2008 Forecast of the Summer Hypoxic Zone Size, Northern Gulf of Mexico

Abstract

The final forecast of the size of the hypoxic zone in the northern Gulf of Mexico for July, 2008, is that it will cover 23,000 km^2 (8,800 mi^2) of the bottom of the continental shelf off Louisiana and Texas. This forecast is based on the May nitrogen loading from the Mississippi and Atchafalaya River as estimated by the US Geological Survey. If the area of hypoxia becomes this large, then it will be the largest than at any time since systematic mapping of the hypoxic zone began in 1985.

Caveats:
1) This predictions discounts the effect of large storm events, which will temporarily disrupt the physical and biological system attributes promoting the formation of the low oxygen zone in bottom waters; 2) The potential space on the shelf where hypoxia occurs may be limited by the bathymetry and physical constraints; and 3) the continued high discharge of the Mississippi River through June and July.

Introduction

1). Hypoxic water mass

Hypoxic water masses form in bottom waters of the northern Gulf of Mexico when the oxygen concentration falls below 2 mg l^{-1}. The hypoxic water is distributed across the Louisiana shelf west of the Mississippi River and onto the upper Texas coast from near shore to as much as 125 km offshore, and in water depths extending from the shore up to 60 m (Rabalais et al. 2007). Hypoxic waters may form in two distinct areas west of the Mississippi and Atchafalaya River deltas, but more often form a single continuous zone.

Systematic mapping and monitoring of the area of hypoxia (dissolved oxygen < 2 mg l^{-1}) in bottom waters began in 1985. Its size has ranged between 40 to 22,000 km^2 during July and averaged 16,700 km^2 from 2000-2007 (excluding years when there were strong storms just before the hypoxia survey). The hypoxic zone size averaged 12,700 km^2 over the period 1985-2005, with a range from negligible in 1988 (a summer drought year for the Mississippi River basin) to 22,000 km^2 in 2002.

Hypoxia, as a large-scale phenomenon, was unlikely to have occurred before the 1970s. Hypoxic water masses form from spring to fall on this coast because the consumption of oxygen in bottom water layers exceeds the re-supply of oxygen from the atmosphere. The re-aeration rate is negatively influenced by stratification of the water column which is primarily dependent on the river's freshwater discharge. The oxygen consumption rate in the bottom water is dependent on the formation of organic matter in the surface layer, its sinking to the bottom layer, and its decomposition. The overwhelming supply of organic matter respired in the bottom layer is from the downward flux of organic matter produced in the surface layer. The organic matter production rate is directly related to the nitrogen supply rate. The transport to the bottom layer is the result of sinking of individual cells (considered a minor contribution), as the excretory products of the grazing predators (zooplankton), which 'package' them as fecal pellets, or as aggregates of cells, detritus and mucus. The respiration of this organic matter declines as it falls through the water column (Turner et al. 1998), but the descent rate alongshore the Louisiana-Texas shelf is rapid enough so that sufficient oxygen consumption on the shallow shelf occurs in the bottom layer and sediments to create a zone of hypoxia that is constrained by the geomorphology of the shelf and water movement. Microbial decomposition in the bottom layer degrades the organic matter and is the principle pathway for oxygen consumption. The significance of reducing nutrient loads to these coastal waters rests on this coupling between the organic matter produced in response to these nutrients and its respiration in the bottom of the water column (MRGOM WNTF 2001; Rabalais et al. 2002, 2007; SAB 2008; U.S. EPA 2008).

Models

2. Predictions using models

Models are used to summarize information, to test assumptions and to make predictions that may be useful for other purposes, including management. There are multiple models of the size of the hypoxic zone that are useful in evaluating the influence of nitrogen load and variations in ocean currents, climate, etc., on the size of the "Dead Zone." These models do not always produce similar results, and model improvement is one focus of ongoing research. The simple statistical model is the most accurate model based on past performance (Turner et al. 2006, 2008). The nitrate+nitrite load delivered to the Gulf of Mexico by the Mississippi River in May is used for predictive purposes. The residence time of the surface waters along this coast is about 2 to 3 months in the summer, hence the 2-3 month lag between the loading rate calculated in May and the size of the hypoxic zone in July. The ecosystem is evolving, however. The size of the hypoxic zone for the same amount of nitrogen loading increases each year, for example, and the model might need to be adjusted to account for the limited space left on the shelf to accommodate the potential size of the hypoxic zone resulting from nitrogen loading larger than observed so far.

The statistical model describes the previous size of the hypoxic zone quite well. The prediction, for example, in 2006 and 2007 was 99% and 107%, respectively, of the measured size.

