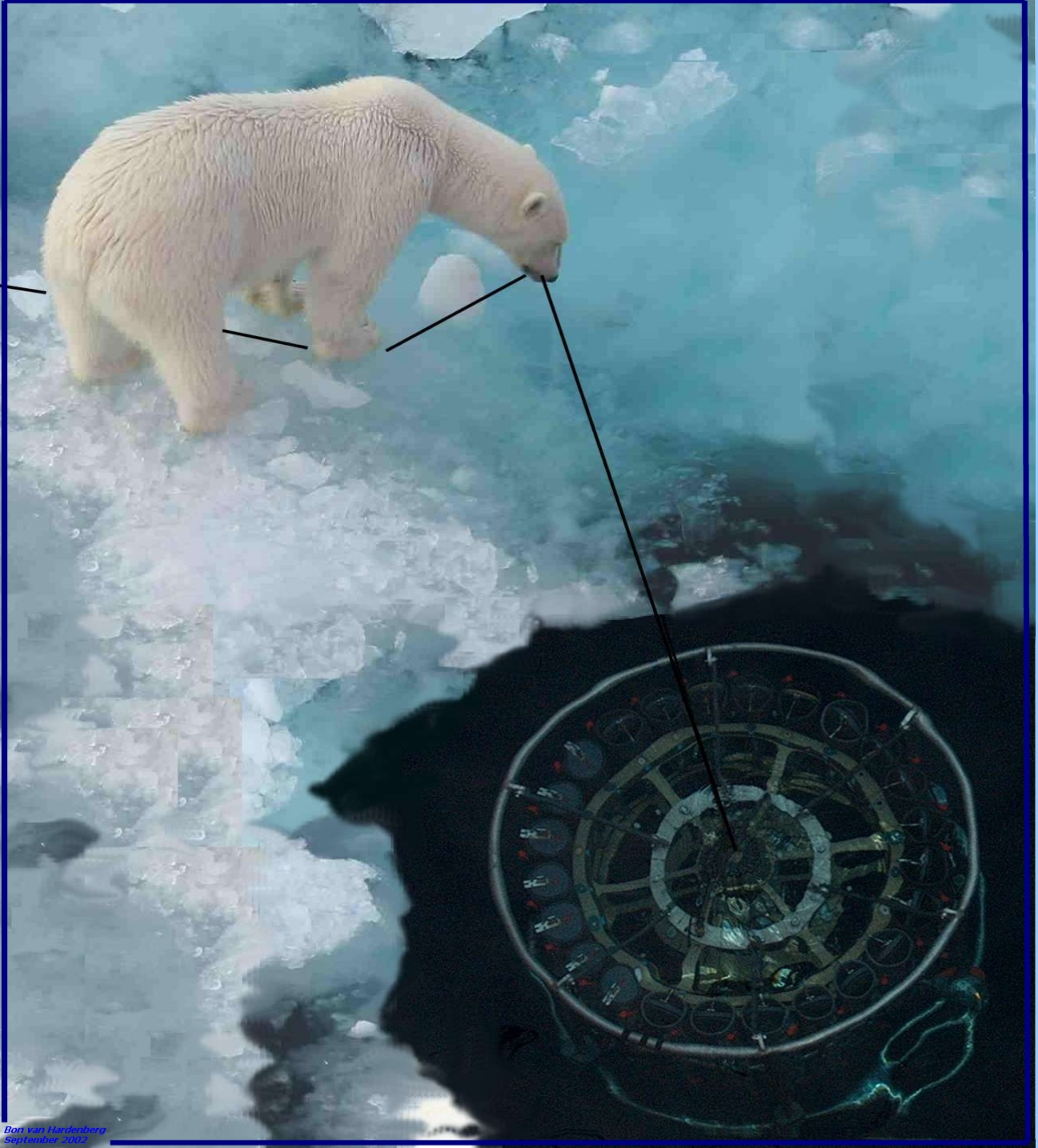
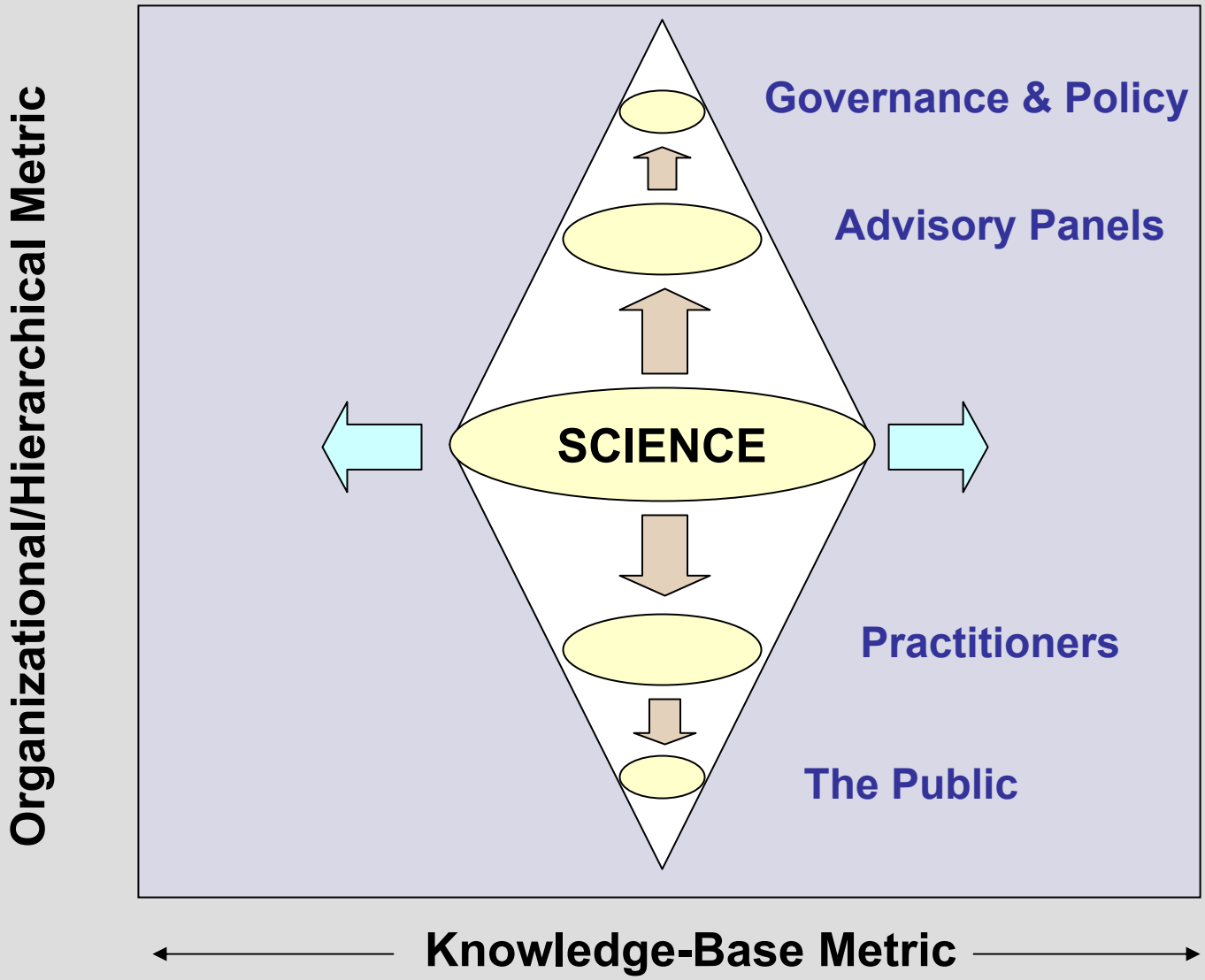
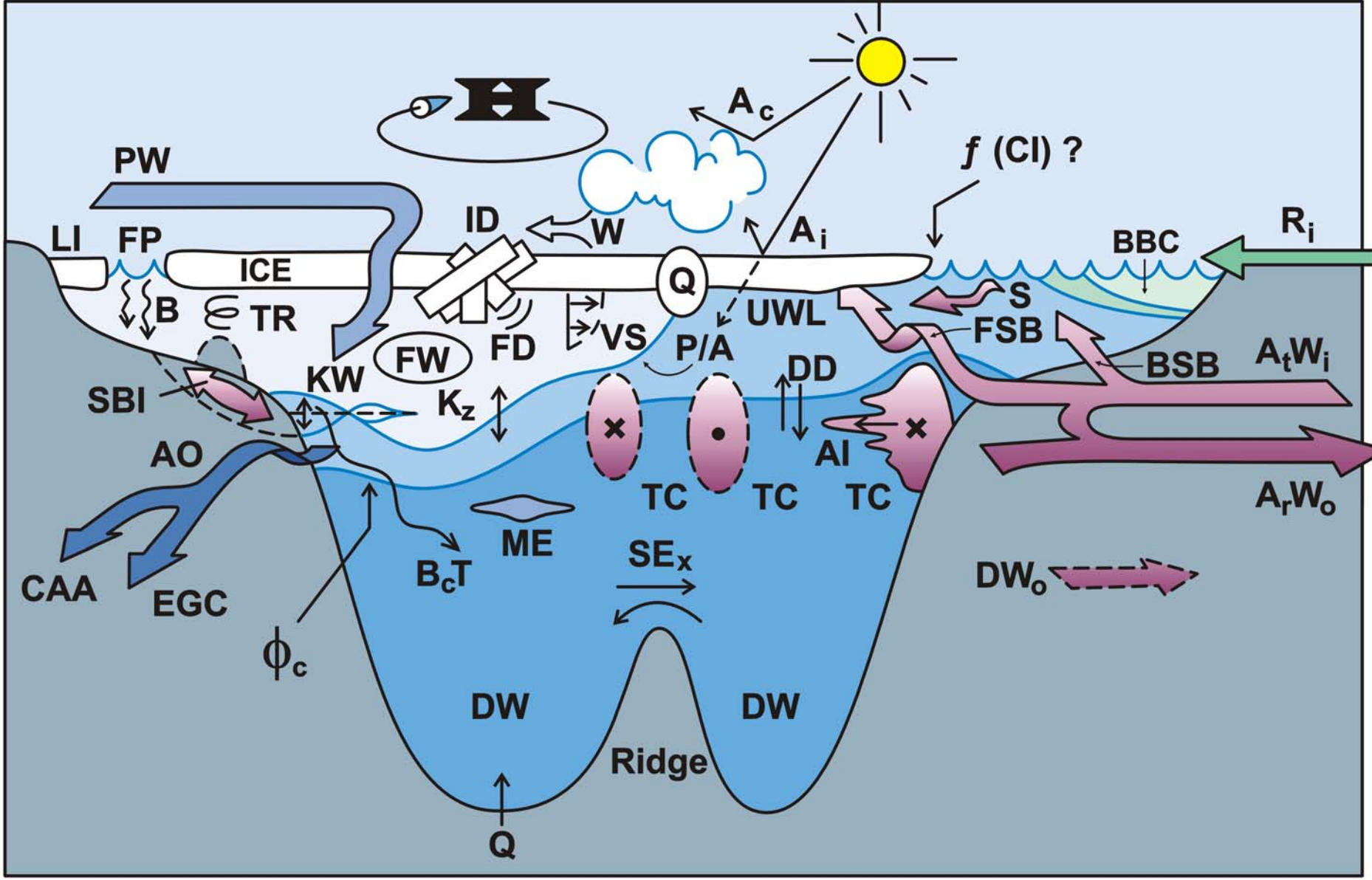


An Ice Tethered Science Program

Why?



The main job of Science is to broaden the knowledge base. But - Knowledge must also move ‘up’ towards advice & governance AND ‘down’ towards good management and the citizenry. These movements require an **action plan** from day one.



SYSTEM	CHALLENGES	BUDGETS	FEEDBACKS
sea ice	structures	sources	thermohaline
glacial ice	pathways	storage	albedo
permafrost	processes	export	frozen GHG

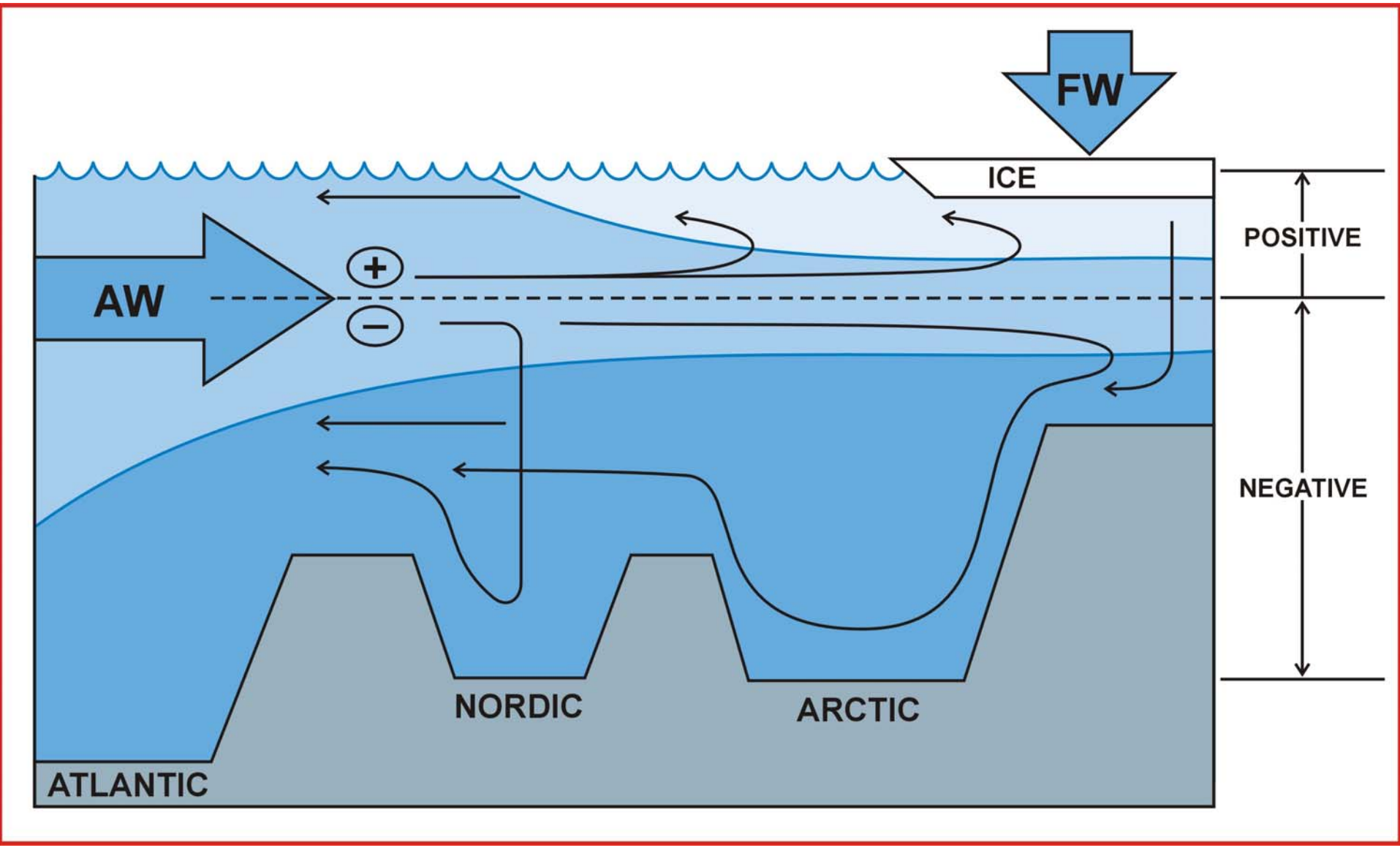
Questions ???

What 'is' the Arctic System & what is it's present state?
How does the Arctic Ocean 'work' as a double estuary?
Does the FW budget 'really' impact the THC & climate?
Can we detect 'real' change & know it's significance?
Should we 'worry' about habitat, contaminants,health?
Should we worry about way-of-life?

