NOAA/NWS Streamflow Forecasts

Global and Regional
Climate Changes
Kiev, Ukraine

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Colorado Basin RFC
November 18, 2010

Outline

- Background
- Forecast Methodology
- Collaboration Opportunities

Colorado Basin River Forecast Center

One of 13 River Forecast Centers

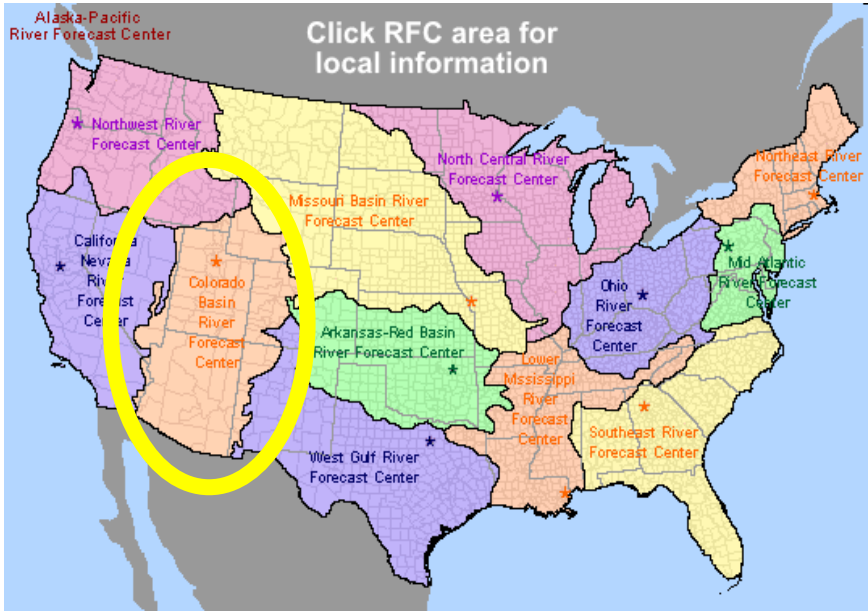
Established in the 1940s for water supply forecasting

Three primary missions:

1. Seasonal **Water supply forecasts** for water management

2. **Daily forecasts** for flood, recreation, water management

3. **Flash flood warning support**

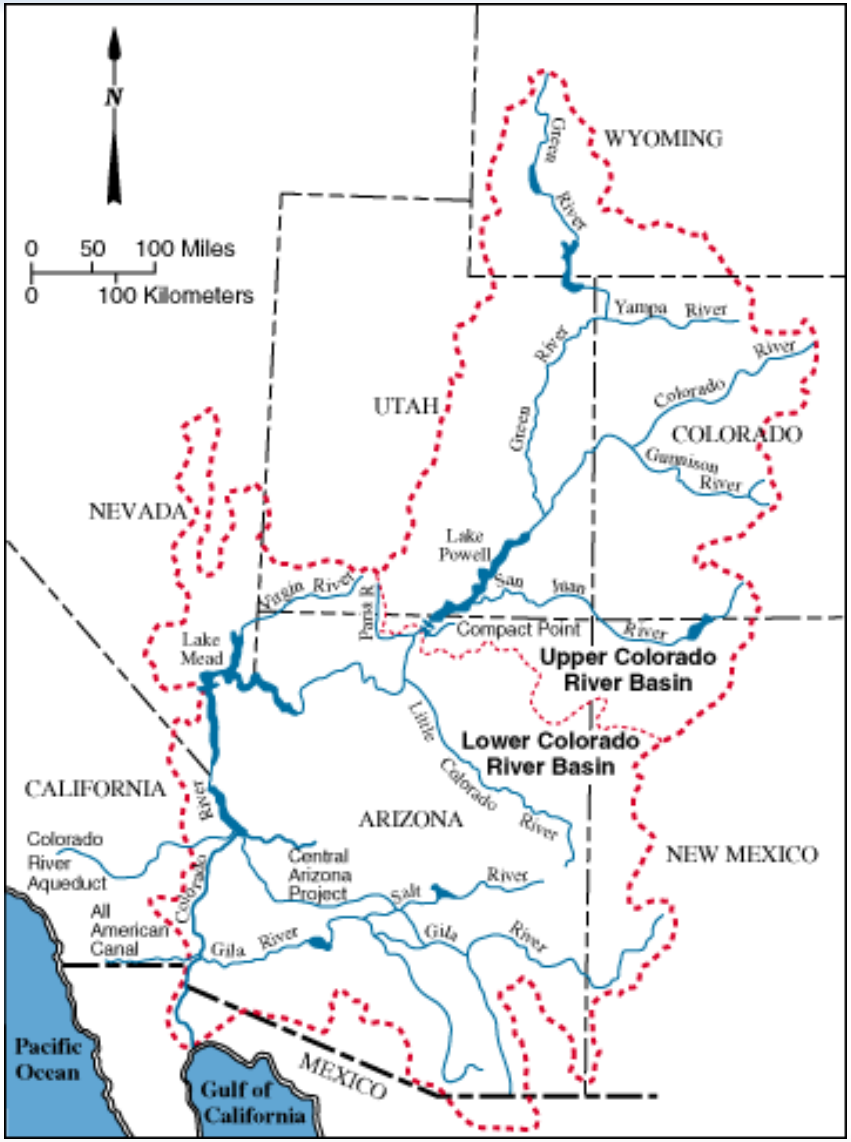


www.cbrfc.noaa.gov

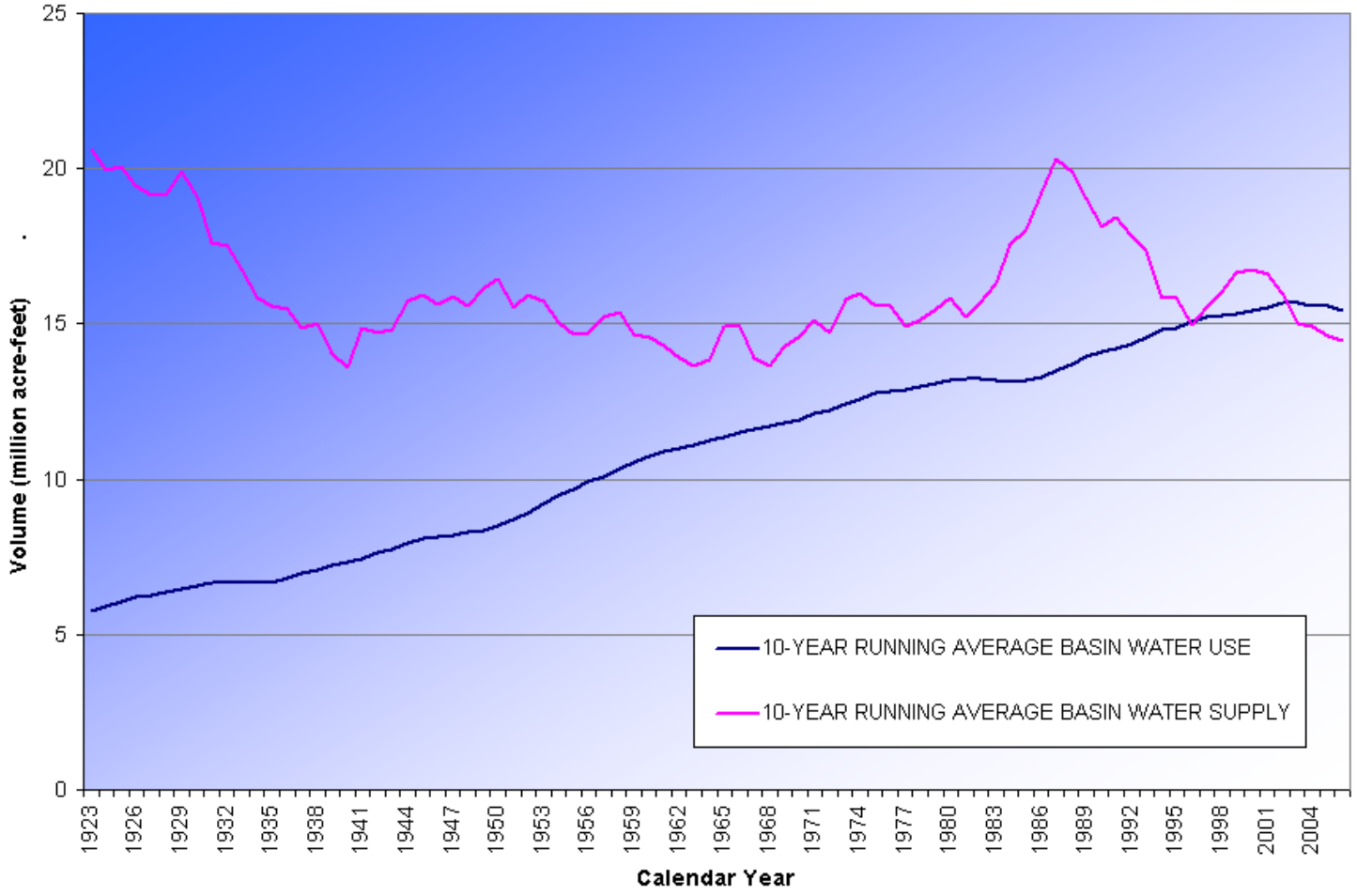
Colorado River Basin

Key Characteristics:

- 640,000 km2
- River is 2300 km long
- Mostly semi-arid with annual precipitation ranging from 3” (8 cm) to 75” (190cm)
- Runoff dominated by snowmelt from mountains
- Reservoir storage capacity (74 km3) is ~4 times mean annual flow
- Average annual water demand approximately equal to supply

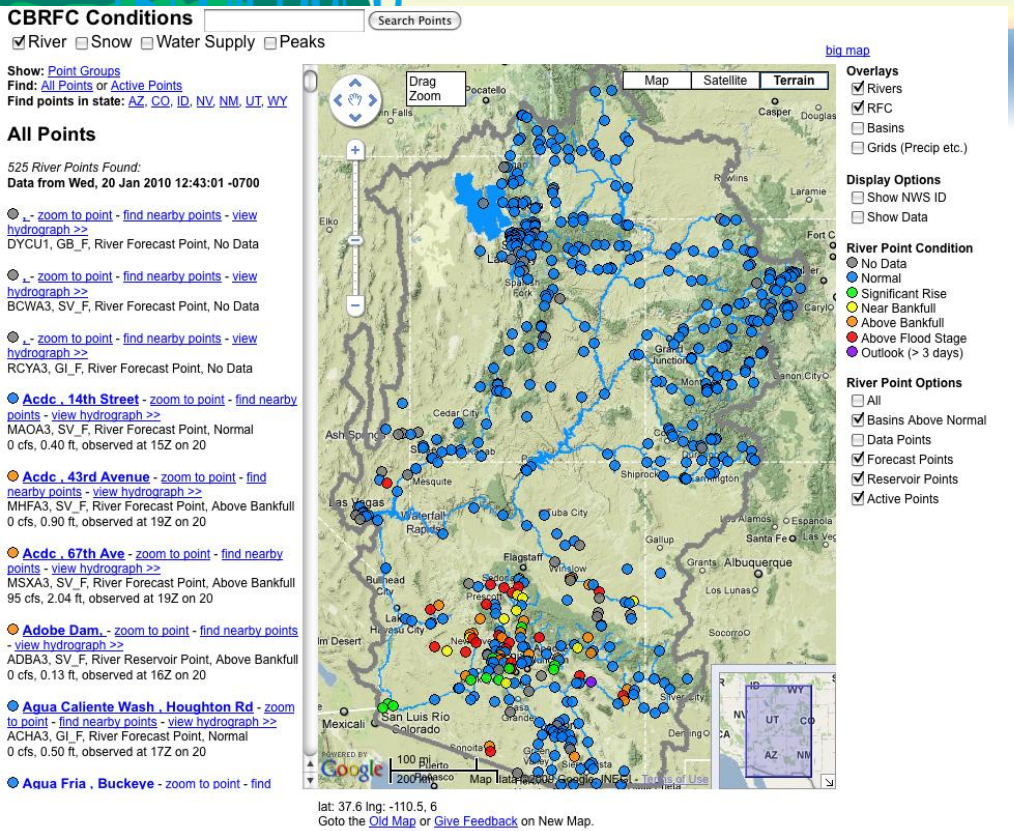


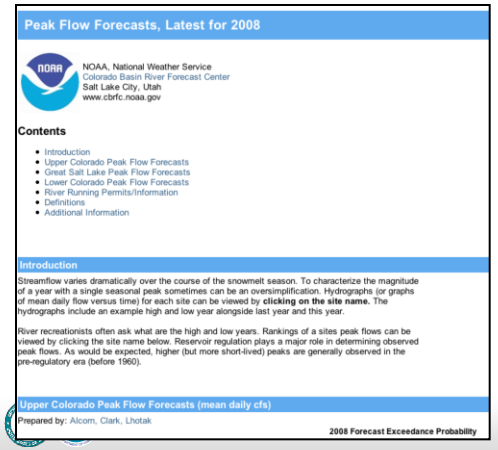
Colorado River Supply and Demand

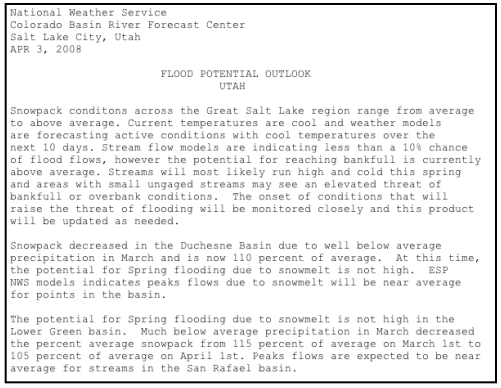


Credit: USBR

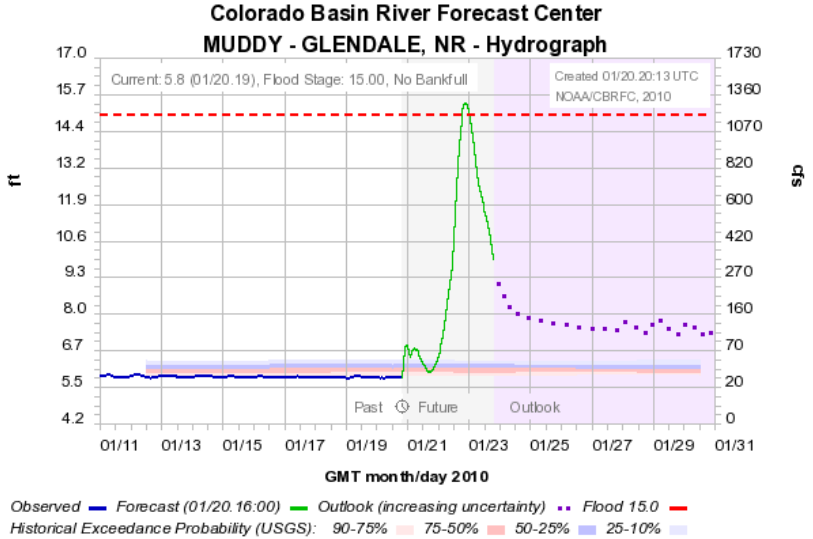
Flood Forecasts / Routine Forecasts



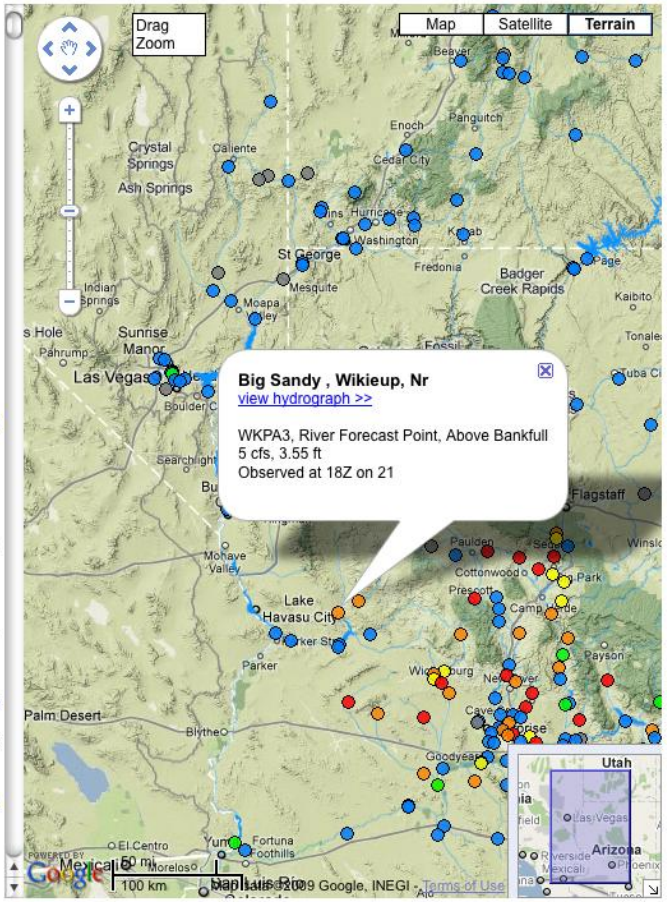




- Nominally provided at ~400 points every 6 hours out to 14 days.
- Flexible web interface to forecasts and data
- Requires large amounts of data (e.g. snow, precip, temps, streamflow)



Flood Forecasts / Routine Forecasts



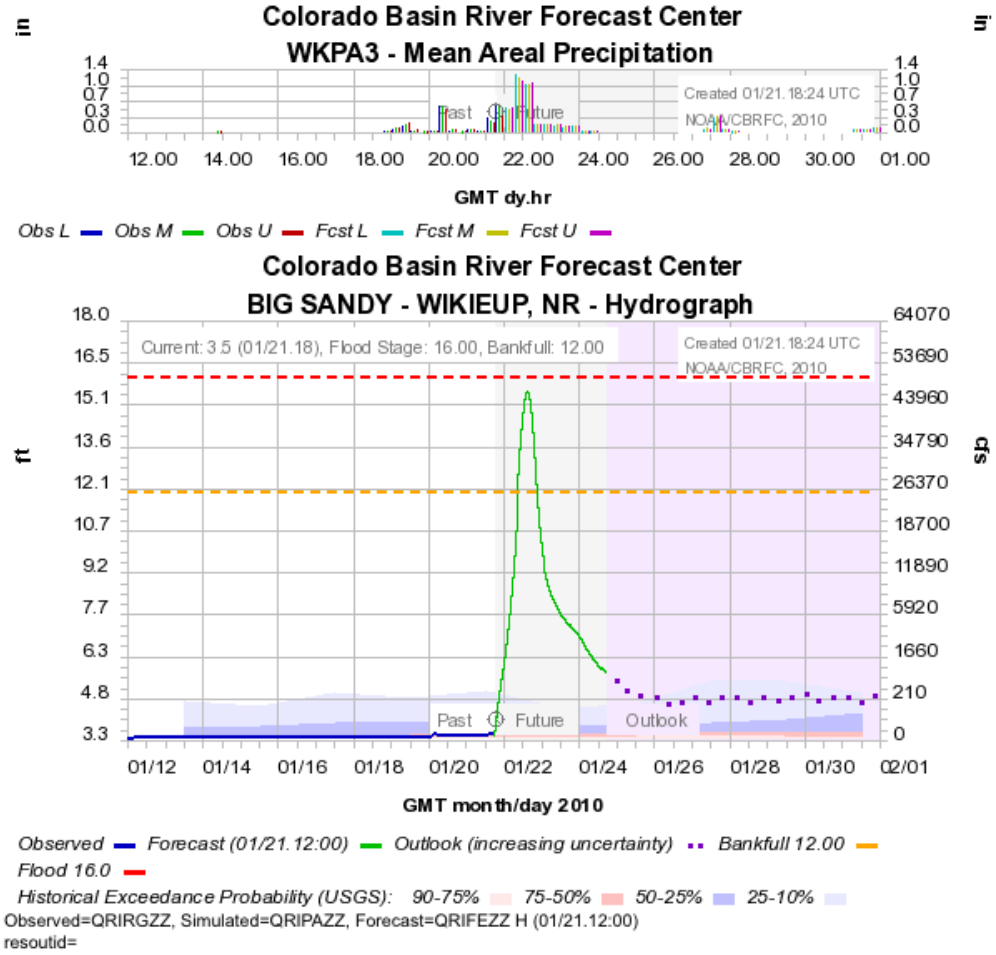
Overlays
- [x] Rivers
- [x] RFC
- [ ] Basins
- [ ] Grids (Precip etc.)

