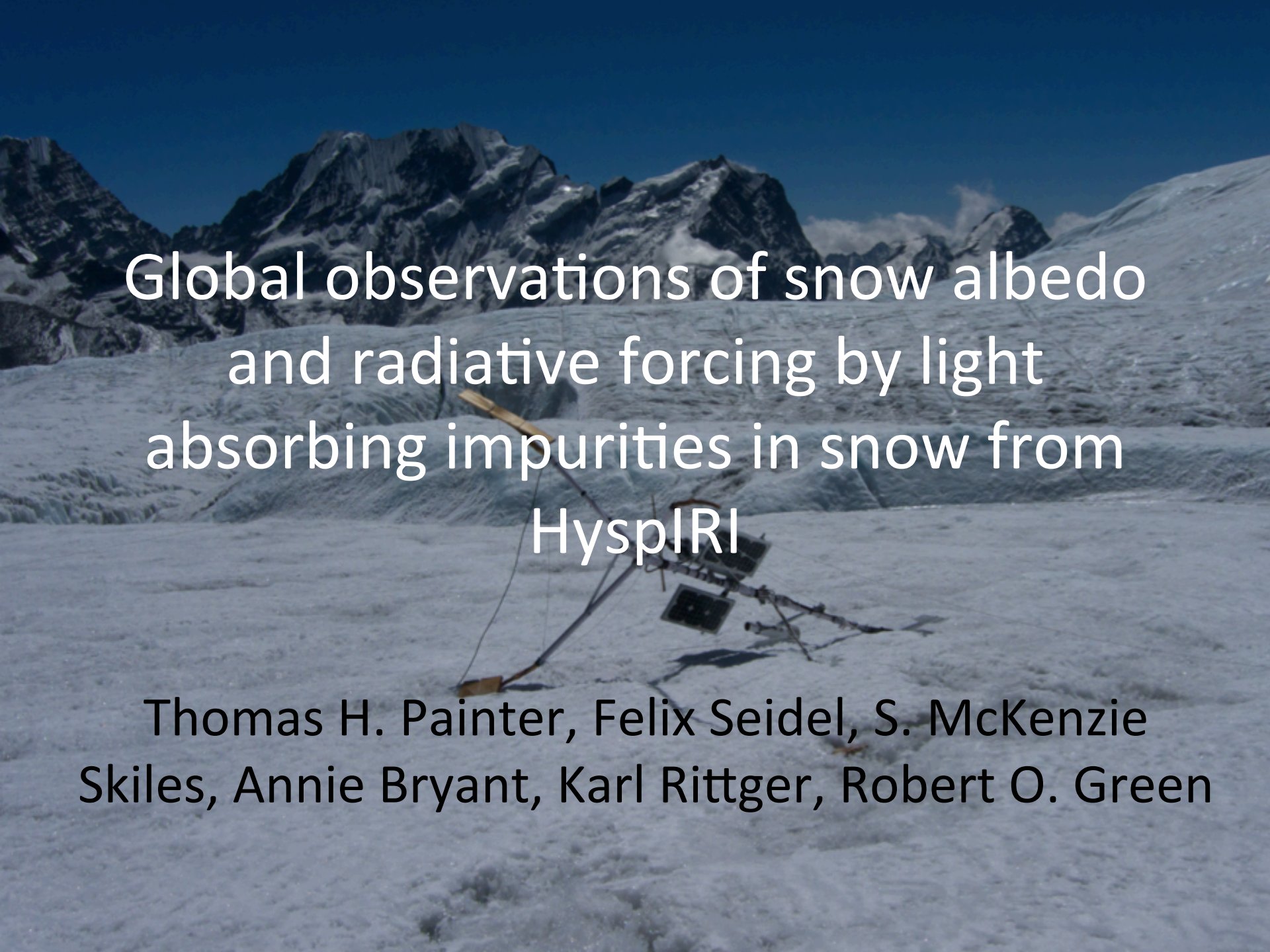


Global observations of snow albedo and radiative forcing by light absorbing impurities in snow from HyspIRI

Thomas H. Painter, Felix Seidel, S. McKenzie Skiles, Annie Bryant, Karl Rittger, Robert O. Green

Guiding Science Questions

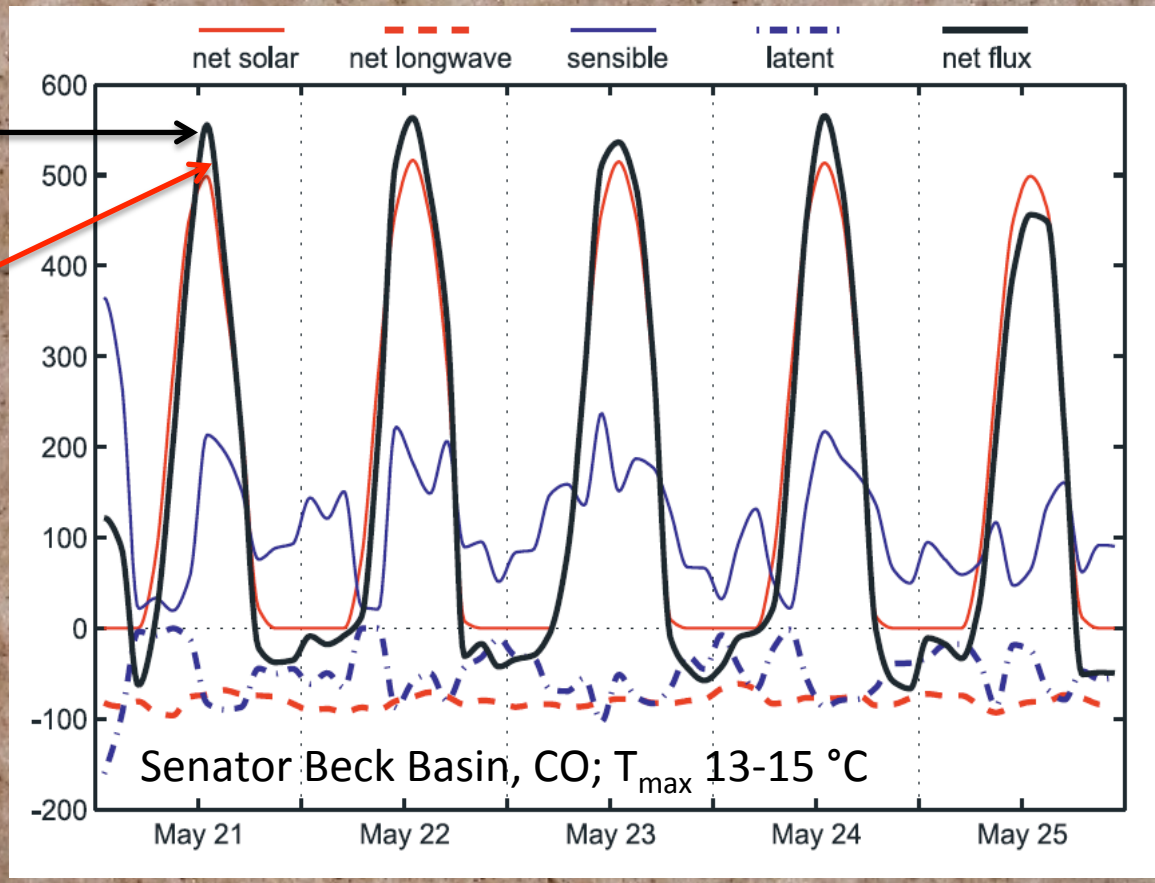
How does variation in snow albedo modulate river runoff and glacier mass balance?

How has radiative forcing by increases in dust and black carbon loading in the Anthropocene changed river runoff and glacier mass balance?

What controls snowmelt?

