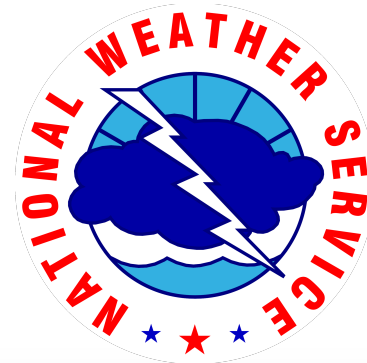
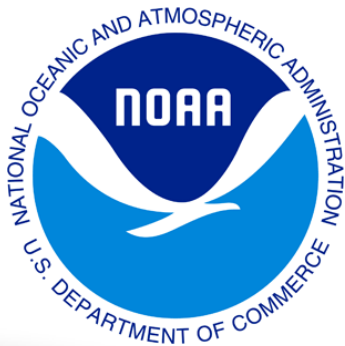
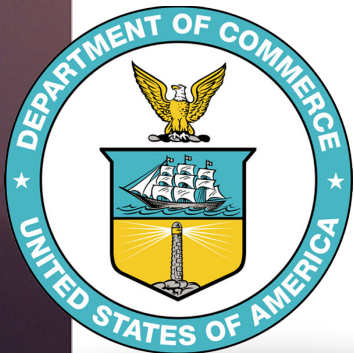


NOAA'S COLORADO BASIN RIVER FORECAST CENTER

AN OVERVIEW OF EFFORTS BETWEEN THE CBRFC AND RECLAMATION



Overview

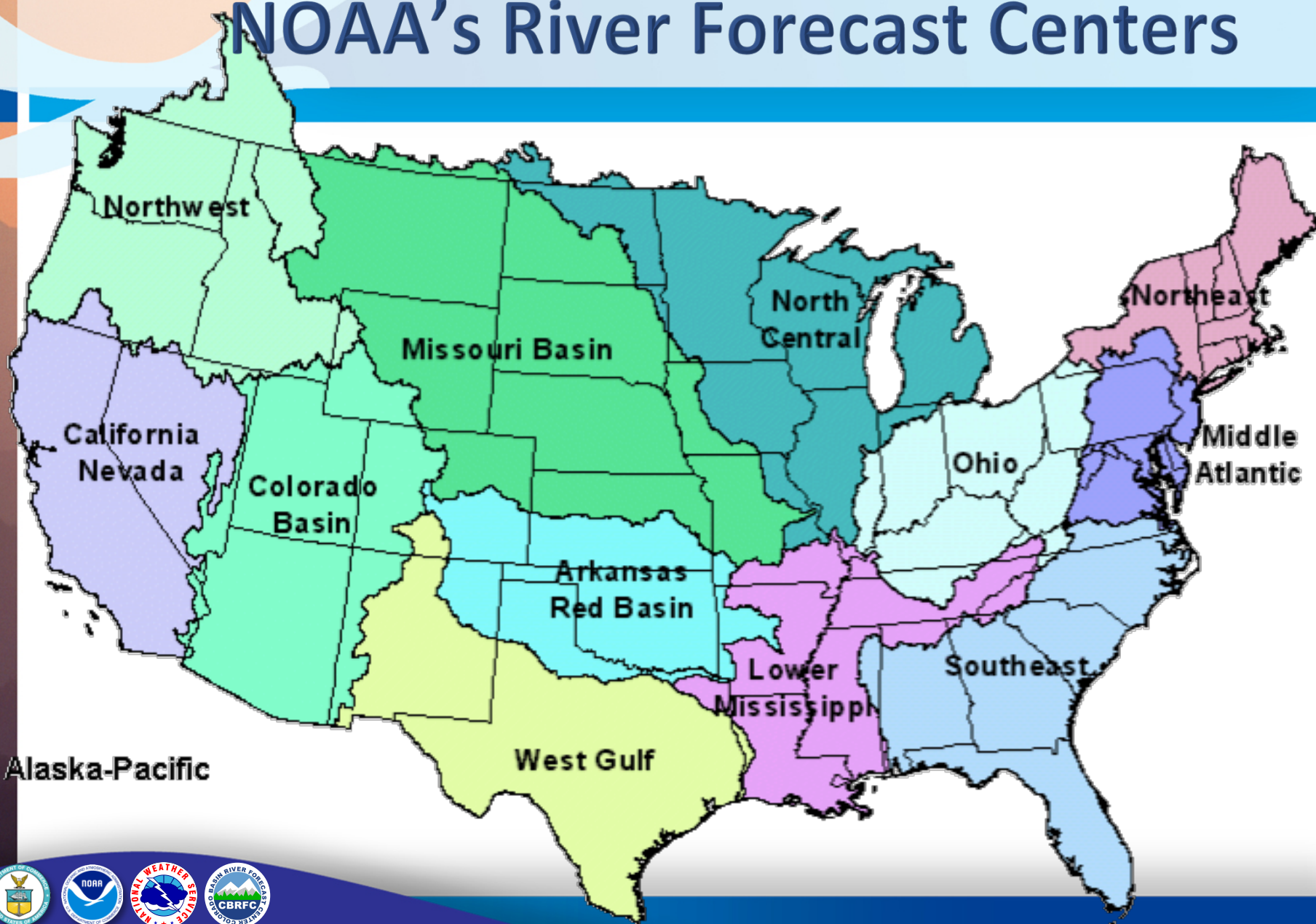
2

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



NOAA's River Forecast Centers

3



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
 - NRCS SNOTEL network
 - USGS streamflow network
 - Many others

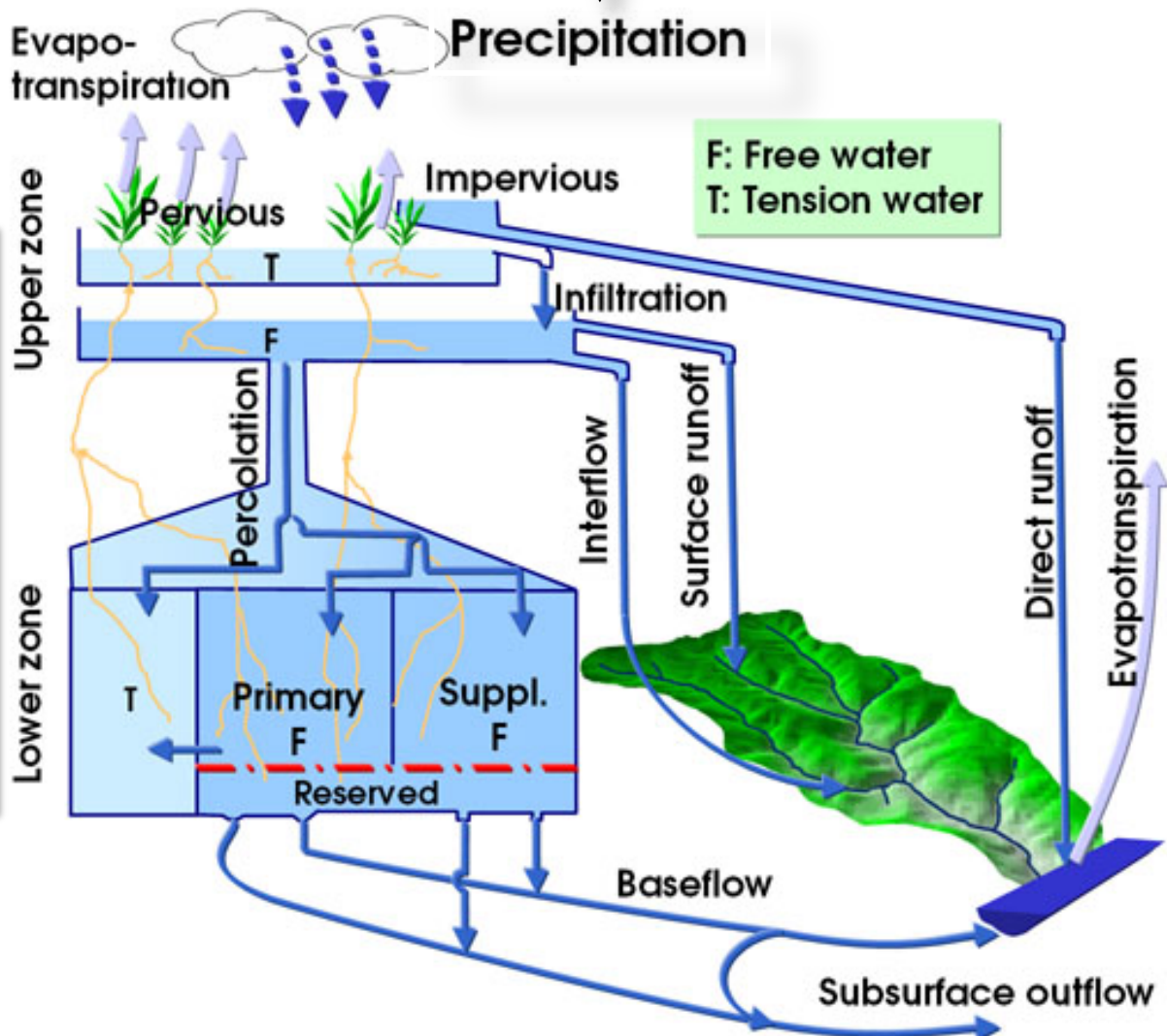
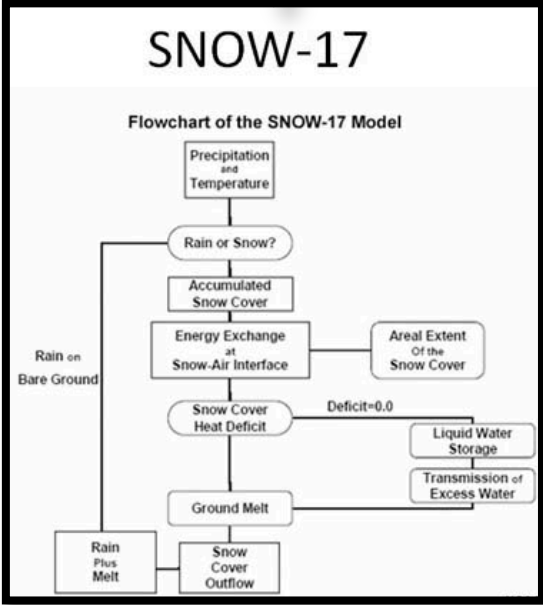
Products and Services

6

- 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

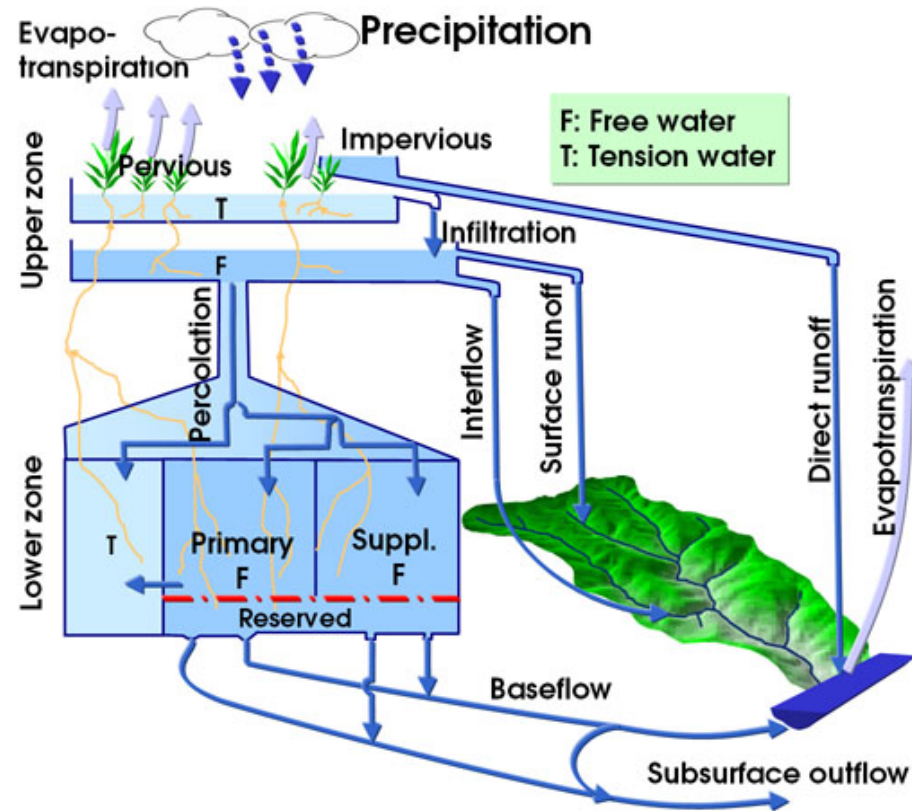


Our models



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

9

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.

