Analysis of shortwave spectrometry of cloudy atmospheres during MAGIC

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Radiation Instruments

Solar Array
Spectrophotometer

SAS-Ze

CIMEL Sunphotometer
operated in cloud mode

CIMEL

SSFR

Same family (NASA Ames) as the Shortwave Spectradiometer (SWS) at SGP

Motivation

- MAGIC's time-resolved hyperspectral meas'ts reveal more details of cloud types/structure as well as cloud aerosol interactions.
- Retrievals of cloud and aerosol properties depend on accuracy of radiance meas'ts.
- Analysis of differences (uncertainties) in radiation meas'ts and sensitivity of the retrieval methods to these uncertainties is required.

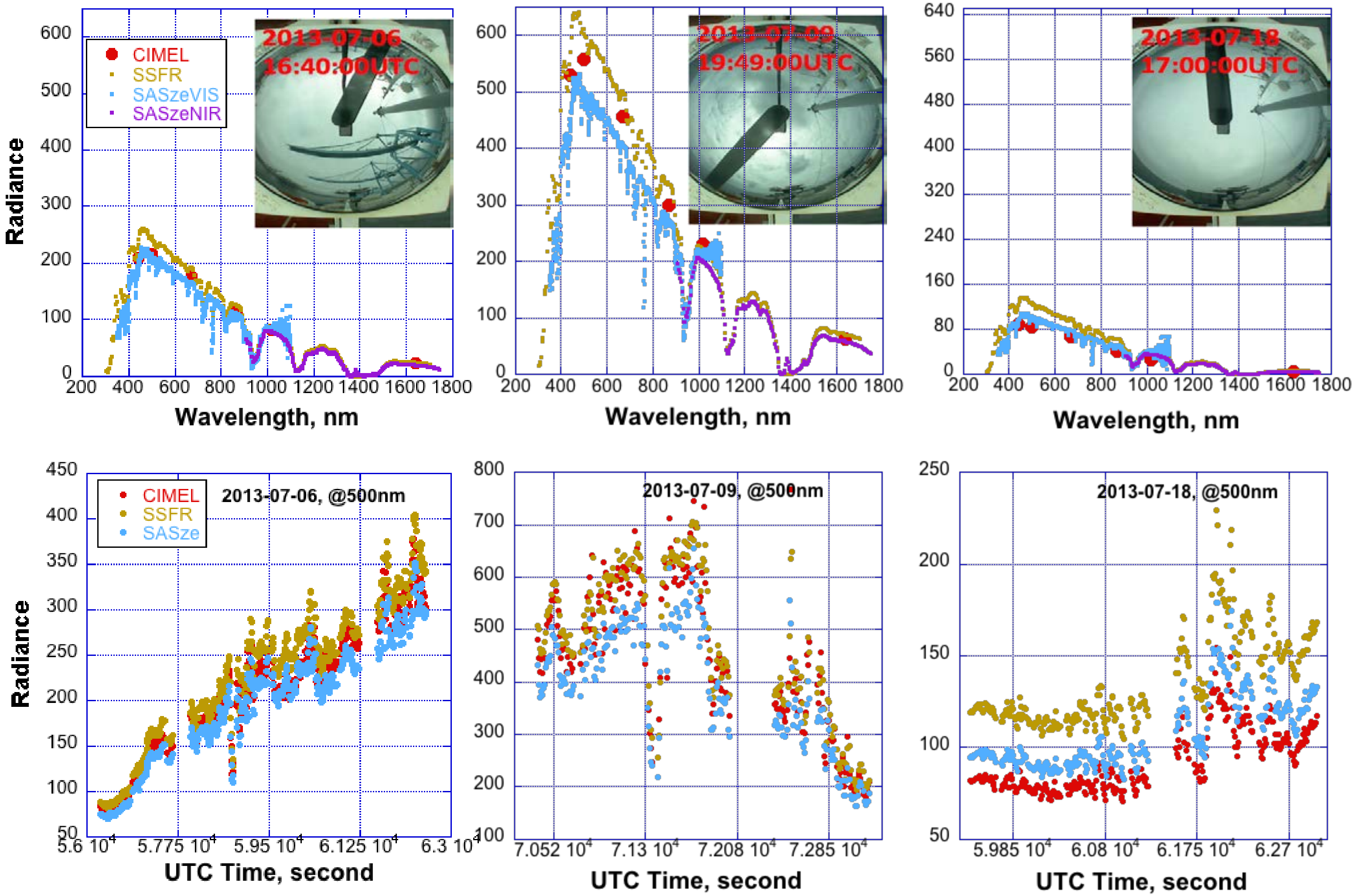
Comparison Methods

- Zenith radiance meas'ts from three instruments: SSFR, SAS-Ze and CIMEL are compared and analyzed.
- Several overcast cases are used in the comparison.
- In comparison with CIMEL, values from SSFR and SAS-Ze are averaged within ± 5s of CIMEL sampling times and ±5nm of CIMEL wavelengths.

Three overcast cases

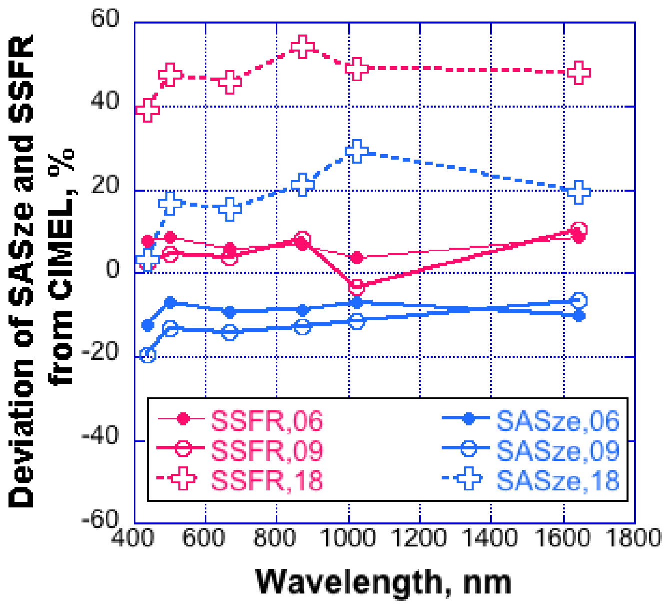
Spectra at time *T*

Time-series at 500 nm

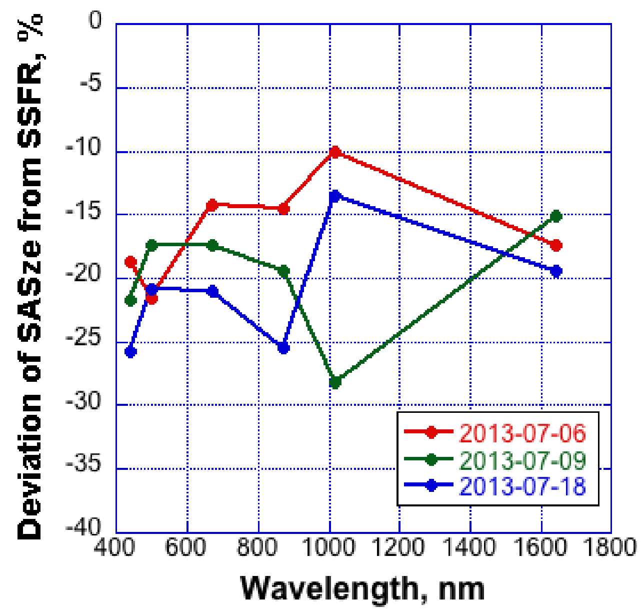


Analysis of deviations between SSFR, SAS and CIMEL

SAS/FSSR-CIMEL (in %)

