Rivers in the Sea

How the Arctic Ocean pays its bills

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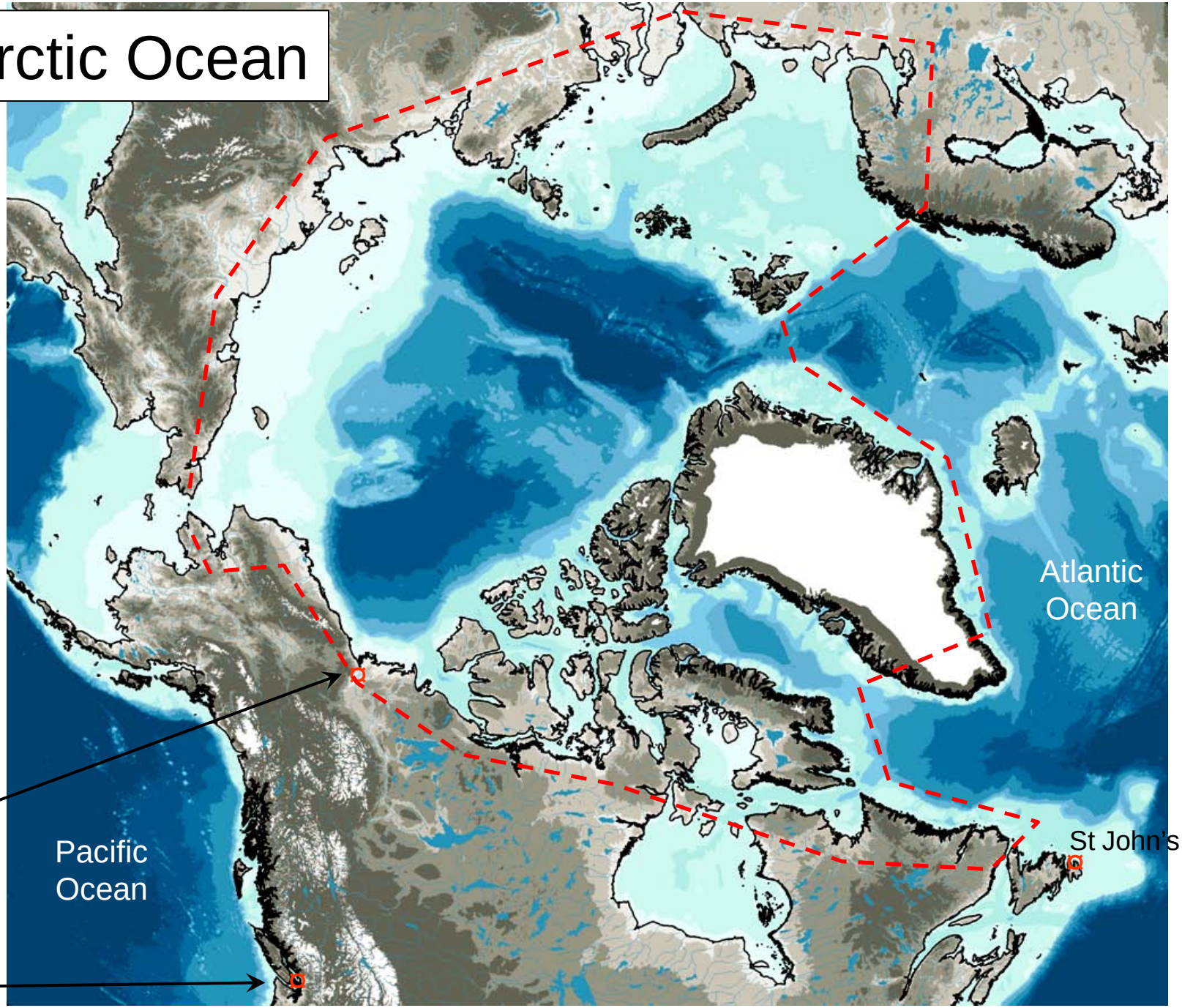
INTERNATIONAL POLAR YEAR 2007-2008
ANNÉE POLAIRE INTERNATIONALE

