

# Water Supply Forecasting Tools and Processes

Forecast Verification Workshop

February 19, 2008

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# Water Supply Forecasting Tools and Processes

- Statistical Water Supply (SWS)
- NWS River Forecast System - Ensemble Streamflow Prediction (ESP)
- Coordination with the Natural Resources Conservation Service (NRCS)
- Sources of Error
- When and What



# Statistical Water Supply (SWS)

- Regression equations that relate observed data to future seasonal streamflow volume.
- Inputs are monthly values.
  - Total precipitation (can be multiple months)
  - First of month snow water equivalent
  - Monthly flow volume
  - Climate indices (SOI)
- Output is a seasonal volume (i.e. April-July).
  - It is really a conditional probability distribution, not a single value; the equation result is the 50% exceedance.
  - Other exceedance levels (10%, 90%, etc.) can be calculated by using the standard error.



# Statistical Water Supply (SWS)

Sample Equation for April 1:

Apr-Jul volume for Dillon Reservoir

Apr 1 swe Fremont Pass Snotel

Apr 1 swe Hoosier Pass Snotel

Apr 1 swe Grizzly Peak Snotel

Nov-Mar precip Dillon

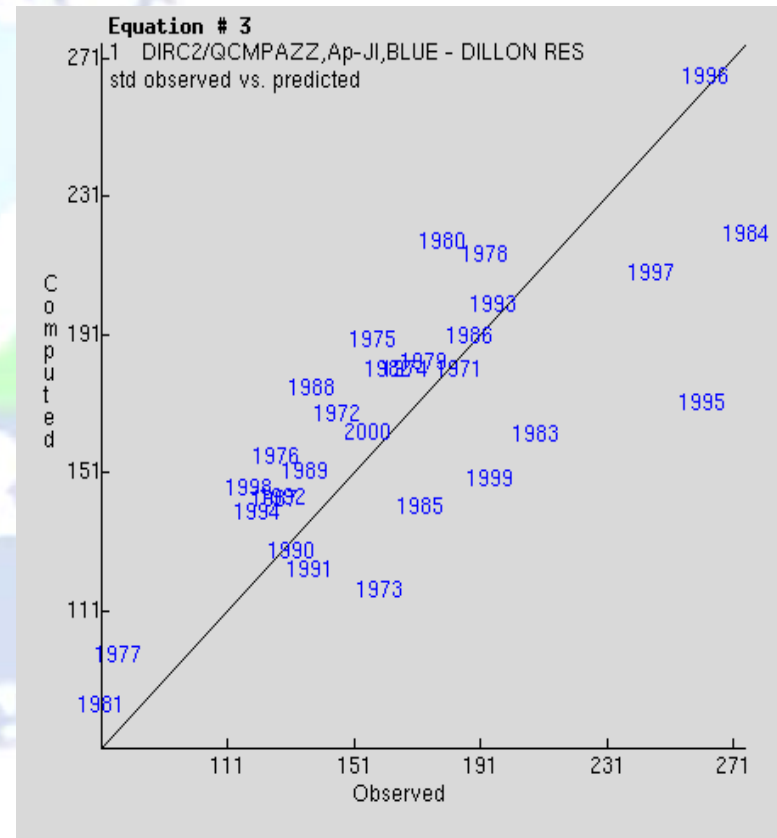
Nov-Mar precip Breckenridge

$R^2 = .60$

Standard Error = 32.02

Number of observations = 30 (1971-2000)

Number of principal components used = 1



# Statistical Water Supply (SWS)

File Options Actions Help

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FREMONT PASS FMTC2/SWIRMZZ
    Apr  16.90Z   104% *   3.197 =   54.03

