Delaware River Basin Commission

Model Development Status

(Recap of Model Expert Panel Meeting)

Water Quality Advisory Committee Meeting

August 24, 2017

Namsoo Suk, Ph.D., DRBC
Li Zheng, Ph. D., DRBC

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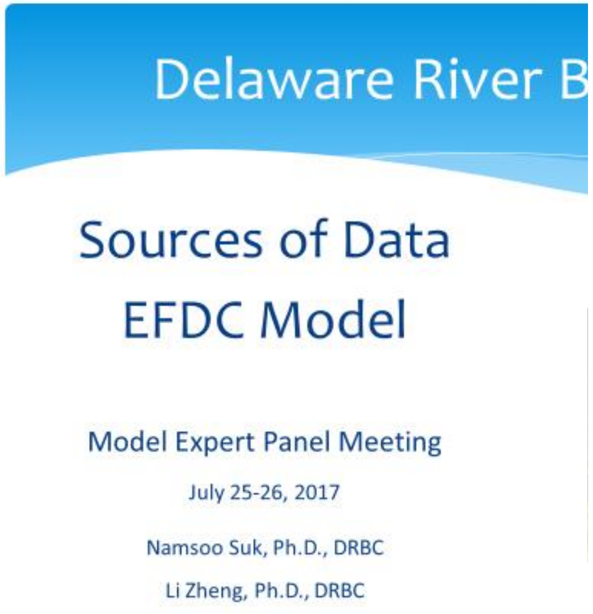
Outline



- ❑ Key Recommendations from Expert Panel
- ❑ Additional updates since the Expert Panel Meeting

Delaware River Basin Commission

Status of Hydrodynamic and Eutrophication Model Development - Part 1

Model Expert Panel Meeting

July 25 – 26, 2017

Namsoo Suk, Ph.D., DRBC

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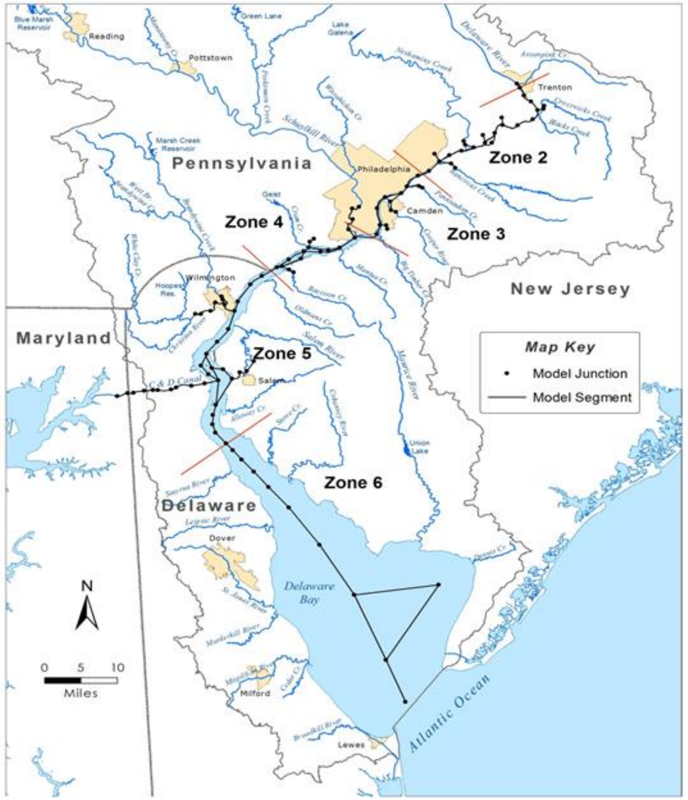
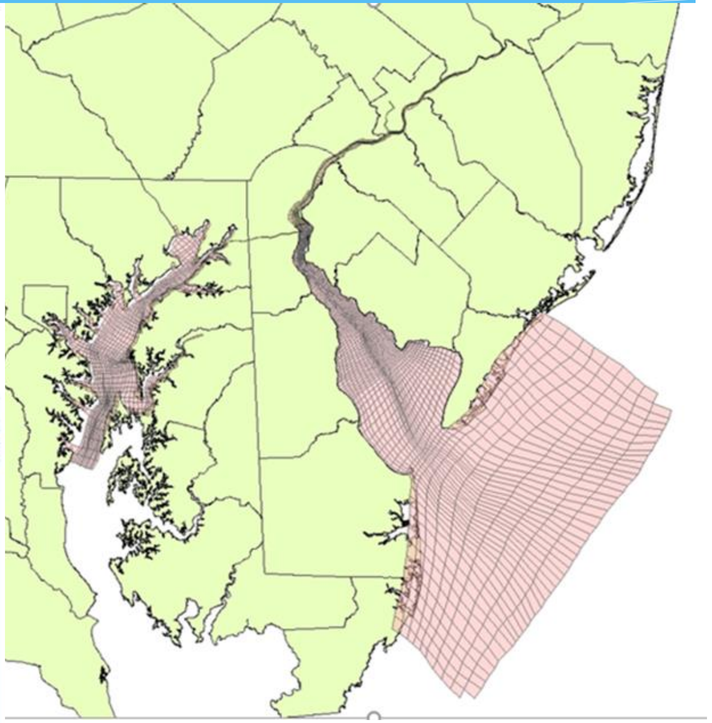
What was Presented at the Previous Meeting?

- Model Setup for CH3D-Z and DYNHYD5/TOXI5
- 2000s and 1965 Simulations
  - CH3D-Z
    - Water Surface Elevation
    - Salinity (Chlorinity)
  - DYNHYD5/TOXI5
    - Water Surface Elevation
    - Salinity (Chlorinity)
- Comparisons between CH3D-Z and DYNHYD5/TOXI5
- DYNHYD5/TOXI5 Sensitivity Simulation



- 105 junctions
- Single vertical layer



- 3,941 horizontal cells
- Max. of 33 vertical layers
- 34,524 total active cells

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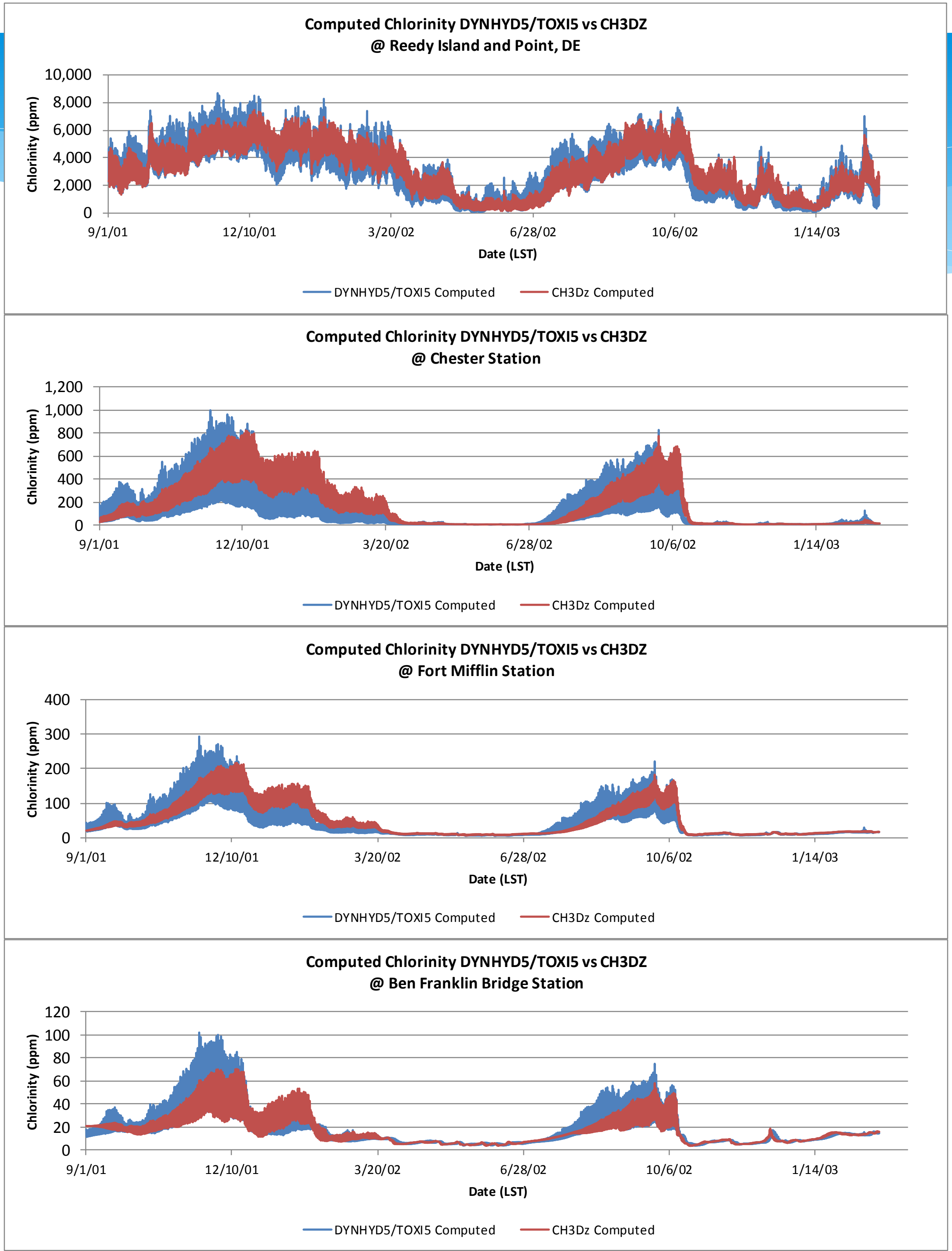
Hourly Chlorinity

CH3Dz vs. DYNHYD5 – 2000s

CL	Salinity
10,000	18.07
5,000	9.03
1,000	1.81
500	0.90
100	0.18



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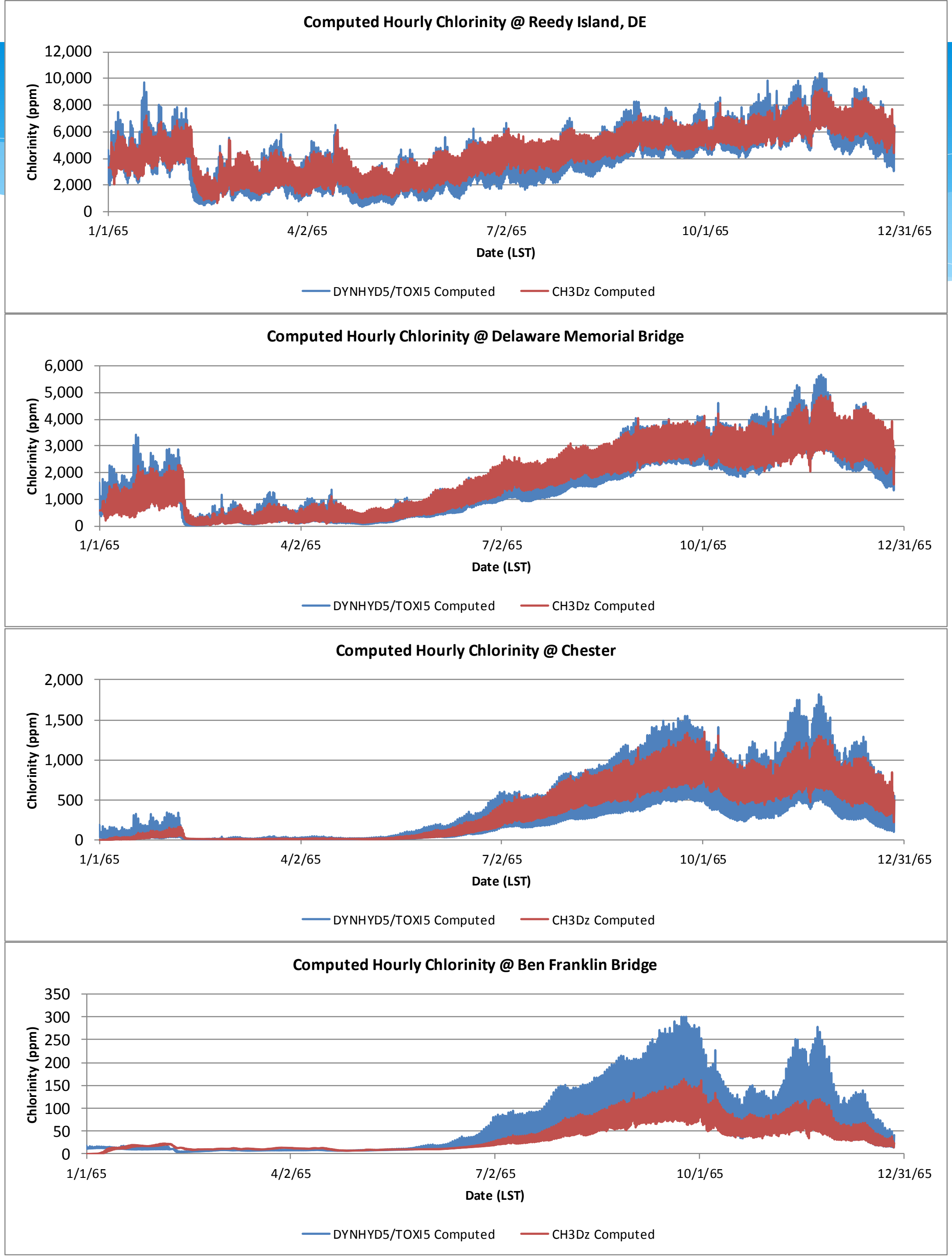
Hourly Chlorinity

