# Spectral and Broadband Albedo: How Difficult Can It Be?

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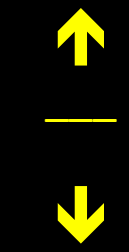
# Reasons to Study Albedo

- Spectral albedo is needed to properly calculate radiative transfer in the atmosphere
- Albedo is often measured incorrectly
- Spectral behavior differs markedly
- Solar-zenith angle behavior can be dramatic
- Green and dry vegetation and snow

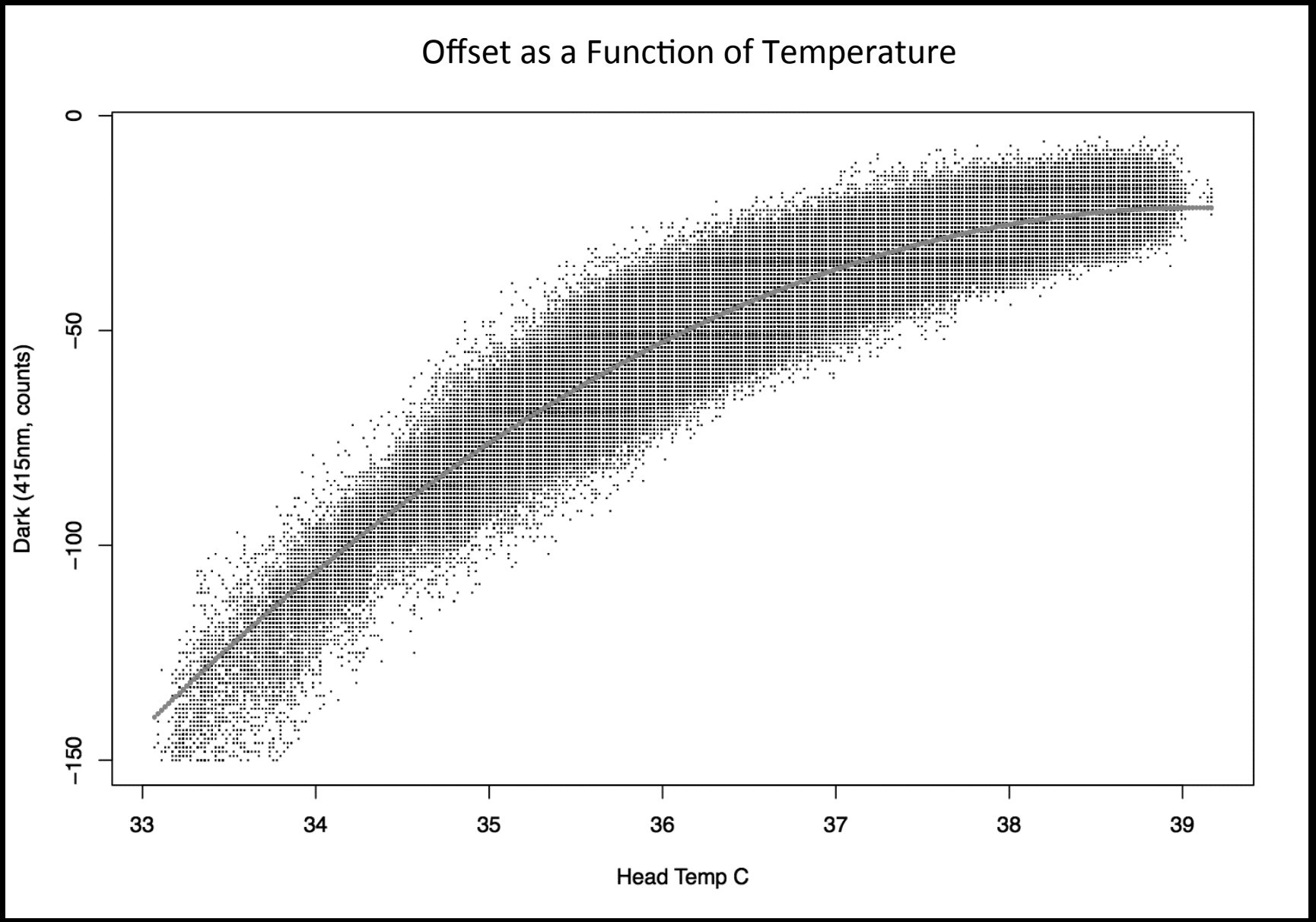


# Measurements at the Table Mountain Test Facility, Boulder, Colorado

- Measurements from March 2008 to April 2012
- MFR wavelengths - 415, 500, 615, 673, 870, 940 nm plus PAR, UVB, as well as broadband solar
- Undisturbed grassland just north of SURFRAD measurements
- Info will be used to retrieve satellite AODs, ground-based aerosol SSAs, cloud OD and $r_{eff}$
- Technique may be useful for drought monitoring

# Quality Control Issues

- Frequent calibrations
- Offset corrections
- Cosine corrections to direct, diffuse, & upwelling

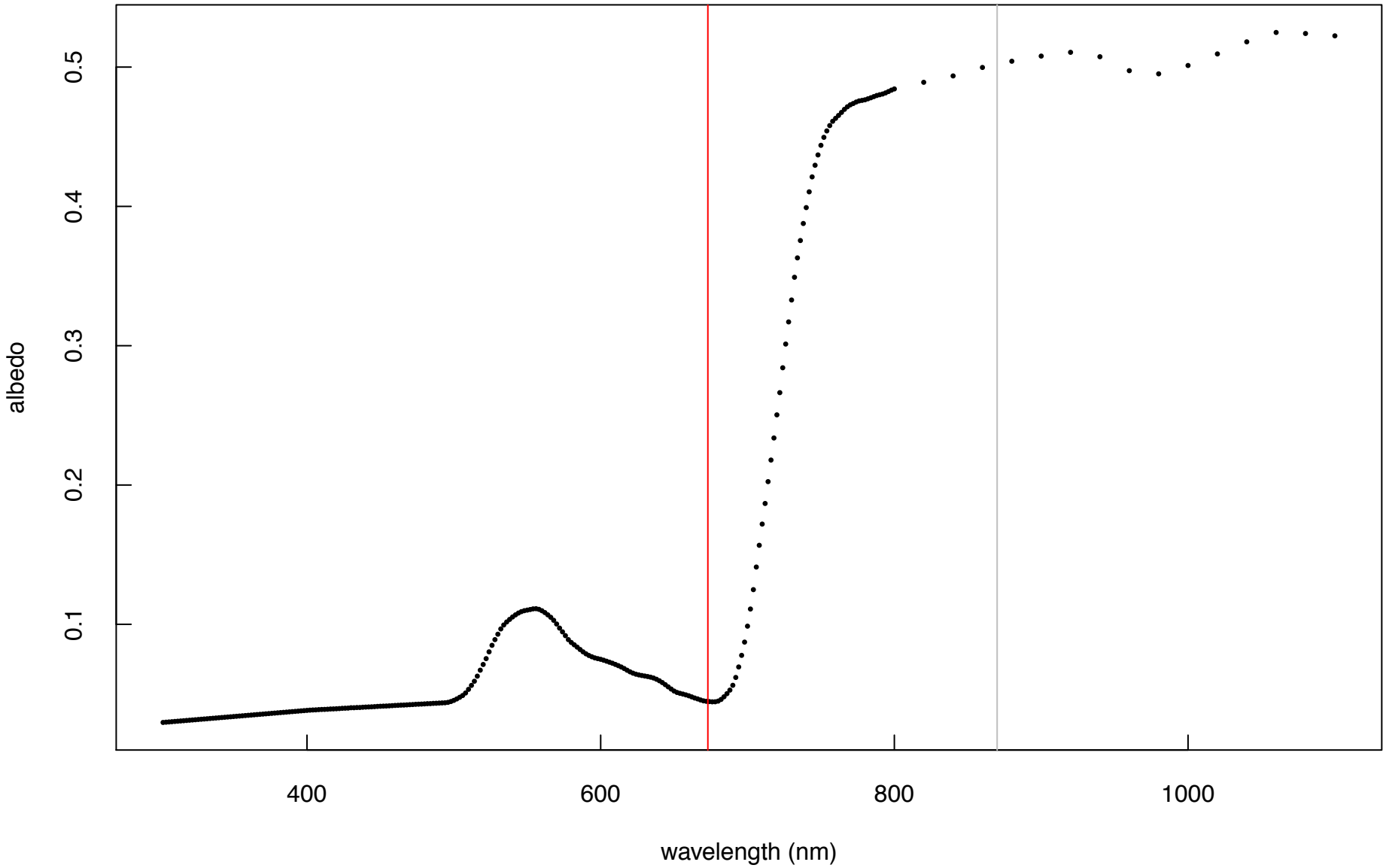

Offset as a Function of Temperature
Dark (415nm, counts)
0
−50
−100
−150
33
34
35
36
37
38
39
Head Temp C

