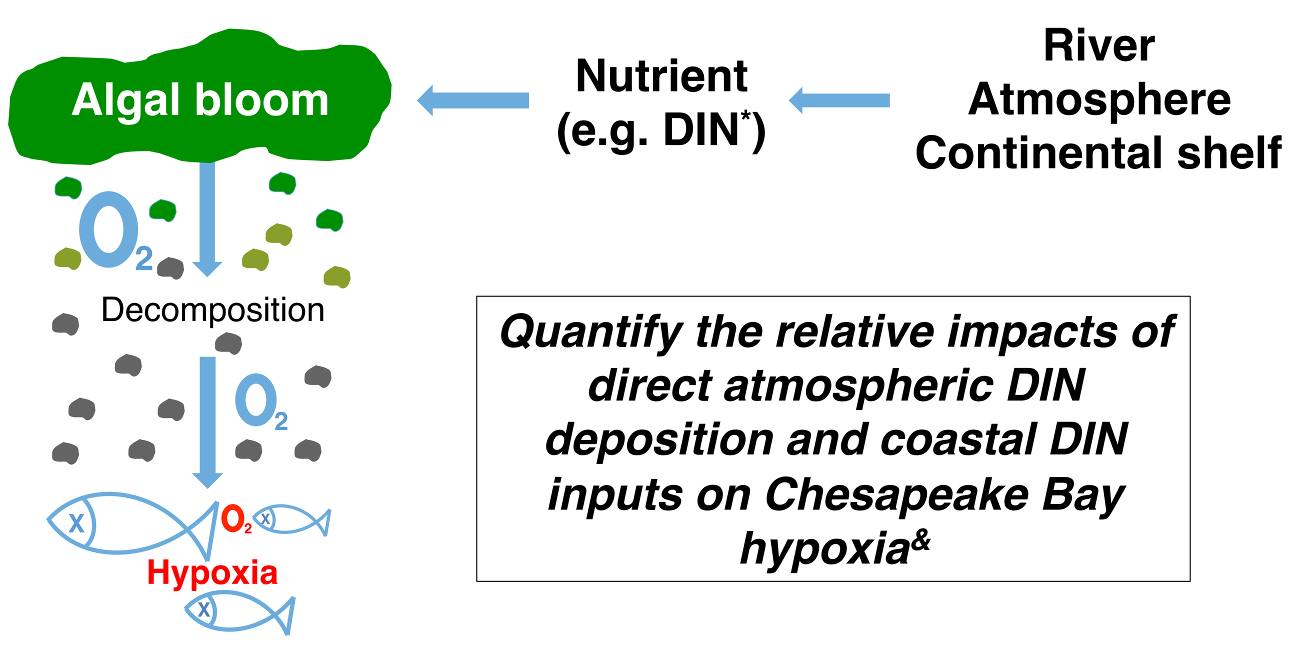
Impacts of atmospheric nitrogen deposition and coastal nitrogen fluxes on oxygen concentrations in Chesapeake Bay

Fei Da[1] (fda@vims.edu), Marjorie A. M. Friedrichs[1], and Pierre St-Laurent[1]

[1]Virginia Institute of Marine Science, William & Mary, Gloucester Point, VA 23062

Motivation and Objective



Quantify the relative impacts of direct atmospheric DIN deposition and coastal DIN inputs on Chesapeake Bay hypoxia&

*DIN refers to dissolved inorganic nitrogen: combination of nitrate (NO_3^-) and ammonium (NH_4^+)

&Hypoxia: dissolved oxygen (O_2) < 2 mg L^{-1}

Methods

Model tools: This study used the estuarine carbon and biogeochemistry model embedded in the Regional Ocean Modeling System (***Ches*ROMS-ECB**; Fig. 1).

