# Colorado Basin River Forecast Center

2015 Water Supply Verification Briefing

October 21st 2015

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Sr. Hydrologist

Please mute your phone until question/ answer sessions, thanks

# 2015 Water Supply Verification Webinar

- 2015 Observed Runoff Volumes vs. 2015 Forecast Runoff Volumes
- Drivers of the Forecast
- Impacts of the wet spring
- Runoff Forecasts:  Accuracy and Performance
- Summary / Conclusion

# 2015 Water Supply Verification Webinar

## Why Do Verification? It's a path to improvement

***We wish to know:***

Did the model do what it was supposed to do ?

Were initial model states correct ?

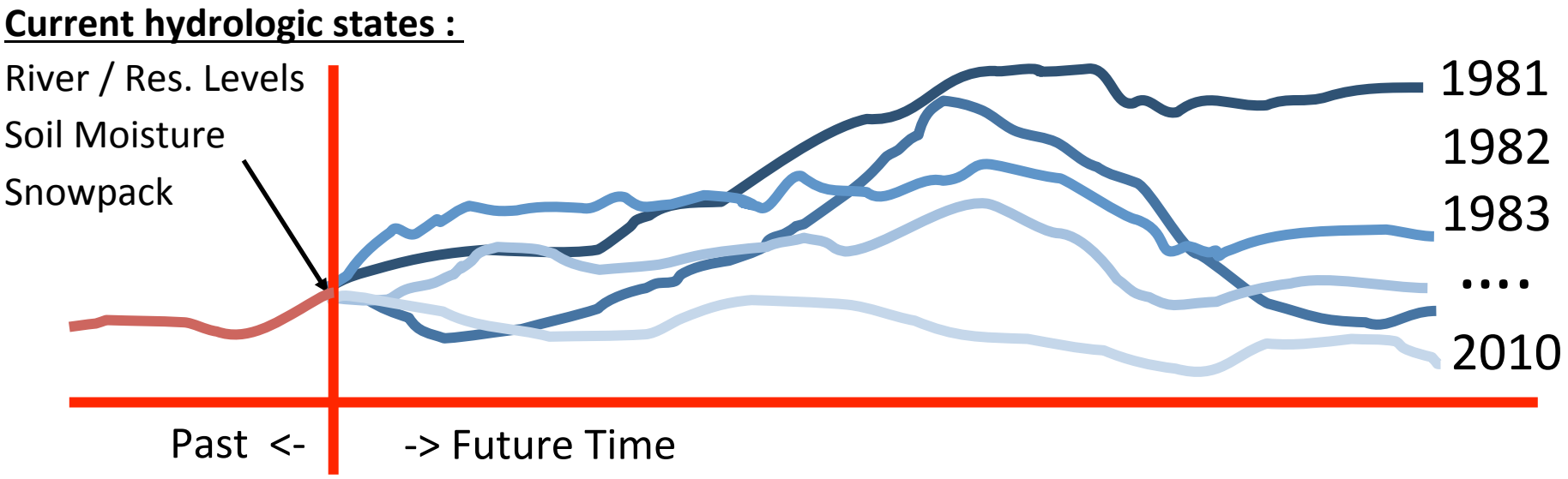
Are we missing important data ?

What would help us improve ?

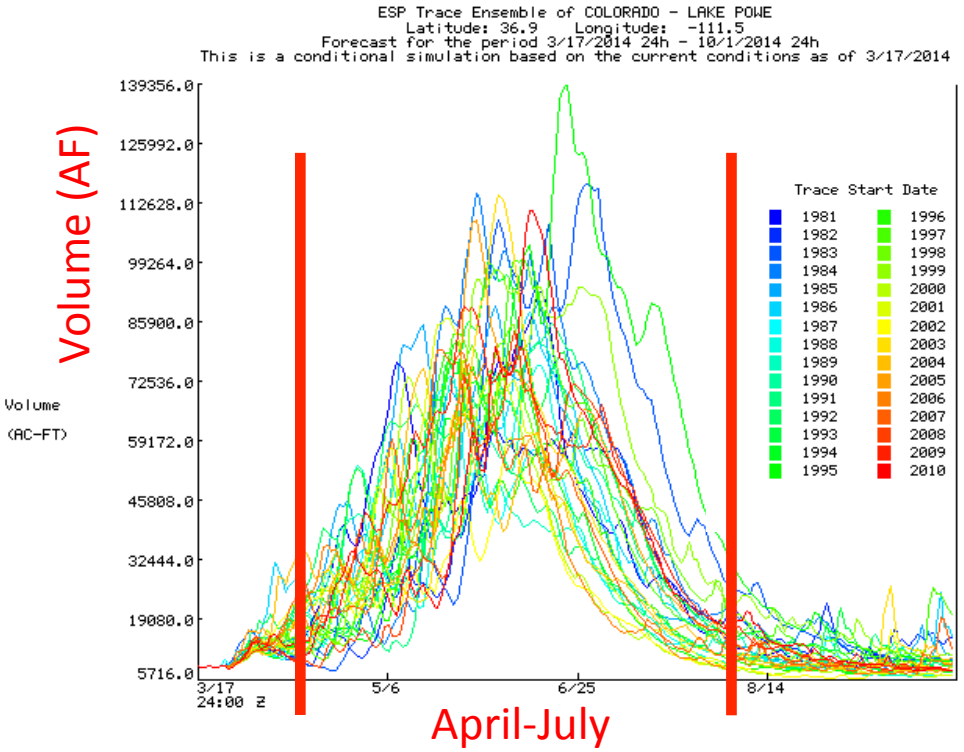
Where do we focus our efforts ?

# Probabilistic Forecasts

- Start with current conditions of streamflow, soil moisture, snowpack
- Apply precipitation and temperature from each historical year (1981-2010) from current date into the future.
- A forecast is generated for each of the years (1981-2010) *as if, going forward,* that year will happen
- This creates 30 possible future streamflow patterns. Each year is given a 1/30 chance of occurring



# Ensemble Prediction System (ESP) - **Probabilistic Forecasts**




1

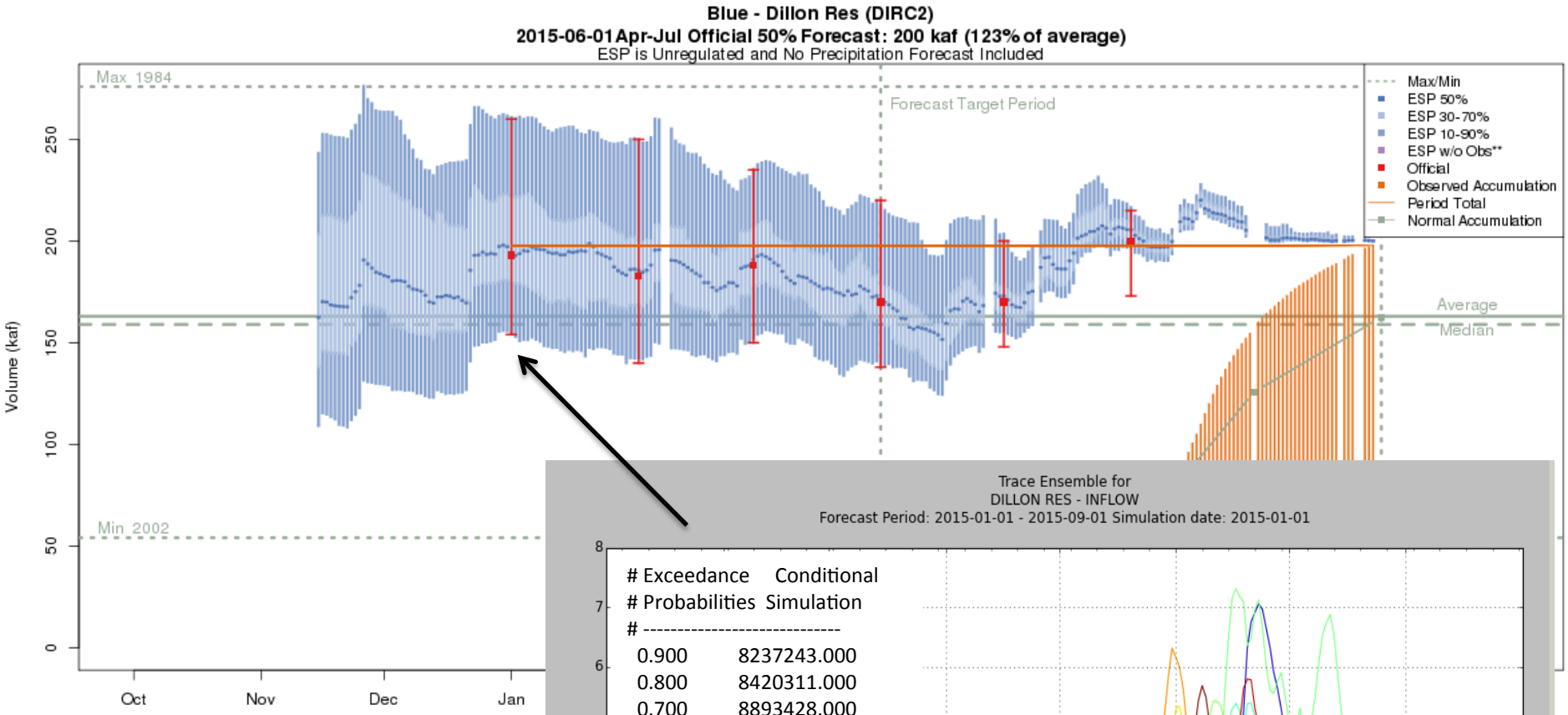
```
# EMPIRICAL SAMPLE POINTS
#            Cond.
#Trace    Year      Data Exceed.
# year  Weight      Point   Prob.
# ---------------------------------
  1981  0.033 10583427.0  0.290
  1982  0.033 8372498.00  0.806
  1983  0.033 12646544.0  0.065
  1984  0.033 11904022.0  0.129
  1985  0.033 11402967.0  0.161
  1986  0.033 10406237.0  0.355
  1987  0.033 8369501.00  0.839
  1988  0.033 8719326.00  0.742
  1989  0.033 7605042.50  0.935
  1990  0.033 9761623.00  0.452
  1991  0.033 9690117.00  0.484
  1992  0.033 9298360.00  0.613
  1993  0.033 10987106.0  0.226
  1994  0.033 9395003.00  0.548
  1995  0.033 14388755.0  0.032
  1996  0.033 8611564.00  0.774
  1997  0.033 10736442.0  0.258
  1998  0.033 10159611.0  0.419
  1999  0.033 12520652.0  0.097
  2000  0.033 8252478.50  0.871
  2001  0.033 9312369.00  0.581
  2002  0.033 6439105.00  0.968
  2003  0.033 9439112.00  0.516
  2004  0.033 8867351.00  0.710
  2005  0.033 10415361.0  0.323
  2006  0.033 8235550.00  0.903
  2007  0.033 8964843.00  0.645
  2008  0.033 8954274.00  0.677
  2009  0.033 11320183.0  0.194
  2010  0.033 10185848.0  0.387
```

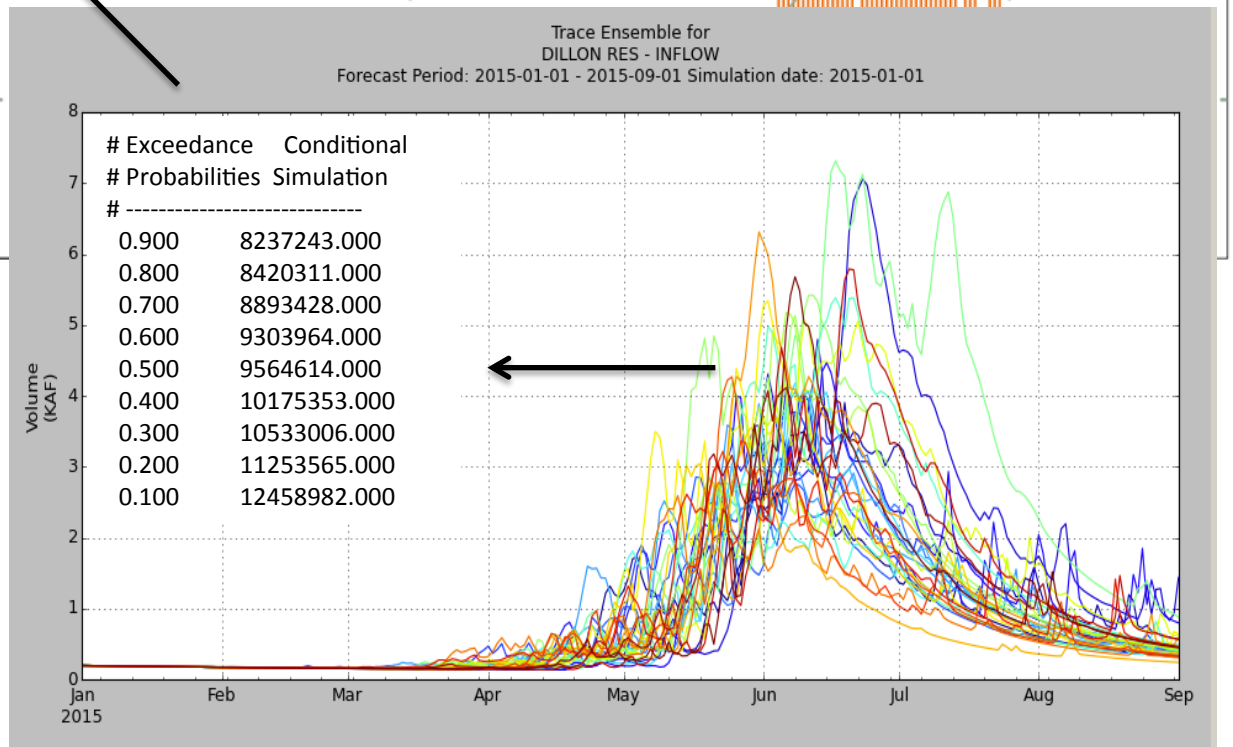
2

```
# Exceedance     Conditional
# Probabilities  Simulation
# ----------------------------
  0.900          8237243.000
  0.800          8420311.000
  0.700          8893428.000
  0.600          9303964.000
3 0.500          9564614.000
  0.400          10175353.000
  0.300          10533006.000
  0.200          11253565.000
  0.100          12458982.000
```

1. The flows are summed into volumes for the period of interest (typically April 1 – July 31)
2. The statistics are simplified
3. 50% exceedance value approximates the most probable forecast

# Range of possible outcomes are summarized in the forecast spread

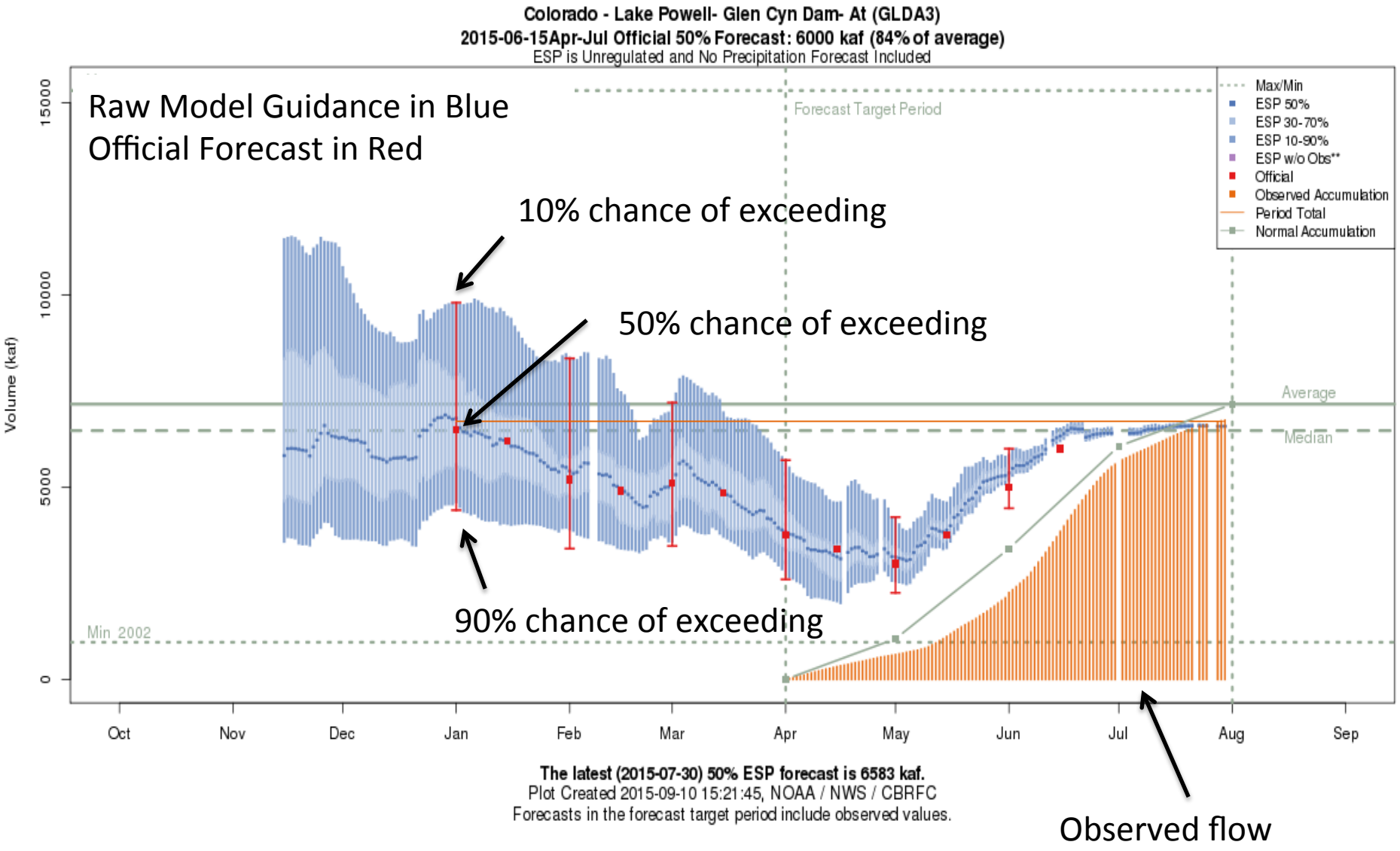



January 1st 2015 Forecast

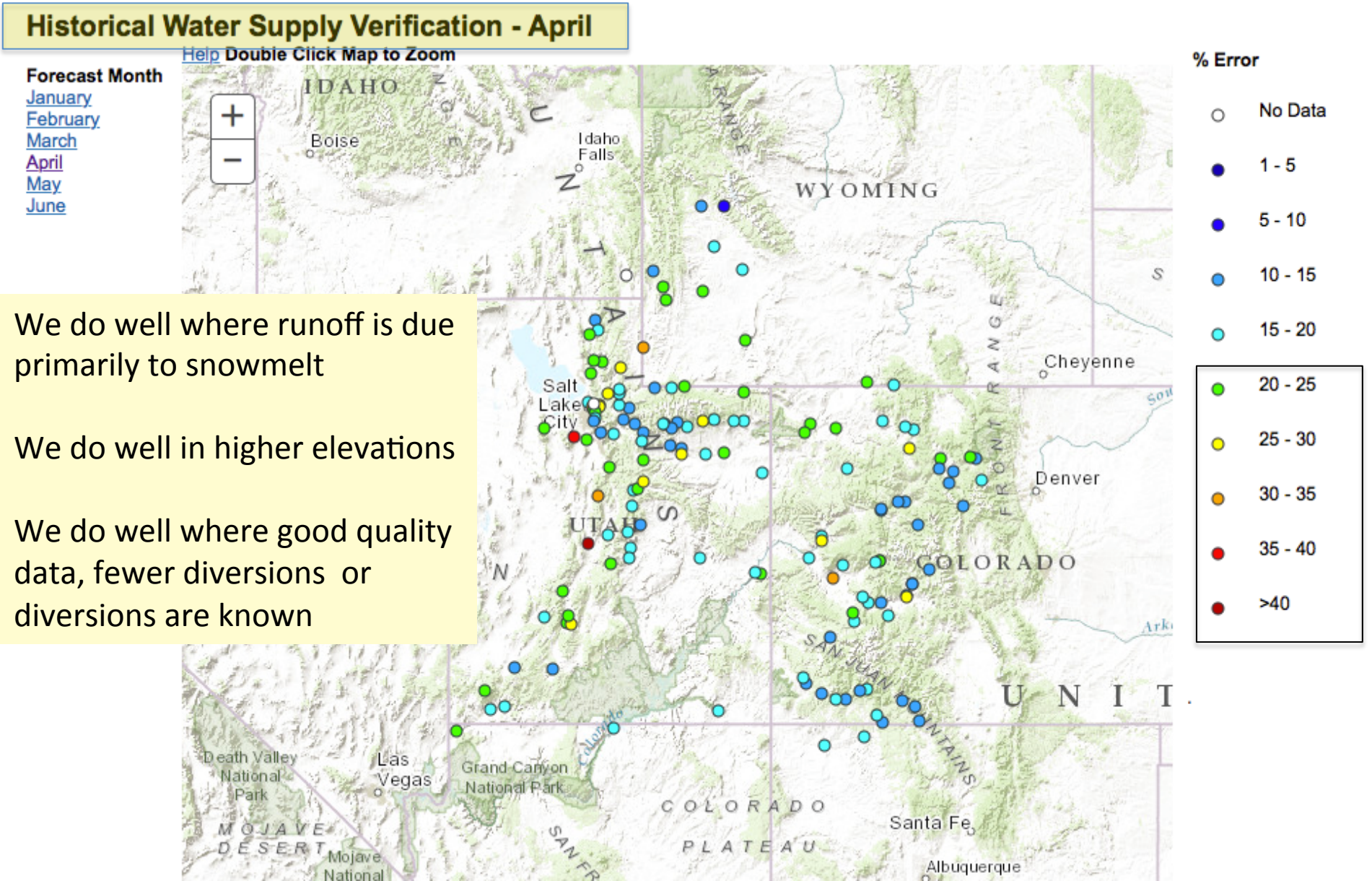
Jan 1 – A primary goal is to capture the resulting runoff in the forecast range

# 2015 Forecast Progression: Lake Powell



# 2015 Water Supply Verification Webinar

## Why Do Verification? It's a path to improvement

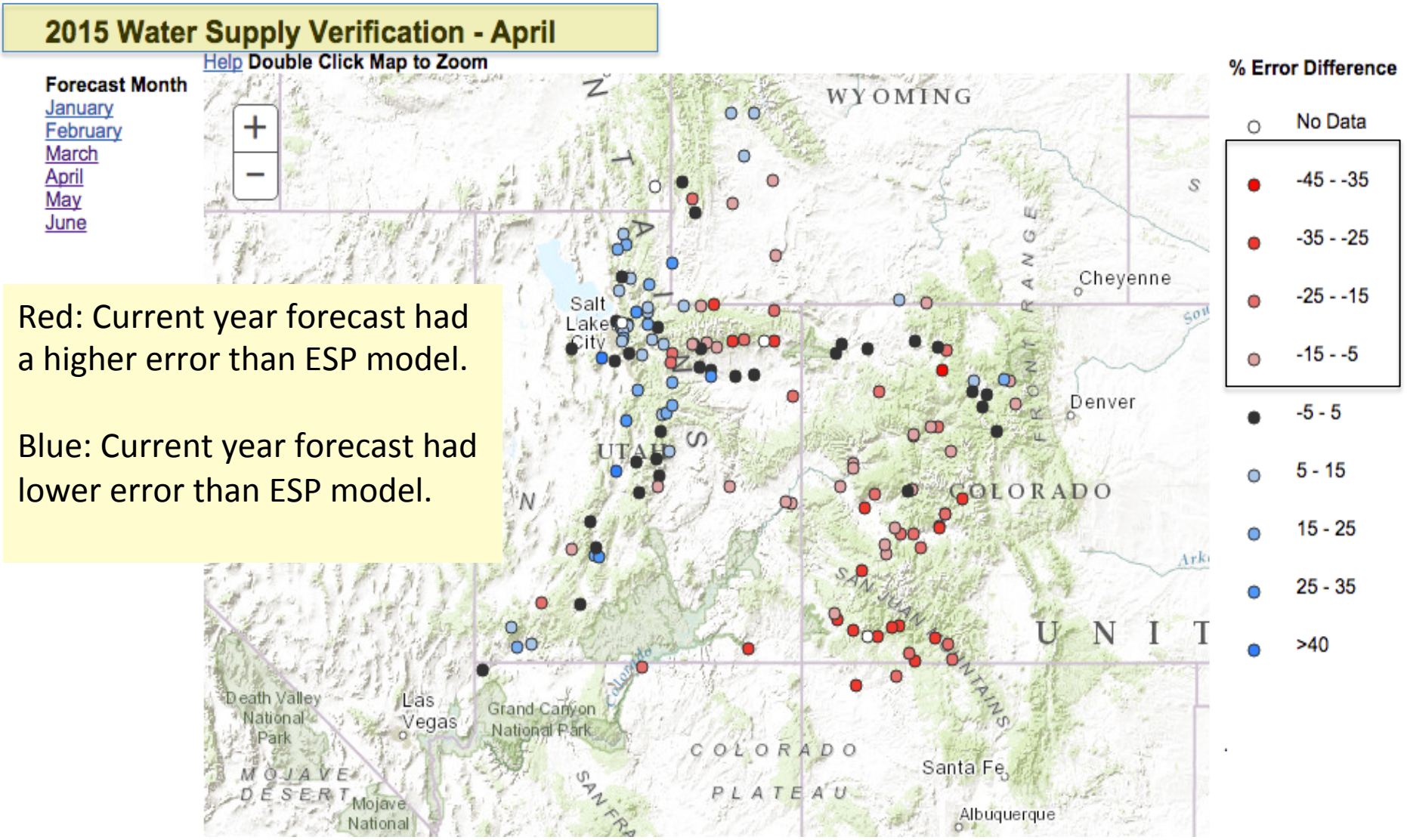



We do well where runoff is due primarily to snowmelt

We do well in higher elevations

We do well where good quality data, fewer diversions or diversions are known

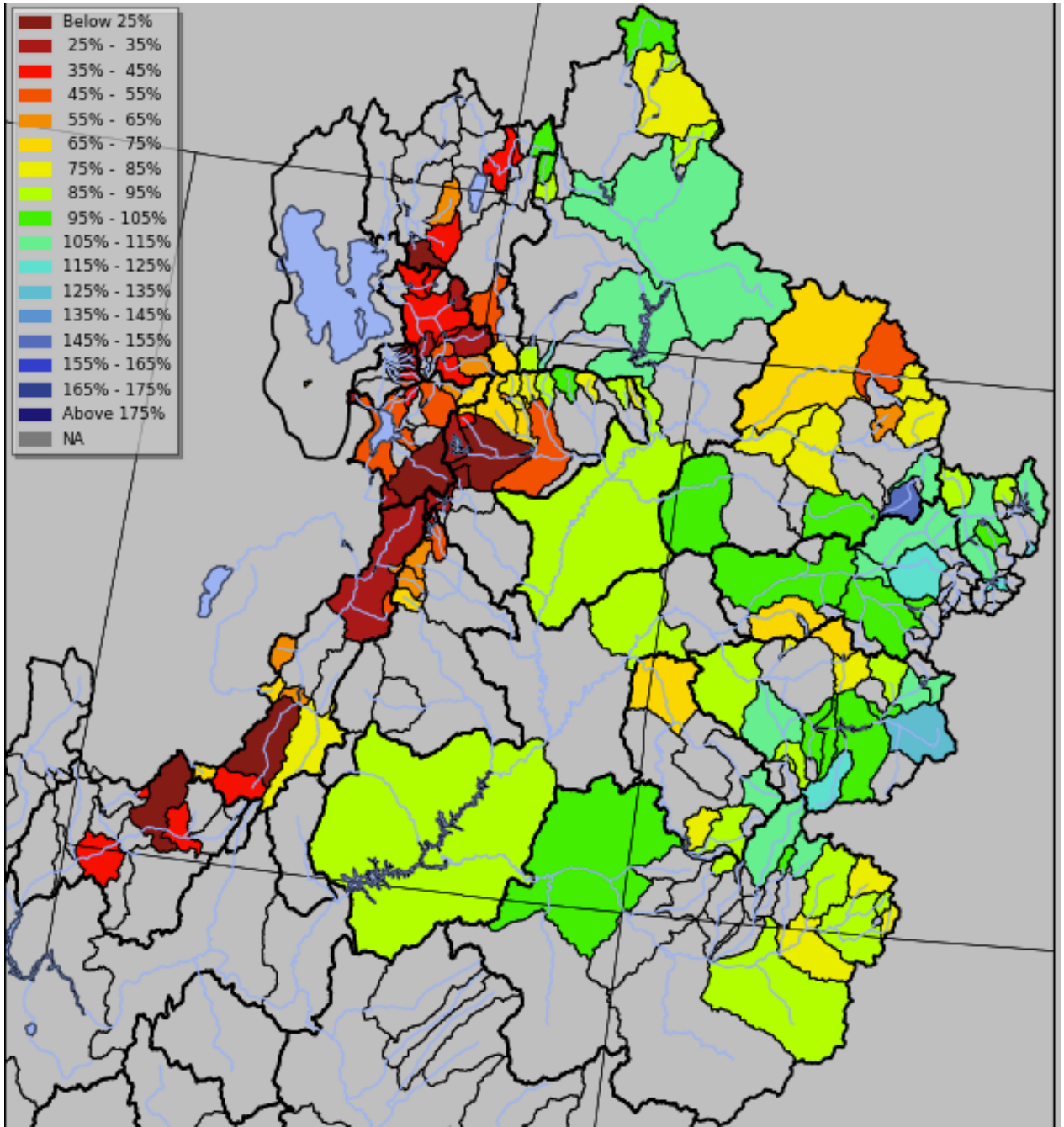
# 2015 Water Supply Verification Webinar




Red: Current year forecast had a higher error than ESP model.

