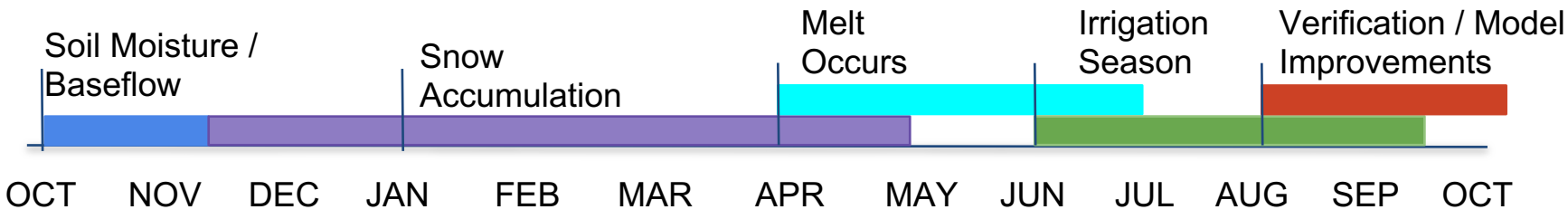
Road to the Forecast

Overview

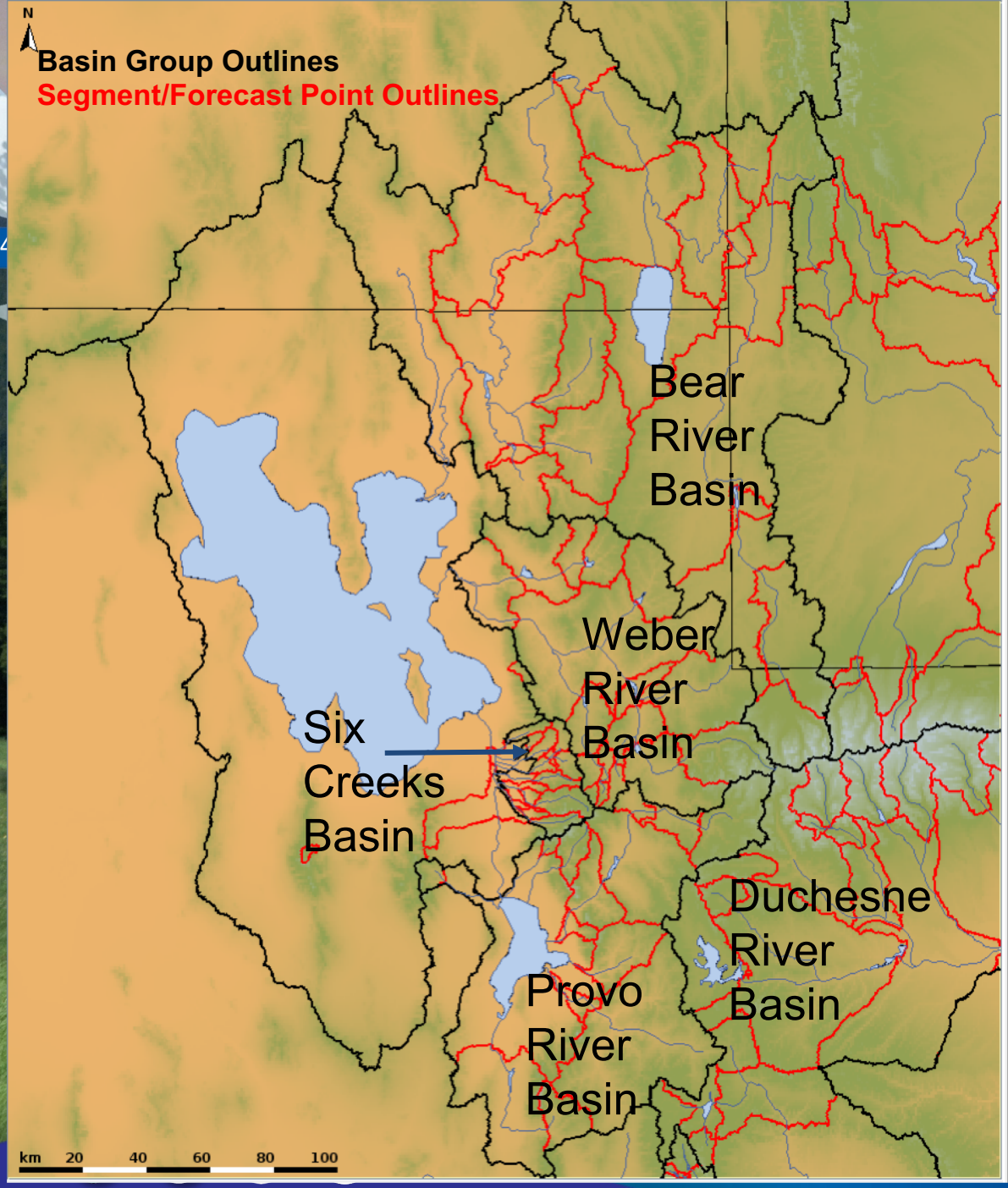
- Calibration Process
- Operational Timeline



Calibrations

- Done for each basin where historical/realtime data exists
  - Bear - 31 basins
  - Weber - 22 basins
  - Provo - 11 basins
  - Six Creeks - 18 basins
- The crux of the forecast process
  - Calibrations are done offline
  - When running in forecast mode we make sure they are run the same as in calibration mode
- The forecasts are objective
- The process is evolutionary
  - We are always look for ways to improve the calibrations

Calibrations



Bear River Basin:
- 23 Segments
- 8 Reservoirs

Weber River Basin:
- 16 Segments
- 6 Reservoirs

Six Creeks Basin:
- 16 Segments
- 2 Reservoirs

Provo River Basin:
- 9 Segments
- 2 Reservoirs

Duchesne River Basin:
- 20 Segments
- 6 Reservoirs

Calibration System

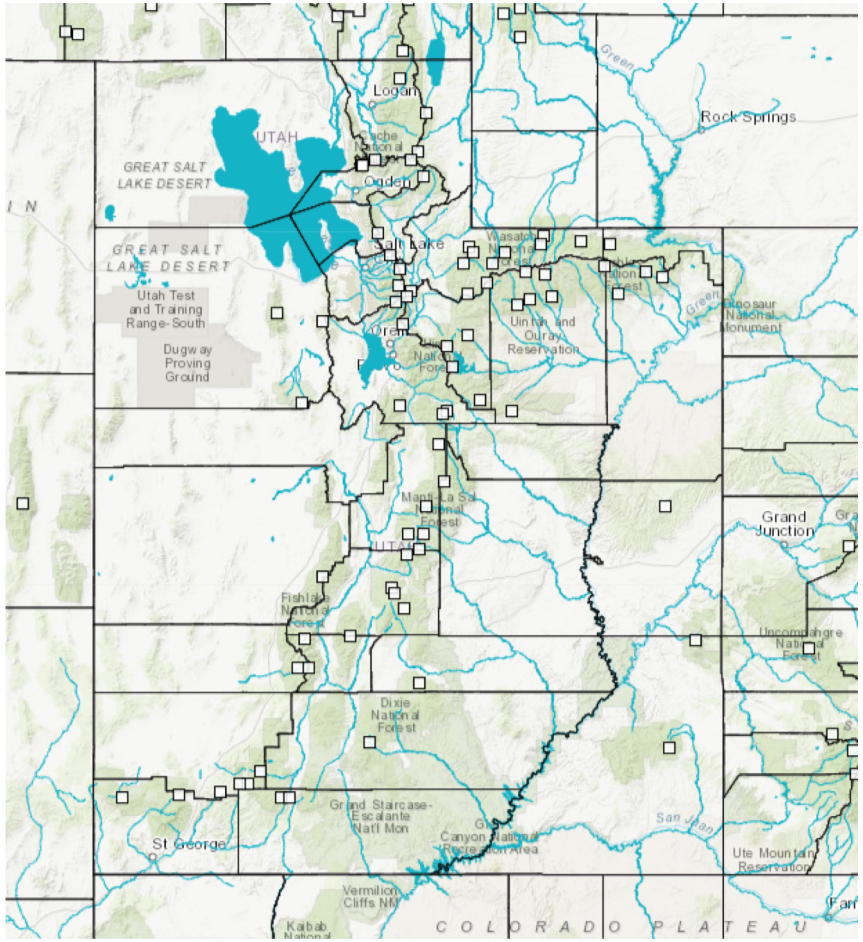
- Store historical precipitation, temperature and flow time series for the basin (1981-2015)
- Choose from a variety of sub-models and processes
  - Snow model
  - Soil moisture model
  - Unit Hydrograph
  - Channel routing
  - Reservoir operations
- Determine the optimal set of parameters for each model, for each sub-area to best simulate *unregulated* flow

