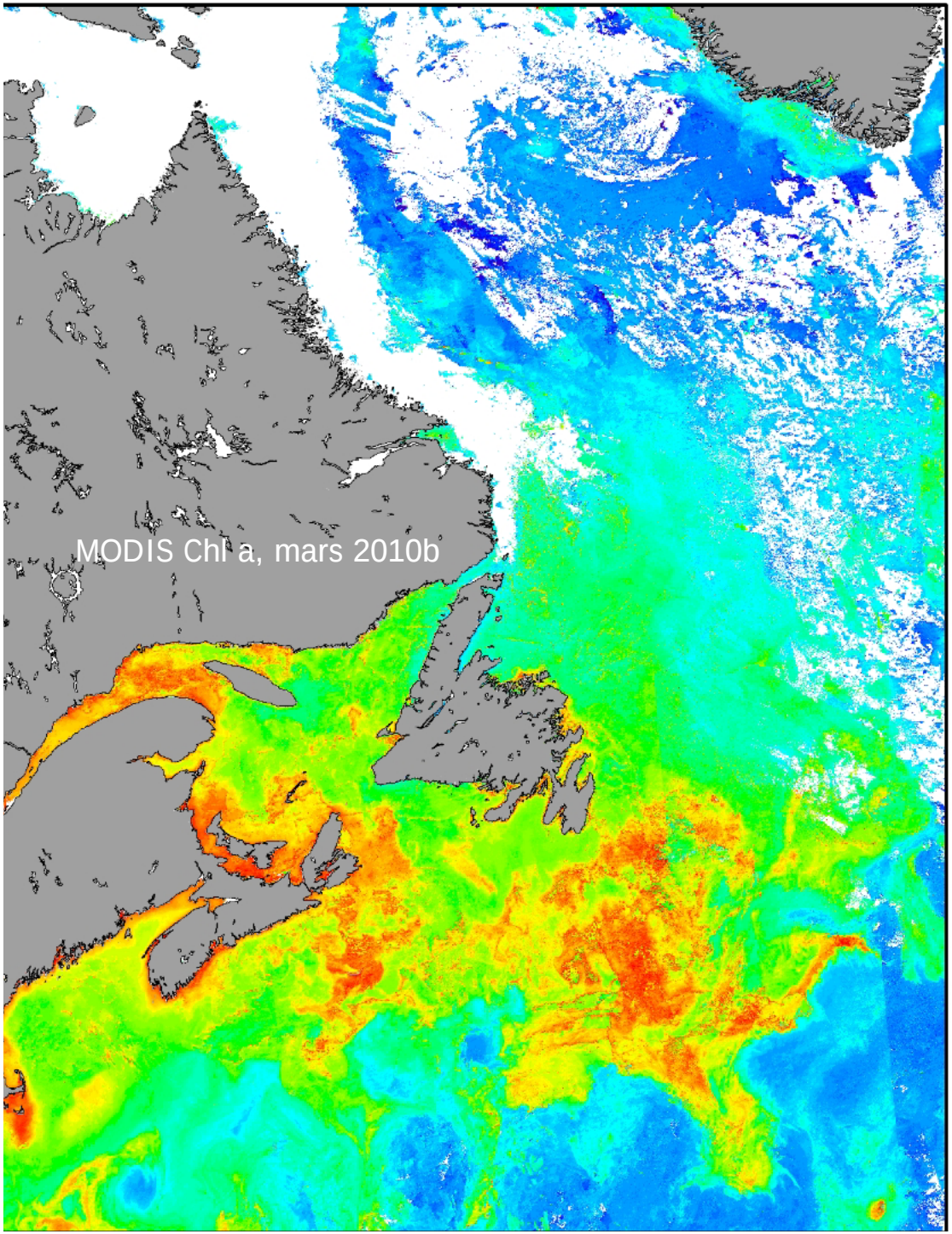


The Gulf of St. Lawrence biogeochemical model: a tool to study past and future human impacts on the ecosystem

D. Lavoie, J. Chassé , D. Brickman, N. Lambert, M. Starr, B. DeTracey, K. Azetsu-Scott, W. Perrie, Z. Long, D. Gilbert

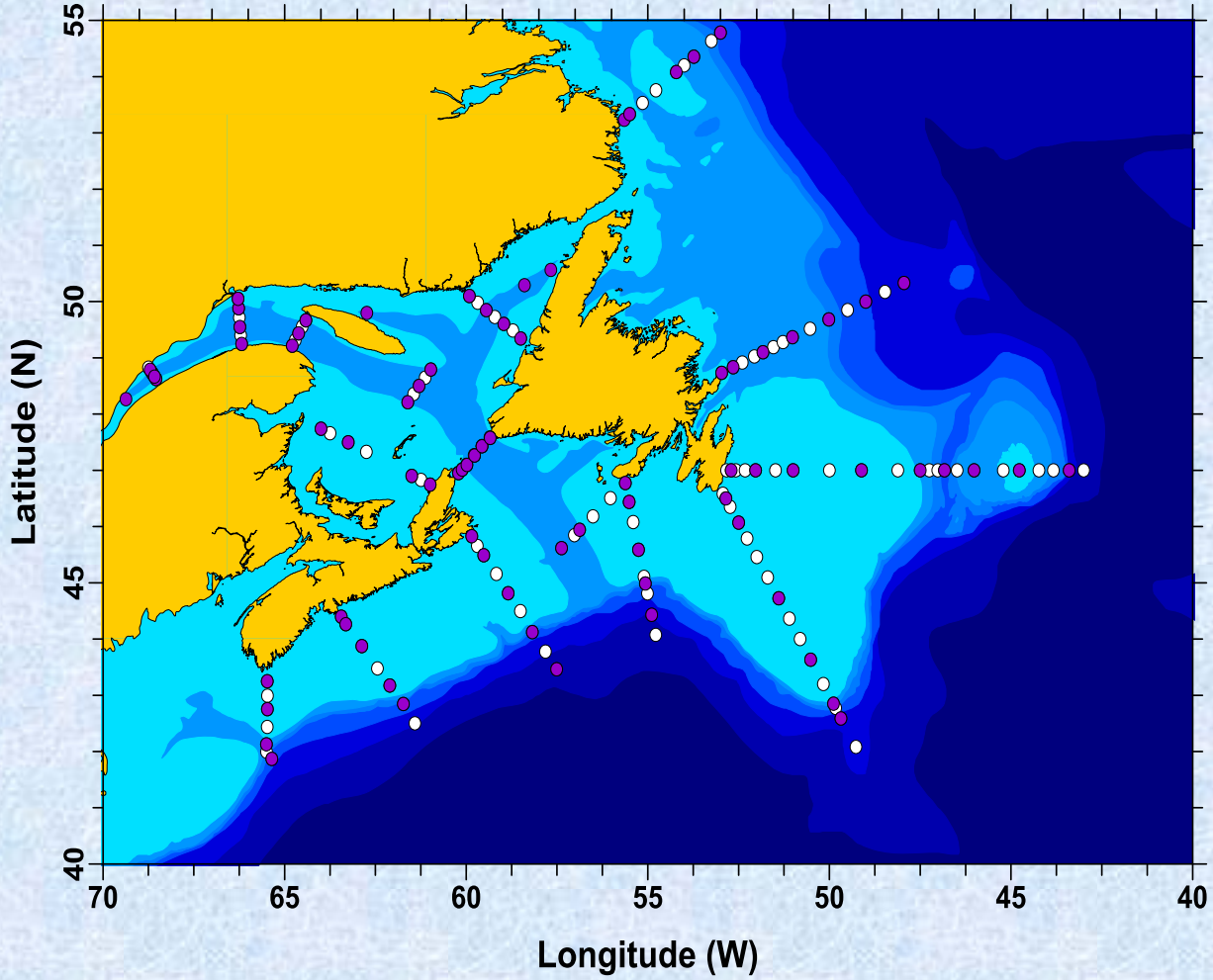
MEOPAR-GODAE meeting
Dalhousie University, Halifax
23-24 June 2015

Outline

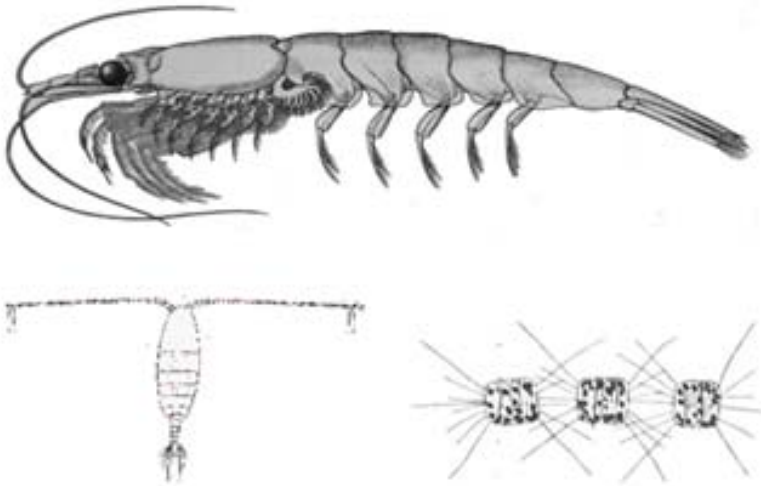
- Applications that need modelling tool:
  - Hindcast to understand variability of the system
  - Long-term projections
  - Seasonal forecasts for fisheries (in development by D. Brickman)
- Description of the model
  - Need simulations in « equilibirum », without restoring or assimilation, for long-term projections
- Some skills and set-up for downscaling

Applications

- Atlantic Zone Monitoring Program, since 1998



OCEANOGRAPHIC CONDITIONS IN THE ATLANTIC ZONE IN 2014



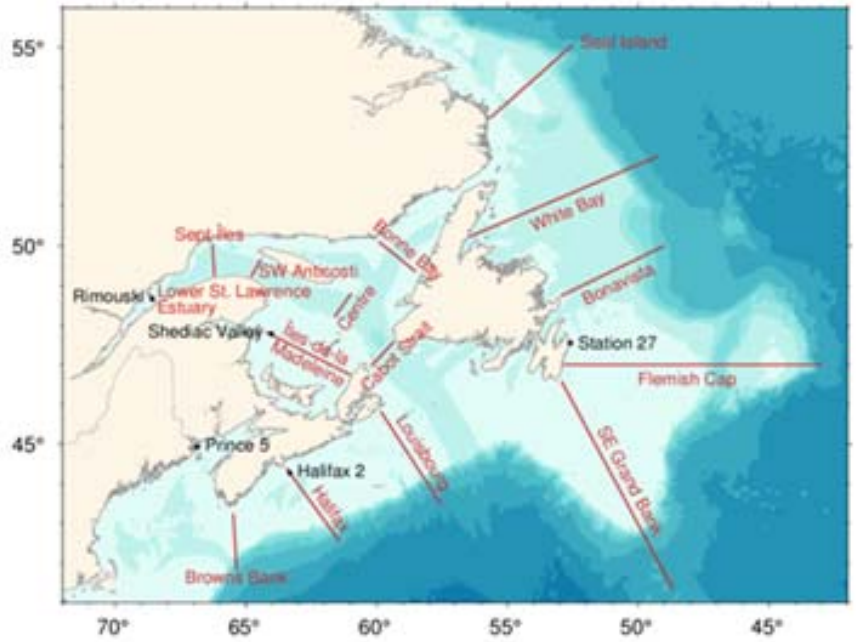


Figure 1. (Left) Key taxa of the pelagic food web: euphausids (top), phytoplankton (bottom right), and copepods (bottom left). Images: Fisheries and Oceans Canada; (Right) Atlantic Zone Monitoring Program high-frequency sampling stations (black) and selected section lines (red).