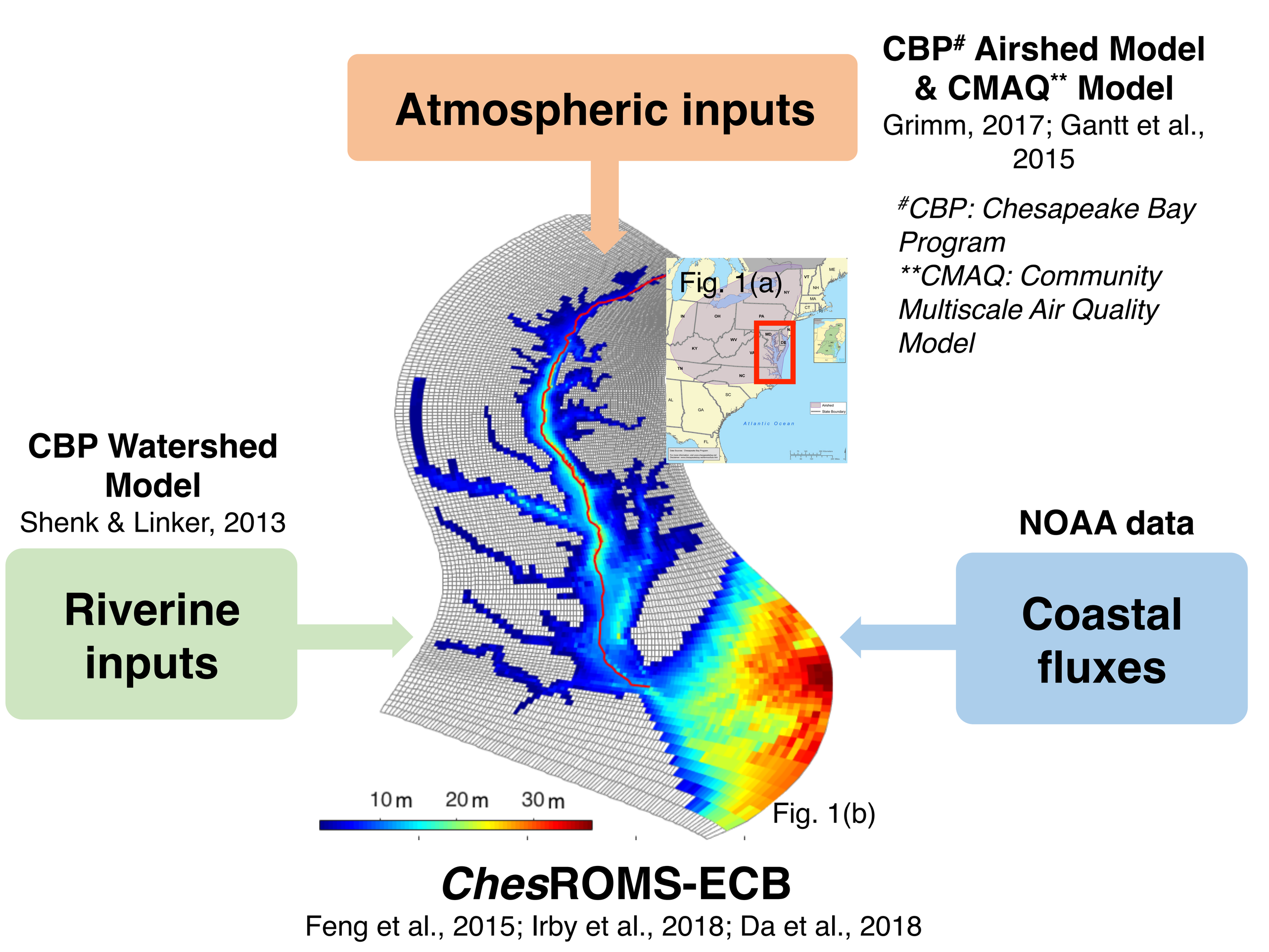


Fig. 1 (a) Chesapeake Bay watershed (red square) and its airshed (gray shading); (b) ChesROMS-ECB model domain and transect along the mainstem (red line)

Model experiments: All model simulations were conducted from 2002-2005 (Table 1).

Reference run	Including all riverine, atmospheric and coastal DIN inputs	**AtmN run**	Doubling or turning off direct atmospheric DIN deposition
CoastalN run	Doubling or removing oceanic boundary DIN concentrations	**ΔRiverN run**	Changing riverine DIN inputs by ± ~9% (8.8 Gg-N y^{-1}≈AtmN)

Table 1 Inputs of DIN to the Chesapeake Bay from direct atmospheric deposition and riverine loading

	Average	2002 Dry†	2003 Wet	2004 Wet	2005 Normal
Atmospheric DIN inputs (G-g N y^{-1})	8.0	7.7	9.3	7.2	7.9
Riverine DIN inputs (G-g N y^{-1})	91	73	120	88	83
100*Atmospheric/ riverine	8.8%	10.5%	7.7%	8.2%	9.5%

