Research and Monitoring

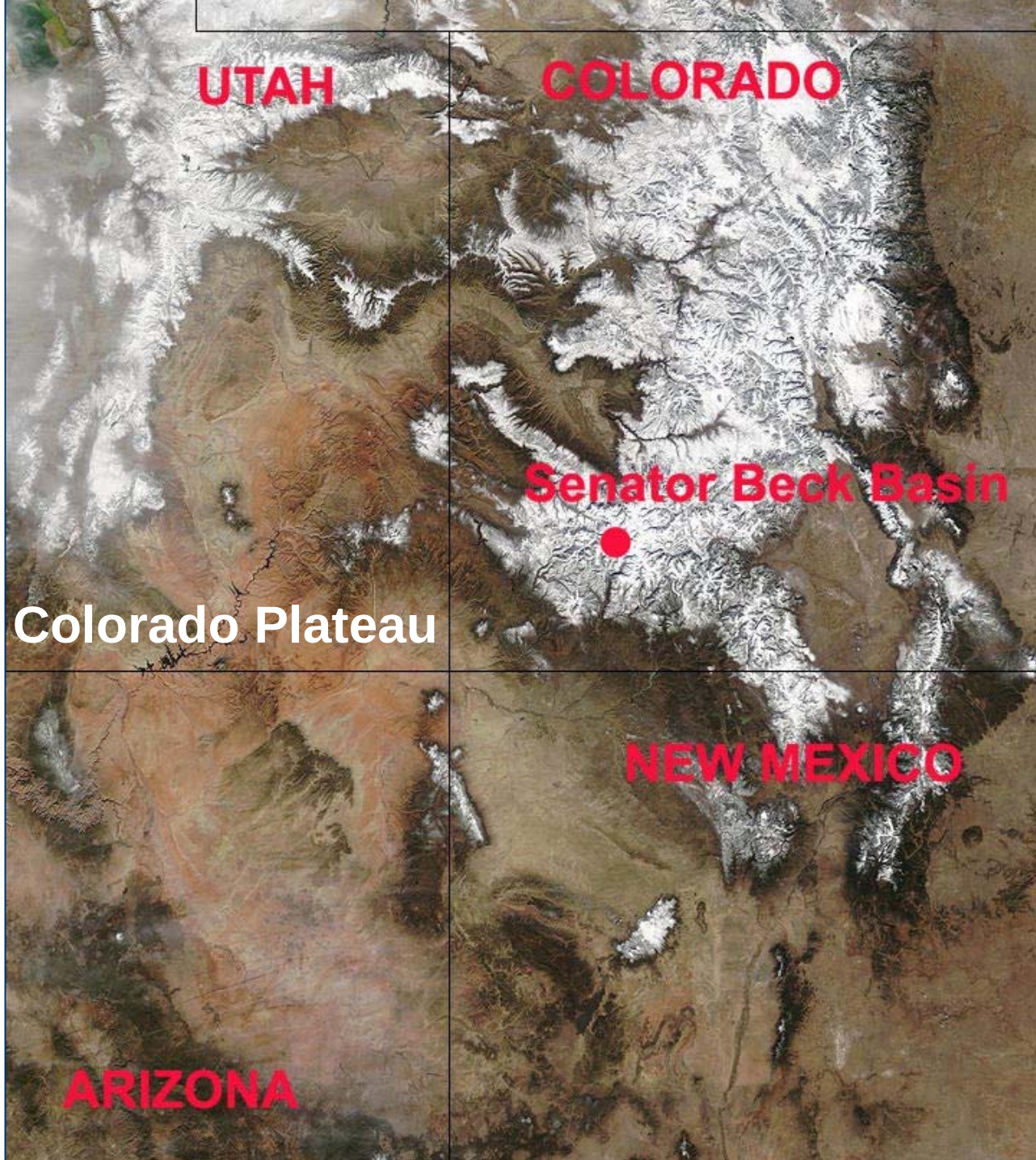
Mountain System Processes and Change

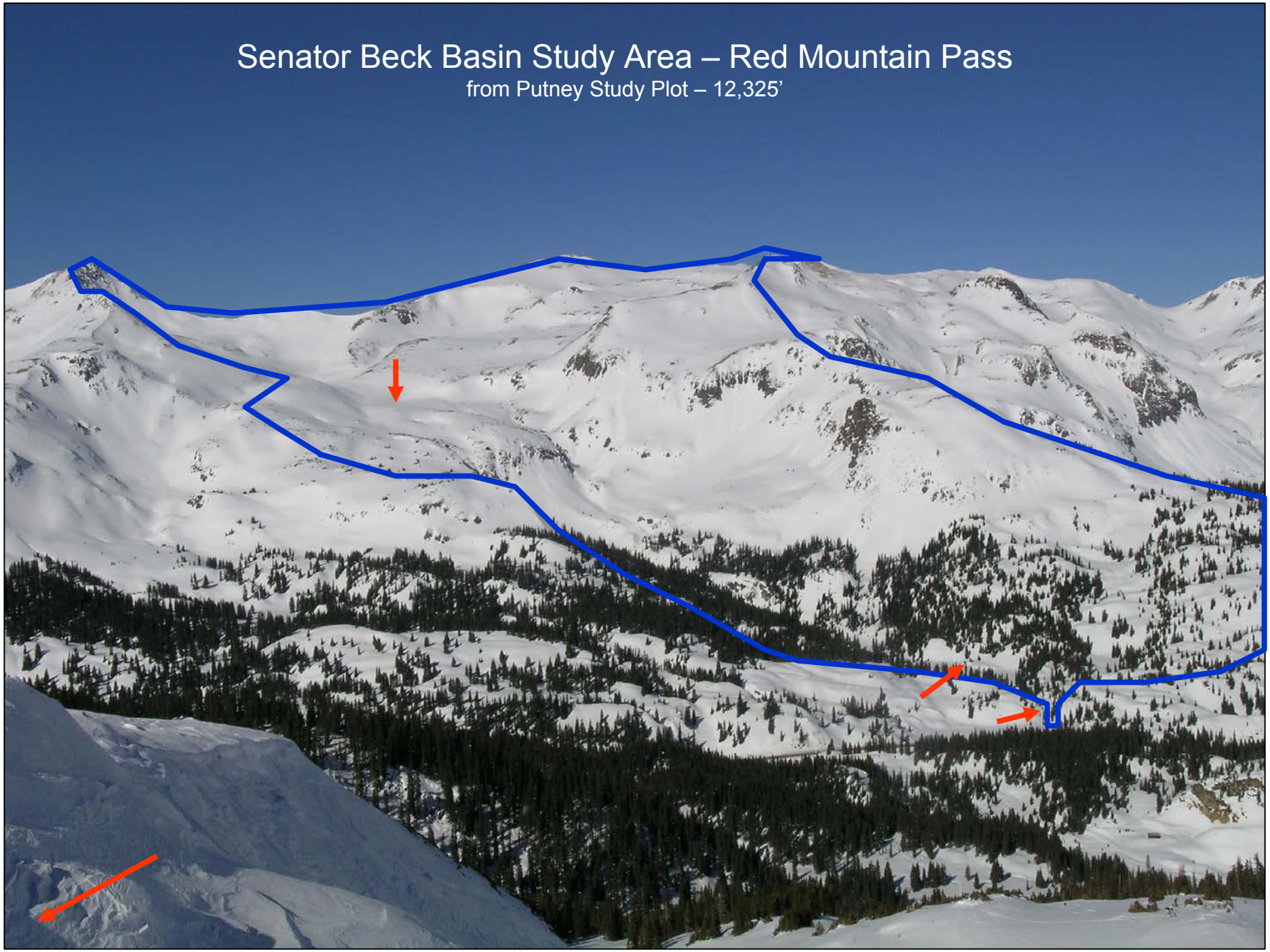
Senator Beck Basin Study Area

Chris Landry

Center for Snow and Avalanche Studies
Silverton, CO

CSAS




Senator Beck Basin Study Area – Red Mountain Pass
from Putney Study Plot – 12,325’

CENTER FOR SNOW & AVALANCHE STUDIES

Swamp Angel Study Plot (subalpine)

Senator Beck Study Plot (alpine)

CAMPAIGN TO SUSTAIN SENATOR BECK BASIN

CSAS and its Senator Beck Basin long-term monitoring study site are in a fight to survive. In order to continue operations past this season, and into our Fiscal Year 2012/2013, we need to raise $135,000 by June 30, 2012.We have already received pledges, but need more stakeholder agencies to step forward!

Why should CSAS get funded?

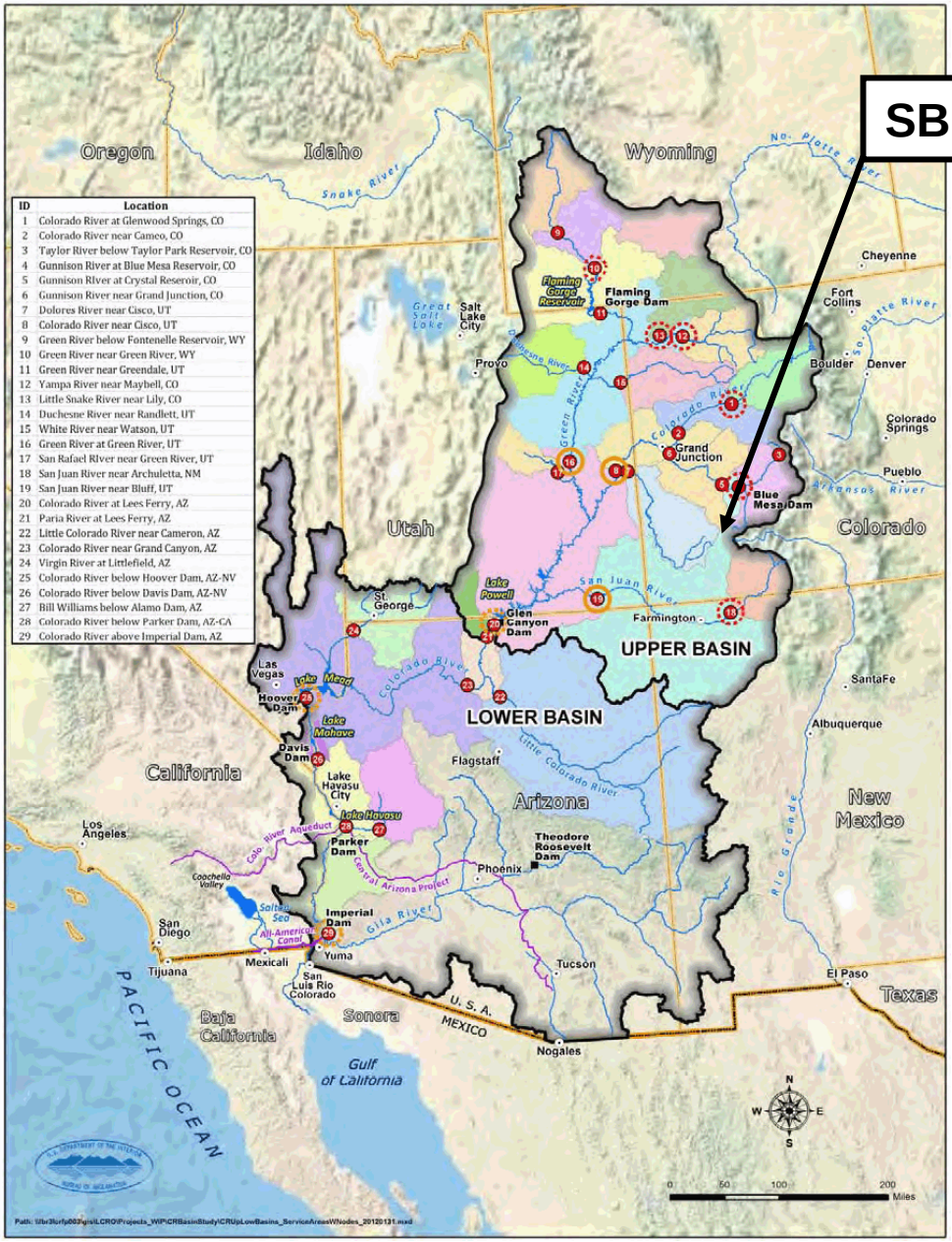
Federal and state natural resource and land managers have a very real stake in the data that CSAS is producing. Sustained Senator Beck Basin data and mountain system monitoring will help managers fulfill their agency's climate change adaptation mandates and provide insights into changes in ecosystem services. Collective stakeholder funding of CSAS's operation of Senator Beck Basin offers agencies a cost-effective opportunity to obtain unique data and research results, with broad applications.

Why isn't CSAS funded by more foundations or by NSF?

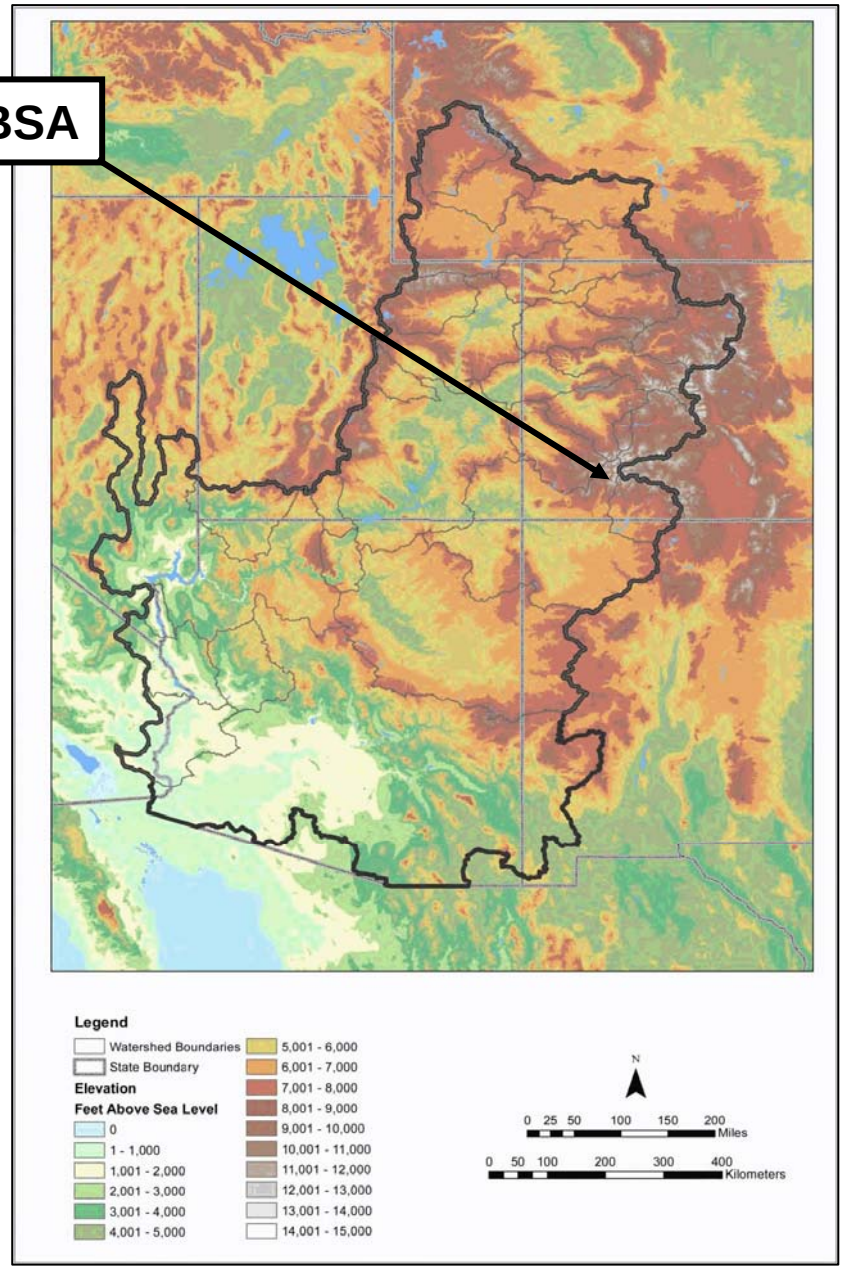
Although CSAS is a 501(c)(3), not-for-profit research organization, we are unable to compete for most private foundations' funding because we are neither an activist or an advocacy organization, proposing "solutions" to climate change, and because our fundamental need is for general (Senator Beck Basin) operations funding for long-term monitoring. Similarly, the National Science Foundation seeks to fund 3-4 year, "new" science research projects (such as our original dust-on-snow research effort). Unfortunately, the CSAS's long-term mountain system monitoring program does not match up with NSF's calls for

