# Interannual Variability of Lateral Nitrogen Fluxes along the Mid-Atlantic Bight

BN44C-1220

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## Introduction

The Mid-Atlantic Bight (MAB) continental shelf is influenced by multiple source waters: Labrador Slope Water in the northeast, outflow from estuaries in the north, Slope Water in the south, and shelf water from the South Atlantic Bight in the southwest (**Fig.1a**). These 4 sources are responsible for supplying vast amounts of dissolved inorganic nitrogen (DIN) to the highly productive MAB. Historical measurements provide insight on the variability of DIN concentrations (**Fig.1b**) but the lack of concurrent velocity data makes shelf-wide estimates of the lateral fluxes impossible. Because of this, the relative importance of the 4 sources of DIN, as well as the physical drivers modulating the supply, remain largely unexplored to this day.

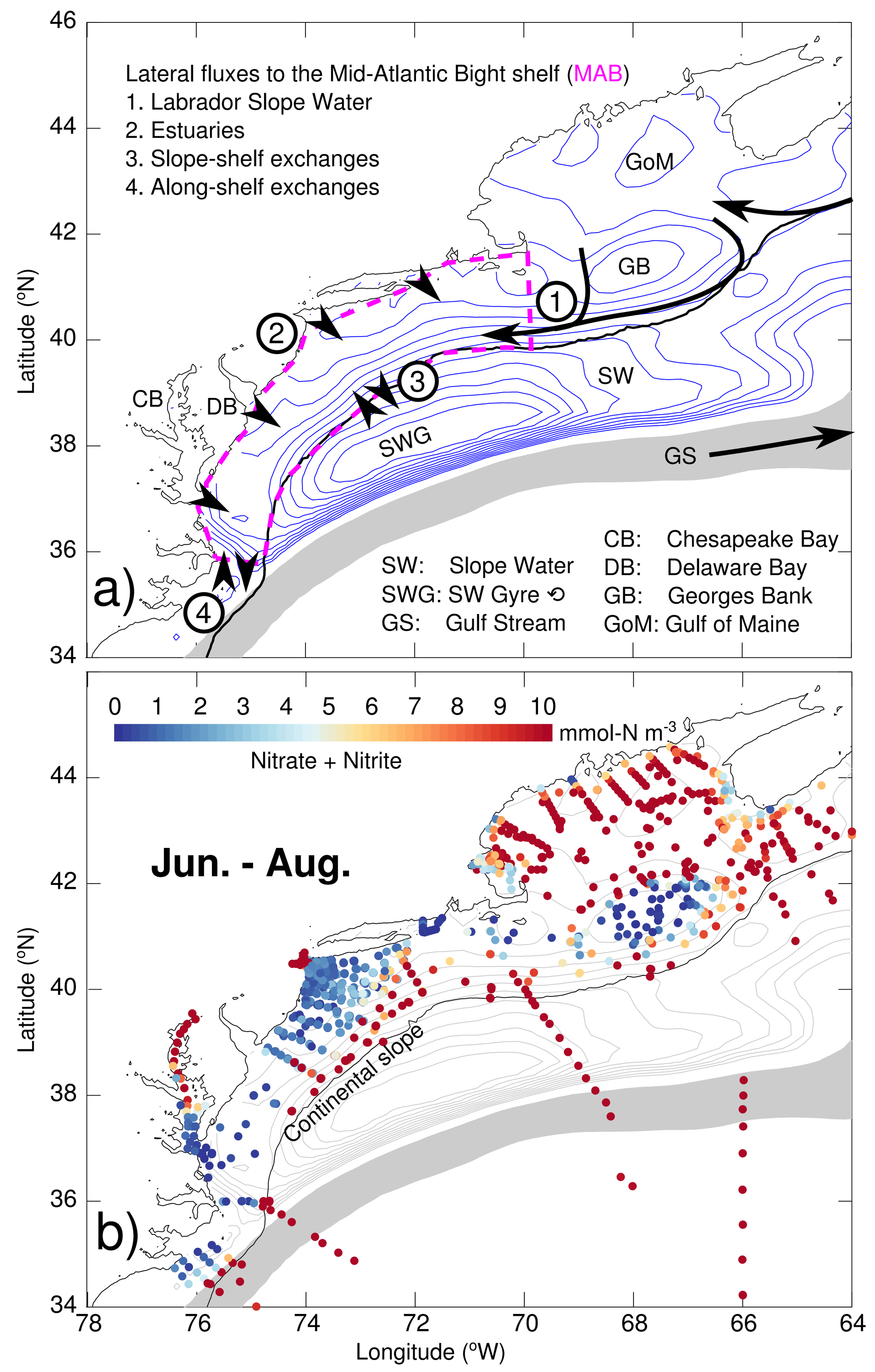


**Fig.1.** Pathways of DIN on the MAB shelf. (a) Schematic of the 4 boundaries and their fluxes. The blue contour lines represent the mean circulation [1]. (b) Maximum nitrate concentration during June-Aug. from casts that cover the surface to the bottom (data from 1972-Present). Source: World Ocean Database, NOAA Fish. Sci. Center, Ches. Bay Program, and K.C.Filippino (pers. comm.,

## Method

We examine the interannual variability of lateral fluxes along the MAB using a 3-D numerical model [2] applied to the US east coast. The simulation covers the period 2004-2008 and features a biogeochemical model of the nitrogen and carbon cycles [3,4]. The model results are used to build time-averaged budgets of organic/inorganic nitrogen (Figs.2,4) and to highlight the physical processes modulating the lateral fluxes (Fig.3).

## Results

The mean (5-yr averaged) budget of inorganic nitrogen on the MAB shelf (**Fig.2**) is dominated by the Net Community Production (NCP), a large DIN input from along- and cross-shelf fluxes (shelf+ocean), and a smaller input from bays/rivers. The NCP of the shelf is balanced by a seaward flux of dissolved and particulate organic nitrogen. Denitrification, burial, atmospheric deposition and temporal derivatives all play a minor role in the budget. However, the average over 5 years masks considerable **interannual variability** in some of these terms (see next section).