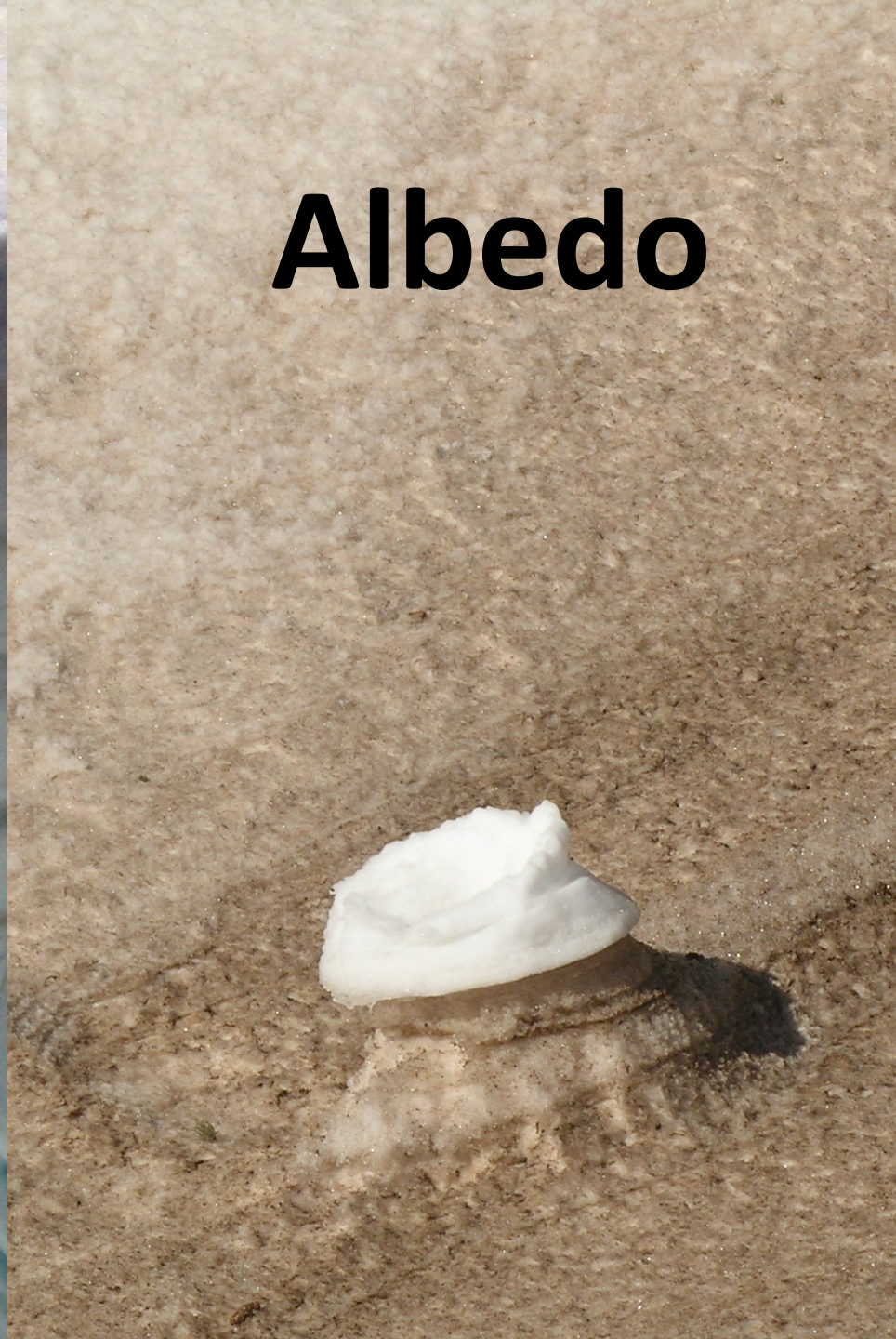
Energy for melting

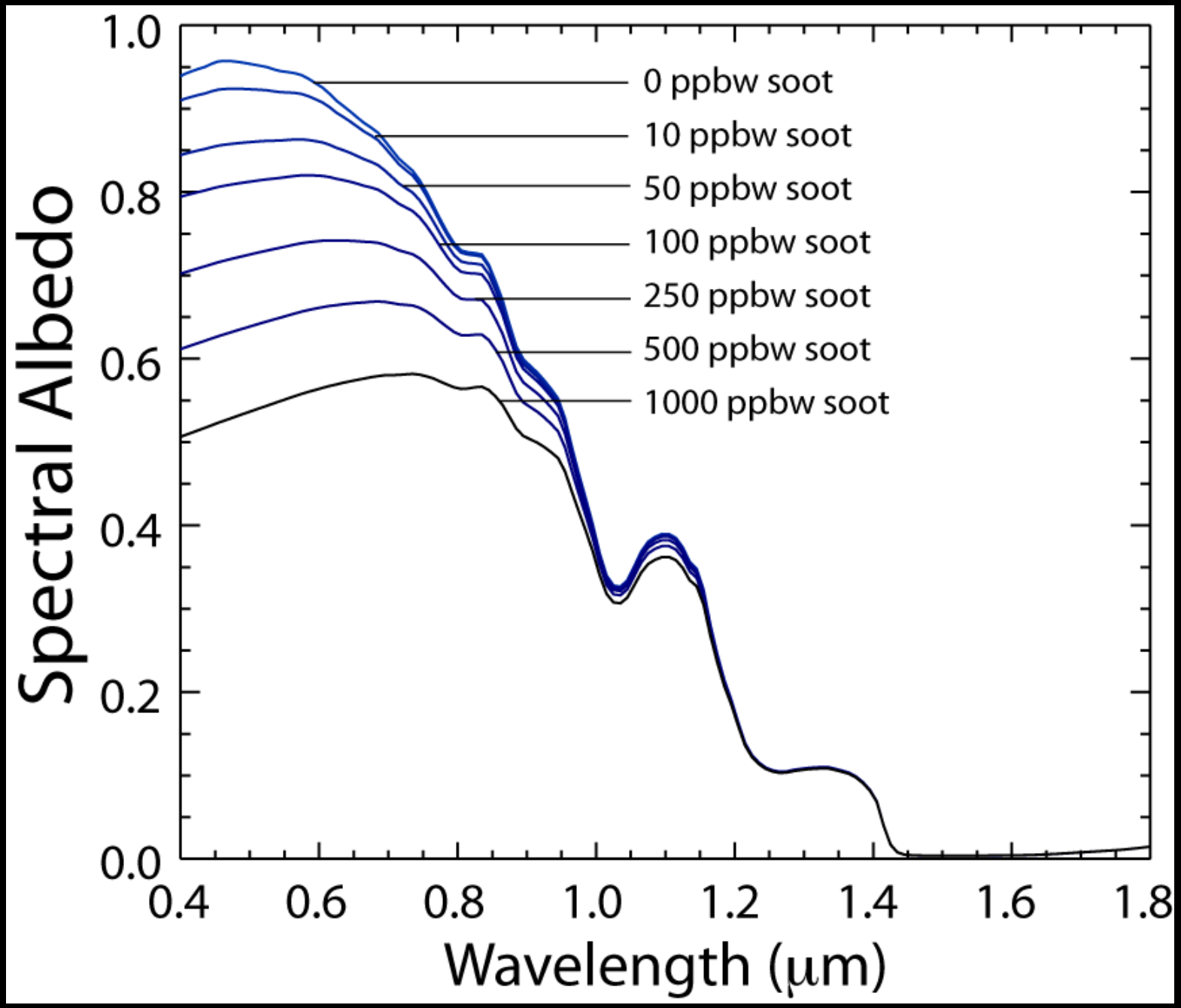
Absorbed sunlight



Elk Range, Colorado River Basin, April 2009

SWE


Albedo


Spectral Albedo
Wavelength (μm)
0 ppbw soot
10 ppbw soot
50 ppbw soot
100 ppbw soot
250 ppbw soot
500 ppbw soot
1000 ppbw soot
1.0
0.8
0.6
0.4
0.2
0.0
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

NASA IDS Project:
Integrated hydrologic response to extreme dust deposition to snow cover of the Colorado River Basin

Principal Investigator:
Thomas H. Painter

WATER RESOURCES RESEARCH, VOL. 48, W07521, doi:10.1029/2012WR011985, 2012

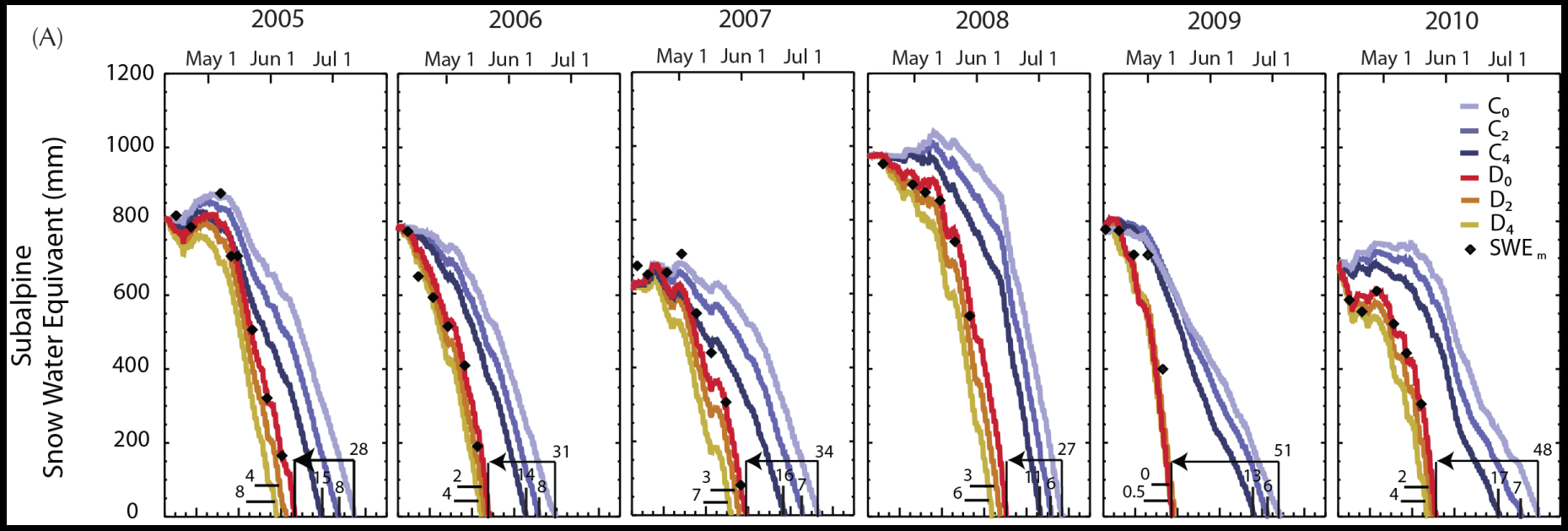
Dust radiative forcing in snow of the Upper Colorado River Basin: 1. A 6 year record of energy balance, radiation, and dust concentrations

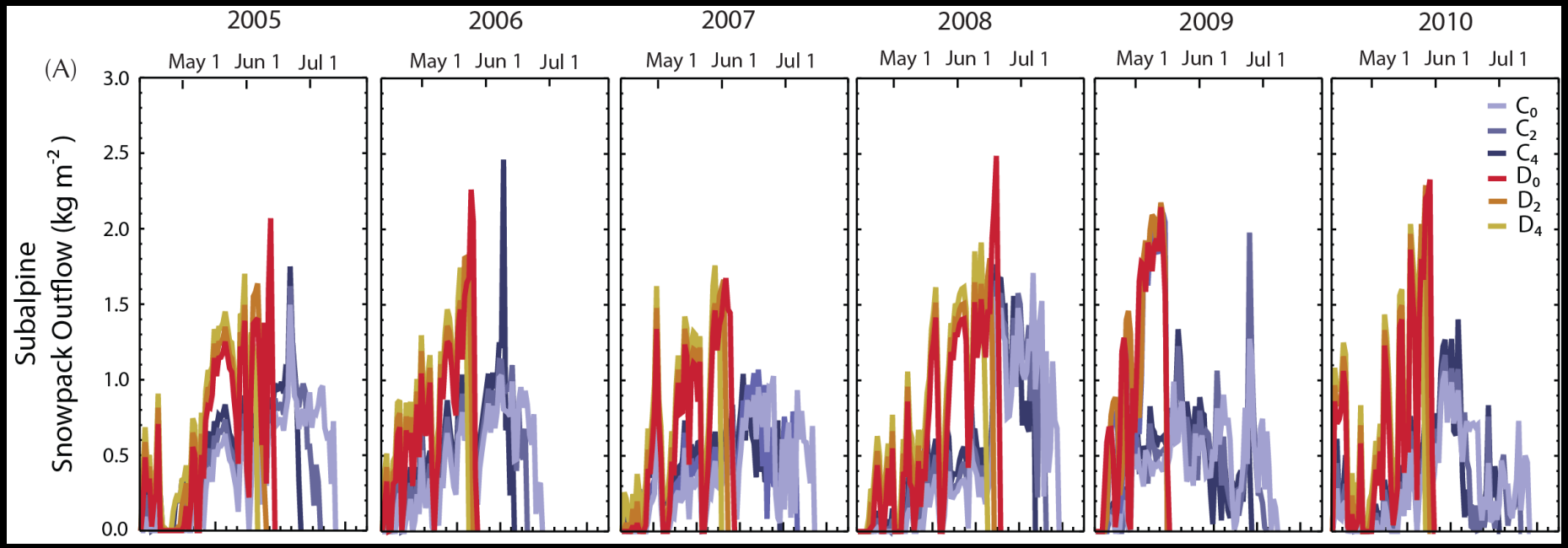
Thomas H. Painter,[1,2,3] S. McKenzie Skiles,[2,3] Jeffrey S. Deems,[4,5] Ann C. Bryant,[6] and Christopher C. Landry[7]

