Variational Assimilation (VAR)

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What is VAR?

- Software that produces initial estimates of soil moisture content for SAC-SMA.
- Based on variational assimilation popularized by widespread use in meteorology and oceanography.
- Solves large-scale inverse problems in dynamic systems via least squares minimization.

VAR

- Given the latest streamflow observation, MAPX, climatological MAPE, and the initial SAC-SMA state variables:
  - VAR adjusts the SAC-SMA state variables and the MAPX and MAPE estimates such that the resulting model simulated flow matches the most recent observed.
- Generates flow forecast based on VAR-adjusted SAC states.

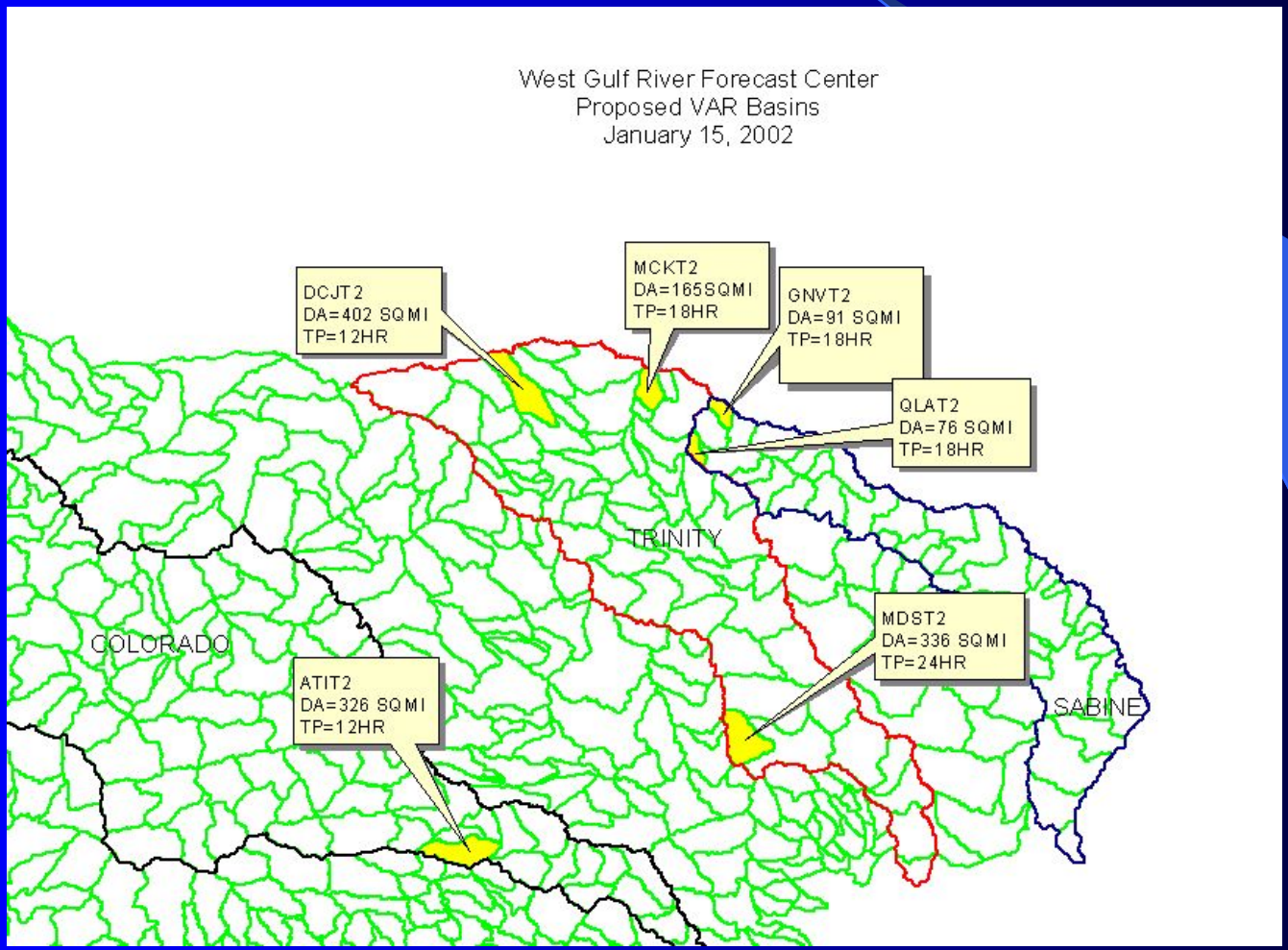
Project History

- Oct 2001 – OH asked WGRFC to test VAR
- Jan 2002 - 6 Basins were chosen for test
- June 2002 – Hourly MAPX and QIN data provided to OH
- Dec 2002 – VAR Version 1.0 installed at WGRFC

Basin Criteria

- Basins selected for the VAR project had to meet the following criteria:
  - Headwater basin
  - Basin defined in operational model
  - Hourly stage data available
- Candidate basins also needed to vary in the following areas:
  - Basin Size (50 – 700 square miles)
  - Time to peak in the unit hydrograph (4 –80 hours)
  - Diverse basin shape and geomorphology

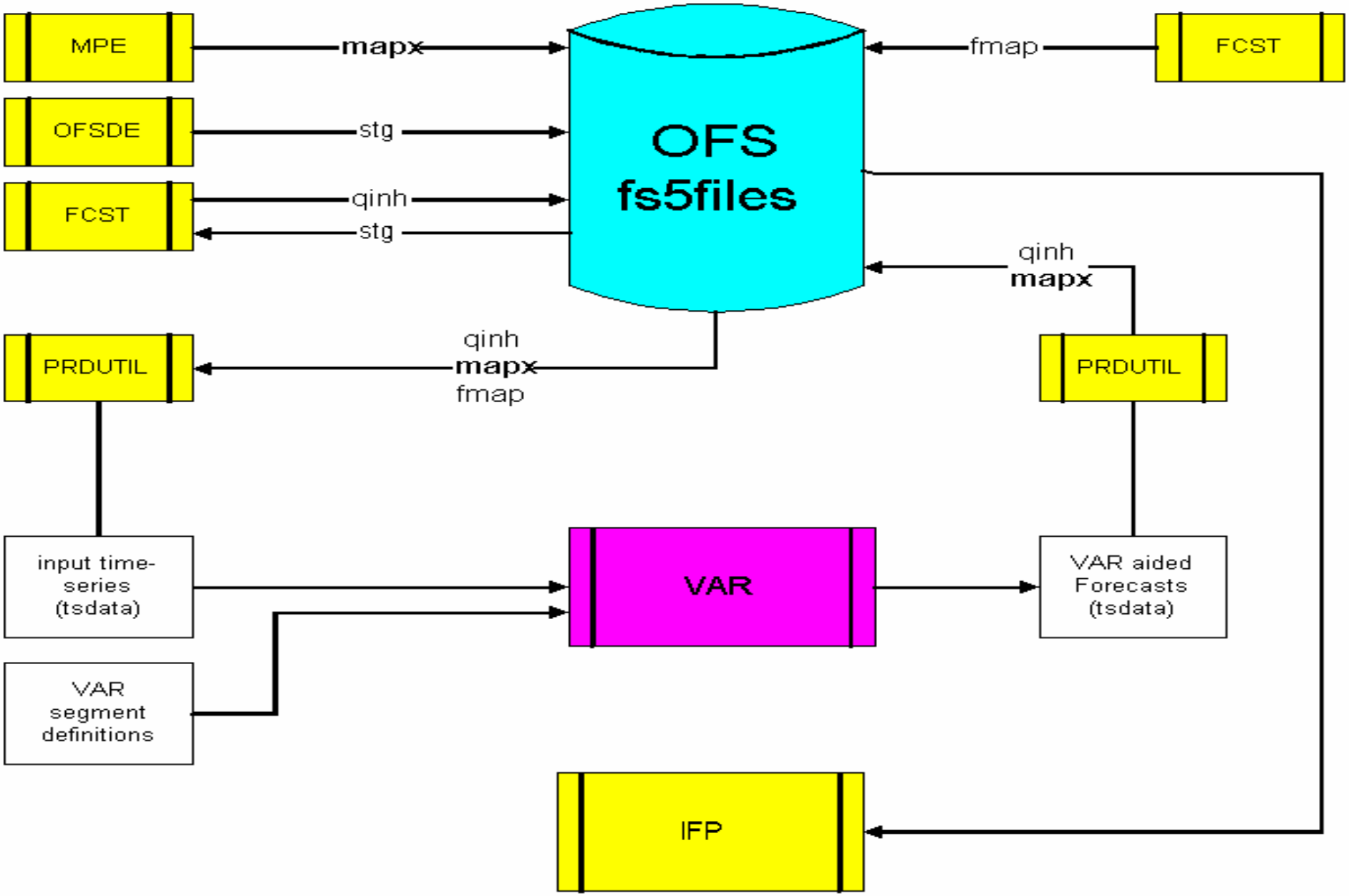
Original VAR Basins



VAR 1.0

- Stand-alone program that runs independent of OFS.
- VAR segment definitions and parameters are outside of OFS.
- Later versions read and write timeseries directly to OFS.

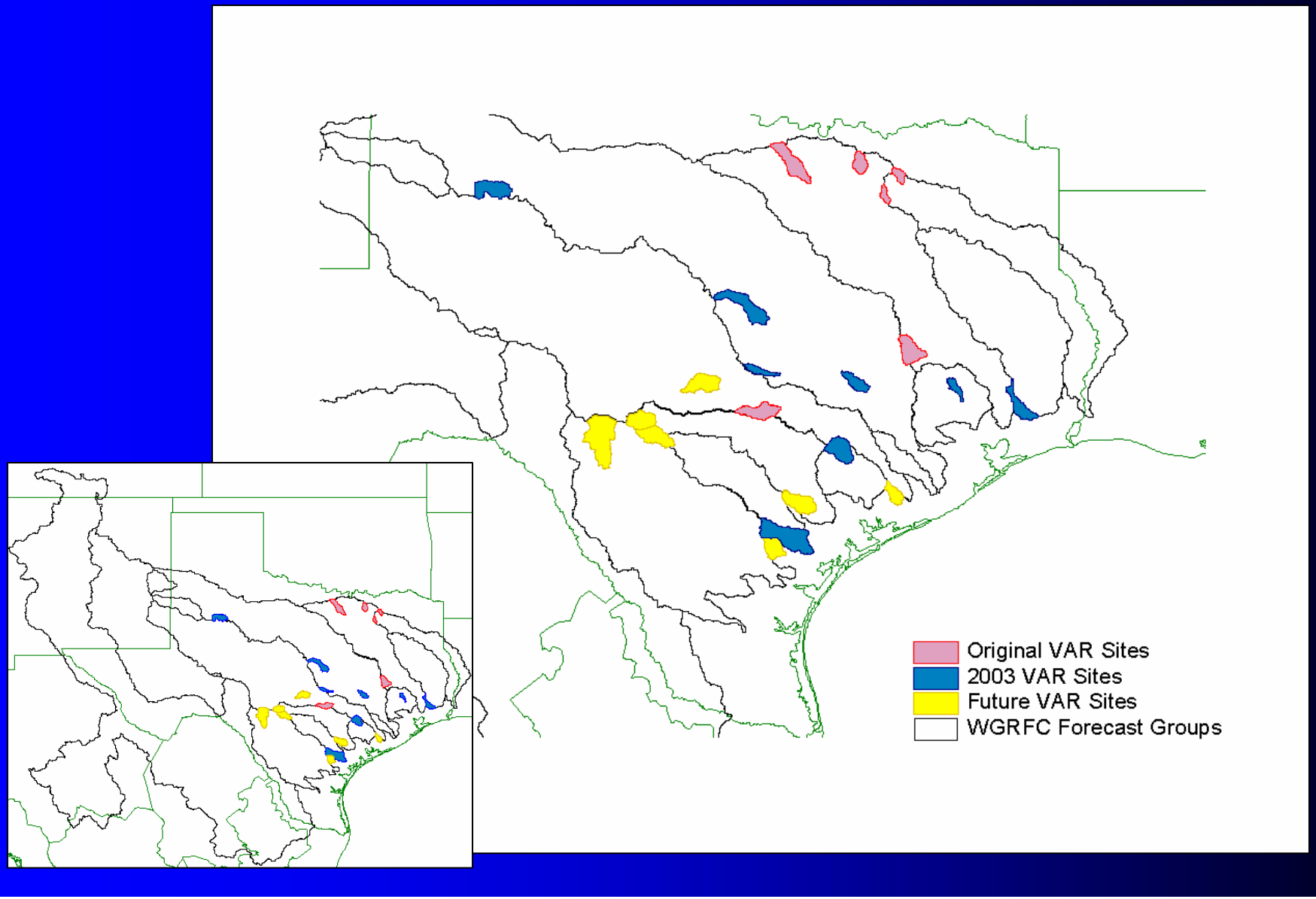
VAR Process Flow Diagram



More History

- Feb 2003 – Additional 17 sites were selected for VAR testing.
- Apr 2003 – WGRFC completed MAPX and QIN timeseries for additional sites.
- Sep 2003 – Began running 14 additional VAR sites (20 total).

