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NOAA Ensemble Hypoxia Forecast

Forecasts of the Gulf of Mexico hypoxic zone have been made since 2002 by academic scientists. In 2017, NOAA transitioned these models operationally and started producing its own independent forecast product, the culmination of a multi-year academic-federal partnership to develop a suite of NOAA-supported hypoxia forecast models.[1] The NOAA forecast integrates the results of multiple models into a separate ensemble forecast that is released in coordination with these external groups, some of which are also continuing to refine independent forecasts.

The 2024 NOAA ensemble predicts the hypoxic zone to be 5,827 square miles with 95% confidence interval[2] of 3,266 to 8,370 square miles (see Figure 1). This forecast is based on average weather conditions in the Gulf of Mexico combined with the May river discharge, and nitrogen and phosphorus loads from the Mississippi River, provided by USGS. The May nutrient loads for 2024 are estimated to be 121,500 metric tons (Figure 2) of nitrate and 21,000 metric tons of phosphorus, which is 7% below and 22% above the long-term averages respectively. In late July, the model predictions are compared to the annual hypoxia cruise survey which has established a 37 year record of hypoxic zone area measurements in the Gulf. Over the past 14 years, the models have shown good agreement with the survey data, except in years that experienced atypical weather events, such as hurricanes, resulting in temporary mixing of the hypoxic water, which cannot be predicted months in advance (Figure 3).

Models are intended to predict reality, however scientists are still learning about the complex factors that drive the formation of the Gulf hypoxic zone. While modelers can get close, they can't yet perfectly match reality.

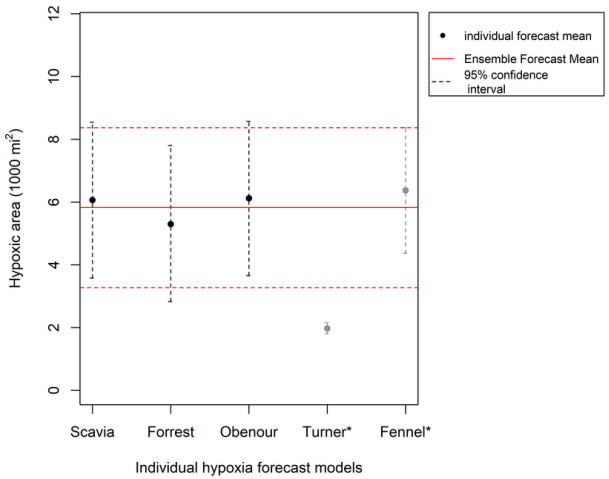

Figure 1. The 2024 NOAA ensemble forecast mean and 95% confidence interval[2](red). The corresponding individual model means and 95% confidence intervals[2] are shown in filled circles with error bars. *The Fennel and Turner experimental models are included for reference purposes.

Different models capture different parts of this complexity, so we use a collection, or ensemble, of different models to forecast the size of the hypoxic zone. When the various models agree, NOAA scientists have more confidence in the forecast. When the models are different, scientists can identify where more research is needed. These models also have measures of uncertainty, or how far off they are from reality. Quantifying that uncertainty helps us understand the level of risk involved in using the models to make decisions and set goals. As models are refined, they are initially considered experimental and not included in the ensemble forecast estimate until able to be fully integrated into operations.

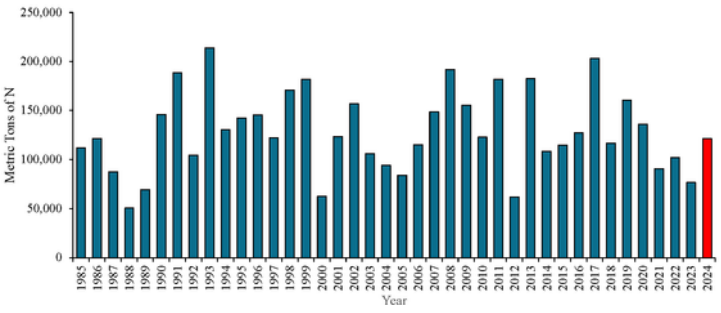

Figure 2. Estimated May dissolved nitrate load to the Gulf of Mexico from 1985 to present. The 2024 load value used in the model forecast is highlighted in red (credit: USGS).

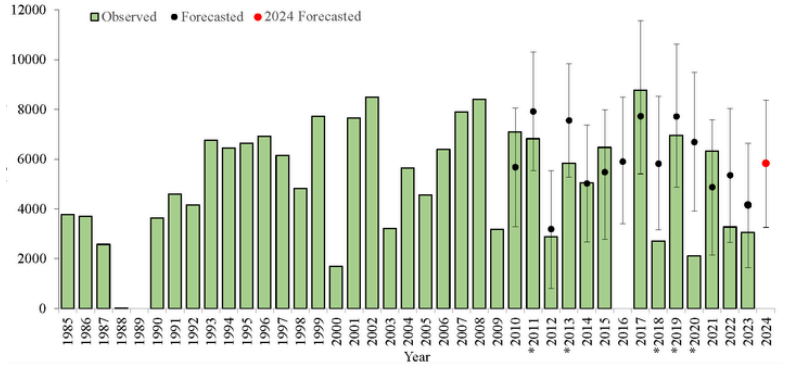

Fig 3. Observed hypoxic area (1985–2023) and forecast ensemble record interval (2010–2024). Green bars are observed hypoxic area (in square miles) measured by the LUMCON mid-summer cruise overlaid with the forecast ensemble predictions (filled circles) with 95% confidence interval[2]. The 2024 forecast is the red filled circle. The annual forecasts are made assuming normal weather conditions with asterisks indicating atypical years prior to the cruise which impacted the observed size (*high winds prior to the cruise).

The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, a group of federal and state agencies and a tribal representative are working to reduce the Gulf dead zone through State led nutrient reduction strategies and targets across the Mississippi River watershed. The NOAA ensemble helps predict how hypoxia in the Gulf of Mexico is linked to nutrient inputs coming from throughout the Mississippi River Basin and informs this group of the overall nutrient reduction targets across the watershed.

Footnotes:

1. Partners- USGS, LUMCON, University of Michigan, William & Mary Virginia Institute of Marine Science, North Carolina State University, Dalhousie University

2. 95% Confidence Interval- a range of values that you can be 95% certain contains the true mean of the observed data

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