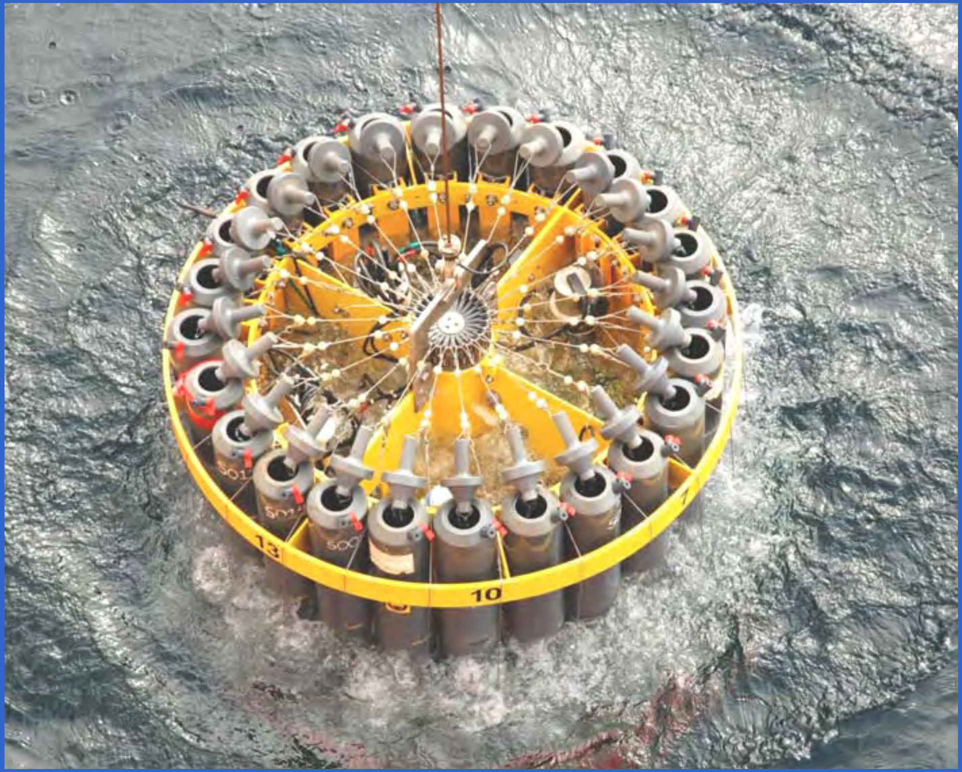
Changes in hydrography and ecosystem structure and function in shelf and deep water regions of the Labrador Sea (1990-2009)



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Fisheries and Oceans, Canada

Canadian (DFO) hydrographic, chemical and biological monitoring in the Labrador Sea

A) Yearly (spring-summer) *in situ* observations: 1990- or 1995-present

1) Hydrography

Temperature/Salinity

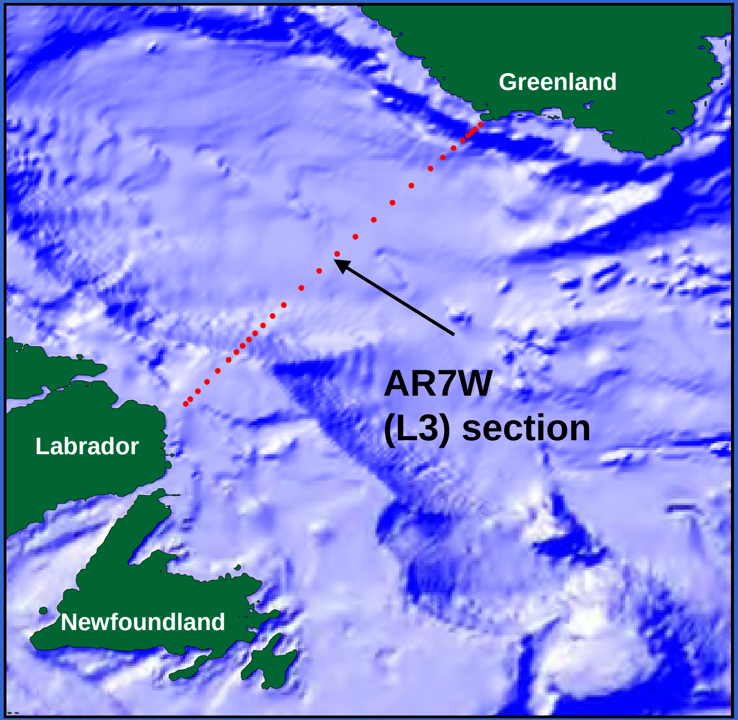
Currents

2) Chemistry

- Nutrients
- Oxygen
- DOM
- CO_2 system
- CFCs

3) Biology

- Bacteria (abundance, productivity, respiration)
- Phytoplankton (abundance, biomass, productivity)
- Zooplankton (abundance, biomass, egg production)

