



United States Department of Agriculture

Colorado Snow Surveys

Snowpack Monitoring for Water Supply Forecasting and Drought Planning

USDA-NRCS Colorado Snow Survey

Brian Domonkos

Hydrologist, Data Collection
Officer

Lexi Landers

Hydrologist

Karl Wetlaufer

Hydrologist





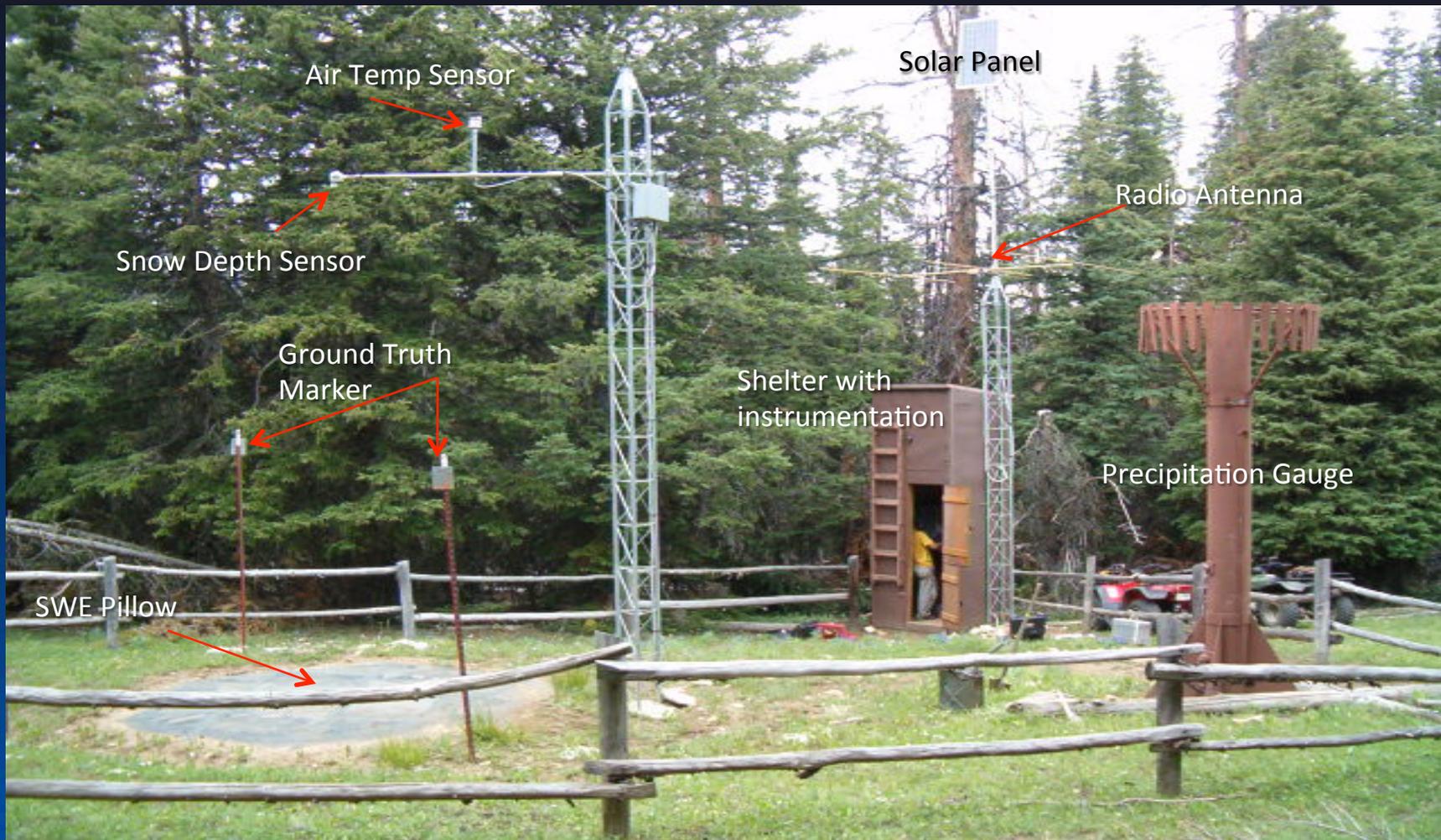
Who is Colorado Snow Surveys?

- USDA NRCS Colorado – We are aligned under CO NRCS
- Brian Domonkos – Snow Survey Supervisor
- Vacant – Asst. Snow Survey Supervisor
- Lexi Landers – Hydrologist
- Karl Wetlaufer – Hydrologist
- Butch Horner – Electronics Technician
- Mike Ardison – Hydrologic Technician
- Zack Wilson – Hydrologic Technician
- 3 Seasonal hires to aid in summer SNOTEL and Snow Course maintenance
- Seven full time employees

By the Numbers - Snow Surveys

- Across west, seasonal snowpack in place Nov – May/June
- Snow Surveys is a Federally funded program
 - 858 Automated SNOTELs
 - 1113 Manual Snow Courses including Canada
 - 219 Soil Climate Analysis Network (SCAN)
 - Staffing
 - 62 Fulltime positions
 - 10 Vacant positions
 - Work in coordination with Canada as watersheds
 - Agreements with Mexico & Canada

Anatomy of a SNOTEL site



Air Temp Sensor

Solar Panel

Radio Antenna

Snow Depth Sensor

Shelter with instrumentation

Precipitation Gauge

Ground Truth Marker

SWE Pillow

Additional Sensors



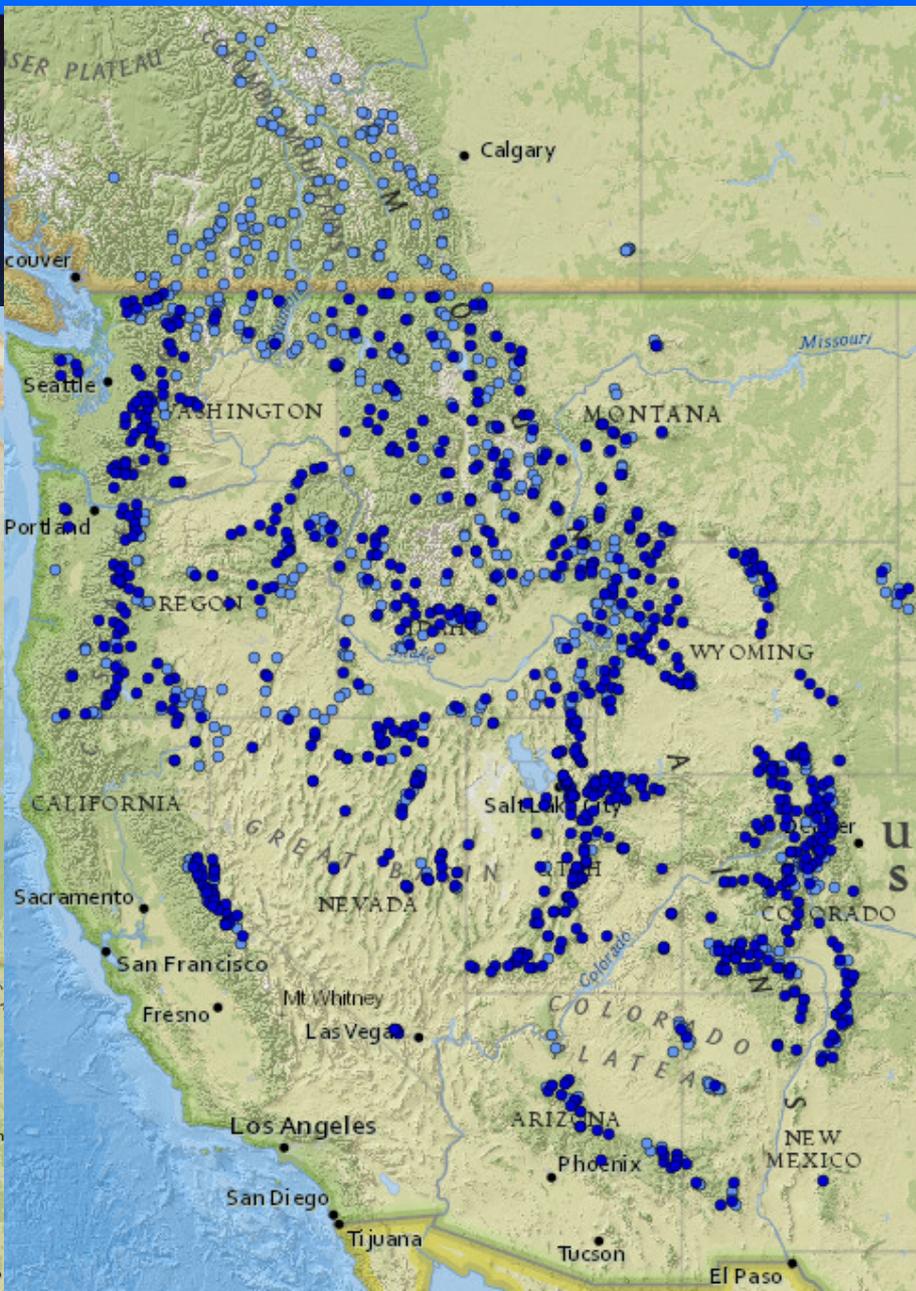
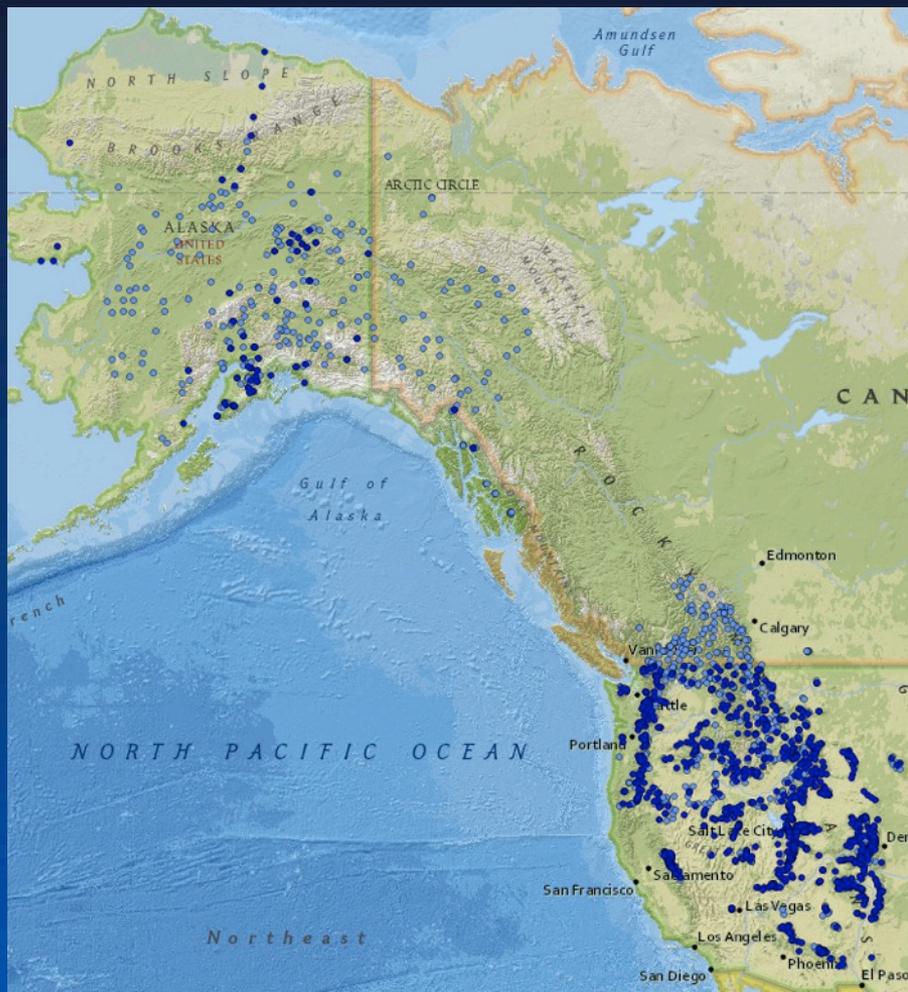
- Soil Moisture
 - Soil Temperature
 - Salinity
- Solar Radiation
- Relative Humidity
- Wind
 - Speed
 - Direction

