Operational Perspectives on Hydrologic Model Data Assimilation

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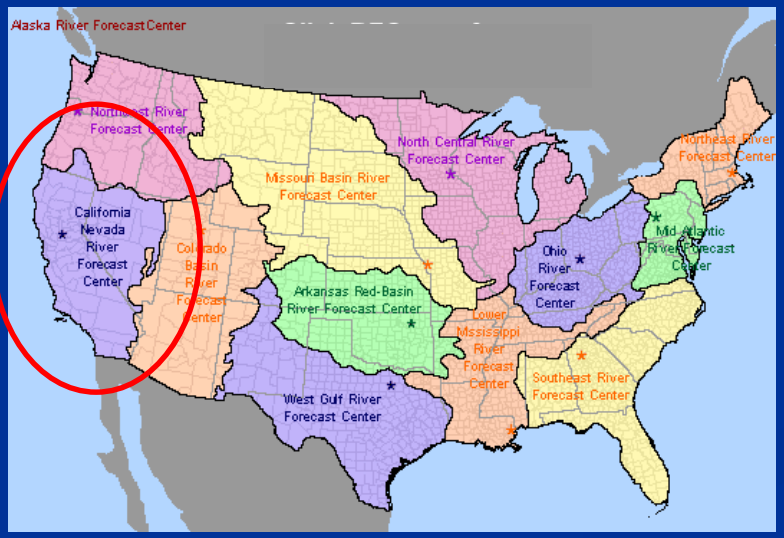
Outline

- Operational Background and Context
- Data Assimilation (DA) Goals
- DA Advantages
- DA Pitfalls
- Common DA Examples
- DA GAPS and Needs

