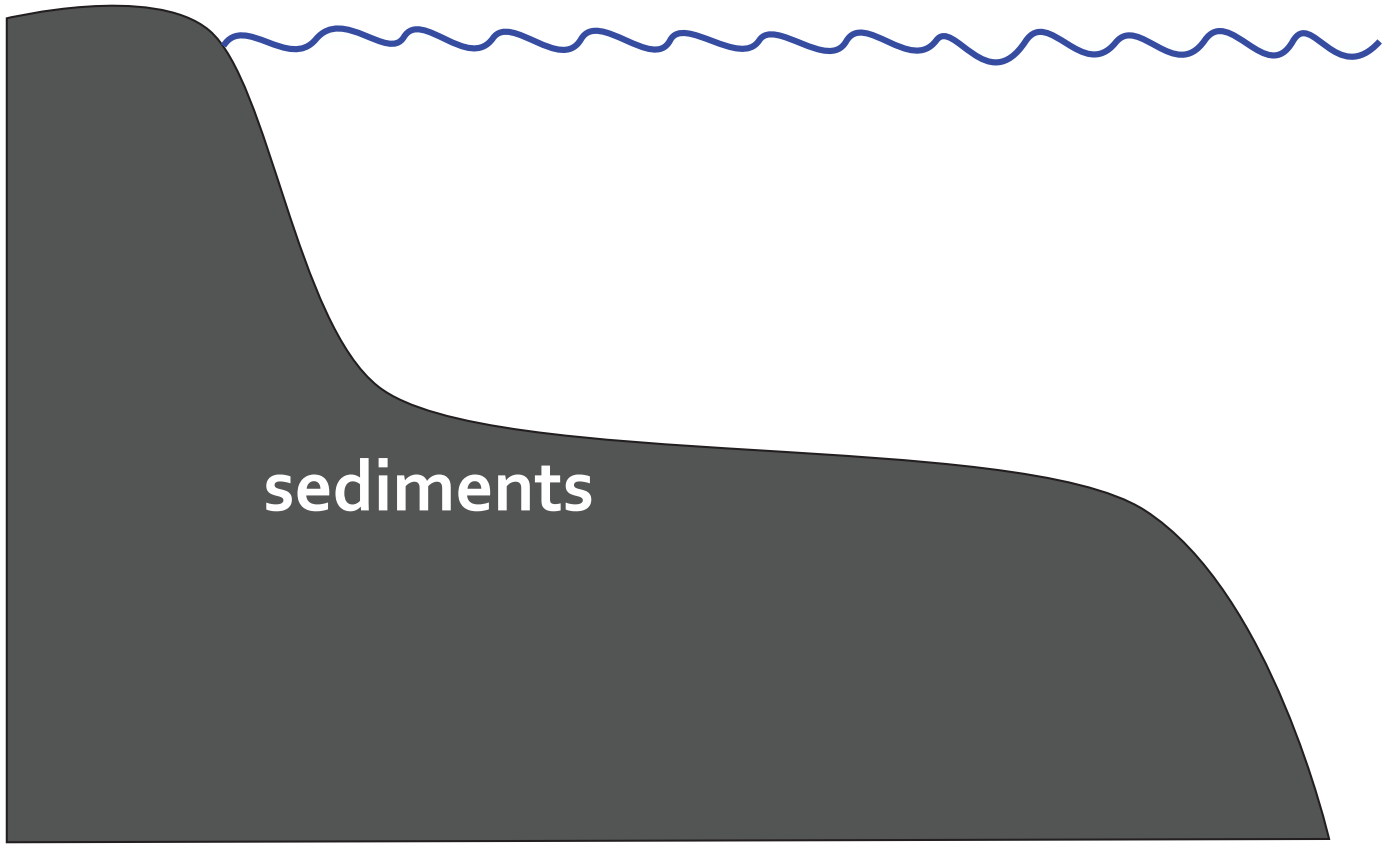
Elucidating carbon transport mechanisms that drive air-sea CO_2 fluxes on continental shelves:

A numerical modeling study of the Scotian Shelf

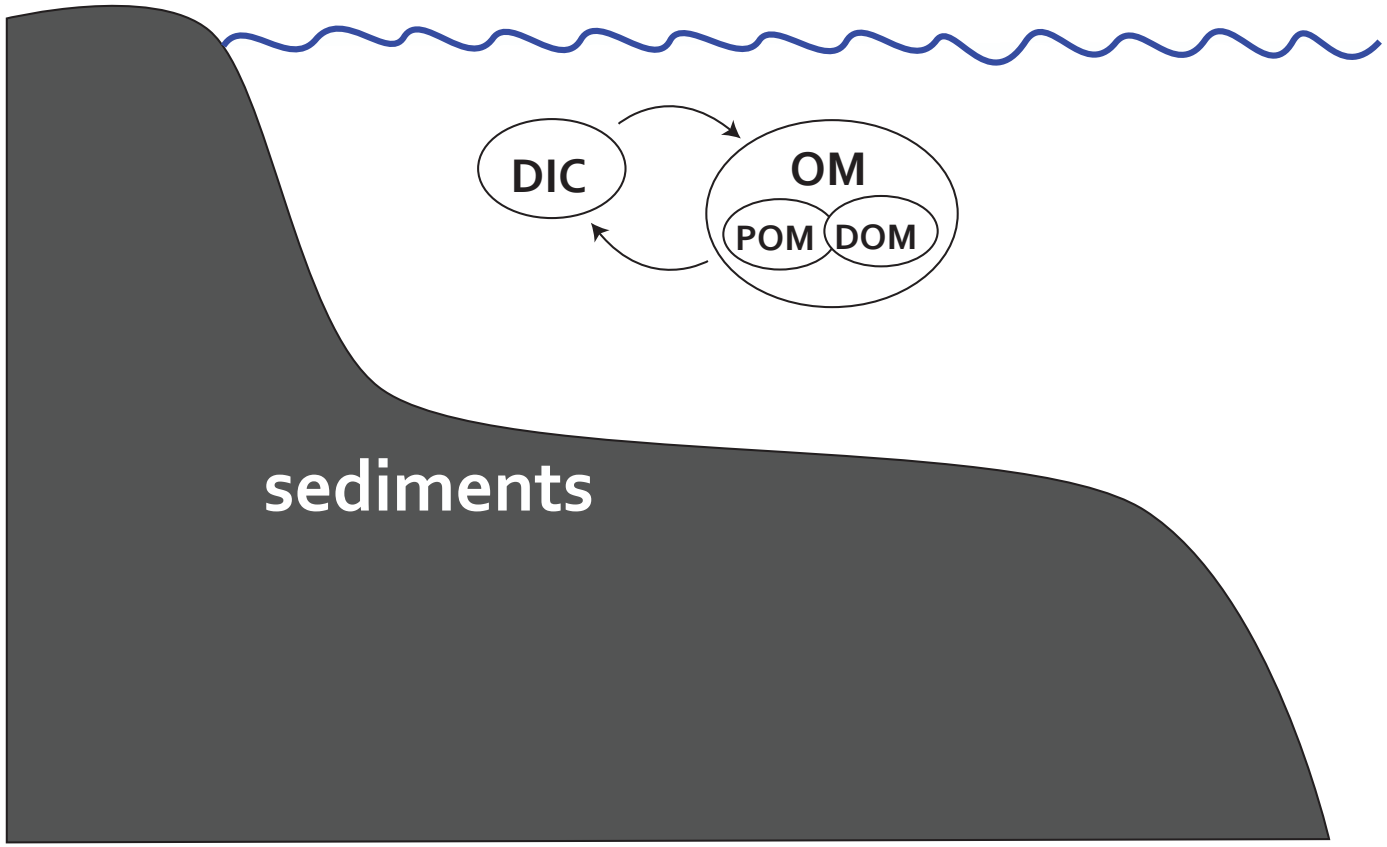
Krysten Rutherford, Katja Fennel, Helmuth Thomas

Ocean Sciences Meeting, February 2018, Portland

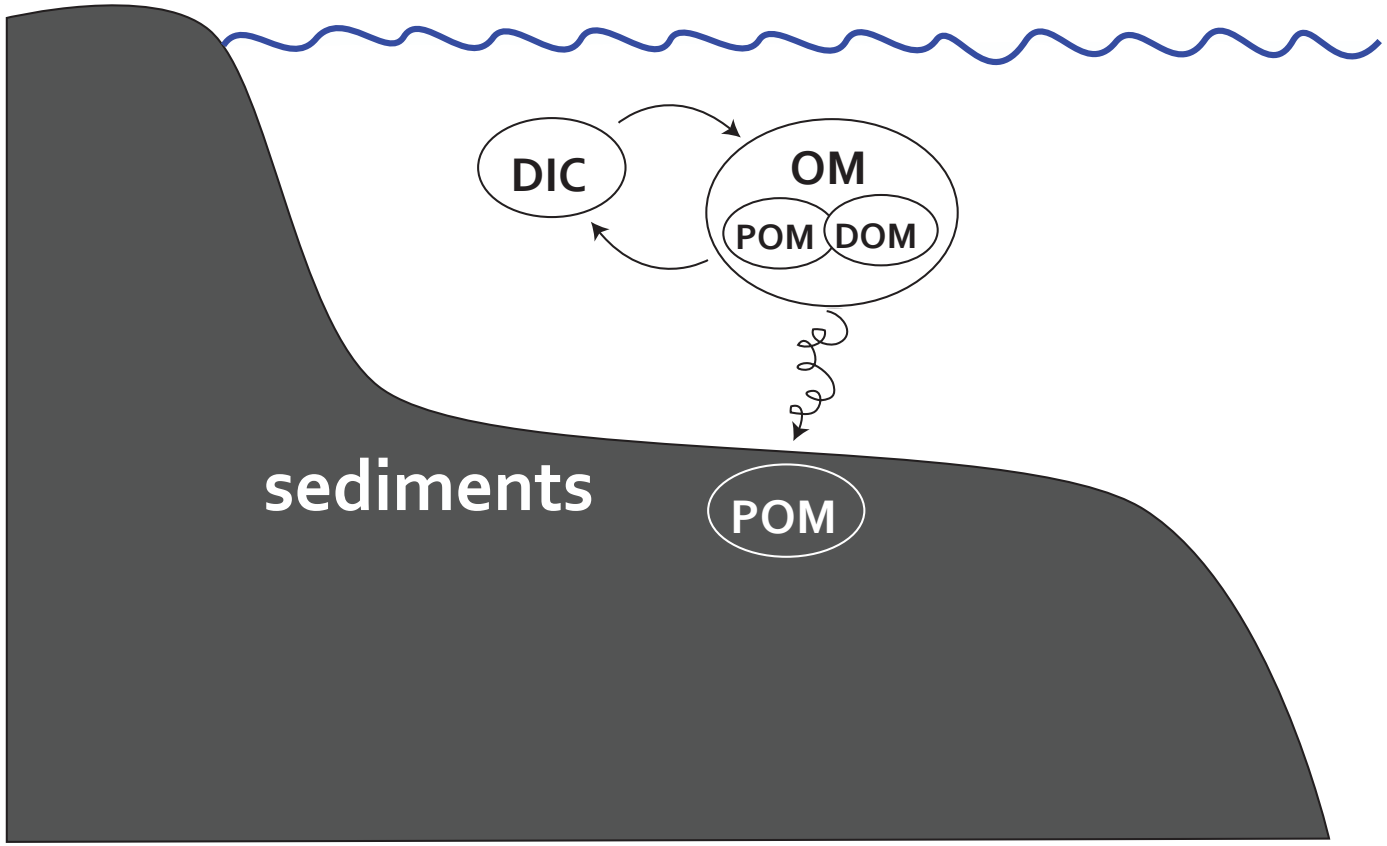
land **coastal & shelf seas** **open ocean**



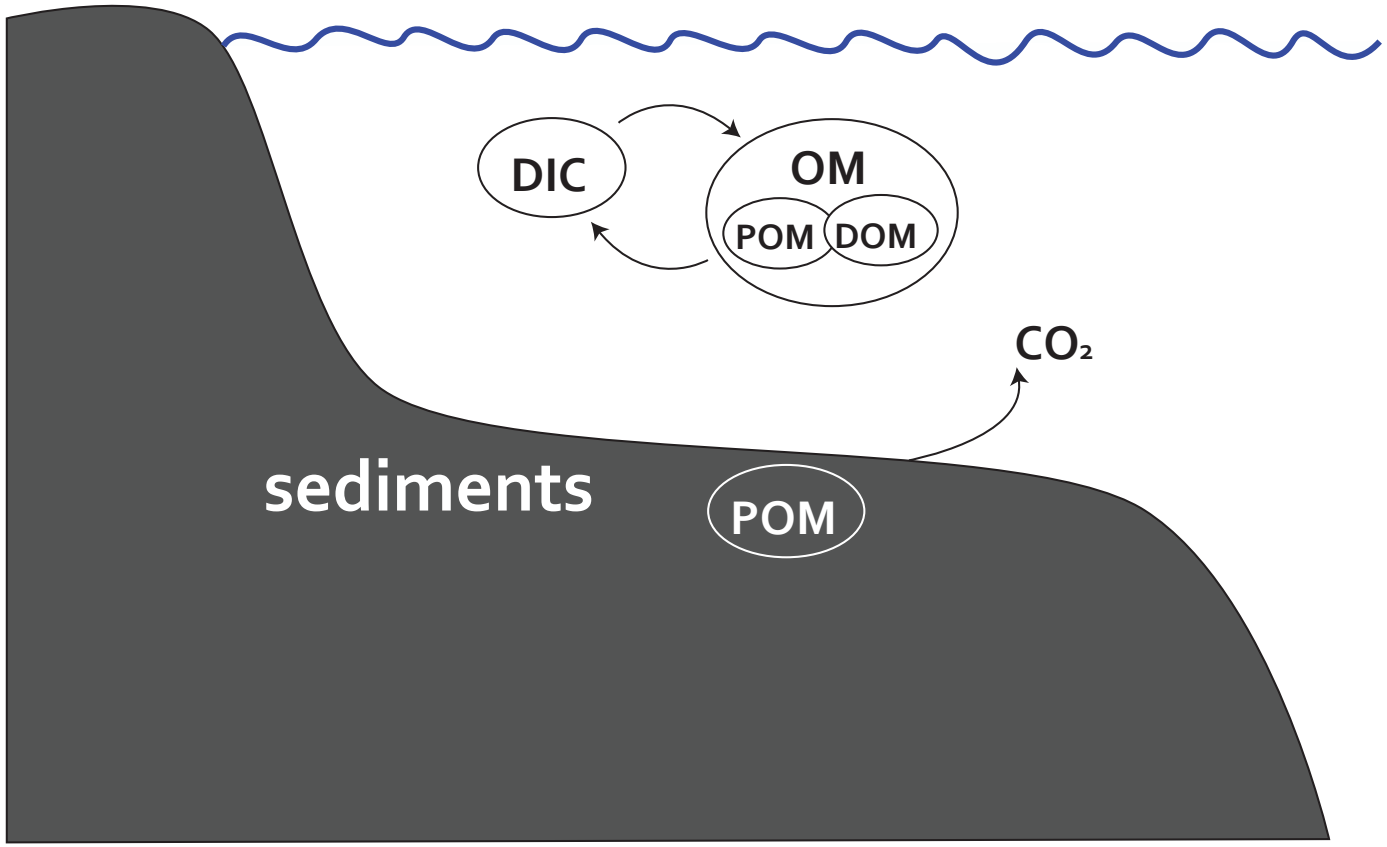
land **coastal & shelf seas** **open ocean**