A SNOTEL Site

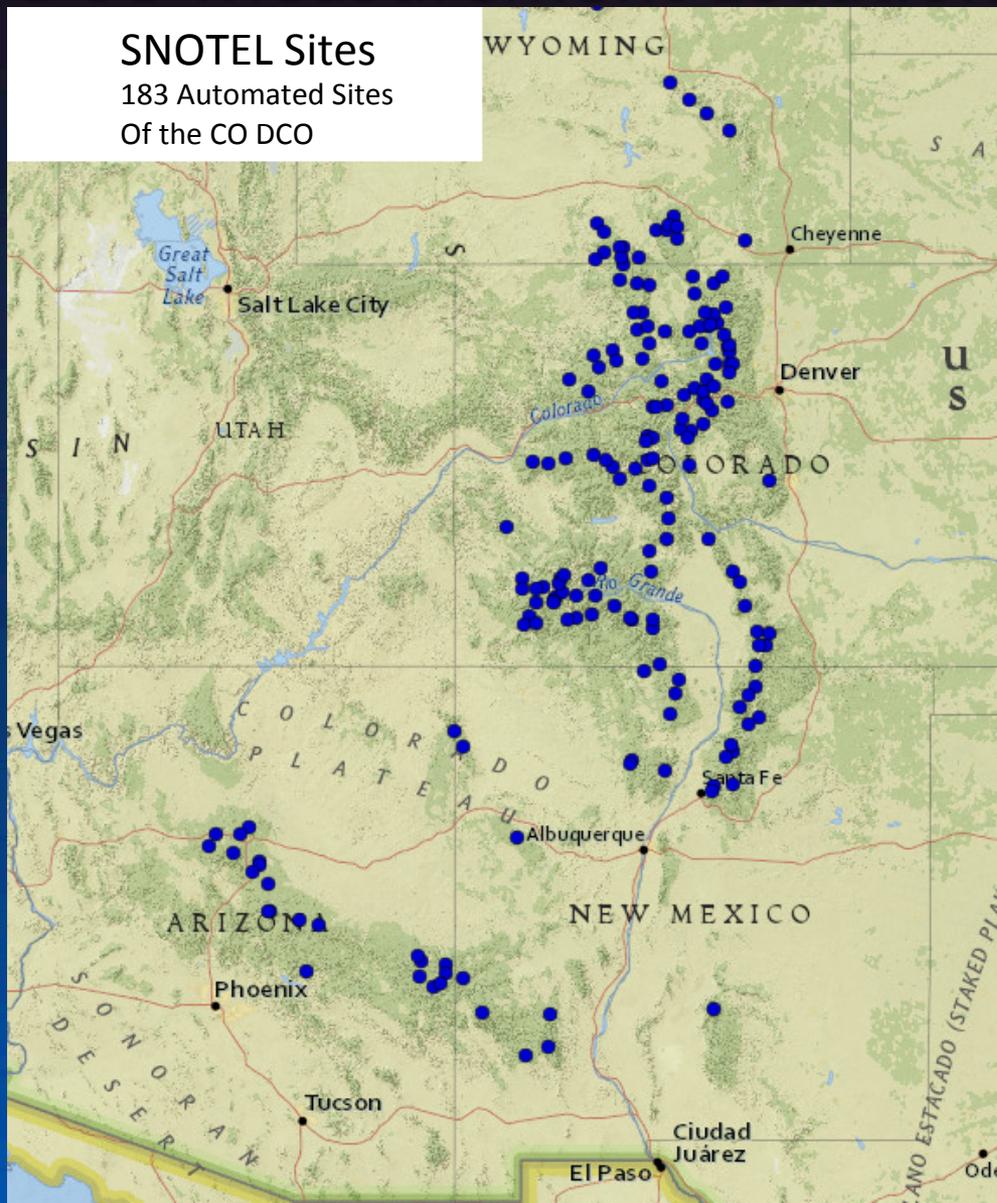
- Cost between \$25,000 and \$35,000 depending on the sensor suite
- About \$3,000 to maintain annually
- Ideally would have 30 years in the period of record
 - For the purposes of normals or averages
 - Have used a 10 year period of record to generate averages
- May often be back estimated/correlated from data gathered by a collocated snow course
- Most sites are facilitated by correlating with a streamflow gauge for snowmelt runoff forecasting purposes
 - Uses and purposes for sites do vary greatly
- Manual Snow Courses
 - Cost about \$3,500 annually to measure when you consider
 - Staff time
 - Training – safety & procedural techniques

Nationally

- 855 Automated SNOTELs
- 1113 Manual Snow Courses including Canada



Colorado DCO Measurement Locations - 2015



How do I access SNOTEL data: Daily Data?

Individual Site Data

Site Selection Map

<http://www.wcc.nrcs.usda.gov/snow/index.html>

Then Click on “Open the Map” otherwise web address is too big, then you can save that to your favorites

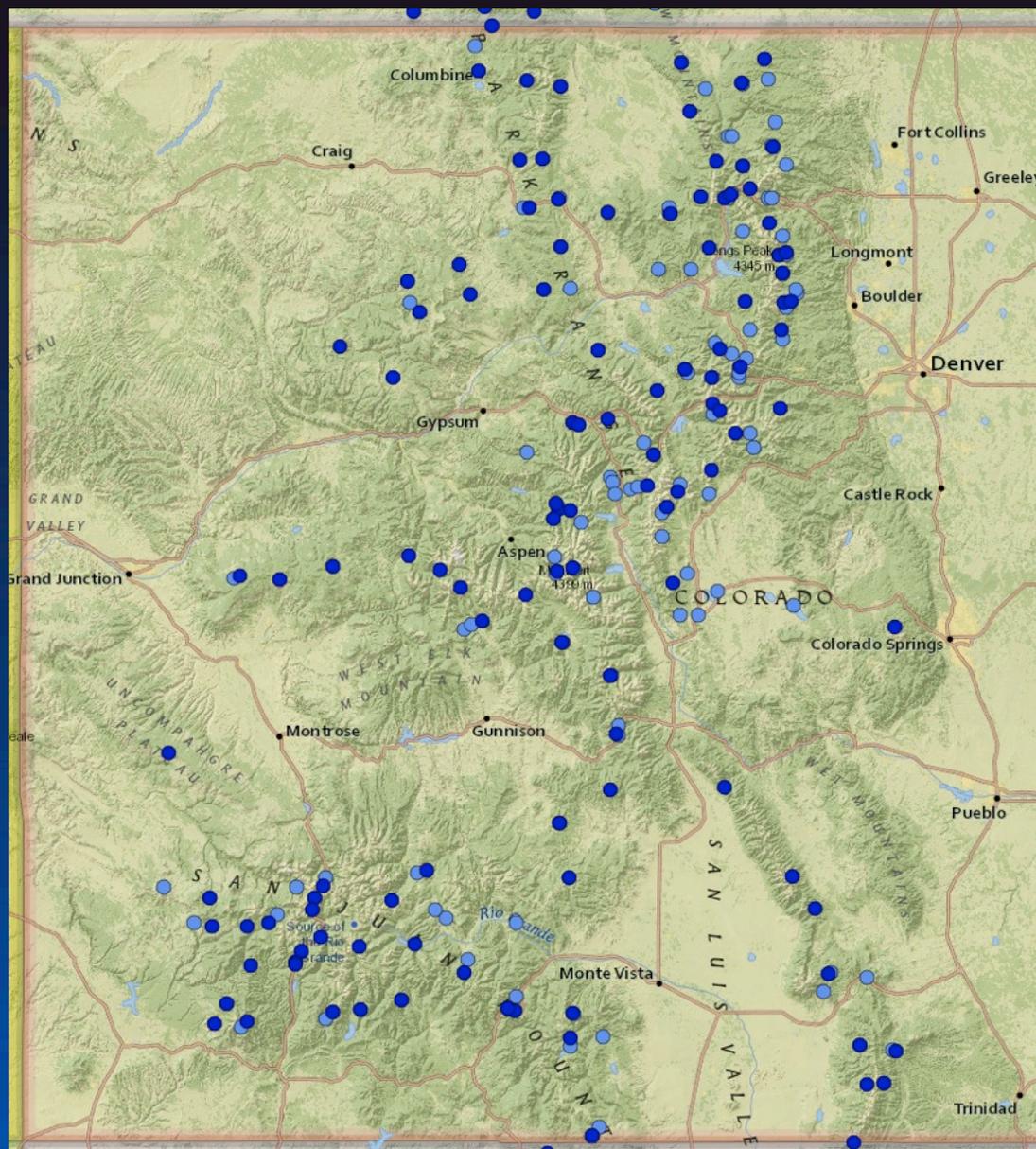
The web based map will provide access:

- Daily and Hourly data for an individual SNOTEL site
- Current Water Year Data (Oct 1st – Sept 30th)
- Historical Data for a SNOTEL site

The screenshot shows the NWCC website interface. At the top, it displays the USDA logo and the text 'United States Department of Agriculture' and 'National Water and Climate Center'. Below this is a navigation menu with links like 'NWCC Home', 'About Us', 'Products', 'Publications', 'News', 'Partnerships', and 'Contact Us'. The main content area features a map of the western United States with numerous blue dots representing SNOTEL sites. A tooltip for 'Battle Creek AM, 5710 ft.' is visible over one of the sites. On the right side, there is a 'MAP CONTROLS' panel with several sections: 'Station Selection' (radio buttons for 'Stations with all checked elements' and 'Stations with any checked elements'), 'Snow' (checkboxes for 'Snow Water Equivalent' and 'Snow Depth'), 'Precipitation' (checkboxes for 'Accumulated Precipitation' and 'Incremental Precipitation'), 'Soils' (checkboxes for 'Soil Moisture' and 'Soil Temperature'), 'Reservoir' (checkbox for 'Reservoir Storage'), and 'Streamflow' (checkboxes for 'Adjusted Volume', 'Observed Volume', 'Diversion Discharge', and 'Forecast Point'). Below these are dropdown menus for 'States' and 'Counties', and input fields for 'HUCs', 'Minimum Elevation', and 'Maximum Elevation'. At the bottom of the sidebar, there is a 'Collection Networks' section with a checked box for 'Active Sites Only' and a legend for 'USDA-NRCS Real-Time Networks' (SNOTEL (853), SCAN (221), SNOLITE (22), Other NRCS Hydromet (10)) and 'USDA-NRCS Non-Real-Time Networks' (Snow Course/Aerial Marker (1111), Manual SNOTEL (3), Manual Precipitation (16)).

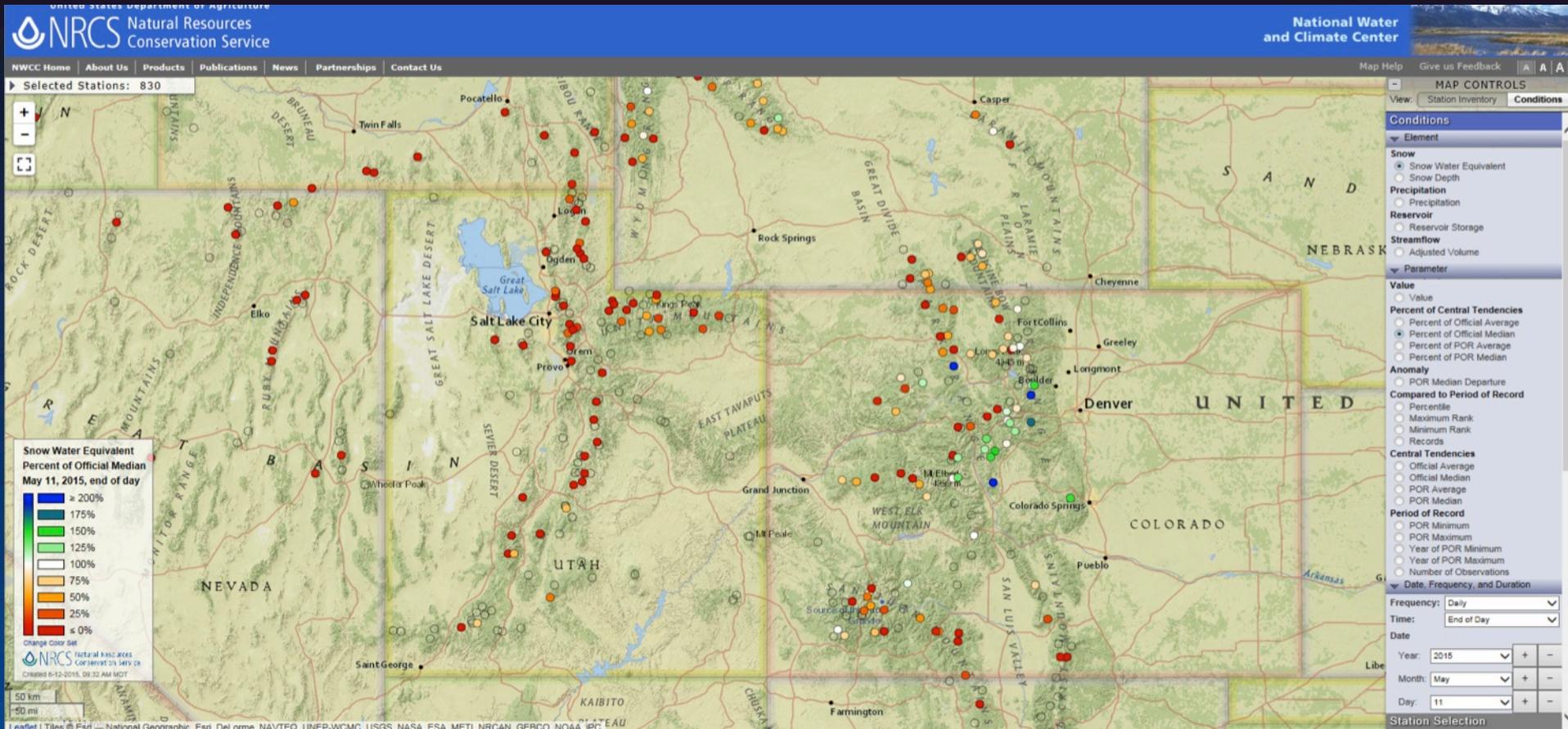


Colorado Snow Surveys





Visualization of daily data parameters



You can save ANY map or data table in your favorites in your browser so every time you click on the favorite the most recent data populates in the color filled map, or even data tables. (there is a quick trick to enable this so feel free to contact me and we can set it up for you)