Project Locations



Recent History

- Feb 2004 – Began Archiving various forecast timeseries for archiving.
- May 2004 – Installed VAR Version 2.0.

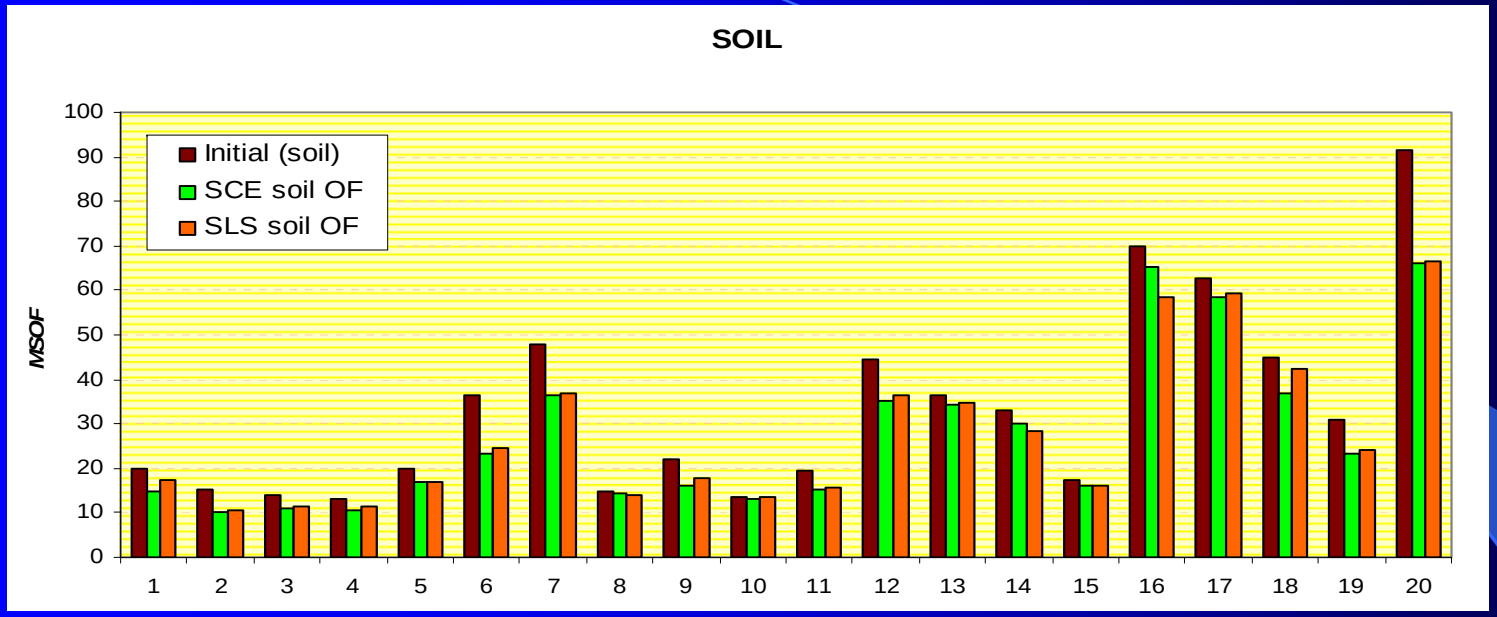
Status

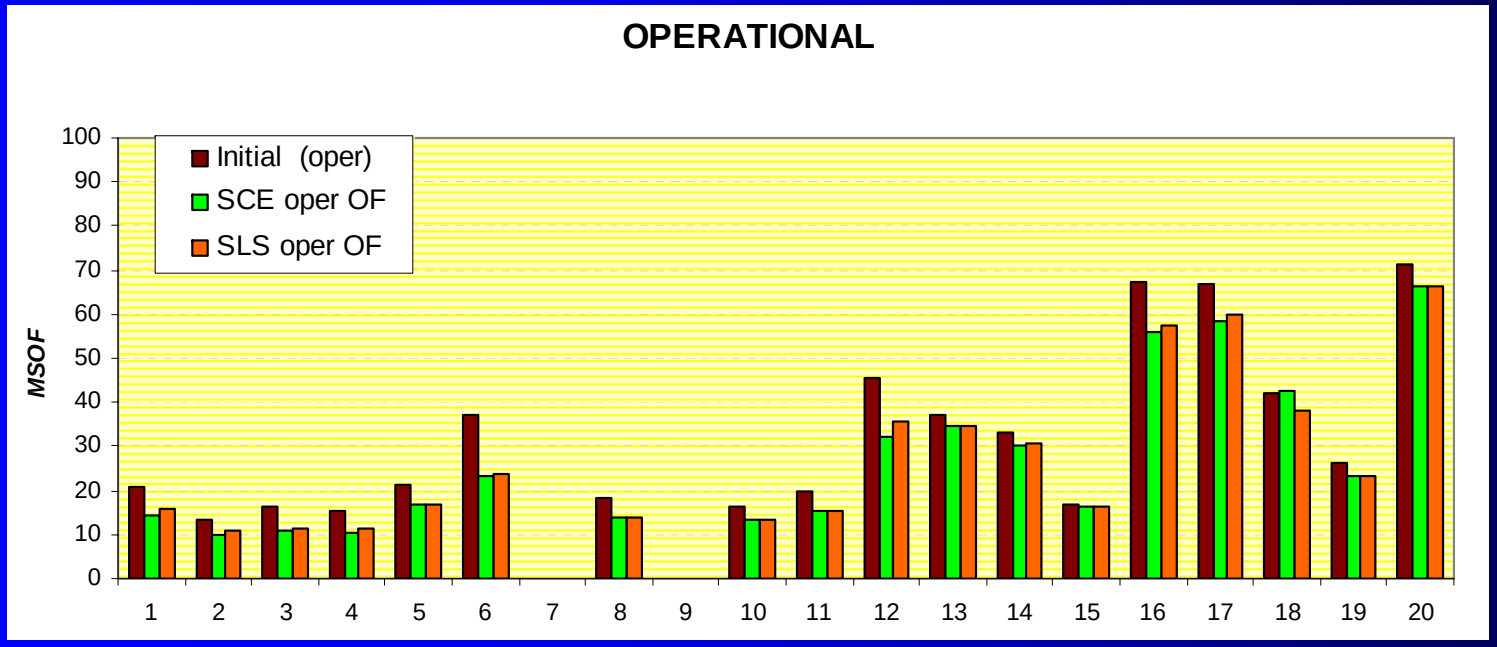
- PXADJ, PEADJ and empirical UH estimated for 23 basins (ab_opt).
- SAC parameters optimized.
  - from the (6-hourly) operational settings (OPER)
  - from the soil-based ‘a priori’ estimates (SOIL)
- A suite of forecast time series being generated.
  - archived for quantitative analysis
  - visually examined for qualitative assessment

Precip & ET Adjustments

LOCATION	PXADJ	PEADJ
ATIT2	1.02	0.99
DCJT2	0.94	1.03
GNVT2	1.08	0.96
MCKT2	1.14	0.90
MDST2	1.12	0.93
QLAT2	1.17	0.92

SAC Parameter Optimization





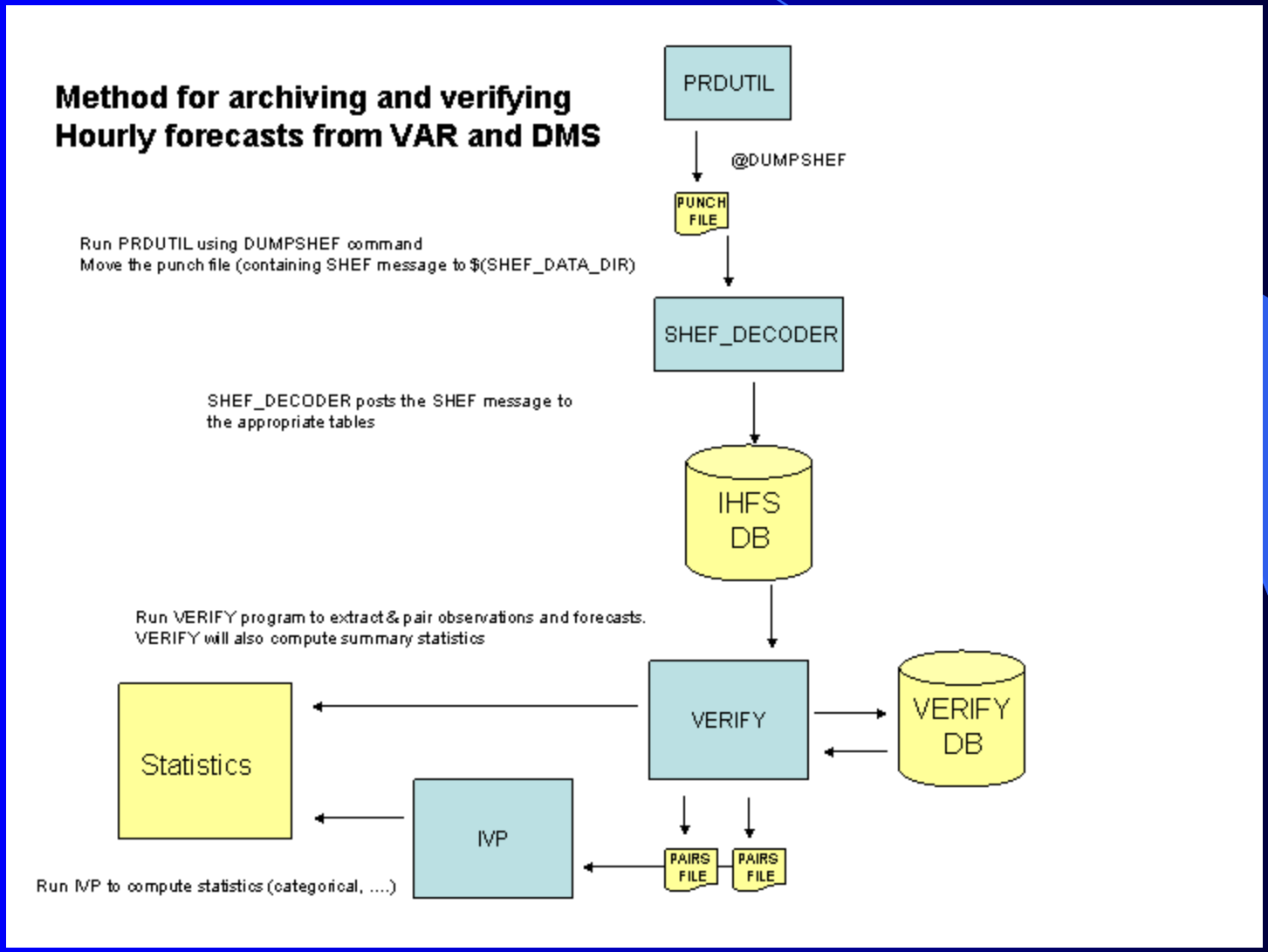
Both operational and soil-based parameters can be improved significantly by optimization

Verification Timeseries

Time Series for WGRFC DMS/VAR Verification Archive

Time Series	ID	Data Type	Type Source Code
1 hr VAR	GNVT2VAR	STGH	FA
1 hr HL-RMS	GNVT2D	STGH	FB
1 hr SAC forecasts (w/mods)	GNVT2VAR	STGE	FC
1hr SAC forecasts (no mods)	GNVT21	SSTG	FU
1 hr SAC simulations	GNVT21	SSTG	FW
6 hr SAC forecasts (w/mods)	GNVT2	SSTG	FD
6 hr SAC forecasts	GNVT2	STGE	FV
6 hr SAC simulations	GNVT2	STGE	FX

