

NOAA/NWS Streamflow Forecasts

Global and Regional
Climate Changes
Kiev, Ukraine

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Service Coordination Hydrologist
Colorado Basin RFC
November 18, 2010



Outline

- 🌐 Background
- 🌐 Forecast Methodology
- 🌐 Collaboration Opportunities

Colorado Basin River Forecast Center

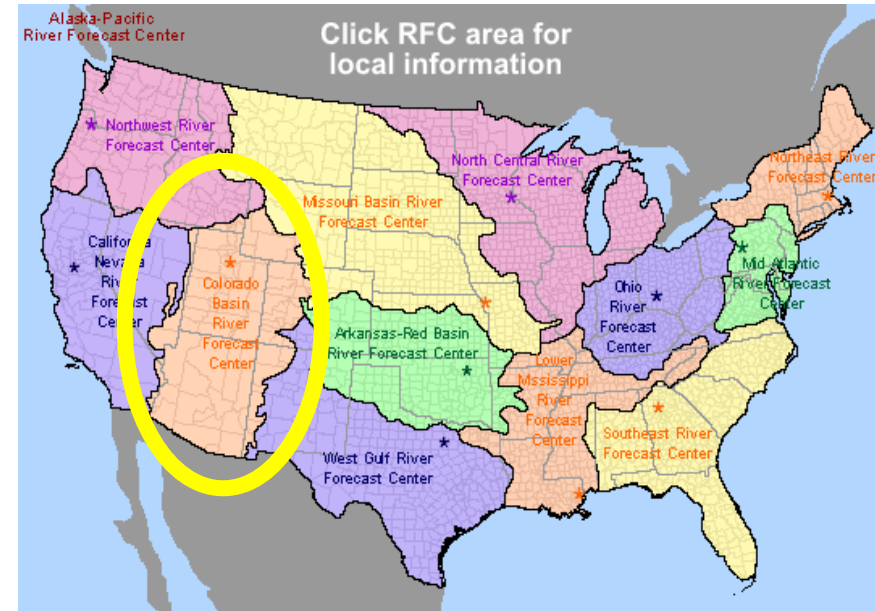


One of 13 River Forecast Centers

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

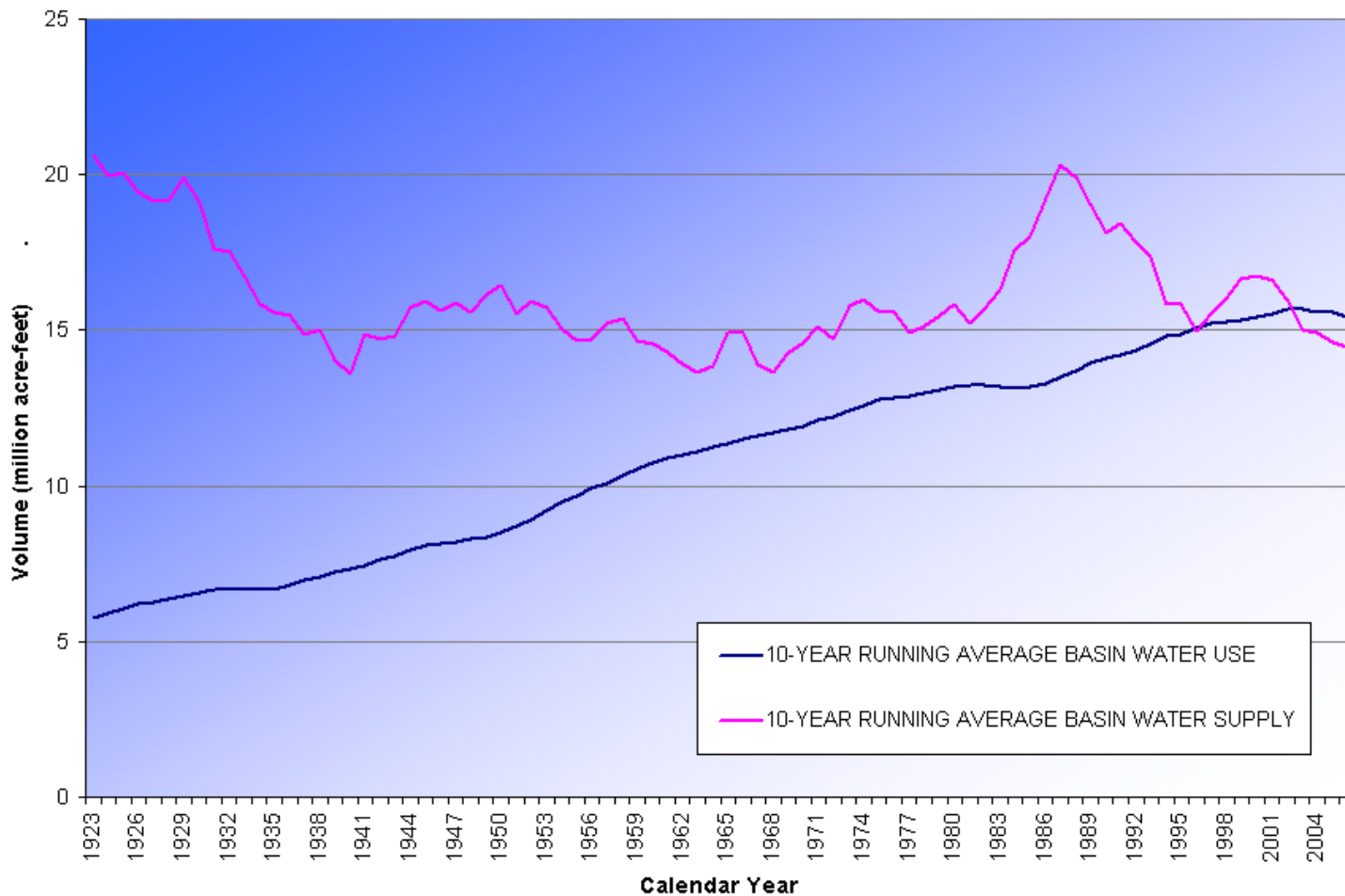


Key Characteristics:

- 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

CBRFC Conditions River Snow Water Supply Peaks

Search Points

Show: Point Groups
Find: All Points or Active Points
Find points in state: AZ, CO, ID, NV, NM, UT, WY

All Points

525 River Points Found:
Data from Wed, 20 Jan 2010 12:43:01 -0700

- [-] zoom to point - find nearby points - view hydrograph >>
DYGU1, GB_F, River Forecast Point, No Data
- [-] zoom to point - find nearby points - view hydrograph >>
BCWA3, SV_F, River Forecast Point, No Data
- [-] zoom to point - find nearby points - view hydrograph >>
RCYA3, GI_F, River Forecast Point, No Data
- [-] zoom to point - find nearby points - view hydrograph >>
MAOA3, SV_F, River Forecast Point, Normal
0 cfs, 0.40 ft, observed at 15Z on 20
- [-] zoom to point - find nearby points - view hydrograph >>
MHFA3, SV_F, River Forecast Point, Above Bankfull
0 cfs, 0.90 ft, observed at 19Z on 20
- [-] zoom to point - find nearby points - view hydrograph >>
MSXA3, SV_F, River Forecast Point, Above Bankfull
95 cfs, 2.04 ft, observed at 19Z on 20
- [-] zoom to point - find nearby points - view hydrograph >>
ADBA3, SV_F, River Reservoir Point, Above Bankfull
0 cfs, 0.13 ft, observed at 16Z on 20
- [-] zoom to point - find nearby points - view hydrograph >>
ACHA3, GI_F, River Forecast Point, Normal
0 cfs, 0.50 ft, observed at 17Z on 20
- [-] zoom to point - find nearby points - view hydrograph >>
Aqua Fria, Buckeye - zoom to point - find

Map Satellite Terrain

Overlays
 Rivers
 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
 Basins Above Normal
 Data Points
 Forecast Points
 Reservoir Points
 Active Points

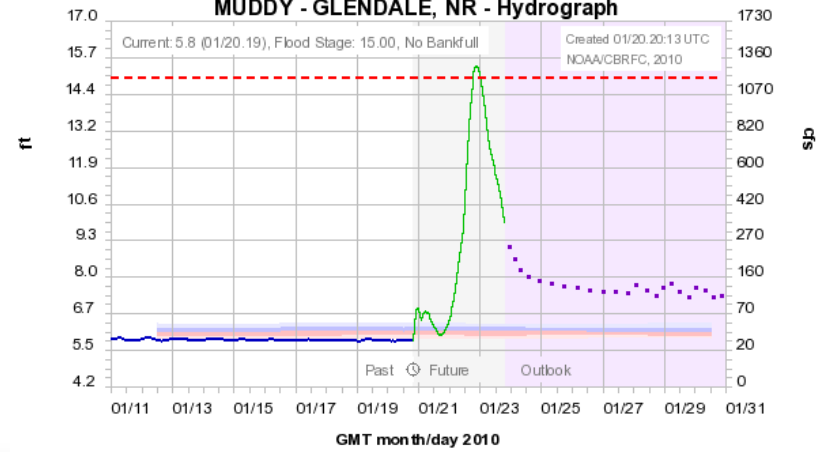
lat: 37.6 lng: -110.5.6
Goto the [Old Map](#) or [Give Feedback](#) on New Map.

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)

Colorado Basin River Forecast Center
MUDDY - GLENDALE, NR - Hydrograph



National Weather Service
Colorado Basin River Forecast Center
Salt Lake City, Utah
APR 3, 2008

FLOOD POTENTIAL OUTLOOK
UTAH

Snowpack conditions across the Great Salt Lake region range from average to above average. Current temperatures are cool and weather models are forecasting active conditions with cool temperatures over the next 10 days. Stream flow models are indicating less than a 10% chance of flood flows, however the potential for reaching bankfull is currently above average. Streams will most likely run high and cold this spring and areas with small ungaged streams may see an elevated threat of bankfull or overbank conditions. The onset of conditions that will raise the threat of flooding will be monitored closely and this product will be updated as needed.

Snowpack decreased in the Duchesne Basin due to well below average precipitation in March and is now 110 percent of average. At this time, the potential for Spring flooding due to snowmelt is not high. ESP NWS models indicates peaks flows due to snowmelt will be near average for points in the basin.

The potential for Spring flooding due to snowmelt is not high in the Lower Green basin. Much below average precipitation in March decreased the percent average snowpack from 115 percent of average on March 1st to 105 percent of average on April 1st. Peaks flows are expected to be near average for streams in the San Rafael basin.

Peak Flow Forecasts, Latest for 2008

NOAA, National Weather Service
Colorado Basin River Forecast Center
Salt Lake City, Utah
www.cbrfc.noaa.gov

Contents

- Introduction
- Upper Colorado Peak Flow Forecasts
- Great Salt Lake Peak Flow Forecasts
- Lower Colorado Peak Flow Forecasts
- River Running Permits/Information
- Definitions
- Additional Information

Introduction

Streamflow varies dramatically over the course of the snowmelt season. To characterize the magnitude of a year with a single seasonal peak sometimes can be an oversimplification. Hydrographs (or graphs of mean daily flow versus time) for each site can be viewed by clicking on the site name. The hydrographs include an example high and low year alongside last year and this year.

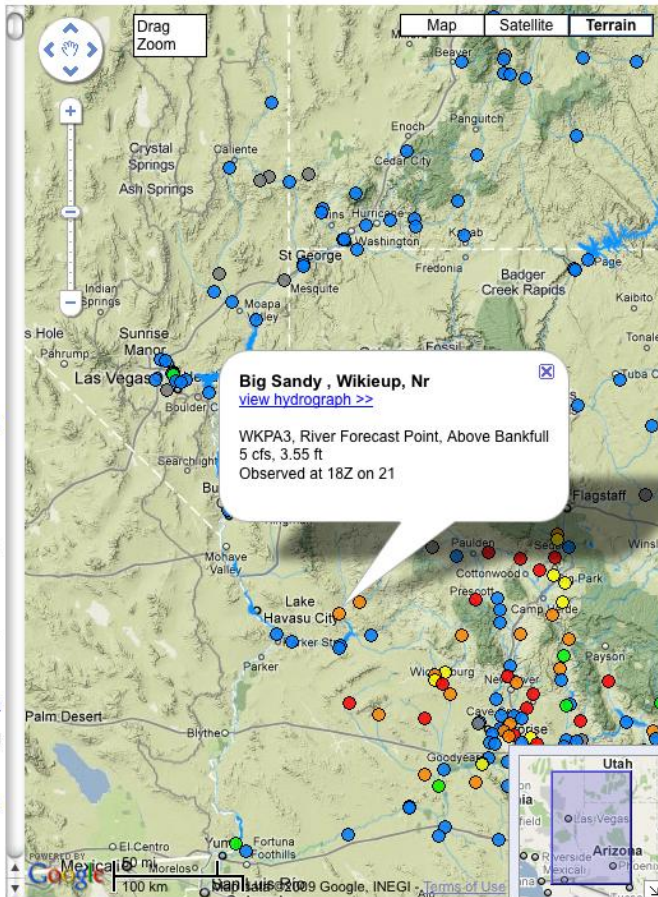
River recreationists often ask what are the high and low years. Rankings of a sites peak flows can be viewed by clicking the site name below. Reservoir regulation plays a major role in determining observed peak flows. As would be expected, higher (but more short-lived) peaks are generally observed in the pre-regulatory era (before 1960).

Upper Colorado Peak Flow Forecasts (mean daily cfs)

Prepared by: Alcorn, Clark, Lhotak

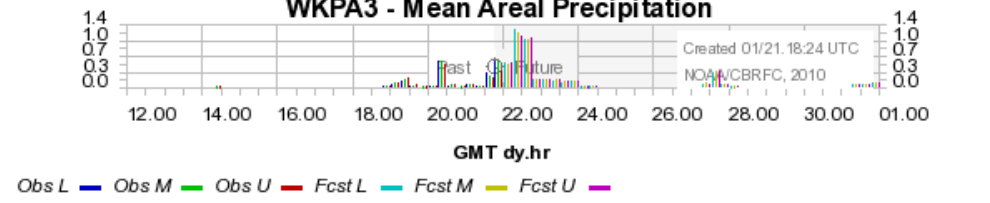
2008 Forecast Exceedance Probability

Flood Forecasts / Routine Forecasts

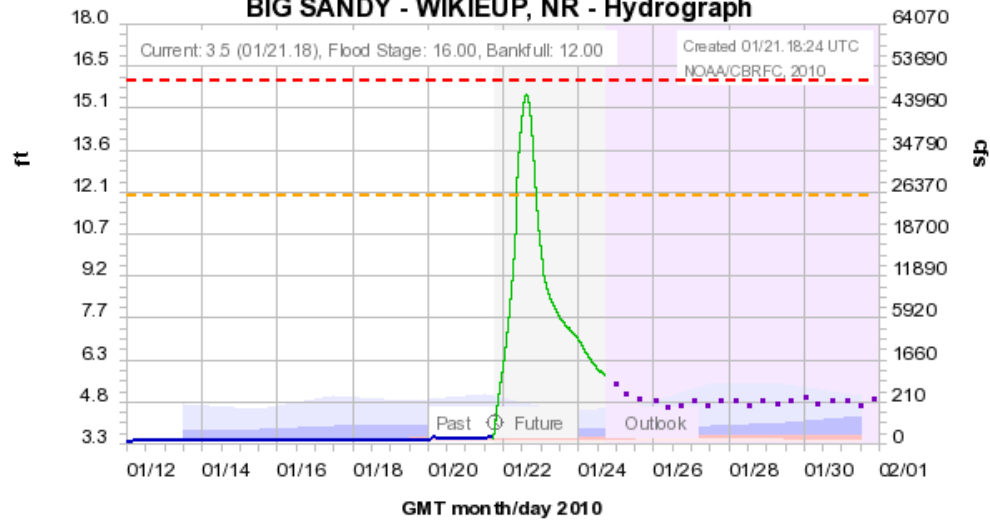


- Overlays**
- Rivers
 - RFC
 - Basins
 - Grids (Precip. etc.)
- Display Options**
- Show NWS ID
 - Show Data
- River Point Condition**
- No Data
 - Normal
 - Significant Rise
 - Near Bankfull
 - Above Bankfull
 - Above Flood Stage
 - Outlook (> 3 days)
- River Point Options**
- All
 - Basins Above Normal
 - Data Points
 - Forecast Points
 - Reservoir Points
 - Active Points

