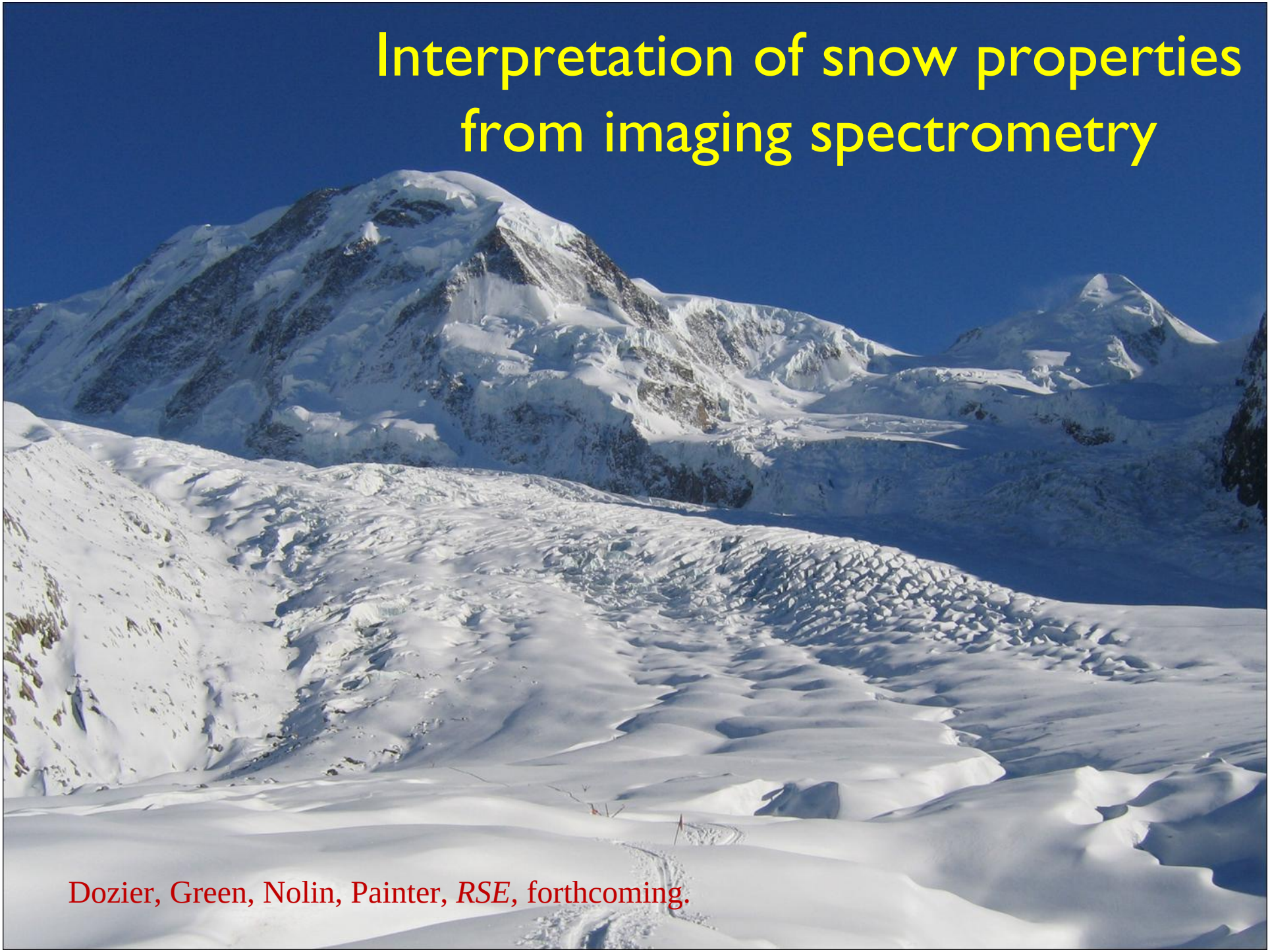
Interpretation of snow properties from imaging spectrometry

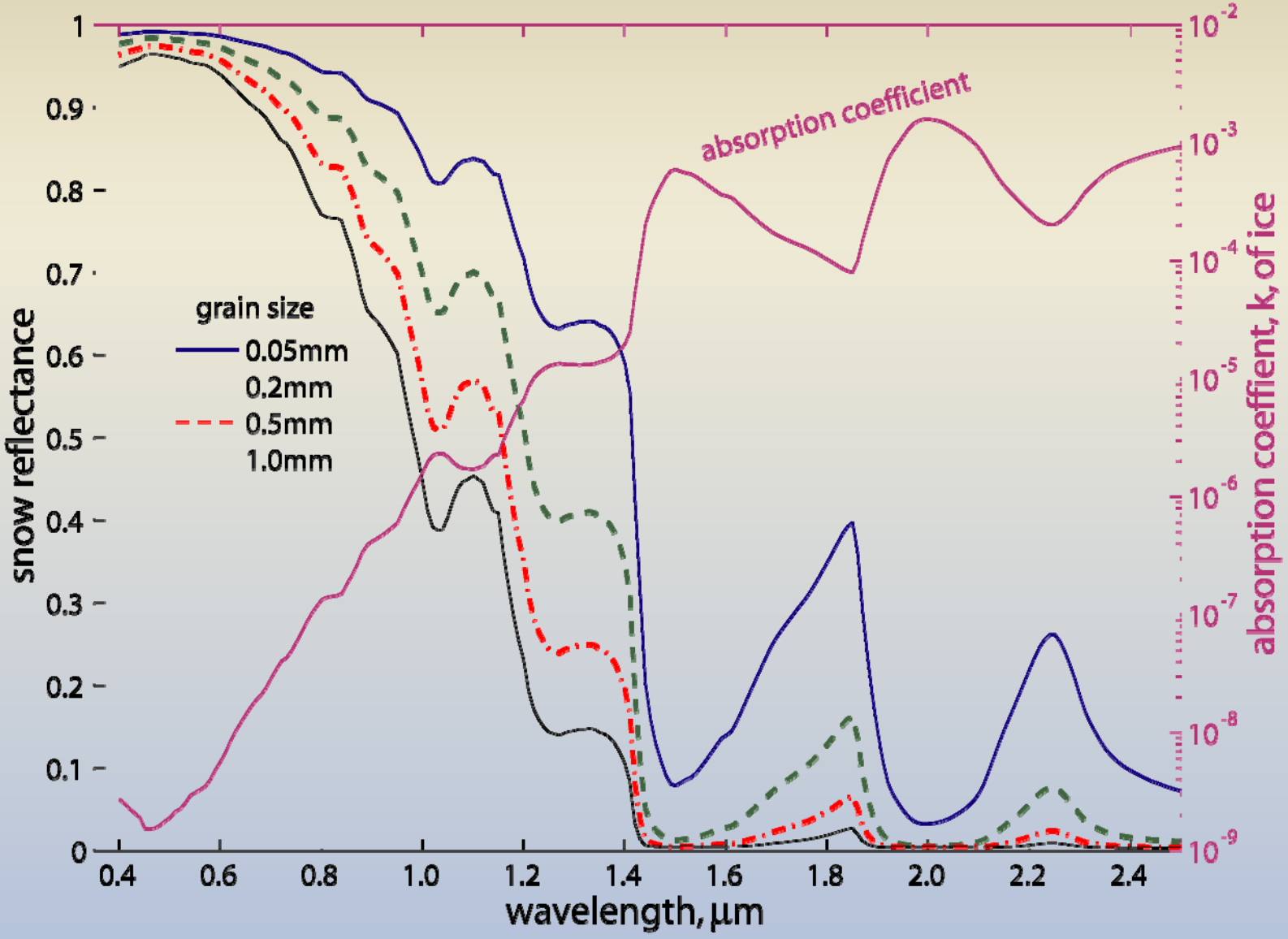


Dozier, Green, Nolin, Painter, *RSE*, forthcoming.

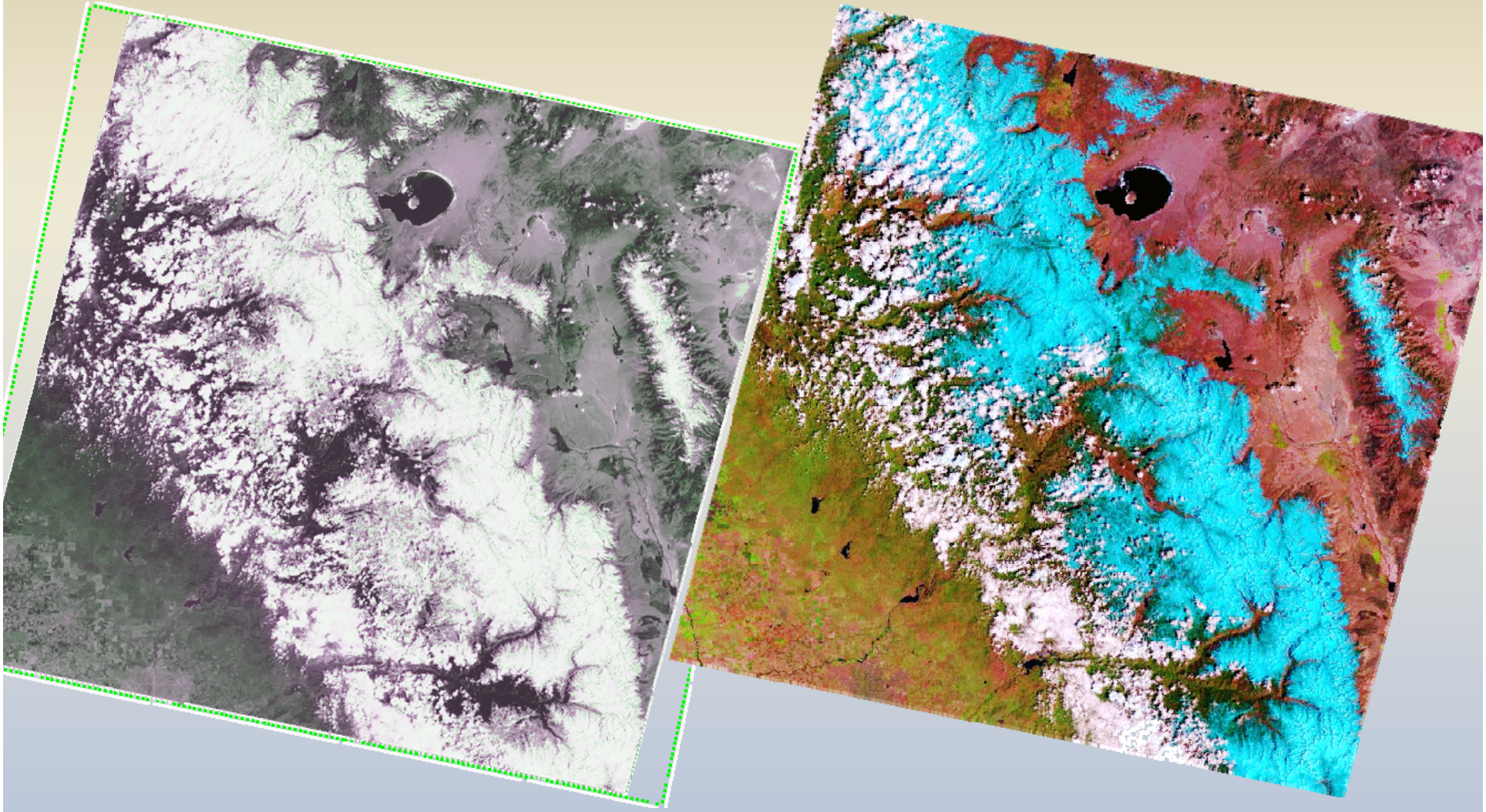
Analyses of snow properties from imaging spectrometry

- Spectral albedo and conversion to broadband albedo
  - [Nolin & Dozier, *Remote Sens. Environ.*, 2000]
- Fractional (subpixel) snow-covered area, along with albedo
  - [Painter et al., *Remote Sens. Environ.*, 2003]
- Liquid water in surface layer
  - [Green et al., *Water Resour. Res.*, 2006]
- Absorbing impurities
  - [Painter et al., *Appl. Environ. Microbiol.*, 2001; work in progress]

