NOAA's Colorado Basin River Forecast Center

CBRFC Hydrologic Model Overview

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2016 Stakeholder Open House

CBRFC Model Description

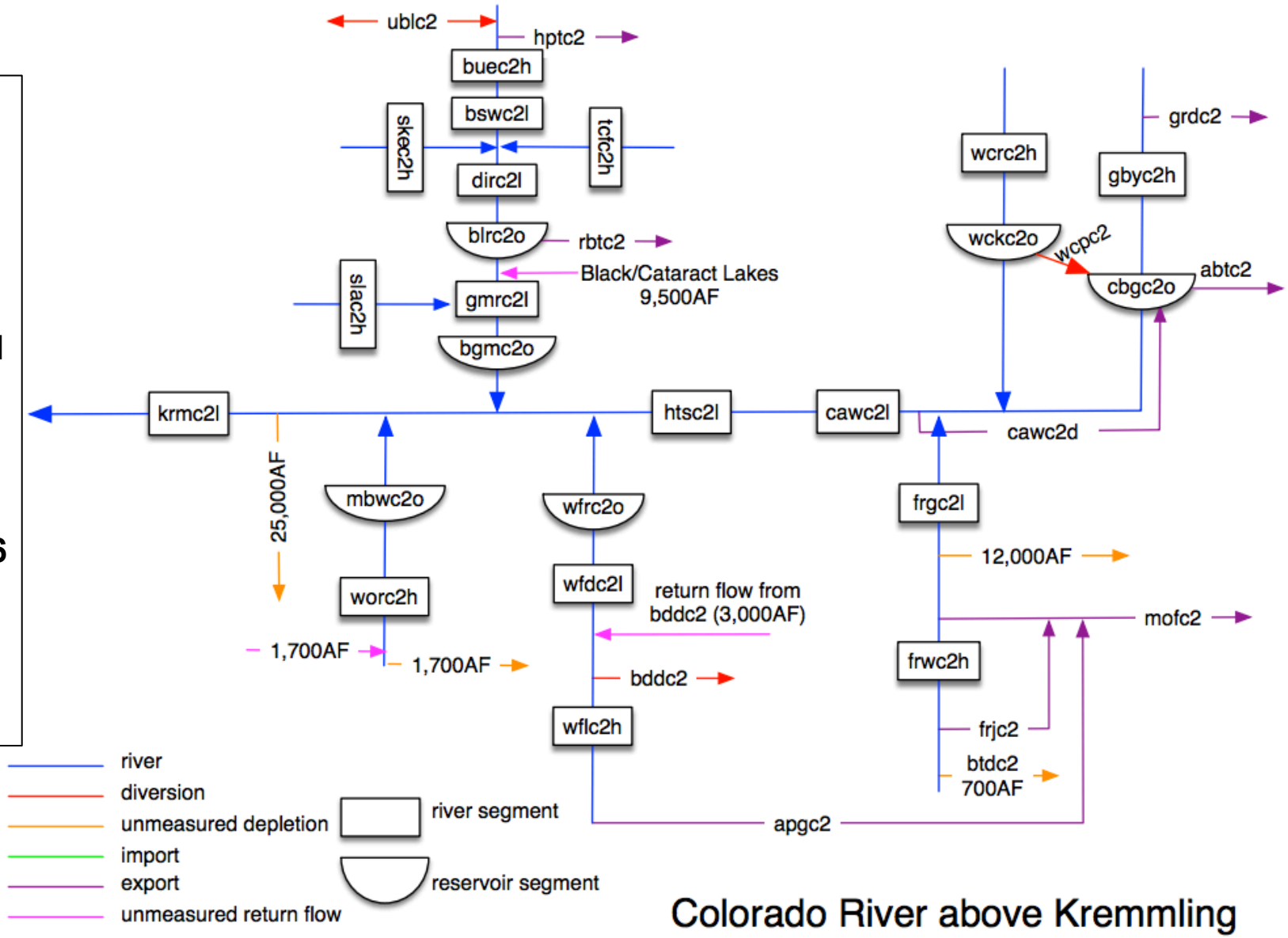
- Continuous
  - meant to be run all the time, not just during events.
- Conceptual
  - physically based, but uses parameters in place of hard-to-get data.
- Lumped
  - uses mean areal inputs; not distributed.
- Main components:
  - Sac-SMA – soil moisture accounting model for generating runoff
  - SNOW-17 – temperature index model for snow accumulation and ablation
- Calibrated using 1981 – 2010 data

CBRFC Model Setup

Each river point in the model is called a segment.

There are 181 segments above Lake Powell

There are 486 segments in the CBRFC area.



CBRFC Model Setup

- Segments are calibrated to the *Unregulated Flow*.
  - *Measured* diversions, imports, exports, and reservoir regulation are accounted for to approximate natural flow.
    - Observations are available in real-time
  - *Unmeasured* depletions and return flows are not accounted for and why this is not the same as 'Natural Flow'.
    - Usually known, unmeasured irrigation.
    - Derived by CBRFC during calibration using a model that is a function of irrigated acres and temperature.

$$Q_u = Q_o + D + E - I + \Delta S$$

Q_u = unregulated flow

Q_o = observed/measured flow

D = measured diversion

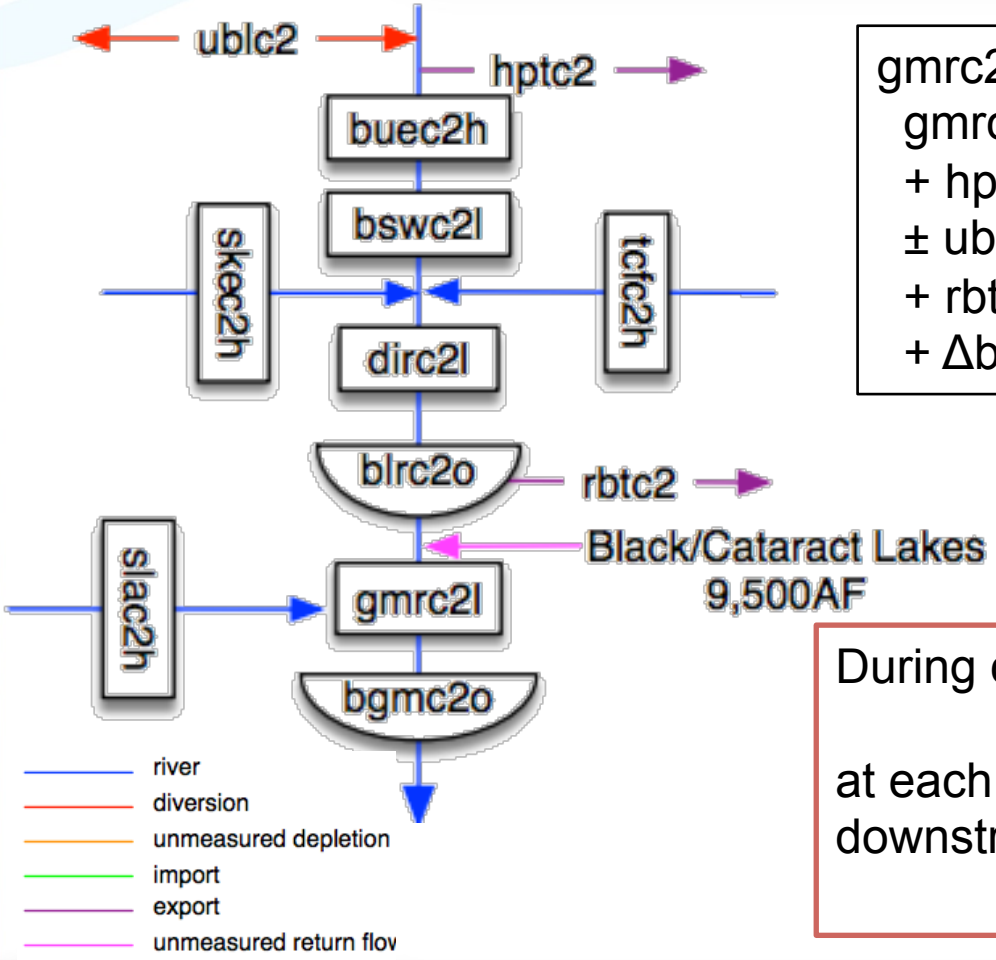
E = measured transbasin/transmountain export