Scorecards of mean June 0-50 m NO_3 (1999-2014)

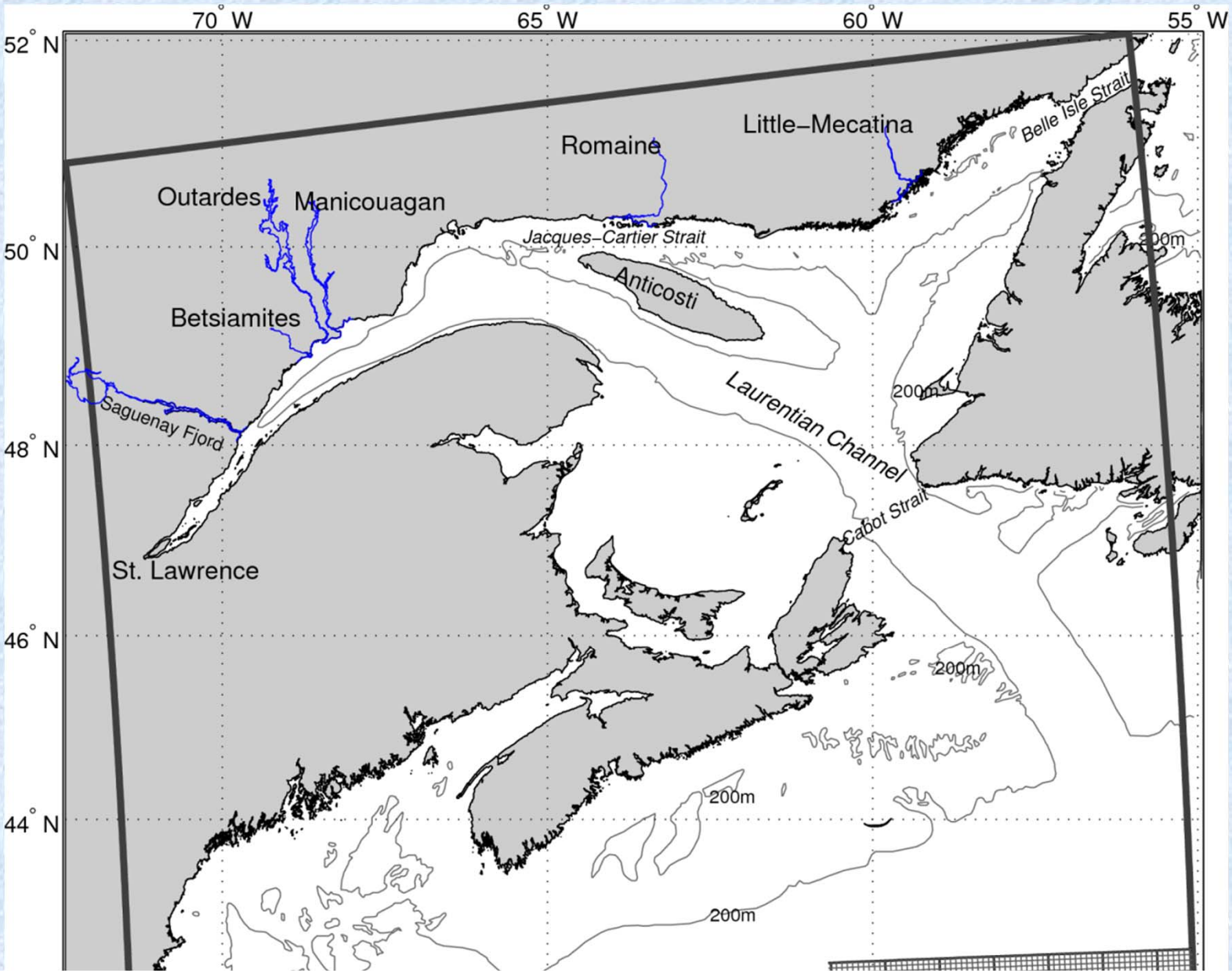
Nitrate 0–50m (June)	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean	STD
Lower Estuary	−1.44	−0.40	−0.69	+2.27	+0.06	−0.14	+1.12	−1.00	+0.60	+0.13	+1.09	−0.92	−0.68	10.938	+/− 0.628
NorthWest Gulf	−1.27	+0.35	+0.90	−0.18	+1.28	+0.34	−0.55	−0.36	+1.27	+0.33	+0.25	+0.19	−2.53	5.497	+/− 0.438
Anticosti Channel	+1.11	−0.04	+1.39	+1.06	+1.01	−0.48	−1.04	−0.09	+0.11	+0.84	−0.98	−0.97	−1.94	1.874	+/− 0.228
Chaleur Bay	+0.54	+0.41	−0.18	+0.57	−1.46	+1.11	−0.87	−0.10	−1.25	+0.26	+2.20	+0.03	−1.25	3.885	+/− 0.340
Esquiman Channel	−0.41	−0.81	+0.40	−1.10	+1.78	−1.01	+0.24	−0.31	+0.40	+1.83	−1.59	+0.64	−0.06	1.232	+/− 0.340
Central Gulf	+0.76	−0.26	+0.20	−1.06	+0.83	+0.13	−0.80	−0.02	−0.91	+2.79	−0.91	−0.64	−0.11	2.630	+/− 0.207
Cabot Strait	−0.25	−2.36	+0.53	−1.56	+1.13	+0.92	−0.81	+0.75	+0.74	+0.59	+0.46	+0.26	−0.41	1.749	+/− 0.157
Magdalen Shallows	−0.89	+0.02	+1.15	−1.21	+0.21	−0.06	+0.75	+1.49	−0.74	+1.47	+0.10	−1.94	−0.36	2.858	+/− 0.291

← Model

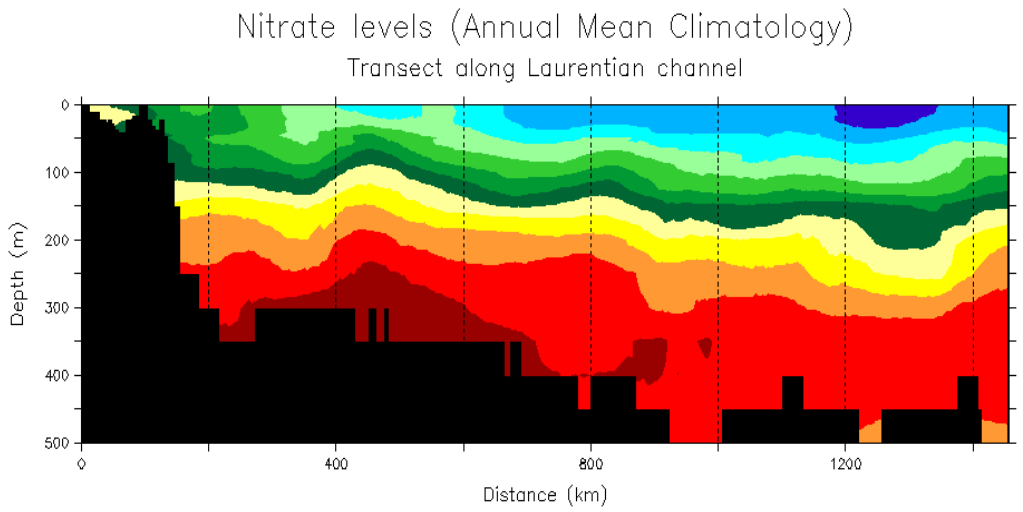
Obs

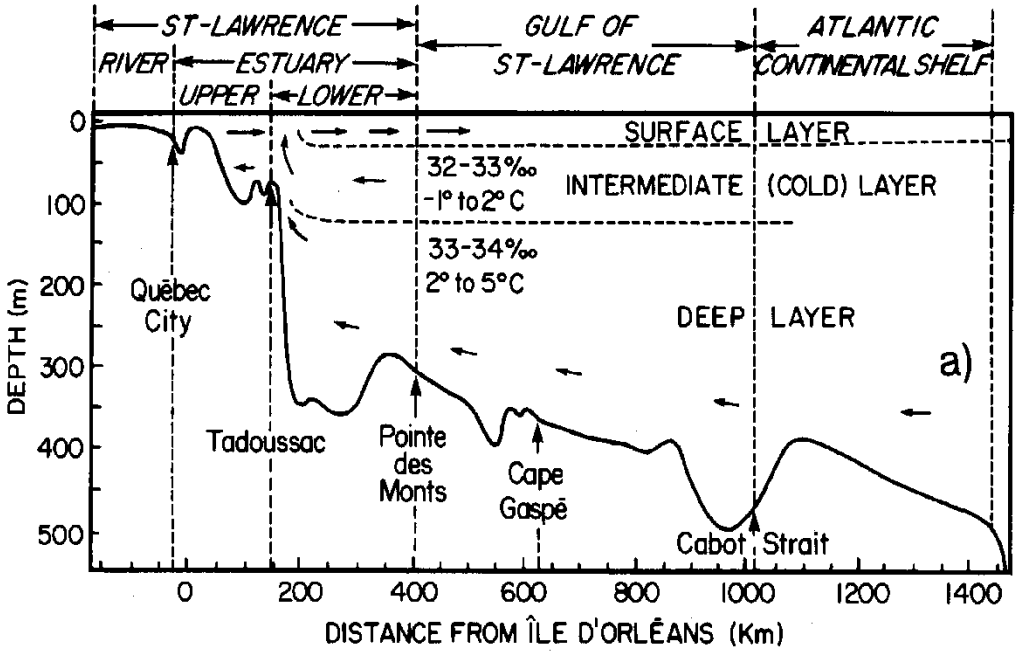
NO_3 à 0-50 m	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Moy. ± E.T.
1 - Estuaire			7.4	11.8	9.9	11.9	8.4	10.4	9.8	10.7	8.1	9.7	7.5	7.0	7.8	9.2	12.1	10.9	9.38 ± 1.70
2 - Nord-ouest du Golfe	4.6	3.7	2.7	3.1	4.5	5.0	5.3	3.7	3.4	3.1	3.5	4.0	3.7	2.1	2.6	2.6	4.6	6.2	3.75 ± 0.88
3 - Chenal Anticosti	0.8	0.7	1.7	1.9	0.5		1.9	0.9	0.3	1.7	1.4	0.8	1.0	0.6	0.6	1.0	1.6	2.4	1.10 ± 0.56
4 - Cuvette de Mécatina	1.6	1.0	1.3								2.4		0.9	0.5	0.4	0.5	0.8	1.0	1.27 ± 0.67
5 - Chenal Esquiman	1.3	1.0	0.8	1.6	1.3	0.9	2.2	0.5	0.9	1.0	1.5	1.8	0.8	1.4	0.6	1.1	0.6	2.6	1.20 ± 0.47
6 - Centre du Golfe	1.0	0.5	1.3	1.4	1.9			0.8	1.9	1.7	1.4	2.0	1.4	1.1	0.9	0.7	2.4	2.5	1.35 ± 0.47
7 - Détroit de Cabot	1.2	1.1	1.2	1.5	1.1	0.7	1.6	1.2	1.2	1.9	1.8	2.2	1.5	0.9	1.2	1.1	1.5	1.4	1.36 ± 0.42
8 - Plateau madelinien	2.7		2.5	2.9	2.3	3.3	3.1	2.5	2.8	4.0	2.7	3.8	3.7	1.3	1.9	1.8	3.6	3.5	2.89 ± 0.71