Senator Beck Basin Study Area – Sentry Site for Upper CRB

CRB Water Supply & Demand Study: Tech Report B – pg's B7 & B13

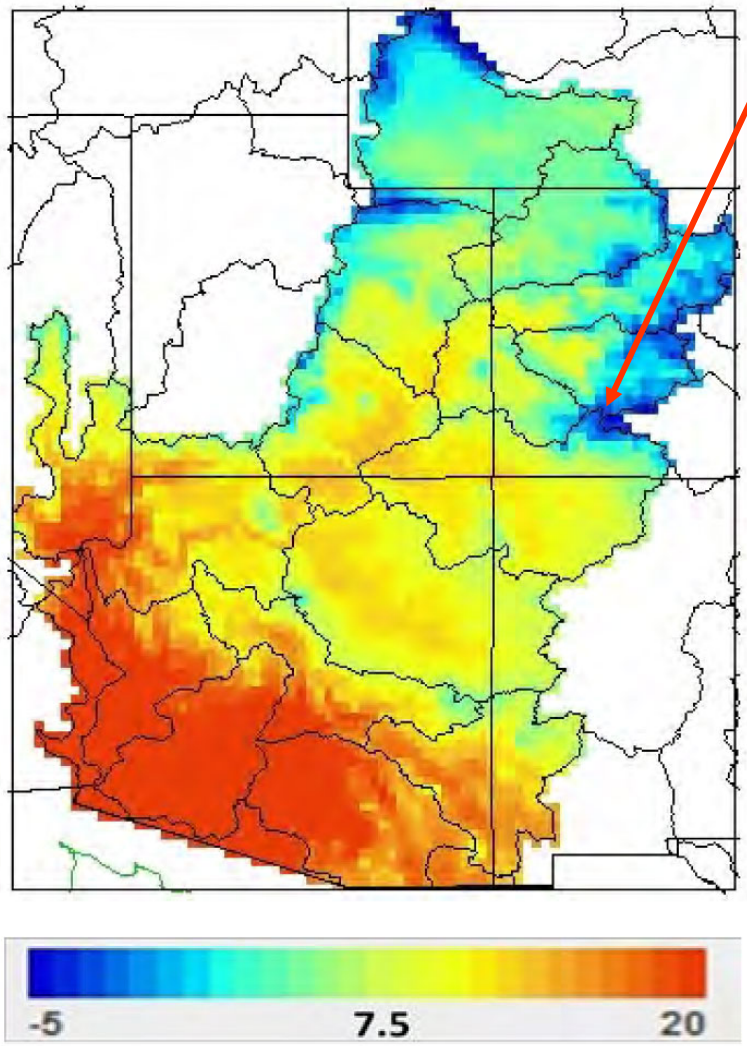


SBBSA

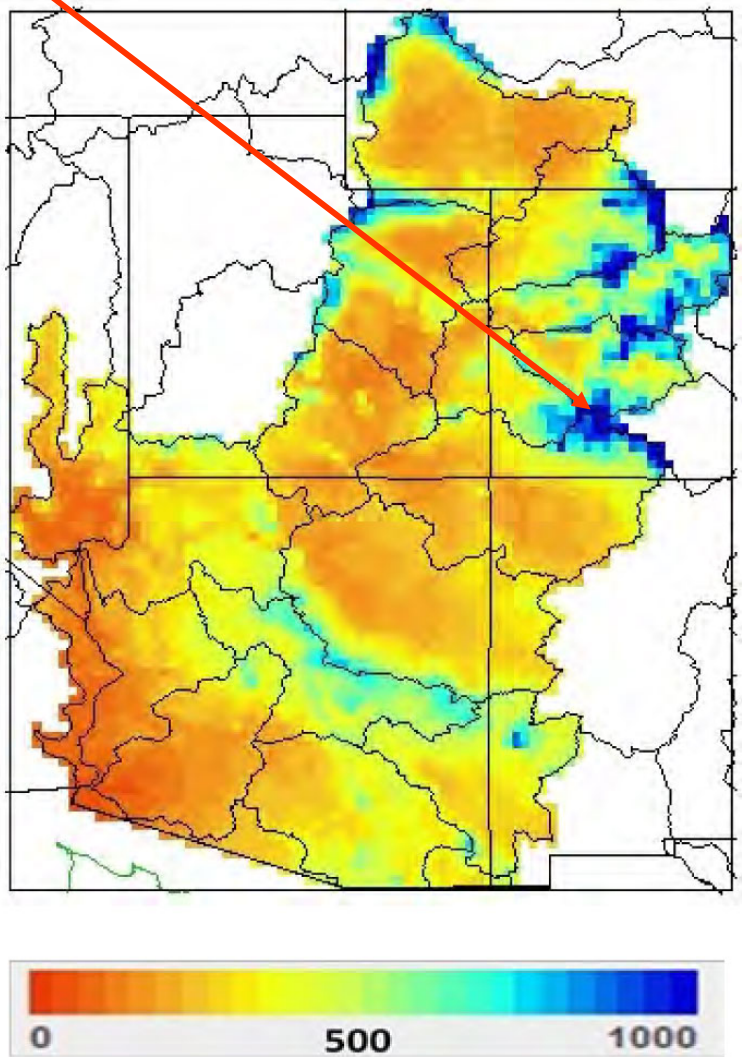


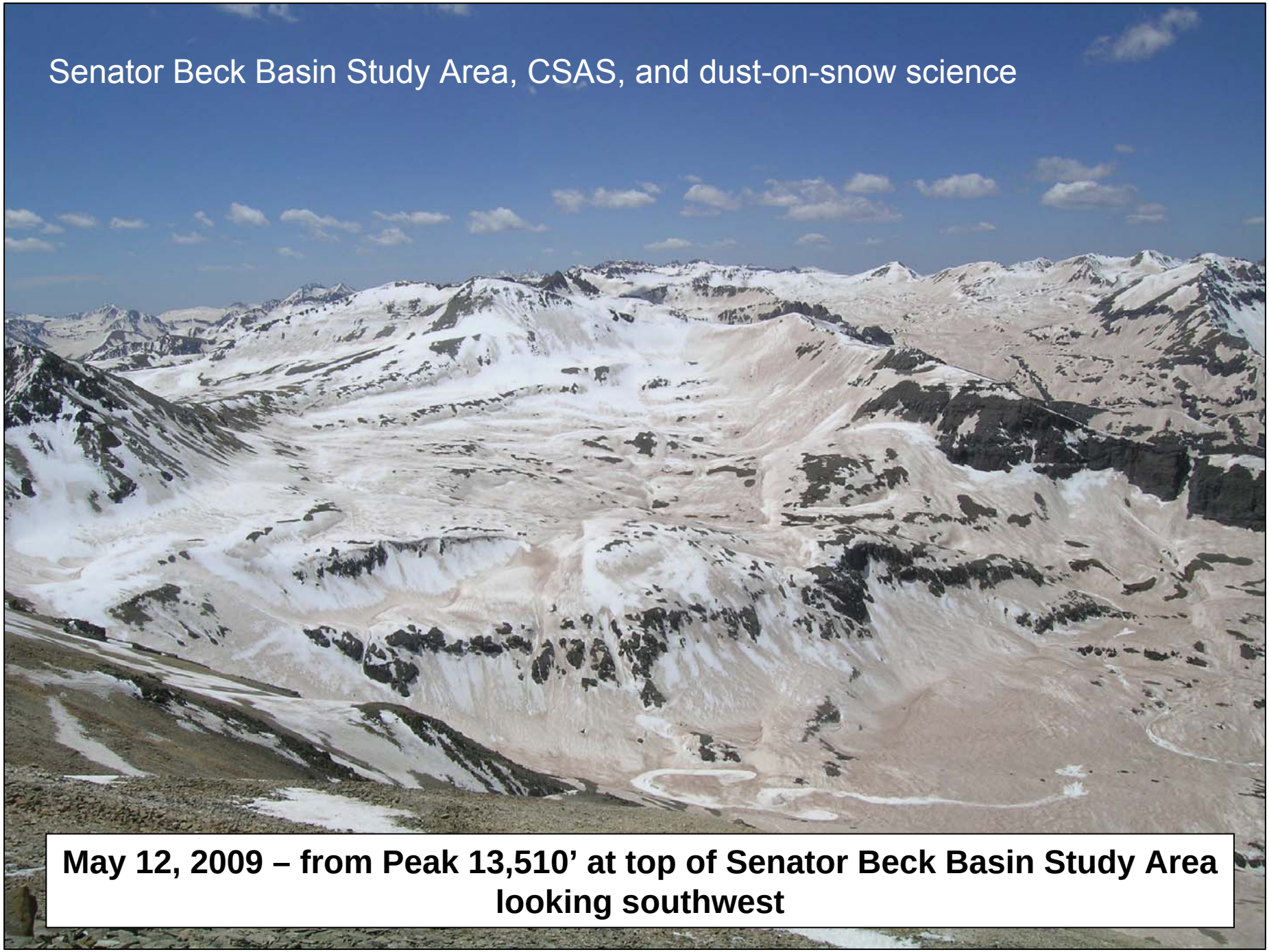
Senator Beck Basin Study Area

Temperature



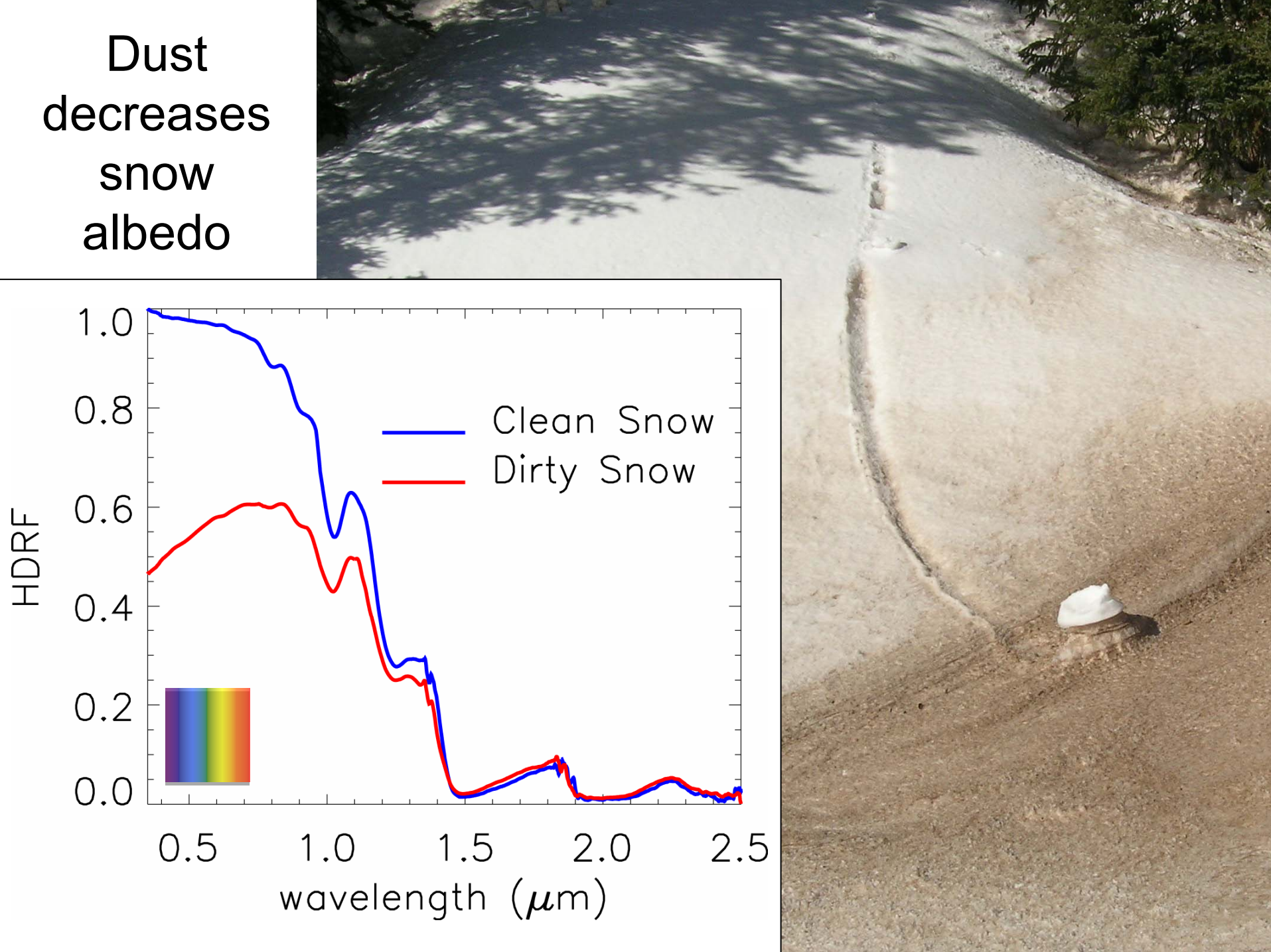
Precipitation



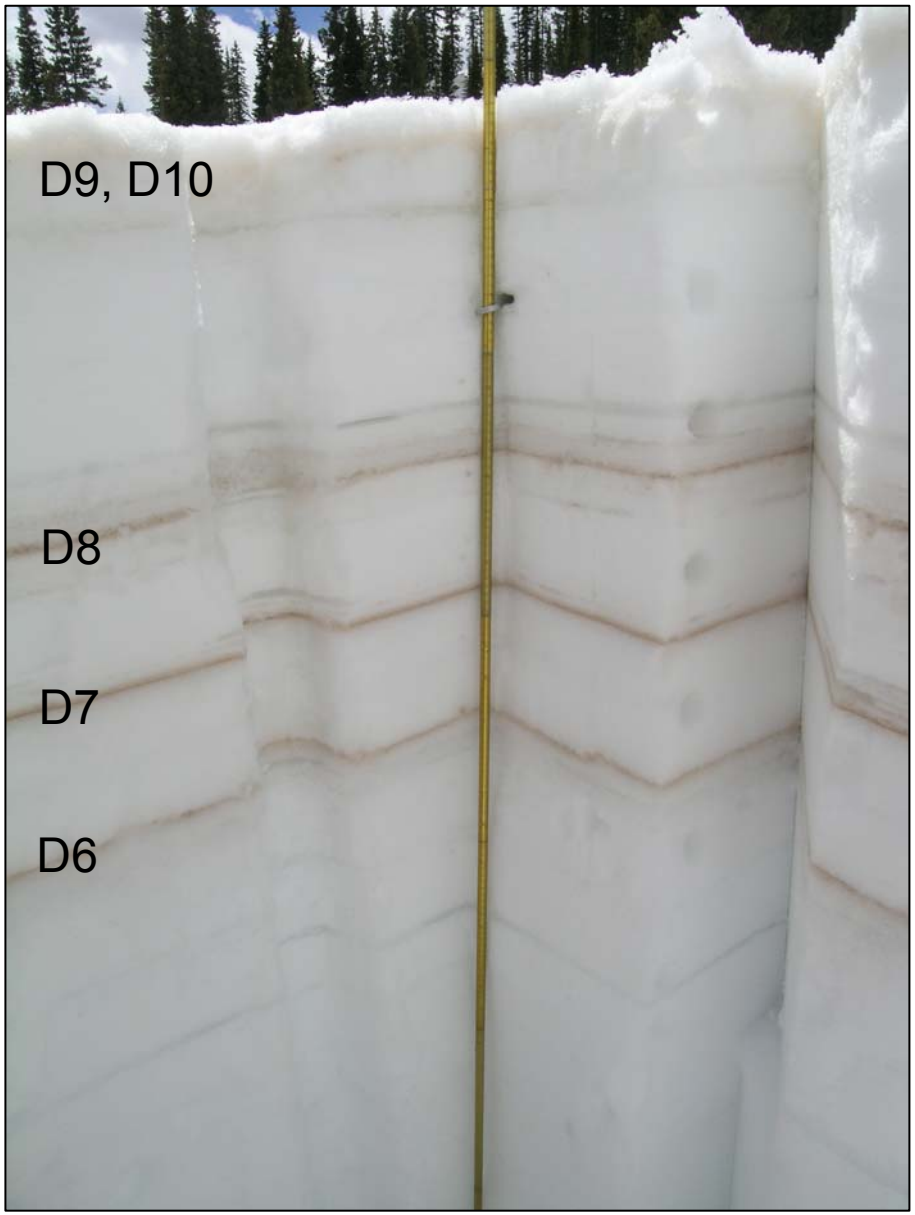


May 12, 2009 – from Peak 13,510' at top of Senator Beck Basin Study Area looking southwest

