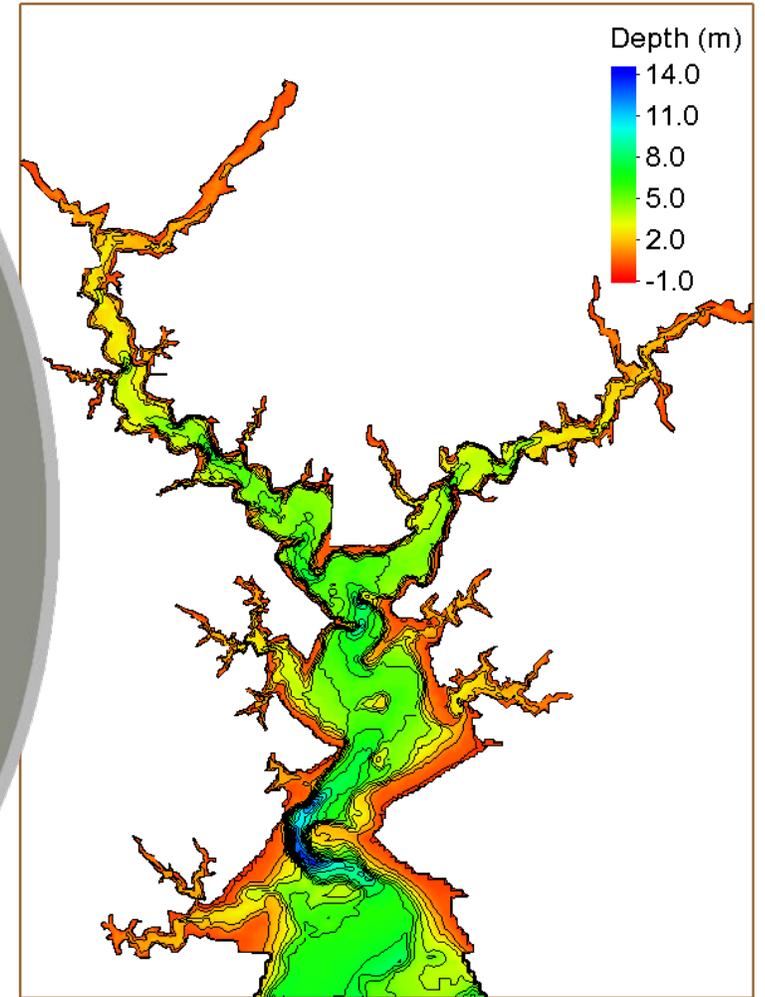




# COASTAL MODELING SYSTEM: ADVANCED TOPICS USING CMS 5.1 AND SMS 13.0

## DAY 4: SALINITY/TEMPERATURE CALCULATIONS

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# Outline

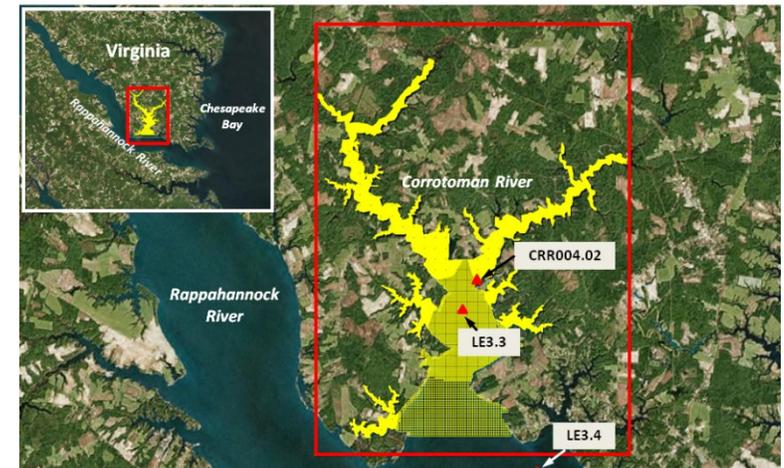
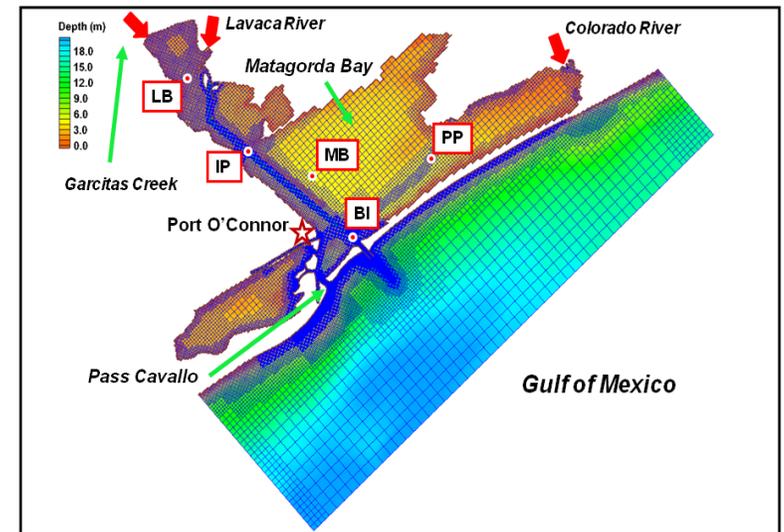


