Studying the Transition from Cloudy to Clear Skies Using the ARM Shortwave Spectrometer

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Background

•It is difficult to distinguish between cloudy and cloud-free air in remote sensing observations.

•This problem has major climatic consequences, in particular on aerosol indirect effect studies, which demand a precise separation of clear and cloudy air (Charlson et al., 2006).

• The regions around clouds are neither precisely clear nor precisely cloudy. Koren et al. (2007) called them the "twilight zone."

ARM Shortwave Spectroradiometer

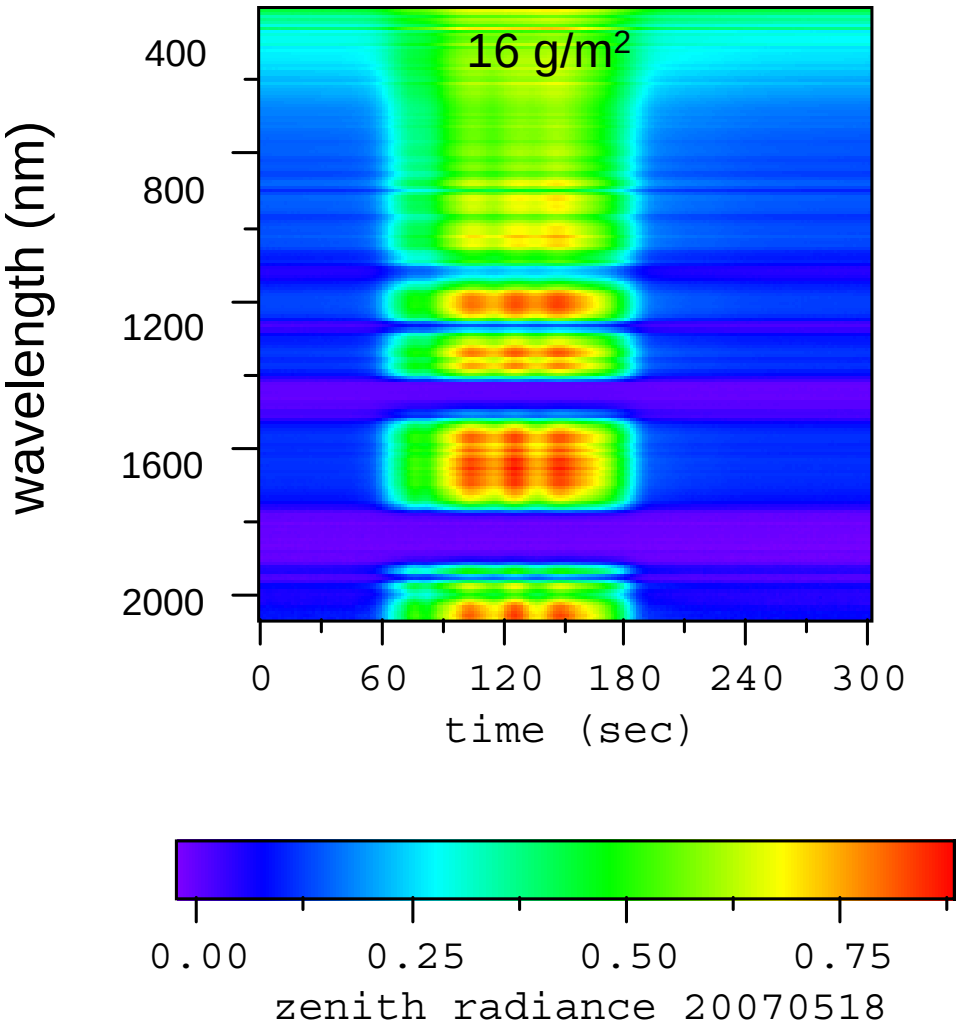
The SWS measures zenith sky spectral radiance from the near UV through near IR spectral range. It was deployed at the ARM Central facility in OK on 4/27/06.

- Spectral Range: 380-2200nm
- Spectral Resolution
  - 380-970 nm: 8nm
  - 970-2200 nm: 12nm
- Spectral Sampling rate: 1 Hz
- Field of view: 1.4°
- 418 wavelengths
- Primary calibration tied to 30 in. integrating sphere at NASA Ames
- Weekly calibration with 12 inch integrating sphere

(from Pilewskie's presentation at the last ARM STM)

SZA=45º

May 18, 2007



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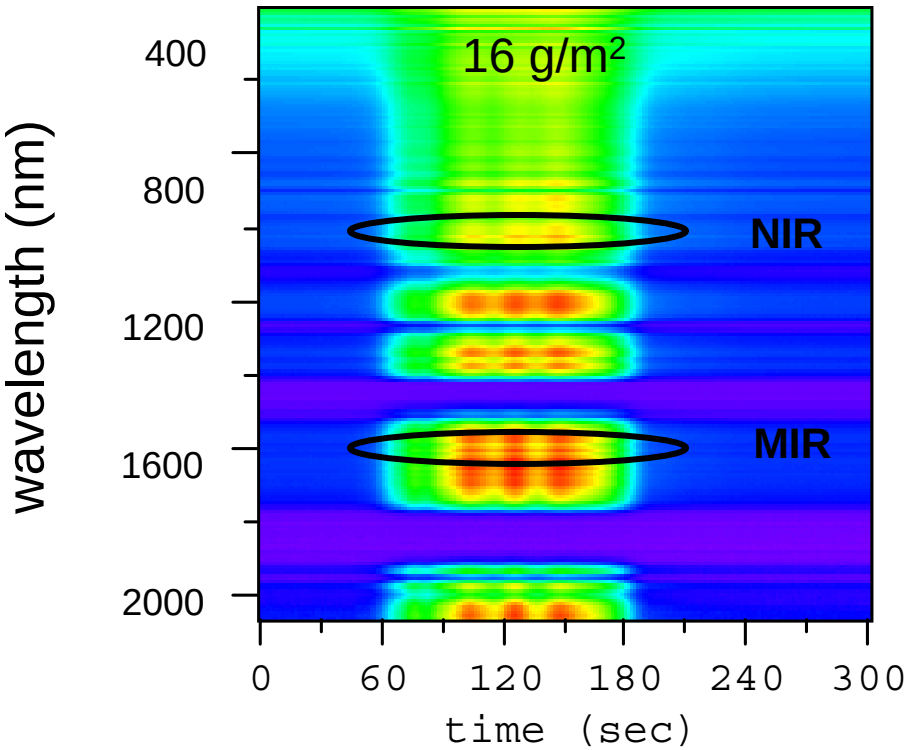
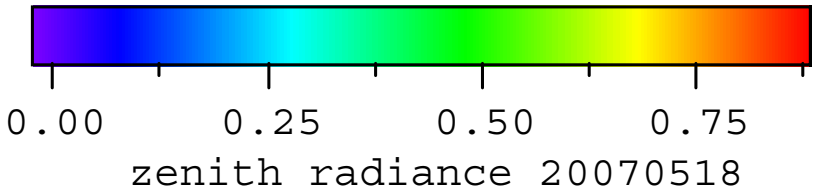
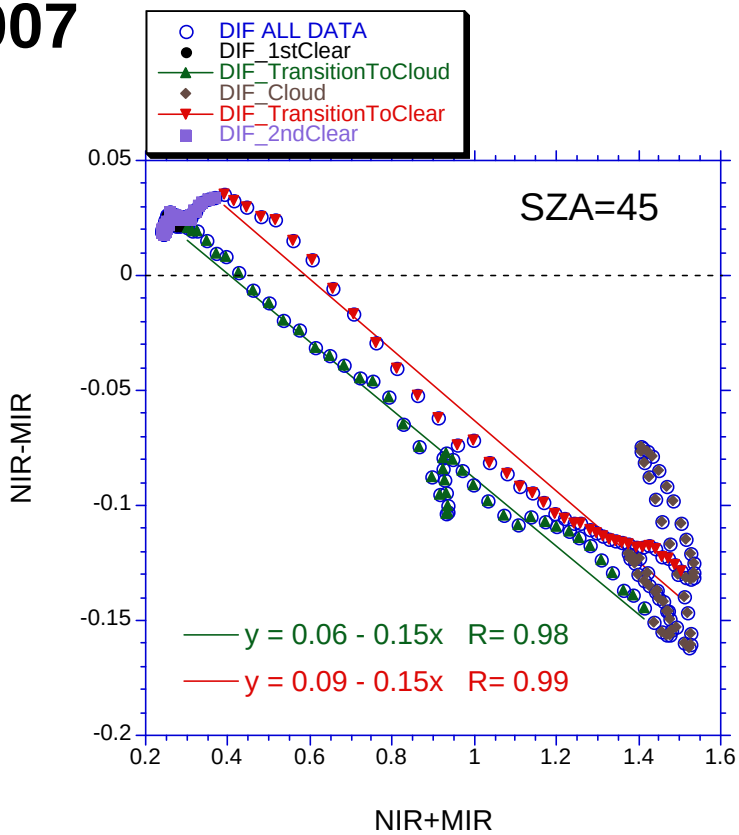