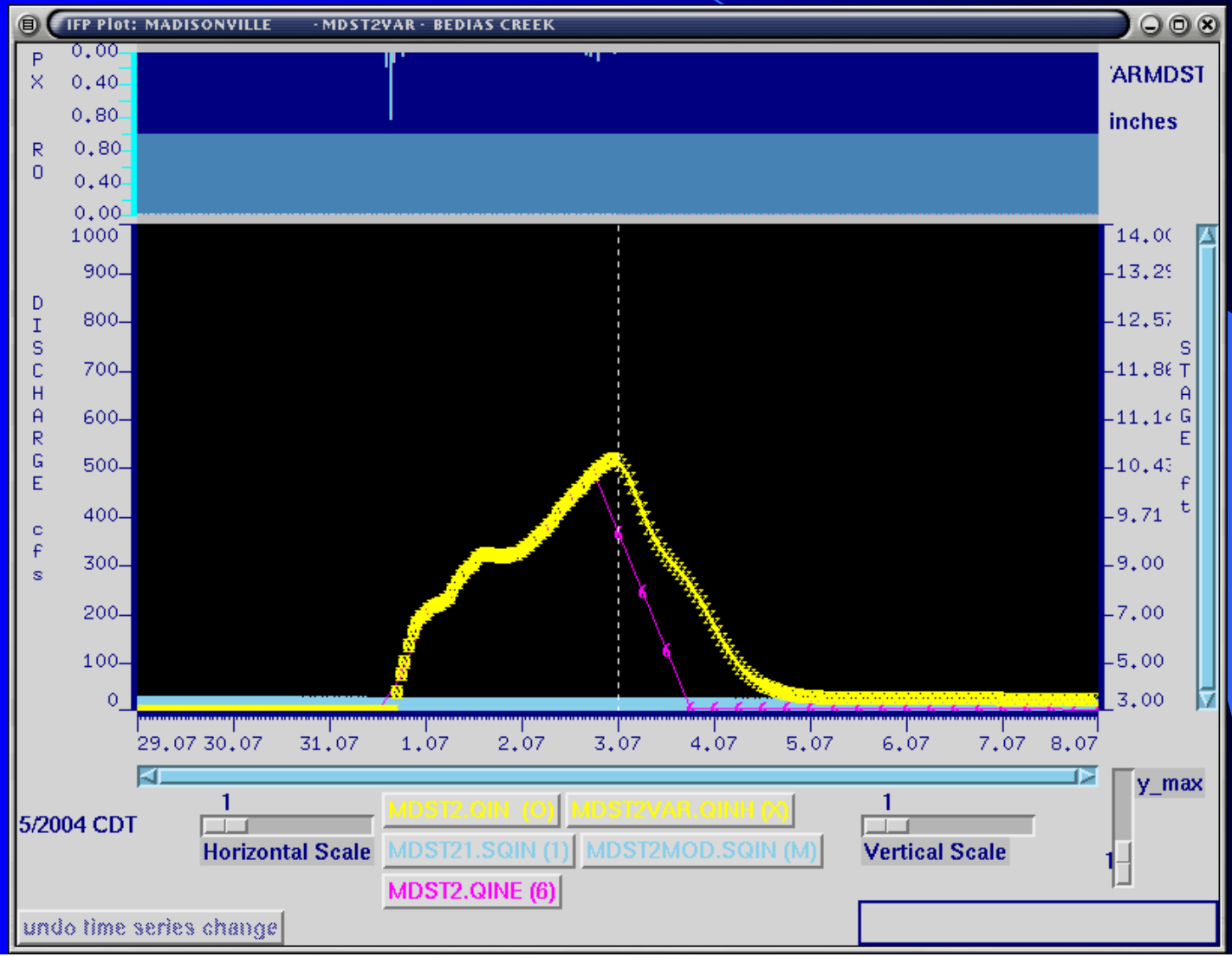
Verification Schematic



Verification Difficulties

- Bogged down shefdecoder.
  - 2200+ ordinates per forecast
- Can not easily track VAR forecasts.
  - OFS only shows most recent forecast
  - VAR simulation set to observations in past

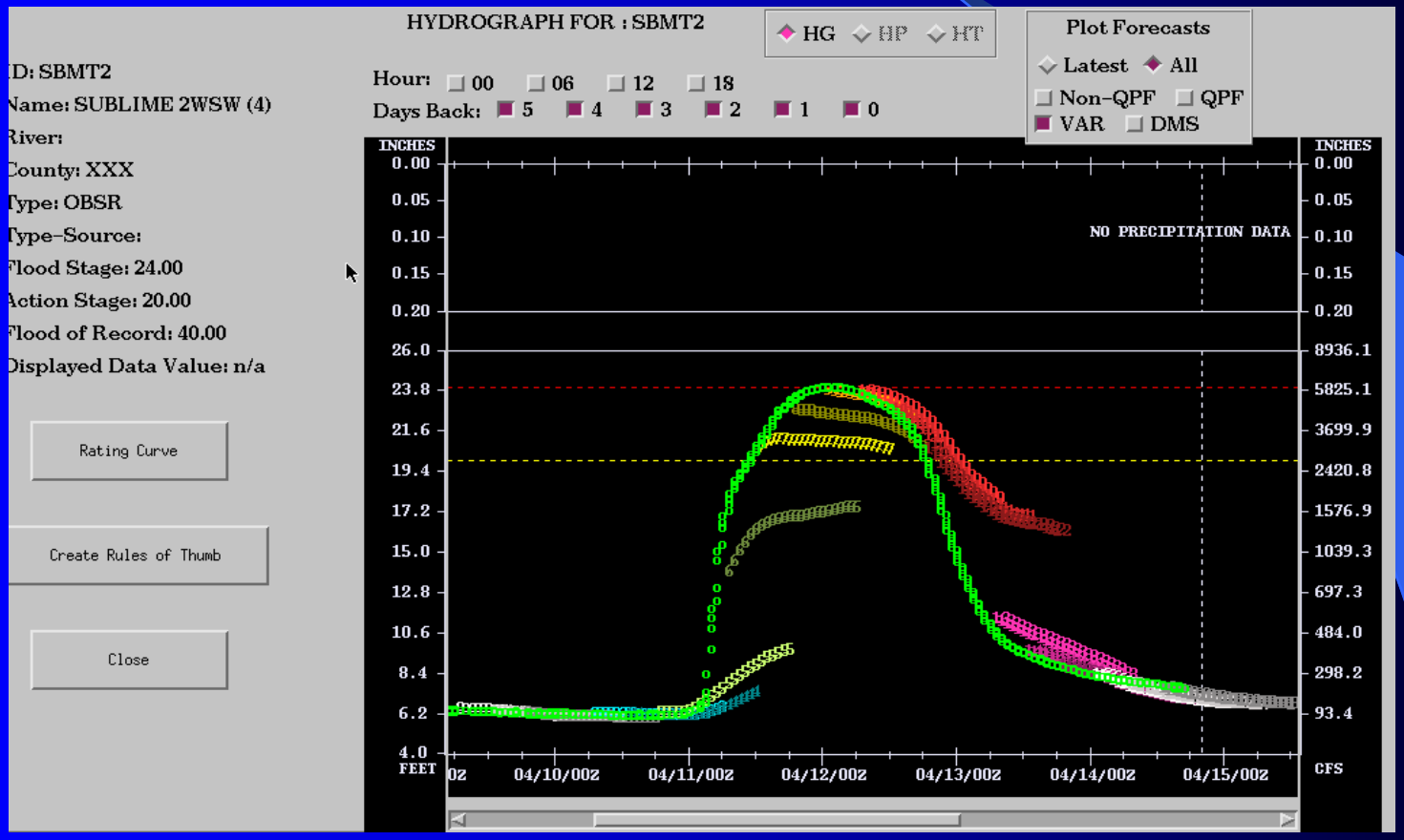
VAR Forecast in IFP



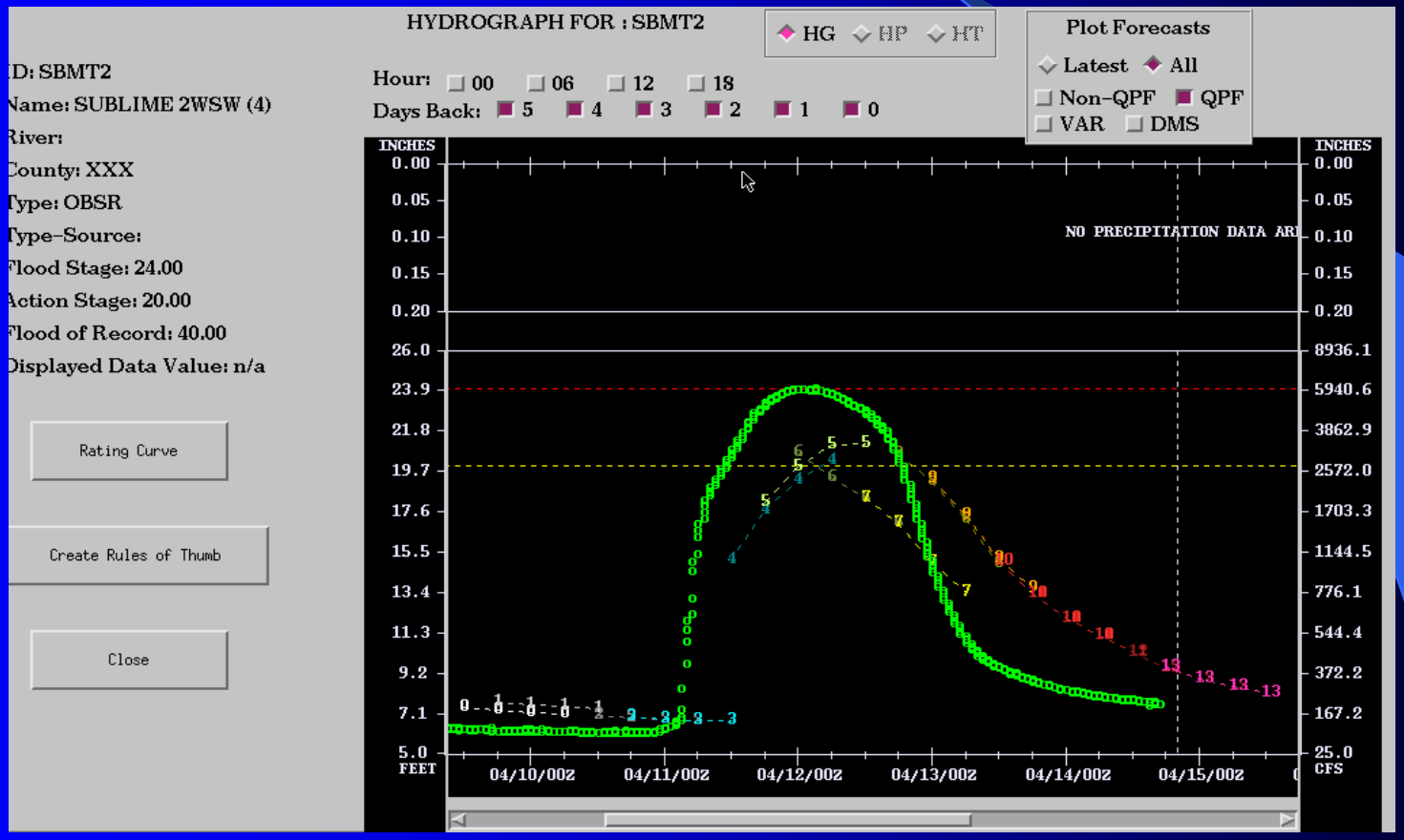
1-hr SAC-UH forecasts

- VAR performs (does not perform) well if the underlying 1-hr SAC-UH simulation has at least some semblance to reality (is grossly erroneous)
- The 1-hr VAR-aided forecasts tend to be a bit ‘jumpier’ than the 6-hr SAC-UH forecasts w/ MODs
- Some examples

