Challenges Applying S2S Forecasts to Hydrology

WSWC/CDWR - S2S Workshop May 2022

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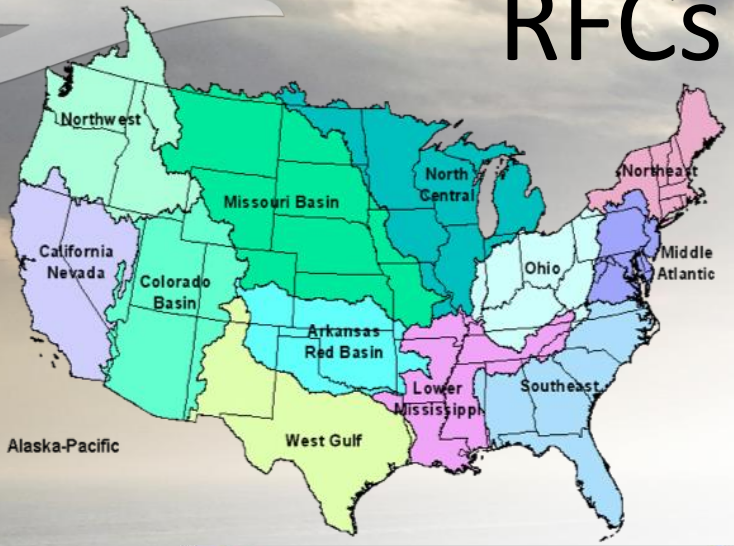
NATIONAL WEATHER SERVICE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Outline

- CBRFC - Colorado River Overview
- Forecast and Ensemble Streamflow Prediction Overview
- Adding S2S/Challenges in implementing S2S
- Case for S2S

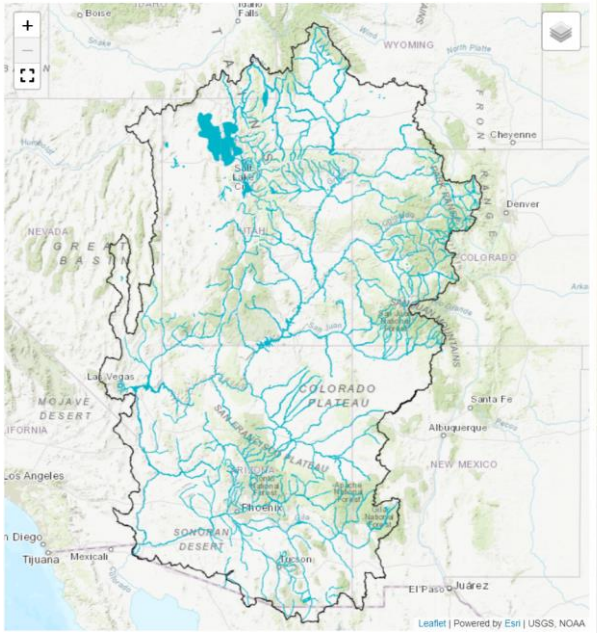
RFCs and WFOs



- 13 River Forecast Centers (RFCs) nationwide
- Work with 122 Weather Forecast Offices (WFOs)
- Support NOAA's hydrologic services and products
- Focused on decision support
- Western RFCs have the additional role of providing water supply services

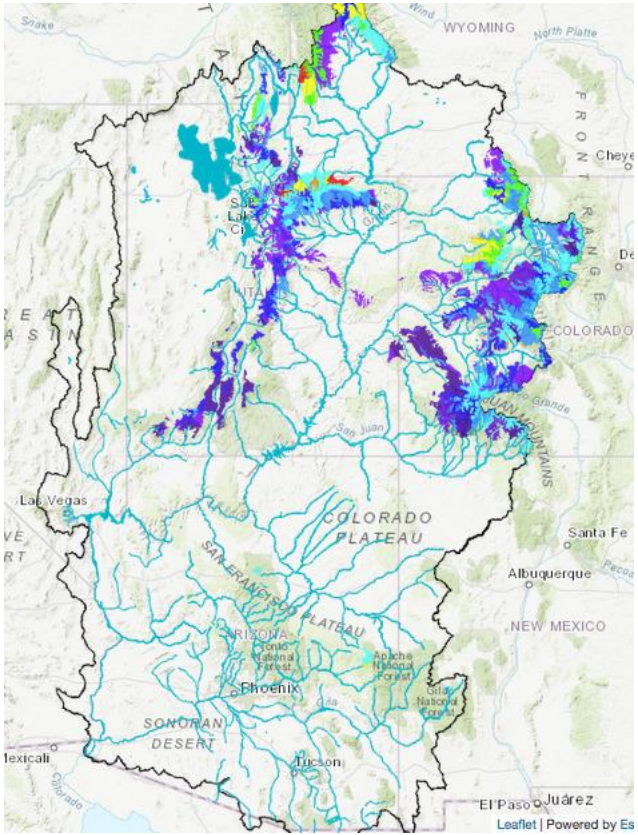
Colorado Basin RFC

- Work with a broad and diverse set of stakeholders
  - Federal agencies (e.g., Reclamation, Army Corps)
  - Municipal and Agricultural Water Users
  - State, academic, NGOs
- Data consumers - we rely on information provided by many of our stakeholders
- Strive to be transparent and accessible
- Operational Office



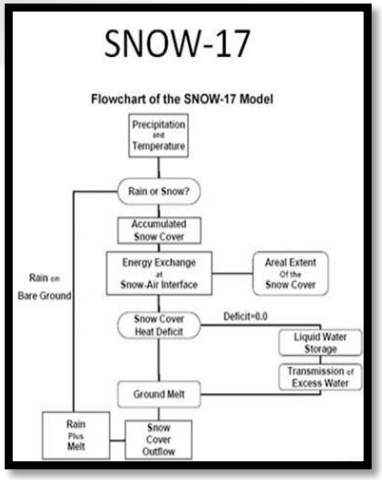
Colorado River Background

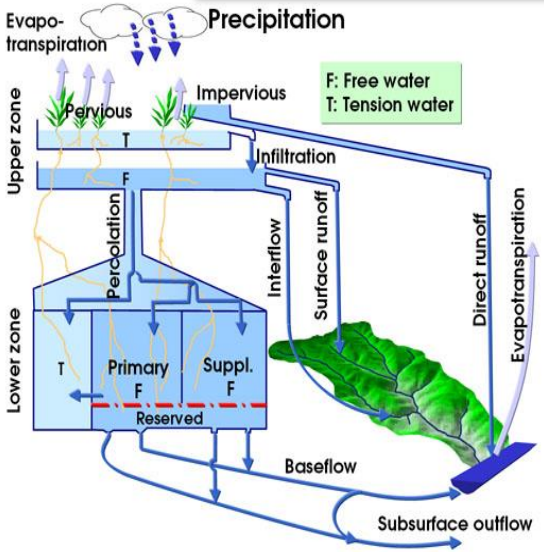
- ~40 million people rely on Colorado River Basin water (15 Tribes)
- 4 million acres of irrigation
- 4,200 MW hydropower generation capacity
- 85% of runoff comes from above 9000 feet (relatively small area)
- Mean annual discharge is about 15 MAF
- Storage capacity is about 60 MAF (4 times mean annual flow)
- River is over allocated, and operated on a tight margin



Model Description

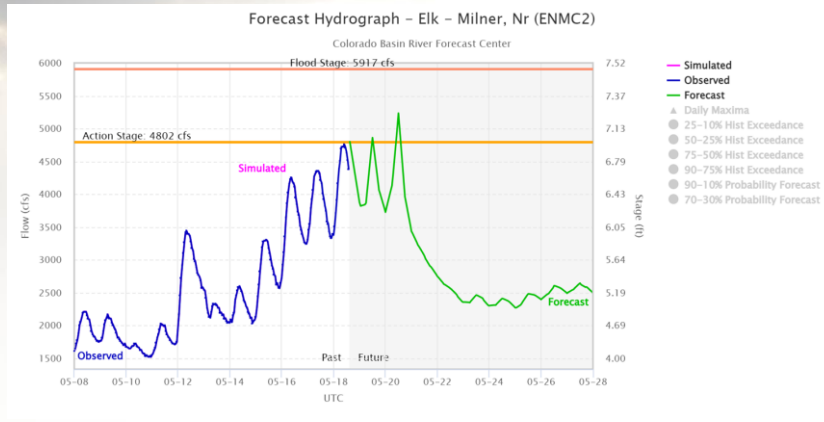
- Continuous
  - model states saved each day
- Conceptual
- Lumped
  - elevation zones
- Main components are:
  - SNOW-17 (snow pack)
  - Sac-SMA (soil moisture)
- Quality of the precipitation data (historical and real time) is the most important part of the model