The Arctic Ocean

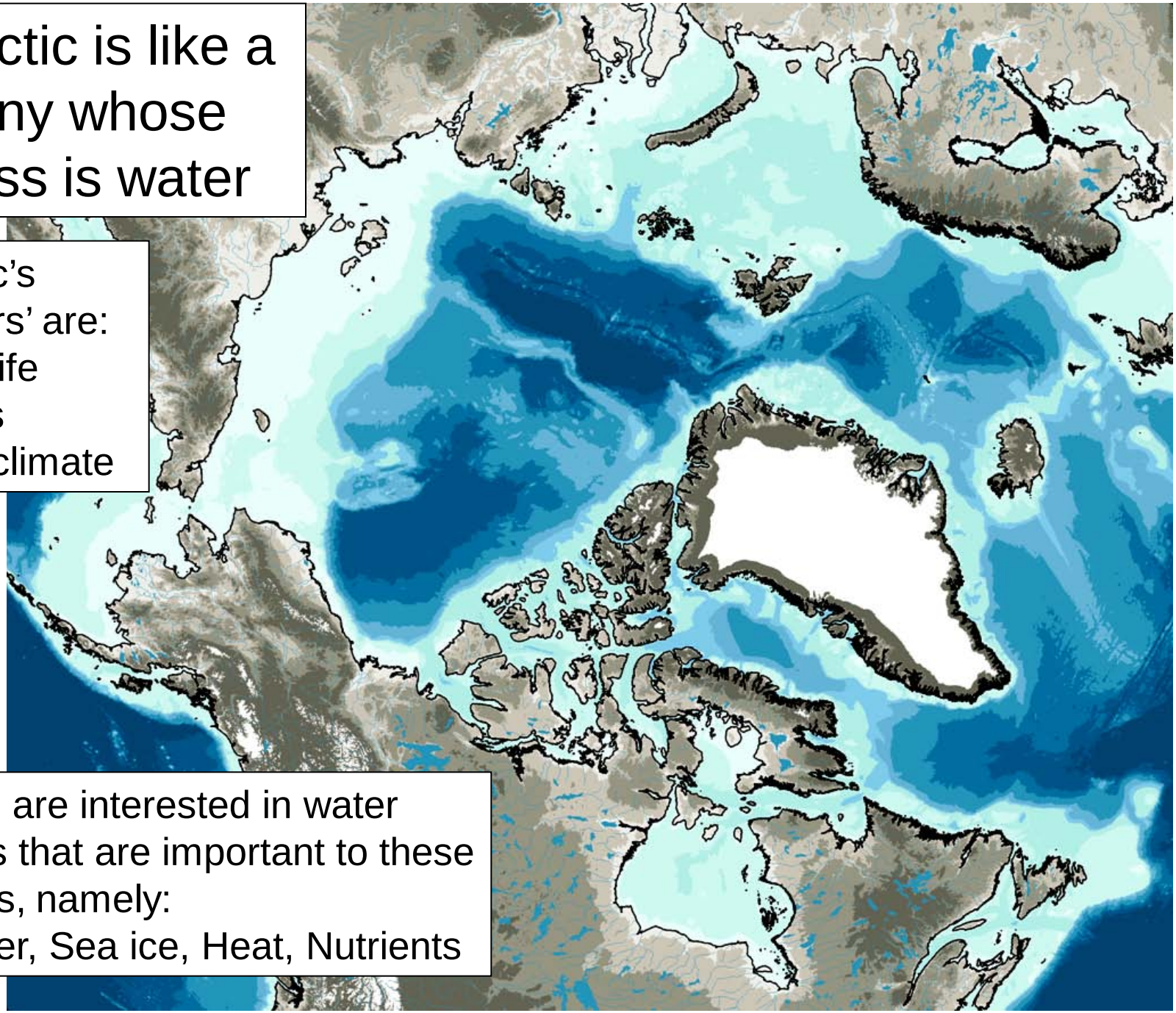
One small ocean, connected to two big oceans

With currents flowing like rivers between them



The Arctic is like a company whose business is water

The Arctic's 'customers' are:
- Marine life
- Humans
- Earth's climate



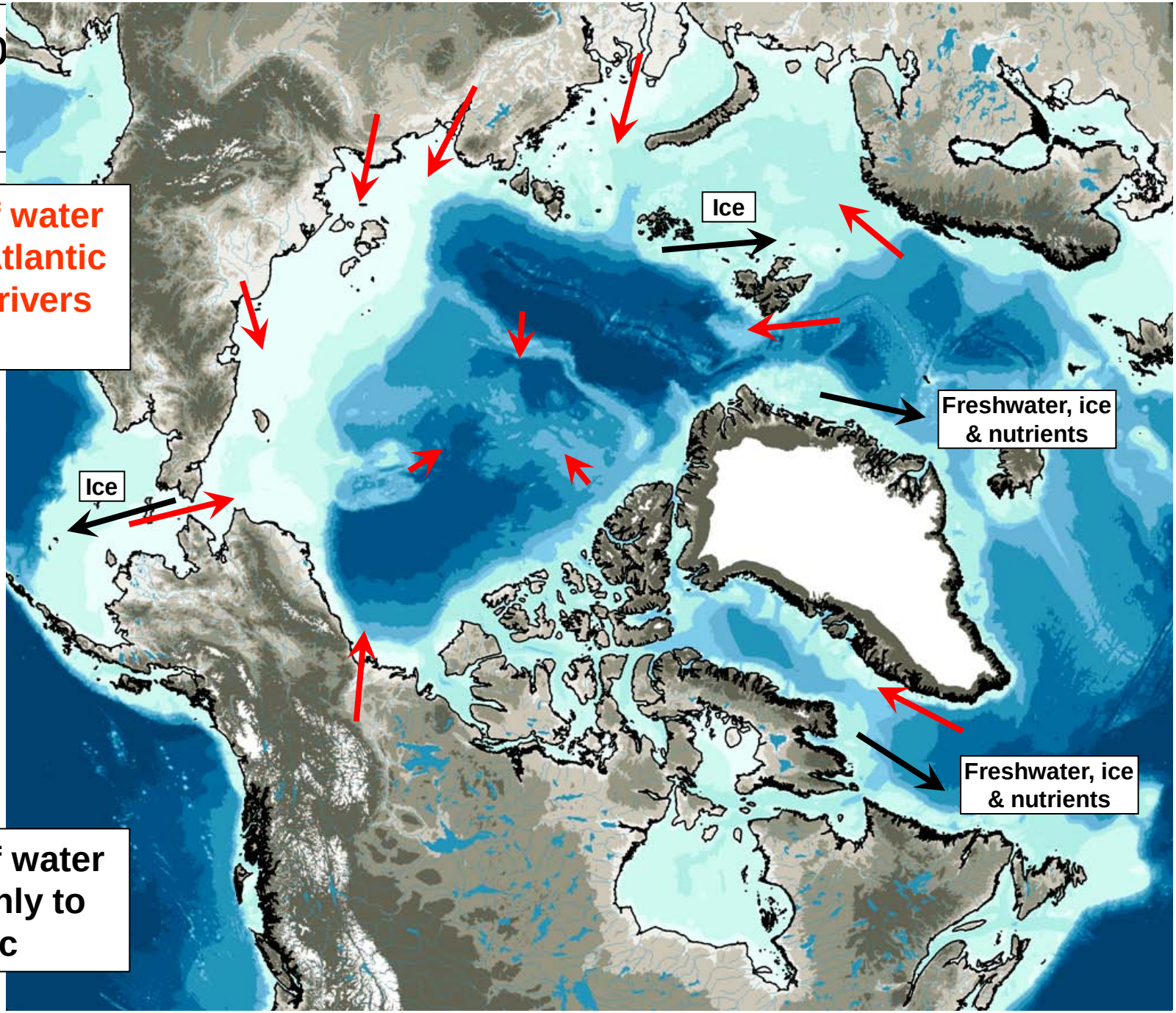
Scientists are interested in water properties that are important to these customers, namely:
Freshwater, Sea ice, Heat, Nutrients

