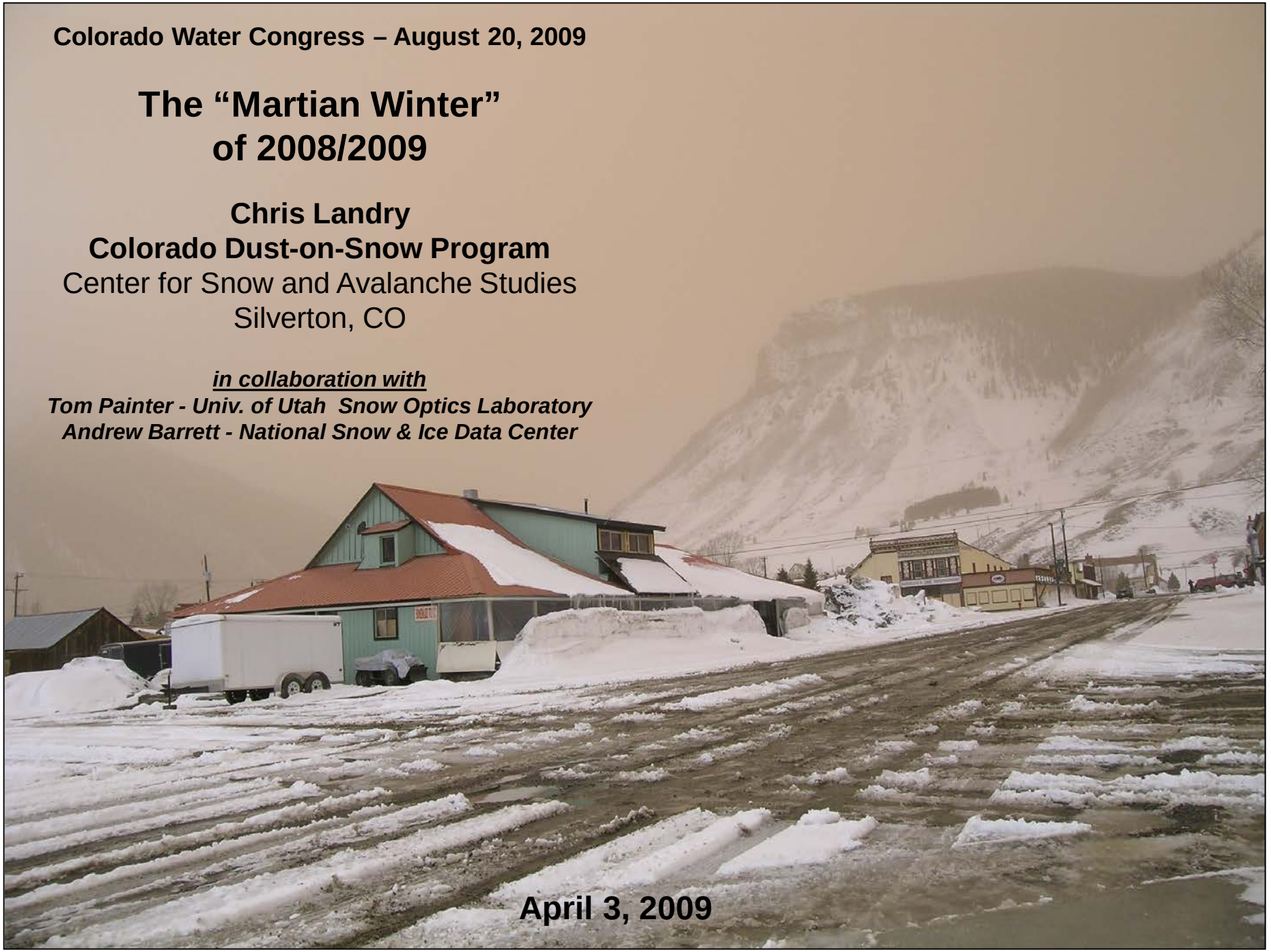
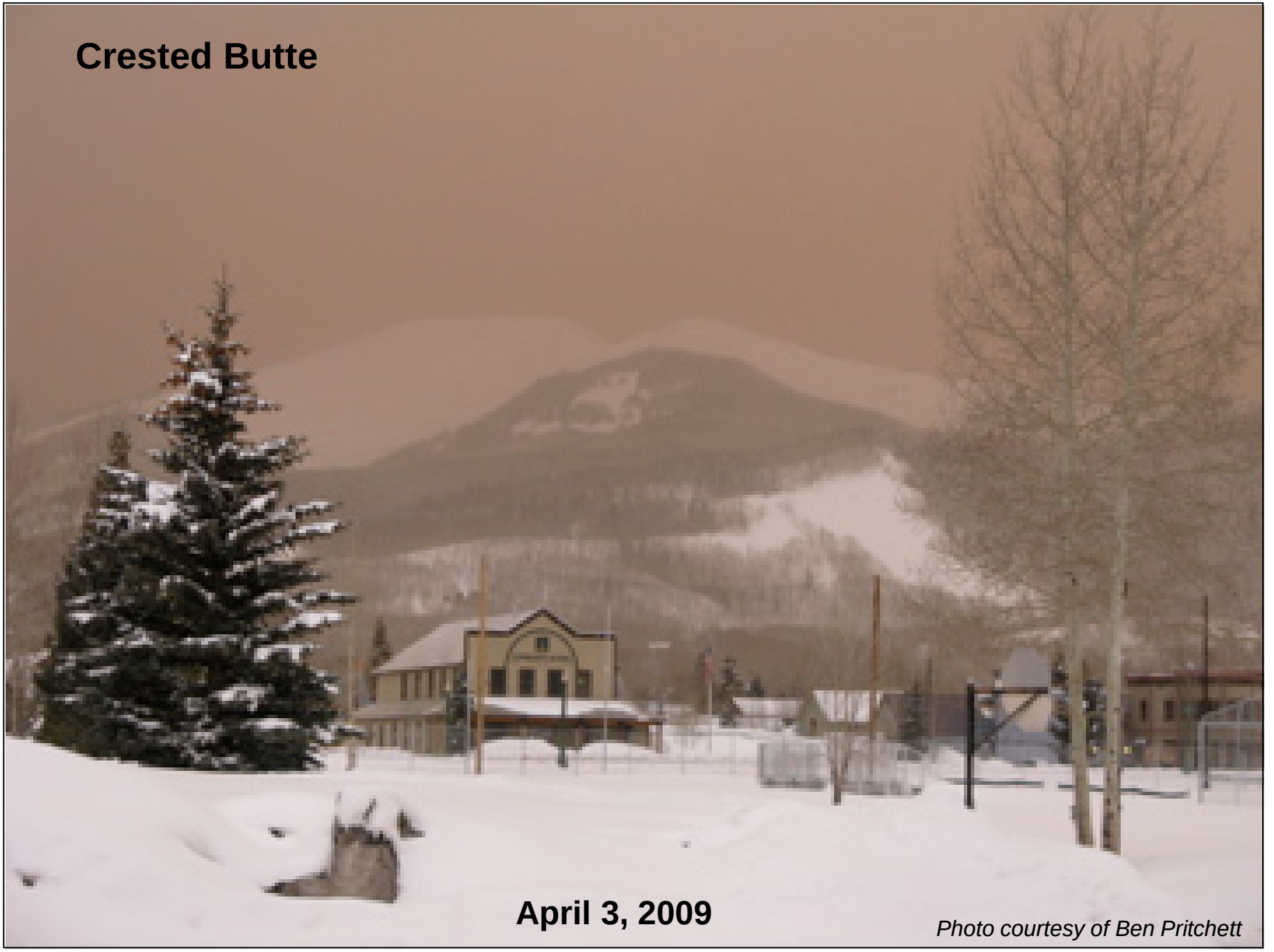
Colorado Water Congress – August 20, 2009

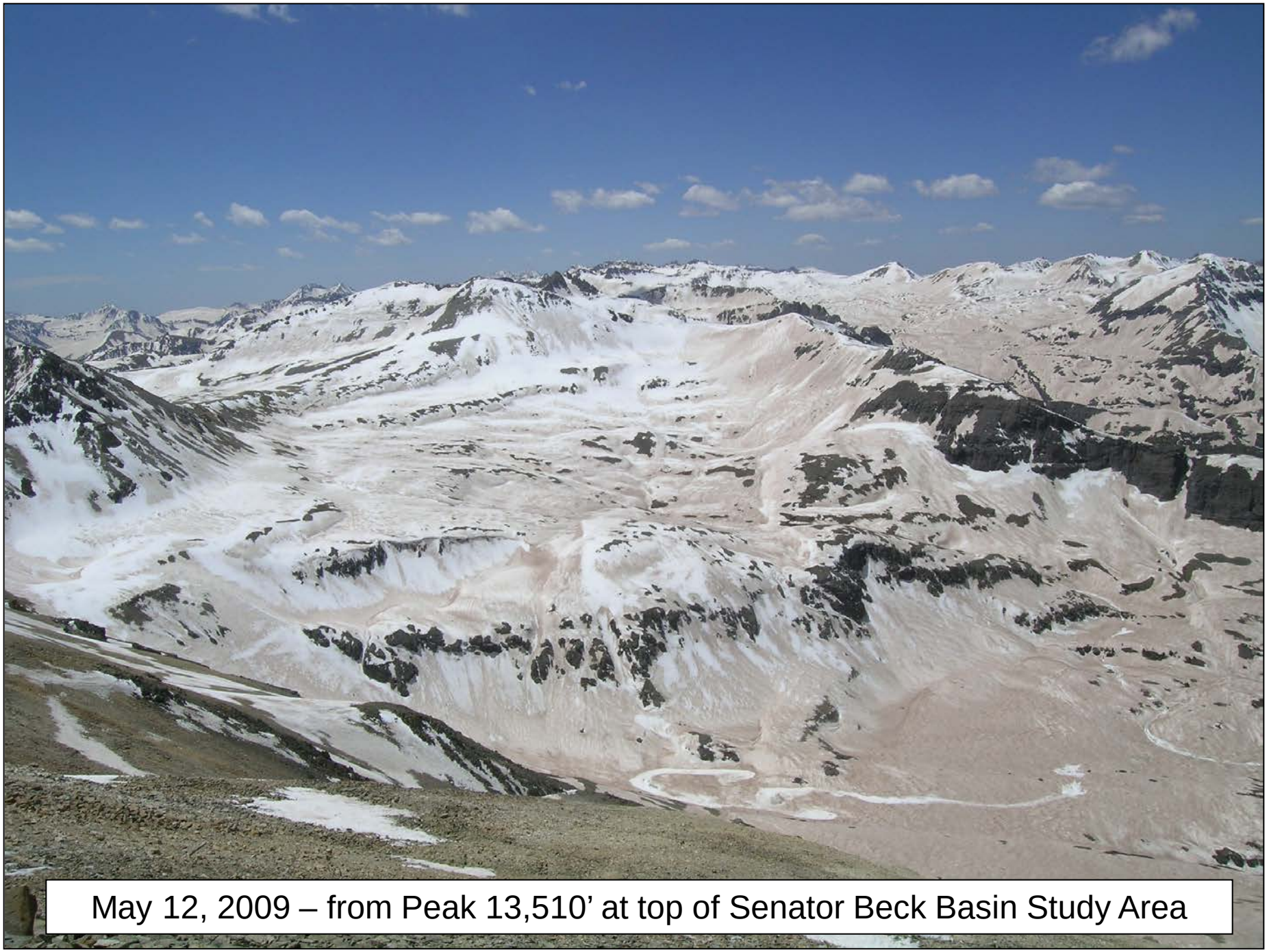
The "Martian Winter" of 2008/2009

Chris Landry
Colorado Dust-on-Snow Program
Center for Snow and Avalanche Studies
Silverton, CO

in collaboration with
Tom Painter - Univ. of Utah Snow Optics Laboratory
Andrew Barrett - National Snow & Ice Data Center




Crested Butte
April 3, 2009
Photo courtesy of Ben Pritchett



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

CSAS Mission Statement

The Center for Snow and Avalanche Studies enhances the interdisciplinary investigation of the alpine snow system's behavior and role in human/environment relationships by offering resources – people, information, and facilities – for field-based research and education.