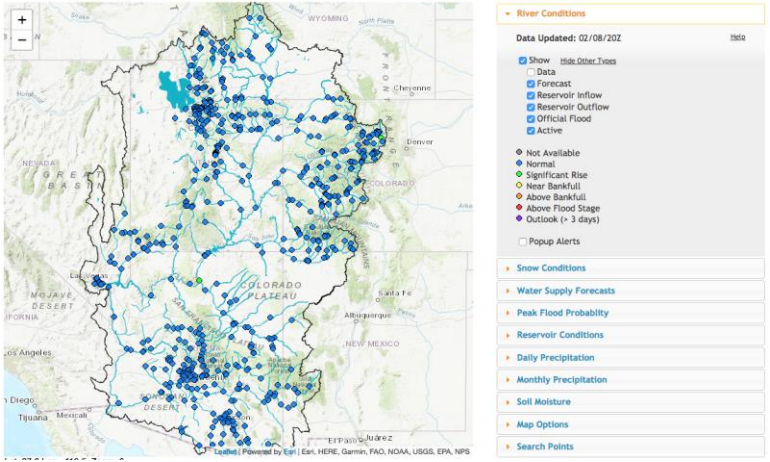




Flood Forecasts

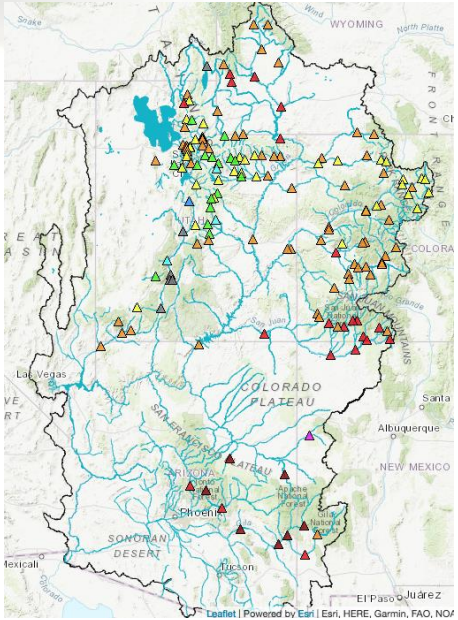
- 10 day deterministic hydrographs issued daily
- WFOs are the key stakeholders
  - WFOs issue Flood Watches and Warnings based on RFC guidance
  - Flexible support abilities
  - Provide actionable, risk-based, information

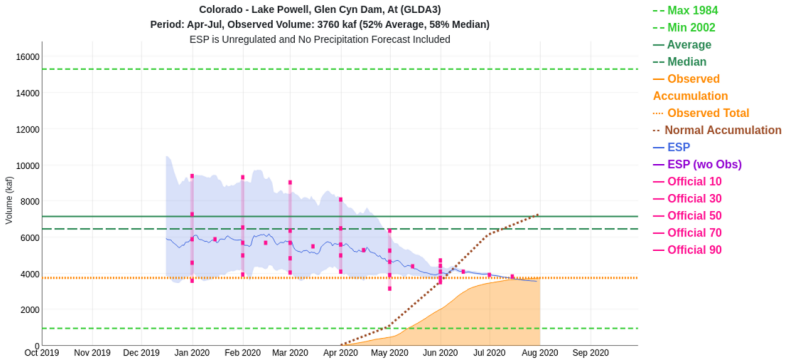




Water Supply Forecasts

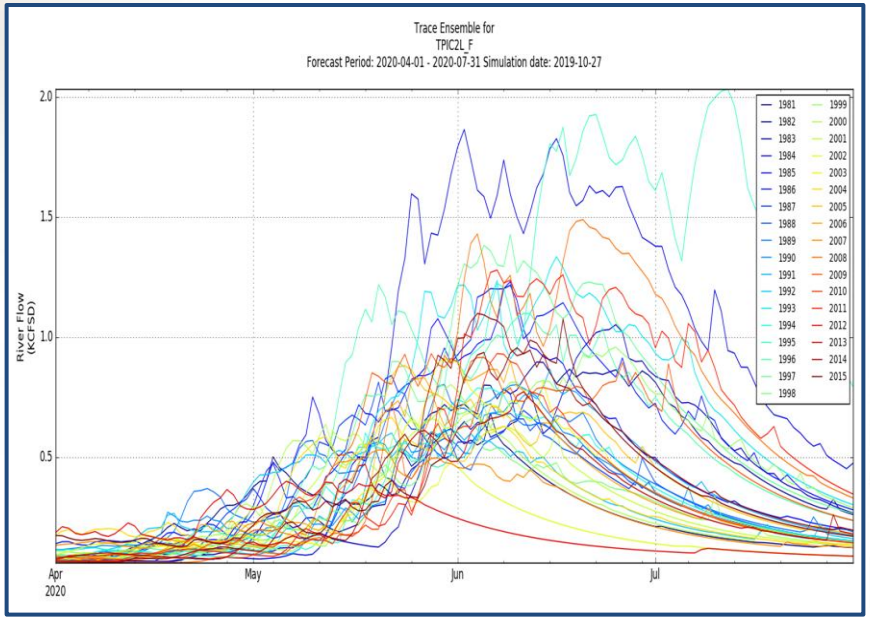
- Probabilistic volumetric forecasts
- Updated daily from January through July, with monthly “official” forecasts
- Monthly and seasonal timesteps
- 1 - 5 year forecasts
- Used by Reclamation in reservoir operations models, and other water managers





ESP Forecasts

- Ensemble Streamflow Prediction
- Starting point is same states as Deterministic forecast
- Up to 40 scenarios (traces) based on historical precipitation and temperature
- Calculate probabilities based on traces
- Can add ability to use meteorology model inputs to hydrology model



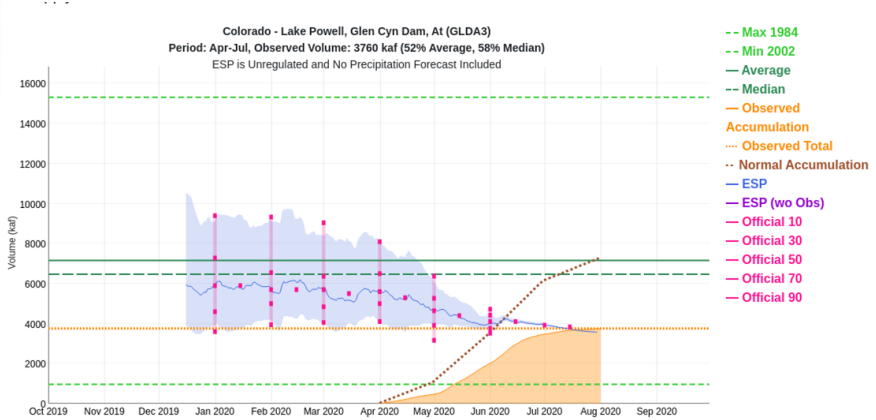
ESP Forecast Flow

WPC/RFC forecasts (1-7 days)

Climatology (0or7+ days)

Hydrologic models (ESP Mode)

NWS and external user applications



ESP w/S2S Forecast = HEFS

WPC/RFC forecasts (1-7 days)

Climatology (0or7+ days)

GEFSv12 forecasts (1-15 days)

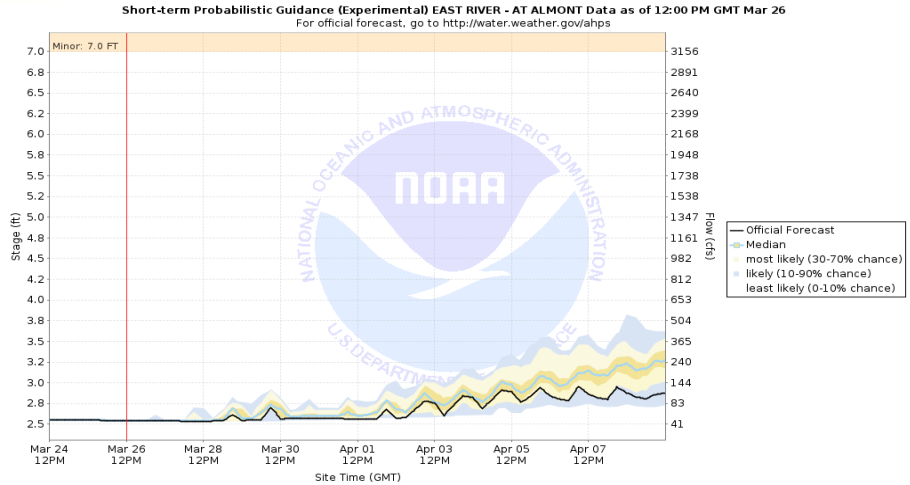
CFSv2 forecasts (16-270 days)

Meteorological Ensemble Forecast Processor (MEFP)

- Correct forcing bias
- Merge in time
- Downscale (basin)

Hydrologic models (ESP Mode)

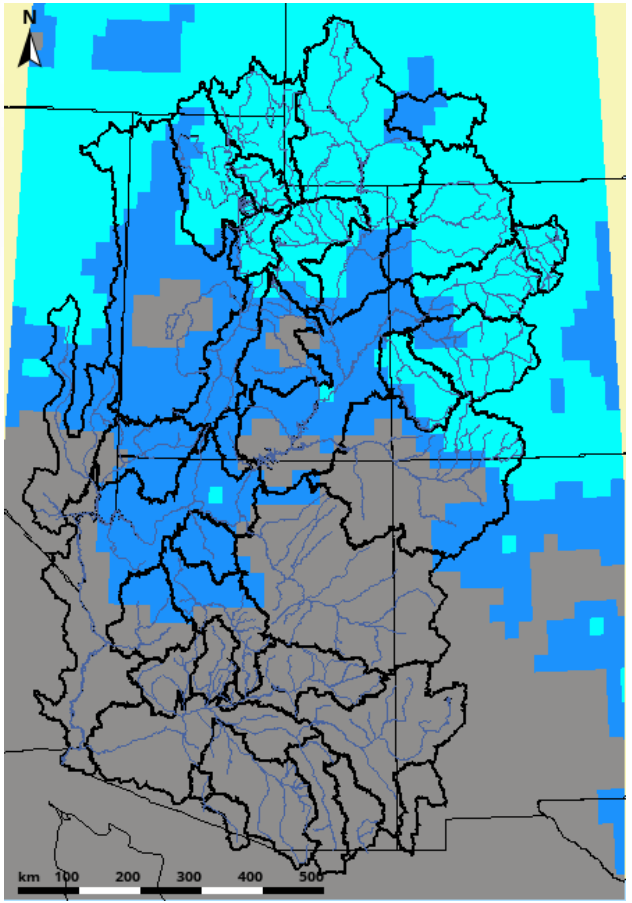
NWS and external user applications



Adding S2S forecasts

GEFSv12 (Global Ensemble Forecast System)

