those from AERONET analysis.
- The SSA values are particularly low when AOT and fine mode fraction are small, and diffuse flux is small compared to the direct beam.
- Testing different aerosol models do not significantly improve the result.
- Possible explanation may be an error in separation between direct and diffuse irradiances by MFRSR shadowbanding process (increasing diffuse and decreasing direct flux by the same amount leads to higher SSA). Direct modeling of shadowbanding is needed.
- SSA in 870 nm channel appears to be higher than in 670 nm channel, which may be an indication of spectral leaks in the first four channels.

SSA: Empirical correction

To correct for an error in separation between direct and diffuse irradiances we adjust Direct/Diffuse ratios:

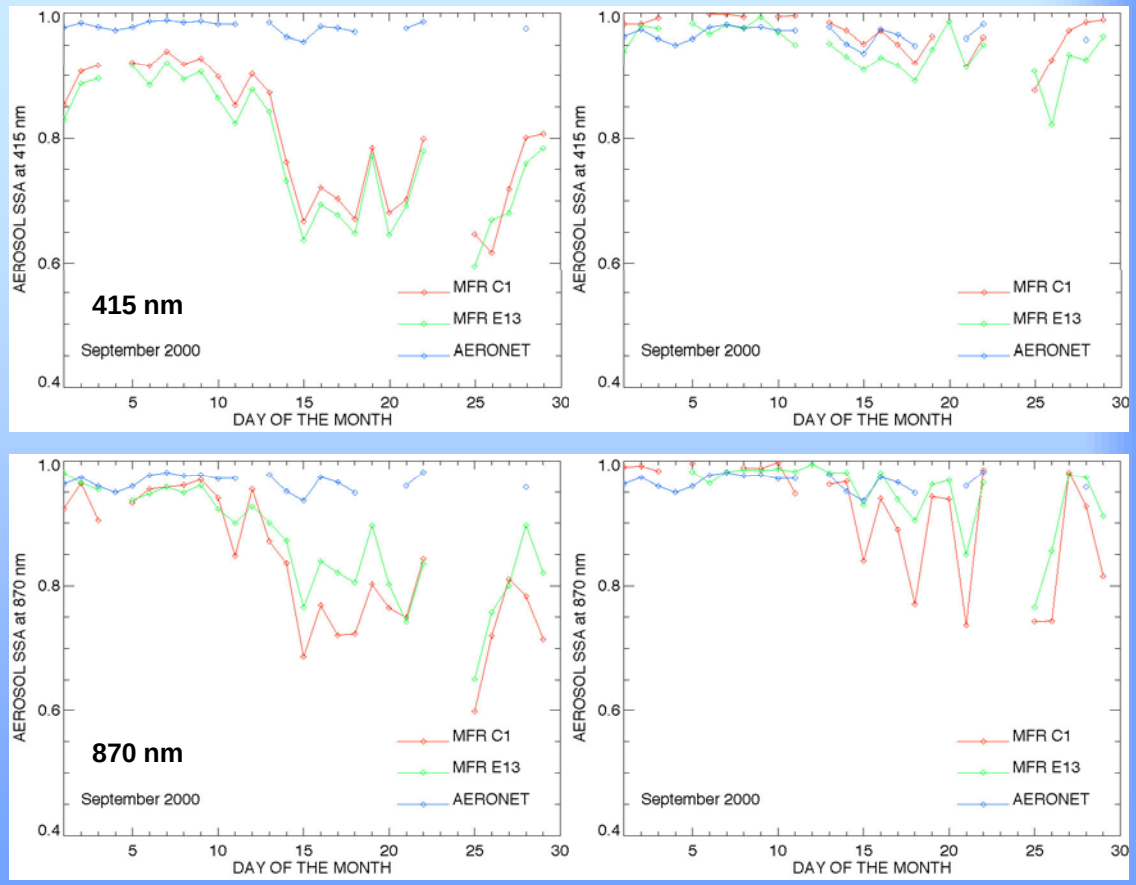
$$D = \frac{I_{dir}}{I_{dif}} \rightarrow D' = \frac{I_{dir} - \delta I_{dif} / \cos(\theta)}{(1+\delta) I_{dir}}$$

where

$$\delta = 0.2\left(1 - \frac{\tau_{fine}(870nm)}{\tau_{total}(870nm)}\right)$$

reflects effective size of aerosol particles.

Original Corrected



Related publications

Alexandrov, M.D., P. Kiedron, J.J. Michalsky, G. Hodges, C.J. Flynn, and A.A. Lacis (2007),
Optical depth measurements by shadow-band radiometers and their uncertainties, *accepted to Applied Optics*.

Alexandrov, M. D., A. A. Lacis, B. E. Carlson, and B. Cairns (2007),
Characterization of atmospheric aerosols using MFRSR measurement
submitted to J. Geophys. Res.

Alexandrov *et al*. (2007),
Columnar water vapor retrievals from MFRSR data,
in preparation.

Conclusions

- We retrieve fine and coarse mode aerosol optical depth (AOD) and fine mode effective radius from MFRSR measurements.

- Sensitivity study demonstrated that for 0.01 accuracy in AOD the trade-offs between the aerosol extinction and NO_2 absorption prevent a conclusive estimate of NO_2 column and may bias aerosol size retrievals.

- The retrieval algorithm uses climatological amounts of NO_2, compiled from SCIAMACHY data, and takes ozone from TOMS.

- Our retrievals of total, fine, and coarse AOD, and fine mode effective radius agree well with the correlative AERONET almucantar scan analysis (Version 2) for a CIMEL sunphotometer co-located with the two MFRSRs (C1, E13) at the SGP's Central Facility.

- Retrievals of Precipitable Water Vapor column agree within 10% with Microwave Radiometer, GPS, and AERONET retrievals. There is a qualitative agreement in PWV spatial distribution between SGP MFRSR network data and MODIS satellite product