HOOSIER PASS H00C2/SWIRMZZ
    Apr  15.40Z   105% *   2.469 =   38.02

GRIZZLY PEAK GZPC2/SWIRMZZ
    Apr  17.80Z   104% *   1.933 =   34.41

DILLON 1E DLLC2/PPMRZZZ (Nov - Mar):
    Nov   0.67V   75%
    Dec   0.49V   59%
    Jan   0.59V   70%
    Feb   0.72V   77%
    Mar   0.96V   85%
-----
    3.43       74% *   5.891 =   20.21

BRECKENRIDGE BRGC2/PPMRZZZ (Nov - Mar):
    Nov   0.91V   66%
    Dec   1.15E   88%
    Jan   1.44V  101%
    Feb   2.38Q  169%
    Mar   1.79V   99%
-----
    7.67       104% *   3.474 =   26.65

-----
-6.762 +           173.31 =   166.55 ( 100%)
    
```

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DIRC2	Coordinated	Model Computed	Comp. w/ Coord.	NWS Preferred.	Other Agency
R. Max	190.00 114%	211.17 126%		199.62 120%	0.00 0%
<b>Most Prob.</b>	<b>150.00 90%</b>	<b>166.55 100%</b>		<b>155.00 93%</b>	<b>150.00 90%</b>
R. Min	116.00 69%	121.93 73%		110.38 66%	0.00 0%

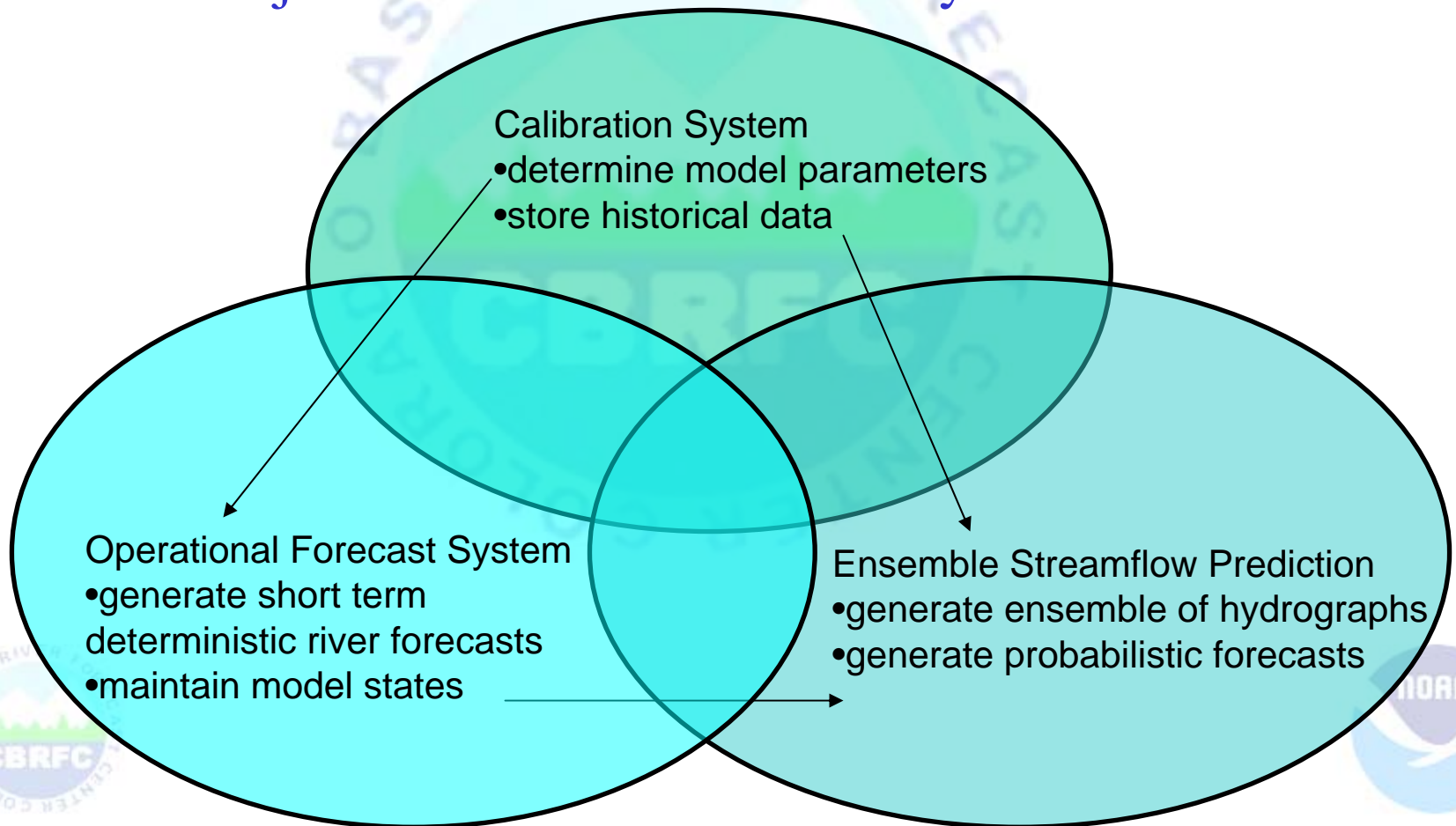
Input Specification | Eqn Output/Fcst Input | Fcst Point Stats | Eqn Stats | Fcst Performance (Oper) | Fcst Performance (Calib) | Log

nextreg ver 2.2.5



# NWS River Forecast System

- Continuous, conceptual hydrologic model composed of three major interrelated functional systems.