WATER RESOURCES RESEARCH, VOL. 48, W07522, doi:10.1029/2012WR011986, 2012

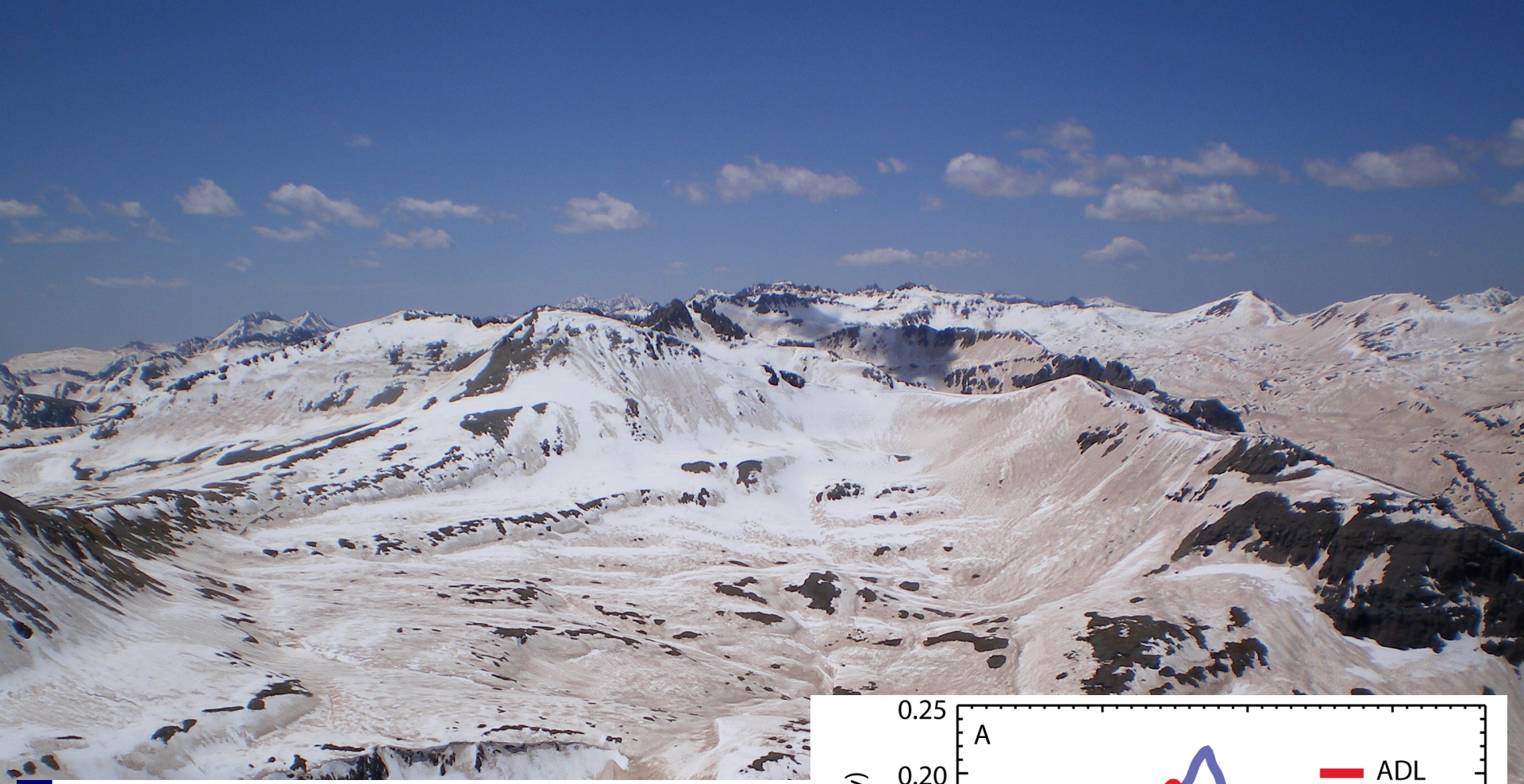
Dust radiative forcing in snow of the Upper Colorado River Basin: 2. Interannual variability in radiative forcing and snowmelt rates

S. McKenzie Skiles,[1,2] Thomas H. Painter,[1,2,3] Jeffrey S. Deems,[4,5] Ann C. Bryant,[6] and Christopher C. Landry[7]





Skiles et al 2012 WRR



PNAS

Response of Colorado River runoff to dust radiative forcing in snow

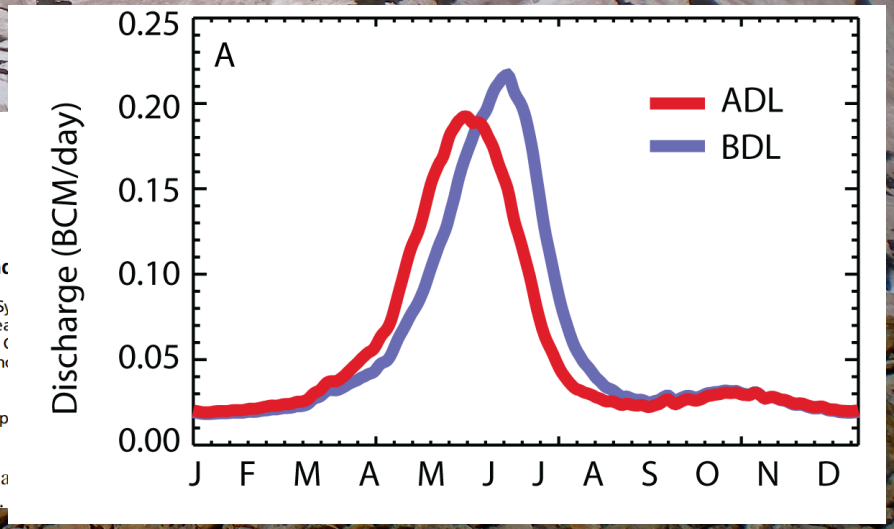
Thomas H. Painter[a,b,1], Jeffrey S. Deems[c,d], Jayne Belnap[e], Alan F. Hamlet[f], Christopher C. Lanc

[a]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109; [b]Joint Institute for Regional Earth Sy
University of California, Los Angeles, CA 90095; [c]National Snow and Ice Data Center, Boulder, CO 80309; [d]National Ocea
Administration Western Water Assessment, Boulder, CO 80309; [e]United States Geological Survey, Southwest Biological (
[f]University of Washington, Department of Civil and Environmental Engineering, Seattle, WA 98195; and [g]Center for Sn
Silverton, CO 81433

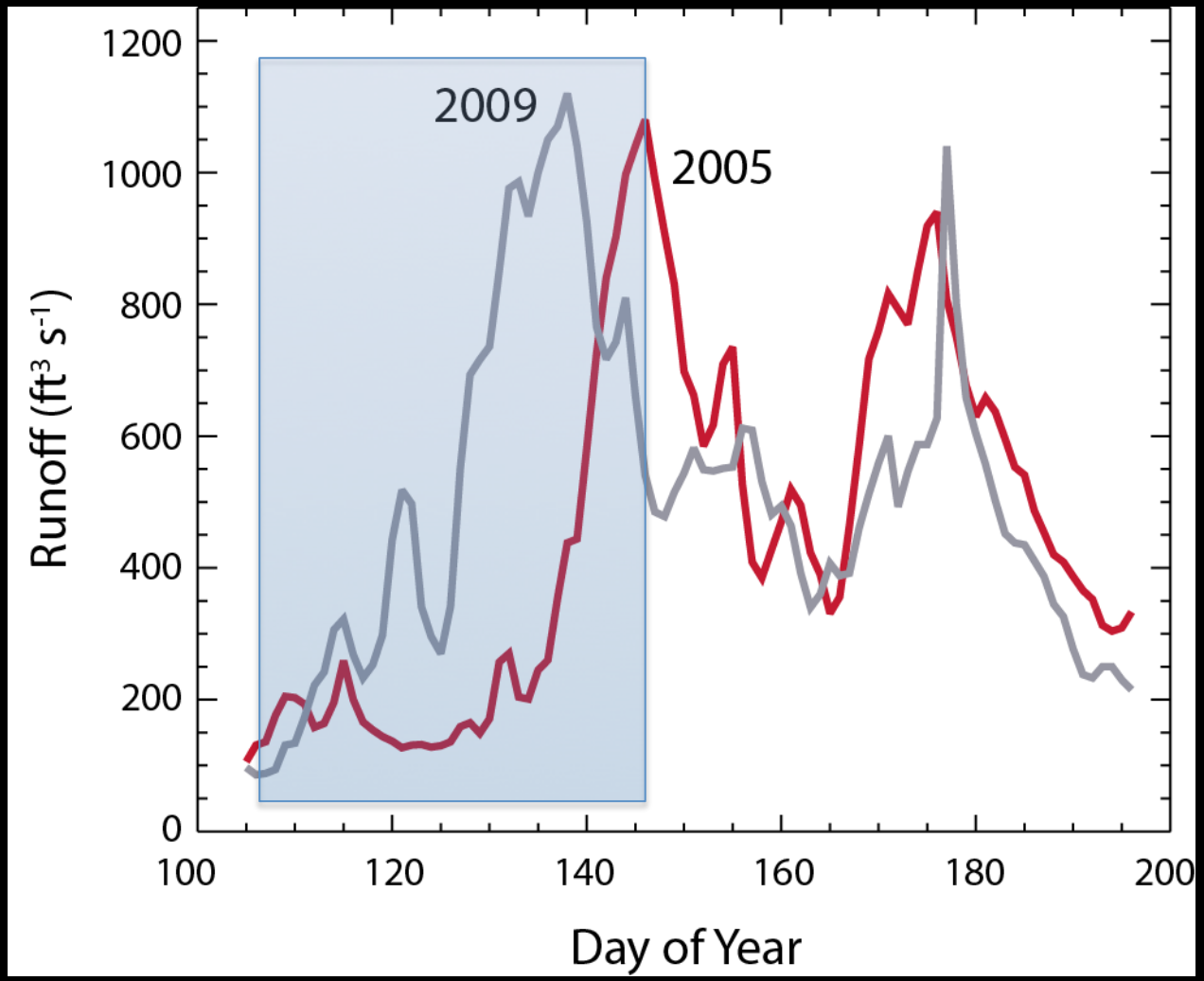
Edited by Peter H. Gleick, Pacific Institute for Studies in Development, Environment, and Security, Oakland, CA, and app
review November 12, 2009)

The waters of the Colorado River serve 27 million people in seven states and two countries but are overallocated by more than 10%

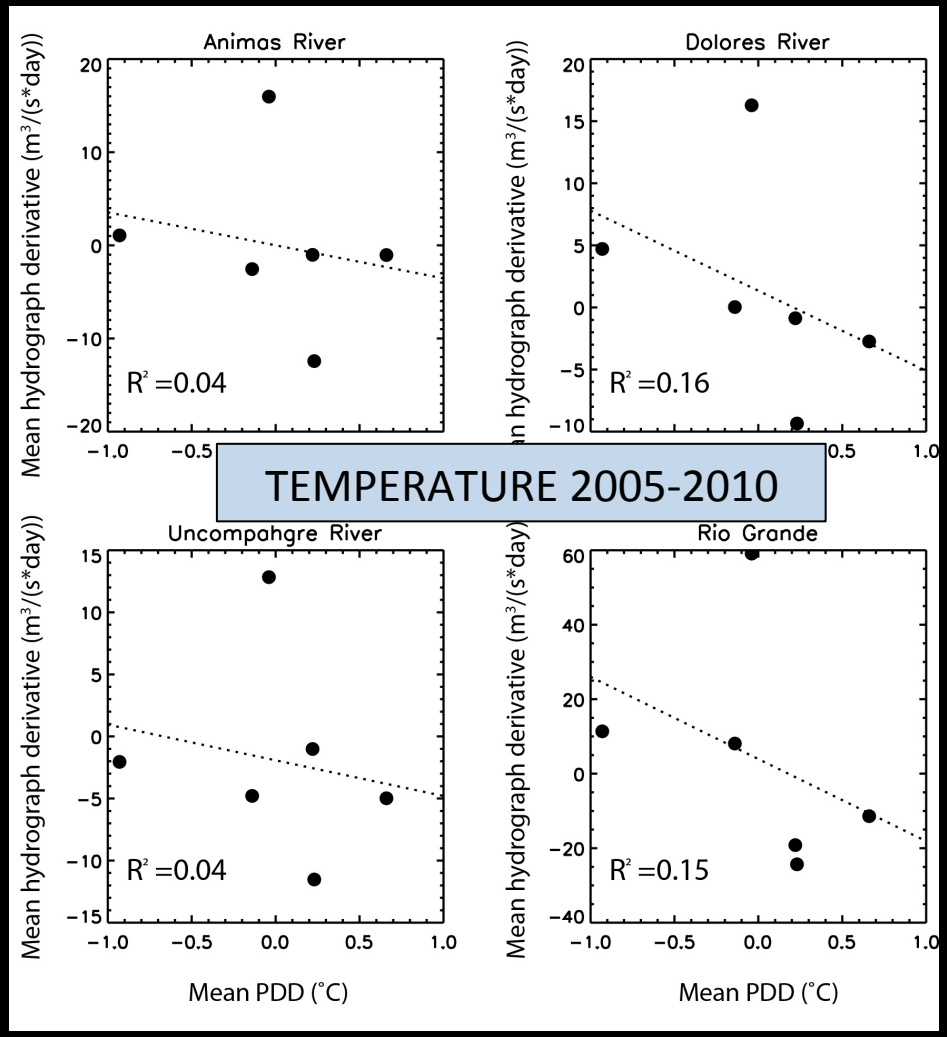
through dust's direct absorption a
accelerated snow metamorphism.