†Dry and wet years are based on annual riverine discharge to the Chesapeake Bay

Results 1: Impacts on O_2 in the summer

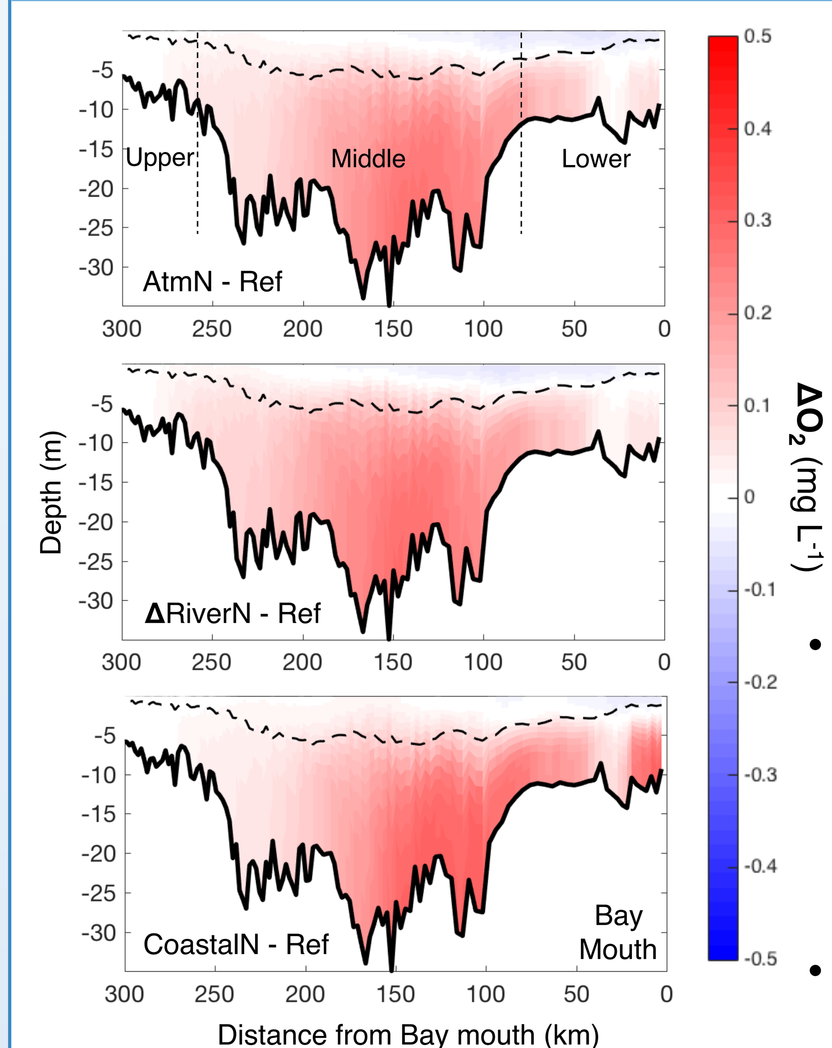


Fig. 2 Four-year (2002-2005) averages of increase in O_2 along the mainstem in the summer resulting from decreased nutrient inputs: AtmN sensitivity experiments (row 1), ΔRiverN sensitivity experiments (row 2), and CoastalN sensitivity experiments (row 3). Dashed lines are four-year (2002-2005) averaged summertime pycnocline (defined as in Irby et al. (2016)). Results are similar but opposite for experiments with increased nutrient inputs.

- Magnitude of impacts on O_2 is similar for atmospheric and coastal DIN inputs (Fig. 2).
- Changes in O_2 are greatest in summer
- The spatial structures of these responses differ slightly: the impact of coastal DIN is greater than the atmospheric DIN in the lower Bay, and smaller in the upper Bay.
- Atmospheric and coastal DIN inputs are as important as ~9% riverine DIN inputs

