Verification Analytics and Delft3D FEWS Integration

Gabriel Miller and Nathan Barber

11/7/2018

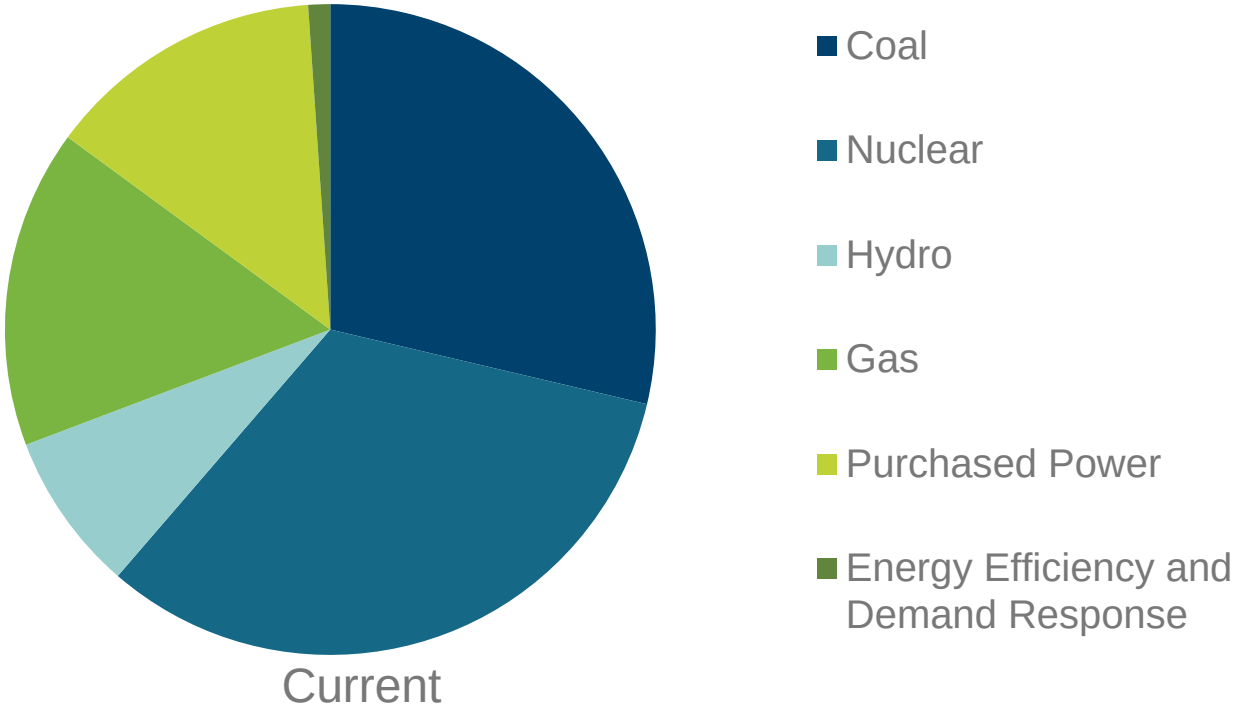

TVA
What is TVA?
A power company
and so much more…

What We Do

Partner with **154** local power companies, to serve **9 million people** and **700,000 businesses** in parts of **seven states.**

Directly serve **58** large industries and federal installations.

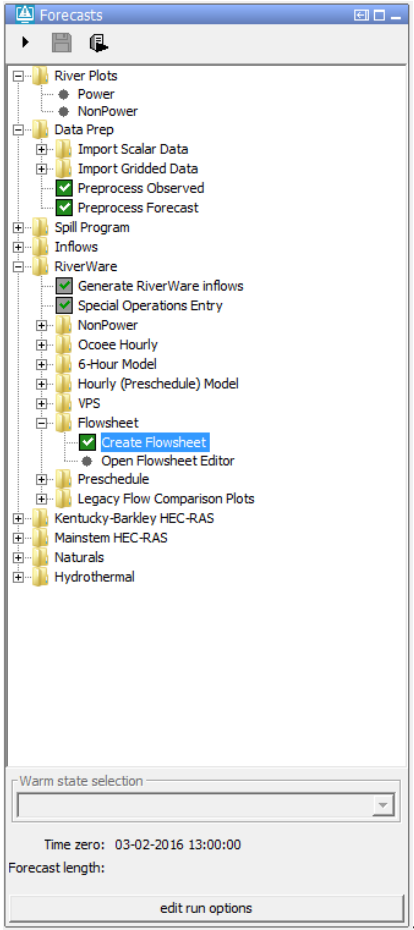
The TVA Power System



Tennessee Valley Watershed

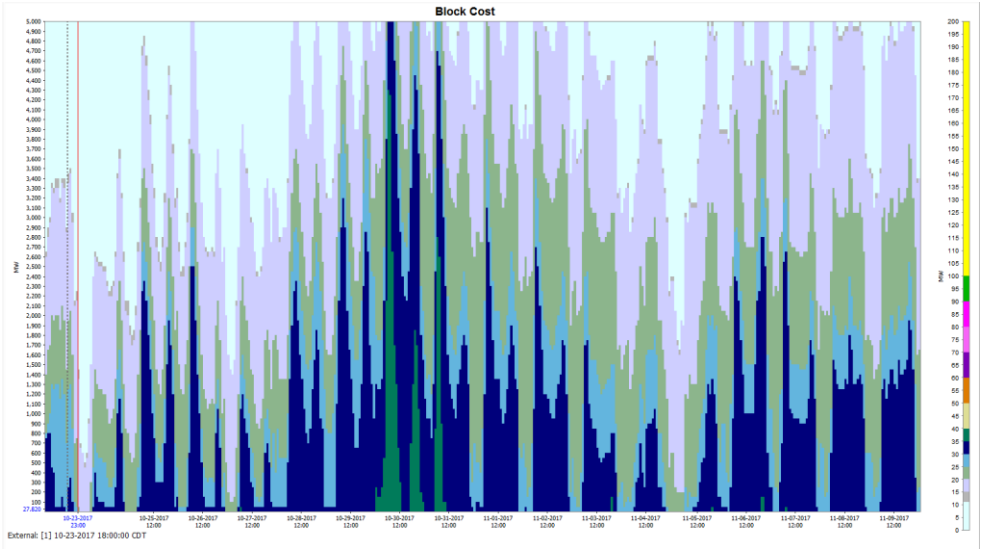
TVA FEWS System

- Three year project
  - Converted in-house forecast system to standard models and FEWS system
  - Migration from 100+ programs to one unified platform
  - Vastly improved data visualization and reports
- Live on Feb 7th 2017



