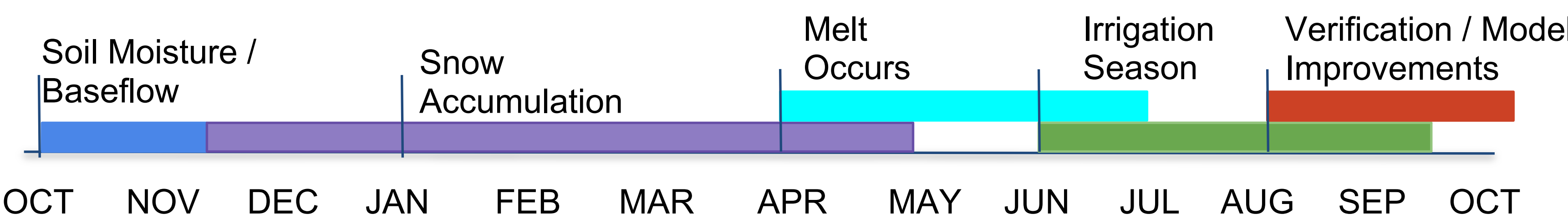
Road to the Forecast

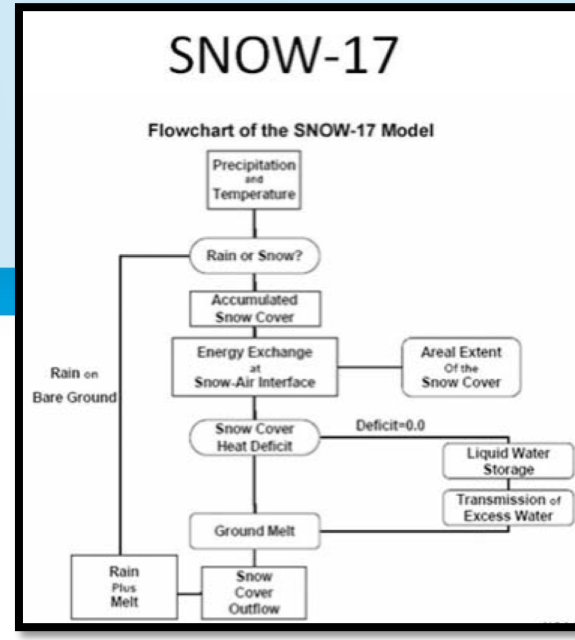
Overview

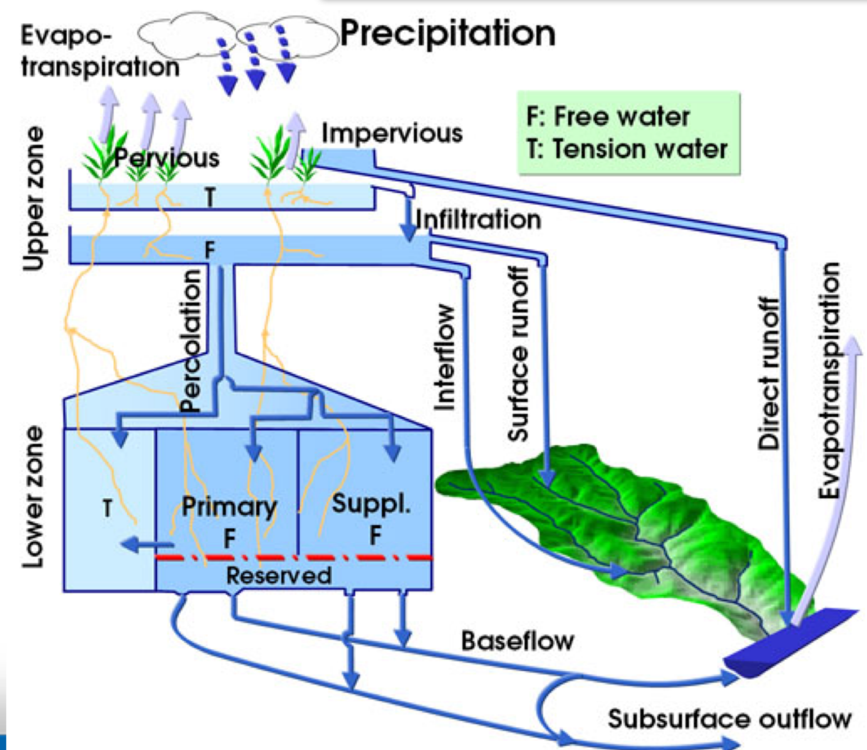
- Calibration Process
- Operational Timeline



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

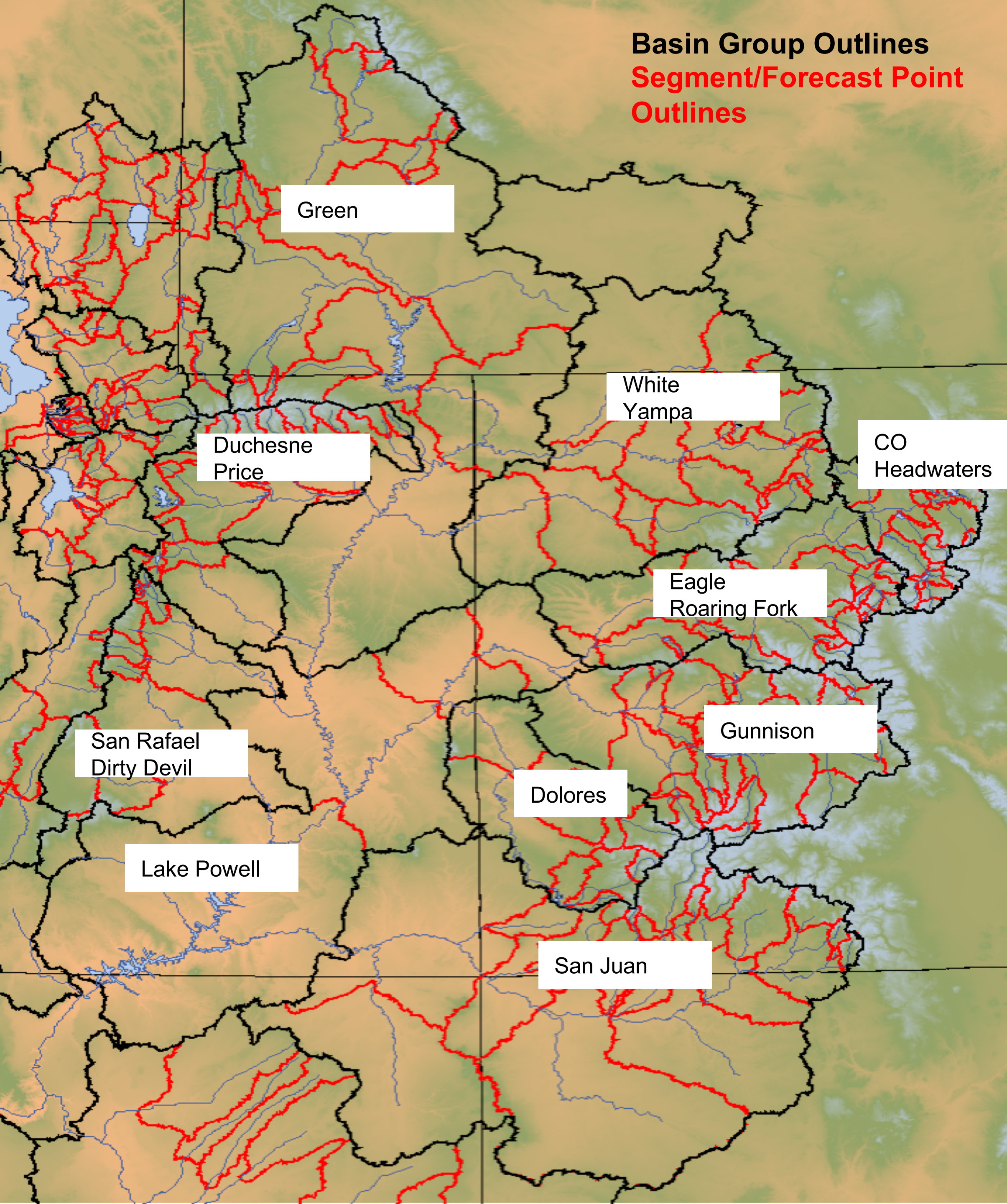




Calibrations

- Done for each basin where historical/real-time data exists
- 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're always seeking ways to improve the calibrations