# Calibration System (CS)

- Choose from a variety of models and processes that can:
  - Simulate snow accumulation and ablation.
  - Compute runoff using a soil moisture model.
  - Time the distribution of runoff from the basin to the outlet.
  - Perform channel routing.
  - Model reservoir operations.
- Determine the optimal set of parameters for each model to best simulate flow.
- Store historical precipitation, temperature and flow time series for the basin.



# Operational Forecast System (OFS)

- Keeps track of model states, including soil moisture and snowpack.
- Inputs are:
  - Observed precipitation, temperature, and streamflow (which have been quality controlled before input).
  - Forecast precipitation (5 days) and temperature (10 days).
  - \*\*Note: snow/swe is not a direct input, the snow model within each segment builds and melts its own snowpack based on precipitation and temperature inputs.
- Segments/states can be adjusted by forecasters in real time.
  - Snow states are updated at the beginning of each winter month by comparing model simulated snowpack to SNOTEL site data (not a one to one relationship).
- Run multiple times per day so there is continual quality control, updating and adjusting.



# Ensemble Streamflow Prediction (ESP)

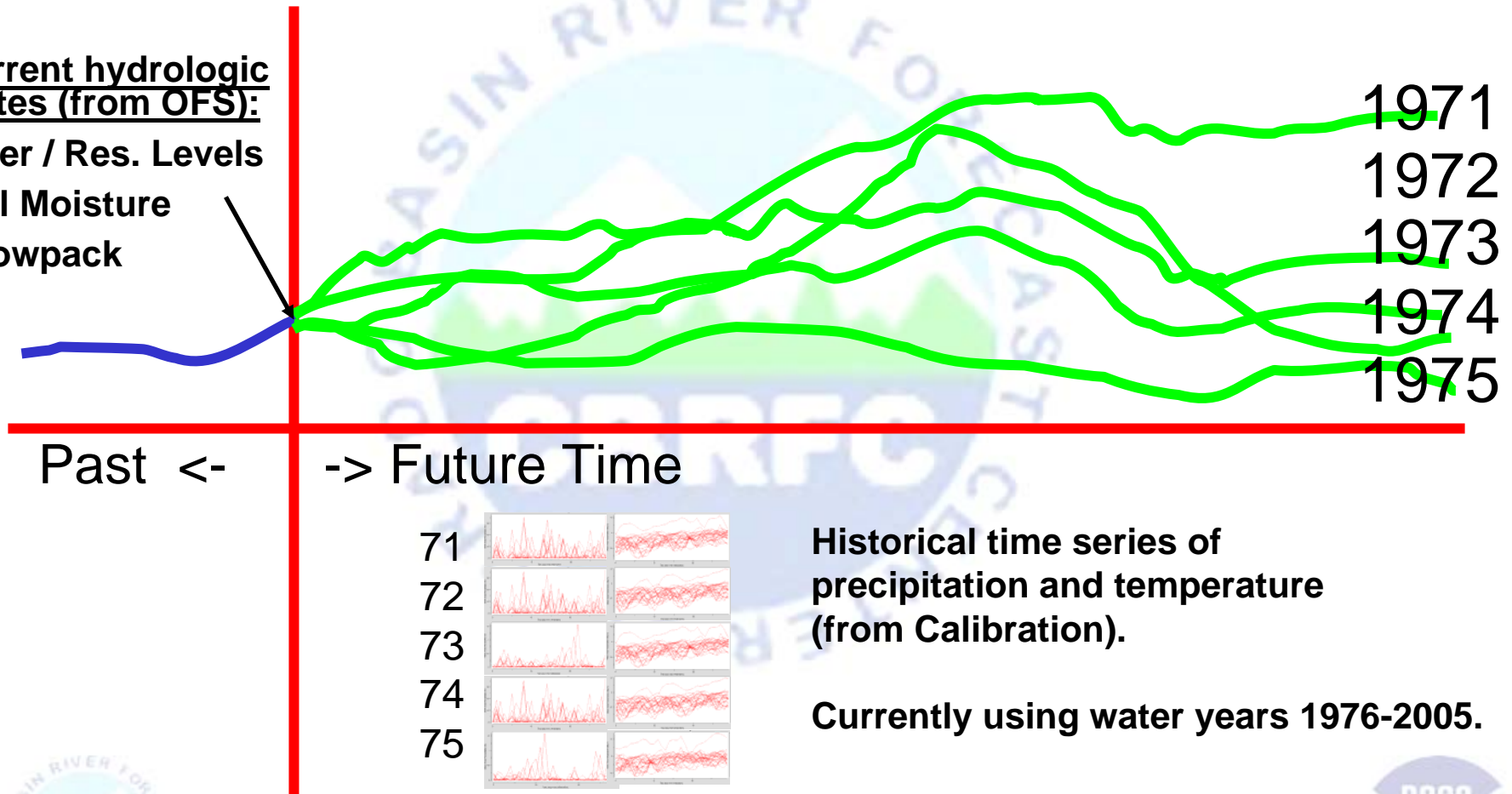
- Uses model states from OFS as starting point and can also use the QPF (5 days) and QTF (10 days) inputs.
- Uses historical precipitation and temperature time series from CS and statistical distributions to derive probabilistic flow forecasts.
  - Can choose different probability distributions (e.g. empirical, log, wakeby).
  - Can display any exceedance levels wanted.
- Can be pre- or post- adjusted with climate forecasts.
- Can adjust output for model (calibration) bias.



# Ensemble Streamflow Prediction (ESP)

Current hydrologic states (from OFS):

River / Res. Levels  
Soil Moisture  
Snowpack



Start with current conditions – Apply each year of historical climate – Create several possible future streamflow patterns

# Ensemble Streamflow Prediction (ESP)

5 days forecast precipitation

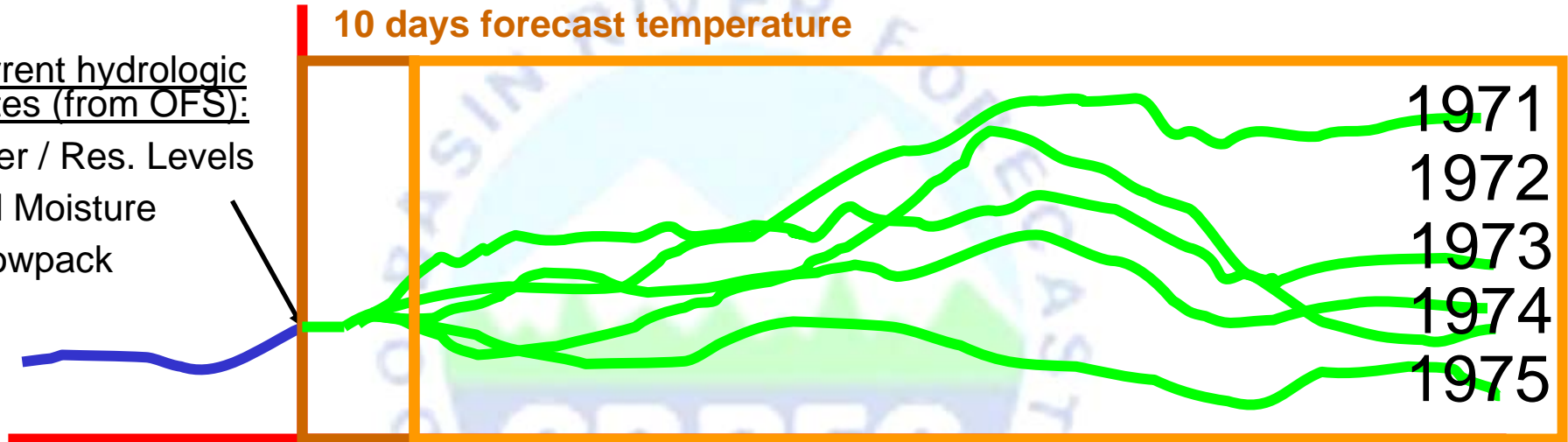
10 days forecast temperature

Current hydrologic states (from OFS):

River / Res. Levels

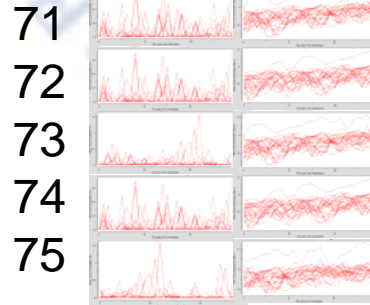
Soil Moisture

Snowpack



Past <-

-> Future Time



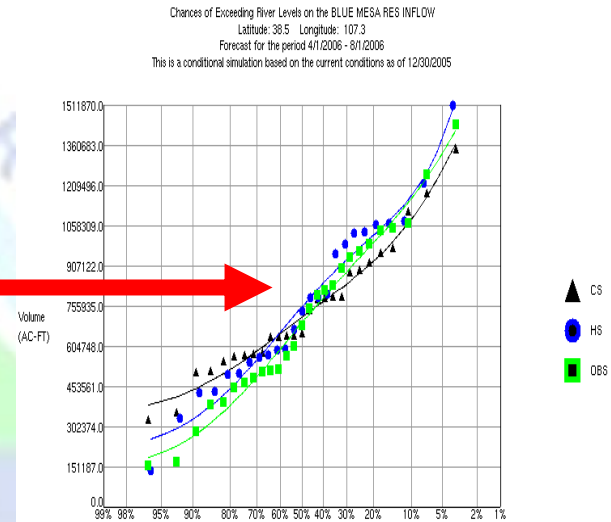
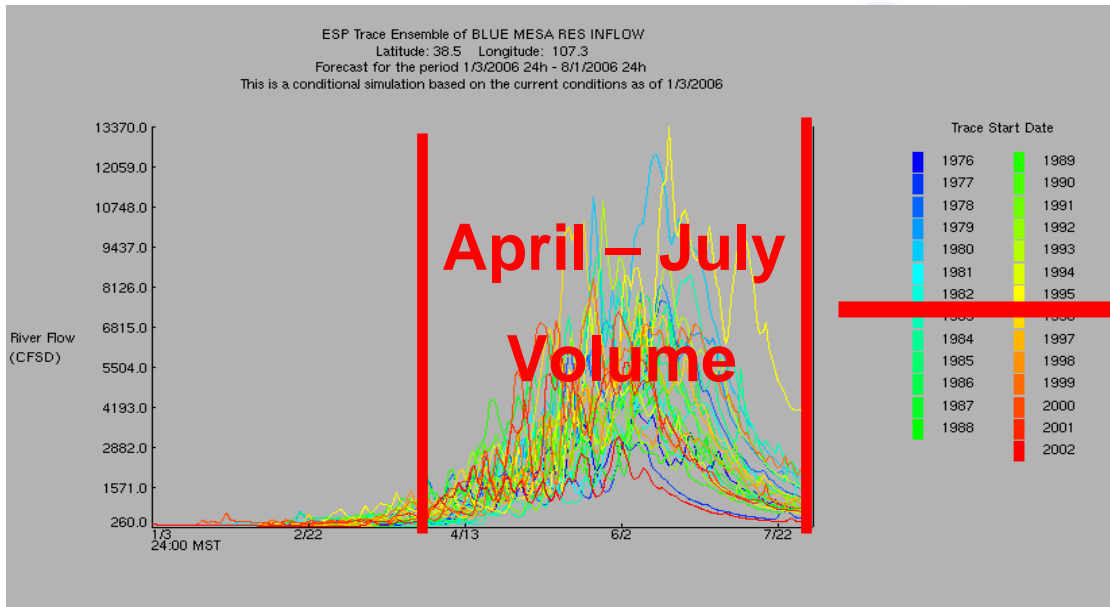