I = measured import

ΔS = change in reservoir storage

CBRFC Model Setup

Blue River Basin



$gmrc2_{unreg}$ =
$gmrc2_{obs}$ (Green Mtn Res inflow)
+ hptc2 (Hoosier Pass Tunnel)
± ublc2 (Upper Blue Res operations)
+ rbtc2 (Roberts Tunnel)
+ Δblrc2 (Dillon Res storage)

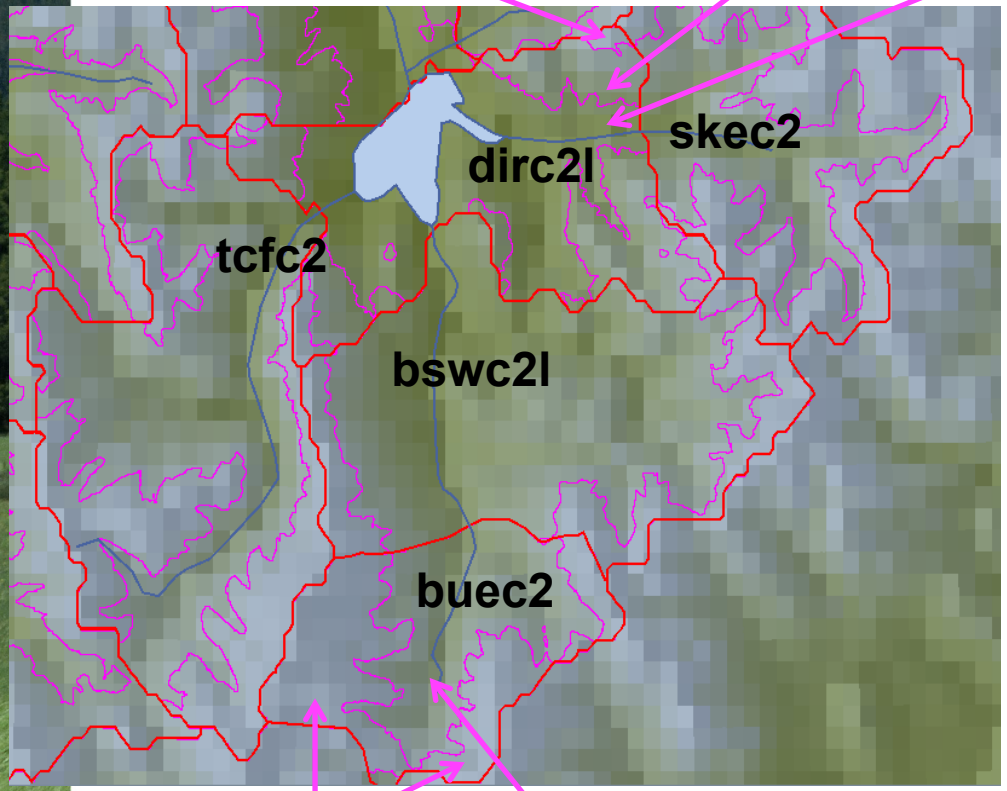
During calibration always check that
Unreg Sim ≈ Unreg Flow
at each segment as we move downstream.
$gmrc2_{sim} \approx gmrc2_{unreg}$

CBRFC Model Setup

Upper Area
11,500 ft – 13,753 ft
3 mi²

Middle Area
10,000 ft – 11,500 ft
34 mi²

Lower Area
8927ft – 10,000 ft
23 mi²



Each segment is broken into 2-3 subareas by elevation.

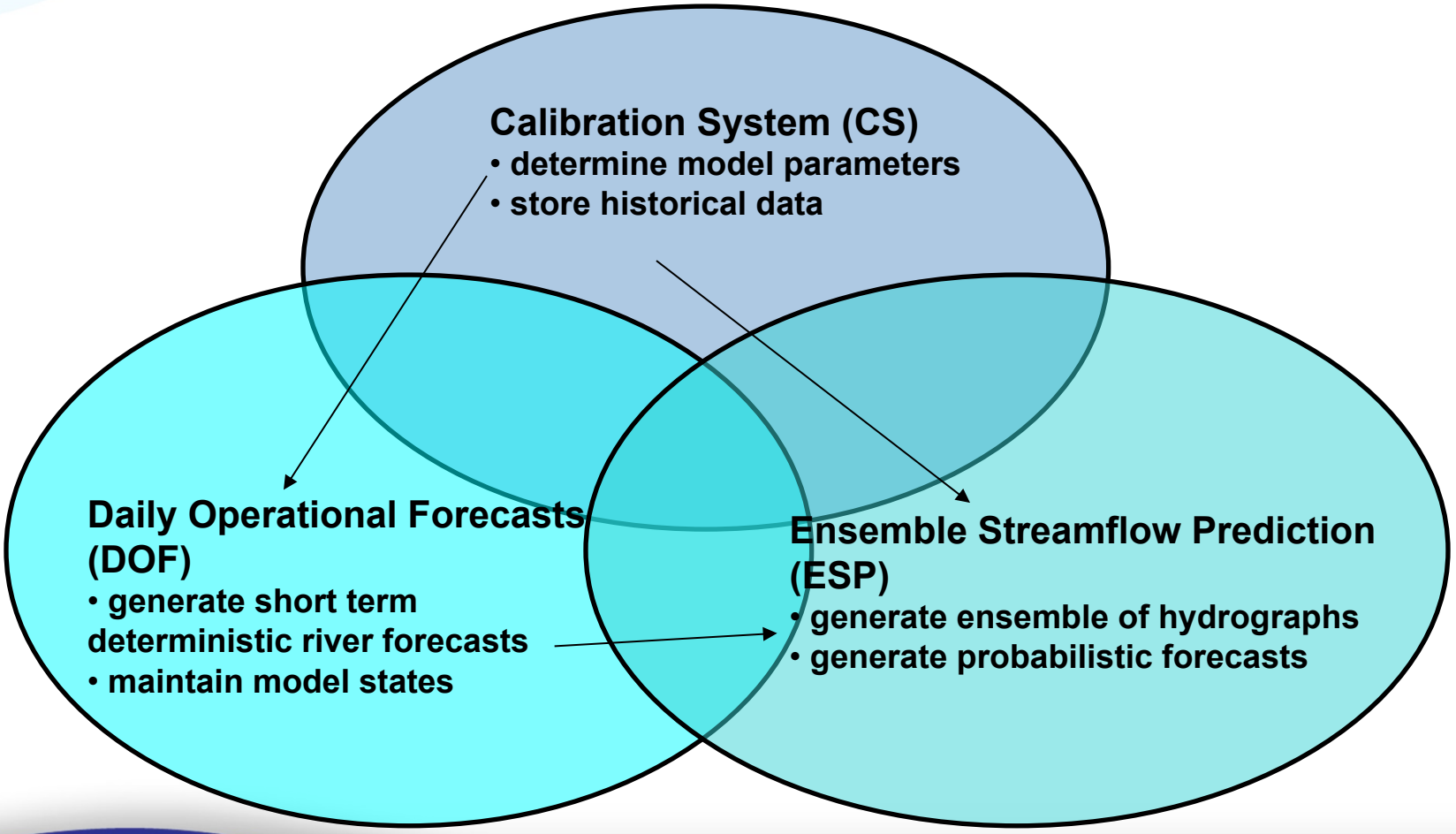
- These subareas should have similar soil, land cover, and snow accumulation/melt characteristics.
- Because it is a lumped model each of these subareas is represented by a single (mean areal) point for precipitation and temperature.

Upper Area
11,500 ft – 13,690 ft
21 mi²

Lower Area
9980 ft – 11,500 ft
21 mi²

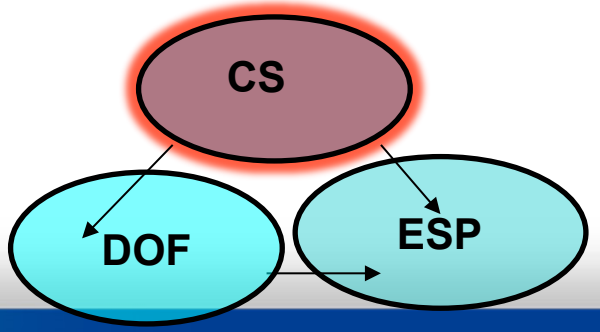
NWS River Forecast Model

Composed of three major interrelated components.



