Three for the Price of Two?

A comparison of circulation in the Neuse River Estuary predicted by a two and three-dimensional model

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A two-dimensional mechanistic model (CE-QUAL-W2) showed similar performance to that of a fully three-dimensional model (EFDC) in predicting temperatures and salinities in the Neuse River Estuary.

Introduction:

Due to numerous algal blooms and fish kills in North Carolina's Neuse Estuary, multiple water quality models have been used to study the effects of nutrient loading on eutrophication.

This project incorporates data from a previously used three-dimensional model (EFDC) to adapt a two-dimensional model (CE-QUAL-W2) to the estuary. In this first part of the modeling project, temperatures and salinities predicted by both models over a five-year time period (2004-2009) are compared to observed data.

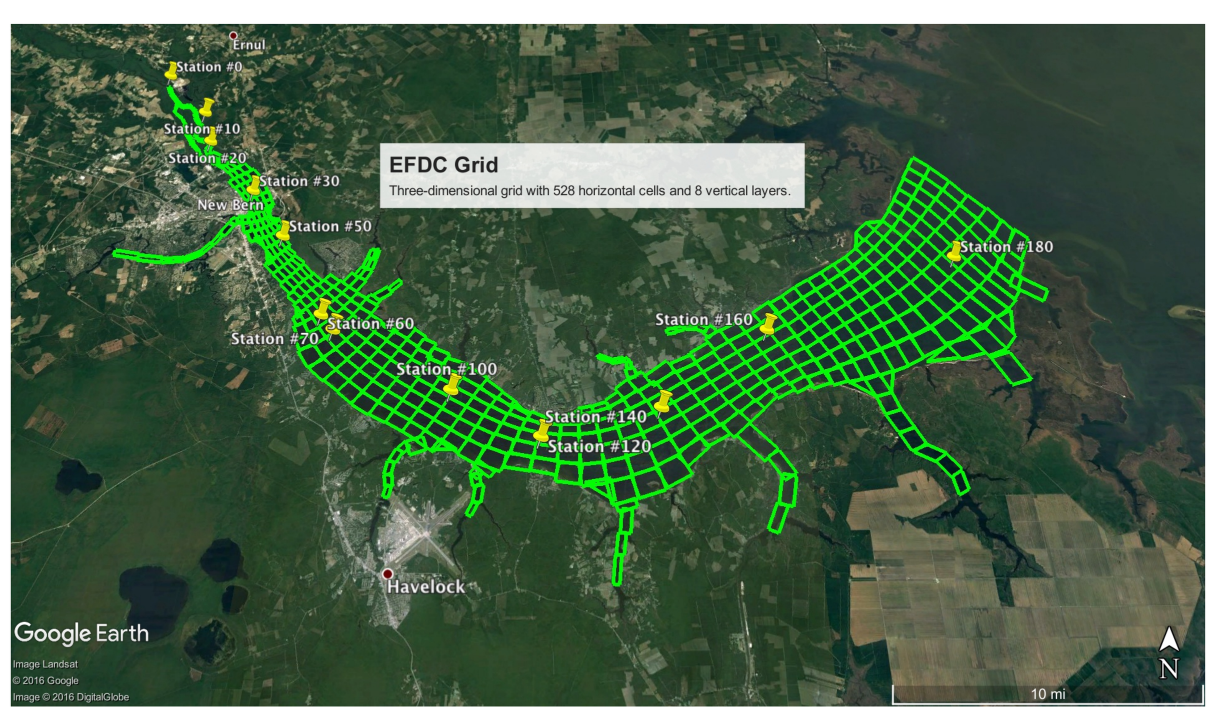

Figure 1: EFDC model grid (2009)