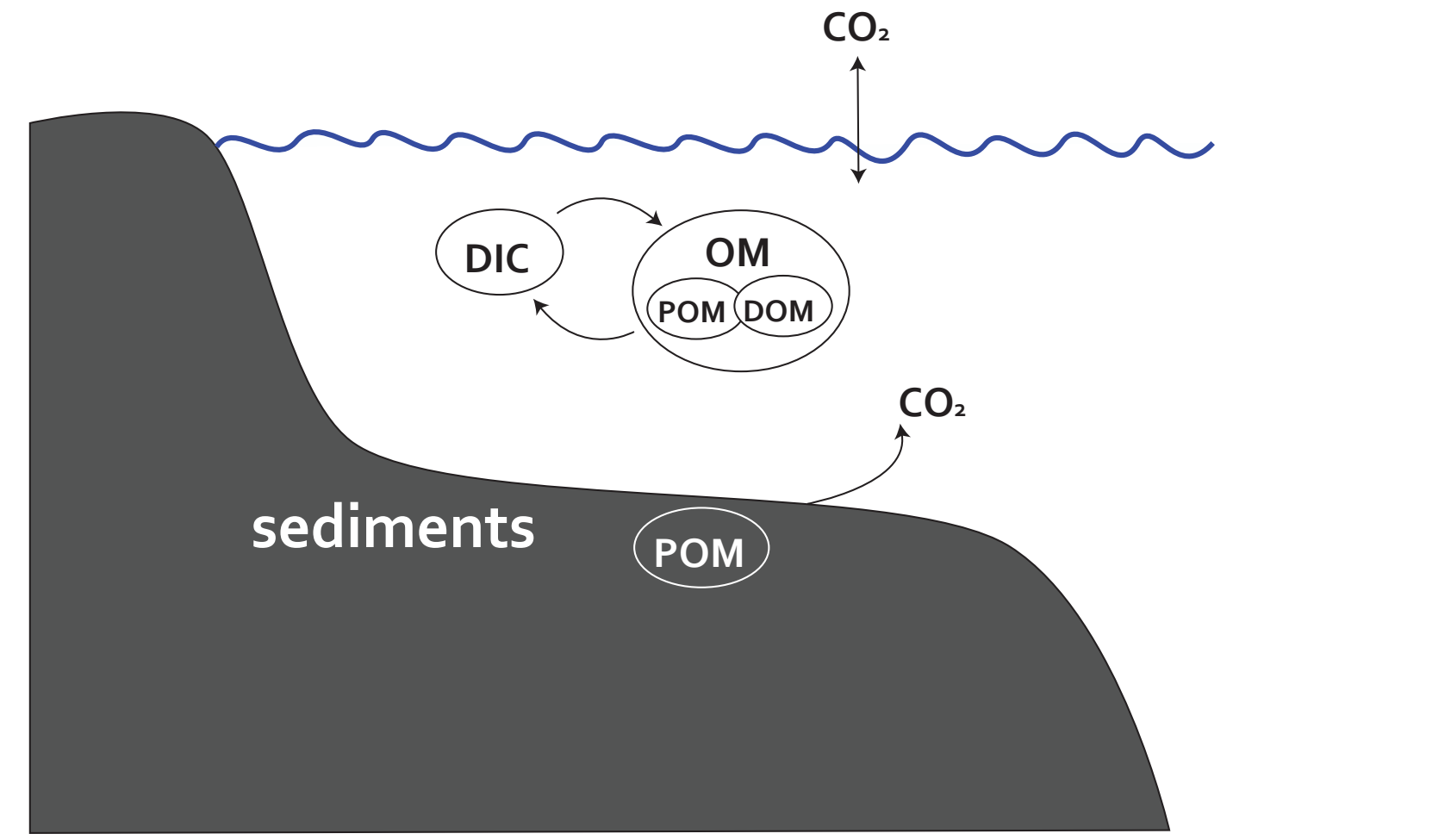


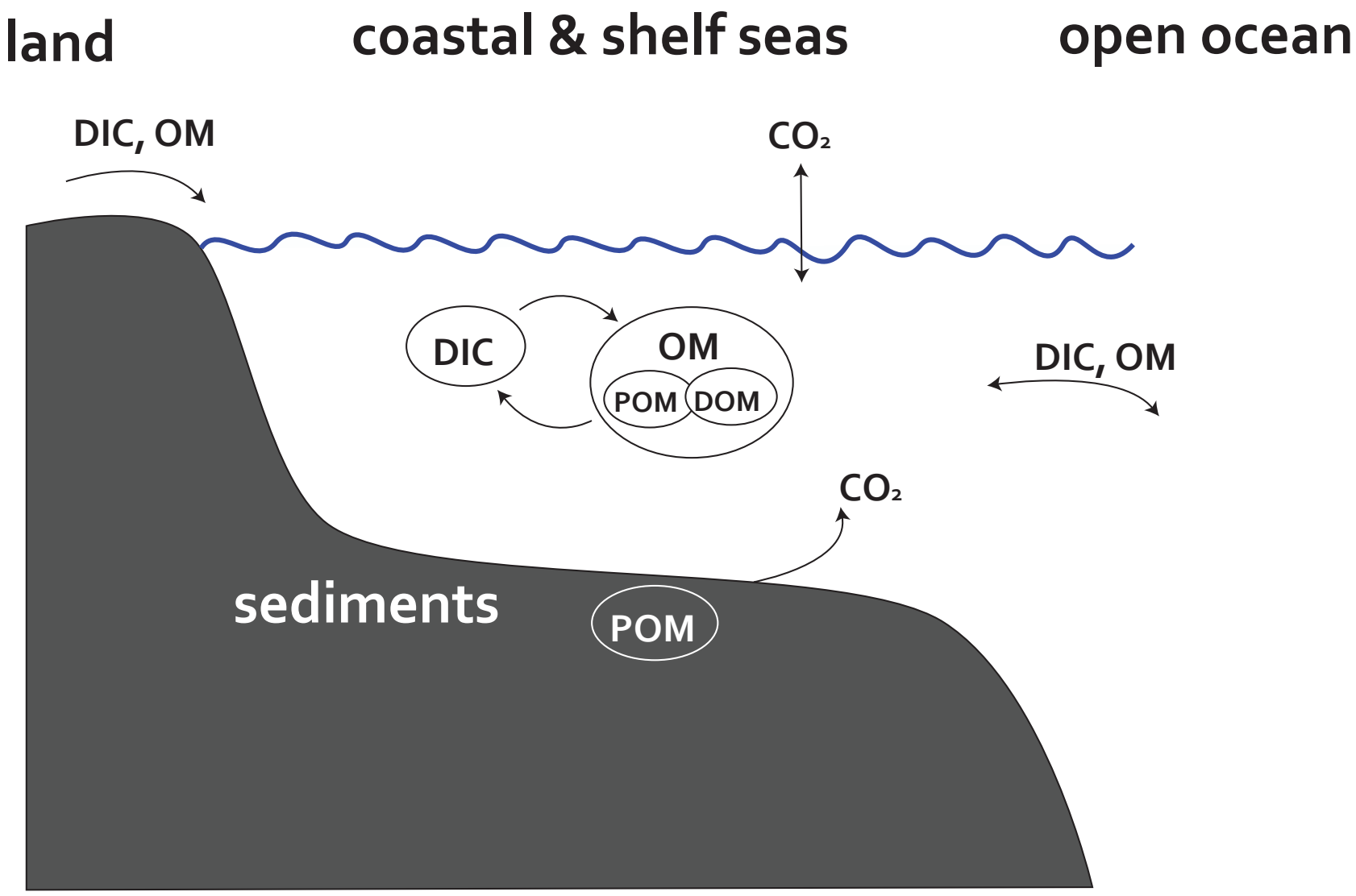
land **coastal & shelf seas** **open ocean**



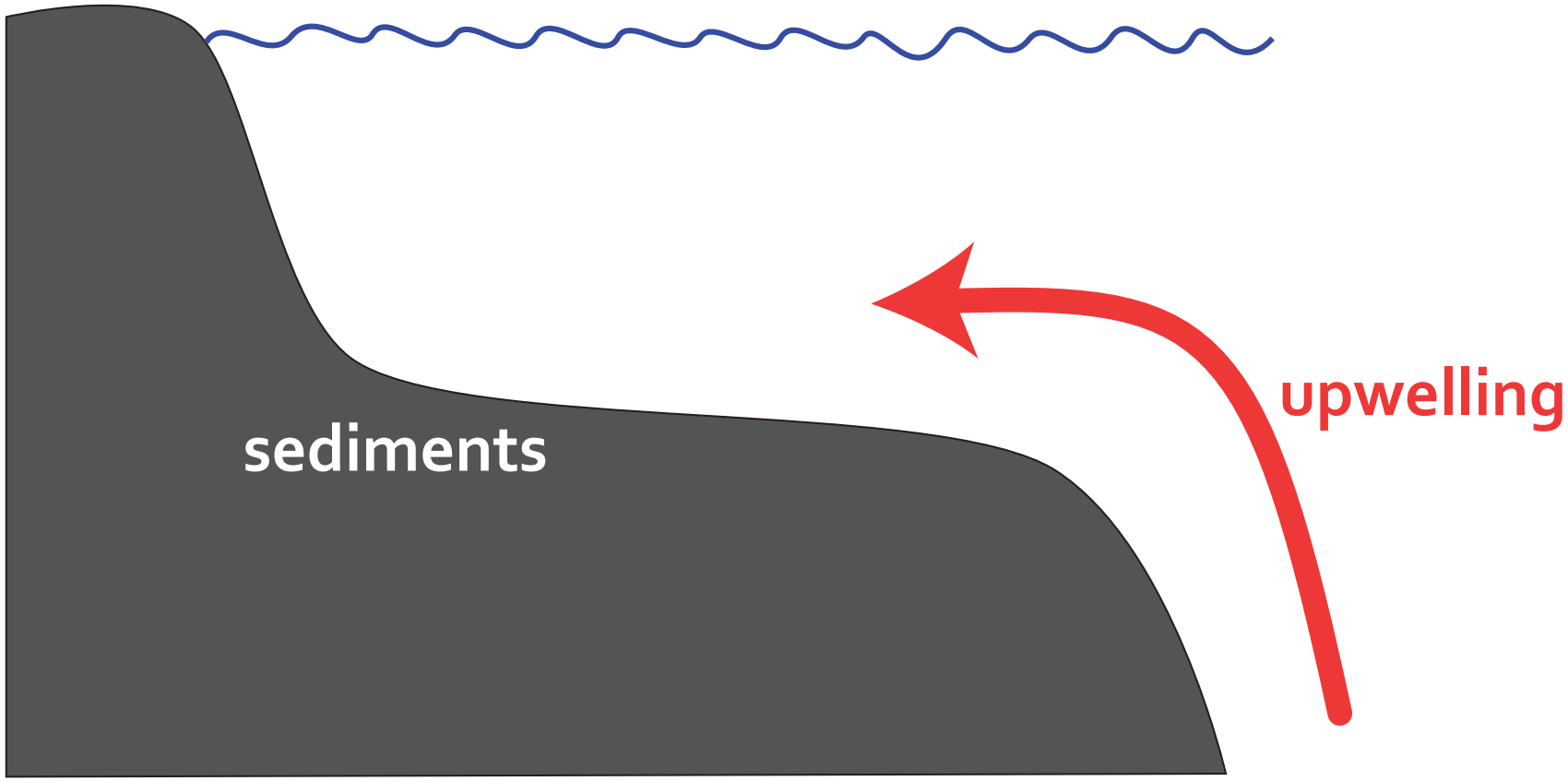
land **coastal & shelf seas** **open ocean**

