Operational Hydrologic Ensemble Forecasting

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Mission of NWS
Hydrologic Services Program

• Provide river and flood forecasts and warnings for the protection of lives and property.

• Provide basic hydrologic forecast information for the nation’s environmental and economic well being.
NWS River Forecast Centers

CNRFC
- 245,000 sq. miles
- 182 Basins modeled
- 76 Forecast Points
- 42 Reservoir Inflows
- 50 Water Supply Points
- Lots of people!
CNRFC Hydrologic Products and Services

Short Range ... ... ... ... ... ... Long Range

Local Flood Warning Systems Support
Flash Flood Guidance
Headwater Guidance
Flood Forecast Guidance
Reservoir Inflow Forecasts
Spring Snow Melt Forecasts
Water Supply Volume
CNRFC Hydrologic Modeling

Short Range … … … … … … … Long Range

(Site Specific)

NWSRFS – OFS
  6 hour time step
  modular, deterministic

ESP

NWSRFS configuration
probablistic (ensemble)

Statistical
simple, efficient,
inflexible
HAS Operations
Hydrometeorological Analysis and Support
Operational HAS Function

- NWS Weather Forecast Offices (11)
- NCEP Hydrometeorological Prediction Center

Local collaboration as required

3-Day Forecasts
Updated every 6 hours

Atmospheric Models
Local Models
Surface Observations
Remotely Sensed Data

HAS

5-Day Forecasts (6 hour interval)
- Precipitation
- Temperature
- Snow Level
Pattern recognition - historical case studies
Gain familiarity with topography and gage network

Develop knowledge base on:
...NCEP model performance
...locally run models and tools
Hydrologic Operations
Operational Flood Forecasting

Hydrologist

River Forecast System

Observing Systems

Calibration

Flood Forecast Guidance

hydrologic expertise & judgment

model guidance

forecast precip / temp

data

parameters

bulletins graphics
Forecaster Experience

- Watershed characteristics
- Model idiosyncrasies
- Data and gage issues
- Customer and partner needs
Flood Forecast Guidance

ORFC1 - SACRAMENTO RIVER - Ord Ferry

Forecast Issuance Time: 12/31 19:44
Next Forecast Issuance: 12/31 14:00

Rain + Melt (in)

Stage (ft)

Discharge (cfs)

Pacific Local Time (Day Hour)

Observed  Forecast  Guidance  Monitor 110.0  Flood 114.0  California Department of Water Resources  California Nevada River Forecast Center (CNRFC), NWS/NOAA

Monitor Stage: 110 feet
Flood Stage: 114 feet
Initial NWS use as an alternative procedure for generating seasonal water supply volumes.

- Regression-based techniques are still dominant, but ESP use is increasing rapidly.

- Initially considered viable in the time domain where weather/climate uncertainty fully dominates.
  - Used to be ~30 days and beyond.
  - Commonly 15 or less today.
Ensemble Streamflow Prediction

- Climate Forecast Adjustments
  - Daily RFC Forecasting
    - Data Ingest
    - Data QC
    - Model Updating

- Current Conditions
  - Soil
  - Reservoir Levels
  - Streamflow

- Historical Time Series
  - All Years of Record

- Mean Areal Time Series
  - Precipitation Temperature

- NWSRFS Hydrologic Models

- April-July

- Forecast Time Series

- Streamflow

- Time

- April-July

- Historical Time Series
  - All Years of Record

- Mean Areal Time Series
  - Precipitation Temperature

- NWSRFS Hydrologic Models

- Streamflow

- Time
April-July Volumes

~50 locations

Monthly Updates

www.wrh.noaa.gov/cnrfc/water_supply.html
Forecast of Runoff Volumes for the Snowmelt Season
Issued Wednesday, June 5, 2002

Produced by the NWS California Nevada River Forecast Center and the California Dept. of Water Resources

Remarks: The 5-day period begins with temperatures well above normal. Into the weekend, a weak trough will move into the intermountain west and lower temperatures closer to normal. High pressure will rebuild early next week and once again warm temperatures to above normal. No precipitation is expected.

Please note: Snowmelt peak flows have occurred or are occurring at all forecast points. This will be the final snowmelt forecast for this season. Any agency requiring additional snowmelt forecast guidance is requested to contact the CNRFC.

Forecasts reflect predicted short-term precipitation and temperature as well as the predicted shift from normal climatology provided by NOAA’s Climate Prediction Center.

Min: Reasonable minimum (50 percent chance of being exceeded)
Prob: Most probable volume (50 percent chance of being exceeded)
Max: Reasonable maximum (10 percent chance of being exceeded)
Pk: VolDate: Most probable peak 1-day volume of runoff (in thousands of acre-feet) and the date of occurrence.

