Energy balance of snow and ice

Thomas H. Painter, JPL/Caltech

NEWS FEATURE

Settling the science on Himalayan glacier

The remote glaciers of the Himalayan mountains h
yet little research. **Mason Inman** looks at the clue
glaciers from ground- and space-based studies.

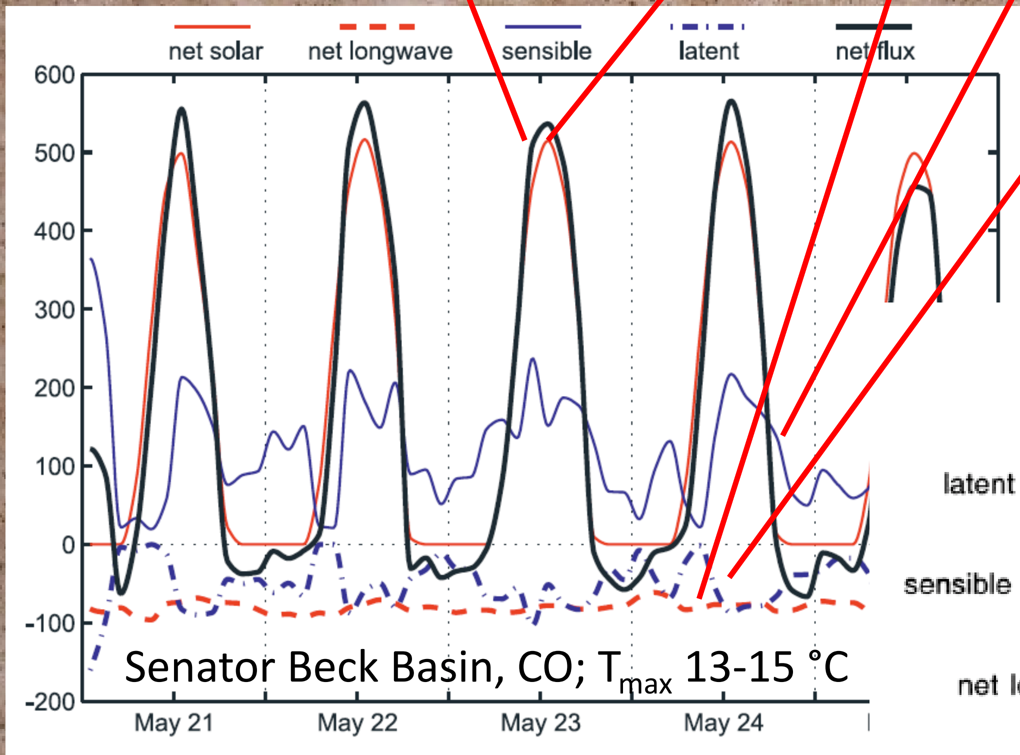
"Every morning you have to rise and decide that it might be a good day not to die," says John Shroder of the University of Oklahoma at Omaha, who has spent decades studying the glaciers of the Karakoram and Himalayan mountains, stretching from Pakistan in the west across India and into Nepal in the east. "Just getting

Pakistan's mountains pr
for Taliban insurgents, a
rebels are holed up in th
countries in the region l

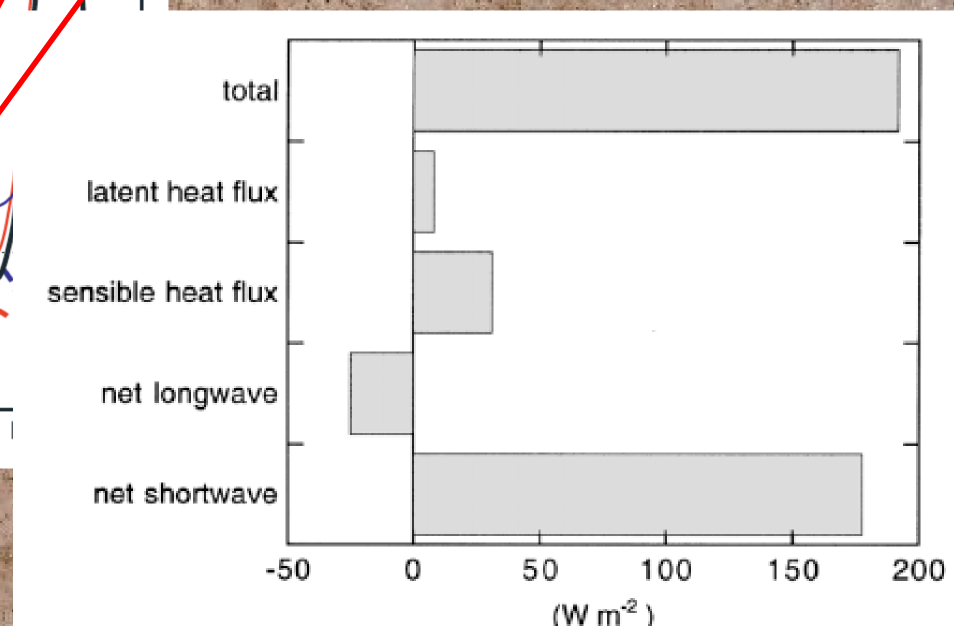
"It is pretty clear
Himalayan glacie

One thing is clear: the glaciers won't vanish by 2035, as the Intergovernmental Panel on Climate Change (IPCC) claimed in its 2007 assessment report[1]. This error and others in the IPCC report's section on Himalayan glaciers — widely reported elsewhere[2] — have now been corrected. But the ensuing furore has highlighted how little is actually known about the fate of glaciers in this region. The errors "were mainly based on the desire to say something", says glaciologist Richard Armstrong of the National Snow and Ice Data Center in Boulder, Colorado. "But you need to know that if there's no data, you shouldn't say anything."