Display Options
- [ ] Show NWS ID
- [ ] Show Data

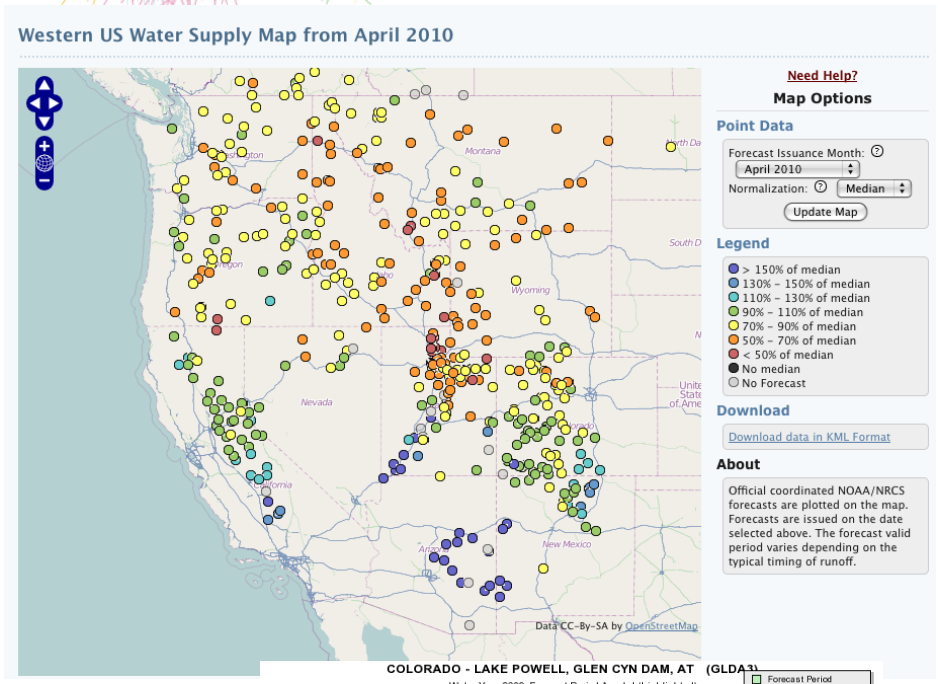
River Point Condition
- No Data
- Normal
- Significant Rise
- Near Bankfull
- Above Bankfull
- Above Flood Stage
- Outlook (> 3 days)

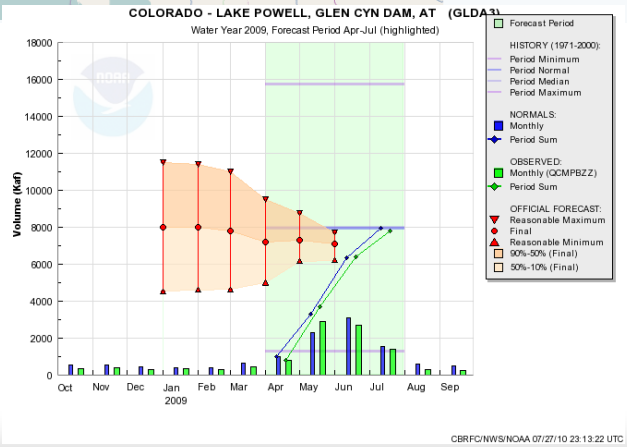
River Point Options
- [ ] All
- [x] Basins Above Normal
- [ ] Data Points
- [x] Forecast Points
- [x] Reservoir Points
- [x] Active Points

lat: 35.59 lng: -113.58, 7
Goto the Old Map or Give Feedback on New Map.

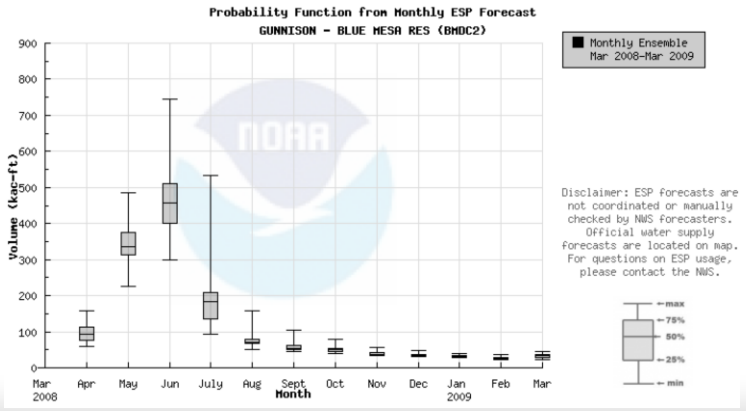


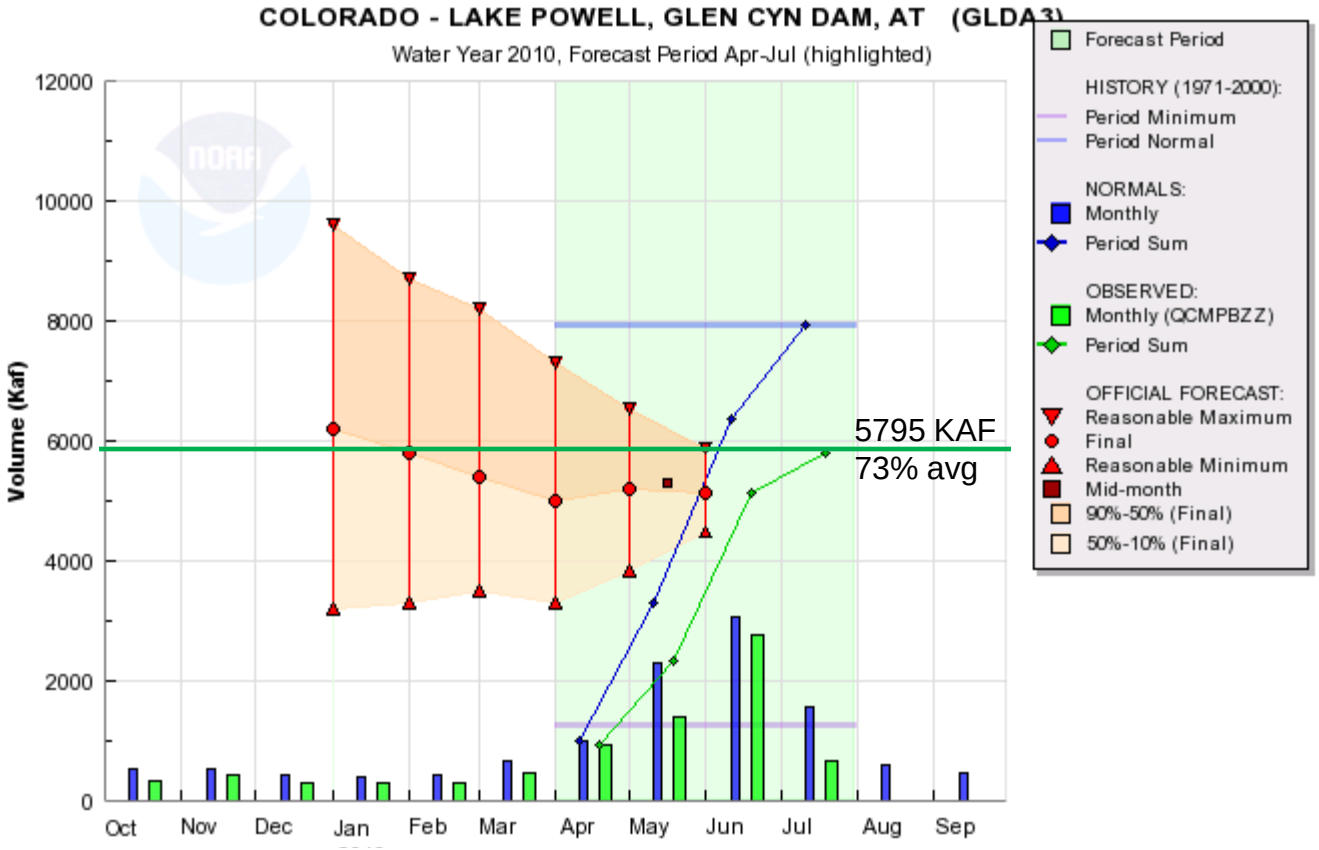
Water Supply Forecasts

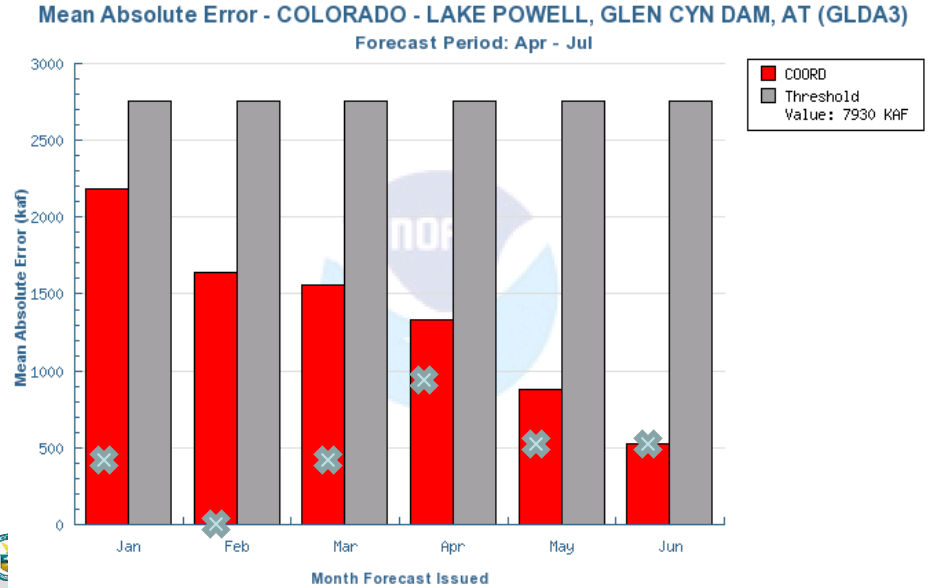


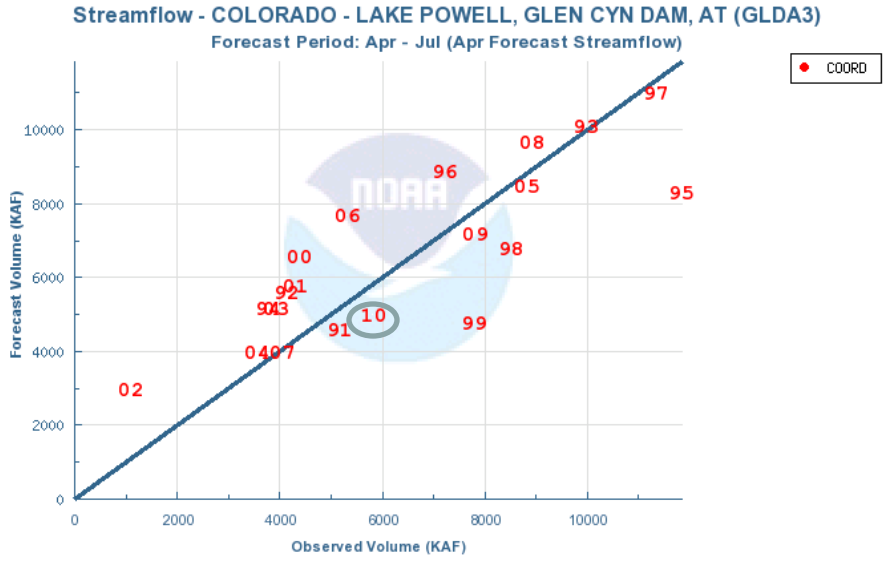


- Forecasts for spring snowmelt runoff volume
- Forecasts at ~100 points in Colorado Basin important for water management
- Forecasts typically issued during winter and spring months (e.g. snow accumulation season)




COLORADO - LAKE POWELL, GLEN CYN DAM, AT (GLDA3)
Water Year 2010, Forecast Period Apr-Jul (highlighted)
Volume (Kaf)
12000
10000
8000
6000
4000
2000
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
5795 KAF
73% avg
Forecast Period
HISTORY (1971-2000):
Period Minimum
Period Normal
NORMALS:
Monthly
Period Sum
OBSERVED:
Monthly (QCMPBZZ)
Period Sum
OFFICIAL FORECAST:
Reasonable Maximum
Final
Reasonable Minimum
Mid-month
90%-50% (Final)
50%-10% (Final)


Mean Absolute Error - COLORADO - LAKE POWELL, GLEN CYN DAM, AT (GLDA3)
Forecast Period: Apr - Jul
Mean Absolute Error (kaf)
3000
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Month Forecast Issued
COORD
Threshold
Value: 7930 KAF


Streamflow - COLORADO - LAKE POWELL, GLEN CYN DAM, AT (GLDA3)
Forecast Period: Apr - Jul (Apr Forecast Streamflow)
Forecast Volume (KAF)
10000
8000
6000
4000
2000
0
0
2000
4000
6000
8000
10000
Observed Volume (KAF)
COORD
97
93
08
96
05
95
06
09
98
00
01
92
03
10
91
99
04
07
02

Forecast Methods

➢Ensemble Streamflow Prediction (ESP)

- A component of a continuous conceptual model (NWSRFS)
- Continuous *real time* inputs (temperature, precipitation, forecasts)
- Accounts for soil moisture states (SAC-SMA) - drives runoff efficiency
- Builds and melts snowpack (Snow-17) – output feeds SAC-SMA
- Flexible run date, forecast period, forecast parameters.
- Evolving toward ESP as primary forecast tool

➢Statistical Water Supply (SWS)

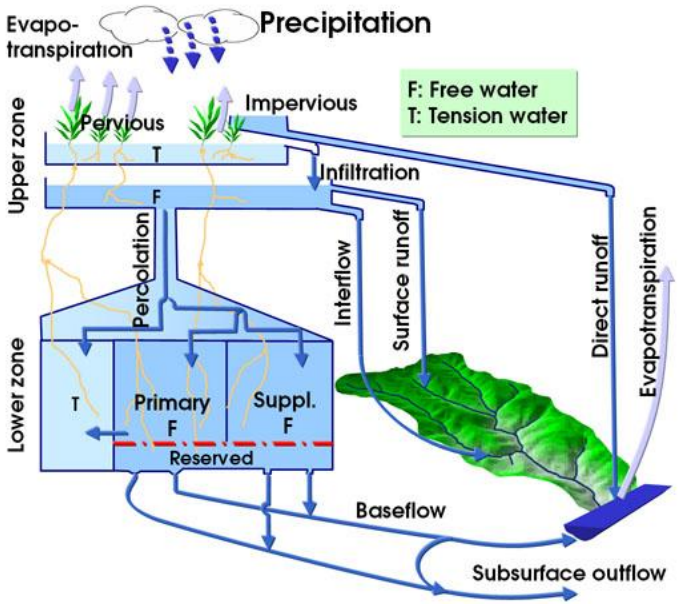
- Statistical Regression Equations
- Primary method from 1940's to mid 1990's.
- Historical Relationships between flow, snow, & precipitation (1971-2000+)
- Tied to first of the month data and for a fixed runoff period (inflexible)

Conceptual Model

RFC forecast uses a snow model and a rainfall-runoff model:

- SNOW-17: Temperature index model for simulating snowpack accumulation and melt
- Sacramento Soil Moisture Accounting Model: Conceptual hydrologic model used to generate runoff

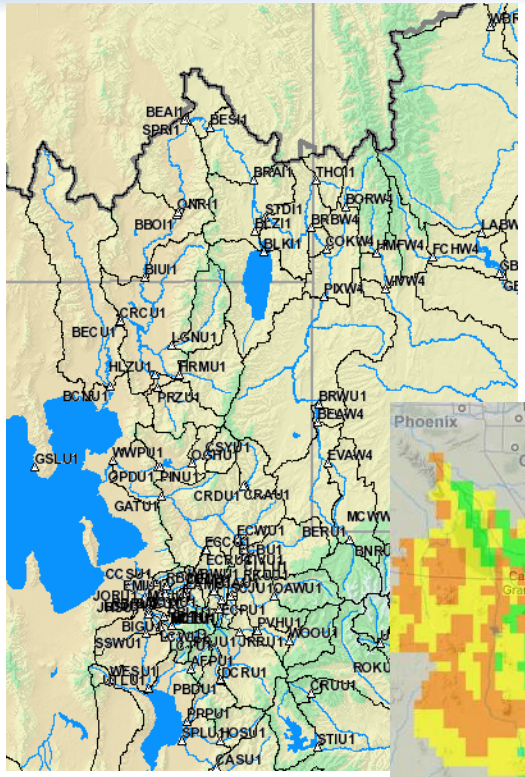
Snow Model: SNOW-17
Temperature Index Snow model

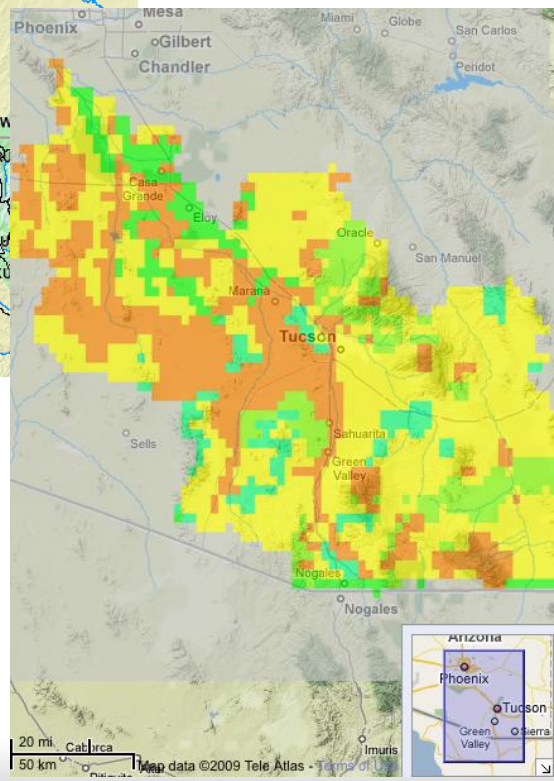


Model Structure

Geographic:

- Lumped over a basin – Traditional RFC models treat entire basin above a gauge as a discrete unit
- Spatially distributed – Many models – including RFC experimental models – model hydrology in geographic grids

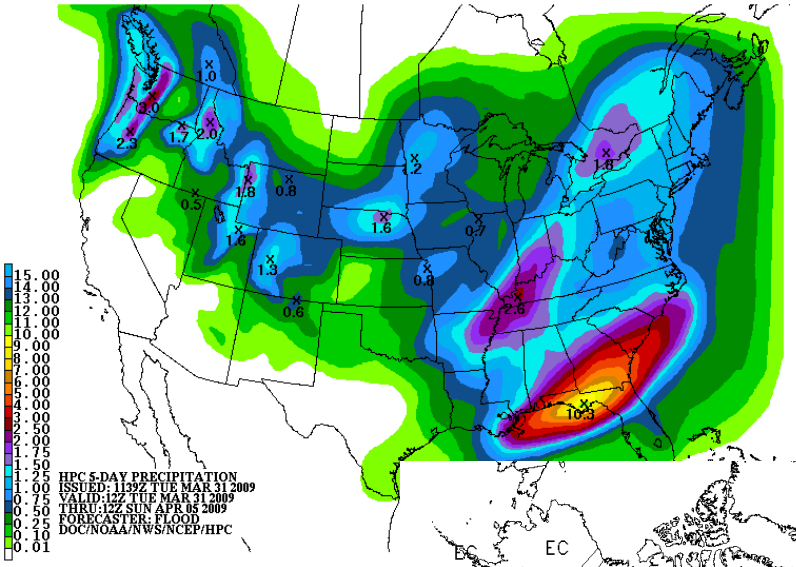


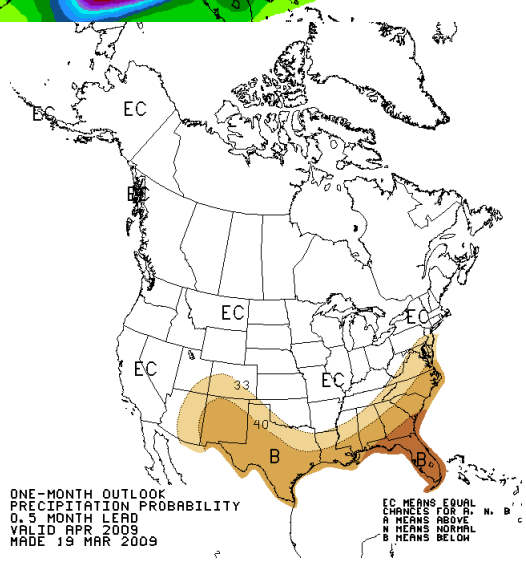


Weather and Climate Forecasts

RFC forecast system incorporates both weather and climate forecasts:

- Weather forecasts integrated into daily operations with forecaster control over point and basin average values
- Climate forecasts integrated into seasonal water supply forecasts through probability shifts of forcing ensemble

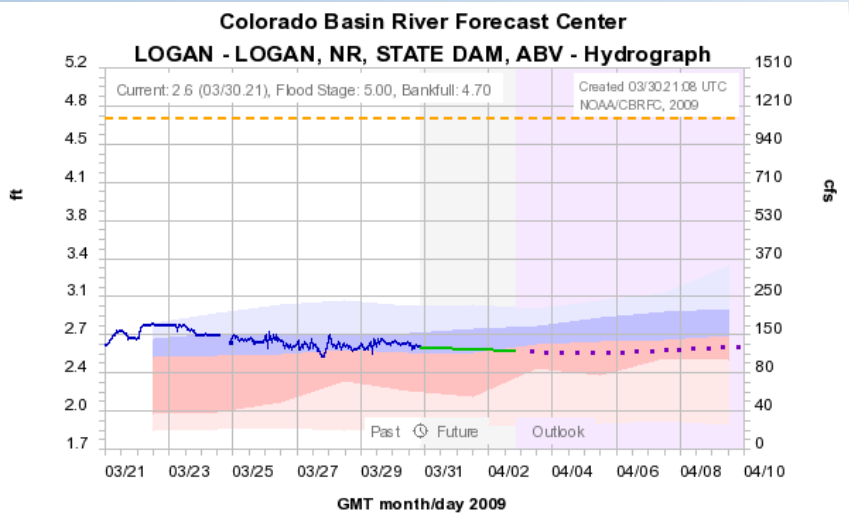


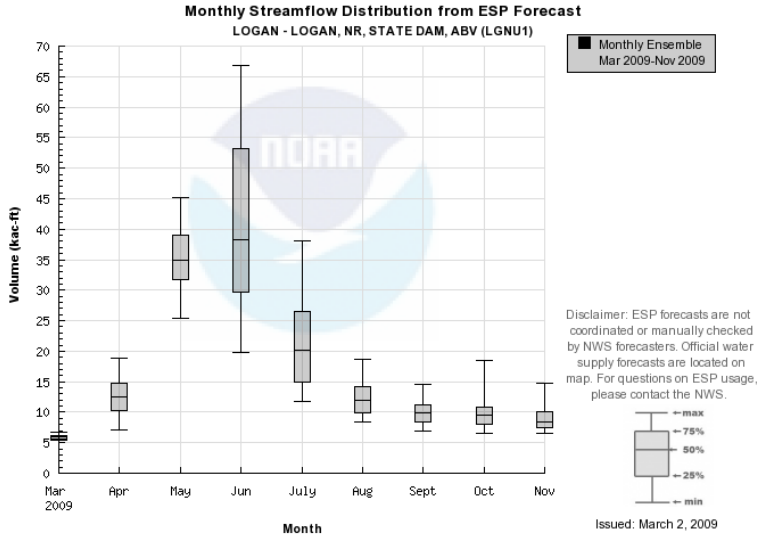


Model Structure

Forecast “mode”:

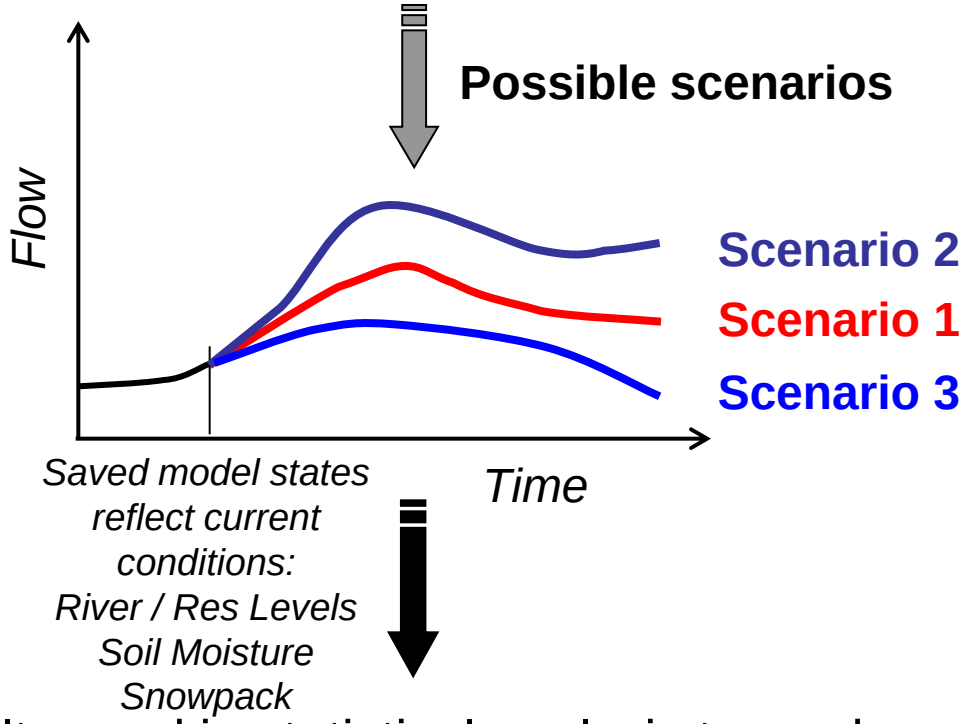
- Deterministic – Single value forecast time series of streamflow, model states, soil moisture, etc.
- Probabilistic – Ensemble of forecast time series





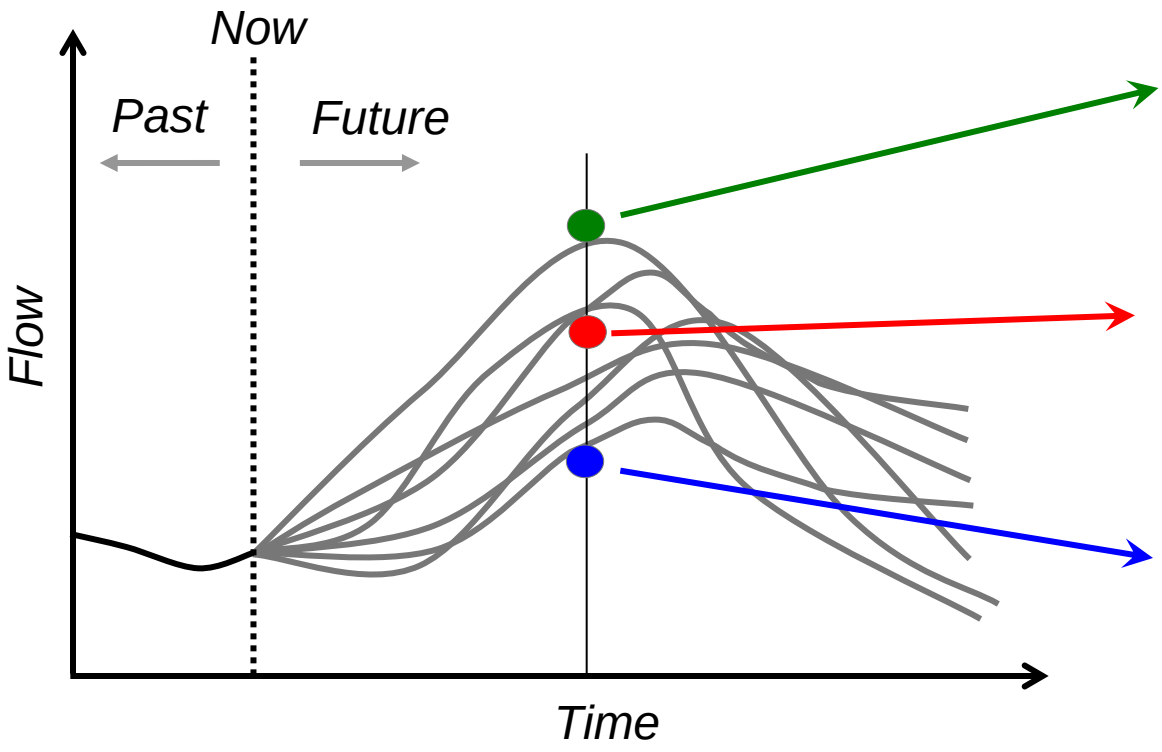
ESP Technique

Multiple streamflow scenarios with historic meteorological or forecast weather/climatic data



Results used in statistical analysis to produce forecasts with probabilistic values

ESP Technique

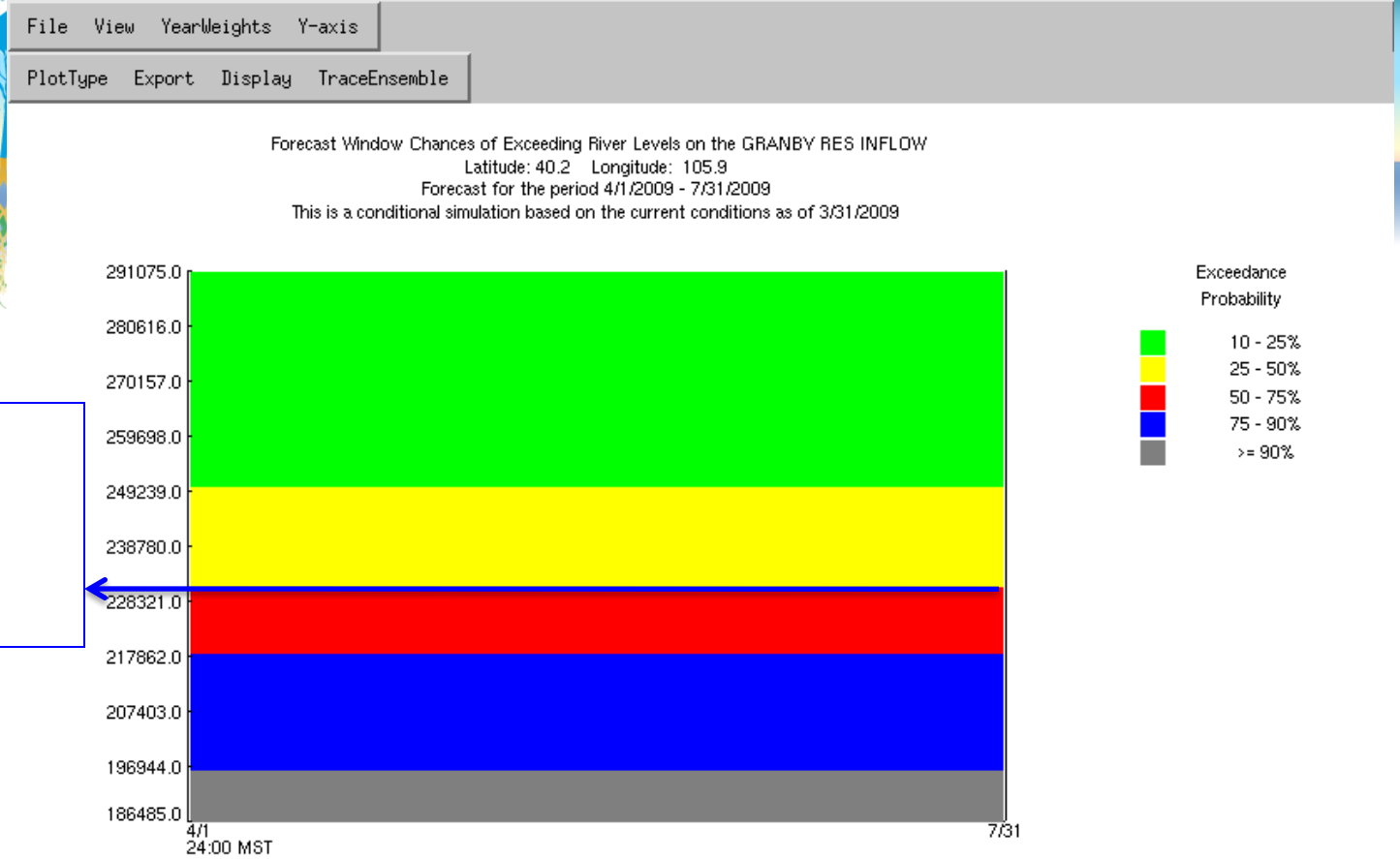


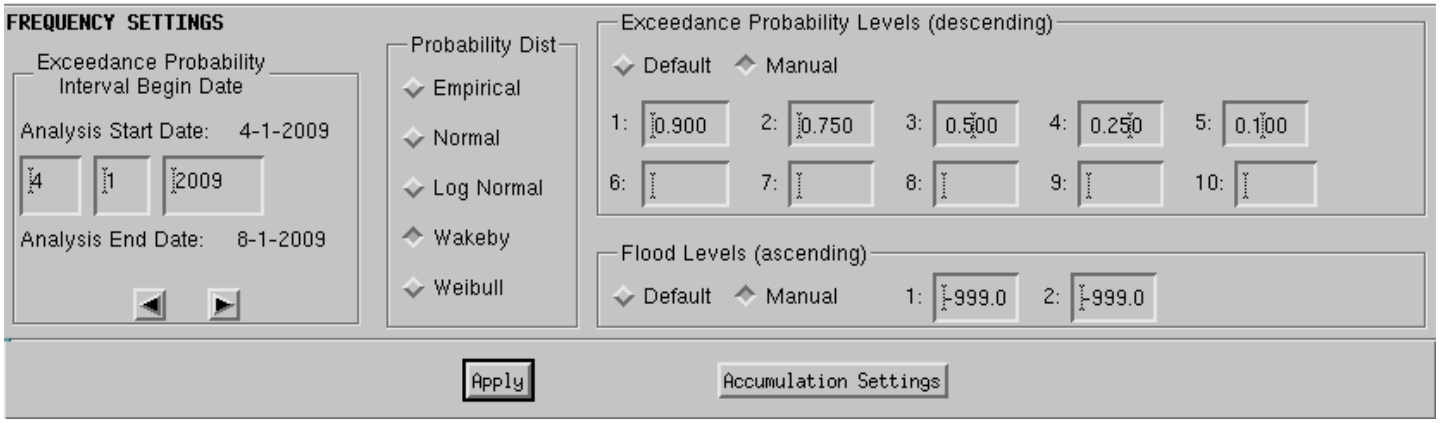
Low chance of this level flow or higher

Medium chance of this level flow or higher

High chance of this level flow or higher

Ensemble 50% exceedance Forecast:
230 kac-ft



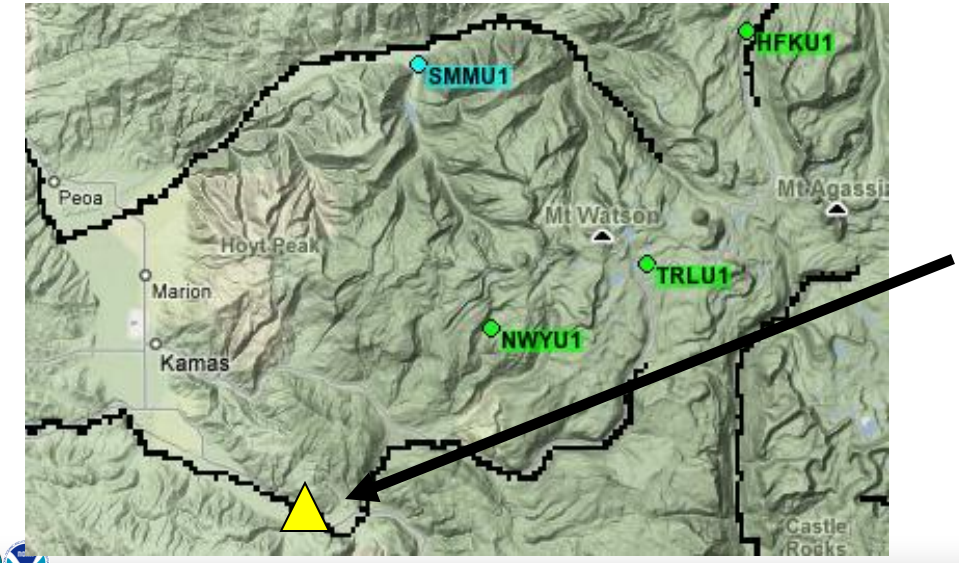


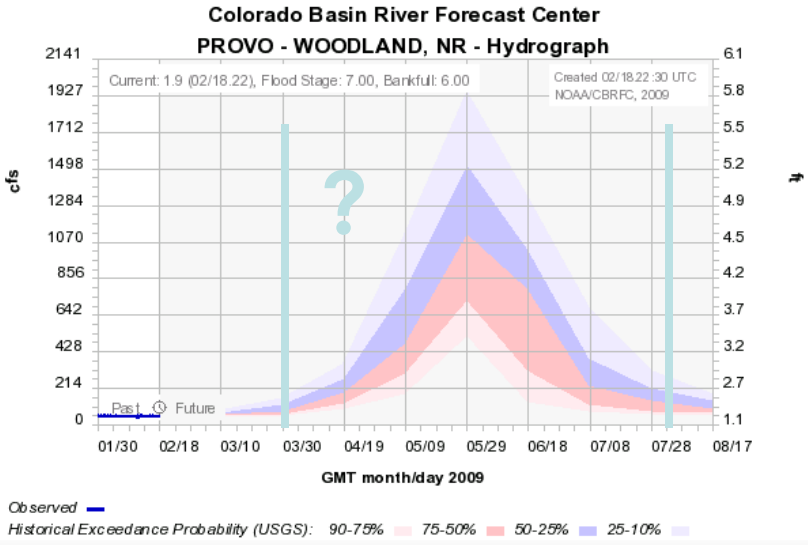
Statistical Water Supply (SWS)