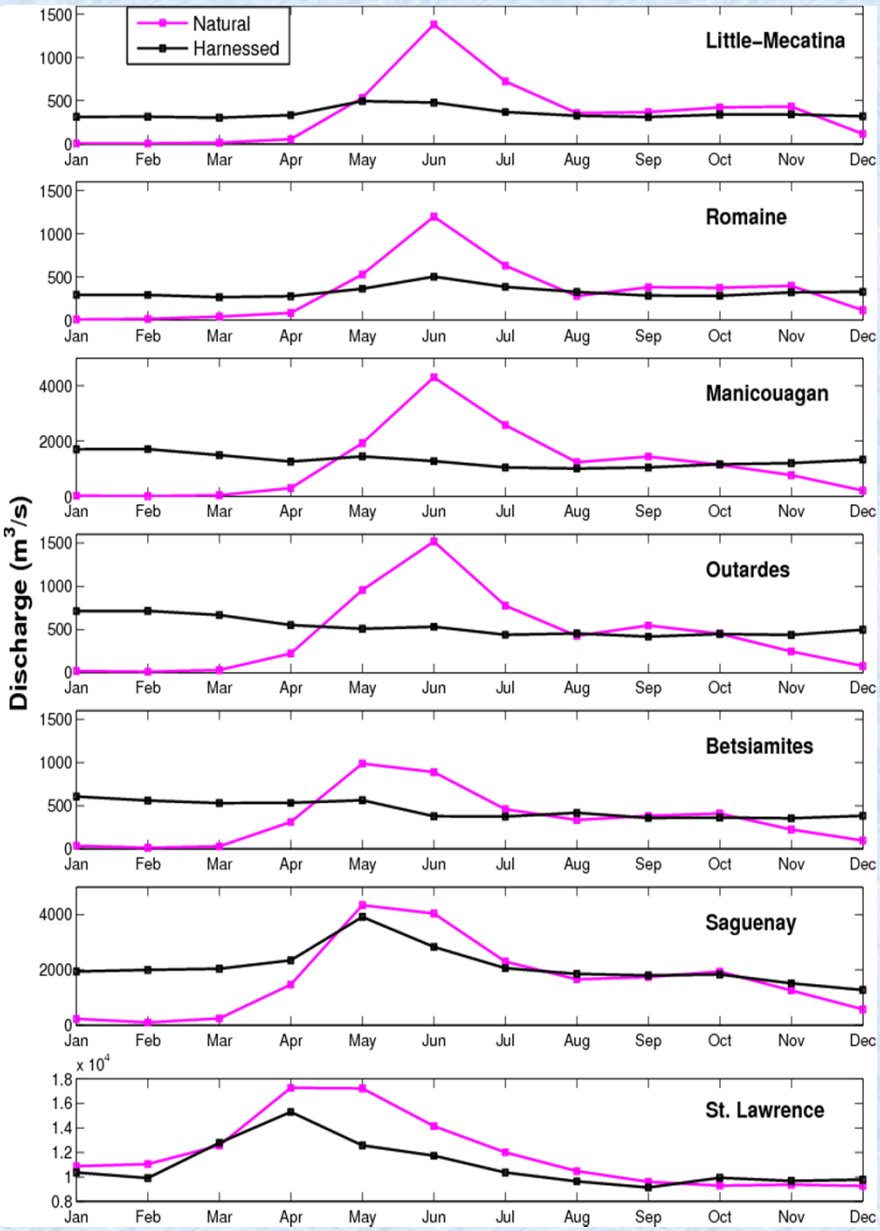
Impact of large hydroelectric dams



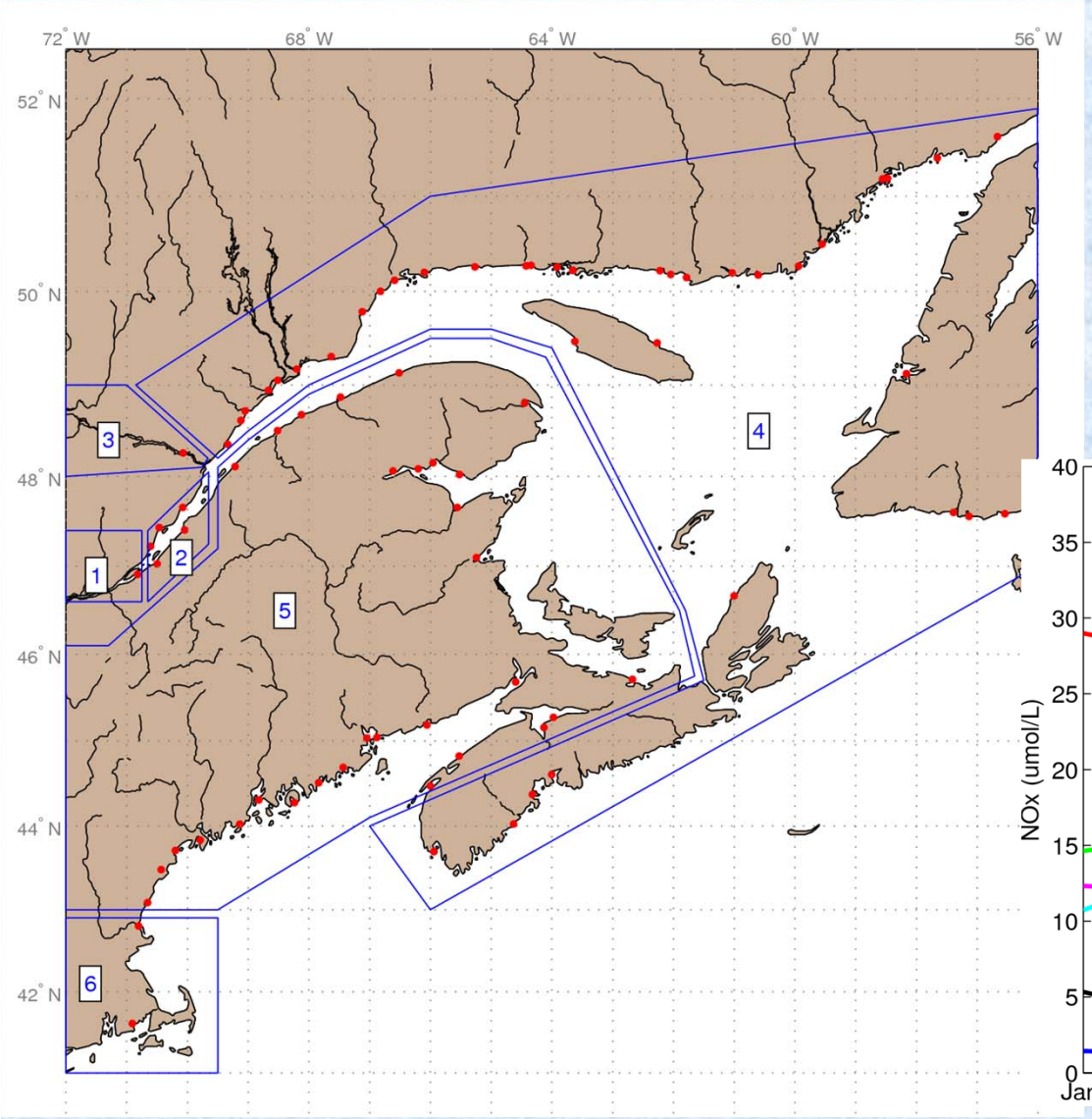
River runoff alterations affect nutrient pump





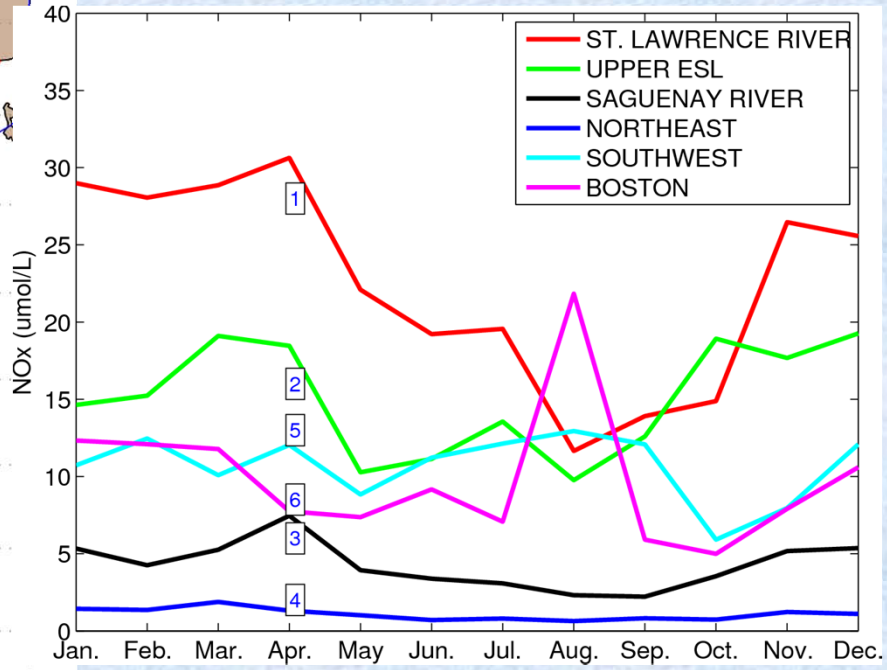


Concentration of nitrate in rivers



Sources:

- MDDEP
- New-Brunswick Gov
- Newfoundland & Lab Gov
- Env. Can.
- US geological survey
- Litterature

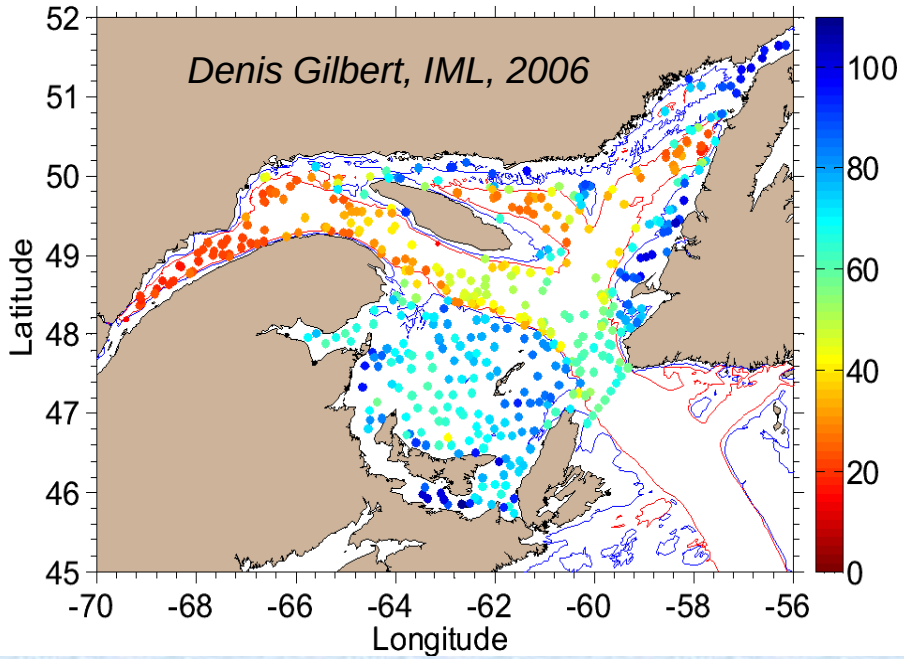


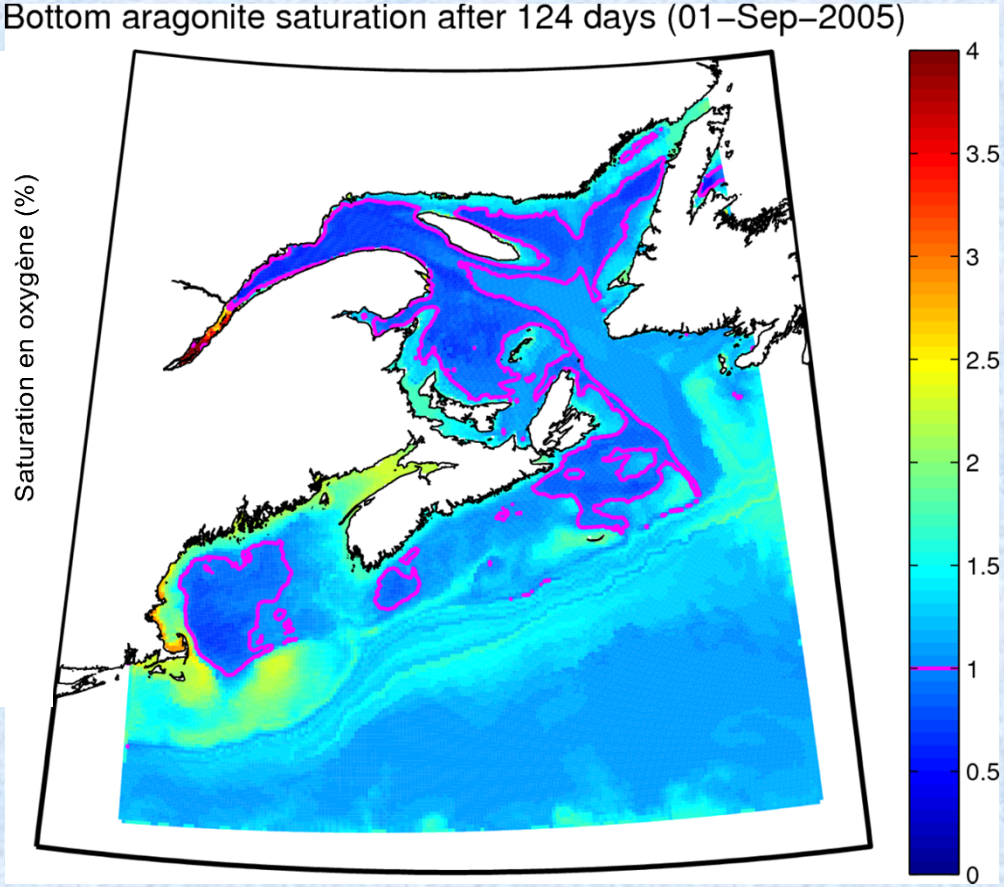
Applications

- Caracterisation of essential habitat for species at risk (e.g. Blue whale)
- Marine Protected Area network

