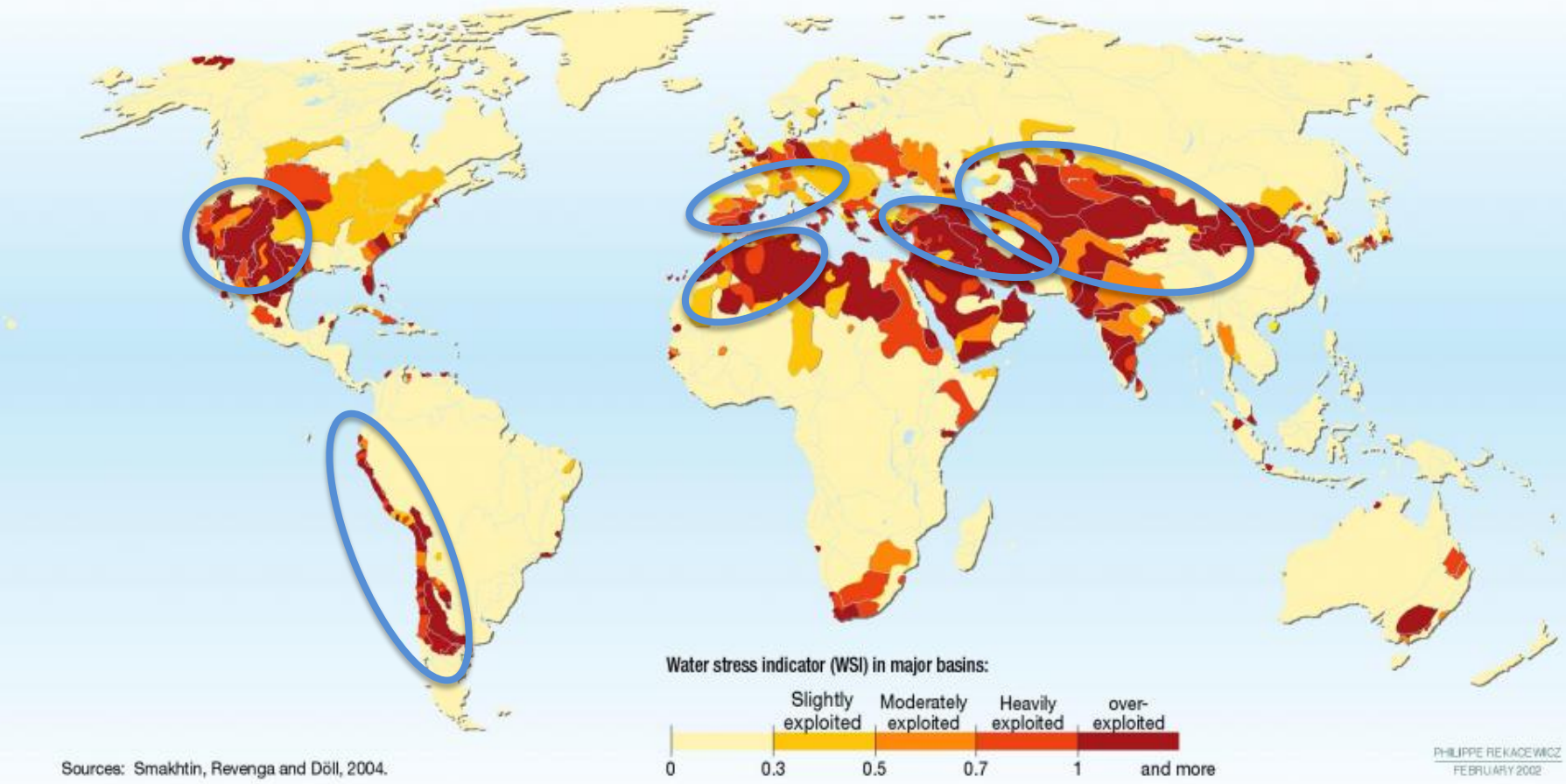
Thomas H. Painter
JPL/Caltech

Entering a New Era of Water Science and Management: The Maturation of Snow Remote Sensing

Water Stress



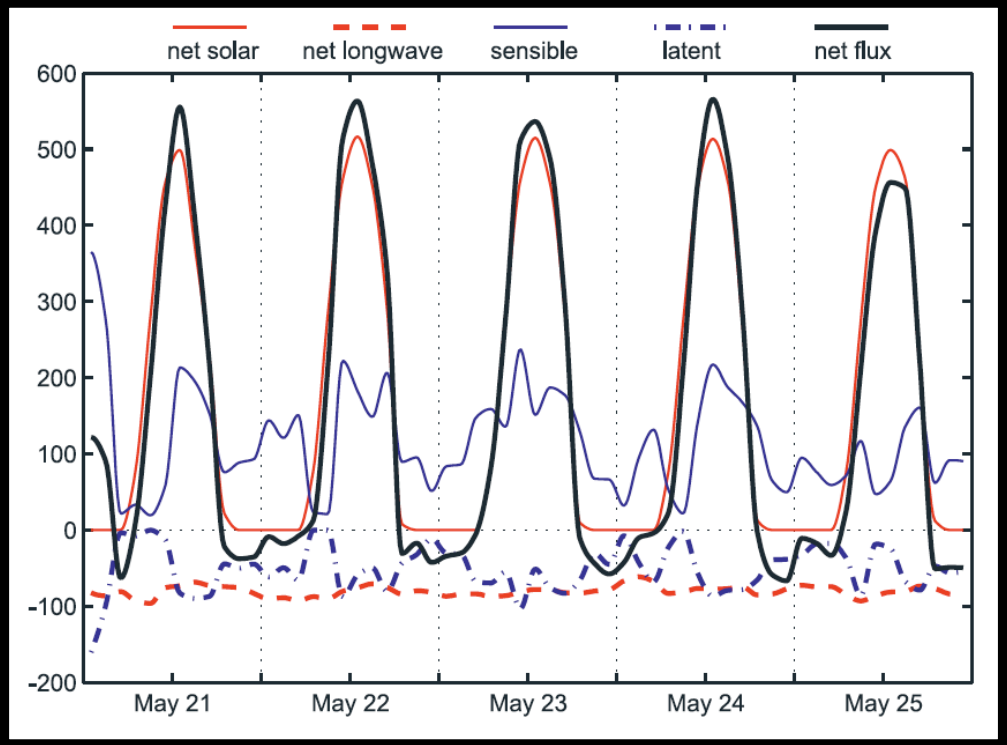
Outline

- Dust impacts on snowmelt and runoff
- Constraining CBRFC forecasting
- Finally getting to distributed mountain SWE – the NASA Airborne Snow Observatory
- What does the future hold?

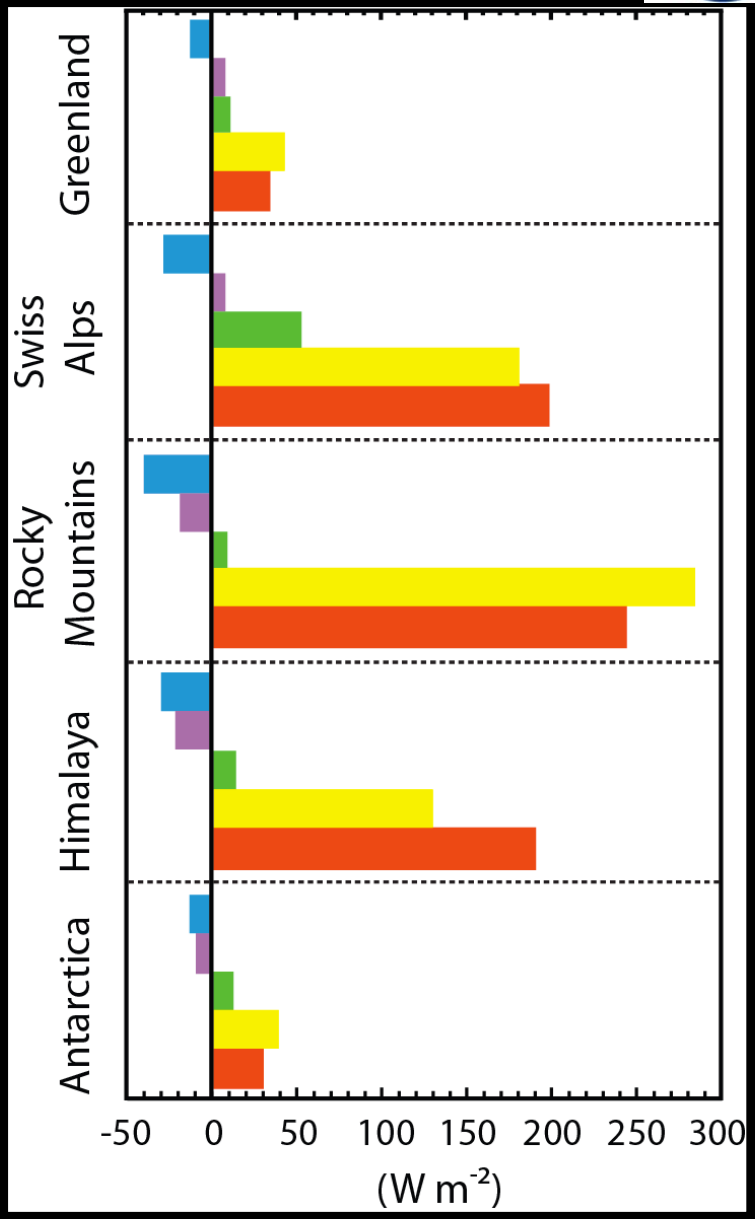
Introduction: What drives snow and ice melt?

Net Flux *Net Solar* *Net Longwave* *Sensible Heat* *Latent Heat*

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

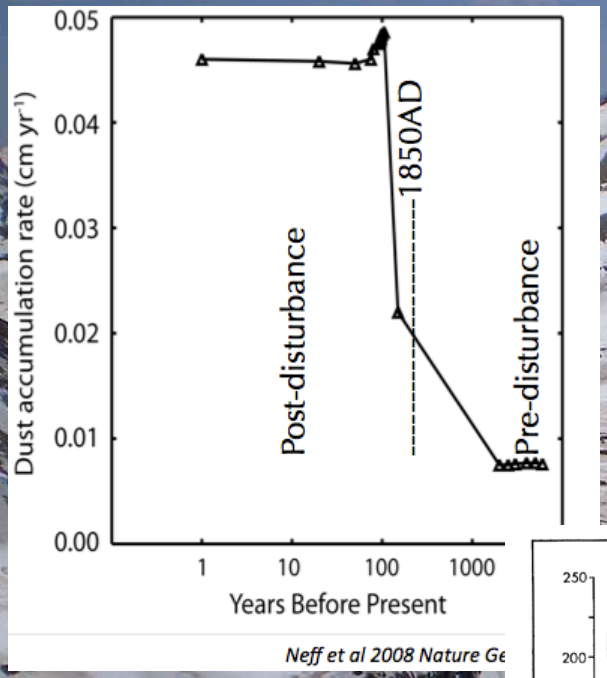


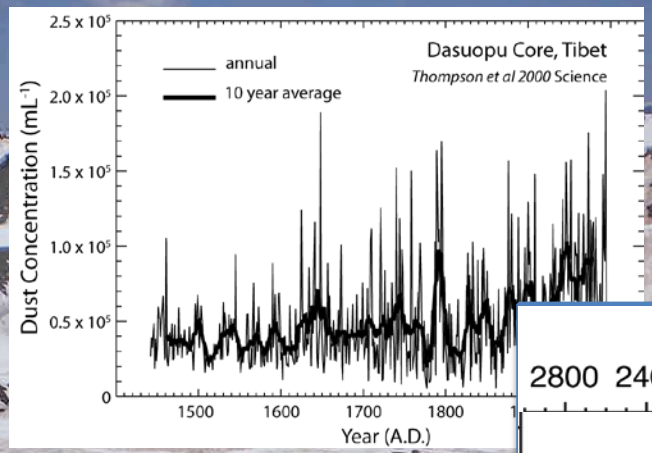
San Juan Mountains, 2005

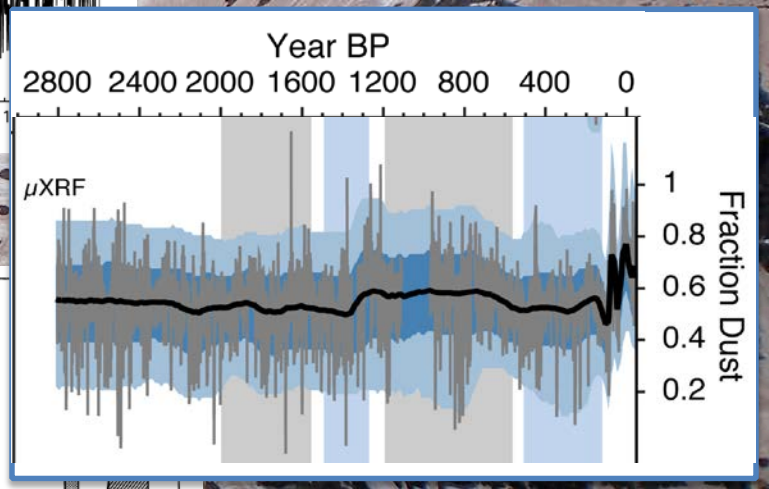


Dirtier snow (dust)

