ARM Shortwave Spectrometer (SWS) to study the cloud-clear transition

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Background

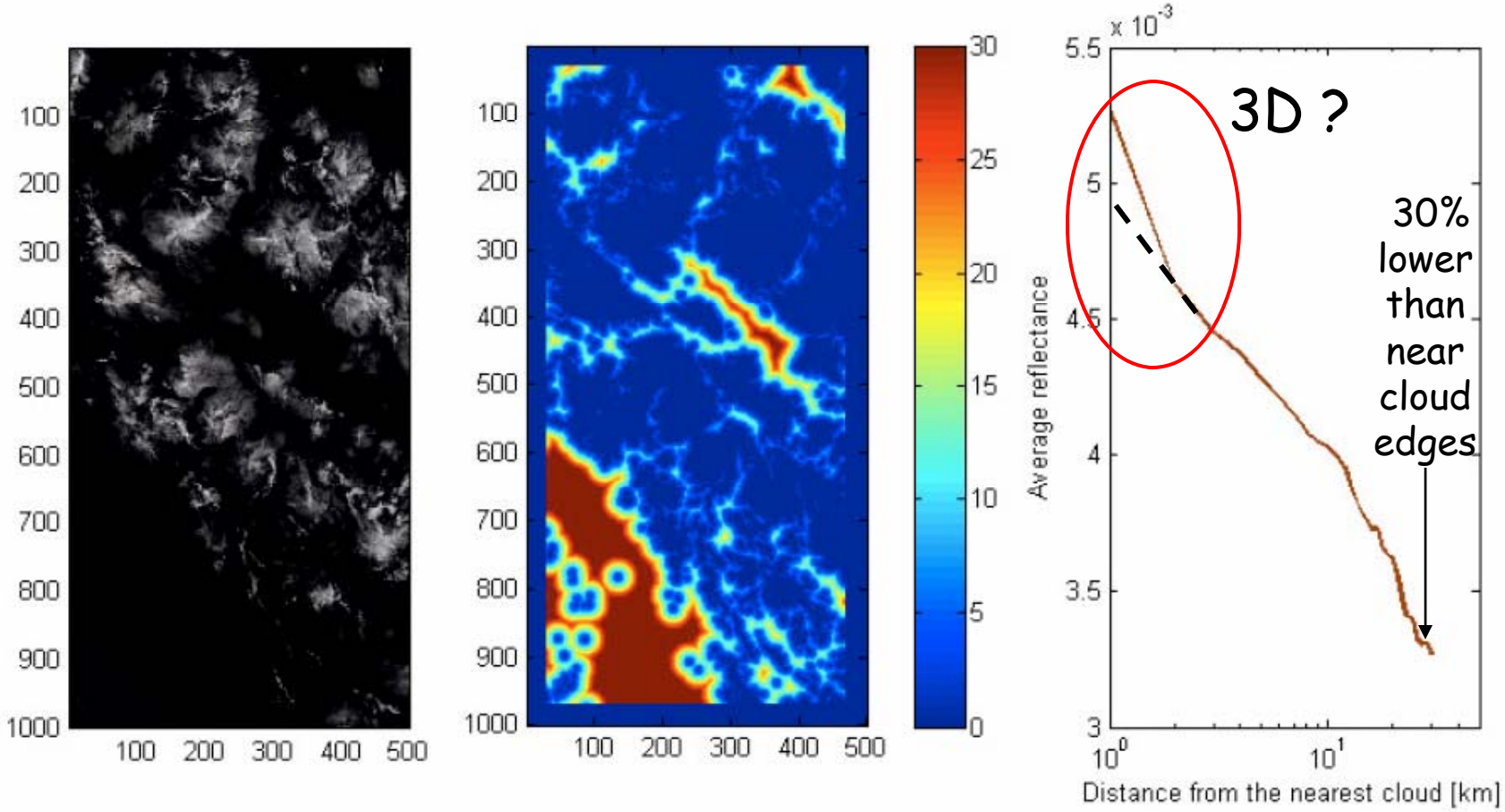
•It is difficult to distinguish between cloudy and cloud free air in remote sensing observations.

•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 (often stretching out 10's of km) are neither precisely clear nor precisely cloudy. Koren et al. (2007) called them the 'twilight zone."

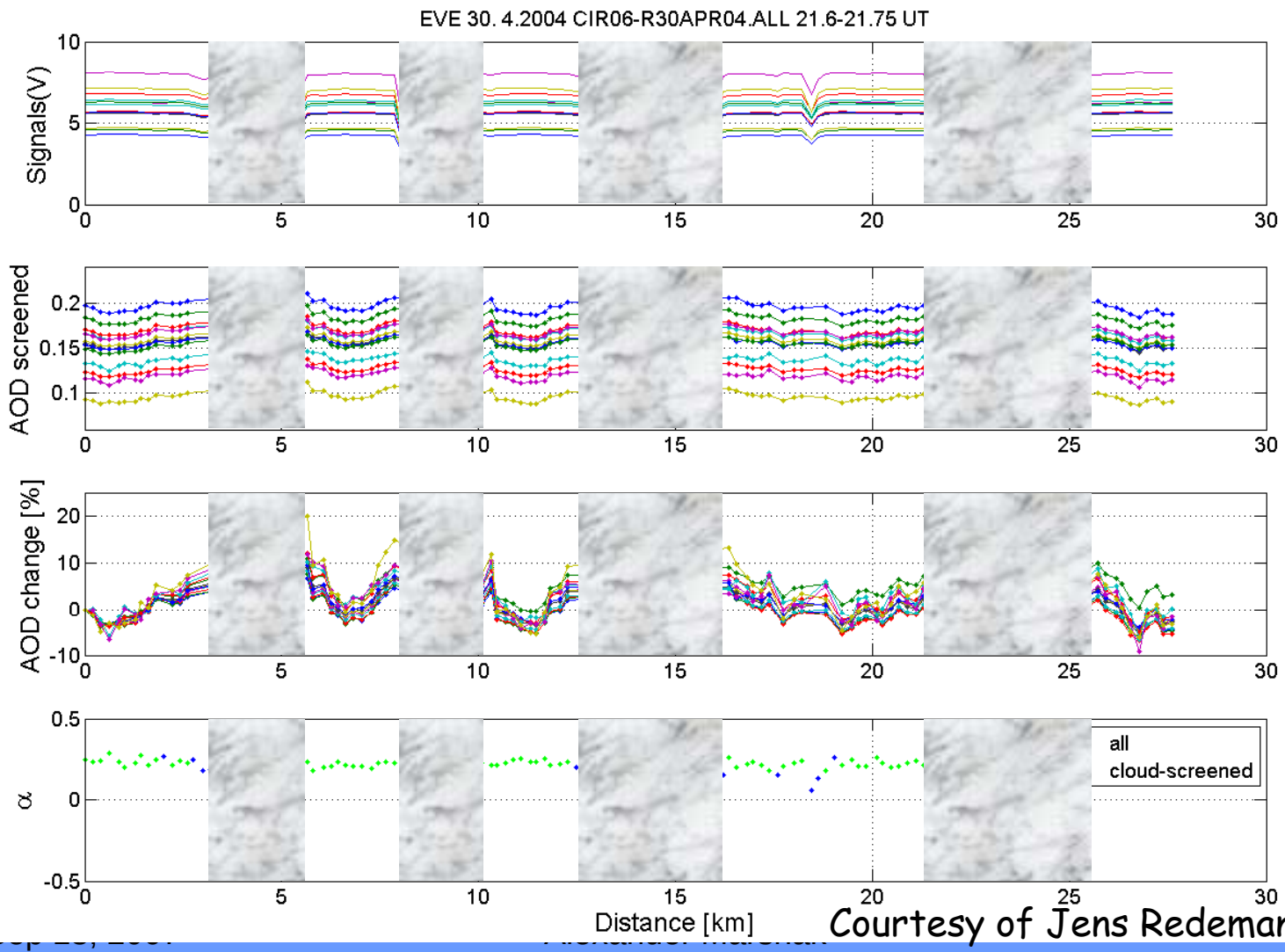
MODIS radiance near clouds

Cumulus clouds over Atlantics



Courtesy of Ilan Koren
(Koren et al., 2007)

Airborne aerosol observations in the vicinity of clouds



Courtesy of Jens Redemann

ARM Shortwave Spectrometer (SWS)

Spectral measurements with the SWS provide an excellent laboratory to study the cloud-clear transition.

ARM Shortwave Spectroradiometer

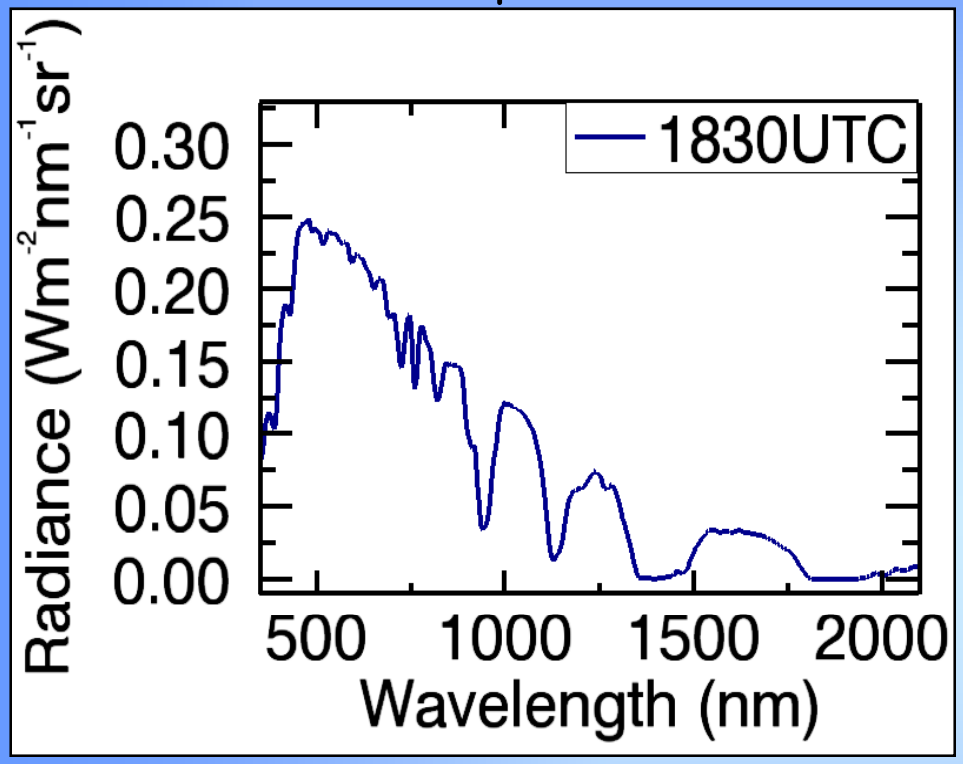
The SWS measures zenith sky spectral radiance from the near UV through near IR spectral range. It was deployed at the SGP Central facility on 4/27/06. Measurements are taken daily from 11:00-02:00 UTC.