CSAS Programs

Hosting Snow System Research

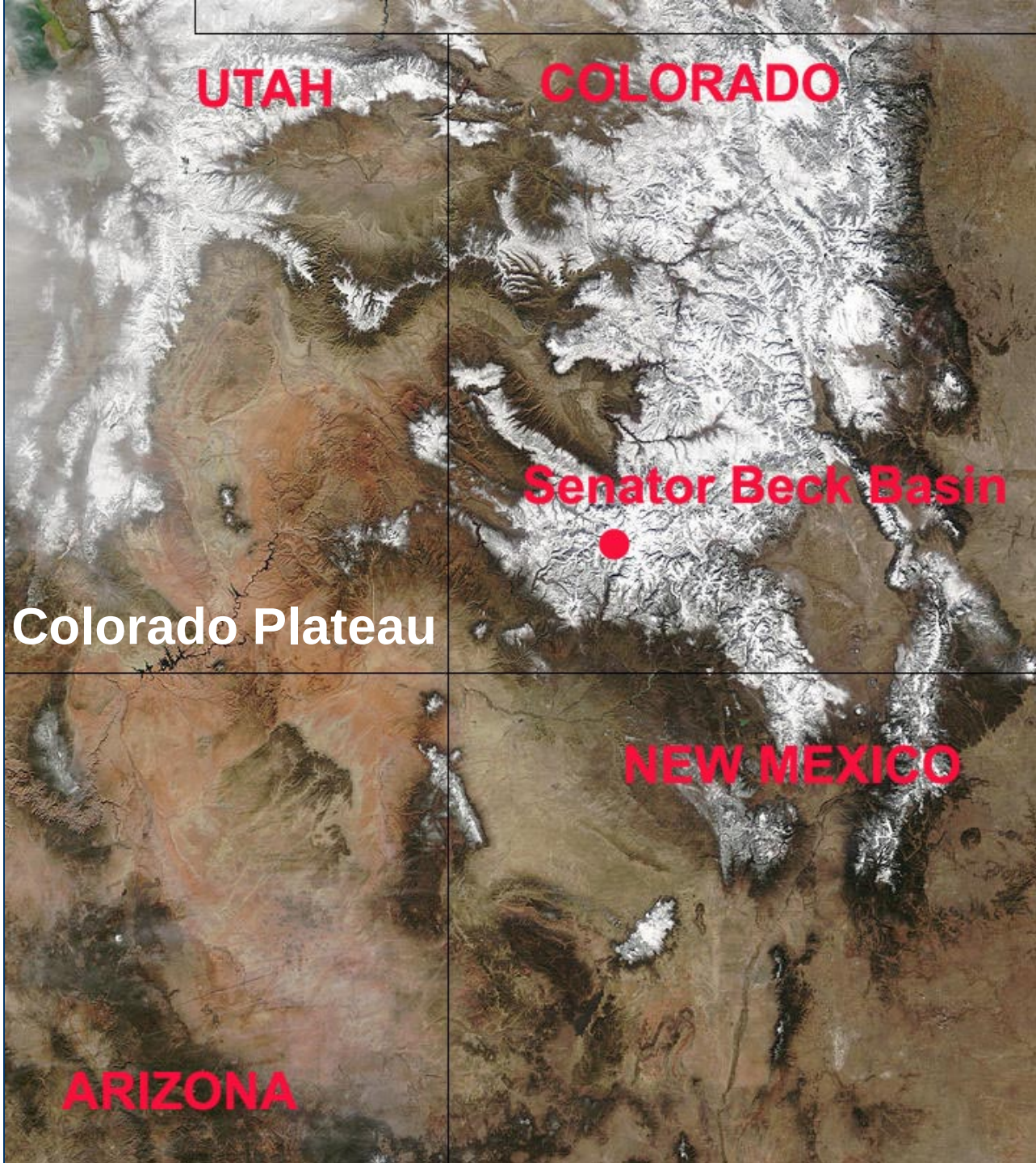
Conducting Snow System Research

Snow System Science Field Education

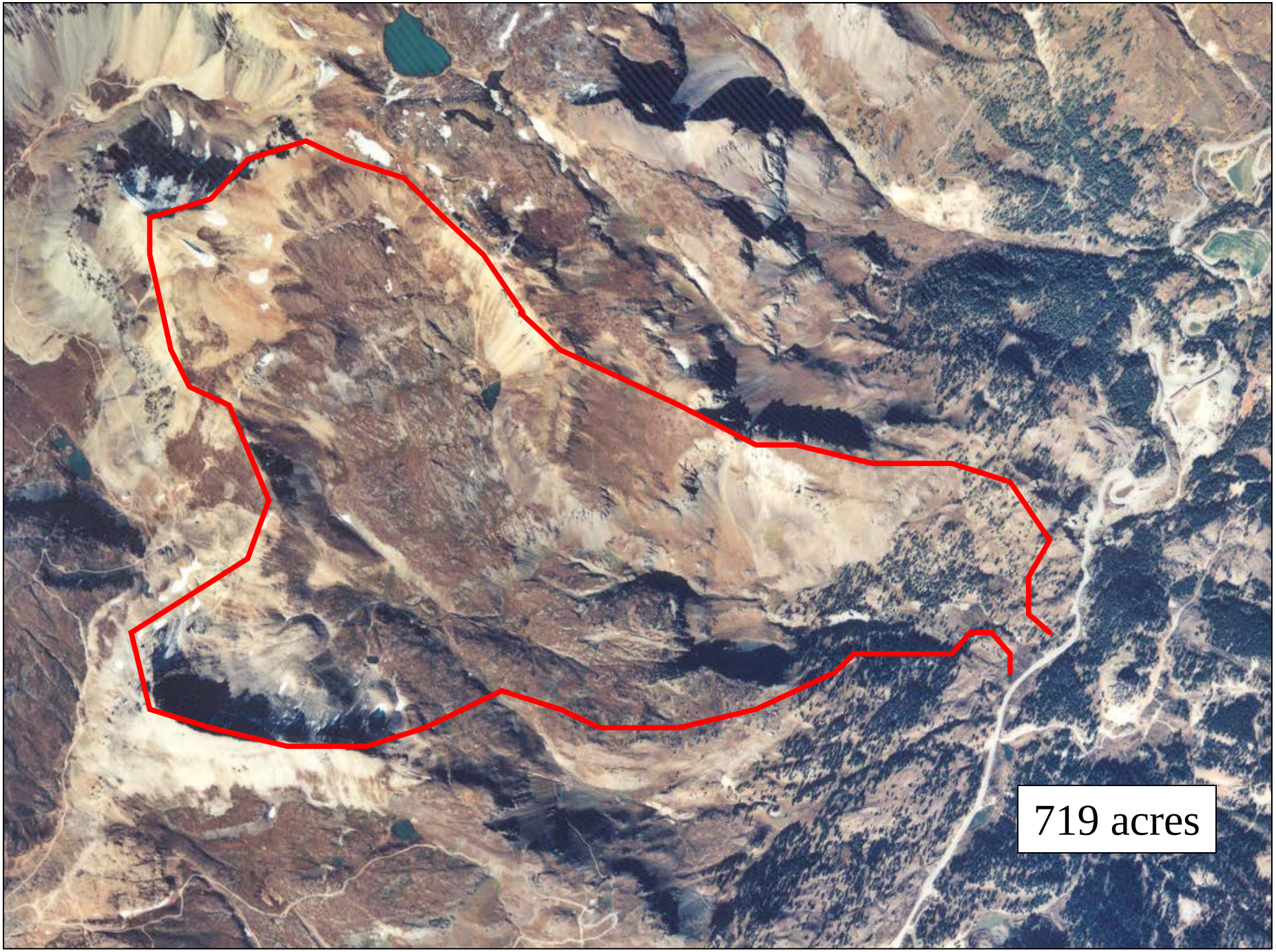
Mountain System Monitoring

Desert/Mountain Interactions

influencing Colorado snowmelt




May 21, 2004
Photo courtesy JPL (Ian McCubbin)


719 acres

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

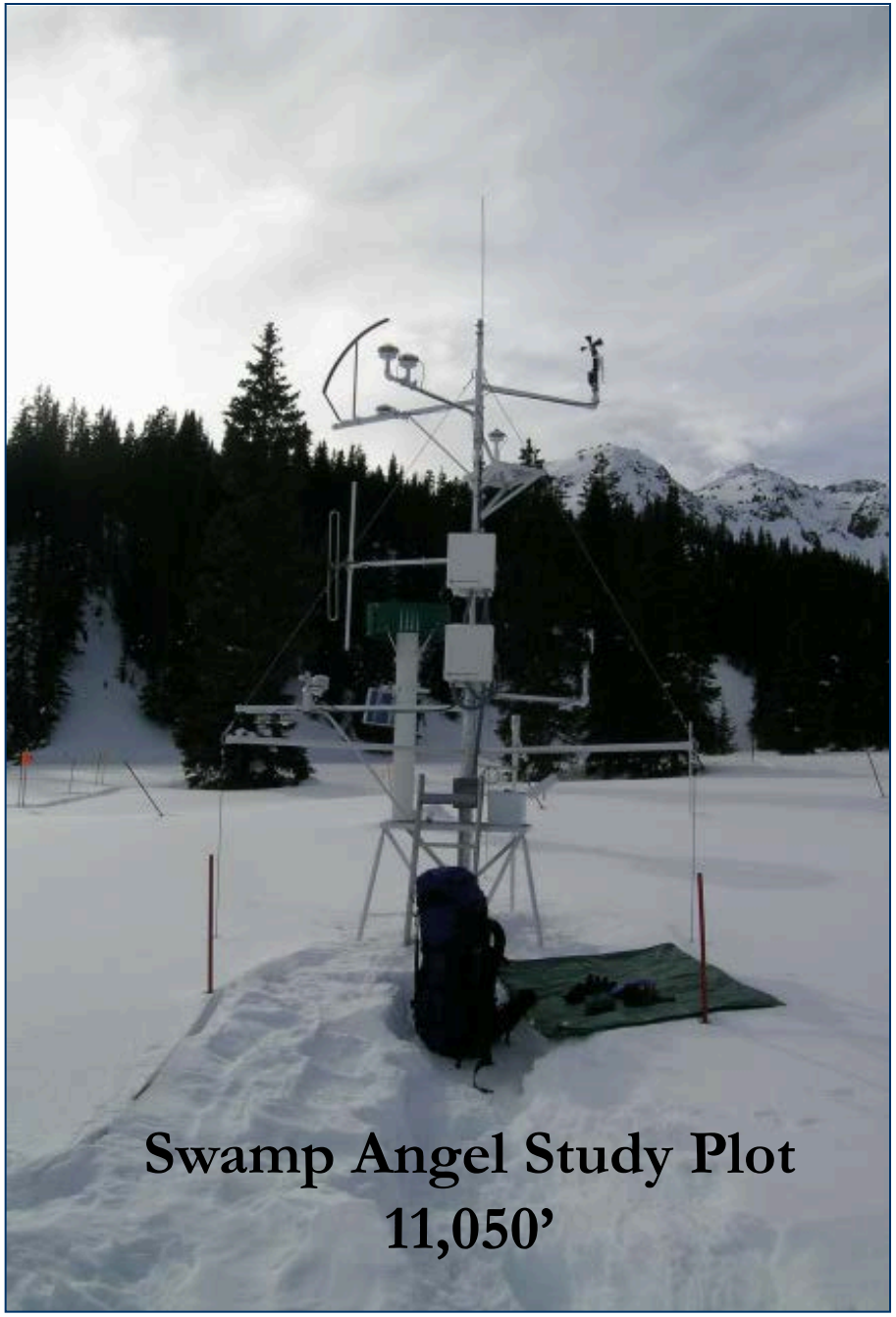
Snow Temperature (5)

Snow Wetness (2)

Soil Temperature (4)

Soil Volumetric Water Content

Soil Heat Flux



SASP Instrumentation

6 m Mast

Campbell 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)

Snow Wetness Sensors (2)

Soil Temperature (4)

Soil Volumetric Water Content

Soil Heat Flux

Experimental Lysimeter

PTSP Instrumentation

10 m Mast

Campbell CR10X Datalogger

Wind Speed & Direction

Air Temp and RH

(data used by operationally by Colorado Avalanche Information Center, CDOT, NWS-GJT)

