Road to the Forecast
• **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 Reservoir
- **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.

Lower Zone: 8,320 ft - 11,000 ft (69 mi²)

Upper Zone: 11,000 ft - 14,172 ft (36 mi²)
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

Observed (unregulated)

Simulated (unregulated)

Lower Area Simulation

Upper Area Simulation
Each river point in the model is called a segment.

There are 486 segments in the CBRFC area.
## Calibration Errors

<table>
<thead>
<tr>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Errors in data used in model calibration</td>
<td>Model is conceptual so many hard-to-measure parameters are estimated</td>
</tr>
<tr>
<td>Density and availability of data over an area</td>
<td>Basin scale model may not capture characteristics at smaller spatial scales</td>
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</tbody>
</table>
Operational Timeline

Soil Moisture / Baseflow

Snow Accumulation

Melt Occurs

Irrigation Season

Verification / Model Improvements

OCT  NOV  DEC  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT
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
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
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
Operational Timeline

- **Soil Moisture / Baseflow**
- **Snow Accumulation**
- **Irrigation Season**
- **Verification / Model Improvements**
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)
• 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

Past -- Future
ESP Range of Possibilities

Trace Ensemble for DRRC2H_F

Initial conditions known for January 1st

A lot of unknown between Jan 1st and start of the forecast period of April 1st

Forecast period of interest
Exceedance Probabilities for DRRC2H_F: DRRC2H_F

Trace Ensemble for DRRC2H_F
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OCT  NOV  DEC  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT
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

Trace Ensemble for DRRC2H_F

Initial conditions known for April 1st
Still a lot possible runoff outcomes primarily due to spring weather
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
We use 5 days of forecast precipitation and 10 days of forecast temperature in our daily streamflow forecasts.

April to June - Melt Occurs

- Increases due to forecast warming

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
Operational Timeline

- Soil Moisture / Baseflow
- Snow Accumulation
- Melt Occurs
- Irrigation Season
- Model Improvements

Timeline:
- OCT
- NOV
- DEC
- JAN
- FEB
- MAR
- APR
- MAY
- JUN
- JUL
- AUG
- SEP
- OCT
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

- **Soil Moisture / Baseflow**
- **Snow Accumulation**
- **Melt Occurs**
- **Irrigation Season**
- **Verification / Model Improvements**
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?