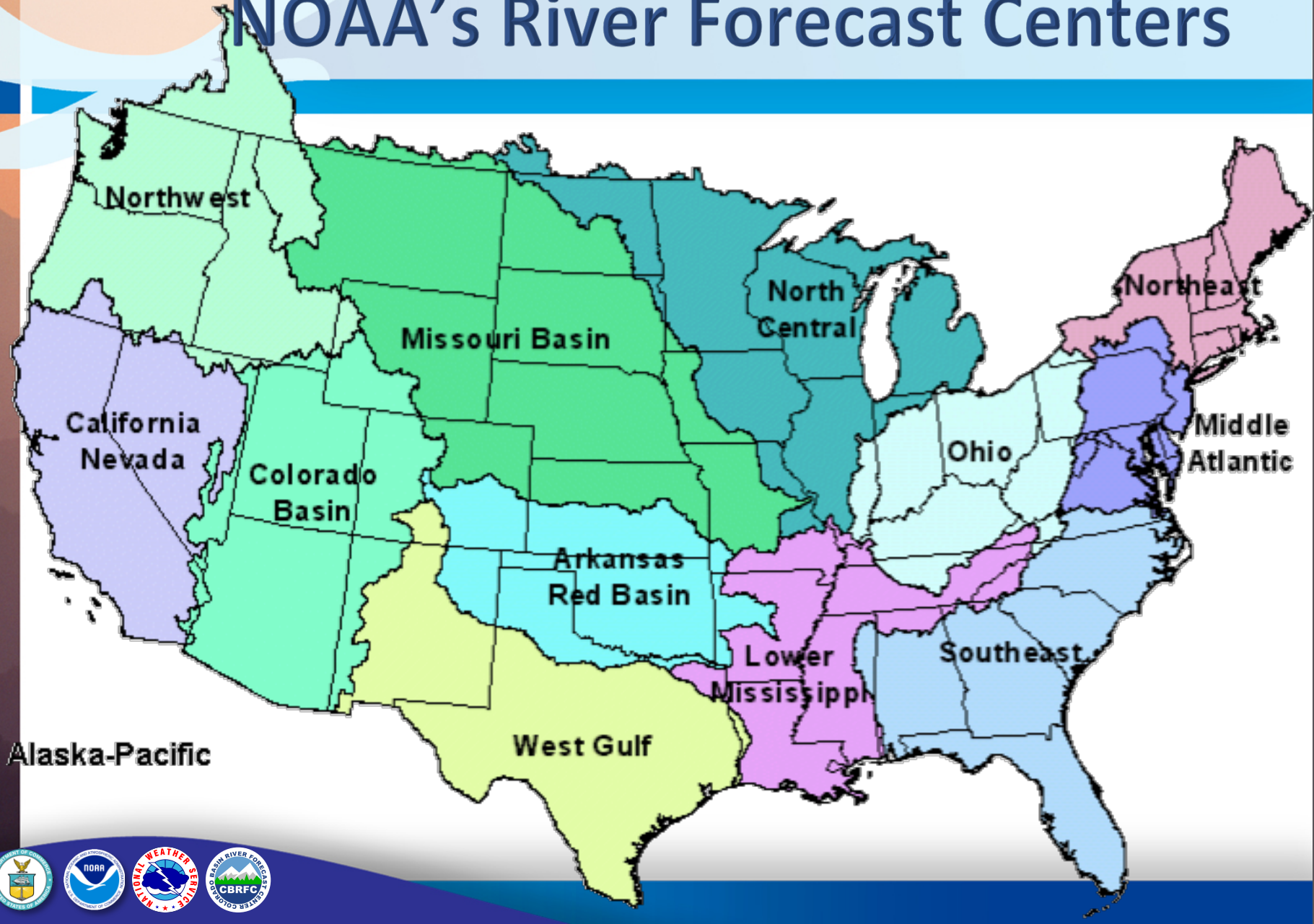
NOAA'S COLORADO BASIN RIVER FORECAST CENTER

AN OVERVIEW OF THE CBRFC – WE'RE HERE TO HELP!

Overview

- Who is the Colorado Basin River Forecast Center?
  - Models, methods used
  - Current products, deliverables, stakeholders
- Work we do that impacts CAP
- The latest on ENSO
- How can we better meet your needs?

NOAA's River Forecast Centers



Colorado Basin River Forecast Center

- An office in NOAA, one of 13 RFCs nationwide
- Part of the NWS – WFOs are a major stakeholder. We're co-located with the SLC WFO
- Nationwide, the CBRFC is the most involved with water supply – each RFC is unique
- Reclamation is our largest stakeholder when it comes to water supply

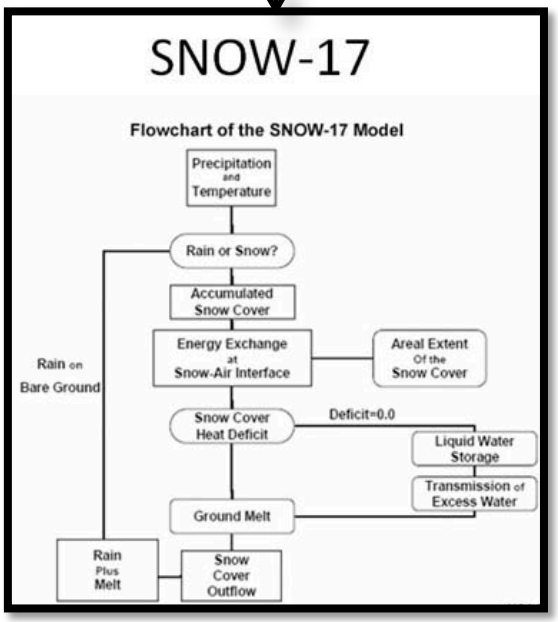
Colorado Basin River Forecast Center

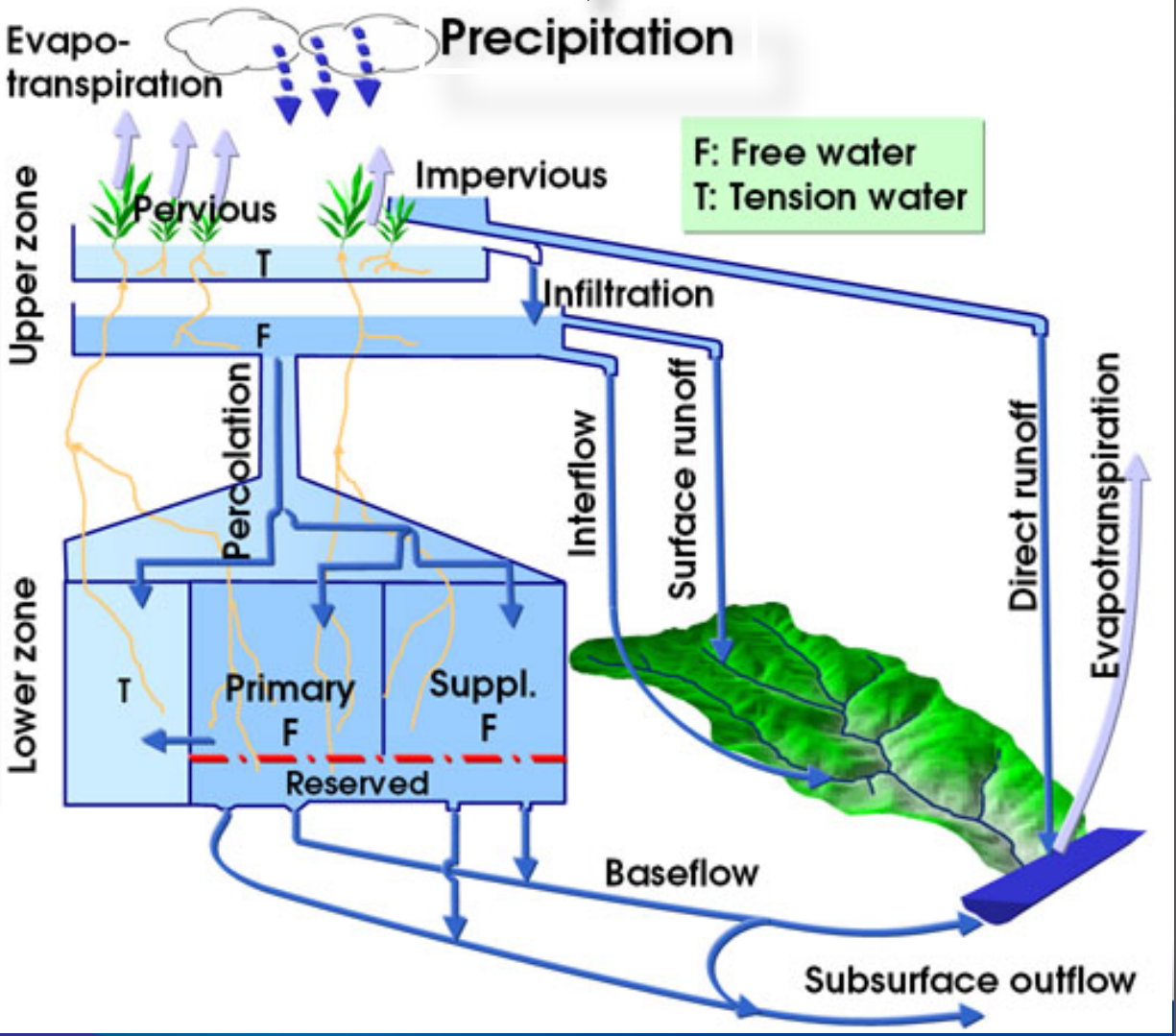
- We are highly dependent on real-time gage information to inform our models and forecasts to meet our stakeholders' needs.
  - Reclamation gages and information (we get CAP info from them)
  - NRCS SNOTEL network
  - USGS streamflow network
  - Many others

Products and Services

- We use a hydrologic model (Sac-SMA) coupled with a snow accumulation and ablation model (SNOW-17) to develop forecasts
  - Calibration is highly dependent on gage observations from both the USGS and NRCS
    - SNOTEL precipitation, not SWE, is used
    - SNOTEL temperature used where records are valid
  - Calibrated using 1981-2010 information

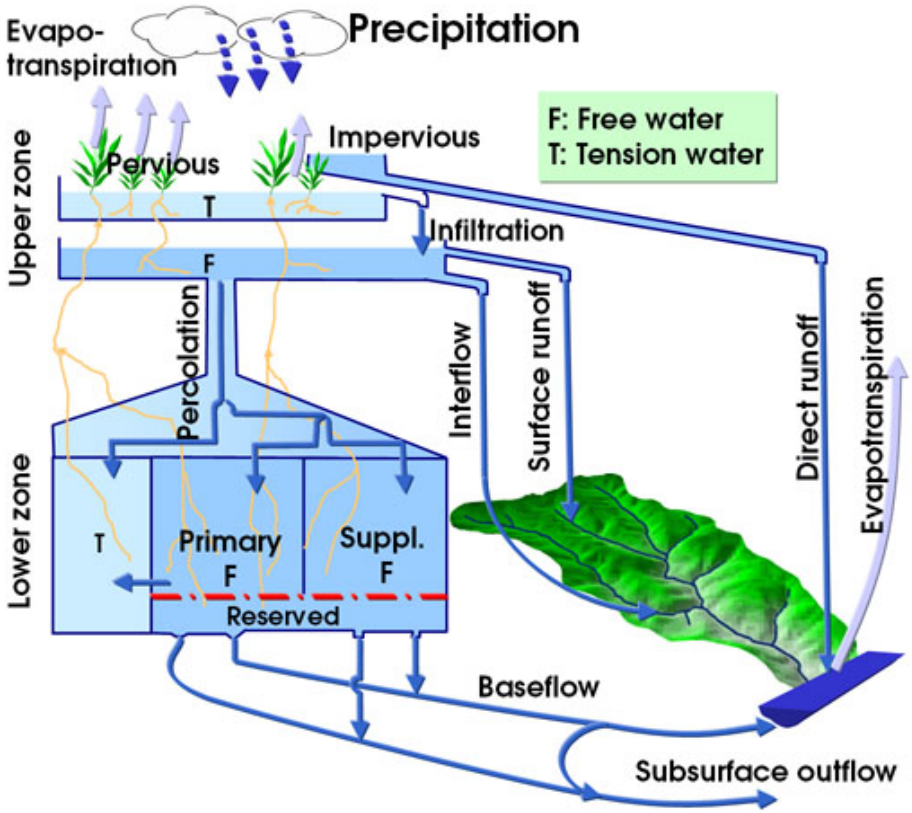
Our models


SNOW-17
Flowchart of the SNOW-17 Model
Precipitation and Temperature
Rain or Snow?
Accumulated Snow Cover
Energy Exchange at Snow-Air Interface
Areal Extent Of the Snow Cover
Rain on Bare Ground
Snow Cover Heat Deficit
Deficit=0.0
Liquid Water Storage
Transmission of Excess Water
Ground Melt
Rain Plus Melt
Snow Cover Outflow


Evapo-transpiration
Precipitation
F: Free water
T: Tension water
Impervious
Pervious
Upper zone
T
F
Infiltration
Percolation
Interflow
Surface runoff
Direct runoff
Evapotranspiration
Lower zone
T
Primary F
Suppl. F
Reserved
Baseflow
Subsurface outflow

Our models

- "Model State"
  - Basically the hydrologic condition of our system
    - Snowpack condition
    - Soil moisture "tanks"
  - Model states are updated each day
  - Used as initial condition for daily ESP model run



Complementary Efforts

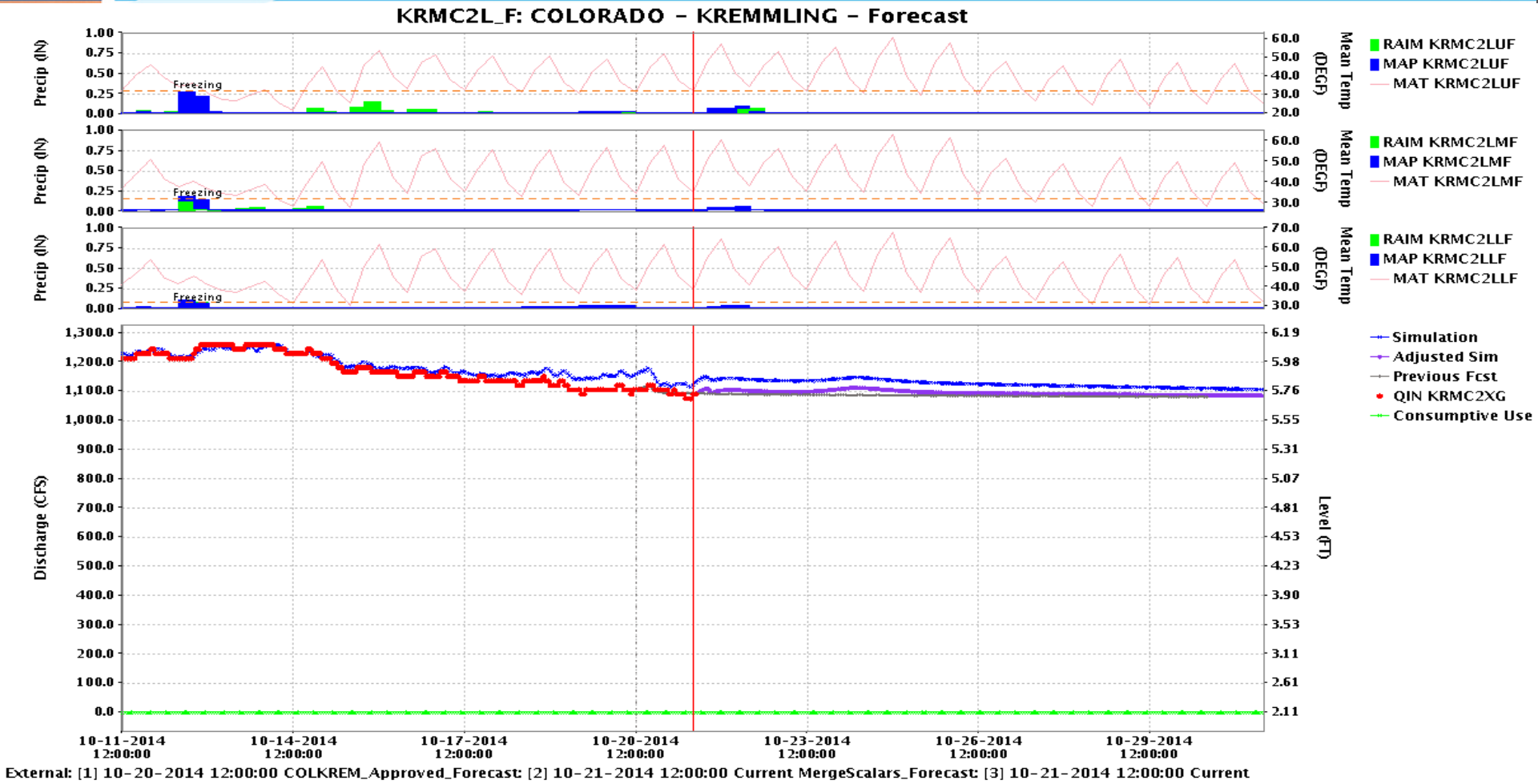
Calibration Model:
30-years of record (1981-2010)
Important for having a model that is accurate and based on historical information.