Three Good Things to Do

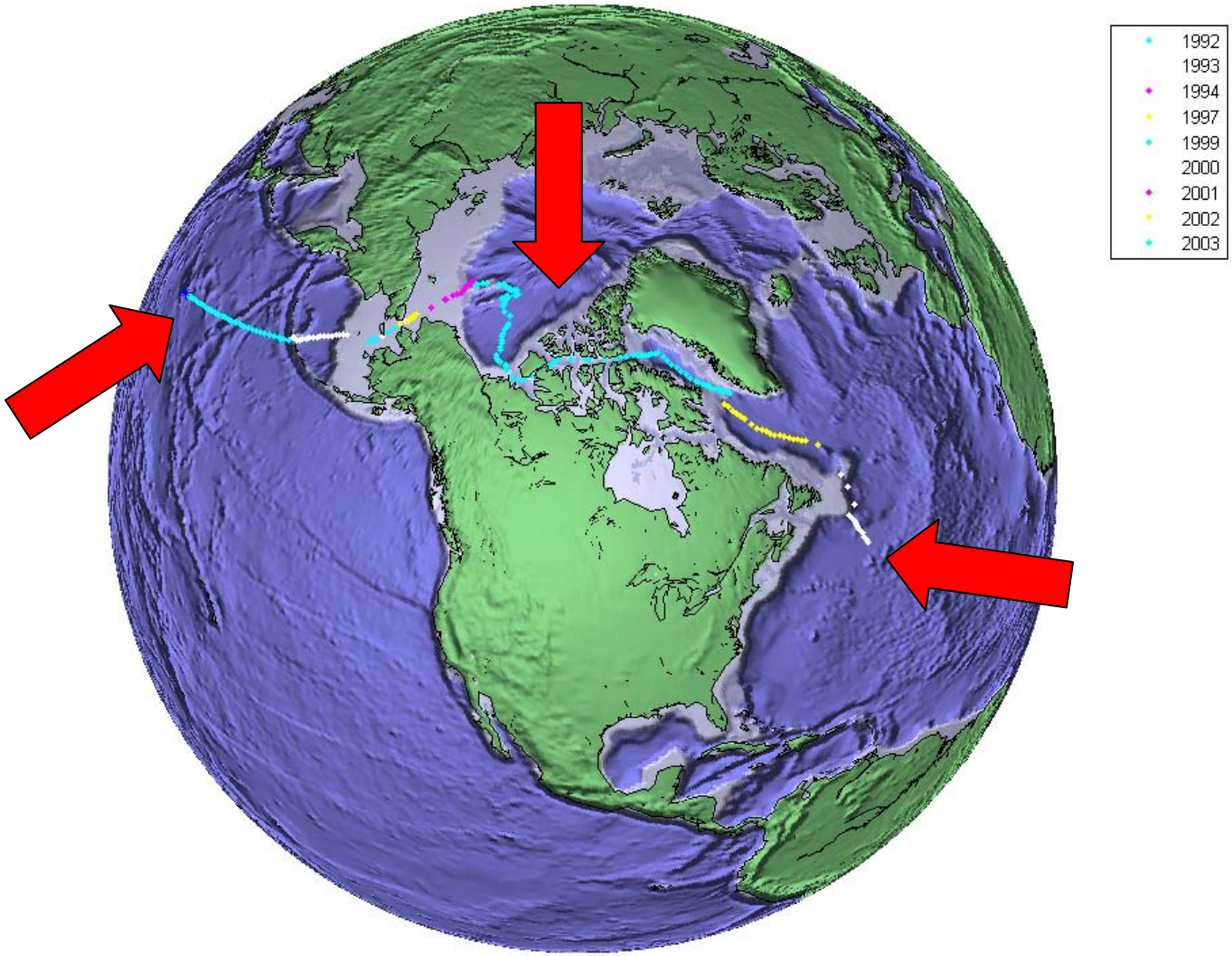
1. Provide an observational basis to develop/verify models
2. Provide a basic framework for palaeo- interpretations
3. Identify ‘tipping’ points prior to their (economic) surprise

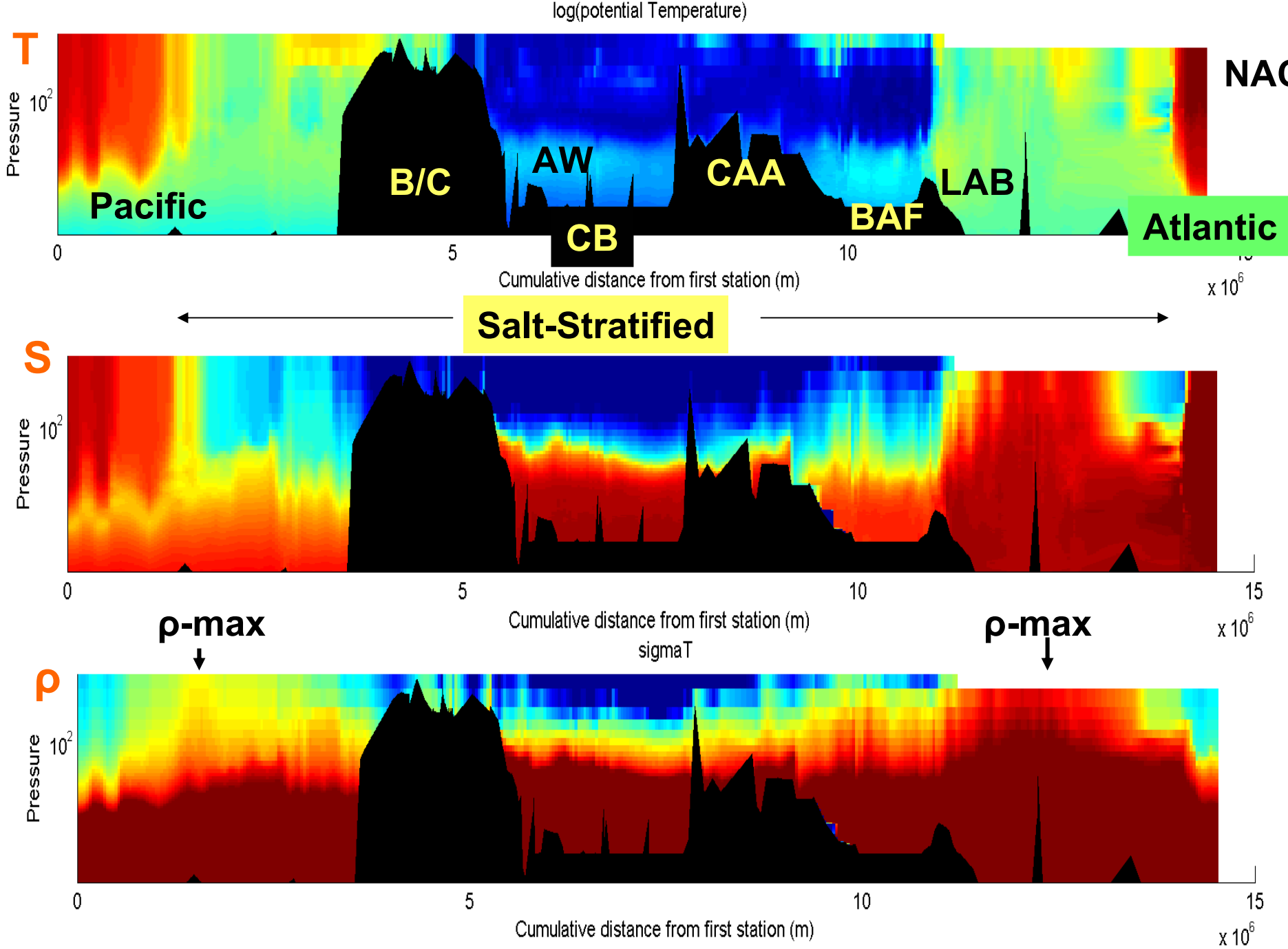
Question: How does the Arctic 'work' as a double (+ -) estuary

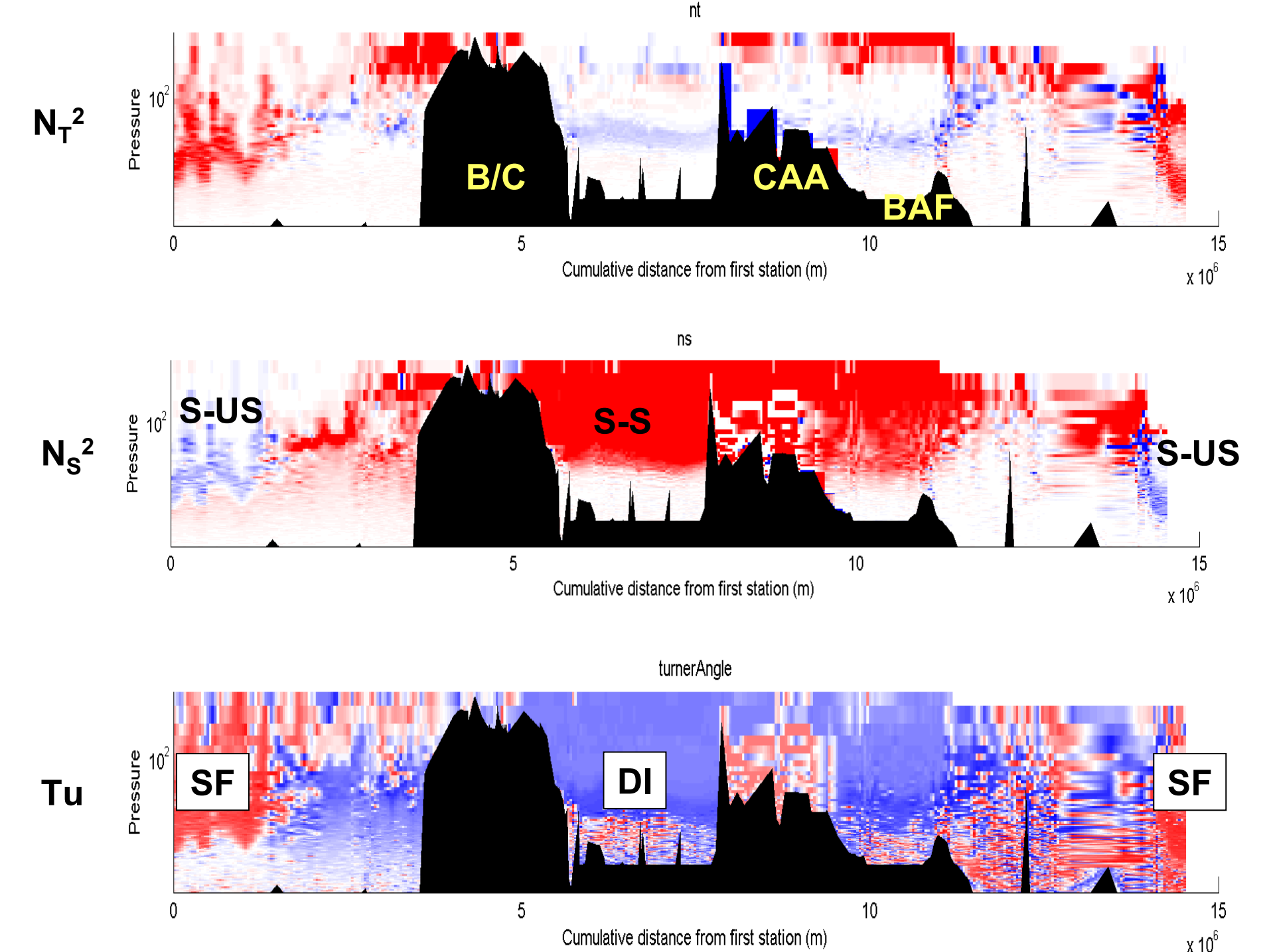


The Arctic Ocean Is a “Beta” Ocean

Around Canada




log(potential Temperature)
T
Pressure
10^2
Pacific
B/C
AW
CB
CAA
BAF
LAB
NAC
Atlantic
0
5
10
Cumulative distance from first station (m)
x 10^6
Salt-Stratified
S
Pressure
10^2
0
5
10
15
Cumulative distance from first station (m)
x 10^6
ρ-max
ρ-max
sigmaT
ρ
Pressure
10^2
0
5
10
15
Cumulative distance from first station (m)
x 10^6


N_T^2
nt
Pressure
10^{-2}
B/C
CAA
BAF
0
5
10
15
Cumulative distance from first station (m)
x 10^6
N_S^2
ns
Pressure
10^{-2}
S-US
S-S
S-US
0
5
10
15
Cumulative distance from first station (m)
x 10^6
Tu
turnerAngle
Pressure
10^{-2}
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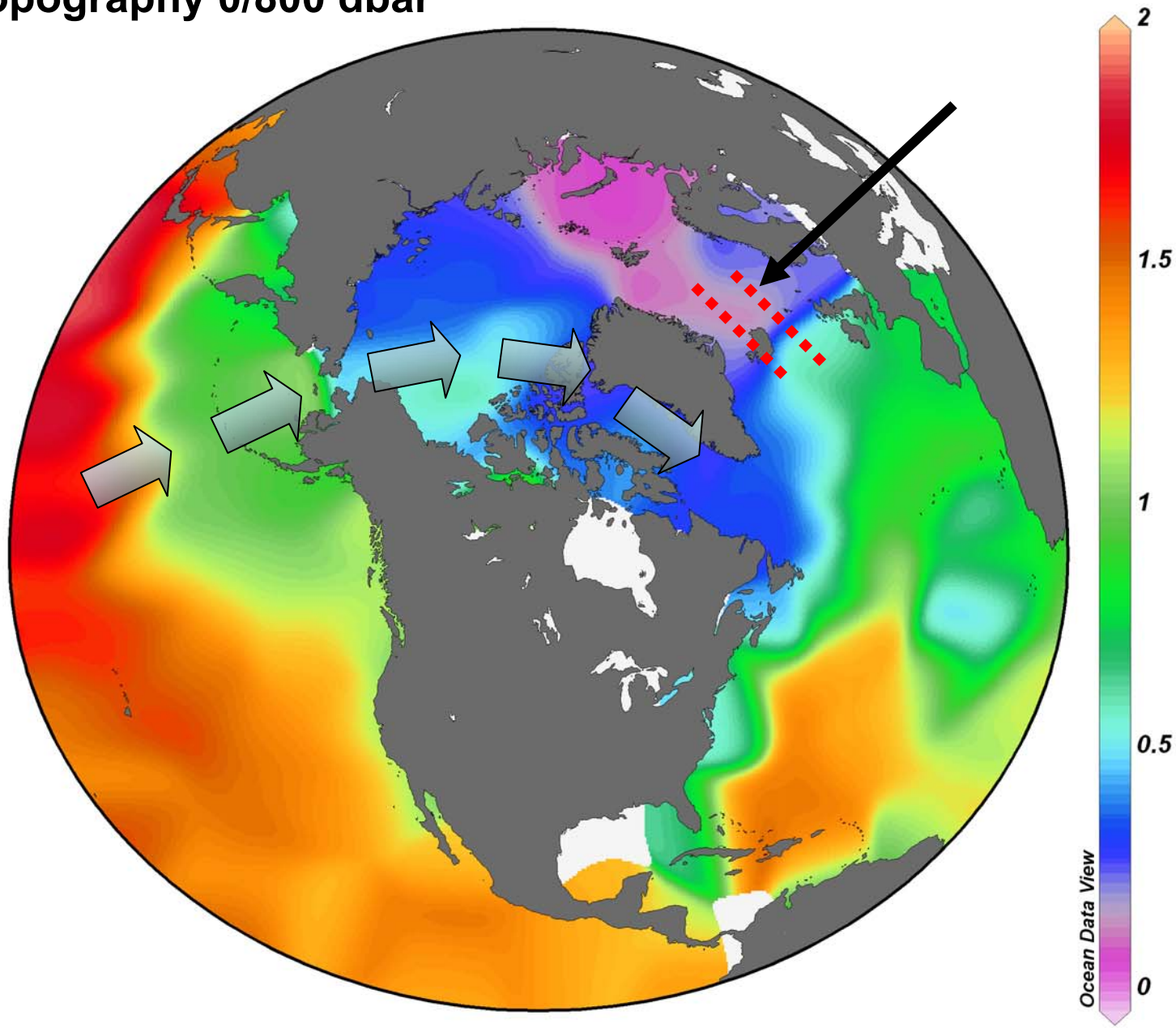
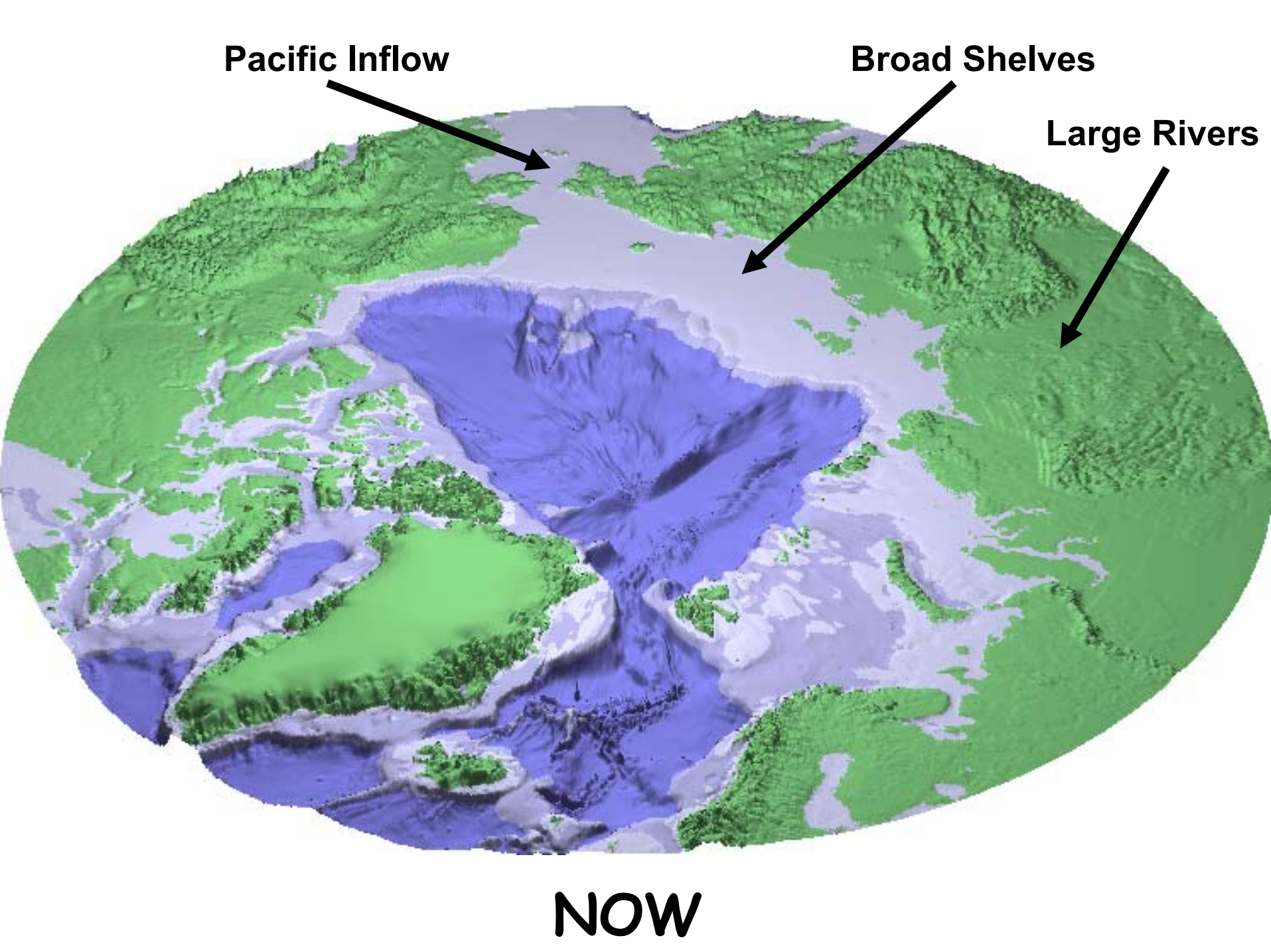
SF
0
5
10
15
Cumulative distance from first station (m)
x 10^6

