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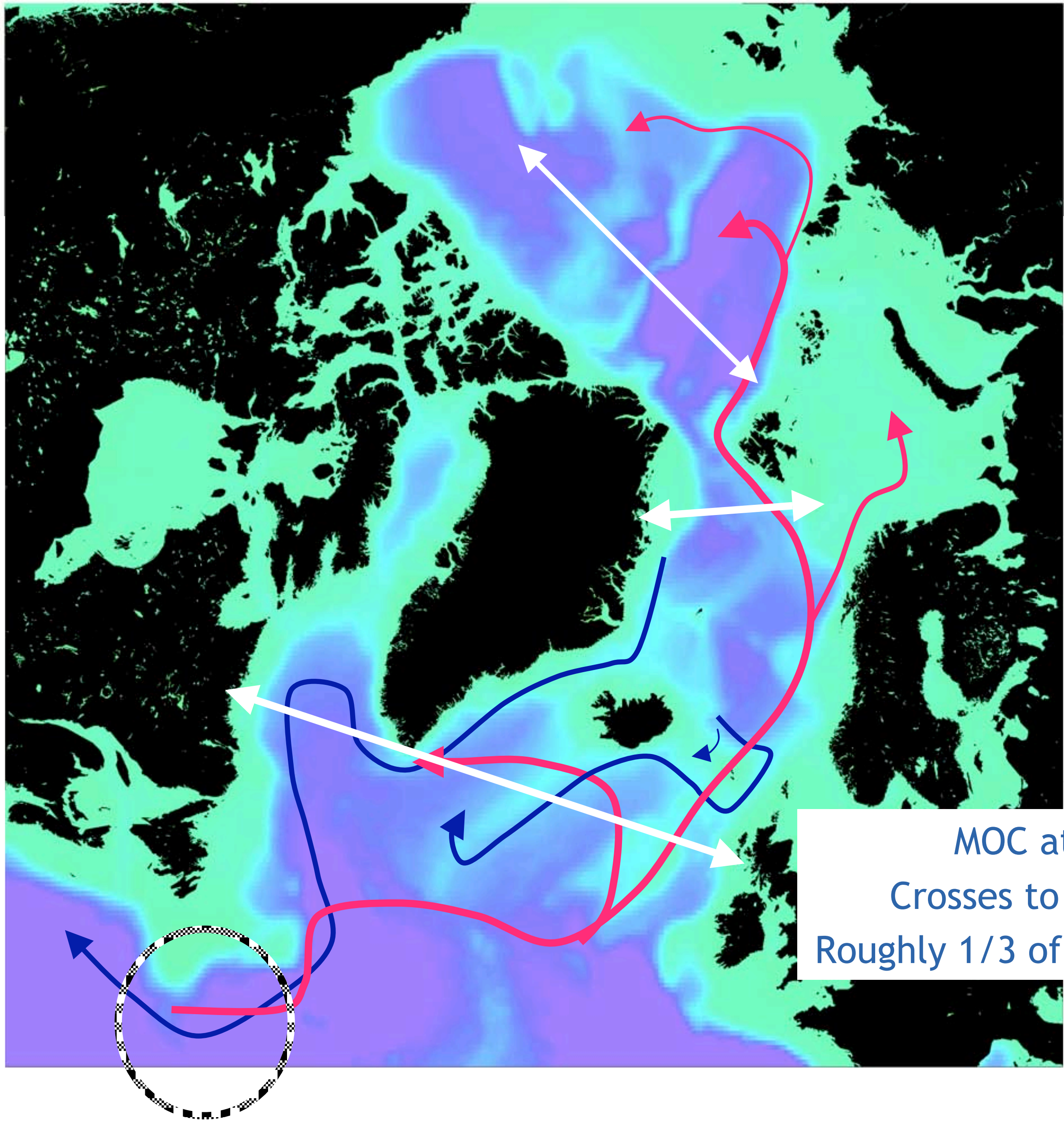
5.1 Arctic Ocean – Status, Issues, Opportunities

Cecilie Mauritzen
CliC Arctic Climate Panel
CLIVAR Atlantic Implementation Panel

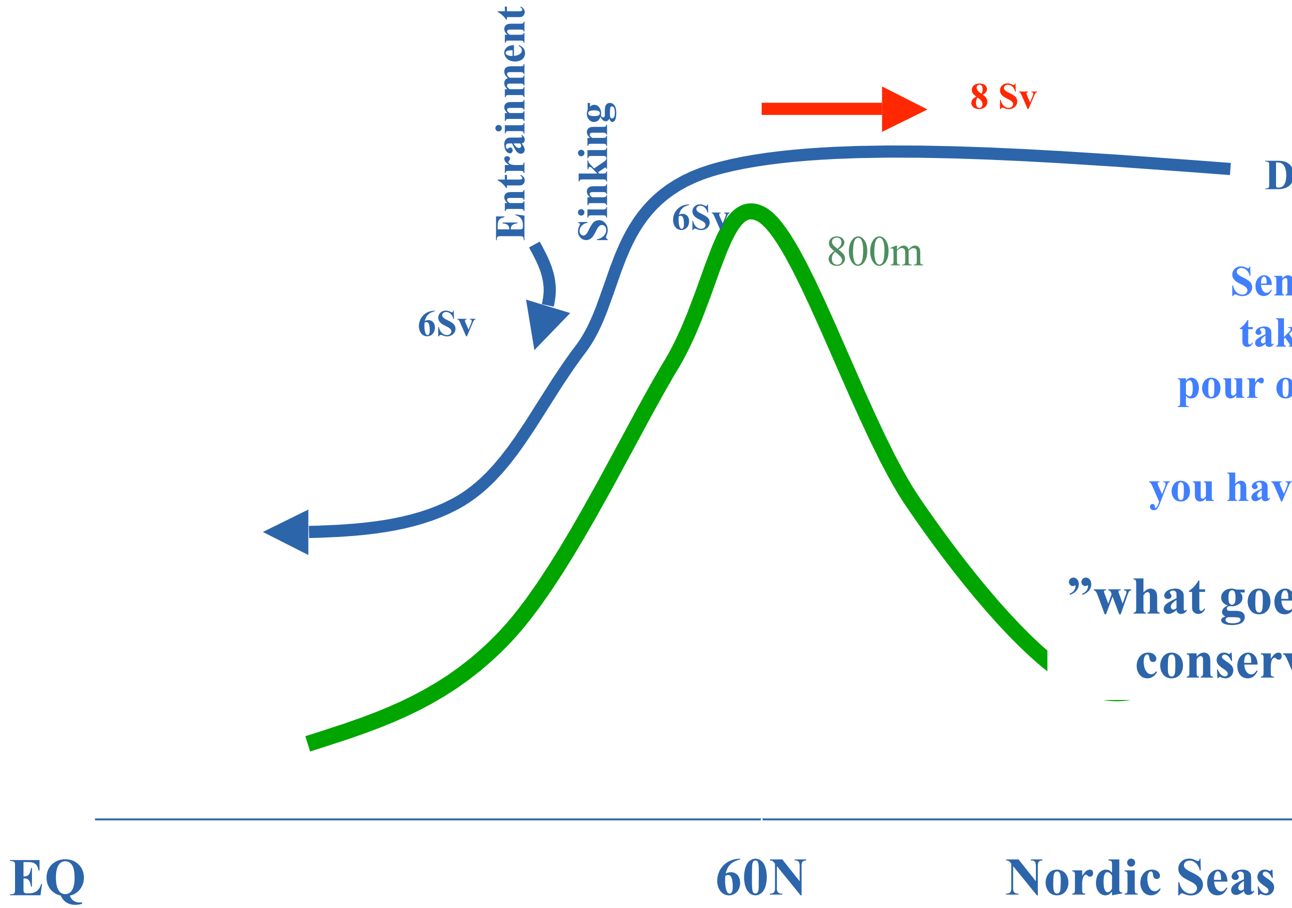


MOC at high latitudes:

Crosses to become eastern BC

Roughly 1/3 of MOC enters Nordic Seas

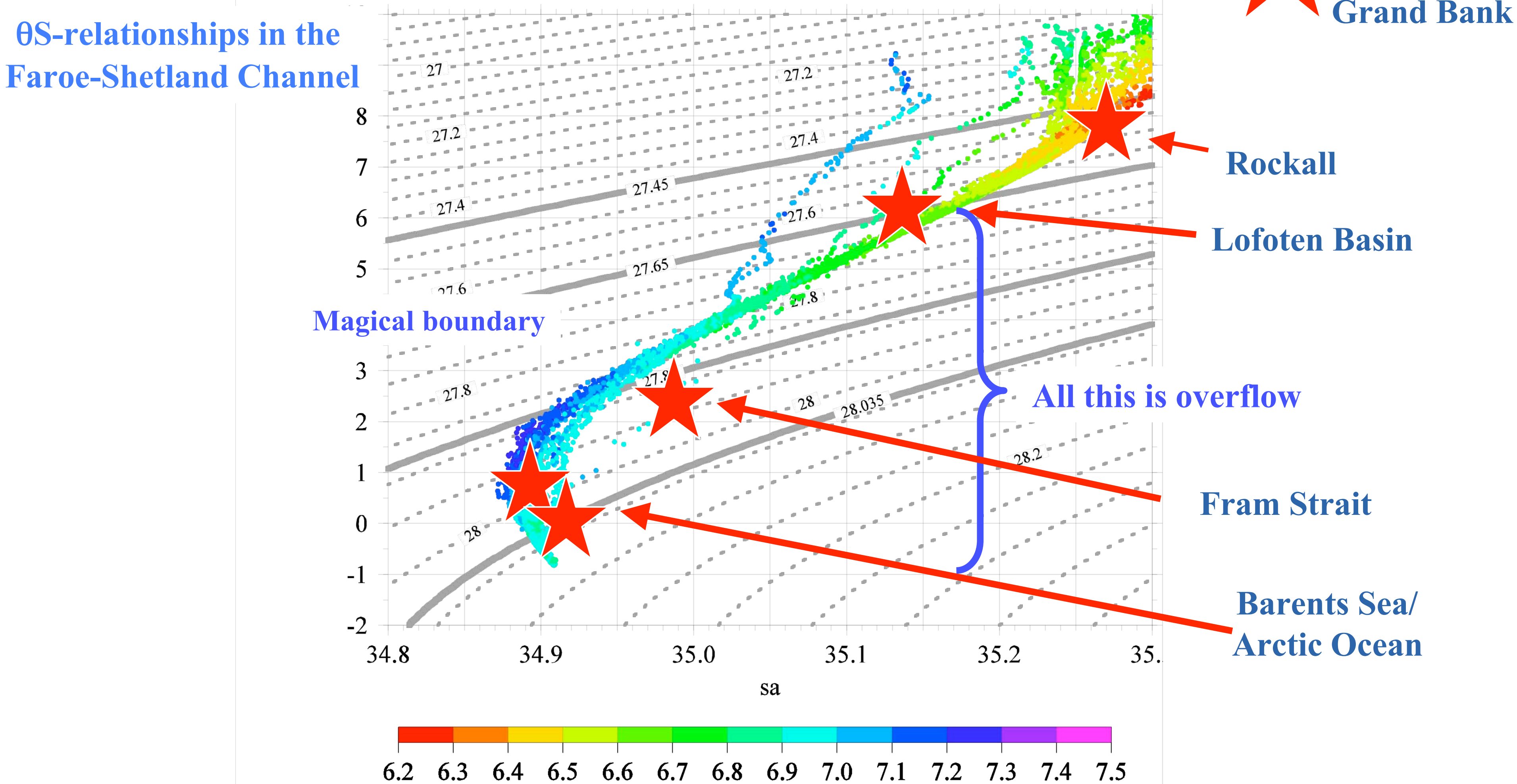
Greenland-Scotland Ridge:

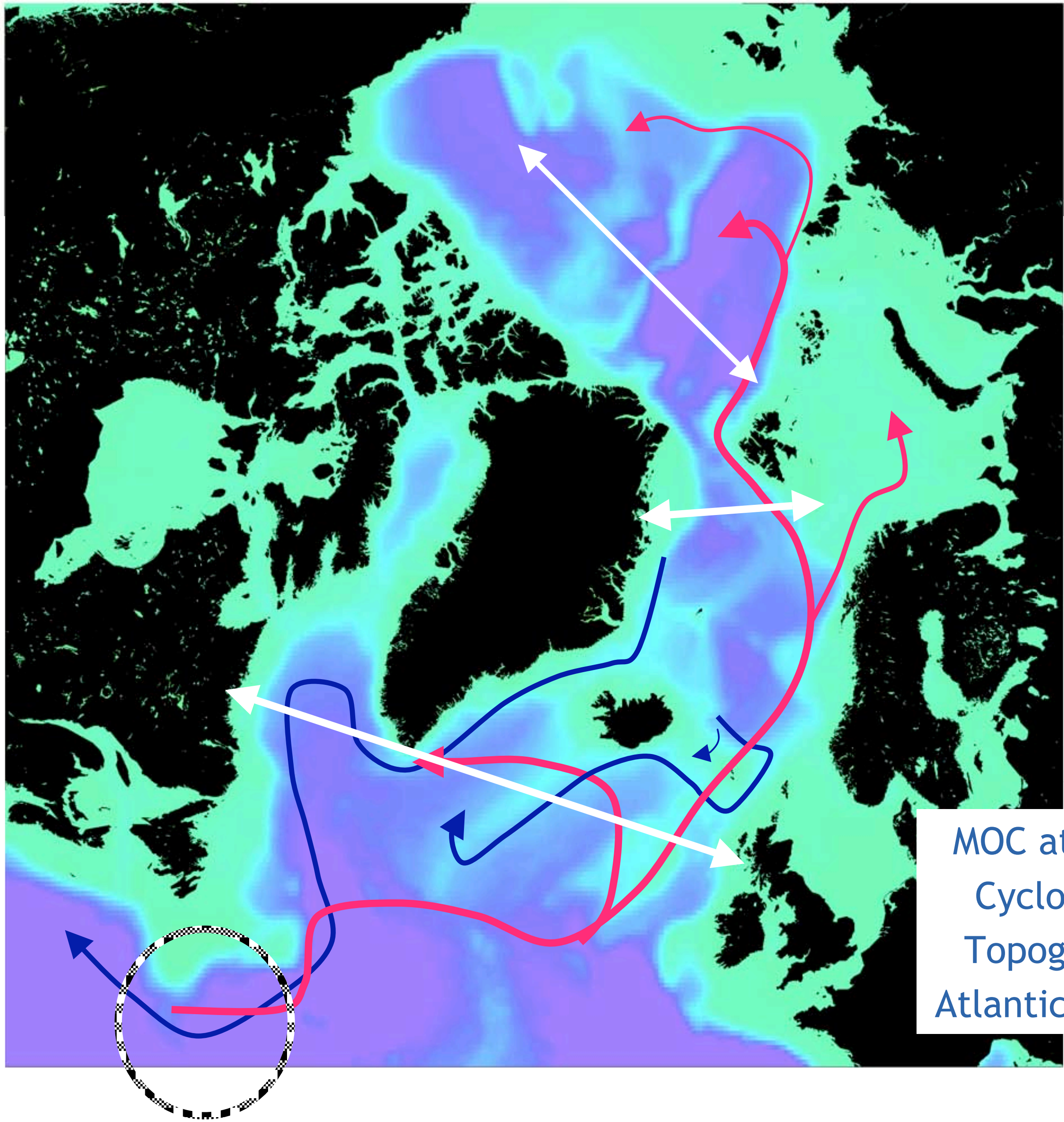


Send in warm water,
take out some heat,
pour on some fresh water,
and voila,
you have the overflow waters.

”what goes in must come out”
conservation statements.