Data Quality Control

Hourly Data

- Not quality controlled by Colorado Snow Survey Staff
- Automated profiles flag data as suspect if out of a defined range or daily change
 - Suspect data is not publicly available
- Should be used for guidance purposes only
- All values, including sensor errors are published

Daily Data

- Midnight readings (00:00) quality controlled and reviewed on business days by office staff
- Data edits are completed on a weekly basis on Friday and may spill over into Monday
- Should be used primarily
- Year-end edits for previous year's data– are often started in November and are typically finalized in February

Quality Assurance/Control

- Majority of SNOTEL sites on hourly reporting
- Some on 3-hr reports b/c of batteries levels
- Automated Data Trapping - Data profiles suspect data in database and restrict data from being available
- On top of automated editing routines, personnel quality check data and edit regularly and when necessary
- Data Editing Frequency
 - Typically data is edited weekly every Friday

Hourly SWE vs Hourly Precip.

PARKER PEAK		WY	MTDCO	683.1	Elev. 9400	Lat. 44.73403	Lon. -109.91482											
Date	Time	#	1 BATT I-1 volt	2 WTEQ I-1 in	3 PREC I-1 in	4 TOBS I-1 degC	5 TMAX D-1 degC	6 TMIN D-1 degC	7 TAVG D-1 degC	8 SNWD I-1 in	9 WTEQ I-2 in	10 PREC I-2 in	11 BA H-1 vol					
2011-03-16	00:00	1	13.05	V 25.9	V 18.6	S -1.0	V 2.4	V -8.5	V -3.0	V 101	S 26.1	V 18.6	V 14.38					
2011-03-16	03:00	2	12.83	V 26.0	V 18.7	S -2.3	V 2.4	V -8.5	V -3.0	V 103	S 26.4	V 18.6	V 14.38					
2011-03-16	06:00	3	13.03	V 26.2	V 18.7	S -2.7	V 2.4	V -8.5	V -3.0	V 103	S 26.4	V 18.6	V 14.38					
2011-03-16	09:00	4	13.03	V 26.3	V 18.7	S -2.7	V 2.4	V -8.5	V -3.0	V 103	S 26.6	V 18.6	V 14.38					
2011-03-16	12:00	5	14.33	V 26.4	V 18.7	S -2.3	V 2.4	V -8.5	V -3.0	V 105	S 26.7	V 18.7	V 14.38					
2011-03-16	15:00	6	14.31	V 26.5	V 18.7	S -2.5	V 2.4	V -8.5	V -3.0	V 102	S 26.8	V 18.7	V 14.38					
2011-03-16	18:00	7	13.42	V 26.5	V 18.7	S -4.5	V 2.4	V -8.5	V -3.0	V 105	S 26.8	V 18.7	V 14.38					
2011-03-16	21:00	8	13.21	V 26.5	V 18.6	S -7.2	V 2.4	V -8.5	V -3.0	V 105	S 26.8	V 18.6	V 14.38					
2011-03-17	00:00	1	13.05	V 26.8	V 18.5	S -8.9	V -1.0	V -8.9	V -3.5	V 111	S 27.1	V 18.6	V 14.34					
2011-03-17	03:00	2	12.93	V 26.9	V 18.6	S -9.2	V -1.0	V -8.9	V -3.5	V 108	S 27.3	V 18.6	V 14.34					
2011-03-17	06:00	3	12.79	V 26.9	V 18.5	S -9.9	V -1.0	V -8.9	V -3.5	V 108	S 27.3	V 18.5	V 14.34					
2011-03-17	09:00	4	12.88	V 27.0	V 18.6	S -5.2	V -1.0	V -8.9	V -3.5	V 109	S 27.3	V 18.6	V 14.34					
2011-03-17	12:00	5	14.35	V 27.1	V 18.7	S -0.4	V -1.0	V -8.9	V -3.5	V 170	S 27.4	V 18.7	V 14.34					
2011-03-17	15:00	6	14.35	V 27.2	V 18.7	S -4.4	V -1.0	V -8.9	V -3.5	V 169	S 27.5	V 18.7	V 14.34					
2011-03-17	18:00	7	13.43	V 27.2	V 18.7	S -10.4	V -1.0	V -8.9	V -3.5	V 112	S 27.5	V 18.7	V 14.34					
2011-03-17	21:00	8	13.17	V 27.1	V 18.6	S -10.7	V -1.0	V -8.9	V -3.5	V 112	S 27.5	V 18.6	V 14.34					
2011-03-18	00:00	1	13.02	V 27.0	V 18.5	S -11.8	V 0.3	V -11.8	V -8.1	V 111	S 27.5	V 18.5	V 14.38					
2011-03-18	03:00	2	12.81	V 27.0	V 18.4	S -14.1	V 0.3	V -11.8	V -8.1	V 111	S 27.4	V 18.4	V 14.38					
2011-03-18	06:00	3	12.79	V 26.9	V 18.3	S -12.1	V 0.3	V -11.8	V -8.1	V 111	S 27.5	V 18.4	V 14.38					

1.1" SWE
In 48 hours

-0.2" Prec
In 48 hours?

Precipitation Gauge is plugged!

Why is the SWE decreasing???

Drops in Temperature impacts the fluid based SWE sensor

- SNOTEL site physical issues:
 - Plugged precipitation gauges
 - Bridging of snow pillow
 - Wind drifted snow on/off pillow
 - Wind induced precip under-catch

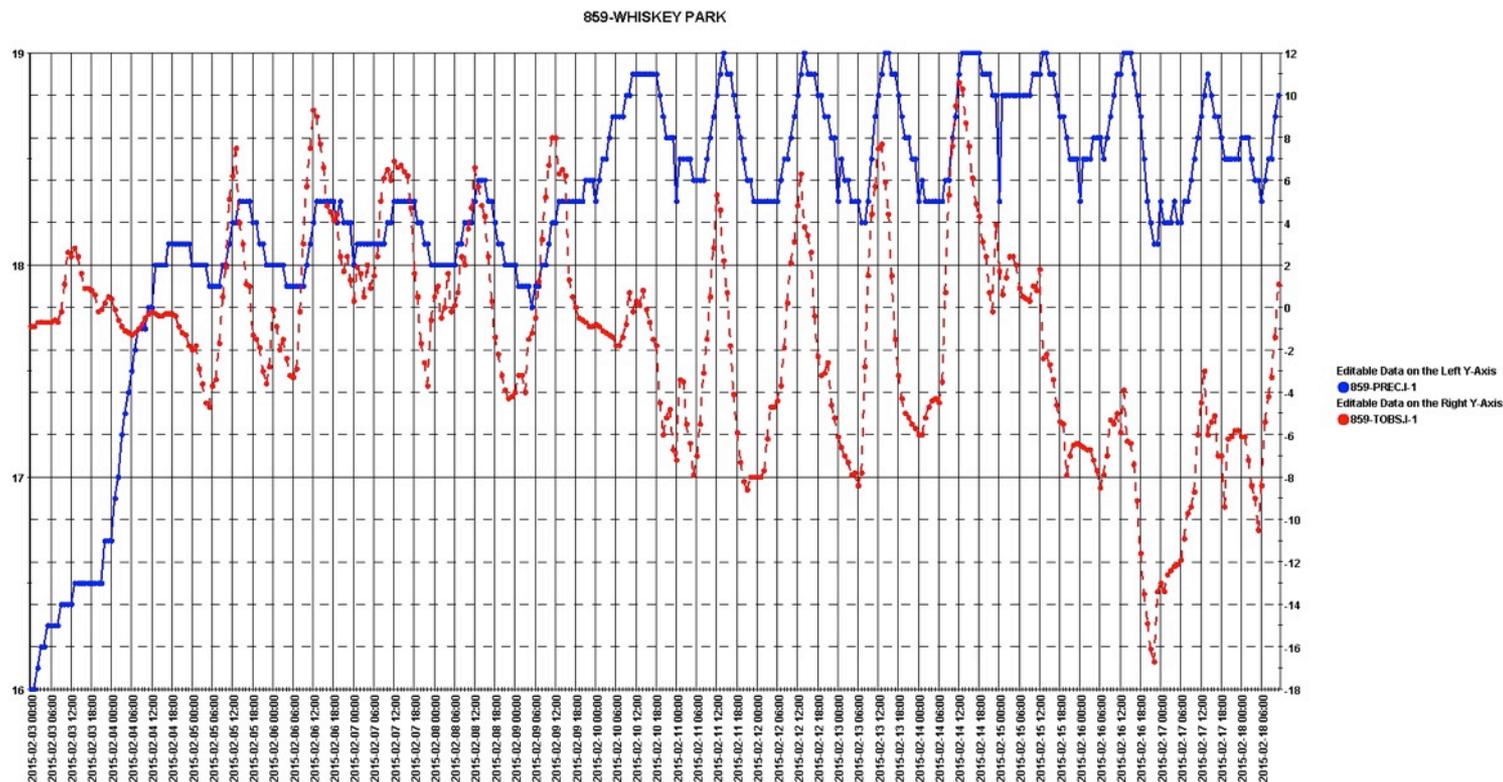
Solution:

- Utilize data from other sensors to help determine what the correct data is most likely to be
- Graphical tools can be very helpful in this process!!



SNOTEL Data Issues: SWE and Precipitation

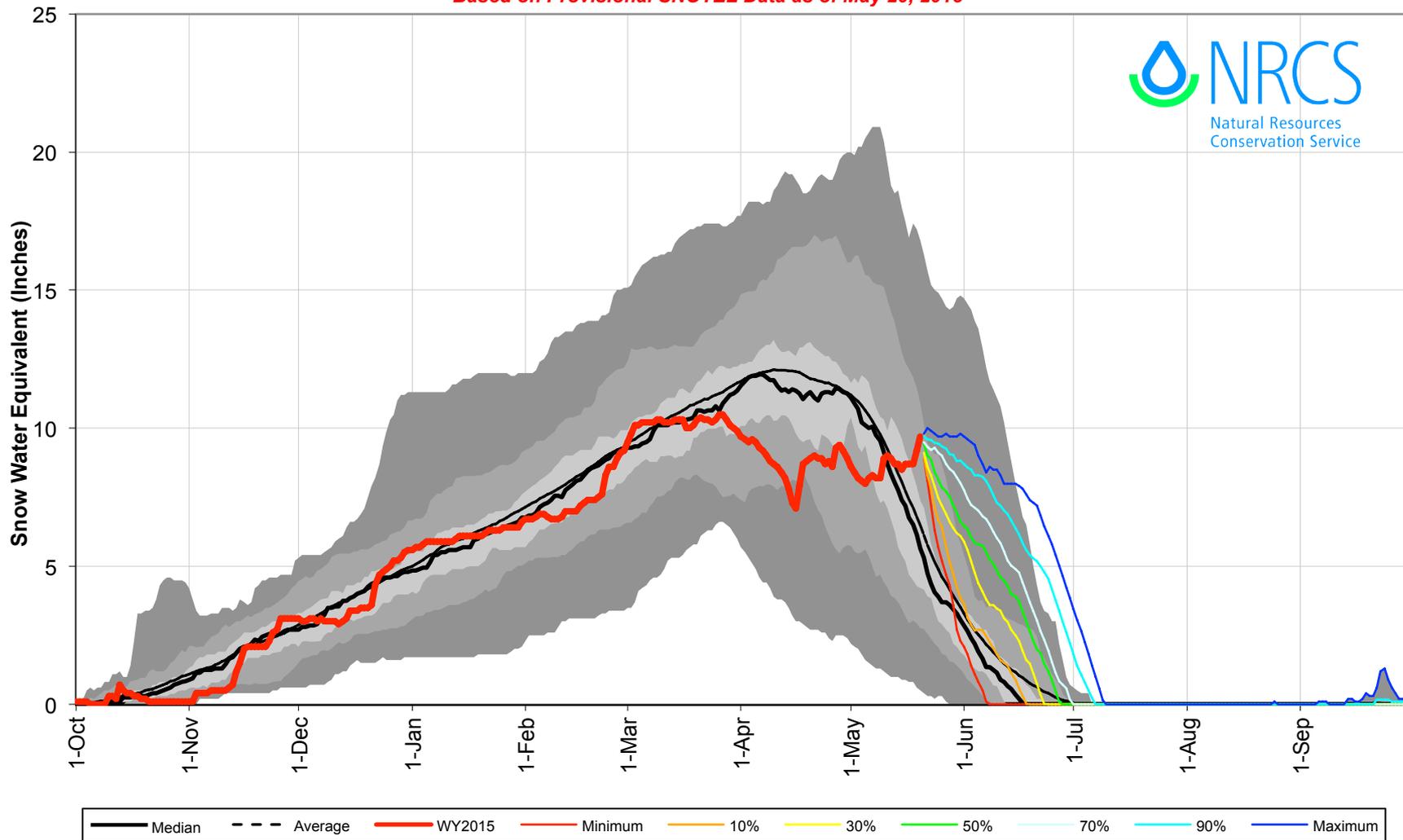
- Temperature induced diurnal fluctuations
 - Commonly due to air in the line or transducer itself
- Can complicate obtaining accurate estimates of storm totals using hourly data