**Colorado Basin River Forecast Center
 WKPA3 - Mean Areal Precipitation**



**Colorado Basin River Forecast Center
 BIG SANDY - WIKIEUP, NR - Hydrograph**



Observed — Forecast (01/21, 12:00) — Outlook (increasing uncertainty) — Bankfull 12.00 — Flood 16.0 —

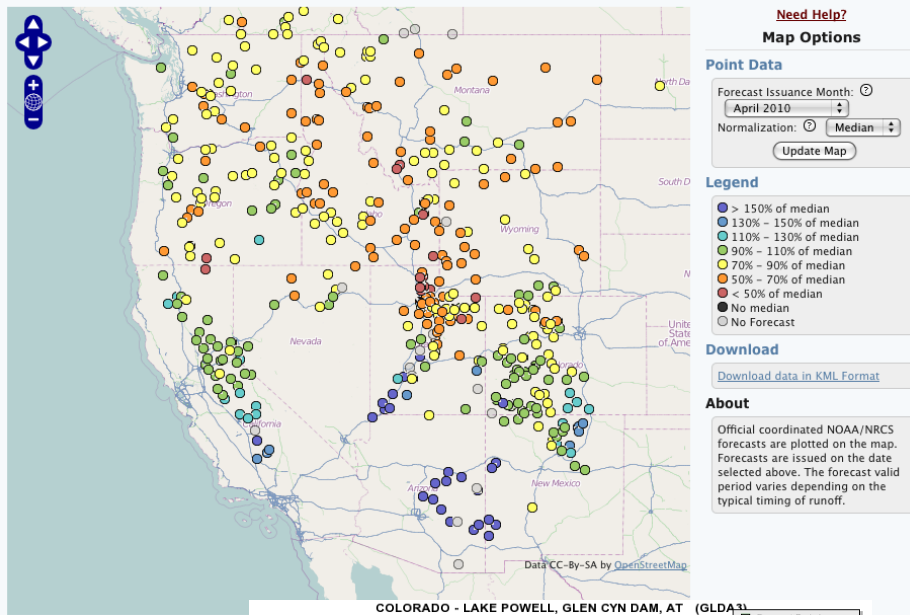
Historical Exceedance Probability (USGS): 90-75% 75-50% 50-25% 25-10%

Observed=QRIRGZZ, Simulated=QRIPAZZ, Forecast=QRIFEZZ H (01/21, 12:00)
 resoutid=

lat: 35.59 lng: -113.58, 7
 Goto the [Old Map](#) or [Give Feedback](#) on New Map.

Water Supply Forecasts

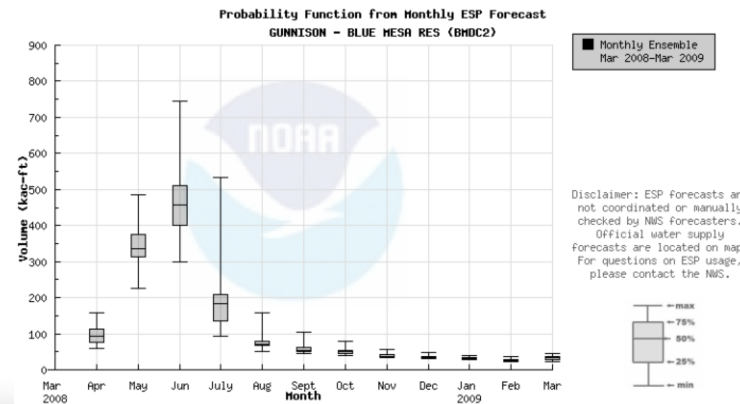
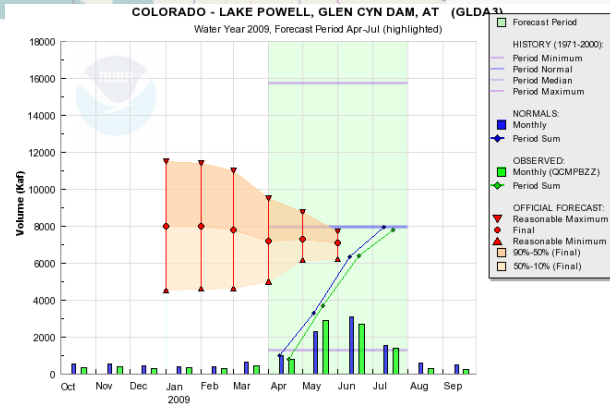
Western US Water Supply Map from April 2010



Forecasts for spring snowmelt runoff volume

Forecasts at ~100 points in Colorado Basin important for water management

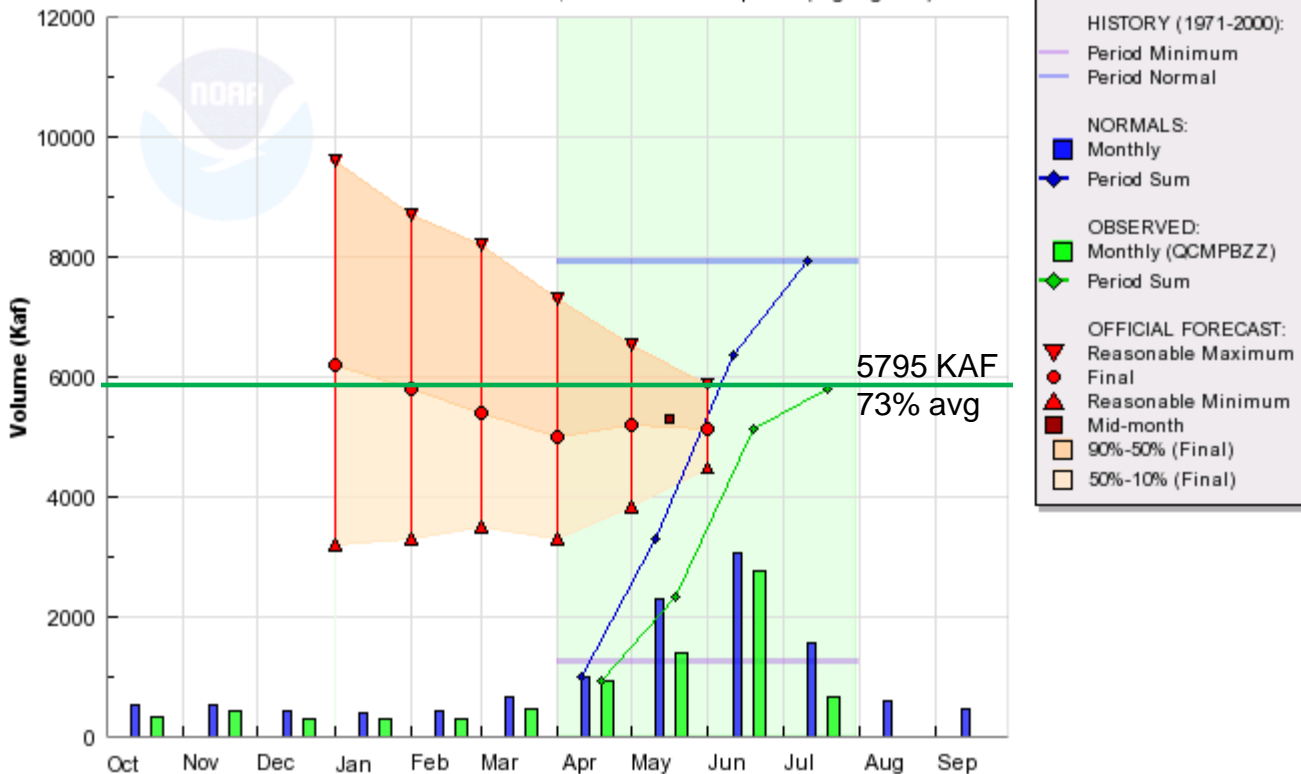
Forecasts typically issued during winter and spring months (e.g. snow accumulation season)



Disclaimer: ESP forecasts are not coordinated or manually checked by NWS forecasters. Official water supply forecasts are located on map. For questions on ESP usage, please contact the NWS.

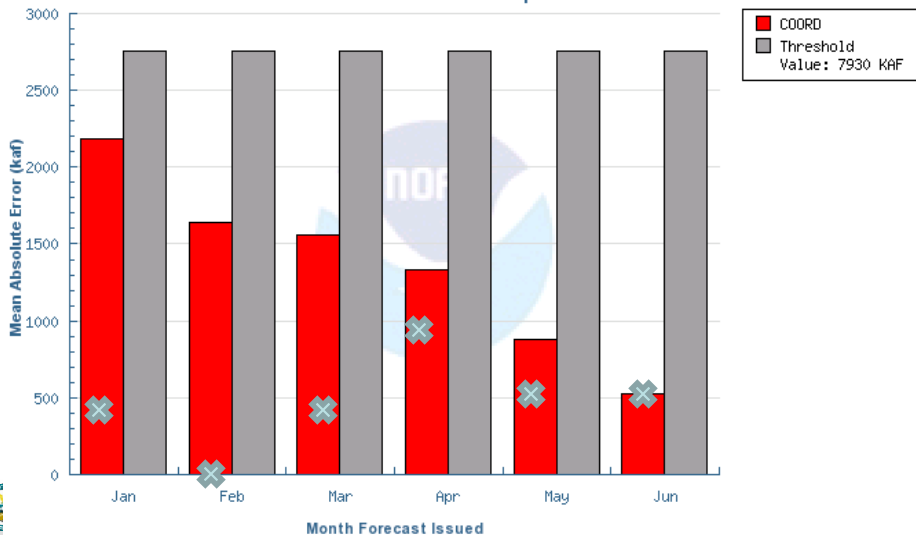
COLORADO - LAKE POWELL, GLEN CYN DAM, AT (GLDA3)

Water Year 2010, Forecast Period Apr-Jul (highlighted)



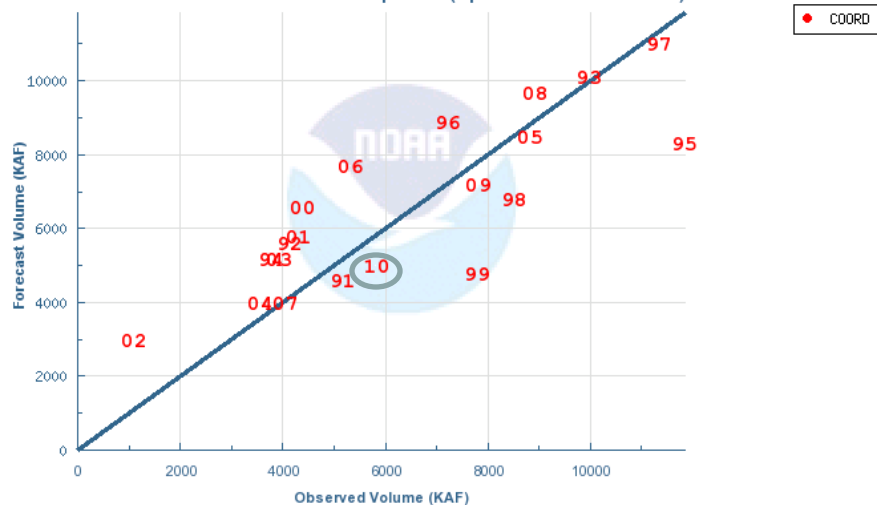
Mean Absolute Error - COLORADO - LAKE POWELL, GLEN CYN DAM, AT (GLDA3)

Forecast Period: Apr - Jul



Streamflow - COLORADO - LAKE POWELL, GLEN CYN DAM, AT (GLDA3)

Forecast Period: Apr - Jul (Apr Forecast Streamflow)



Forecast Methods



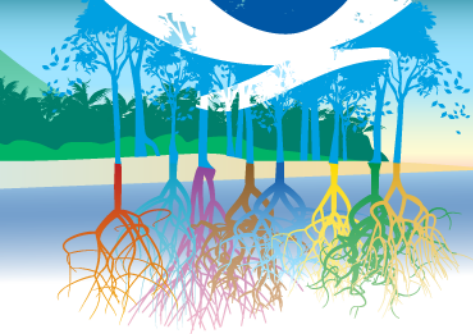
➤ Ensemble Streamflow Prediction (ESP)

- ✓ 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)

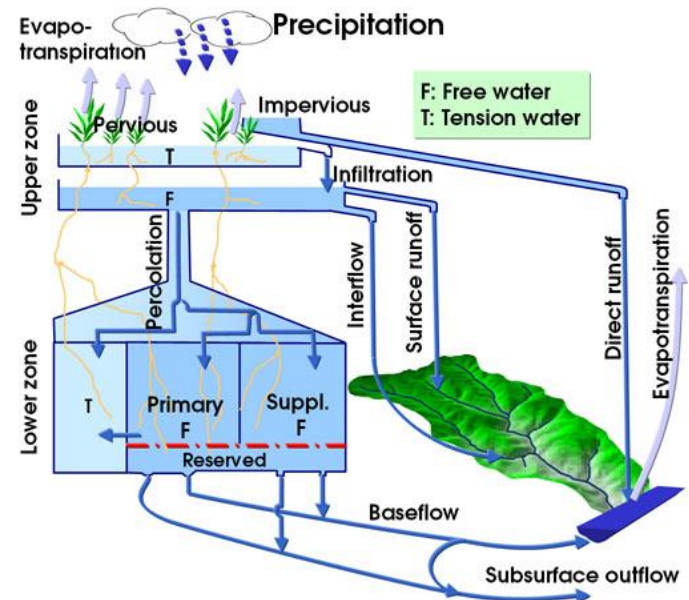
Conceptual Model



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

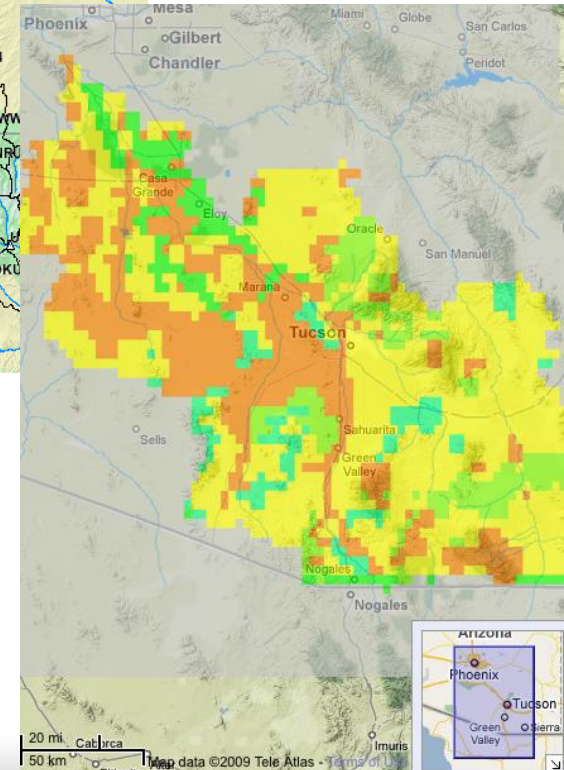
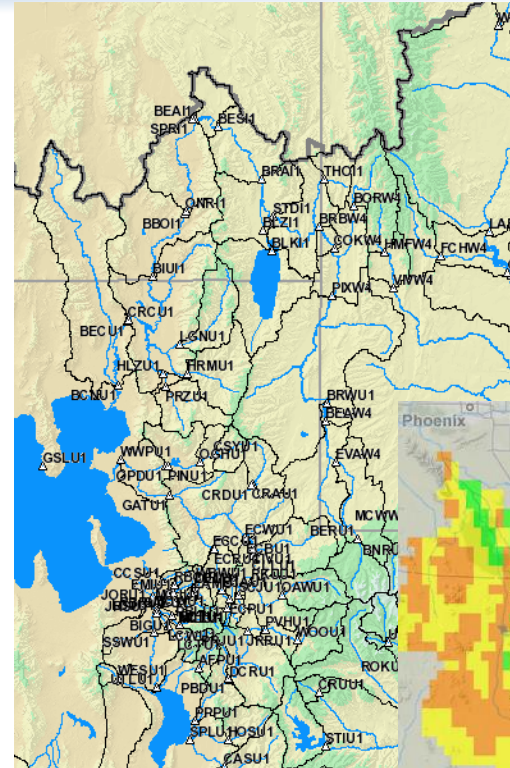