Dust decreases snow albedo



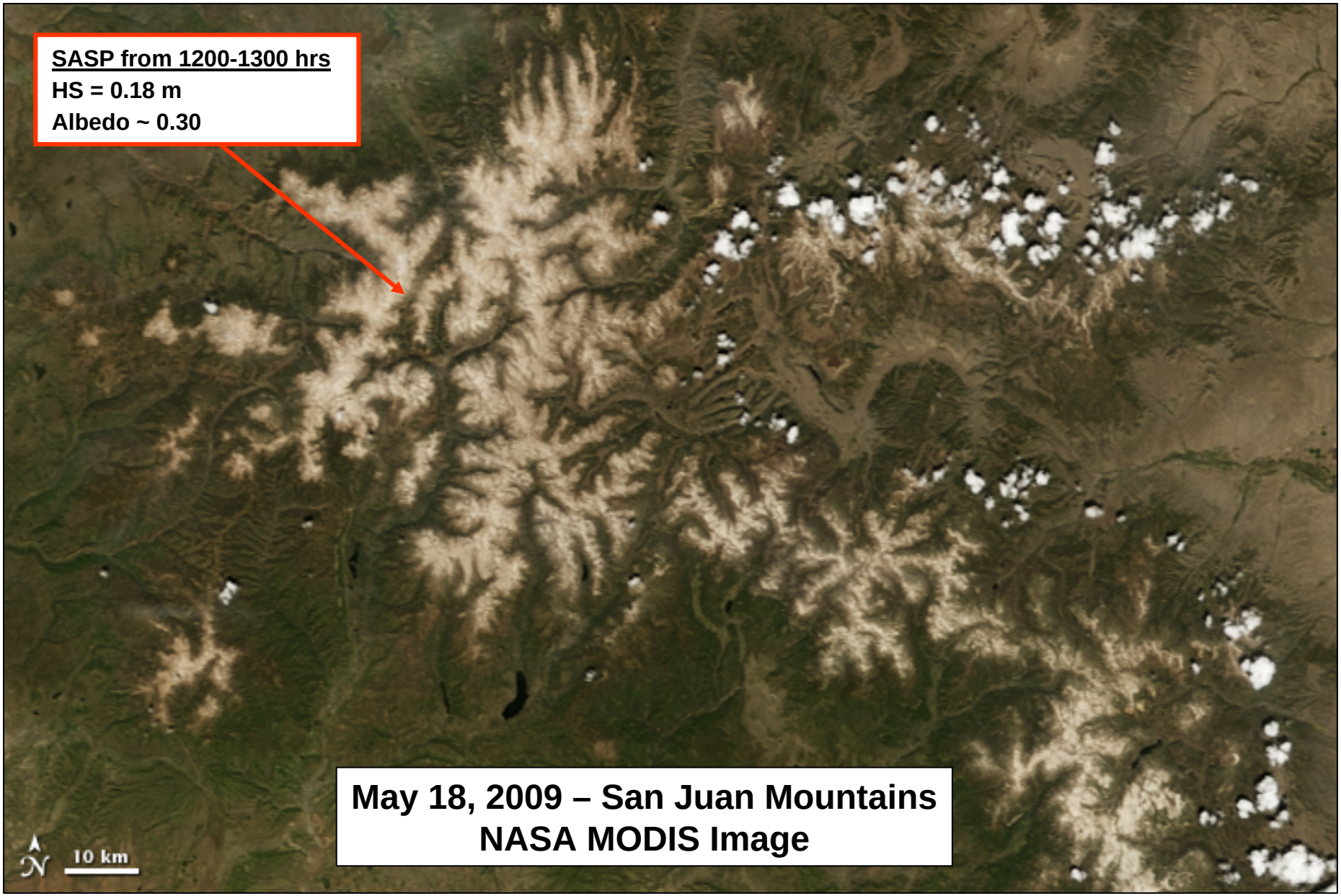
Senator Beck Basin: March and April 2009 Dust Layers