Snow spectral reflectance and absorption coefficient of ice



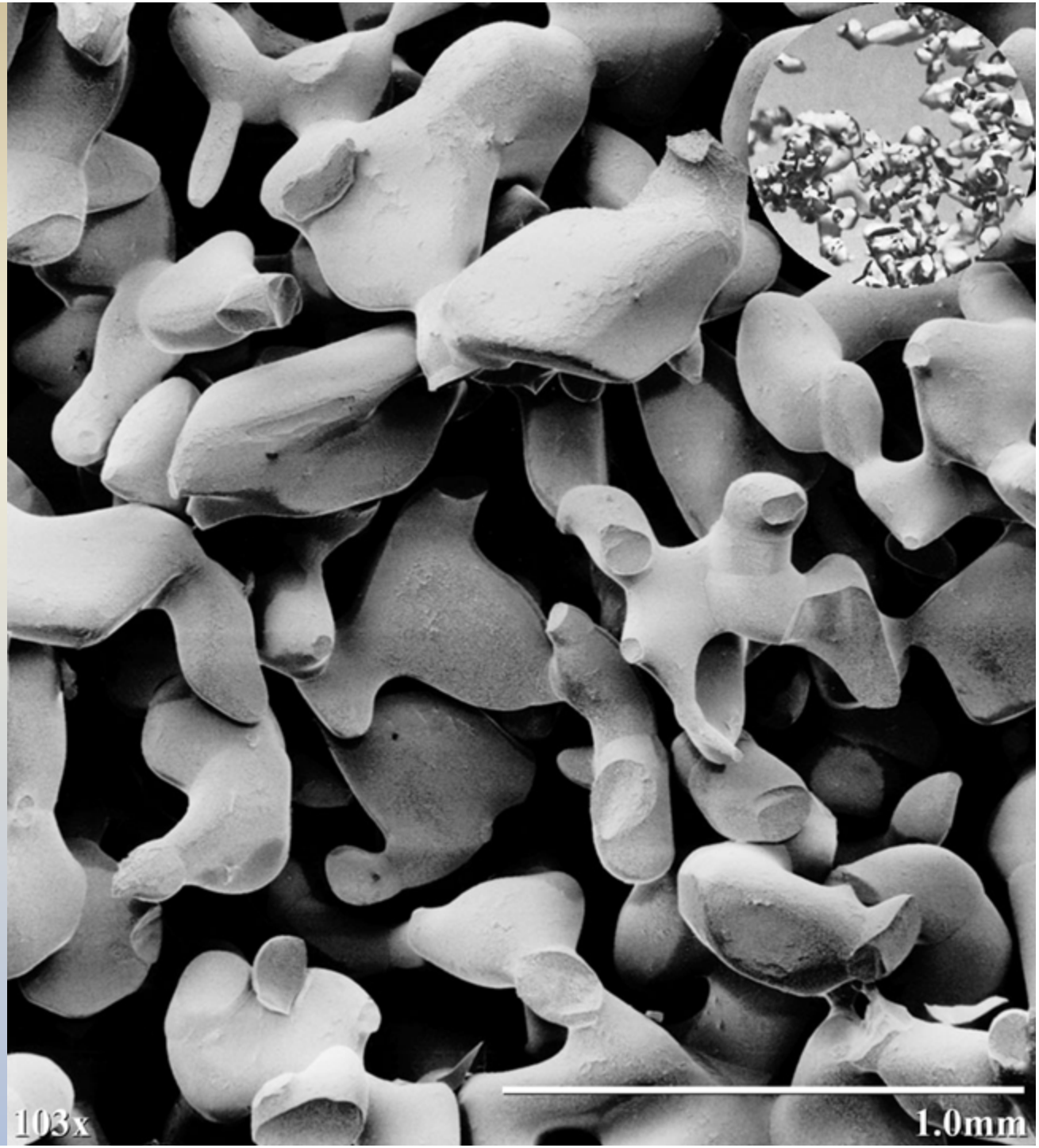
Snow/cloud discrimination with Landsat

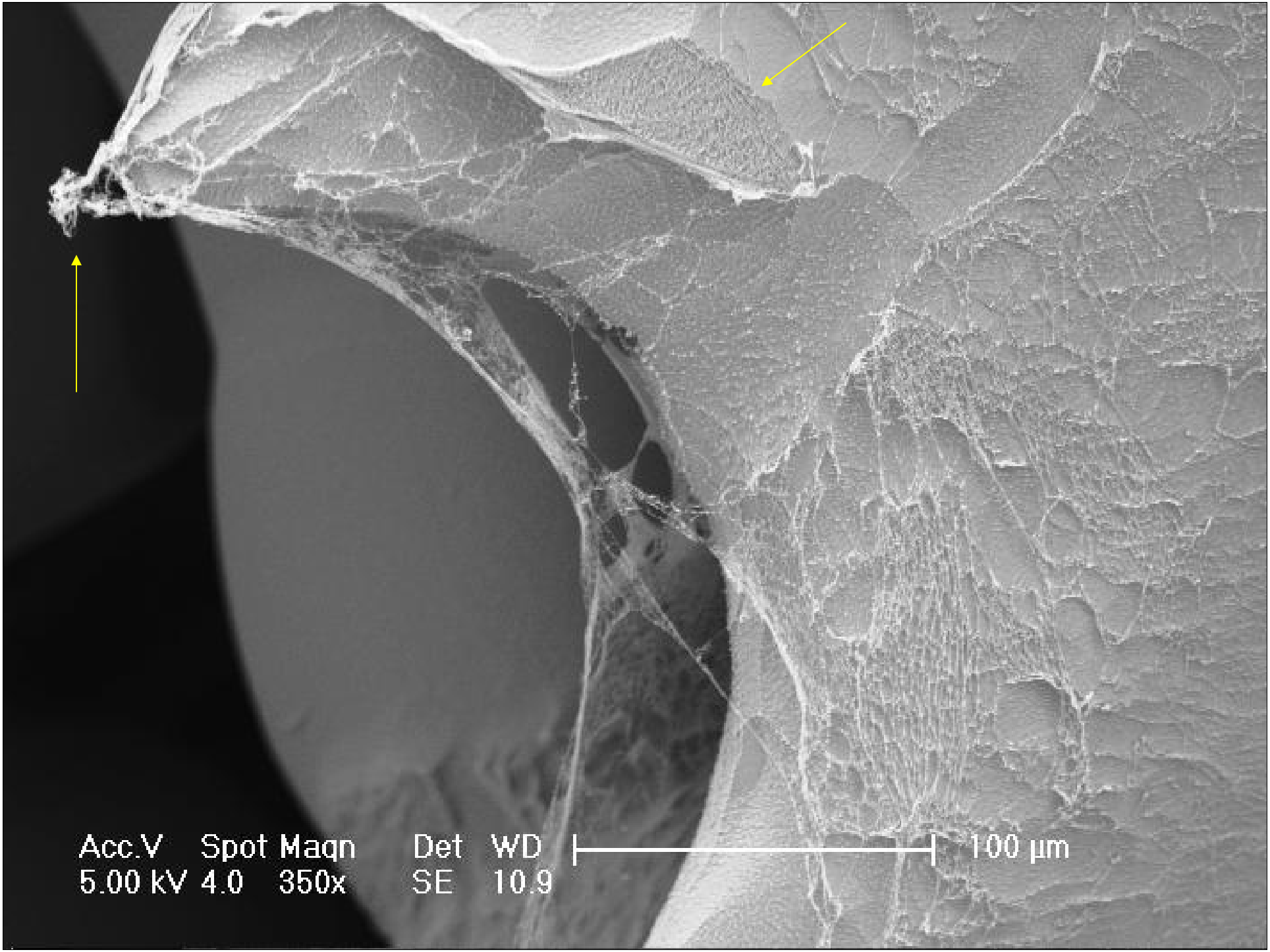


Bands 3 2 1 (red, green, blue)

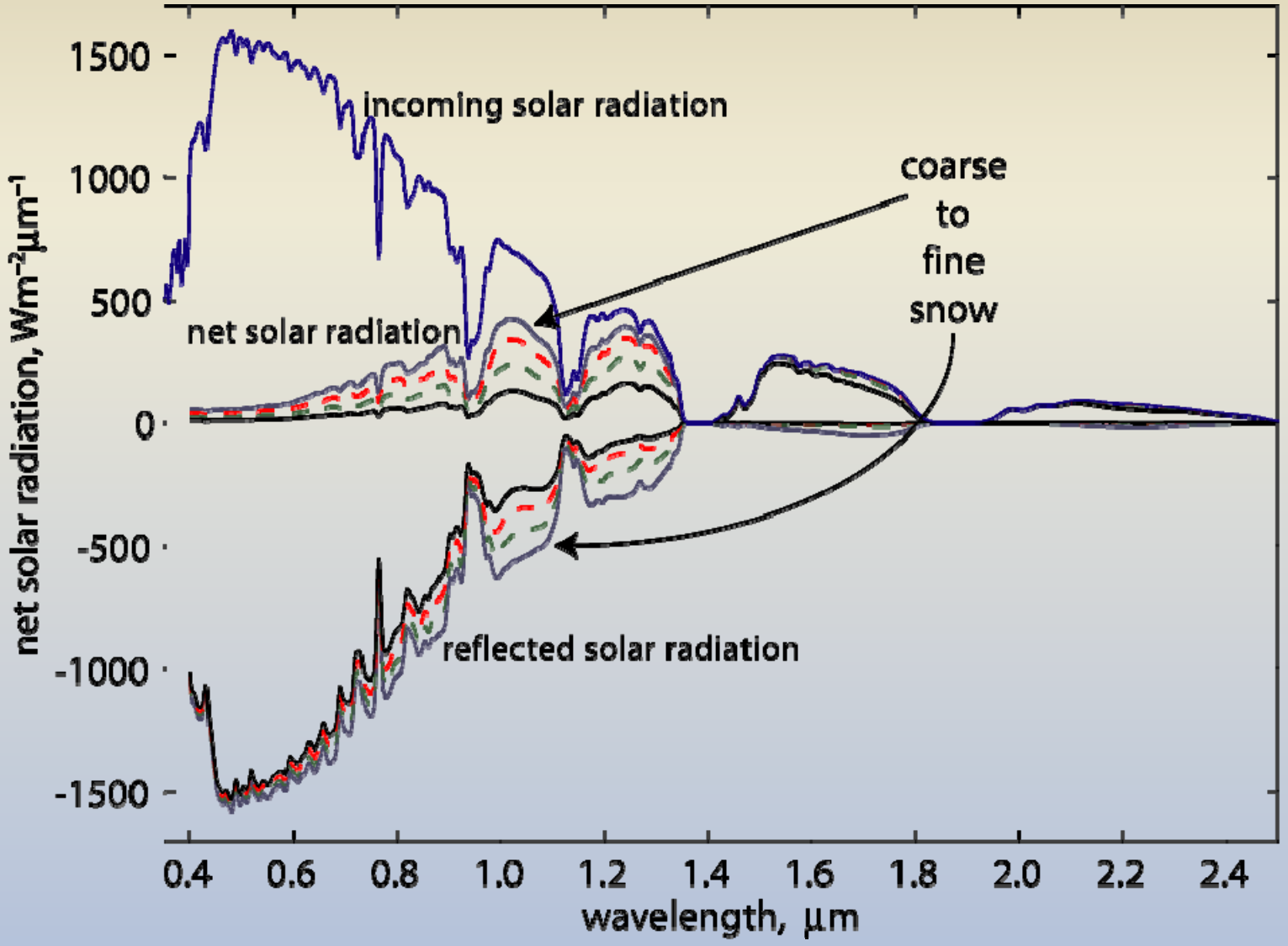
Bands 5 4 2

Snow is a collection of scattering grains

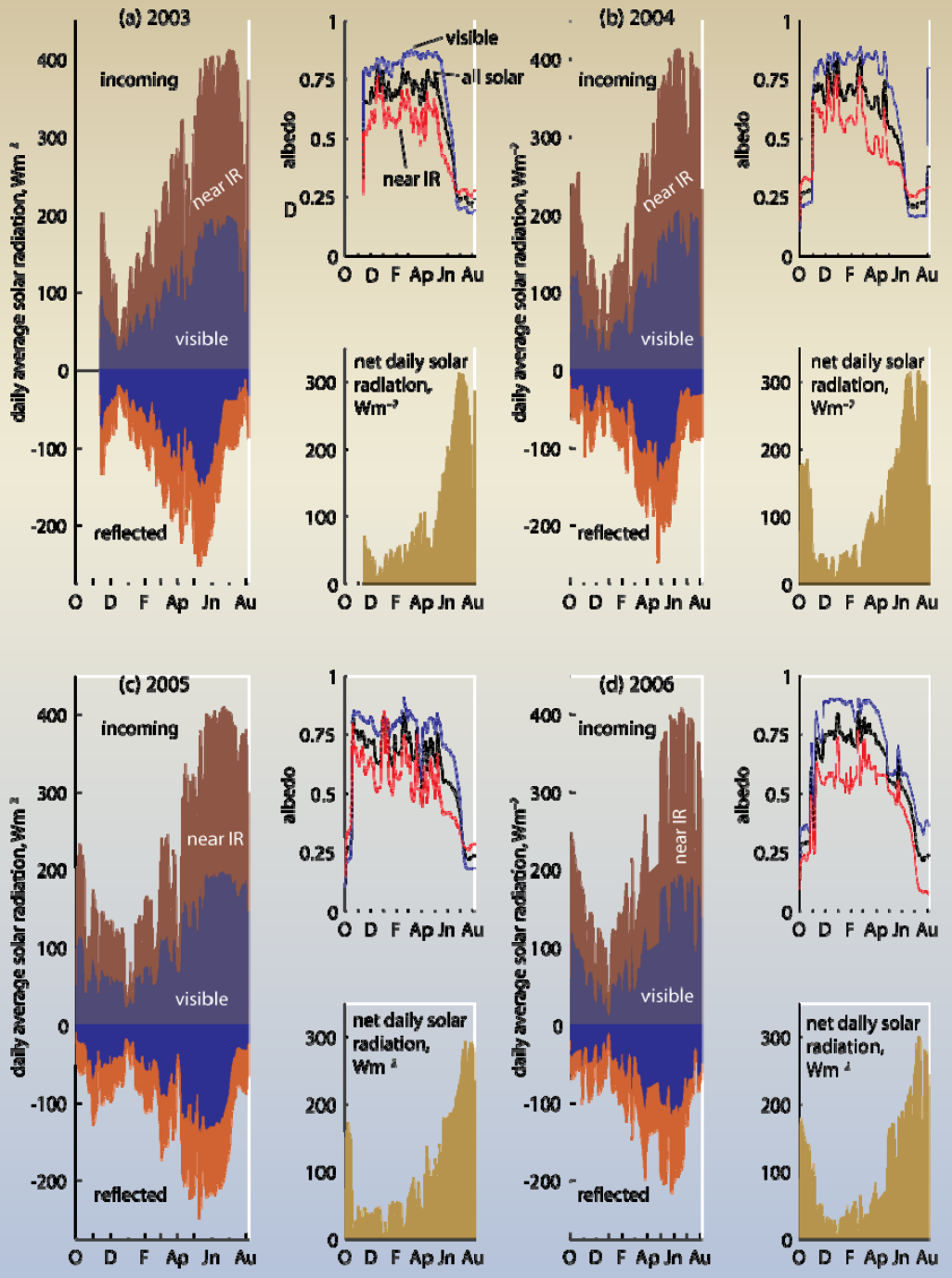



Acc.V Spot Magn Det WD
5.00 kV 4.0 350x SE 10.9
100 µm

Net solar radiation



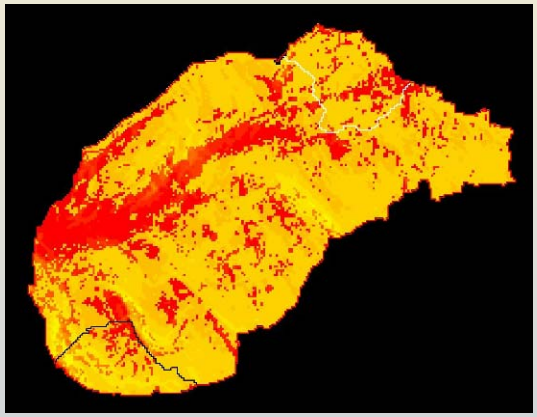
Seasonal solar radiation, Mammoth Mountain