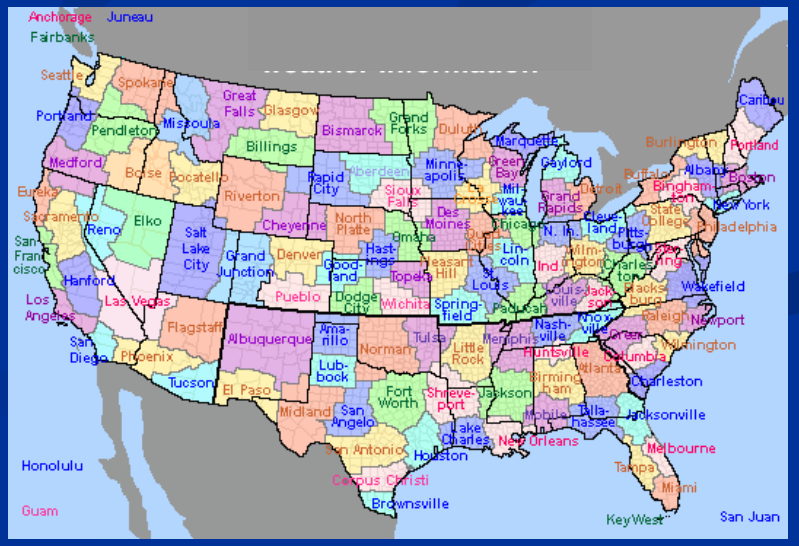
USA NWS Field Offices

9 National Centers
for Environmental Prediction (NCEP)

13 RFCs
River Forecast Centers

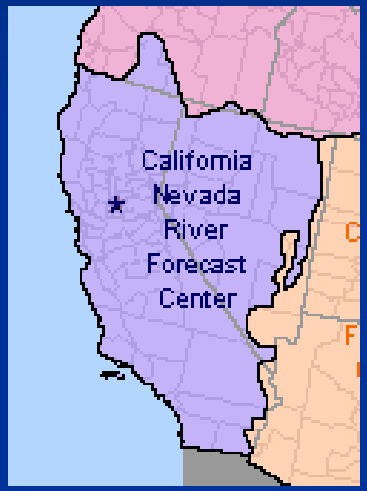


122 WFOs
Weather Forecast Offices

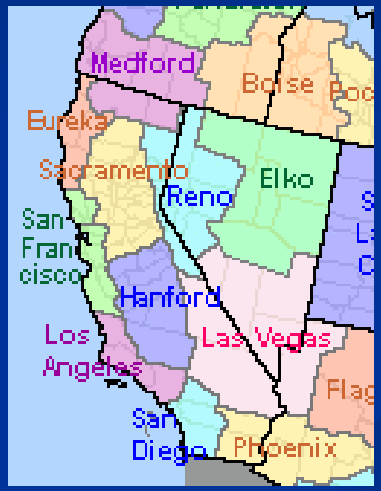


CNRFC Customers

RFC



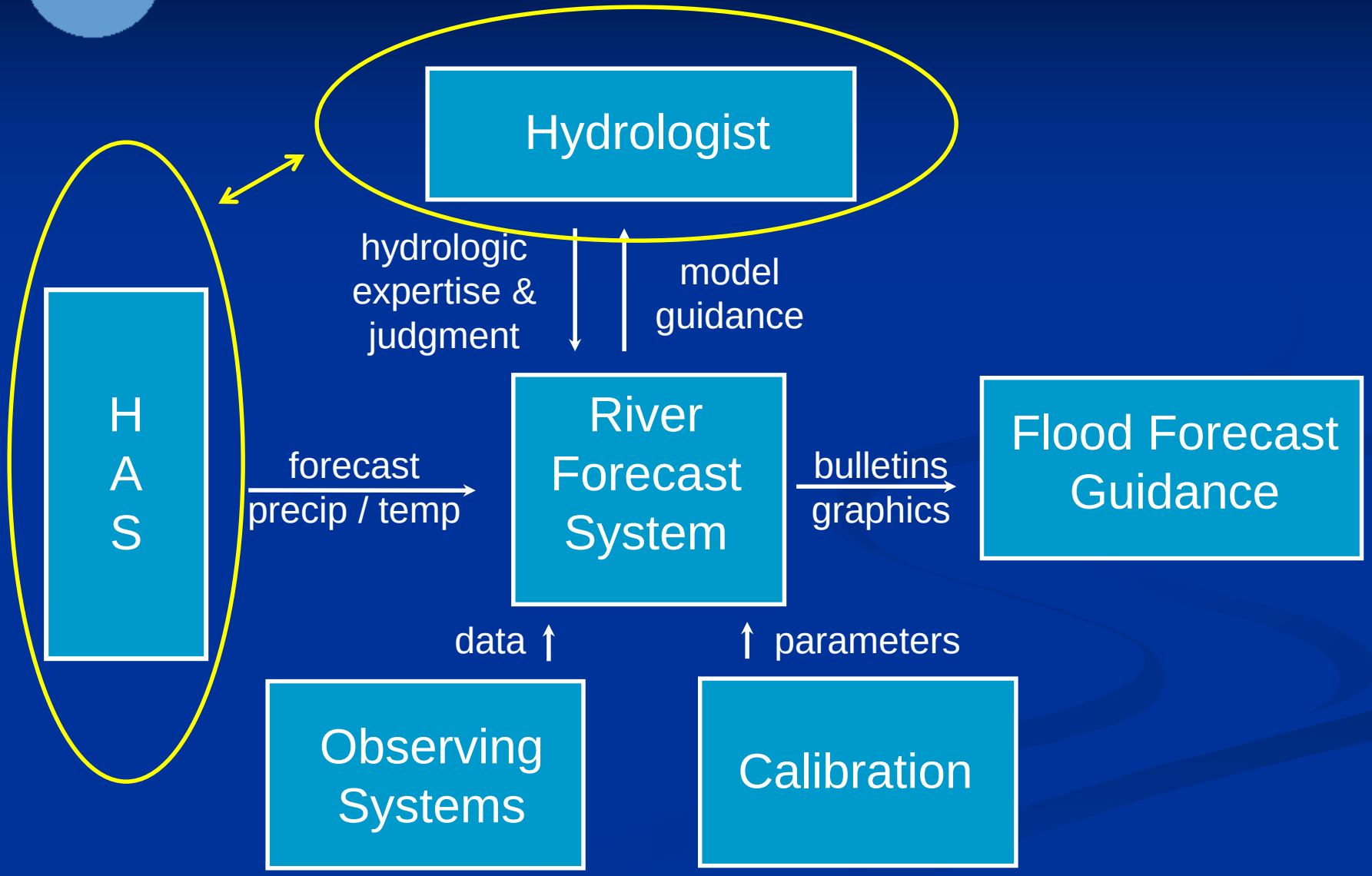
WFOs



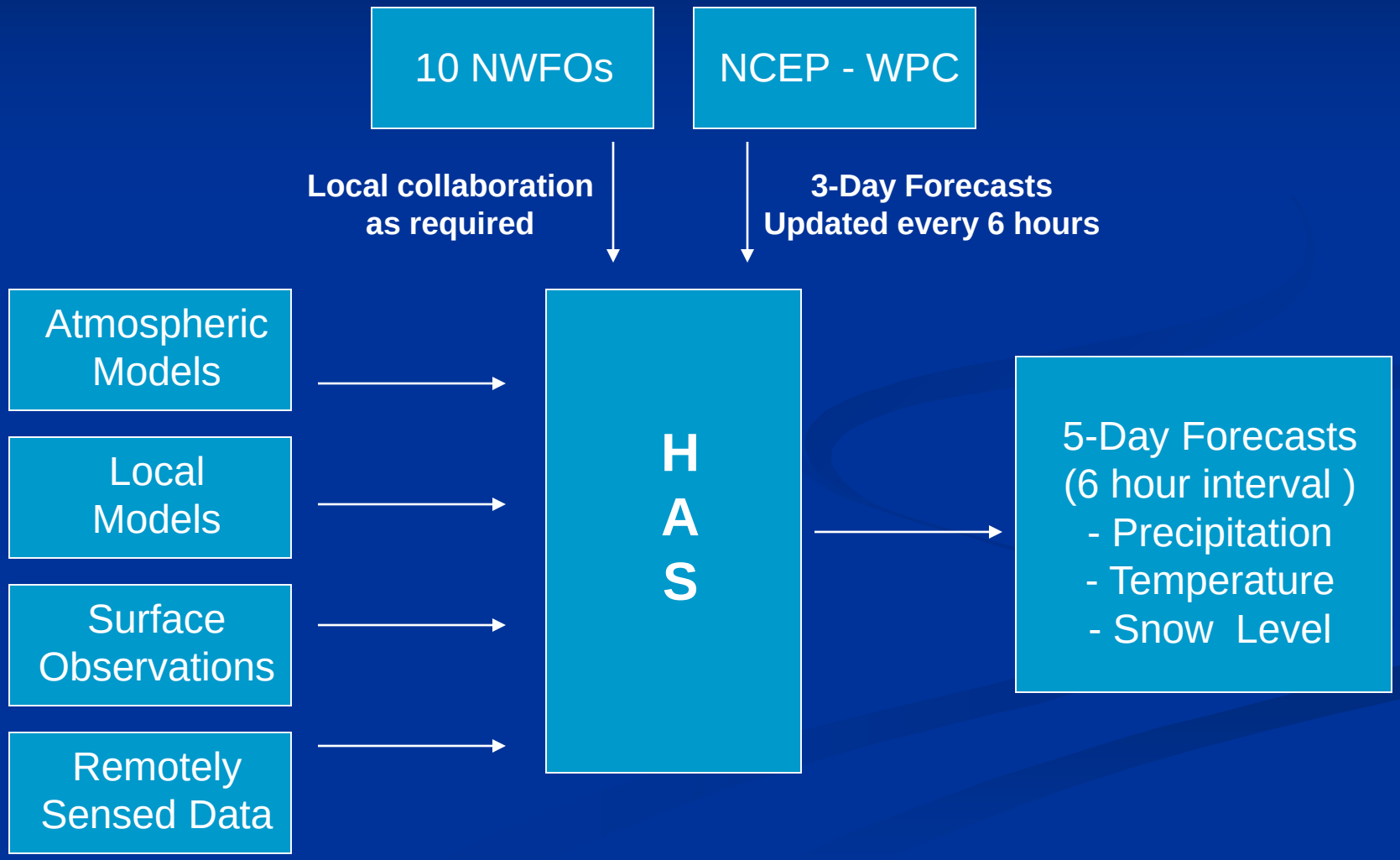
Public Warning

Water and Flood Management Agencies, Utilities

Operational River Forecasting



Operational HAS Function
(Meteorology)



Available CNRFC Forecasts

Short Range … … … … Medium Range… … … … … Long Range

0-5 days | **6-14 days** | **> 14 days**

Driven by weather forecasts & scheduled reservoir releases

Driven by a combo of weather forecasts & climatology

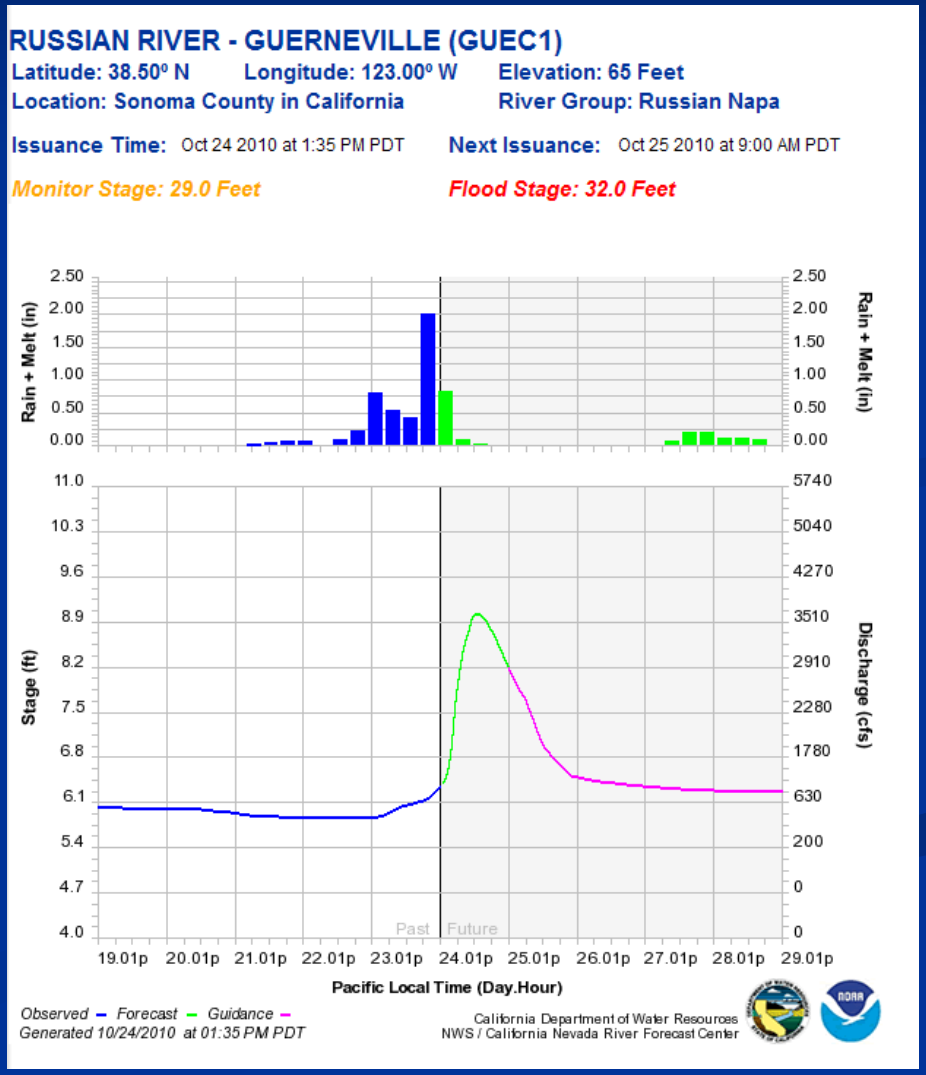
Driven by climatology

Forecast	Duration	Season	Frequency	Probabilities
Flood / Routine	5 Days	Year-round	Daily +	No
Ensemble Streamflow Prediction	User selectable to ~1 year	Year-round	Daily	Yes

River Guidance - Graphics

- Issued with each model run
- -/+ 5 days
- Obs + Forecast + Guidance
- Available
  - CNRFC Website
  - CDEC Website
- Interpretation
  - Online help
  - 1 page flier

(www.cnrfc.noaa.gov)



Ensemble Streamflow Prediction

- Use same forecasting infrastructure as Flood/Routine forecasts (CHPS)
  - Same models, observed data, model states
- Modeling system run with multiple scenarios of future precipitation and temperature
  - Scenarios are
    - Spatially and temporally coherent
    - Equally likely
- Resulting streamflow scenarios form a set that can be statistically sampled and analysed