- **Background**
- **Salinity/temperature calculations in CMS-Flow**
- **Setup of salinity/temperature calculations**
  - **Initial condition**
  - **Boundary condition**
- **Export CMS-Flow files**

# Background



- **Water salinity and temperature influence environmental conditions in aquatic systems**
- **Changes in salinity can change the aggregation and consolidation of cohesive sediment**
- **Salinity and temperature can alter the water physical environment that impacts marine organisms with the change of water turbidity in coastal and estuarine systems**
- **Water quality and ecological models often require input of water temperature and salinity information from a hydrodynamic model**
- **Modifications of coastal inlets, such as channel deepening and widening and rehabilitation or extension of jetties, may alter the salinity/temperature distributions within the estuary**
- **Salinity/temperature calculations do not affect hydrodynamics in CMS**





# Salinity/Temperature Calculations in CMS-Flow

$$\frac{\partial(Sd)}{\partial t} + \frac{\partial(Sq_x)}{\partial x} + \frac{\partial(Sq_y)}{\partial y} = \frac{\partial}{\partial x} \left[ K_x d \frac{\partial S}{\partial x} \right] + \frac{\partial}{\partial y} \left[ K_y d \frac{\partial S}{\partial y} \right] + (P - E)S$$

$$\frac{\partial(Td)}{\partial t} + \frac{\partial(Tq_x)}{\partial x} + \frac{\partial(Tq_y)}{\partial y} = \frac{\partial}{\partial x} \left[ K_x d \frac{\partial T}{\partial x} \right] + \frac{\partial}{\partial y} \left[ K_y d \frac{\partial T}{\partial y} \right] + \frac{J_T}{\rho c_p}$$

**S:** depth-averaged salinity

**$\rho$ :** water density

**T:** depth-averaged temperature

**$c_p$ :** specific heat

**d:** total water depth

**$J_T$ :** net heat flux across water surface

**$q_x, q_y$ :** flow per unit width

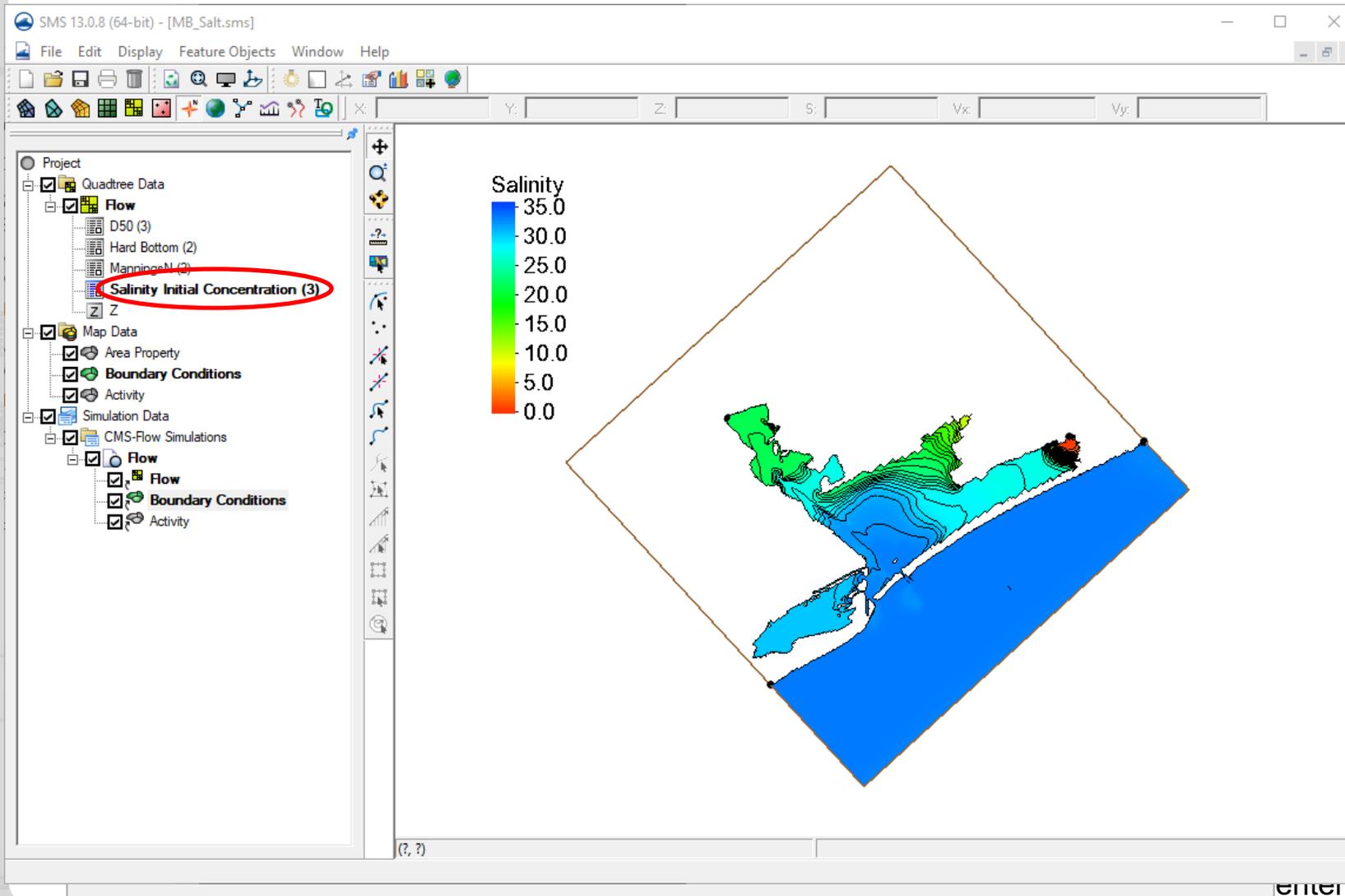
**$K_x, K_y$ :** diffusion or mixing coefficients of salt and heat