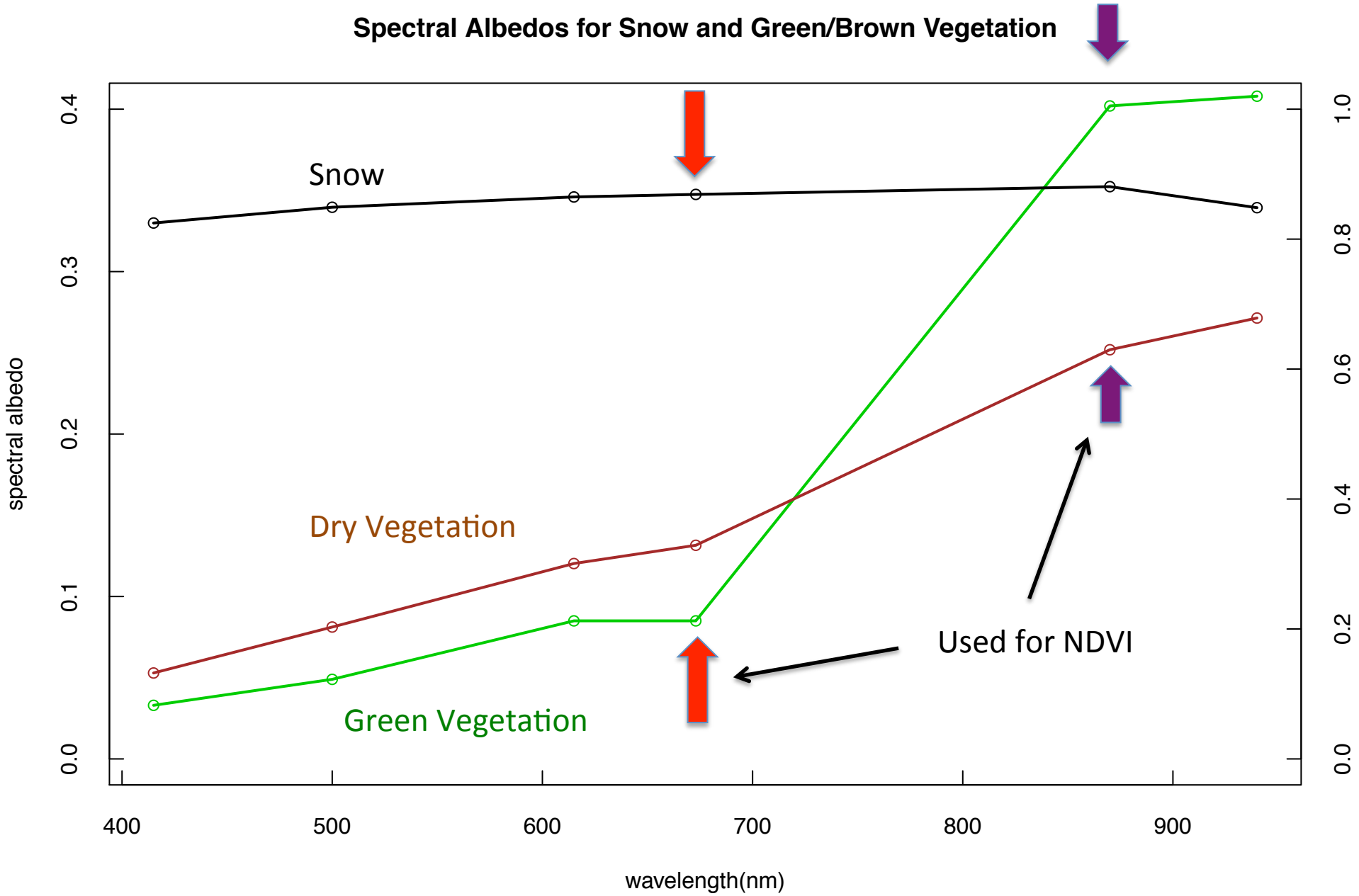
# Spectral Dependence

# Normalized Difference Vegetative Index

$$NDVI_{mfrsr} = \frac{A_{870} - A_{673}}{A_{870} + A_{673}}$$

# Green Grass Spectral Albedo




Spectral Albedos for Snow and Green/Brown Vegetation
Snow
Dry Vegetation
Green Vegetation
Used for NDVI
spectral albedo
wavelength(nm)
0.0
0.1
0.2
0.3
0.4
0.0
0.2
0.4
0.6
0.8
1.0
400
500
600
700
800
900

