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THE ARCTIC OCEAN IN THE GLOBAL CLIMATE

Climate change and future scenarios in the Arctic Region

Stefano Aliani

(CNR – Institute Marine Science – Lerici SP)

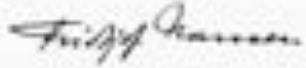
12th December 2014 - San Servolo , Venice

CNR Consiglio Nazionale delle Ricerche

ISMAR Istituto di Scienze Marine

OCEANOGRAPHIC ARCTIC EXPEDITION #1

Fridtjof Nansen

Born	10 October 1861 Store Frøen, Christiania, Norway
Died	13 May 1930 (aged 68) Polhøgda, Lysaker, Norway
Education	University of Christiania
Occupation	Scientist, explorer and humanitarian worker
Spouse	Eva Sars (died 1 December 1907) Sigrun Munthe
Children	2 daughters, 3 sons
Parents	Baldur Nansen and Adelaide (née Wedel-Jarlsberg) Nansen
Signature	

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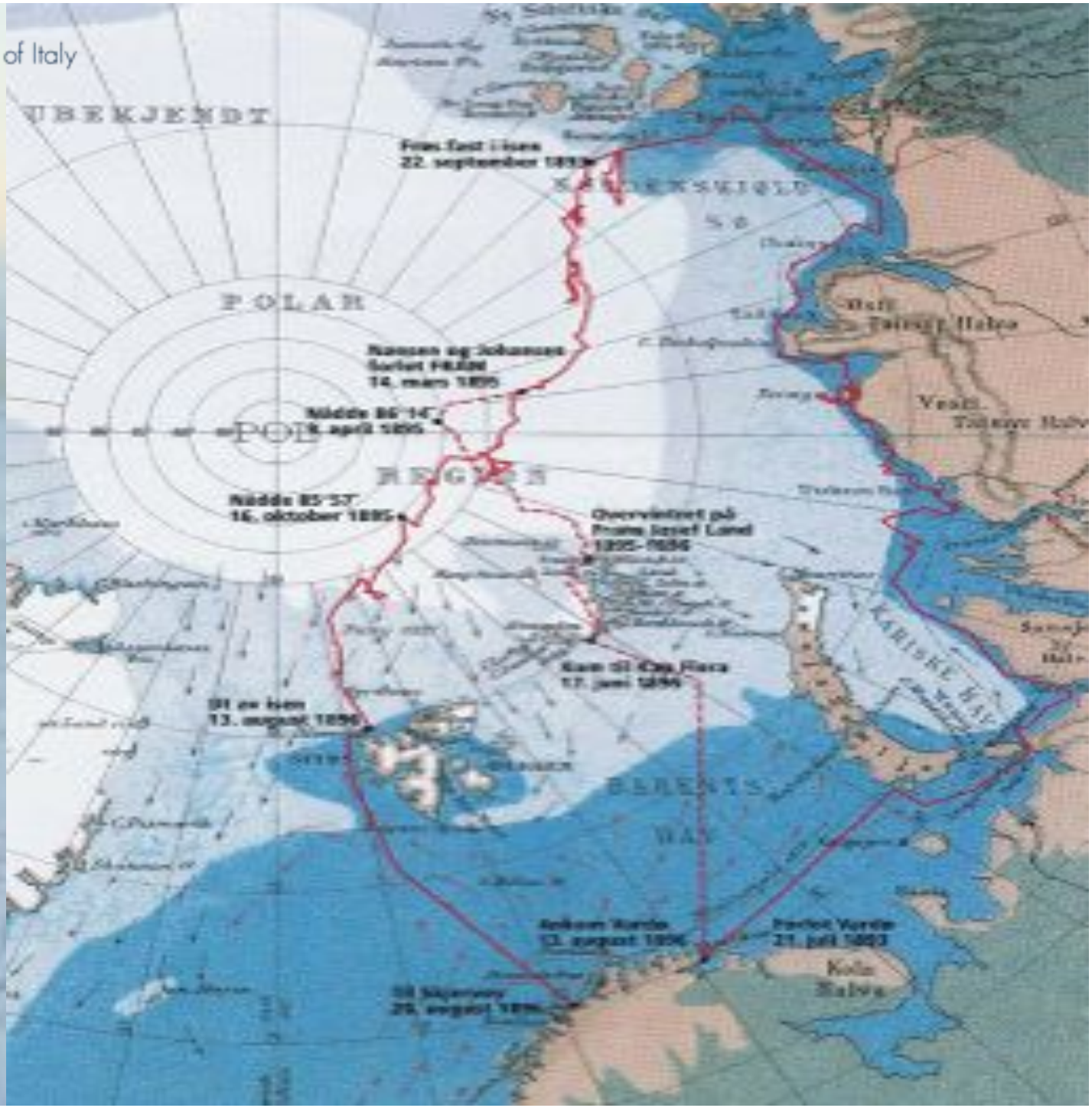
THE FRAM VOYAGE

from

21 july 1893

to

20 August 1896



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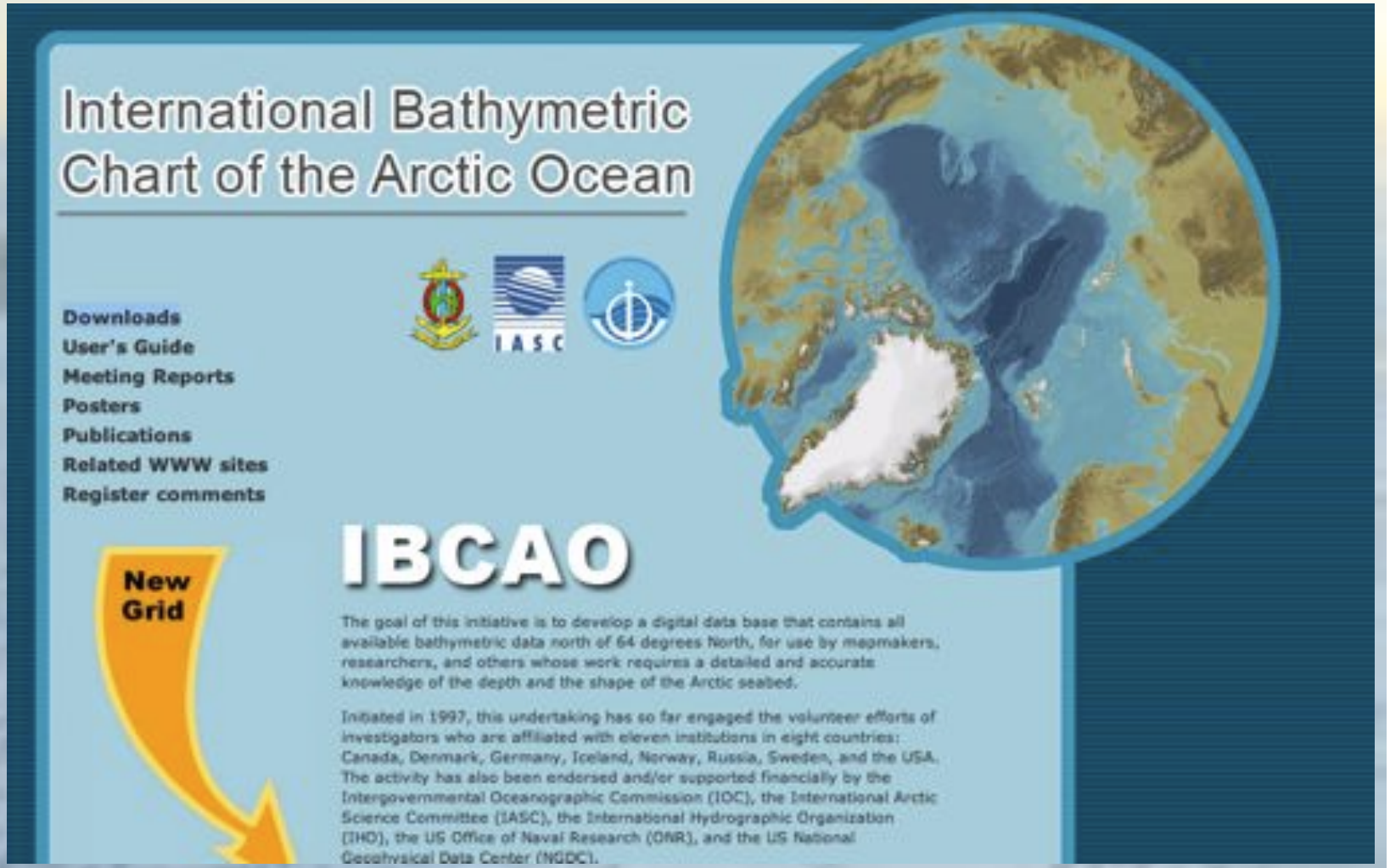
ARCTIC OCEAN CIRCULATION

BEAUFORT GYRE

TRANSPOLAR DRIFT


International Bathymetric Chart of the Arctic Ocean
IASC
Downloads
User's Guide
Meeting Reports
Posters
Publications
Related WWW sites
Register comments
New Grid
IBCAO
The goal of this initiative is to develop a digital data base that contains all available bathymetric data north of 64 degrees North, for use by mapmakers, researchers, and others whose work requires a detailed and accurate knowledge of the depth and the shape of the Arctic seabed.
Initiated in 1997, this undertaking has so far engaged the volunteer efforts of investigators who are affiliated with eleven institutions in eight countries: Canada, Denmark, Germany, Iceland, Norway, Russia, Sweden, and the USA. The activity has also been endorsed and/or supported financially by the Intergovernmental Oceanographic Commission (IOC), the International Arctic Science Committee (IASC), the International Hydrographic Organization (IHO), the US Office of Naval Research (ONR), and the US National Geophysical Data Center (NGDC).