Ensemble Streamflow Prediction

Daily RFC Operations
- Data Ingest
- Data QC
- Model Updating

Current Conditions
- Soil Moisture
- Snowpack
- Reservoir Levels
- Streamflow

HAS Unit Forecasts

Historical Time Series

All Years of Record

Numerical Weather Model Forecasts

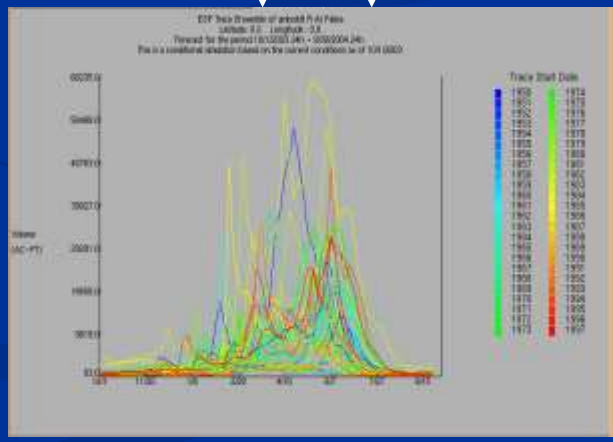
Met Ensemble Preprocessor

Mean Areal Time Series

Precipitation Temperature

CHPS Hydrologic Models

Flexible Period of Interest



Time →

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

ESP Product Generation

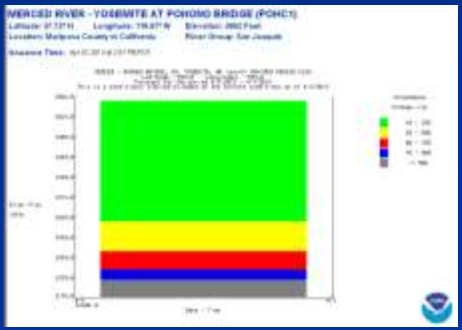
- Significant flexibility
  - User selectable time aggregation
    - 6 hrs to 1 year
  - User selectable window
    - Days, weeks, months or multiples there of
  - Information on
    - Peaks and minimums
    - Number of days to critical thresholds (e.g. Flood Stage)
    - Volumes

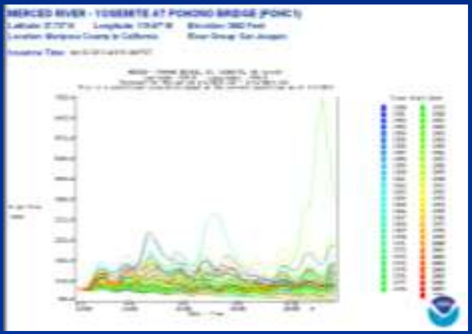
CNRFC Ensemble Forecasts

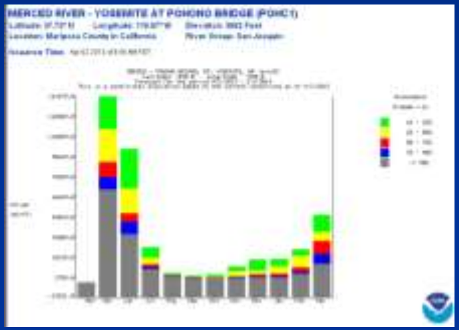
- Updated daily
- 150+ locations
- 365 day duration
- 8 standard graphics
- Build your own interface