Operations Model:
Important for disseminating timely information and data to our stakeholders, protecting life and property, and maintenance of our model states.

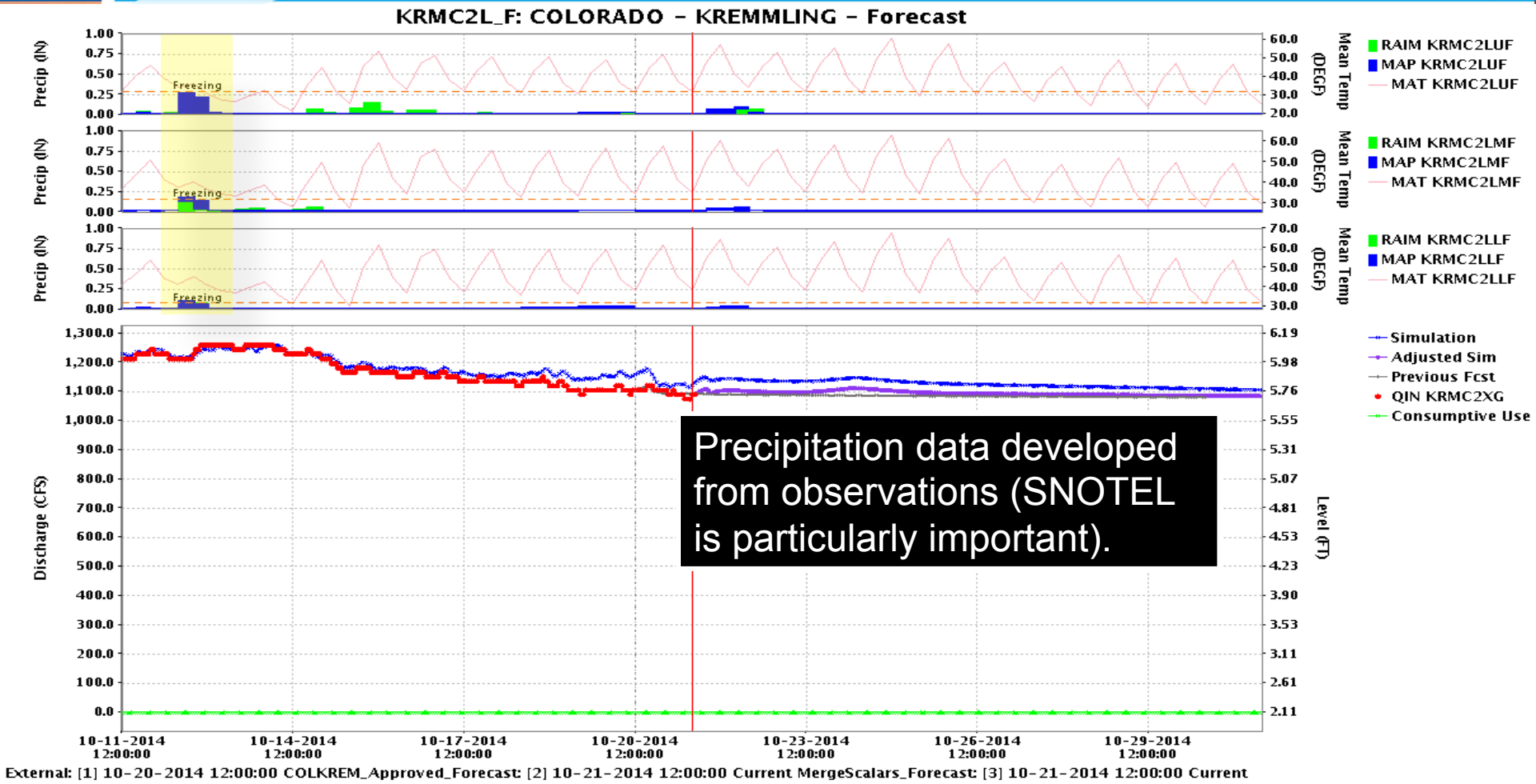
ESP Model:
Important for decision support services we provide, especially with how it relates to water supply. Forecasts made with this information have big policy implications.

Fitting Together

Developing Forecasts

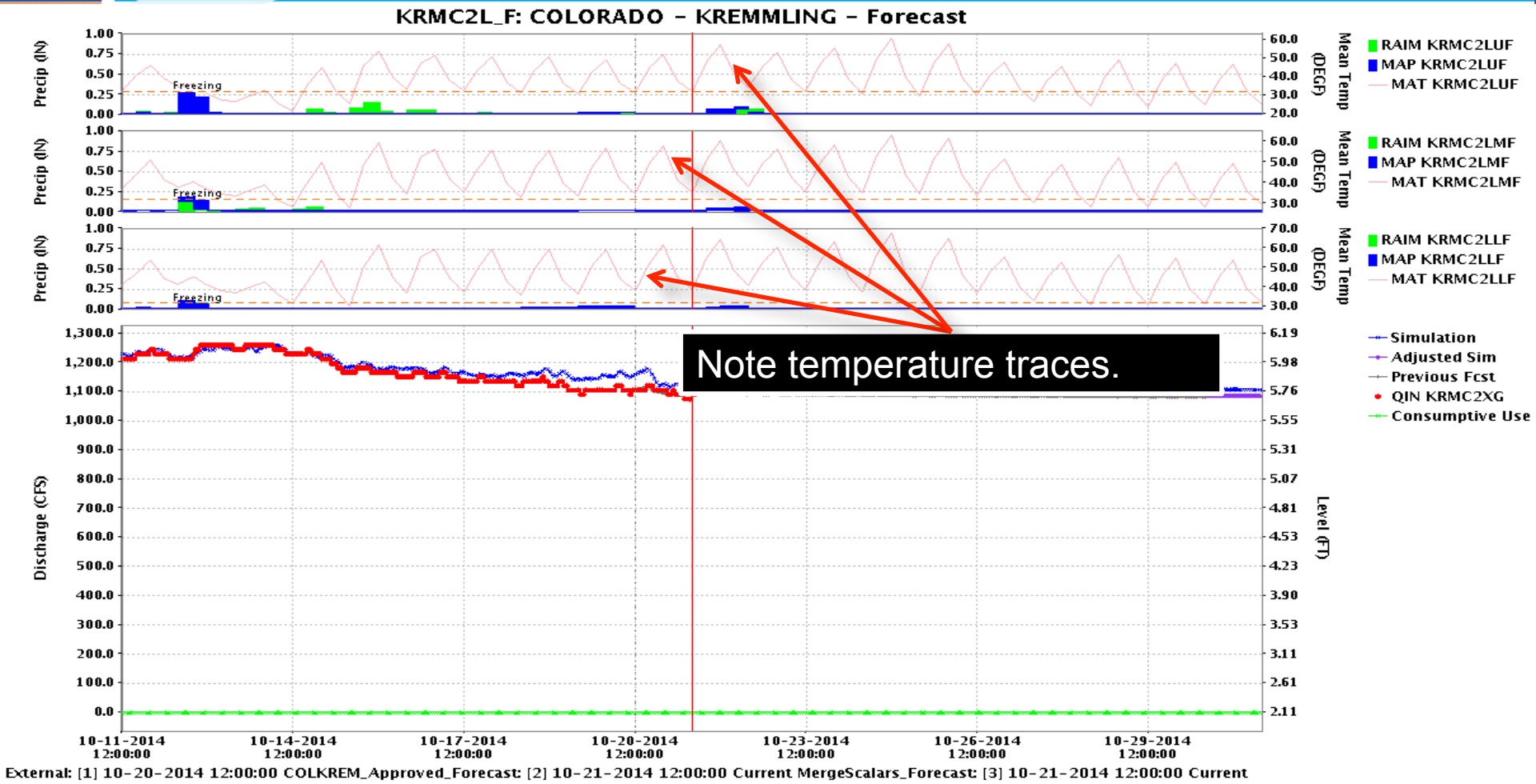


Developing Forecasts

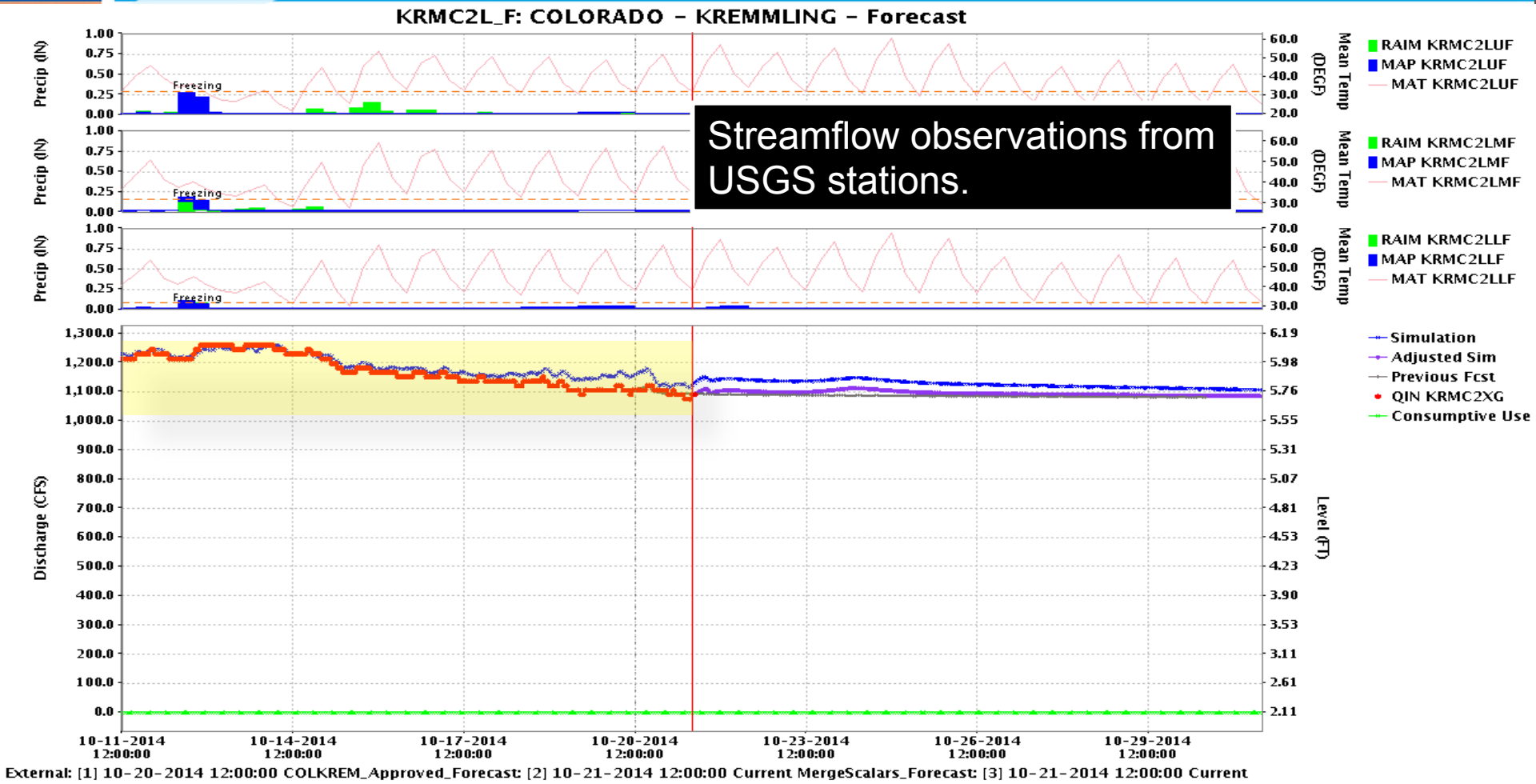


Precipitation data developed from observations (SNOTEL is particularly important).

Developing Forecasts

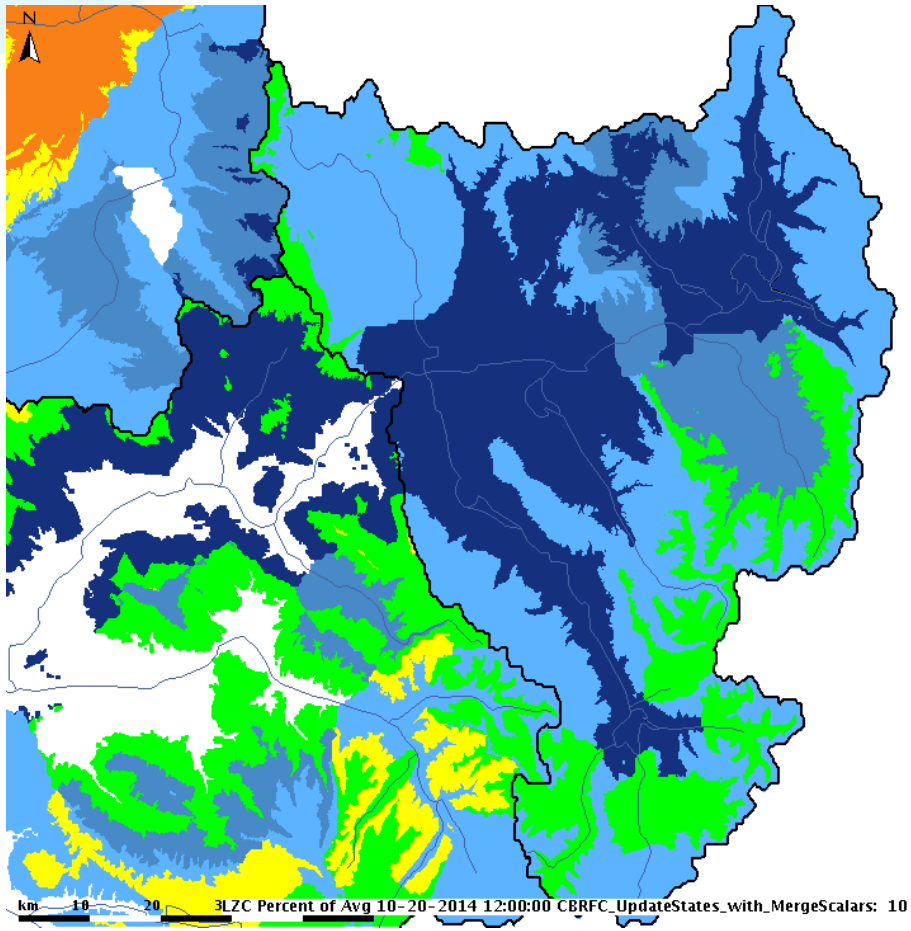


Developing Forecasts



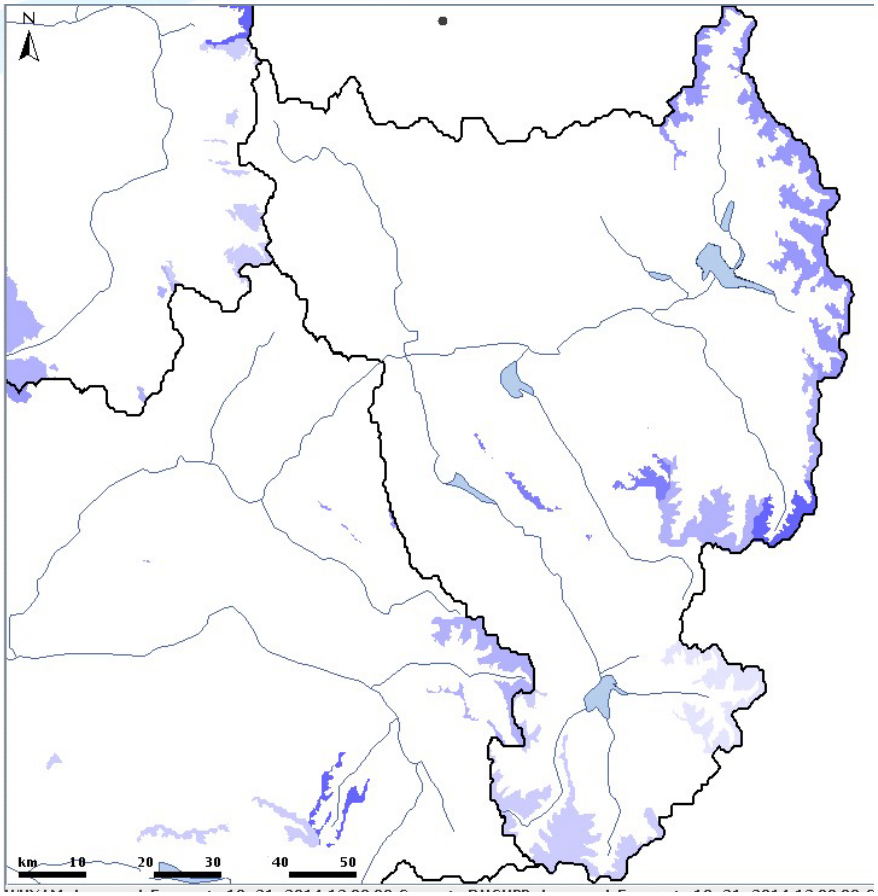
Streamflow observations from USGS stations.