Calibration System (CS)

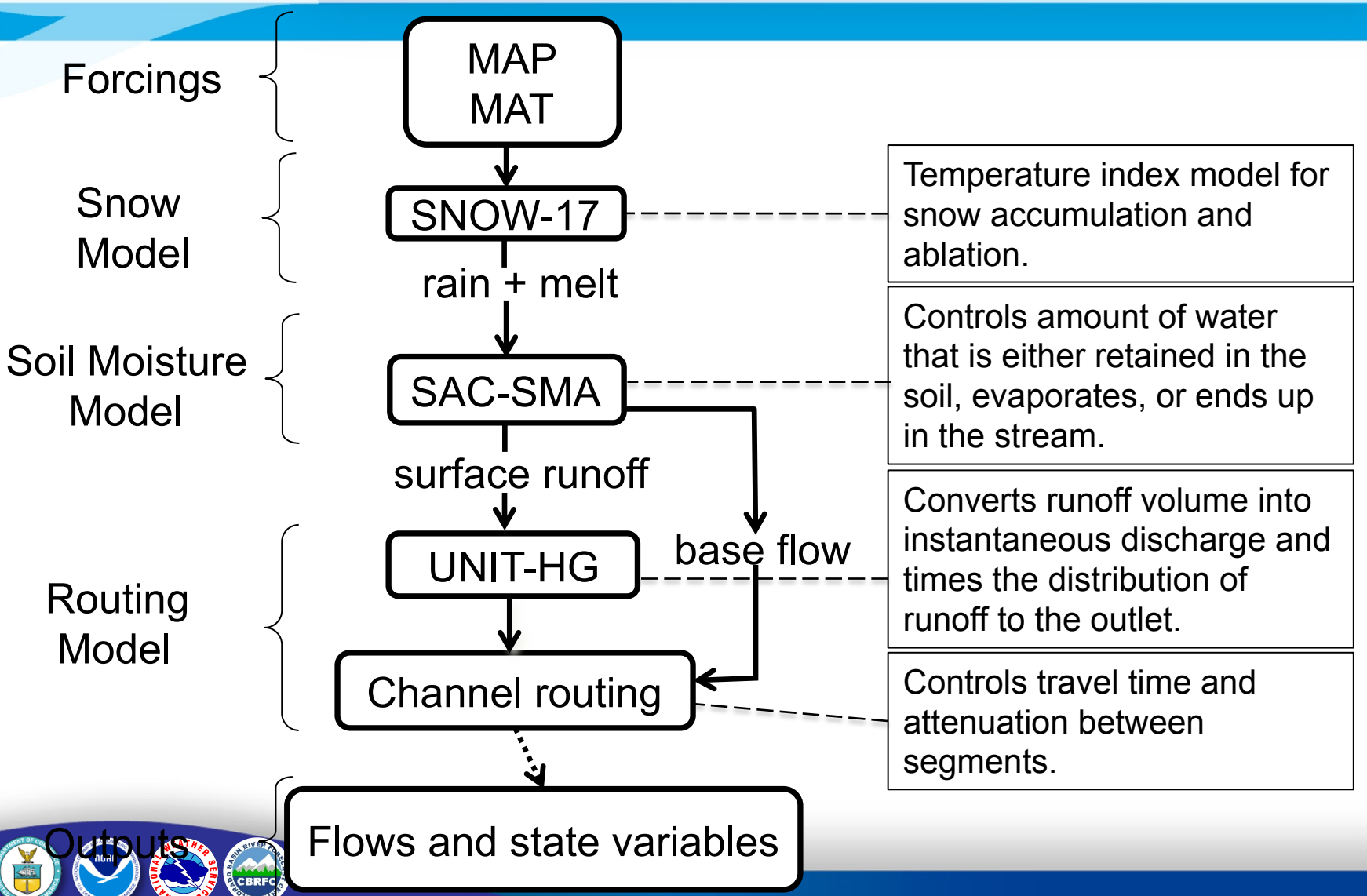
- Store historical precipitation, temperature and flow time series for the basin
- Choose from a variety of sub-models and processes
  - Snow model
  - Soil moisture model
  - Unit Hydrograph
  - Channel routing
  - Reservoir operations
- Determine the optimal set of parameters for each model, for each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



Calibration – Basics

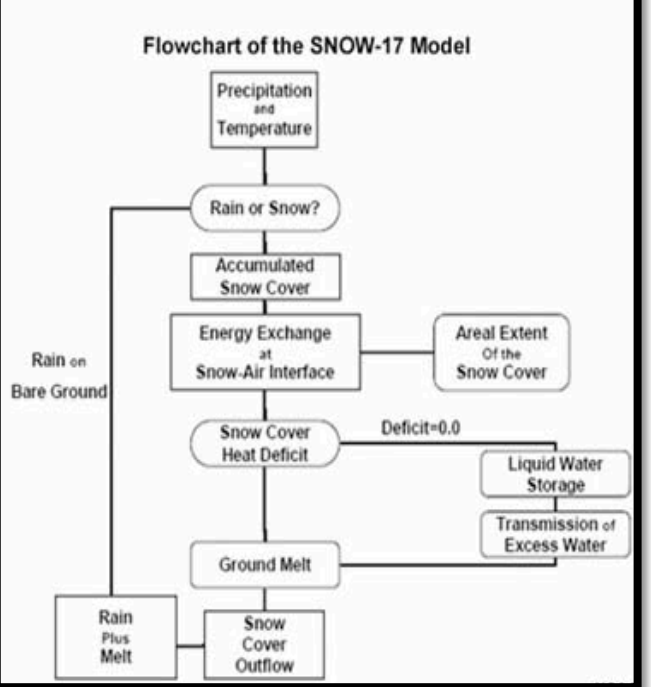
- Evaporation is determined through water balance and is regionalized.
  - Based on PRISM data sets.
- Forced by 30 years (1981-2010) of 6 hourly precipitation and temperature.
  - Mean Areal Precipitation (MAP) for each subarea is calculated using pre-determined station weights.
    - Use precipitation 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 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 30 years of calibration.