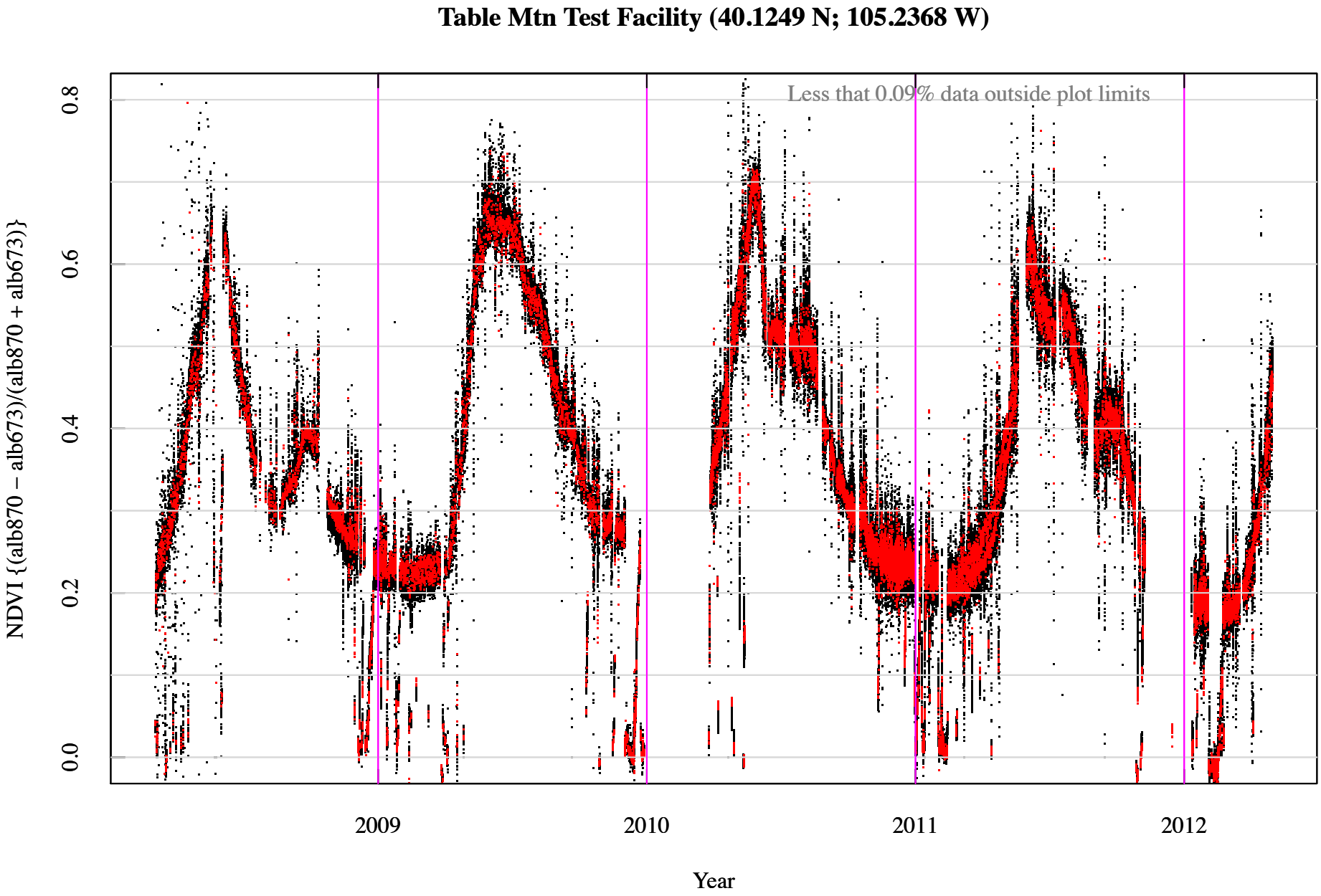
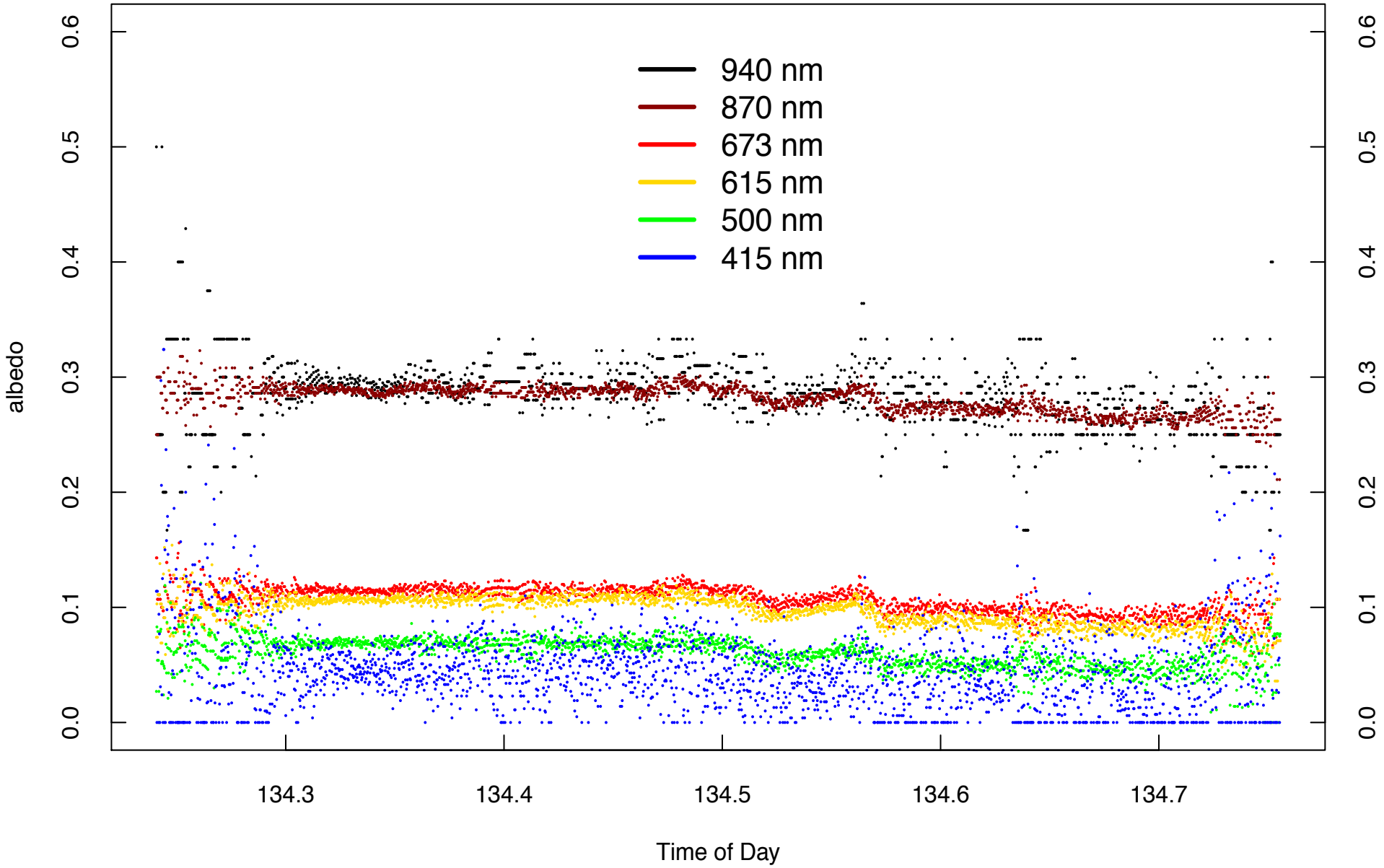
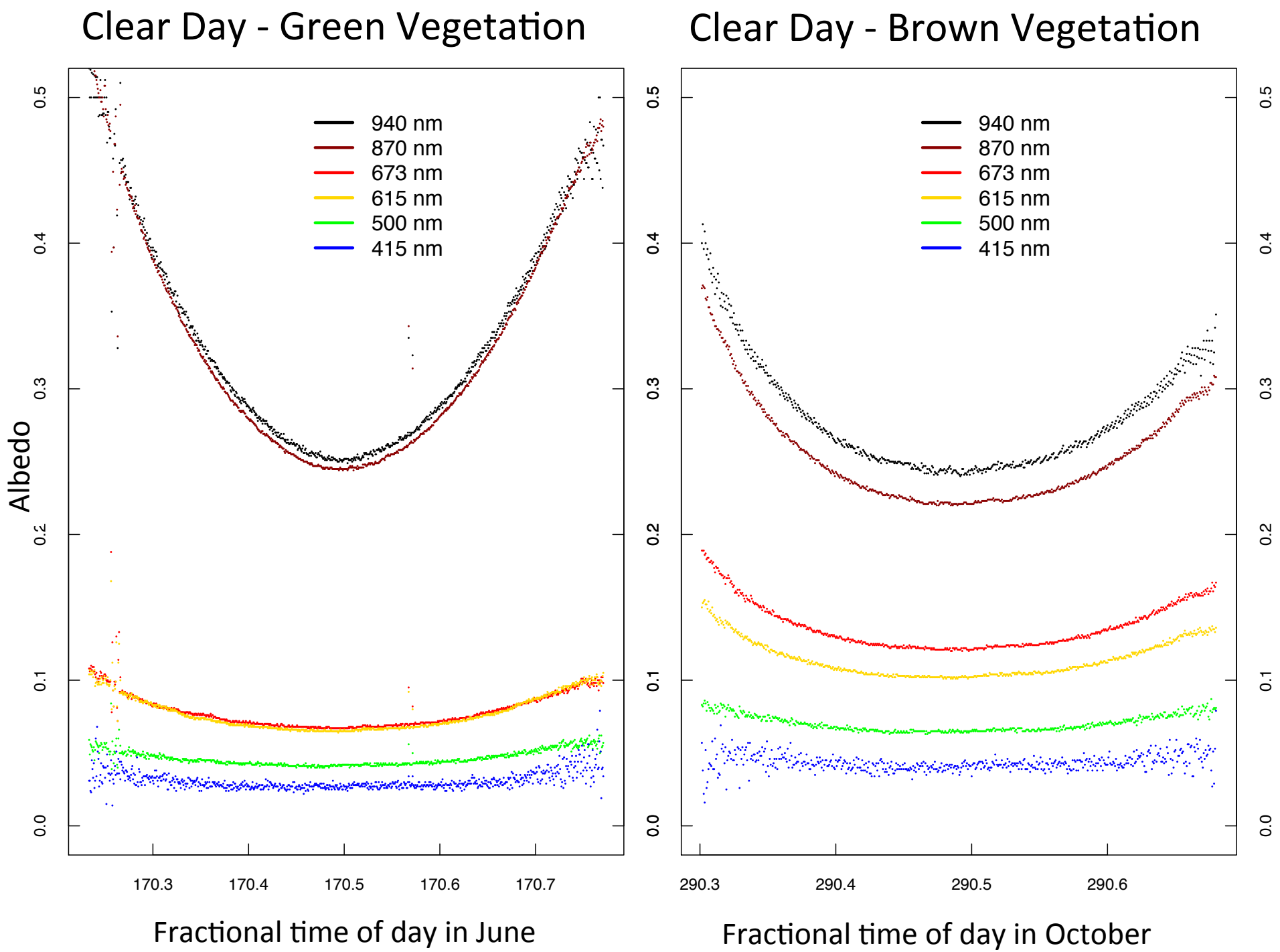
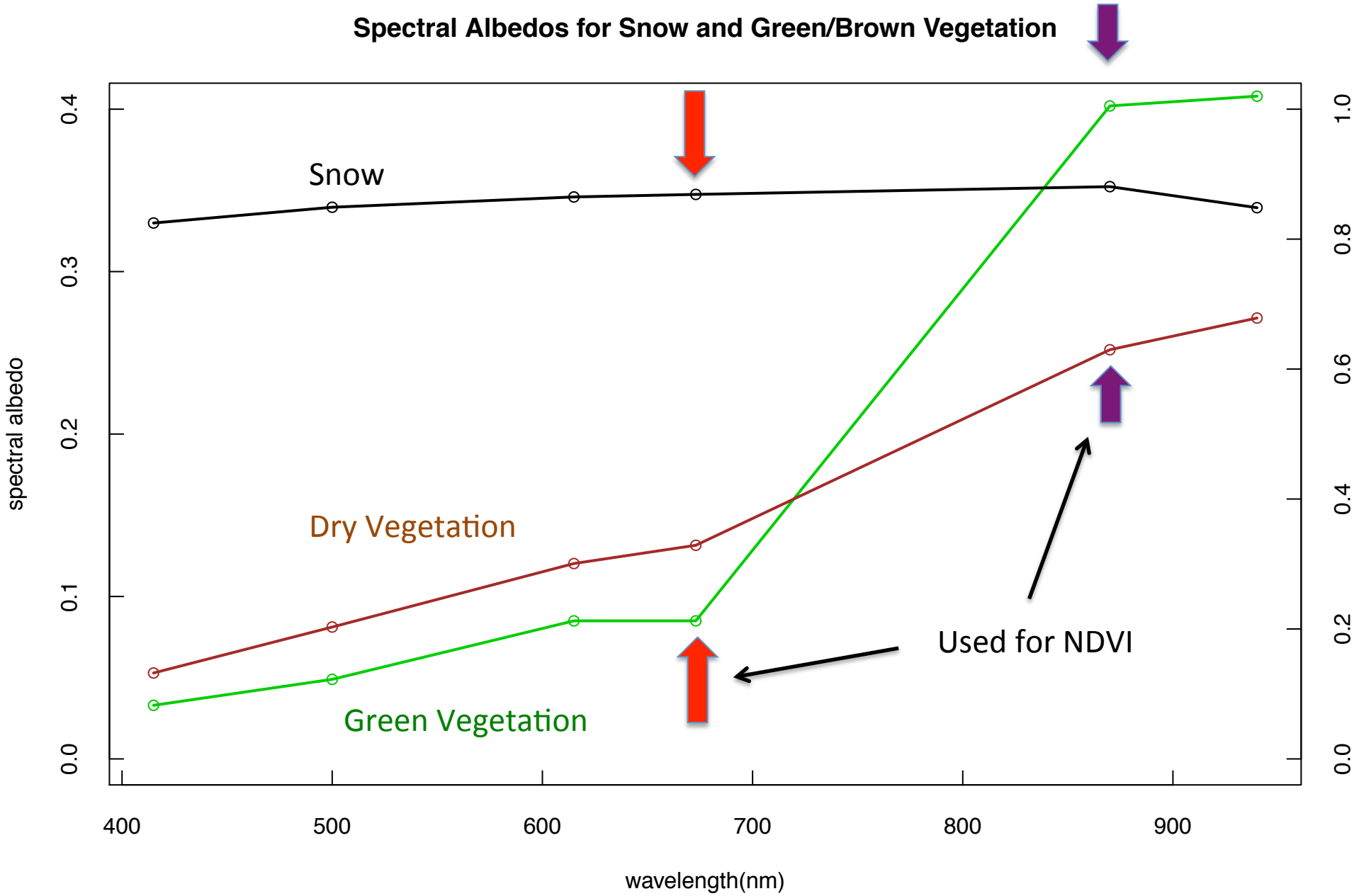


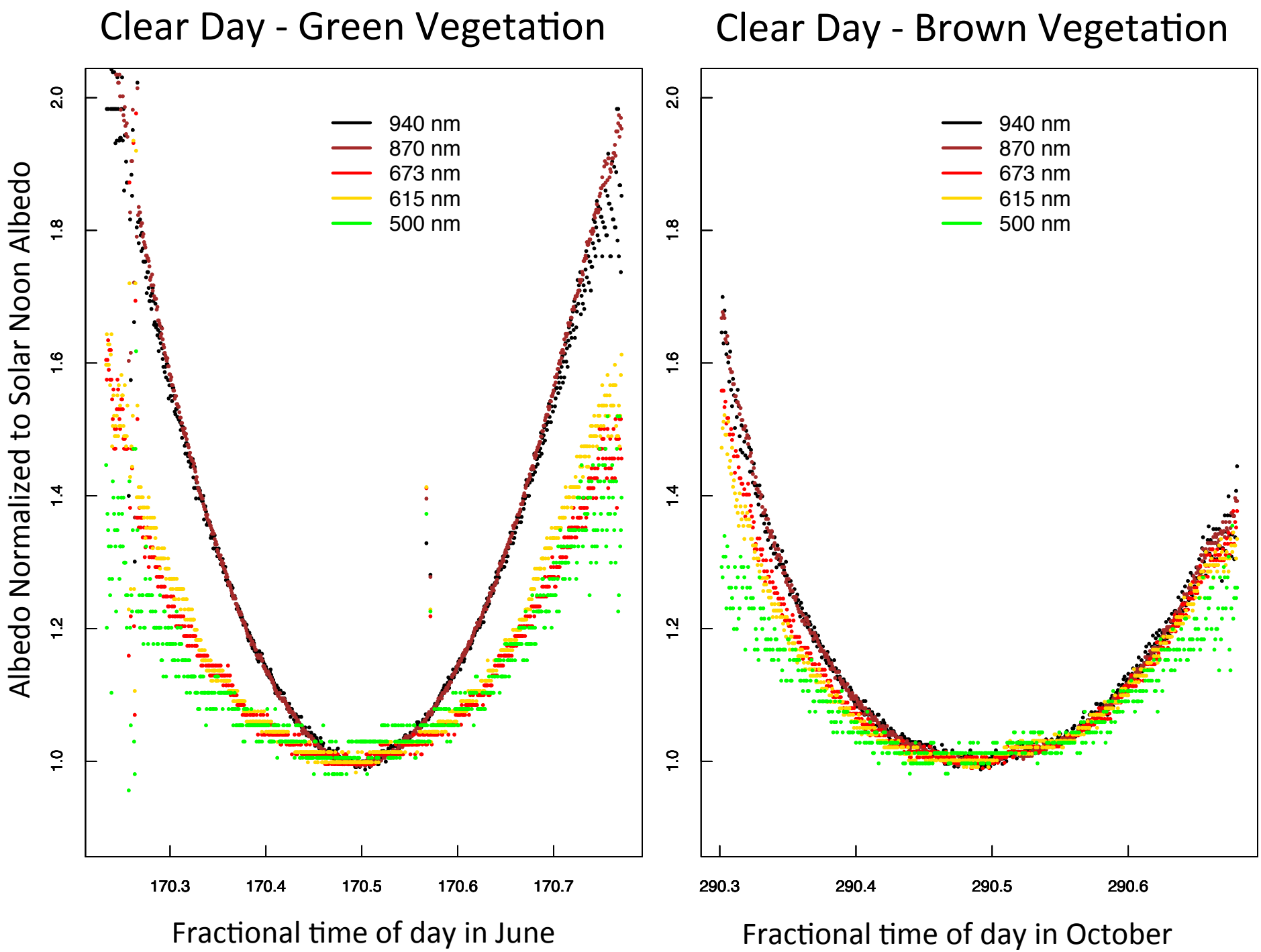
Table Mtn Test Facility (40.1249 N; 105.2368 W)
Less that 0.09% data outside plot limits
NDVI {(alb870 – alb673)/(alb870 + alb673)}
0.0
0.2
0.4
0.6
0.8
2009
2010
2011
2012
Year