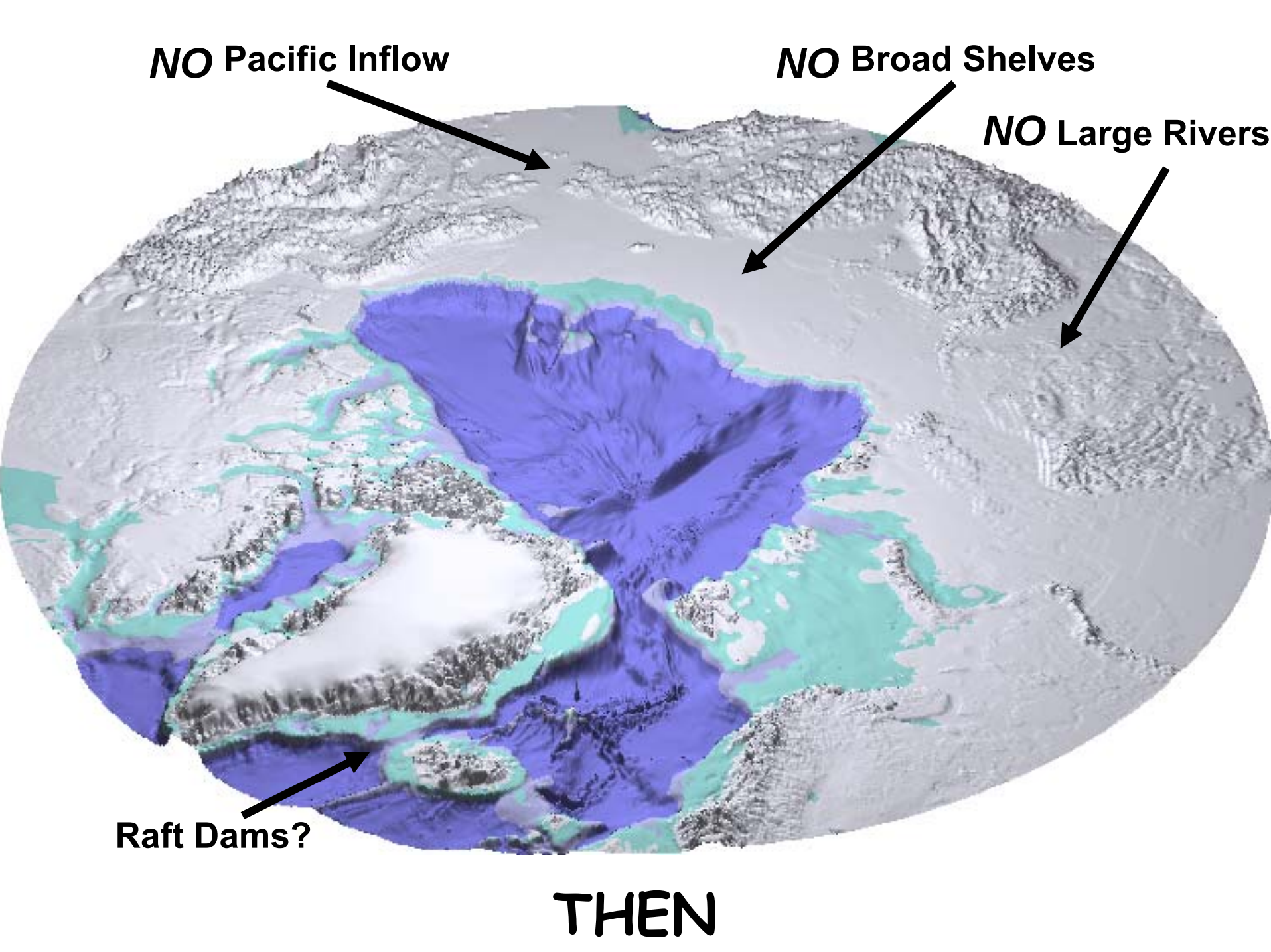
Dynamic Topography 0/800 dbar



Remember: Fresh water is ‘sticky’

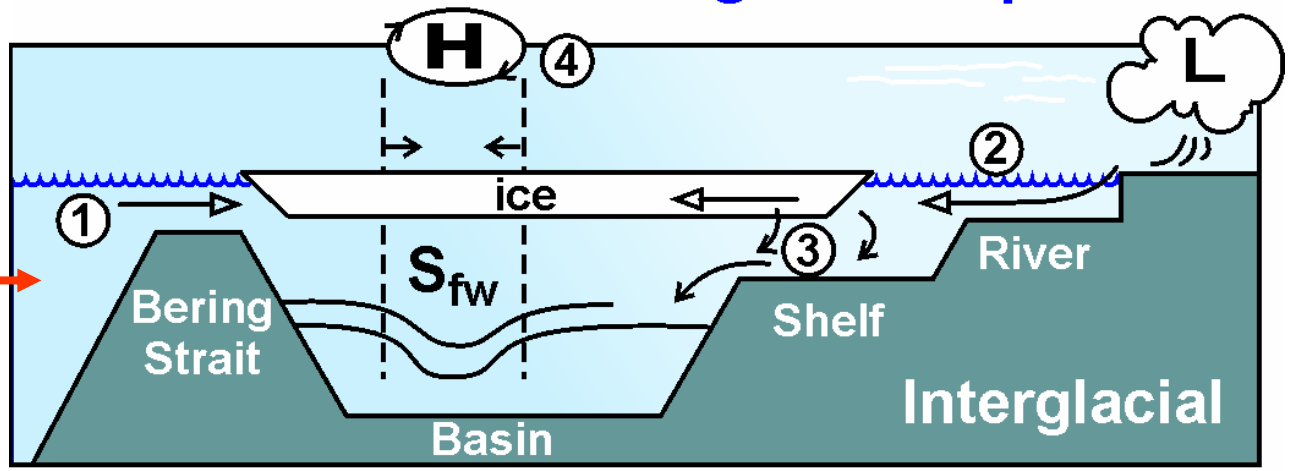
A Palaeo-framework?


Pacific Inflow
Broad Shelves
Large Rivers
NOW


NO Pacific Inflow
NO Broad Shelves
NO Large Rivers
Raft Dams?
THEN

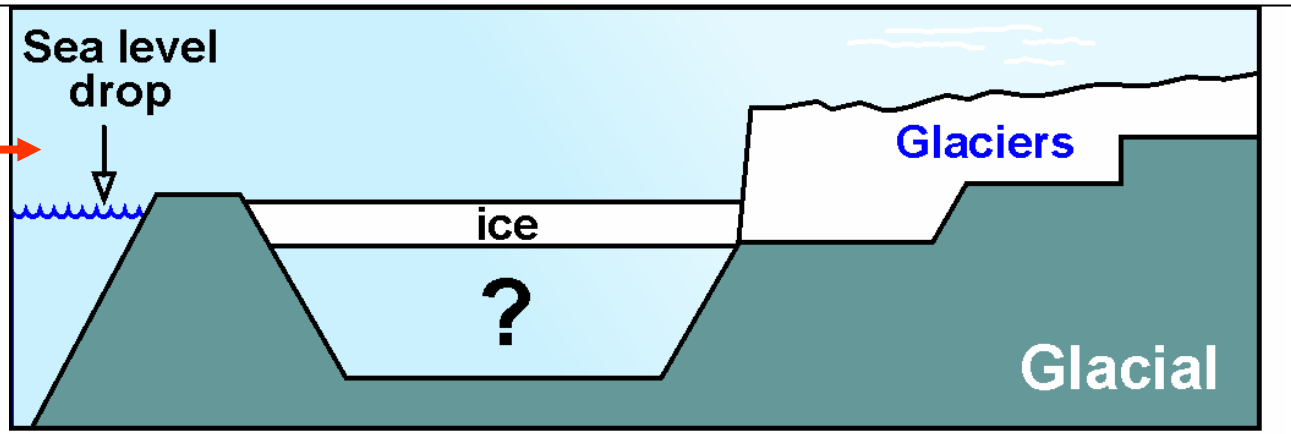
What Makes Today's Arctic Ocean Special *viz* Freshwater Storage and Export?

Now

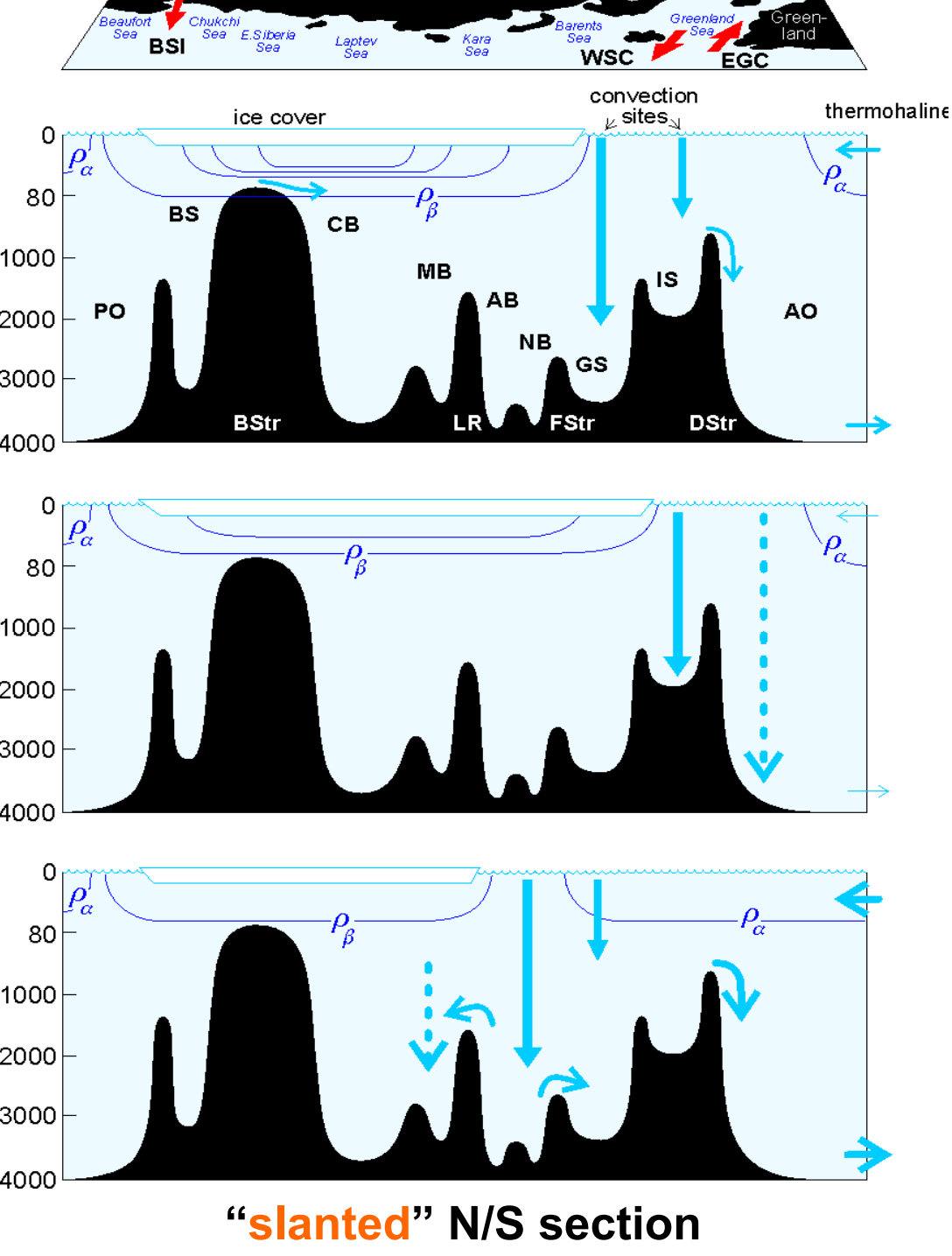


1. Pacific Inflow via Bering Strait
2. River Inflow (cyclone pathways)
3. Ice/brine distillation on broad (!) shelves
4. Gyre storage under the Beaufort HIGH

Then



1. No Bering Strait Inflow
2. Little (No?) River Inflow
3. No shelves for ice/brine distillation
4. Beaufort High (?) - Mobile Pack (?)