Calibration – Basics

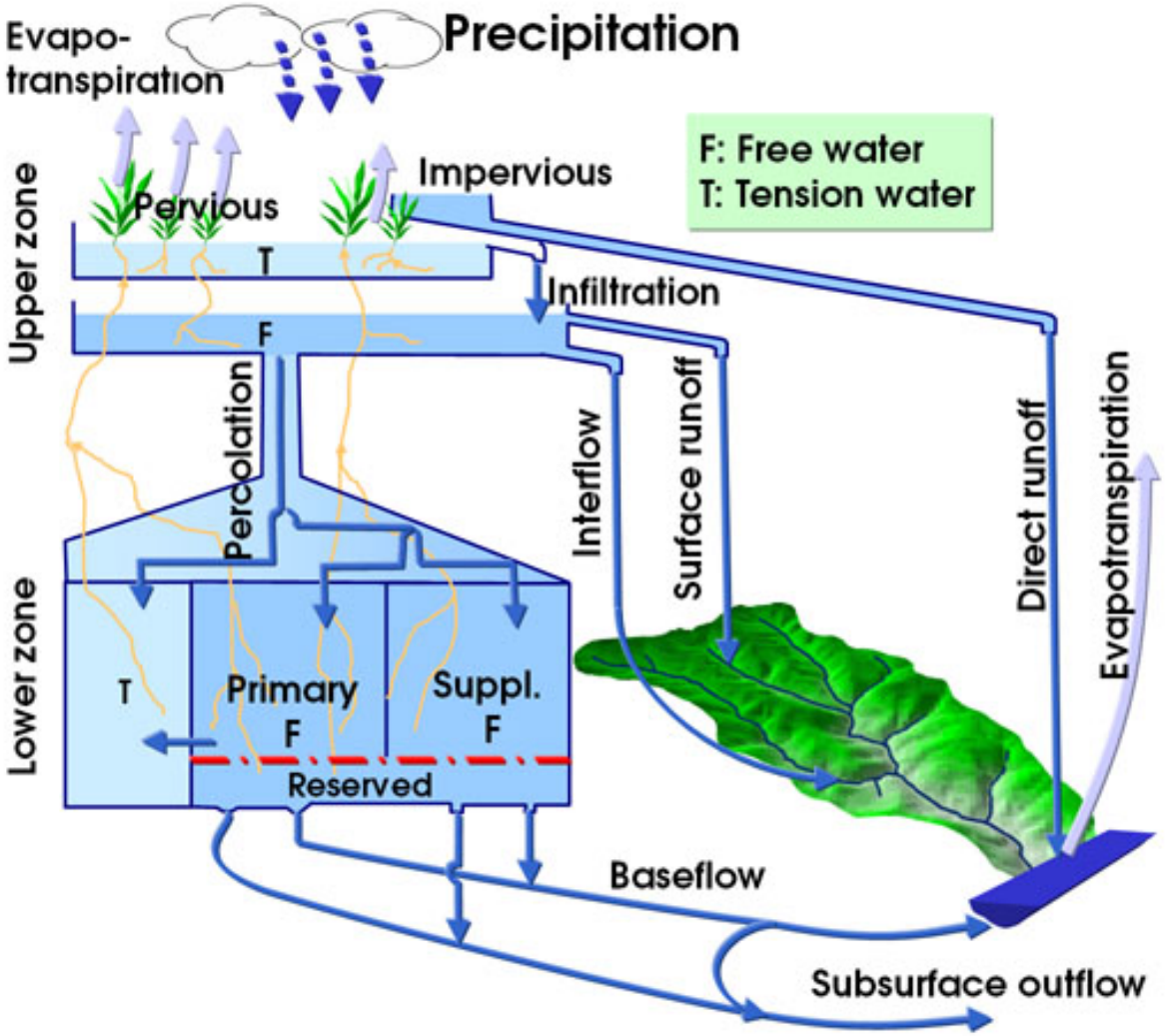


Snow and Soil Models

SNOW-17



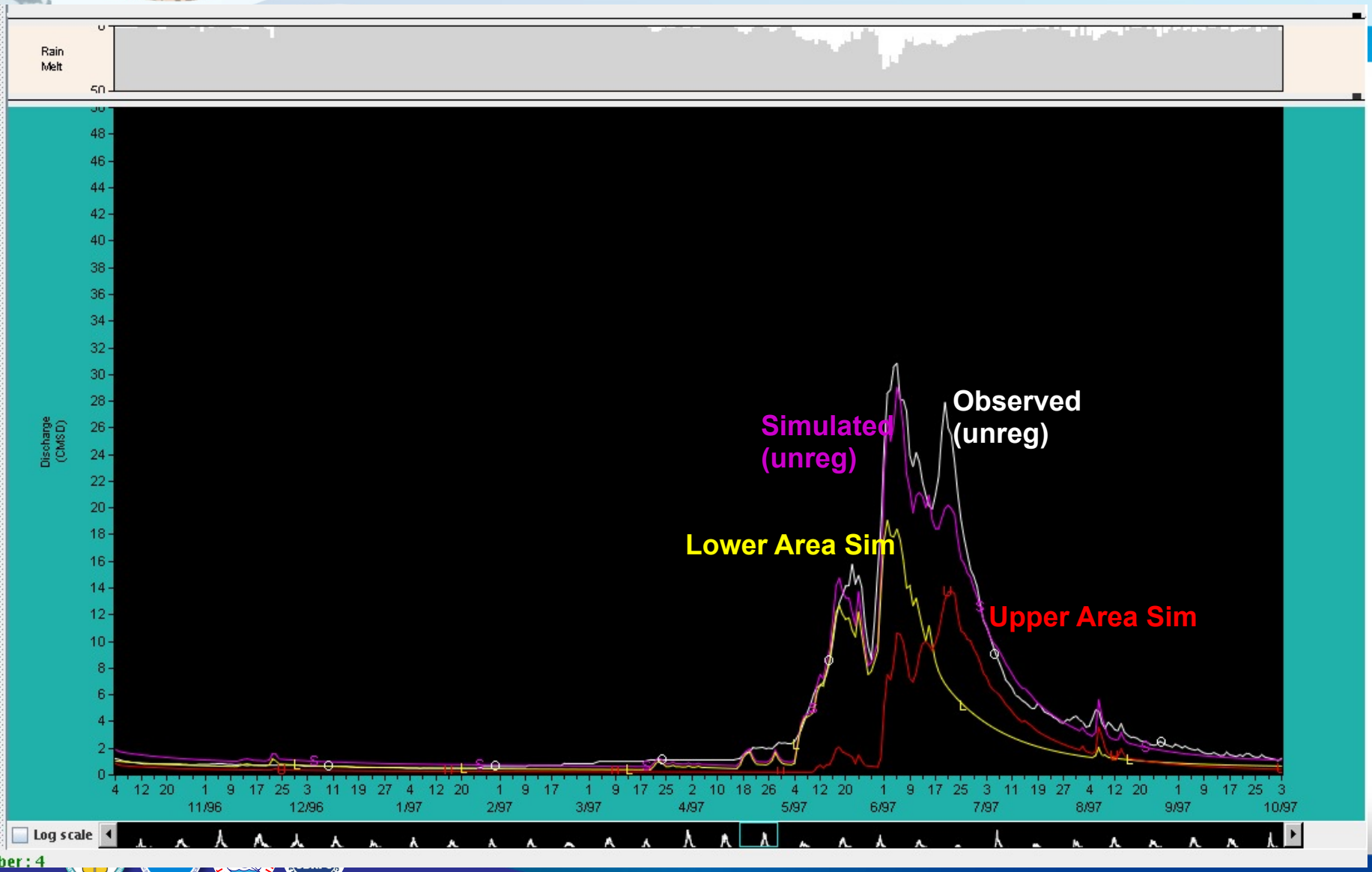
SAC-SMA



Calibration – Parameters

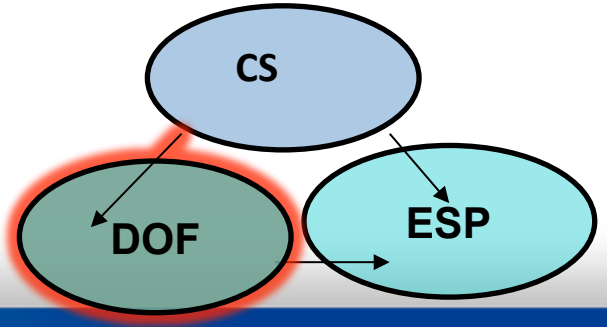
- Determine calibration parameters for each subarea
  - SNOW-17
    - 5 Major
      - Snow Correction Factor, Max and Min Melt Factors, Wind Function, Snow Cover Index, Areal Depletion Curve
    - 5 Minor
      - Temperature indexes and minor melt parameters
  - SAC-SMA
    - 11 Major
      - Tank sizes (5) and rates of drainage (interflow, percolation)
    - 5 Minor
      - Impervious area, Riparian Vegetation effects