Also at Putney

GPS Base Station - RG20

for

University of Colorado Rio Grande Rift Research

SBSG Instrumentation

Broad-crested, notched weir

0.1 – 30 cfs capacity

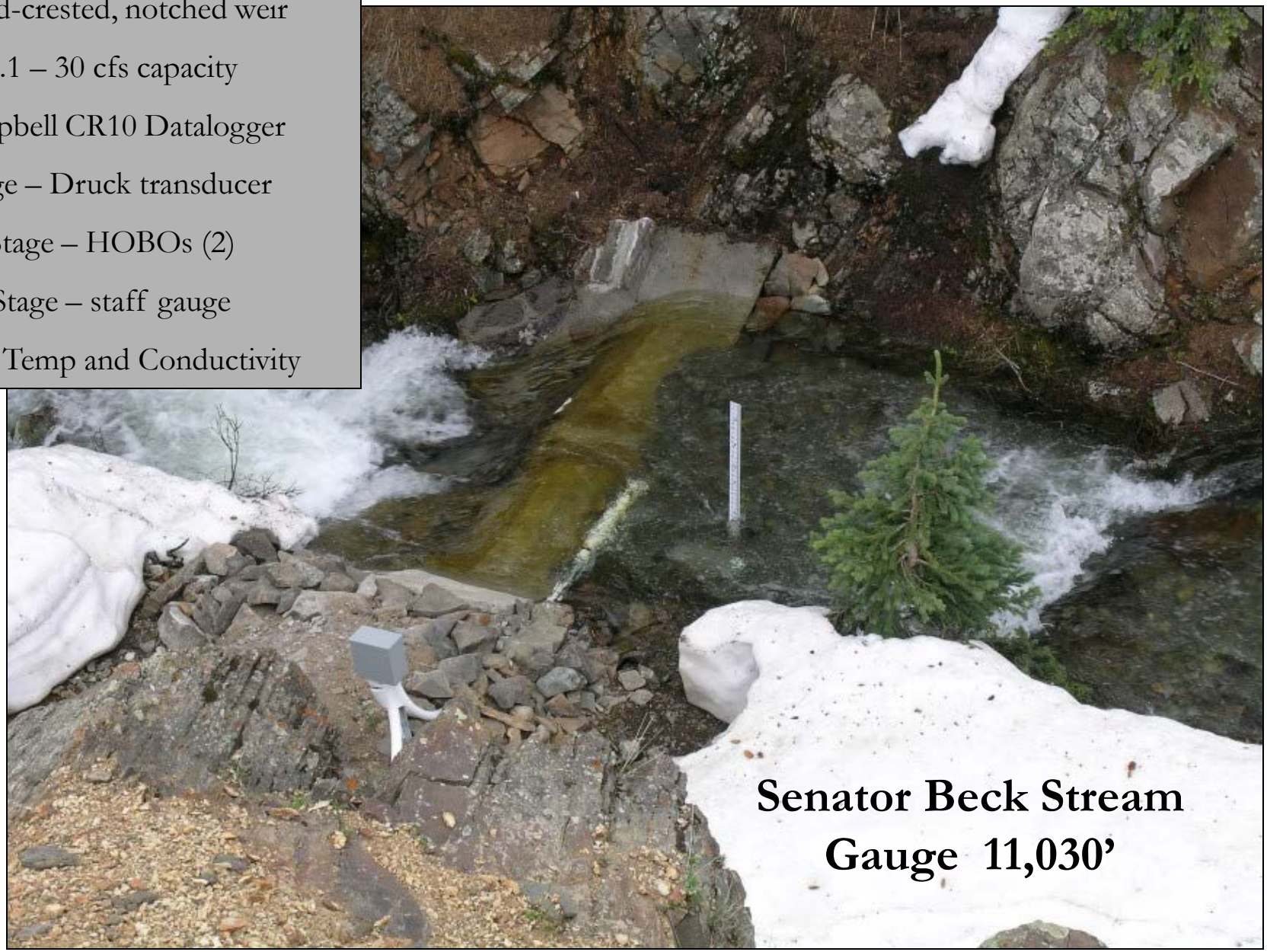
Campbell CR10 Datalogger

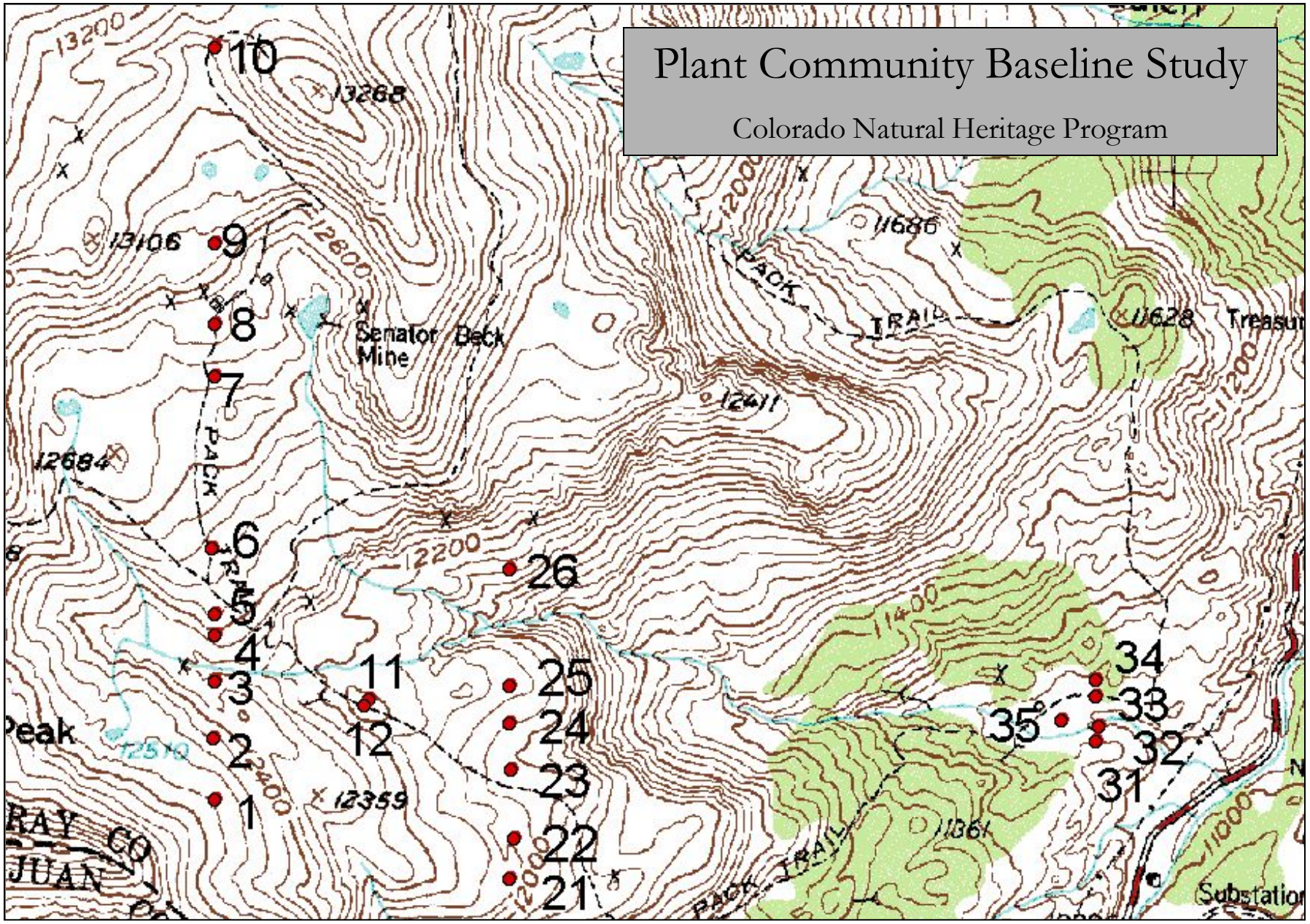
Stage – Druck transducer

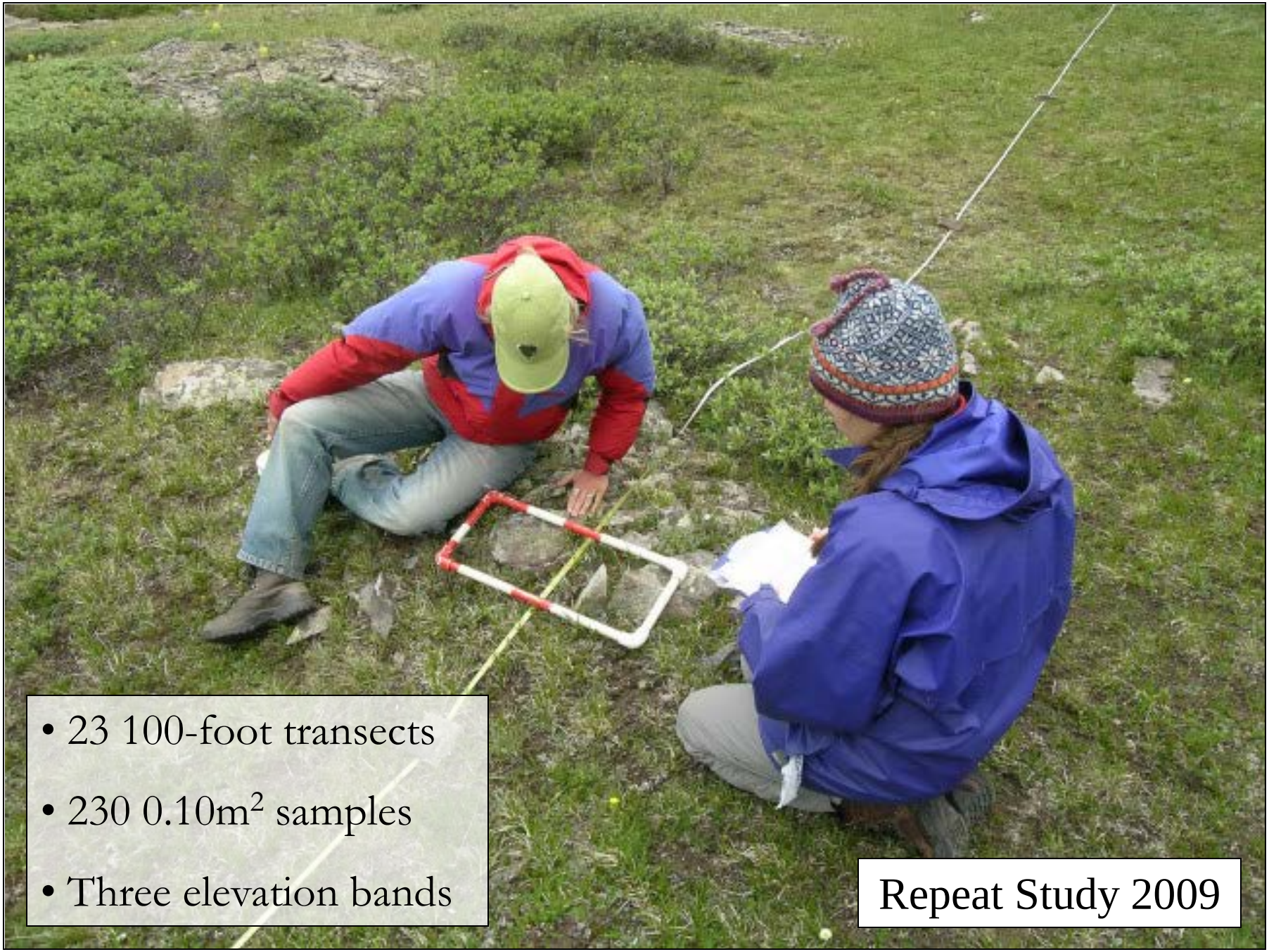
Stage – HOBOs (2)

Stage – staff gauge

Water Temp and Conductivity




Plant Community Baseline Study
Colorado Natural Heritage Program
10
9
8
7
6
5
4
3
2
1
11
12
26
25
24
23
22
21
34
33
32
31
35
Senator Beck Mine
PACK TRAIL
Substation


• 23 100-foot transects
• 230 0.10m^2 samples
• Three elevation bands
Repeat Study 2009

National Snow and Ice Data Center
Supporting Cryospheric Research Since 1976

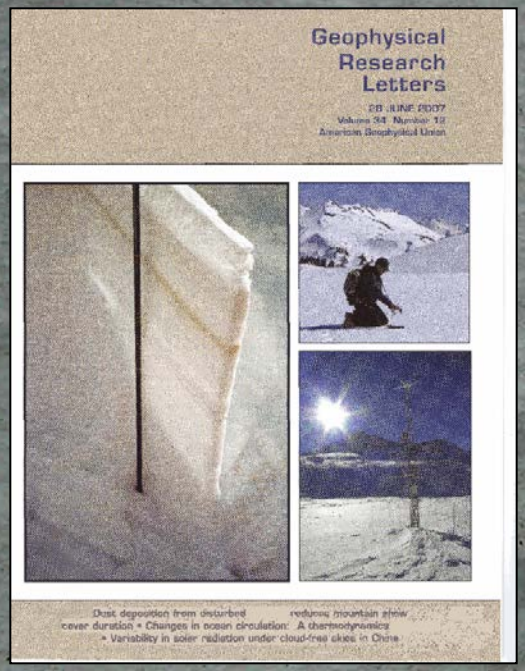
Radiative and hydrologic effects of desert dust deposits in alpine snow

TH Painter[1], C Landry[2], J Neff[3], AP Barrett[1]

[1]National Snow and Ice Data Center,
[2]Center for Snow and Avalanche Studies,
[3]CU-Boulder, Dept of Geological Sciences

Collaborative Research Funded by the National Science Foundation

Findings …



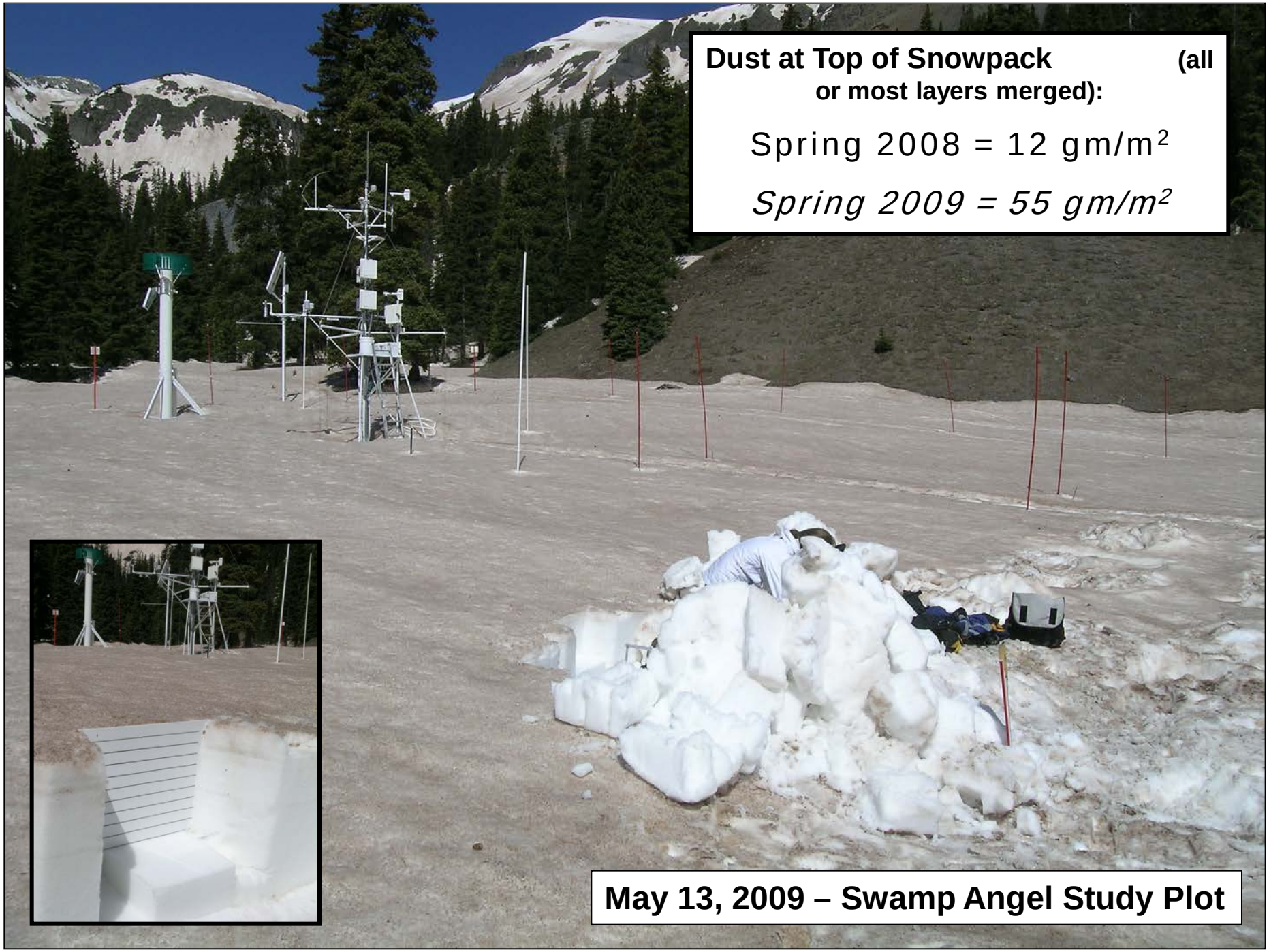
Painter, T.H., A.P. Barrett, C.C. Landry, J.C. Neff, M.P. Cassidy, C.R. Lawrence, K. E. McBride, and G.L. Farmer, 2007. Impact of disturbed desert soils on duration of mountain snow cover, Geophysical Research Letters, Vol. 34, L12502, doi:10.1029/2007GL030284.

