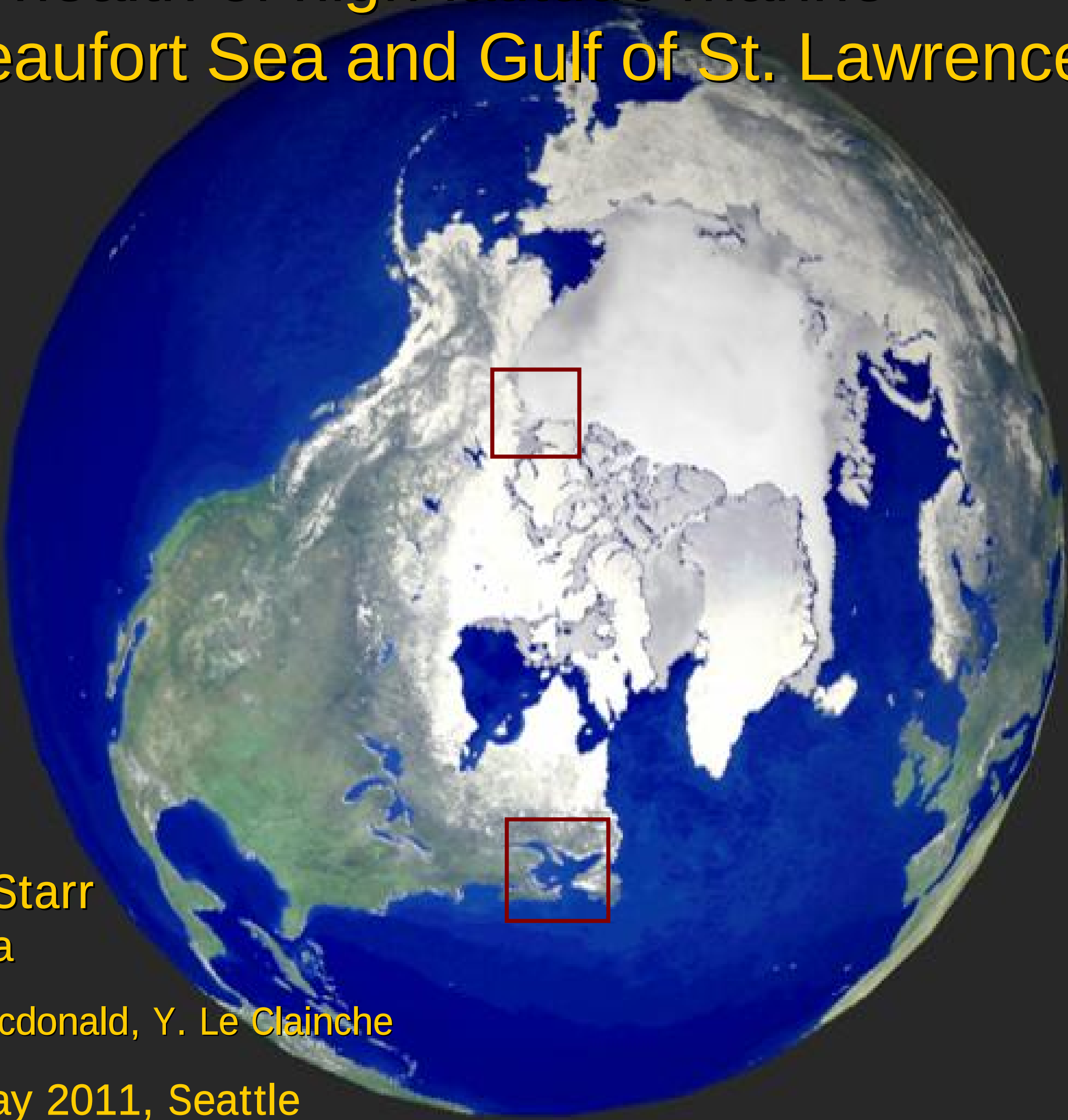
Modelling the impacts of climate change and variability on productivity and health of high-latitude marine ecosystems: the Beaufort Sea and Gulf of St. Lawrence case studies



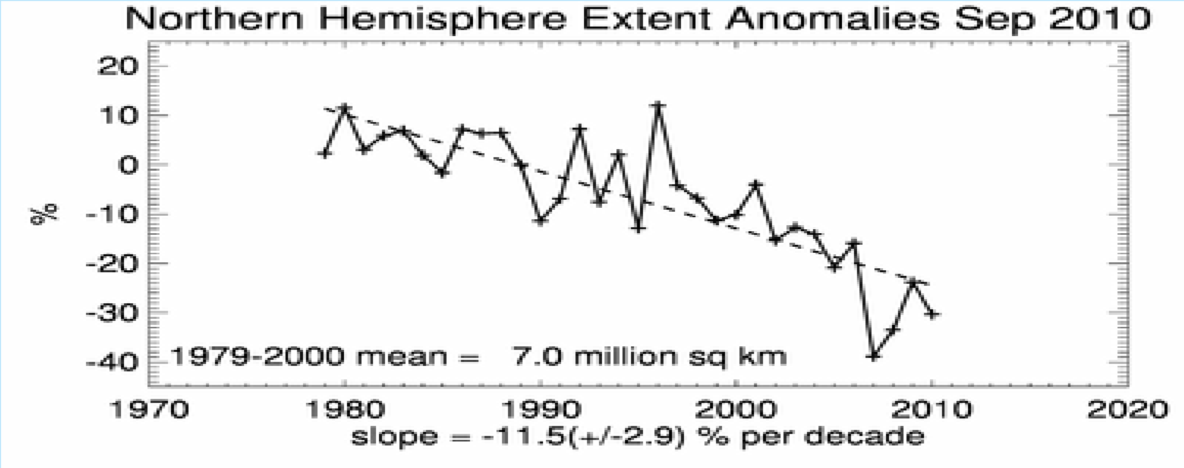
D. Lavoie, J. Chassé , M. Starr
Fisheries and Oceans Canada

Contributors: K. Denman, R. Macdonald, Y. Le Clainche

ESSAS symposium, 22-27 May 2011, Seattle

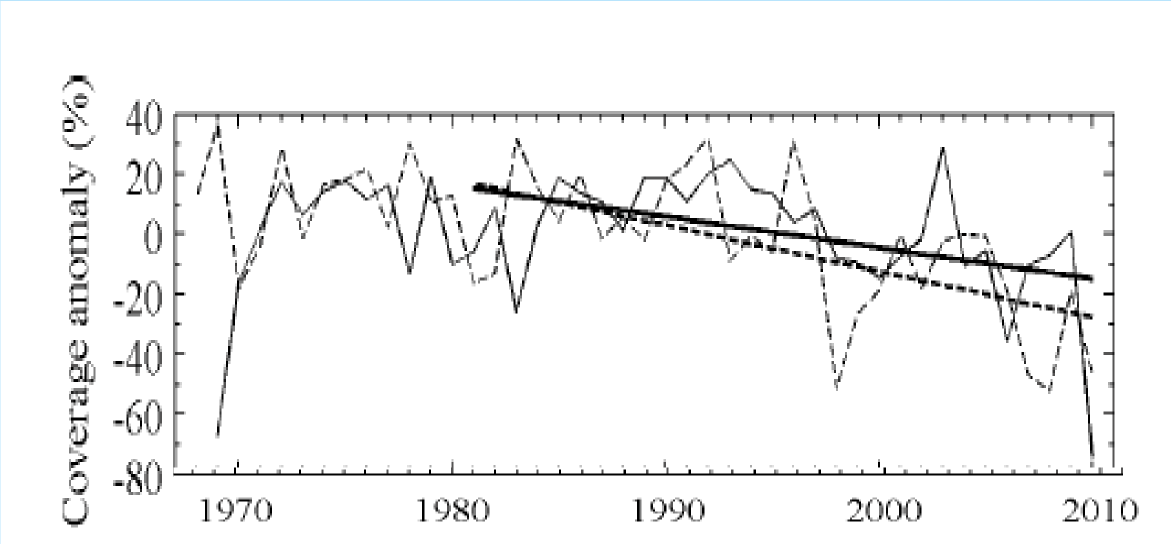
Climate change: Reduction in ice extent and volume

Sea ice extent trend for the Northern Hemisphere (from NSIDC)



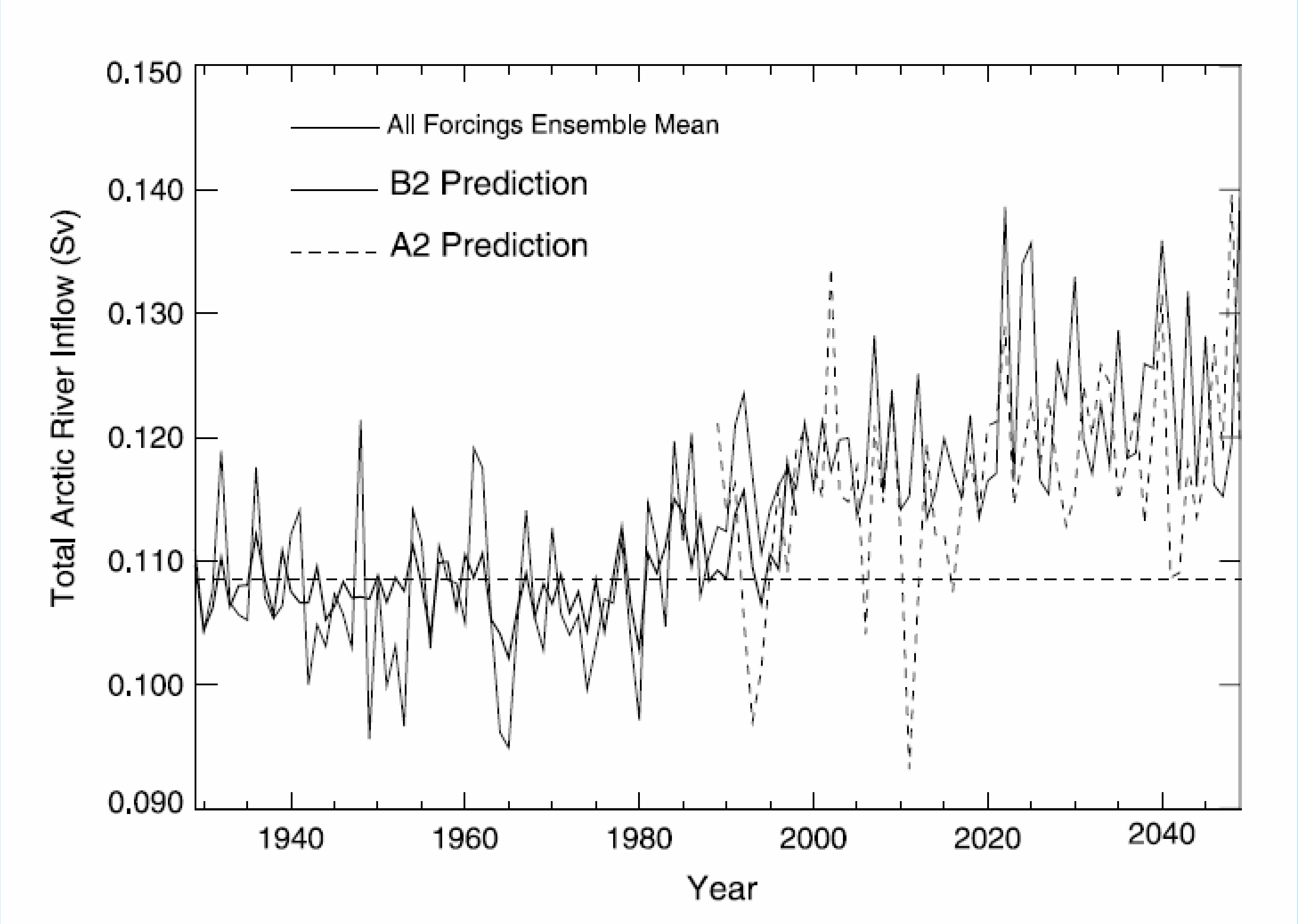
http://www.arctic.noaa.gov/detect/ice-seaice.shtml

Sea ice extent trend for the Canadian Arctic (dashed) and Gulf of St. Lawrence (bold)