**P:** Precipitation

**E:** Evaporation

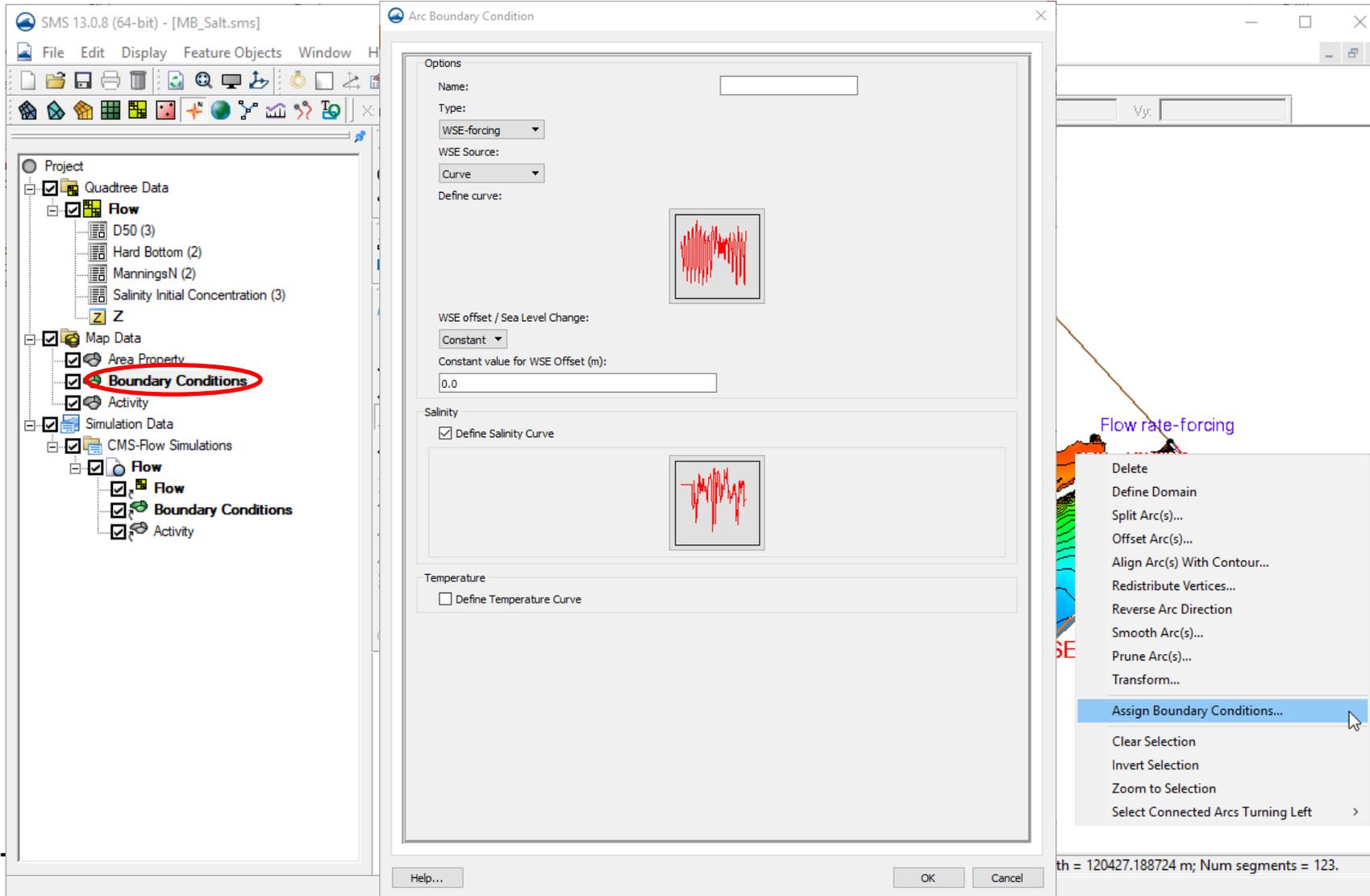
- **CMS-Flow lateral open and flux boundaries allow water exchanges with specifications of input salinity and temperature**
- **Surface boundary requires specifications of precipitation and evaporation for salinity and air-water heat exchange for temperature**
- **Initial condition files need to be prepared based on measured data**