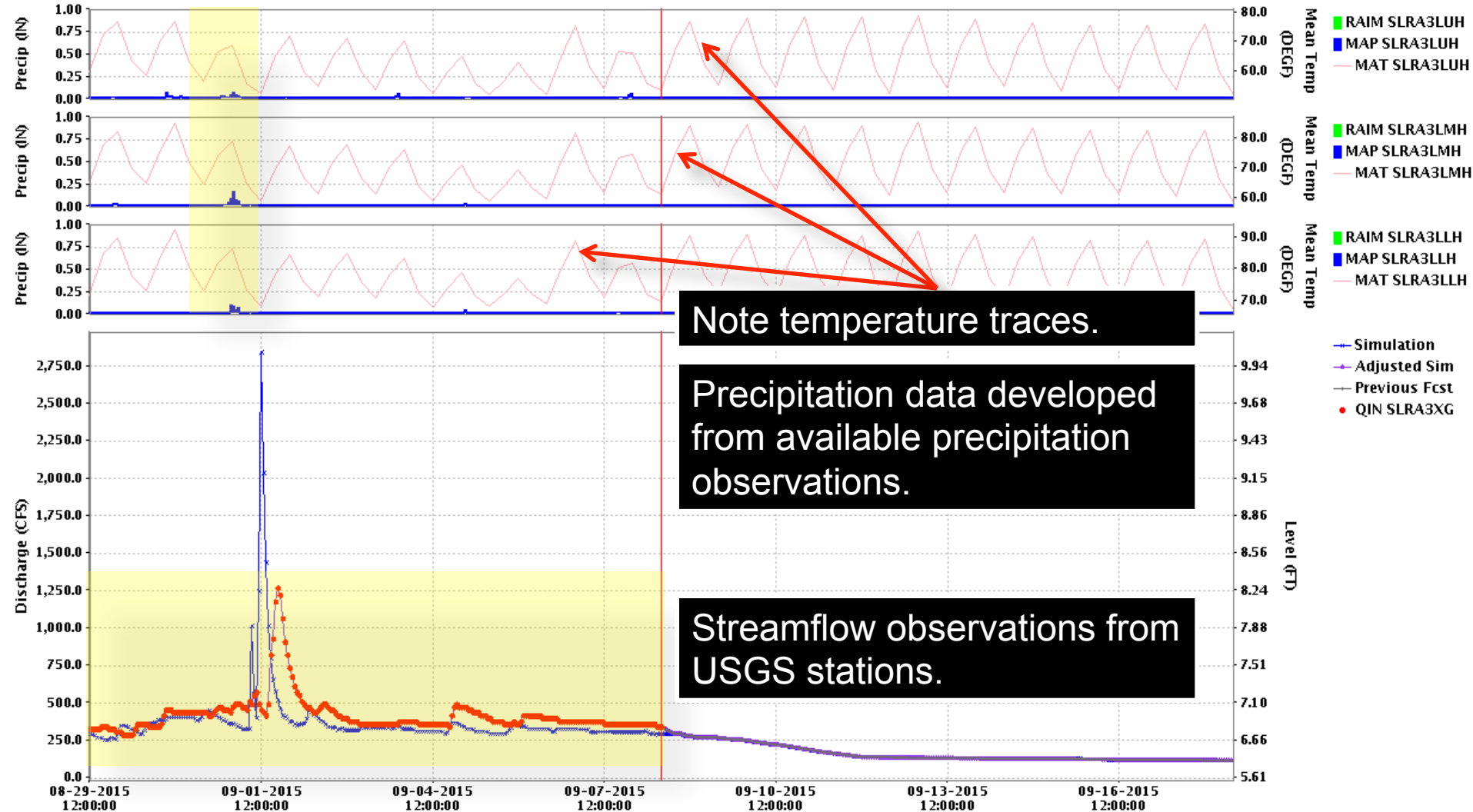


Fitting Together



Developing Forecasts

SLRA3L_H: SALT - ROOSEVELT - Forecast



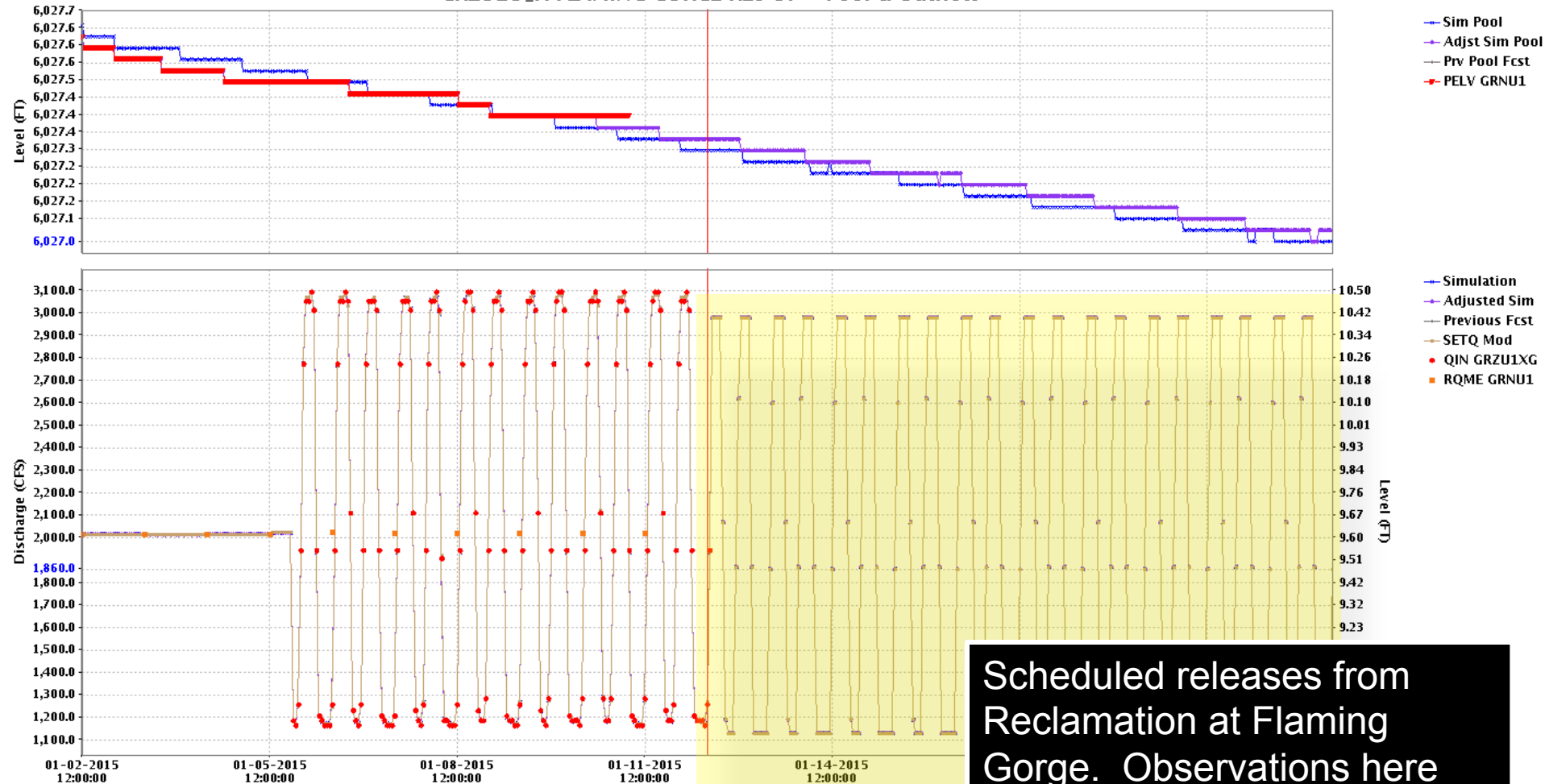
Note temperature traces.

Precipitation data developed from available precipitation observations.

Streamflow observations from USGS stations.

Developing Forecasts

GRZU10_F: FLAMING GORGE RES OP - Pool & Outflow



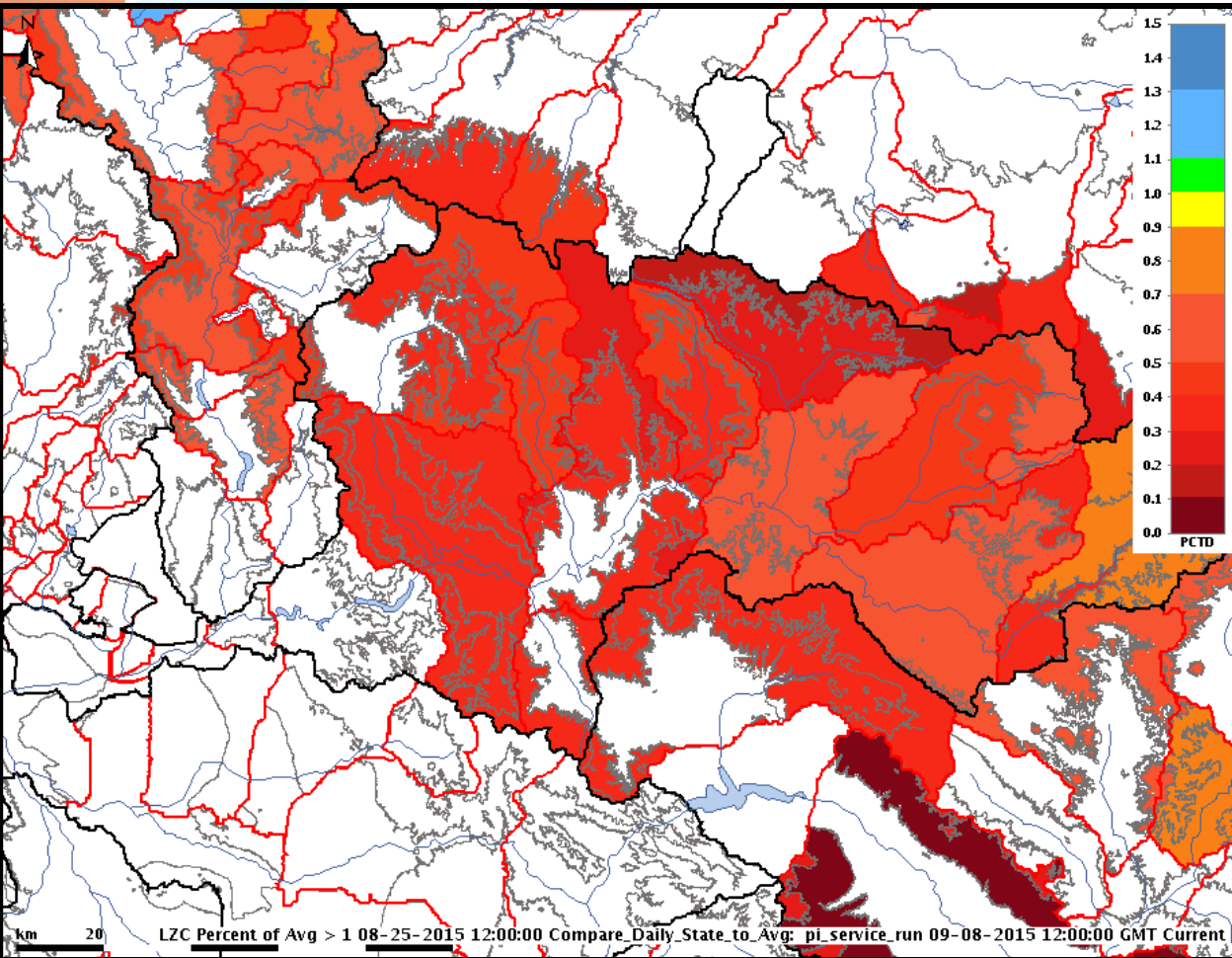
Scheduled releases from Reclamation at Flaming Gorge. Observations here are from Reclamation sources.

External: [1] 01-12-2015 12:00:00 GREEN_Approved_Forecast; [2] 01-12-2015 12:00:00 Current



Developing Forecasts

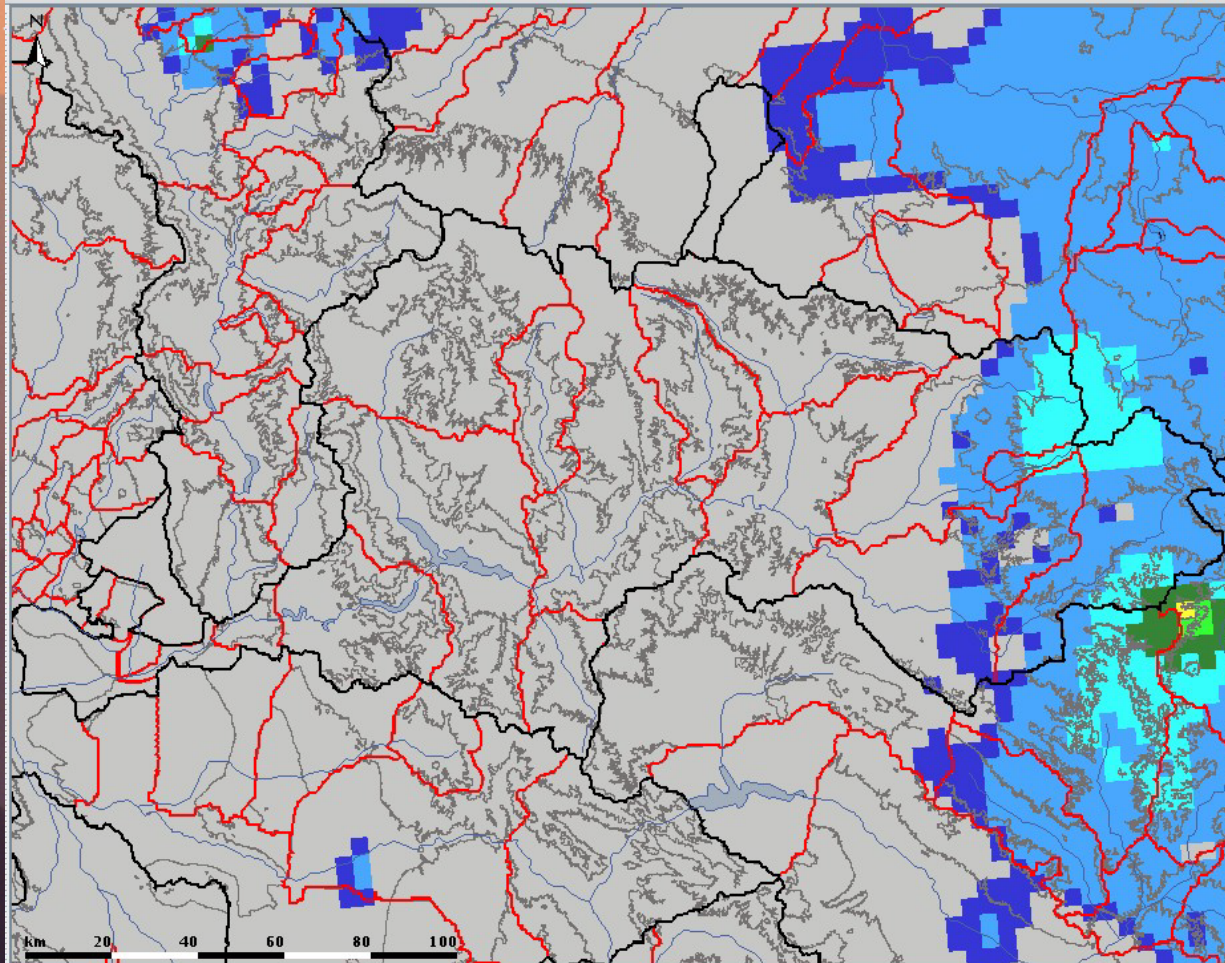
13



Soil moisture states are displayed to the left as a percent of average. In the Salt River Basin, dry, **modeled**, soil moisture conditions persist, despite a historically wet May and active monsoon season.

