CBRFC 2023
Stakeholder Meeting

Station B: Current Snow and Soil Models

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Station B: Current Snow and Soil Models

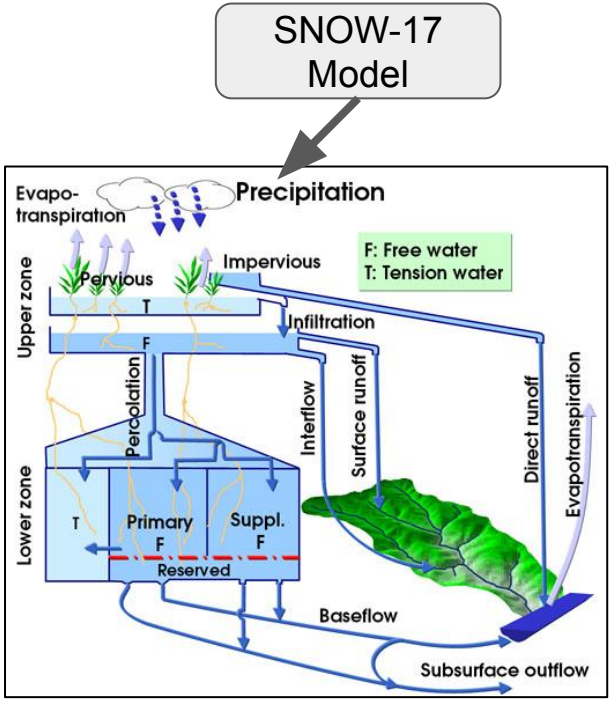
- Model Intro
- Snow Model: SNOW-17
- Soil Moisture Model: SAC-SMA
- Incorporating new datasets
- Where to find information and data on our webpage

Summary

- The CBRFC hydrologic modeling system includes:
  - Snow model - all elevation zones
  - Soil moisture model - all elevation zones
- These models are conceptual, but still account for the primary physical processes
- These models provide skillful and reliable streamflow forecasts for many different weather scenarios and for multiple time horizons when:
  - Well calibrated
  - Have high quality data input
  - → Hard to beat with more sophisticated models
- We are aware of new advances in modeling and data availability
- We are always looking for ways to improve our forecasts

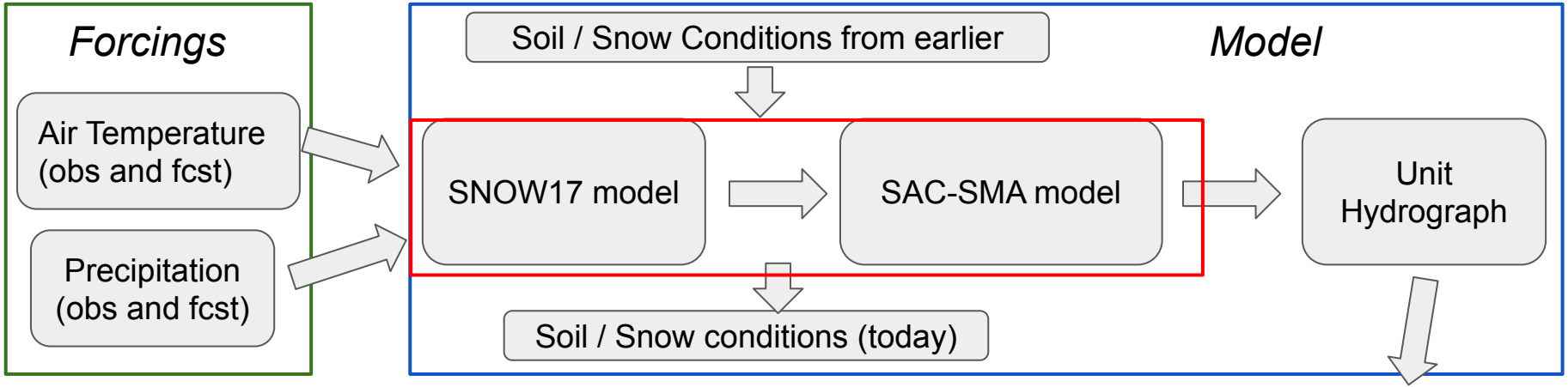
CBRFC Hydrologic Model Description

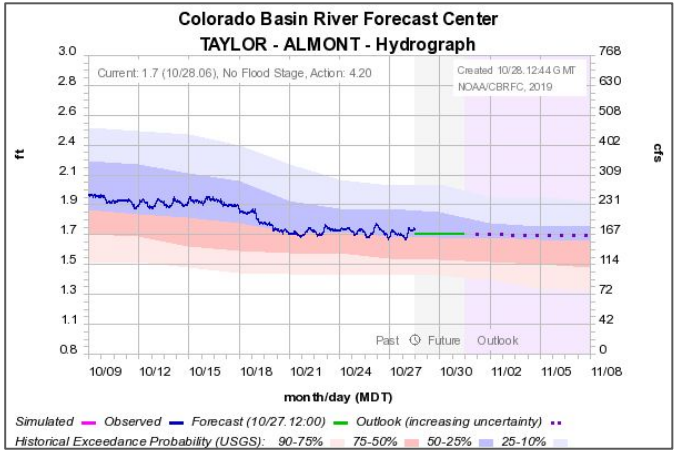
- Continuous
  - Meant to be run all the time, not just during events
- Conceptual
  - Physically based but uses parameters in place of hard-to-get data.
- Lumped
  - Uses mean areal inputs; not distributed
- Main components
  - **SNOW-17**: temperature index model for snow accumulation and ablation
  - **SAC-SMA**: soil moisture accounting model for generating runoff
- Sub components
  - Unit hydrograph
  - Agricultural water use model
  - Reservoir model
  - Routing model



SAC-SMA

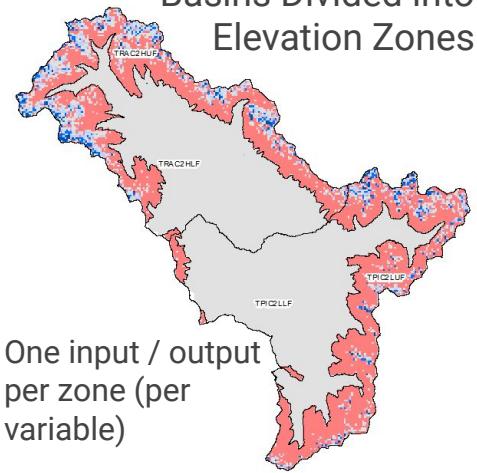
General Model Flowchart





Mean Areal Inputs

Basins Divided into Elevation Zones

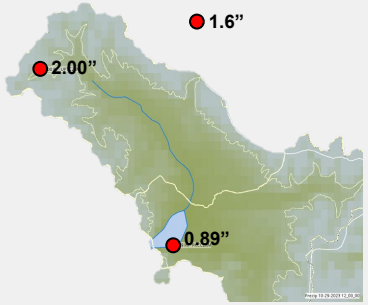


One input / output per zone (per variable)