Calibration – Basics

- Water balance is calculated using the PRISM data set
- Evaporation is determined through water balance and is regionalized
- Forced by 35 years (1981-2015) of 6 hourly precipitation and temperature
  - Mean Areal Precipitation (MAP) for each subarea is calculated using pre-determined station weights
    - Use precipitation stations that (hopefully) have similar characteristics to that area
    - Weights are chosen to guarantee water balance in each area
  - Mean Areal Temperature (MAT) for each subarea represents the mid-point elevation
    - Nearby stations (climatologies known) are used to calculate the temperature of the MAT (climatology of basin calculated using climatologies of the nearby stations)
  - Operationally MAP and MAT are calculated in a similar way to ensure our forecasts will have similar quality/characteristics to 35 years of calibration
  - Mostly use SNOTELS

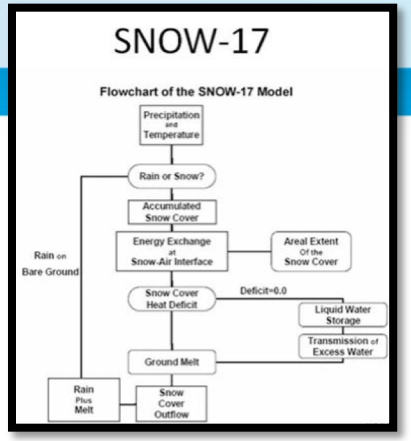
SNOTEL Stations

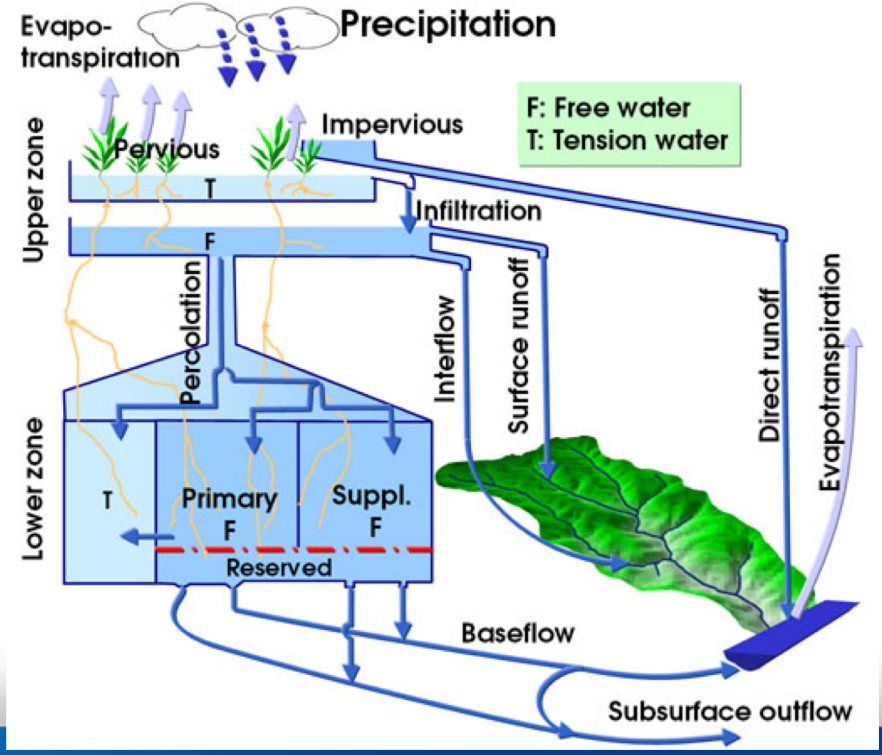
- Use SNOTEL stations with long, uniform records
  - 10 to 15 years of data minimum
- High elevation precip stations
  - Well correlated with high elevation areas
  - Produce most of the runoff
- SNOTEL temperature stations
  - Do not have the biases low elevation urban stations have
  - Snow ablation uses a temperature index model
  - Temperature well correlated with snowmelt physical processes



CBRFC Model Description

- Continuous
- Conceptual
- Lumped
- Main components are the Sac-SMA and SNOW-17 models
- 1981 – 2015 data
- The quality of the precipitation data is the most important part of the model





