Guest Lecture

Chris Landry, Executive Director
Center for Snow and Avalanche Studies

Wednesday, April 18, 2:30 p.m.
Building 1400 (Green Building), Conference Room 246

Topics:

- The Colorado Dust-on-Snow Program: an applied science effort that monitors the presence/absence of dust layers at mountain passes throughout Colorado. CODOS provides a series of "Update" analyses of how dust-on-snow is likely to influence snowmelt timing and rates during the snowmelt runoff season.

- Other Center Activities

The **Center for Snow and Avalanche Studies** is an independent Colorado not-for-profit corporation founded in 2003 and located in Silverton, CO. The Center serves the mountain science community and regional resource managers by hosting & conducting interdisciplinary research and monitoring that captures weather, snowpack, radiation, soils, plant community, and hydrologic signals of regional climate trends. Programs include Mountain System Monitoring, Colorado Dust-on-snow, Interdisciplinary Research, and Field and Education Workshops.

Chris Landry began skiing at the age four at Big Mountain, Montana. His skiing career progressed from fledgling jumps to a junior and college racing career. Ski racing eventually turned into a passion for climbing, ski mountaineering, and even a few pioneering ski descents in North America. Along the way, Chris pursued instruction in avalanche safety, became an instructor for the American Avalanche Institute, published a field workbook for backcountry skiers and guides, and established a practice as a private avalanche consultant/forecaster. Most recently, Chris earned a MS in the Department of Earth Sciences at Montana State University - Bozeman, where he researched the spatial variability of snow stability on uniform slopes.

Center for Snow & Avalanche Studies
http://www.snowstudies.org

Research and Monitoring

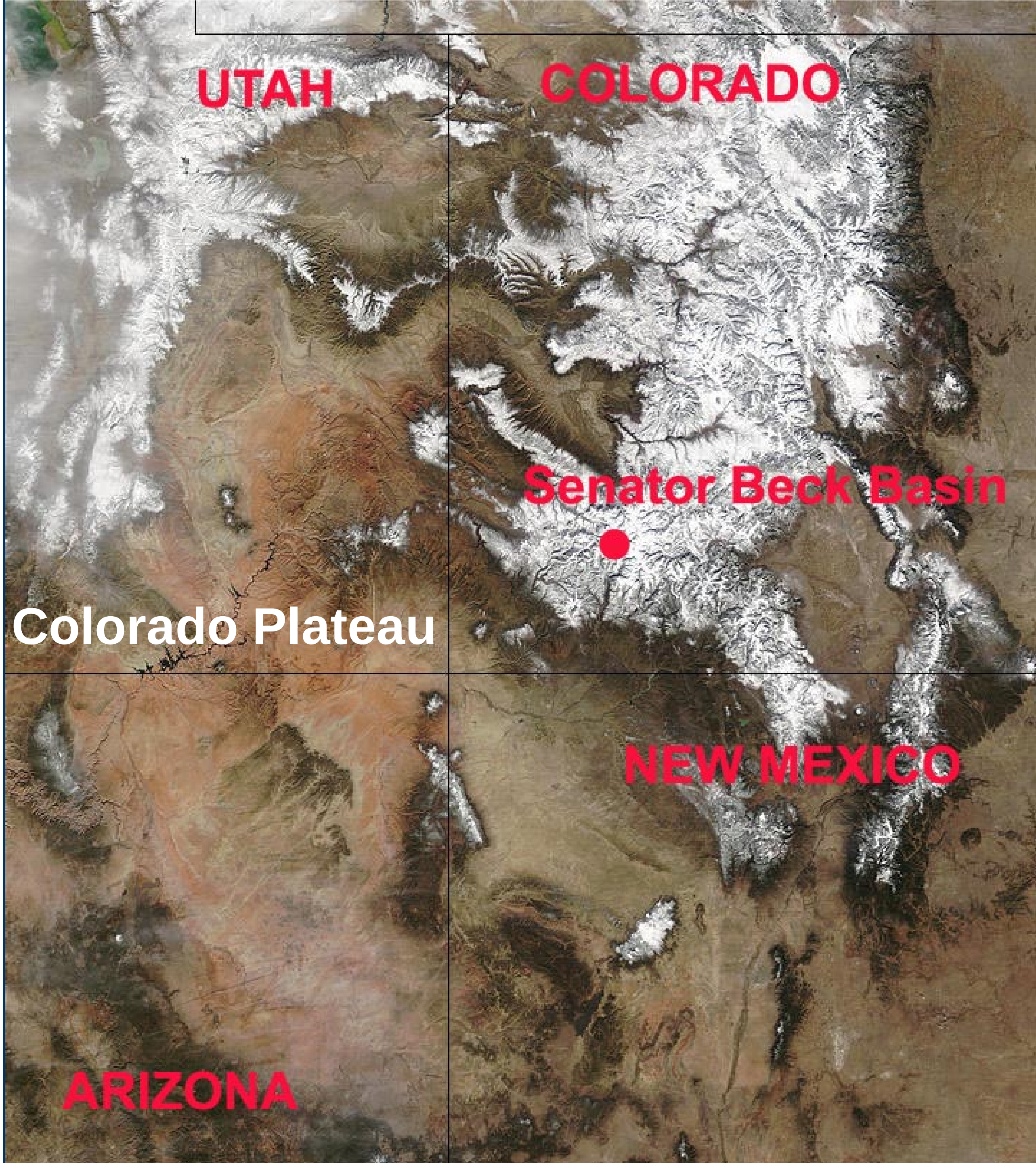
Mountain System Processes and Change

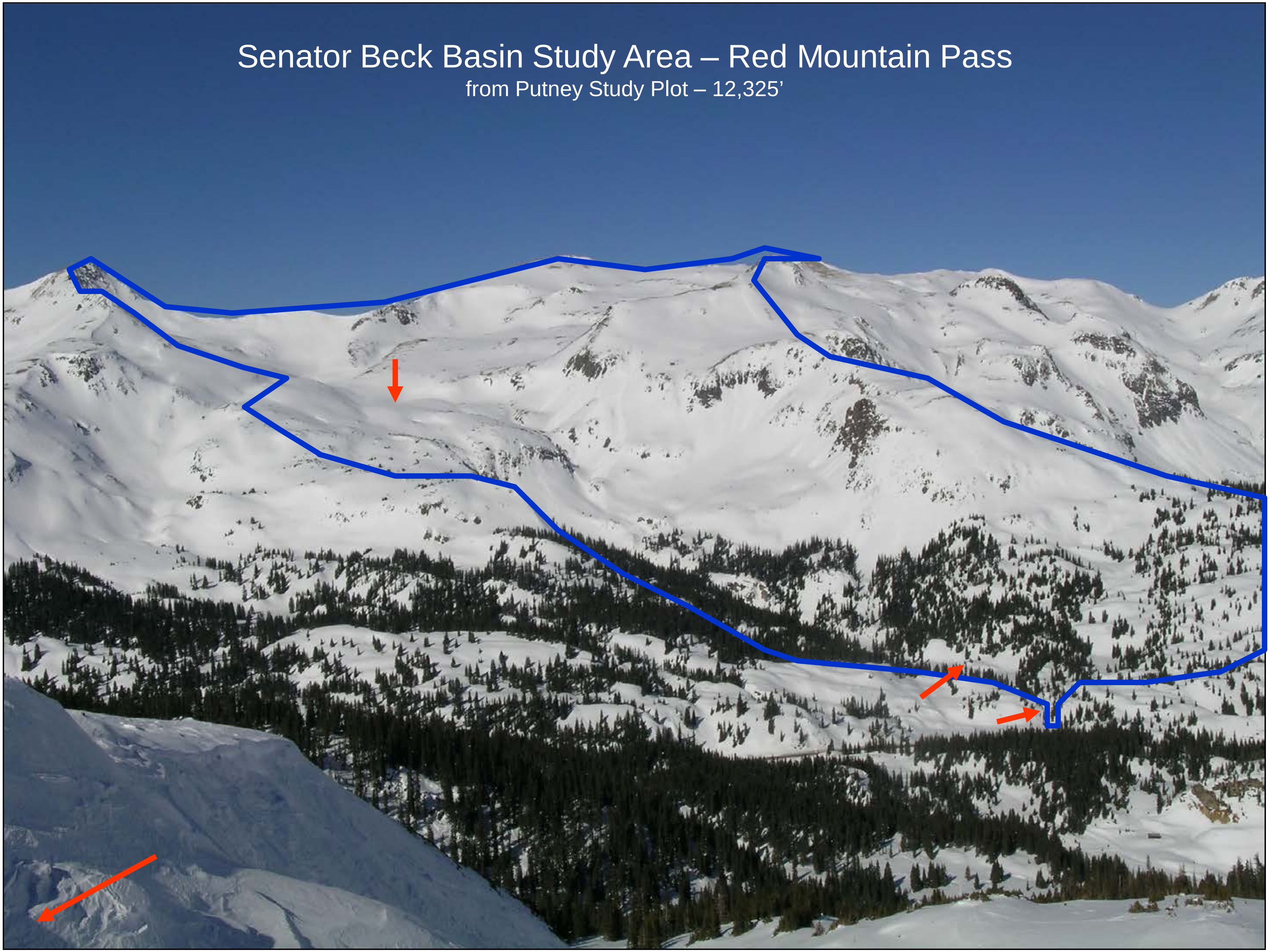
Senator Beck Basin Study Area

Chris Landry

Center for Snow and Avalanche Studies
Silverton, CO

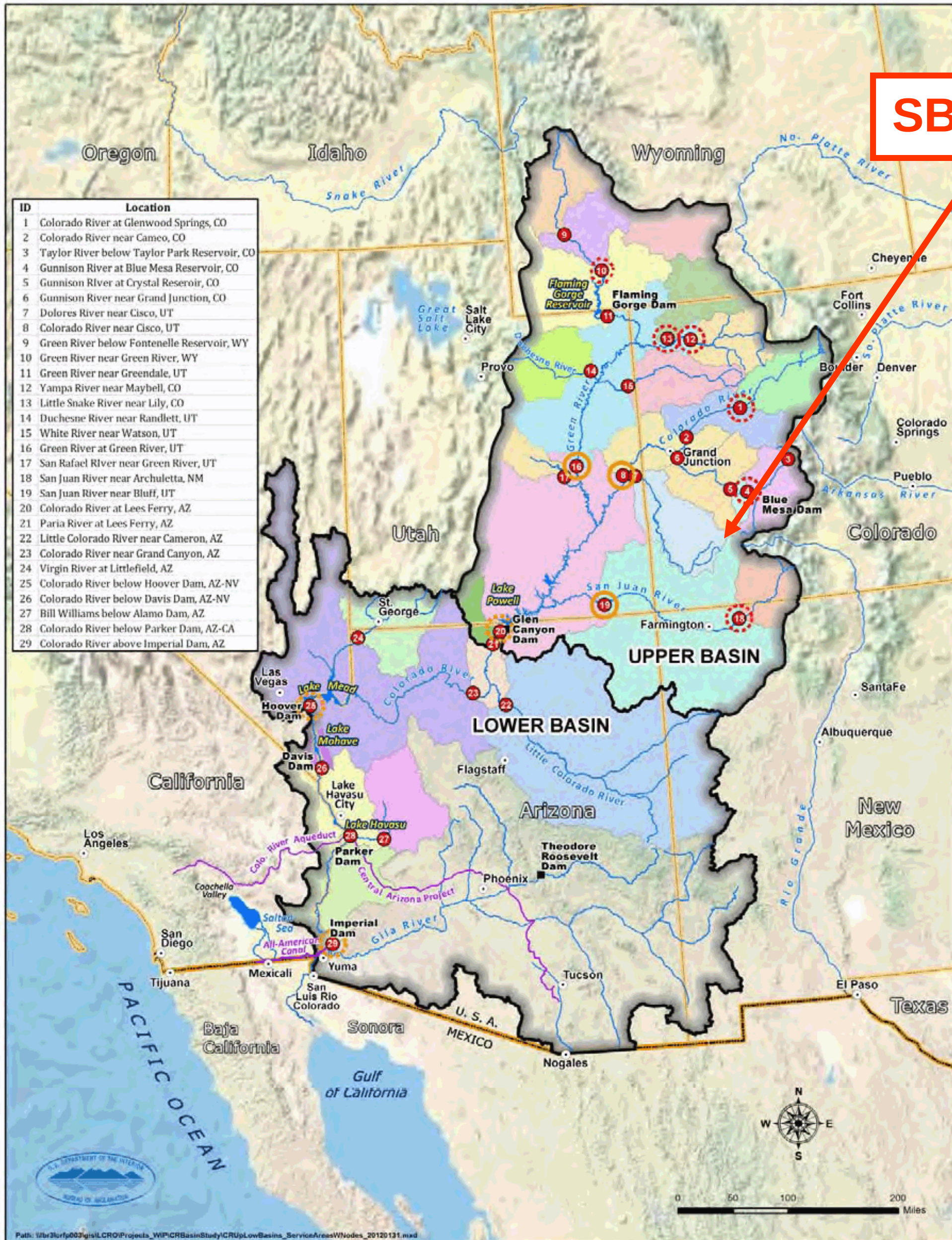
CSAS



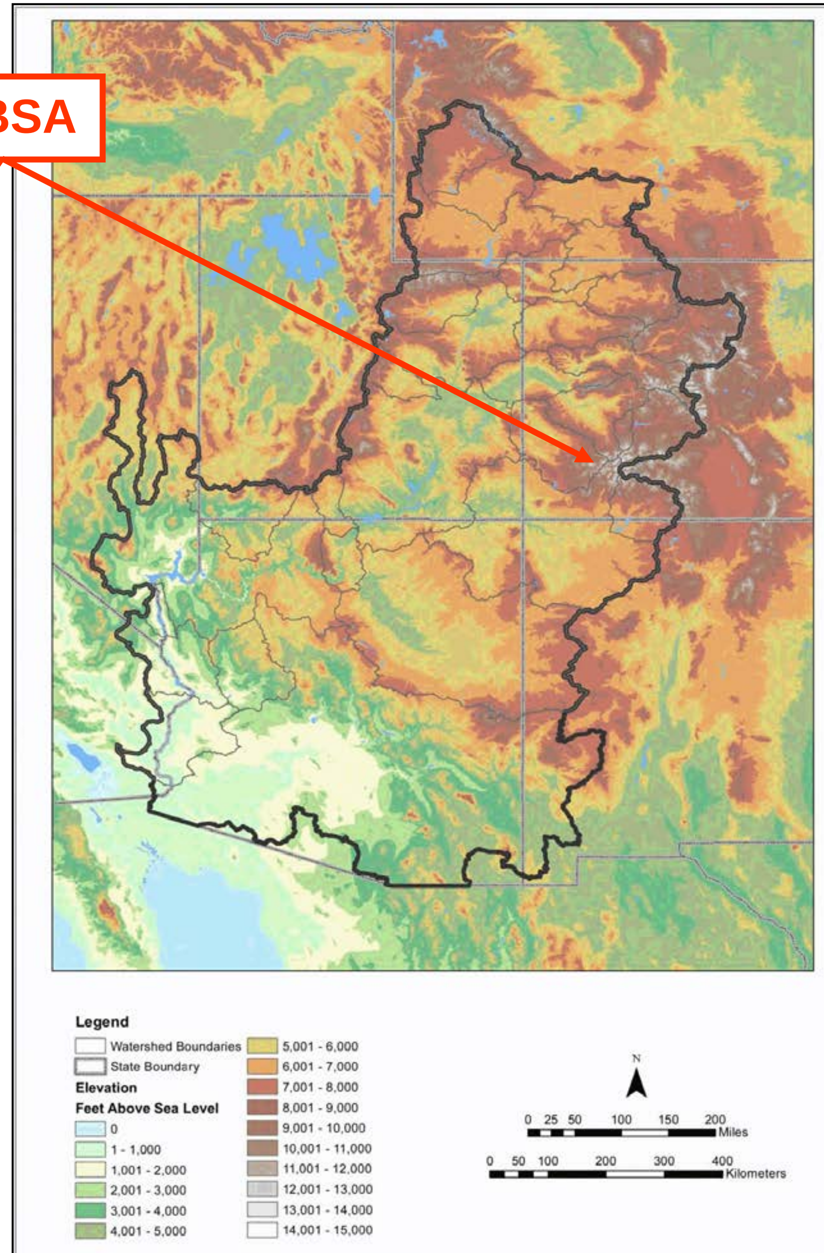

Senator Beck Basin Study Area – Red Mountain Pass
from Putney Study Plot – 12,325'

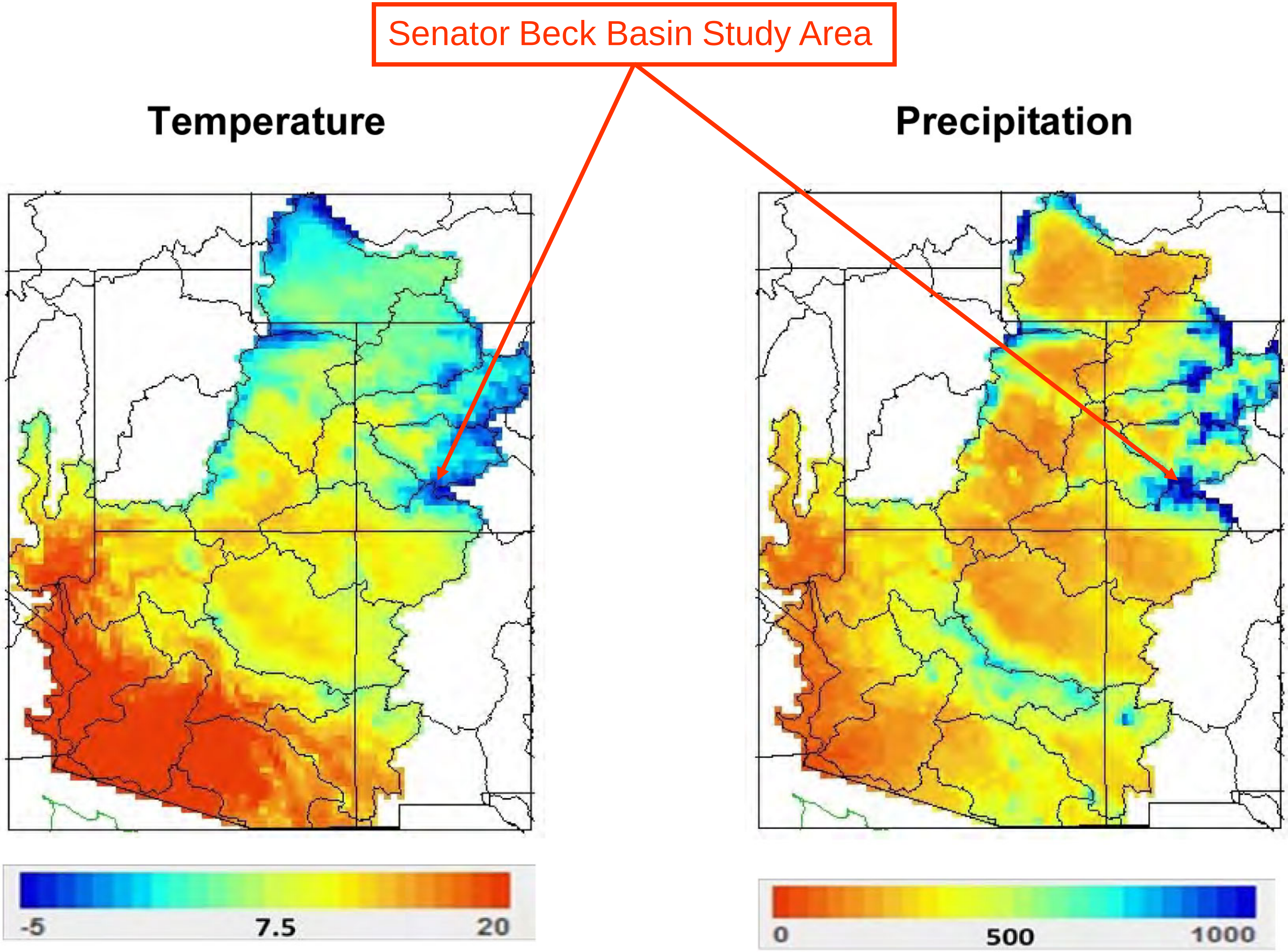
Senator Beck Basin Study Area – Sentry Site for Upper CRB

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



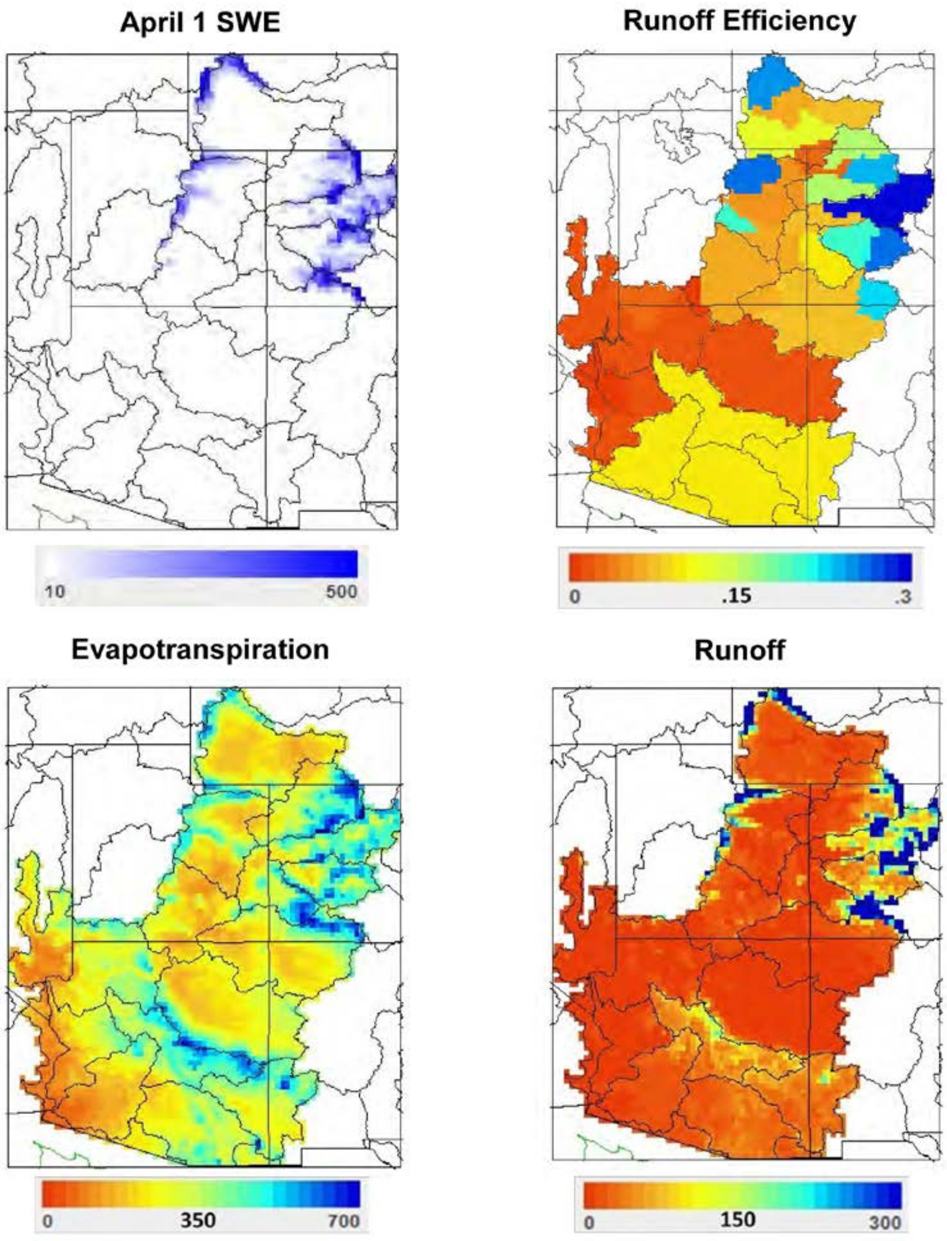
SBBSA





CRB Water Supply & Demand Study: Tech Report B - pg B14

FIGURE B-8
Estimated Average Annual ET and Runoff (millimeters), April 1 SWE (millimeters), and Annual Average Runoff Efficiency (fraction of precipitation converted into runoff) for 1971–2000
Derived from historical VIC simulations.



CRB Water Supply & Demand Study: Tech Report B - pg B18

USGS
science for a changing world

US Army Corps of Engineers

Climate Change and Water Resources Management: A Federal Perspective

Circular 1331

U.S. Department of the Interior
U.S. Geological Survey

2 Tracking Climate Change Impacts

Monitoring data is essential for understanding and tracking the impacts of climate change. This chapter seeks to address the following questions:

- How are monitoring data used to track climate impacts?
- How do data inform physical system understanding?
- What monitoring networks currently exist?