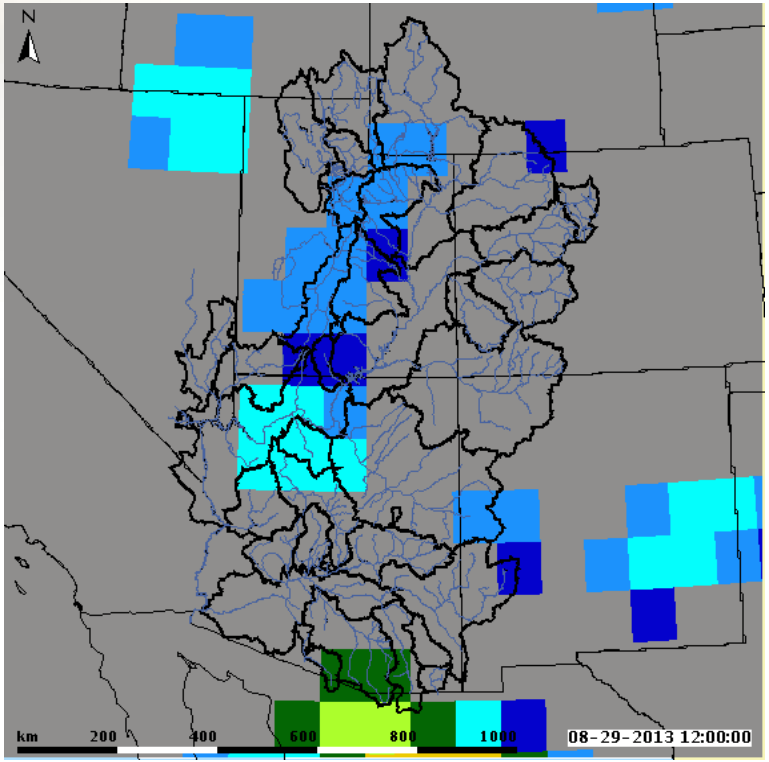
- short term forecast 15 days out
- 0z run goes out 35 days
- precipitation and temperature max/min
- comes as gridded product
- .25 degree resolution out 10 days
- .50 degree resolution after day 10
- reforecasts available for 2000-2019



Adding S2S forecasts

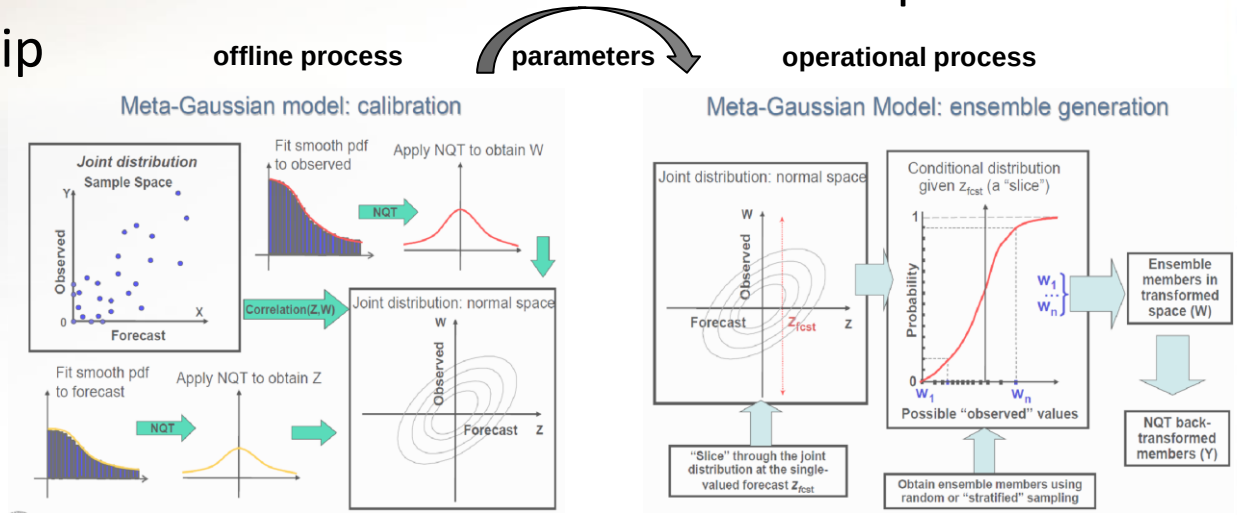
CFSv2 (Climate Forecast System)

- long term forecast out 9 months (270 days)
- precipitation and temperature max/min
- comes as gridded product
- 1 degree resolution
- use the lagged ensemble mean
- reforecasts available for 1982-2011



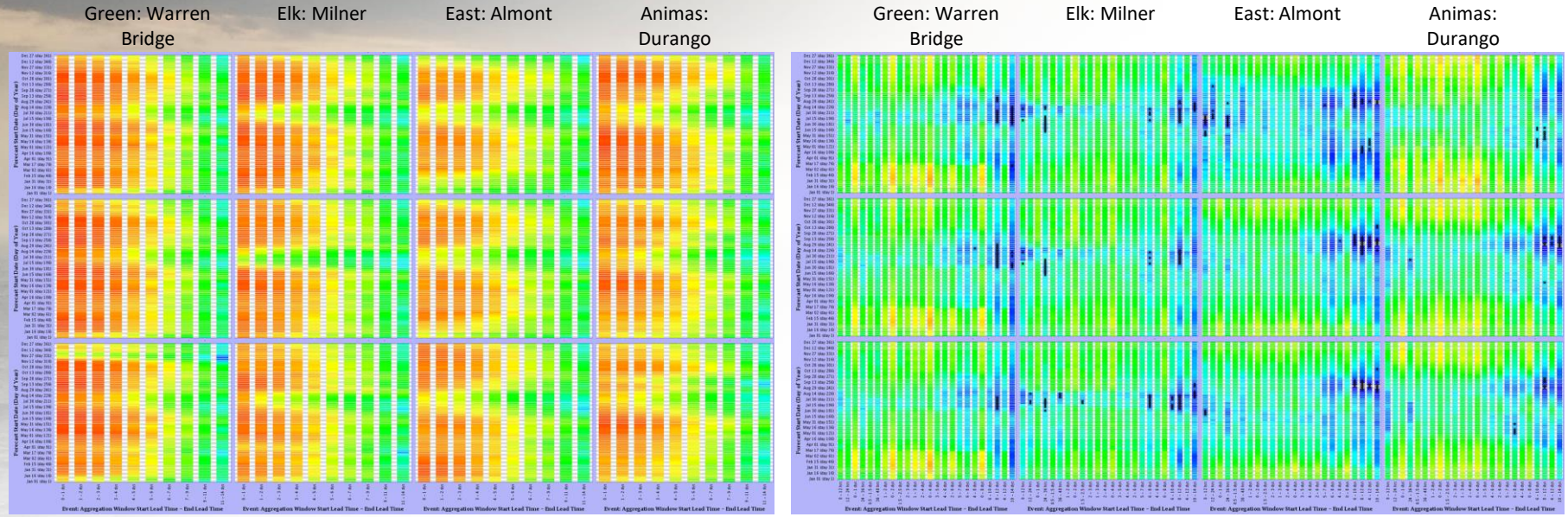
Adding S2S forecasts

- Meteorological Ensemble Forecast Processor (MEFP)
- Historical Observation, precipitation and max/min temperature, are statically related to GEFS and CFS hindcasts to develop a bivariate relationship
- Parameters used in forecast process
- One time process

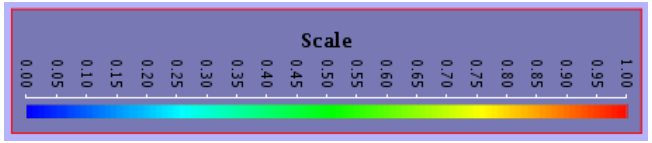


Adding S2S forecasts

- GEFS skill forecast lead time 1 day to 2 weeks



max temperature



precipitation

Adding S2S forecasts

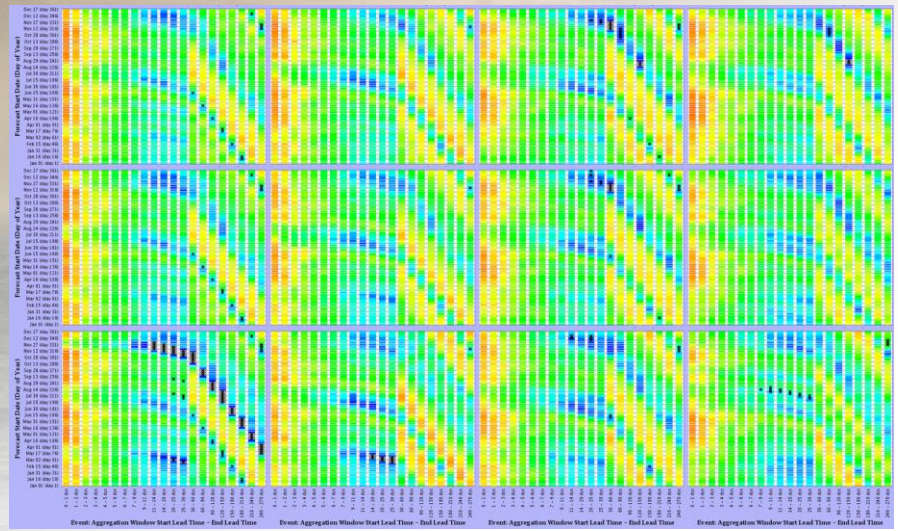
- CFS skill forecast lead time 1 day to 9 months