# Solar Zenith Angle Dependence


Spectral Albedo on a Cloudy Day
940 nm
870 nm
673 nm
615 nm
500 nm
415 nm
albedo
0.0
0.1
0.2
0.3
0.4
0.5
0.6
134.3
134.4
134.5
134.6
134.7
Time of Day


Clear Day - Green Vegetation
Clear Day - Brown Vegetation
940 nm
870 nm
673 nm
615 nm
500 nm
415 nm
Albedo
0.0
0.1
0.2
0.3
0.4
0.5
170.3
170.4
170.5
170.6
170.7
290.3
290.4
290.5
290.6
Fractional time of day in June
Fractional time of day in October


Spectral Albedos for Snow and Green/Brown Vegetation
Snow
Dry Vegetation
Green Vegetation
Used for NDVI
spectral albedo
wavelength(nm)
0.0
0.1
0.2
0.3
0.4
0.0
0.2
0.4
0.6
0.8
1.0
400
500
600
700
800
900


Clear Day - Green Vegetation
Clear Day - Brown Vegetation
Albedo Normalized to Solar Noon Albedo
940 nm
870 nm
673 nm
615 nm
500 nm
1.0
1.2
1.4
1.6
1.8
2.0
170.3
170.4
170.5
170.6
170.7
290.3
290.4
290.5
290.6
Fractional time of day in June
Fractional time of day in October

# Snow Albedos

For the rest of the time will focus on snow:
Reflectance as a function of wavelength
Reflectance as a function of solar-zenith angle

# Various Measurements of the Wavelength Dependence of Snow

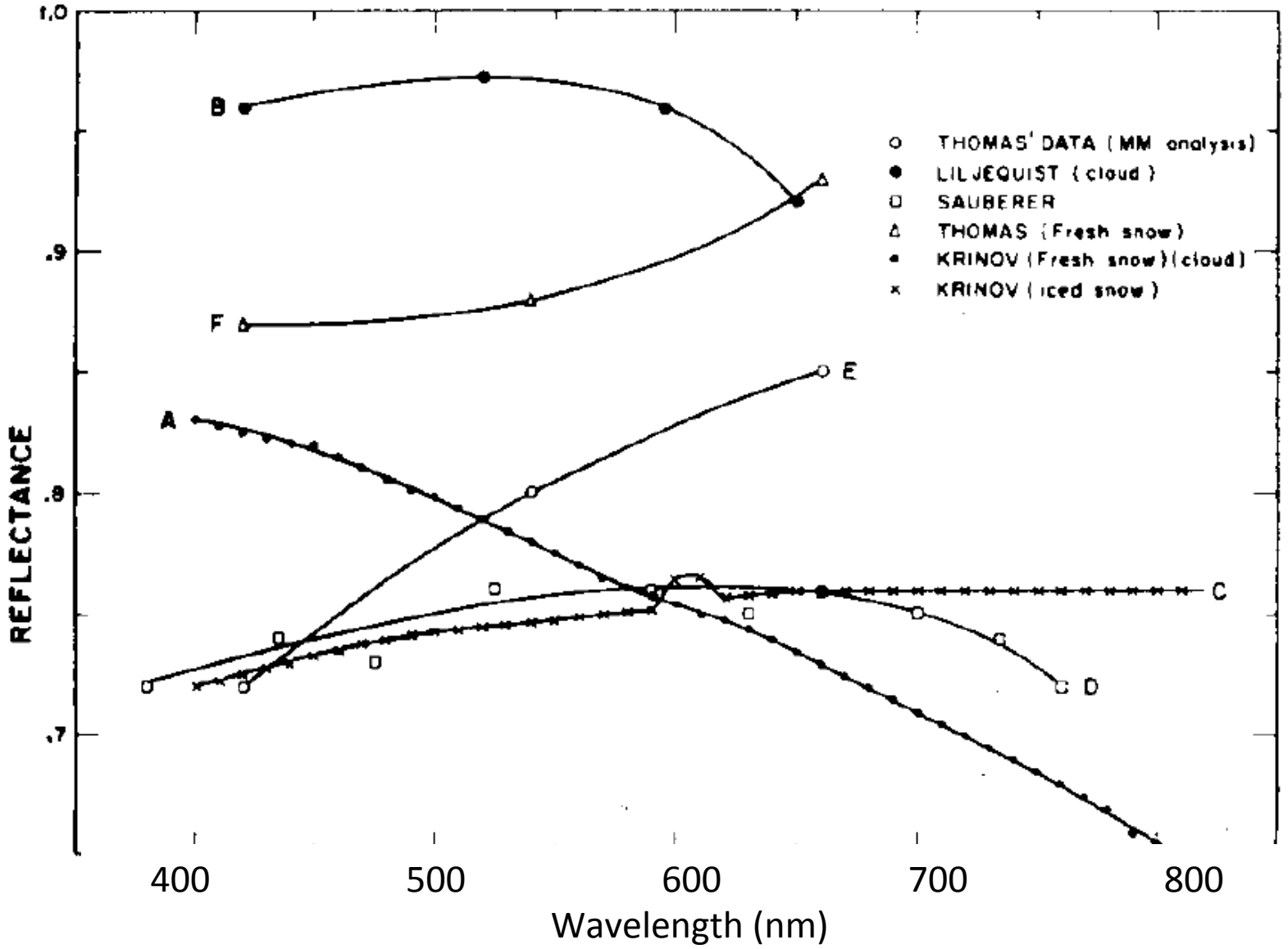
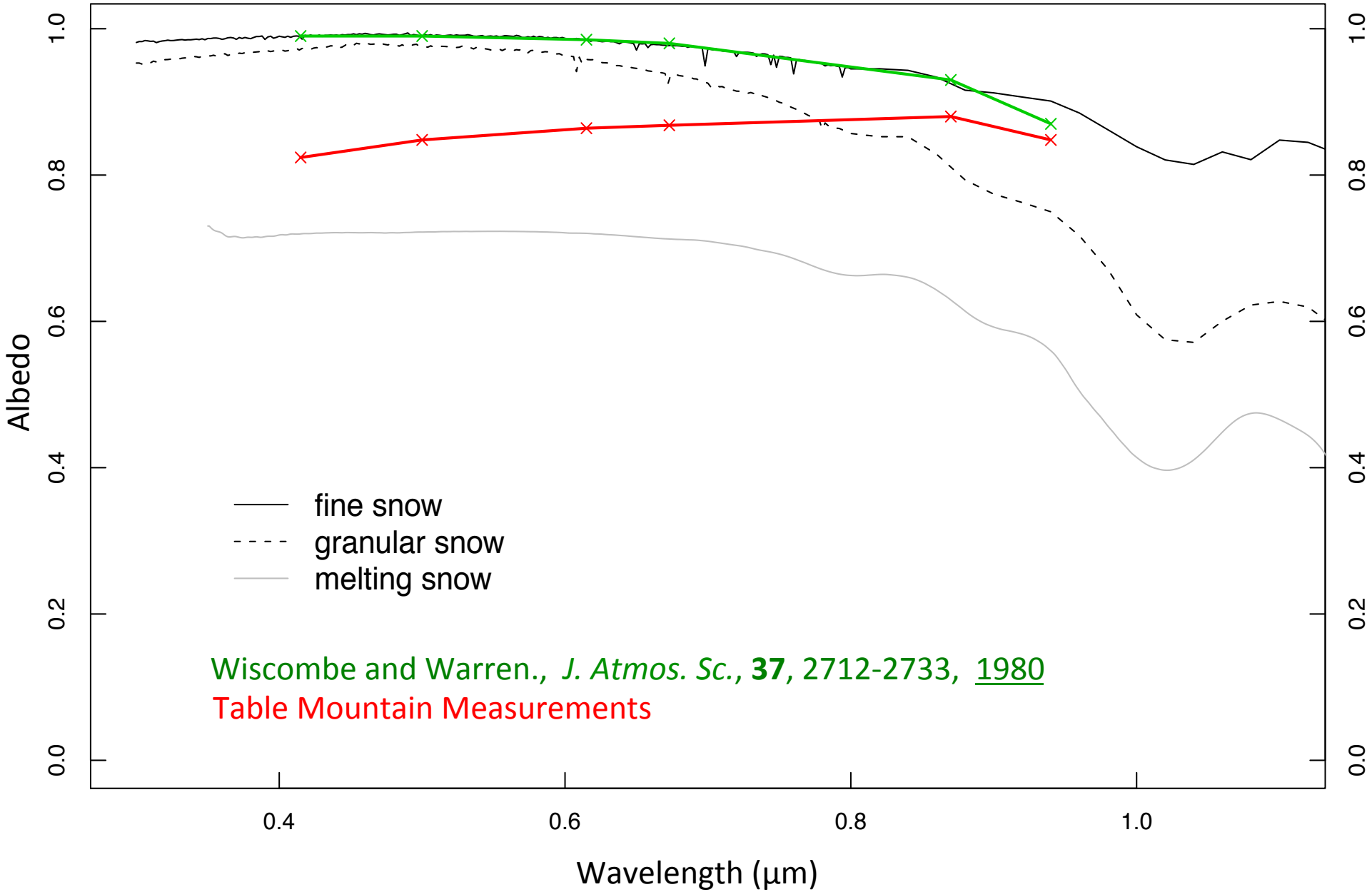



FIG. 16. Reflectance of snow as a function of wavelength in the visible, according to various investigators. From Mellor (1977).