2.1 Tracking Hydrologic Change: Monitoring Networks

Current projections of climate changes and their potential impacts harbor many uncertainties, and these uncertainties are unlikely to dissipate in the near term. Within these uncertainties are the possibility for surprises, which could be unpleasant and quick to appear. In this context, a strategy that balances detecting and adjusting to changes against extrapolating (including modeling) and anticipating changes will be most prudent. Thus, monitoring of climatic and hydrologic conditions plays an important role in addressing potential climate changes.

To detect hydrologic changes due to climate change or other causes, data from long-term monitoring networks are essential for establishing baseline conditions and tracking any changes over time. Monitoring networks are also essential for fully understanding the hydrologic processes that lead to changes in water resources and for calibrating and validating models used to project future conditions. In turn, information about possible or likely future changes to climate improves the effectiveness of planning studies and allows the development and implementation of reasonable strategies for adapting to a changing climate.

Key Point 4: Long-term monitoring networks are critical for detecting and quantifying climate change and its impacts. Continued improvement in the understanding of climate change, its impacts, and the effectiveness of adaptation or mitigation actions requires continued operation of existing long-term monitoring networks and improved sensors deployed in space, in the atmosphere, in the oceans, and on the Earth's surface.

Monitoring networks include in situ methods as well as remote sensing technologies such as radar and satellites. Existing data allow us to look at data retrospectively. However, monitoring networks must continue to operate into the future if we are to detect future changes in hydrologic systems due to climate change (or the lack thereof) and to craft effective responses.

To be useful for climate change studies, monitoring networks need to be in place in locations relevant to water managers. For example, monitoring stations should be located in watersheds important for water supply or vulnerable to changes in water quality. In addition to monitoring of the natural system, data on human water use can be valuable in planning for climate change. The USGS periodically publishes estimates of water use in the United States by sector (for example, Hutson and others, 2004) compiled from data collected by State and local agencies. The periodic nature of these reports and the varying data-collection methods limit their utility for evaluating demand interactions with climate.

Climate change is easier to detect on global to regional scales. Monitoring networks for detecting change are especially valuable when they are regional or involve local networks that are integrated to allow regional analyses. Also needed for planning and operational analysis is a comprehensive set of parameters that characterize current and future climate conditions.

A number of Federal, State, and local agencies operate observation networks that are valuable for climate change analysis. The USGS operates the largest water monitoring network in the United States, as well as biological-monitoring networks. These are briefly described in the inset box. NOAA operates the Nation's largest meteorological network and provides data on oceans. The NOAA observational networks are also described in an inset box. Other Federal agencies also maintain important water-monitoring networks, such as the Natural Resources Conservation Service's snow surveys and Snowtel network. State and local agencies are able to supplement these larger networks with needed local data. USACE and Reclamation also conduct project-specific water resources-monitoring activities.

Key Point 5: Monitoring needs to focus on locations that describe the climate signal (for example, upstream and downstream from major water-management infrastructure or in vulnerable ecological reaches).

2.2 Tracking Hydrologic Change: Trend Analysis

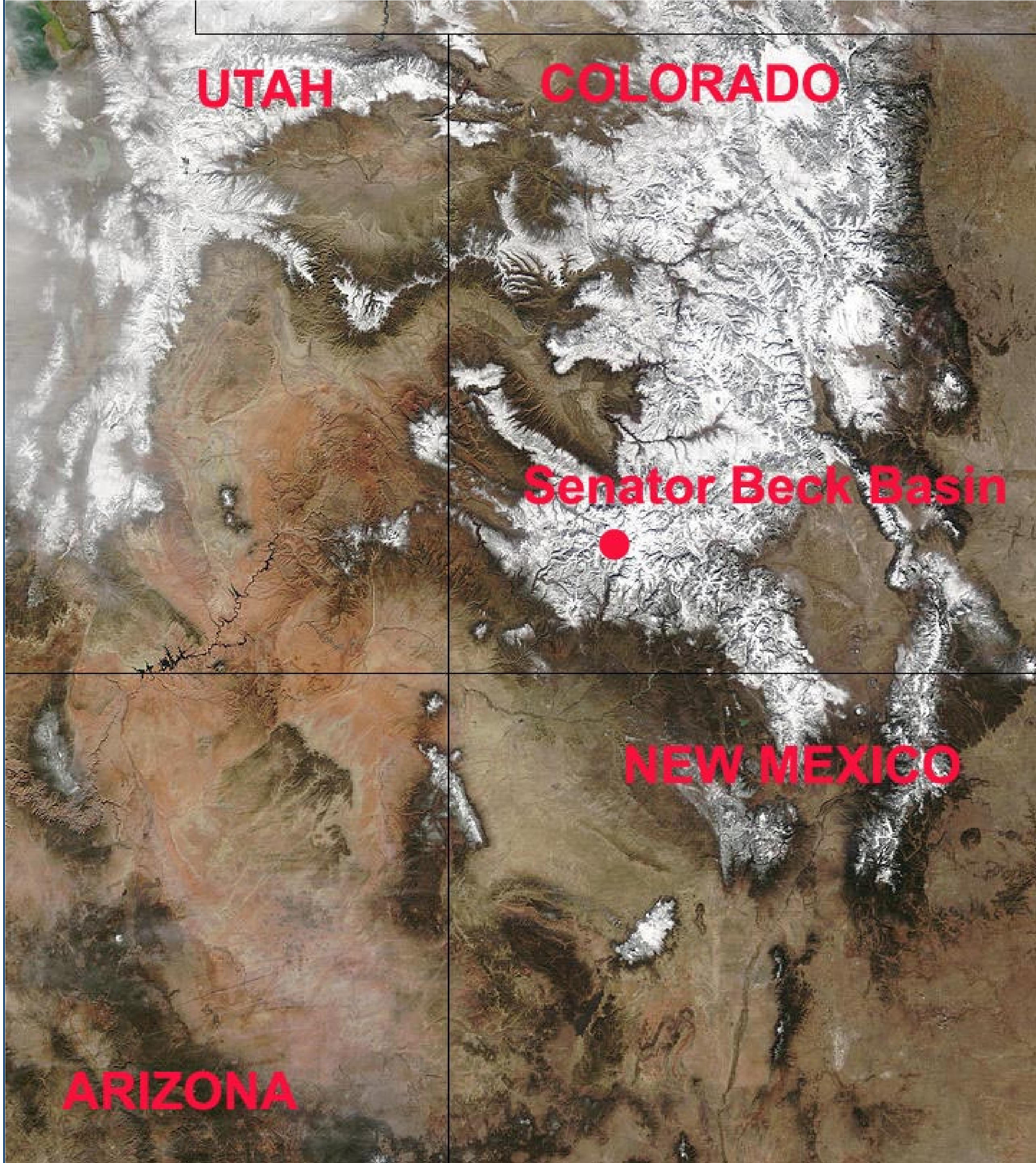
As discussed in chapter 1, climate change is expected to cause changes to streamflow, precipitation, and other hydroclimatic variables. The continuous long-term streamflow and meteorological records described in the preceding section are critical for detecting trends or shifts in the statistics of historical streamflow or other hydroclimatic variables. Such nonstationarity in hydroclimatic conditions would represent a change from the assumptions that have been used to design and manage water resource systems. Consequently, it is important to know if and how trends manifest themselves.

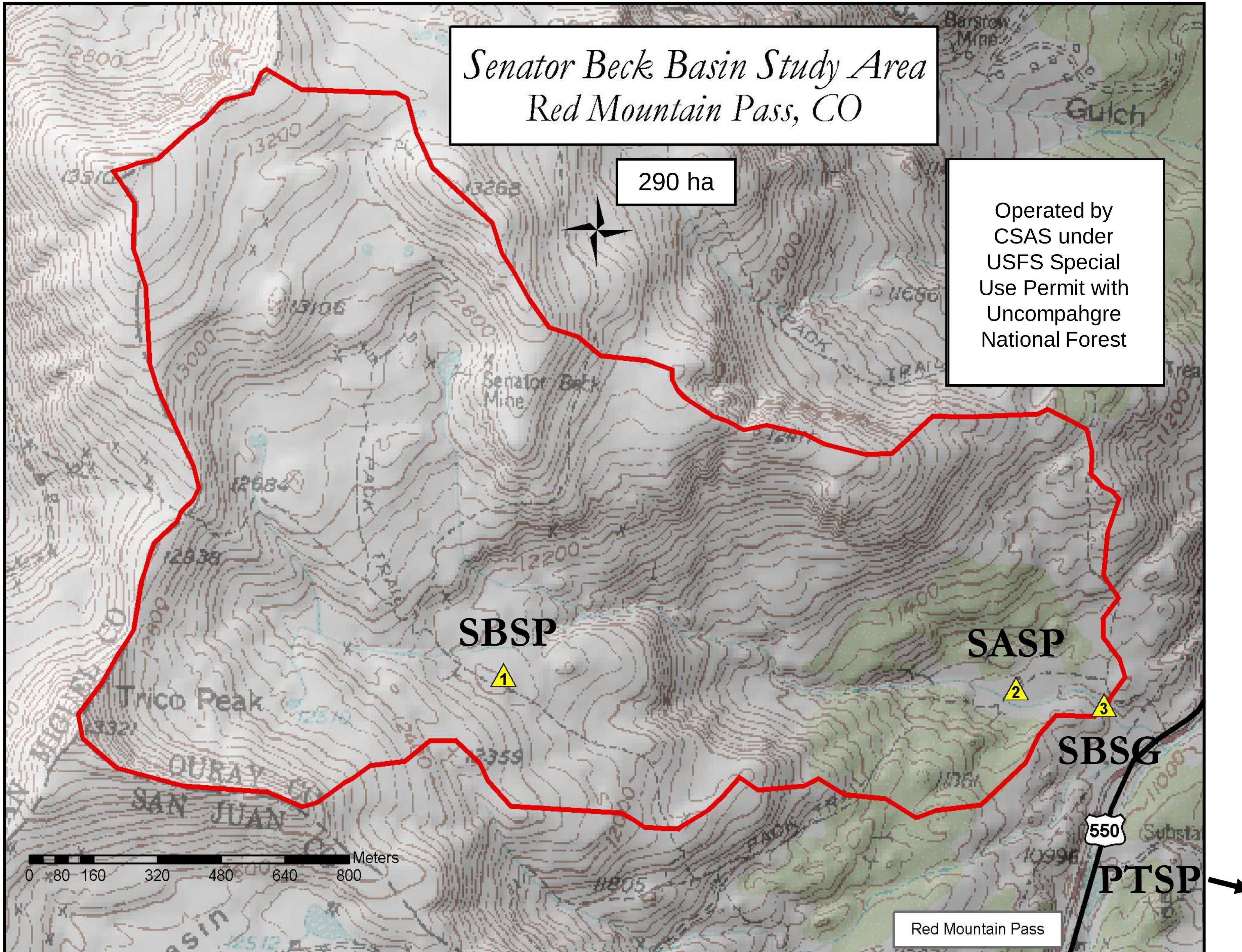
Trend detection must be carried out with care, as trends may also be caused by land use changes, changes in water infrastructure, or other factors. Furthermore, while the magnitude of a trend may be relatively easy to quantify, its statistical significance may be more ambiguous because of natural climate variability and long-term persistence, which can cause oscillatory patterns in long-term hydroclimatic records (Cohn and Lins, 2005).

SBBSA

Sentry Site for change in Upper CRB …

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




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
Senator Beck Mine
Trico Peak
Red Mountain Pass
550
Meters
0 80 160 320 480 640 800

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)

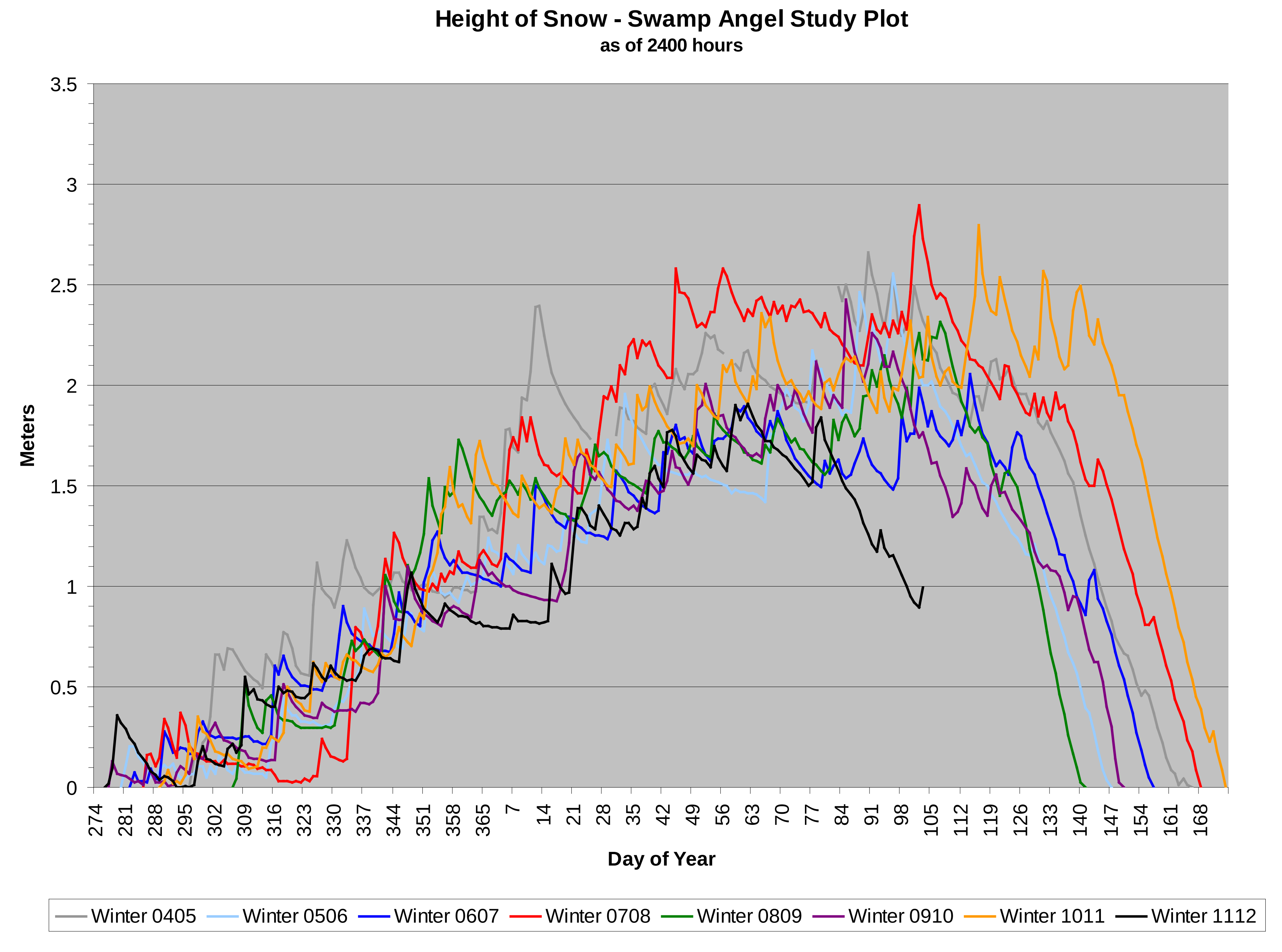
Infrared Snow Surface Temp

Snow Temperature (5)

Soil Temperature (4)

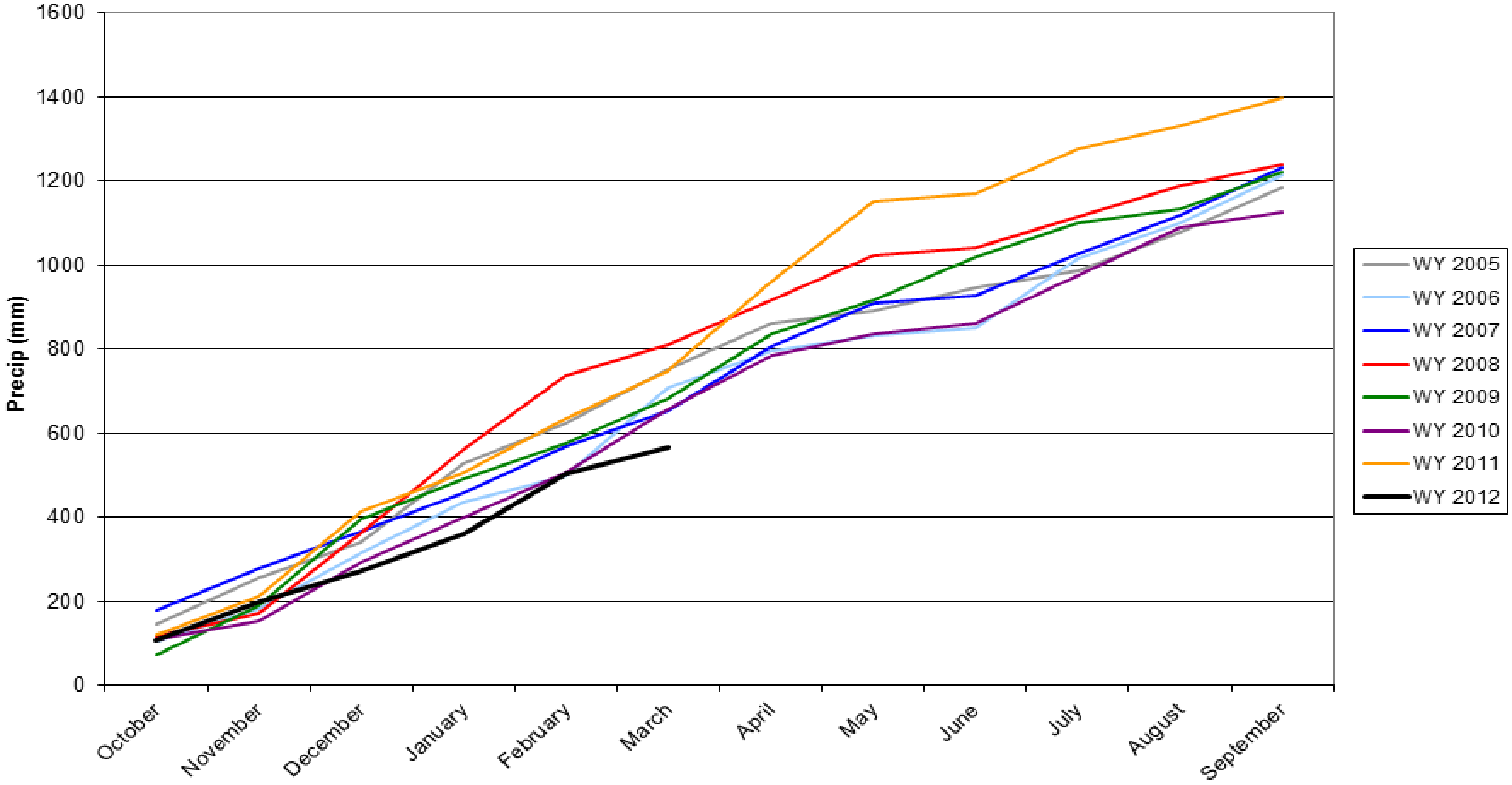
Soil Volumetric Water Content

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



Annual Precipitation Quantity, Timing, and Phase
Senator Beck Basin Study Area - Swamp Angel Study Plot

Water Year Monthly Means	Month	Mean Winter Storms	Mean Days Precip	Mean Total Precip - mm	Mean YTD Precip - mm	Mean Snow precip - mm	Mean Rain precip - mm
	October	2.2	11.4	108.3	108.3	79.6	28.8
Period of Record	November	3.3	11.6	93.1	201.4	90.9	2.2
= WY 2004 - WY 2012 (9 yrs)	December	3.7	16.1	137.0	338.4	135.2	1.8
= WY 2004 - WY 2011 (8 yrs)	January	3.4	13.1	117.2	455.7	117.2	0.0
= WY 2005 - WY 2011 (7 yrs)	February	3.3	15.9	118.2	573.9	118.2	0.0
	March	3.1	14.4	109.7	683.6	109.7	0.0
	April	4.4	15.0	138.4	836.6	138.4	0.0
	May	2.4	10.9	77.0	913.6	68.5	8.5
	June	0.4	6.6	36.0	973.1	6.1	29.9
	July	0.0	14.6	97.3	1070.4	0.0	97.3
	August	0.0	15.0	77.9	1148.3	0.0	77.9
	September	0.1	12.1	82.1	1230.4	12.7	69.4

Water Year Annual Means	Winter Storms	Days Precip	Total Precip - mm	YTD Precip - mm	Snow precip - mm	Rain precip - mm
Annual Means	26.3	161	1,230	1,230	910	321
Period of Record - Water Years	*2004-2011*	*2005-2011*	*2005-2011*	*2005-2011*	*2005-2011*	*2005-2011*
					73.9%	*26.1%*

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)

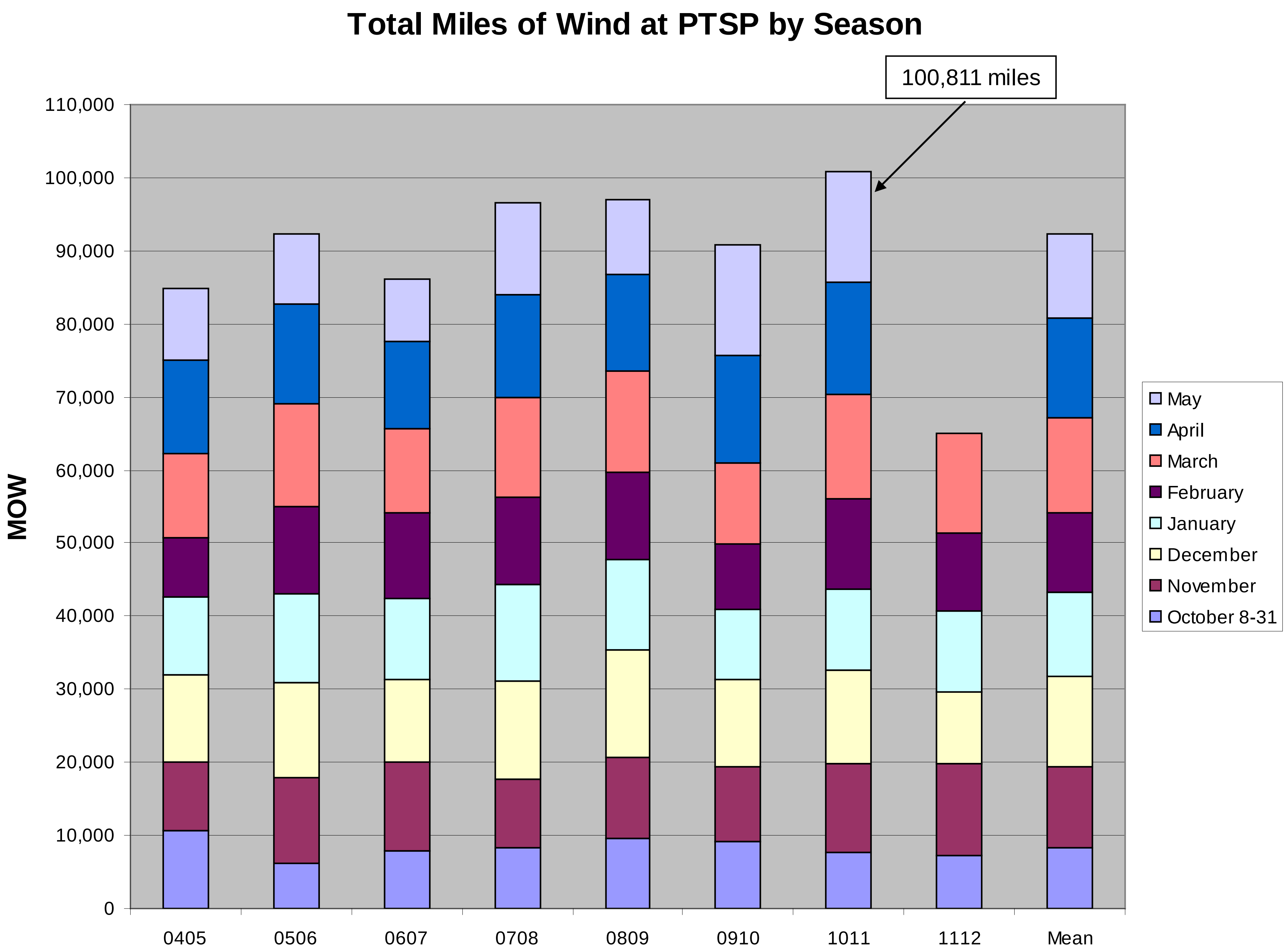
Soil Volumetric Water Content

Soil Heat Flux

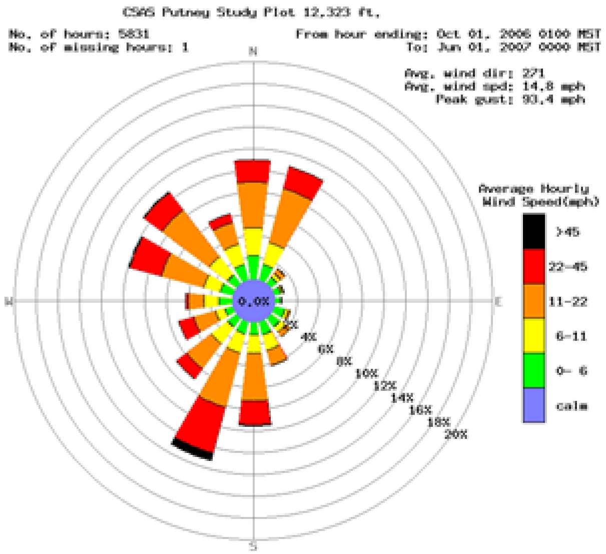
Snow Profile Plot

PTSP Instrumentation

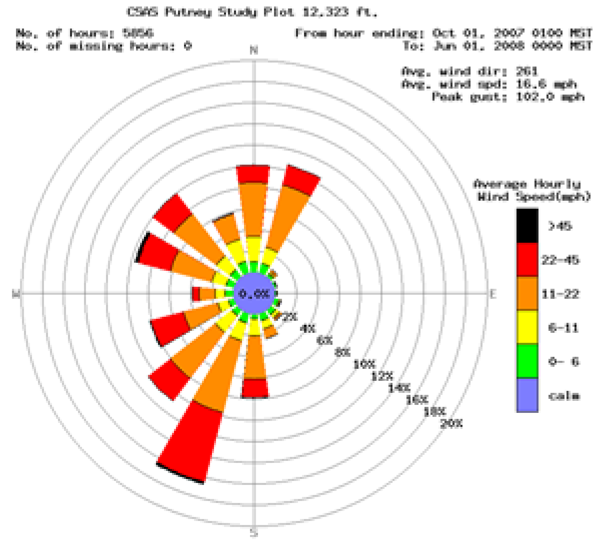
10 m Mast
Campbell CR10X Datalogger
Wind Speed & Direction
Air Temp and RH