Green: Warren Bridge | Elk: Milner | East: Almont | Animas: Durango

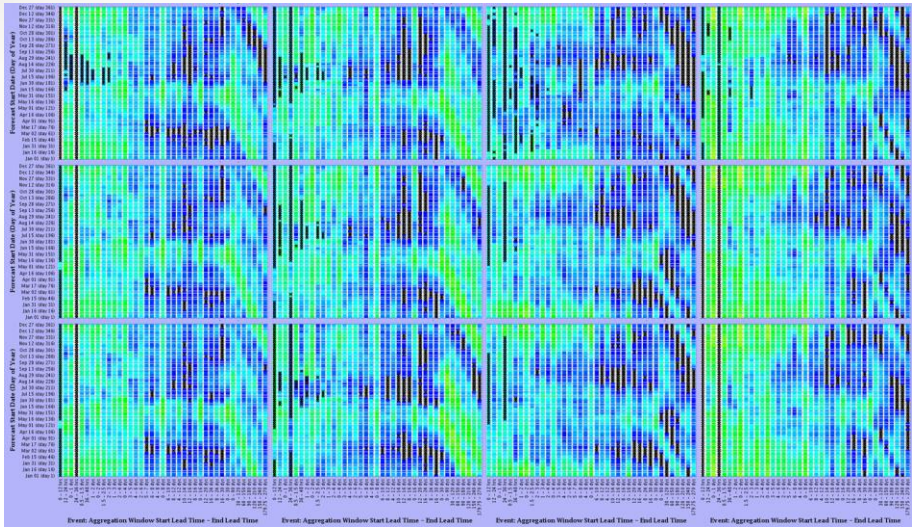
Upper

Mid

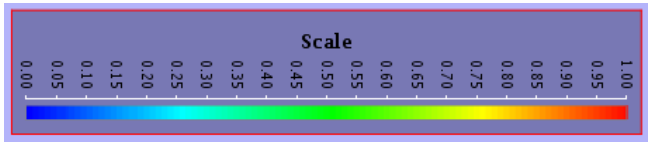
Lower



Green: Warren Bridge | Elk: Milner | East: Almont | Animas: Durango



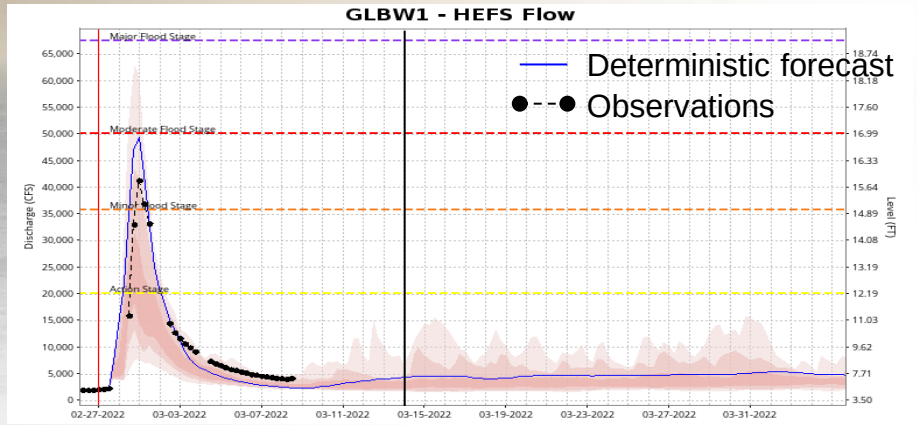
max temperature

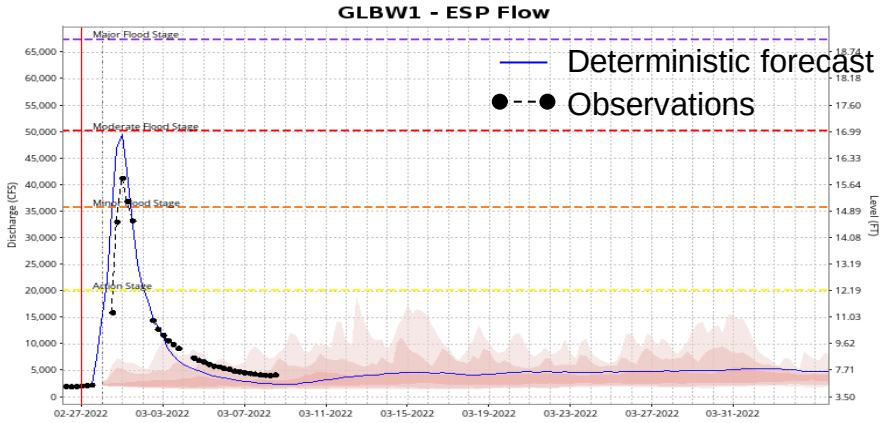


precipitation

Adding S2S forecasts

- Weather model input varies less from climatology further out in time
- Historical forcings are appended beyond the availability of weather models





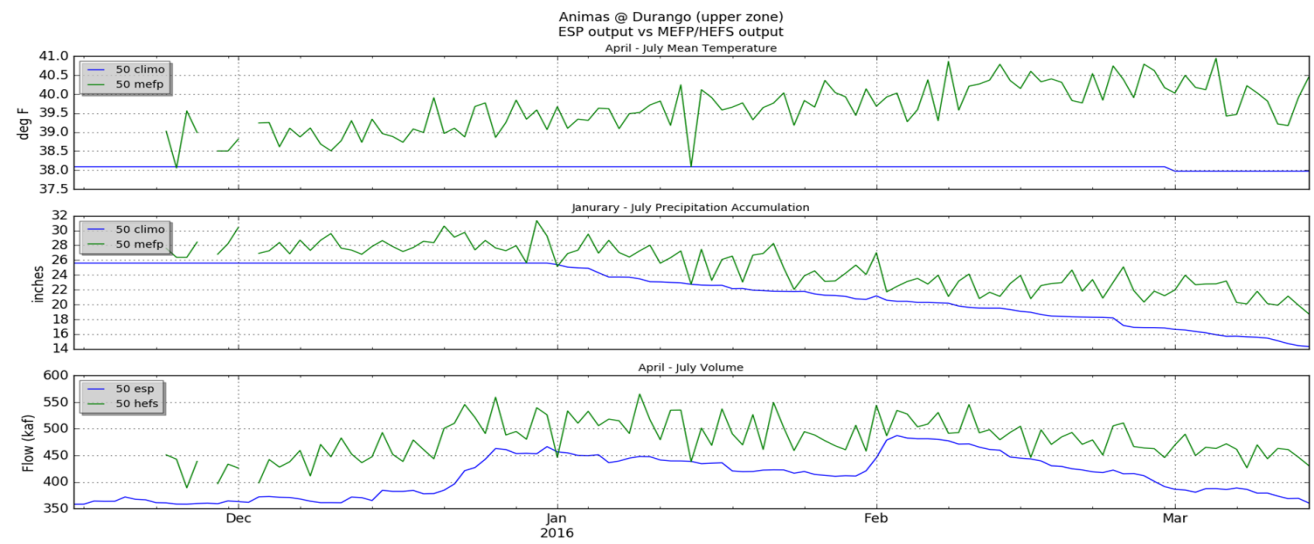
Dynamic forcings

Historical forcings

Historical forcings

Adding S2S forecasts

- Day to day forecast variation with CFS possess issues when using the full 270 day forecast