- Spectral Range: 380-2200nm
- Spectral Resolution
  - 380-970 nm: 8nm
  - 970-2200 nm: 12nm
- Spectral Sampling rate: 1Hz
- 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

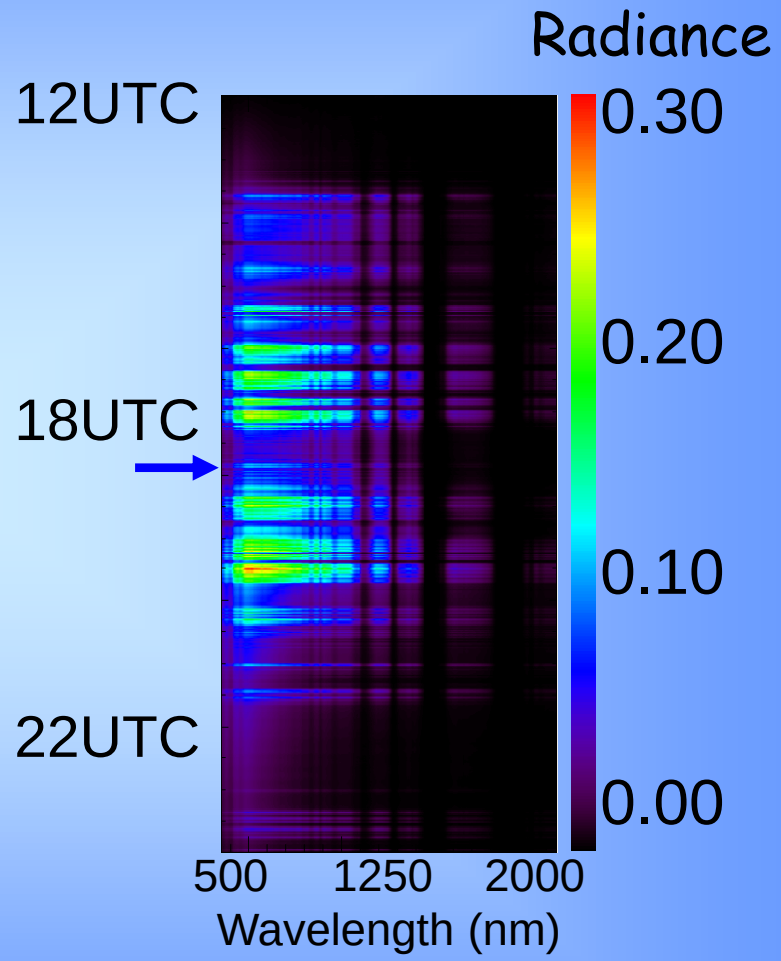
(from Pilewskie's presentation at the ARM STM)

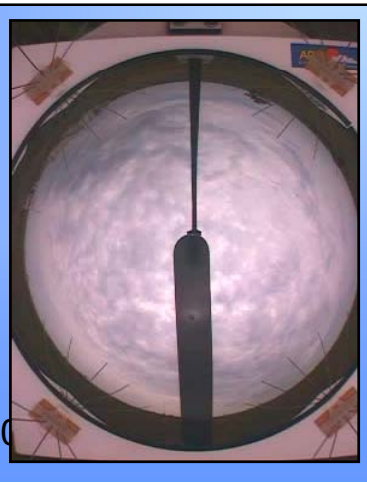
8/31/2006 1830 UTC : Alto cumulus

SWS Spectrum



SWS full-day image

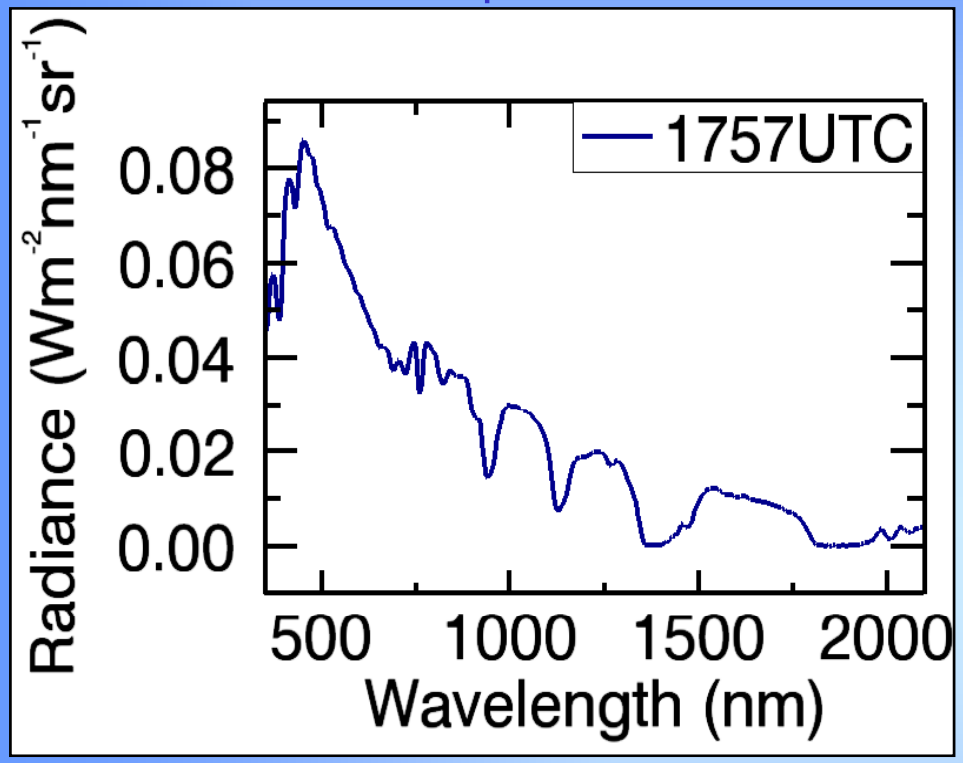




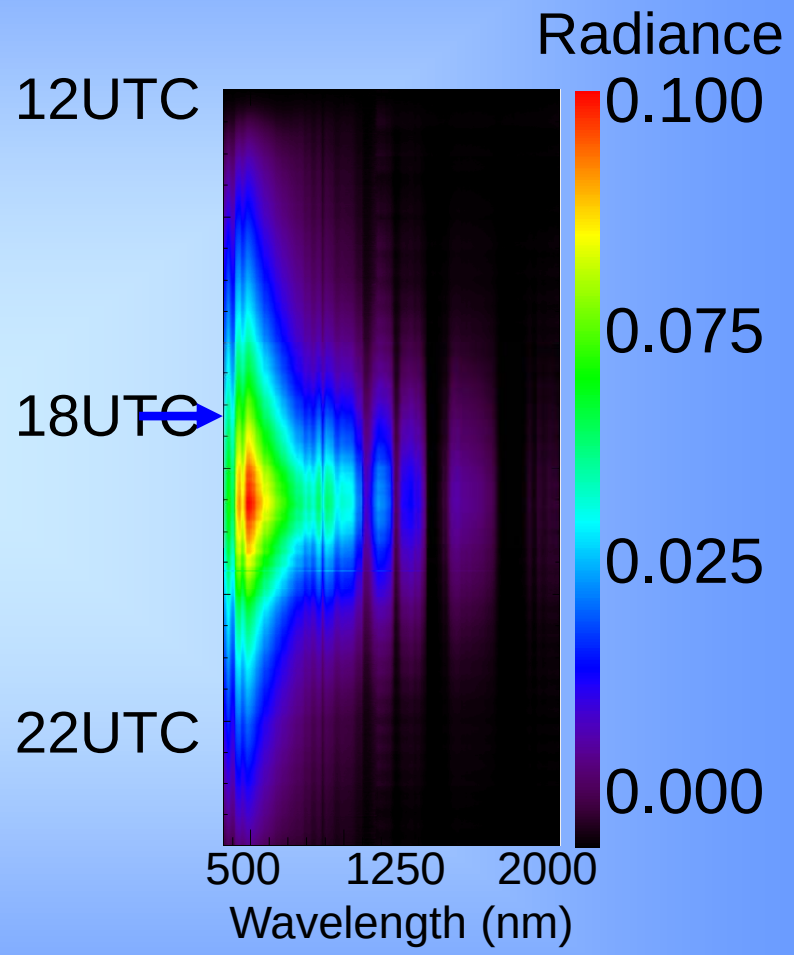
(from Pilewskie's presentation at the ARM STM)

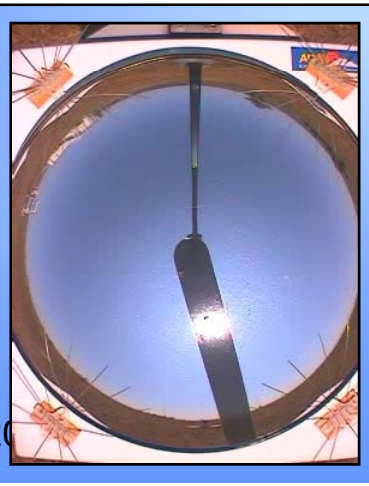
9/13/2006 17:57 UTC : Cloud-free

SWS Spectrum



SWS full-day image





(from Pilewskie's presentation at the ARM STM)