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

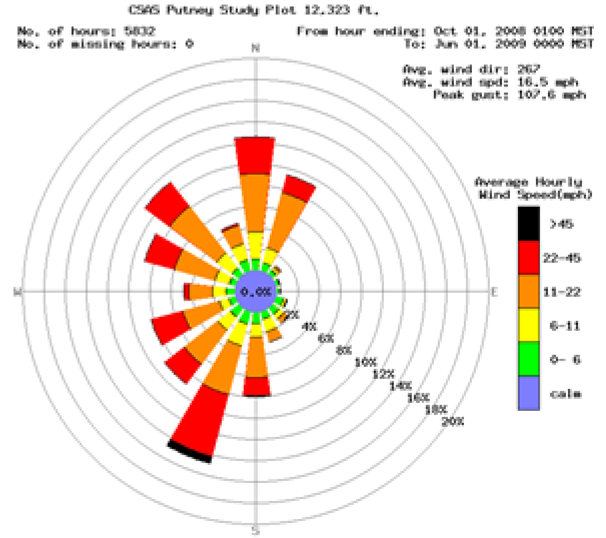
PTSP Winter Wind Roses (10/1 – 5/31)



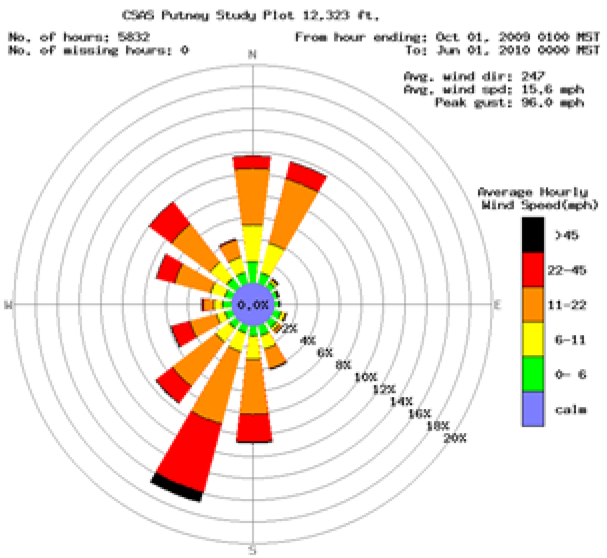
2006/2007



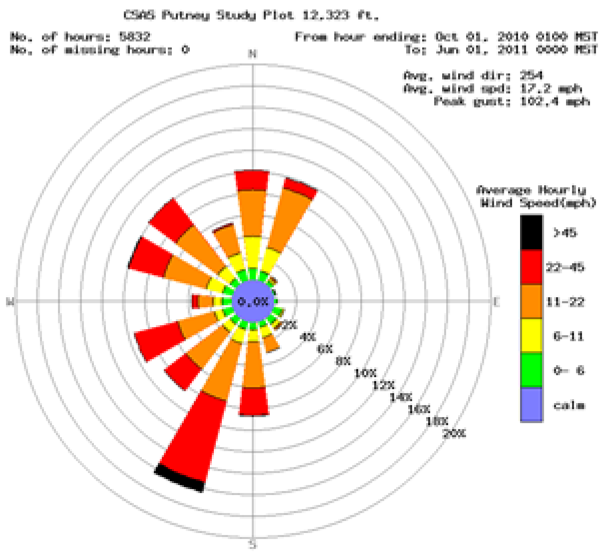
2007/2008



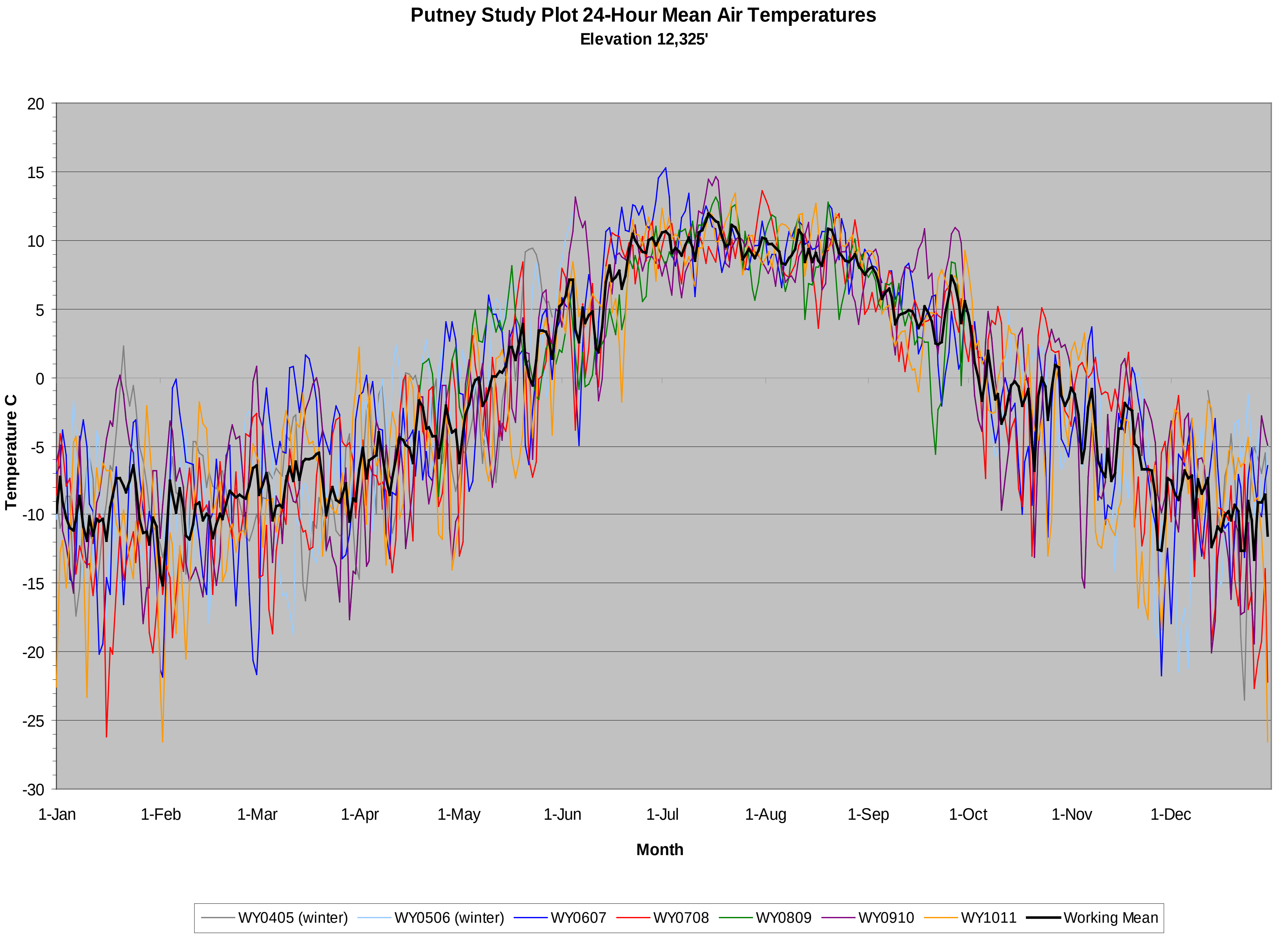
2008/2009



2009/2010



2010/2011


Putney Study Plot 24-Hour Mean Air Temperatures
Elevation 12,325'
Temperature C
20
15
10
5
0
-5
-10
-15
-20
-25
-30
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
Month
WY0405 (winter)
WY0506 (winter)
WY0607
WY0708
WY0809
WY0910
WY1011
Working Mean

SBSG Instrumentation

Broad-crested, notched weir

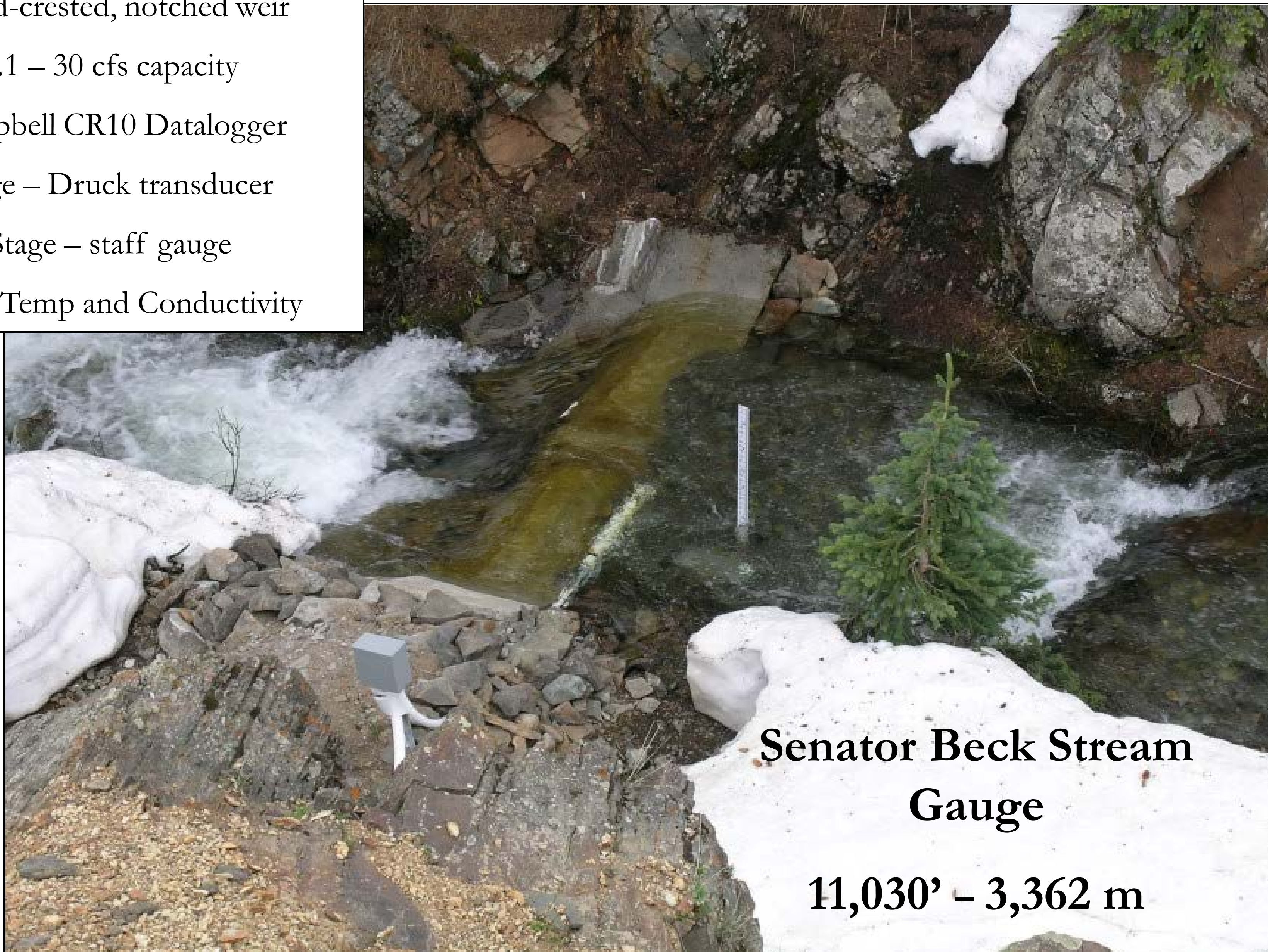
0.1 – 30 cfs capacity

Campbell CR10 Datalogger

Stage – Druck transducer

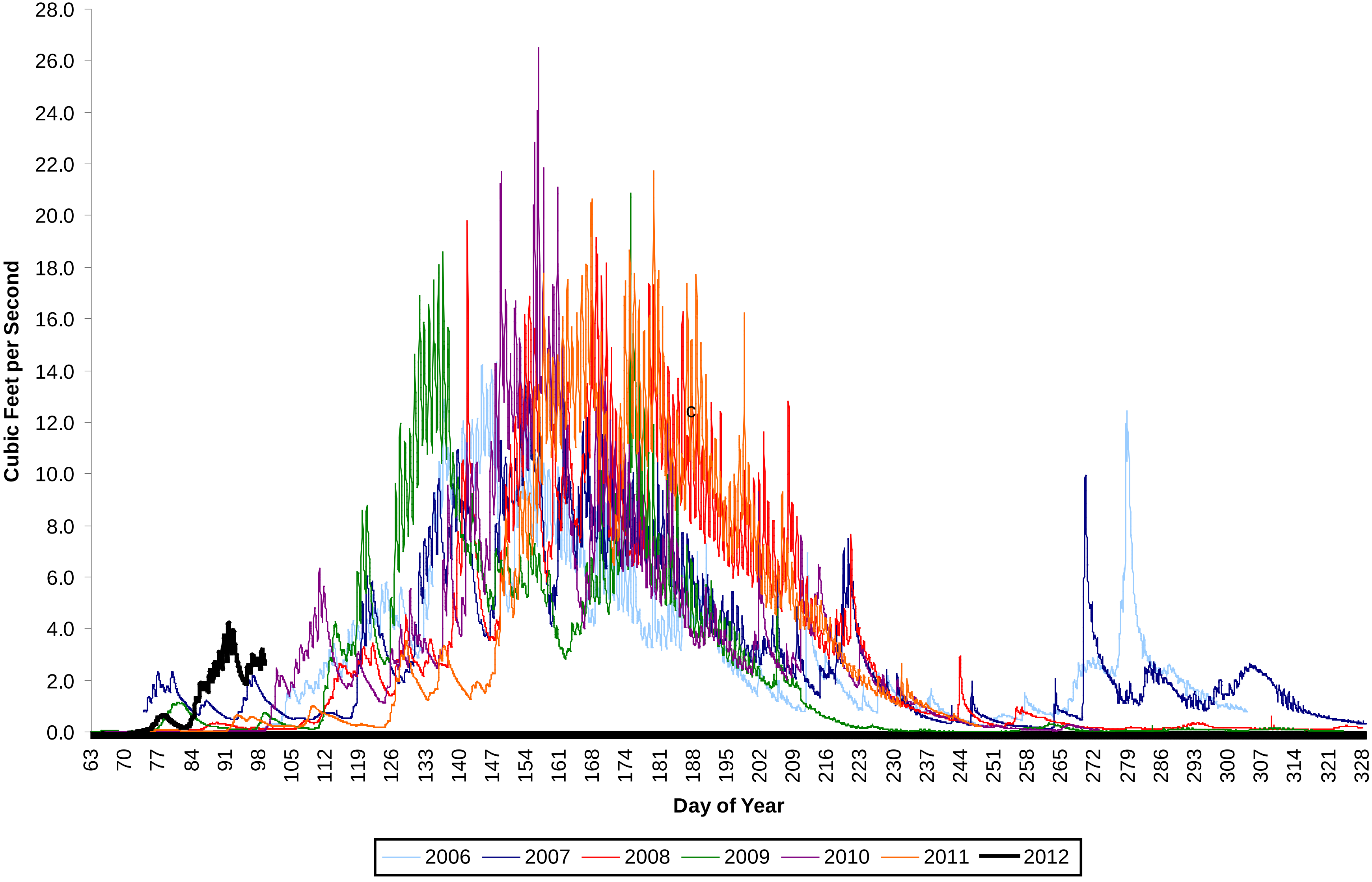
Stage – staff gauge

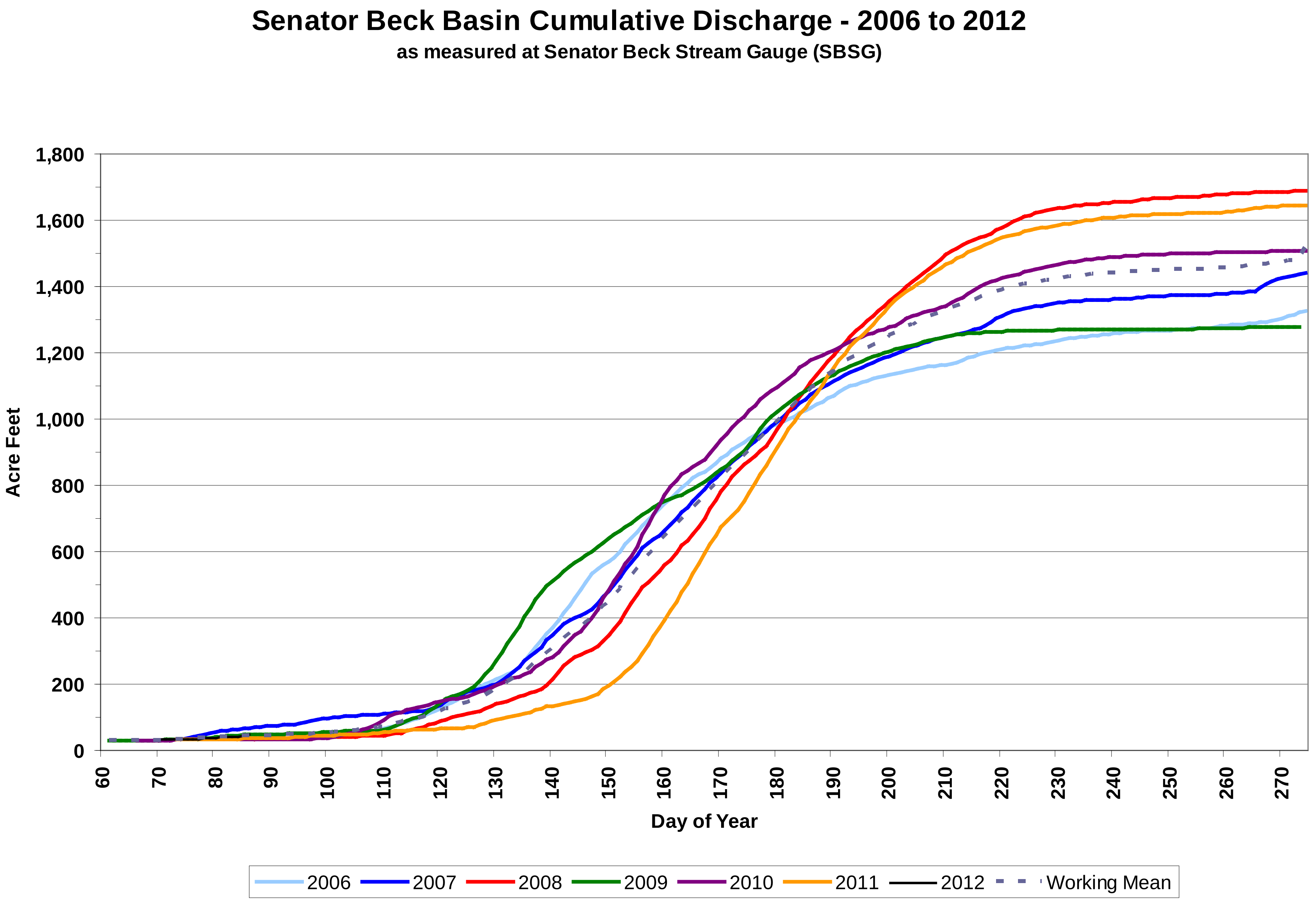
Water Temp and Conductivity



Senator Beck Basin Hourly Discharge

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





Senator Beck Basin Cumulative Discharge - 2006 to 2012
as measured at Senator Beck Stream Gauge (SBSG)
Acre Feet
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
Day of Year
2006
2007
2008
2009
2010
2011
2012
Working Mean

Senator Beck Basin Long-term Vegetation Study 2009 Re-Survey

Final Report Presented to the
Center for Snow and Avalanche Studies, Silverton, Colorado

January 2010

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			

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).