SASP – April 22, 2009

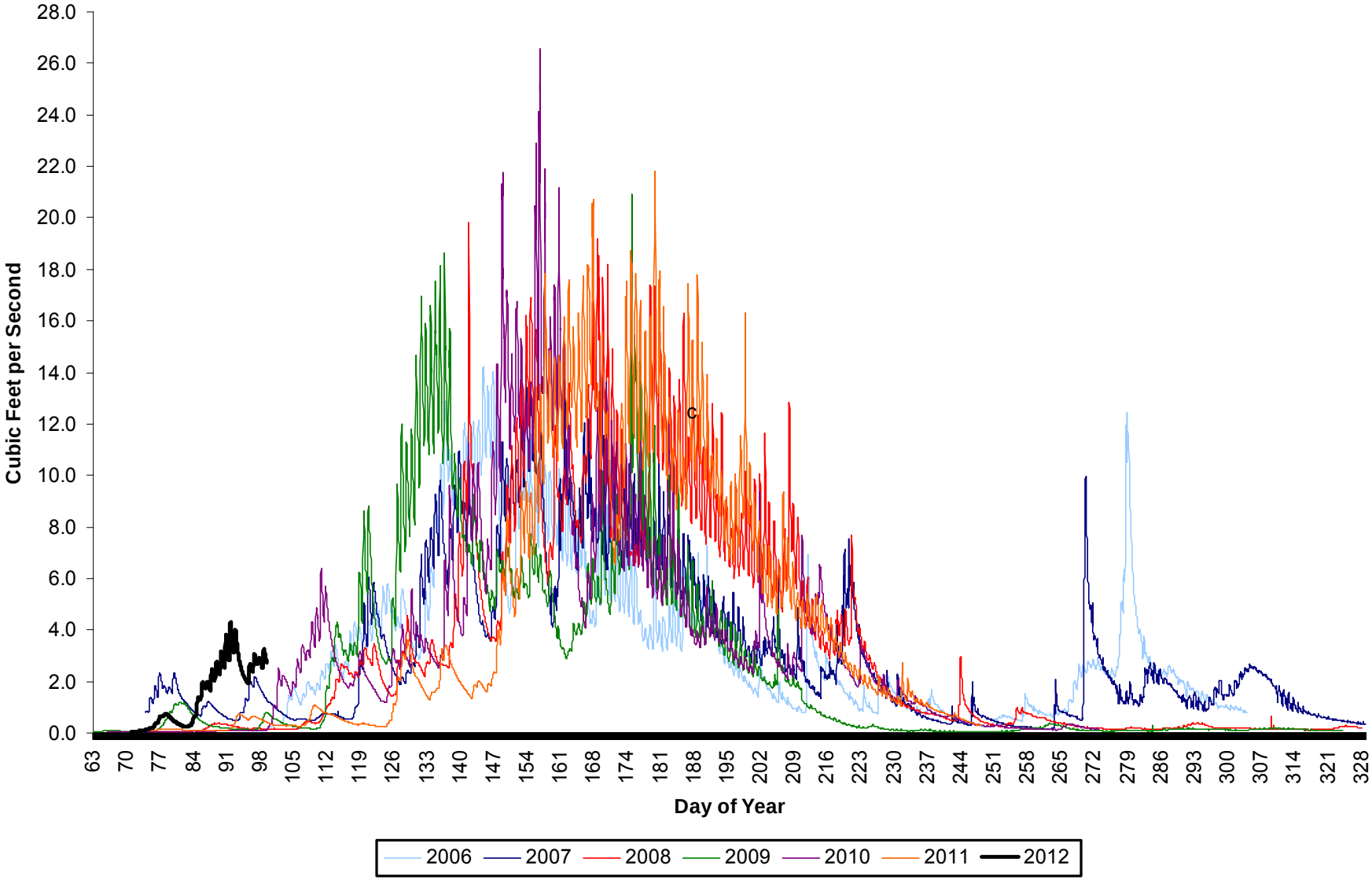
SBSP – April 24, 2009

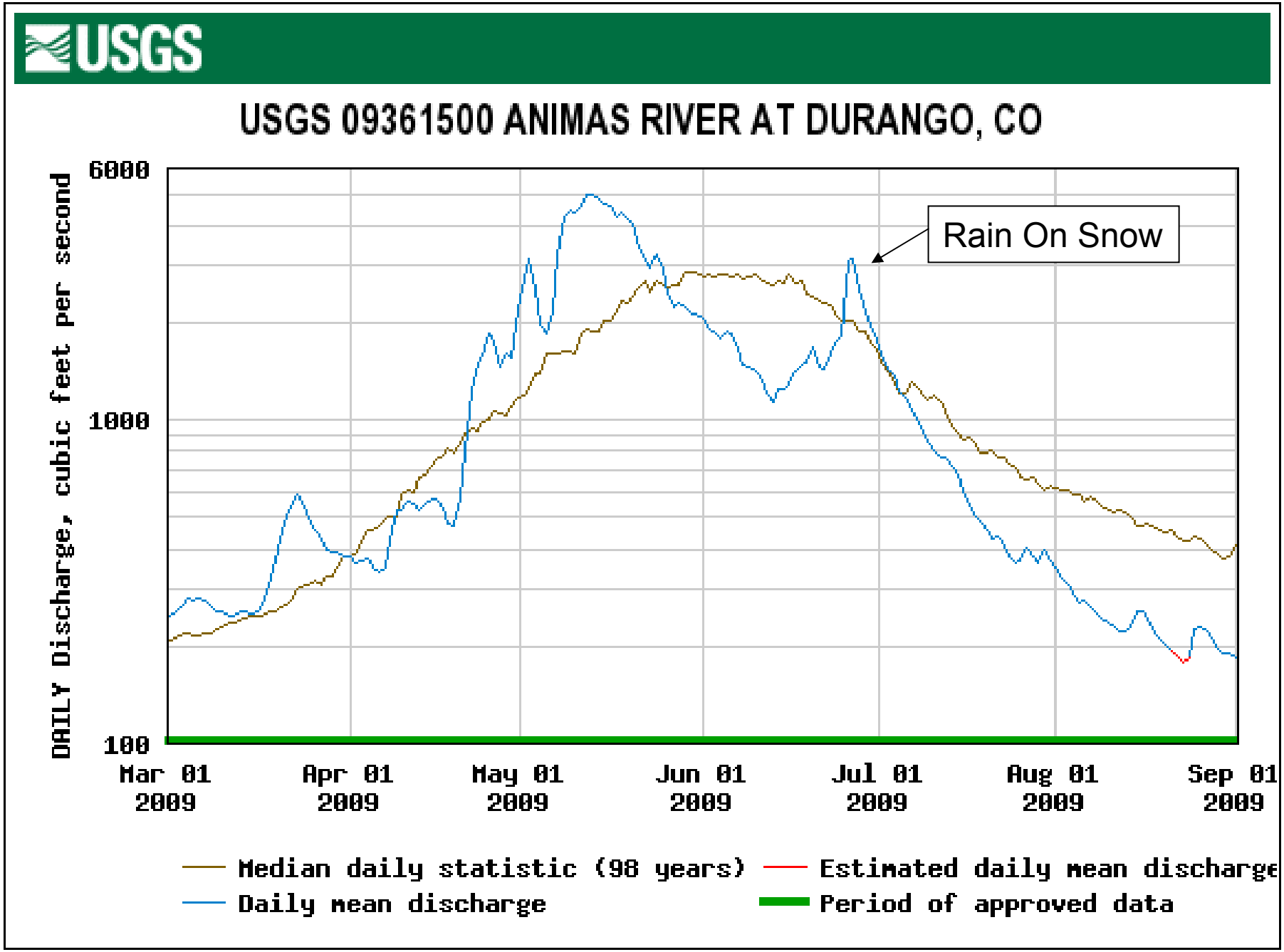
Large-Scale Albedo Reductions

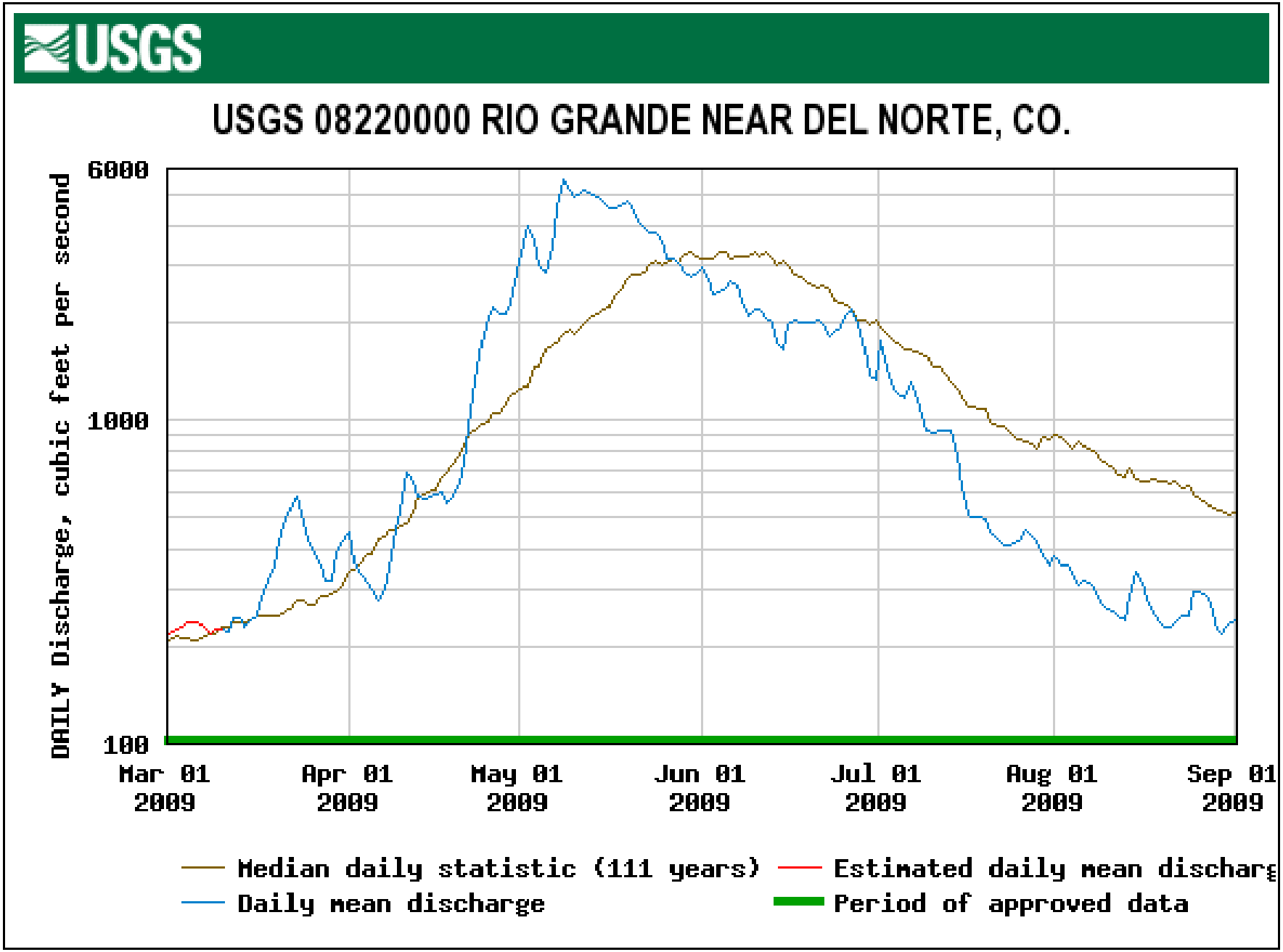


Senator Beck Basin Hourly Discharge

WY 2006, 2007, 2008 & 2009, 2010, 2011, 2012

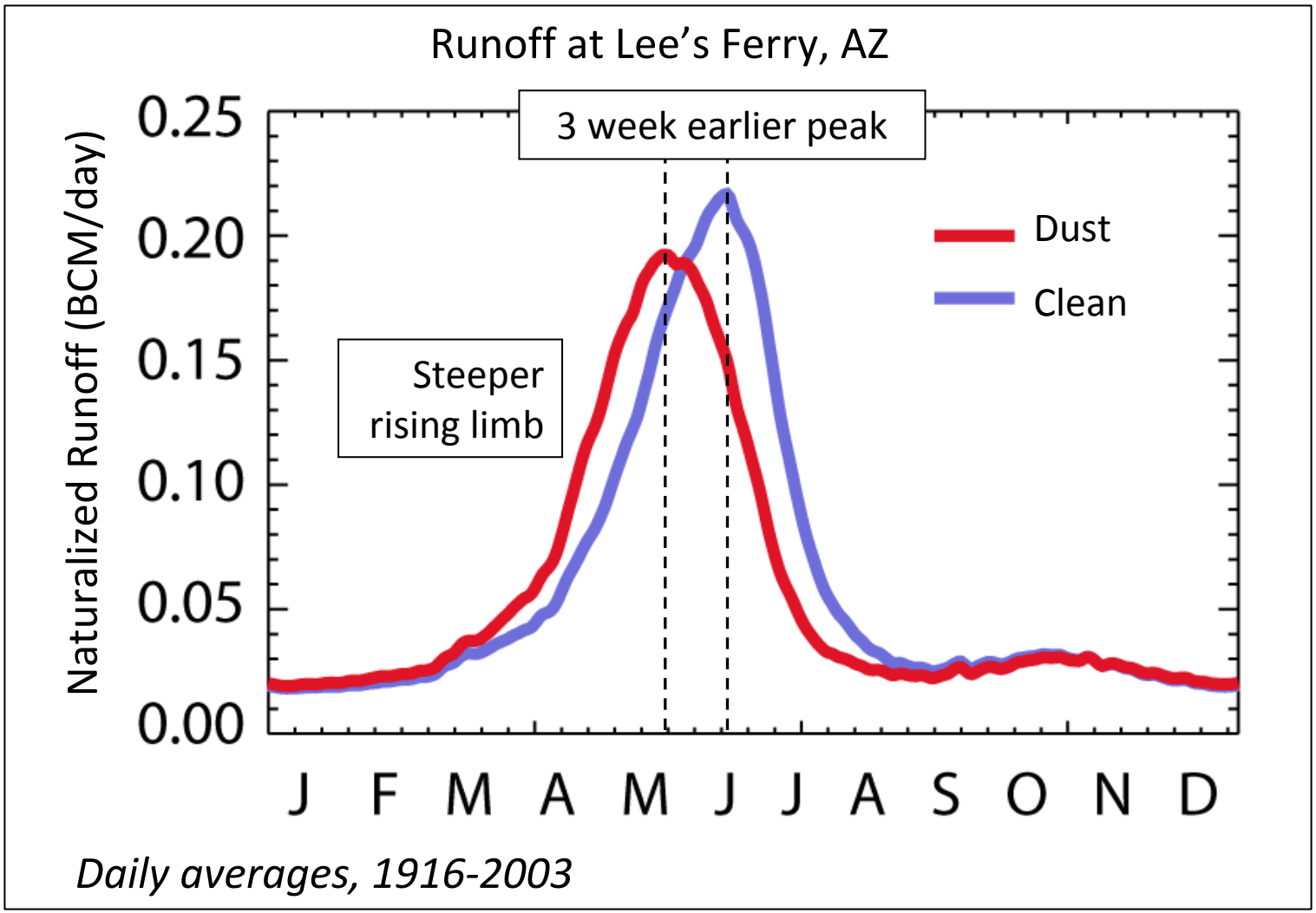



USGS
USGS 09361500 ANIMAS RIVER AT DURANGO, CO
DAILY Discharge, cubic feet per second
6000
1000
100
Rain On Snow
Mar 01 2009
Apr 01 2009
May 01 2009
Jun 01 2009
Jul 01 2009
Aug 01 2009
Sep 01 2009
Median daily statistic (98 years)
Daily mean discharge
Estimated daily mean discharge
Period of approved data


USGS
USGS 08220000 RIO GRANDE NEAR DEL NORTE, CO.
DAILY Discharge, cubic feet per second
6000
1000
100
Mar 01 2009
Apr 01 2009
May 01 2009
Jun 01 2009
Jul 01 2009
Aug 01 2009
Sep 01
Median daily statistic (111 years)
Estimated daily mean discharg
Daily mean discharge
Period of approved data

Dust-on-Snow Shifts Upper CRB Hydrograph*

*not including 2009, 2010 dust deposition rates

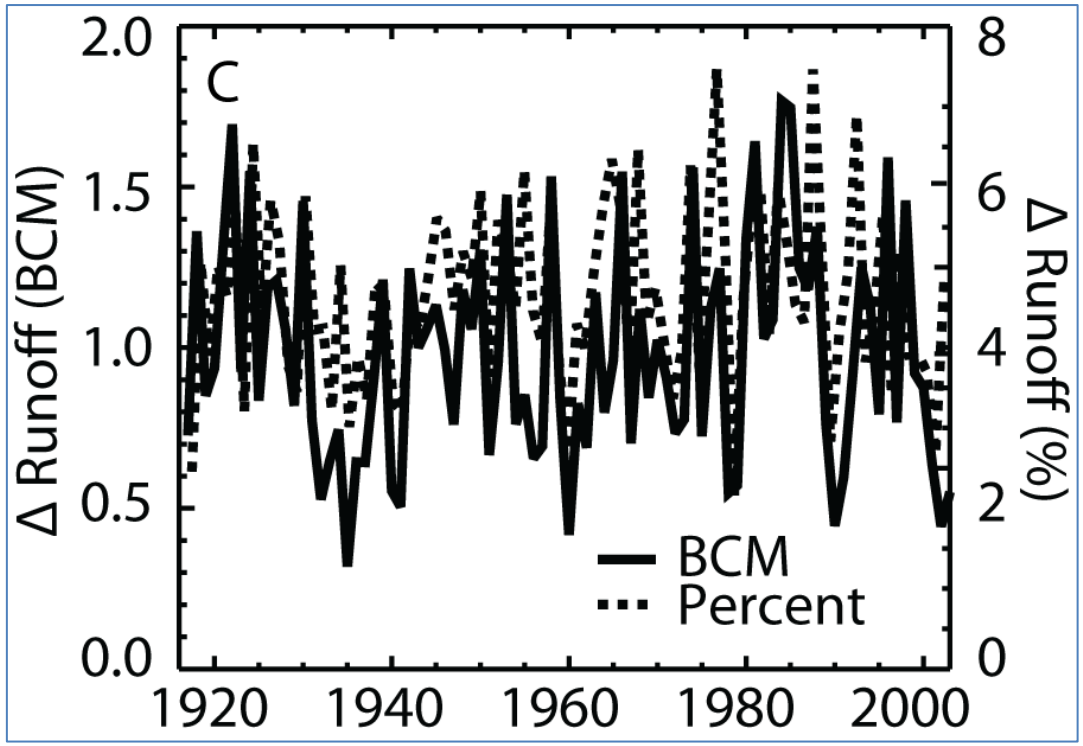


Painter, Deems, *et al.*, *PNAS* (*2010*)

At the scale of the Upper CRB, modeling shows:

DOS = Earlier SAG = Increased ET = Reduced Runoff

- Mean Δ Runoff:
  - -4.9%
  - -811,000 acre-ft
- Range:
  - -2.3 to -7.6%
  - -243k to -1,460k acre-ft



**based on pre-2009 dust loading*

Painter, Deems, *et al.*, *PNAS* (2010)

Besides dust,

SBB is a Sentry Site

for changes in Upper CRB:

- Snowmelt Runoff
- Mountain Precip
- Mountain Temps
- Mountain Winds
- Mountain Radiation
- Mountain Vegetation
- Mountain Soils

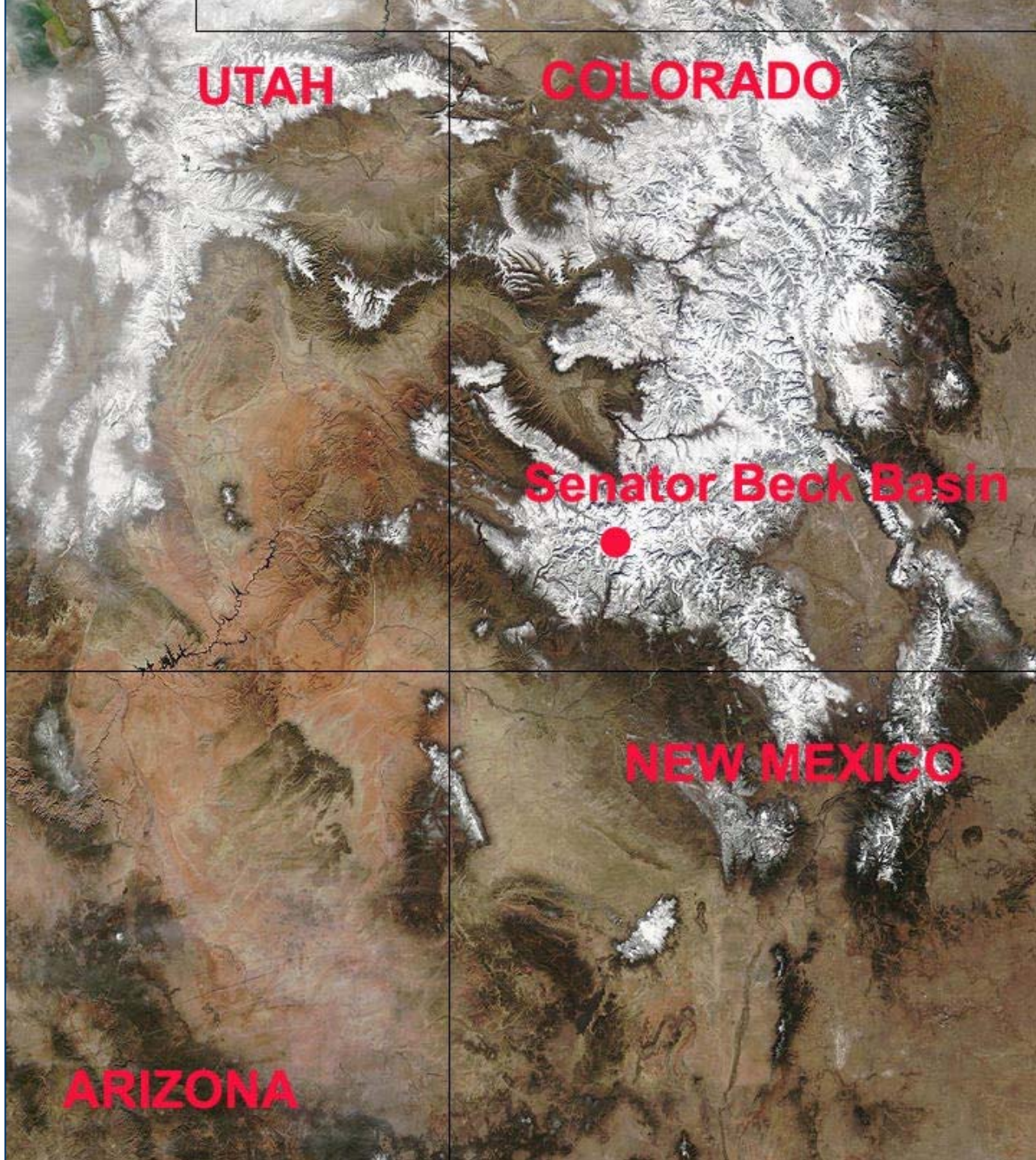


FIGURE B-40

Mean Projected Percent Change in Annual ET and Median Projected Percent Change in Runoff[8]

2025 (2011 – 2040) versus 1985 (1971-2000), 2055 (2041 – 2070) versus 1985 (1971-2000), and 2080 (2066 – 2095) versus 1985 (1971-2000).