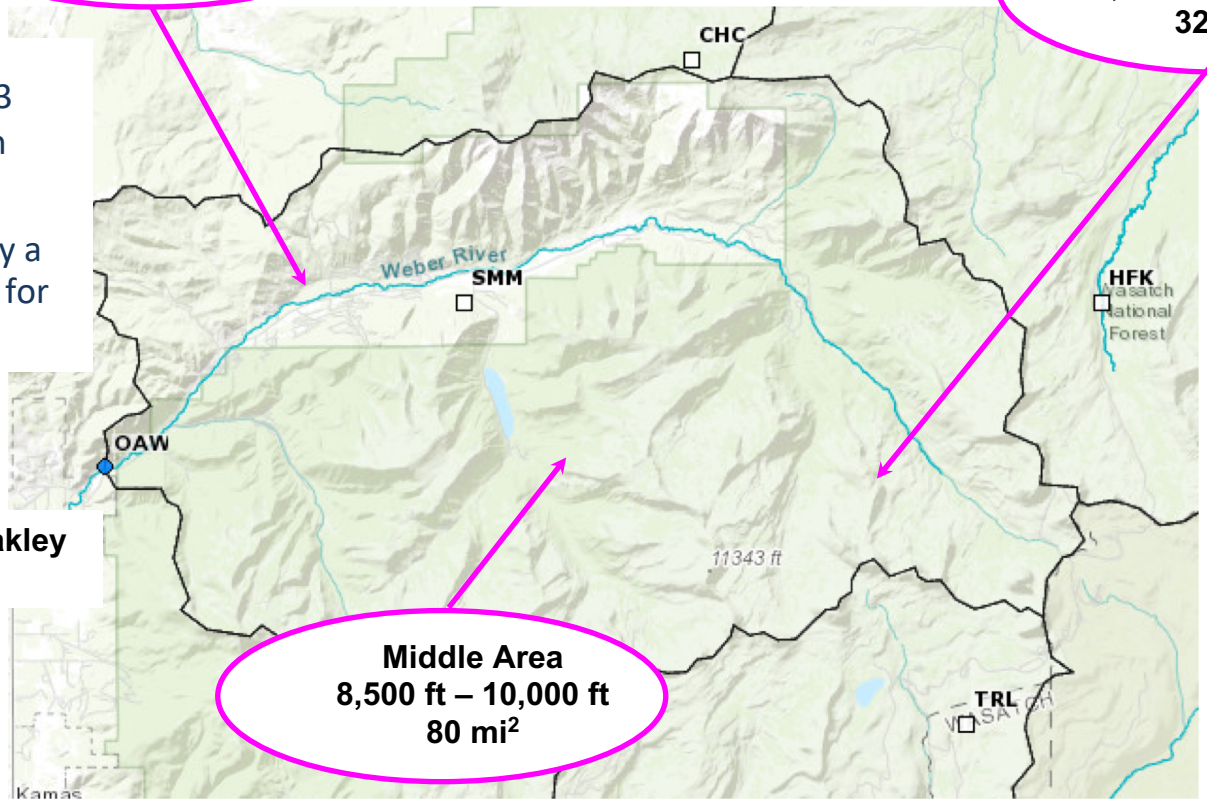
CBRFC Model Setup

Each area broken into 2-3 elevation zones based on similar characteristics

Each zone represented by a single, mean areal, point for precip and temp

Lower Area
6,827 ft – 8,500 ft
50 mi^2

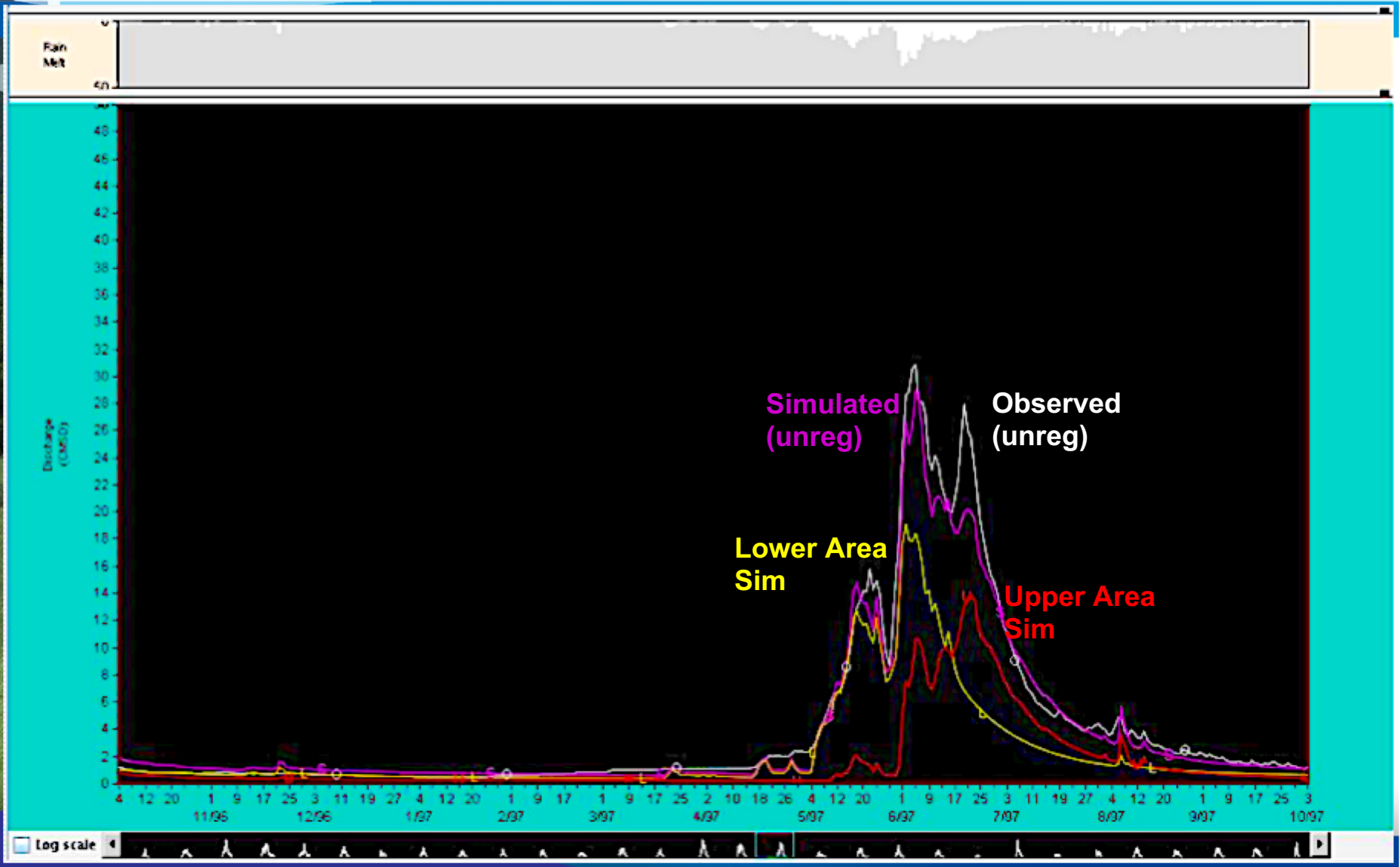
Upper Area
10,000 ft – 10,974 ft
32 mi^2



Weber at Oakley
(OAWU1)

Middle Area
8,500 ft – 10,000 ft
80 mi^2

Calibration – Results

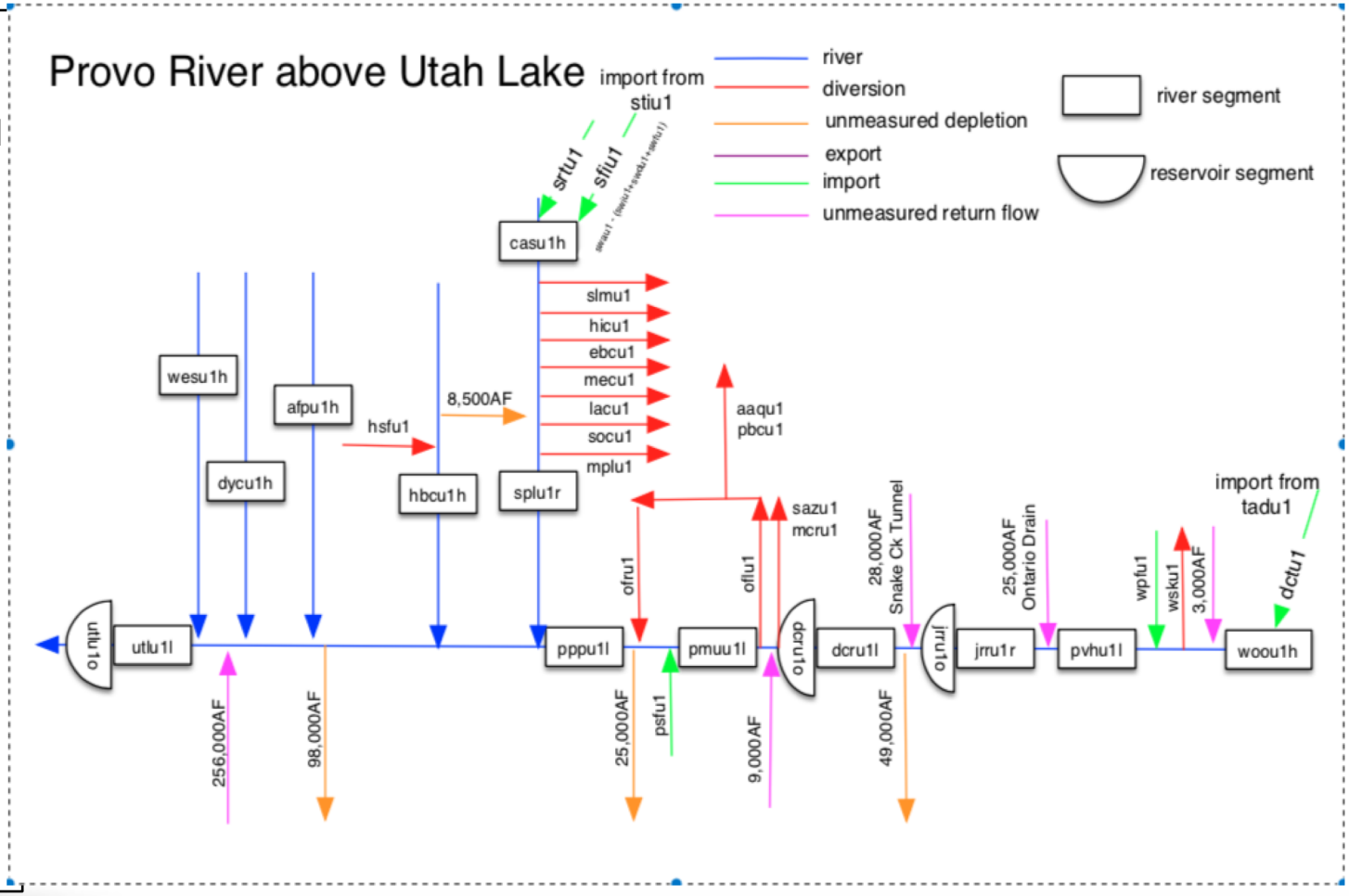


CBRFC Model Setup

Each river point in the model is called a segment

There are about 50 segments in the Duchesne and Provo River Area

There are 486 segments in the CBRFC area



Calibration Errors

Data

Errors in data used in model calibration

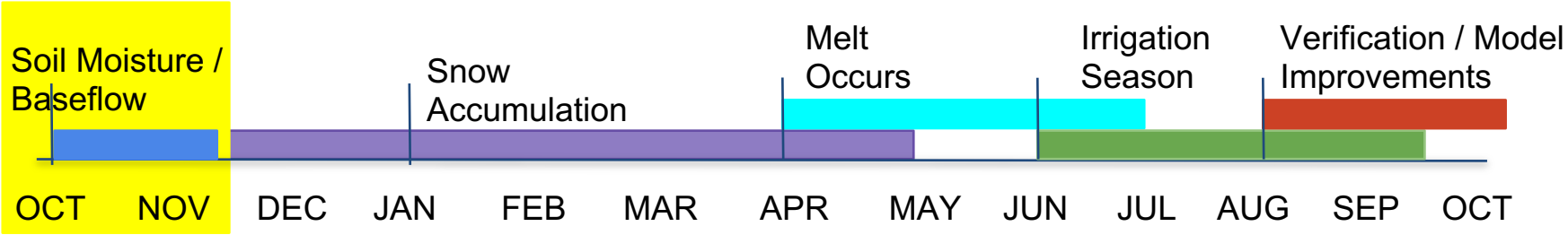
Density and availability of data over an area