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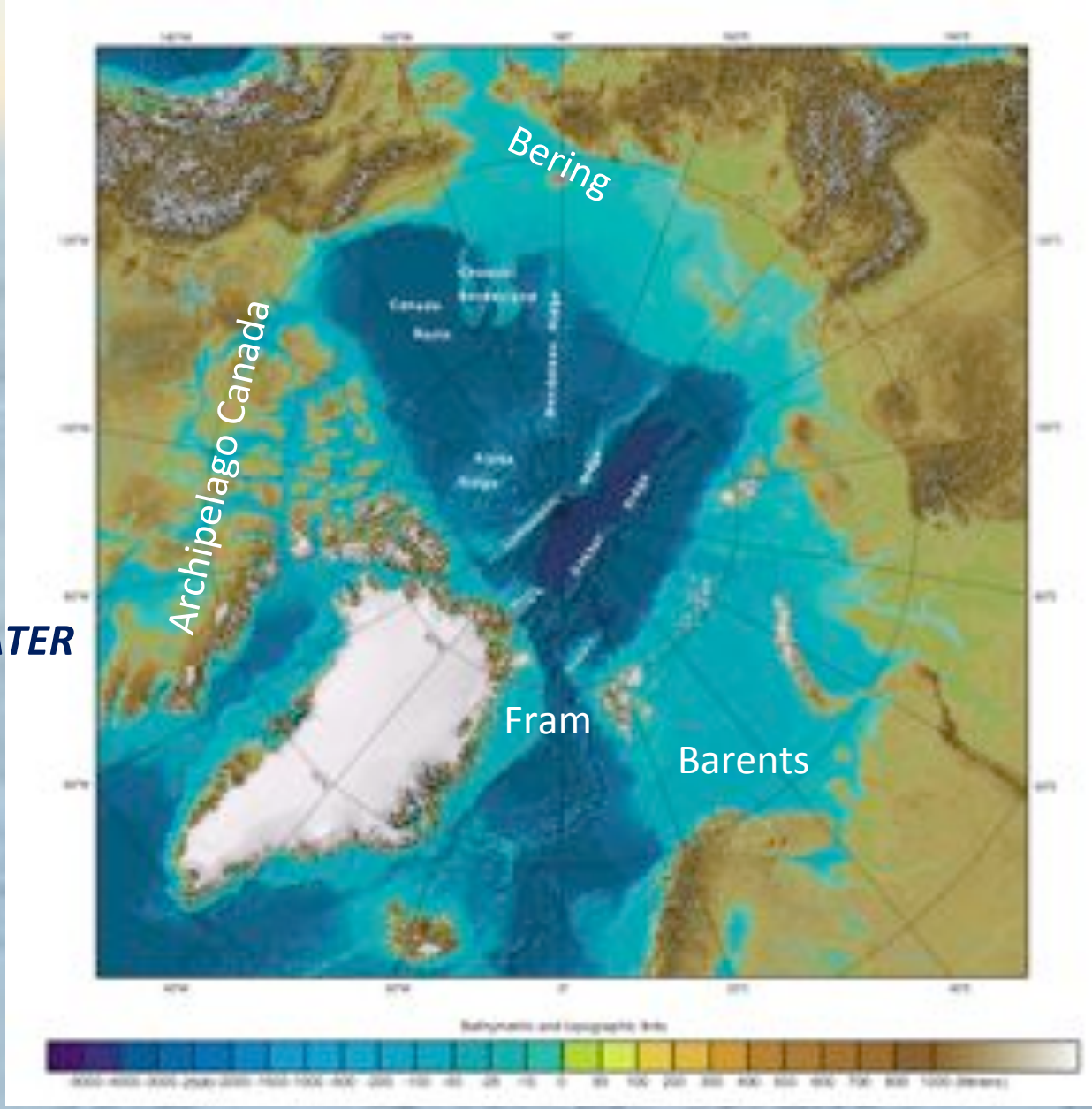
MORPOHOLOGY OF ARCTIC OCEAN

PASSAGES TOWARD OCEANS

BERING STRAIT: SHALLOW WATER
FRAM STRAIT: DEEEP WATER
BARENTS SEA
CANADIAN ARCHIPELAGO



ANTARCTICA IS A CONTINENT SURROUNDED BY OCEAN

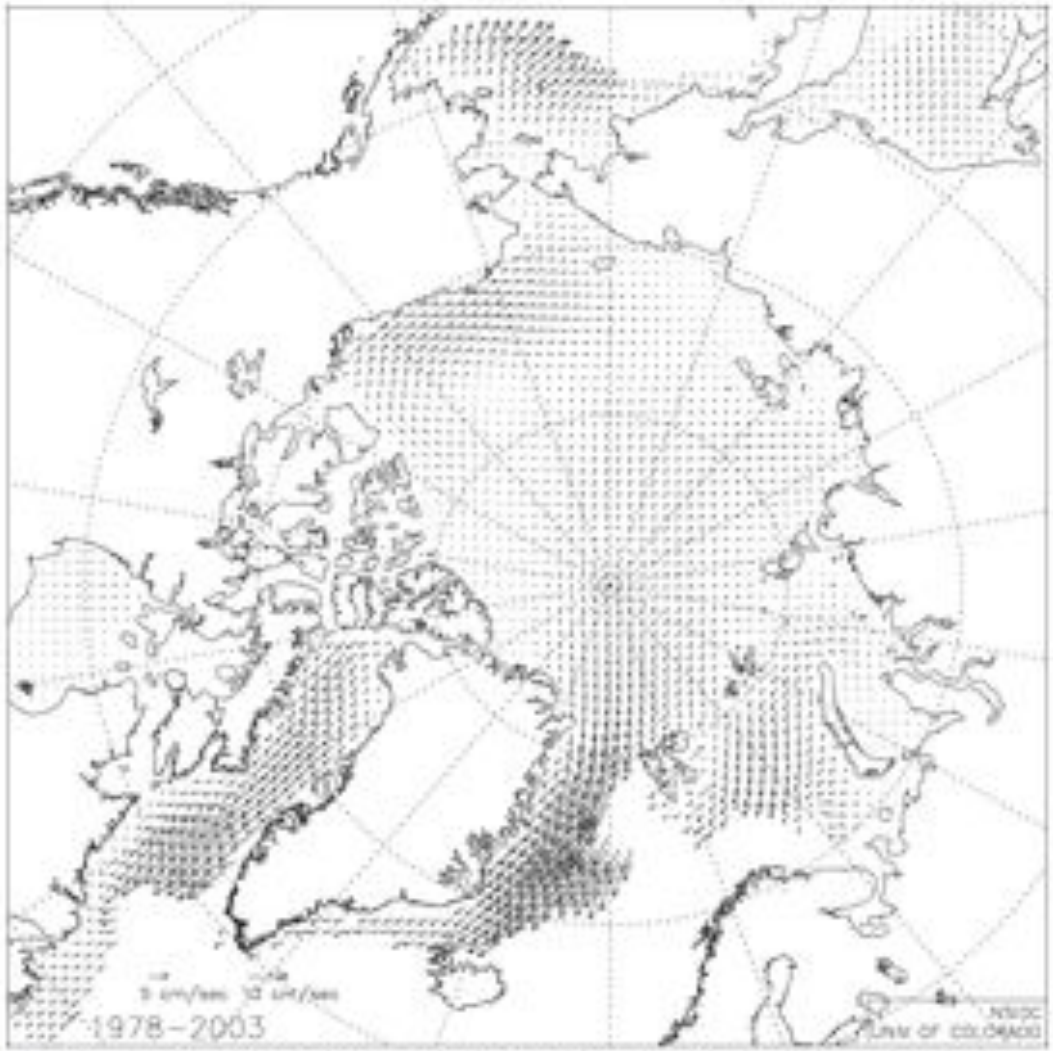
*ARCTIC IS AN OCEAN SURROUNDED BY LANDS → IT IS A **MEDITERRANEAN** SEA*

CONCENTRATION BASIN	*DILUTION BASIN*
EVAPORATION > PRECIPITATION	*EVAPORATION < PRECIPITATION*
SURFACE DENSITY INCREASES=>	*SURFACE DENSITY DECREASES*
CASCADING DENSE WATER	*SUFACE OURFLOW*
NO STRATIFICATION	*STRATIFICATION*
OXYGEN IN THE DEEP	*LOW OXYGEN IN THE DEEP*


GENERAL FEATURES OF ARCTIC SURFACE CIRCULATION

SEA ICE THAT FORMS OR BECOMES TRAPPED IN THE BEAUFORT GYRE MAY CIRCULATE AROUND THE ARCTIC FOR SEVERAL YEARS

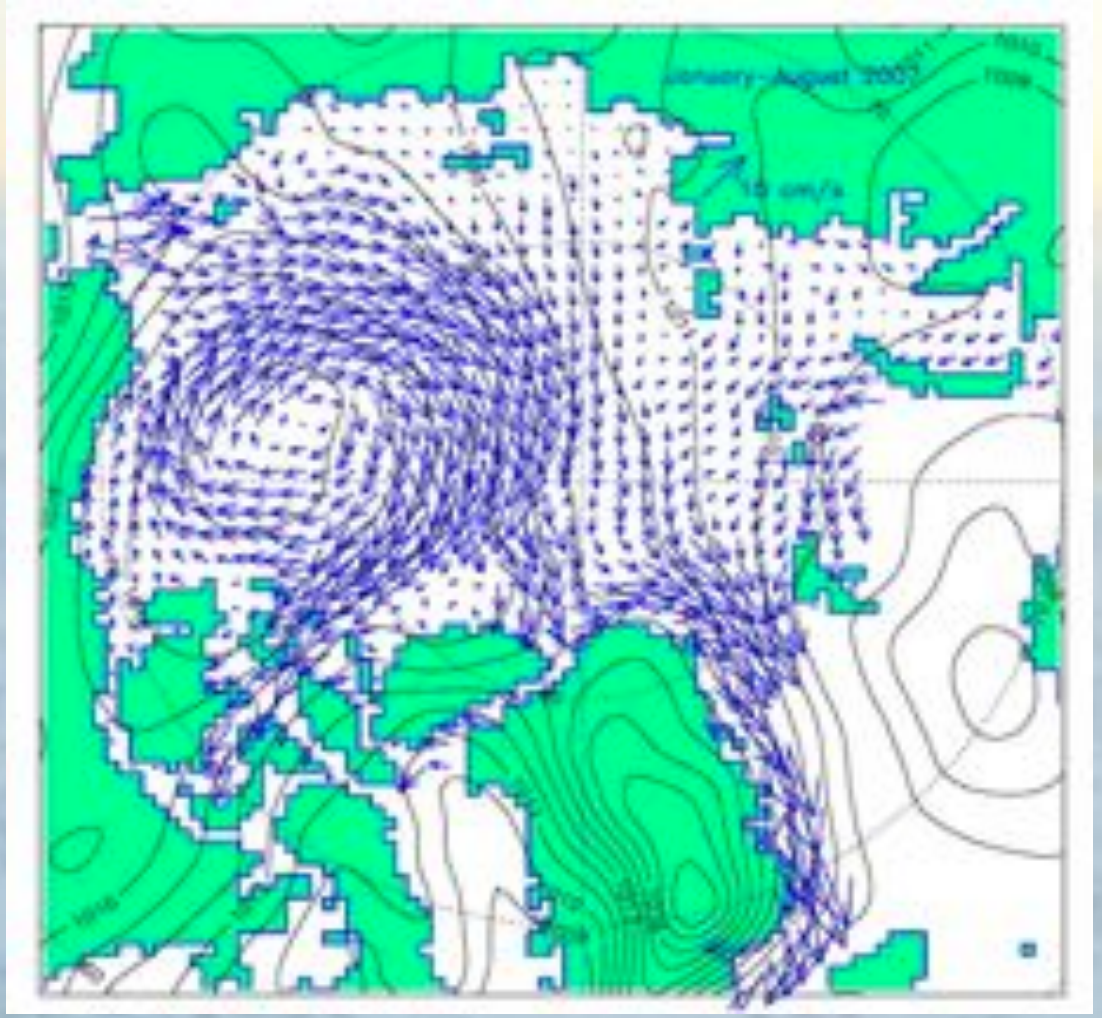
BECAUSE OF THIS, SEA ICE IN THE BEAUFORT SEA HAS MORE TIME TO GROW AND REACH THE THERMODYNAMIC EQUILIBRIUM THICKNESS, SO IT IS THICKER.



Plot showing mean (average) Arctic ice motion from 1978 to 2003. Arrows show the direction and velocity of the ice, with longer arrows representing higher velocities. Image courtesy of the National Snow and Ice Data Center, University of Colorado, Boulder, CO.