CH3Dz vs. DYNHYD5 – 1965



CL	Salinity
10,000	18.07
5,000	9.03
1,000	1.81
500	0.90
100	0.18

Selected Models
from the previous 2016 meeting

Screening Level Model

- Use the existing 1-D DYNHYD5 model linking with WASP8
- Logical decision because
  - 1-D model has been calibrated and readily available
  - Traditionally, DYNHYD-WASP has been a packaged modeling system
  - Familiarity with the model
  - Will serve as a quick diagnostic tools for multiple scenarios

Full Scale Model

- Use the existing 3-D CH3DZ model linking with WASP8
- Logical decision because
  - Model is available through USACE Philadelphia District
  - CH3DZ and DYNHYD5 re-produced comparable results for 1965 and 2000s periods
  - Model domain extended to Continental Shelf and included upper Chesapeake Bay
  - Use a single type of WQ Model (WASP8)

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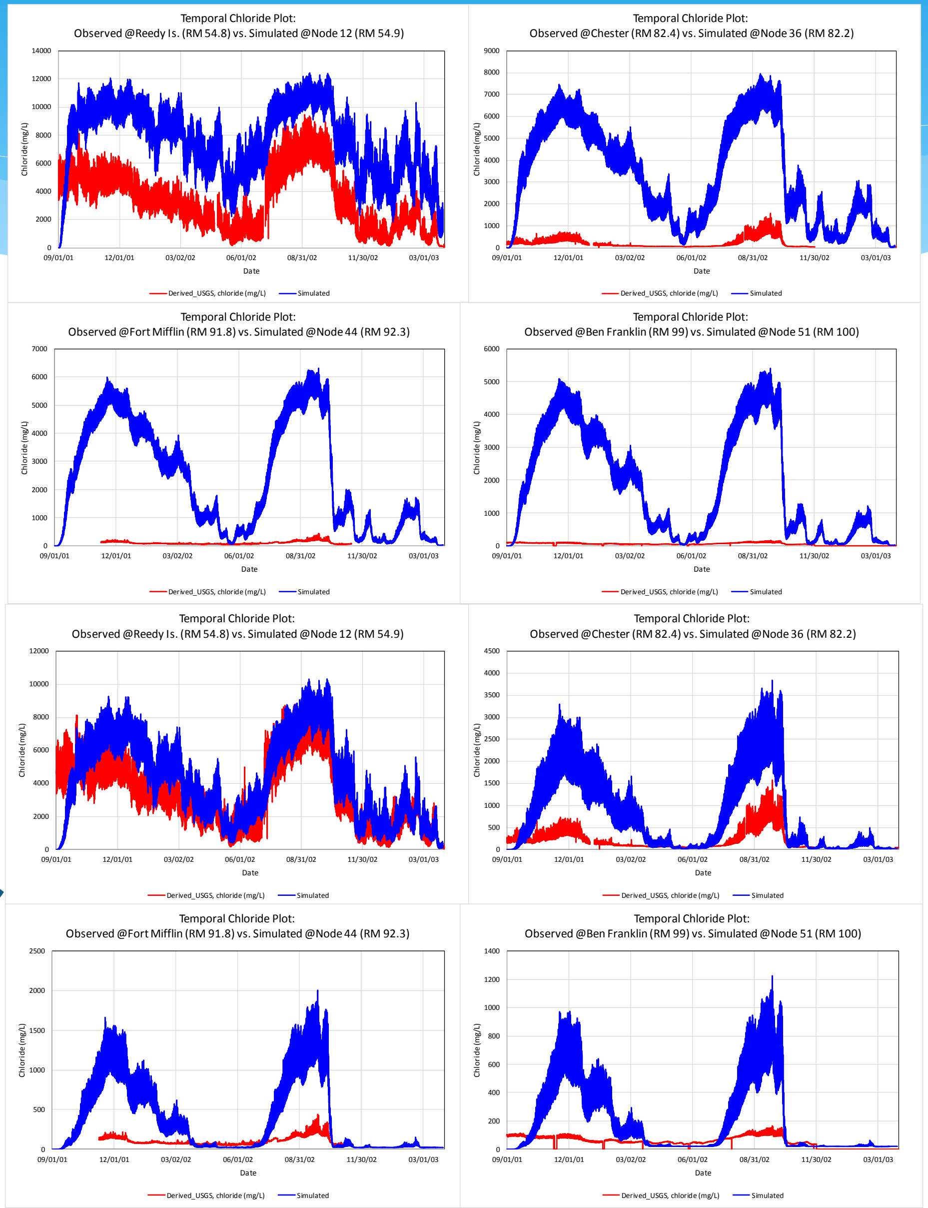
Progress

- Two DRBC staffs trained for WASP8 in November 2016
- Cleaned-up DYNHYD5 segmentation
  - Tested for continuity and mass balance
- Linked DYNHYD5 and WASP8
- Realized issues with inconsistency between DYNHDY5-TOXi5 vs. DYNHDY5-WASP8
- EPA provided WASP8 version with re-enabled ADF – model still over predicted chlorinity in mid- to upper- Estuary



New Tool

- EFDC model was selected as a tool for a hydrodynamic model after consultation with LimnoTech
- Logical decision because
  - Numerical dispersion of the 1-D model (DYNHYD5) can be an recurrent issue
  - Bathymetry of the 1-D model needs to be updated anyway
  - It is better to have a finer horizontal segmentation to distinguish loads from either side of estuary (e.g., PA vs. NJ dischargers)
  - EFDC-WASP8 is widely used modeling package in recent years – likely has few linkage issues
- Screening Level Model – under development (Dr. Li Zheng's presentation)
- Full Scale Model – import CH3DZ grid into EFDC then link with WASP8

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Sources of Data
EFDC Model

Credit: CA Ministry of Natural Resources
(c/o http://fisherynation.com/archives/date/2015/04/page/5)

Model Expert Panel Meeting

July 25-26, 2017

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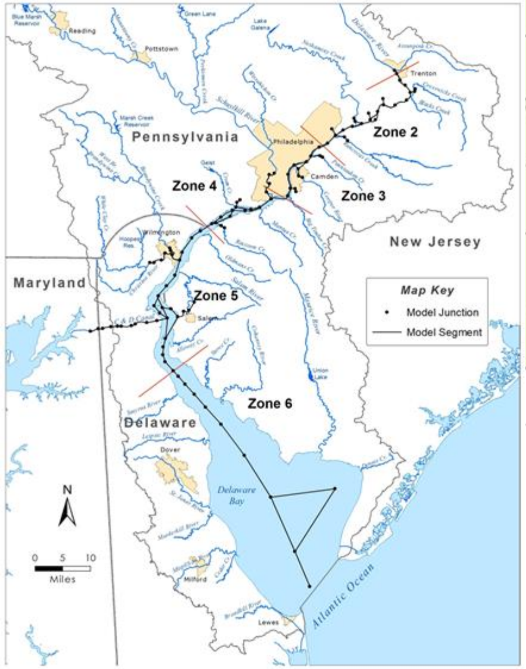
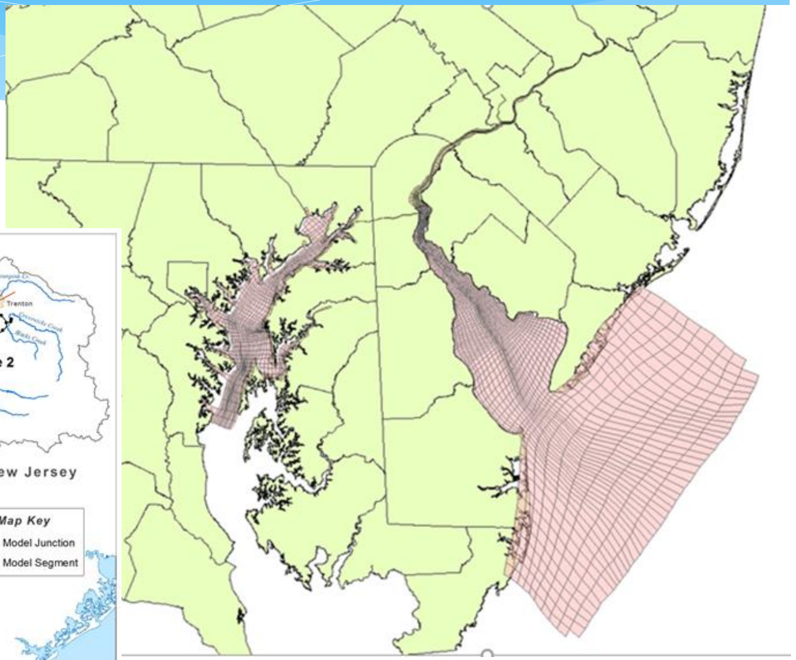
Introduction

* Purpose: documentation of sources of data (focused on hydrodynamic model)
* Two types of data
  * Model input data
  * Model calibration target data
* Two temporal periods
  * 1/1/2012 ~ 12/31/2013: Data rich period (PWD model development)
  * 1/1/2018 ~ 12/31/2019: DRBC's intensive data collection period
* Two spatial coverages
  * 2-D screening level model
  * 3-D fine grid model





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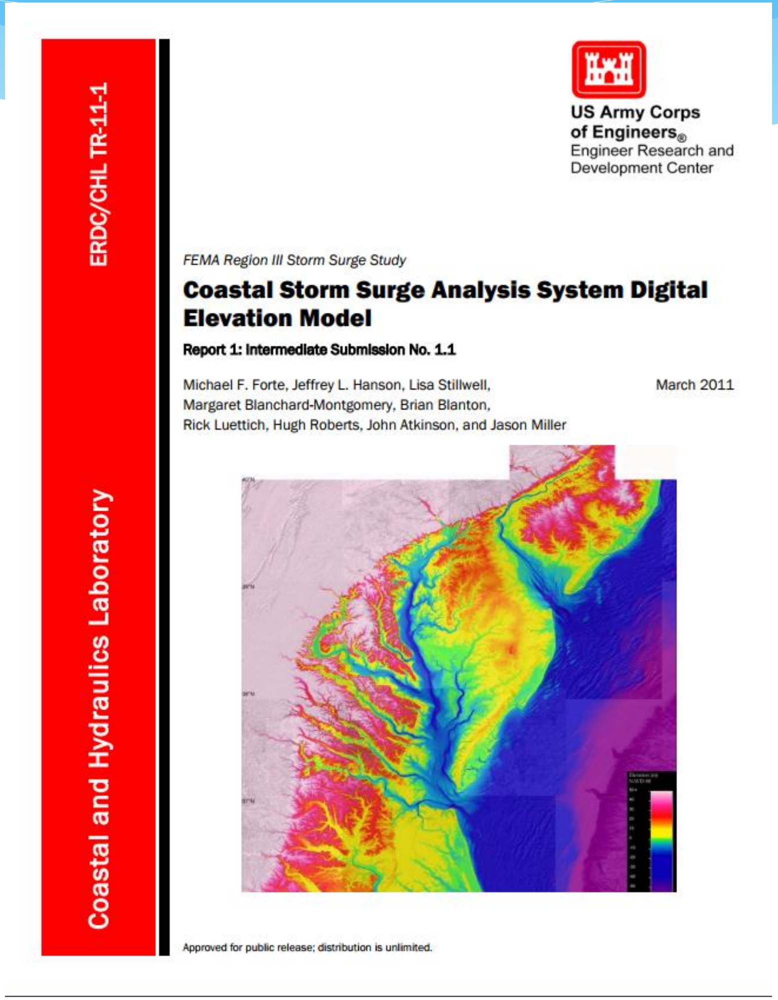
Bathymetry Data

* U.S. Army Engineer Research and Development Center – Coastal & Hydraulics Laboratory (ERDC/CHL) performed for FEMA Region III in 2011.
* Topography and bathymetry data through personal communication.