Model

Model is physically based, but many hard-to-measure parameters are estimated

Basin scale model may not capture characteristics at smaller spatial scales

Operational Timeline



October 1 - Soil Moisture

- First day of the Water Year (e.g., Oct. 1, 2018 is the first day of WY 2019)
- The most important known state affecting the forecast is soil moisture. There are two components in the CBRFC soil moisture model
  - Baseflow
  - Tension water
- Soil moisture can affect early season forecasts +/- 10 percent
- As the water year proceeds, the soil moisture becomes less important
  - Very little melt at the soil/snow interface
  - SWE starts to dominate

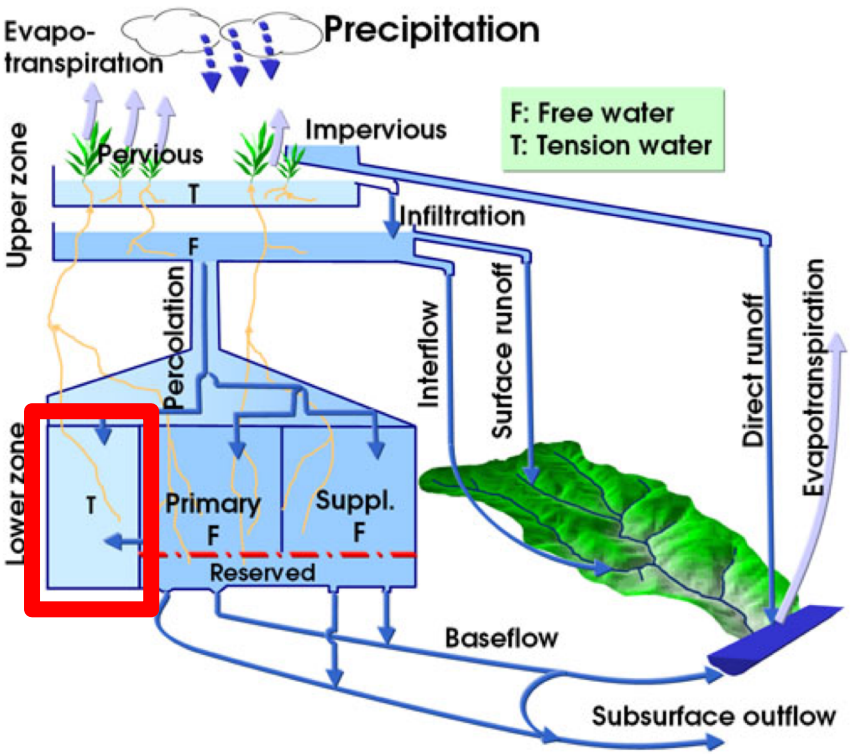
Baseflow

- We adjust baseflows as irrigation ends using streamflow observations
  - Observations are critical to get initial conditions correct
- Baseflow is typically driven by:
  - Spring snowmelt
  - Fall rain events (Smaller)
  - Large recharge can affect baseflow for several years

Ash Creek Baseflow in May 2008, photo by Victor Ponce, San Diego State University

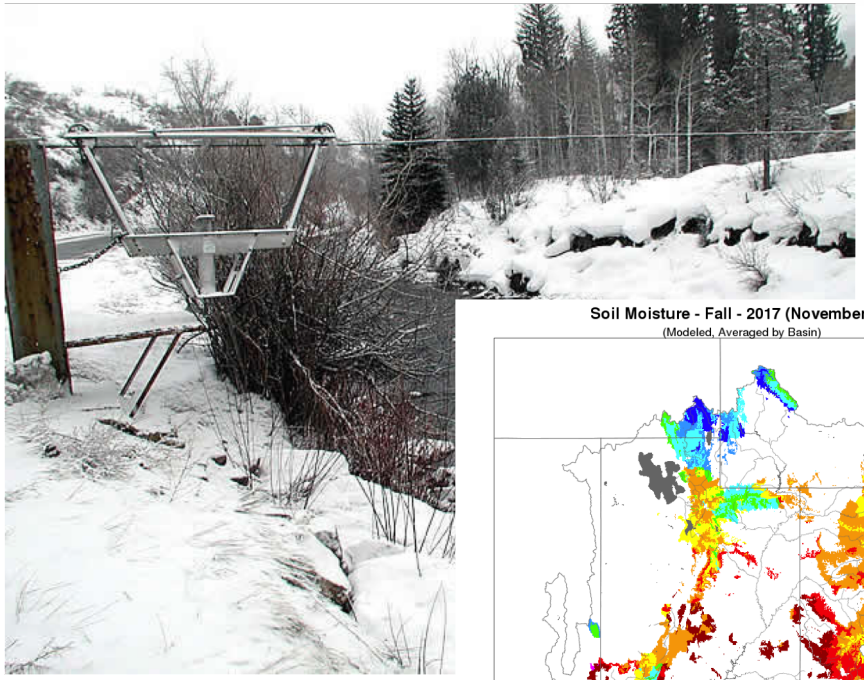
Tension Water

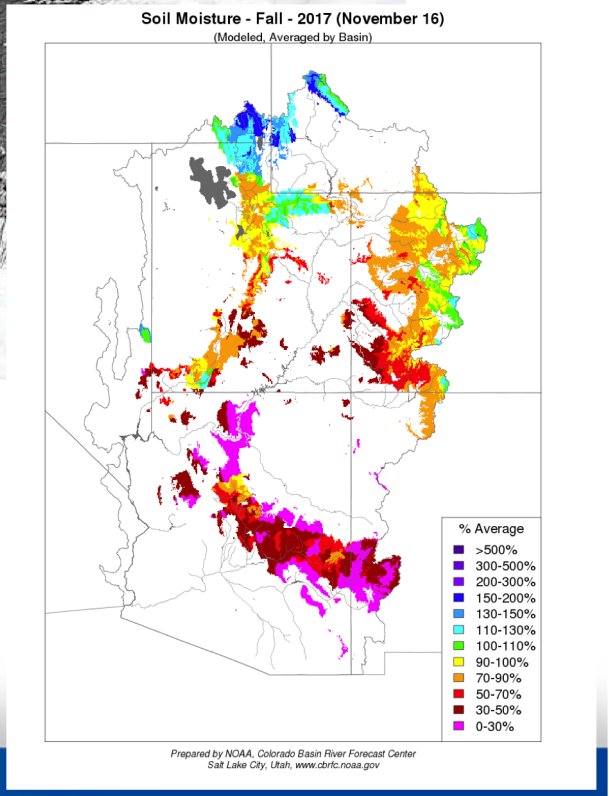
- Tension water is typically recharged every Spring
  - Mostly depleted due to Spring/Summer ET
- Rainfall events can recharge tension water in the Fall
- Extensive QC process for fall precipitation to keep track of these events
- Not measured
  - NRCS soil moisture sensors