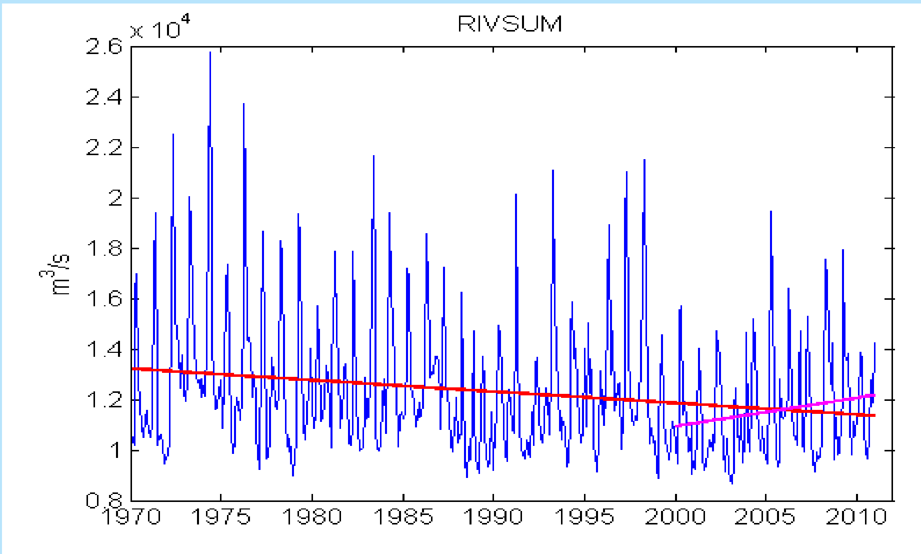
Courtesy of D. Bourgault (ISMER)

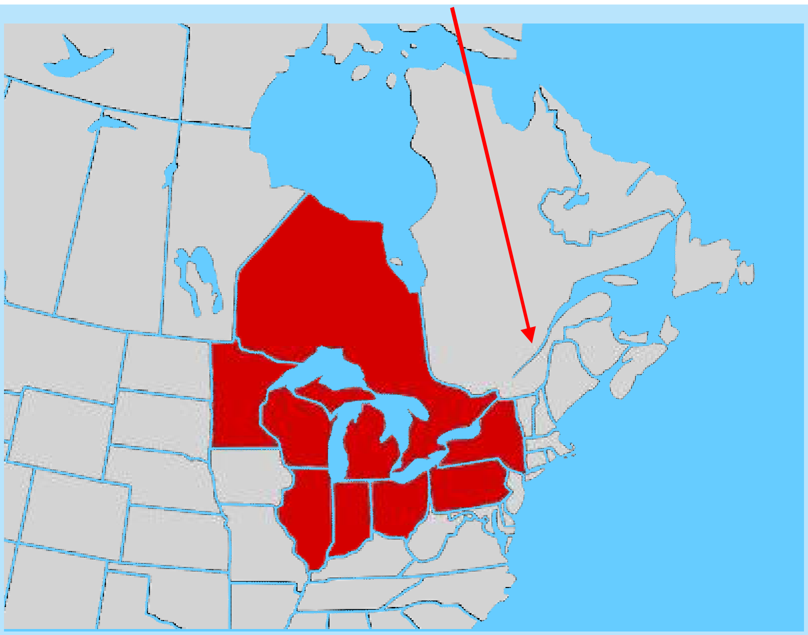
Changes in Freshwater runoff in the Arctic



Wu et al. (2005)

Changes in Freshwater runoff in the GSL





St. Lawrence River freshwater runoff at Québec City

<u>Future trend?</u>

Angel and Kunkel (2009): Positive or negative trend in Great Lakes water level depending on climate change scenario

Two downscaling methods

Downscaling: method for obtaining high-resolution climate or climate change information from relatively coarse-resolution global climate models (GCMs).

Statistical downscaling:

• use statistical relationships between observed small-scale variables and larger scale GCM variables
• requires low human, financial and computing resources

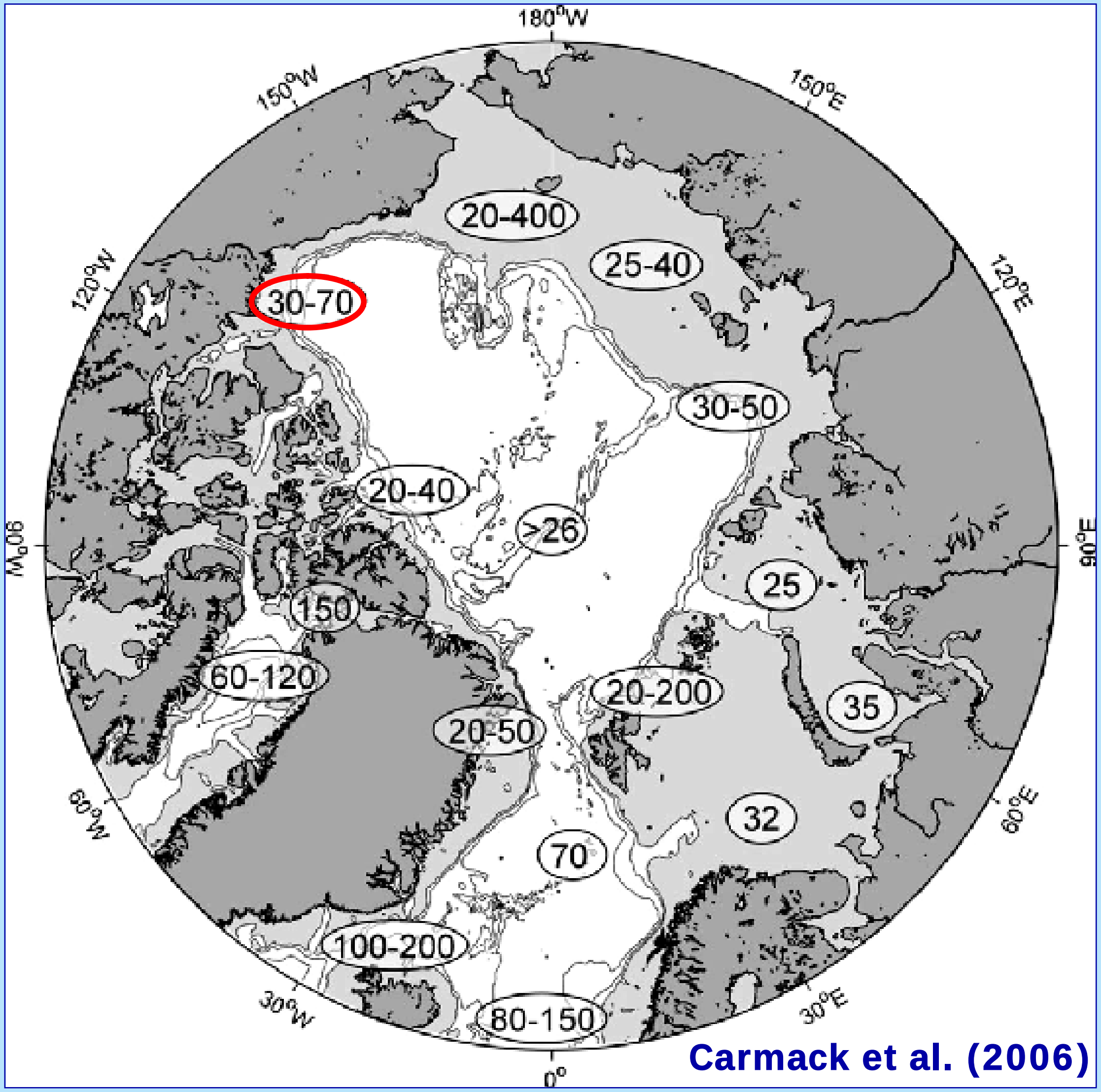
Dynamical downscaling:

• use a regional climate model driven by boundary conditions from a GCM model
• requires high human, financial and computing resources

The Beaufort Sea case

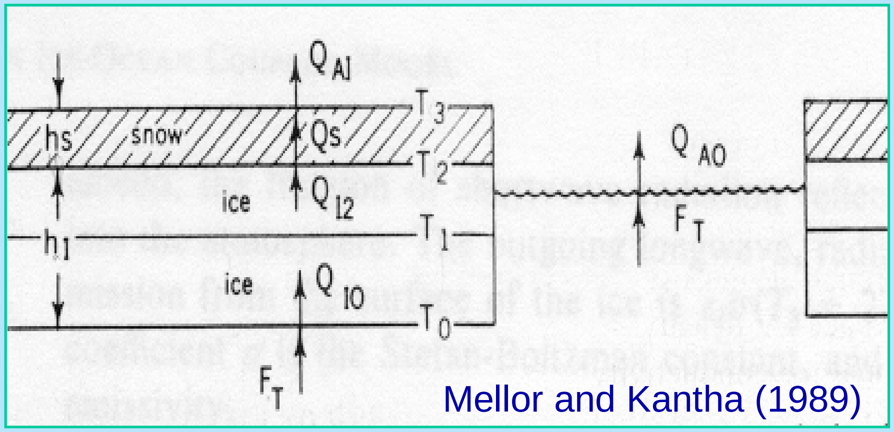
- •PP on most shelves is nutrient limited due to the strong stratification
- •Considering the increasing freshwater flux, will nutrient supply to the mixed layer increase, and will that increase be enough to sustain a large increase in PP (e.g. Arrigo et al. 2008)?

Panarctic distribution of total primary production



Carmack et al. (2006)

The coupled model

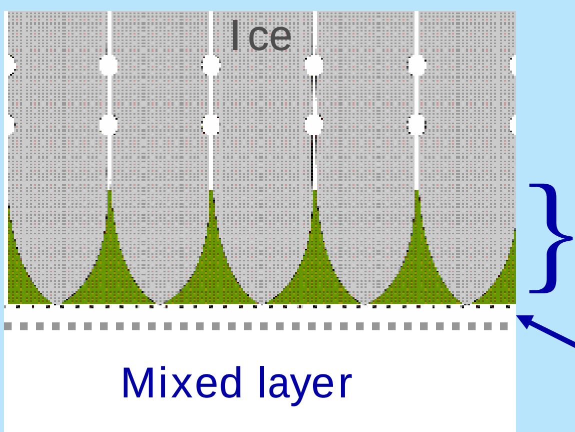


Mellor and Kantha (1989)

