

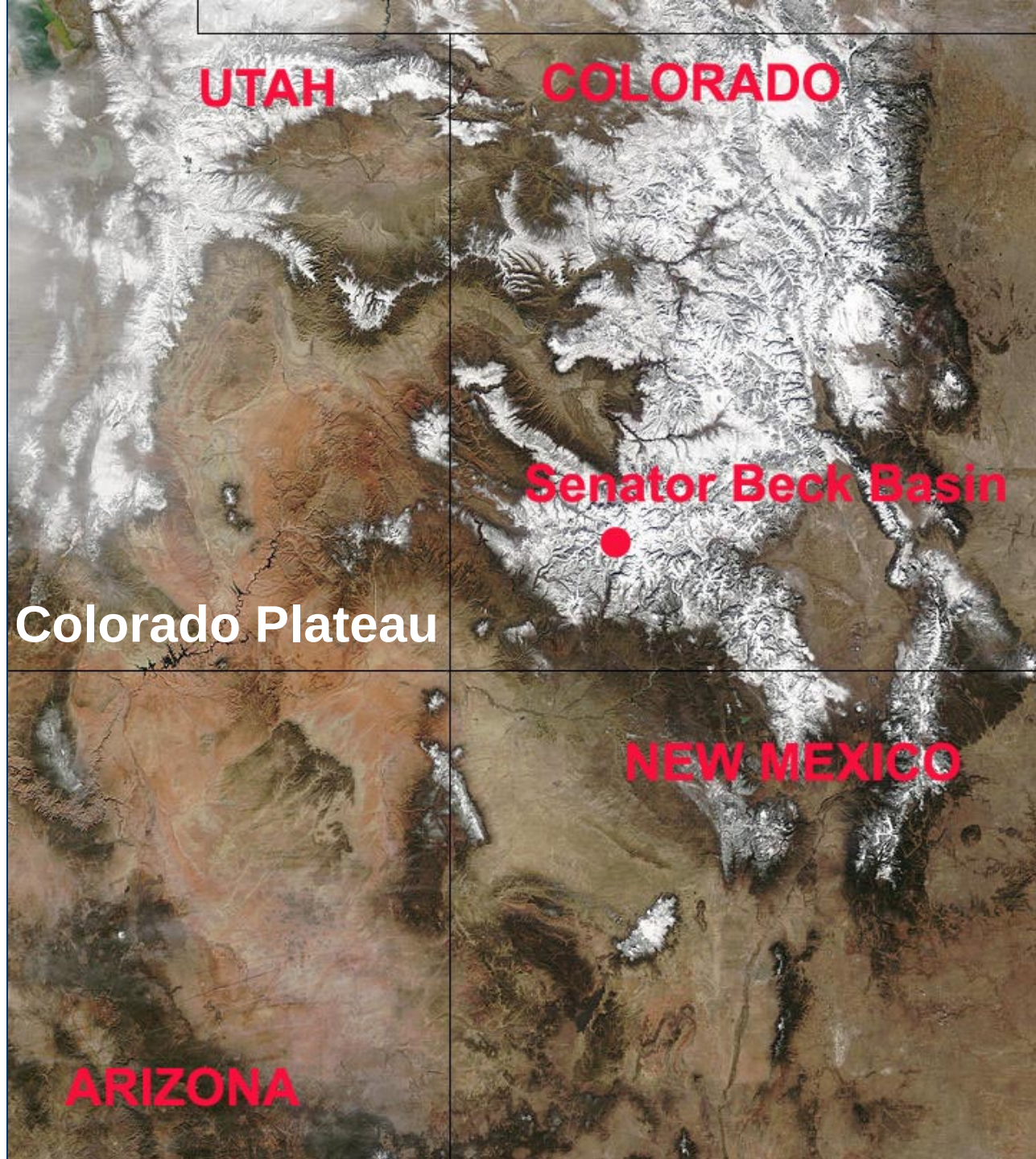
Upper Rio Grande Watershed Snowmelt Impacts of Dust-on-Snow