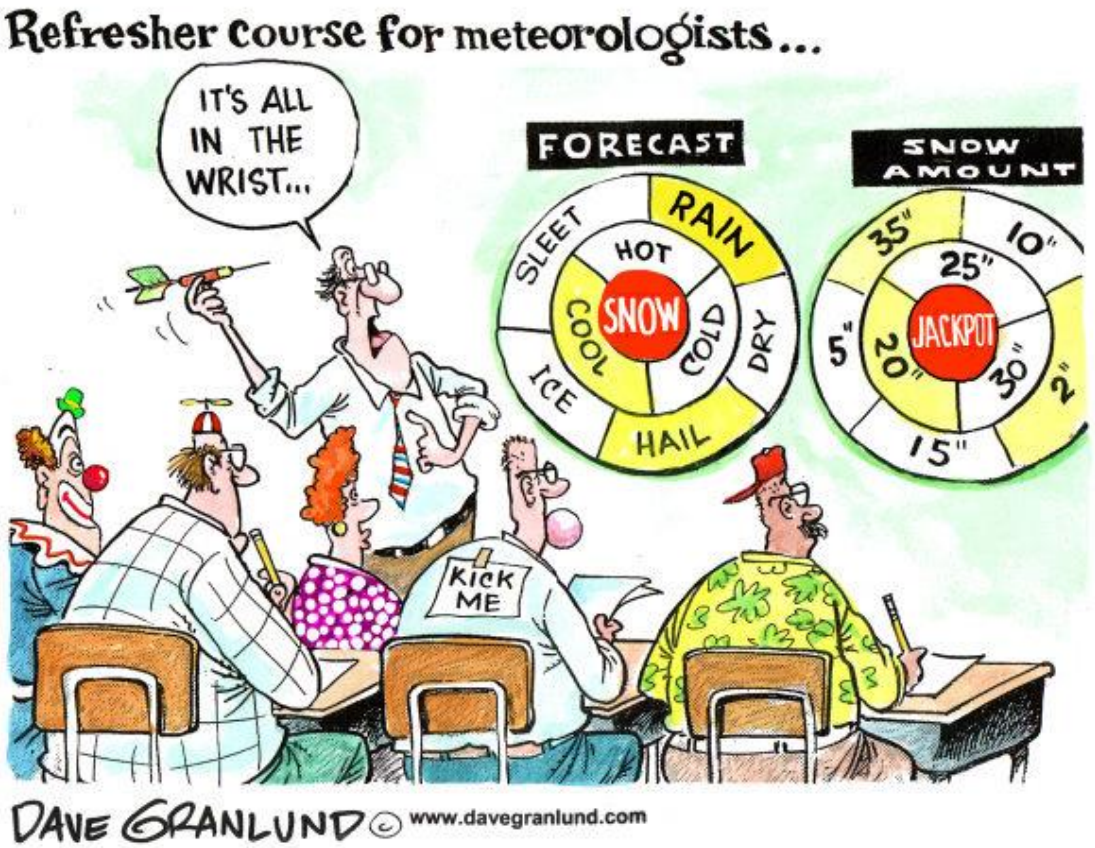
The Value of Forecasts to TVA

- TVA is a forecast-driven agency due to the expensive and long-term nature of our capital investments
- We forecast
  - Load growth
  - Gas prices
  - Coal prices
  - River flows
  - Budget spends
  - Equipment life….



- For TVA, better forecast = lives saved, more $$$, better decisions.

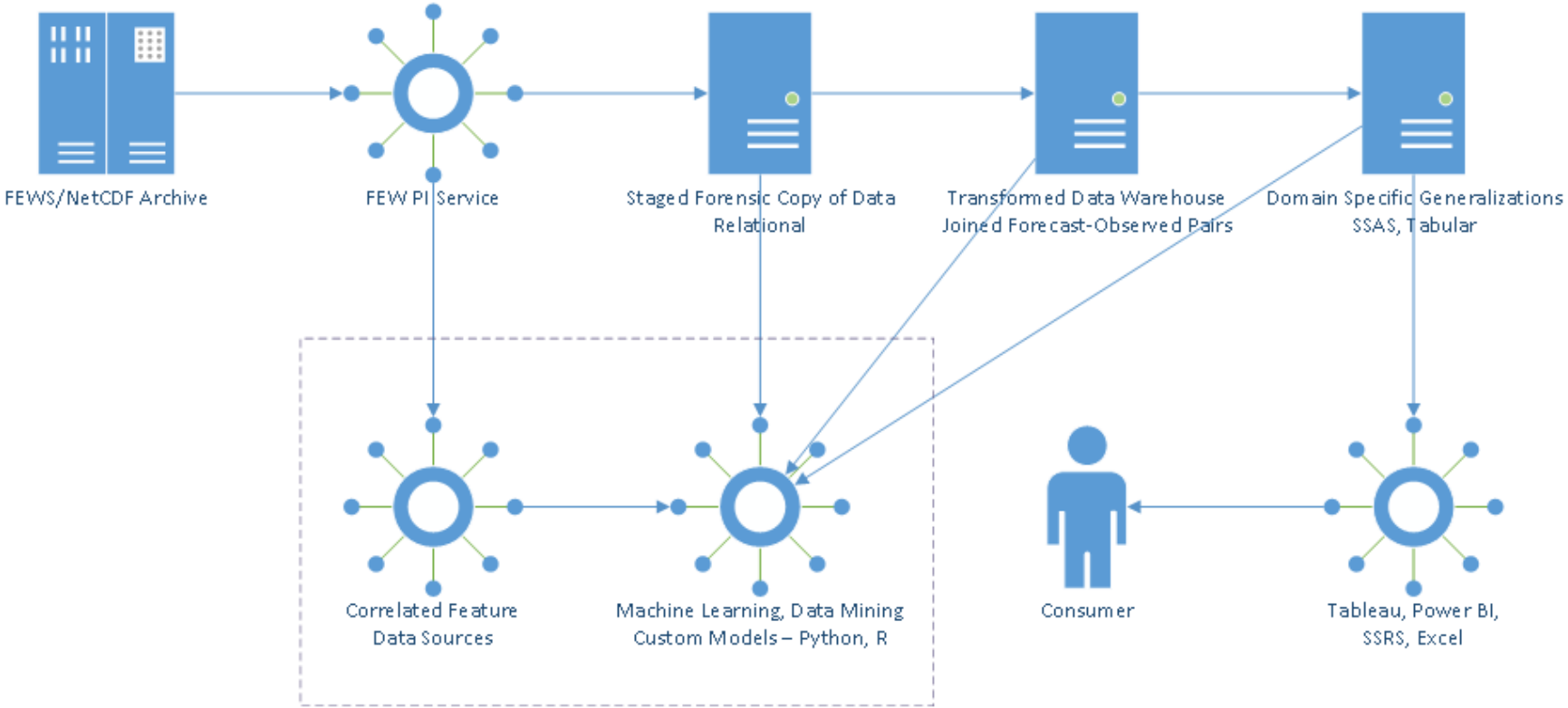
What Next? How bad are my forecasts?