$$\frac{dU}{dt} + Q_m = (1-\alpha)S + L^* + Q_s + Q_v + Q_g + Q_r$$



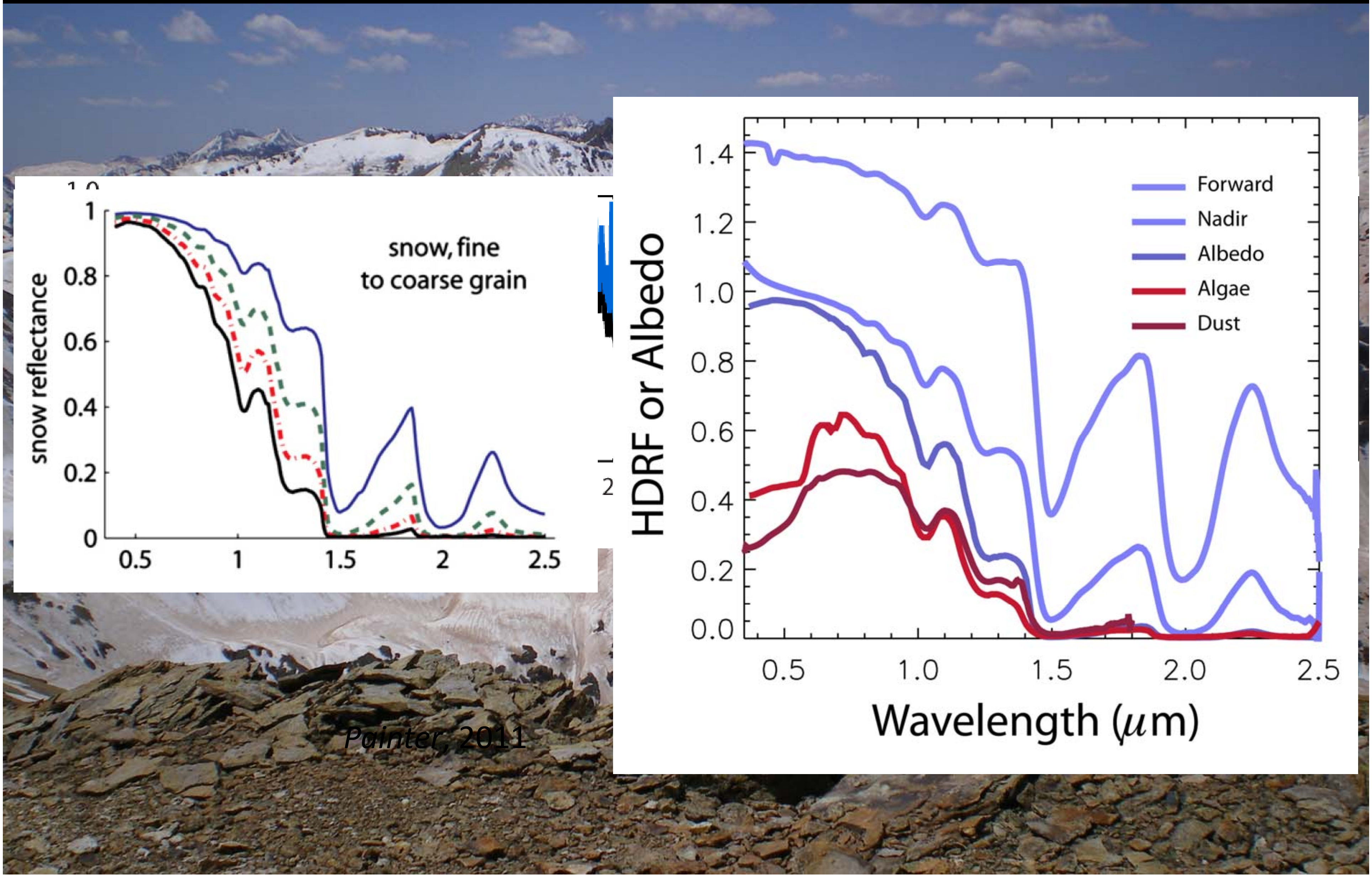
Senator Beck Basin, CO; T_{max} 13-15 °C



Morteratschgletscher (*Oerlemans, 2000*)