The Co budget

Imports of water from the Atlantic & Pacific, rivers & snow

Inventory: Arranging & stacking of imports

Exports of water & ice, mainly to the Atlantic



The organization of inventory – imported freshwater, heat & nutrients – is critical for the ‘customers’

<u>The imports are distributed unevenly across the Arctic Ocean</u>:

Wind patterns cause freshwater & nutrients to be stored on ‘our’ side

<u>The imports are distributed unevenly over depth</u>:

Nutrients & heat that are imported in saltwater go down deep,

because imported freshwater takes up the space near the surface

<u>This organization traps nutrients out of reach of sunlight, heat out of contact with sea ice</u>

Marine life – primary production – requires nutrients in the sunlit layer

→ Freshwater storage is ‘bad’

Sea ice suffers where ocean heat reaches the surface

→ Freshwater storage is ‘good’

Like sugar in a coffee cup, stirring or tipping is needed to get nutrients & heat to the surface … … Stormy weather does this

Why study the ‘Arctic water business’ during the IPY?

The Ocean-Atmosphere System

Winds carrying warmth from the tropics to the Arctic also bring moisture (freshwater).

The ocean moves the excess freshwater back to the tropics.

Ocean flow through the Canadian Arctic to the Atlantic is driven by this global cycle.

The Ecosystem

The movement of Pacific water towards the Atlantic brings nutrient-rich water to the Canadian Arctic.

Physical processes act in some places to move nutrients to the surface zone of biological production

Varying storage of fresh water in the Arctic affects ocean structure, sea ice & marine productivity.

Climate Change

Atmospheric delivery of moisture to the Arctic will increase as climate warms.

Ocean fresh water storage may change, with implications for Arctic ice.

The rate & routing of Arctic Ocean fresh water outflows may change.

Enhanced delivery of ocean fresh water to the Atlantic may slow deep ocean circulation.

Two Canadian IPY marine science projects were focused on the 'Arctic water business'

Canada's Three Oceans study (C3O)

Ed Carmack, Institute of Ocean Sciences, DFO

+ Melling, McLaughlin, Vagle, Williams
+ cast of thousands

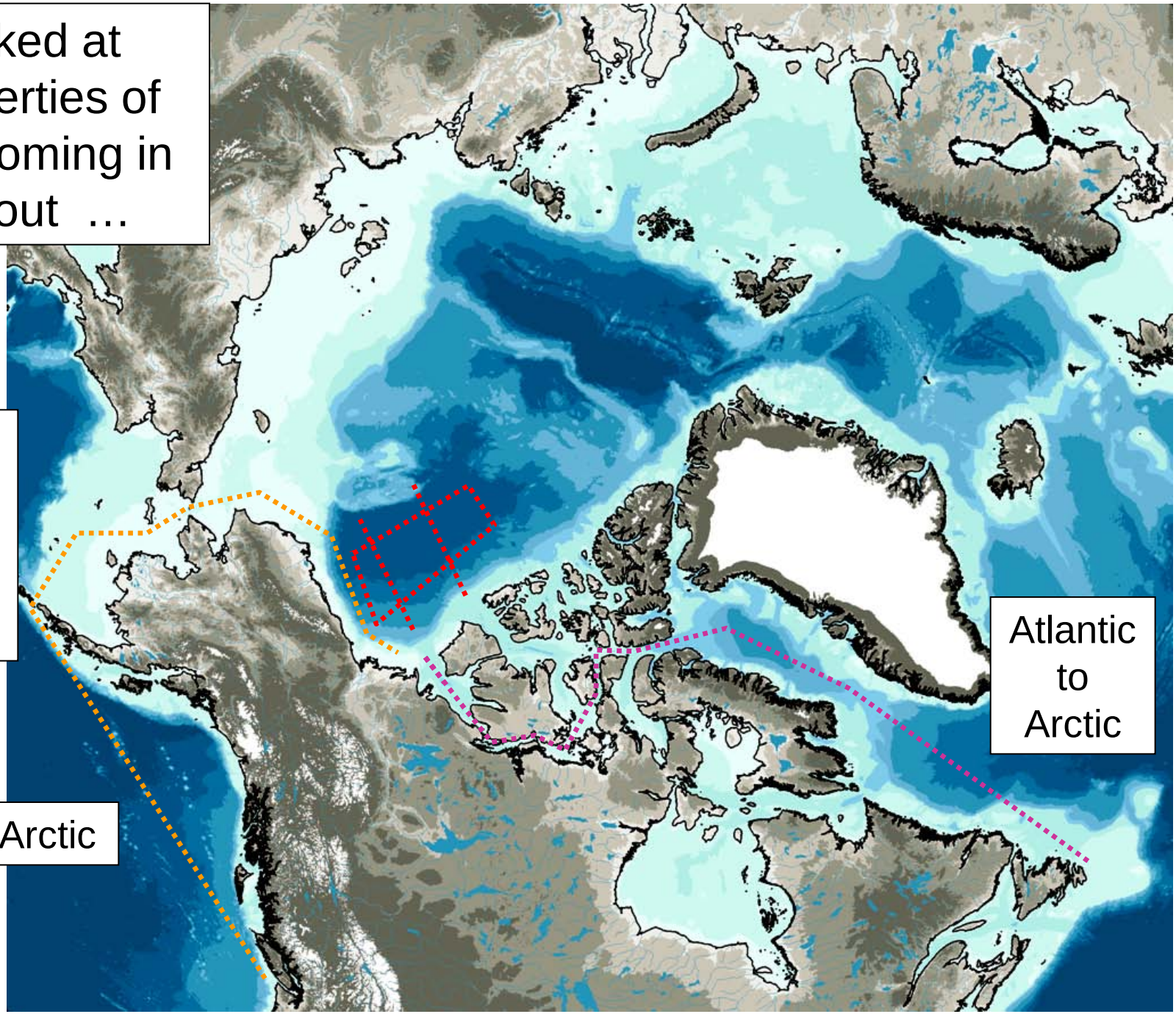
Canadian Arctic Through-flow study (CATs)