# Bowker et al. Measurements



# Solar Zenith-Angle Dependence

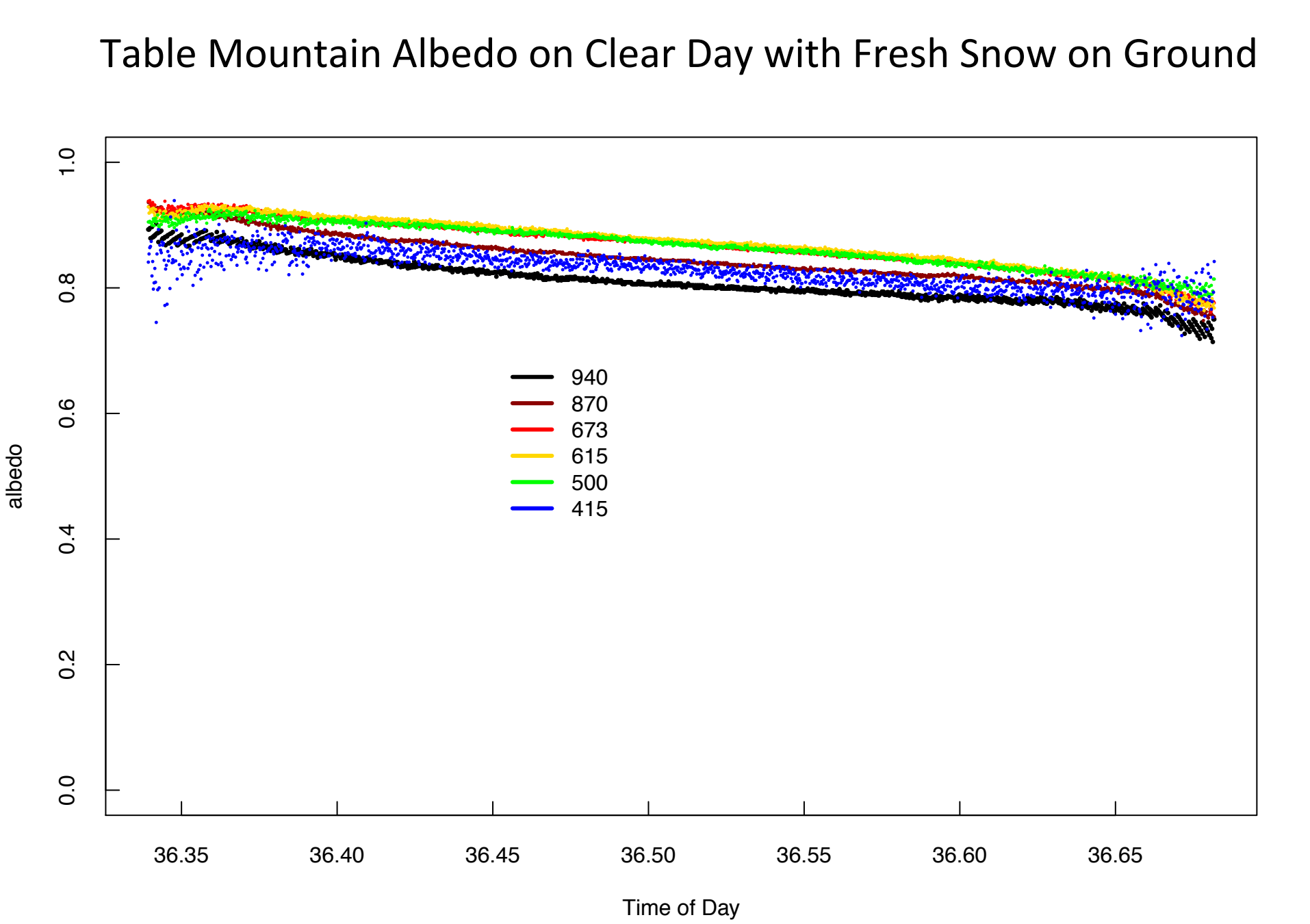
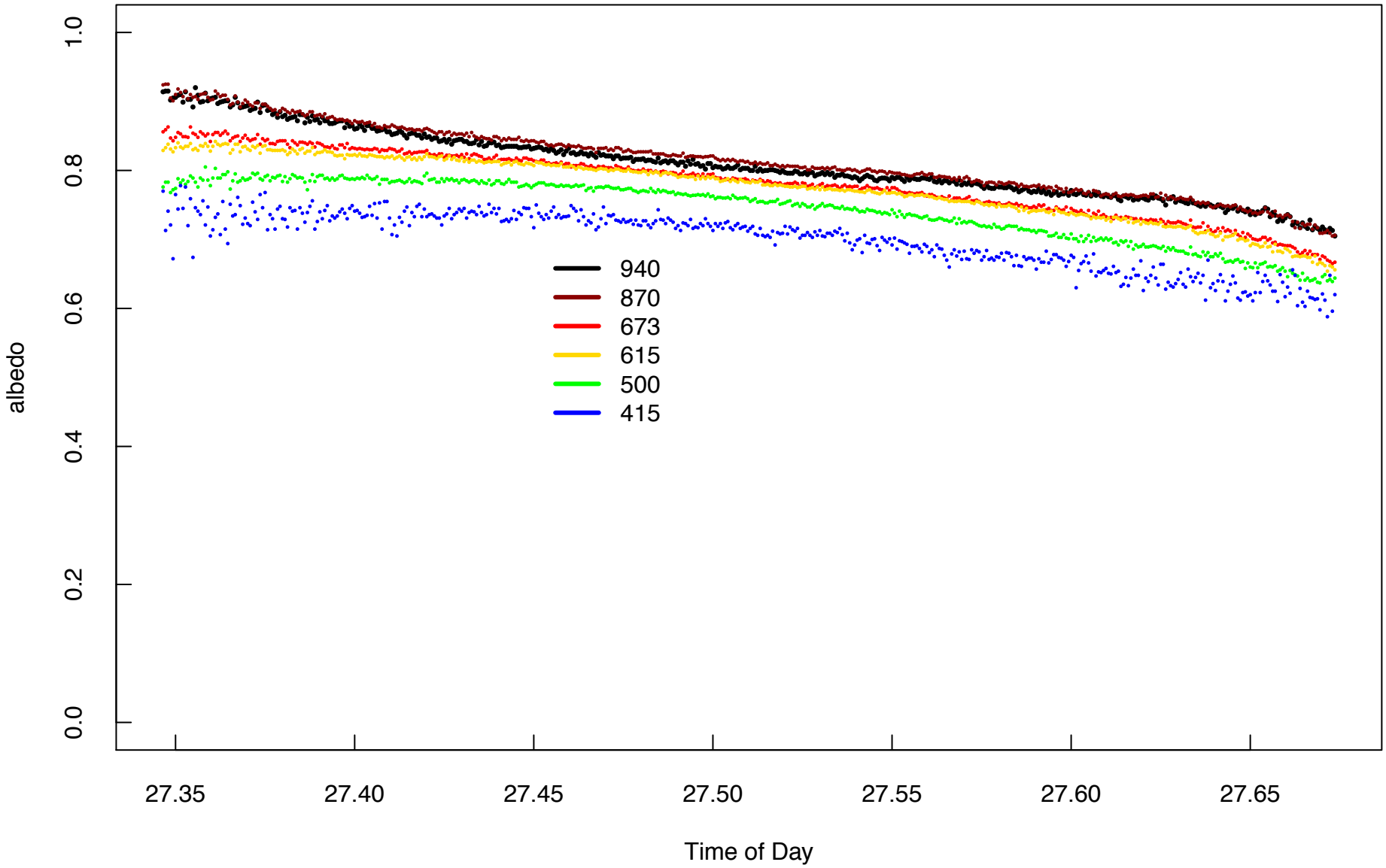
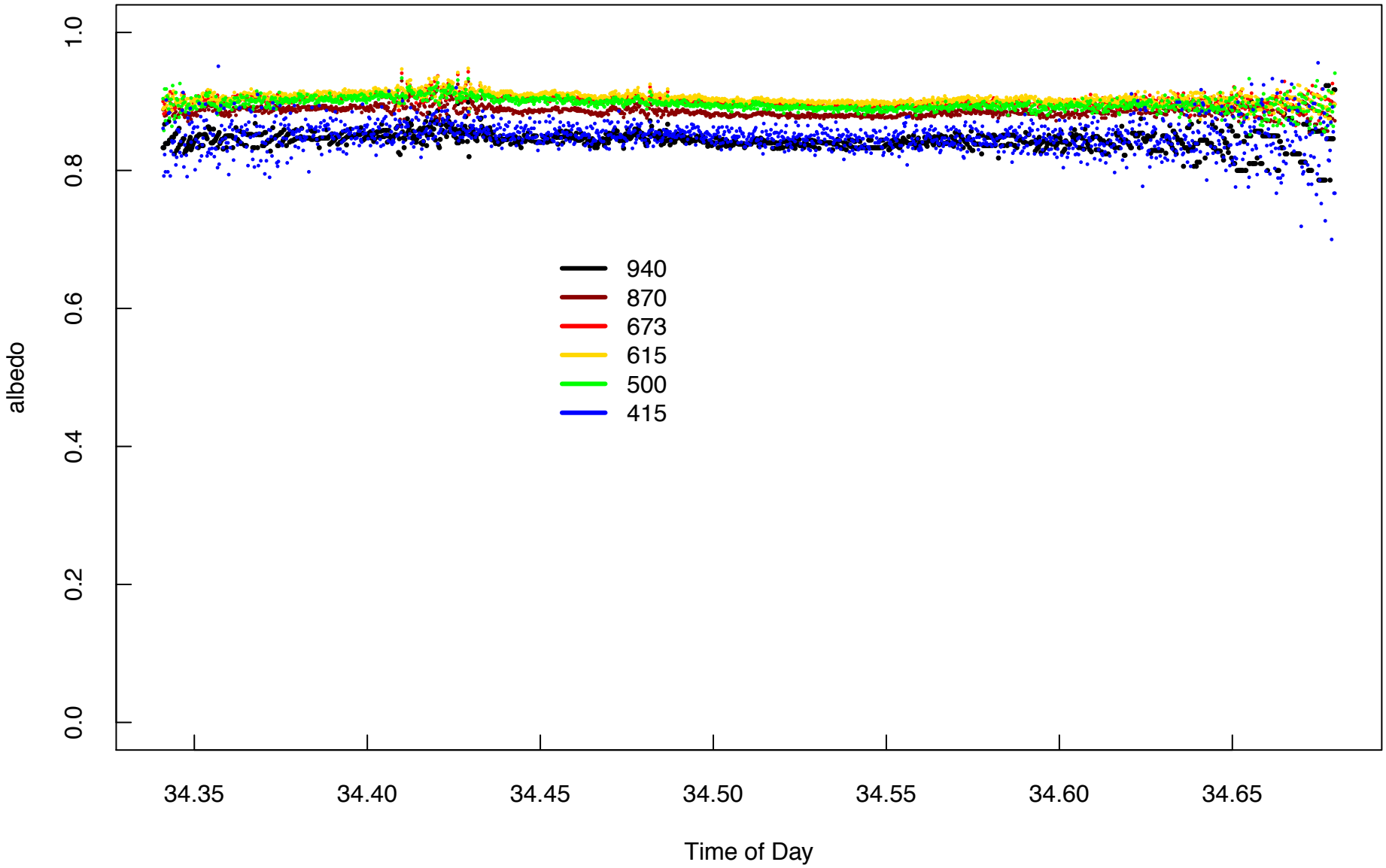