Developing Forecasts

14

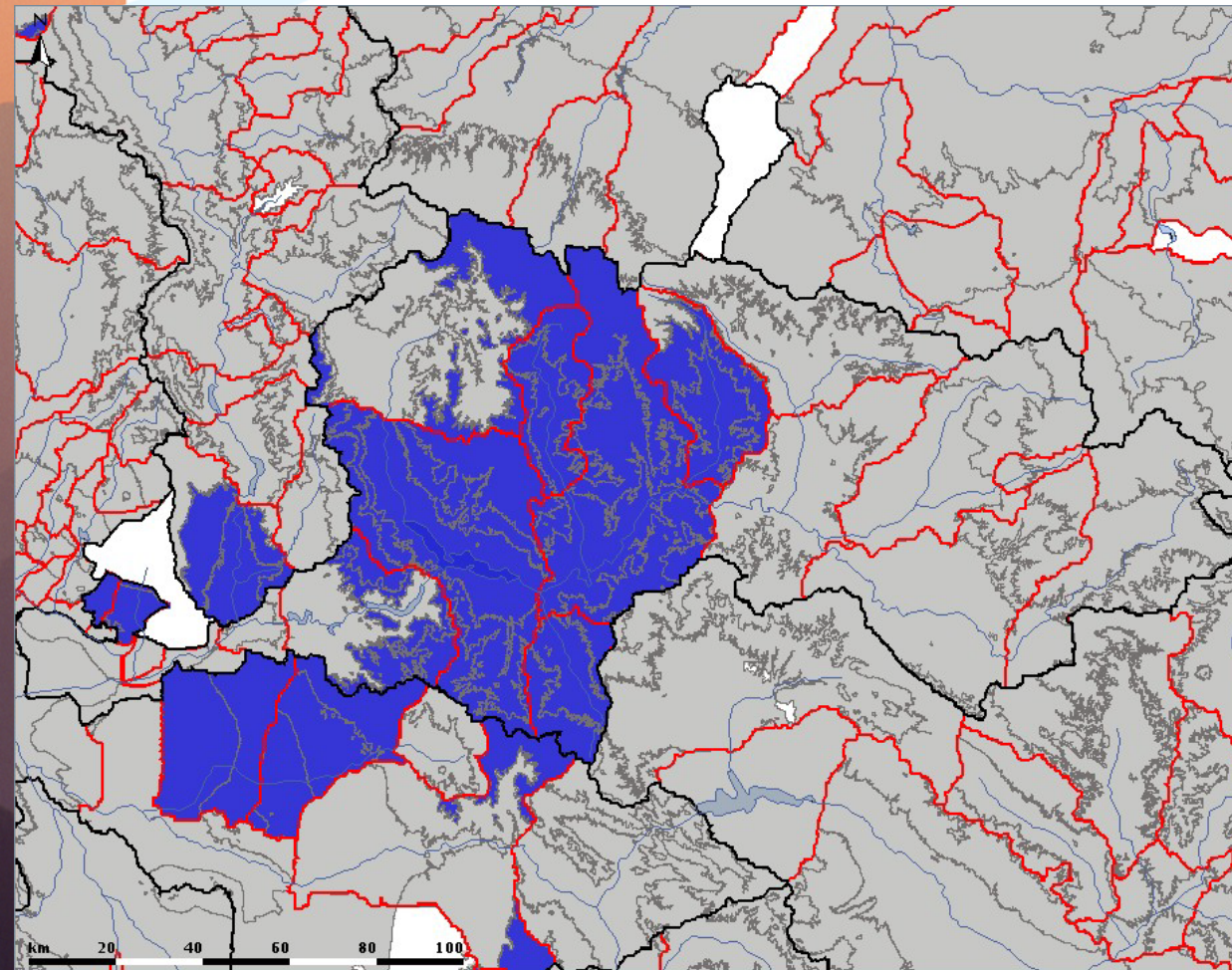


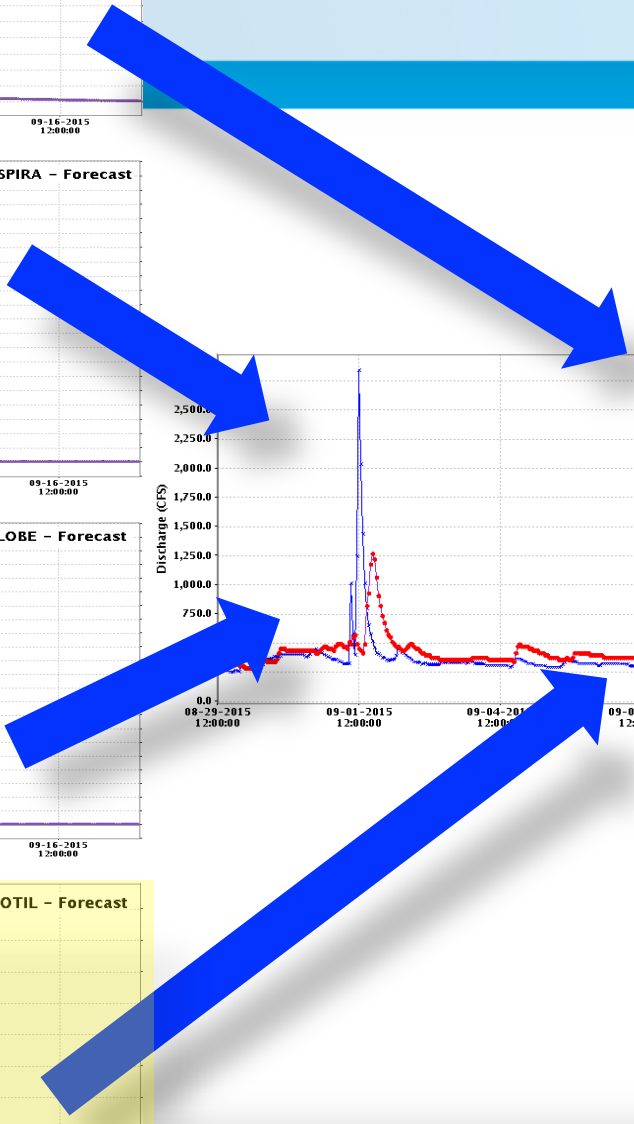
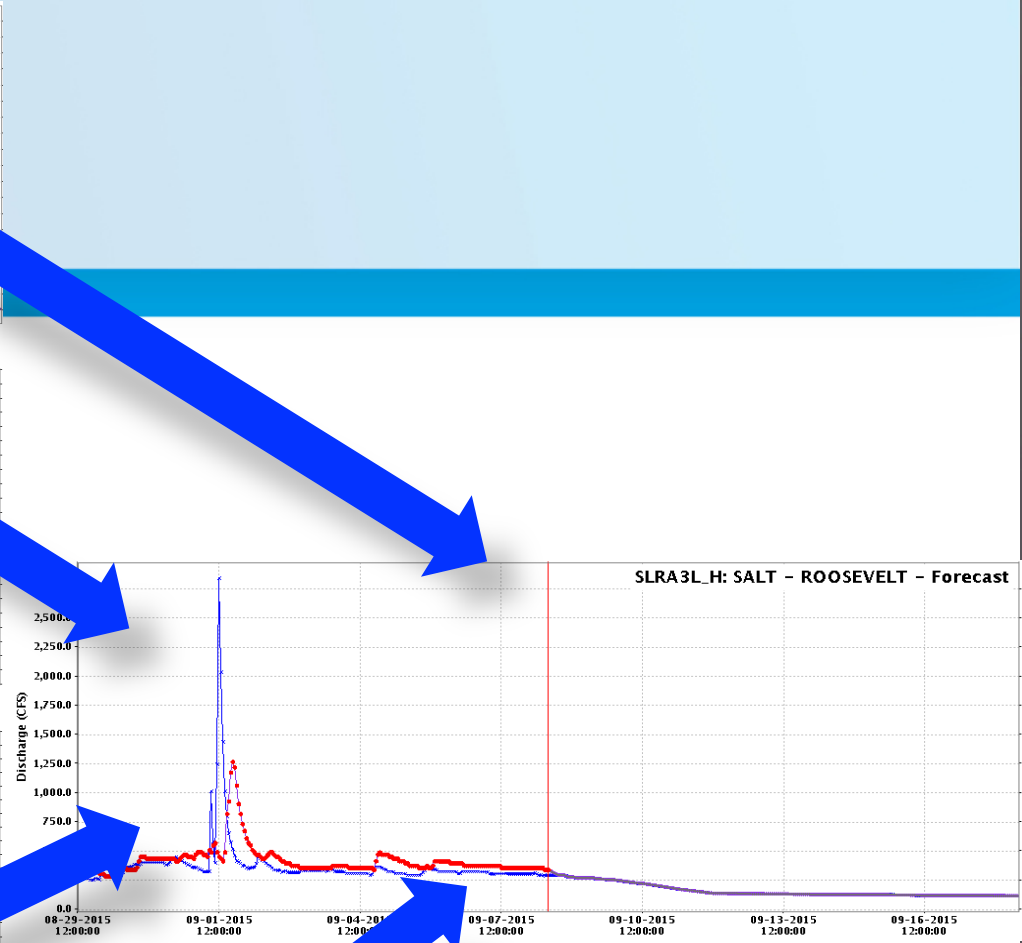
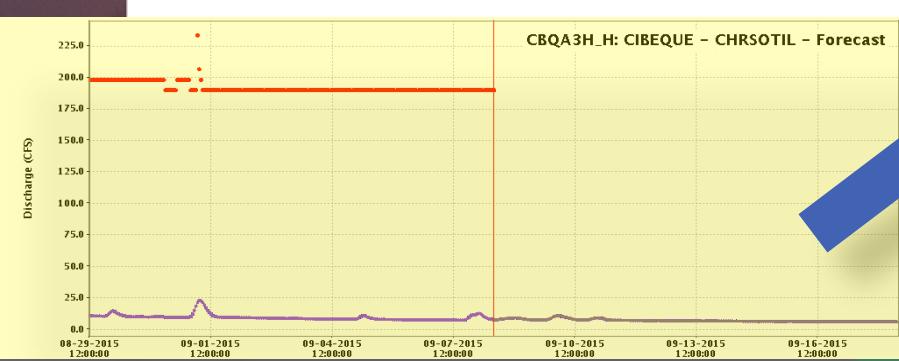
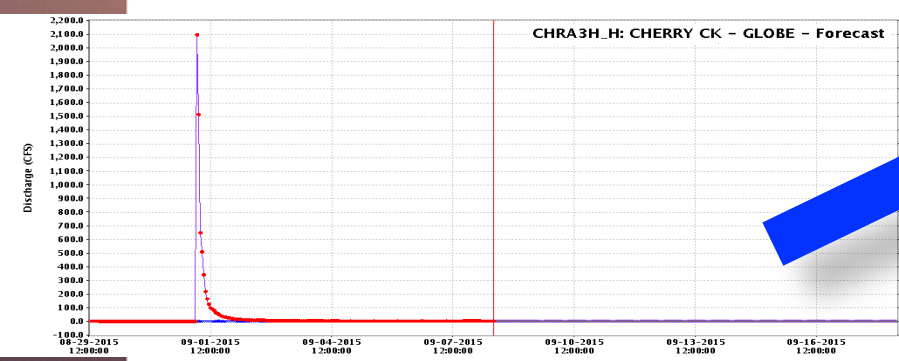
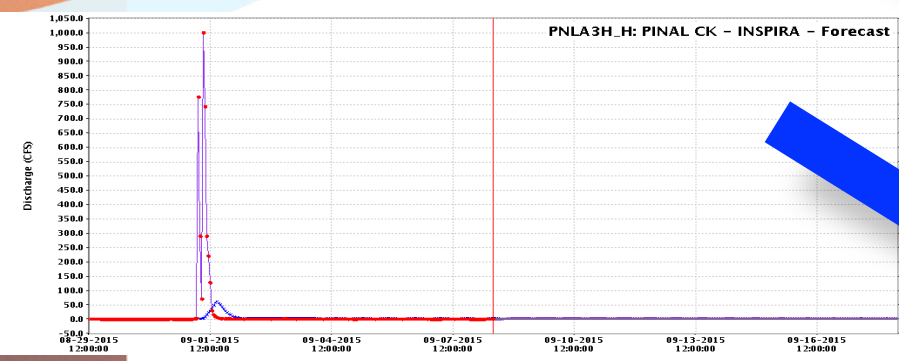
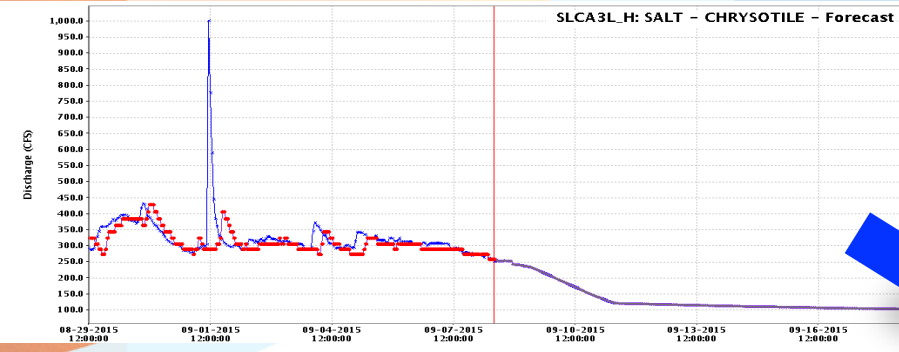
In the Lower Colorado River Basin, we utilize hourly precipitation observations to capture localized, convective precipitation events as best as we can, but forecasting them is difficult.