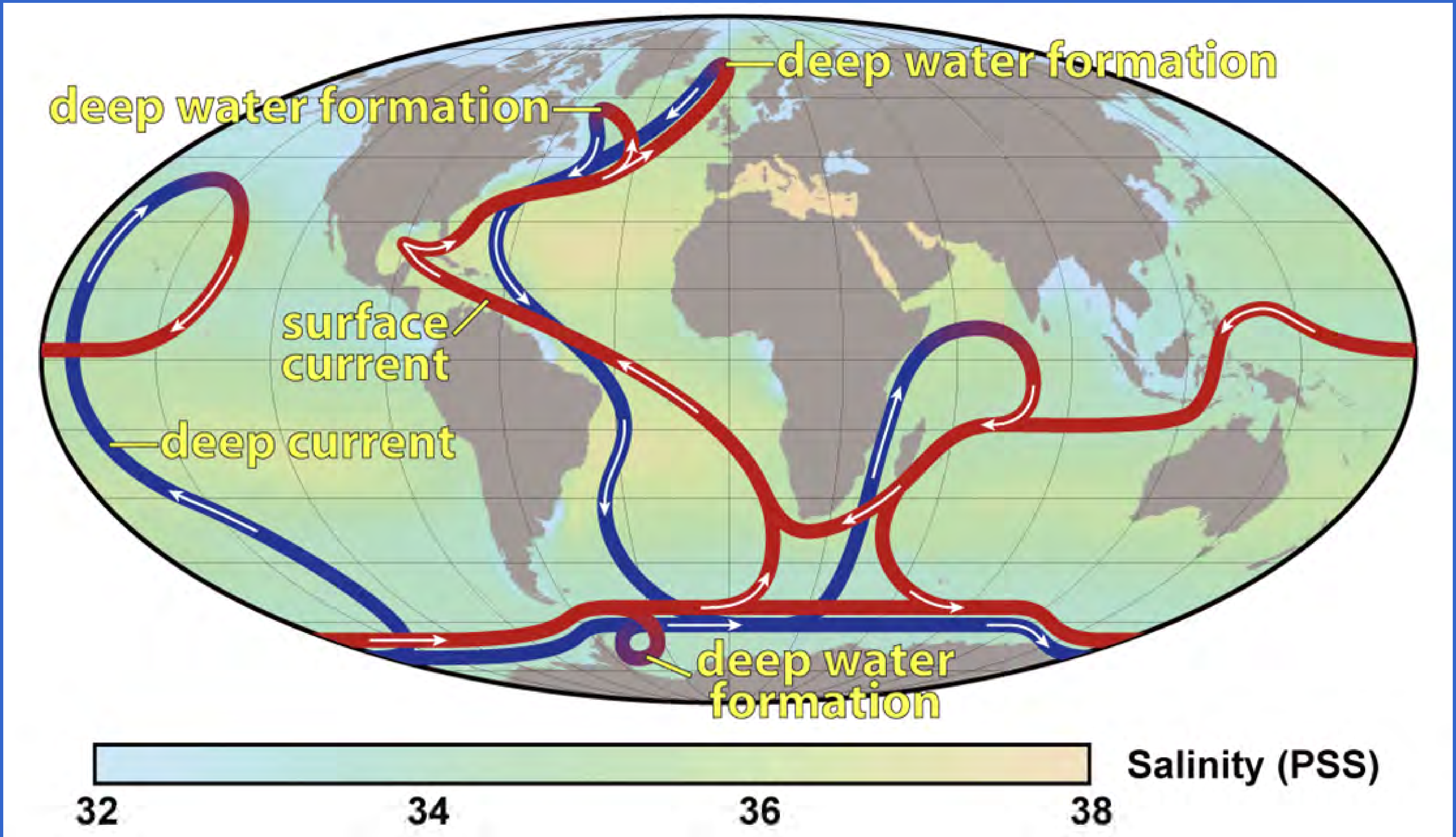


B) Year-round remote-sensing: 1998-present

SST and ocean colour

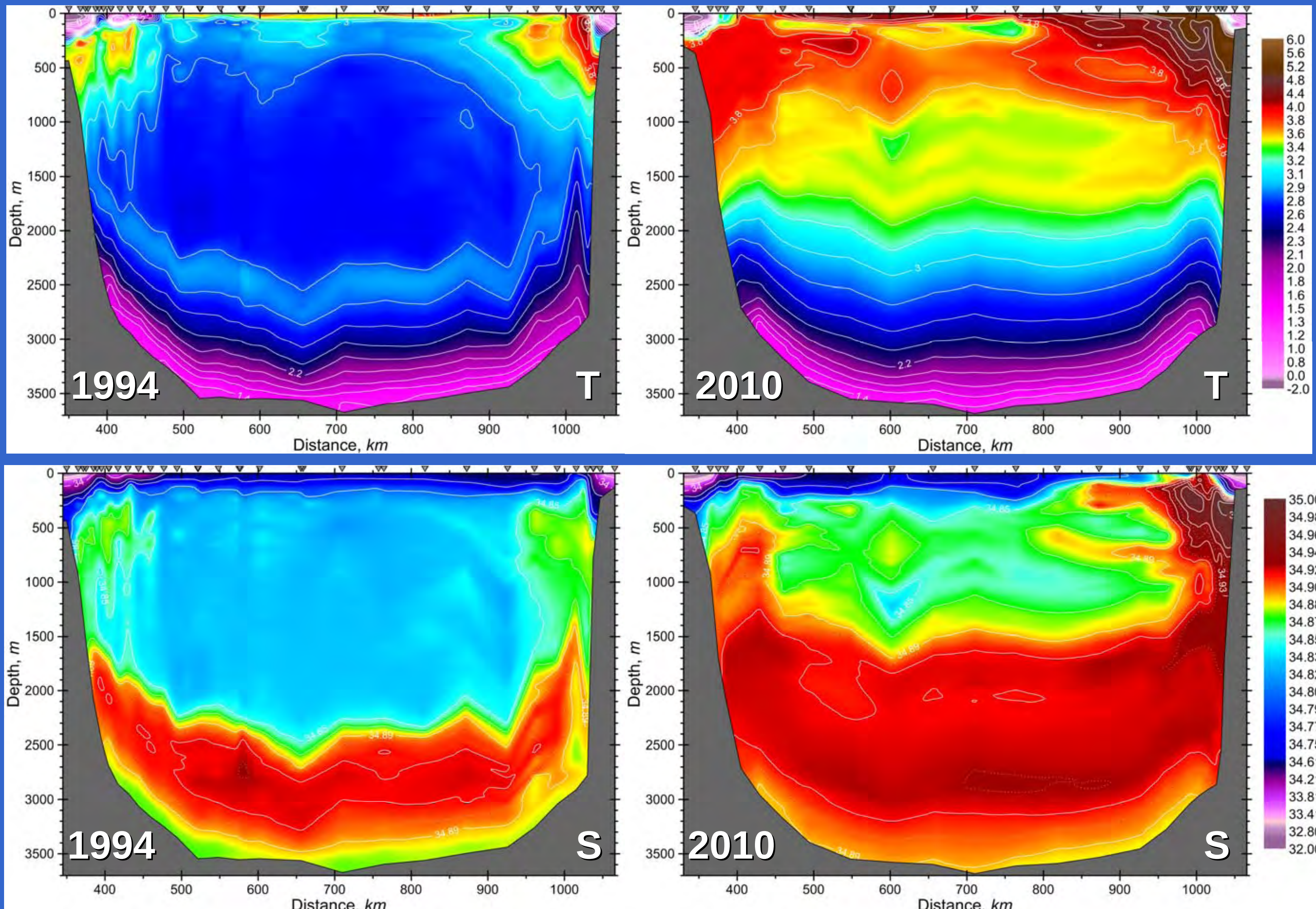
http://www.bio.gc.ca/monitoring-monitorage/azomp-pmzao/index-eng.htm

Role of the Labrador Sea in the Global Conveyor Belt

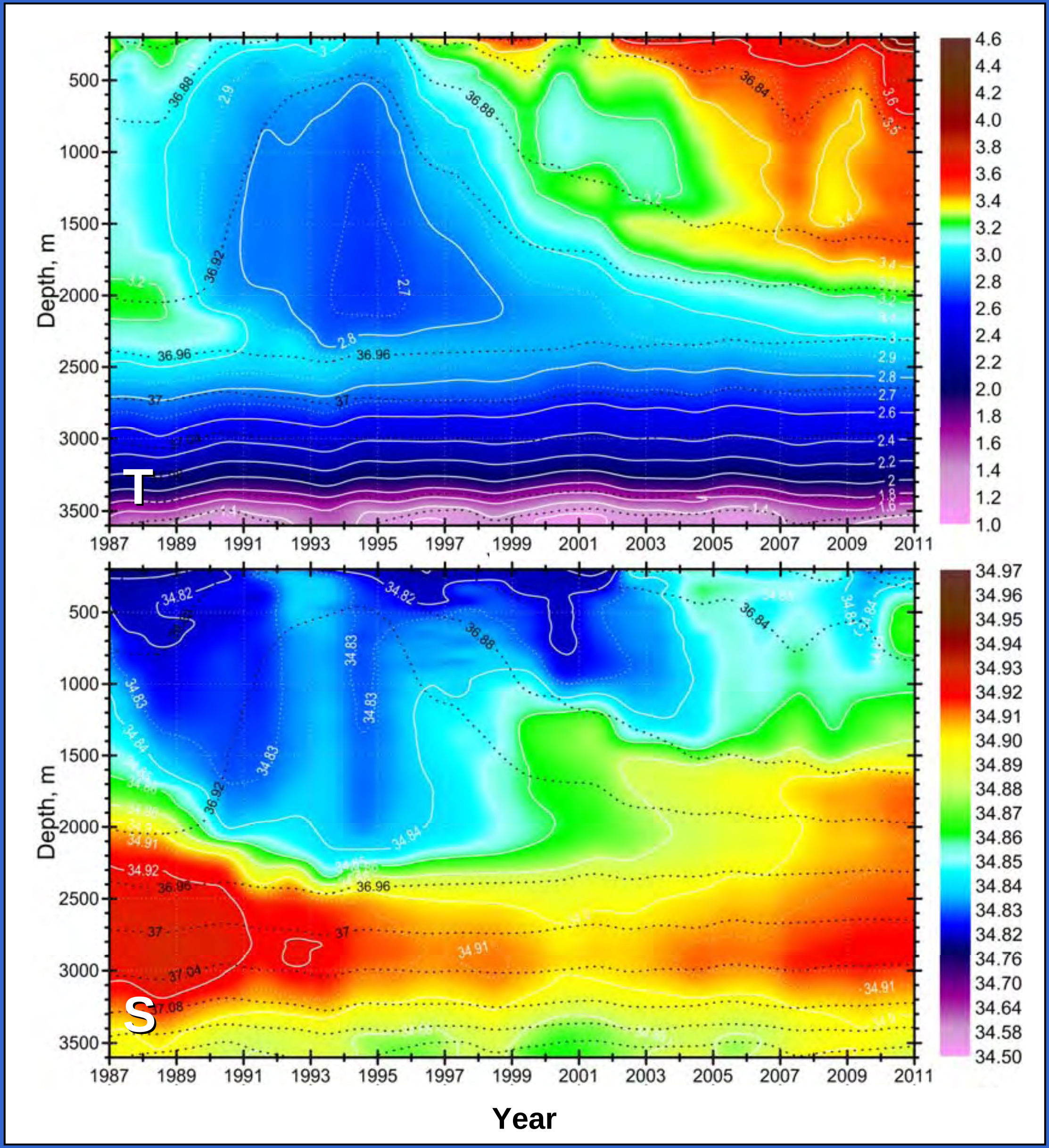


Source - http://marinesciencetoday.com/wp-content/uploads/2011/01/conveyor-belt.png

Hydrographic conditions on the AR7W section 1994 *versus* 2010



Temperature and salinity time series in the Labrador Sea 1987-2011



There was convection to ~2500 m in 1993.

