Tracing variability in the budget balance of bottom water dissolved oxygen in the Texas-Louisiana shelf (TLS)

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I. Background and motivation

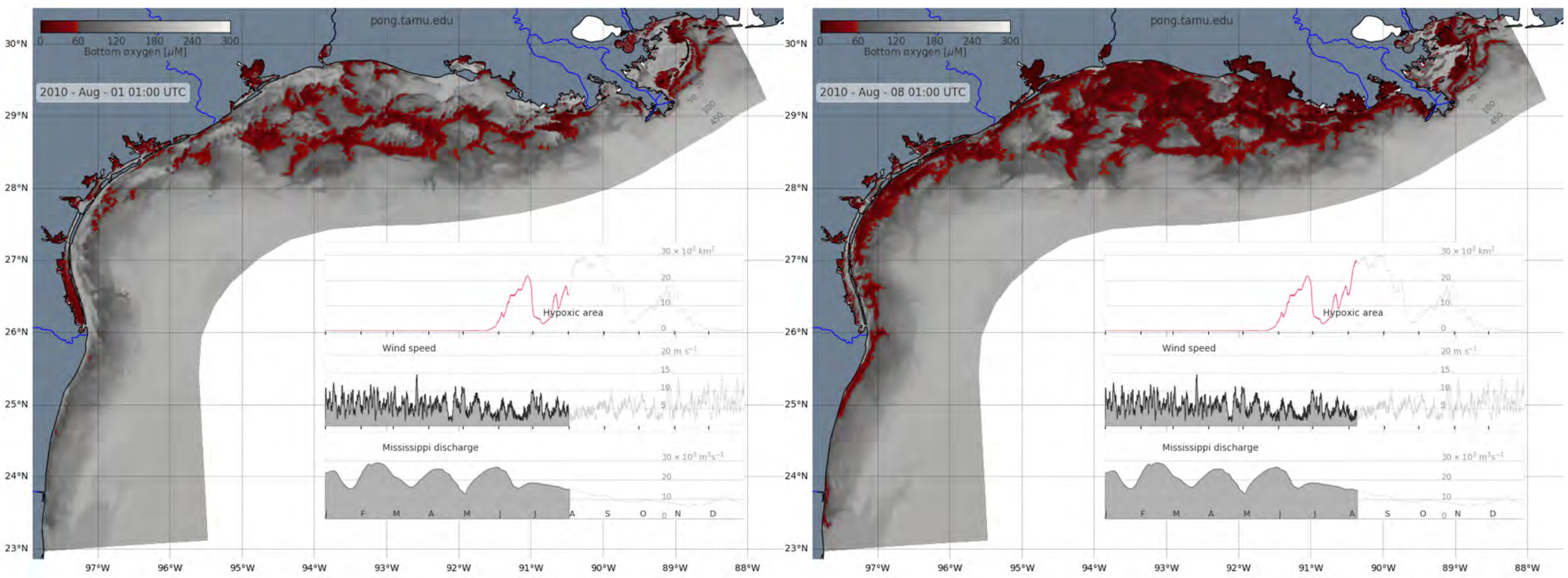
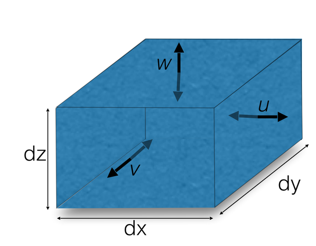


Fig 1: Simulated bottom dissolved oxygen. In a week time span in August 2010, patchy eddy-like features evolve into a more continuous hypoxic region. The increase in the hypoxic area can also be seen in the time-series shown in the upper inner panel. Middle and bottom inner panels show times-series of windspeed and river discharge.The red line and filled color in the time-series mark the time of the model snapshot. The dynamic nature of these features can be also seen in movies of model simulations by scanning the QR code.

- Hypoxic area in the TLS is patchy & difficult to observe (DiMarco et al, 2010, DiMarco & Zimmerle, 2017).
- Ecological implications of patchiness: e.g. time of exposure to hypoxia & distance to normoxia (Zhang et al, 2009).
- High-resolution hydrodynamic model simulations (ROMS) show the formation of patches in the bottom oxygen concentration: very dynamic eddy-like features (**Fig.1**).
- Modeled rate of change of oxygen concentration: physical mechanisms used in the formulation of the oxygen equation (e.g. Li et al, 2015).
- Hypothesis: different mechanisms are more relevant at different time scales in the process of patch formation and displacement.