Calibration – Results

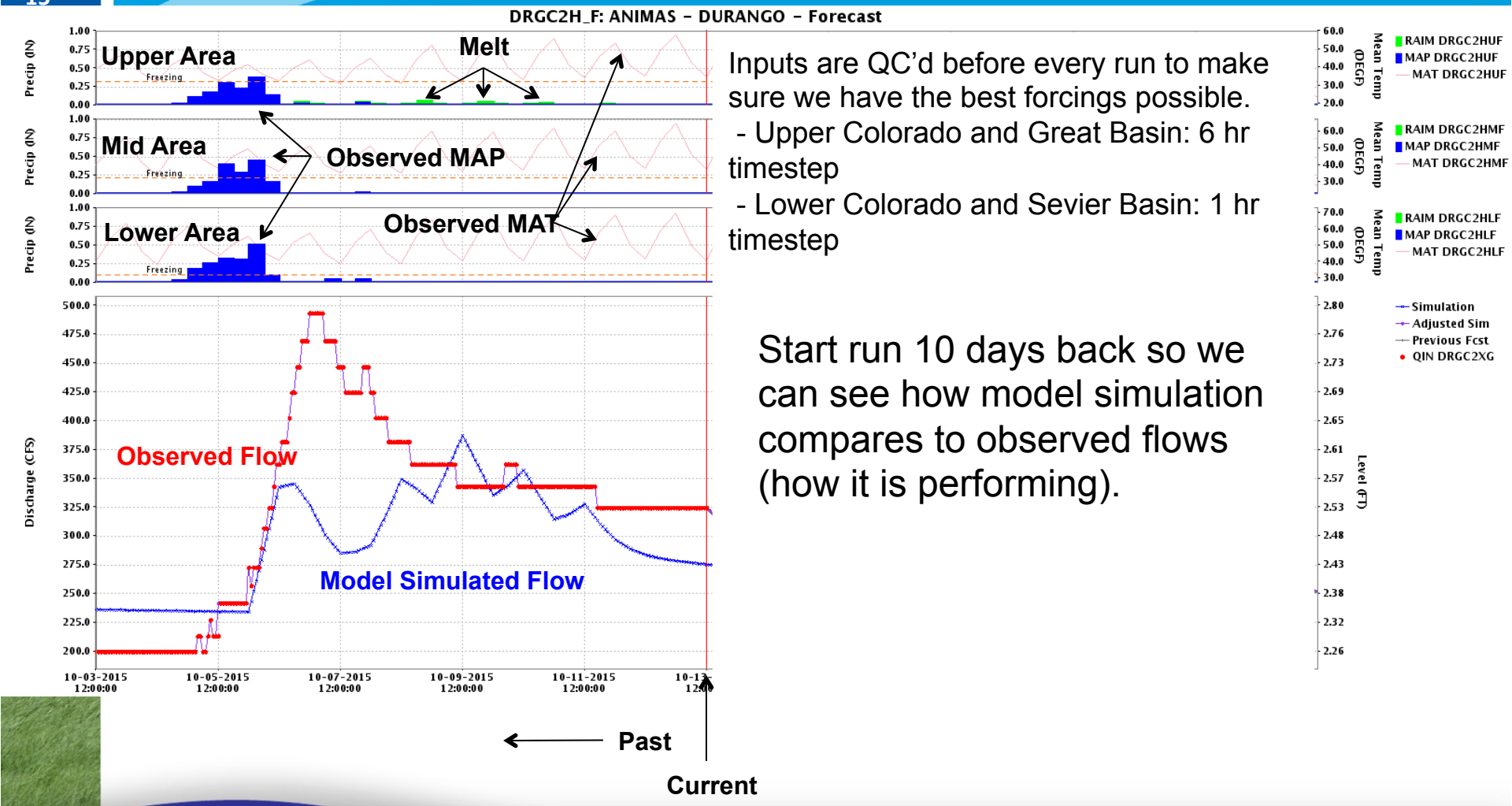


Daily Operational Forecast(DOF)

- Quality Controlled Inputs
  - Observed precipitation, temperature, and streamflow
  - Forecast precipitation (5 days) and temperature (10 days)
- Model adjusted by forecasters in real time
- Keeps track of model states, including soil moisture and snowpack
- Can be run multiple times per day so there is continual quality control, updating and adjusting
- Outputs 10 day *regulated* deterministic streamflow forecast



Daily Operational Forecasts

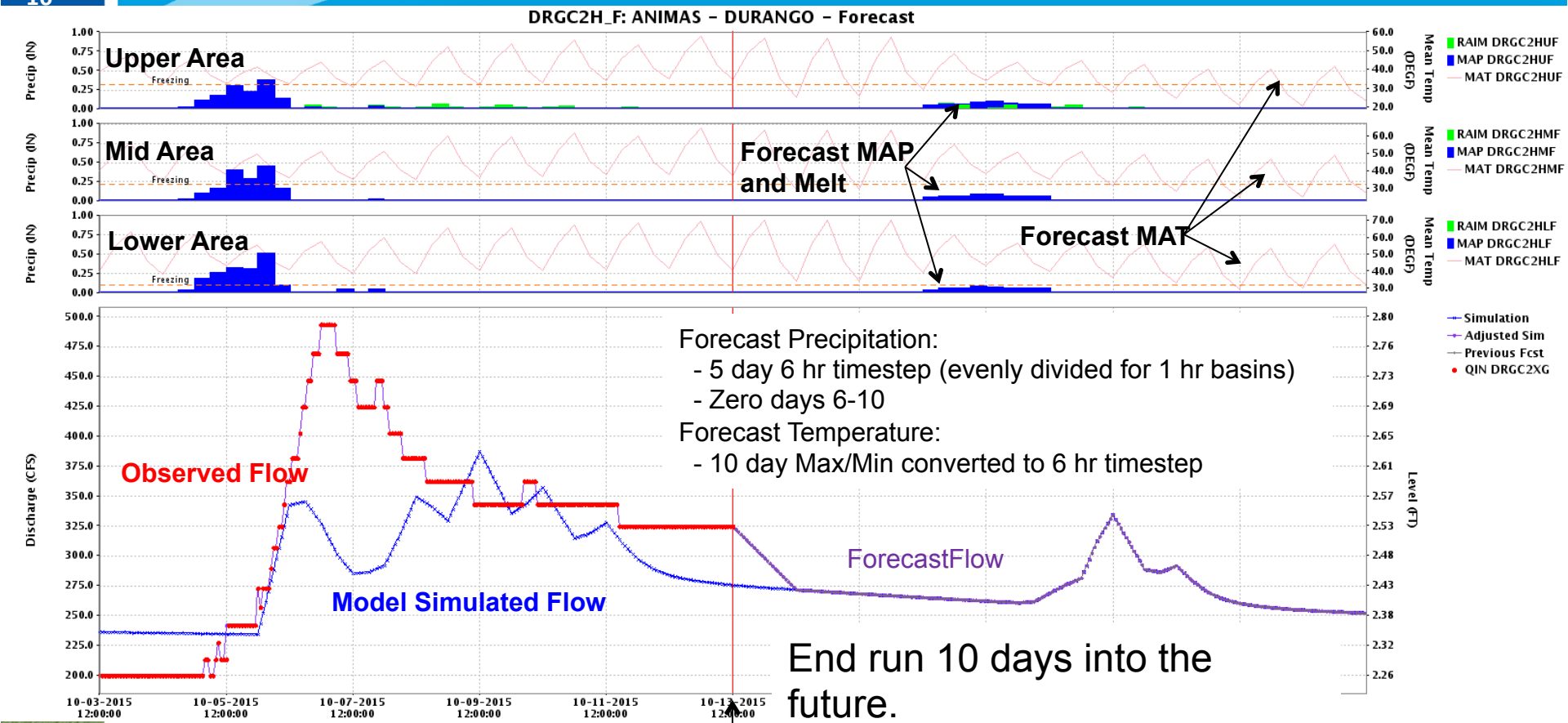


Inputs are QC'd before every run to make sure we have the best forcings possible.

- Upper Colorado and Great Basin: 6 hr timestep
- Lower Colorado and Sevier Basin: 1 hr timestep

Start run 10 days back so we can see how model simulation compares to observed flows (how it is performing).

Daily Operational Forecasts



Forecast Precipitation:
- 5 day 6 hr timestep (evenly divided for 1 hr basins)
- Zero days 6-10

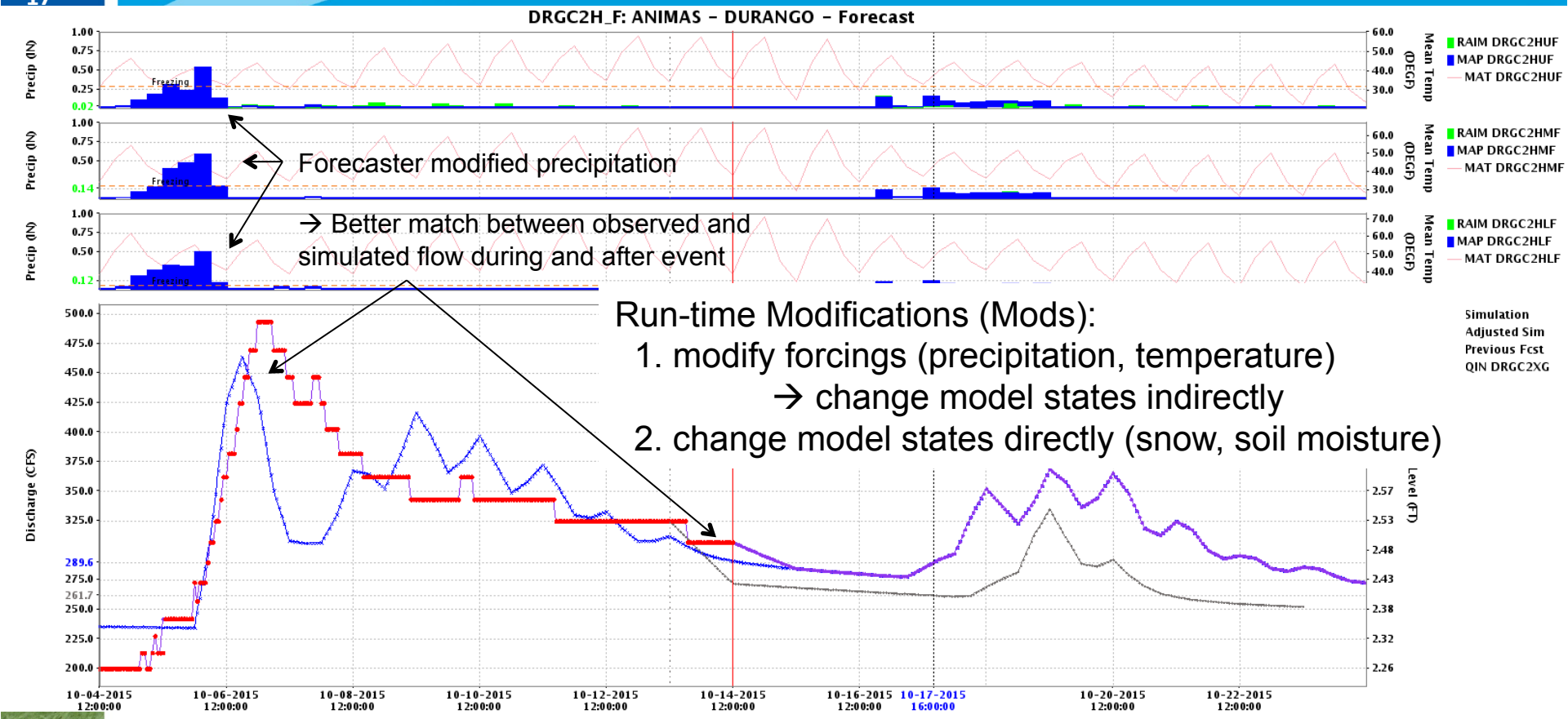
Forecast Temperature:
- 10 day Max/Min converted to 6 hr timestep