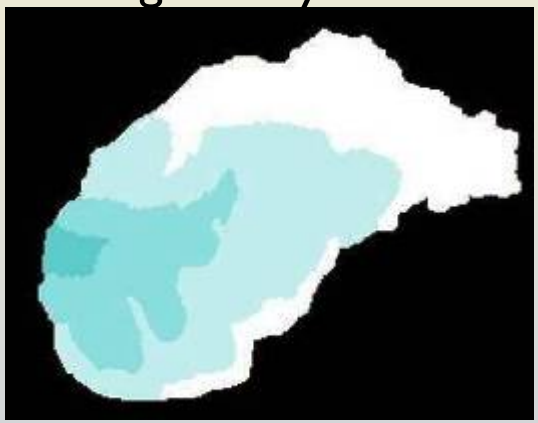
Applications: snowmelt modeling, Marble Fork of the Kaweah River

$$\text{Melt Flux} = \left(R_{net} m_q + T_d a_r \right) \times SCA$$

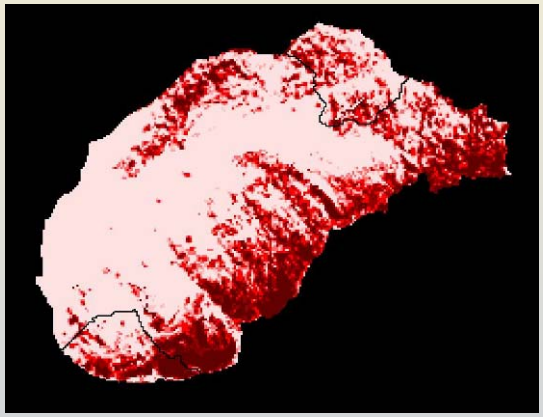
net radiation > 0



degree days > 0



Snow Covered Area

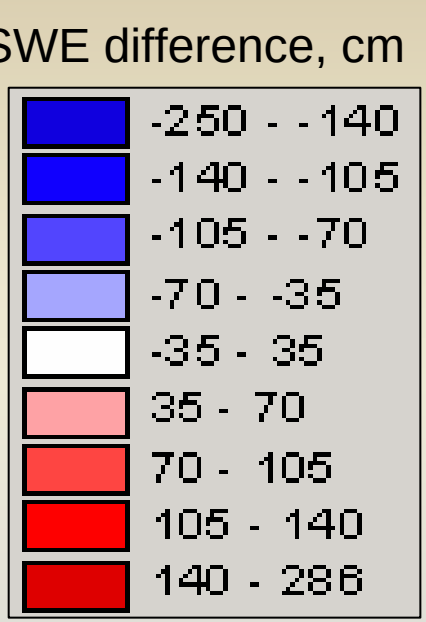


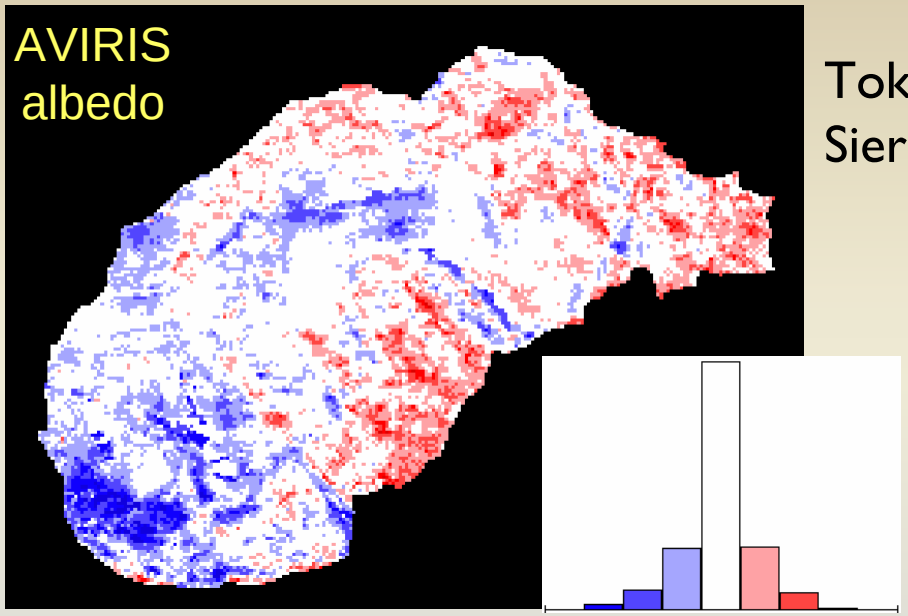
where:

m_q = Energy to water depth conversion, 0.026 cm W^{-1} m^2 day^{-1}

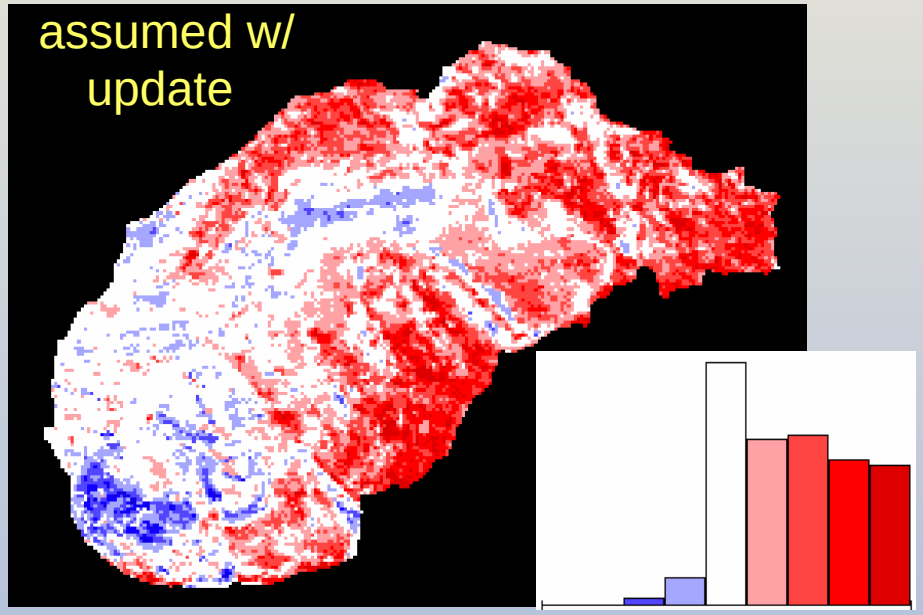
a_r = Convection parameter, based on wind speed, temperature, humidity, and roughness

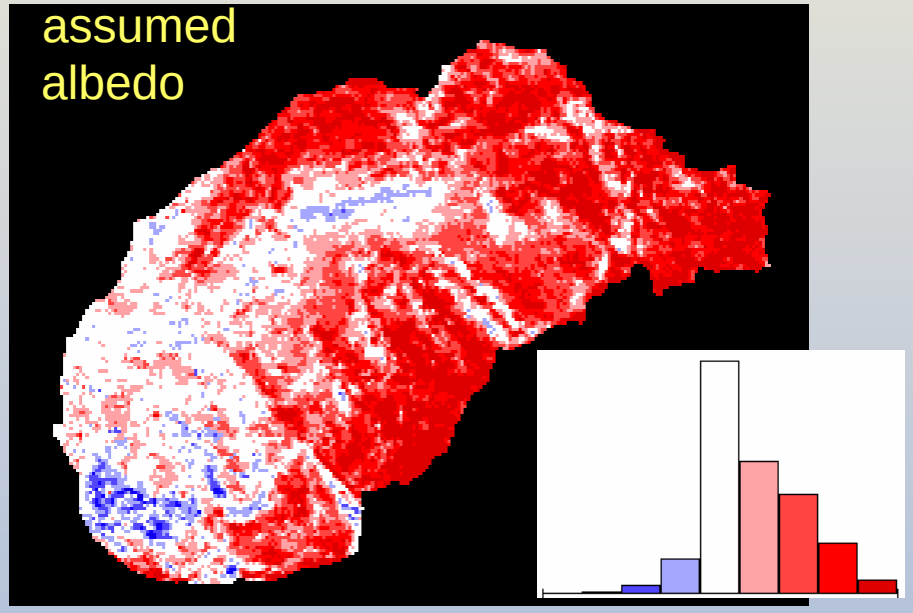
Magnitude of snowmelt: Modeled – Observed snow water equivalent