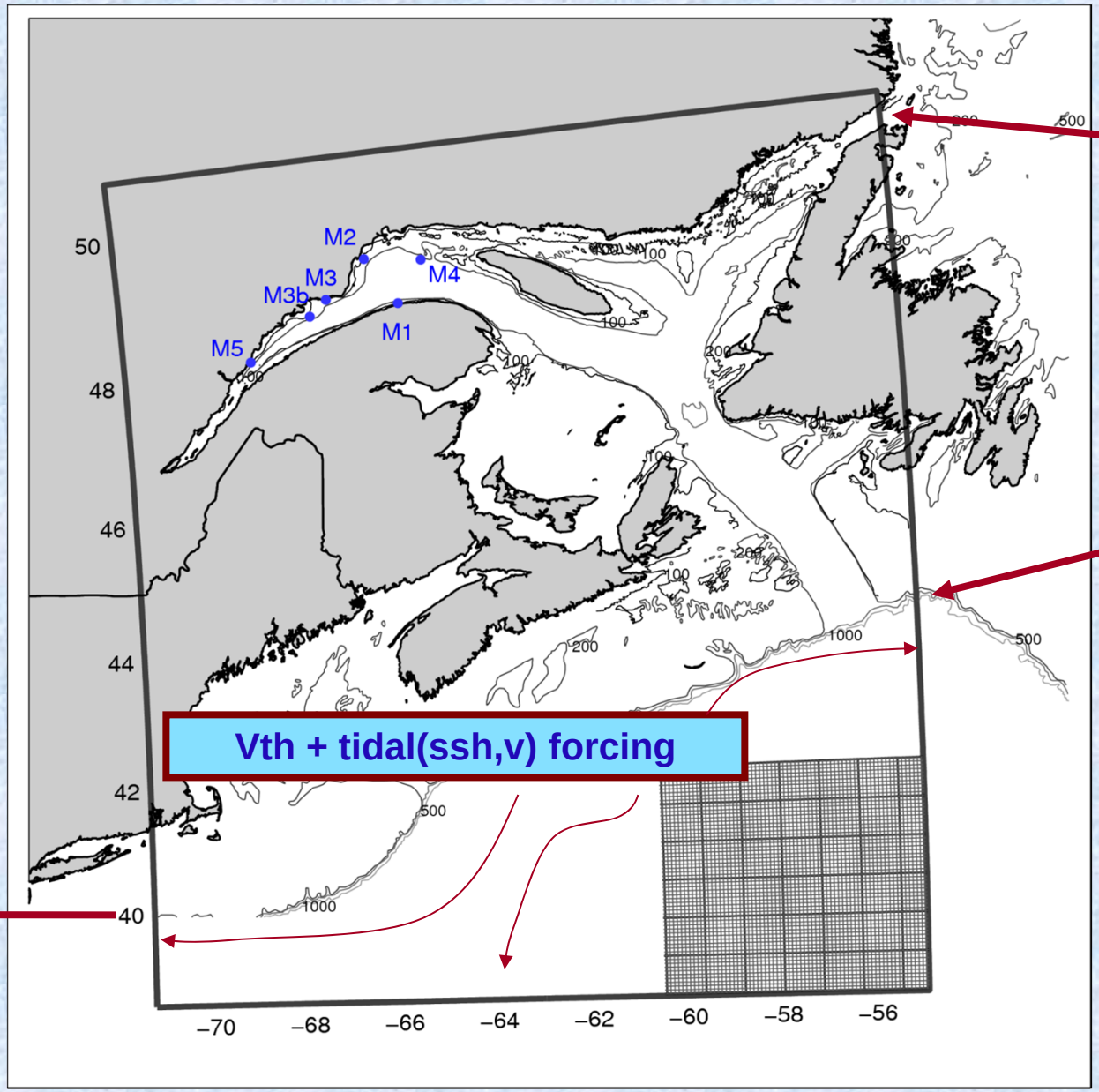
Applications

- Expansion of hypoxic and low pH zones -> impact on fisheries





CANOPA configuration



Seasonal cycle

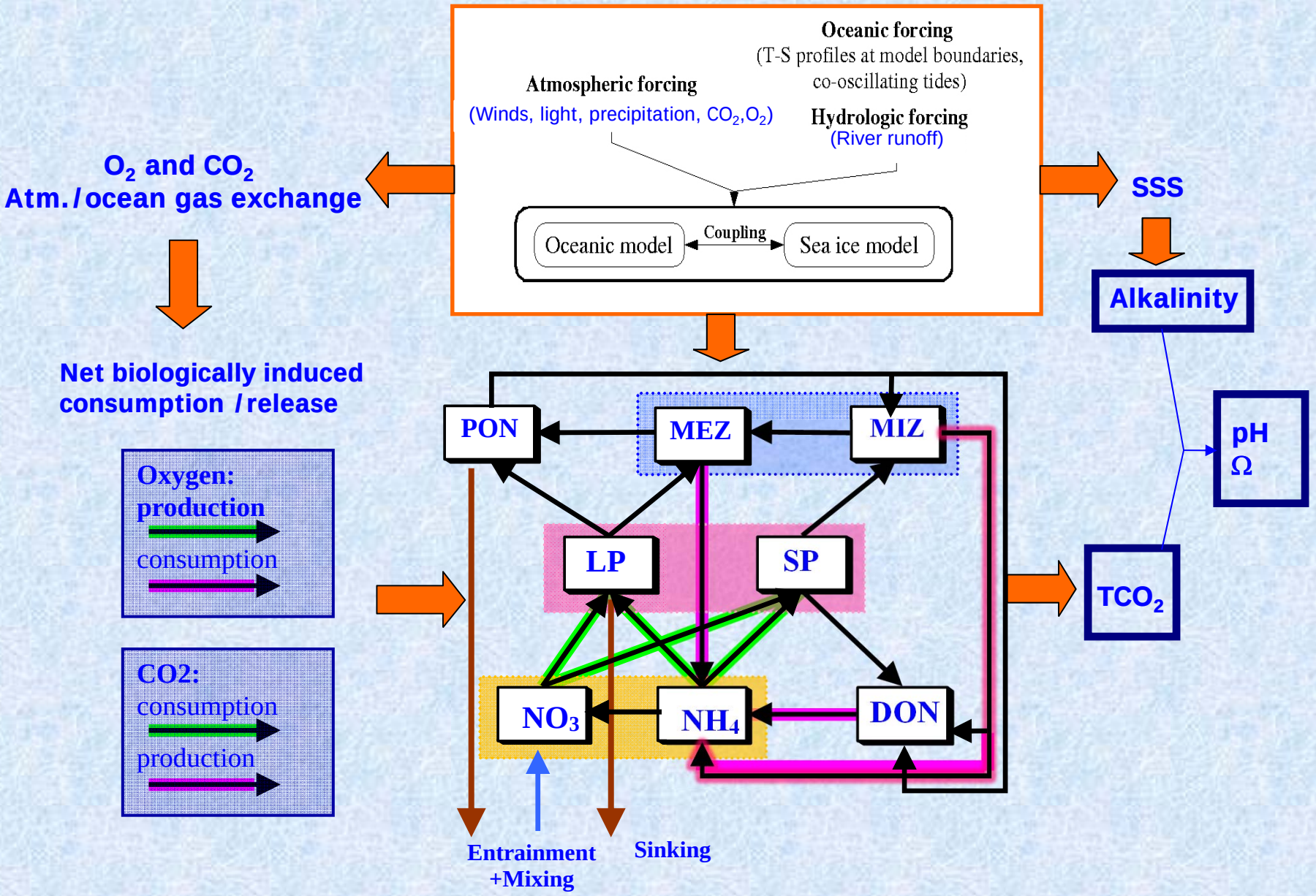
Strait of Belle Isle transport

Shelfbreak East transport

Shelfbreak West transport

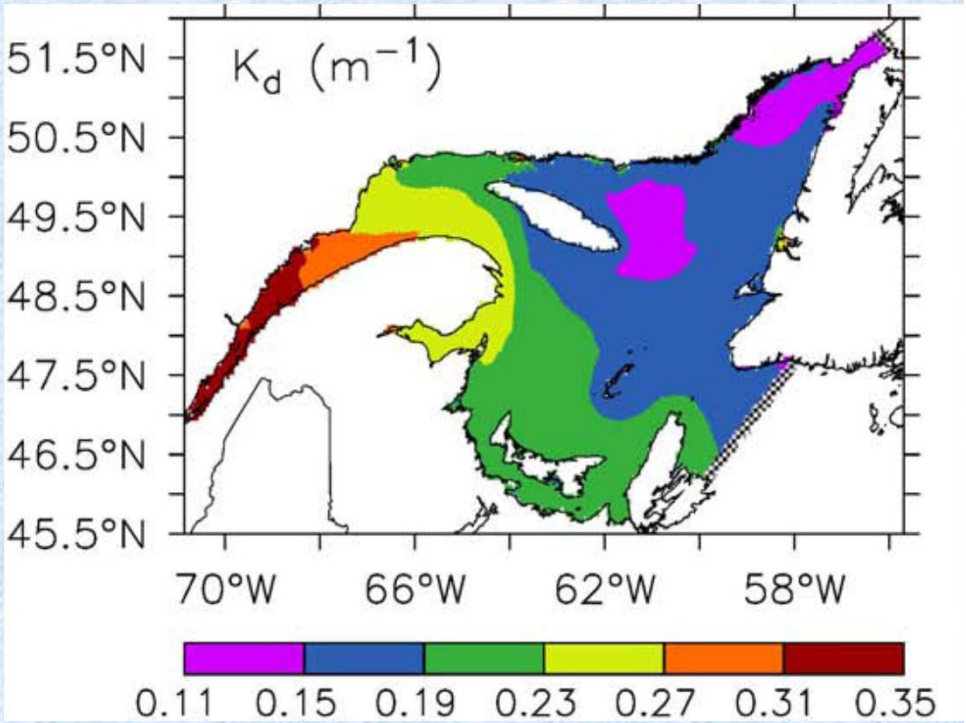
- "Valve" transports are analytic functions of yearday
- Transports balanced with SBW = SBE + SBI
- Volume conservation performed for non-tidal transports

The coupled model (GSBM-OPA): NPZD, O_2, and pH modules

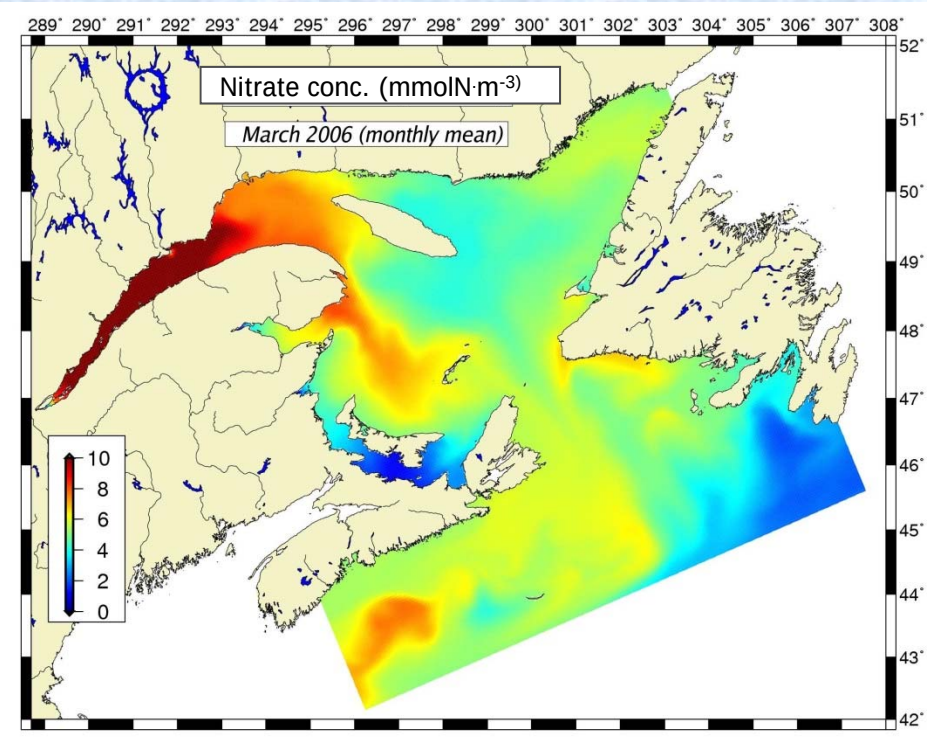


Light attenuation function of freshwater

Annual mean depth-averaged (0-10m)
total diffuse attenuation coefficient

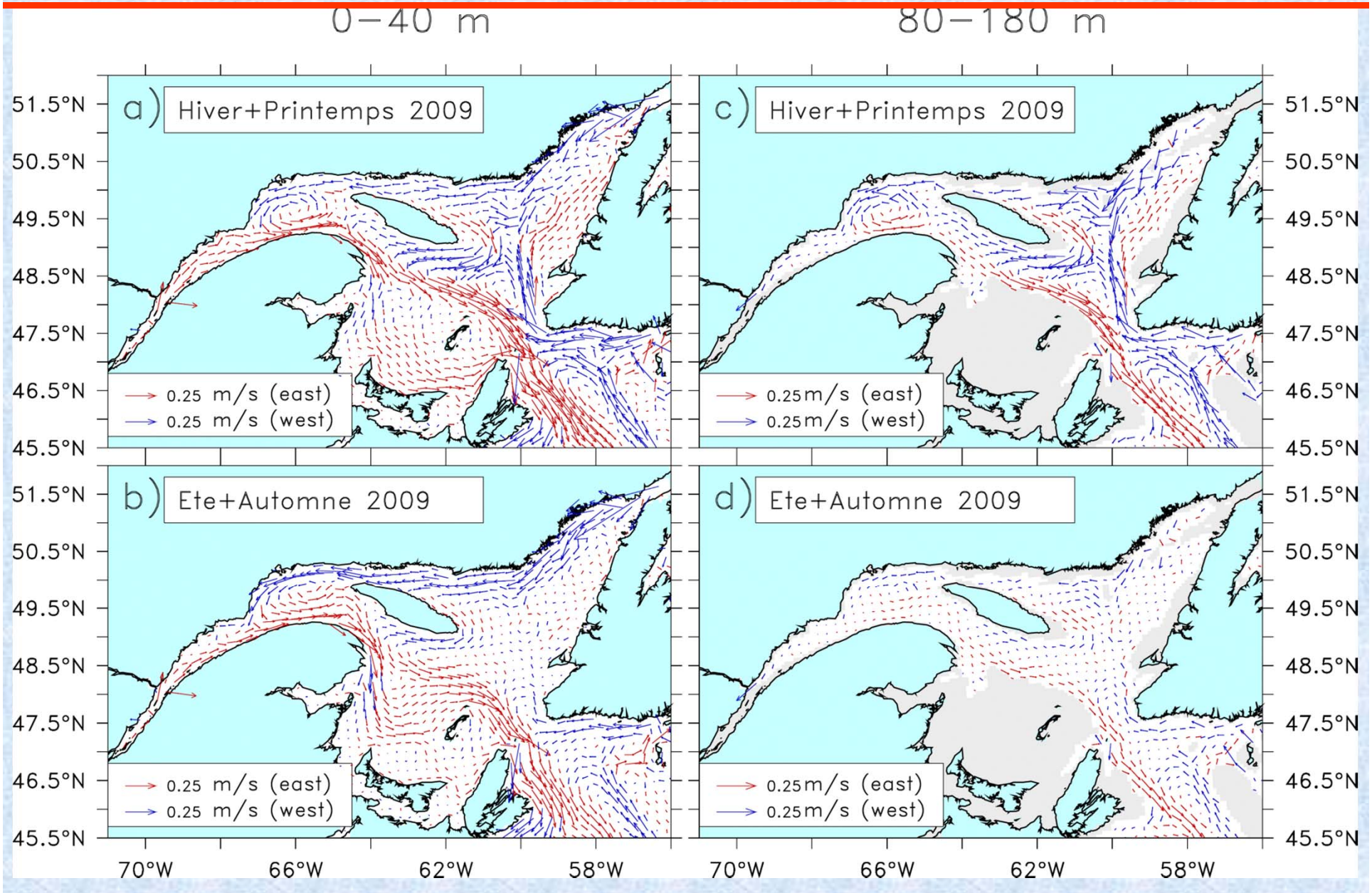


Le Fouest et al. (2010)