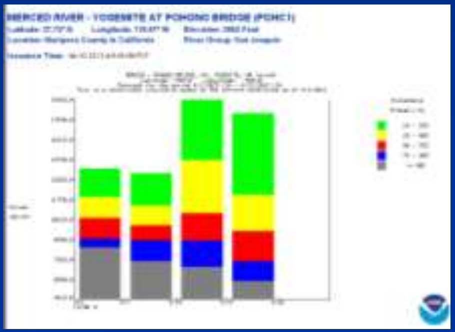
- Includes 14 days of weather forecasts

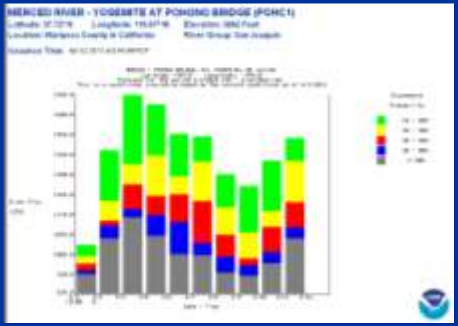
Sample Ensemble Products

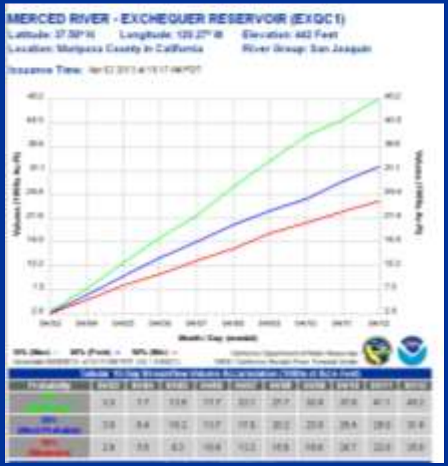


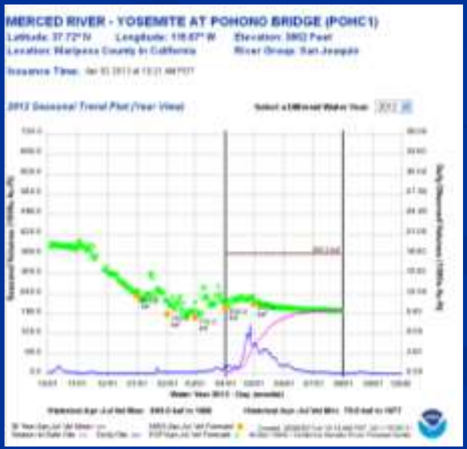


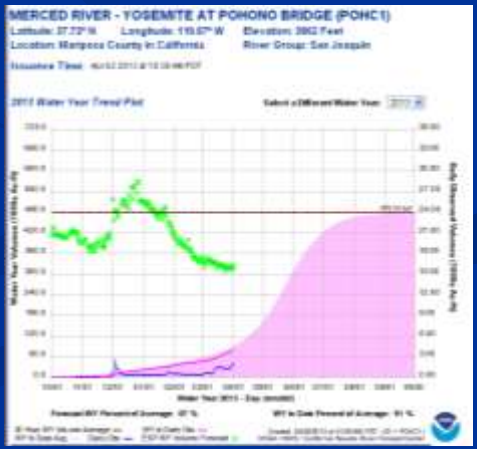










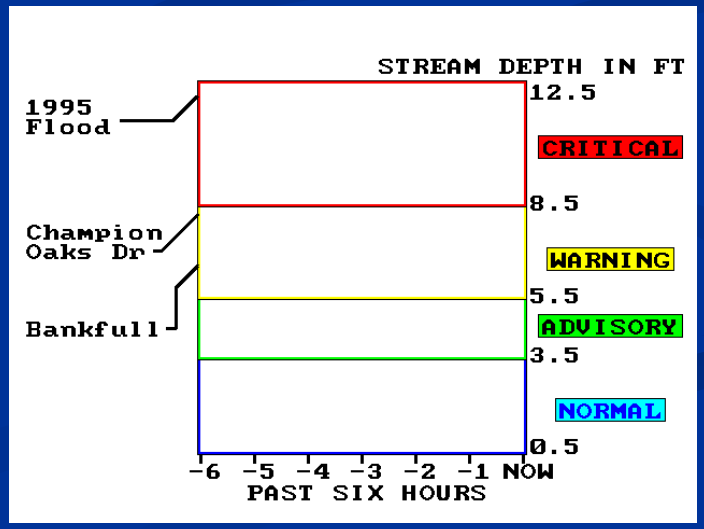


DA Goals

- Use available “information” to improve the performance of a specific model or model outcome

DA Advantages

- Essential in “fast response” situations where there is no time for manual analysis
  - Flash flooding
  - Fully automated short-term forecasting systems



DA Advantages

- Consistent DA is more reproducible than subjective forecaster specified adjustments
  - Implications for post-processing and hind-casting

OBSERVATIONS
precipitation
air temperature
streamflow

MODEL STATES
snow
soil moisture
basin routing

MODELING SYSTEM
simplifications
temporal issues
scale issues

Sources of Uncertainty

???

MODEL PARMS
snow
soil moisture
basin routing

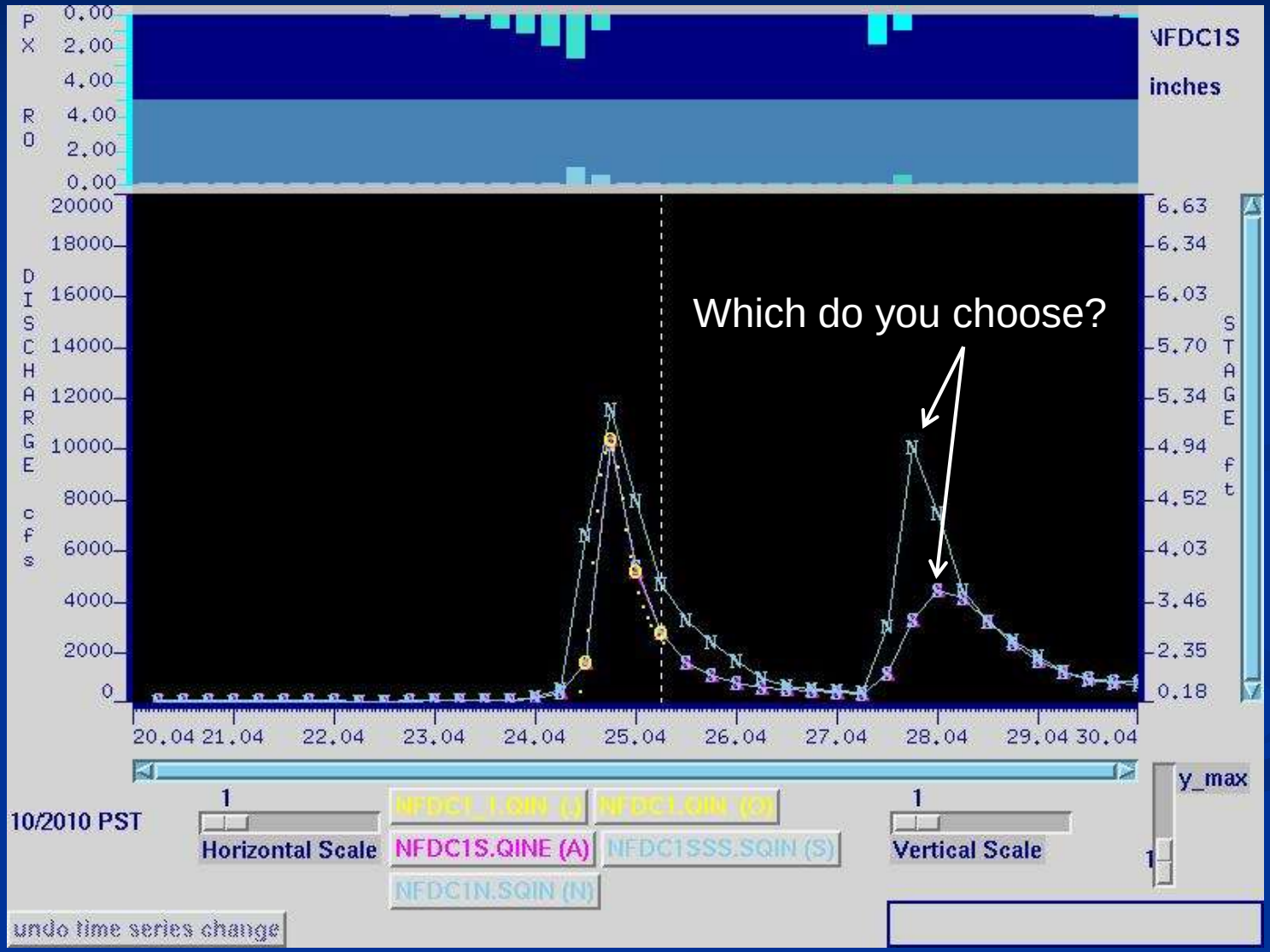
HUMAN INPUT
education
training
experience
mental state

