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NOAA Ensemble Hypoxia Forecast

Forecasts of the Gulf of America 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 (NOAA-1[1], NOAA-2[2], NOAA-3[3], NOAA-4[4], NOAA-5[5]). 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 2025 NOAA ensemble predicts the hypoxic zone to be 5,574 square miles with a 95% confidence interval[6] of 2,839 to 8,237 square miles (see Figure 1). This forecast is based on average weather conditions in the Gulf of America combined with the May river discharge and nitrogen and phosphorus loads from the Mississippi River, provided by USGS. The May nutrient loads for 2025 are estimated to be 99,300 metric tons of nitrate (Figure 2) and 22,600 metric tons of phosphorus, which is 24% below and 31% above the long-term averages respectively. In late July, the model predictions are compared to the annual hypoxia cruise survey, which has established a 38 year record of hypoxic zone area measurements in the Gulf. Over the past 15 years, the models have shown good agreement with the survey data, except in years with atypical weather events, such as hurricanes, which cannot be predicted months in advance (Figure 3).

Scientists are still learning about the complex factors that drive the formation of the Gulf hypoxic zone and anticipating how conditions may change over time. While model predictions can get close, they often don't perfectly match reality.

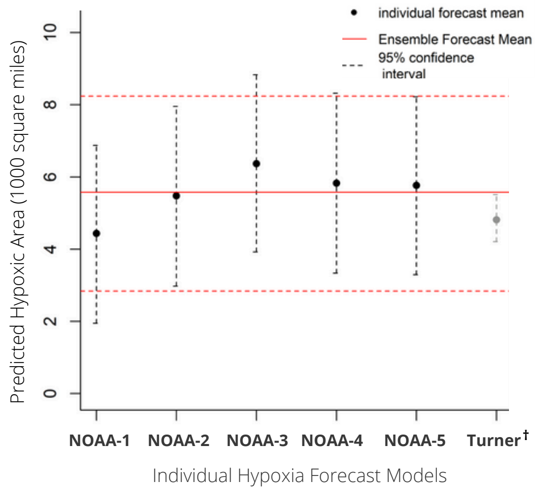

Figure 1. The 2025 NOAA ensemble forecast mean and 95% confidence interval[6] (red). The corresponding individual model means and 95% confidence intervals[6] are shown in filled circles with error bars. An updated Turner model[7] being run independently is included for reference purposes.[†]

Different models characterize different parts of this complex system, 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 differ, 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 run independently and not included in the ensemble forecast estimate until peer reviewed and able to be fully integrated into operations.

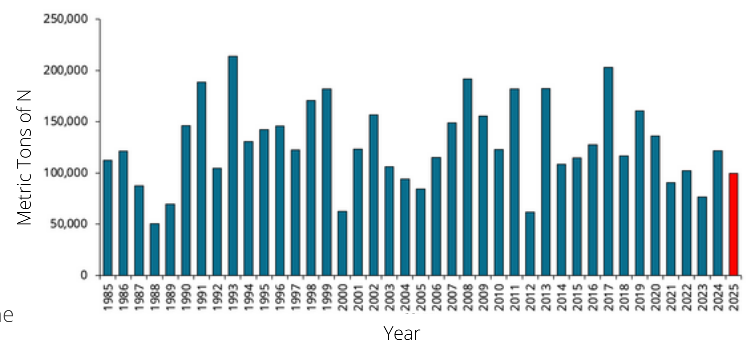

Figure 2. Estimated May dissolved nitrate load to the Gulf of America from 1985 to present. The 2025 load value used in the model forecast is highlighted in red (credit: USGS).

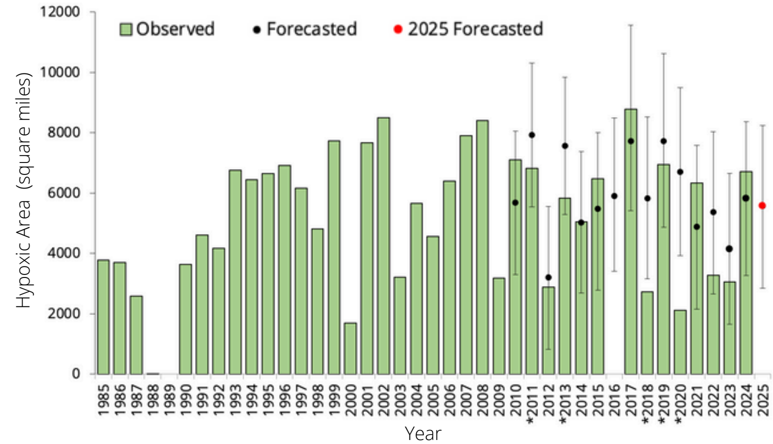

Figure 3. Observed hypoxic area (1985–2024) and forecast ensemble record interval (2010–2025). Green bars are observed hypoxic area (in square miles) measured by the LUMCON mid-summer cruise overlaid with the forecast ensemble predictions (filled circles) with 95% confidence intervals.[6] The 2025 forecast is the red filled circle. The annual forecasts are made assuming normal weather conditions, with asterisks indicating atypical conditions prior to or during the cruise (including strong winds and waves) which may have impacted the observed size.*

The Mississippi River/Gulf of America Hypoxia Task Force, a group of federal and state agencies and tribal representatives, is 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 America is linked to nutrient inputs coming from throughout the Mississippi-Mississippi-Atchafalaya River Basin and informs the overall nutrient reduction targets across the watershed.

Footnotes:

1. Forrest, D. R., Hetland, R. D. & DiMarco, S. F. Multivariable statistical regression models of the areal extent of hypoxia over the Texas–Louisiana continental shelf. Environ. Res. Lett. 6, 045002 (2011).
2. Obenour, D. R., Michalak, A. M. & Scavia, D. Assessing biophysical controls on Gulf of Mexico hypoxia through probabilistic modeling. Ecological Applications 25, 492–505 (2015).
3. Laurent, A. & Fennel, K. Time-Evolving, Spatially Explicit Forecasts of the Northern Gulf of Mexico Hypoxic Zone. Environ. Sci. Technol. 53, 14449–14458 (2019).
4. Scavia, D., Evans, M. A. & Obenour, D. R. A Scenario and Forecast Model for Gulf of Mexico Hypoxic Area and Volume. Environ. Sci. Technol. 47, 10423–10428 (2013).
5. Turner, R. E., Rabalais, N. N. & Justić, D. Predicting summer hypoxia in the northern Gulf of Mexico: Redux. Marine Pollution Bulletin 64, 319–324 (2012).
6. A range of values that you can be 95% certain contains the true mean of the observed data.
7. Turner, R. E., Rabalais, N. N. & Glaspie, C. N. A temperature tipping point in hypoxic zone size. Limnology & Oceanography 69, 2954–2962 (2024).

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