Humfrey Melling, Institute of Ocean Sciences, DFO

+ Bedford Institute (Prinsenberg, Hamilton, Azetsu-Scott)
+ University of Alberta (Myers, Haas)
+ many others

C3O looked at the properties of waters coming in & going out …

& how they are organized on ‘our side’



C3O was a demonstration project for future ocean monitoring

It was built around observing the ocean from ships of the Canadian Coast Guard already committed to annual Arctic Patrols

Three-oceans surveys in 2007 & 2008

<u>Advantages of multi-tasking for science</u>

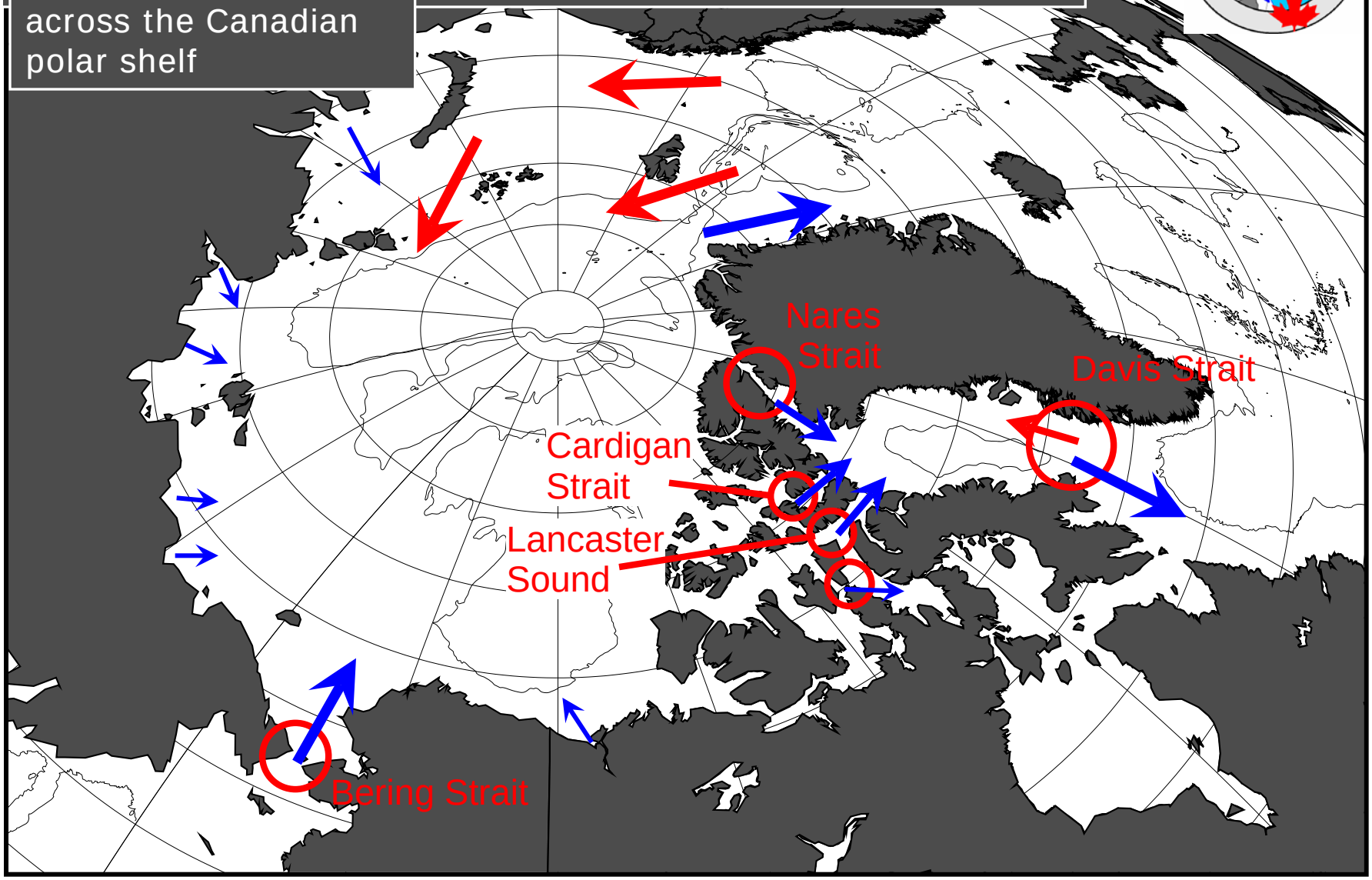
Reliable annual schedule

Predictable route

Cost-effective use of government asset

CATs looked at how much water was moving

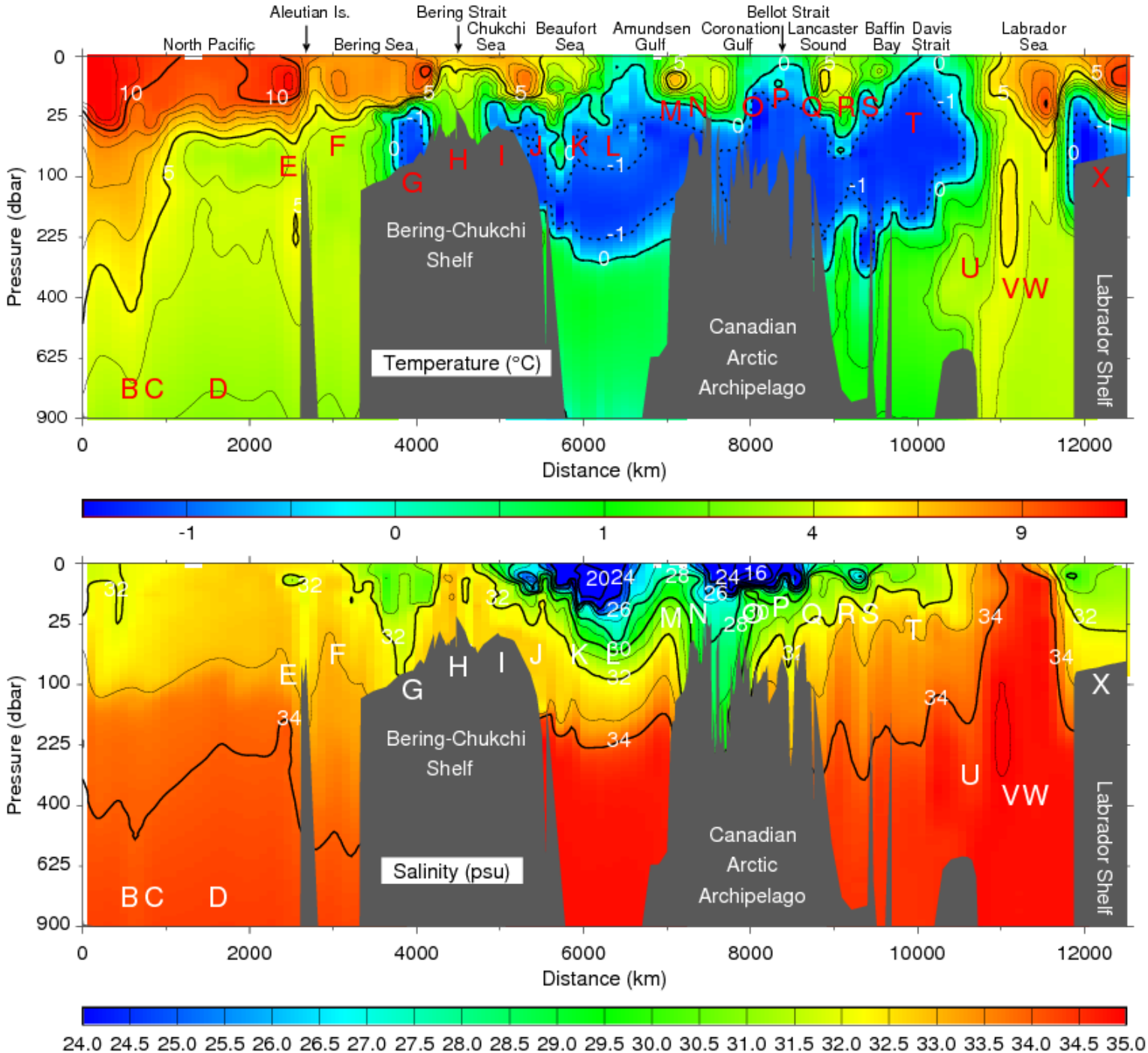
At 4 gateways for flow across the Canadian polar shelf



In CATs, we used instruments on sub-sea moorings to observe year-round at gateways