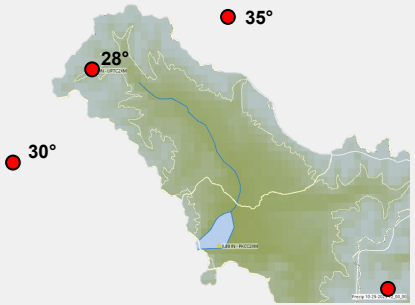
Note: Lower basin forecast points use gridded inputs aggregated to mean areal values.

Point Data

Precipitation Observations



Temperature Observations

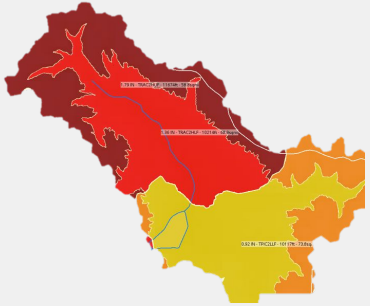


Zone Equations

Zone Equations

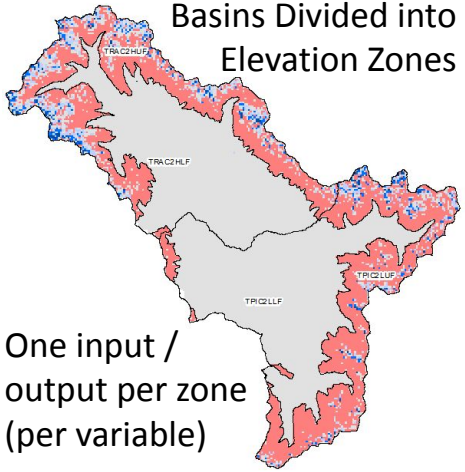
Zone Data

Mean Areal Precipitation (MAP)



Mean Areal Temperature (MAT)

Mean Areal Inputs



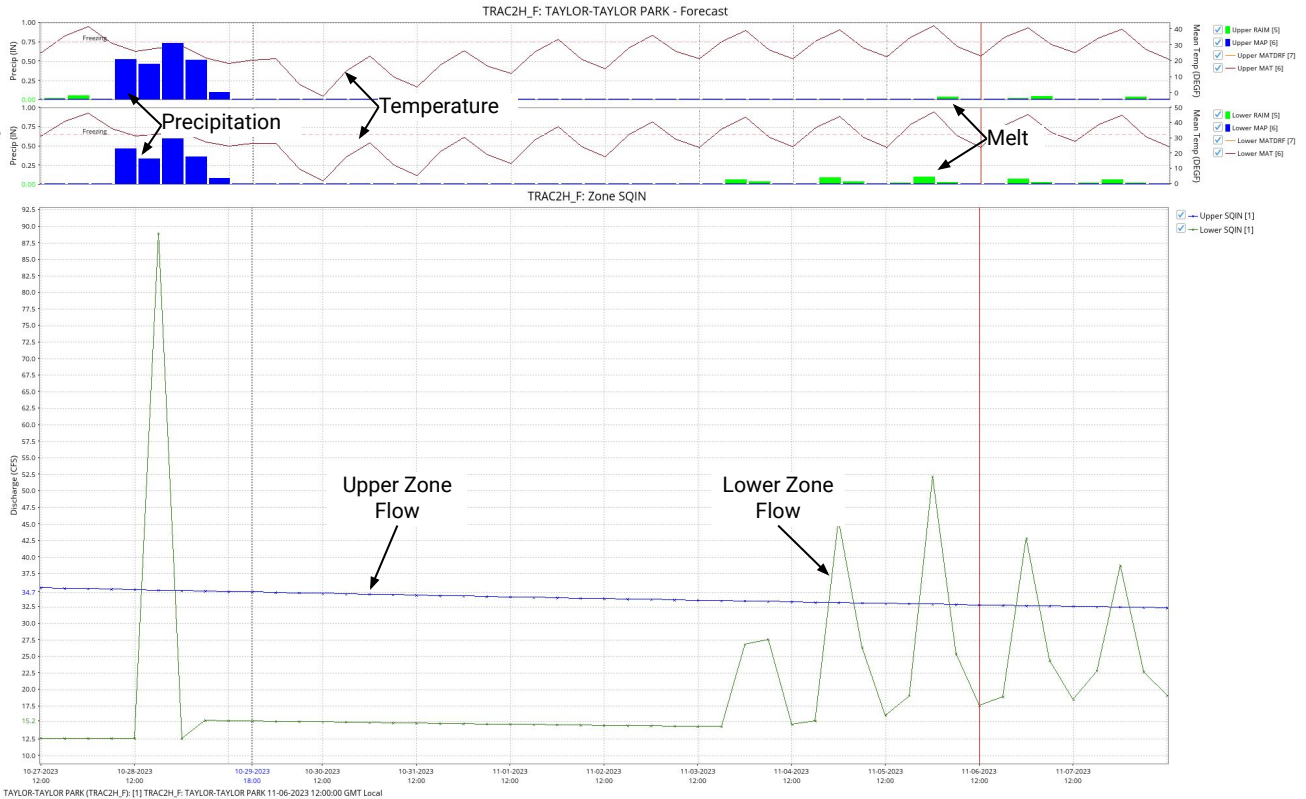
Basins Divided into Elevation Zones

One input / output per zone (per variable)

Upper Zone Inputs

Lower Zone Inputs

Outputs

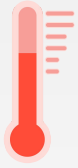


Snow Model: SNOW-17 Overview

SNOW-17 is a Temperature Index Model:
Air temperature is the only value that determines energy exchange