Colorado Rockies







Caucasus

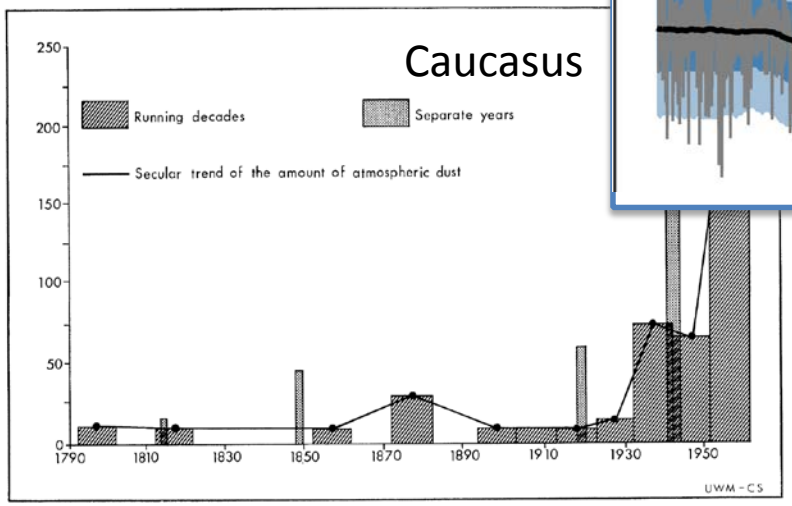


FIG. 4. Amounts of dust in firn layers deposited during decades, the Maili Plateau, Kazbek, milligrams per liter

Routson et al, 2016

Aeolian Research xxx (2013) xxx–xxx

Contents lists available at SciVerse ScienceDirect

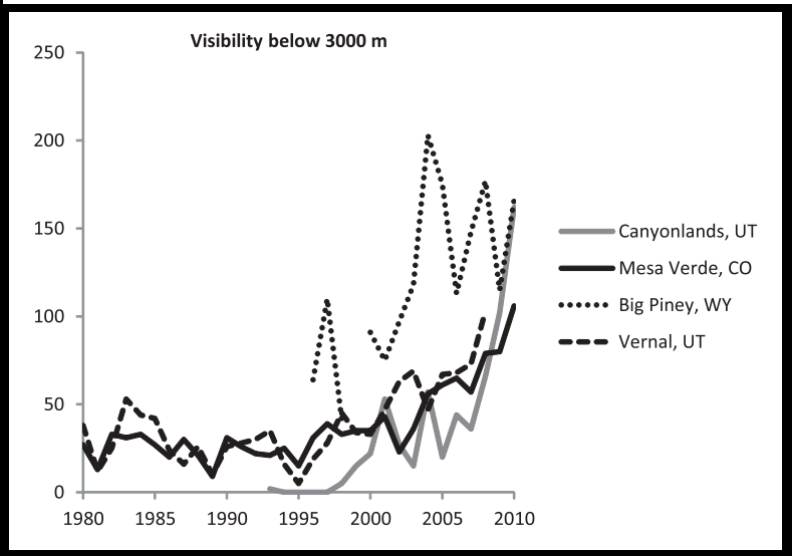
Aeolian Research

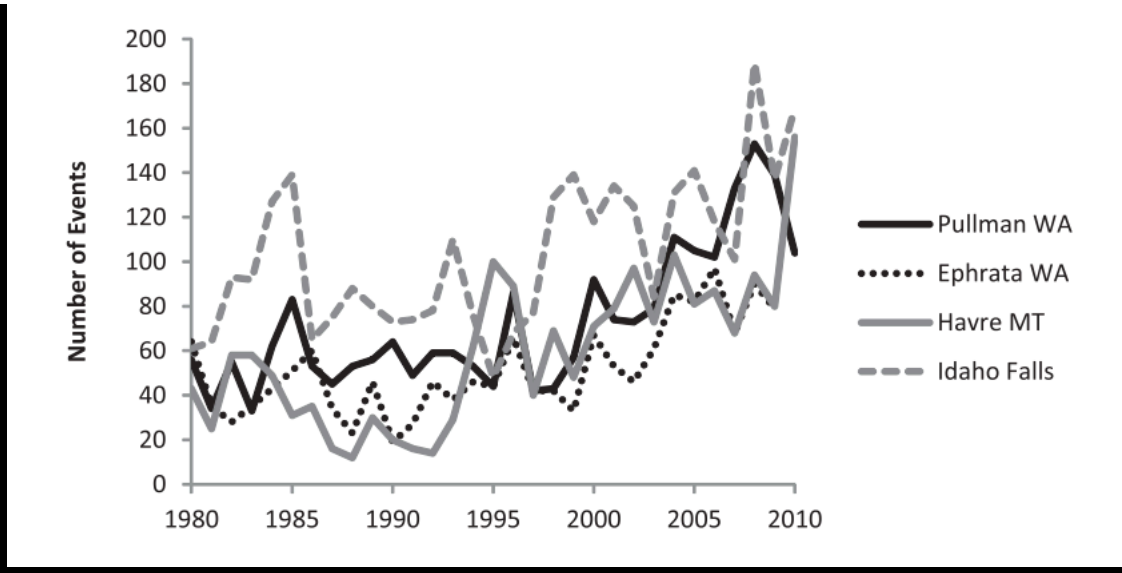
journal homepage: www.elsevier.com/locate/aeolia

Increasing Ca^{2+} deposition in the western US: The role of mineral aerosols

J. Brahney [a,*], A.P. Ballantyne [a], C. Sievers [b], J.C. Neff [a]

[a] University of Colorado, Department of Geological Sciences, 2200 Colorado Ave, Boulder, CO 80309-399, USA
[b] University of Colorado, Department of Physics, 2000 Colorado Ave, Boulder, CO 80309-390, USA





GEOPHYSICAL RESEARCH LETTERS, VOL. 39, L17502, doi:10.1029/2012GL052457, 2012

MODDRFS

Radiative forcing by light absorbing impurities in snow from MODIS surface reflectance data

Thomas H. Painter,[1] Ann C. Bryant,[2] and S. McKenzie Skiles[3]

JOURNAL OF GEOPHYSICAL RESEARCH: ATMOSPHERES, VOL. 118, 1–13, doi:10.1002/jgrd.50520, 2013

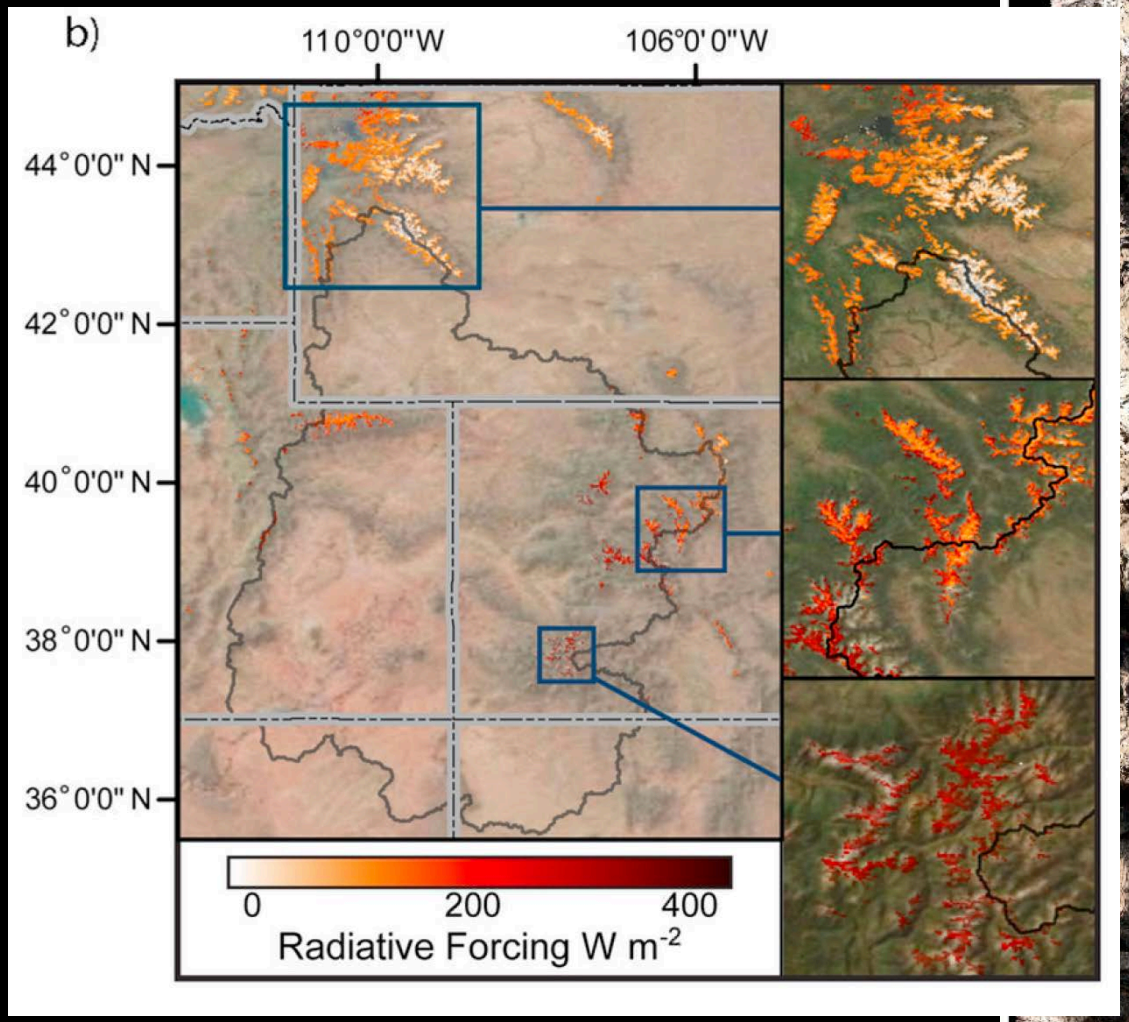
IS-DRFS

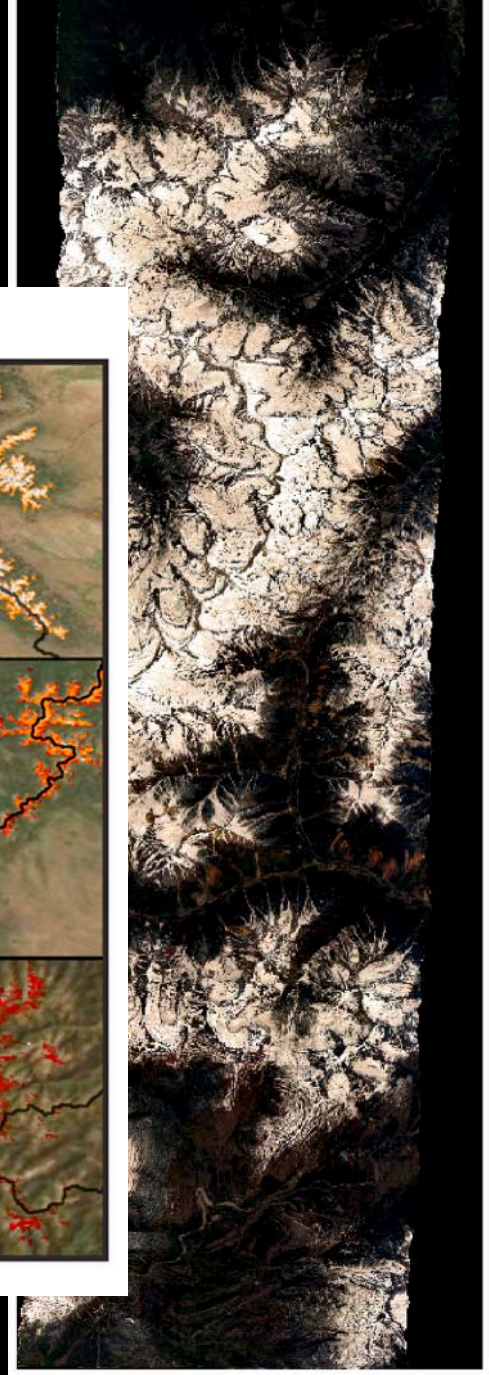
Imaging spectroscopy of albedo and radiative forcing by light-absorbing impurities in mountain snow