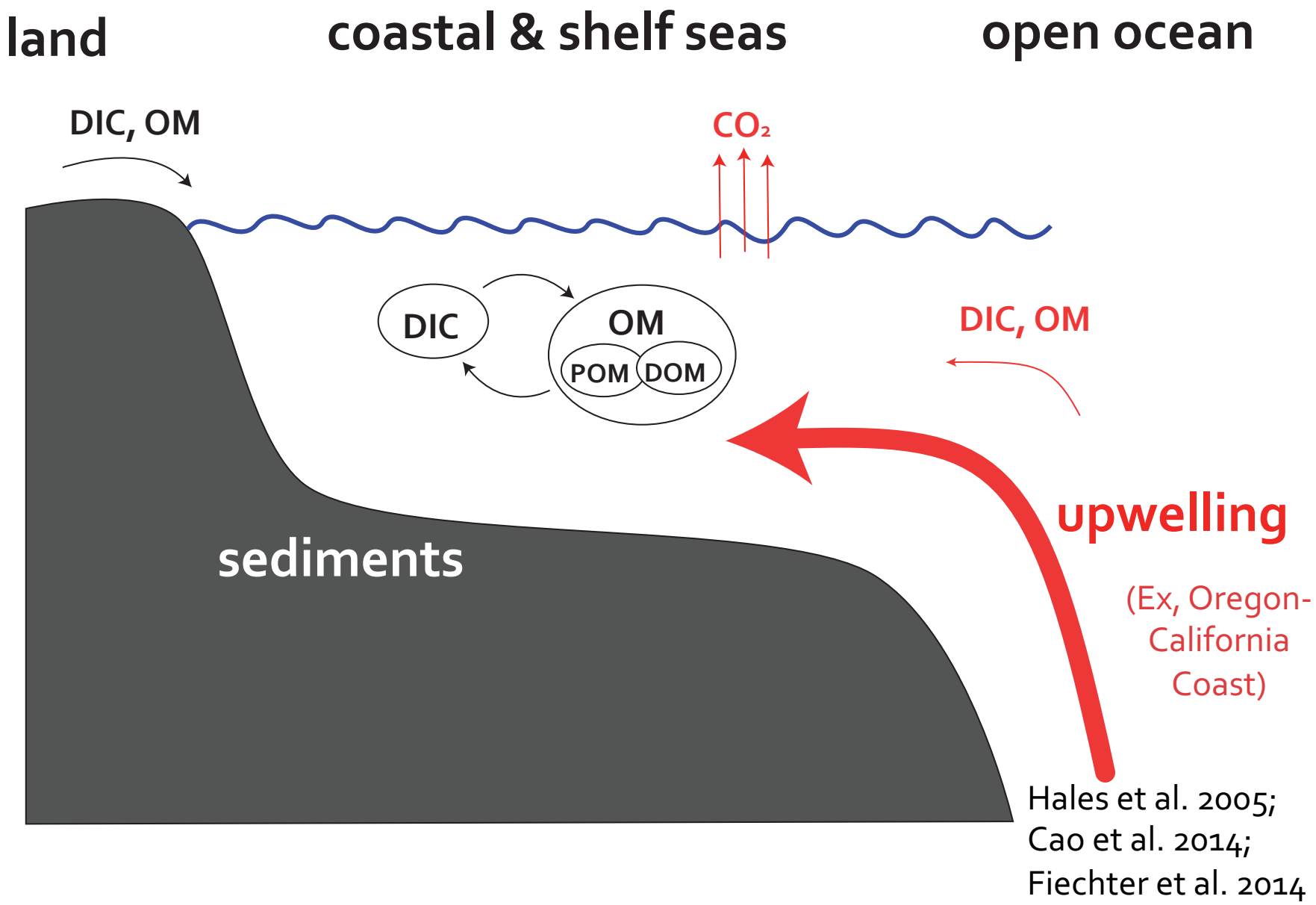


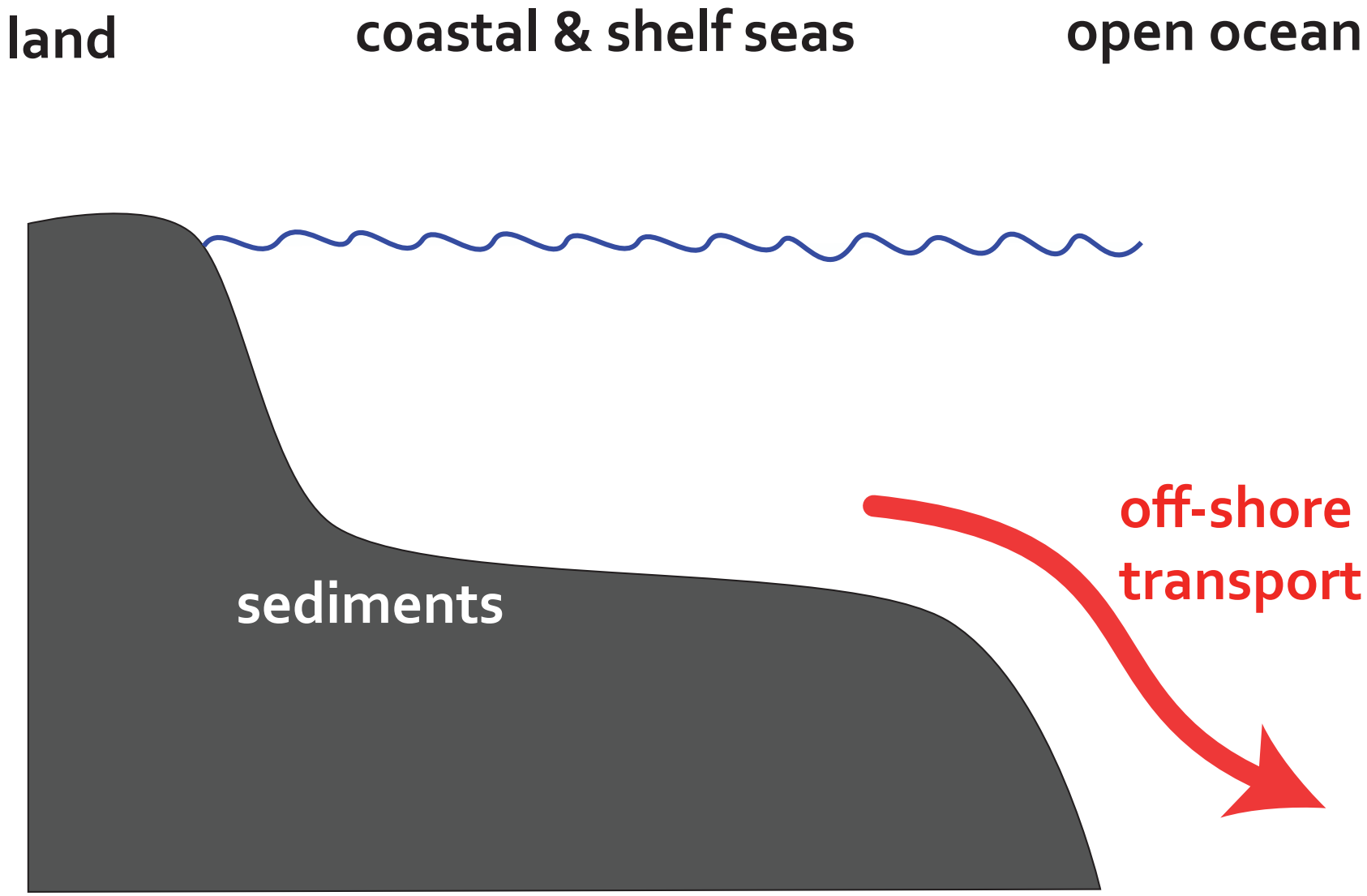

land
coastal & shelf seas
open ocean
CO_2
DIC
OM
POM
DOM
CO_2
sediments
POM

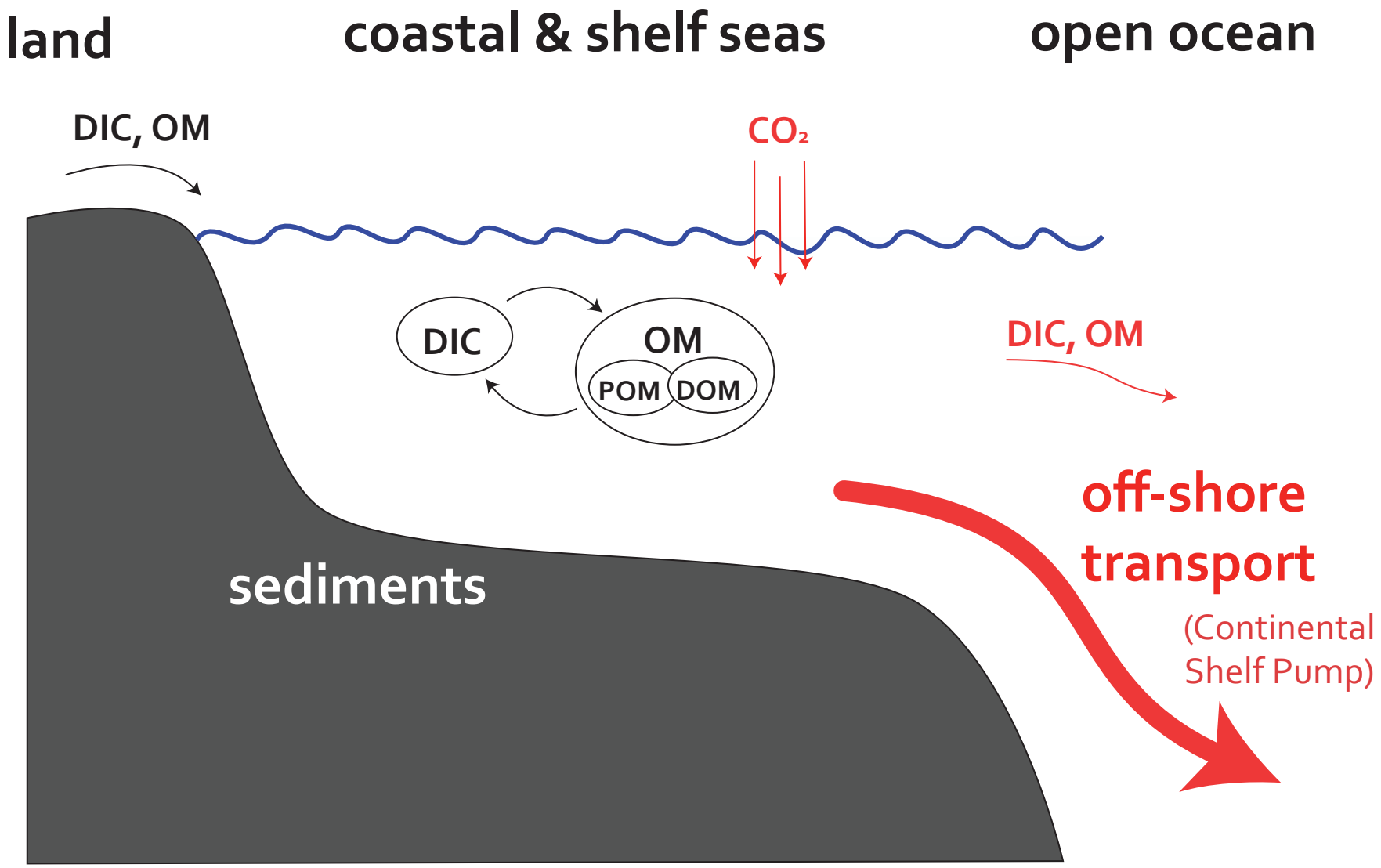

land
coastal & shelf seas
open ocean
DIC, OM
CO₂
DIC
OM
POM
DOM
DIC, OM
CO₂
sediments
POM

land coastal & shelf seas open ocean

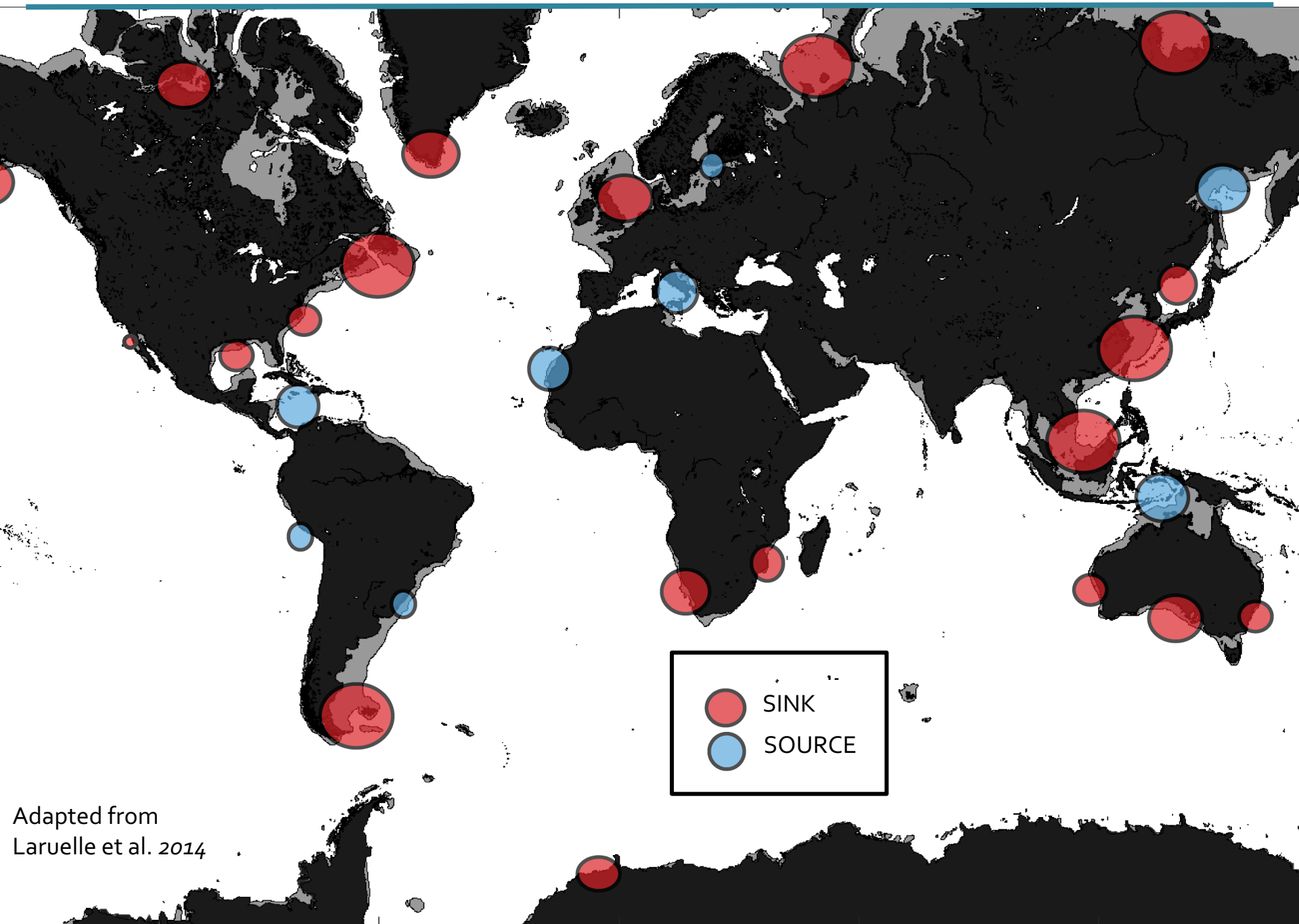



land
coastal & shelf seas
open ocean
DIC, OM
CO_2
DIC
OM
POM
DOM
DIC, OM
sediments
upwelling
(Ex, Oregon-California Coast)
Hales et al. 2005;
Cao et al. 2014;
Fiechter et al. 2014