- **Equations built on relationships between the inputs and the output**

Output Variable:

April-July streamflow volume at Provo-Woodland

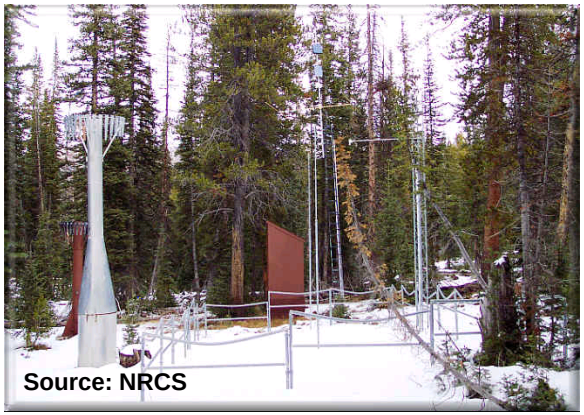


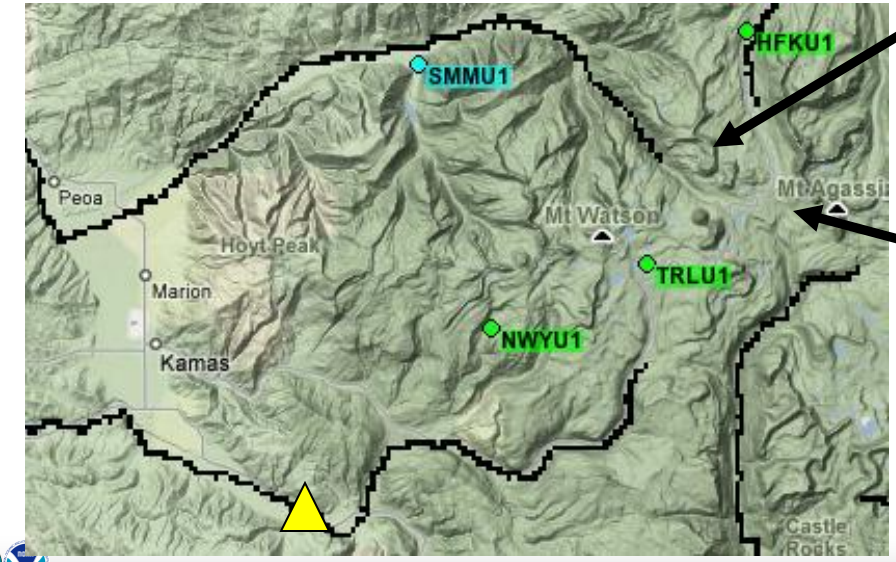


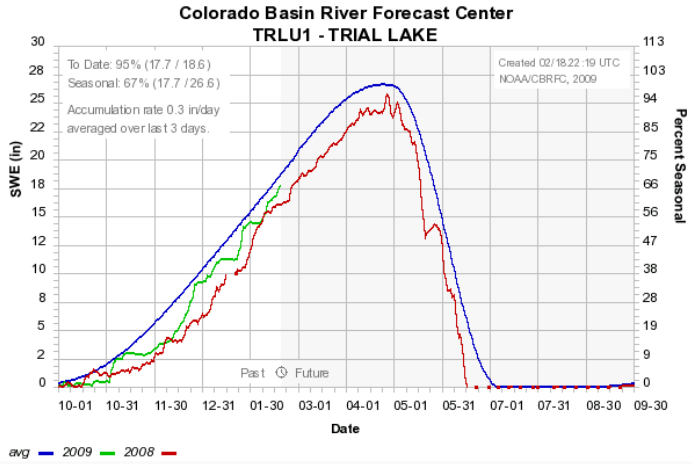
Statistical Water Supply (SWS)

- **Equations built on relationships between the inputs and the output**

Input Variable: Trial Lake Snow







File Options Actions Help

```
-------------------------------------------------------------------------------
GBYC2 QCMPAZZ P  Apr-Jul (COLORADO - LAKE GRANBY, GRANBY, NR) JR2: 0.360 # yrs: 30
      AVG:      225.000   YTRANS: none
-------------------------------------------------------------------------------

  LAKE IRENE LKIC2/SWIRMZZ
                  Apr   25.30Z     98%   *    2.623  =      66.36

  PHANTOM VALLEY PHTC2/SWIRMZZ
                  Apr    9.90Z    107%   *    4.481  =      44.36

  STILLWATER CREEK SCSC2/SWIRMZZ
                  Apr    6.90Z     88%   *    1.886  =      13.01

  GRAND LAKE 1NW GLKC2/PPMRZZZ (Nov - Mar):
                  Nov     1.05V     77%
                  Dec     2.10E    133%
                  Jan     2.37V    130%
                  Feb     0.92V     61%
                  Mar     0.74V     49%
                       -------  ------
                          7.18      92%   *    5.238  =      37.61
                                                         --------
                                      60.493 +          161.35  =     221.84 (    99%)
-------------------------------------------------------------------------------
GBYC2 QCMPAZZ a  Apr-Jul (COLORADO - LAKE GRANBY, GRANBY, NR) JR2: 0.479 # yrs: 30
      AVG:      225.000   YTRANS: none
-------------------------------------------------------------------------------

  LAKE IRENE LKIC2/SWIRMZZ
                  Apr   25.30Z     98%   *    1.825  =      46.17

  PHANTOM VALLEY PHTC2/SWIRMZZ
                  Apr    9.90Z    107%   *    2.837  =      28.09

  STILLWATER CREEK SCSC2/SWIRMZZ
                  Apr    6.90Z     88%   *    2.468  =      17.03

  GRAND LAKE 1NW GLKC2/PPMRZZZ (Nov - Mar):
                  Nov     1.05V     77%
                  Dec     2.10E    133%
                  Jan     2.37V    130%
                  Feb     0.92V     61%
                  Mar     0.74V     49%
                       -------  ------
                          7.18      92%   *    5.552  =      39.86

  COLORADO - LAKE GRANBY, GRANBY, NR GBYC2/QCMPAZZ
```

Statistical 50% exceedance Forecast:
222 kac-ft

GBYC2 QCMPAZZ_0710	Coordinated		Model Computed		Comp. w/ Coord.		NWS Preferred.		Other Agency	
R. Max	275.00	122%	288.04	128%		%	291.20	129%	0.00	0%
Most Prob.	**225.00**	**100%**	**221.84**	**99%**		%	**225.00**	**100%**	**220.00**	**98%**
R. Min	178.00	79%	155.64	69%		%	158.80	71%	0.00	0%

Input Specification | Eqn Output/Fcst Input | Fcst Point Stats | Eqn Stats | Fcst Performance (Oper) | Fcst Performance (Calib) | Log

nextreg ver 2.3.3

Forecast Coordination

Forecasts are coordinated with NRCS on a monthly basis. Forecasters at each agency compare forecasts, analyze differences, and come up with a official, coordinated forecast.

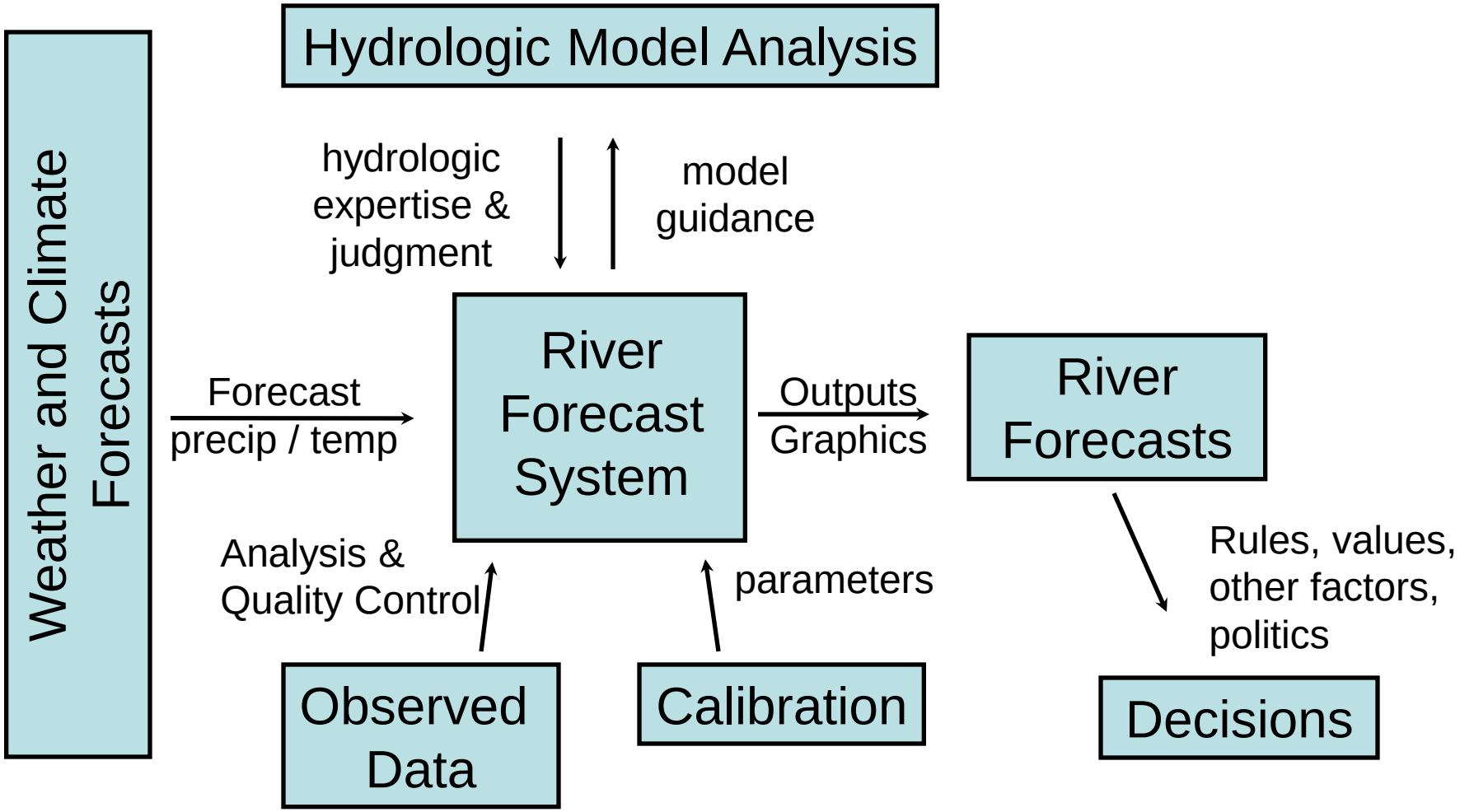
NRCS
Natural Resources Conservation Service

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

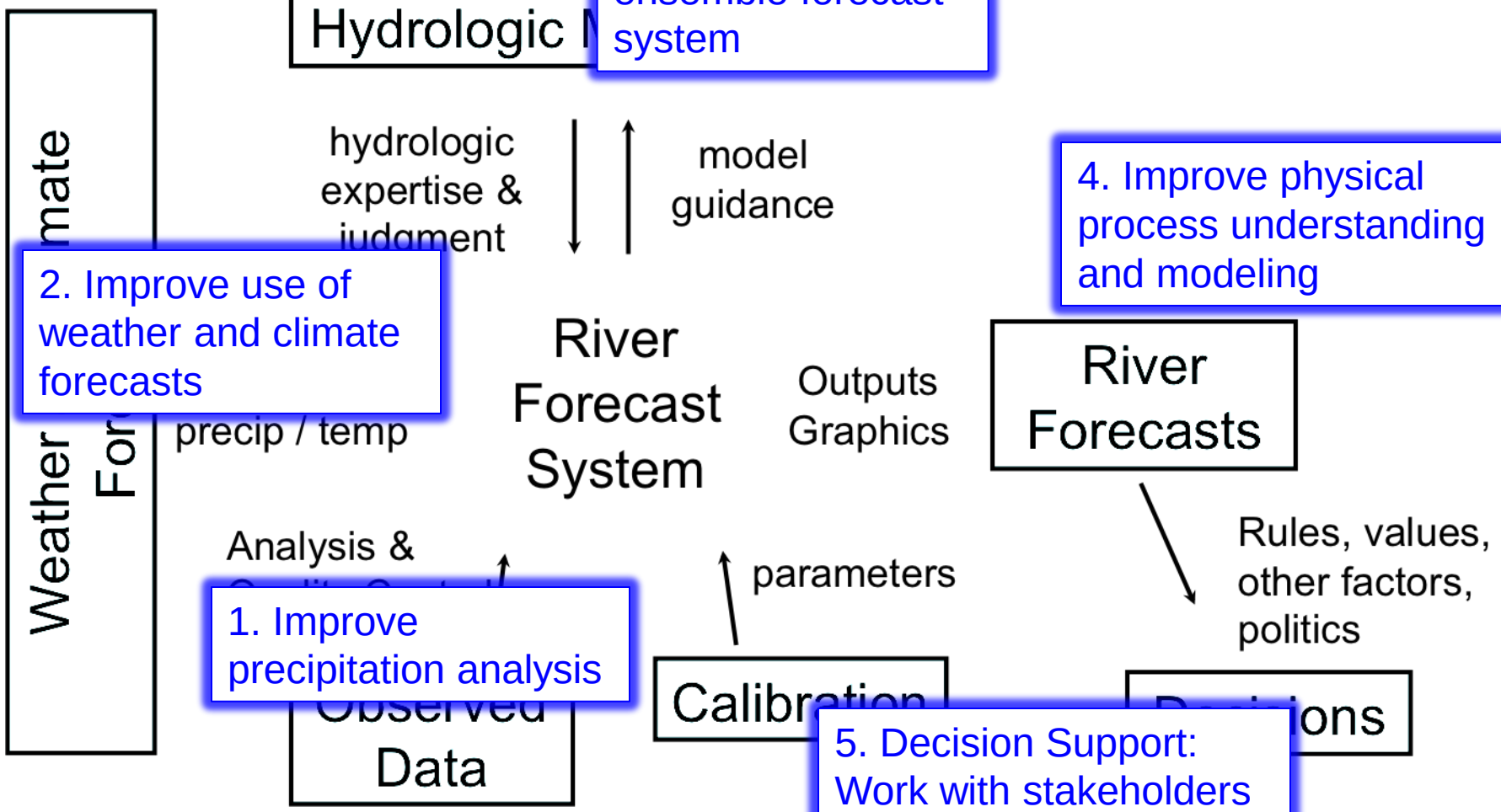
NRCS 50% exceedance Forecast:
220 kac-ft