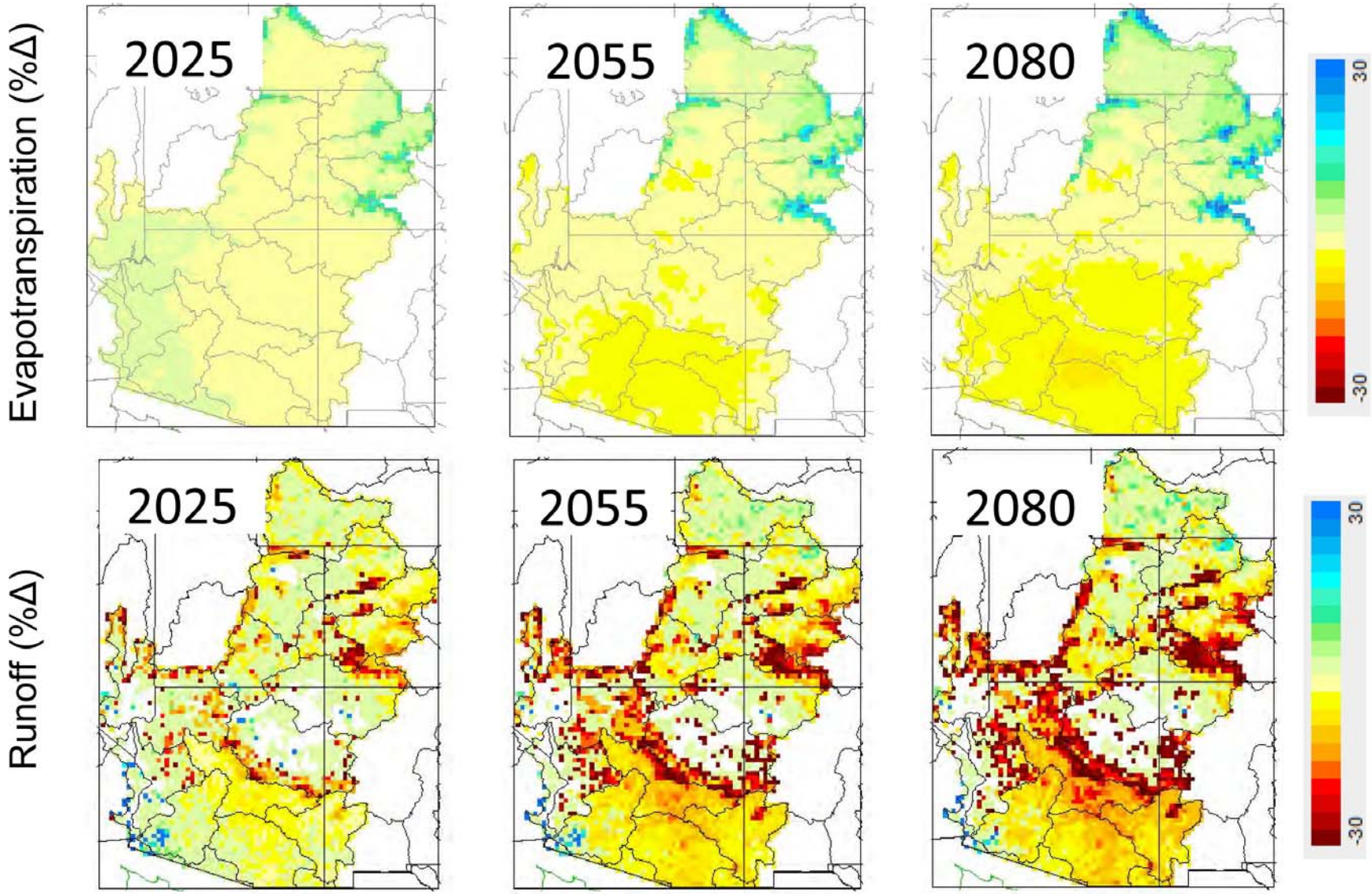
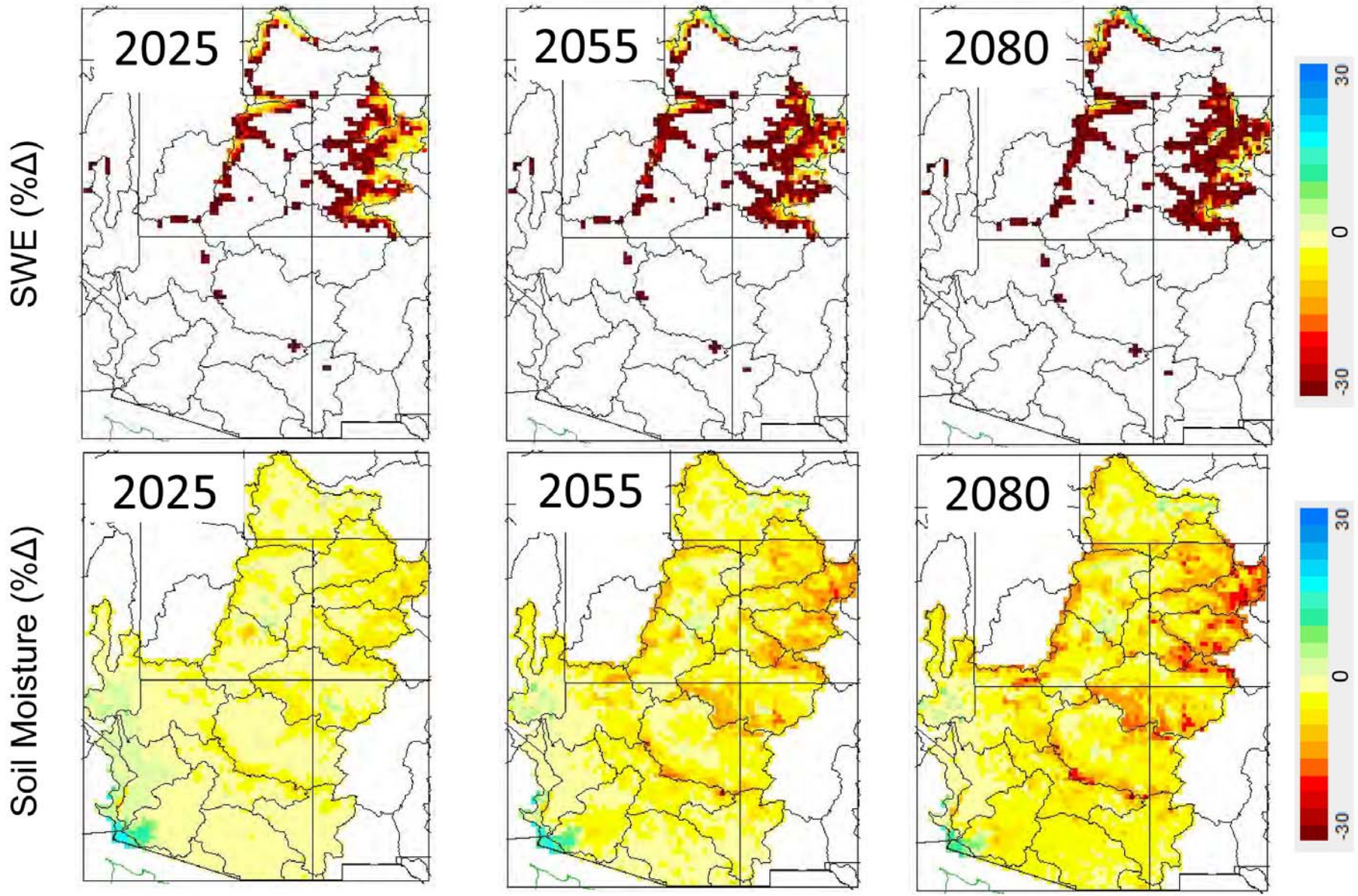
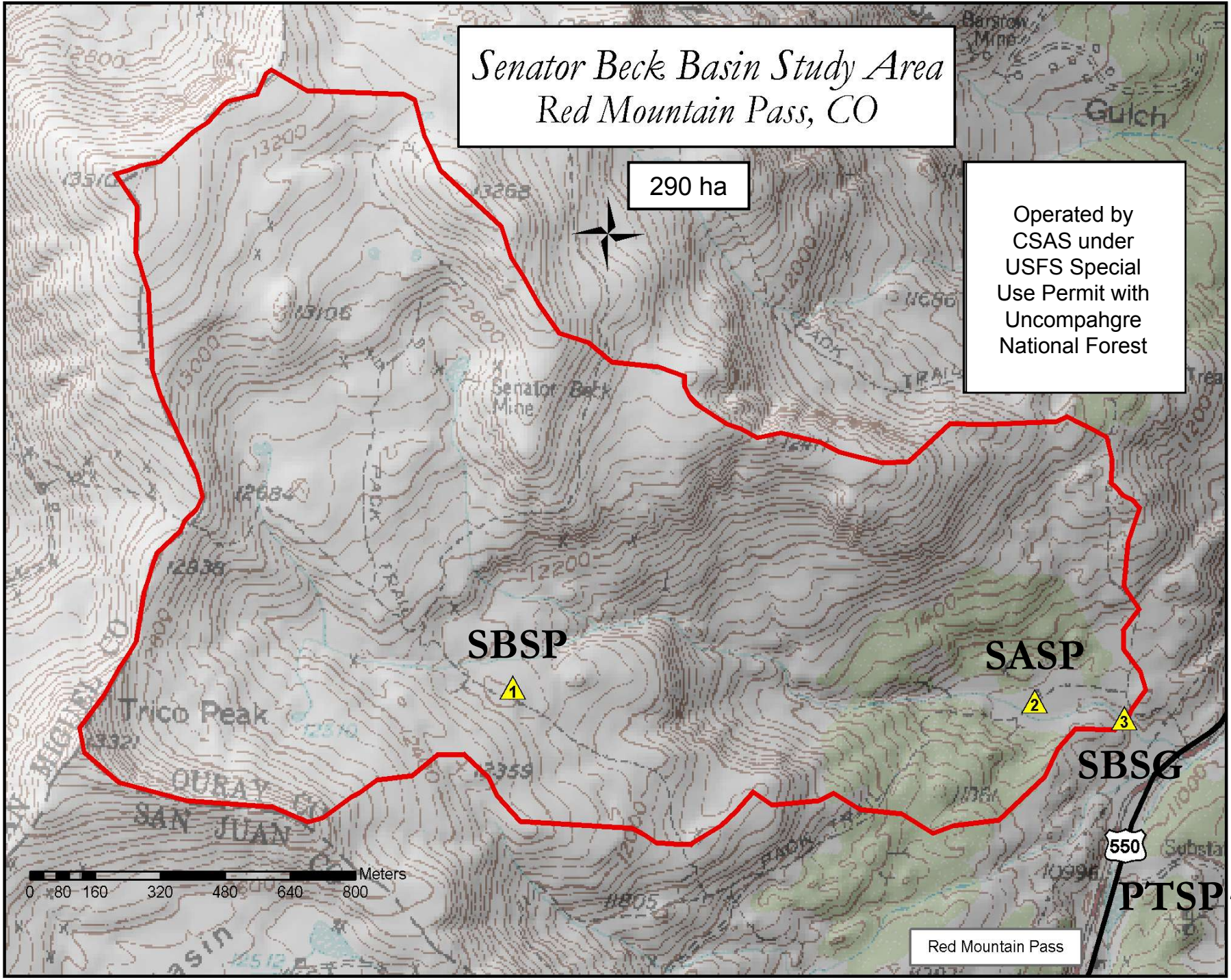


FIGURE B- 41

Mean Projected Percent Change in April 1 SWE and July 1 Soil Moisture

2025 (2011–2040) versus 1985 (1971–2000); 2055 (2041–2070) versus 1985 (1971–2000); and 2080 (2066–2095) versus 1985 (1971–2000).




Senator Beck Basin Study Area
Red Mountain Pass, CO
290 ha
Operated by CSAS under USFS Special Use Permit with Uncompahgre National Forest
SBSP
SASP
SBSG
PTSP
1
2
3
Trico Peak
OURAY CO
SAN JUAN CO
Senator Beck Mine
Bonanza Mine
Gulch
550
Red Mountain Pass
Meters
0 80 160 320 480 640 800

Swamp Angel Study Plot
11,050’ (3368 m)

SASP Instrumentation

6 m Mast

CR10X Dataloggers (2), Multiplexer (1)

ETI Precipitation Gauge

Wind Speed & Direction (2)

Air Temp and RH (2)

Barometric Pressure

Height of Snow

Broadband SW (2 up, 1 down, shadow array)

NIR SW (1 up, 1 down)

Pyrgeometer (1 up)

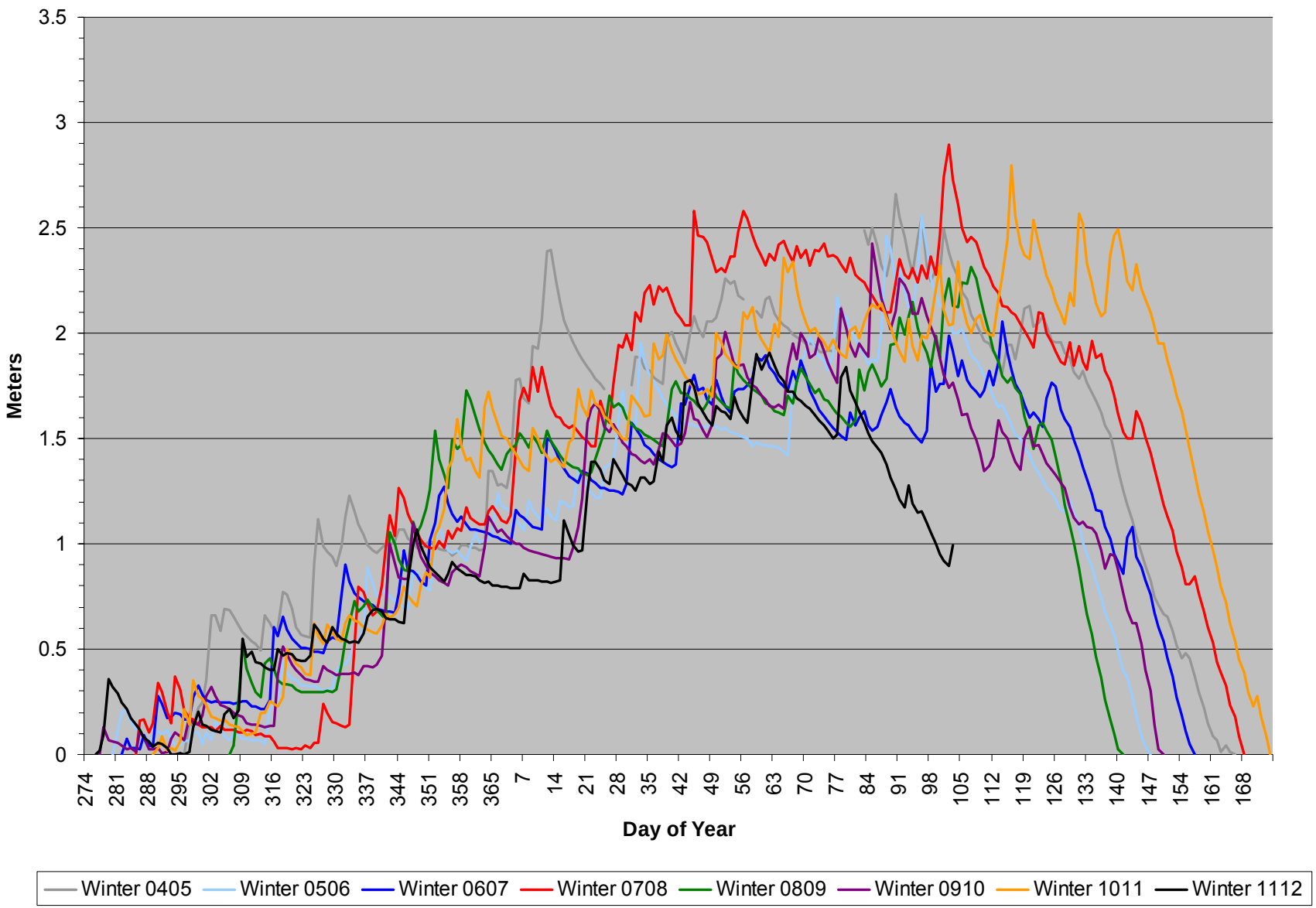
Infrared Snow Surface Temp

Snow Temperature (5)