- **Exposing layers of dust-in-snow decreases snow albedo and increases radiative forcing on a *regional scale*, accelerating SWE ablation**

- **Observed reductions in snow albedo have advanced snowmelt by up to *one month* and resulted in a *higher amplitude* and *shorter duration* hydrograph**

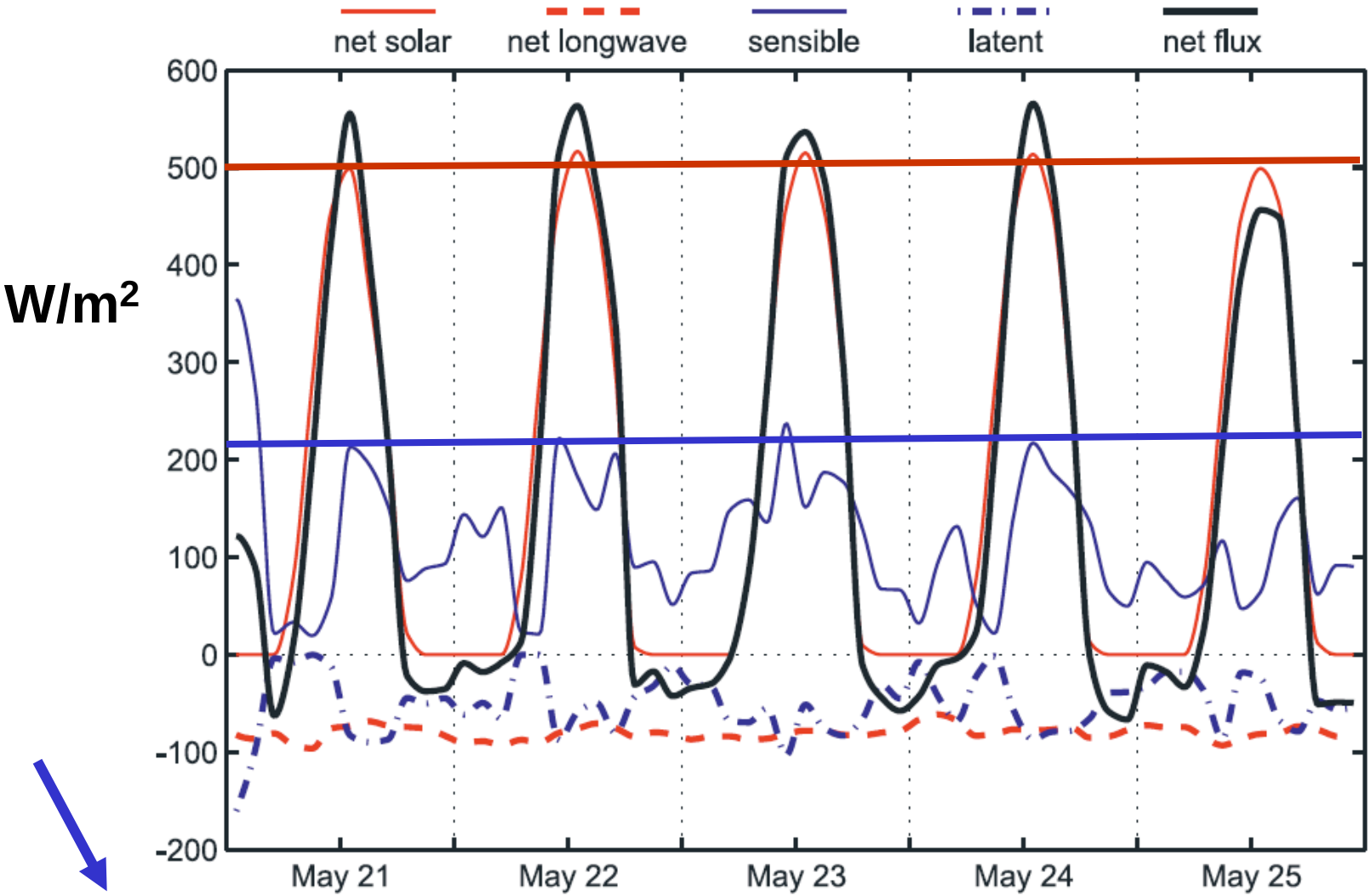
Snow Albedo Measurement

Senator Beck Study Plot 12,200’


Dust at Top of Snowpack (all or most layers merged):
Spring 2008 = 12 gm/m²
Spring 2009 = 55 gm/m²
May 13, 2009 – Swamp Angel Study Plot

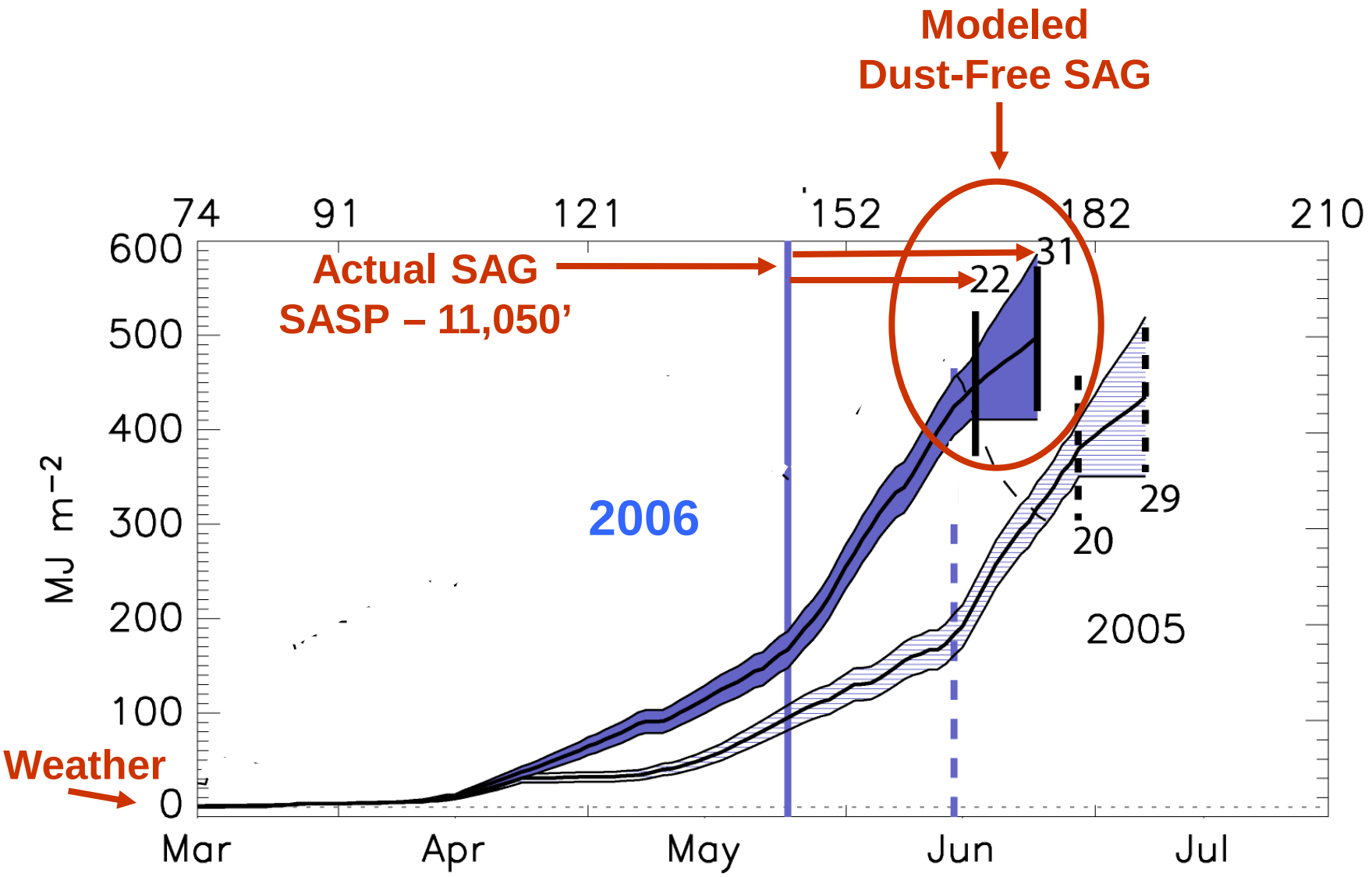
Snowmelt Energy Budget

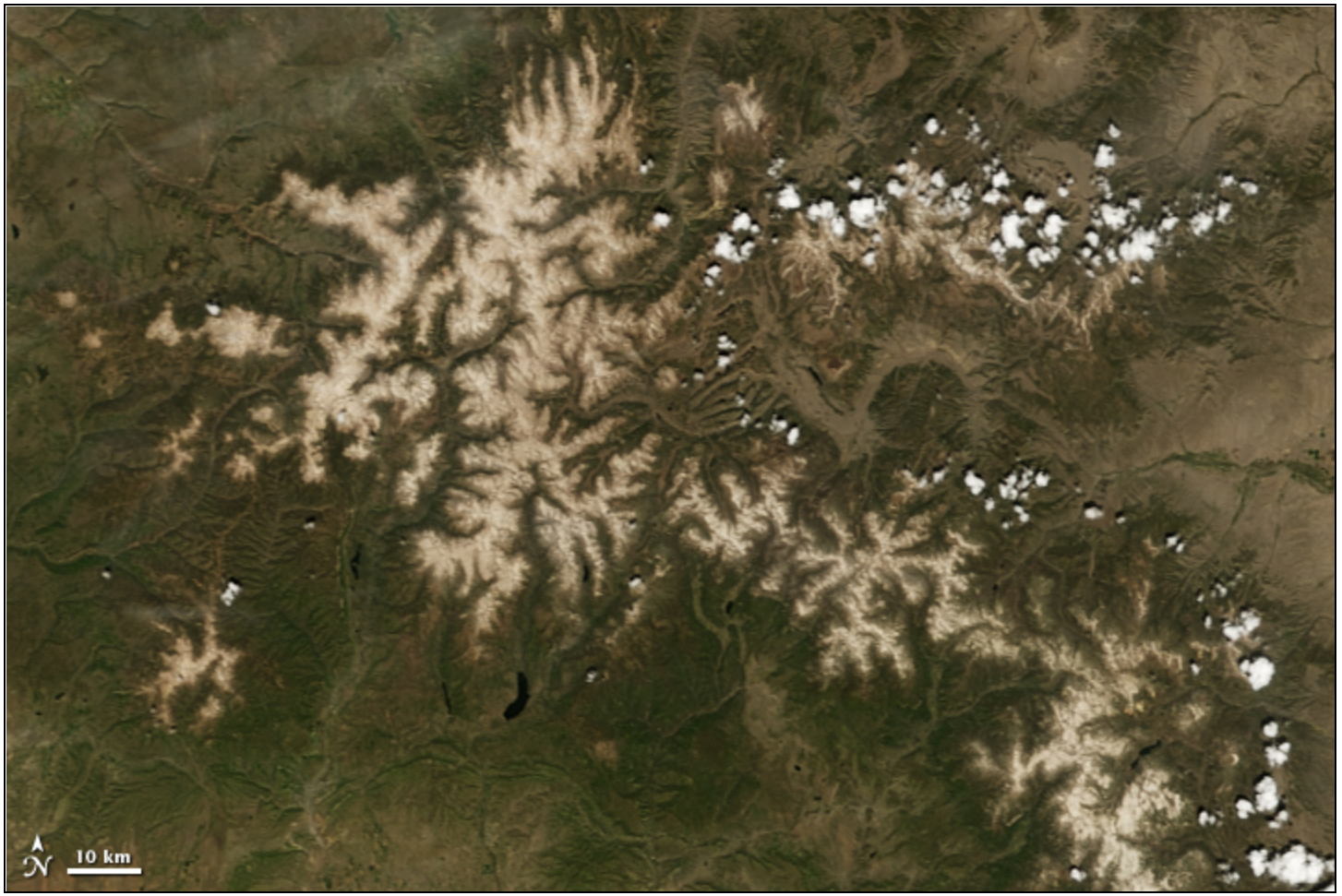
Dusty Snow Surface, Clear Skies – Senator Beck Study Plot, May 2005