Model Inputs

Temperature



Precipitation

Snow Column Processes

Precipitation Type
Rain vs Snow

Snow Cover Accumulation

Surface energy exchange

Snow cover ripening
heat storage
liquid water storage

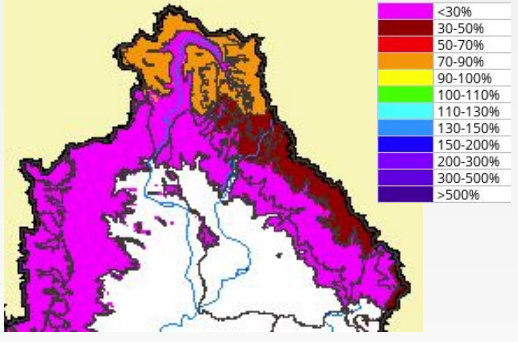
Transmission of water through the snowpack

Ground heat exchange

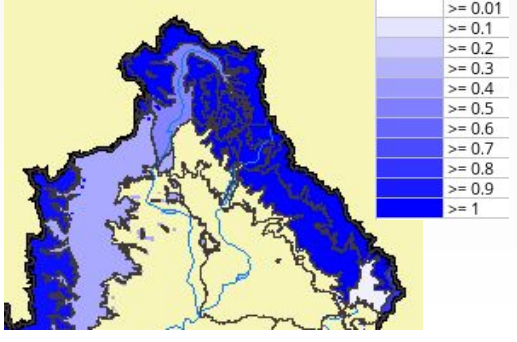
Model Outputs

Rain + Melt

Simulated Snow Water Equivalent (SWE)



Simulated Areal Extent of Snow Cover

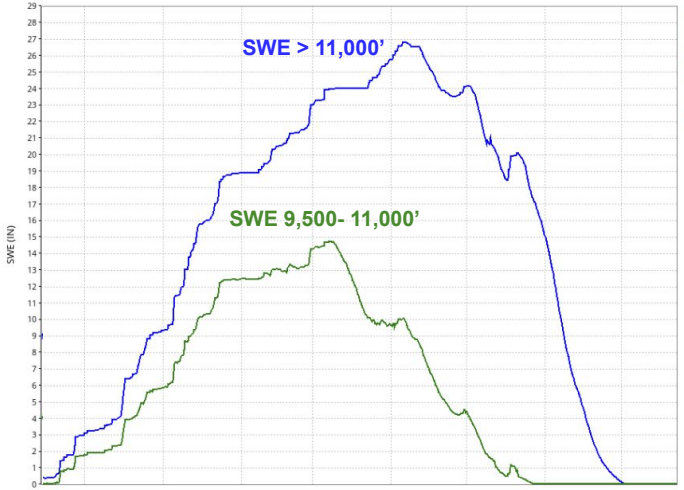


Snow Model: SNOW-17 Calibration

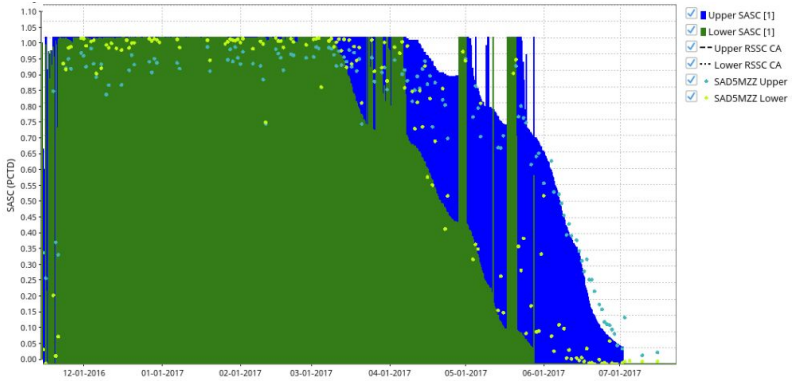
Major Parameters	Minor Parameters
Max/Min Melt Factors	Temperature Indices
Wind Function	Minor Melt Parameters
Snow Cover Index	
Areal Depletion Curve	
Snow Correction Factor	

Used satellite data (snow covered area) and dust radiative forcing grids during last calibration update to fine tune snow model areal depletion curve and improve model snowmelt timing.

Model Snow Water Equivalent



Snow Cover: Simulated and Satellite Observations

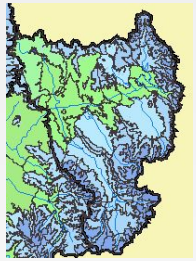


Snow Model: SNOW-17 Daily Operations

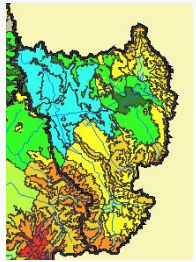
QC/review observed and forecast precipitation, temperature, and freezing level data.

Model Inputs

Temperature



Precipitation



Freezing Level

SNOW-17 Model

Initial Internal Variable States

Observed and Forecast Inputs

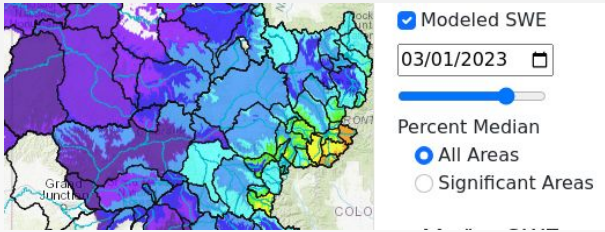
- Temperature determines accumulation, ripening, and melt.
- Freezing level determines precipitation type (rain/snow).