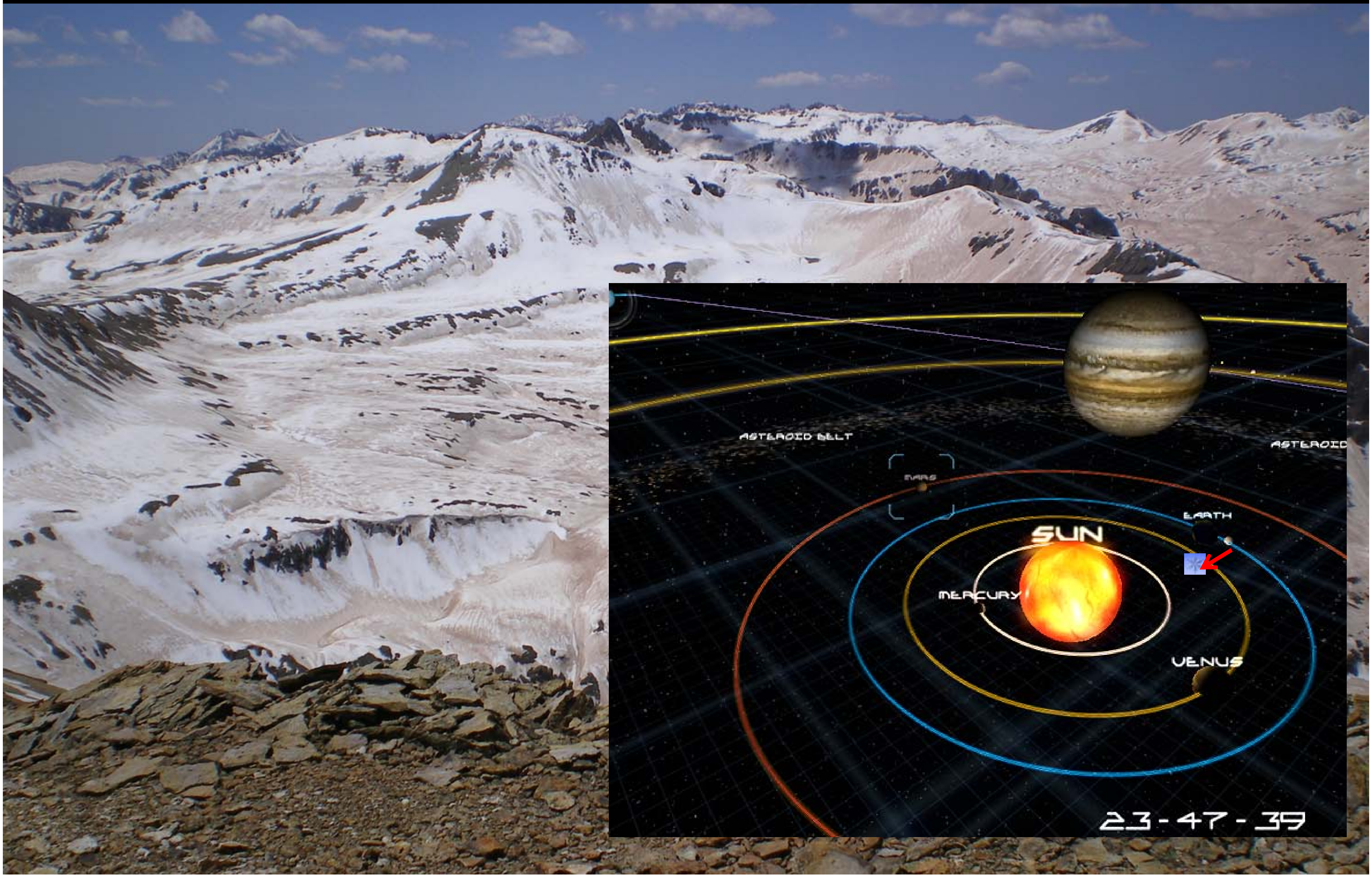
Elk Range, Colorado River Basin, April 2009