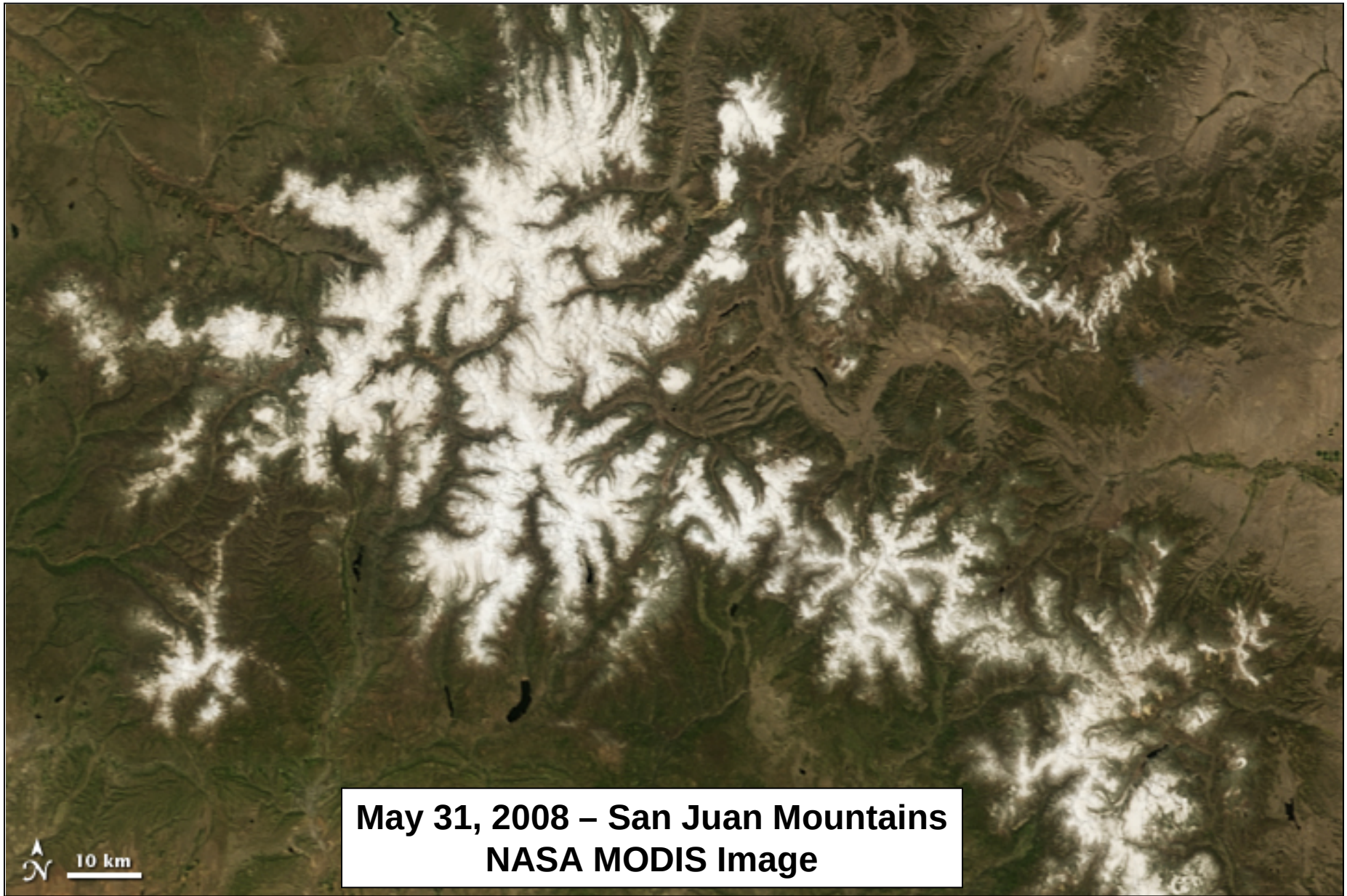
Chris Landry

Colorado Dust-on-Snow Program

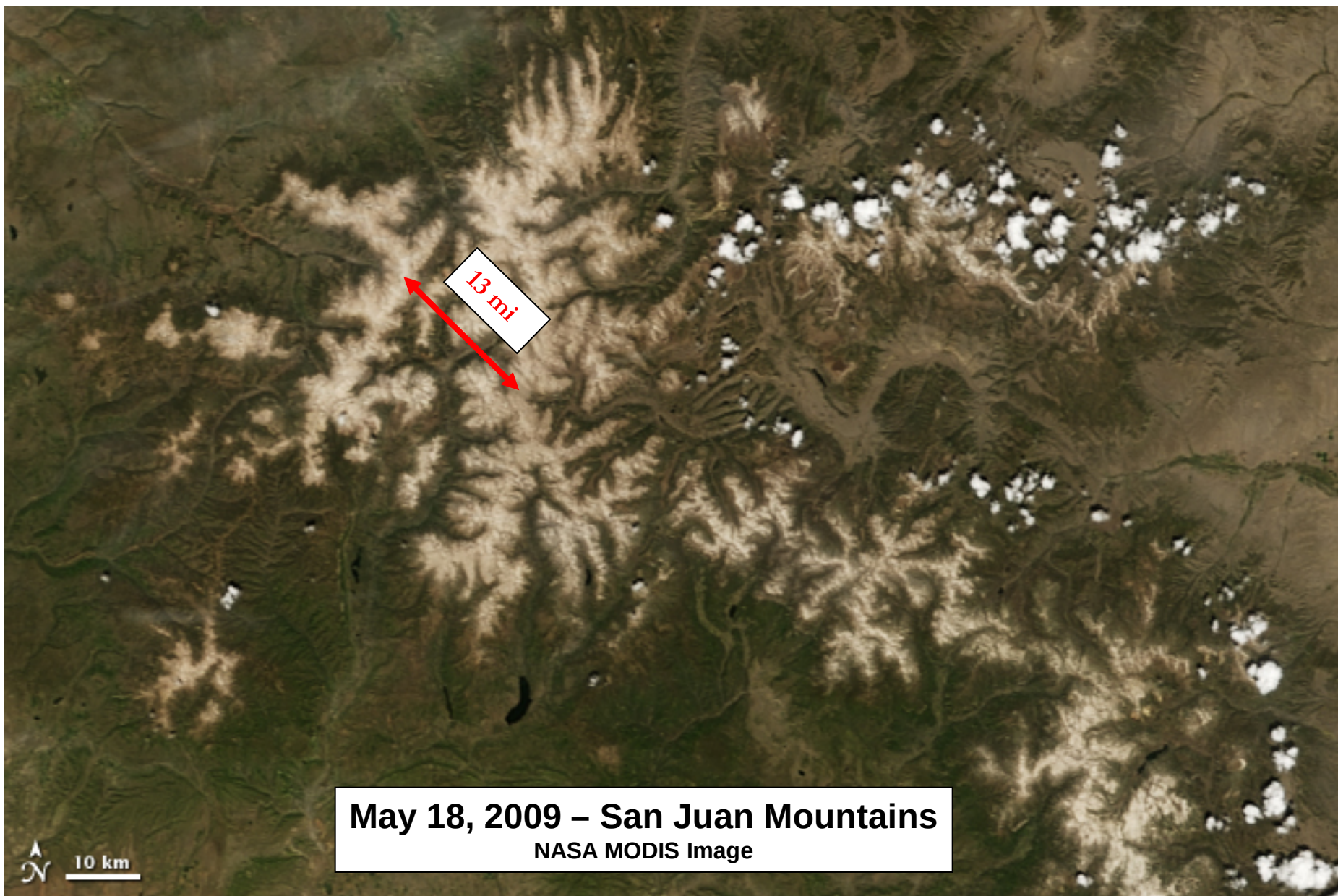
CODOS

Center for Snow and Avalanche
Studies





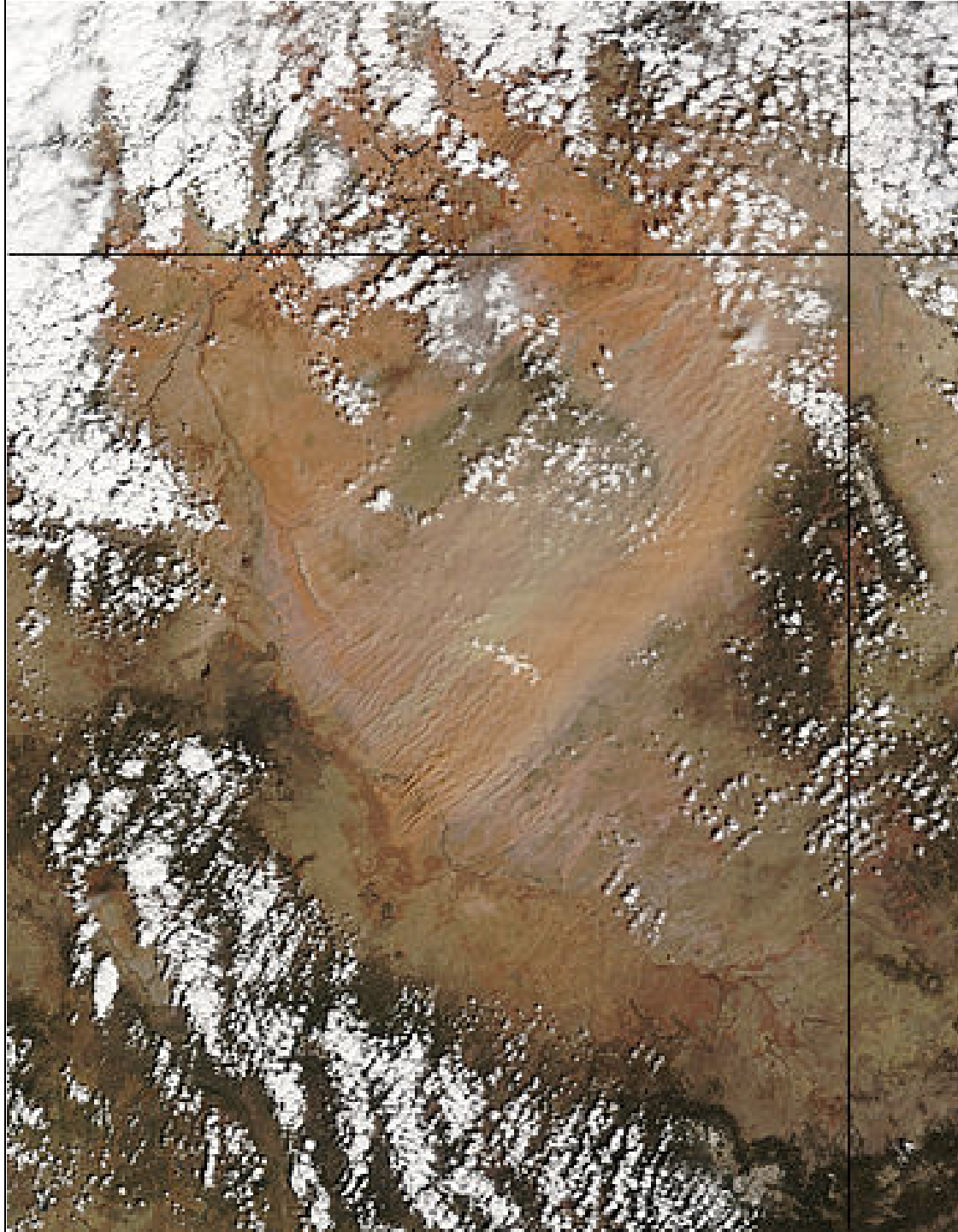
**May 31, 2008 – San Juan Mountains
NASA MODIS Image**



May 18, 2009 – San Juan Mountains
NASA MODIS Image

From Senator Beck Basin - May 12, 2009





D8 – WY2009
April 3, 2009

Silverton
April 3, 2009



D4 – WY2010

April 5, 2010



Silverton
April 5, 2010



Dust-on-Snow Deposition Log

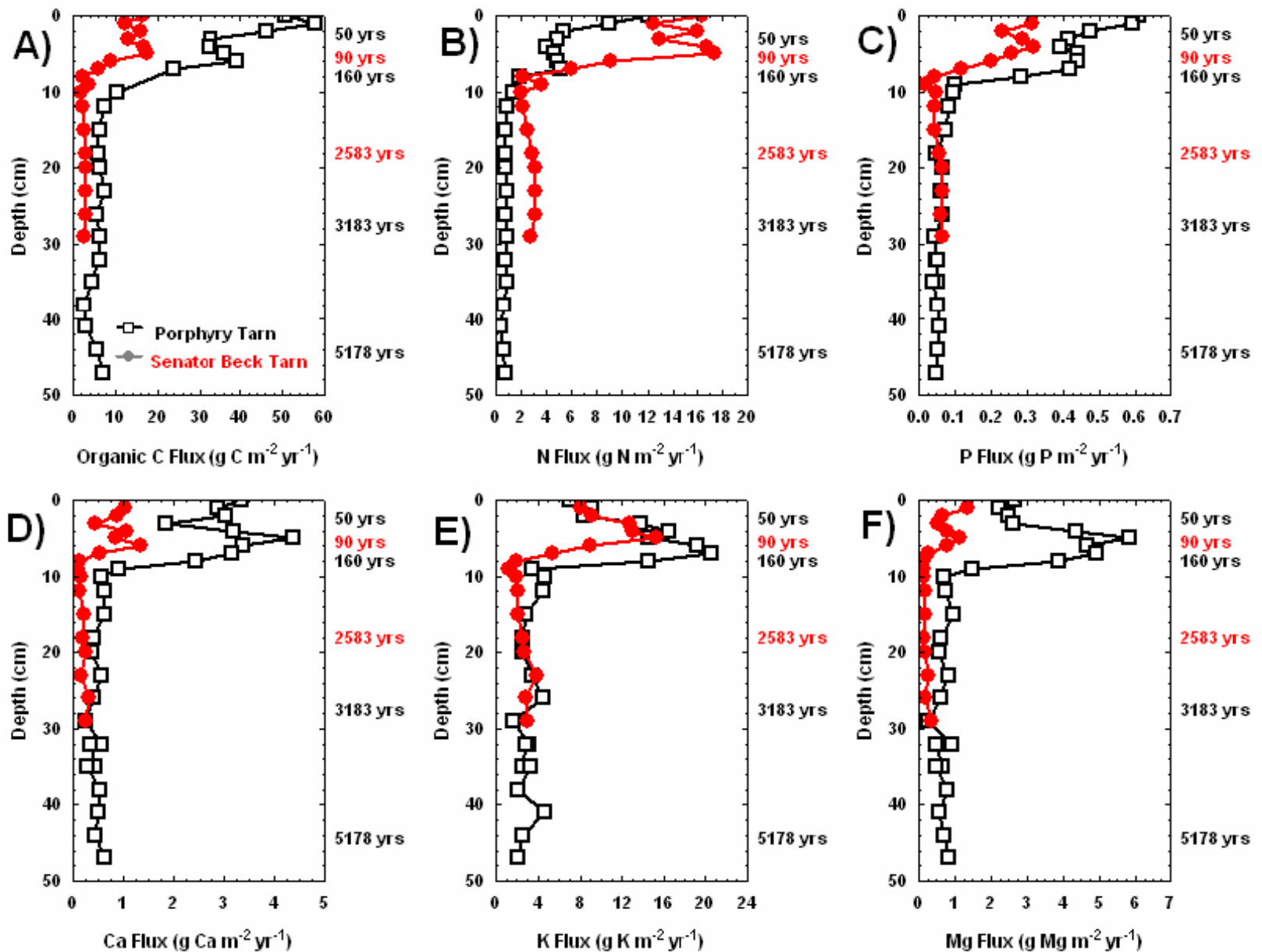
Senator Beck Basin Study Area – Red Mountain Pass

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

Paleo History of Dust Deposition



Neff, J.C., A.P. Ballantyne, G.L. Farmer, N.M. Mahowald, J.L. Conroy, C.C. Landry, J.T. Overpeck, T.H. Painter, C.R. Lawrence and R.L. Reynolds. 2008. Increasing eolian dust deposition in the western United States linked to human activity, *Nature Geoscience*, Vol. 1, No. 3, pp. 189-195, March 2008, doi: 10.1038/ngeo136



Neff, J.C., A.P. Ballantyne, G.L. Farmer, N.M. Mahowald, J.L. Conroy, C.C. Landry, J.T. Overpeck, T.H. Painter, C.R. Lawrence and R.L. Reynolds, 2008. Increasing eolian dust deposition in the western United States linked to human activity, *Nature Geoscience*, Vol. 1, No. 3, pp. 189-195, March 2008, doi: 10.1038/ngeo136

Senator Beck Basin Study Area
Red Mountain Pass, CO

290 ha

Operated by
CSAS under
USFS Special
Use Permit with
Uncompahgre
National Forest,
Ouray Ranger
District