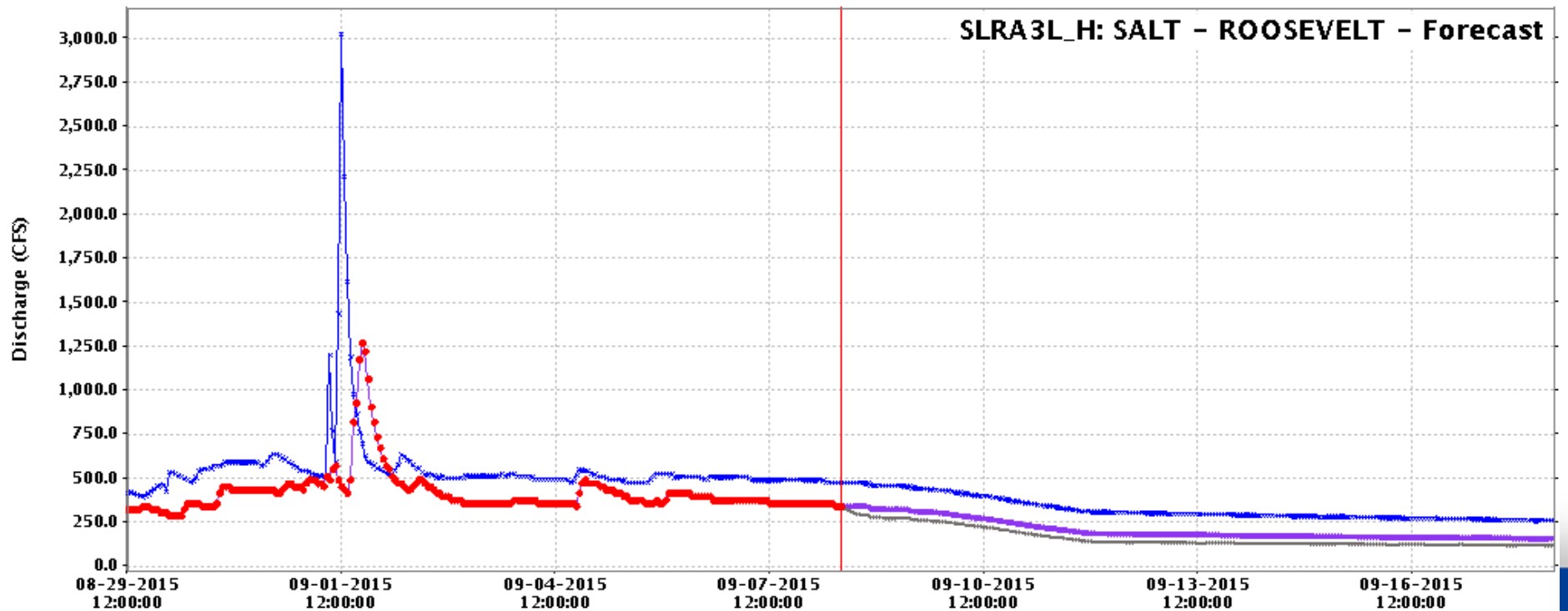
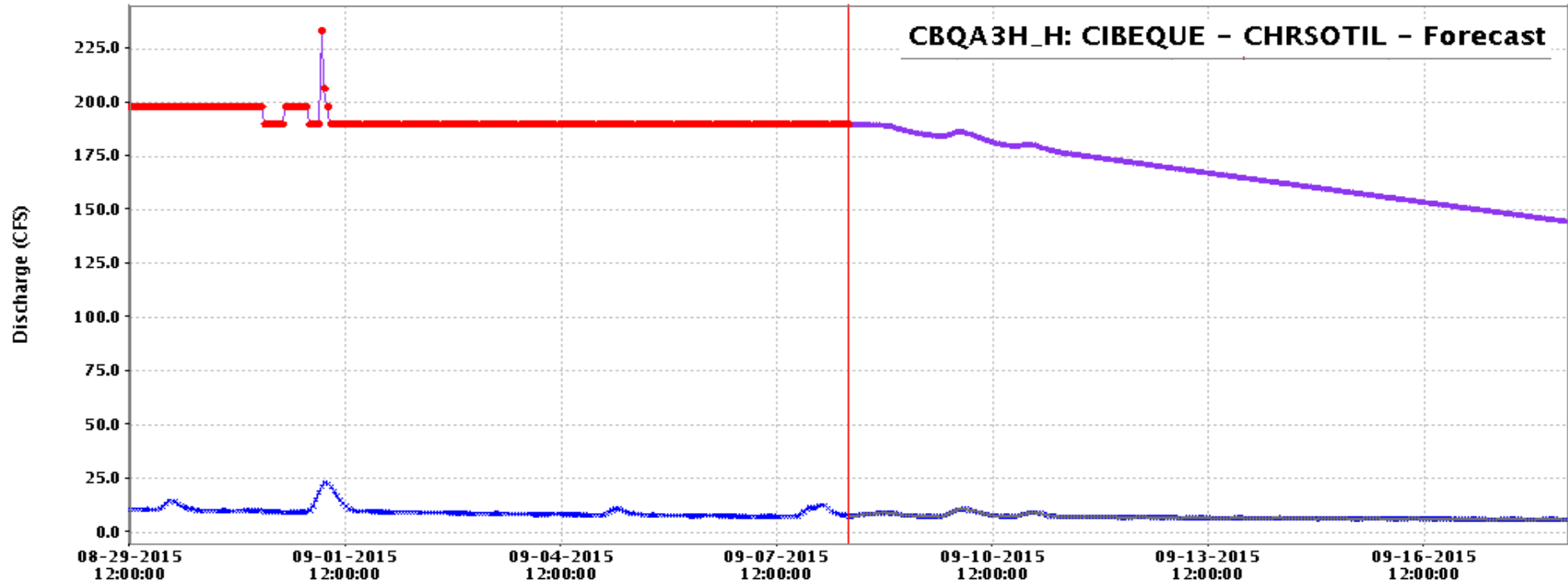
Developing Forecasts

15

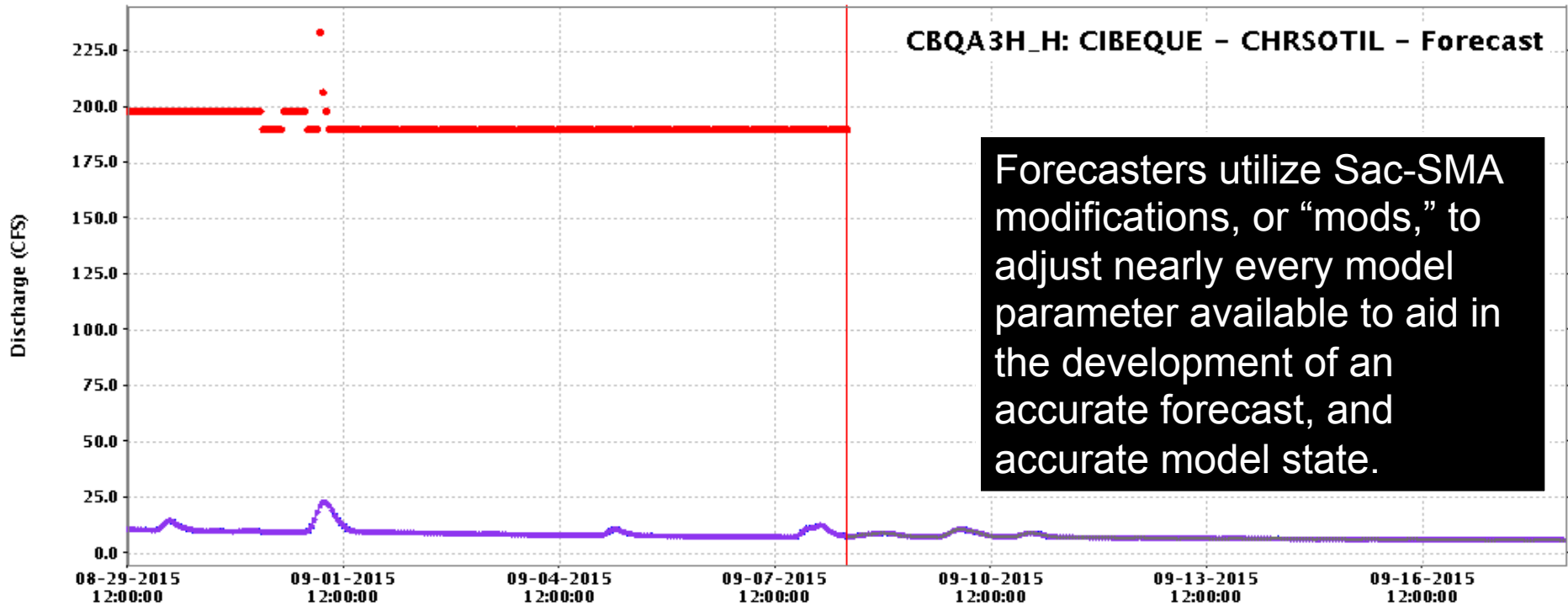
Because we utilize a lumped model, precipitation observations are converted to lumped, areal inputs.





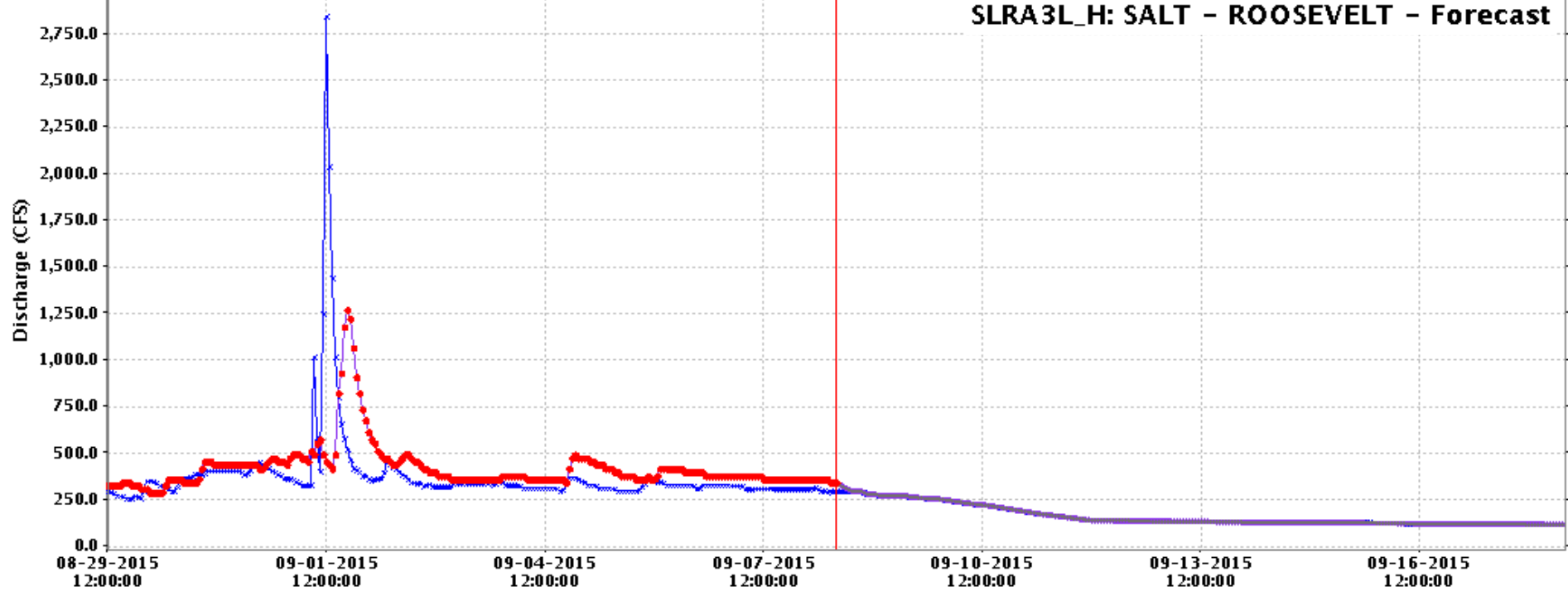


CBQA3H_H: CIBEQUE - CHRSTIL - Forecast



Forecasters utilize Sac-SMA modifications, or "mods," to adjust nearly every model parameter available to aid in the development of an accurate forecast, and accurate model state.

SLRA3L_H: SALT - ROOSEVELT - Forecast



Products and Services

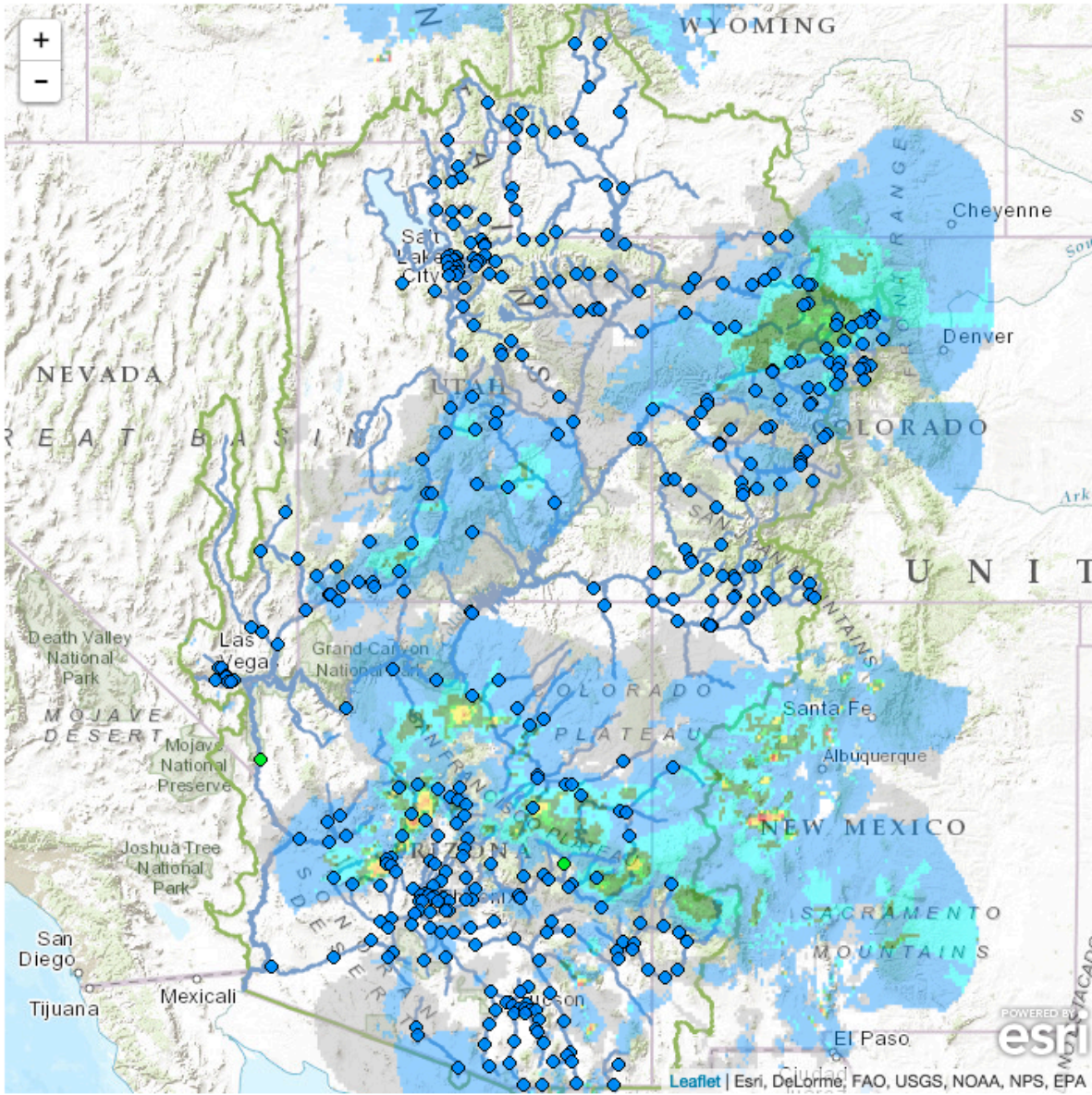
19

- 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 Probability
- ▶ Reservoir Conditions
- ▼ Weather Conditions