End run 10 days into the future.

← Past | Future →

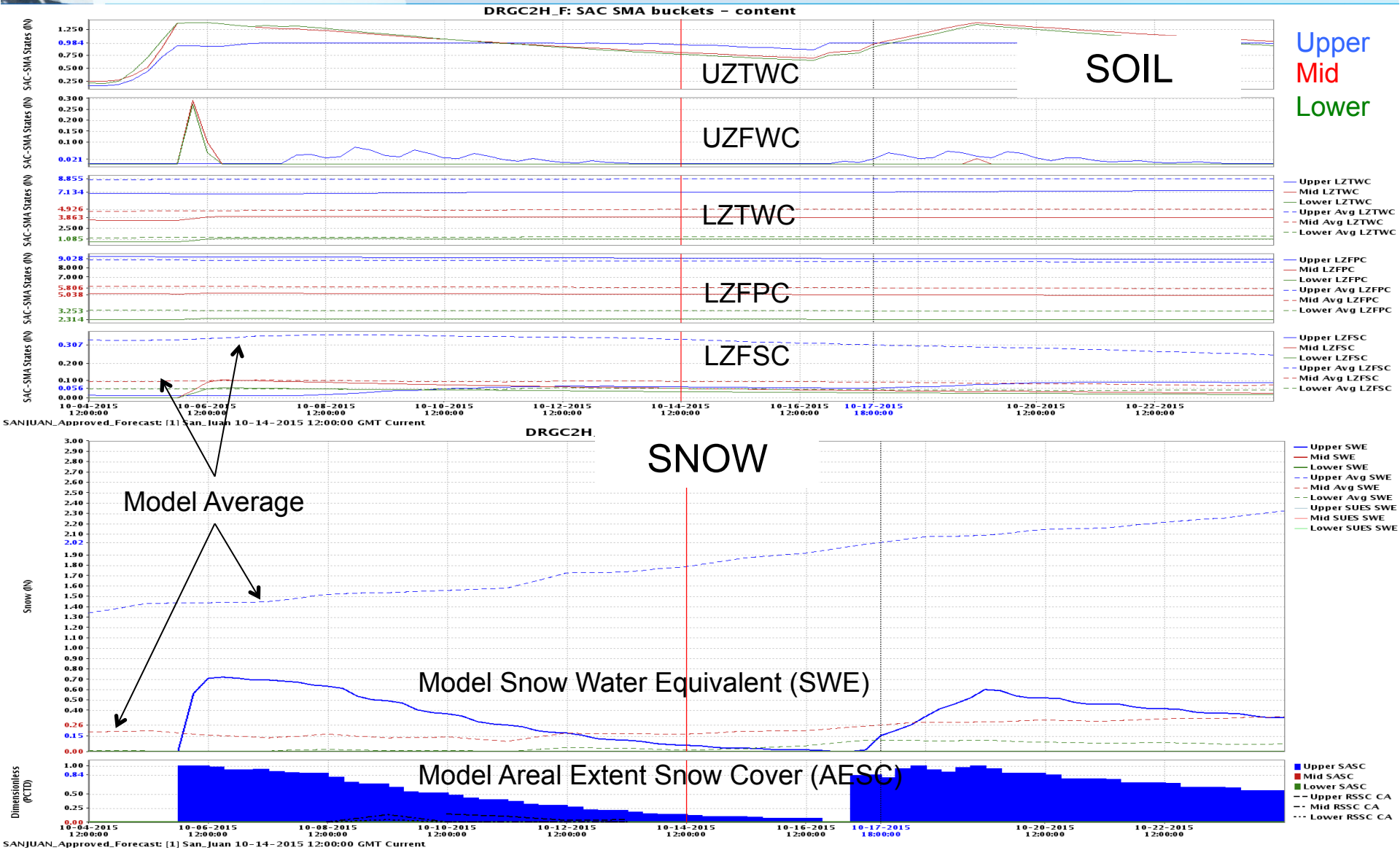
Current

Daily Operational Forecasts



Modifications must be reasonable and make sense – don't want to do whatever is necessary to make it match exactly. This gives us a better chance of simulating the next event correctly.

Daily Operational Forecasts

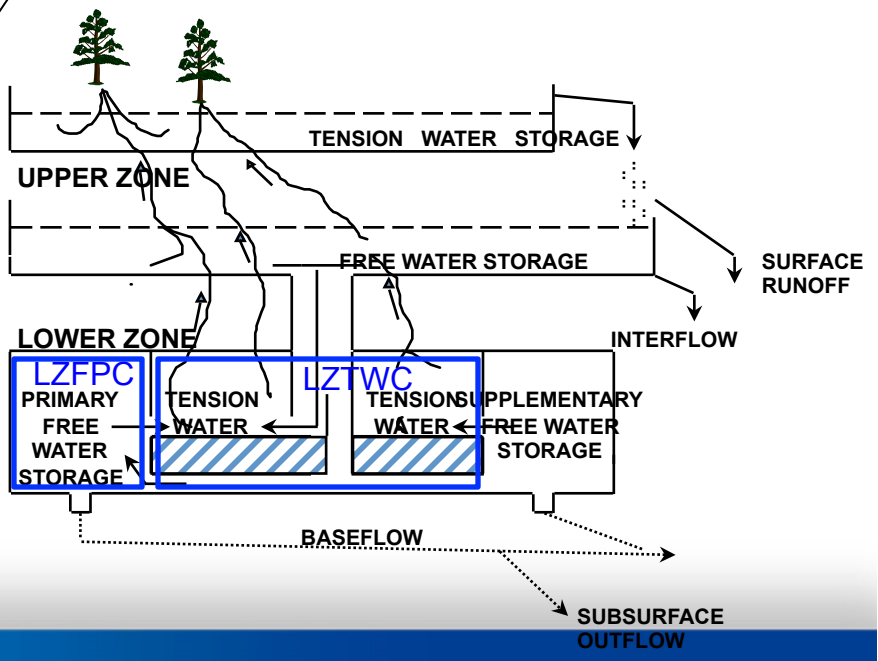


Operations
Initial Conditions – Soil Moisture

LZFPC (baseflow or free water)
1. Carryover from previous season
2. Affected some by fall precipitation
3. Adjusted by flow observations in fall/early winter

LZTWC (tension water)
1. Little carryover from previous season
2. Affected strongly by fall precipitation
3. Regionally adjusted

Initial fall soil moisture
1. Can have a moderate impact on spring runoff (+/- 5-10 %)
2. Typical Capacity of LZTWC +LZFPC ~ 15 inches