"slanted" N/S section

Global (THC) Ocean Response to Altered Freshwater Export from the Arctic Ocean

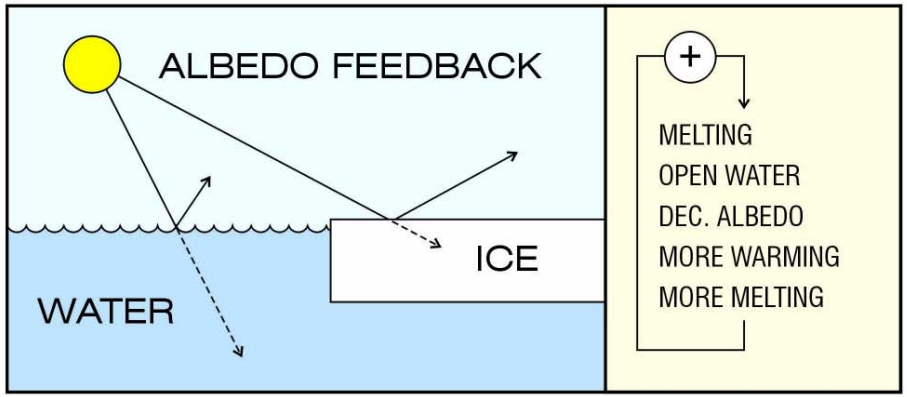
a) Current FW Condition

b) Increased FW Exports

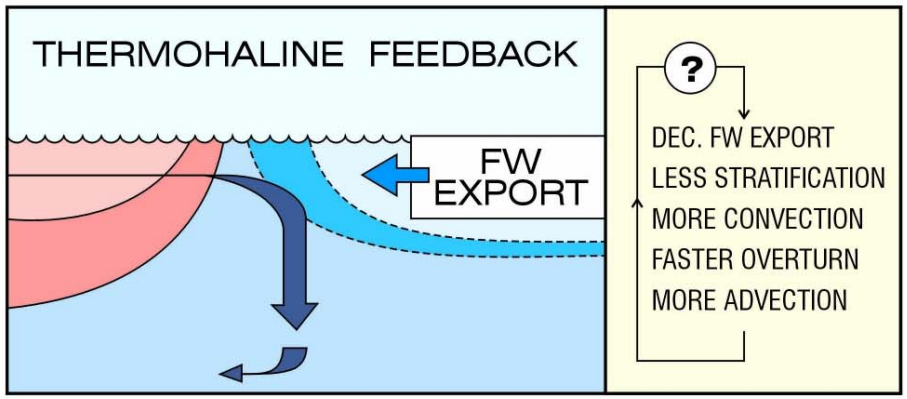
c) Decreased FW Exports

Troublesome Feedbacks

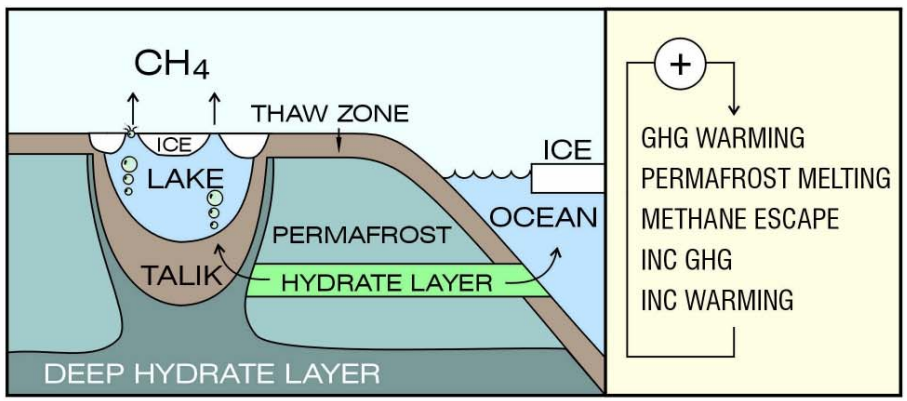
ARCTIC CLIMATE FEEDBACKS



But, More that 1-D



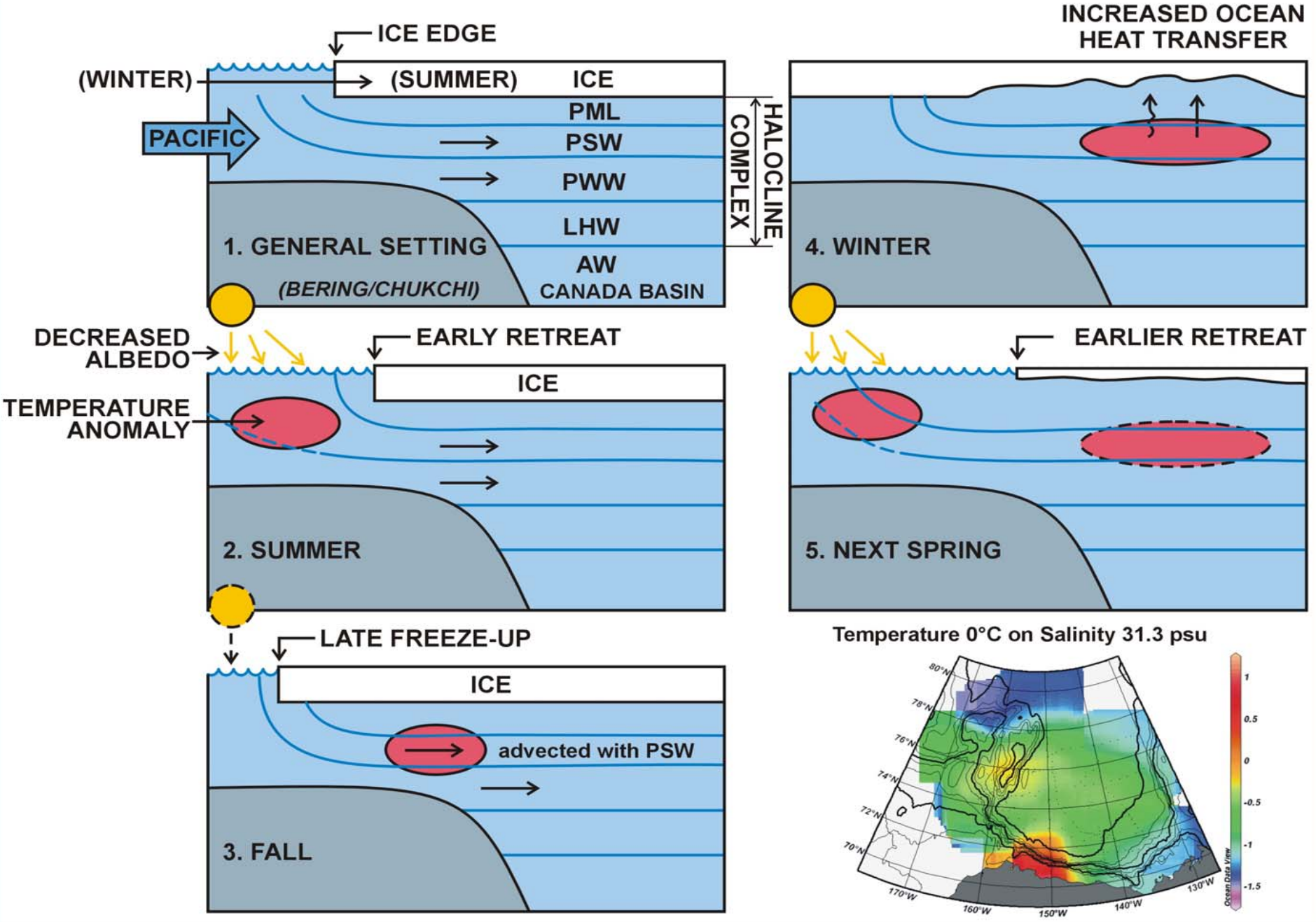
Our Only Hope

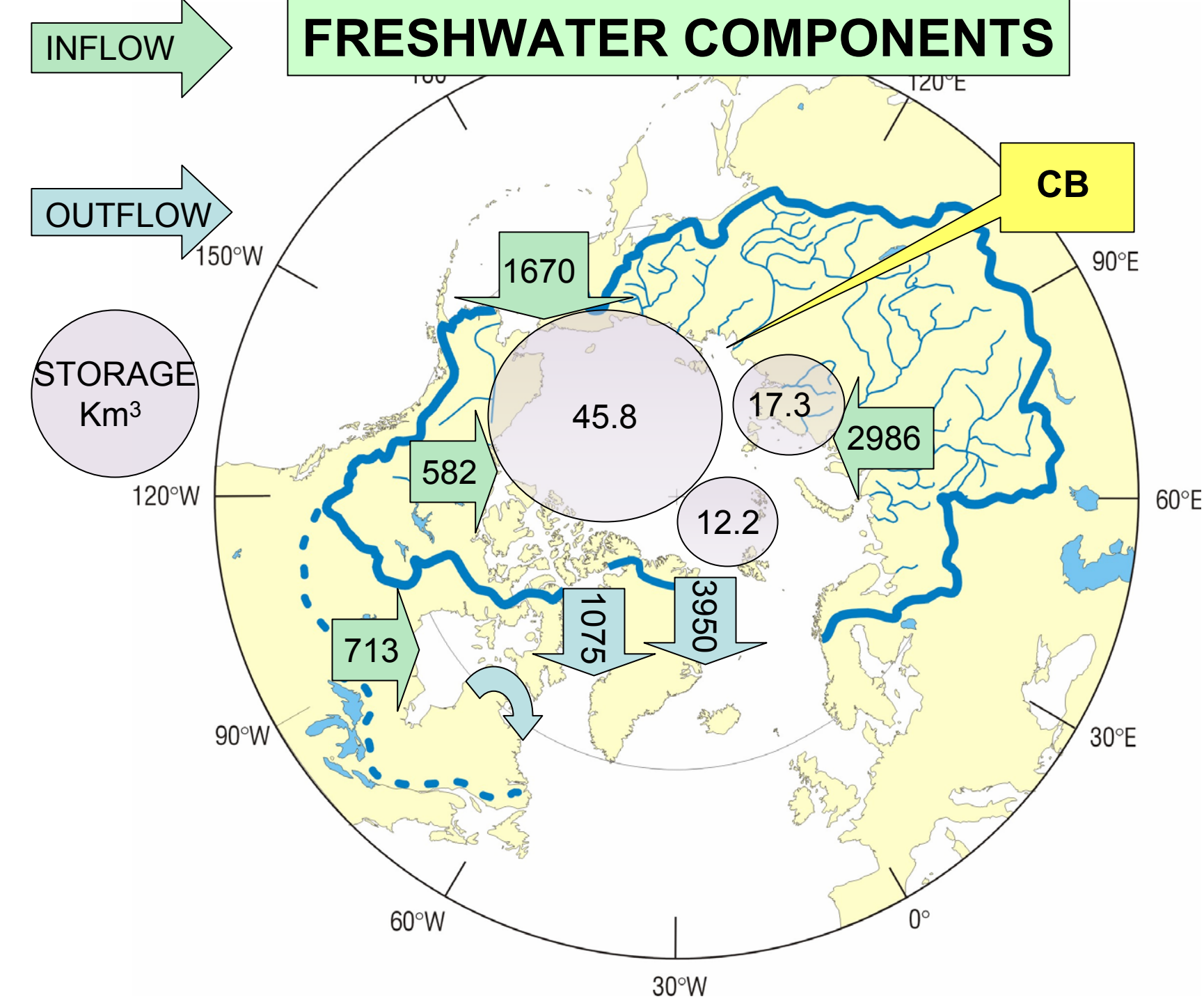


Dr. Strangelove!

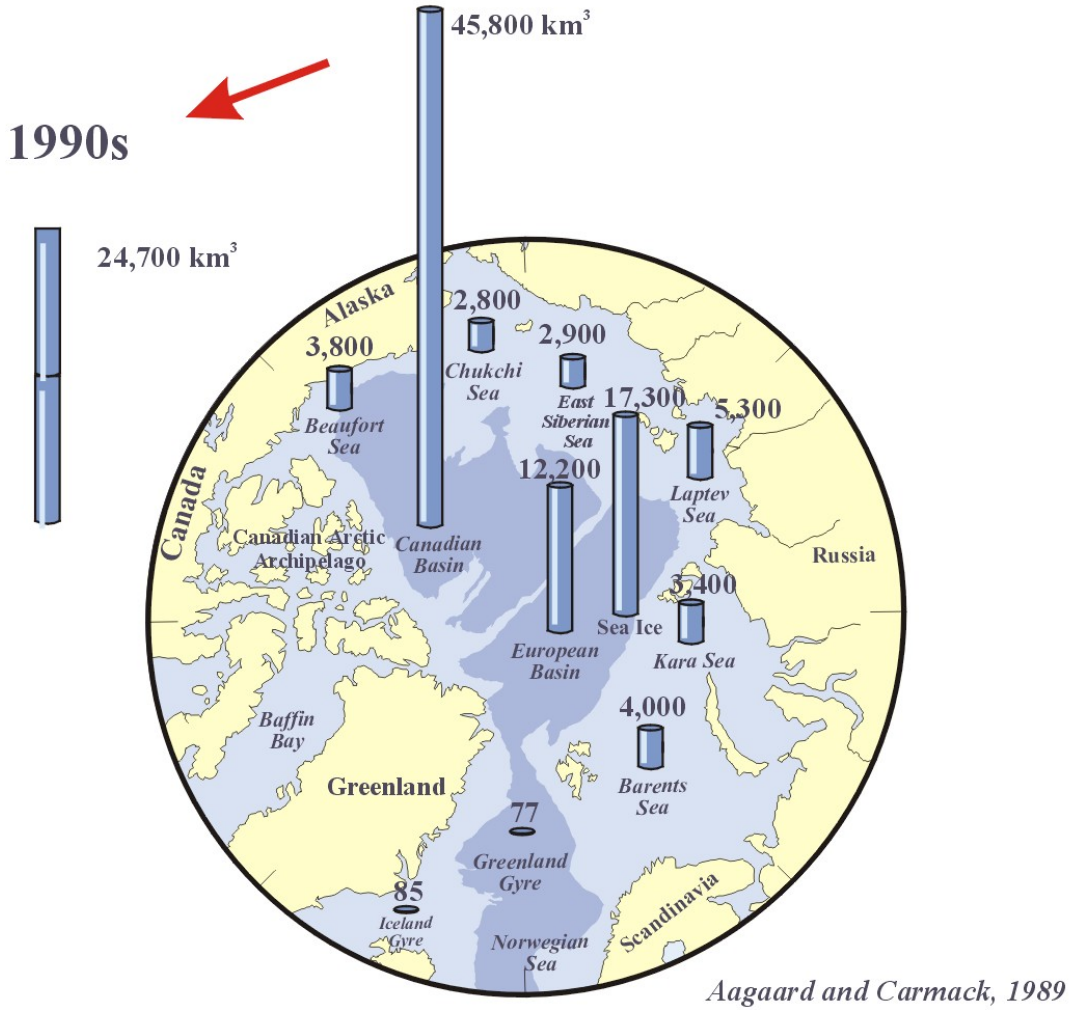
CARMACK

ALBEDO FEEDBACK: A SPACE / TIME LAG




INFLOW
FRESHWATER COMPONENTS
OUTFLOW
STORAGE
Km3
CB
1670
2986
582
713
1075
3950
45.8
17.3
12.2
120°E
150°W
90°E
120°W
60°E
90°W
30°E
60°W
0°
30°W

Distribution of fresh water storage in the Arctic Ocean.



Aagaard and Carmack, 1989

The Reservoir can Change very fast!

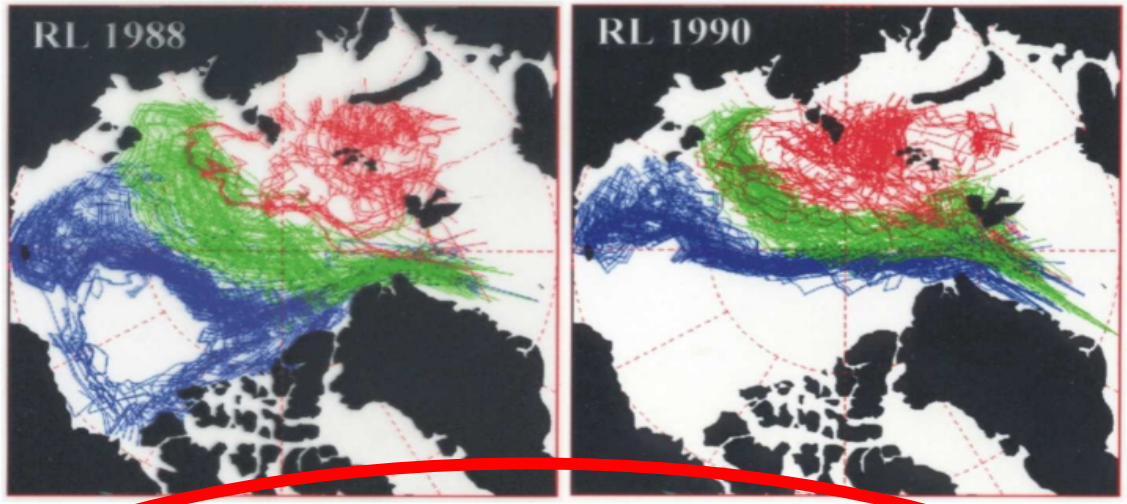
2 WAYS?

During the 1990s:

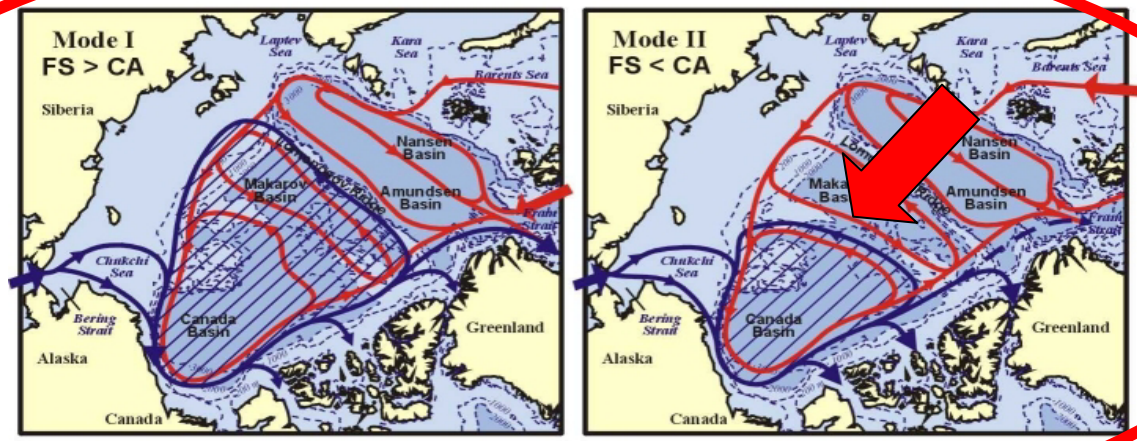
- Shift of the A/P front
  loss of Pacific water from the Makarov Basin
- shallowing of Pacific water in the Canada Basin

McLaughlin, pers. comm.