land
coastal & shelf seas
open ocean
sediments
off-shore
transport



Tsunogai et al. 1999



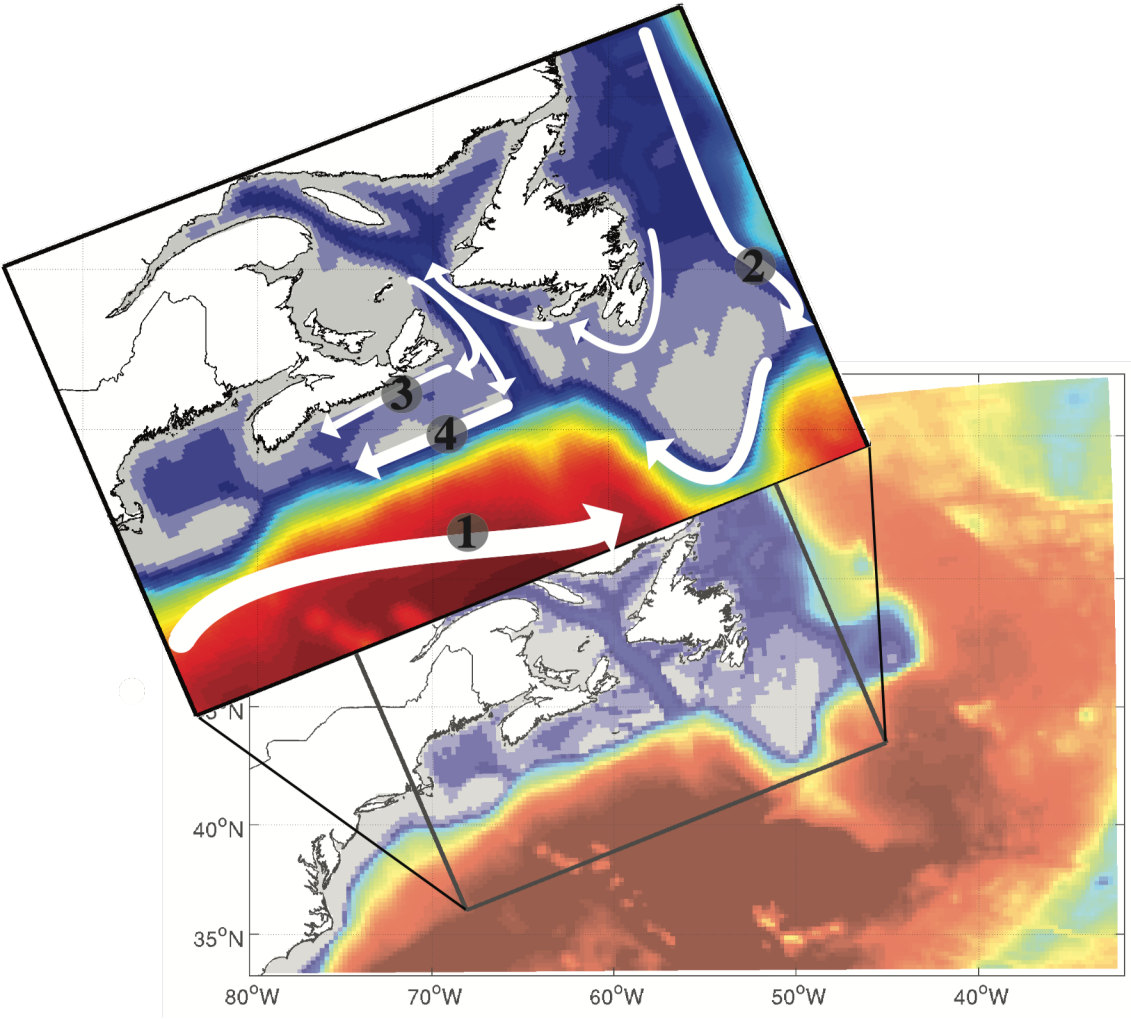
Adapted from
Laruelle et al. *2014*

+ Source
- Sink

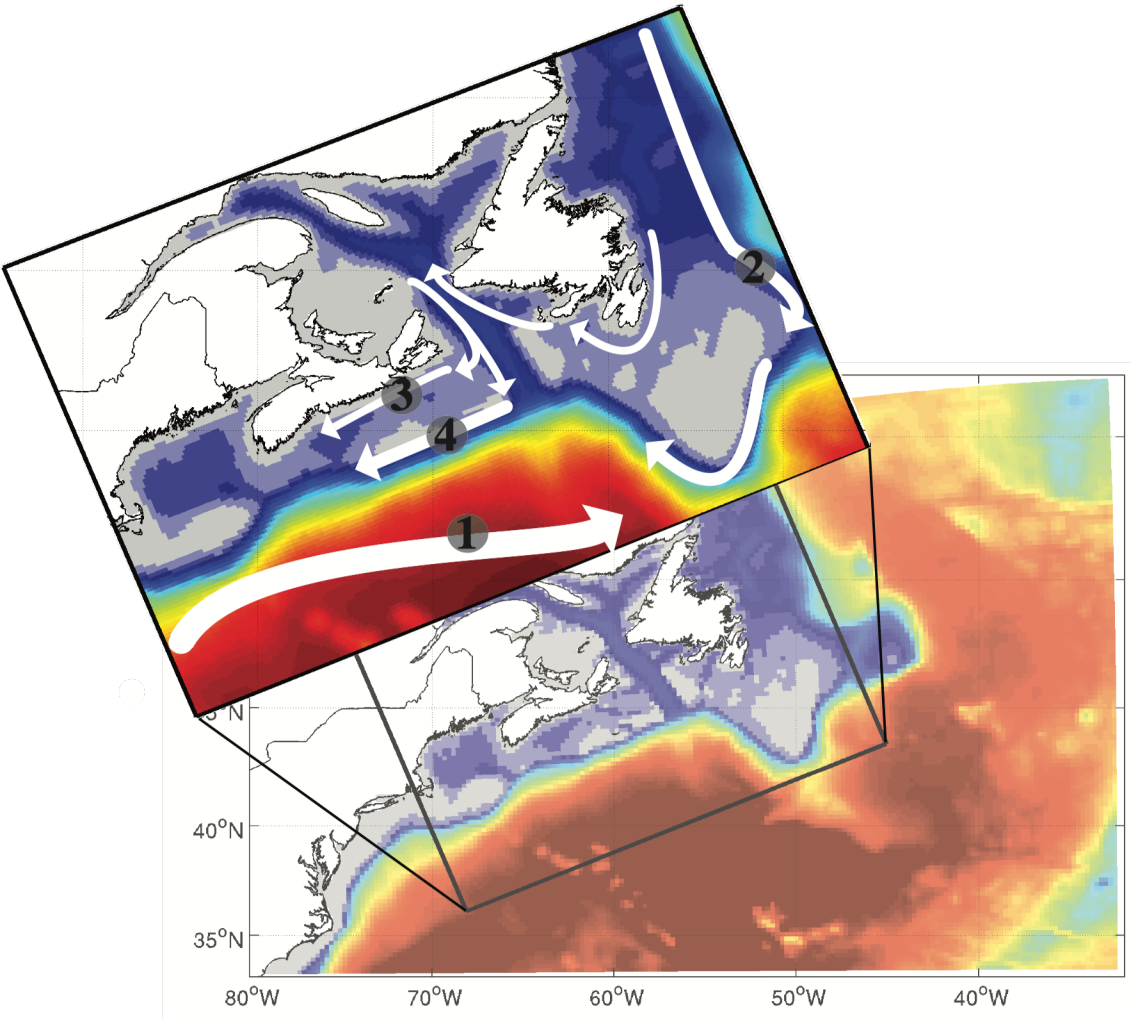
Scotian Shelf

	Sea-Air CO_2 Flux (mol C m^{-2} yr^{-1})
Laruelle et al. 2014	-0.33 ± 0.25

Biogeochemical ROMS implementation for Atlantic Canada

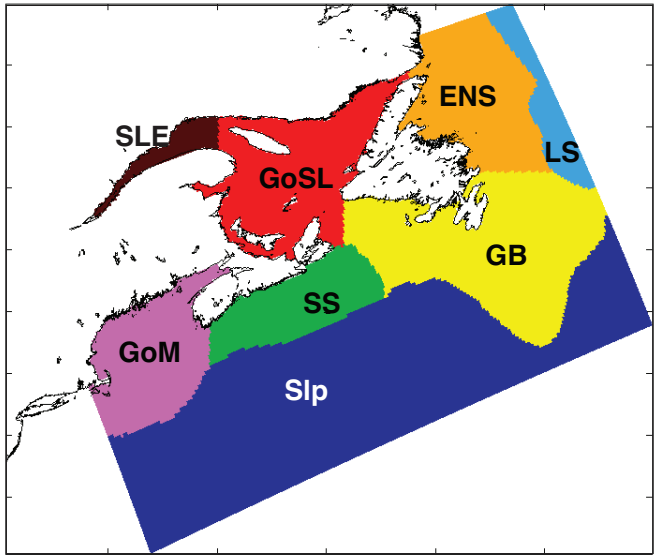


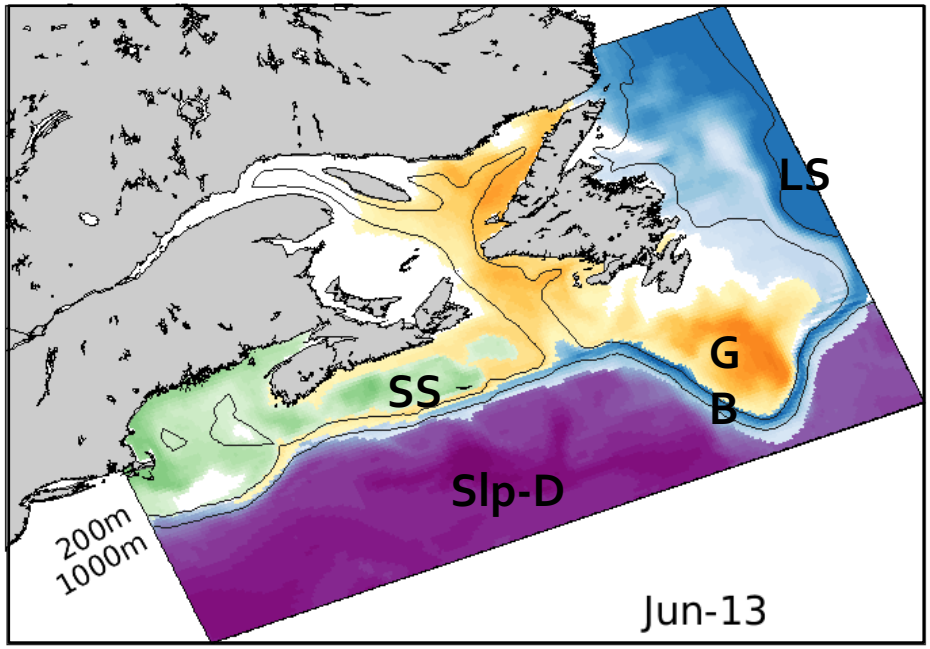
- 10 km horizontal resolution
- 30 vertical layers
- Physical B.C. from Urrego-Blanco & Sheng (2012)
- Biochemical B.C. from observations
- 3-hourly ECMWF ERA-Interim atmospheric forcing
- 12 major rivers
- Tides
- No ice
- HSIMT advection scheme



1. Gulf Stream
2. Labrador Current
3. Nova Scotia Current
4. Shelf Break Current

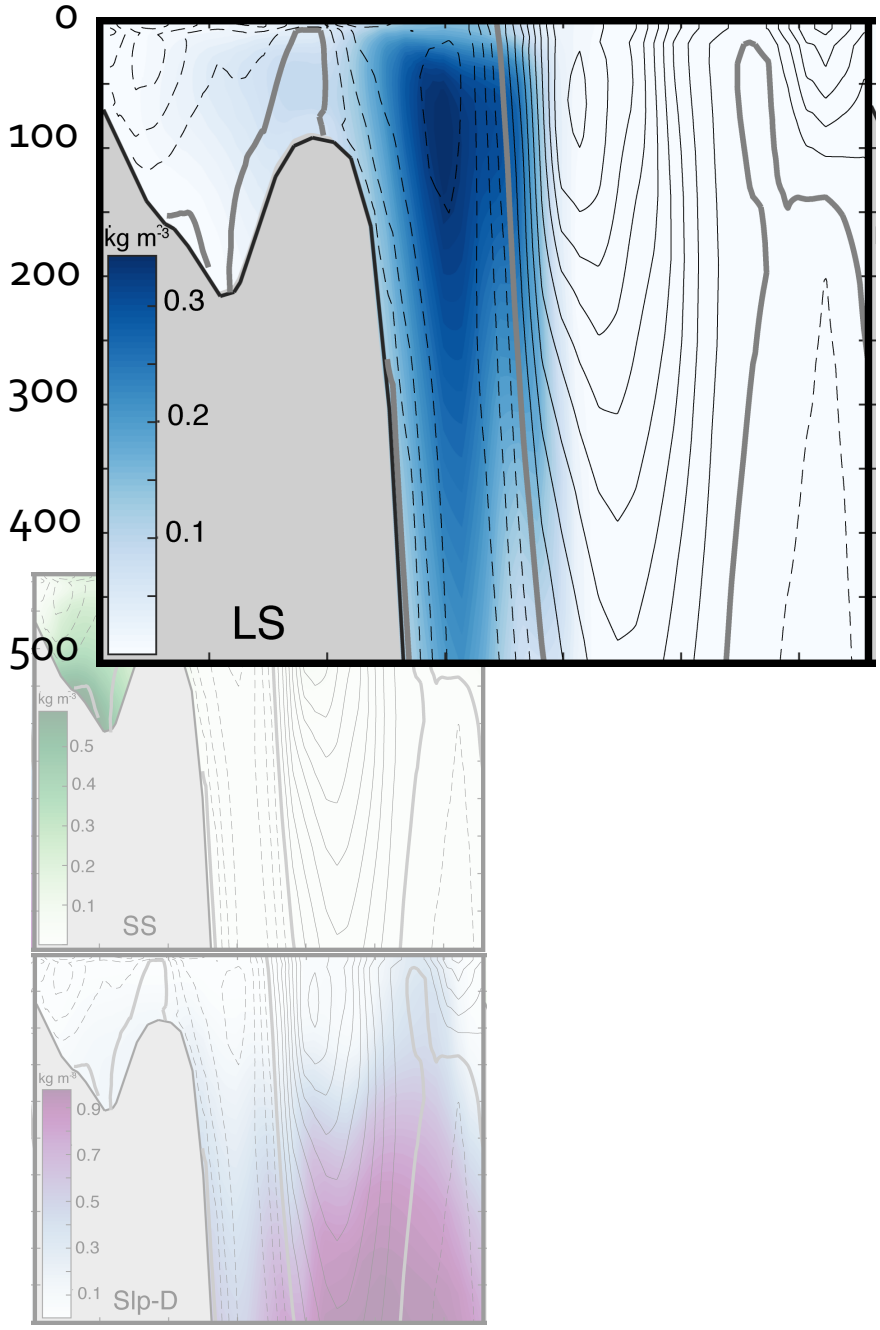
Dye Tracer Initialization





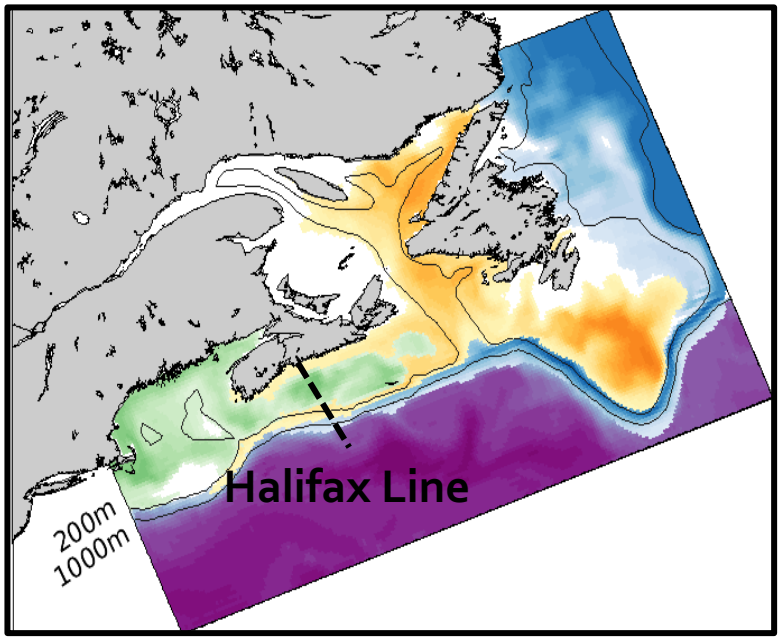
- LS dye moves around Grand Banks, following bathymetry and along the slope of the Scotian Shelf
- Slp-D dye does not move onto the shelf
- SS dye moves quickly to the south, with some dye remaining mid-shelf
- A portion of the GB dye remains on the shallow portion of Grand Banks