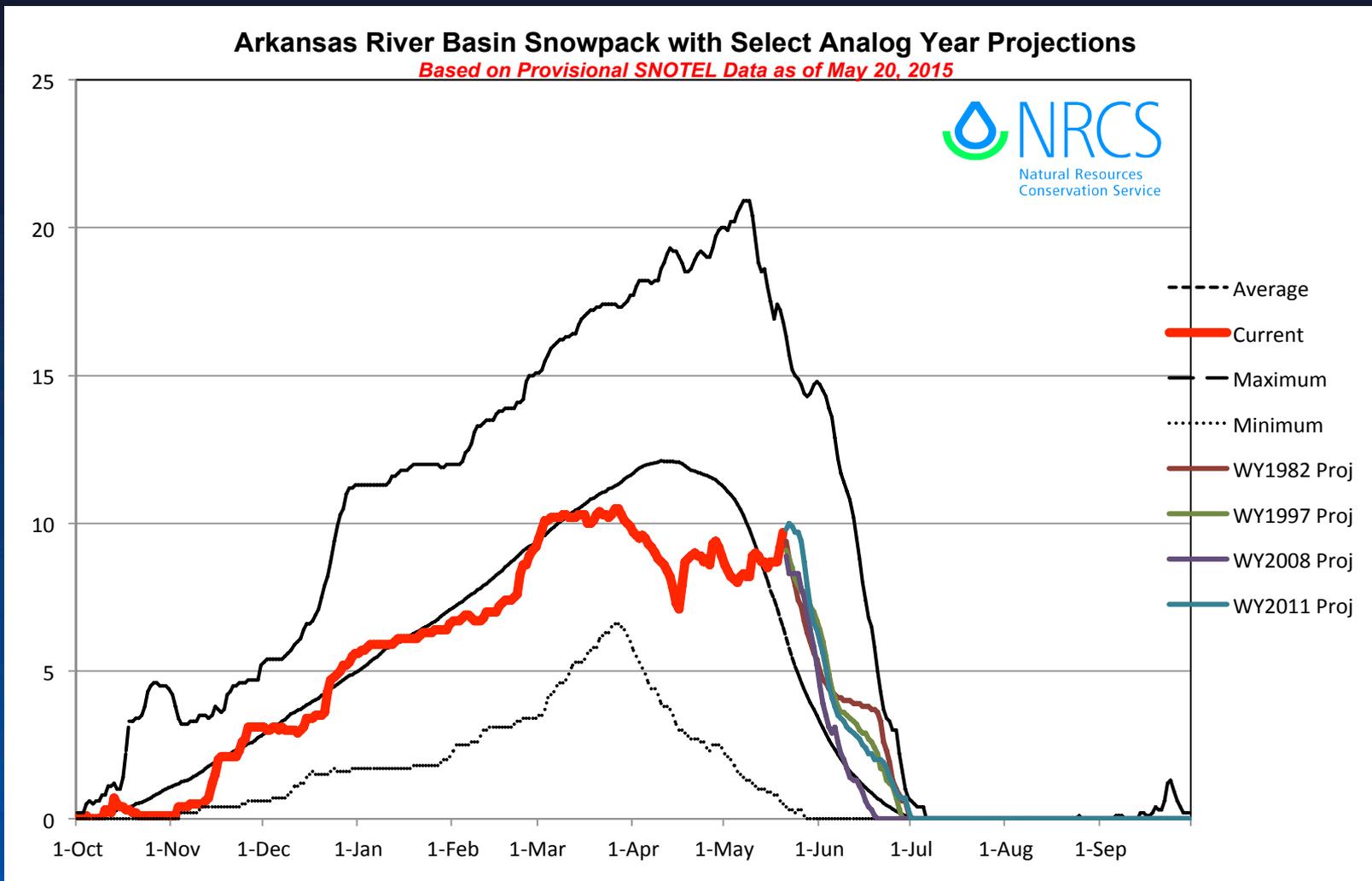
Non-Exceedance Snowpack Projections

Arkansas River Basin Snowpack with Non-Exceedance Projections

Based on Provisional SNOTEL Data as of May 20, 2015

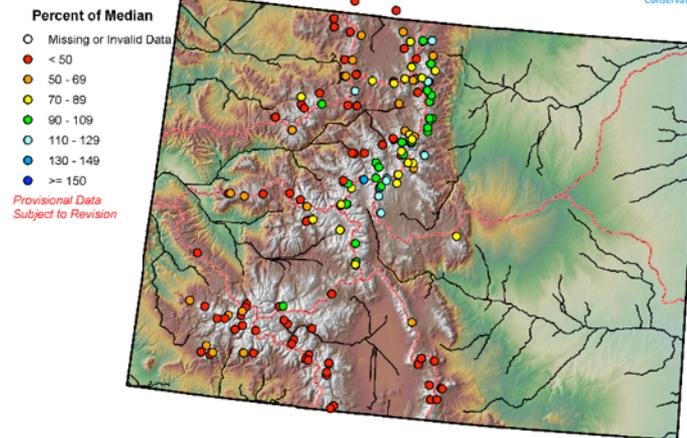


Analog Year Snowpack Projections



Various Snowpack Map Products

Colorado Snowpack Point Map

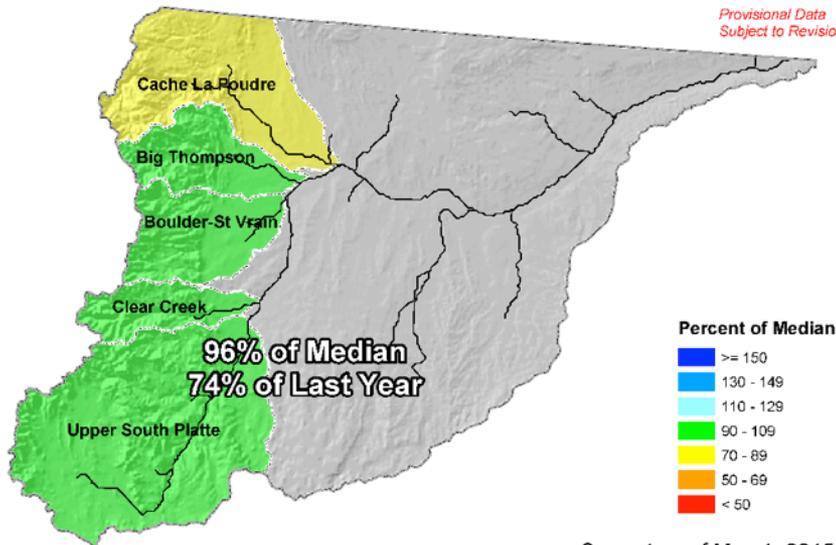


Current as of May 1, 2015

South Platte River Basin Snowpack Map



Provisional Data Subject to Revision

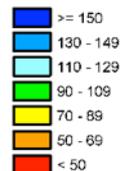


Current as of May 1, 2015

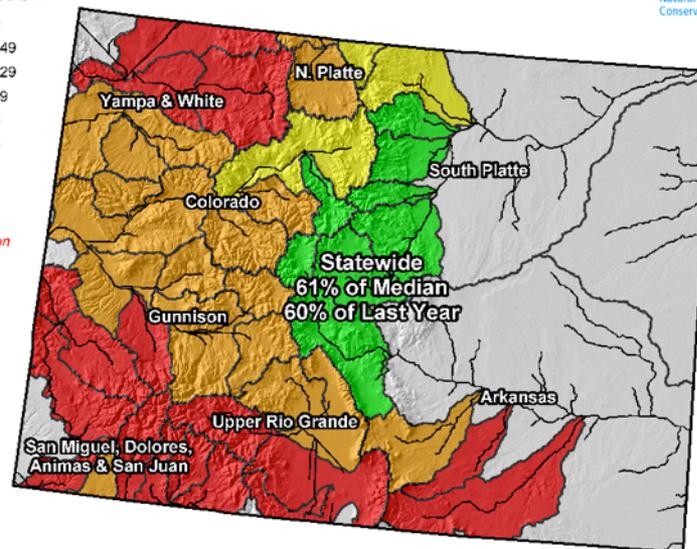
Colorado Snowpack Map



Percent of Median

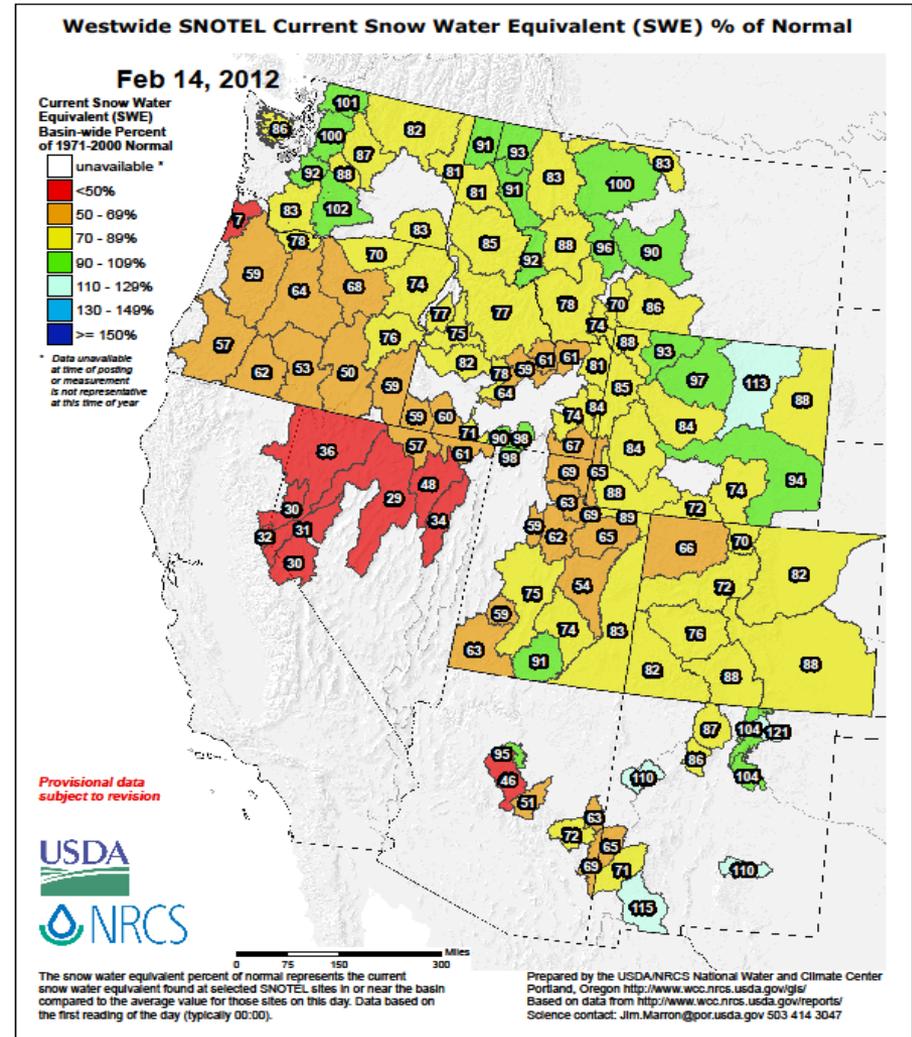
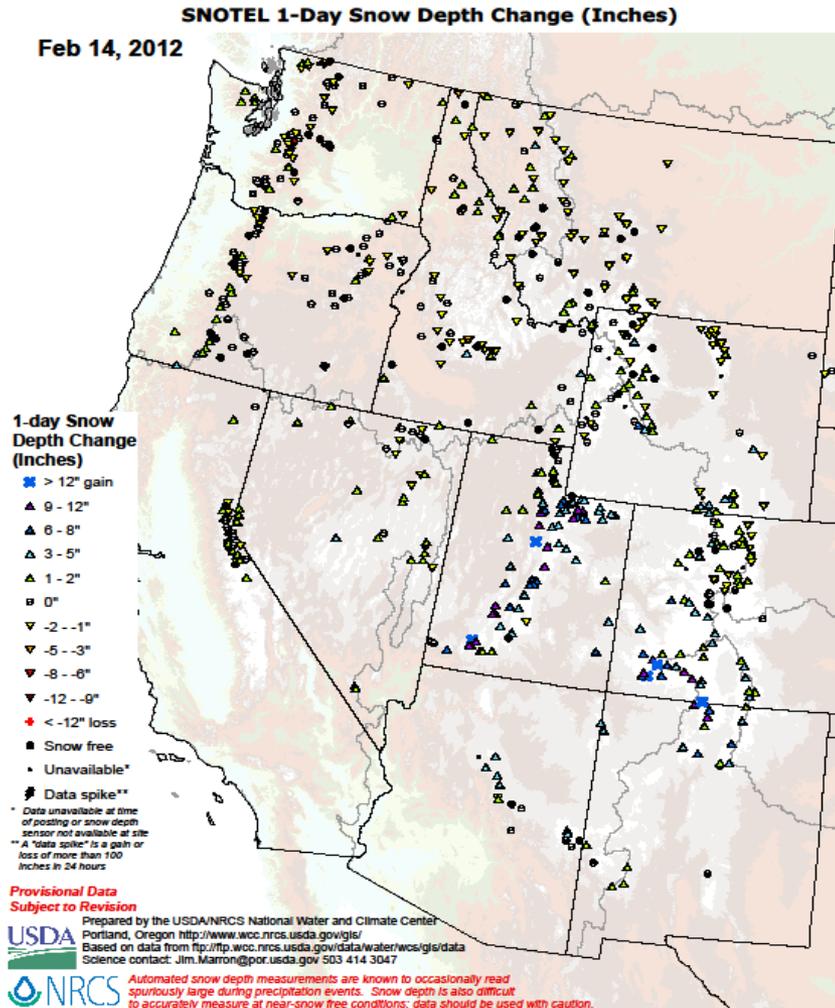