# Setup of Salinity/Temperature Calculations (Initial Condition)



- Specify a constant initial value for the entire model domain or generate a spatially varying initial salinity field
- Go to *CMS-Flow Simulations* → *Model Control*
  - Check *Calculate salinity* and choose the *Spatially varied* toggle under the *Initial condition*
  - Click *Select* → *Create* toggle and *Data Set Toolbox* pops up
  - Assign a value and name the initial condition dataset in the pop-up window
  - “*Salinity Initial Concentration*” appears in the *Flow* data tree
  - Highlight the dataset to specify different salinity values in the CMS domain

# Setup of Salinity/Temperature Calculations (Lateral Boundary Condition)



The screenshot displays the SMS 13.0.8 (64-bit) interface for setting up a lateral boundary condition. The main window is titled "Arc Boundary Condition" and shows the following configuration:

- Options:**
  - Name: [Empty field]
  - Type: WSE-forcing
  - WSE Source: Curve
  - Define curve: [Graph showing a red salinity curve]
  - WSE offset / Sea Level Change: Constant
  - Constant value for WSE Offset (m): 0.0
- Salinity:**
  - Define Salinity Curve
  - [Graph showing a red salinity curve]
- Temperature:**
  - Define Temperature Curve

A context menu is open over a boundary arc, with the following options:

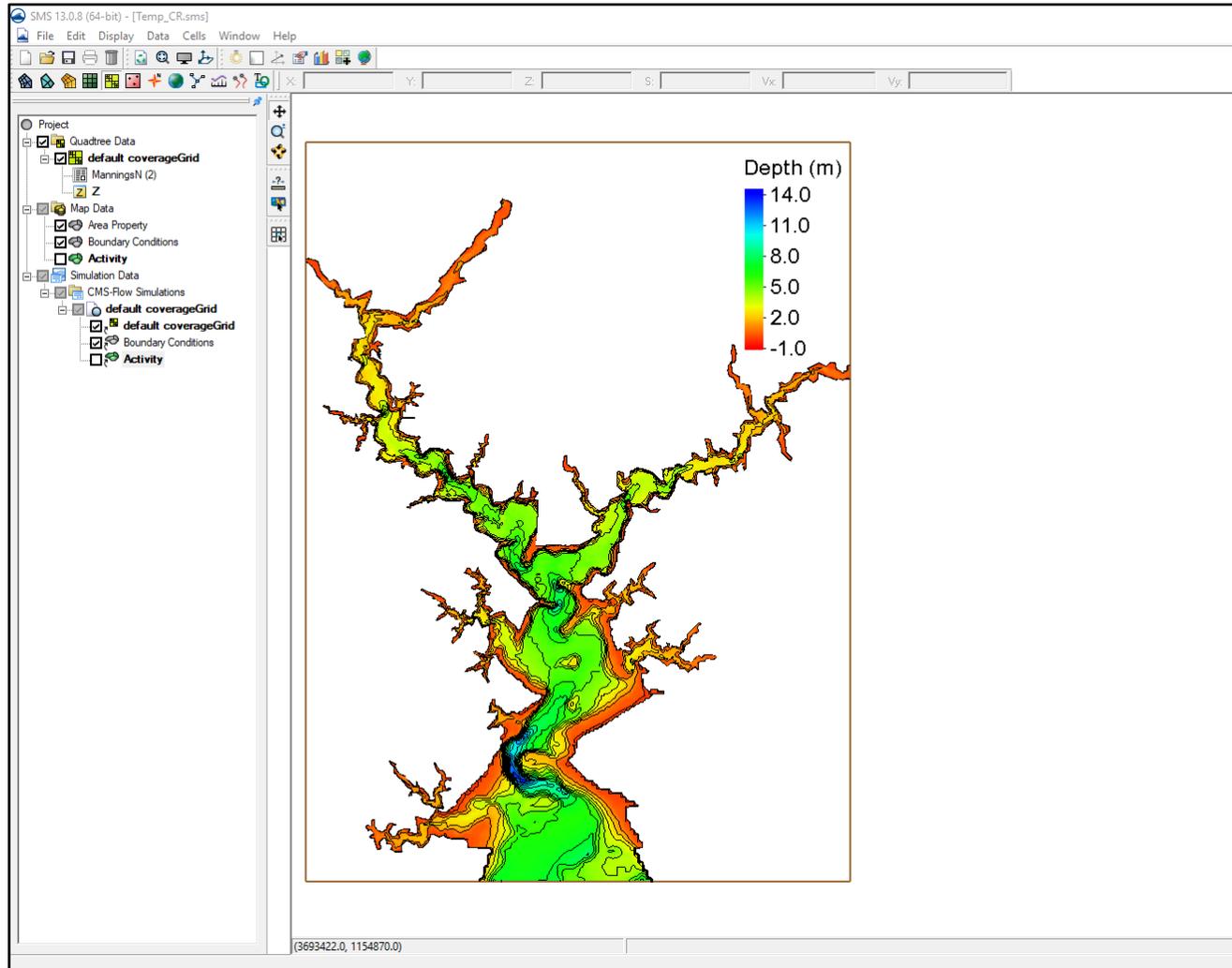
- Delete
- Define Domain
- Split Arc(s)...
- Offset Arc(s)...
- Align Arc(s) With Contour...
- Redistribute Vertices...
- Reverse Arc Direction
- Smooth Arc(s)...
- Prune Arc(s)...
- Transform...
- Assign Boundary Conditions...** (highlighted)
- Clear Selection
- Invert Selection
- Zoom to Selection
- Select Connected Arcs Turning Left >