So, how then should we verify?

- Leveraged FEWS Open Archive and PI Webservice to:
  - Extract data
  - Pair forecasts and observations by parameter and timestep
  - Calculate predefined verification statistics
  - Provide accessible data cubes that can be accessed by Excel, PowerBI, SSRS, Tableau.
- 1,000,000,000 rows of data (and growing).

Software Architecture



Demo

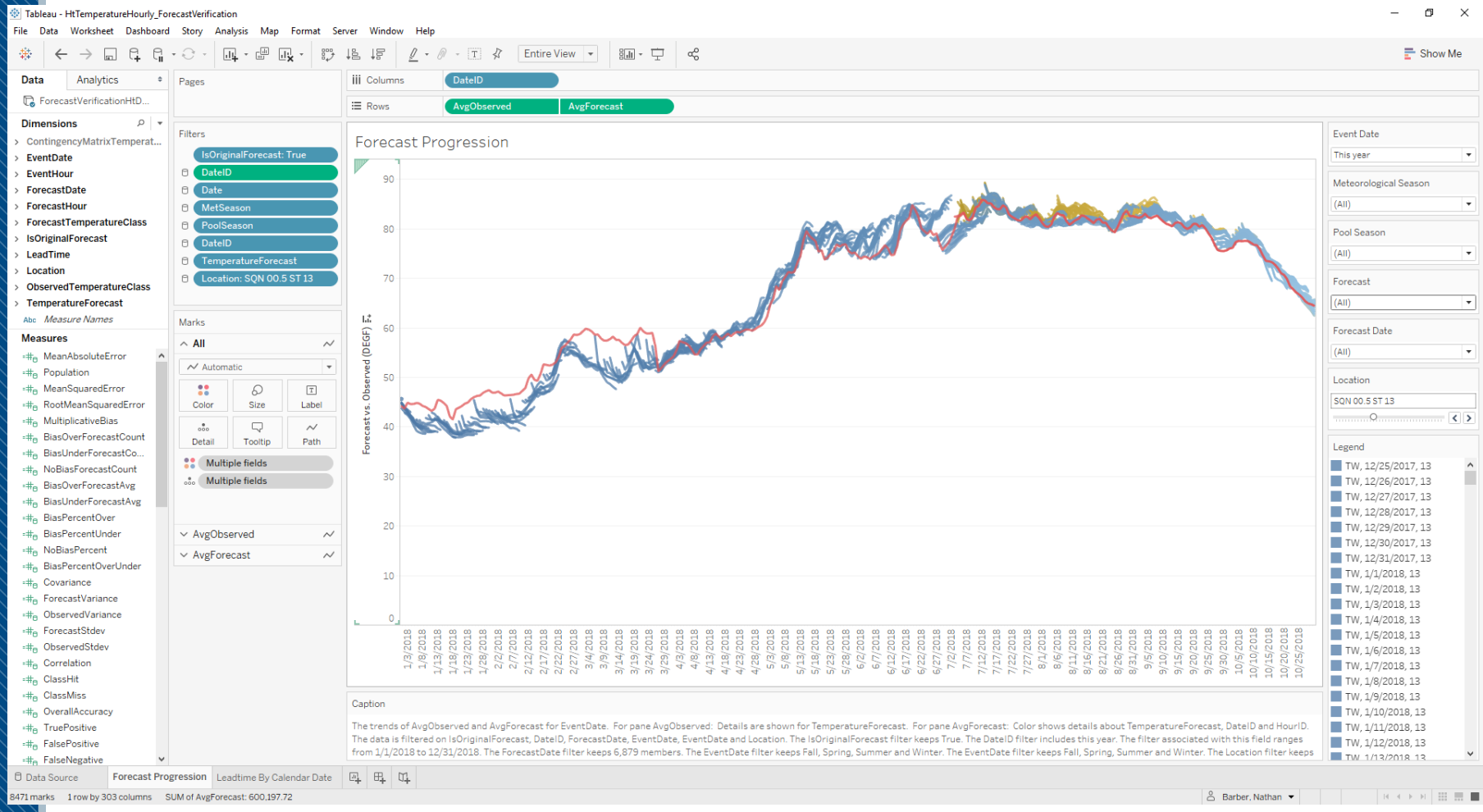


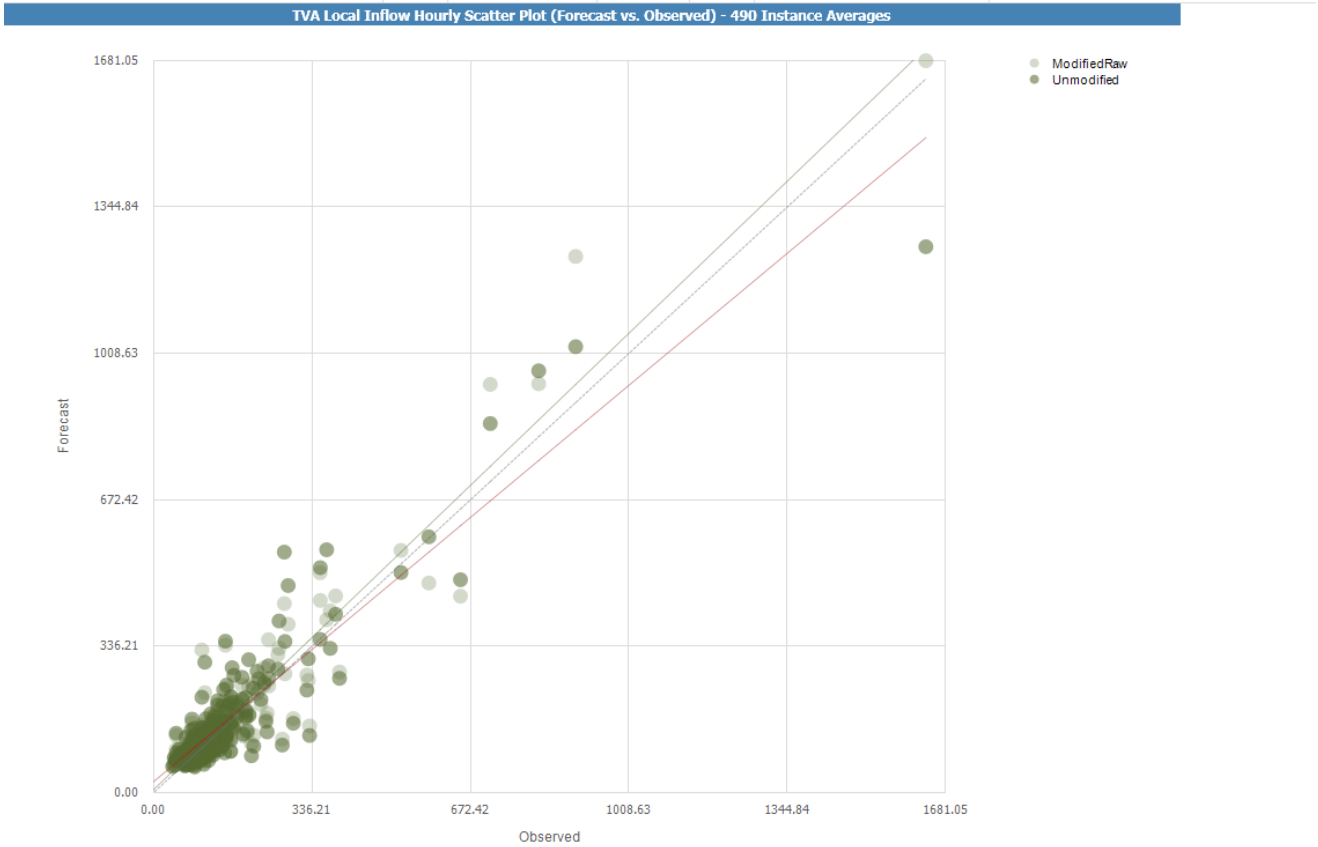
Tableau - HtTemperatureHourly_ForecastVerification
File Data Worksheet Dashboard Story Analysis Map Format Server Window Help
Entire View
Show Me
Data
Analytics
ForecastVerificationHtD...
Dimensions
ContingencyMatrixTemperat...
EventDate
EventHour
ForecastDate
ForecastHour
ForecastTemperatureClass
IsOriginalForecast
LeadTime
Location
ObservedTemperatureClass
TemperatureForecast
Measure Names
Measures
MeanAbsoluteError
Population
MeanSquaredError
RootMeanSquaredError
MultiplicativeBias
BiasOverForecastCount
BiasUnderForecastCo...
NoBiasForecastCount
BiasOverForecastAvg
BiasUnderForecastAvg
BiasPercentOver
BiasPercentUnder
NoBiasPercent
BiasPercentOverUnder
Covariance
ForecastVariance
ObservedVariance
ForecastStdev
ObservedStdev
Correlation
ClassHit
ClassMiss
OverallAccuracy
TruePositive
FalsePositive
FalseNegative
Pages
Filters
IsOriginalForecast: True
DateID
Date
MetSeason
PoolSeason
DateID
TemperatureForecast
Location: SQN 00.5 ST 13
Marks
All
Automatic
Color
Size
Label
Detail
Tooltip
Path
Multiple fields
Multiple fields
AvgObserved
AvgForecast
Columns
DateID
Rows
AvgObserved
AvgForecast
Forecast Progression
Forecast vs. Observed (DEGF)
90
80
70
60
50
40
30
20
10
0
1/3/2018
1/8/2018
1/13/2018
1/18/2018
1/23/2018
1/28/2018
2/2/2018
2/7/2018
2/12/2018
2/17/2018
2/22/2018
2/27/2018