SWE Accumulation Period

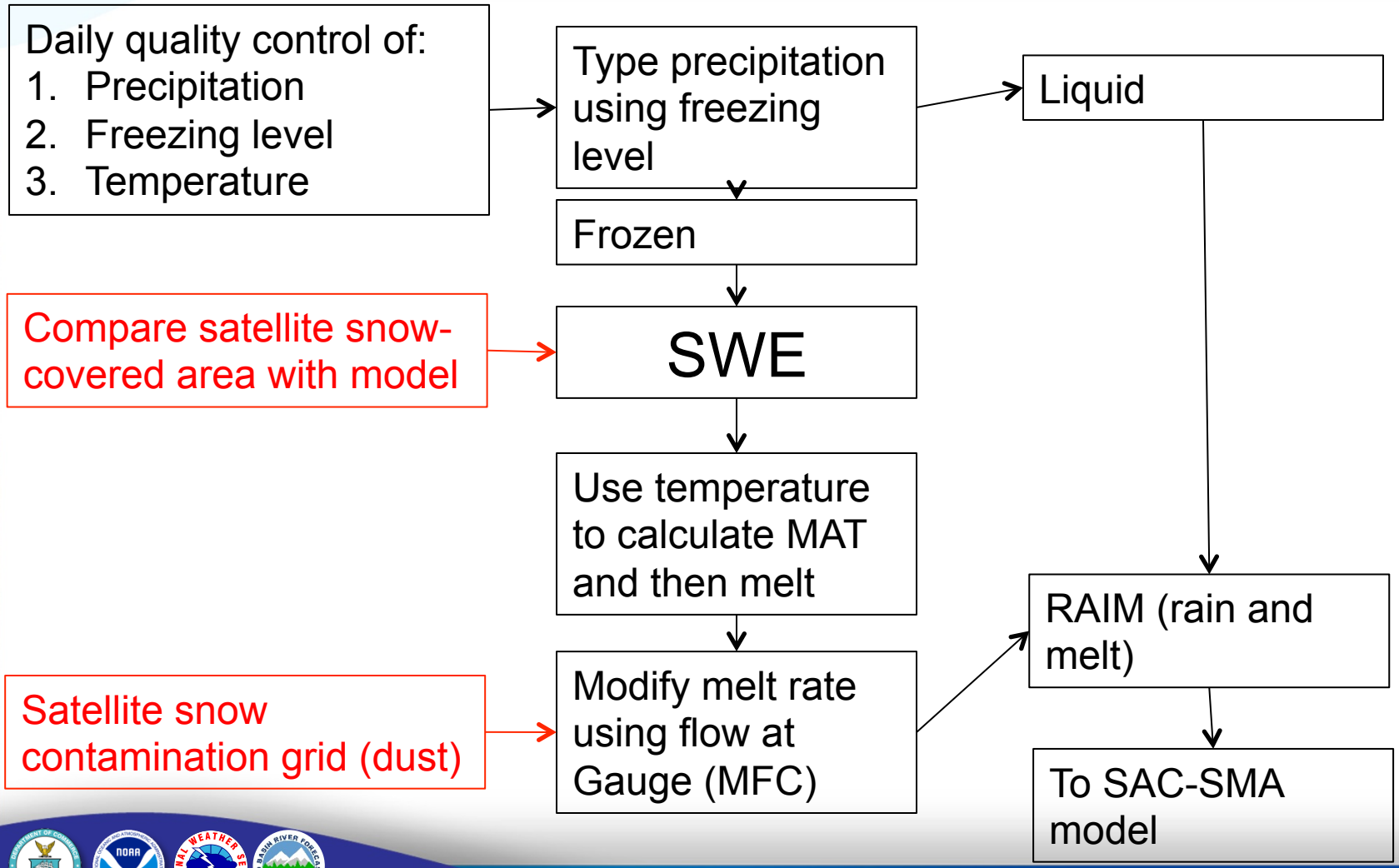
Daily quality control of:
1. Precipitation
2. Freezing level
3. Temperature

Create MAPS from points using pre-determined station weights (from calibration)

Update by calculating precipitation over a longer time step (weeks to months). This update done every 1-2 weeks.

SWE

SWE Melt Period

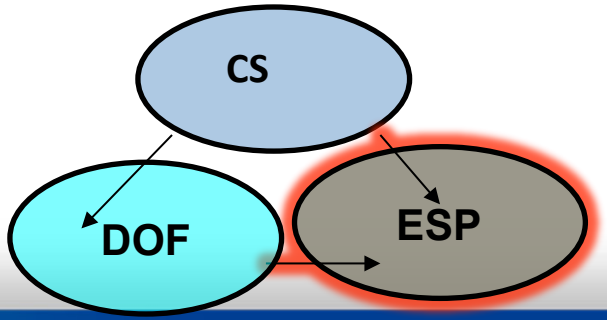


Daily Operational Forecasts

- Regulated (trying to match observed flow in river)
  - Future diversions:
    - Set to current
    - Specified
    - Best guess
  - Future reservoir releases:
    - Set to current
    - Specified (input a schedule)
    - Spill

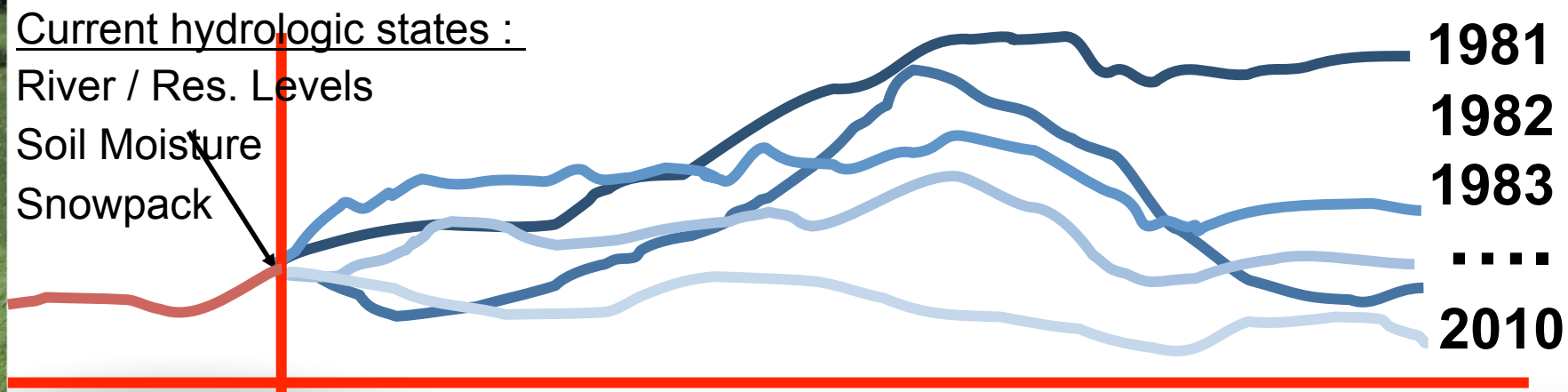
Ensemble Streamflow Prediction (ESP)

- Uses model states from DOF as starting point and can also use forecast precipitation (5 days) and temperature (10 days) inputs
- Uses historical precipitation and temperature time series from CS and statistical distributions to derive probabilistic flow forecasts
- Can adjust output for model bias

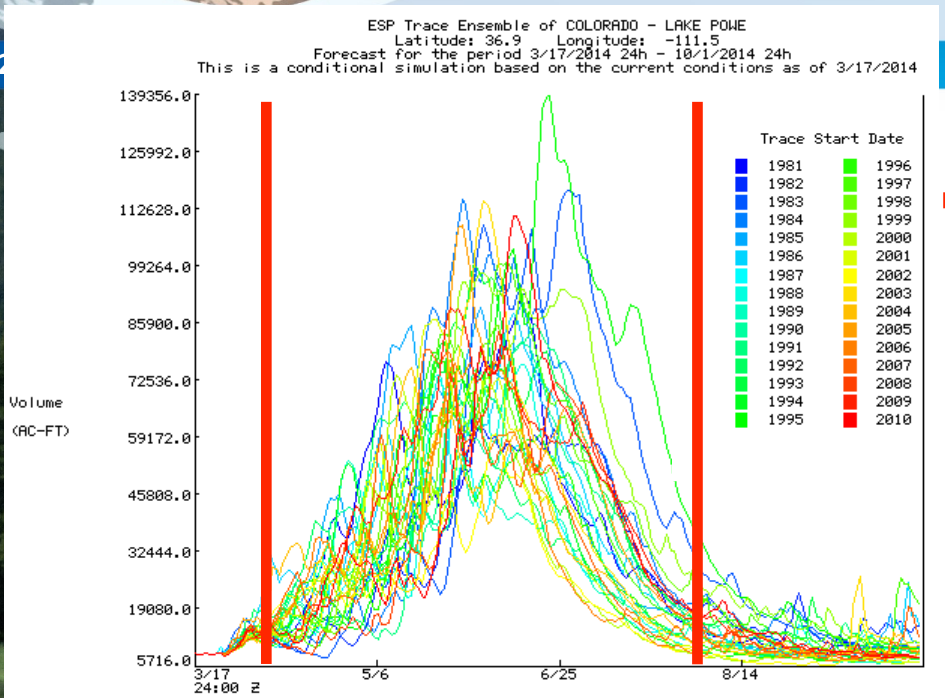


ESP Probabilistic Forecasts

- Start with current conditions (from the daily model run)
- Apply precipitation and temperature from each historical year (1981-2010)
- A forecast is generated for each of the years (1981-2010) *as if, going forward,* that year will happen
- This creates 30 possible future streamflow patterns. Each year is given a 1/30 chance of occurring