Thomas H. Painter,[1,2] Felix C. Seidel,[1] Ann C. Bryant,[3] S. McKenzie Skiles,[2] and Karl Rittger[1]

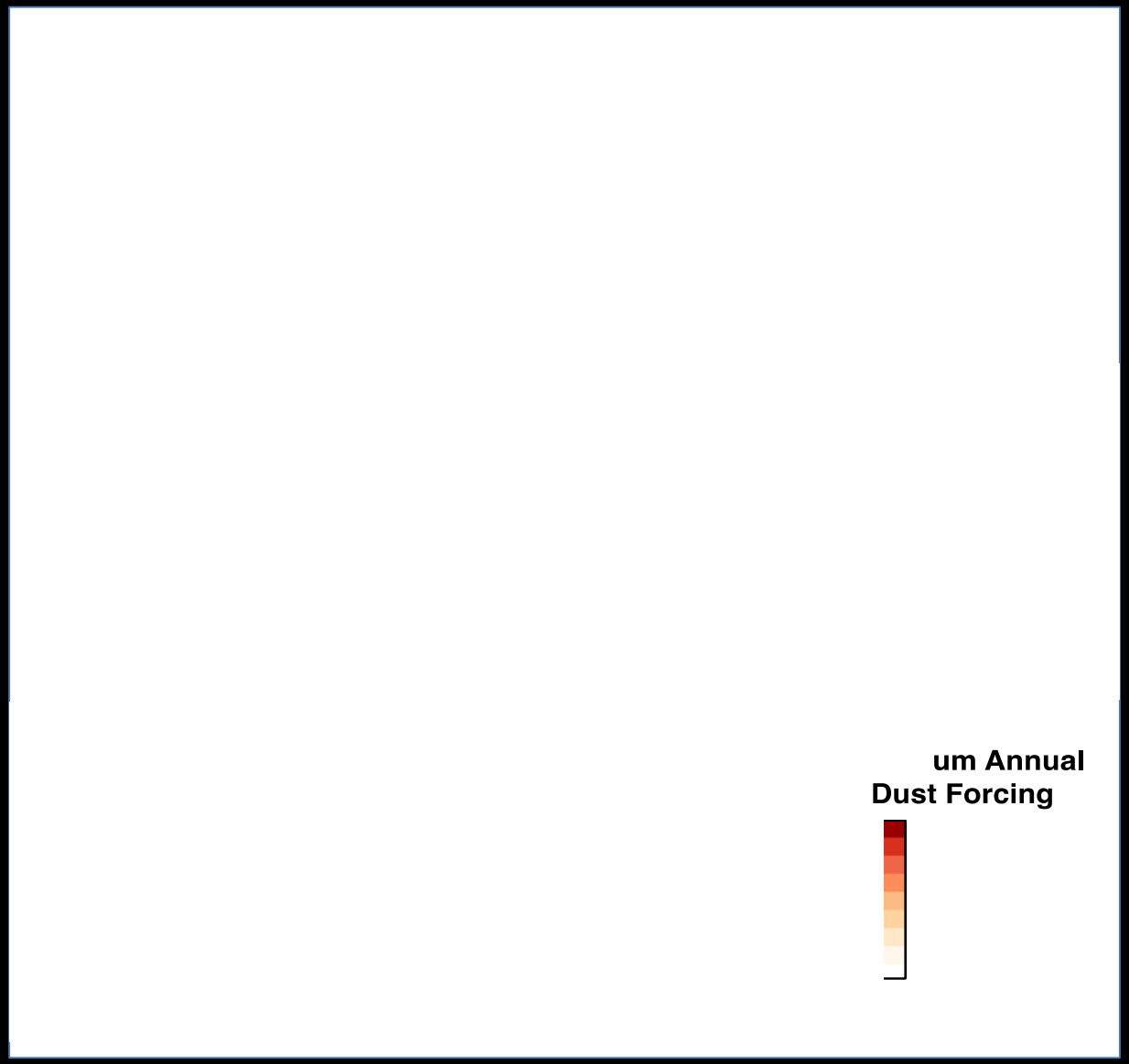
IS-DRFS

MODDRFS





Dust loading growing - MODDRFS

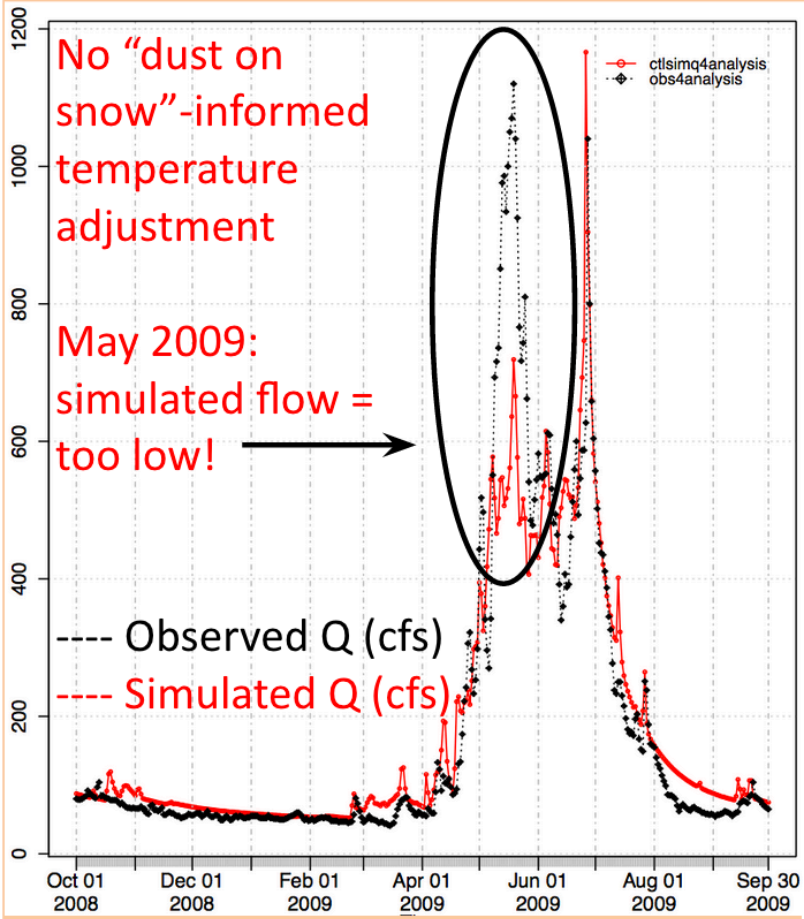


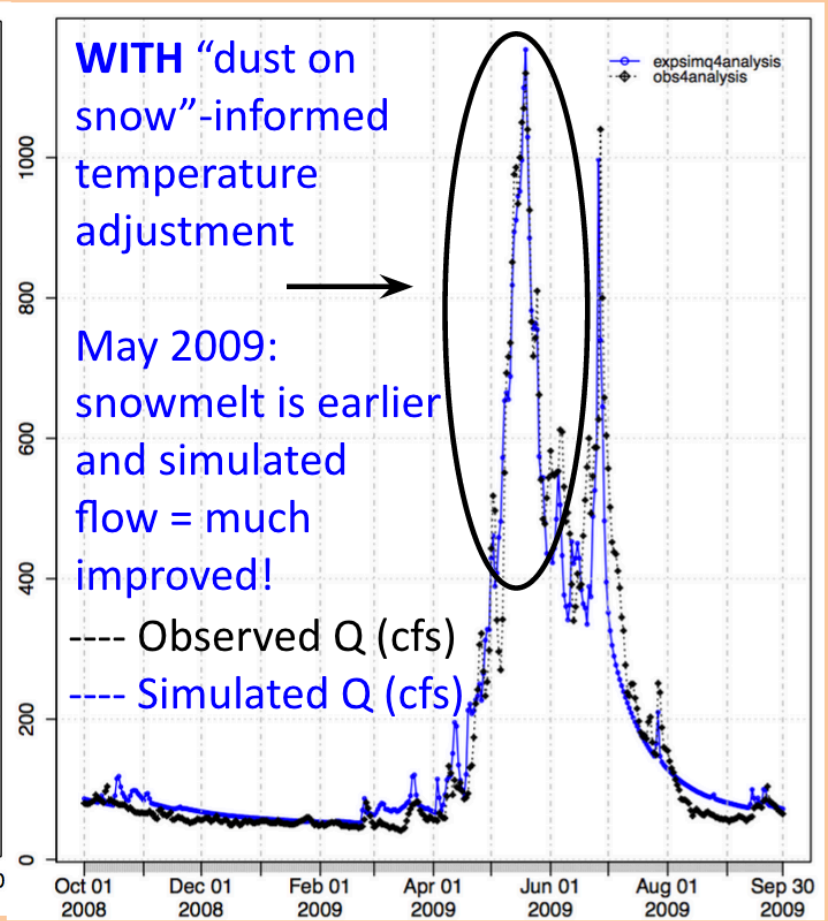
Bryant and Painter, in preparation

Operational Forecast Errors and Correction

WY2009 (dusty snowpack) application of the MODDRFS-informed adjustment to SNOW17 temperature inputs:

- more prominent impacts in UCRC2 streamflow than for the "clean snowpack"
- noticeable shifts of snowmelt-driven streamflow to *earlier* in runoff season