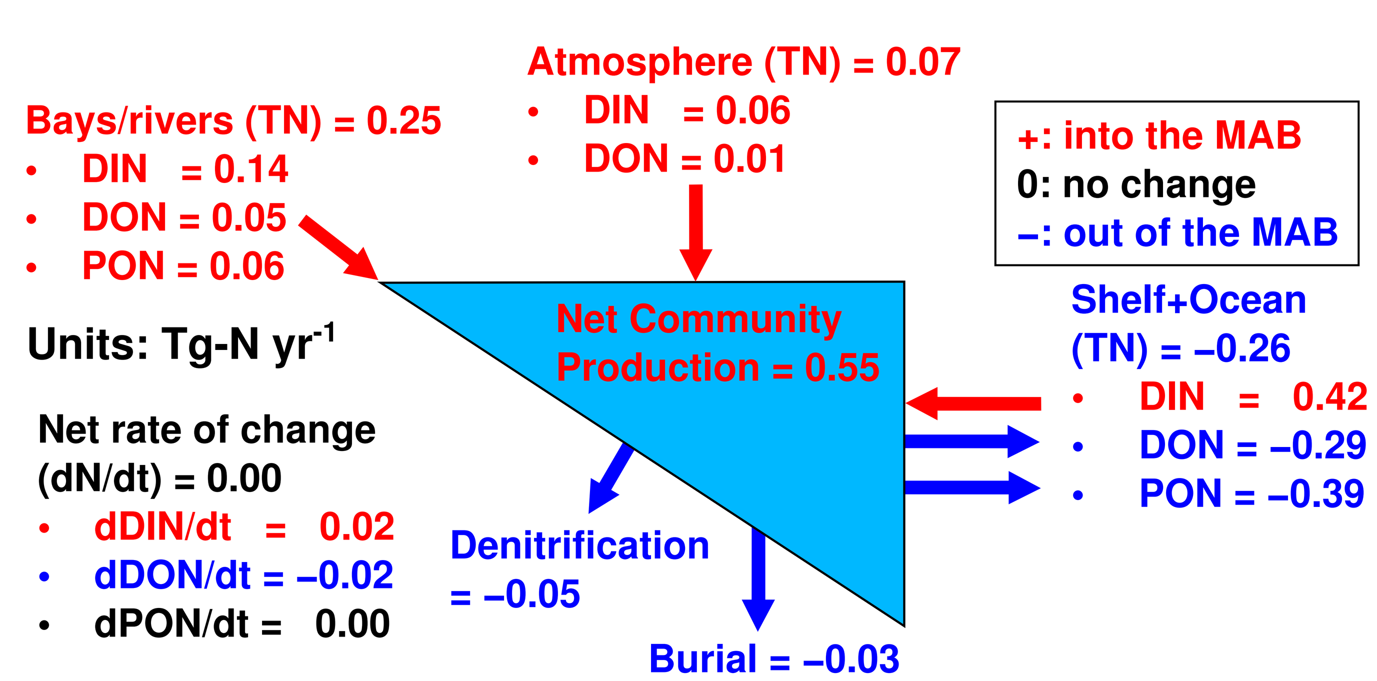


**Fig.2.** Mean nitrogen budget (2004-2008) for the MAB shelf.

$$\frac{\partial \mathrm{DIN}}{\partial t} = flux^{\mathrm{DIN}}_{\mathrm{bays+rivers}} + flux^{\mathrm{DIN}}_{\mathrm{shelf+ocean}} + flux^{\mathrm{DIN}}_{\mathrm{atmos}} - denitrification - NCP$$

$$\frac{\partial \mathrm{DON+PON}}{\partial t} = flux^{\mathrm{DON+PON}}_{\mathrm{bays+rivers}} + flux^{\mathrm{DON+PON}}_{\mathrm{shelf+ocean}} + flux^{\mathrm{DON}}_{\mathrm{atmos}} - burial + NCP$$

## Results (continuing)

The lateral flux of nitrate to the MAB shelf oscillates on weekly timescales but also exhibits sustained periods of +/- sign (**Fig.3a**). Annual mean values vary by as much as a factor of two (year 2004 versus 2007). The annual new primary productivity follows the nitrate fluxes with variations *O*(35%) (0.6 Tg-N yr$^{-1}$). **Figs.3b,c** illustrate two mechanisms (cross-shelf exchanges and estuarine fluxes) contributing to the variability of nitrate supply.