FORECASTS
precipitation
air temperature
regulation

DA Pitfalls

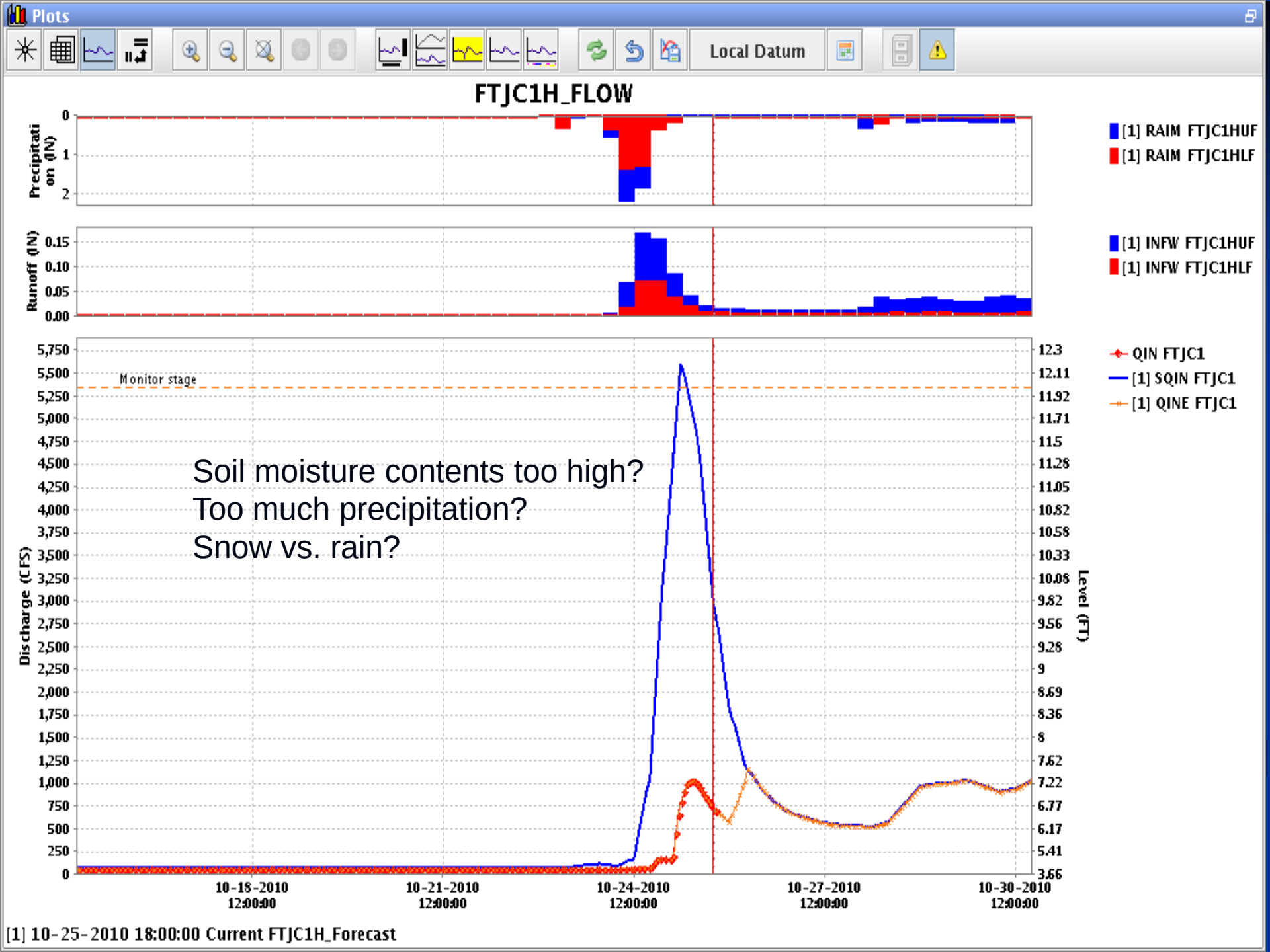
- Updates to improve performance in one time domain (e.g. short) may degrade performance in another (e.g. long)
- Improved simulation does not guarantee improved forecast performance
- Forecasters don't (won't) trust what they can't see or understand
- May reduce the need for the forecaster to understand what the models are doing (Robotic Operations)