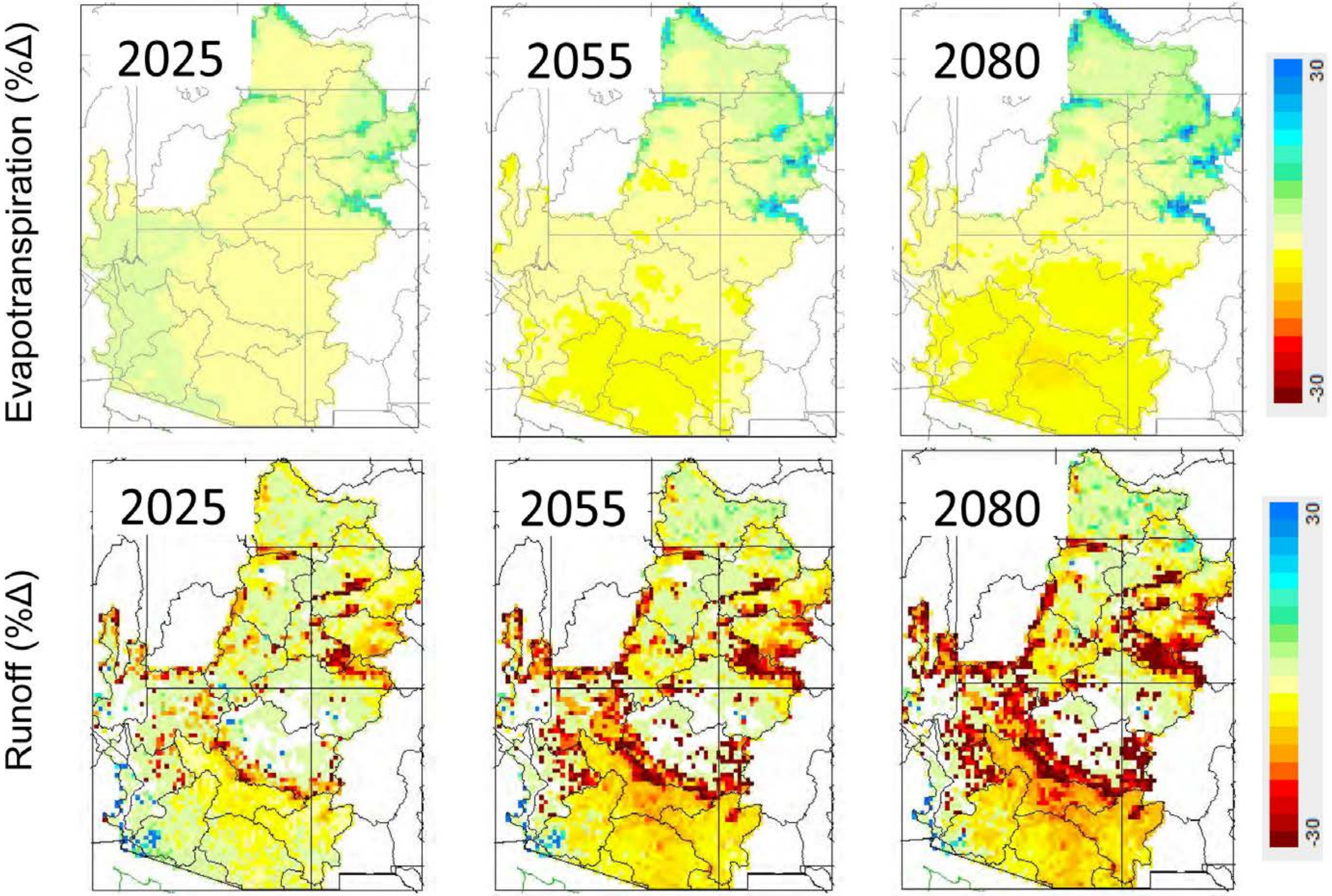
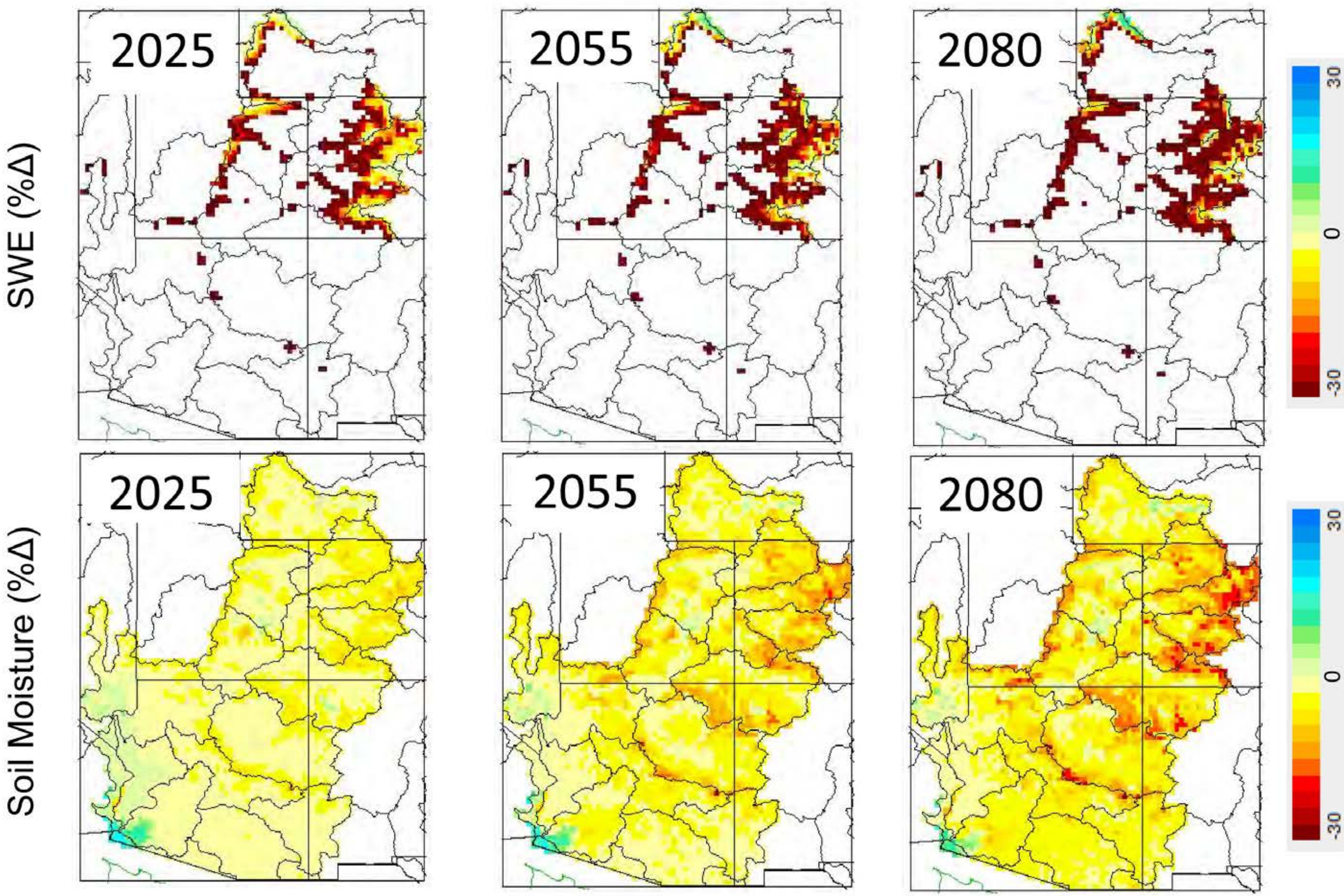
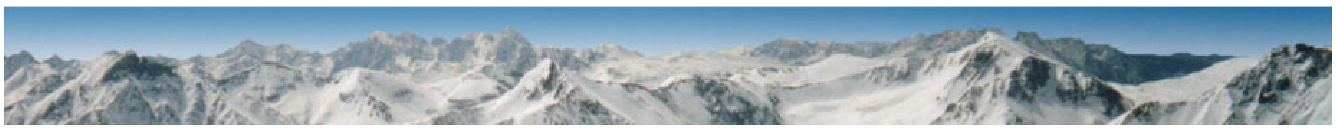


FIGURE B- 41
Mean Projected Percent Change in April 1 SWE and July 1 Soil Moisture
2025 (2011–2040) versus 1985 (1971–2000); 2055 (2041–2070) versus 1985 (1971–2000); and 2080 (2066–2095) versus 1985 (1971–2000).



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!

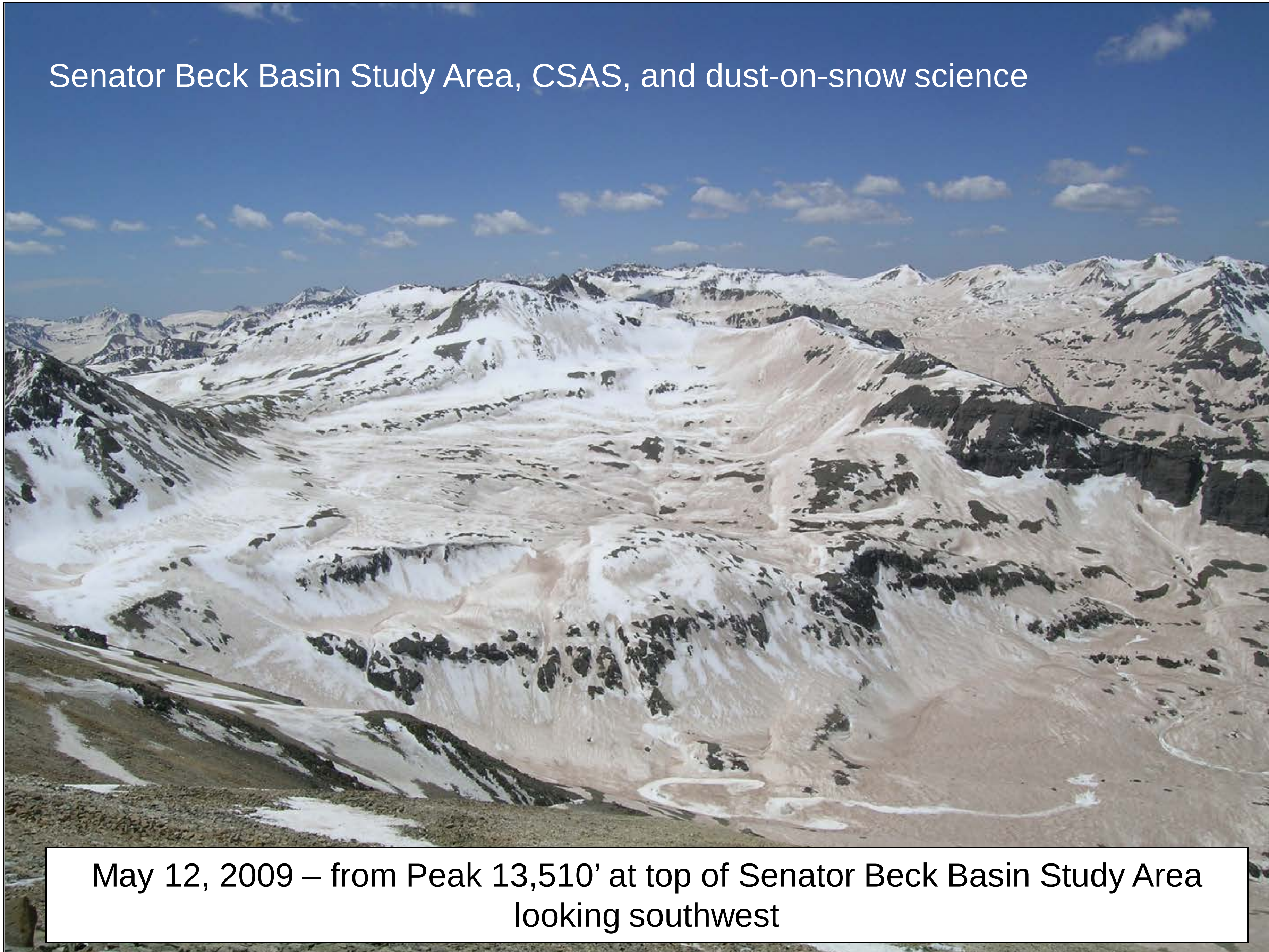
Why should CSAS get funded?

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.

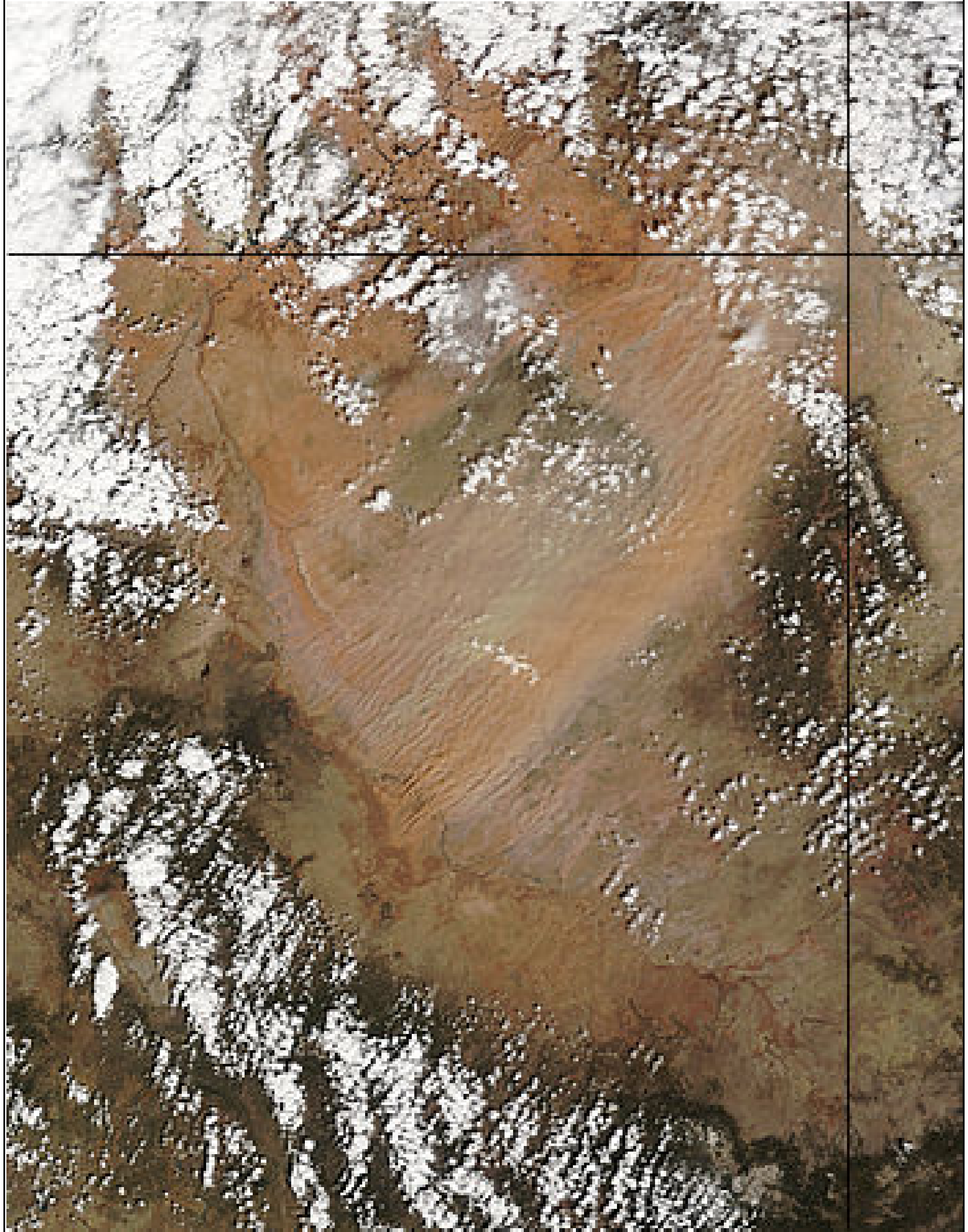
Why isn't CSAS funded by more foundations or by NSF?

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, CSAS, and dust-on-snow science



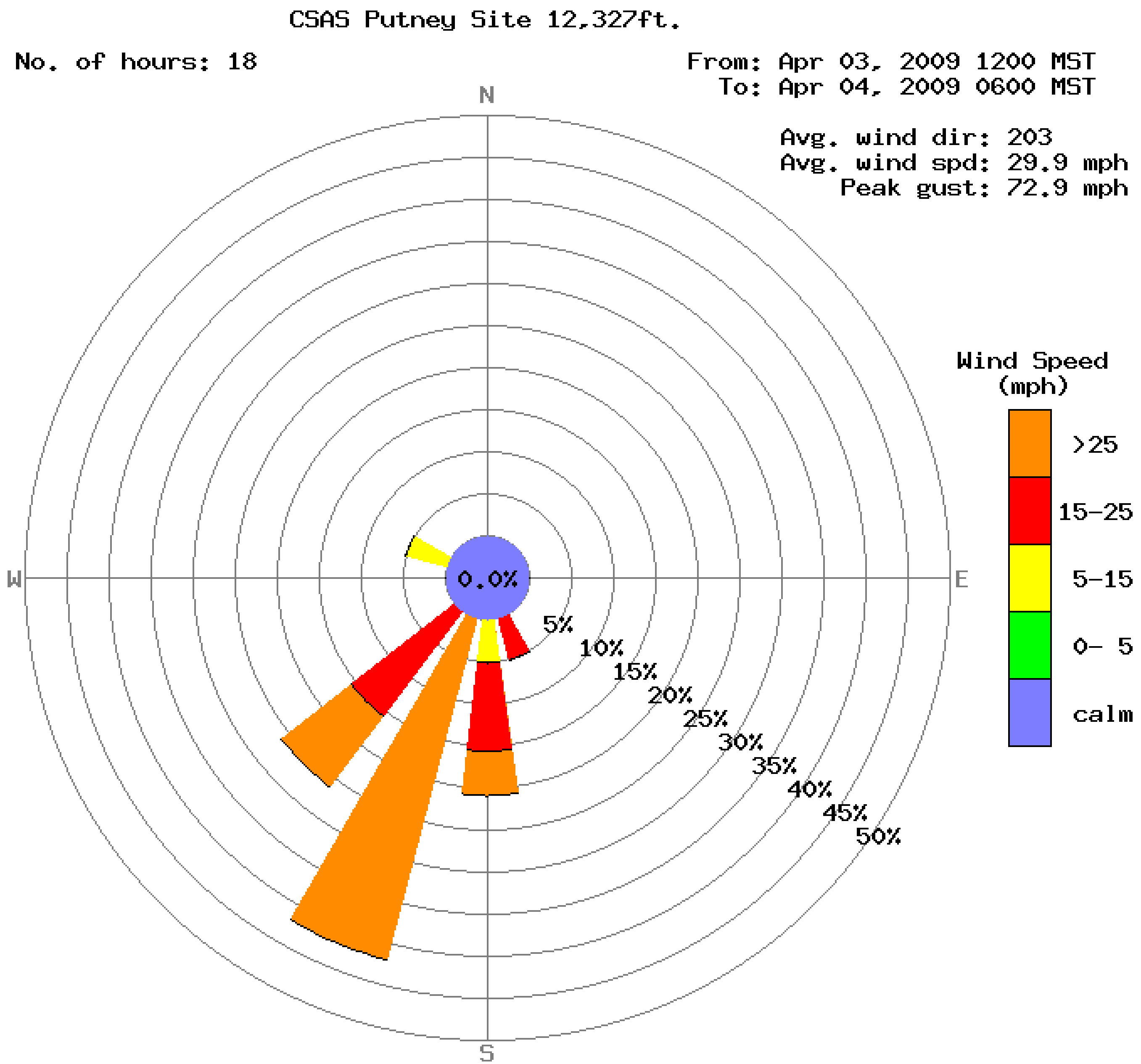
May 12, 2009 – from Peak 13,510' at top of Senator Beck Basin Study Area looking southwest



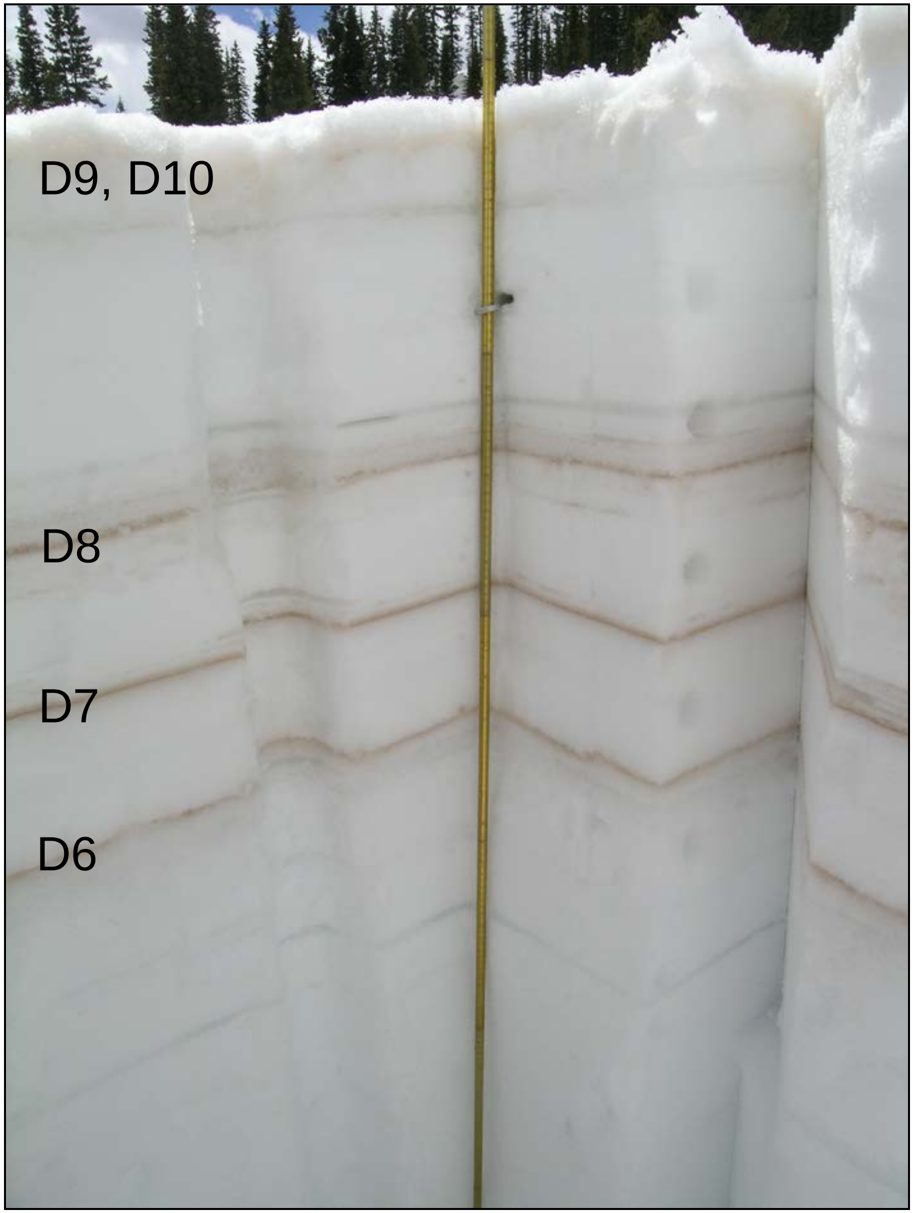
D8 – WY2009
Little Colorado River
April 3, 2009


D8 – WY2009
Silverton
April 3, 2009

D8 – WY2009 – Senator Beck Basin



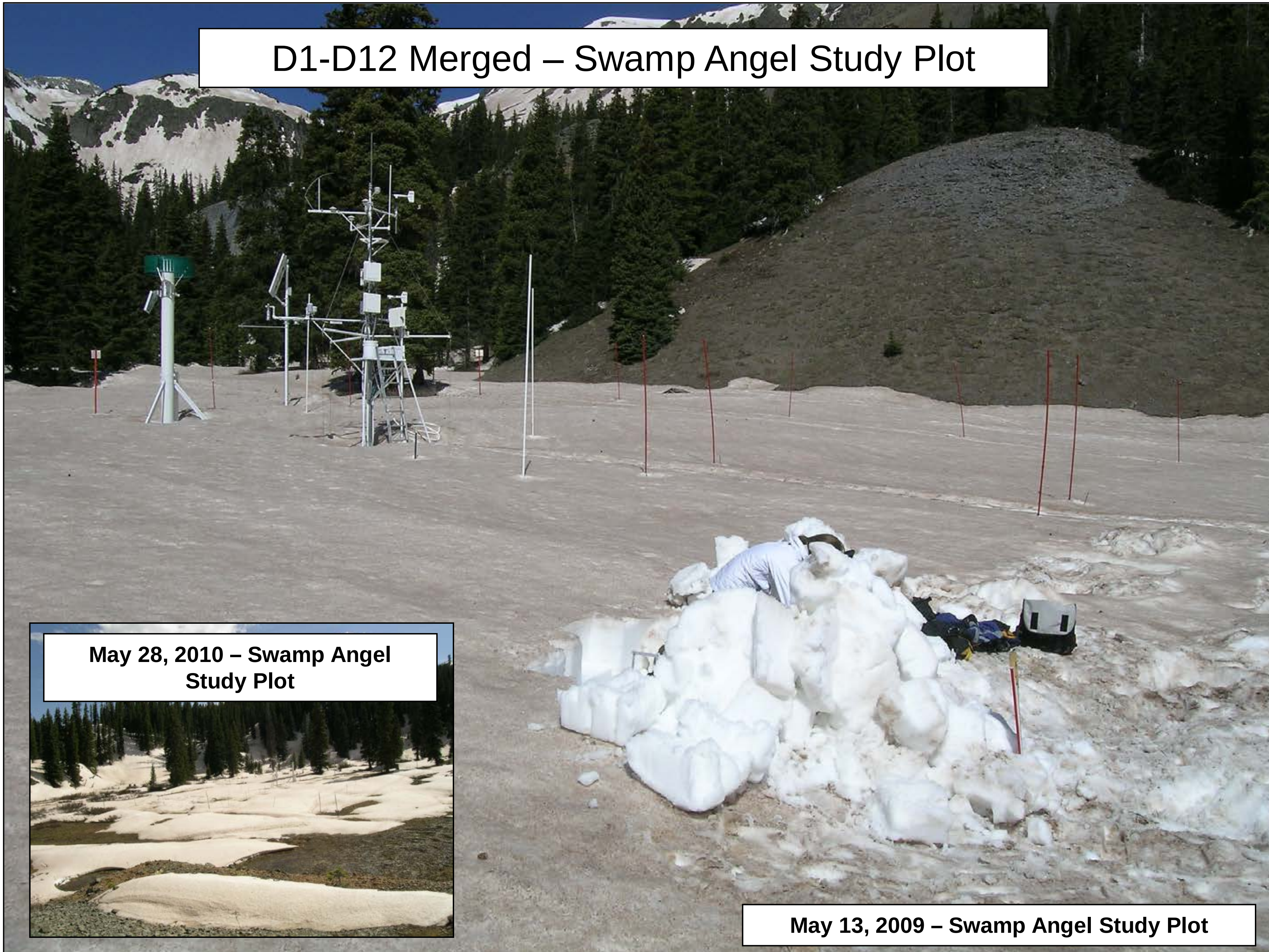
Senator Beck Basin: March and April 2009 Dust Layers