3/4/2018
3/9/2018
3/14/2018
3/19/2018
3/24/2018
3/29/2018
4/3/2018
4/8/2018
4/13/2018
4/18/2018
4/23/2018
4/28/2018
5/3/2018
5/8/2018
5/13/2018
5/18/2018
5/23/2018
5/28/2018
6/2/2018
6/7/2018
6/12/2018
6/17/2018
6/22/2018
6/27/2018
7/2/2018
7/7/2018
7/12/2018
7/17/2018
7/22/2018
7/27/2018
8/1/2018
8/6/2018
8/11/2018
8/16/2018
8/21/2018
8/26/2018
8/31/2018
9/5/2018
9/10/2018
9/15/2018
9/20/2018
9/25/2018
9/30/2018
10/5/2018
10/10/2018
10/15/2018
10/20/2018
10/25/2018
Caption
The trends of AvgObserved and AvgForecast for EventDate. For pane AvgObserved: Details are shown for TemperatureForecast. For pane AvgForecast: Color shows details about TemperatureForecast, DateID and HourID. The data is filtered on IsOriginalForecast, DateID, ForecastDate, EventDate, EventDate and Location. The IsOriginalForecast filter keeps True. The DateID filter includes this year. The filter associated with this field ranges from 1/1/2018 to 12/31/2018. The ForecastDate filter keeps 6,879 members. The EventDate filter keeps Fall, Spring, Summer and Winter. The EventDate filter keeps Fall, Spring, Summer and Winter. The Location filter keeps
Event Date
This year
Meteorological Season
(All)
Pool Season
(All)
Forecast
(All)
Forecast Date
(All)
Location
SQN 00.5 ST 13
Legend
TW, 12/25/2017, 13
TW, 12/26/2017, 13
TW, 12/27/2017, 13
TW, 12/28/2017, 13
TW, 12/29/2017, 13
TW, 12/30/2017, 13
TW, 12/31/2017, 13
TW, 1/1/2018, 13
TW, 1/2/2018, 13
TW, 1/3/2018, 13
TW, 1/4/2018, 13
TW, 1/5/2018, 13
TW, 1/6/2018, 13
TW, 1/7/2018, 13
TW, 1/8/2018, 13
TW, 1/9/2018, 13
TW, 1/10/2018, 13
TW, 1/11/2018, 13
TW, 1/12/2018, 13
TW, 1/13/2018, 13
Data Source
Forecast Progression
Leadtime By Calendar Date
8471 marks
1 row by 303 columns
SUM of AvgForecast: 600,197.72
Barber, Nathan