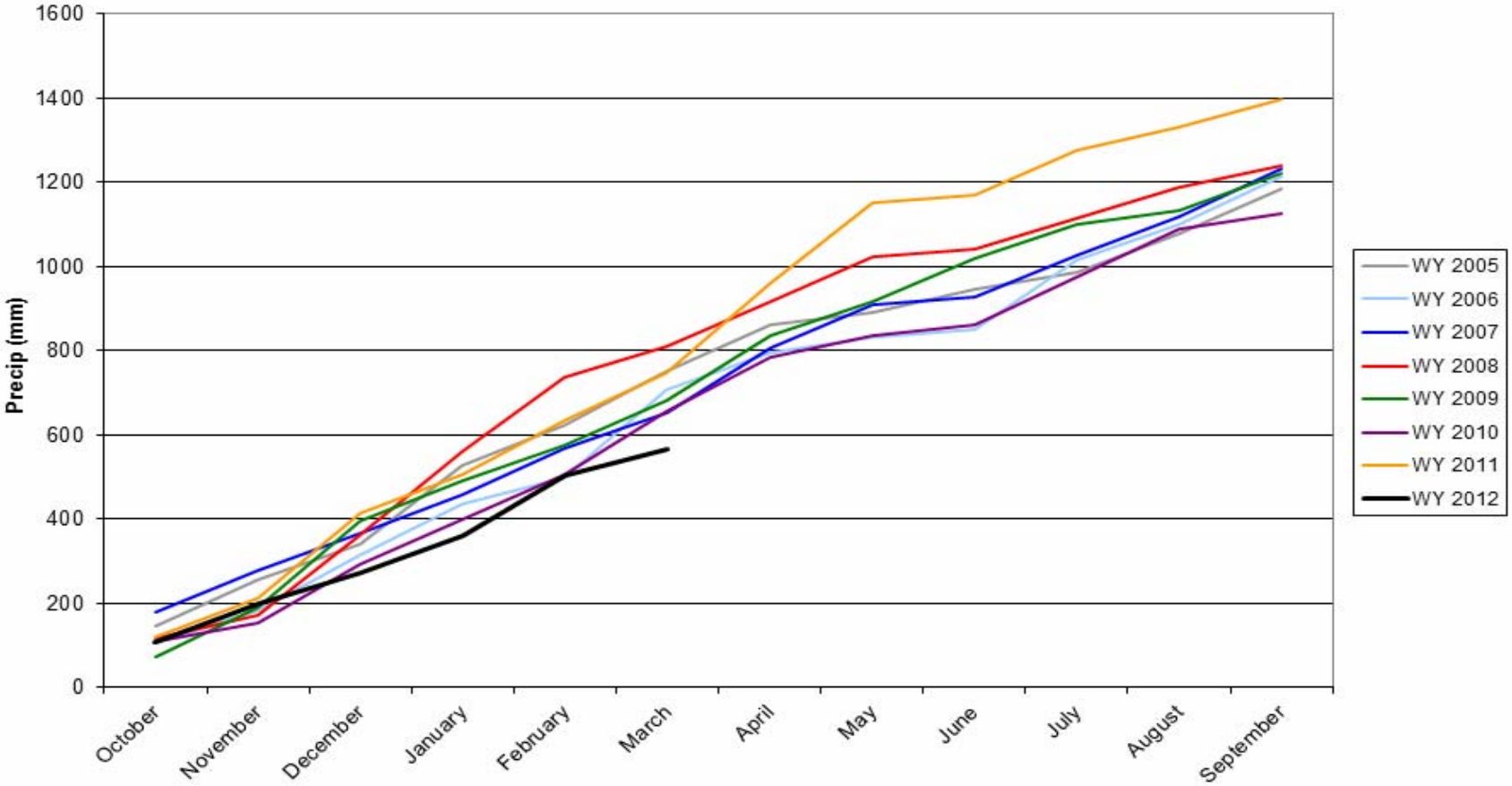
Soil Temperature (4)

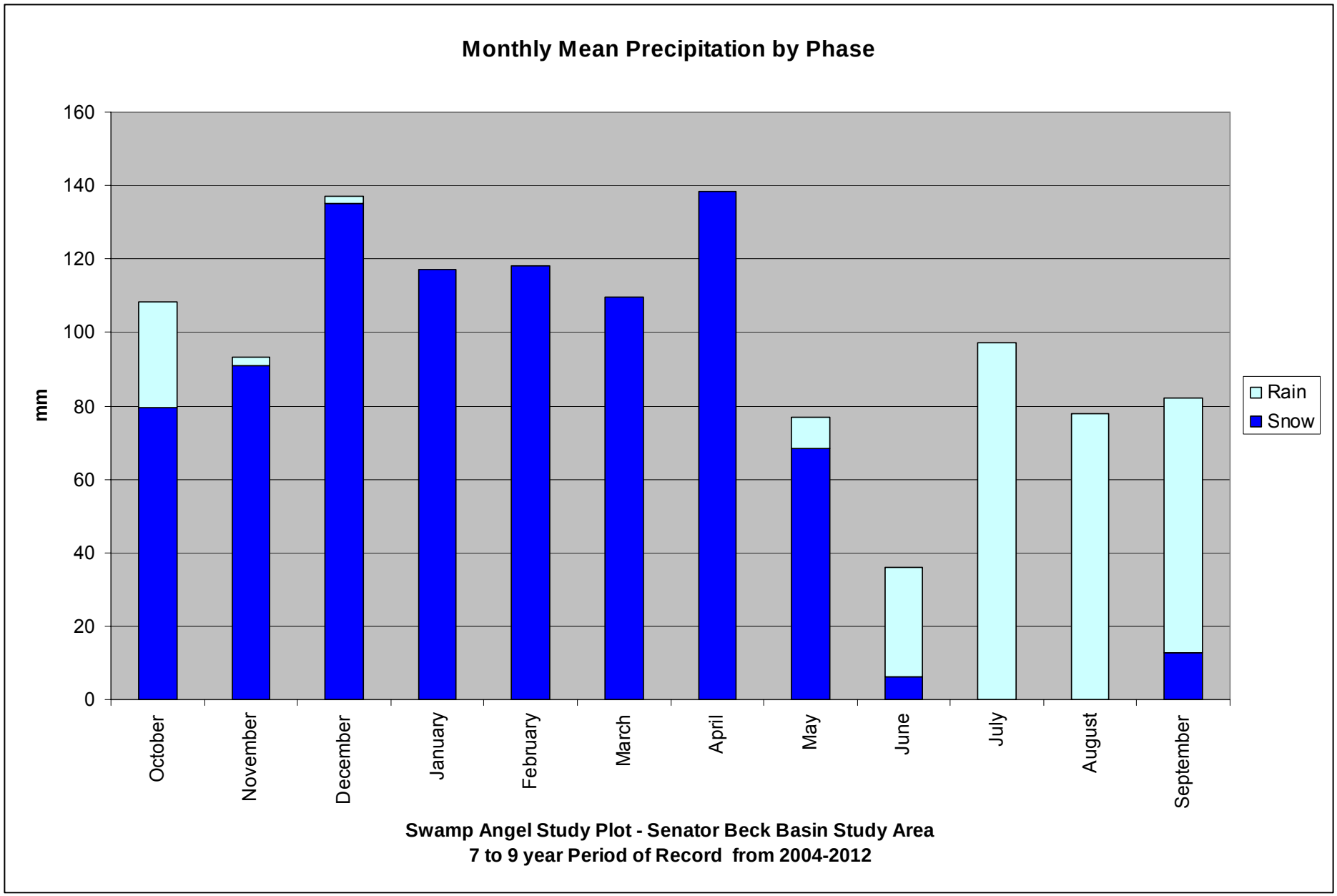
Soil Volumetric Water Content

Soil Heat Flux


Height of Snow - Swamp Angel Study Plot
as of 2400 hours
Meters
3.5
3
2.5
2
1.5
1
0.5
0
274
281
288
295
302
309
316
323
330
337
344
351
358
365
7
14
21
28
35
42
49
56
63
70
77
84
91
98
105
112
119
126
133
140
147
154
161
168
Day of Year
Winter 0405
Winter 0506
Winter 0607
Winter 0708
Winter 0809
Winter 0910
Winter 1011
Winter 1112

Water Year Cumulative Precipitation at End of Month
Swamp Angel Study Plot - Senator Beck Basin Study Area at Red Mountain Pass




Monthly Mean Precipitation by Phase
mm
160
140
120
100
80
60
40
20
0
October
November
December
January
February
March
April
May
June
July
August
September
Rain
Snow
Swamp Angel Study Plot - Senator Beck Basin Study Area
7 to 9 year Period of Record from 2004-2012

SBSP Instrumentation

10 m Mast

Campbell CR10X Dataloggers (2), Multiplexer (1)

Wind Speed & Direction (2)

Air Temp and RH (2)

Height of Snow

Broadband SW (2 up, 1 down, shadow array)

NIR SW (1 up, 1 down)

Pyrgeometer (1 up)

Infrared Snow Surface Temp

Snow Temperature (5)

Soil Temperature (4)

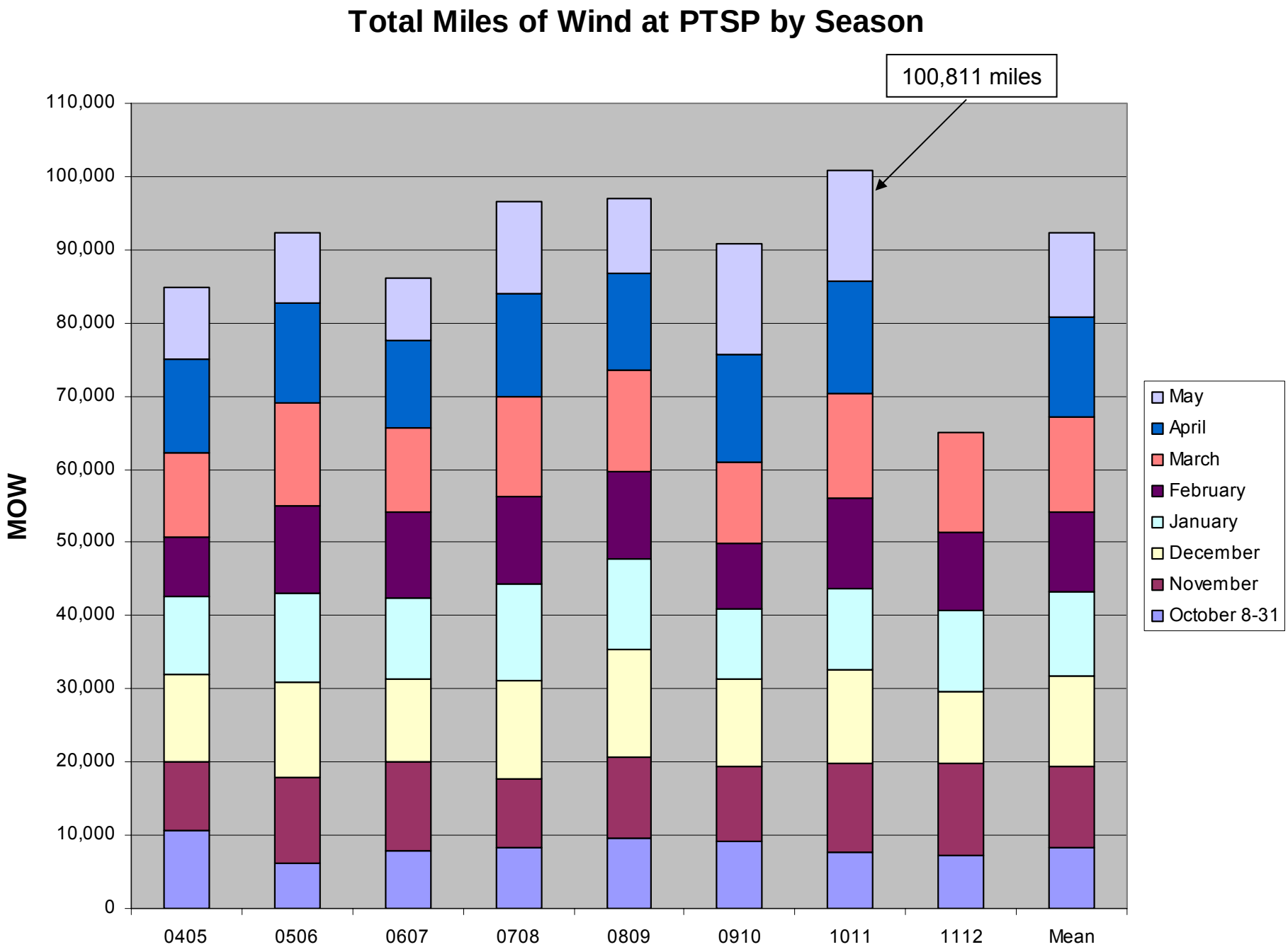
Soil Volumetric Water Content

Soil Heat Flux

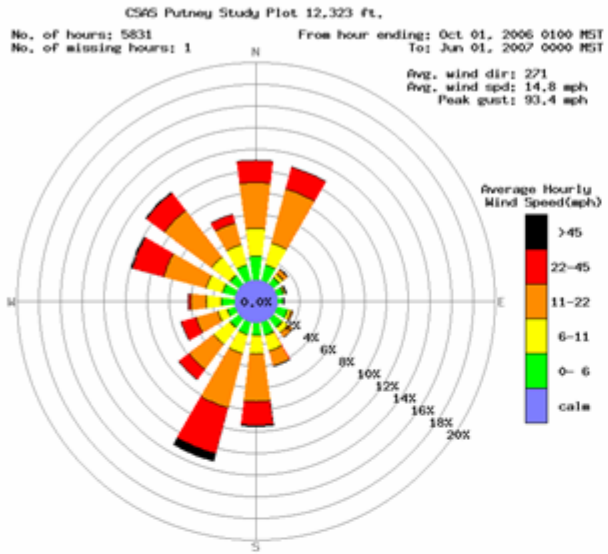
Snow Profile Plot

PTSP Instrumentation

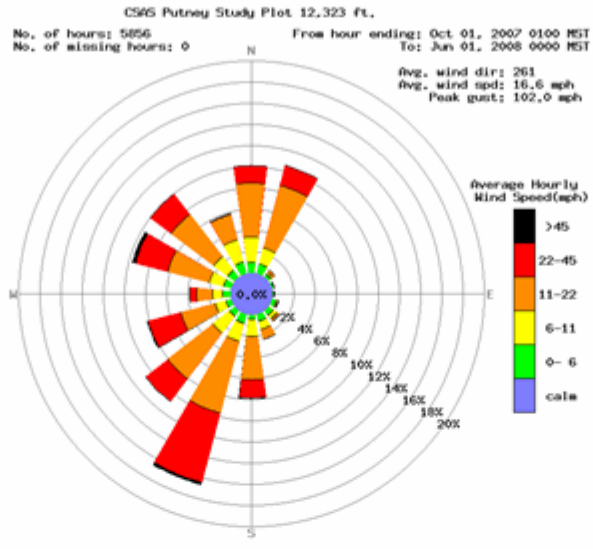
10 m Mast
Campbell CR10X Datalogger
Wind Speed & Direction
Air Temp and RH