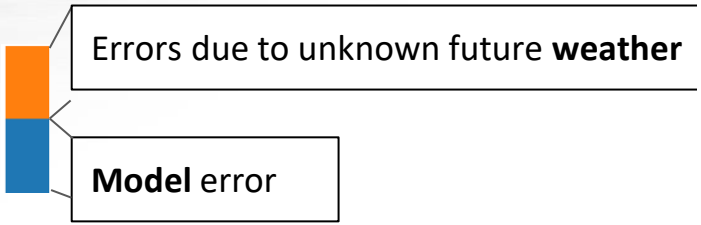


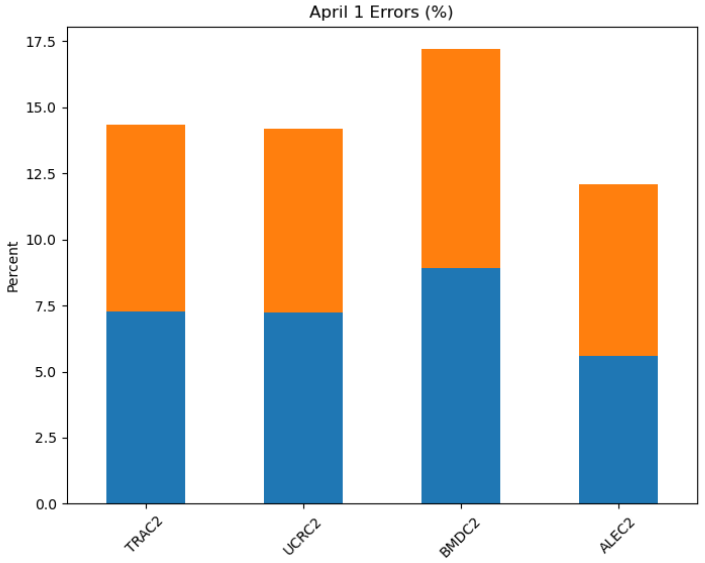
Adding S2S forecasts HEFS

Feature	ESP (legacy service)	HEFS (new service)
Forecast horizons	Weeks to years, depending on the inputs	Hours to years, depending on the inputs
Inputs	Historical weather observations	Short- to medium - to long - range weather forecasts, historical weather observations
Uncertainty modeling	Static inputs; climate-based	Dynamic inputs; based on calibrated relationships between historical forecasts and observations
Products	Limited number of graphical products (mainly focused on longer-range)	More customizable and user-tailored products are planned (at all leads)

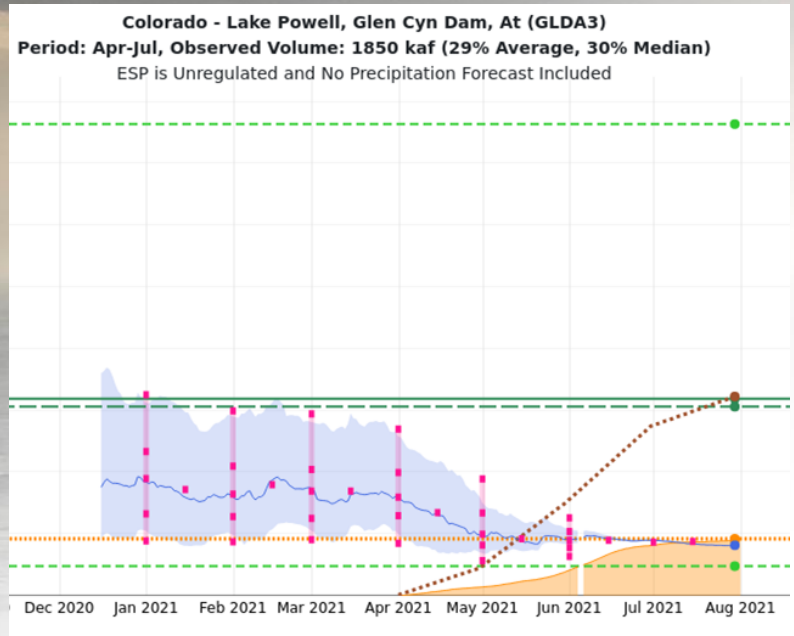
Case for more skillful S2S forecasts

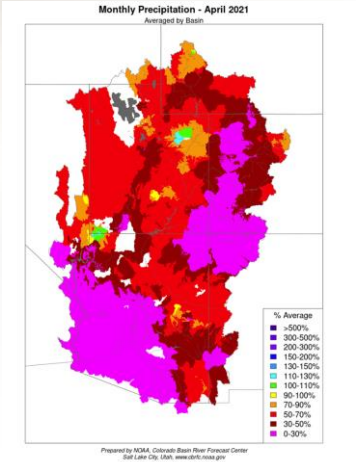
- Uncertainty in water supply forecasts are a combination of model errors and unknown future weather (mostly future precipitation)
- Model errors can be attributed to…
  - Errors in model soil moisture
  - Errors in model snow pack
  - Errors in model parameters
  - Errors in model structure
- Patrick Kormos, CBRFC