Albedo



Painter, 2011

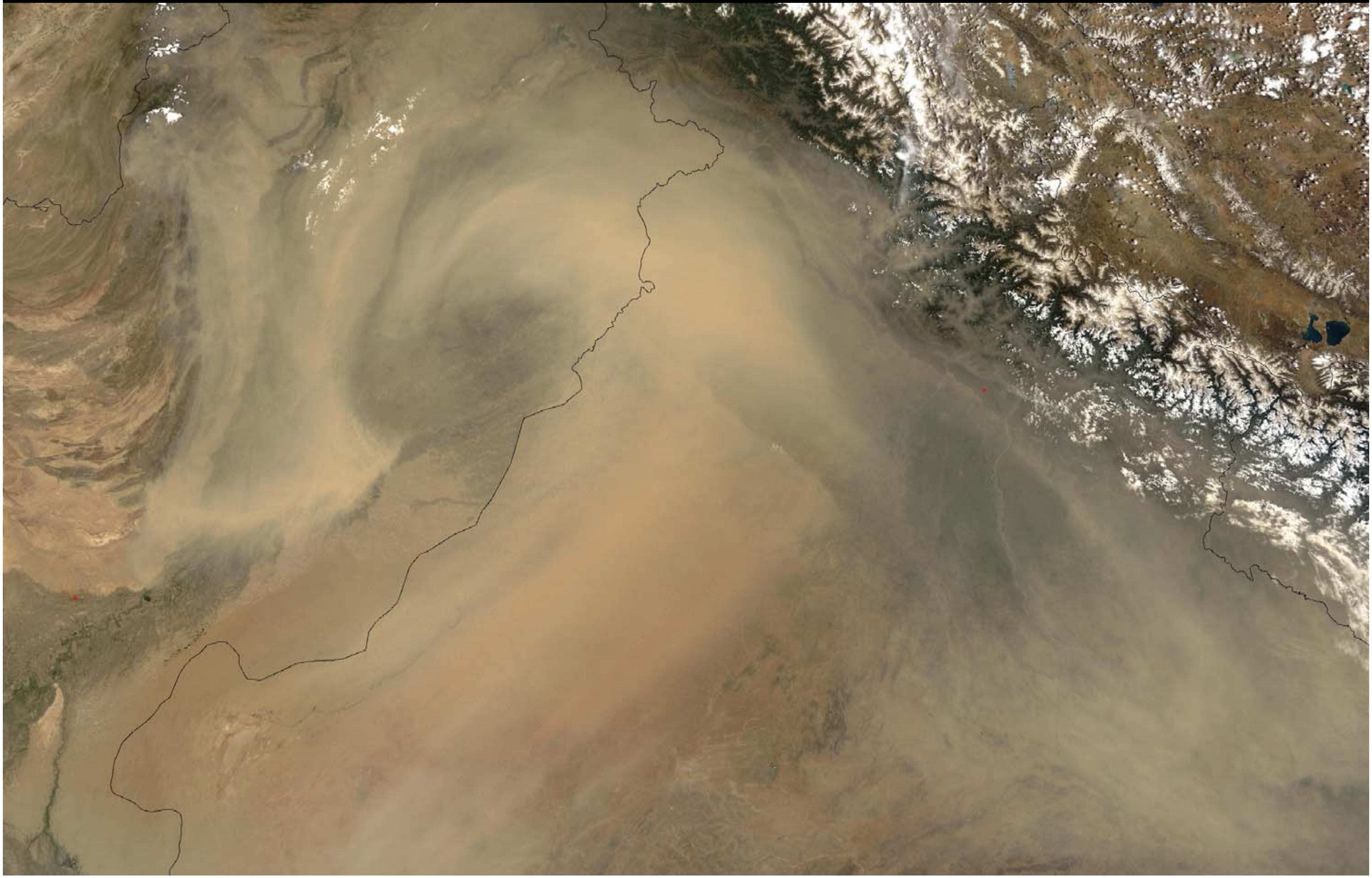
Upper Colorado River Basin



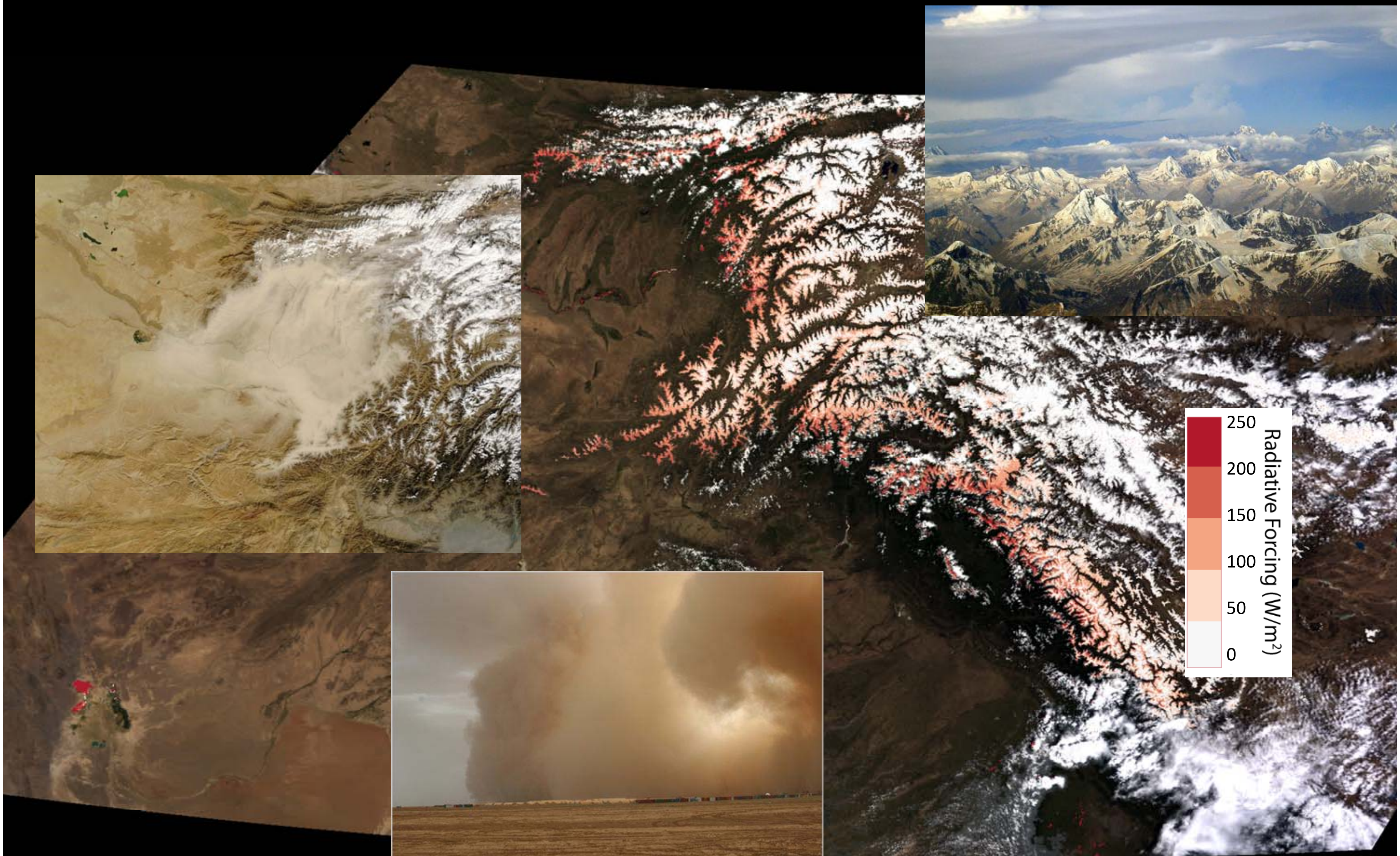
Alaska glaciers

Mt. Kosciuszko, Australia

Indian Himalaya + Tibet



Dust Radiative Forcing, Hindu Kush, Afghanistan

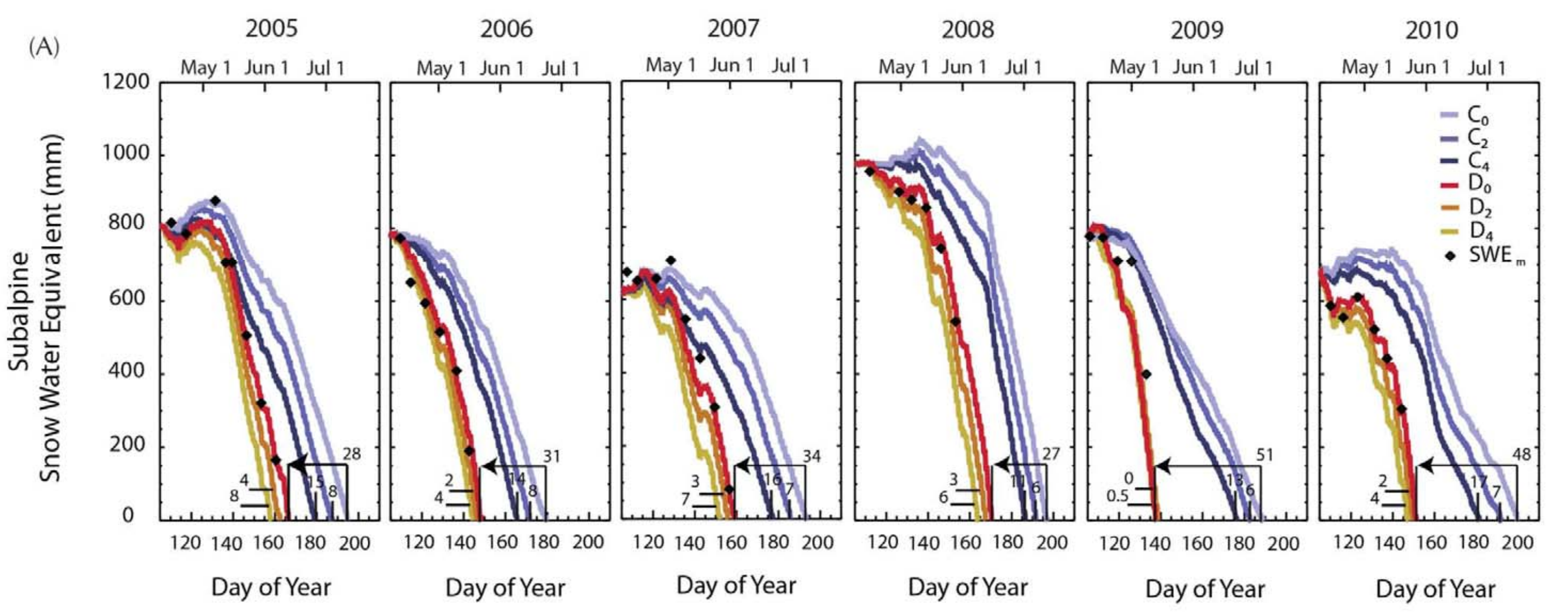


MOD-DRFS model (*Painter and Bryant,* 2011)


Tien Shan,
Kazakhstan

Mera Glacier looking south toward Mera summits, May 2009 Source: Susan Kaspari (CWU)

Dust vs CO_2 radiative forcings



nature climate change

LETTERS