SEA ICE THAT FORMS OR BECOMES TRAPPED IN THE TRANSPOLAR DRIFT GENERALLY LEAVES THE ARCTIC MORE QUICKLY, USUALLY IN ONE TO TWO YEARS

THE TRANSPOLAR DRIFT STREAM PUSHES ICE AGAINST NORTHERN GREENLAND AND THE CANADIAN ARCHIPELAGO

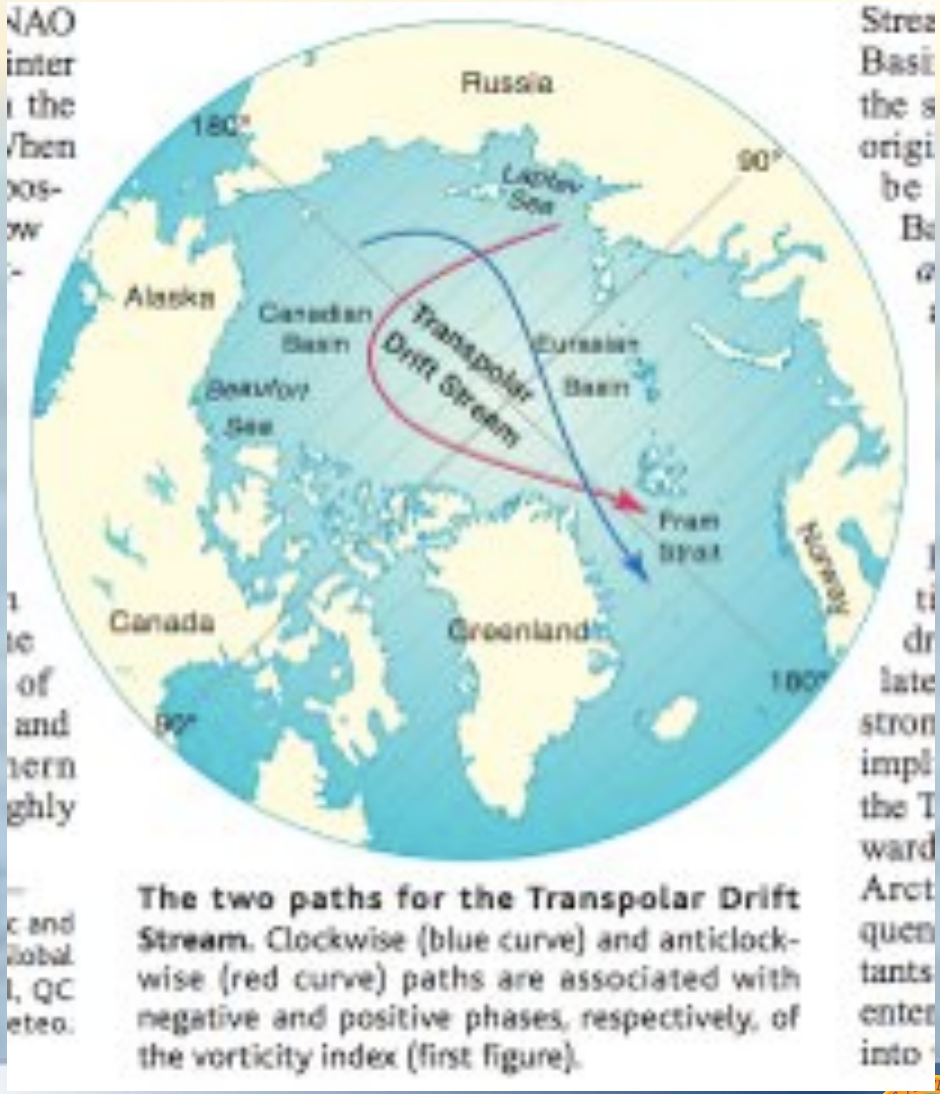


MOST OF THE ICE FOLLOWS A LARGE-SCALE PATTERN WHEN CONSIDERED OVER A LONG PERIOD OF TIME; HOWEVER, WITHIN THIS LONG-TERM PATTERN OF MOVEMENT, THERE CAN BE A GREAT DEAL OF VARIATION.

FOR EXAMPLE, THE BEAUFORT GYRE MAY COMPLETELY REVERSE DIRECTIONS--AND OFTEN DOES FOR SHORT PERIODS OF TIME, SUCH AS AFTER A STORM FROM A LOW-PRESSURE SYSTEM THAT MOVES ACROSS THE REGION.

THE TRANSPOLAR DRIFT MAY ALSO REVERSE DIRECTION

… NANSEN WOULD HAVE REACHED THE NORTH POLE UNDER REVERSE CONDITIONS



The two paths for the Transpolar Drift Stream. Clockwise (blue curve) and anticlockwise (red curve) paths are associated with negative and positive phases, respectively, of the vorticity index (first figure).

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Circulation and Vorticity

Decadal Oscillations between (+) and (-) vorticities

Positive and Negative vorticities affect where the current travels.

There are 2 paths.

– Positive Vorticity Phase: Weak High Pressure in Arctic allows fresh water/sea ice to drift counterclockwise.

– Negative Vorticity Phase: Strong High Pressure forces fresh water clockwise

Transpolar Drift Paths:Source: Mysak: Patterns of Arctic Circulation

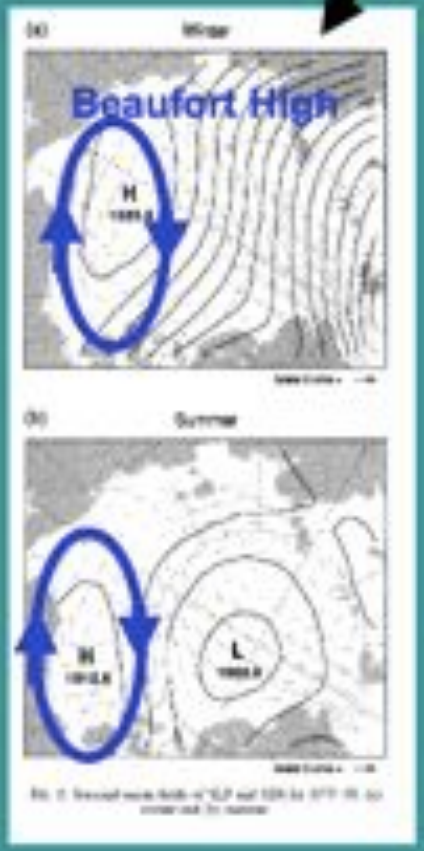
Shorthand atmospheric circulation – the Arctic Oscillation (AO)

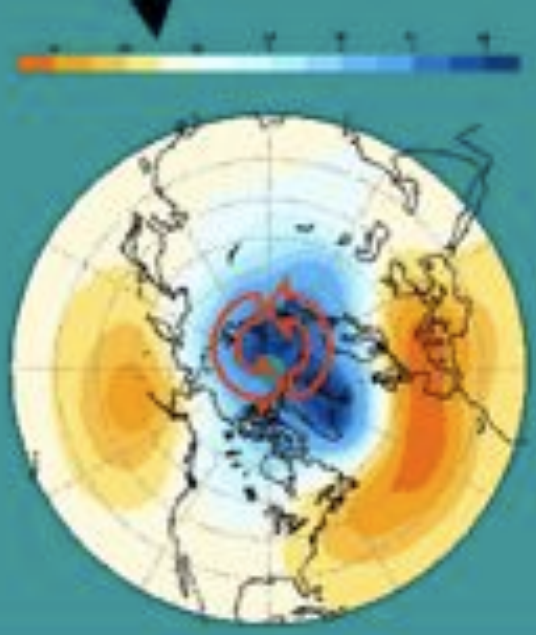
SEA LEVEL PRESSURE = MEAN + VARIABILITY

WHAT THE ARCTIC SEES

Hi AO
- small Beaufort gyre
- more Atlantic influence

Lo AO
- large Beaufort gyre
- less Atlantic influence





Covariance of Sea Level Pressure with AO index (hPa/30 years)

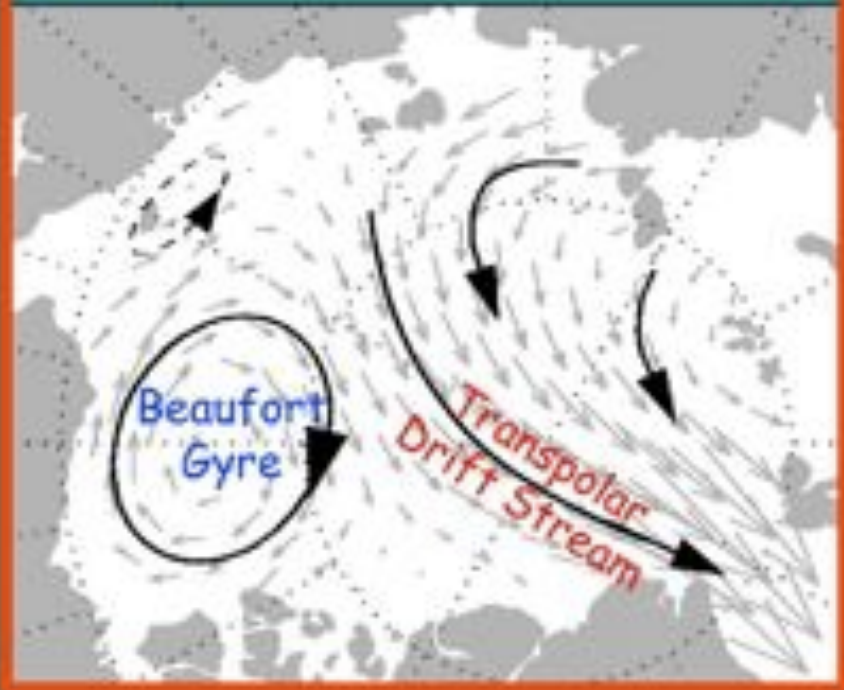
From D.Thompson, based on Thompson and Wallace 1998