3. Model parameters for 2008

<u>3b. Nitrogen loading to the Gulf of Mexico</u>

The total nitate+nitrite nitrogen load to the Gulf of Mexico is based on the May discharge from the main stem of the Mississippi River and the Atchafalaya River. The concentration × discharge equals the nitrate-nitrite load. The final prediction of nitrate-nitrate loading from the Mississippi River into the Gulf of Mexico is the United States Geological Survey (USGS), which publishes estimates of the flow-adjusted nutrient loads to the Gulf including nitrate+nitrite N, total phosphorus (TP), and total nitrogen (TN), and also loadings from the main channel of the

Mississippi River and from the Atchafalaya River. The nitrate+nitrite load in May is about 89% of the N total nitrogen load ($R^2 = 0.91$). The USGS includes an estimate of the 95% confidence range for the nitrogen load, which averages 41% of the predicted value. The USGS web site (http://toxics.usgs.gov/hypoxia/mississippi/oct_jun/index.html) has more information on the calculation and data.

The nitrogen loading to the Gulf of Mexico in May this year will be 7.4 % higher than last year. The intensive farming of more land, including crops used for biofuels, has contributed to this high nitrogen loading rate (Donner and Kucharik 2008).

3b. Hypoxic zone data

Data on the size of the hypoxic zone in late July from 1985 to 2007 are based on annual field measurements (data available at http://www.gulfhypoxia.net). The 2008 mapping cruise will be conducted on July 21-29. Hypoxia data will be posted daily at the web site above. The values for 1989 (no funding available) and 1978-1984 are estimated from contemporary field data. The values for before 1978 assume that there was no significant hypoxia then and are based on results from various models. Data for three years were not included in the analysis because there were strong storms just before or during the cruise (1998, 2003 and 2005). These storms, by comparison to the pre-cruise sampling and data collected during the cruise, disrupted the water column and re-aerated the water column. It may take several weeks, depending on water temperature and initial dissolved oxygen concentration, for respiration to reduce the dissolved oxygen concentration to <2 mg l^{-1} after the water column stratification is re-established.

Prediction for 2008

4. Predictions for 2008, including final prediction

The revised and final forecast of the size of the hypoxic zone in the northern Gulf of Mexico for July, 2008, is that it will cover 23,000 km^2 (8,000 mi^2) of the bottom of the continental shelf off Louisiana and Texas (Figure 1). This is equivalent to an area about the size of the state of Massachusetts. The average size of the annual hypoxia-affected area since 1990 has been approximately 15,660 km^2 (6,046 mi^2). The largest size was 22,000 km^2 (8,894 mi^2) in 2002. Tropical storms and hurricanes have the potential of disrupting the physical structure of the water column and aerating the bottom layer. If no strong storms appear, then this year's Dead Zone is predicted to be 4.7 % larger than previously measured, and to stretch into Texas continental shelf waters. Note that preliminary prediction released in early June was for a larger size than predicted using this updated estimate of nitrogen loading.

A post-cruise assessment will be made at the end of the summer.

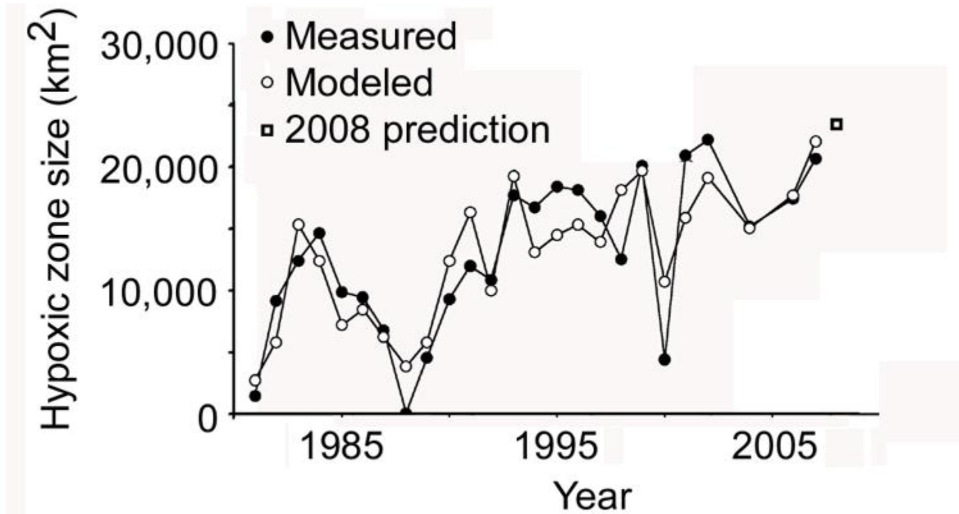

Figure 1. The measured and model output and the predicted the size of the hypoxic zone for 2008.

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Appendix. Mississippi River discharge (cubic feet per second ×1000) at Tarbert Landing, MS from 1930 to 13 July 2008. http://www.mvn.usace.army.mil/eng/edhd/tar.gif