Developing Forecasts



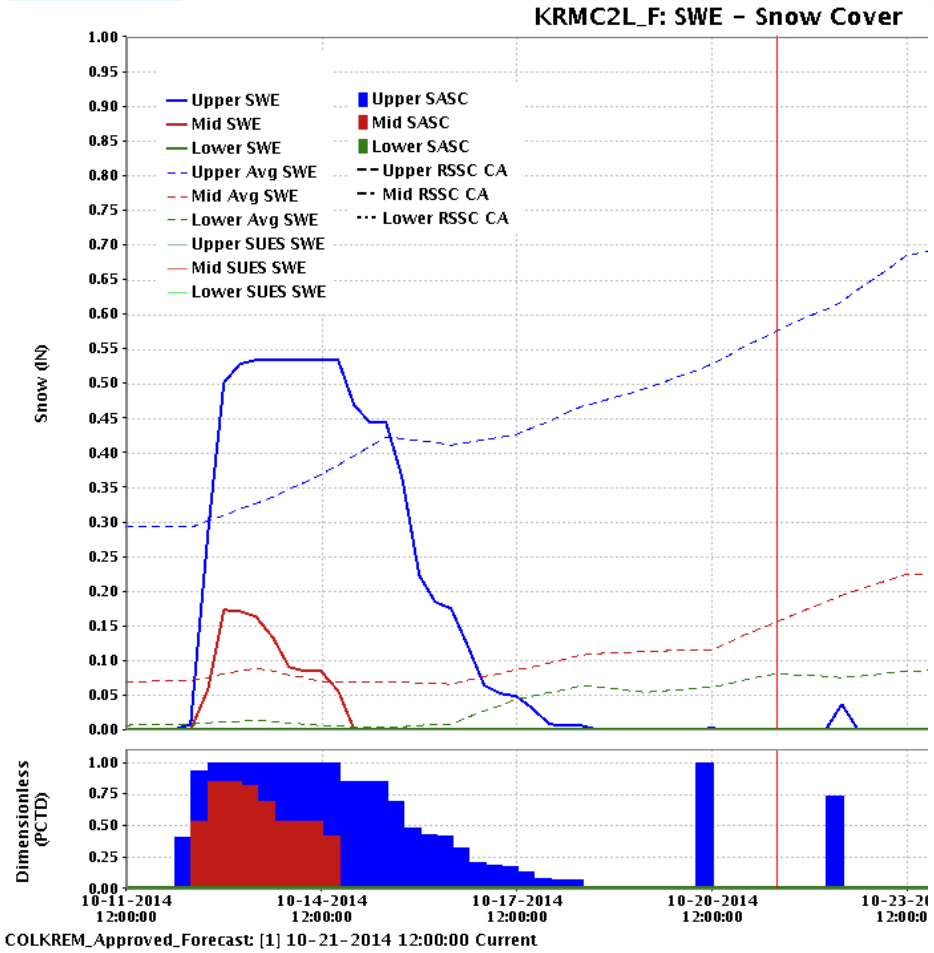
Soil moisture states are displayed to the left as a percent of average. Recent storms have yielded modeled soil moisture conditions that are above average.

Developing Forecasts



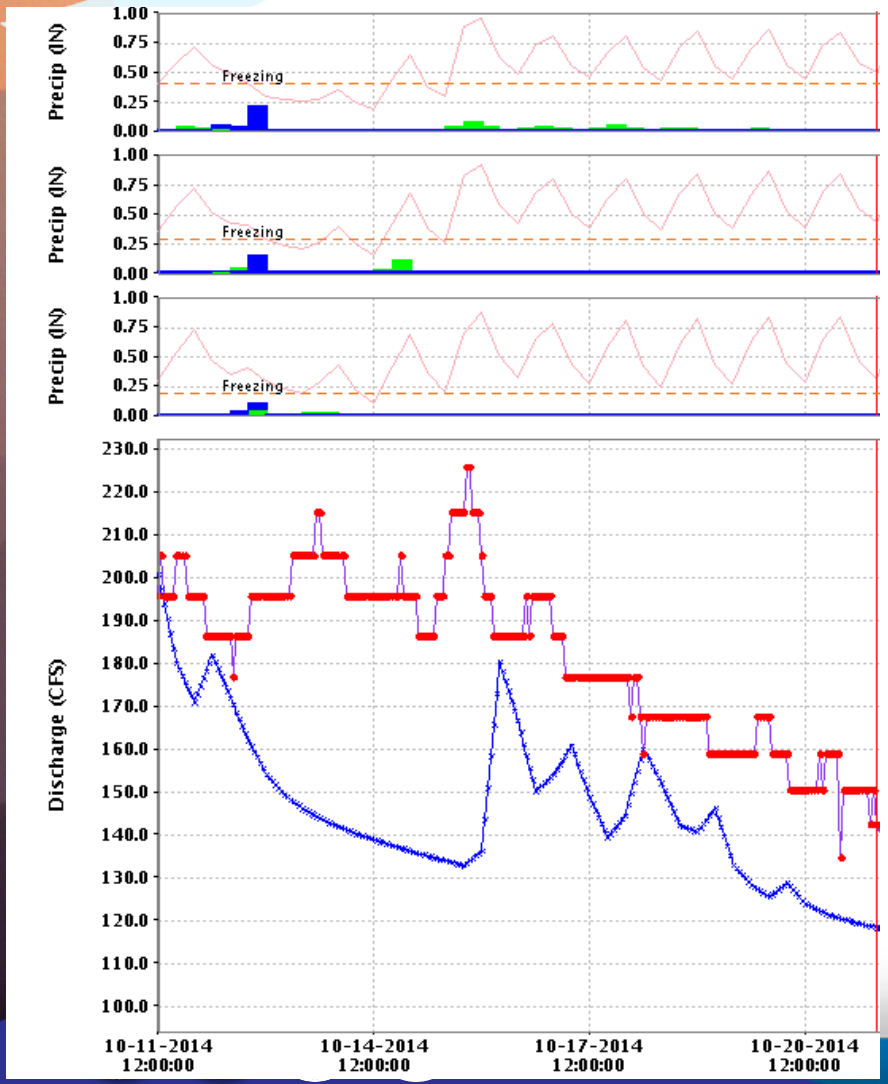
SNOW-17 is a temperature-index model which uses precipitation data to model snowpack accumulation and ablation. A storm event from last year that illustrates this is to the left.

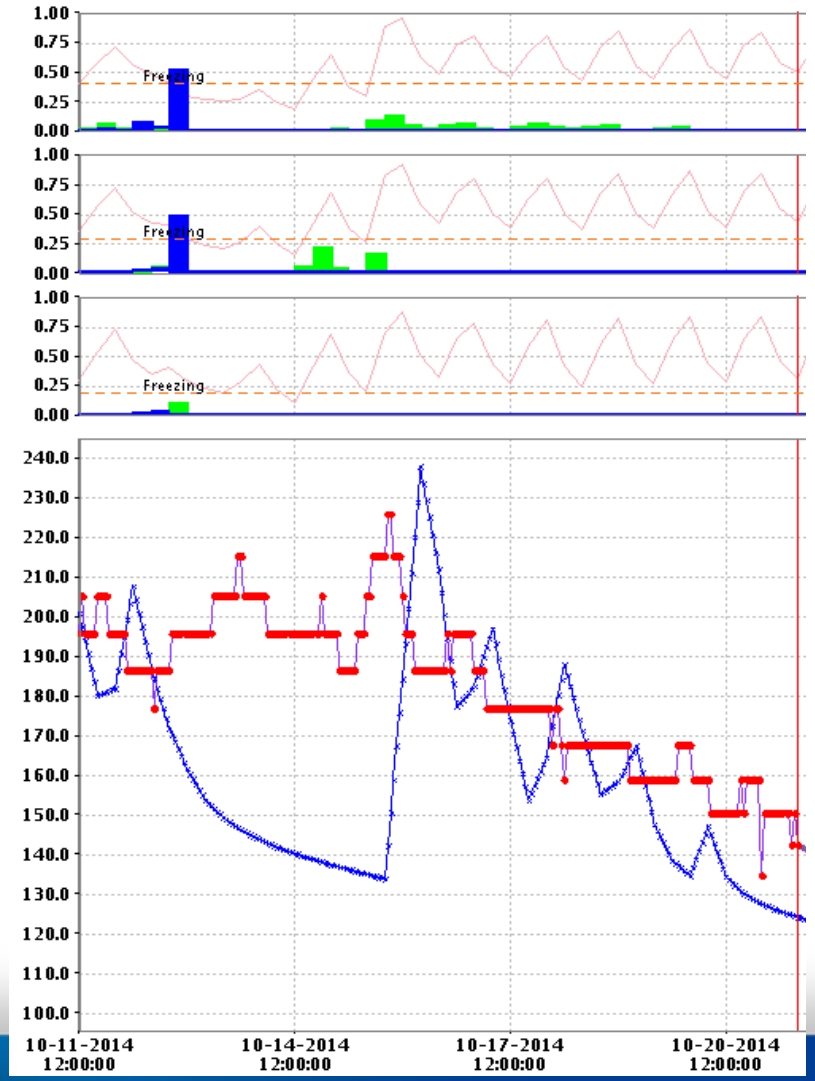
Fitting Together



Forecasters have the ability to modify the model's behavior through the use of "mods". Mods can adjust virtually every aspect of the model's behavior.