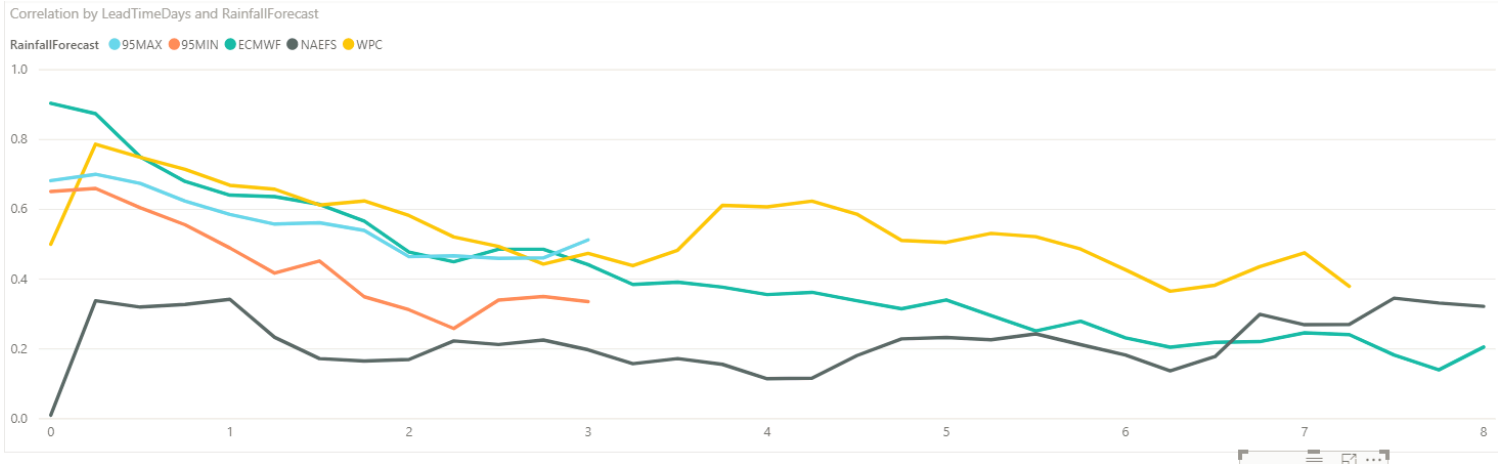
ForecastProvider: Unmodified,ModifiedRaw | LeadTimeDays: 006 (0.25 days) | PoolSeason: Winter,Spring,Summer,Fall

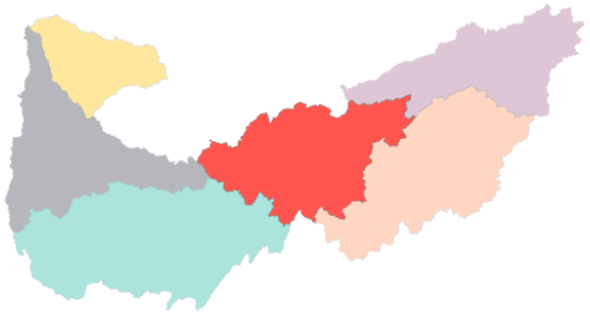
EventStart: 10/29/2017 | LocationGroup: Individual Locations | AverageBy: ForecastProvider,Date

EventEnd: 10/29/2018 | Location: Bear Creek Dam (BCRA1),Bear Creek nr | CompareBy: ForecastProvider

1 of 1 | 100% | Find | Next







RainfallClass...
- ZERO
- LOW
- LOW-MID
- MID-LOW
- MEDIUM
- MID-HIGH
- HIGH-MID
- HIGH

MetSeason
- Fall
- Spring
- Summer
- Winter

DateID
9/28/2014 10/31/2018

LeadTimeDays
0.00 8.00

RainfallForecast
- 95MAX
- 95MIN
- Avg95MinMax
- ECMWF
- Extended,HR...
- HRRR
- ML
- NAEFS
- Normal
- Selected
- WPC


Correlation
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Extended,HRRR
HRRR
MeanAbsoluteError
0.02
0.015
0.01
0.005
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Extended,HRRR
HRRR
MeanError
0.005
0
-0.005
-0.01
-0.015
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Extended,HRRR
HRRR
MeanSquaredError
0.0025
0.002
0.0015
0.001
0.0005
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Extended,HRRR
HRRR

http://riverwiki/wiki/Main_Page/Verification

Main Page/Verification - Riv... | Waiting for knxawtableaupri | LocalFlowHourlyScatterPlot - ... | MapHourlyLeadTime - Report ...

Page | Safety | Tools

Main page
Recent changes
Email Questions

Checklists
- Roles
- Lead
- Preschedule
- Kentucky Barkley
- Data Steward

FEWS Basics

River Forecast System

Hydrothermal

System Documentation

Wiki Basics

Tools

Main Page/Verification

Contents [hide]

Why Verify?

"*Forecasts are almost always made and used in the belief that having a forecast available is preferable to remaining in complete ignorance about the future event of interest. It is important [however] to test this belief a posteriori by assessing how skillful or valuable a given forecast is.*" - Ian T. Jolliffe/David B. Stephenson (Mathematics Research Institute, University of Exeter".

In the context of TVA's River Management, forecasts and decisions are an integral and essential component of the mission. In fact, many of the forecasts and subsequent decisions are based on other forecasts - These come from other federal agencies, private utilities, vendors, and TVA organizations. TVA River Management's River Forecast Center is then tasked with integrating all of these forecasts in a variety of models and then coming up with the best decision on when and where to move water within the Tennessee River Valley. While expert experience naturally lends itself to a qualitative understanding of uncertainty/performance/skill in these forecasts and decisions, much of this can be hidden just below the surface. This verification system will allow forecasters, managers, and hydrologists, the opportunity to look as shallow or deep as necessary with respect to forecasts and the corresponding "truth". This system can be used to

1. Track performance in forecasts
2. Help forecasters choose which forecast to use in the models (when many exist)
3. Identify bias or persistent errors in TVA forecasts
4. Identify bias or persistent errors in external forecasts
5. Understand data integrity
6. Identify process improvements/issues
7. Propose new projects and identify funding opportunities based on above results
8. Compare common forecasts between TVA and external agencies (NWS) for the purposes of mutually improving
9. Train forecasters on how modifications can affect performance

What is Verification?

Verification allows River Management the ability to quantify how well a given forecast or set of forecasts perform(s) with respect to a corresponding observation. Forecasts that do not have a corresponding observation are not part of this system. Since performance is subjective and depends on the question and measure, the roughly 156 pre-calculated statistics are available to the user to choose from. Many of these are common to all forecasts (such as Mean Error) while some are specific to the measure (such as skill scores - only relevant to MAP). Yet others are specific to the way the measures are sliced (Class-based performance measures). The variety of verification statistics allows the user to ask a specific question and choose the statistic(s) that best answer(s) or inform(s) that question. For instance, if I am interested in the magnitude of error for a given forecast, I would likely choose **mean absolute error** as my statistic. If I am interested in understanding how a given forecast performs over time with respect to an unskilled forecast, I would likely choose **skill score mean absolute error**. If I am interested in identifying how a given forecast represents reality, I would likely choose **correlation**. In some cases, several statistics are necessary to answer the question. In the rare case that none of the 156 pre-calculated statistics are sufficient, many of the access tools provide a means to generate specific calculations. An expert user could even bypass the verification system and manipulate the raw data via the tools, to inform a highly-specialized study.