Table Mountain Albedo on Clear Day with Fresh Snow on Ground
albedo
0.0
0.2
0.4
0.6
0.8
1.0
940
870
673
615
500
415
36.35
36.40
36.45
36.50
36.55
36.60
36.65
Time of Day

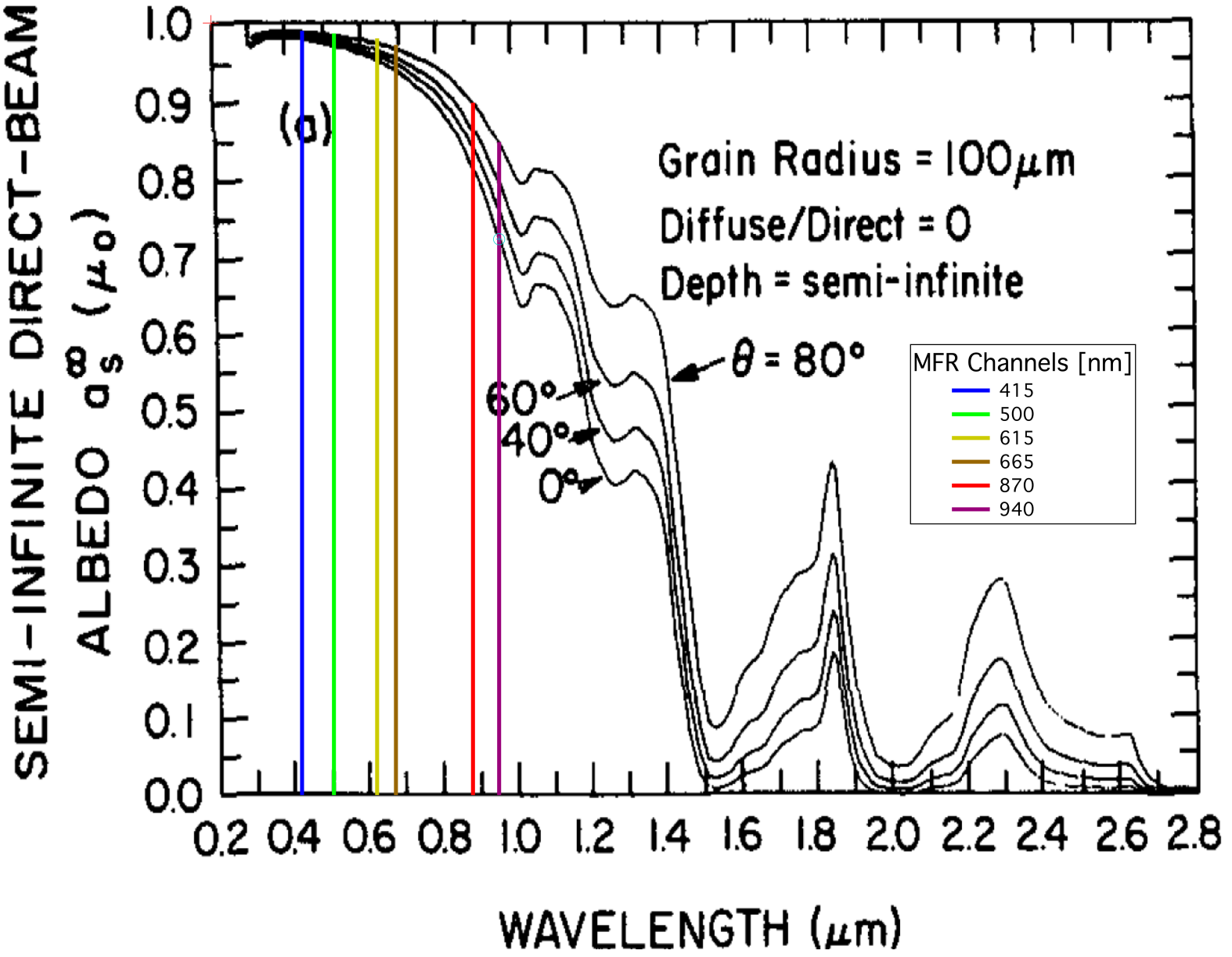
# Table Mountain Albedo on Another Clear Day with Fresh Snow



# Table Mountain Albedo on Cloudy Day with Fresh Snow on Ground



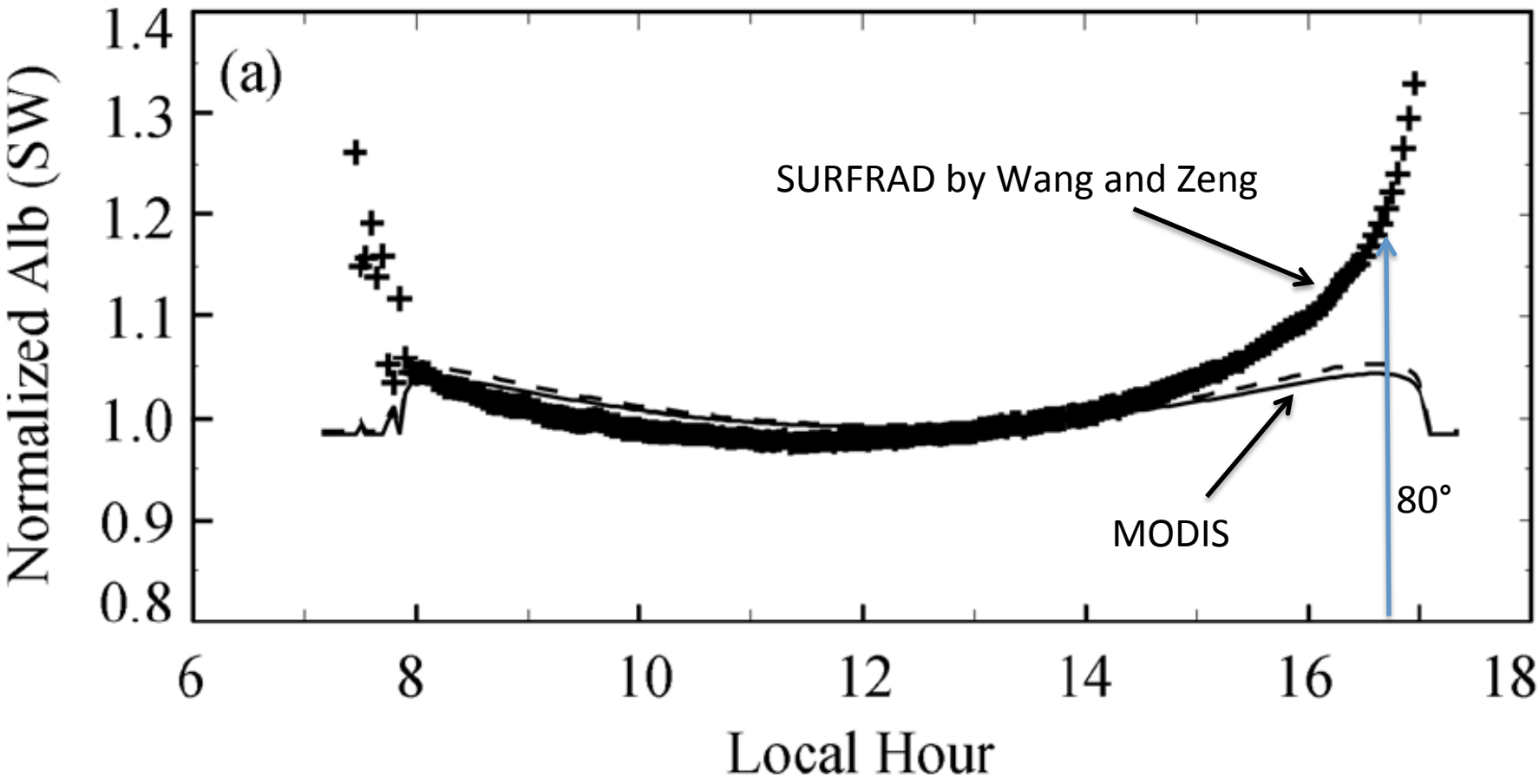
## Snow Spectral Albedo Calculated from Model (Mie Scattering)