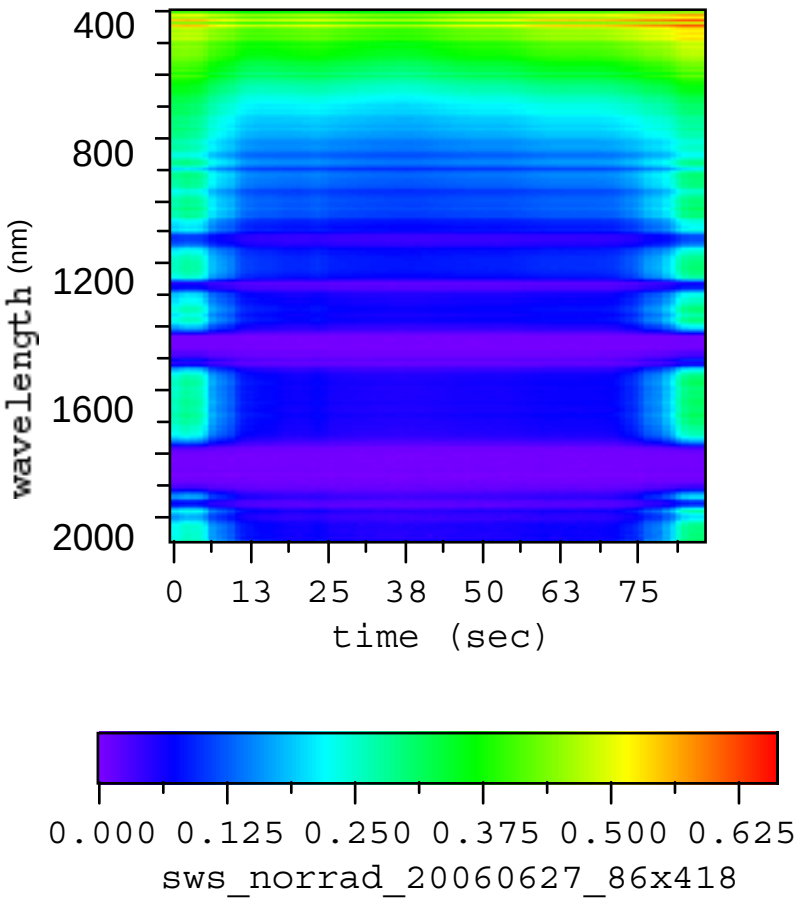




0.87 μm (NIR) and 1.6 μm (MIR)