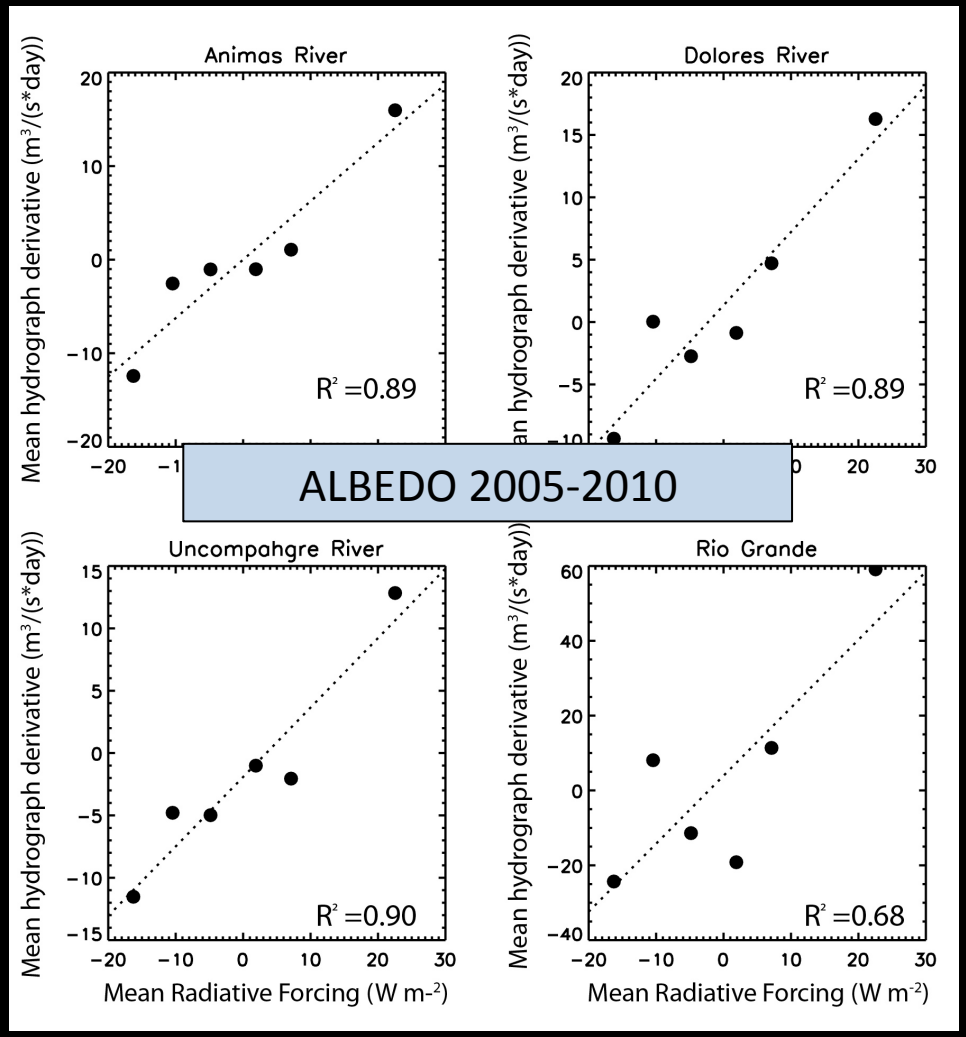


What controls the interannual variability of the snowmelt runoff hydrograph?

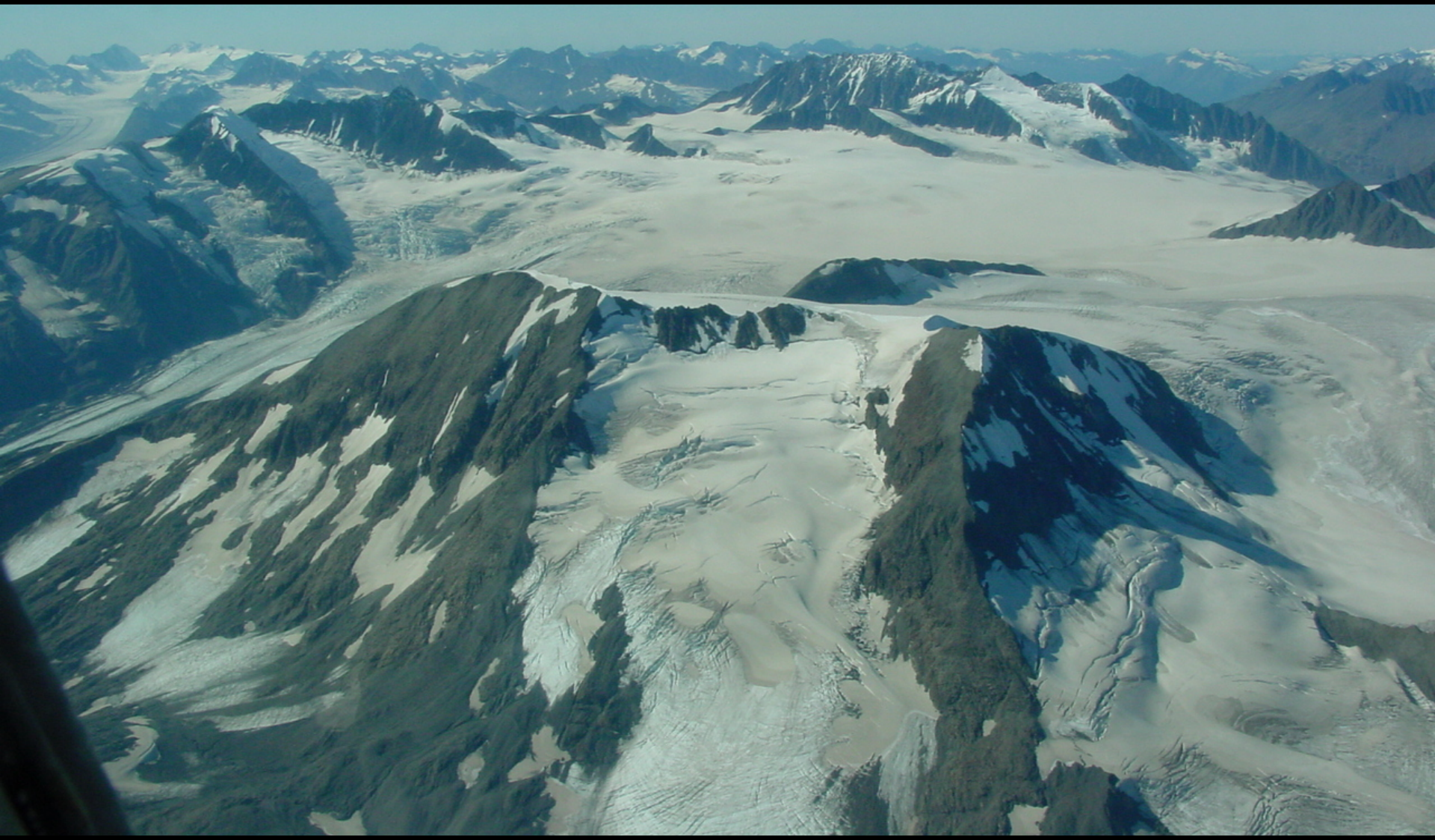


Explain steepness of rising limb

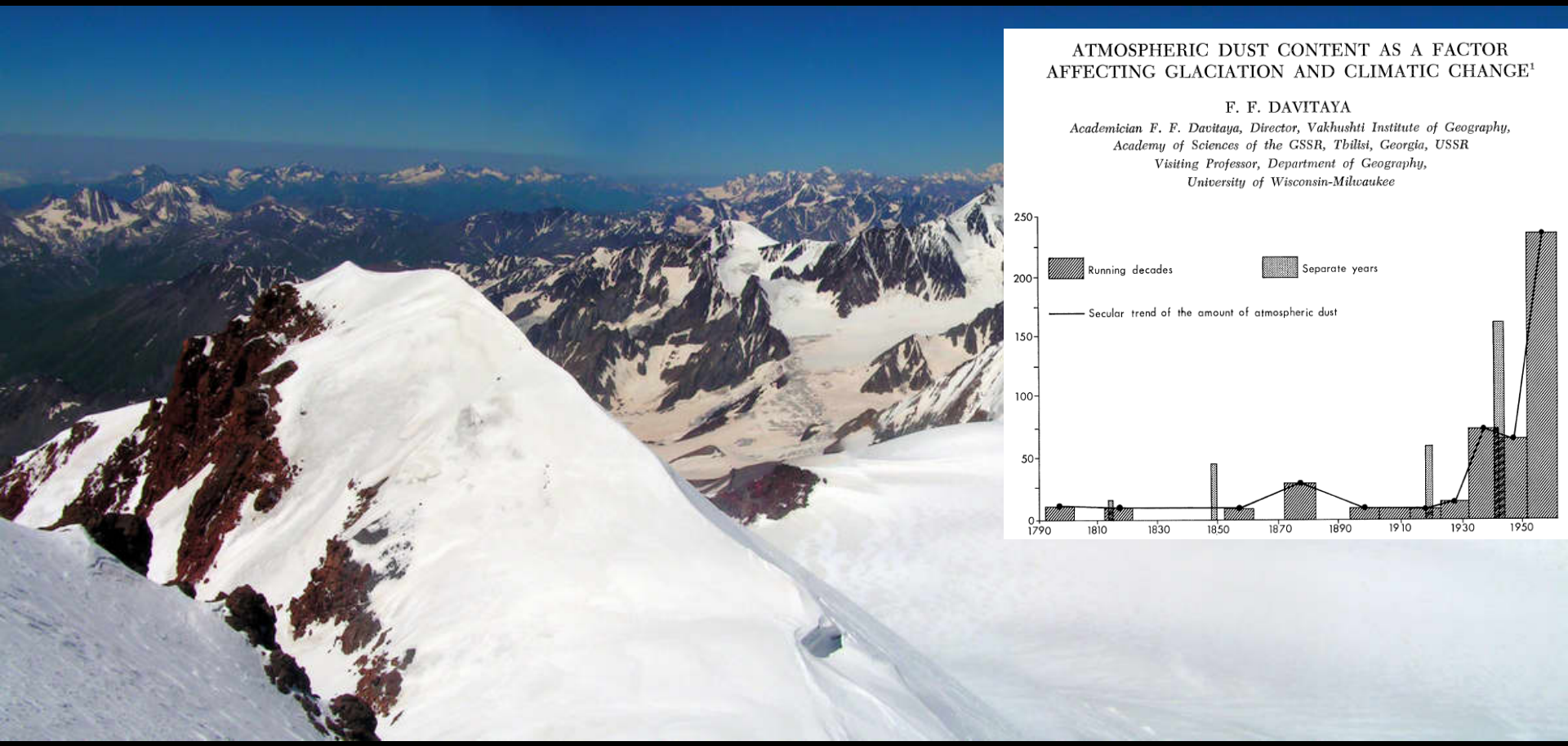




Painter et al (in preparation)



Wrangell-St Elias, Alaska



ATMOSPHERIC DUST CONTENT AS A FACTOR AFFECTING GLACIATION AND CLIMATIC CHANGE[1]