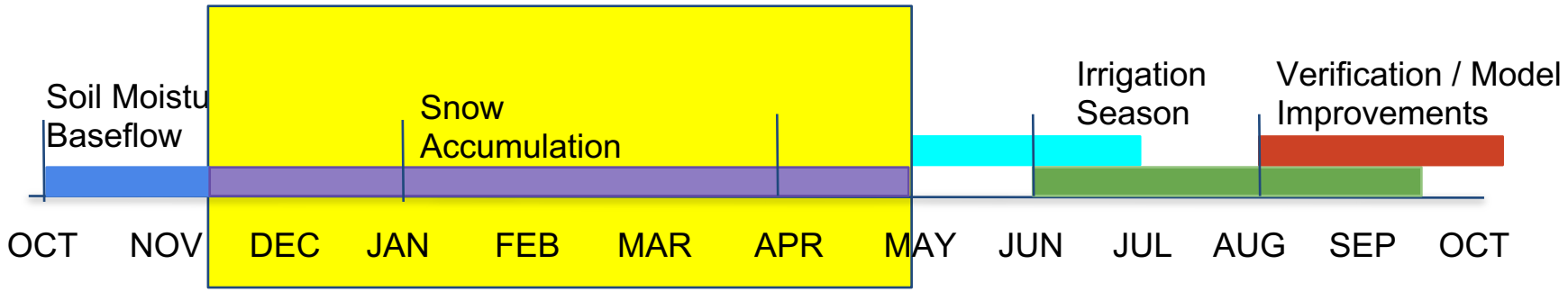
Post Baseflow Analysis

- Gages begin to freeze, we lose observed flow data
- Publish summary of soil moisture conditions
  - A reflection of recently completed water year impacts
  - Provides some insight into what future runoff efficiency could be



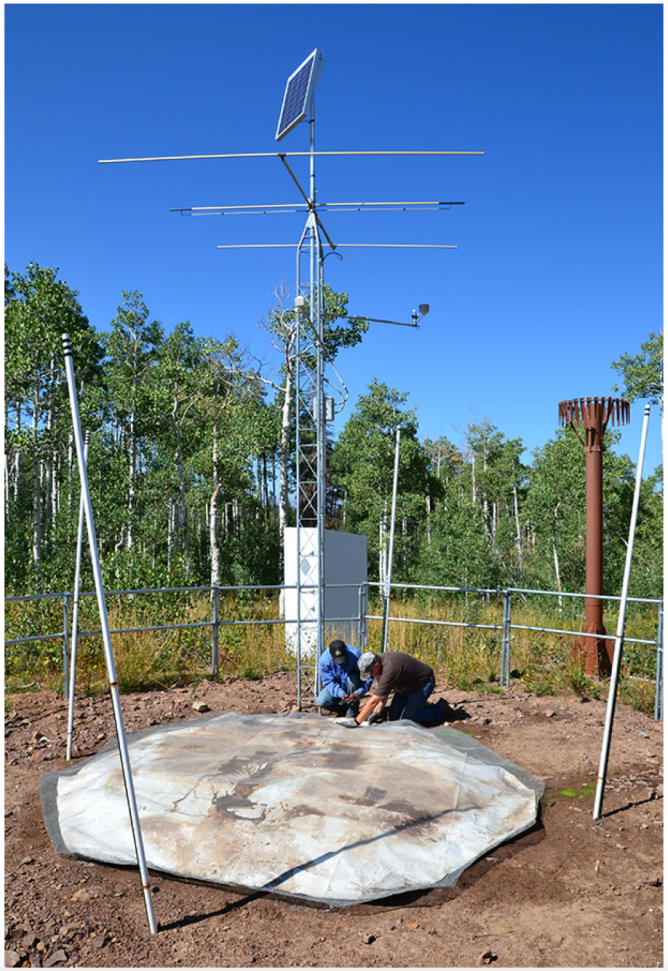


Operational Timeline



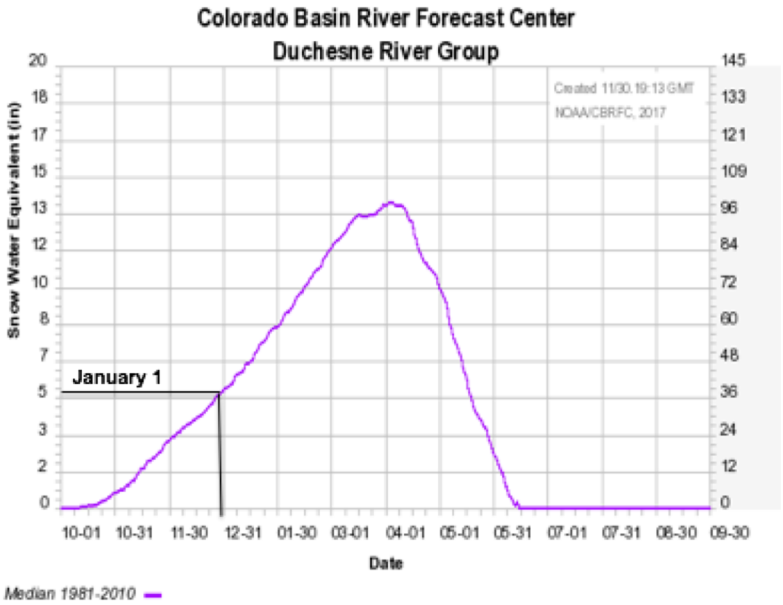
January 1 - First Water Supply Forecasts Issued

- Snow accumulation underway
- SWE begins to dominate Water Supply Forecasts
  - Use SNOTEL *precip* sensor (not SWE)
  - Updated model precipitation daily
  - Update monthly and biweekly to account for short-term inaccuracies
- Compare SNOTEL snow pillow percent of normal to model
  - Rough error check
  - SNOTELs only give information where they are located

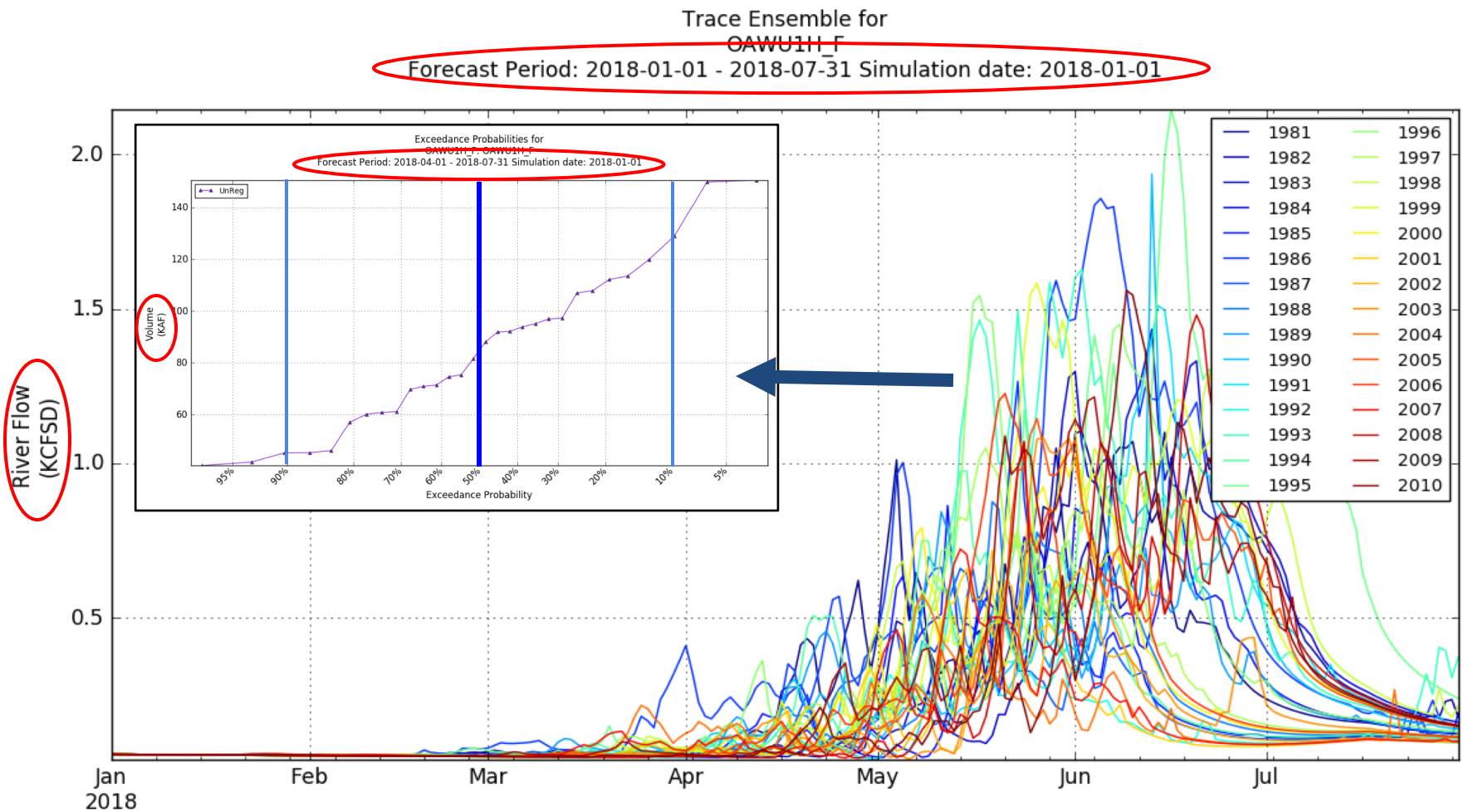


January 1 Forecasts

- What we know:
  - About 40% of snowpack accumulation
- What we don't know:
  - January through May weather (4 months)
  - About 60% of snowpack accumulation