SWS measurements June 27 2006
SZA=14°

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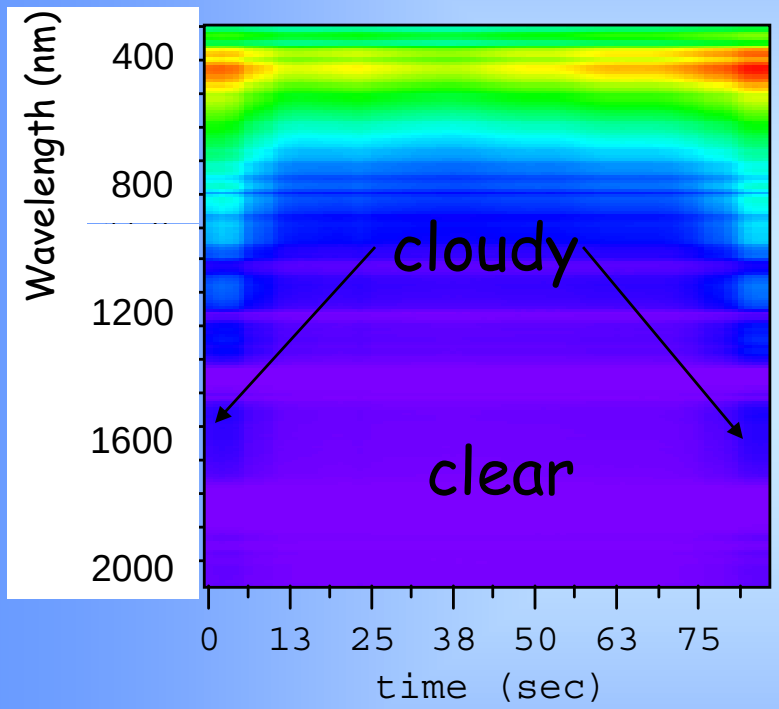
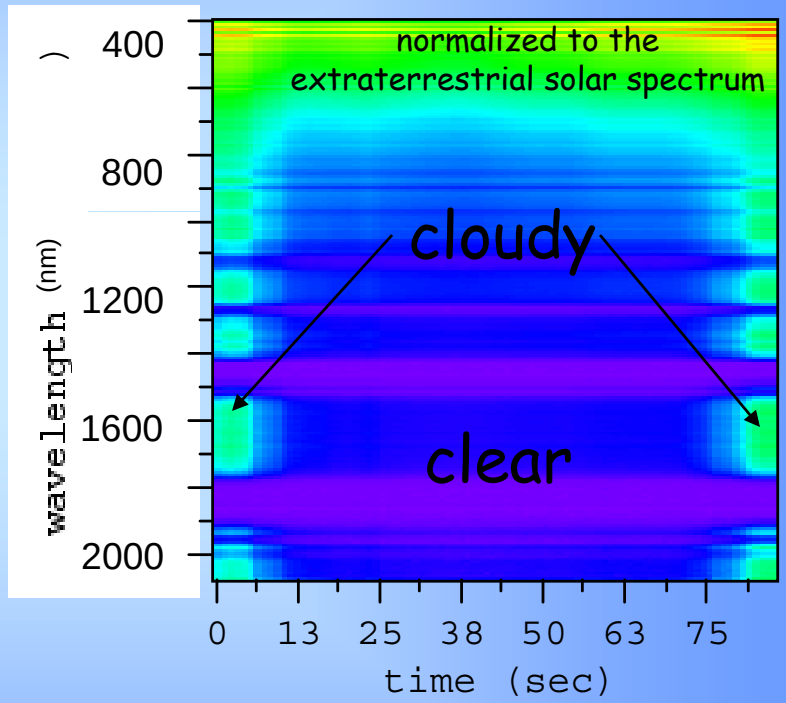
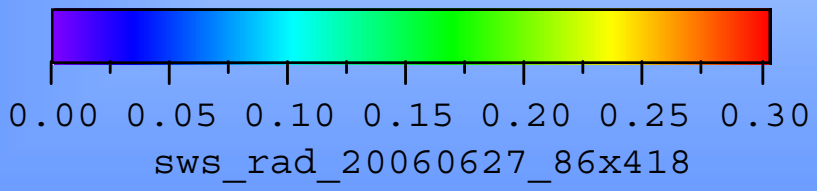
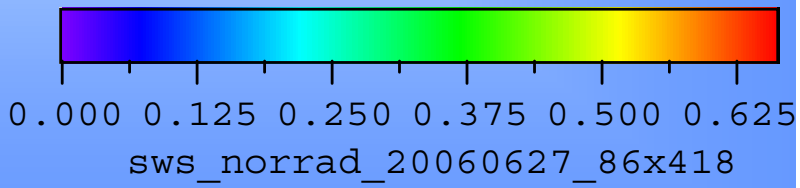
SZA=14°

SWS measurements June 27 2006 SZA=14°

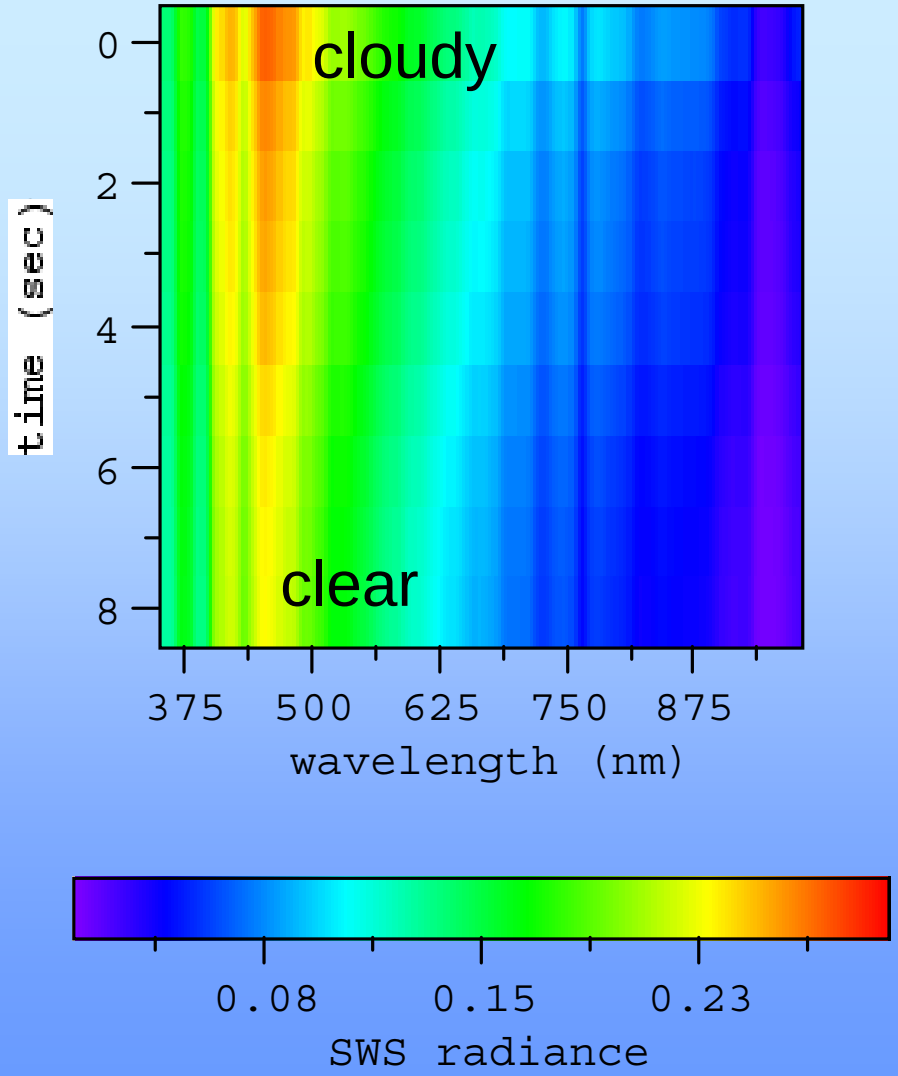

Wavelength (nm)
400
800
1200
1600
2000
cloudy
clear
0 13 25 38 50 63 75
time (sec)


normalized to the
extraterrestrial solar spectrum
wavelength (nm)
400
800
1200
1600
2000
cloudy
clear
0 13 25 38 50 63 75
time (sec)