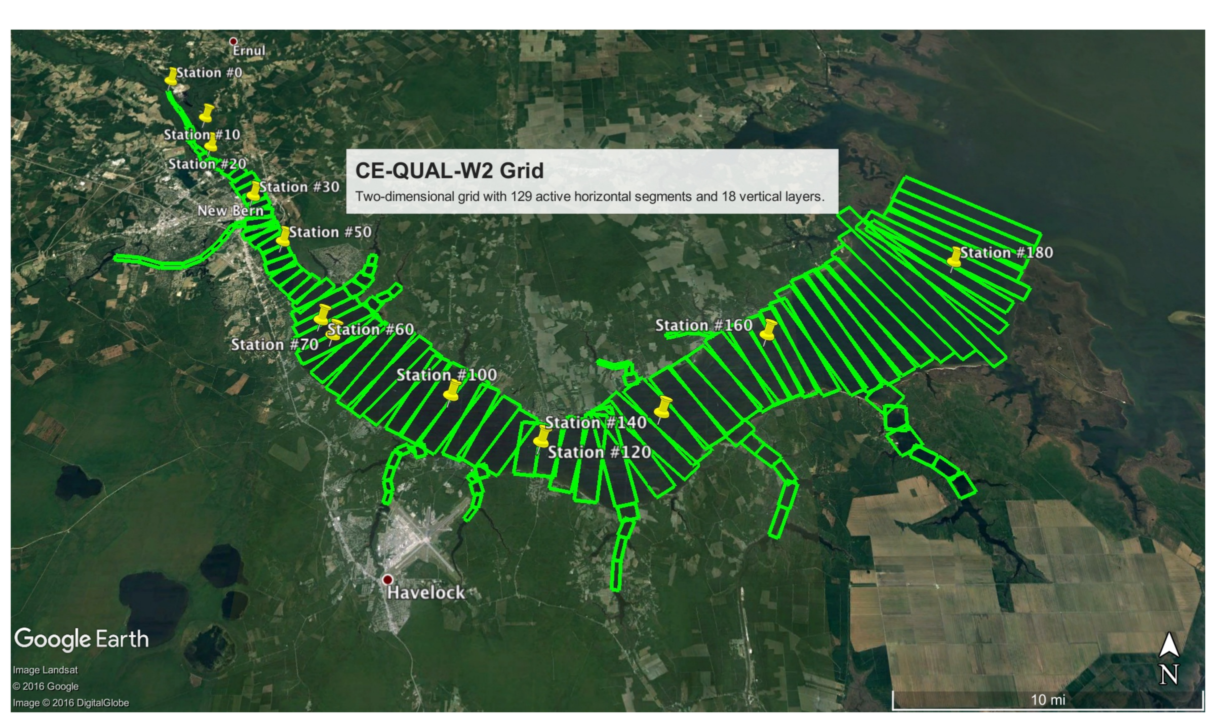

Figure 2: W2 model grid (2016)

Methods:

Bathymetry data from the EFDC model (Figure 1) and measurements made using Google™ Earth were used to create a W2 grid (Figure 2).

Calibration was performed by comparing model predictions of temperature and salinity to data observed in ModMon stations #0-180 from 3/27/04 to 6/1/09. Downstream boundary salinity, bottom depth and roughness, wind sheltering, and vertical mixing were varied to provide the best fit between predicted and observed data.

Results and Discussion:

Temperatures predicted by both models fit the observed top and bottom temperatures well (Table 1), although the mean error for W2 is slightly higher than EFDC. The W2 temperature time history at station 100 (Figure 3) indicates that the error is mostly confined to the top layer during the summer months.

Table 1: Temperature fit comparison

Model	# obs	ME		RMSE		R^2
		°C	%	°C	%	
EFDC	2670	0.37	1.9	1.44	7.4	96.4
W2	2670	1.01	5.2	1.81	9.3	96.0