Horizontal Datum	NAD83
Vertical Datum	NAVD88
Grid Spacing	1/3 arc-seconds (~10 meters)
Grid Area	Eastern and coastal North Carolina, Virginia, District of Columbia, Maryland, West Virginia, Delaware, Pennsylvania, and New Jersey: extending offshore approximately 73.00° to 78.00° W; 36.00° to 40.00° N, following the 15 meter contour inland and extending to the 50 meter bathymetric contour


ERDC/CHL TR-11-1

Coastal and Hydraulics Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

FEMA Region III Storm Surge Study

Coastal Storm Surge Analysis System Digital Elevation Model

Report 1: Intermediate Submission No. 1.1

Michael F. Forte, Jeffrey L. Hanson, Lisa Stillwell, Margaret Blanchard-Montgomery, Brian Blanton, Rick Luettich, Hugh Roberts, John Atkinson, and Jason Miller

March 2011

Approved for public release; distribution is unlimited.

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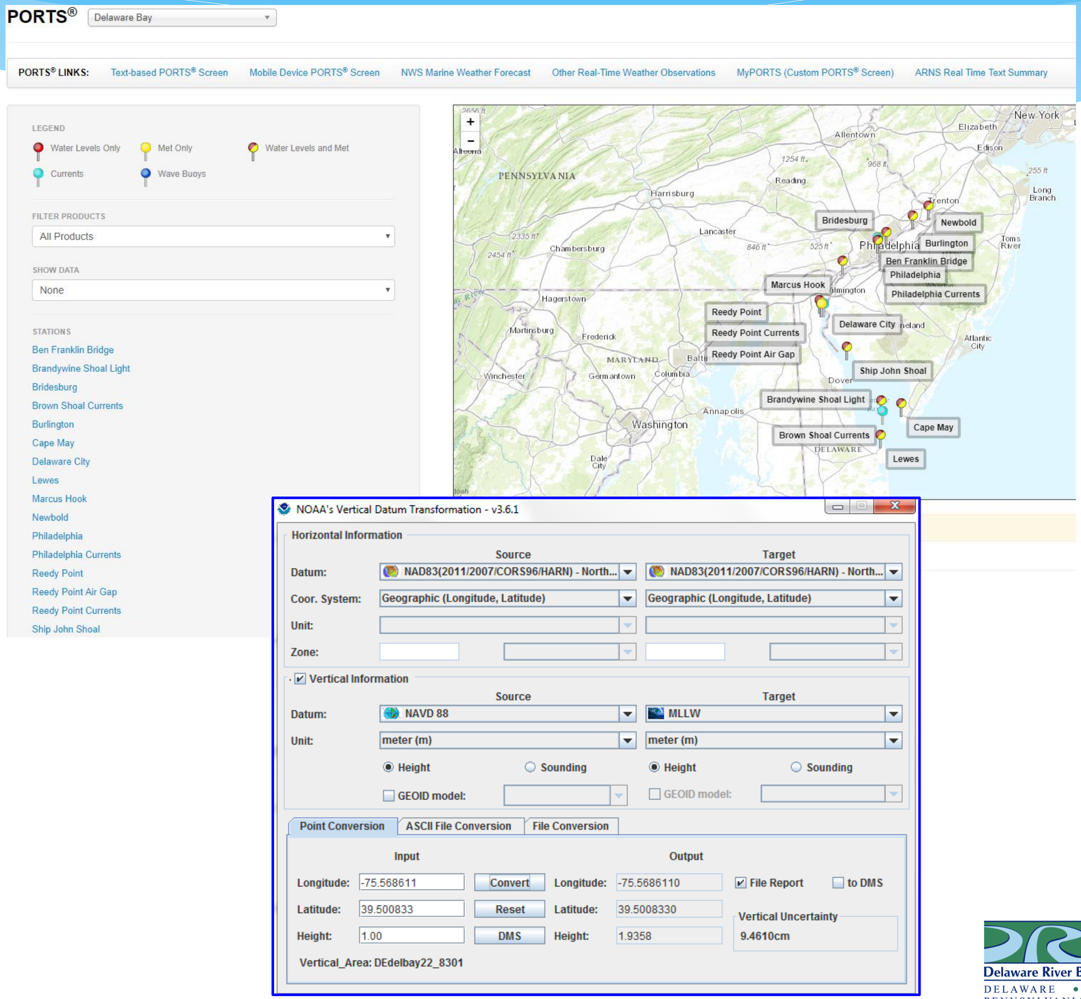
Forcing Tides and Calibration Target WSEs

- Downloaded hourly Water Surface Elevations (WSEs) from NOAA PORTs Website (MLLW datum)
- MLLW to NAVD88 datum: NOAA's Vertical Datum Transformation Program - v3.6.1
- WSEs were corrected to NAVD88 datum
- Boundary at the mouth of the Bay – WSE at Lewes, DE
- Boundary at Chesapeake and Delaware Canal (C&D) – WSE at Chesapeake City
- Source: https://tidesandcurrents.noaa.gov/ports/index.html?port=db



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Inflows

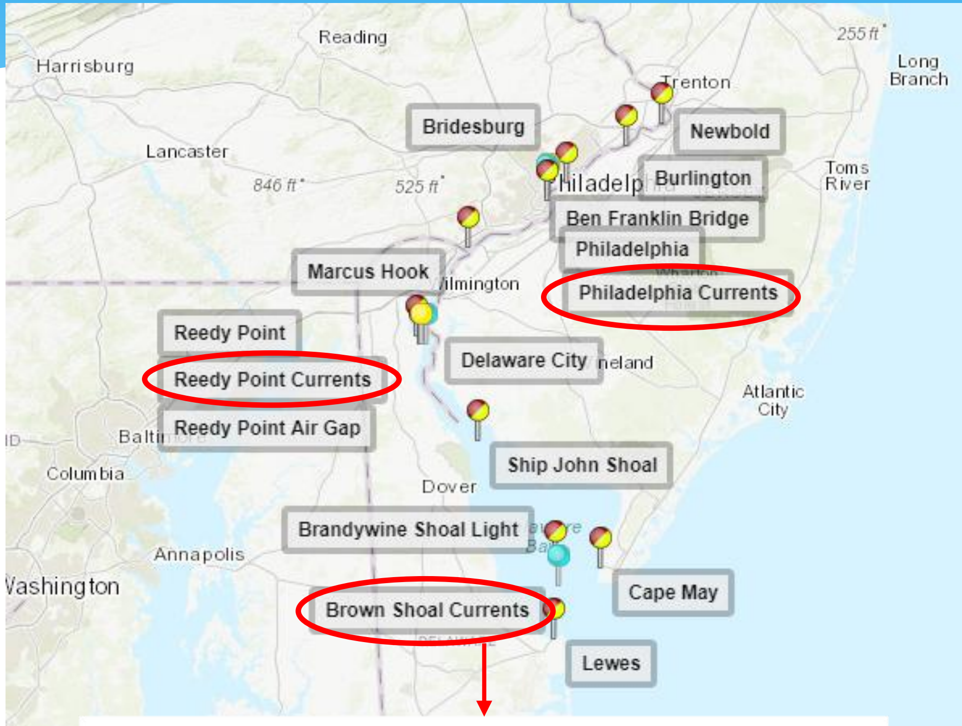
Non-point Sources

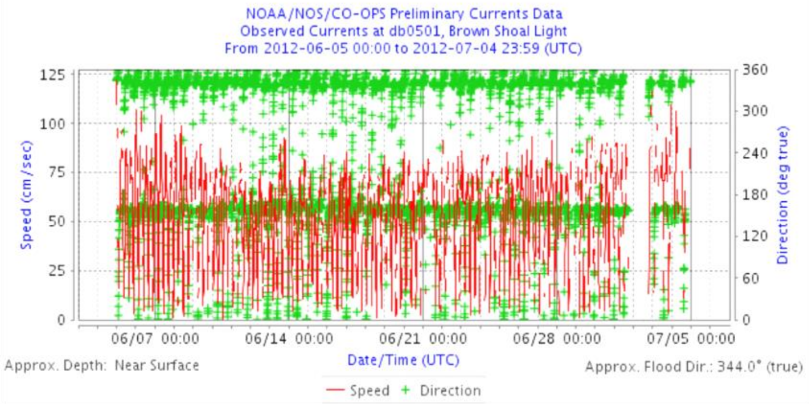
* Hourly or more frequent flows for Delaware River at Trenton and Schuylkill River
* Daily flows for ~ 25 tributaries
* Daily NPS runoffs (flows) will be estimated based on drainage area and precipitation
* Daily, direct precipitation volume onto water body
* Source: https://waterdata.usgs.gov/usa/nwis/uv?01463500

Point Sources

* Hourly flows for top 10~15 traditional NPDES discharges
* Daily flows for the rest of traditional NPDES discharges
* Daily flows for CSOs
* Estimate daily flows for MS4s
* Source: will be requested by DRBC product

Calibration Target – Current Velocity





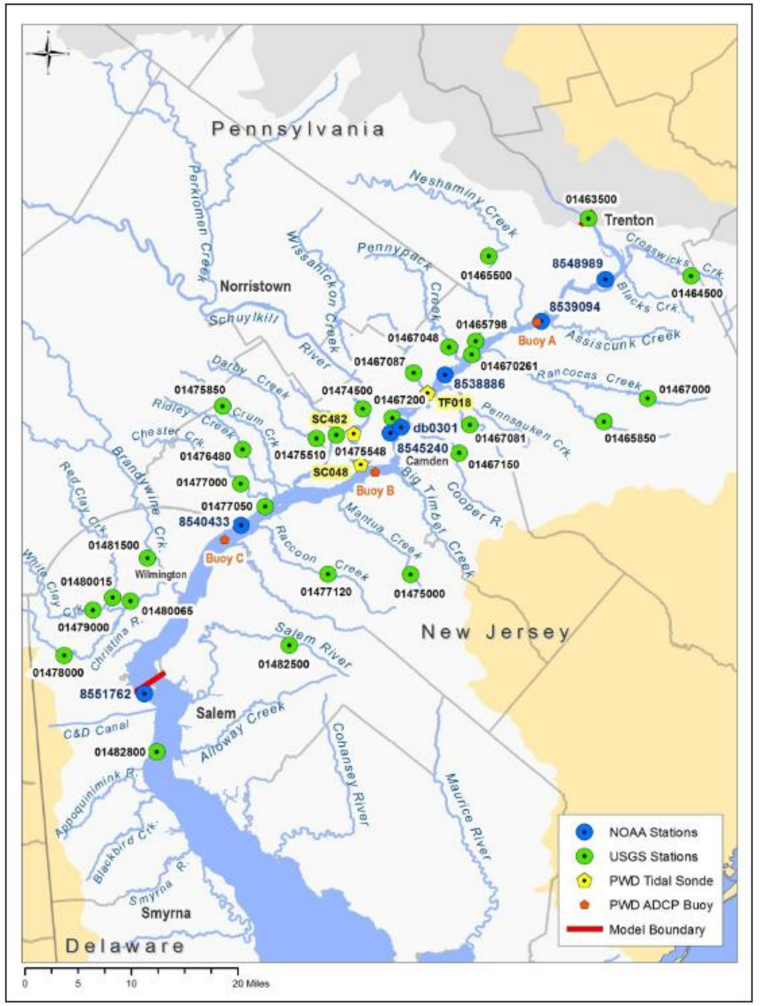


Figure 2-4: Water Level and Current Observation Meters in the Model Domain
Section 2: Hydrodynamic Model Page 15
Philadelphia Water Department June 2015

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Salinity

- Convert hourly specific conductance or conductivity to salinity (2 to 42 ppt) using Practical Salinity Scale (1978)
- The relationships extended to 0 ppt by Standard Method (American Public Health Association, 1989)
- Conductivity data from
  - NOAA PORTs and
  - Four USGS gage Stations
- Three NOAA PORTs stations, Cape May, Lewes, DE and Chesapeake City were enhanced to measure conductivity in 2017.
- Source:
  - https://tidesandcurrnts.noaa.gov/ports/index.html?port=db
  - https://waterdata.usgs.gov/nwis/uv?site_no=01477050

Practical Salinity Scale (PPS 78) **Salinity in the range of 2 to 42**

Constants from the 19th Edition of Standard Methods

R cond.ratio	0.0280	$R = \dfrac{C}{42.914 mS/cm}$
C Cond at t	1.2	Input conductivity in mS/cm of sample
t deg. C	25.00	Input temperature of sample solution
P dBar	0	Input pressure at which sample is measured in decibars
Rp	1.0000000	$R_p = 1 + \dfrac{p(e_1 + e_2p + e_3p^2)}{1 + d_1t + d_2t^2 + (d_3 + d_4t)R}$
rt	1.2365374	$r_t = c_0 + c_1t + c_2t^2 + c_3t^3 + c_4t^4$
Rt	0.0226139	$R_t = \dfrac{R}{R_p \times r_t}$
Delta S	-0.0051	$\text{Delta S} = \dfrac{(t-15)}{1+k(t-15)}(b_0 + b_1R_t^{1/2} + b_2R_t + b_3R_t^{3/2} + b_4R_t^2 + b_5R_t^{5/2})$
S = Salinity	**0.596**	$S = a_0 + a_1R_t^{1/2} + a_2R_t + a_3R_t^{3/2} + a_4R_t^2 + a_5R_t^{5/2} + \text{delta S}$

a0	0.0080	b0	0.0005	c0	0.67661	d1	3.426E-02	e1	2.070E-04
a1	-0.1692	b1	-0.0056	c1	0.02006	d2	4.464E-04	e2	-6.370E-08
a2	25.3851	b2	-0.0066	c2	0.00011	d3	4.215E-01	e3	3.989E-12
a3	14.0941	b3	-0.0375	c3	0.00000	d4	-3.107E-03		
a4	-7.0261	b4	0.0636	c4	0.00000				
a5	2.7081	b5	-0.0144						
		k	0.0162						

R = ratio of measured conductivity to the conductivity of the Standard Seawater Solution

Conductivity Ratio R is a function of salinity, temperature, and hydraulic pressure. So that we can factor R into three parts i.e.

