SESSION: 061
ABSTRACT ID: 11855

STRATIFICATION LIMITED VERTICAL VENTILATION: EFFECTS OF WATER COLUMN STABILITIES ON THE FORMATION OF HYPOXIA ON THE TEXAS-LOUISIANA SHELF

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ABSTRACT

We examine the vertical structure of water column stability and vertical current shear and their relationship with near bottom dissolved oxygen concentration in the hypoxic zone of the Texas-Louisiana Shelf, using observations from cruises made in June and August 2010 and 2011. High resolution of water property data were collected by an undulating towed vehicle (Sea Science Acrobat) and current velocity profiles were obtained using a ship-mounted 300-kHz ADCP on cross-shelf sections, both of which were used to estimate the water column stability by N (Brunt-Väisälä Frequency) and Ri (Gradient Richardson Number). Strong stratification conditions were considered to decrease the vertical DO transport through the pycnocline and limit the resupply of DO to bottom water masses. The stratification is preliminary caused by the salinity differences, due to fresh water inflow from Mississippi-Atchafalaya River System. Several possible forcings (hurricanes, strong currents, mesoscale circulation features) can break down the stratification and mix the DO to the bottom to supply the oxygen demand. Observations are compared to an idealized numerical model of vertical mixing, horizontal advection, current shear, and parameterized oxygen consumption.

INTRODUCTION

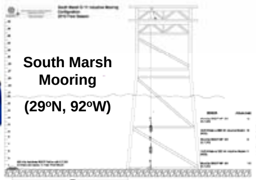
While nutrient loading has traditionally been regarded as the most important element in controlling hypoxia on the northern GOM continental shelf, water column stability also plays an important role in controlling the formation and spatial distribution of hypoxic water mass. In this study, both observational data and model tools are used to understand how the stratification limits the vertical ventilation and results in the bottom low oxygen water mass.

Hypoxia, defined as 1.4 ml/L (2.0 mg/L) of dissolved oxygen (DO) concentration on the Texas-Louisiana shelf, occurs seasonally and is believed to be largely the result of organic and nutrient loading from the Mississippi River and coastal wetlands and the increased vertical stratification and reduced mixing that occurs in the summer months (*Bianchi et al. 2010*).

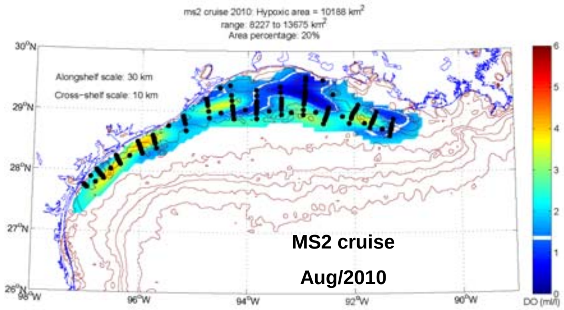
INSTRUMENTS AND METHODS

SeaScience Acrobat towed vehicle

RDI 600-kHz shipboard ADCP



South Marsh Mooring (29°N, 92°W)



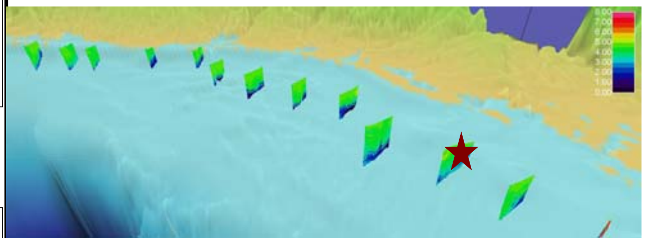


Fig. 1 Acrobat towed sections along the Texas-Louisiana shelf. Top: hypoxia zone estimated at Aug/2010 (cruise MS2); Bottom: DO transections along the shelf;

Ri (Gradient Richardson Number) is calculated using vertical profiles of density and current shear to qualify the vertical mixing of the water column.

$$Ri = \frac{N^2}{\left(\frac{\partial V}{\partial z}\right)^2} \quad \begin{cases} Ri < 0.25, \text{mixing} \\ Ri > 0.25, \text{stable} \end{cases}$$

where $N^2 = -\frac{g}{\rho}\frac{\partial \rho}{\partial z}$,

N is the buoyancy frequency. Potential density is calculated from the T, S, P data.