h = snow/ice thickness

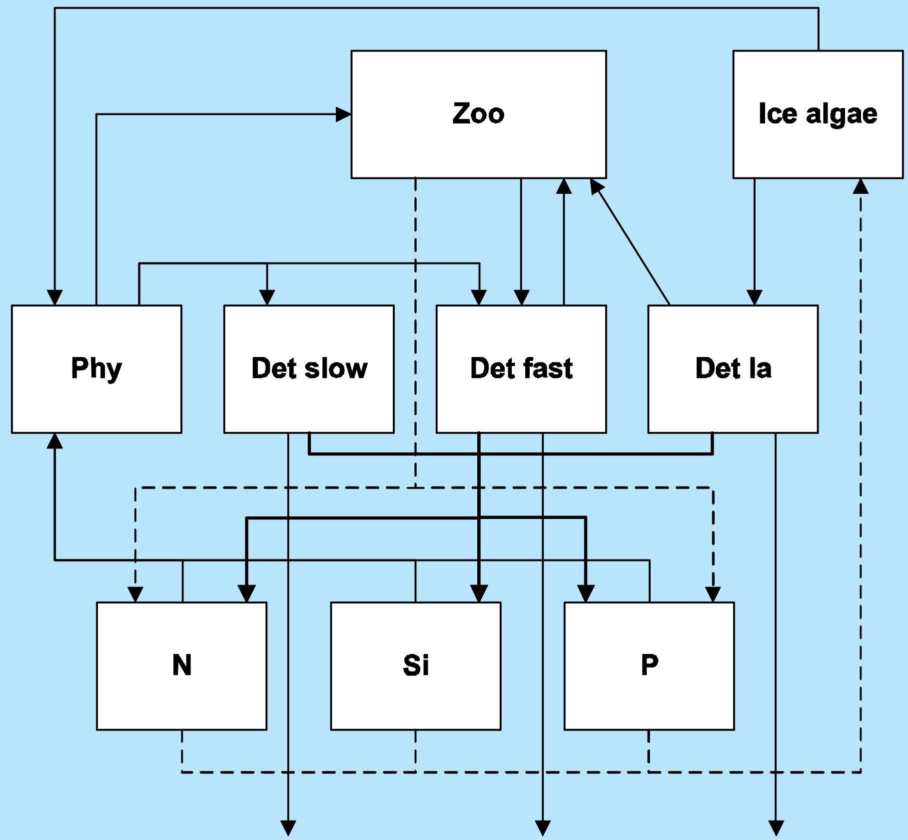
T = temperature

F and Q = heat fluxes



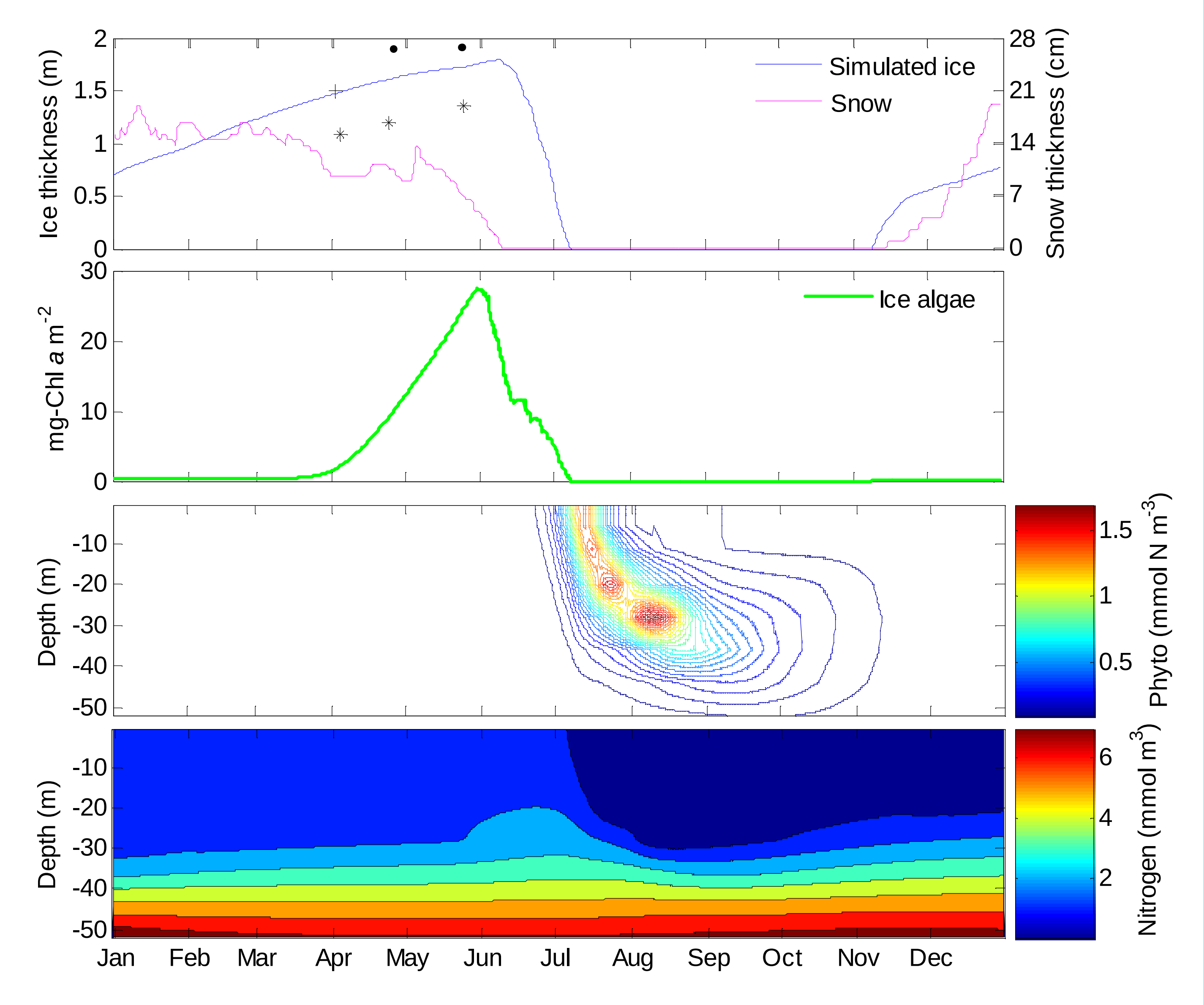
skeletal layer, ~2 cm

Molecular sublayer O(mm)

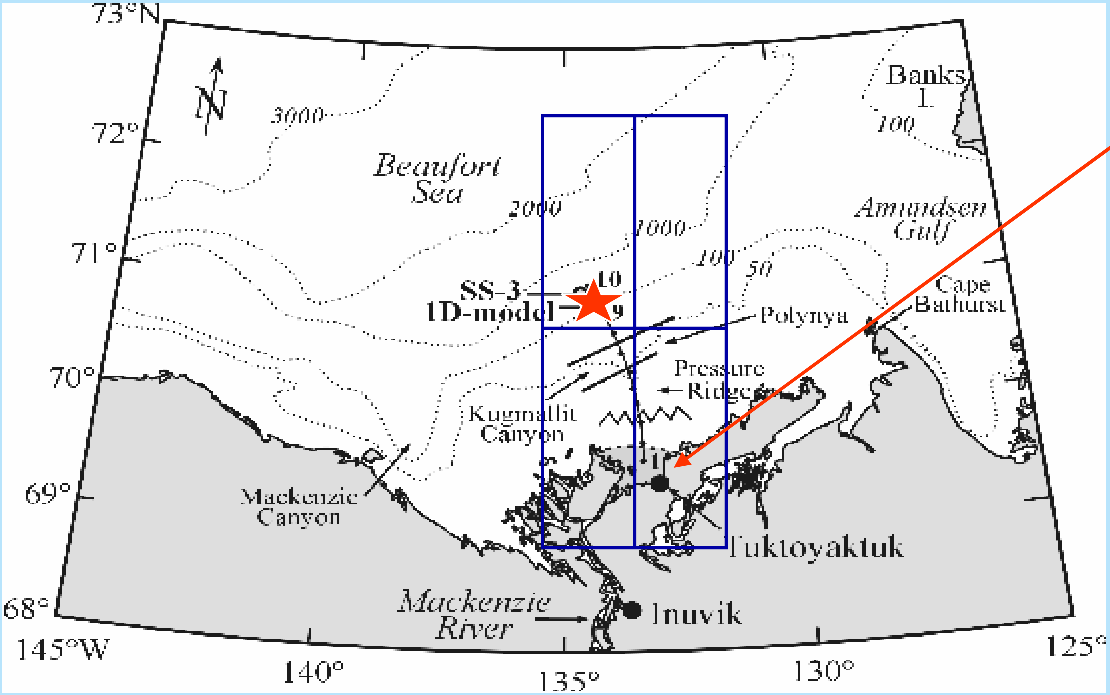


Lavoie et al. (2005, 2009)

Simulated seasonal cycle (1987)



Historical data and CGCM2 projections



Tuktoyaktuk Airport Data (1972-1994):

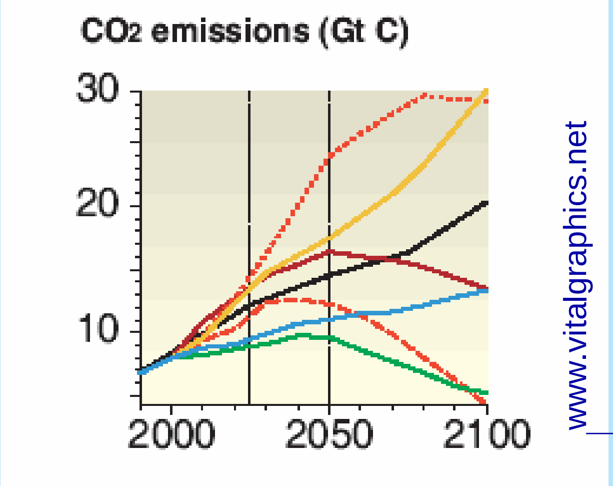
- surface air temperature
- wind speed
- cloud amount
- relative humidity
- snow thickness

CGCM2 model results: 1961-1989 → 1970-1989

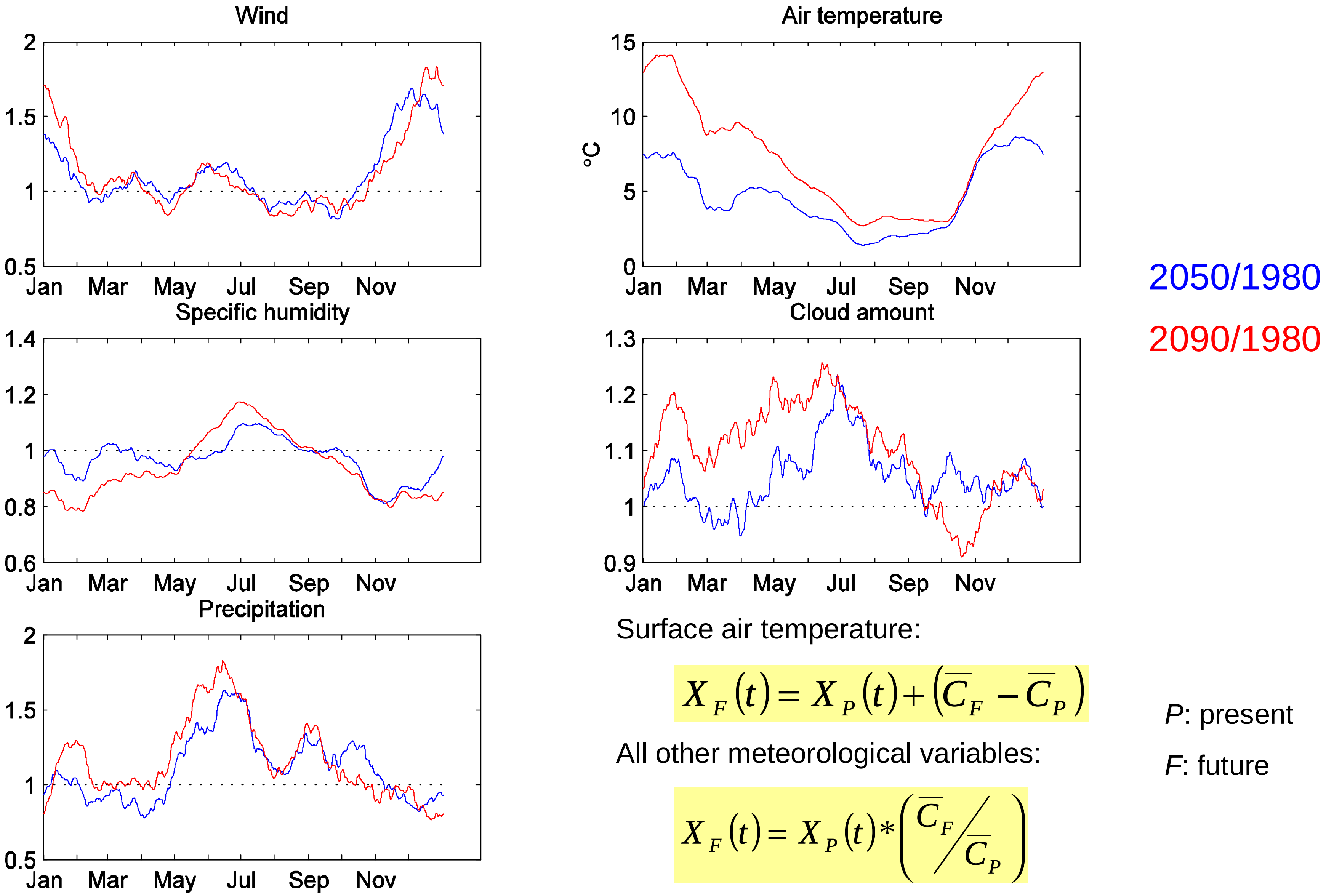
2041-2060 → 2041-2059

2081-2100 → 2081-2099

Using the **A2** IPCC emission scenario



Changes in forcing between each period



Surface air temperature:

$$X_F(t) = X_P(t) + \left(\overline{C}_F - \overline{C}_P\right)$$

All other meteorological variables:

$$X_F(t) = X_P(t) * \left(\overline{C}_F \big/ \overline{C}_P\right)$$

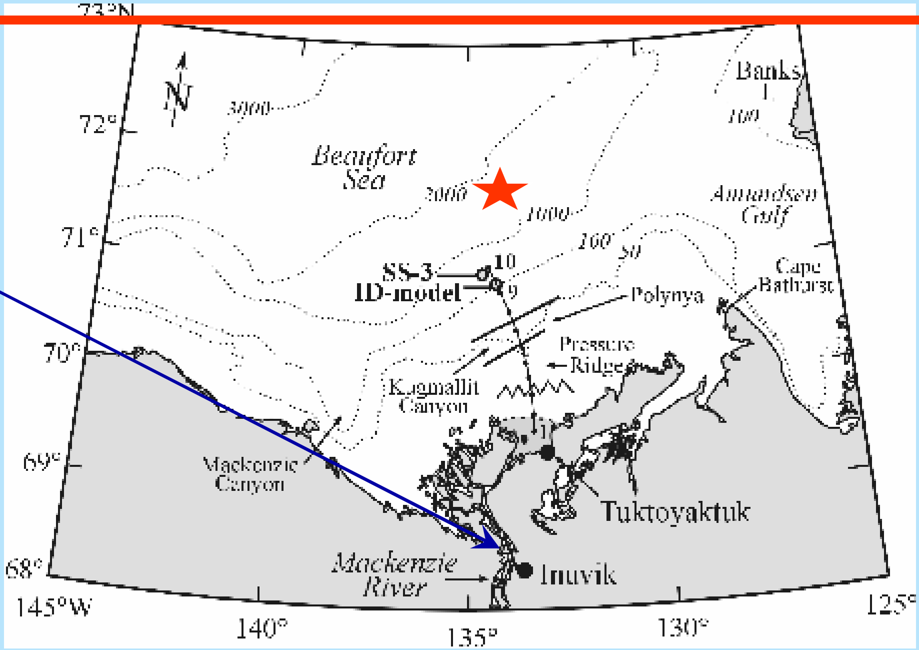
P: present

F: future

Freshwater flux

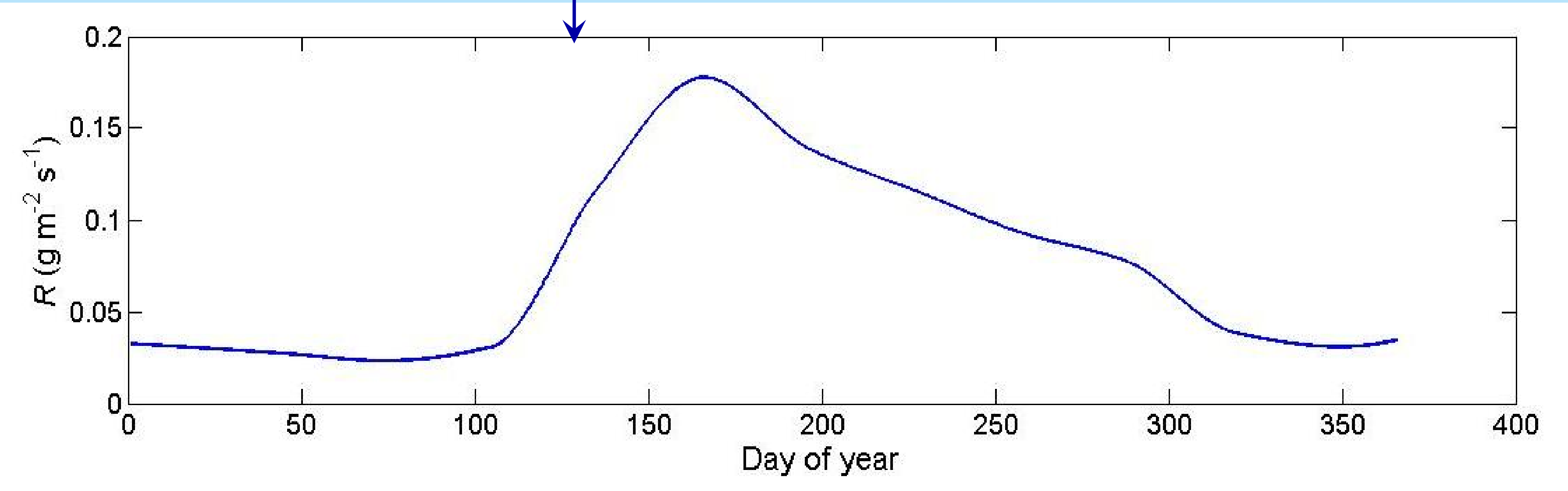
Using shape of Mackenzie River runoff

Applied 9% + 2% increases for future periods
(Wu et al. 2005, and P-E in CGCM2)

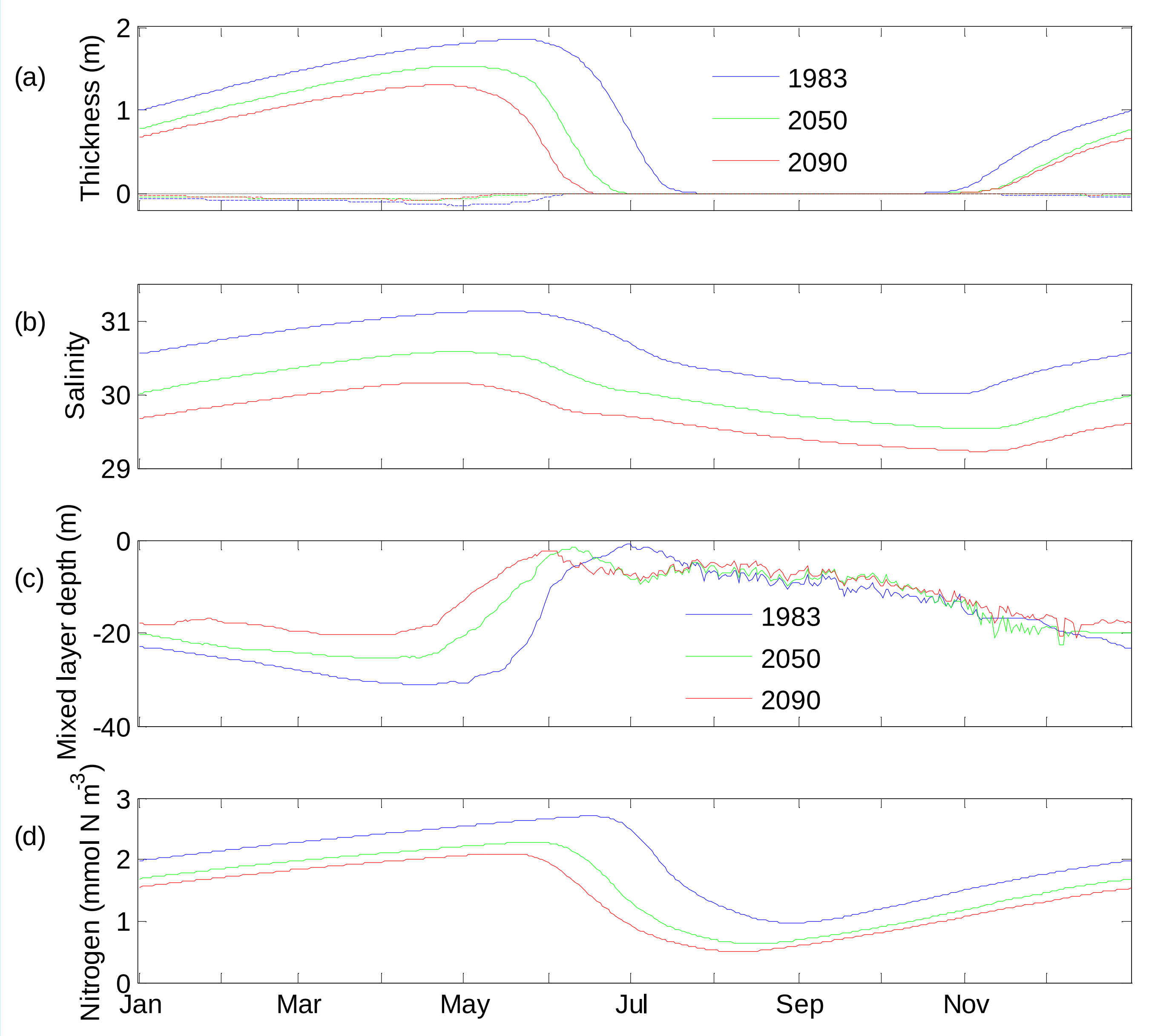


$$F_S = (W_O - W_{RO})(S_I - S_0) + S_0\mathbf{R}$$

(similar to Holland et al. 1997)