Provisional Data Subject to Revision



Current as of May 1, 2015

Products – Westwide

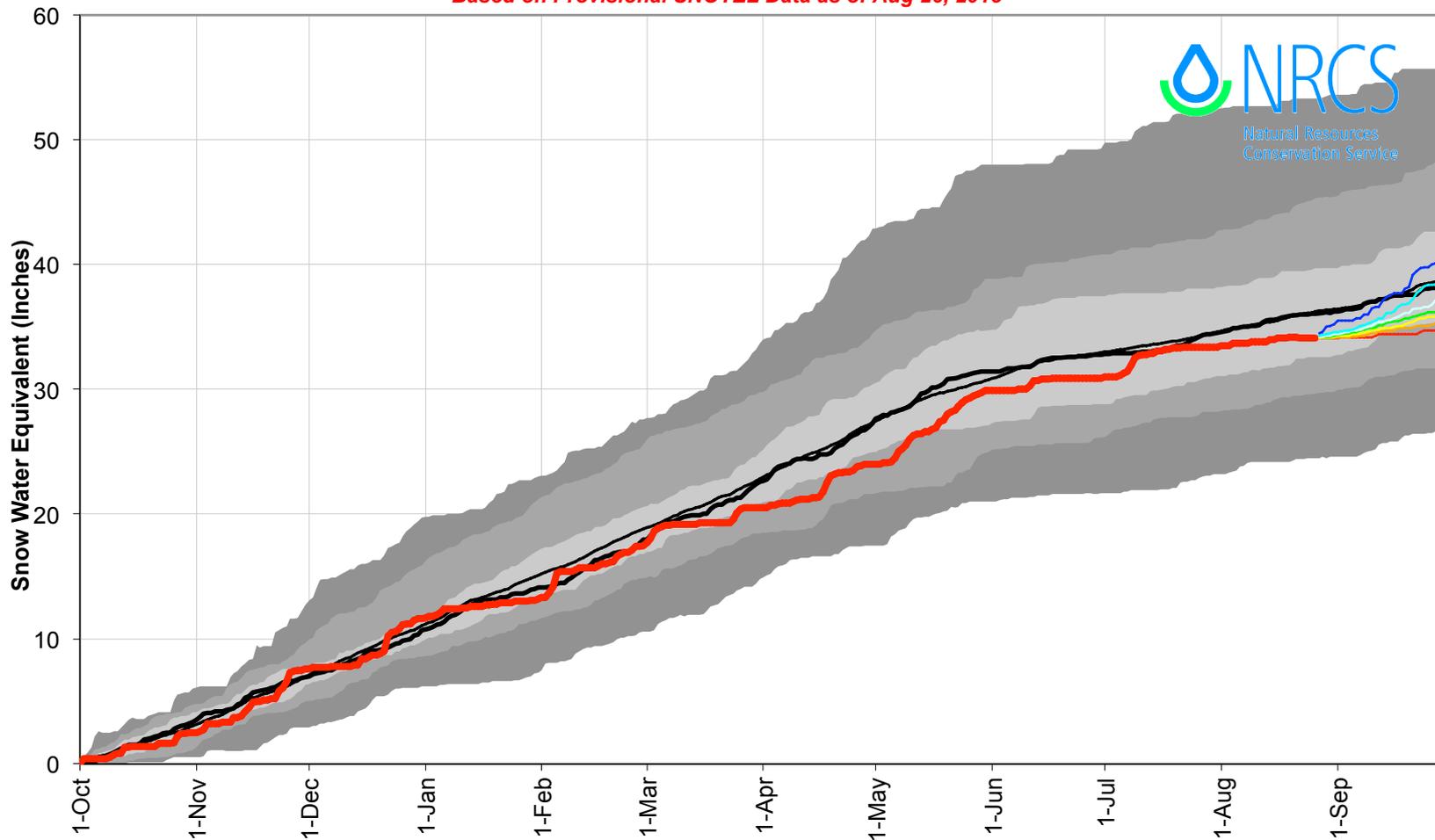




Non-Exceedance YTD Precip Projections

Laramie & North Platte River Basins Precipitation with Non-Exceedance Projections

Based on Provisional SNOTEL Data as of Aug 26, 2015

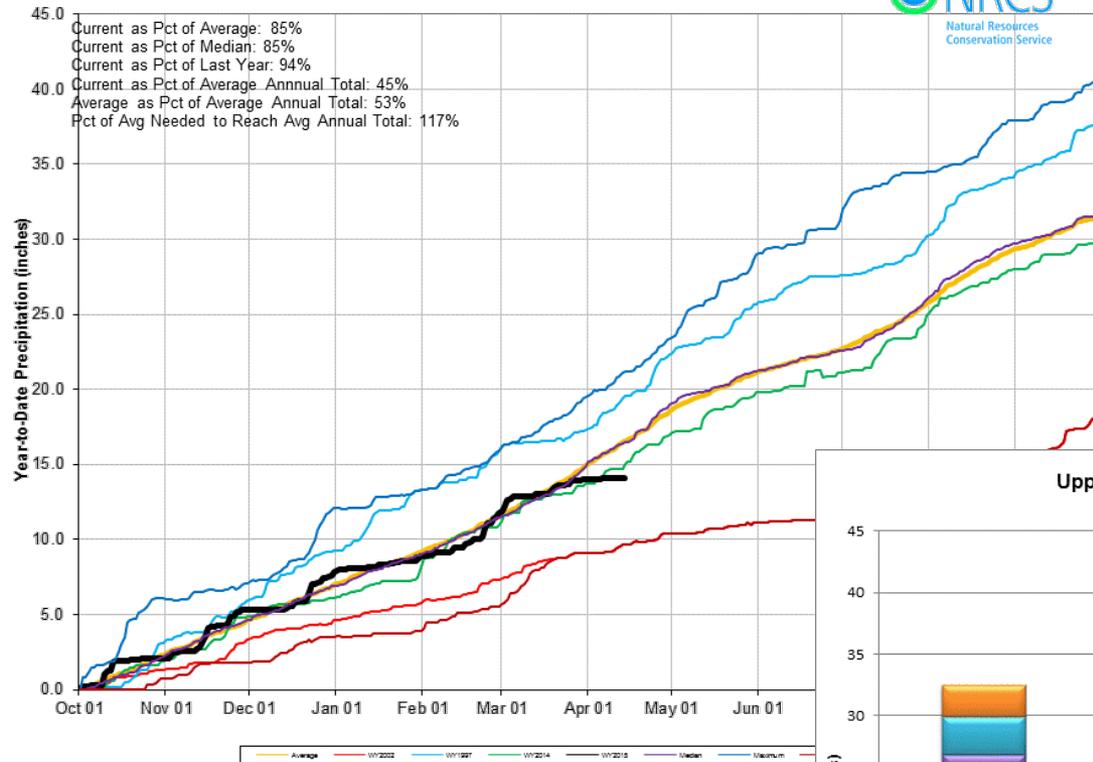


— Media - - - Average — WY2015 — Minimum — 10% — 30% — 50% — 70% — 90% — Maximum



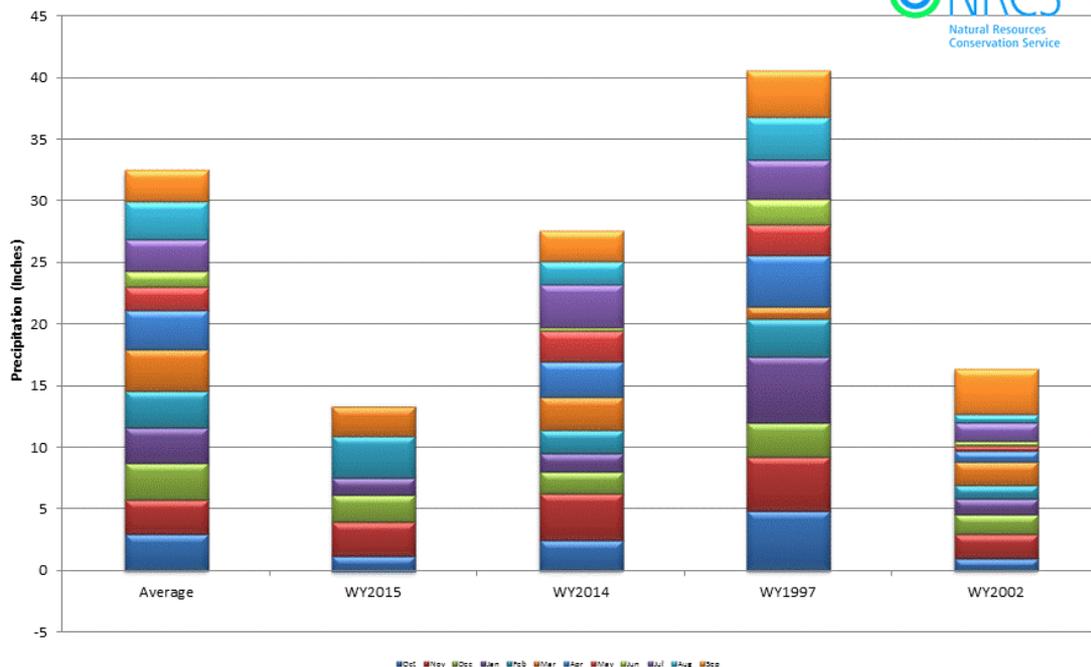
Arkansas River Basin High/Low Year-to-Date Precipitation Summary