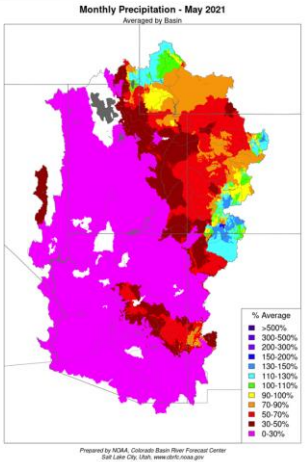


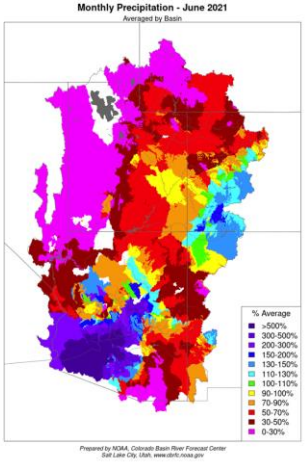


Case for more skillful S2S forecasts

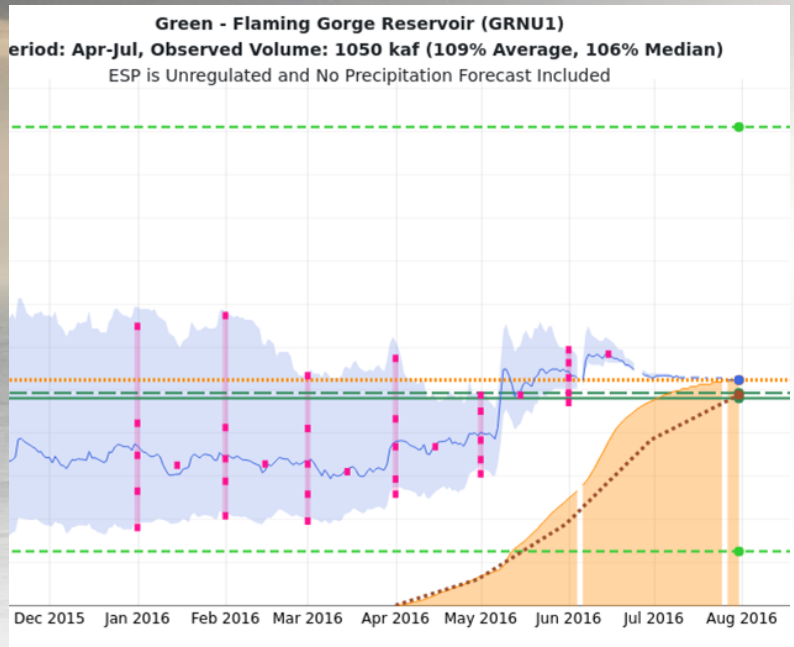


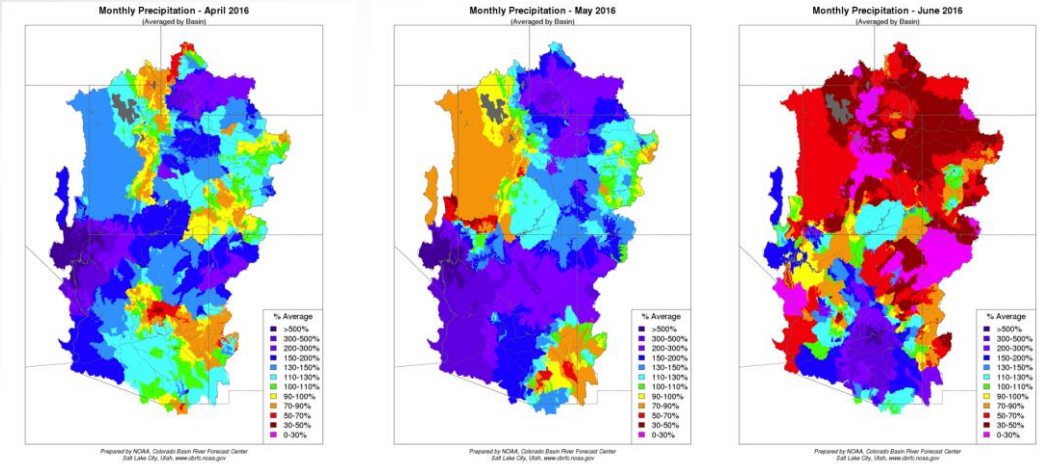






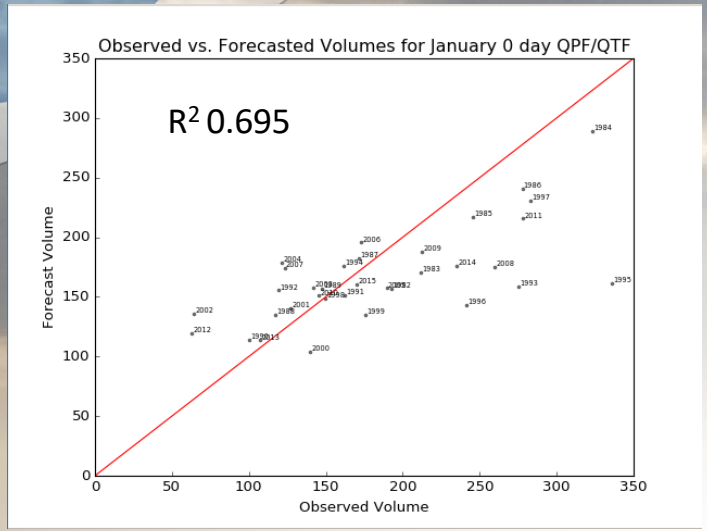
Case for more skillful S2S forecasts

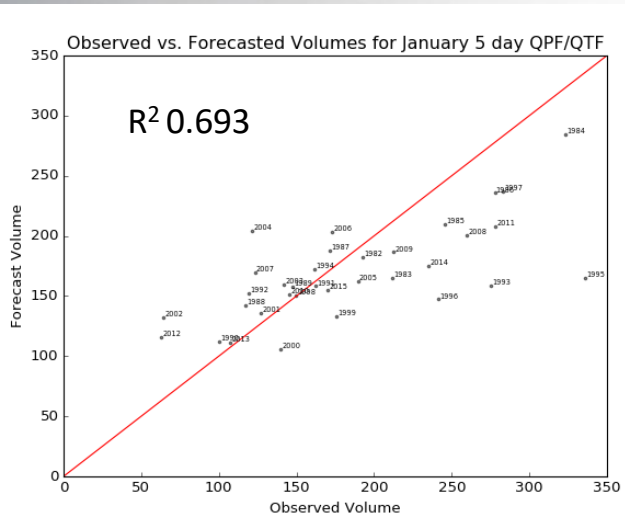


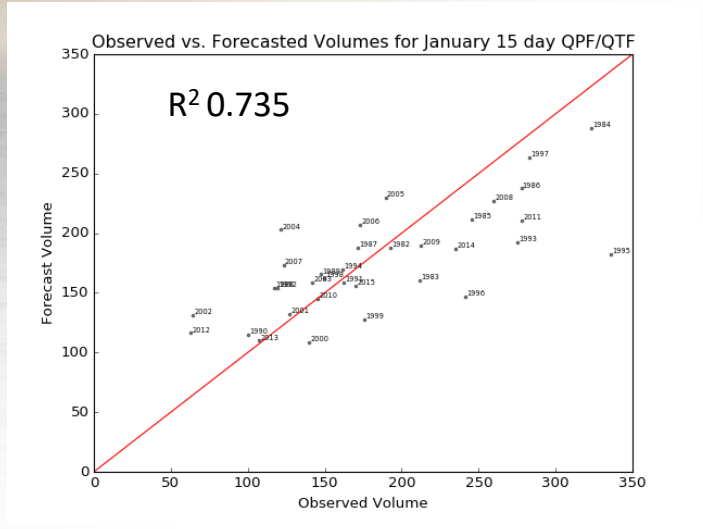


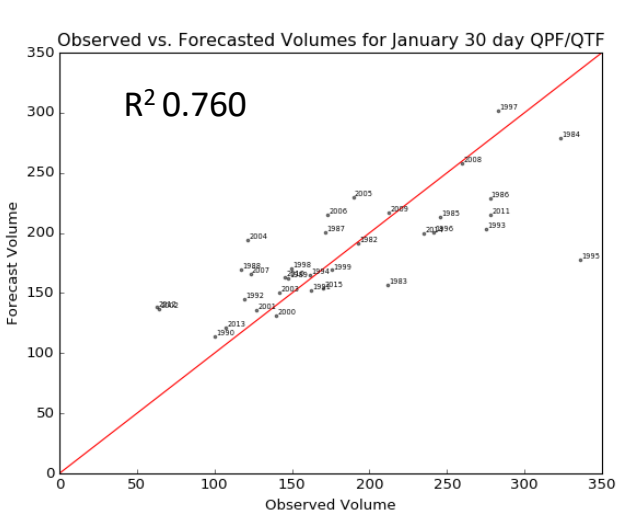
Case for more skillful S2S forecasts

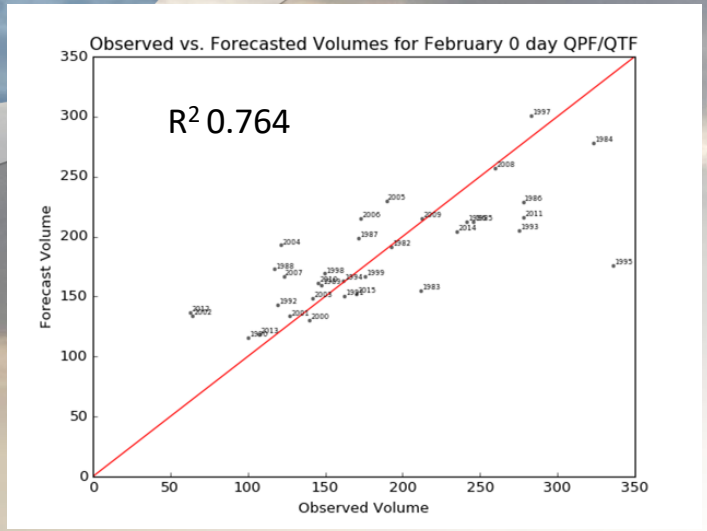
- “Perfect” Precipitation Temperature study (Kirsten Jensen)
- Run ESP reforecasts but feed the historical data with 0, 5, 15, 30 days of known precipitation and temperature
- See at what lead time, if any, skill improves
- Looked at April to July volumes for Jan 1, Feb 1, Mar 1 and Apr 1 lead times

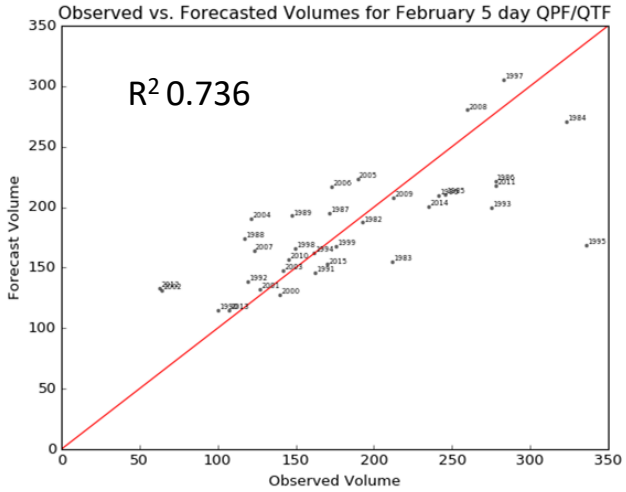

Observed vs. Forecasted Volumes for January 0 day QPF/QTF
R^2 0.695
Forecast Volume
Observed Volume
0
50
100
150
200
250
300
350

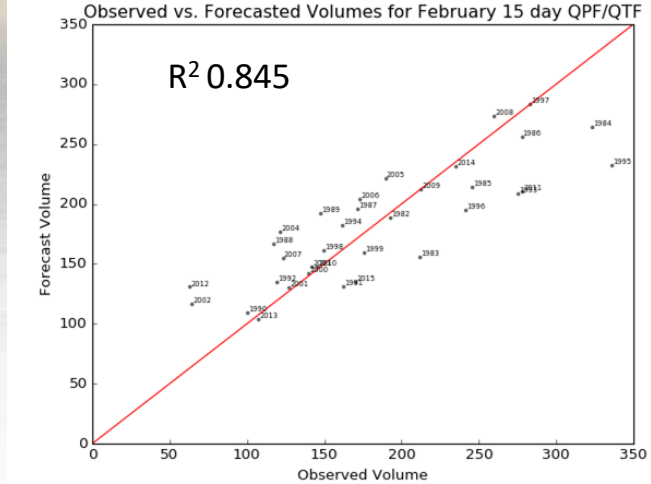

Observed vs. Forecasted Volumes for January 5 day QPF/QTF
R^2 0.693
Forecast Volume
Observed Volume
0
50
100
150
200
250
300
350

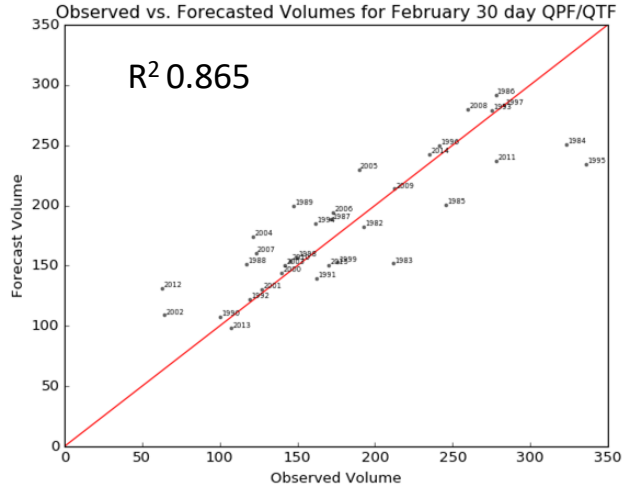

Observed vs. Forecasted Volumes for January 15 day QPF/QTF
R^2 0.735
Forecast Volume
Observed Volume
0
50
100
150
200
250
300
350

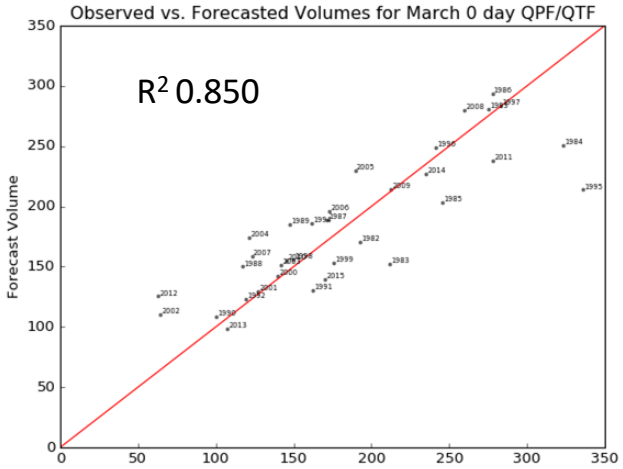

Observed vs. Forecasted Volumes for January 30 day QPF/QTF
R^2 0.760
Forecast Volume
Observed Volume
0
50
100
150
200
250
300
350