Total Miles of Wind at PTSP by Season
100,811 miles
MOW
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0405
0506
0607
0708
0809
0910
1011
1112
Mean
May
April
March
February
January
December
November
October 8-31

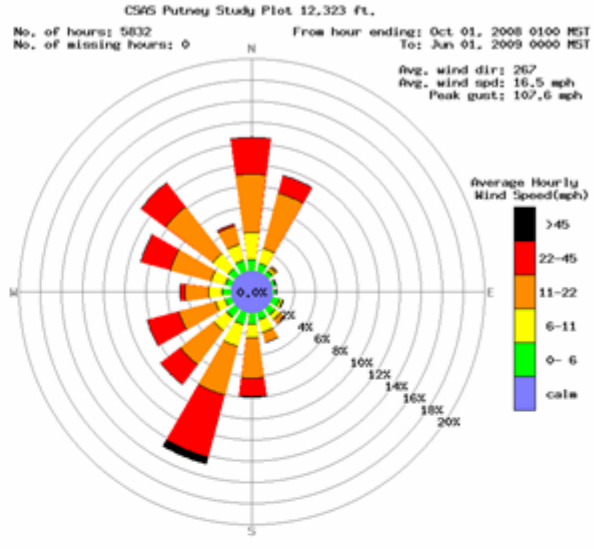
PTSP Winter Wind Roses (10/1 – 5/31)



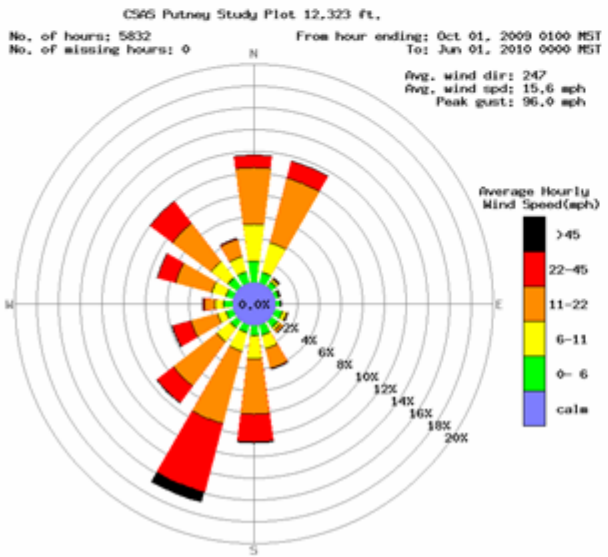
2006/2007



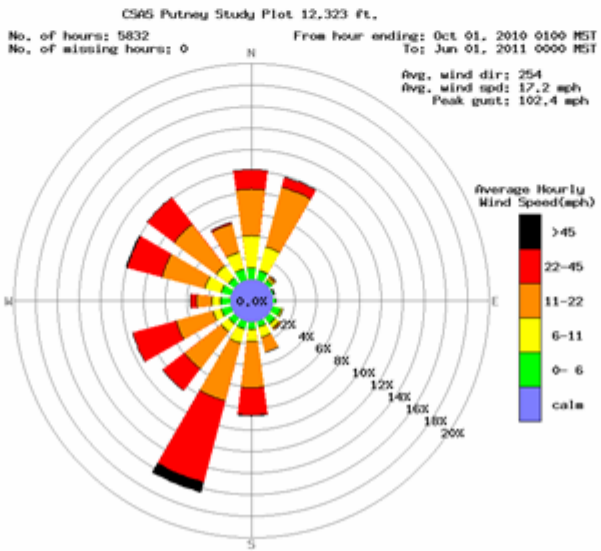
2007/2008



2008/2009



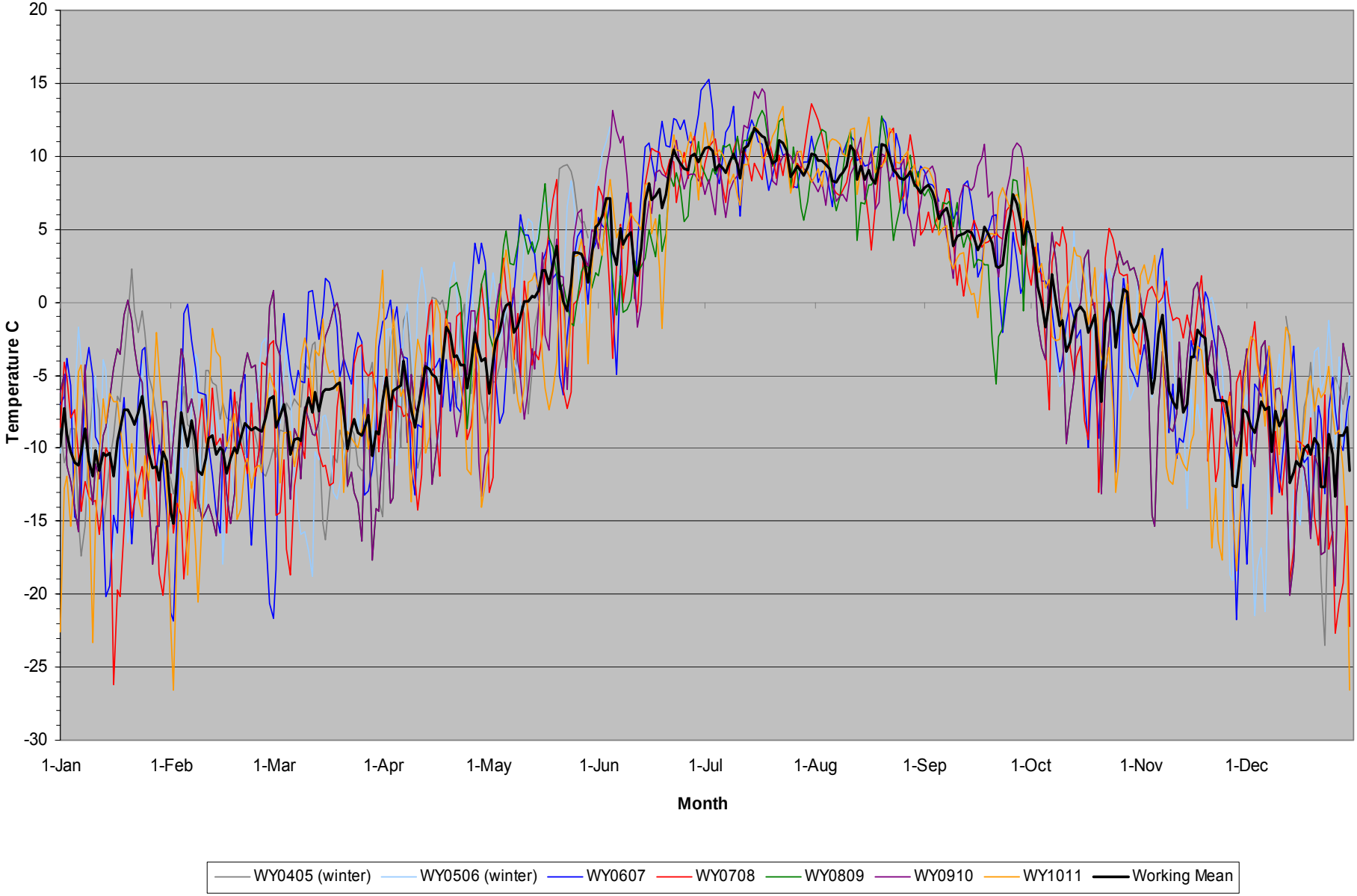
2009/2010



2010/2011

Putney Study Plot 24-Hour Mean Air Temperatures

Elevation 12,325'



SBSG Instrumentation

Broad-crested, notched weir

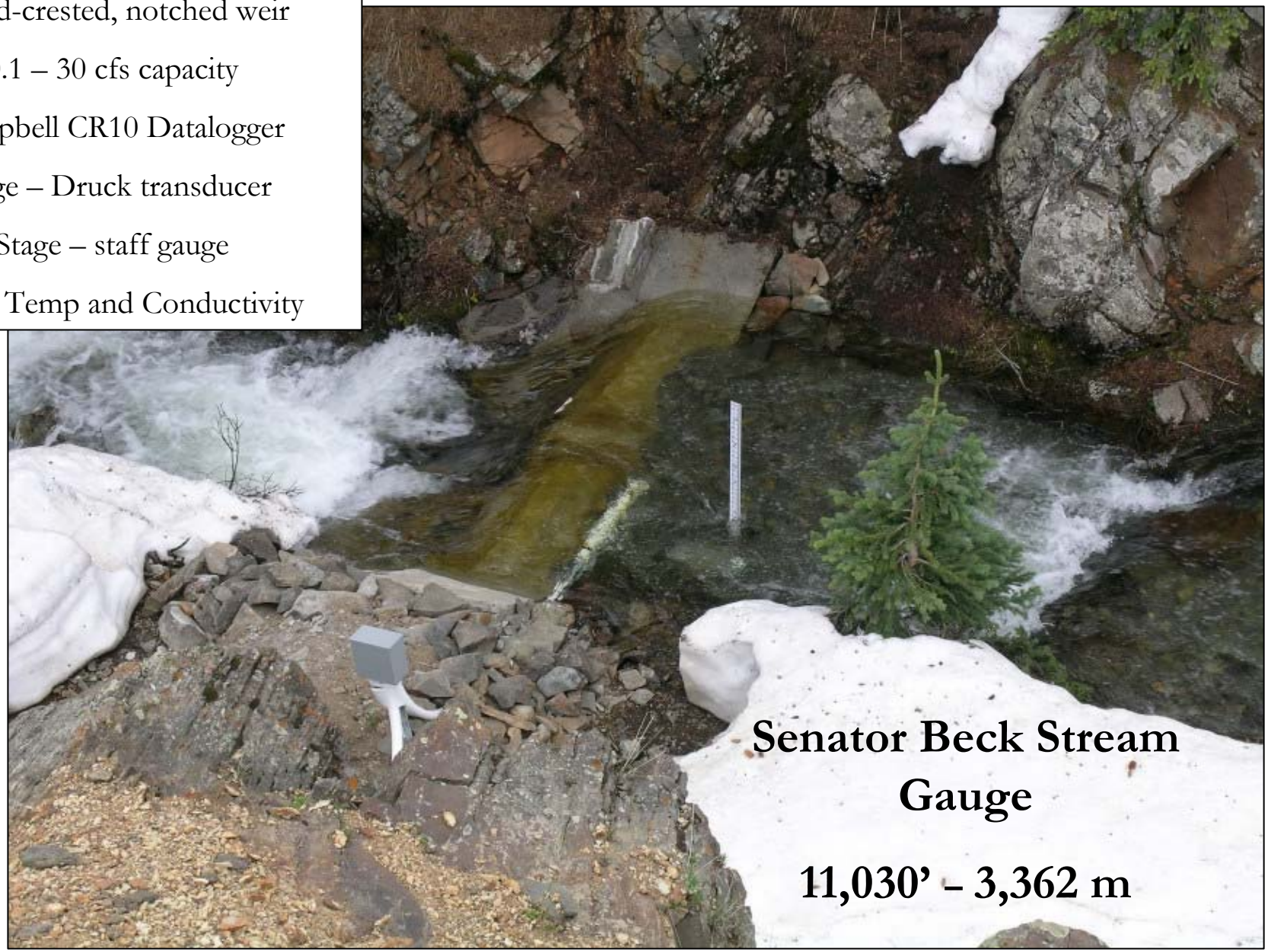
0.1 – 30 cfs capacity

Campbell CR10 Datalogger

Stage – Druck transducer

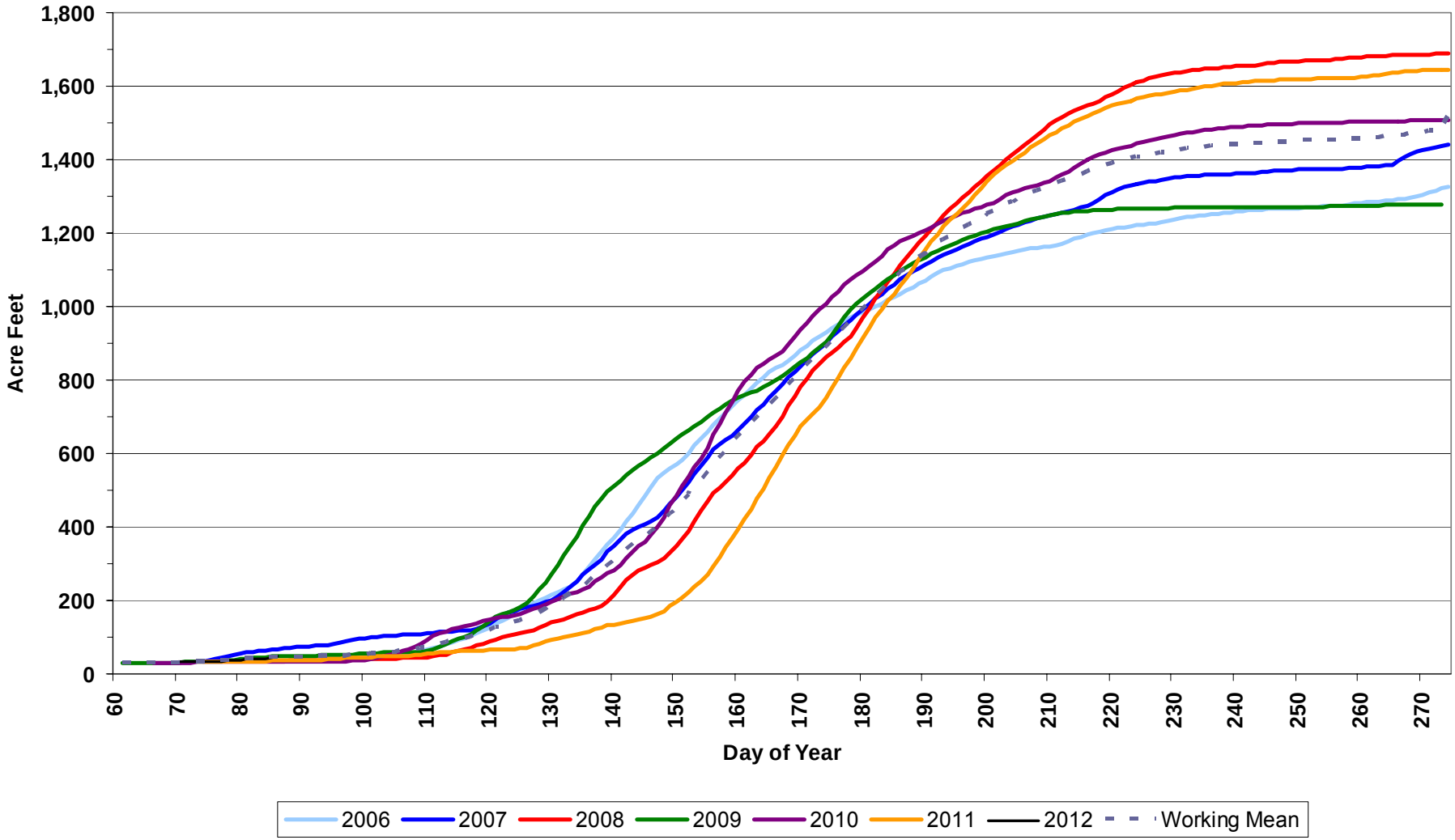
Stage – staff gauge

Water Temp and Conductivity



Senator Beck Basin Cumulative Discharge - 2006 to 2012

as measured at Senator Beck Stream Gauge (SBSG)



Mountain System Monitoring

Monitoring the plant community as a bellwether for regional climate 'state' in 5-year repeat studies

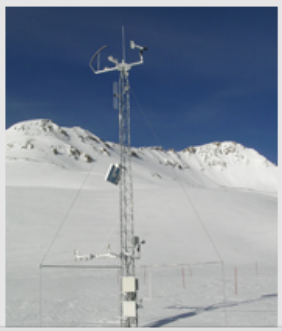
Vegetation Change =

- **Change in Snowcover,**
- **Change in ET,**
- **Change in Albedo,**
- **Change in Runoff**

August 2009

CENTER FOR SNOW & AVALANCHE STUDIES

Swamp Angel Study Plot (subalpine)



CSAS ARCHIVAL DATA FROM SENATOR BECK BASIN

Before using any of the following data, you must agree to the policies governing use of CSAS data. Please contact kbuck@snowstudies.org for assistance in working with CSAS data and in interpreting radiation/energy budget data from Swamp Angel Study Plot. Click links below for access to data, metadata and snow profile sets.