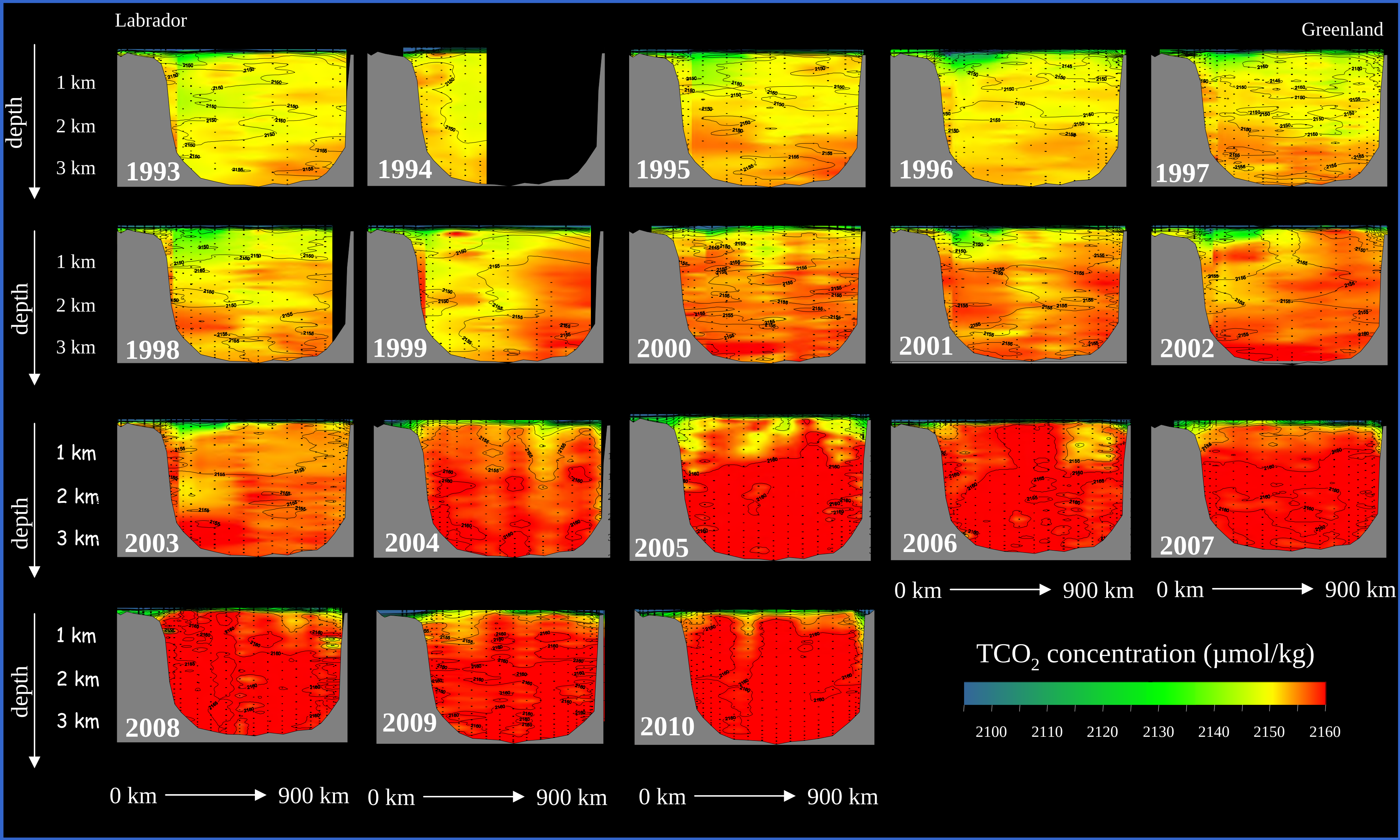
Since then the depth of convection has been shallower but variable.

This has led to the formation of a series of layers of Labrador Sea Water at intermediate depths.

These can be characterised by T and S (and chemical tracers).

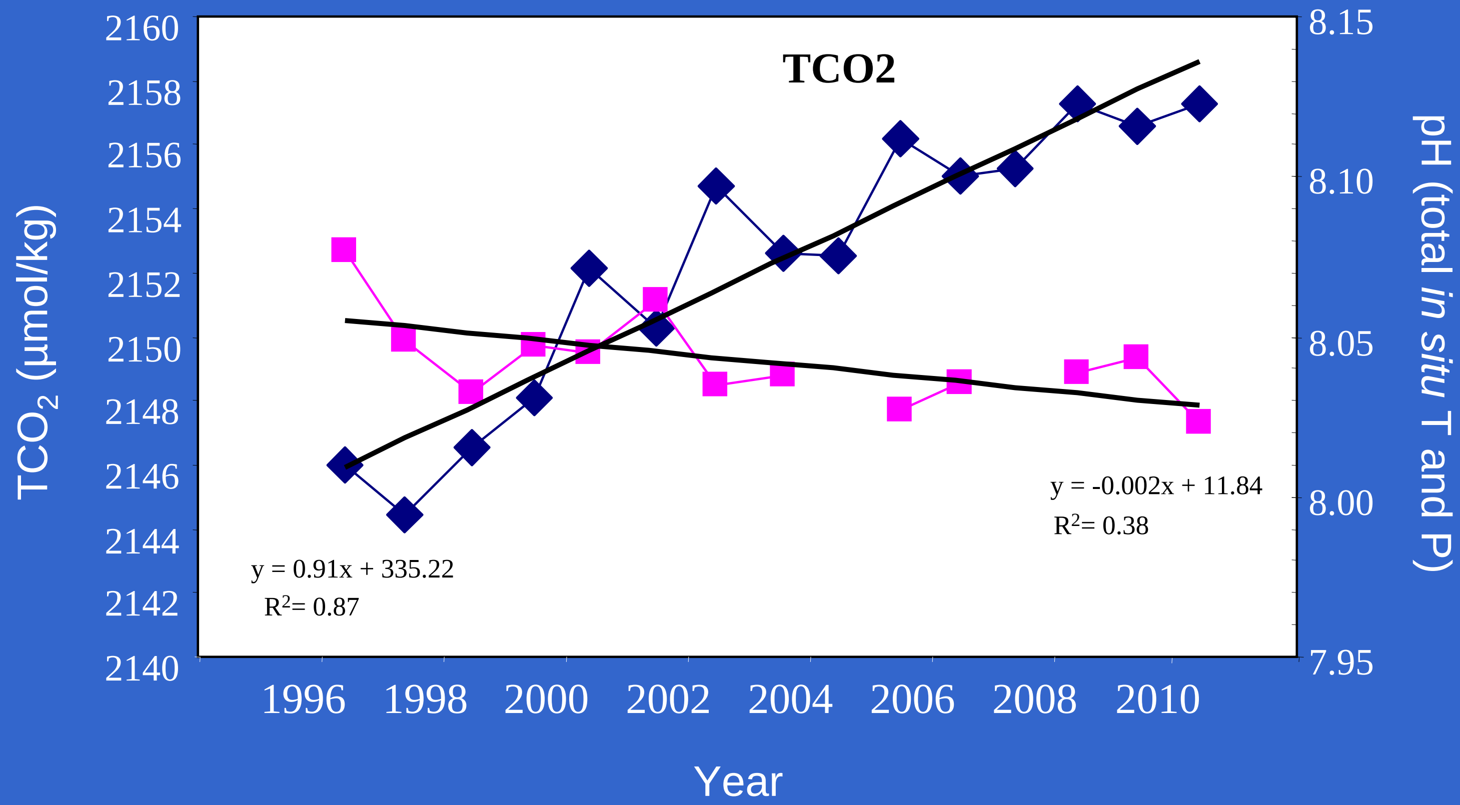
CO_2 concentrations along the Labrador Sea AR7W section 1993 to 2010

CO_2 levels have increased progressively since time series measurements began.