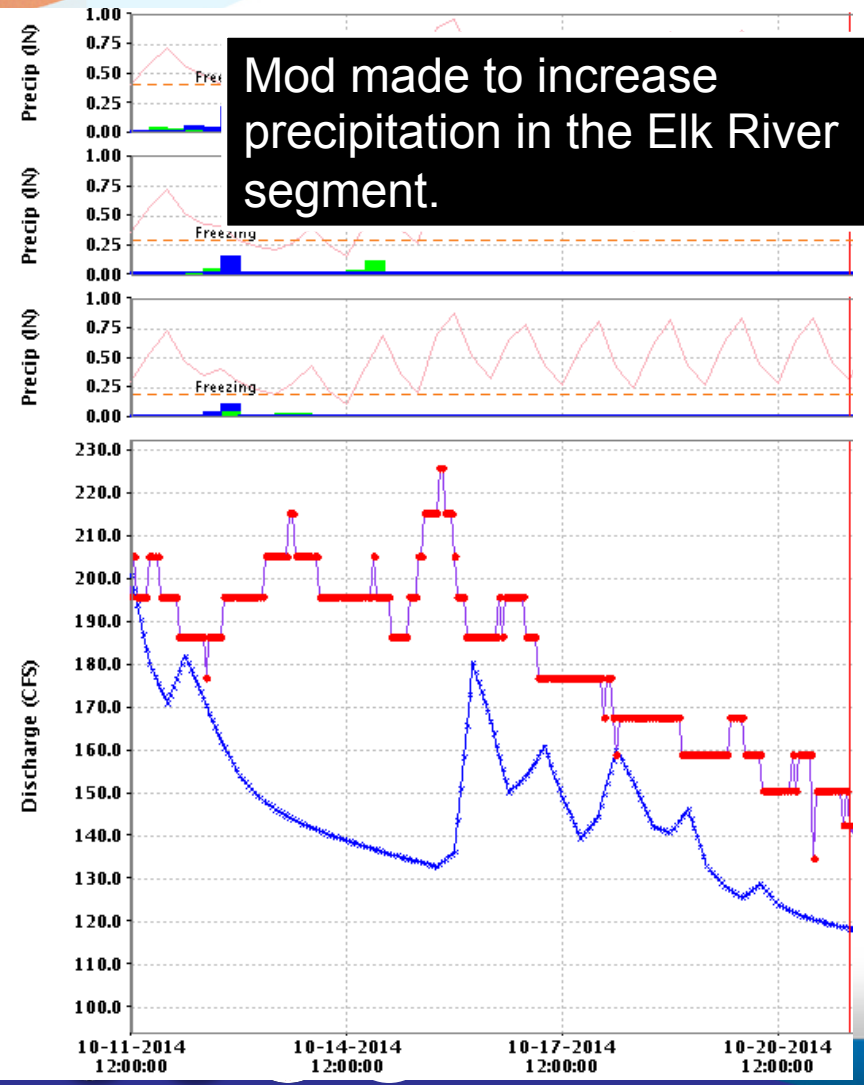
Developing Mods

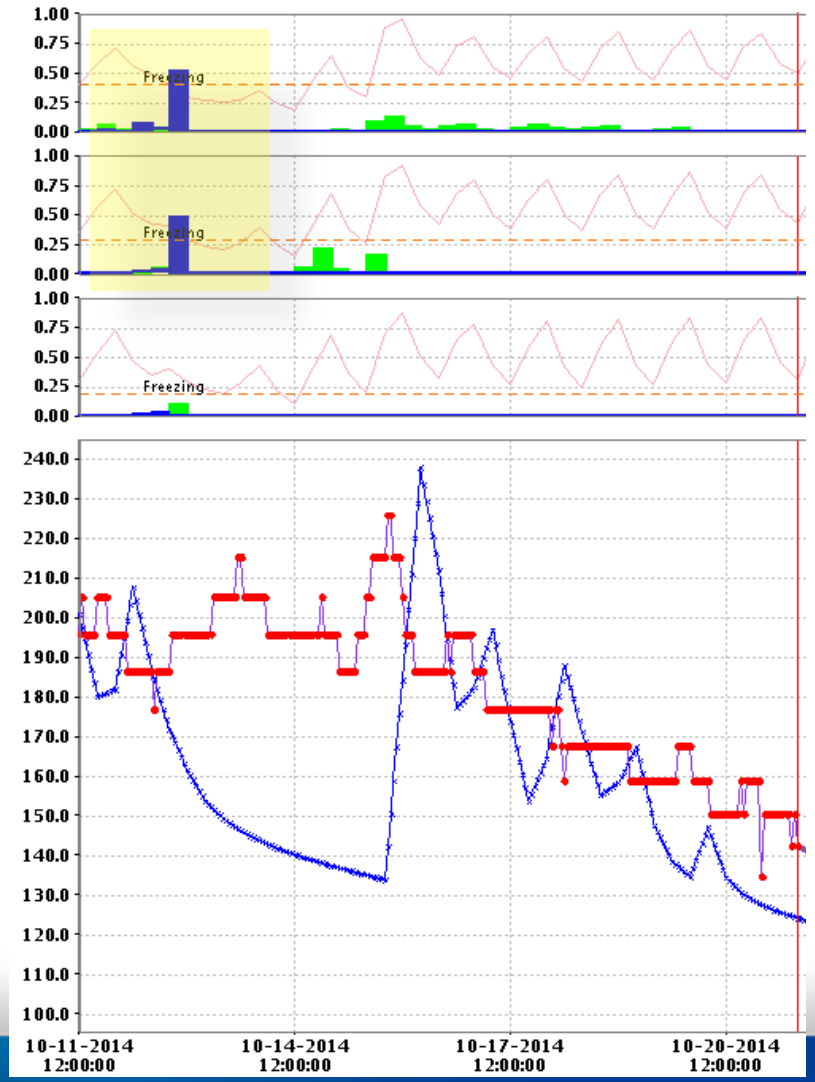




Developing Mods

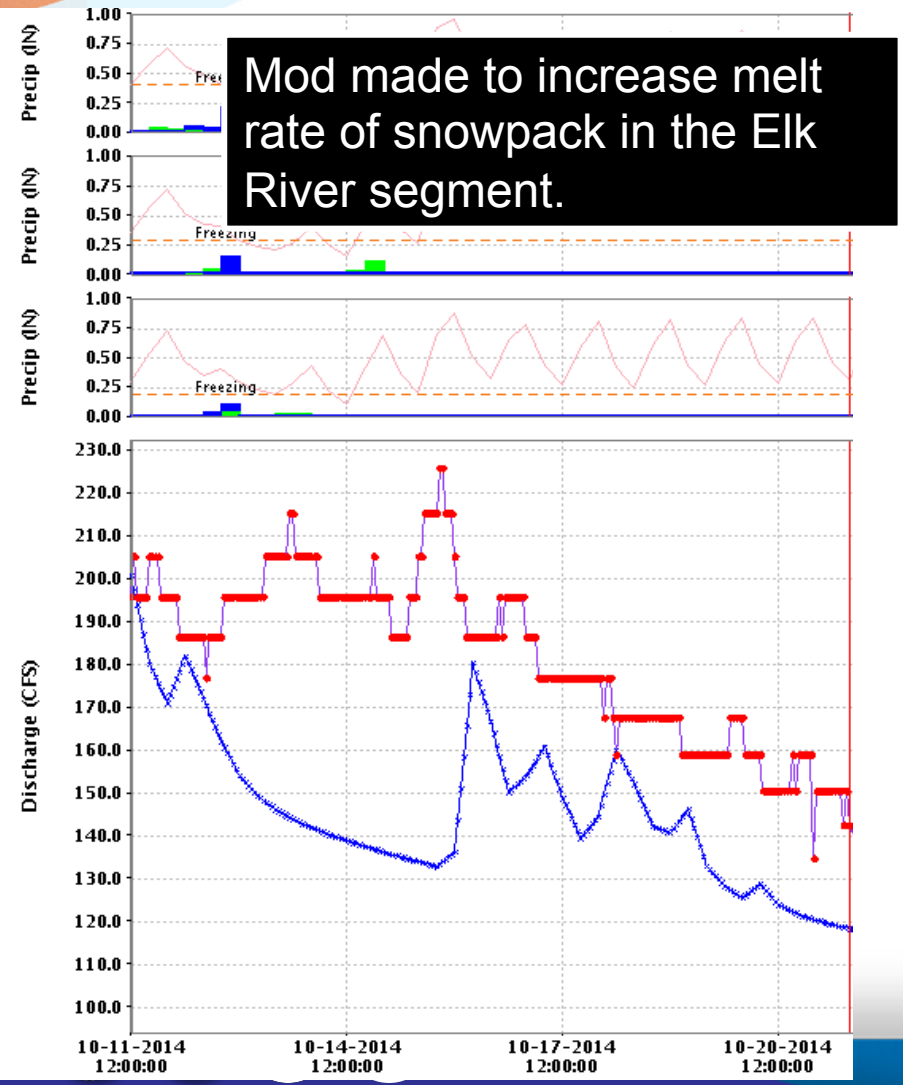
Mod made to increase precipitation in the Elk River segment.

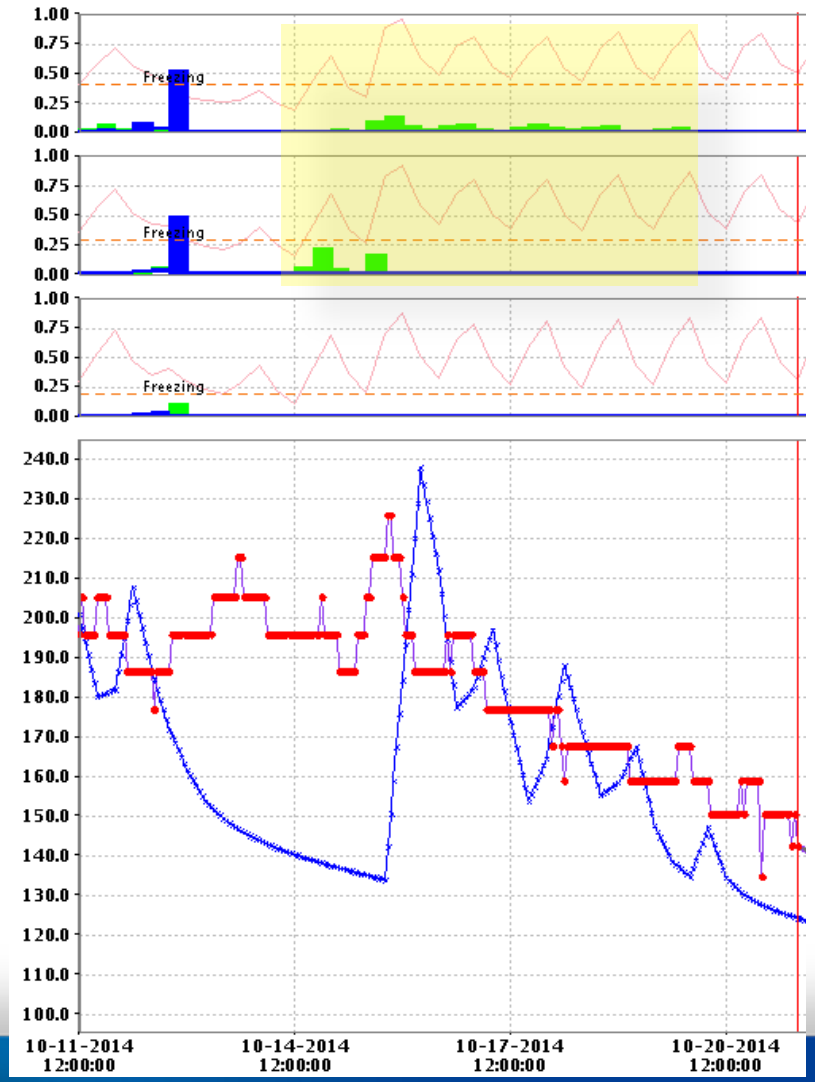




Developing Mods

Mod made to increase melt rate of snowpack in the Elk River segment.

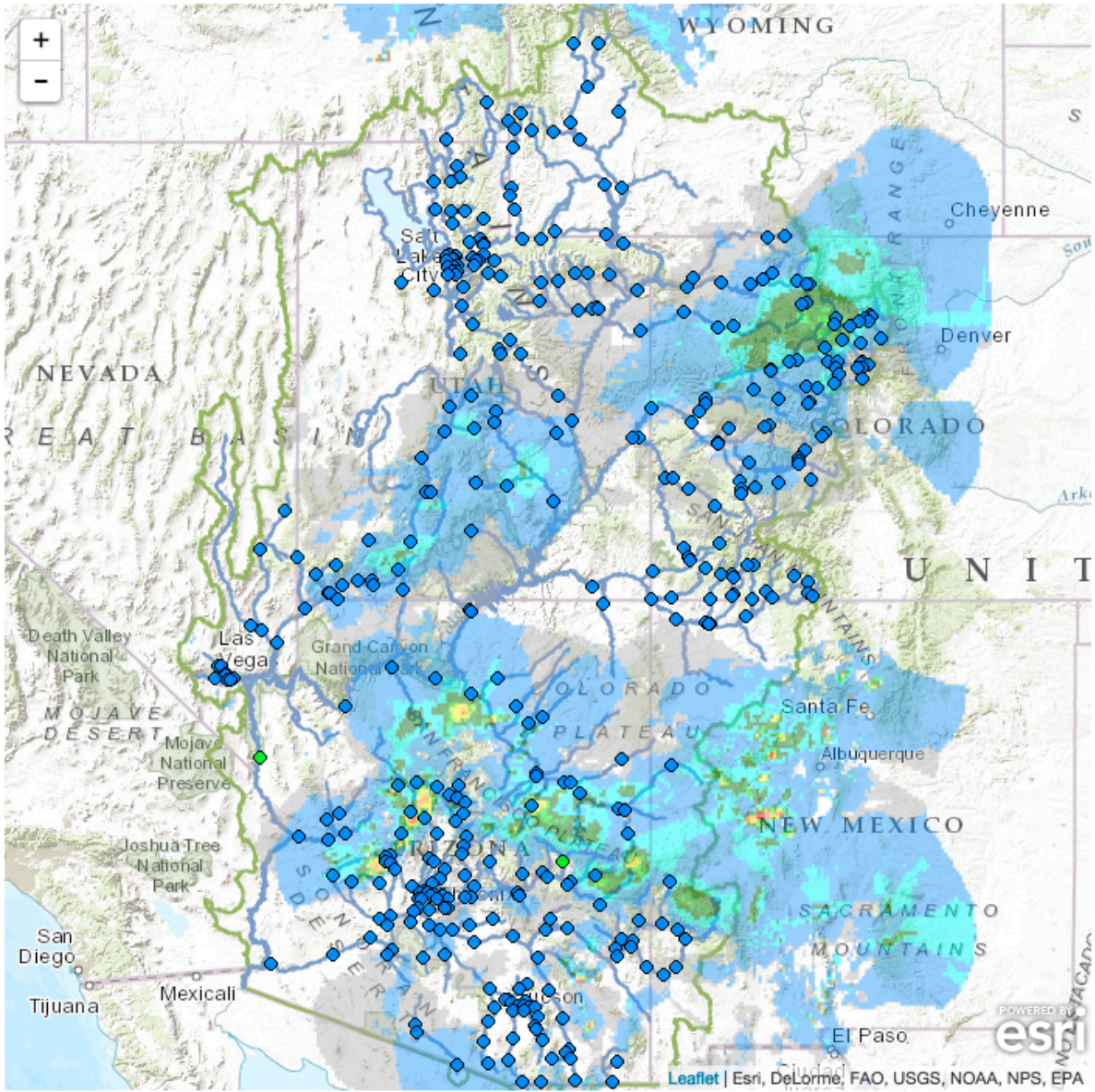




Products and Services

- 10-Day Forecasts
  - Rely recent streamflow observations to assess how well our model is performing
  - Gage observations aid in how/when mods are implemented. The more information we have the better!
  - Reservoir release schedules are important; if we do not get notified of changes, we often assume operations will remain constant
  - Defining the model states daily is the foundation for our ESP forecasts

Products and Services



- River Conditions
- Snow Conditions
- Water Supply Forecasts
- Peak Flood Probablity
- Reservoir Conditions
- Weather Conditions

Precipitation

Observed 2015-09-08

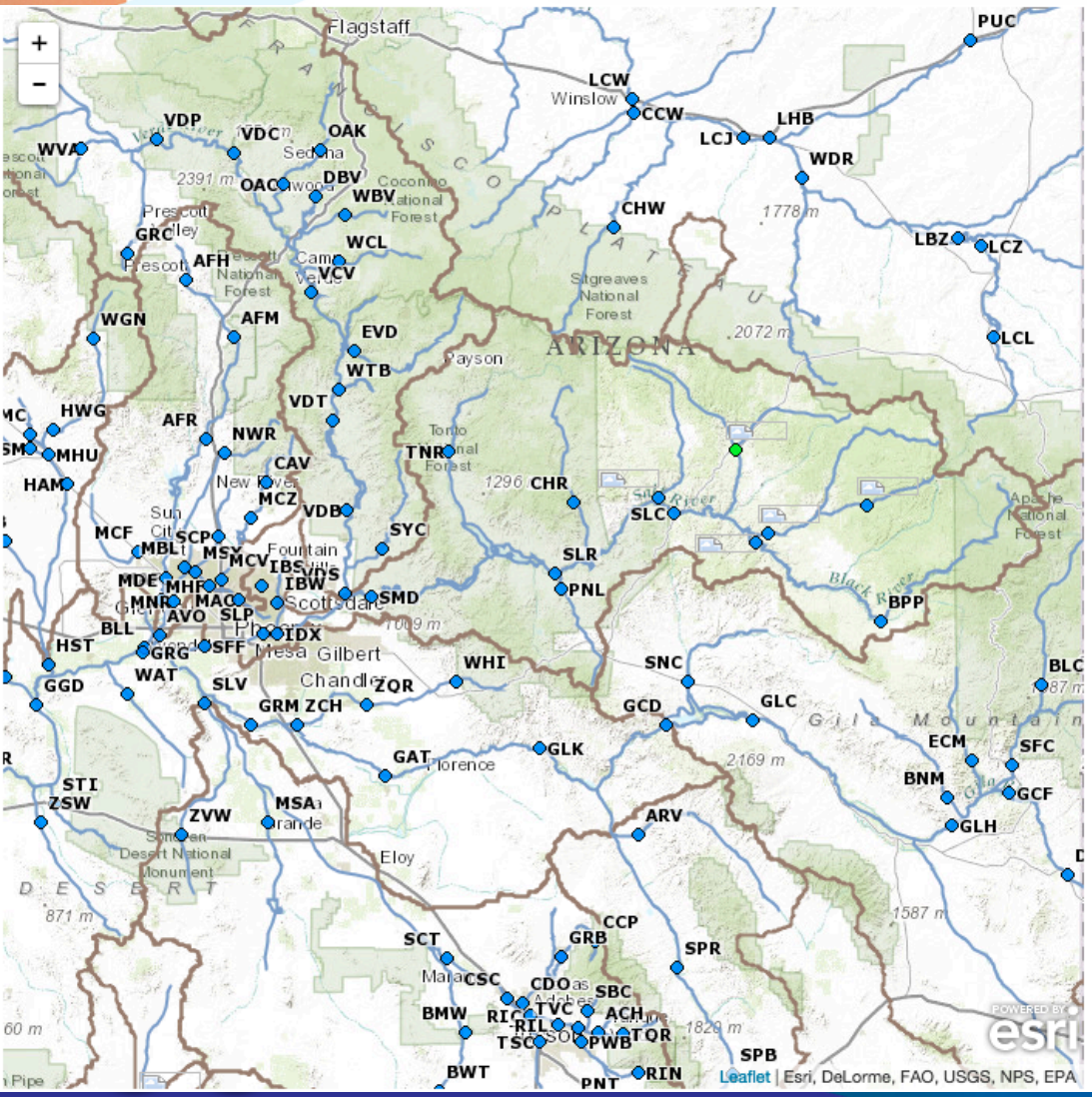
Gage and Radar (MPE)

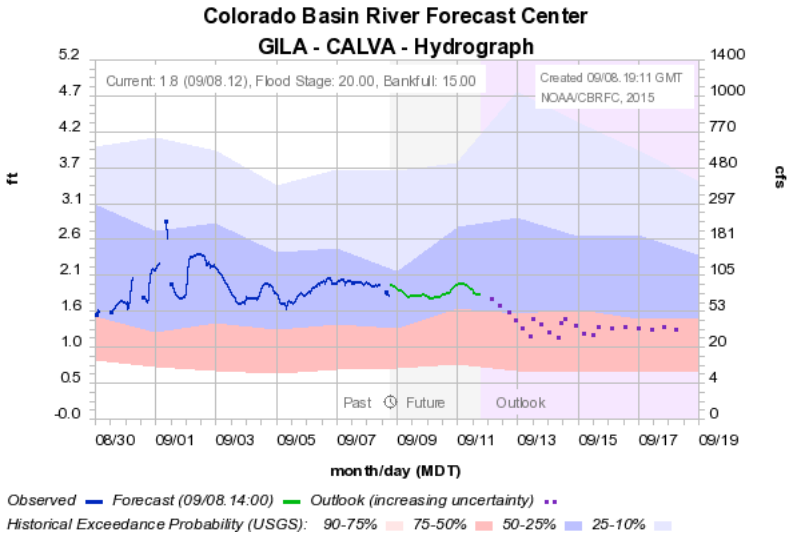
Gage Data Only (MM)