SBSP

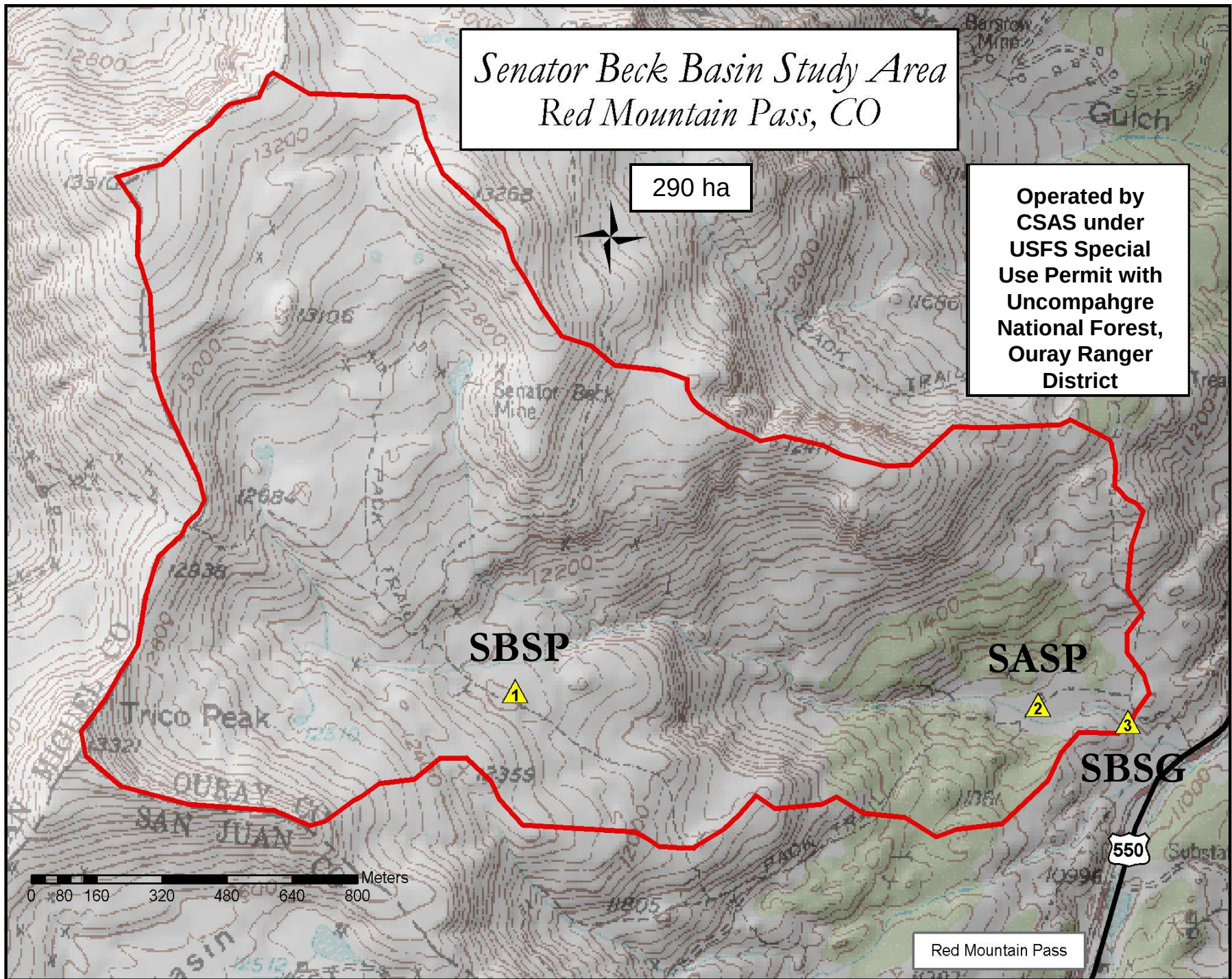
SASP

SBSG



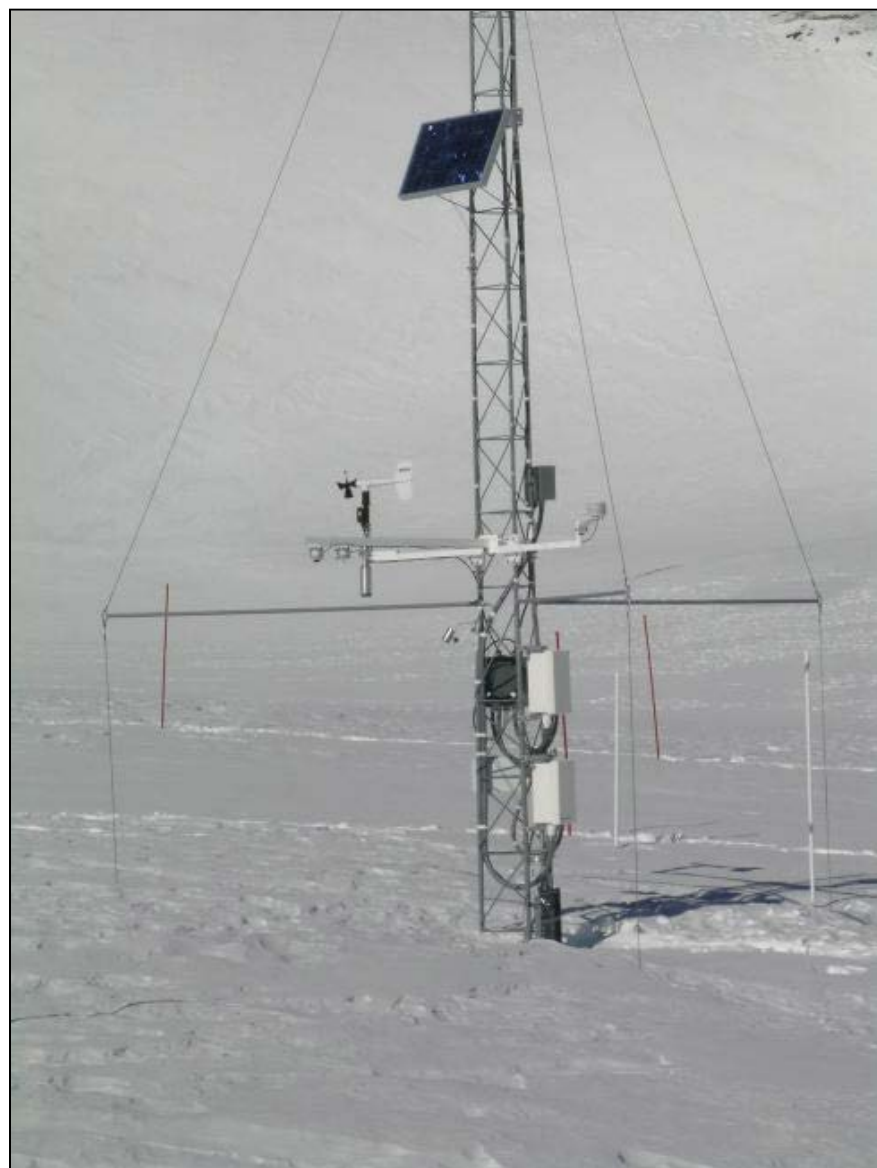
0 80 160 320 480 640 800 Meters

Red Mountain Pass

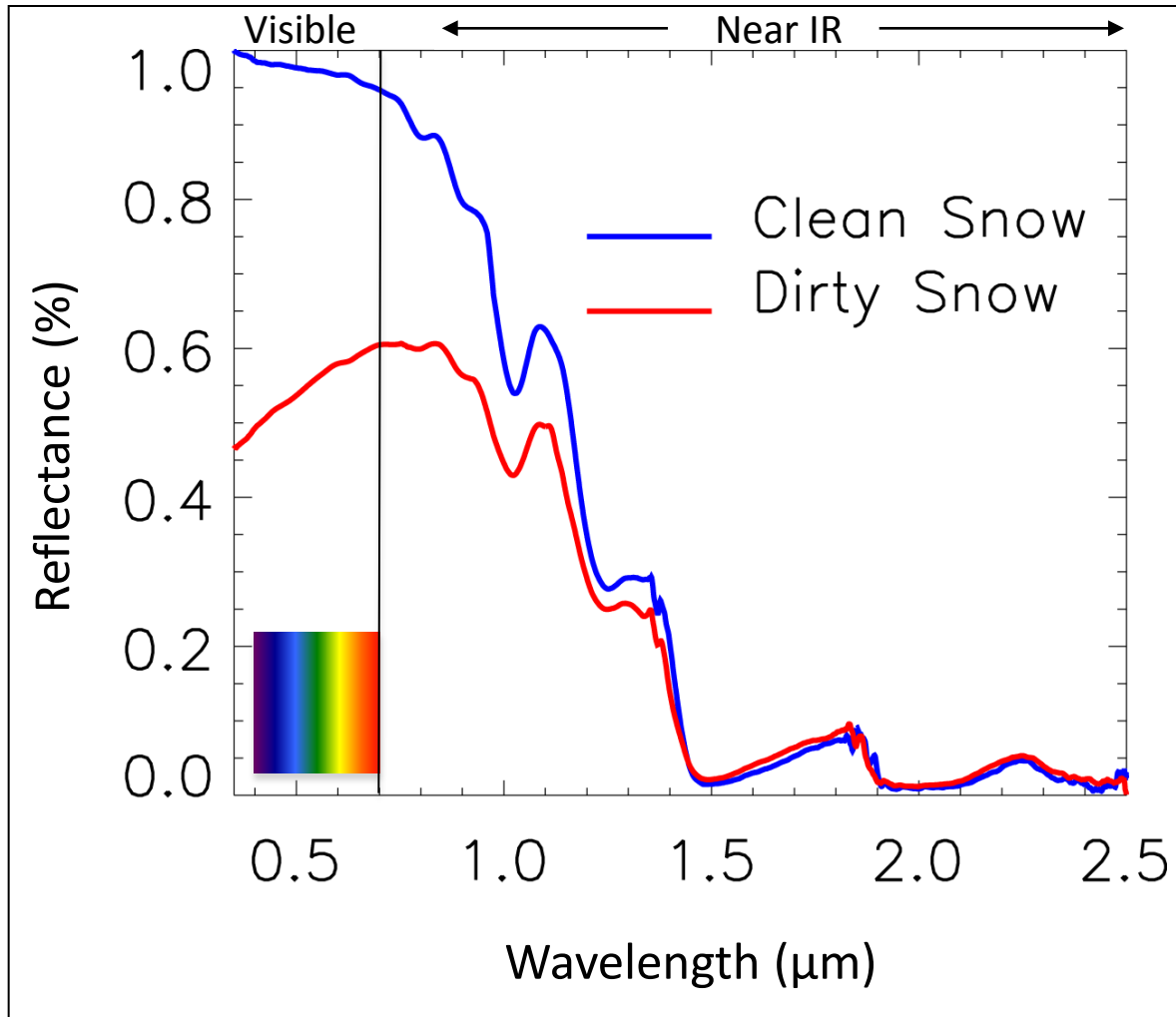


Snow Albedo Measurement

Senator Beck Study Plot 12,200'