Measures

3:53 PM
11/5/2018

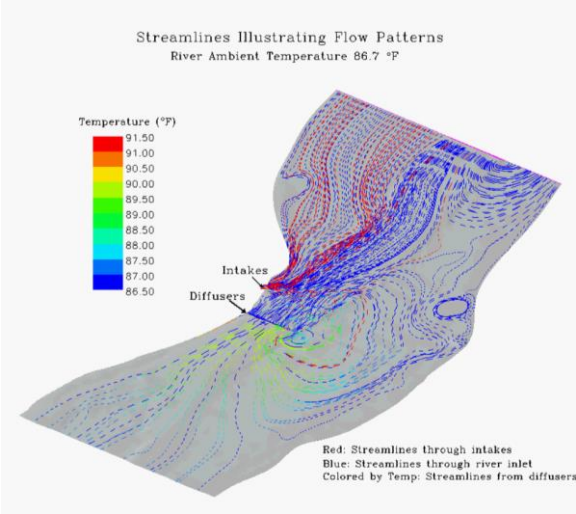
River Temperature Modeling

Hydrothermal Modeling

- The hydrothermal team supports TVA power plants in maintaining environmental compliance (river temperature)
  - Assist the power plants in maintaining environmental compliance for river temperature
  - Generate river temperature forecasts
  - Coordinate use of cooling towers
  - Coordinate river operations and hydroelectric generation

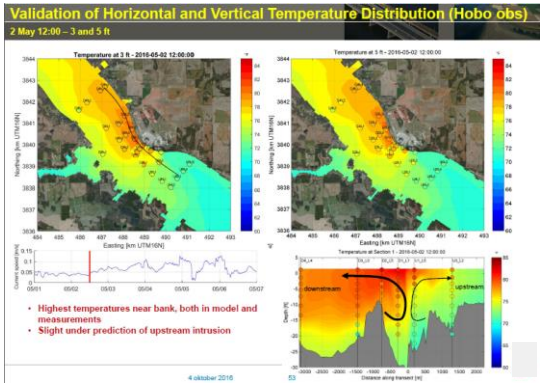
Project Overview

- Complex flow patterns occur in the vicinity of the power plants due to the withdrawal of cooling water
  - 1D hydraulics in TVA models cannot accurately represent localized 3D flow (recirculation)
- To ensure environmental compliance, TVA operates the river and cooling tower equipment conservatively during summer months
  - Steady flows (forego income from hydro peaking)
  - Forecast uncertainty can result in extended operation of cooling towers
- Goal: generate a 48-hour river temperature forecast in 30-minutes with an accuracy of 1°F using a 3D model



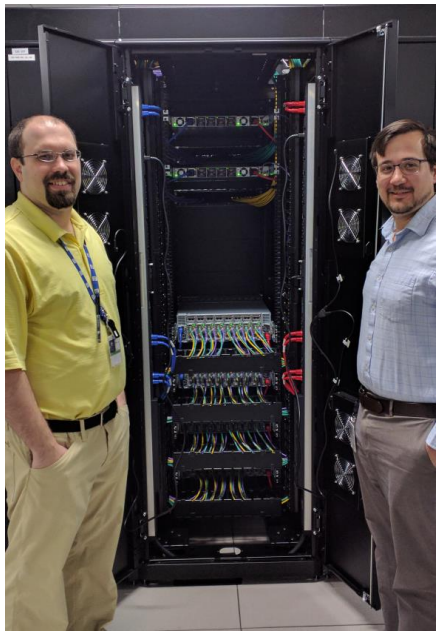
Modeling Framework

- Coupled model framework required to simulate plant induced recirculation while meeting project run-time constraint
  - Plant equipment (TVA)
  - Plume (TVA, Deltares)
  - Reservoir (Deltares Delft3D)
- Model interaction coordinated by COSUMO
- Deltares developed Delft3D models in conjunctions with a large field campaign.
- Delft3D changes were required to meet operational constraints



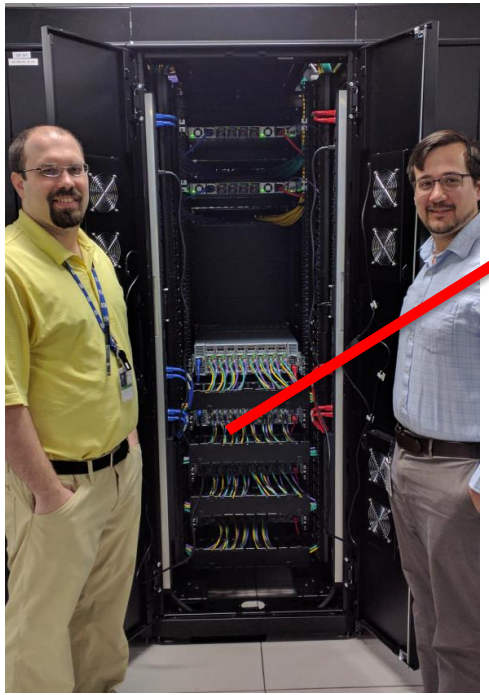
Hardware

- Ability to run 8 river temperature forecasts concurrently
  - Analyze multiple hydro generation schedules during daily scheduling of river
  - Support 3 power plants during critical periods
- Specs
  - 8 FEWS forecasting shells (Virtual machines)
  - Supermicro Servers (Physical servers)
    - > 54 blades / nodes total
    - > 6 per model scenario
  - Intel Xeon Processor E3-1285 v6 @ 4.1 Ghz
    - > 4 core / partitions
    - > 216 cores / partitions total
    - > 18 per model scenario (3 nodes for Delft3D, 1 for OS)
  - Cisco Nexus 93108TC-EX
    - > 2 switches
    - > 10 Gigabit (necessary because of MPI)