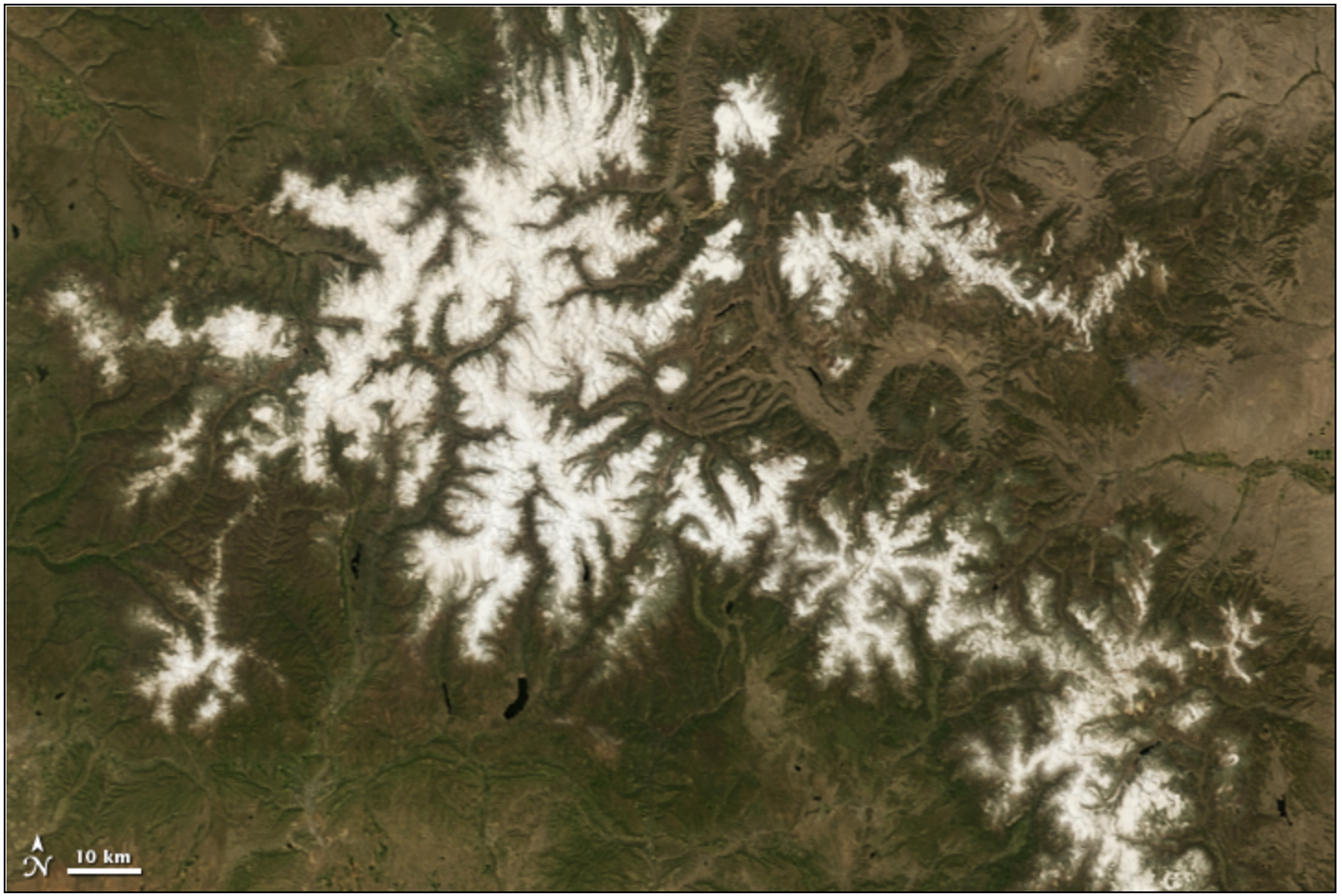
Max Air T	**57 F**	**57 F**	**56 F**	**53 F**	**56 F**

Reduced Albedo = Snowmelt "Forcing"