SASP – April 22, 2009

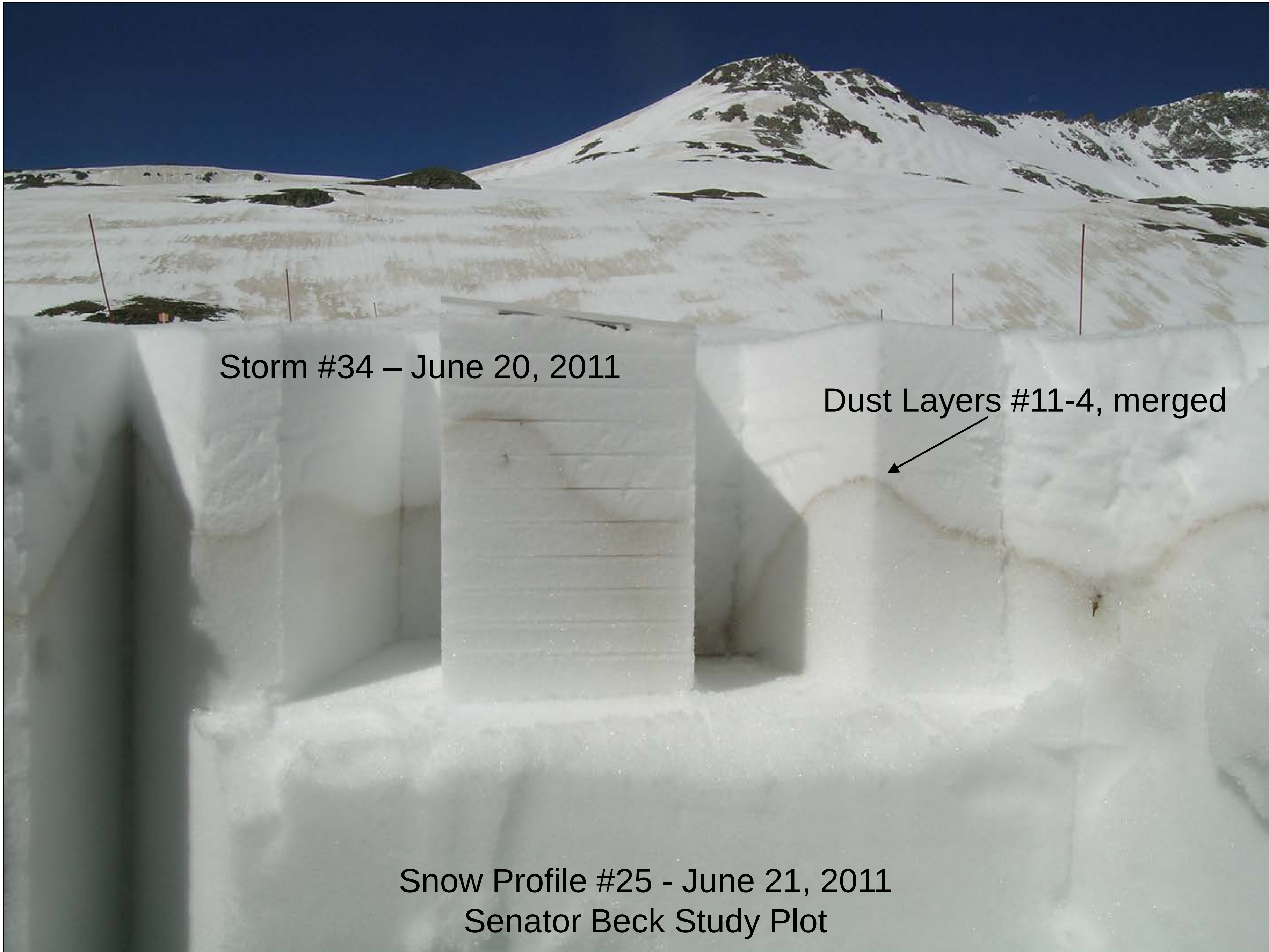
SBSP – April 24, 2009

D1-D12 Merged – Swamp Angel Study Plot

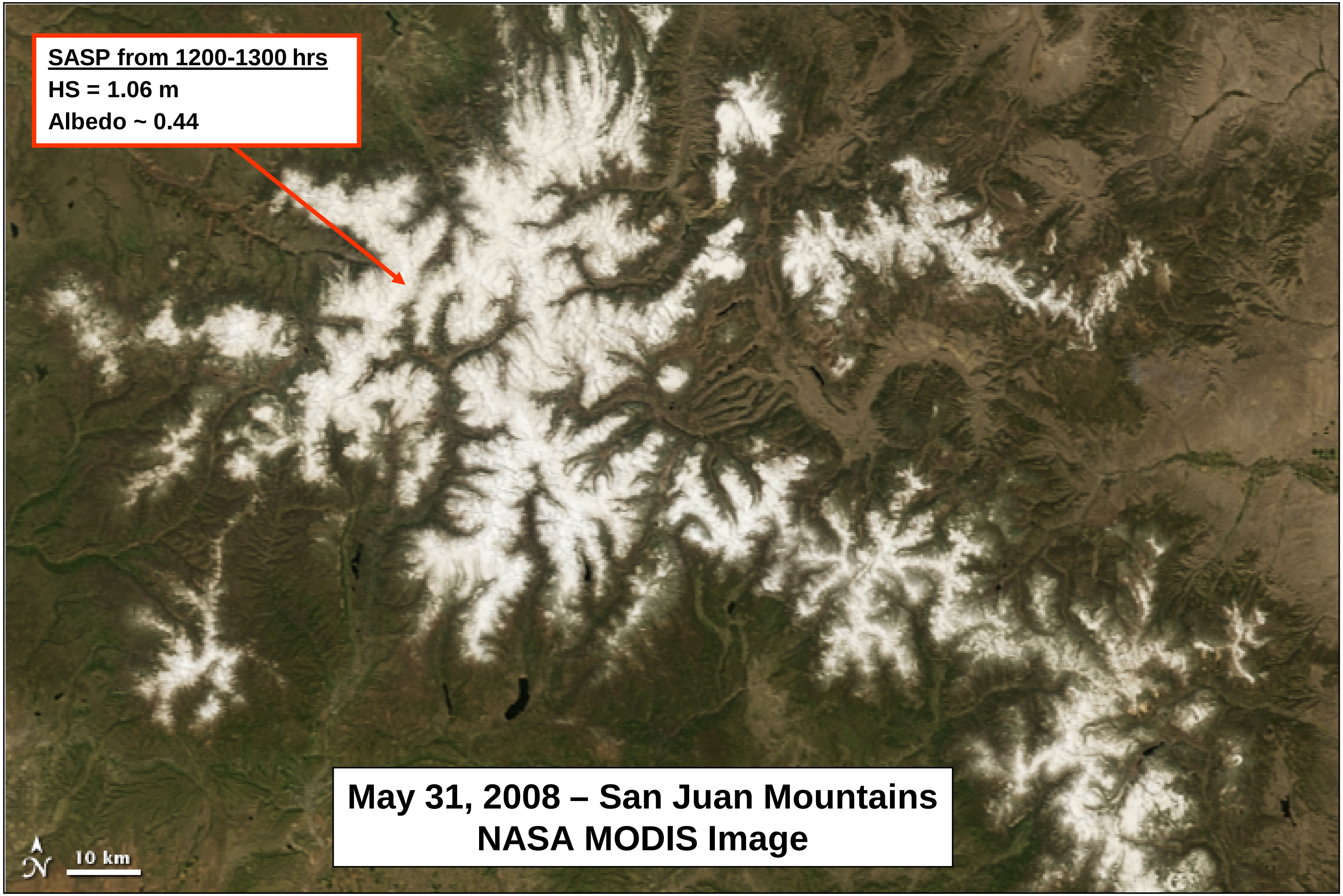


May 28, 2010 – Swamp Angel Study Plot

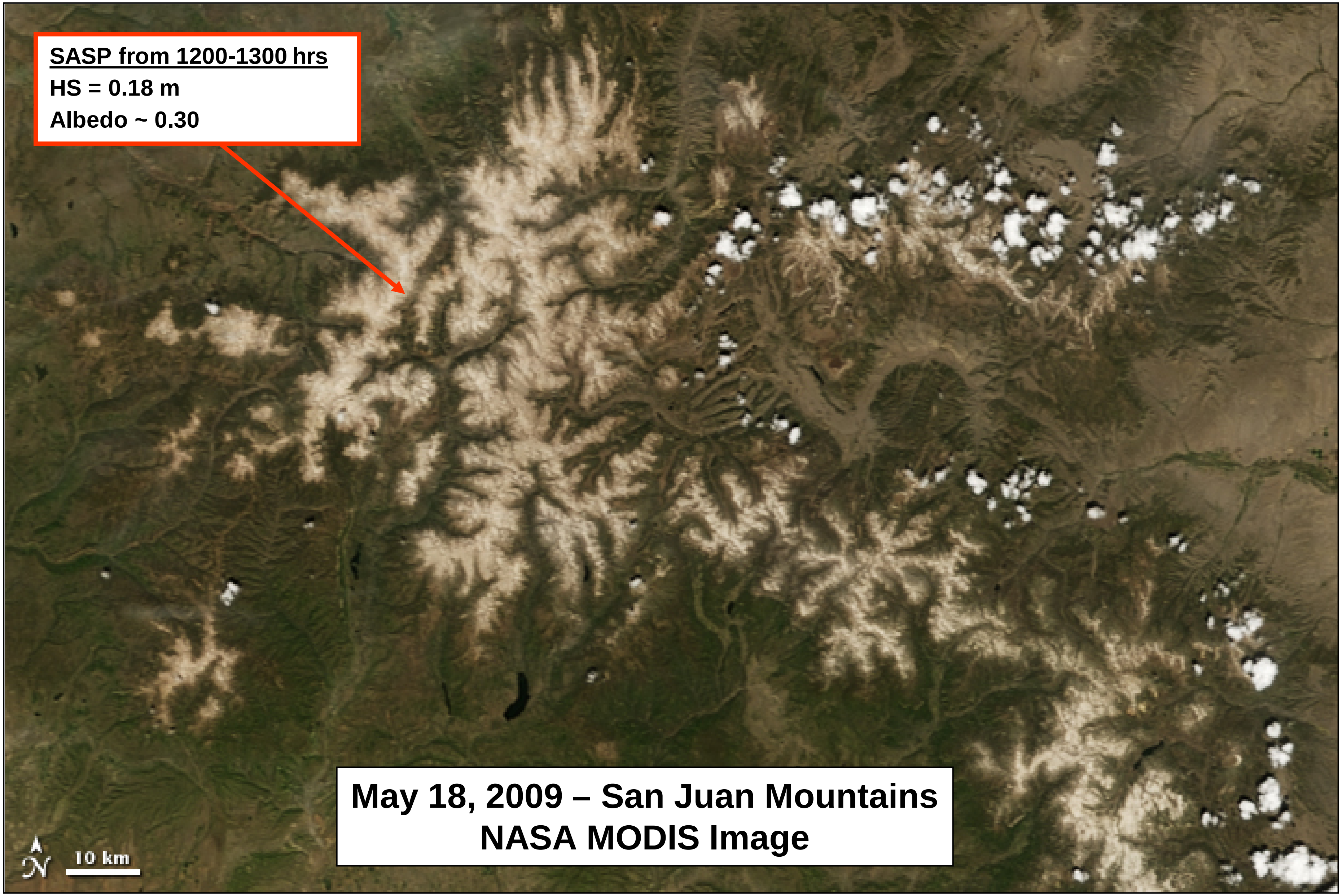
May 13, 2009 – Swamp Angel Study Plot


Storm #34 – June 20, 2011
Dust Layers #11-4, merged
Snow Profile #25 - June 21, 2011
Senator Beck Study Plot

Large-Scale Albedo Reductions



Large-Scale Albedo Reductions

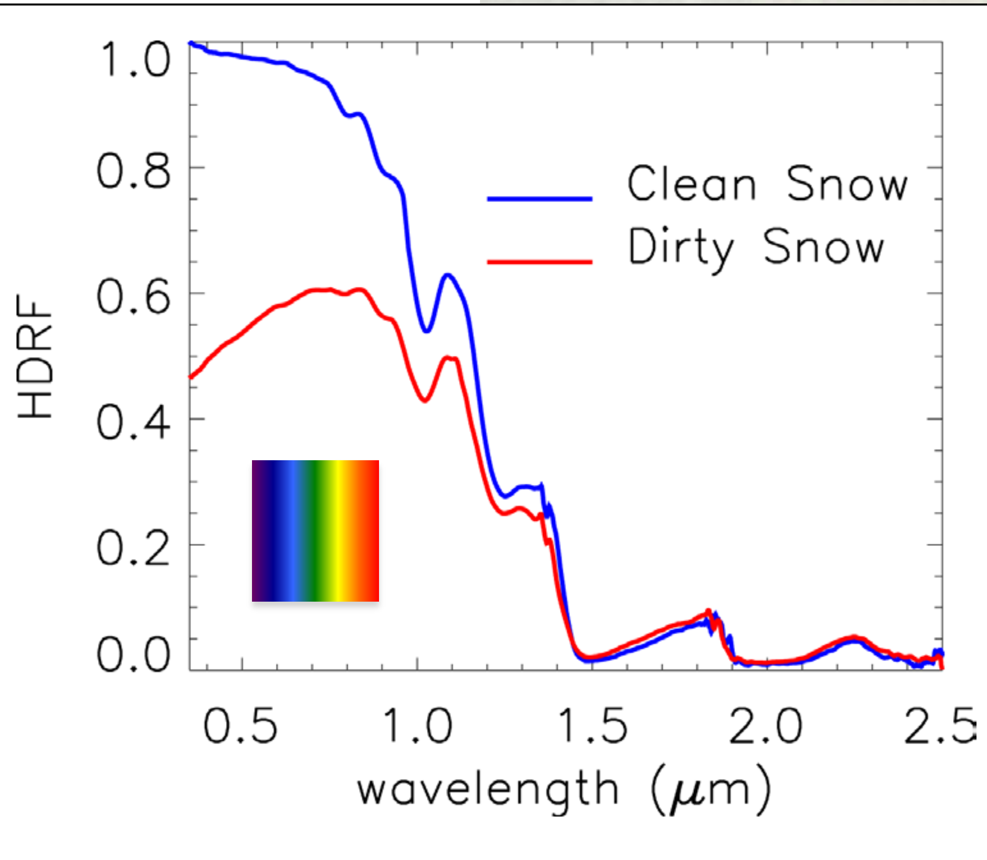


Dust-on-Snow Events Documented per Month, by Winter

Senator Beck Basin Study Area at Red Mountain Pass – San Juan Mountains

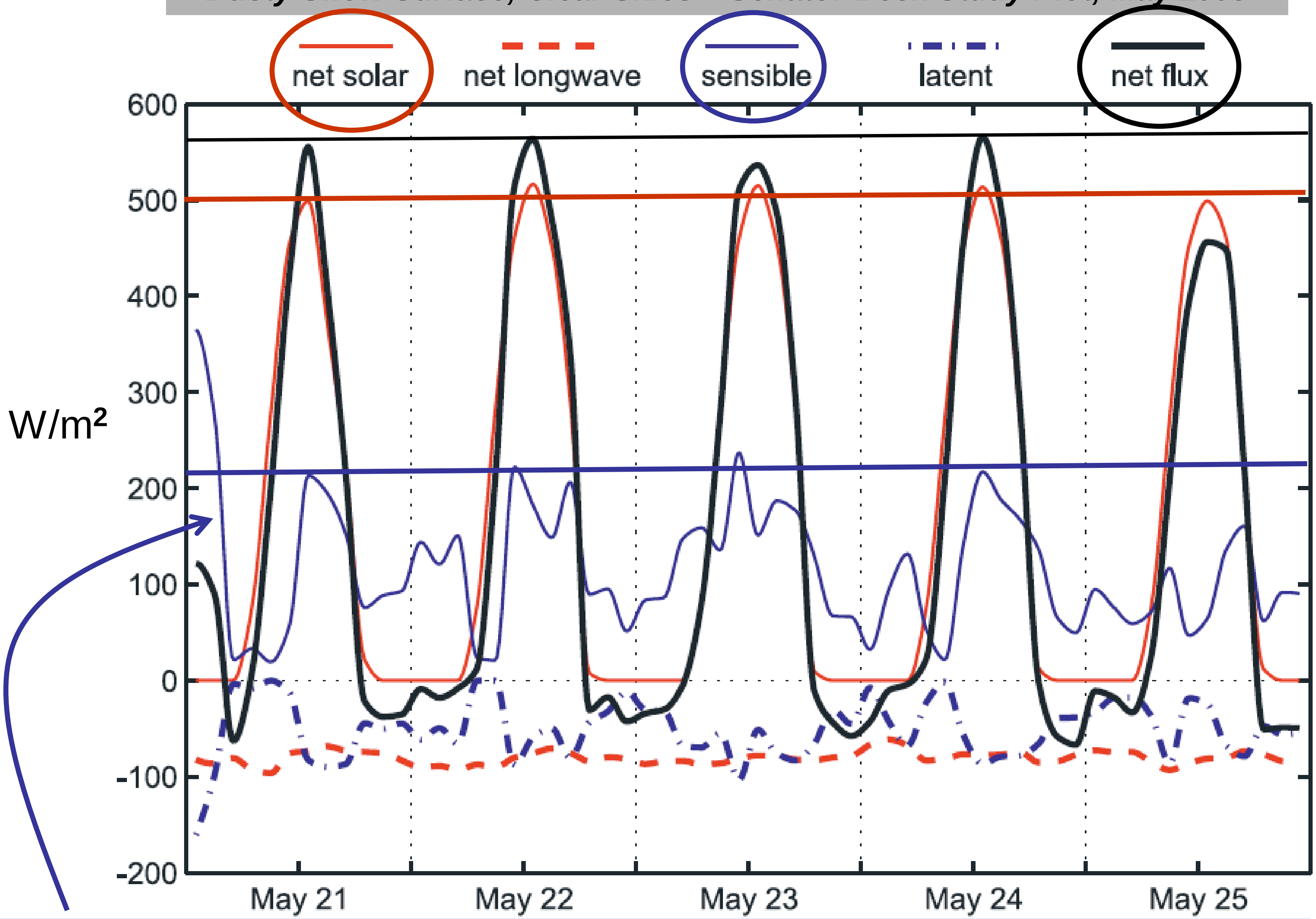
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
2002/2003					2		1			**3**
2003/2004							2	1		**3**
2004/2005	0	0	0	0	0	1	2	1	0	**4**
2005/2006	0	0	1	0	1	1	3	2	0	**8**
2006/2007	0	0	1	0	1	1	3	1	1	**8**
2007/2008	0	0	0	0	0	3	3	1	0	**7**
2008/2009	1	0	1	0	1	4	5	0	0	**12**
2009/2010	1	0	0	0	0	1	4	3	0	**9**
2010/2011	0	0	0	0	1	3	3	4	0	**11**
2011/2012	0	2	1	0	0	3	*2*			8 to-date