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Consistent increase in High Asia's runoff due to increasing glacier melt and precipitation

A. F. Lutz[1,2★], W. W. Immerzeel[1,2,3], A. B. Shrestha[3] and M. F. P. Bierkens[2,4]

The actual runoff which is calculated for each grid cell consists of four possible contributing factors: rainfall-runoff, snow melt, glacier melt, and baseflow. For each grid cell the total runoff generated per time step (Q_{TOT}) is calculated:

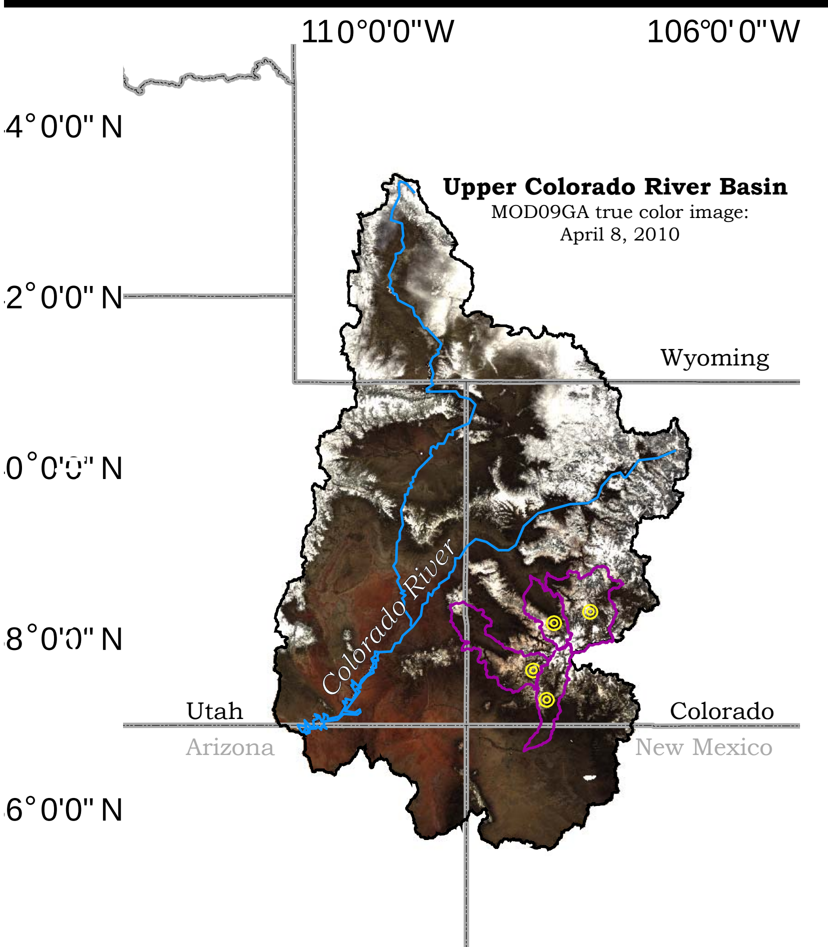
$$Q_{TOT} = Q_{GM} + Q_{SM} + Q_{RR} + Q_{BF} \qquad (1)$$