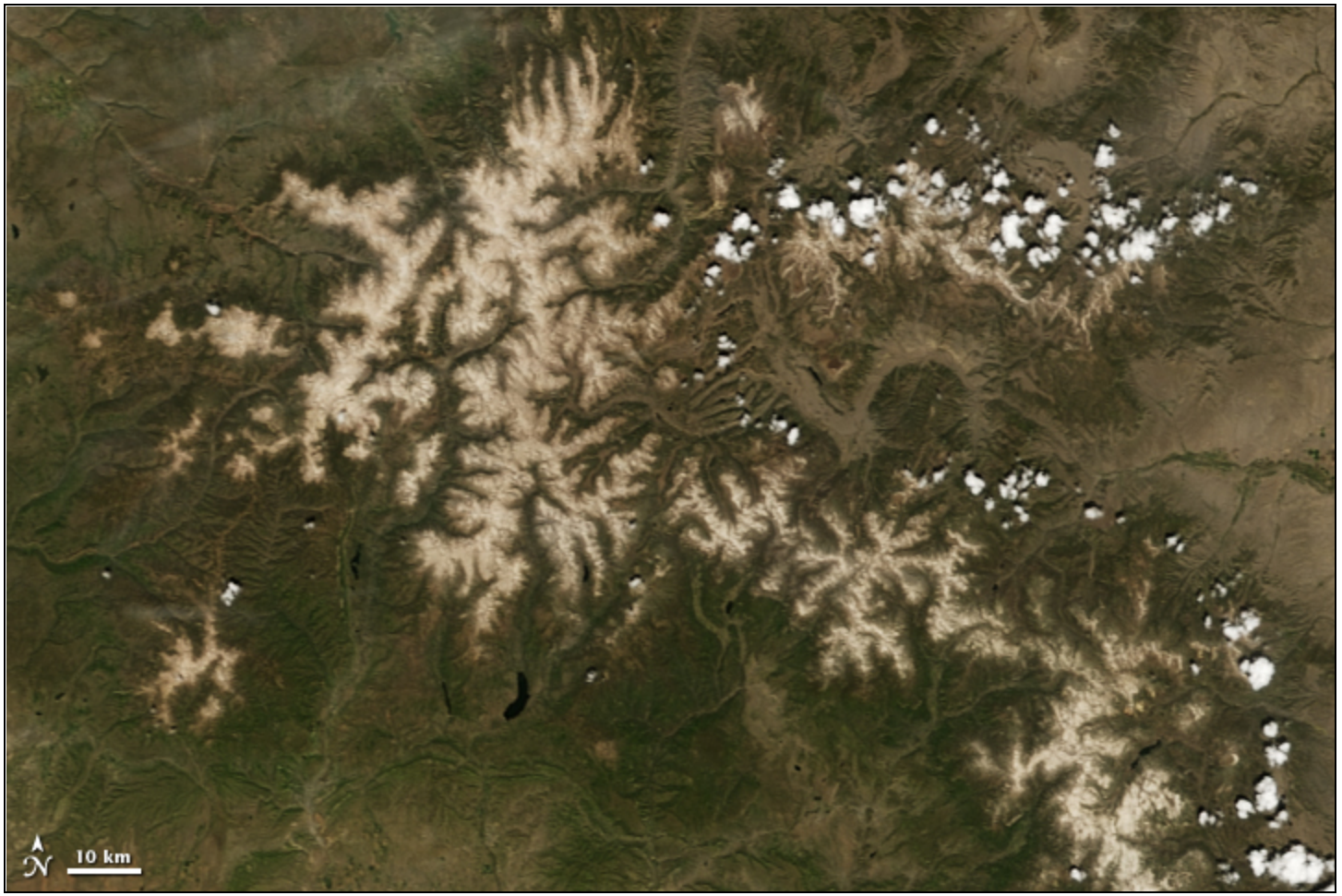




May 18, 2009 – San Juan Mountains
NASA MODIS Image



May 31, 2008 – San Juan Mountains
NASA MODIS Image

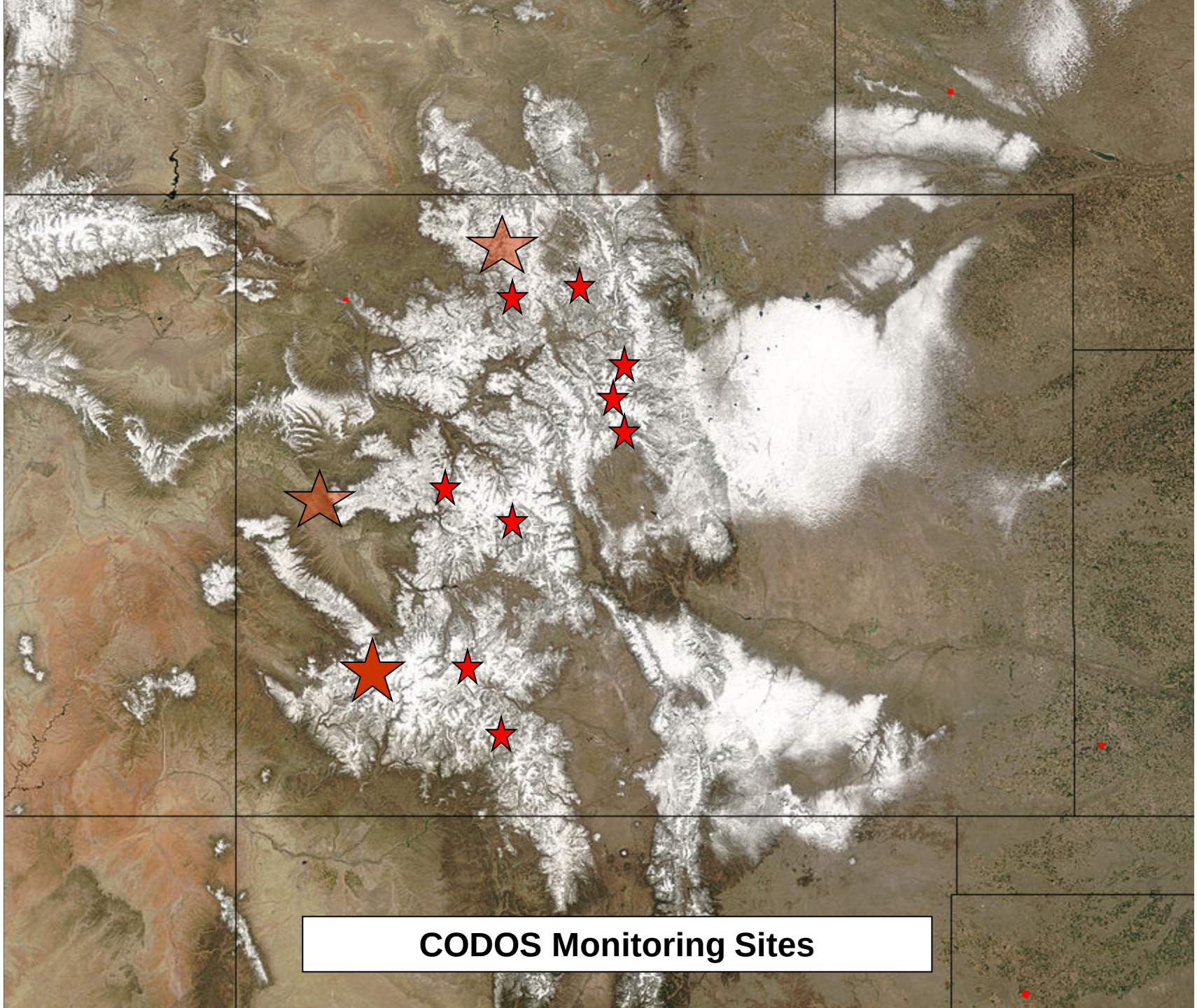


May 18, 2009 – San Juan Mountains
NASA MODIS Image

Senator Beck Basin: March 22, March 29, April 3, April 8, April 15 layers

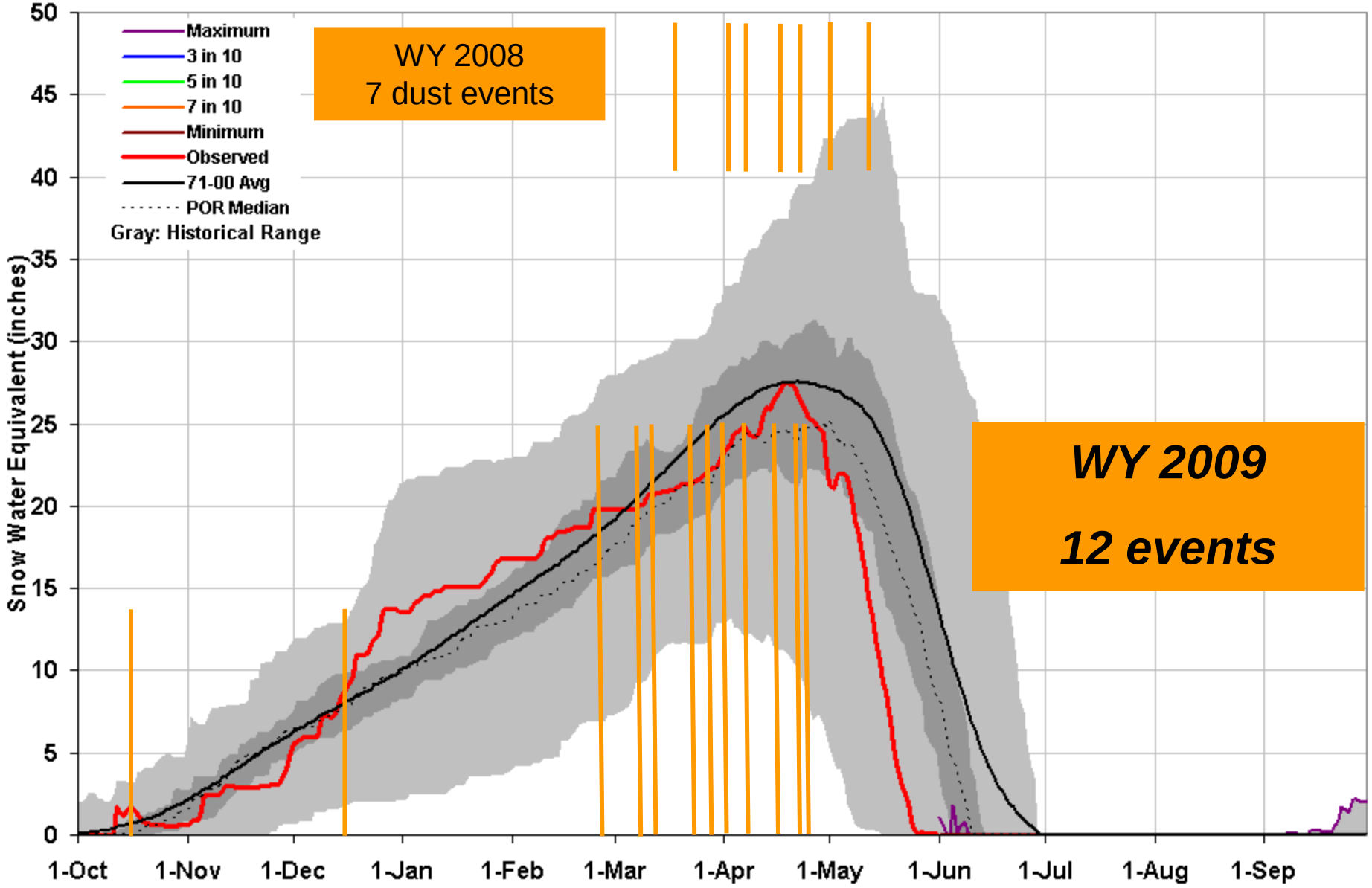
Below Treeline – April 22

Above Treeline – April 24


CODOS Monitoring Sites

Created: 10:48 AM May 31, 2009

07M33S:Red Mountain Pass



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

April 10, 2009 – Wolf Creek Pass

May 11, 2009 – Wolf Creek Pass

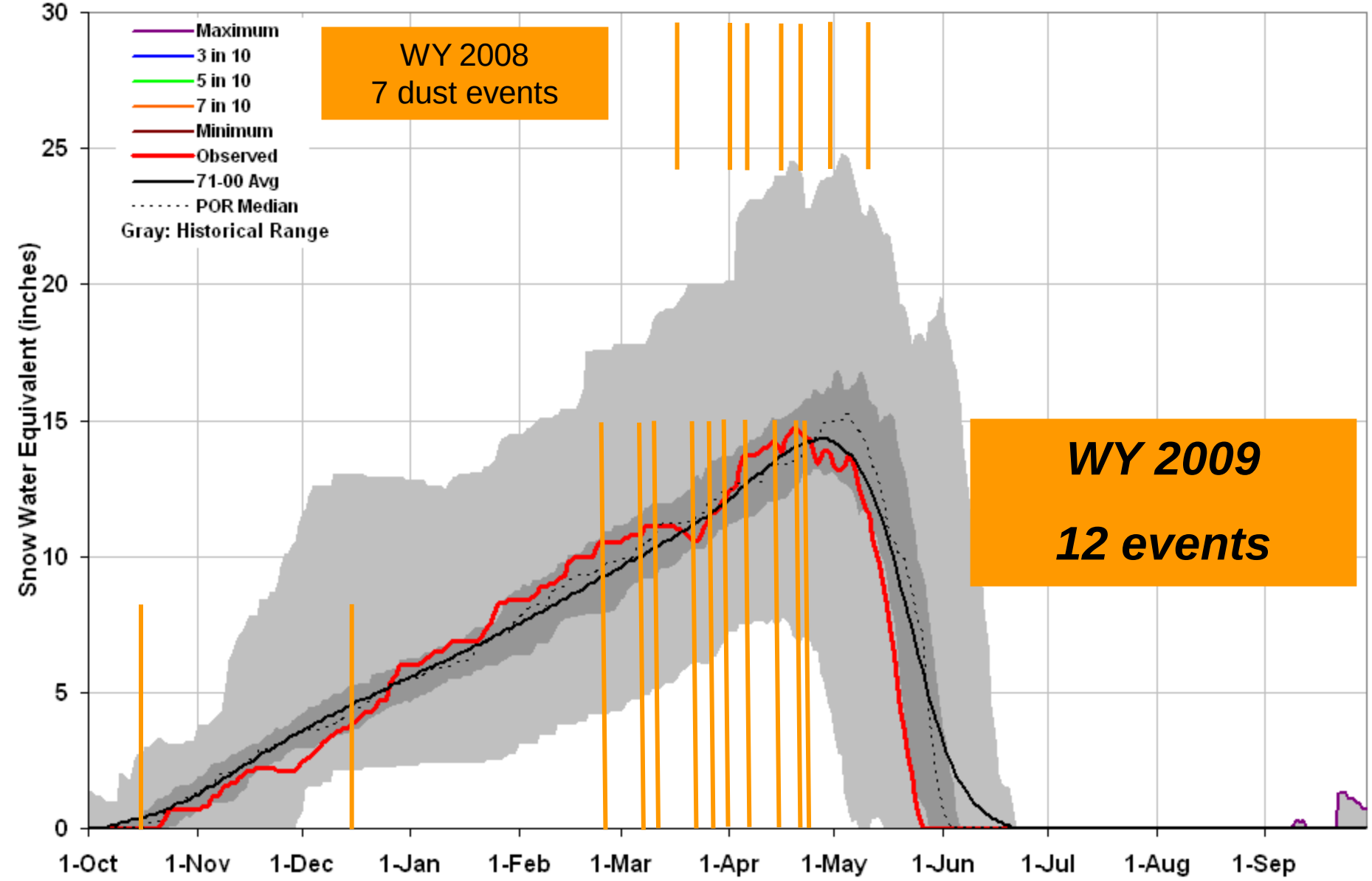

April 17, 2009 – Berthoud Pass

April 18, 2009 – Rabbit Ears Pass

April 18, 2009 – Willow Creek Pass

Created: 03:31 AM Jul 17, 2009

06J05S:Willow Creek Pass



NRCS

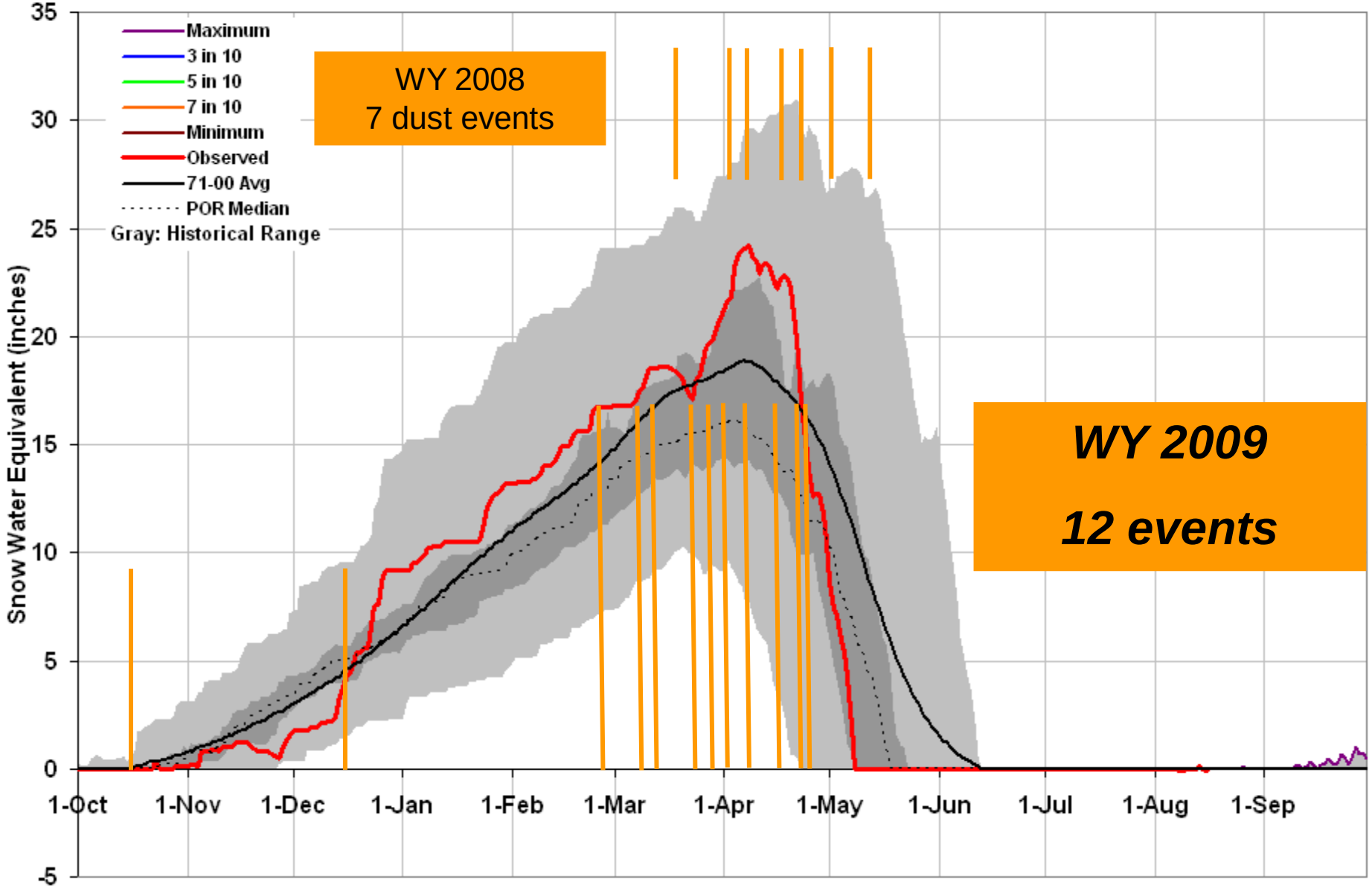
This is an automated product based on SNOTEL data, provisional data are subject to change.