Future scenarios



Ice and snow

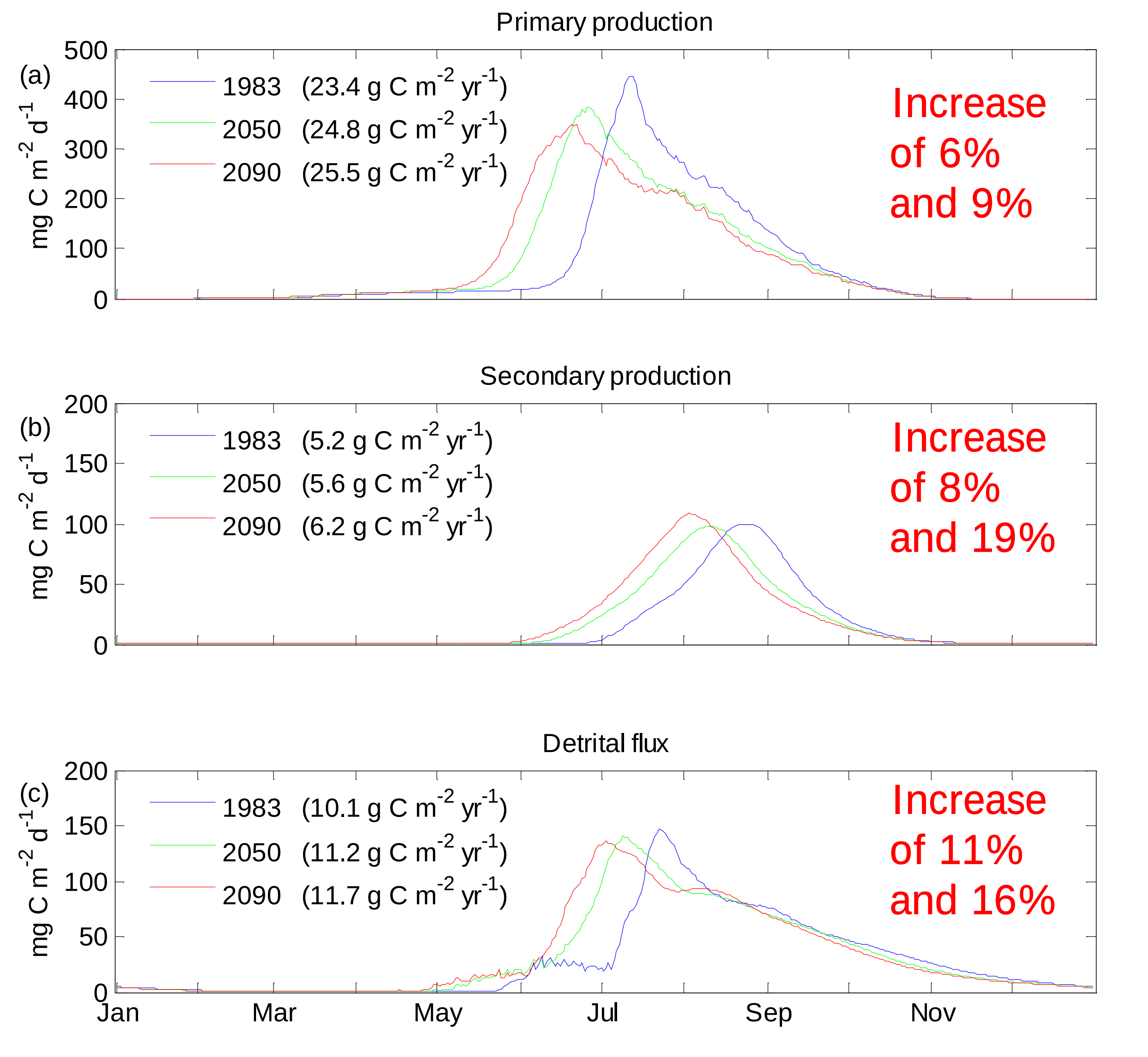
—1983
—2050
—2090

Salinity 0-40 m

Mixed layer depth

Nitrogen 0-40 m

Future scenarios



—1983
—2050
—2090

Summary for Beaufort Sea

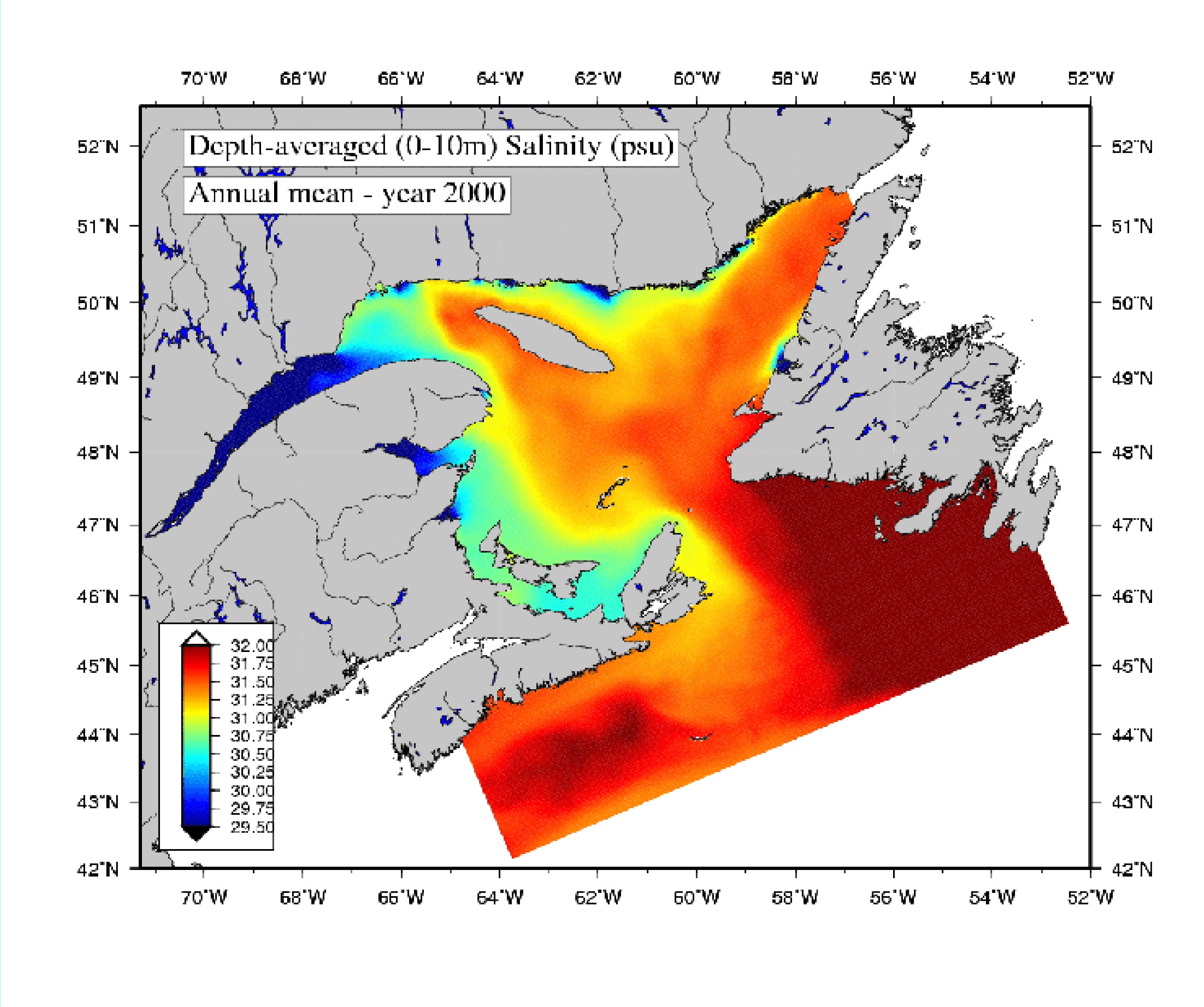
Results of 1D modelling study suggest that:

- Relative importance of the spring bloom decreases while the importance of the subsurface bloom increases

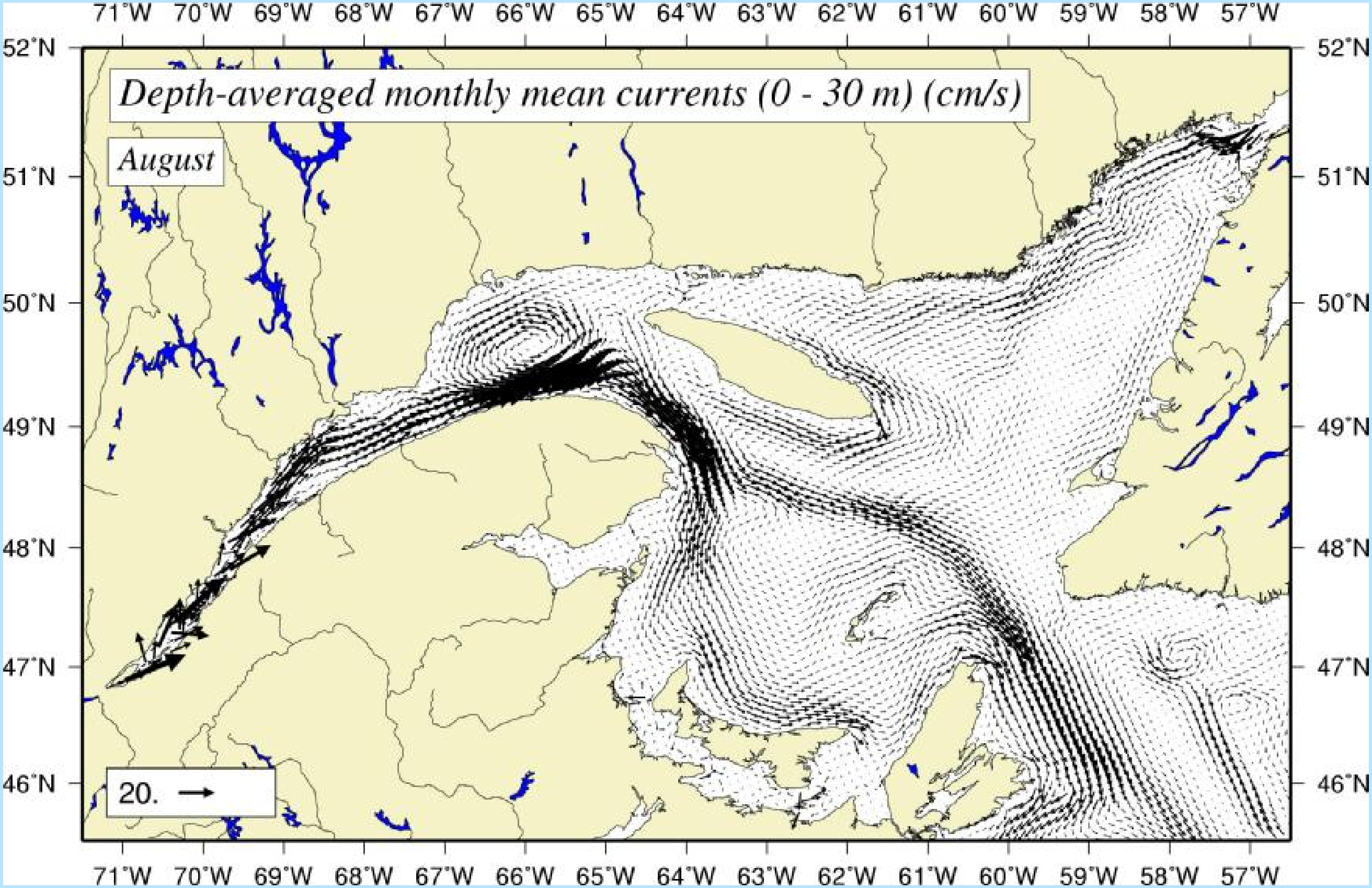
- the increase in *in situ* primary and export production in the Beaufort Sea, and potentially in other areas as well, will be moderate due to the strong stratification

See Lavoie et al. (2010)