Calibrations



White Yampa River Basin
- 21 Segments

Duchesne Price River Basin
- 20 Segments, 6 Reservoirs

Green River Basin
- 13 Segments, 6 Reservoirs

San Rafael Dirty Devil River Basin
- 9 Segments, 7 Reservoirs

Colorado Headwaters River Basin
- 11 Segments, 6 Reservoirs

Eagle Roaring Fork River Basin
- 18 Segments, 4 Reservoirs

Gunnison River Basin
- 22 Segments, 8 Reservoirs

Dolores River Basin
- 8 Segments, 1 Reservoirs

San Juan River Basin
- 23 Segments, 3 Reservoirs

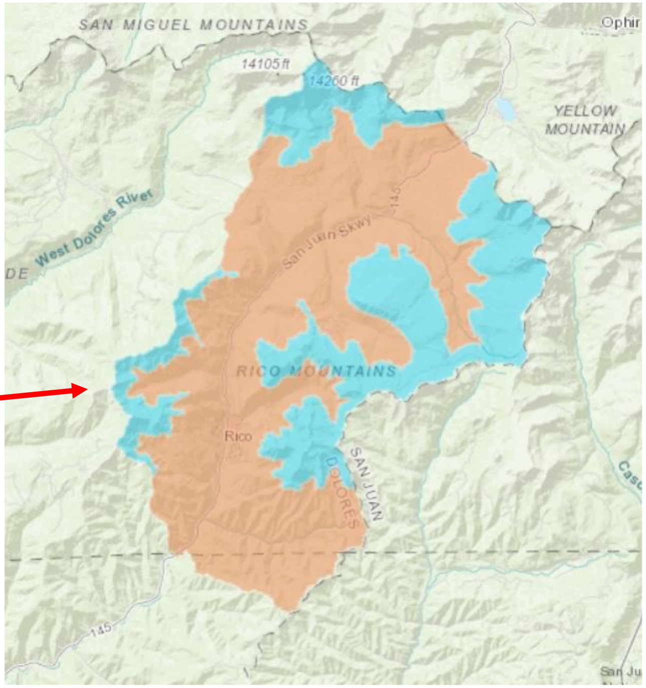
Lake Powell
- 4 Segments, 1 Reservoir

CBRFC Calibration - Model Setup

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

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

Dolores River below Rico, CO (DRRC2)



Lower Zone: 8,320 ft - 11,000 ft (69 mi^2)

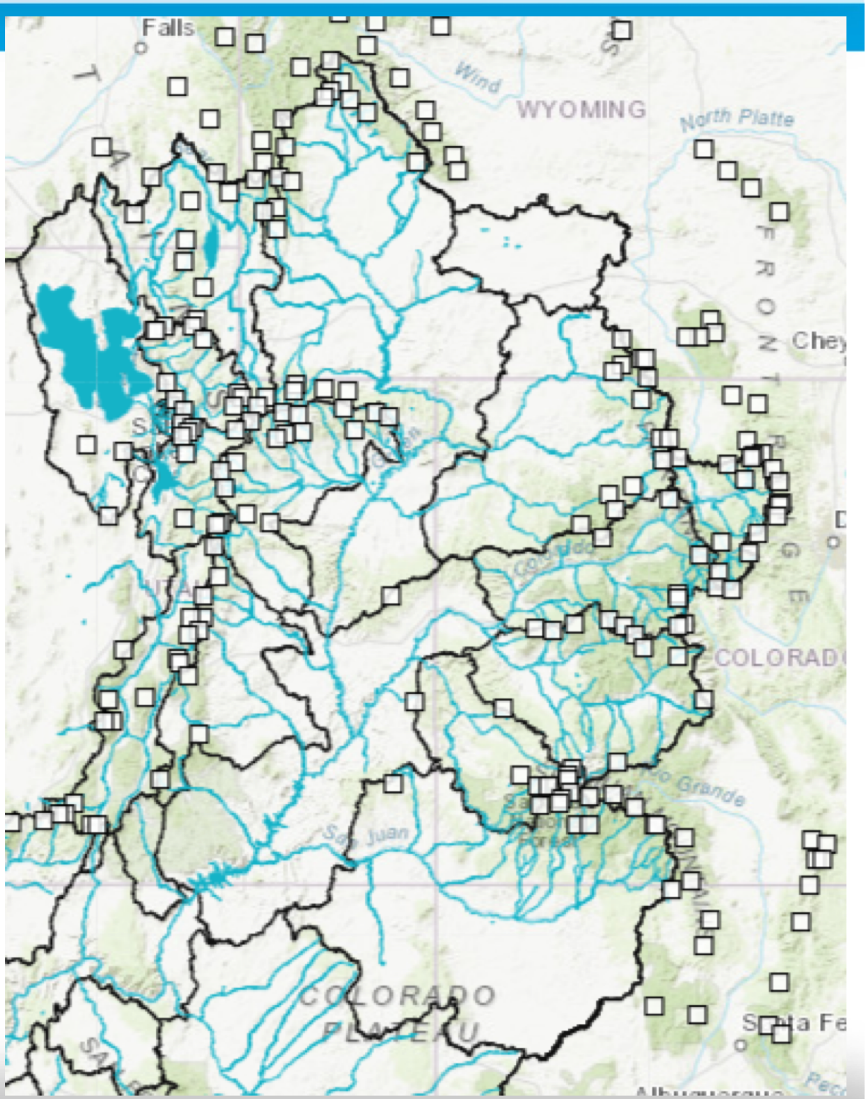
Upper Zone: 11,000 ft - 14,172 ft (36 mi^2)

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

SNOTEL Stations

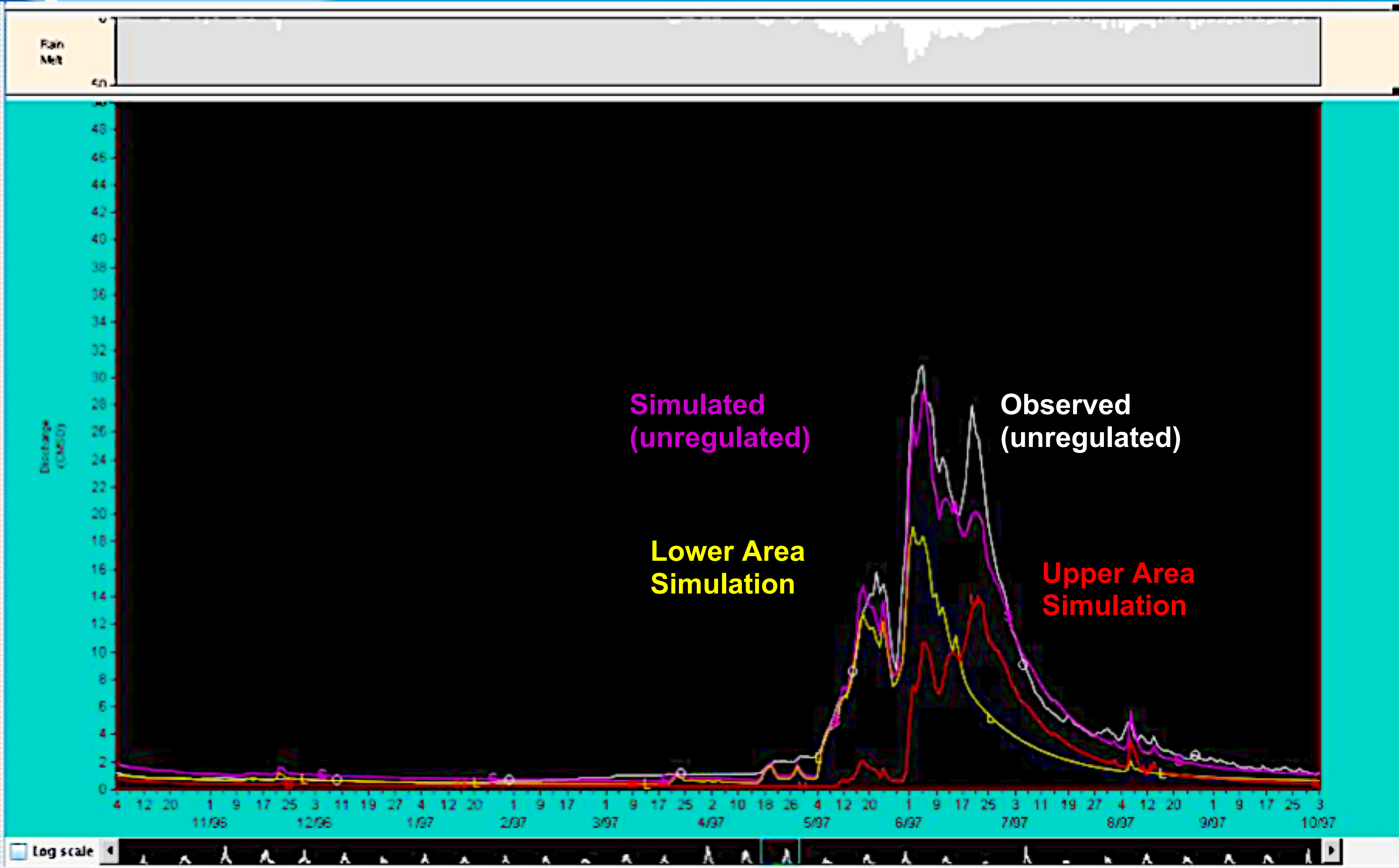
- Use SNOTEL stations with long, uniform records
  - 10 to 15 years of data minimum
- High elevation precip stations
  - Best correlated with runoff
- SNOTEL temperature stations
  - Do not have the biases low elevation urban stations have
  - Snow ablation uses a temperature index model
  - Temperature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