SZA=14º

June 27, 2006



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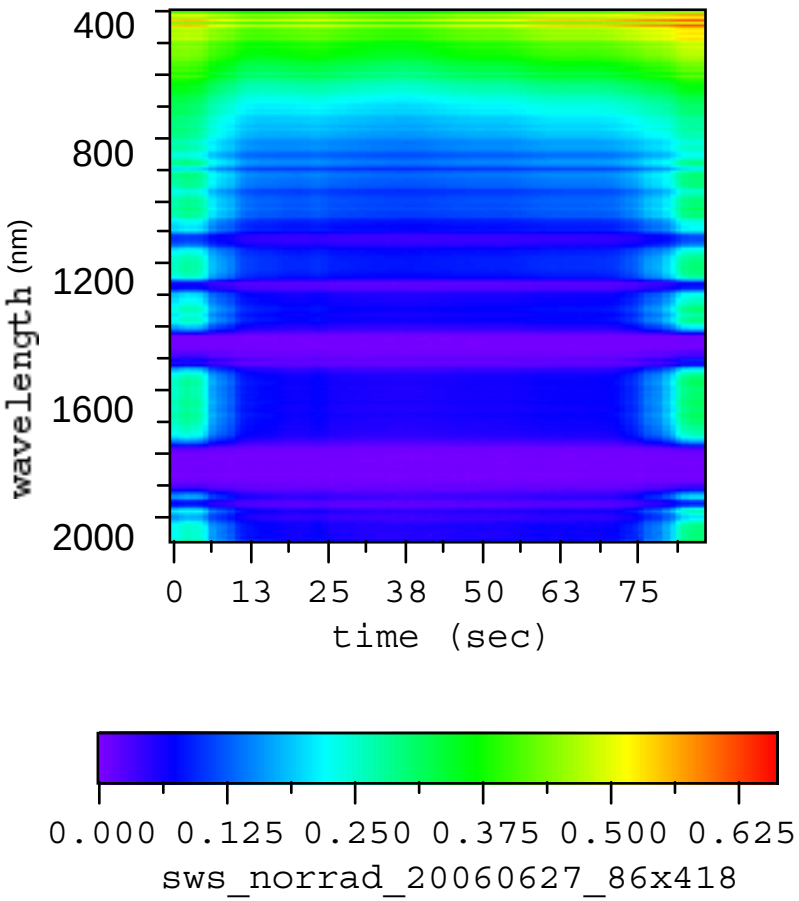
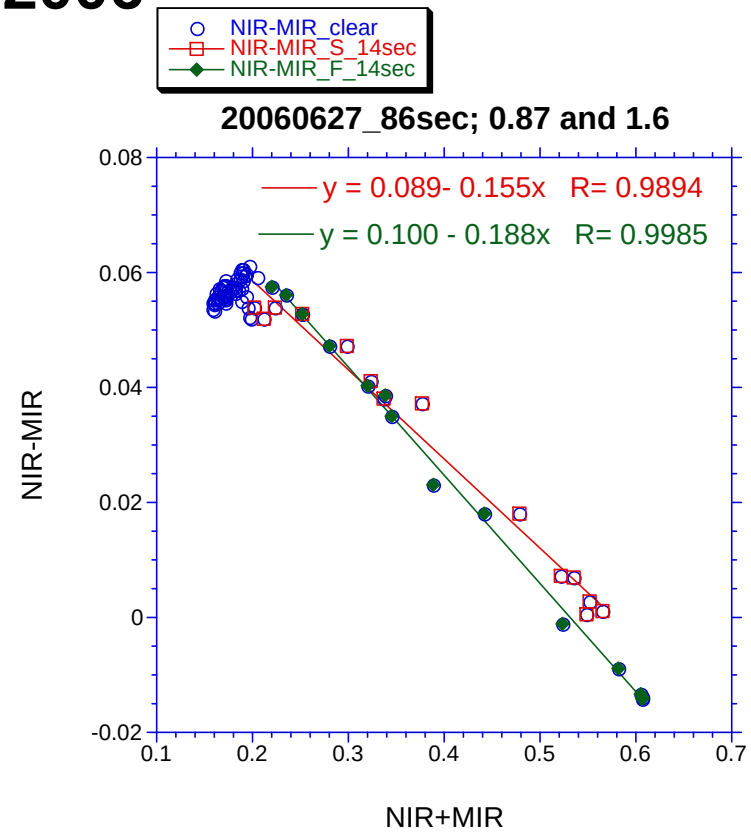
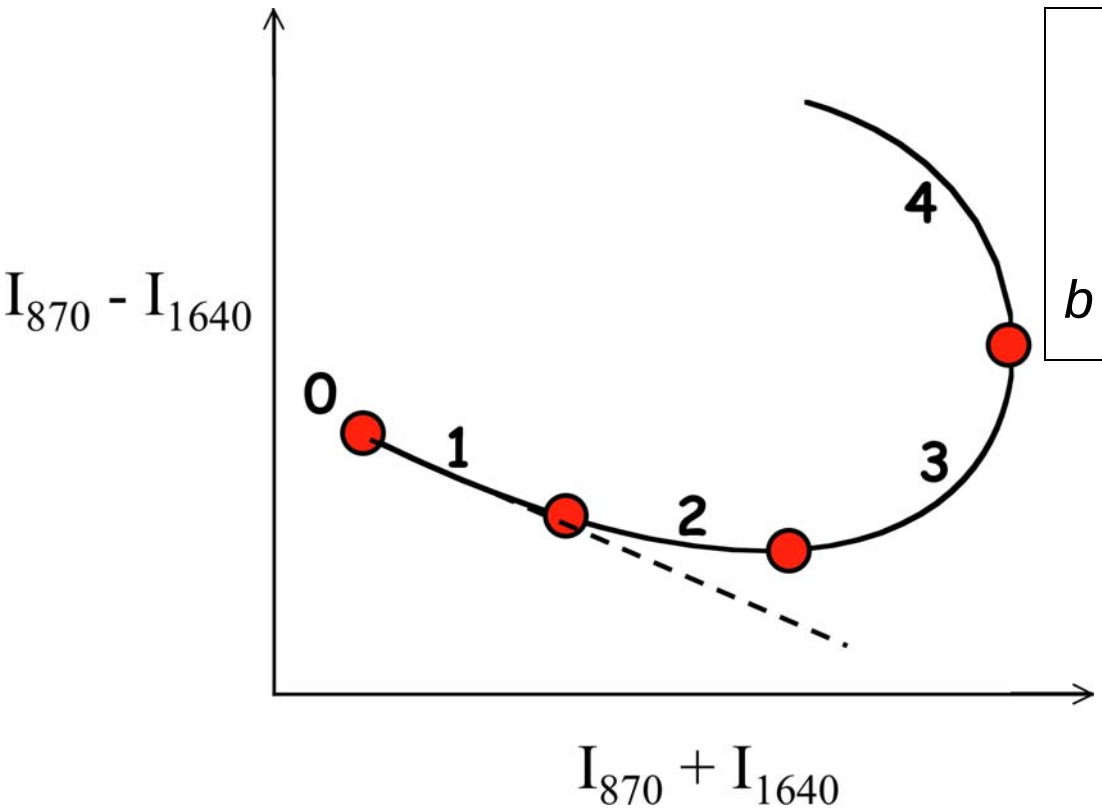




Radiative signature regimes

0: Cloud-free (Rayleigh + aerosol)
1: Transition to cloud: single scat. dominates (aerosol + very thin clouds: $\tau<0.2$)
2: In-cloud single scat. domin. but no longer linear (aerosol + thin clouds: $0.2<\tau<1$)
3: In-cloud multiple scattering + surface-cloud interaction (clouds + surface: $1<\tau<5$)
4: Multiple scattering + surface-cloud interaction (thicker clouds + surface: $\tau>5$)