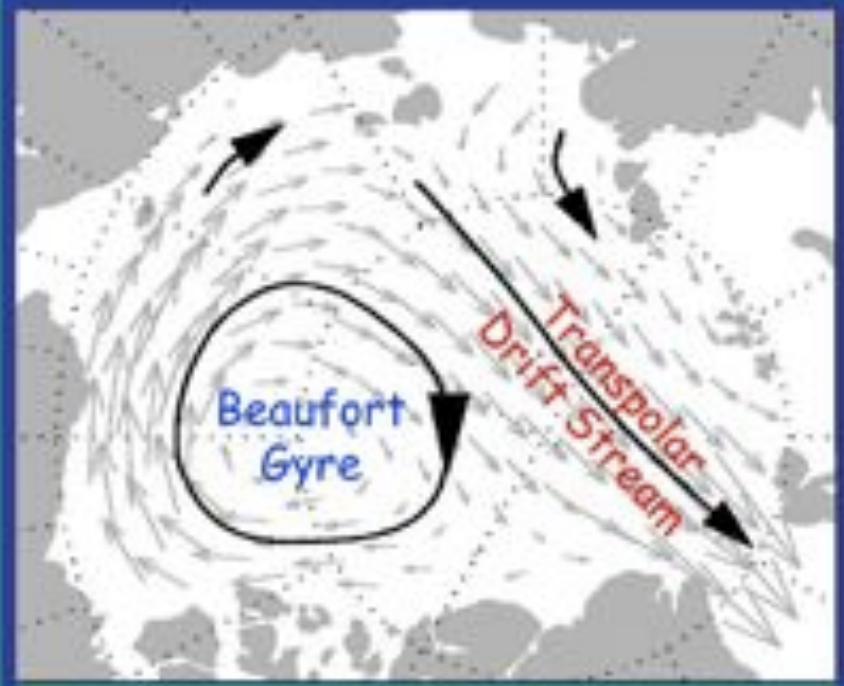
Sea-ice motion

Rigor et al, 2002, Response of Sea Ice to the Arctic Oscillation, J Climate

HIGH AO

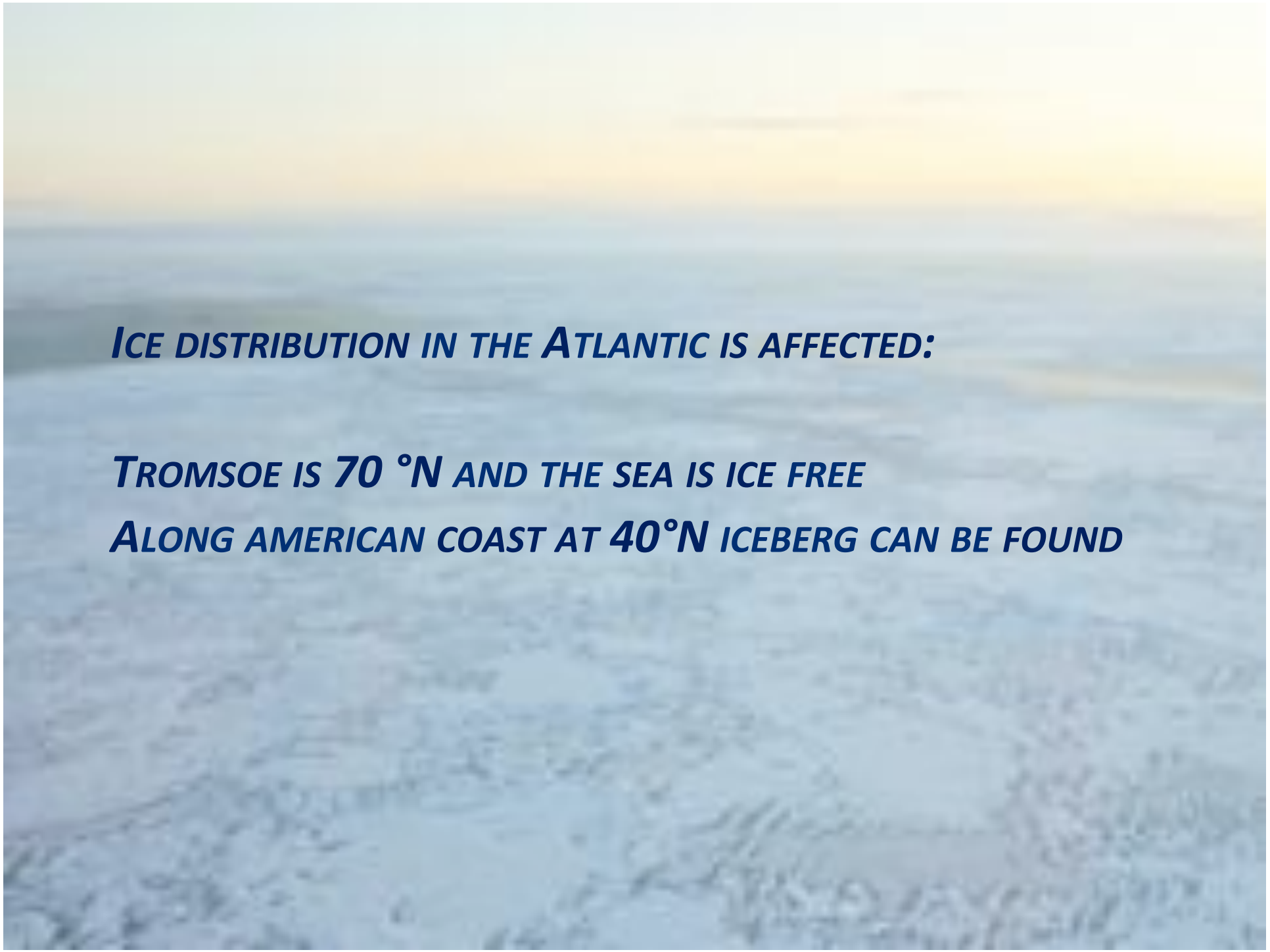
Lower sea-level pressure
Smaller (weaker) Beaufort Gyre
(more Atlantic Influence)
(Warm Phase)
More ice swept out with TransPolar drift





LOW AO

Higher sea-level pressure
Bigger (stronger) Beaufort Gyre
(less Atlantic Influence)
(Cold Phase)
Less ice swept out with TransPolar drift
More ice stored in Beaufort Gyre


ICE DISTRIBUTION IN THE ATLANTIC IS AFFECTED:
TROMSOE IS 70 °N AND THE SEA IS ICE FREE
ALONG AMERICAN COAST AT 40°N ICEBERG CAN BE FOUND

41°43’57” N, 49°56’49”W


TITANIC

ARCTIC OSCILLATION AND MID-LATITUDES CLIMATE

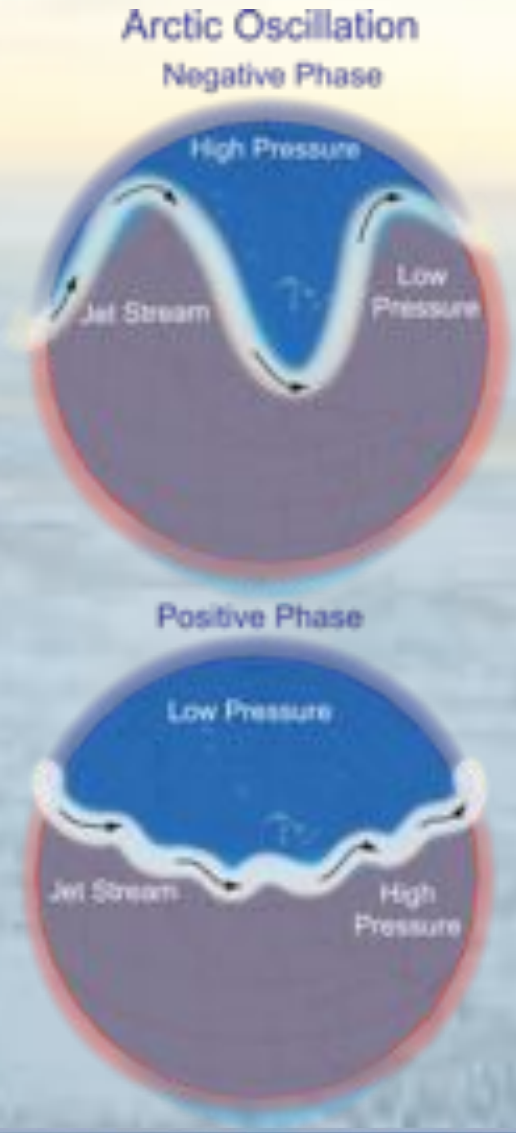
THE ARCTIC OSCILLATION (AO) OR NORTHERN ANNULAR MODE/NORTHERN HEMISPHERE ANNULAR MODE (NAM) IS AN INDEX (WHICH VARIES OVER TIME WITH NO PARTICULAR PERIODICITY) OF THE DOMINANT PATTERN OF NON-SEASONAL SEA-LEVEL PRESSURE VARIATIONS NORTH OF 20N LATITUDE,

ARCTIC OSCILLATION AND MID-LATITUDES CLIMATE

"THE DEGREE TO WHICH ARCTIC AIR PENETRATES INTO MIDDLE LATITUDES IS RELATED TO THE AO INDEX, WHICH IS DEFINED BY SURFACE ATMOSPHERIC PRESSURE PATTERNS.

WHEN THE AO INDEX IS POSITIVE, SURFACE PRESSURE IS LOW IN THE POLAR REGION. THIS HELPS THE MIDDLE LATITUDE JET STREAM TO BLOW STRONGLY AND CONSISTENTLY FROM WEST TO EAST, THUS KEEPING COLD ARCTIC AIR LOCKED IN THE POLAR REGION.

WHEN THE AO INDEX IS NEGATIVE, THERE TENDS TO BE HIGH PRESSURE IN THE POLAR REGION, WEAKER ZONAL WINDS, AND GREATER MOVEMENT OF FRIGID POLAR AIR INTO MIDDLE LATITUDES."



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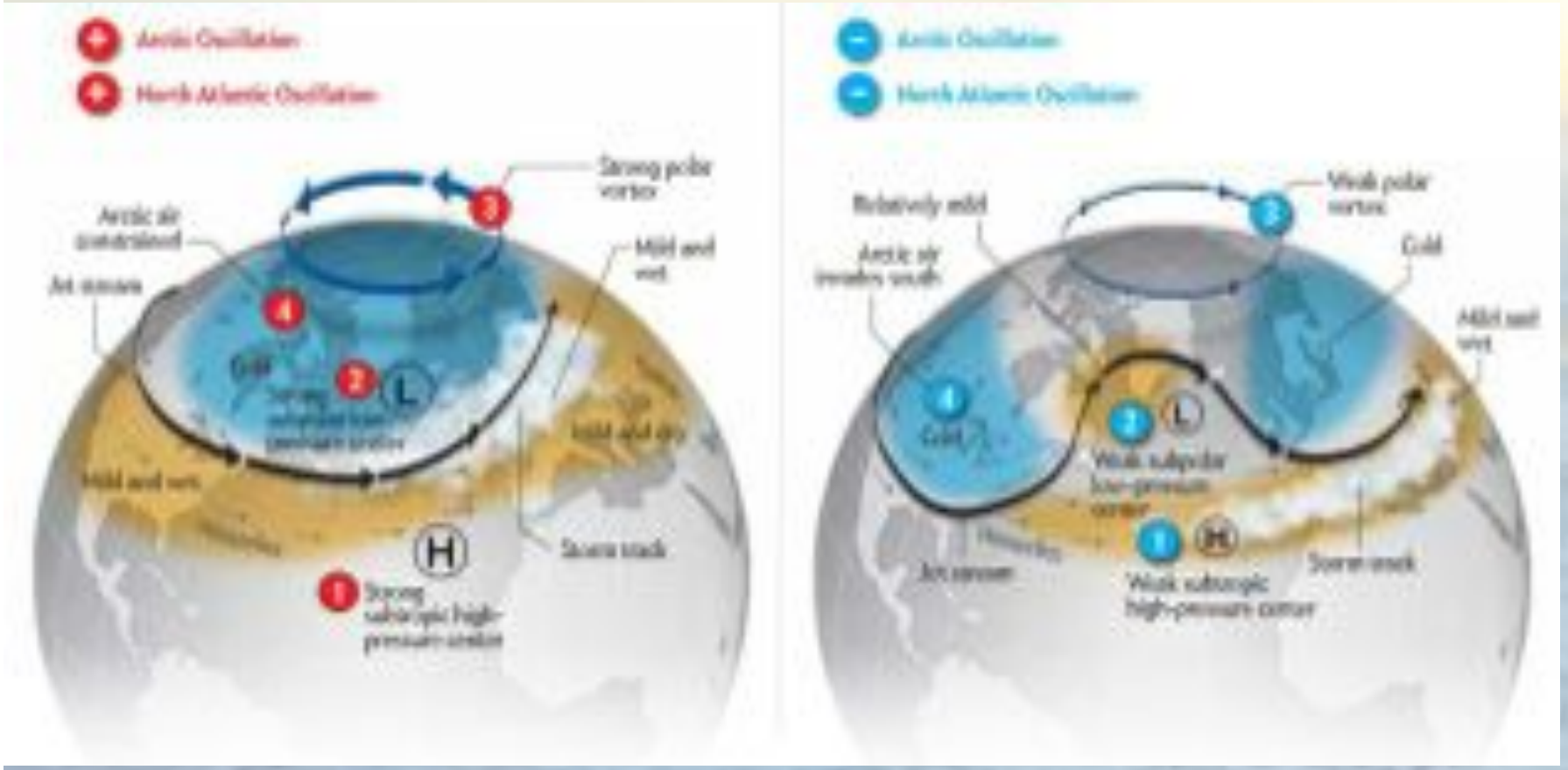
ARCTIC OSCILLATION AND MID-LATITUDES CLIMATE



GRAPHICS: GREENE SCIENTIFIC AMERICAN

POLAR AMPLIFICATION

POLAR AMPLIFICATION REFERS TO THE OBSERVATION THAT ANY CHANGE IN THE NET RADIATION BALANCE (FOR EXAMPLE GREENHOUSE INTENSIFICATION) THEN TENDS TO PRODUCE A LARGER CHANGE IN TEMPERATURE NEAR THE POLES THAN THE PLANETARY AVERAGE.