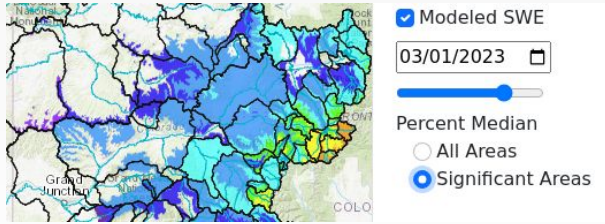
Model Outputs

New Internal Variable States

Rain + Melt → SAC-SMA Model

Snow is modeled in all elevation zones

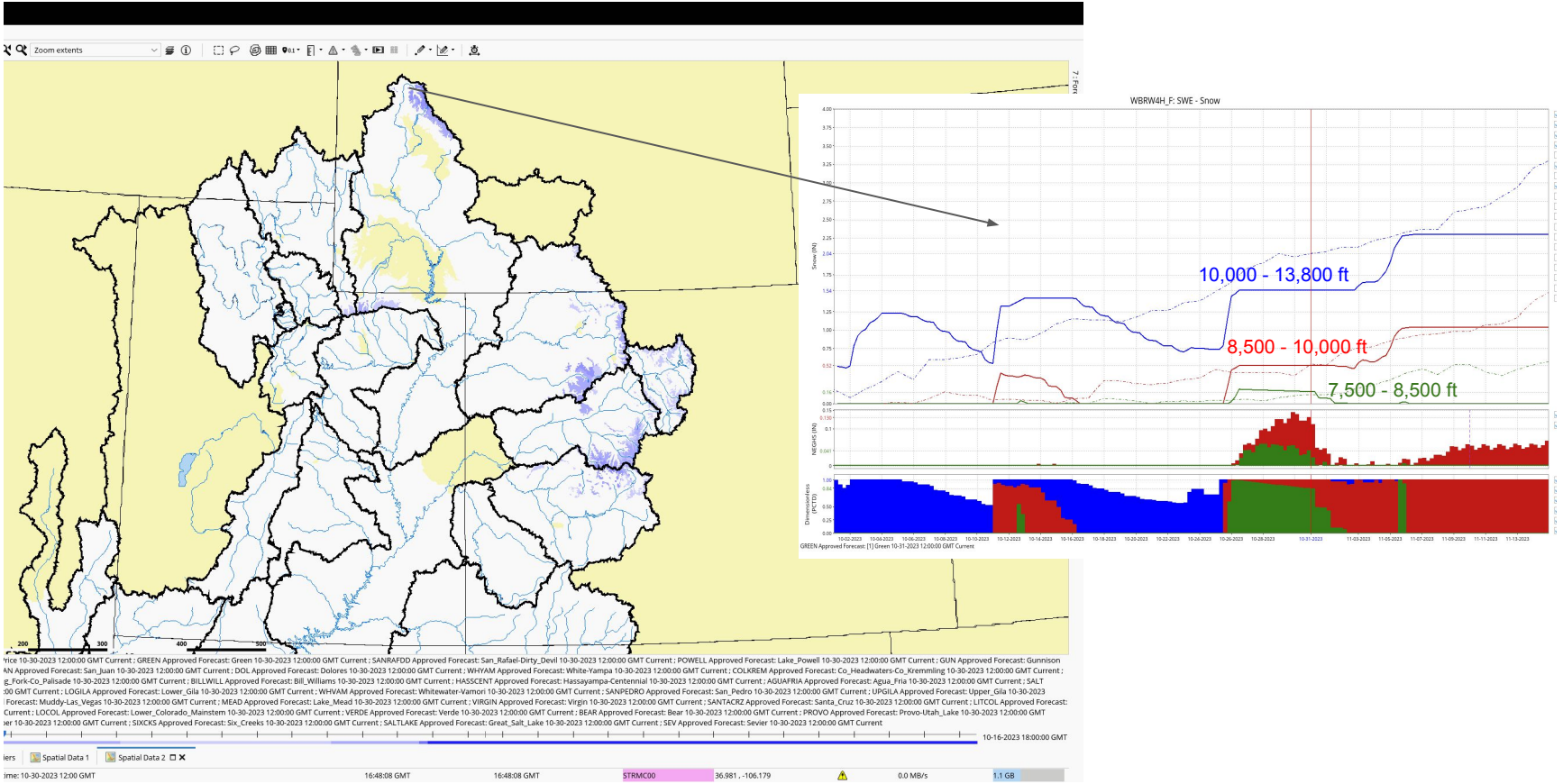




Because these maps display %median, no color areas on the 'All Areas' map may be places with a median value ~0 rather than no snow.

Snow Model: SNOW-17 Daily Operations - CHPS Displays

CBRFC Model SWE: Melt & Accumulation - Oct/Nov 2023



Snow Model: SNOW-17 Modifications - Accumulation Period

Calculate MAP and how much SWE the model should have accumulated over a longer time step (weeks to months).

- **Use the same weighted station equation as in calibration and daily operations.**
- **This update is done manually every ~2 weeks Dec-Apr.**

Also compare SNOTEL snow pillow %normal to model %normal as a rough error check.

1: Calculate Zone SWE	2: Compare Model and Observed Values	3: Update Model SWE
Zone Snotels: SOSC2 and NLSC2	**3/29 Model SWE:** 43.54 **3/29 Calculated SWE:** 43.81	**New 3/29 Model SWE = Calculated SWE**
3/29 Calculated SWE: 43.81	**Difference:** 0.28	

Notes

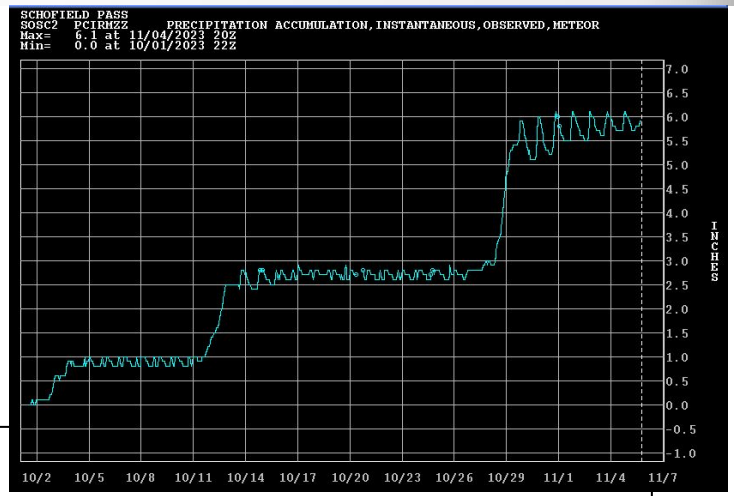
This method is only used in the areas that use weighted equations for MAP's (Upper Basin) and only when and where the precipitation is all snow (no rain).