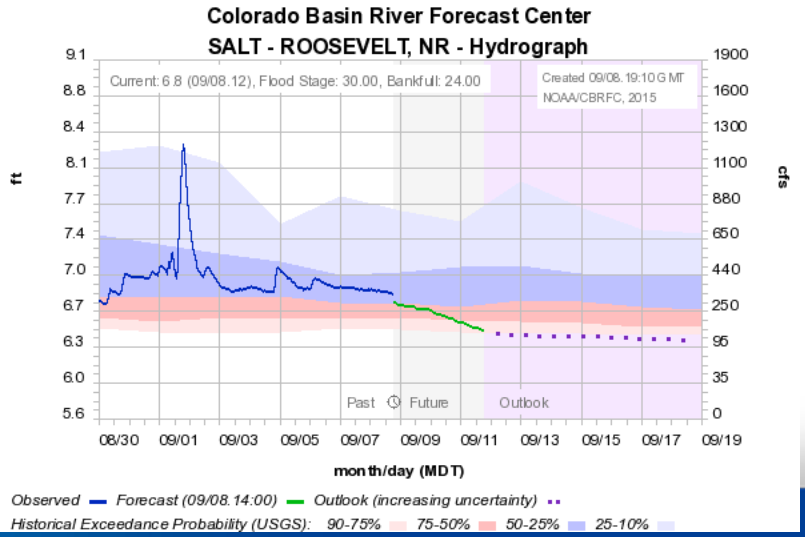
- <0.01
- 0.01-0.1
- 0.1-0.2
- 0.2-0.3
- 0.3-0.4
- 0.4-0.5
- 0.5-0.75
- 0.75-1.0
- 1.0-1.25
- 1.25-1.5
- 1.5-1.75
- 1.75-2
- 2-2.5

- Map Options
- Search Points

Products and Services

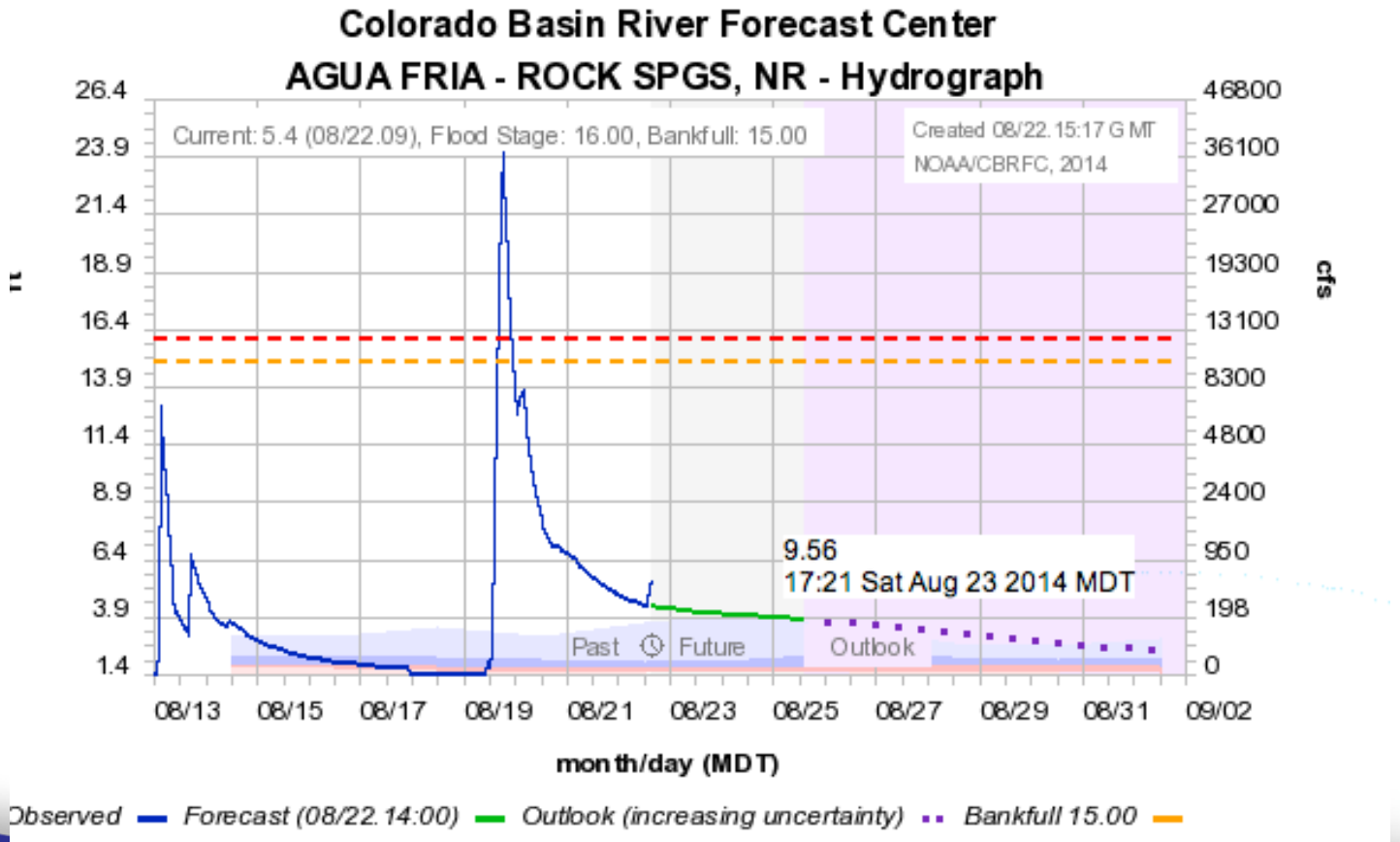






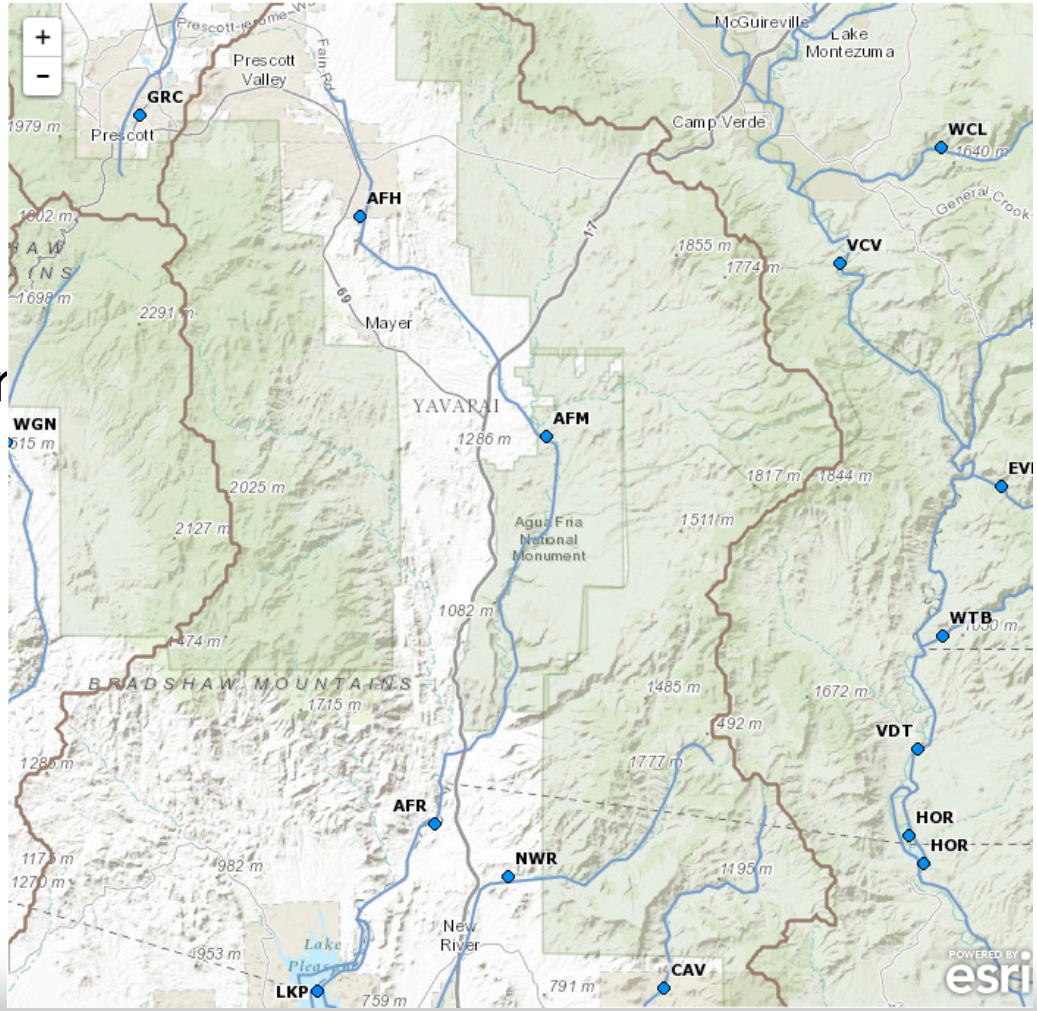
Products and Services

- Support flood warning efforts by weather forecast offices



Products and Services - Gaps

- Black Canyon Creek
  - Data poor
  - Flooding in the area typically doesn't show up until Agua Fria near Rock Springs
  - Potential impacts to Lake Pleasant operations?

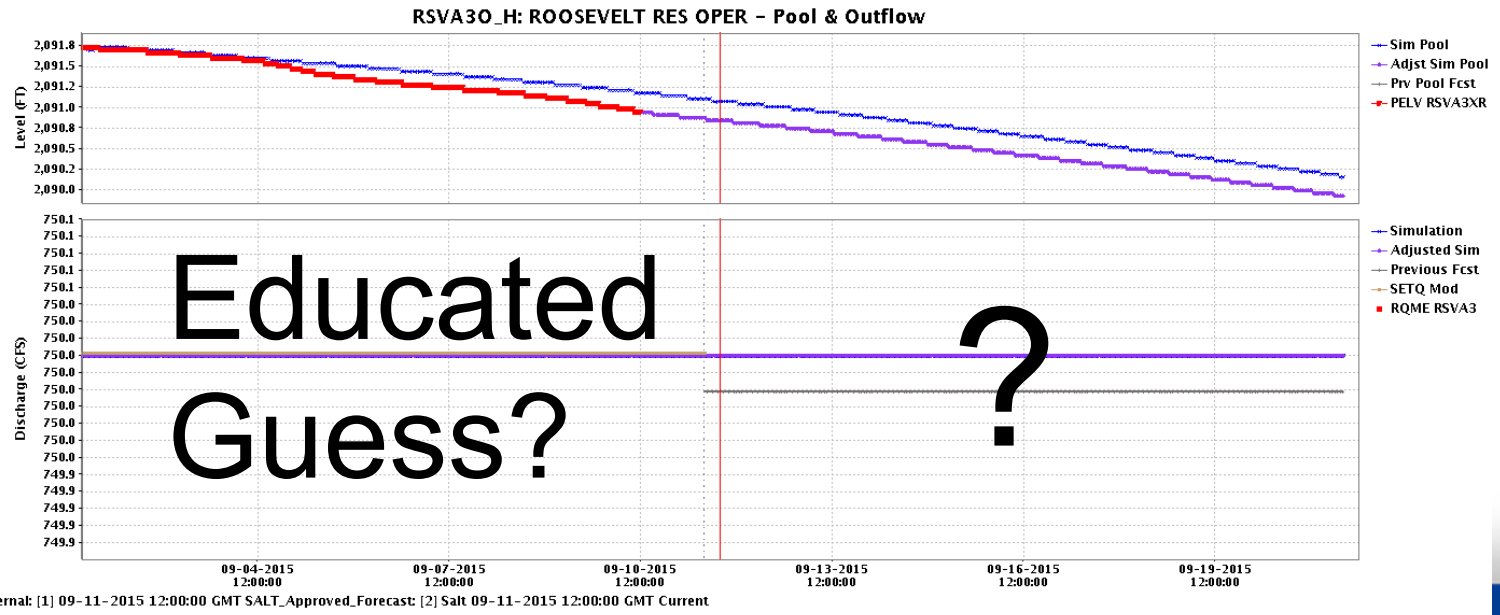


Coordination Needs

- We work most closely with CAP when precipitation affects operations at Lake Pleasant
  - What kind of lead time do you need to make operational decisions?
  - How can we better facilitate communication?

Products and Services - Gaps

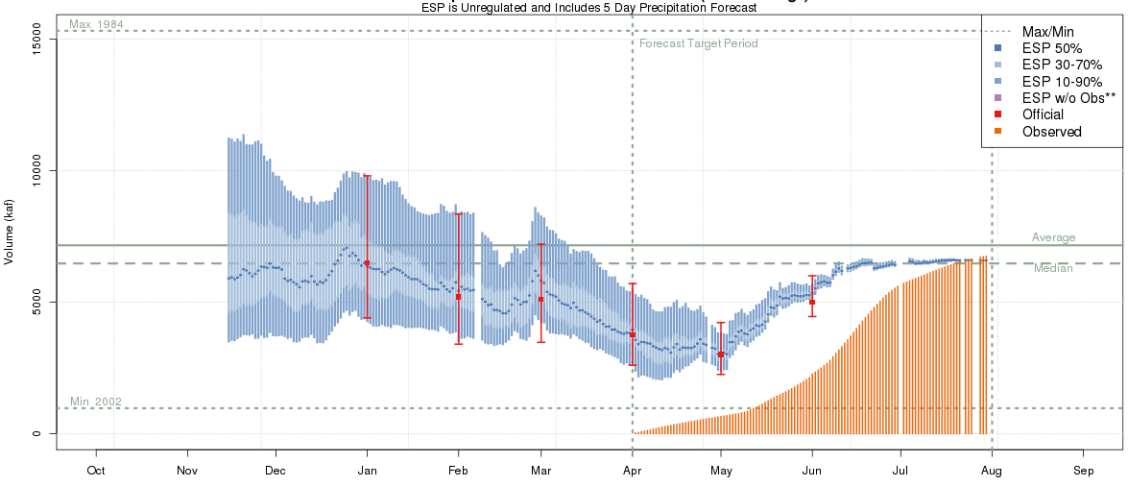
- Reservoir Operations
  - No schedules available for Horseshoe or Roosevelt
  - Would help in 10-day forecasts
  - Could be potentially useful in flooding situations



Products and Services

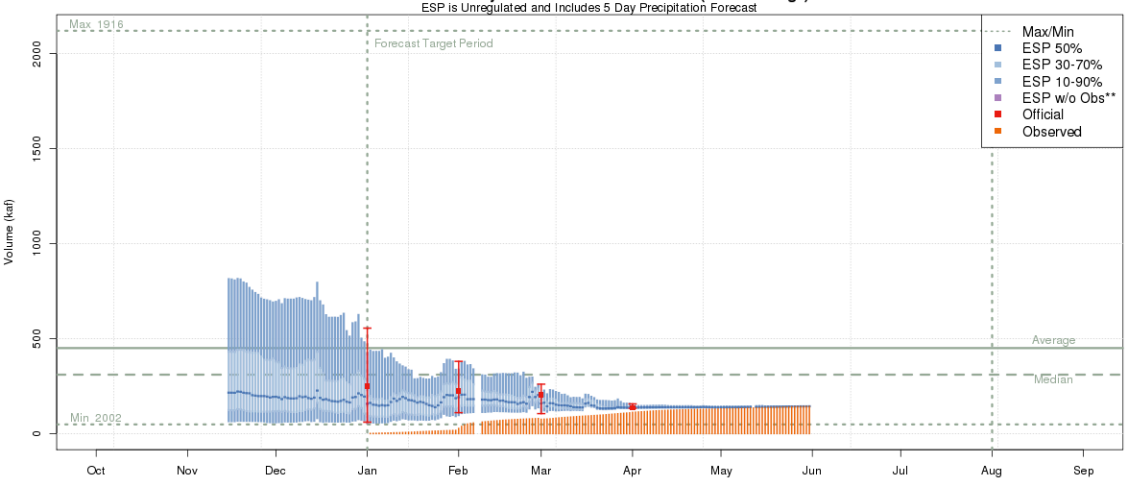
- Volumetric Water Supply Forecasts
  - Arguably the most important product that we provide to Reclamation (and impacts CAP the most?)
  - Drives Reclamation's 24-Month Study model (determines the operation of Lakes Powell and Mead)
- Ensemble Streamflow Prediction (ESP) forecasts
  - Utilized extensively for water supply forecasts
  - Dependent on precipitation information during the runoff season, most of which is derived using the SNOTEL network
  - Ensemble used to drive Reclamation's MTOM

Colorado - Lake Powell- Glen Cyn Dam- At (GLDA3)
2015-06-01 Apr-Jul Official 50% Forecast: 5000 kaf (70% of average)
ESP is Unregulated and Includes 5 Day Precipitation Forecast