Polar Amplification

On a planet with an atmosphere that can restrict longwave radiation to space (a greenhouse effect), surface temperatures will be warmer than a simple planetary equilibrium temperature calculation would predict.

Where the atmosphere or an extensive ocean is able to convect heat polewards, the poles will be warmer and equatorial regions cooler than their local net radiation balances would predict.

POLAR AMPLIFICATION
AND SCENARIOS OF CLIMATE CHANGE

… A WARMER EARTH …

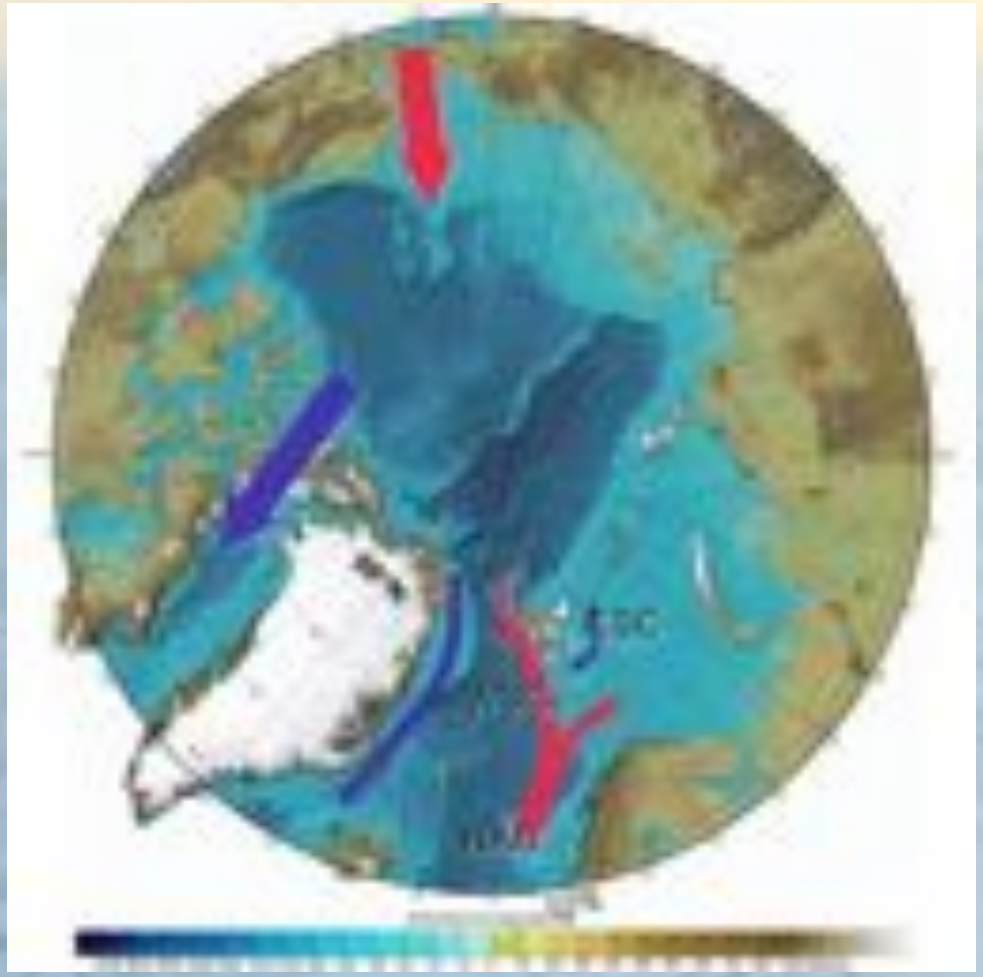
INCREASES THE MELTING OF SEA ICE DURING SUMMER,
EXPOSING MORE DARK OCEAN WATER TO INCOMING SUNLIGHT.
THIS CAUSES INCREASED ABSORPTION OF SOLAR RADIATION
AND EXCESS SUMMERTIME HEATING OF THE OCEAN —
FURTHER ACCELERATING THE ICE MELT.

Polar Amplification

The excess heat is released to the atmosphere, especially during the autumn, decreasing the temperature and atmospheric pressure gradients between the Arctic and middle latitudes.

A diminished latitudinal pressure gradient is linked to a weakening of the winds associated with the polar vortex and jet stream.
Since the polar vortex normally retains the cold Arctic air masses up above the Arctic Circle, its weakening allows the cold air to invade lower latitudes..."

CIRCULATION TOWARD ARCTIC OCEAN



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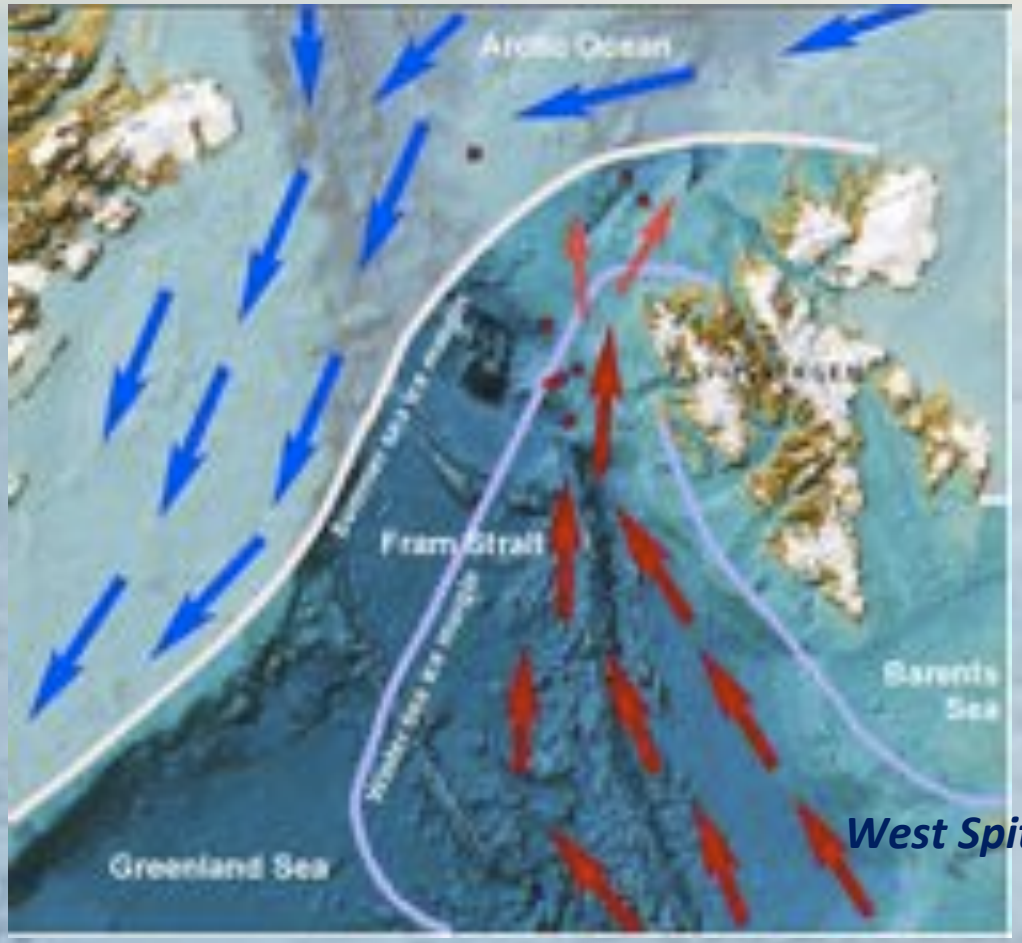
CIRCULATION TOWARD ARCTIC OCEAN