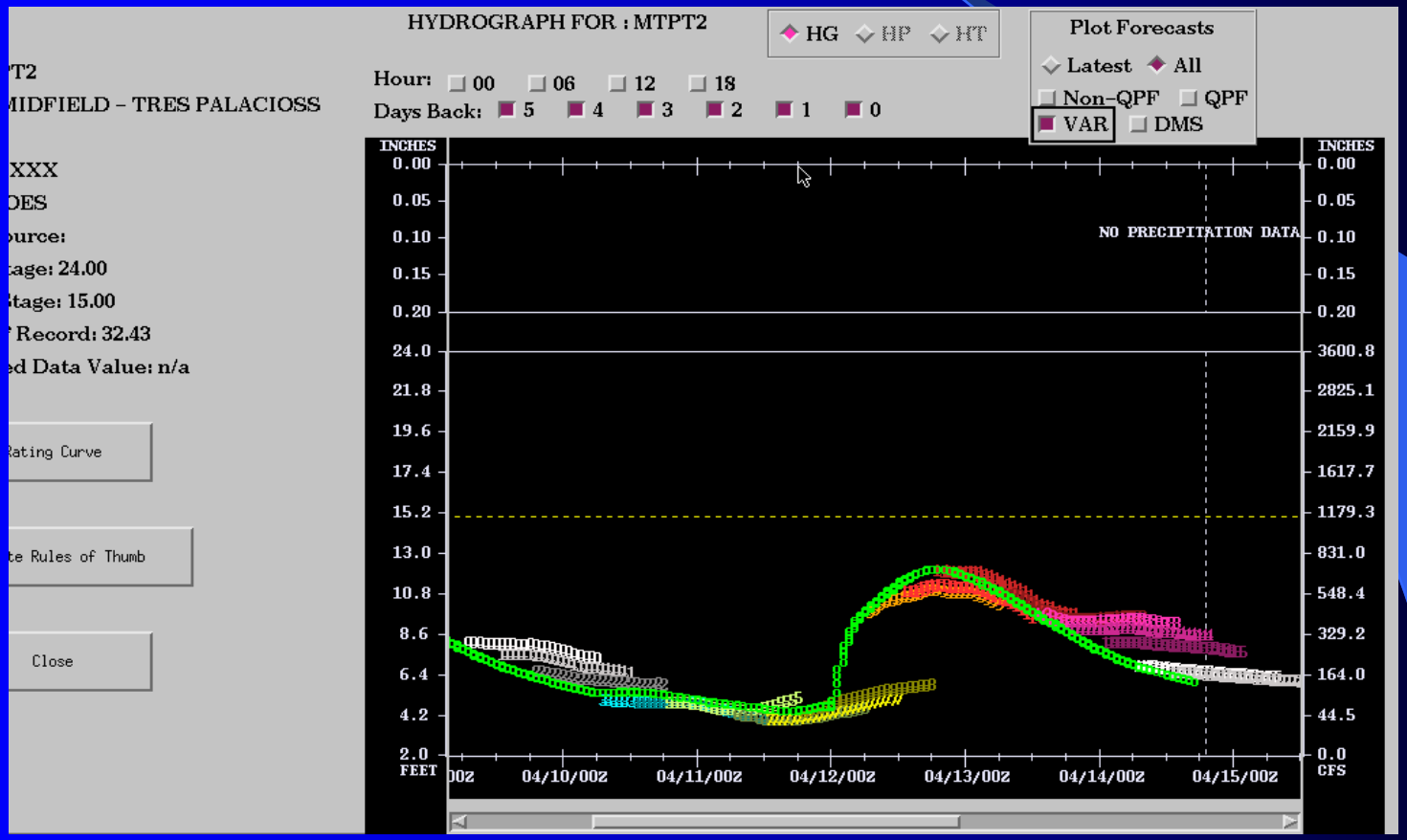
1-hr VAR-aided forecasts



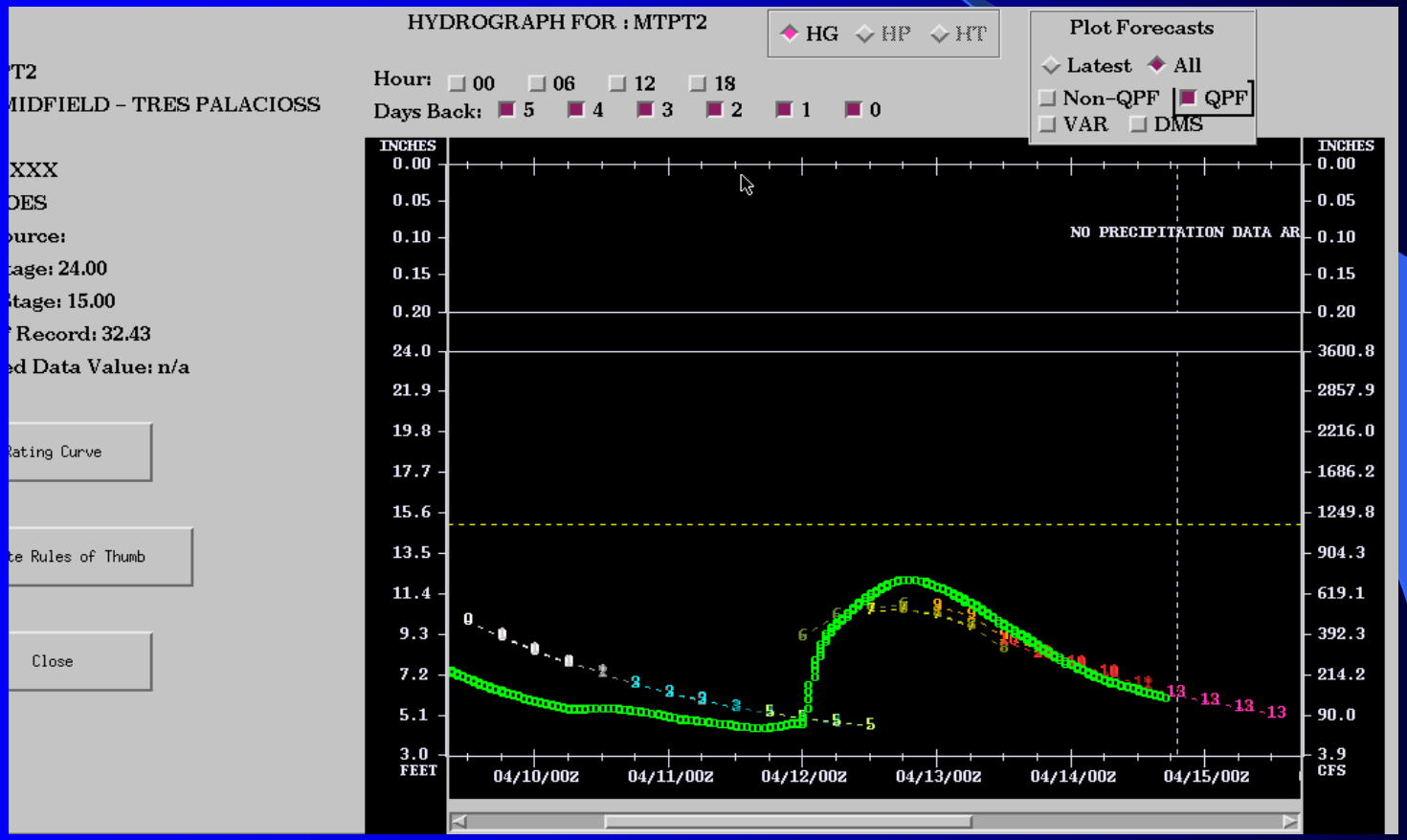
6-hr SAC-UH forecasts w/ MODs

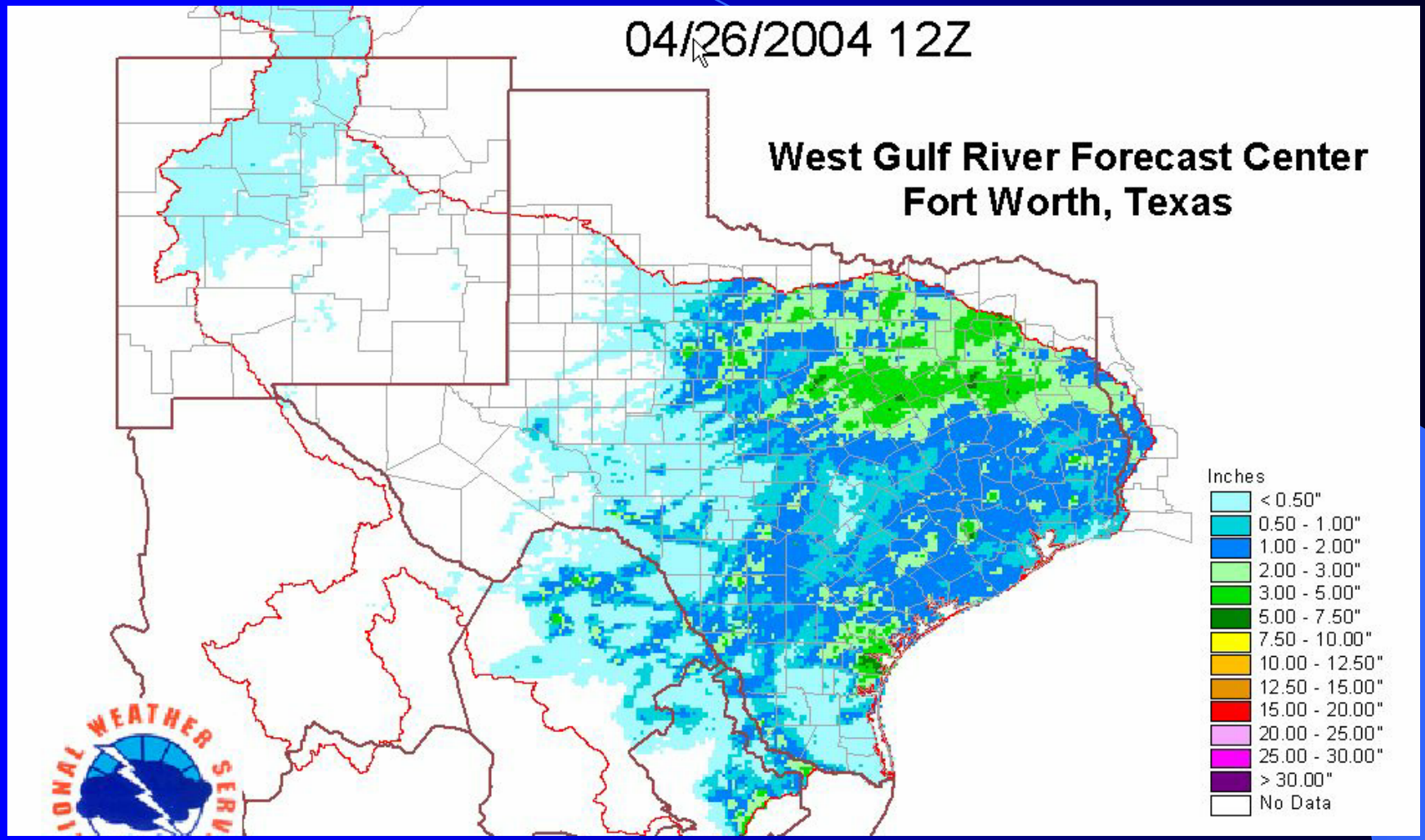


1-hr VAR-aided forecasts

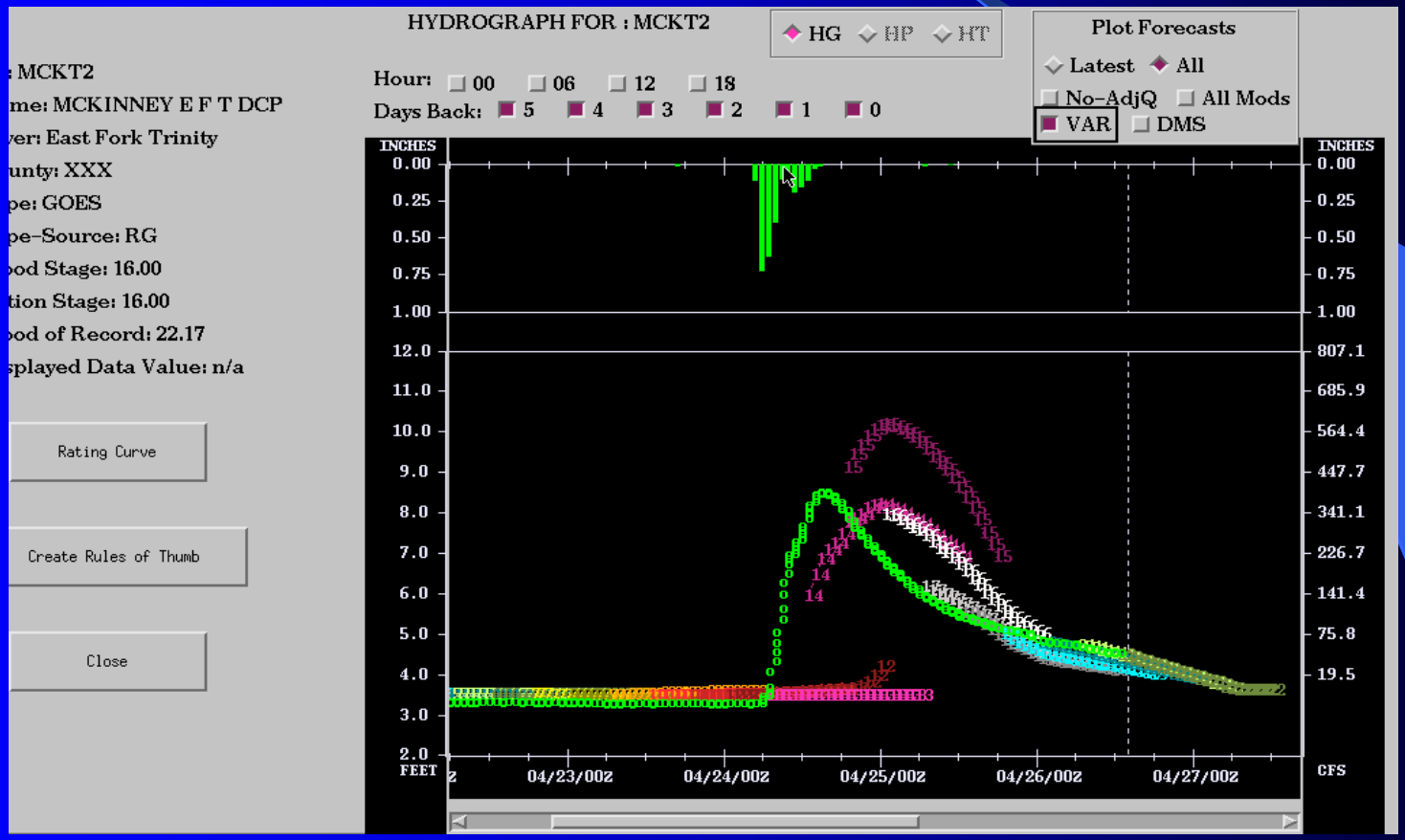


6-hr SAC-UH forecasts w/ MODs