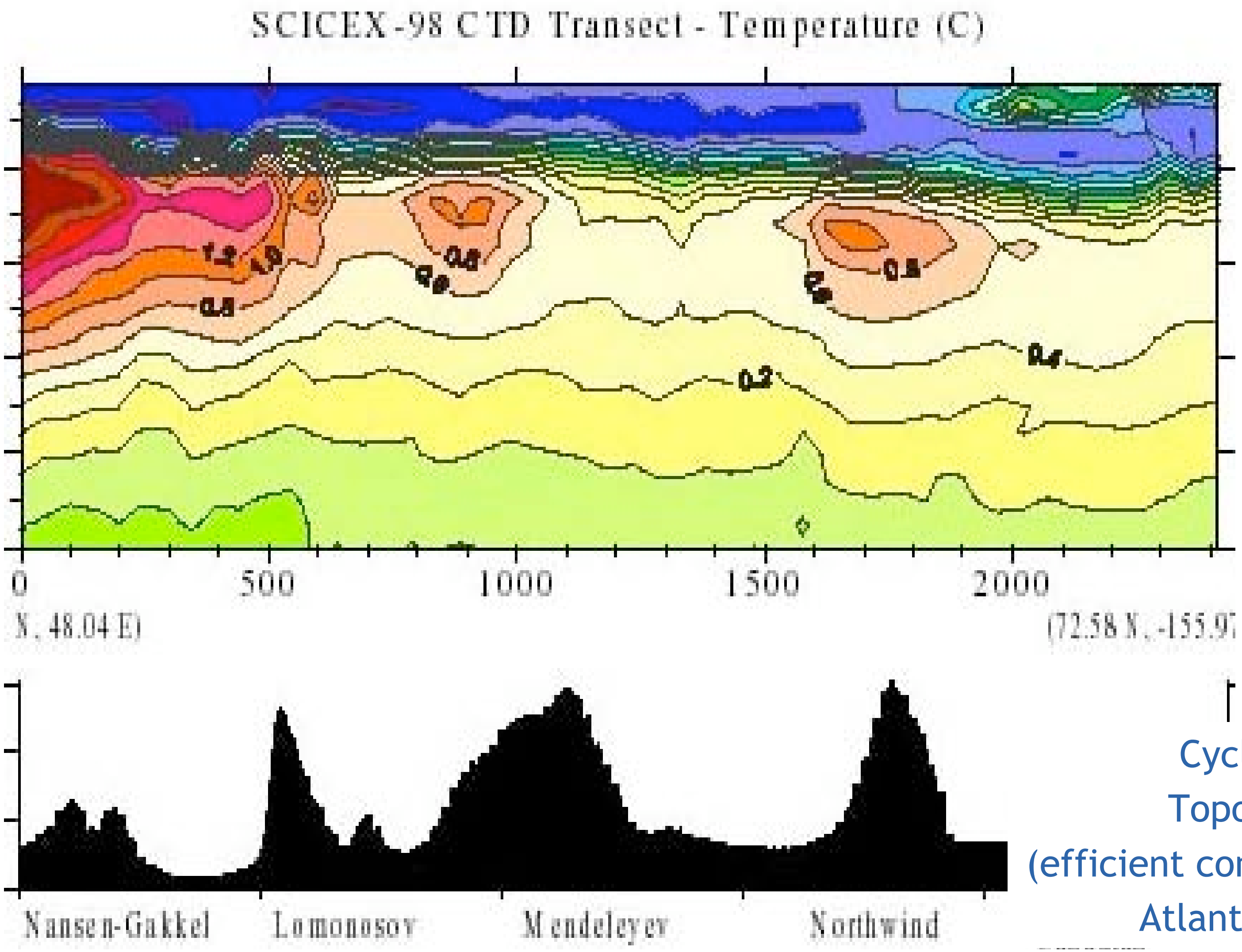
Transformations of the Atlantic Water





MOC at high latitudes:
Cyclonic circulation
Topographic steering
Atlantic layer fills Arctic

Nature's own "flushing experiment"
(efficient mixing; halocline waters)

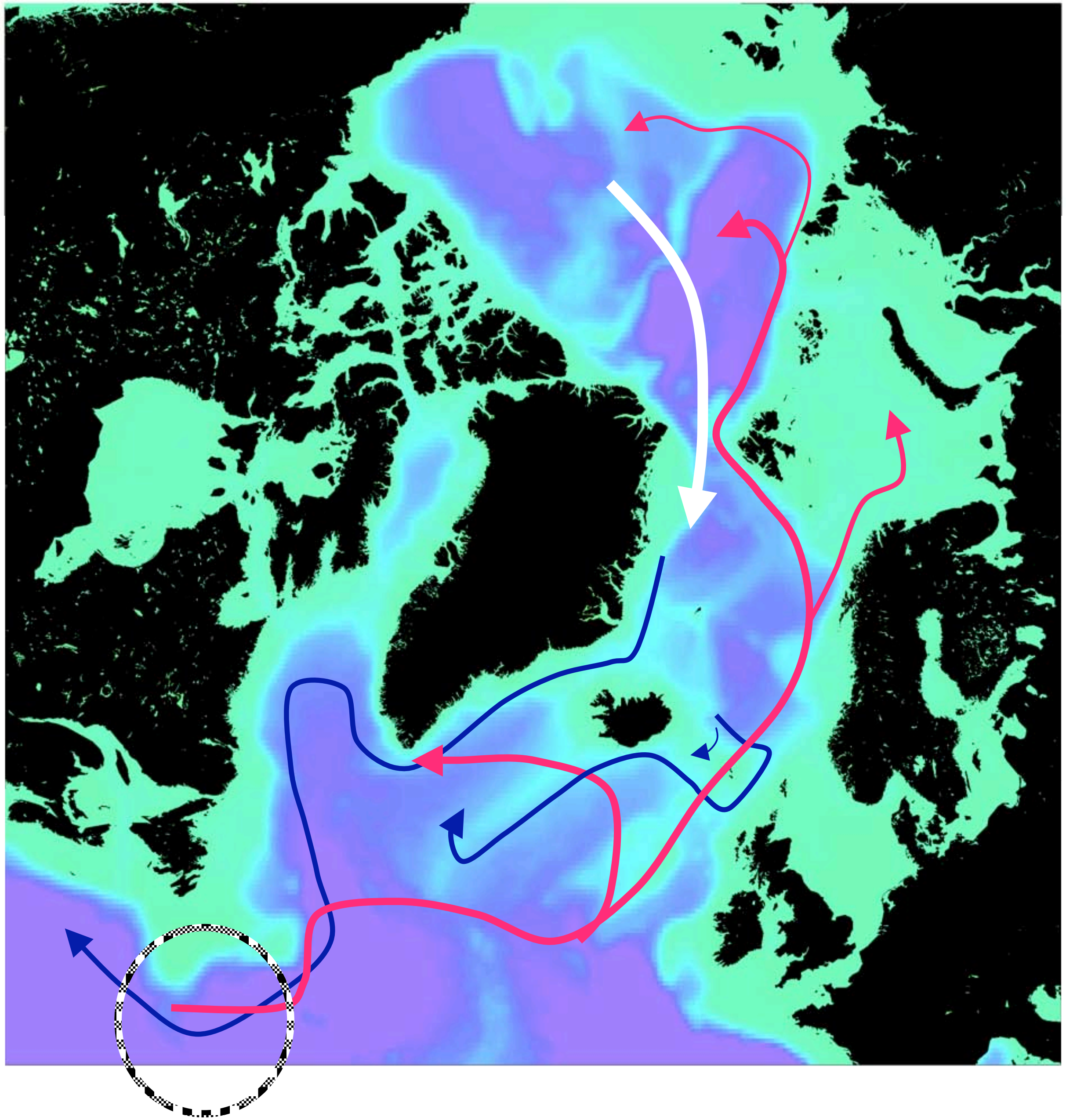


Cyclonic circulation

Topographic steering

(efficient continental slope moorings)