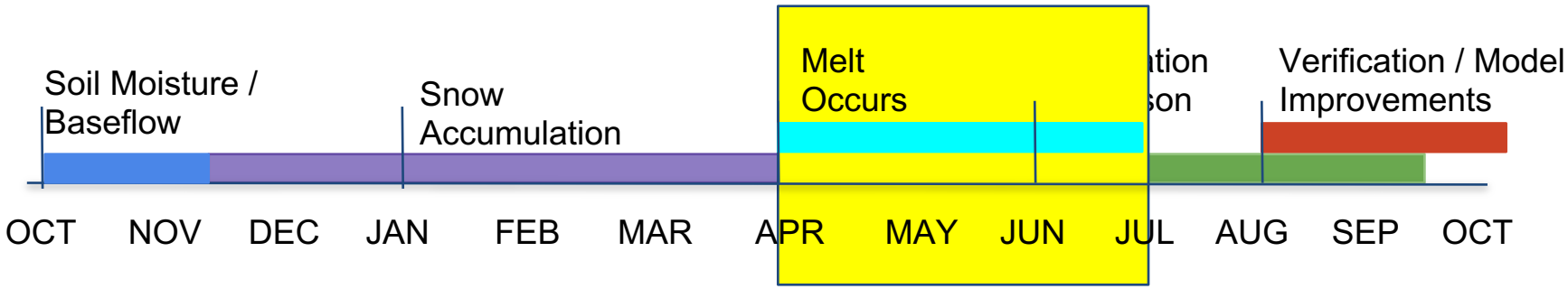
ESP Range of Possibilities



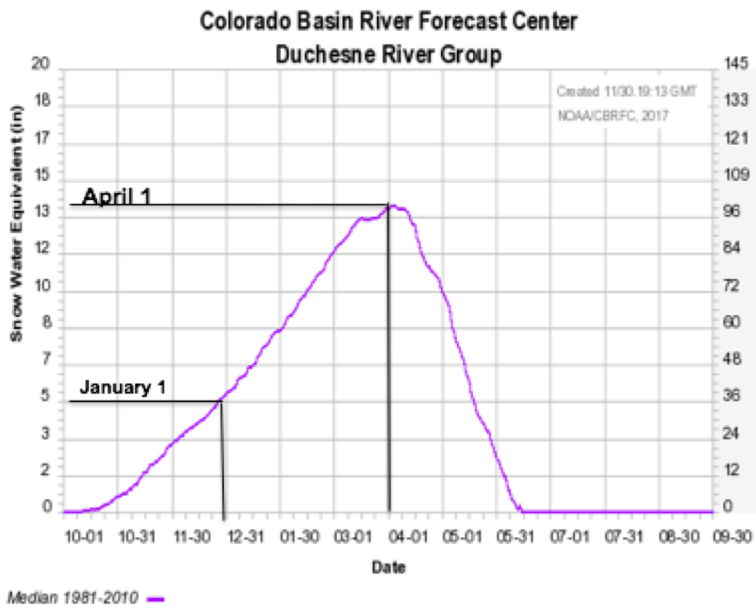
Use of Seasonal Forecasts

- We do not use long term climate outlooks like those developed at the Climate Prediction Center
  - Lack of skill in forecasts in our area
    - We verified 25 years of winter and spring forecast in the Great Basin. We found that the CPC rarely varied from EC (equal chances) which indicates no skill in the CPC seasonal forecasts
  - We are working with the CPC to improve this
    - Use the SNOTEL stations to develop techniques
    - CPC recalibrating climate model
    - Focus on March-May forecasts
  - Local study on seasonal patterns

Operational Timeline



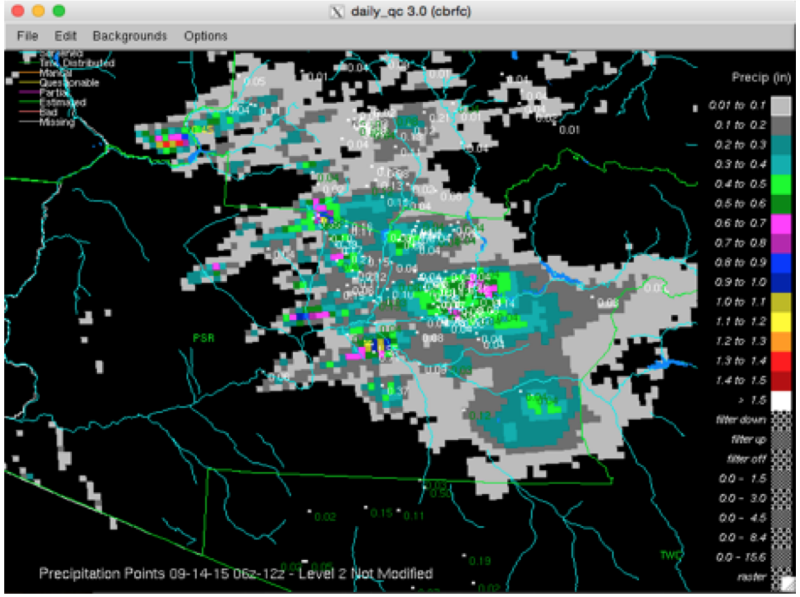
April 1 - Melt Begins



- What we know:
  - Around 90% of snowpack accumulatio
  - December through March weather
- What we don't know:
  - April through May precipitation
  - Snowmelt pattern (temperature)
- April 1st Water Supply Forecast
  - Usually last forecast before snowmelt begins
  - Snowpack typically near peak
- Extensive effort put into making sure that modeled SWE is as correct as it can be
  - Consistent with calibrations
  - Initial conditions are important to developing a reliable forecast

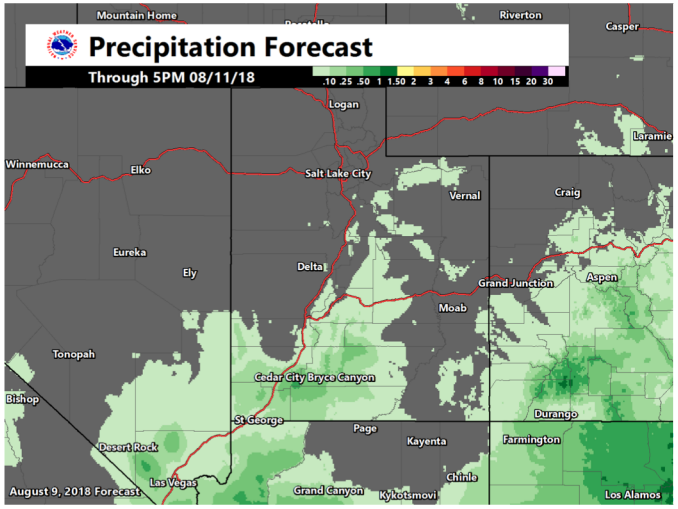
April to June - Melt Occurs

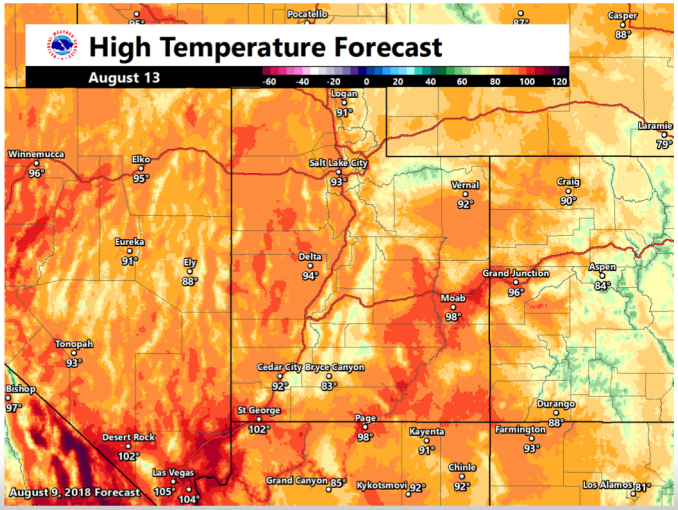
- The cycles of warming/melting and cooling/precipitation make it difficult to know the snow and soil states with absolute certainty
- Streamflow
  - As the gages come out of ice, accurate early spring flow measurements are crucial
- Precipitation
  - Rain events begin to dominate; QC of the data is very important
- Snow melt
  - We adjust the model melt rates to match the observed flows
  - Precise location/elevation of melt difficult to determine
- SNOTEL
  - SNOTEL pillows become less useful as melting occurs; SNOTEL SWE and model SWE typically diverge
- Anecdotal evidence can be misleading