Dust decreases snow albedo



Courtesy Jeff Deems

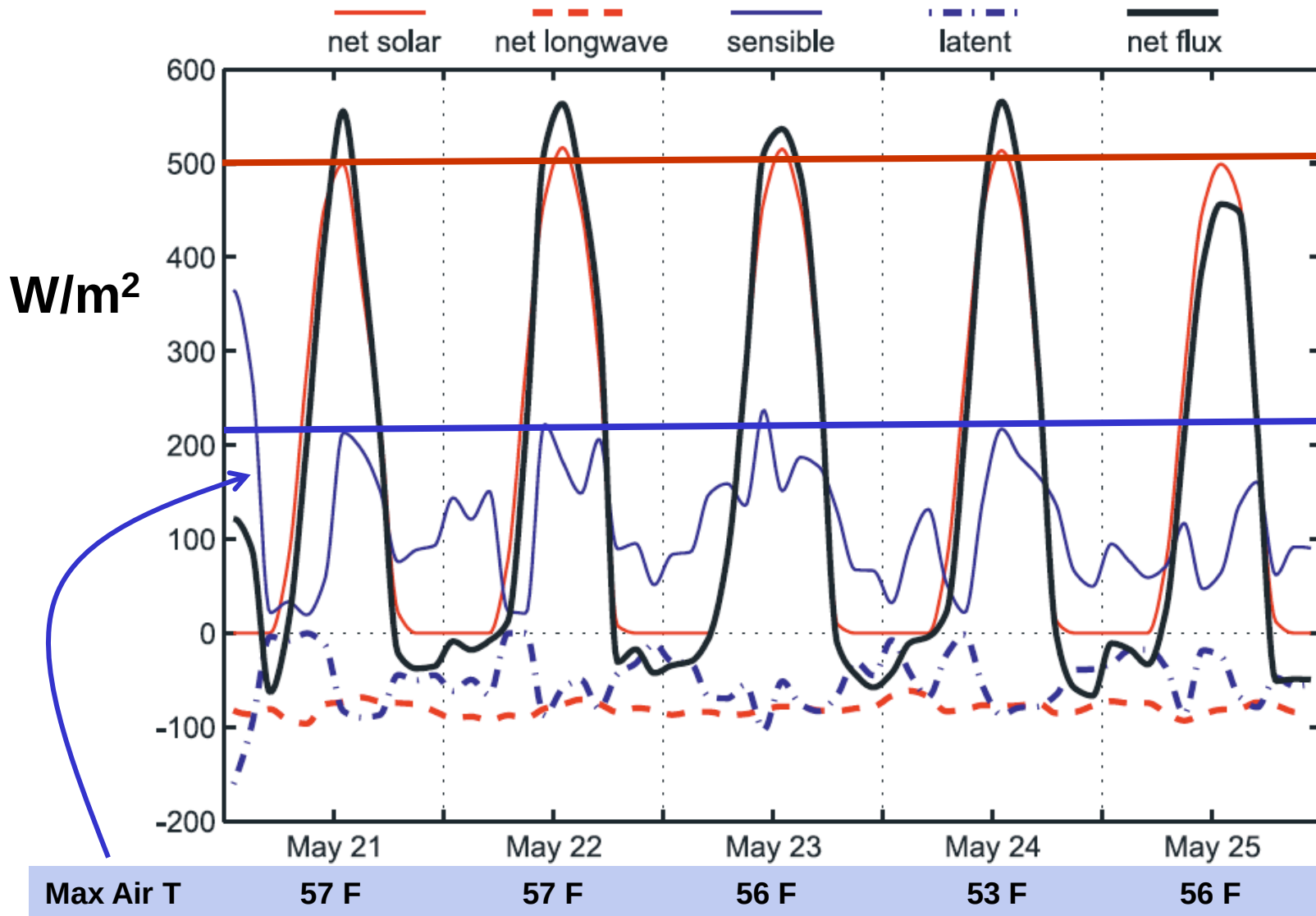




Accelerated Melt Rates

Snowmelt Energy Budget

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



Accelerated Snowmelt

Swamp Angel Study Plot

Senator Beck Basin

15.0 inches SWE May 20, 2003

0.0 inches SWE May 28, 2003
1.7 inch loss/day



Senator Beck Basin: March 22, March 29, April 3, April 8, April 15 2009 layers



Below Treeline – April 22, 2009



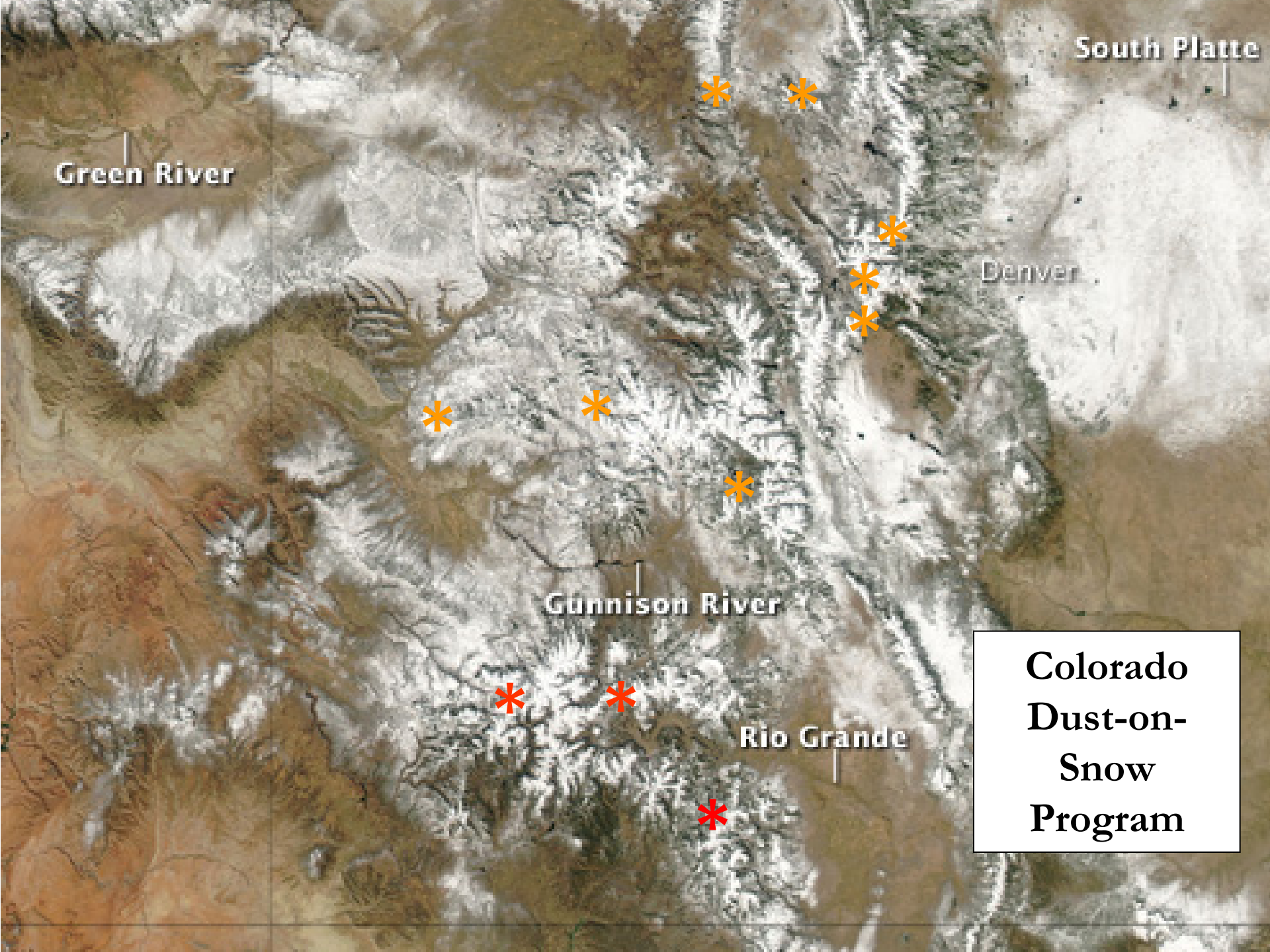
Above Treeline – April 24, 2009

Gravimetric Sampling



Bulk Sampling





Green River

South Platte

Denver

Gunnison River

Rio Grande

Colorado
Dust-on-
Snow
Program