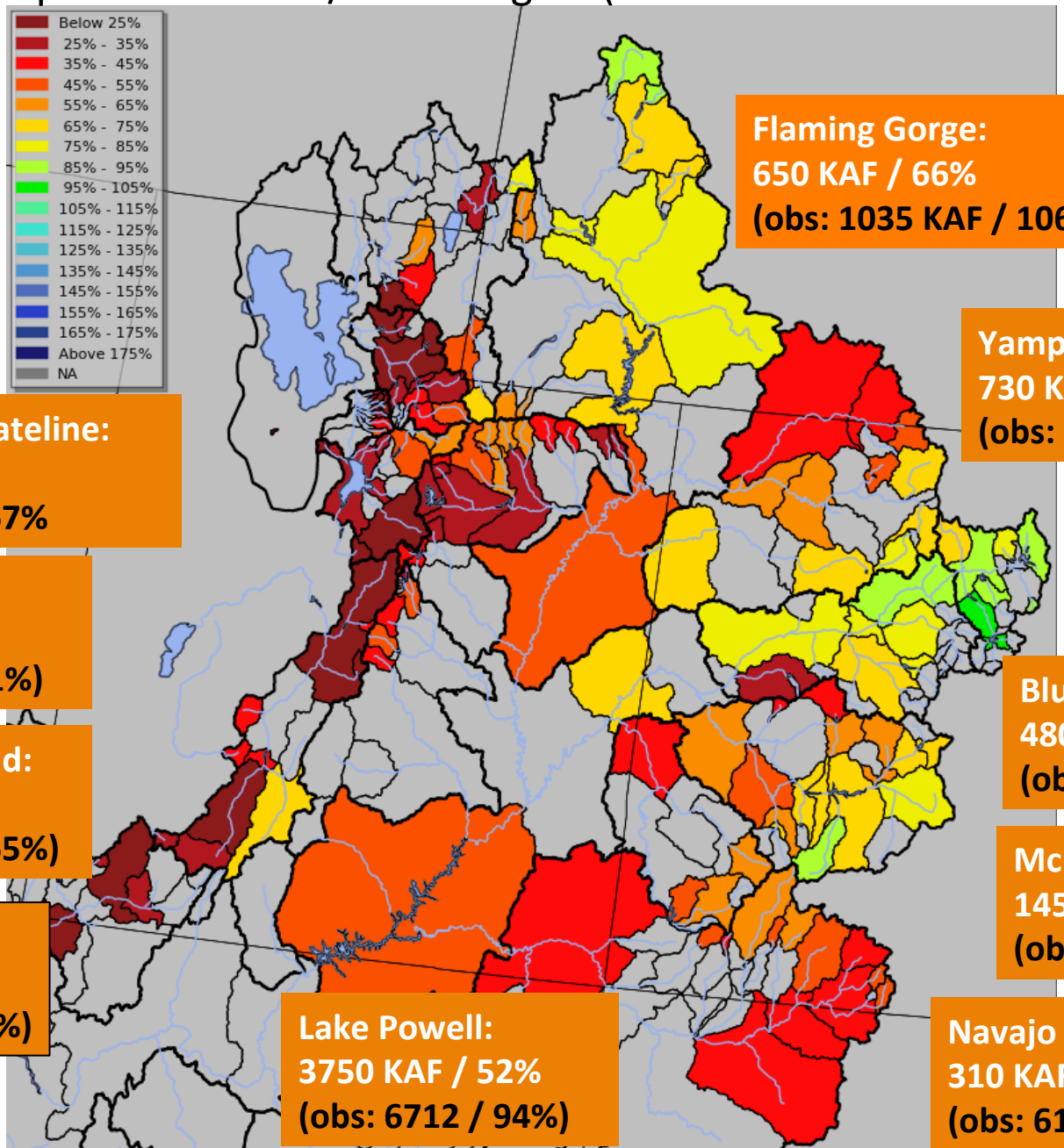
Blue: Current year forecast had lower error than ESP model.

# Apr-Jul 2015 observed Volumes (% of average)



# April 1st Water Supply Forecasts

## Apr-Jul Volumes / % Average – (50% exceedance forecasts)




**Flaming Gorge:**
**650 KAF / 66%**
**(obs: 1035 KAF / 106%)**

**Yampa-Deerlodge:**
**730 KAF / 59%**
**(obs: 1042 KAF / 86%)**

**Bear-UT/WY Stateline:**
**80 KAF / 71%**
**(obs: 75 KAF / 67%**

**Colorado-Cameo:**
**1840 KAF / 78%**
**(obs: 2346 / 99%)**

**Weber-Oakley:**
**62 KAF / 53%**
**(obs: 72 KAF 61%)**

**Blue Mesa:**
**480 KAF / 71%**
**(obs: 708 KAF / 105%)**

**Provo-Woodland:**
**62 KAF / 62%**
**(obs: 65 KAF / 65%)**

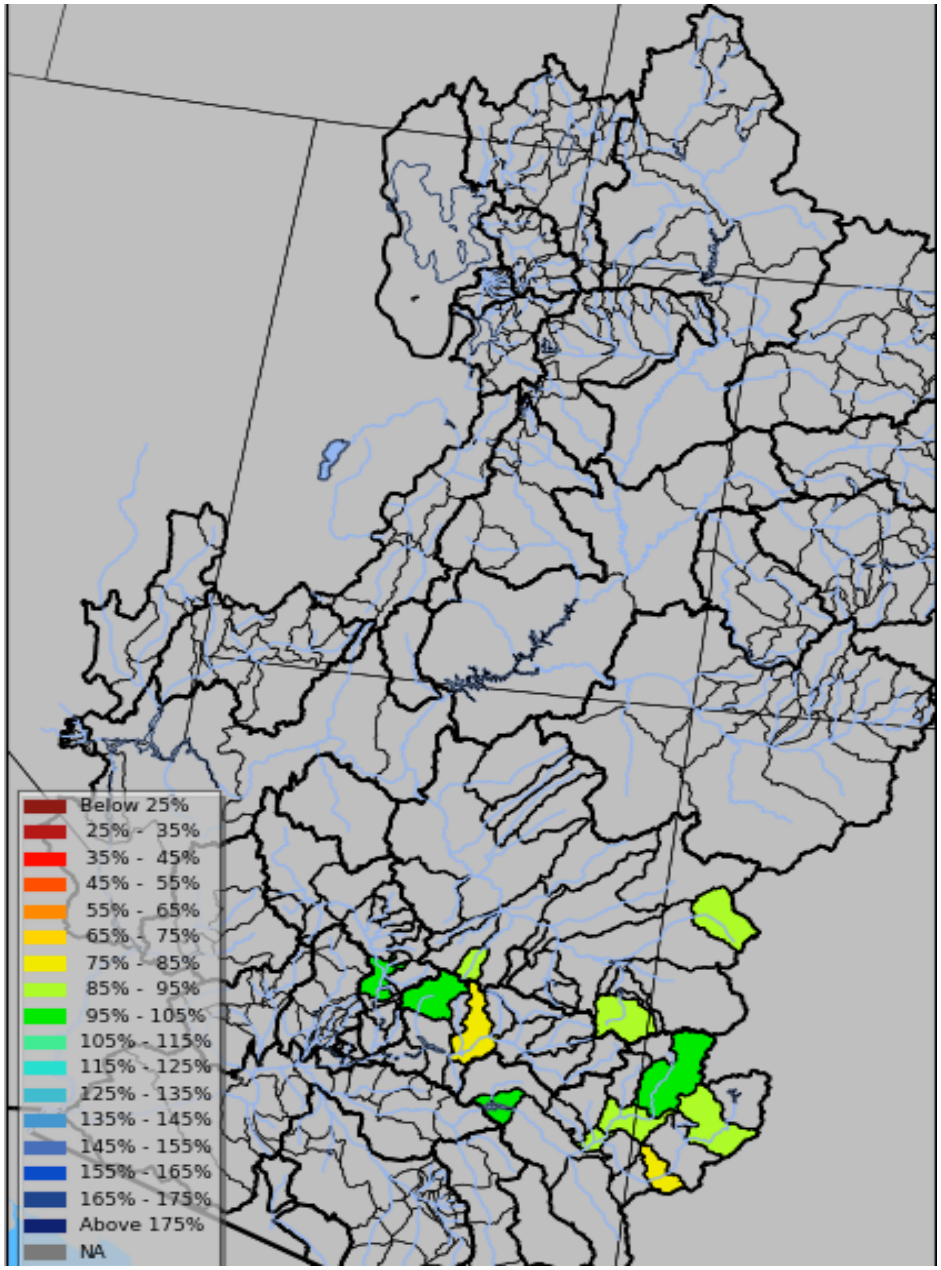
**McPhee Res:**
**145 KAF / 49%**
**(obs: 226 / 77%)**

**Virgin-Virgin:**
**20 KAF / 34%**
**(obs 21 KAF/36%)**

**Lake Powell:**
**3750 KAF / 52%**
**(obs: 6712 / 94%)**

**Navajo Res:**
**310 KAF / 42%**
**(obs: 619 / 84%)**

# January 1st Water Supply Forecasts
## Jan-May Volumes / % Median – (50% exceedance forecasts)




**Verde-Horseshoe:**
**150 KAF / 96%**
**Obs: 160 KAF / 102 %**

**Salt - Roosevelt:**
**250 KAF / 81%**
**Ob: 145 KAF / 47%**

**Gila-Gila:**
**48 KAF / 86%Obs:**
**obs: 62 KAF / 110 %**

# Lets Look At How We Got Here:

## Winter vs. Spring - A Tale of Two Extremes

Salt Lake City: Yours Truly on the Links
Early February 2015

Durango: Heavy Rain and Runoff Animas River
Early June 2015

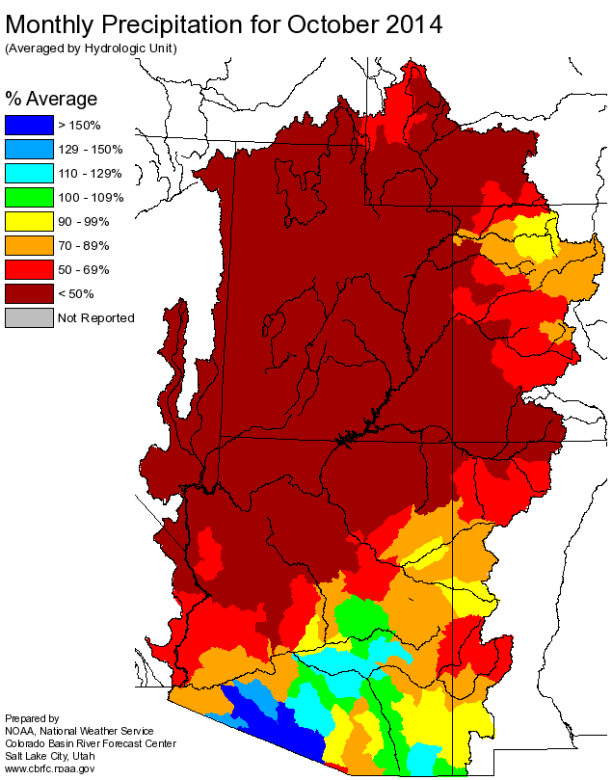
Shaun Stanley / Durango Herald

Winter: Record Warmth and Dry

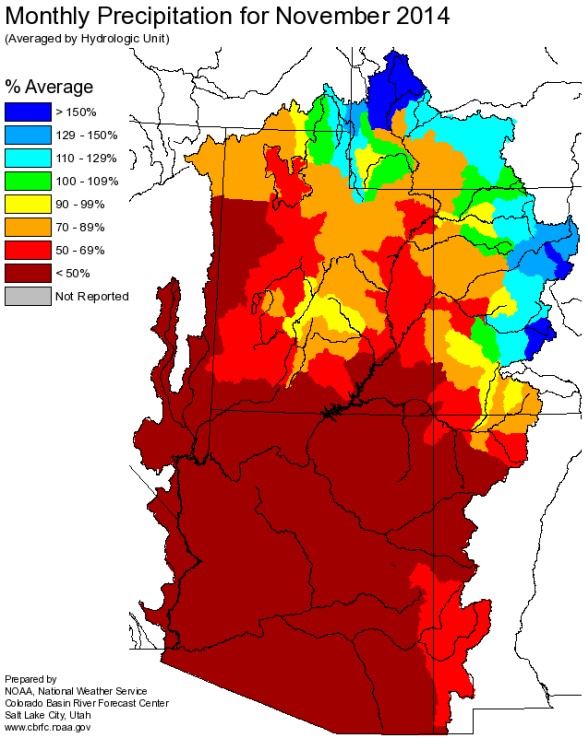
Spring: Record wet and cool

# **Fall Weather:** Heading into the water supply forecast season

## December Was Important

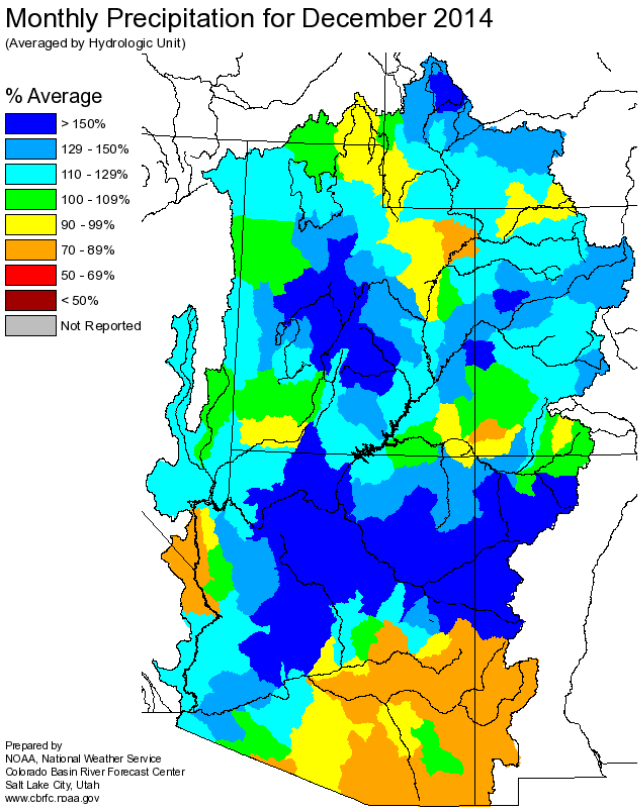



Didn't really see October Snow

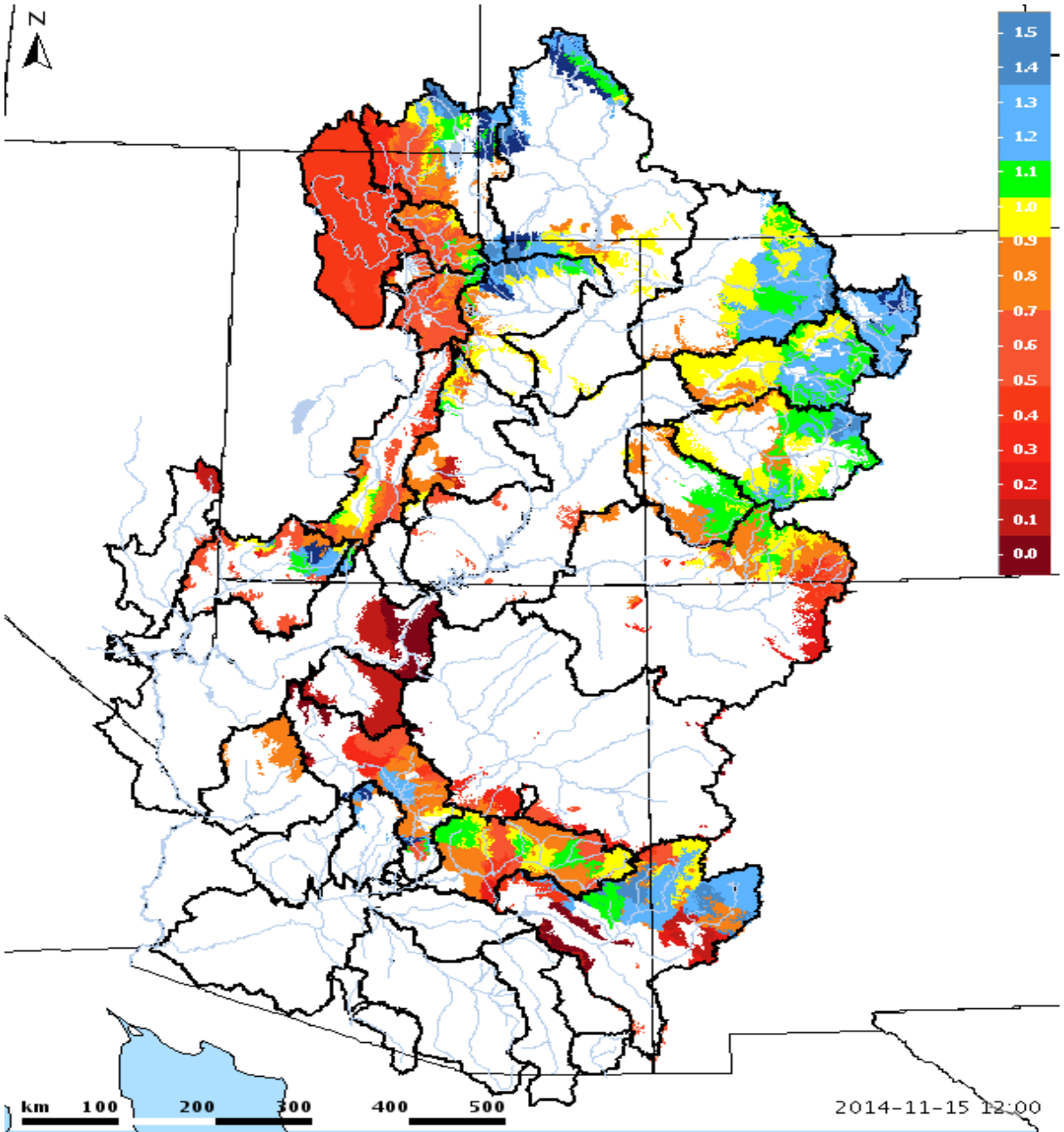


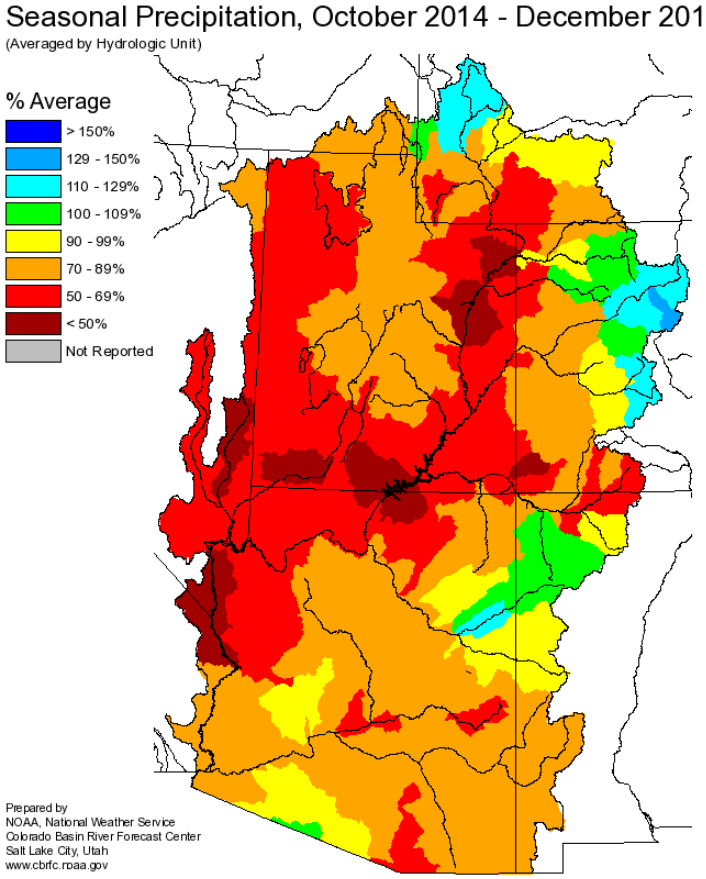

Still very dry Great & Duchesne Basins

Finally a Wet Month
Mild Temperatures



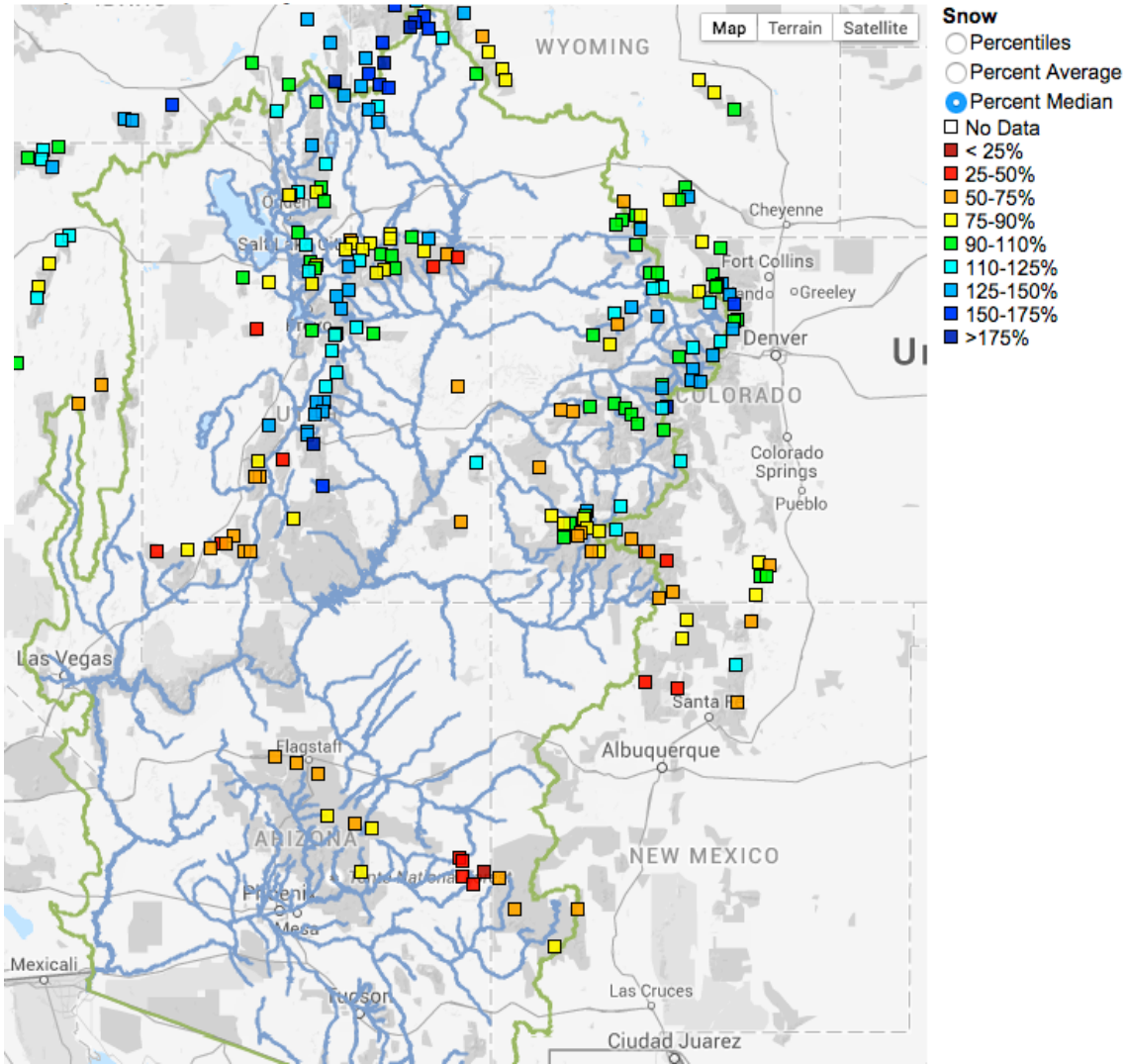
# Soil Moisture – Entering The 2014/2015 Winter