Dust decreases snow albedo



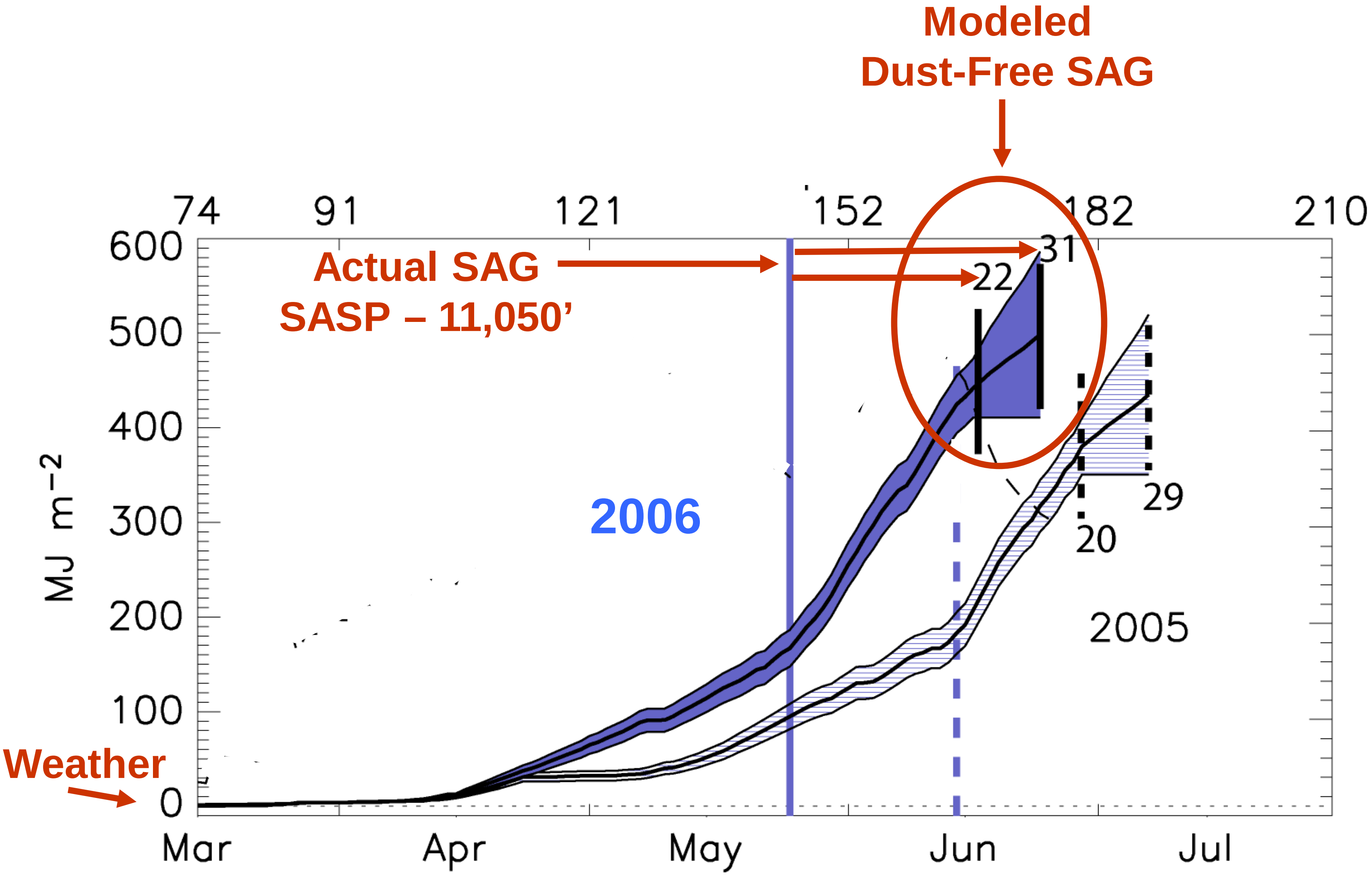
Enhanced Snowmelt Energy Input

Dusty Snow Surface, Clear Skies – Senator Beck Study Plot, May 2005

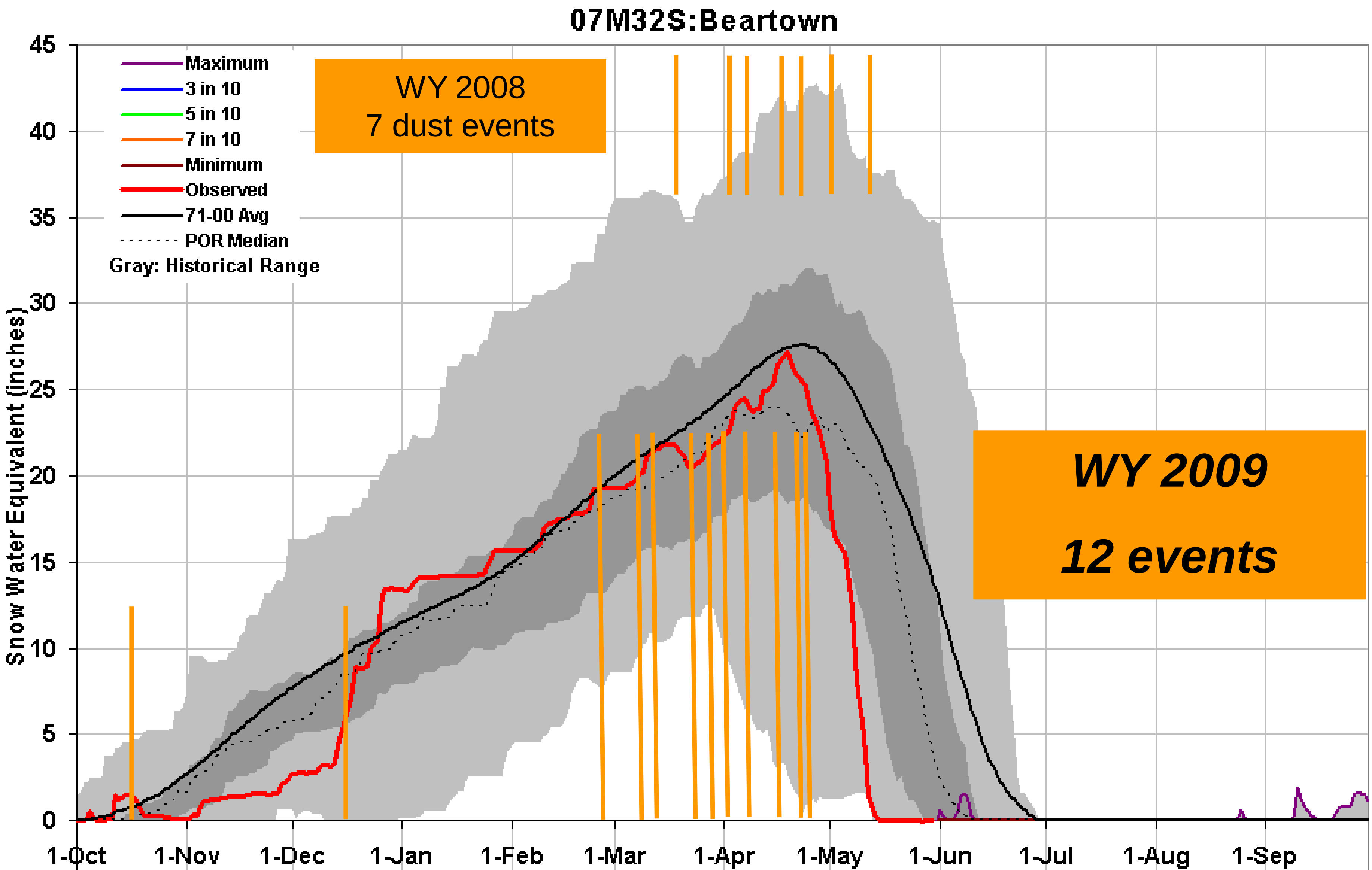


Max Air T	57 F	57 F	56 F	53 F	56 F

Radiative Forcing by Dust

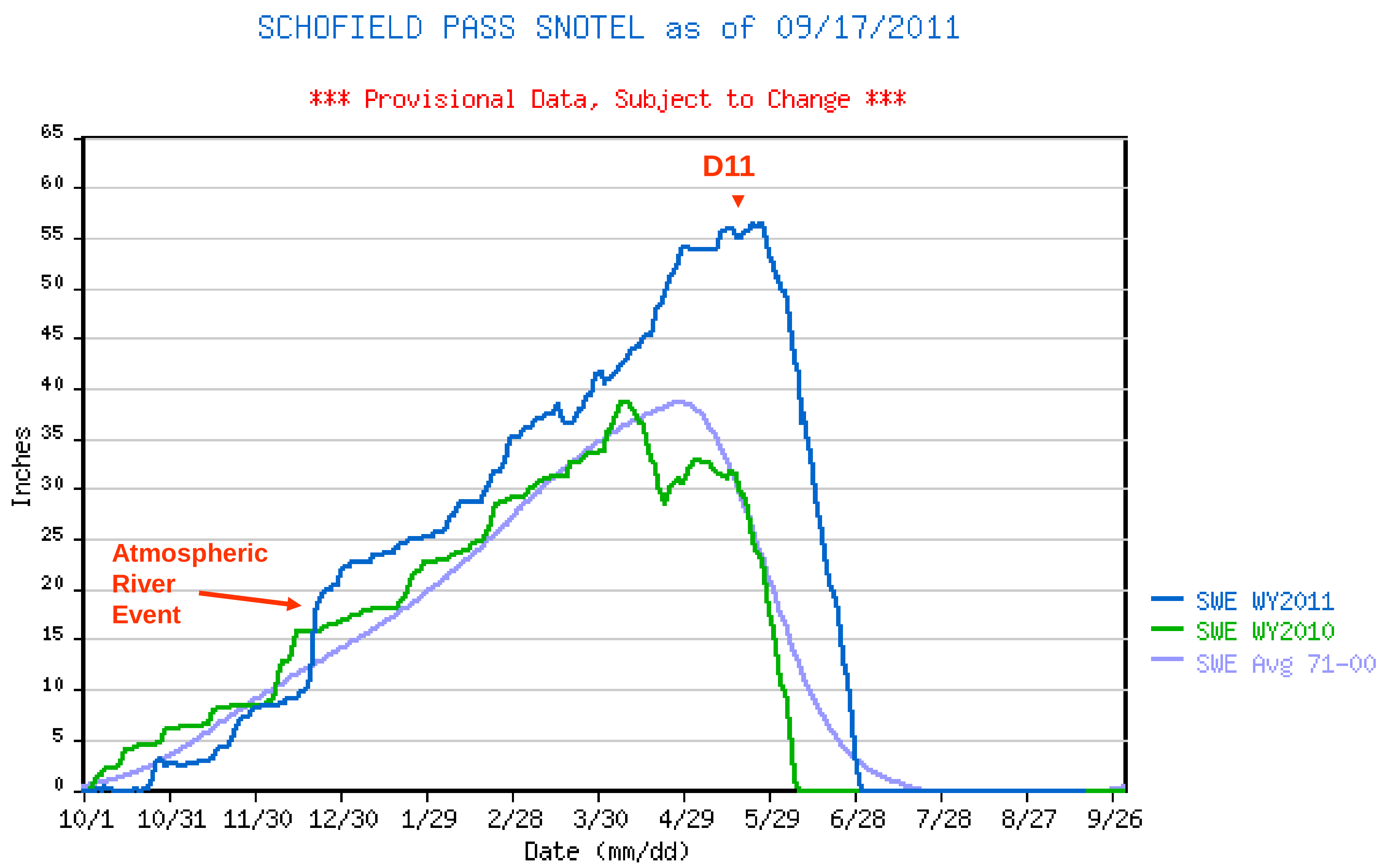


Created: 10:48 AM May 31, 2009



NRCS

This is an automated product based on SNOTEL data, provisional data are subject to change.
This product combines the historical period of record data (**gray background**) with the recent daily data (**heavy red, left**) to project into the future (**colored lines, right**). This product does not consider climate information such as El Nino or short range weather forecasts and therefore should only be used as a seasonal planning tool. Contact Tom.Pagano@por.usda.gov 503 414 3010

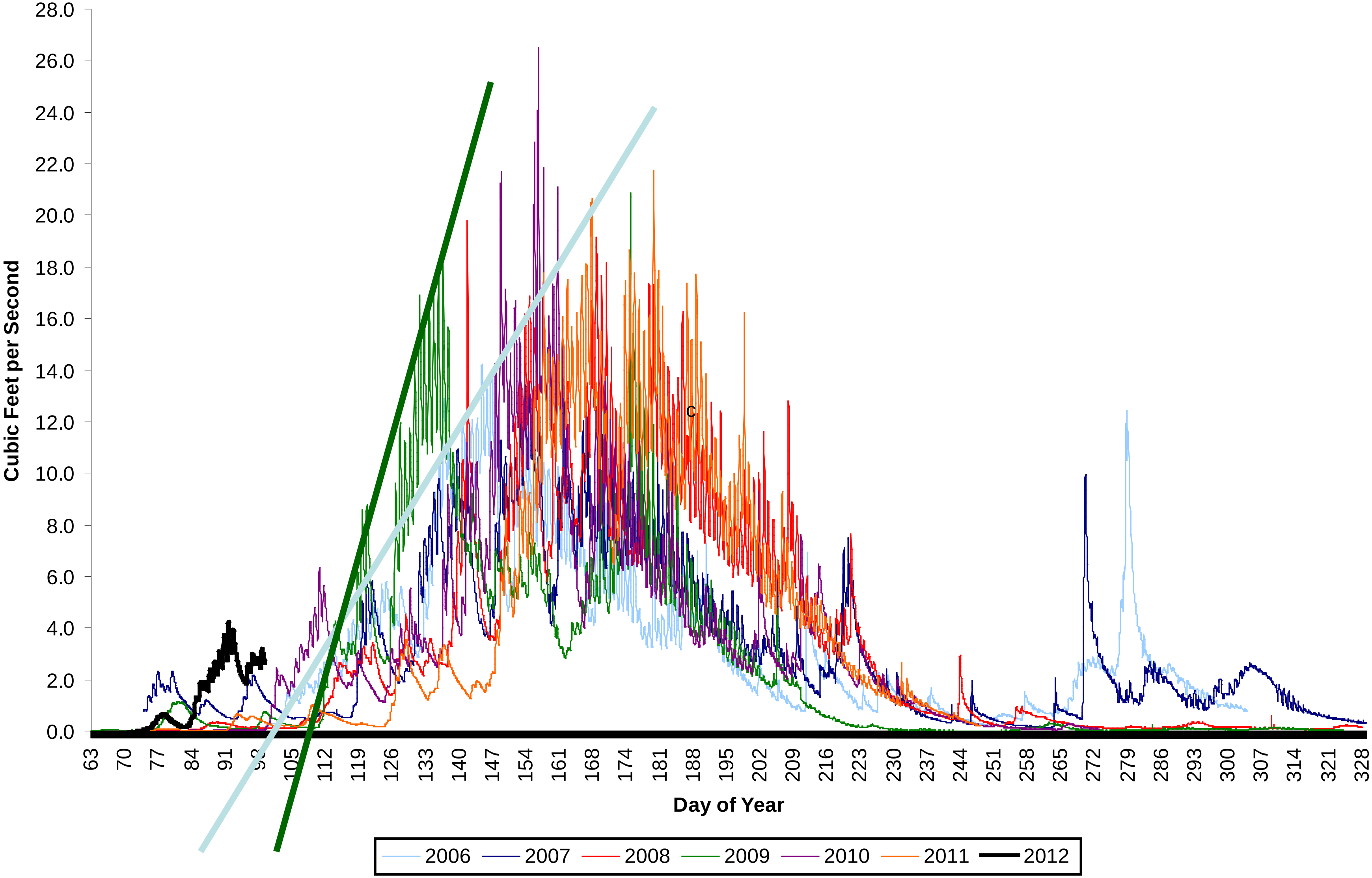


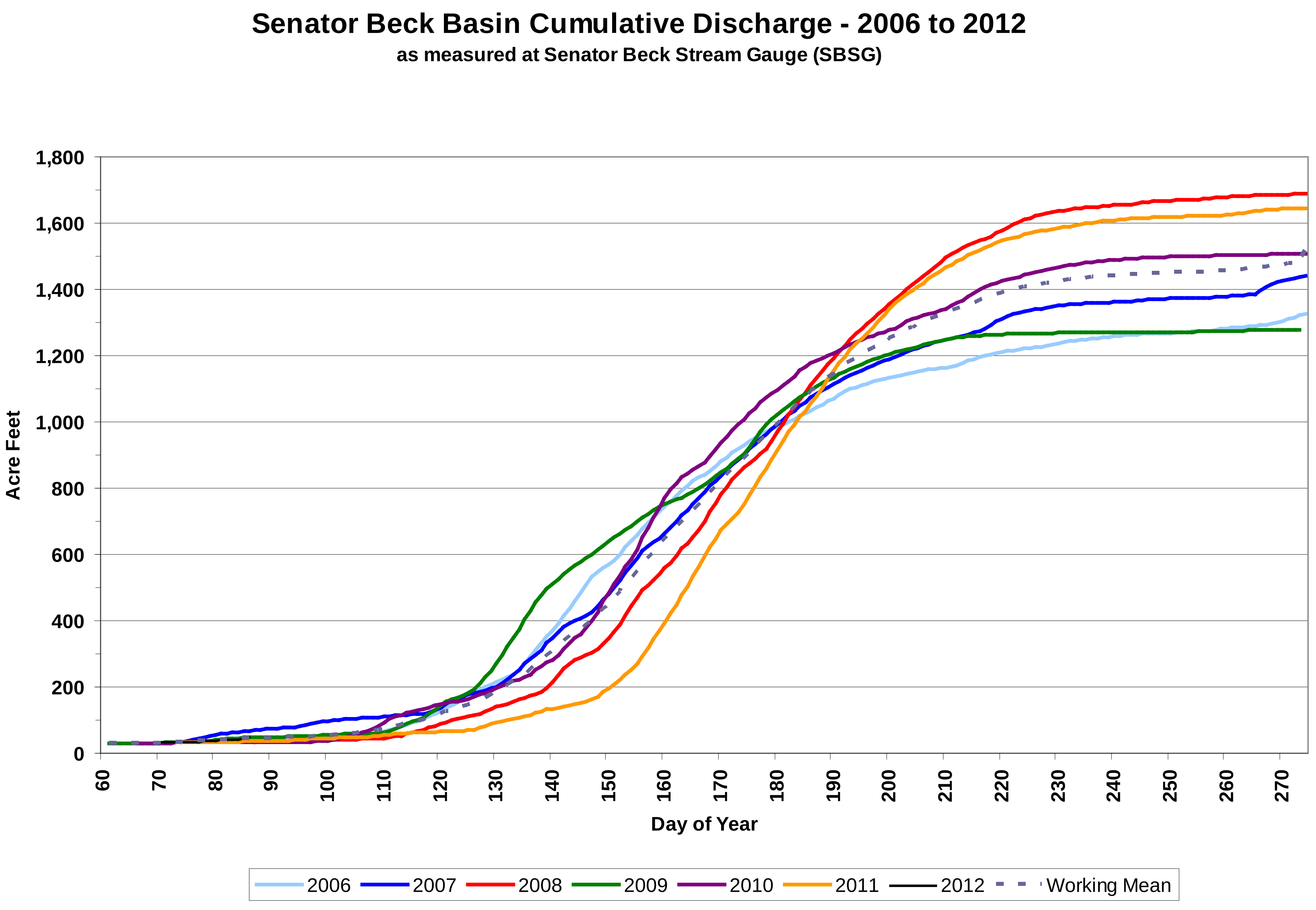
SCHOFIELD PASS SNOTEL as of 09/17/2011
*** Provisional Data, Subject to Change ***
D11
Atmospheric River Event
Inches
65
60
55
50
45
40
35
30
25
20
15
10
5
0
10/1
10/31
11/30
12/30
1/29
2/28
3/30
4/29
5/29
6/28
7/28
8/27
9/26
Date (mm/dd)
SWE WY2011
SWE WY2010
SWE Avg 71-00

June 5, 2010 –Senator Beck Stream Gauge at ~26 cfs

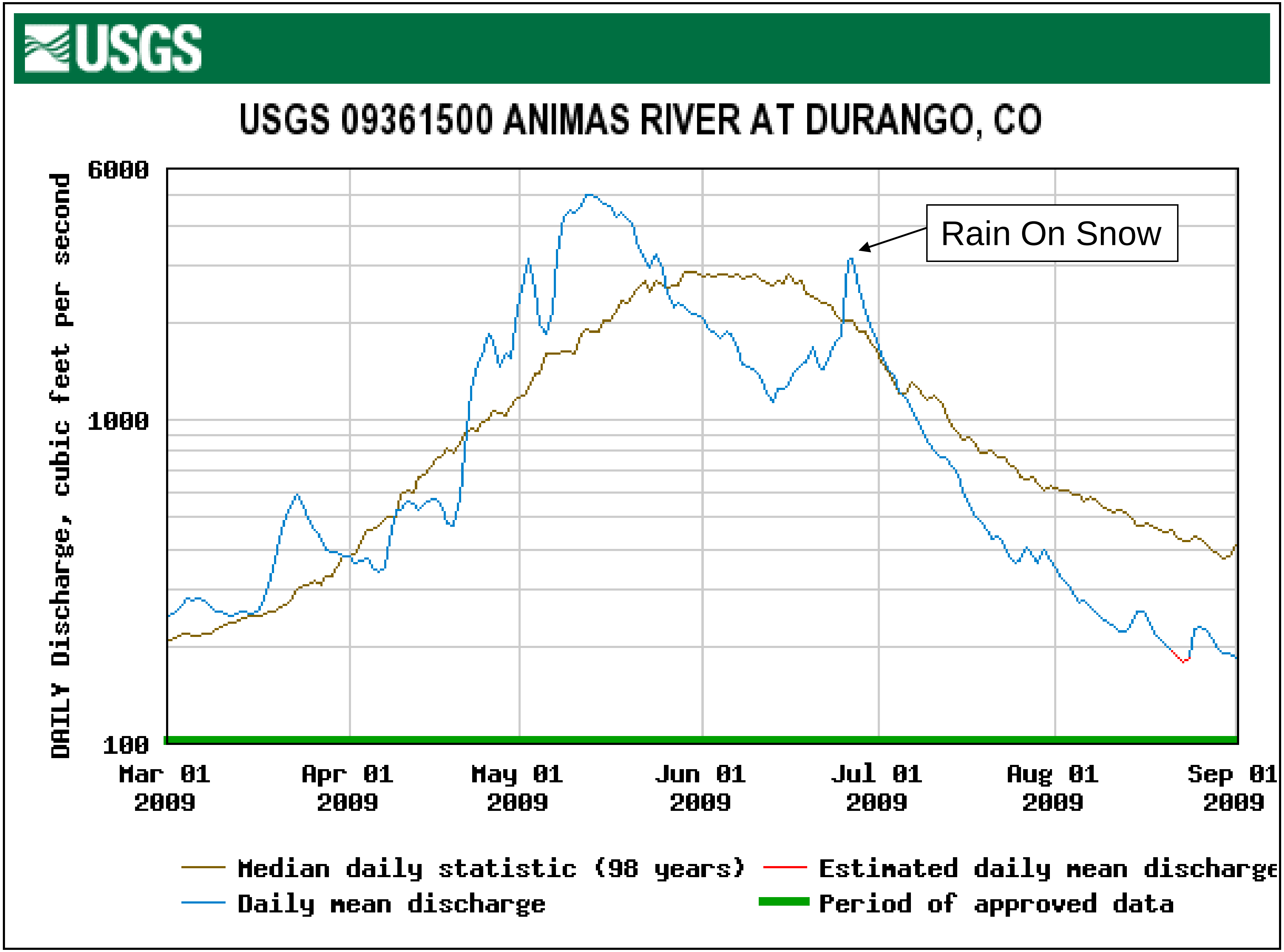
Senator Beck Basin Hourly Discharge

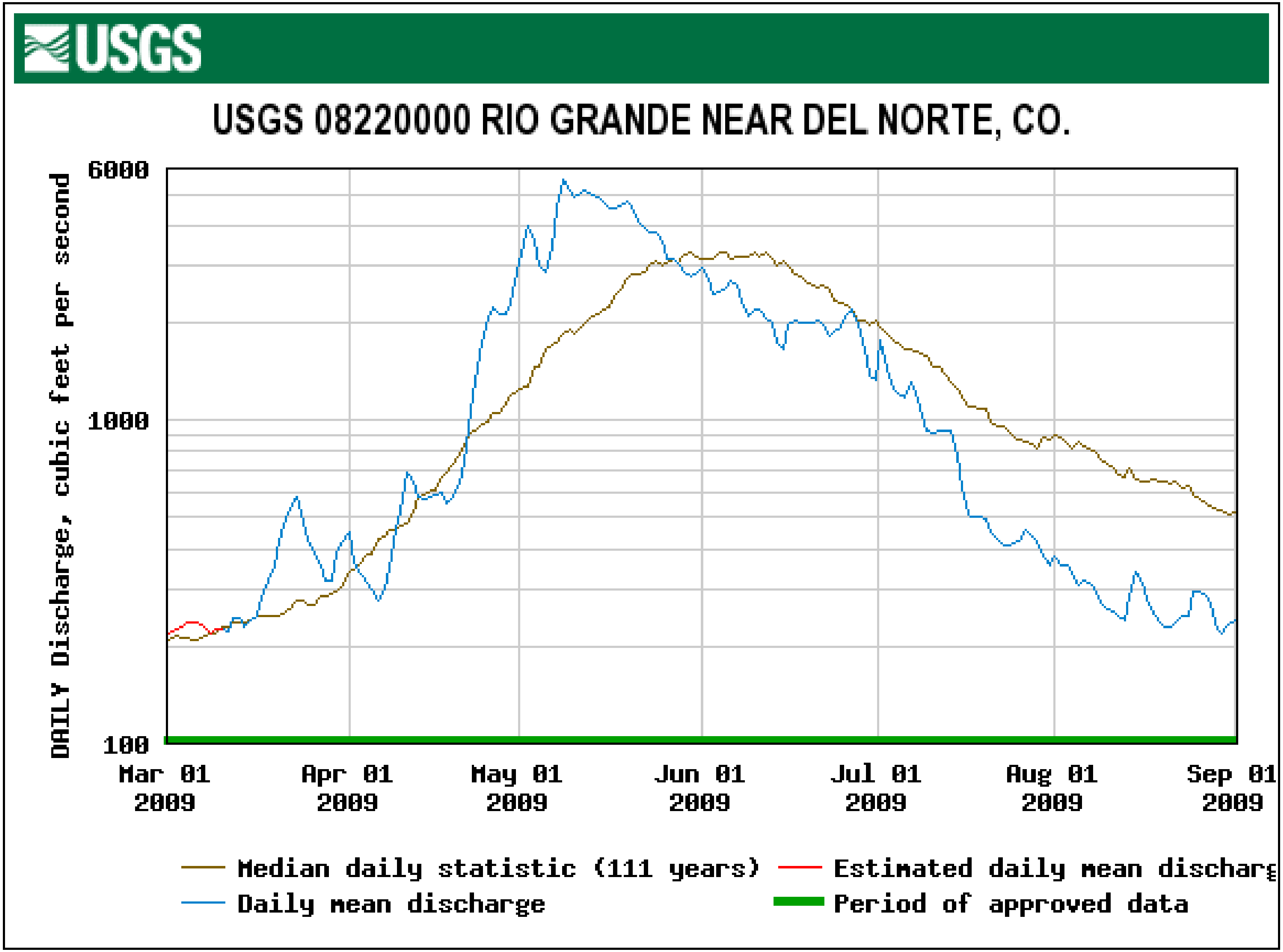
WY 2006, 2007, 2008 & 2009, 2010, 2011, 2012

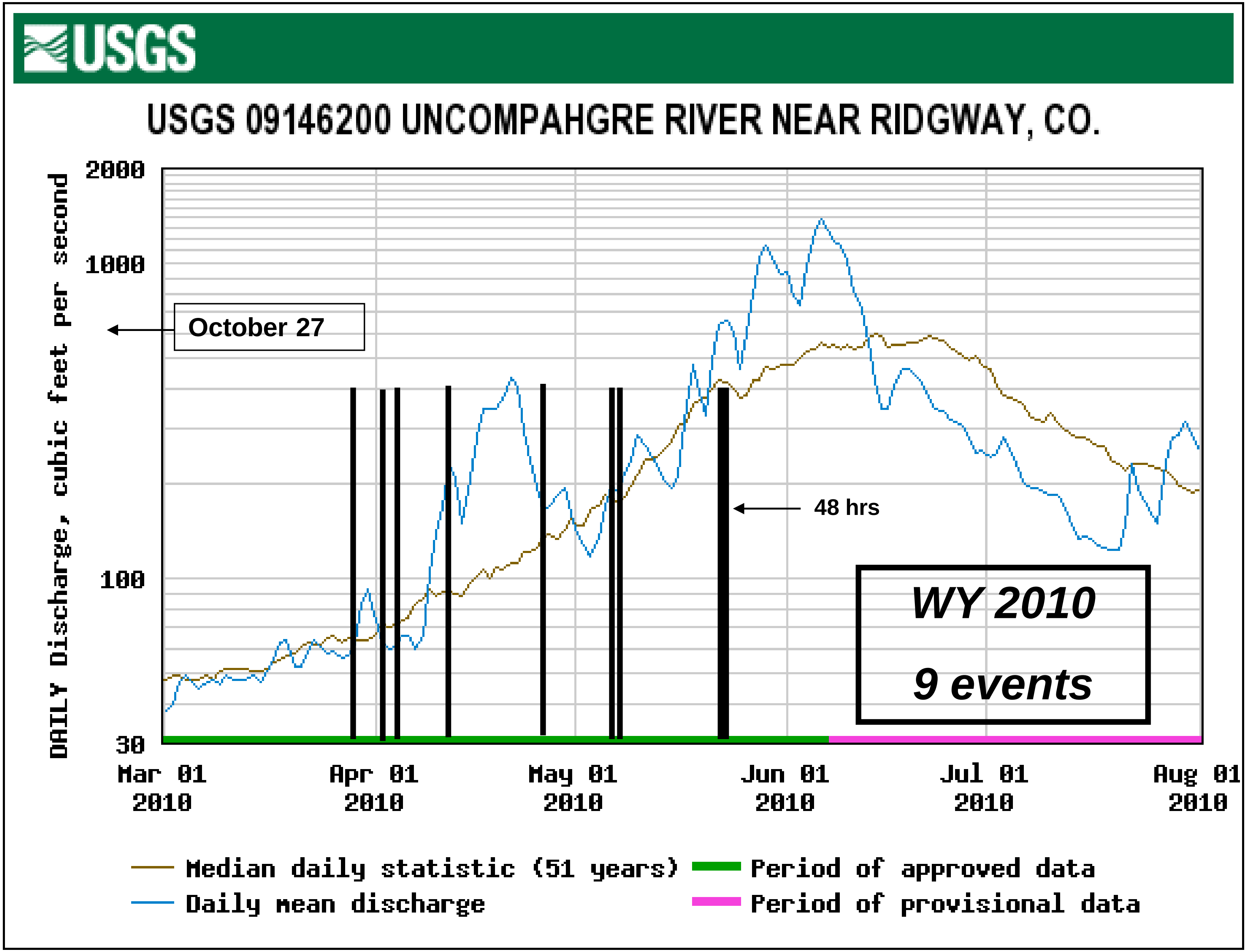




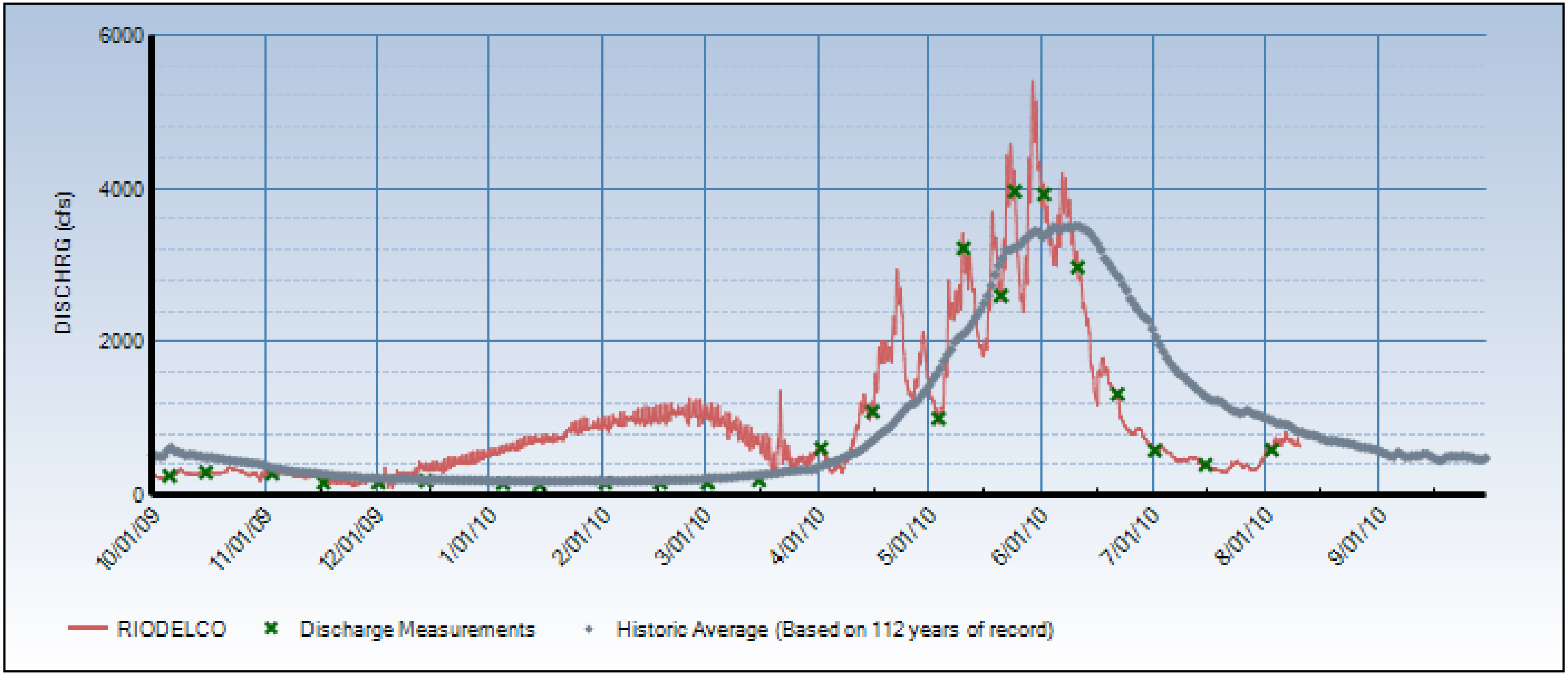
Senator Beck Basin Cumulative Discharge - 2006 to 2012
as measured at Senator Beck Stream Gauge (SBSG)
Acre Feet
Day of Year
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
2006
2007
2008
2009
2010
2011
2012
Working Mean