Wiscombe and Warren., *J. Atmos. Sc.*, **37**, 2712-2733, 1980, **Figure 11a**

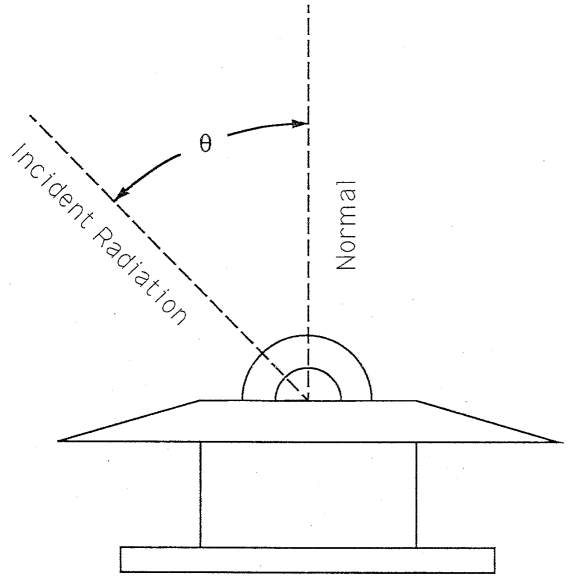
# Broadband Snow Albedo

Wang and Zeng, Atmos. Oceanic Sci. Lett. **1**:45-50, 2008

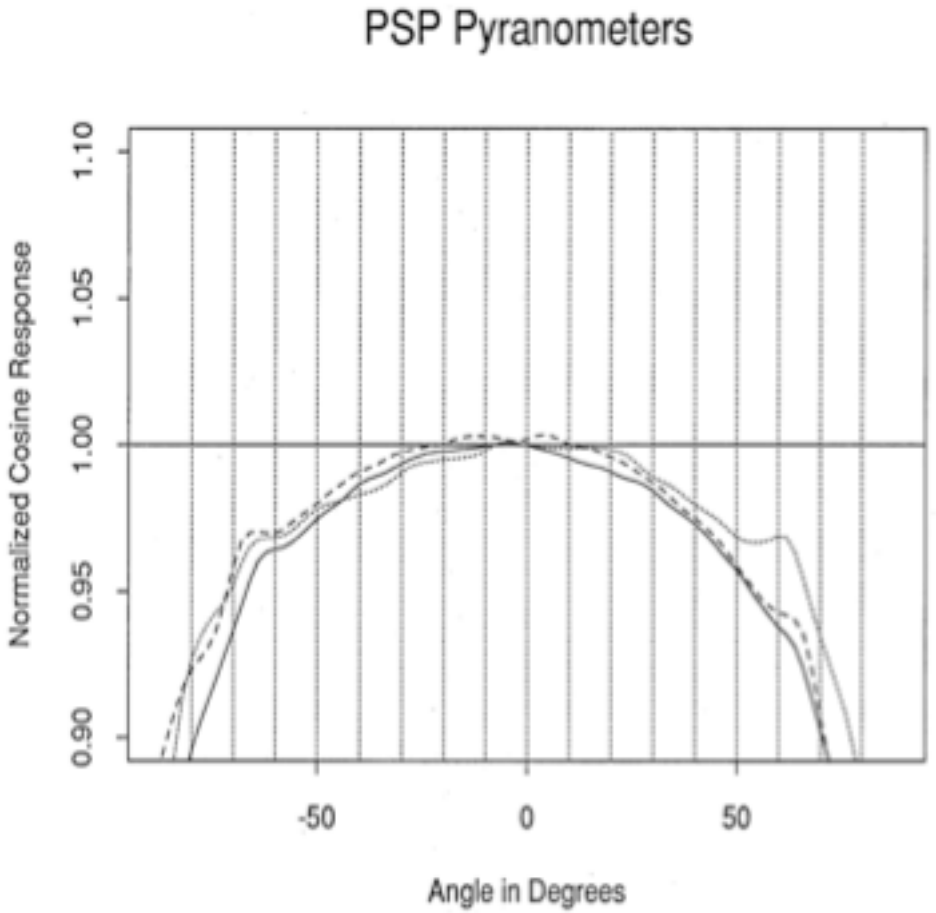


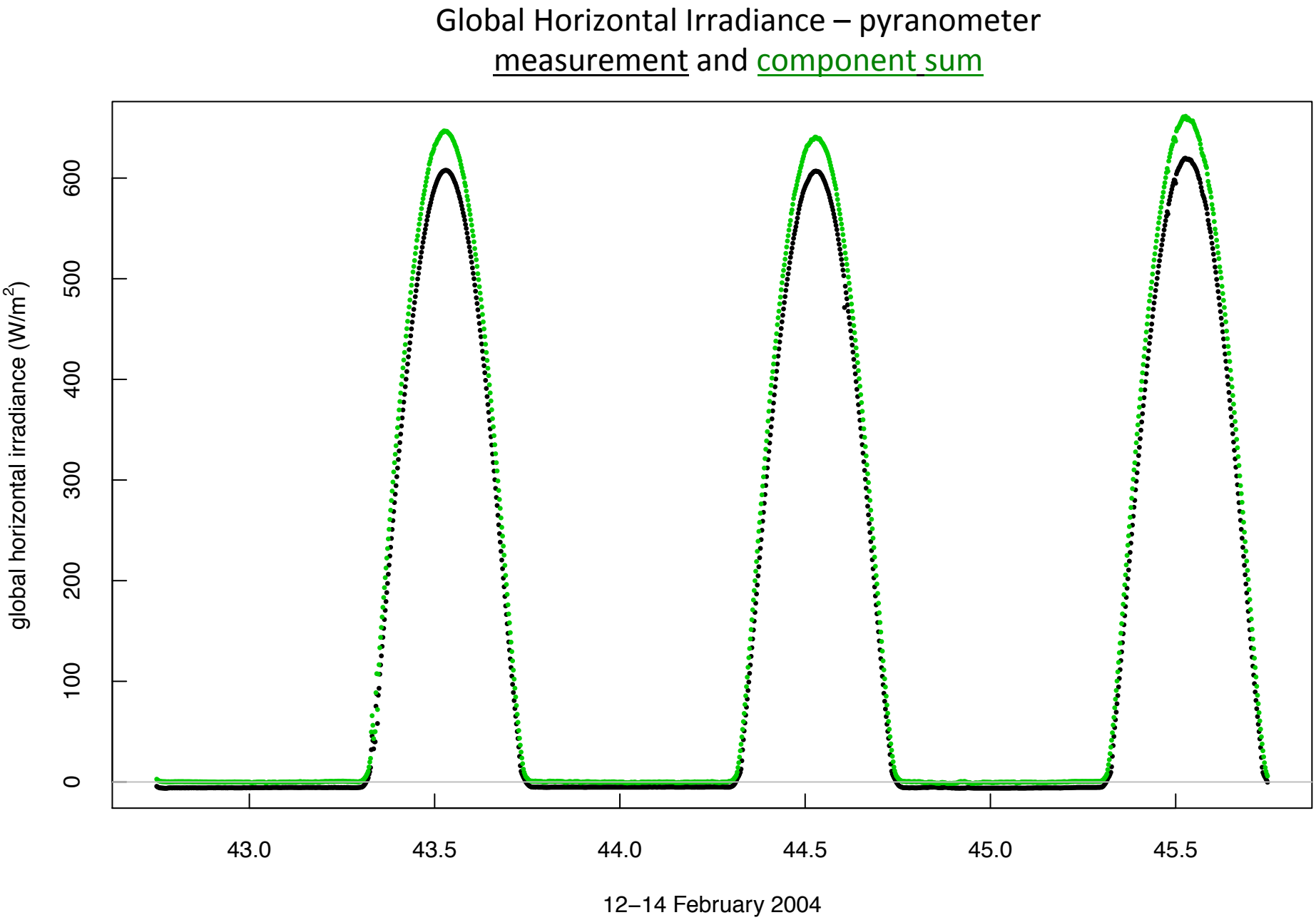

**Broadband solar albedo for Sioux Falls, South Dakota**

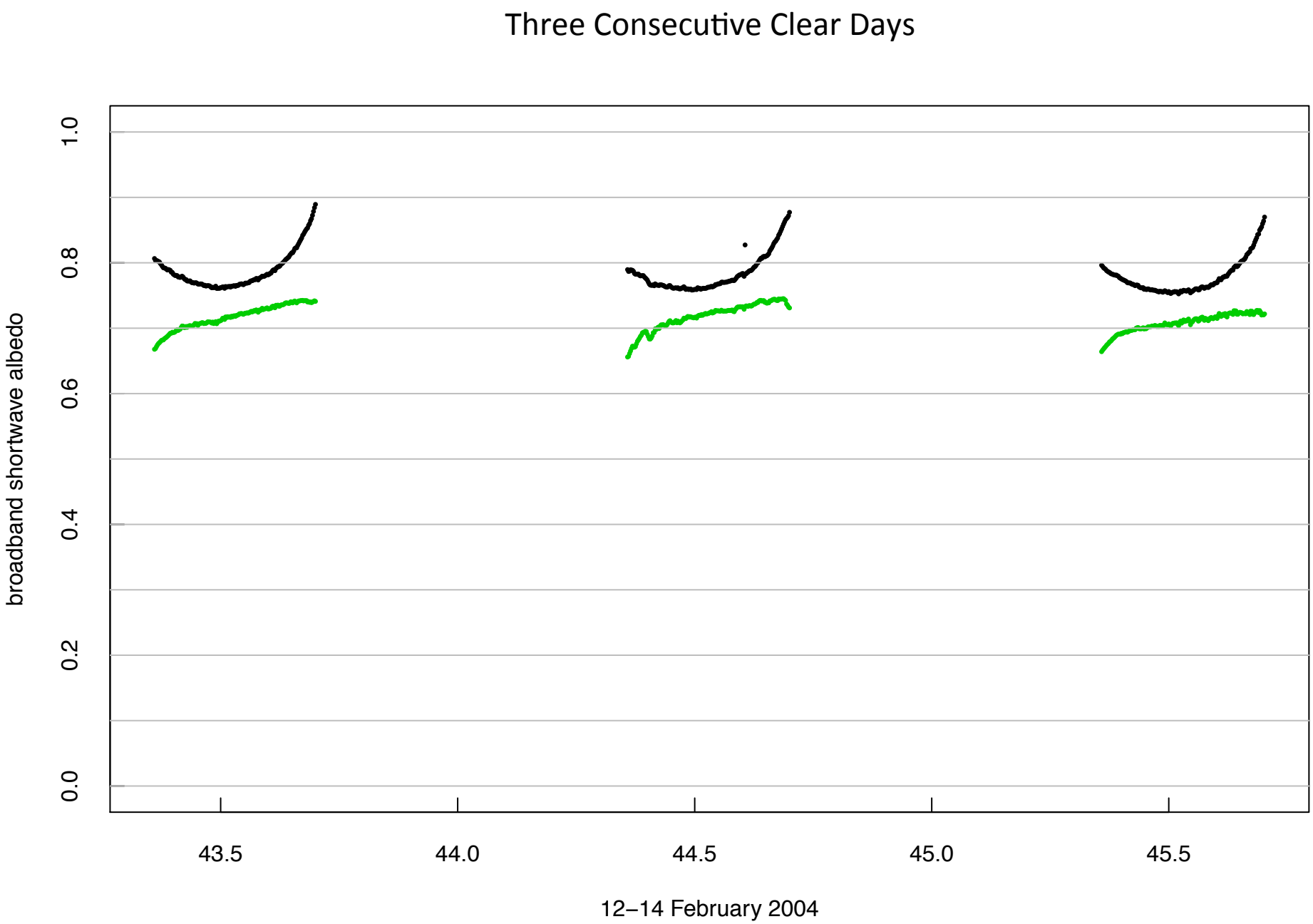
Real pyranometers do not have perfect cosine response