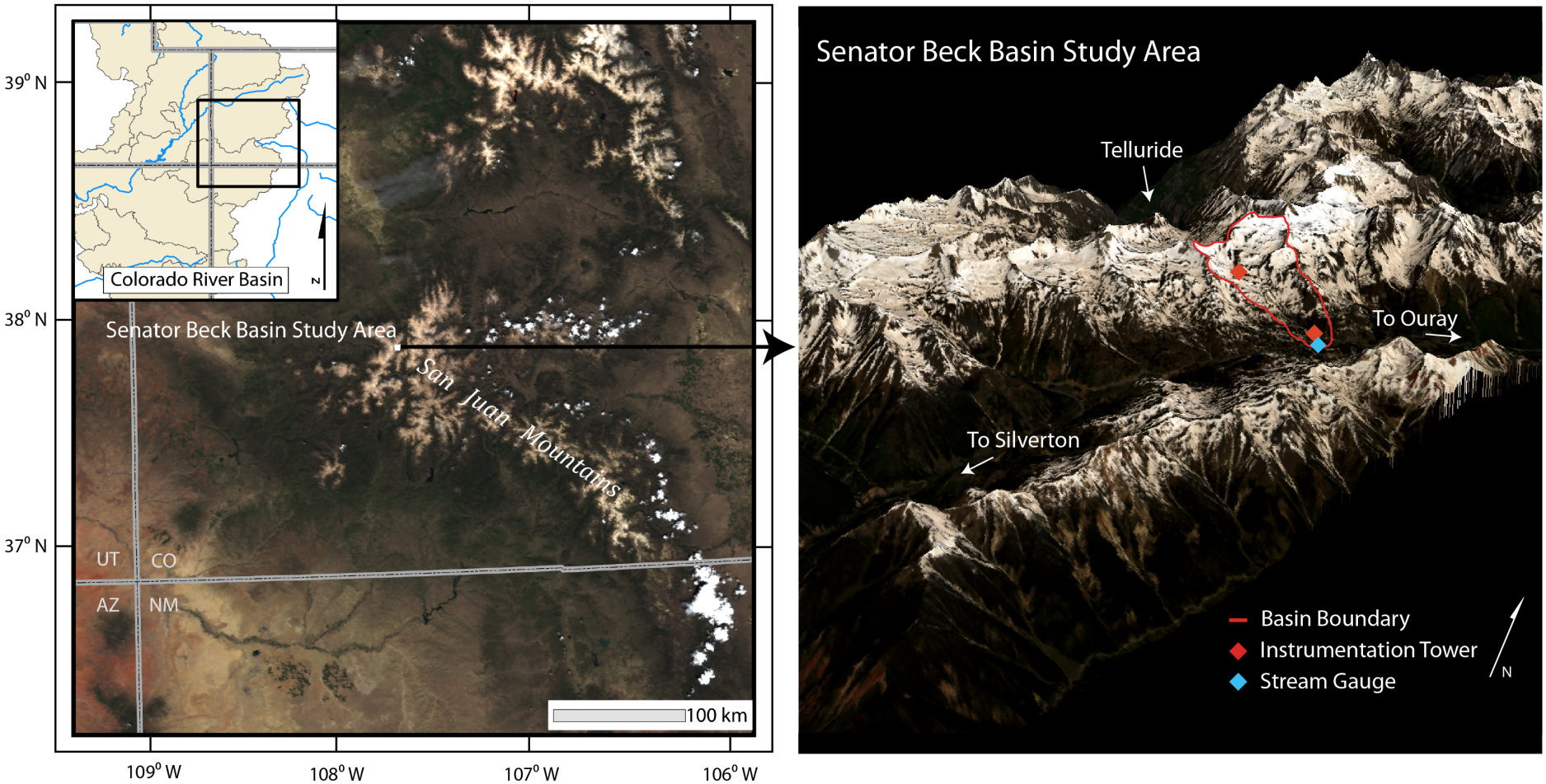
F. F. DAVITAYA

Academician F. F. Davitaya, Director, Vakhushti Institute of Geography, Academy of Sciences of the GSSR, Tbilisi, Georgia, USSR
Visiting Professor, Department of Geography, University of Wisconsin-Milwaukee