Based on Provisional SNOTEL data as of Apr 14, 2015



Upper Rio Grande Basin High/Low Monthly Precipitation Summary

Based on Provisional SNOTEL data as of Apr 14, 2015



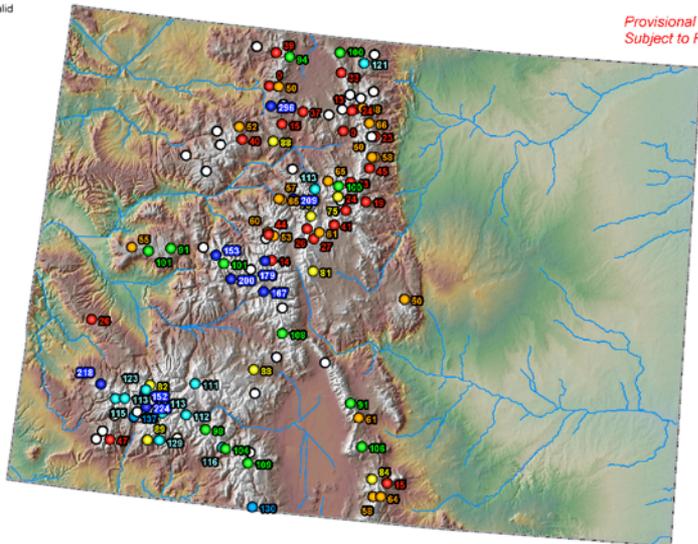
Various Precip Map Products

Colorado SNOTEL Month-to-Date Precipitation

Percent of Average

- Missing or Invalid
- < 50
- 50 - 69
- 70 - 89
- 90 - 109
- 110 - 129
- 130 - 149
- ≥ 150

*Provisional Data
Subject to Revision*



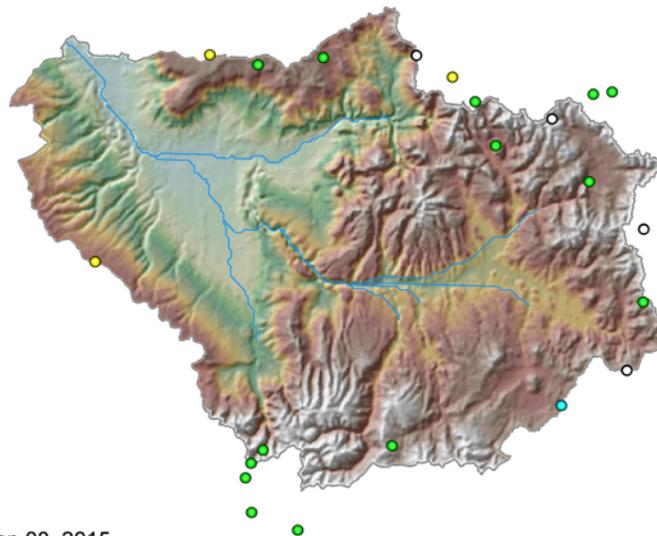
Current as of Aug 12, 2015

Gunnison River Basin SNOTEL Year-to-Date Precipitation

Percent of Average

- Missing or Invalid
- < 50
- 50 - 69
- 70 - 89
- 90 - 109
- 110 - 129
- 130 - 149
- ≥ 150

*Provisional Data
Subject to Revision*

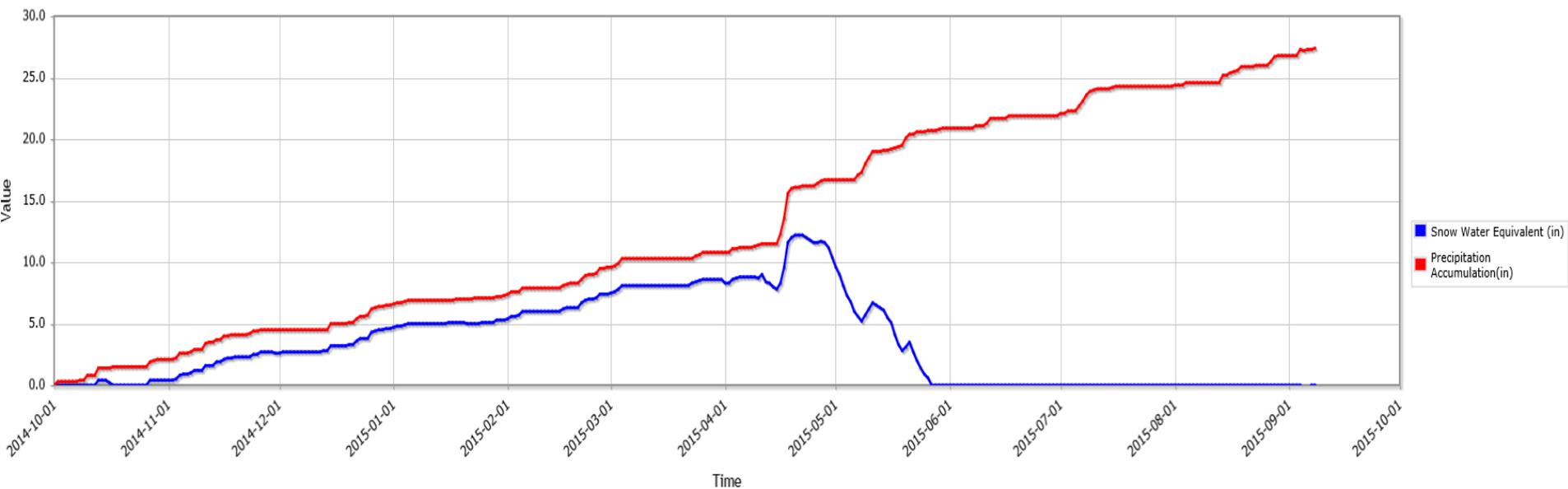


Current as of Sep 08, 2015



Colorado Snow Surveys

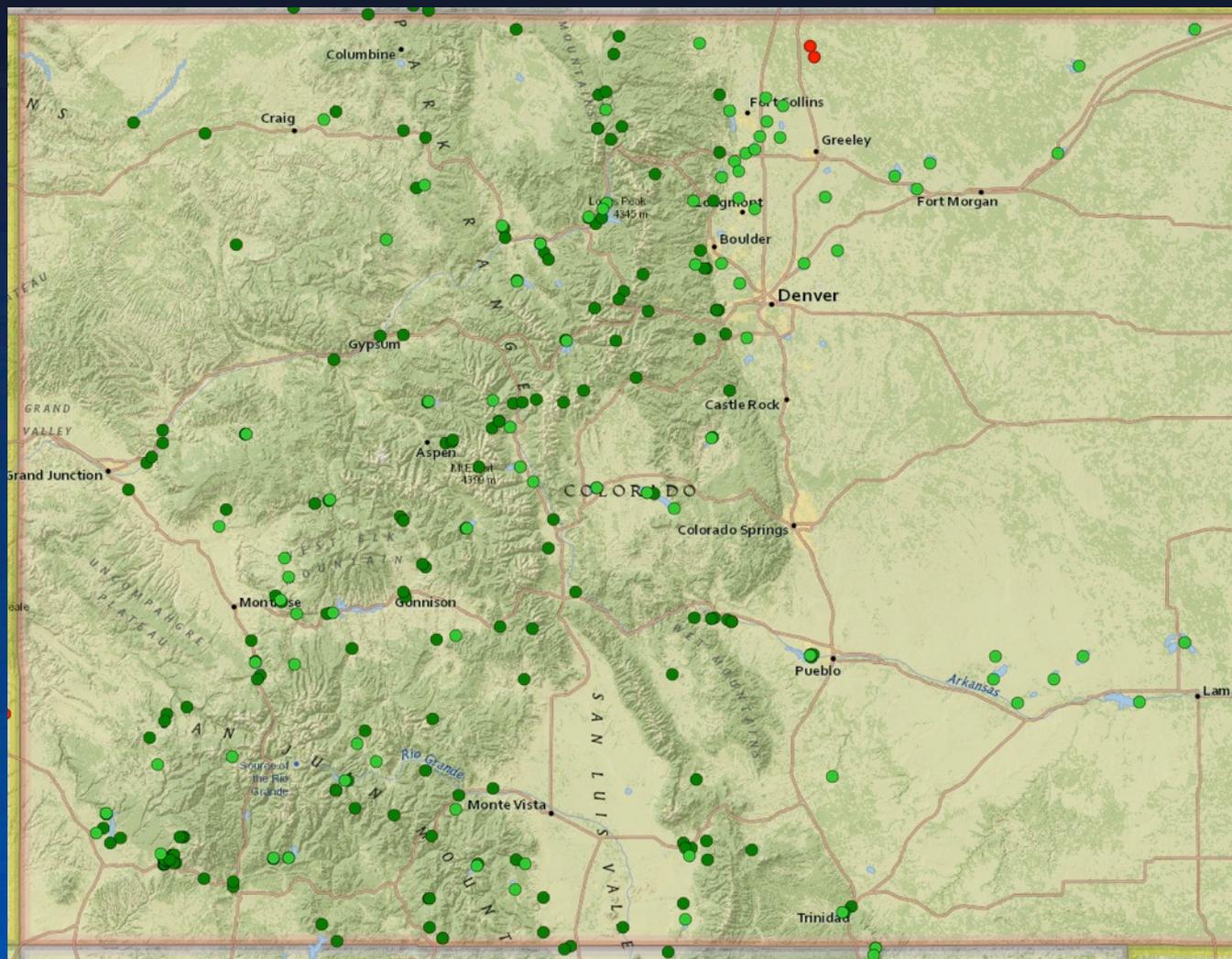
Black Mountain (1161) Colorado SNOTEL Site - 8920 ft



1981 – 2010 Normals

- Normals are simply a way to compare the current value to a baseline.
- Every decade, normals are recalculated to reflect the current climactic conditions because we are most familiar with the last 30 years.
- Addition of 2001 – 2010 and removal of 1971-1980 has shifted the new normal down several percentage points.
- Daily averages and medians were smoothed with a 7-day running average except at the truncation to zero and at the beginning and end of the year.

Reservoir and Streamflow Locations & Data



Stations by Network

- SNOTEL
- SCAN
- SNOLITE
- Other NRCS Hydromet
- Snow Course/Aerial Marker
- Manual SNOTEL
- Manual Precipitation
- Reservoir
- Streamflow
- ACIS

Natural Resources Conservation Service
 Created 9-08-2015, 05:00 PM MDT

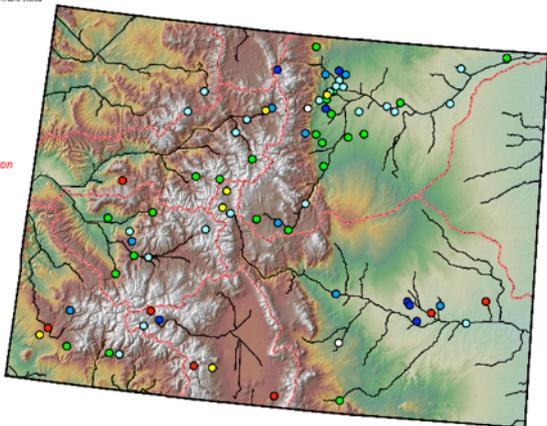
Products – Aggregated Reservoir Data

Colorado Reservoir Storage Point Map

Percent of Average

- Missing or Invalid Data
- < 50
- 50 - 69
- 70 - 89
- 90 - 109
- 110 - 129
- 130 - 149
- ≥ 150