Historical time series of precipitation and temperature (from Calibration).

Climate Model Forecasts:

- 1) Pre-adjust: input time series are shifted based on the CPC forecast probability anomalies.
- 2) Post-adjust: output traces are weighted by year; alters the likelihood (probability) of a value occurring, not the individual ensemble values.



# Ensemble Streamflow Prediction (ESP)



1. Select a forecast window
2. Select a forecast variable
3. Model derives a distribution function
4. 50% exceedance value = most probable forecast
5. Correct for model bias

# Statistics based on all years.

#	Conditional Simulation	Historical Simulation	Historical Observed
0.900	438320.500	328520.656	262730.375
0.750	552369.562	499977.531	435810.375
0.500	711742.375	751782.938	691946.625
0.250	877104.812	973699.188	935549.938
0.100	1080490.375	1170393.125	1157333.250

# SWS

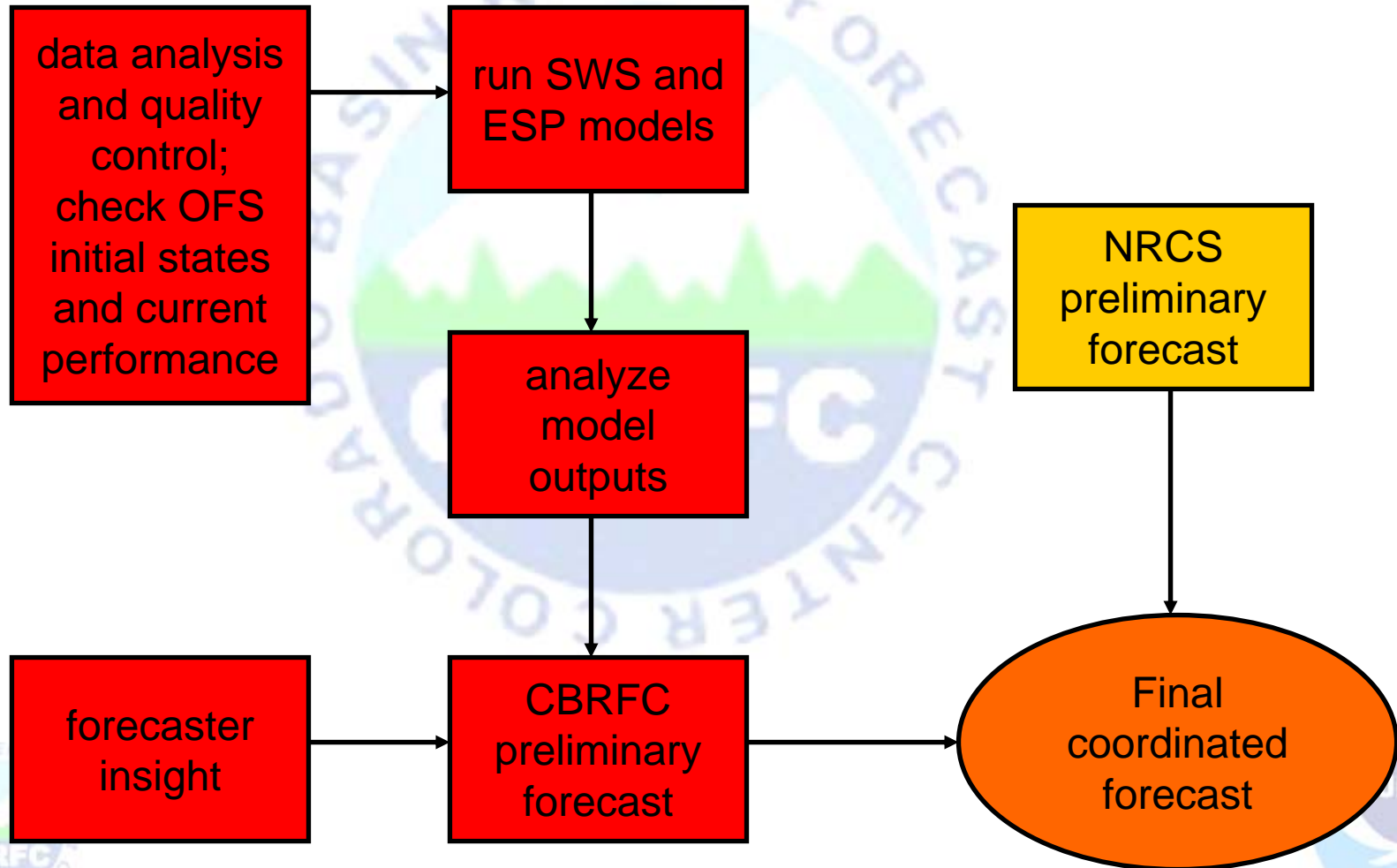
vs.

# ESP

- Easy to calibrate, maintain and run.
- Works only for seasonal volumes.
- Equations are made to be run only at specific times (i.e. first of month).
- Requires extensive calibration and maintenance.
- Can compute many hydrologic variables over any period.
- Can be run at any time.
- Keeps track of soil moisture.