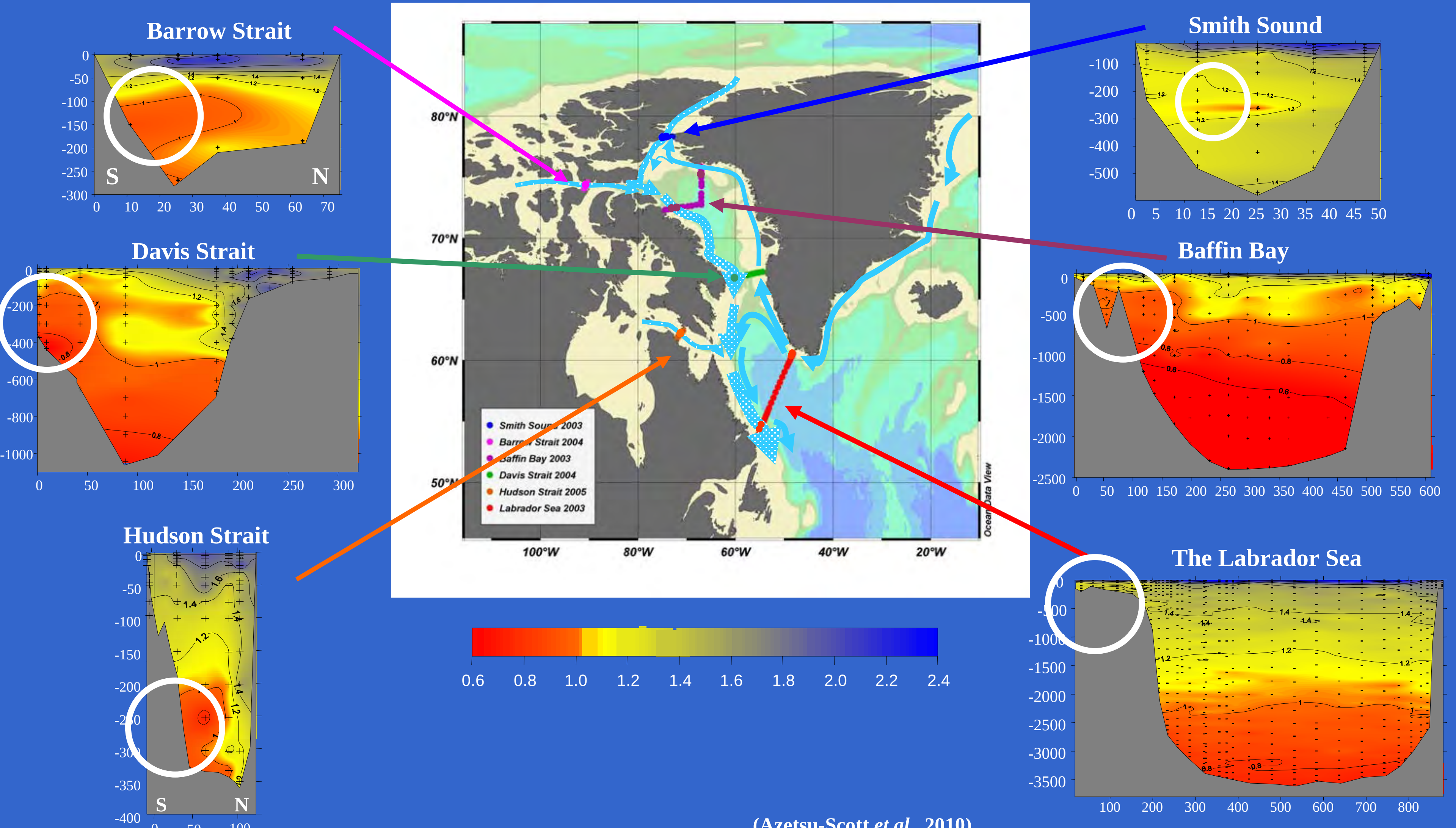
Total CO_2 concentration and calculated pH in the newly ventilated Labrador Sea Water (100-500 m)

pH has been decreasing as the result of anthropogenically generated increases in CO_2



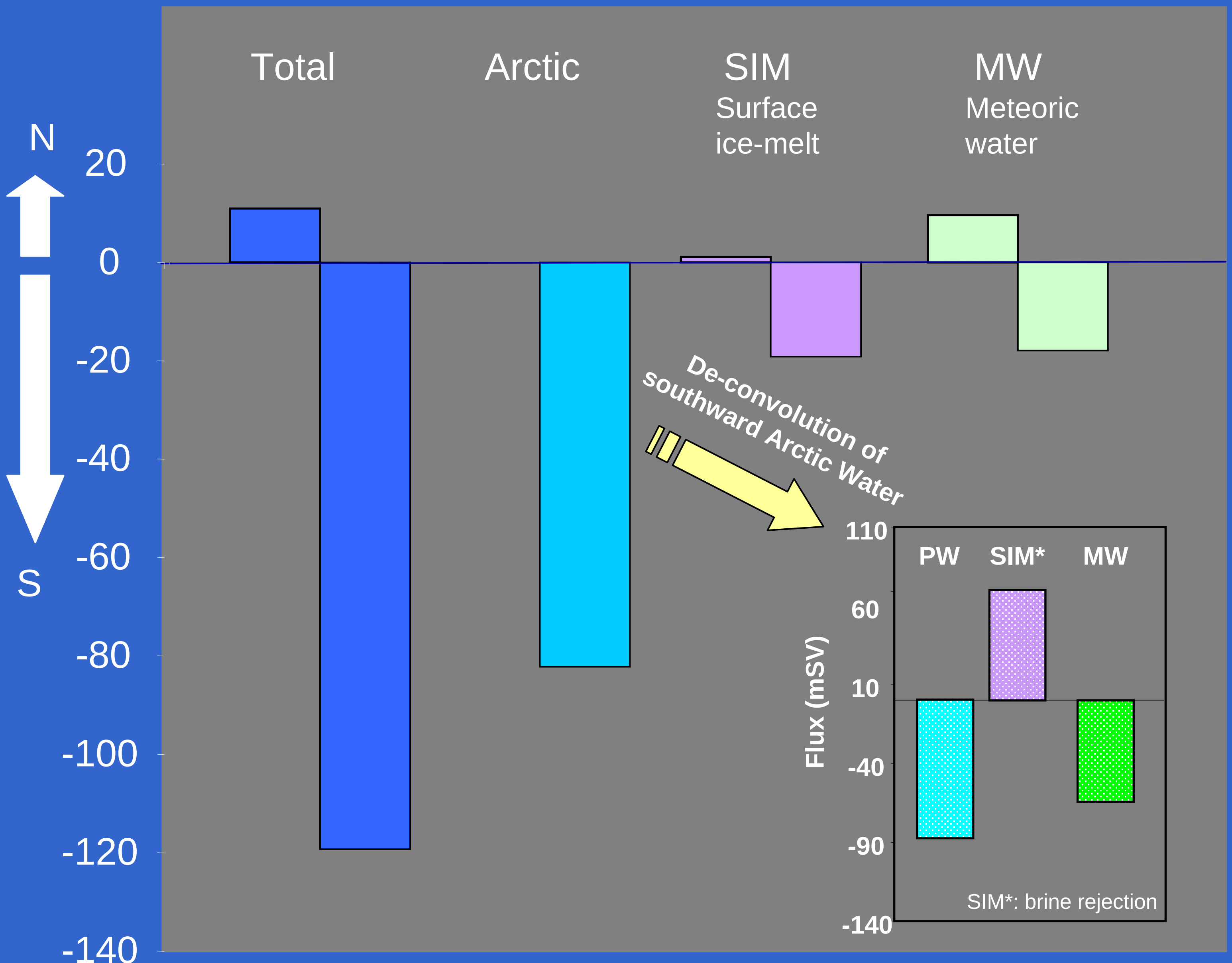
Saturation state for seawater with respect to aragonite (Ω_{arg}) in the Canadian Arctic Archipelago and the Labrador Sea

Ω_{arg} < 1 may be detrimental to organisms that use aragonite (*e.g.* pteropods and corals)



(Azetsu-Scott *et al.*, 2010)

Freshwater flux in mSV integrated across Davis Strait



Southward flux is mainly in the W

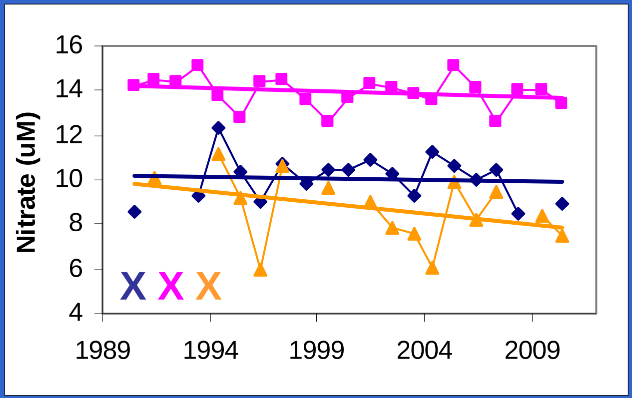
Southward MW sources are local (Baffin Island)