R = Rt x Rp x rt

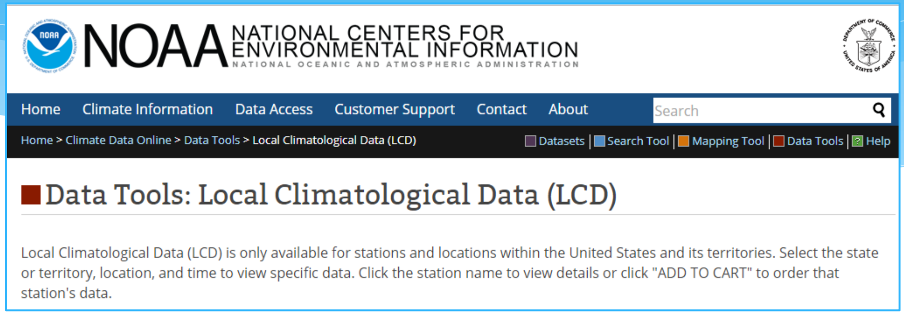
R = C(S,t,p)/C(35,15,0)

C = 42.914 mS/cm at 15 deg C and 0 dbar pressure ie C(35,15,0) where 35 is the salinity

Ocean pressure is usually measured in decibars. 1 dbar = 10^-1 bar = 10^5 dyne/cm^2 = 10^4 Pascal.

Climatic Data

* WBAN:13739 (Weather Bureau Army Navy): Philadelphia International Airport
* Accessed NCEI and NCDC web sites
* ~ hourly data for:
  * Dry-air, wet-bulb, dew point temperatures,
  * Precipitation rate,
  * Cloud cover, relative humidity, atmospheric Pressure,
  * Wind speed and direction
* Climate data from additional weather stations (Wilmington, Mt. Holly, etc.) will be compiled
* Source:
  * https://www.ncdc.noaa.gov/cdo-web/datatools/lcd
  * https://www7.ncdc.noaa.gov/CDO/cdopoemain.cmd?datasetabbv=DS3505&countryabbv=&georegionabbv=&resolution=40

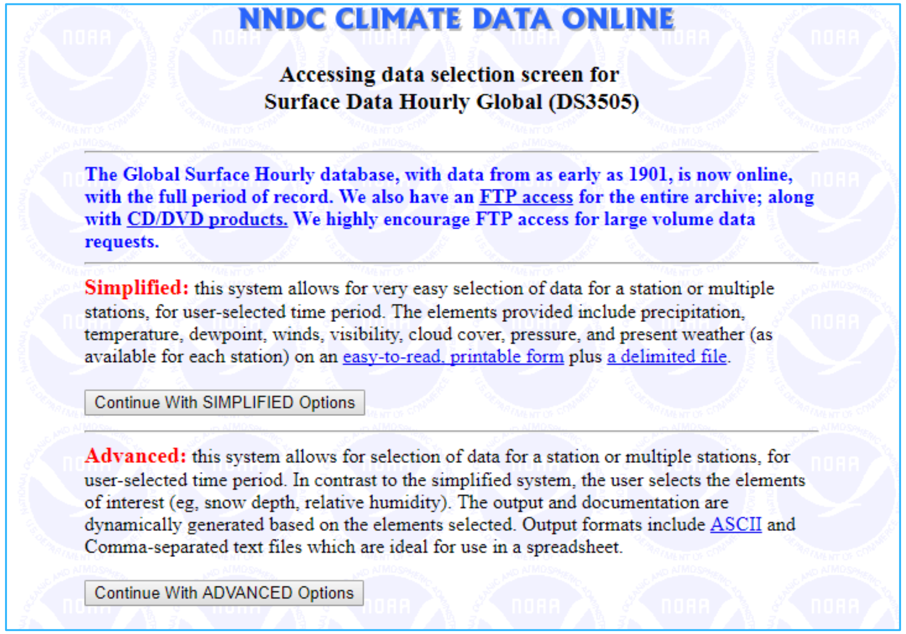

NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Home | Climate Information | Data Access | Customer Support | Contact | About | Search

Home > Climate Data Online > Data Tools > Local Climatological Data (LCD) | Datasets | Search Tool | Mapping Tool | Data Tools | Help

Data Tools: Local Climatological Data (LCD)

Local Climatological Data (LCD) is only available for stations and locations within the United States and its territories. Select the state or territory, location, and time to view specific data. Click the station name to view details or click "ADD TO CART" to order that station's data.


NNDC CLIMATE DATA ONLINE

Accessing data selection screen for
Surface Data Hourly Global (DS3505)

The Global Surface Hourly database, with data from as early as 1901, is now online, with the full period of record. We also have an FTP access for the entire archive; along with CD/DVD products. We highly encourage FTP access for large volume data requests.

Simplified: this system allows for very easy selection of data for a station or multiple stations, for user-selected time period. The elements provided include precipitation, temperature, dewpoint, winds, visibility, cloud cover, pressure, and present weather (as available for each station) on an easy-to-read, printable form plus a delimited file.

Continue With SIMPLIFIED Options

Advanced: this system allows for selection of data for a station or multiple stations, for user-selected time period. In contrast to the simplified system, the user selects the elements of interest (eg, snow depth, relative humidity). The output and documentation are dynamically generated based on the elements selected. Output formats include ASCII and Comma-separated text files which are ideal for use in a spreadsheet.

Continue With ADVANCED Options

Climatic Data – Solar Radiation

- Point retrieval (39.89N, 75.14W) at RM95.5: 5 miles north of Philadelphia Airport
- Accessed NSRDB for Physical Solar Model (PSM) output
- 30-minute data for:

  Global Horizontal Irradiance (GHI) in W/m^2

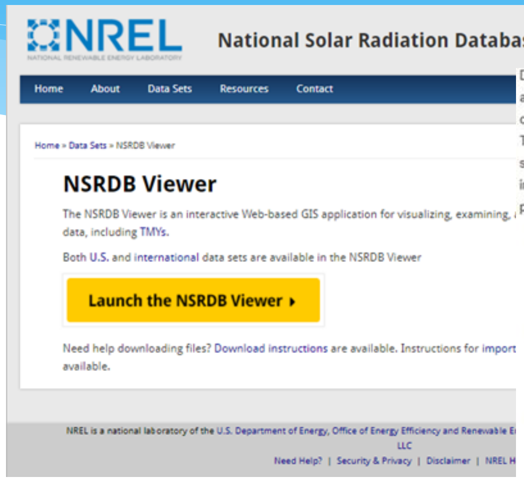
  $= DNI \cos\theta + DHI$

  Where,

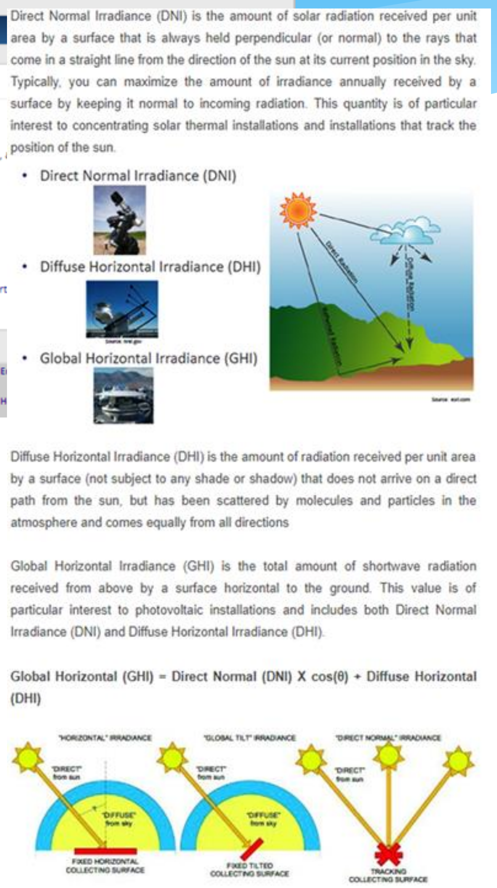
  DNI: Direct Normal Irradiance

  DHI: Diffused Horizontal Irradiance (long-wave radiation?)

- Source: https://nsrdb.nrel.gov/nsrdb-viewer



Additional data available for DHI, DNI, clear-sky DHI, clear-sky DNI, clear-sky GHI, cloud type, dew point temperature, pressure, relative humidity, solar zenith angle, precipitable water, wind direction, wind speed



Direct Normal Irradiance (DNI) is the amount of solar radiation received per unit area by a surface that is always held perpendicular (or normal) to the rays that come in a straight line from the direction of the sun at its current position in the sky. Typically, you can maximize the amount of irradiance annually received by a surface by keeping it normal to incoming radiation. This quantity is of particular interest to concentrating solar thermal installations and installations that track the position of the sun.

- Direct Normal Irradiance (DNI)
- Diffuse Horizontal Irradiance (DHI)
- Global Horizontal Irradiance (GHI)

Diffuse Horizontal Irradiance (DHI) is the amount of radiation received per unit area by a surface (not subject to any shade or shadow) that does not arrive on a direct path from the sun, but has been scattered by molecules and particles in the atmosphere and comes equally from all directions

Global Horizontal Irradiance (GHI) is the total amount of shortwave radiation received from above by a surface horizontal to the ground. This value is of particular interest to photovoltaic installations and includes both Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DHI).

Global Horizontal (GHI) = Direct Normal (DNI) X cos(θ) + Diffuse Horizontal (DHI)

Data to be Compiled

* Dye study (2011)
* Sediment type (2003)
* Salinity profiles (data source not identified yet)
  * Vertical
  * Horizontal
* Any other key data?