The project tree on the left shows the following structure:

- Project
  - Quadtrees Data
    - Flow
      - D50 (3)
      - Hard Bottom (2)
      - ManningsN (2)
      - Salinity Initial Concentration (3)
    - Z
    - Map Data
      - Area Property
      - Boundary Conditions** (circled in red)
      - Activity
    - Simulation Data
      - CMS-Flow Simulations
        - Flow
          - Flow
          - Boundary Conditions**
          - Activity

- Specify time series of salinity values along lateral boundaries
  - Go to *CMS-Flow Simulations* → *Boundary Conditions*
  - Right-click boundary arc. Select *Assign Boundary Conditions* and check *Define Salinity Curve* under *Salinity*
  - Click small icon and import salinity values (manually key in the values or read from a \*.xys data file)

# Setup of Salinity/Temperature Calculations (Air-water Heat Exchange)



Use meteorological parameters: solar radiation, cloud cover, air temperature, wind speed, and surface water temperature and the bulk formulas to calculate the heat flux components

- Short Wave Solar Radiation

$$J_{SW} = J_{SW,CLR} (1 - 0.65C_{CLD}^2) (1 - R_{SW}) (1 - f_{SHD})$$

- Long Wave Atmospheric Radiation

$$J_{LW} = \varepsilon_{AIR} \sigma T_{AIR}^4 (1 + 0.17C_{CLD}^2) (1 - R_{LW}) - \varepsilon_{WTR} \sigma T_{WTR}^4$$

- Latent Heat Flux

$$J_E = f(U_{WND})(e_{AIR} - e_s)$$

- Sensible Heat Flux

$$J_S = C_B f(U_{WND})(T_{AIR} - T_{WTR})$$

Total Heat Flux:  $J_T = J_{SW} + J_{LW} + J_E + J_S$

# Setup of Salinity/Temperature Calculations (Air-water Heat Exchange)



Wind, air temperature, and cloud cover were obtained from National Centers for Environmental Information:

<https://www.ncdc.noaa.gov/cdo-web/datatools/lcd>

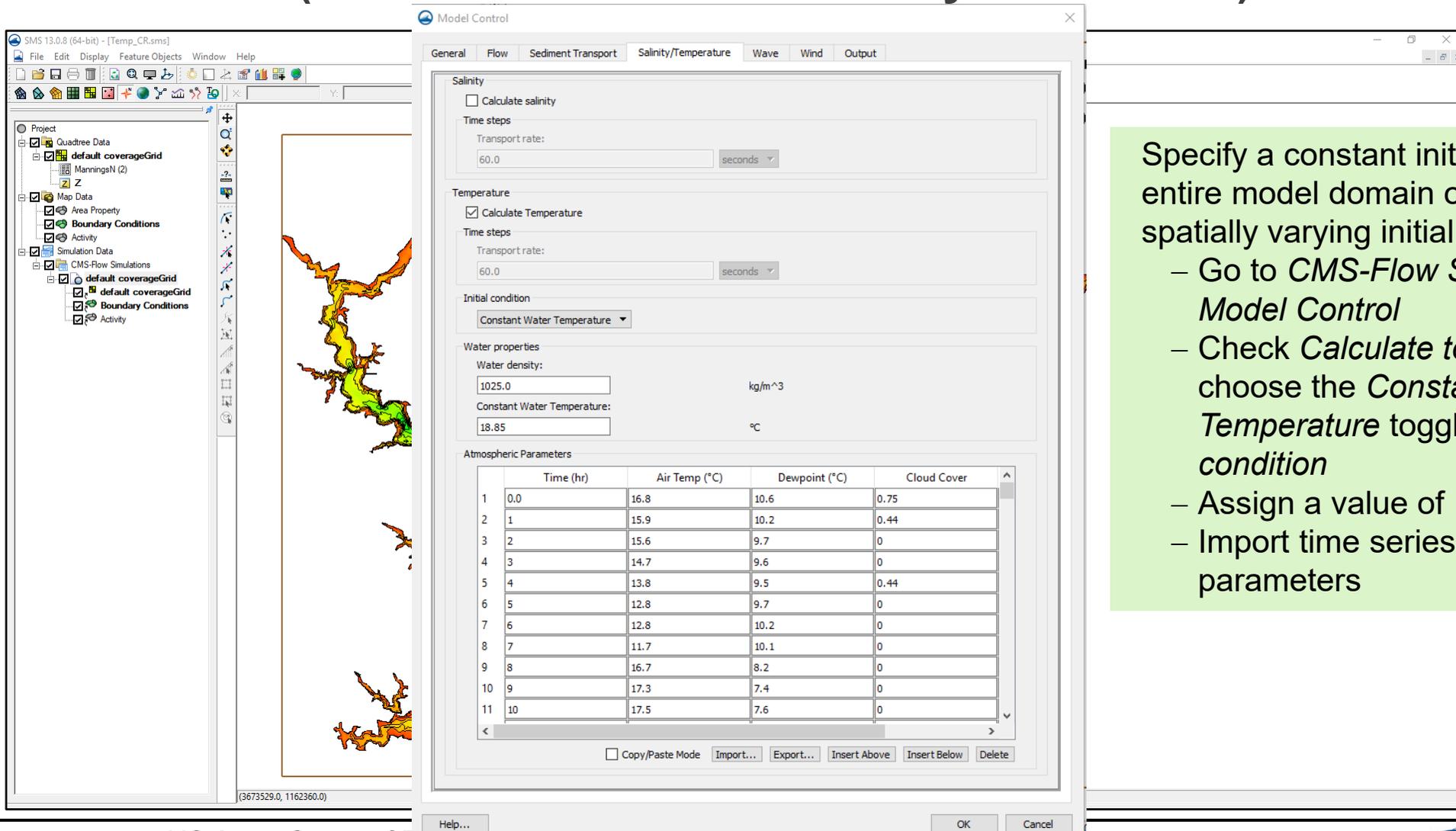
The screenshot shows the NOAA website's 'Data Tools: Local Climatological Data (LCD)' page. It includes a search bar, navigation menu, and a 'Map Tool' section with a dropdown menu for selecting a location type (Country, US Territory, State, County, Zip Code) and a list of states (New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon). Below this, it shows 'Local Climatological Data > State > Virginia' with a list of stations, including 'ABINGDON VIRGINIA HIGHLANDS AIRPORT, VA US' and 'ASHLAND HANOVER CO MUNICIPAL AIRPORT, VA US', each with an 'ADD TO CART' button.

Solar radiation data from National Solar Radiation Data Base:

[http://rredc.nrel.gov/solar/old\\_data/nsrdb/](http://rredc.nrel.gov/solar/old_data/nsrdb/)

The screenshot shows the 'National Solar Radiation Data Base' website. It features a header with a sun icon and the title 'National Solar Radiation Data Base'. Below the header, there are three columns of information: 'National Solar Radiation Database 1961-1990', 'National Solar Radiation Database 1991-2010 Update', and 'National Solar Radiation Database 1998-2014 Update'. Each column contains a brief description of the data set and a list of available products, such as 'Hourly Solar Data', 'Statistical Summaries', and 'Solar Radiation Data Manual for Buildings'. At the bottom, there are links to 'Documentation & User's Manuals', including 'National Solar Radiation Data Base User's Manual (1961-1990)', 'National Solar Radiation Database 1991-2010 Update: User's Manual', and 'Standard Time Series Data File Format'.

# Setup of Salinity/Temperature Calculations (Initial and Surface Boundary Conditions)



**Salinity**

Calculate salinity

**Time steps**

Transport rate: 60.0 seconds

**Temperature**

Calculate Temperature

**Time steps**

Transport rate: 60.0 seconds

**Initial condition**

Constant Water Temperature

**Water properties**

Water density: 1025.0 kg/m<sup>3</sup>

Constant Water Temperature: 18.85 °C

**Atmospheric Parameters**

	Time (hr)	Air Temp (°C)	Dewpoint (°C)	Cloud Cover
1	0.0	16.8	10.6	0.75
2	1	15.9	10.2	0.44
3	2	15.6	9.7	0
4	3	14.7	9.6	0
5	4	13.8	9.5	0.44
6	5	12.8	9.7	0
7	6	12.8	10.2	0
8	7	11.7	10.1	0
9	8	16.7	8.2	0
10	9	17.3	7.4	0
11	10	17.5	7.6	0