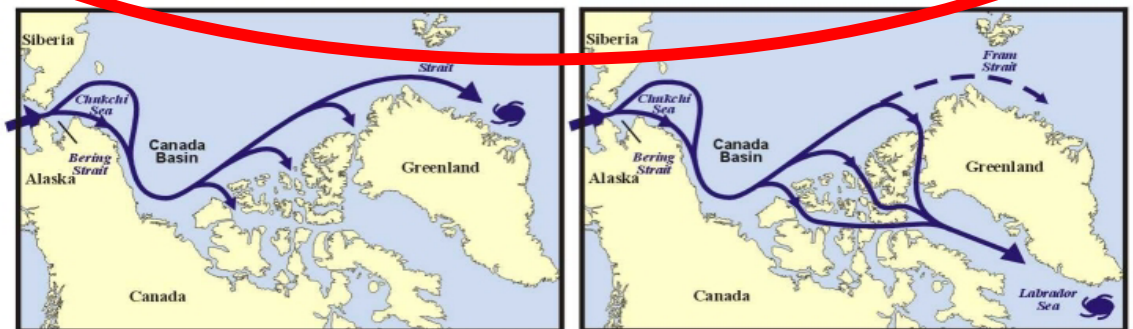
ATMOSPHERE: THE ARCTIC OSCILLATION



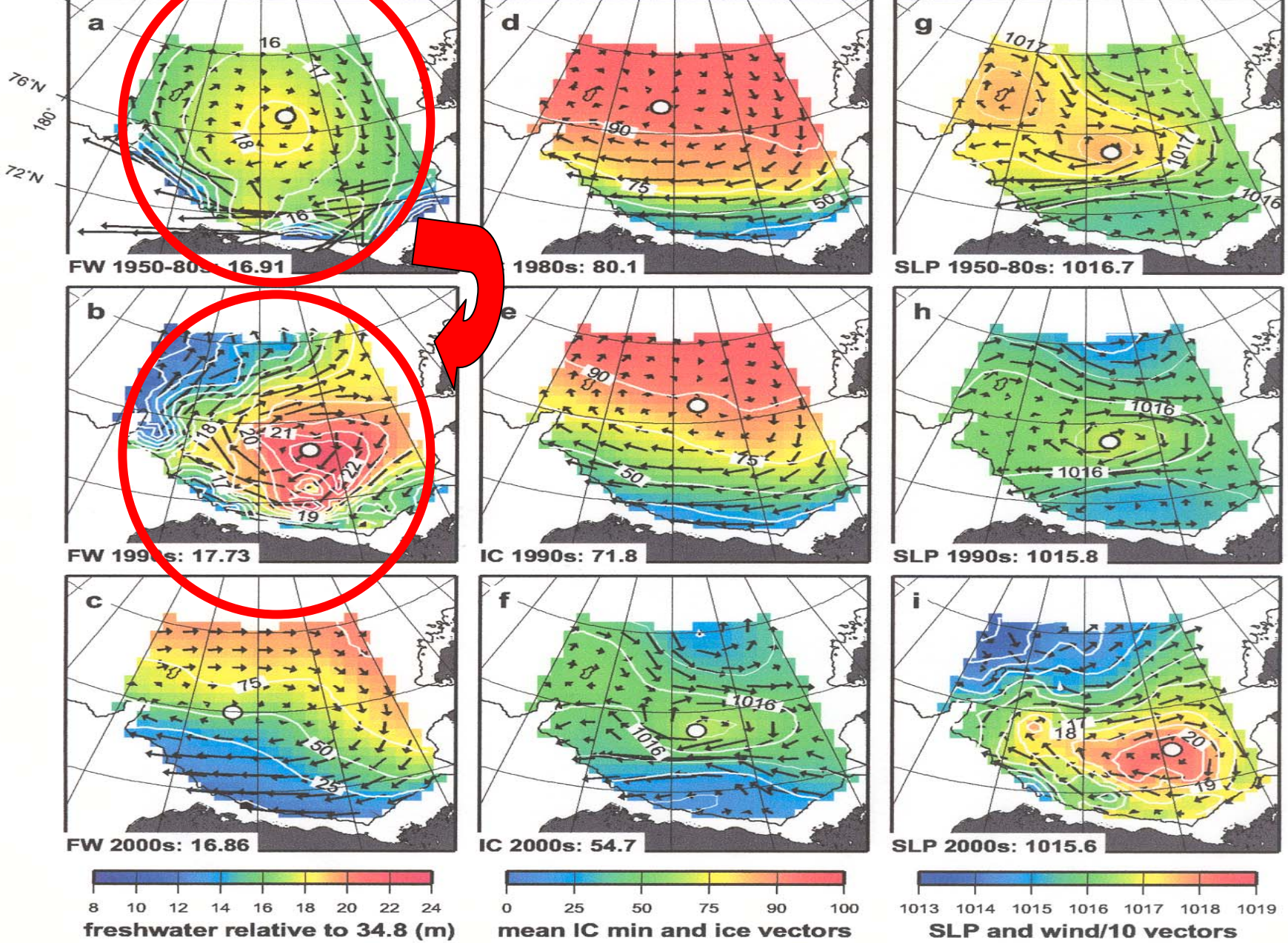
SEA ICE: RETENTION VS EXPORT



CIRCULATION: PACIFIC VS ATLANTIC MODE



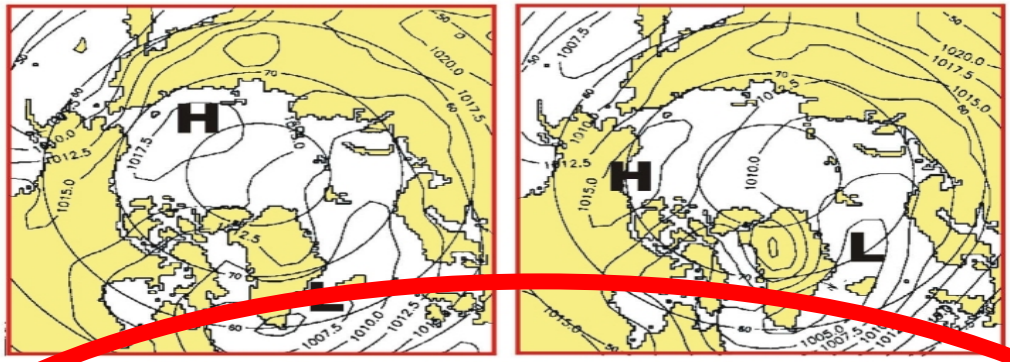
1st Way



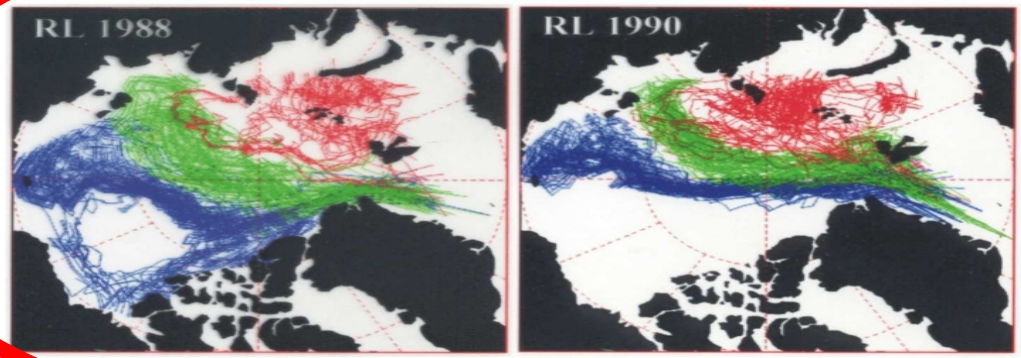
2nd Way…

Proshutinsky, pers. comm. 2004

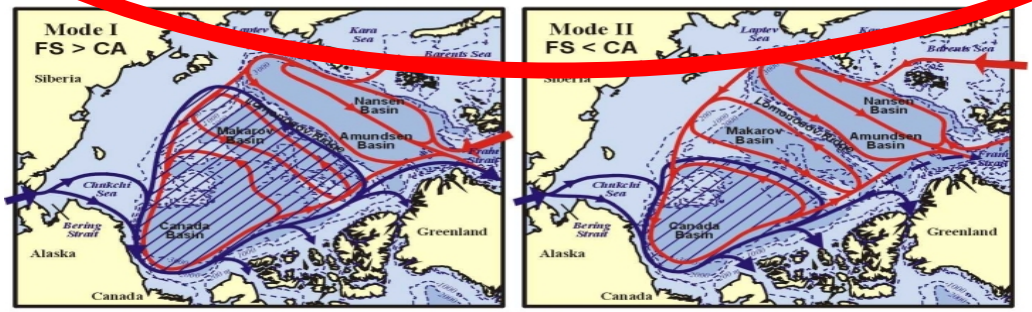
INTERDECADAL CHANGE



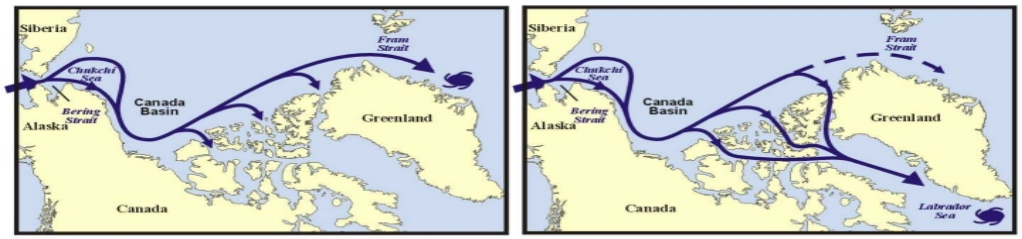
ATMOSPHERE: THE ARCTIC OSCILLATION



SEA ICE: RETENTION VS EXPORT

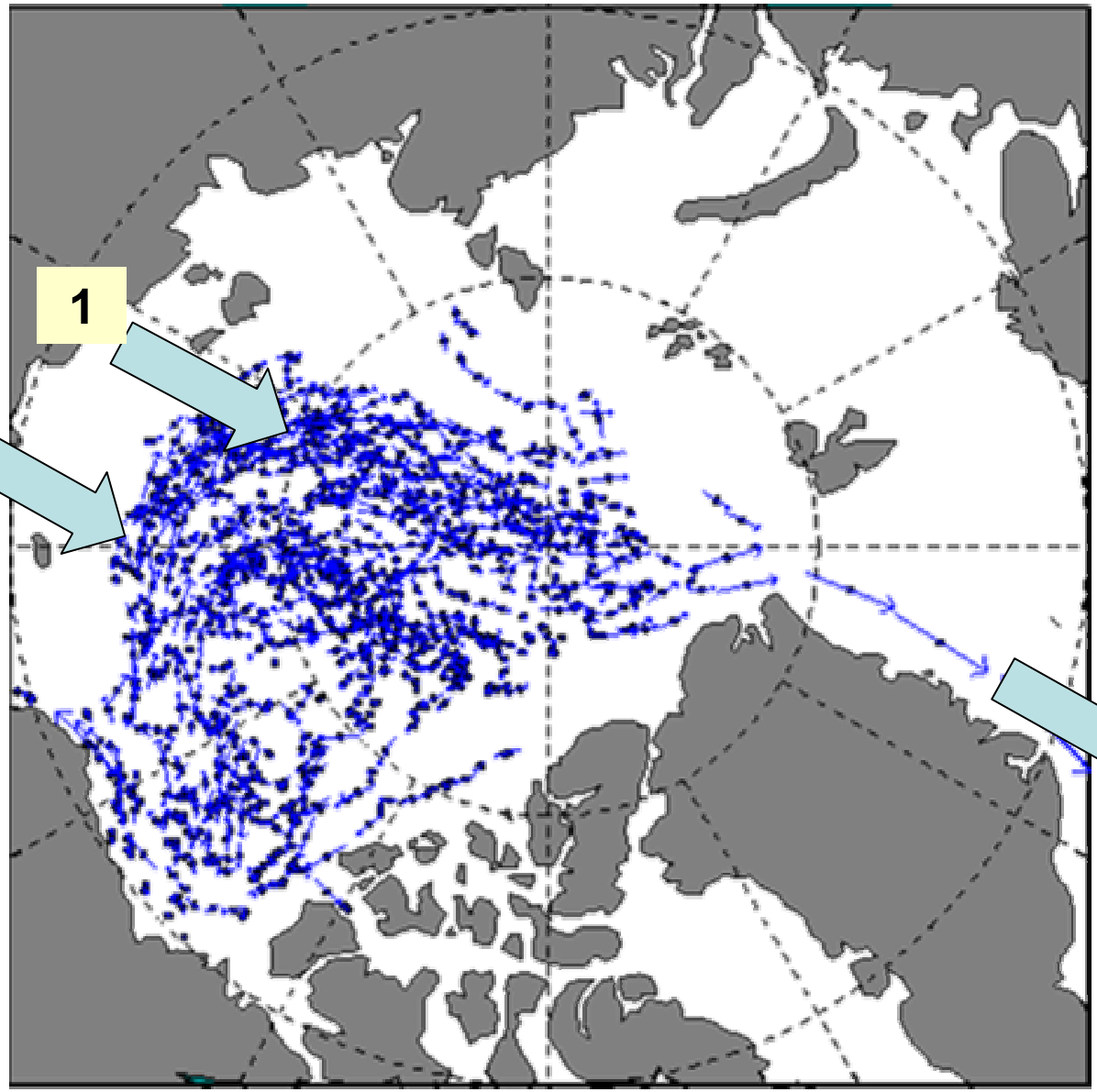


CIRCULATION: PACIFIC VS ATLANTIC MODE



FRESHWATER EXPORT: GREENLAND VS LABRADOR SEA

Russian Station (1950-1991)

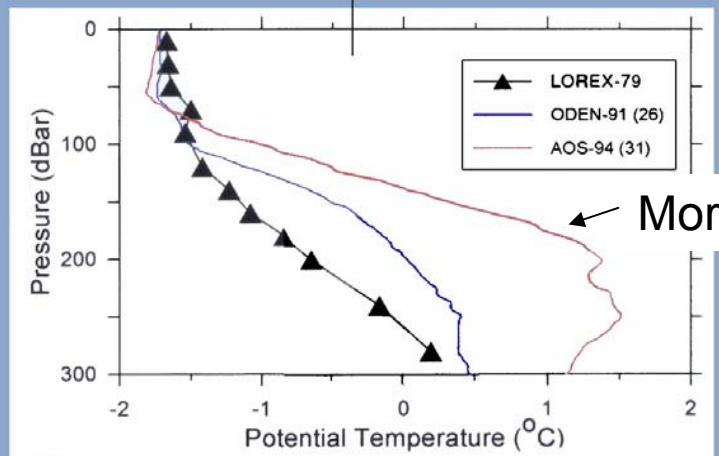


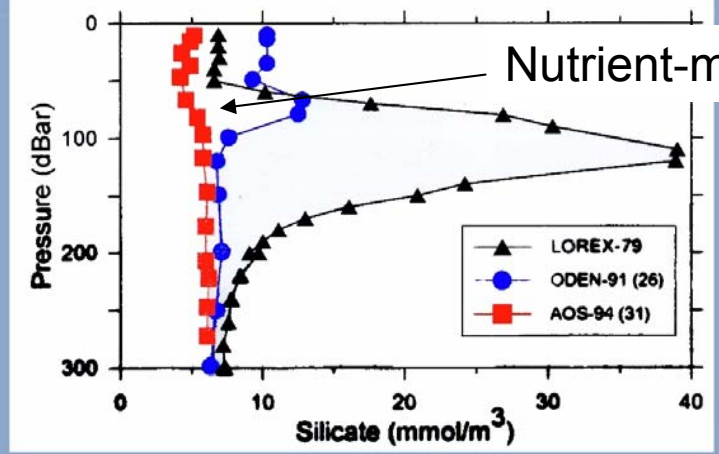
K. Shimada
Pers. Comm.

WHY IS THIS?