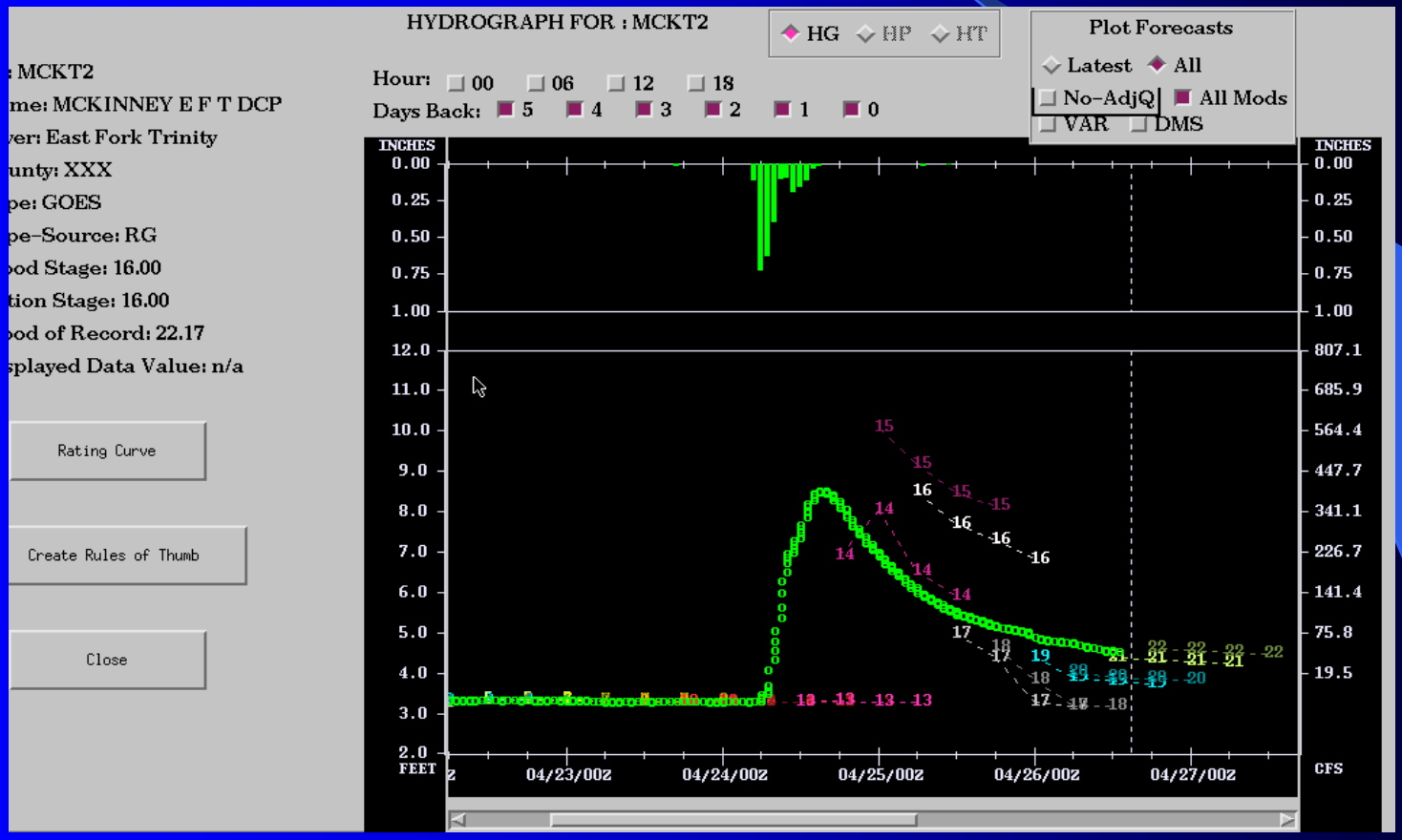



04/26/2004 12Z
West Gulf River Forecast Center
Fort Worth, Texas
Inches
< 0.50"
0.50 - 1.00"
1.00 - 2.00"
2.00 - 3.00"
3.00 - 5.00"
5.00 - 7.50"
7.50 - 10.00"
10.00 - 12.50"
12.50 - 15.00"
15.00 - 20.00"
20.00 - 25.00"
25.00 - 30.00"
> 30.00"
No Data