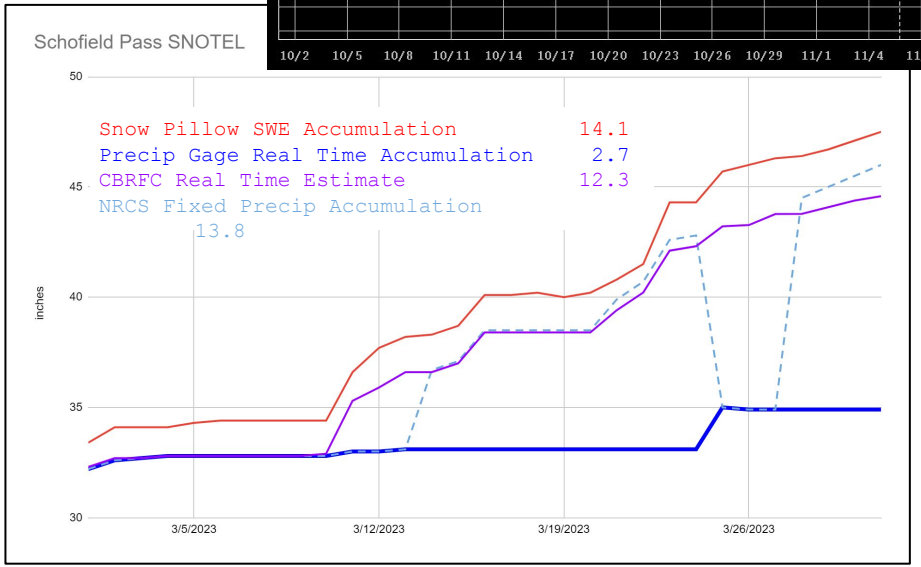
Update methodology for lower elevations and in the lower basin are more subjective, but still manually reviewed throughout the winter/spring.

Snow Model: SNOW-17 Modifications - Accumulation Period

We love the SNOTEL network, but there can be data issues:

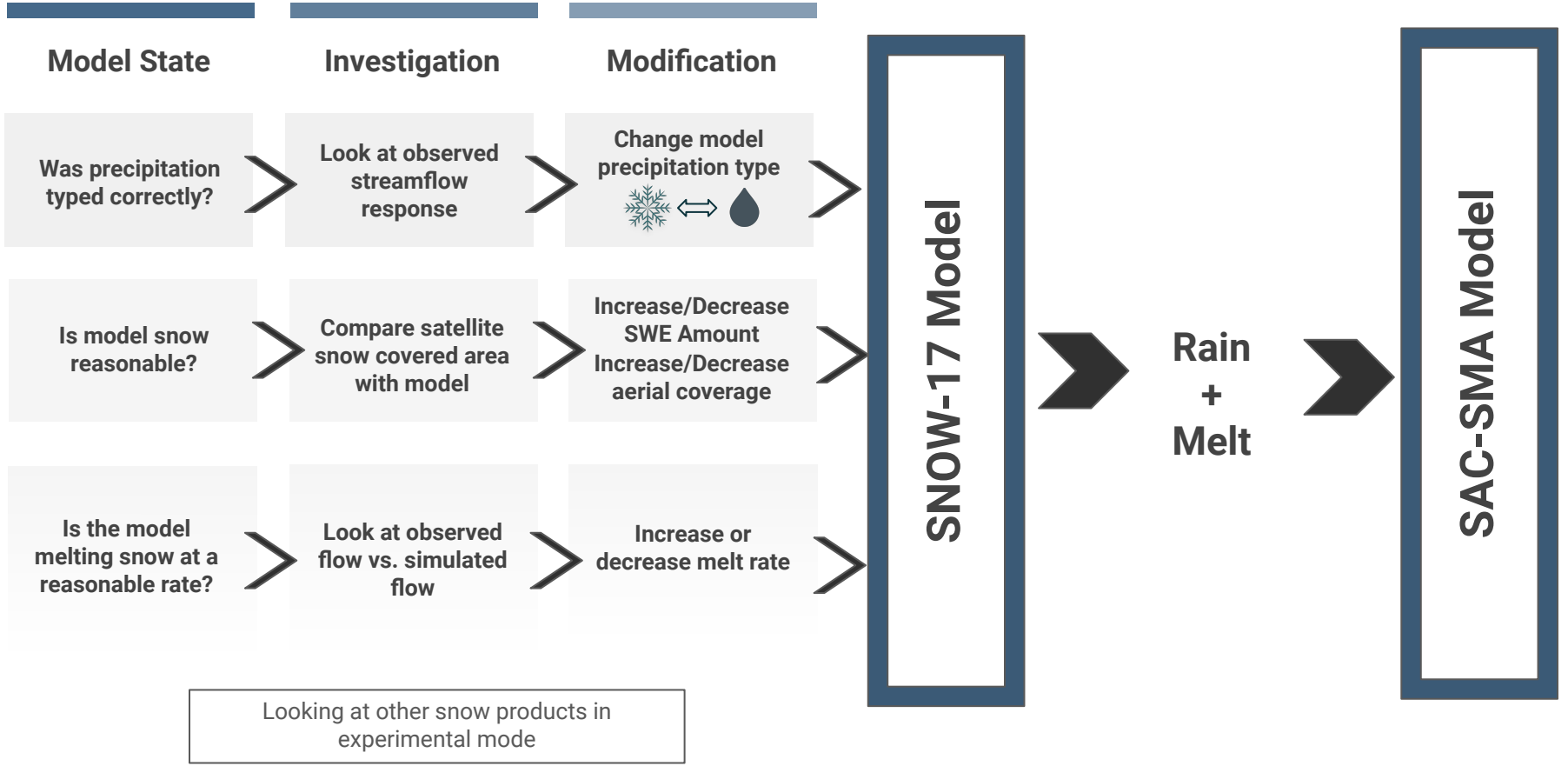
- Precipitation accumulation traces can be noisy
  - Small events sometimes hard to determine
- Winter errors related to snow capping on the tube
  - Precipitation reported on wrong day or missed
- The NRCS does correct the precipitation data
  - Not always available in a timely manner for real time forecasting
  - Final monthly precipitation report usually good
- CBRFC QC not perfect
  - Generally catch obvious errors and either let the value be estimated from surrounding gages or use the change in SWE instead
  - Snow pillow ΔSWE ≠ Precipitation gage increment





Schofield Pass SNOTEL
-historical monthly average SW/PP ratio = 1.2
→ 14.1” SWE = 11.8” precipitation
-historical ratio range 1.0 - 1.5

Snow Model: SNOW-17 Modifications - Melt Period



Soil Moisture Model: SAC-SMA Overview

Conceptual Model

Soil moisture modeled: not directly measured

Model Inputs

Rain + Snow Melt

Model Processes

- Percolation
- Soil Moisture Storage
- Drainage
- Evapotranspiration

Soil Representation: Layers

Represented in two layers

Upper Zone : Surface processes (fast response)