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 2009
Median daily statistic (111 years)
Estimated daily mean discharg
Daily mean discharge
Period of approved data

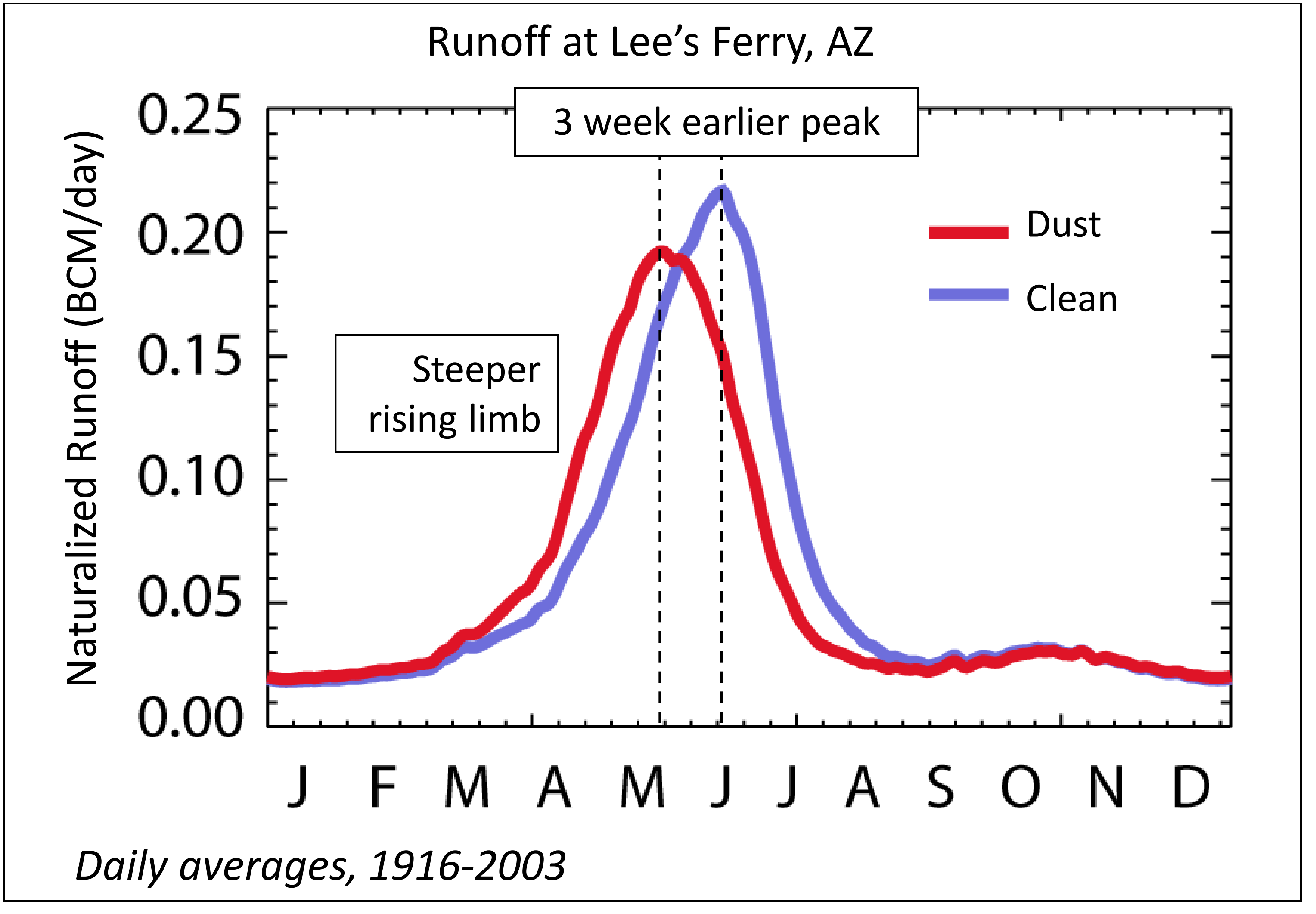

USGS
USGS 09146200 UNCOMPAHGRE RIVER NEAR RIDGWAY, CO.
DAILY Discharge, cubic feet per second
2000
1000
100
30
October 27
48 hrs
WY 2010
9 events
Mar 01 2010
Apr 01 2010
May 01 2010
Jun 01 2010
Jul 01 2010
Aug 01 2010
Median daily statistic (51 years)
Daily mean discharge
Period of approved data
Period of provisional data

Rio Grande at Del Norte
WY 2010



Dust-on-Snow Shifts Upper CRB Hydrograph*

***<u>not including</u> 2009, 2010 dust seasons**

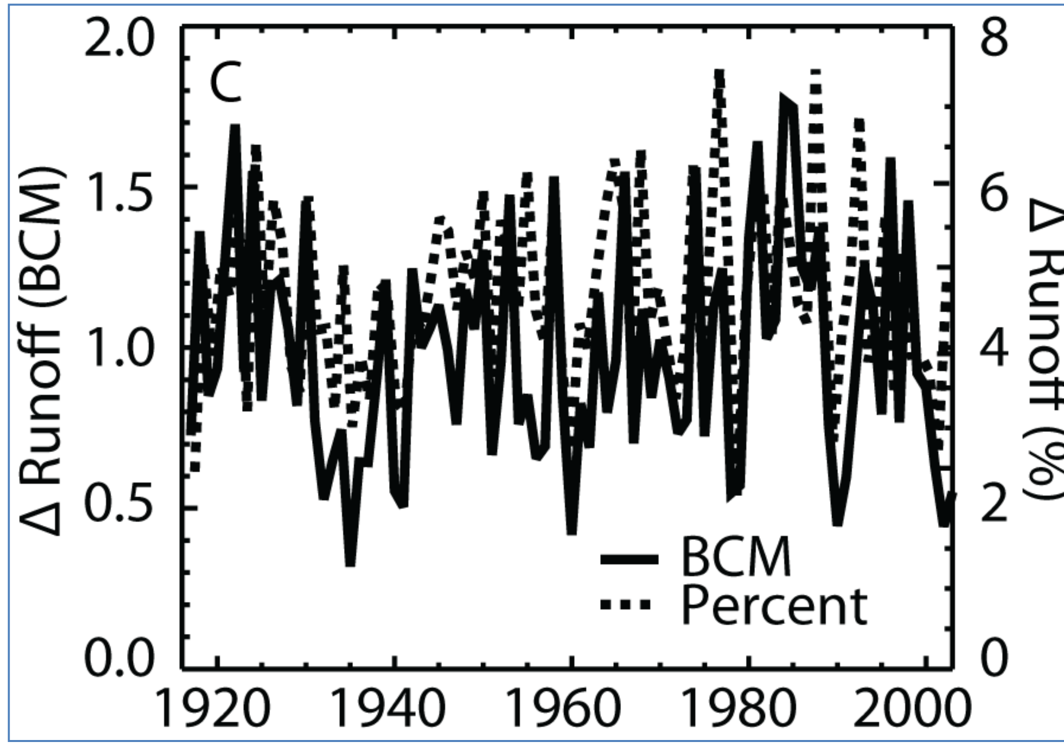


Painter, Deems, *et al.*, *PNAS* (*2010*)

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 AF



**based on pre-2009 dust loading*

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

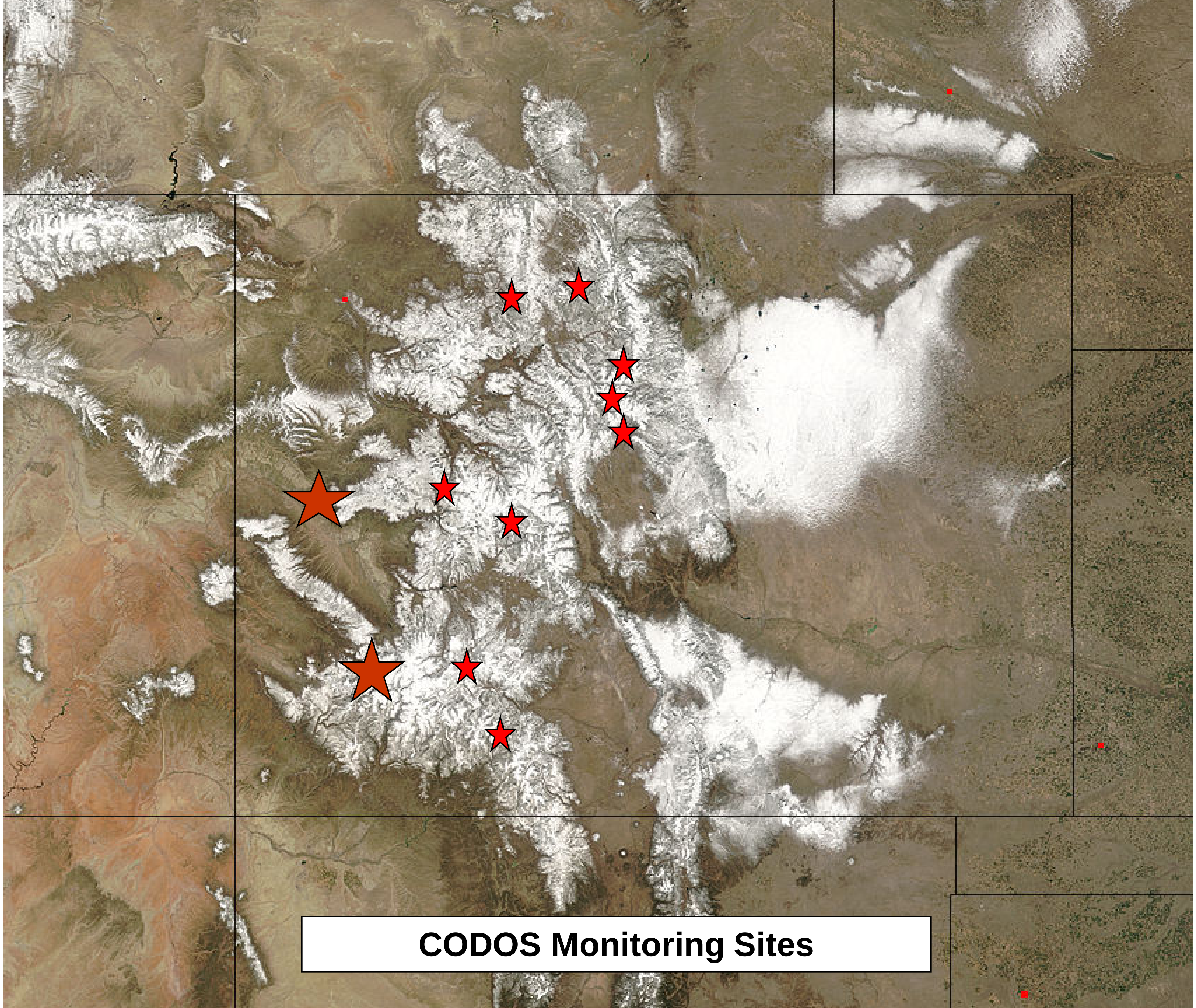
CSAS Colorado Dust-on-Snow (CODOS) Program

Timely, iterative monitoring and analysis of dust effects on snowmelt timing and rates throughout the Colorado mountains … supplemental to CBRFC forecasts.

Spring 2009 – From Senator Beck Basin Study Area

CSAS Colorado Dust-on-Snow Program

CODOS Program Funders	WY 2007	WY 2008	WY 2009	WY 2010	WY 2011	**Actual WY 2012**
Colorado River Water Conservation District	8,000	8,000	8,000	10,000	10,000	**10,000**
Southwestern Water Conservation District	5,000	5,000	4,000	5,000	5,000	**5,000**
Rio Grande Water Conservation District		3,000	4,000	5,000	5,000	**5,000**
Upper Gunnison River Water Conservancy Dist.		5,000	7,500	7,500	7,500	**7,500**
Northern Colorado Water Conservancy District			1,500	2,500	2,000	
Tri-County Water Conservancy District	1,000	1,000	1,500	2,500	2,500	**2,500**
Animas-La Plata Water Conservancy District			500	600	600	**750**
Dolores Water Conservancy District				600	600	**750**
Denver Water	2,500	2,500	2,500	5,000	5,000	**5,000**
Bureau of Reclamation – Western Colorado Area			5,000	7,500	7,500	
Bureau of Reclamation – Lower Colorado Region				7,500	10,000	**10,000**
Bureau of Reclamation – Eastern Colorado Area					2,500	
Bureau of Reclamation – Albuquerque Area						
Western Water Assessment – Univ of Colorado			20,072			
Colorado Water Conservation Board				28,034	15,000	**25,000**
City of Grand Junction					2,500	**2,500**
TOTAL	16,500	24,500	54,572	81,734	75,700	**74,000**


CODOS Monitoring Sites

May 26, 2010 – Grizzly Peak Snotel, A-Basin


April 18, 2009 – Willow Creek Pass

COLORADO DUST-ON-SNOW: WATER YEAR 2012 UPDATES

Welcome! This portion of our website is **exclusively for CODOS stakeholder organizations** . You won't find a link to this page from our public website. However, you are welcome to share the link to this page with your colleagues and partners: dust.snowstudies.org.

CODOS Quick Links

- About CODOS
- Updates & Analysis (prior years)
- Dust Log & Wind Roses
- SNOTEL datasets
- Stakeholder Funding
- Map of CODOS Sites
- Press Releases & Articles
- Photo Gallery

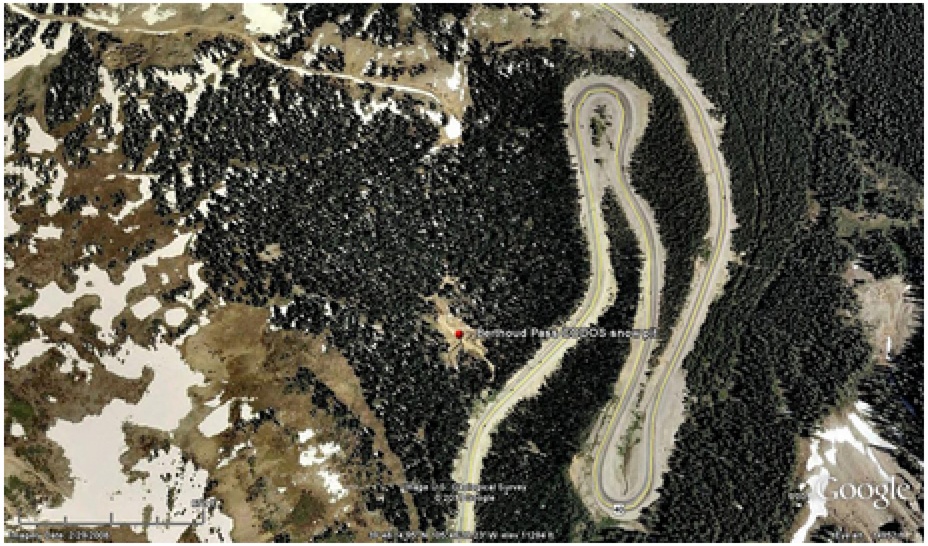
UPDATES & ALERTS BY DATE

- **April 13, 2012: Summary of April 4-11 Circuit**
- April 12, 2012: McClure Pass, Wolf Creek Pass, & Spring Creek Pass Updates
- April 10, 2012: Grizzly Peak, Berthoud Summit, Willow Creek Pass & Rabbit Ears Pass Updates
- April 9, 2012: Park Cone & Hoosier Pass Updates
- April 8, 2012: Senator Beck Basin Update
- April 6, 2012: Dust alert [D8]
- April 5, 2012: Grand Mesa update
- April 2, 2012: Dust-on-dust Alert [D7]
- **March 28, 2012: Update #3**
- March 26, 2012: Dust event underway [D6]

CENTER FOR SNOW & AVALANCHE STUDIES

CODOS UPDATE FOR BERTHOUD SUMMIT: VISITED APRIL 10, 2012

Summary | Snowpack | Melt Rate | Forecast | Stream Flows | Earlier Updates



SUMMARY

Sustained periods of unseasonably warm air temperatures and exposed dust at the snowpack surface during late March and early April 2012 have, together, initiated accelerating rates of snowmelt and SWE loss at some, but not all, CODOS Snotel sites. Some CODOS Snotel sites report significant declines in SWE approaching the lowest values in the period of record (for a given date) or even falling outside of the historic range. Those sites *may* have experienced Peak SWE for WY 2012 in early or mid-March. Recent CODOS snowpits near those CODOS sites mirror those losses of SWE.

In contrast, other CODOS Snotel sites and CODOS snowpits show only small losses of SWE. At those sites, energy inputs from warm air and direct absorption of solar energy by dust at the snowpack surface was consumed in warming the snowpack towards an isothermal state at 0° C, as a precursor to the loss of SWE and onset of snowmelt runoff. Since our prior site visit on March 14 the snowpack at the Berthoud Summit CODOS site has lost all cold content and is now isothermal.

The National Weather Service expects warming weather in the Colorado mountains through Wednesday with strong SW'ly winds developing on Wednesday afternoon ahead of a cooler but largely dry airmass. Unsettled and cooler weather will finish the week and run through the weekend, including chances for rain and/or snow showers each day.

SNOWPACK DISCUSSION

The snowcover at the Berthoud Summit CODOS site has undergone complete warming to 0°C thoughout since our March 15 snowpit and is beginning to more rapidly melt. We walked to this site on dry ground for much of the approach. Dust loading at the Berthoud Summit site is similar to that observed at Grizzly Peak - more intense than at Hoosier Pass, but still less intense than at our Senator Beck Basin study sites. Reduction in snow surface albedo has been sufficient to absorb additional solar energy at the snowpack surface and contribute to warming and ablation of the snowcover. As previously discussed, the Berthoud Summit Snotel site is in an open meadow, unshaded by the adjoining forest. As a consequence, Snotel snowmelt rate and snowpack depth data fully capture the influence of direct radiative forcing when snow albedo is lowered by dust, in contrast to other, shaded Snotel sites. Our CODOS snowpit site is located immediately in front of the Snotel station, in the same open meadow.

On March 15th the snowpack at our Berthoud Summit CODOS snowpit site was 44" (112 cm) deep and most of the snowpack consisted of very weak "depth hoar" grains; mean snowpack temperature was -2.6°C. Dust event D4 was clearly evident on the snow surface at the snowpit and in terrain around Berthoud Pass. SWE content in the snowpit was 13.2" (336 mm) and mean density of the snowpack was 308 kg/m^3 (30.8% water content). As a result of the subsequent, prolonged period of warm, dry, and sunny weather, and some additional small reductions in snow albedo from additional dust events, the snowpack on April 10th was fully isothermal (0°C), with wet or very wet snow throughout. Total SWE in this pit was 8.7" (220 mm), a loss of 4.6" (116 mm) since March 15th; total snow depth was down to 20.5" (52 cm) and density had risen to 393 kg/m^3 (39.3% water content).

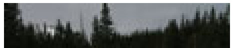
April 10, 2012:

Pit profile

Completed pit

Pit with Snotel in background

March 15, 2012:



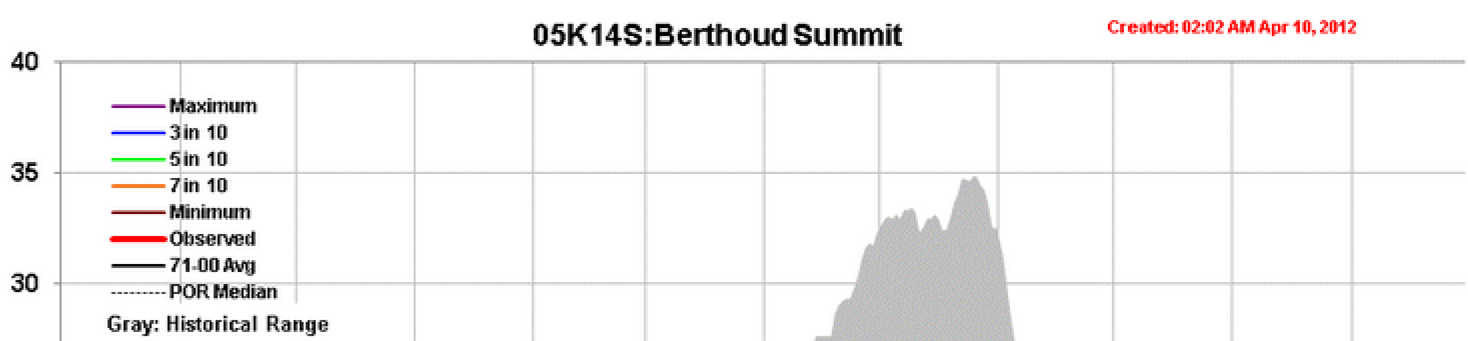
MELT RATE

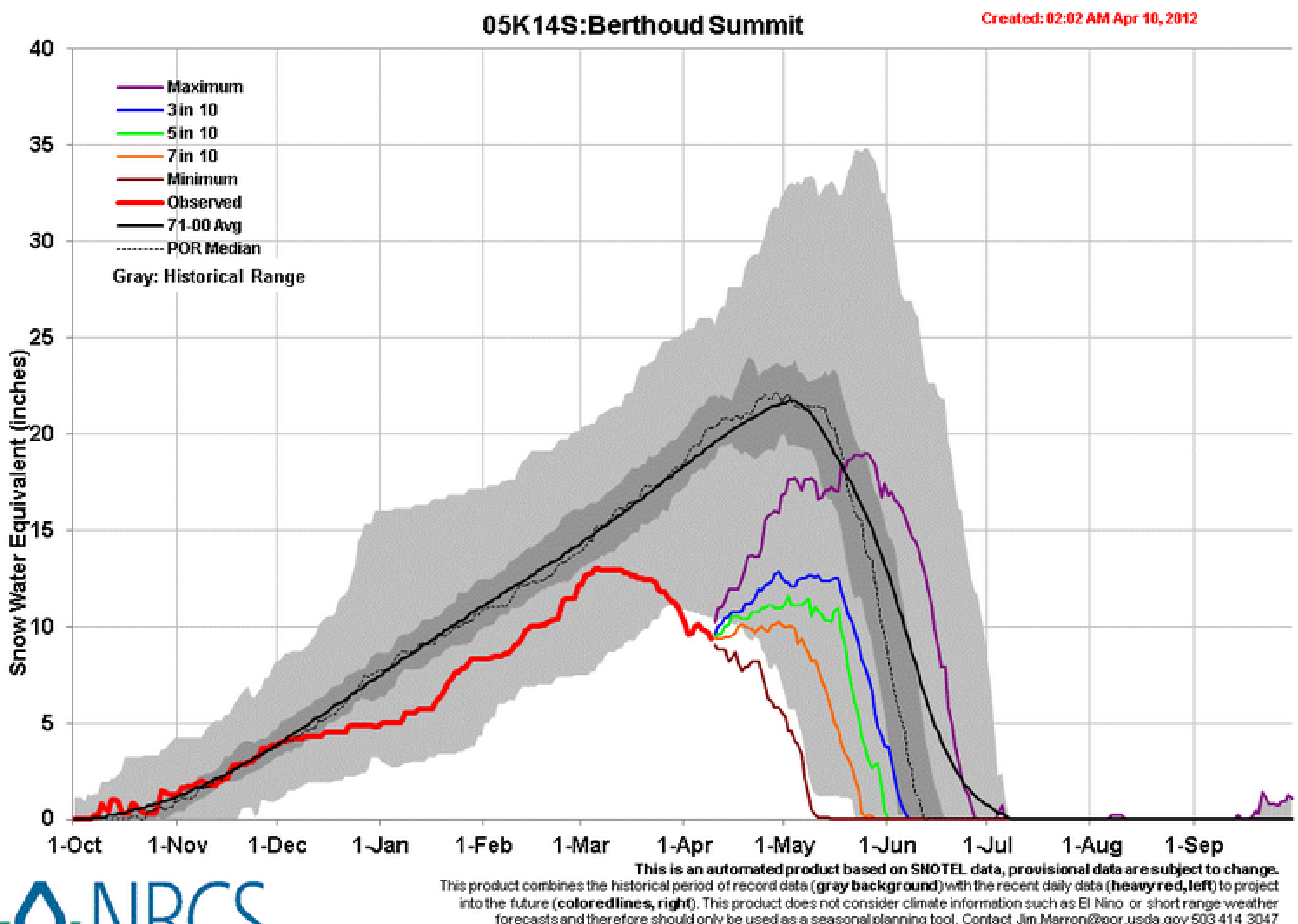
Berthoud Summit Snotel has reported a loss of 3.8" of SWE since our last site visit on March 15, 2012, not long after what may have been Peak SWE for WY 2012. This melt rate falls well short of the mean daily loss of SWE at Berthoud Summit observed in prior snowmelt seasons, as shown in the table below. However, even at current melt rates, SWE values may remain below the lowest quartile for the duration of WY 2012.