Causasus Mountains

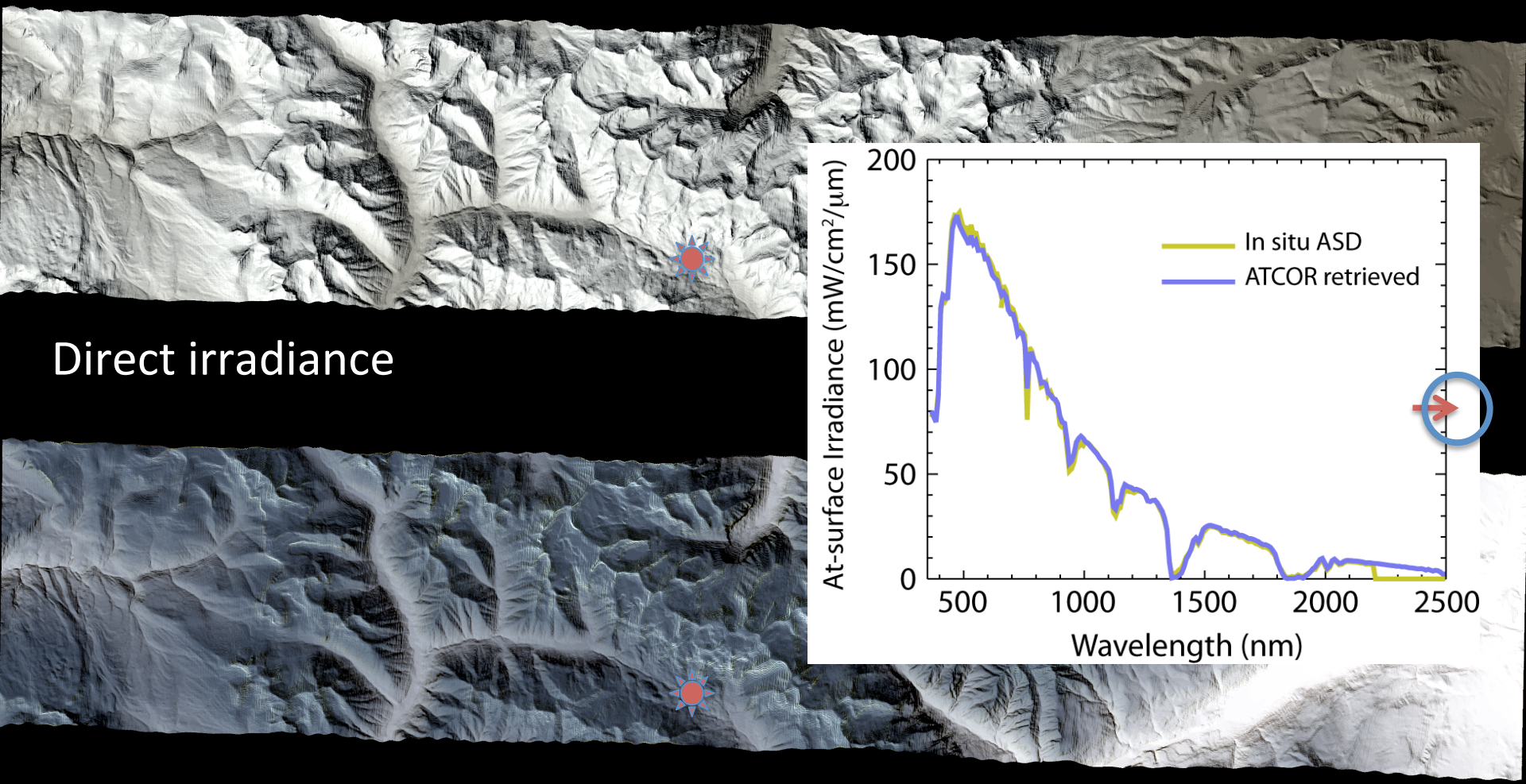
Tien Shan, Kazakhstan

AVIRIS



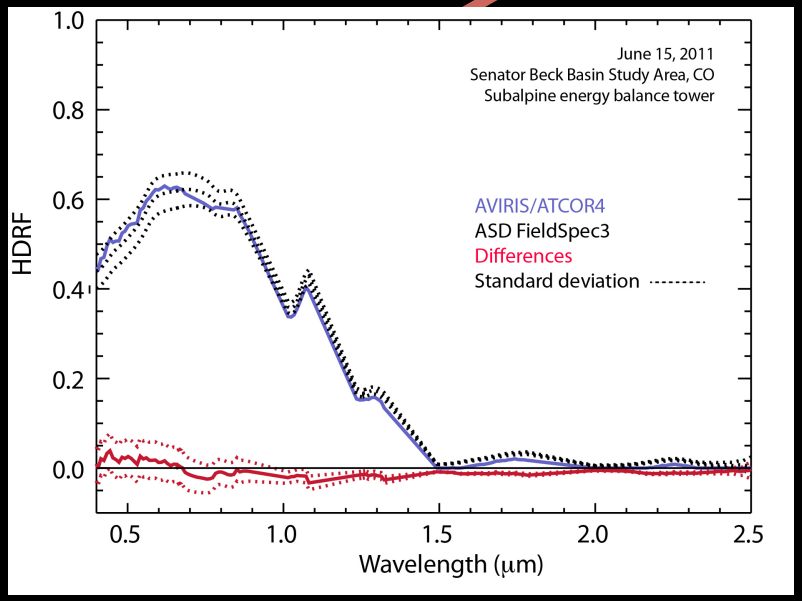
AVIRIS – San Juan Mountains 2011

Irradiances



ATCOR4.0 - 15 June 2011, San Juan Mtns

Reflectance Validation

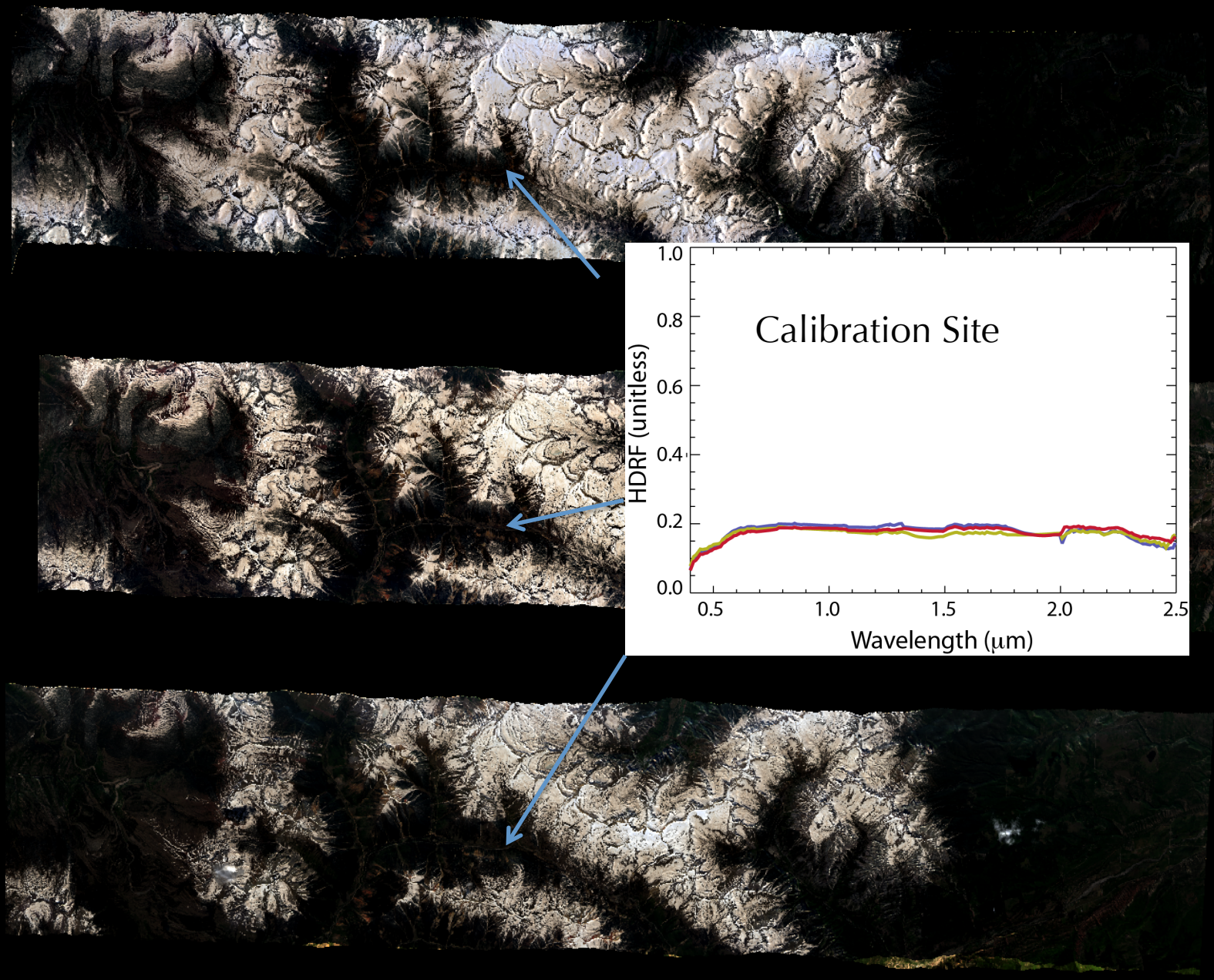


ATCOR4.0 - 15 June 2011, San Juan Mtns

June 9, 2011

June 15, 2011

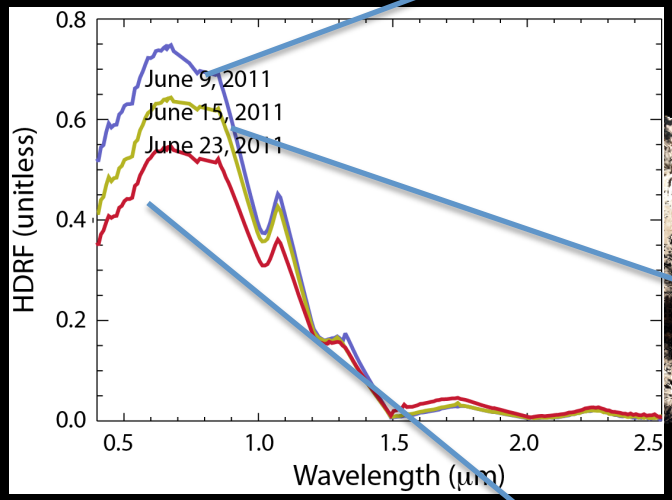
June 23, 2011



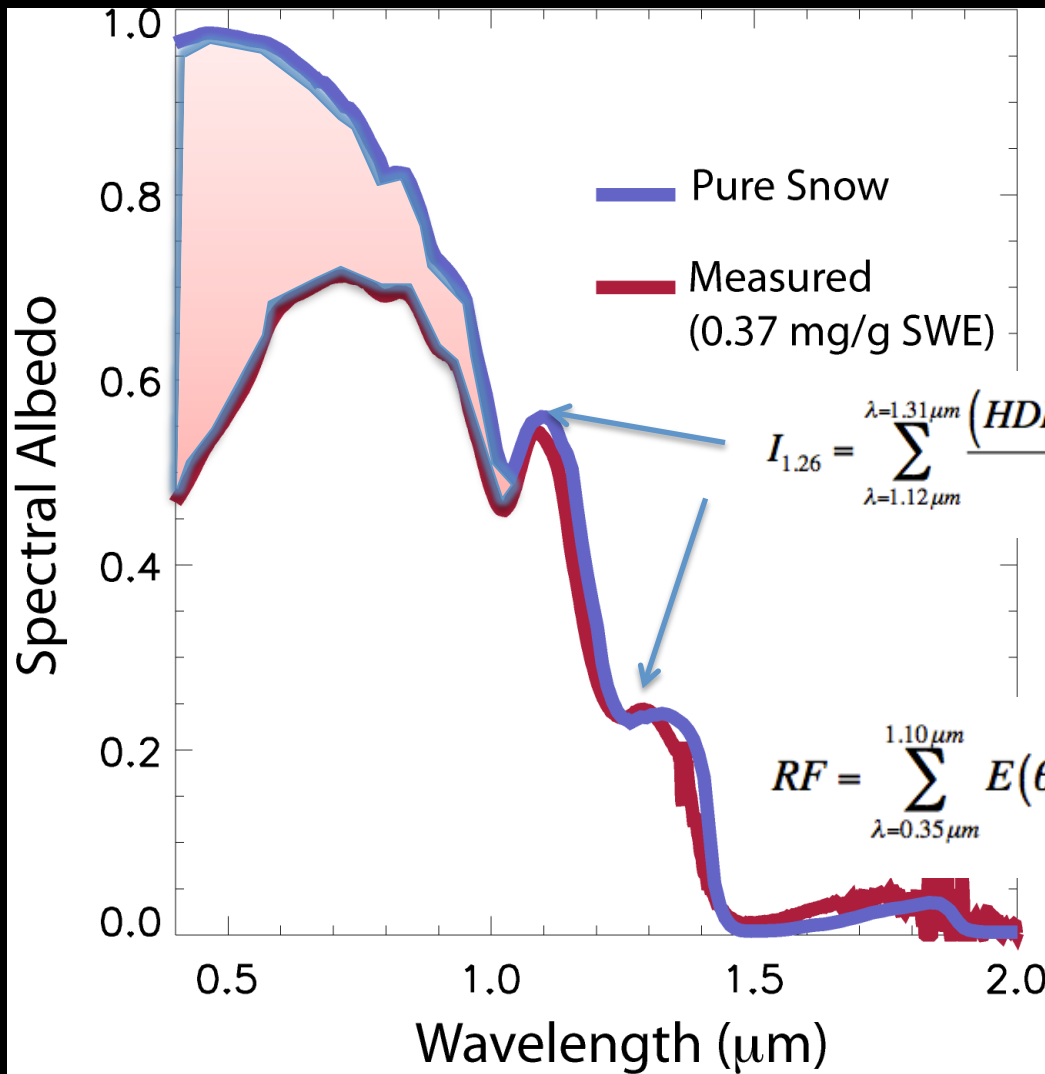
June 9, 2011

June 15, 2011

June 23, 2011

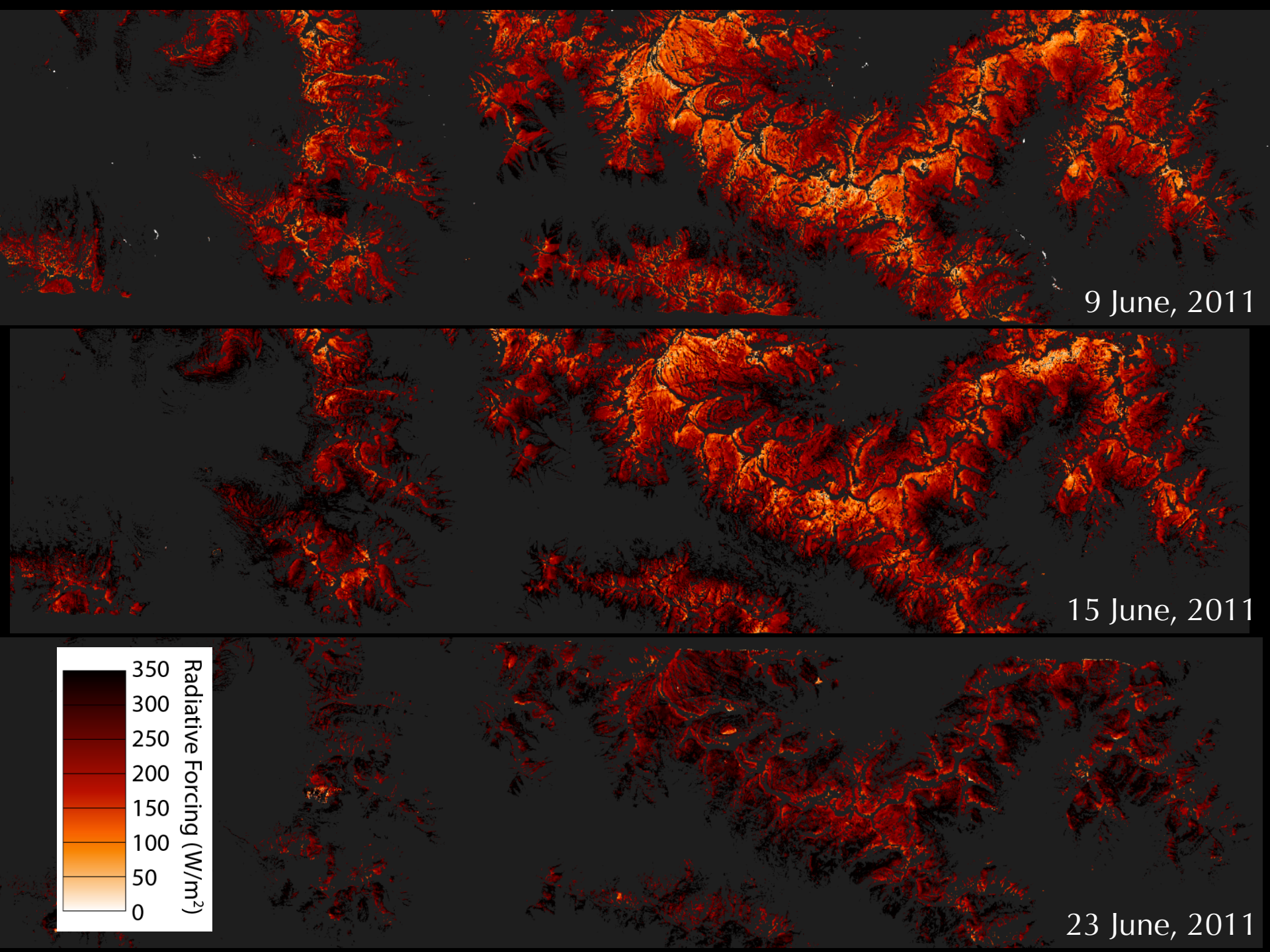


Radiative Forcing in Snow



$$I_{1.26} = \sum_{\lambda=1.12\mu m}^{\lambda=1.31\mu m} \frac{\left(HDRF_{sfc}^{obs,cont}(\theta_0;\theta_r,\phi_r;\lambda) - HDRF_{sfc}^{obs}(\theta_0;\theta_r,\phi_r;\lambda)\right)}{HDRF_{sfc}^{obs,cont}(\theta_0;\theta_r,\phi_r;\lambda)}\Delta\lambda$$

$$RF = \sum_{\lambda=0.35\mu m}^{1.10\mu m} E(\theta_0;\lambda)\cdot\left(\alpha^{clean}(\lambda;r) - \alpha^{obs}(\lambda;r)\cdot\frac{\alpha_{1.10\mu m}^{clean}}{\alpha_{1.10\mu m}^{obs}}\right)\Delta\lambda$$