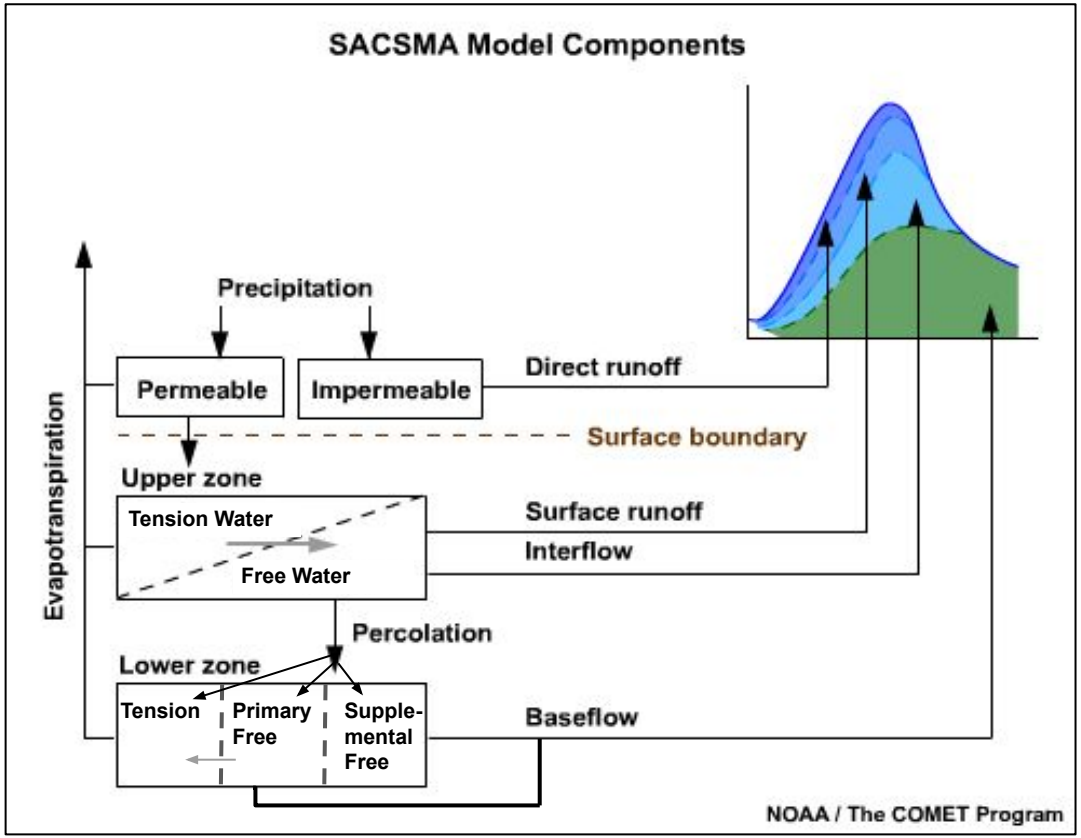
Lower Zone: Groundwater (slow response)

Soil Representation: Tanks

Each layer has two water tank types

Tension Water: Driven by evapotranspiration

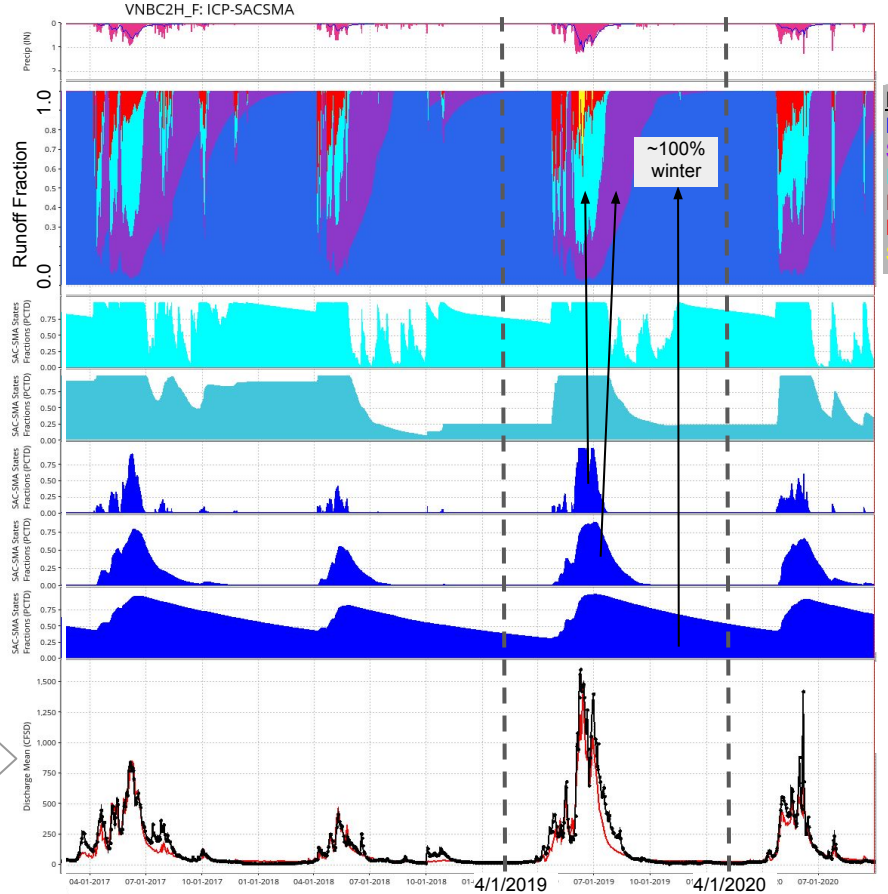
Free Water: Driven by gravitational forces