Spring Creek Pass CODOS Site

April 10, 2009



Spring Creek Pass CODOS site – May 4, 2010



Spring Creek Pass CODOS Site

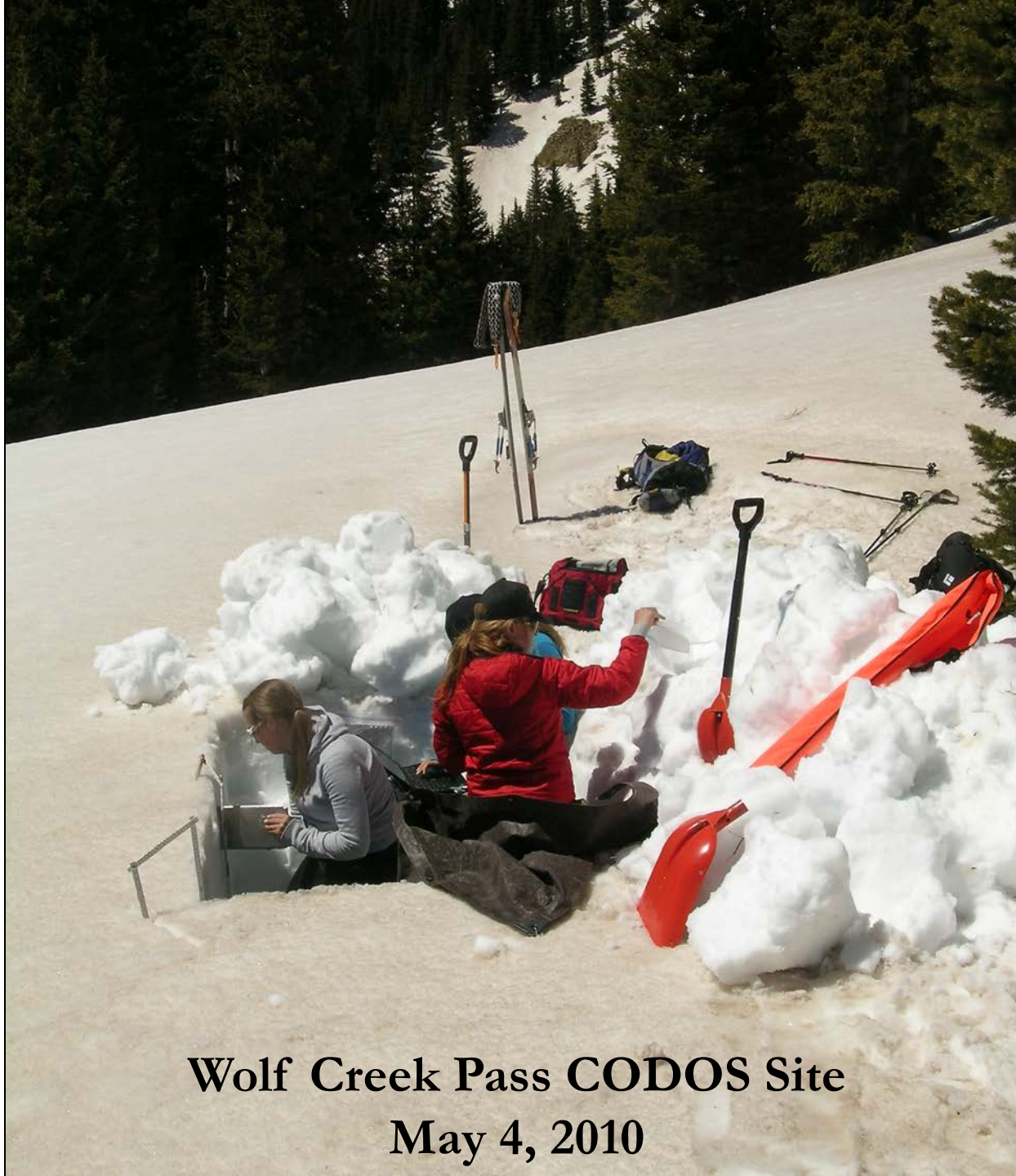
May 25, 2010



Wolf Creek Pass CODOS Site

April 16, 2009





Wolf Creek Pass CODOS Site
May 4, 2010

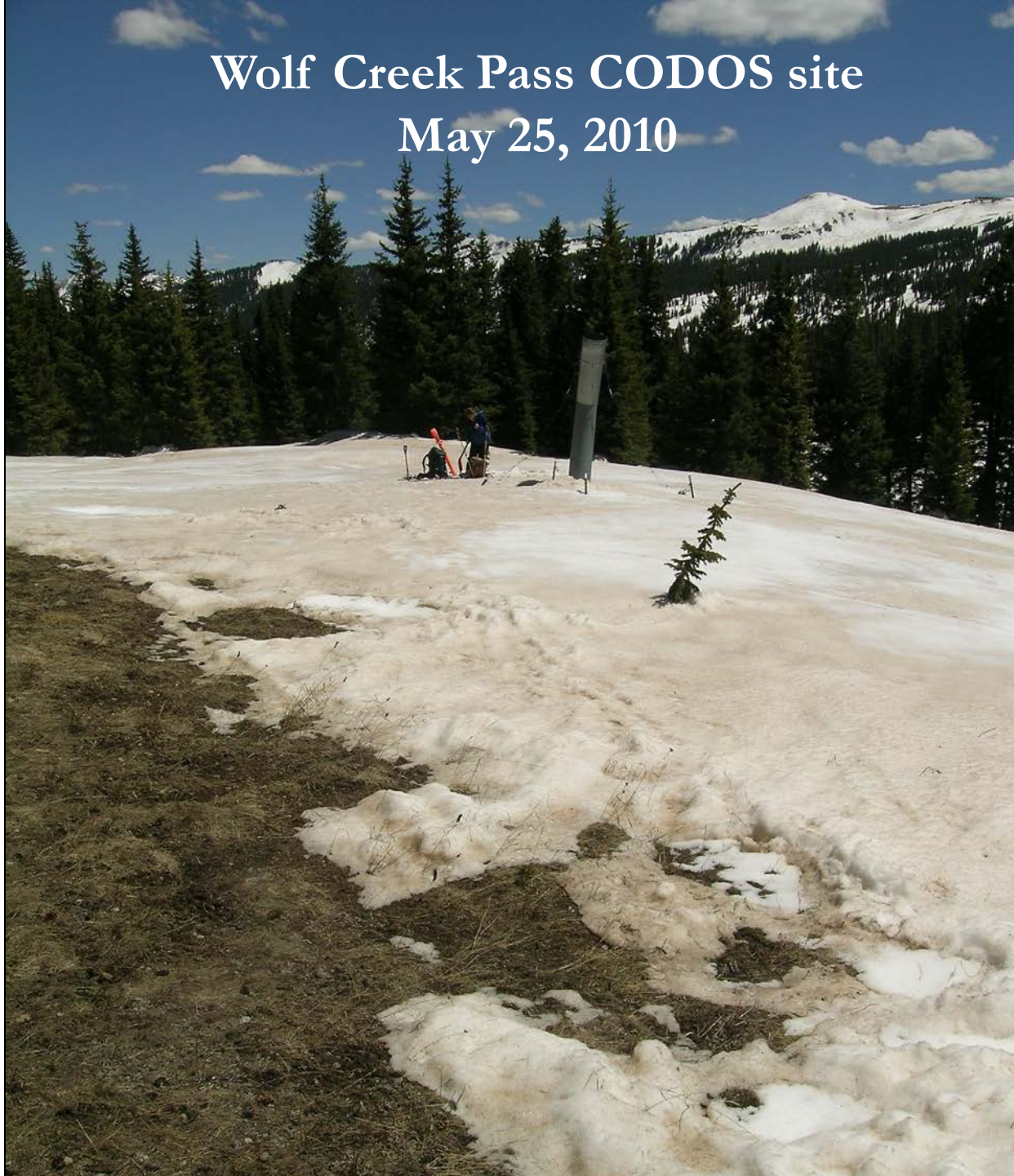


Wolf Creek Pass CODOS Site

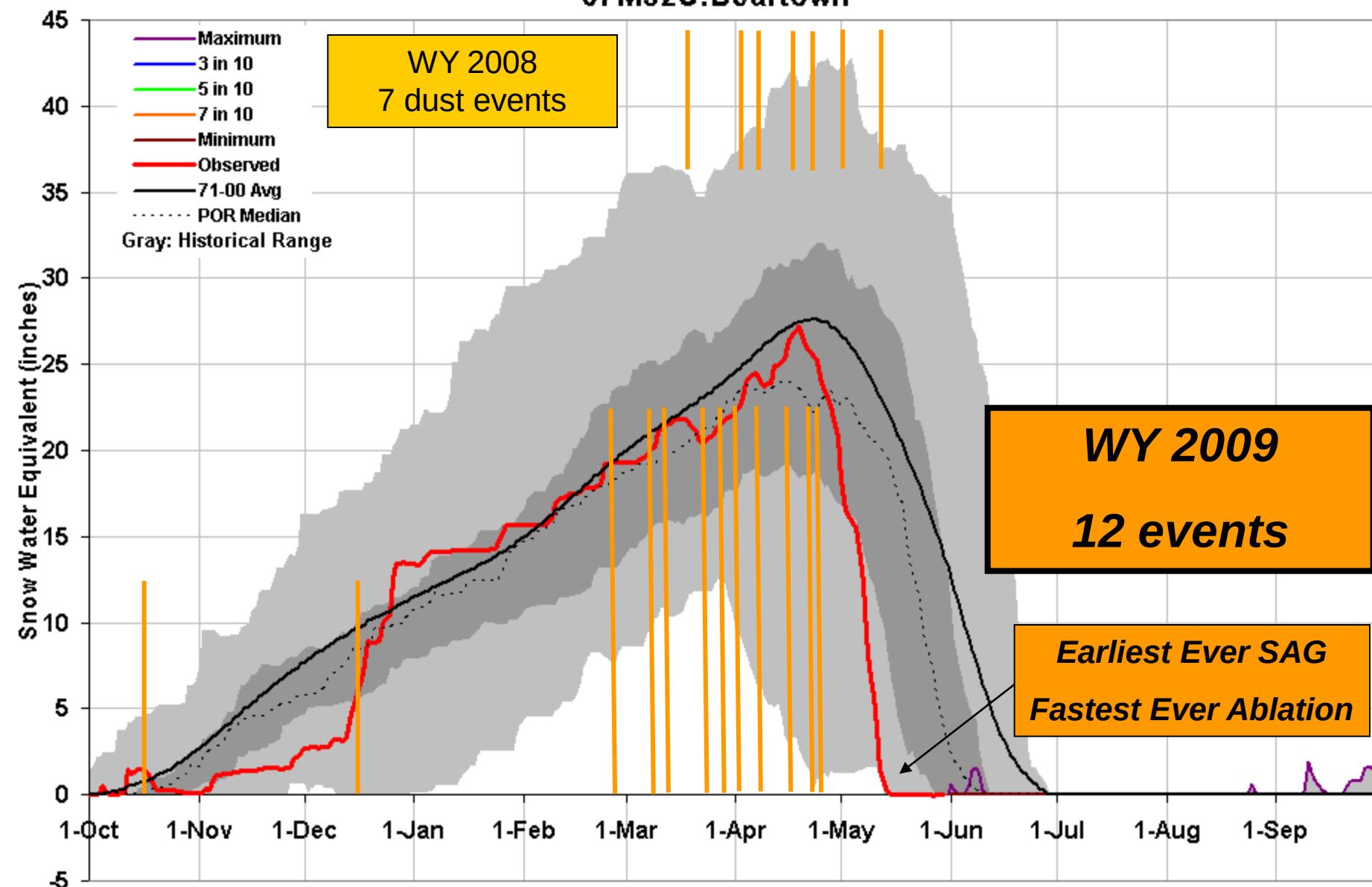
May 25, 2010

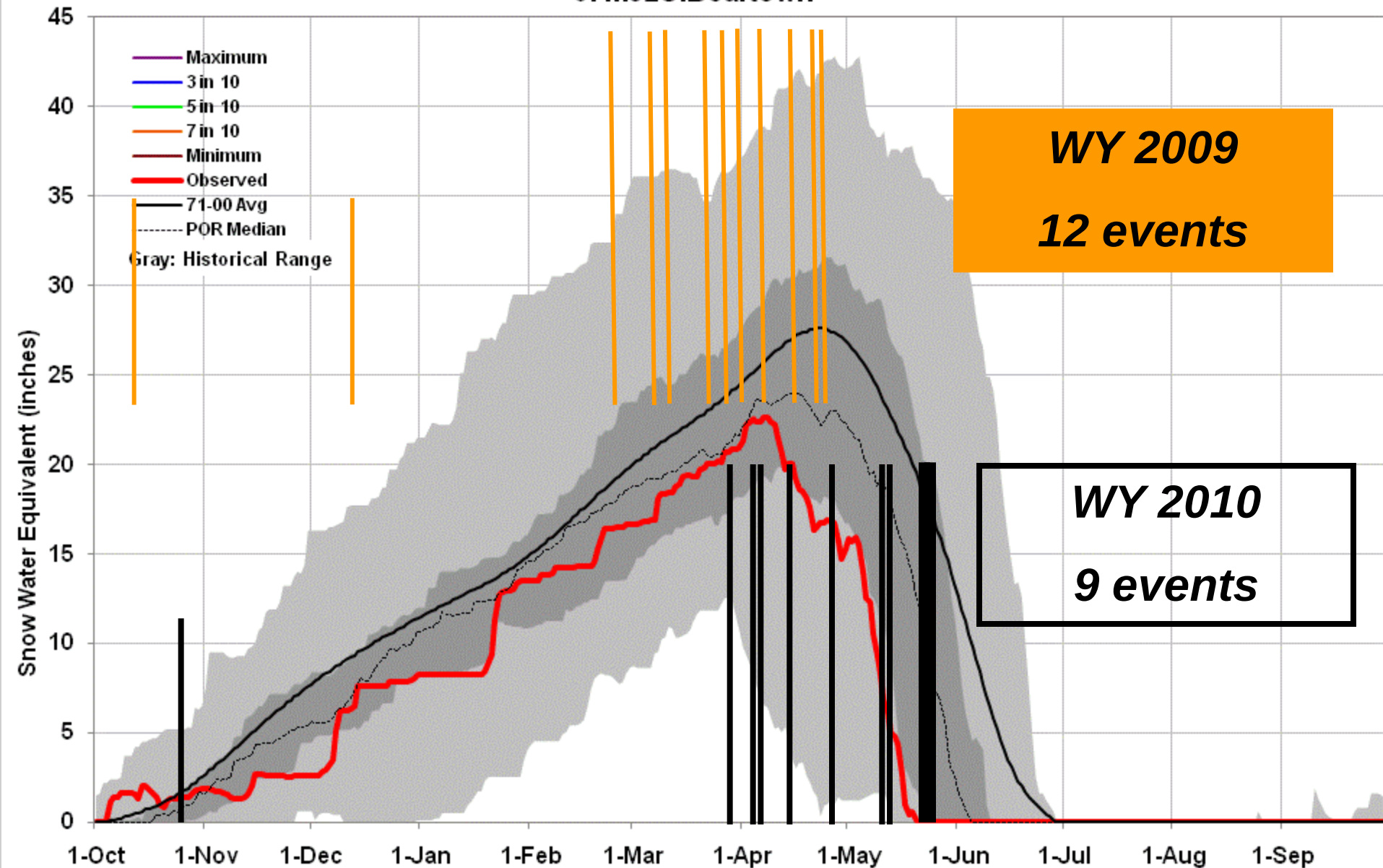
Wolf Creek Pass CODOS site

May 25, 2010

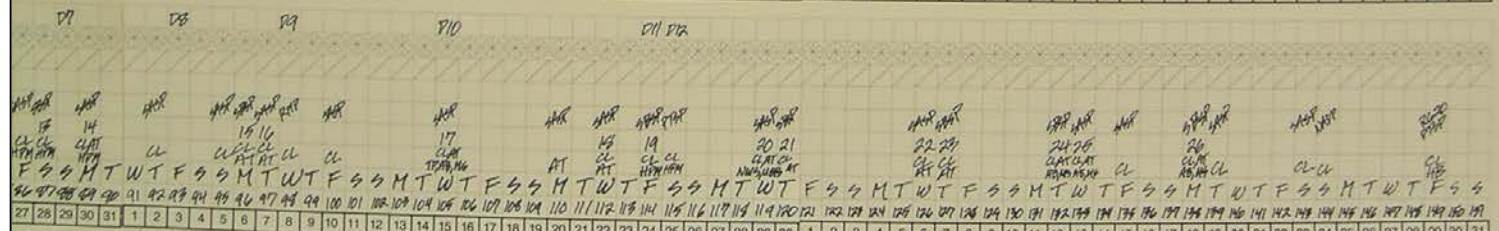
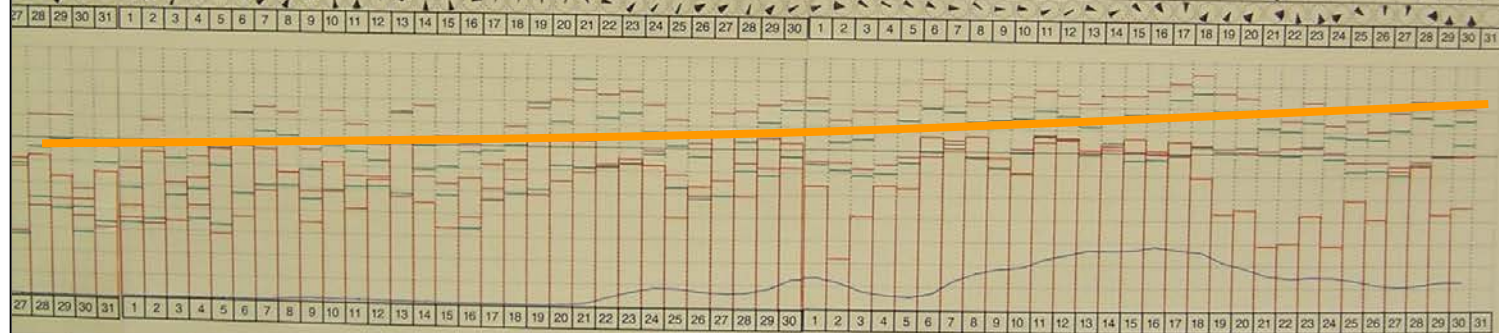


07M32S:Beartown





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 Niño 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