Results 2: Dry vs. wet years

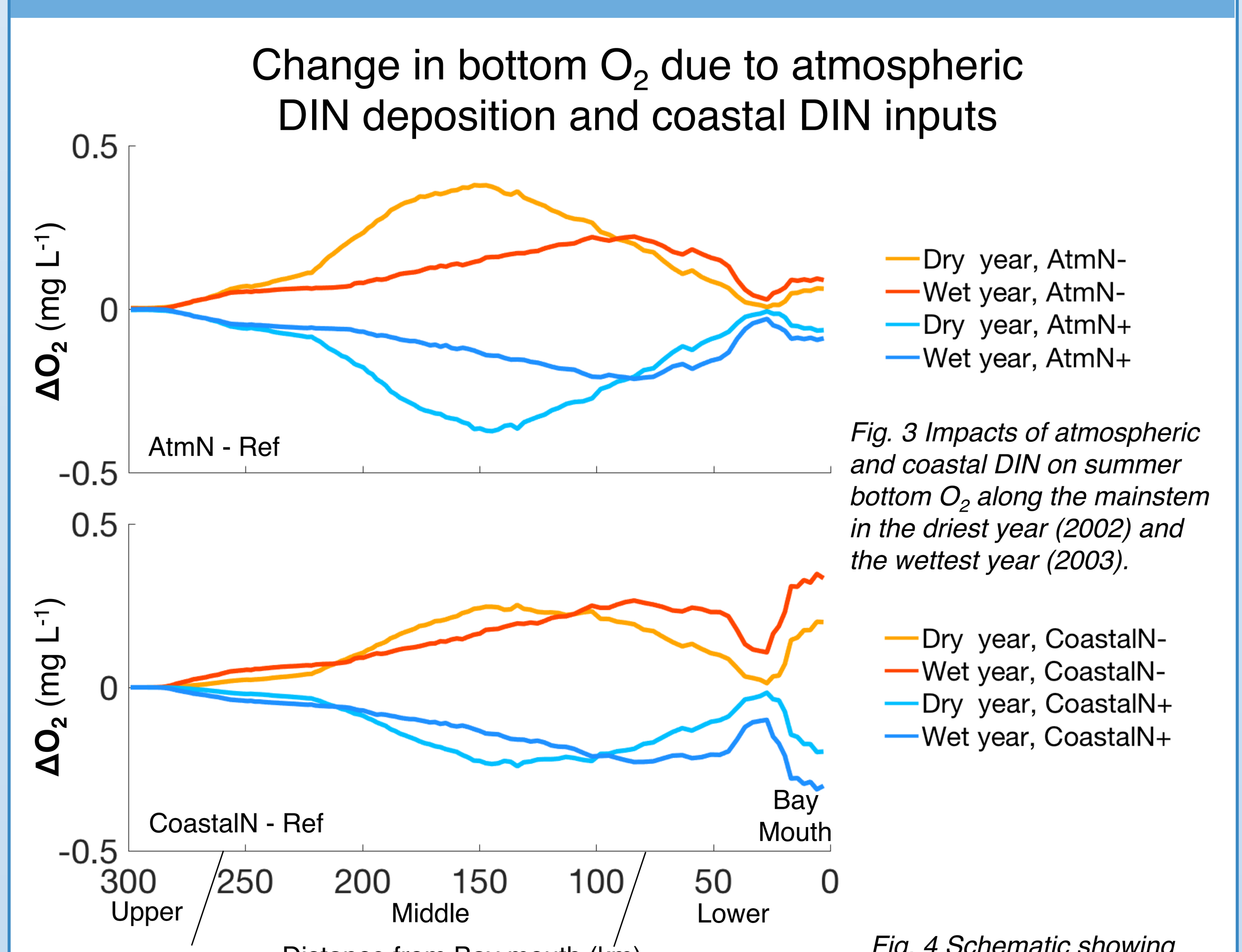