Model Structure



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

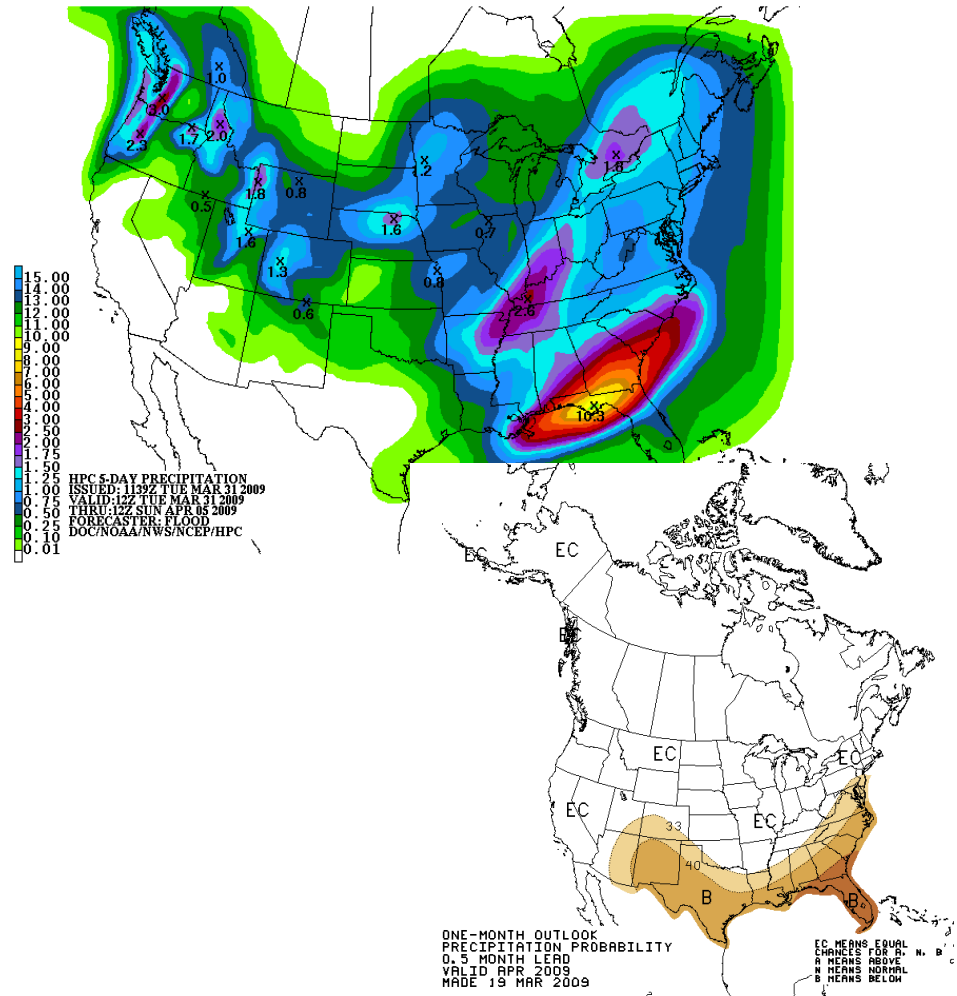


Weather and Climate Forecasts



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

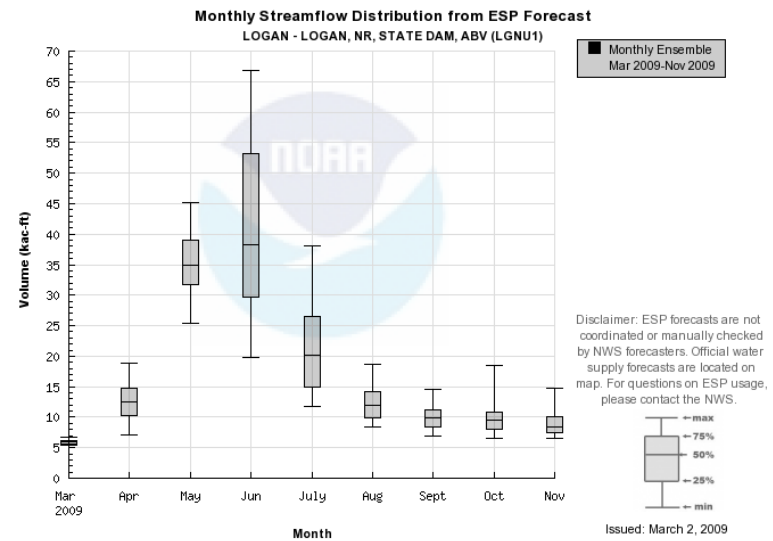
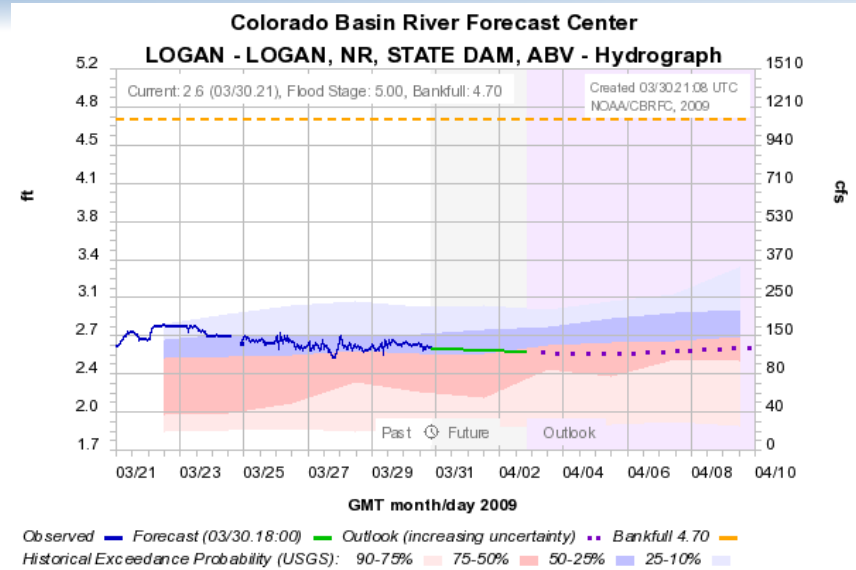


Model Structure



Forecast “mode”:

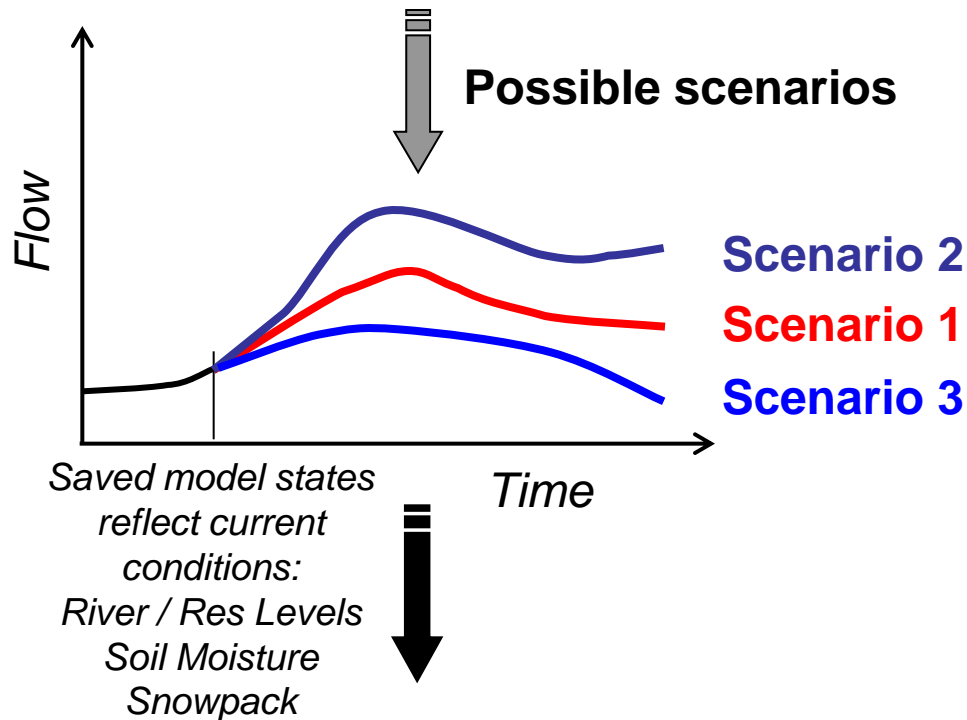
- **Deterministic** – Single value forecast time series of streamflow, model states, soil moisture, etc.
- **Probabilistic** – Ensemble of forecast time series



ESP Technique

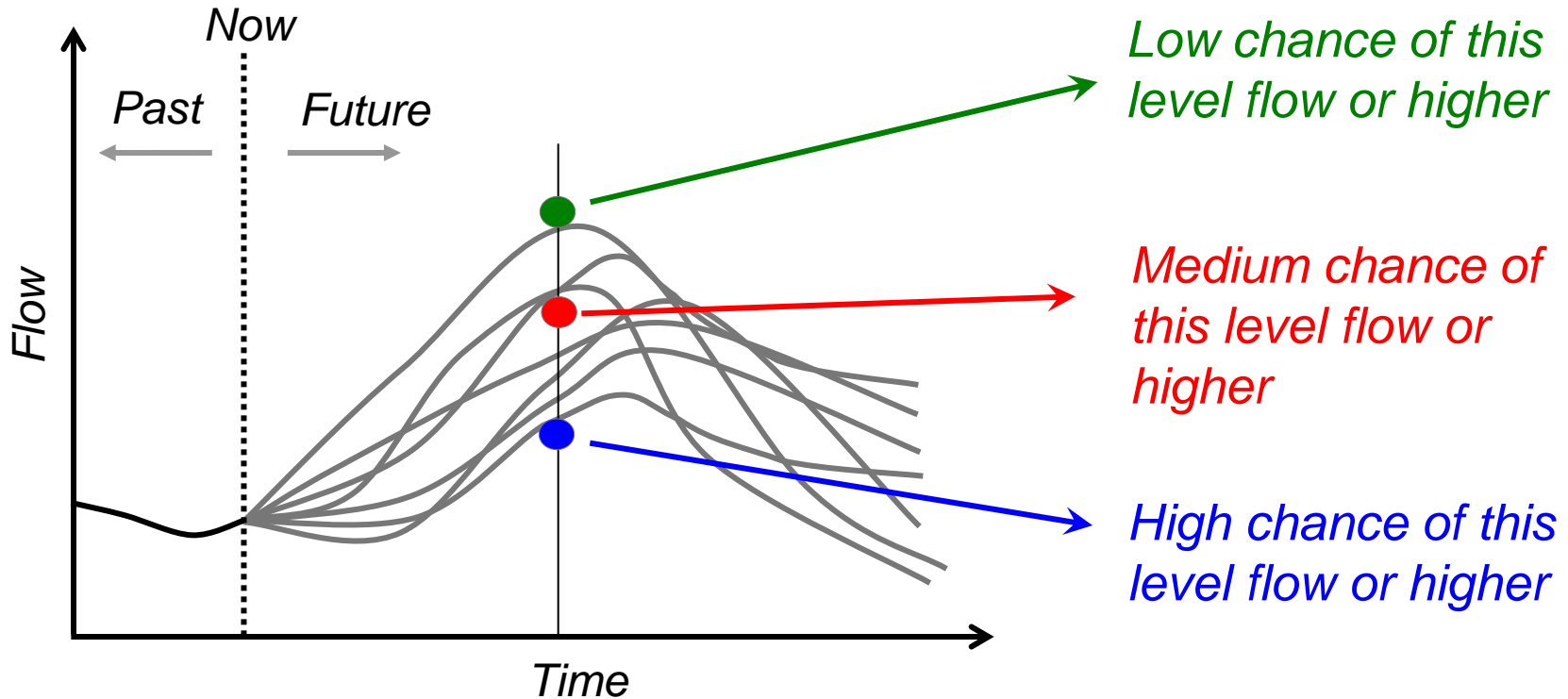


Multiple streamflow scenarios with historic meteorological or forecast weather/climatic data



Results used in statistical analysis to produce forecasts with probabilistic values

ESP Technique





Forecast Window Chances of Exceeding River Levels on the GRANBY RES INFLOW
Latitude: 40.2 Longitude: 105.9
Forecast for the period 4/1/2009 - 7/31/2009
This is a conditional simulation based on the current conditions as of 3/31/2009



Ensemble 50%
exceedance
Forecast:
230 kac-ft

FREQUENCY SETTINGS

Exceedance Probability
Interval Begin Date

Analysis Start Date: 4-1-2009

4 1 2009

Analysis End Date: 8-1-2009



Probability Dist

- Empirical
- Normal
- Log Normal
- Wakeby
- Weibull

Exceedance Probability Levels (descending)

Default Manual

1: 0.900 2: 0.750 3: 0.500 4: 0.250 5: 0.100
 6: 7: 8: 9: 10:

Flood Levels (ascending)

Default Manual 1: 999.0 2: 999.0

Apply

Accumulation Settings

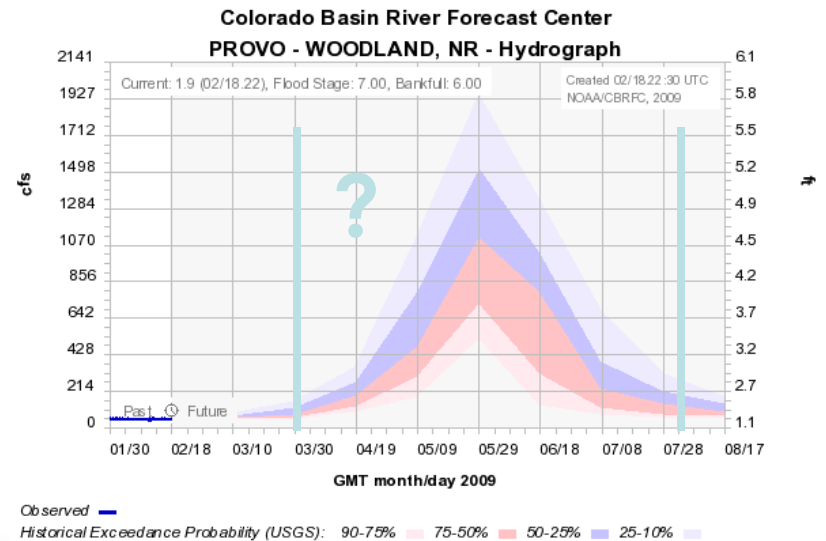
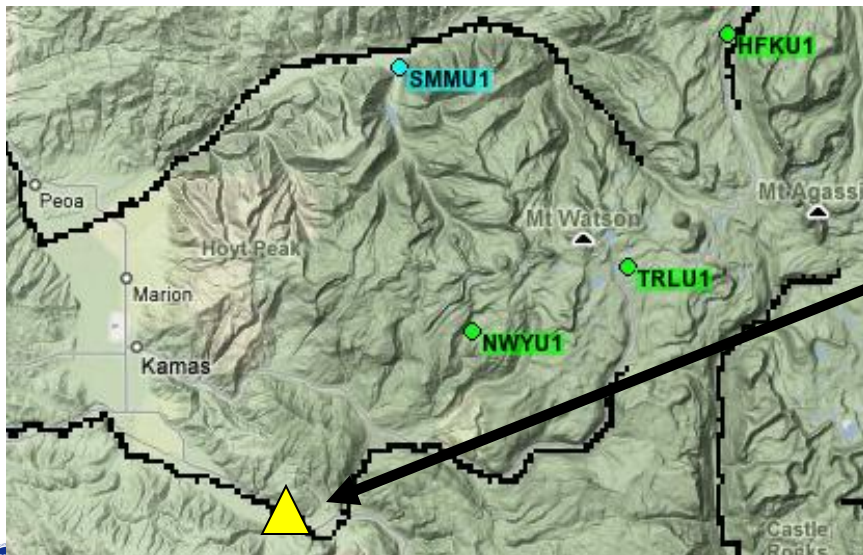
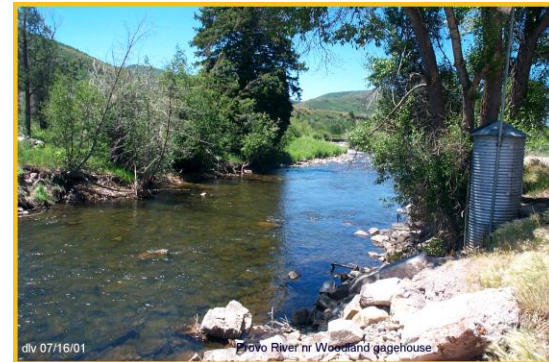
Statistical Water Supply (SWS)