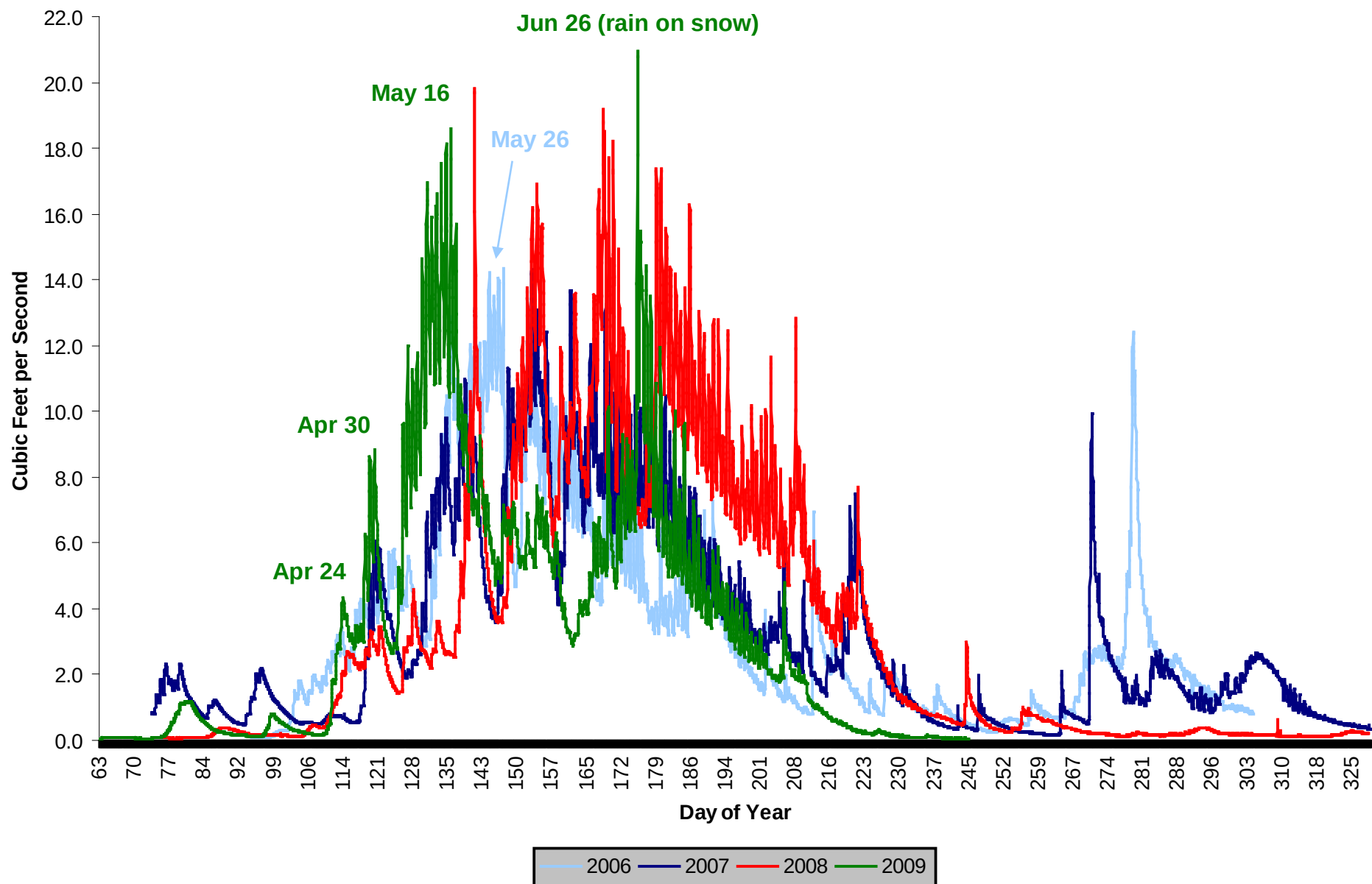


YTD → April '09: 152 mm H₂O 834 mm H₂O YTD → May '09:



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

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



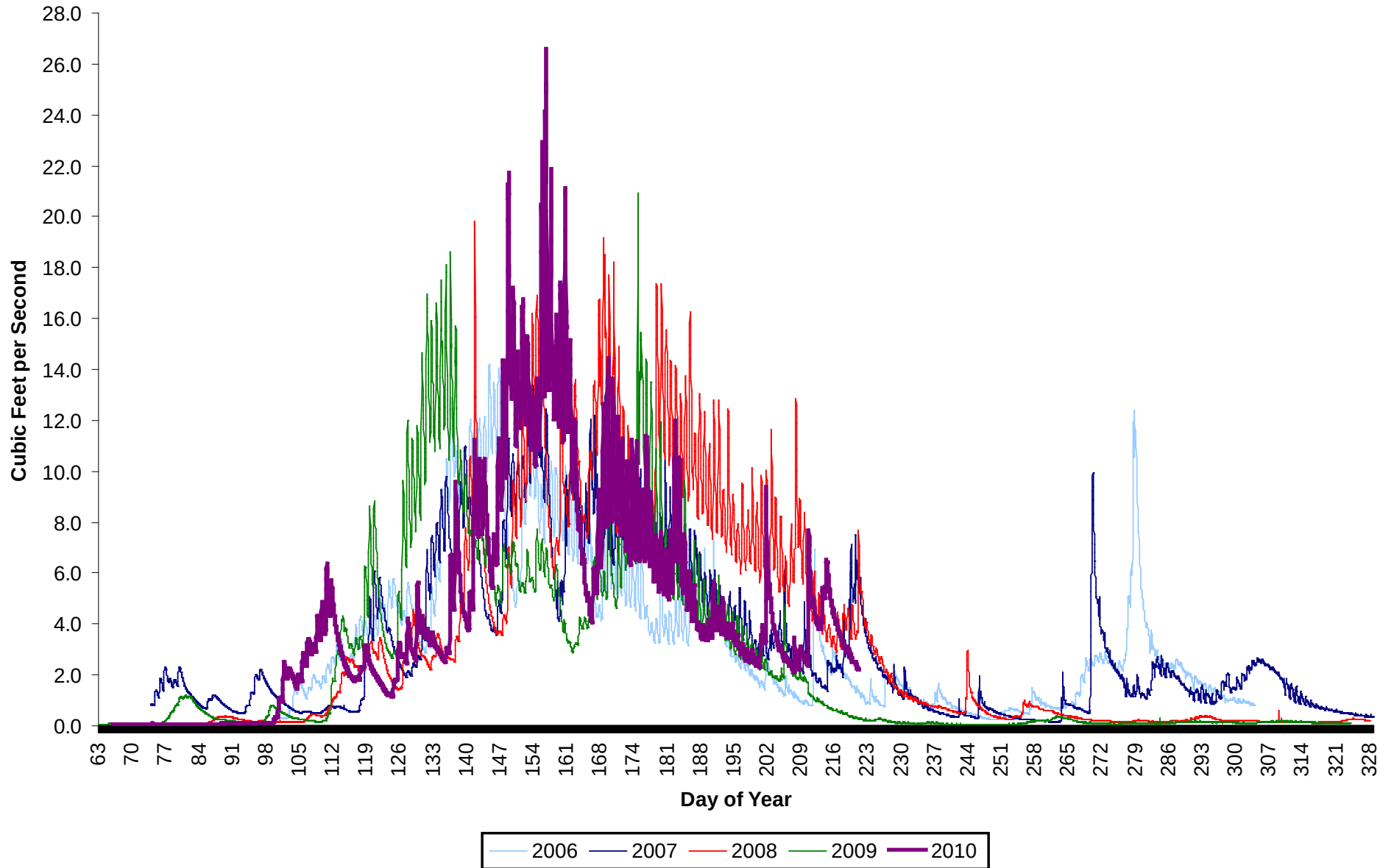


May 11, 2009 – east of Wolf Creek Pass



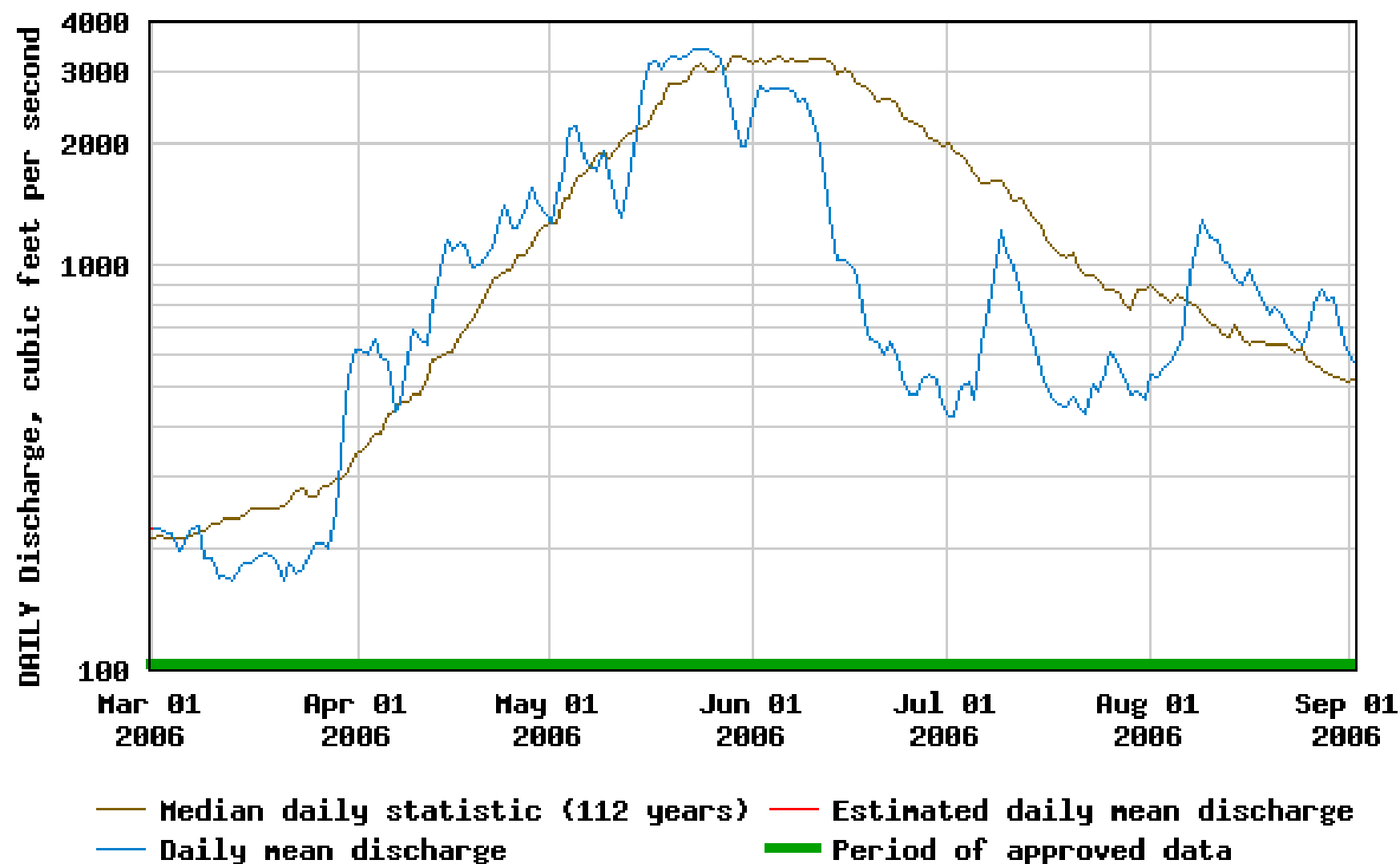
June 5, 2010 – Senator Beck Stream Gauge at 26 cfs