NOAA 50% exceedance Forecast:
225 kac-ft

Forecast Process



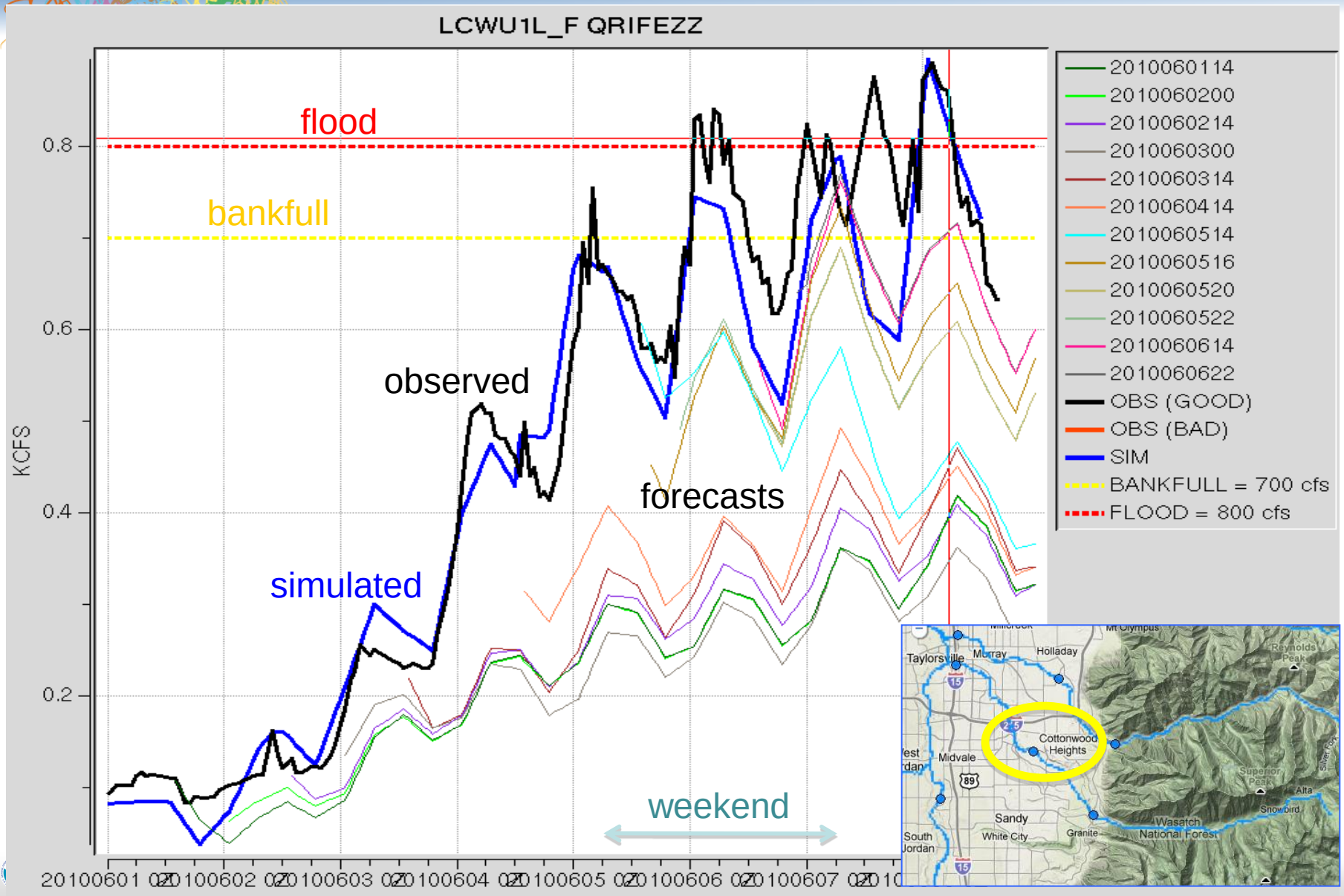
Research Needs

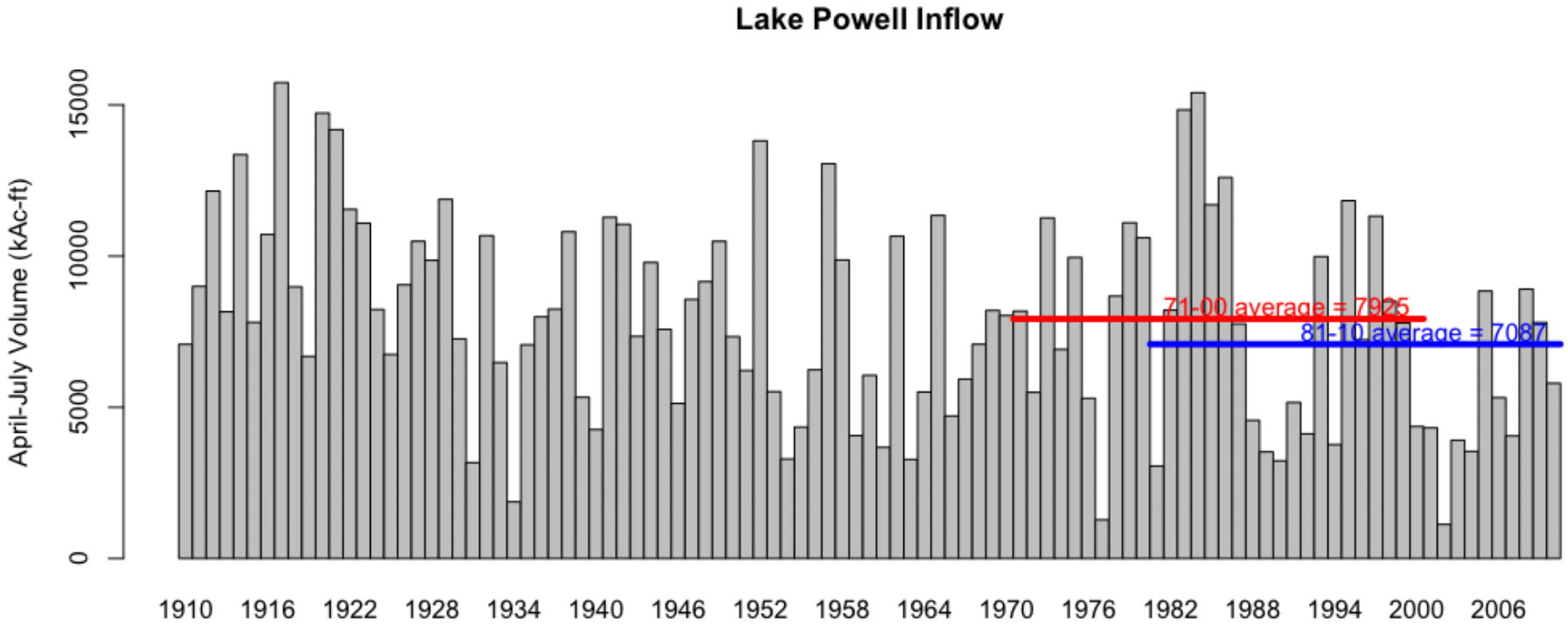


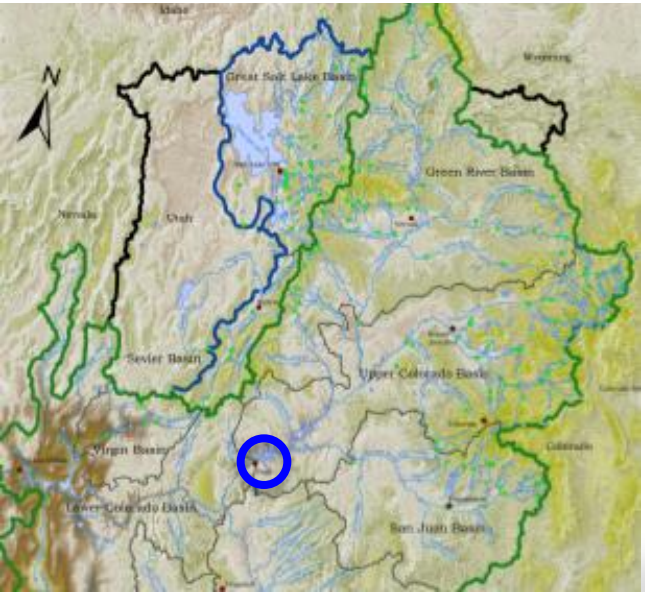
Projects

- Implementing Hydrologic Ensemble Forecasting System
- Major software change: Community Hydrologic Prediction System
- Testing spatially distributed models
- Modeling PET for improved modeling and demand forecast
- Event post mortems
- 30 year average update
- Improving stakeholder engagement

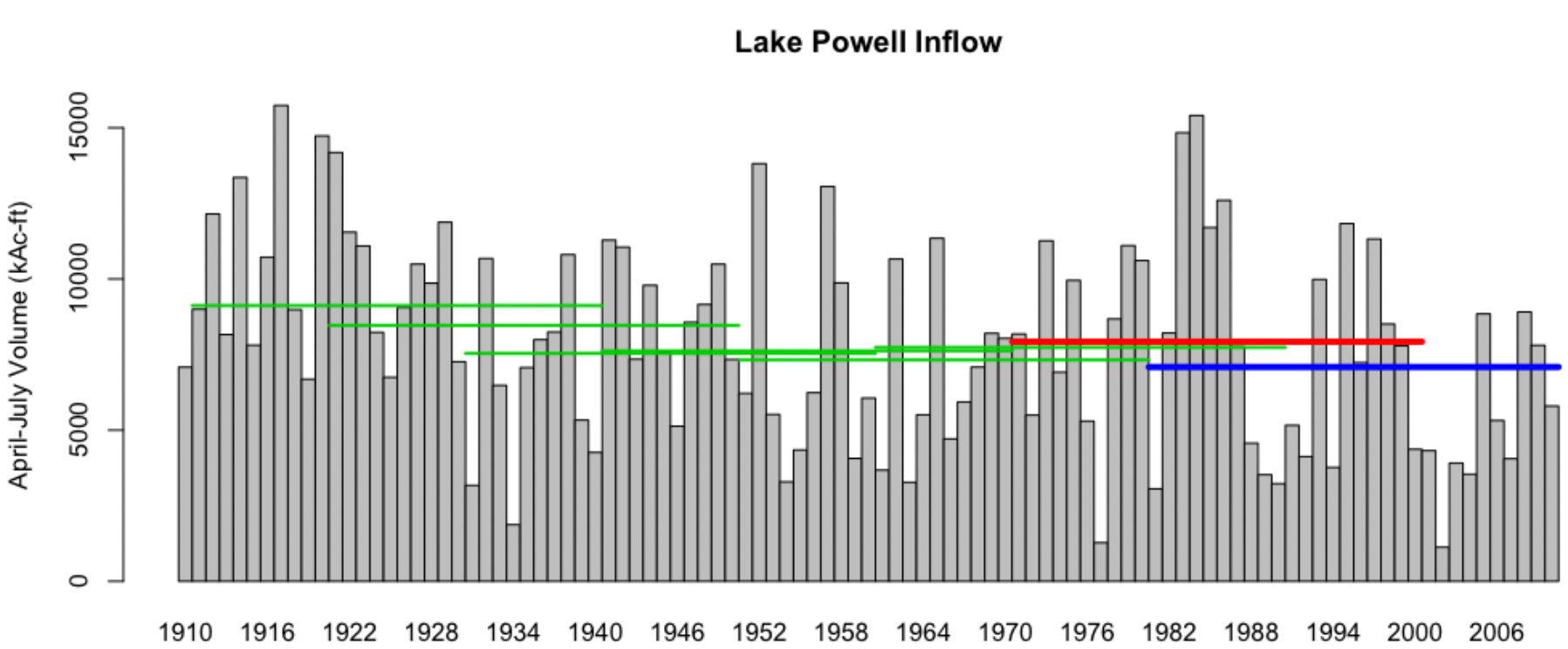
Little Cottonwood at Crestwood Park flow under forecast

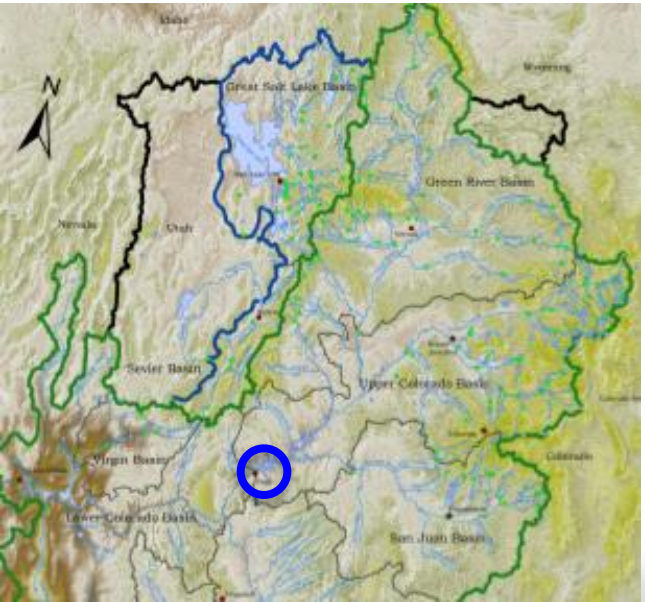






- Preliminary Data
- 11% reduction in mean





- Preliminary Data
- All 30 year means since 1911-1940

Potential Collaboration Opportunities

1.NOAA/NESDIS – Ukrainian Academy of Science and Ukrainian Meteorological Service agreement
2.US-Ukraine Science and Technology Agreement – Ongoing discussions and working group in place
3.WMO Voluntary Cooperation Program – Annual call for proposals less than $100k generally covering equipment and/or travel expenses
4.NOAA – Russian Hydromet services agreement – Possible model or template for regional engagments

NOAA/NWS contact: Renee Tatusko

Kevin Werner

CBRFC Service Coordination Hydrologist
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Email: kevin.werner@noaa.gov

Back up slides

Post-Mortem for June 6-10 flooding

Forecasts generally poor and under simulated for peak flows that occurred June 6-10, 2010 in northern Utah and western Colorado

General conditions leading into event:

- Very cool May
- Warm, moist air mass beginning June 5
- Temperature forecasts generally good
- SNOTEL sites in flooding catchments near average for this time of year
- Streamflow forecasts were almost uniformly too low

Ongoing study to understand why

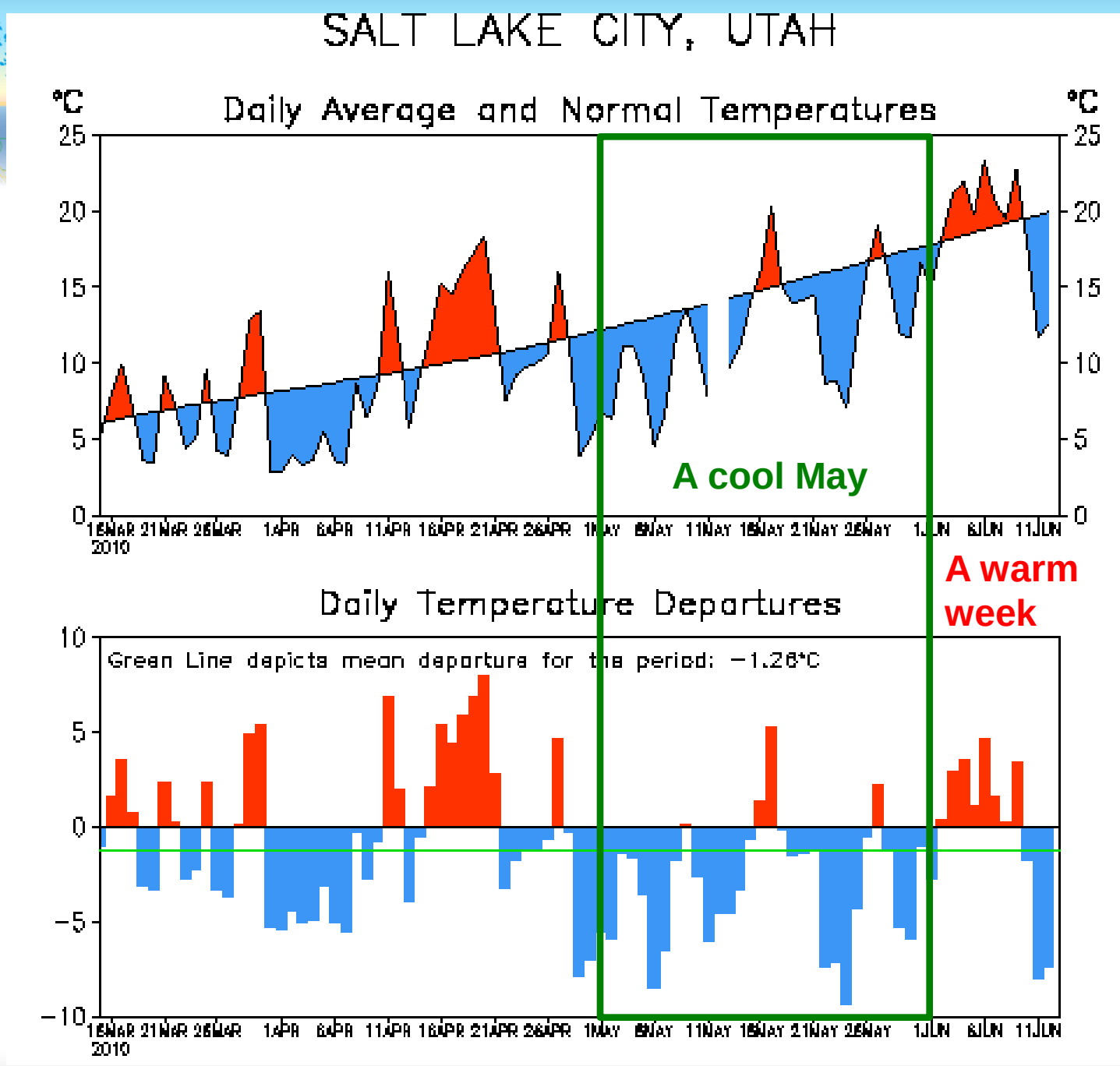
Preliminary results focus on Little Cottonwood Creek

- What happened in the ***real*** world?
- What happened in the ***model*** world?