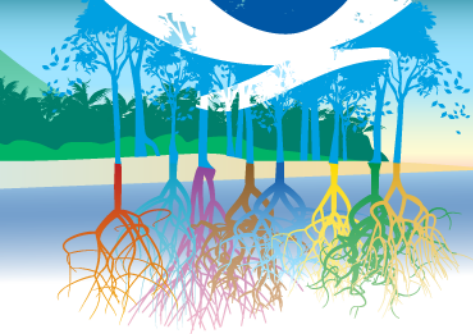
➤ Equations built on relationships between the inputs and the output

Output Variable:

April-July streamflow volume
at Provo-Woodland

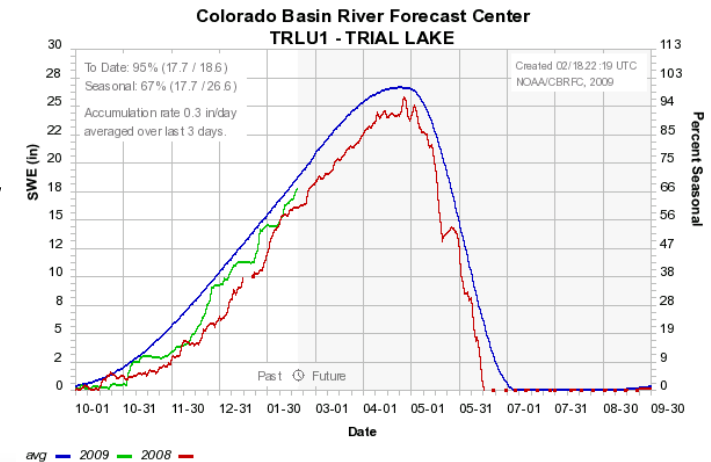
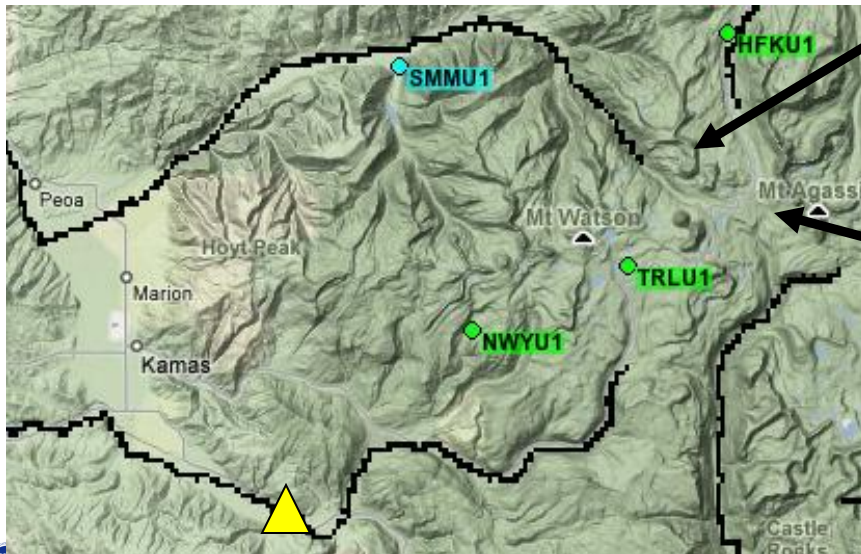
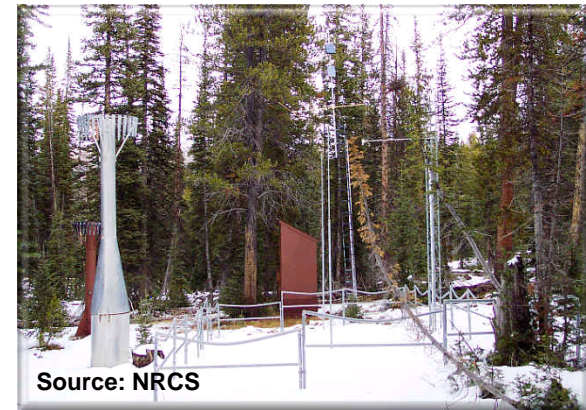


Statistical Water Supply (SWS)



➤ Equations built on relationships between the inputs and the output

Input Variable: Trial Lake Snow



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%)

Statistical 50%
 exceedance
 Forecast:
222 kac-ft



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

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%



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.



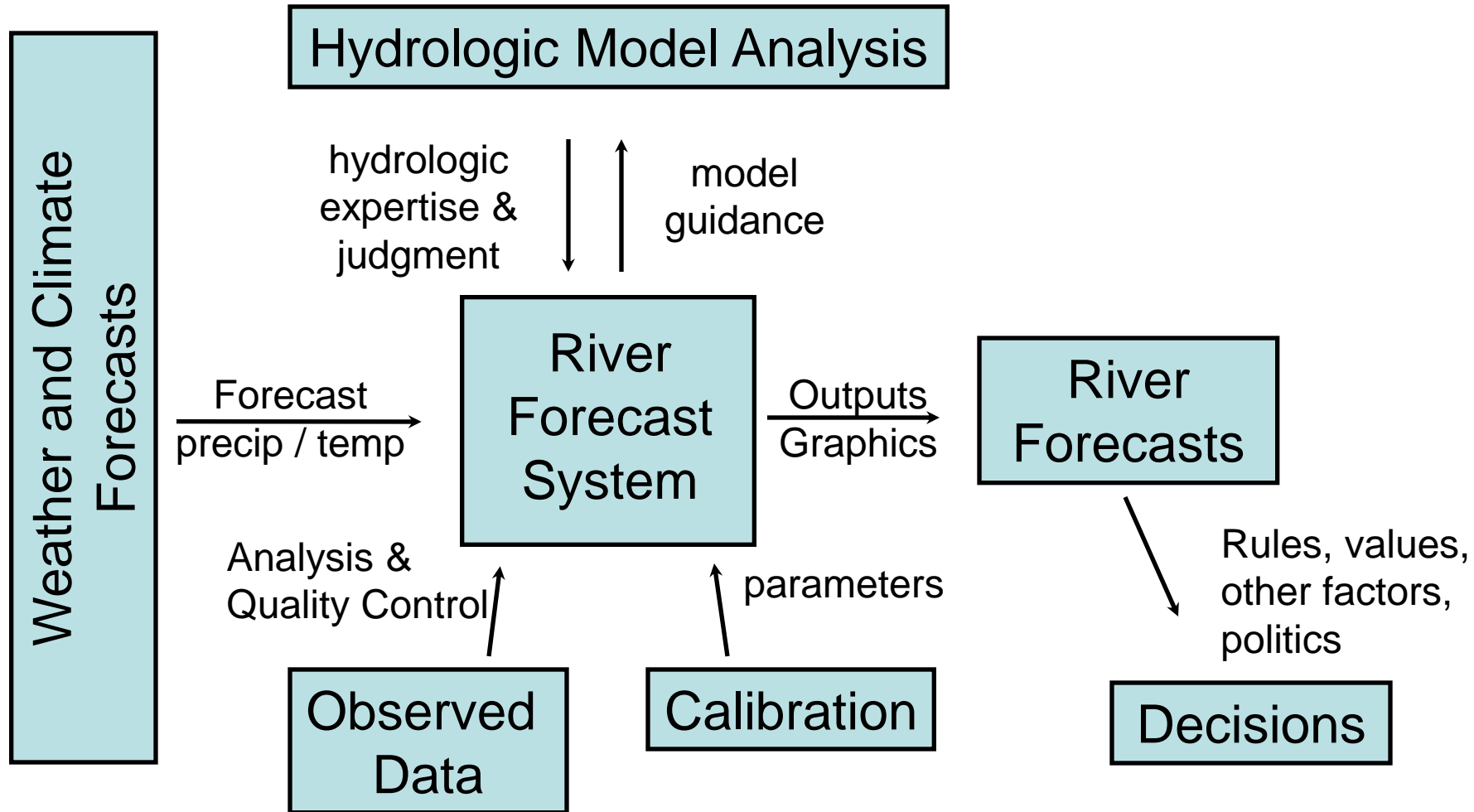
NRCS 50%
exceedance
Forecast:
220 kac-ft



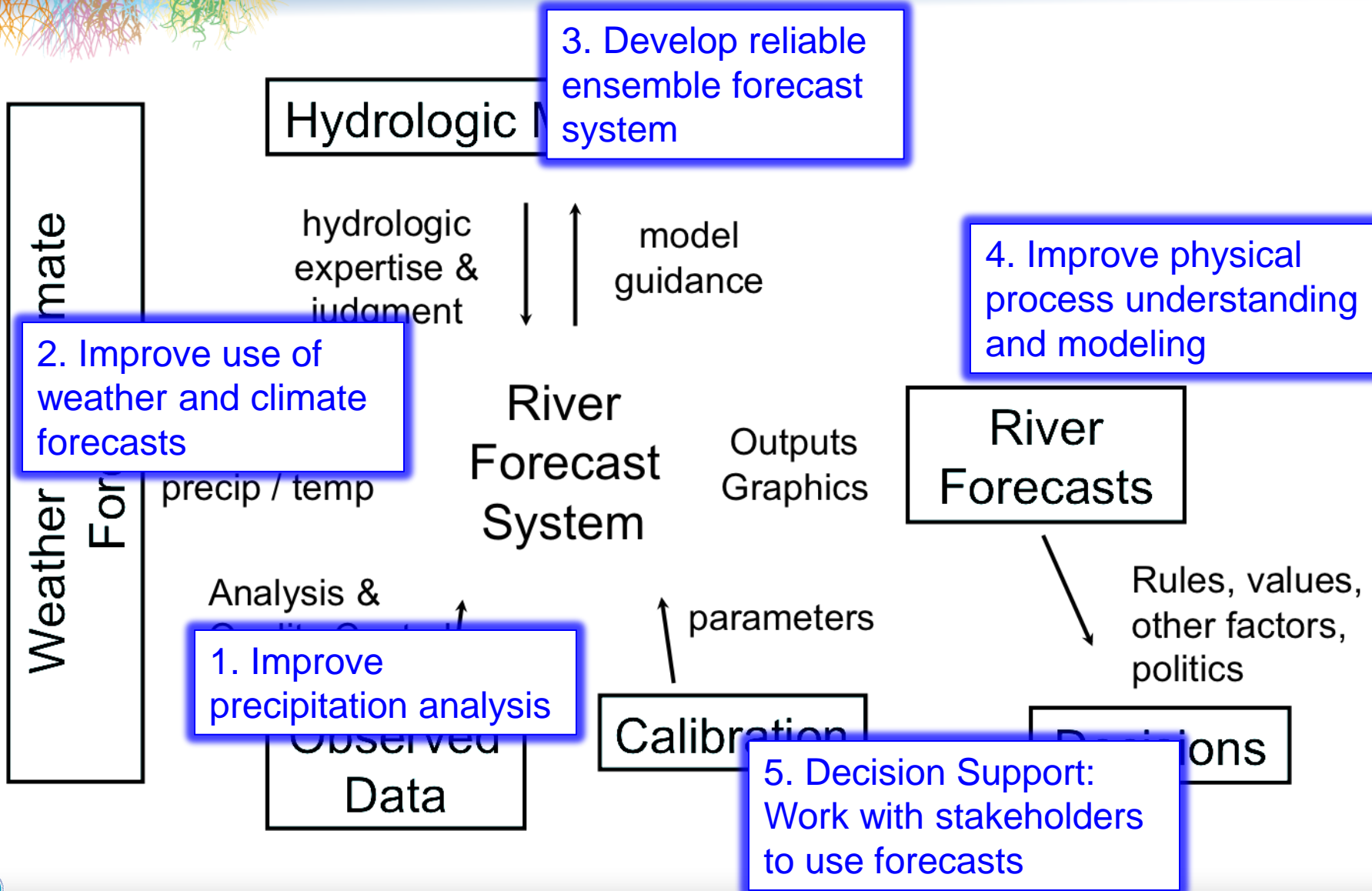
NOAA 50%
exceedance
Forecast:
225 kac-ft