March mean surface concentration

Seasonal circulation pattern



Particular focus on the microbial loop

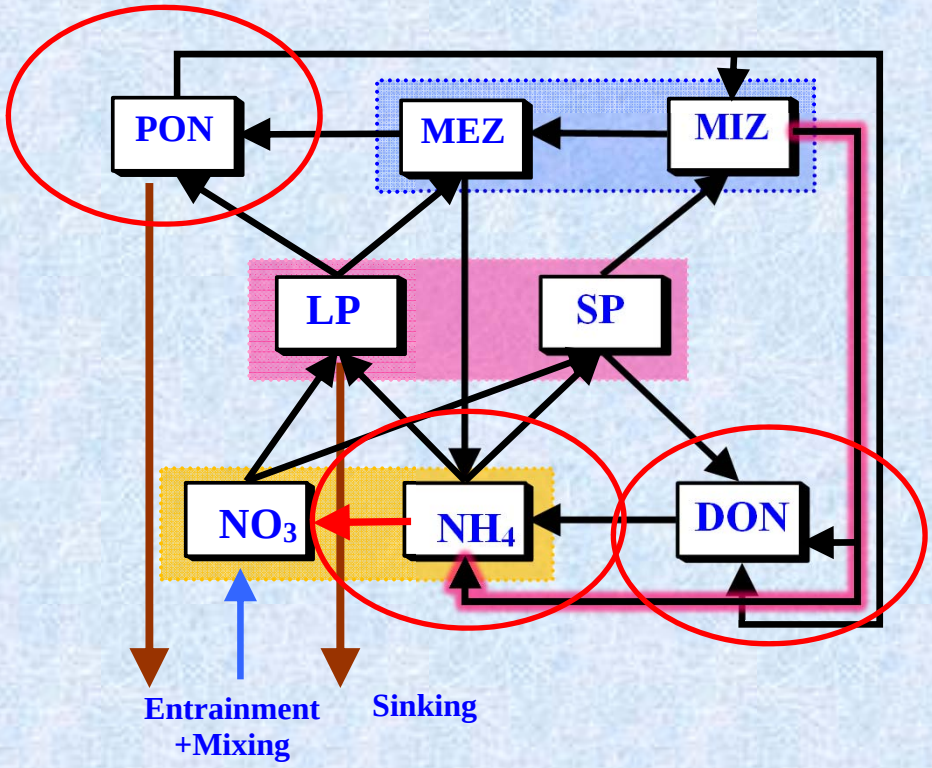
MIZ grazing on PON

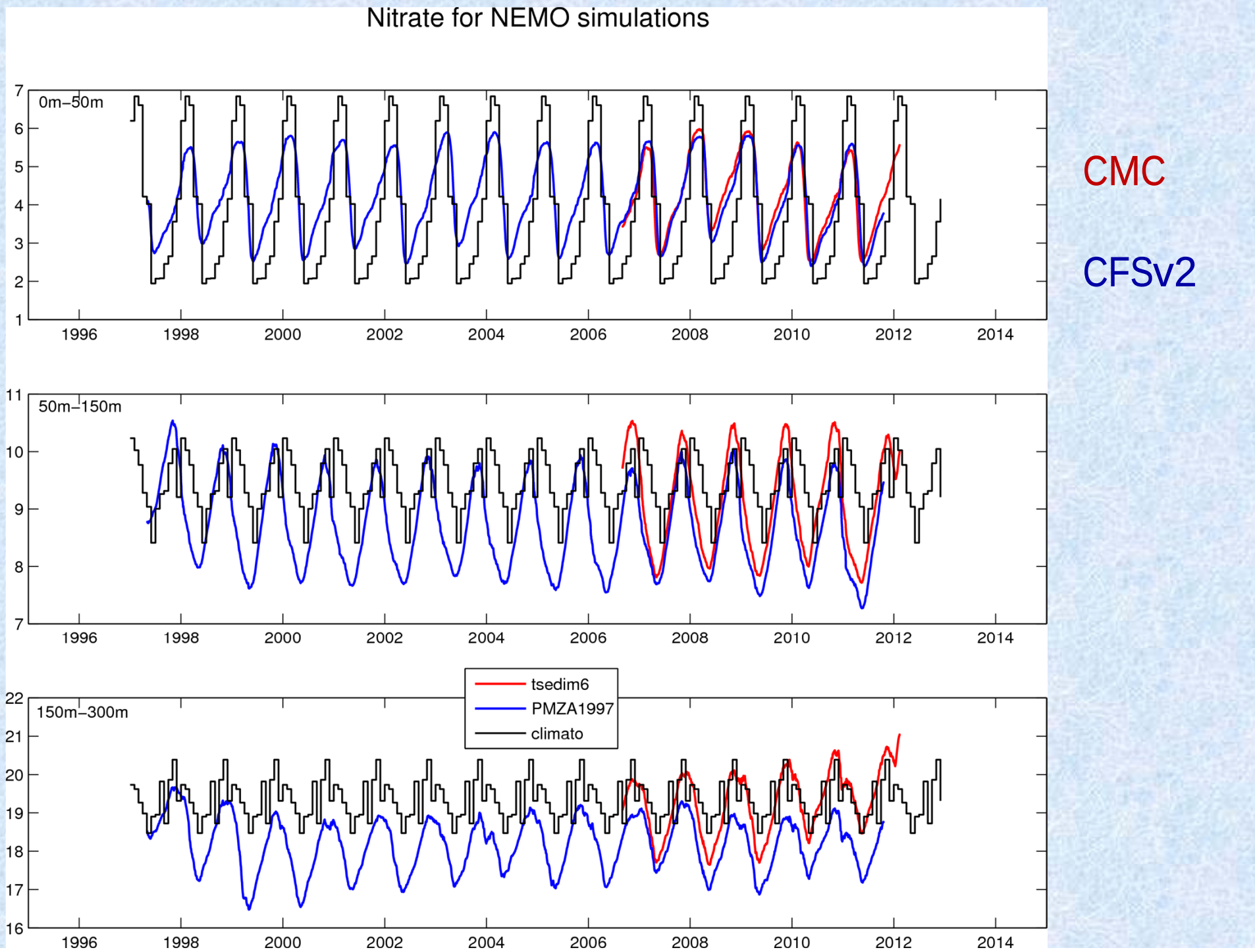
Nitrification

PON sedimentation rate

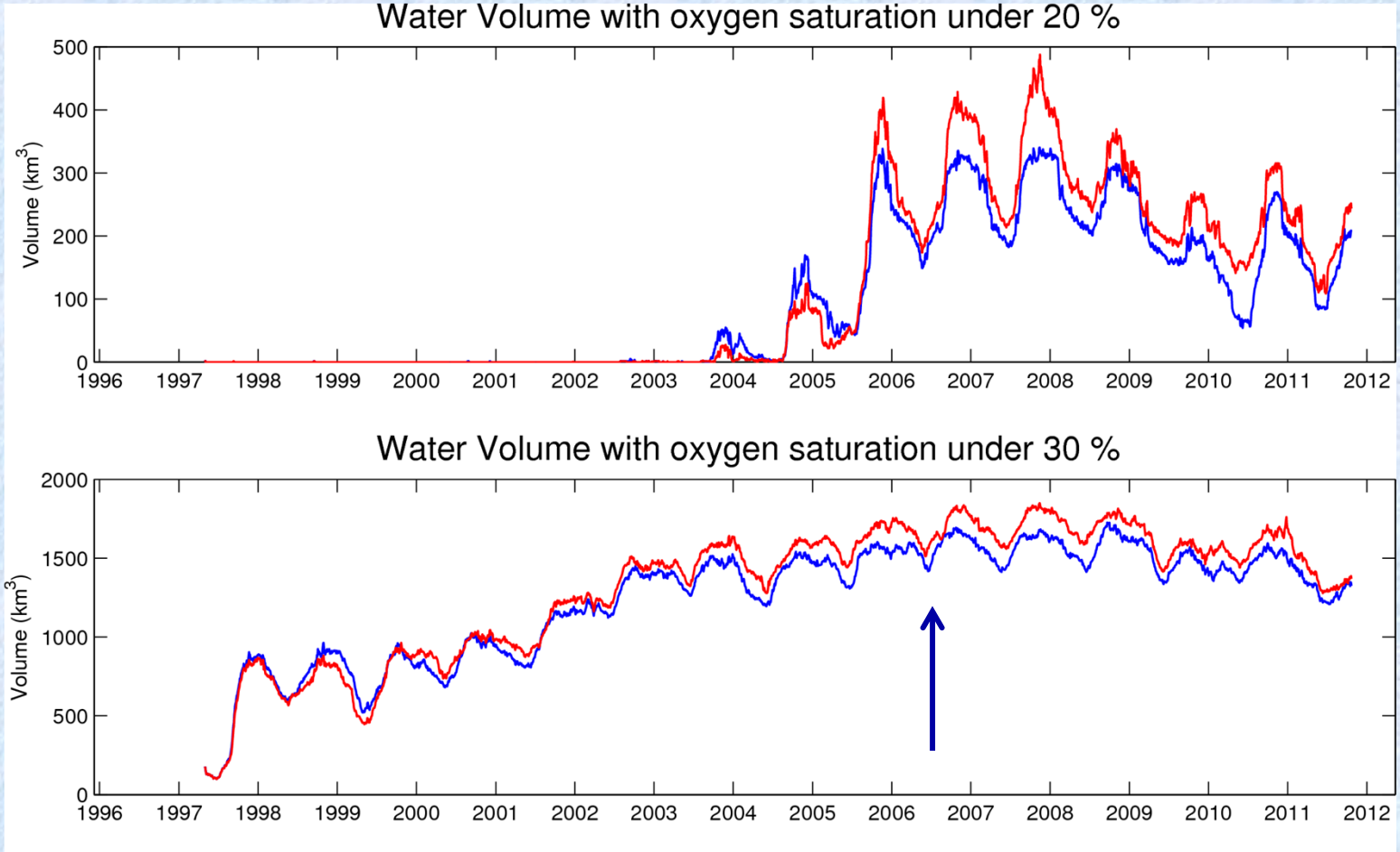
PON fragmentation rate

DON remineralization rate

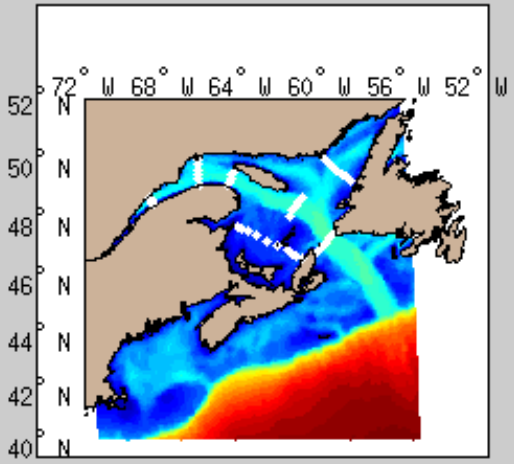


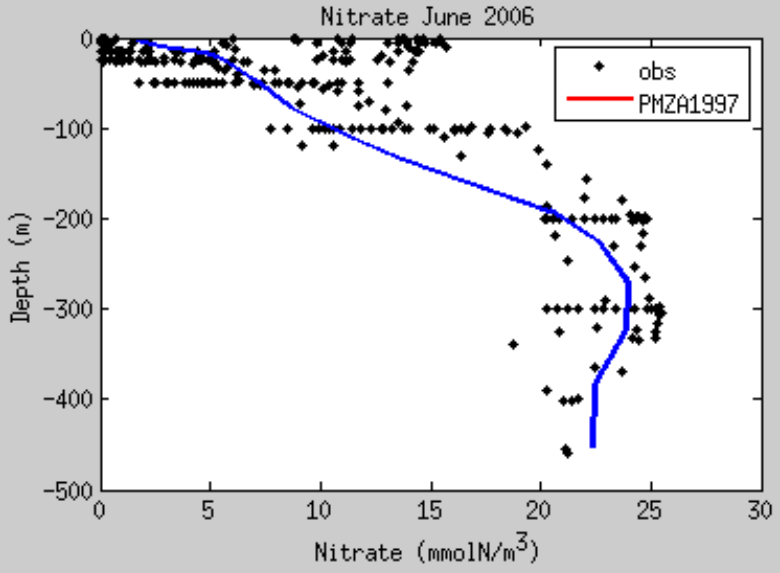

Nitrate for NEMO simulations
0m–50m
50m–150m
150m–300m
tsedim6
PMZA1997
climato
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
CMC
CFSv2