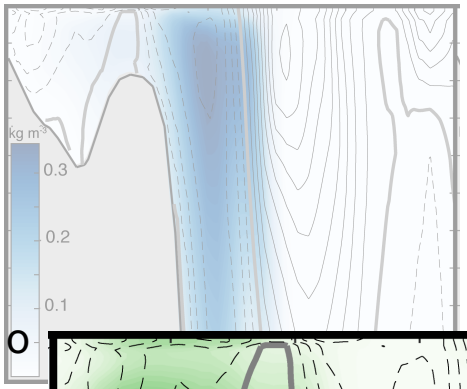
** vertically integrated dye concentrations*

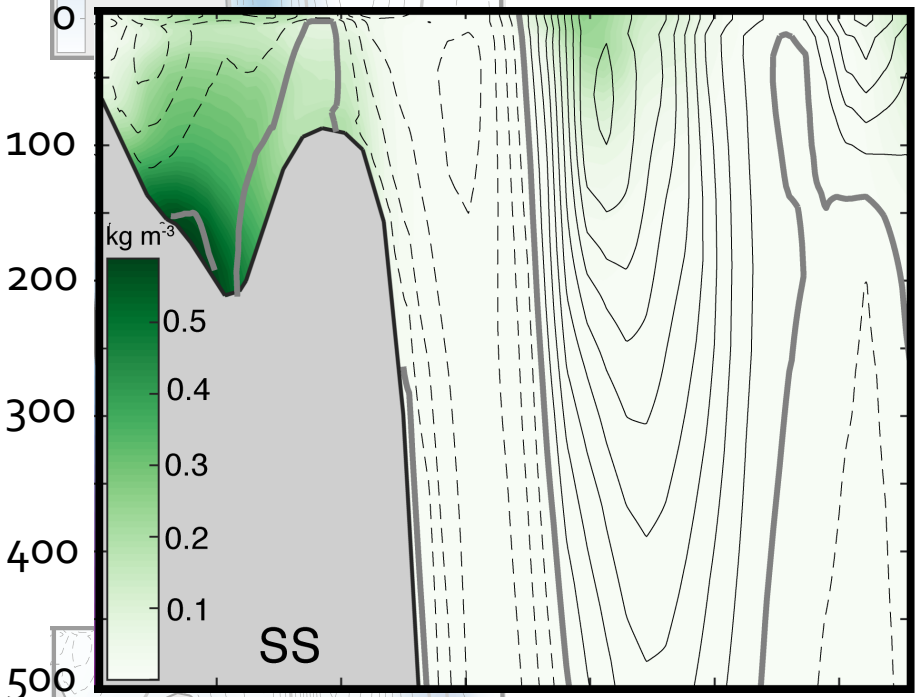


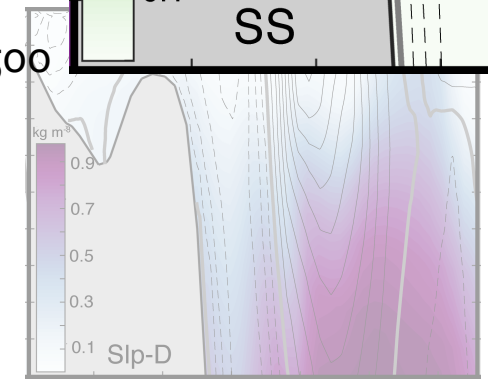
Zero flow
Northward flow (into the page)
Southward flow (out of the page)

* Transects from June 16, 1999 (6 months into simulation)



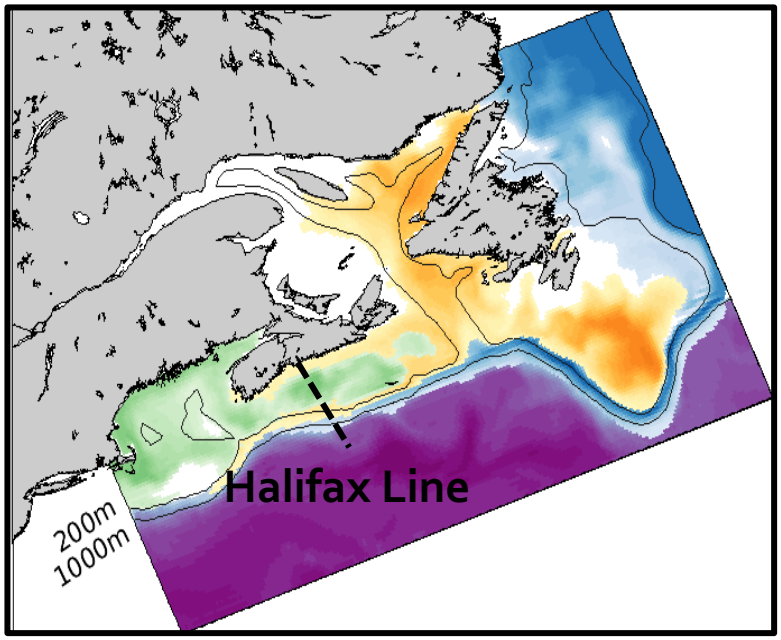


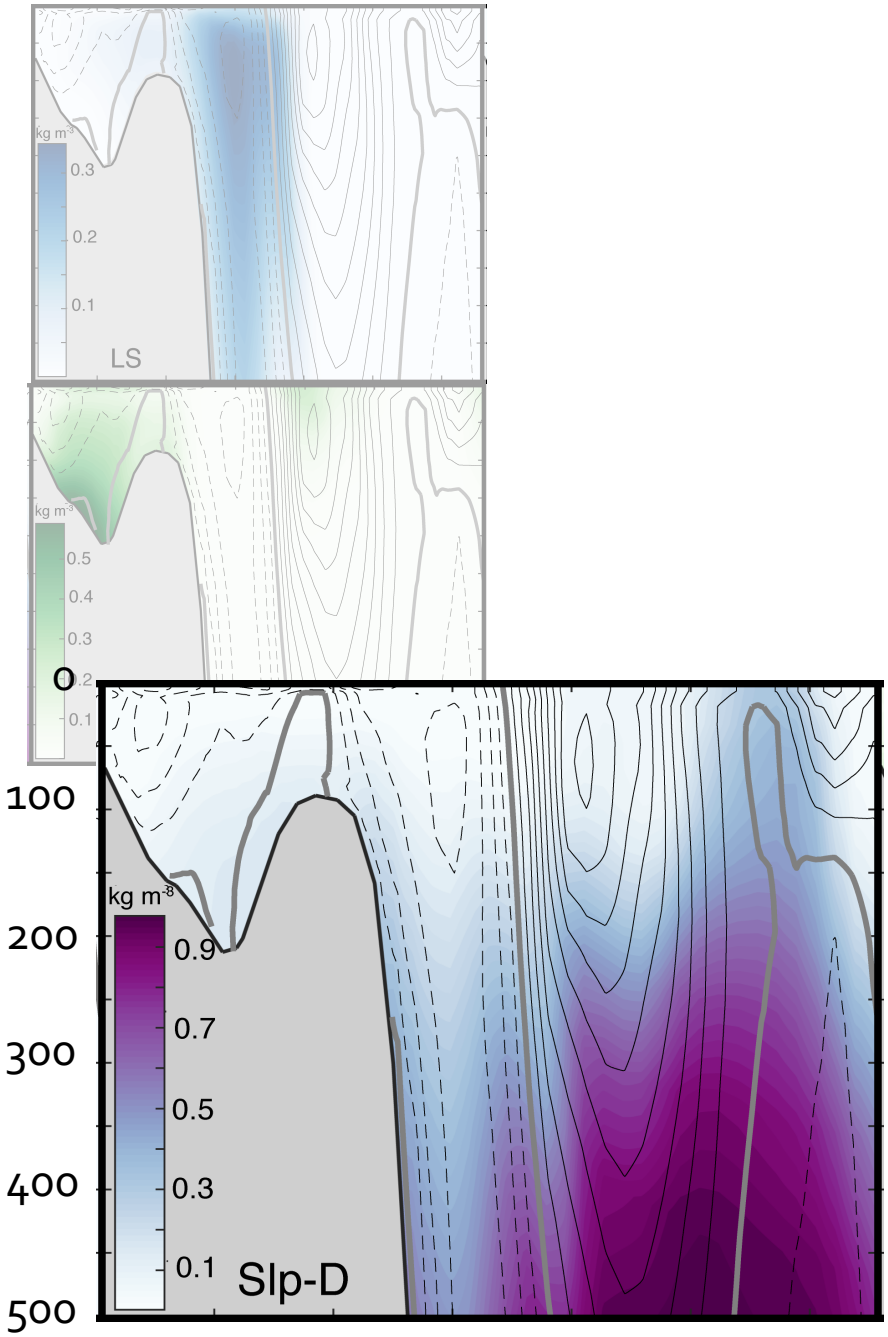




Zero flow
Northward flow (into the page)
Southward flow (out of the page)

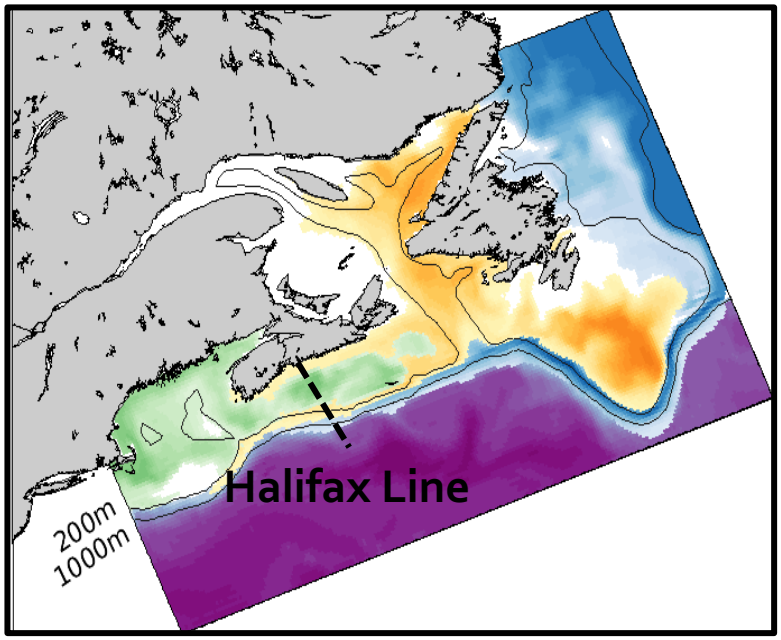
* Transcects from June 16, 1999 (6 months into simulation)