Forecast Process



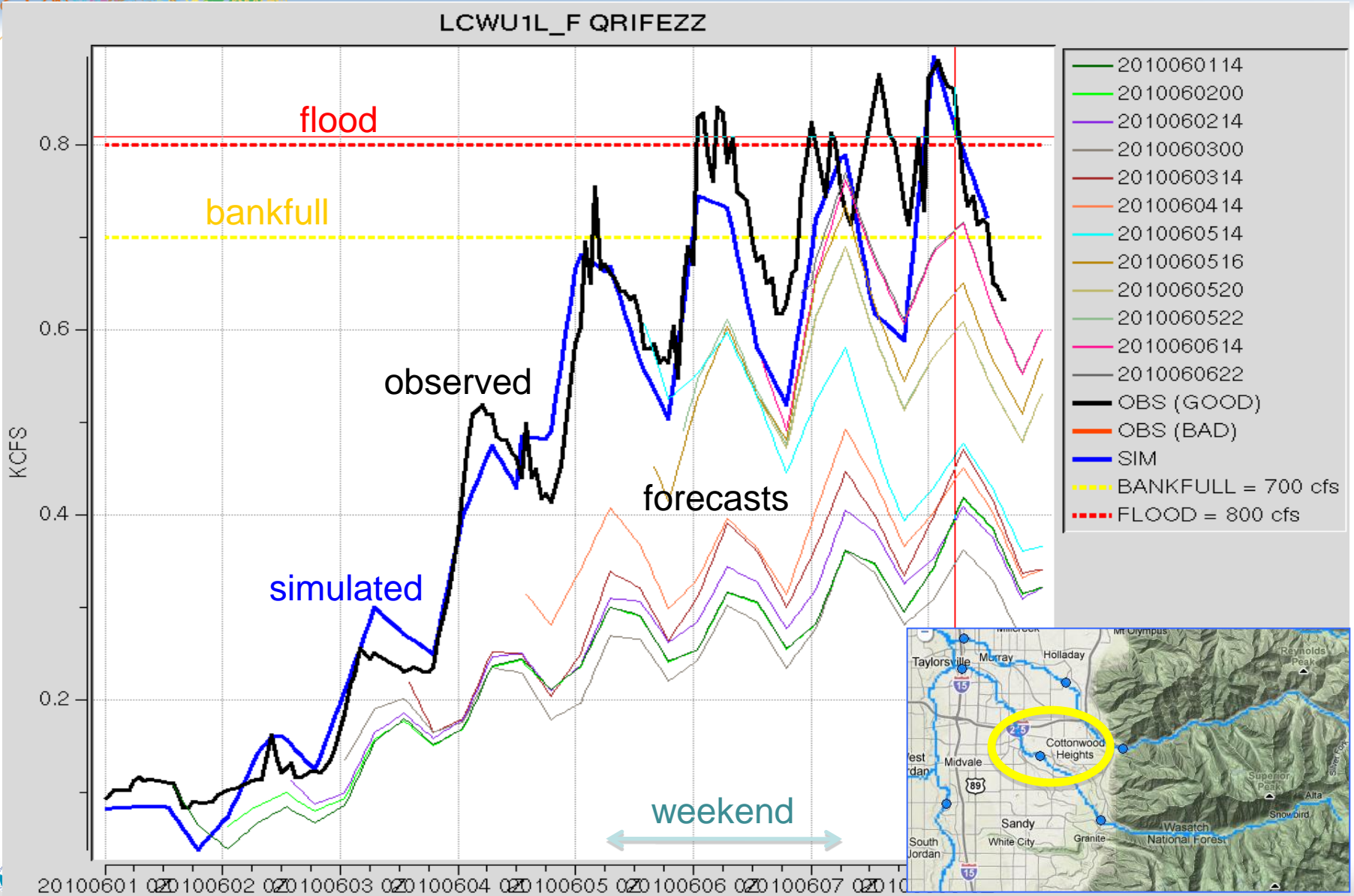
Research Needs



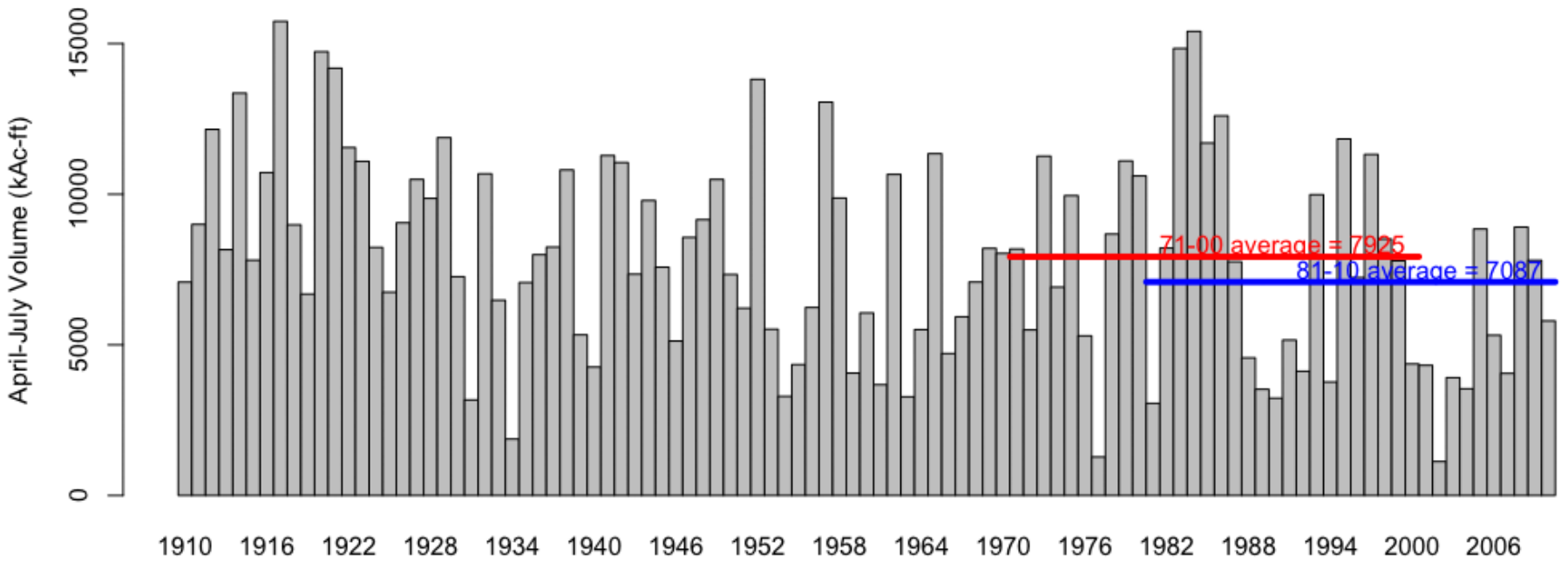
Projects

- 
- ☑ 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

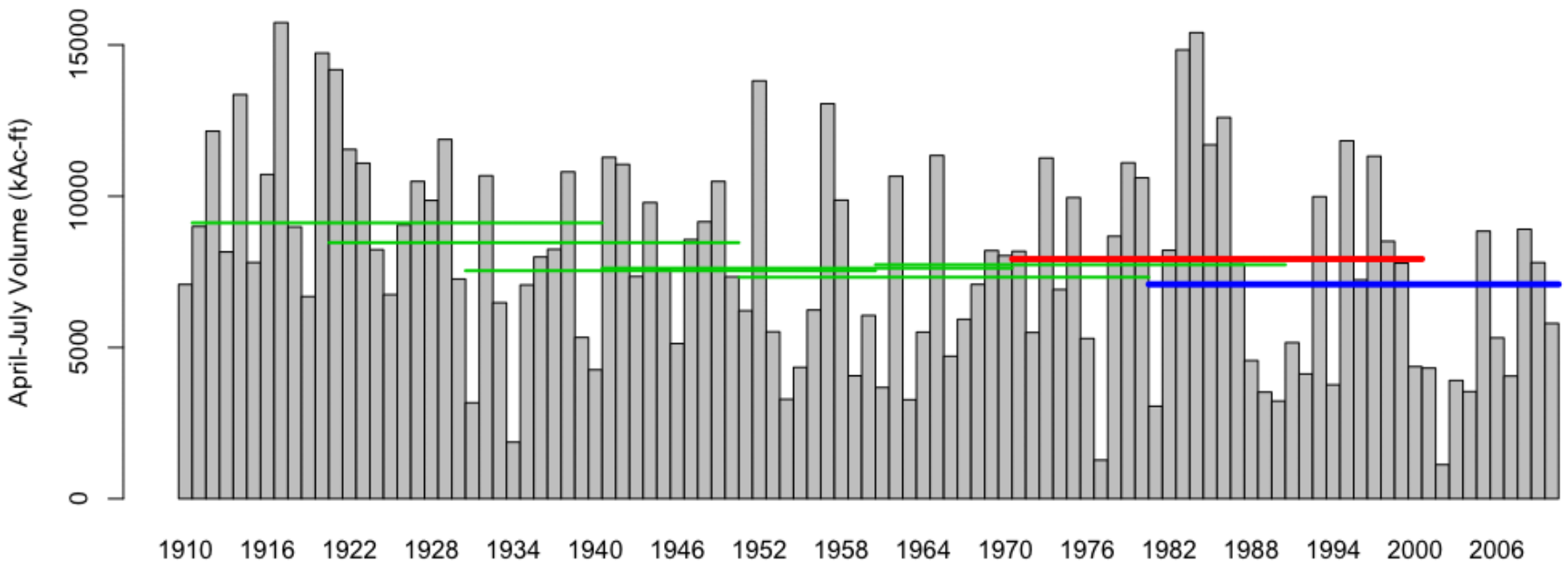


Lake Powell Inflow



- Preliminary Data
- 11% reduction in mean

Lake Powell Inflow



- 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 engagements

NOAA/NWS contact: Renee Tatusko



Kevin Werner

CBRFC Service Coordination Hydrologist

Phone: 801.524.5130

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

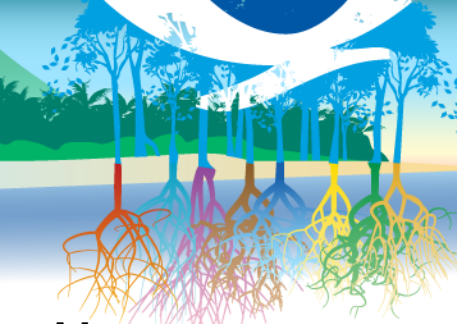
General conditions leading into event:

- ✔ 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?

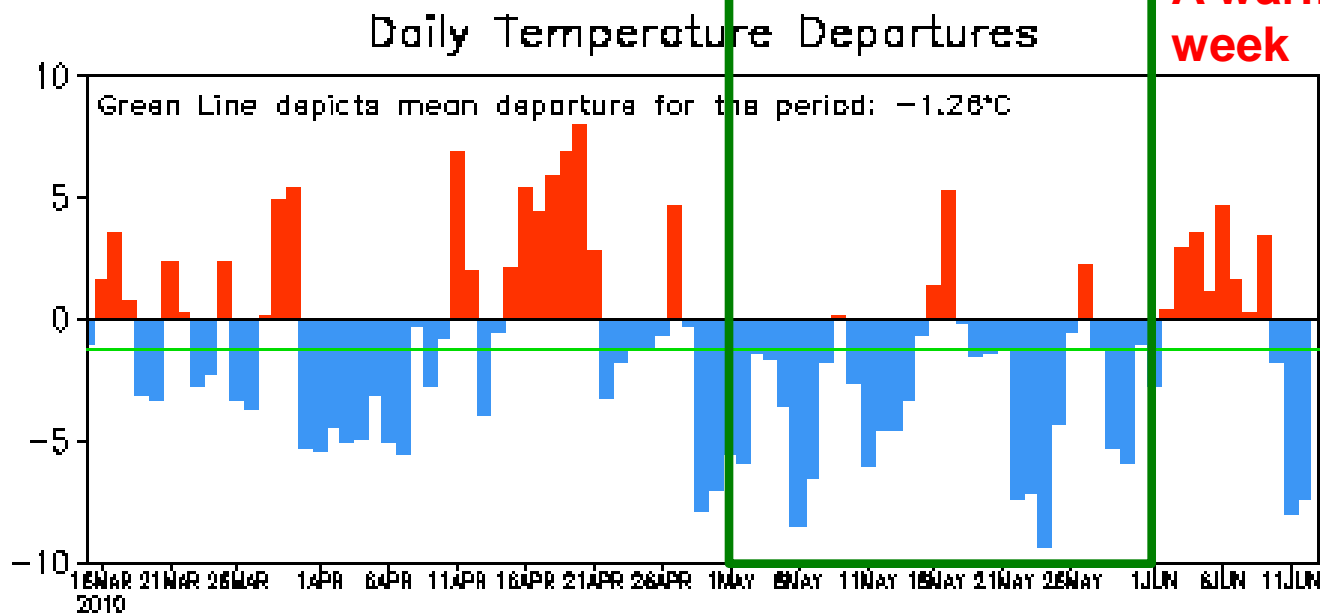
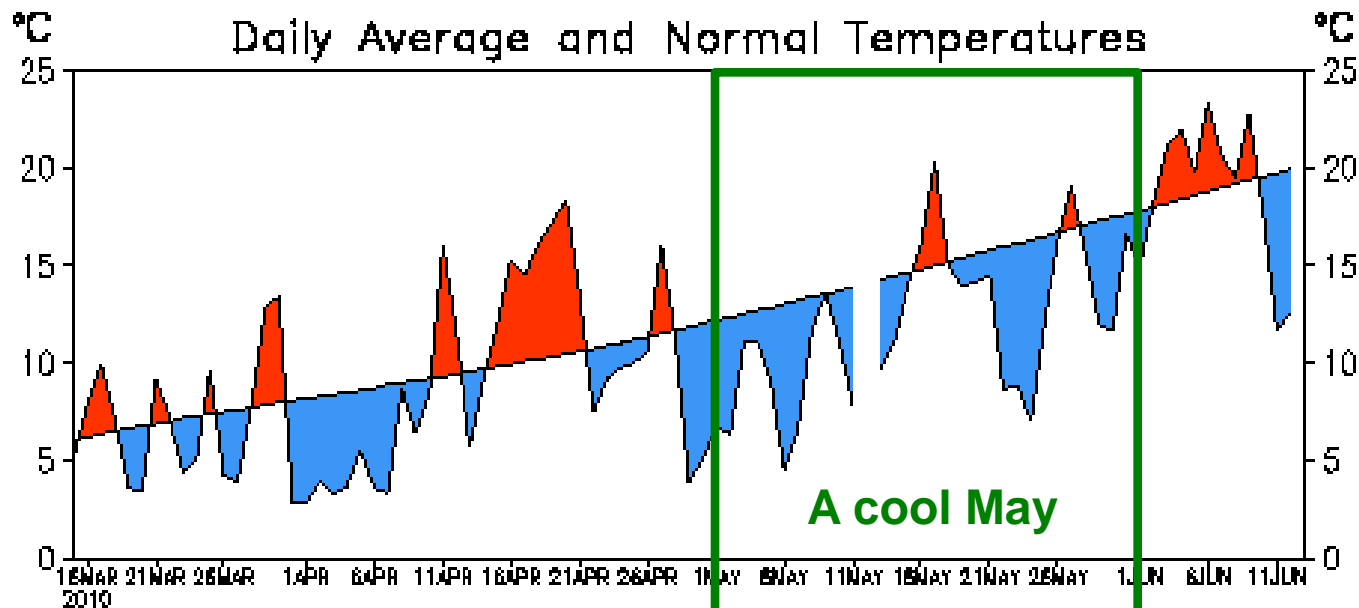