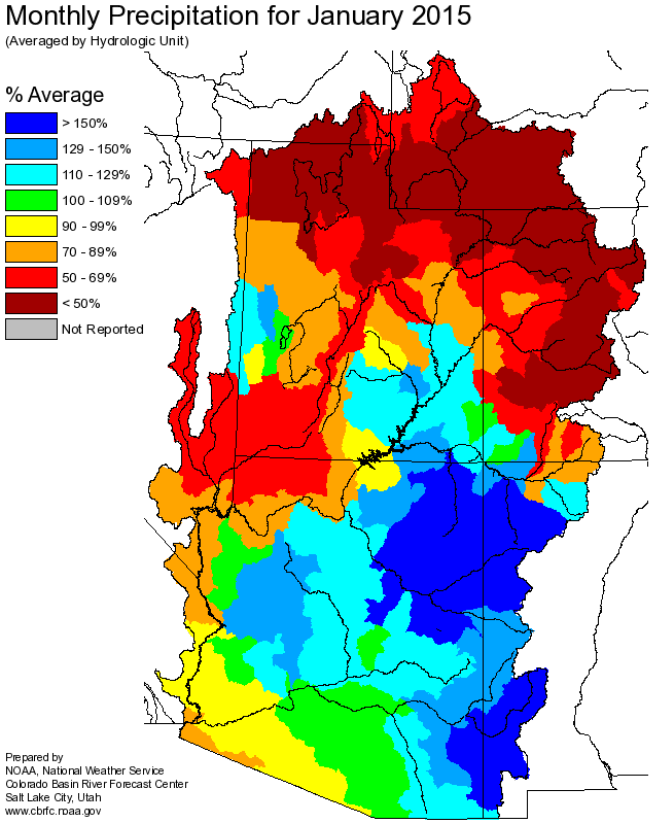

**Water Year Precipitation: October - December**

## Early January SNOTEL Snow Water Equivalent

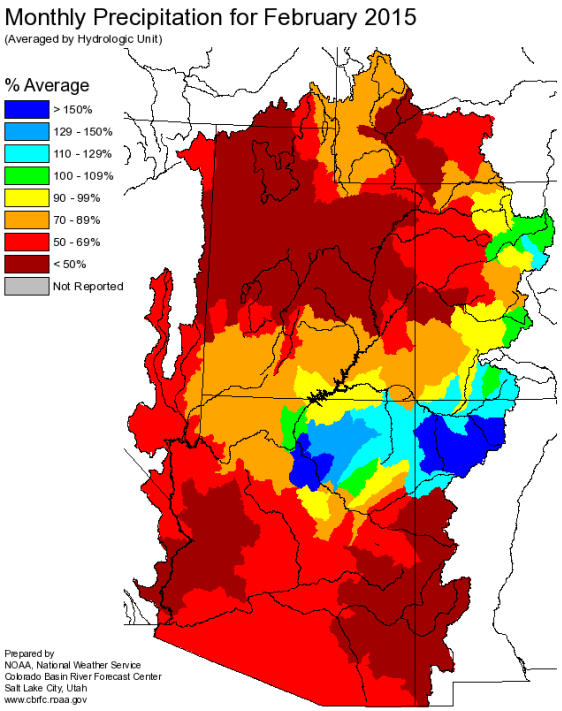


# **Winter:** Snow Accumulation Season

## **Dominated by Dry / Warm Pattern**

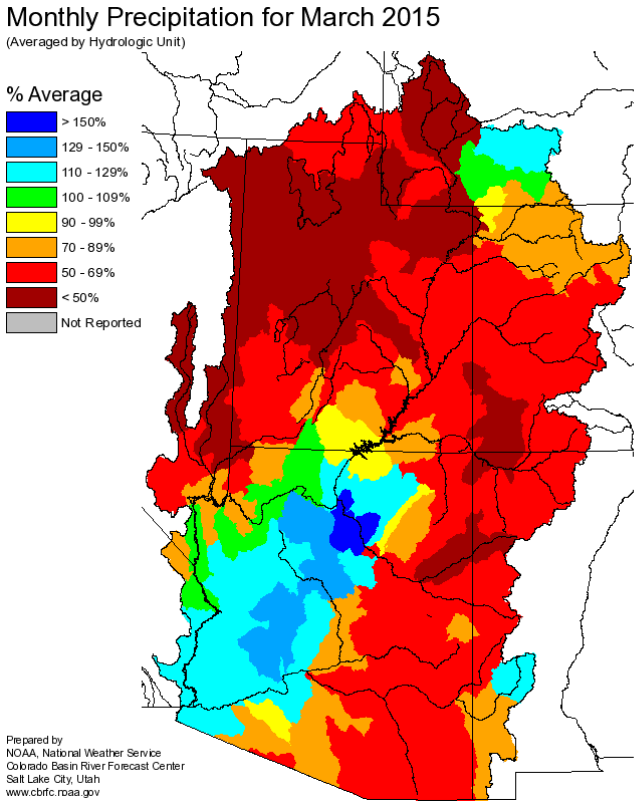



Wet in parts of Lower Colorado River Basin

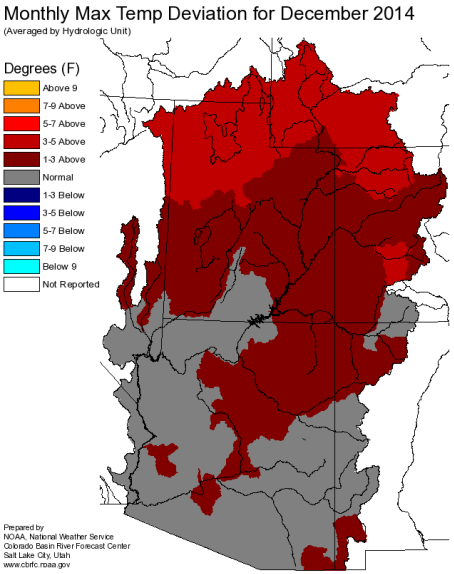


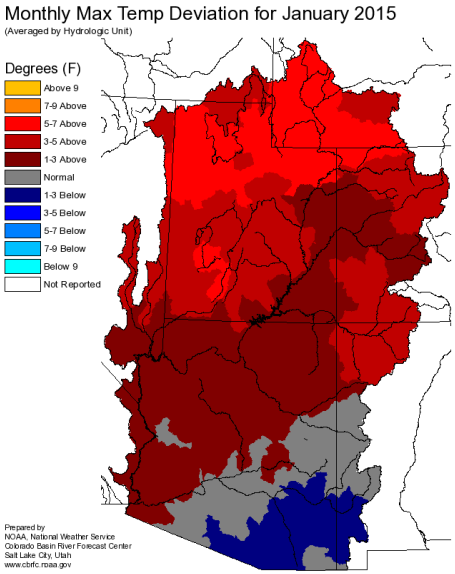

Dry and very mild – San Juan the Exception

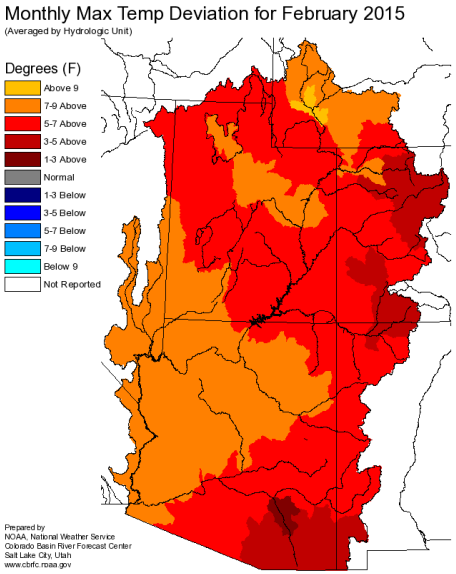
Dry and warm

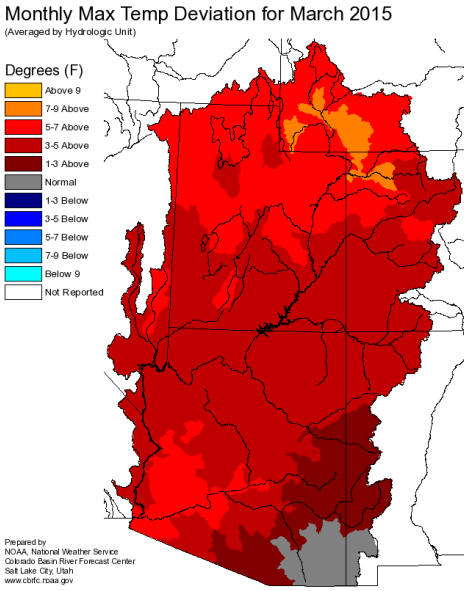


# Winter Temperatures - Record Heat



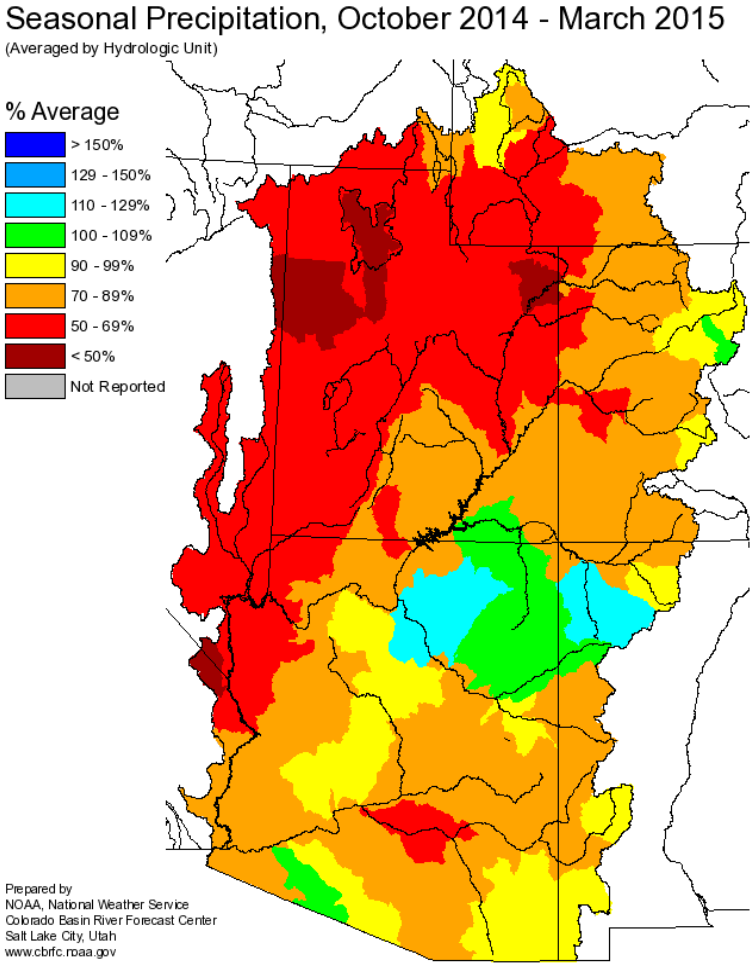




Impacts:

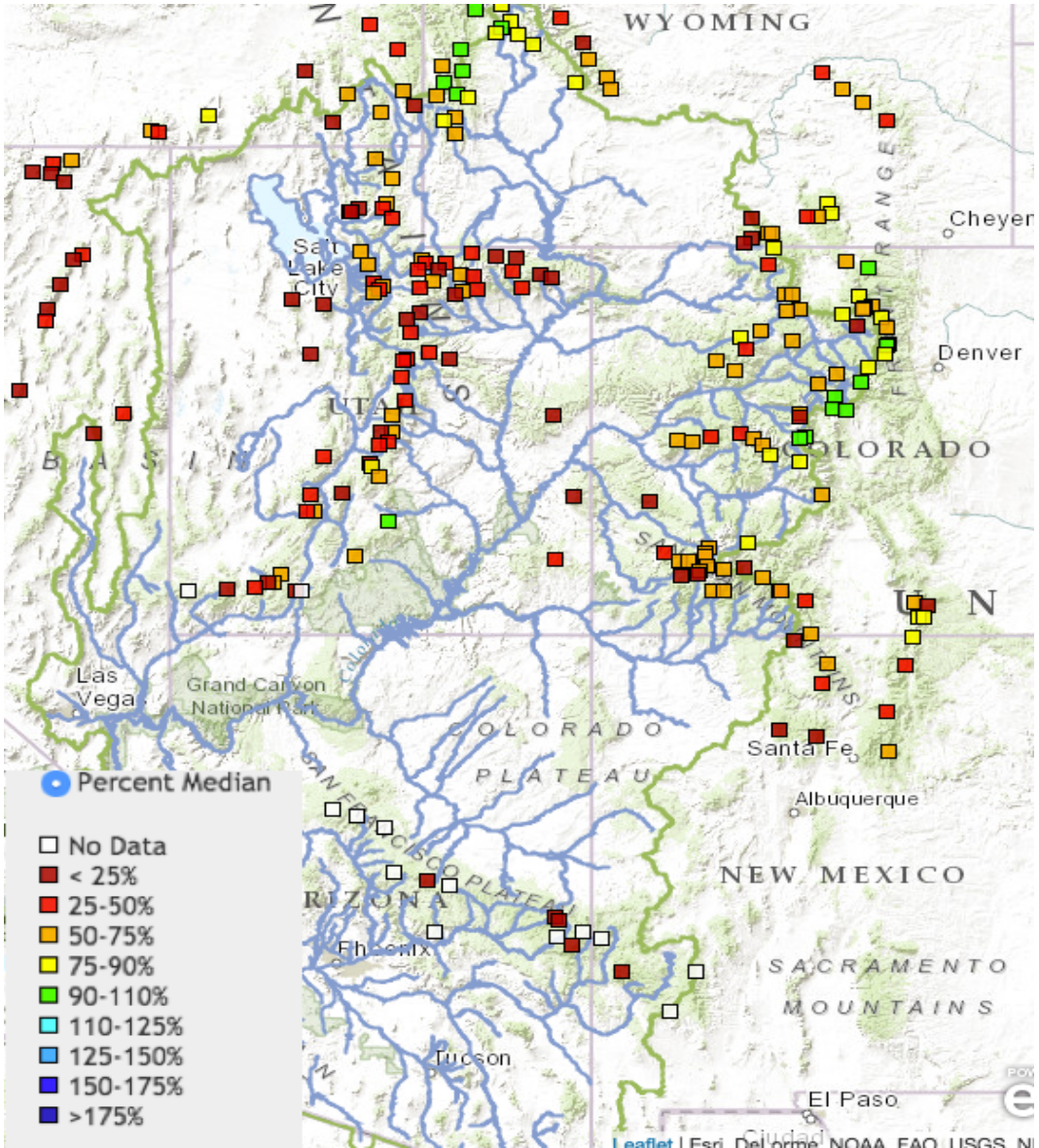
Highly variable snowpack - (Rain falling during typical snow periods)
Winter snow melt – especially lower / middle elevations
Early depletion of the snowpack – lead to record low SWE in early April / May

# A Spring Snowpack Left in Tatters

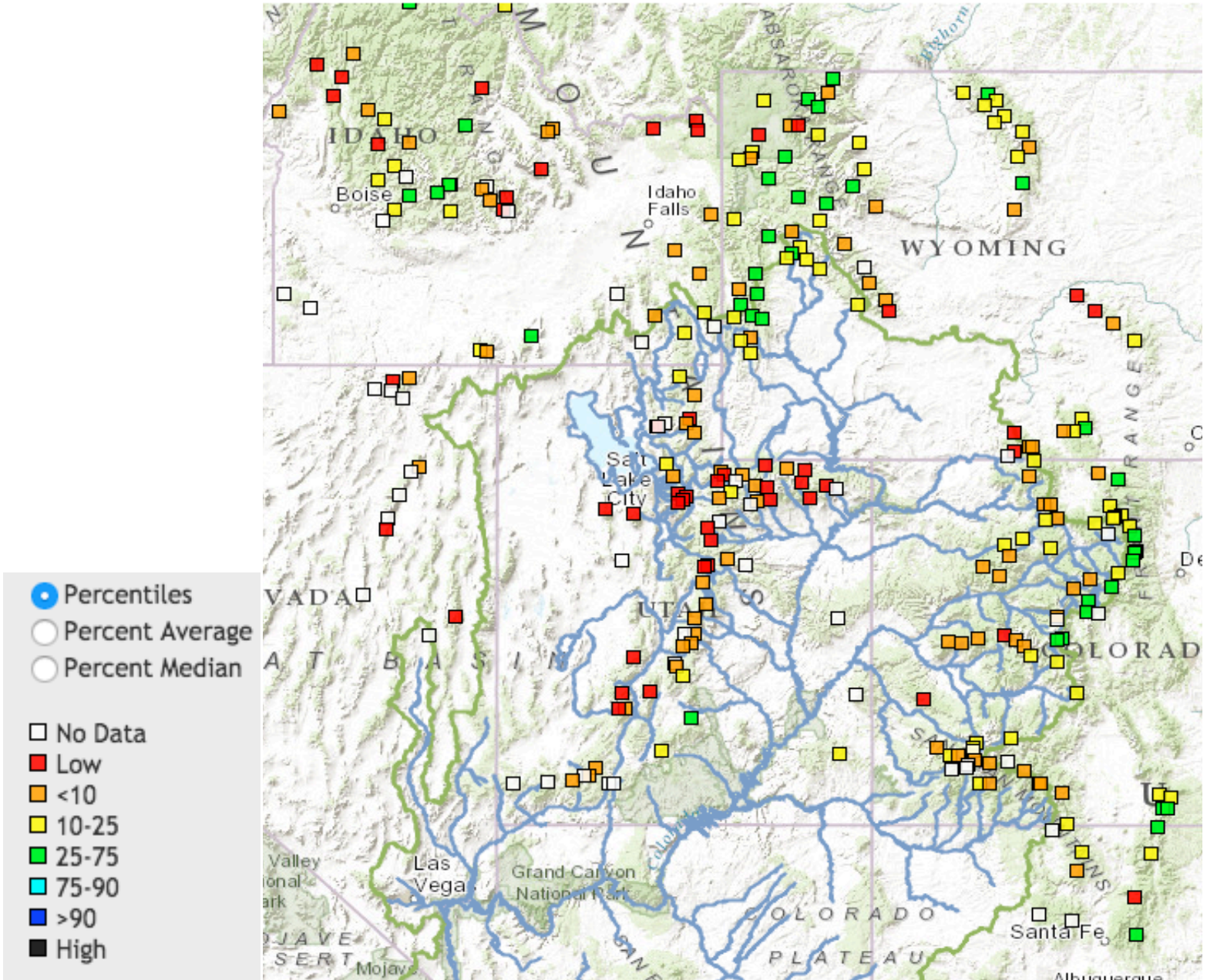



**Water Year Precipitation:**
**October 2014 – March 2015**

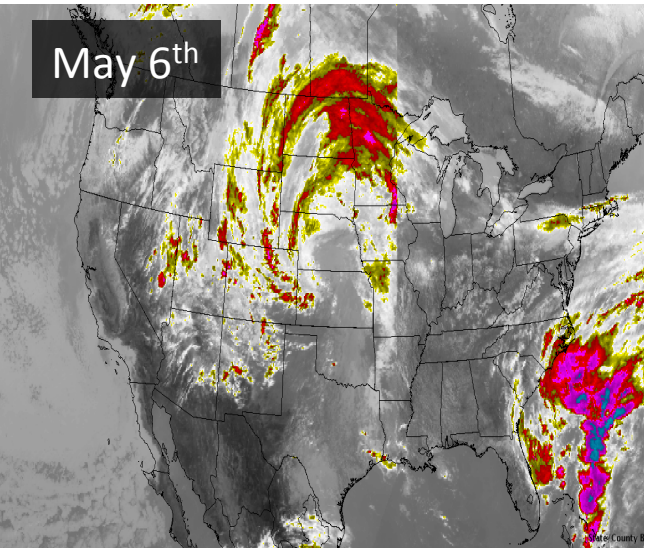
## Early April Snow Water Equivalent

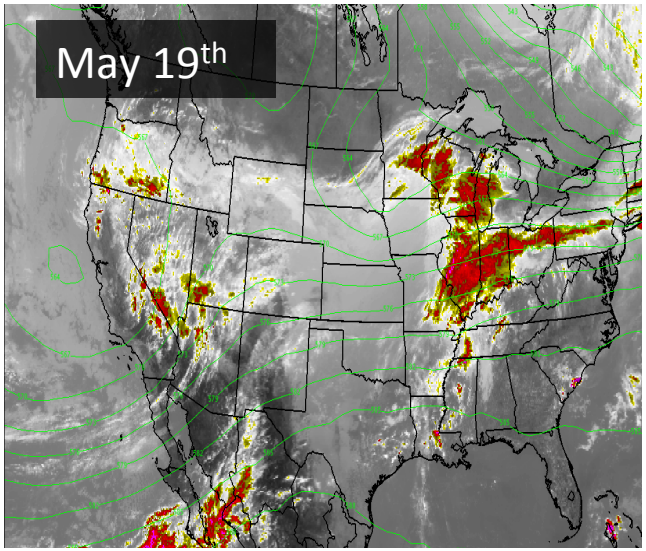


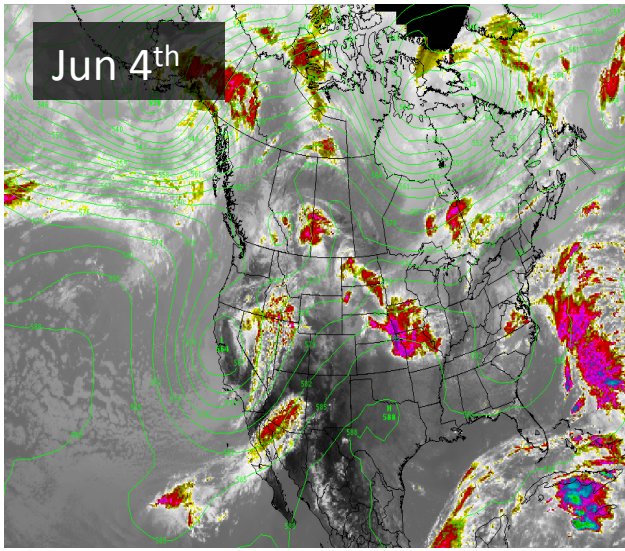
# April 1st Snowpack Ranking: Red = Lowest on record / Orange= 2nd or 3rd lowest



# A big change in the weather

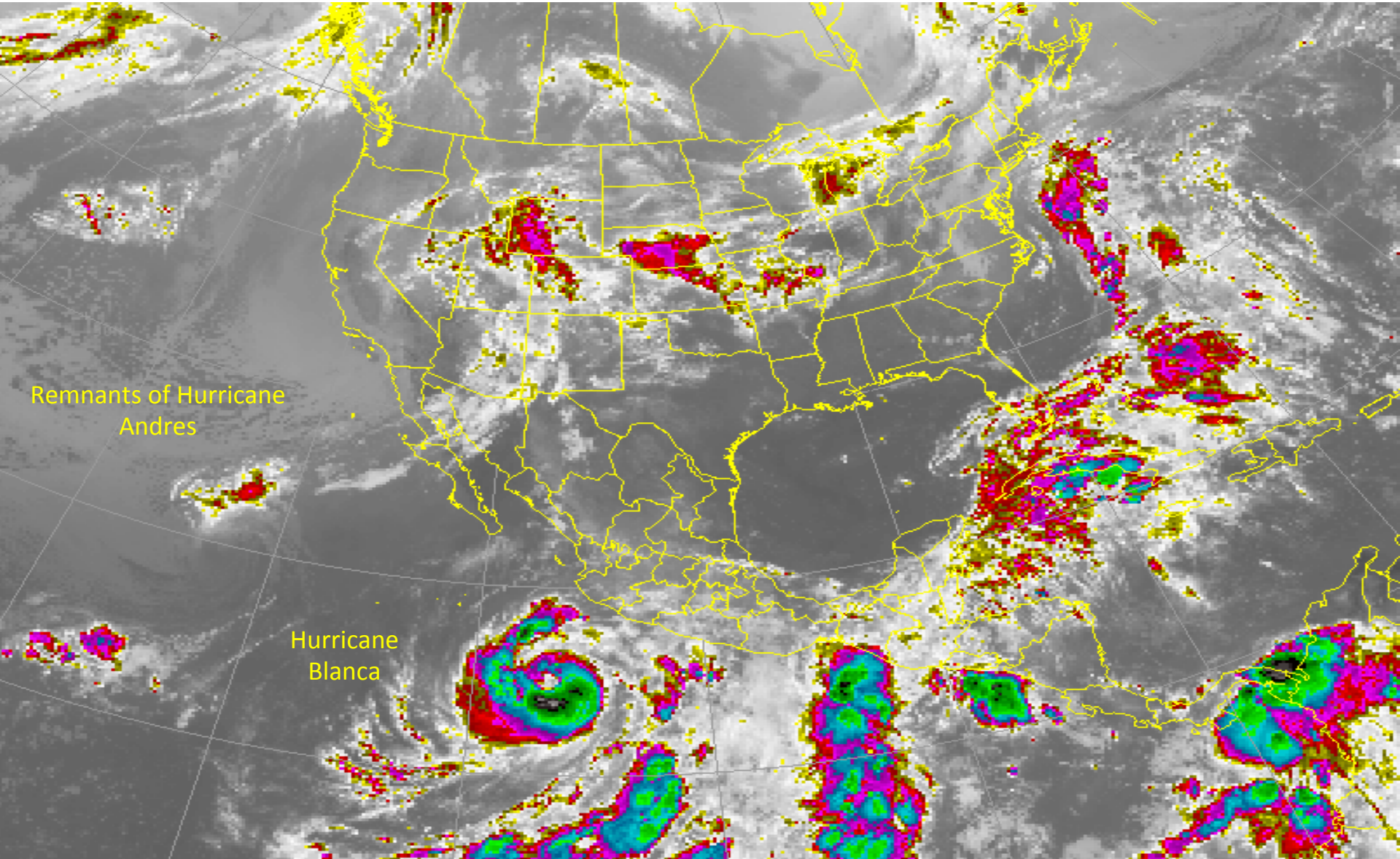


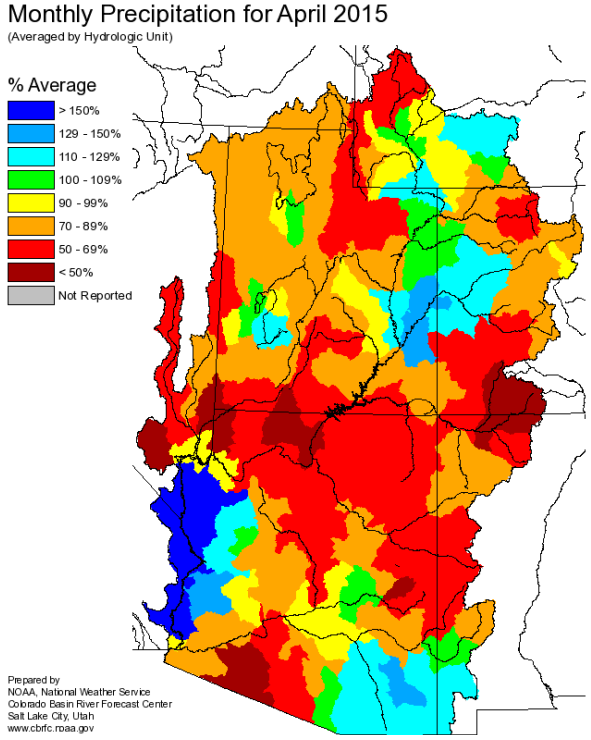



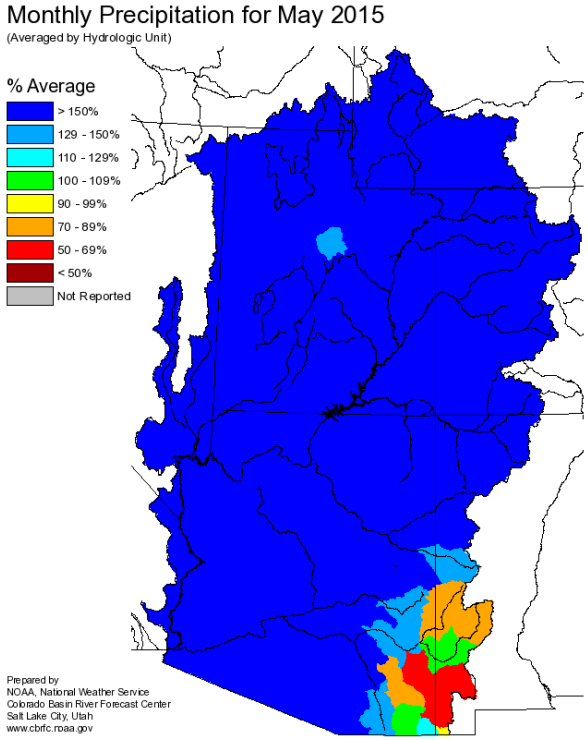



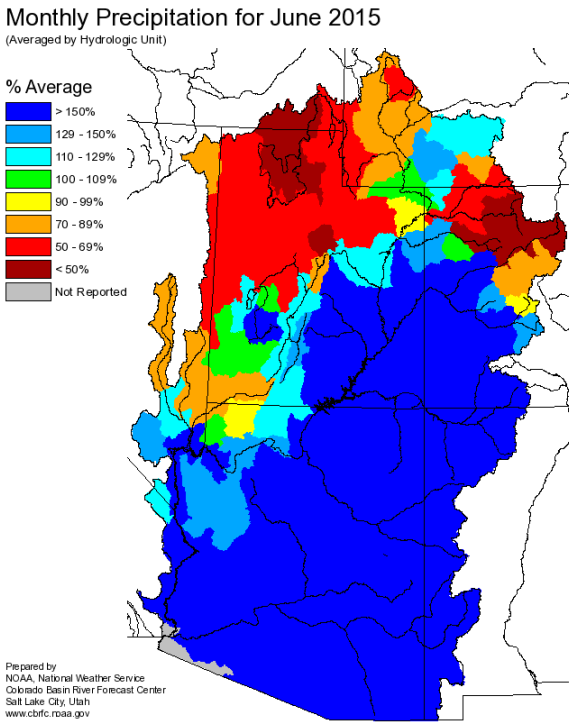

- Pattern started to change in mid April & carried into June.
- Frequent moist storms systems (tropical moisture source).
- Much below average temperatures May into early June.
- Moisture tropical in nature with significant precipitation.