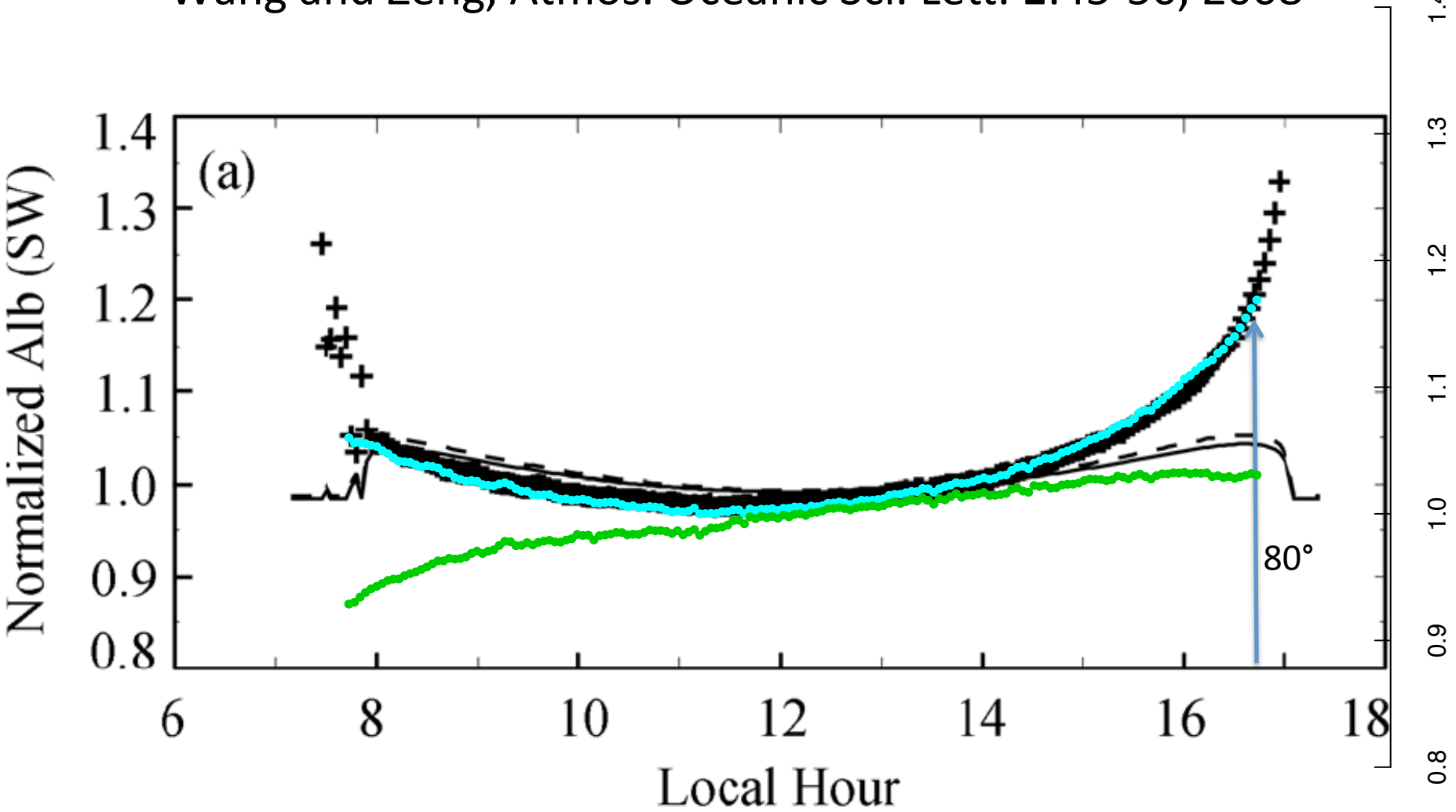

Three examples of real pyranometers



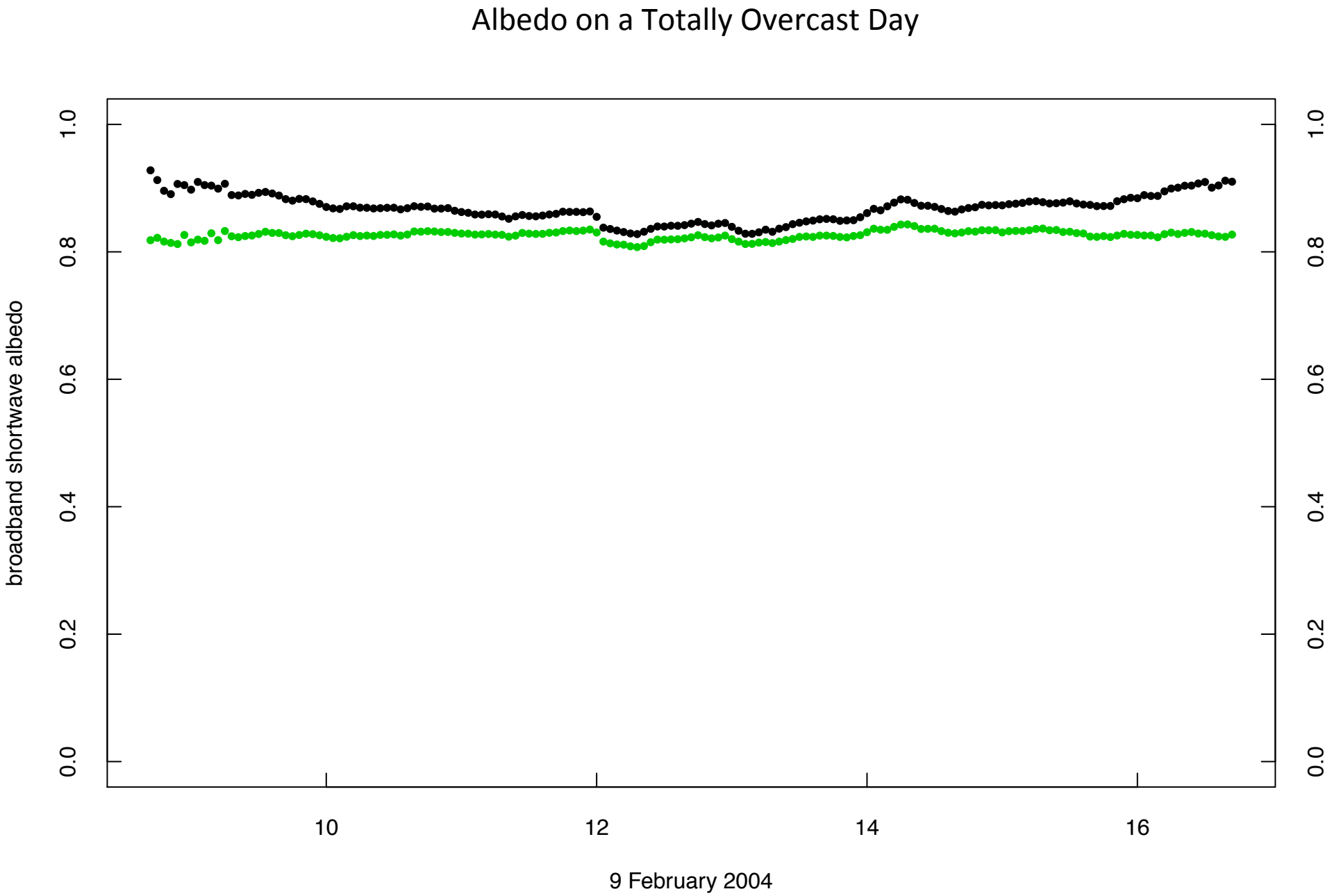

Global Horizontal Irradiance – pyranometer
measurement and component sum
global horizontal irradiance (W/m2)
0
100
200
300
400
500
600
43.0
43.5
44.0
44.5
45.0
45.5
12–14 February 2004


Three Consecutive Clear Days
broadband shortwave albedo
0.0
0.2
0.4
0.6
0.8
1.0
43.5
44.0
44.5
45.0
45.5
12–14 February 2004

Wang and Zeng, Atmos. Oceanic Sci. Lett. **1**:45-50, 2008




**Note: This is broadband solar albedo**


Albedo on a Totally Overcast Day
broadband shortwave albedo
0.0
0.2
0.4
0.6
0.8
1.0
10
12
14
16
9 February 2004

## Conclusions

- Solar – zenith angle dependence appears to be measured and modeled somewhat incorrectly for snow-covered surfaces
- Spectral dependence of snow needs more study
- Albedo measurements need to be made spectrally and continuously for radiative transfer to be calculated correctly

Thank You