Calibration – Basics

- Water balance is calculated using the PRISM climate 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 (elevation zone) is calculated using pre-determined station weights
    - Use precipitation stations that (ideally) have similar characteristics to that area
    - Weights are chosen to guarantee water balance in each area
  - Mean Areal Temperature (MAT) for each subarea (elevation zone) represents the mid-point elevation
    - Nearby stations are used to calculate the temperature of the MAT
  - 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 (desire high elevation sites when available)
  - **Extensive analysis & quality control of historical data is performed.**

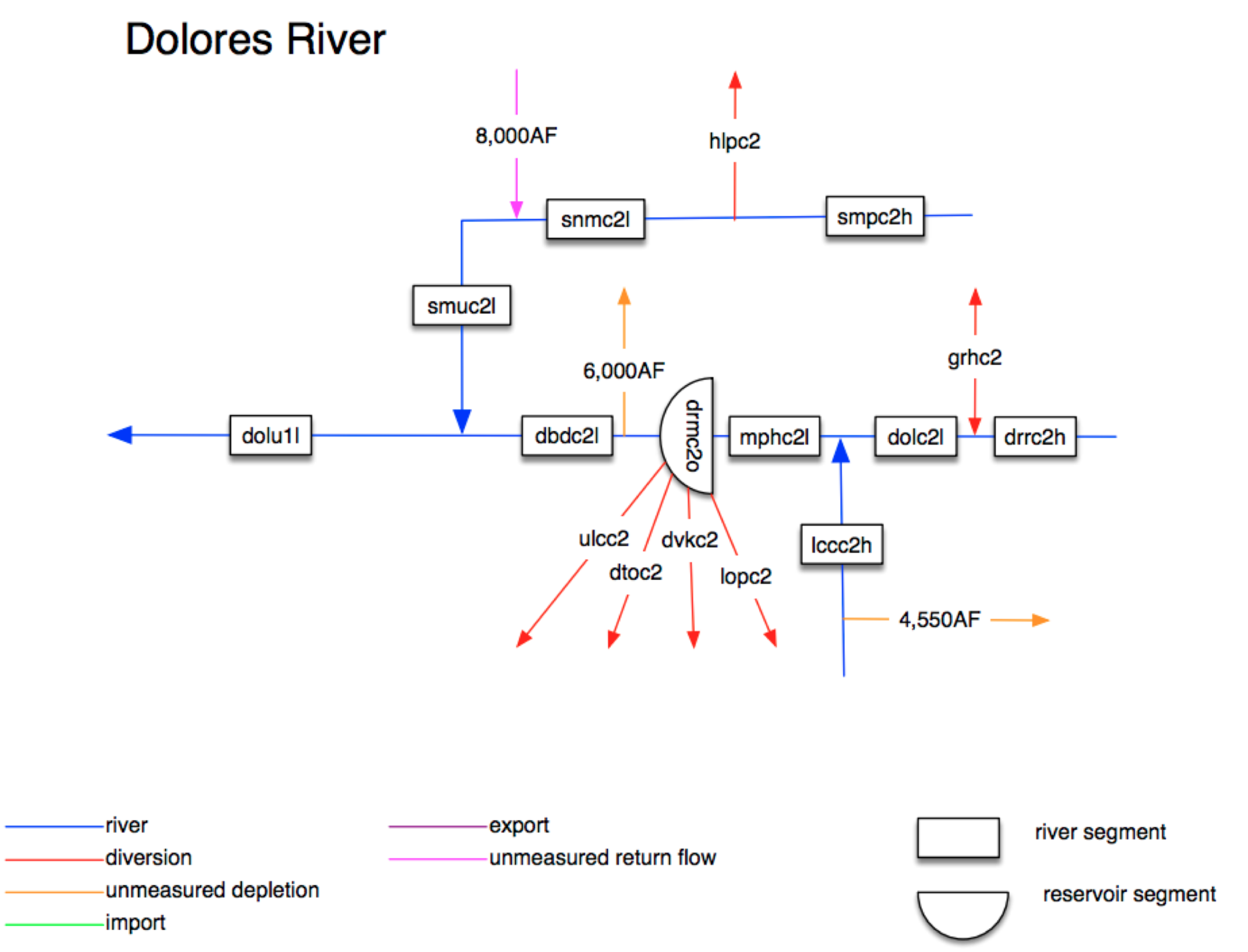
Calibration – Results



CBRFC Model Setup

Each river point in the model is called a segment

There are 486 segments in the CBRFC area



Calibration Errors

Data

Errors in data used in model calibration

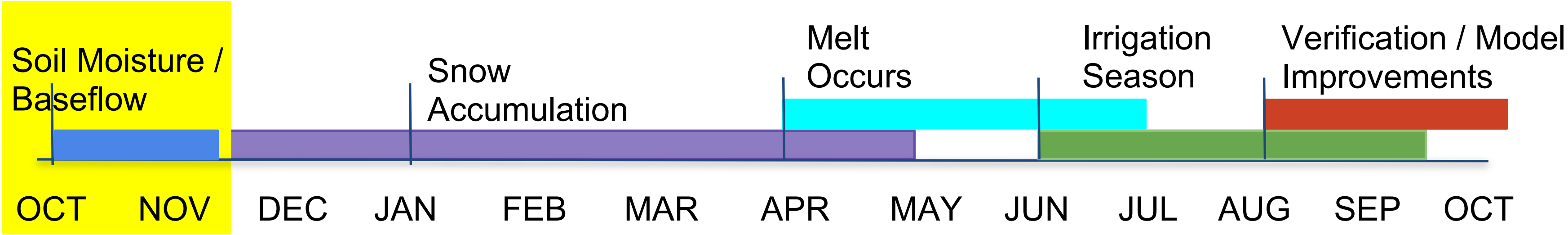
Density and availability of data over an area

Model

Model is conceptual so 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)
- Soil moisture is the most important model state affecting the long term forecast at this time. 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 in the upper Colorado River Basin.
  - Very little melt at the soil/snow interface
  - SWE starts to dominate