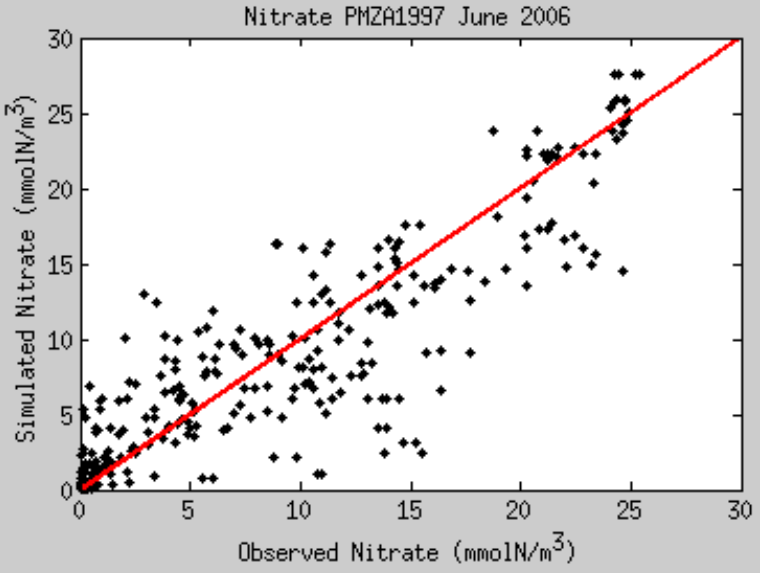
Poorer initial conditions for oxygen



Nitrate after 9 years of simulations

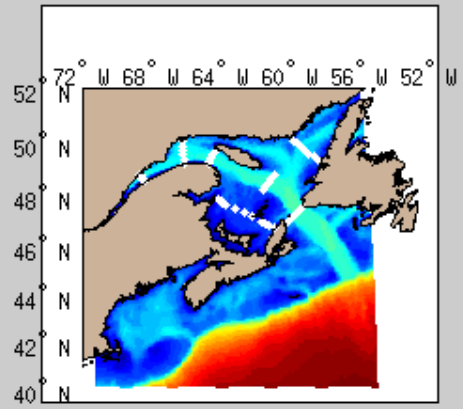


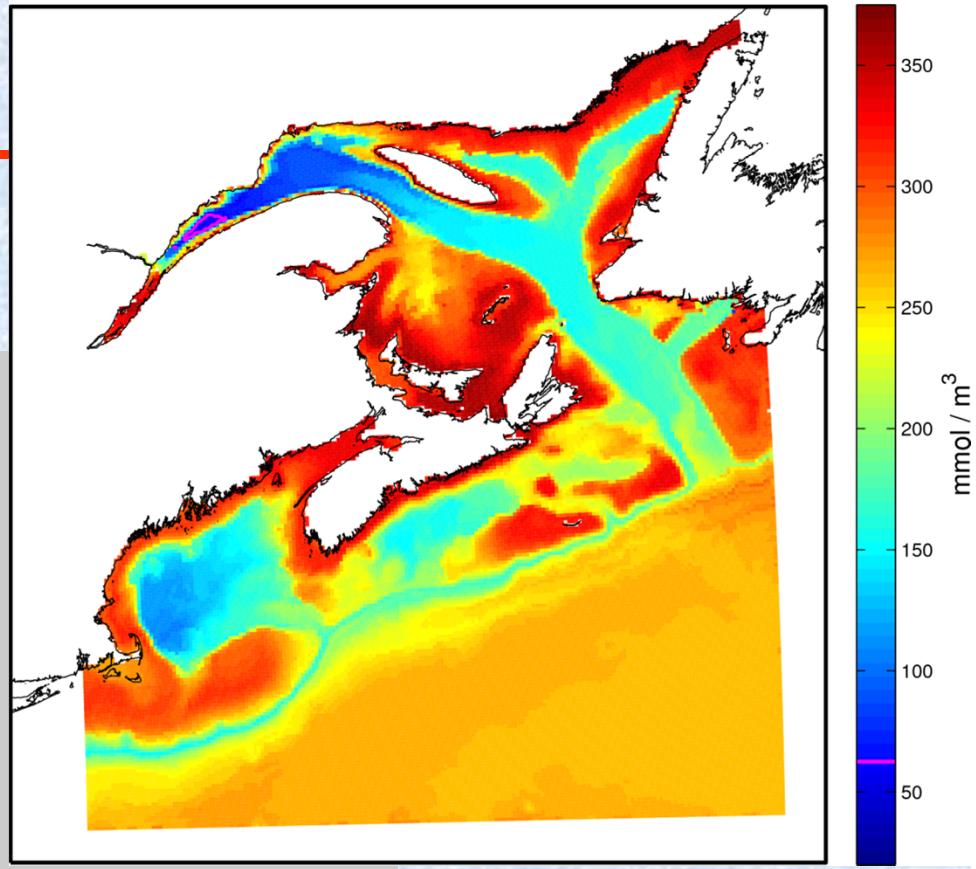


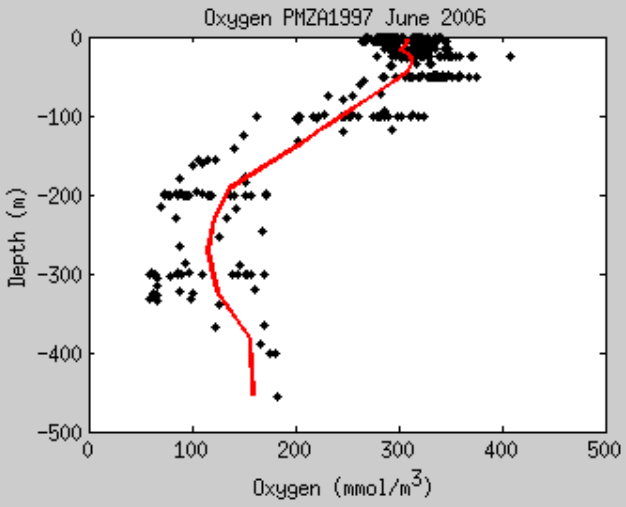


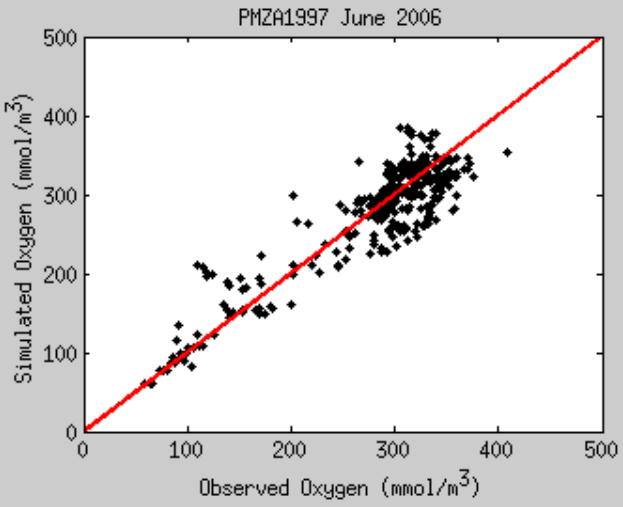
O_2 after 9 years

PMZA1997

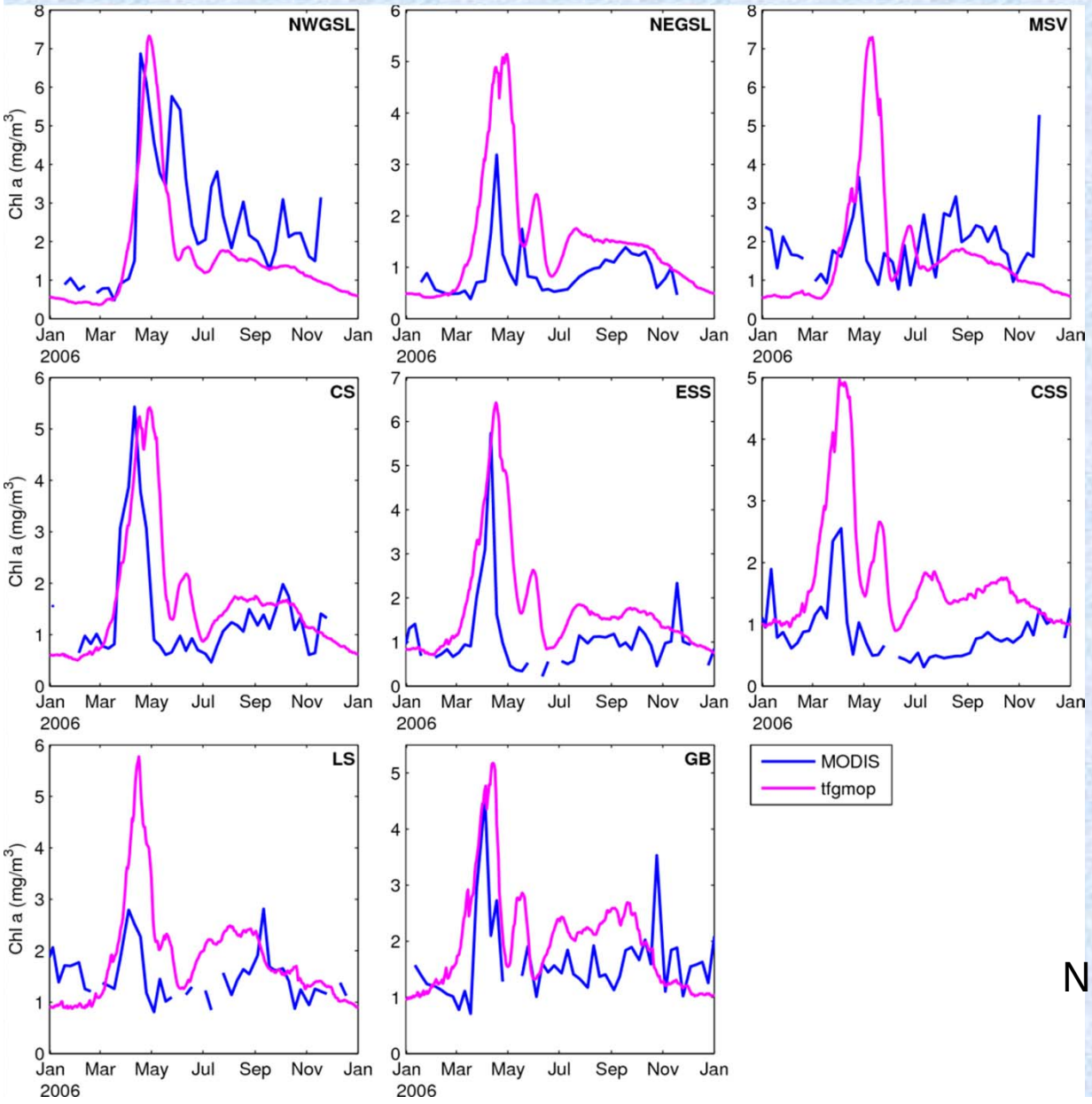


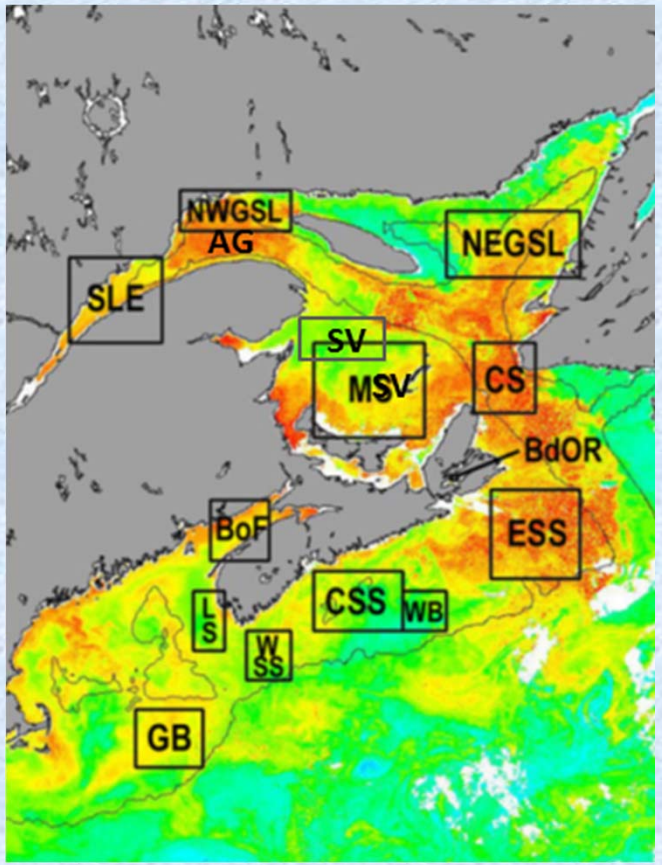