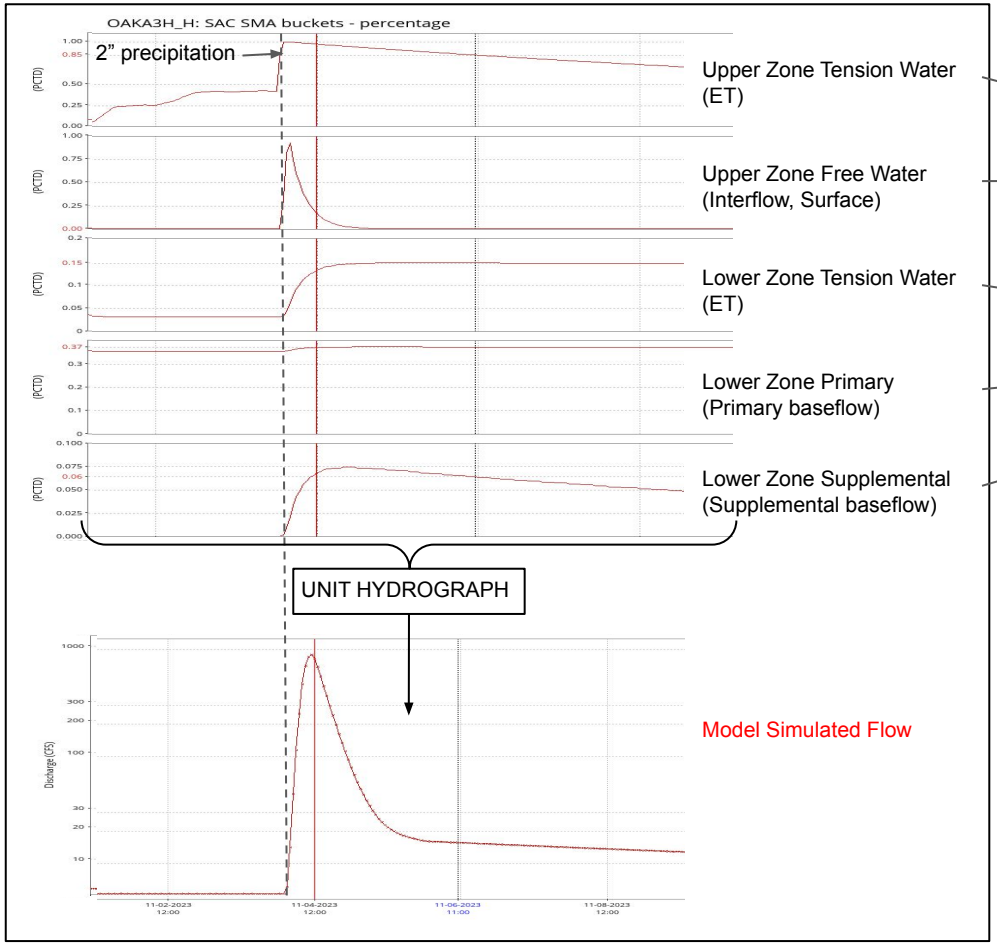
Soil Moisture Model: SAC-SMA Calibration

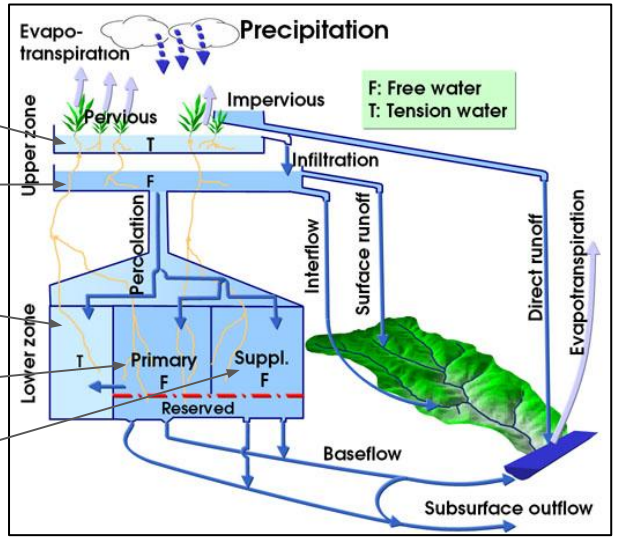
Major Parameters	Minor Parameters
5 tank sizes	Impervious area
Rates of drainage	Riparian vegetation effects

Goal in calibration is to set parameters to reasonable values that create a simulated streamflow that matches the observed flow as well as possible for all events.



Soil Moisture Model: Daily Operations





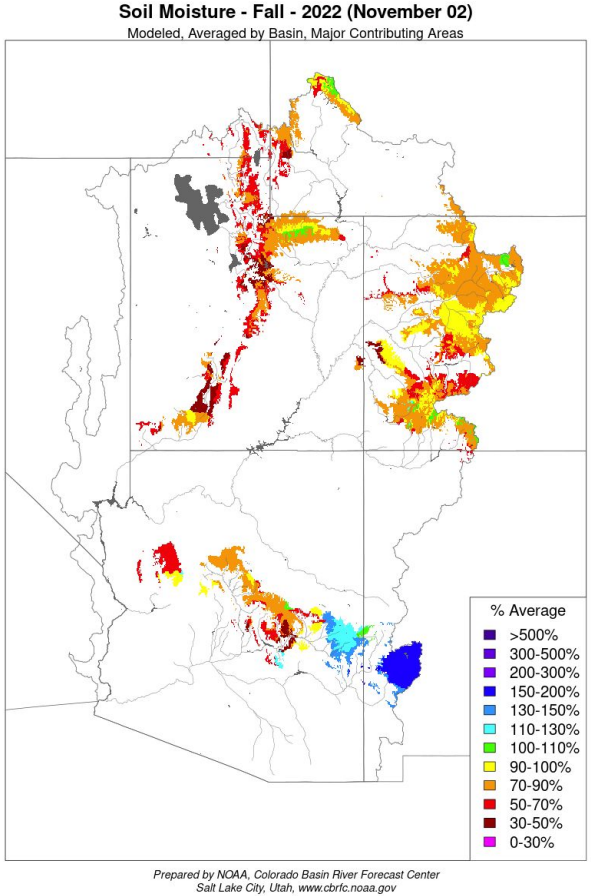
In general we do not make modifications to the soil moisture states outside of our fall review unless it is obviously needed.

- We prefer to get the precipitation and temperature inputs correct (or make modifications to those).
- This ensures that the water moves through all the tanks as it is designed to.
- An example of an exception is if the USGS visits a gage an makes a large adjustment to the flow.
  - We may have been increasing/decreasing precipitation or melt to match the incorrect flow and those events are now out of our 10 day observed window.