ESTIMATES OF DIAPYCNAL EDDY DIFFUSIVITY

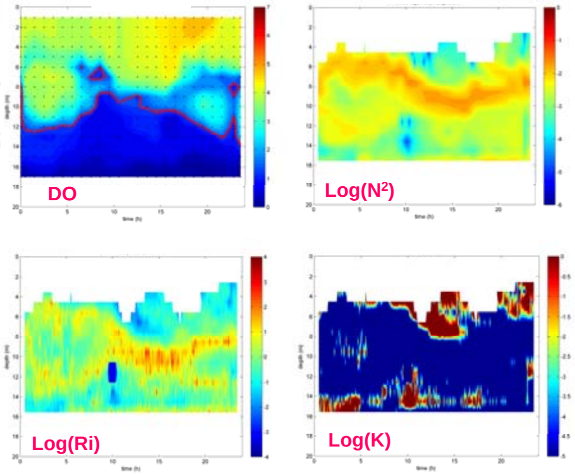
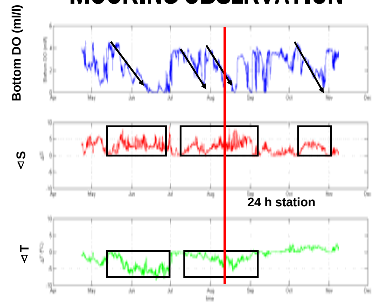


Fig. 2 24-hours continuous profile (29° N, 92° W) during August 2010. From top left to bottom right: DO concentration (black dots denote CTD measurement); B-V frequency (N); Richardson number; vertical eddy diffusivity plotted in log scale.

$$\begin{cases} Ri > 0.25, & K_\rho = \frac{5.0}{(1.0+5.0Ri)^{2.5}} + 0.01 & \text{[Peters et al. 1988]} \\ Ri < 0.25, & \varepsilon = (\Delta z)^2 \left\langle \left(\frac{V_z \cdot V_z - 4N^2}{24} \right) \left(\frac{V_z - 2N}{4} \right) \right\rangle & \text{[Kunze et al. 1990] [Mackinnon and Gregg et al. 2003]} \\ & K_\rho = \Gamma \varepsilon / N^2 & \text{[Osborn, 1980]} \end{cases}$$

MOORING OBSERVATION

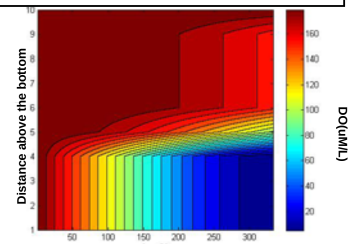


1-D IDEALIZED MODEL

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial z}\left(k_v \frac{\partial C}{\partial z}\right) - R$$

$$\text{Bottom } O_2 \text{ flux} = 6.0\,[O_2 m^{-2} days^{-1}] \times 2^{T/10.0^\circ C} \times \left[1 - \exp\left(\frac{O_2}{30.0\mu M\ O_2}\right)\right].$$

[*Rowe et al.* 2002], [*Hetland and DiMarco*, 2008]



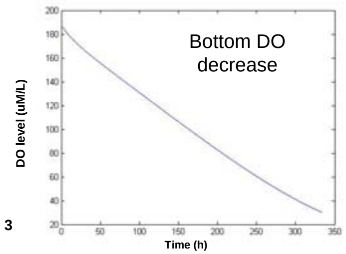


Fig. 3 Top: simulated hypoxia formation under a stratified condition; Bottom: bottom DO concentration decrease with time.

CONCLUSIONS

- The cross shelf transections showed varied vertical distribution of bottom low oxygen water, which is controlled by the stratification envelope.
- The diapycnal eddy diffusivity is estimated to be at the order of 10^{-5}~10^{-6} cm²/s at the pycnocline.
- High frequency, sudden events can rapidly alter the stratification conditions and change the DO level.
- Stratification limited vertical ventilation dominates the formation of bottom low oxygen water mass off the Atchafalaya Bay.

ACKNOWLEDGEMENTS

This study is funded by the NOAA Center for Sponsored Coastal Ocean Research under contract Nos. NA06NOS4780198 and NA09NOS4780208. Thanks the crew of the R/V Pelican and R/V Manta. Thanks also the TAMU Geochemical and Environmental Research Group for technical help.

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