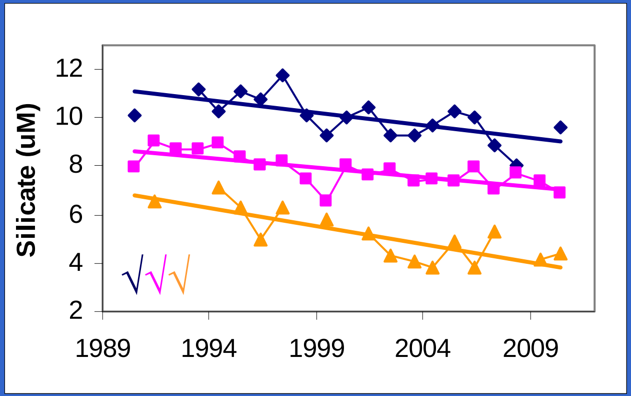
Southward Arctic W is a mixture of Pacific Water and MW mainly from the Mac-kenzie outflow.
Negative SIM indicates brine rejection.

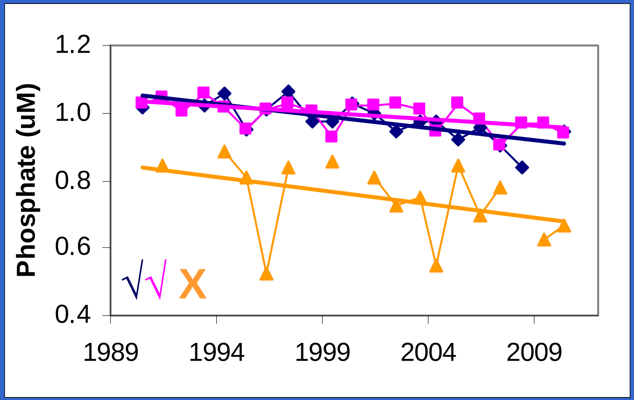
Northward flux is mainly in the E

Northward MW is from Greenland glaciers and precipitation

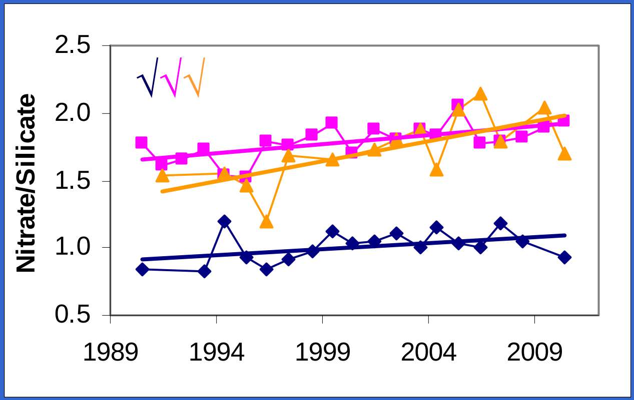
Nutrient concentrations in the 60-200 m depth range for regions of the AR7W section







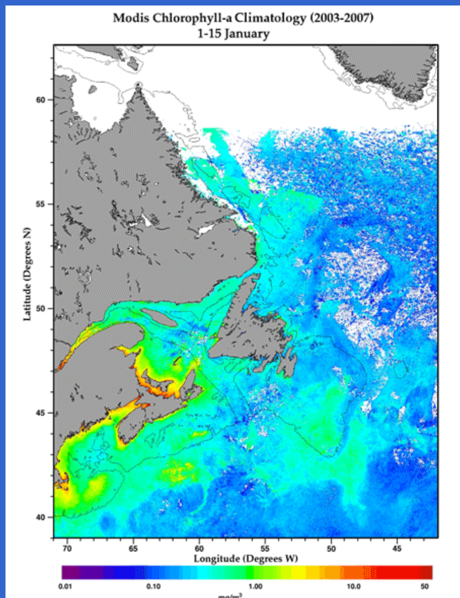
- Nitrate concentrations are not changing
- Silicate concentrations are decreasing
- Phosphate concentrations are decreasing in two (and possibly all) regions
- Nitrate:silicate ratios are increasing



Labrador Shelf
Labrador Basin
Greenland Shelf

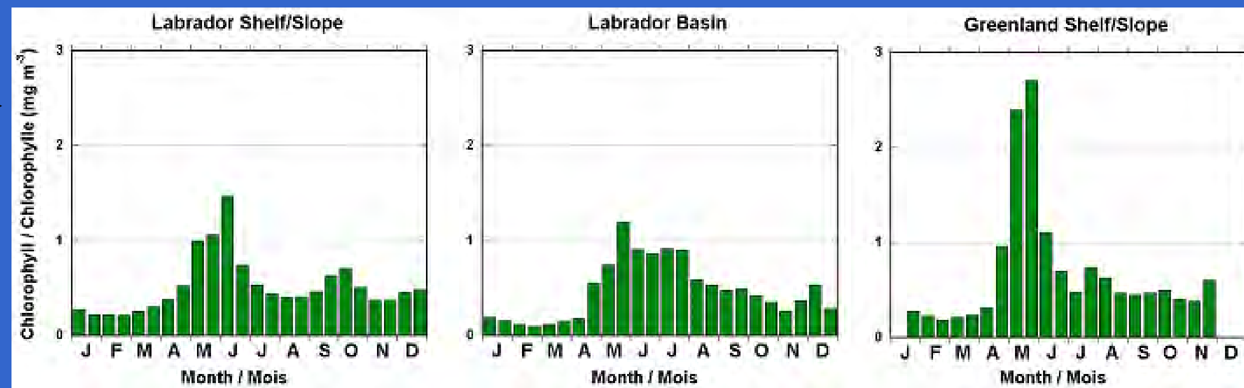
√ = significant trend
X = non-significant trend

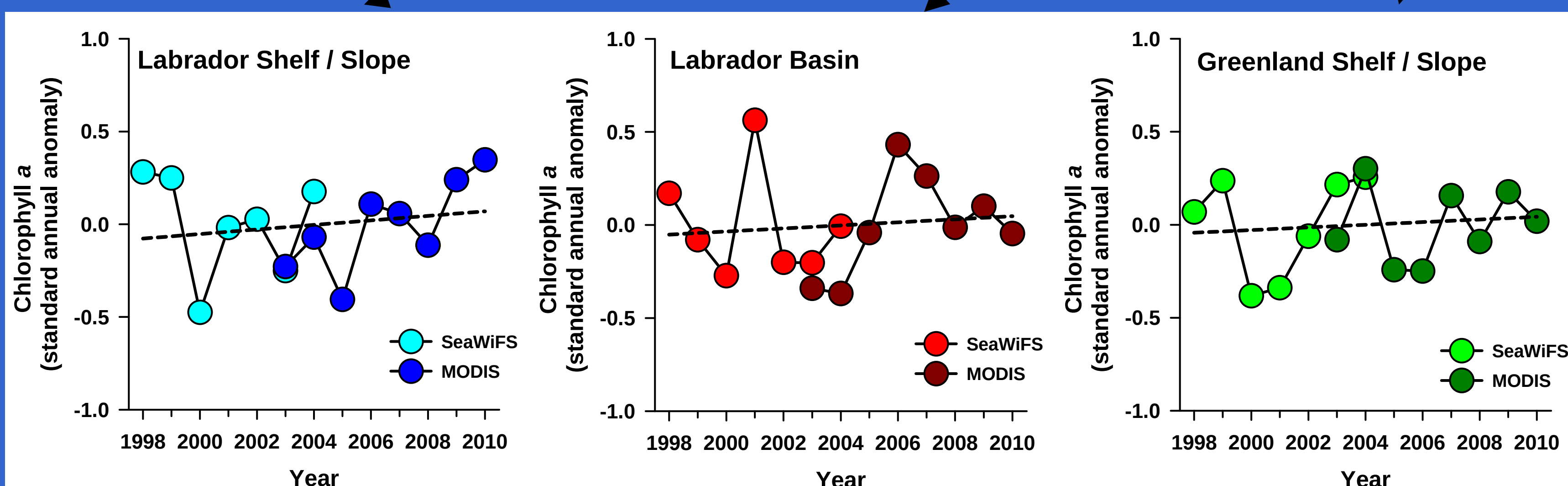
Satellite observations of sea-surface chlorophyll (phytoplankton) concentration