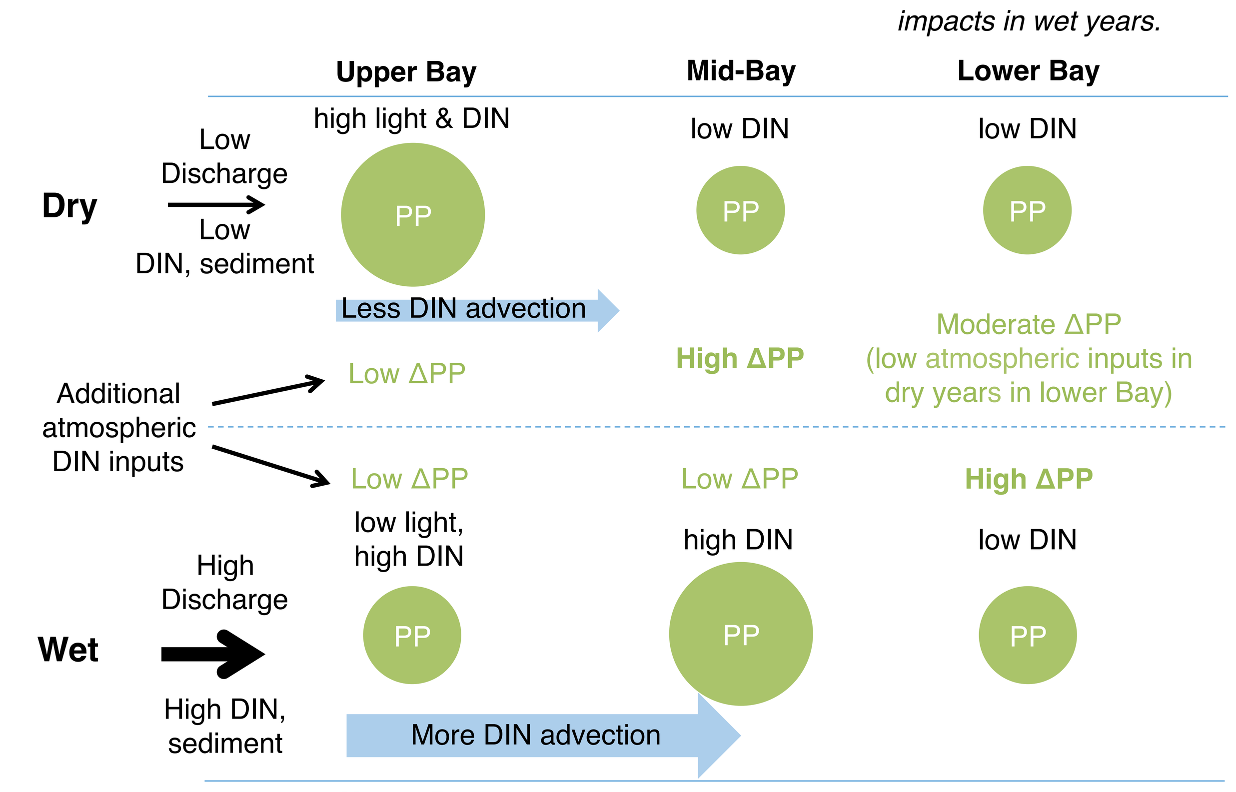