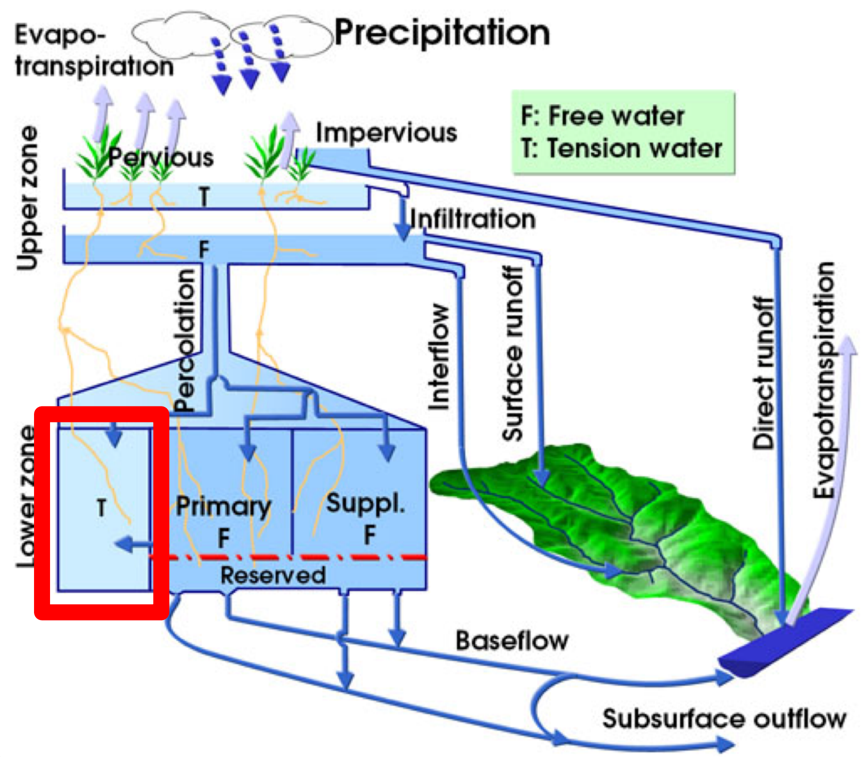
Baseflow

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

Colorado River near Moab, Utah near baseflow conditions (USGS)

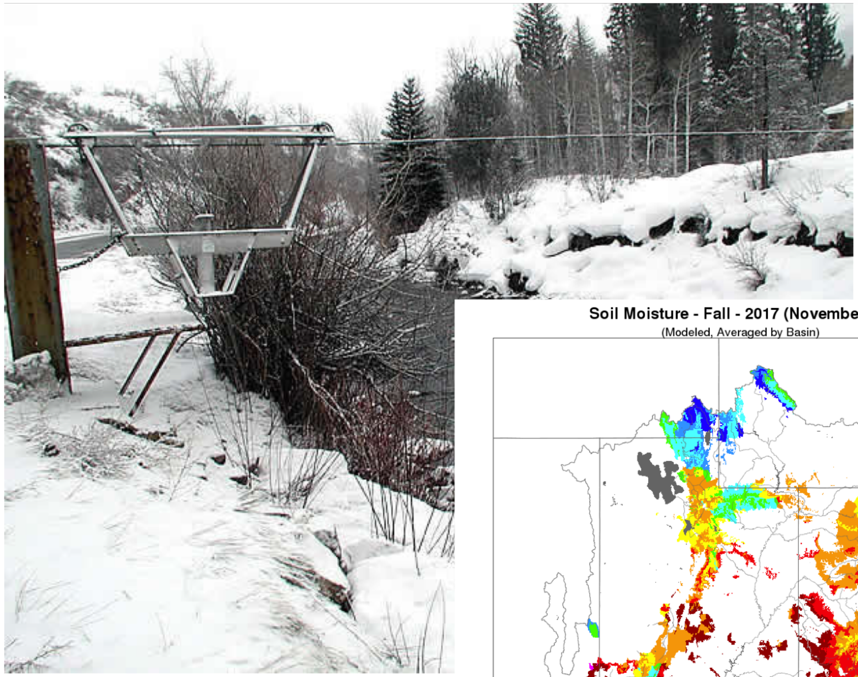
Tension Water

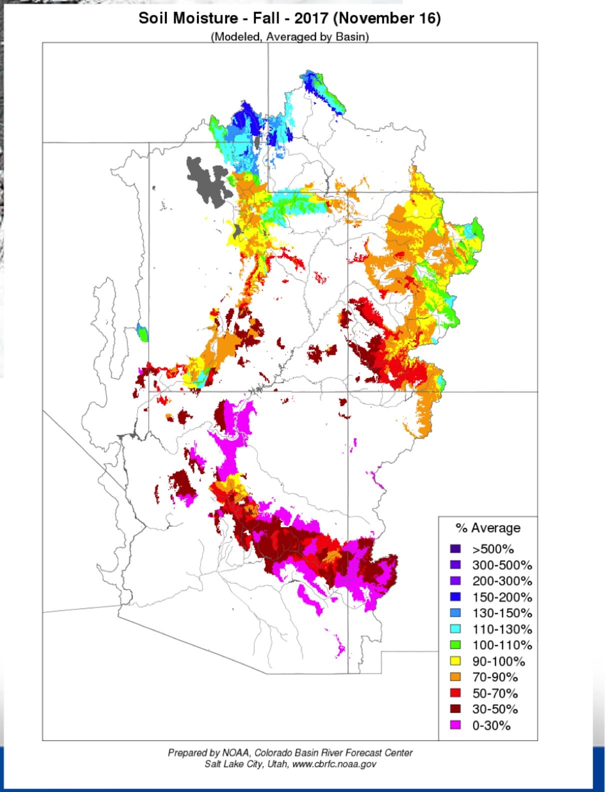
- Tension water is typically recharged every Spring
  - Mostly depleted due to Spring/Summer ET
- Rainfall events can recharge tension water in the Fall
- Extensive QC process for fall precipitation to keep track of these events
- Not measured directly
  - NRCS soil moisture sensors



Post Baseflow Analysis

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





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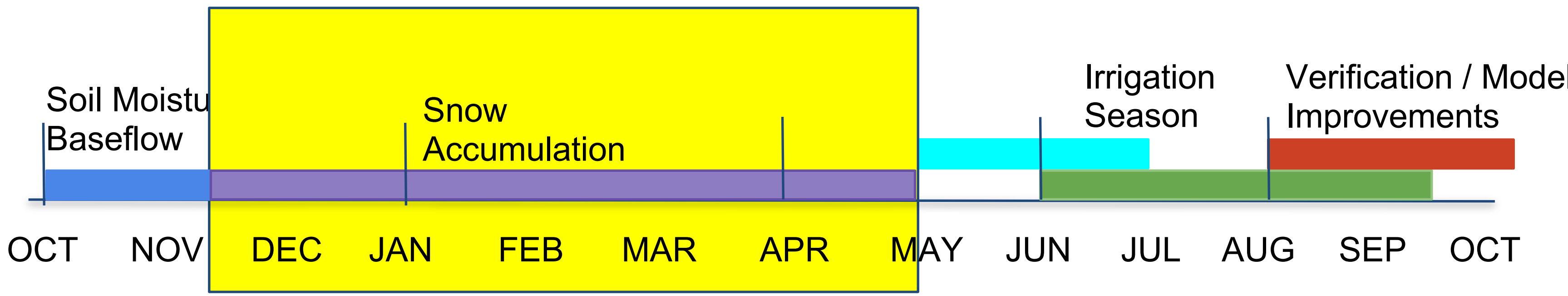
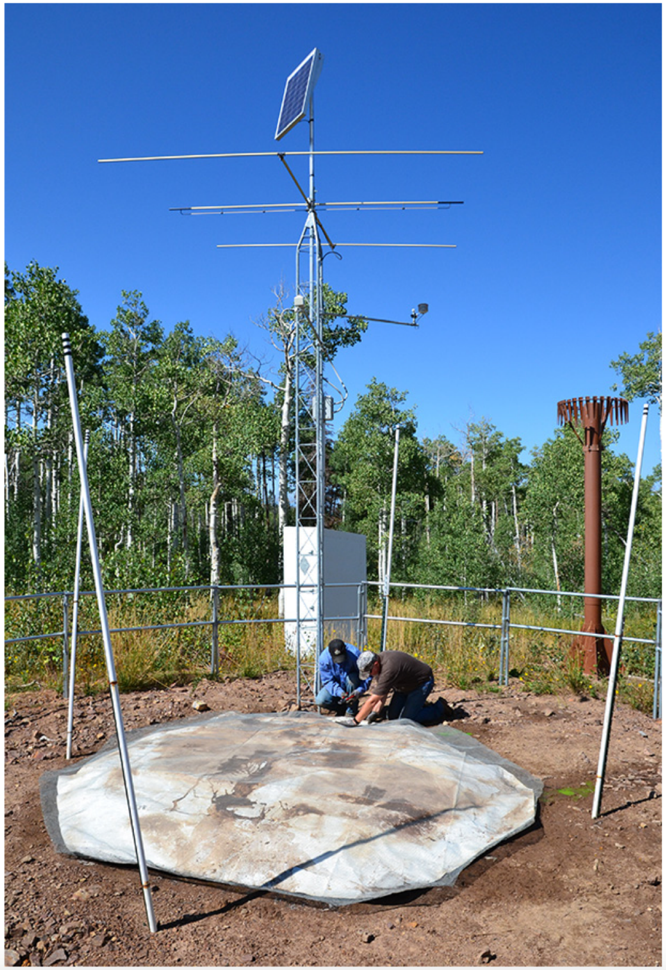