Precipitation

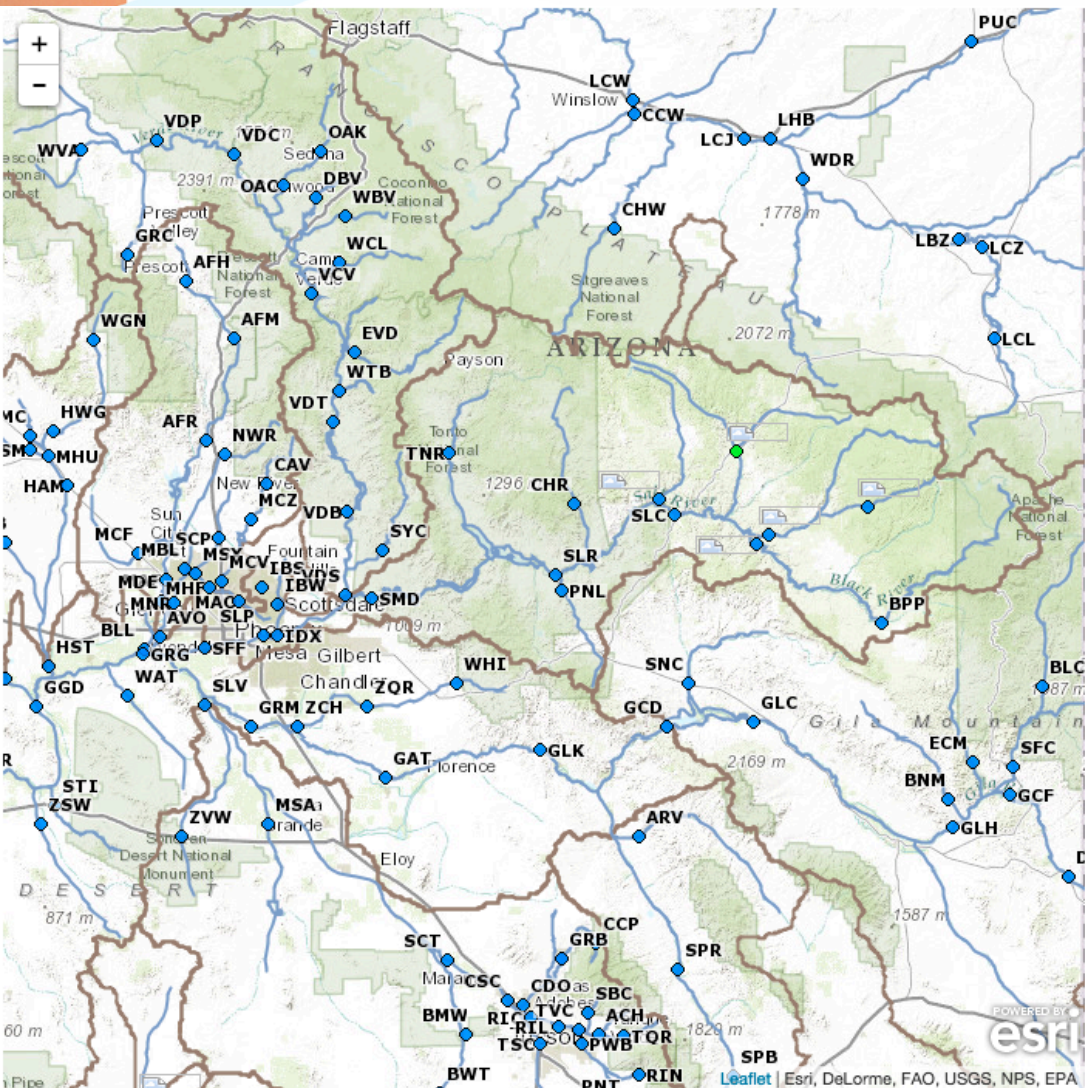
Observed 2015-09-08

- Gage and Radar (MPE)
- Gage Data Only (MM)

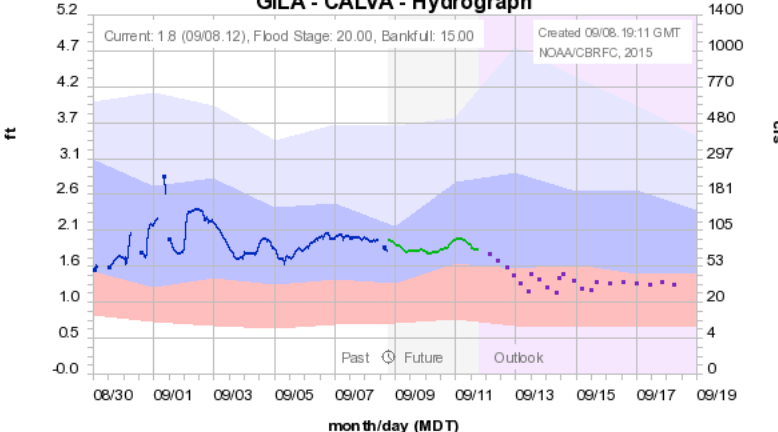
□	<0.01
■	0.01-0.1
■	0.1-0.2
■	0.2-0.3
■	0.3-0.4
■	0.4-0.5
■	0.5-0.75
■	0.75-1.0
■	1.0-1.25
■	1.25-1.5
■	1.5-1.75
■	1.75-2
■	2-2.5

- ▶ Map Options
- ▶ Search Points

Products and Services

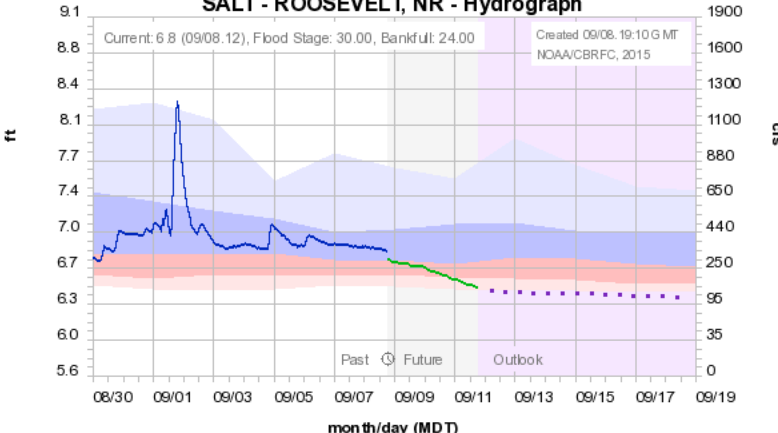


Colorado Basin River Forecast Center
GILA - CALVA - Hydrograph



Observed — Forecast (09/08 14:00) — Outlook (increasing uncertainty) - - -
Historical Exceedance Probability (USGS): 90-75% 75-50% 50-25% 25-10%

Colorado Basin River Forecast Center
SALT - ROOSEVELT, NR - Hydrograph

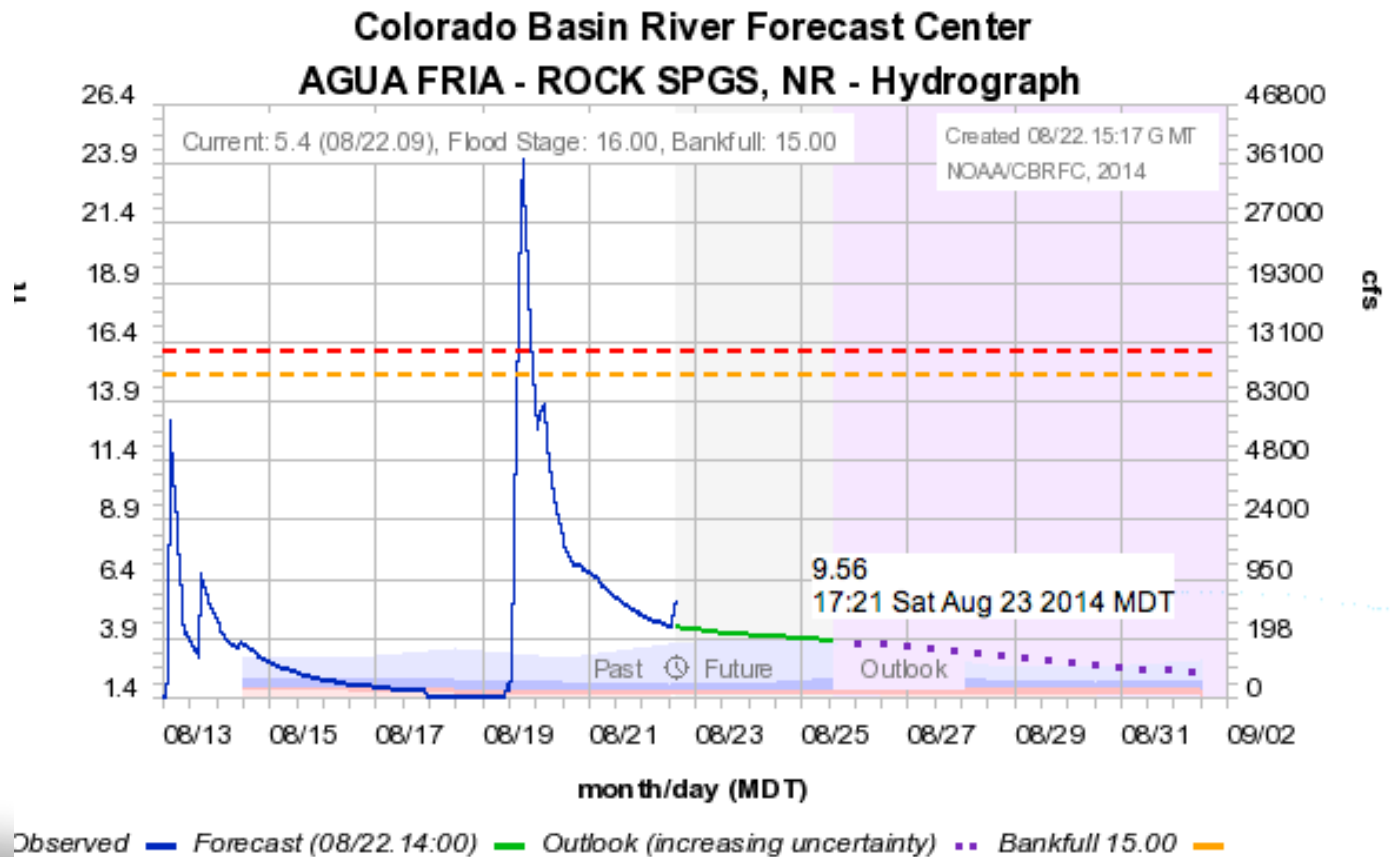


Observed — Forecast (09/08 14:00) — Outlook (increasing uncertainty) - - -
Historical Exceedance Probability (USGS): 90-75% 75-50% 50-25% 25-10%

Products and Services

22

- Support flood warning efforts by weather forecast offices



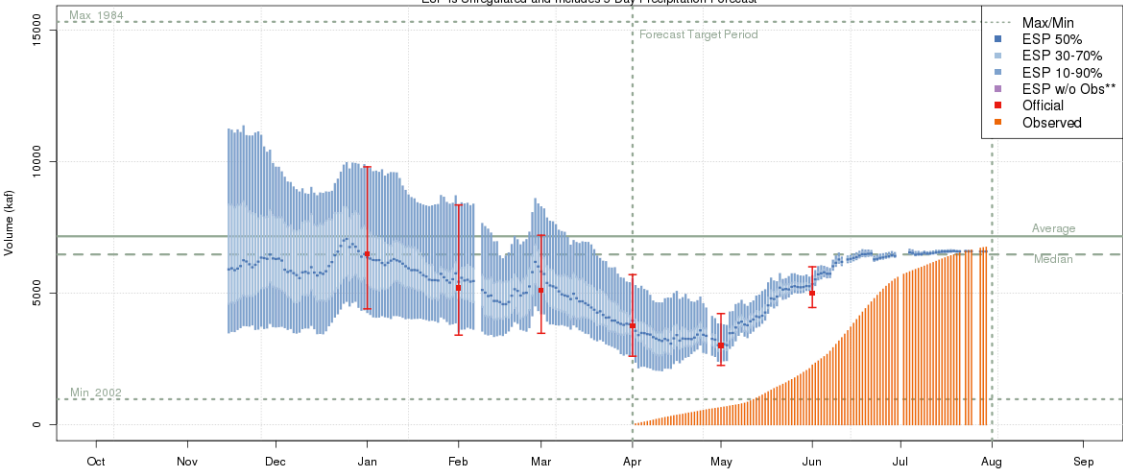
Products and Services

23

- **Volumetric Water Supply Forecasts**
 - Arguably the most important product that we provide to Reclamation
 - 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

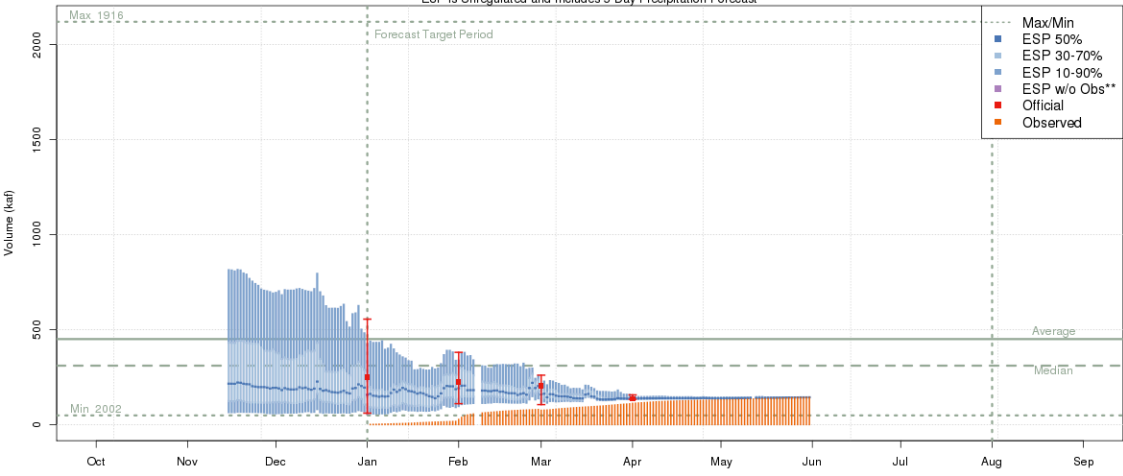


Colorado - Lake Powell- Glen Cyn Dam- At (GLDA3)
 2015-06-01 Apr-Jul Official 50% Forecast: 5000 kaf (70% of average)
 ESP is Unregulated and Includes 5 Day Precipitation Forecast