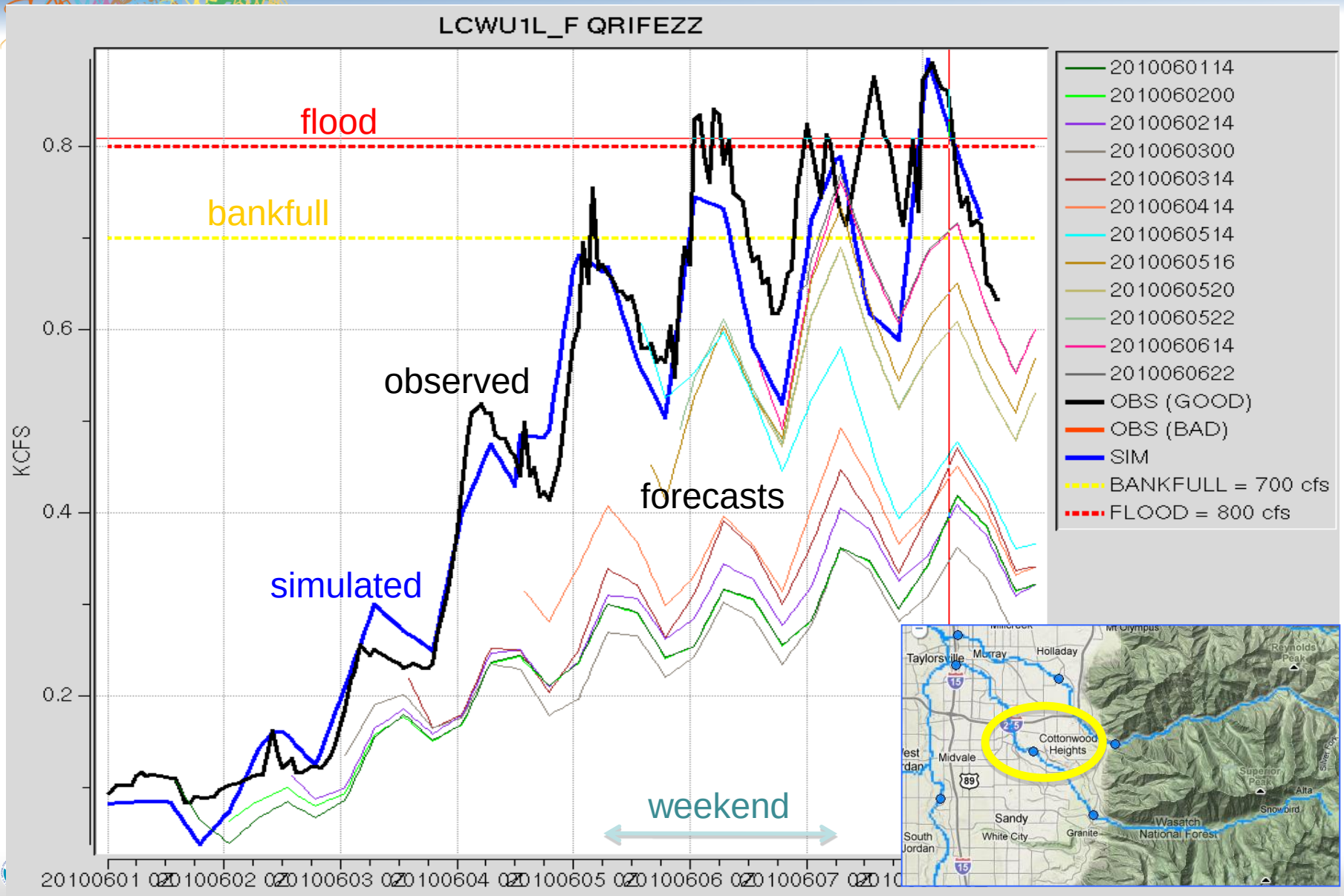
May was generally cool, delayed melt

First week in June was warm

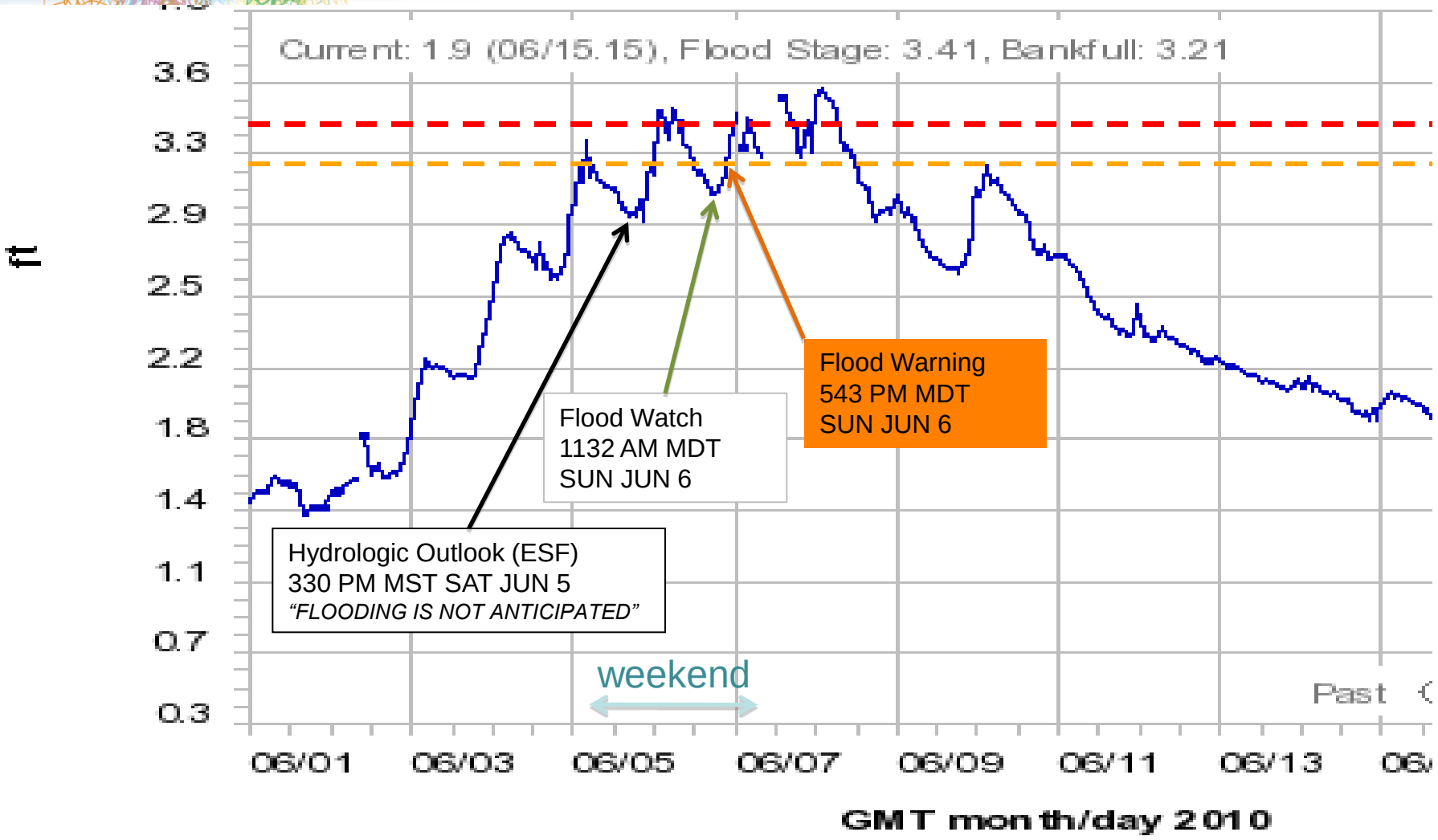
From NOAA CPC



Little Cottonwood at Crestwood Park flow under forecast

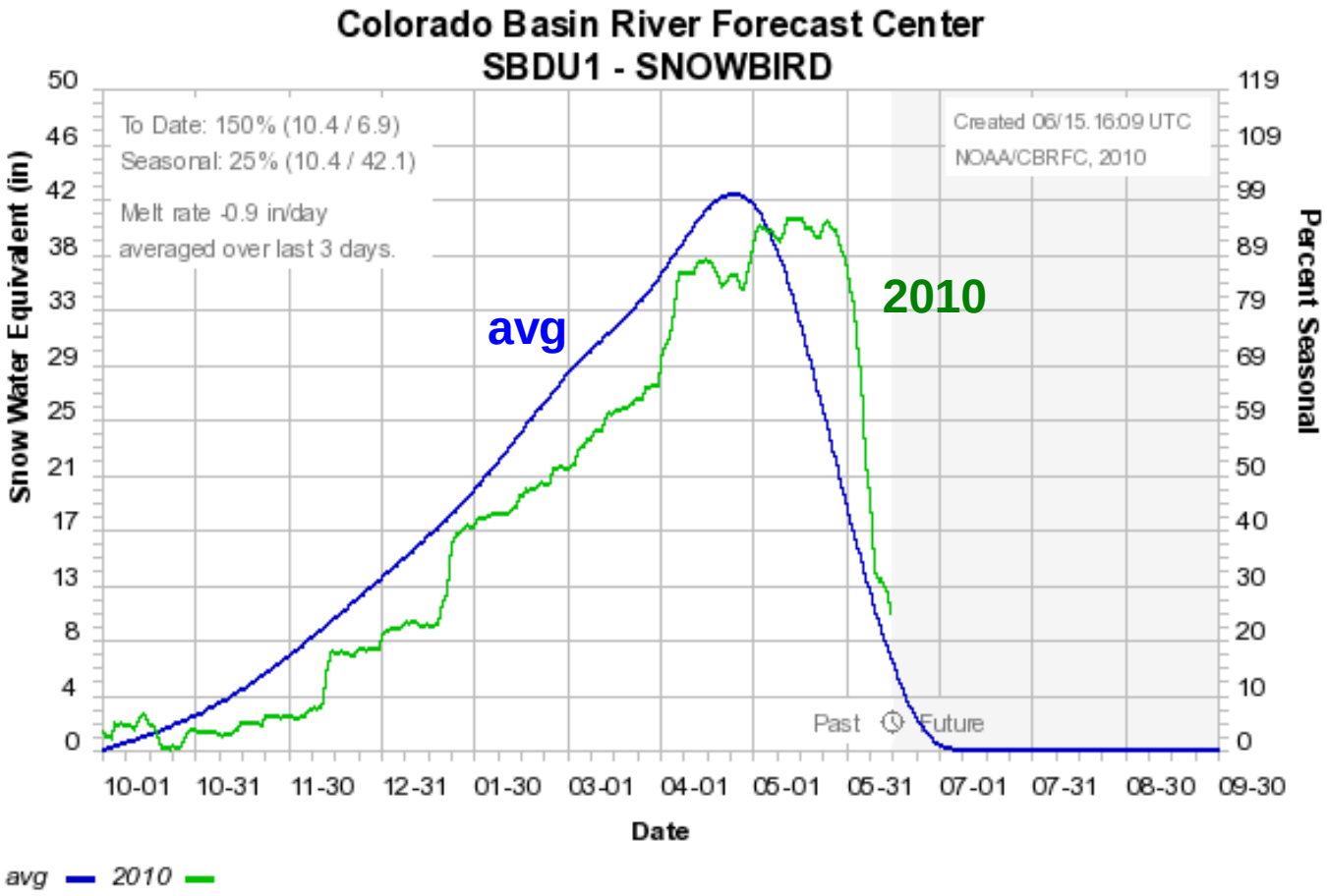


Flood watches and warnings for Little Cottonwood (Cottonwood, Crestwood Park hydrograph shown)



Little Cottonwood snow year

- Snowmelt rate extraordinarily large? (no)
- Snowmelt extraordinarily late? (no)



Snow Measurements (SNOTEL) in Cottonwoods

Mill-D North

(8960', southwest face)

- **"middle"**

Brighton

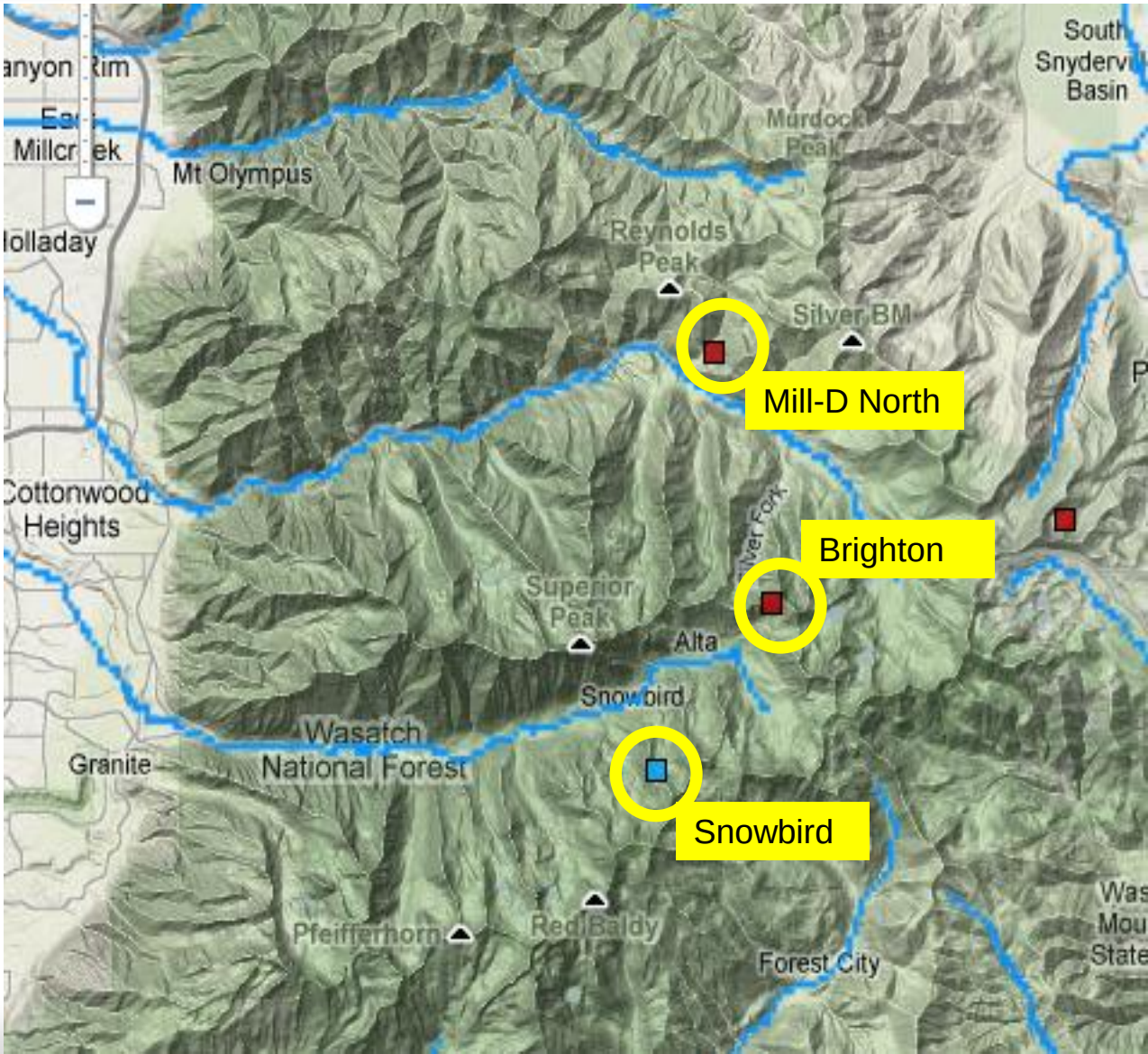
(8750', southeast face)

- **"middle"**

Snowbird

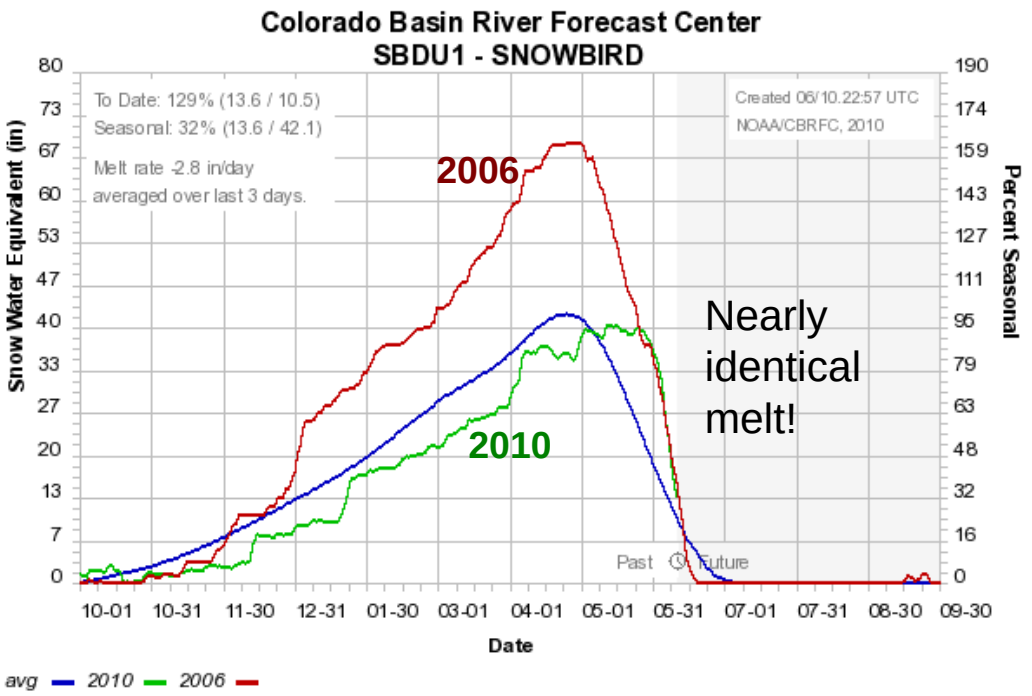
(9640', northeast face)