Fram Strait and Svalbard

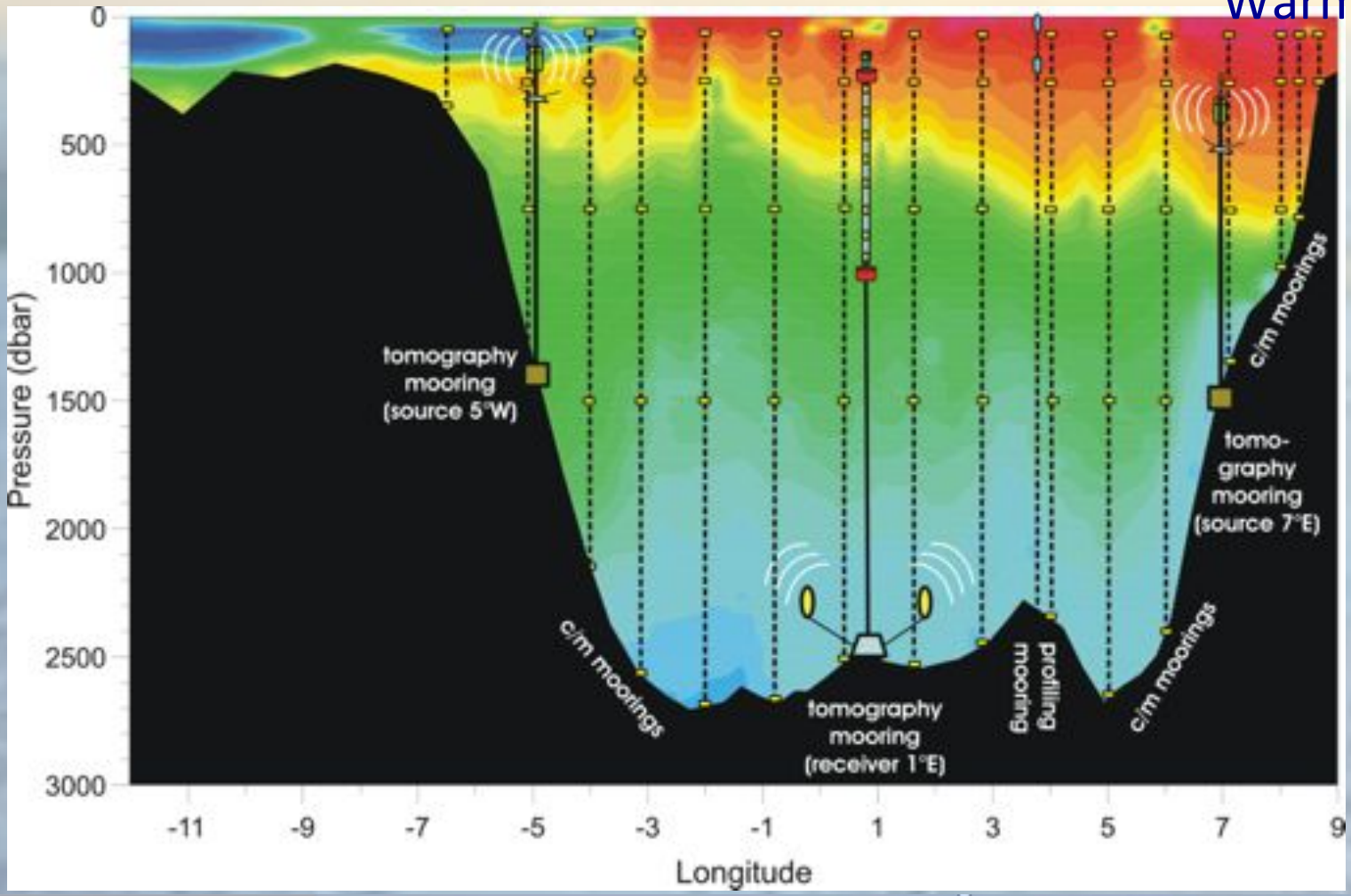
East Greenland Current



West Spitzbergen Current

Fram Strait and Svalbard

Warm core



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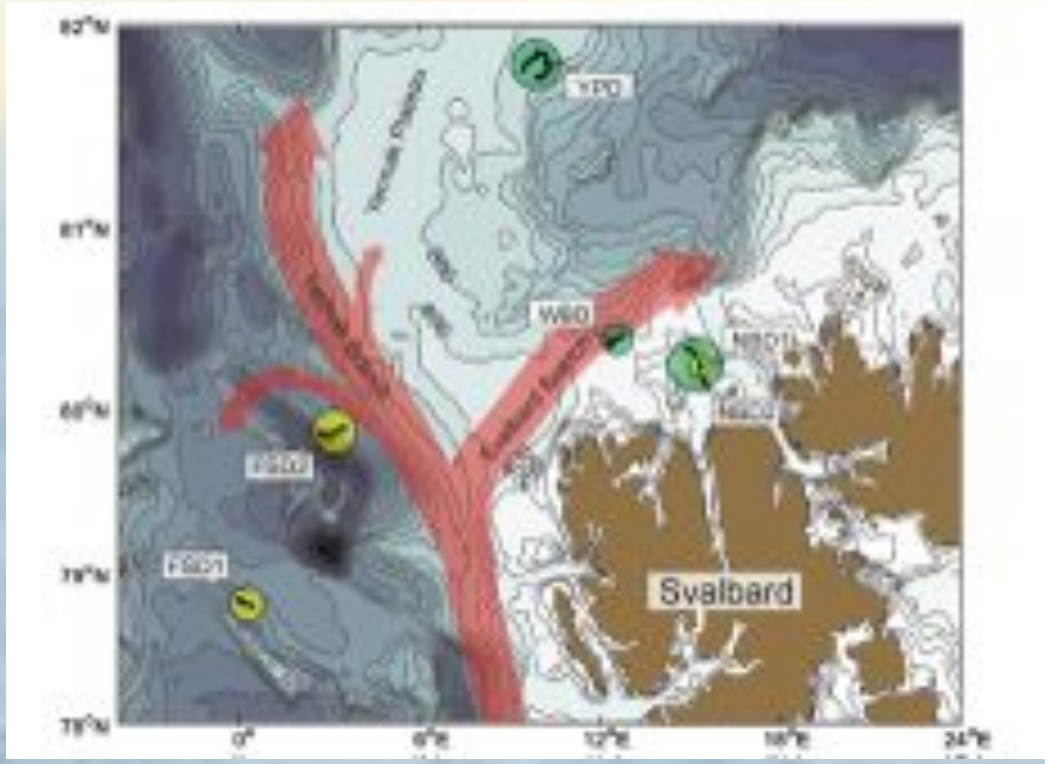
Atlantic water => Arctic Surface water

As the current flows north, ice is advected over the warm core, and water cools and freshens rapidly.

Mixing at the surface occurs through wind, waves, and ice motion.

This leads to the conversion of Atlantic water to Arctic Surface Water, whose temperature and salinity characteristics depend on the amount of ice melting and atmospheric cooling.

The WSC (West Spitzvergen Current) is the northernmost extension of the Norwegian Atlantic Current.
It flows poleward through eastern Fram Strait along the western coast of Spitsbergen.



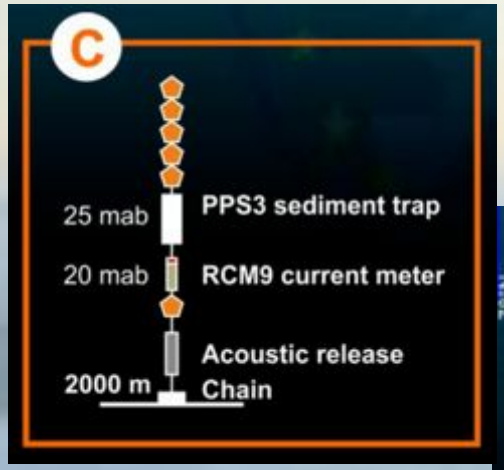
It is about 100 km wide and is confined over the continental slope, where it reaches its maximum current speed of 24 to 35 cm s-1 at the surface.

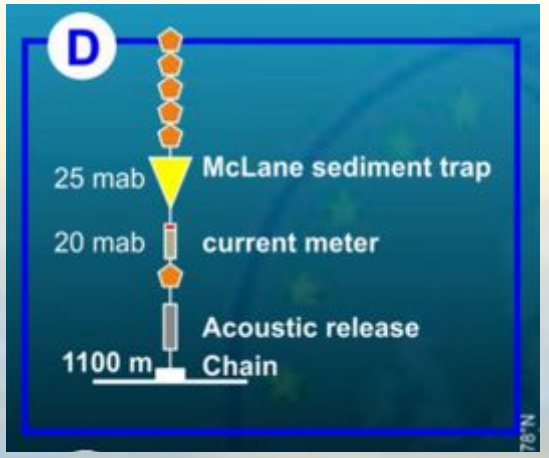
It transports relatively warm (6 to 8°C) and salty (35.1 to 35.3) Atlantic Water

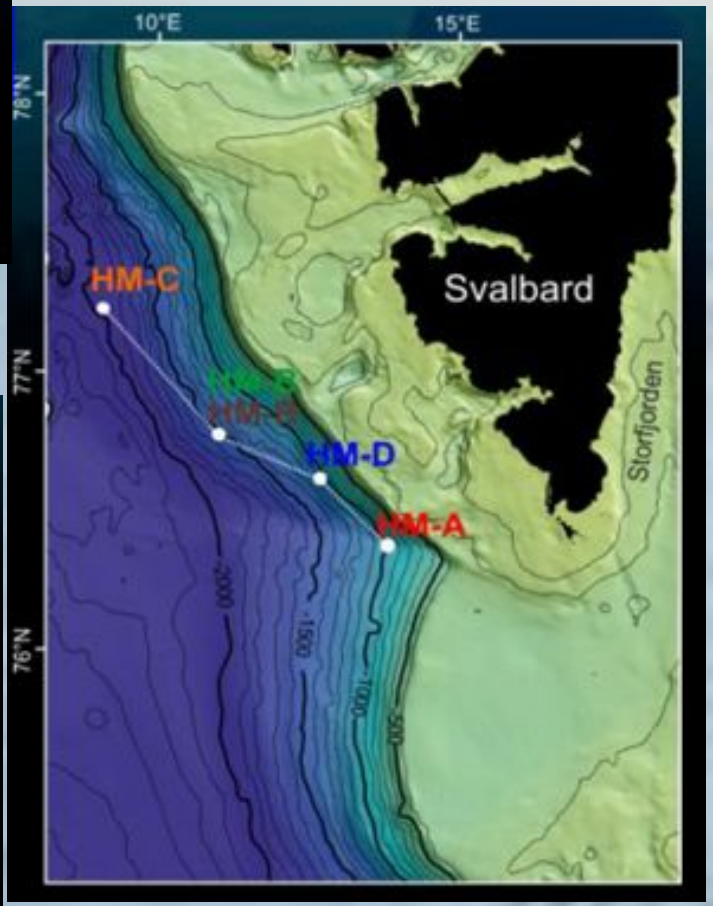
If the warm core becomes separated from the surface by a layer of stratification (e.g. rain..), it is then insulated from further surface mixing, heavy ice conditions west of Spitsbergen during spring could prevent the current from losing heat to the atmosphere by generating a surface layer of meltwater.

This, in turn, could allow the current to transport more heat to the Arctic Ocean, which would result in warm summers north of Svalbard.