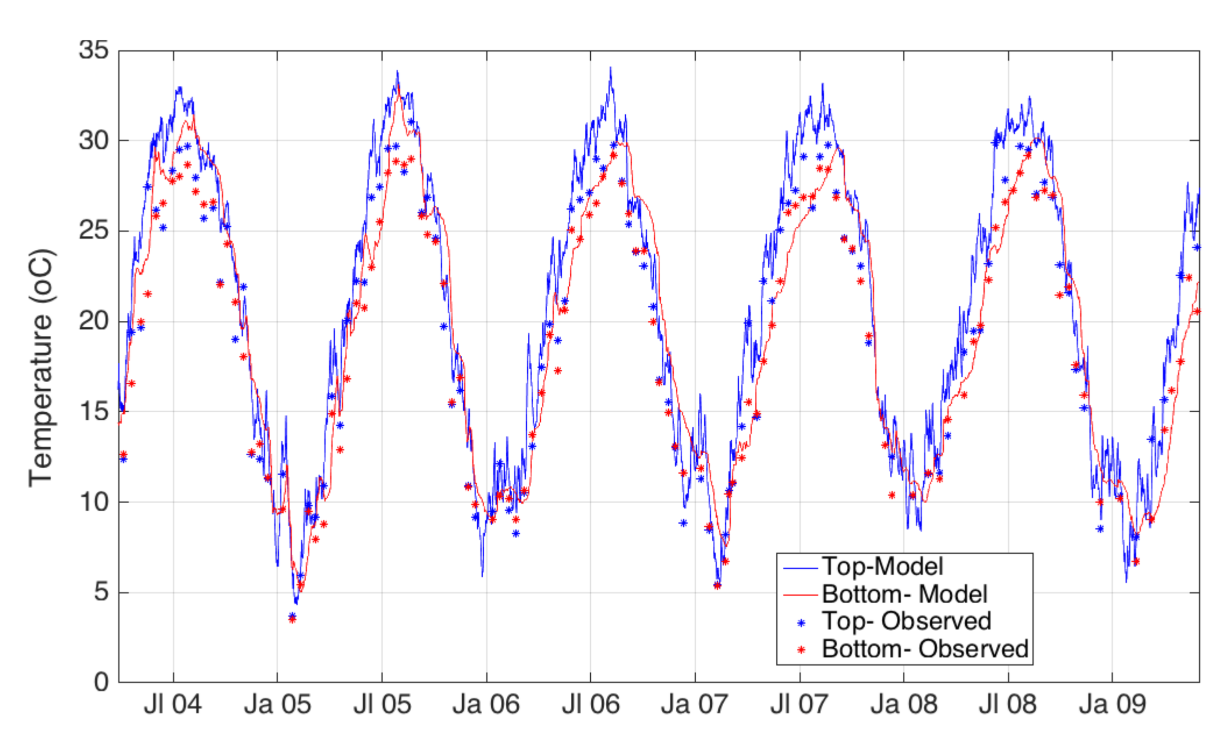

Figure 3: W2 predicted vs observed temperatures at station 100

Salinity predictions for both models were also closely correlated to observed data (Figure 4). W2 underperformed EFDC slightly in terms of correlation (R^2), but outperformed it in terms of mean error (ME) of the top and bottom salinities.

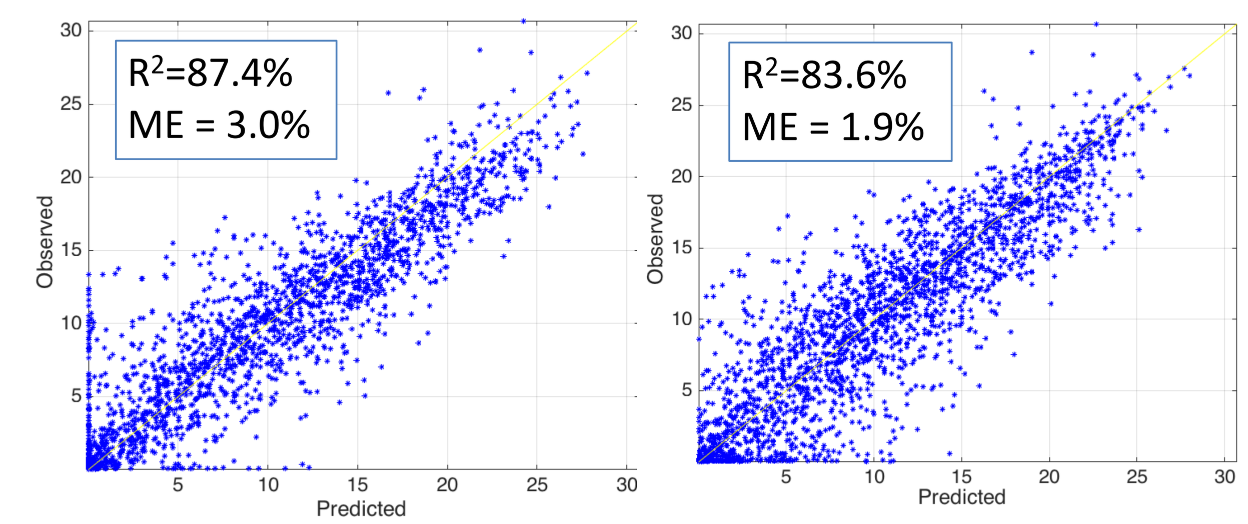

Figure 4: Correlation between predicted and observed salinities for EFDC (left) and W2 (right)

A station-by-station plot of correlation coefficients for salinity (Figure 5) reveals that Station 20 shows the largest difference between the two models.