Atlantic layer fills Arctic



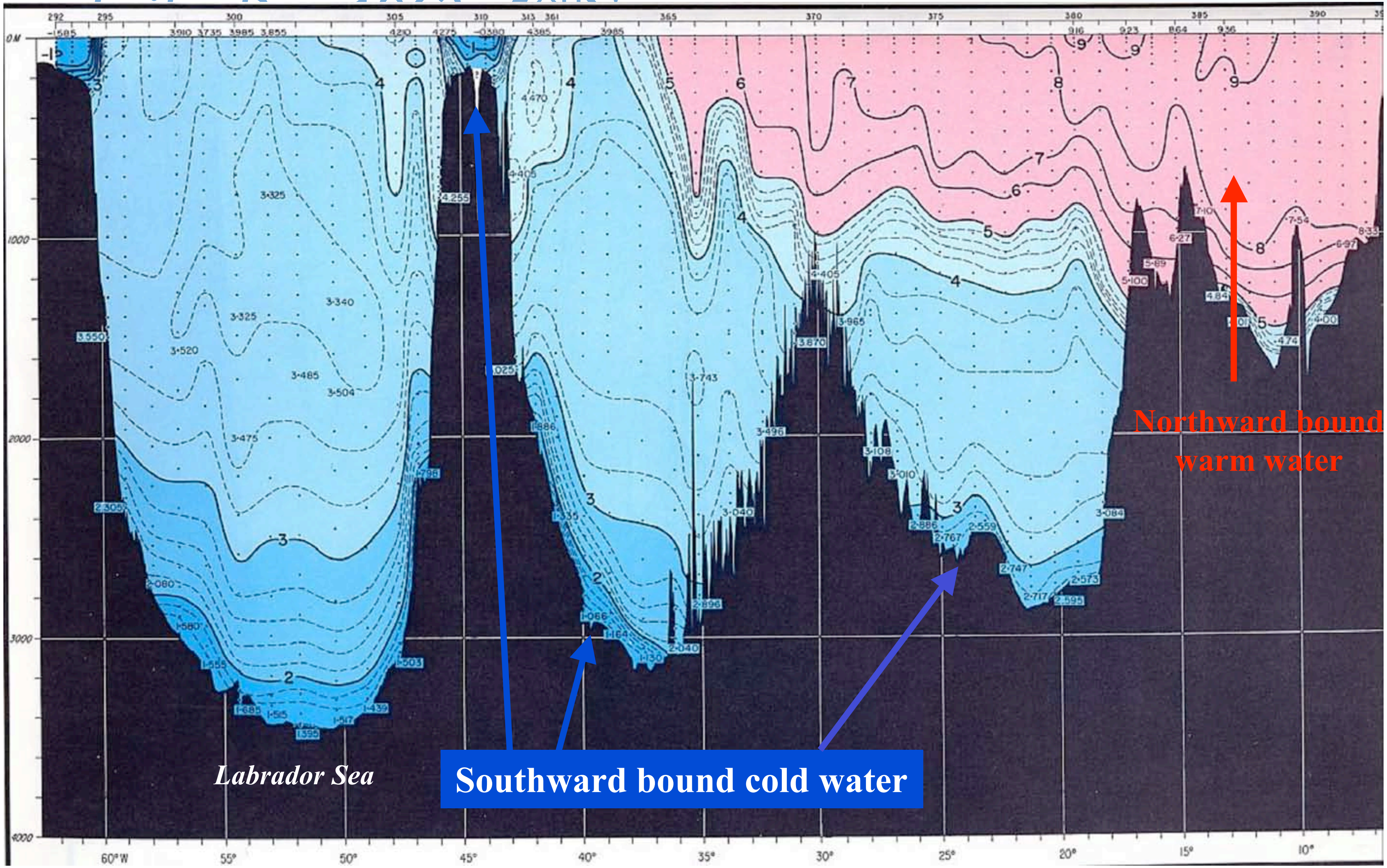
Transpolar drift:

Sea ice

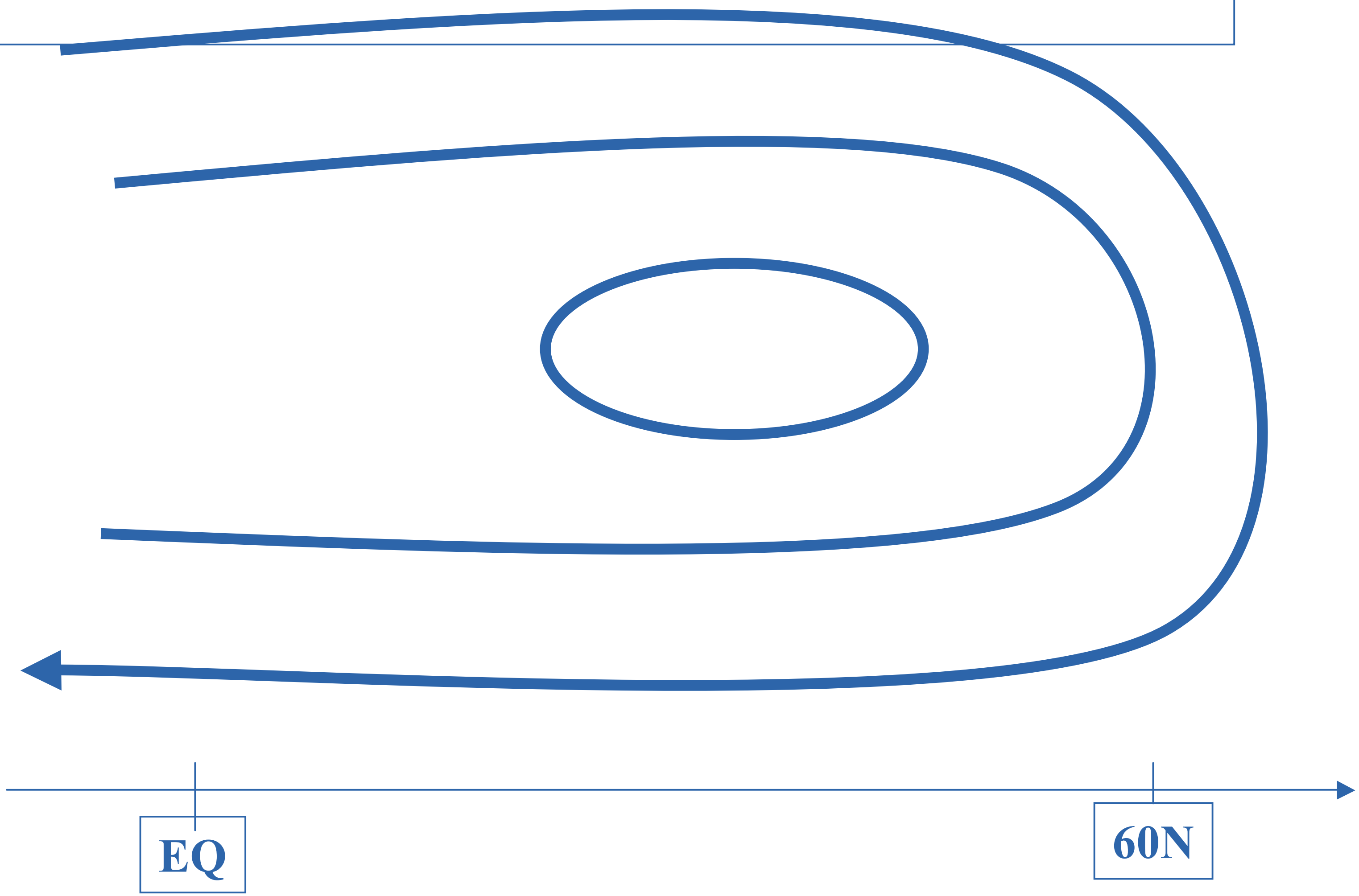
Surface waters

Halocline waters

59N


Labrador Sea
Southward bound cold water
Northward bound warm water

Synthesized to.... (the ”MOC”)