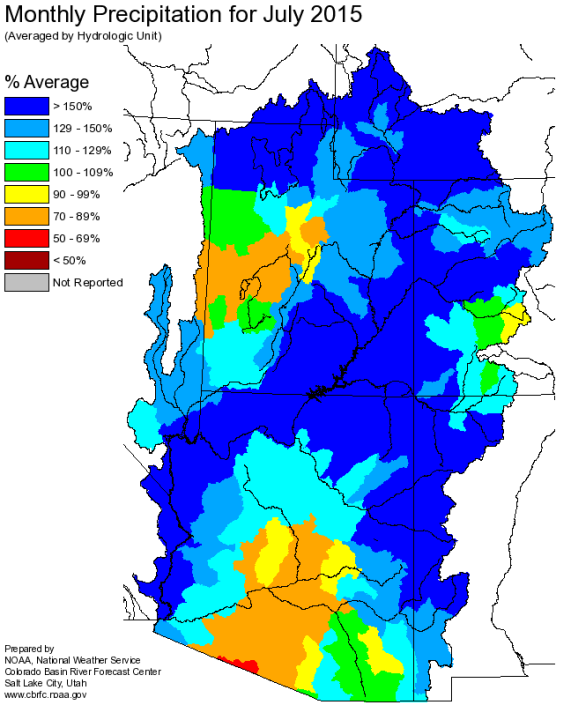
# Late May/Early June 2015
# Impacted by Two Pacific Hurricanes






**May:**

Widespread heavy rain

Some areas 200 to more than 400 percent of average

San Juan 6-11 inches of precipitation

**June:**

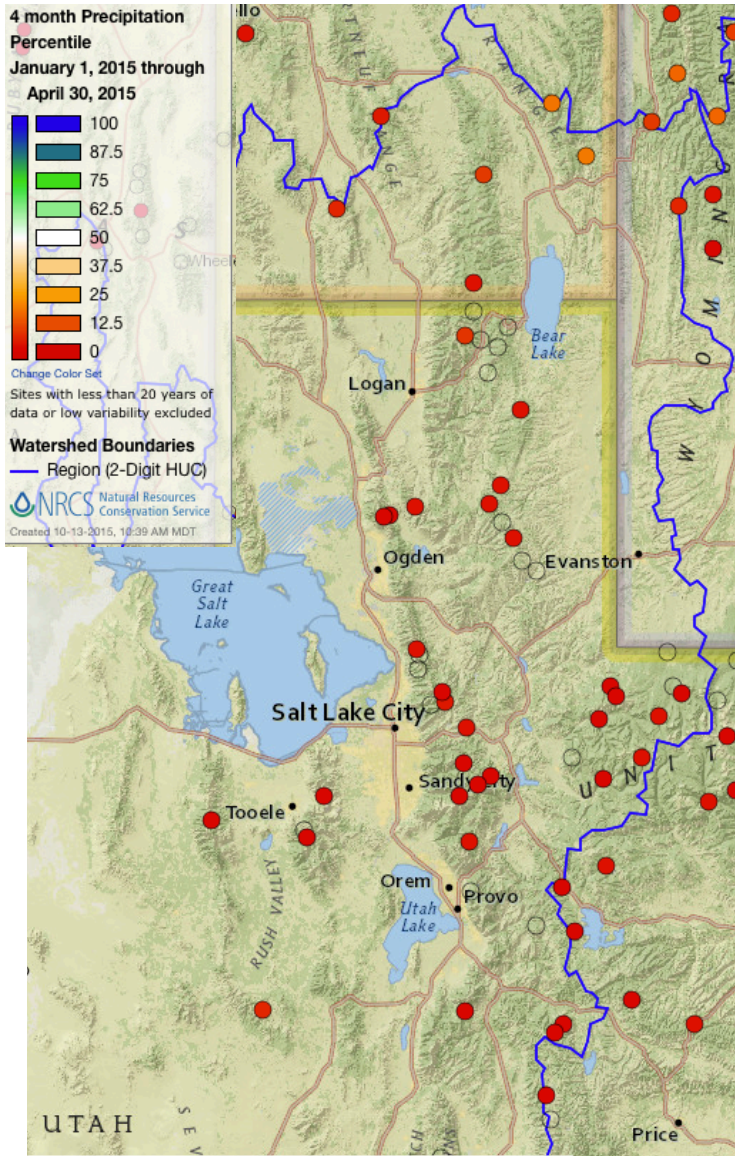
Significant precipitation continues in the Gunnison, San Juan, and Lower Colorado River Basin.

**July:**

Above average precipitation widespread

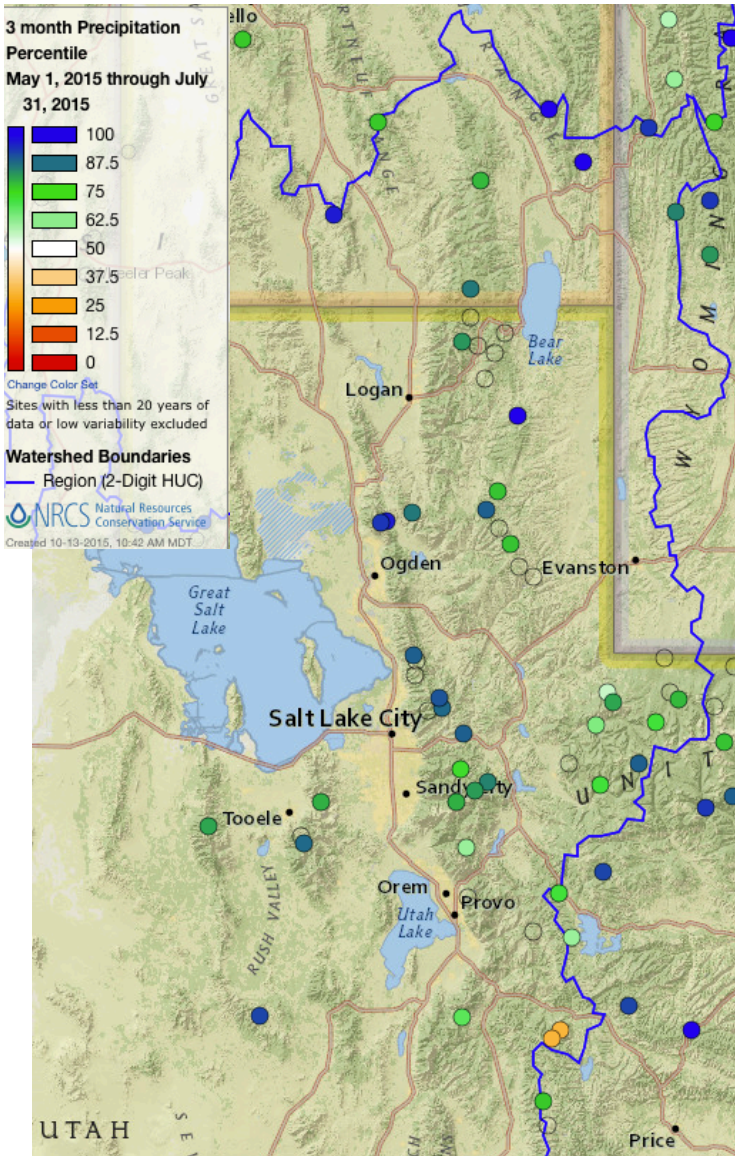
# Great Basin: SNOTEL Precipitation Rankings

## January through April 2015




Driest 1-3 on record

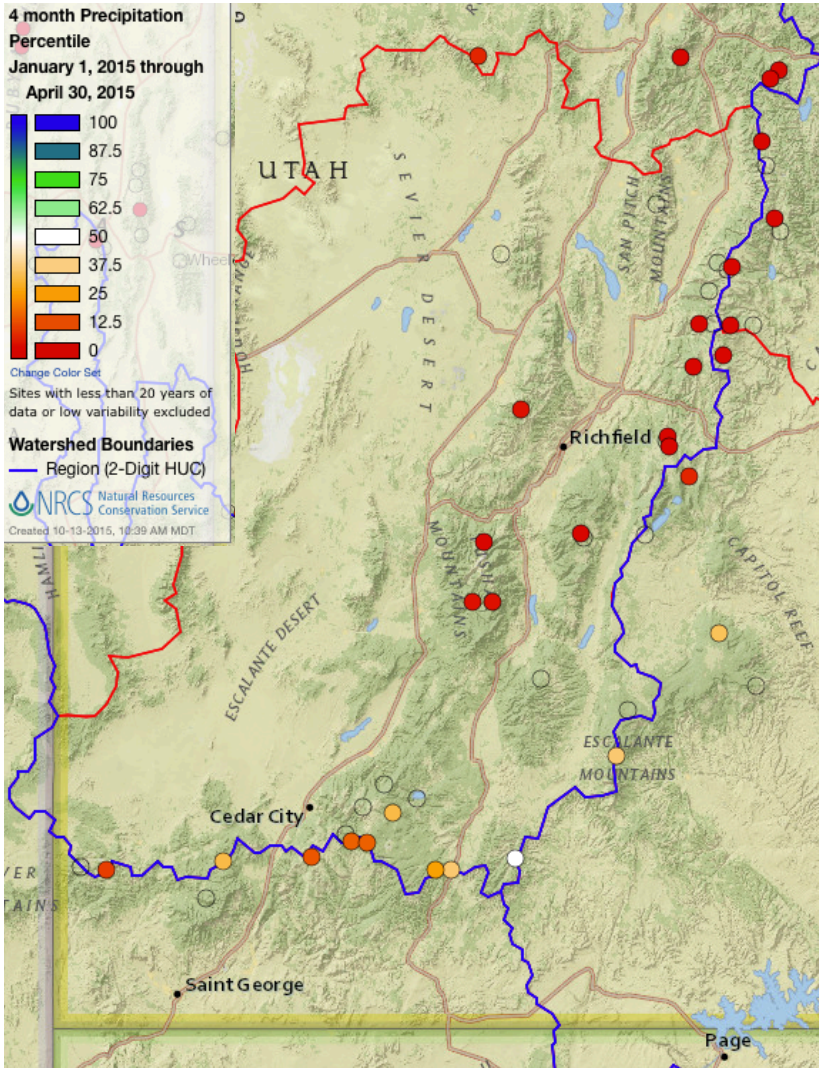
## May through July 2015




Several sites top 10 wettest

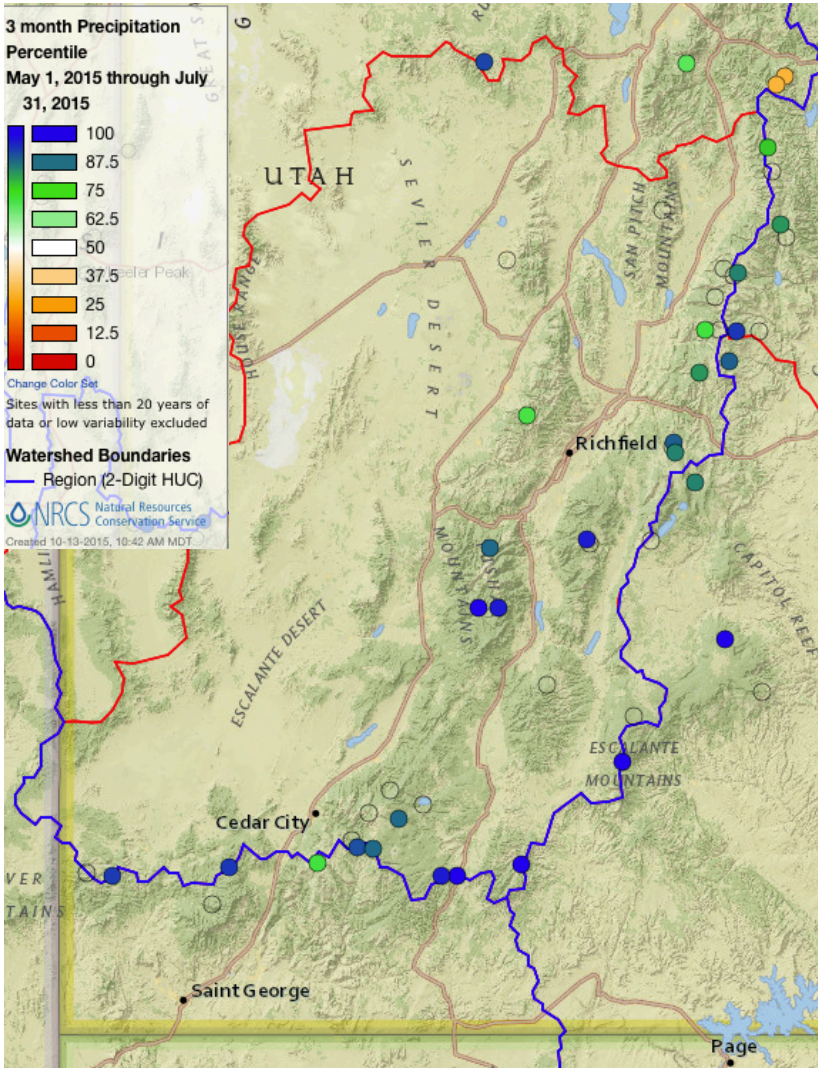
# Southern Utah – Sevier and Virgin River Basins: SNOTEL Precipitation Rankings

## January through April 2015




Among the direst in the Sevier

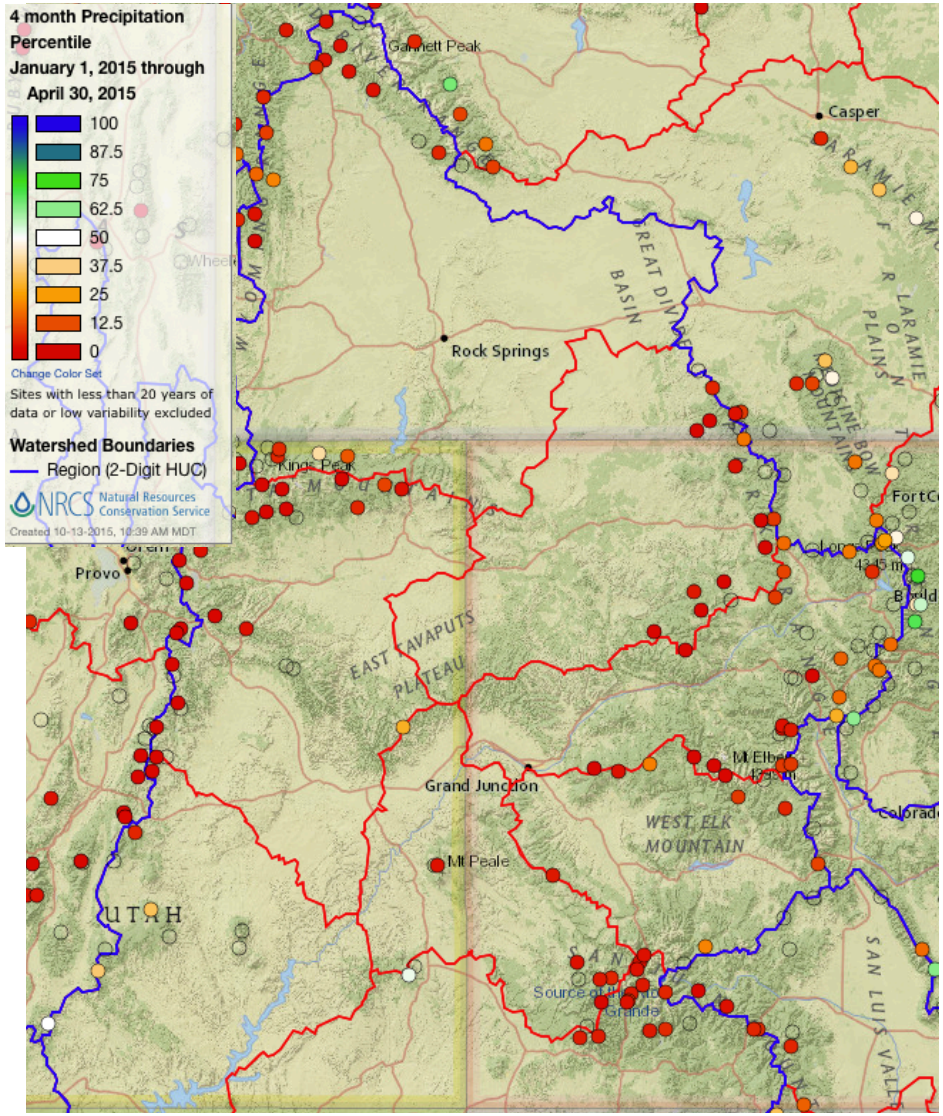
## May through July 2015




Among the wettest in the Sevier

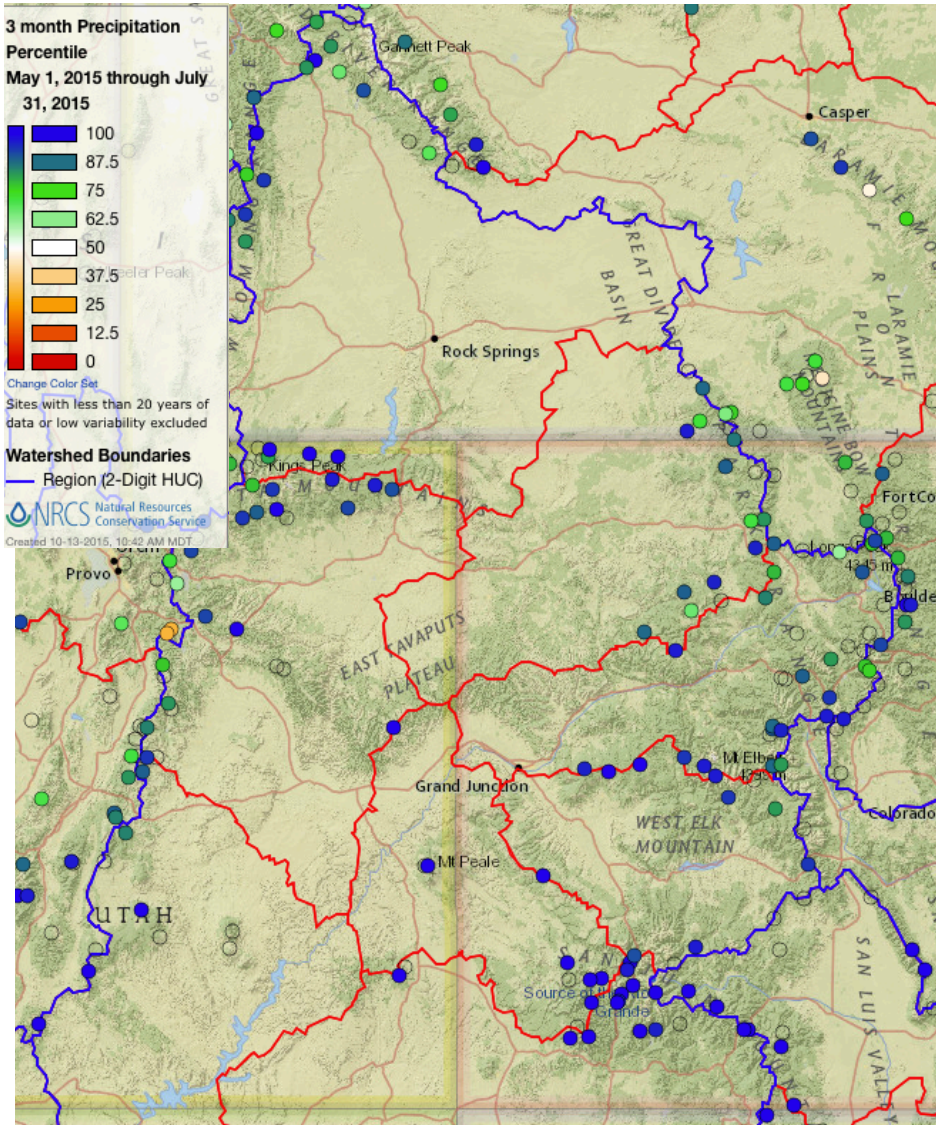
# Colorado River above Lake Powell : SNOTEL Precipitation Rankings

## January through April 2015




Many sites driest 1-2 on record

## May through July 2015



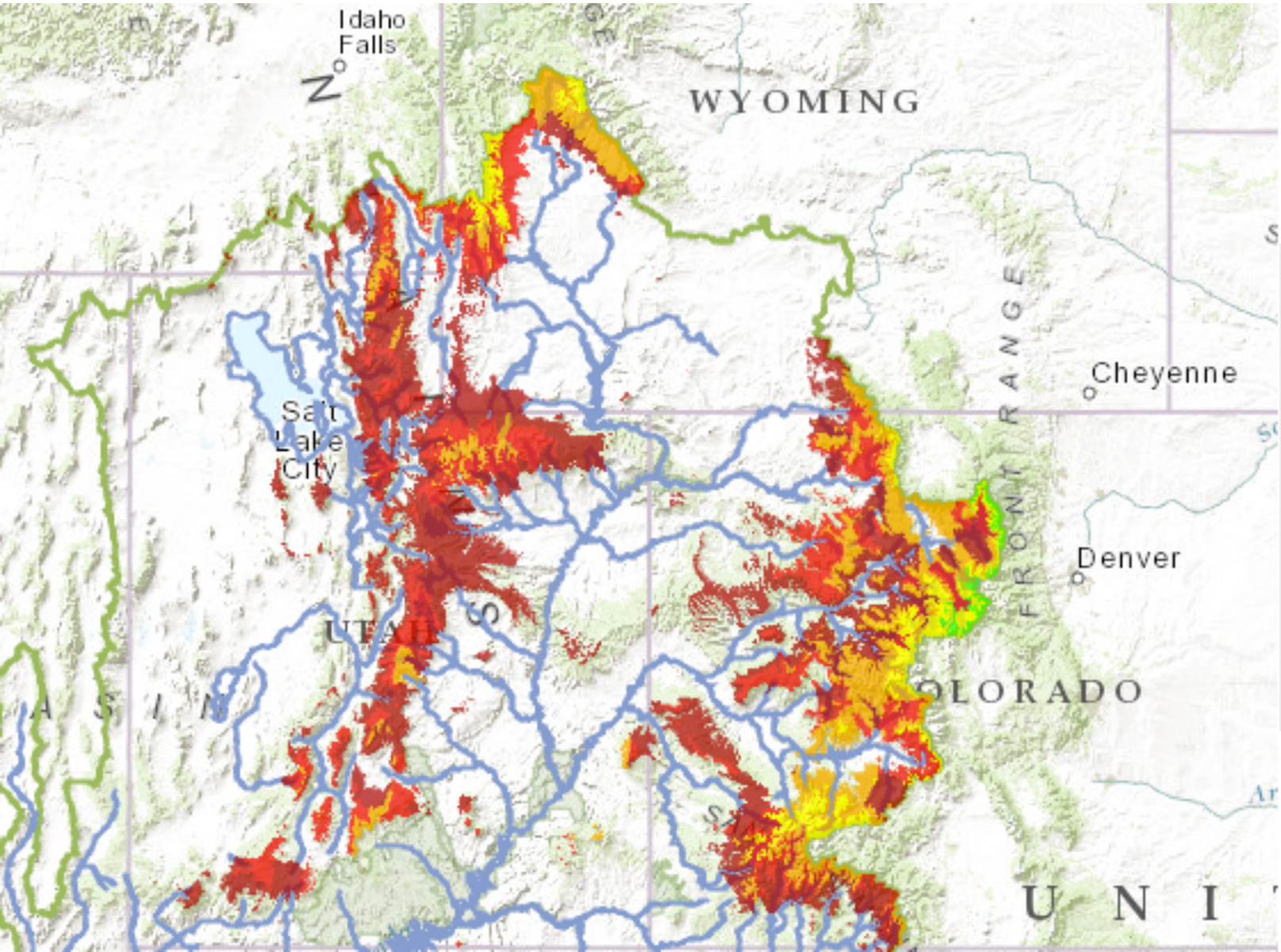

Many sites wettest 1-3 on record

How did the very wet spring impact:

- Late season high elevation snowpack
- Observed streamflow volumes and peak
- Forecasts and forecast accuracy

The progression of the CBRFC hydrologic model snowpack April to June 2015

April 1st 2015 Snow Water Equivalent (% average)



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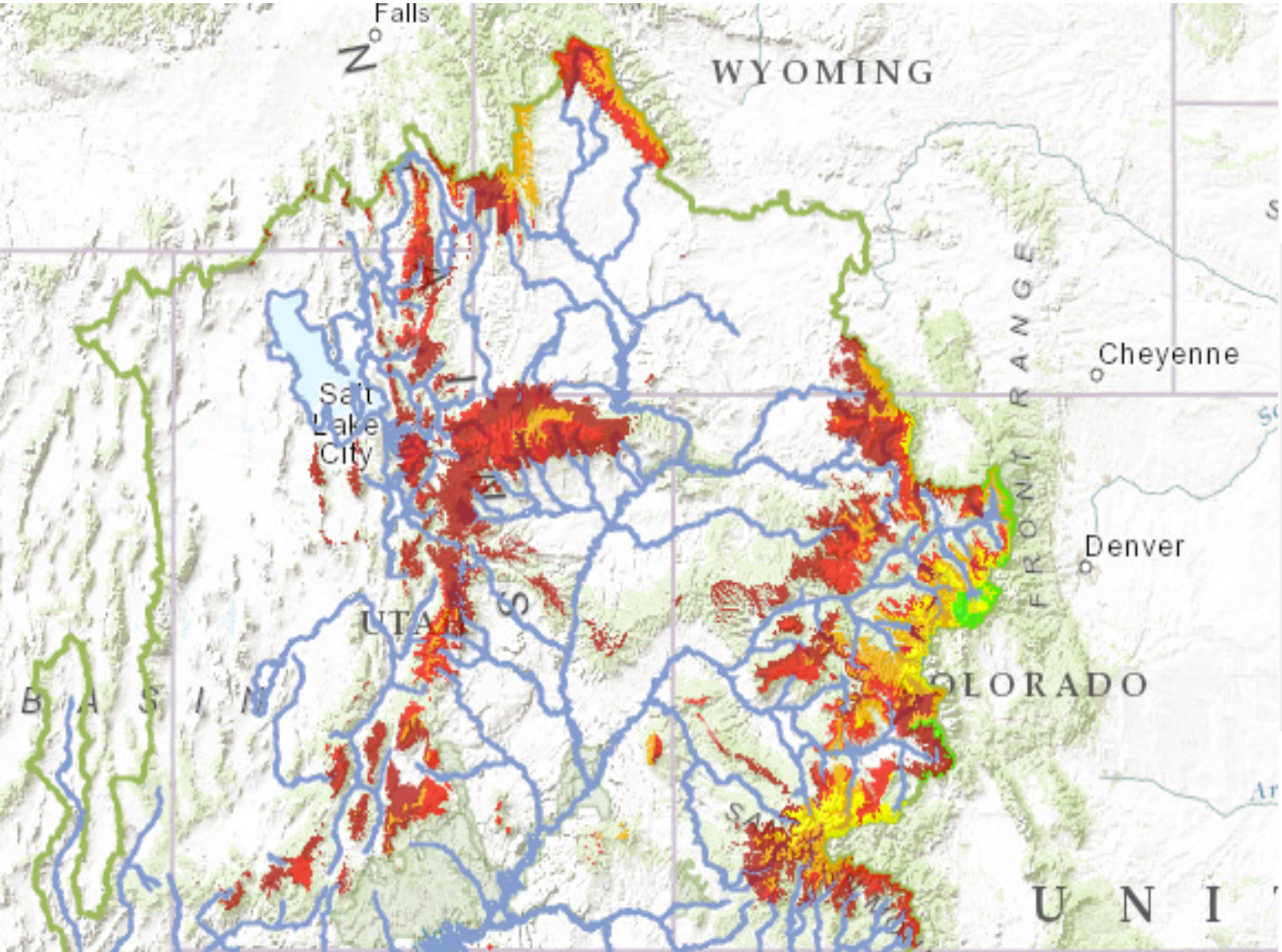
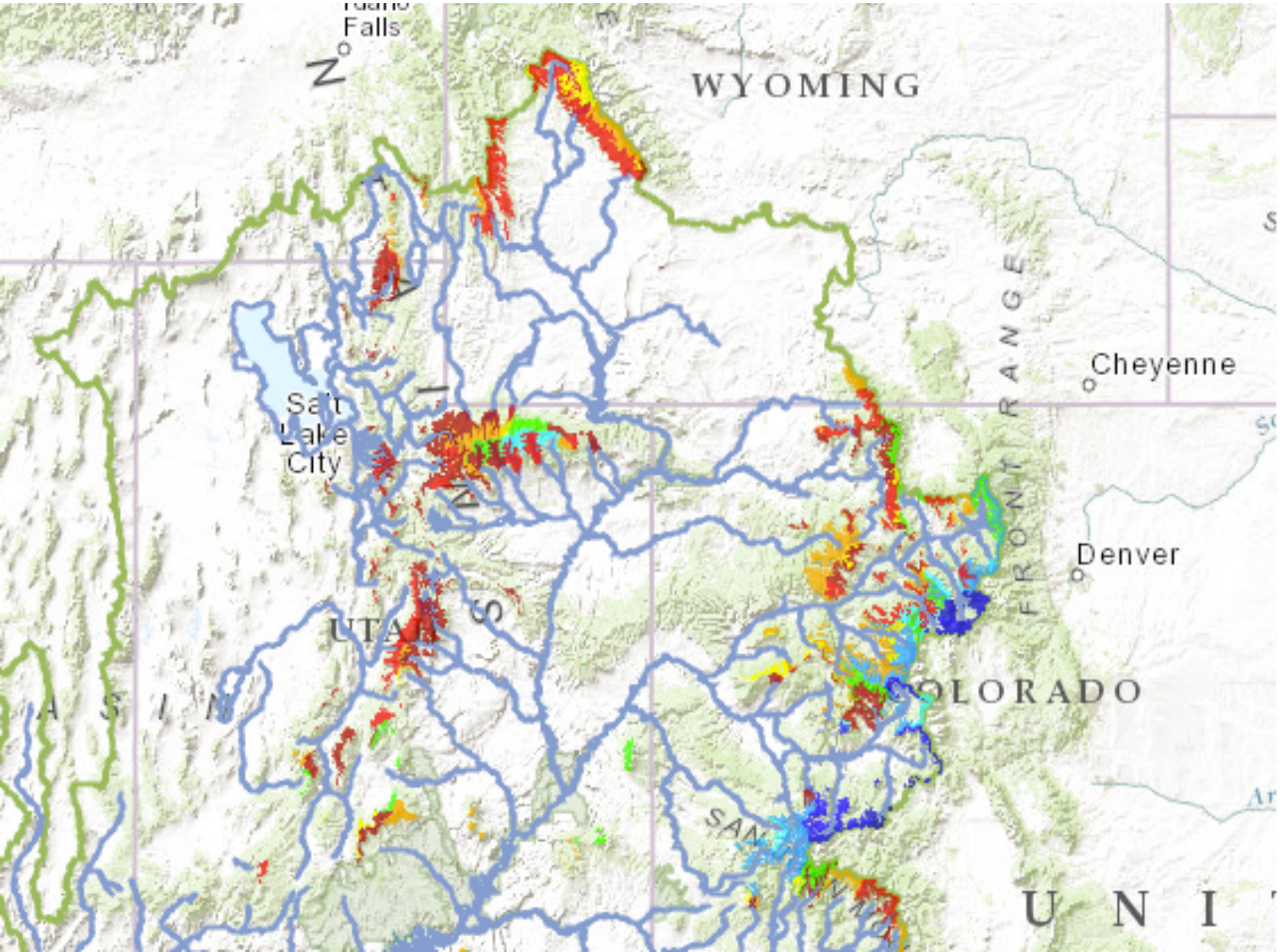
May 1st 2015 Snow Water Equivalent (% average)