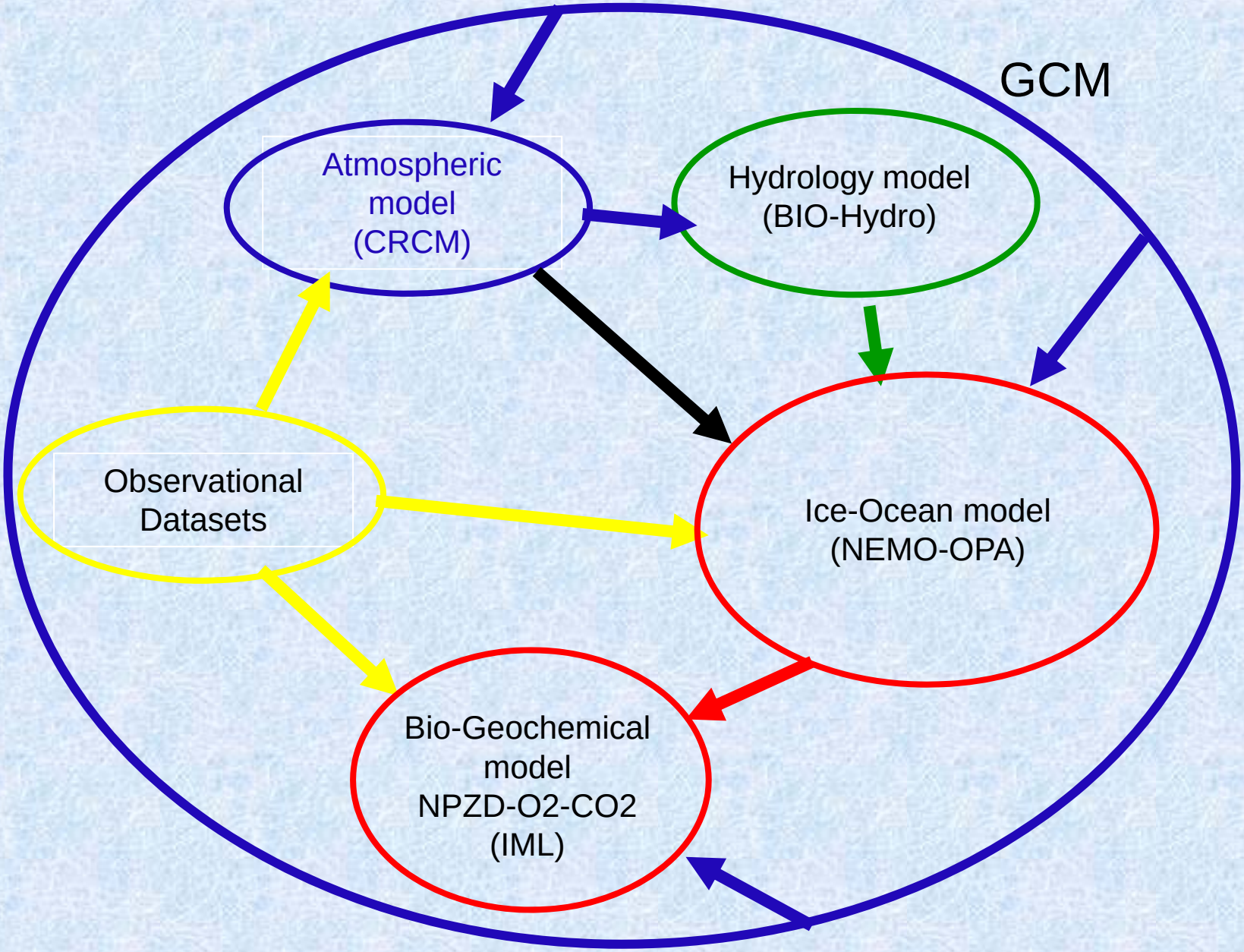
Adjust bloom timing depending on forcing -> MODIS





Note: Different vertical scales

DFO Regional Ocean Climate Dowscalling System: Gulf of Saint-Lawrence, Scotian Shelf and Gulf of Maine

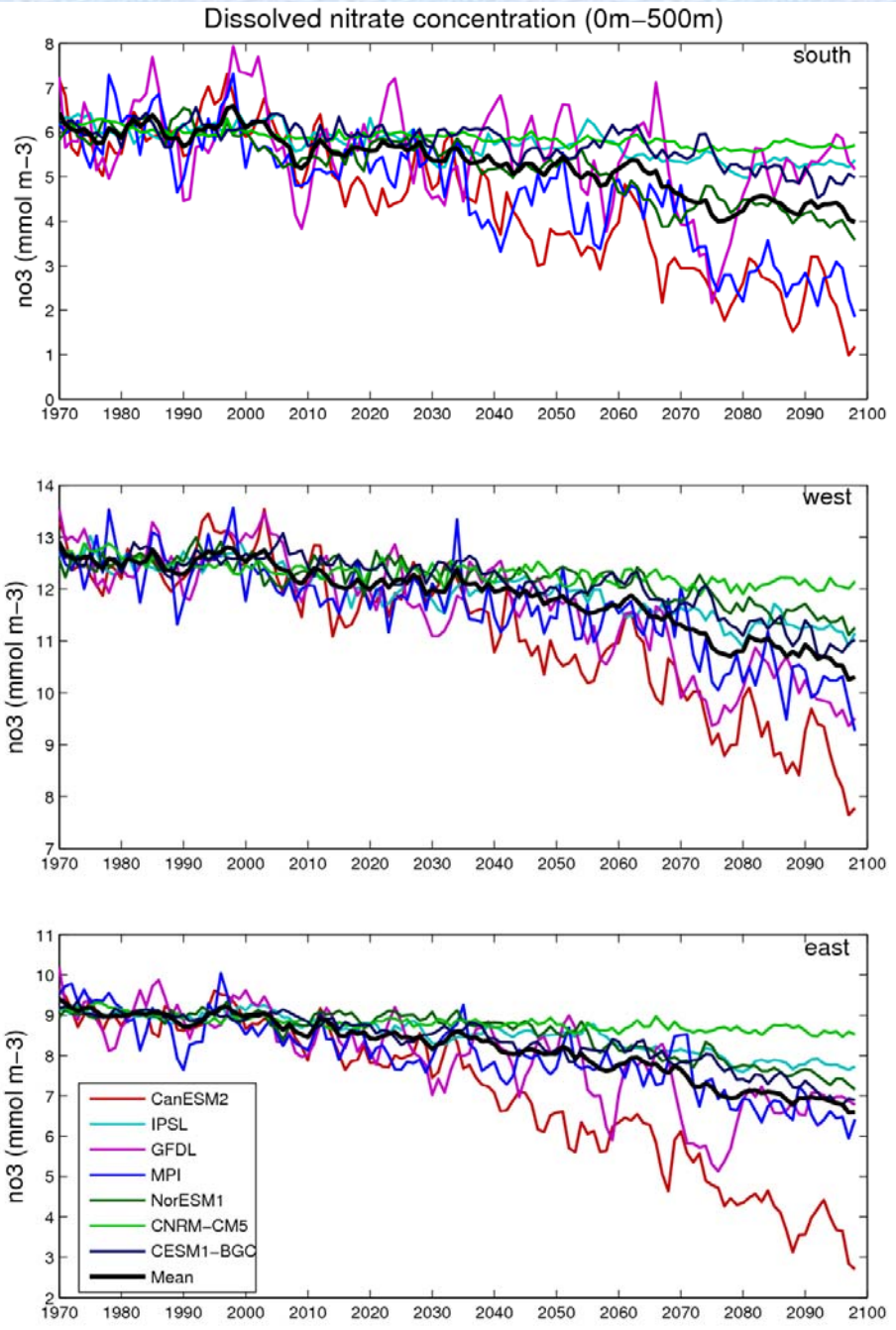


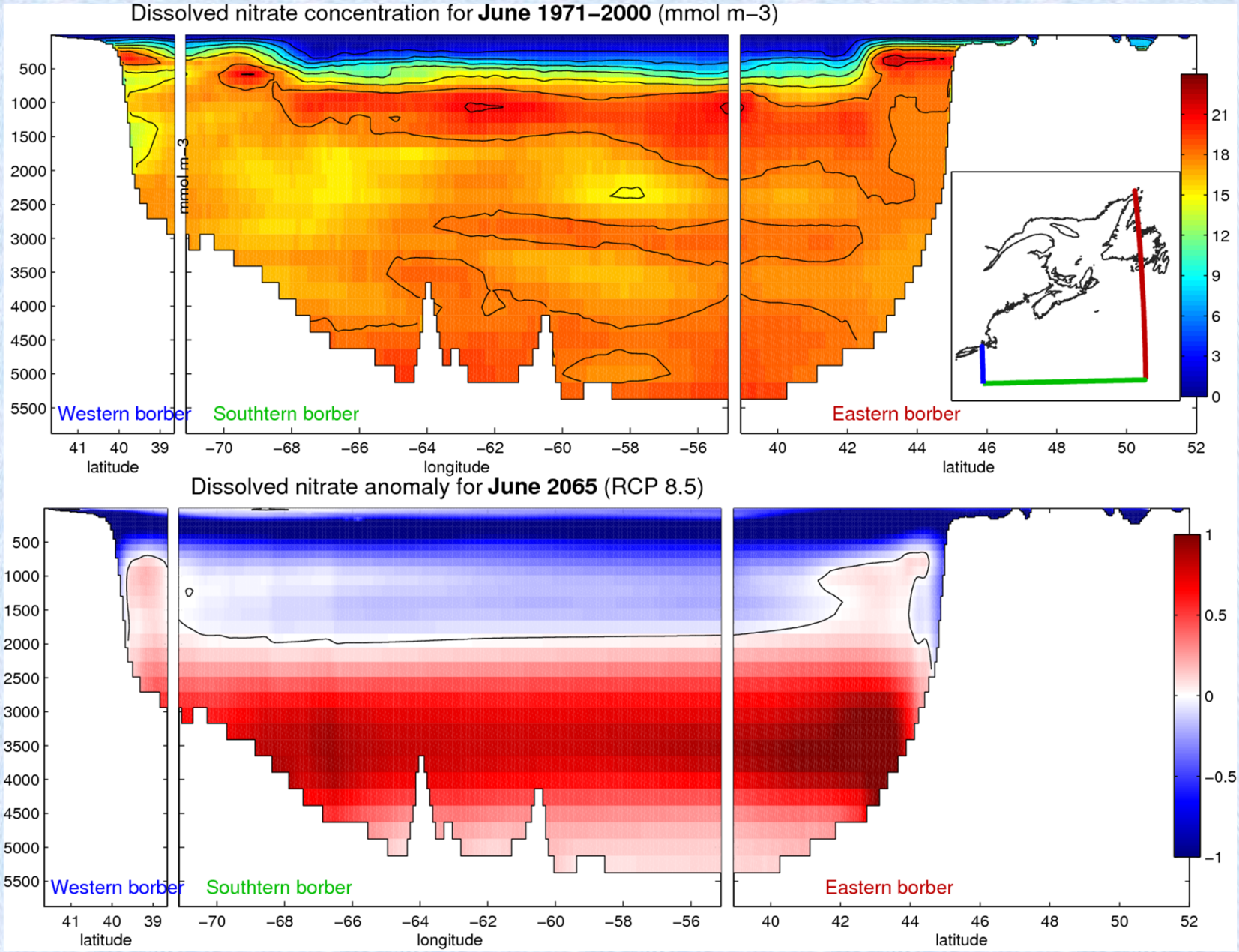
Seven 130-year long simulations (1970-2100):