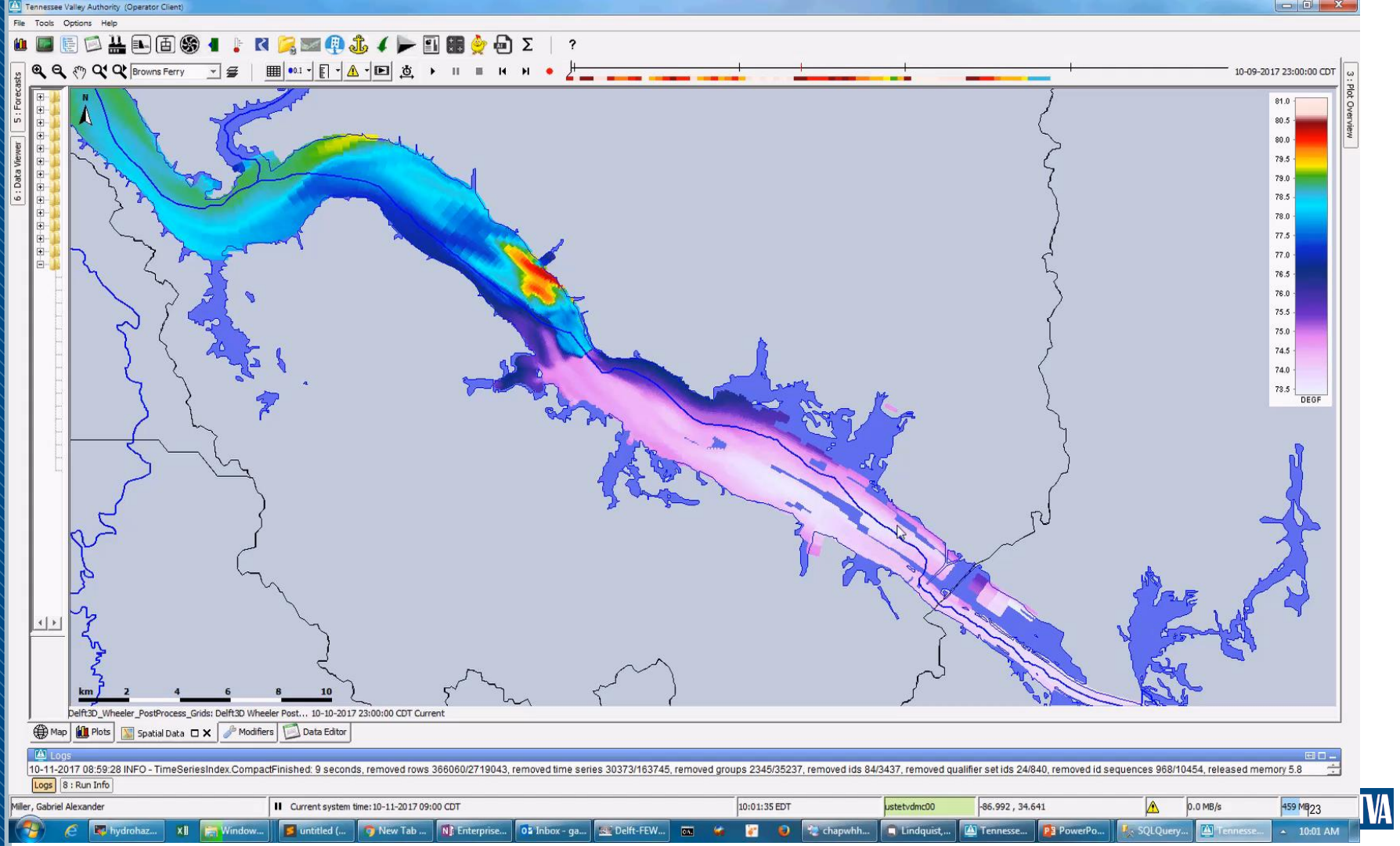


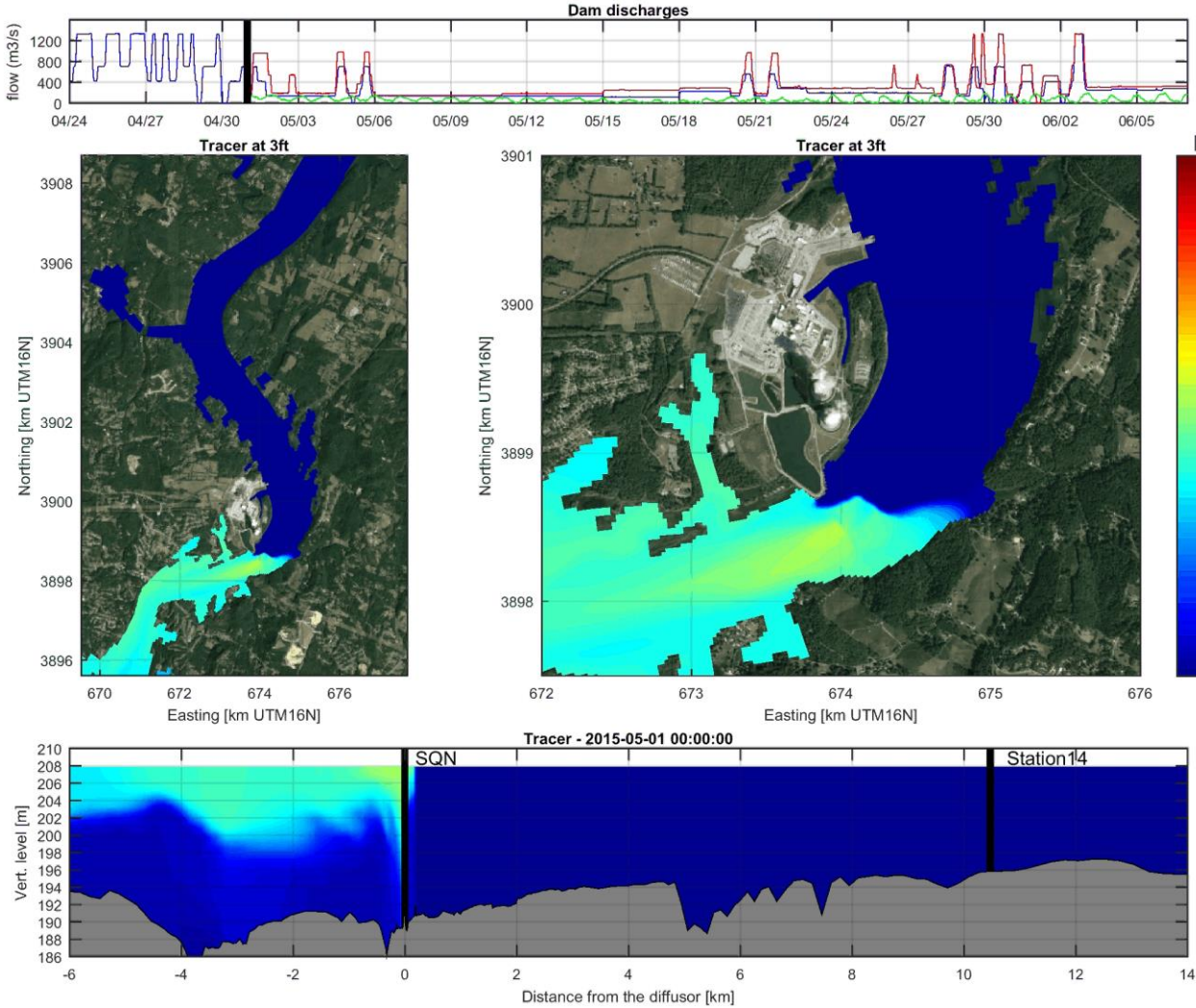
Hardware

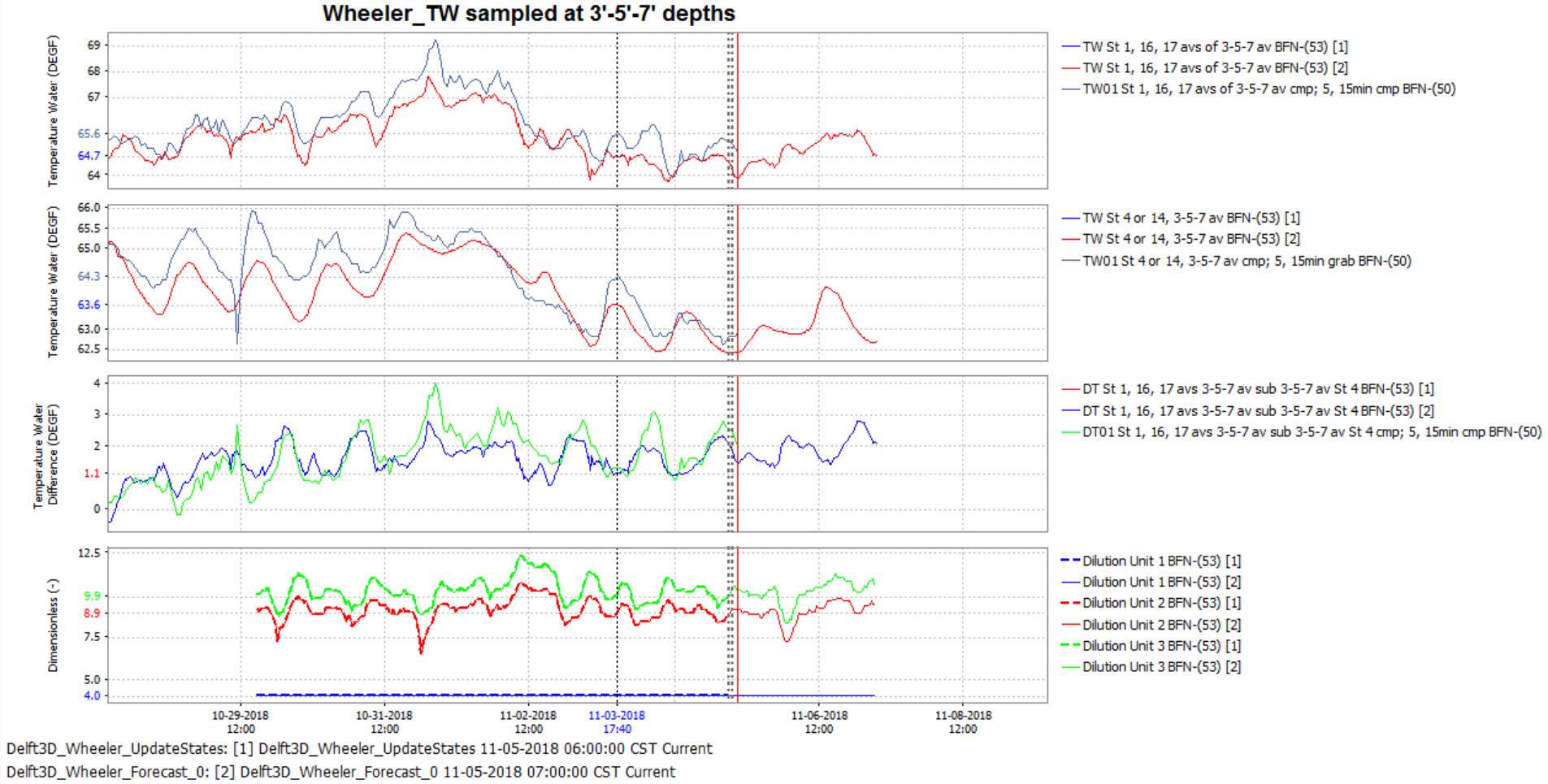
Network Switch



Server / Node


Tennessee Valley Authority (Operator Client)
File Tools Options Help
Browns Ferry
10-09-2017 23:00:00 CDT
5 : Forecasts
6 : Data Viewer
3 : Plot Overview
81.0
80.5
80.0
79.5
79.0
78.5
78.0
77.5
77.0
76.5
76.0
75.5
75.0
74.5
74.0
73.5
DEGF
km 2 4 6 8 10
Delft3D_Wheeler_PostProcess_Grids: Delft3D Wheeler Post... 10-10-2017 23:00:00 CDT Current
Map Plots Spatial Data Modifiers Data Editor
Logs
10-11-2017 08:59:28 INFO - TimeSeriesIndex.CompactFinished: 9 seconds, removed rows 366060/2719043, removed time series 30373/163745, removed groups 2345/35237, removed ids 84/3437, removed qualifier set ids 24/840, removed id sequences 968/10454, released memory 5.8
Logs 8 : Run Info
Miller, Gabriel Alexander