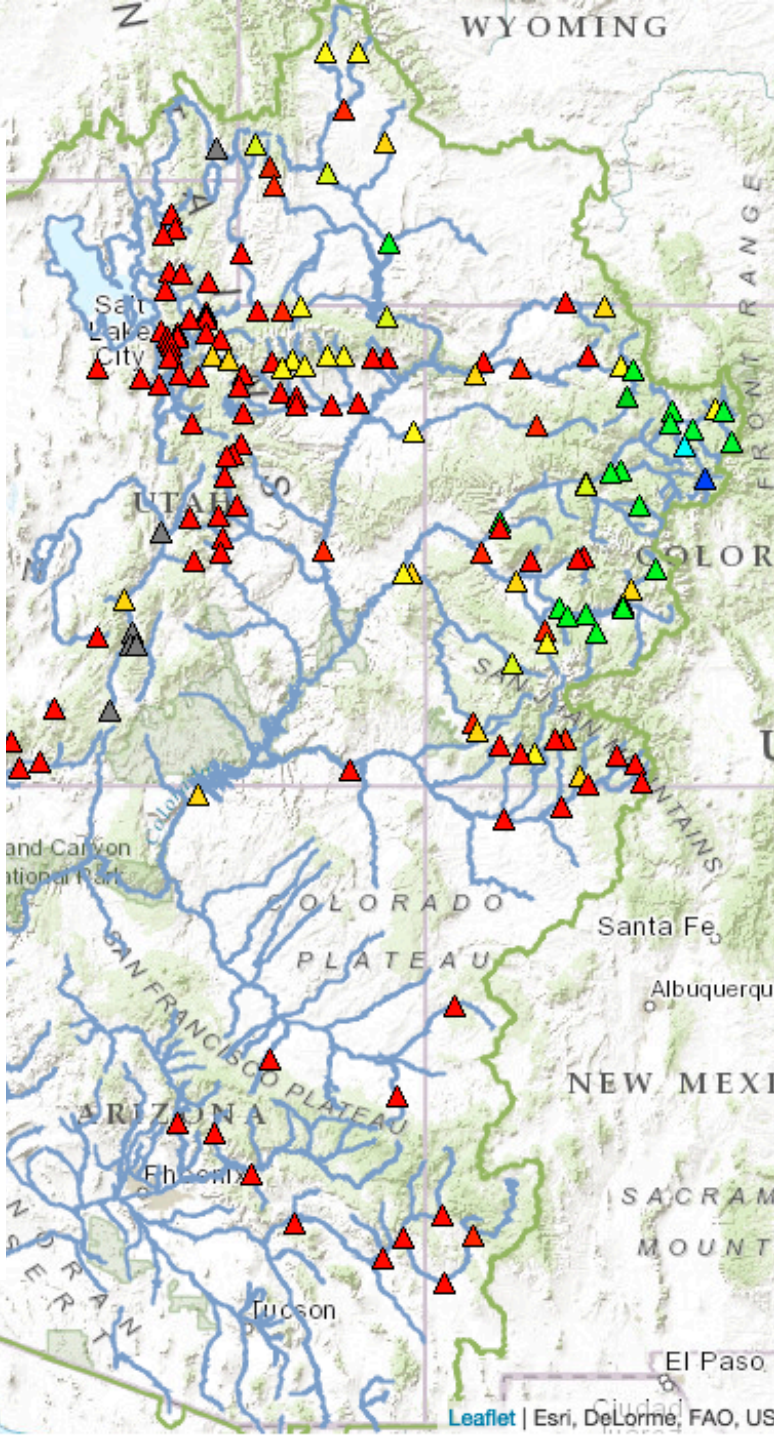


The latest (2015-07-30) 50% ESP forecast is 6583 kaf.
Plot Created 2015-08-07 11:29:19, NOAA / NWS / CBRFC
Forecasts in the forecast target period include observed values.

Salt - Roosevelt- Nr (SLRA3)
2015-04-01 Jan-May Official 50% Forecast: 135 kaf (30% of average)
ESP is Unregulated and Includes 5 Day Precipitation Forecast



The latest (2015-05-31) 50% ESP forecast is 143 kaf.
Plot Created 2015-08-07 11:48:07, NOAA / NWS / CBRFC
Forecasts in the forecast target period include observed values.



Who we work with directly impacts CAP

- Reclamation
  - Water supply forecasts that drive the 24-Month Study
  - Ensemble forecasts for use in the MTOM
  - Provide information that allows us to make accurate forecasts
- SRP
  - Provide information through their website
  - More information would be beneficial!
- National Weather Service

Coordination Efforts

- Annual CRFS Meeting
  - Broad range of stakeholders, CAP has presented and provided updates in the past
  - Introduce new products and services
  - Reinforce traditional products and services
  - Important to get feedback
- Frequent webinars
  - Water supply
  - Peak Flow Forecasts

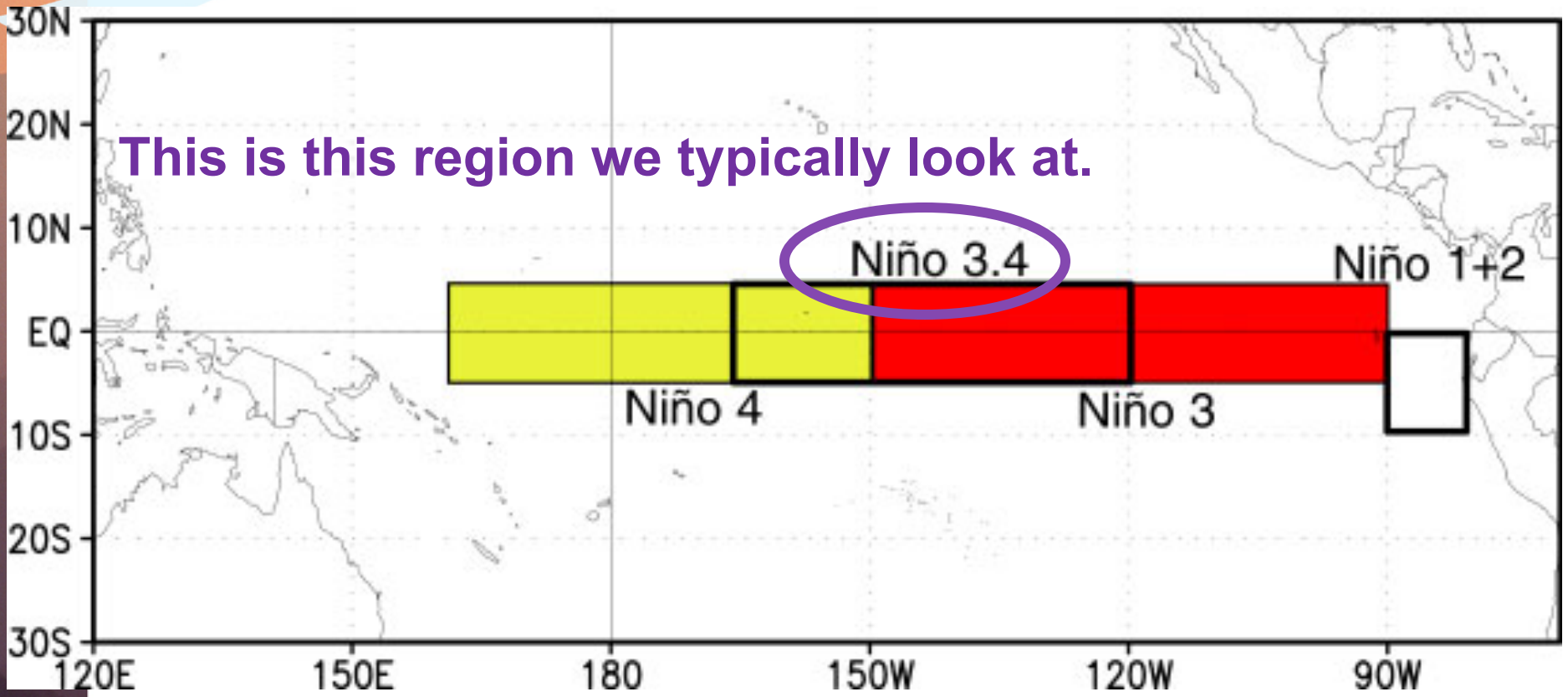
Coordination Efforts

- Participation in stakeholder-run meetings and events (e.g., BSTC)
- Participation in multi-agency efforts
  - Landscape Conservation Cooperatives
  - Climate Science Centers
  - NOAA RISAs
  - Others
- Direct contact by phone, e-mail, etc…

The Latest on ENSO

- The ENSO is a large scale phenomenon identified through departures (deviations from average) in sea surface temperatures (SSTs) along the central equatorial Pacific
  - Persistent warmer than average SSTs is an El Niño event and typically correlates with wetter winter conditions in the Lower Colorado River Basin
  - Persistent cooler than average SSTs is a La Niña event and typically correlates to drier winter conditions in the Lower Colorado River Basin
- Correlations with ENSO and other parts of the CBRFC basin are not well defined, but in the Lower Colorado River Basin it is relevant.

SST Monitoring Regions



How do we define ENSO?

When departures, over a three month period, are >= 0.5°C (El Niño) or <= -0.5°C (La Niña) for 5 consecutive periods, then an ENSO event is defined

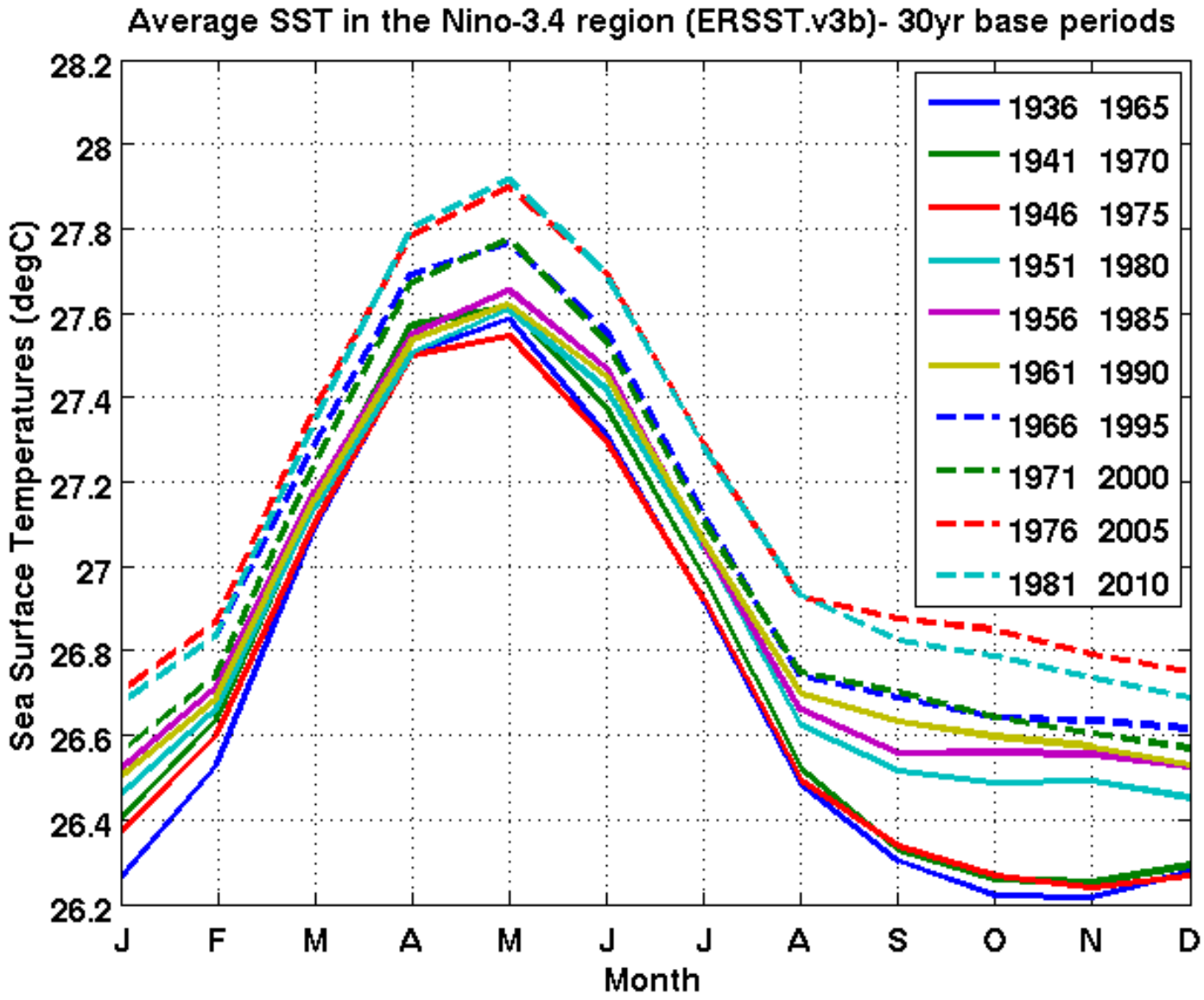
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2002	-0.2	-0.1	0.1	0.2	0.4	0.7	0.8	0.9	1.0	1.2	1.3	1.1
2003	0.9	0.6	0.4	0	-0.2	-0.1	0.1	0.2	0.3	0.4	0.4	0.4
2004	0.3	0.2	0.1	0.1	0.2	0.3	0.5	0.7	0.7	0.7	0.7	0.7
2005	0.6	0.6	0.5	0.5	0.4	0.2	0.1	0	0	-0.1	-0.4	-0.7
2006	-0.7	-0.6	-0.4	-0.2	0.0	0.1	0.2	0.3	0.5	0.8	0.9	1.0
2007	0.7	0.3	0	-0.1	-0.2	-0.2	-0.3	-0.6	-0.8	-1.1	-1.2	-1.3
2008	-1.4	-1.3	-1.1	-0.9	-0.7	-0.5	-0.3	-0.2	-0.2	-0.3	-0.5	-0.7
2009	-0.8	-0.7	-0.4	-0.1	0.2	0.4	0.5	0.6	0.7	1.0	1.2	1.3
2010	1.3	1.1	0.8	0.5	0	-0.4	-0.8	-1.1	-1.3	-1.4	-1.3	-1.4
2011	-1.3	-1.1	-0.8	-0.6	-0.3	-0.2	-0.3	-0.5	-0.7	-0.9	-0.9	-0.8
2012	-0.7	-0.6	-0.5	-0.4	-0.3	-0.1	0.1	0.3	0.4	0.4	0.2	-0.2
2013	-0.4	-0.5	-0.3	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.3
2014	-0.5	-0.6	-0.4	-0.2	0	0	0	0	0.2	0.4	0.6	0.6
2015	0.5	0.4	0.5	0.7	0.9	1.0	1.2					

How do we define ENSO?

- It is important to remember that these departures are basically compared to 30-year averages updated every 10 years*
  - Important due to the impacts of climate change
  - As oceans warm, weak El Niño events may no longer qualify; cold events previously not defined as La Niña may now qualify
  - Currently using the 1981-2010 average
- AND we need to see a coupling between the atmosphere and ocean!
  - Weakened Walker Circulation
  - More rain over the Central Pacific and less rain over Indonesia

It's actually slightly more complicated than that, with departures also being developed relative to recent 5-year periods. But for most purposes, it is probably okay to use the data as derived by the most recent 30-year period. For those interested in the details please take a look at: "In Watching for El Niño and La Niña, NOAA adapts to Global Warming at: http://www.climate.gov/news-features/understanding-climate/watching-el-ni%C3%B1o-and-la-ni%C3%B1a-noaa-adapts-global-warming. Also, see "Linear trends in sea surface temperature of the tropical Pacific Ocean and Implications for the El Niño-Southern Oscillation" by L'Heureux et al. 2012 in *Climate Dynamics.

How do we define ENSO?



How do we define ENSO?