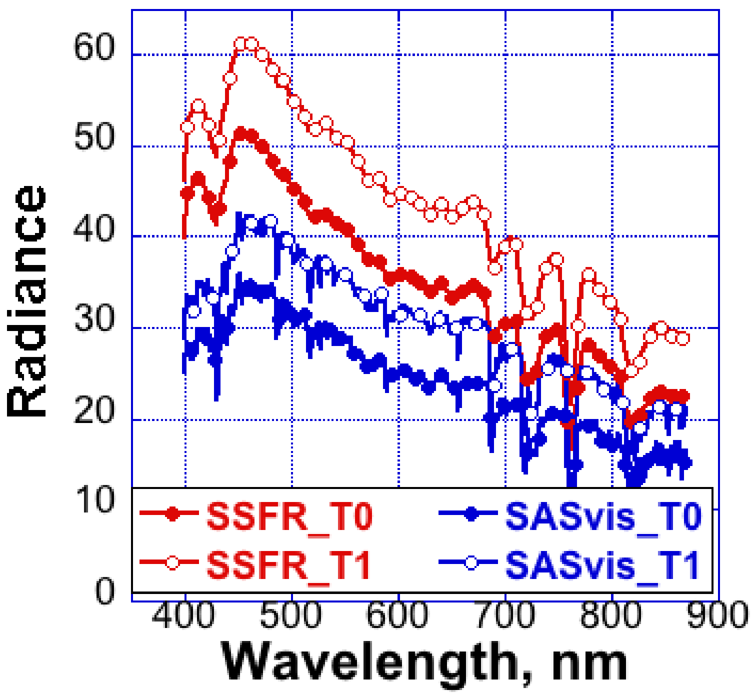


SAS-FSSR (in %)

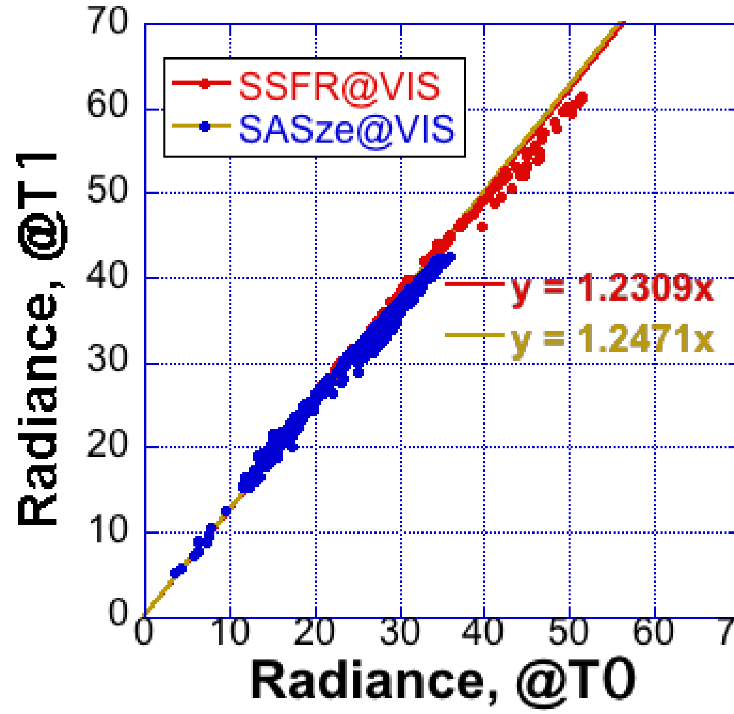


- In the 'good' cases, SSFR is higher than CIMEL by ~10%, while SASze is smaller than CIMEL by 10-20%;
- Deviations of SSFR and SASze from CIMEL have weak spectral dependence;
- The differences between SASze and SSFR are between 10% and 30%;
- In the 'bad' cases, deviations of both SSFR and SASze from CIMEL are large, but the differences relative to each other are comparable to the 'good' cases.