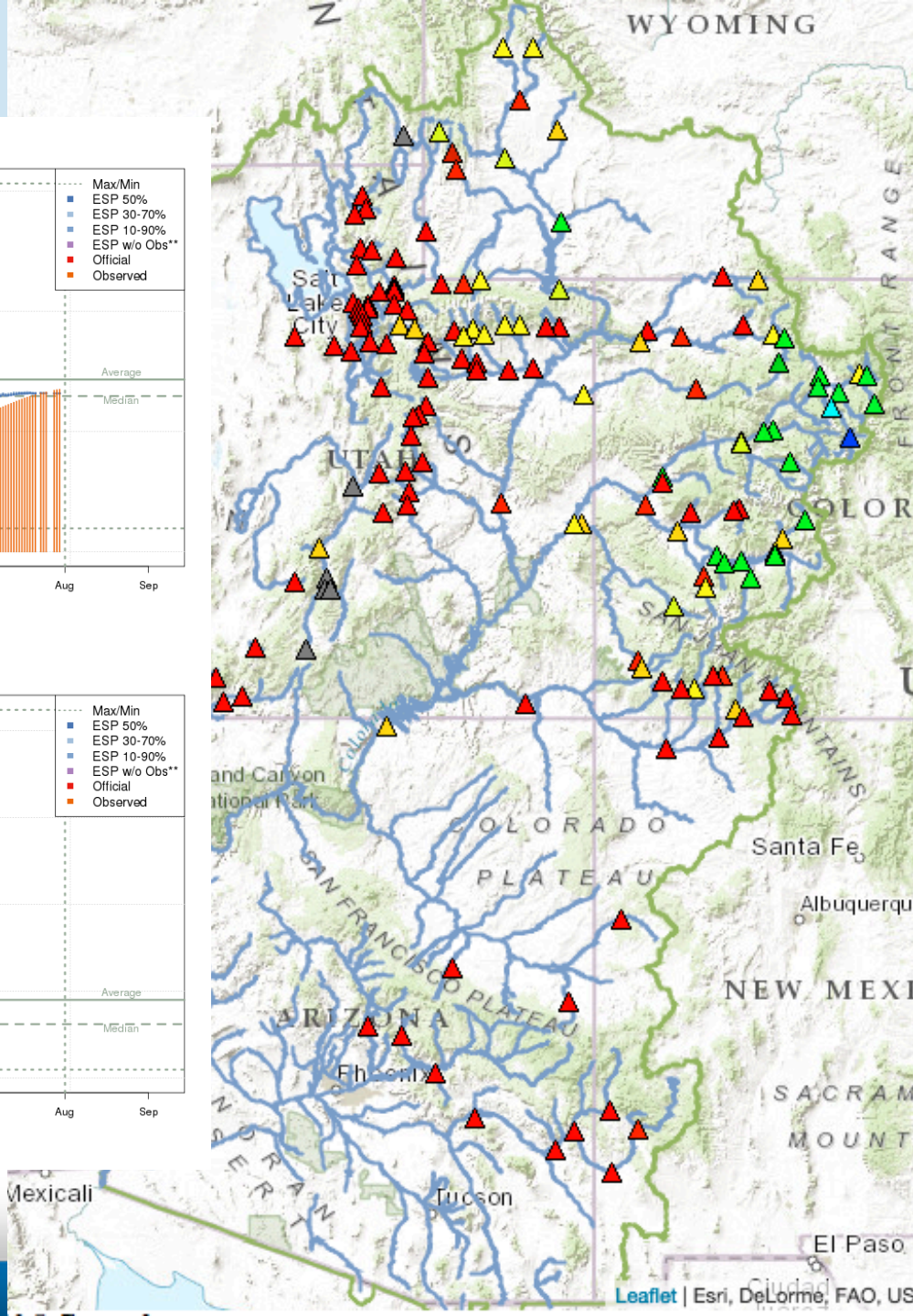


The latest (2015-07-30) 50% ESP forecast is 6583 kaf.
 Plot Created 2015-08-07 11:29:19, NOAA / NWS / CBRFC
 Forecasts in the forecast target period include observed values.

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.



Work we do with Reclamation

25

- Upper Colorado and Lower Colorado Regional Offices
 - Water supply forecasts that drive the 24-Month Study
 - Ensemble forecasts for use in the MTOM
- Provo Area Office
 - Eastern Great Basin Water Supply Forecasts
 - Planning of Weber River and Bear River resources
- Western Colorado Area Office
 - Information exchanged
 - Dam Conditions



Coordination Efforts

26

- Annual CRFS Meeting
 - Broad range of stakeholders, Reclamation usually presents or provides updates
 - Introduce new products and services
 - Reinforce traditional products and services
 - Important to get feedback
- Frequent webinars
 - Water supply
 - Peak Flow Forecasts



Coordination Efforts

27

- 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...



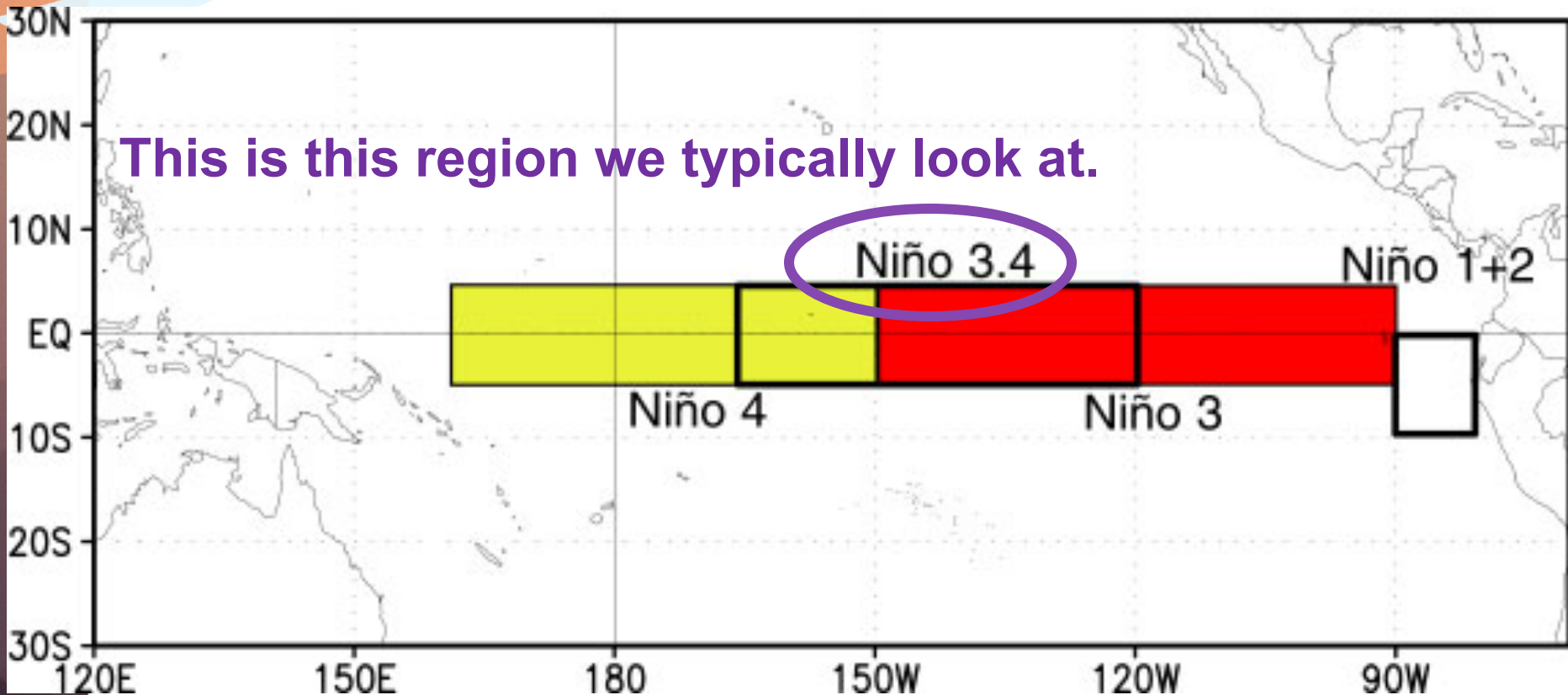
The Latest on ENSO

28

- 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

29



How do we define ENSO?

When departures, over a three month period, are $\geq 0.5^{\circ}\text{C}$ (El Niño) or $\leq -0.5^{\circ}\text{C}$ (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?

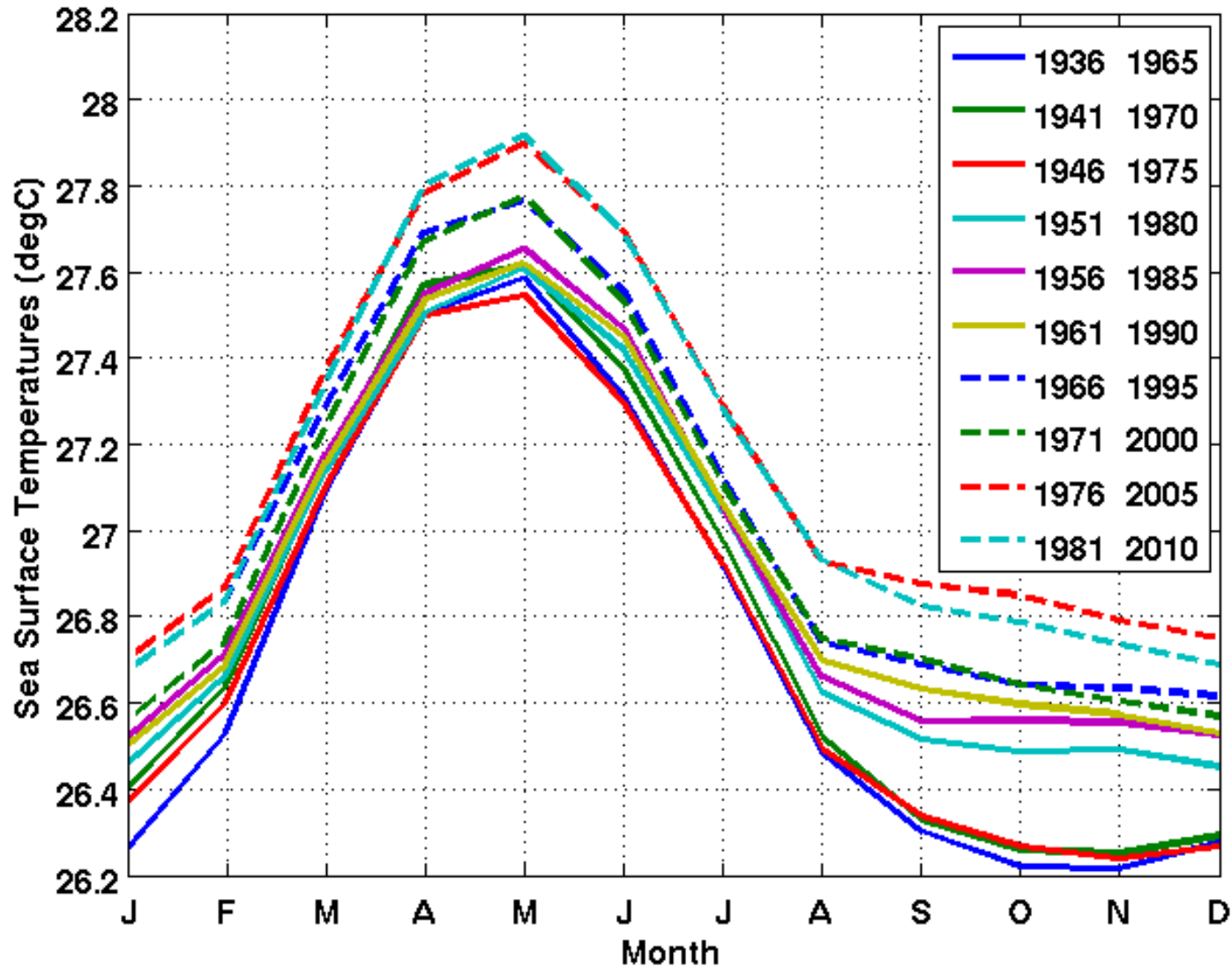
31

- 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?

Average SST in the Nino-3.4 region (ERSST.v3b)- 30yr base periods



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

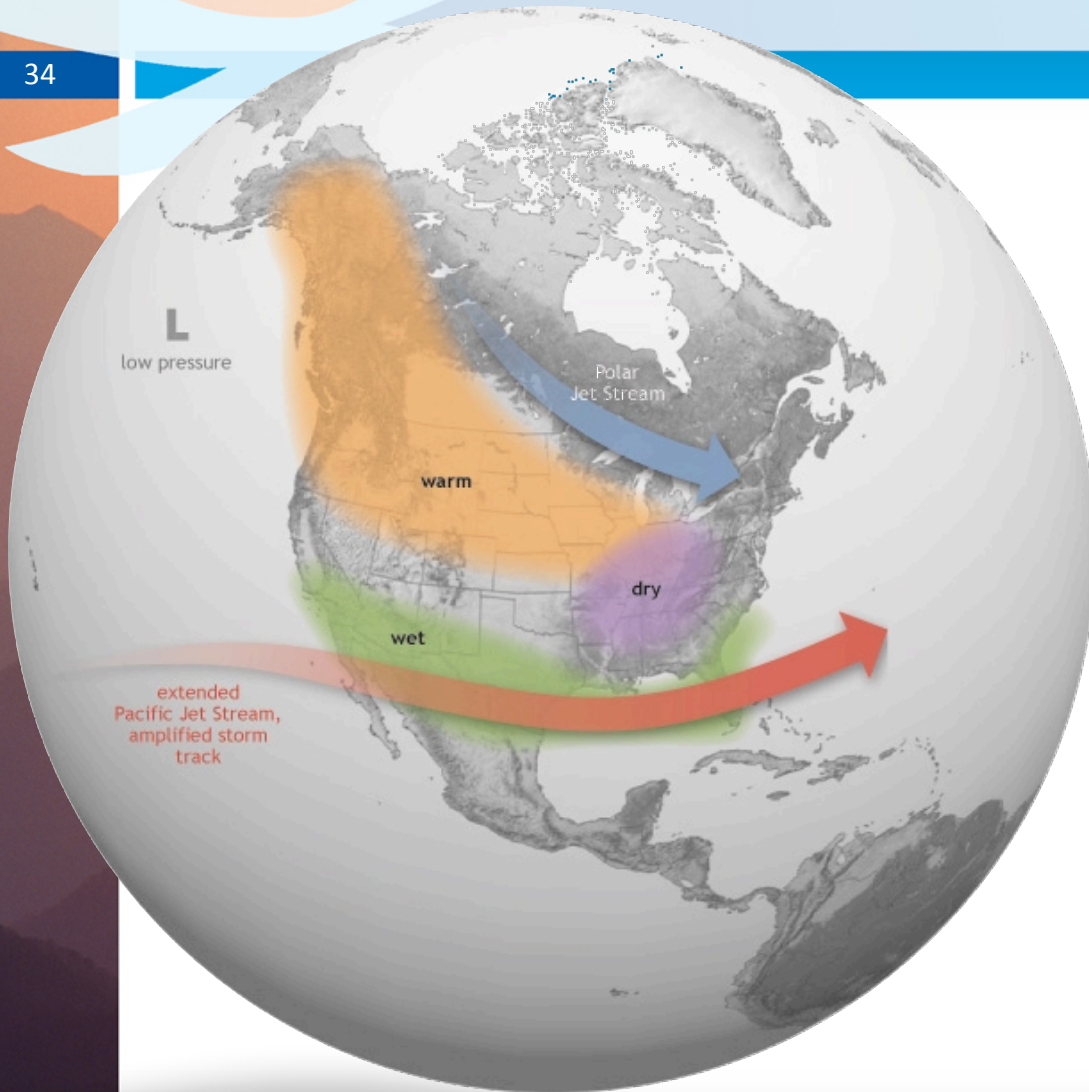
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2000	-1.7	-1.5	-1.2	-0.9	-0.8	-0.7	-0.6	-0.5	-0.6	-0.6	-0.8	-0.8
2001	-0.7	-0.6	-0.5	-0.4	-0.2	-0.1	0.0	0.0	-0.1	-0.2	-0.3	-0.3
2002	-0.2	0.0	0.1	0.3	0.5	0.7	0.8	0.8	0.9	1.2	1.3	1.3
2003	1.1	0.8	0.4	0.0	-0.2	-0.1	0.2	0.4	0.4	0.4	0.4	0.3
2004	0.3	0.2	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