Seasonal temperature anomalies since 2000

La Niña, El Niño, neutral

relative to 1971-2000

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2000	-1.6	-1.4	-1.0	-0.8	-0.6	-0.5	-0.4	-0.4	-0.4	-0.5	-0.6	-0.7
2001	-0.6	-0.5	-0.4	-0.2	-0.1	0.1	0.2	0.2	0.1	0.0	-0.1	-0.1
2002	-0.1	0.1	0.2	0.4	0.7	0.8	0.9	1.0	1.1	1.3	1.5	1.4
2003	1.2	0.9	0.5	0.1	-0.1	0.1	0.4	0.5	0.6	0.5	0.6	0.4
2004	0.4	0.3	0.2	0.2	0.3	0.5	0.7	0.8	0.9	0.8	0.8	0.8
2005	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.2	-0.1	-0.4	-0.7
2006	-0.7	-0.6	-0.4	-0.1	0.1	0.2	0.3	0.5	0.6	0.9	1.1	1.1
2007	0.8	0.4	0.1	-0.1	-0.1	-0.1	-0.1	-0.4	-0.7	-1.0	-1.1	-1.3
2008	-1.4	-1.4	-1.1	-0.8	-0.6	-0.4	-0.1	0.0	0.0	0.0	-0.3	-0.6
2009	-0.8	-0.7	-0.5	-0.1	0.2	0.6	0.7	0.8	0.9	1.2	1.5	1.8
2010	1.7	1.5	1.2	0.8	0.3	-0.2	-0.6	-1.0	-1.3	-1.4	-1.4	-1.4
2011	-1.3	-1.2	-0.9	-0.6	-0.2	0.0	0.0	-0.2	-0.4	-0.7	-0.8	-0.9
2012	-0.8	-0.6										

relative to 1981-2010

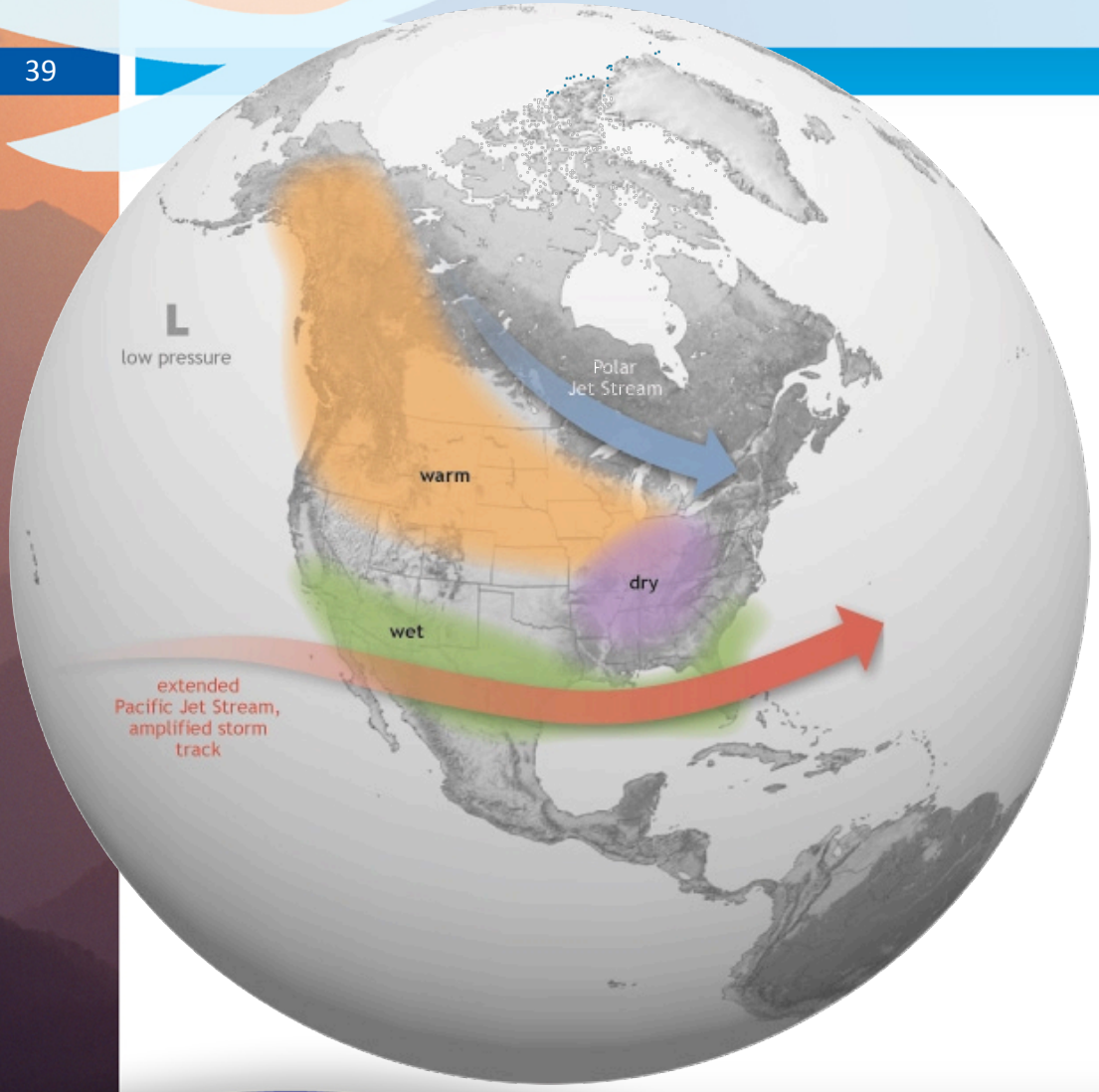
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2000	-1.7	-1.5	-1.2	-0.9	-0.8	-0.7	-0.6	-0.5	-0.6	-0.6	-0.8	-0.8
2001	-0.7	-0.6	-0.5	-0.4	-0.2	-0.1	0.0	0.0	-0.1	-0.2	-0.3	-0.3
2002	-0.2	0.0	0.1	0.3	0.5	0.7	0.8	0.8	0.9	1.2	1.3	1.3
2003	1.1	0.8	0.4	0.0	-0.2	-0.1	0.2	0.4	0.4	0.4	0.4	0.3
2004	0.3	0.2	0.1	0.1	0.2	0.3	0.5	0.7	0.8	0.7	0.7	0.7
2005	0.6	0.4	0.3	0.3	0.3	0.3	0.2	0.1	0.0	-0.2	-0.5	-0.8
2006	-0.9	-0.7	-0.5	-0.3	0.0	0.1	0.2	0.3	0.5	0.8	1.0	1.0
2007	0.7	0.3	-0.1	-0.2	-0.3	-0.3	-0.4	-0.6	-0.8	-1.1	-1.2	-1.4
2008	-1.5	-1.5	-1.2	-0.9	-0.7	-0.5	-0.3	-0.2	-0.1	-0.2	-0.5	-0.7
2009	-0.8	-0.7	-0.5	-0.2	0.2	0.4	0.5	0.6	0.8	1.1	1.4	1.6
2010	1.6	1.3	1.0	0.6	0.1	-0.4	-0.9	-1.2	-1.4	-1.5	-1.5	-1.5
2011	-1.4	-1.2	-0.9	-0.6	-0.3	-0.2	-0.2	-0.4	-0.6	-0.8	-1.0	-1.0
2012	-0.9	-0.6	-0.5	-0.3	-0.2	0.0	0.1	0.4	0.5	0.6	0.2	-0.3

La Niñas that we didn't know we had when using the 1971-2000 average!

Blue = La Niña event

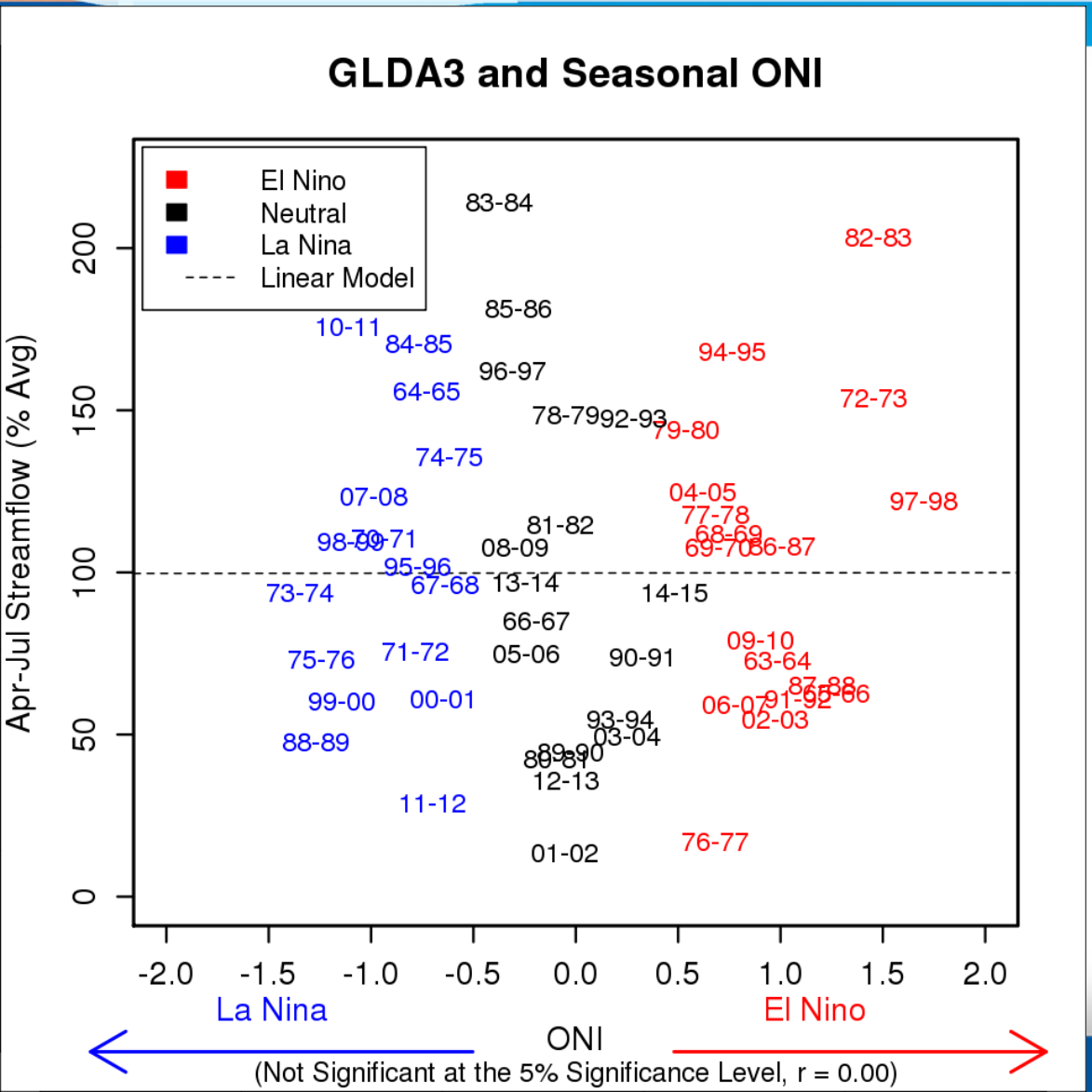
Red = El Niño event

ENSO Impacts



We typically look at ENSO impacts in the winter, because global atmospheric flow is more influential then. In the summer, small-scale events like thunderstorms (monsoon season!) tend to be more important.

ENSO Impacts



CPC Strong Events:

1957-1958* (pre-Powell)

1965-1966 (below avg)

1972-1973 (above avg)

1982-1983 (above avg)

1991-1992 (below avg)

1997-1998 (near avg)

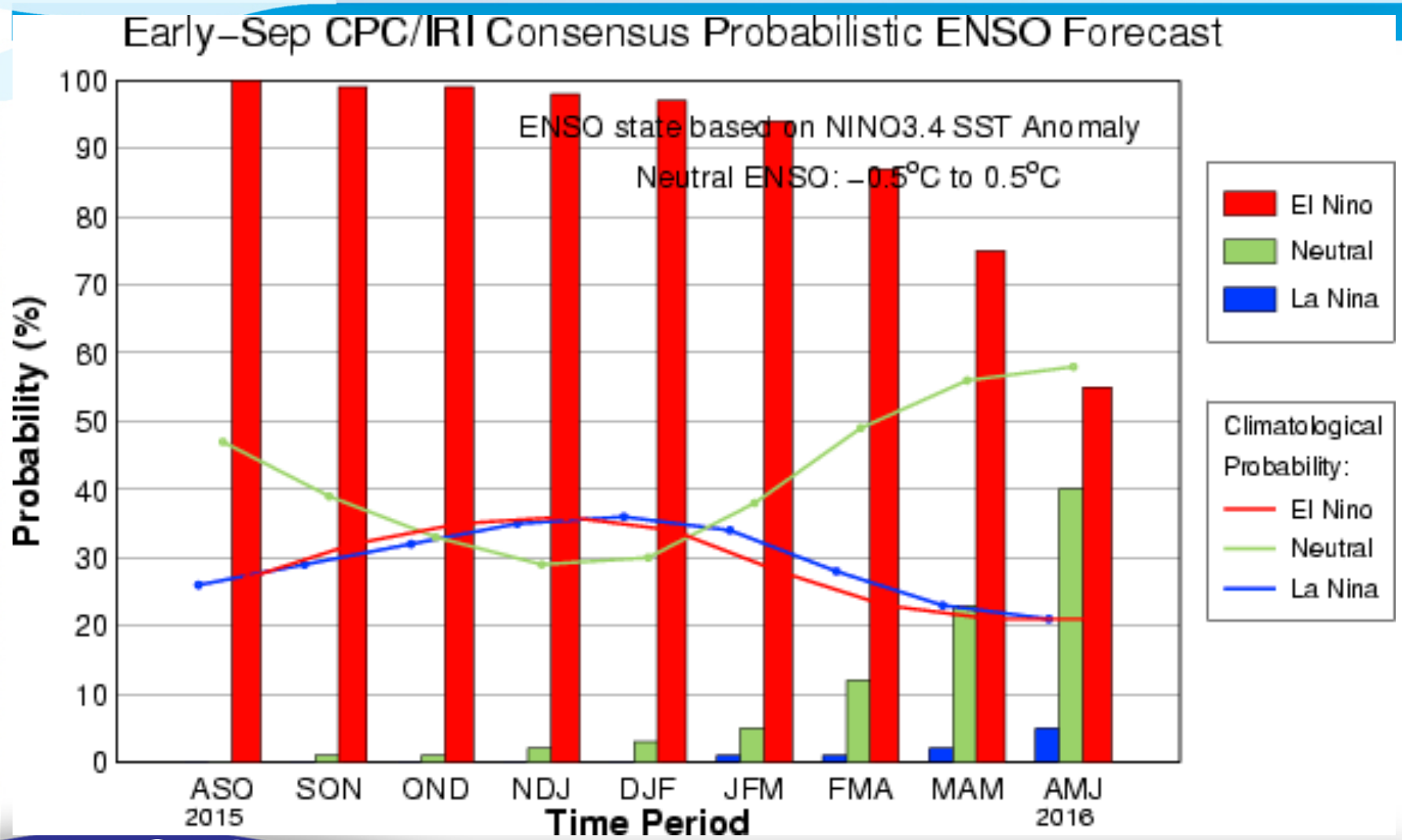
*Based on Reclamation Natural Flow, this was an above average year