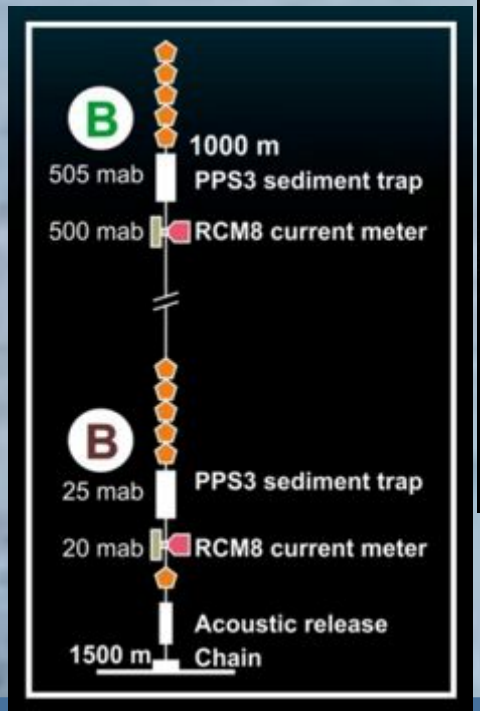
Svalbard Margin

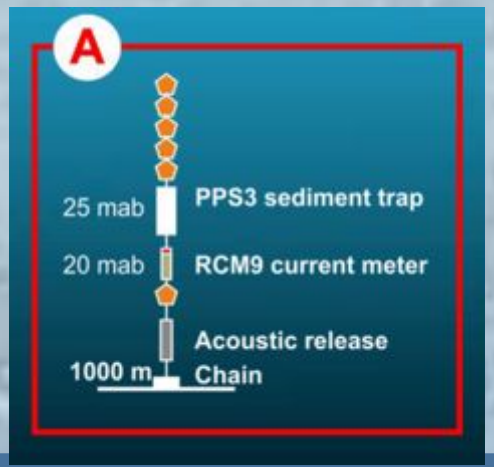




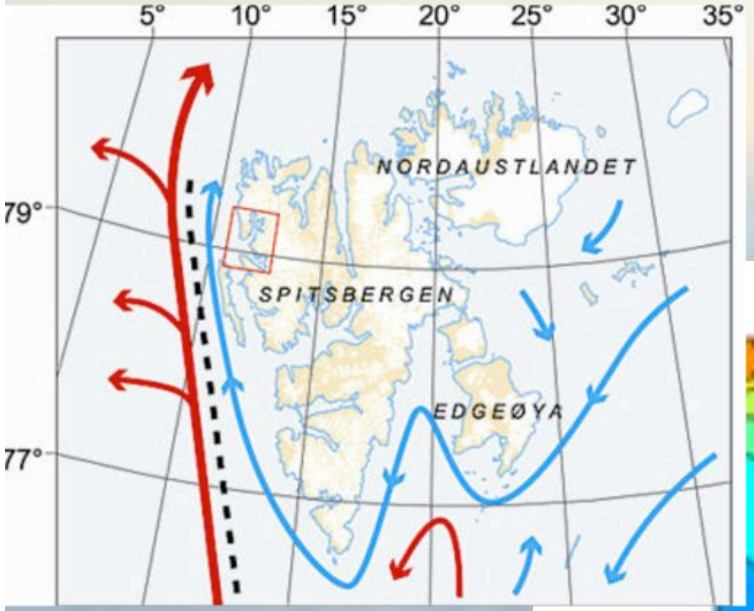


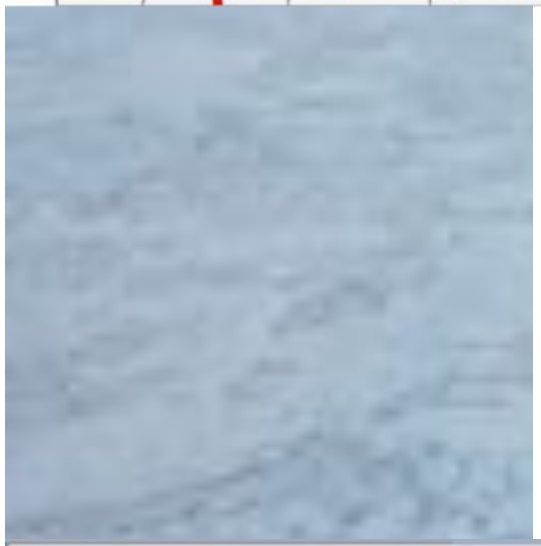
Mooring design

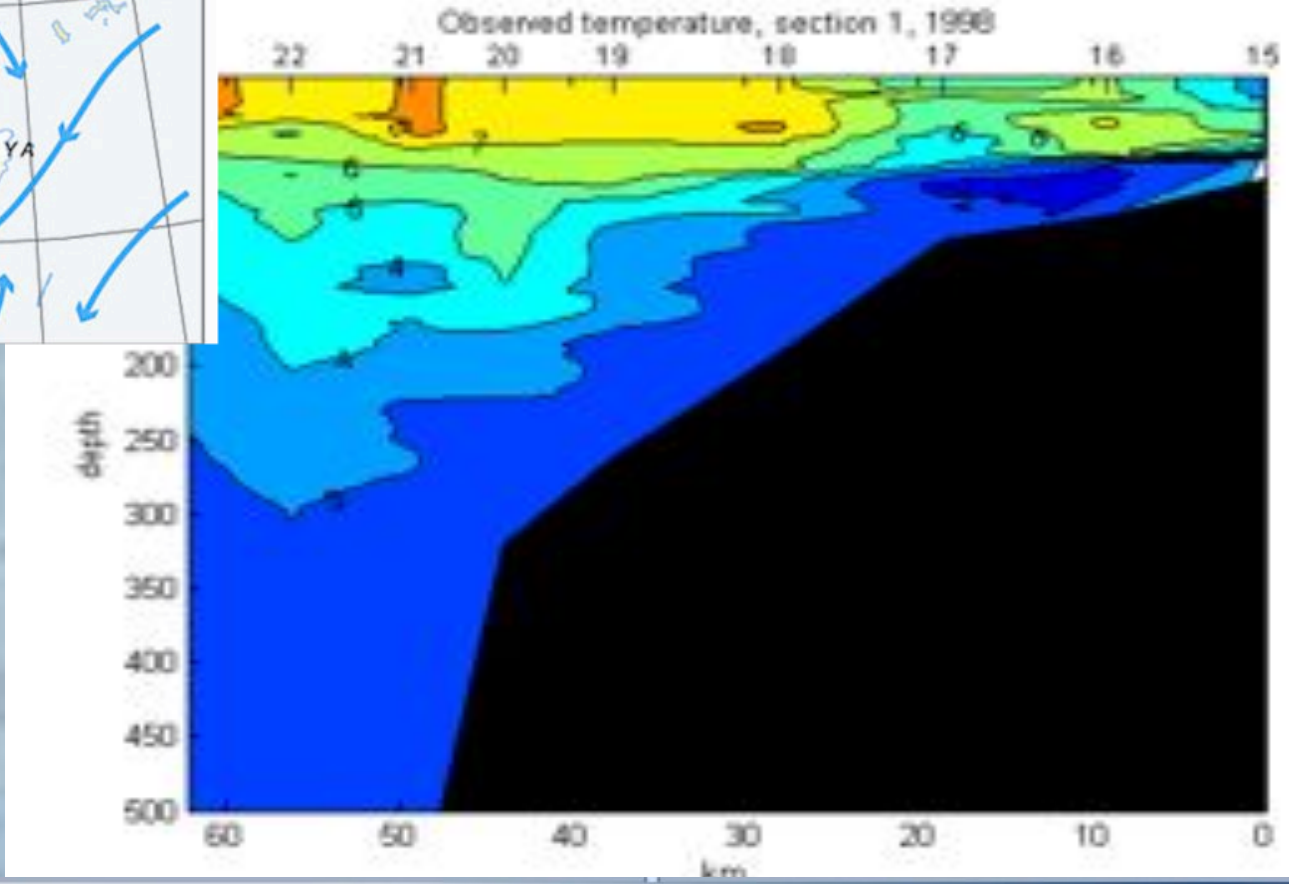




Kongsfiord







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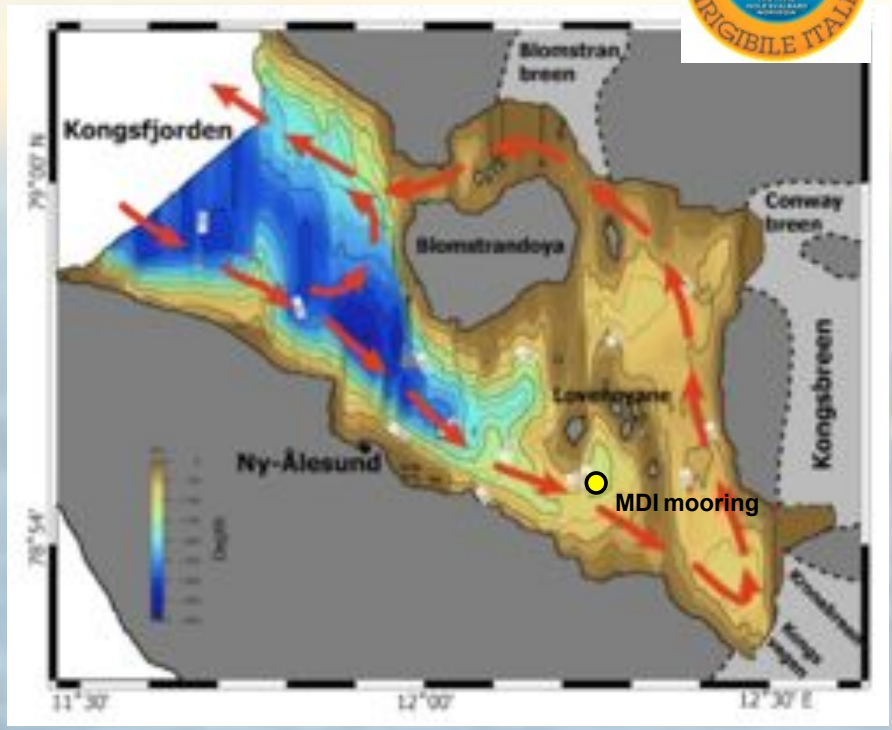
Oceanic interactions