9 June, 2011
15 June, 2011
23 June, 2011
Radiative Forcing (W/m²)
350
300
250
200
150
100
50
0

Albedo retrieval

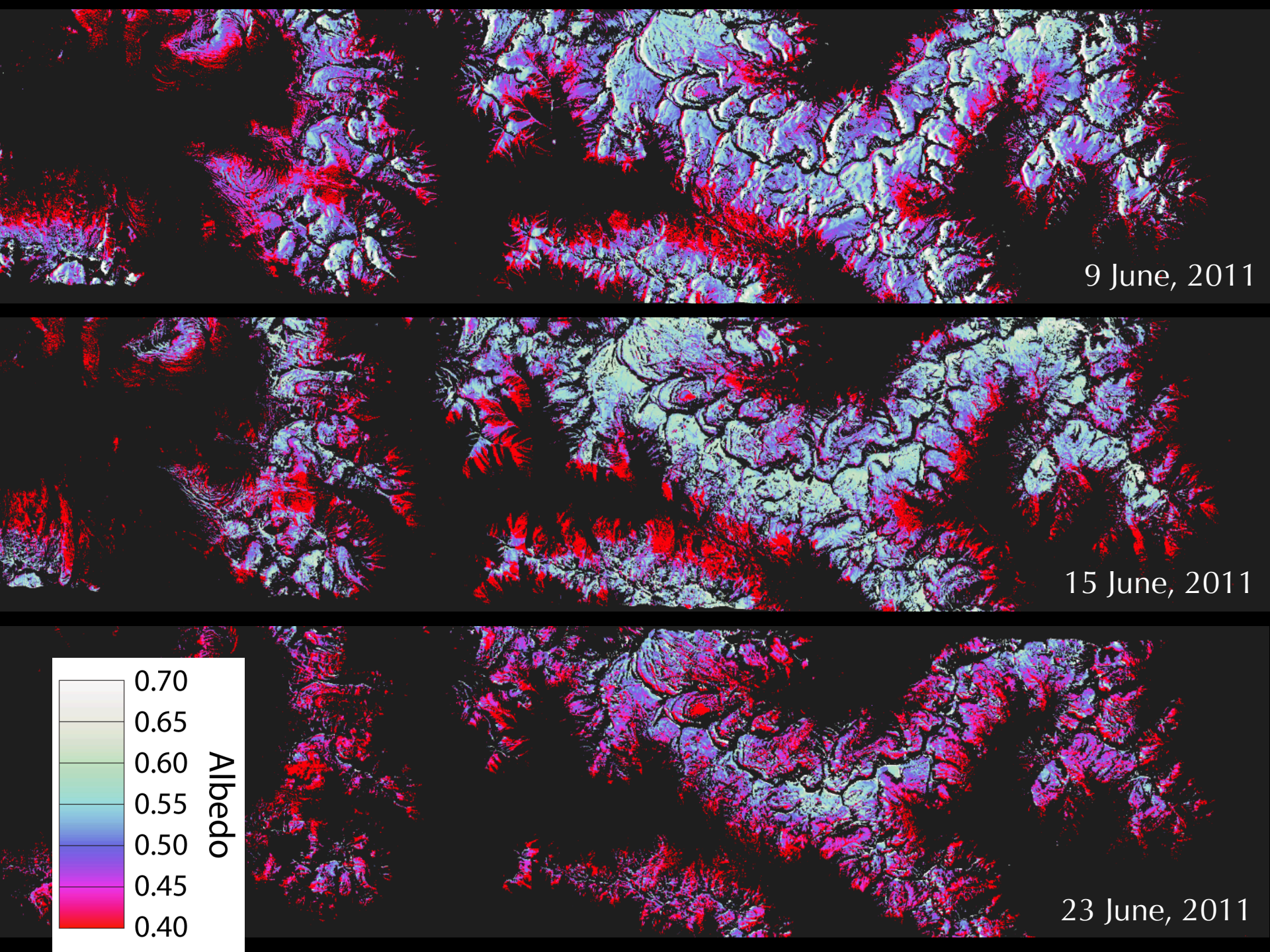
Spectral albedo

$$a_{sfc}^{obs}(r;\lambda) = HDRF_{sfc}^{obs}(\theta_0;\theta_r,\phi_r;r;\lambda)\cdot\frac{a_{sfc}^{mdl}(r;\lambda)}{HDRF_{sfc}^{mdl}(\theta_0;\theta_r,\phi_r;r;\lambda)}$$

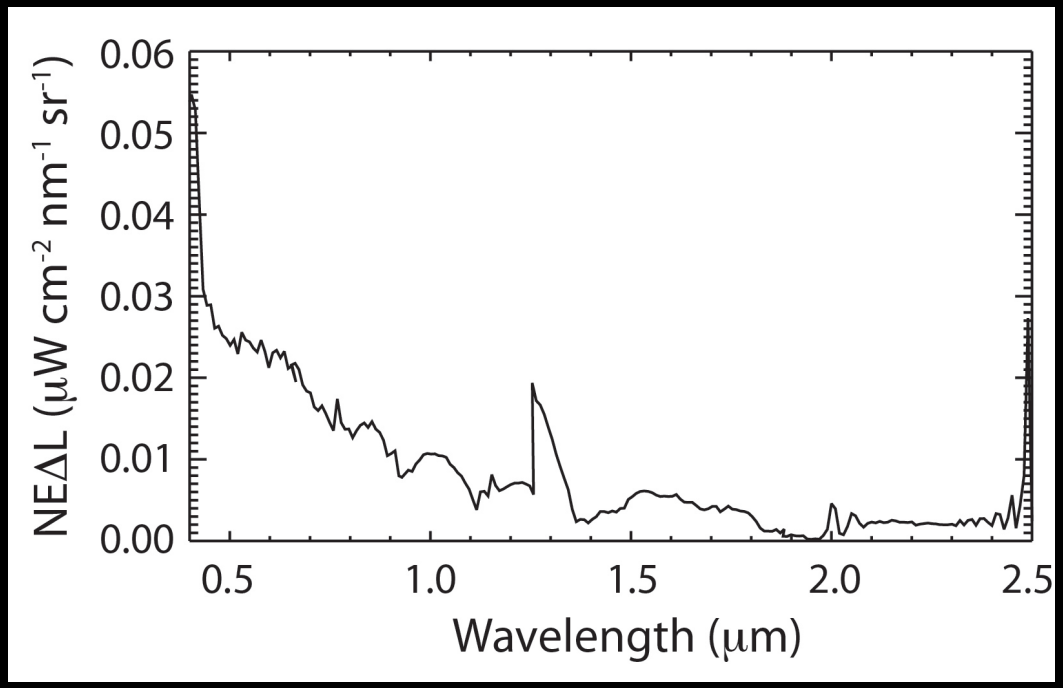
$$= HDRF_{sfc}^{obs}(\theta_0;\theta_r,\phi_r;r;\lambda)\cdot c_{\lambda;\theta_r,\phi_r;r;\lambda}$$

Spectrally-integrated albedo

$$\alpha_{sfc}(r) = \sum_{\lambda=0.35\,\mu m}^{2.50\,\mu m} E(\lambda;\theta_0)\cdot\alpha_{sfc}(\lambda;r)\Delta\lambda$$


9 June, 2011
15 June, 2011
23 June, 2011
Albedo
0.70
0.65
0.60
0.55
0.50
0.45
0.40

Sensitivity/validation



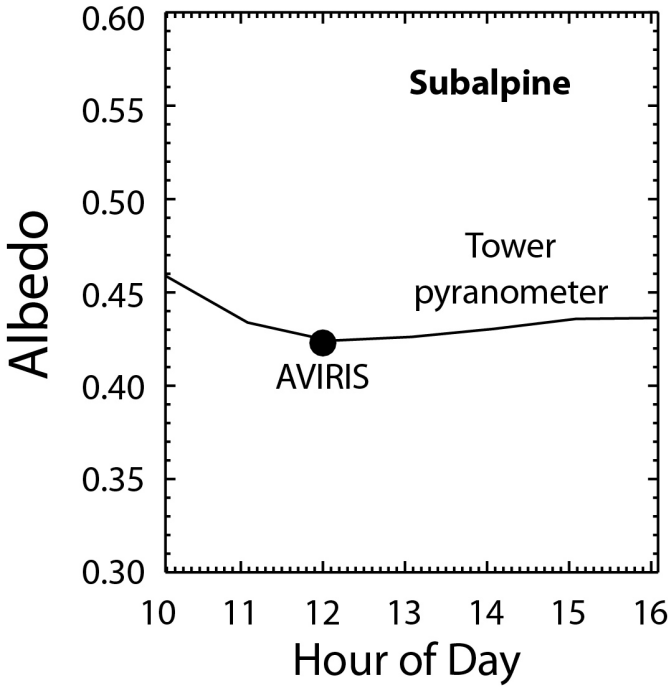
Uncertainties from AVIRIS spectral NEΔL

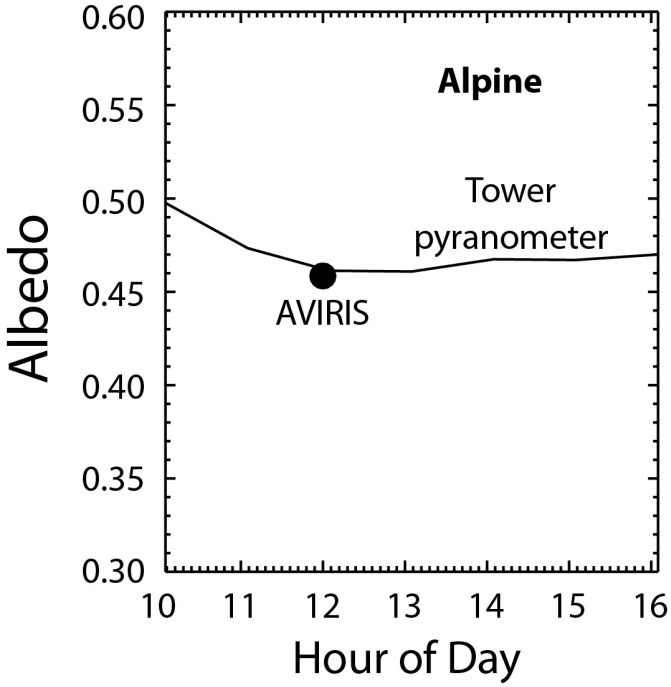
Water vapor uncertainty: ±0.0007 cm.

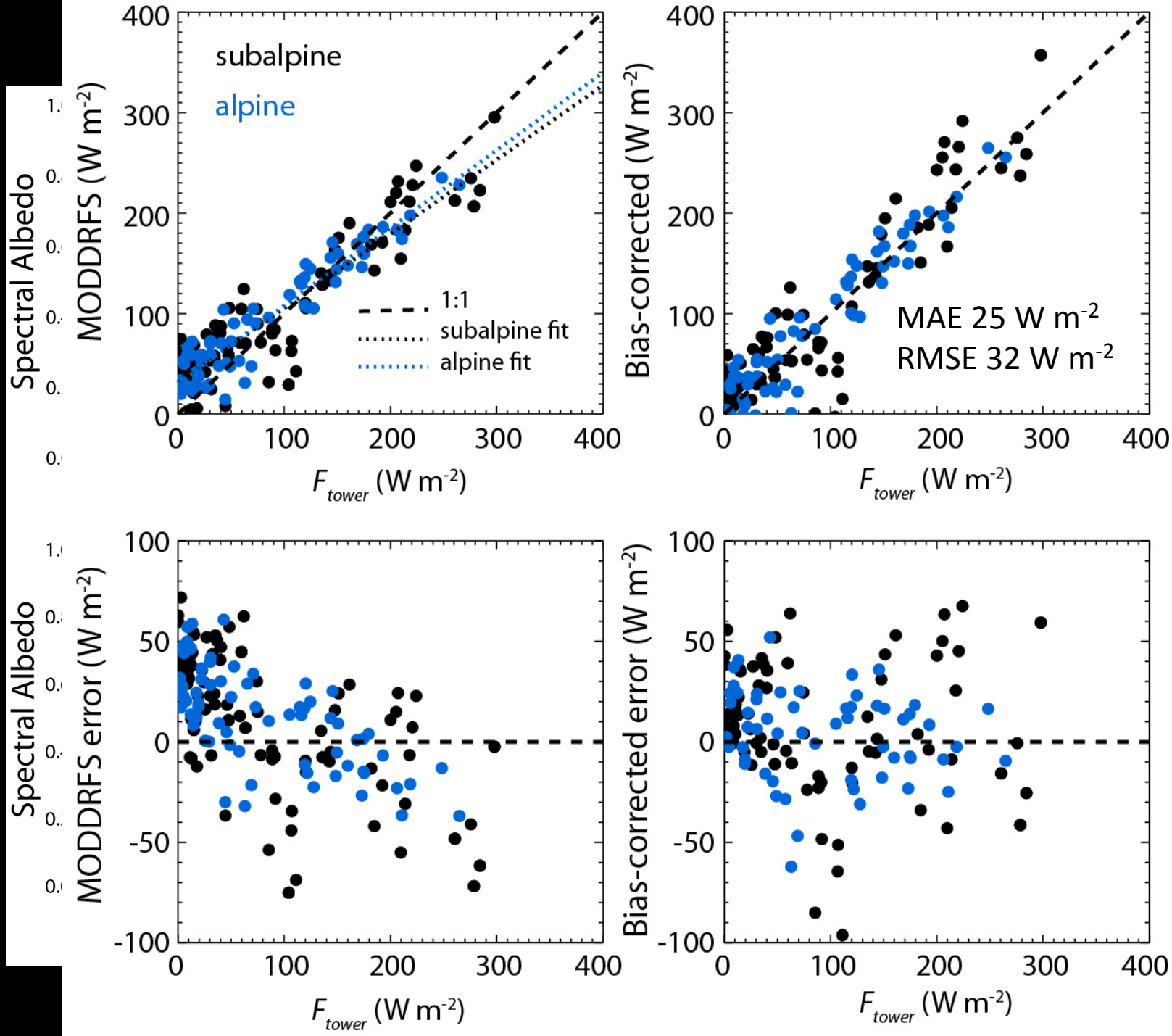
Grain size from 1.03 & 1.26 μm, ±5.4 μm & ±7.1 μm.