FINAL REPORT

to

DELAWARE RIVER BASIN COMMISSION

25 State Police Drive
PO Box 7360
West Trenton, New Jersey
08628-0360

SEDIMENTOLOGICAL AND GEOPHYSICAL SURVEY OF THE UPPER DELAWARE ESTUARY

by

Christopher K. Sommerfield[1] and John A. Madsen[2]

[1]College of Marine Studies
University of Delaware
700 Pilottown Road
Lewes, Delaware 19958

[2]Department of Geology
University of Delaware
Penny Hall
Newark, Delaware 19716

October 2003

Delaware River Basin Commission

Preliminary Model Simulations

Model Expert Panel Meeting

July 25, 2017

Namsoo Suk, Ph.D., DRBC

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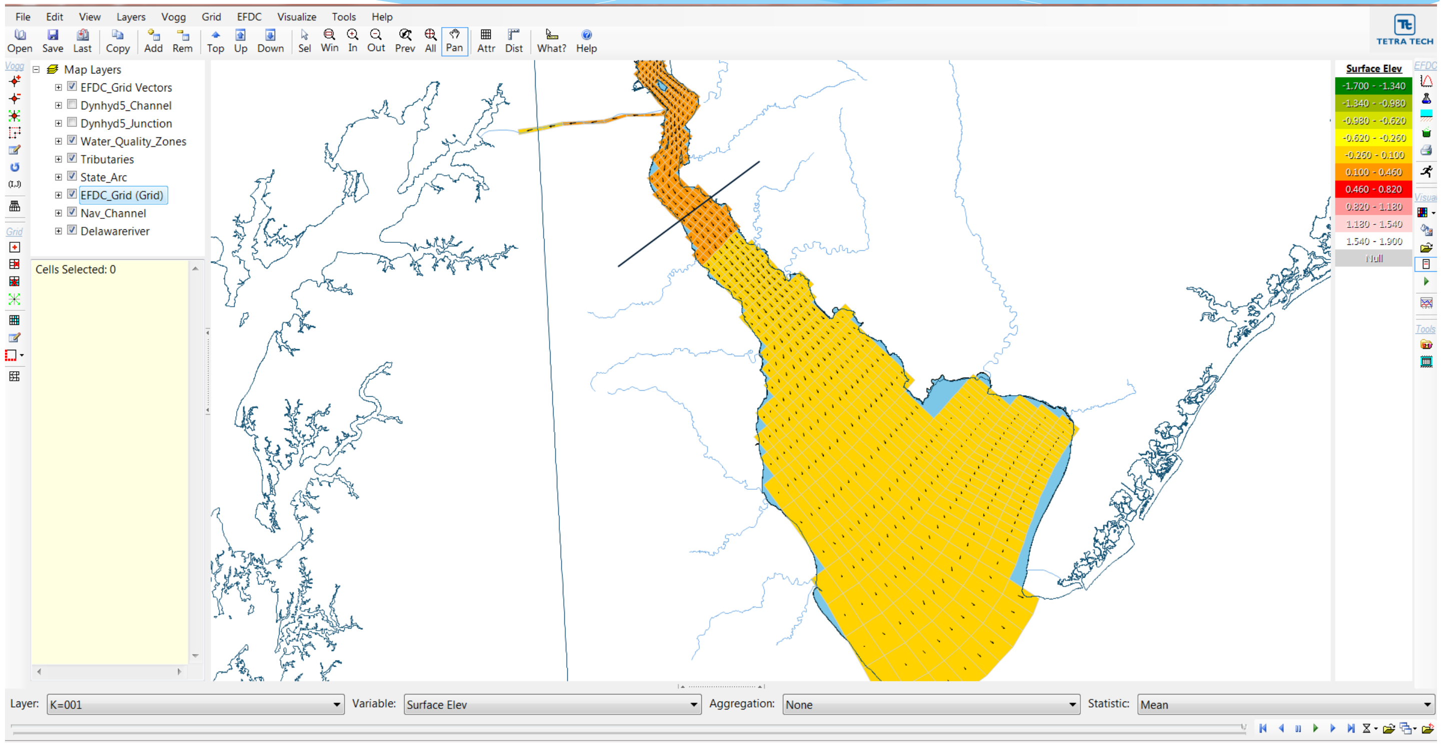
Hydrodynamic Model - EFDC

* Environmental Fluid Dynamics Code (EFDC)
  * Physics and numerical scheme equivalent to POM
  * Applied to a wide range of environmental studies
  * Build-in linkage with WASP
* Executable file from EPA R4
* Visual EFDC 2.0 – from Tetra Tech, Inc.



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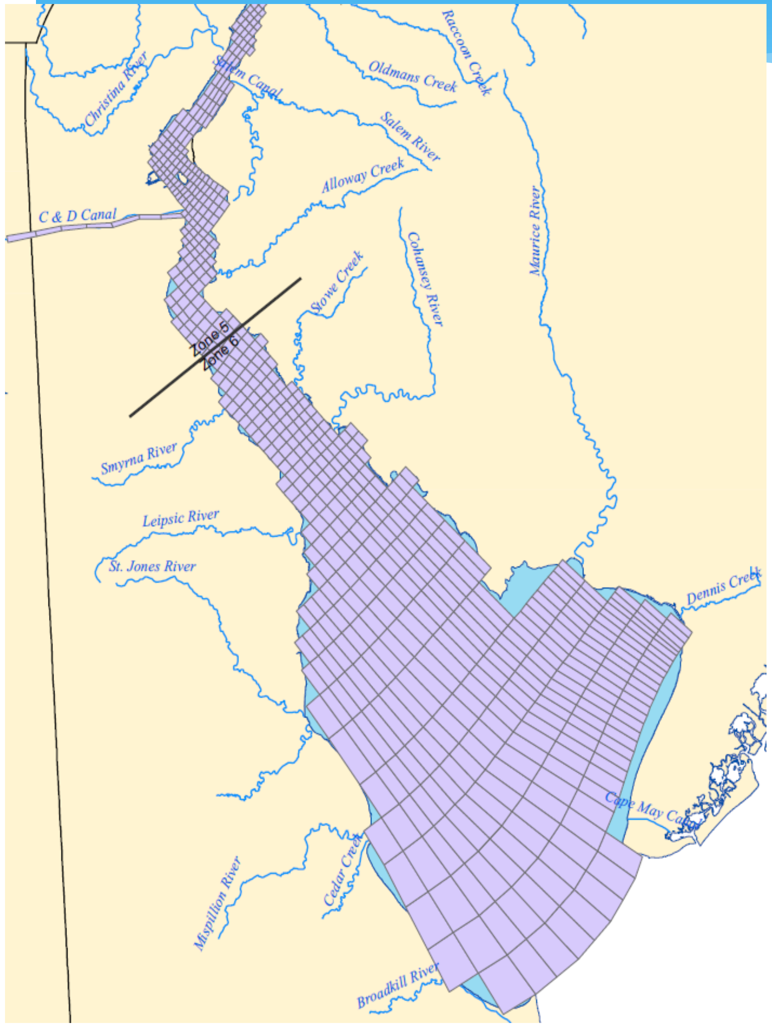
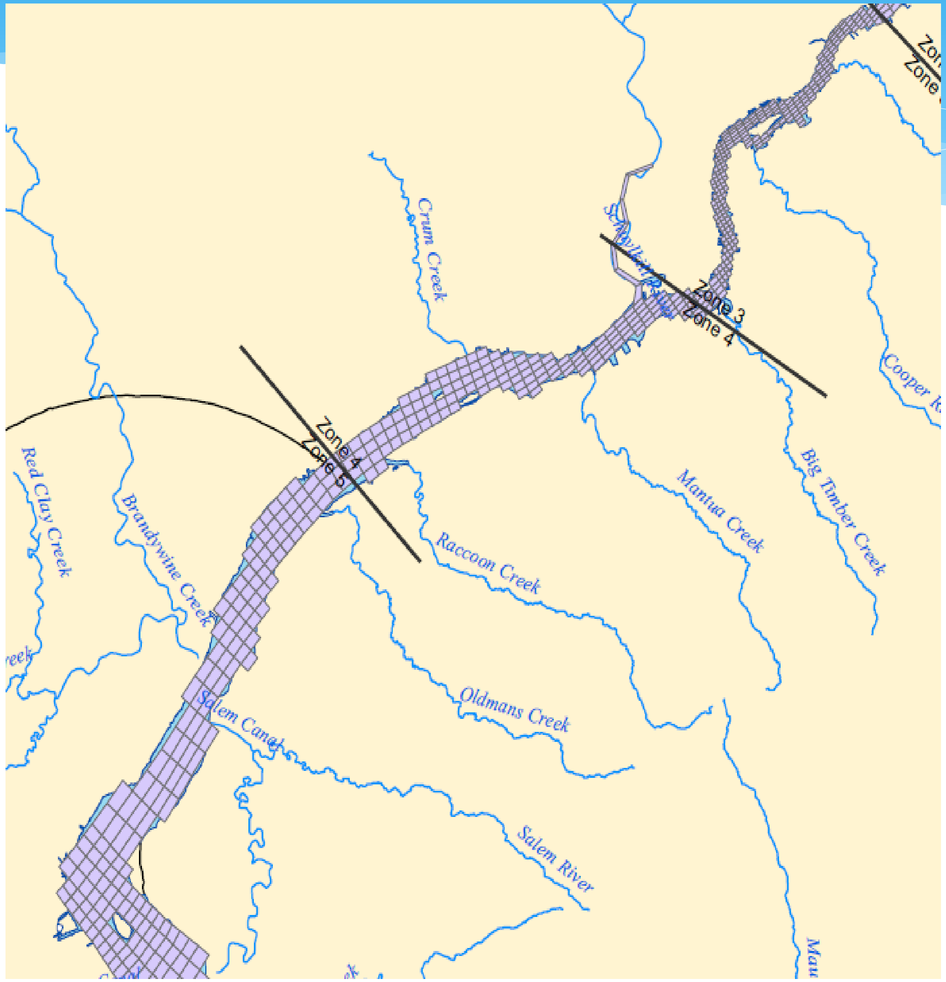
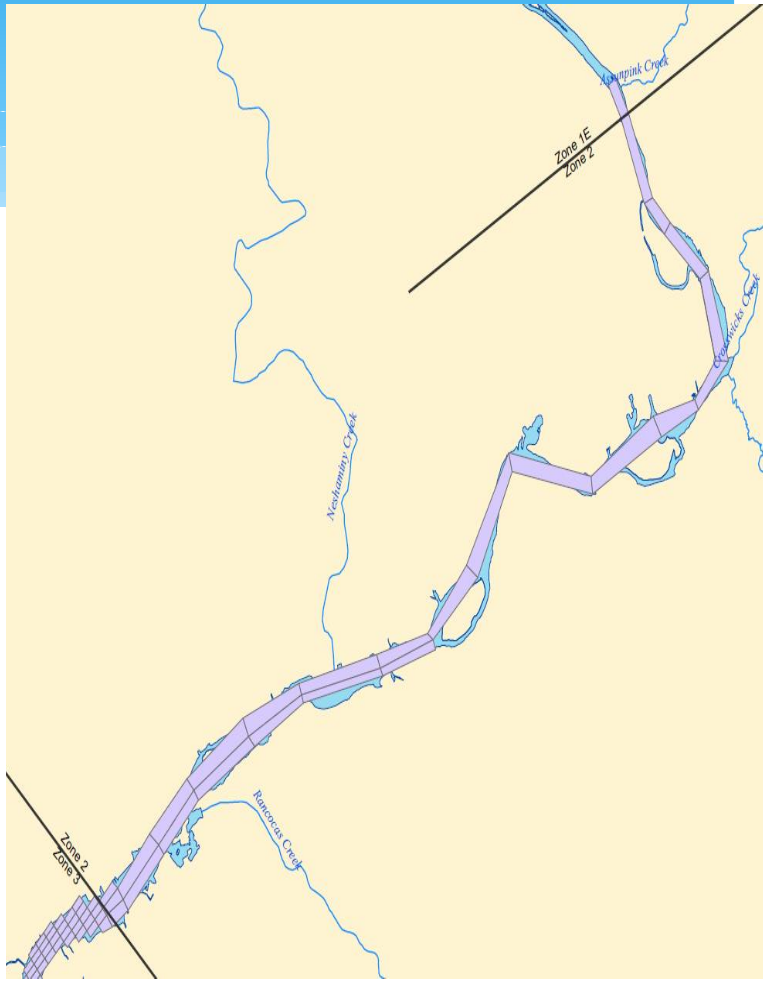
Preliminary Coarse Grid