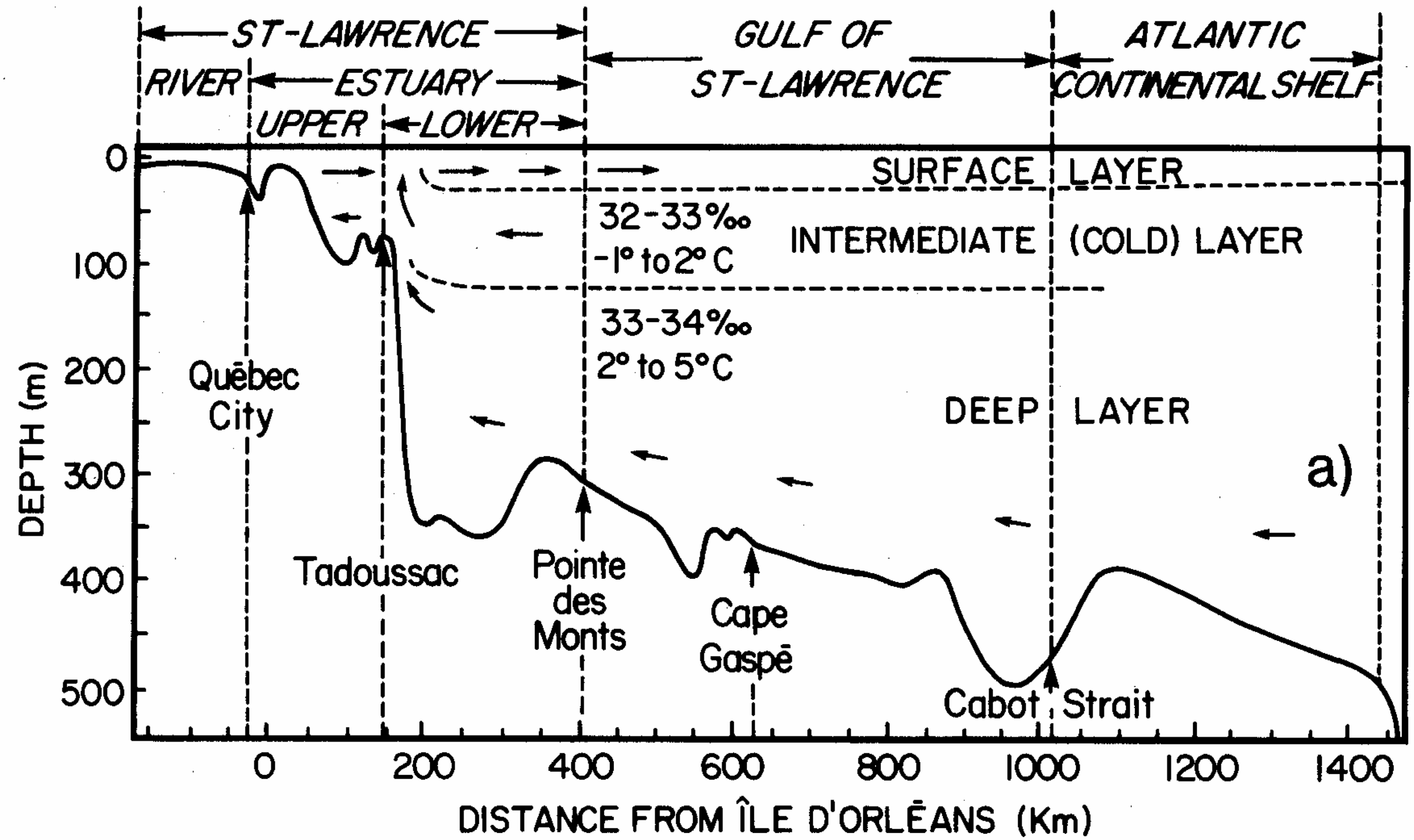
The Gulf of St. Lawrence case



Horizontal circulation

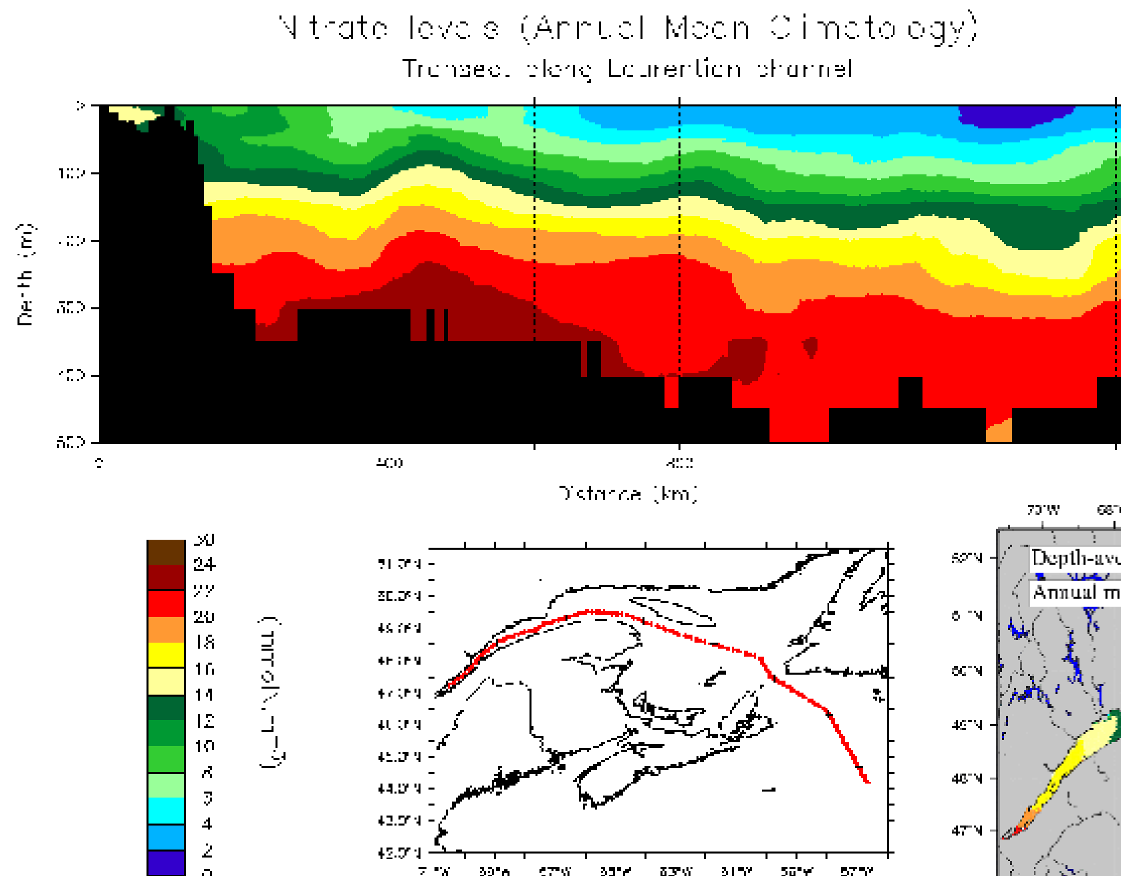


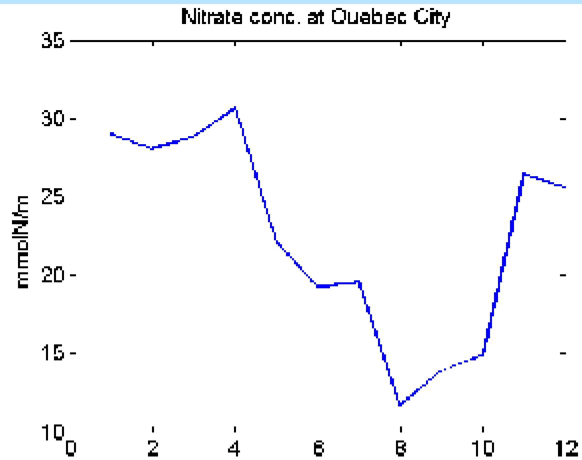
Horizontal circulation

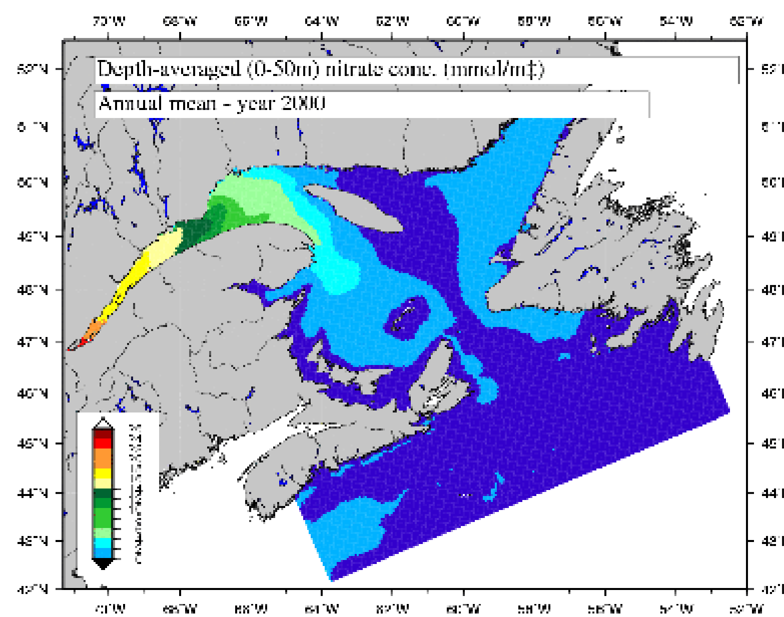


From Koutitonsky and Bugden (1991)

Nutrient pump



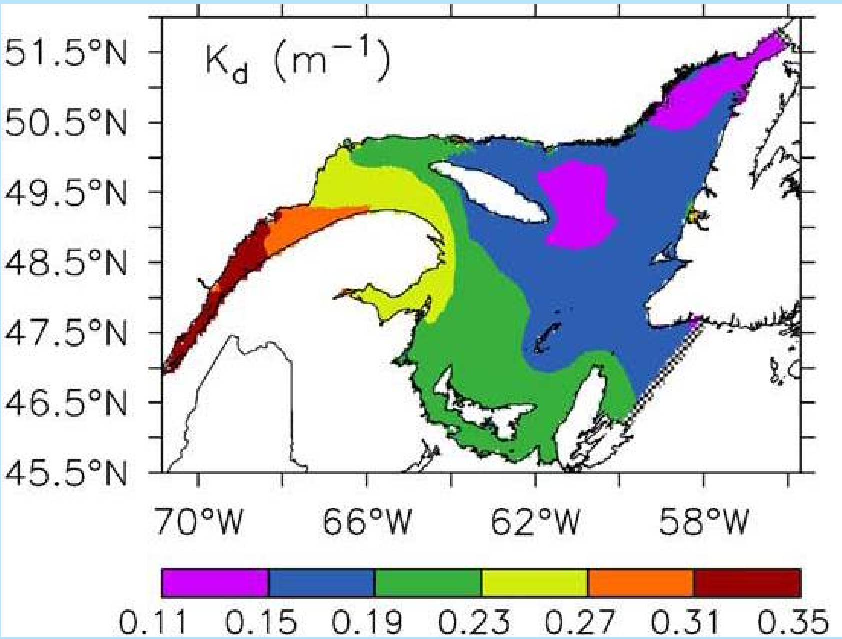


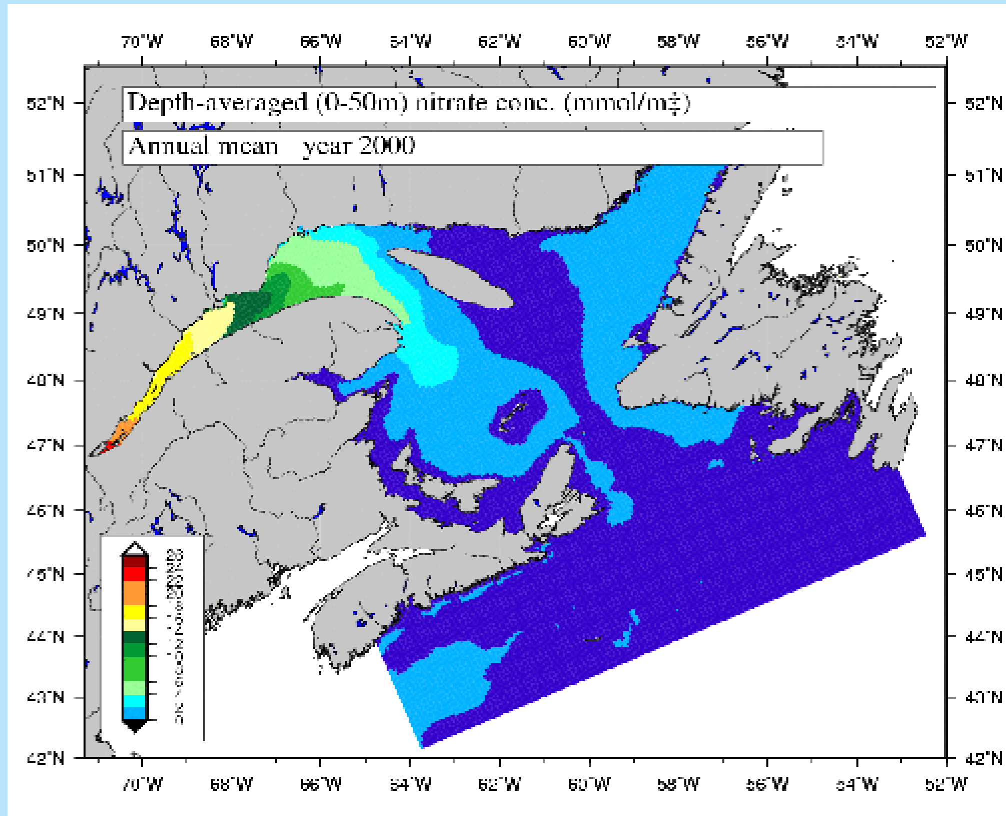


Annual mean depth-averaged (0-50 m) nitrate concentration

Light attenuation function of freshwater

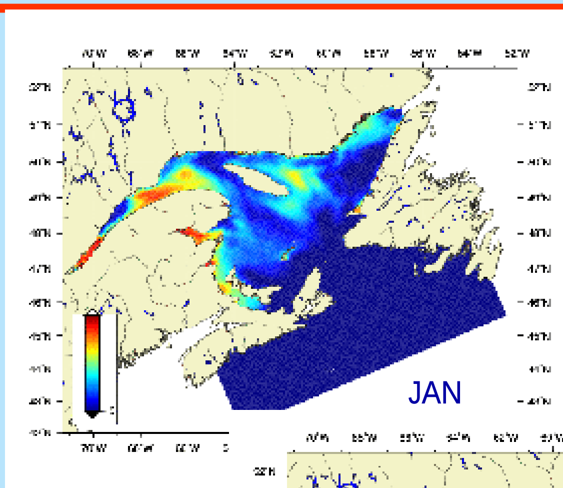
Annual mean depth-averaged (0-10m)
total diffuse attenuation coefficient