	Swamp Angel Study Plot	Senator Beck Study Plot	Putney Study Plot	Senator Beck Stream Gauge
Summer 2011	Data (Excel 3.4 Mb)	Data (Excel 3.6 Mb)	Data (Excel 1.5 MB)	Data (Excel 3.5 MB)
	Metadata (MS Word)	Metadata (MS Word)	Metadata (MS Word)	Metadata (MS Word)
Winter 2010/2011	Data (Excel 12.3 Mb)	Data (Excel 12.8 Mb)	Data (Excel 3.7 Mb)	
	Metadata (MS Word)	Metadata (MS Word)	Metadata (MS Word)	
	• Snow Profiles (pdf) 25 pits in Senator Beck Basin during the '10-'11 season			

Swamp Angel Study Plot (subalpine)

CSAS-ASSISTED SCHOLARLY PUBLICATIONS

Naud, C. M., J. R. Miller, and C. Landry (2012), Using satellites to investigate the sensitivity of longwave downward radiation to water vapor at high elevations, *J. Geophys. Res.*, 117, D05101, doi:10.1029/2011JD016917.

Marshall, H.P., C. Pielmeier, S. Havens, and F. Techel (2010), Slope-scale Snowpack Stability Derived from Multiple Snowmicropen Measurements and High-resolution Terrestrial FMCW Radar Surveys. *Proceedings of the 2010 International Snow Science Workshop*, Squaw Valley, California.

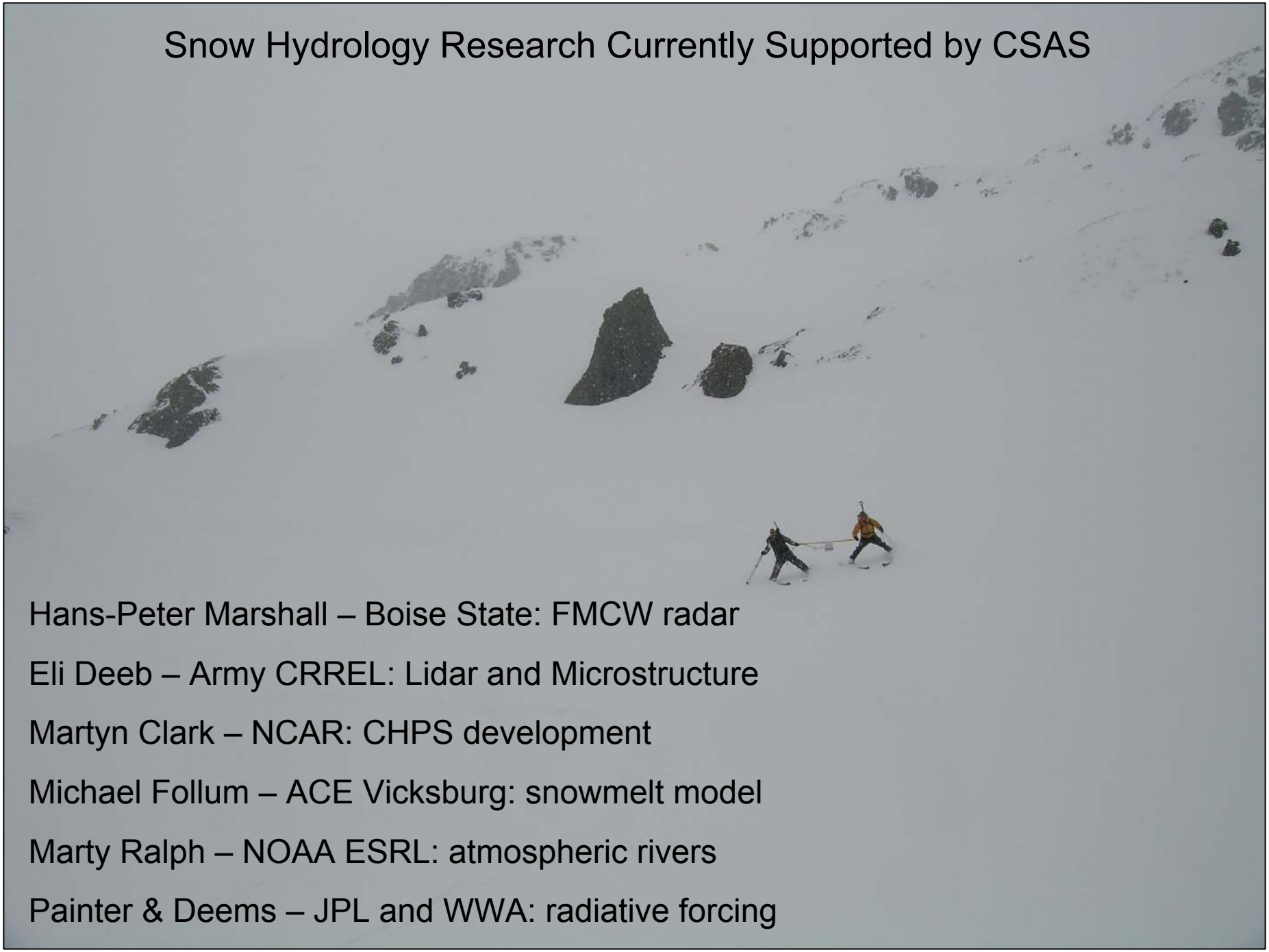
Simonson, S.E., E. Greene, S. Fasnacht, T. Stohlgren and C. Landry (2010) Practical Methods for Using Vegetation Patterns to Estimate Avalanche Frequency Magnitude. *Proceedings of the 2010 International Snow Science Workshop*, Squaw Valley, California.

Painter, T. H., J. Deems, J. Belnap, A. Hamlet, C. C. Landry, and B. Udall (2010), Response of Colorado River runoff to dust radiative forcing in snow, *Proceedings of the National Academy of Sciences*, published ahead of print September 20, 2010,doi:10.1073/pnas.0913139107.

Lawrence, C. R., T. H. Painter, C. C. Landry, and J. C. Neff (2010), Contemporary geochemical composition and flux of aeolian dust to the San Juan Mountains, Colorado, United States, *Journal of Geophysical Research*, 115, G03007, doi:10.1029/2009JG001077.

Steltzer, H., C. Landry, T. H. Painter, J. Anderson, and E. Ayres. 2009.Biological consequences of earlier snowmelt from desert dust deposition in alpine landscapes. *Proceedings of the National Academy of Sciences.* 106: 11629-

Snow Hydrology Research Currently Supported by CSAS



Hans-Peter Marshall – Boise State: FMCW radar

Eli Deeb – Army CRREL: Lidar and Microstructure

Martyn Clark – NCAR: CHPS development

Michael Follum – ACE Vicksburg: snowmelt model

Marty Ralph – NOAA ESRL: atmospheric rivers

Painter & Deems – JPL and WWA: radiative forcing

Climate Change in Mountains

JGR Journal of Geophysical Research Atmospheres

AGU American Geophysical Union

Abstract | Cited By (0)

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, D05101, 12 PP., 2012
doi:10.1029/2011JD016917

Using satellites to investigate the sensitivity of longwave downward radiation to water vapor at high elevations

Key Points

- PWV vs. q universal for large q but elevation dependent for low q
- MODIS PWV and CERES LDR as accurate at high as at low elevations
- Satellites observe high sensitivity of LDR to changes in q in dry locations

Catherine M. Naud
NASA GISS, Columbia University, New York, New York, USA

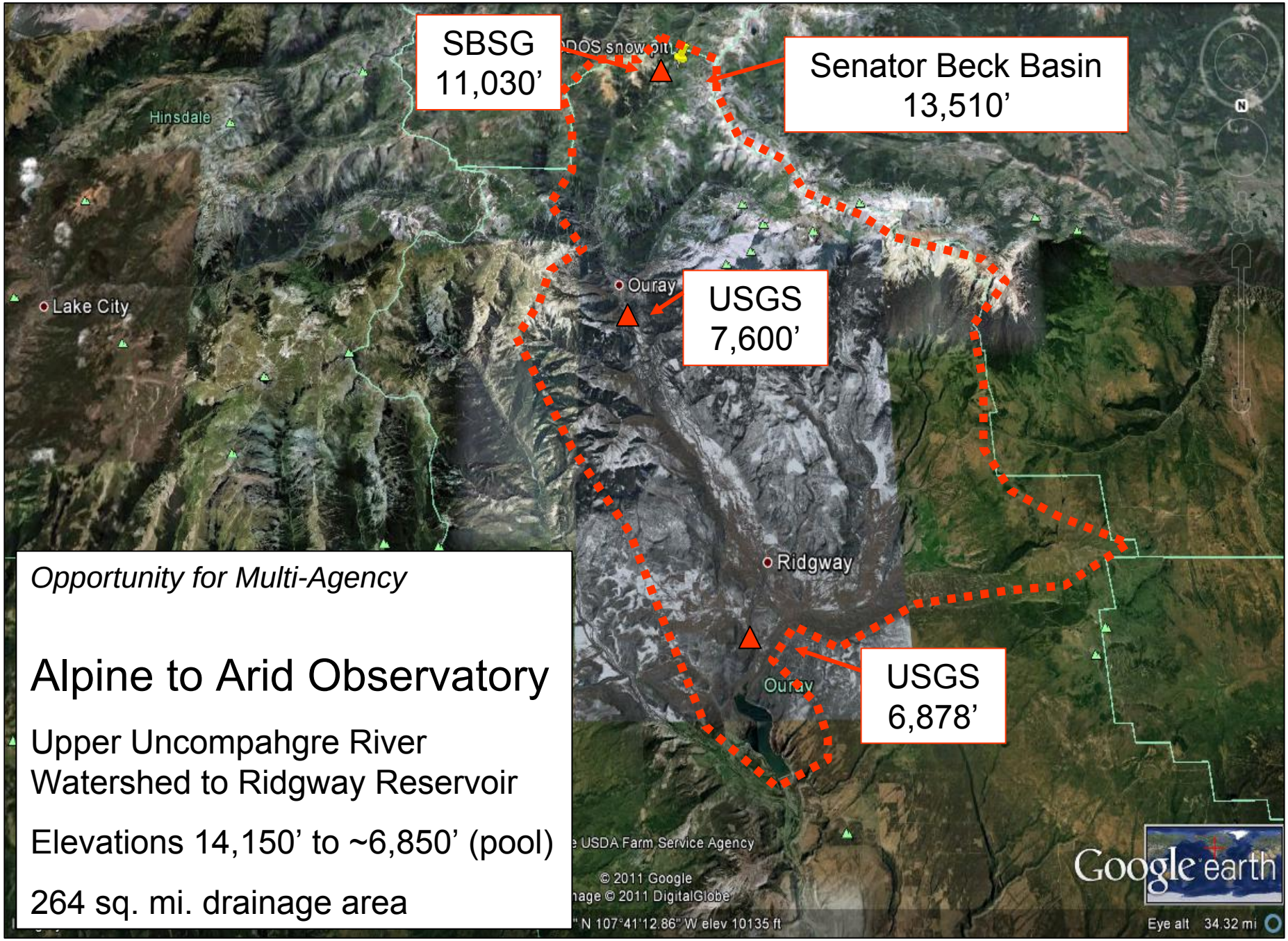
James R. Miller
Marine and Coastal Sciences, Rutgers University, New Brunswick, New Jersey, USA

Chris Landry
Center for Snow and Avalanche Studies, Silverton, Colorado, USA

Many studies suggest that high-elevation regions may be among the most sensitive to future climate change. However, in situ observations in these often remote locations are too sparse to determine the feedbacks responsible for enhanced warming rates. One of these feedbacks is associated with the sensitivity of longwave downward radiation (LDR) to changes in water vapor, with the sensitivity being particularly large in many high-elevation regions where the average water vapor is often low. We show that satellite retrievals from the Moderate Resolution Imaging Spectroradiometer (MODIS) and Clouds and the Earth's Radiant Energy System (CERES) can be used to expand the current ground-based observational database and that the monthly averaged clear-sky satellite estimates of humidity and LDR are in good agreement with the well-instrumented Center for Snow and Avalanche Studies ground-based site in the southwestern Colorado Rocky Mountains. The relationship between MODIS-retrieved precipitable water vapor and surface specific humidity across the contiguous United States was found to be similar to that previously found for the Alps. More important, we show that satellites capture the nonlinear relationship between LDR and water vapor and confirm that LDR is especially sensitive to changes in

Keywords
- high elevation
- longwave downward flux
- precipitable water vapor
- satellite observations
- specific humidity

Index Terms
- Global Change: Regional climate change (4321)
- Global Change: Remote sensing (1855, 4337)



Opportunity for Multi-Agency

Alpine to Arid Observatory

Upper Uncompahgre River Watershed to Ridgway Reservoir

Elevations 14,150’ to ~6,850’ (pool)

264 sq. mi. drainage area

CENTER FOR SNOW & AVALANCHE STUDIES

Swamp Angel Study Plot (subalpine)

Senator Beck Study Plot (alpine)

CAMPAIGN TO SUSTAIN SENATOR BECK BASIN

CSAS and its Senator Beck Basin long-term monitoring study site are in a fight to survive. In order to continue operations past this season, and into our Fiscal Year 2012/2013, we need to raise $135,000 by June 30, 2012.We have already received pledges, but need more stakeholder agencies to step forward!

Why should CSAS get funded?

Federal and state natural resource and land managers have a very real stake in the data that CSAS is producing. Sustained Senator Beck Basin data and mountain system monitoring will help managers fulfill their agency's climate change adaptation mandates and provide insights into changes in ecosystem services. Collective stakeholder funding of CSAS's operation of Senator Beck Basin offers agencies a cost-effective opportunity to obtain unique data and research results, with broad applications.

Why isn't CSAS funded by more foundations or by NSF?

Although CSAS is a 501(c)(3), not-for-profit research organization, we are unable to compete for most private foundations' funding because we are neither an activist or an advocacy organization, proposing "solutions" to climate change, and because our fundamental need is for general (Senator Beck Basin) operations funding for long-term monitoring. Similarly, the National Science Foundation seeks to fund 3-4 year, "new" science research projects (such as our original dust-on-snow research effort). Unfortunately, the CSAS's long-term mountain system monitoring program does not match up with NSF's calls for

CSAS

Center for Snow & Avalanche Studies

PO Box 190, Silverton, CO 81433

Phone: (970) 387-5080 Email: clandry@snowstudies.org

Web: www.snowstudies.org