Soil Moisture Model: SAC-SMA Modifications - Fall Adjustment

Fall soil moisture

- Most important model state affecting early season (fall/early winter) forecasts of spring runoff
  - Can have a moderate impact on spring runoff forecasts
- We display it as the sum of the lower zone tanks compared to the average from the 1991-2020 calibration states for that day
- Basin-wide modifications generally take place in late fall/early winter
  - after irrigation has ended
  - before gages become ice affected
  - ideally want rivers near baseflow conditions



Soil Moisture Model: SAC-SMA Modifications - Fall Adjustment

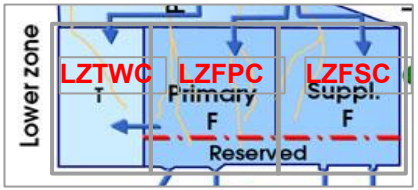
Compare last year's Jul-Oct precipitation and tank values to this year

- Trend should be the same (higher precip = higher tension water)

Spatial pattern analysis

- Pattern similar to precipitation
- Smooth with nearby similar elevations

This will not affect the current simulated flow, but is important for simulating next spring runoff correctly.

Tension Water (LZTWC)		**Baseflow Free Water** (LZFPC)
✗	**Carryover from previous season snowmelt**	✓
✓	**Significantly affected by fall precipitation**	✗
✗	**Measured directly**	✗
regionally	**Adjustment approach**	**baseflow observations**

Compare last year's baseflow and tank values to this year

- Trend should be the same (higher baseflow = higher free water)

Quality of the observed flow

- Has USGS visited recently
- Examine upstream and downstream gage consistency
- Use reservoir inflow/outflow as a quality check

Adjust tank value (within reason) so that the simulated flow matches observed flow.

Incorporating New Datasets

Dataset Requirements

Has a long, continuous historical record:

Minimum 10 years.

20 is better, 30 is best

Available in real time: minimal lag

Analysis Methodology

Build a relationship between the data and a variable/state in our model over the calibration period

Use In Calibration

Use In Reforecasts

Examples

Satellite snow covered area and dust radiative forcing

Used during calibration to fine tune snowmelt timing

Can be seen in real time forecasting mode (when available)

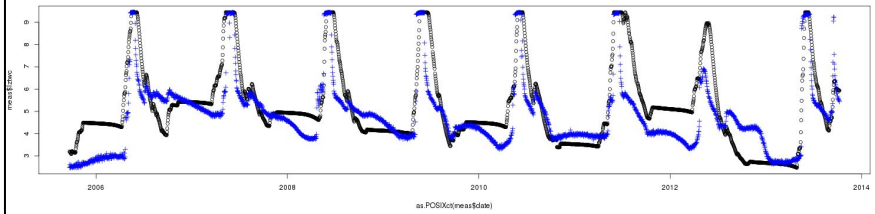
NRCS soil moisture measurements

Analyzed when fairly new and did not find widespread correlation to SAC-SMA states

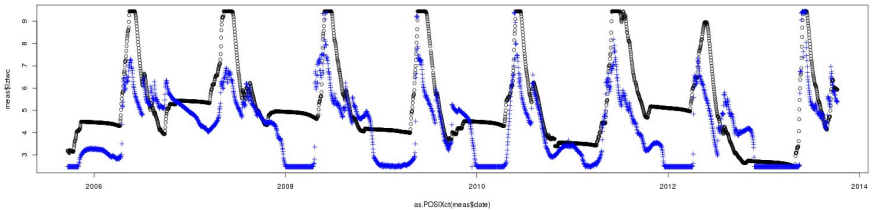
Needs to be looked at again (along with newer soil moisture datasets)

NRCS Soil Moisture Analysis

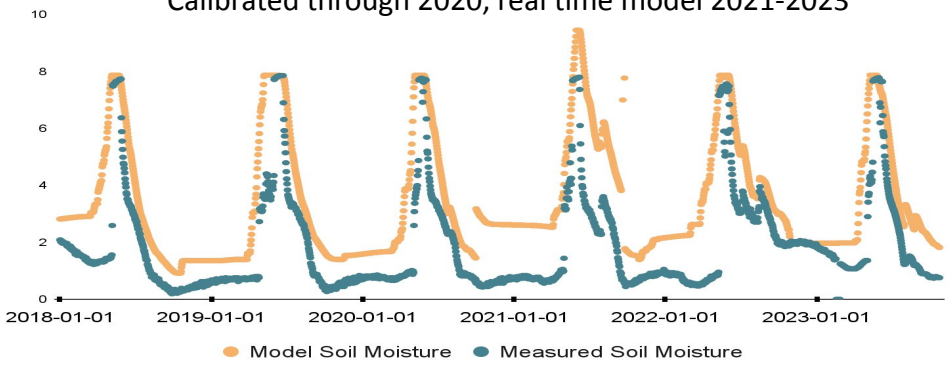
Hoosier Pass Snotel 40 inch soil moisture (blue)
Blue - Blue River (9,800-11,000') Lower Zone Tension Water (black)
Calibrated through 2010, real time model 2010-2013



Hoosier Pass Snotel 20 inch soil moisture (blue)
Blue - Blue River (9,800-11,000') Lower Zone Tension Water (black)
Calibrated through 2010, real time model 2010-2013



Hoosier Pass Snotel 40 inch soil moisture (green)
Blue - Blue River (9,800-11,000') Lower Zone Tension Water (orange)
Calibrated through 2020, real time model 2021-2023



Initial results:

- There may be a relationship between the SNOTEL 40" sensor and SAC-SMA Lower Zone Tension Water in some areas
- The 20" sensor did not show the same
- → there are not many 40" sensors throughout the basin

Need to re-analyze with longer period of record. Additionally, calibrations have been updated and more stations have been installed.

Summary

- The CBRFC hydrologic modeling system includes:
  - Snow model - all elevation zones
  - Soil moisture model - all elevation zones
- These models are conceptual, but still account for the primary physical processes
- These models provide skillful and reliable streamflow forecasts for many different weather scenarios and for multiple time horizons when:
  - Well calibrated
  - Have high quality data input
  - → Hard to beat with more sophisticated models
- We are aware of new advances in modeling and data availability
- We are always looking for ways to improve our forecasts

Where to Find Model Snow and Soil Information on CBRFC Web

- Model snow conditions maps (Snow → Model Snow Grid)
  - Interactive
    - Can overlay SNOTEL points
    - Can overlay model points → link to plots
  - Static
    - Model Dust Impact maps
  - Documentation (Help → Snow Model)
- Model soil moisture maps (Water Supply → Soil Moisture)
  - Fall Interactive
  - Fall Static - Model real time operations
    - Calibration
    - Model Yearly Differences
  - Documentation (Help → Soil Moisture)