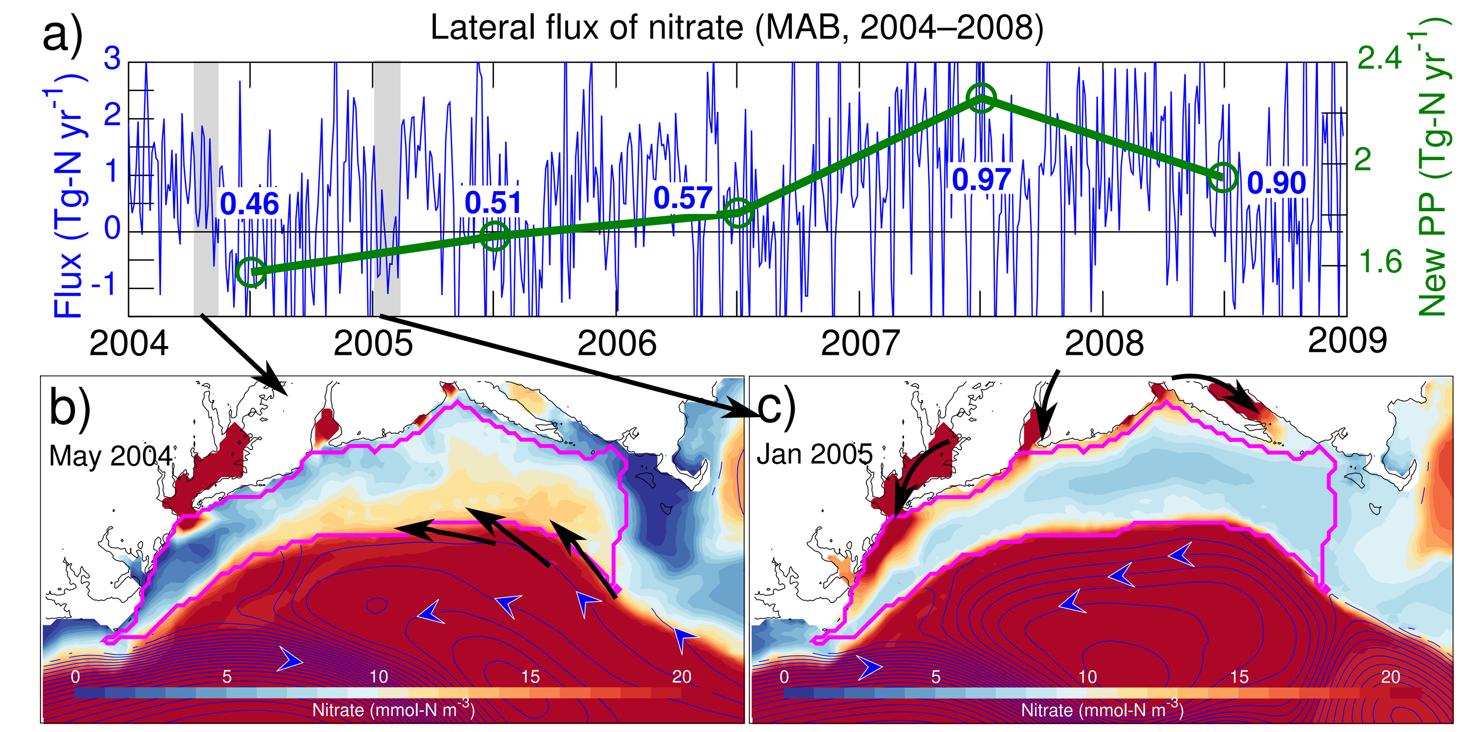


**Fig.3.** Lateral flux of nitrate to the MAB shelf (magenta contour in b,c; model outputs are from [1]). (a) Three-daily (blue line) and annual (blue numbers) averages of the net lateral nitrate flux (positive indicates a source; lateral fluxes are integrated vertically). Green curve is annual new primary productivity. (b) Example of cross-shelf exchanges supplying nitrate to the shelf. The shading represents the maximum nitrate concentration over the water column in May 2004 and the blue contour lines are the sea surface height. (c) Example of riverine inputs of nitrate in Jan. 2005.