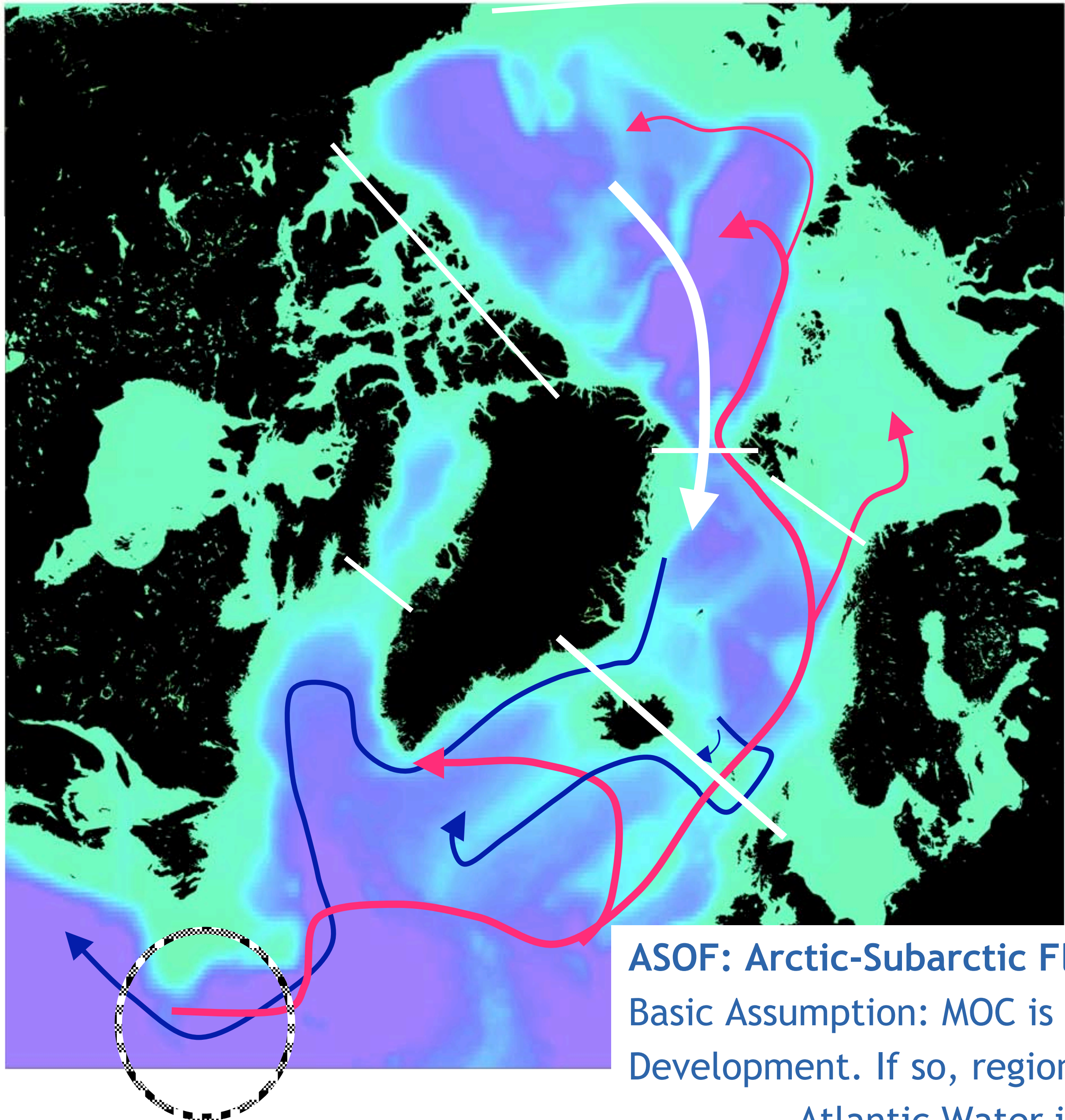
Budget for the Arctic

- 3-5 Sv dense Atlantic Water enters in Fram Strait
- 1-2 Sv denser (further transformed) Atlantic water enters through the Barents Sea
- 1 Sv light Pacific Water enters through the Bering Strait
- 0.1 Sv freshwater runoff from continents

→

- 5-8 Sv exits through the Canadian Archipelago and the western Fram Strait
- Residence time anything between 1 and 100 years, depending on pathways
- Fastest turnaround for waters above sill level (800m; Greenland-Scotland R.

- **Atlantic Water is the main contributor of volume *and* heat: Tracking the fate of the heat of the Atlantic Water is a necessary ingredient of any monitoring program of the Arctic**



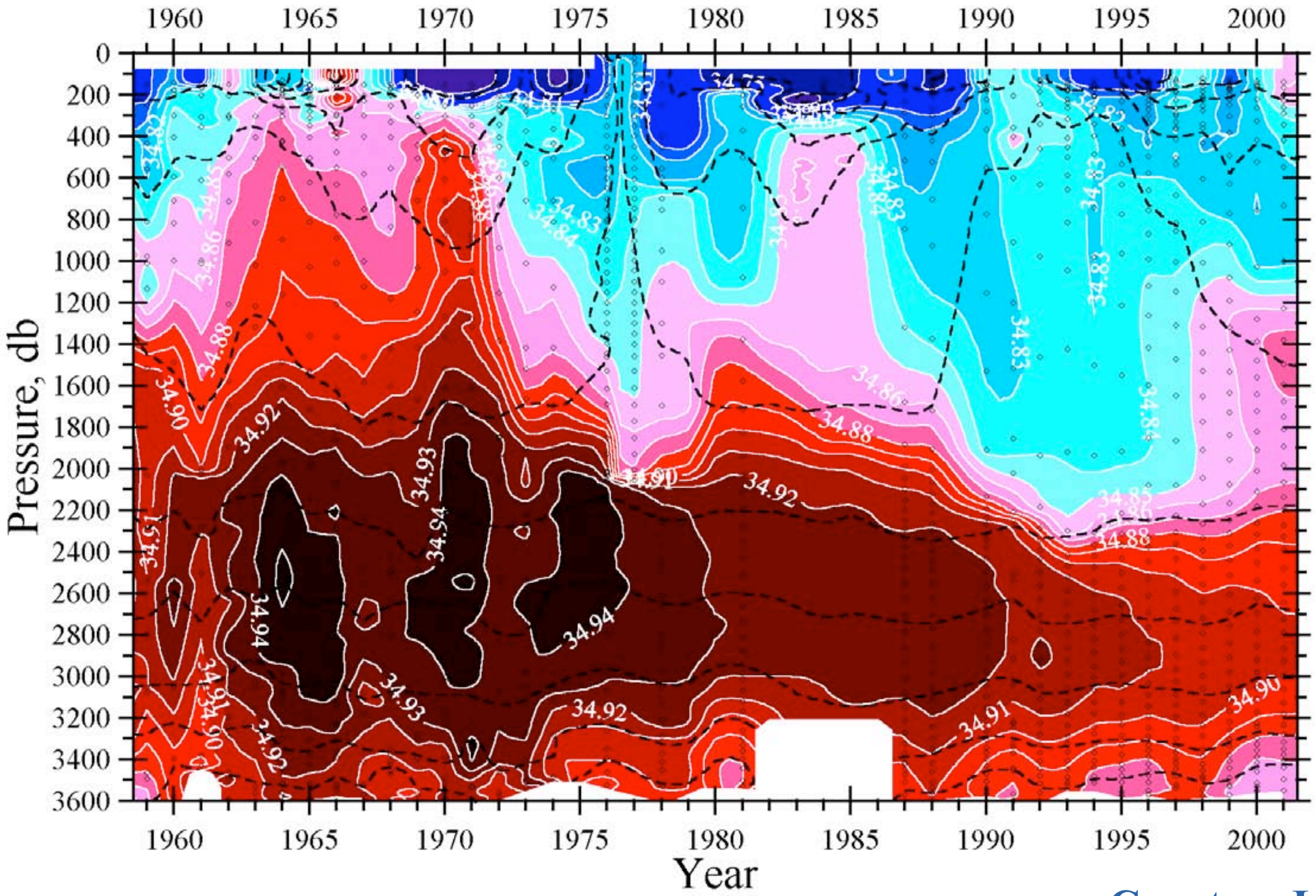
ASOF: Arctic-Subarctic Flux Programme

Basic Assumption: MOC is crucial for climate Development. If so, region is convenient:

Atlantic Water influences Arctic

freshwater influences MOC

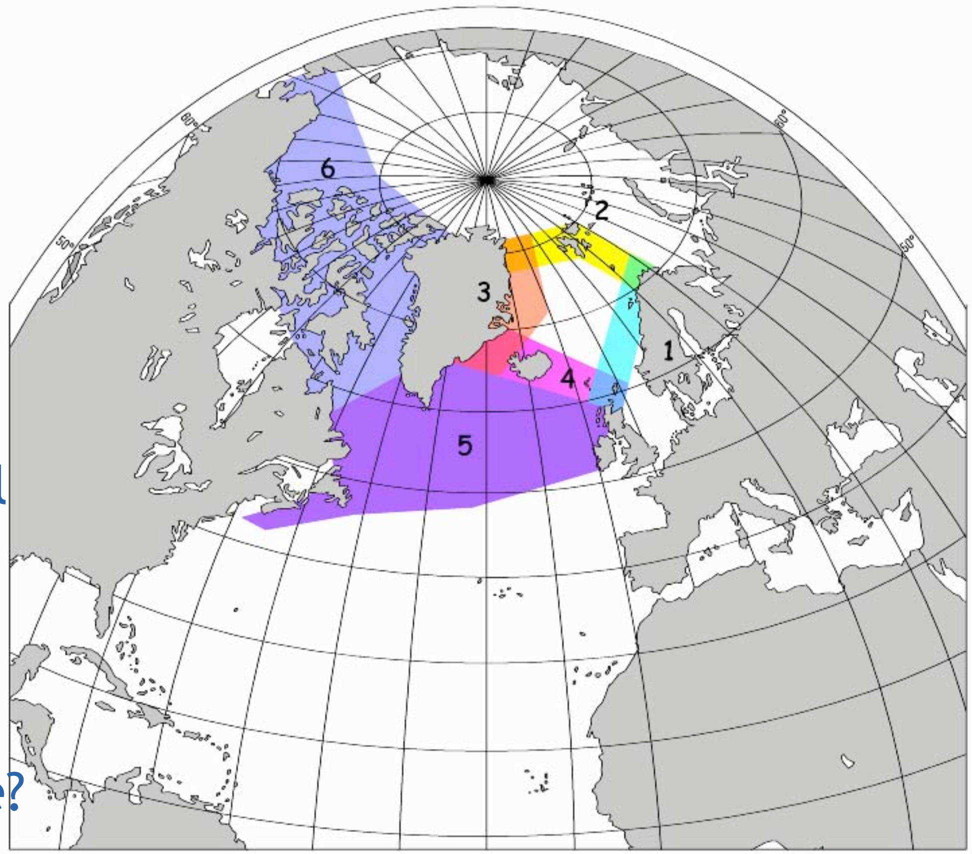
Salinity in the Labrador Sea



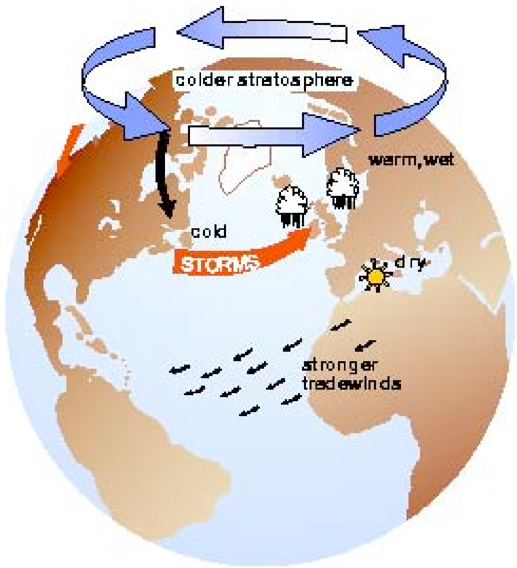
Courtesy Igor Yashayaev

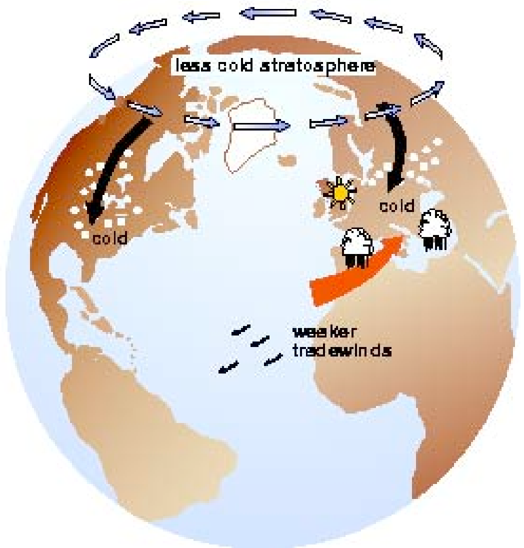
Arctic - SubArctic Ocean Fluxes

ASOF is a great program for monitoring the oceanic fluxes between the North Atlantic and the Arctic (Endorsed by CLIVAR; will be by CliC?)
Funded presently for many, but not all aspects.
Barents Sea – Arctic Ocean Entrance?



Arctic's Role in Climate Change?



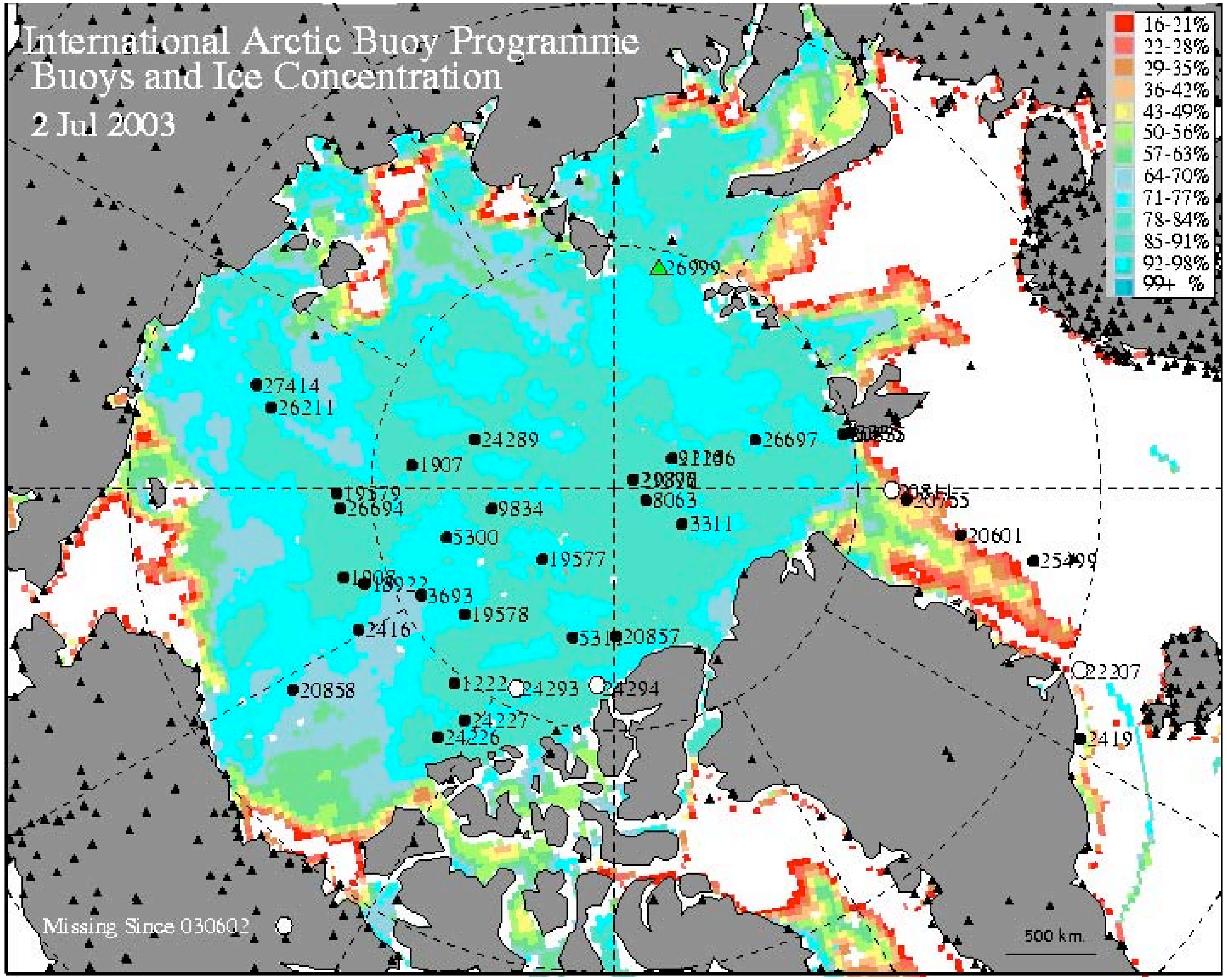


- Connections to subarctic may not be limited to ocean and ice.
- Ex: high vs. low AO/NAO: predictors of NAO associated with subtropical/tropical SST; involves ENSO?
- Important to consider the three media (ice, ocean, atmosphere) jointly - one pulsating muscle
- Everything seems to be happening at the same time: causal relationships?
- Smoking guns?