No. of cells: 1047; average cell size: 970 m x 1500 m

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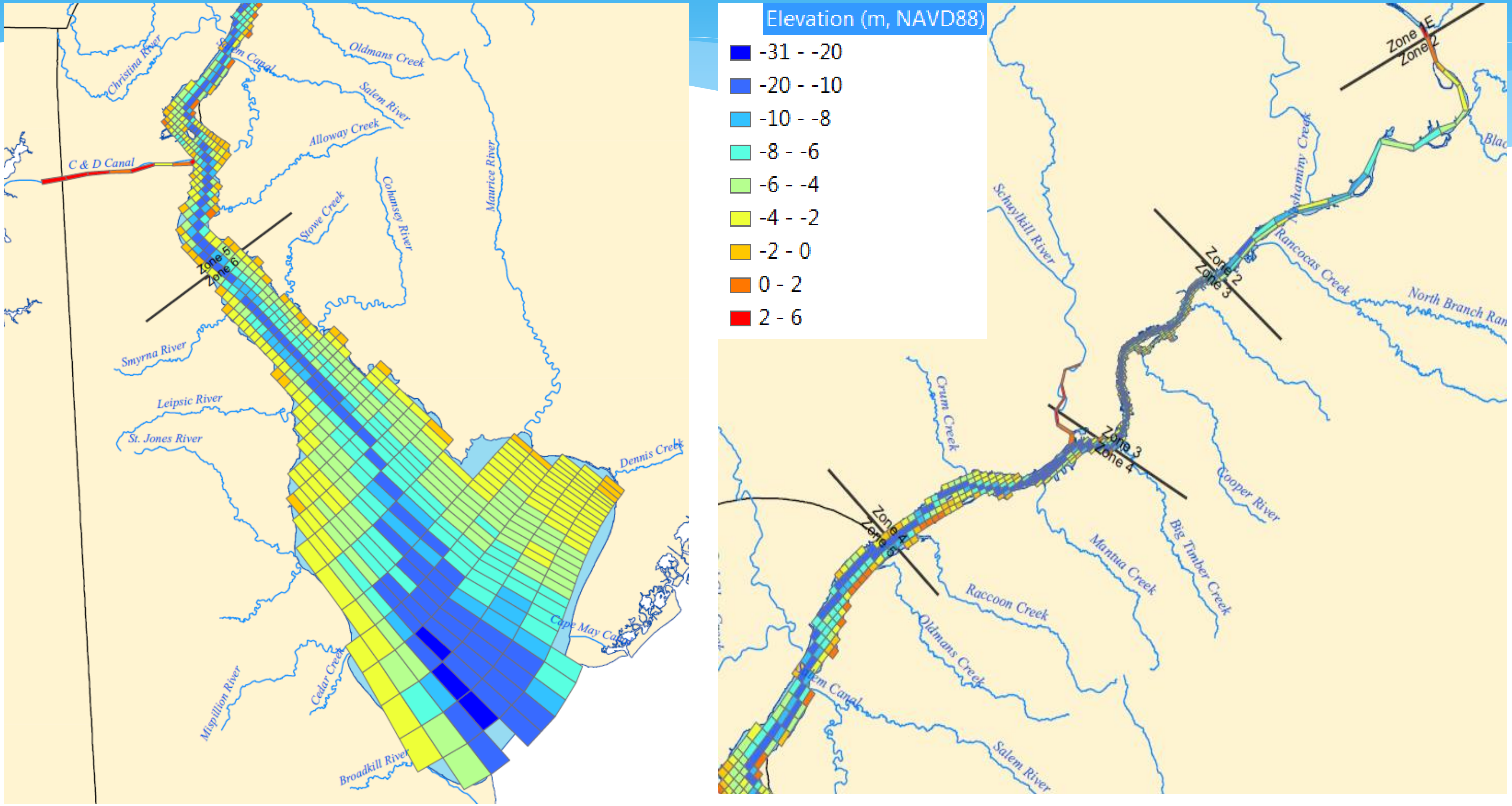
Bathymetry Projection

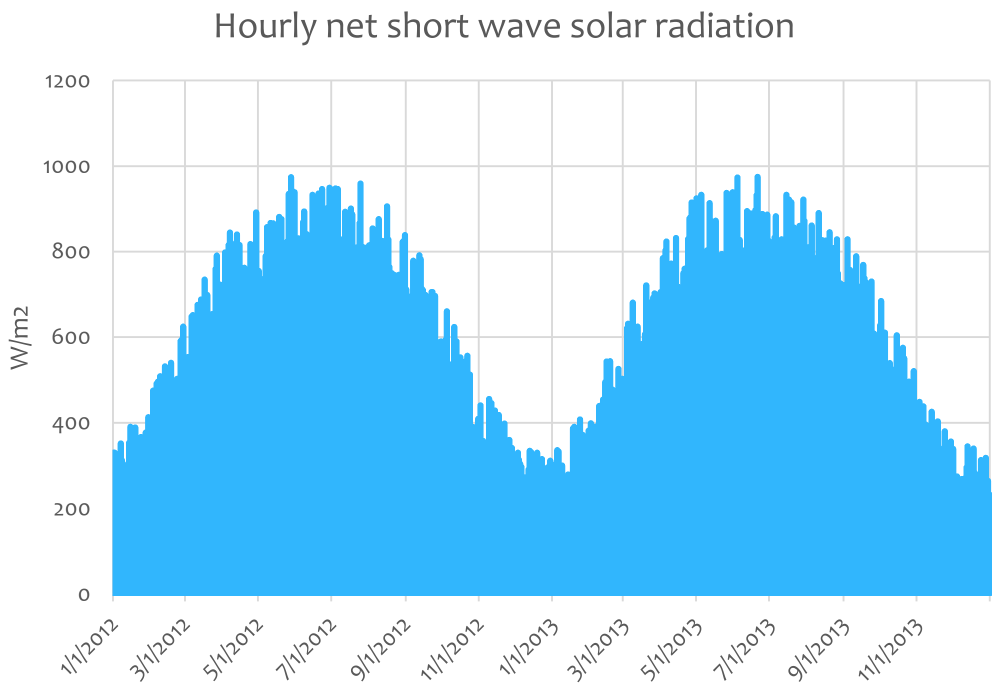


Scenario Setup

* Calibration period: 2012 ~ 2013
* Boundary conditions: (Namsoo's presentation)
* A simple scenario
  * Stream flow: Delaware River @ Trenton, Schuylkill River
  * Point source: three PWD WWTP
  * A three month test run with a time step of 30 s

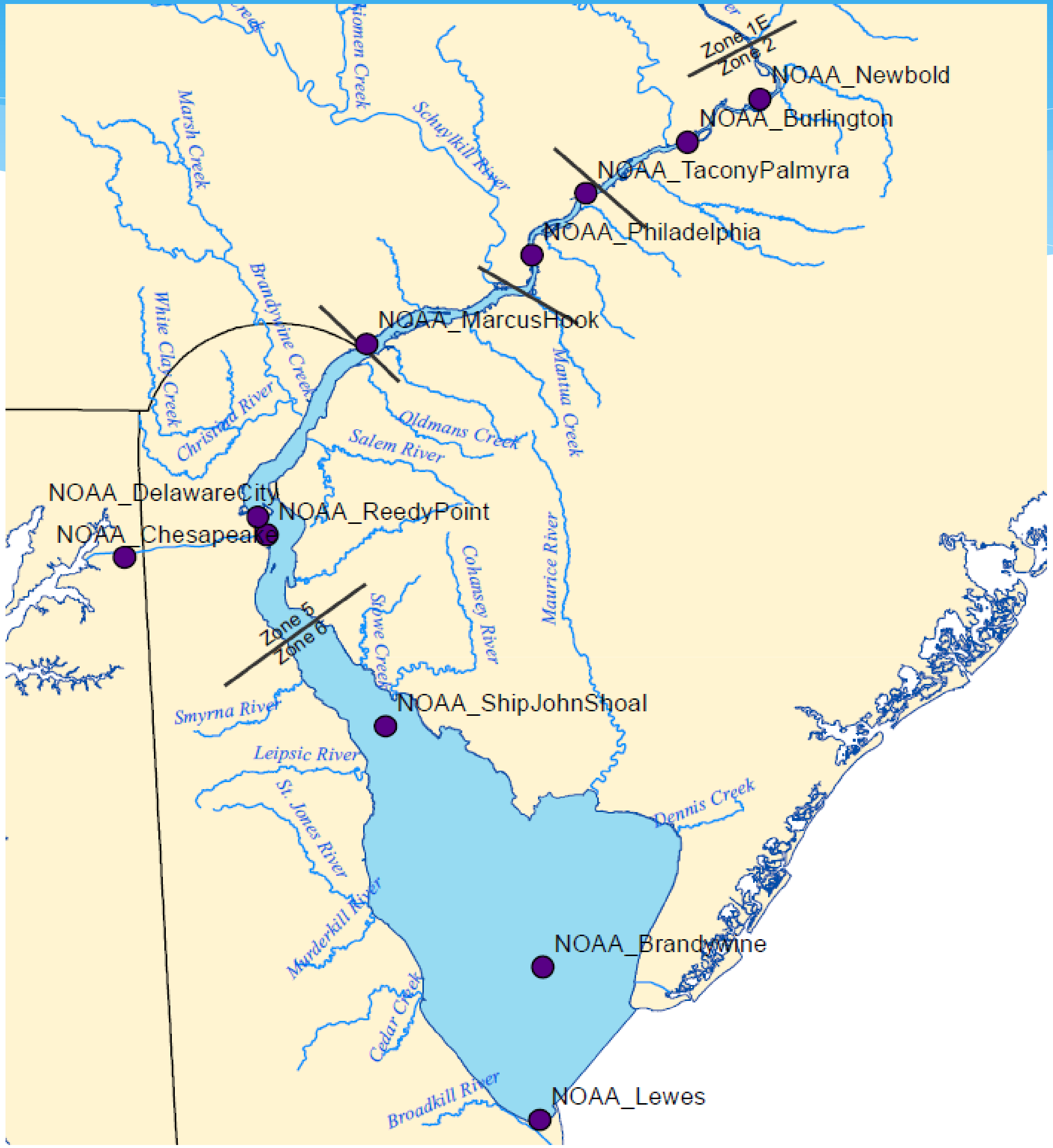
Short wave solar radiation

* Estimated from Iqbal (1983) and Rosati and Miyakoda (1988)
  * Total extraterrestrial solar radiation
  * Atmospheric attenuation
  * Cloud attenuation
  * Water albedo
* Lat./Long. And cloud cover
  * NOAA Philadelphia station



NOAA Stations @ Delaware Estuary

* Total 11 stations
  * Water surface elevation
  * Water temperature
* Brandywine and Ship John Shoal
  * Conductivity (part of 2012)
* Lewes
  * Conductivity since 2017



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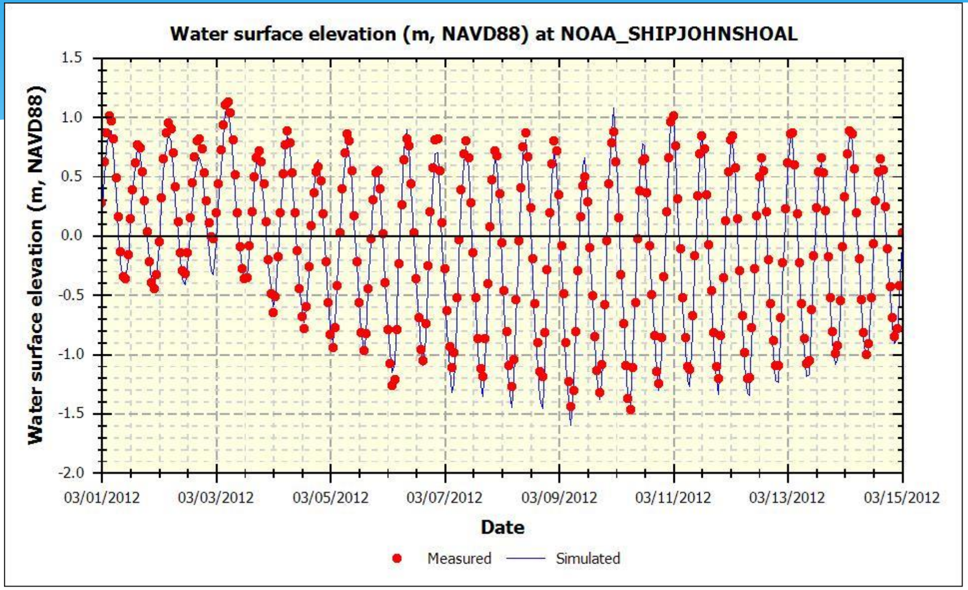
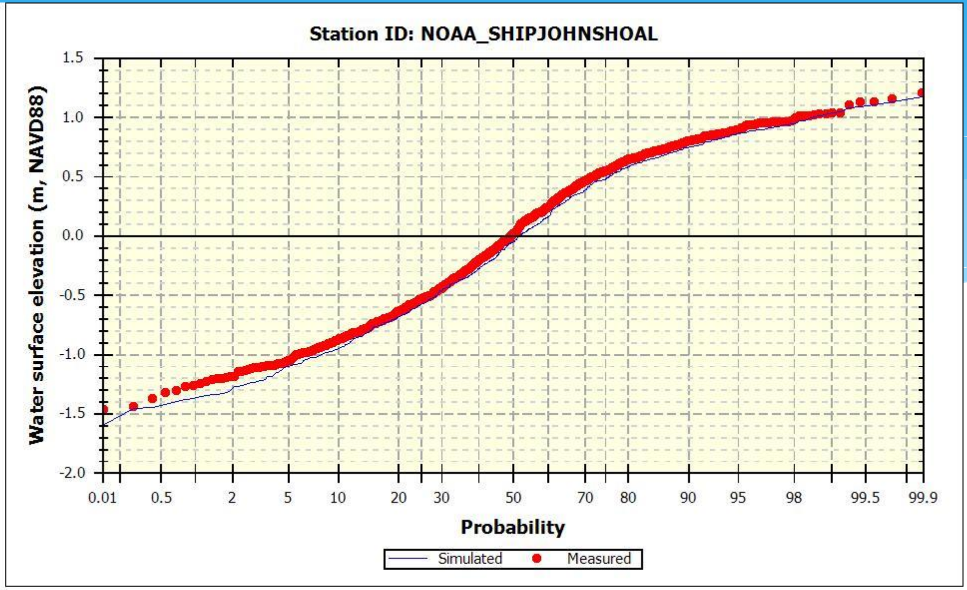
Water Surface Elevation @ Ship John Shoal