Short Term Precipitation and Temperature Forecasts

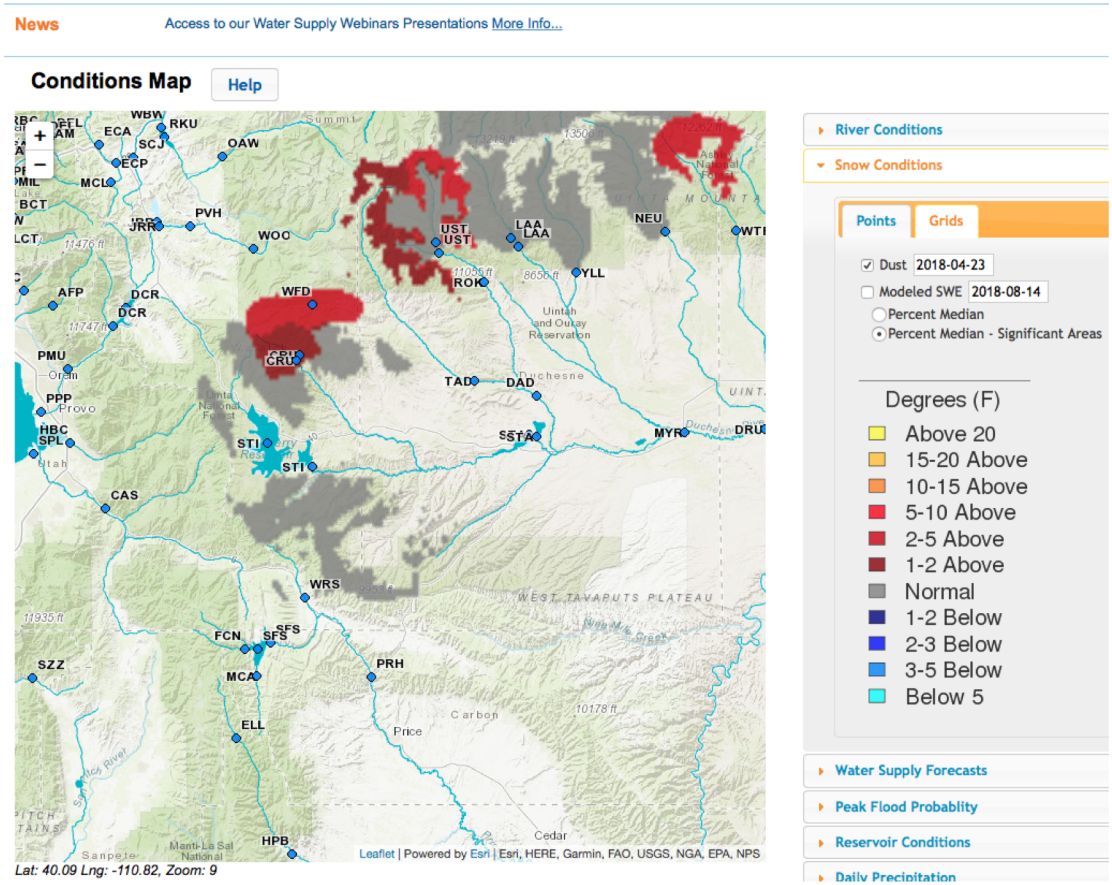
- We use 5 days of forecast precipitation and 10 days of forecast temperature in our daily forecasts
  - Informed by Weather Prediction Center and Weather Forecast Offices
  - We can adjust these forecasts to better inform model



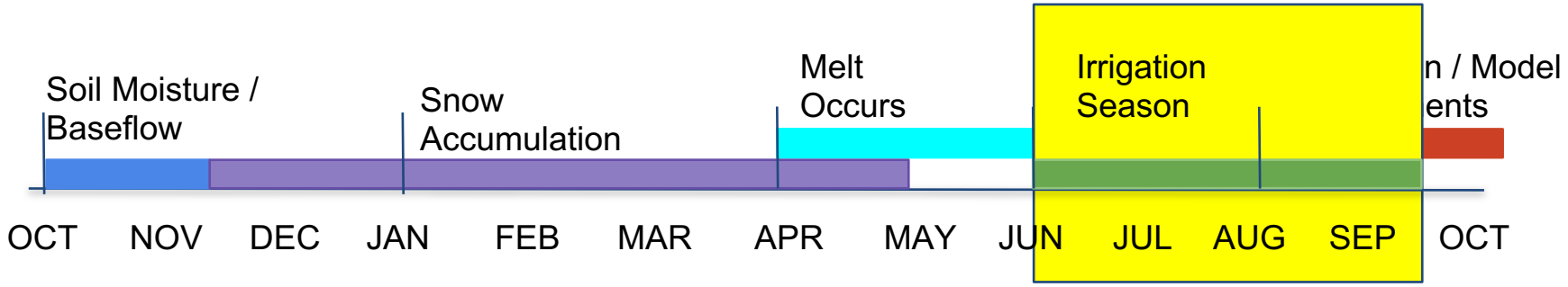


JPL Remotely Sensed Data - MODSCAG

- Dust on snow
  - We have calculated the departure from average contamination from 2000-2015
  - We then apply a temperature increase or decrease
  - Does not change volumes but improves timing of melt
  - Not a huge factor in Utah most years



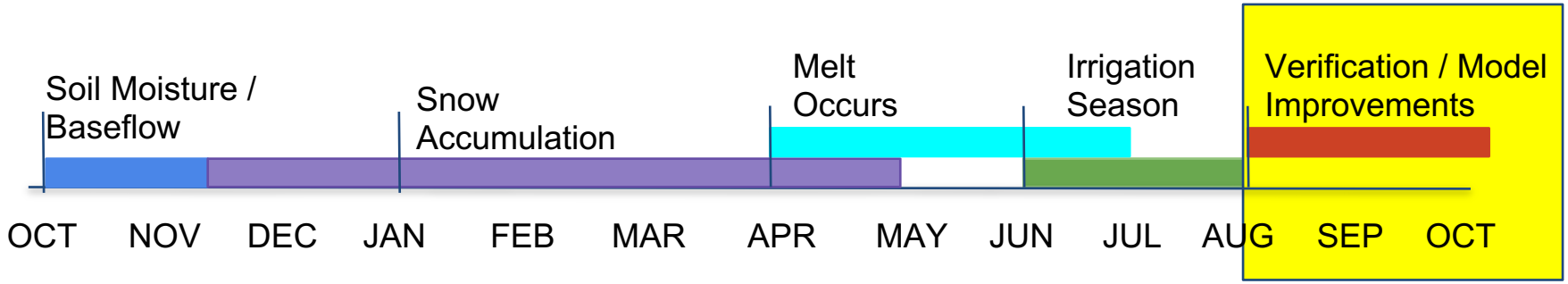
Operational Timeline



June to September - Irrigation

- Irrigation increases and is often the largest uncertainty in the daily streamflow forecast
  - Use real time diversion information where available
    - however no return flow data available and is variable
  - Otherwise we estimate depletions using a model
    - Function of temperature and acreage
    - Some areas have diversion records which are used in the calibration process, but lack real time information for day to day forecasts
- Obtaining real time information on water use and diversions is always helpful