Berthoud Summit SNOTEL Snowmelt Season Summary Data

	Date Peak SWE	Peak SWE	Days to SAG	Post-Peak Added SWE	Adjusted Daily Mean Loss SWE	Period Mean Temp
WY 2006	4/21/2006	24.0	41	3.8	0.68	3.5
WY 2007	4/27/2007	22.2	46	4.5	0.58	4.4
WY 2008	5/16/2008	24.4	34	1.4	0.76	5.8
WY 2009	4/20/2009	24.7	50	5.2	0.60	4.0
WY 2010	5/16/2010	24.5	23	0.6	1.09	6.6
WY 2011	5/26/2011	34.8	35	2.0	1.05	8.4
Max	5/26	34.8	50	5.2	1.09	8.4
Min	4/20	22.2	23	0.6	0.58	3.5
Range	37	12.6	27	4.6	0.51	4.9

Adjusted Daily Mean Loss SWE rates include additional SWE received after date of Peak SWE





NRCS

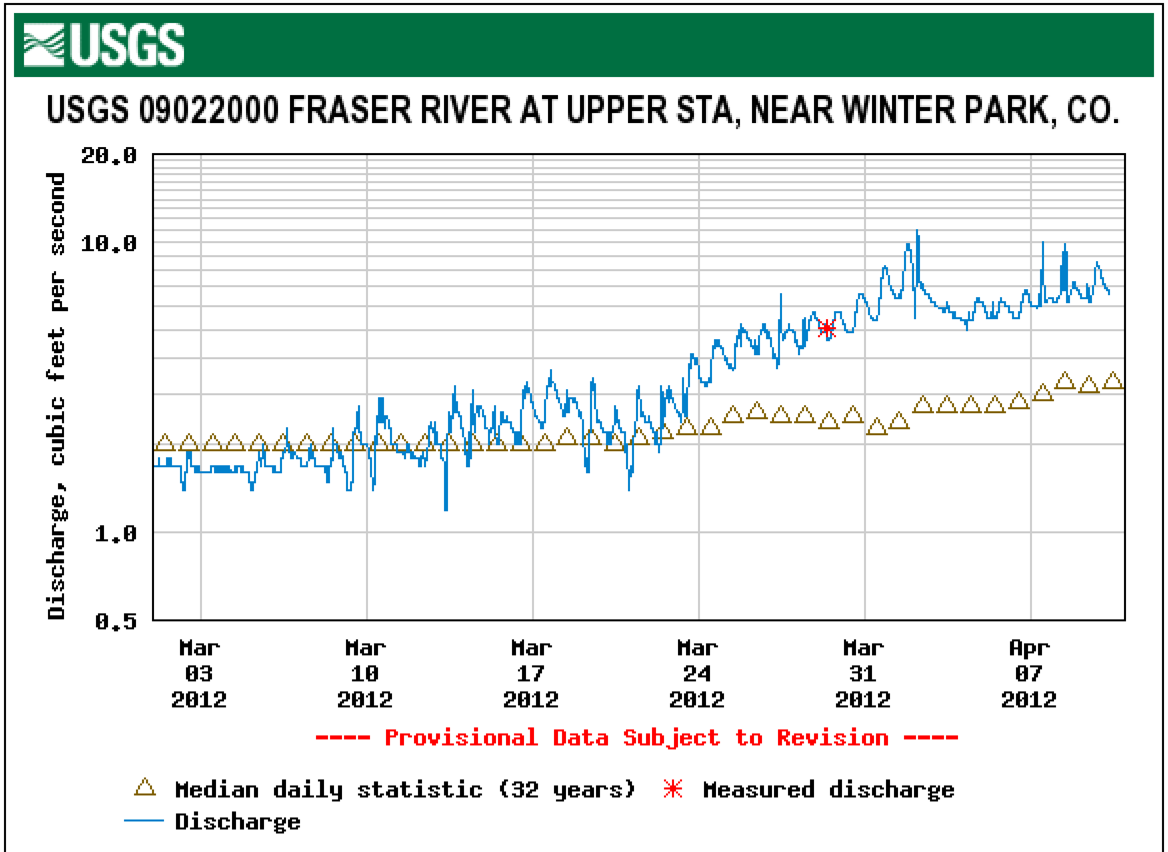
STREAM FLOWS

Streamflow behavior at the USGS Fraser River Upper Staion near Winter Park gauge reports a brief decline in discharge in early April, after a significant

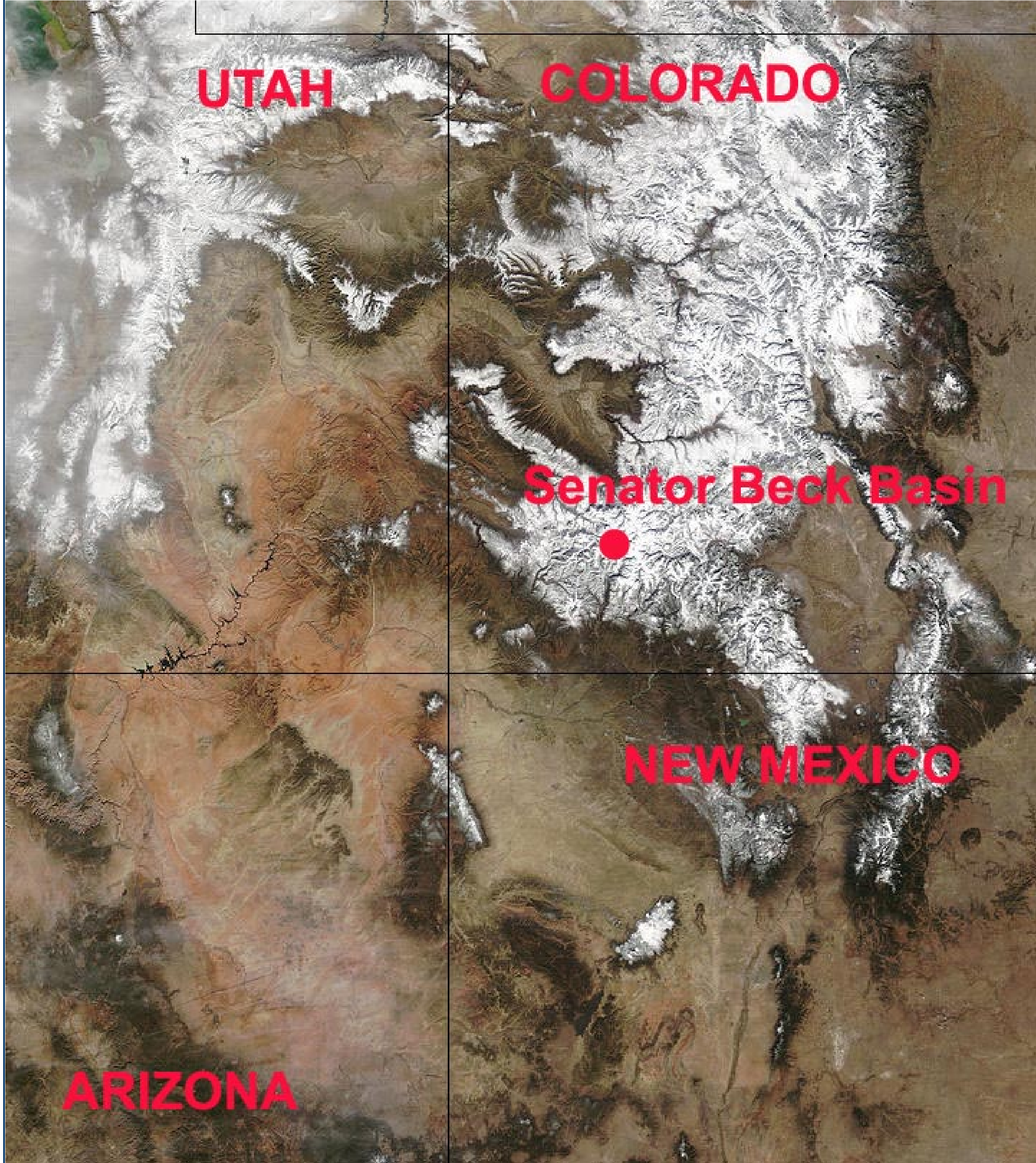
This is an automated product based on SNOTEL data, provisional data are subject to change.
This product combines the historical period of record data (**gray background**) with the recent daily data (**heavy red, left**) to project into the future (**colored lines, right**). This product does not consider climate information such as El Nino or short range weather forecasts and therefore should only be used as a seasonal planning tool. Contact Jim.Marron@por.usda.gov 503 414 3047

STREAM FLOWS

Streamflow behavior at the USGS Fraser River Upper Staion near Winter Park gauge reports a brief decline in discharge in early April, after a significant surge in late March. Flows in late March were high, compared to median levels at that gauge, for that period. Unsettled weather in early April ushered in cooler air and cloudier skies for the following several days. Interestingly, flows stabilized during that period at more than double the median values.



Senator Beck Basin research has broad application



Swamp Angel Study Plot (subalpine)

Senator Beck Study Plot (alpine)

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: 11629-11634, doi_10.1073_pnas.0900758106.

Snow Hydrology Research Currently Supported by CSAS

Hans-Peter Marshall – Boise State: FMCW radar

Eli Deeb – Army CRREL: Lidar and Microstructure

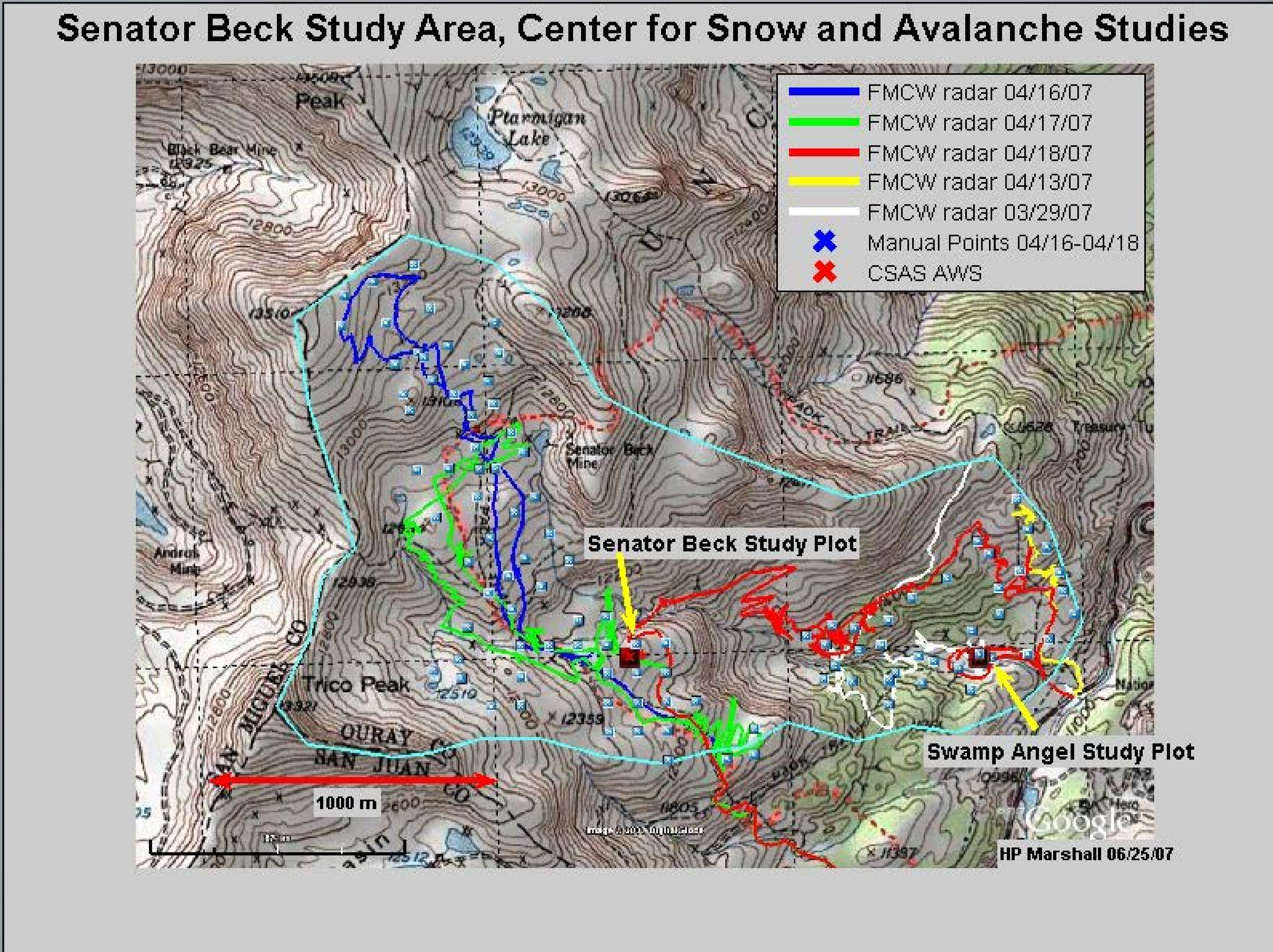
Martyn Clark – NCAR: CHPS development

Michael Follum – ACE Vicksburg: snowmelt model

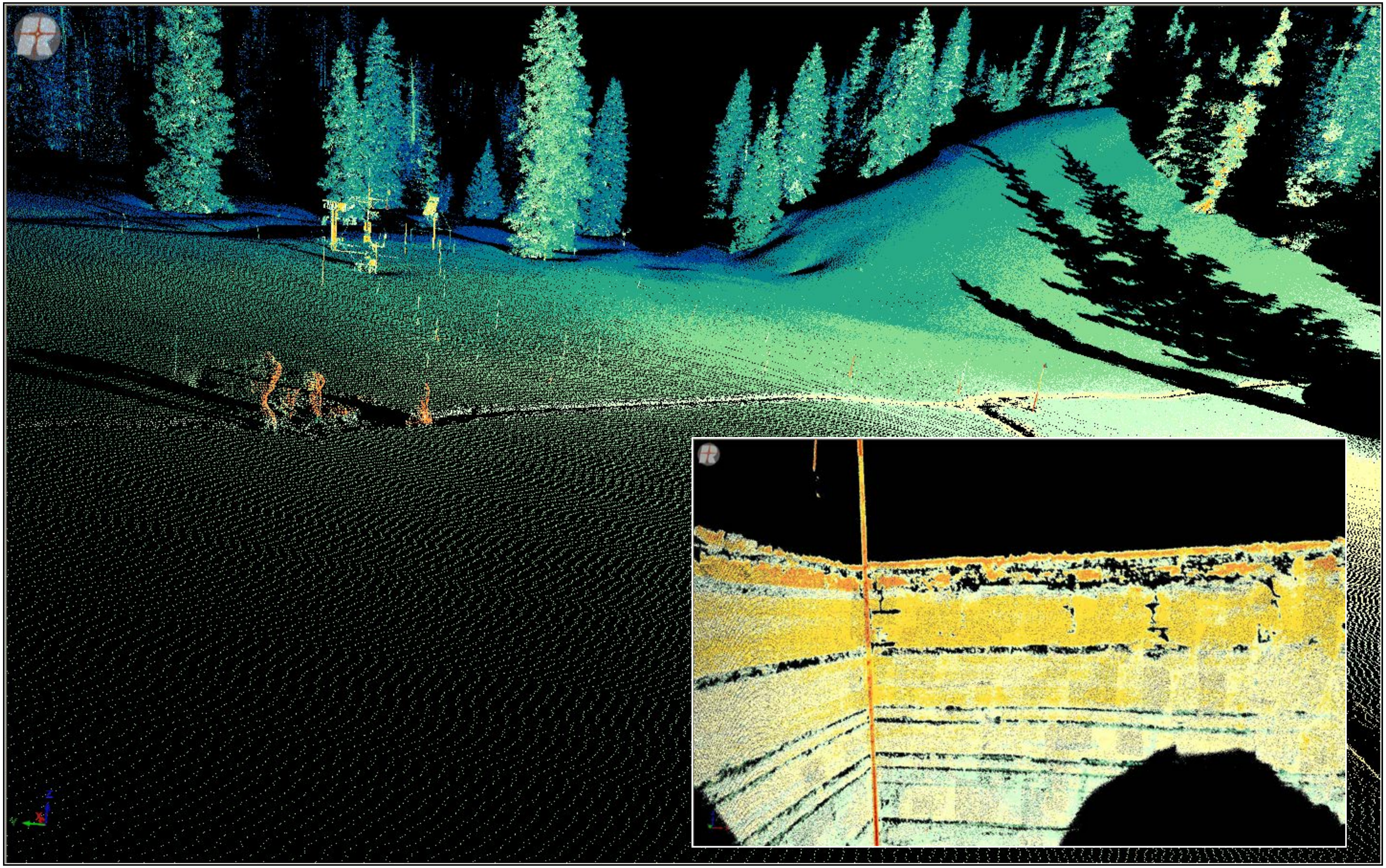
Marty Ralph – NOAA ESRL: atmospheric rivers

Painter & Deems – JPL and WWA: radiative forcing

Hans Peter Marshall - FMCW Radar Development



Army Cold Regions Research & Engineering Lab – Lidar & Microstructure



Climate Change in Mountains

JGR Journal of Geophysical Research Atmospheres

AGU American Geophysical Union

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

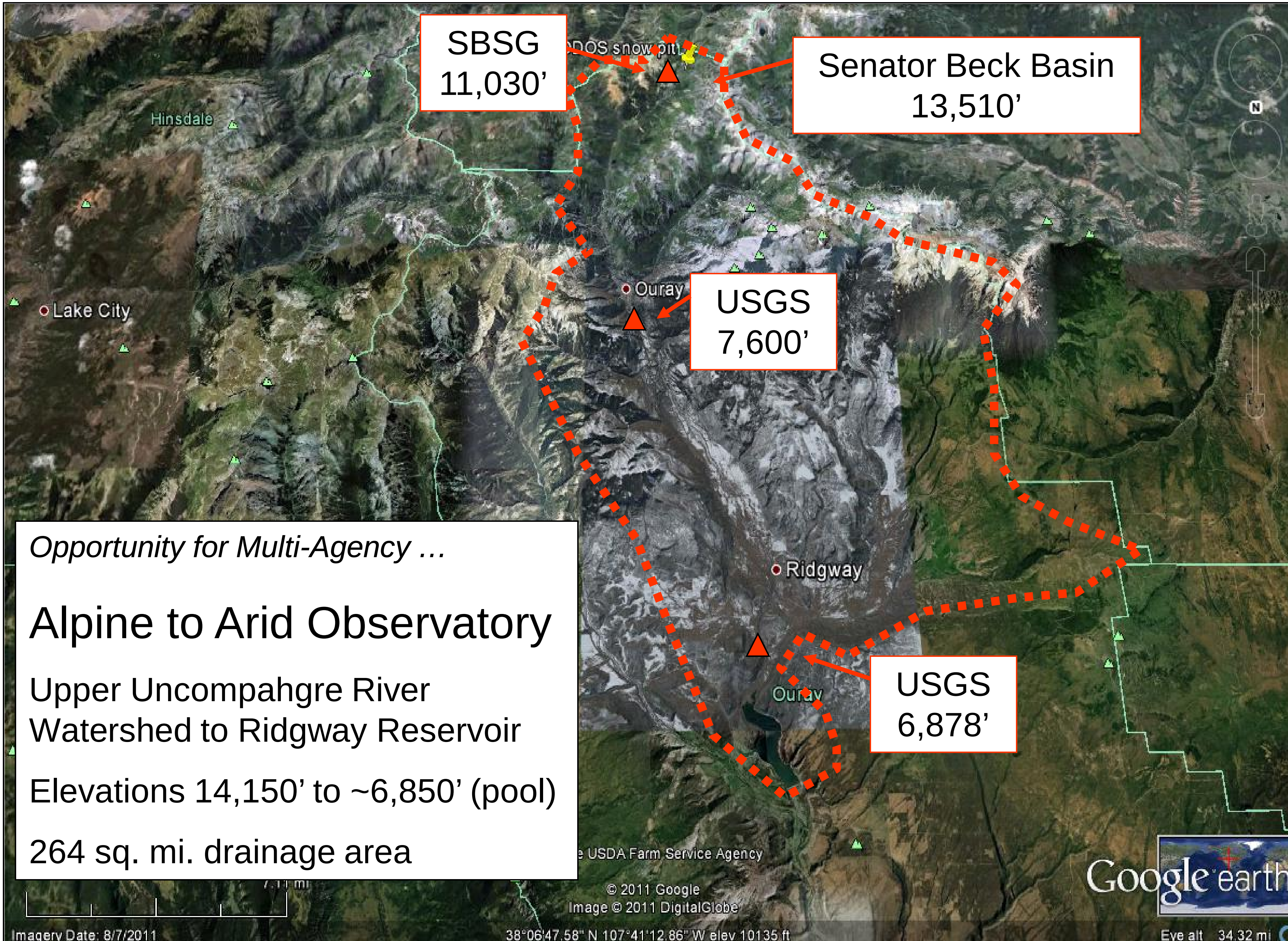
Many studies suggest that high-elevation regions may be among the most sensitive to future climate change. However, in situ observations in these often remote locations are too sparse to determine the feedbacks responsible for enhanced warming rates. One of these feedbacks is associated with the sensitivity 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)


SBSG
11,030'
Senator Beck Basin
13,510'
Hinsdale
Lake City
Ouray
USGS
7,600'
Ridgway
USGS
6,878'
Ouray
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
USDA Farm Service Agency
© 2011 Google
Image © 2011 DigitalGlobe
Google earth
Imagery Date: 8/7/2011
38°06'47.58" N 107°41'12.86" W elev 10135 ft
Eye alt 34.32 mi

Center For Snow and Avalanche Studies - Silverton, Colorado - Windows Internet Explorer

http://snowstudies.org/funding/index.html

CENTER FOR SNOW & AVALANCHE STUDIES

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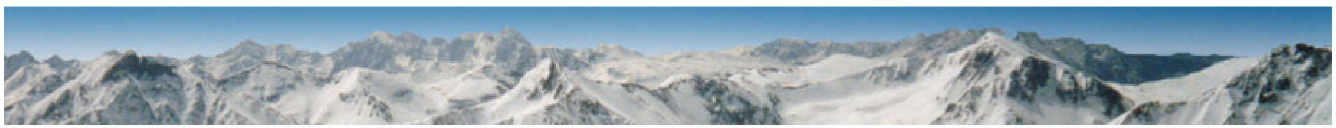

Swamp Angel Study Plot (subalpine)

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

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Web: www.snowstudies.org