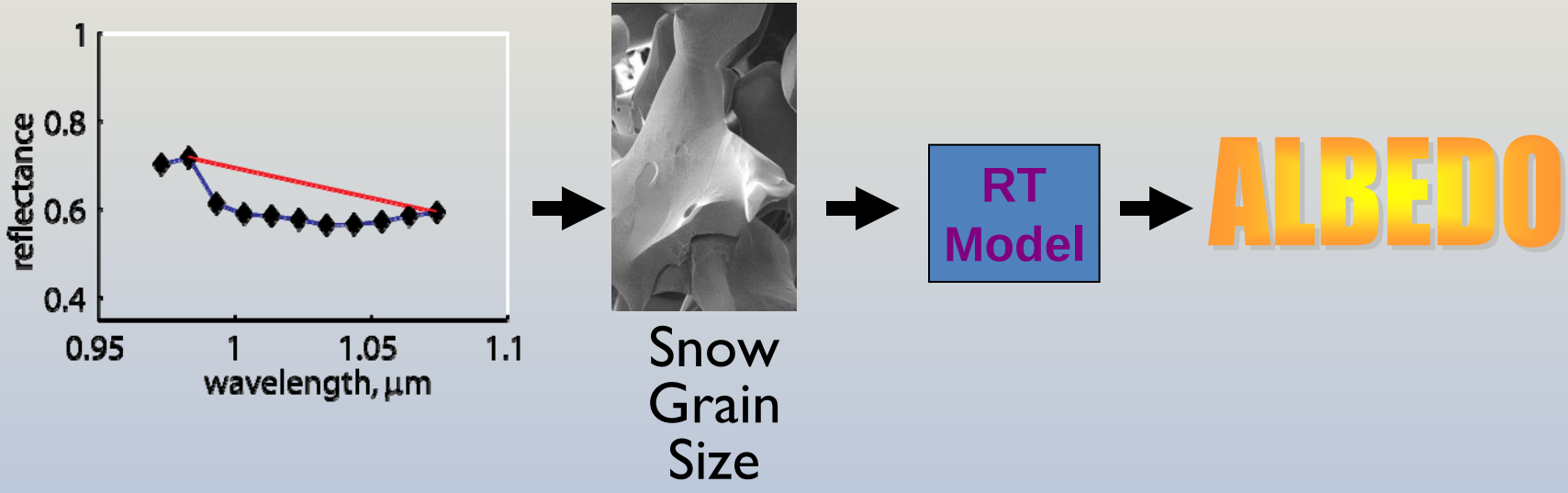
Tokopah basin,
Sierra Nevada



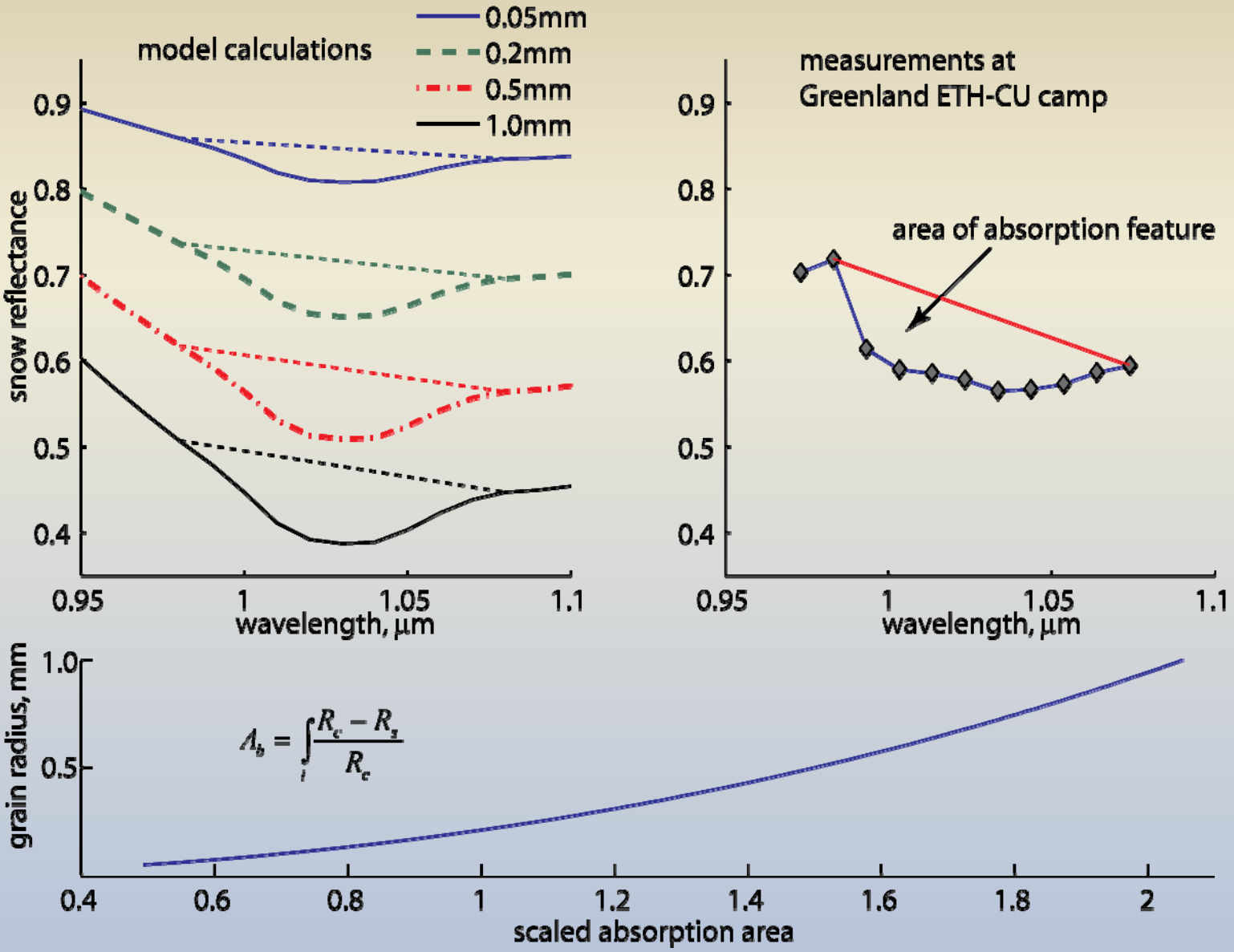


Different paradigm, based on physical properties and radiative transfer theory

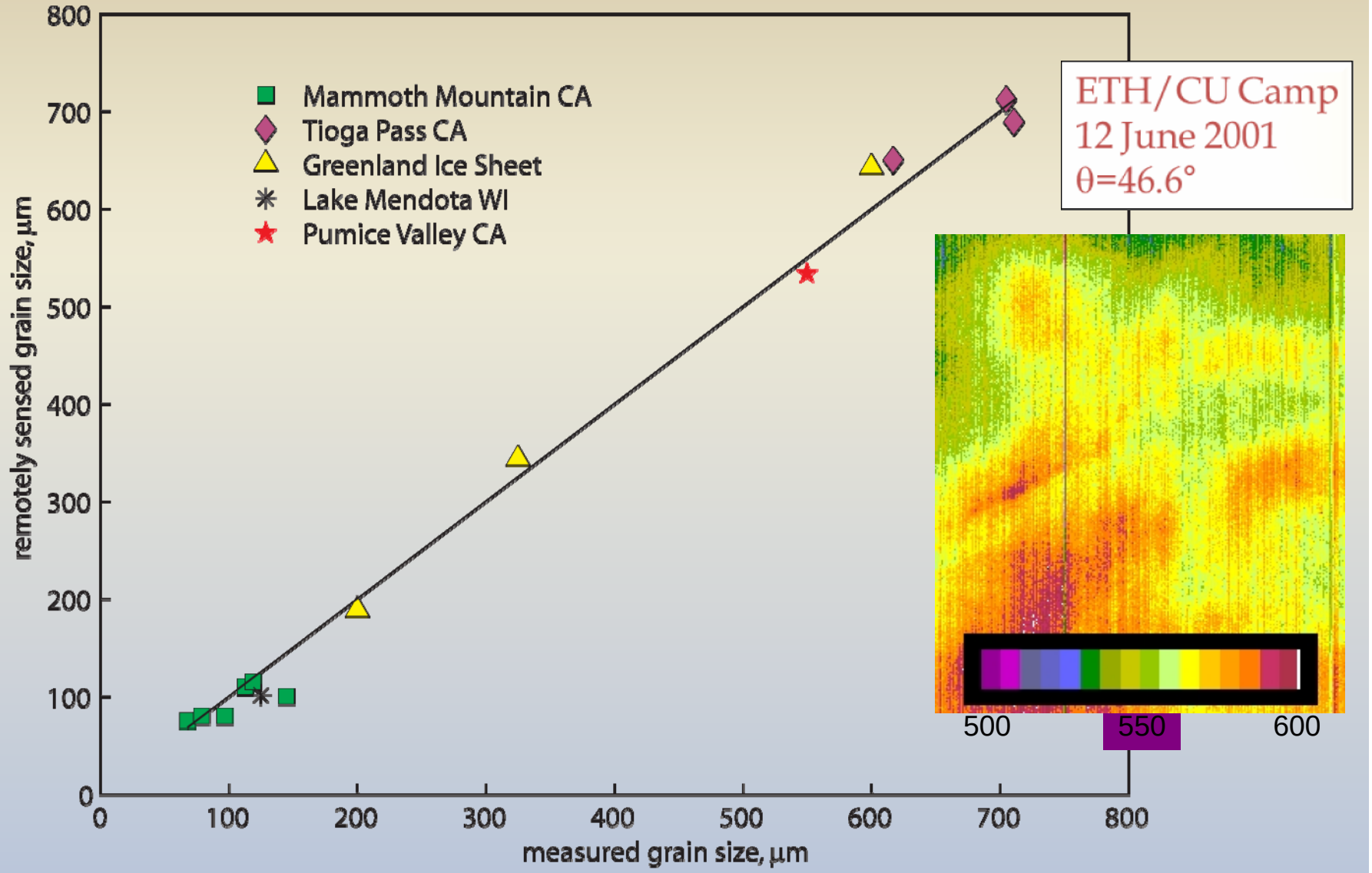
- Measure 1.03μm absorption feature
- Estimate grain size
- Model spectral reflectance over all wavelengths
- Convolve with solar irradiance to estimate broadband albedo



Estimate grain size from the 1.03μm absorption feature



Measured vs remotely sensed grain size



Spectral mixture analysis

$$\overline{R_\lambda} = \sum_{t=1}^{N} F_t R_{\lambda t} + \varepsilon_\lambda$$

Spectral mixture equation, per pixel

$$\varepsilon_\lambda = \overline{R_\lambda} - \sum_{t=1}^{N} F_t R_{\lambda t}$$

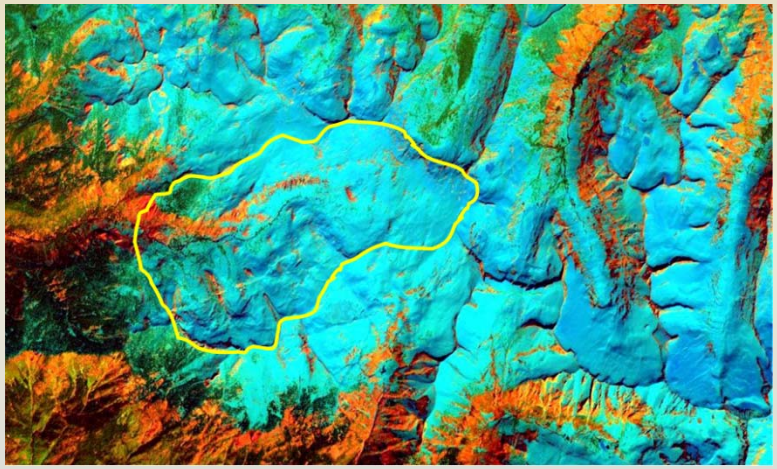
Spectral residuals, per pixel

$$RMSE = \sqrt{\frac{1}{M} \sum_{\lambda=1}^{M} \varepsilon_\lambda^2}$$

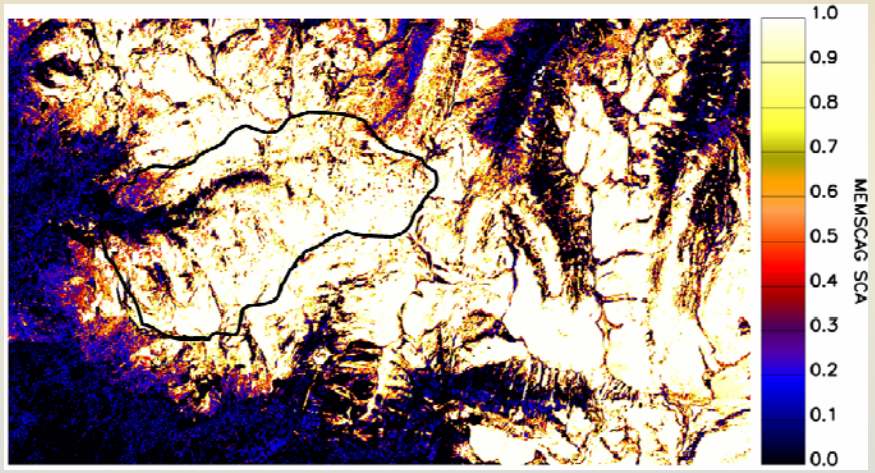
RMS error, per pixel

Snow-covered area in the Tokopah Basin (Kaweah River drainage), Sierra Nevada

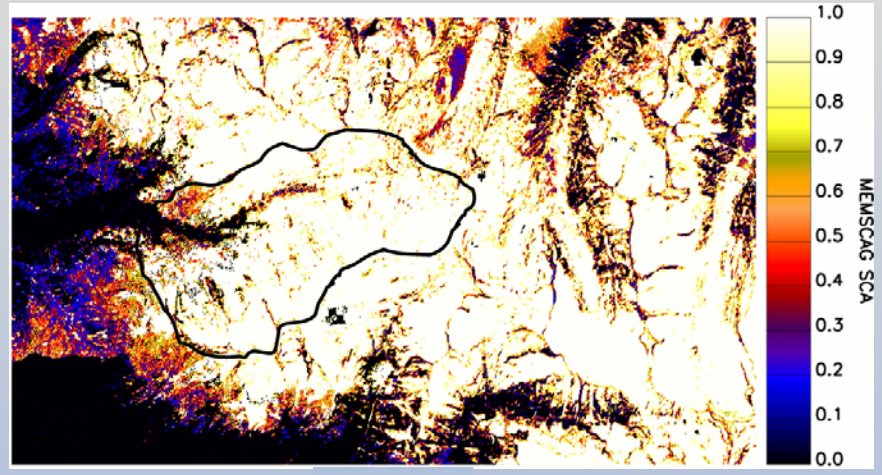
AVIRIS



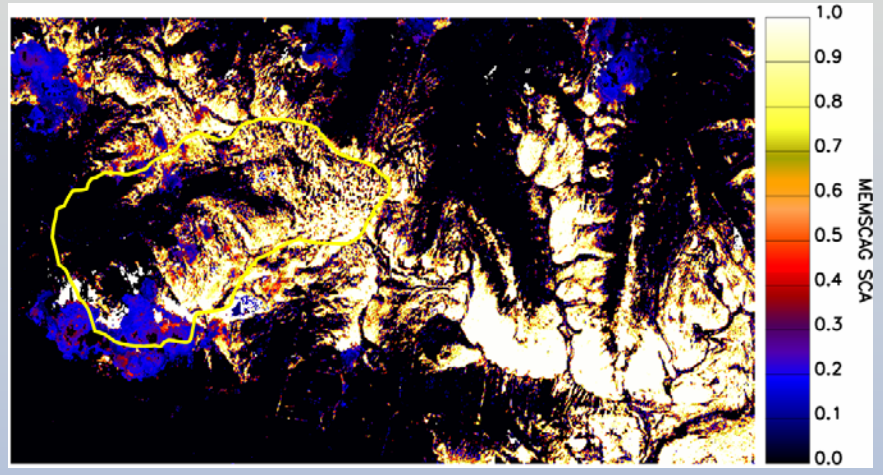
21 May 1997



05 May 1997



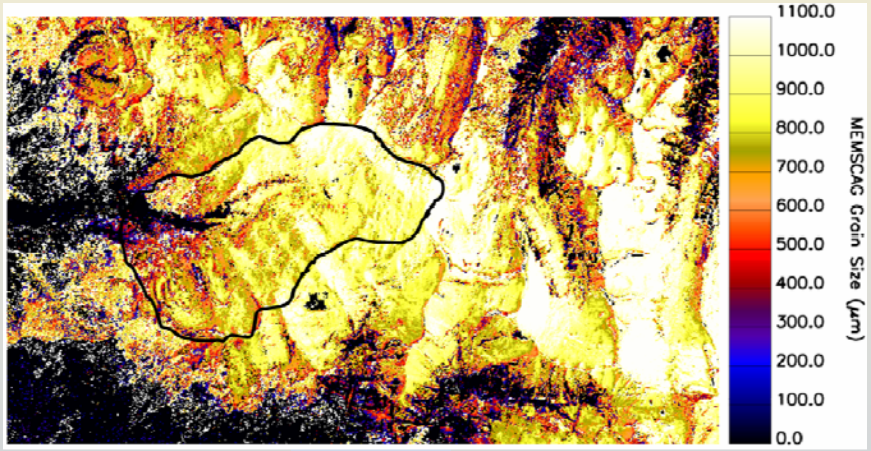
18 June 1997



20 km

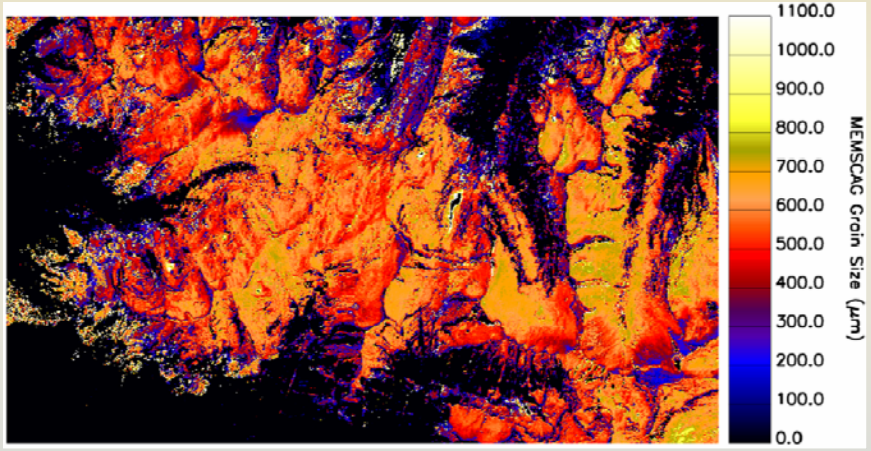
Grain size in the Tokopah Basin (Kaweah River drainage), Sierra Nevada