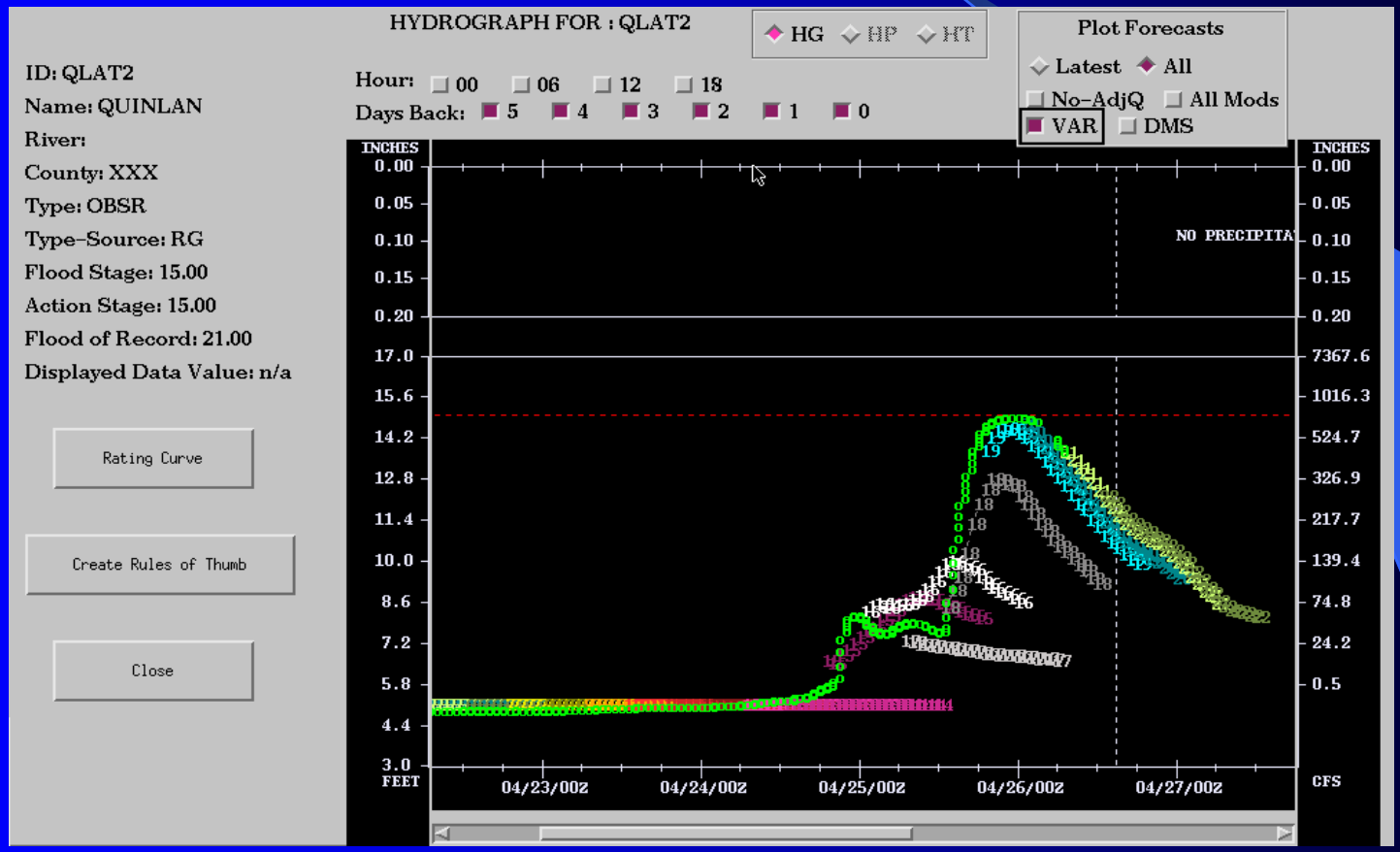
1-hr VAR-aided forecasts



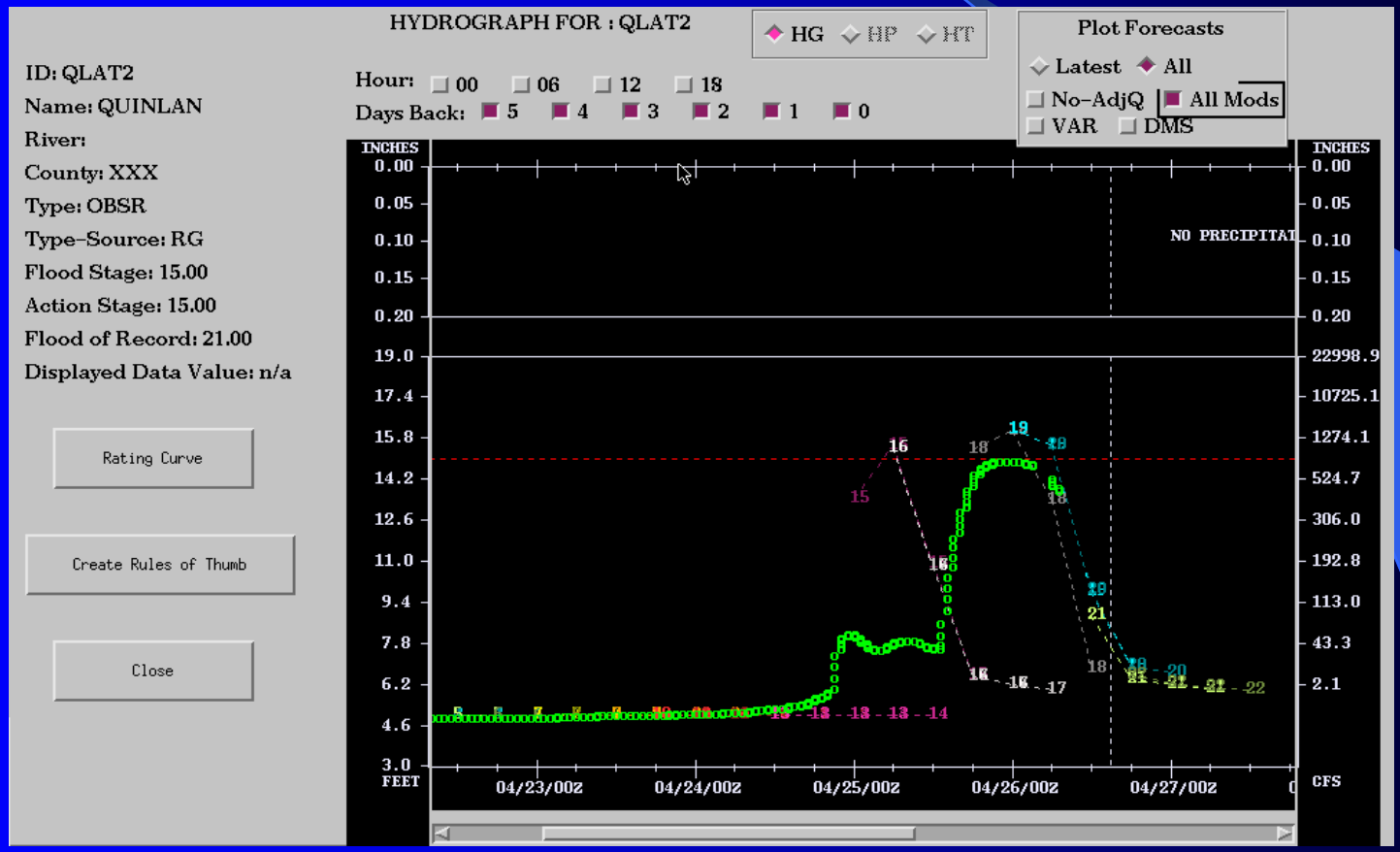
6-hr SAC-UH forecasts w/ MODs



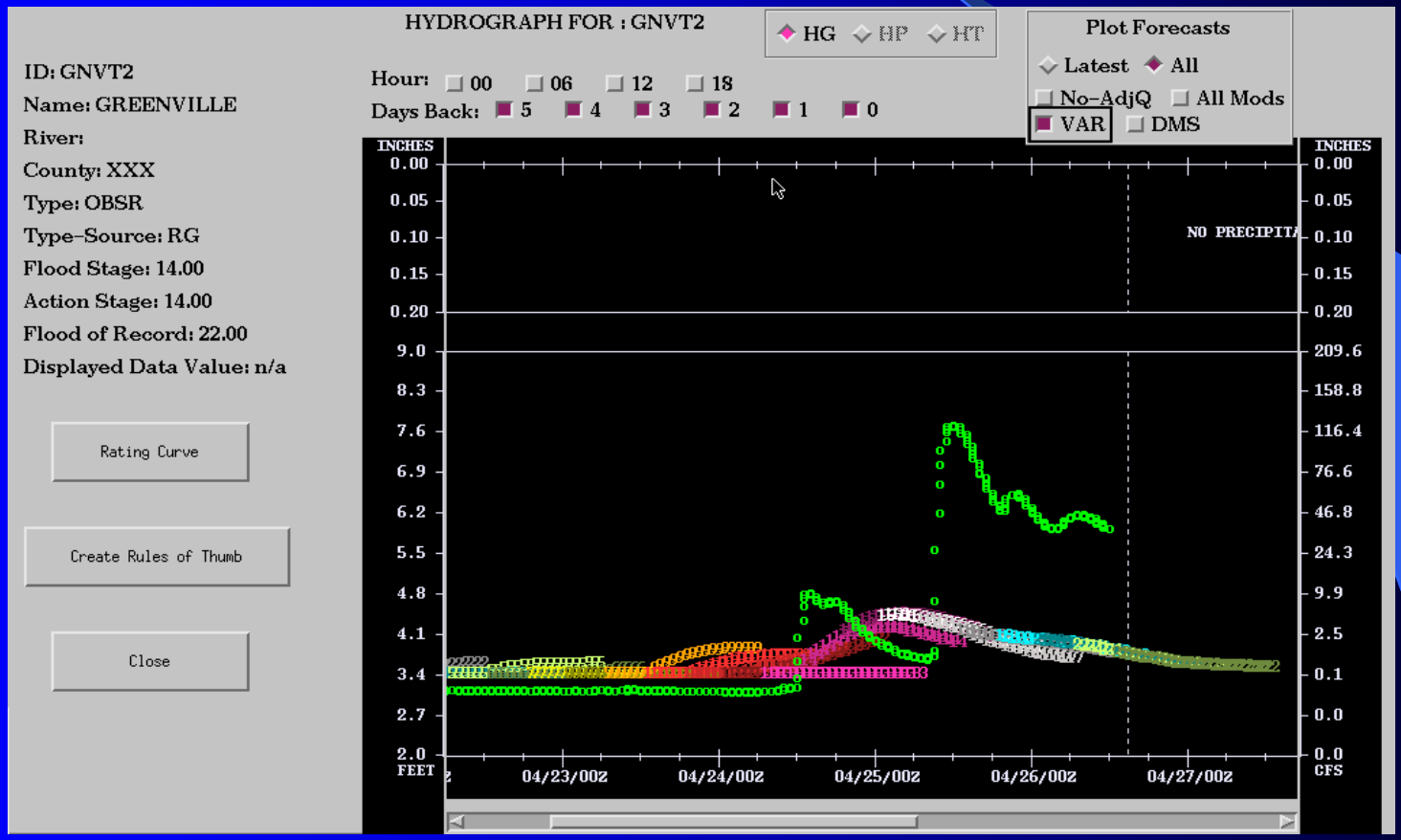
1-hr VAR-aided forecasts



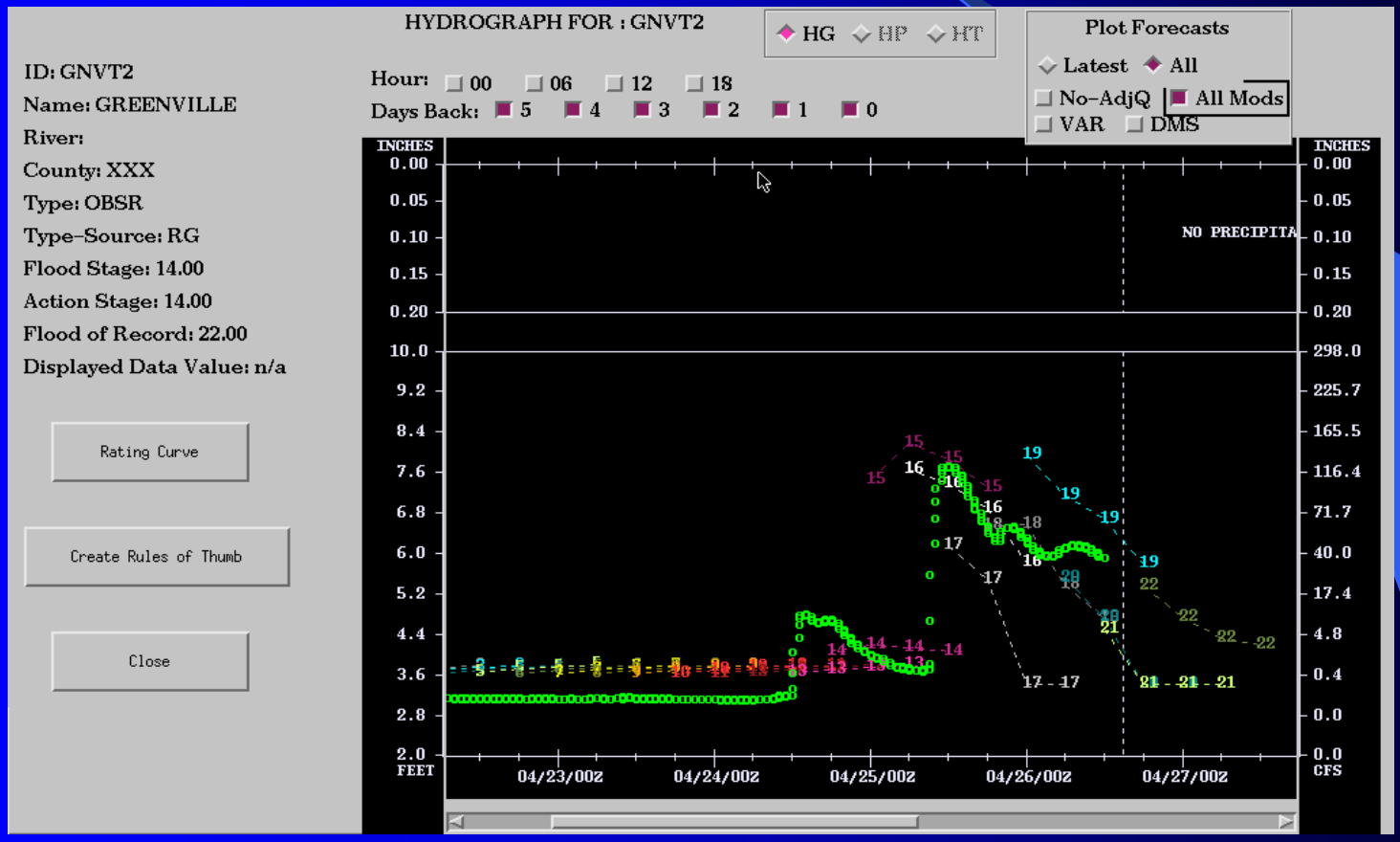
6-hr SAC-UH forecasts w/ MODs

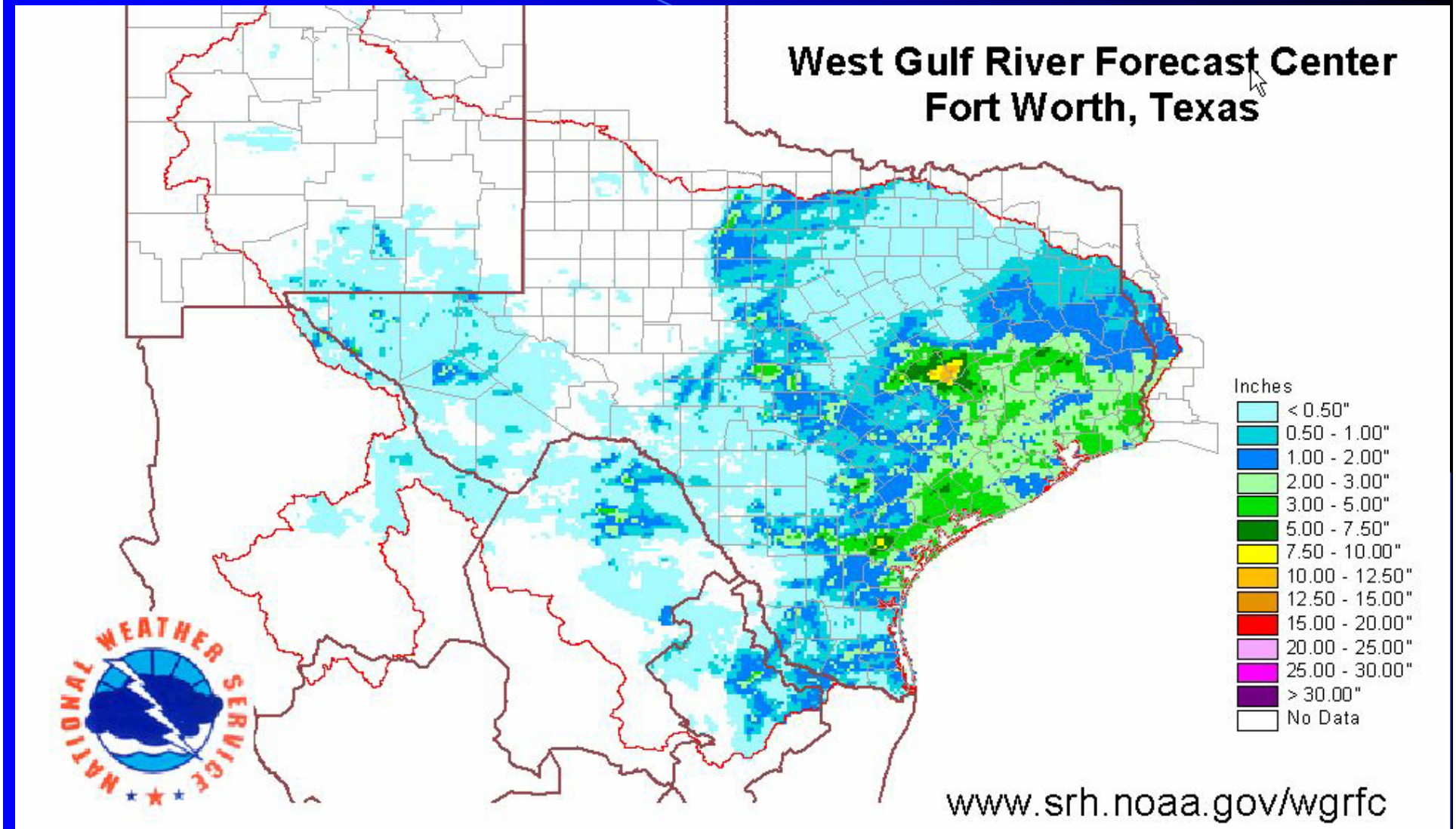


1-hr VAR-aided forecasts