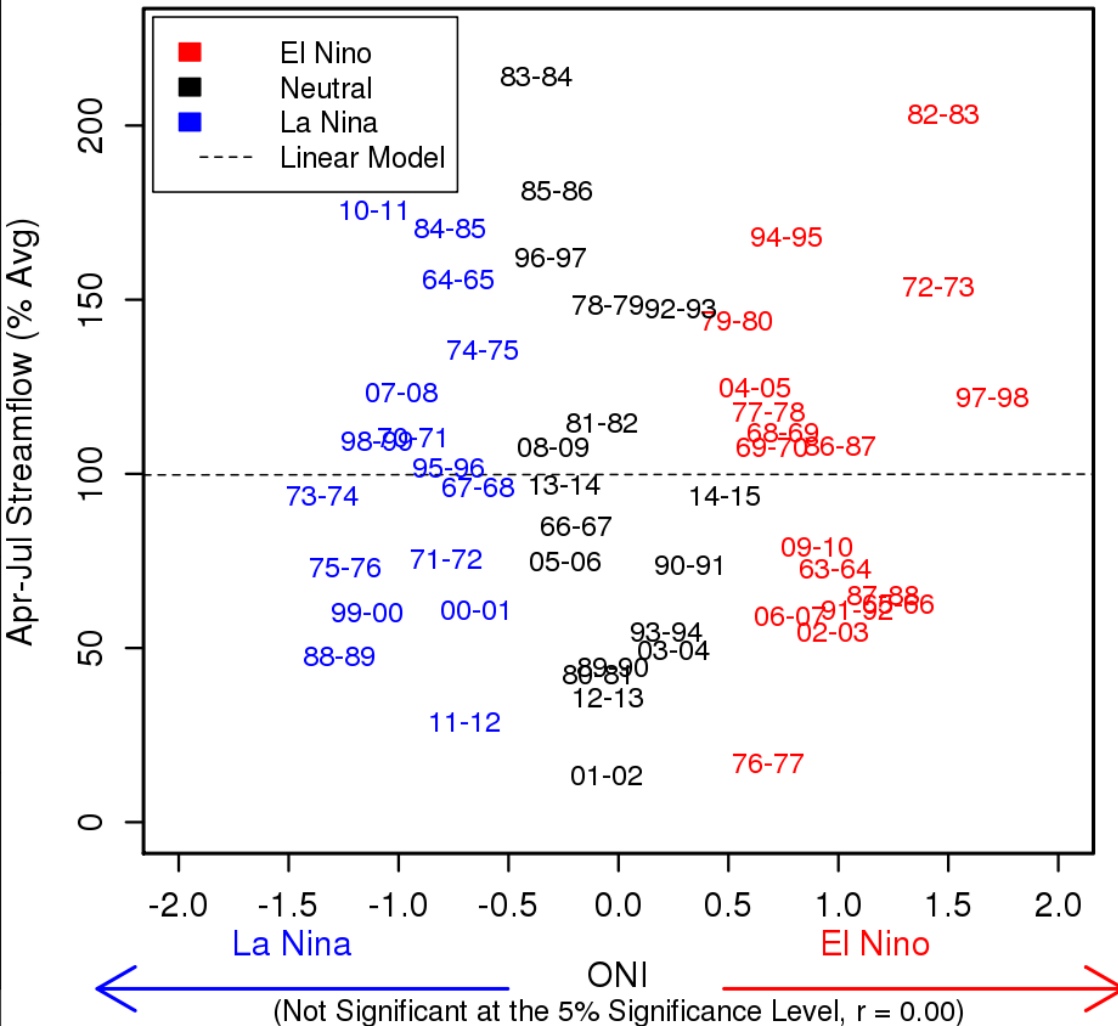
34



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

GLDA3 and Seasonal ONI



- 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

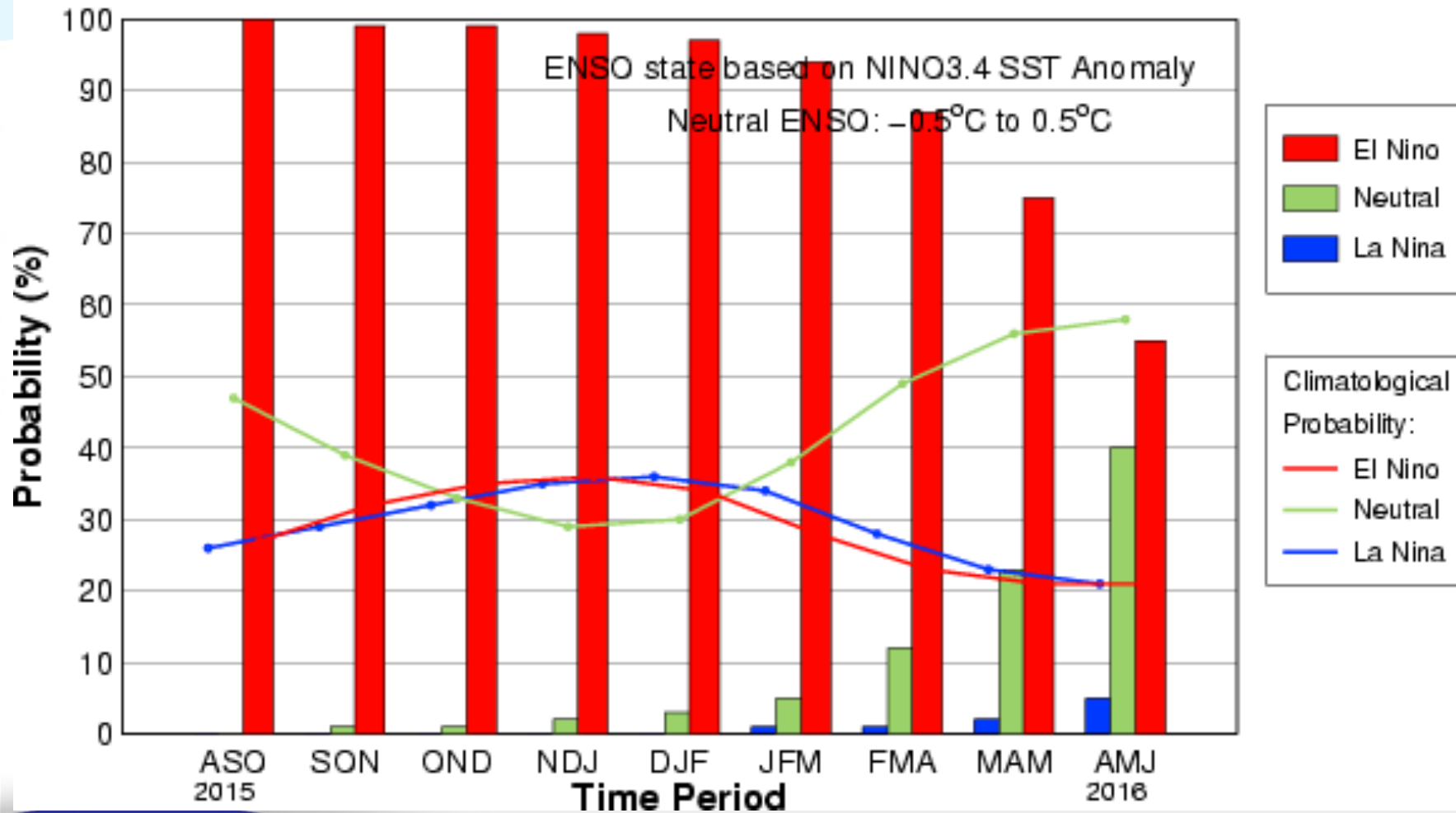
36

- 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



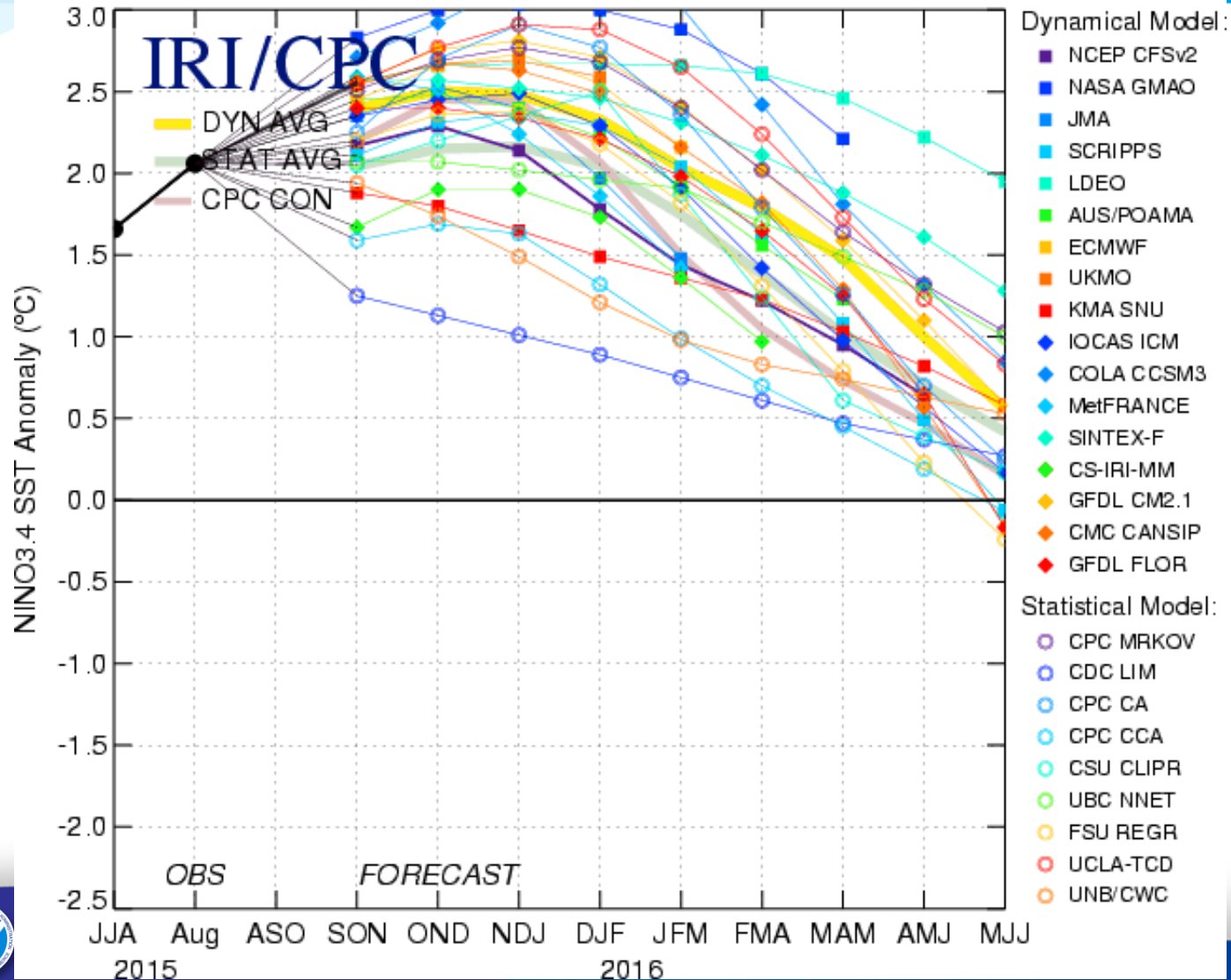
Latest Projections

Early-Sep CPC/IRI Consensus Probabilistic ENSO Forecast



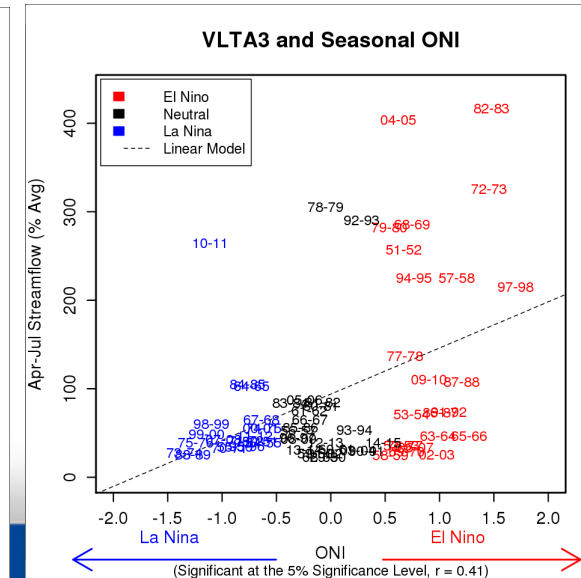
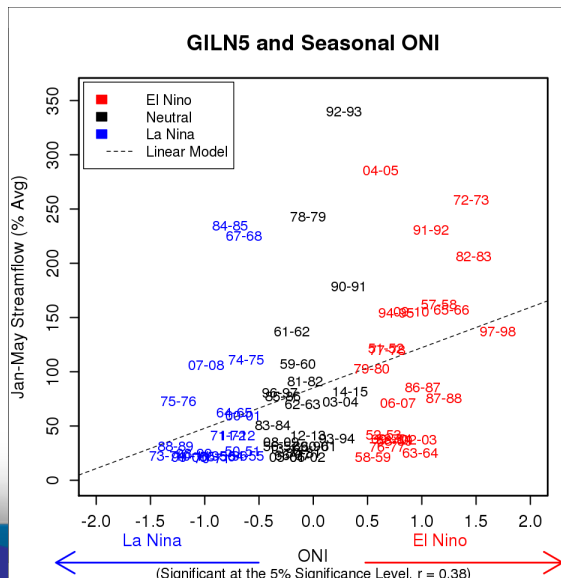
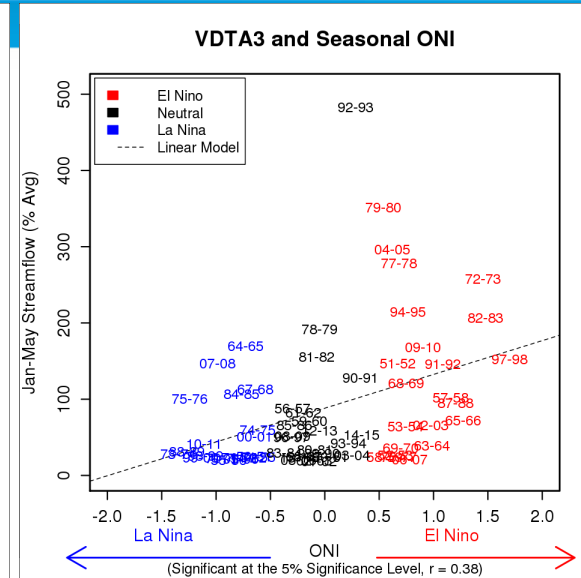
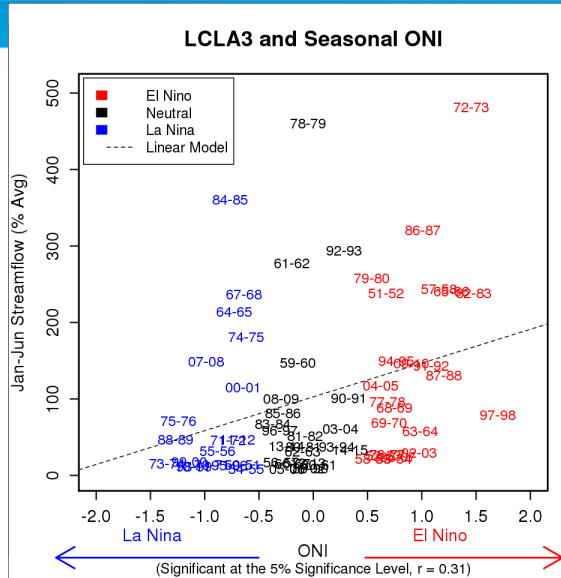
Latest Projections