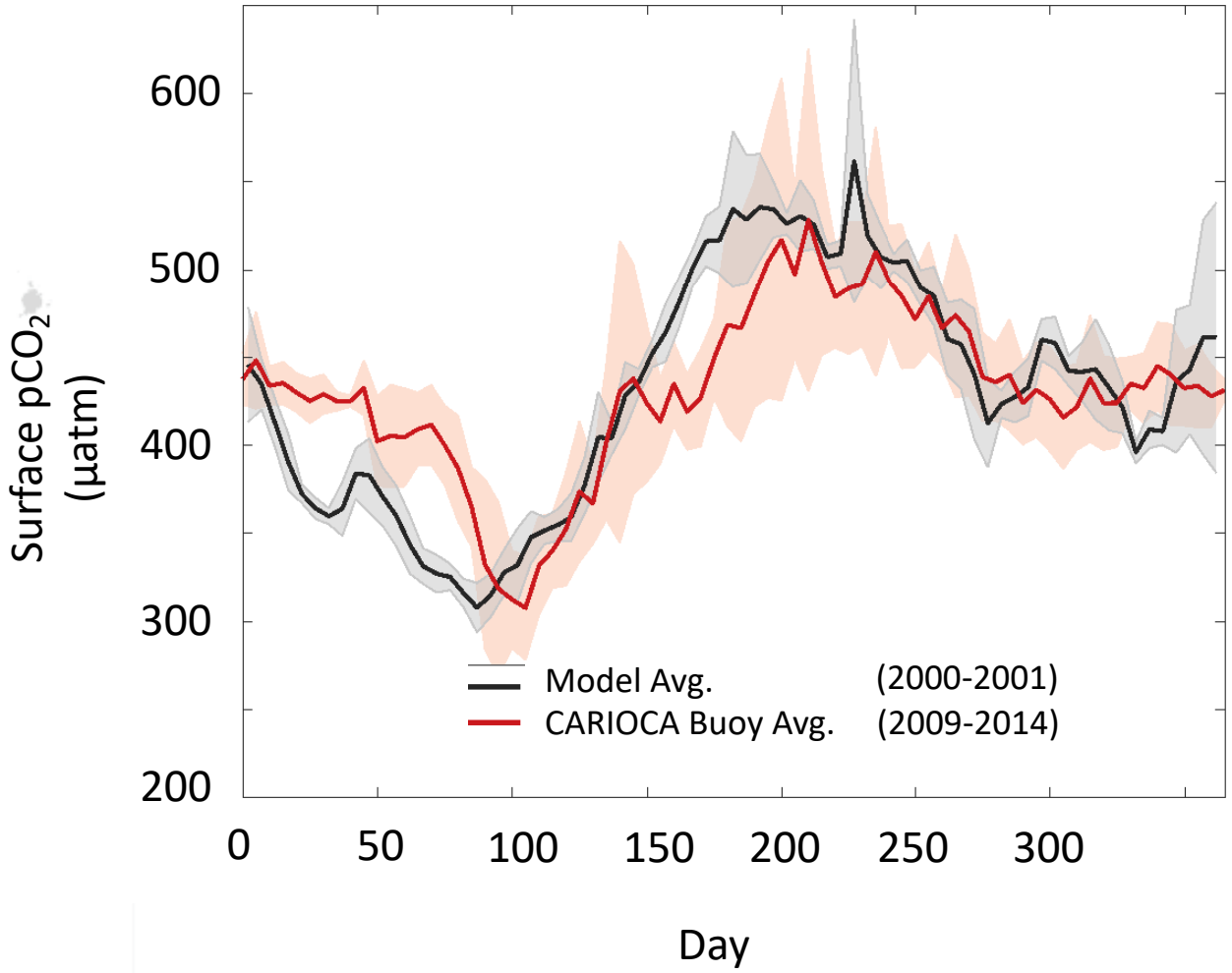


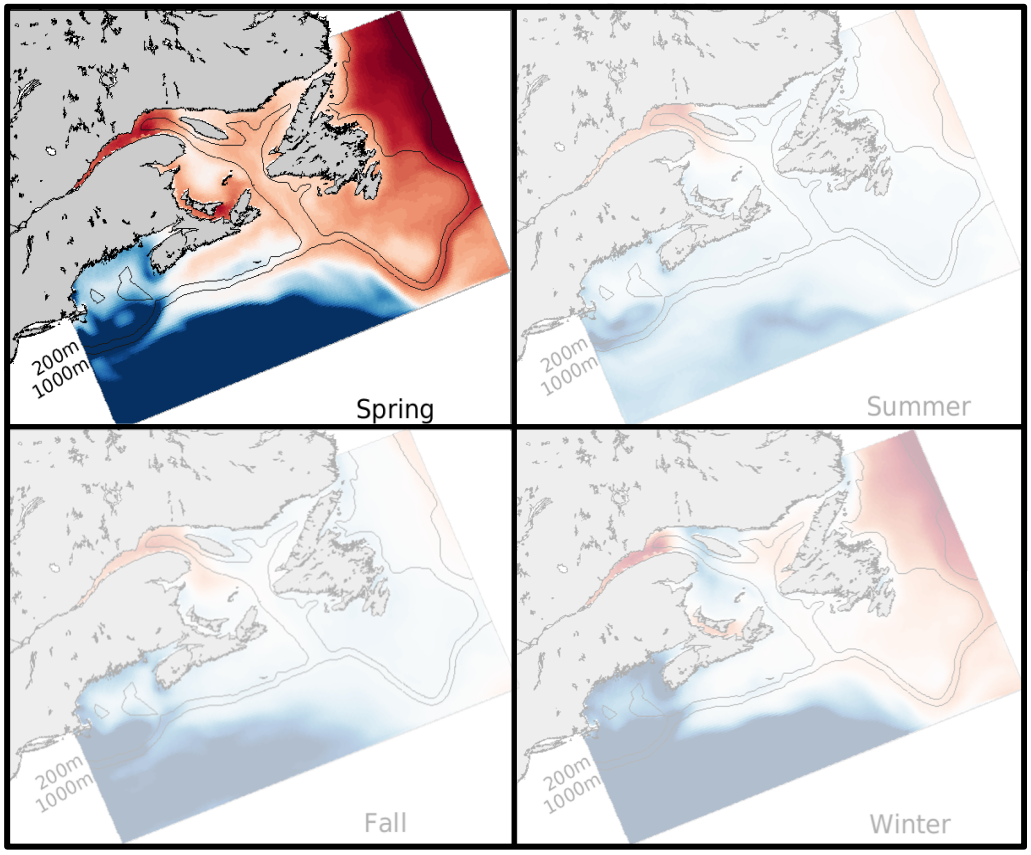


Zero flow
Northward flow (into the page)
Southward flow (out of the page)

* Transects from June 16, 1999 (6 months into simulation)




Surface pCO_2 (µatm)
600
500
400
300
200
0
50
100
150
200
250
300
Day
Model Avg. (2000-2001)
CARIOCA Buoy Avg. (2009-2014)