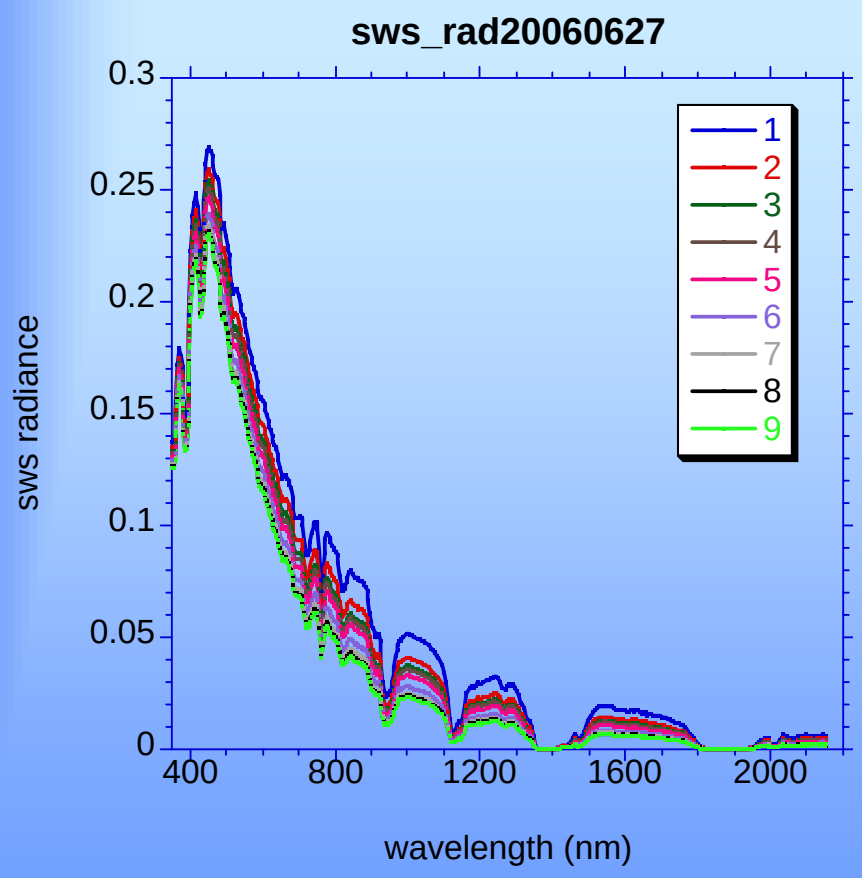

0.00 0.05 0.10 0.15 0.20 0.25 0.30
sws_rad_20060627_86x418

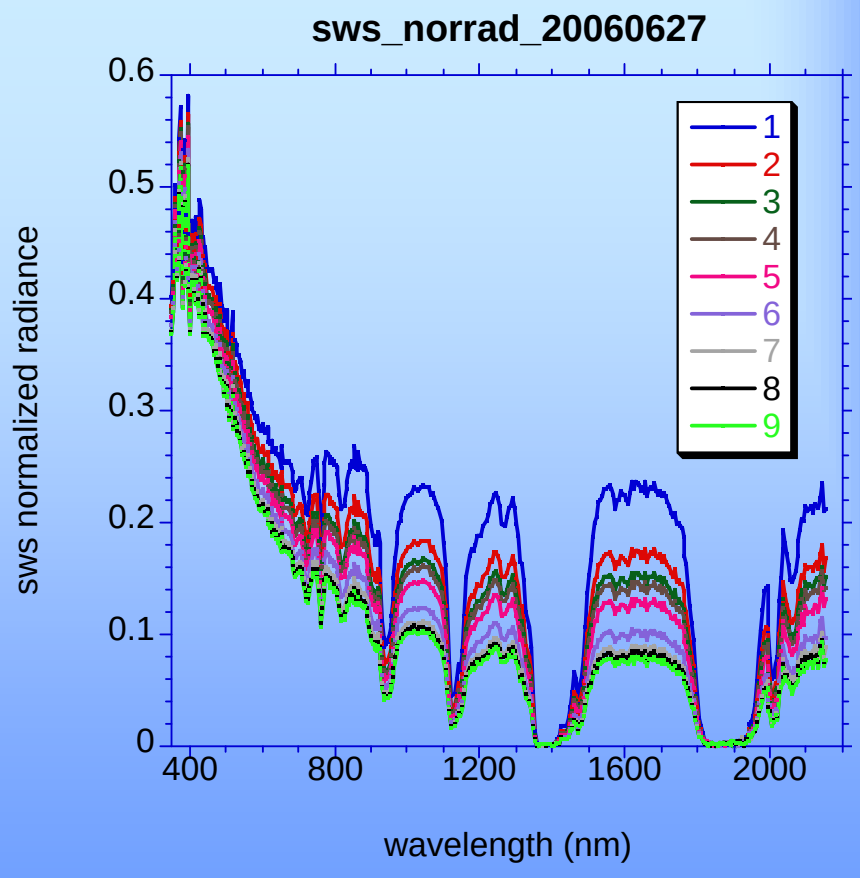

0.000 0.125 0.250 0.375 0.500 0.625
sws_norrad_20060627_86x418

First 9 seconds between cloudy and clear

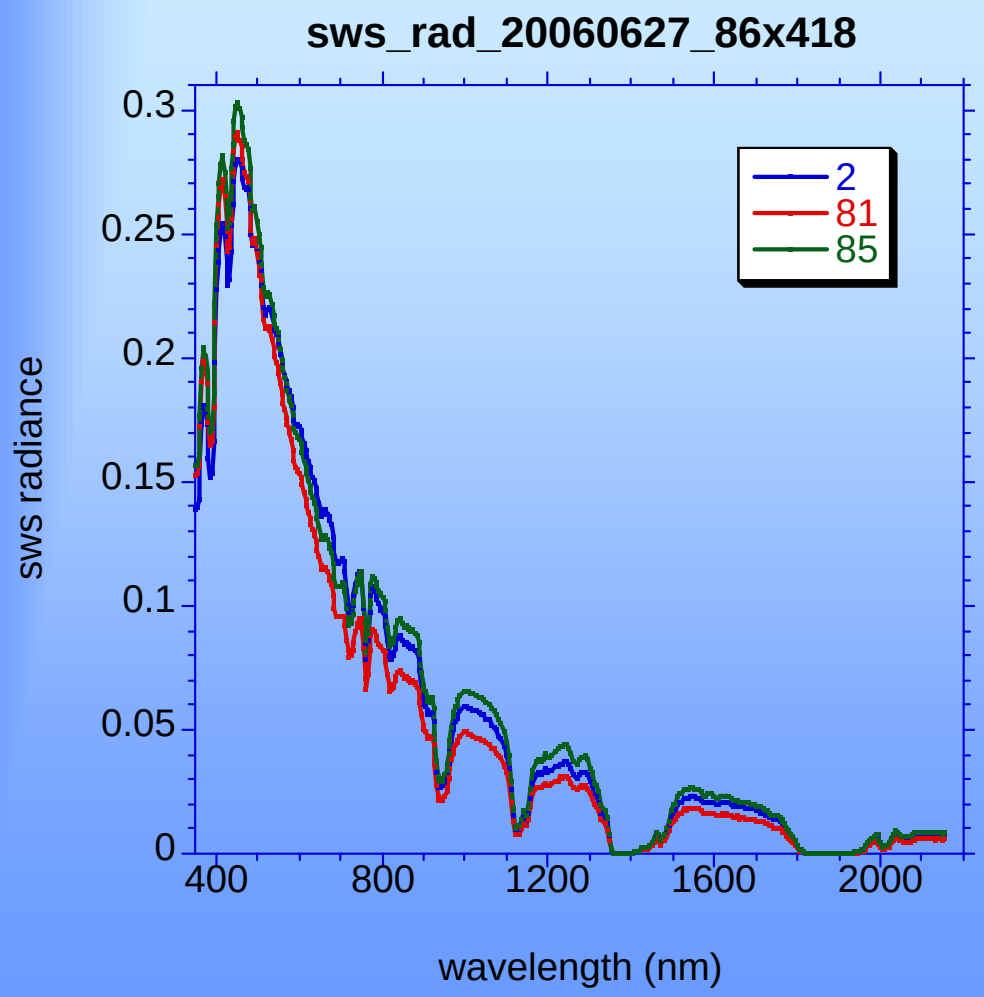


First 9 seconds between cloudy and clear

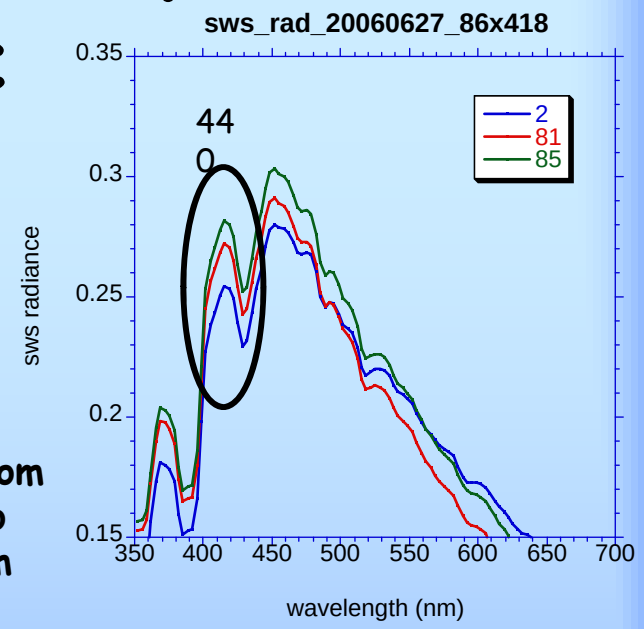




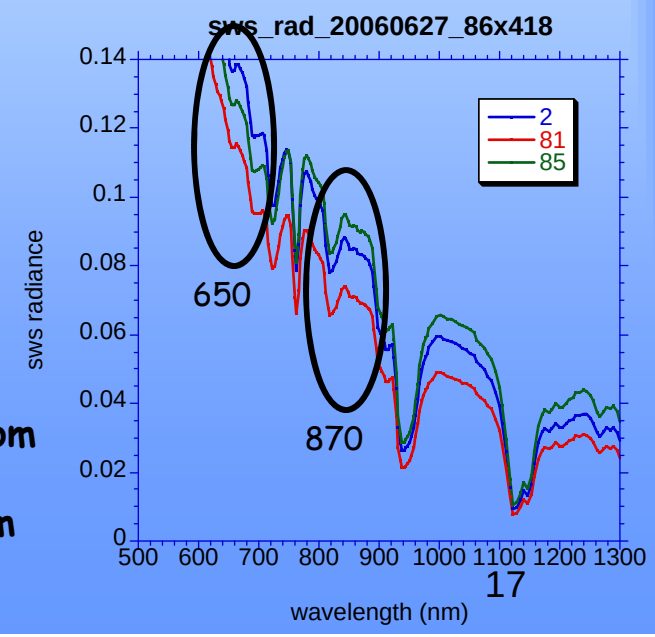
Two different clouds separated by 80 sec