May was generally cool, delayed melt

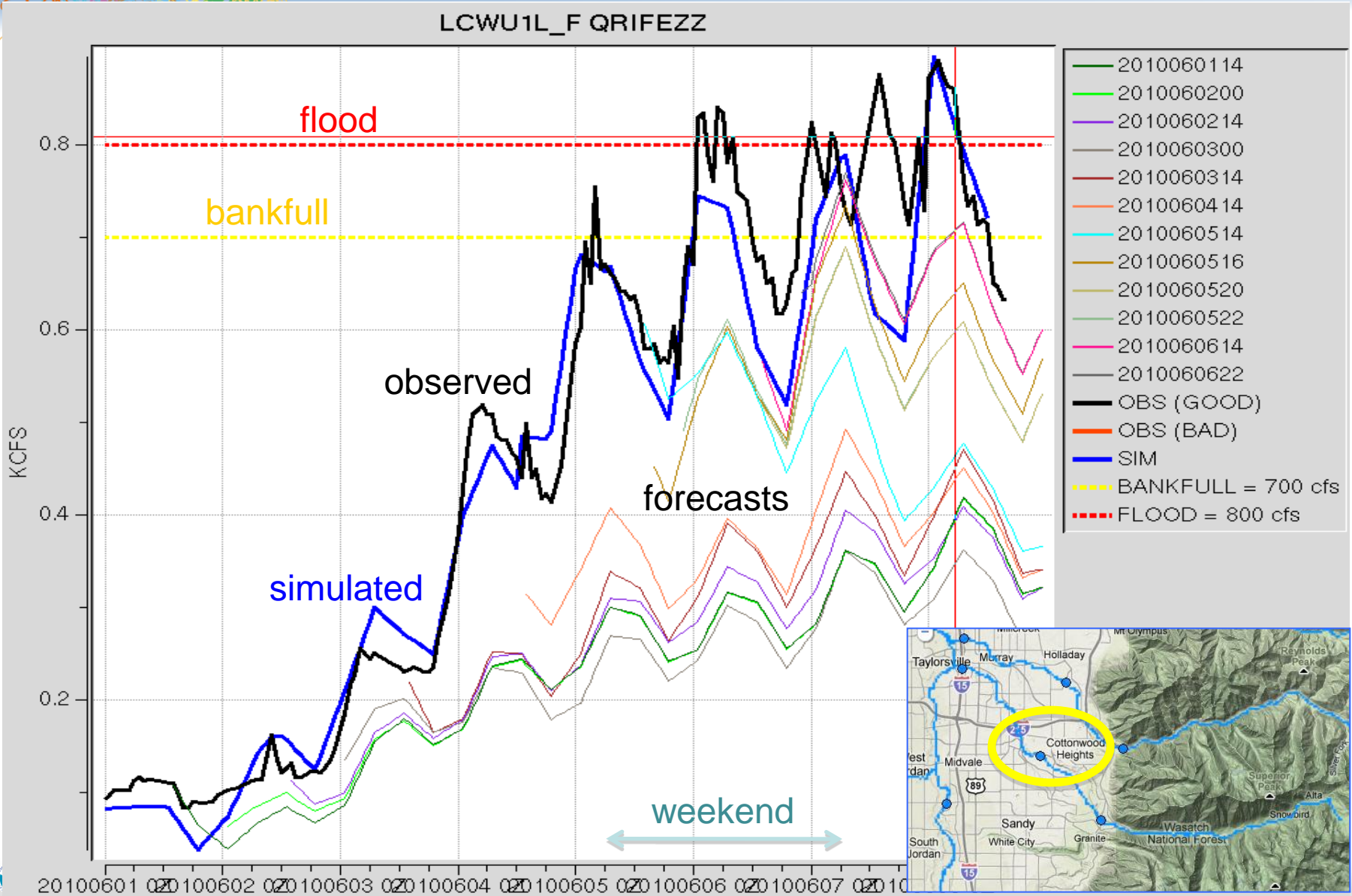
First week in June was warm

From NOAA CPC

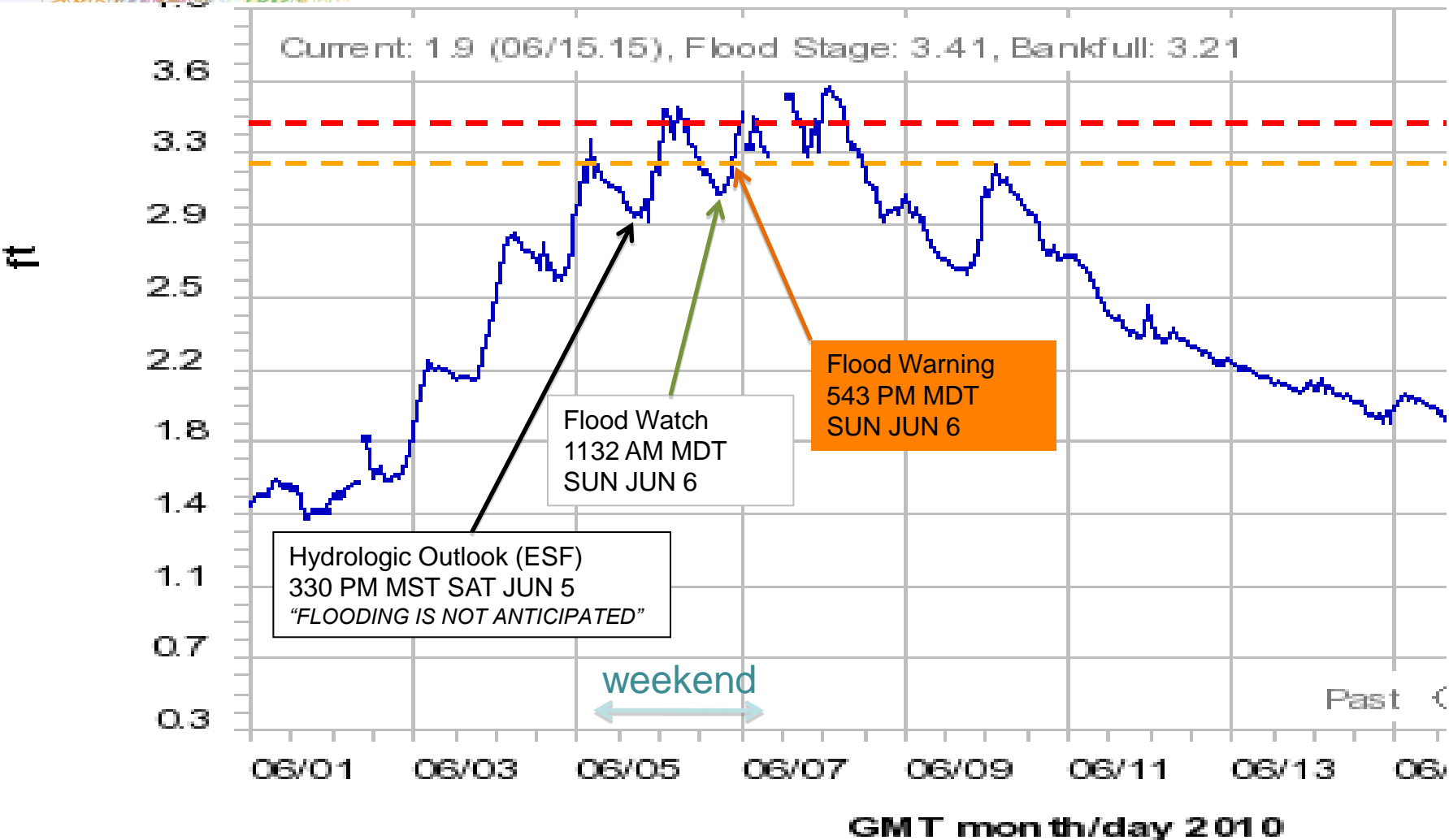
SALT LAKE CITY, UTAH



Little Cottonwood at Crestwood Park flow under forecast



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

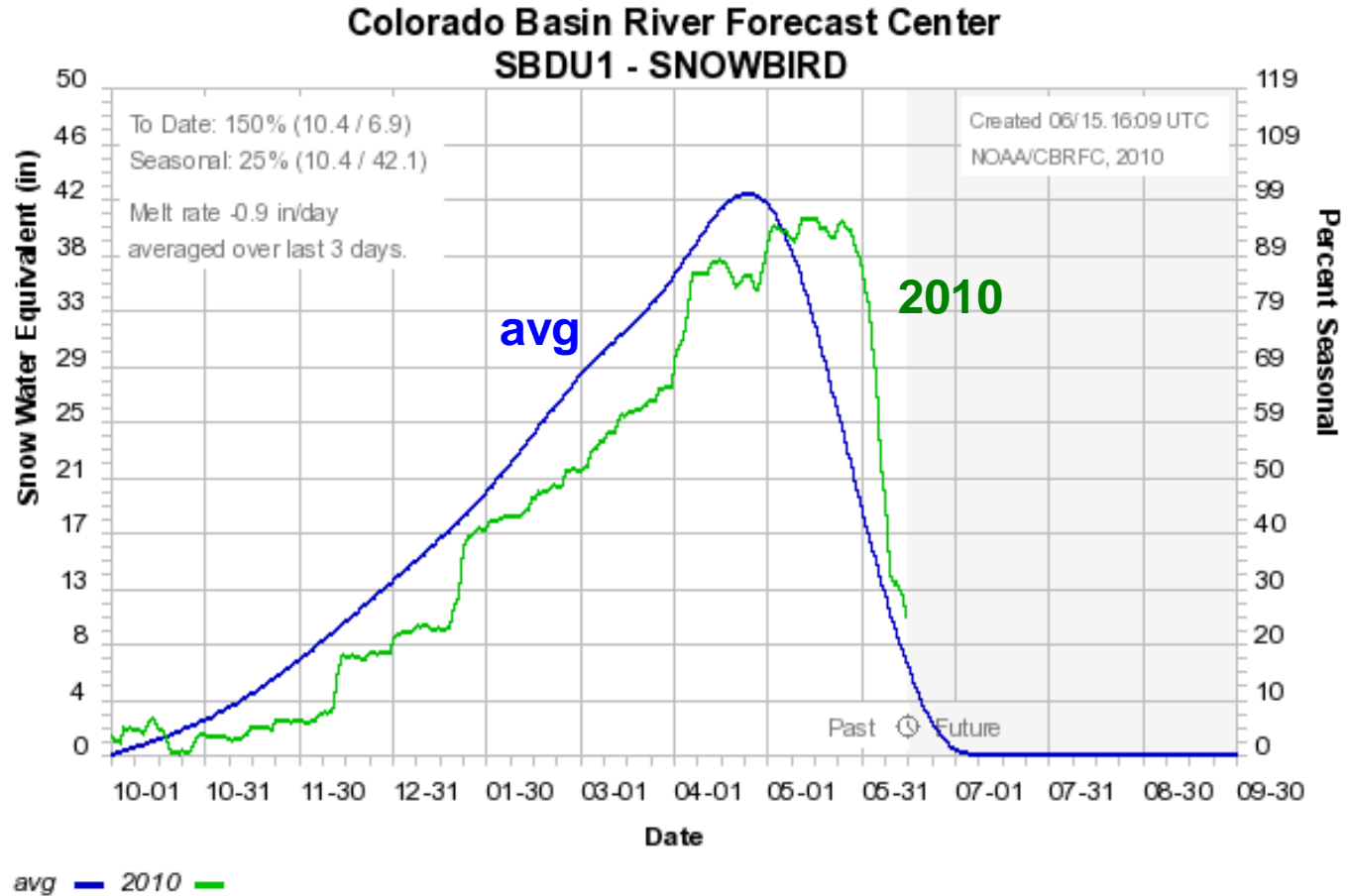


Little Cottonwood snow year



Snowmelt rate
extraordinarily
large? (no)

Snowmelt
extraordinarily
late? (no)



Snow Measurements (SNOTEL) in Cottonwoods

Mill-D North

(8960', southwest face)

☑ "middle"

Brighton

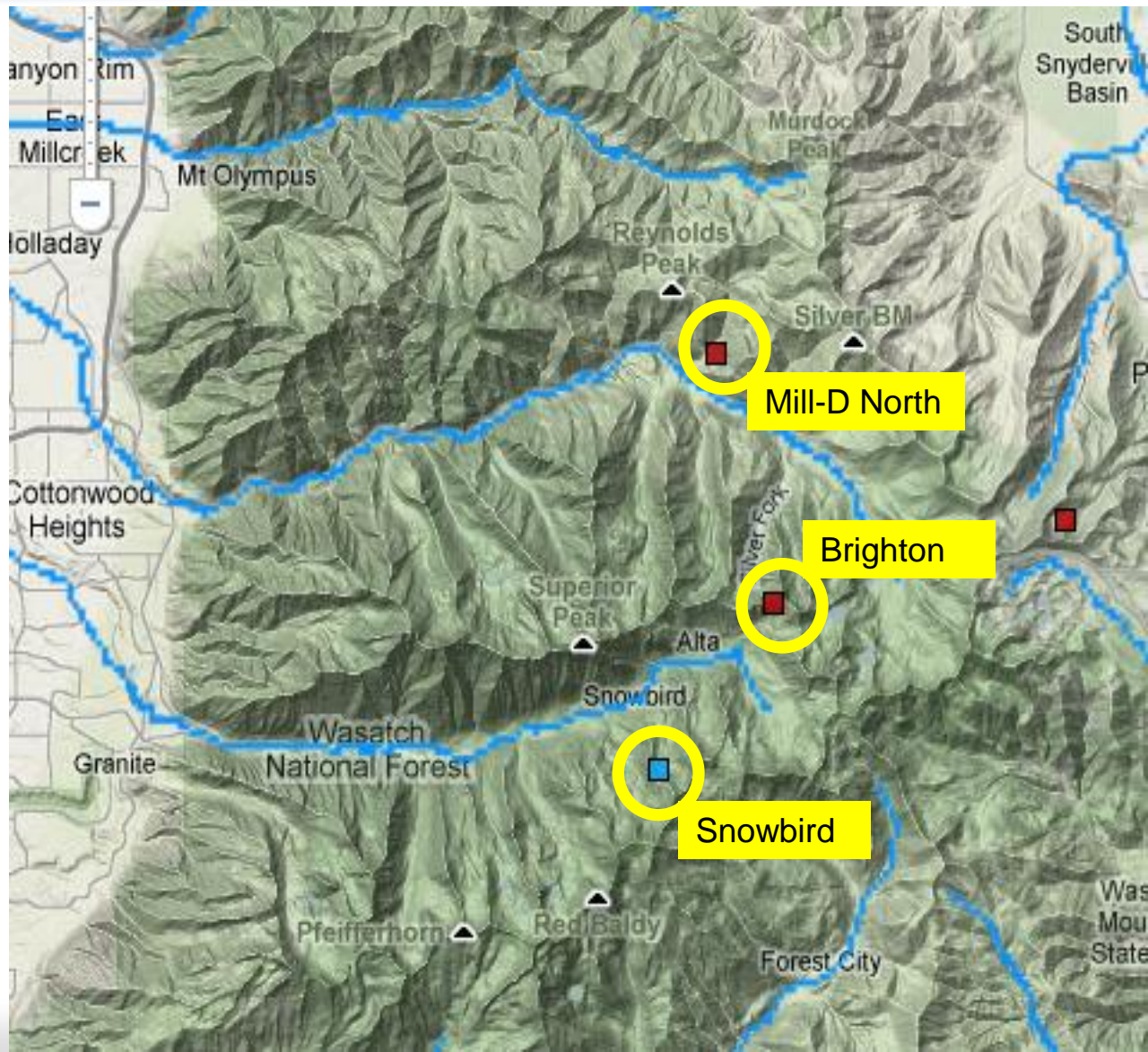
(8750', southeast face)

☑ "middle"

Snowbird

(9640', northeast face)