II. Methods

- Oxygen in the model: simple parametrization as by Hetland and DiMarco (2006).
- Time step and period: hourly, Aug - Sep 2010.
- Area: constrained zonally (95ºW-91ºW) and by bottom depth (10-50 m).
- Volume control: Area x 10 m above the bottom.
- Oxygen rate of change: As defined in **Eq 1.**



rate | horizontal adv. | vertical adv. | vertical diffusion

$$\iiint_{vc} \frac{\partial Ox}{\partial t} dxdydz = \iint_{uface} uOxdydz + \iint_{vface} vOxdxdz + \iint_{10srf} -wOxdxdy + \iint_{10srf} Ak_s \frac{\partial Ox}{\partial z} dxdy + \iint_{btmA} SODdxdy$$

Eq 1: Dissolved oxygen (Ox) equation integrated over the volume control (vc) constrained by the 10 m above the bottom surface (10srf). Rate of change is balanced by advection (horizontal and vertical) and diffusion (horizontal diffusion is neglected). u, v and w are the velocities in the x, y and z directions of the model grid, and the advective and diffusive fluxes cross the perpendicular face of the grid. Ak_s is the vertical diffusivity constant, and SOD is the parametrized sediment oxygen demand, treated as a diffusive boundary flux crossing the bottom area (btmA).

- Fluxes are weighted by grid cell volume and integrated over the volume control.

III. Results

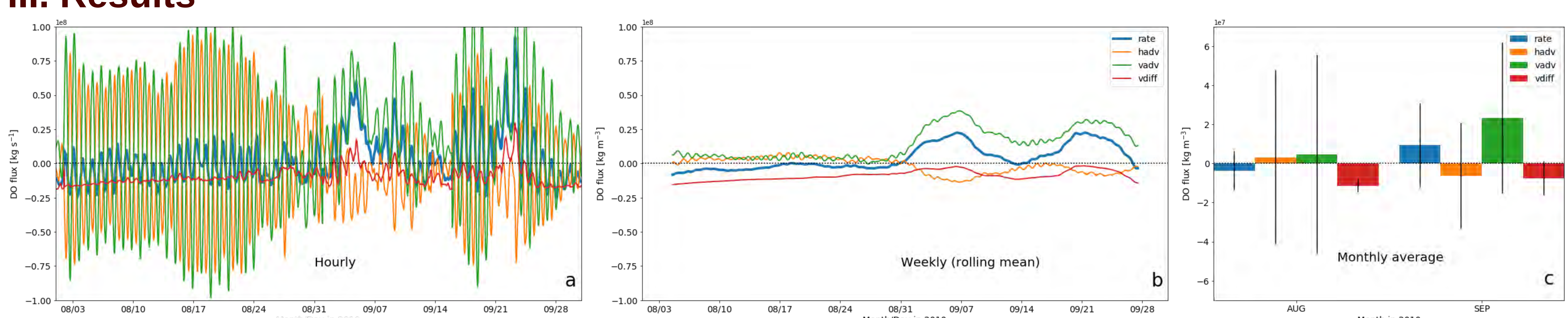


Fig 2: Rate of change of dissolved oxygen concentration (**rate**) in the volume control, decomposed in contributions by horizontal advection (**hadv**), vertical advection (**vadv**), and vertical diffusion (**vdiff**). Panel **a** shows hourly simulation, panel **b** is the weekly rolling mean, and panel **c** shows monthly mean and standard deviation. Notice vertical axis scale (magnitude x10^8) in panels **a** and **b**, and the scale change in **c**.

- Rate oscillates in phase with vertical advection on quasi-diurnal frequency. Similar to dissolved oxygen oscillations observed by Rabalais et al,1994).
- Quasi-diurnal convergence-divergence flux balances horizontal advection.
- Daily (not shown), weekly and monthly averages show oxygen decline (rate<0) in August, dominated by vertical diffusion. Short episodes of oxygenation (rate>0) are lost.
- Daily (not shown) and weekly filters reveal ~14 days period oscillations (~storms) in September (similar to observations by Rabalais et al, 2007).
- Oxygenation episodes in September (rate>0) dominated by vertical advection.

IV. Conclusions and future work

- Advective fluxes have a strong quasi diurnal signal (~near inertial oscillations), which would be lost by lower frequency sampling.
- Current mapping strategies of the hypoxic area in the Louisiana shelf might be overestimating extent, unknown ecological interactions with dynamic field.
- Biweekly atmospheric episodes affect downward vertical diffusive and advective fluxes. Inter-annual variations in storm season would change flux balance.
- Dominant processes change between months (more data needed for comparison).
- This analysis will be extended to the existing 20 years' simulation to investigate other scales of temporal variability.
- Following the volume of a feature over time instead of a volume control might help explain the mechanisms of patch formation and maintenance.