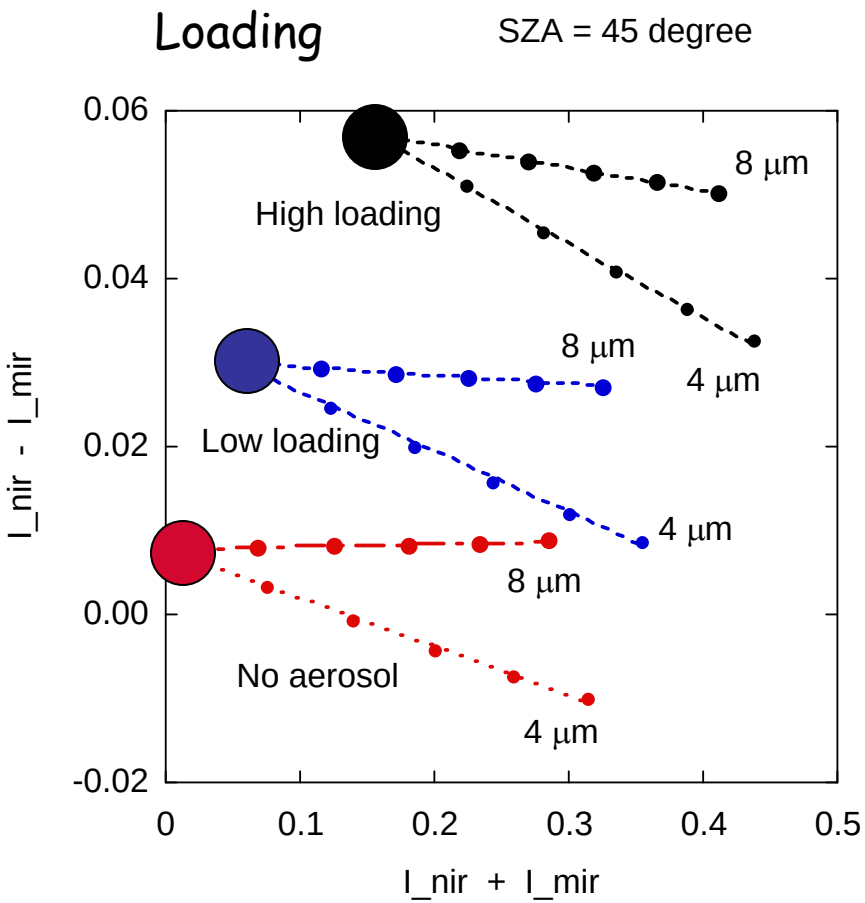


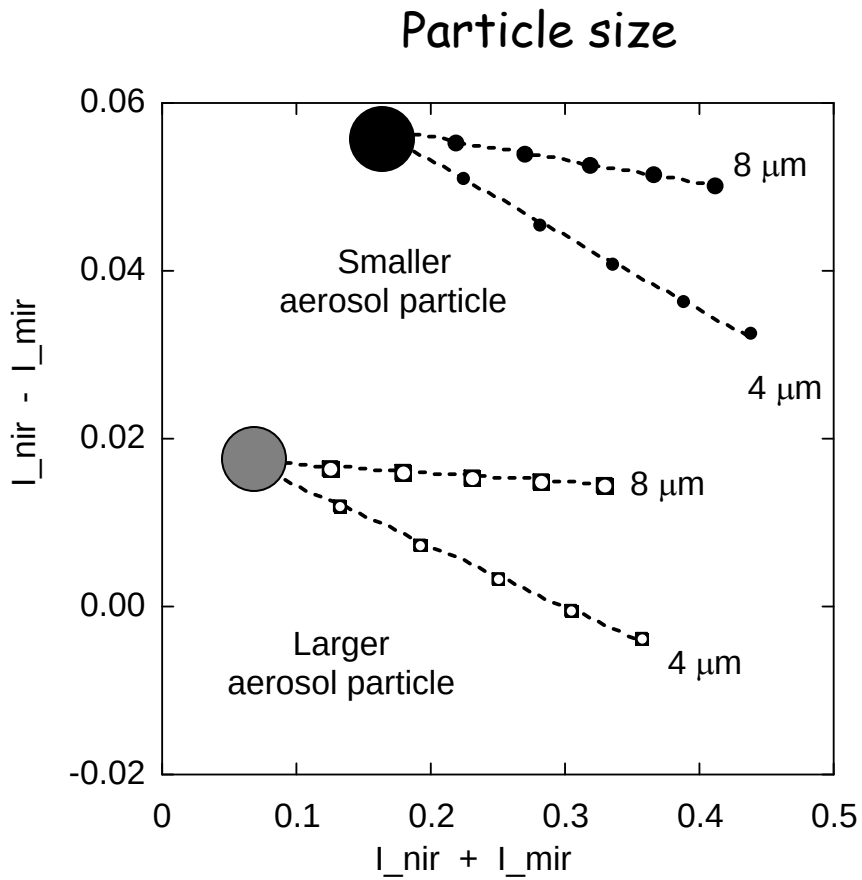
Transition zone:

DIF = *a* + *b**SUM

a is sensitive to aerosols
b is sensitive to droplet size

Regime 0: different aerosols

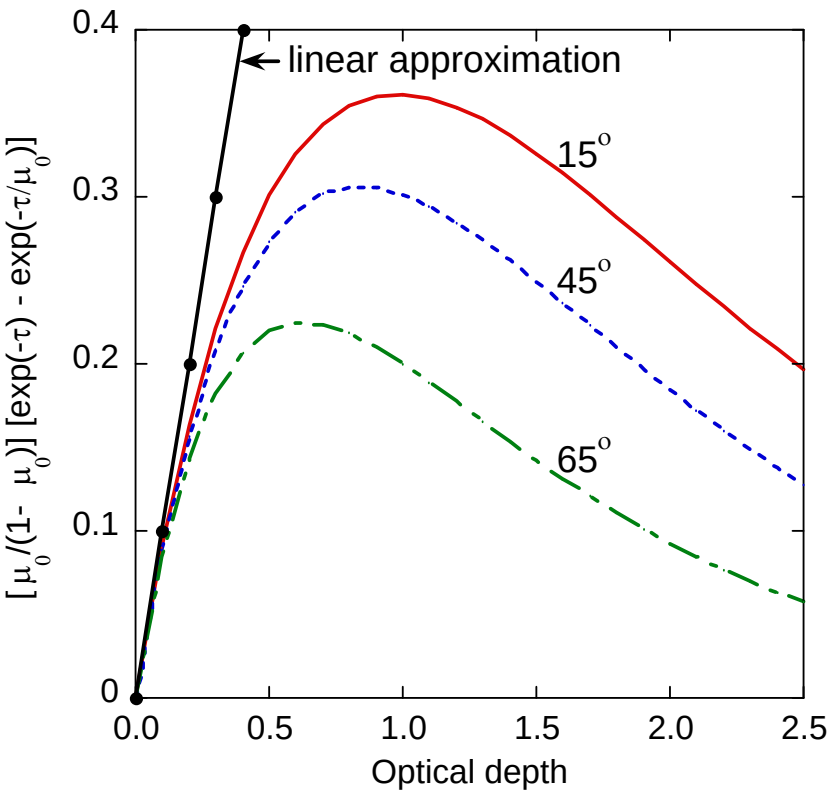




Cloud optical depth grows from 0 to 0.5 in steps of 0.1

Single scattering approximation

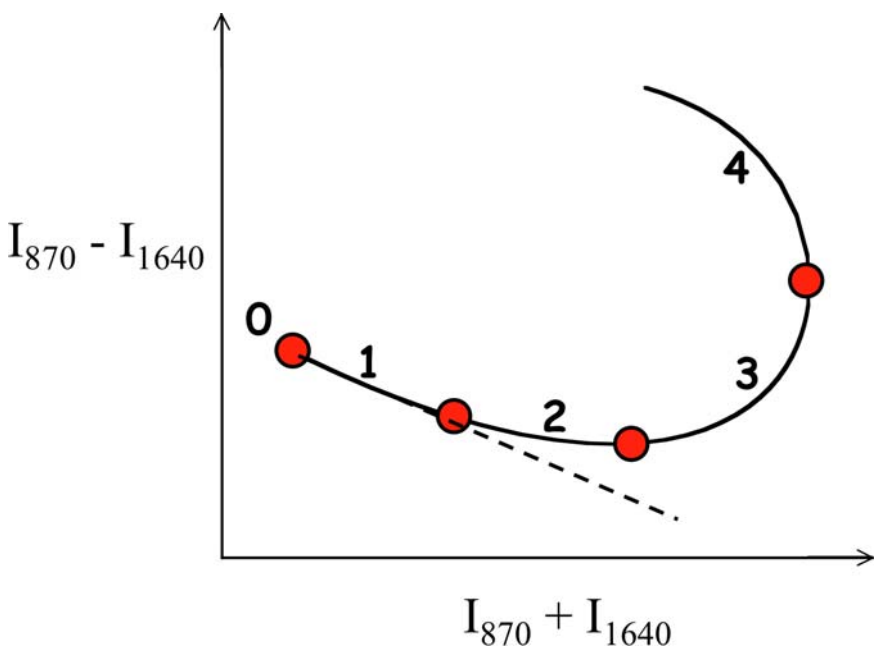
$$I_\lambda \propto \varpi_\lambda \cdot P_\lambda \cdot \frac{\mu_0}{1-\mu_0}[\exp(-\tau_\lambda) - \exp(-\tau_\lambda / \mu_0)]$$