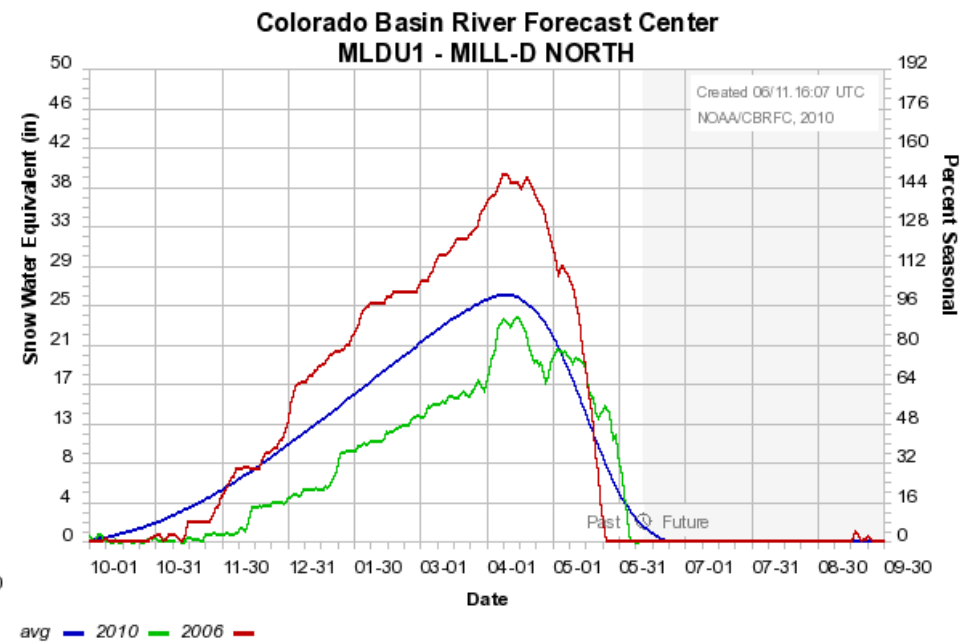
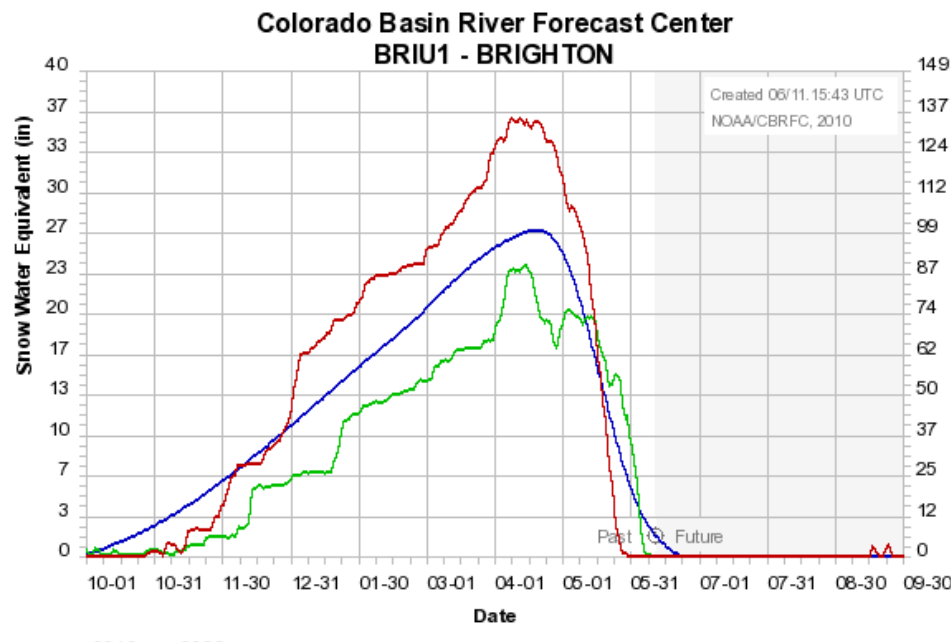
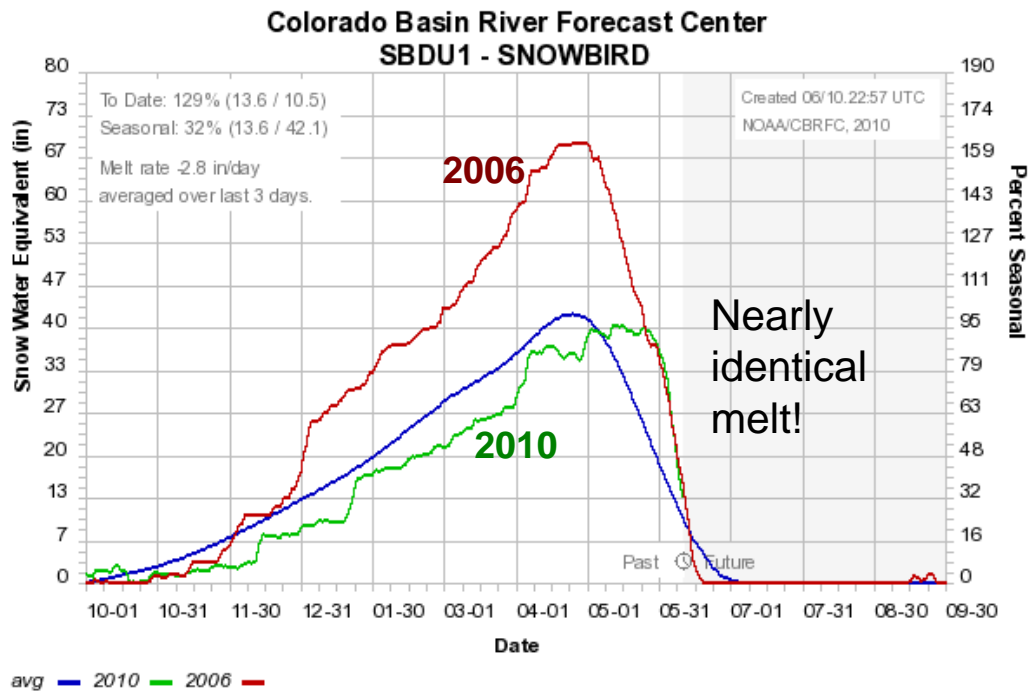
☑ "high"



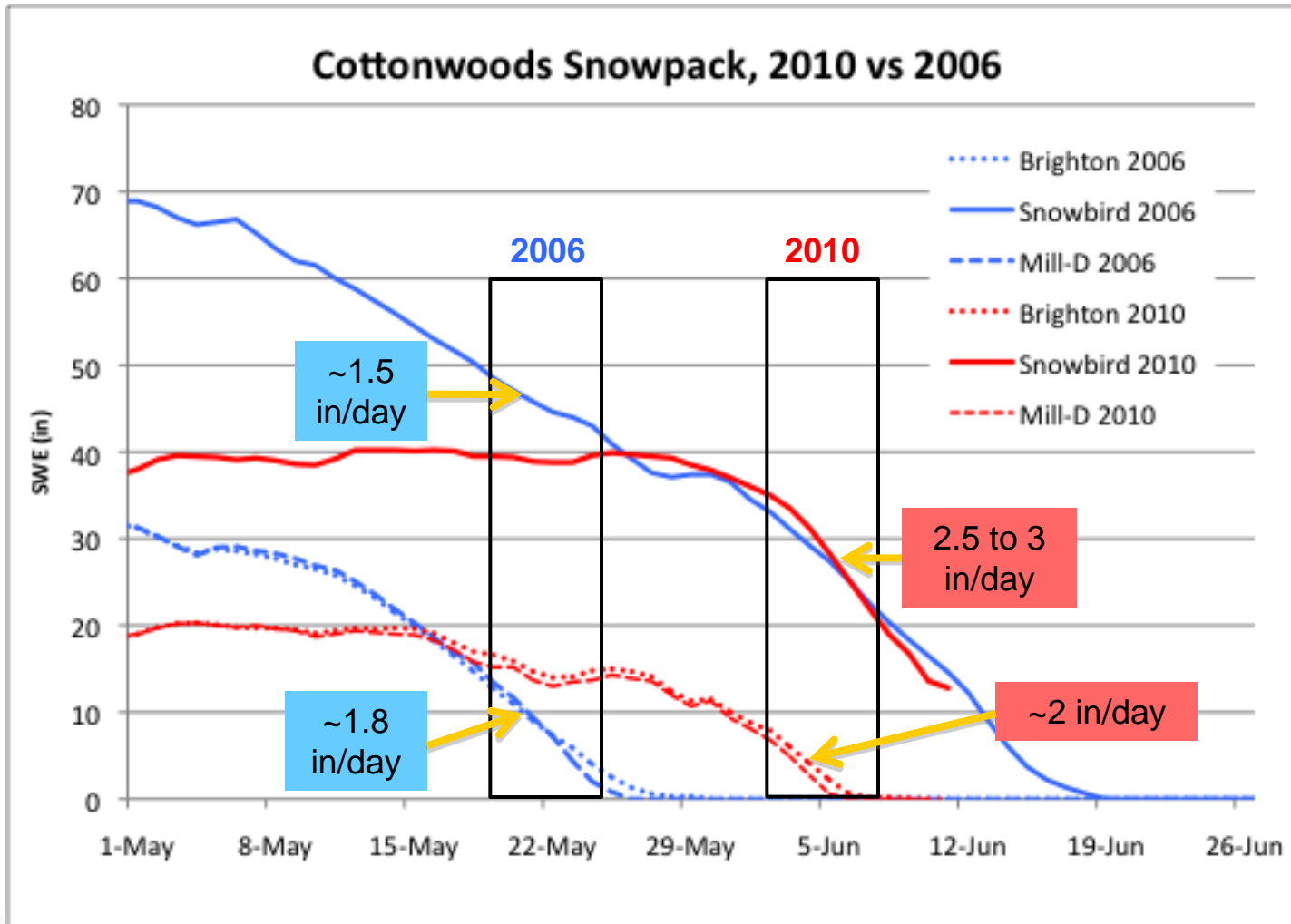


Snow Water

2010 compared to 2006



SWE/Snotel Comparison



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

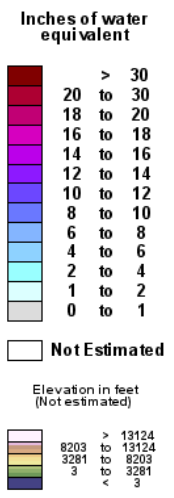
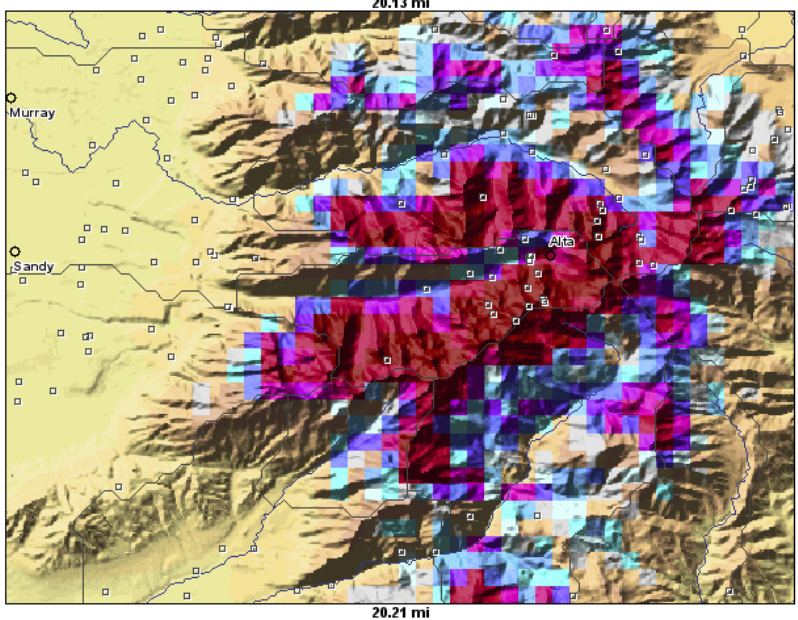
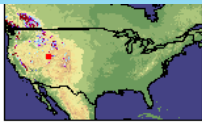
2010 June 1

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

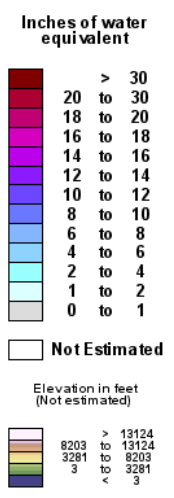
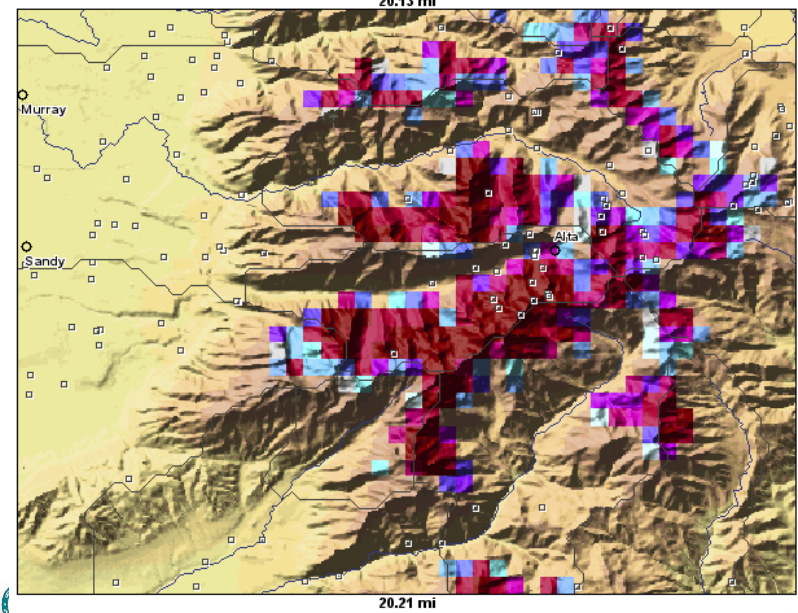
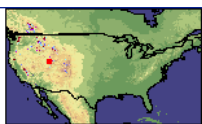
However, NOHRSC indicates south facing slopes had already melted out in 2006

2006 June 1, for comparison

Modeled Snow Water Equivalent (updated hourly) for 2010 June 1, 12:00 Z



Modeled Snow Water Equivalent (updated hourly) for 2006 June 1, 12:00 Z



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

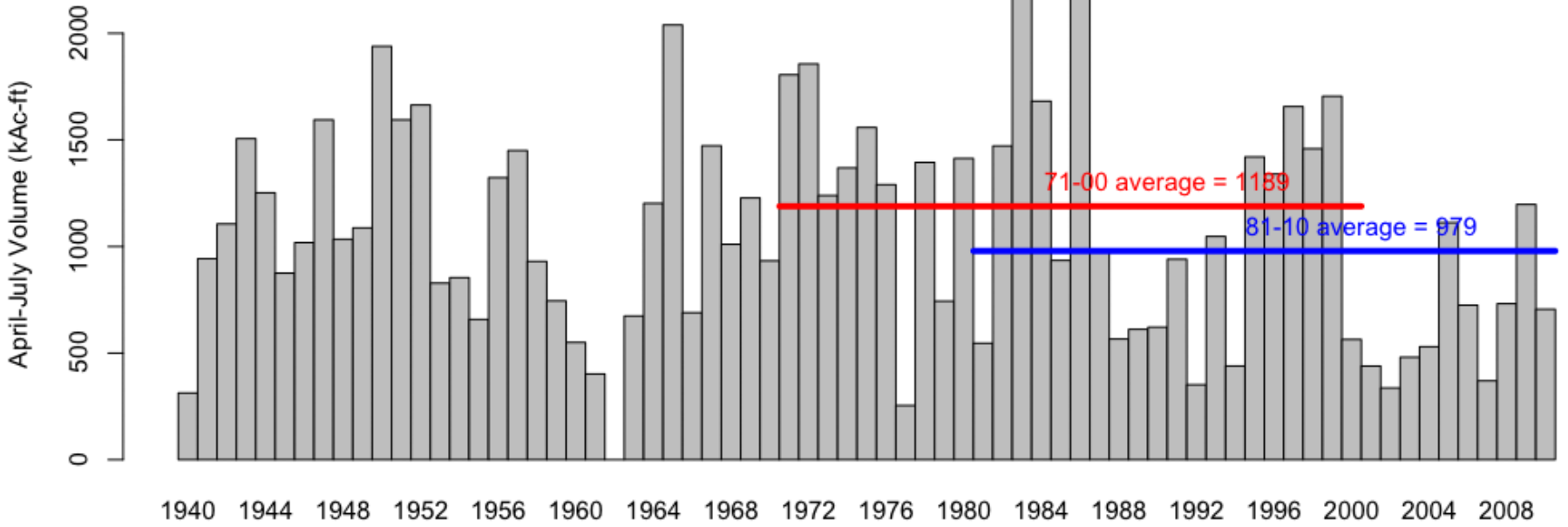
SNOTEL network much stronger for 1981-2010 period than in 1970s. This network is critical for forecast skill.