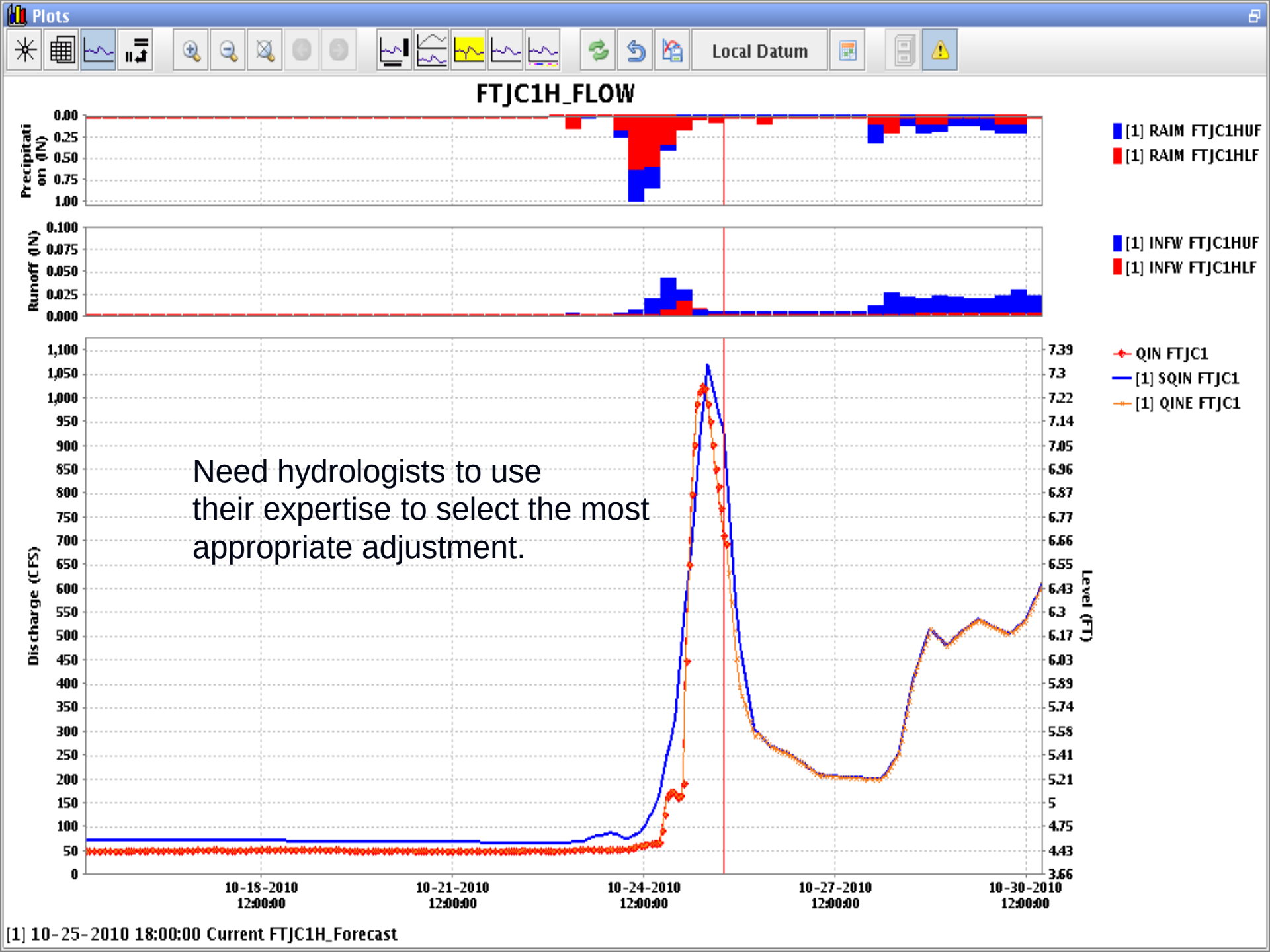
State-Space Updating



Common DA

- Runtime MODIFICATIONS
  - Using observed streamflow to infer appropriate adjustments to:
    - Model states
    - Timing and magnitude of forcings


Plots
Local Datum
FTJC1H_FLOW
Precipitation (IN)
0
1
2
[1] RAIM FTJC1HUF
[1] RAIM FTJC1HLF
Runoff (IN)
0.15
0.10
0.05
0.00
[1] INFW FTJC1HUF
[1] INFW FTJC1HLF
Monitor stage
Soil moisture contents too high?
Too much precipitation?
Snow vs. rain?
Discharge (CFS)
5,750
5,500
5,250
5,000
4,750
4,500
4,250
4,000
3,750
3,500
3,250
3,000
2,750
2,500
2,250
2,000
1,750
1,500
1,250
1,000
750
500
250
0
Level (FT)
12.3
12.11
11.92
11.71
11.5
11.28
11.05
10.82
10.58
10.33
10.08
9.82
9.56
9.28
9
8.69
8.36
8
7.62
7.22
6.77
6.17
5.41
3.66
QIN FTJC1
[1] SQIN FTJC1
[1] QINE FTJC1
10-18-2010 12:00:00
10-21-2010 12:00:00
10-24-2010 12:00:00
10-27-2010 12:00:00
10-30-2010 12:00:00
[1] 10-25-2010 18:00:00 Current FTJC1H_Forecast


Plots
Local Datum
FTJC1H_FLOW
Precipitation (IN)
0.00
0.25
0.50
0.75
1.00
[1] RAIM FTJC1HUF
[1] RAIM FTJC1HLF
Runoff (IN)
0.100
0.075
0.050
0.025
0.000
[1] INFW FTJC1HUF
[1] INFW FTJC1HLF
Discharge (CFS)
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
Level (FT)
7.39
7.3
7.22
7.14
7.05
6.96
6.87
6.77
6.66
6.55
6.43
6.3
6.17
6.03
5.89
5.74
5.58
5.41
5.21
5
4.75
4.43
3.66
QIN FTJC1
[1] SQIN FTJC1
[1] QINE FTJC1
Need hydrologists to use their expertise to select the most appropriate adjustment.
10-18-2010 12:00:00
10-21-2010 12:00:00
10-24-2010 12:00:00
10-27-2010 12:00:00
10-30-2010 12:00:00
[1] 10-25-2010 18:00:00 Current FTJC1H_Forecast