Impact
runoff

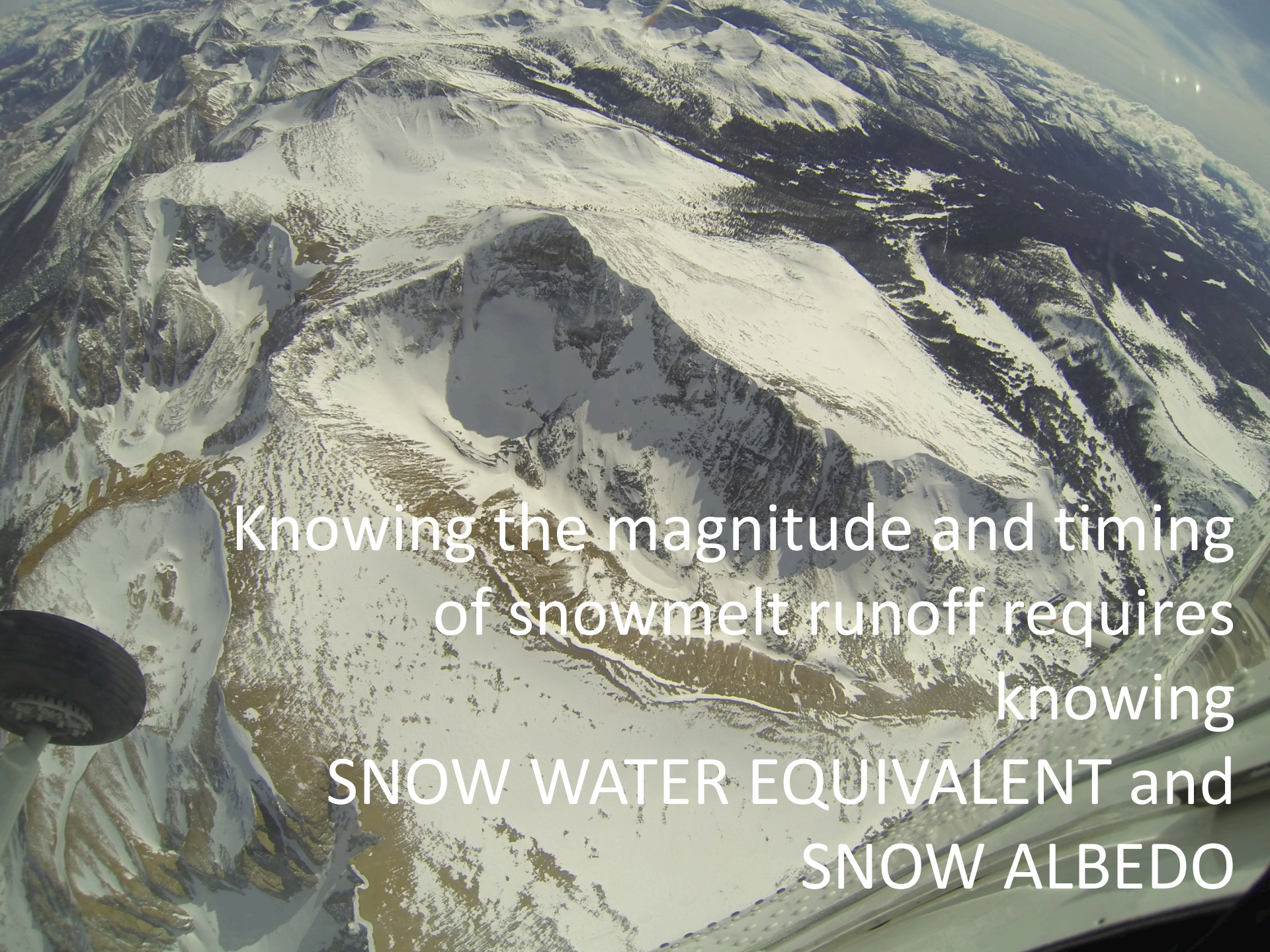
Ann C. B

Airborne Snow Observatory

Path to Operational Snowpack Quantification

Thomas H. Painter and the ASO team

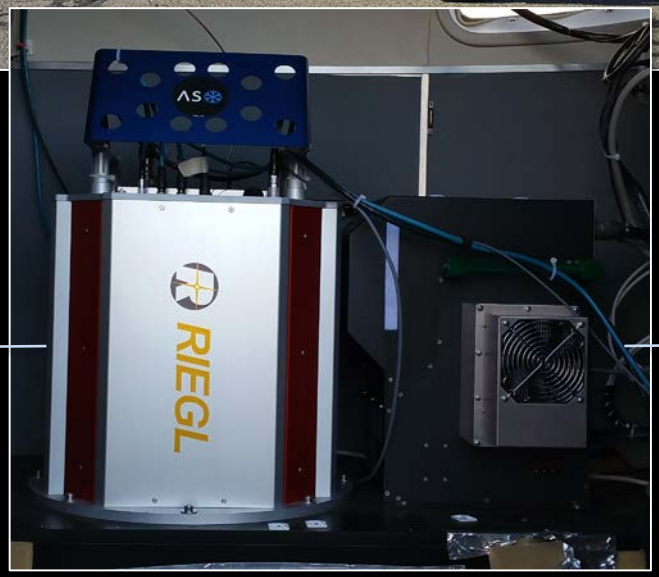
Jet Propulsion Laboratory
California Institute of Technology



Knowing the magnitude and timing of snowmelt runoff requires knowing

SNOW WATER EQUIVALENT and SNOW ALBEDO

NASA Airborne Snow Observatory



Snow Depth

- Riegl Q1560 dual laser scanning lidar
- 1064 nm
- Full-waveform
- 60° field of view

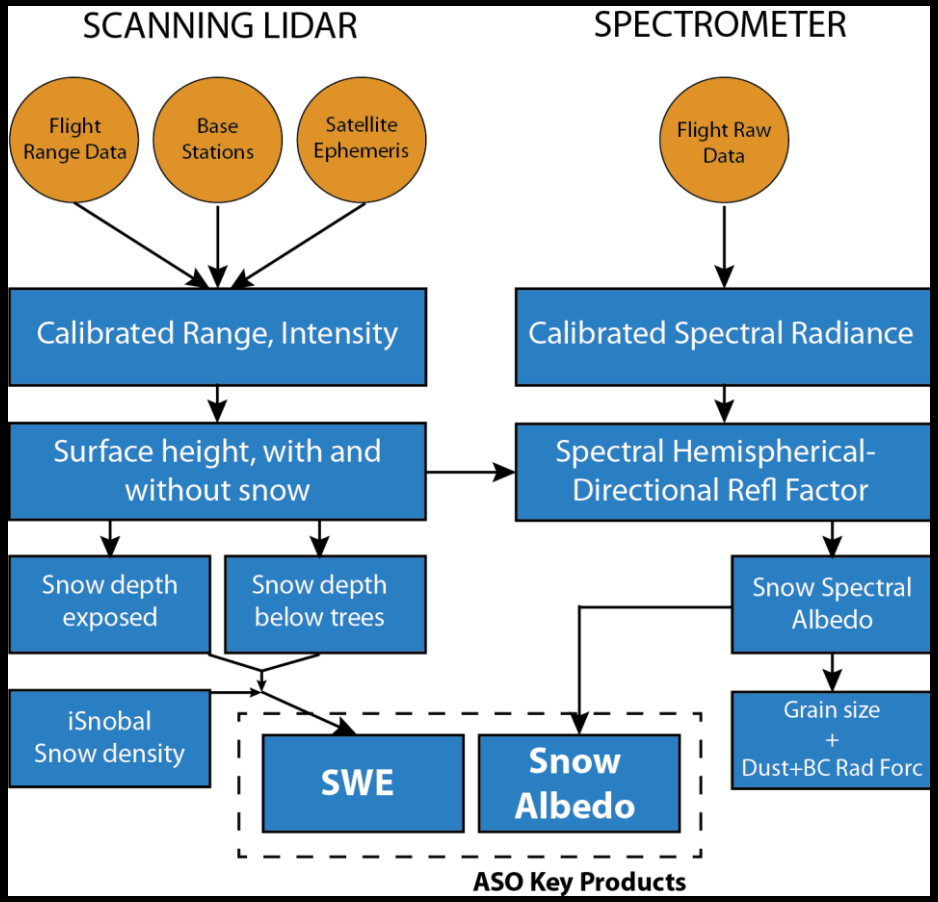
Snow Albedo

- CASI-1500 Imaging Spectrometer
- 72 bands between 0.35 and 1.05 μm
- 40° field of view