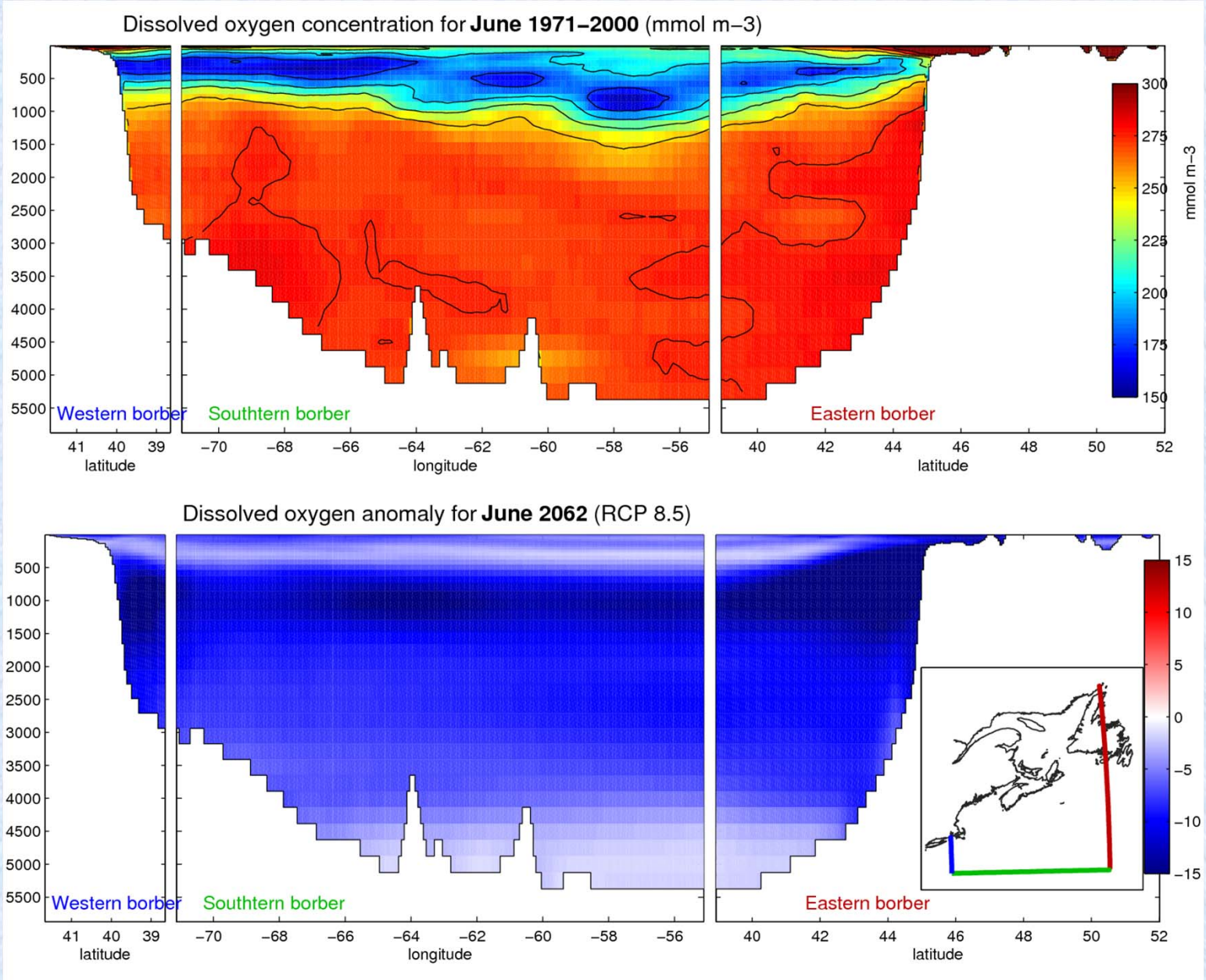
- CGCM3 A1B (M3, M4 and M5)
- CCSM3 A1B
- CCSM4 RCP8.5
- HADLEY RCP8.5
- CANESM2 RCP 8.5
- MPI RCP 4.5
- MPI RCP 8.5

Chemical boundary conditions:

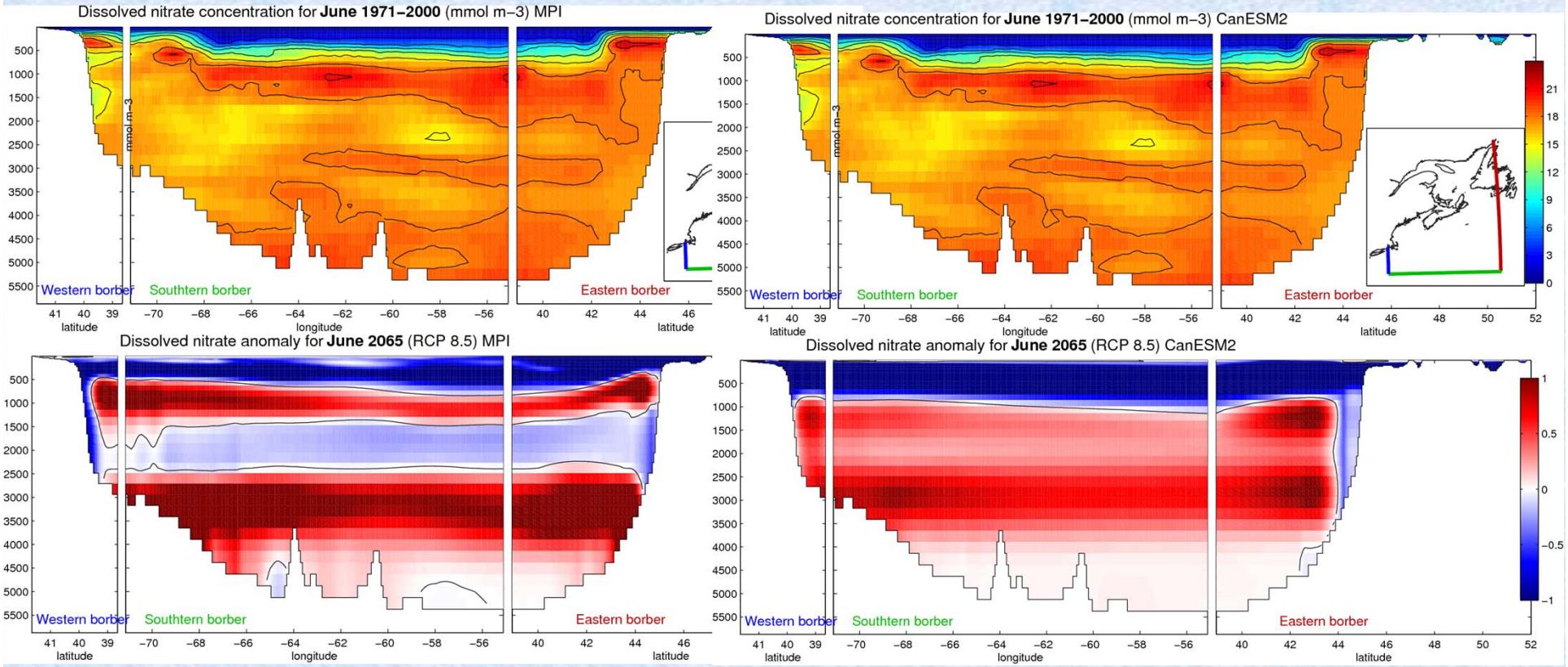
- CANESM2
- IPSL
- GFDL
- MPI
- NorESM1
- CNRM-CM5
- CESM1-BGC

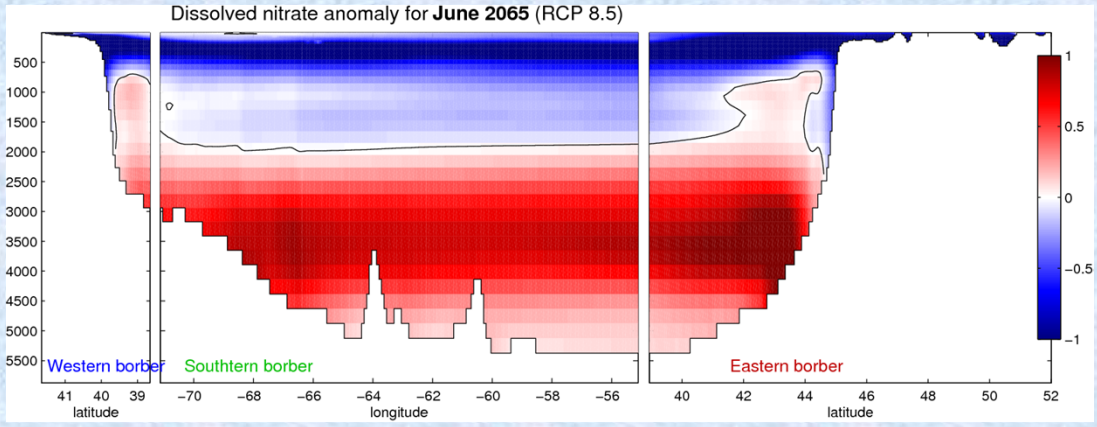


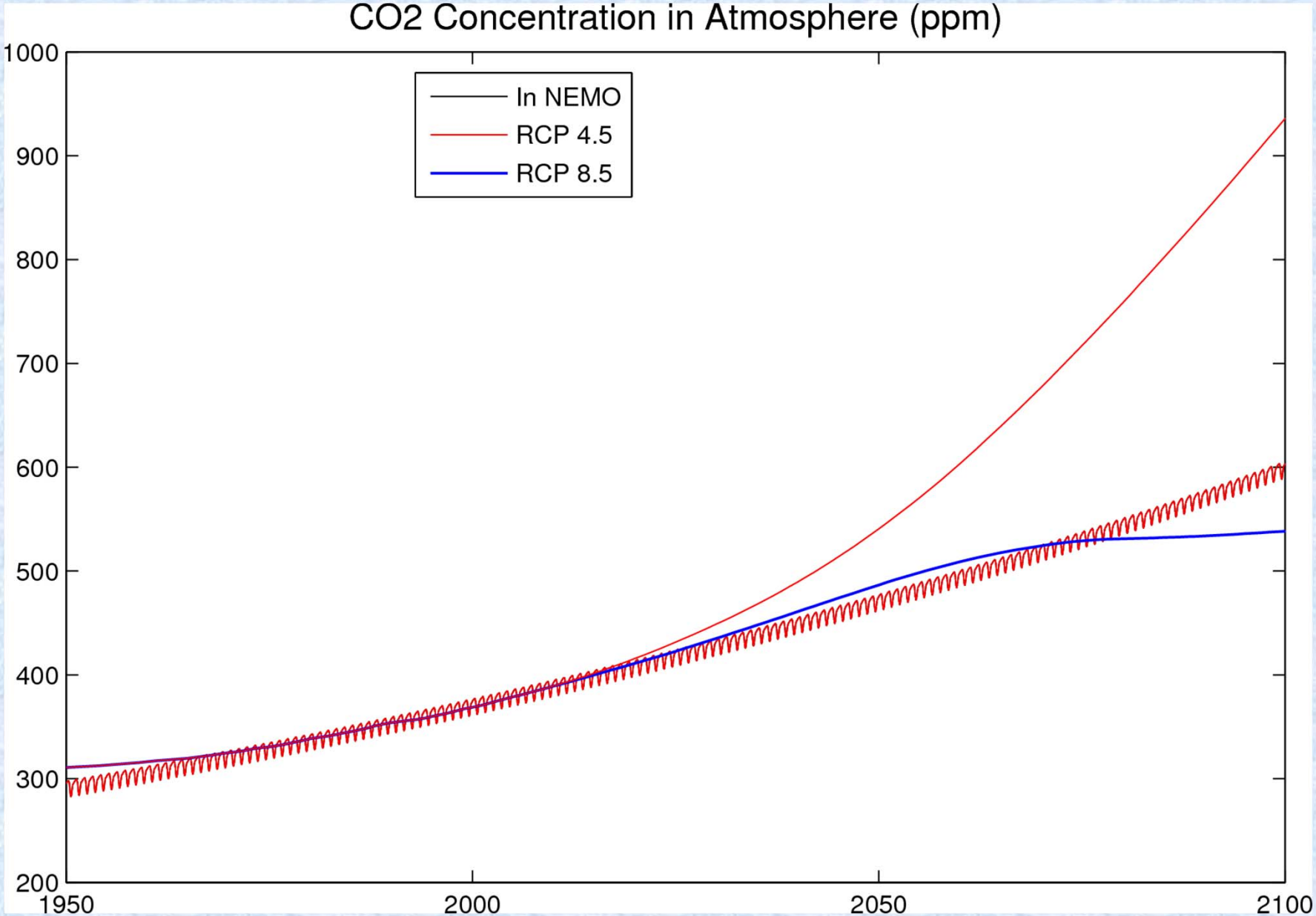

Dissolved nitrate concentration for **June 1971–2000** (mmol m−3)
mmol m−3
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
Western borber
Southtern borber
Eastern borber
41 40 39
latitude
−70 −68 −66 −64 −62 −60 −58 −56
longitude
40 42 44 46 48 50 52
latitude
21
18
15
12
9
6
3
0
Dissolved nitrate anomaly for **June 2065** (RCP 8.5)
Western borber
Southtern borber
Eastern borber
1
0.5
0
−0.5
−1


Dissolved oxygen concentration for **June 1971–2000** (mmol m–3)
Western borber
Southtern borber
Eastern borber
latitude
longitude
latitude
mmol m–3
Dissolved oxygen anomaly for **June 2062** (RCP 8.5)
Western borber
Southtern borber
Eastern borber
latitude
longitude
latitude

Mean vs individual anomaly






CO2 Concentration in Atmosphere (ppm)
In NEMO
RCP 4.5
RCP 8.5
1000
900
800
700
600
500
400
300
200
1950
2000
2050
2100

Next steps

- Need to include temperature effects on rates
- Improved DIC initial and boundary conditions
- Compute the long term simulations -> ensemble statistics