1st time ever PAA ocean sections, via C3O

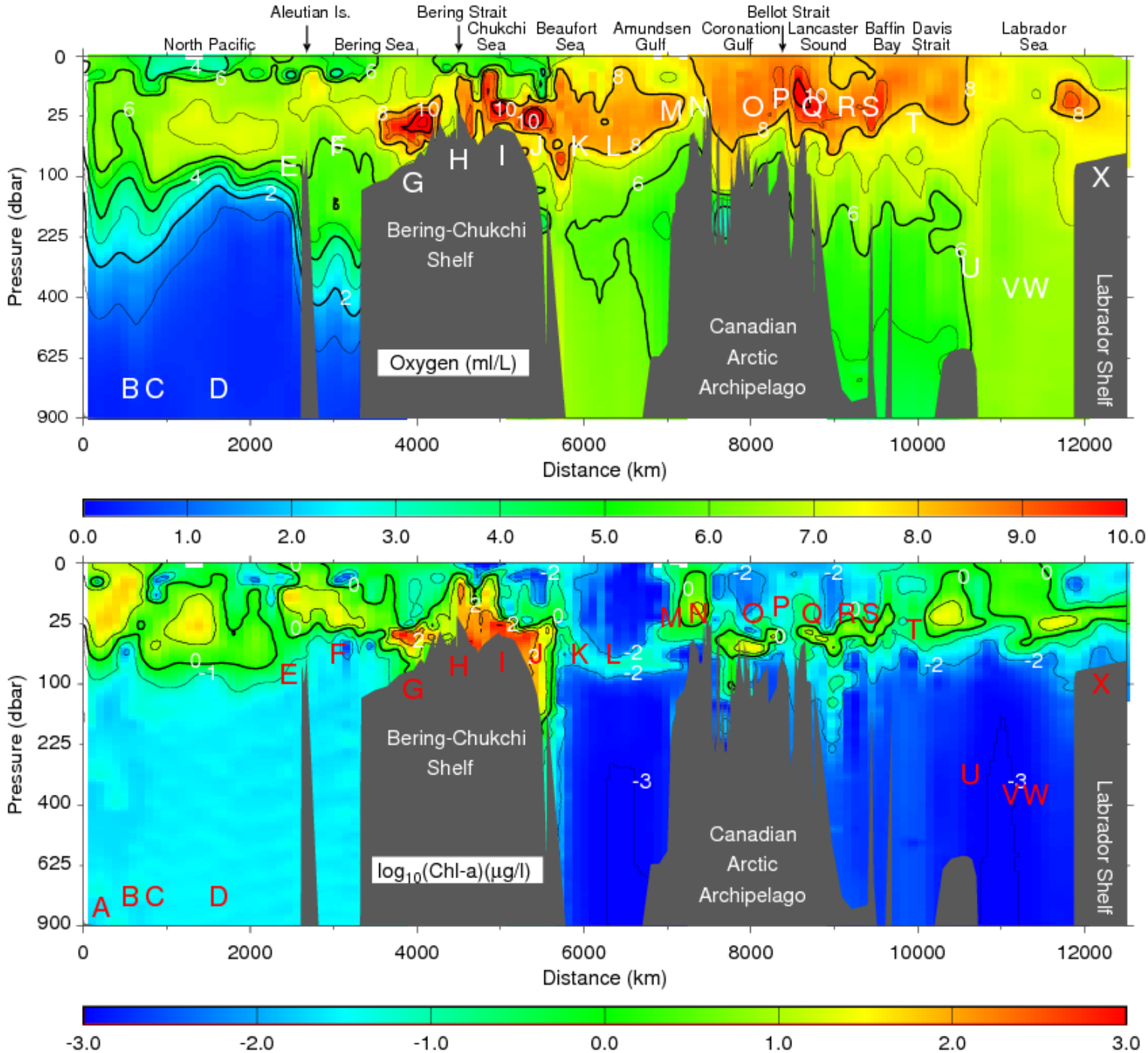
Temperature (top)
&
Salinity (bottom)



Victoria (left)
to
St John's (right)

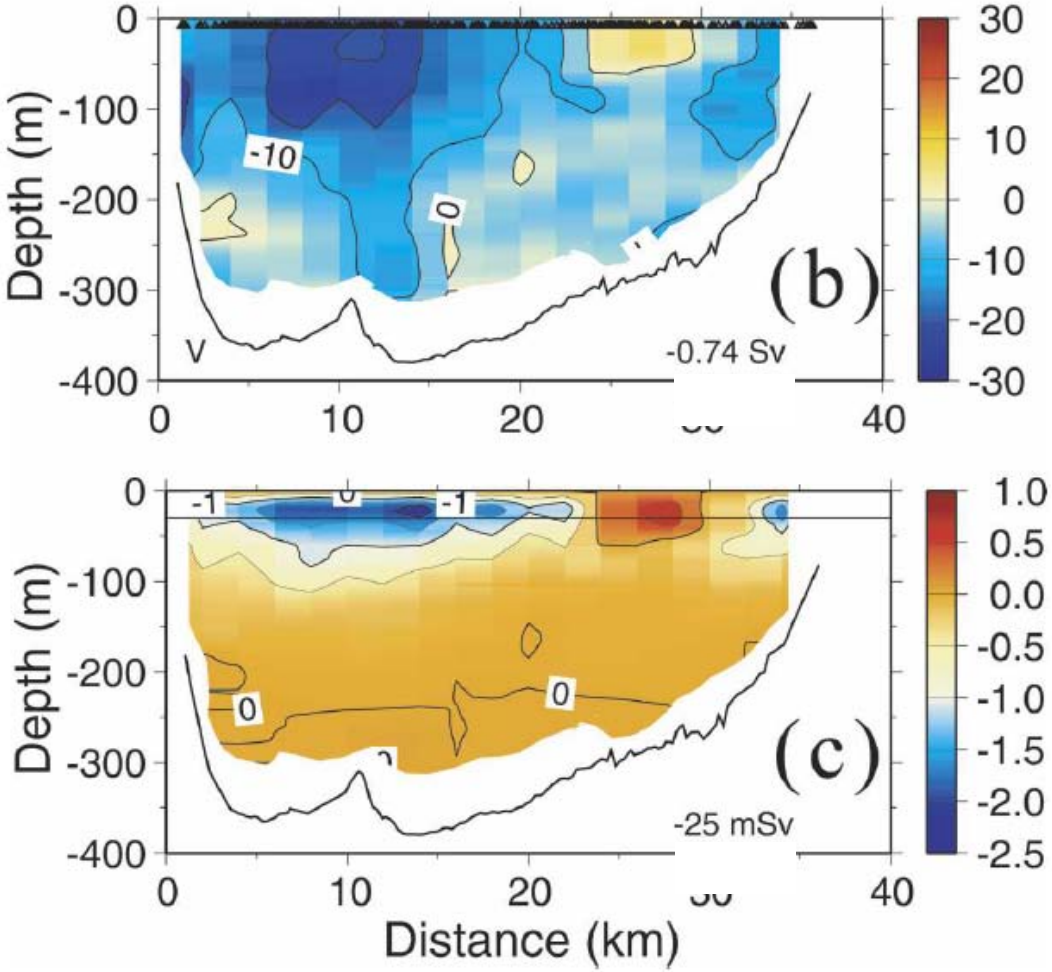
1st time ever PAA ocean sections, via C3O