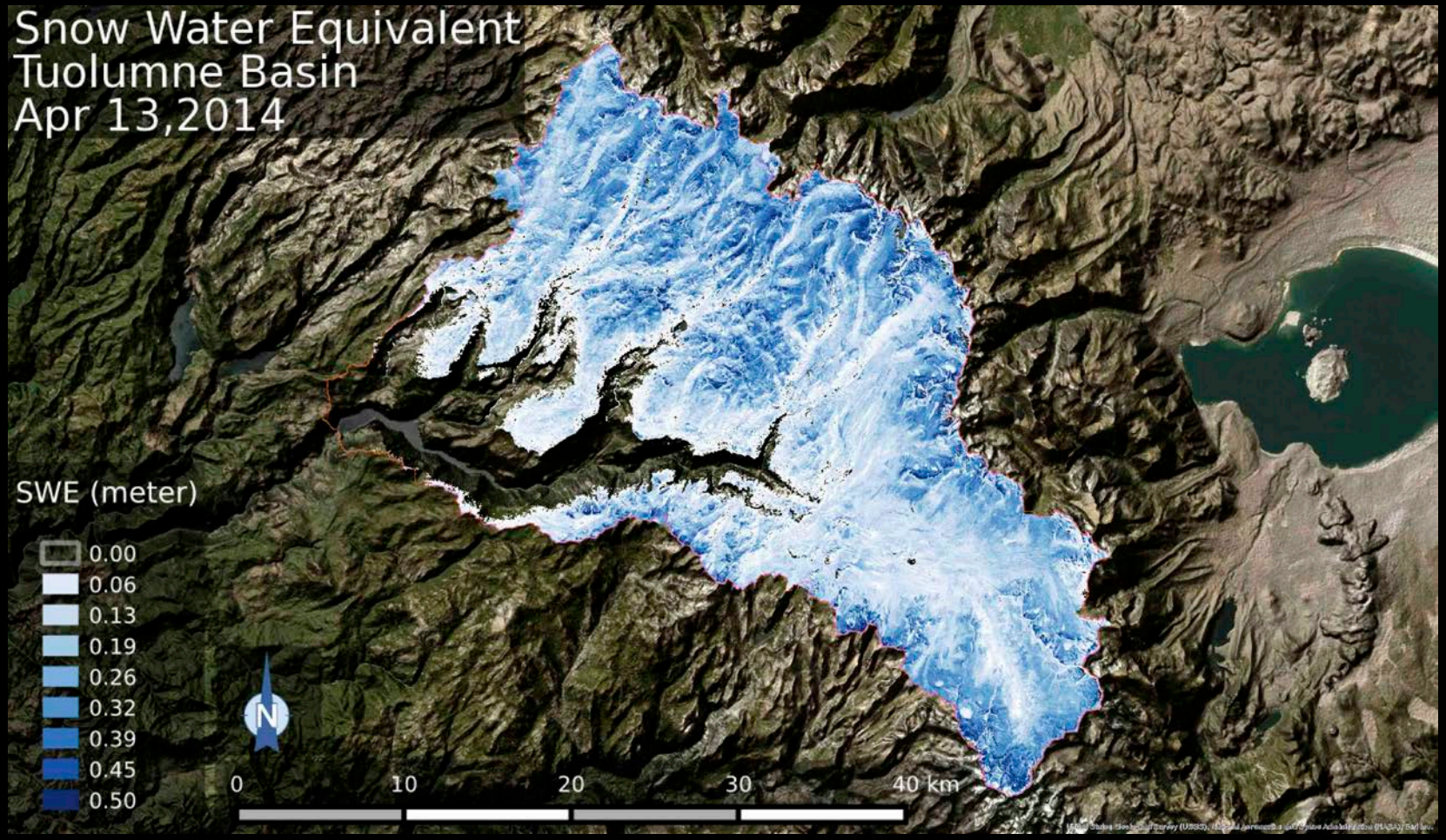
ASO Compute System

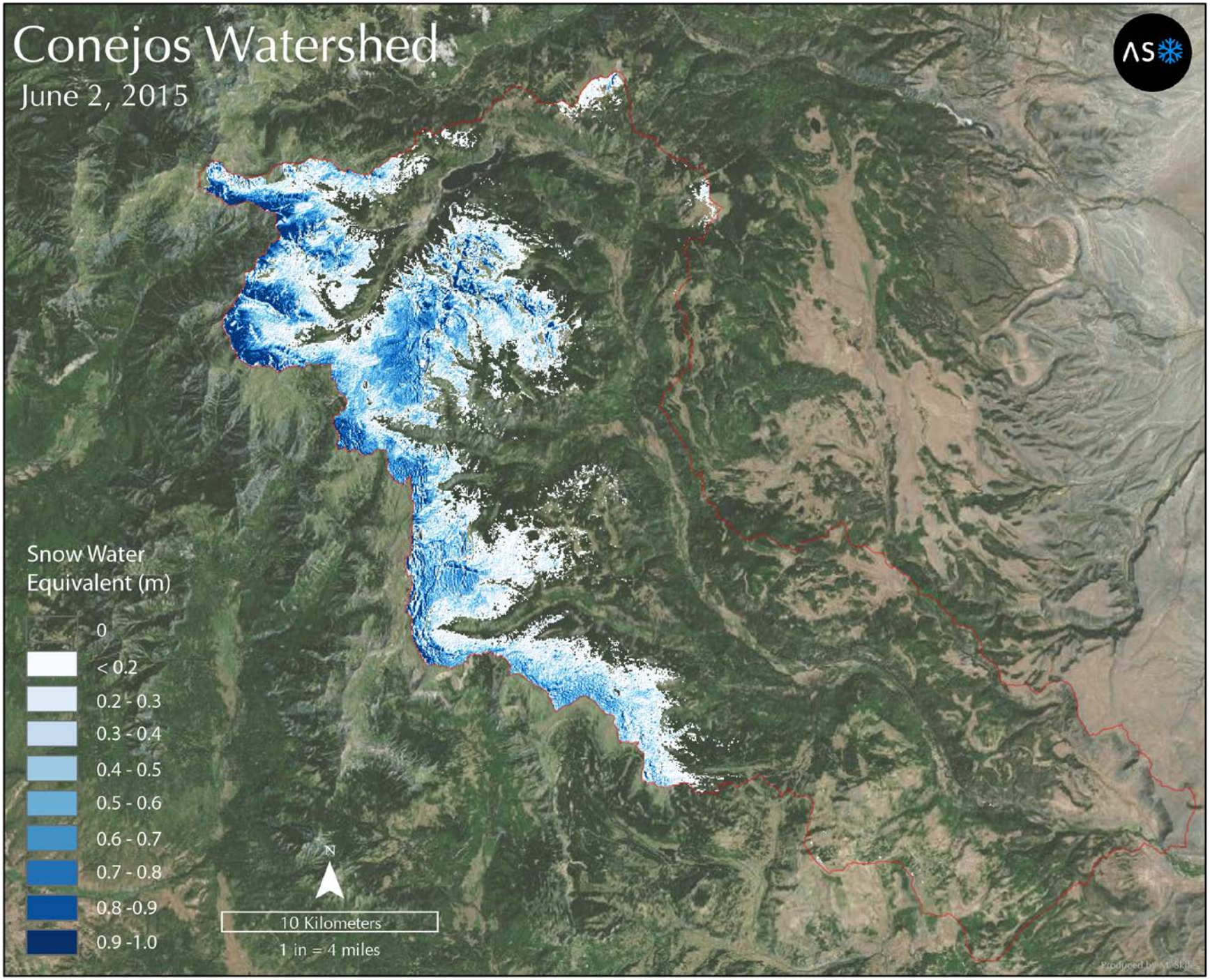
operational products

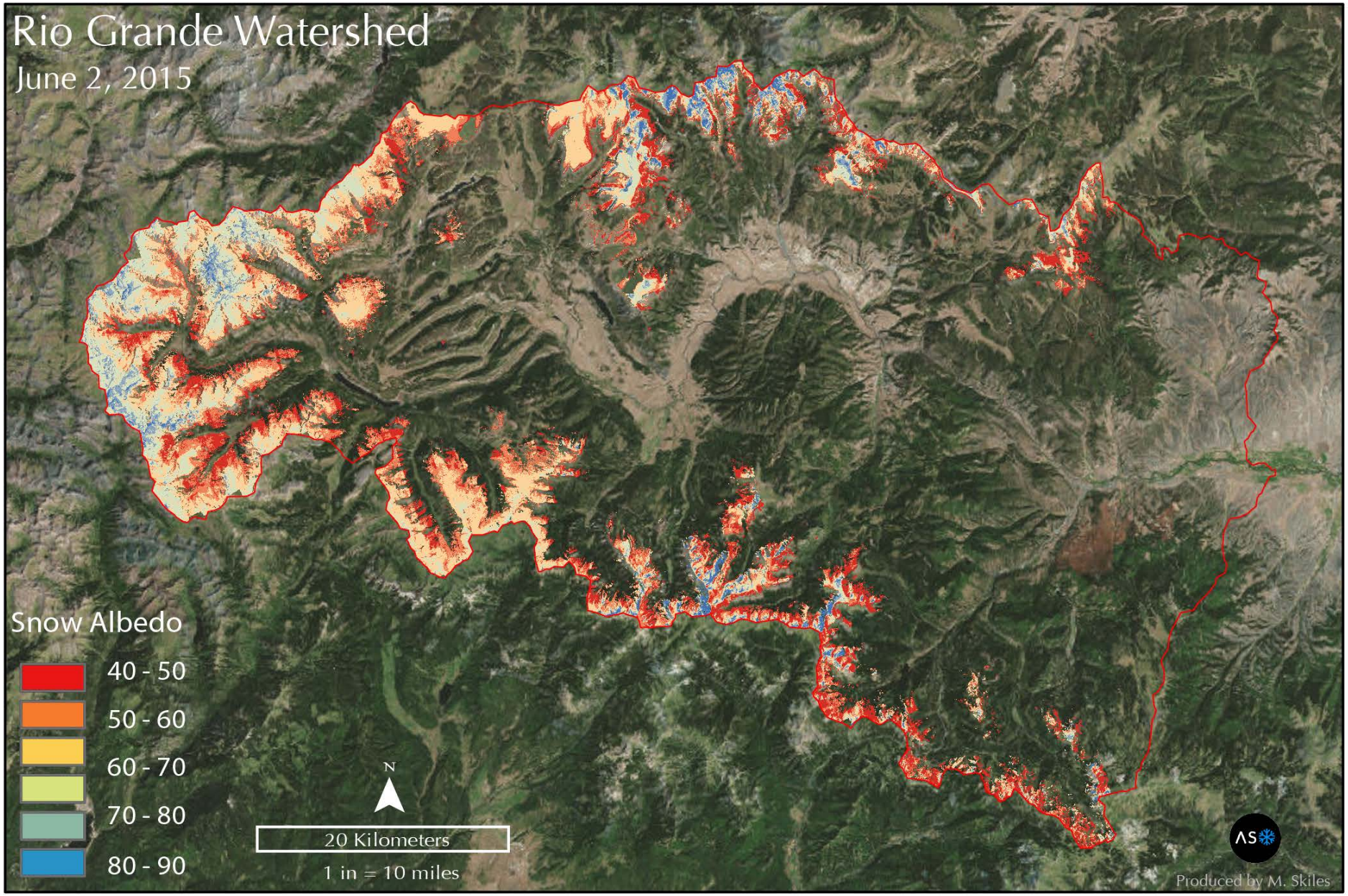
- 24-hour turnaround
- maps of:
  - snow depth
  - SWE (using snow pillow densities)
  - albedo
- aggregated to operational model resolution (PRMS HRUs)



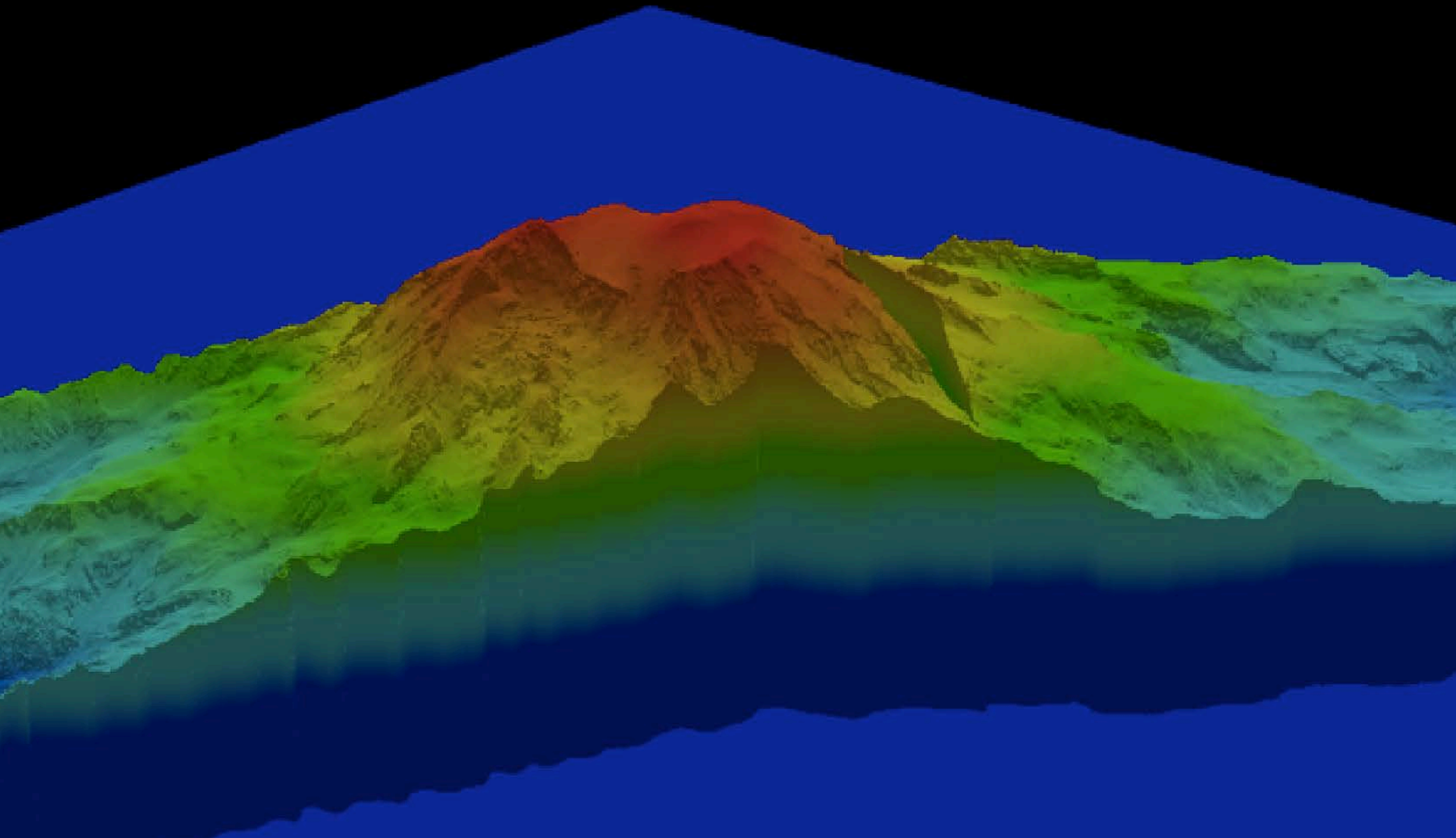
Tuolumne River Basin
Water supply to SFO and other cities



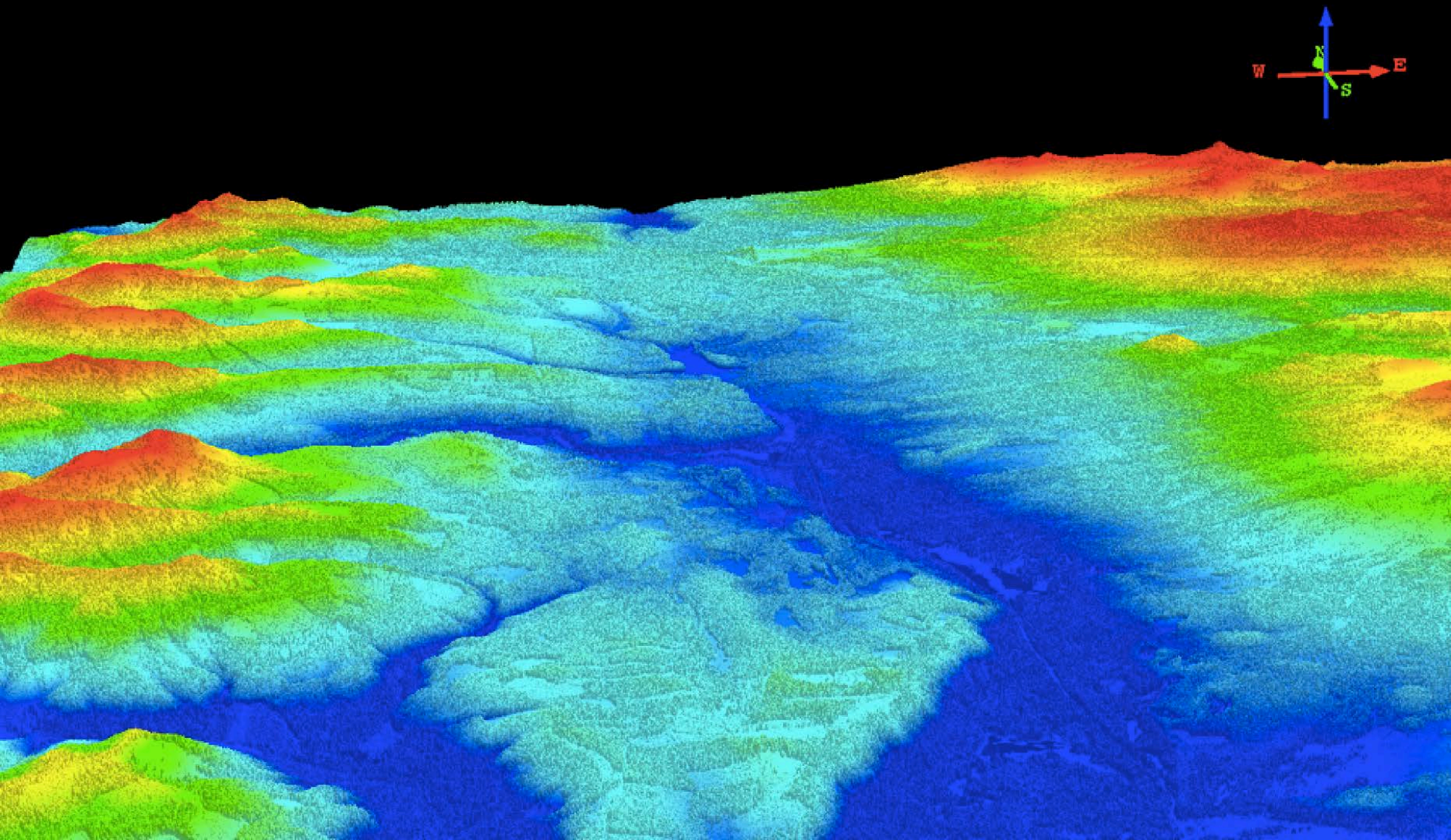

Conejos Watershed
June 2, 2015
Snow Water Equivalent (m)
0
< 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 -0.9
0.9 -1.0
N
10 Kilometers
1 in = 4 miles


Rio Grande Watershed
June 2, 2015
Snow Albedo
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
N
20 Kilometers
1 in = 10 miles
Produced by M. Skiles