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

April 19, 2009 – McClure Pass

Created: 03:33 AM Aug 17, 2009

07K09S:Mc Clure Pass



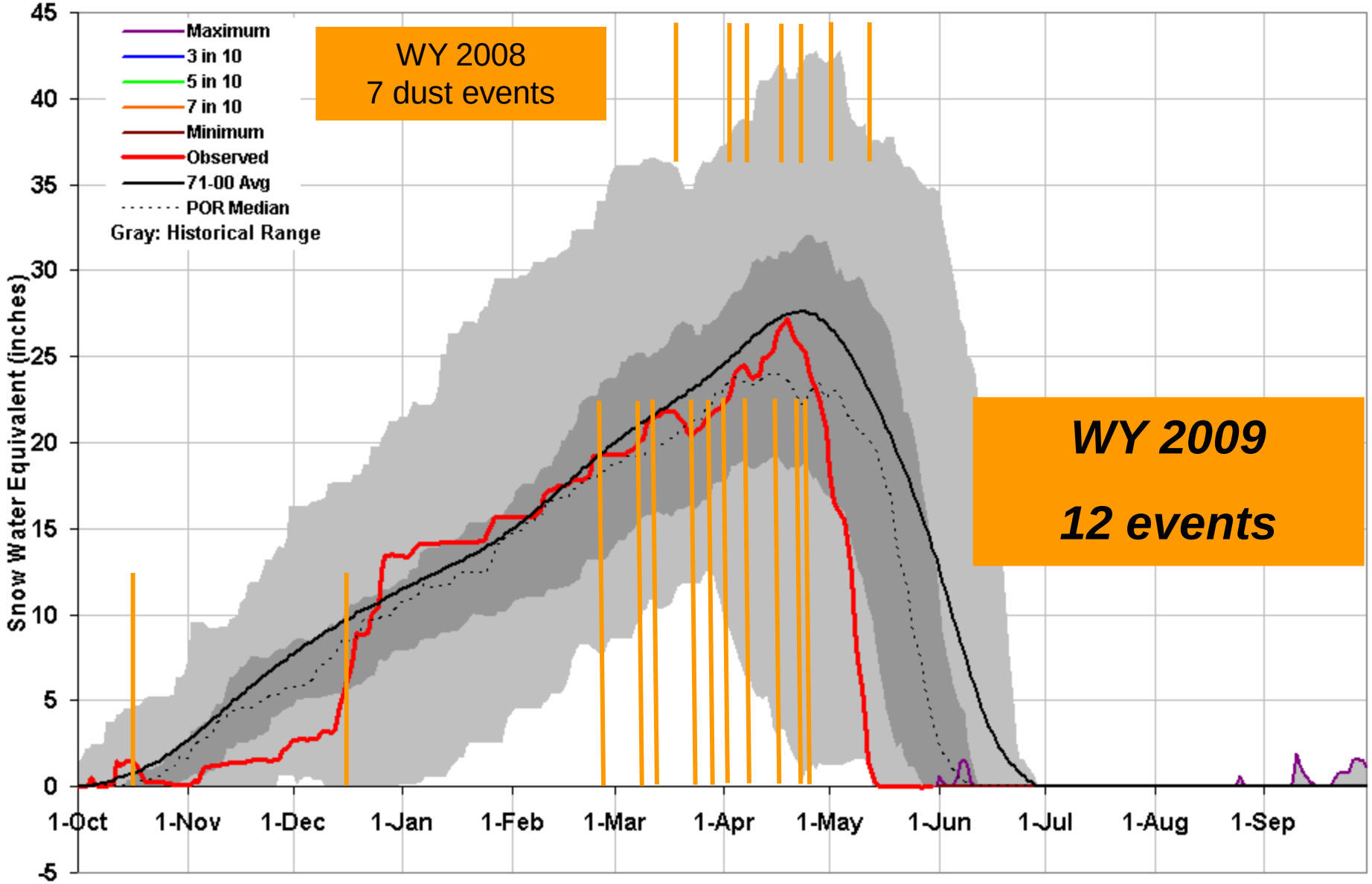
NRCS

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

Created: 10:48 AM May 31, 2009

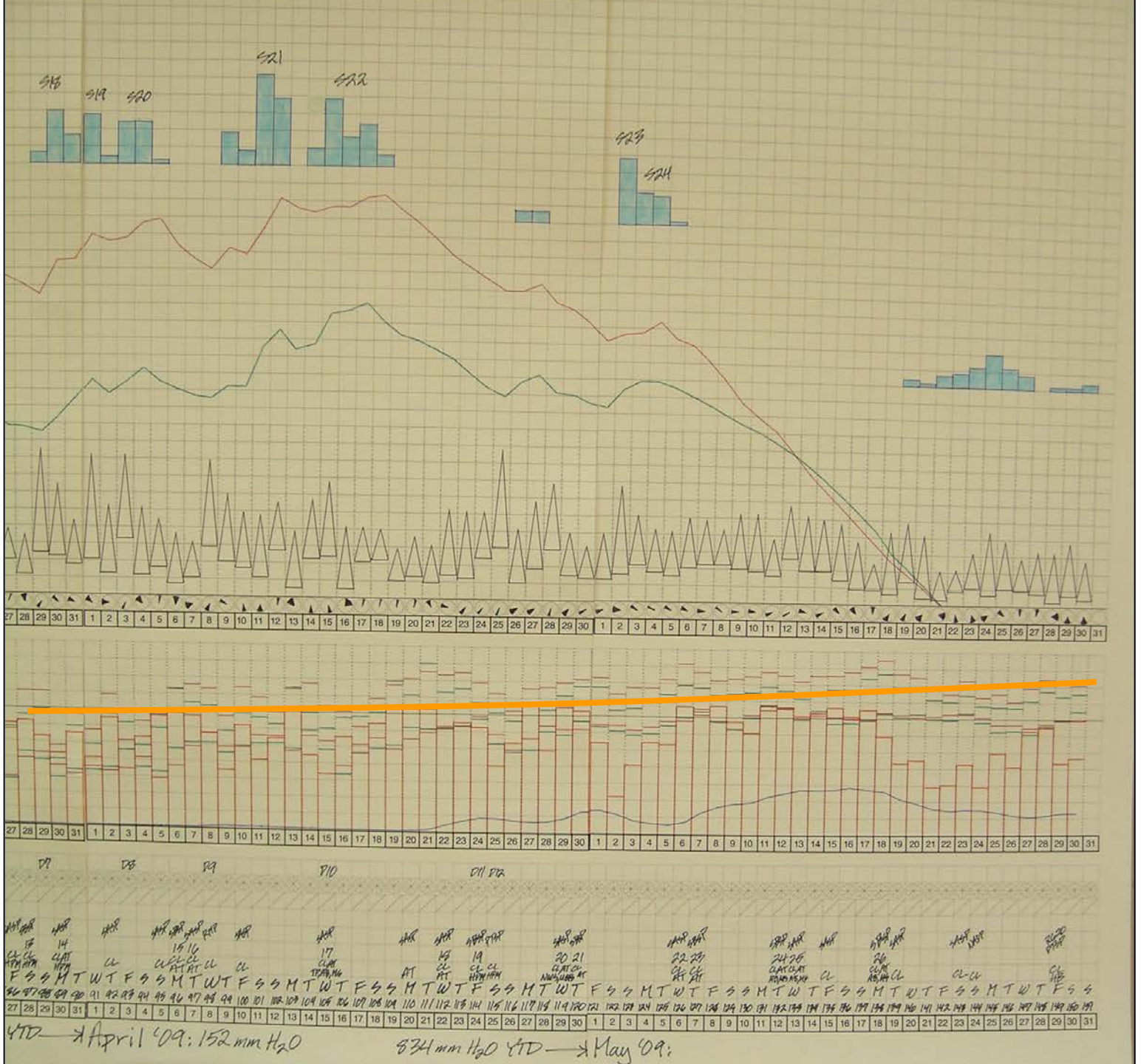
07M32S:Beartown



NRCS

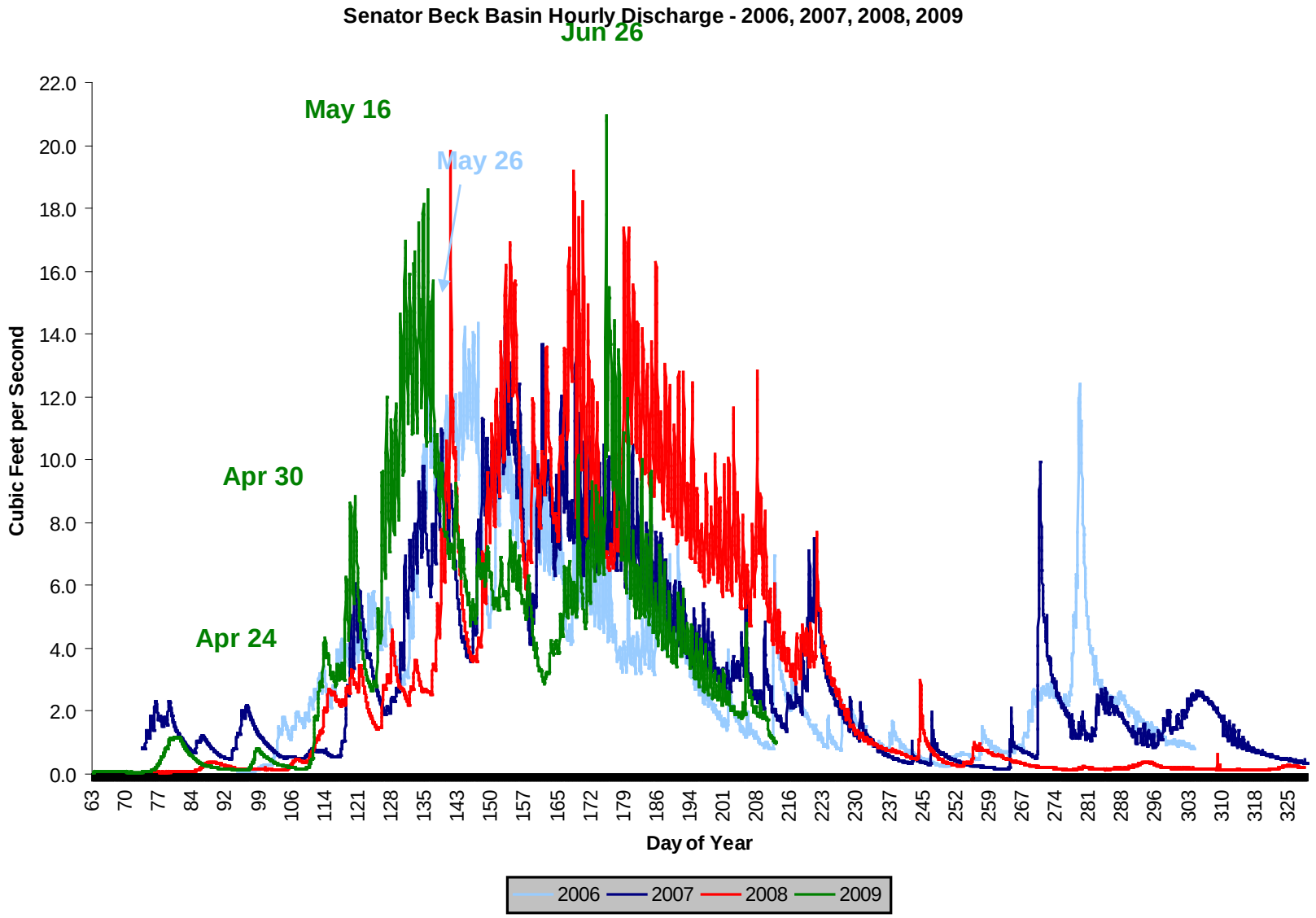
This is an automated product based on SNOTEL data, provisional data are subject to change.

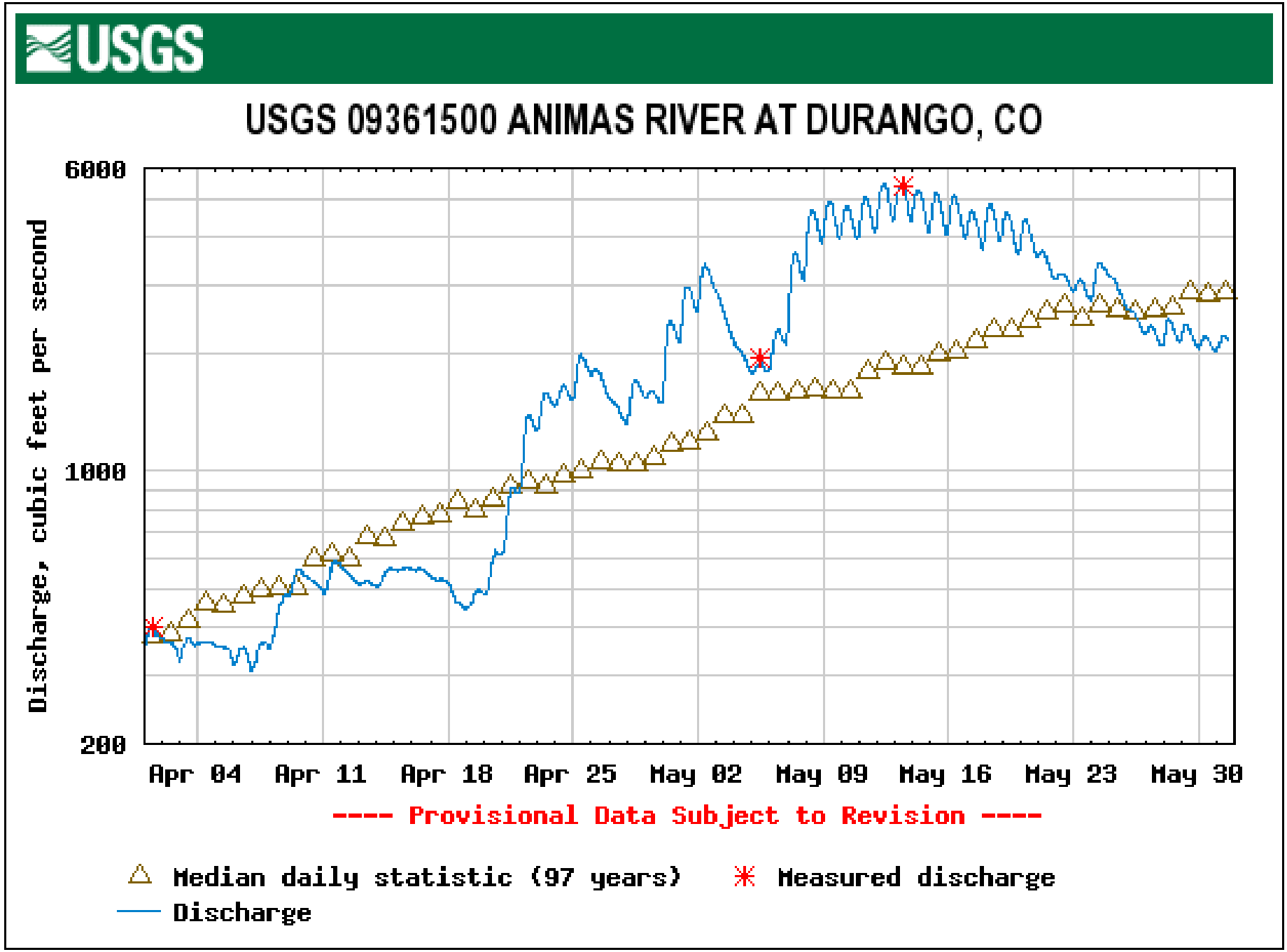
This product combines the historical period of record data (**gray background**) with the recent daily data (**heavy red, left**) to project into the future (**colored lines, right**). This product does not consider climate information such as El Nino or short range weather forecasts and therefore should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


S18
S19
S20
S21
S22
S23
S24
D7
D8
D9
D10
D11
D12
YTD → April '09: 152 mm H2O
834 mm H2O YTD → May '09:

May 13, 2009 –Senator Beck Stream Gauge at 16 cfs

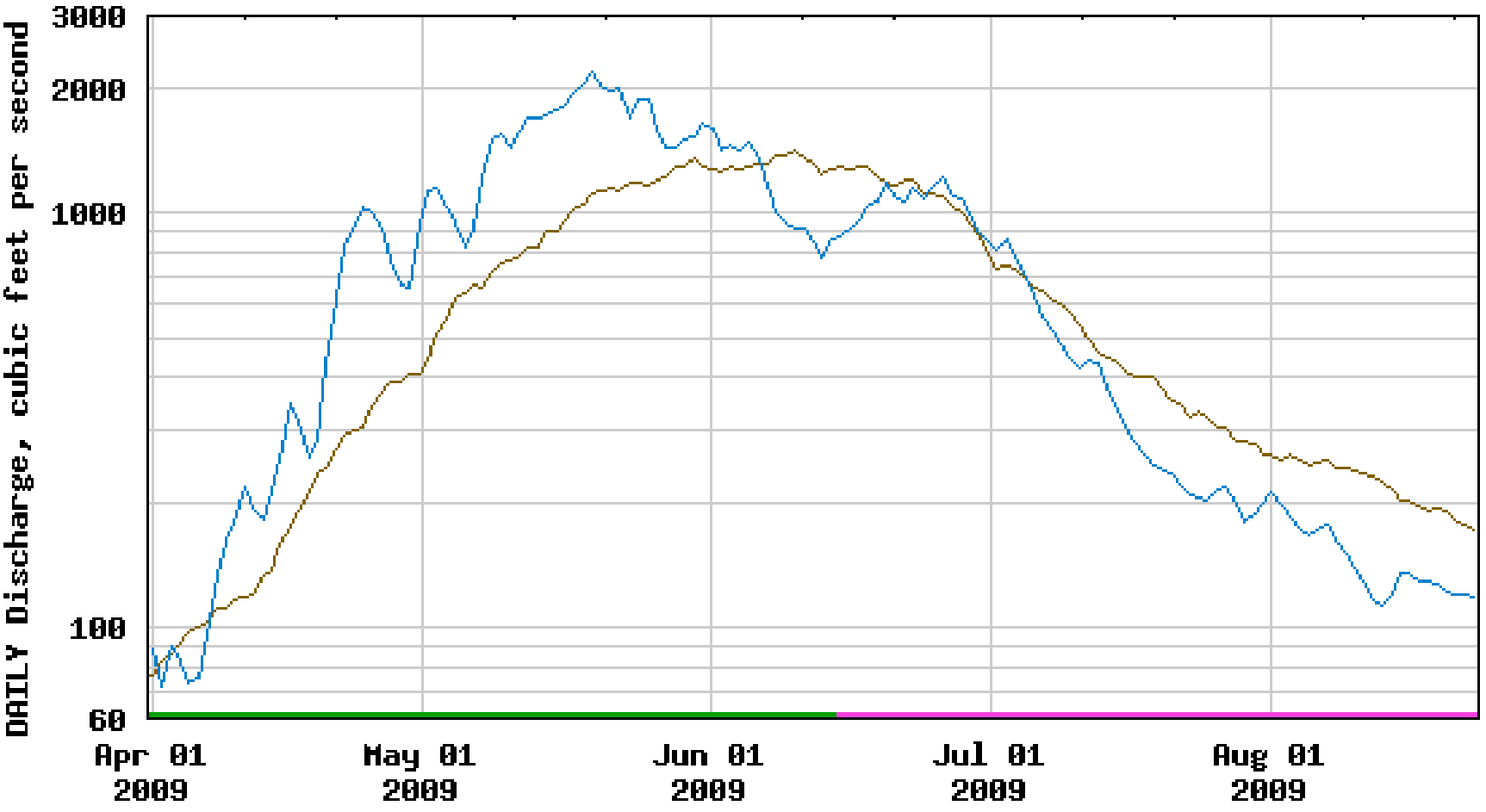
Senator Beck Basin Discharge – WY 2006, 2007, 2008 & 2009