Oxygen (top) & Chlorophyll (bottom)



Victoria (left) to St John's (right)

1st time ever values for Canadian Arctic through-flow, via CATs



Shown here for Nares Strait

Southward movement of water

910,000 tons per second

Pacific vs. Atlantic

40% of the outflow comes from the Pacific Ocean, rich in nutrients

Southward movement of freshwater

31,000 tons per second or 1,000 km^3/year

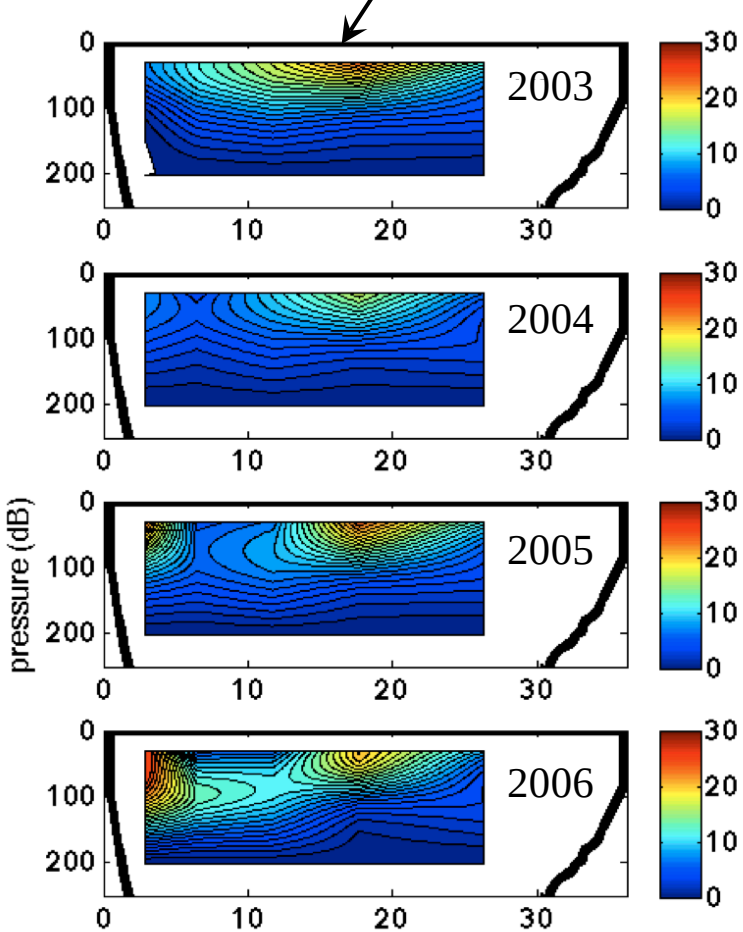
… comparable to the peak flow of the Mackenzie River, year-round

Adding the movements through Lancaster Sound doubles these numbers

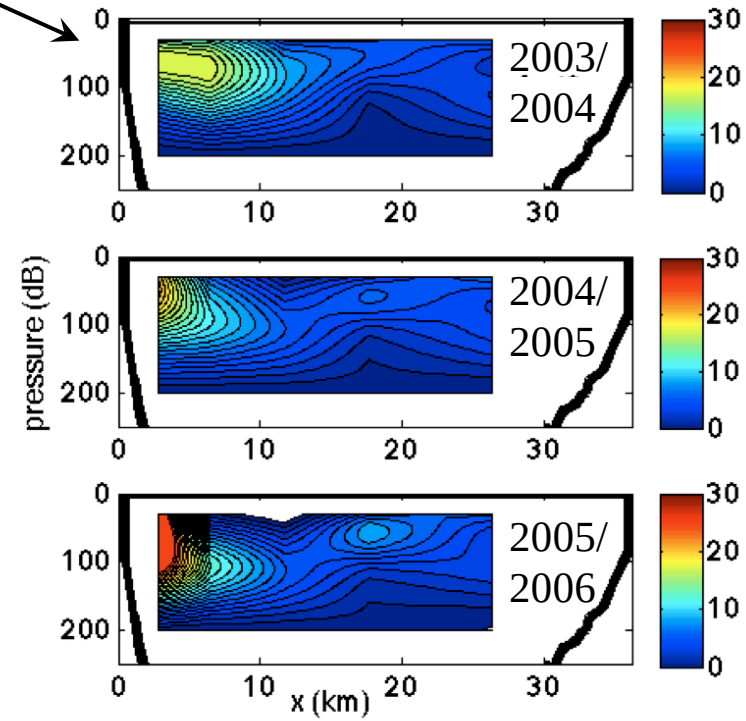
However, these ocean flows vary greatly from season to season & year to year