6-hr SAC-UH forecasts w/ MODs




West Gulf River Forecast Center
Fort Worth, Texas
Inches
< 0.50"
0.50 - 1.00"
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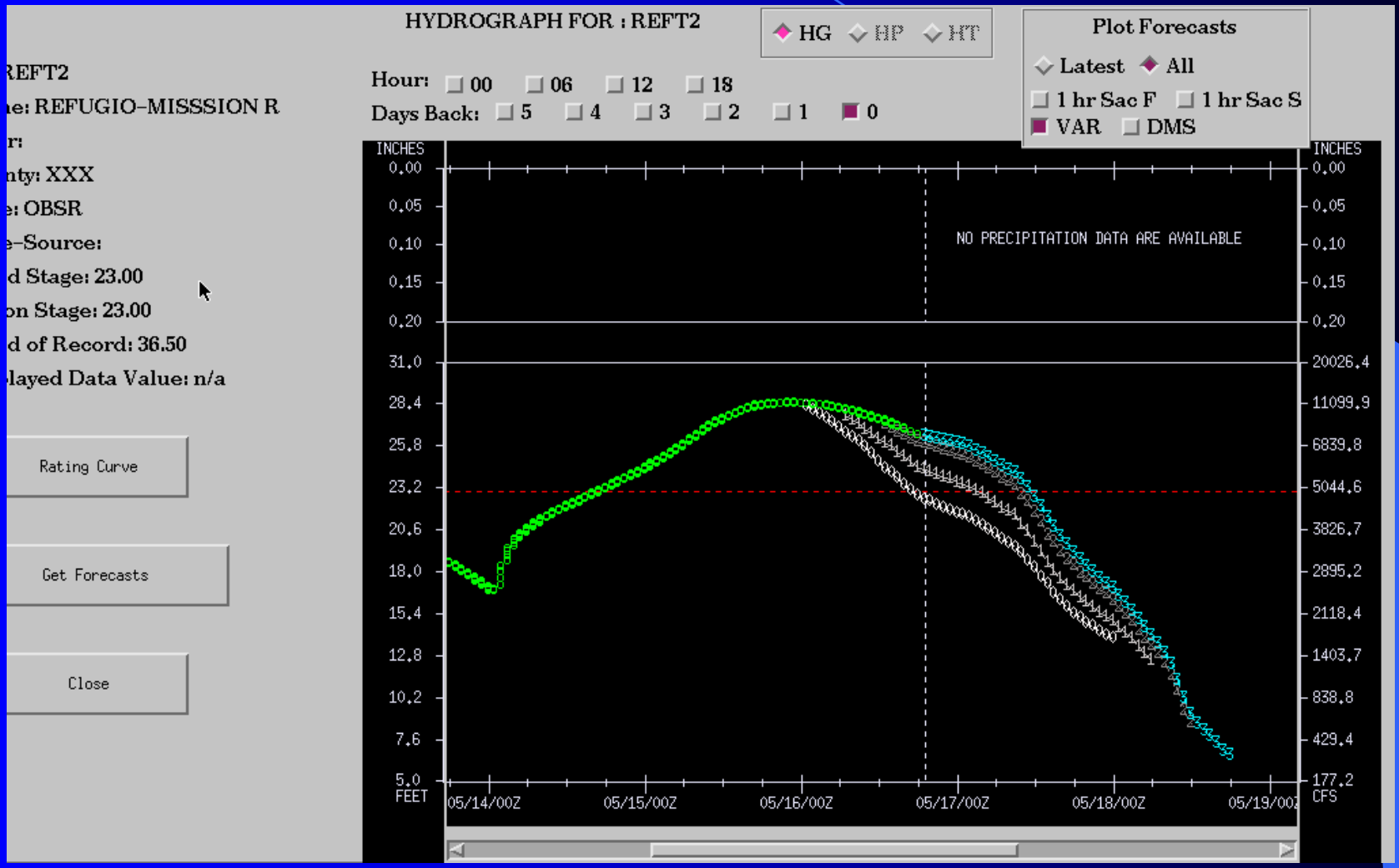
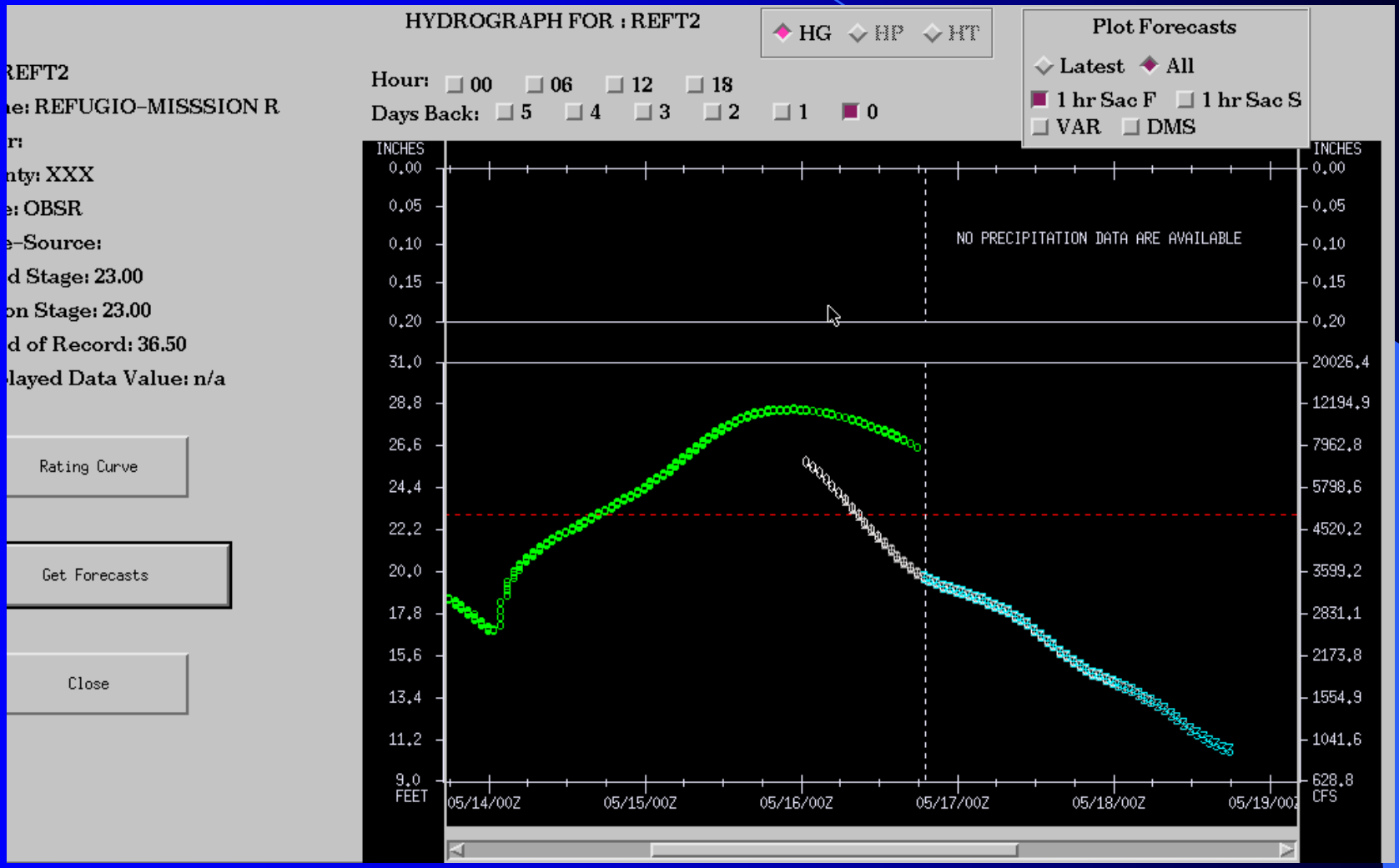
10.00 - 12.50"
12.50 - 15.00"
15.00 - 20.00"
20.00 - 25.00"
25.00 - 30.00"
> 30.00"
No Data
NATIONAL WEATHER SERVICE
www.srh.noaa.gov/wgrfc