and its linear approximation

$$I_\lambda \propto \varpi_\lambda \cdot P_\lambda \cdot \tau_\lambda$$

Single scattering approximation

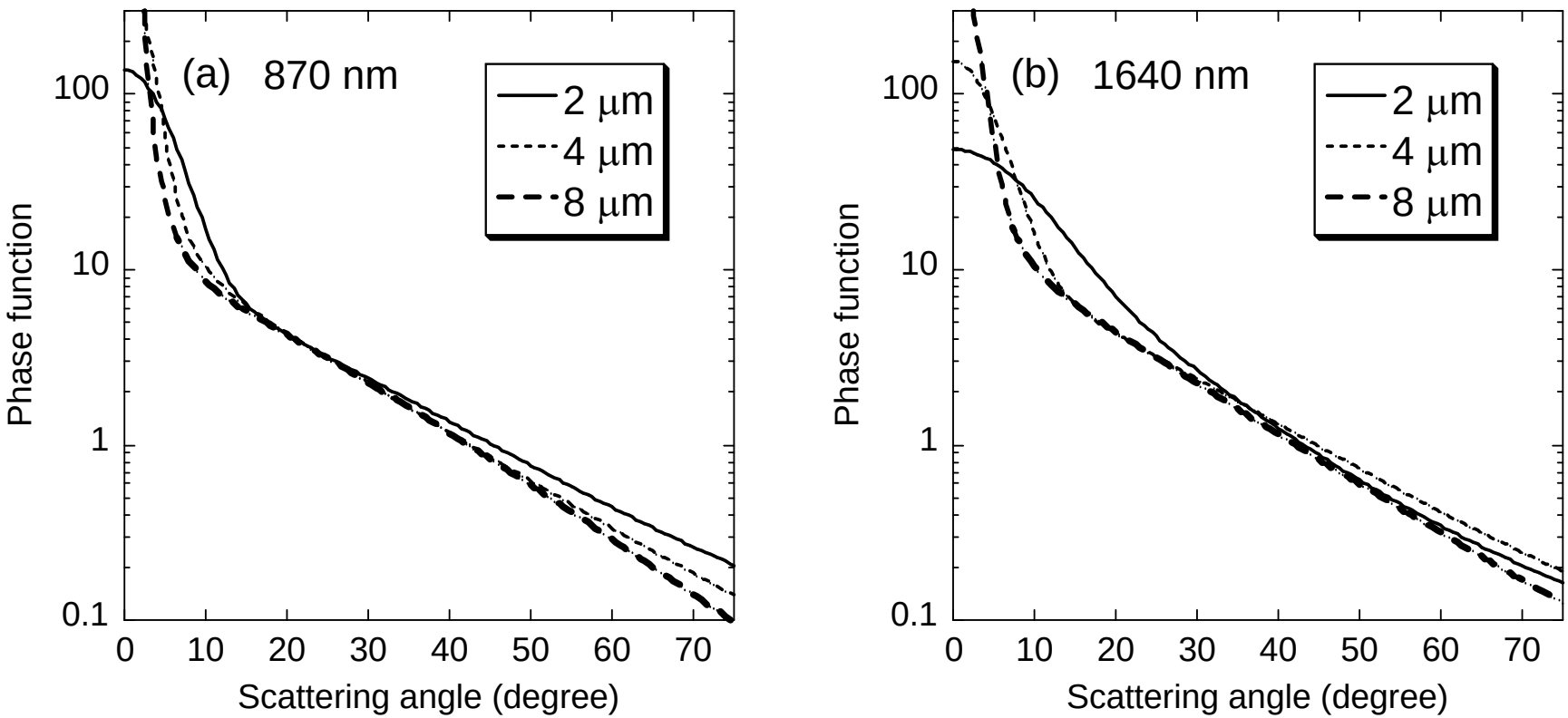


Slope =

$$\frac{P_{870}^{c} - \varpi_{1640}^{c} P_{1640}^{c}}{P_{870}^{c} + \varpi_{1640}^{c} P_{1640}^{c}} = \frac{1 - \varpi_{1640}^{c} \cdot \chi}{1 + \varpi_{1640}^{c} \cdot \chi}$$

where $\chi = \chi\left(\mu_0; r_{c,eff}\right) = \frac{P_{1640}^{c}}{P_{870}^{c}}$