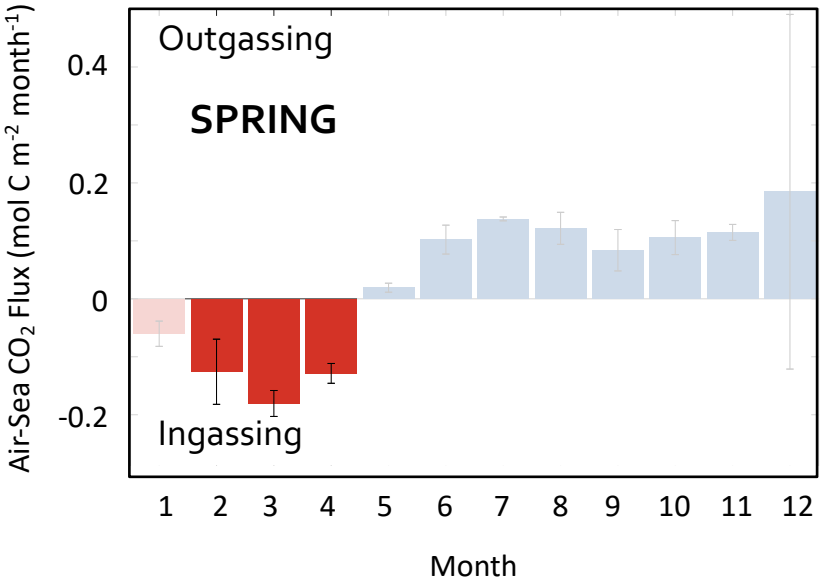


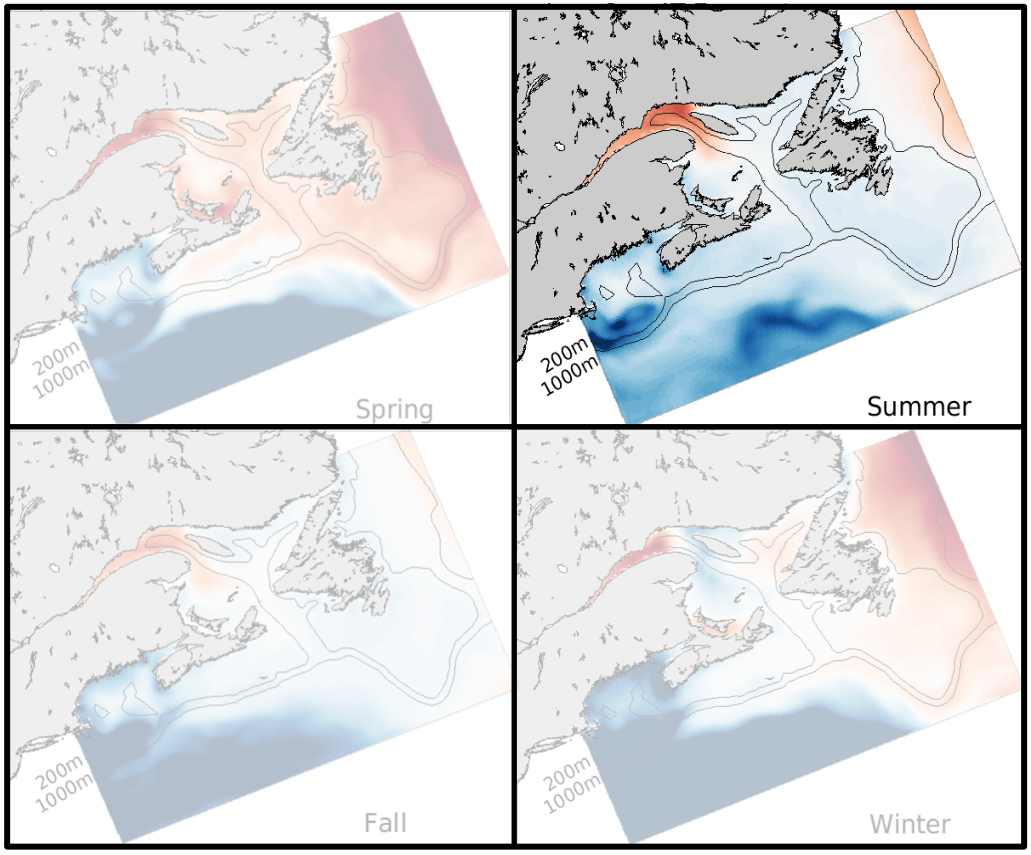
Seasonal Average CO_2 Flux

Ingassing Neutral Outgassing

-0.5 0 0.5

mol C m^{-2} $month^{-1}$



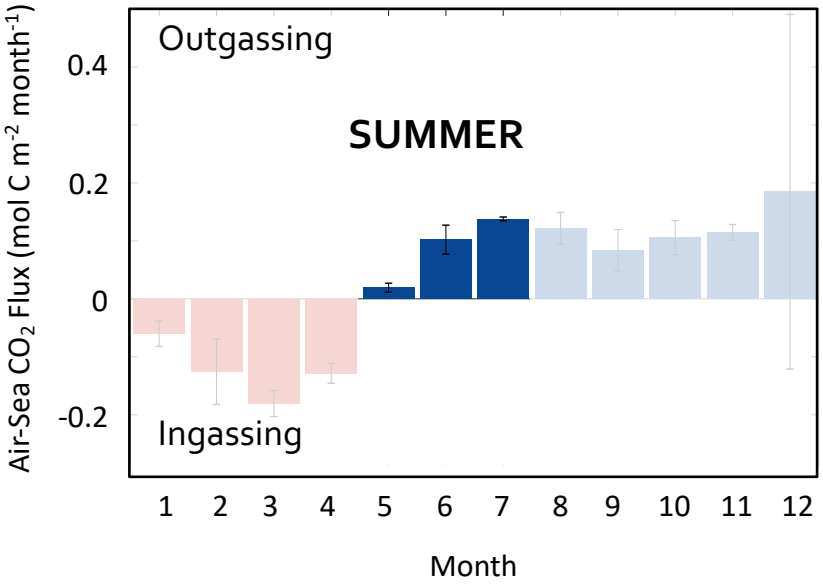


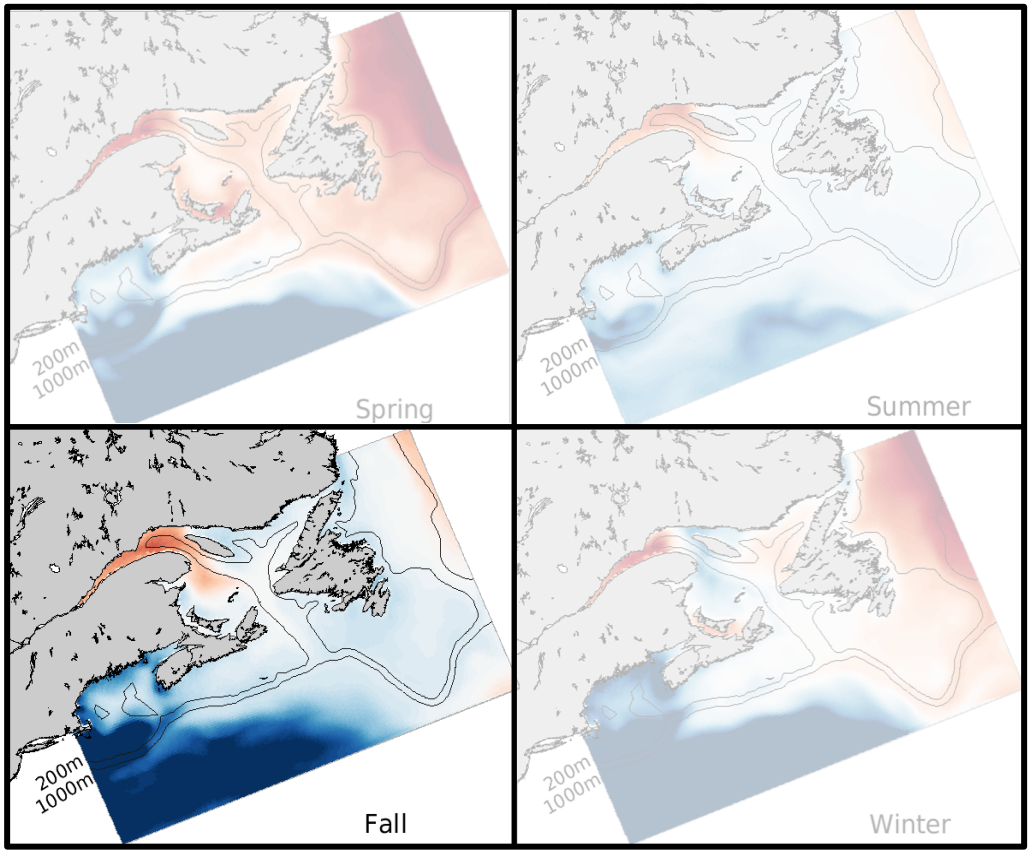
Seasonal Average CO_2 Flux

Ingassing Neutral Outgassing

-0.5 0 0.5

mol C m^{-2} $month^{-1}$



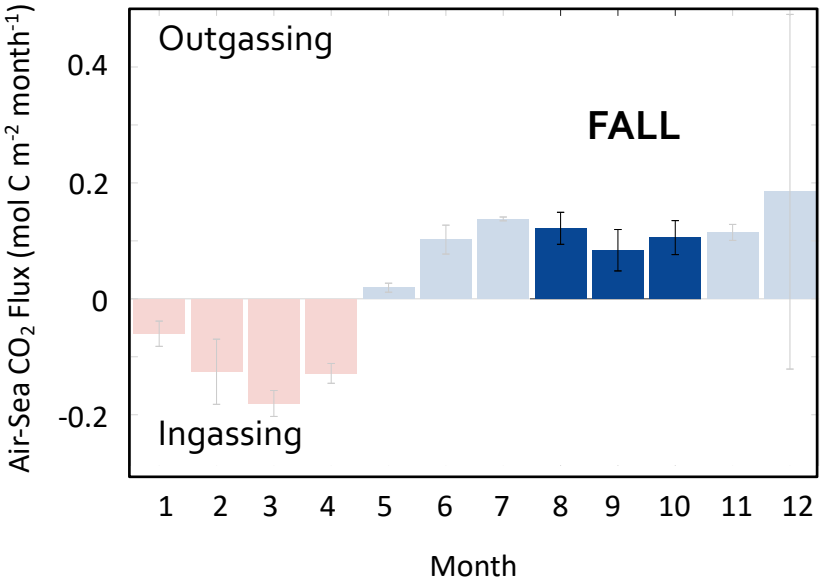


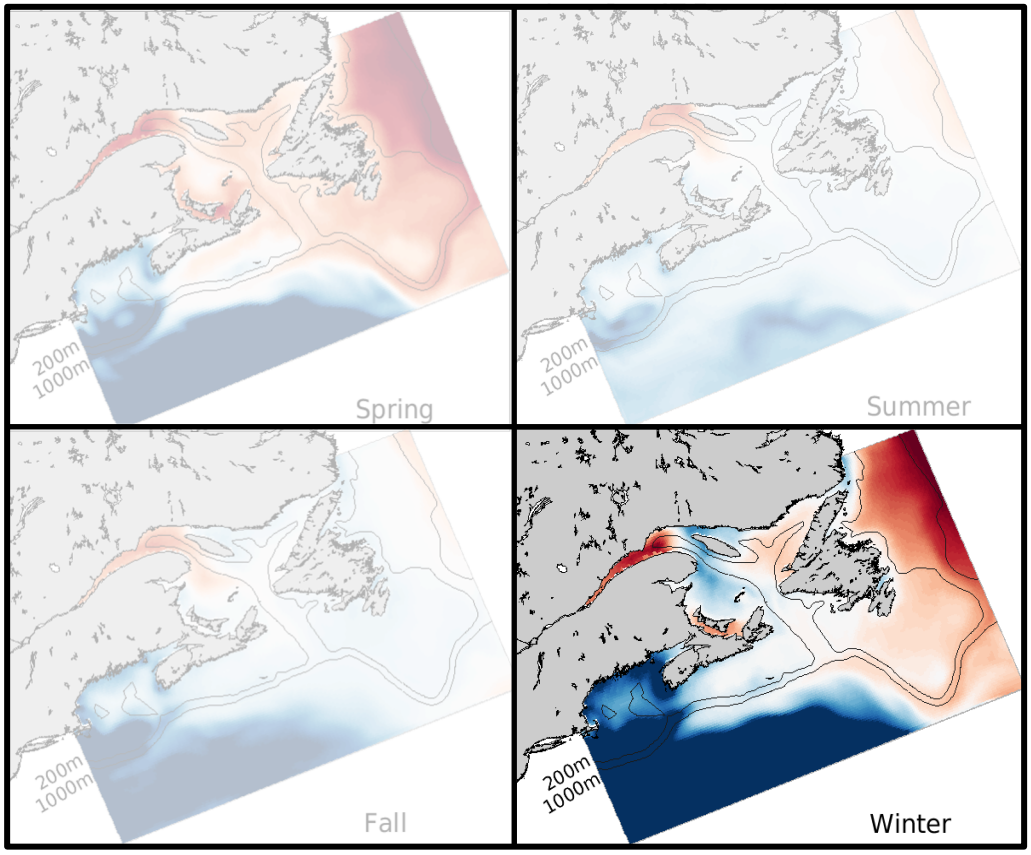
Seasonal Average CO_2 Flux

Ingassing Neutral Outgassing

-0.5 0 0.5

mol C m^{-2} $month^{-1}$



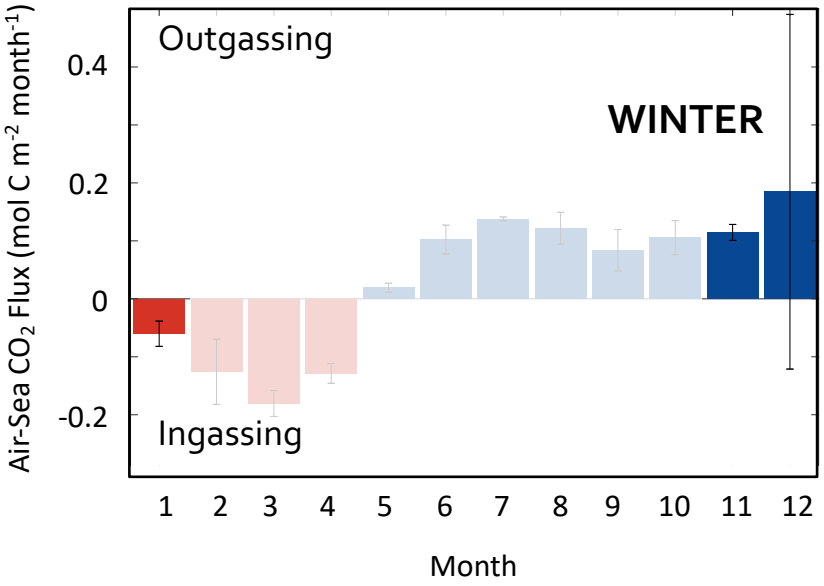


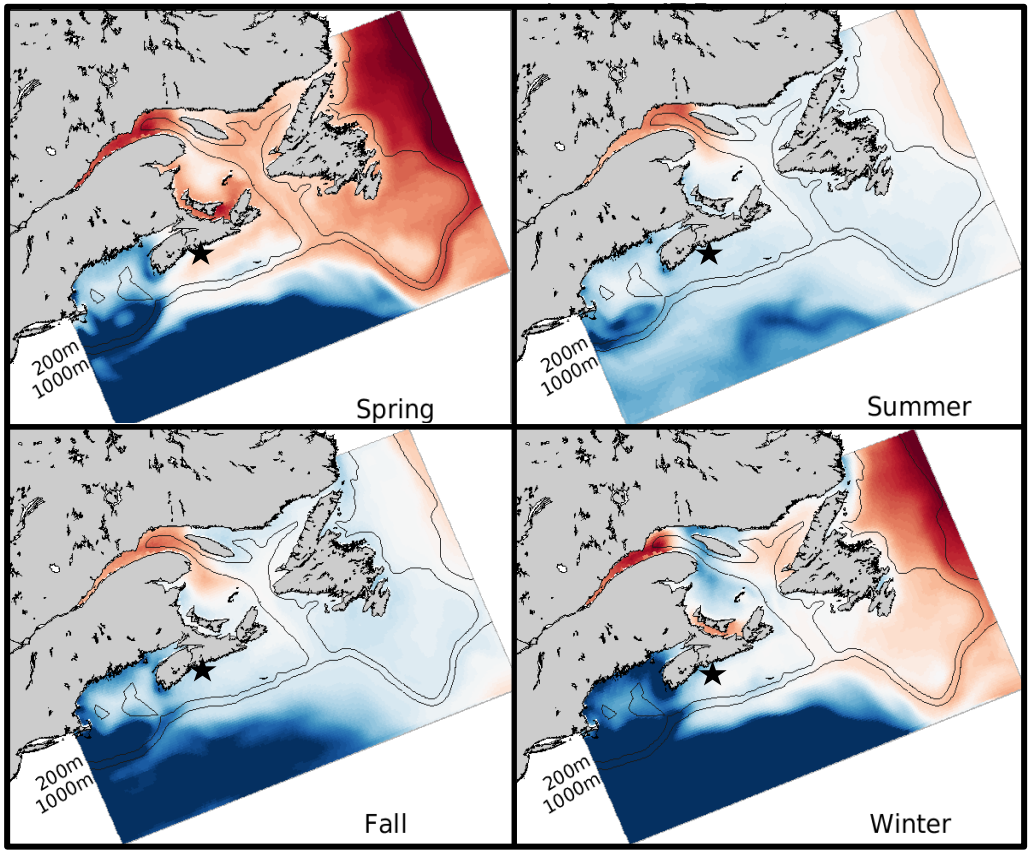
Seasonal Average CO_2 Flux

Ingassing Neutral Outgassing

-0.5 0 0.5

mol C m^{-2} $month^{-1}$





Seasonal Average CO_2 Flux

Ingassing Neutral Outgassing

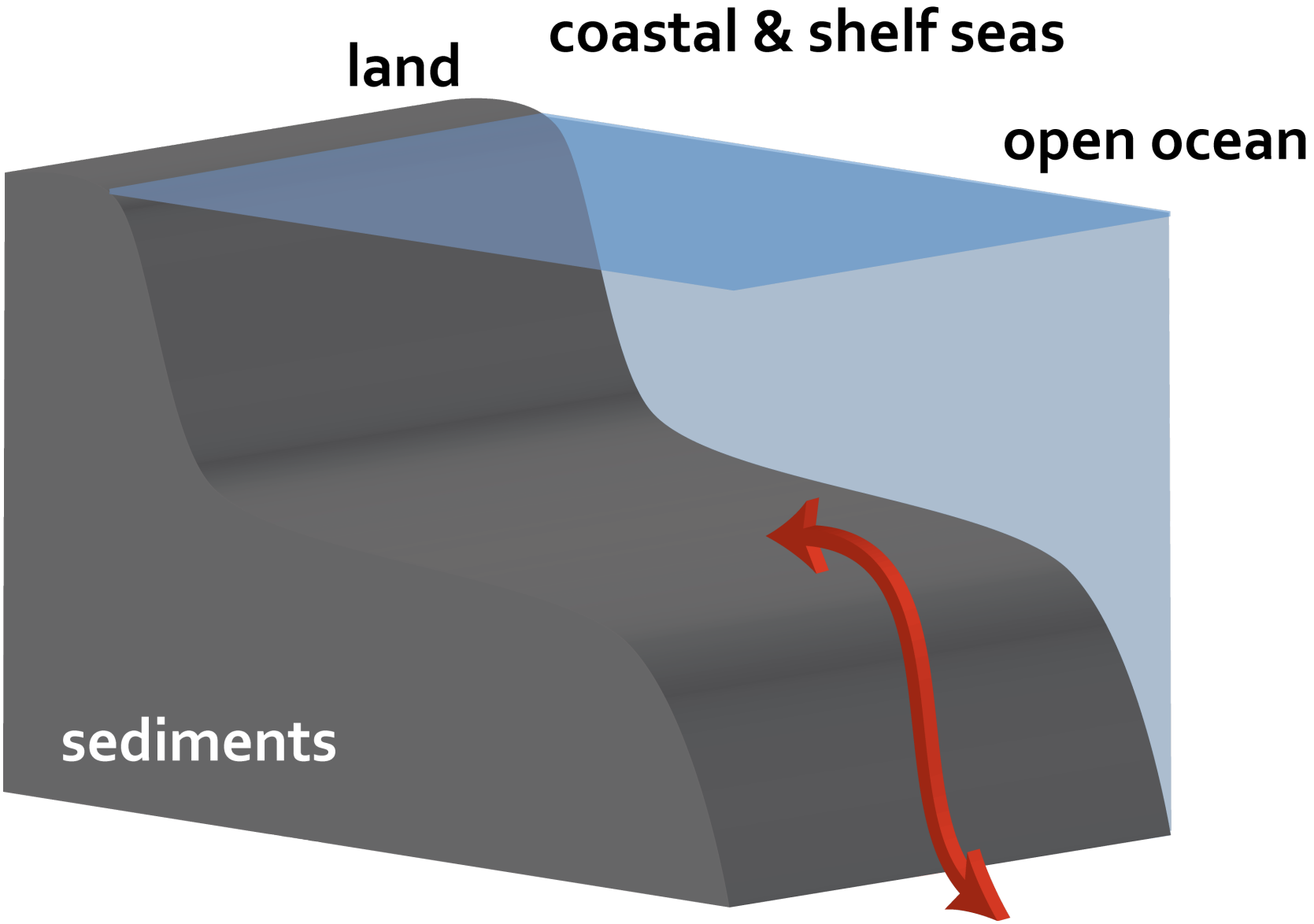
-0.5 0 0.5

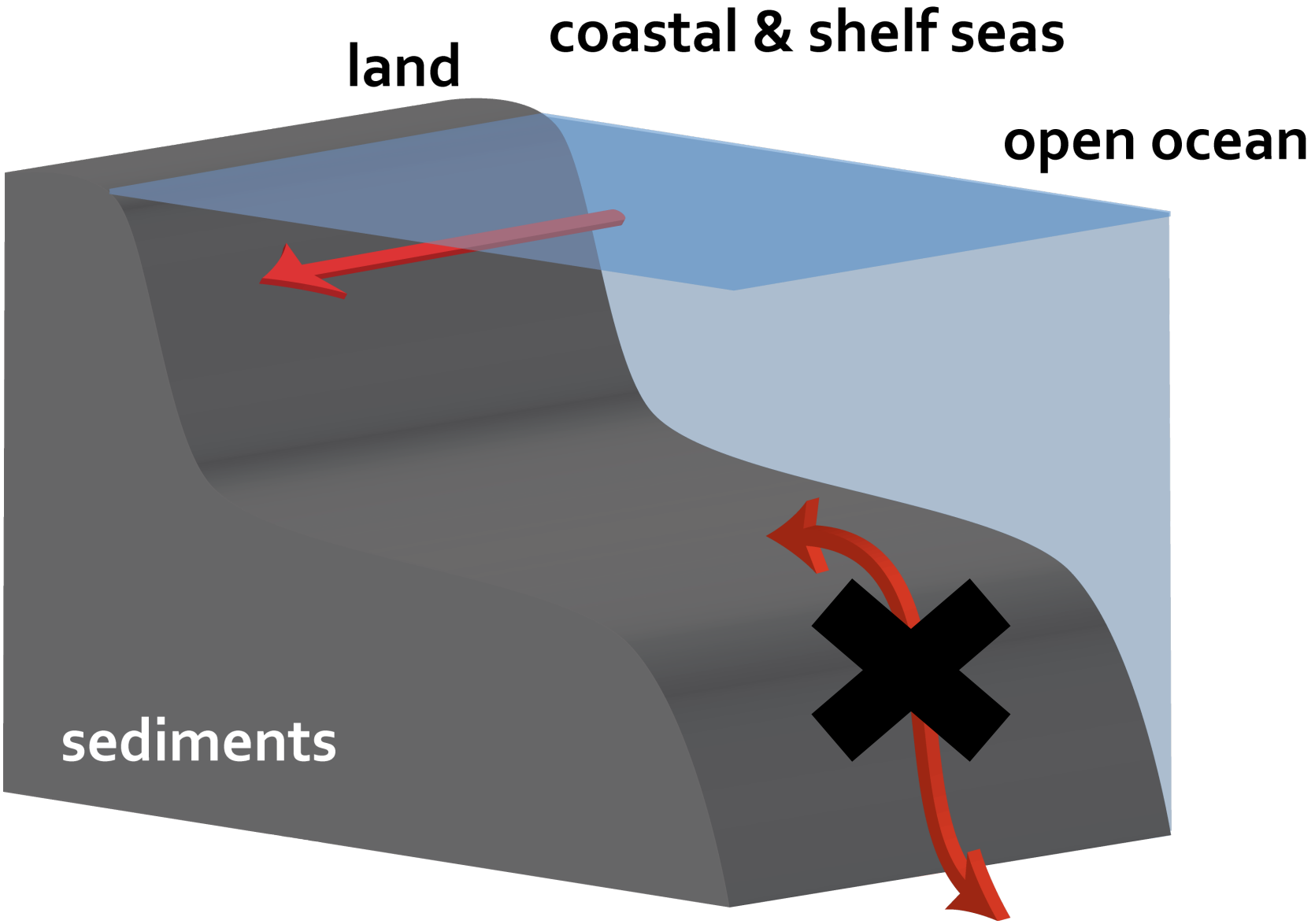
mol C m^{-2} $month^{-1}$

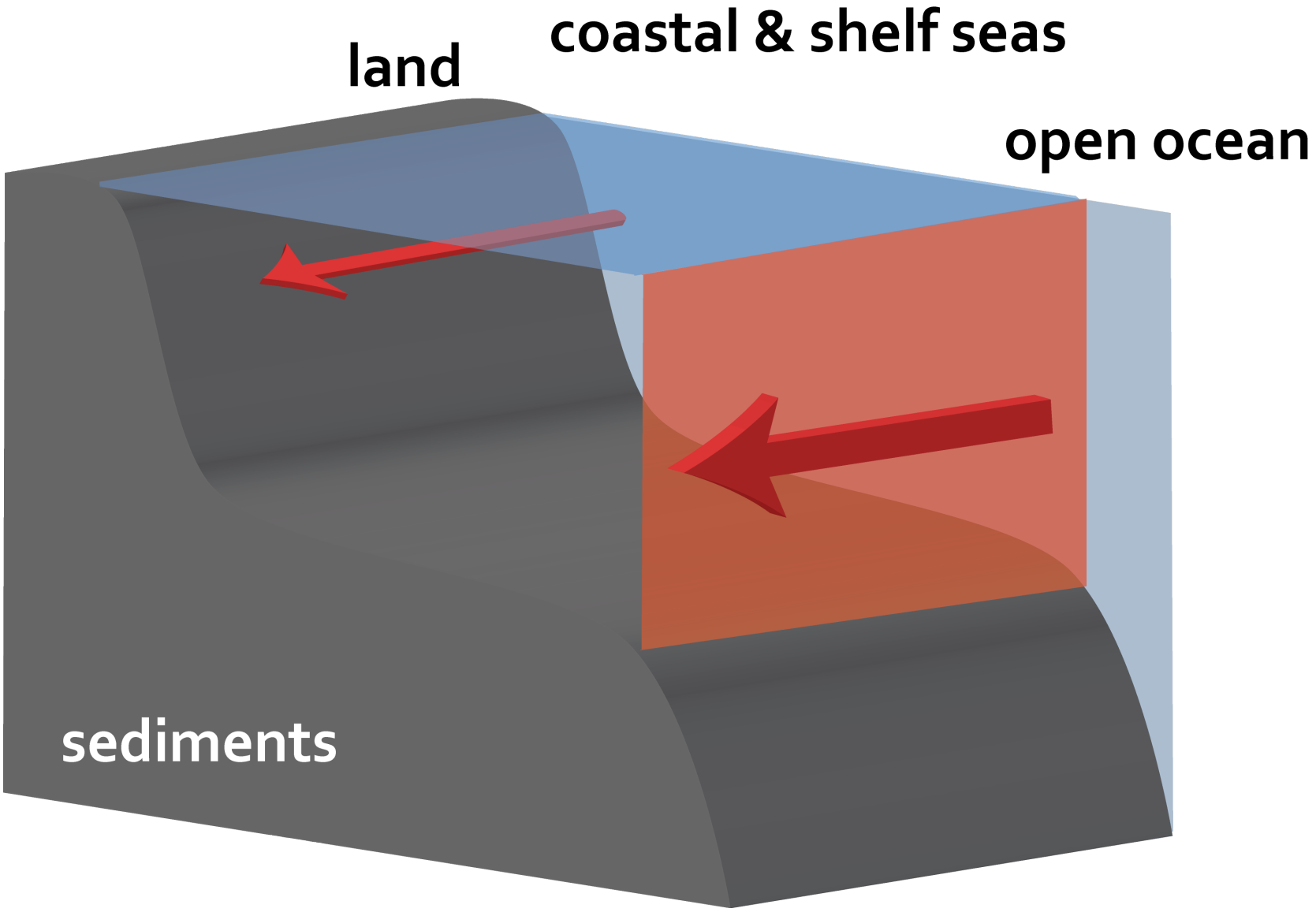
Yearly Flux Estimates (mol C m^{-2} yr^{-1})

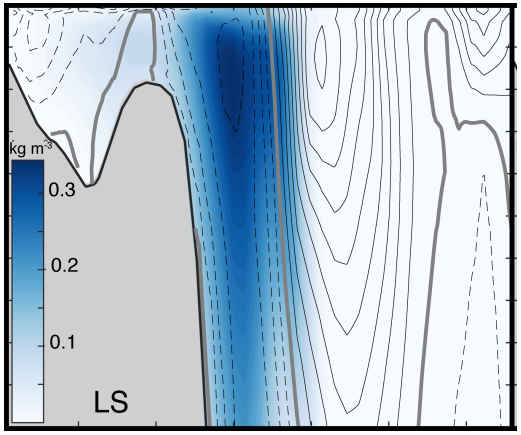
Laruelle et al. 2014	-0.33 ± 0.25
Laruelle et al. 2015	- 0.25 ± 0.08