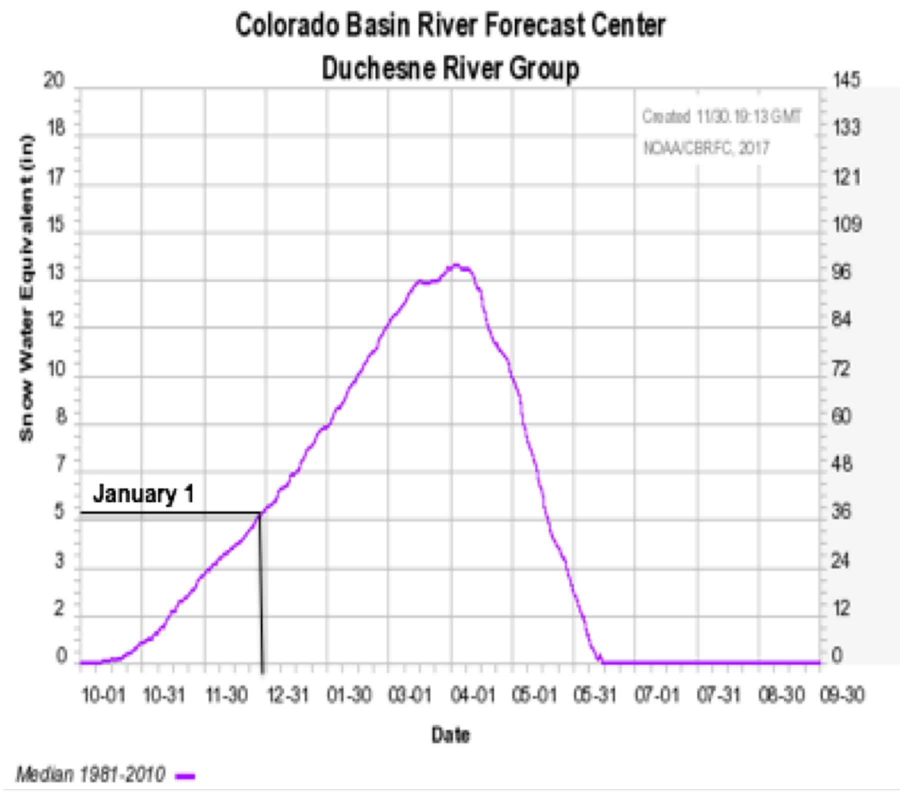
January 1 - First Water Supply Forecasts Issued

- Snow accumulation underway
- SWE begins to dominate Water Supply Forecasts
  - Use SNOTEL *precip* sensor (not SWE)
  - **QC observed precipitation daily**
  - Update model SWE biweekly to account for short-term inaccuracies in SNOTEL precipitation
- 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:
  - Future Weather
  - About 60% of snowpack accumulation



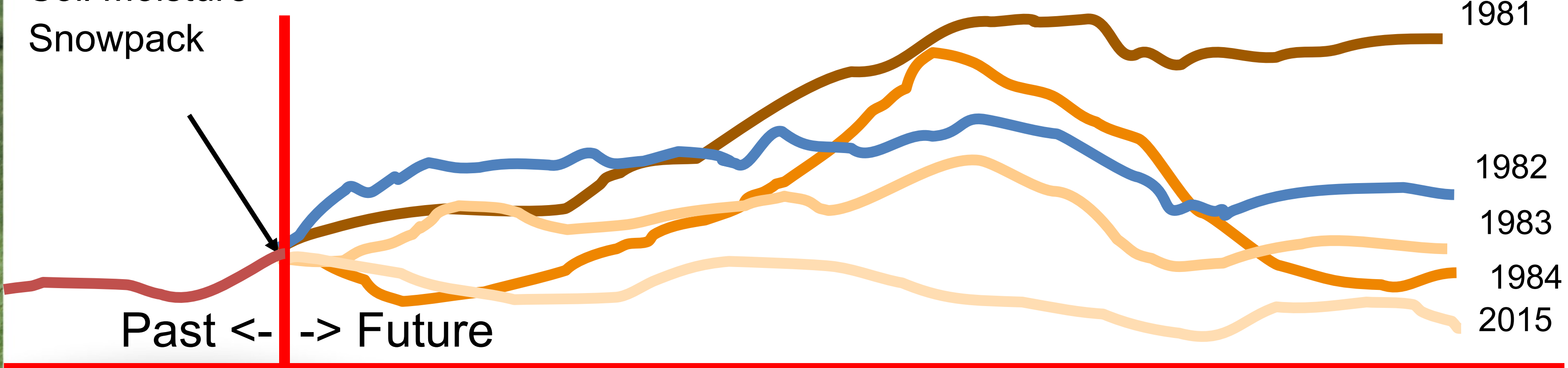
Normal snow accumulation / ablation plot for the Duchesne River Basin (NE Utah)

CBRFC Water Supply Forecasting
ESP Overview

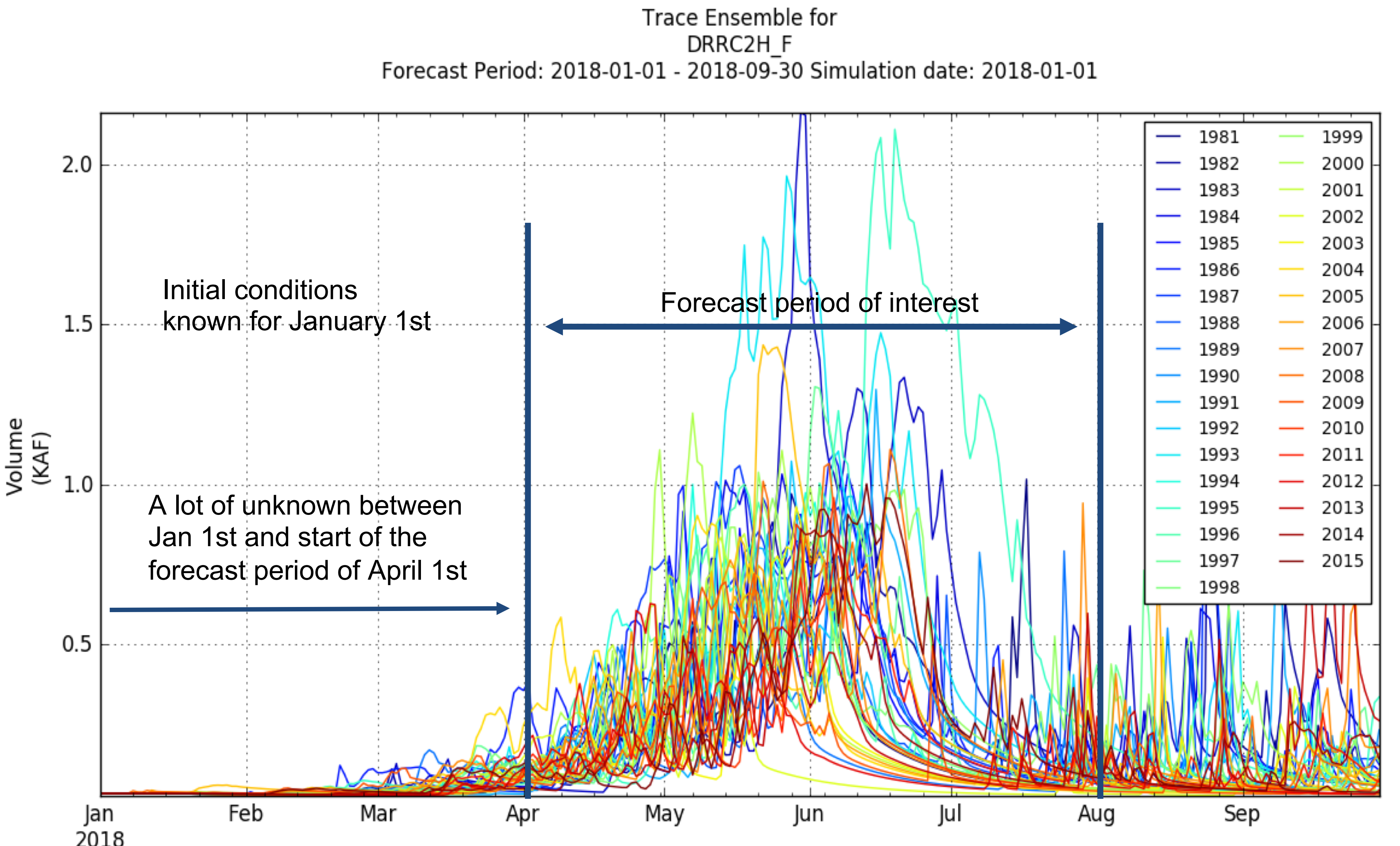
- Start with current conditions of streamflow, soil moisture, snowpack
- Apply precipitation and temperature from each historical year used in model calibration (1981-2015)
- A forecast is generated for each of the years (1981-2015)
  - This creates 35 possible future streamflow patterns
  - Each year is given a 1/35 chance of occurring