05 May 1997

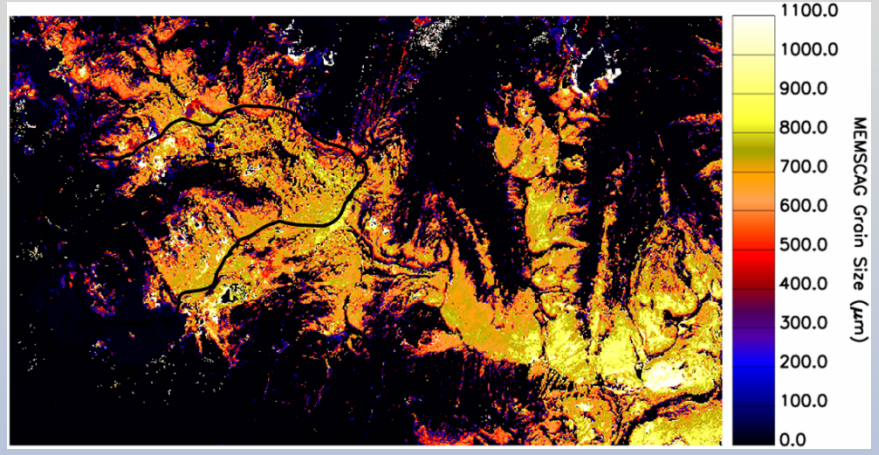


20 km

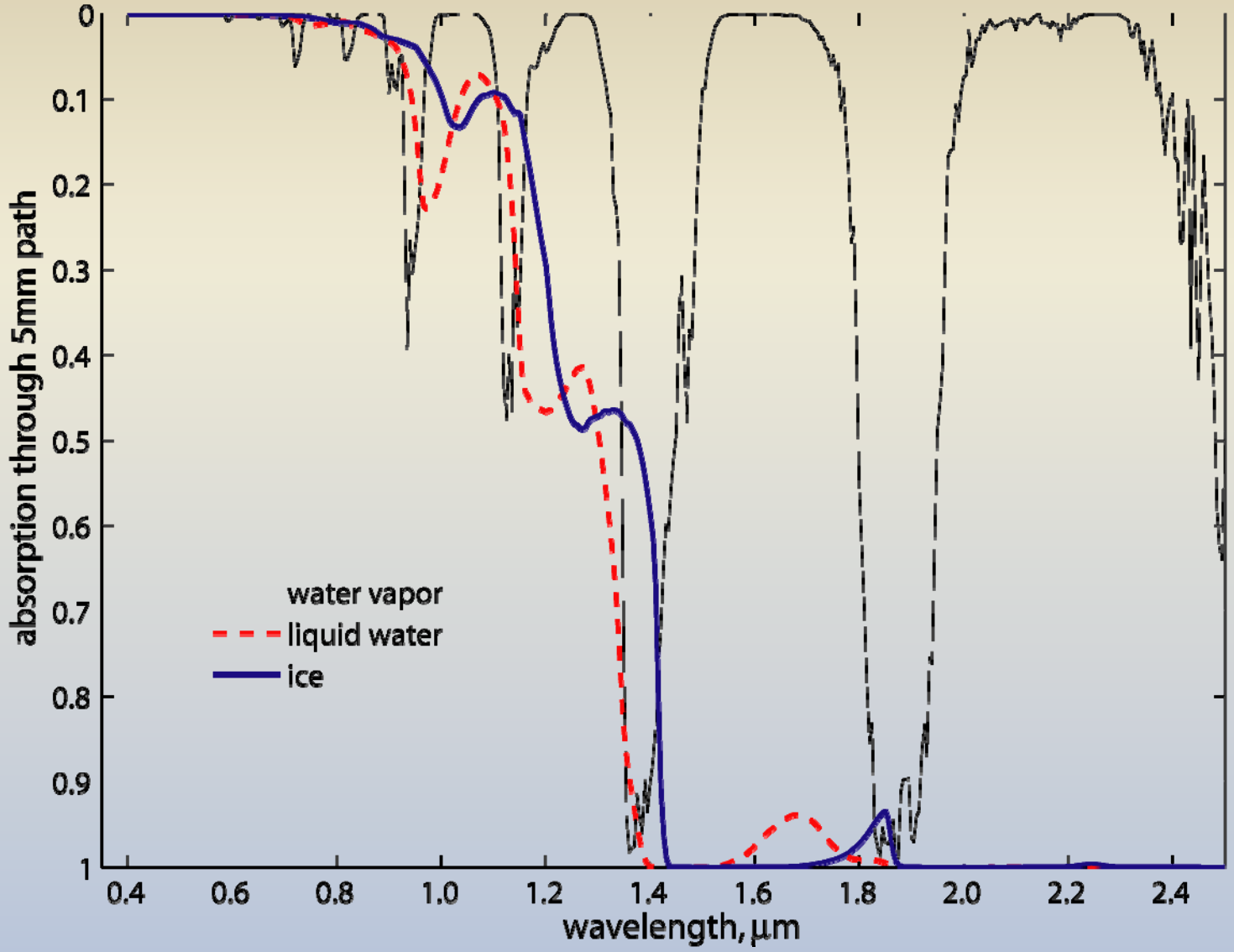
21 May 1997



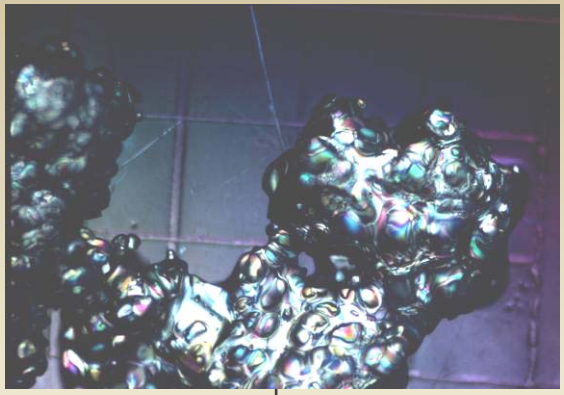
18 June 1997

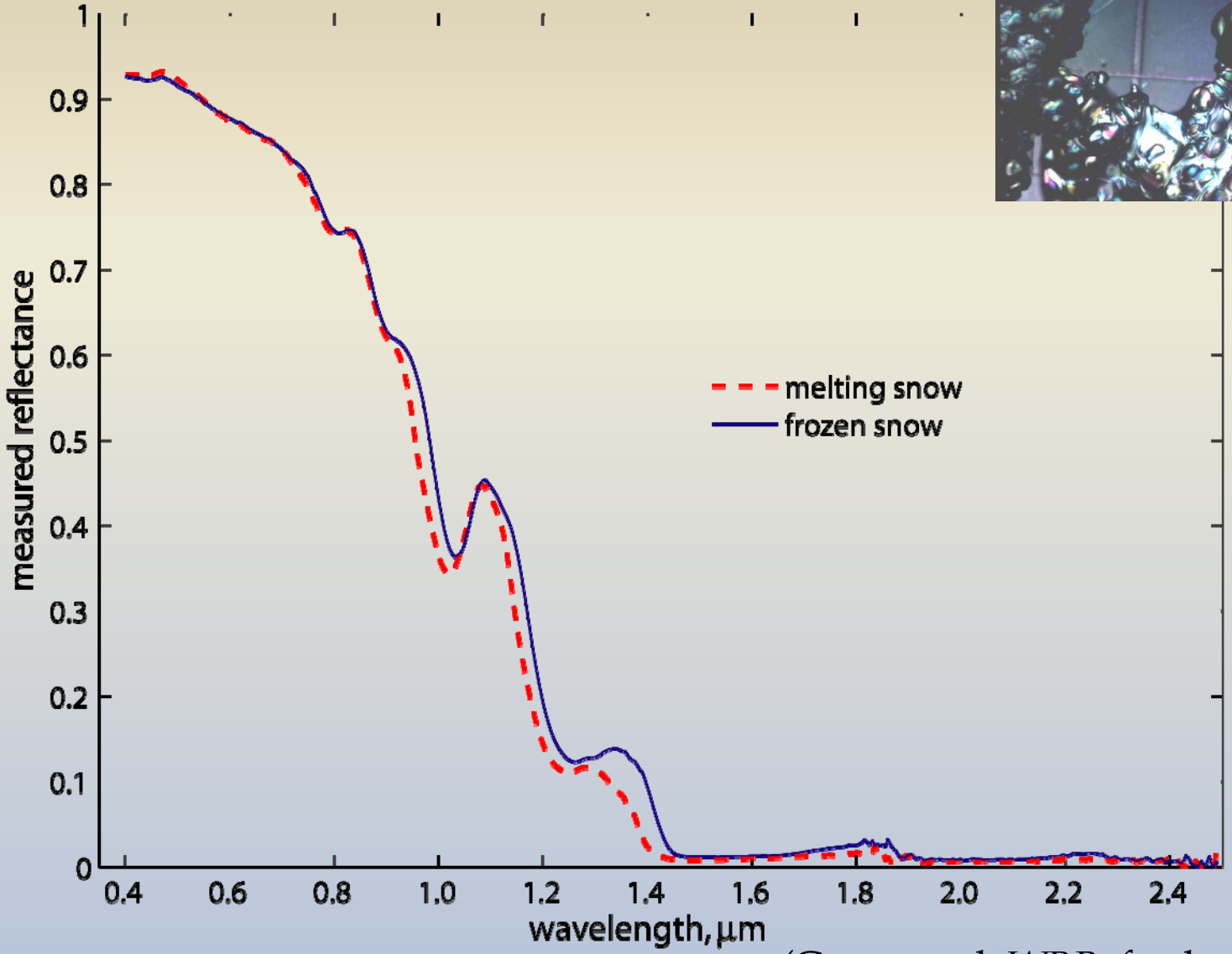


Absorption by three phases of water



Wet snow

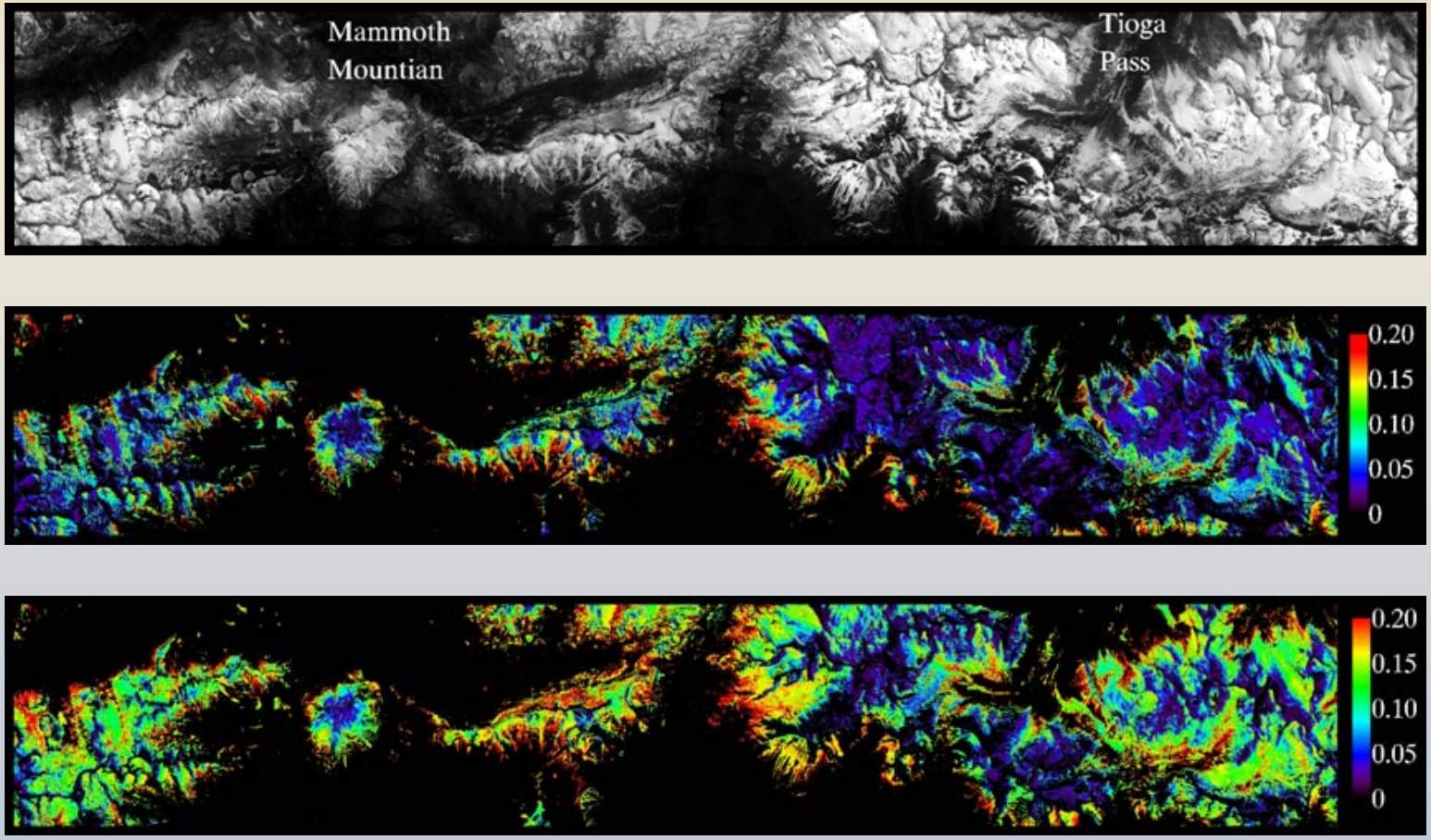




(Green et al, *WRR*, forthcoming)