# Summary of Water Supply Forecast Process



# Sources of Error

- Data
  - Undetected errors in historical as well as current observations
    - Errors in streamflow measurements due to poor channel ratings/controls
  - Lack of data in some areas
  - Ungaged/unknown diversions (especially in low years)
  - Consumptive use
  - Distribution of snow vs. point measurements
- Model
  - Initial conditions (see data errors)
  - Calibration error (bias)
- Future weather
  - Temperature and precipitation



# When and What

- **WHEN:**
  - At the beginning of each month January-May.
  - Mid-month updates for some points.
- **WHAT:**
  - Seasonal volume (April-July most common).
  - “Natural” flow.
    - Flow that would be expected given no water management activities.
    - We attempt to account for all known and measured diversions and reservoir regulation upstream for which data is available.
      - Many unknown/unmeasured diversions.
      - Sometimes hard to get all adjustment data in real-time.
    - Adjustments we account for available at:  
<http://www.cbrfc.noaa.gov/wsup/guide/>



# Adjustment Example

EAGLE - GYPSUM, BLO adjusted flow =  
+ EAGLE - GYPSUM, BLO observed flow  
+ HOMESTAKE TUNNEL observed flow  
+ EWING DITCH observed flow  
+ COLUMBINE DITCH observed flow  
+ WURTZ DITCH observed flow  
+ HOMESTAKE RESERVOIR change in storage



# Adjustment Example

COLORADO - CAMEO, NR CAMC2 QCMPAZZ  
+ COLORADO - CAMEO, NR CAMC2 QCMRZZZ  
+ TWIN LAKES TUN - TWIN LAKES, NR, EAST PORTAL, AT TWTC2 QCMRZZZ  
+ CHARLES H. BOUSTED TUN CBTC2 QCMRZZZ  
+ FRYING PAN - RUEDI RES, BASALT, NR RURC2 LSMRZZZ  
+ HAROLD D. ROBERTS TUN - DILLON RES DIV, GRANT, NR RBTC2 QCMRZZZ  
+ MOFFAT TUN - EAST PORTAL MOFC2 QCMRZZZ  
+ ALVA B ADAMS TUN - ESTES PARK, NR, EAST PORTAL, AT ABTC2 QCMRZZZ  
+ HOMESTAKE TUN - GOLD PARK, NR HSTC2 QCMRZZZ  
+ GRAND RIVER DITCH - LA POUUDRE PASS GRDC2 QCMRZZZ  
+ COLORADO - SHADOW MTN RES, GRAND LK, NR SMRC2 LSMRZZZ  
+ COLORADO - LAKE GRANBY, GRANBY, NR GBYC2 LSMRZZZ  
+ WILLIAMS FORK - WILLIAMS FORK RES, PARSHALL, NR WFDC2 LSMRZZZ  
+ BLUE - GREEN MTN RES GMRC2 LSMRZZZ  
+ BLUE - DILLON RES DIRC2 LSMRZZZ  
+ WILLOW CK - WILLOW CK RES, GRANBY, NR WCRC2 LSMRZZZ  
+ HOMESTAKE CK - HOMESTAKE RES HMAC2 LSMRZZZ  
+ HOOSIER PASS TUN - HOOSER PASS, NR HPTC2 QCMRZZZ  
+ WOLFORD MOUNTAIN RESERVOIR WORC2 LSMRZZZ AVG  
+ COLUMBINE DITCH CLMC2 QCMRZZZ  
+ EWING DITCH - LEADVILLE, NR EWDC2 QCMRZZZ  