Copy/Paste Mode    Import...    Export...    Insert Above    Insert Below    Delete

- Specify a constant initial value for the entire model domain or generate a spatially varying initial temperature field
- Go to *CMS-Flow Simulations* → *Model Control*
  - Check *Calculate temperature* and choose the *Constant Water Temperature* toggle under the *Initial condition*
  - Assign a value of 18.85 ° C
  - Import time series of meteorological parameters



# Setup of Salinity/Temperature Calculations (Lateral Boundary Condition)

The screenshot displays the SMS 13.0.8 interface. The 'Arc Boundary Condition' dialog box is open, showing options for Name, Type (WSE-forcing), WSE Source (Curve), and Define curves. Below this, there are options for WSE offset / Sea Level Change (Constant) and Constant value for WSE Offset (m) (0.0). The 'Salinity' section has 'Define Salinity Curve' unchecked, and the 'Temperature' section has 'Define Temperature Curve' checked. A small icon of a red flame is visible in the dialog box.

The 'XY Series Editor' dialog box is also open, showing a table of time series data and a line graph. The table has the following data:

Time (hrs)	Temperature (dec C)
1 0.0	18.85
2 264.0	15.5
3 600.0	15.5
4 2160.0	2.6
*	

The graph plots Temperature (dec C) on the y-axis (ranging from 2 to 18) against Time (hrs) on the x-axis (ranging from 0 to 2000). The data points are connected by a green line, showing a sharp drop from 18.85 at 0 hours to 15.5 at 264 hours, a constant value of 15.5 until 600 hours, and then a linear decrease to 2.6 at 2160 hours.

Specify time series of temperature values along lateral boundaries

- Go to *CMS-Flow Simulations* → *Boundary Conditions*
- Right-click boundary arc. Select *Assign Boundary Conditions* and check *Define Temperature Curve* under *Temperature*
- Click small icon and import temperature values (manually key in the values or read from a \*xys data file)