1-hr VAR-aided forecasts



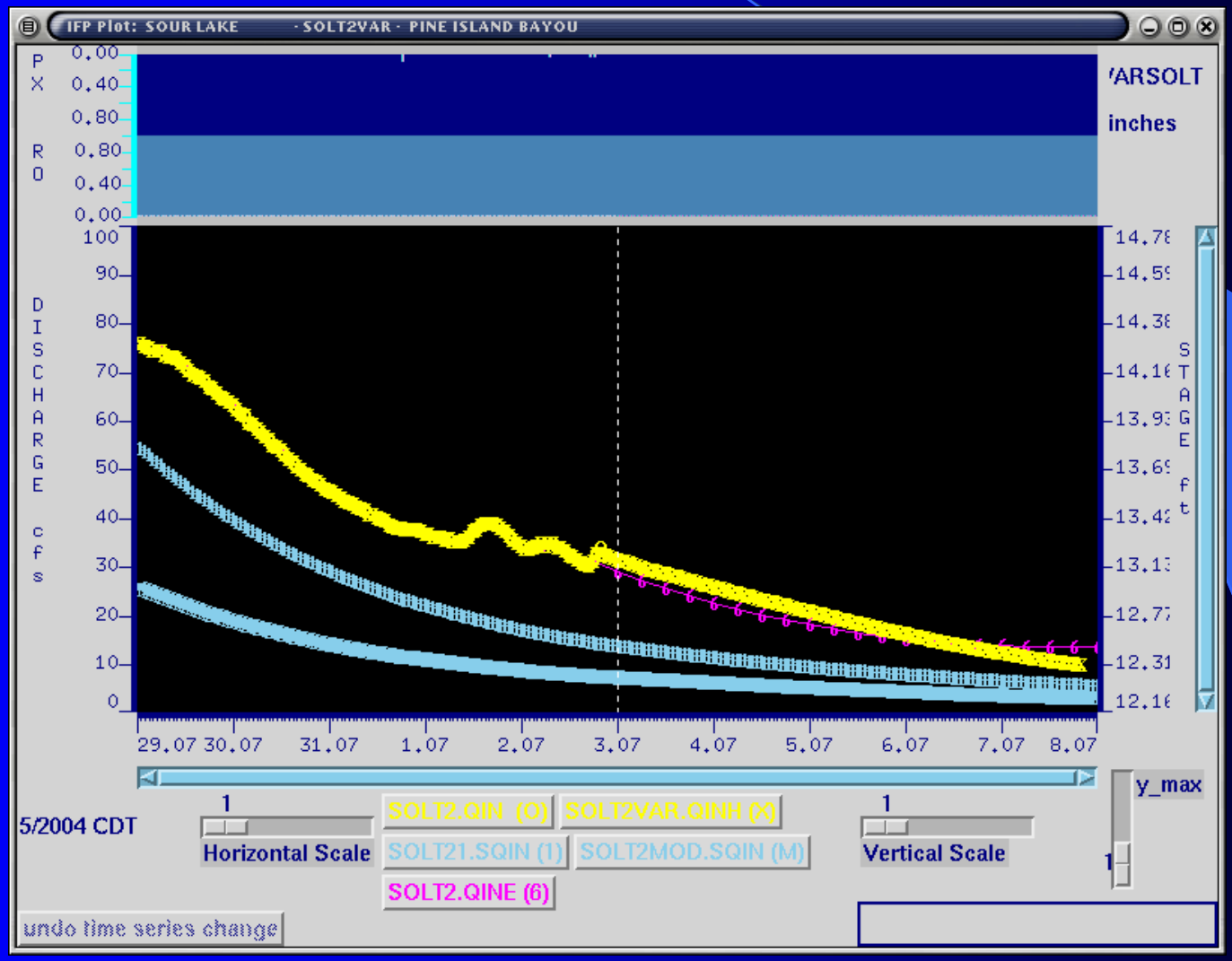
1-hr SAC-UH forecasts



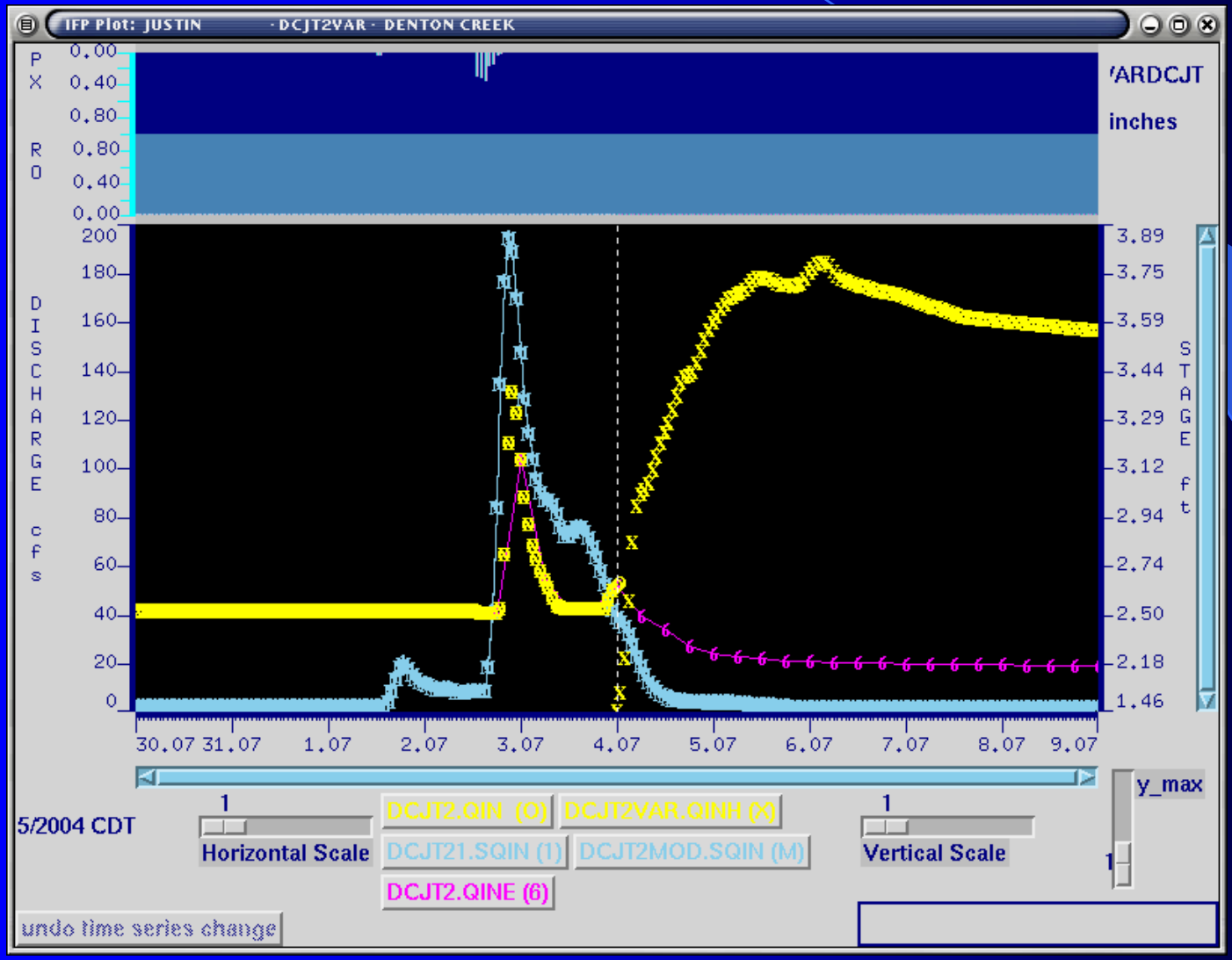
VAR V2.0

- If model errors (i.e. structural and/or parametric) are very large, often V1.0 cannot match simulated flow to the observed
- V2.0 includes an explicit model error term (hourly-varying, random) to account for the aggregate errors in SAC and UH

VAR 2.0 Model Error



Not Perfect


IFP Plot: JUSTIN
·DCJT2VAR· DENTON CREEK
PX RO
0.00
0.40
0.80
0.80
0.40
0.00
'ARDCJT
inches
DISCHARGE cfs
200
180
160
140
120
100
80
60
40
20
0
STAGE ft
3.89
3.75
3.59
3.44
3.29
3.12
2.94
2.74
2.50
2.18
1.46
30.07 31.07
1.07
2.07
3.07
4.07
5.07
6.07
7.07
8.07
9.07
5/2004 CDT
1
Horizontal Scale
DCJT2.QIN (O)
DCJT2VAR.QINH (X)
DCJT21.SQIN (1)
DCJT2MOD.SQIN (M)
DCJT2.QINE (6)
1
Vertical Scale
y_max
1
undo time series change

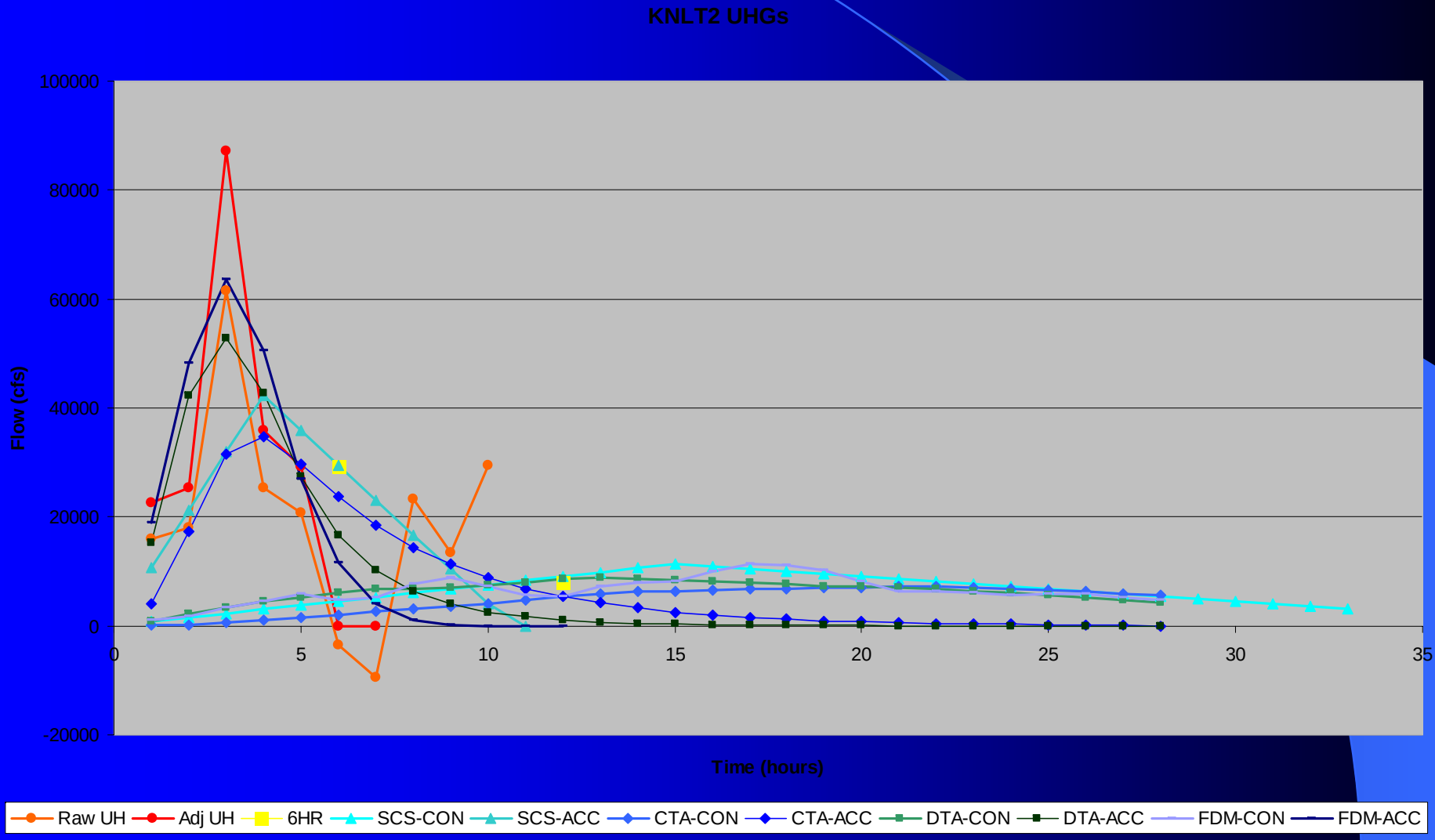
Near-Term Plan

- Refine science and gain operational experience for national implementation
  - Generate quantitative verification from the time series archive
  - Continue archival and (near) real-time evaluation
  - Implement Sequential Line Search (SLS) in AB_OPT
  - Display of adjusted control variables

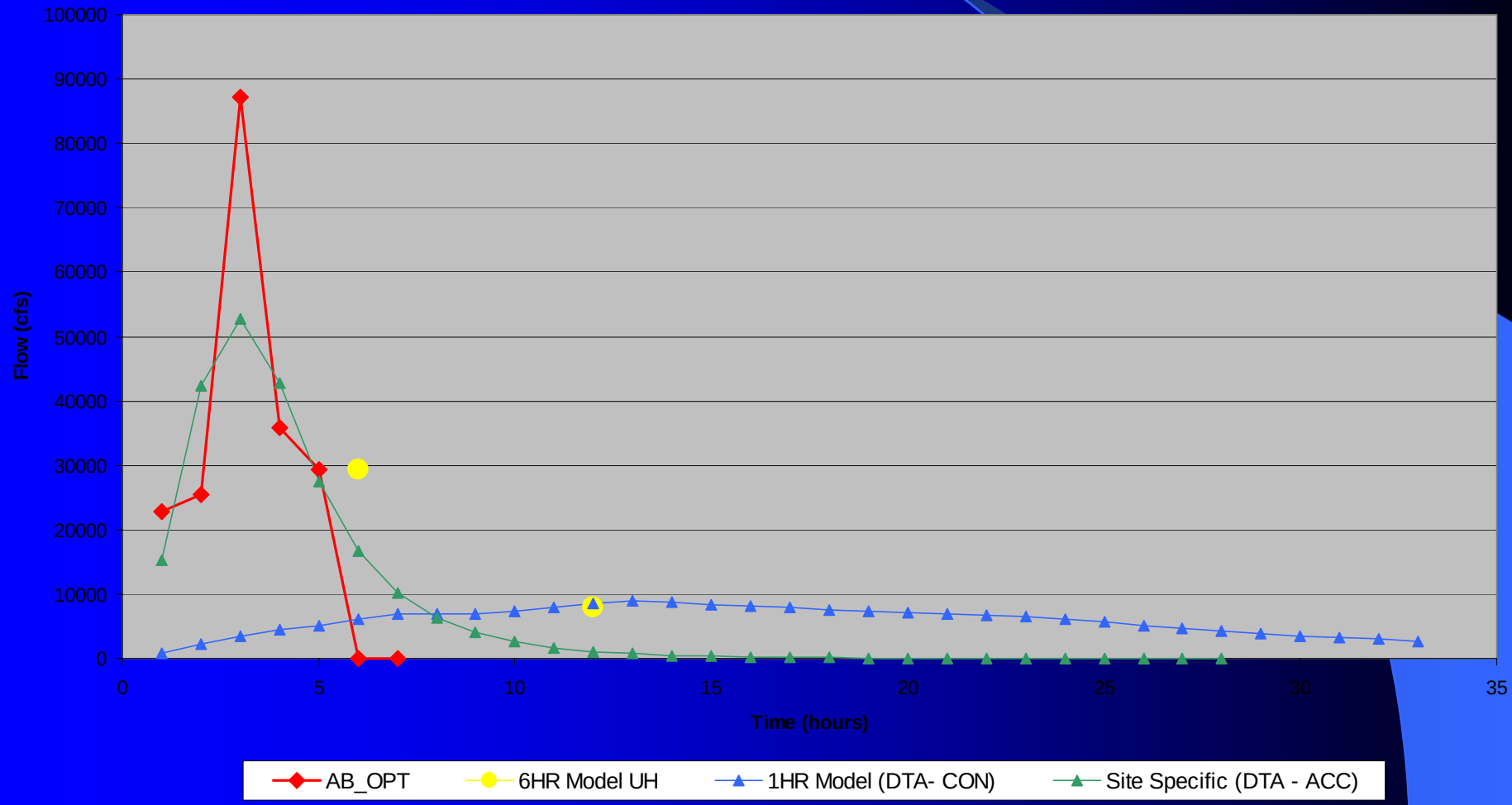
AB_OPT Software

- Created by OHD for assistance in the implementation of VAR.
- Ingests historical stage and MAPX data.
- Software estimates long term biases in MAPX and MAPE climatology based upon the historical data.
- Uses these biases to develop a 1 hour empirical unit hydrograph and refined SAC-SMA parameters.

KNLT2 UHG


KNLT2 UHGs
100000
80000
60000
40000
20000
0
-20000
Flow (cfs)
0
5
10
15
20
25
30
35
Time (hours)
Raw UH
Adj UH
6HR
SCS-CON
SCS-ACC
CTA-CON
CTA-ACC
DTA-CON
DTA-ACC
FDM-CON
FDM-ACC

KNLT2 UHG


KNLT2 UHGs - Model and Selected IHABBS Methods
Flow (cfs)
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0
5
10
15
20
25
30
35
Time (hours)
AB_OPT
6HR Model UH
1HR Model (DTA- CON)
Site Specific (DTA - ACC)

Contacts

- Please contact the following people with any questions relating to VAR:
  - OHD Team :
    - Dongjun Seo — Dongjun.Seo@noaa.gov
    - Lee Cajina — Lee.Cajina@noaa.gov
  - WGRFC Team:
    - Bob Corby — Robert.Corby@noaa.gov
    - Tracy Howieson — Tracy.Howieson@noaa.gov