It's role in global climate change:

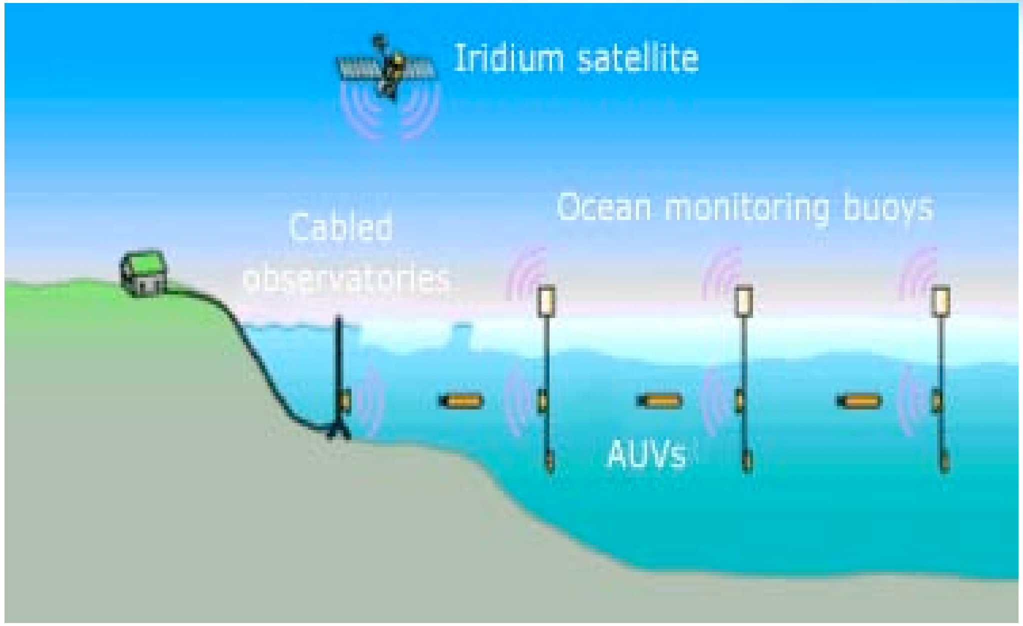
CliC's Arctic Climate Panel (at the beginning stages…)

Food for thought….



- •Quantifying circulation and its variation in the Arctic
- •Understand the time-varying budgets of heat, and freshwater in the Arctic
- • Understand the causal relationships of change in the Arctic
- •Will ice sea-ice vanish?

➢NEW TECHNOLOGY!



New technology, autonomous monitoring:

•Ice-tethered platforms (workshop WHOI late June): real-time download of data; ice drift, thickness, surface met. obs., subsurface ocean profiles (depth limitation?)

•Subsurface floats (navigation under ice the big issue): lagrangian velocities, T & S profiles

•Tomography (very low frequencies necessary): integrated temperatures

•Gliders (programmable vehicles): salinity, temperature profiles, cross-track velocity profiles

•Communication between these devices: real-time download + relative speed

•In addition to: conventional bottom-anchored moorings, ship surveys

Challenges

- Expensive, high risk development
- Changes are happening now – need to go operational quickly, not slowly

SEARCH:

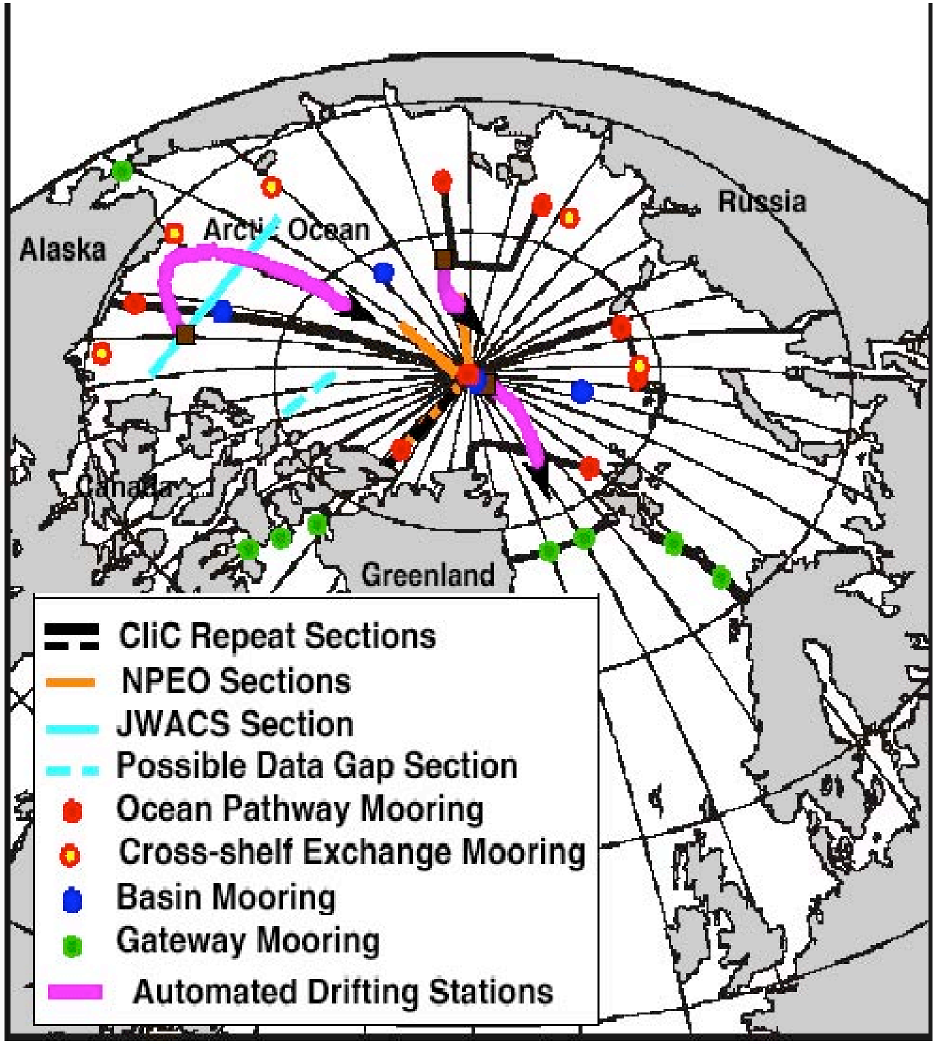
understanding ***Unaami***

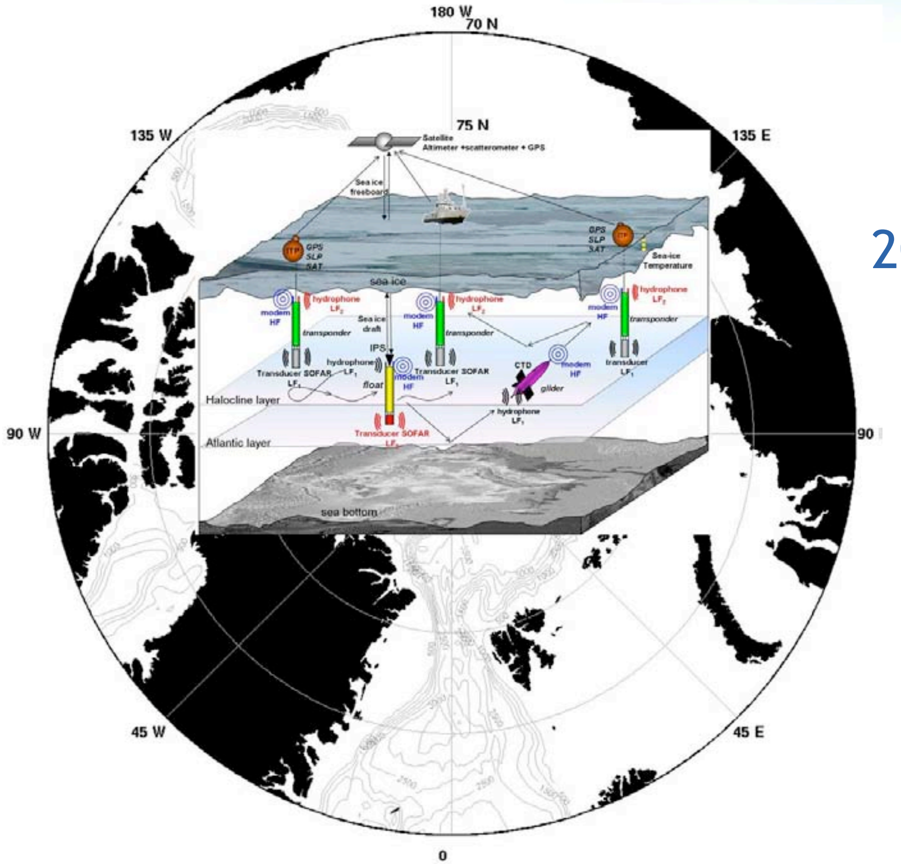
”recent and ongoing decadal pan-Arctic changes”