Spectral ratios as a linear approximation between two different times



Spectra of SSFR (red) and SAS (blue) measured at time T0 and T1

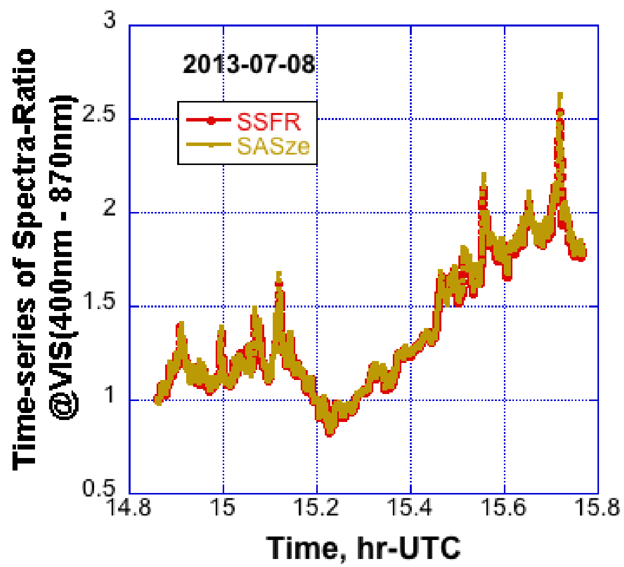


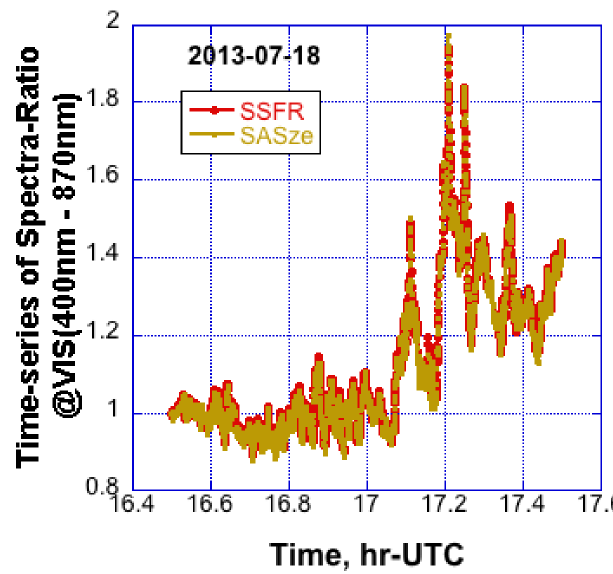
Linear-fit slopes of R(T1) vs. R (T0) for both instruments. The slopes are very close.

Comparison of spectral ratios

$Radiance(\lambda, t)/Radiance(\lambda, t_0)$

Small differences in spectral radiances





Large differences in spectral radiances

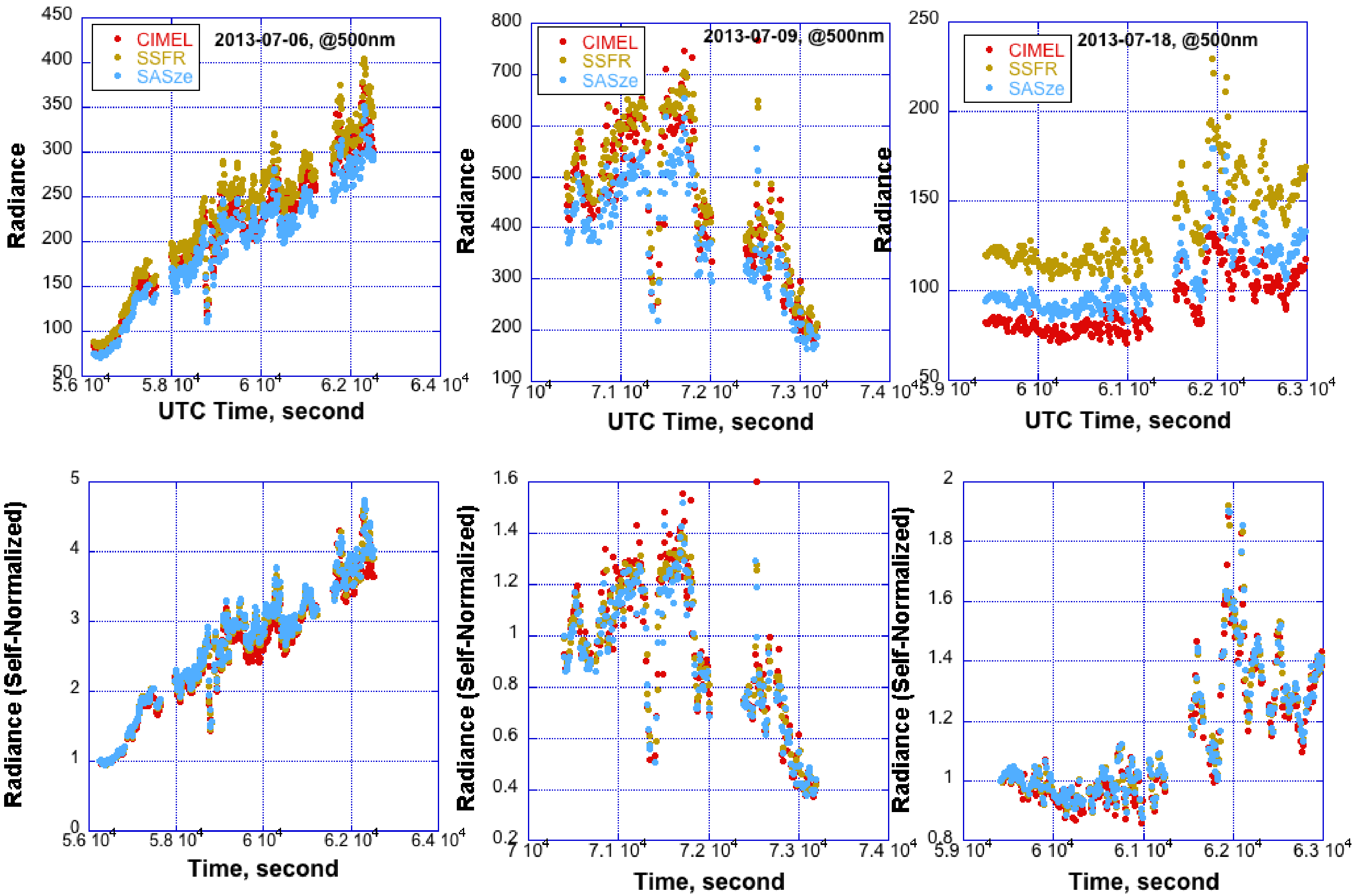
The 'self-normalized' spectra of SSFR and SAS are in *unison* though their radiances can be very different.