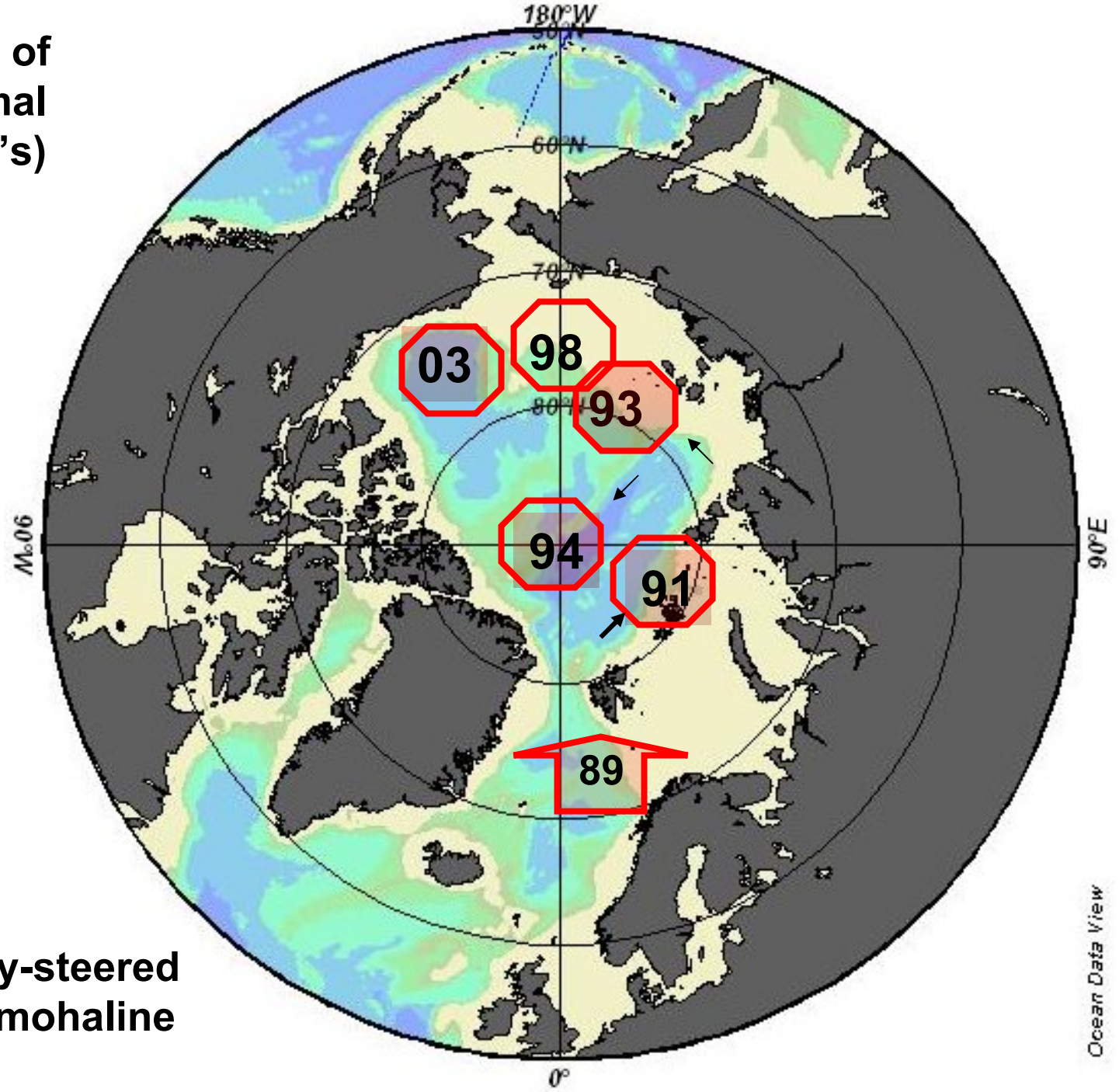
NOW…

Atlantic Water

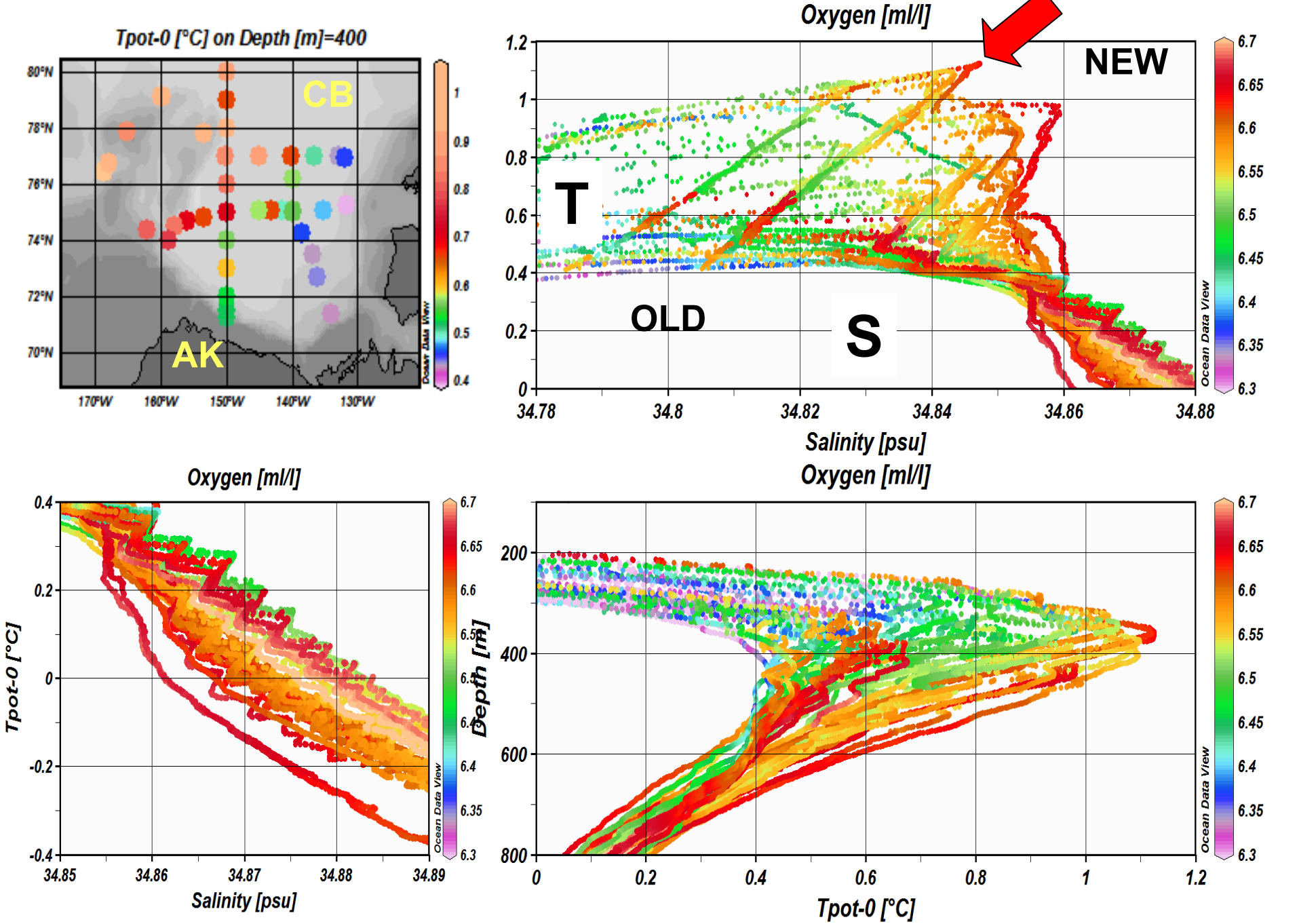




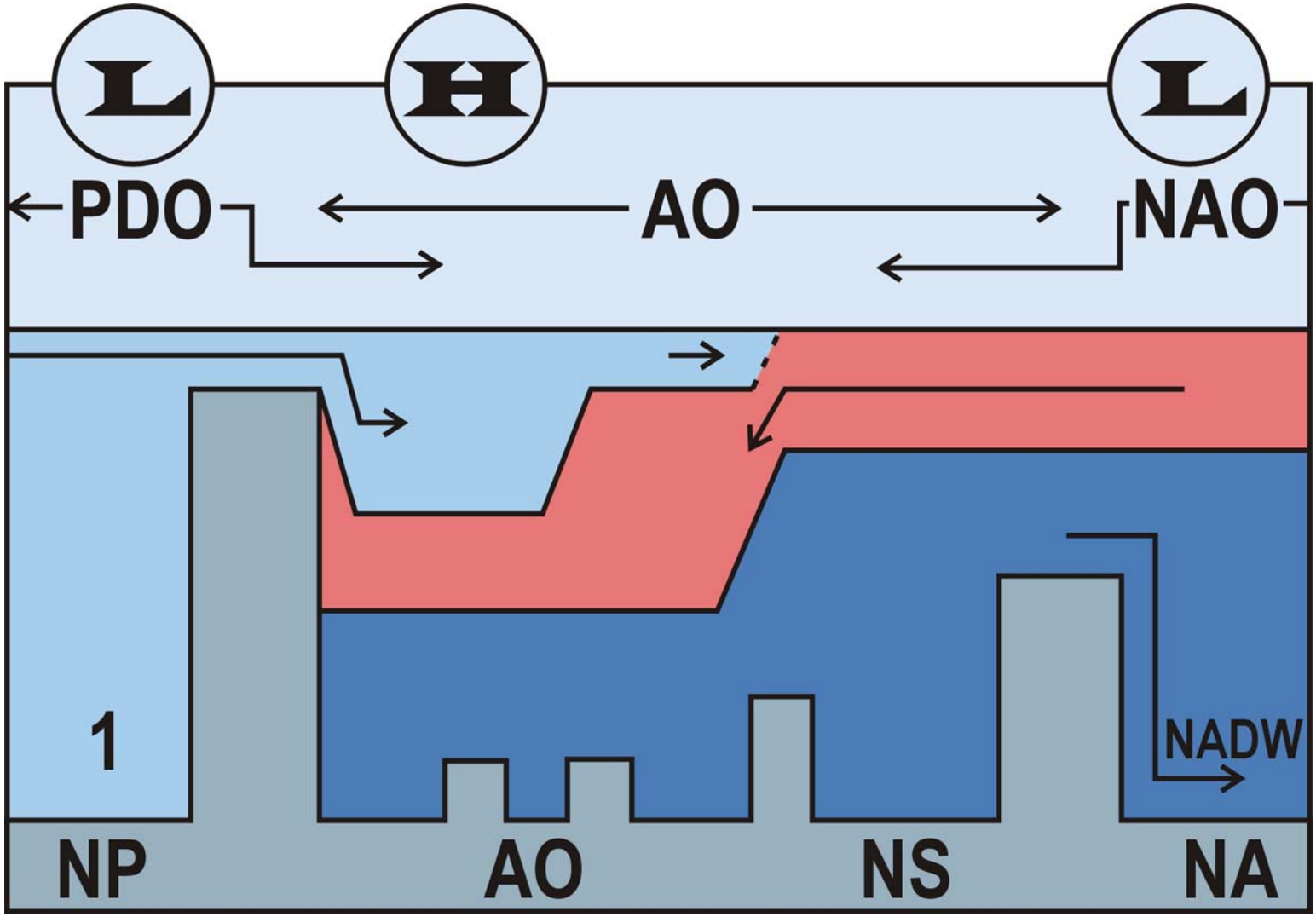
Penetration of The Great Thermal Anomaly - (1990's)

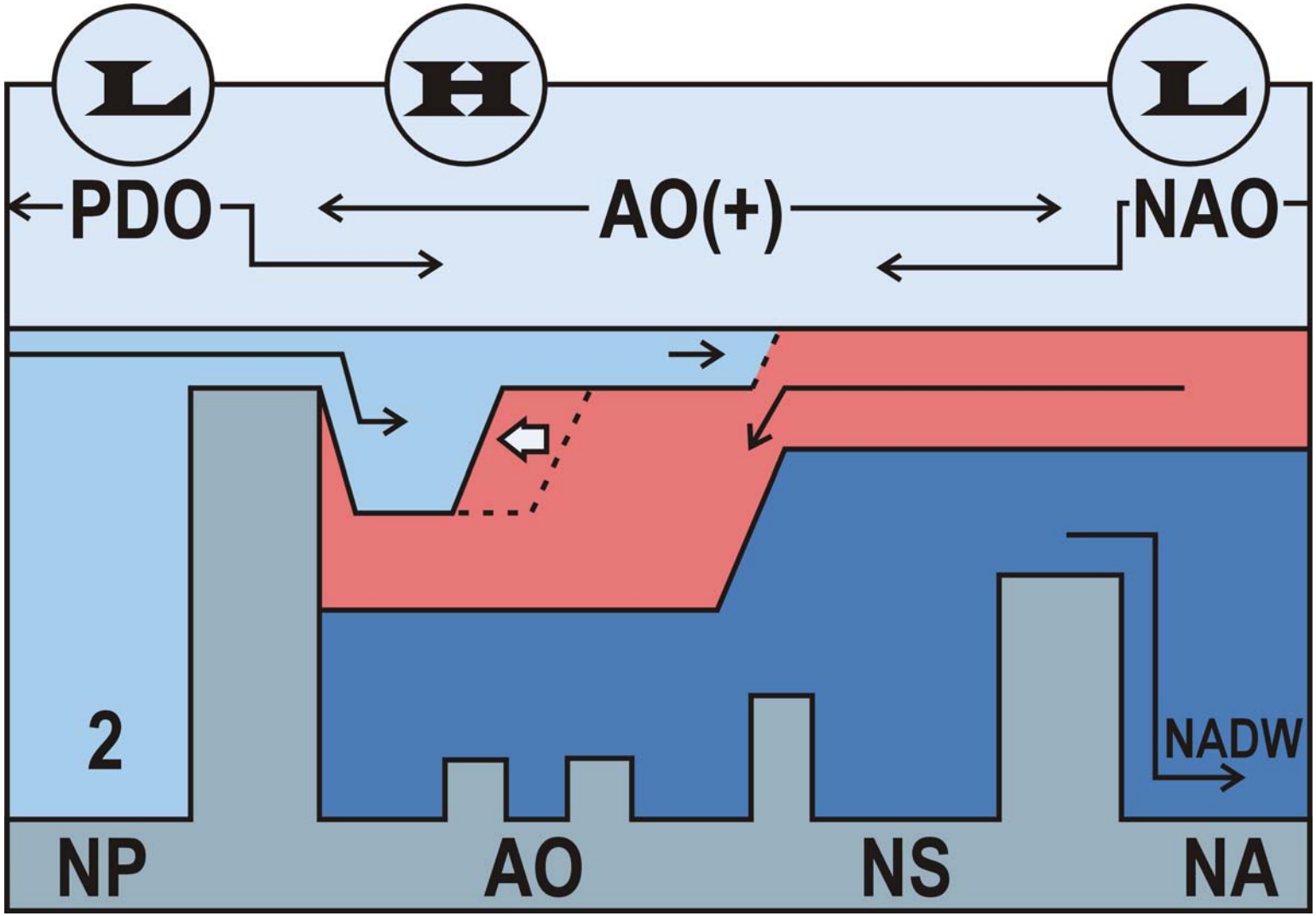


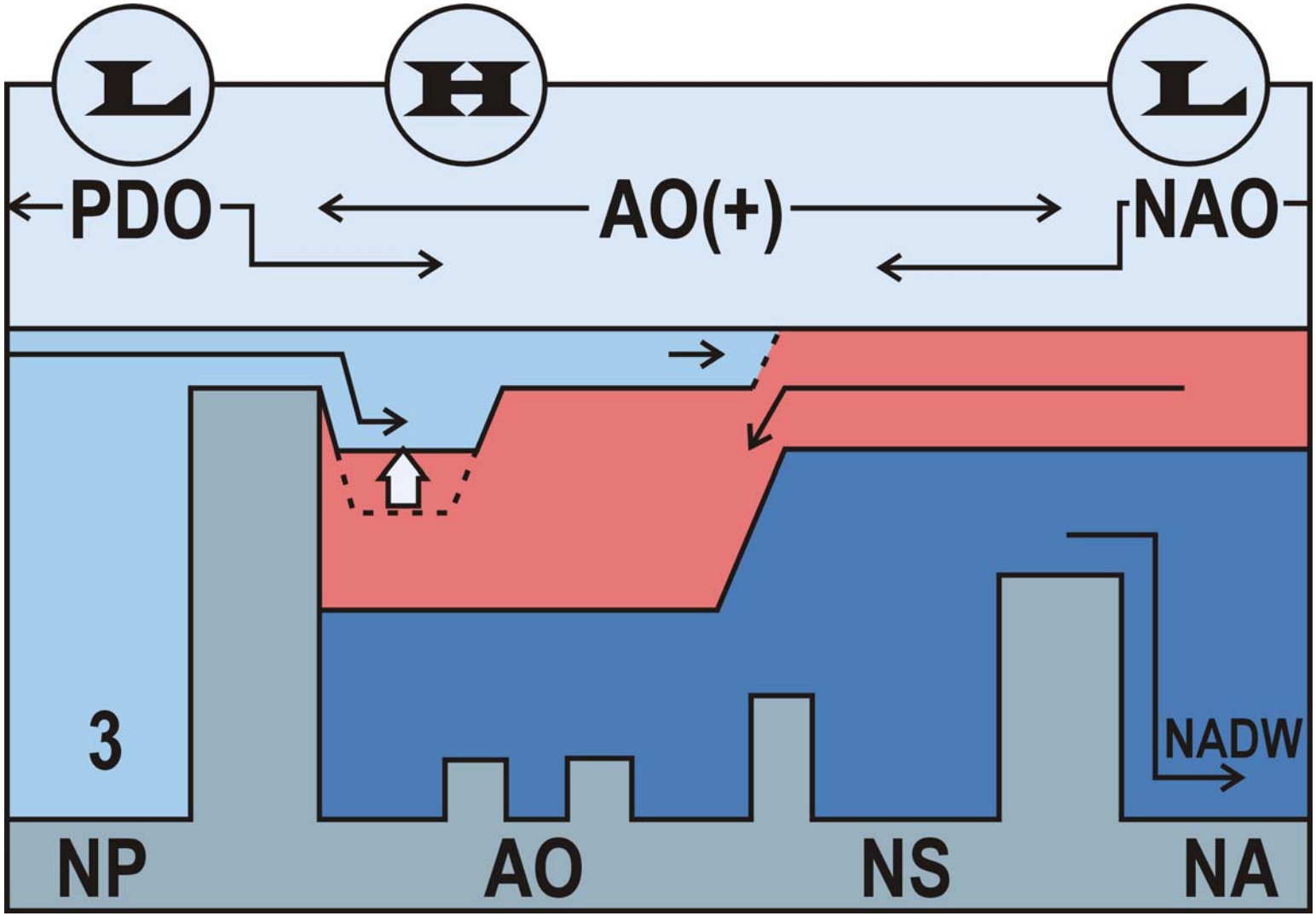
By topographically-steered Currents and thermohaline Intrusions