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)

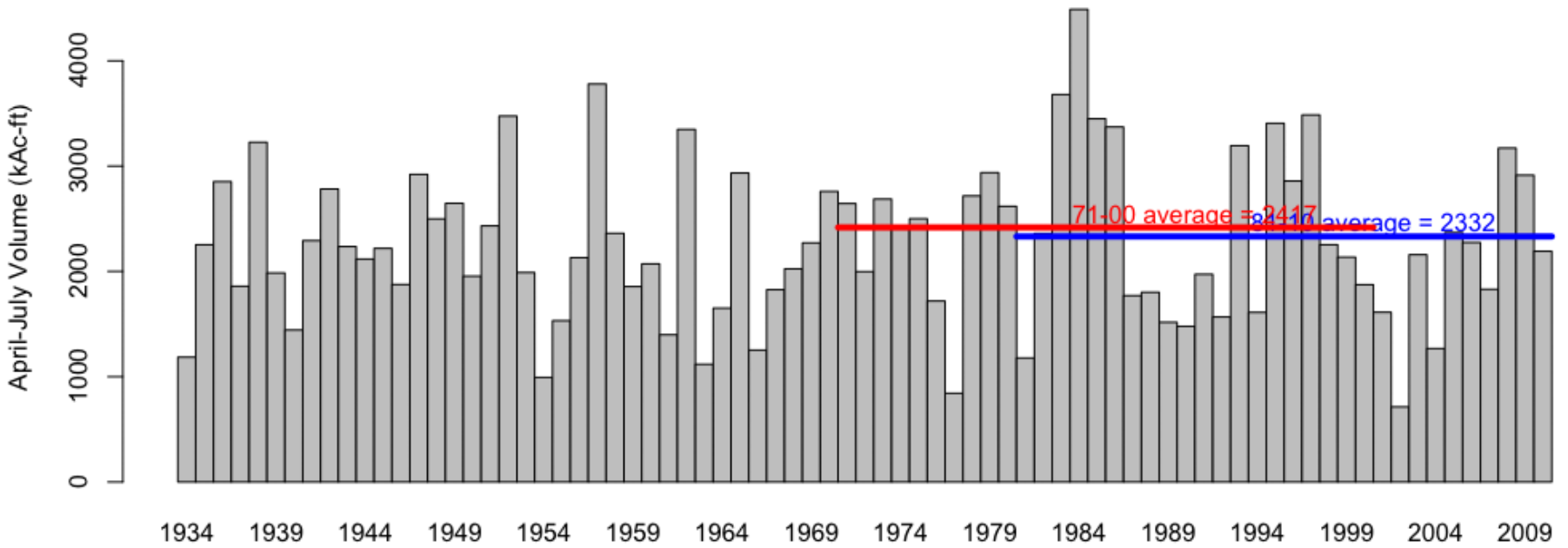
Flaming Gorge Inflow



Preliminary Data

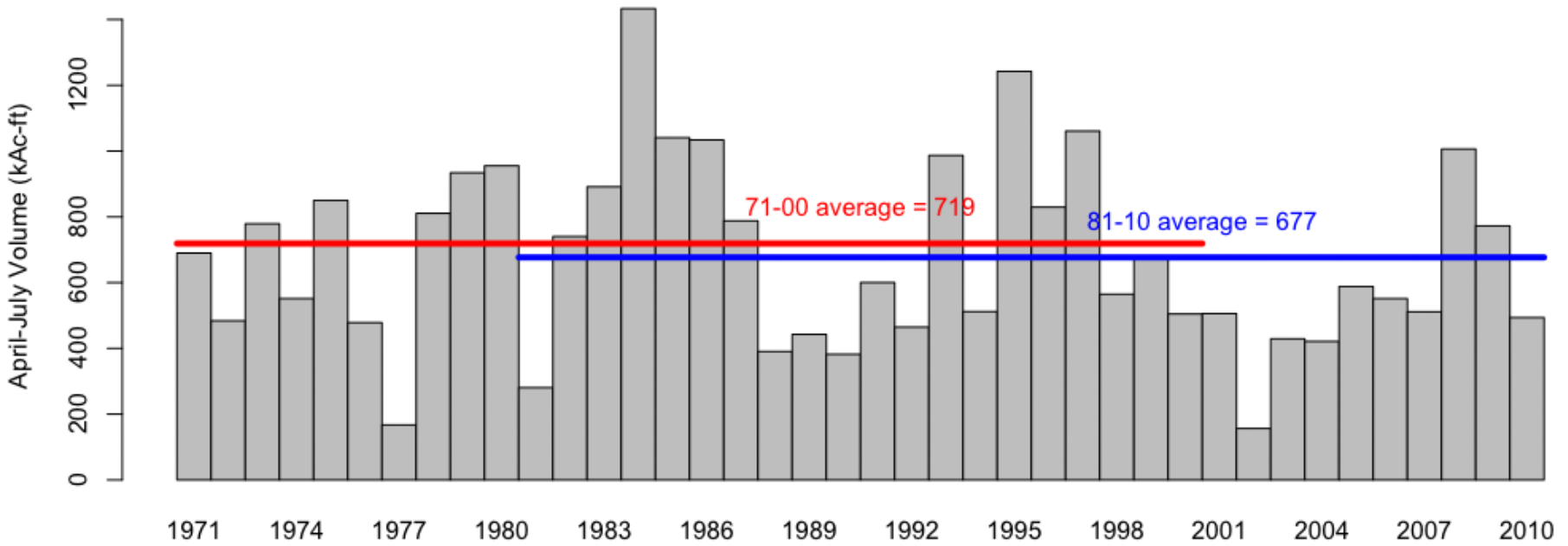
18% reduction in mean

Colorado @ Cameo



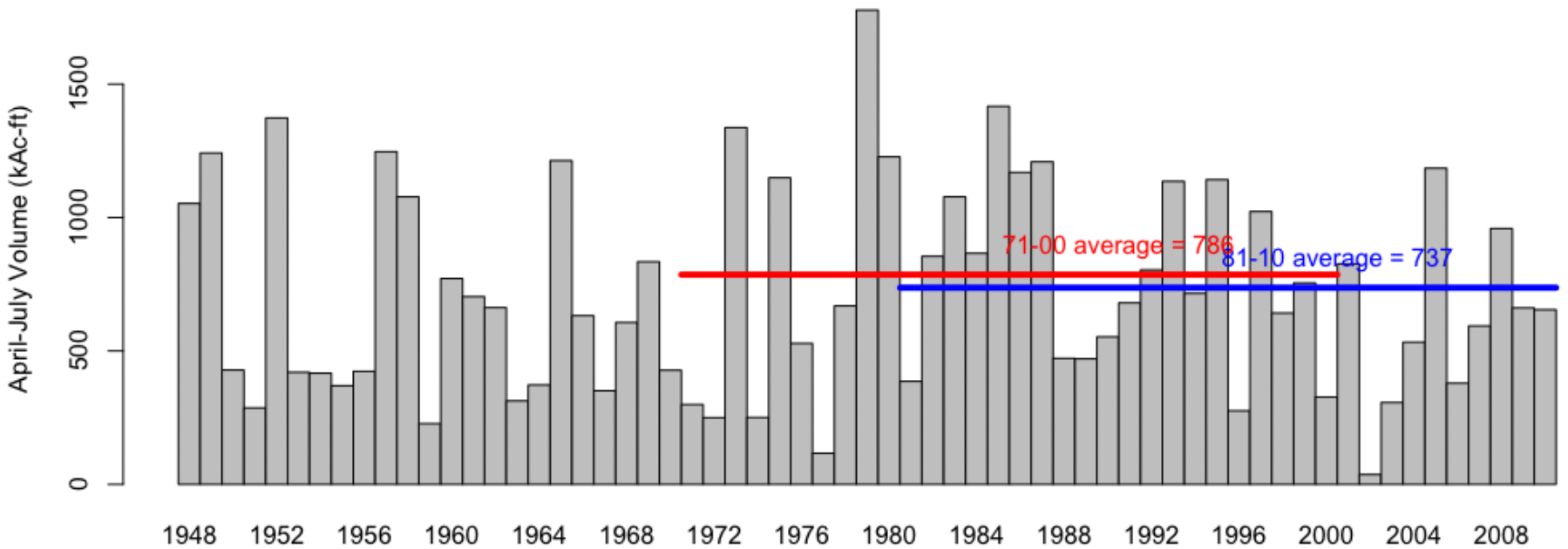
- Preliminary Data
- 4% reduction in mean

Blue Mesa Inflow



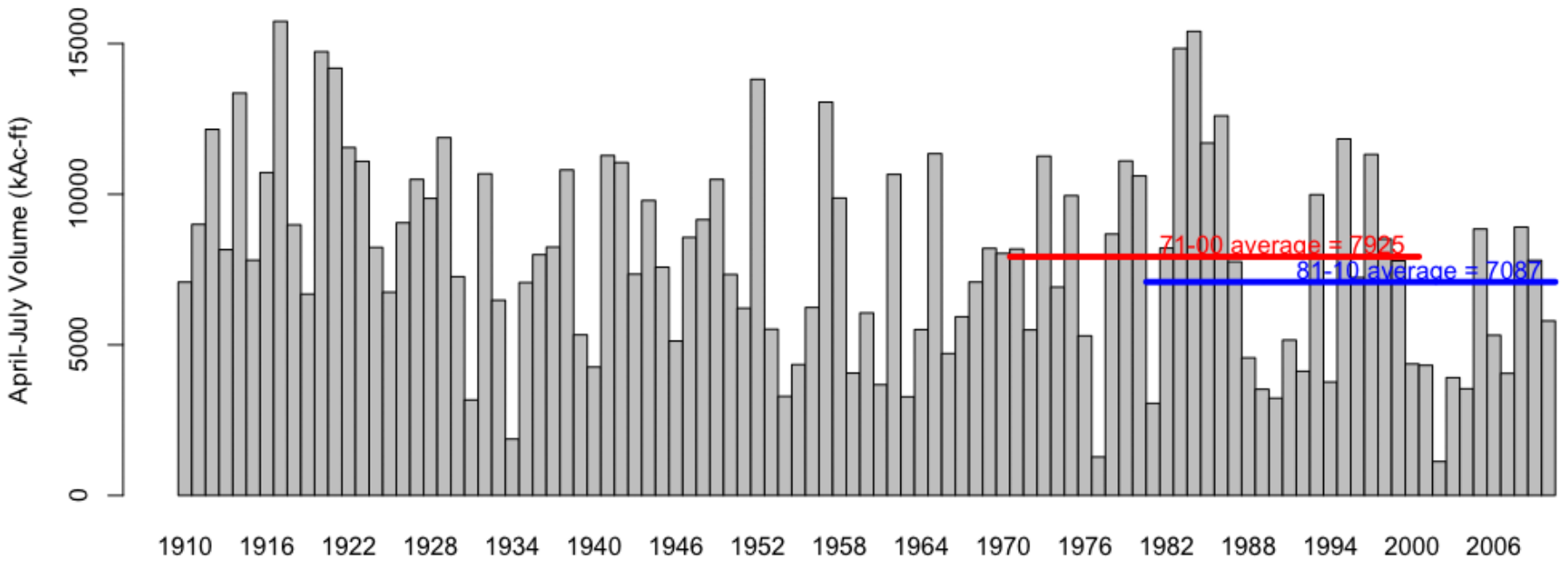
- Preliminary Data
- 6% reduction in mean

Navaja Inflow



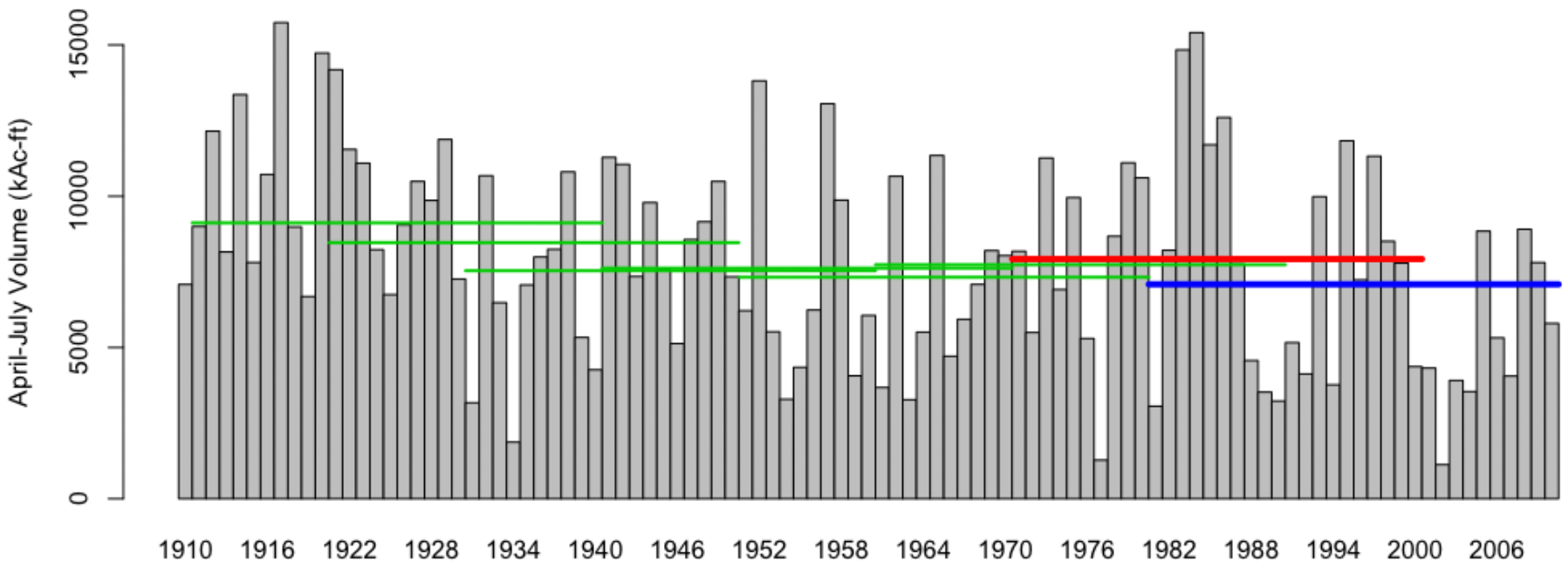
- Preliminary Data
- 6% reduction in mean

Lake Powell Inflow



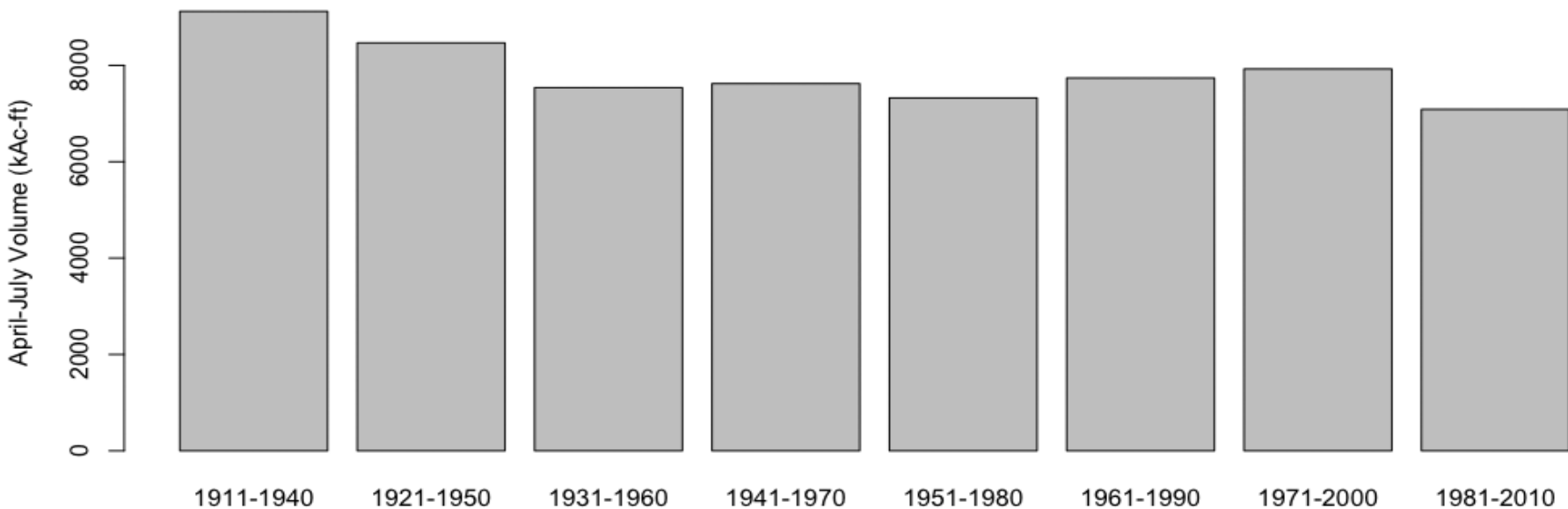
- Preliminary Data
- 11% reduction in mean

Lake Powell Inflow



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

Lake Powell Inflows 30 year averages



1981-2010 is the driest 30 year period on record