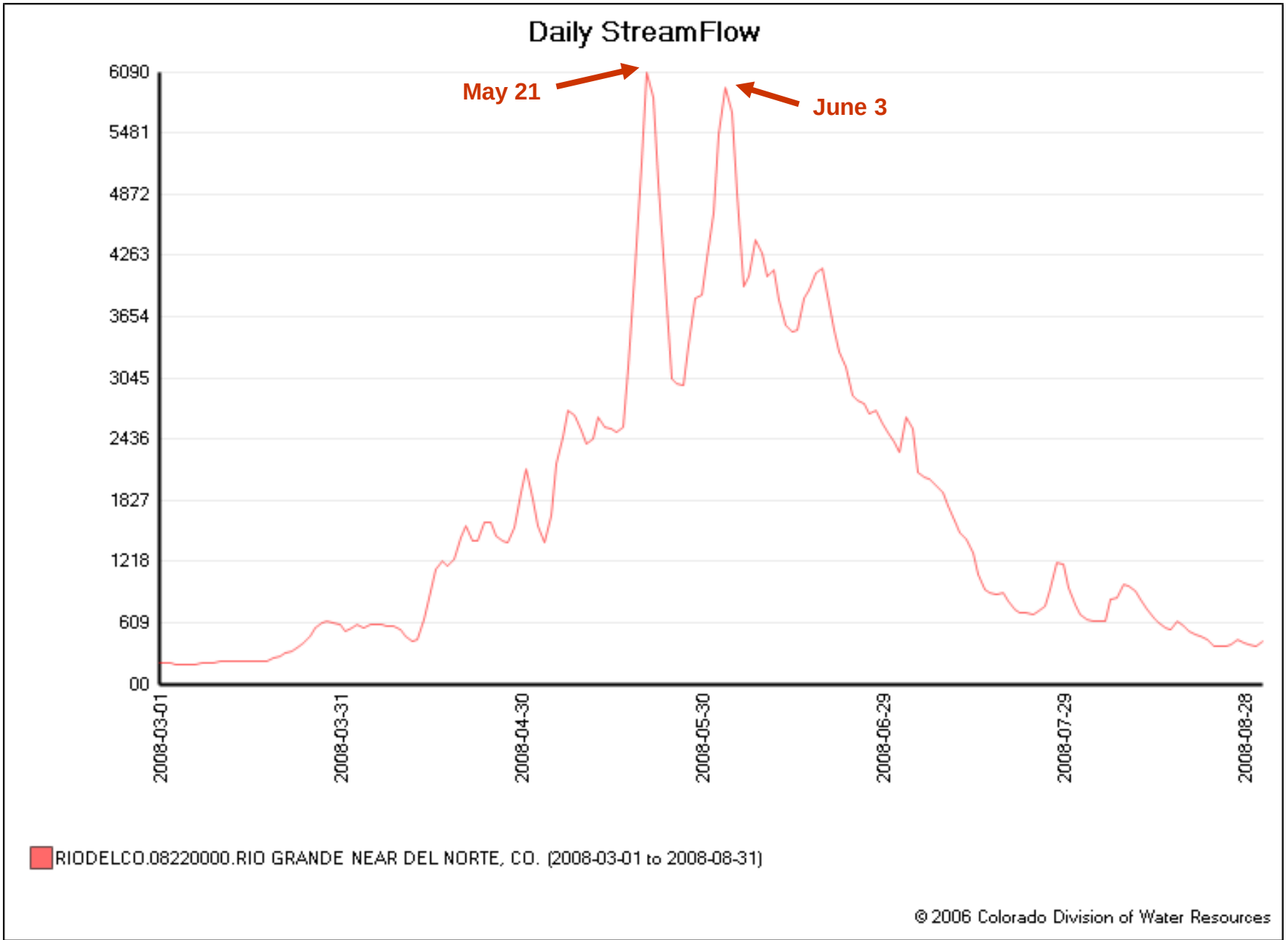



USGS
USGS 09361500 ANIMAS RIVER AT DURANGO, CO
6000
1000
200
Discharge, cubic feet per second
Apr 04
Apr 11
Apr 18
Apr 25
May 02
May 09
May 16
May 23
May 30
---- Provisional Data Subject to Revision ----
Median daily statistic (97 years)
Measured discharge
Discharge

USGS

USGS 09112500 EAST RIVER AT ALMONT, CO




Daily StreamFlow
May 21
June 3
6090
5481
4872
4263
3654
3045
2436
1827
1218
609
00
2008-03-01
2008-03-31
2008-04-30
2008-05-30
2008-06-29
2008-07-29
2008-08-28
RIODELCO.08220000.RIO GRANDE NEAR DEL NORTE, CO. (2008-03-01 to 2008-08-31)
© 2006 Colorado Division of Water Resources

Dust Updates

THE UNIVERSITY OF UTAH — CENTER FOR SNOW & AVALANCHE STUDIES — NSIDC

Colorado Dust-on-Snow Alert #8, June 1, 2008

Following the expected brief pause in snowmelt discussed in Alert #7 of May 24th, all Snotel sites that we've been monitoring this spring have shown a second steep decline in SWE during the past week. All sites showed losses in SWE of equal or greater magnitude than the drop seen earlier, in mid-May, and some sites have reached "Snow All Gone (SAG). The substantial dust layer (composed of multiple, 'merged' layers) that was temporarily covered by clean new snow over the weekend of May 24th and 25th has extensively re-emerged at the snowpack surface, first at lower elevations on all aspects, and more recently at the highest elevations on even northerly aspects. Lingering patches of the May 23/24 storm snow stand in stark, bright white contrast to the surrounding dirty snow, as seen in the May 31st photo below, looking westward at the Senator Beck Basin Study Area (far right) and nearby terrain at Red Mountain Pass, here in the San Juan Mountains.

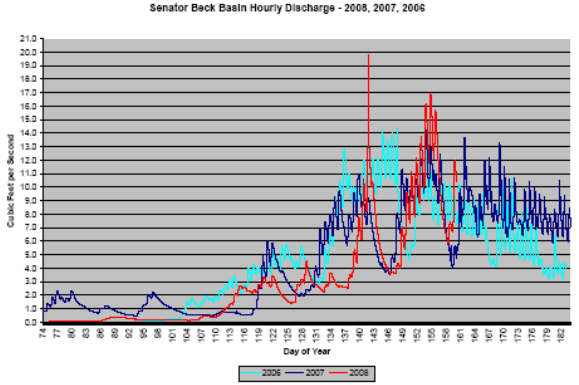
The direct absorption of solar energy by this dust layer, in tandem with two periods of sunny weather and warm air temperatures, has produced two periods of much-greater-than-average rates of snowmelt, as compared to the 30-year average rate of decline in SWE. This is clearly evident in Snotel 2007/2008 Water Year graphs around the State. Thus, even though all the Snotel sites we monitor reported substantially greater-than-average SWE values this season, most sites are also currently on a snowmelt trajectory that will result in earlier-than-average dates of SAG (Snow All Gone), some perhaps several weeks earlier than average. Some lower elevation sites that have recently reached SAG on/about their average date have done so beginning with a much above-average season maximum SWE, under very high snowmelt rates.

6/1/2008

THE UNIVERSITY OF UTAH — CENTER FOR SNOW & AVALANCHE STUDIES — NSIDC

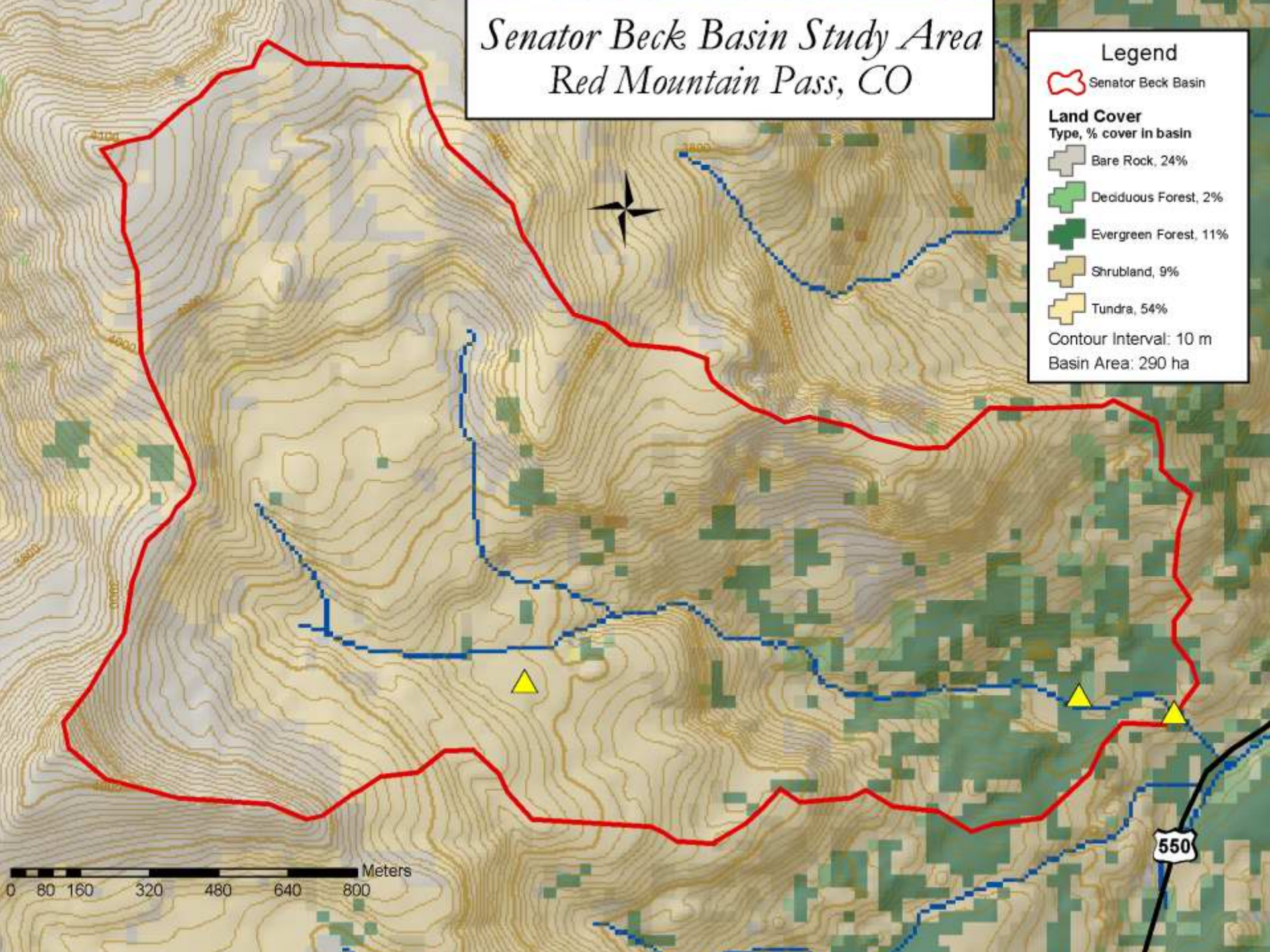
Colorado Dust-on-Snow Alert #9, June 8, 2008

As anticipated by NWS – Grand Junction, fresh snow and cool air 'reset' the snowmelt clock on Wednesday and Thursday of last week; we received 16 mm of SWE in the Senator Beck Basin Study Area, as 4-8" of new snow, varying by elevation. We did not detect any fresh dust with this storm here in our study area, and have received no reports of fresh dust elsewhere. That fresh snow layer resulted in a temporary return to a high albedo that, combined with cooler temperatures, dropped our Basin discharge from near 17 cfs on June 3 to 6 cfs by June 6, as seen below, ending our second major surge of snowmelt and stretching the date of snow-all-gone (SAG) a few days further into the future. Following that low point in streamflow on June 6, however, the new clean new snow quickly succumbed to sunny skies and the absorption of direct solar radiation by the underlying dust, revealing the underlying dirty snow surface once again. Our third surge in flows this season has now begun, as of this writing, despite somewhat cooler air temperatures here in the San Juans over the past weekend.



Based on our first-hand observation of extensive dust layers in mid-May, it is our assumption that a similar return to high albedo (caused by new snow) occurred throughout most of the remaining Colorado mountain snowpack last Wednesday and Thursday, followed by a similar, subsequent ablation of the clean new snow and re-emergence of the underlying dirty snow surface. Some Central and Northern mountain areas may have received additional snow showers on Saturday or Sunday, but not in amounts that will cause a prolonged return to high snowcover albedo values. Therefore, given that the current NWS – Grand Jct. 7-day forecast calls for generally sunny skies through Sunday, June 15th, except for a brief disturbance on Wednesday the 11th, and temperatures at 10,000' in the 60's (except Wednesday and Thursday), another surge of dust-enhanced snowmelt is expected.

6/8/2008


Senator Beck Basin Study Area
Red Mountain Pass, CO
Legend
Senator Beck Basin
Land Cover
Type, % cover in basin
Bare Rock, 24%
Deciduous Forest, 2%
Evergreen Forest, 11%
Shrubland, 9%
Tundra, 54%
Contour Interval: 10 m
Basin Area: 290 ha
Meters
0 80 160 320 480 640 800
550

Colorado Dust-on-Snow (CODOS) Program Participants:

Colorado River, Southwestern, and Rio Grande Water Conservation Districts

Upper Gunnison River, Tri-County, Animas-La Plata, and Northern Water Conservancy Districts

Colorado Water Conservation Board

Bureau of Reclamation – Western Colorado, Denver Water, Western Water Assessment

Center for Snow & Avalanche Studies

SOL SNOW OPTICS LABORATORY

NSIDC National Snow and Ice Data Center