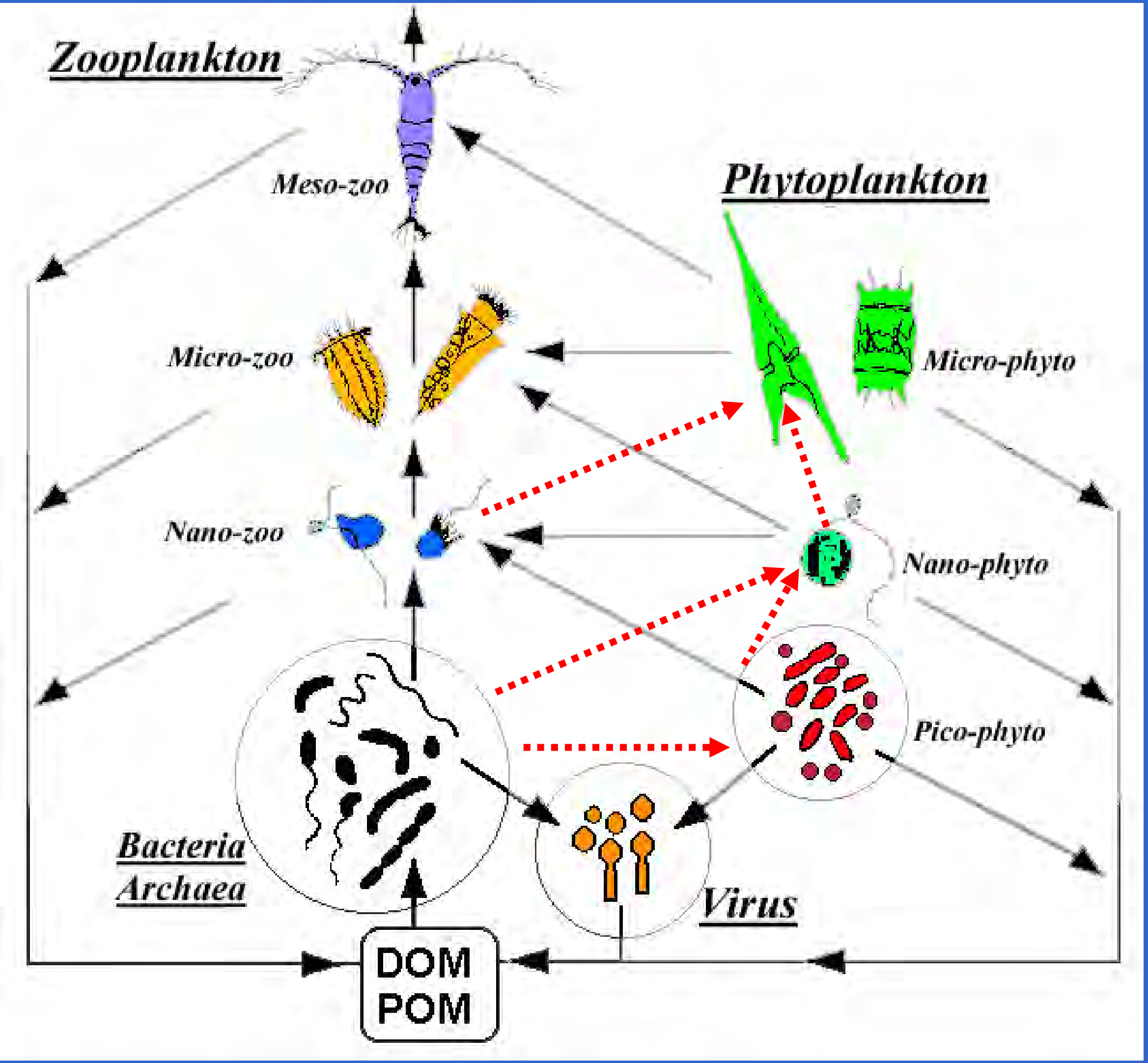
Phytoplankton bloom dynamics and vary regionally – blooms earliest and most intense in Greenland Shelf/Slope region

Annual average chlorophyll concentrations show slight (but insignificant) upward trends since 1998





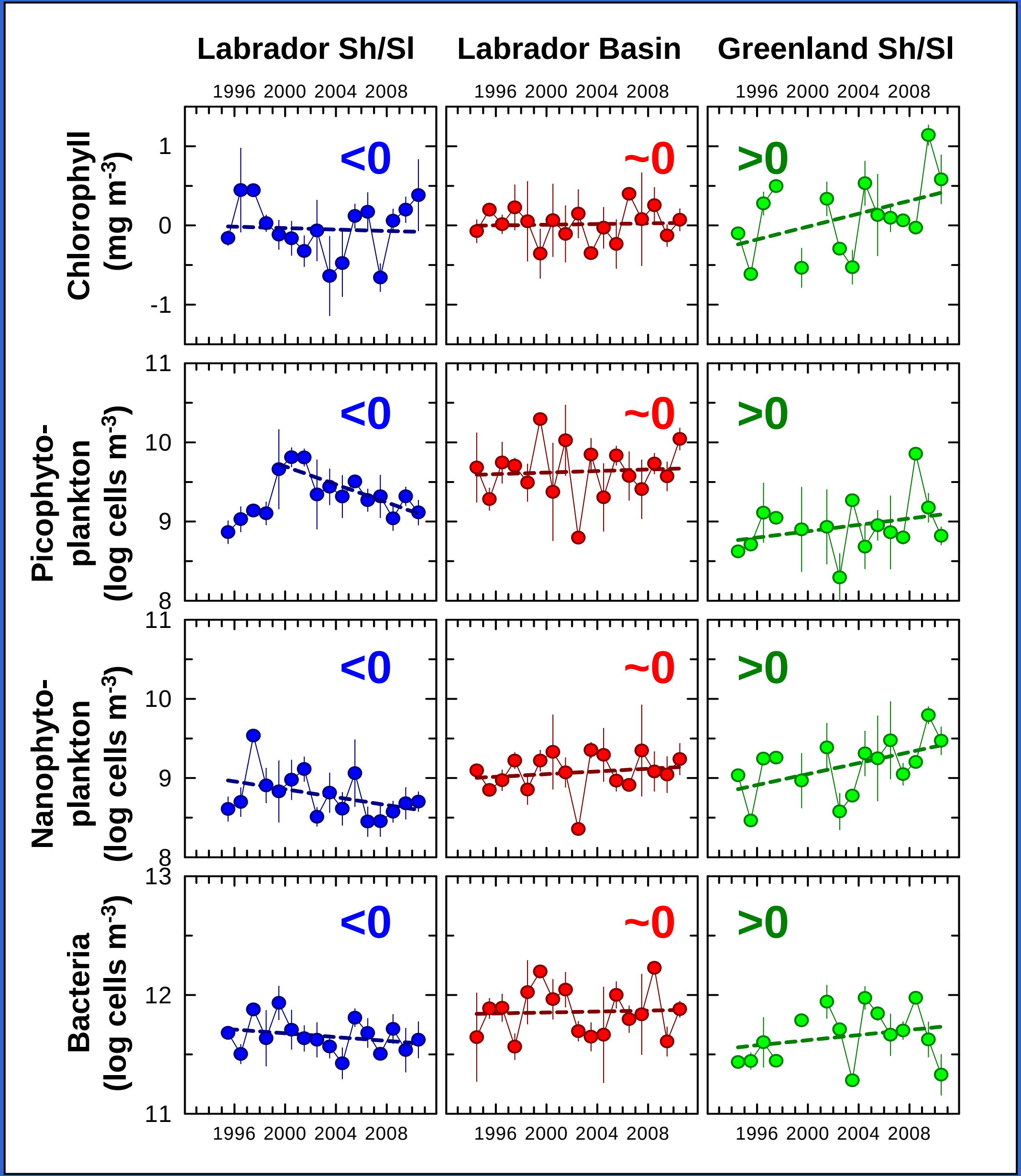
Components of the food web found in all marine ecosystems including the Labrador Sea