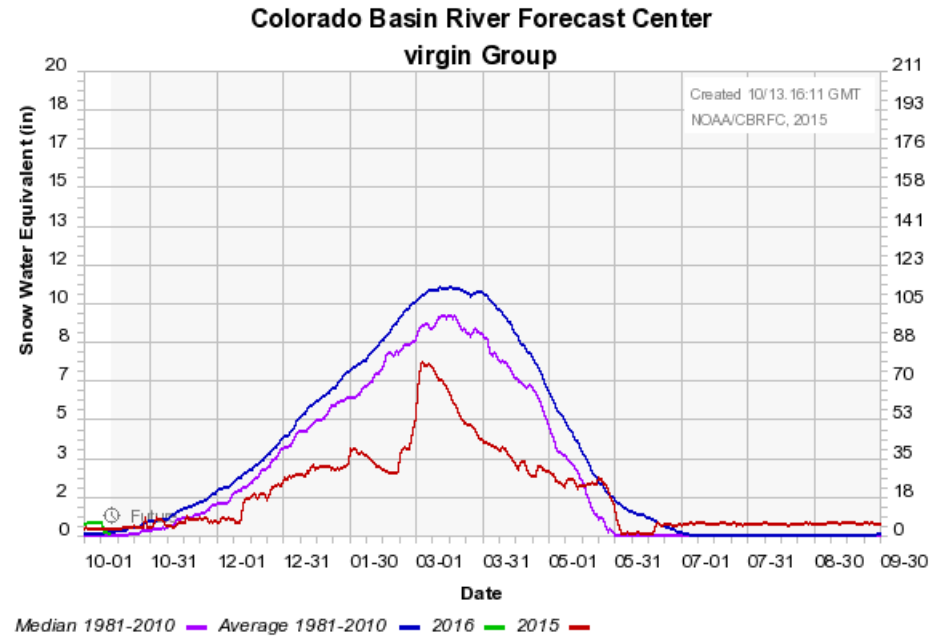


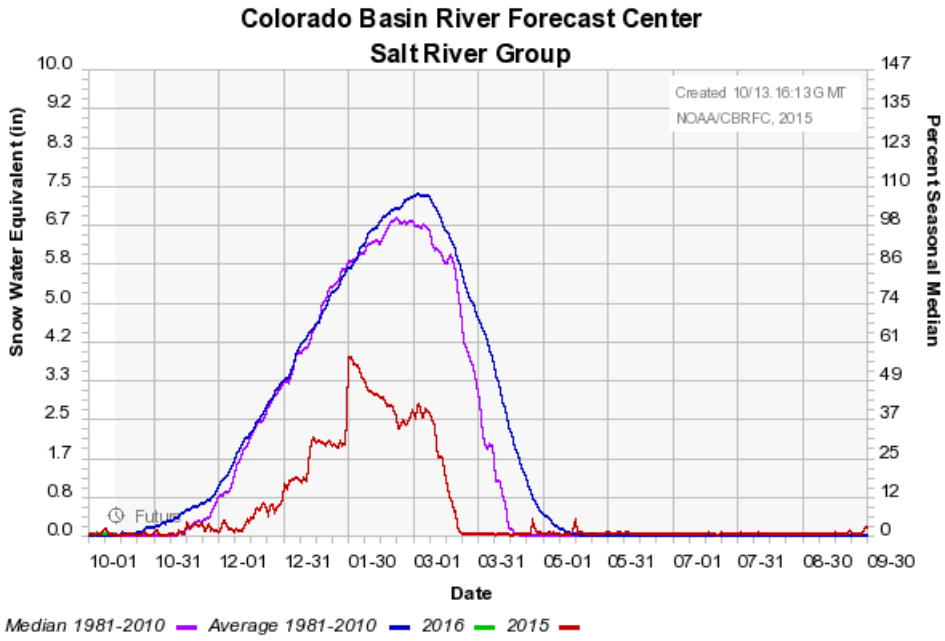
# The progression of the CBRFC hydrologic model snowpack April to June 2015

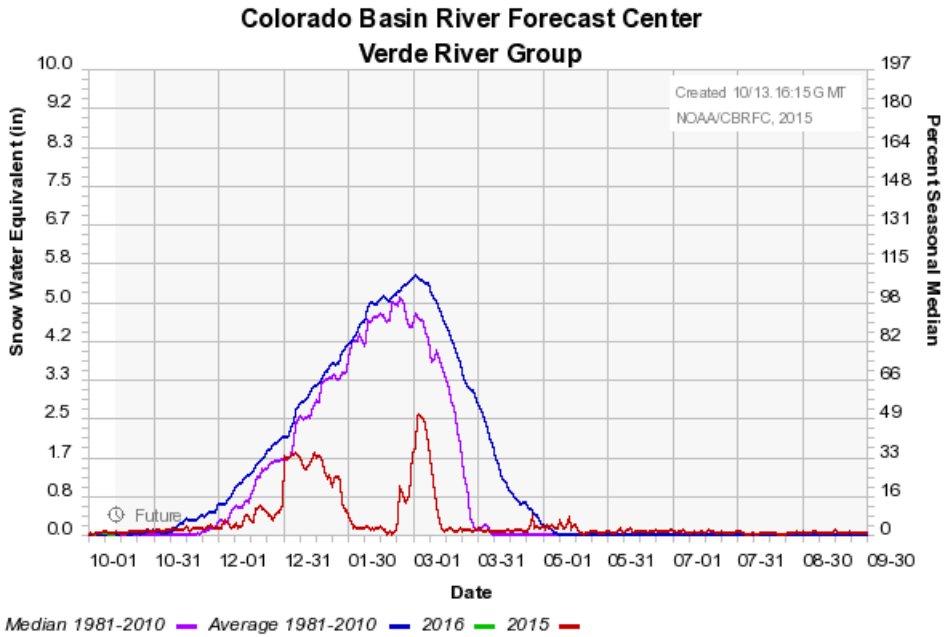
June 1st 2015 Snow Water Equivalent (% average)

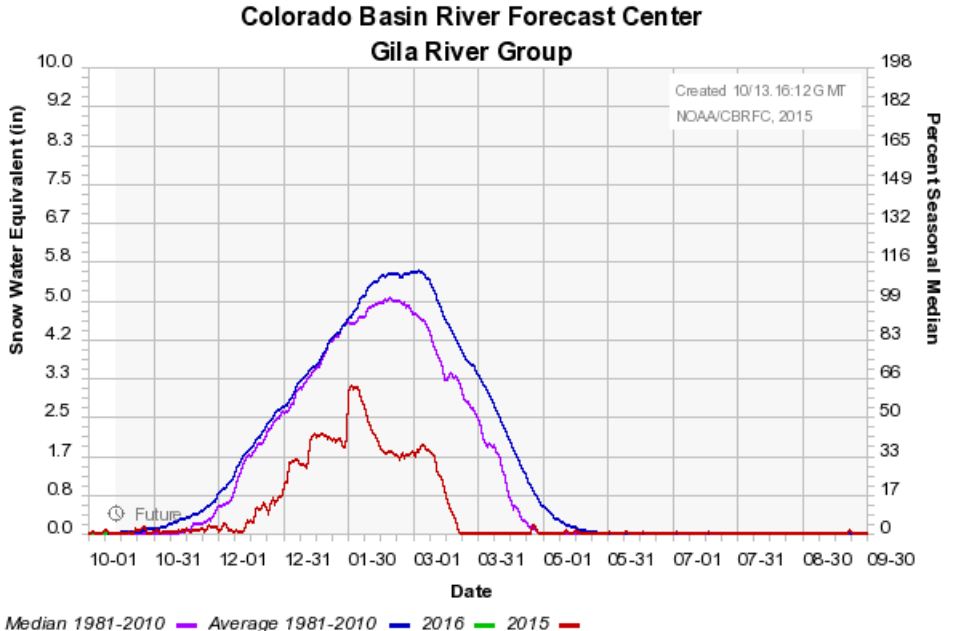


# Basin Snow Groups: Lower Colorado River Basin

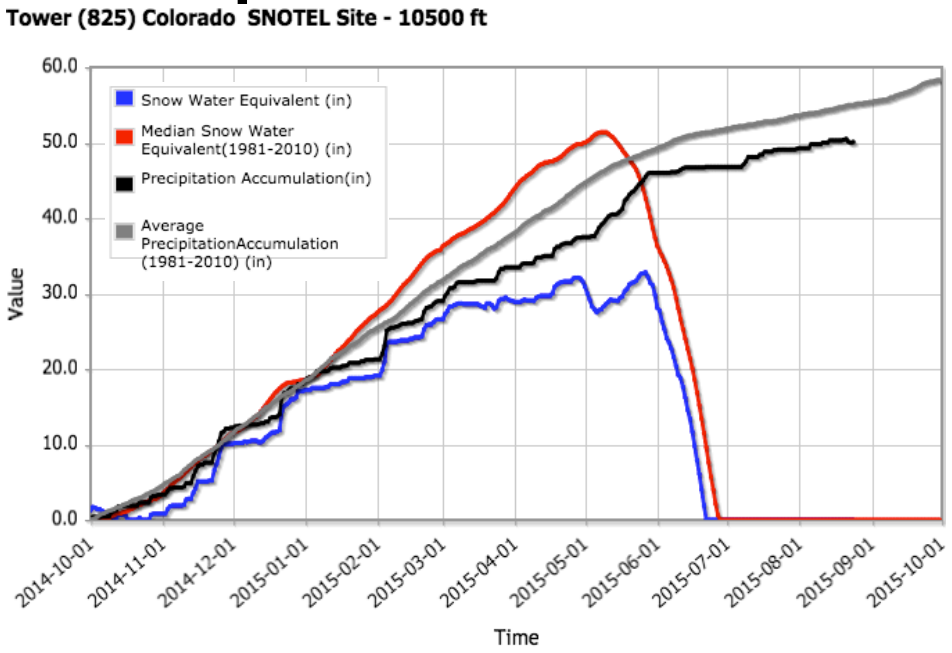


# Yampa: Snow vs Rain

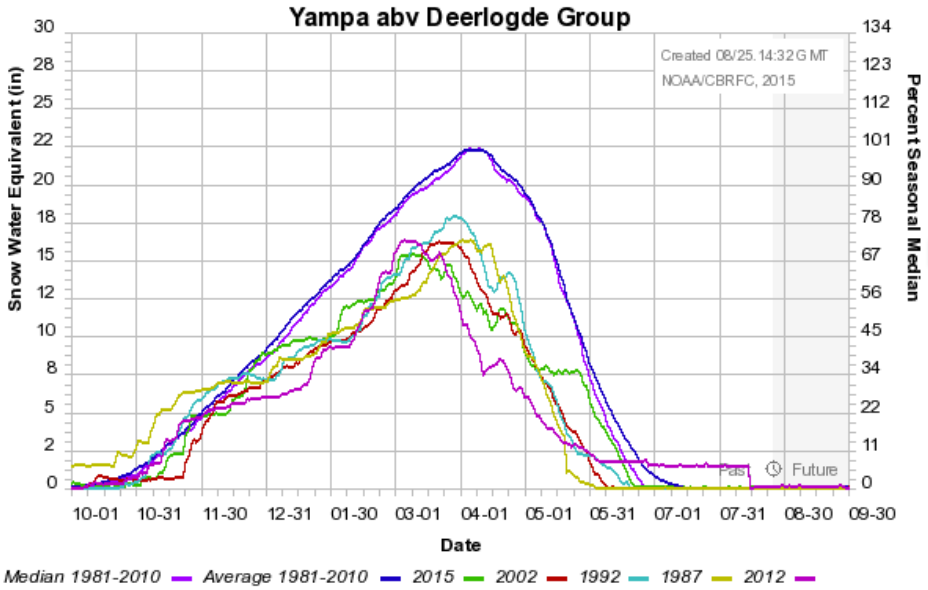



**2015**

Snow= 65% of Seasonal Precipitation

**Normal**

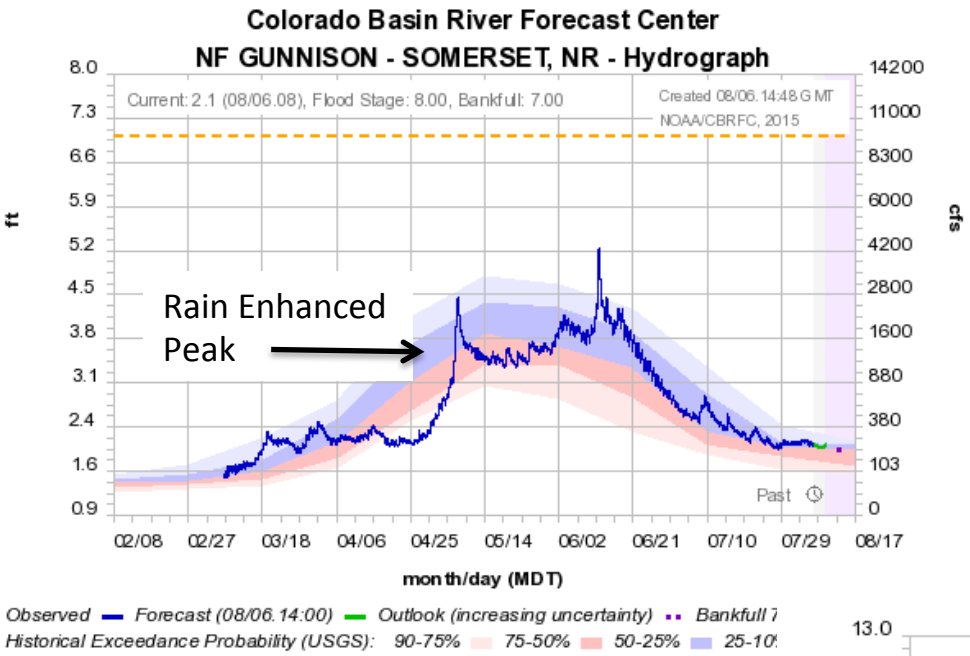
Snow= 95 % of Seasonal Precipitation




| Year | April-July (KAF) |
|---|---|
| 2015 | 1042 (84%) |
| 2012 | 418 (34%) |
| 2002 | 366 (30%) |
| 1992 | 596 (48%) |
| 1987 | 763 (62%) |

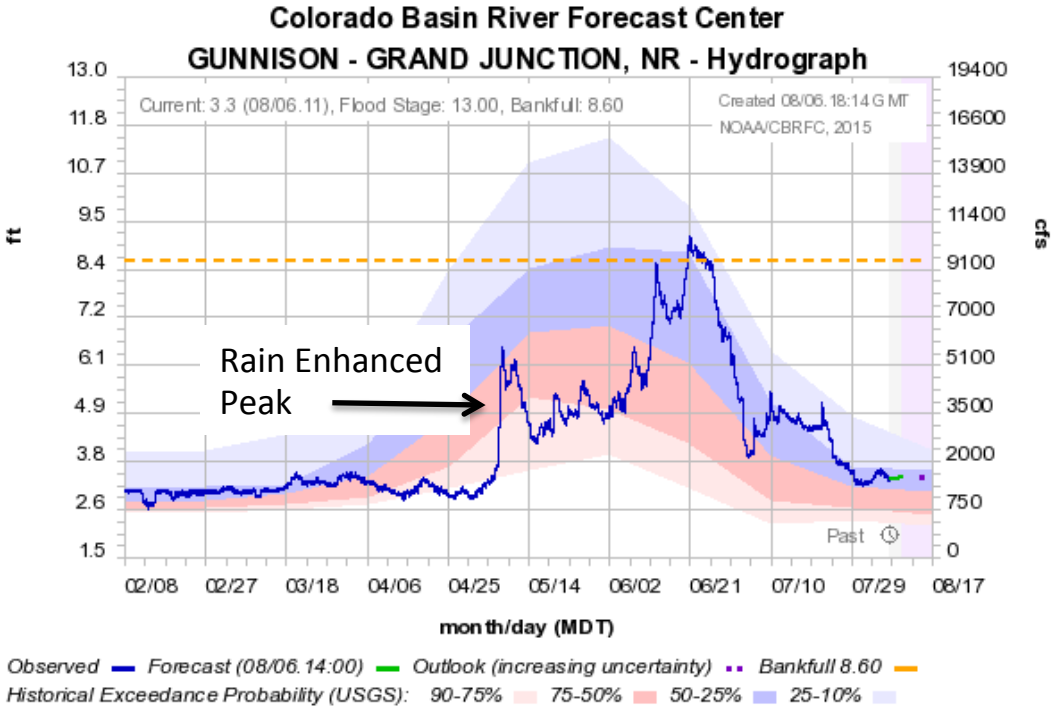
Similar snow years that didn't have wet springs had lower April-July runoff volumes.

Peak flows were significantly enhanced and volumes impacted by the spring precipitation



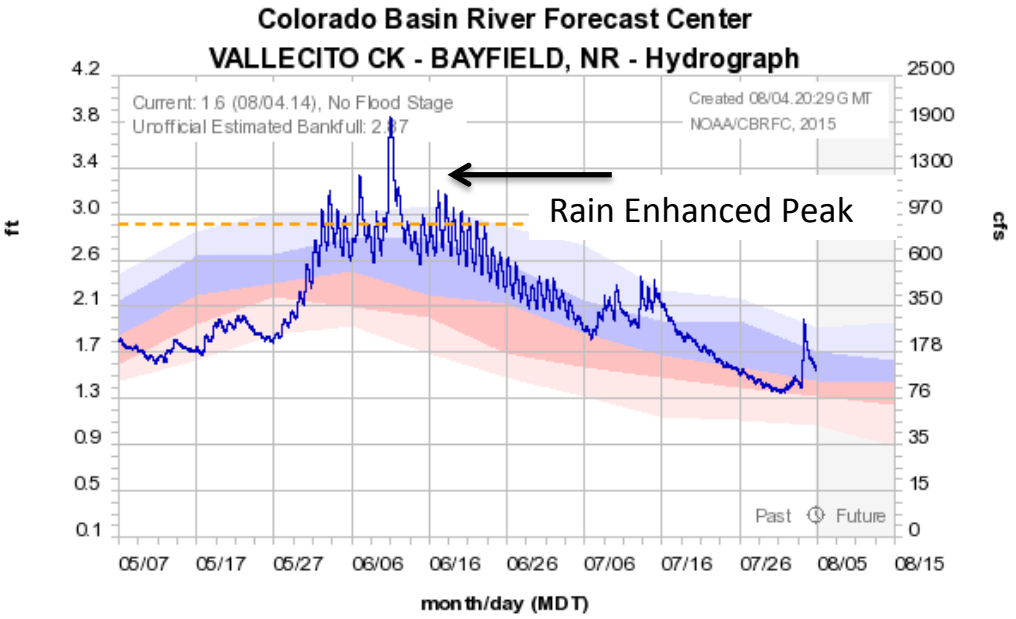

April early season peak flow forecasts ended up being too low. They were based on snow conditions not future rainfall.

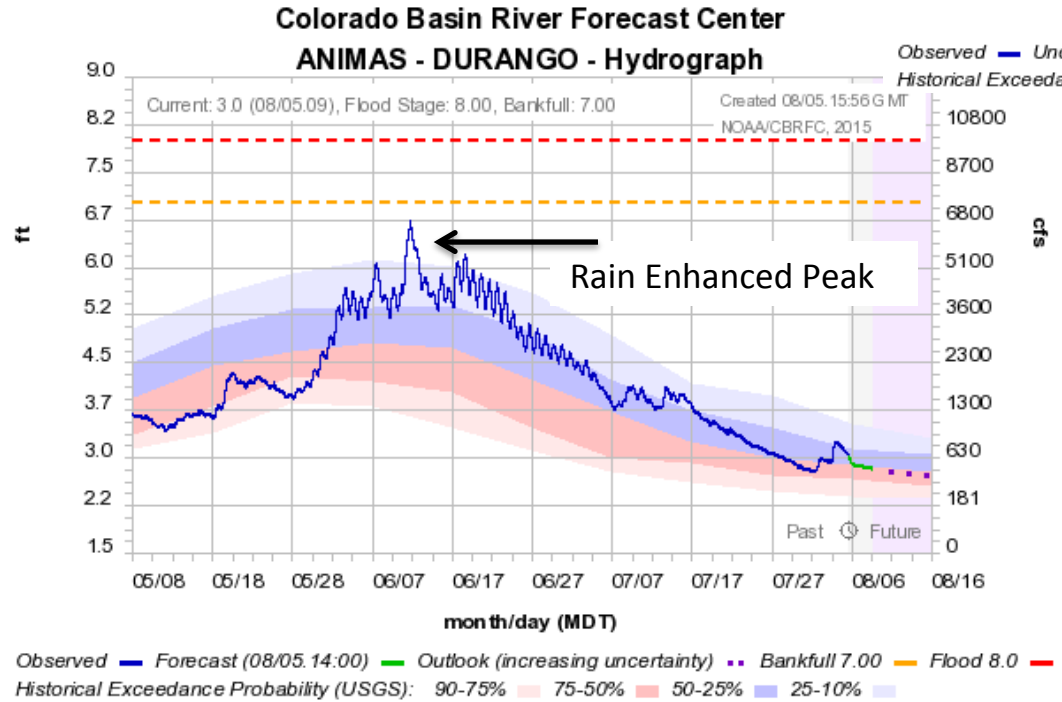
Rain (of a tropical nature) continued to influence peaks into June as it combined with late season snowpack.



Peak flows were significantly enhanced and volumes impacted by the spring precipitation

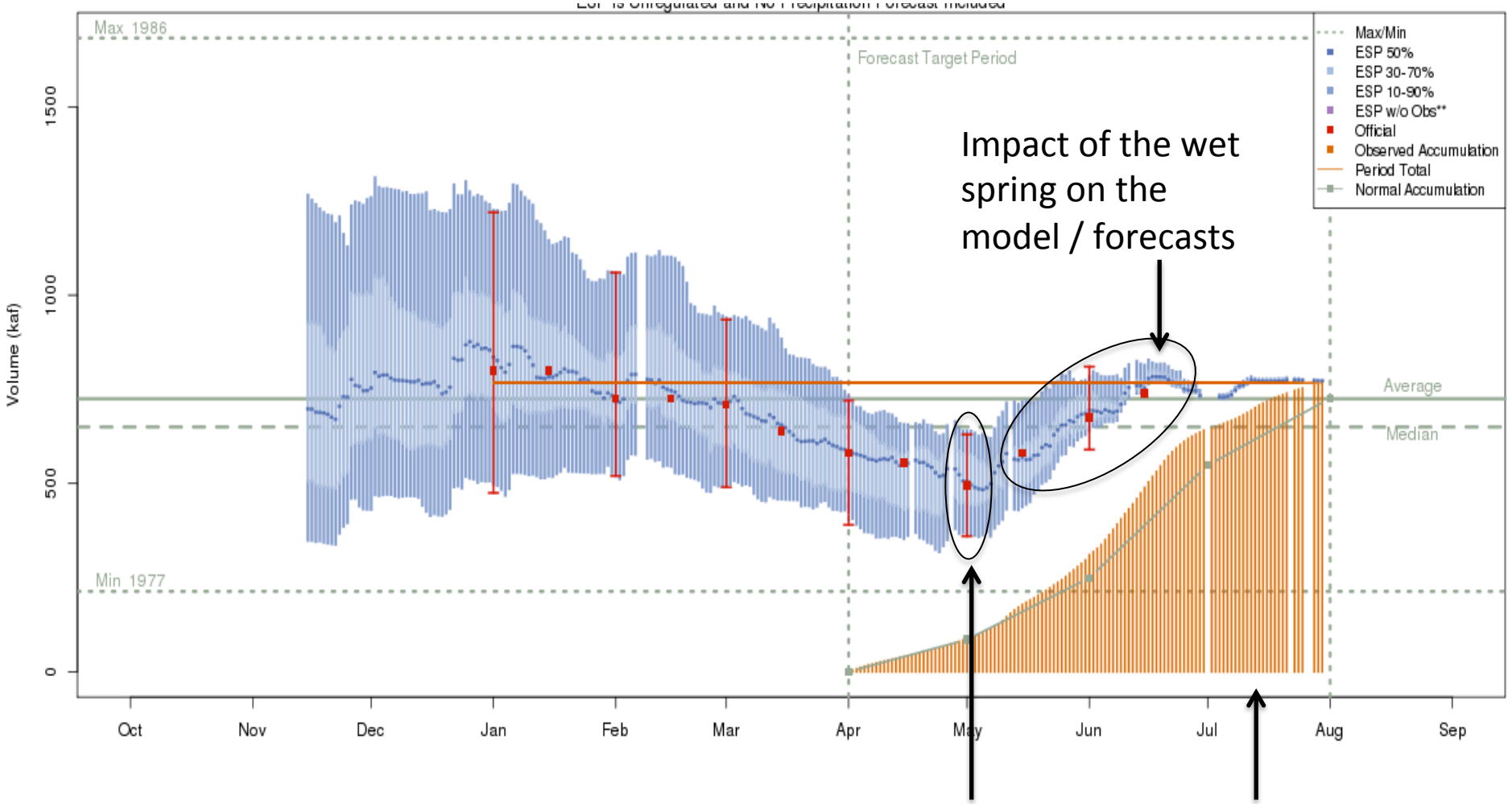
April early season peak flow forecasts ended up being too low. They were based on snow conditions not future rainfall.



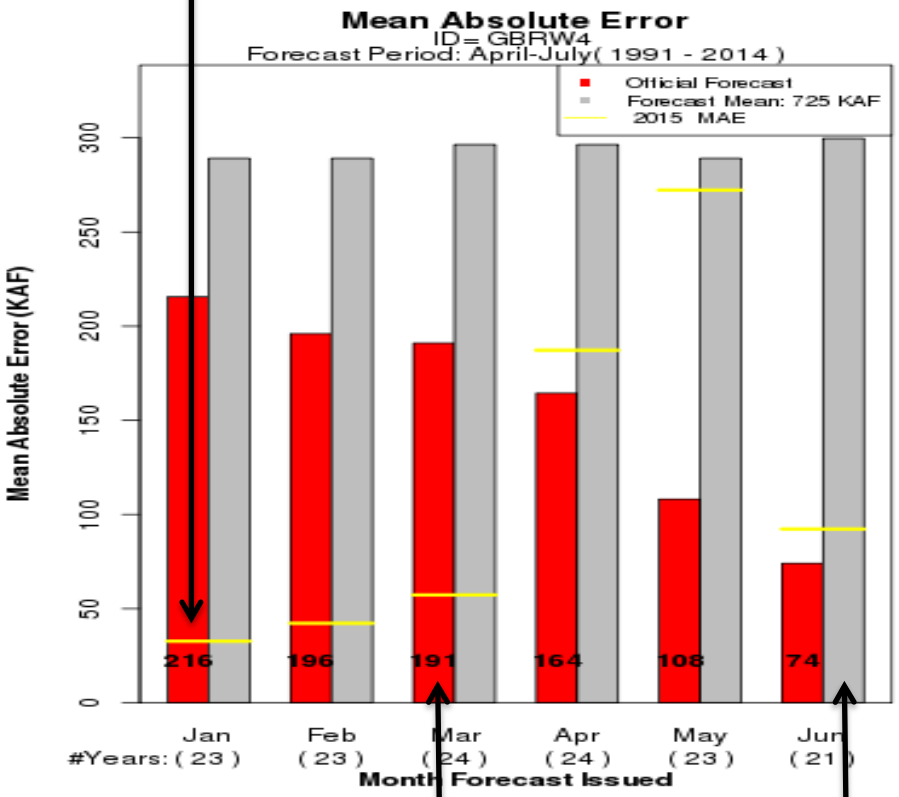

Rain (of a tropical nature) continued to influence peaks into June as it combined with late season snowpack.