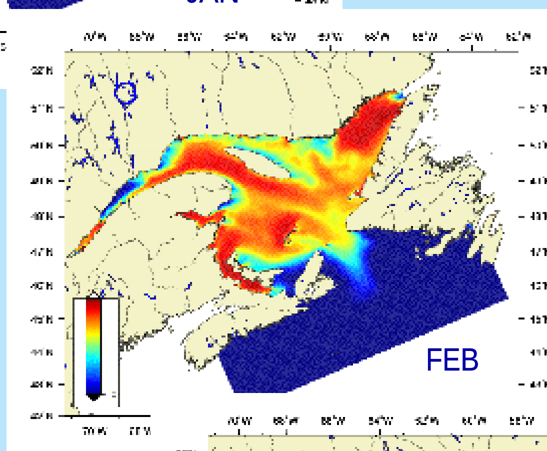


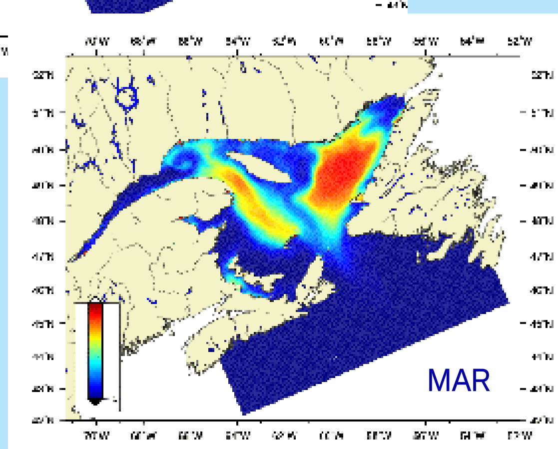


Le Fouest et al. (2010)

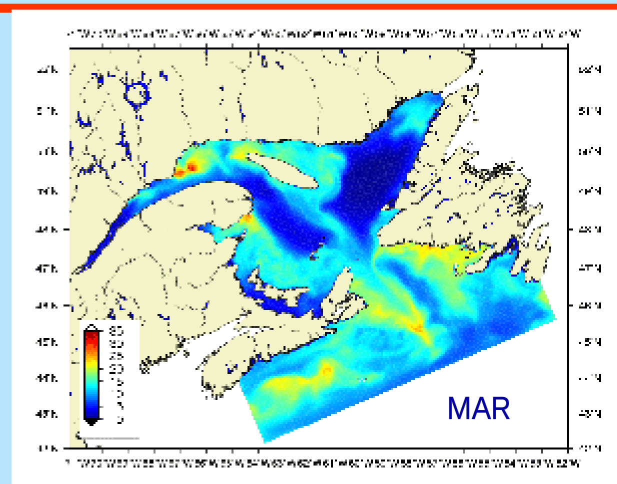
Simulated Chl a and ice concentration

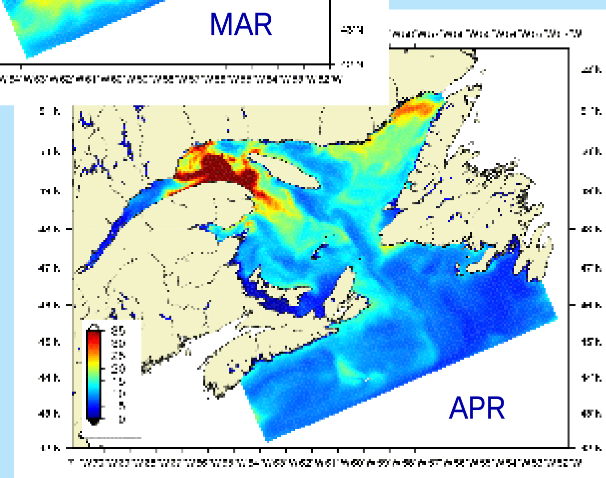


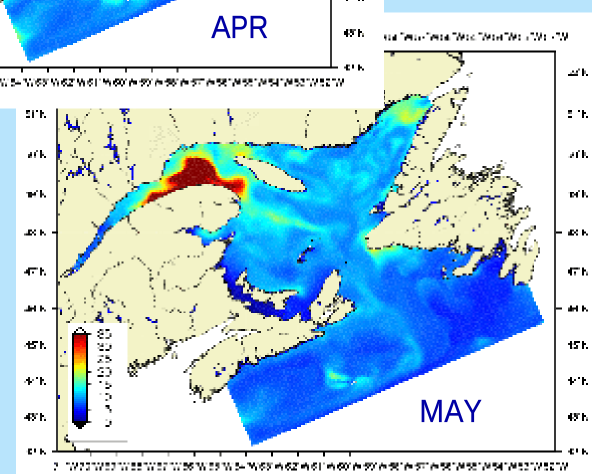




Ice concentration

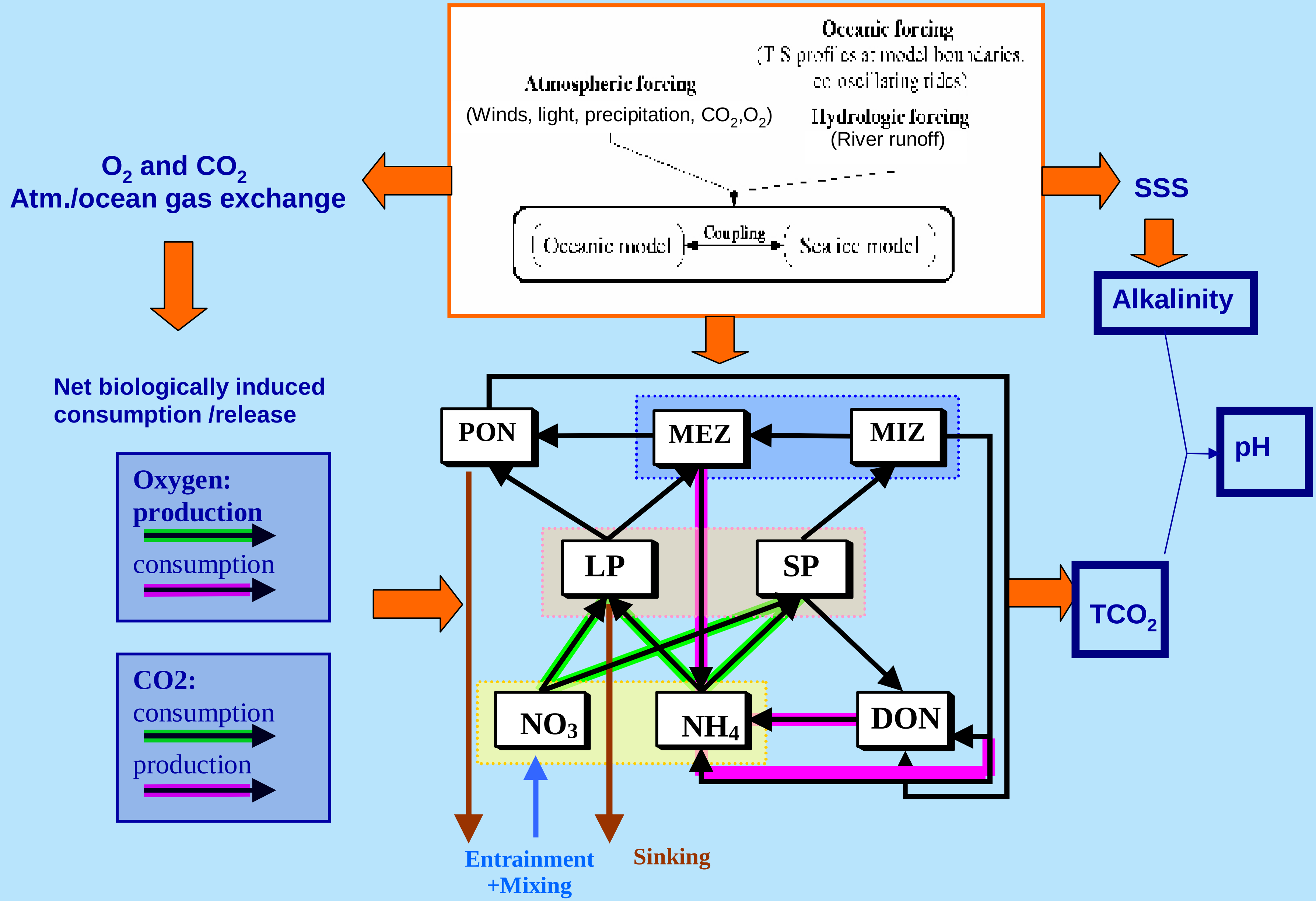




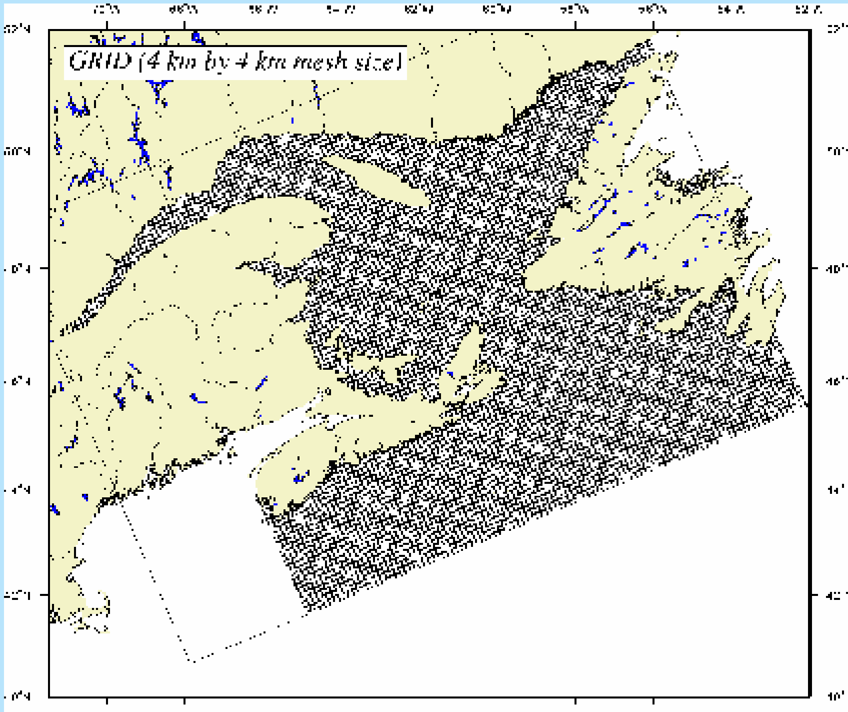


Depth-integrated (0-50 m) primary production (gC/m^2)

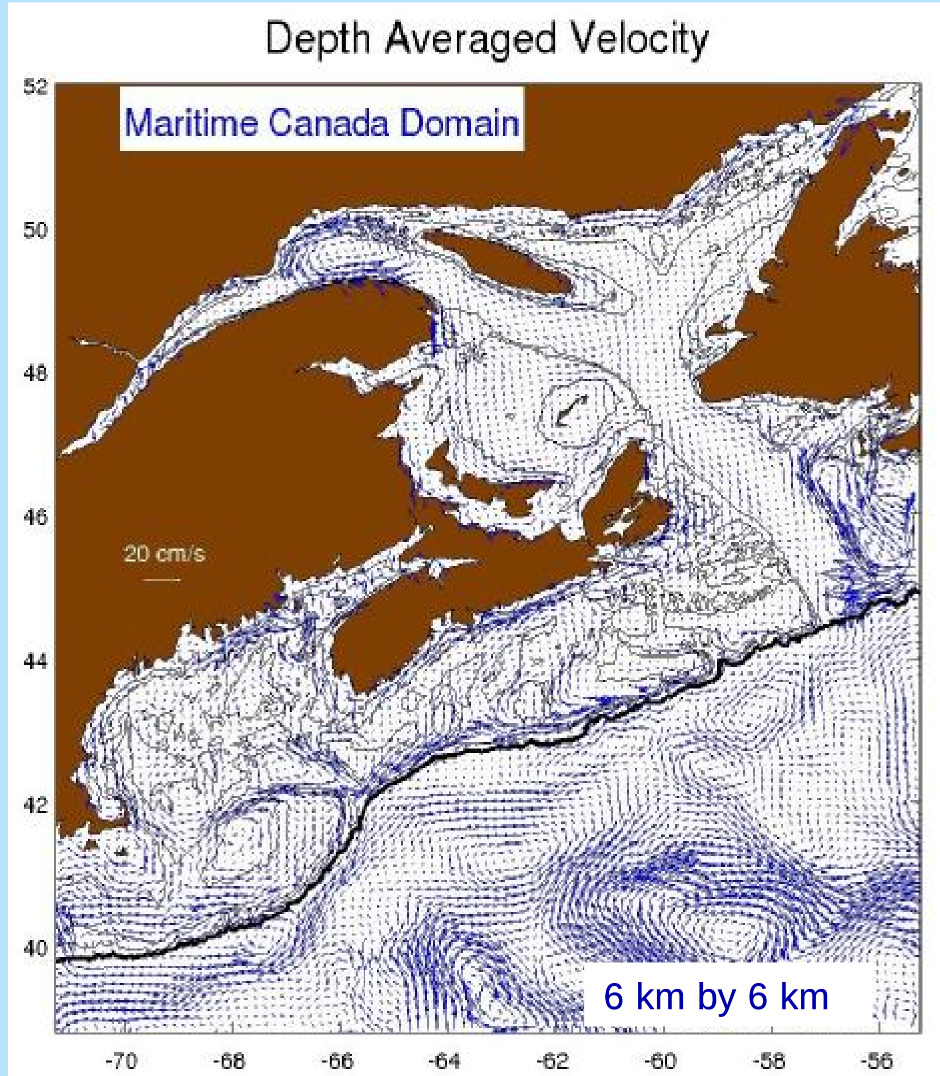
The coupled model (GSBM-GSS4): NPZD, O_2, and pH modules