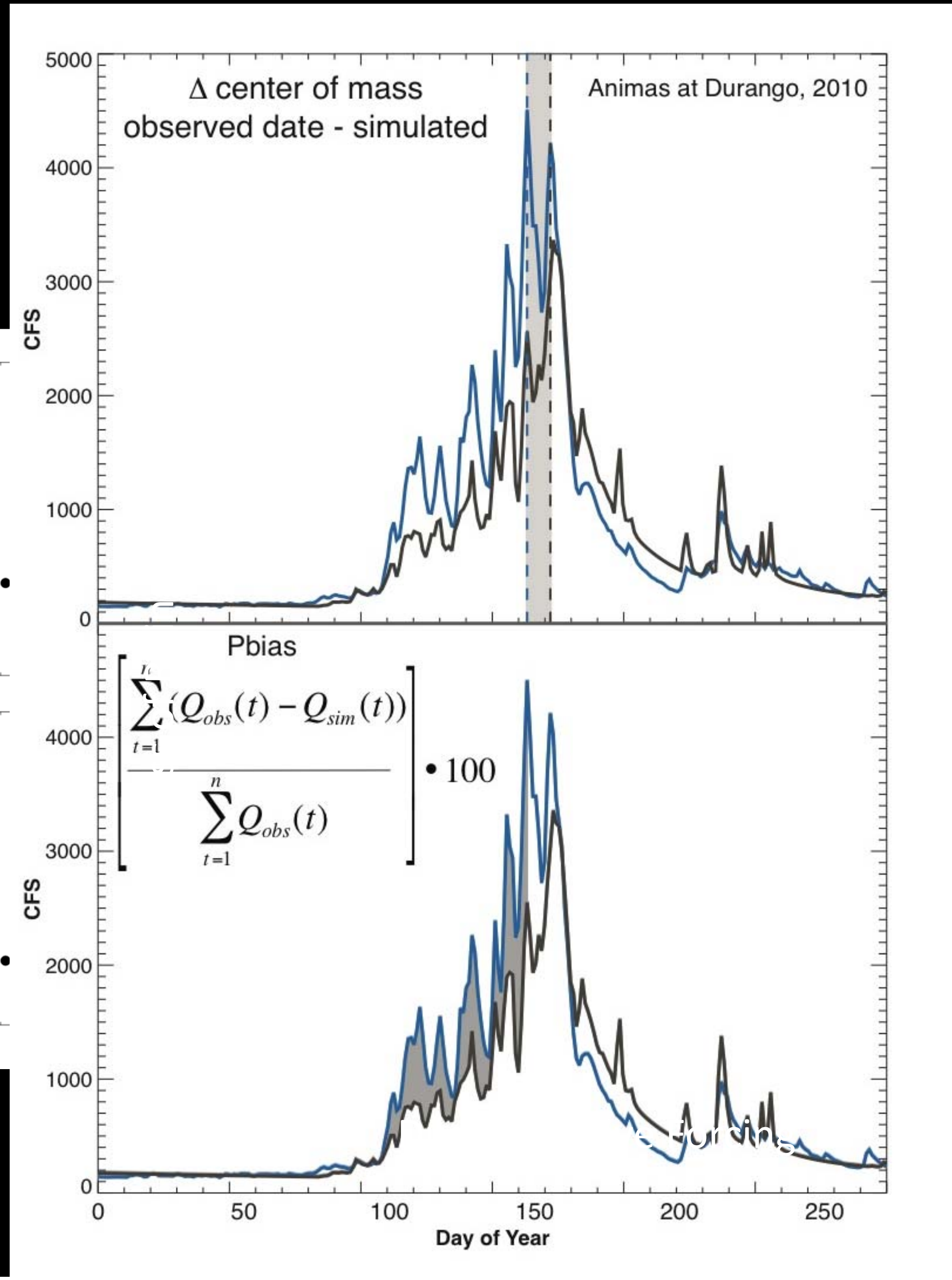
Where Q_{GM} is runoff from glacier melt, Q_{SM} is runoff from snow melt, Q_{RR} is rainfall-runoff and Q_{BF} is baseflow. To determine the contribution of each of the four components to the total runoff

The daily melt from debris free glaciers (A_{CI},[mm we]) is calculated as:

$$A_{CI} = \max(T_{AVG}, 0) \cdot DDF_{CI} \cdot F_{CI} \qquad (2)$$

Where T_{AVG} is the average air temperature, DDF_{CI} is a degree day factor for debris free glaciers (mm °C^{-1}day^{-1}) and F_{CI} is the fraction of debris free glaciers within the fractional glacier cover (G_F) of a grid cell. The daily melt from debris covered glaciers (A_{DC}, [mm we]) is calculated in a similar way, but with a different degree day factor:





Positive Degree Days

Climate change and forest fires synergistically drive widespread melt events of the Greenland Ice Sheet

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In July 2012, over 97
surface melt, the firs
remote sensing. Anal
the dry snow region
spread melt occurred
sheet demonstrated
bined with black ca
forest fires reduced
snow region, and ca

End of the Little Ice Age in the Alps forced by industrial black carbon

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ıs using glacier flow and
ımental and proxy tem-
ı the timing and magni-
retreat (8–12). Matches
ave only been achieved
ɔsed after 1865, or when
would fit the glacier re-
tion records (8, 10, 12,
treat with climatic vari-
e inconsistent with the

the LIA discrepancy be-
the glacier-length record
nass balance history [with
omalies] brought to light,
treat since about 1850 is
improved model simu-
ng an additional negative
mass balance perturbation during roughly the last 150 y, *seems to*