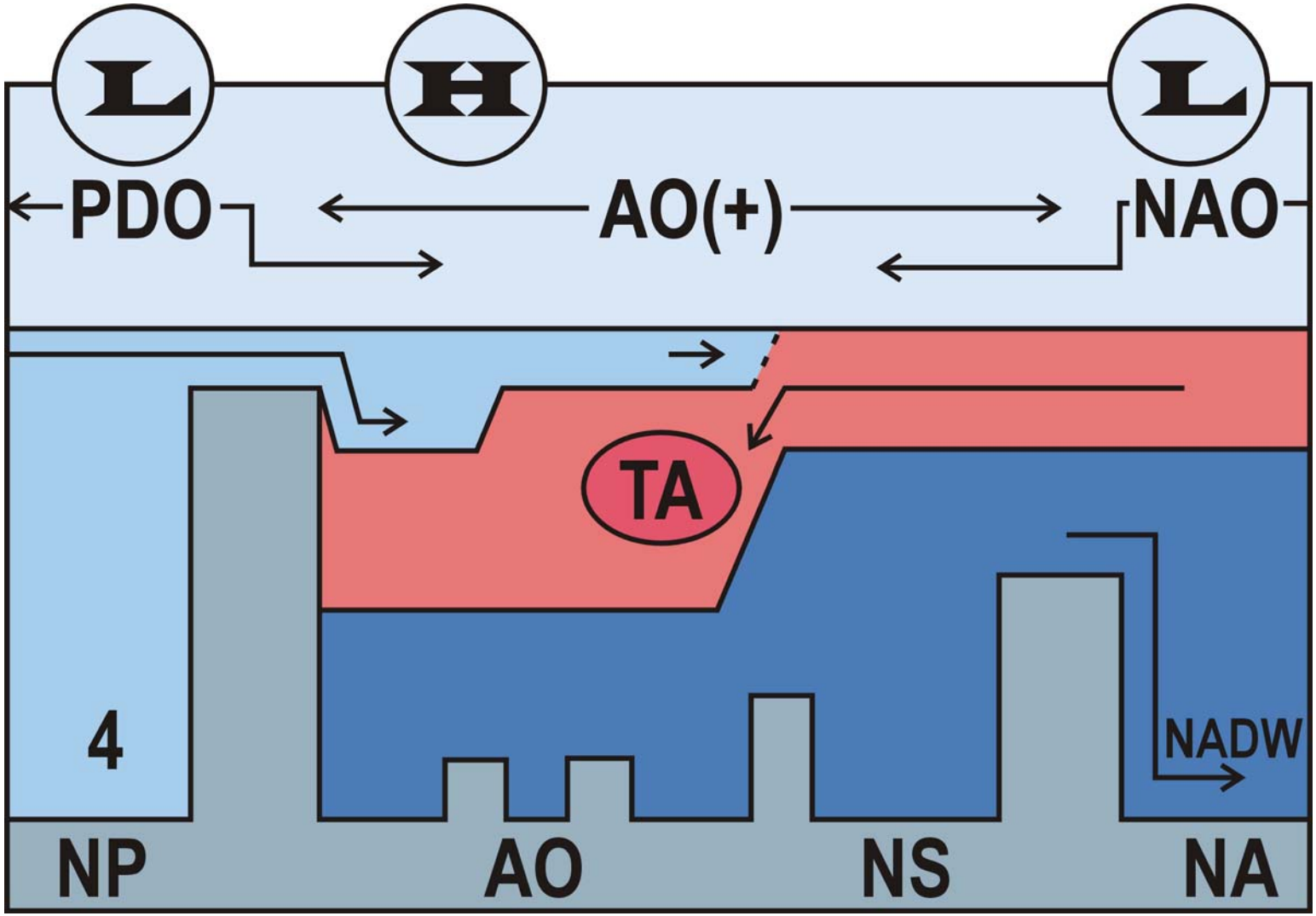

Tpot-0 [°C] on Depth [m]=400
80°N
78°N
76°N
74°N
72°N
70°N
170°W
160°W
150°W
140°W
130°W
CB
AK
Ocean Data View
Oxygen [ml/l]
NEW
T
OLD
S
Salinity [psu]
Tpot-0 [°C]
Depth [m]

The Atlantic/Pacific Showdown


L
H
L
PDO
AO
NAO
1
NADW
NP
AO
NS
NA


L
H
L
PDO
AO(+)
NAO
2
NADW
NP
AO
NS
NA


L
H
L
PDO
AO(+)
NAO
3
NADW
NP
AO
NS
NA


L
H
L
PDO
AO(+)
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4
NADW
NP
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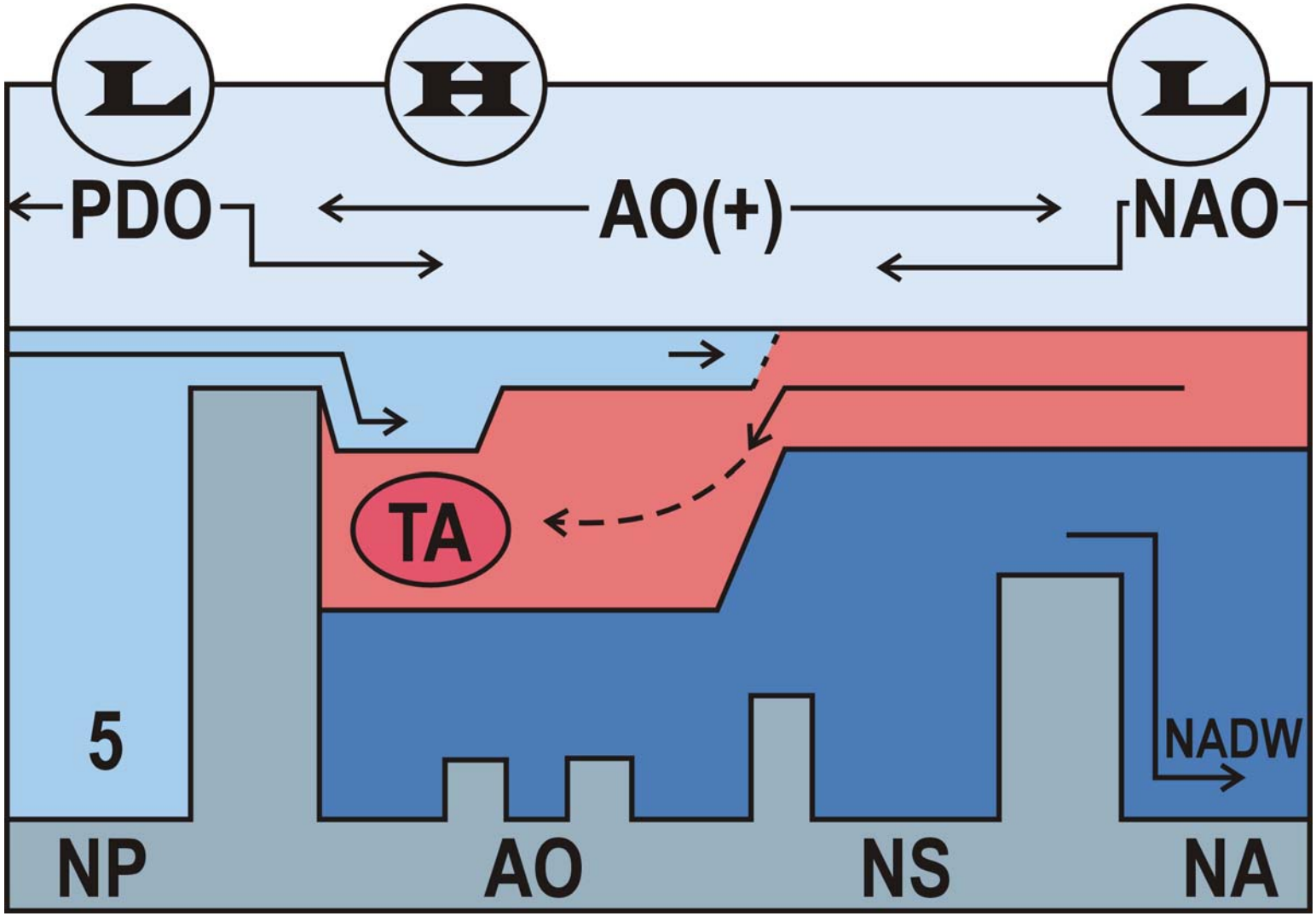
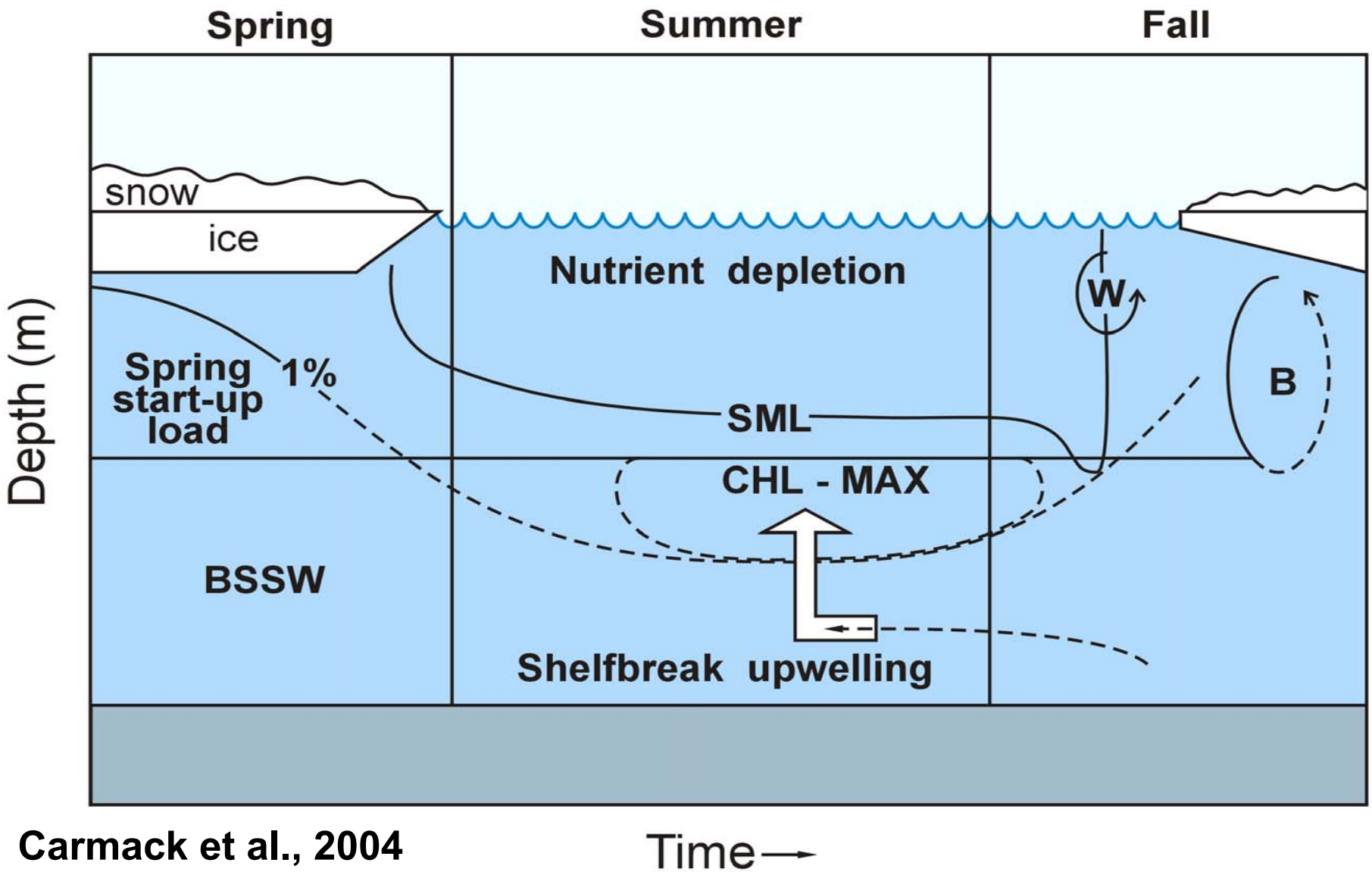
NA

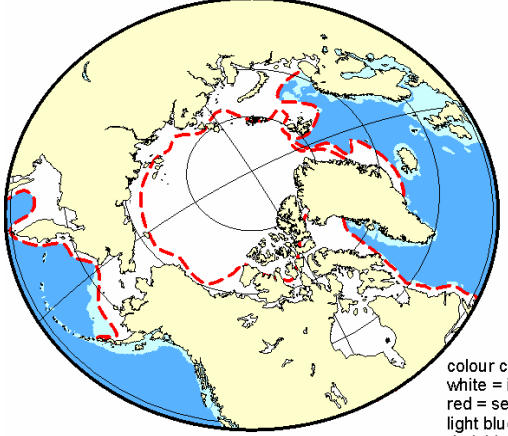

L
H
L
PDO
AO(+)
NAO
TA
5
NADW
NP
AO
NS
NA


What about us?

Too Damn Much FW? ..Dunbar

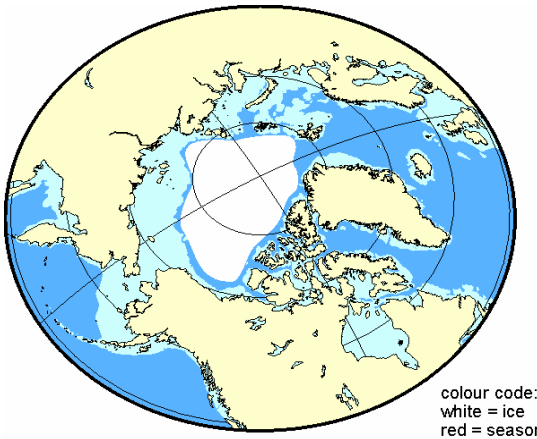


Carmack et al., 2004



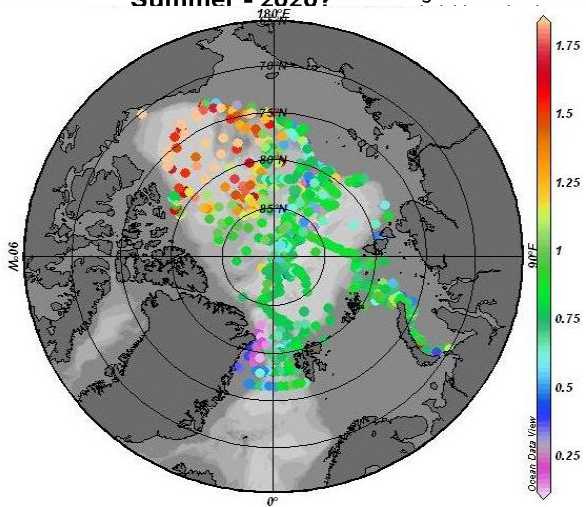
colour code:
white = ice
red = seasonal ice zone
light blue = shelves
dark blue = basin