Provisional Data
Subject to Revision



End of May 2015

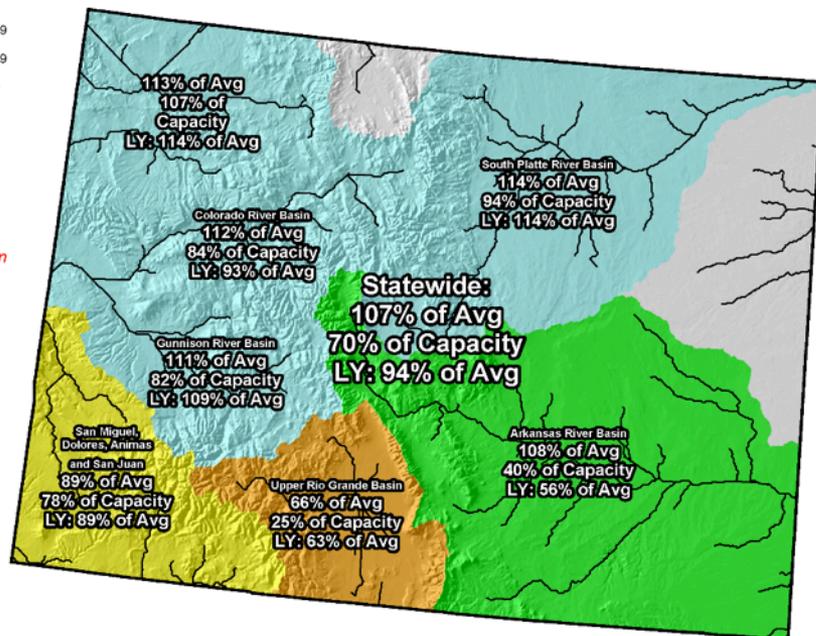


Colorado Reservoir Storage Map

Percent of Average

- ≥ 150
- 130 - 149
- 110 - 129
- 90 - 109
- 70 - 89
- 50 - 69
- < 50

Provisional Data
Subject to Revision



End of May 2015



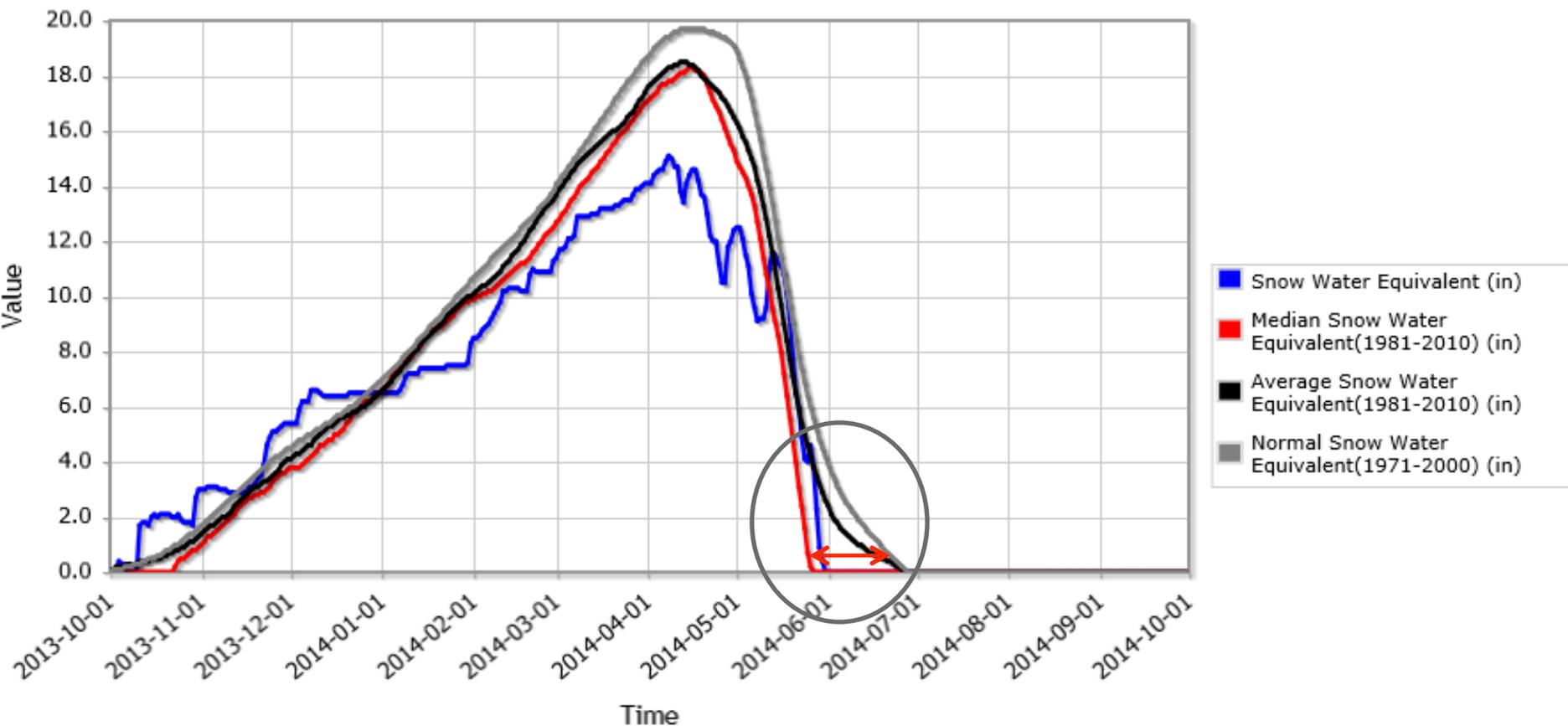
1981 – 2010 Normals

- Default is the value that will be most frequently represented in reports and graphs unless otherwise stated.
- “Yes” specifies those values have been calculated and stored in our database.
- Elements not specified here have no calculated normals for this 30yr period.

Element	Default	Average	Median
Temperature	Average	Yes	No
Precipitation	Average	Yes	Yes
Snow Water Eq.	Median	Yes	Yes
Snow Depth	Median	Yes	Yes
Streamflow	Average	Yes	Yes
Reservoir Storage	Average	Yes	No

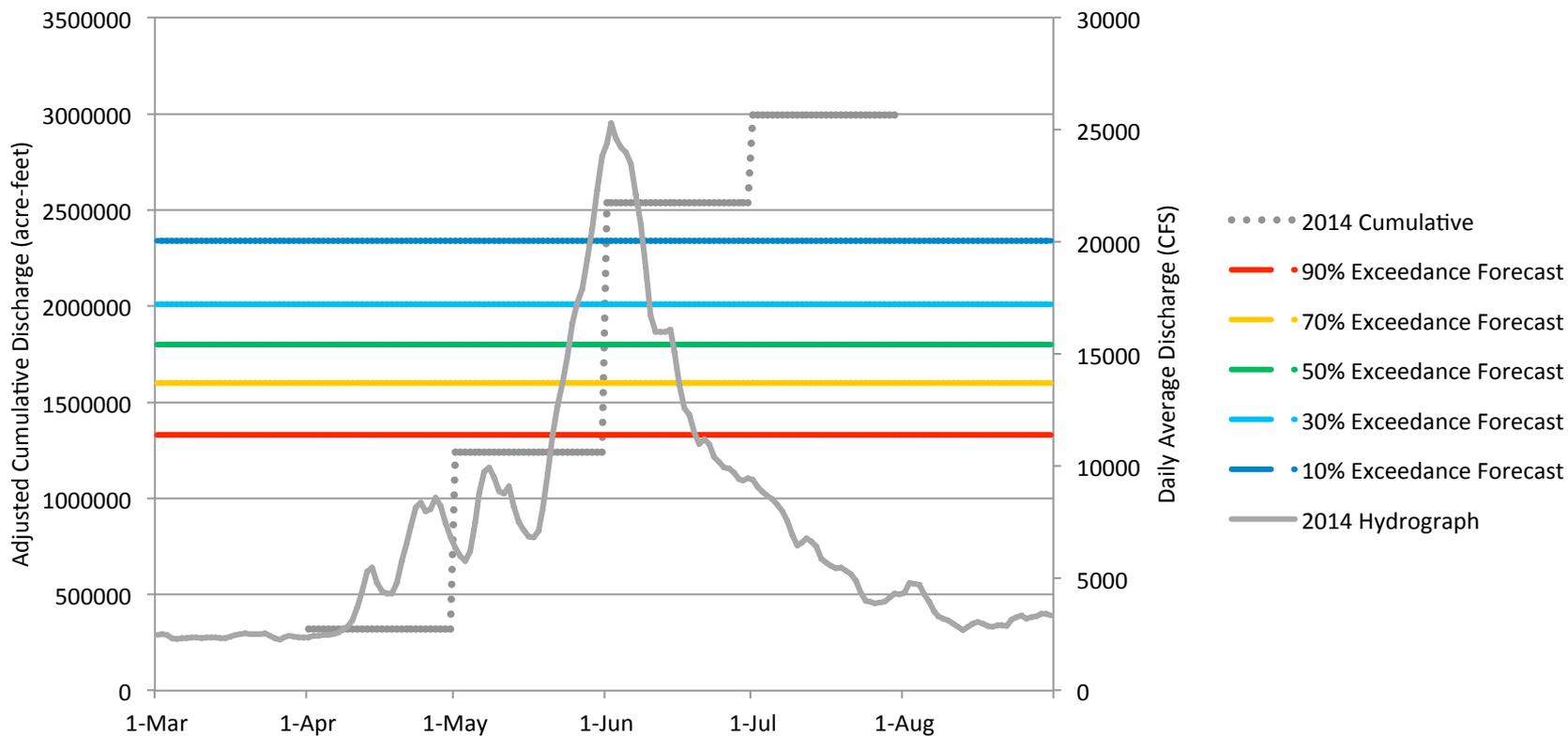
So why did we use medians?

Mesa Lakes (622) Colorado SNOTEL Site - 10000 ft



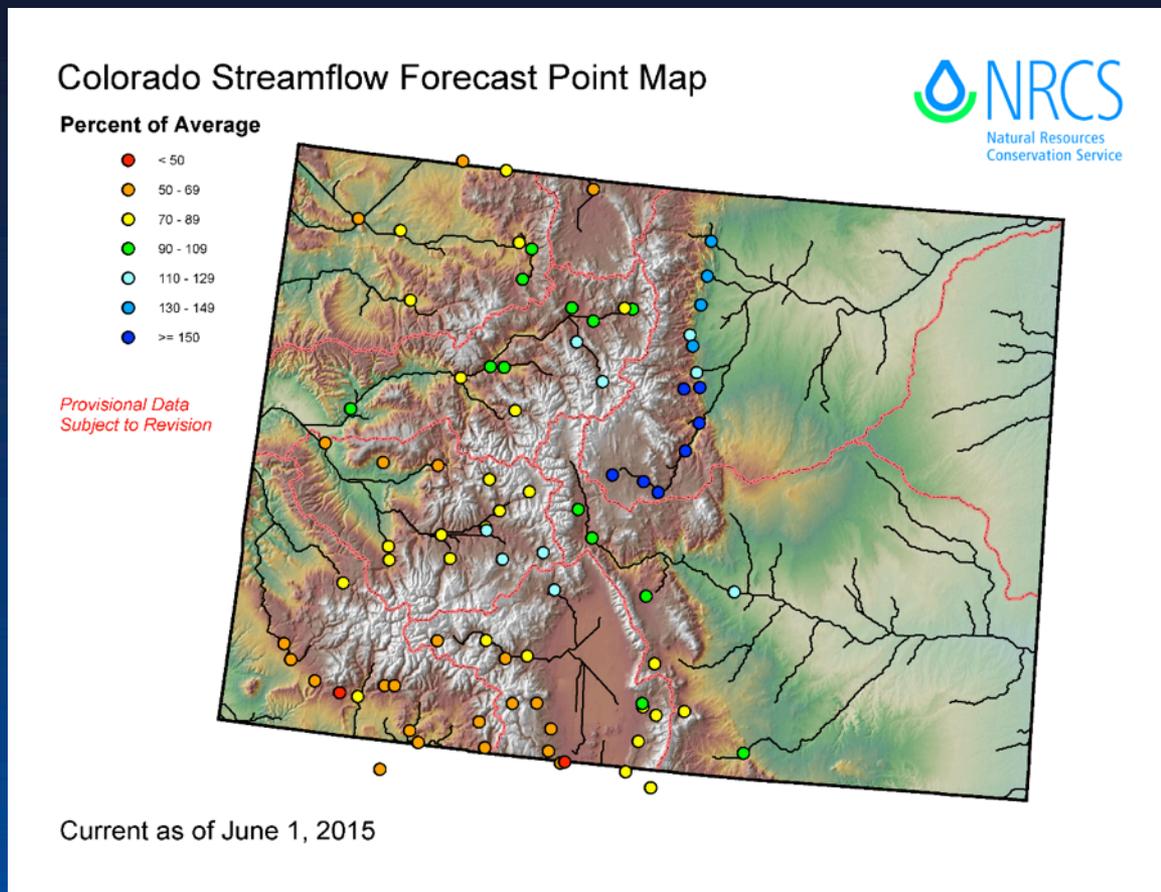
Streamflow Graphics

Colorado River at Cameo, CO: Last Year's Hydrograph and Cumulative Discharge Compared to Current Streamflow Forecasts



Streamflow Forecasting

- Volumetric – the total amount of water predicted to pass through a gauge, example; April 1 – July 31
 - Use various forecast periods
 - Water Supply forecasts updated monthly Jan 1 – Jun 1
- Forecasts produced using multiple regression analysis
- Forecast inputs optimized with principal components analysis



Streamflow Forecasting

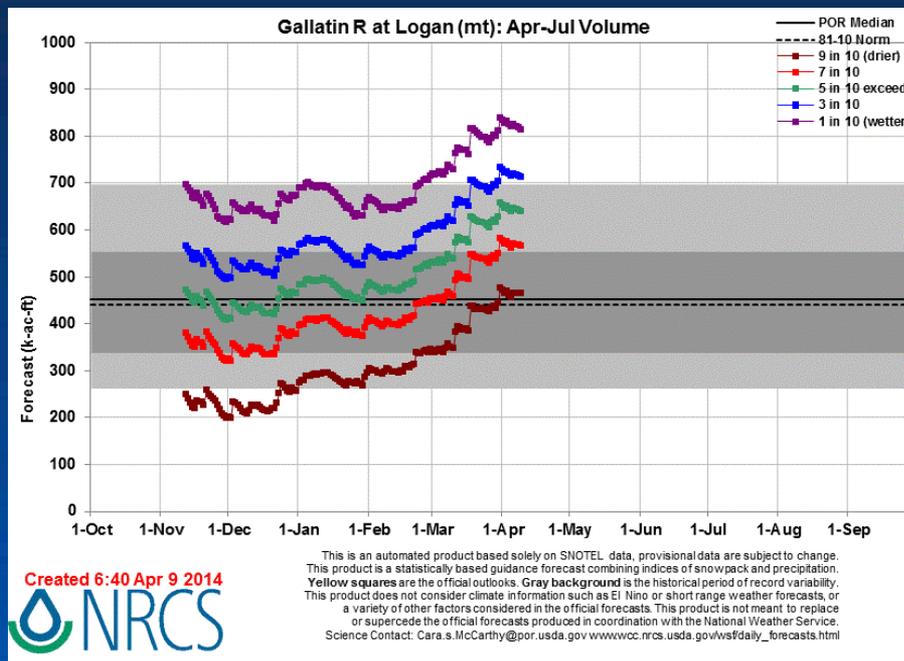
- Forecasts are provided in exceedances to provide probability of occurrence for each volumetric forecast
- Coordinate our forecasts with other federal agencies
- Also provide daily “guidance” forecasts for select locations