Mie phase function



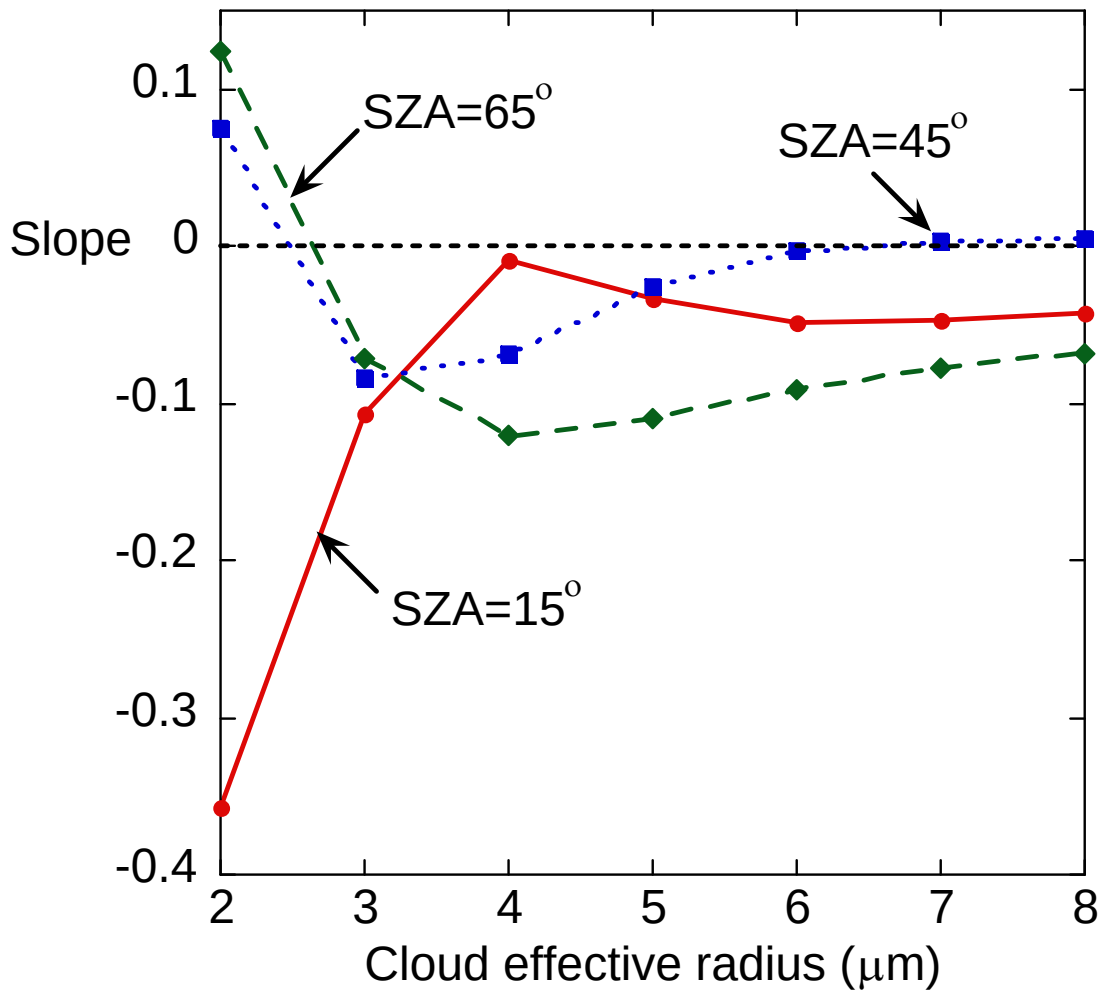
Conclusion

- The 1-sec-resolution *ARM SWS* provides a unique opportunity to study the transition zone (in the range of 50 -150 m unavailable for satellites and airborne lidars).

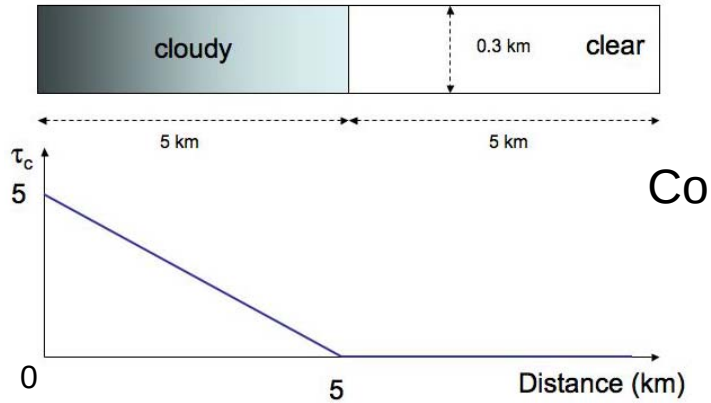
- There is a remarkable *linear relationship* between SUM and DIF of zenith radiance at 870 and 1640 nm wavelengths.

- The *intercept* of the relationship is determined by aerosol properties and the *slop* by cloud properties.

Model calculations of the slope

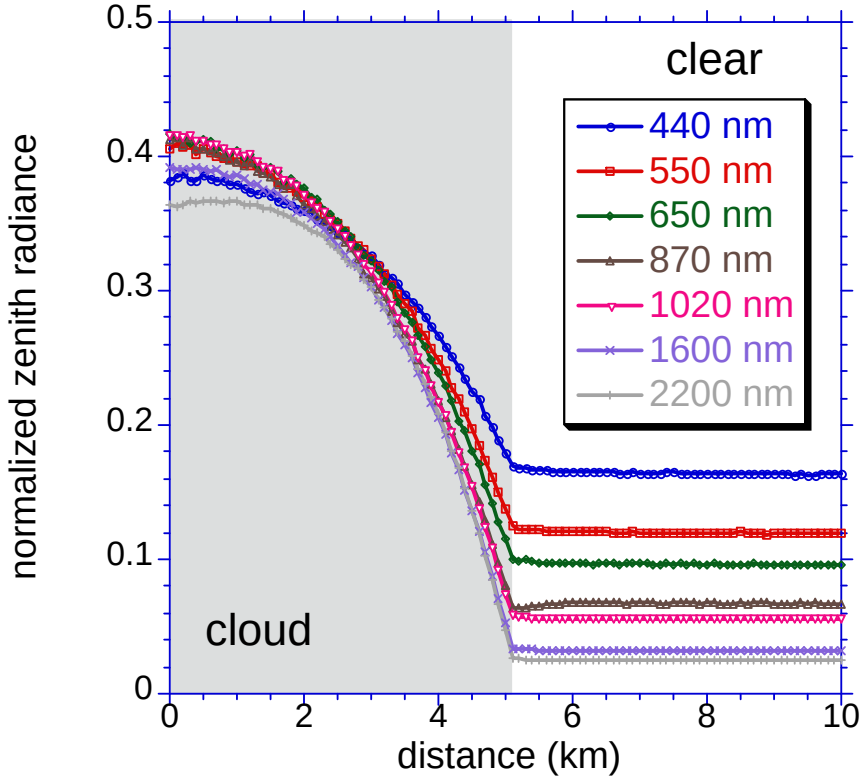


A simple 3D RT experiment

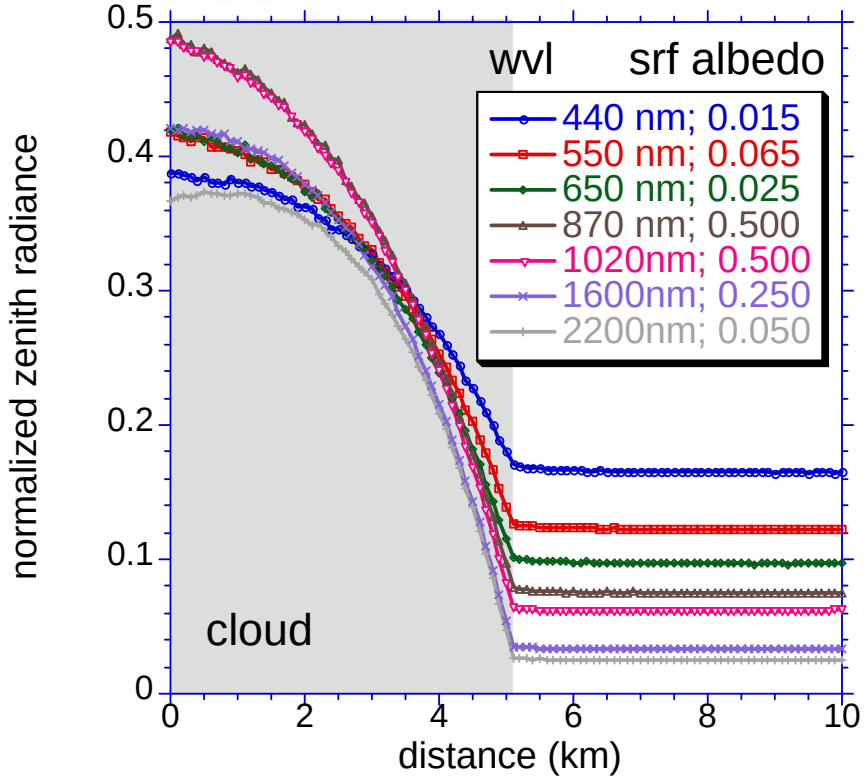


Courtesy of T. Zinner (DLR)