In Kongsfiorden warm core of Atlantic water drives submarine ice melting

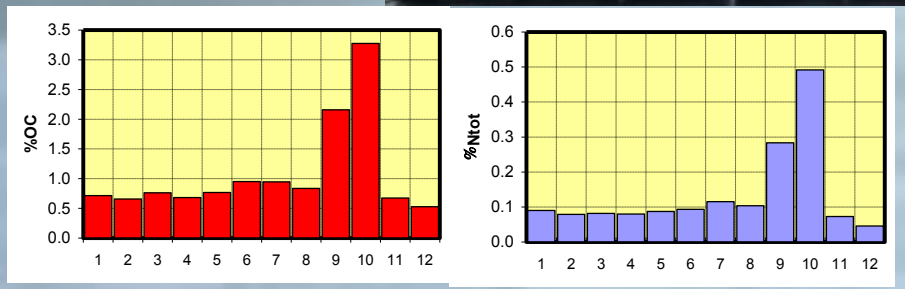
=> Freshwater input

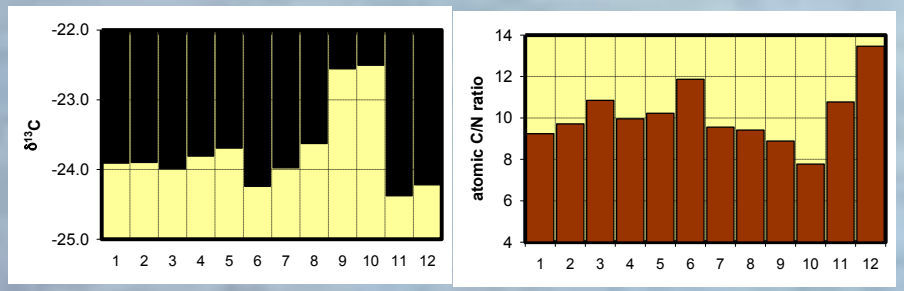


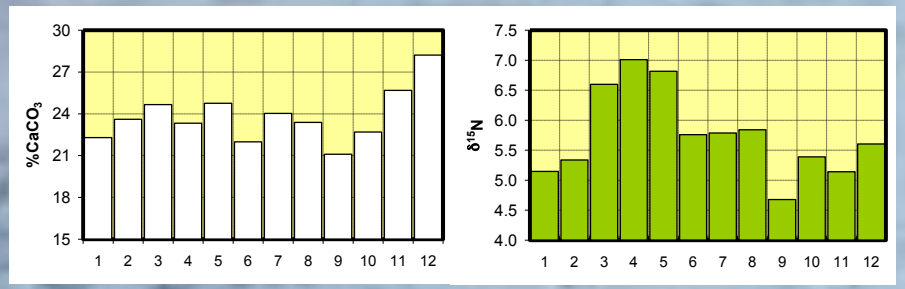
Warm water intrusion

Permanent observations
Moorings

MDI-2010







TRAP SERIES 2010

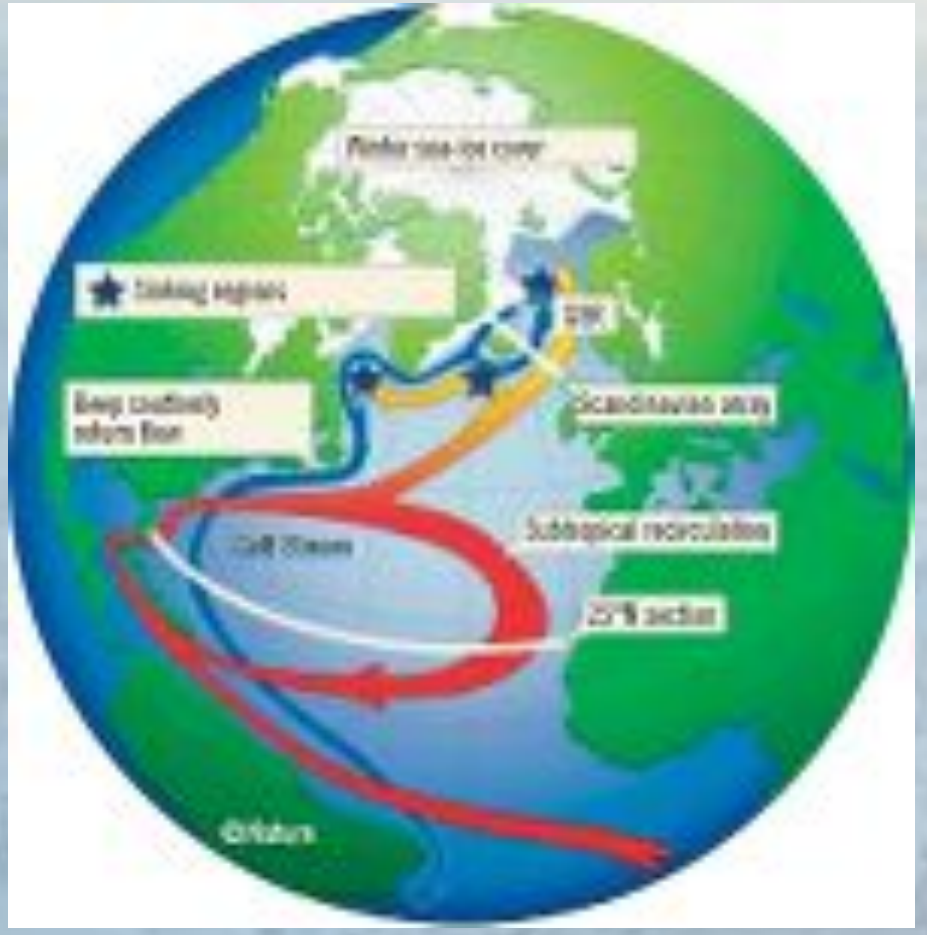
Organic Carbon Nitrogen

δ^{13} C C/N ratio

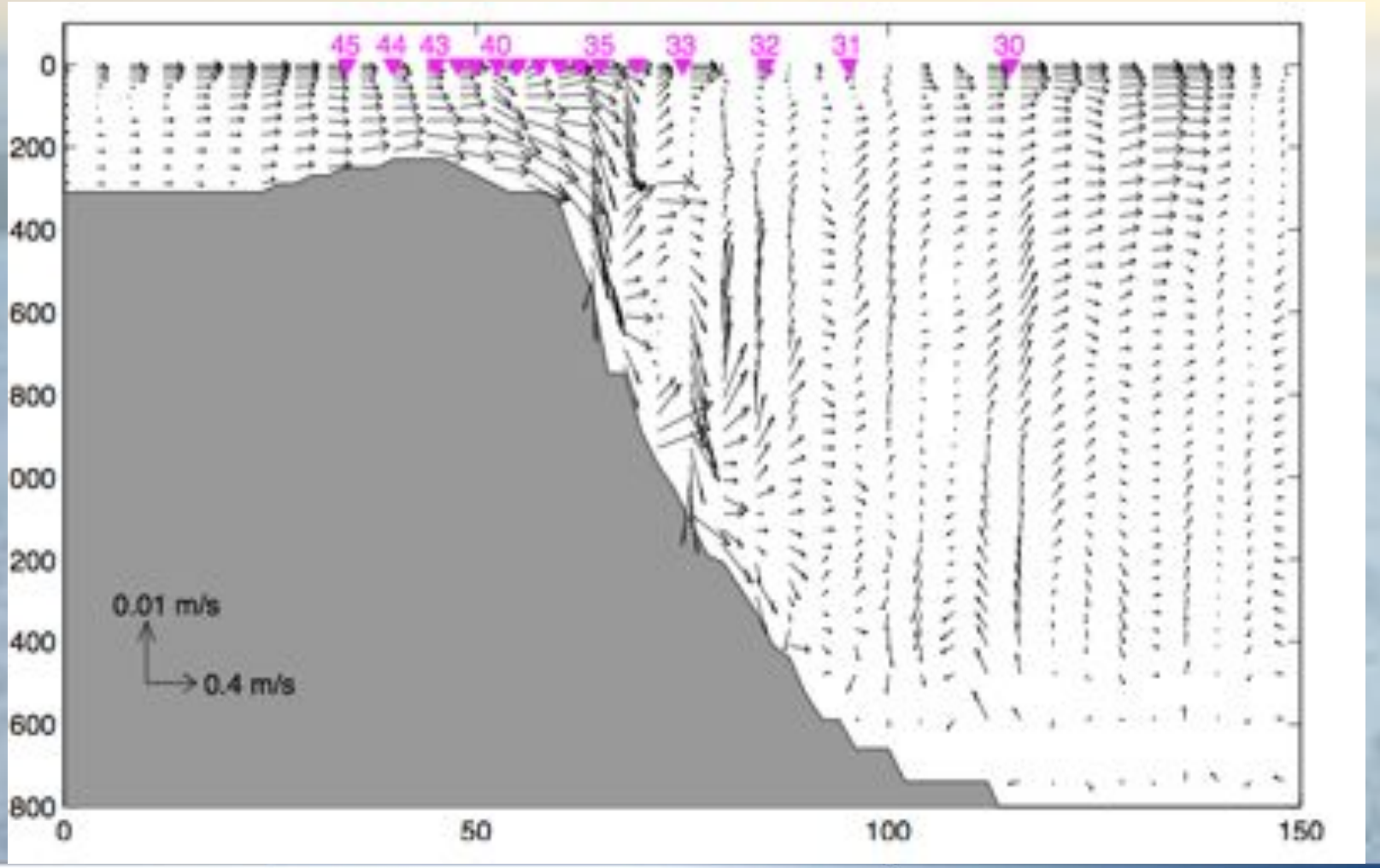
CaCo3 δ^{15}N

OCEAN OBSERVING INFRASTRUCTURES

CIRCULATION FROM ARCTIC OCEAN
OVERTURNING CIRCULATION



CIRCULATION FROM ARCTIC OCEAN CASCADING EAST GREENLAND



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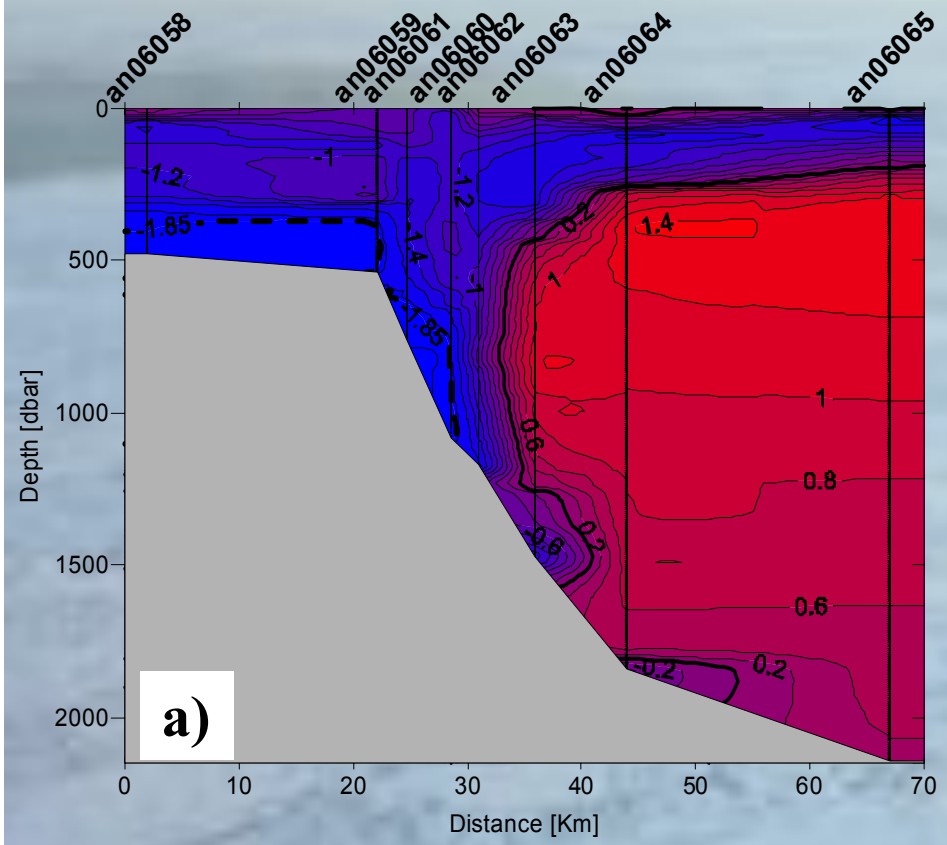
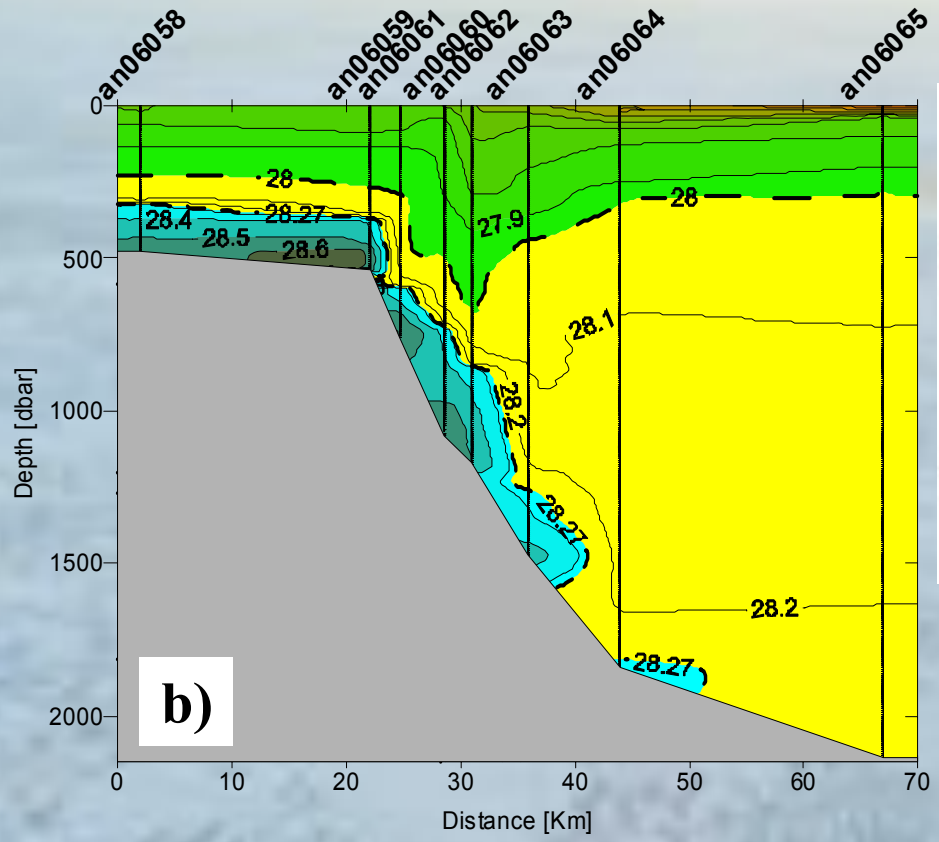
CIRCULATION FROM ARCTIC OCEAN CASCADING EAST GREENLAND





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THE CNR PROJECT "PREMIALE **ARCA**"

Arctic: Climatic change and past extreme events

Acronym: ARCA

Programme: Ministry of Education, University and Research MIUR - Ordinary Fund for government agencies and research institutions (FOE) - National Program for Research - Projects reward

The purpose of the project is to study

- ice sheets and the flow of fresh water and sediments
- Air ocean iteractions
- Reconstructing extreme events of glacial melting in the last 20,000 years on continental shelf off Svalbard.

CONCLUSIONS

ARCTIC IS IMPORTANTI FOR GLOBAL CLIMATE

WSC E KONGSFIORD ARE IMPORTANT

SIOS INFRASTRUCTURE NEEDS NATIONAL SUPPORT

UNDERSTANDING EAST GREENLAND DYNAMICS AND OVERTURNING CIRCULATION

THE ARCA PROJECT PROGETTO PREMIALE CNR

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Thanks for your attention!!

And thanks to
Arctic station Dirigibile Italia
CNR DTA
Kings Bay and Teisten
Sysselmann of Svalbard
All Ny Alesund colleagues

THE ARCA PROJECT PROGETTO PREMIALE CNR

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