Indicated values are unimpaired flow volumes in thousands of acre-feet in 5-day intervals for the next 20 days. The data indicated above each column is the mid-point of the 5-day interval.

www.wrh.noaa.gov/cnrfc/snowmelt.pdf
Current Benefits of ESP

- **Flexibility**
  - Time periods (hours to seasons)
  - Flow attributes (peaks, lows, volumes, times)

- **Ability to objectively integrate weather and climate forecasts**
  - Pre-adjustment techniques
  - Post-processing techniques
Potential Benefits ESP

- Accurate short and medium range probabilistic forecasts.
- Objective integration of forecaster and model information and skill.
- Accurate forecast reliability information.
  - For forecasters!
  - For customers.
Hydrologic Ensemble Uses

- **Short-range** (hours to days)
  - Watch and warning program
  - Local emergency management activities
  - Reservoir and flood control system management

- **Medium-range** (days to weeks)
  - Reservoir management
  - Local emergency management preparedness
  - Snowmelt runoff management

- **Long-range** (weeks to months)
  - Water supply planning
  - Reservoir management
CNRFC
Ensemble Implementation (AHPS)

- Phase I - Medium and long-range ESP
  - Headwaters and unregulated points. (FY03-07)

- Phase II - Medium and long-range ESP
  - Regulated points (FY06-10)

- Phase III - Short-term ESP
  - All flood forecast points and reservoirs (FY08-12)
Short-term Ensemble Prototype

- 5 day Precipitation and temperature ensembles
- Based on operational deterministic precipitation and temperature forecasts
- Uses forecast (skill) and watershed climatology
- Reliability is unknown
  - Need to develop retrospective analysis.
5 day temperature ensembles

Calib. Trace Ensemble
Latitude: 0.0  Longitude: 0.0
Forecast for the period 2/25/2004 8h - 2/28/2004 24h INTL
This is a conditional simulation based on the current conditions as of 2/25/2004
5 day precipitation ensembles
American River – 5 day ESP

6 Hour Chances of Exceeding River Levels on the AMERICAN-FOLSOM FNF
Latitude: 38.7  Longitude: 121.2
This is a conditional simulation based on the current conditions as of 2/25/2004

Exceedance Probability:
- 10 - 25%
- 25 - 50%
- 50 - 75%
- 75 - 90%
- >= 90%

River Flow (CFS)

23347.0
21151.0
19855.0
16759.0
14563.0
12367.0
10171.0
7975.0
5779.0
3583.0
1387.0
25.06
26.12
27.18
28.24
Ensemble Challenges

• Appropriately integrate the uncertainty introduced from model, data, and human sources.

OBSERVATIONS
precipitation
air temperature
streamflow

MODEL STATES
snow
soil moisture
basin routing

MODELLING SYSTEM
simplifications
temporal issues
scale issues

MODEL PARMS
snow
soil moisture
basin routing

HUMAN INPUT
education
training
experience
mental state

FORECASTS
precipitation
air temperature
regulation

?
Ensemble Challenges

- Mesh ensemble forcing from short, medium, and long range techniques.

- 
  - Mesoscale wx models
  - Medium range wx models
  - Long range global circulation models

- Downscaling
- Downscaling
- Downscaling

- Time

- Variable

- Forecaster skill

- Climate forecasts and indexes
Ensemble Challenges

• Maintain spatial and temporal relationships across very large areas.
Ensemble Challenges

- Include forecaster skill in short-term inputs (QPF, temperature, etc.)
- Forecasters add value to short-term QPF.
  - HPC adds value to models
  - RFC adds value to HPC
Ensemble Challenges

- Include forecaster guidance of hydrologic model operation
- Hydrologic models require on-going tuning.
- Forecasters commonly adjust or influence raw model output.
Ensemble Challenges

- Maintain coherence between deterministic and ensemble forecasts
Where Are We Headed?

• Shorter time step modeling (1 hr vs. 6 hr).
  • Significant benefits for smaller fast responding watersheds.

• Production of uncertainly information.
  • Essential to forecasters.
  • Increasingly useful for many customers.

• Broader support for ungaged and smaller watersheds.
  • Distributed modeling?

• Visualization of impacts.
  • Flood inundation mapping (static, near real time).

• Broader application of hydrologic forecasts and information.
  • Low flow information and drought information.
What Do We Need?

- Better precipitation and temperature forecasts (QPF and QTF).
- Reasonable operational assessment of hourly gridded hydrologic model inputs.
  - Precipitation, Temperature, Freezing Level.
- Operationally functional ensemble techniques for all time domains.
- Better assessment of diversions, accretions throughout the year.
- Meaningful reliability statistics for customers.
- Feedback from customers.
  - Are we providing the right information?
Thank You