Shadwick et al. 2011	+ 1.42 ± 0.28
Signorini et al. 2013	- 1.10 ± 0.25

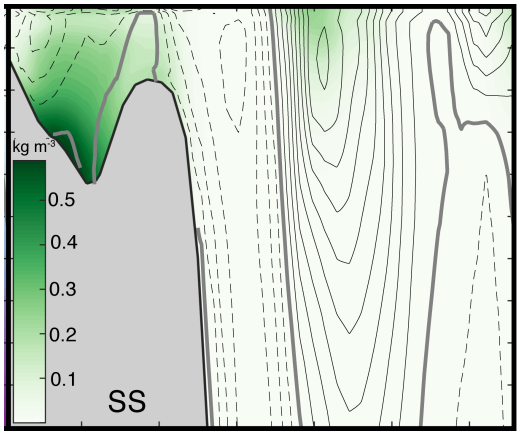
Scotian Shelf (ROMS):	+0.37 ± 1.17
CARIOCA Buoy (ROMS):	+1.13 ± 0.30
CARIOCA Buoy (Observations):	+1.15 ± 1.38

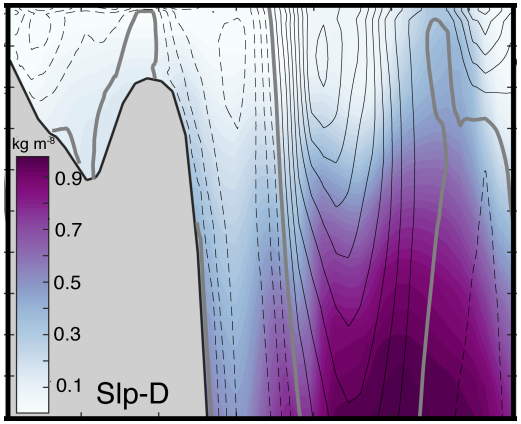

land
coastal & shelf seas
open ocean
sediments

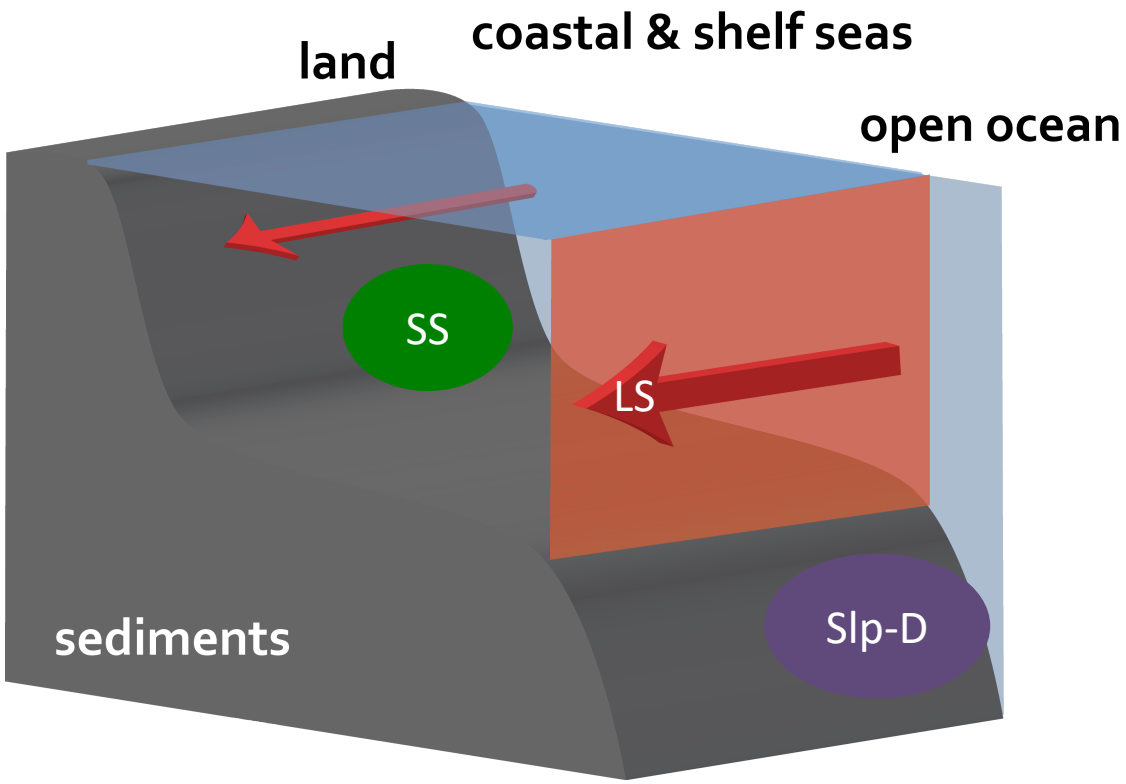

land
coastal & shelf seas
open ocean
sediments


land
coastal & shelf seas
open ocean
sediments



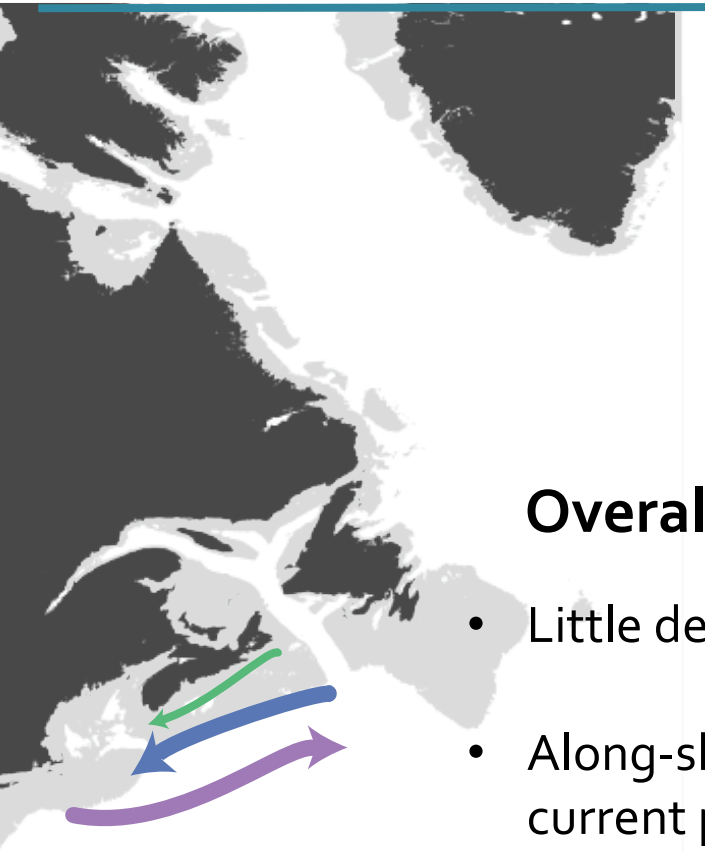


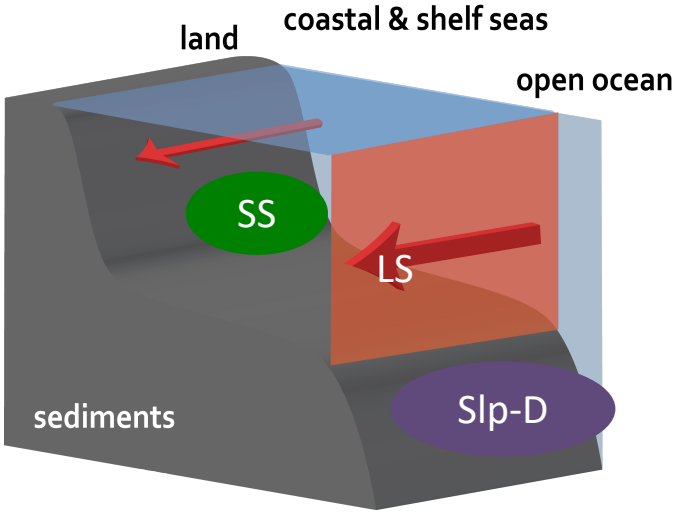




Zero flow
Northward flow (into the page)
Southward flow (out of the page)

* Transects from June 16, 1999 (6 months into simulation)





Overall…

- Little deep slope water is upwelled onto the Scotian Shelf
- Along-shelf transport pathways and a strong shelfbreak current prevent the continental shelf pump here
- Instead, dominant pathways are delivering waters from GoSL and GB to SS, and quick along-shelf transport
- Pathways result in high carbon concentrations near-shore (outgassing) but net neutral annual CO_2 flux on the shelf as a whole