Mid-Sep 2015 Plume of Model ENSO Predictions



More Local ENSO Impacts

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



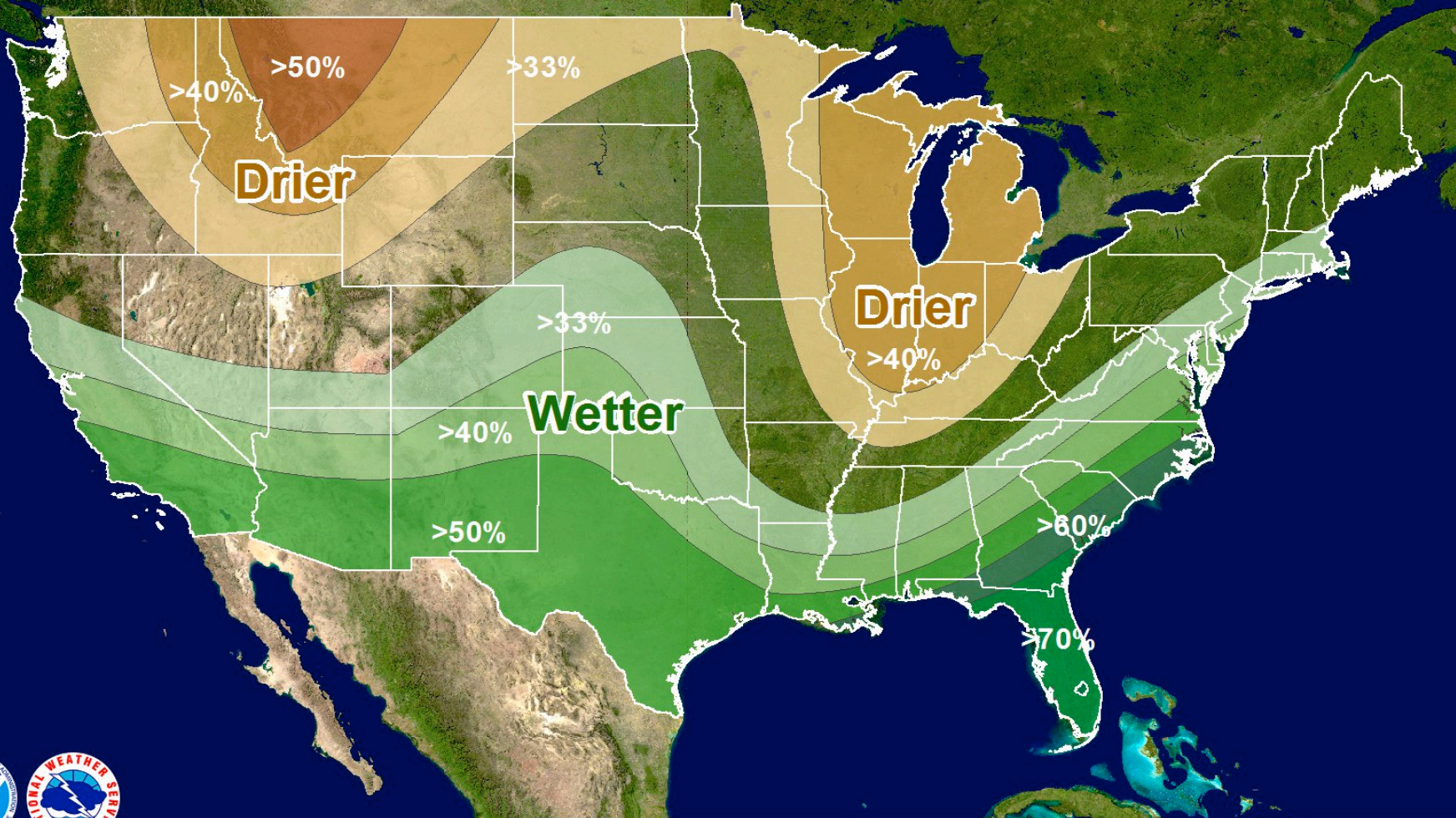
Latest Projections

40

- 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

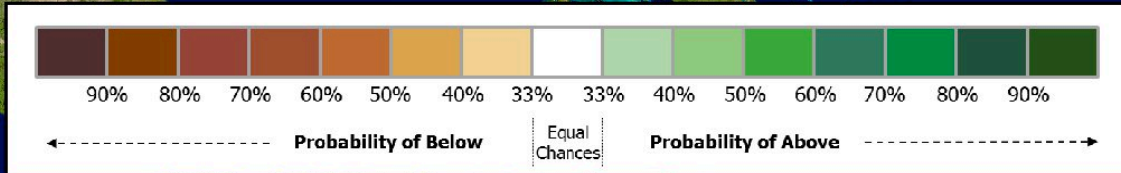
Seasonal Precipitation Outlook

Dec-Jan-Feb 2015-2016



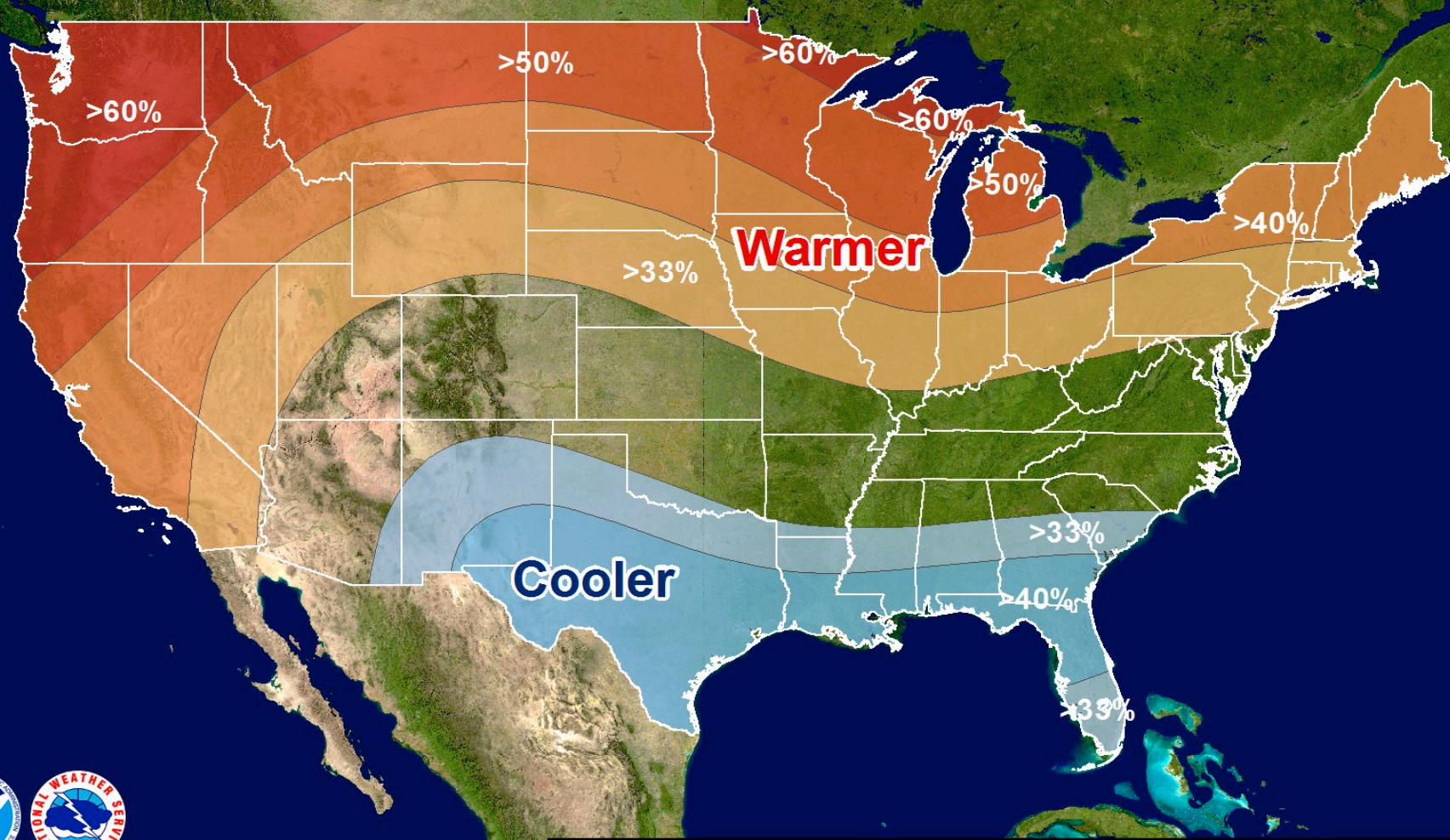
Climate Prediction Center

Issued: 09/17/15



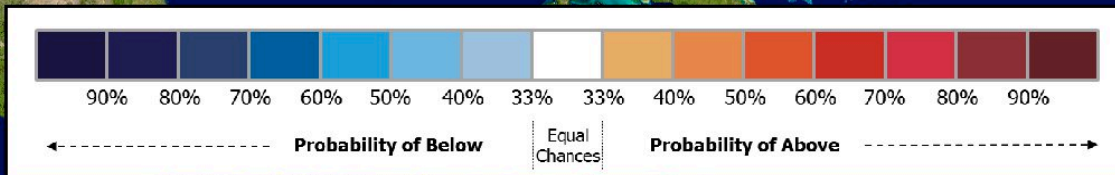
Seasonal Temperature Outlook

Dec-Jan-Feb 2015-2016



Climate Prediction Center

Issued: 09/17/15



How can we help?

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- 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!



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

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Mission

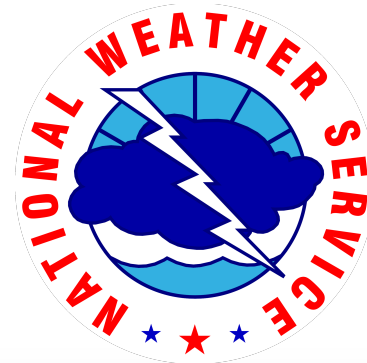
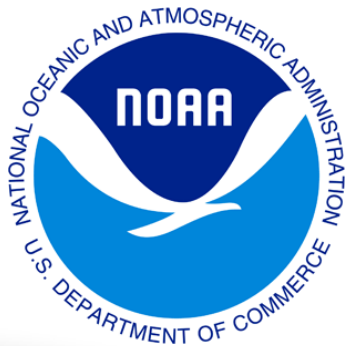
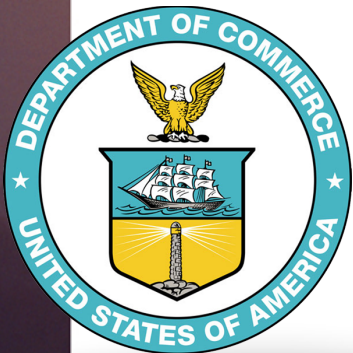
The National Water Center collaboratively researches, develops and delivers state-of-the science National hydrologic analyses, forecast information, data, decision-support services and guidance to support and inform essential emergency services and water management decisions.

- 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?



Extra slides

50

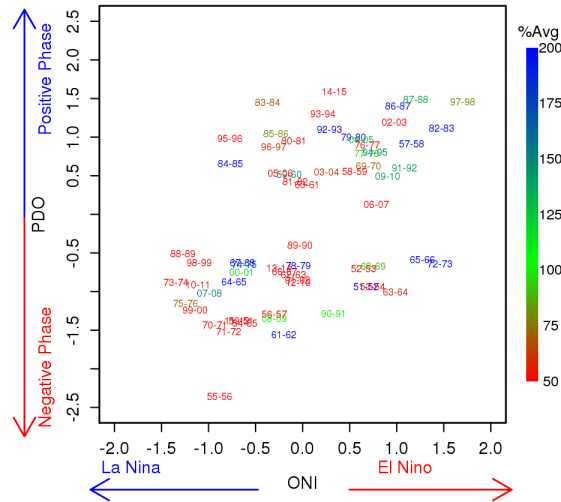


More Local ENSO Impacts

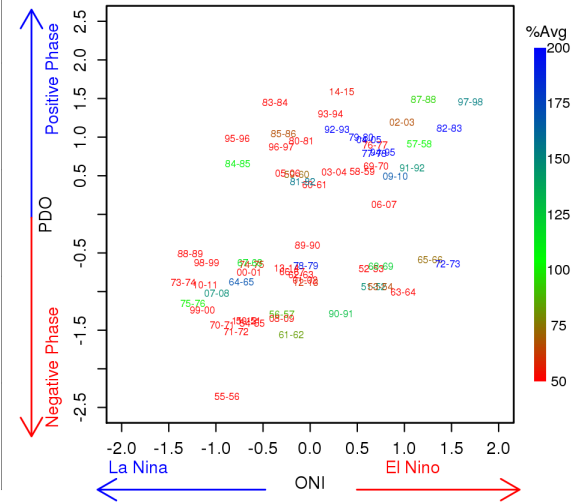
51

Incorporating other atmospheric teleconnections, like PDO, has not provided additional confidence.

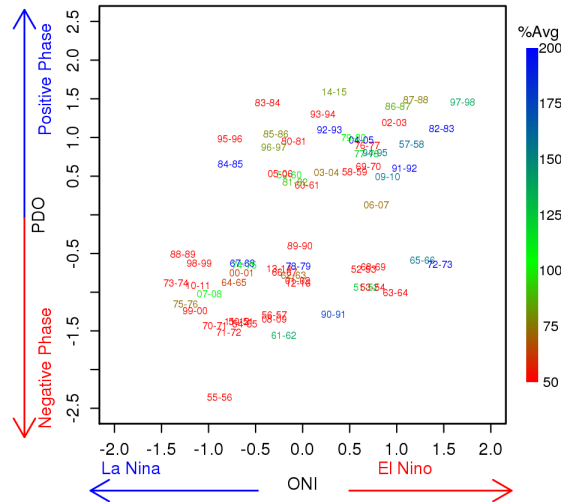
Relationship of Seasonal ONI and PDO Phase with LCLA3 Unregulated Streamflow



Relationship of Seasonal ONI and PDO Phase with VDTA3 Unregulated Streamflow



Relationship of Seasonal ONI and PDO Phase with GILN5 Unregulated Streamflow



Relationship of Seasonal ONI and PDO Phase with VLTA3 Unregulated Streamflow