Progression of snow wetness throughout morning

N



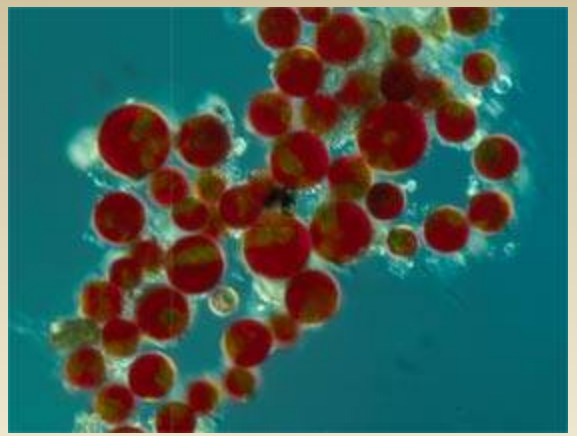
AVIRIS
20 May 1996

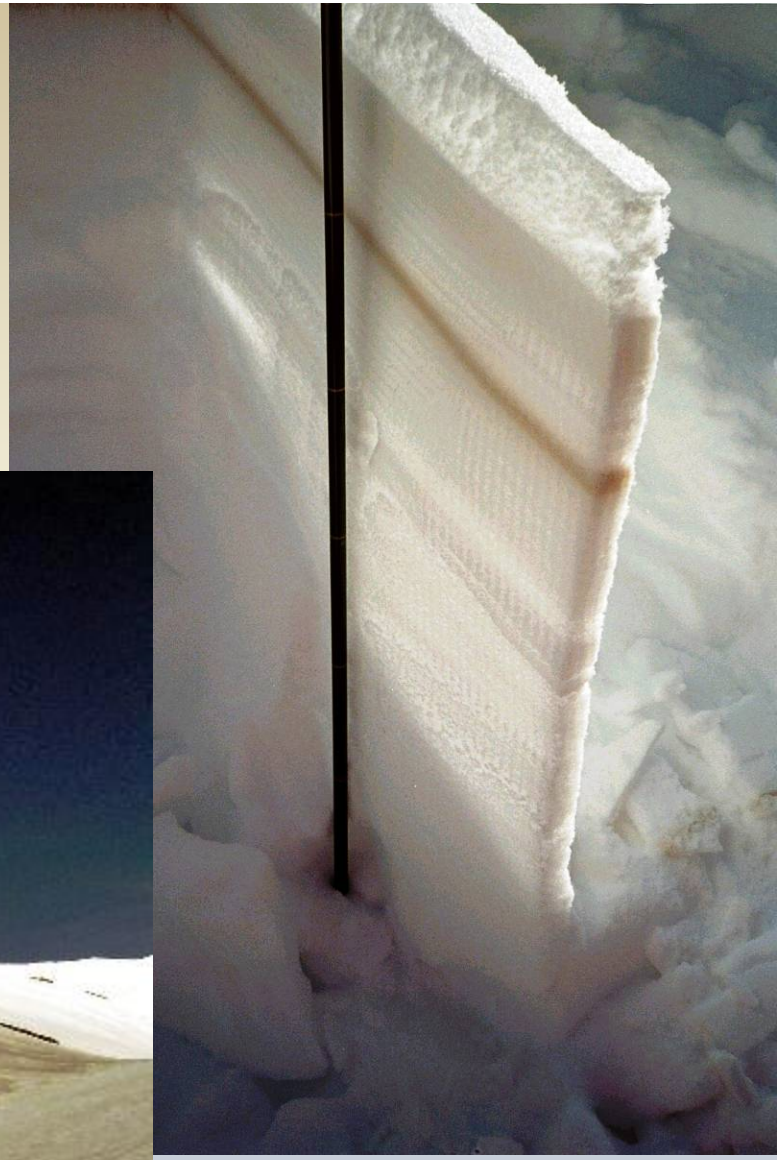
Surface wetness
09:54 am

Surface wetness
11:32 am

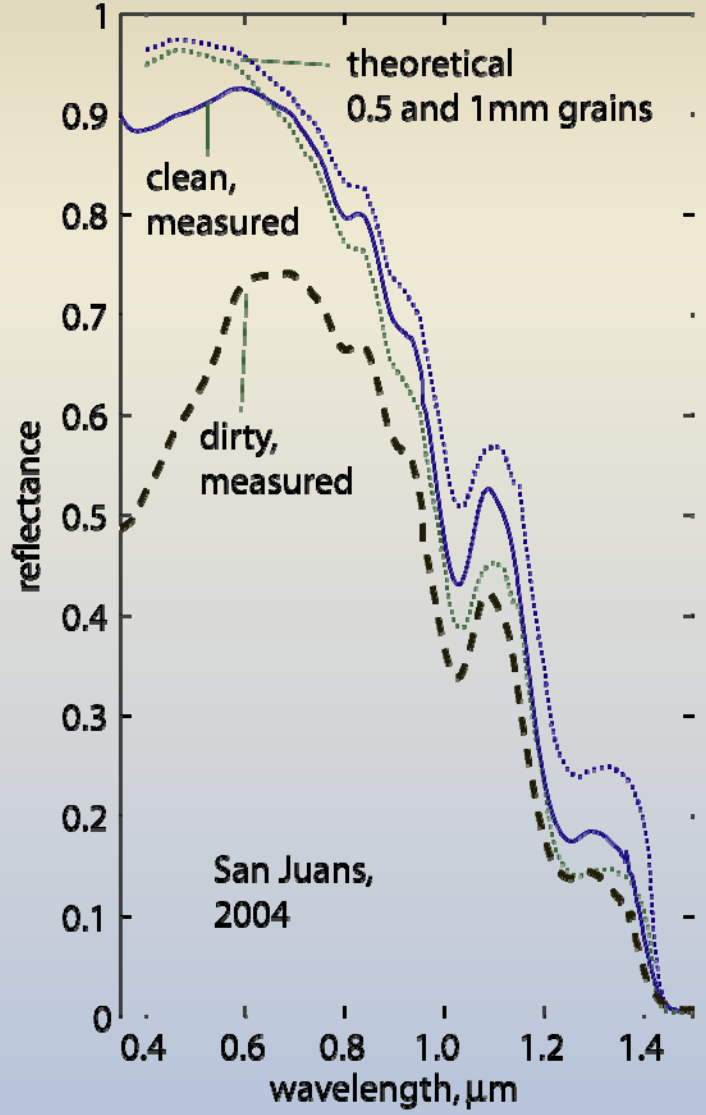
70 km

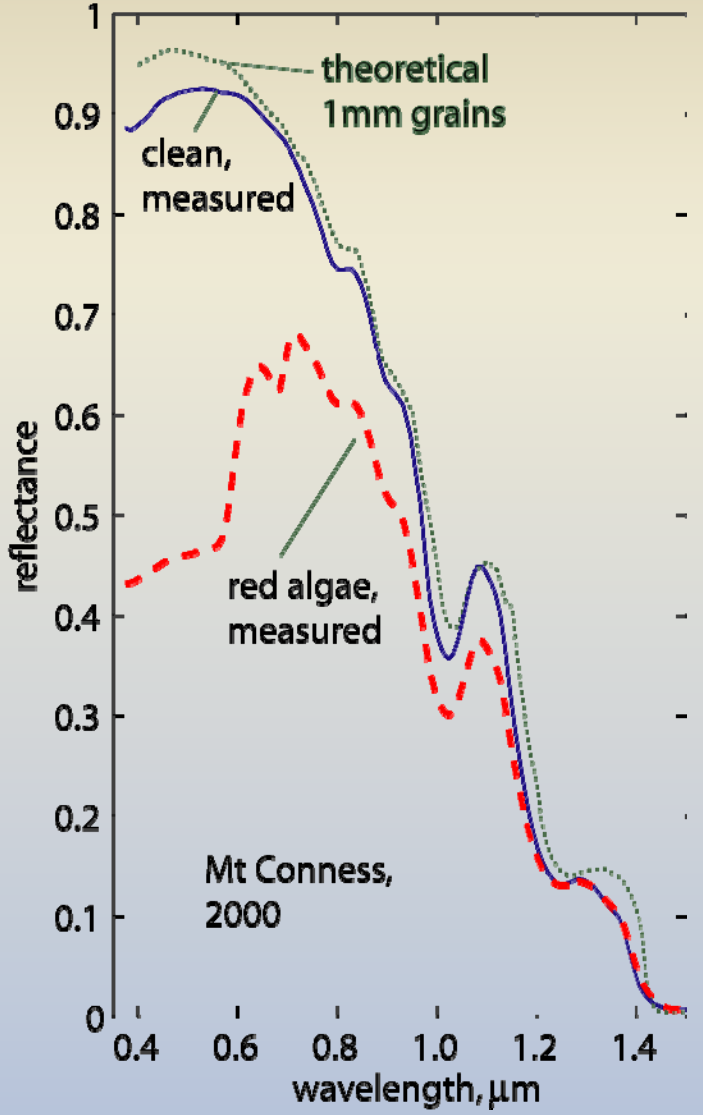
Dust and algae





Spectral reflectance of dirty snow and snow with red algae (*Chlamydomonas nivalis*)

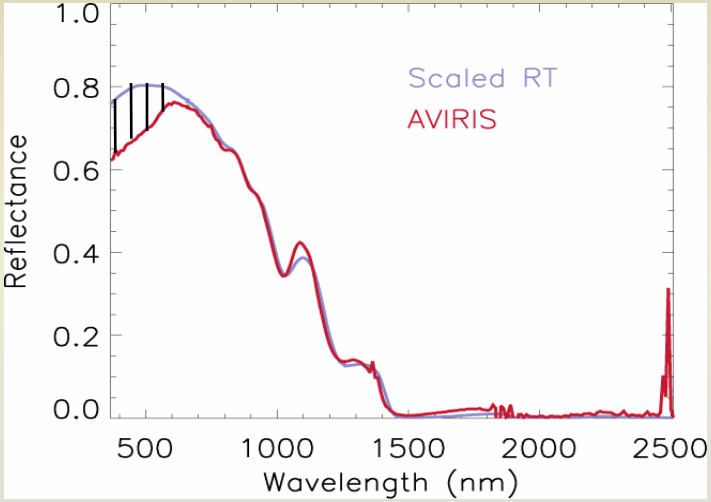


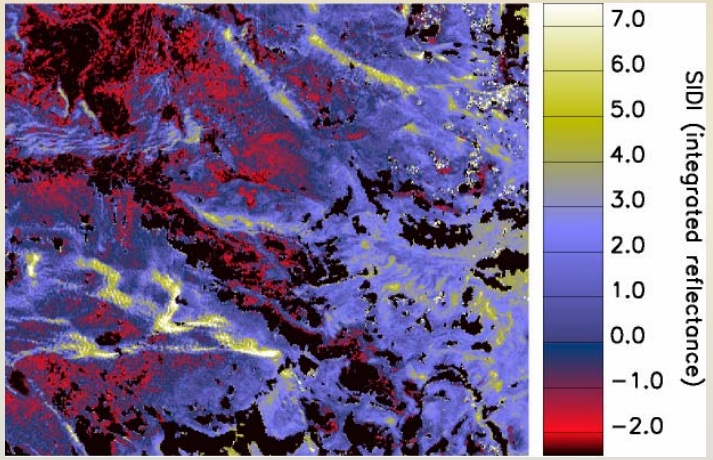


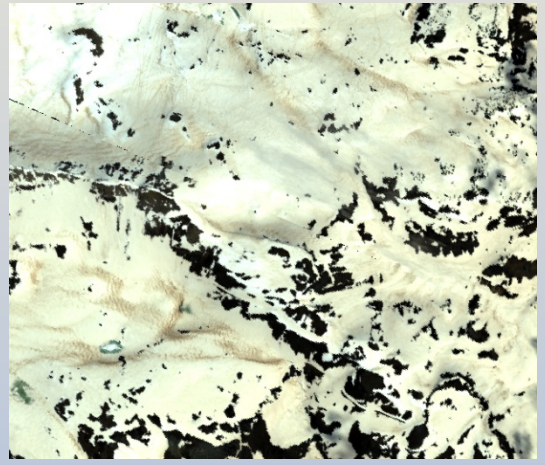
Snow algae concentration

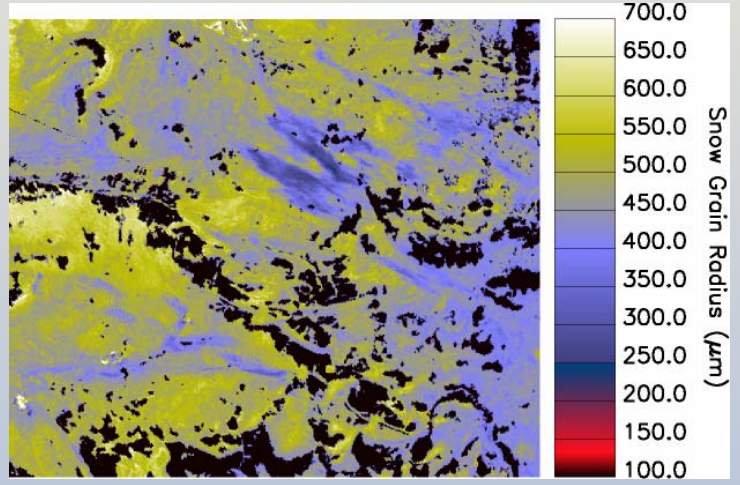
[Painter et al, 2001, *Appl. Environ. Microbiol.*]