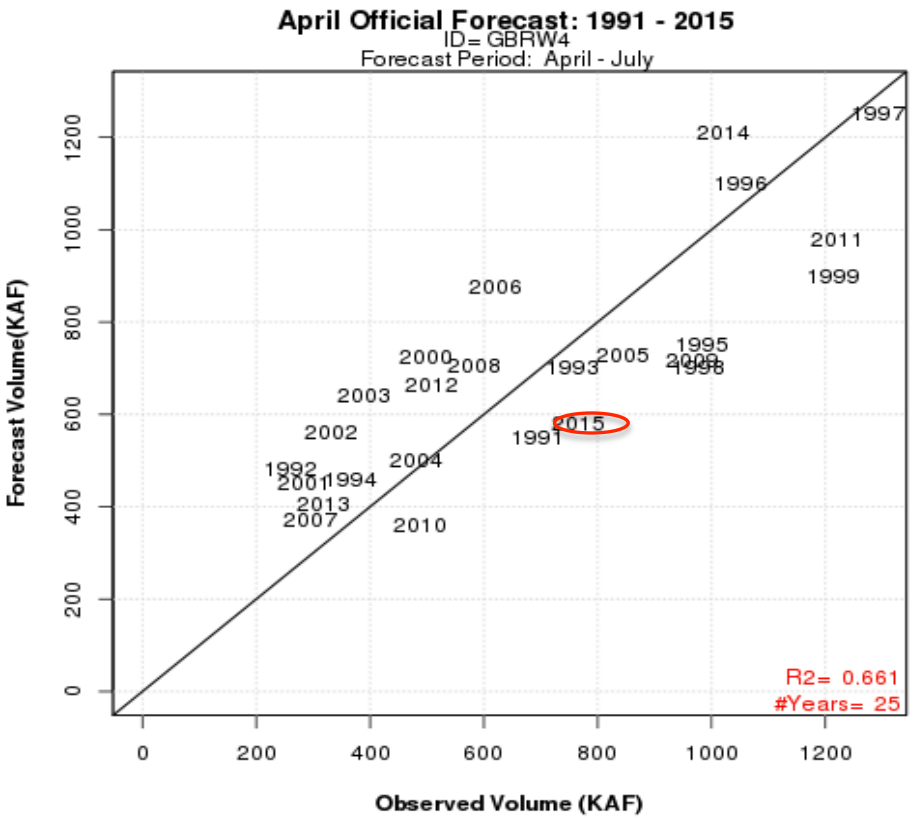
# Forecast Performance: Fontenelle Reservoir Inflow



# Forecast Performance: Fontenelle Reservoir Inflow

2015 Forecast Error

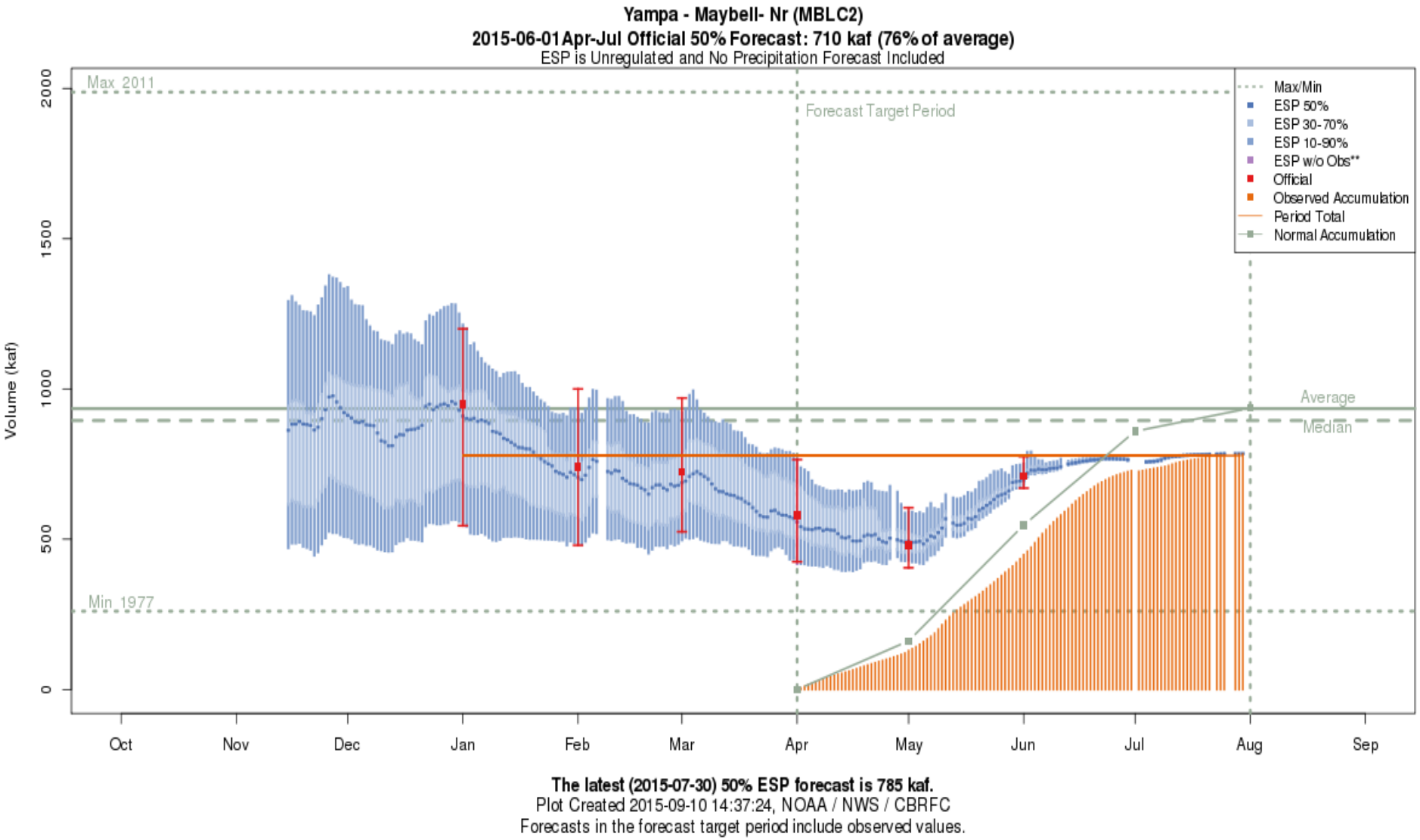



Historically: Forecast error typically decreases throughout the season

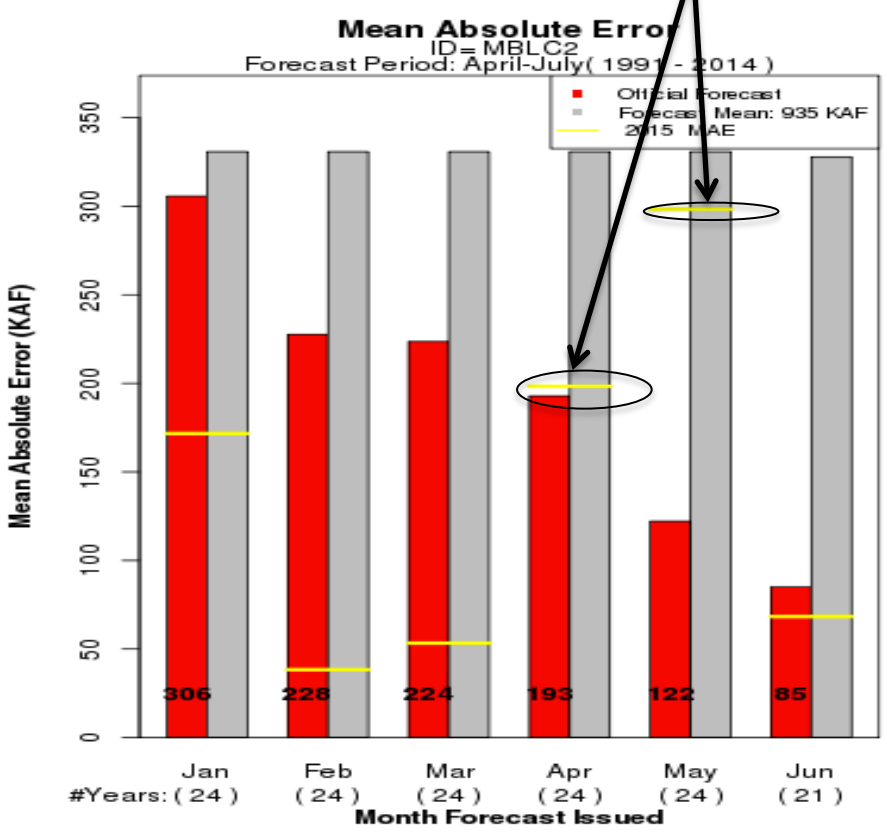
Historical forecast error if we were to just forecast average each month.

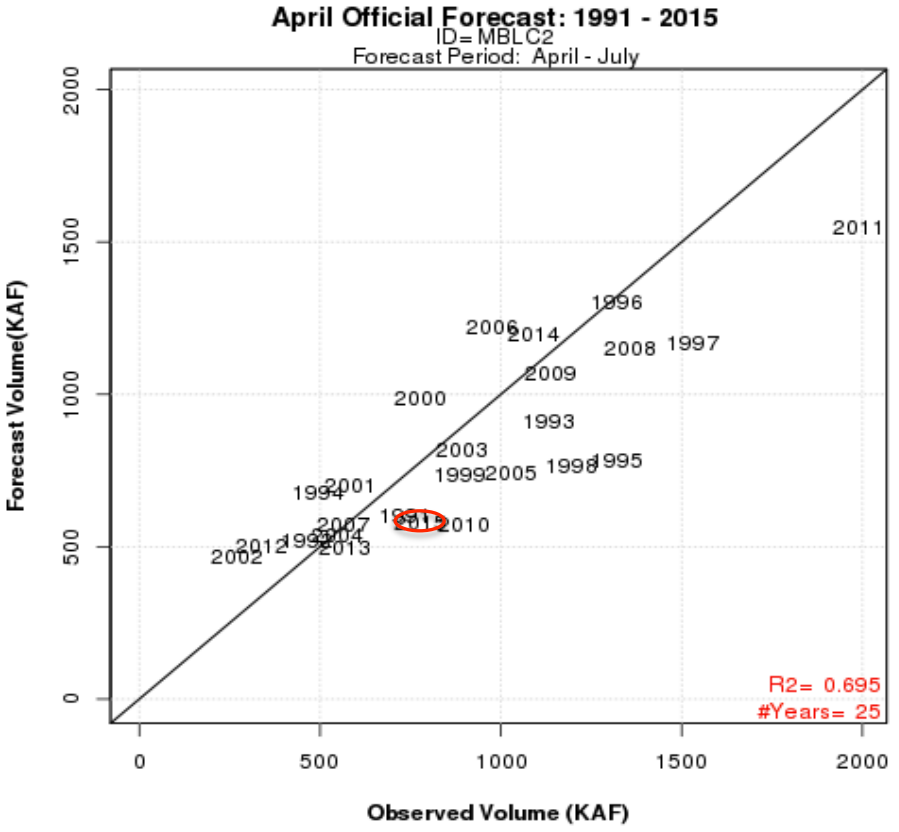
# Forecast Performance: Yampa River - Maybell



# Forecast Performance: Yampa River - Maybell

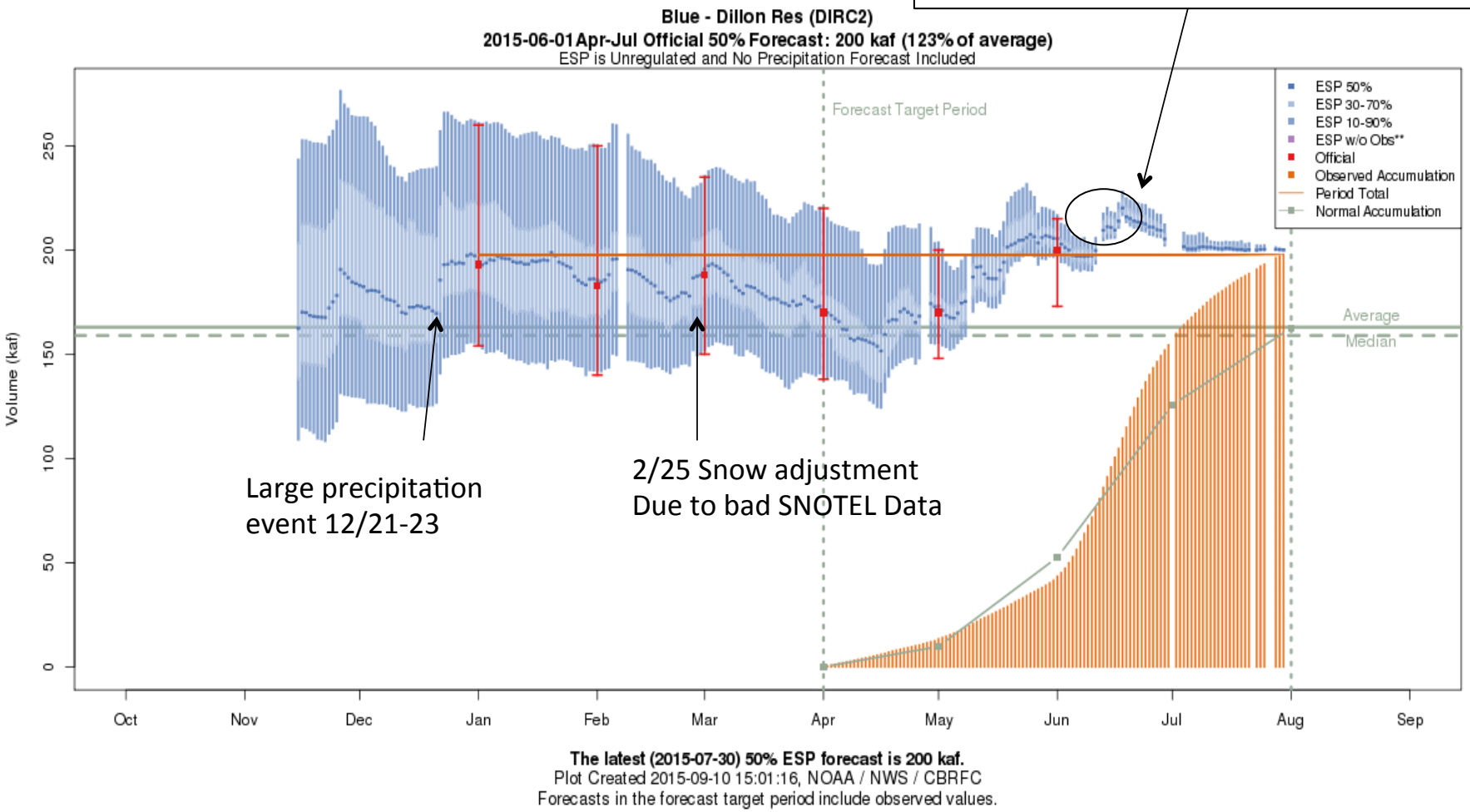
For many areas the April and May errors were much larger than normal



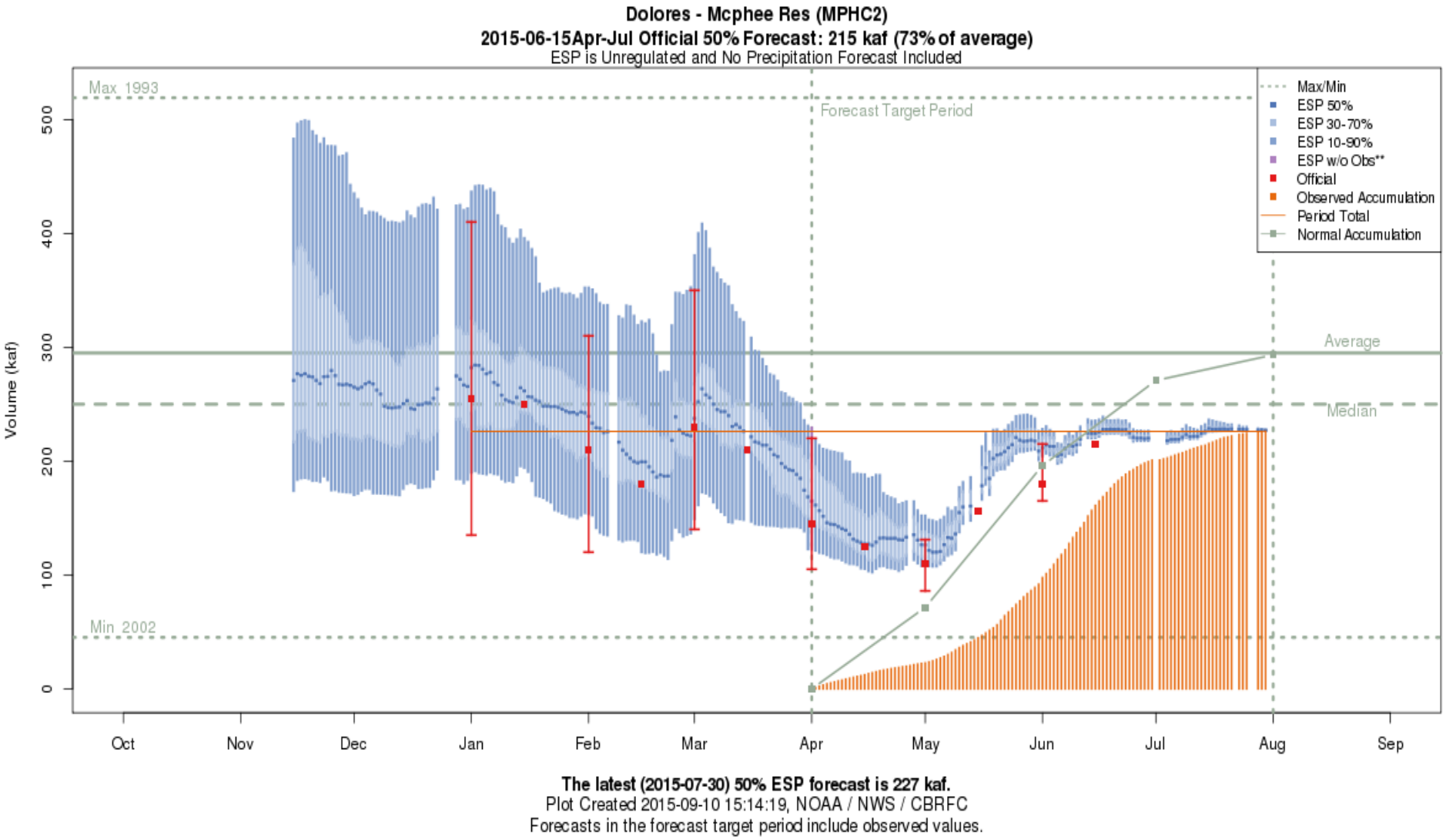



# Forecast Performance: Blue – Dillon Reservoir

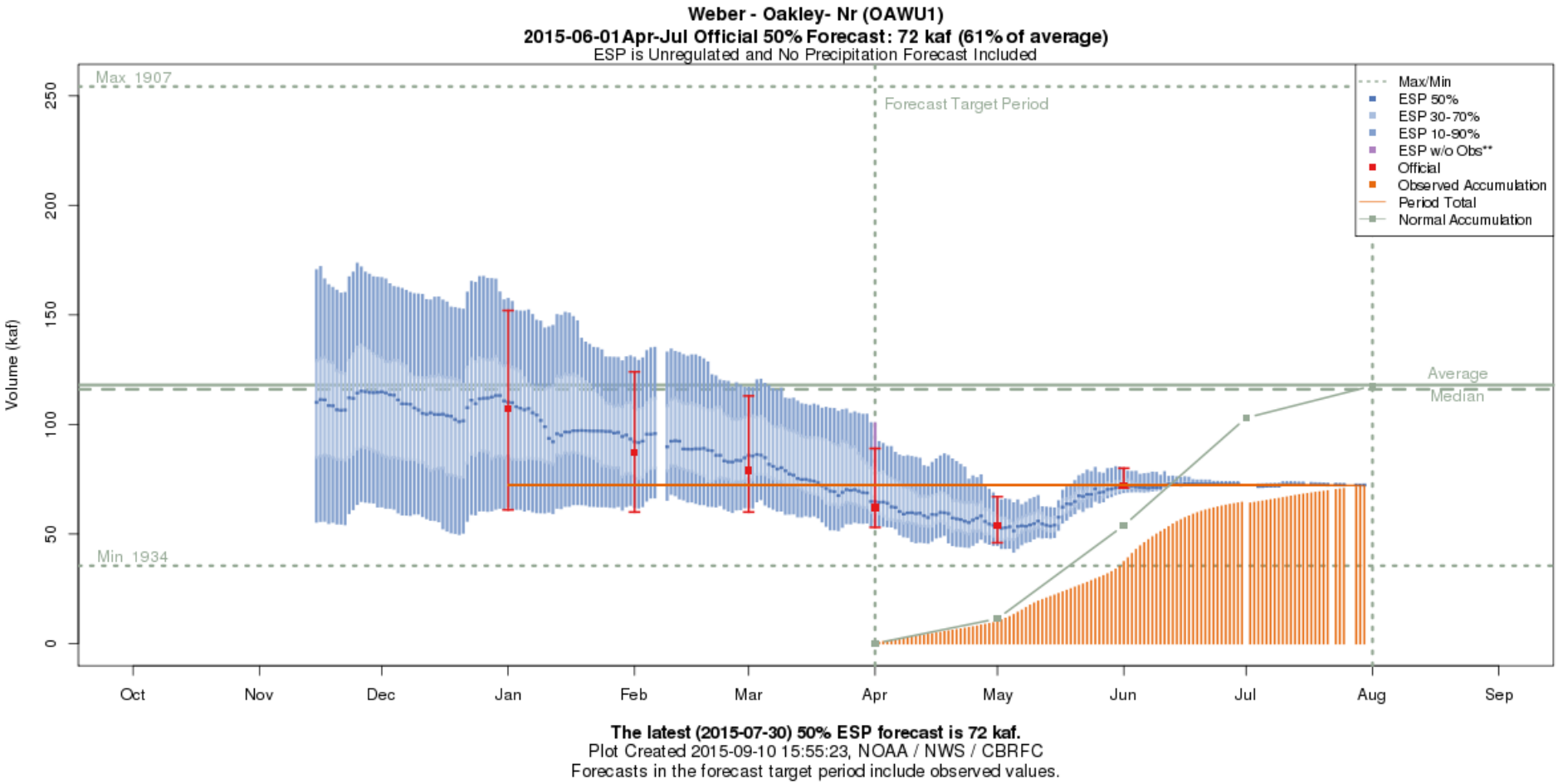
6/8: add snow to lower areas
-needed more flow in daily model;
probably should have been coming from upper elevations
6/12: precip event
6/15-24: remove snow (upper and lower)



# Forecast Performance: McPhee Reservoir Inflow



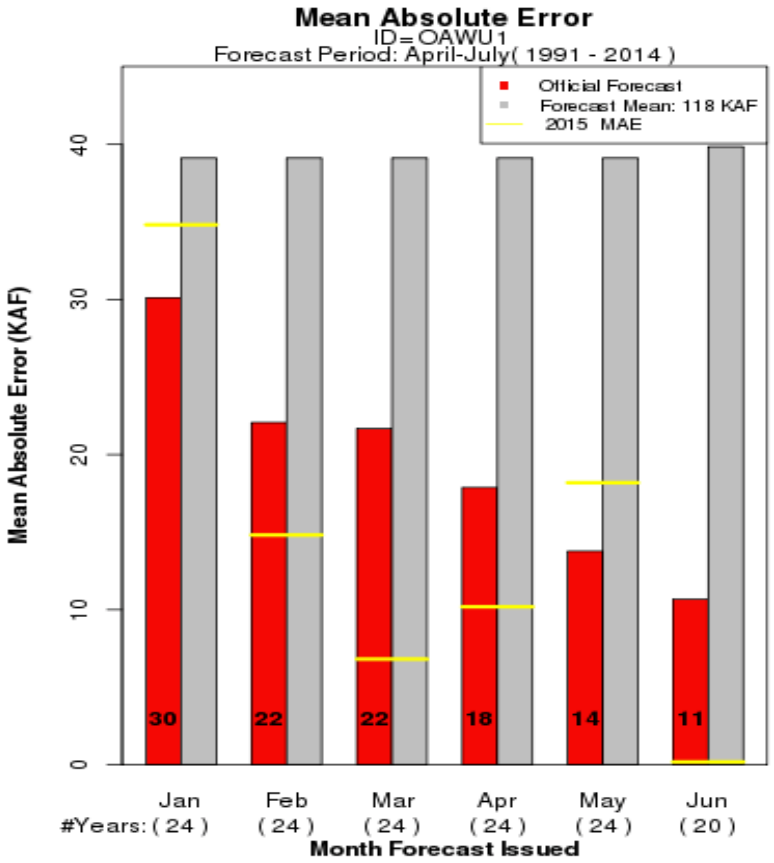
# Forecast Performance: Weber River - Oakley