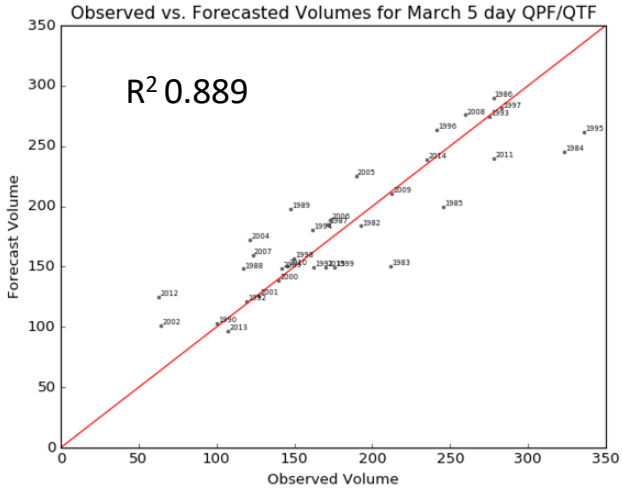

Observed vs. Forecasted Volumes for February 0 day QPF/QTF
R2 0.764
Forecast Volume
Observed Volume

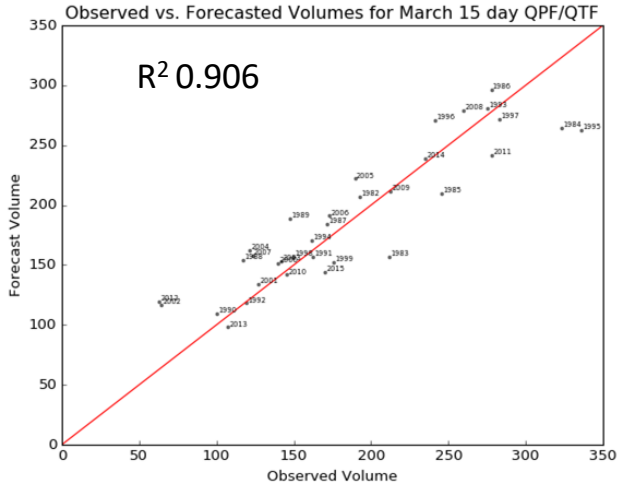

Observed vs. Forecasted Volumes for February 5 day QPF/QTF
R2 0.736
Forecast Volume
Observed Volume

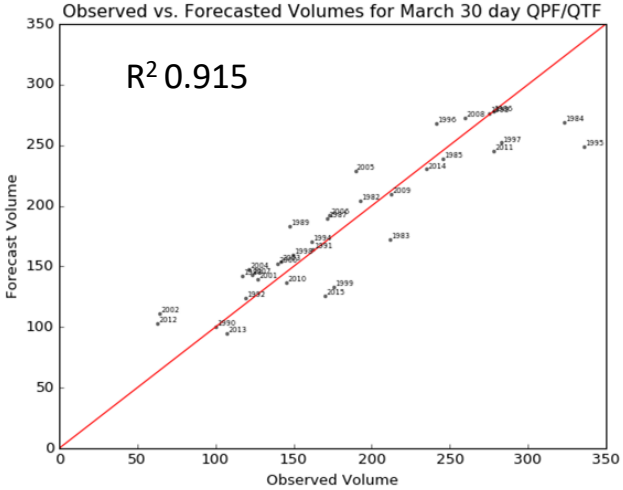

Observed vs. Forecasted Volumes for February 15 day QPF/QTF
R2 0.845
Forecast Volume
Observed Volume

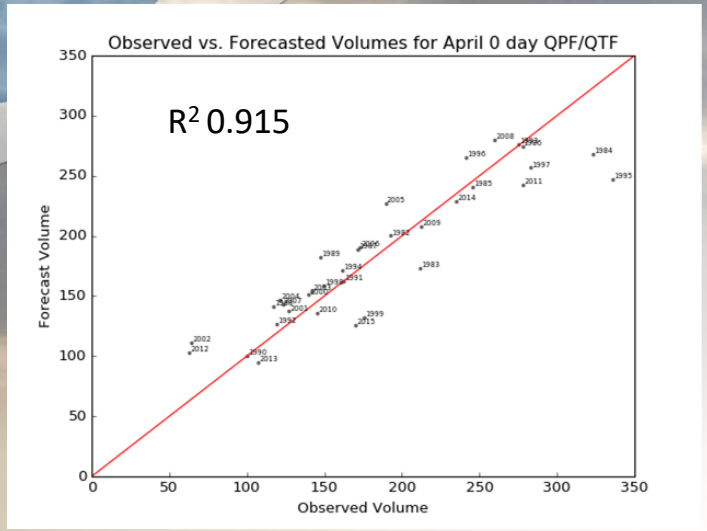

Observed vs. Forecasted Volumes for February 30 day QPF/QTF
R2 0.865
Forecast Volume
Observed Volume

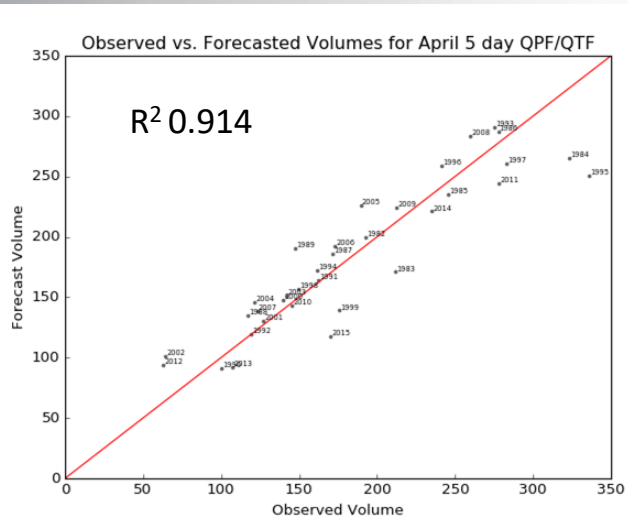

Observed vs. Forecasted Volumes for March 0 day QPF/QTF
R2 0.850
Forecast Volume
Observed Volume
0
50
100
150
200
250
300
350

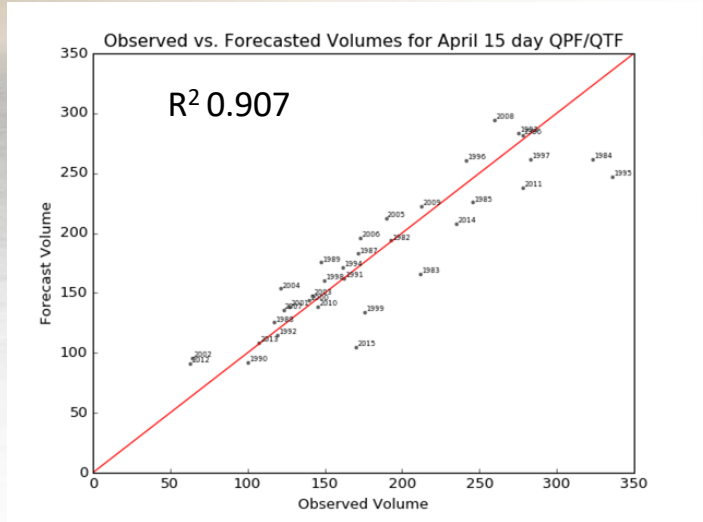

Observed vs. Forecasted Volumes for March 5 day QPF/QTF
R2 0.889
Forecast Volume
Observed Volume
0
50
100
150
200
250
300
350

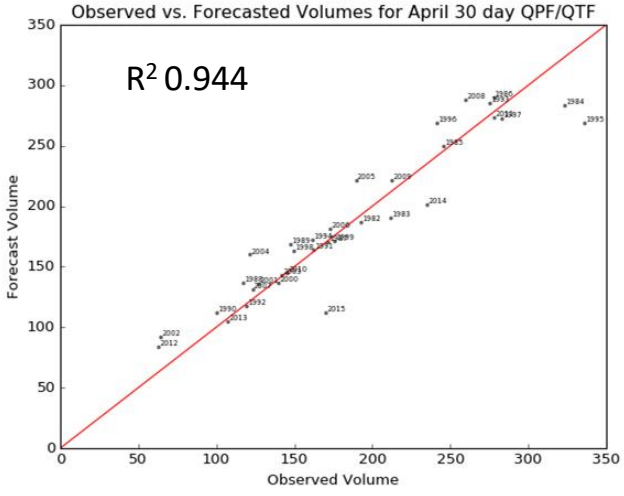

Observed vs. Forecasted Volumes for March 15 day QPF/QTF
R2 0.906
Forecast Volume
Observed Volume
0
50
100
150
200
250
300
350


Observed vs. Forecasted Volumes for March 30 day QPF/QTF
R2 0.915
Forecast Volume
Observed Volume
0
50
100
150
200
250
300
350


Observed vs. Forecasted Volumes for April 0 day QPF/QTF
R2 0.915
Forecast Volume
Observed Volume
0
50
100
150
200
250
300
350