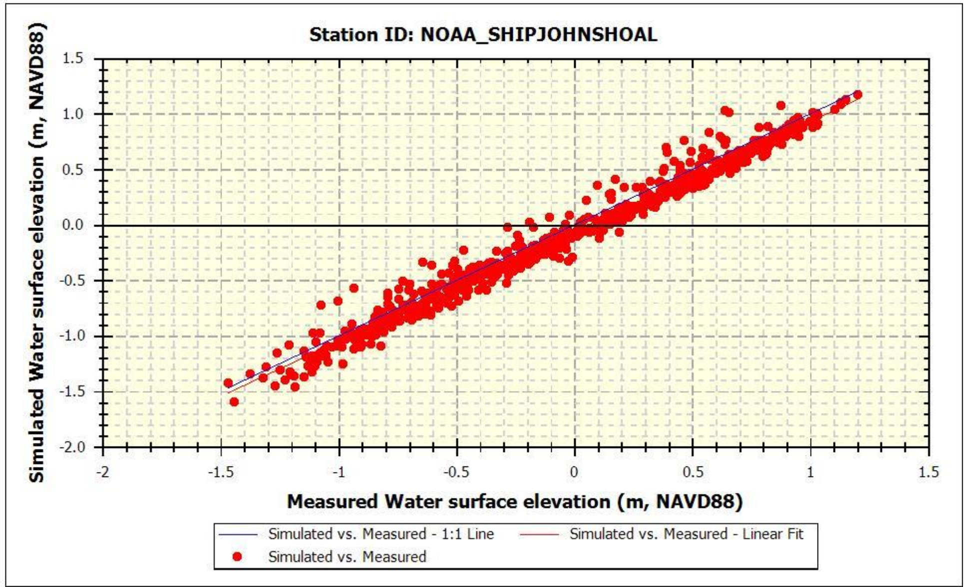




Calibration Statistics

Date Range: 3/1/2012 - 3/31/2012

Statistic	Measured	Simulated
Station: NOAA_SHIPJOHNSHOAL; Parameter: Water surface elevation (m, NAVD88)		
Count:	721	719
Mean:	-0.014	-0.073
Median:	0.146	0.055
Std Dev:	0.629	0.632
Min:	-1.469	-1.596
Max:	1.201	1.172
5 %tile:	-1.053	-1.100
10 %tile:	-0.886	-0.957
90 %tile:	0.798	0.743
95 %tile:	0.890	0.864
Coef of Det (R^2):	0.98	
Mean Abs Error:	0.092	
RMS Error:	0.110	
Norm RMS Error:	0.176	
Index of Agreement:	0.99	



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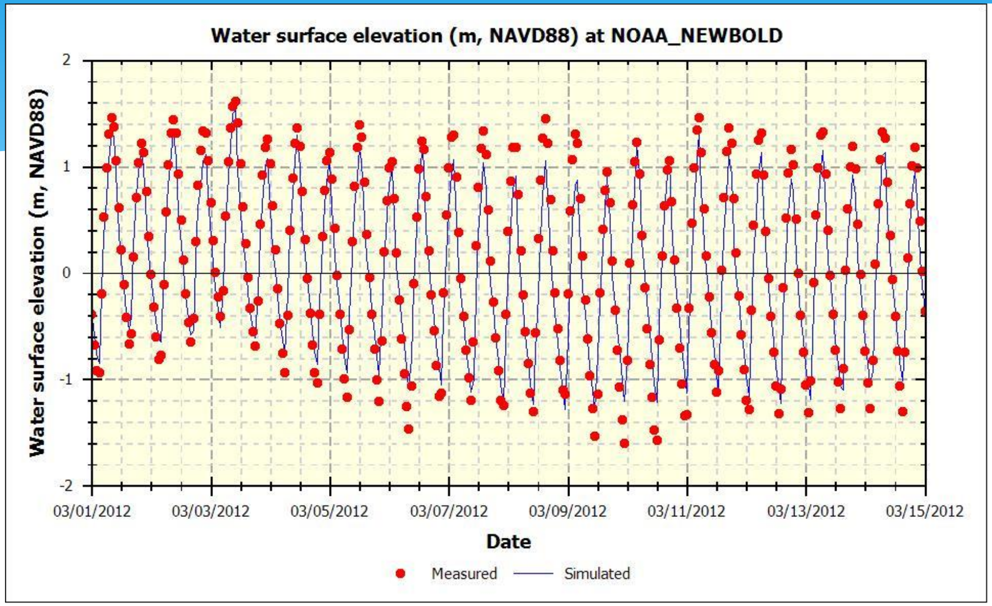
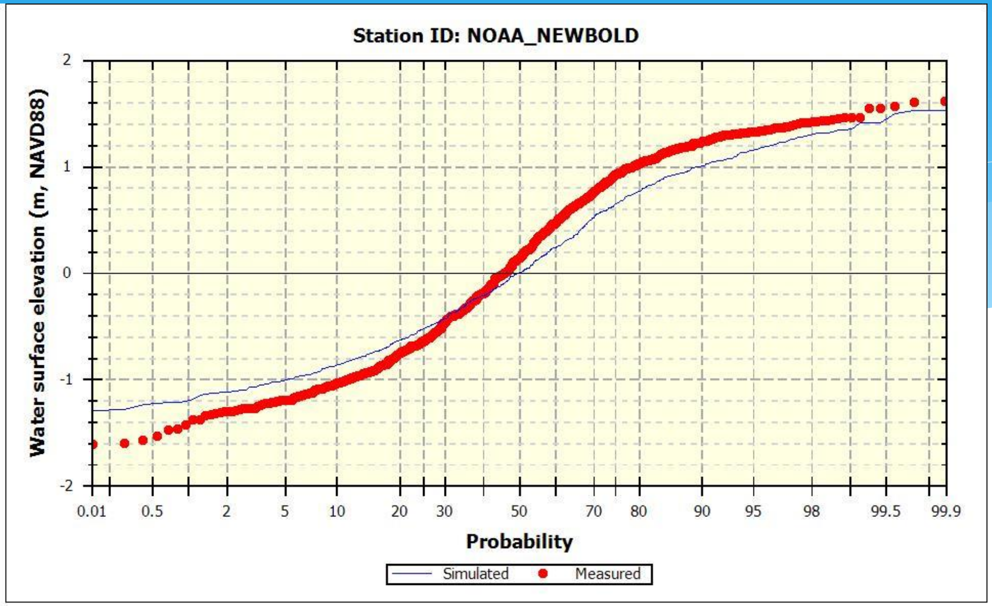
Water Surface Elevation @ Newbold

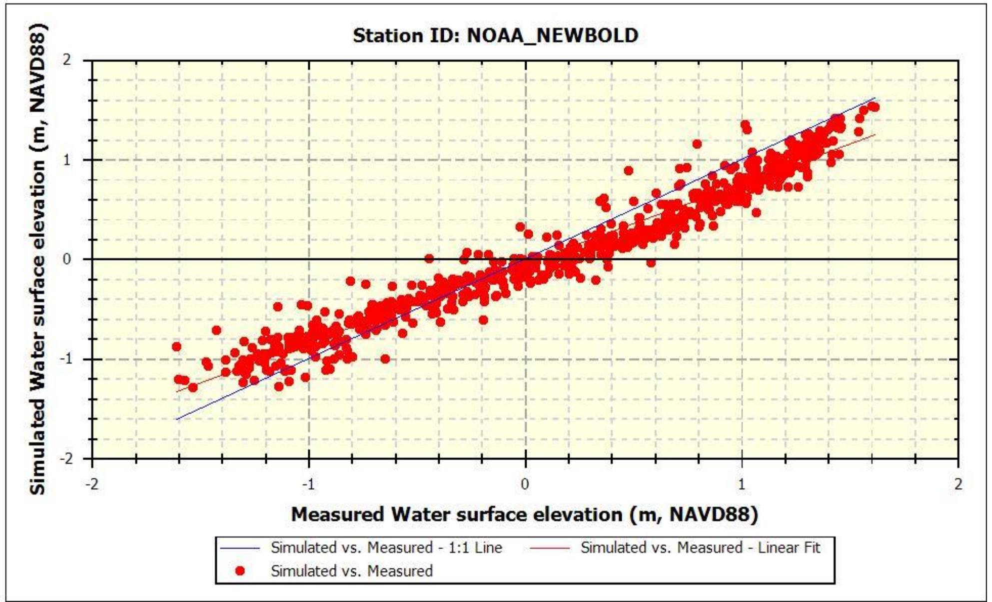




Calibration Statistics

Date Range: 3/1/2012 - 3/31/2012

Statistic	Measured	Simulated
Station: NOAA_NEWBOLD; Parameter: Water surface elevation (m, NAVD88)		
Count:	721	719
Mean:	0.116	0.045
Median:	0.317	0.120
Std Dev:	0.845	0.692
Min:	-1.610	-1.295
Max:	1.615	1.530
5 %tile:	-1.198	-1.007
10 %tile:	-1.040	-0.867
90 %tile:	1.230	1.004
95 %tile:	1.324	1.152
Coef of Det (R^2):	0.96	
Mean Abs Error:	0.201	
RMS Error:	0.236	
Norm RMS Error:	0.310	
Index of Agreement:	0.98	



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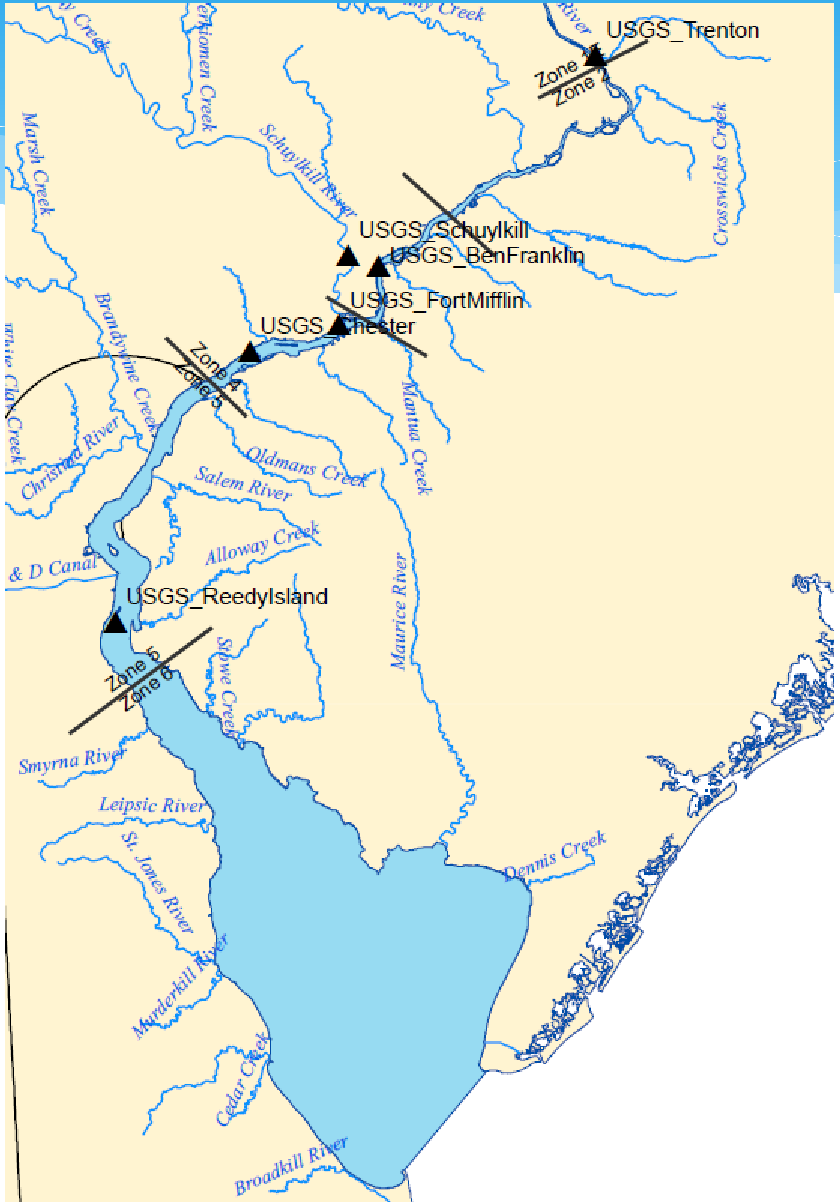
USGS Stations @ Delaware Estuary