Mt Rainier – last month

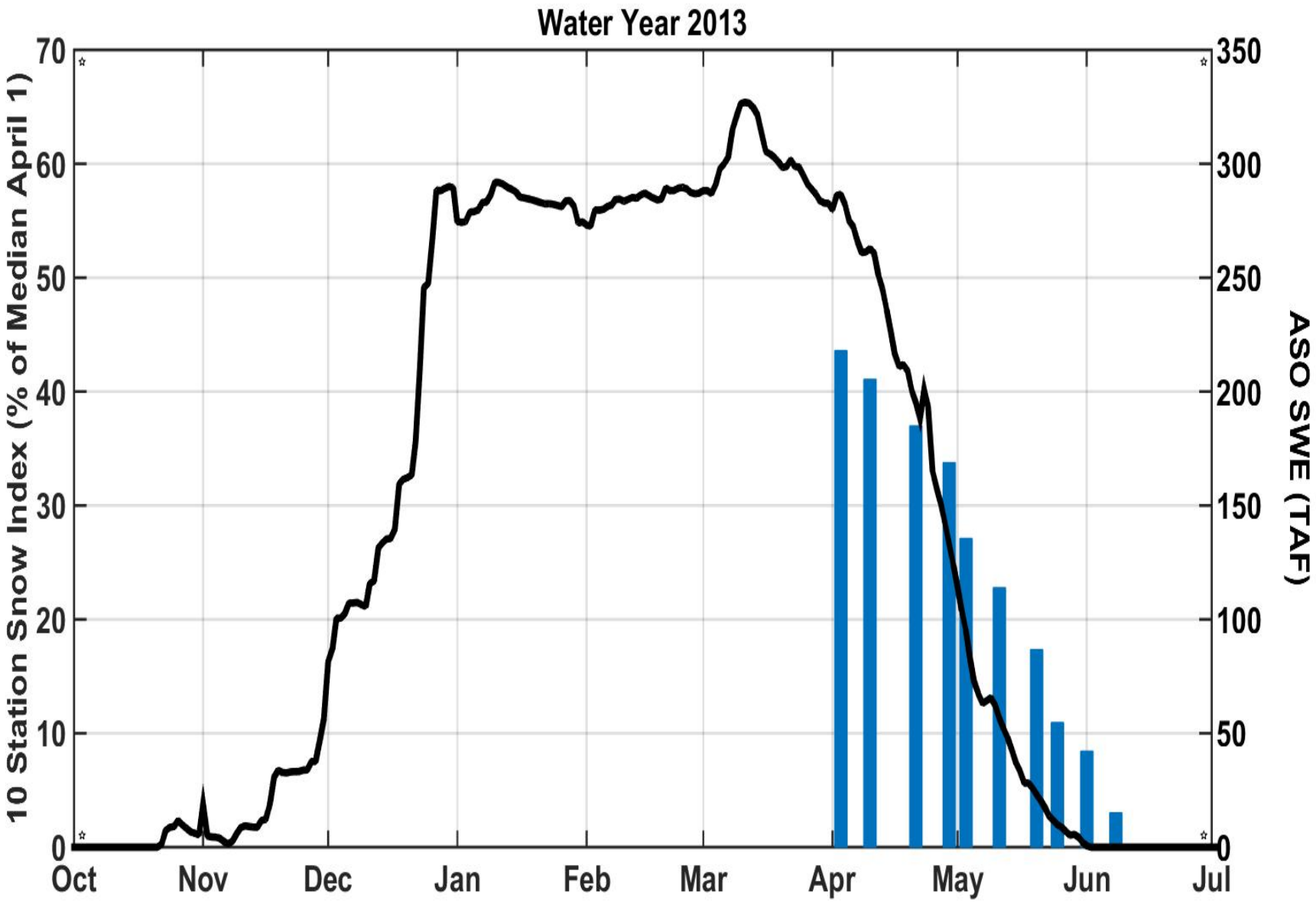


McKenzie River/HJ Andrews, OR

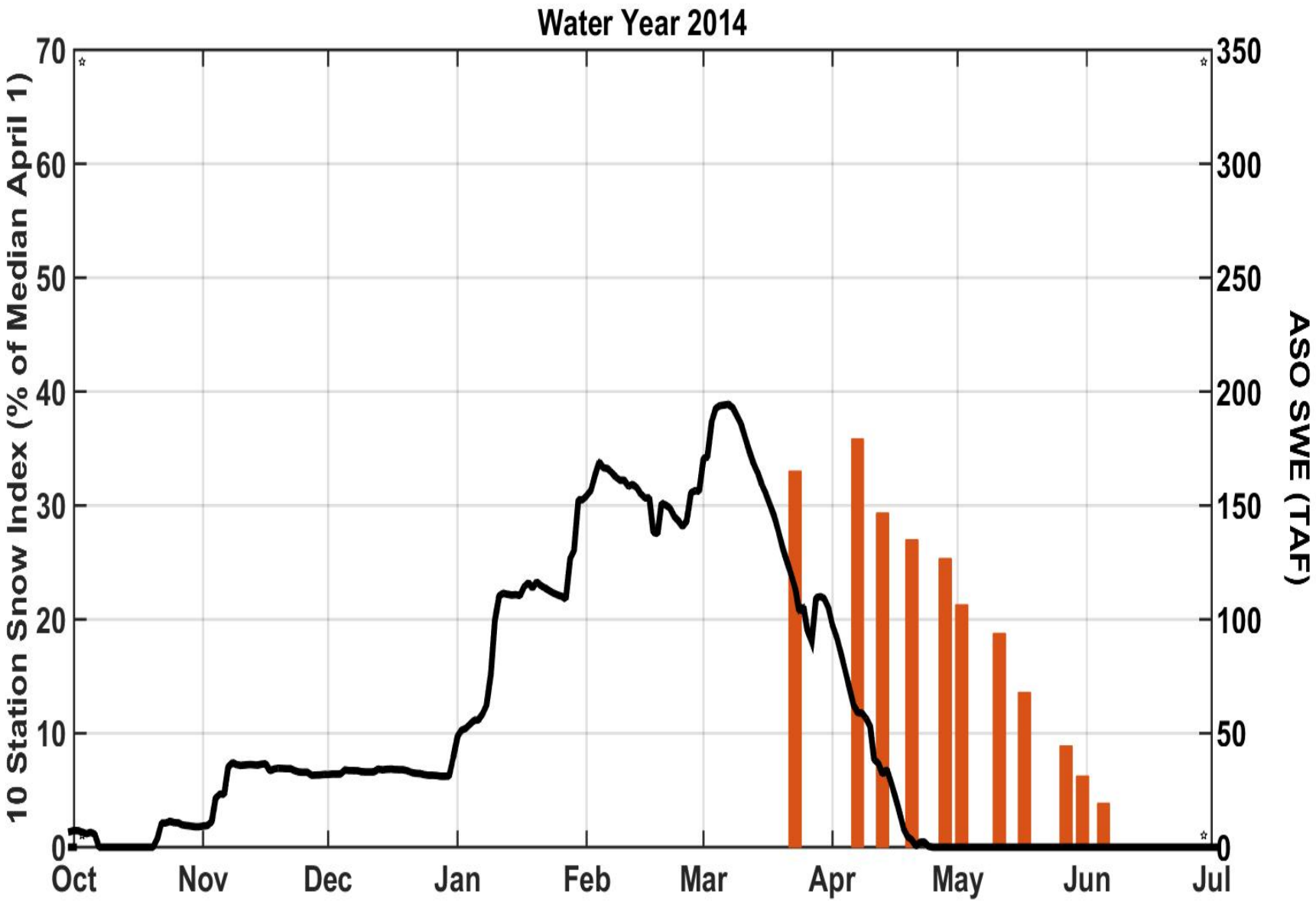


SWE INFORMATION IN CHANGING CLIMATE

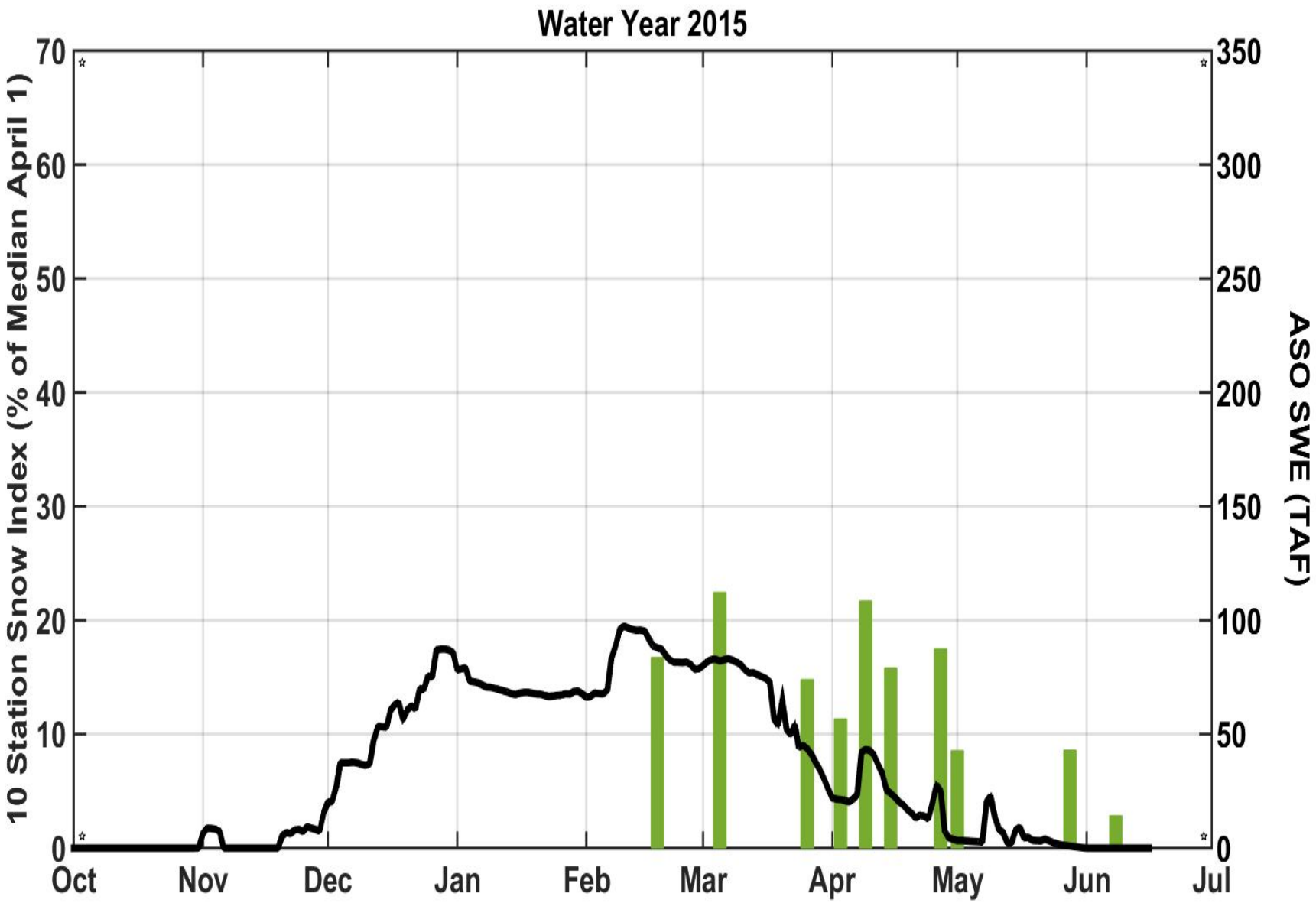
Tuolumne River Basin above Hetch Hetchy



Tuolumne River Basin above Hetch Hetchy

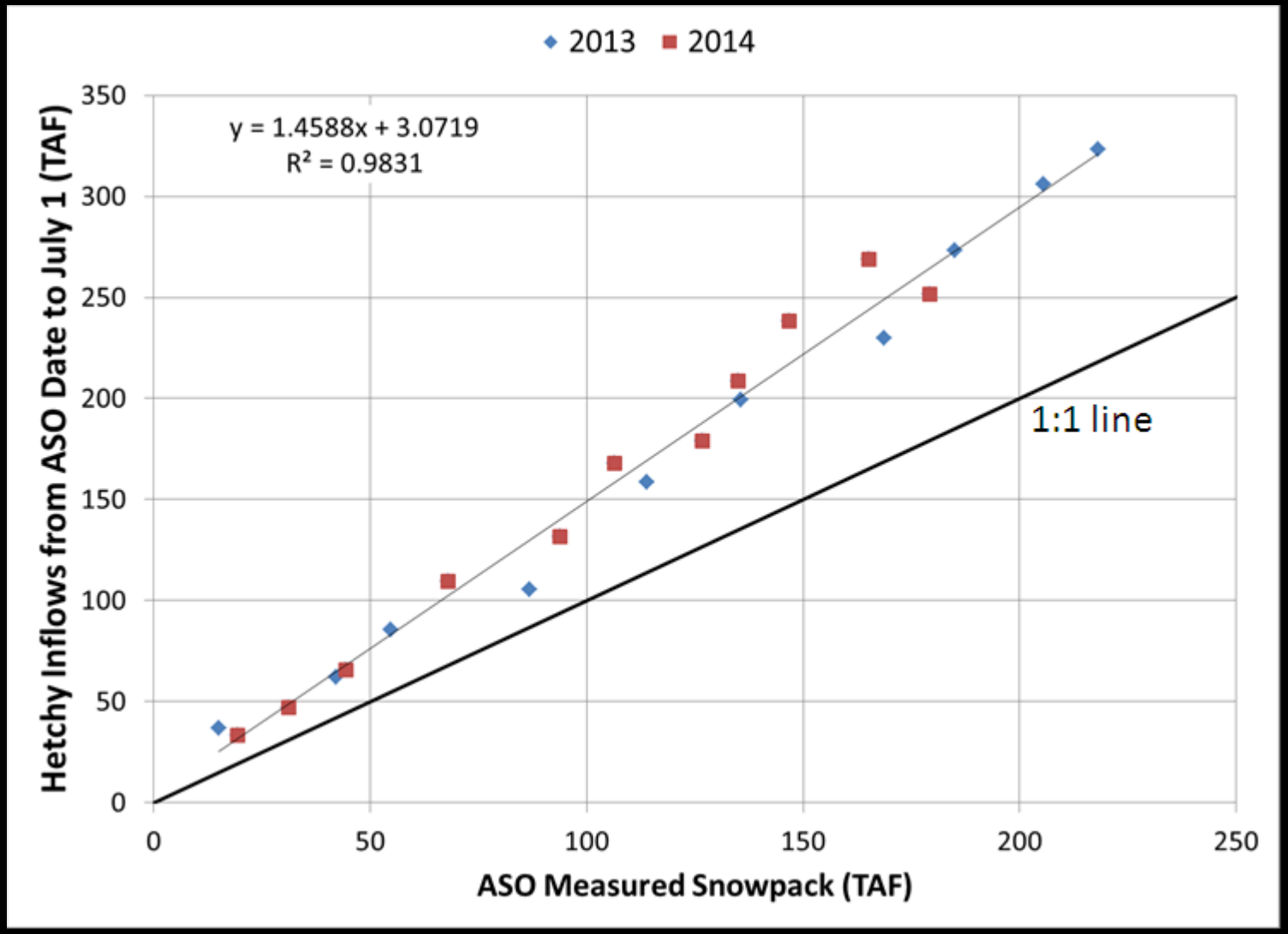