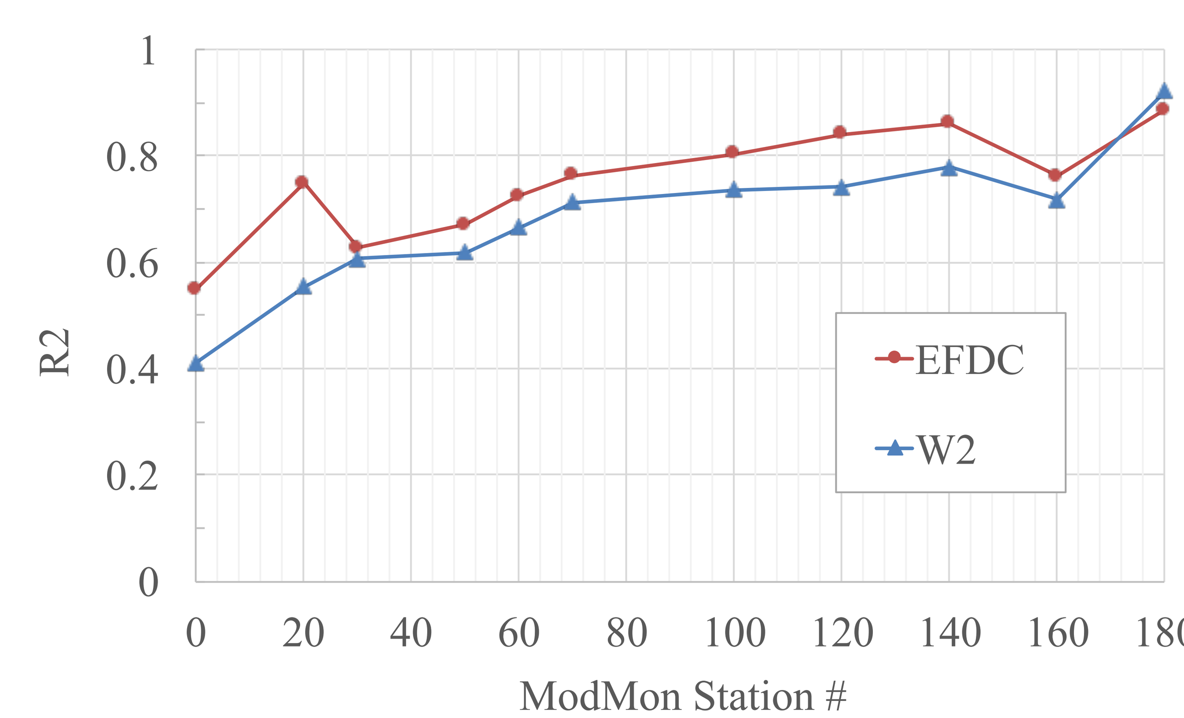

Figure 5: Salinity fit for each model by station

Salinity time histories at stations 20 (Figures 6 and 7) illustrate that both models follow the overall trend in the observed data, but the three-dimensional model is quicker to respond to short-term changes in salinity, capturing the variations above and below the main trend.