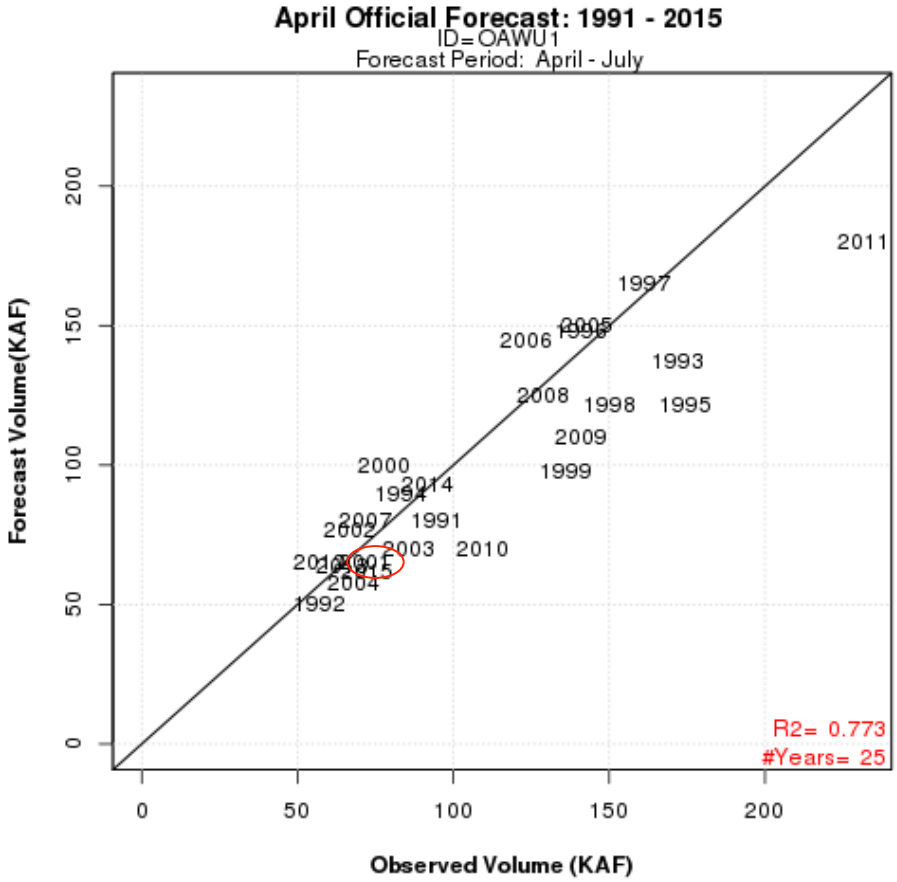



Great Basin June Forecasts increased an average of 52% over May Forecasts

Many pulled out of record low territory but were still way below average

# Forecast Performance: Weber River - Oakley

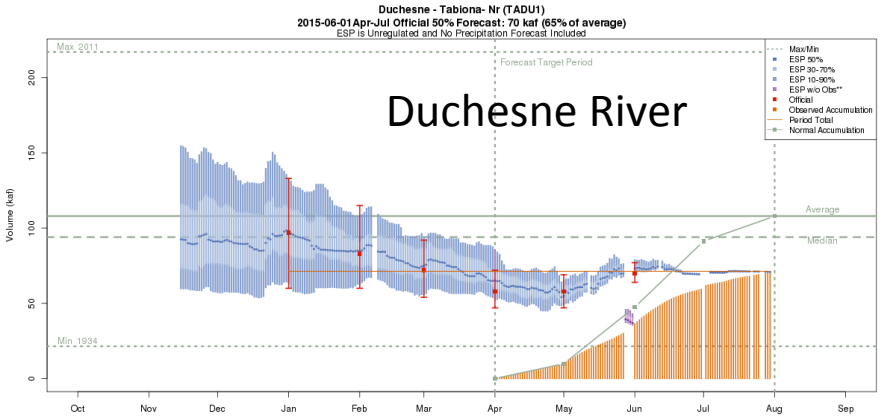


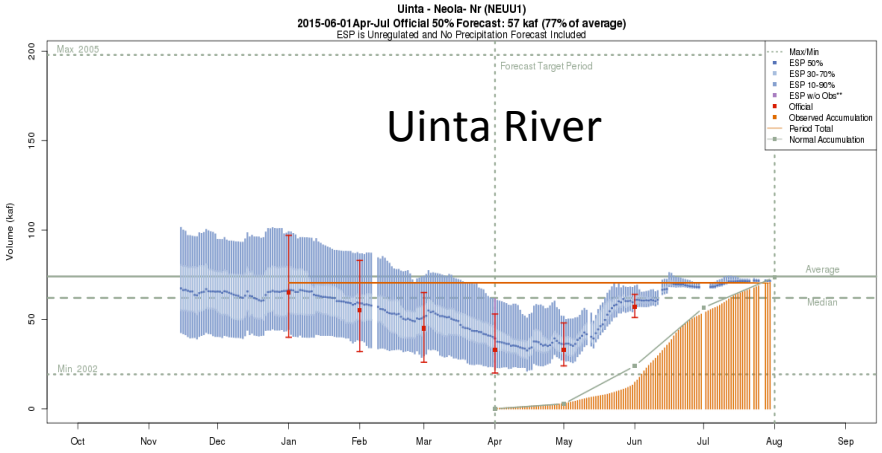



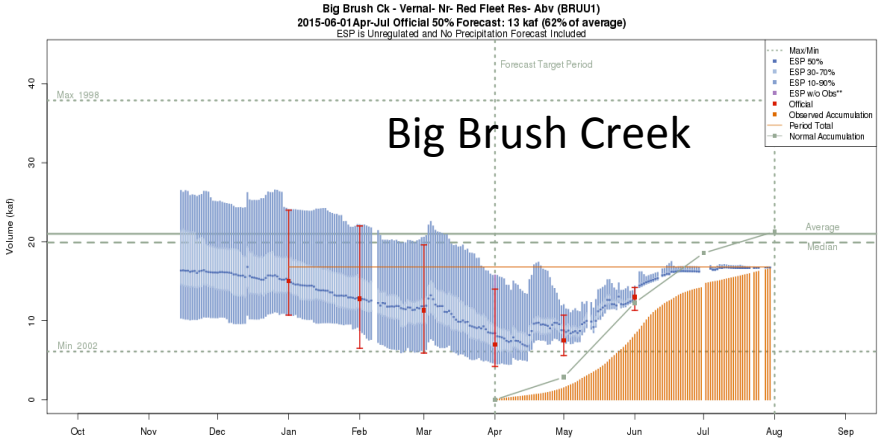
# Great Basin (May to June Forecast Increase)

- Early runoff, poor SWE, and continued dry and warm temperatures led to record low forecasts at some points
  - Salt Creek (19% of average)
  - West Canyon Creek (6%)
  - Little Cottonwood (47%)
  - Mill Creek (20%)
  - Red Butte (15%)
- Near record May precipitation throughout most of Utah
- Forecasts increased by an average of 52%, but dry stayed dry!
  - Salt Creek (23% of average)
  - West Canyon Creek (8%)
  - Little Cottonwood (52%)
  - Mill Creek (27%)
  - Red Butte (27%)

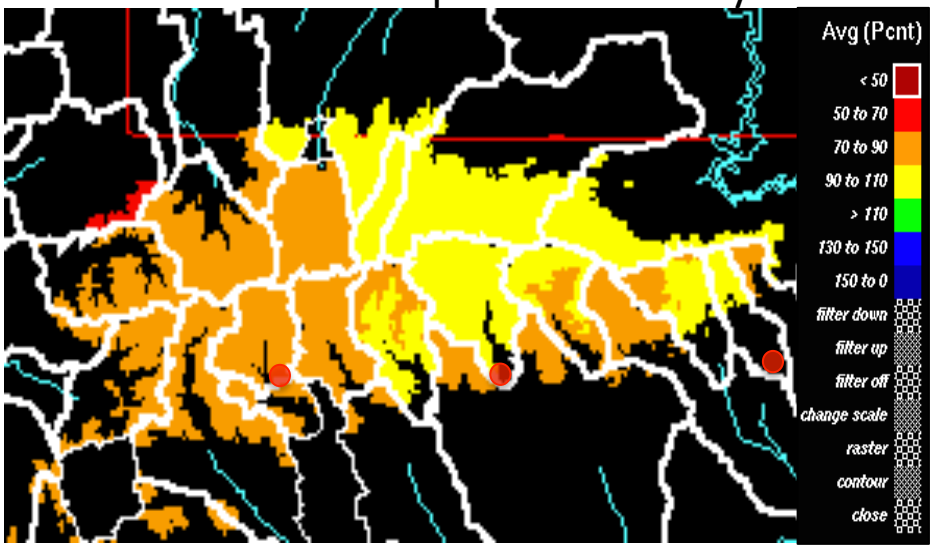
# Duchesne: West to East



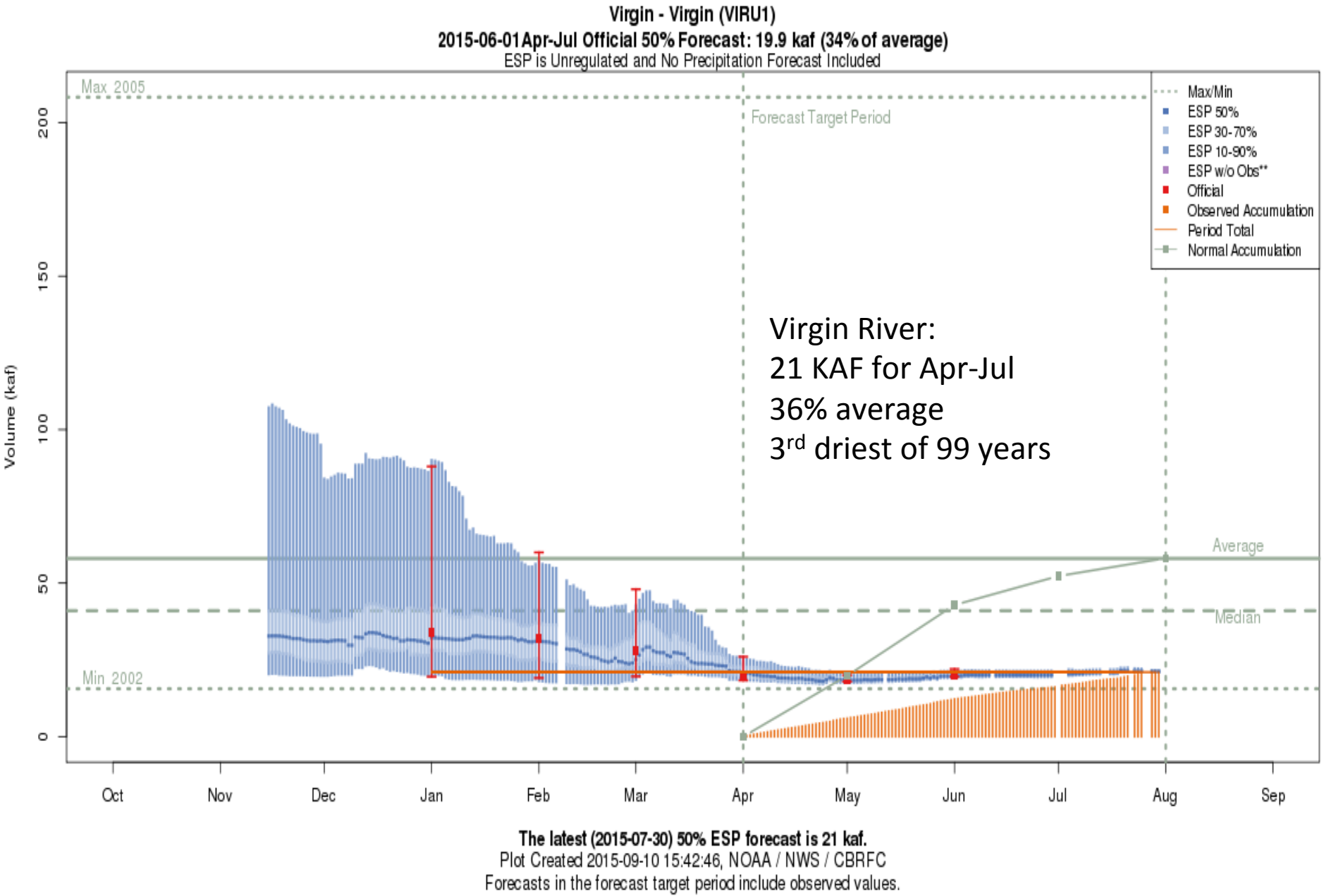

## Seasonal Precipitation Oct-July



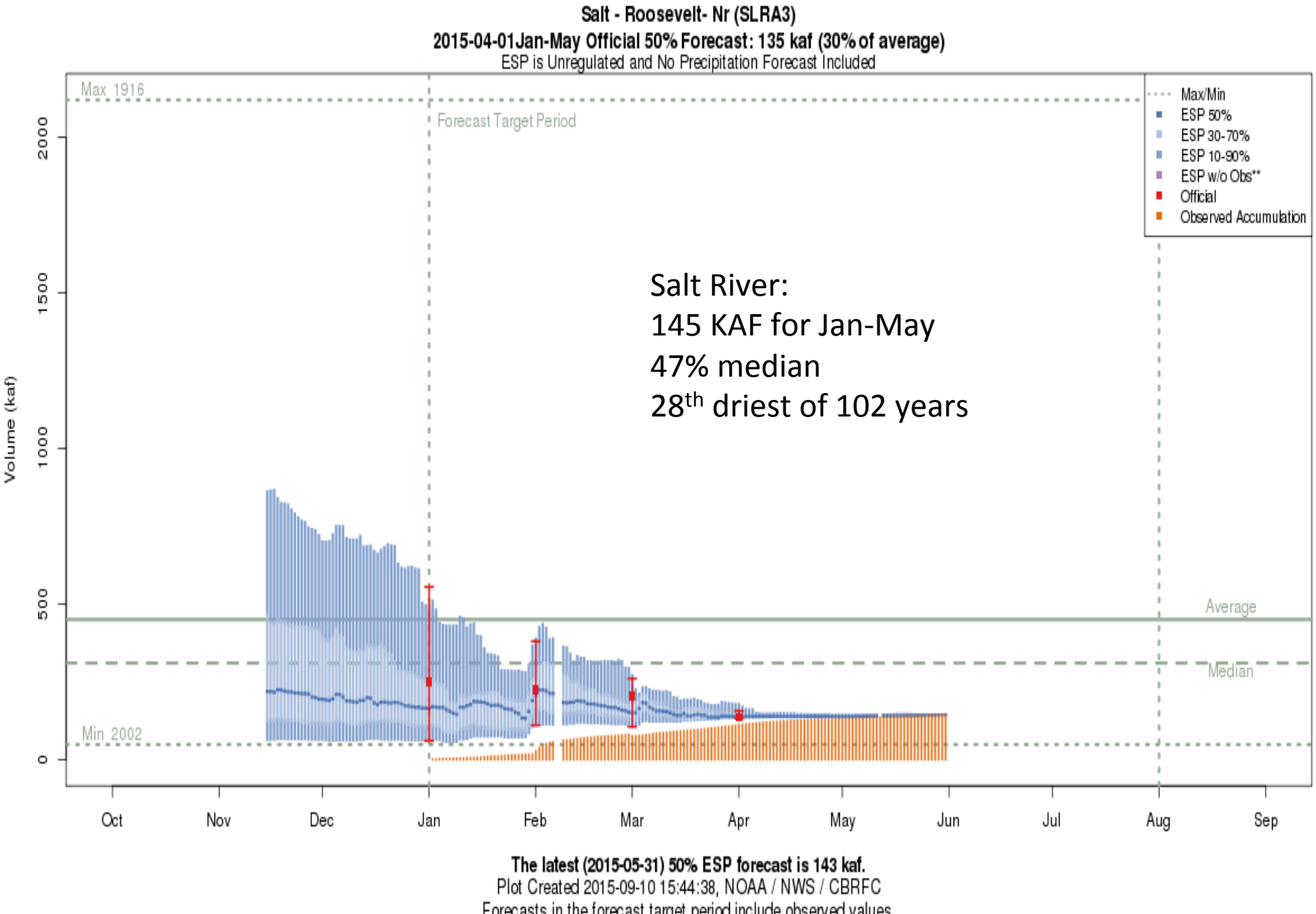

| | May 1 Forecast | Observed |
|---|---|---|
| Currant Ck | 25% | 66% |
| Duchesne - Tabiona | 54% | 62% |
| West Fork Duchesne | 39% | 69% |
| Rock Ck - Upper Stillwater | 61% | 85% |
| Lake Fork- Moon Lake Res | 45% | 80% |
| Yellowstone - Altonah | 52% | 85% |
| Uinta – Neola | 45% | 98% |
| Whiterocks - Whiterocks | 46% | 78% |
| Big Brush Ck | 36% | 80% |

-Early snowmelt -↑ Soil moisture
-Late season snow accumulation
-Efficient runoff

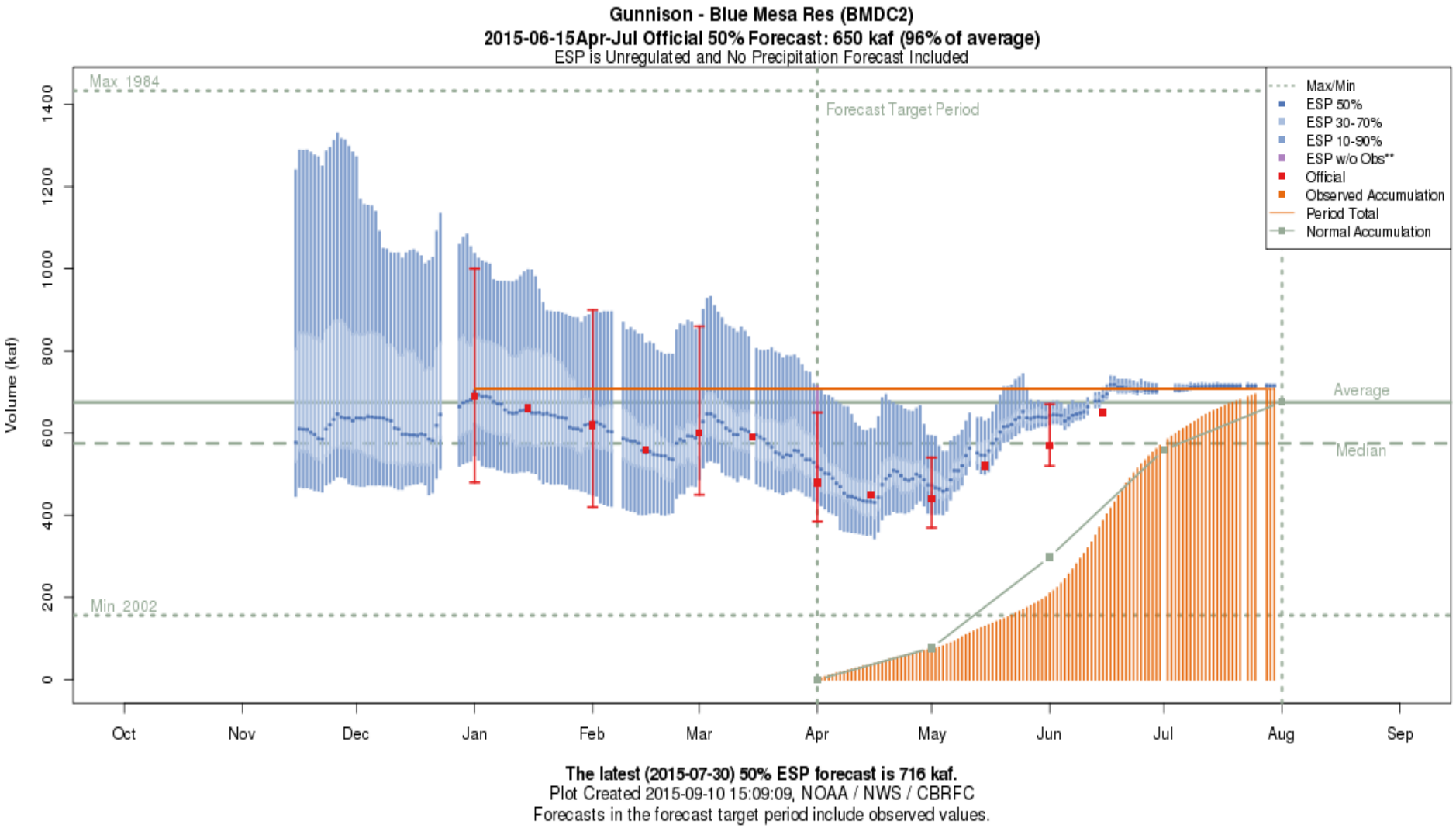
# Virgin


Virgin - Virgin (VIRU1)
2015-06-01 Apr-Jul Official 50% Forecast: 19.9 kaf (34% of average)
ESP is Unregulated and No Precipitation Forecast Included
Max 2005
Forecast Target Period
Min 2002
Average
Median
Volume (kaf)
0
50
100
150
200
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Max/Min
ESP 50%
ESP 30-70%
ESP 10-90%
ESP w/o Obs**
Official
Observed Accumulation
Period Total
Normal Accumulation
Virgin River:
21 KAF for Apr-Jul
36% average
3rd driest of 99 years
The latest (2015-07-30) 50% ESP forecast is 21 kaf.
Plot Created 2015-09-10 15:42:46, NOAA / NWS / CBRFC
Forecasts in the forecast target period include observed values.

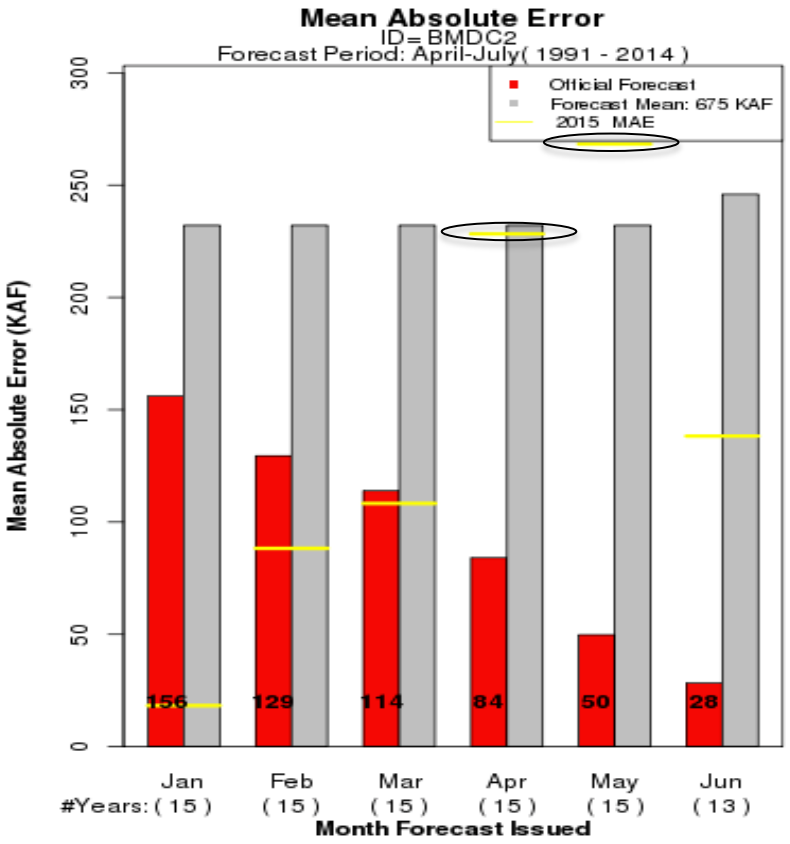
# Salt

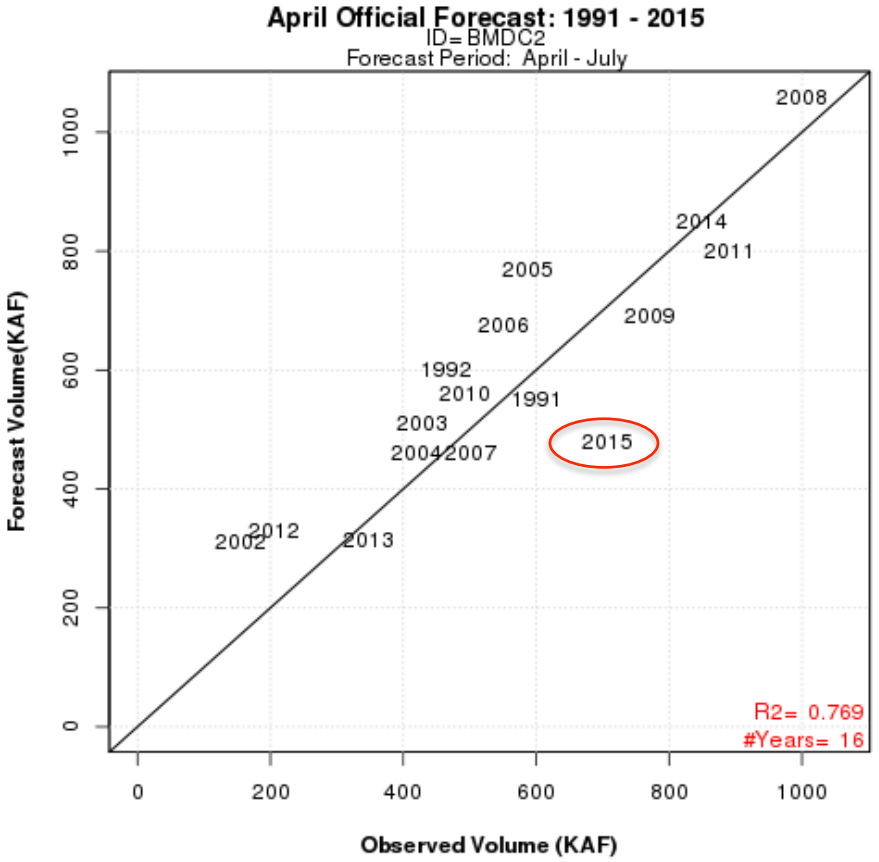

Salt - Roosevelt- Nr (SLRA3)
2015-04-01Jan-May Official 50% Forecast: 135 kaf (30% of average)
ESP is Unregulated and No Precipitation Forecast Included
Max 1916
Forecast Target Period
Max/Min
ESP 50%
ESP 30-70%
ESP 10-90%
ESP w/o Obs**
Official
Observed Accumulation
Salt River:
145 KAF for Jan-May
47% median
28th driest of 102 years
Average
Median
Min 2002
Volume (kaf)
0
500
1000
1500
2000
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
The latest (2015-05-31) 50% ESP forecast is 143 kaf.
Plot Created 2015-09-10 15:44:38, NOAA / NWS / CBRFC
Forecasts in the forecast target period include observed values

# Forecast Performance: Blue Mesa Reservoir Inflow



# Forecast Performance: Blue Mesa Reservoir Inflow



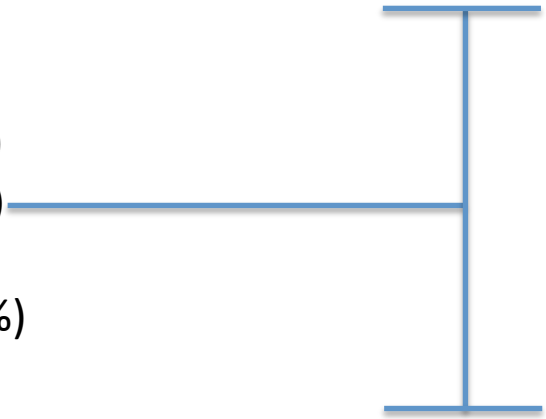
# Model / Forecast Performance & Uncertainty

## Blue Mesa Reservoir Inflow Forecast Progression 2015

1st of month Forecasts

| | |
|---|---|
| Jan: | 690 KAF (102%) |
| Feb: | 620 KAF (92%) |
| Mar: | 600 KAF (89%) |
| Apr: | 480 KAF (71%) |
| May: | **440 KAF** (65%) |
| June: | 570 KAF (84%) |
| July: | 700 KAF (104%) |

**April-July Observed**
**708 KAF (105%)**



10 % Chance of Exceeding : 540 KAF

50% Chance of Exceeding: 440 KAF

90 % Chance of Exceeding: 370 KAF

Highest Forecast Trace on May 1 was 741 KAF: (3% exceedance probability)

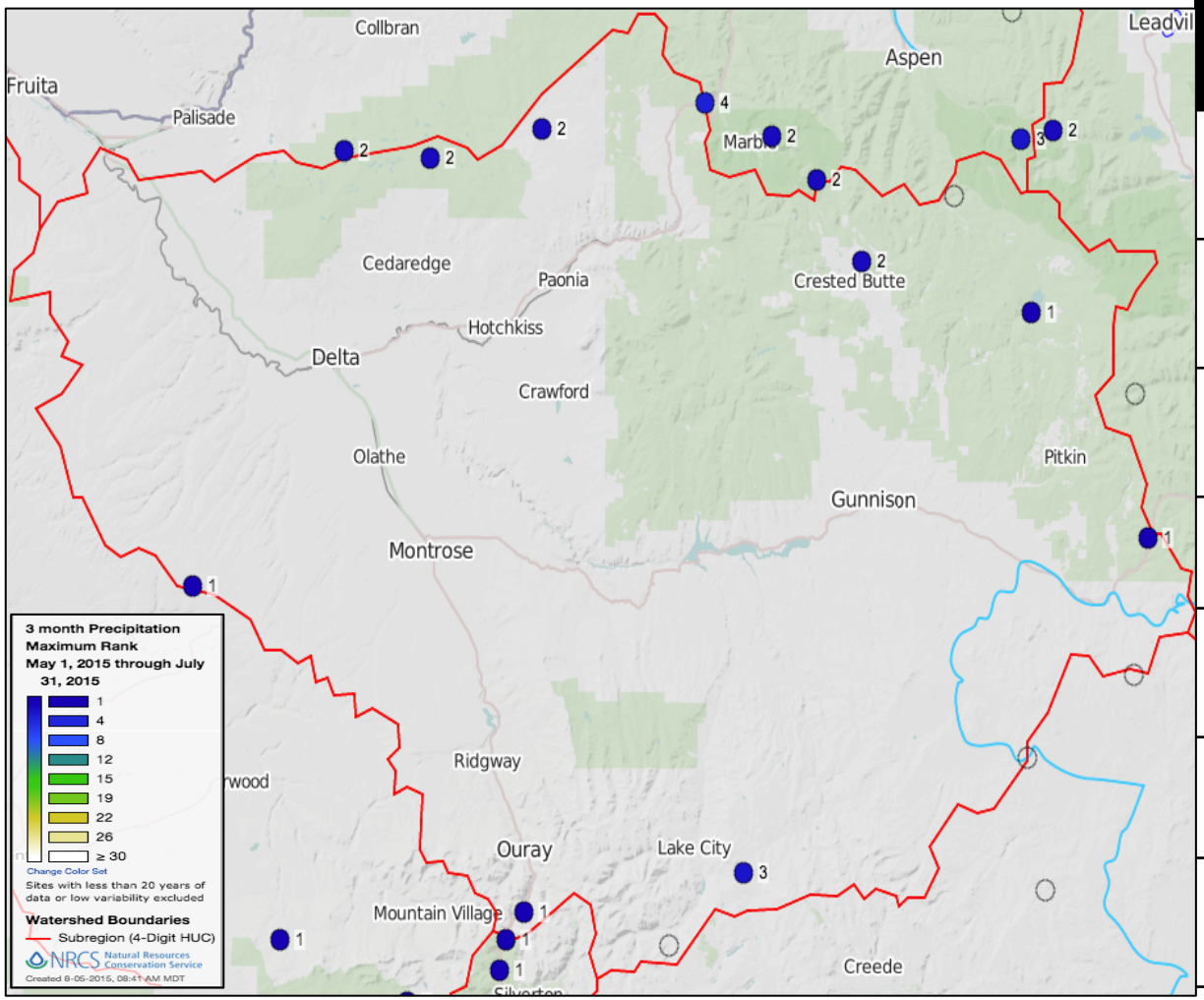
Second Highest Forecast Trace on May 1 was 604 KAF: (7% exceedance probability)

We would expect May-July precipitation to be in that top 3-7% of record to reach the observed volume of 708 KAF.