Zoom from 350 to 700 nm

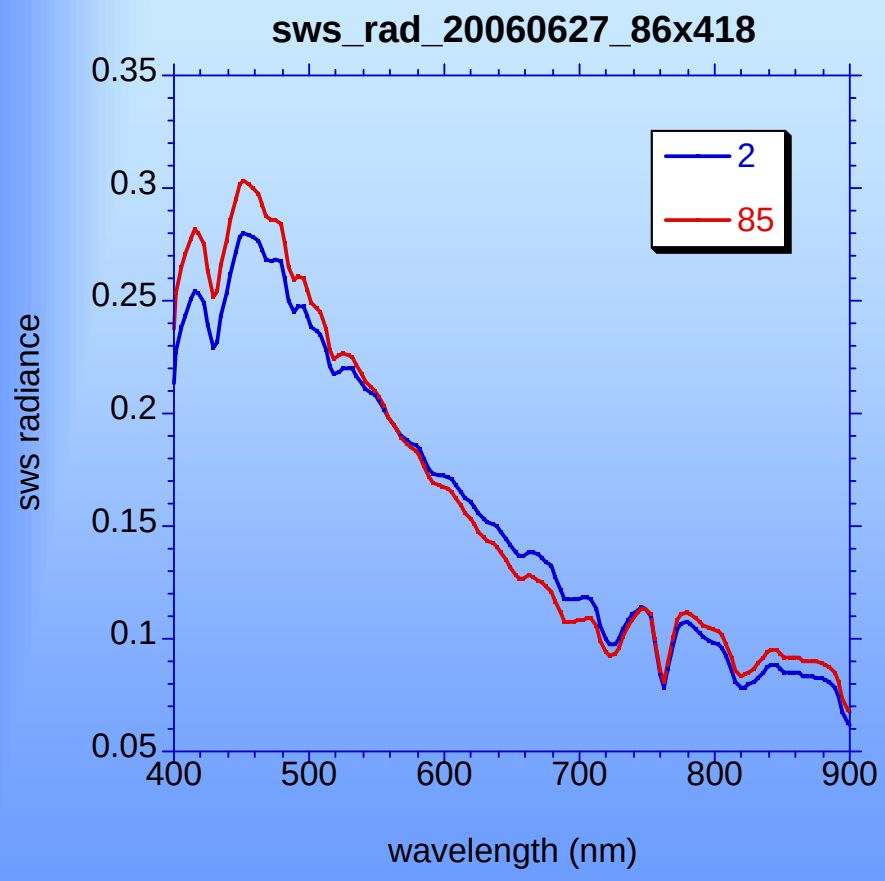


Zoom from 500 to 1300 nm

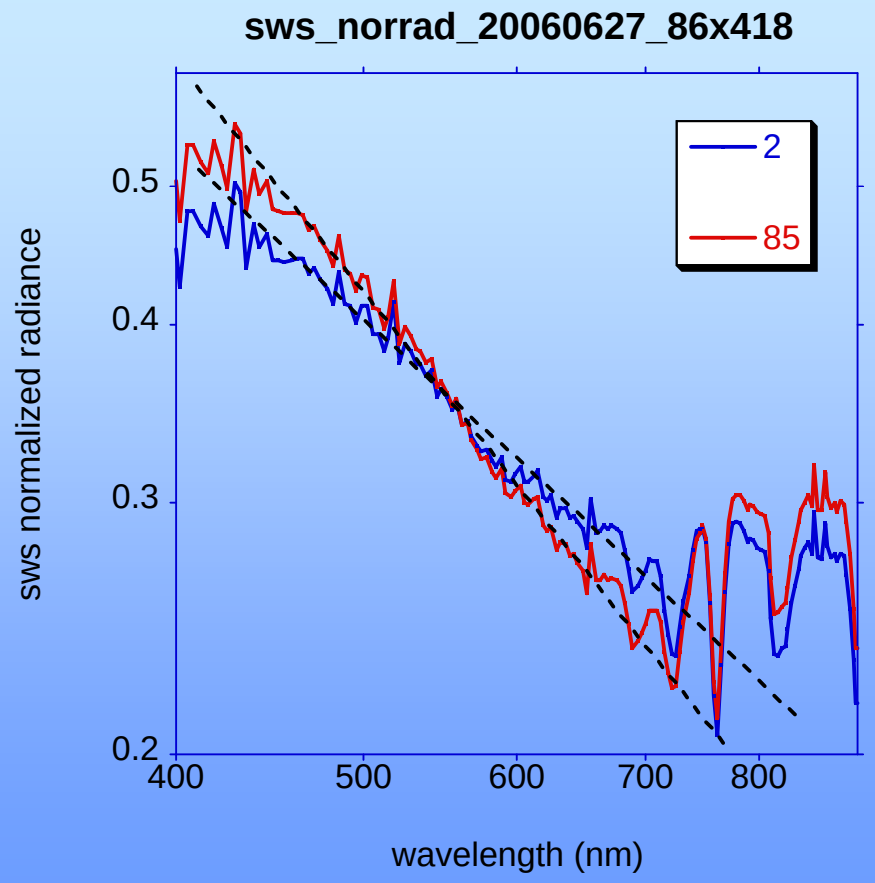


Two different clouds separated by 80 sec

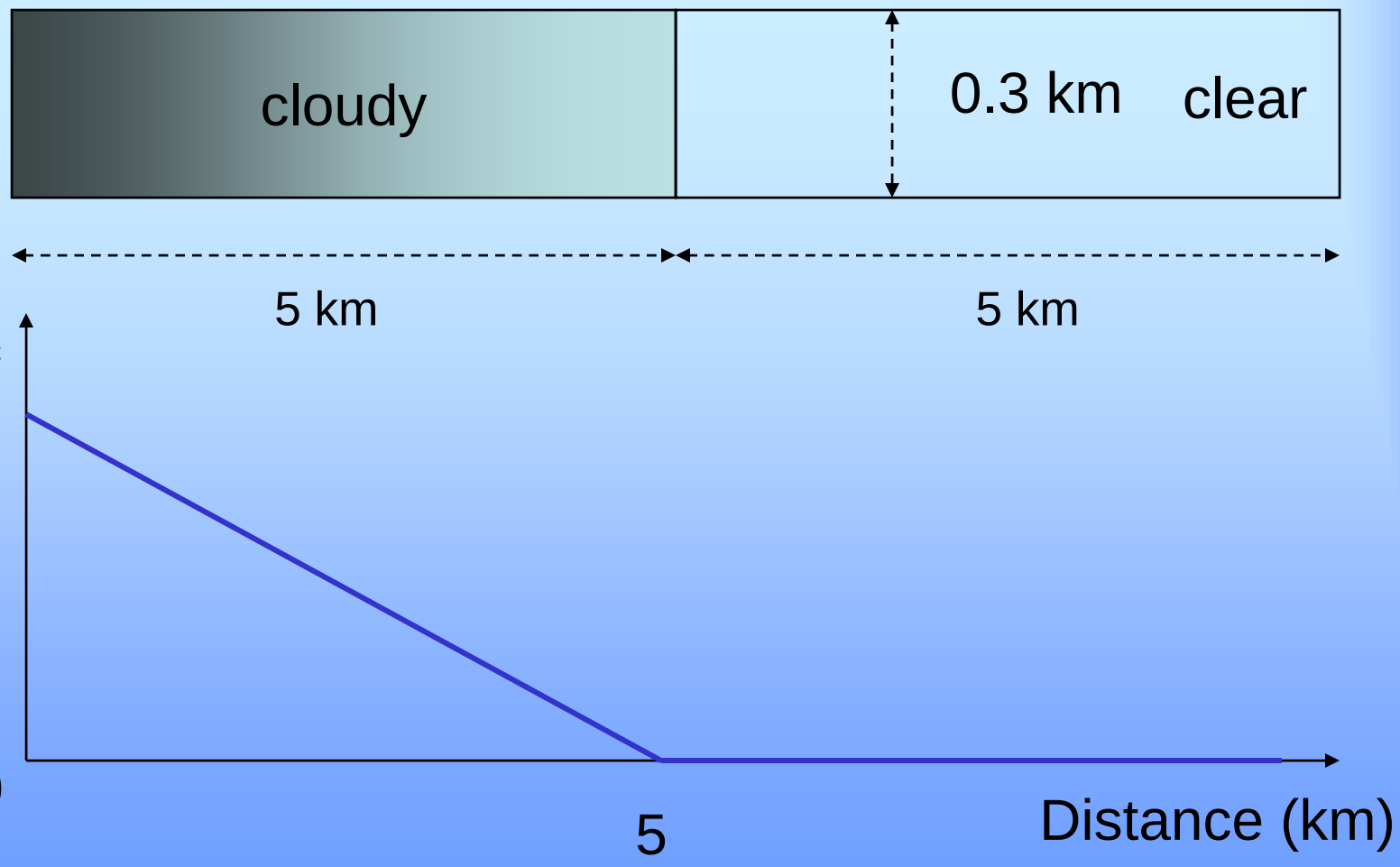
Non-normalized radiance



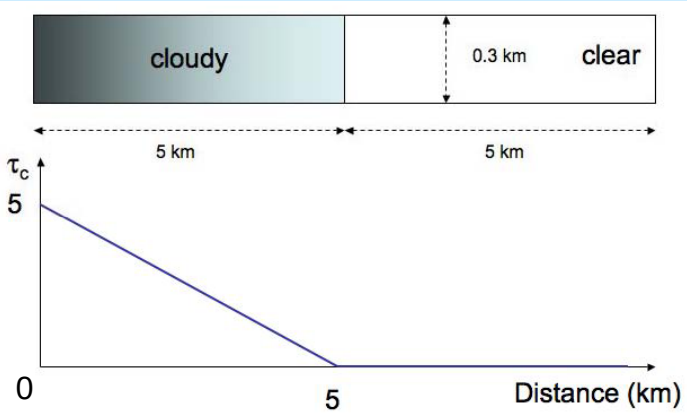
Normalized radiance



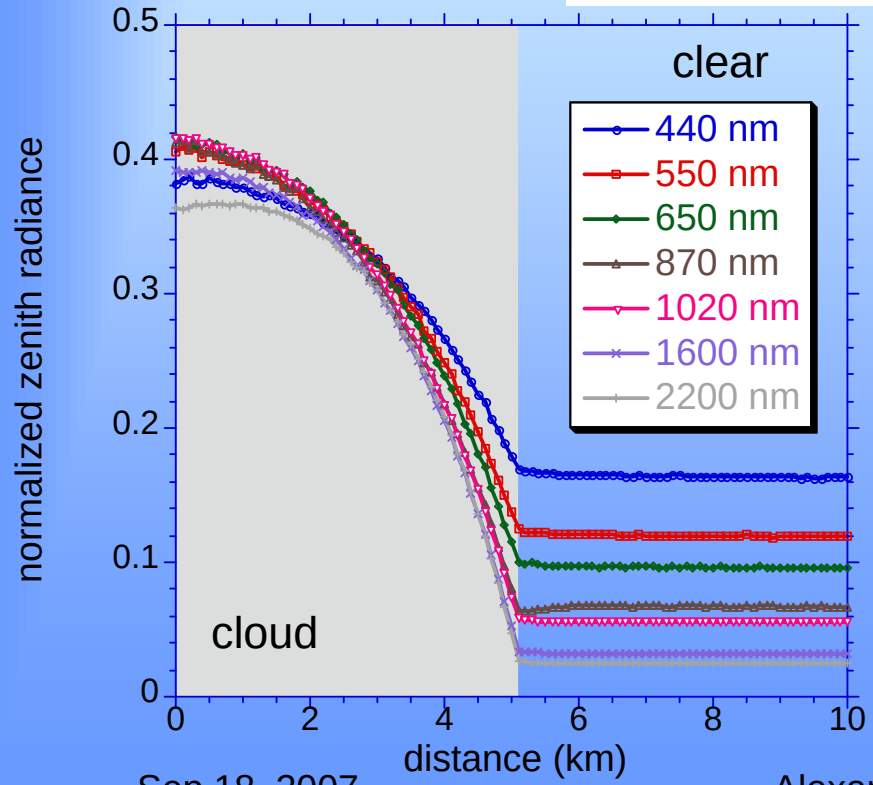
A simple 3D RT experiment



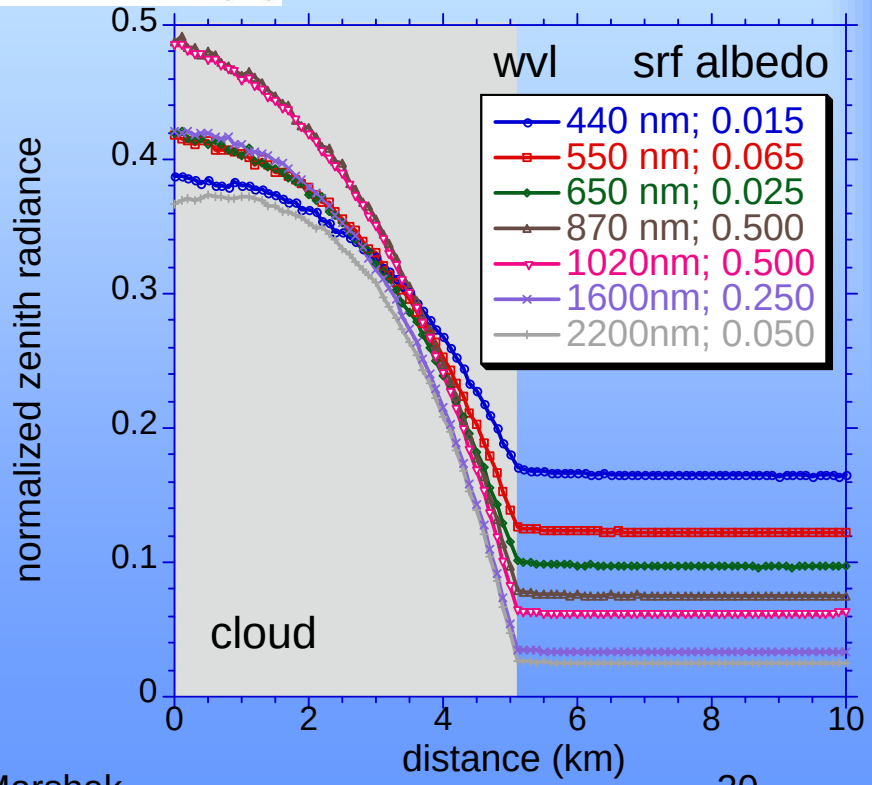
A simple 3D RT experiment



black surface



vegetated surface



Spectral inequalities

Four common cases (just from DISORT):

1. I_440 > I_673 > I_870 — clear sky or $\tau < 0.2$
2. I_440 > I_870 > I_673 — $0.2 < \tau < \sim 1.5$
3. I_870 > I_440 > I_673 — $\sim 1.5 < \tau < \sim 2.5$ OR $\tau > \sim 55$
4. I_870 > I_673 > I_440 — $\sim 2.5 < \tau < \sim 55$