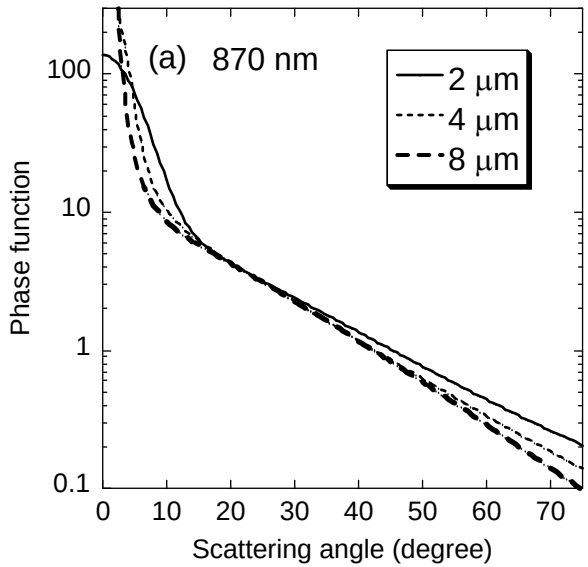
black surface

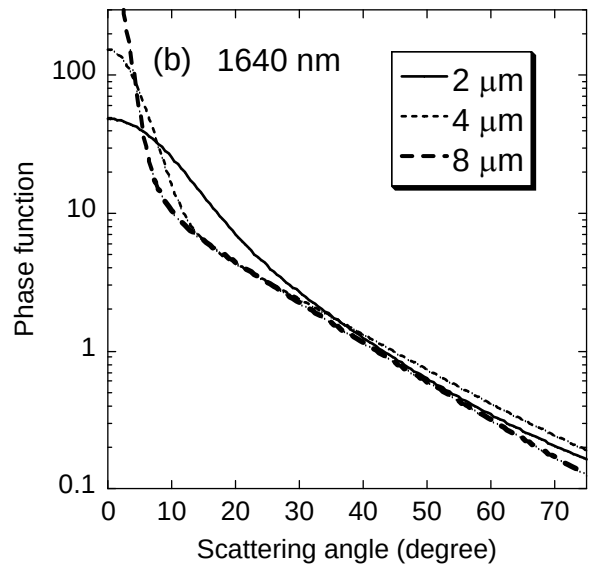


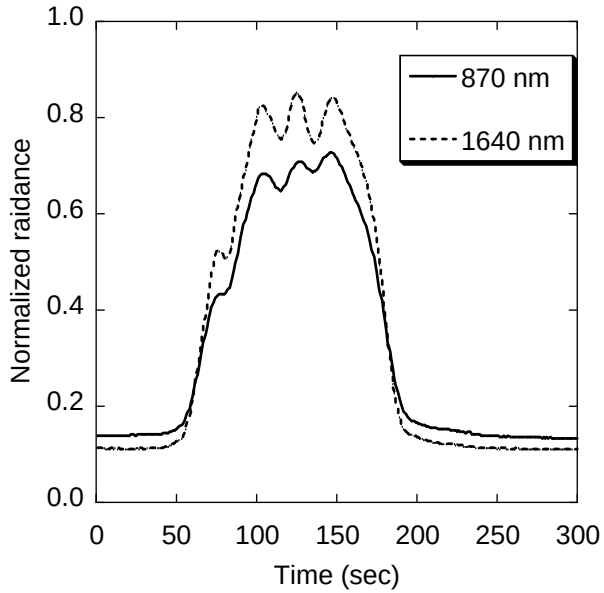
vegetated surface

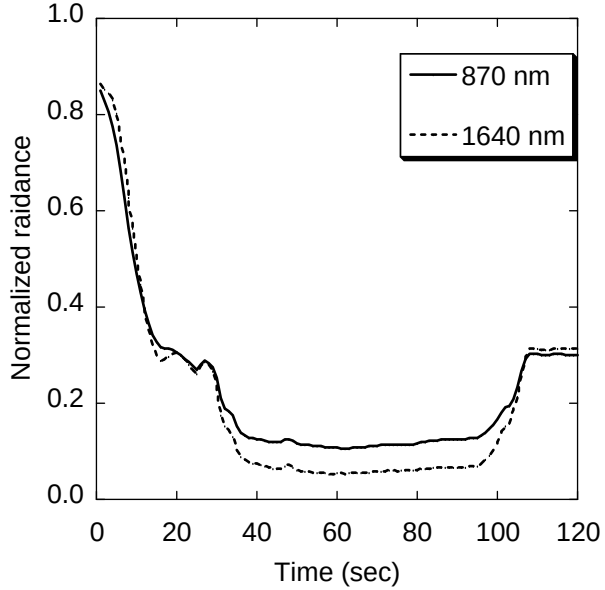


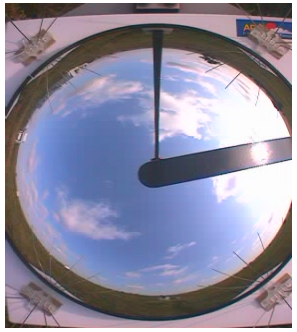
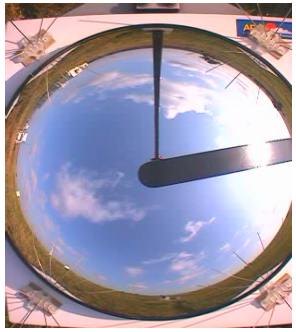
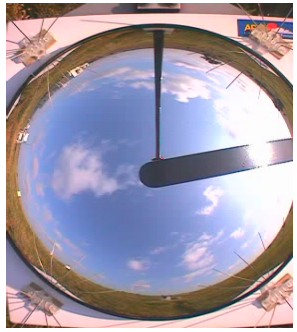
Mie phase function