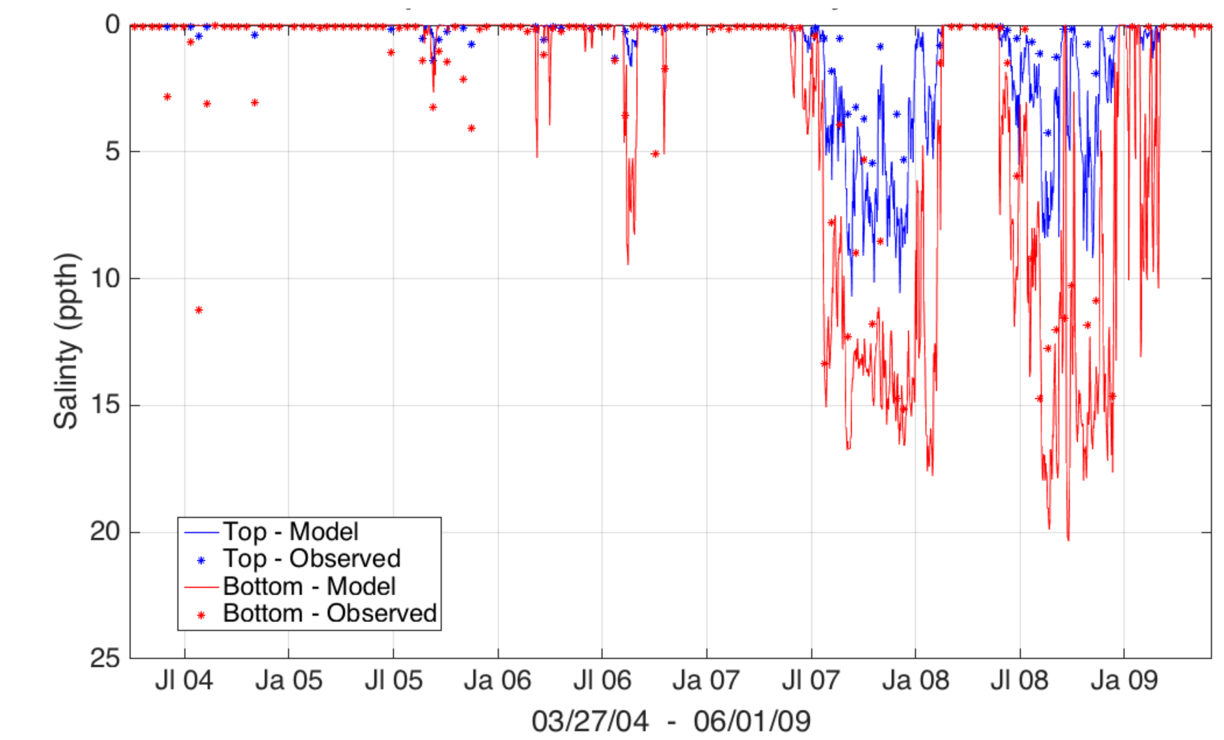

Figure 6: EFDC predicted vs. observed salinities at station 20

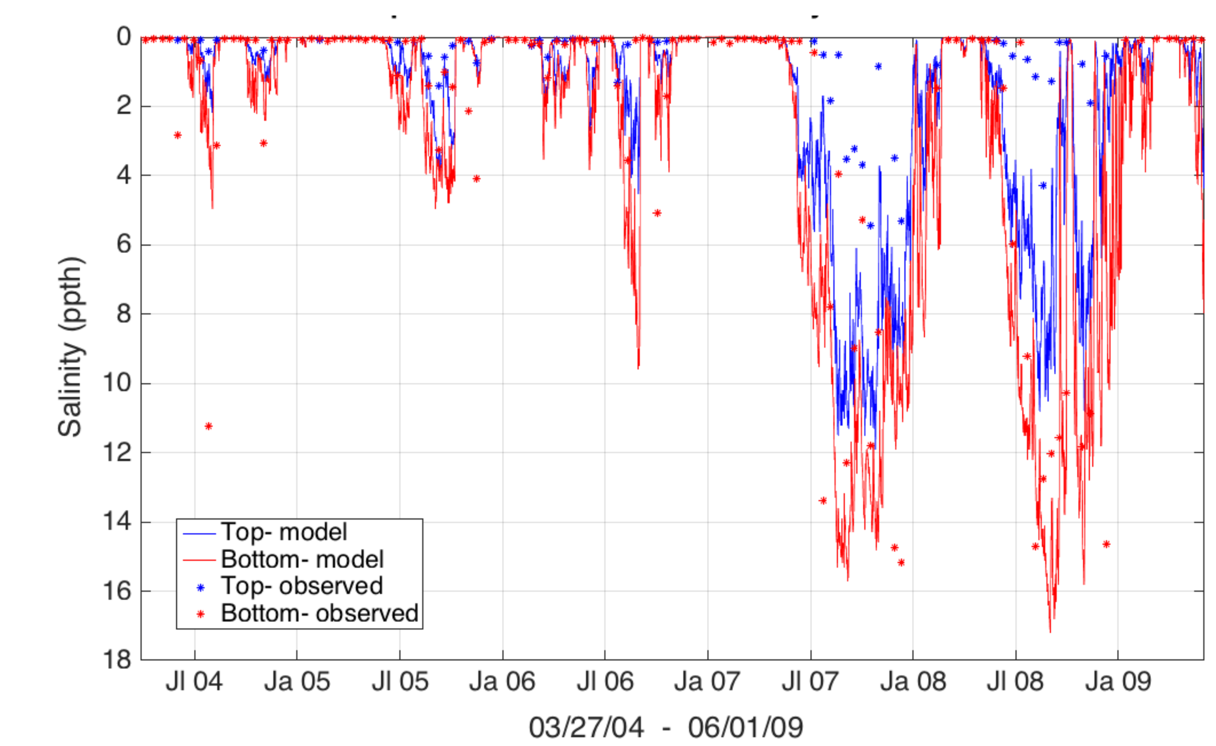

Figure 7: W2 predicted vs. observed salinities at station 20

Conclusions:

Despite its relative simplicity, W2 provided comparable performance in predicting temperatures and salinities in the estuary. This is of benefit since it uses less computational resources and time, and it is a better match for the monitoring program already in place.

Next steps:

Despite a reduction in cumulative inorganic nitrogen loading, water quality problems have continued in the estuary. After undergoing water quality calibration, the W2 model will be used to investigate the effect of changes in the spatial pattern of loading and a shift towards organic, rather than inorganic, nitrogen loading that have occurred over the past 15 years.