Observed vs. Forecasted Volumes for April 5 day QPF/QTF
R2 0.914
Forecast Volume
Observed Volume
0
50
100
150
200
250
300
350


Observed vs. Forecasted Volumes for April 15 day QPF/QTF
R2 0.907
Forecast Volume
Observed Volume
0
50
100
150
200
250
300
350


Observed vs. Forecasted Volumes for April 30 day QPF/QTF
R2 0.944
Forecast Volume
Observed Volume
0
50
100
150
200
250
300
350

Case for more skillful S2S forecasts

- Greater gains in skill with increased lead time earlier in season
- Predicting extreme precipitation at greater lead time periods can generally improve the skill of forecasts
  - But not always, It is important to consider variability within season as well
- better weather forecasts = better forecast = better management = better big expensive decisions being made on forecasts

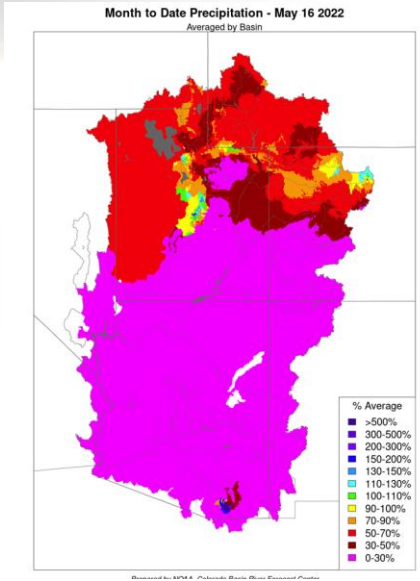
Projects in Work

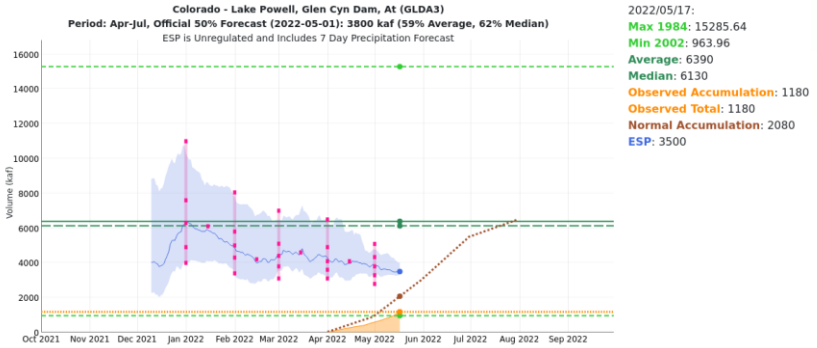
- Assess/Utilize GEFSv12 35 day forecast
- Colorado River Climate and Hydrology Workgroup
- Integrate CPC forecast
- Detrend temperature climatology
- ESRL Lab directly use GEFSv12 forecast (down scale for RFC use)

Thank You

Questions?

Location	Avg	May 1st Forecast	%Avg	May 16th Forecast	%Avg
Flaming Gorge Reservoir	965 kaf	550 kaf	57	520 kaf	54
Blue Mesa Reservoir	635 kaf	490 kaf	77	445 kaf	70
Navajo Reservoir	630 kaf	380 kaf	60	340 kaf	54
Lake Powell	6390 kaf	3800 kaf	59	3500 kaf	55





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Law of the River Highlights

- **Colorado Compact (1922)** - upper basin and lower basin – 7.5 MAF each
- **Boulder Canyon Project Act (1928)** - allocated water among AZ, CA and NV. Secretary of the Interior is the water master in the Lower Basin - unique role of the federal government, and carried out by Reclamation in practice
- **Mexican Water Treaty (1944)** - Mexico 1.5 MAF
- **Arizona v. California (1964)** - Supreme Court allows AZ to develop their tributaries -> CAP project, but California solidifies senior rights
- **Interim Guidelines (2007)** - specify shortages and surpluses through 2026 - Tied to CBRFC forecasts

An Over Allocated River

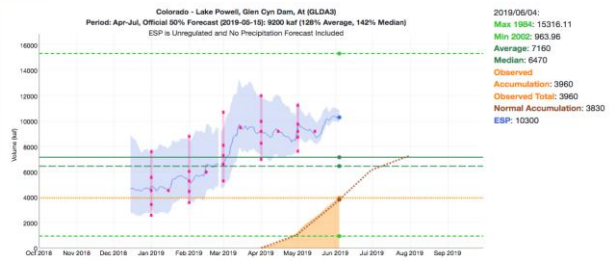
- Original allocation of 16.5 MAF - based on a series of wet years. Actual average flow is about 15 MAF (average flow since 2000 has only been about 12.6 MAF)
- Lower Basin states (AZ, CA, NV) use full 7.5 MAF each year
- Mexico uses its full 1.5 MAF
- Upper basin states (CO, WY, UT, NM) still developing their 7.5 MAF
- Shortage was declared for the first time ever in August 2021
- NV and AZ - reductions to annual apportionment
- Mexico - reductions to annual apportionment
- Drought Response Operations Agreement (DROA) and Drought Contingency Plans have further mitigated drought impacts

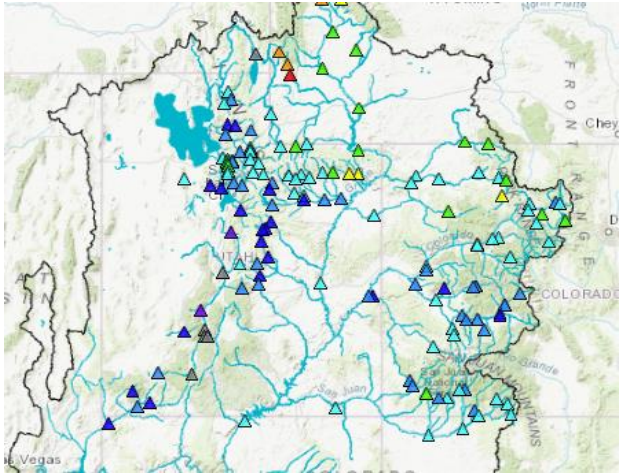
Reclamation's role

- Manages major reservoirs for the 7 States
- "24 Month Study": reservoir model projecting releases for major reservoirs
- Follows rules set in 2007 Interim Guidelines
  - August projections set operations for Lakes Mead and Powell for upcoming year
  - Possibility for an April Adjustment

CBRFC's role

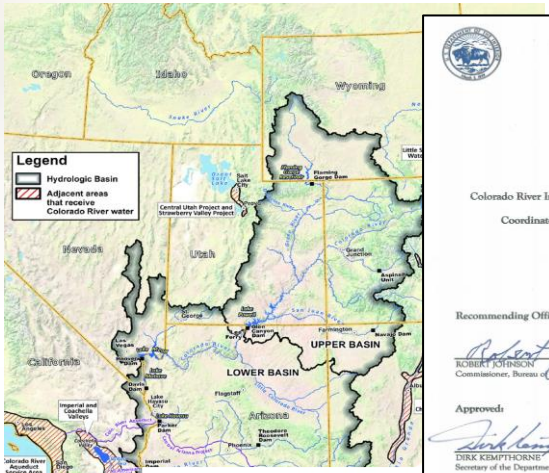
- Reclamation uses CBRFC's water supply forecast to drive their reservoir model. Forecasts are the single most impactful variable to the model
- Forecasts updated daily, adapted to Reclamation's requirements
- CBRFC forecasts are based on best hydroclimatic conditions, unaffected by policy

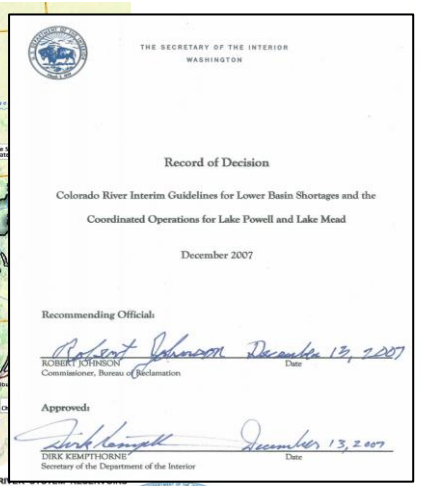




Importance of CBRFC Forecasts

- CBRFC's forecasts drive Reclamation's operations
- Determine operations of Lakes Powell and Mead
- Determine shortage declarations
- Direct impact to State, municipal, agricultural, water and energy managers and Mexico





THE SECRETARY OF THE INTERIOR
WASHINGTON

Record of Decision

Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead

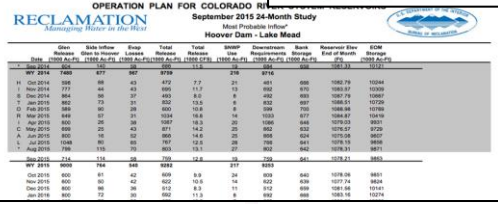
December 2007

Recommending Official:

ROBERT JOHNSON
Commissioner, Bureau of Reclamation
Date

Approved:

DIRK KEMPTHORNE
Secretary of the Department of the Interior
Date



OPERATION PLAN FOR COLORADO RIVER RESERVOIRS

RECLAMATION
Managing Water in the West

September 2015 24-Month Study
Most Probable Inflow*
Hoover Dam - Lake Mead

AOP consultation process. In making these projections, the Secretary shall utilize the April 1 final forecast of the April through July runoff, currently provided by the National Weather Service's Colorado Basin River Forecast Center.