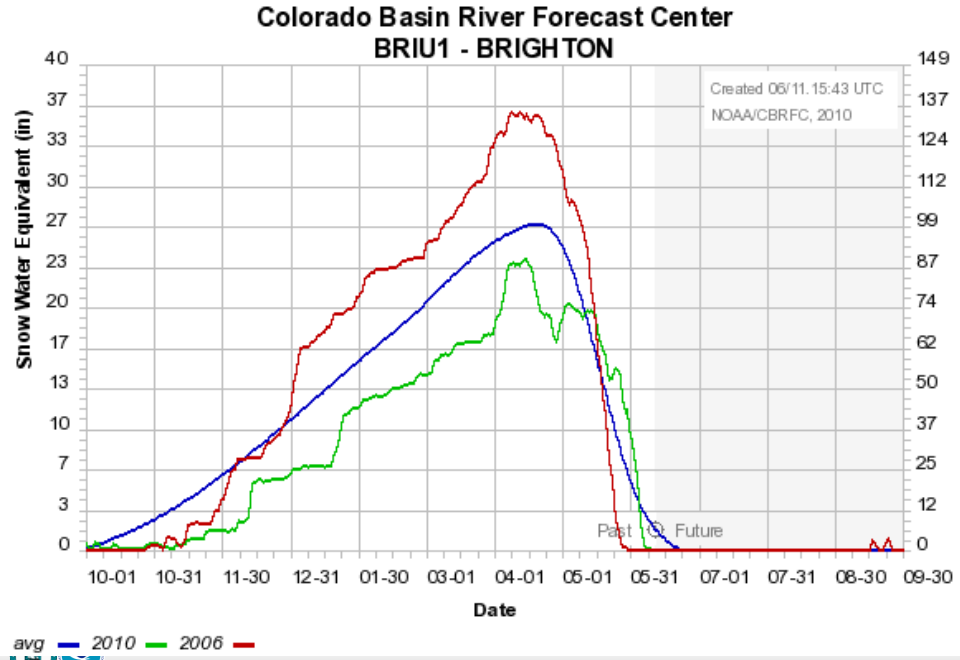
- **"high"**

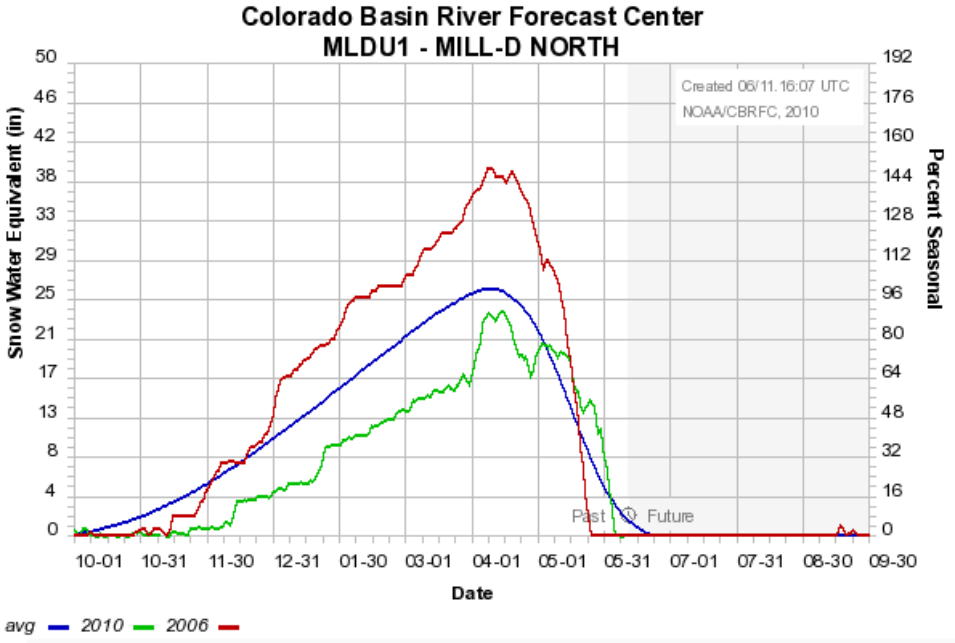


Snow Water

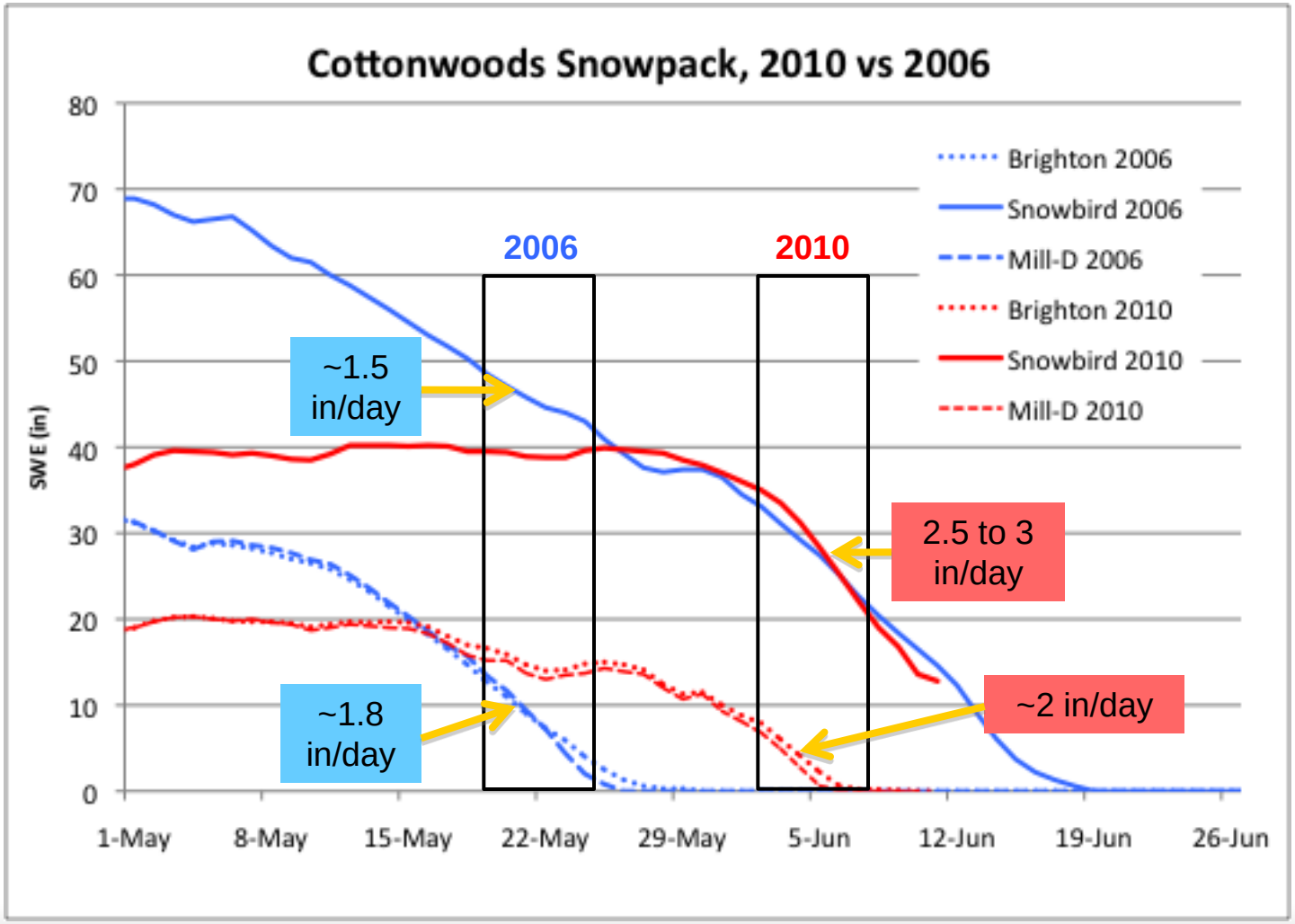
2010 compared to 2006



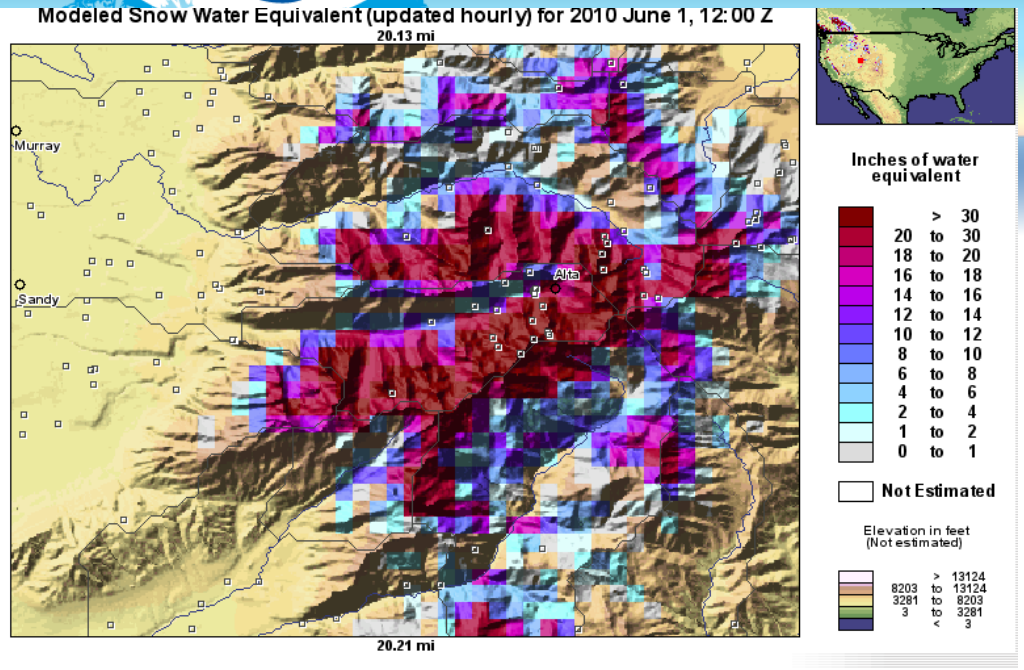




SWE/Snotel Comparison



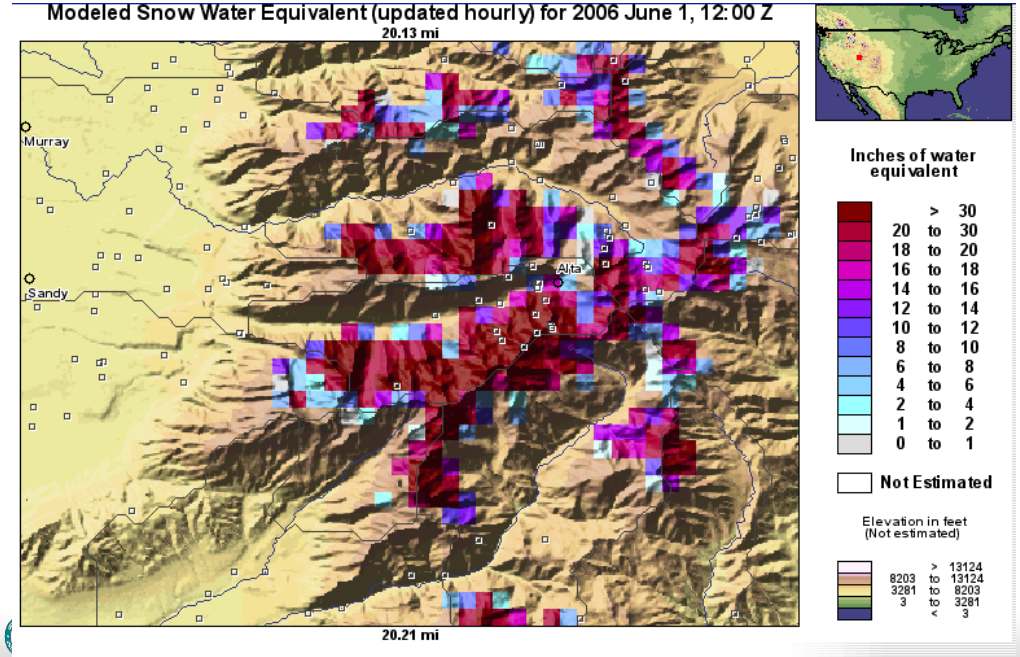
Snow Distribution – corroborates presence of lower elevation snow in 2010 at start of event



2010 June 1

2006 Snowbird SNOTEL trace almost identical to 2010 trace from June 1-10

However, NOHRSC indicates south facing slopes had already melted out in 2006



2006 June 1, for comparison

June 2010 event conclusions

Hypotheses:

1. Snow Covered Area data may have improved June 2010 forecasts
2. More sophisticated snow model may have improved June 2010 forecasts

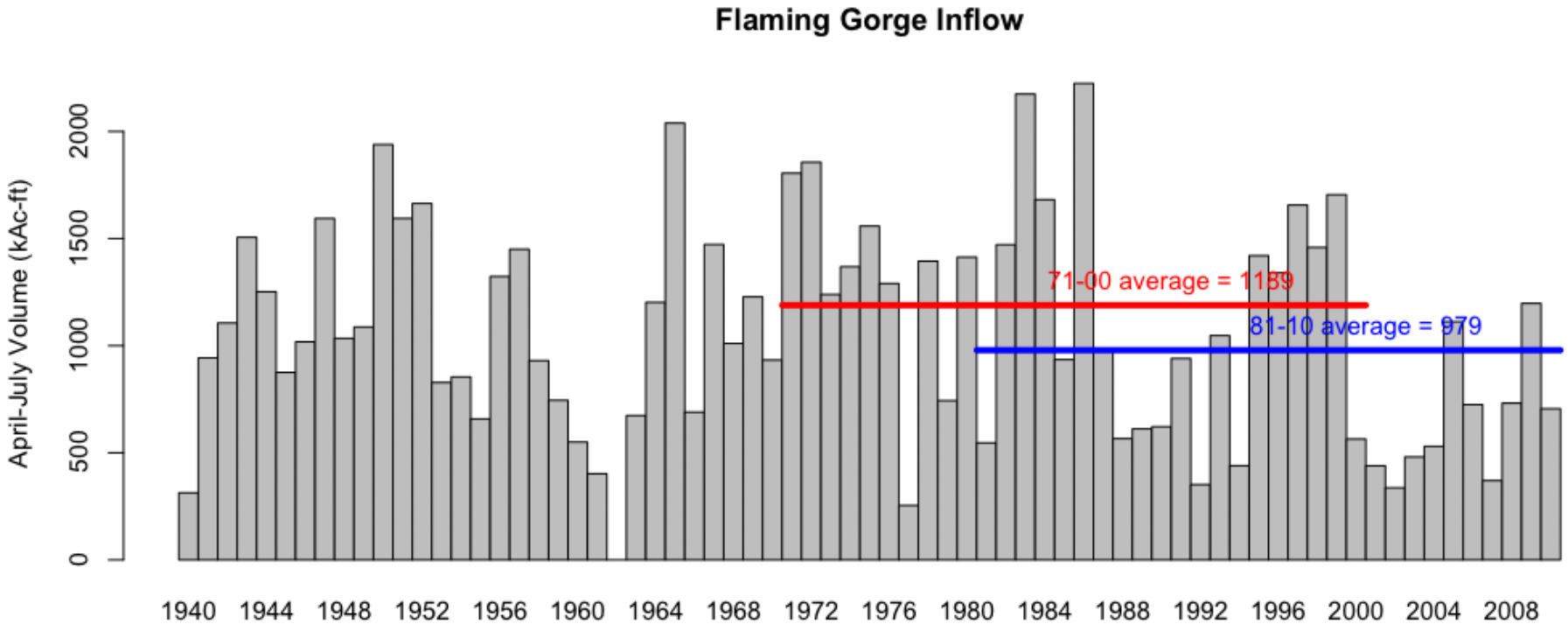
30 Year Average Updates

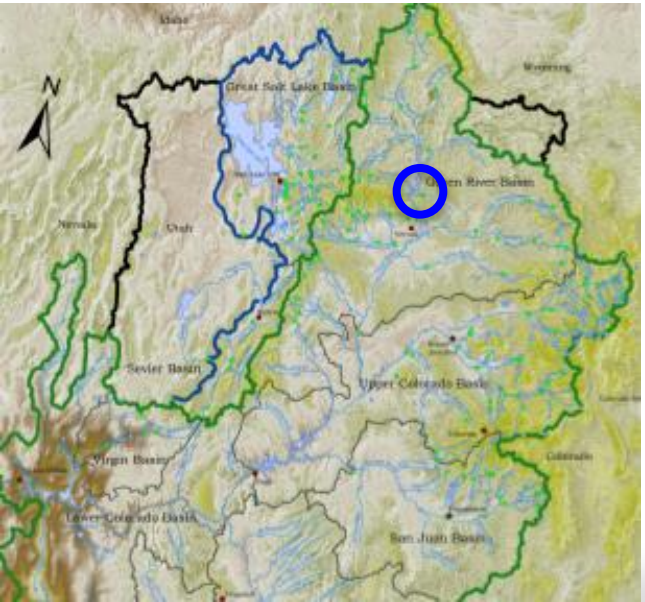
WY2012 forecasts will be based on 1981-2010 inputs in both forecast models
- ESP and SWS will both use the same period

SNOTEL network much stronger for 1981-2010 period than in 1970s. This network is critical for forecast skill.

All things equal, these forecasts will be lower since input data sets are drier in the 30 year average
- Especially true in early season forecasts
- Later season forecasts more controlled by observed snowpack

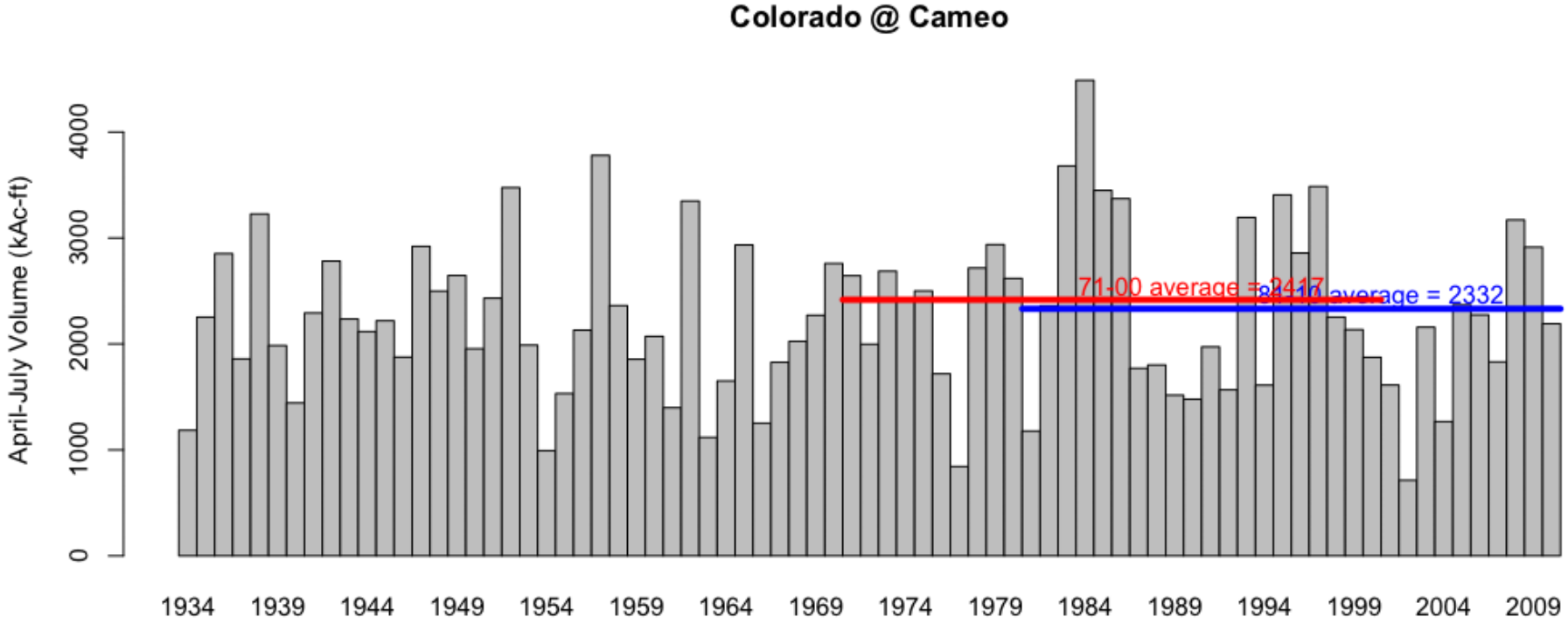
Percent of normal forecast values should remain largely unchanged (since normals AND forecasts will be lower)