Current hydrologic model states:

River / Res. Levels
Soil Moisture
Snowpack

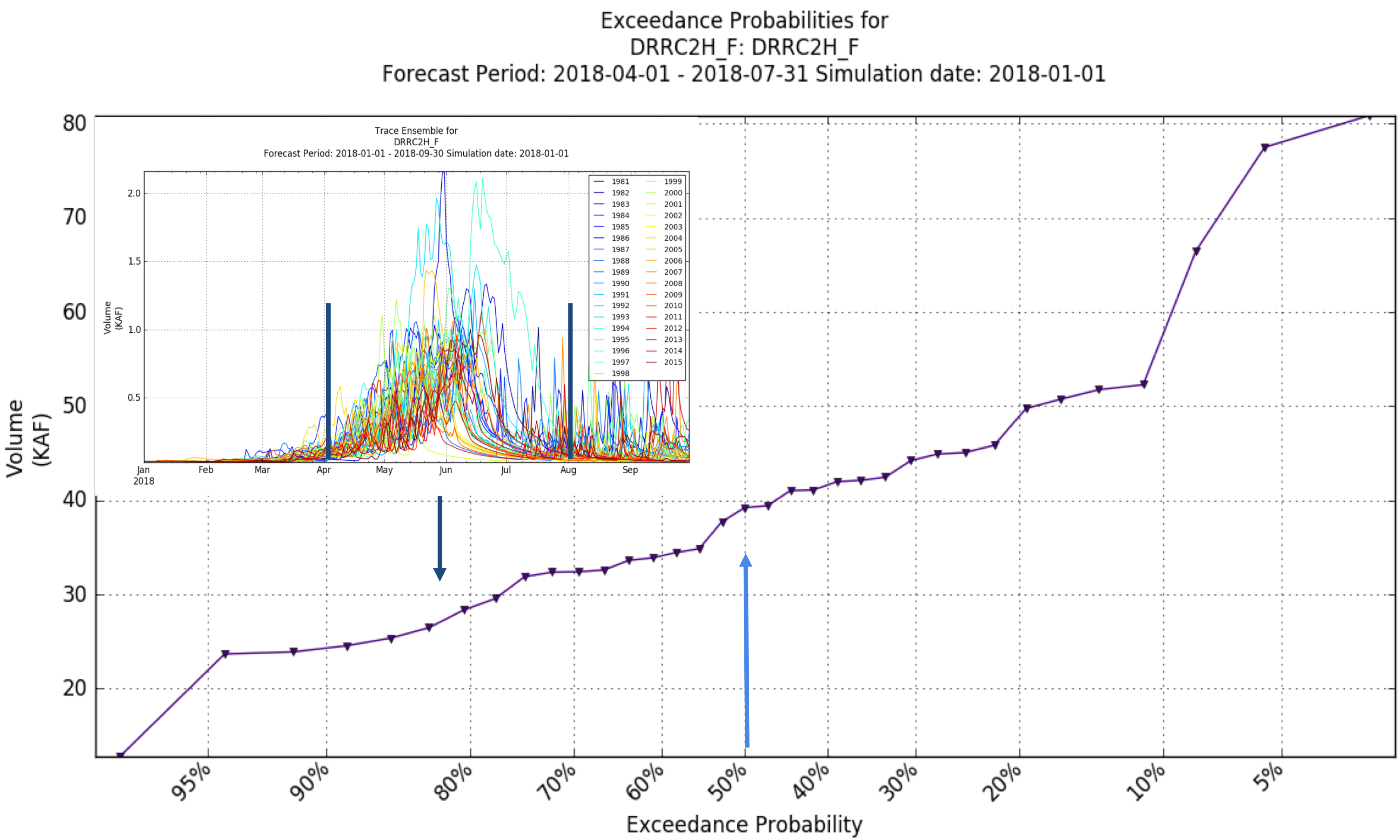


ESP Range of Possibilities

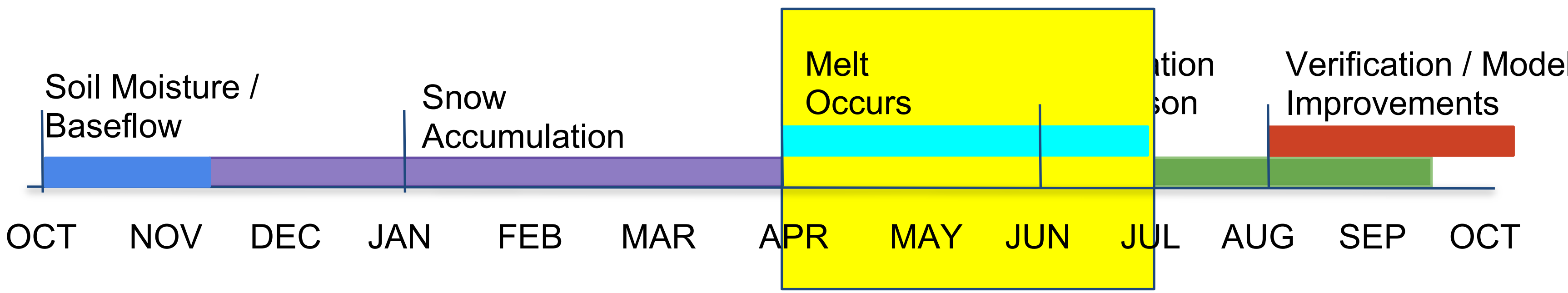


CBRFC Water Supply Forecasting

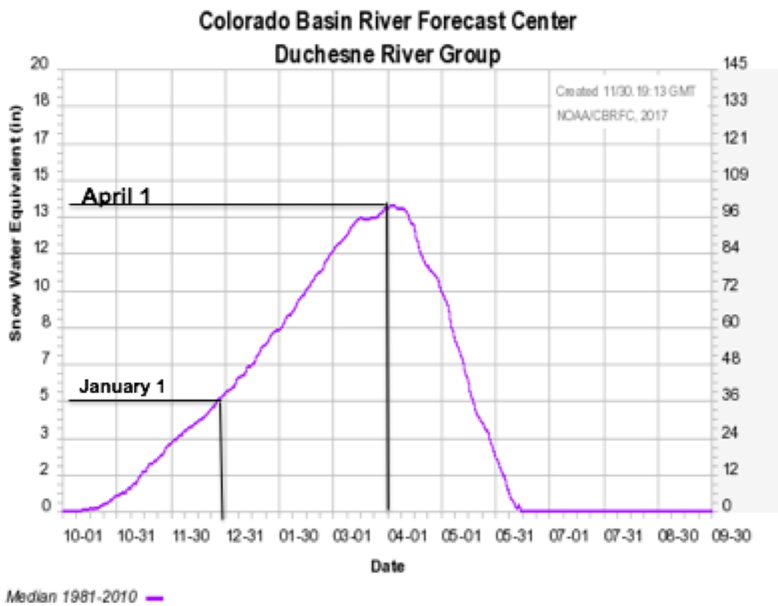
ESP Overview



Operational Timeline

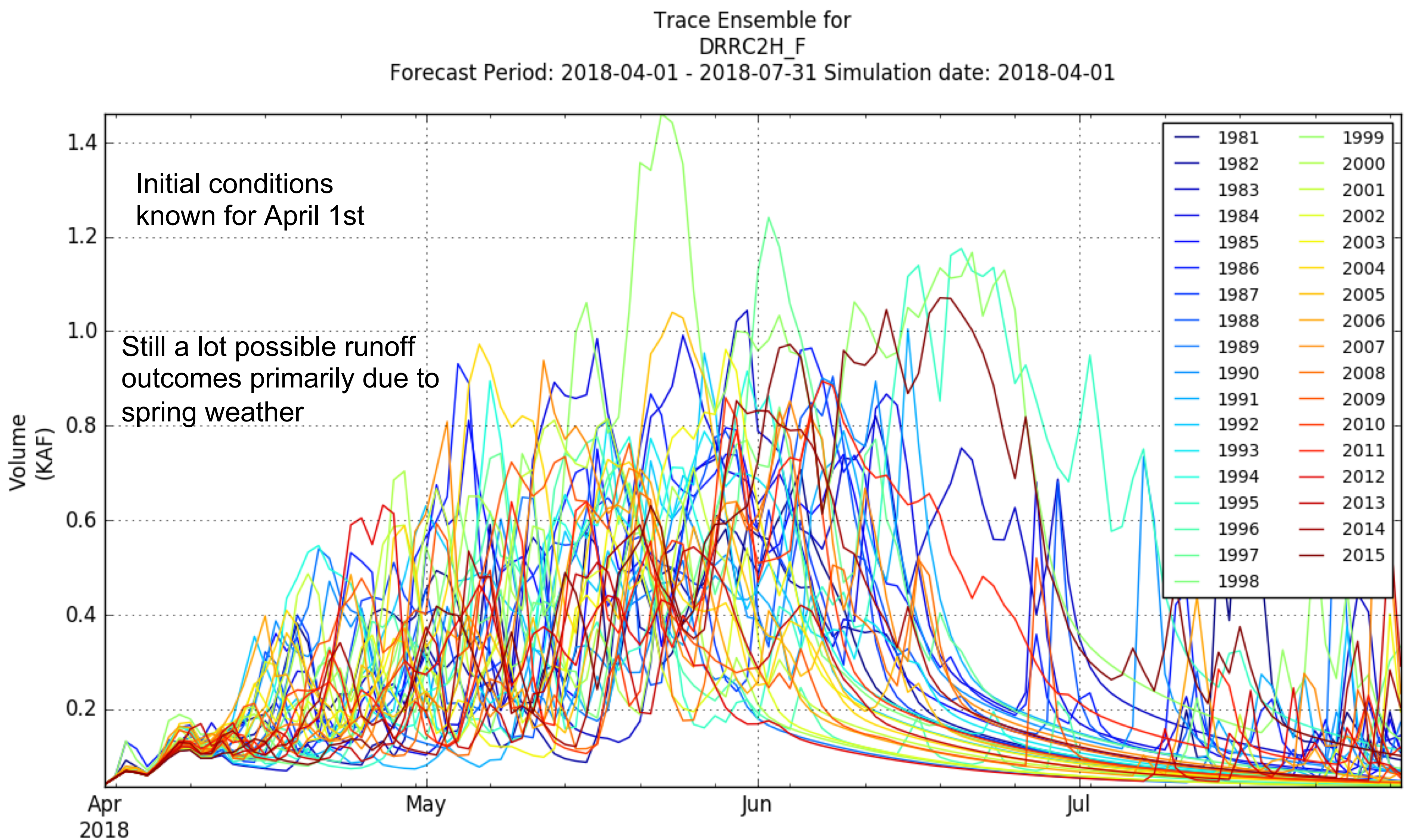


April 1 - Melt Begins



- What we know:
  - Around 90% of snowpack accumulation
  - December through March weather
- What we don't know:
  - April through May precipitation
  - Snowmelt pattern (temperature)
- April 1st Water Supply Forecast
  - Usually the 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

ESP Range of Possibilities

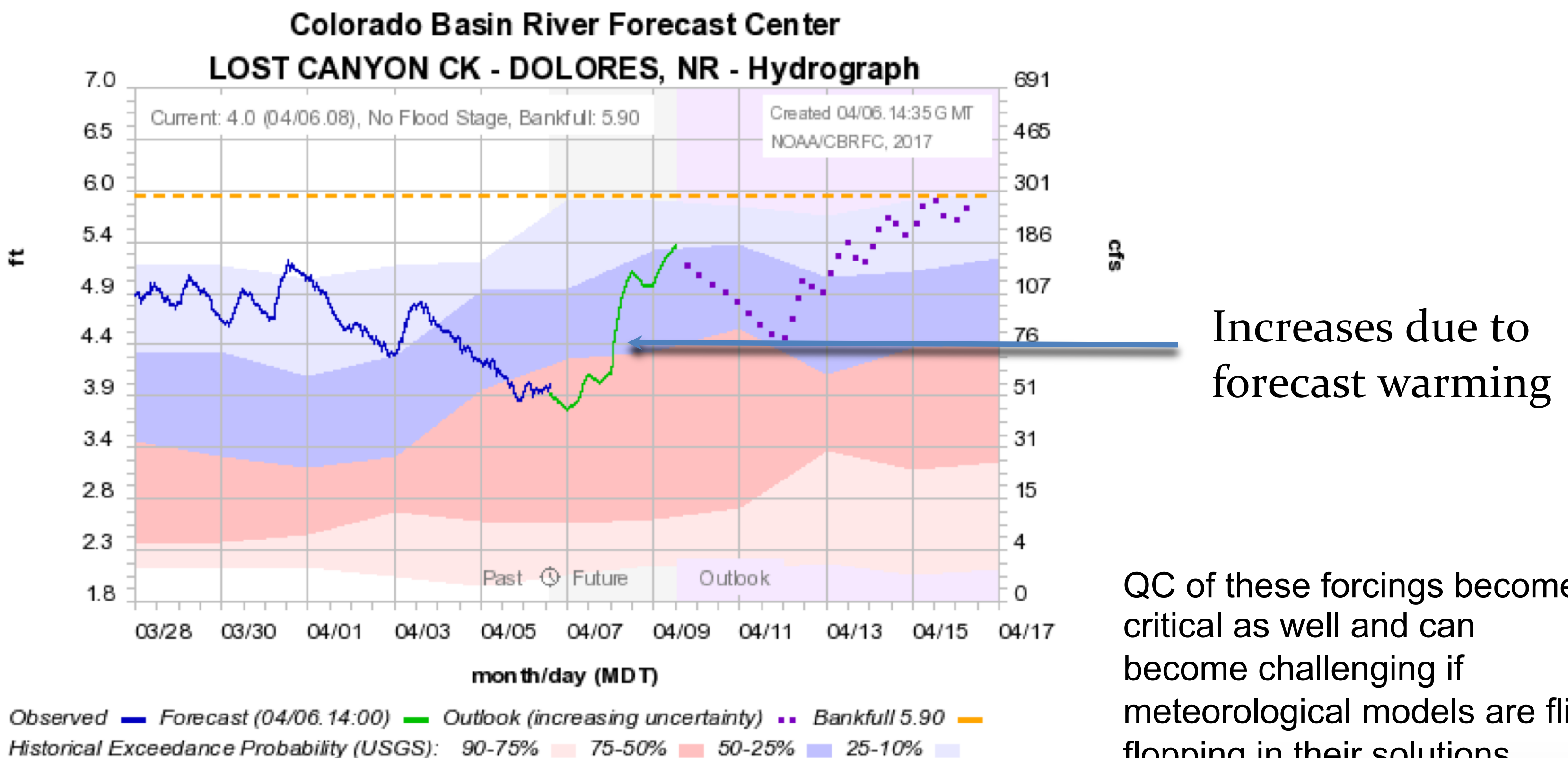


April to June - Melt Occurs

- 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 SWE
  - SNOTEL pillows become less useful as melting occurs; SNOTEL SWE and model SWE typically diverge
- Anecdotal evidence can be misleading