Senator Beck Basin Discharge – WY 2006, 2007, 2008 & 2009, 2010

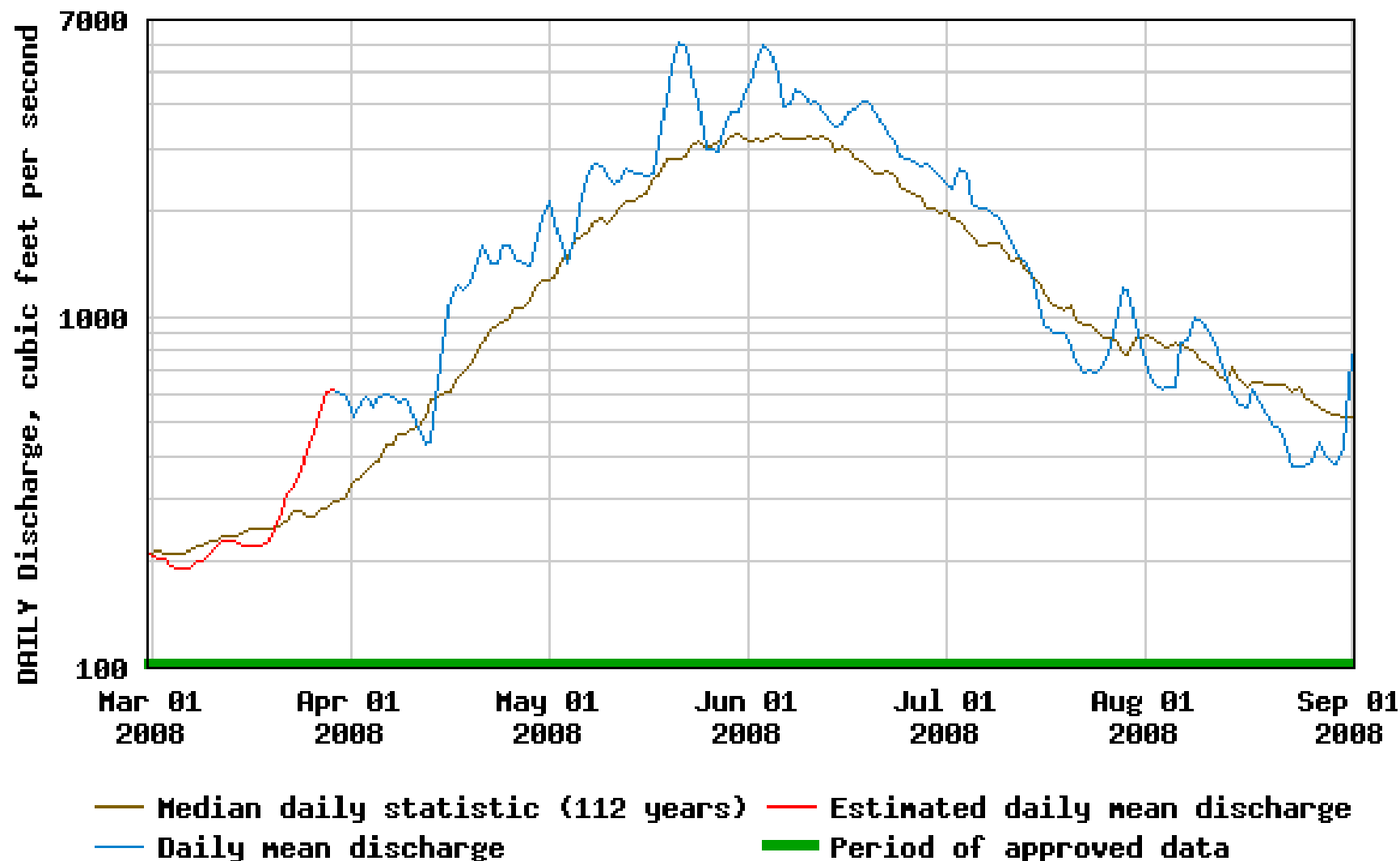




USGS 08220000 RIO GRANDE NEAR DEL NORTE, CO.

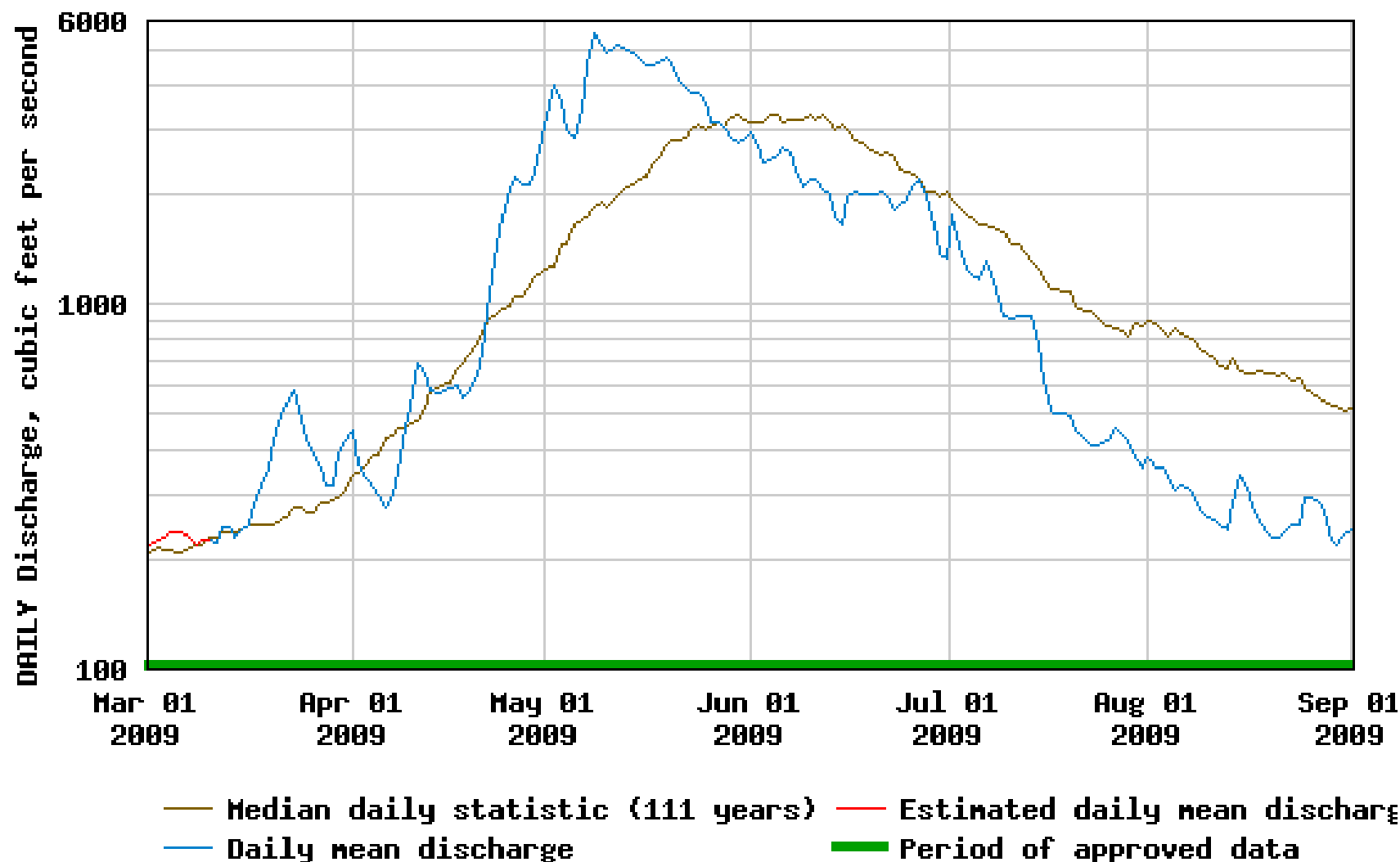


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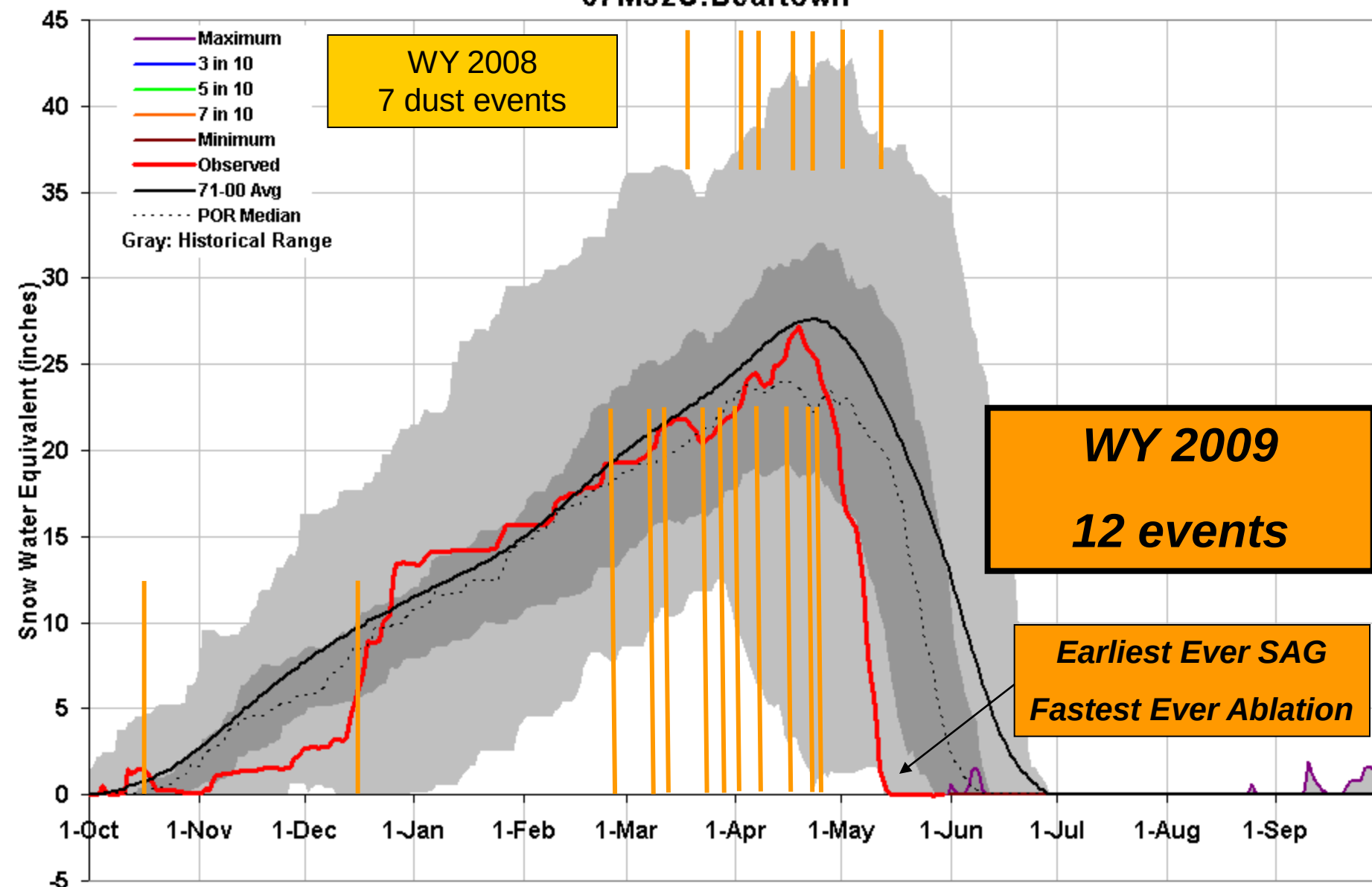