Flow & Forecasts in 1000*Ac-ft

Period	Forecasts					Avg	Last Year's Observed Flow	% of Avg	% of Last Year
	Min (90%)	70	50	30	Max (10%)				

Dillon Reservoir Inflow

APR-JUL	168	210	235	260	300	330	282.18207	71%	83%
APR-SEP	275	325	360	395	445	485	420.33338	74%	86%

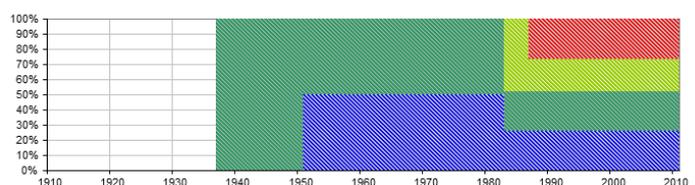




VIPER – NRCS Forecasting Model

- Multiple Regression Analysis w/ unlimited input options

Type	Target	Start	End
SnowSwe	07M17, CO, Santa Maria	Apr F	Apr F
Type	Predictors	Start	End
1	SnotelSwe	762, CO, Slumgullion	Apr F
2	SnotelSwe	839, CO, Upper Rio Grande	Apr F
3	SnotelSwe	327, CO, Beartown	Apr F
4	SnowSwe	06M04, CO, Silver Lakes	Apr F
5	SnowSwe	07M20, CO, Porcupine	Apr F
6	SnowSwe	06M14, CO, Pool Table Mountain	Apr F
7		Jan-1 F	Jan-1 L
8		Jan-1 F	Jan-1 L
9		Jan-1 F	Jan-1 L
10		Jan-1 F	Jan-1 L
11		Jan-1 F	Jan-1 L
12		Jan-1 F	Jan-1 L
13		Jan-1 F	Jan-1 L
14		Jan-1 F	Jan-1 L
15		Jan-1 F	Jan-1 L
16		Jan-1 F	Jan-1 L
17		Jan-1 F	Jan-1 L
18		Jan-1 F	Jan-1 L



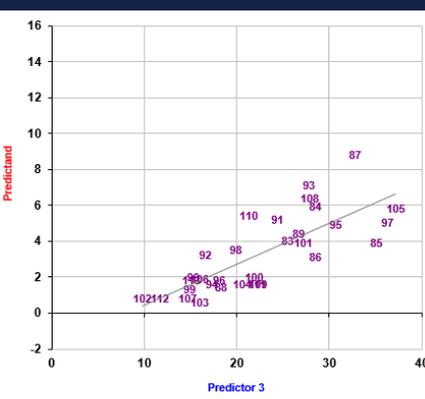
Cross-Correlation

X-Variable: Predictor 3
Transformation: None

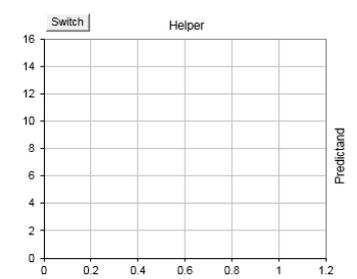
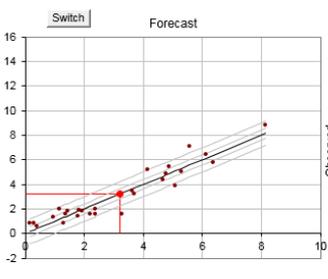
Y-Variable: Predictand
Transformation: None

Slope: 0.22758
Intercept: -1.84977
R: 0.778
R2: 0.606

Original: X 19.9, Y 2.67908
Estimated: O - E



Station	1	2	3	4	5	6
Correl		0.861	0.778	0.855	0.859	
Years		27/27	31/31	75/77	63/63	
CurrZ		0.472	-0.368	0.096	-0.711	
PctNorm		138%	90%	100%	77%	
Pred		4.06	2.68	4.12	1.98	



Analysis Type: Principal Components

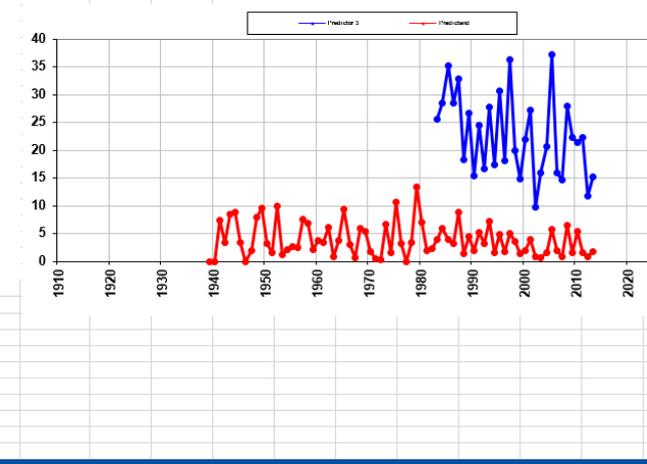
Forecast Volume	Pct
10	4.20
30	3.61
50	3.20
70	2.80
90	2.20

Transformation: None
First Year Used: 0
Last Year Used: 9999
Target Data Src: AWDB
Publication Date: Dec 15
Published?:

More Predictors... (none active)
Advanced Settings... (none active)
Helper Predictand... (not active)

Clear Recalculate

comp: 1
% var: 0.837



Group	SnotelSwe	SnowSwe	SnotelPrpc	CoopPrpc	USGSStrm	NRCSStrm
Correl	0.862	0.899				
Years	31	75				
CurrZ	0.094	-0.308				
Pred	3.35	2.97				

Group	Climate Index	Reservoir	Routed	BEARStrm	SoilMoisture	All
Correl						0.951
Years						27
CurrZ						-0.115
Pred						3.20237449

Statistics	Average	Median	Min	MinYear	Max	MaxYear
POR	3.8	3.1	0.0	1939	13.4	1979



Basin Outlook Report



Colorado

Water Supply Outlook Report

April 1, 2015



Snow surveyors Zack Wilson and Lexi Landers perform measurements along the Deer Ridge snow course in Rocky Mountain National Park. Temperatures were warm and snow was patchy along the snow course late in March, but Zack and Lexi measured an average depth of 17 inches and an average snow water equivalent (SWE) of 6.4 inches. These measurements were above the normal median depth of 15 inches and SWE of 4 inches typically observed on April 1st.

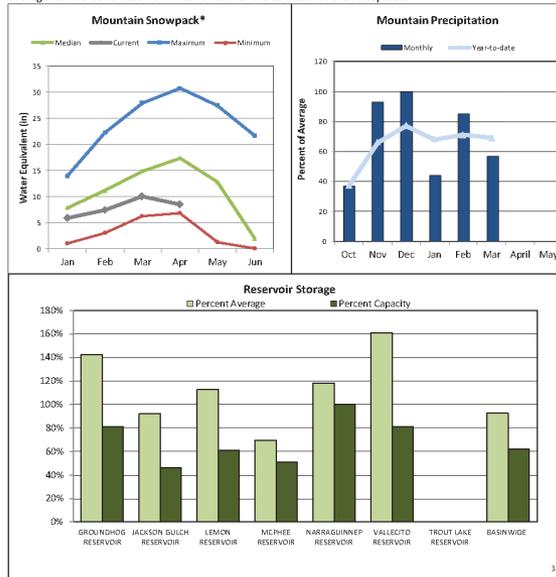
Date: 3/30/2015
Photo By: Pamela Johnson (Loveland Reporter-Herald)

REMINDER: We are soliciting field work photos from our snow surveyors again this year. Each month we will pick one to grace the cover of this report! The photographer will be given proper credit of course. Please include information on where, when and of who/what the photo was taken.

SAN MIGUEL, DOLORES, ANIMAS, AND SAN JUAN RIVER BASINS

April 1, 2015

Snowpack in the combined southwest river basins is below normal at 49% of median. Precipitation for March was 57% of average which brings water year-to-date precipitation to 69% of average. Reservoir storage at the end of March was 90% of average compared to 82% last year. Current streamflow forecasts range from 67% of average for the Cone Reservoir Inlet to 43% for the La Plata River at Hesperus.



Data Current as of: 4/7/2015 10:30:26 AM

San Miguel-Dolores-Animas-San Juan River Basins Streamflow Forecasts - April 1, 2015

Forecast Exceedance Probabilities for Risk Assessment
Chance that actual volume will exceed forecast

SAN MIGUEL-DOLORES-ANIMAS-SAN JUAN RIVER BASINS	Forecast Period	90% (P4F)	70% (P4F)	50% (P4F)	% Avg	30% (P4F)	10% (P4F)	30yr Avg (P4F)
Dolores R at Dolores	APR-JUL	89	115	135	55%	156	190	245
McPhee Reservoir Inflow	APR-JUL	83	113	135	46%	159	199	295
San Miguel R nr Placerville	APR-JUL	51	68	80	63%	94	116	128
Cone Reservoir Inlet	APR-JUL	1.34	1.72	2	67%	2.3	2.8	3
Gunley Reservoir Inlet	APR-JUL	7.5	9.3	10.6	65%	12.1	14.3	16.4
Litlands Reservoir Inlet	APR-JUL	0.58	0.95	1.25	65%	1.59	2.2	1.92
Rio Blanco at Blanco Diversion ²	APR-JUL	19.4	25	30	56%	35	43	54
Navajo R at Osio Diversion ²	APR-JUL	23	30	36	55%	41	50	65
San Juan R nr Carracas ²	APR-JUL	119	161	194	51%	230	285	380
Piedra R nr Aboltes	APR-JUL	64	85	100	48%	117	143	210
Vallejo Reservoir Inflow	APR-JUL	81	100	115	59%	131	156	194
Navajo Reservoir Inflow ²	APR-JUL	205	275	330	45%	395	490	735
Animas R at Durango	APR-JUL	170	215	245	59%	280	335	415
Lemon Reservoir Inflow	APR-JUL	19.8	25	29	53%	33	40	55
La Plata R at Hesperus	APR-JUL	6.5	8.5	10	43%	11.6	14.2	23
Mancos R nr Mancos ²	APR-JUL	7.8	11.3	14	45%	17	22	31

1) 90% and 10% exceedance probabilities are actually 95% and 5%
2) Forecasts are for unimpounded flows. Actual flow will be dependent on management of upstream reservoirs and diversions
3) Median value used in place of average

Reservoir Storage	Current (P4F)	Last Year (P4F)	Average (P4F)	Capacity (P4F)
End of March, 2015				
Groundhog Reservoir	17.8	7.3	12.0	22.0
Jackson Gulch Reservoir	4.6	3.5	5.0	10.0
Lemon Reservoir	24.4	18.2	21.7	40.0
McPhee Reservoir	195.4	180.3	282.2	381.0
Narragunnet Reservoir	19.0	13.6	16.1	19.0
Trout Lake Reservoir	0.0	1.2	1.4	3.2
Vallejo Reservoir	101.9	84.4	63.3	126.0
Basin-wide Total	383.1	331.0	402.2	601.2
# of reservoirs	7	7	7	7

Watershed Snowpack Analysis	# of Sites	% Median	Last Year % Median
April 1, 2015			
ANIMAS RIVER BASIN	11	53%	85%
DOLORES RIVER BASIN	7	46%	79%
SAN MIGUEL RIVER BASIN	6	52%	86%
SAN JUAN RIVER BASIN	4	48%	75%
SAN MIGUEL-DOLORES-ANIMAS-SAN JUAN RIVER BASINS	26	49%	81%

Data Feeds – Web Services

- Written in:
 - Java
 - Visual Basic for Applications (VBA)
- Near Real-Time Data
- Provides direct feed to database
- Data profiles auto QC data and blank out if data is suspect
- Database updated as soon as live person QCs data
- Database provides latest 30-year normals for select data types

Questions? Comments?

Global Warming Protest