Hence retrievals and analysis of cloud/aerosol properties based on 'self-normalized' spectra are more reliable than using radiances directly

Three instruments comparison @500nm: before and after self-normalization

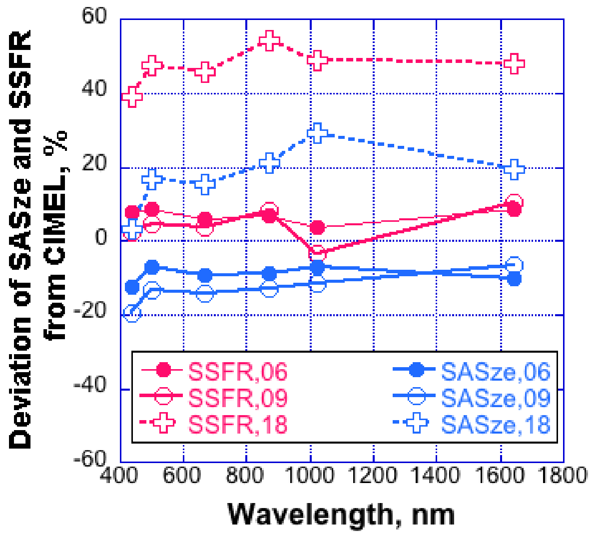
Before

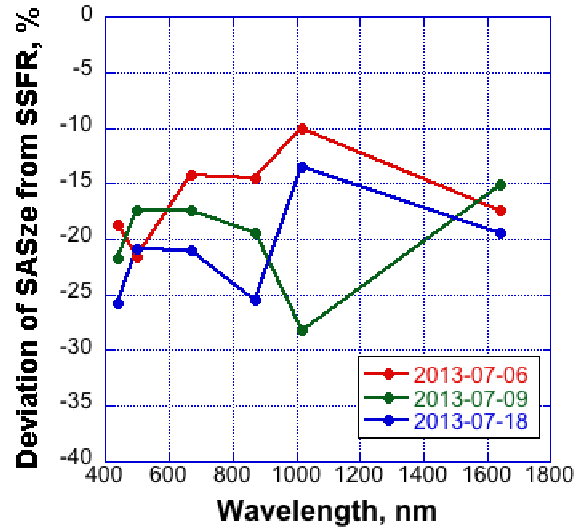
After



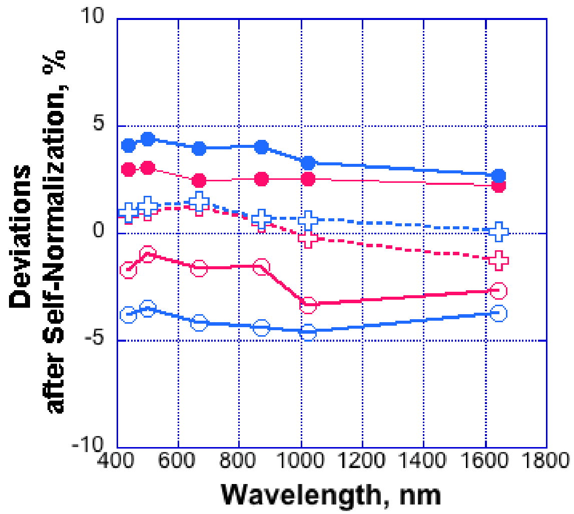
Spectral difference between instruments: before and after self-normalization