So was it ?

# Gunnison May-July SNOTEL Precipitation

## Historical Ranking

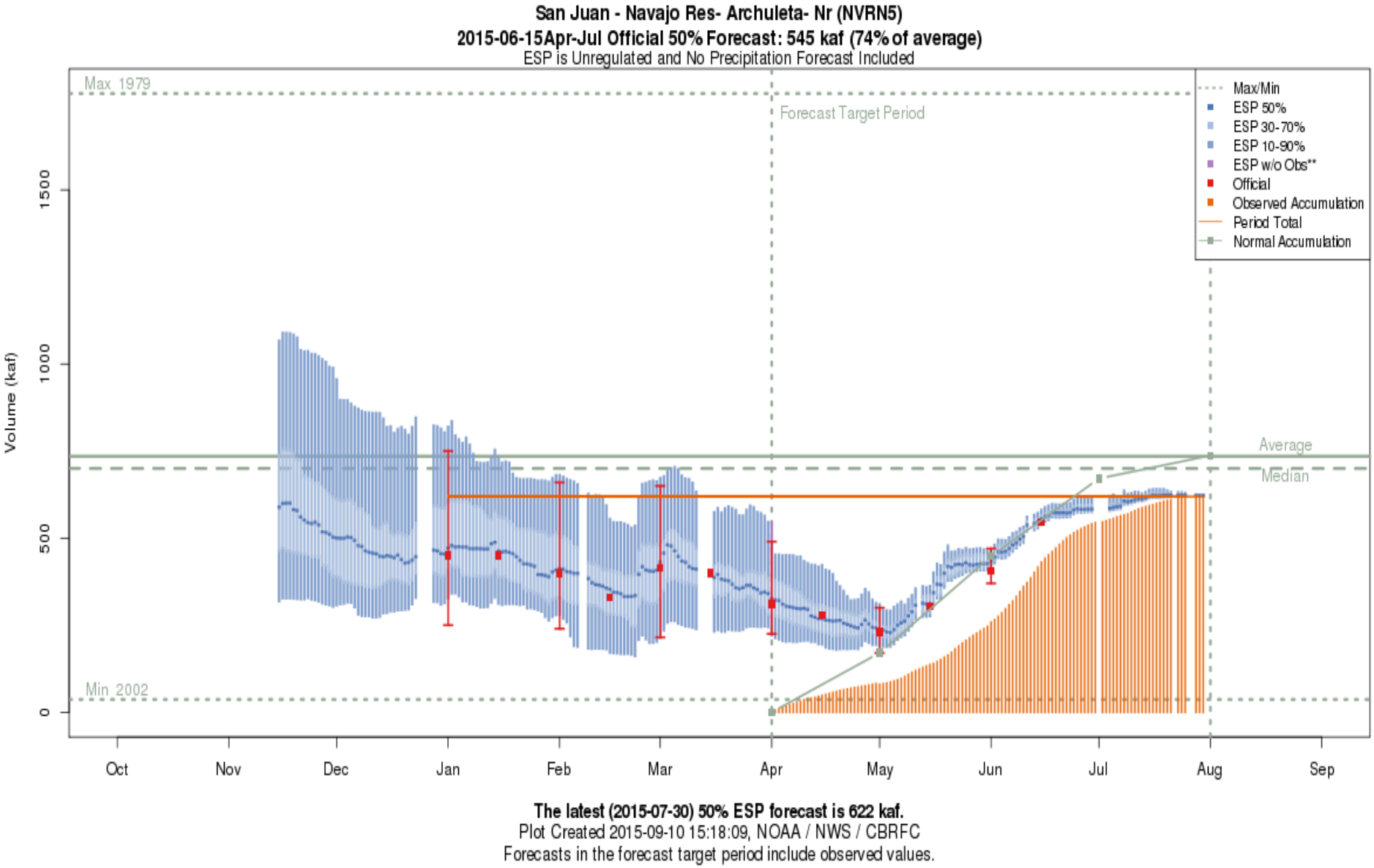



| SNOTEL | Anomaly (in) | % of Avg |
|---|---|---|
| Park Reservoir | +8.9 | 240% |
| Overland Reservoir | +4.8 | 173% |
| Schofield Pass | +8.0 | 216% |
| Butte | +4.1 | 178% |
| Porphyry Creek | +3.5 | 162% |
| Slumgullion | +3.6 | 169% |
| Columbine Pass | +6.7 | 260% |

May-July precipitation at SNOTEL sites were in the top 2 of the historical record (30-35 years)

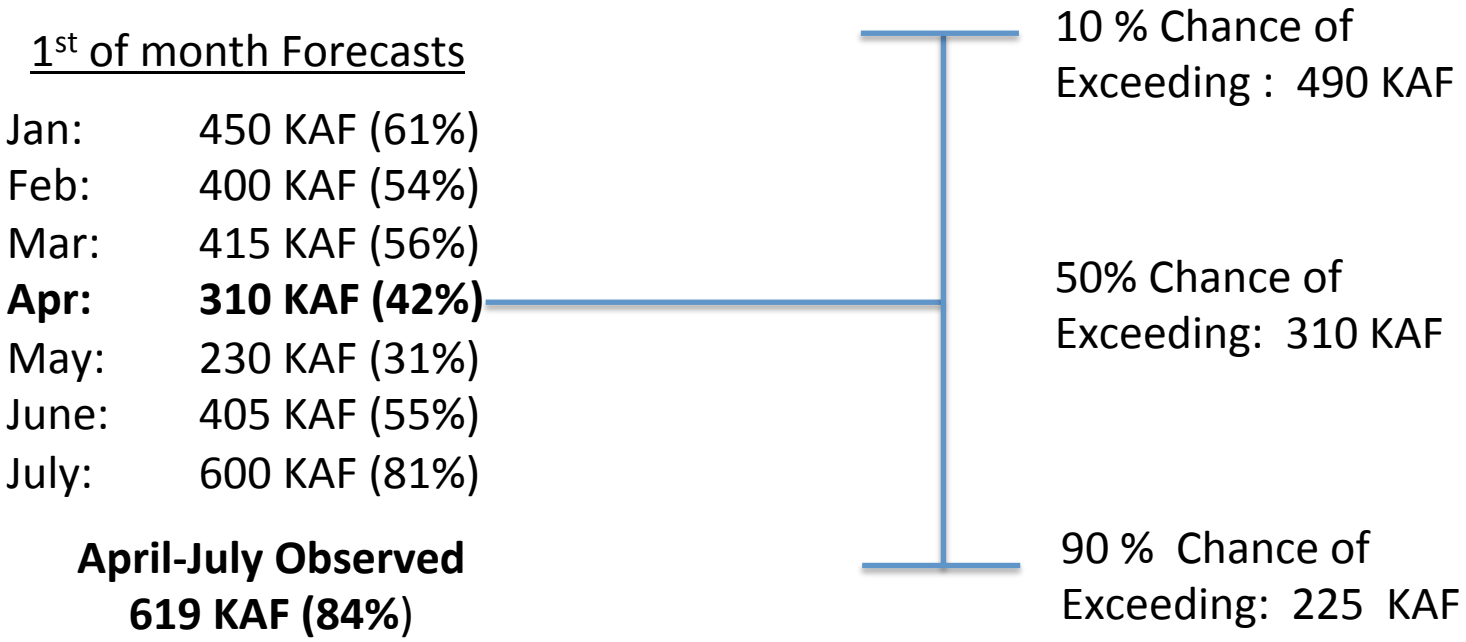
Precipitation fell in the 3-6% historical exceedance probability range

# Forecast Performance: Navajo Reservoir Inflow



# Model / Forecast Performance & Uncertainty

## Navajo Reservoir Inflow Forecast Progression 2015



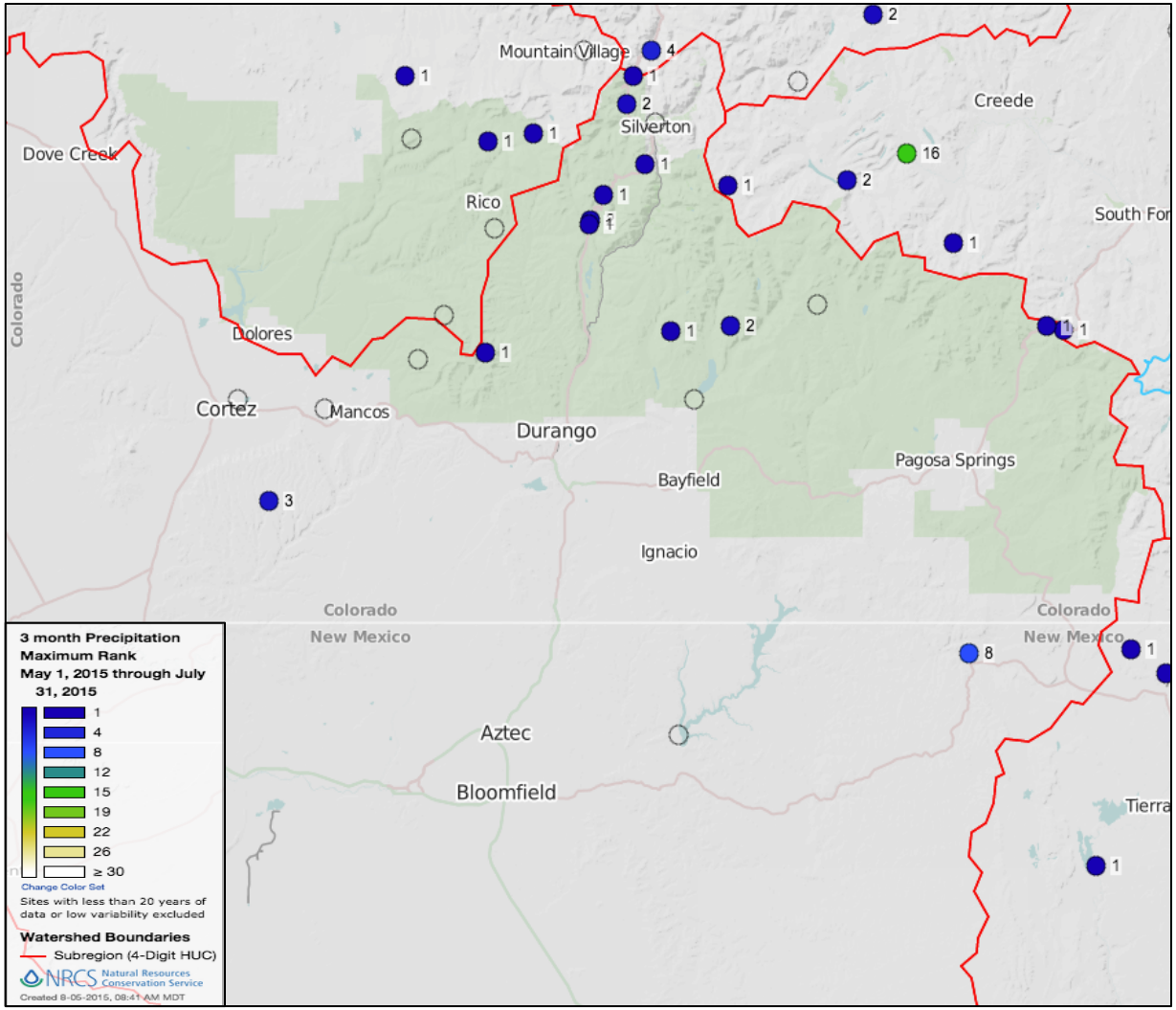

Highest Forecast Trace on April 1 was 698 KAF: (3% exceedance probability)

Second Highest Forecast Trace on April 1 was 584 KAF: (7% exceedance probability)

We would expect spring precipitation to be in that top 3-7% of record to reach the observed volume of 600 KAF.

So was it ?

# San Juan May-July SNOTEL Precipitation
## Historical Ranking

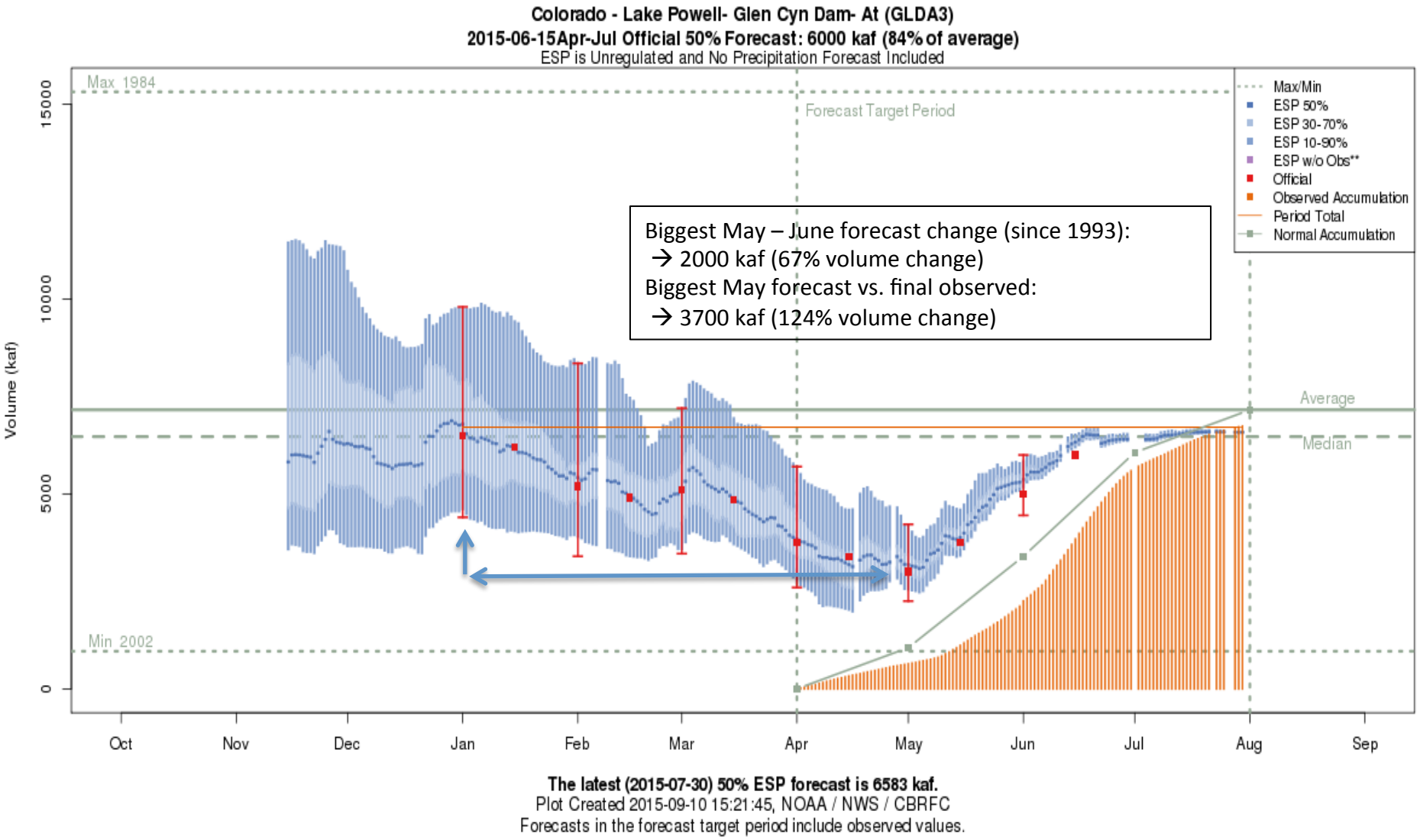



| SNOTEL | Anomaly (in) | % of Avg |
|---|---|---|
| Red Mountain | +6.9 | 196% |
| Molas Lake | +7.0 | 235% |
| Spud Mt | +11.6 | 301% |
| Cascade | +7.8 | 227% |
| Columbus | +11.5 | 254% |
| Stump Lakes | +6.3 | 201% |
| Upper San Juan | +9.6 | 242% |
| Wolf Creek | +11.7 | 281% |

Many sites registered the wettest May-July period in their historical record (30-35 years)

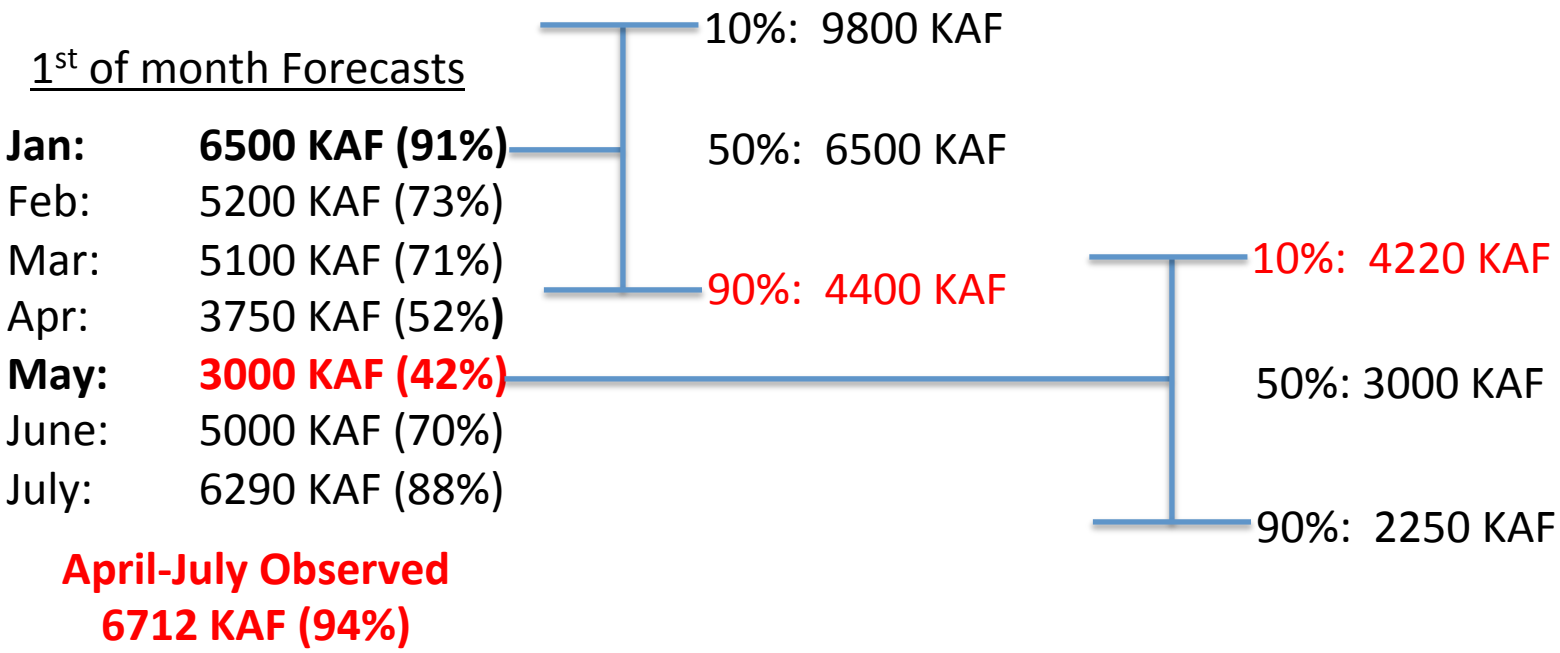
Precipitation fell in the 3-7% historical exceedance probability range

# 2015 Forecast Progression: Lake Powell



# Model / Forecast Performance & Uncertainty

## Lake Powell Inflow Forecast Progression 2015




Lowest Forecast Trace on Jan 1 was 2374 KAF: (97% exceedance probability)

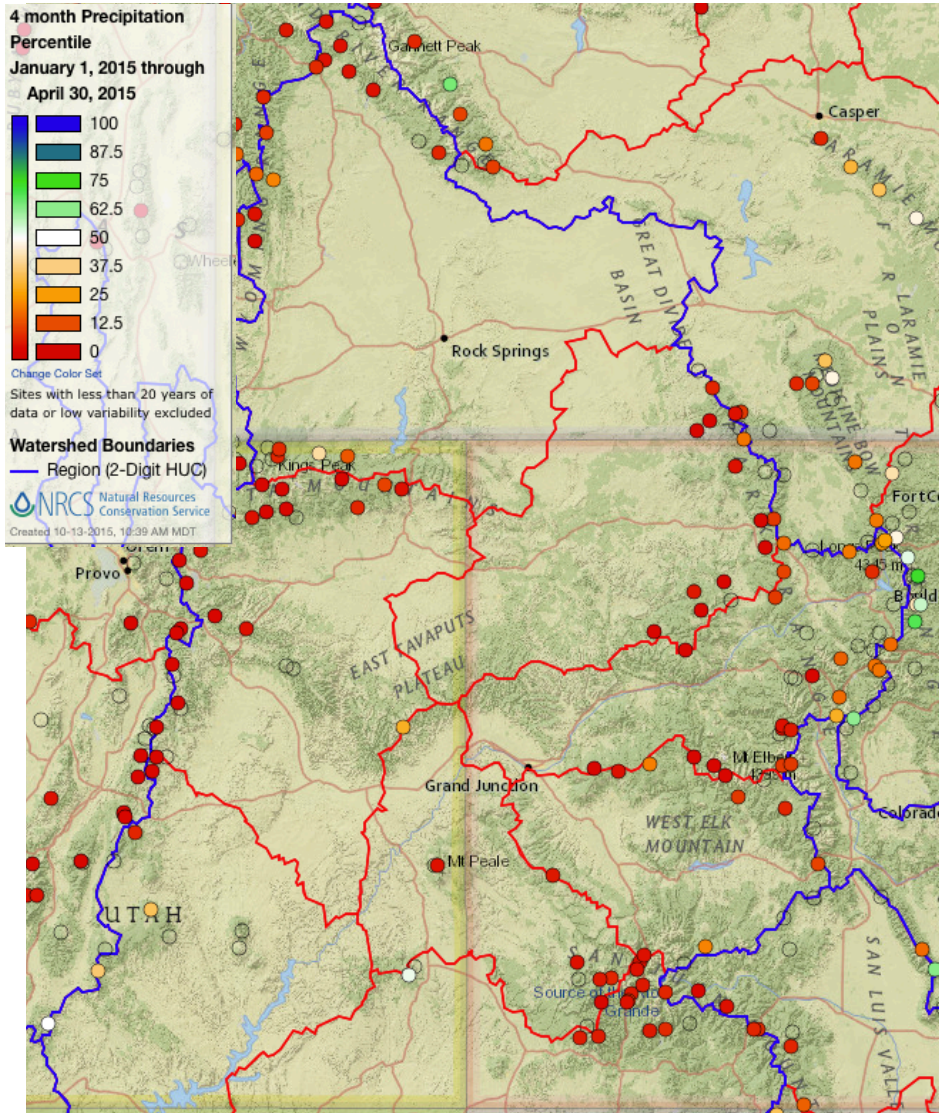
Second Lowest Forecast Trace on Jan 1 was 4371 KAF: (93% exceedance probability)

Highest Forecast Trace on May 1 was 5836 KAF: (3% exceedance probability)

Second Highest Forecast Trace on May 1 was 4390 KAF: (7% exceedance probability)

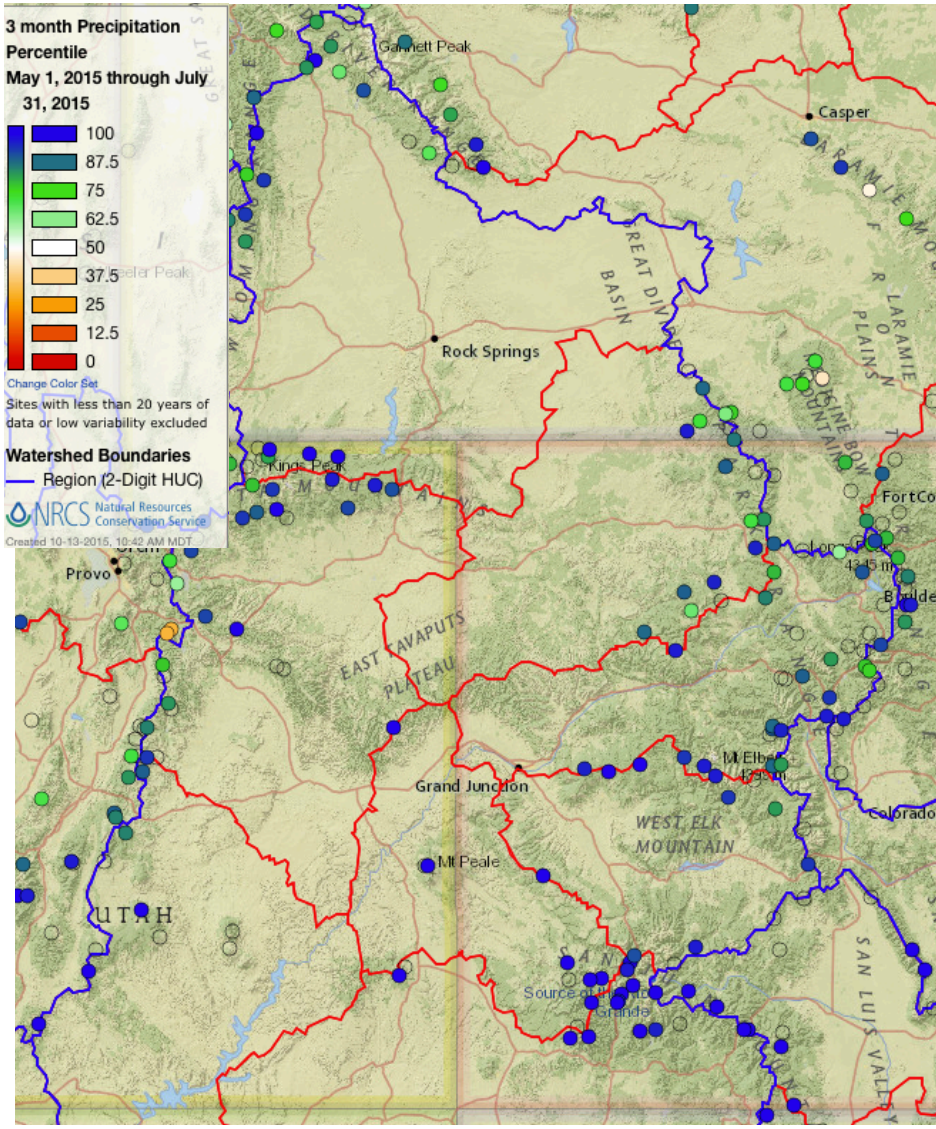
# Colorado River above Lake Powell : SNOTEL Precipitation Rankings – Two Extreme Periods

## January through April 2015




Many sites driest 1-2 on record

## May through July 2015




Many sites wettest 1-3 on record

What can we take-away from 2015?

Forecast/Model errors exist - Calibration Data, Observed Data, **Future Weather**

Model in general **performed as expected** in many areas with large April and May forecast errors. The extreme conditions were caught within the full forecast distribution even though we weren't focusing on that type of scenario developing.

The ability to catch such future weather extremes in water supply forecasts is very limited. It depends upon if these events exist in the calibration period used. Also requires improved and quantifiable longer-term seasonal climate forecasts.

The full forecast distribution is important to consider depending on your level of risk.

The spring rain coming when it did, following lower elevation melt that increased soil moisture conditions, resulted in more efficient runoff.

Late season high elevation snow carries a lot of uncertainty. There is limited to no ground truth and the use satellite data this past spring was limited due to extended and extensive cloud cover.

Unmeasured depletions from the river systems were lower than typical due to reduced demands. This extra water showed up in the final observed volumes at many sites.

Upcoming:

Early waster supply outlook briefing December 2015

Water supply discussions and briefings resume in January

- Water Supply Contacts:
  - Michelle Stokes (Hydrologist in Charge)
  - Brenda Alcorn (Upper Colorado, Lake Powell)
  - Ashley Nielson (Green + Yampa / White)
  - Greg Smith (San Juan + Gunnison + Dolores)
  - Paul Miller (Great Basin – Bear, Weber, Provo, Six-Creeks/Jordan)
  - Tracy Cox (Lower Colorado + Virgin + Sevier)

Please contact us with any specific questions