equivalent changes in atmospheric temperatures result in con-

ENVIRONMENTAL SCIENCES

Response of Colorado River runoff to dust radiative forcing in snow

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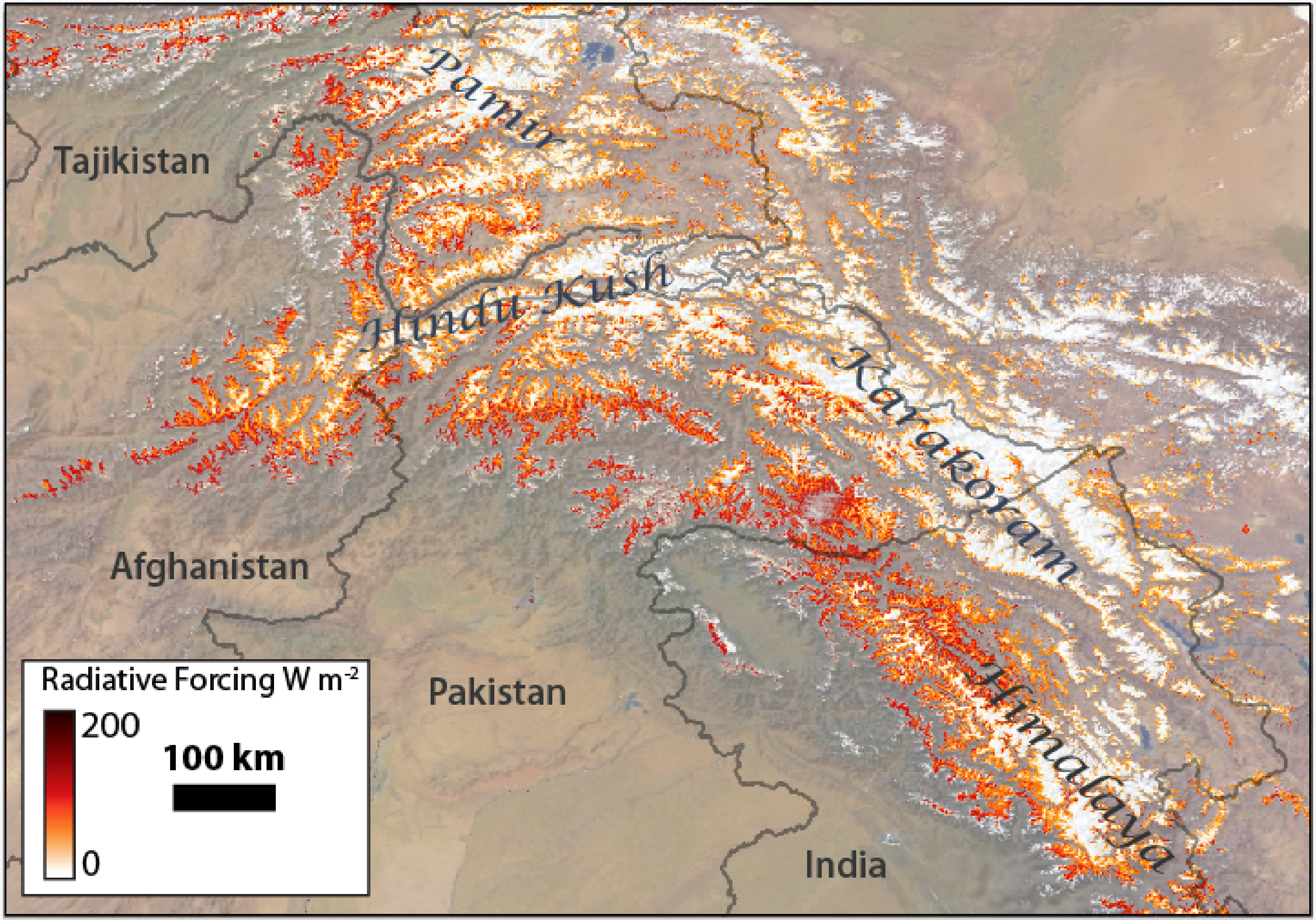
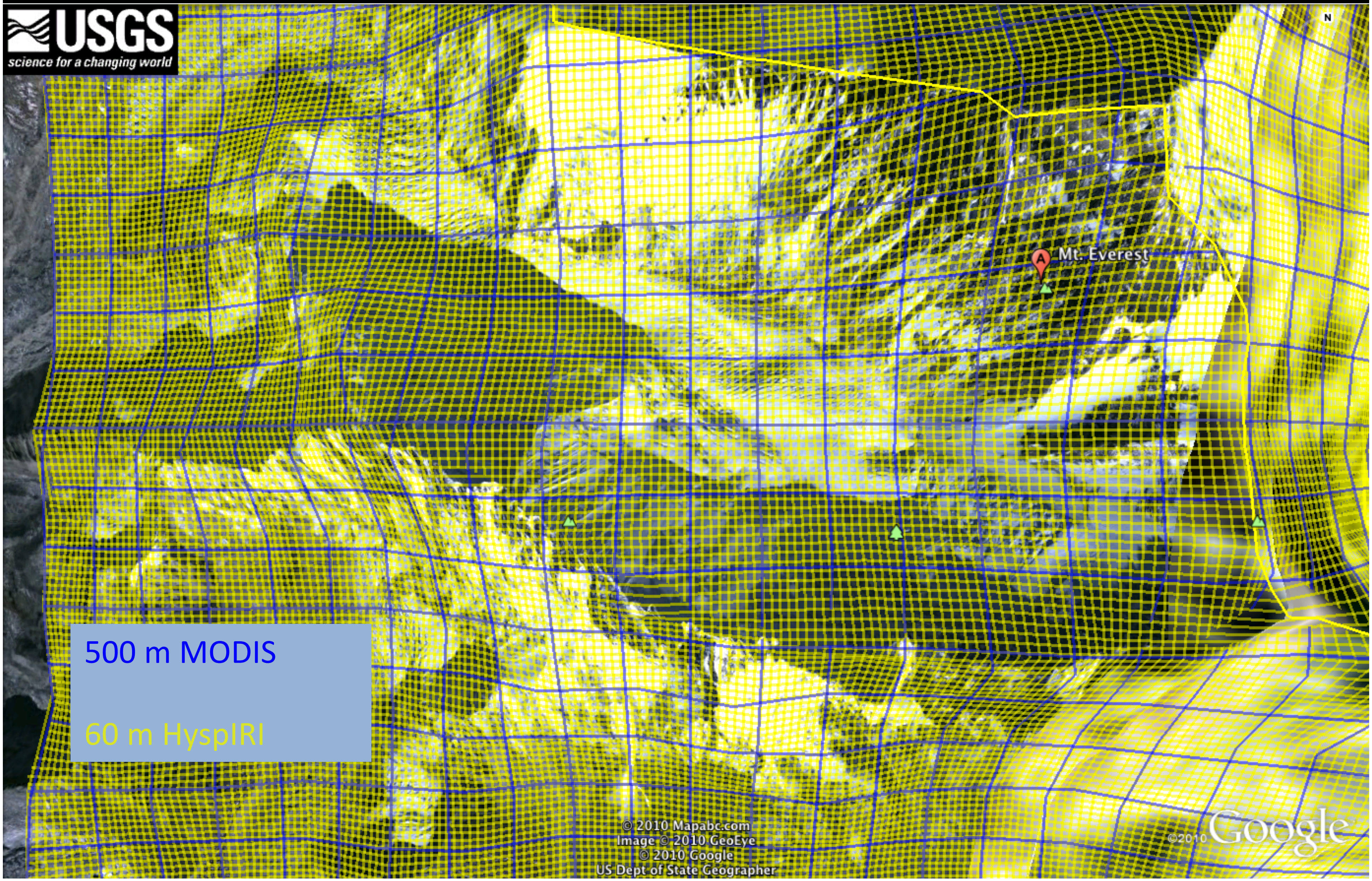
Edited by Peter H. Gleick, Pacific Institute for Studies in Development, Environment, and Security, Oakland, CA, and approved August 3, 2010 (received for review November 12, 2009)