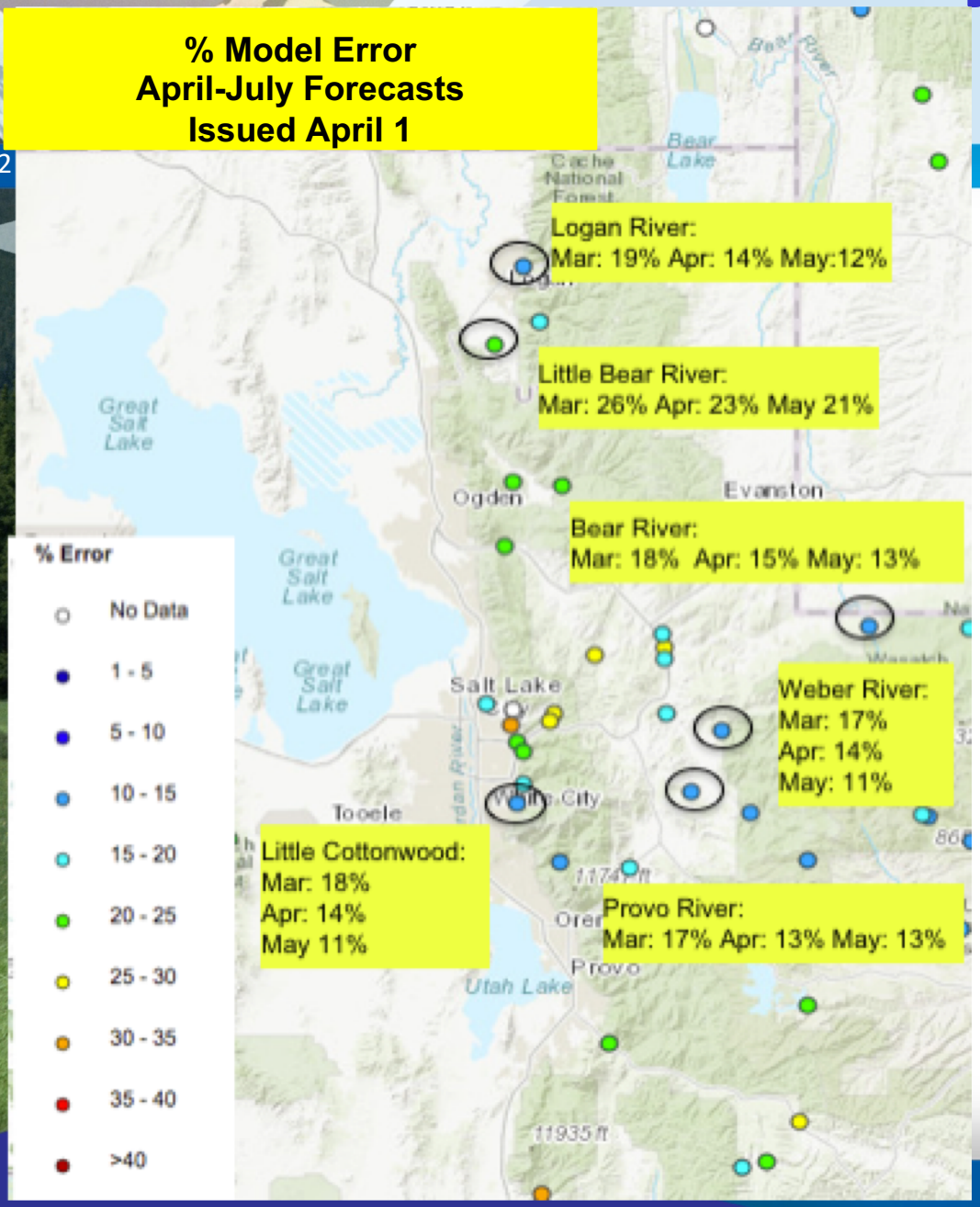
Operational Timeline



August to October - Verification and Model Improvements

- Verification of forecasts
  - How did we do?
  - Determine sources of error
  - Available on our website
- Model Improvements
  - Address errors identified in verification
  - Incorporate new information
  - Stakeholder requests

Historical Water Supply Verification



Historical Model Error
1981-2010

How good can you expect the forecasts to be

- Available for each month Jan - Jun
- Generally improves through the spring

Where we do better:

- Headwaters
- Primarily snow melt basins
- Little/no diversions or historical and real time diversion data available

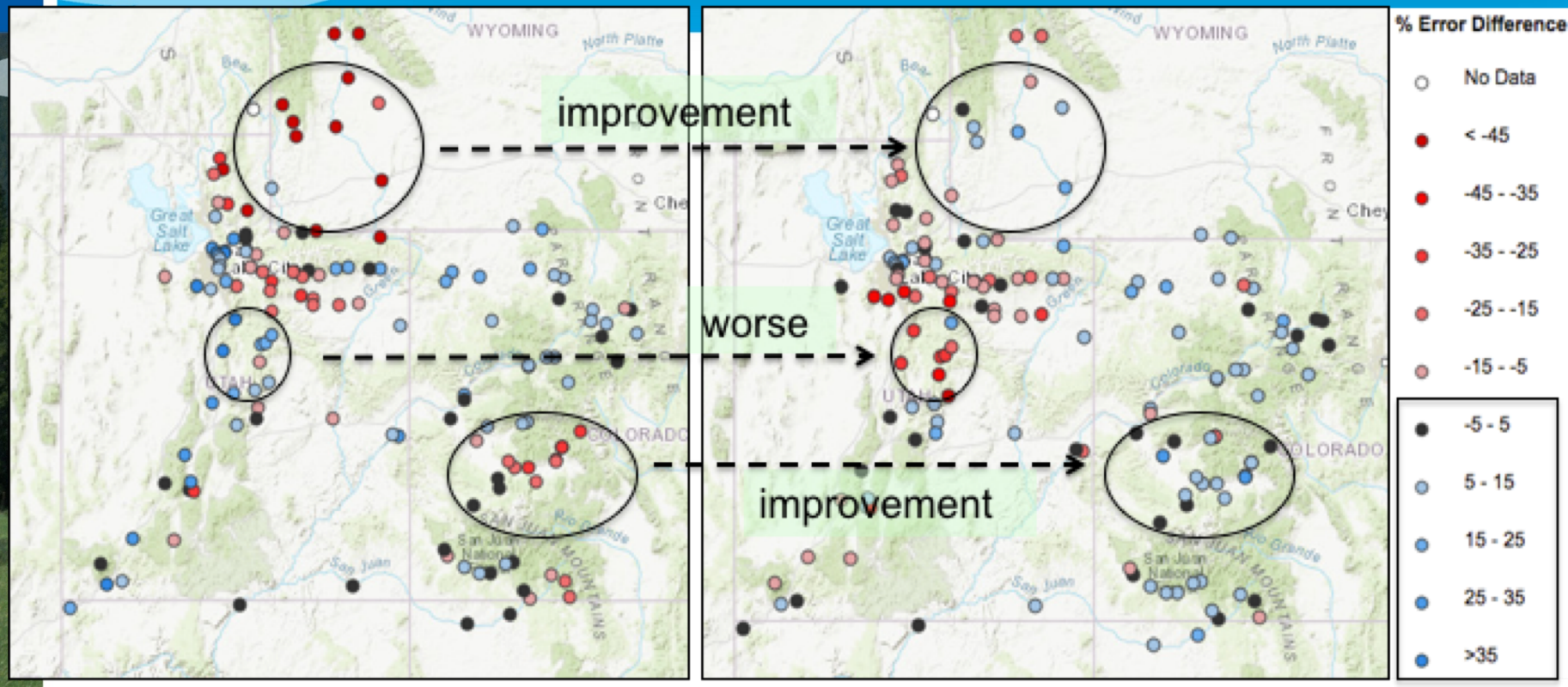
Where we do worse:

- Lower elevations (rain or early melt)
- Downstream of diversions / irrigation when little is known and/or no data

Yearly Water Supply Verification

January 2017 Verification Map

April 2017 Verification Map



Reds – This years forecast higher than ESP historical model error.
Blues – This years forecast lower than the ESP historical model error.
Blacks – This years forecast similar to the ESP historical model error.

Going Forward

- How does our operations timeline align with the timing of your decision making process?
- What are the gaps you face when making decisions? How can we help fill those gaps?
- Where do you look for information when making a decision?