+ WURTZ DITCH WZDC2 QCMRZZZ  
+ BUSK-IVANHOE TUN BITC2 QCMRZZZ  
+ BOREAS PASS DITCH BORC2 QCMRZZZ



Thank You!

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Address <http://www.cbrfc.noaa.gov/>

NOAA's National Weather Service  
**Colorado Basin River Forecast Center**

News Organization Search  Go

### River Forecasts & Data

Forecasts on this web page are not official and should be used only as guidance. Official warnings and forecasts can be found [here](#).

Legend. Map data updated 10/13 20:12 GMT, 10/13 14:12 MDT. Click map to zoom.

Data Type: [River Forecasts](#) | [Reservoirs](#) | [Recreational](#) | [Snow Conditions](#)

Click to: [Select](#) [Zoom](#) Zoom to: [1x](#) [4x](#) [8x](#) [Help](#)

**Legend**

**Basin Conditions (0-3 days)**

- 1 = Normal, 0 = No Data
- 2 = Significant Rise
- 3 = Near Bankfull
- 4 = Above Bankfull
- 5 = Above Flood Stage
- Observed (Solid)
- Simulated (Striped)
- Outlook (beyond 3 days)

**Station Types**

- AHPS Point
- Forecast Point
- Data Point

**Quick Plot**

NWS ID

**Display Options**

- Topography
- States
- RFC
- Rivers
- HSAs
- Basins
- Basins Above Normal
- Data Points
- Forecast Points
- AHPS Points
- Stations Above Normal
- Station Labels