Albedo: ±0.006

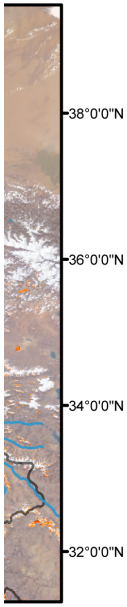
Instantaneous radiative forcing: ±1.8 W m^{-2}.

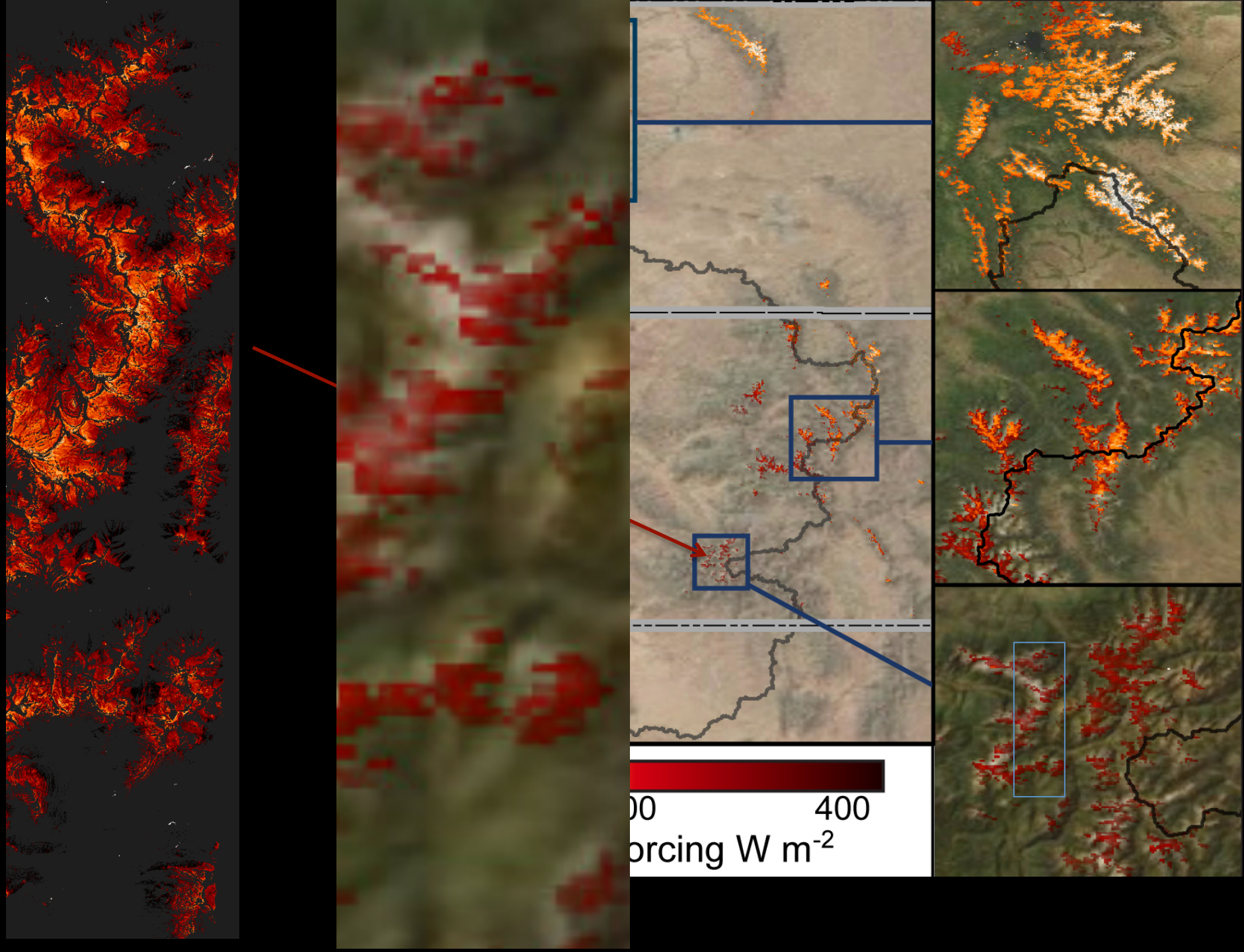




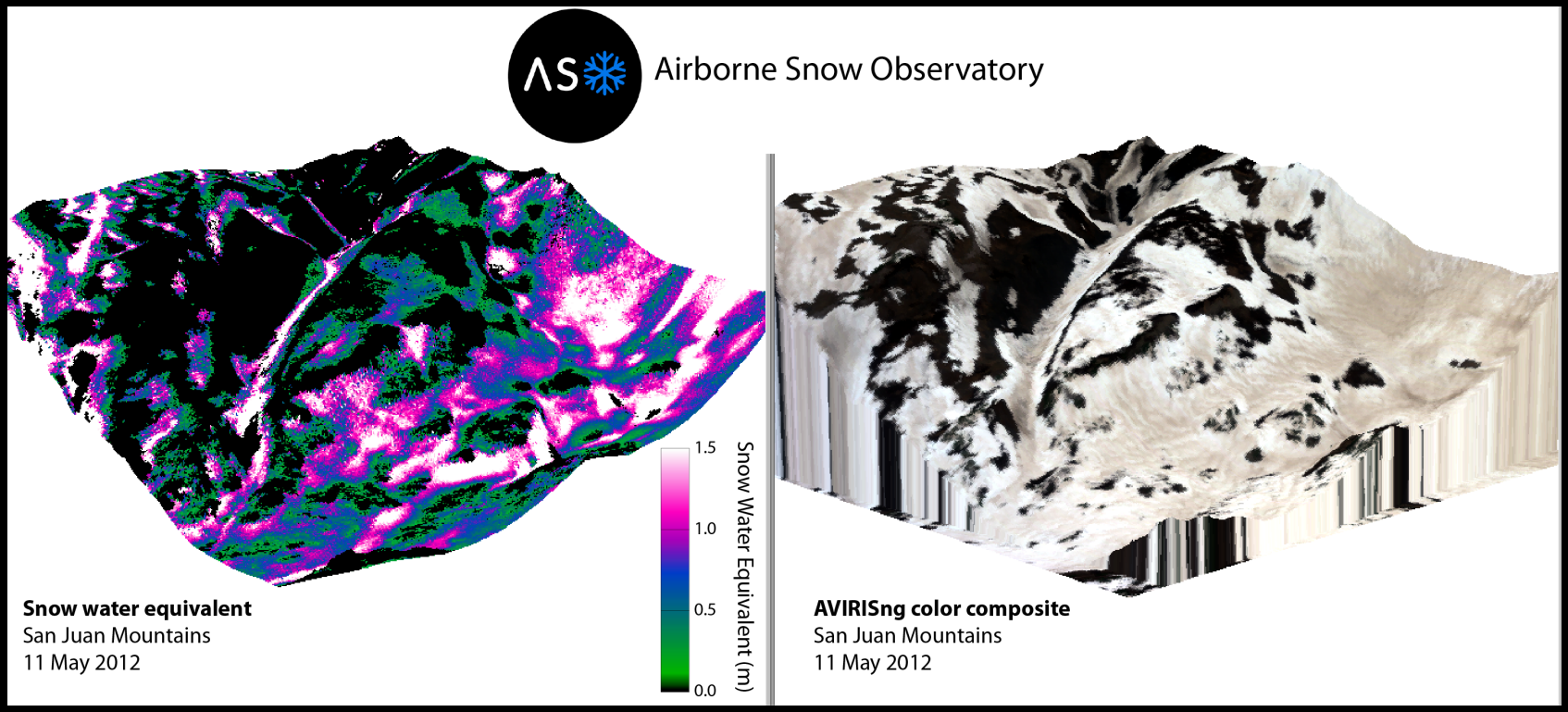

subalpine
alpine
1:1
subalpine fit
alpine fit
MODDRFS (W m-2)
Bias-corrected (W m-2)
MAE 25 W m-2
RMSE 32 W m-2
F tower (W m-2)
Spectral Albedo
MODDRFS error (W m-2)
Bias-corrected error (W m-2)
0
100
200
300
400
50
-50
-100

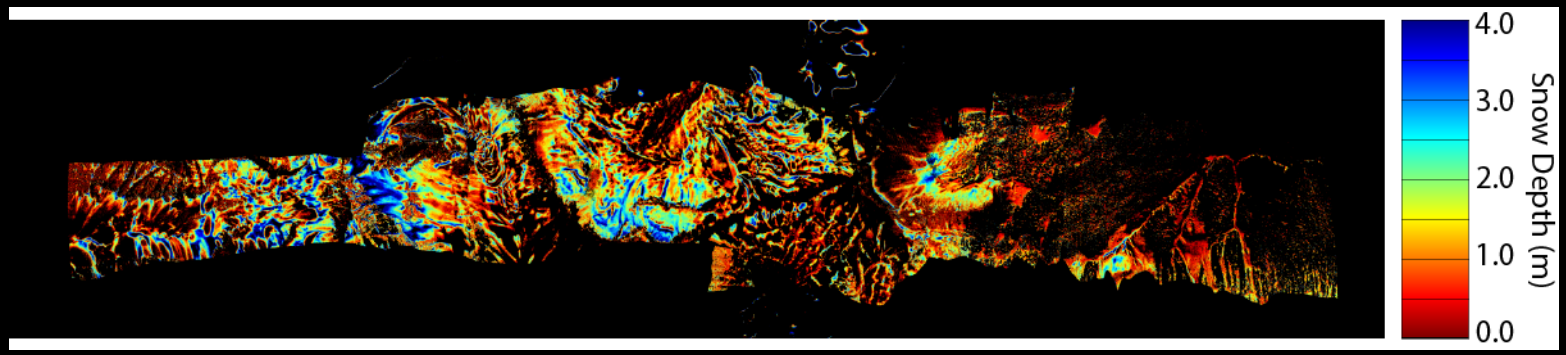
.052457, 2012


38°0'0"N
36°0'0"N
34°0'0"N
32°0'0"N


00
400
orcing W m-2

Airborne Snow Observatory





Summary

- Critical void in knowledge of the impacts of dust/BC on snowmelt and glacier melt
- New multispectral algorithms provide qualitative retrievals
- The imaging spectrometer provides the quantitative retrieval needed to understand this impact
- HyspIRI will give us the global access to that knowledge
- MODIS/VIIRS and the Airborne Snow Observatory will anchor HyspIRI at the temporal and spatial ends