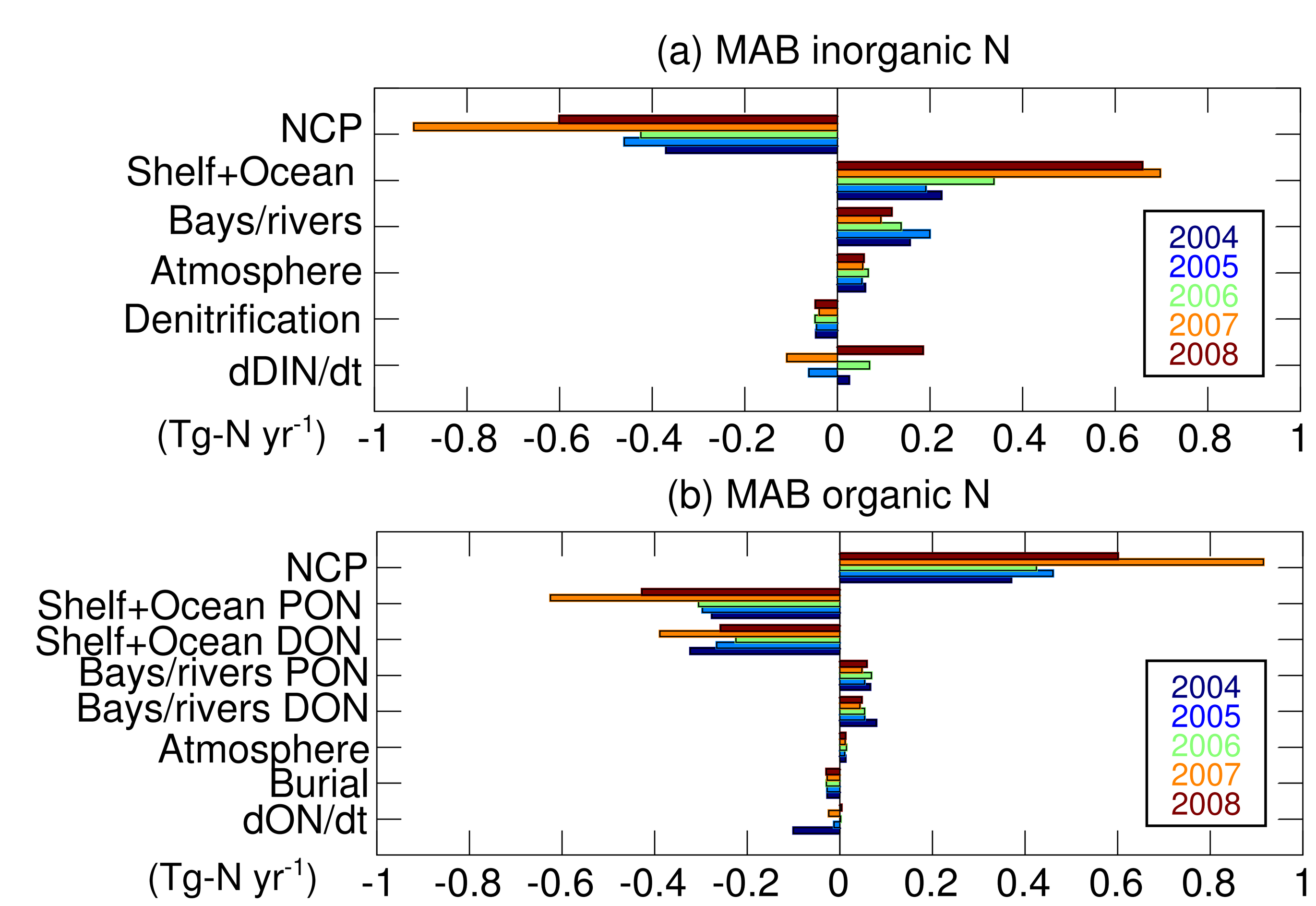


**Fig.4.** Interannual variability of the terms in the nitrogen budget.

Along- and cross-shelf fluxes of DIN (Shelf+Ocean, **Fig.4a**) are the primary cause of interannual variability in the nitrogen budgets. The variations mostly affect the NCP (with year-to-year fluctuations of ~100%) and dDIN/dt. The latter term exhibits fluctuations comparable in magnitude to the annual DIN input from bays/ rivers. The seaward export of organic nitrogen generally follows the variations of the NCP with a similar contribution from DON and PON (**Fig.4b**).

## Discussion

The simulation reveals that the supply of DIN to the MAB shelf is highly variable and that key components of the nitrogen budget require averages over >=5 years to converge. Historical data (DIN and current) are insufficient to capture such variability and thus the physical drivers modulating the lateral supply remain largely unexplored to this day. This represents a major roadblock if our goal is to understand and ultimately predict the response of shelf ecosystems to local and larger-scale perturbations such as the North Atlantic Oscillation [5].

## References

[1] AVISO, 2017, Mean dyn. topo. MDT-CNES-CLS13.
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[3] Hofmann et al., 2008, Oceanography, 21, 32-40.
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[5] Nye et al., 2014, J. Mar. Syst., 133, 103-116.

## Acknowledgments

This research was supported by NASA's Interdisciplinary Research in Earth Science (IDS) program (grant NNX14AF93G)...
...and by the National Science Foundation (award OCE-1259187).
VIMS | William & Mary | Virginia Institute of Marine Science
This work was performed using HPC facilities at W&M.