Two impossible orders:

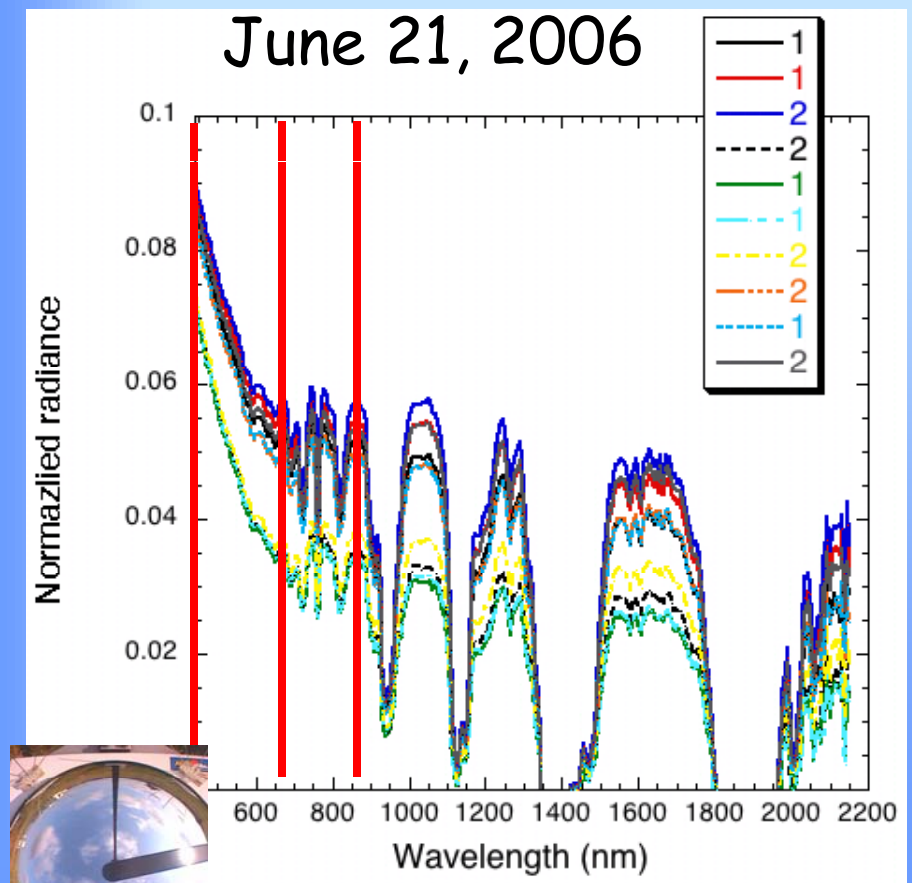
5. I_673 > I_440 > I_870

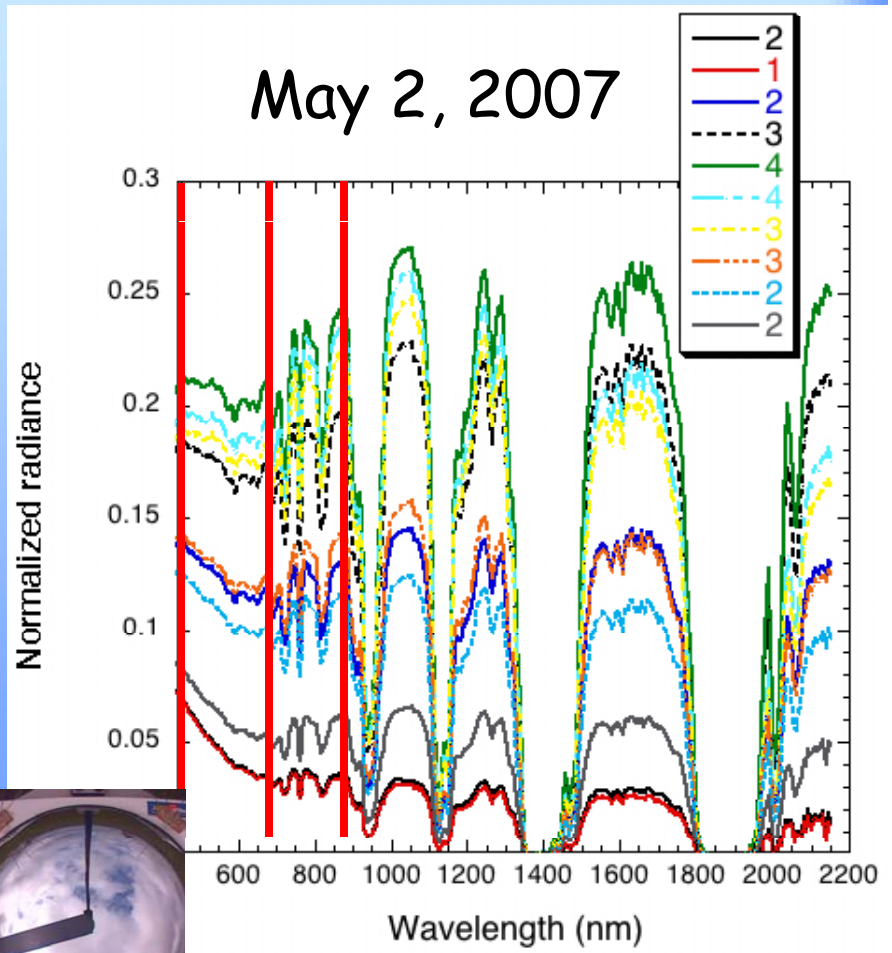
and

6. I_673 > I_870 > I_440.

Spectral inequalities: examples from SWS

1: I_440 > I_673 > I_870 clear sky or $\tau < 0.2$
2: I_440 > I_870 > I_673 $0.2 < \tau < \sim 1.5$
3: I_870 > I_440 > I_673 $\sim 1.5 < \tau < \sim 2.5$ OR $\tau > \sim 55$
4: I_870 > I_673 > I_440 $\sim 2.5 < \tau < \sim 55$





Summary

Before summary (next slide) show the movie,
if time permits

Summary

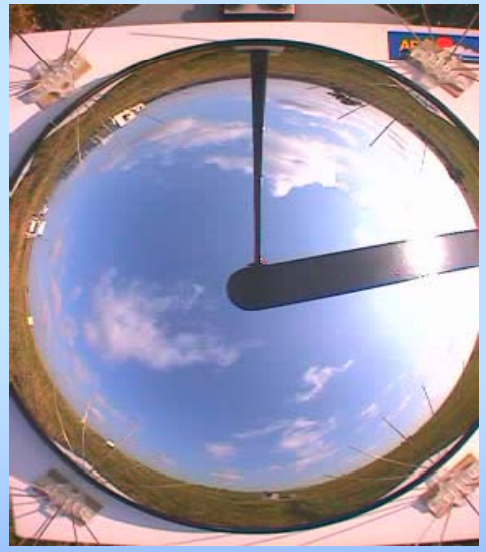
- SWS spectral measurements is an excellent lab. to study the cloud-clear transition.

- Cloud 3D structure and variability in cloud properties around cloud edges alone can explain many observed features of the cloud-clear transition; don't rush to add unknown aerosols to complicate the problem.