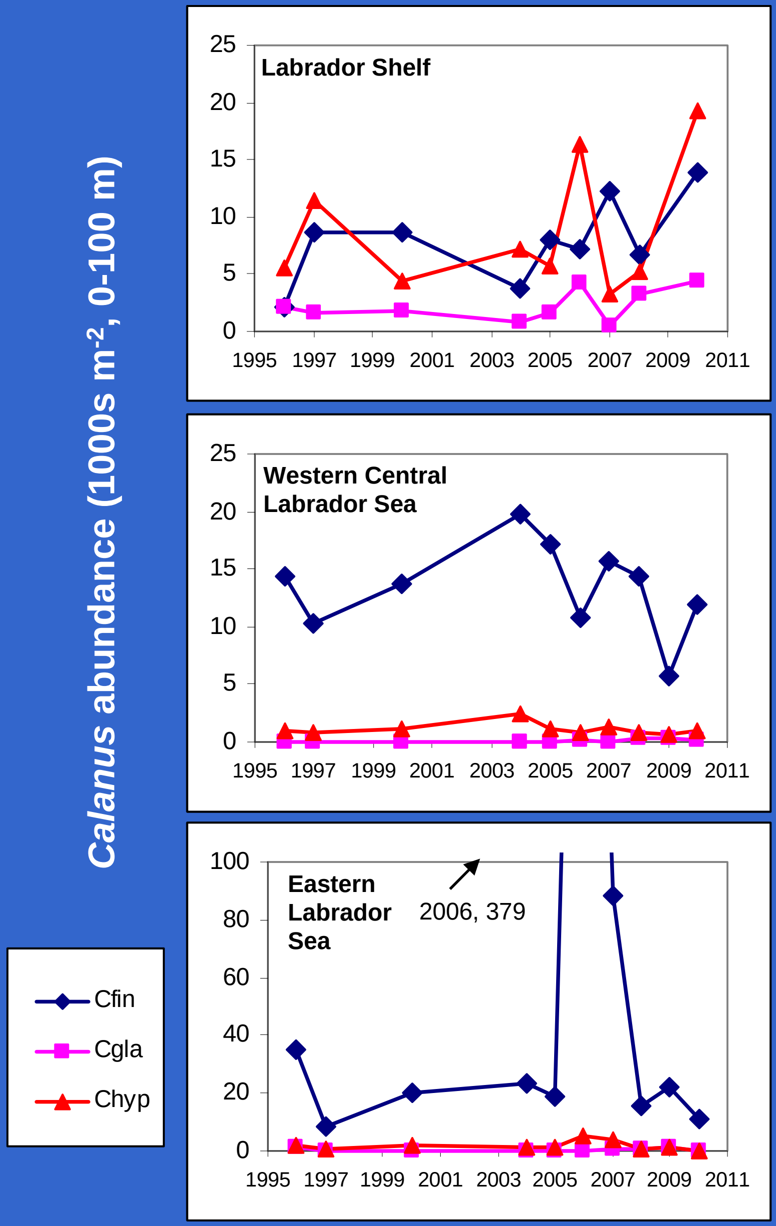
In situ observations of chlorophyll concentration and the abundance of picophytoplankton, nanophytoplankton and bacteria in the Labrador Sea

All variables show parallel changes within a region, but upward (Greenland Shelf) and downward (Labrador Shelf) trends are not significant

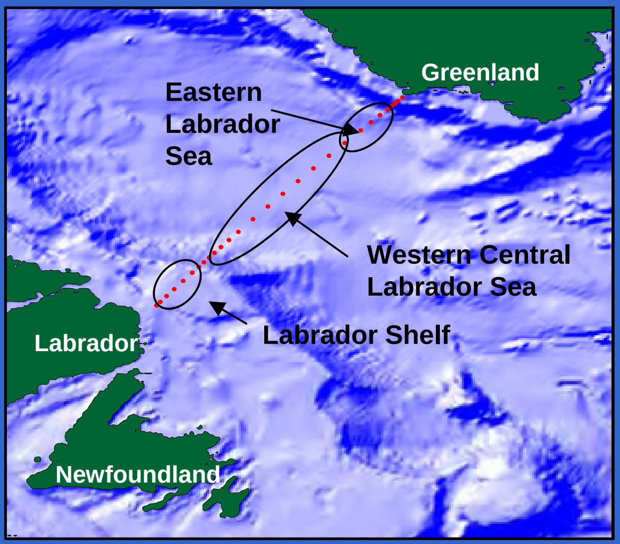
Microplankton (*e.g*. diatoms, dinoflagellates) are not enumerated, but are included in the chlorophyll concentration



Abundance of *Calanus finmarchicus*, *Calanus glacialis* and *Calanus hyperboreus* along the AR7W line in late May

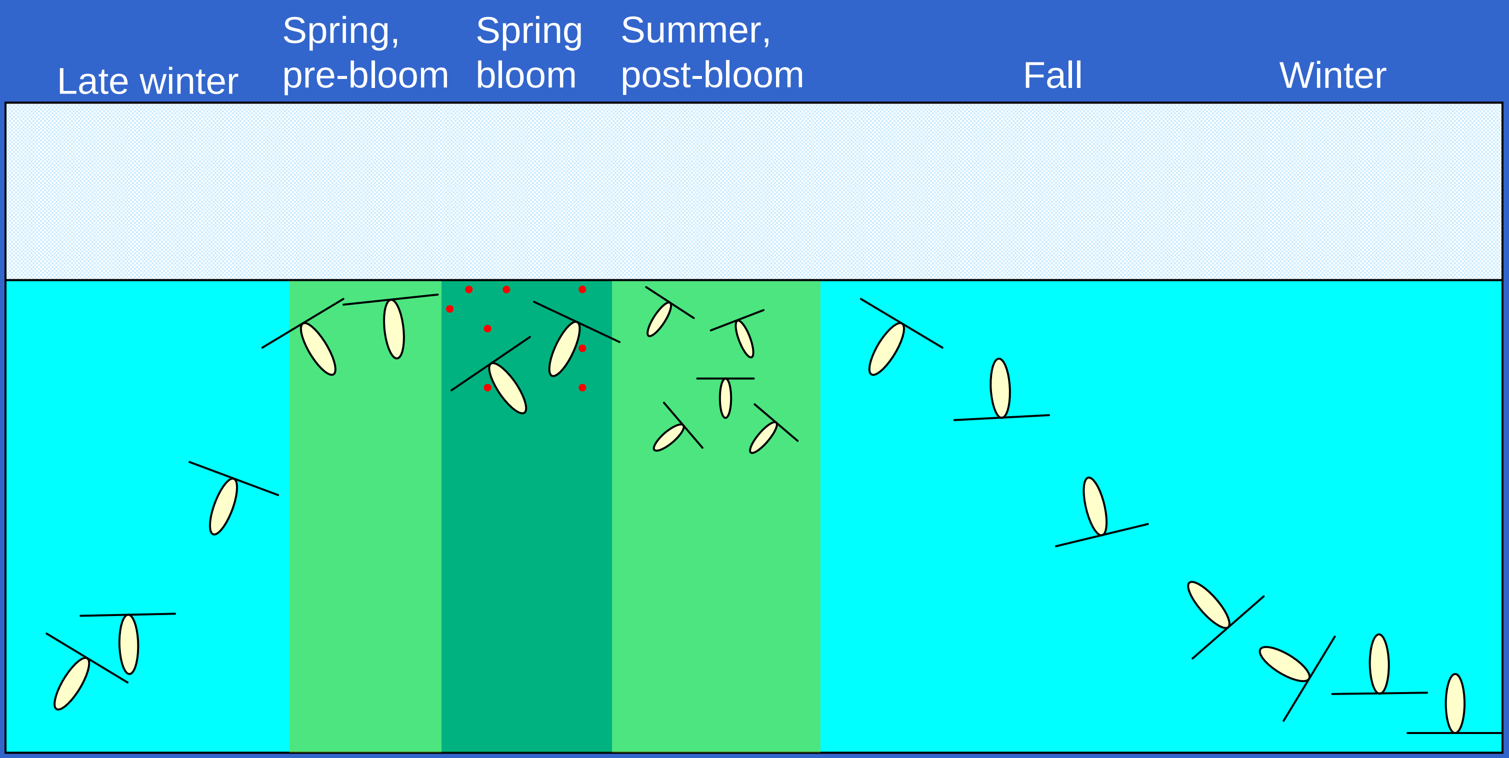


- Three species of *Calanus* dominate the meso-zooplankton biomass in the Labrador Sea
- Two are important only on the Labrador Shelf
- The abundance of *C. finmarchicus* (and the other species) is strongly influenced by the timing of its seasonal production cycle, which varies regionally and from year-to-year, relative to the sampling period



Idealised scheme for the life cycle of *Calanus finmarchicus*

Calanus finmarchicus dominates the mesozooplankton in the NW Atlantic.