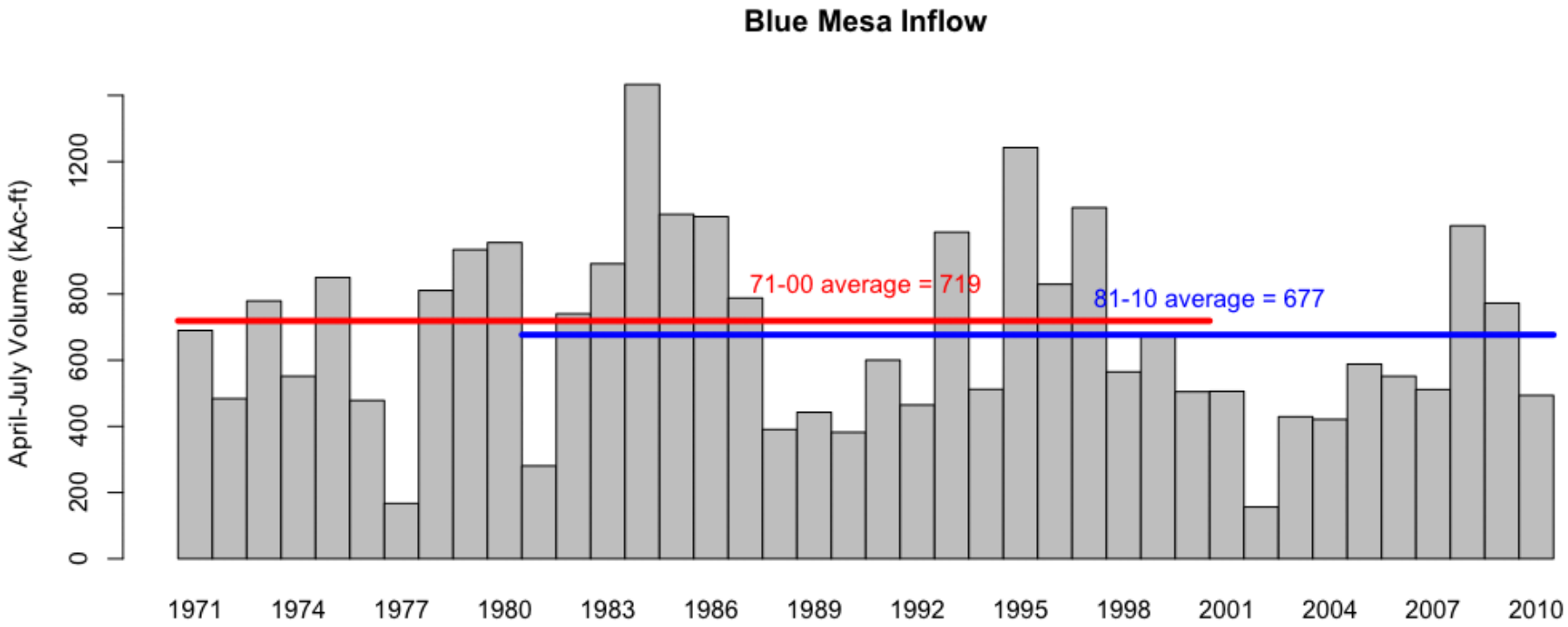


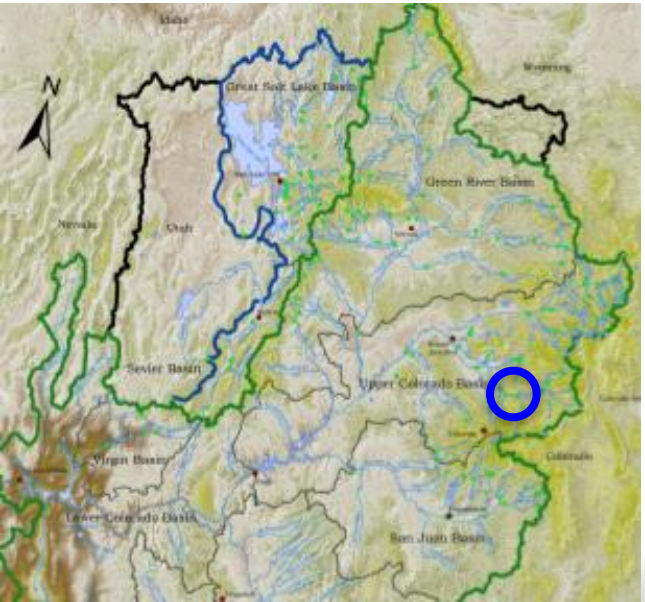
Preliminary Data

18% reduction in mean

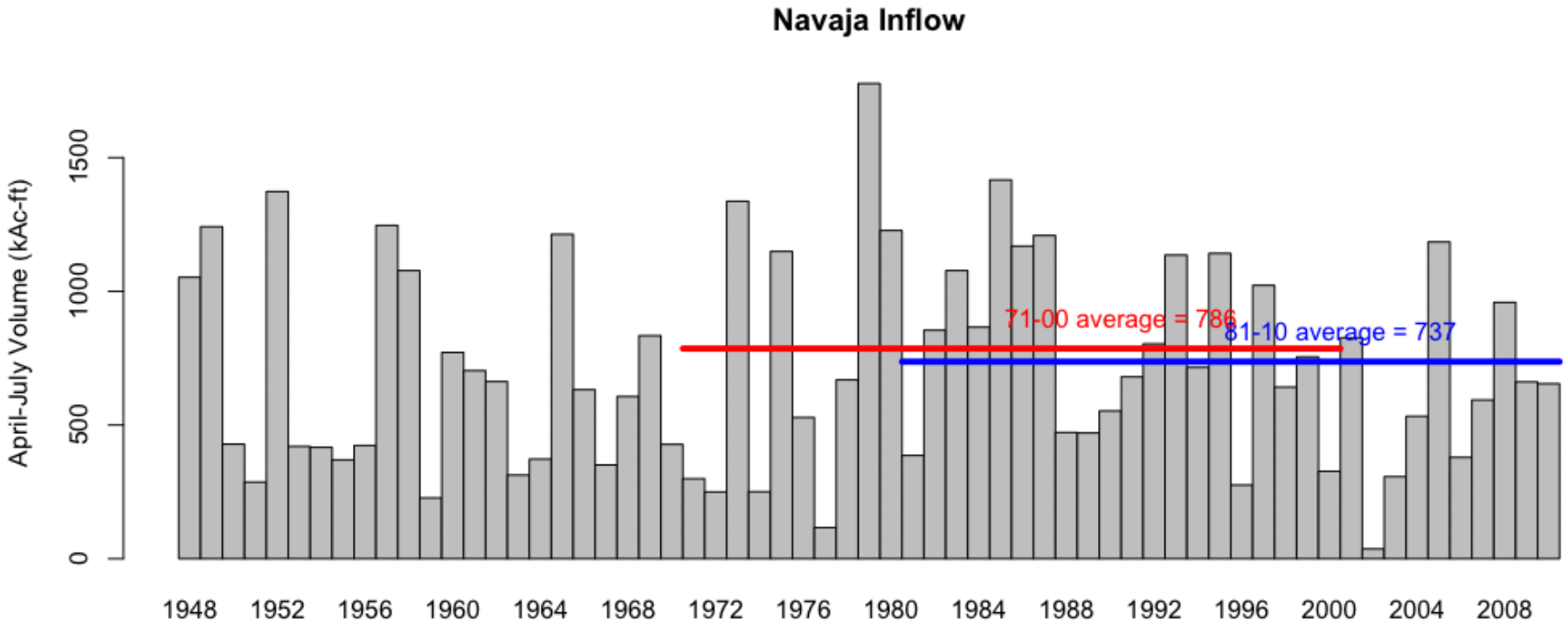


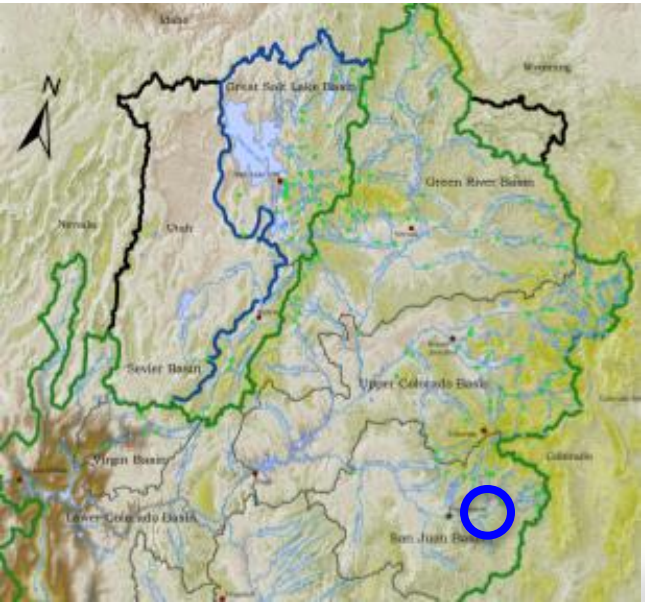
- Preliminary Data
- 4% reduction in mean



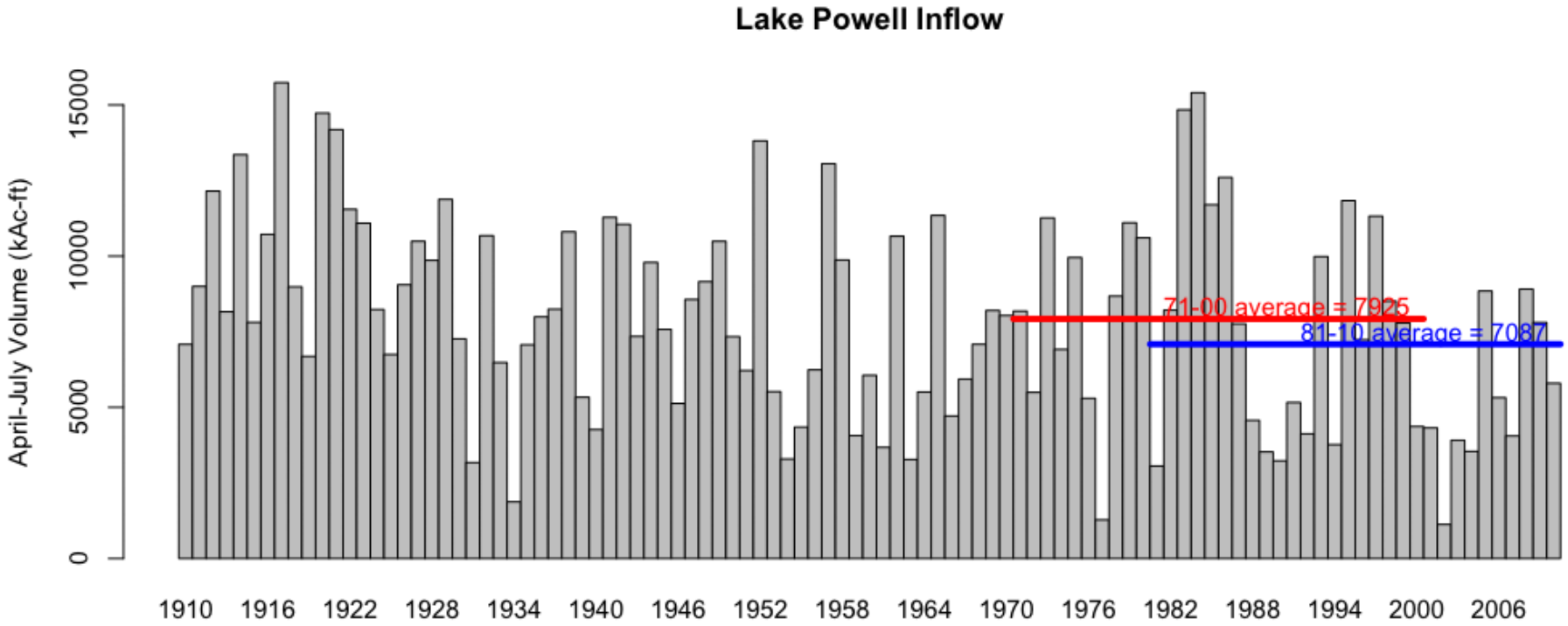


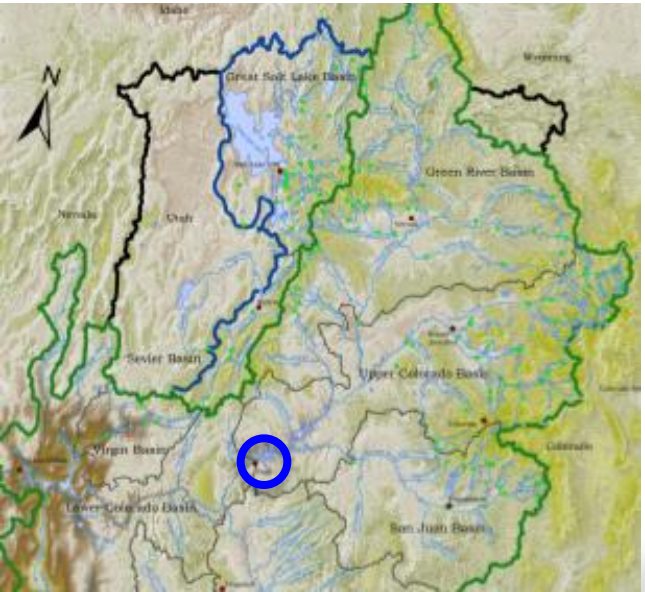
- Preliminary Data
- 6% reduction in mean



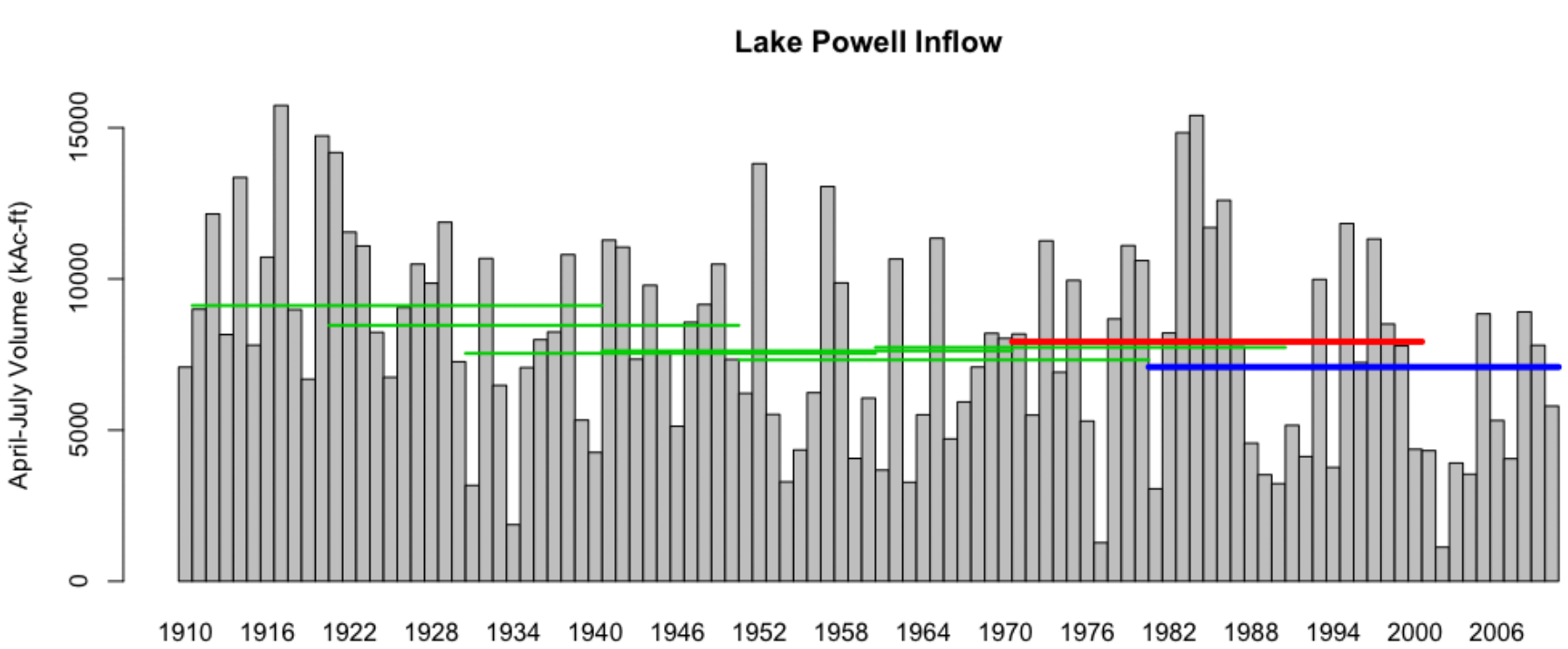


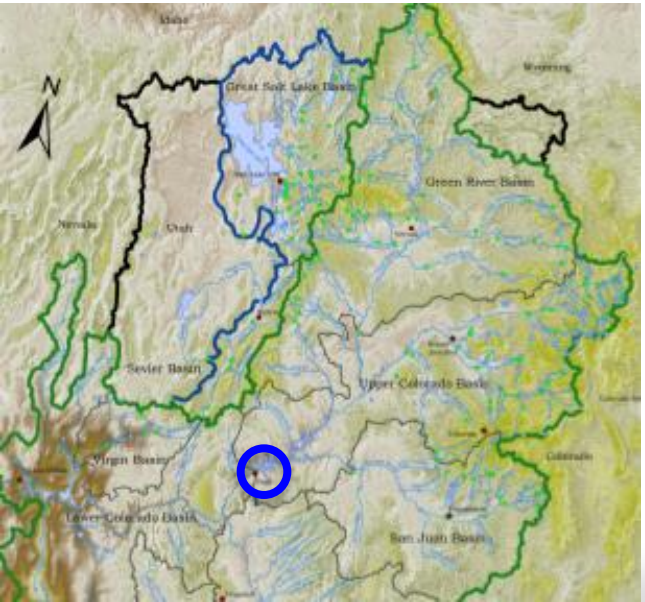
- Preliminary Data
- 6% reduction in mean



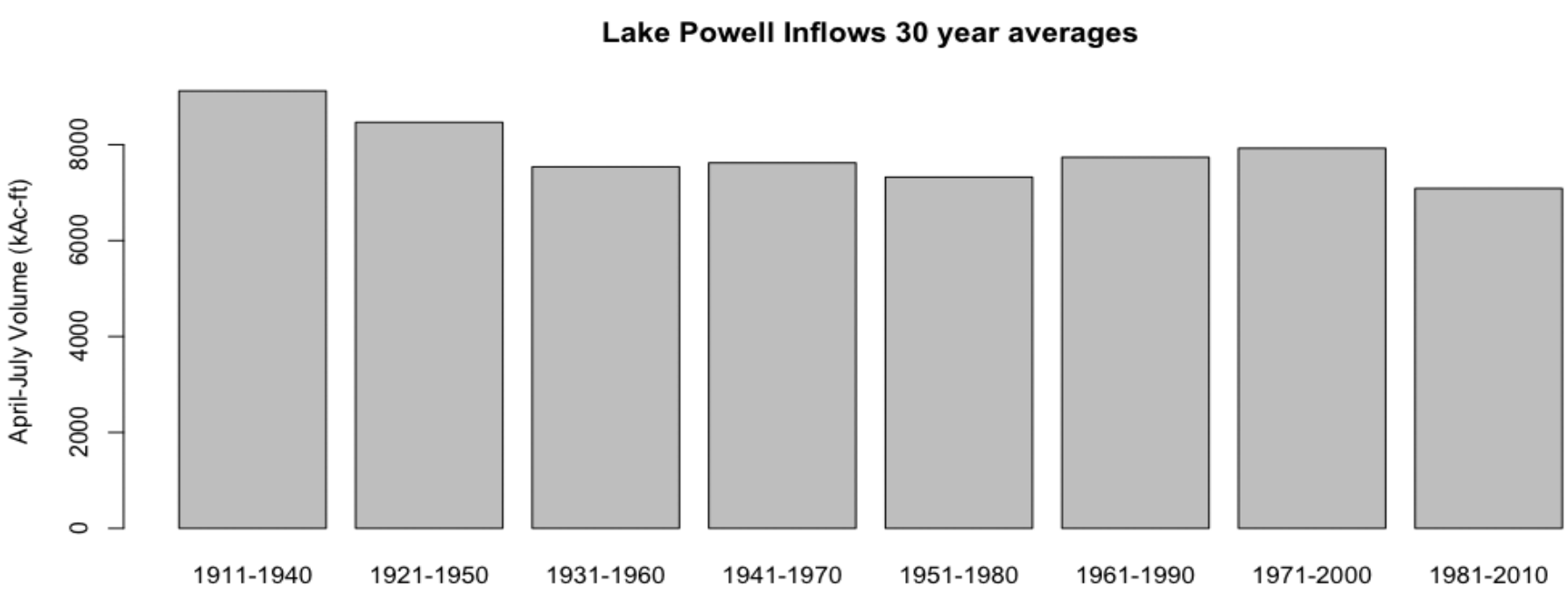


- Preliminary Data
- 11% reduction in mean





- Preliminary Data
- All 30 year means since 1911-1940



1981-2010 is the driest 30 year period on record