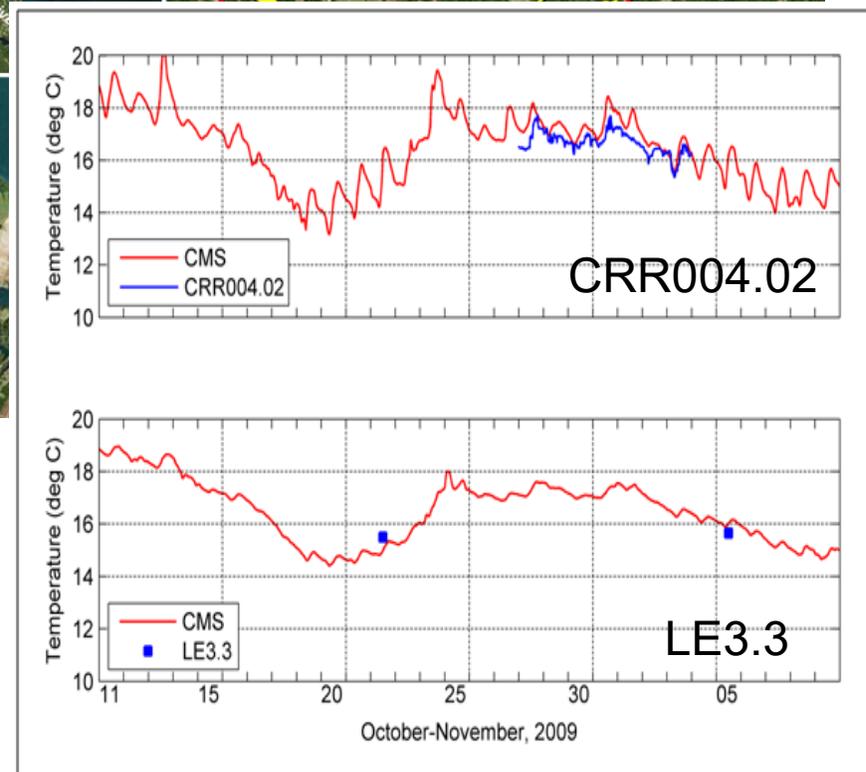
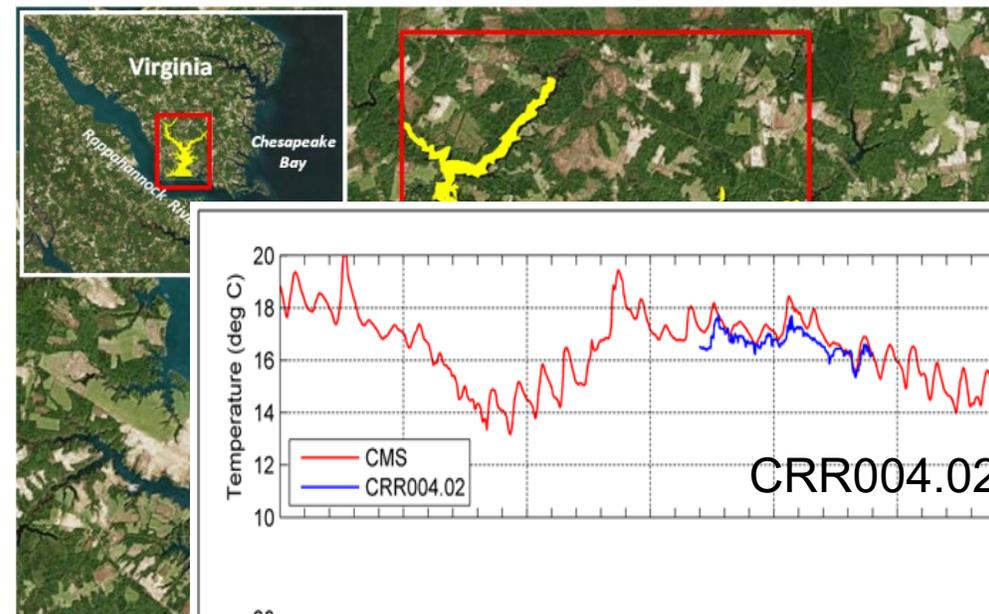
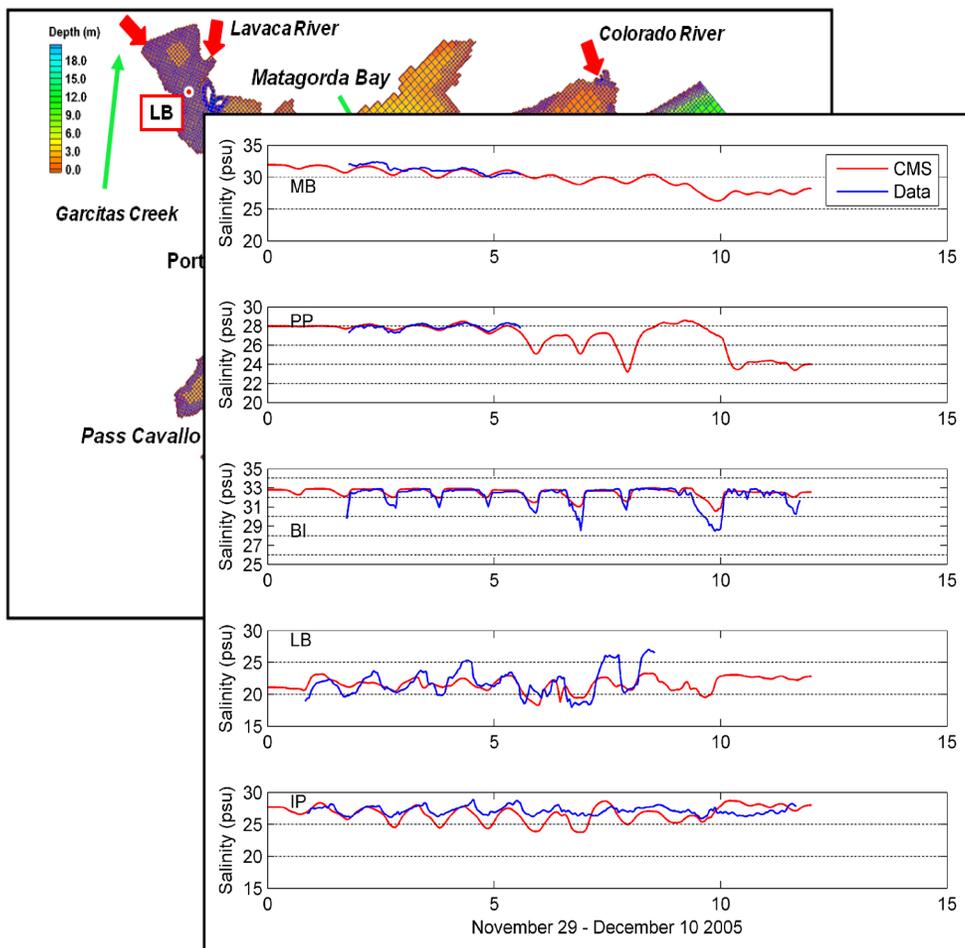




# Simulation Results

## Salinity – Matagorda Bay

## Temperature – Corrotoman River



# References

## Salinity Calculations in the Coastal Modeling System

Li, H., Reed, C., and Brown, M. (2012)

<https://erdc-library.erdcdren.mil/xmlui/handle/11681/1981>

## Temperature Calculations in the Coastal Modeling System

Li, H. and Brown, M. (2017)

<https://erdc-library.erdcdren.mil/xmlui/handle/11681/21666>