Tuolumne River Basin above Hetch Hetchy



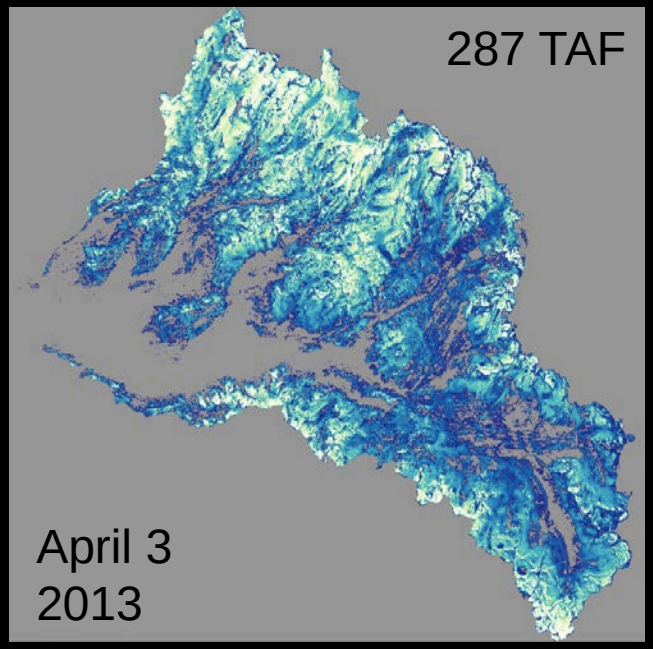
FORECASTING WITH ASO AT DIFFERENT TIME SCALES

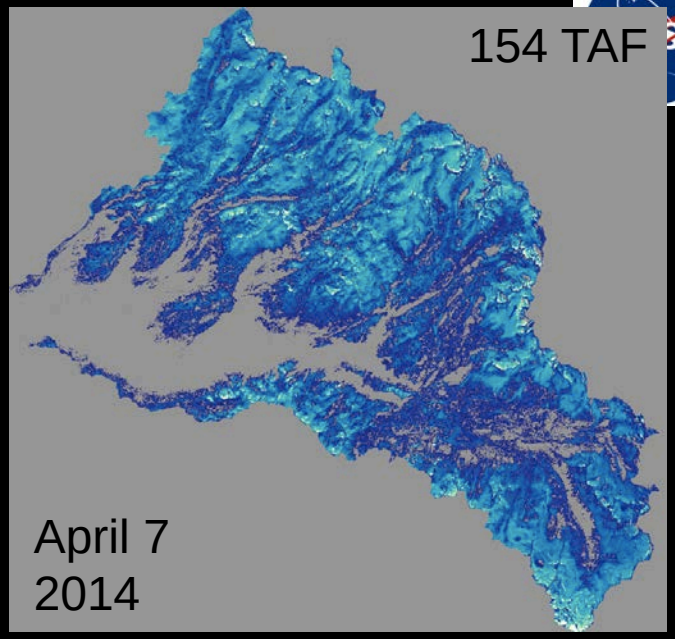
Predicting inflow from ASO

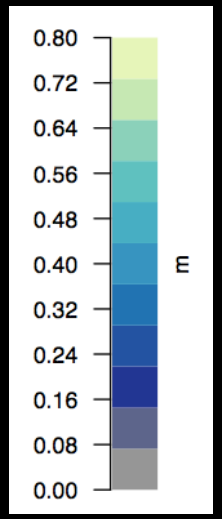


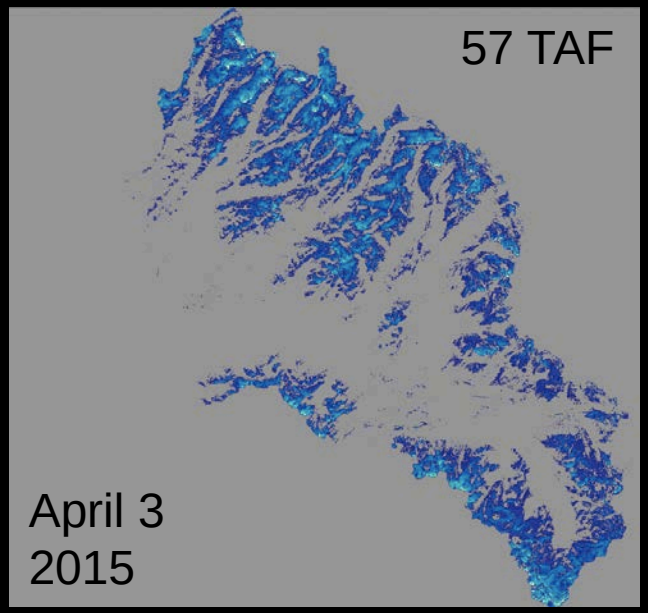
H51T-02 Chris Graham et al.