ESP Probabilistic Forecasts



1. The flows are summed into volumes for the period of interest (typically April 1 – July 31)
2. The statistics are simplified
3. 50% exceedance value approximates the most probable forecast

1

```
# EMPIRICAL SAMPLE POINTS
#          Cond.
#Trace     Year       Data Exceed.
# year     Weight     Point   Prob.
# ---------------------------------
  1981  0.033 10583427.0  0.290
  1982  0.033 8372498.00  0.806
  1983  0.033 12646544.0  0.065
  1984  0.033 11904022.0  0.129
  1985  0.033 11402967.0  0.161
  1986  0.033 10406237.0  0.355
  1987  0.033 8369501.00  0.839
  1988  0.033 8719326.00  0.742
  1989  0.033 7605042.50  0.935
  1990  0.033 9761623.00  0.452
  1991  0.033 9690117.00  0.484
  1992  0.033 9298360.00  0.613
  1993  0.033 10987106.0  0.226
  1994  0.033 9395003.00  0.548
  1995  0.033 14388755.0  0.032
  1996  0.033 8611564.00  0.774
  1997  0.033 10736442.0  0.258
  1998  0.033 10159611.0  0.419
  1999  0.033 12520652.0  0.097
  2000  0.033 8252478.50  0.871
  2001  0.033 9312369.00  0.581
  2002  0.033 6439105.00  0.968
  2003  0.033 9439112.00  0.516
  2004  0.033 8867351.00  0.710
  2005  0.033 10415361.0  0.323
  2006  0.033 8235550.00  0.903
  2007  0.033 8964843.00  0.645
  2008  0.033 8954274.00  0.677
  2009  0.033 11320183.0  0.194
  2010  0.033 10185848.0  0.387
```

2

```
# Exceedance     Conditional
# Probabilities  Simulation
# ----------------------------
  0.900          8237243.000
  0.800          8420311.000
  0.700          8893428.000
  0.600          9303964.000
  0.500          9564614.000
  0.400          10175353.000
  0.300          10533006.000
  0.200          11253565.000
  0.100          12458982.000
```

3

ESP Probabilistic Forecasts

Unregulated Mode

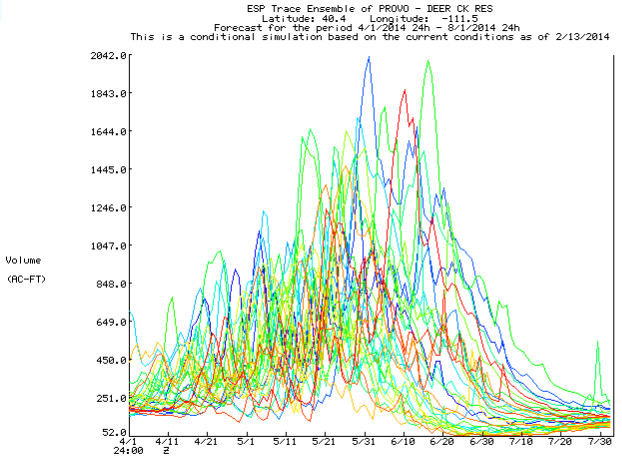
- Reservoirs ignored
  - Water is just passed through them.
- Measured diversions set to zero
  - No water diverted into or out of the basin.
- Unmeasured depletions still removed
- Used for Water Supply volume forecasts
  - Some exceptions in Sevier and Great Basin

Regulated Mode

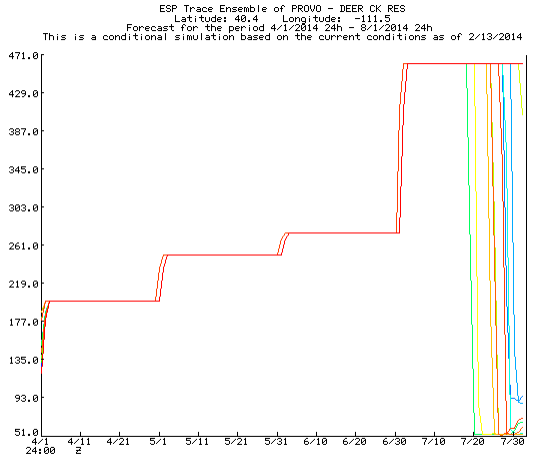
- Reservoirs use rules defined in model
  - Releases set based on time of year or simulated elevation of reservoir.
  - Spill, pass flow.
  - Can input a single release schedule if known that far into future.
- Diversions use historical data
  - Trace that uses 1995 MAP/MAT also uses 1995 diversions.
- Unmeasured depletions still removed
- Used mostly for mean daily Peak Flow forecasts

ESP Probabilistic Forecasts

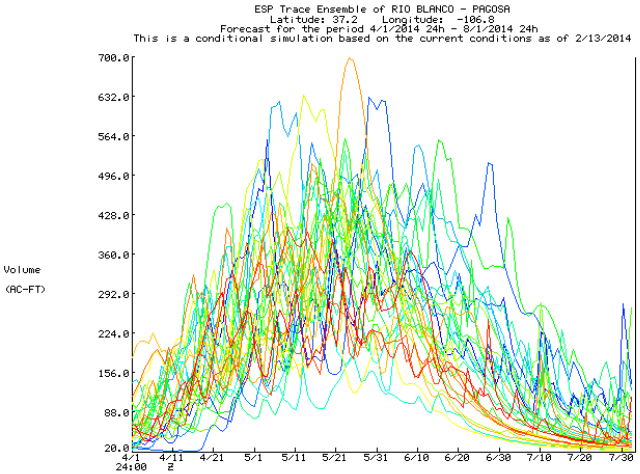
Unregulated Mode



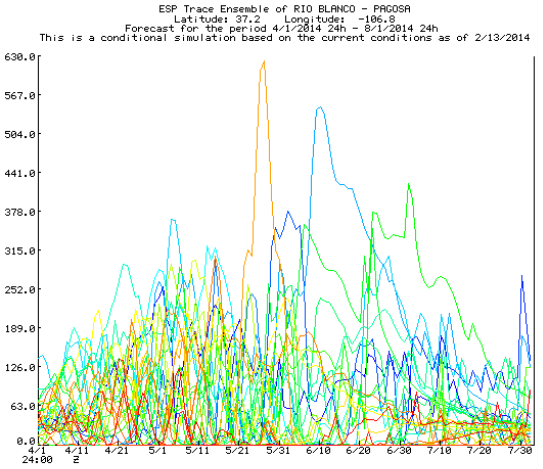
Regulated Mode



Reservoir



Diversion



DOF vs. ESP

Daily Deterministic Forecasts

- Regulated
- INITIAL CONDITIONS ARE VERY IMPORTANT
  - Soil moisture
  - SWE
  - Reservoir elevations/releases
  - Diversions
- Forcings are deterministic
  - Five days of forecast precipitation (QPF)
    - Zero beyond this
  - 10 days of forecast temperature (QTF)
    - Climatological average beyond this
- Creates and saves model states that become starting point for ESP

ESP Probabilistic Forecasts

- Unregulated or Regulated
- INITIAL CONDITIONS ARE VERY IMPORTANT
  - Soil moisture, SWE
  - Current reservoir information *not used in unregulated mode*.
  - Diversion data *used in regulated mode only* is from historical years.
- Forcings are probabilistic
  - Uses 30 years of MAP and MAT from calibration to create 30 hydrologic traces/ scenarios.
  - QPF and QTF
    - Deterministic QPF (5 days) and QTF (10 days)
    - Can use ensemble QPF and QTF from weather and/or climate models (test mode)