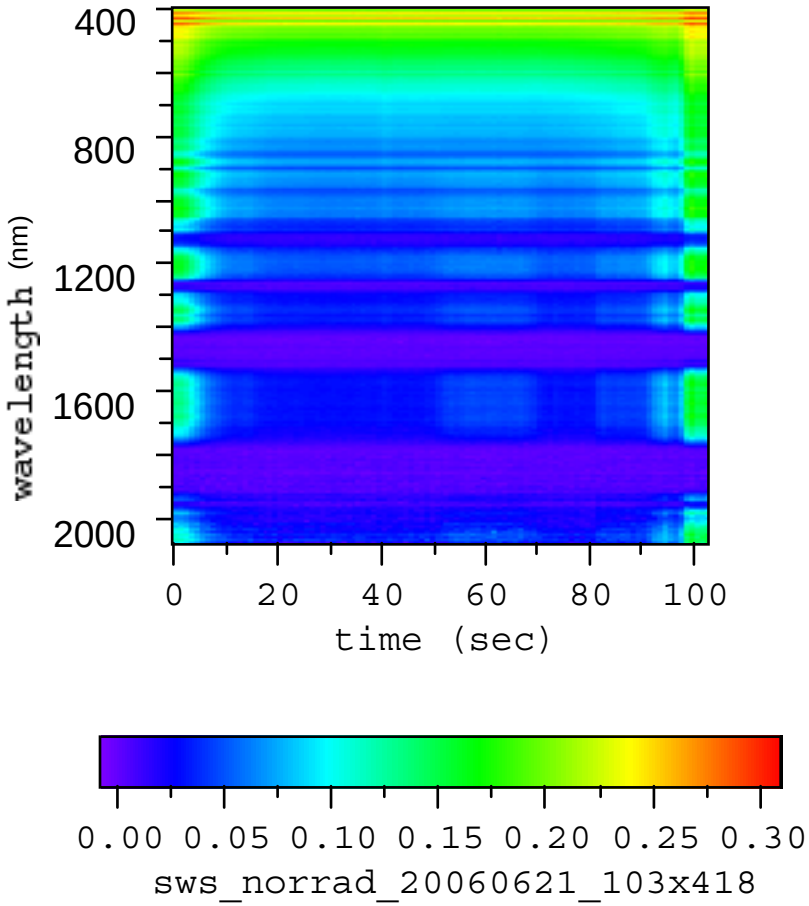


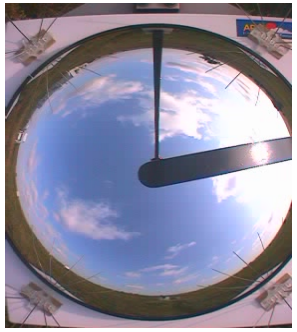
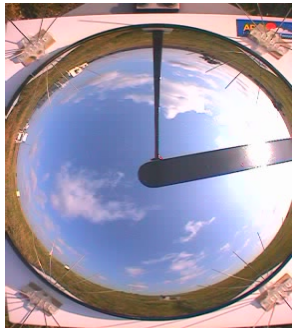
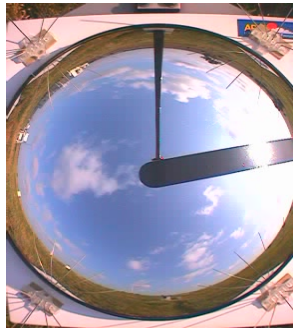


June 21, 2006

SZA=62.5^{o}



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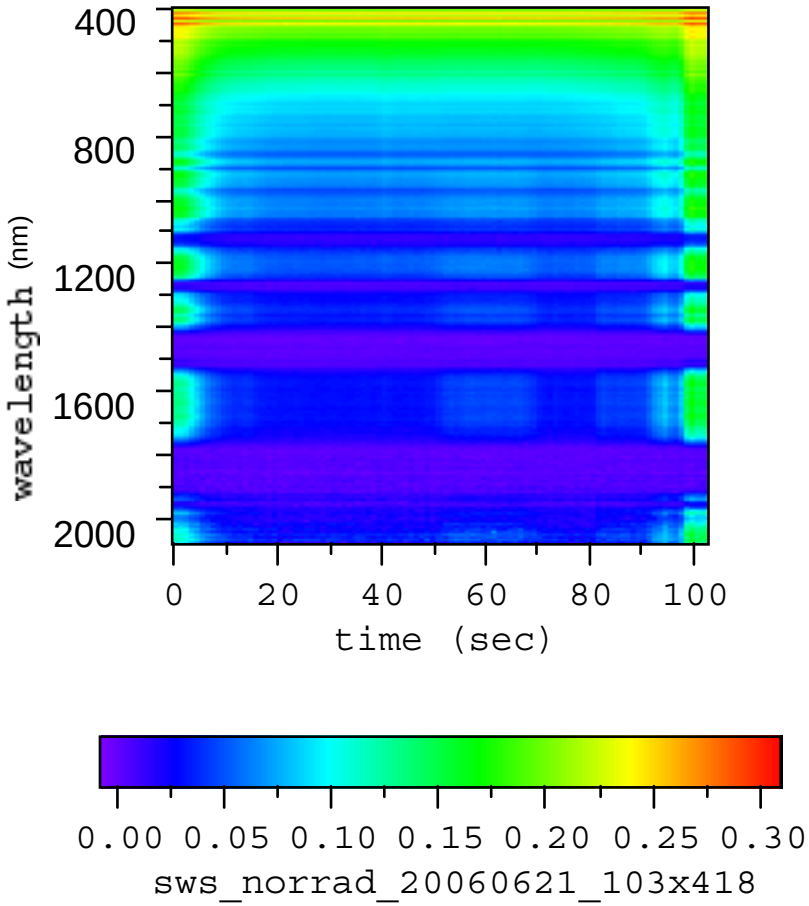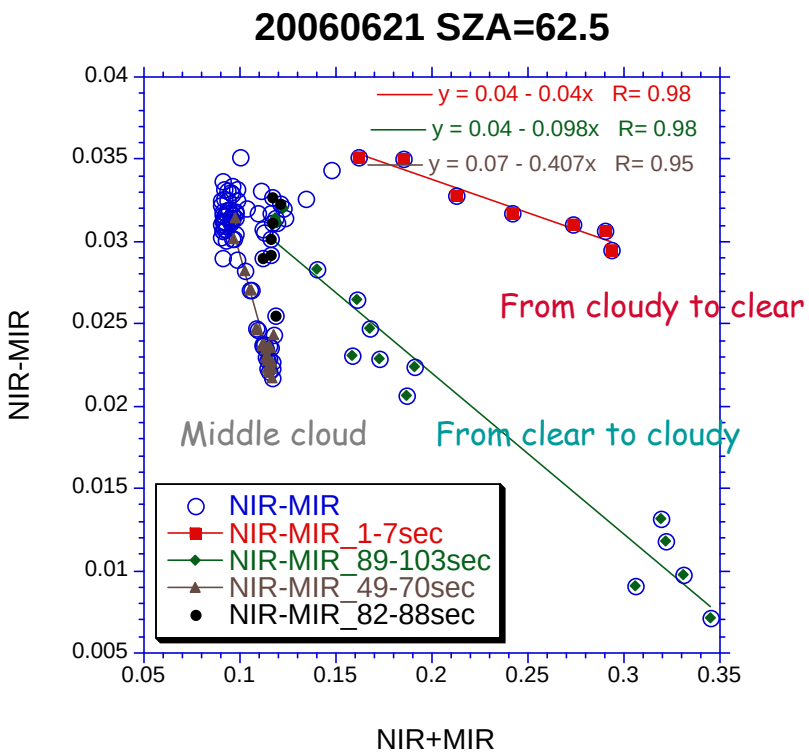
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