Current system time: 10-11-2017 09:00 CDT
10:01:35 EDT
ustetvdmc00
-86.992 , 34.641
0.0 MB/s
459 MB
10:01 AM


Dam discharges
flow (m3/s)
1200
800
400
0
04/24
04/27
04/30
05/03
05/06
05/09
05/12
05/15
05/18
05/21
05/24
05/27
05/30
06/02
06/05
Tracer at 3ft
Northing [km UTM16N]
3908
3906
3904
3902
3900
3898
3896
670
672
674
676
Easting [km UTM16N]
Tracer at 3ft
Northing [km UTM16N]
3901
3900
3899
3898
672
673
674
675
676
Easting [km UTM16N]
[-]
0.35
0.325
0.3
0.275
0.25
0.225
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0
Tracer - 2015-05-01 00:00:00
SQN
Station14
Vert. level [m]
210
208
206
204
202
200
198
196
194
192
190
188
186
-6
-4
-2
0
2
4
6
8
10
12
14
Distance from the diffusor [km]



Delft3D_Wheeler_UpdateStates: [1] Delft3D_Wheeler_UpdateStates 11-05-2018 06:00:00 CST Current

Delft3D_Wheeler_Forecast_0: [2] Delft3D_Wheeler_Forecast_0 11-05-2018 07:00:00 CST Current


TVA