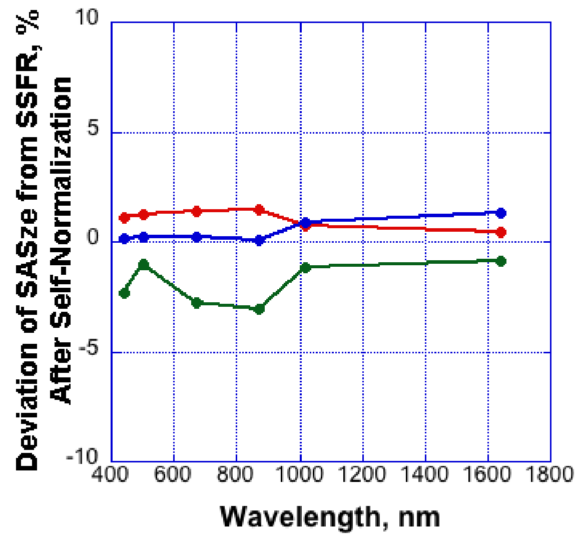
Before



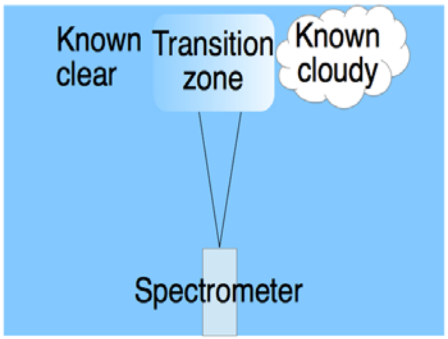


After





Understanding of cloud properties in the transition zone

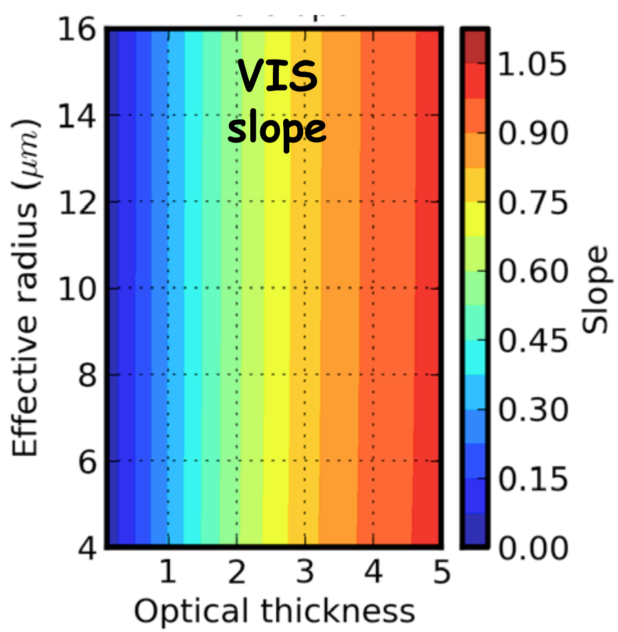


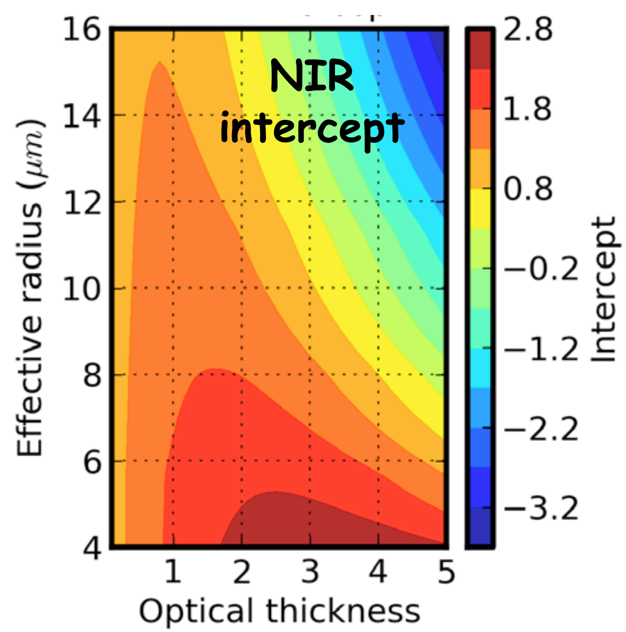
$$R_{transition}(\lambda) \approx aR_{cloudy}(\lambda) + bR_{clear}(\lambda)$$

$$\frac{R_{transition}(\lambda)}{R_{clear}(\lambda)} \approx a\frac{R_{cloudy}(\lambda)}{R_{clear}(\lambda)} + b$$

$$Y_{\lambda} \approx aX_{\lambda} + b$$

Slope *a* and intercept *b* contain information of cloud optical depth and droplet size.

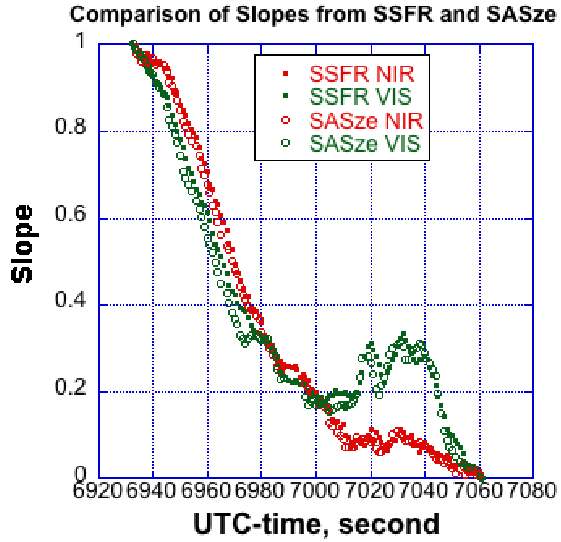




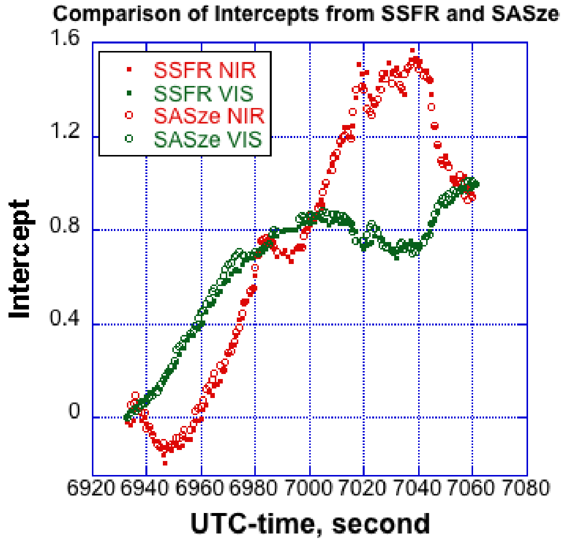
Transition zone between cloudy and clear air

$$\frac{R_{transition}(\lambda,t)}{R_{clear}(\lambda)} = a(t)\frac{R_{cloudy}(\lambda)}{R_{clear}(\lambda)} + b(t)$$

Slope $a(t)$



Intercept $b(t)$



- Slopes and intercepts in the VIS and NIR are used in the spectrally-invariant approach for understanding/retrievals of cloud properties in the transition zone (optical depth and droplet size).
- The consistency of the slopes and intercepts for two instruments tells us that the algorithm relying on the spectra ratios will not be sensitive to different instruments and yield reliable results.

Summary

- Differences in radiance measurements of the three radiation instruments (SSFR, SAS and CIMEL) can be large.
- Differences between these measurements show weak spectral dependence.
- Though differences in the spectral radiance measurements can be large, the 'self-normalized' spectra are well consistent between SSFR and SAS.
- Analysis and retrievals of cloud properties based on the slopes and intercepts of the spectral invariance approach can be robust.