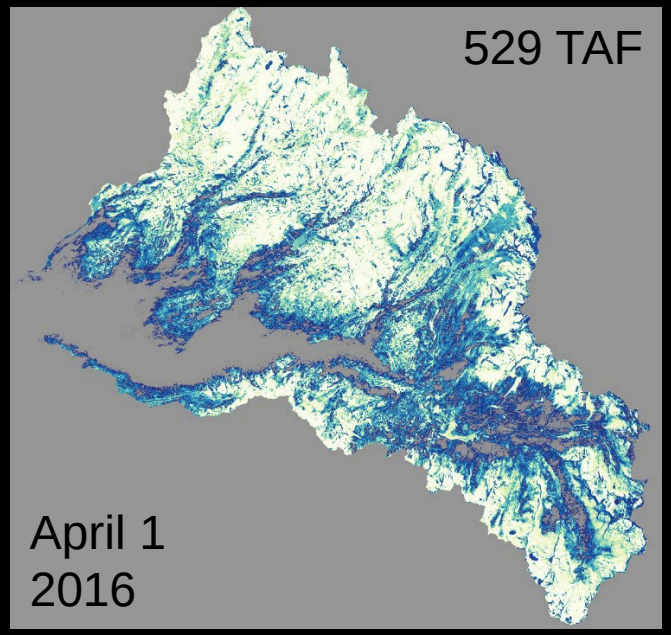
Snow Water Equivalent





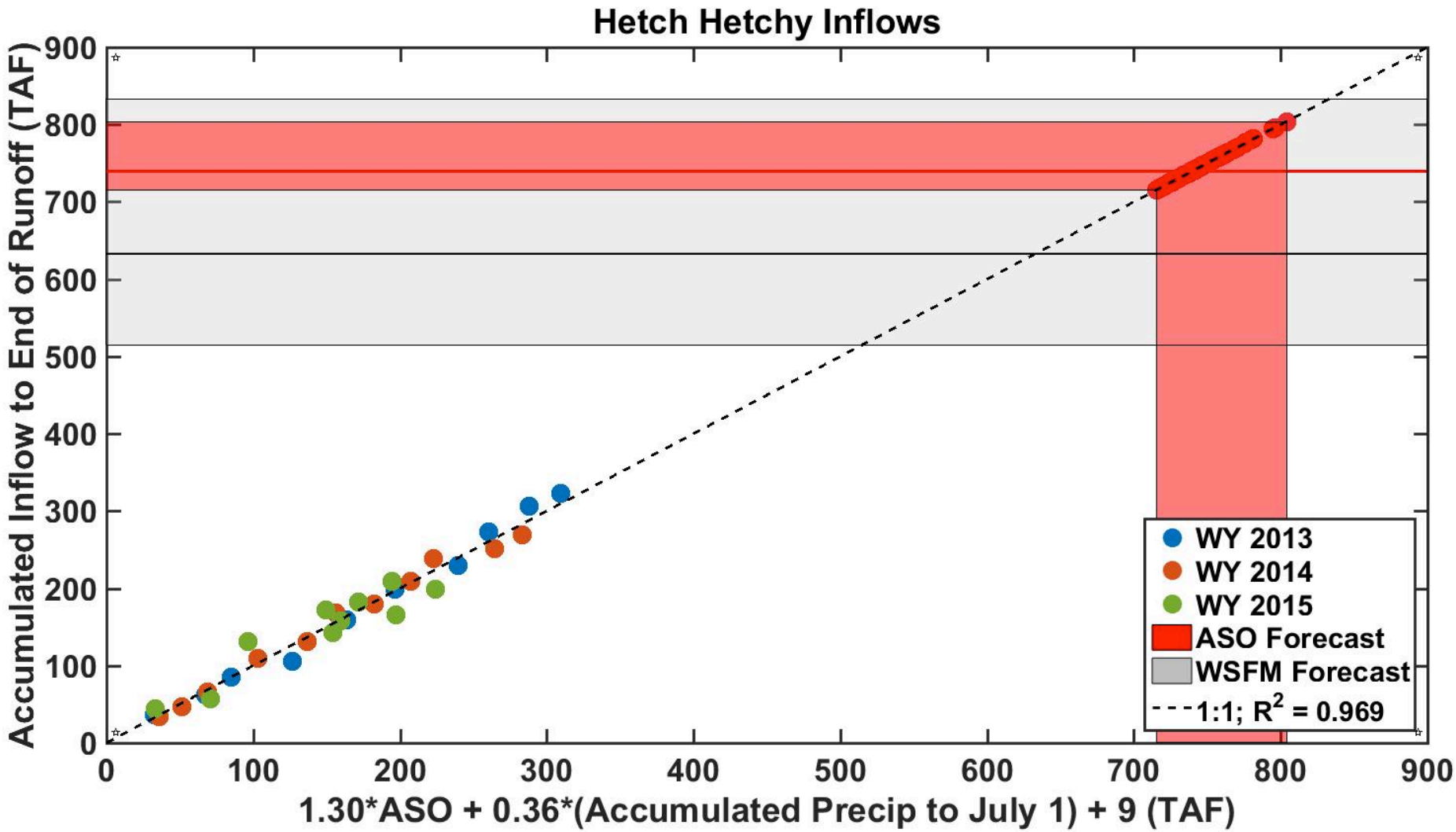






TAF = thousand acre-feet

Predicting inflow from ASO



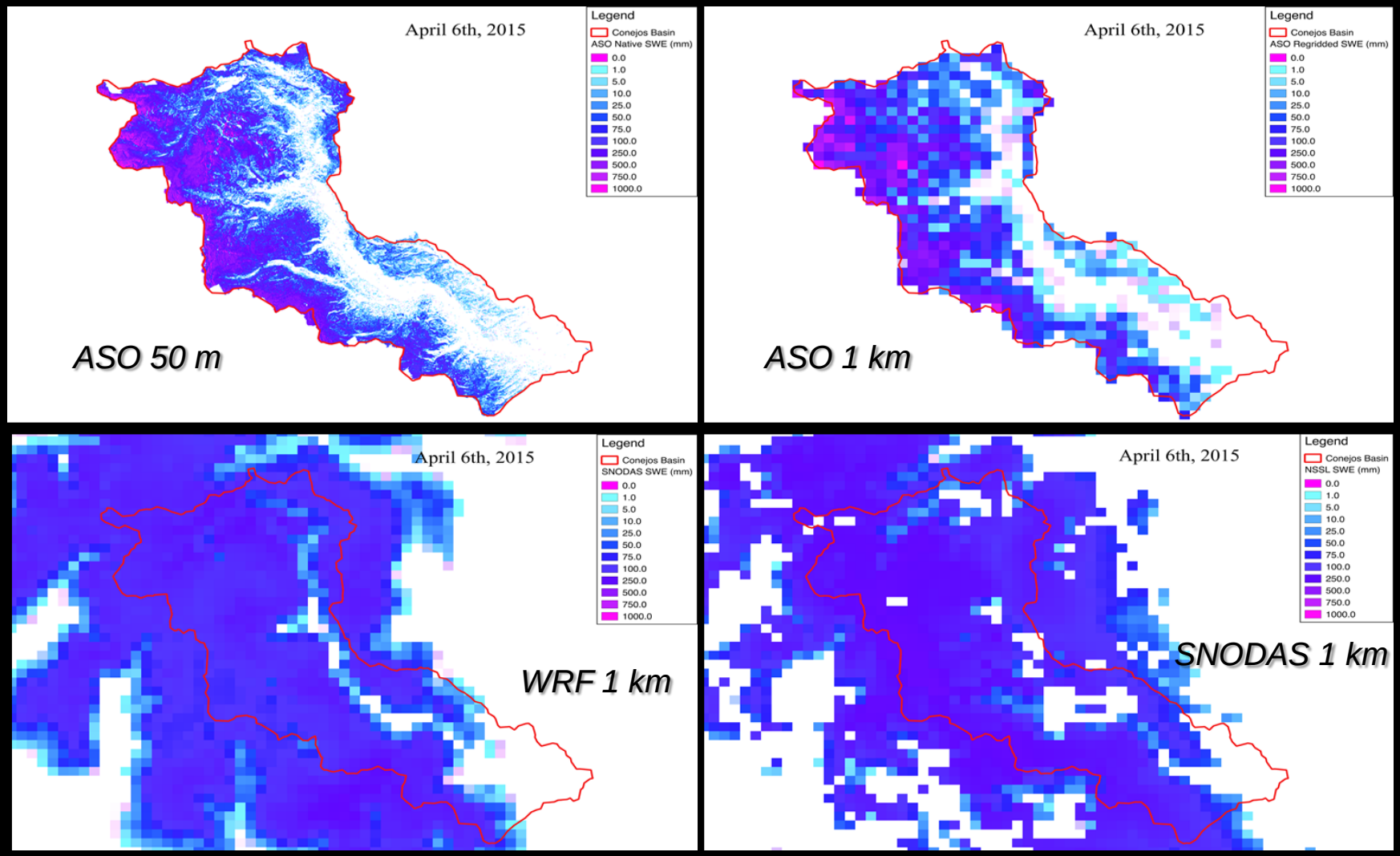
ASO INTEGRATION WITH PRMS AND ISNOBAL

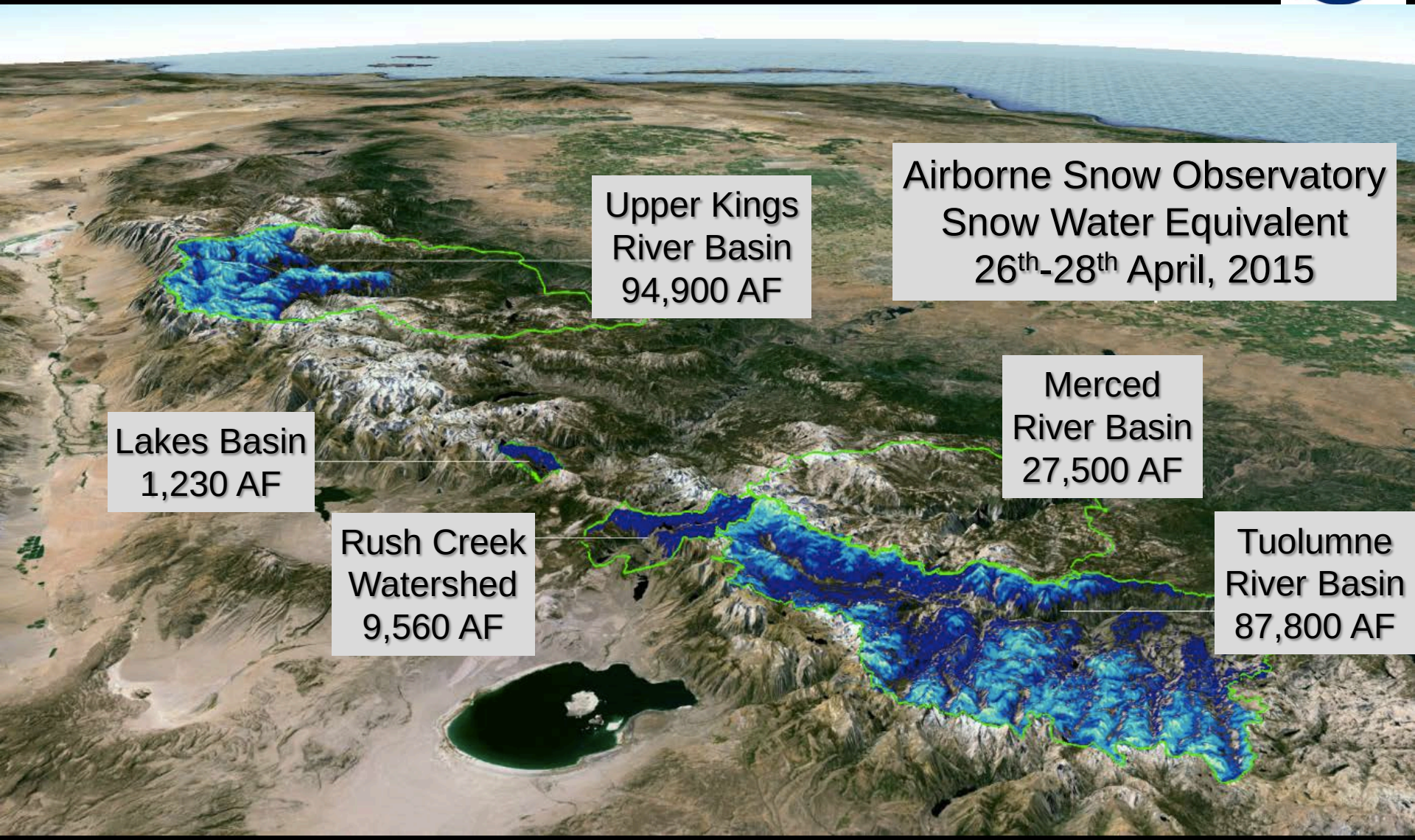
Updating distributed model state

SWE – WY 2015

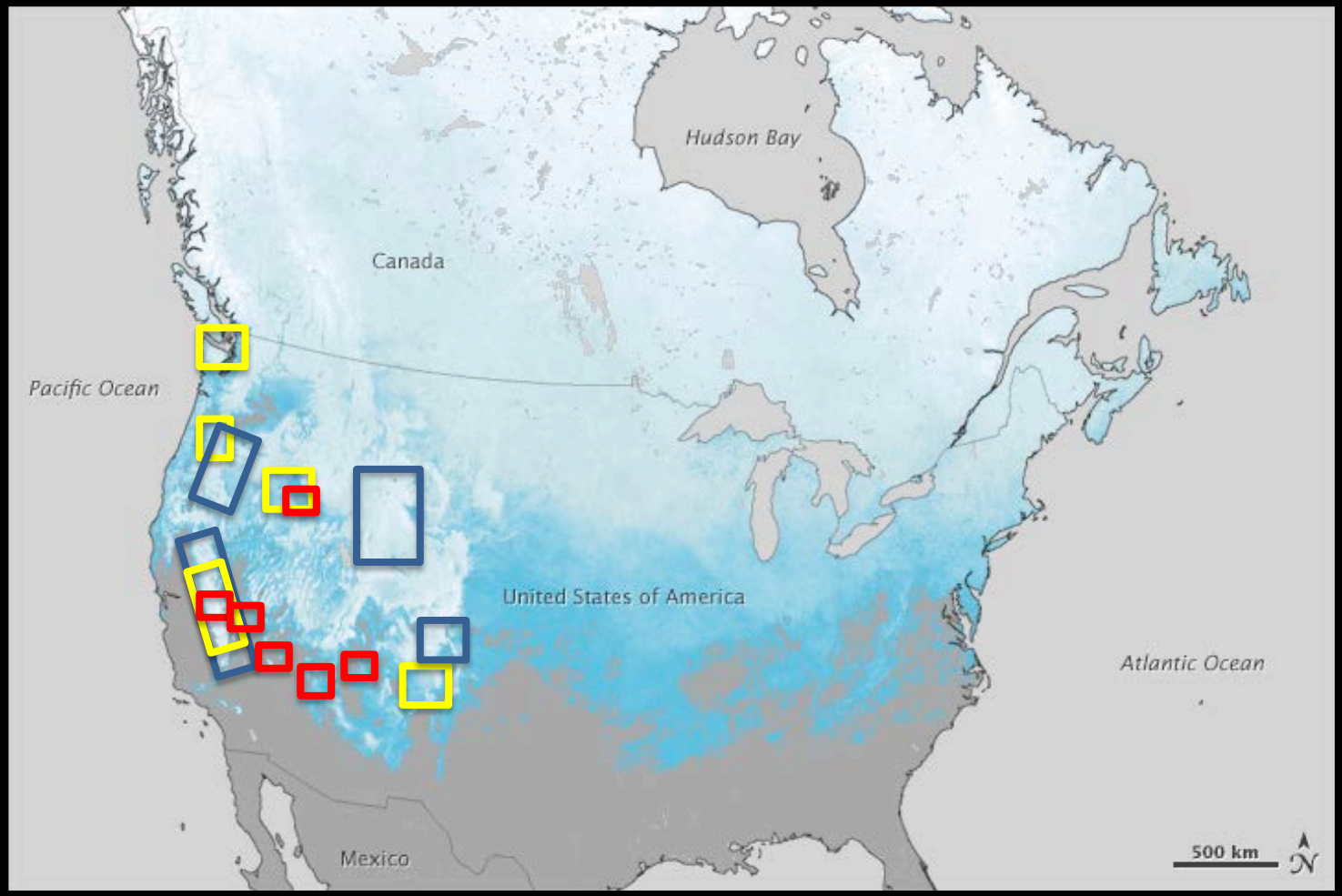
Hedrick et al. - *C44B-07*

Validating NOAA SNODAS




Airborne Snow Observatory
Snow Water Equivalent
26th-28th April, 2015
Upper Kings
River Basin
94,900 AF
Merced
River Basin
27,500 AF
Lakes Basin
1,230 AF
Rush Creek
Watershed
9,560 AF
Tuolumne
River Basin
87,800 AF

Airborne Measurements



Snow hydrology measurements

Ecosystem/desert disturbance/fire scar

ASO flight programs in development

Growing partnerships

- USDA ARS modeling
- NRCS modeling
- San Francisco Public Utilities Commission
- Turlock Irrigation District
- Modesto Irrigation District
- Colorado Water Conservation Board
- National Center for Atmospheric Research
- Southern California Edison
- Pacific Gas and Electric
- Mono Lake Committee
- US Forest Service
- Lawrence Berkeley National Laboratory
- Deschutes River Conservancy

ASO Workshop

1st Annual NASA Airborne Snow Observatory Workshop

June 28, 2016 - June 30, 2016 | California Institute of Technology Pasadena, CA

RSVP

Please submit the form below if you plan to attend.

First name *

Last name *

Email *

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http://climatesciences.jpl.nasa.gov/events/1090

URL – aso.jpl.nasa.gov