* Total 4 stations
  * Specific conductance
  * Water temperature
  * DO
* Fort Mifflin
  * No data for 2012 ~ 2013



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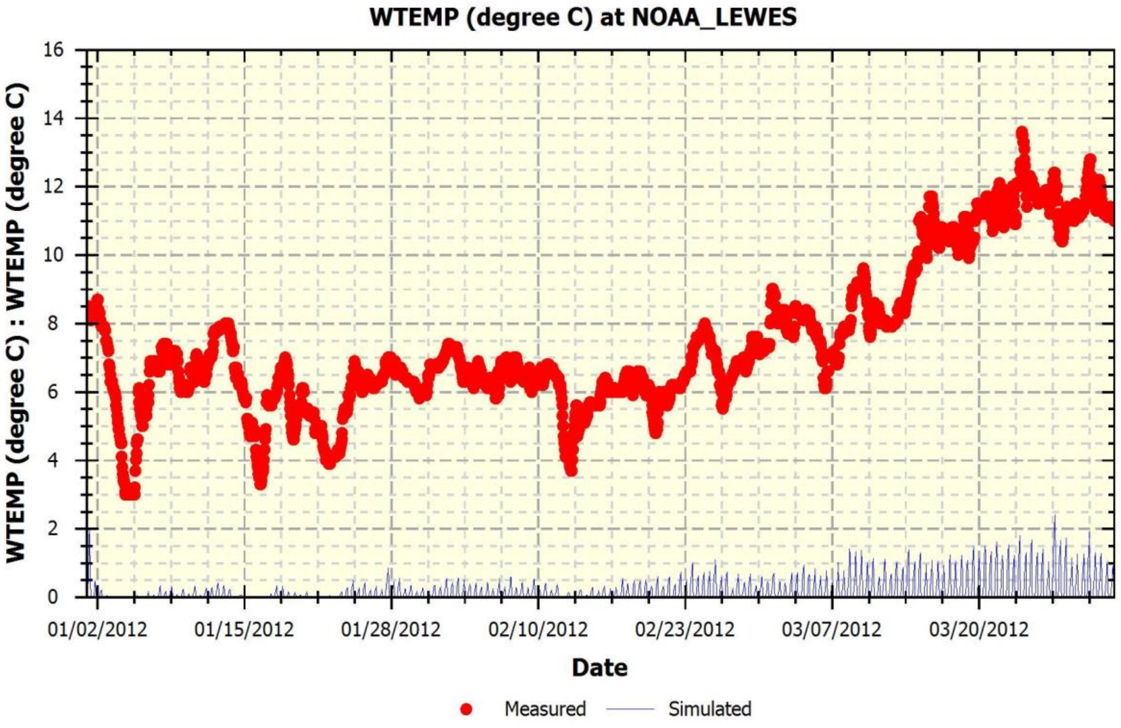
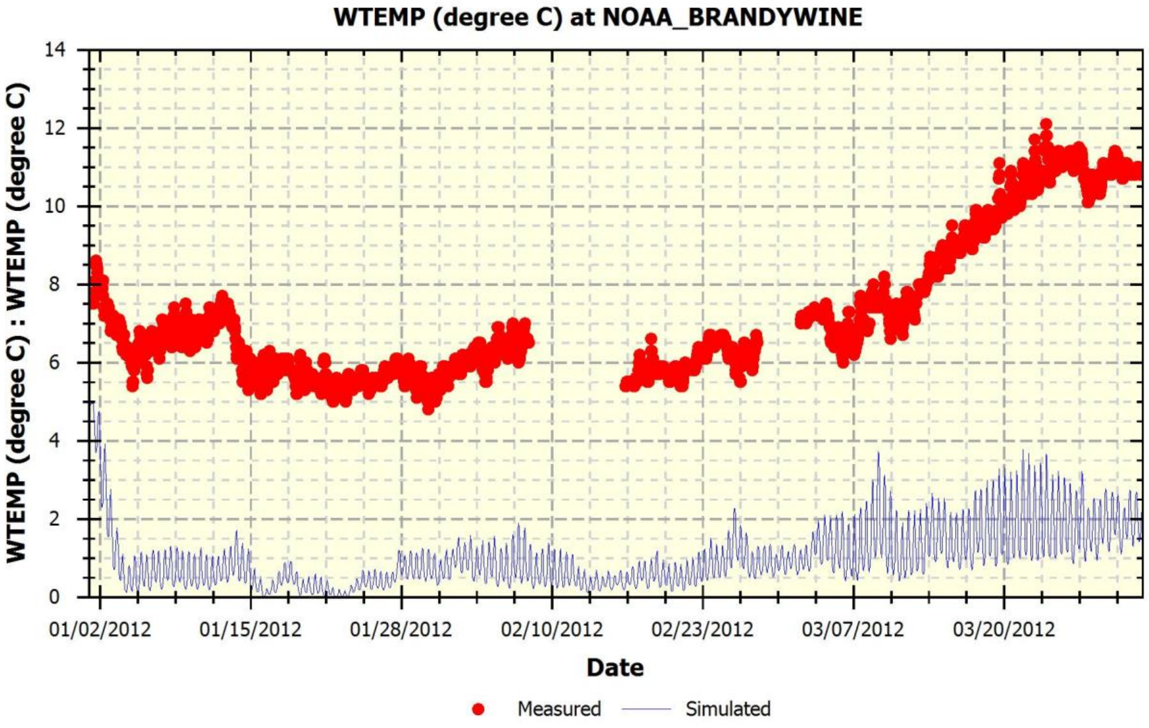
Water Temperature

Lewes & Brandywine





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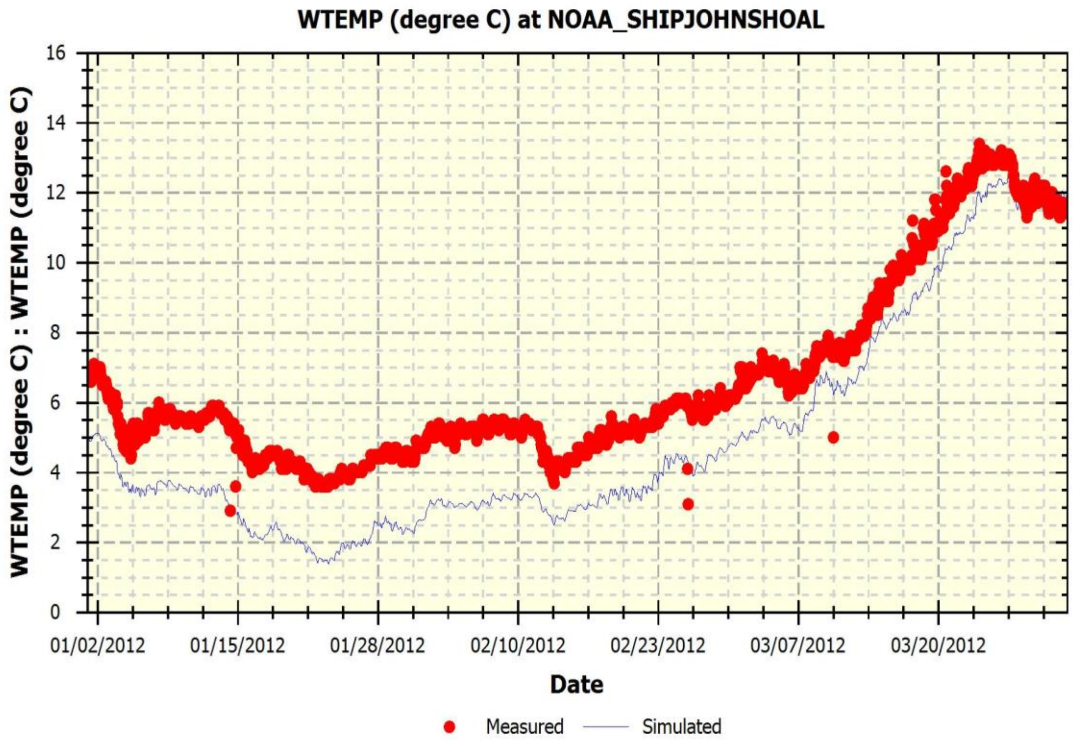
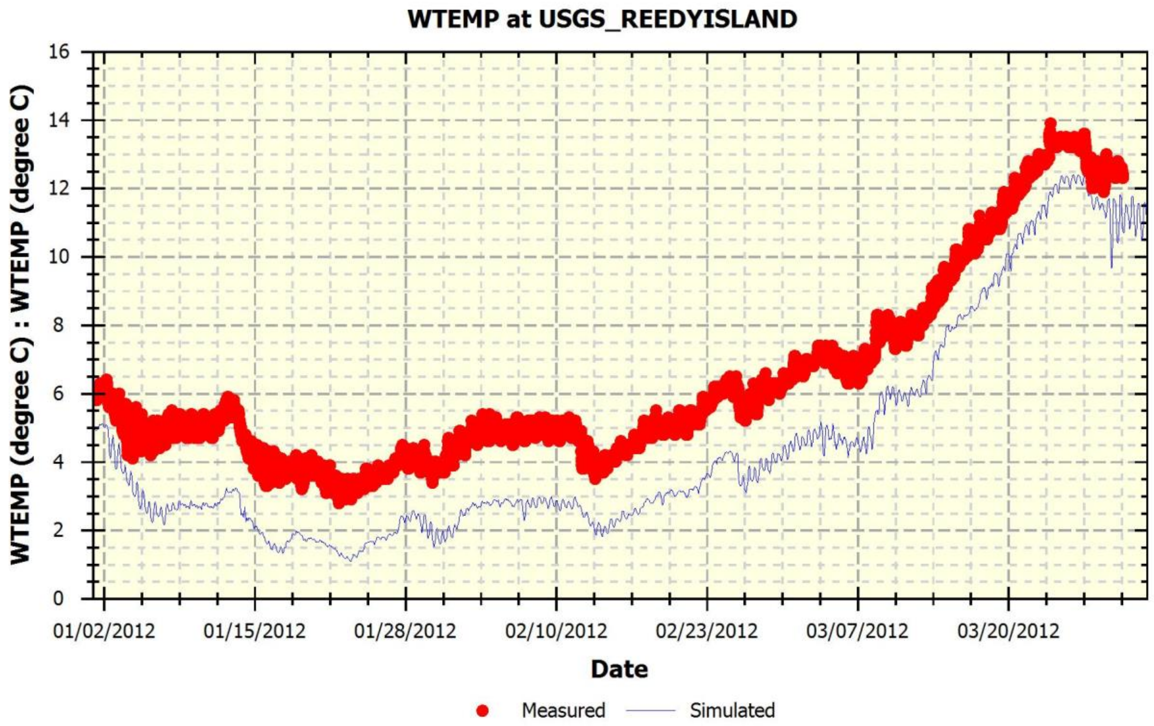
Water Temperature

Ship John Shoal & Reedy Island





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Tasks Next Step - Hydrodynamics

* Refine coarse grid with boundary-fitted cells
* Develop fine grid input based on CH3DZ grid
* Adjust navigational channel delineation
* Conduct harmonic analysis of tidal constituents (amplitude & phase)
* Include current velocity in model-data comparison
* Conduct low-pass filter analysis to determine long-term flow @ C&D Canal
* Incorporate Coriolis acceleration

Key Recommendations from EP

- Parallel efforts in development of EFDC hydrodynamic models for
  - 2-D coarse grid screening scale level Model, and 3-D finer grid full scale level Model
  - Develop a smoother grid for the navigation channel to improve screening level model
- Full scale hydrodynamic model domain
  - Use the regional ocean model output (salinity) to assign downstream boundary of the full scale model (e.g., NYHOPS model)
  - Use hybrid Z-level option
  - Test the model with 1:1 mapping with the CH3Dz grid
  - Test the model with subset of the CH3Dz grid

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Key Recommendations from EP

- Full scale WQ model domain
  - Can be a subset of CH3Dz – Mouth of the Bay and Chesapeake City in the C&D Canal
  - WASP8 can utilize a subset of the hydrodynamic model domain
- Check consistencies between TOXI5 and WASP8 models using finer time steps in DYNHYD5
  - DYNHYD5 will not be further developed for use in a coarse grid eutrophication model
- Check solar radiation with the complete equation (Chapra) similar to QUAL2K model

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