Radiative forcing by dust in snow

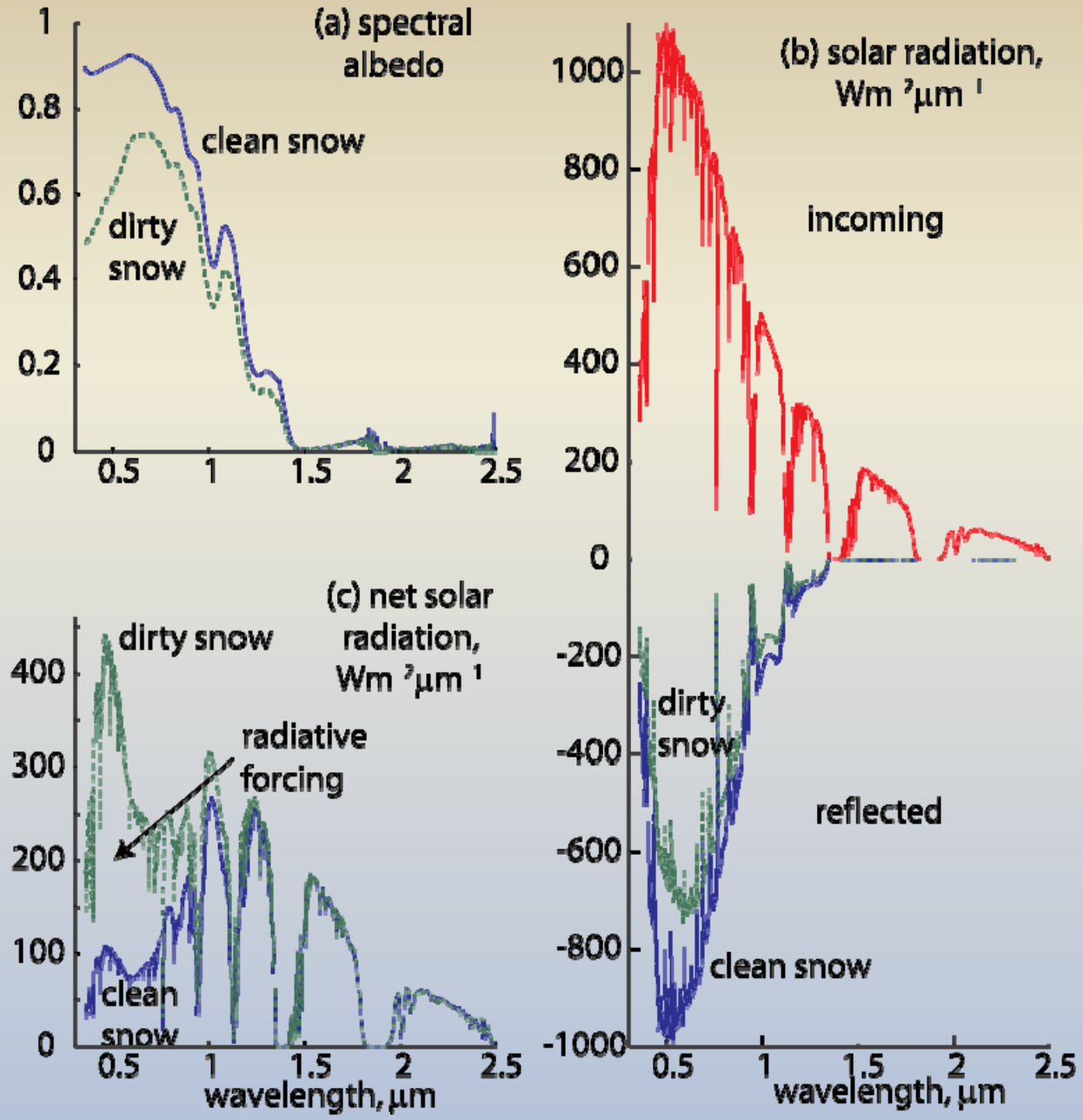




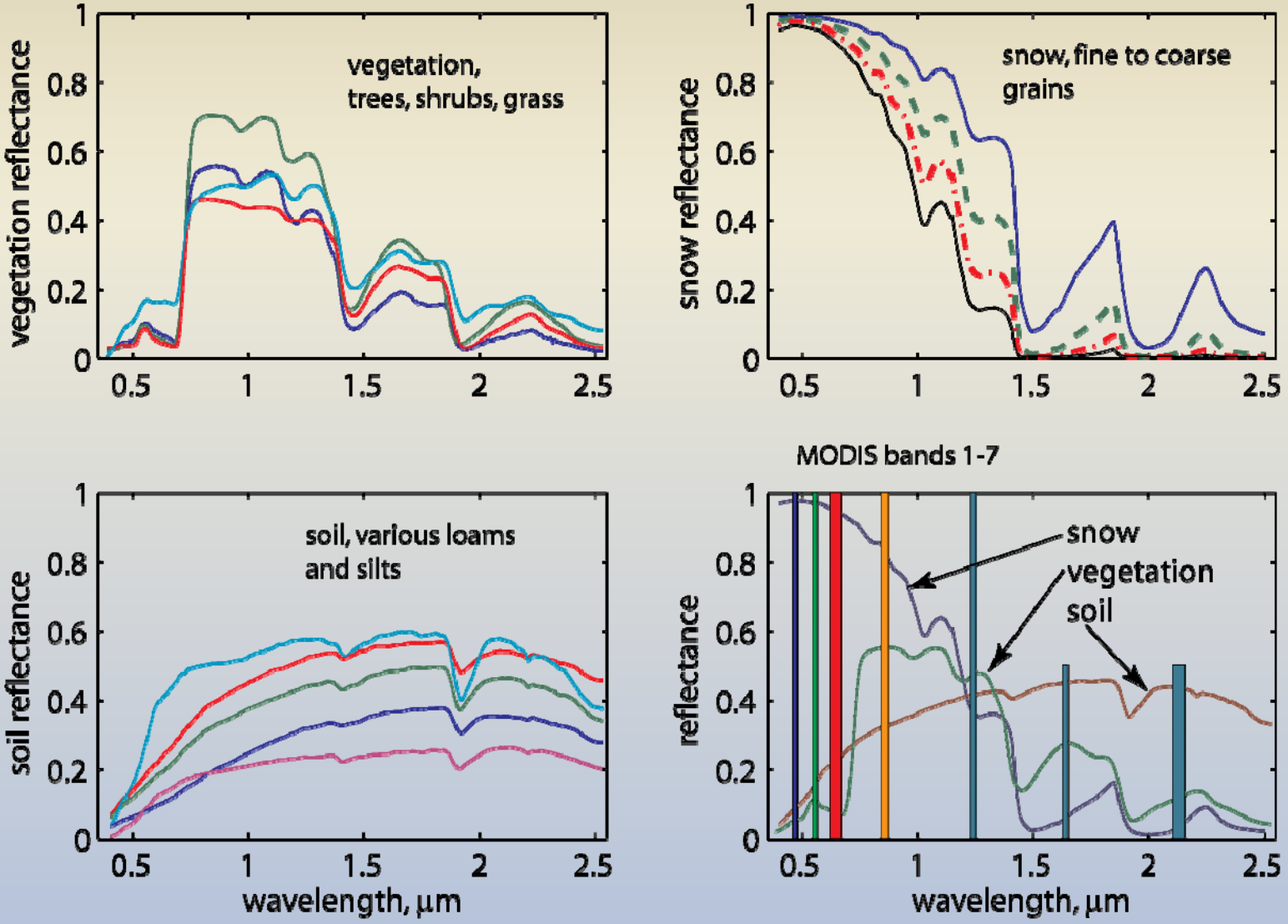




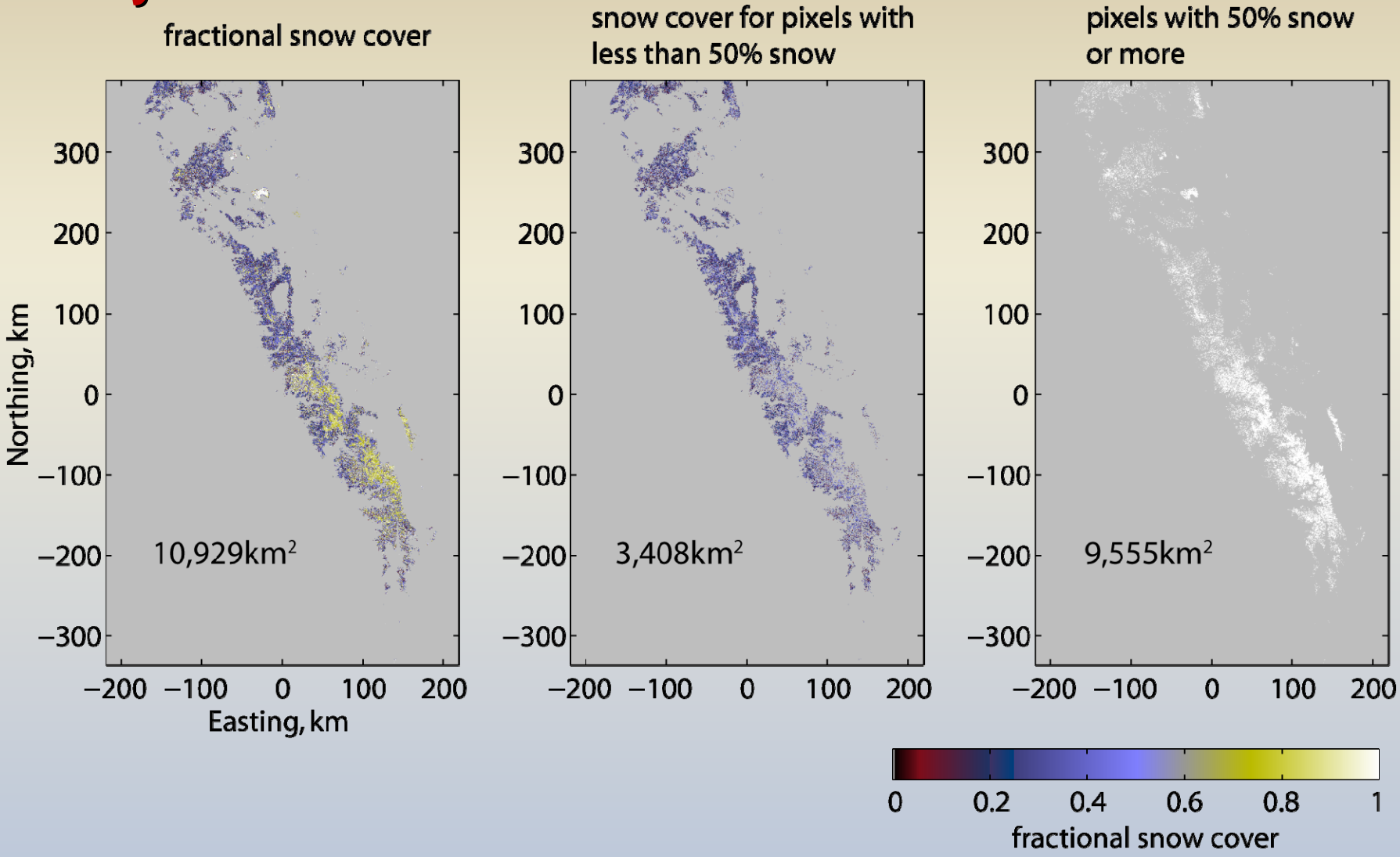
Radiative forcing concept



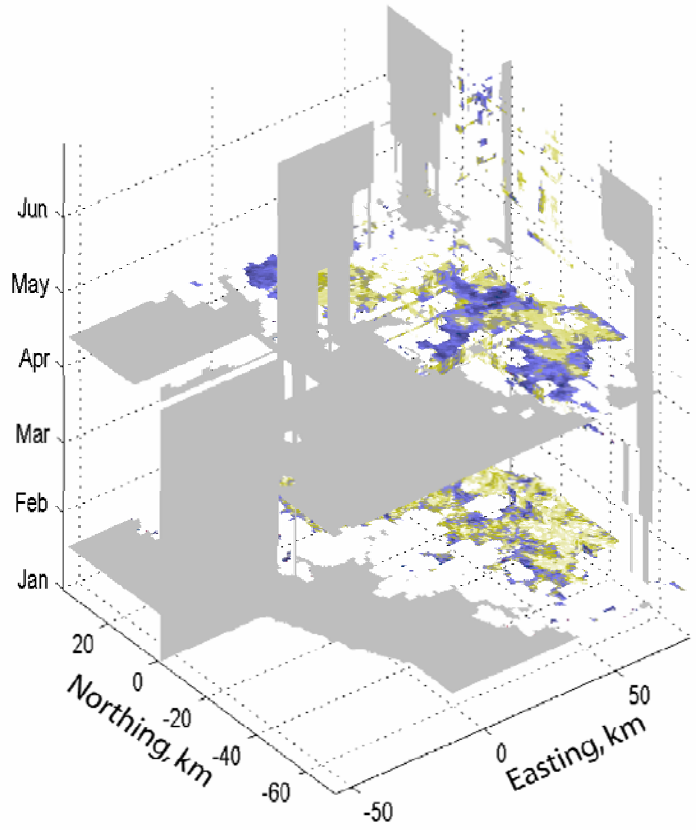
Spectra with MODIS "land" bands

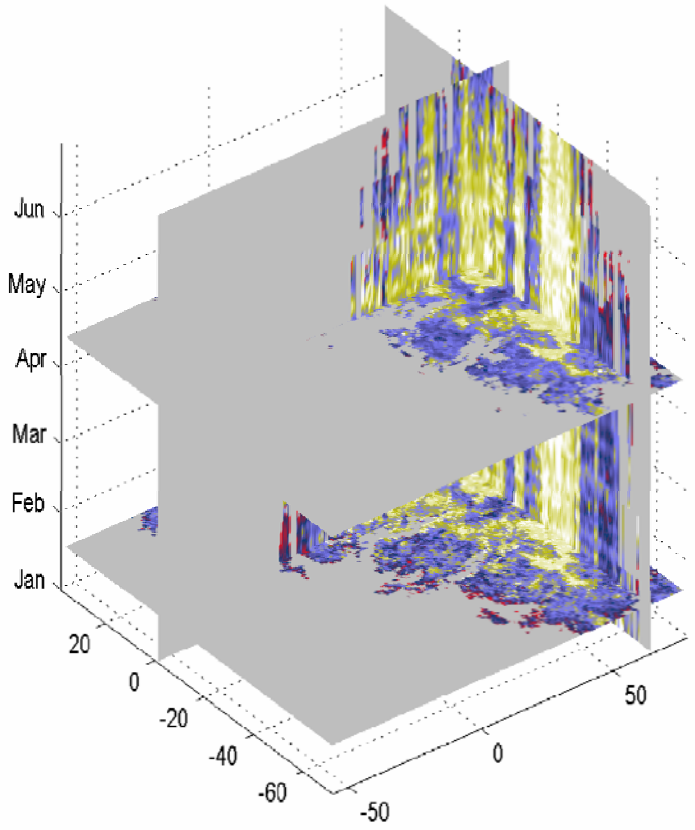


Fractional snow cover vs. binary, Sierra Nevada, 31 Jan 2007

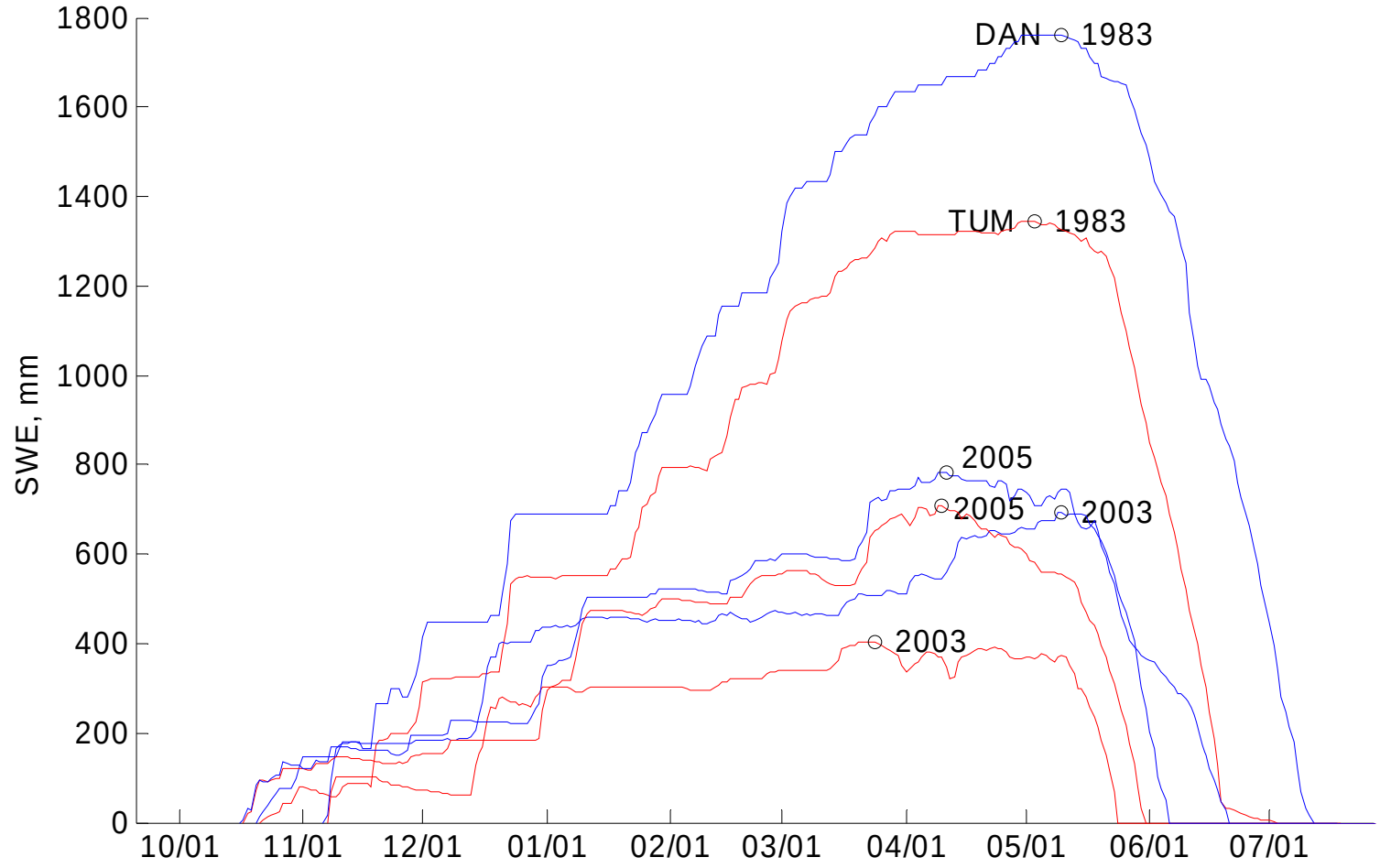