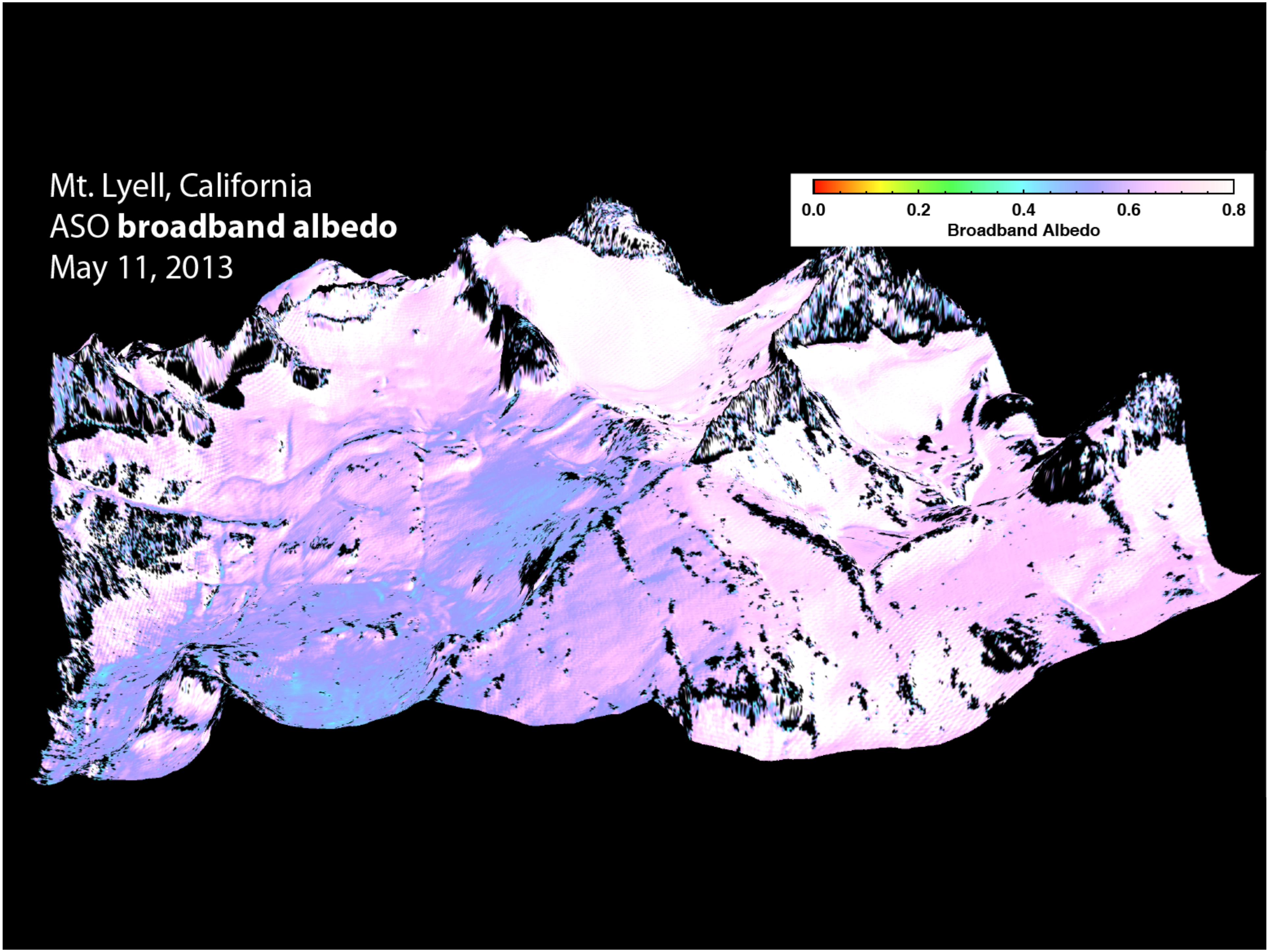
The waters of the Colorado River serve 27 million people in seven states and two countries but are overallocated by more than 10% of the river's historical mean. Climate models project runoff losses of

through dust's direct absorption and increased grain size from accelerated snow metamorphism. Present day dust concentrations cause an average March/April/May radiative forcing in


Pamir
Tajikistan
Hindu Kush
Karakoram
Afghanistan
Pakistan
Himalaya
India
Radiative Forcing W m-2
200
0
100 km

Spatial Resolution in Rough Terrain




Mt. Lyell, California
ASO **broadband albedo**
May 11, 2013
0.0
0.2
0.4
0.6
0.8
Broadband Albedo

Mt. Lyell, California
ASO **snow depth**
May 11, 2013