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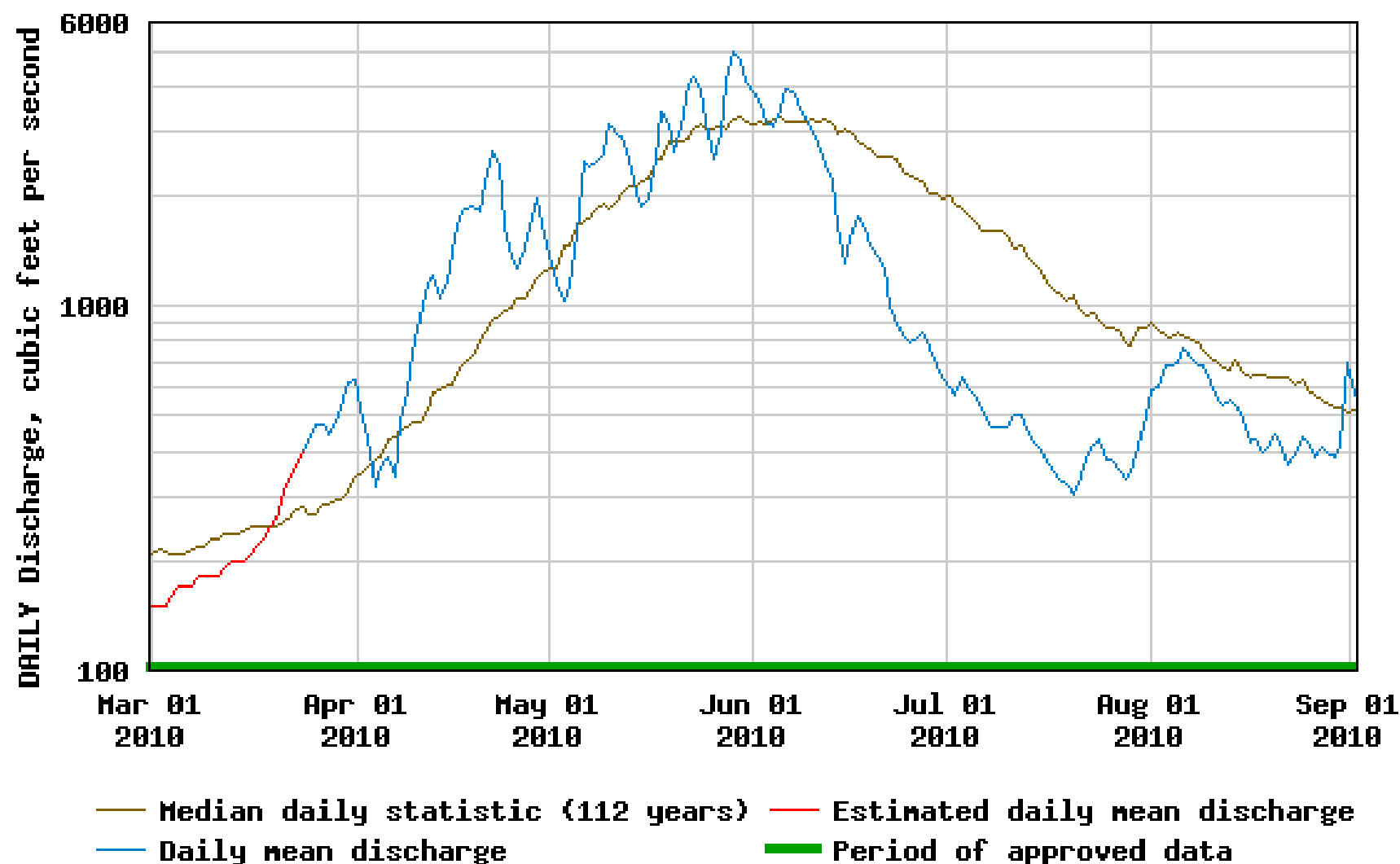
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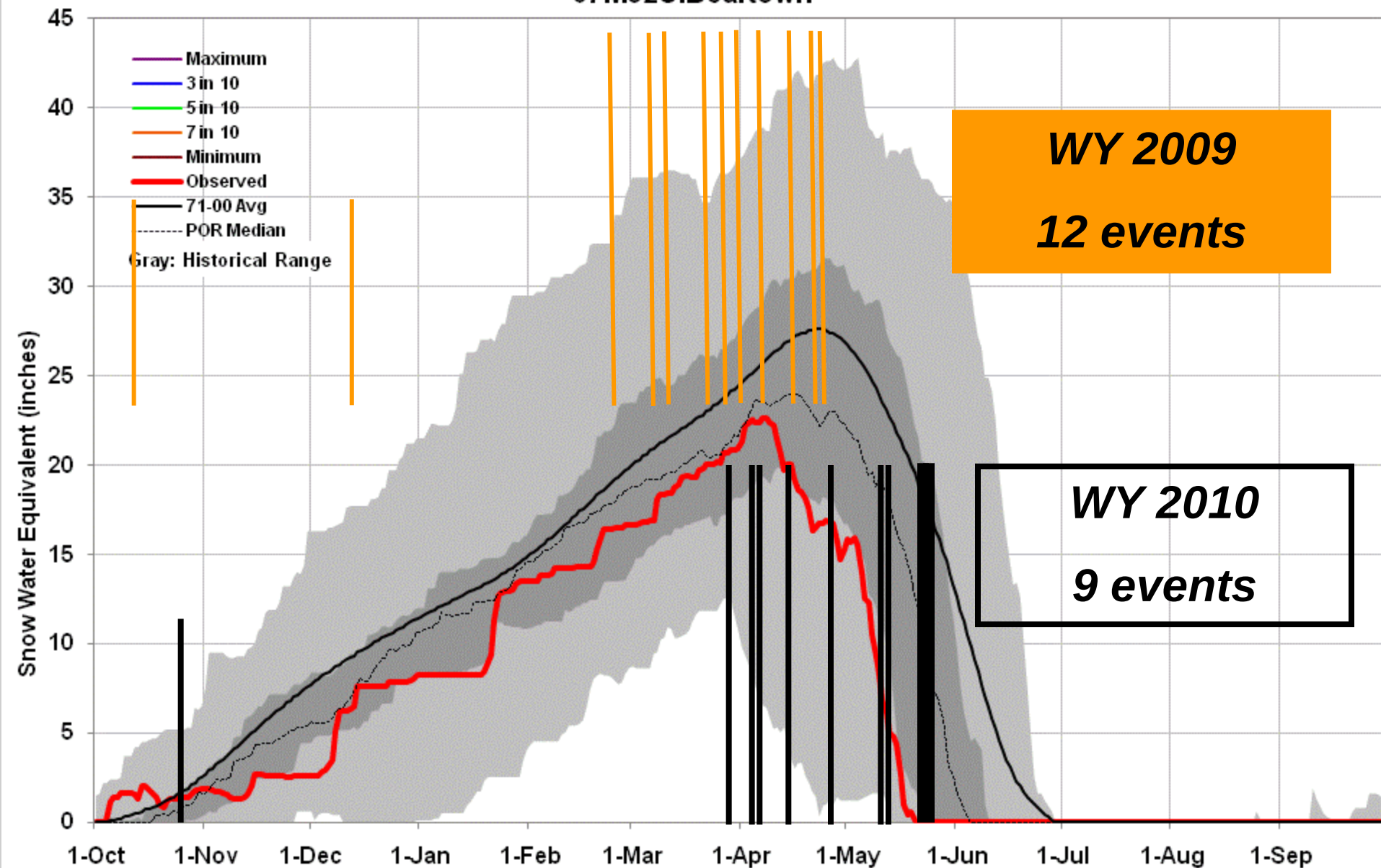


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USGS 08220000 RIO GRANDE NEAR DEL NORTE, CO.

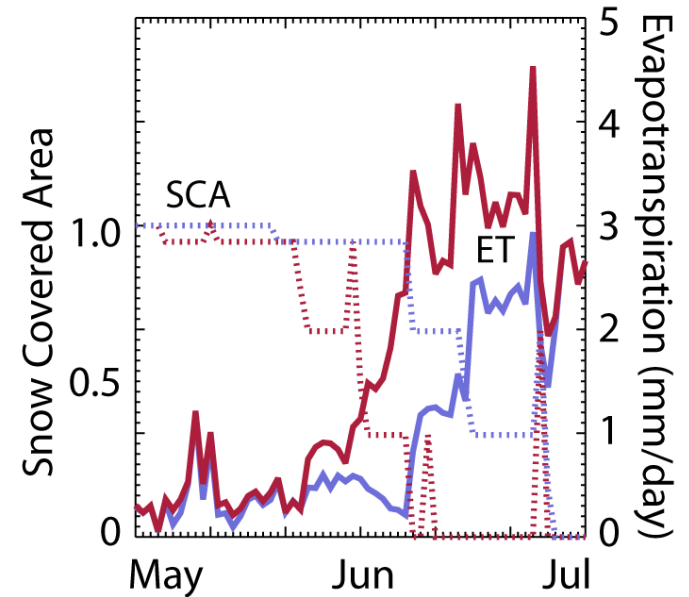
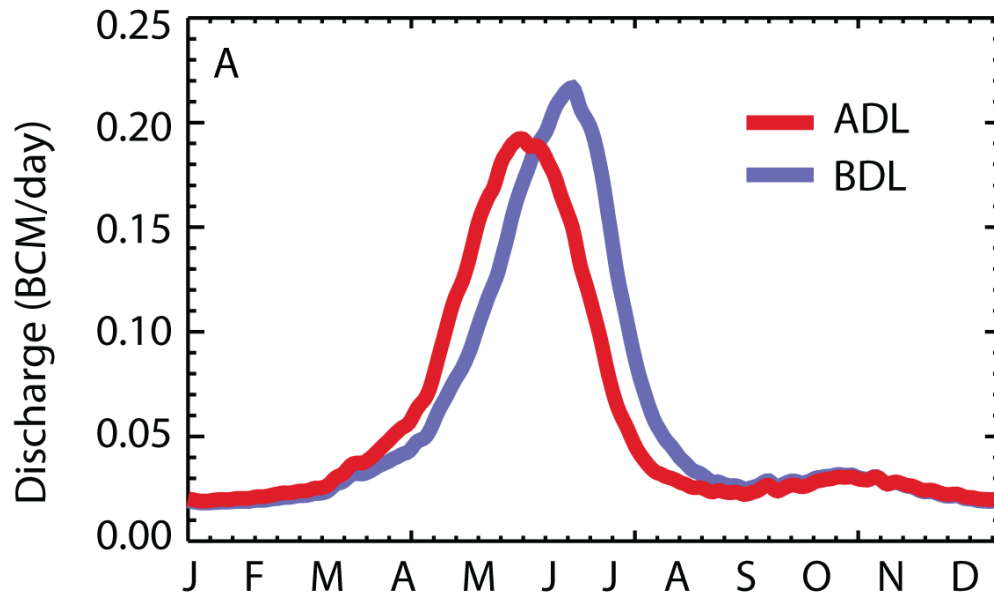




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5% Reduction in Snowmelt Runoff at Lees Ferry, AZ 1916-2003

Painter et al., www.pnas.org/content/107/40/17125



Upper Rio Grande Basin effects on yield ... ?



Climate Change and Water Resources Management: A Federal Perspective



Circular 1331

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

What we have learned since 2003/2004 ...

- Dust-on-snow is extensive, affecting all Colorado mountain watersheds
- Dust deposition rates are about 5X higher than pre-settlement rates
- The Colorado Plateau is the dominant source of dust on Colorado snow

Dust effects vary year-to-year ...

- Reduced albedo = 2x to 3x more melt energy available (vs. air temp only)
- Snowpack ripening and snowmelt onset are advanced (vs. air temp only)
- Melt rates accelerate, advancing SAG up to 50 days (vs. air temp only)
- Dust effects already exceed climate forcing (warming) effects
- Dust-on-snow has reduced Upper CRB flows at Lees Ferry by 3-7%

What we do not yet know ...

- Exactly why the winters of 2008/2009 and 2009/2010 were so dusty
- Whether 2008/2009 and 2009/2010 are a new normal
- Shares of dust attributable to the variety of agents disturbing CP soils



CODOS Operational Monitoring, Consulting

CODOS – Colorado Dust-on-Snow – WY 2010

Update #6, Monday, May 10, 2010

Last week's tour of CODOS's eleven dust-on-snow monitoring sites focused on the April 28th D6-WY2010 dust layer. Reports of the geographic extent and intensity of that event were confirmed – D6 was found as a discrete and very substantial layer (Figure 1) at almost all of our sites that still retained a snowpack, or else already merged with and intensifying earlier dust layers. Table 1 presents recent snowpit data from each of our CODOS monitoring sites including the depth of burial of the D6 (currently the uppermost) dust layer below the snowpack surface.



Figure 1: The April 28th D6-WY2010 layer is seen here at the Swamp Angel Study Plot, on May 3rd, as the uppermost dust layer buried under 5" of clean new snow that fell afterward, and separated from the dust layers below by about 4" of clean snow. Compare this to Figure 1 of Update #5, April 26, 2010.

CODOS Site	Date of Most Recent Snowpit	Total Snow Depth	Thickness of Clean Snow Overlying D6 Dust Layer
Swamp Angel Study Plot	5/3/10	50"	5"
Park Cone	5/3/10	0"	0" (SAG)
Spring Creek Pass	5/4/10	9"	0"
Wolf Creek Summit	5/4/10	46"	0"
Hoosier Pass	5/5/10	51"	5"
Grizzly Peak	5/5/10	34"	3"
Berthoud Summit	5/5/10	63"	6"
Willow Creek Pass	5/5/10	20"	0"
Rabbit Ears (1)	5/6/10	67"	12"
McClure Pass	5/6/10	0"	0" (SAG)
Grand Mesa Study Plot	5/6/10	54"	3"

Table 1: Depth of burial of D6-WY2010 on May 3-6, 2010.



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