GSS4 and NEMO domain



J. Chassé (DFO)

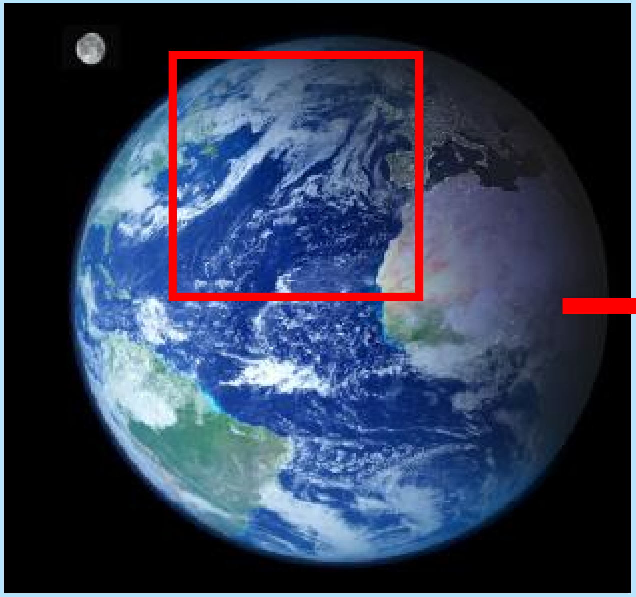


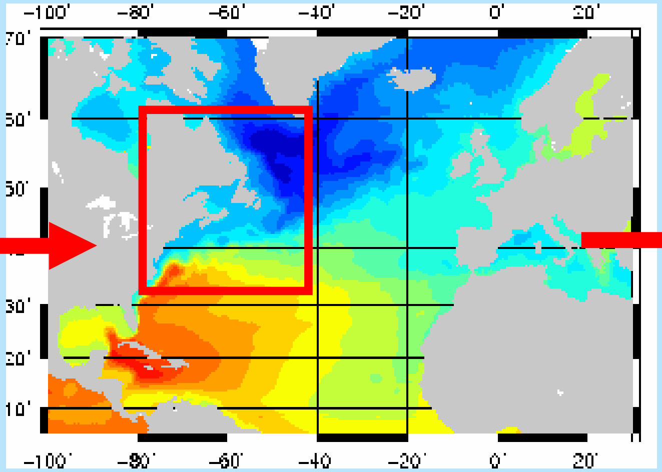
D. Brickman, A. Drozdowski and J. Chassé (DFO)

DFO - Climate Change Science Initiative (CCSI)

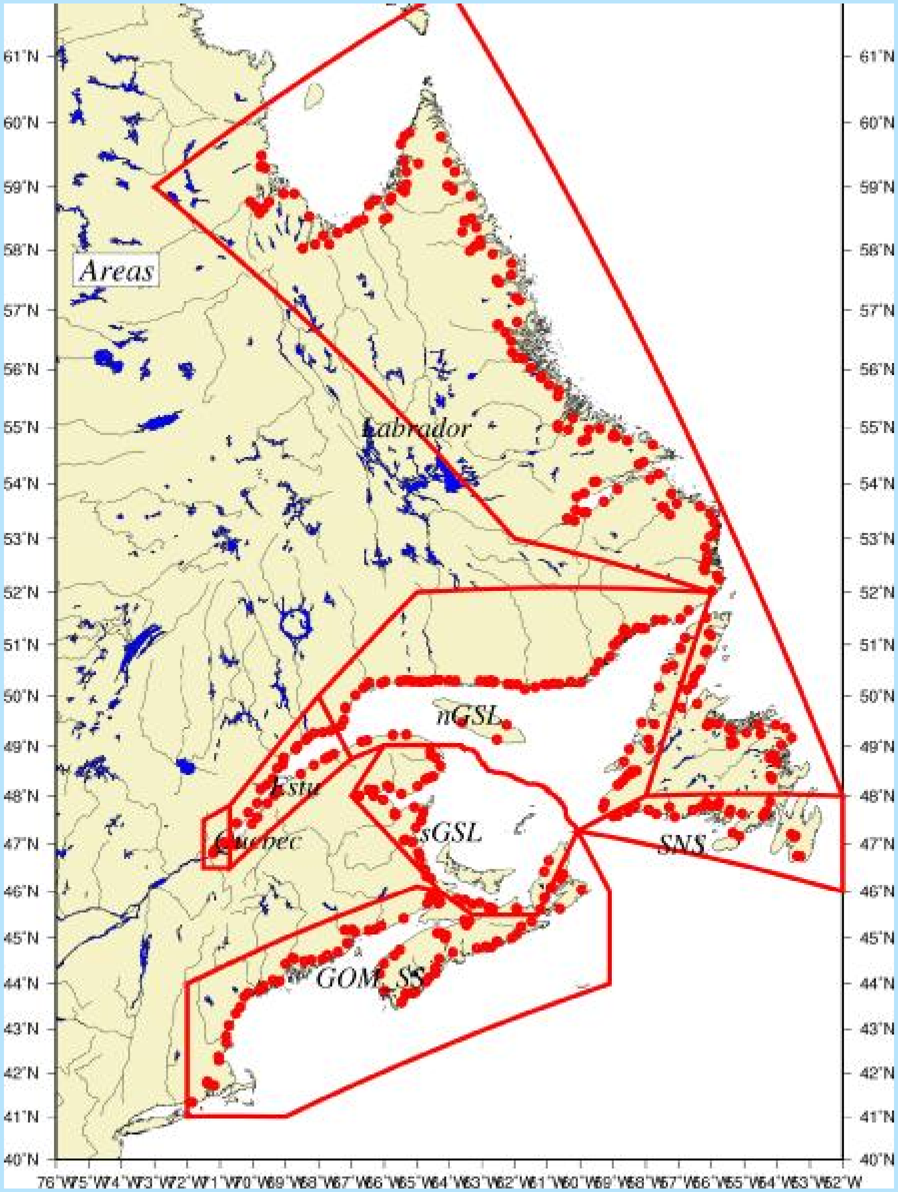
A regional atmosphere-ocean climate downscaling system for the Gulf of St. Lawrence, Scotian Shelf and Gulf of Maine

CCSI Thematic area:	Predictions and Scenarios
DFO regions:	Maritimes, Gulf and Quebec
Institutions:	BIO, GFC and IML
Participants:	J. Chassé (GFC), W. Perrie (BIO),
Main collaborators:	Z. Long (BIO), D. Brickman (BIO),
	L. Guo (BIO), A. Drozdowski,
	J. Loder (BIO), Cody Sipkema (BIO)
	D. Lavoie (IML), M. Starr (IML)





Estimation and Prediction of Fresh Water Runoff Based on Atmospheric Data

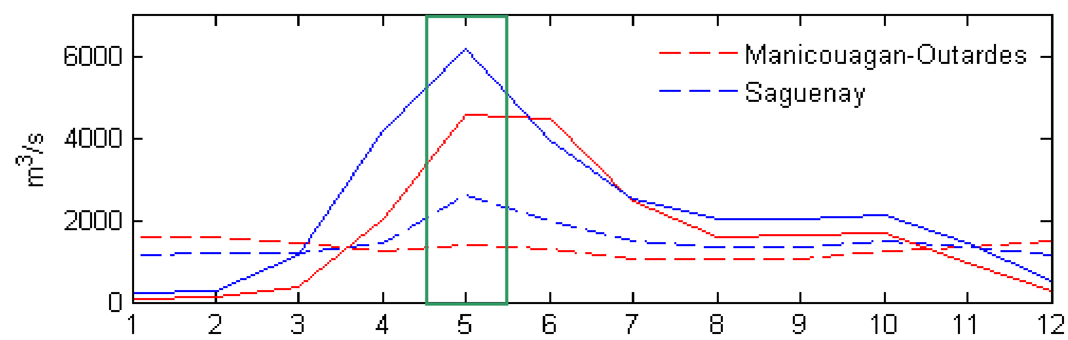


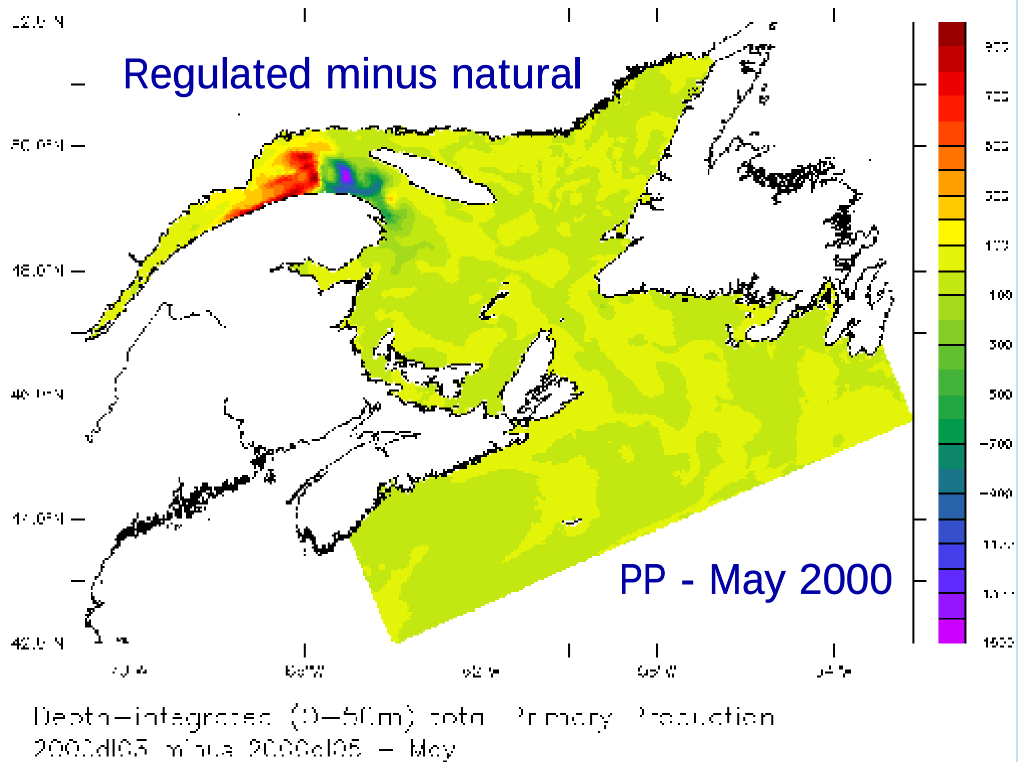
Cody D. S. Sipkema
and Joël. Chassé, DFO

How will PP change in the St. Lawrence system?

- We don't know yet …
- Effect of an increase in FW:
  - Decreases pumping at the head of the channel
  - Increases estuarine circulation and entrainment
    - Less nutrients but carried further away where light is available
  - Shift towards flagellates?
- and vice versa

Effect of river regulation





More answers, or questions, coming this year …