April to June - Melt Occurs

- We use 5 days of forecast precipitation and 10 days of forecast temperature in our daily streamflow forecasts

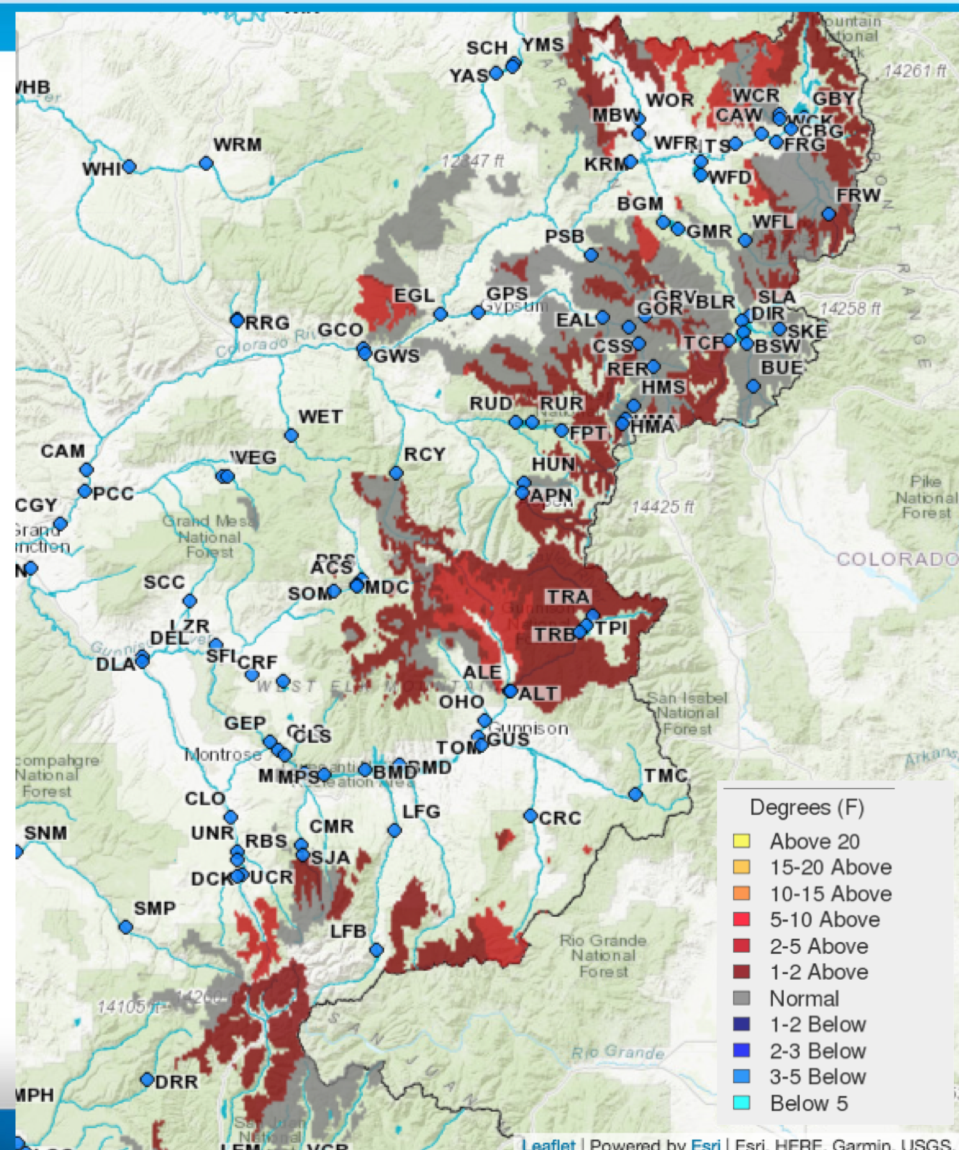


QC of these forcings becomes critical as well and can become challenging if meteorological models are flip flopping in their solutions.

JPL Remotely Sensed Data

- *MODSCAG (Dust)
  - We have calculated the departure from average contamination from 2000-2015
  - We then apply a temperature increase or decrease
  - Does not significantly impact volumes but improves timing of melt
- Snow Cover Grids
  - Using qualitatively (binary)
  - Limited when cloudy

*MODIS Snow Covered-Area and Grain size retrieval algorithm



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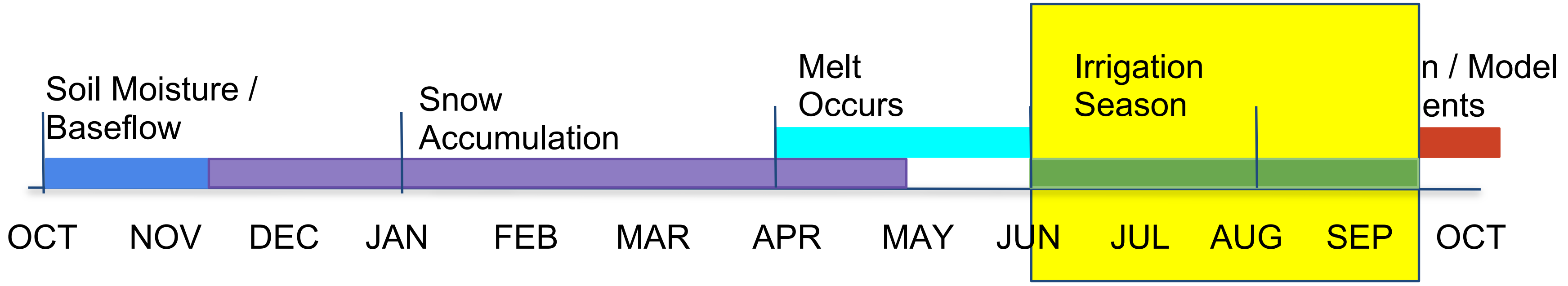
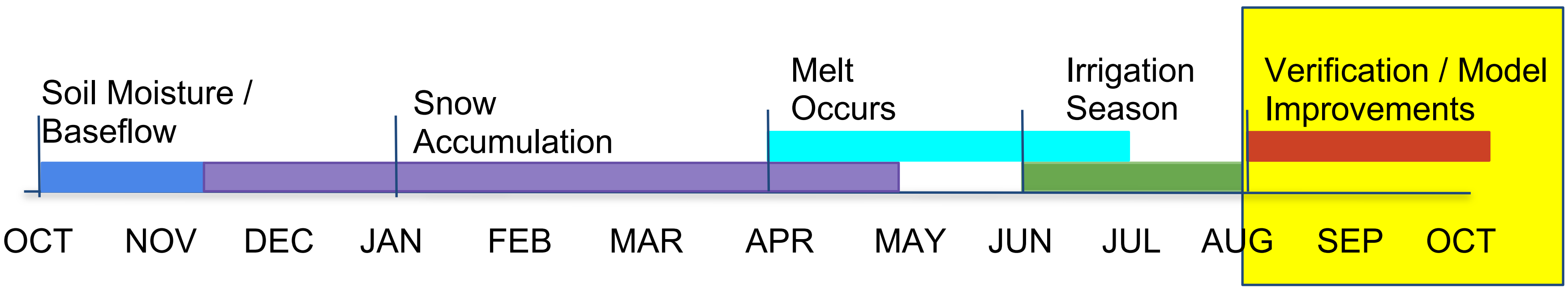


June to September - Irrigation

- 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



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?