Rivers in the sea

This means that the 'company's' inventory & budgets vary too



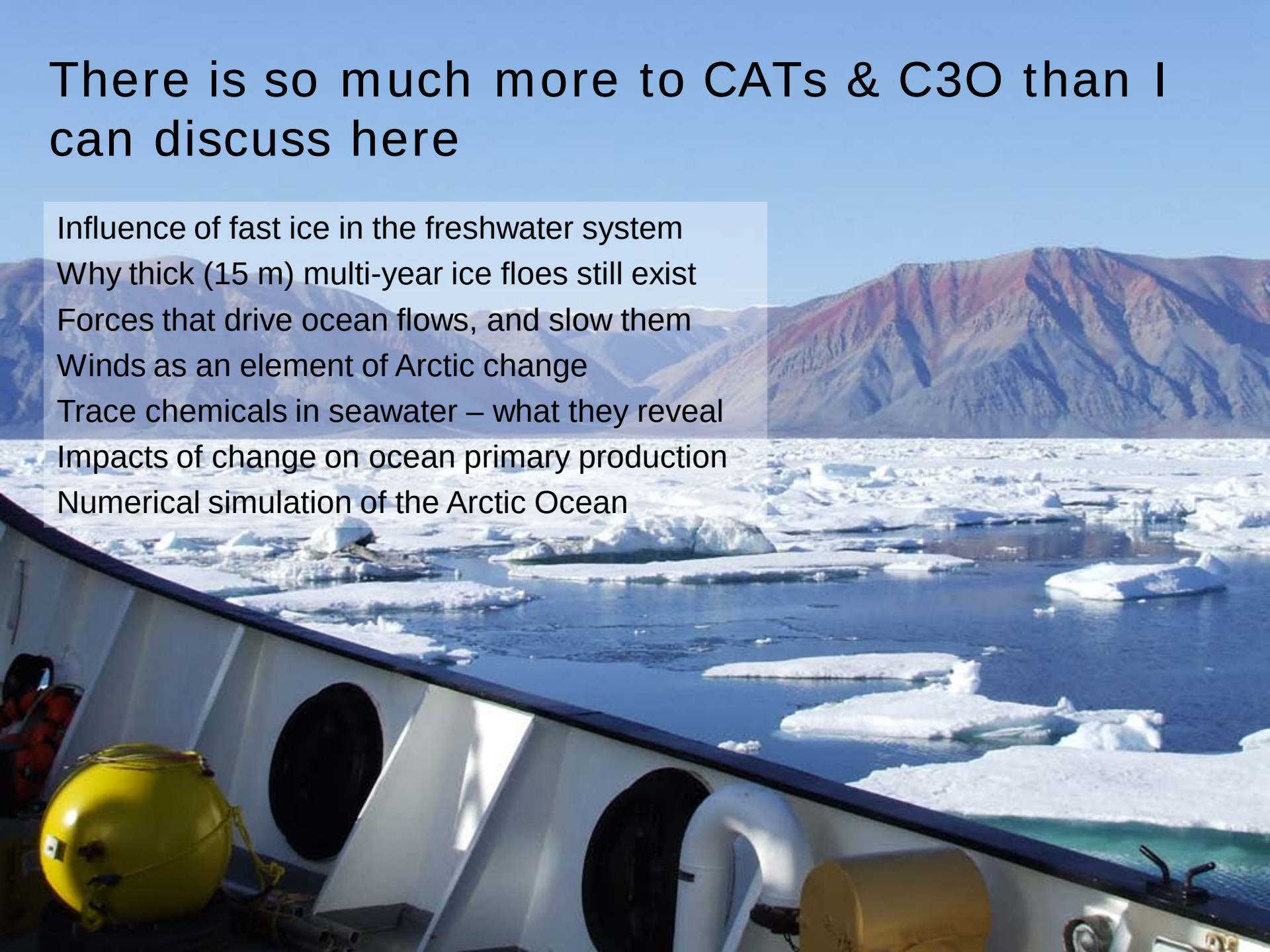
… when ice is moving



… when ice is land-fast

It also means that it is very difficult to detect permanent change with a one-shot IPY

There is so much more to CATs & C3O than I can discuss here



Influence of fast ice in the freshwater system

Why thick (15 m) multi-year ice floes still exist

Forces that drive ocean flows, and slow them

Winds as an element of Arctic change

Trace chemicals in seawater – what they reveal

Impacts of change on ocean primary production

Numerical simulation of the Arctic Ocean

Here is how we are using data & new knowledge from CATs & C3O

“From knowledge to applications”

They have provided baseline data on the northern marine environment – ice, ocean & marine productivity – in advance of offshore development

They have expanded existing knowledge on how the Arctic Ocean has changed – ice, ocean & marine productivity

They are guiding our prescription of the environmental challenges facing offshore development projects – sea ice, storm waves, currents

They are guiding government regulation of Arctic shipping, seismic survey, offshore oil development, crisis response, ballast water discharge

They are providing test cases for the assessment of ocean forecast techniques – sea ice, storm waves, surge, drift of contaminant spills

They are guiding the design of future sustained ocean monitoring

They are providing insights concerning the Arctic Ocean of the future

But … IPY hasn't done it all

The ocean seen by CATs & C3O is the distant background of local ocean management issues faced by communities

We have a regrettable knowledge gap in the coastal ocean

The two IPY years provided only a glimpse of an ever changing ocean

We need sustained monitoring of key ocean properties in the Arctic

Science advances slowly, through decades not years

We need funding for a prolonged effort in Arctic science