ENSO Impacts

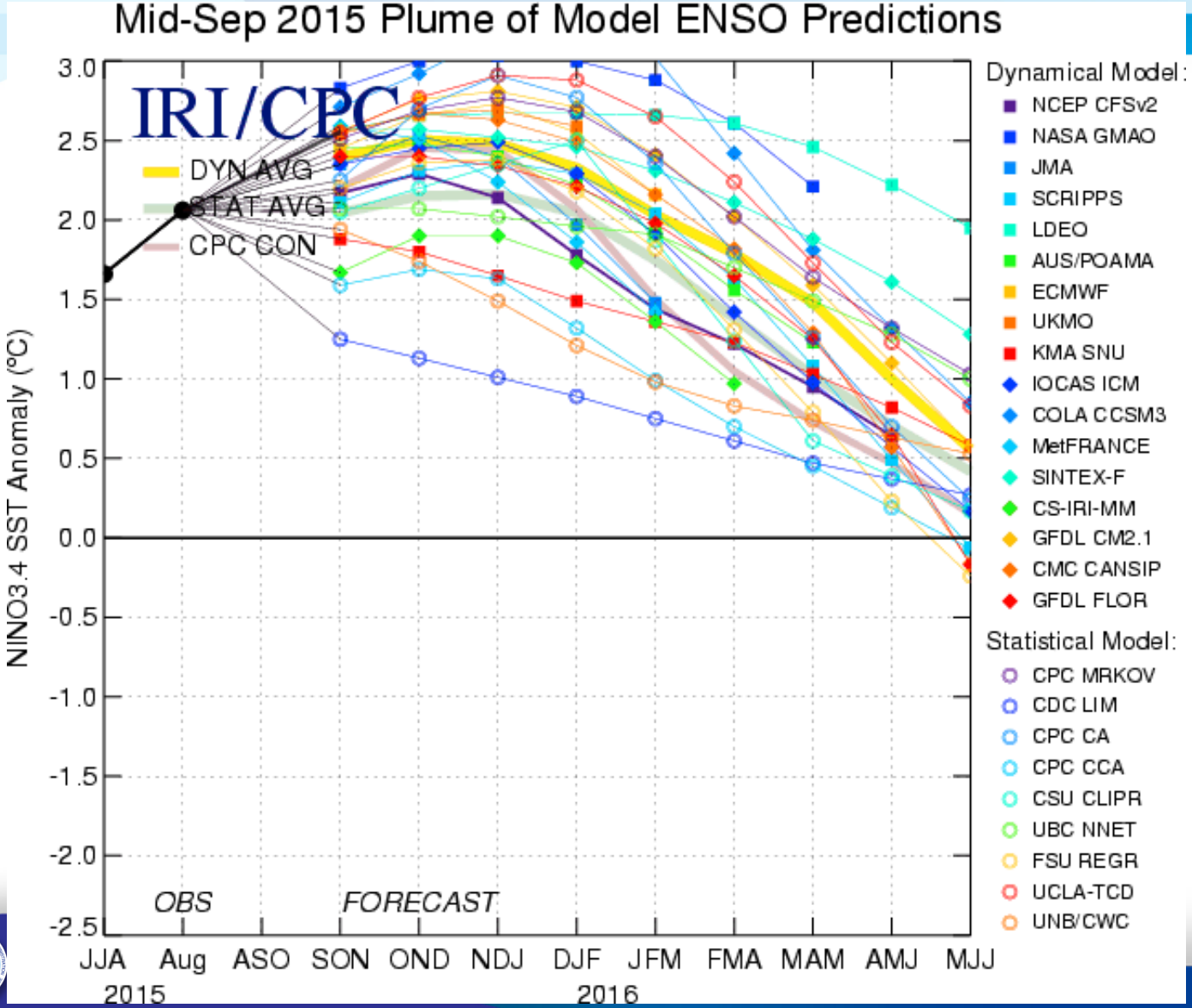
- It is important to remember that the correlation between ENSO and most of the area in the CBRFC region is not strong, and probably only applicable to the Lower Colorado Region, which doesn't have as much impact on basin water supply

- Also important to remember is that the ENSO phenomenon has been correlated with precipitation, not streamflow, so antecedent conditions could still play a large role

Latest Projections

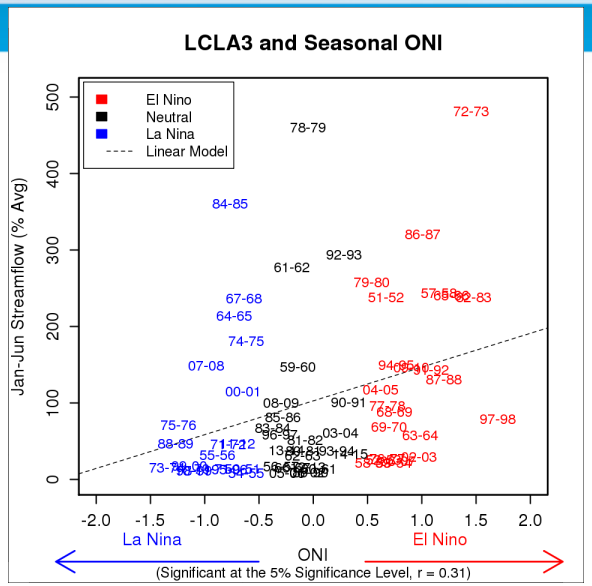


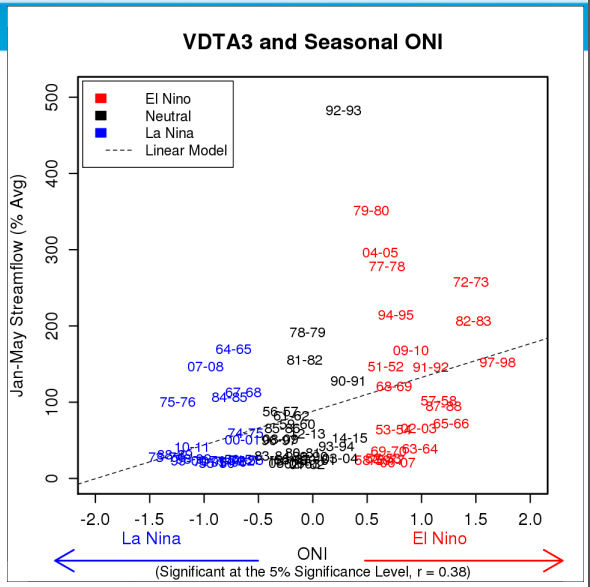
Latest Projections

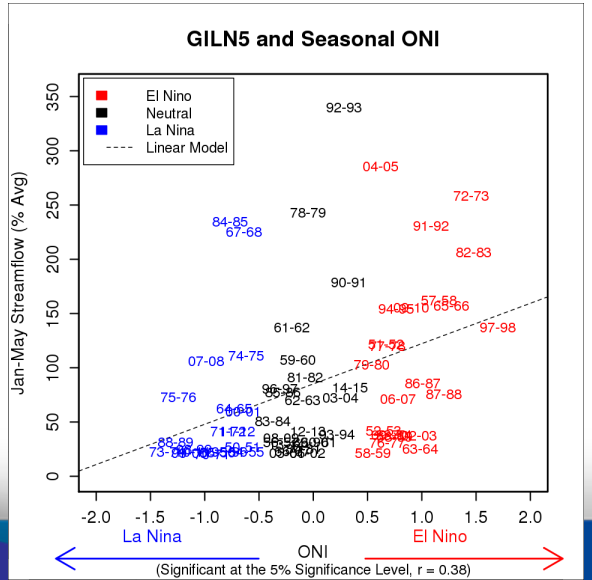


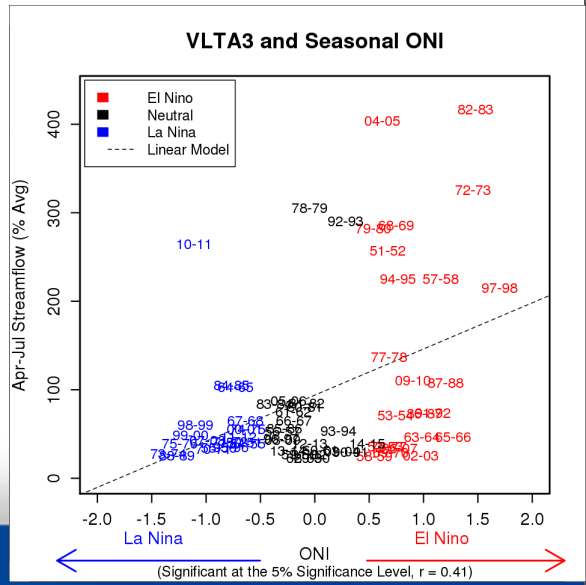
More Local ENSO Impacts

We actually see a statistically significant relationship between ENSO and streamflow in the Lower Basin, but correlations are relatively low.







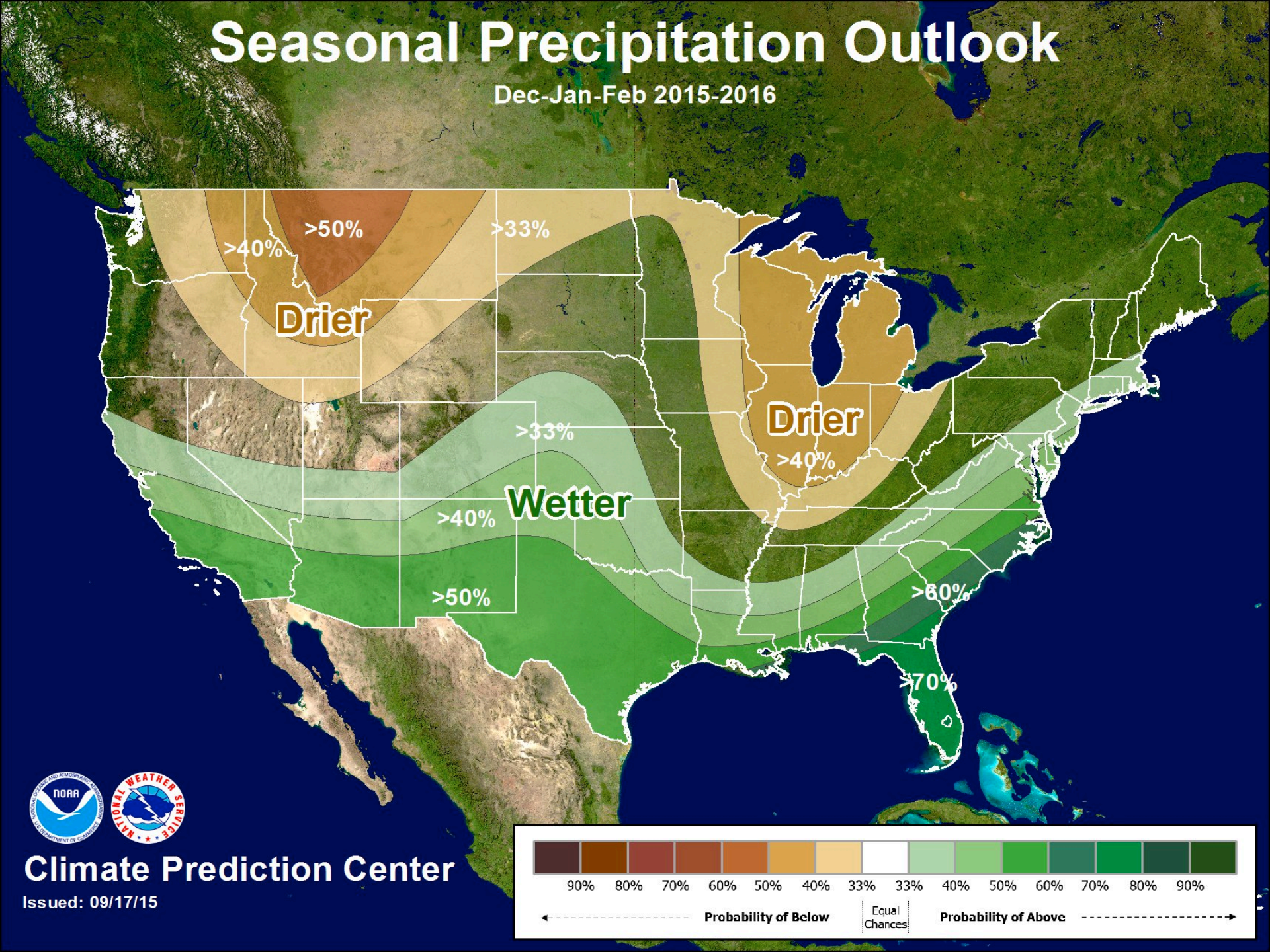


Latest Projections

- Current models are showing 100% chance that El Niño conditions develop by summer
- Most models are projecting a strong event, with just a few statistical models projecting a moderate or weak event
- CPC consensus is for a strong event peaking in NDJ 2015 and weakening through Spring 2016

Seasonal Precipitation Outlook

Dec-Jan-Feb 2015-2016



NOAA

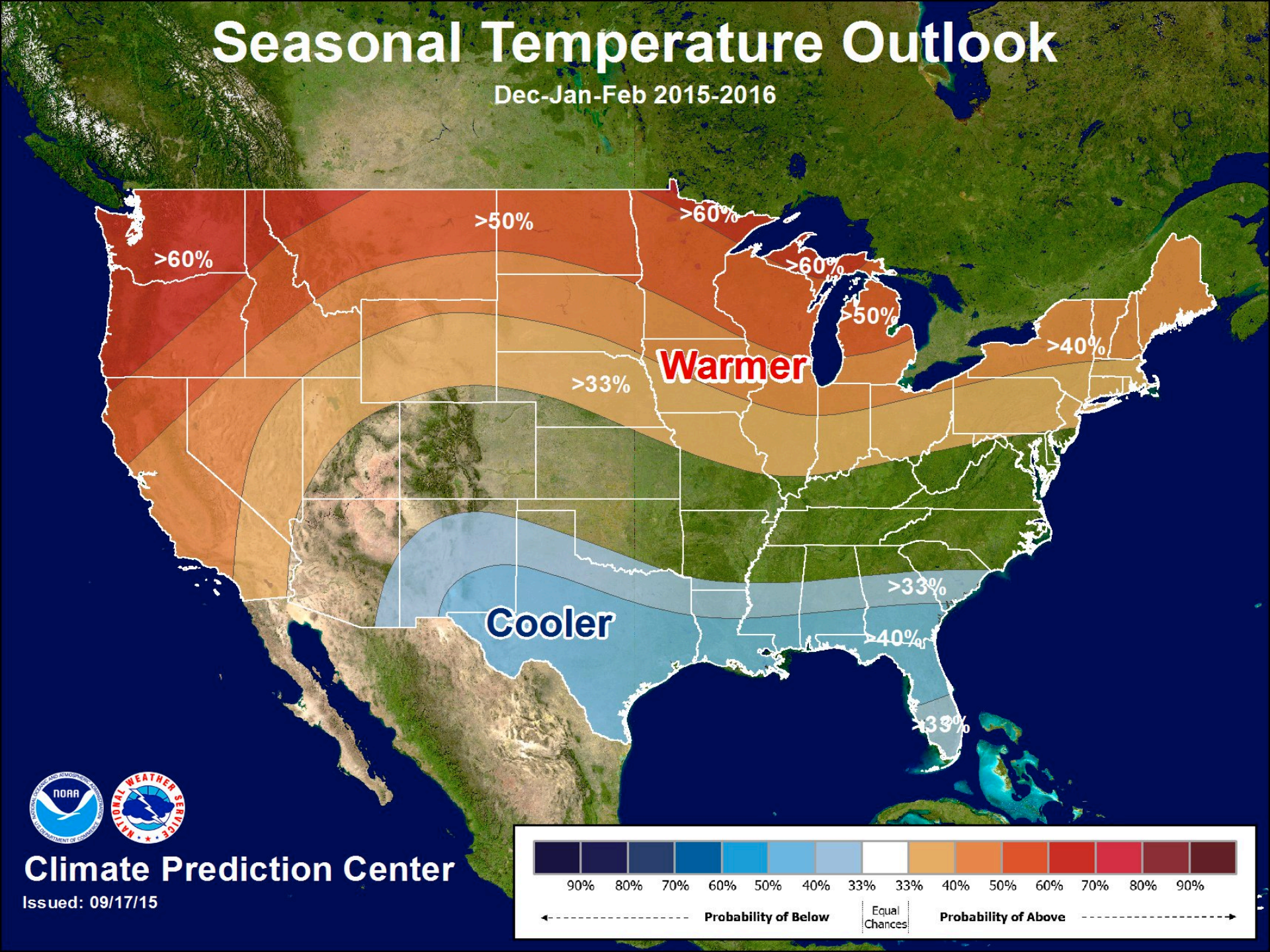
NATIONAL WEATHER SERVICE

Climate Prediction Center

Issued: 09/17/15

Seasonal Temperature Outlook

Dec-Jan-Feb 2015-2016



Climate Prediction Center

Issued: 09/17/15

How can we help?

- Able to communicate physical basis for streamflow forecasts
- Provide forecasts for additional locations if needed
- Provide forecast information in a format that is most convenient for you
- We can work to develop additional products to meet your needs
  - Seriously, let us know if you need something and we will do our best to make it happen!
  - We can always use more data!

Contact us!

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National Water Center

The first-ever U.S. center for water forecast operations, research, and collaboration across federal agencies

60,000 sq ft “green” building

University of Alabama Campus, Tuscaloosa, AL

Opened in May 2015, staffing being ramped up

National Water Center

Mission

The National Water Center collaboratively researches, develops and delivers state-of-the science National hydrologic analyses, forecast information, data, decision-support services and guidance to support and inform essential emergency services and water management decisions.

- A foundation for developing a national "common operating picture" to enable critical decisions effecting the Nation's most valuable resource
- Fully integrated water resources program directed towards consistent products for impact-based decision support services
- Catalyst for accelerating research to operations
- Nerve center for optimization of data-flow among RFCs and IWRSS partners

A Catalyst for Modernizing the NWS Hydrology Program

QUESTIONS?