Time-space continuity of snow properties

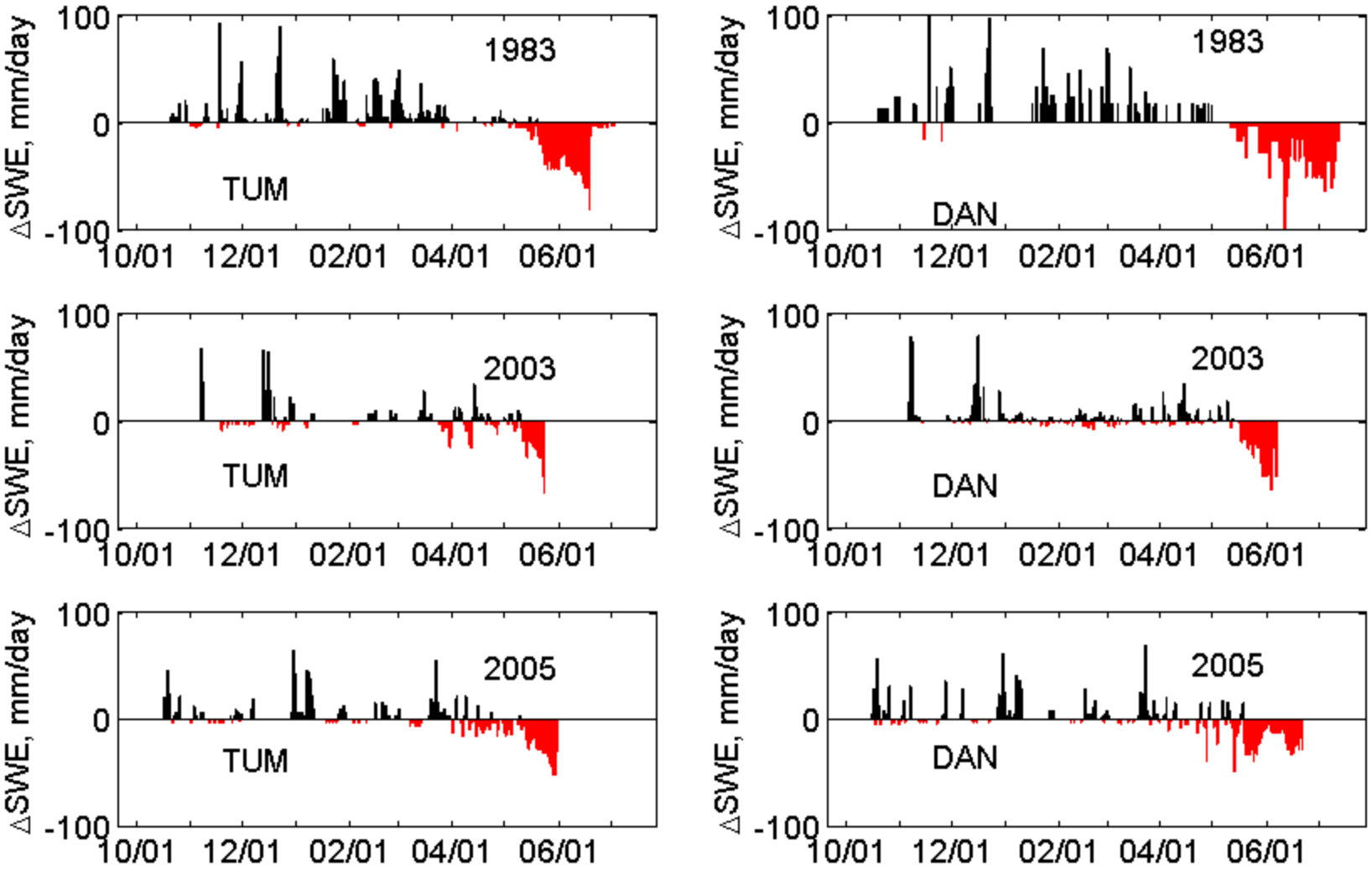




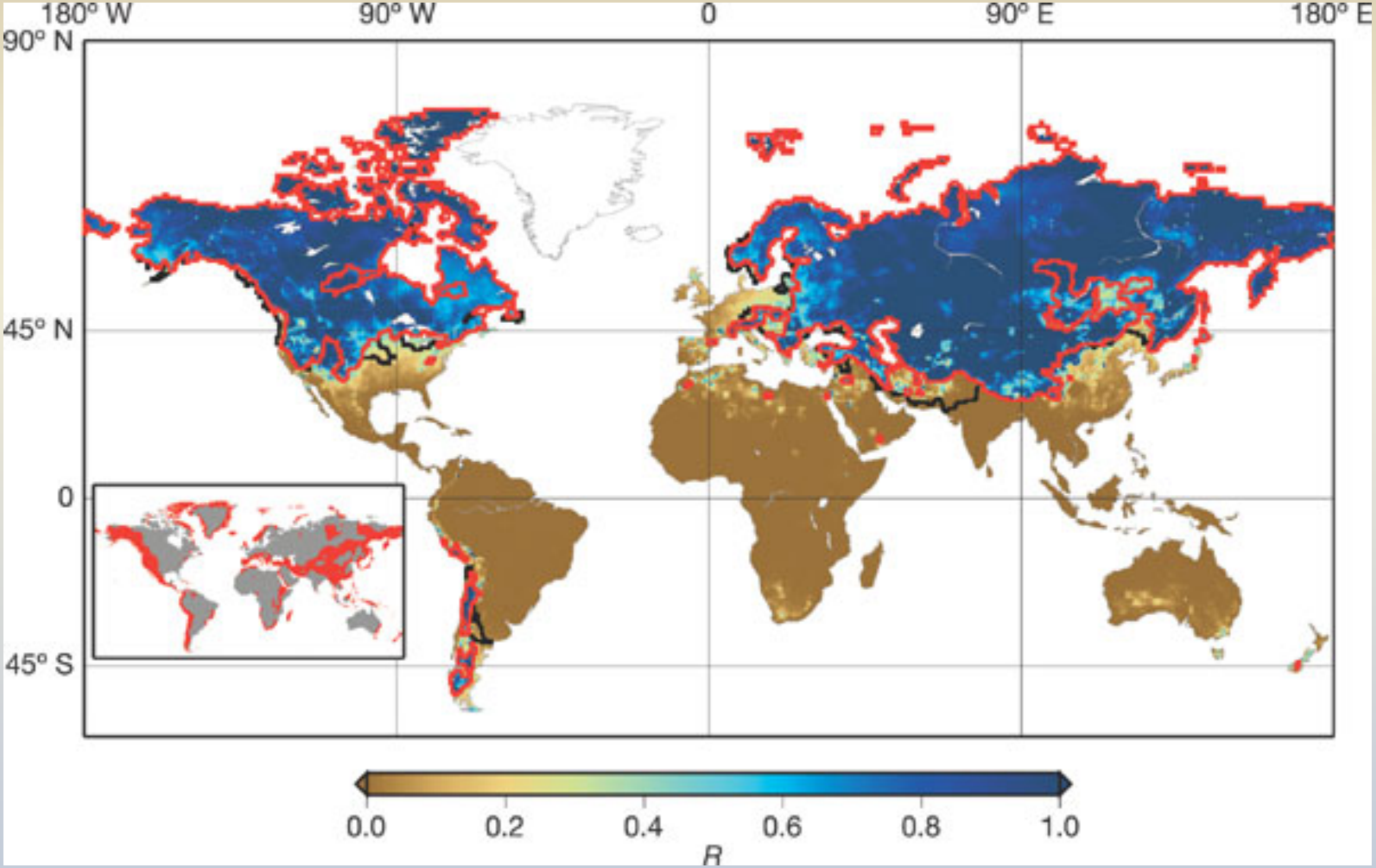
Snow-pillow data for Dana Meadows and Tuolumne Meadows



Accumulation and ablation inferred from snow pillow data, Tuolumne Meadows and Dana Meadows



Worldwide importance of the mountain snowpack



Barnett et al., *Nature*, 17 Nov 2005

1/6 of Earth's population relies on glaciers or seasonal snow for their water supply