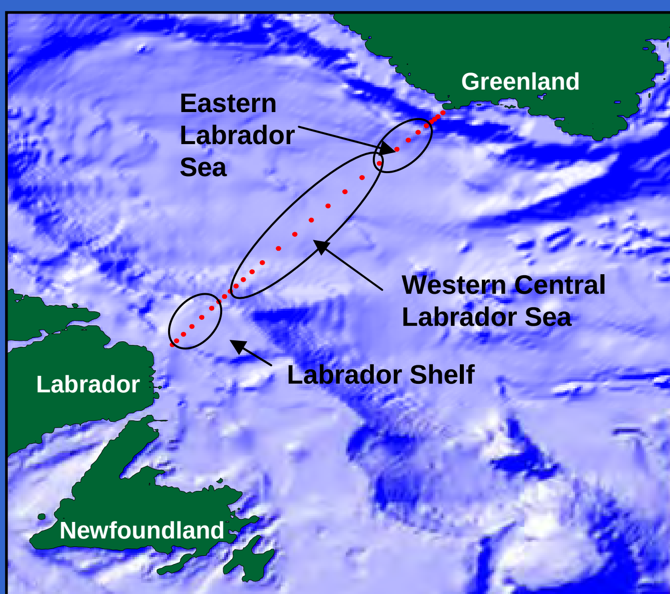
During the seasonal cycle

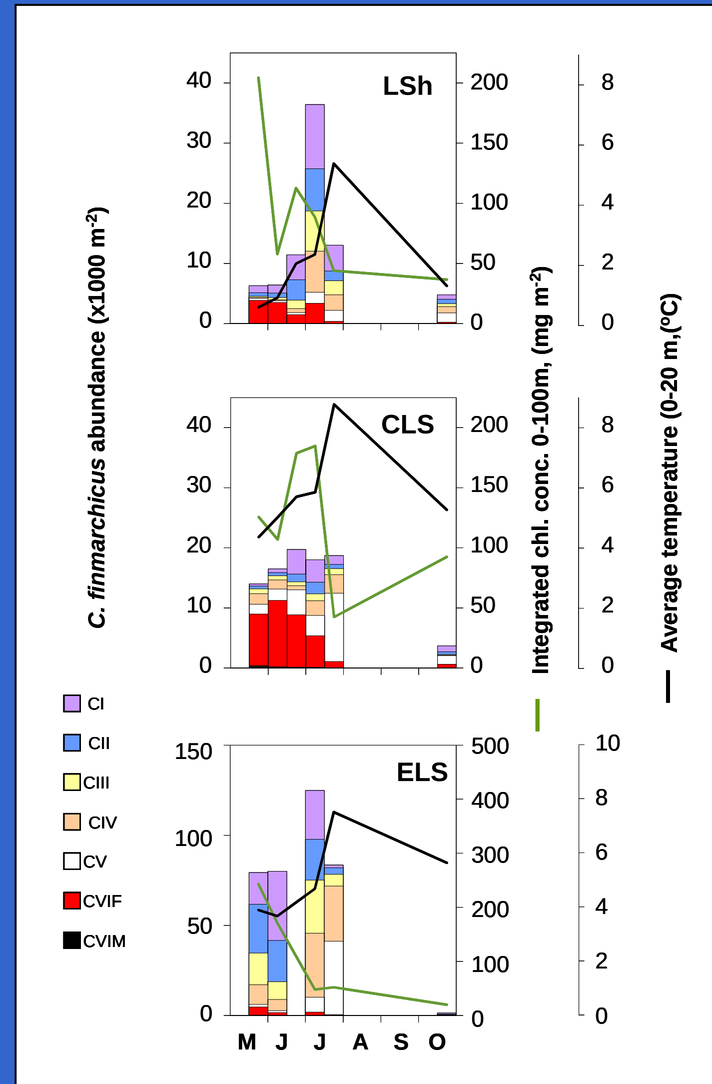
Adults (CVI) → Eggs → 6 Naupliar stages (NI-NVI) → 5 Copepodite stages (CI-CV)

Calanus finmarchicus abundance by stage in late May – late July (1995-2006)

Late May
Labrador Shelf (LSh) - females dominant
Western Central Labrador Sea (CLS) – females dominant
Eastern Labrador Sea (ELS) - young stages dominant

June-July
LSh – young stages dominant in early July
CLS – young stages never dominant (CVs dominant in late July)
ELS - young stages + CVs very abundant





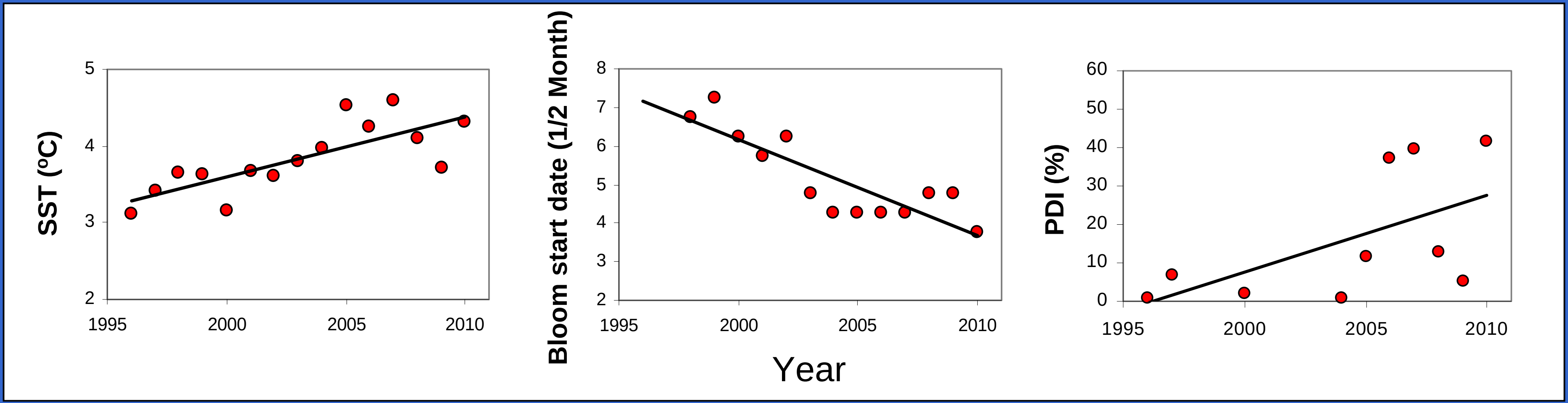
Regional differences are probably linked to differences in phytoplankton bloom dynamics.

Trends in population development in *Calanus finmarchicus* in late May *versus* environmental conditions in the Western Central Labrador Sea

Mar-May Sea-Surface Temperature

Two-week period when Sea-Surface Chlorophyll reaches 0.6 mg m^{-3}

Percent young stages (CIs-CIIIs) of the total *C. finmarchicus* population



As Mar-May temperatures have increased and the bloom has been starting earlier, the *Calanus finmarchicus* population sampled in late May has become more developed

This could mean (a) that reproduction has started progressively earlier, (b) that eggs/nauplii produced “early” have had progressively better survival, or (c) that eggs, nauplii and young stages have been developing progressively faster

OR – all three!

Summary

There was deep convection in the Labrador Sea in the early 1990s, which caused temperatures to drop throughout the 0-2500 m depth range.

Since then surface and sub-surface temperatures have generally been increasing.

CO_2 concentrations throughout the water column have also been increasing and pH has been decreasing such that in some areas at some depths, some calcifying organisms may have become vulnerable.

Sources of freshwater to the Central Labrador Sea, which were dominated by Arctic outflow prior to 2002, now seem to contain mainly glacier melt-water and precipitation from Greenland.

Since 1990 nitrate concentrations in the near surface layers have not changed, but silicate and phosphate concentrations have decreased.

There have been no significant changes in phytoplankton biomass, although the spring bloom has shown a trend towards an earlier start date in the central basin.

Earlier blooms and higher temperatures appear to be leading to an advance in the life cycle of the dominant meso-zooplankton species, the copepod *Calanus finmarchicus*.