June 21, 2006

June 21, 2006

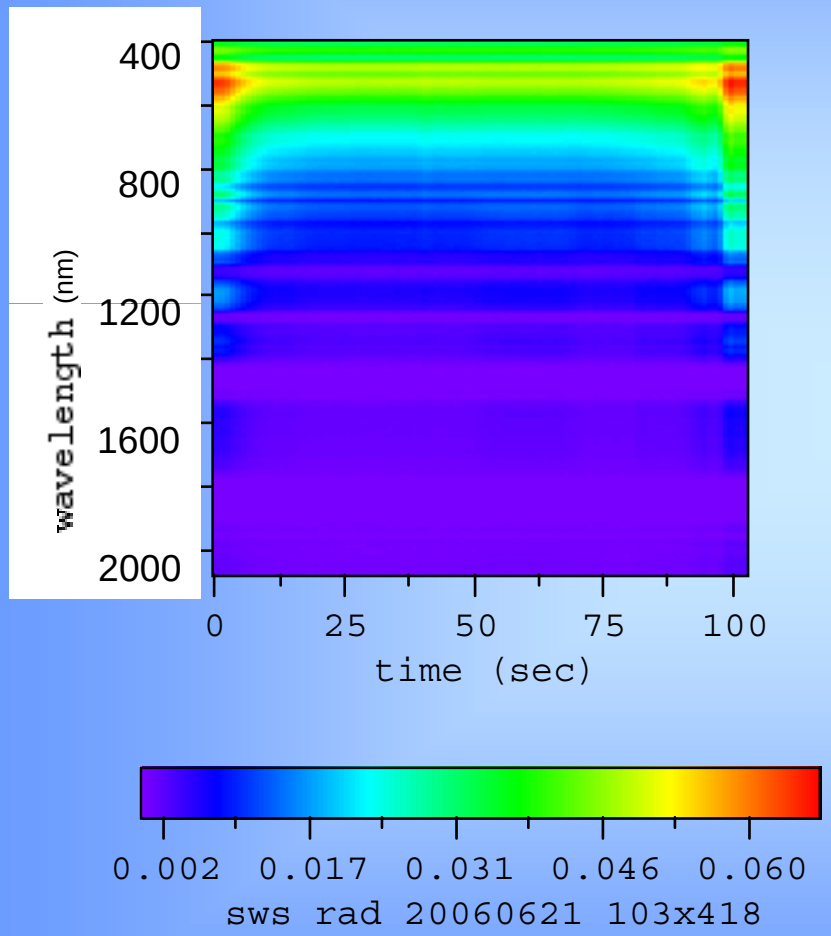
June 21, 2006



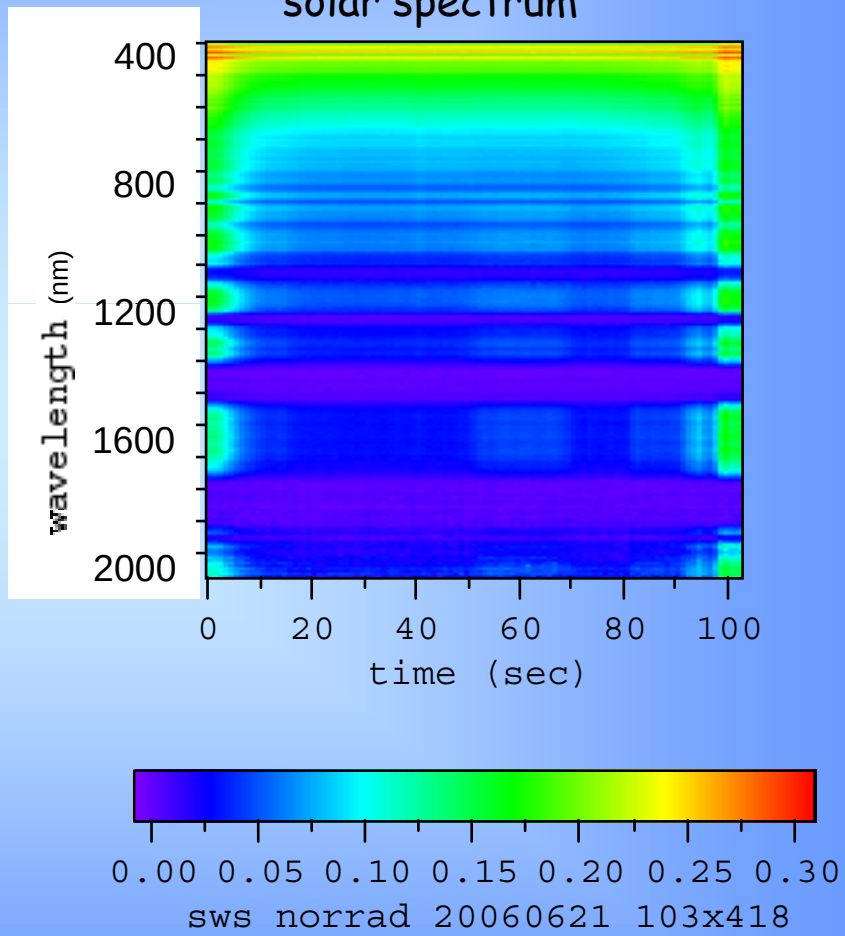
June 21, 2006

103 sec. of SWS measurements: SZA=62.5°

measured SWS data
103 sec x 418 wvls



normalized to the
extraterrestrial
solar spectrum

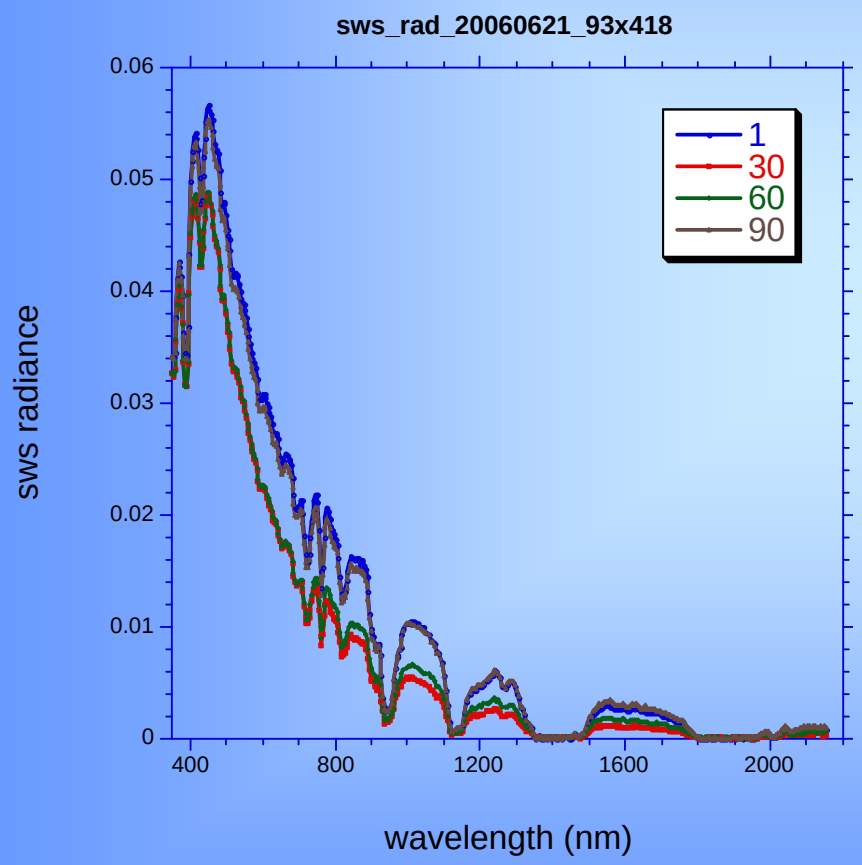


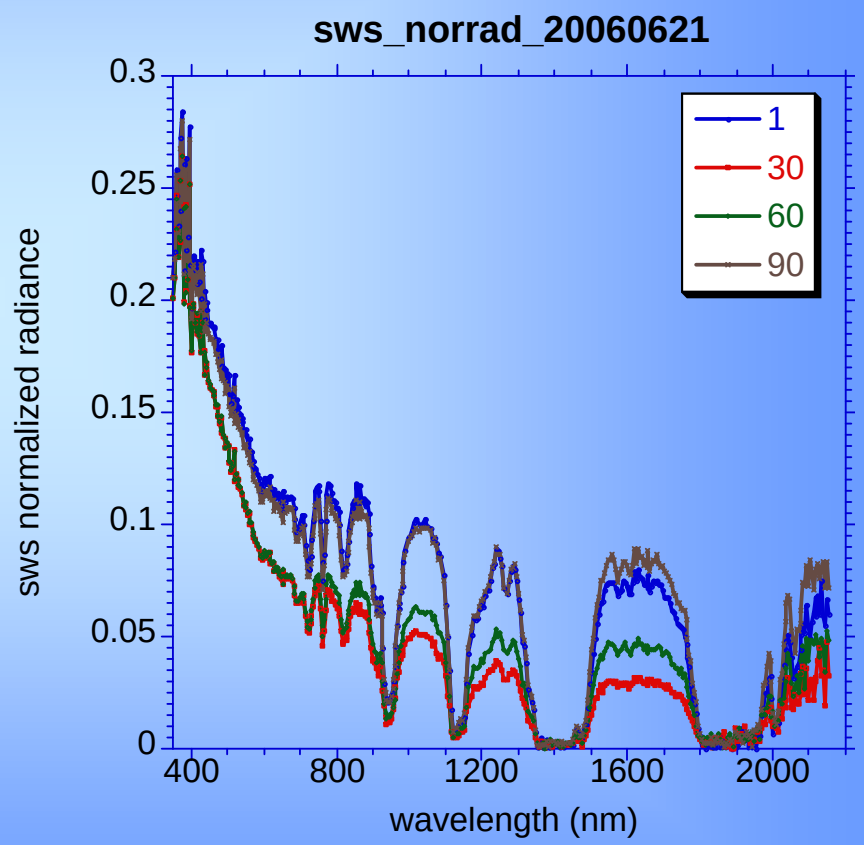
1

30

60

90

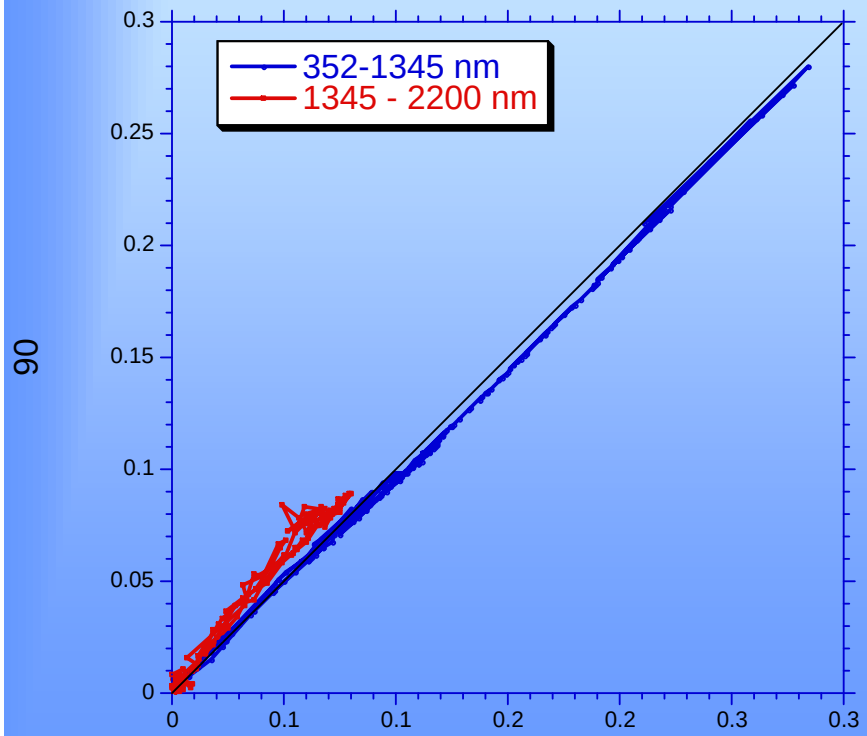

sws_rad_20060621_93x418
sws radiance
wavelength (nm)
0.06
0.05
0.04
0.03
0.02
0.01
0
400
800
1200
1600
2000
1
30
60
90

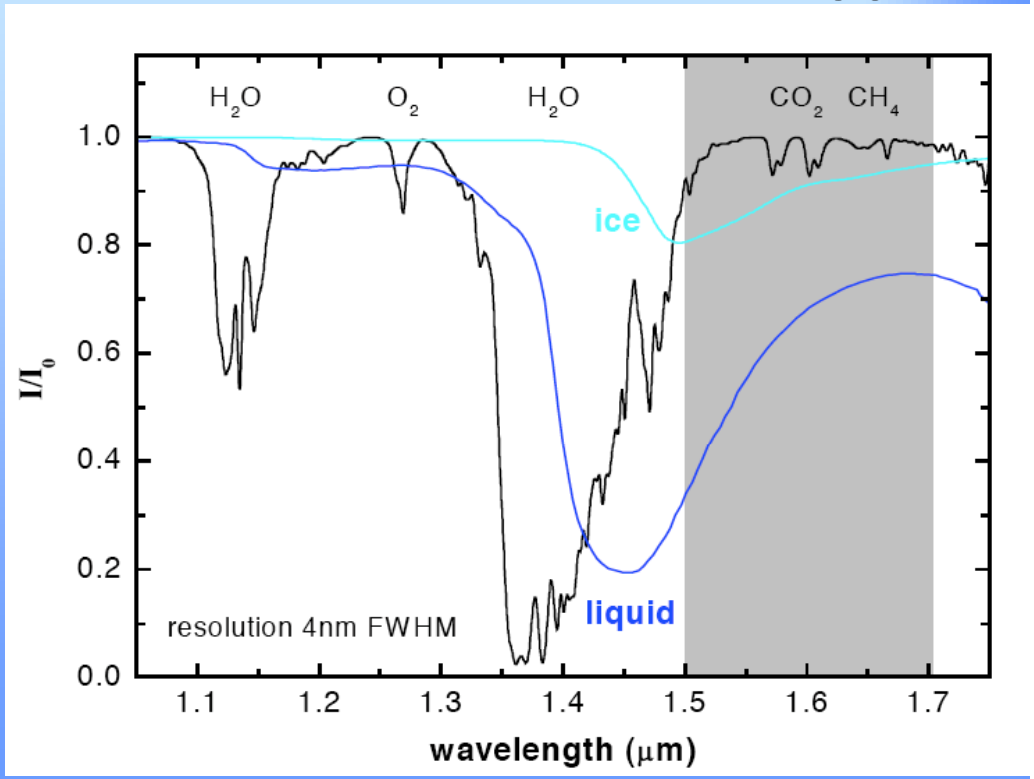

sws_norrad_20060621
sws normalized radiance
wavelength (nm)
0.3
0.25
0.2
0.15
0.1
0.05
0
400
800
1200
1600
2000
1
30
60
90