(Modelled after TOGA which was developed to understand El Nino)

Originally a US plan, now International SEARCH Hereunder funded: Shelf Basin Exchange Program; Fresh water cycle; North Pole Observatory,…

Here: implementation plan for marine observations





Arctic Ocean Observatory System

Strawman Document, proposed spring 2004 for the Arctic Ocean Science Board

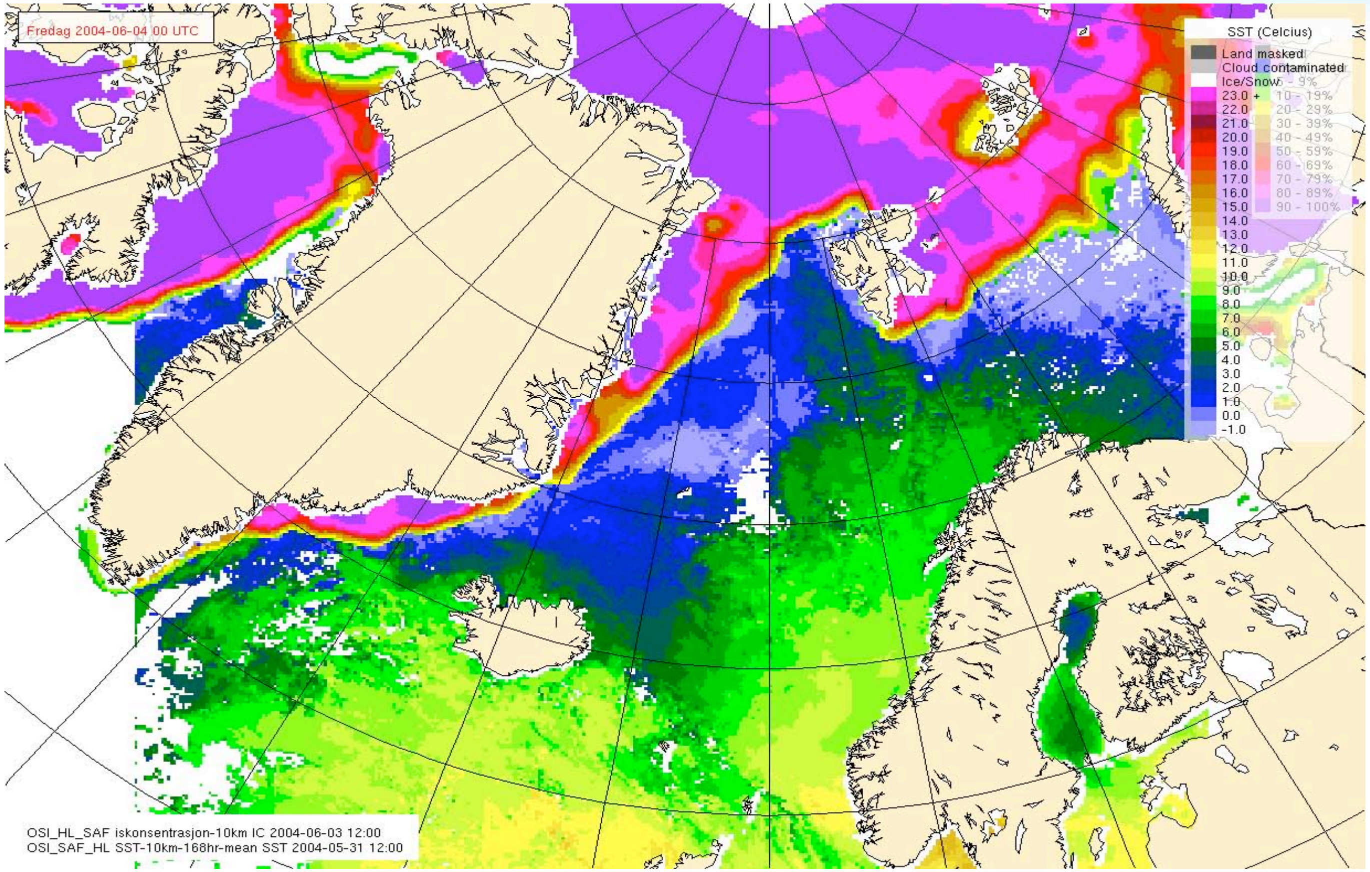
"to evaluate the fate of the Arctic perennial sea-ice in the near future and for the next 30 to 50 years"

Schematic representation of the basic underwater components of the AOOS:

•Floats (yellow), (b) Gliders (pink) and (c) transponders (green) equipped with SOFAR/RAFOS long-range acoustics capability for underwater navigation and acoustic modem for short-range data transfer. Ice Profiling Sonar will be installed on Floats and CTD on Gliders. Transponders will be ice-tethered and connected to GPS geolocated surface satellite transmitters.

- The Arctic Ocean cannot be considered separately from the ice and atmosphere above. We need simultaneous, coordinated observations of the first-order variables, and that includes the **deep Arctic Ocean**(through the Atlantic Layer (800 meters), preferrably deeper).

More food….



Sea ice concentration (10 km res. Daily, based on DMSP: SSM/I) and SST (10 km res. Weekly, based on NOAA: AVHRR) june 3 2004

EUMETSAT, OSI SAF products (http://saf.met.no/)

Challenges

- Issue number 1: These are typically operational products (nowcasting, forecasting): storage for easy-access of timeseries of fields necessary for climate research
- Issue number 2: The various fields are not necessarily dynamically consistent_ Multi sensor analysis combining information from several instruments and assimilation of observations into coupled models for the "best" ocean, ice and atmosphere fields (as is done for the atmospheric fields in numerical weather prediction) – "reanalysis"

Issue number 3: ground truthing:

- SST: Use of IR channels, difficulties to distinguish between open ice and low clouds
- Sea ice: thickness and drift
  - Combined use of different sensors (SAR, scatterometer…)
  - New instruments (Cryosat-altimeter ….)
  - In situ measurements
- Atmosphere (clouds, temperature- and humidity profiles, wind)
  - Generally few observations over the Artic (and Antarctic)
  - Problems with utilization of RS data over sea ice and ice clouds
  - Better utilization of existing polar orbiting programs and new programs (new RS soundings: IASI/AIRS, atmospheric winds)
  - Needs of in situ measurements: near surface (temperature, pressure..), profiles (soundings from automated air planes and ground stations

Numerical weather prediction improved by information in the Arctic; remote sensing data improved by information in the Arctic; climate research improved by information in the Arctic – affordable Arctic Observation System must possible, but demand major coordination (think "seamless prediction systems" - COPES)

International Polar Year 2007/2009

- Planning coordinated through ICSU (International Council of Science; see www.ipy.org)

- Likely to be a unique opportunity to channel sufficient funds for the kickoff of a coordinated Arctic Observing System (IPY is receiving wide acceptance within individual countries where ultimately the funding originates)

- Scientific payoff hinges on a clever international plan

- Time is running out for developing new technology (where are funding opportunities NOW? - European initiative (CARE) submitted as IP to EU 02/2004 without success; US has call for nominations from NSF Polar Research Board to design an Arctic Observing Network)

Conclusions

- An Observing System for the Arctic is missing. Based on the Arctic's importance for global climate, and the high cost and high risk involved in developing such a system for an ice-covered ocean, this omission should be taken seriously. We (CliC) propose that OOPC recommends to the GOOS Steering Committee to consider establishing a working group to **design an Arctic Ocean Observing System** and recommend the design to GOOS implementing agencies.

- Arctic Ocean cannot dynamically be considered separately from the ice and atmosphere above. Similarly the Arctic cannot be considered separately from the rest of the globe. An observing system for the Arctic should recognize these facts, and **ensure simultaneous, coordinated observations of the first-order variables** (The observing system could well be named "Arctic Ocean-Ice-Atmosphere Observing System"; or an "Arctic Integrated Observing System"; or an "Arctic Observing System"…)

- For climate studies we need **timeseries** of (preferrably **dynamically consistent**) fields:
  - Continual monitoring (no-brainer)
  - Assimilation into numerical models (in the spirit of numerical weather prediction) and user-friendly storage of these fields for scientific studies (not quite in that spirit…)