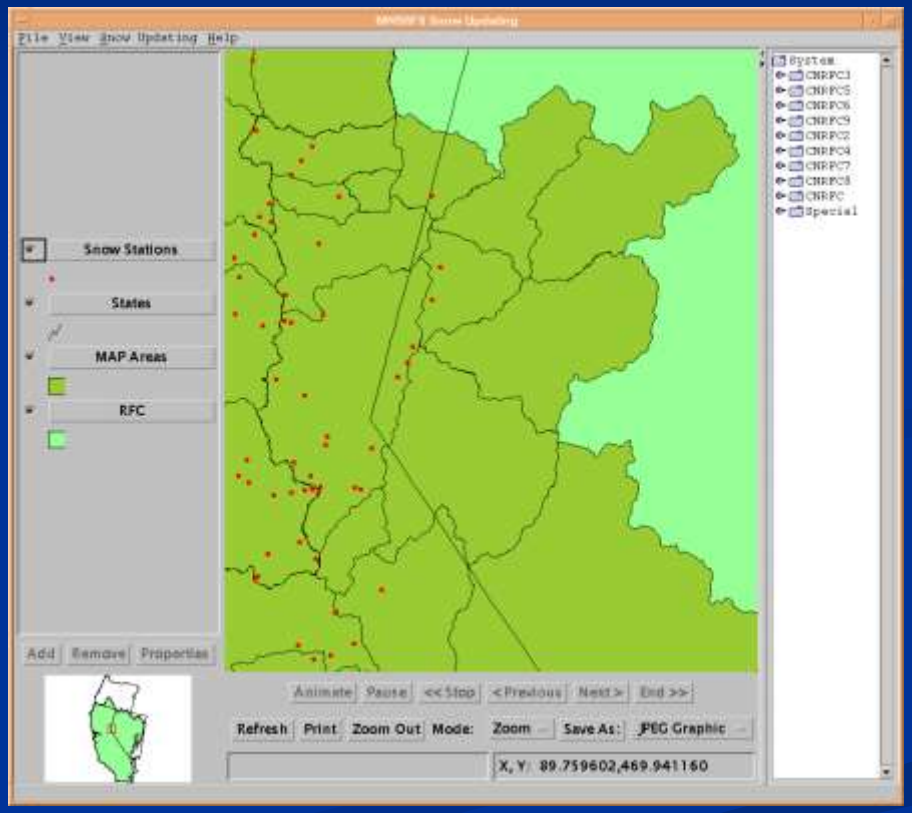
Common DA

- Model state adjustment based on field observations
  - Snow model updating
    - Observed point SWE

Snow Model Updating

- Regession-based
  - Principal components
  - Combination analysis
  - Automatic selection
- Historical snow water observations
- Historical simulated SWE from calibration

- Predict simulated SWE based on currently available SWE observations.



DA GAPS

- Using observed streamflow to make model state adjustments when the model is complex
  - Multiple model components (snow, soil, etc.)
  - Multiple (elevational) subareas
- Snow pack temperature (heat content)
- Soil moisture observations

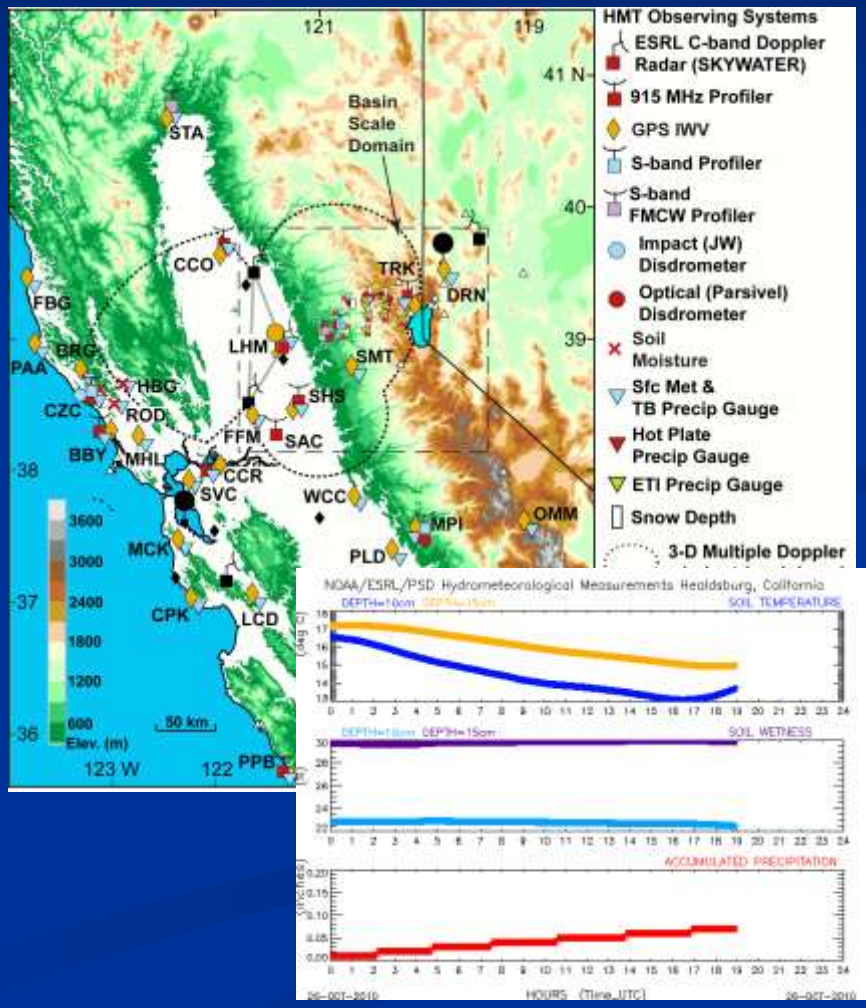
Snowpack Temperature

- High level of uncertainty in the heat content of the snowpack in late winter and early spring

- Forecasters accommodate simulation errors by making melt factor corrections to the snow model
  - Observed period
  - Forecast period (very risky)

Soil Moisture Observations

- Fair number of observations are becoming available
- Can be a high spatial frequency data set
- Need tools to relate observations to model states
  - Especially important to CNRFC in the Fall
- Some models may be better structured for updating



Summary

- Operational forecasters perform *manual* data assimilation by leveraging their expertise
- Automatic DA is critical for very short lead times where manual analysis is not feasible
- DA techniques should be engineered to assist the forecaster in *understanding and applying* the most appropriate adjustments suggested by the data

Thank You