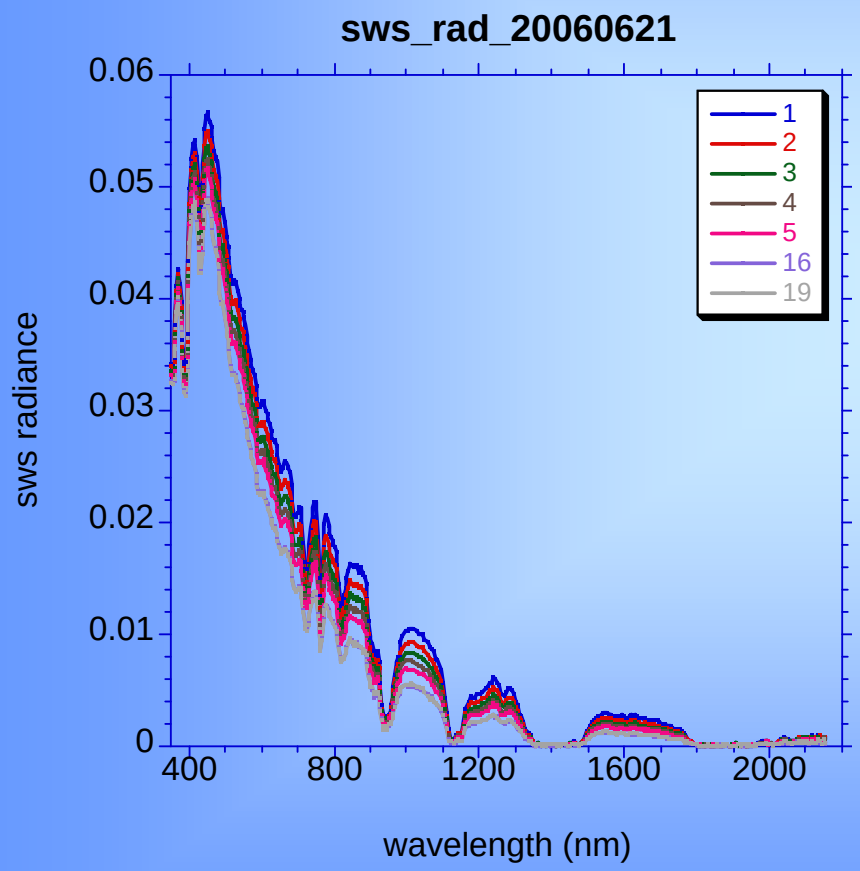
Two different clouds separated by 90 sec

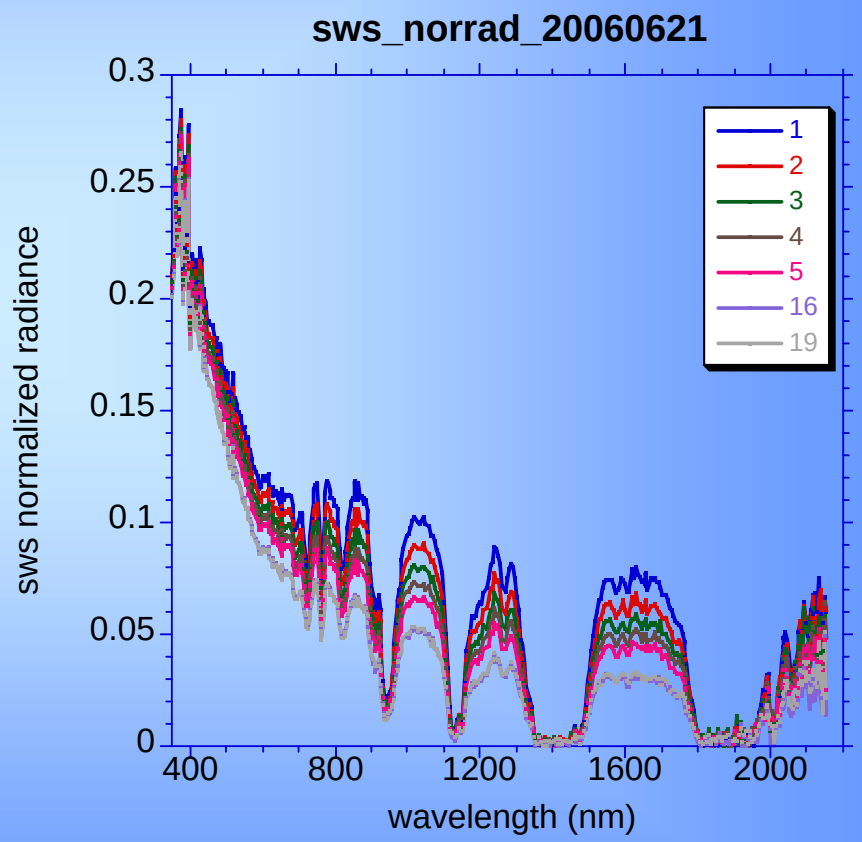
1

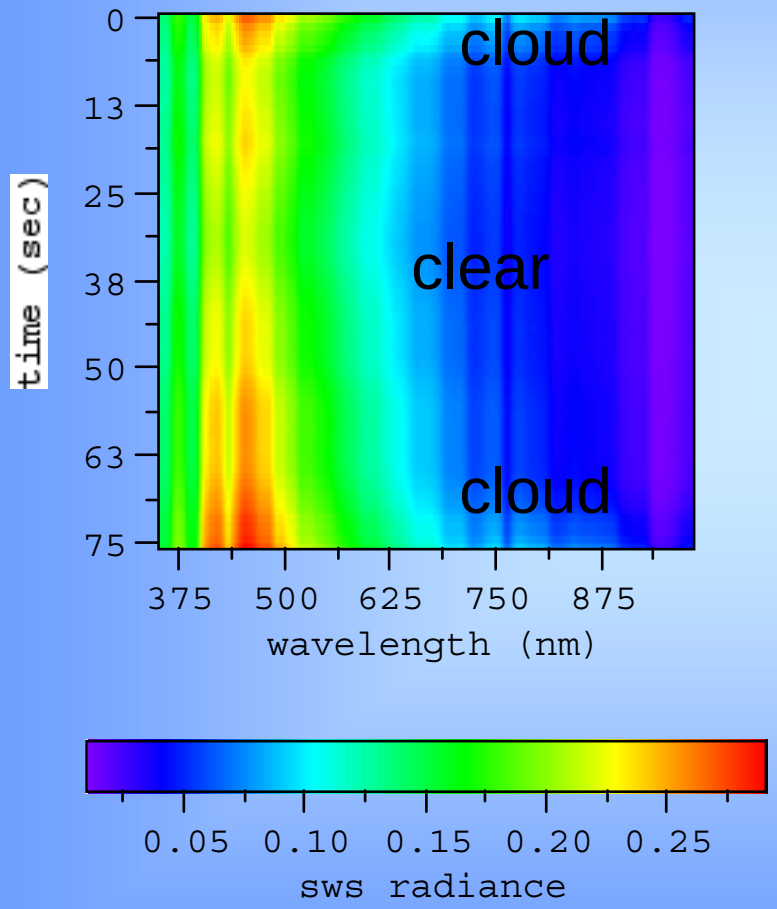
90

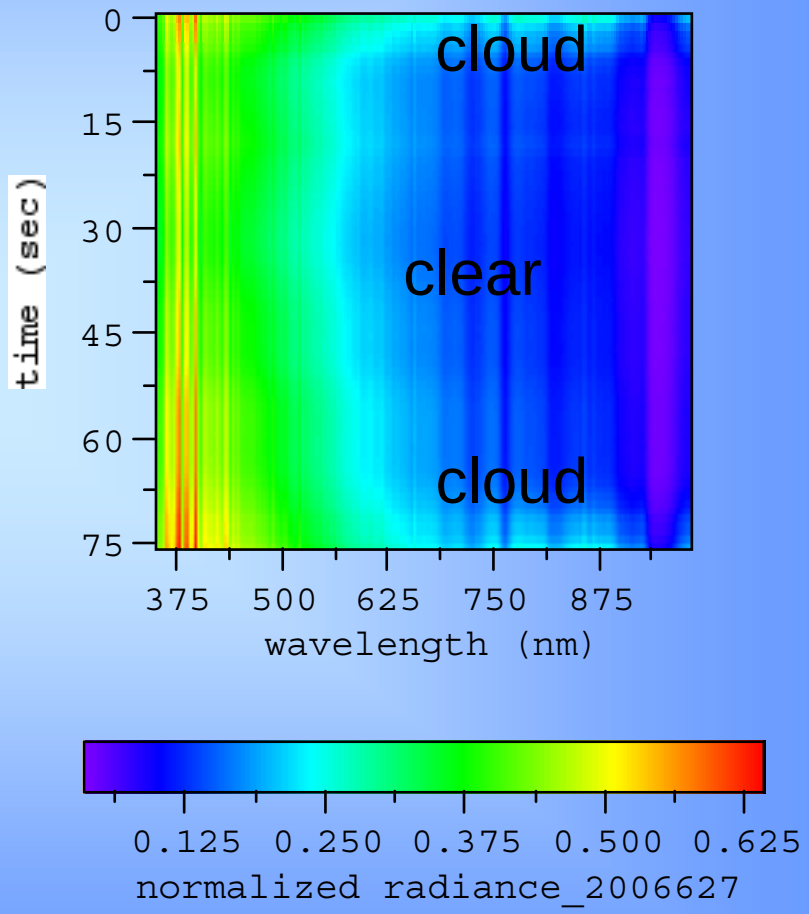





sws_rad_20060621
sws radiance
wavelength (nm)
0.06
0.05
0.04
0.03
0.02
0.01
0
400
800
1200
1600
2000
1
2
3
4
5
16
19


sws_norrad_20060621
sws normalized radiance
wavelength (nm)
0.3
0.25
0.2
0.15
0.1
0.05
0
400
800
1200
1600
2000
1
2
3
4
5
16
19


cloud
clear
cloud
time (sec)
0
13
25
38
50
63
75
375
500
625
750
875
wavelength (nm)
0.05
0.10
0.15
0.20
0.25
sws radiance


cloud
clear
cloud
time (sec)
0
15
30
45
60
75
375
500
625
750
875
wavelength (nm)
0.125
0.250
0.375
0.500
0.625
normalized radiance_2006627