Fig. 3 Impacts of atmospheric and coastal DIN on summer bottom O_2 along the mainstem in the driest year (2002) and the wettest year (2003).

Fig. 4 Schematic showing downstream shift of maximum impacts in wet years.



- In the mid-Bay DIN is more limiting in dry years than wet years, so atmospheric DIN inputs have a greater impact on primary production and O_2 in dry years (Fig. 3-4)
- In the lower Bay DIN is always limiting, but atmospheric impacts are greater in wet years because atmospheric DIN deposition is larger in wet years (Fig. 3-4)

Results 3: Spatial variability

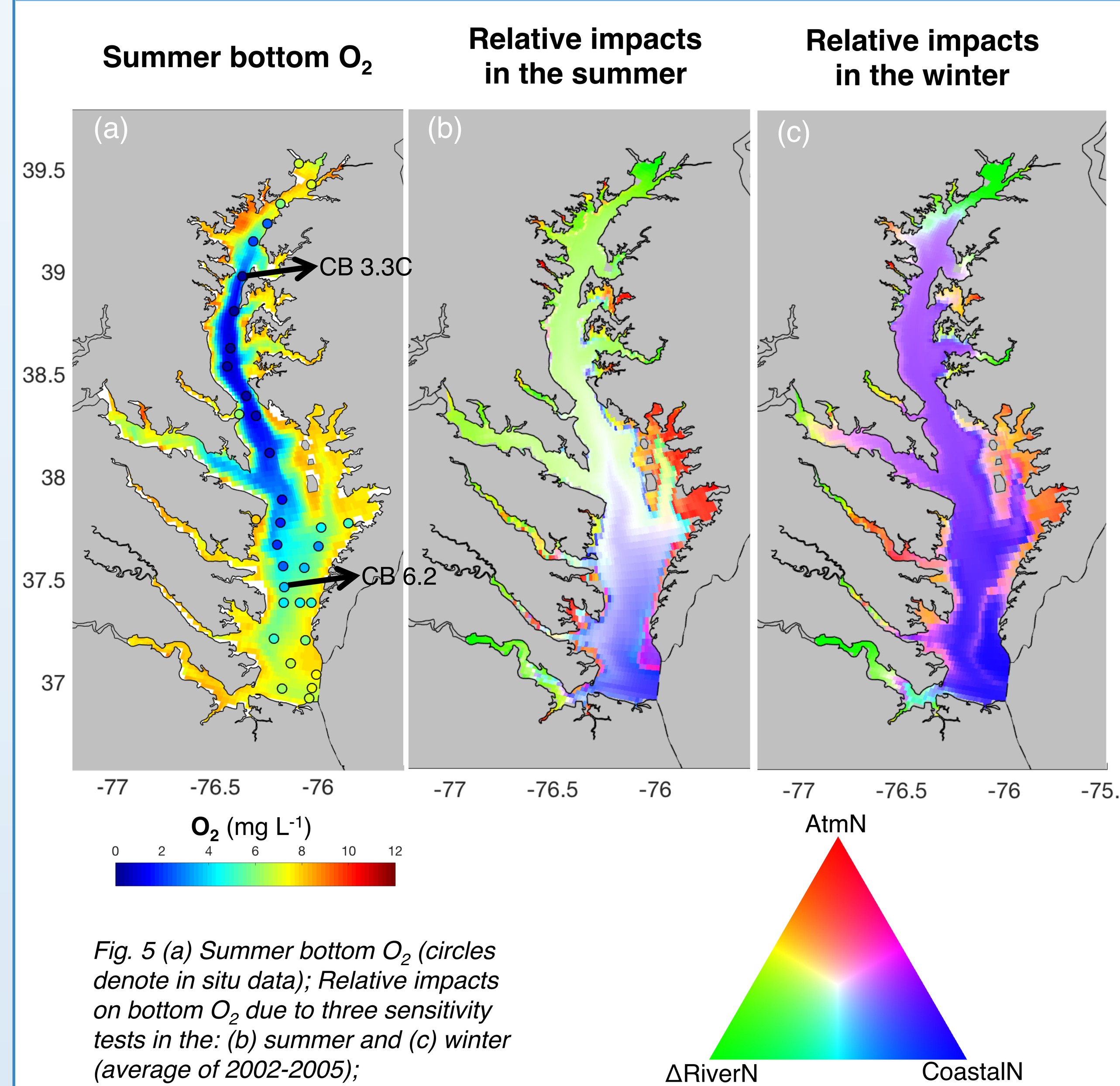


Fig. 5 (a) Summer bottom O_2 (circles denote in situ data); Relative impacts on bottom O_2 due to three sensitivity tests in the: (b) summer and (c) winter (average of 2002-2005);

Table 2 Absolute difference in bottom O_2 (mg L^{-1}) between the three sensitivity experiments and the reference run

	Annual	Spring	Summer	Fall	Winter
AtmN	0.09	0.09	0.17	0.09	0.03
ΔRiverN	0.08	0.08	0.18	0.06	0.01
CoastalN	0.10	0.12	0.16	0.07	0.05

Numbers are computed along the mainstem transect between stations CB3.3C and CB6.2 (Figure 5a), where hypoxia is the most prevalent.

- Spatially greatest impacts on bottom O_2 (Fig. 5):
  (1) Atmospheric DIN ➔ shallow eastern shoals in mid-Bay, where atmospheric DIN is relatively large
  (2) Coastal DIN ➔ lower Bay
  (3) Riverine DIN ➔ upper Bay and largest tributaries
- Temporal impacts on bottom O_2 (Table 2):
  (1) in the summer, all three DIN sources are important to hypoxia in the Bay
  (2) in the winter, coastal DIN has the greatest impact in most of the Bay

Conclusions

- In Chesapeake Bay, atmospheric DIN deposition has about the same gram for gram impact on hypoxia as riverine loading.
- Continental shelf DIN concentrations have a similar overall impact on hypoxia as DIN from the atmosphere; both impacts are greatest in summer.
- The greatest impacts of atmospheric DIN deposition and shelf DIN concentrations are farther downstream in wet years compared to dry years (See Da et al. (2018) for more information).

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