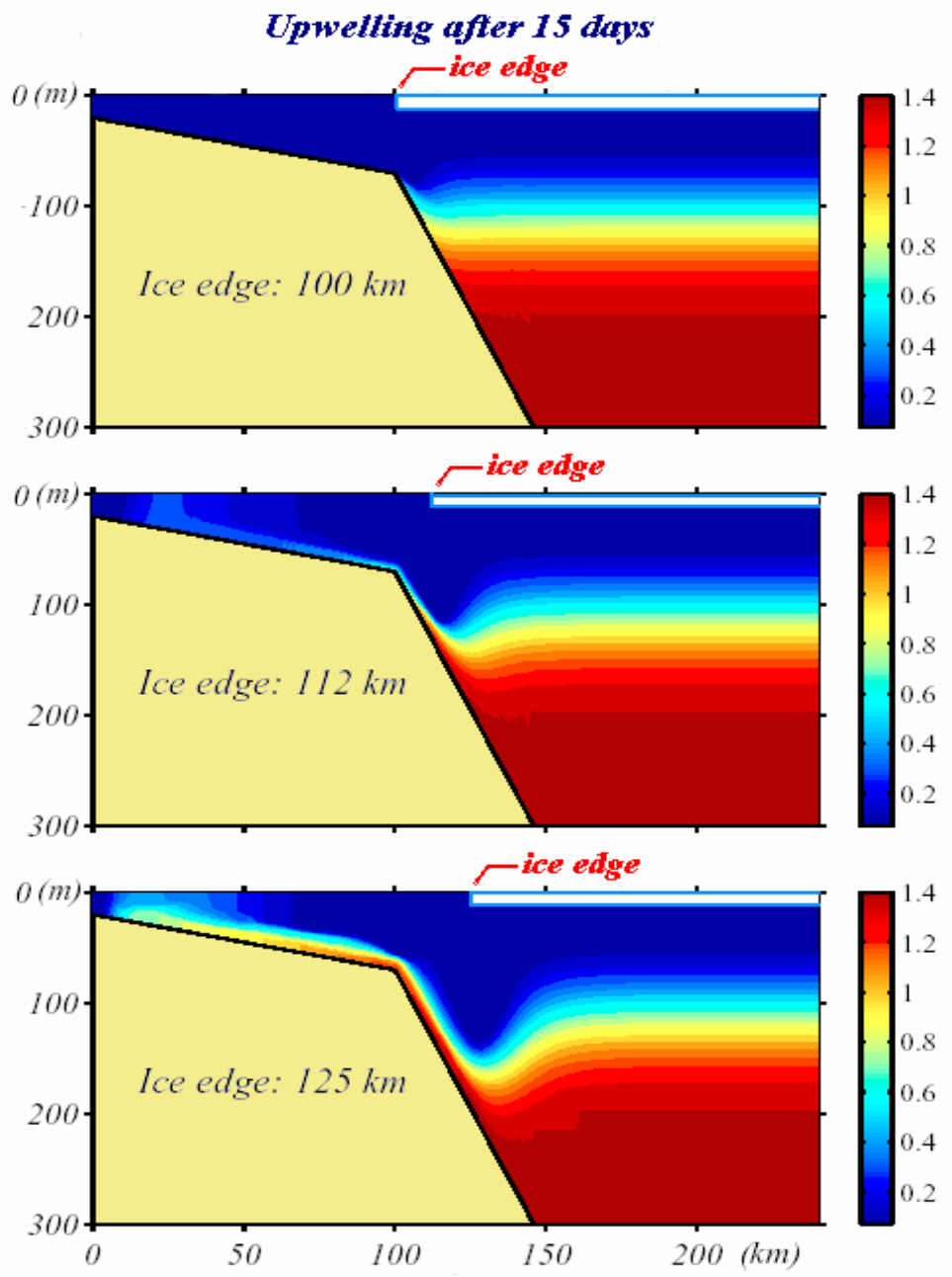
Present day - summer/winter



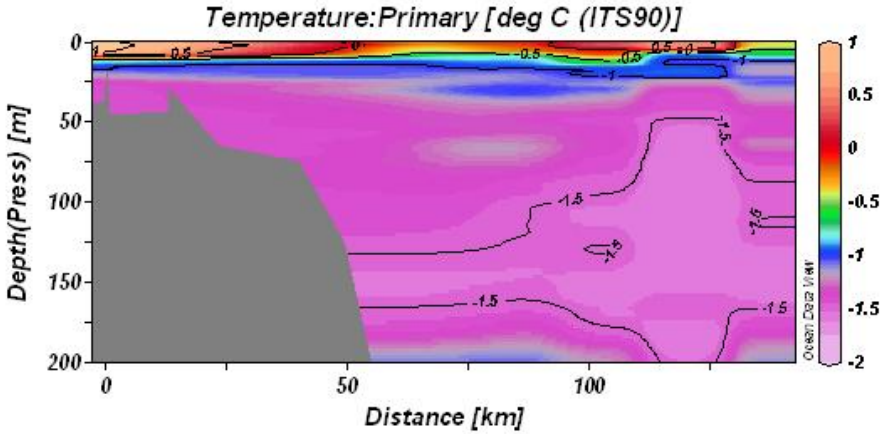
colour code:
white = ice
red = seasonal ice zone
light blue = shelves

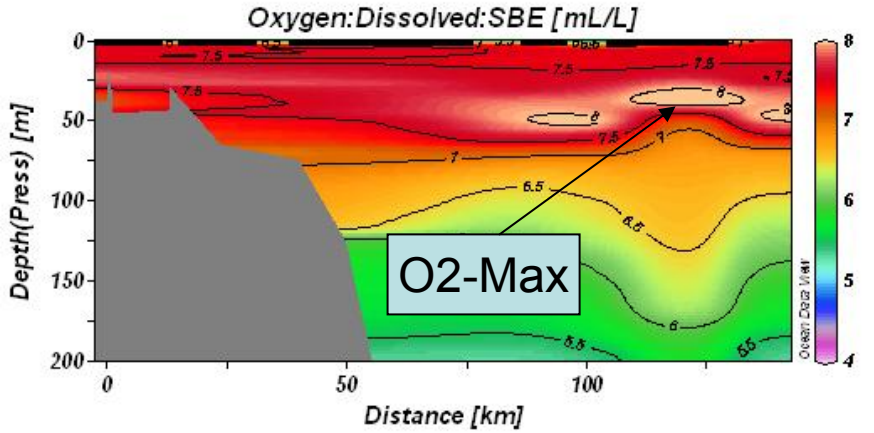
Summer - 2020?

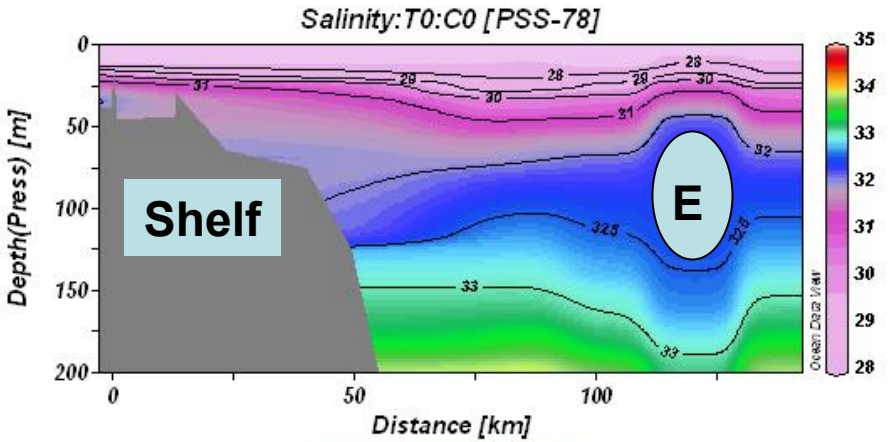


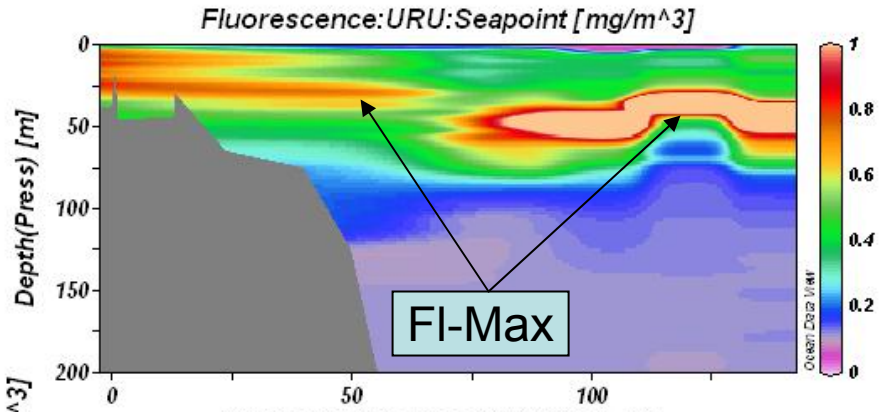


Carmack & Chapman, 2003

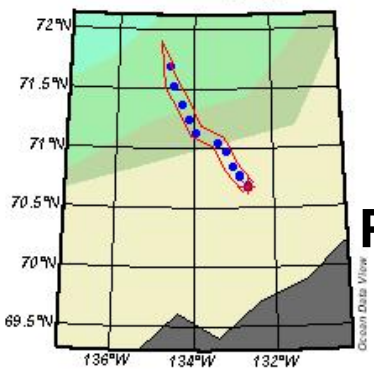




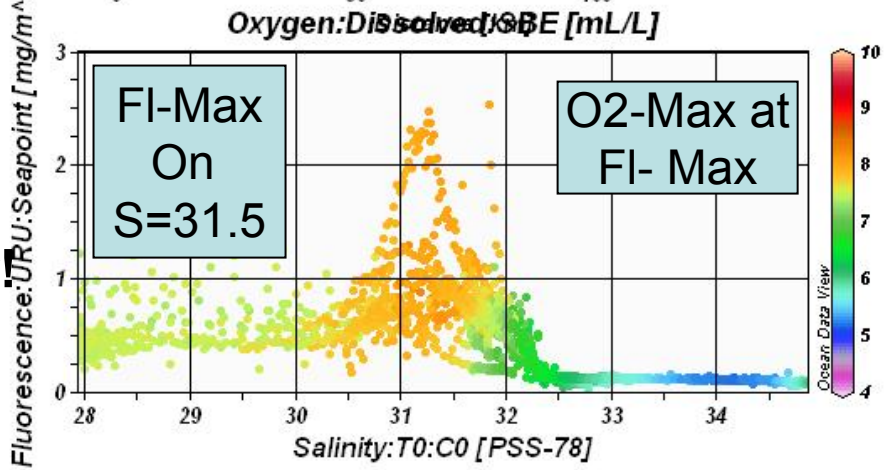




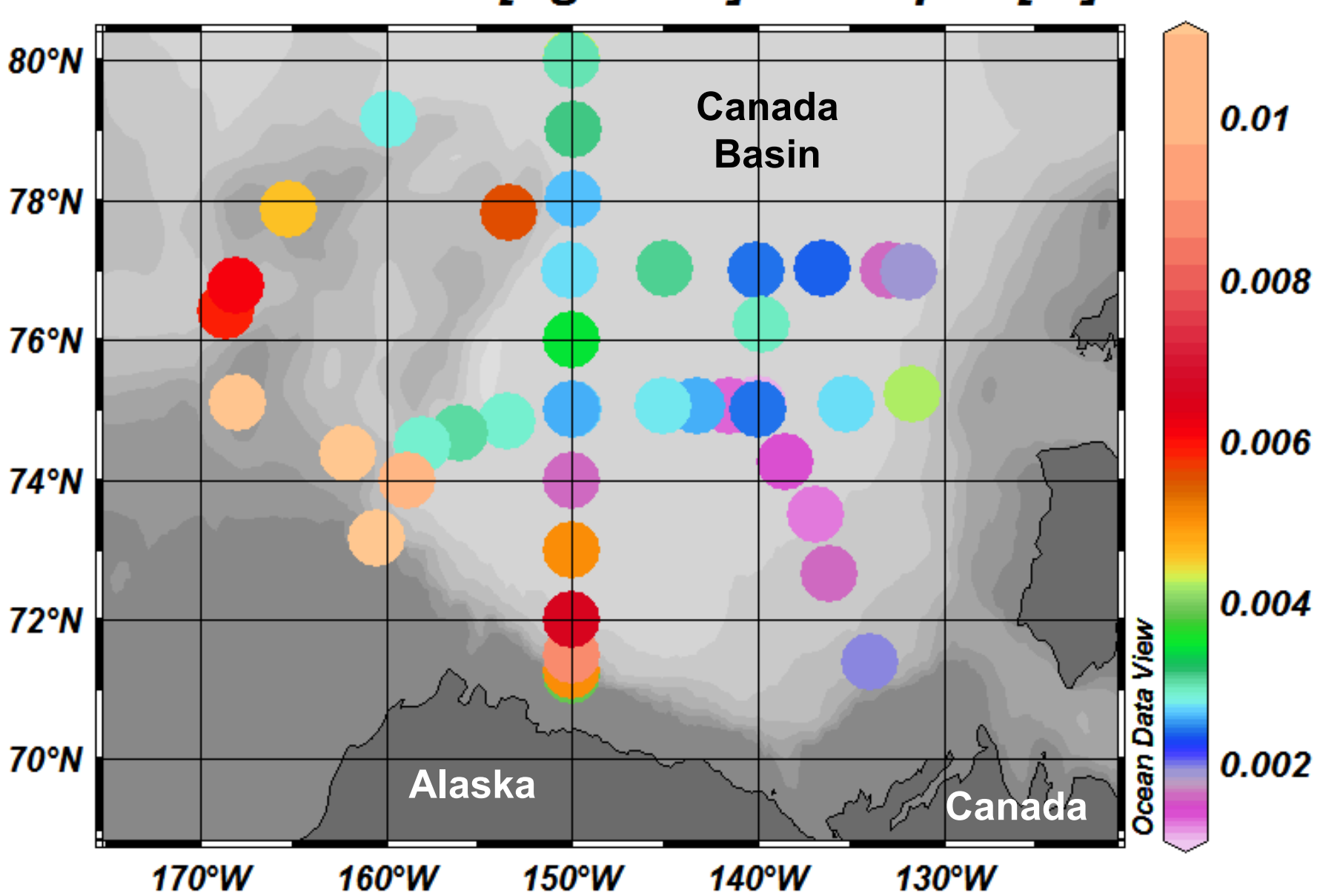
Canadian Shelf



NOTE: All this is Because of Pacific Water!

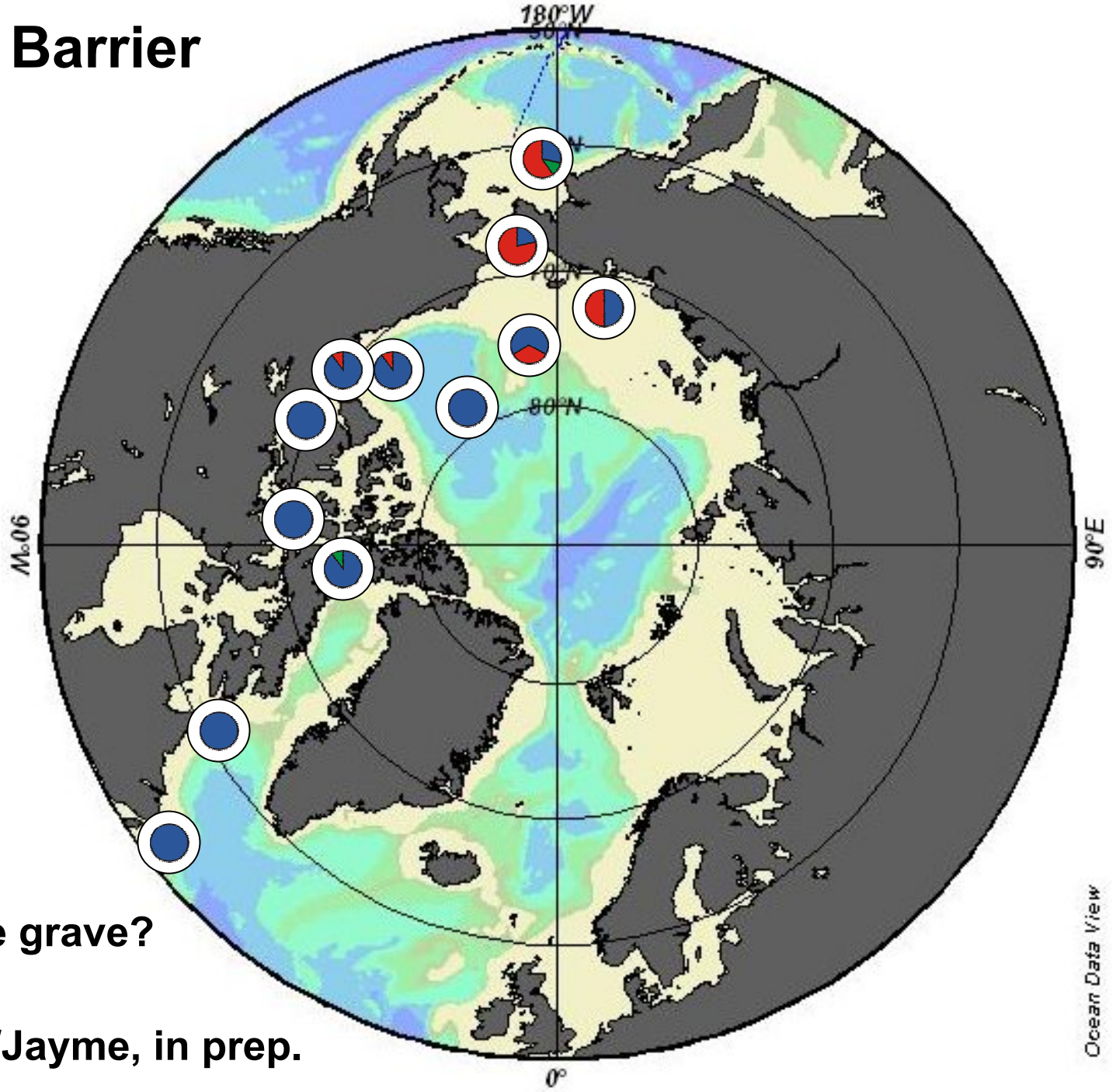


JWACS Team, 2004


òFluorescence dz [ug/L*km] on Depth [m]=40
80°N
78°N
76°N
74°N
72°N
70°N
170°W
160°W
150°W
140°W
130°W
Canada
Basin
Alaska
Canada
0.01
0.008
0.006
0.004
0.002
Ocean Data View
JWACS Team, 2004

Bering DNA Barrier

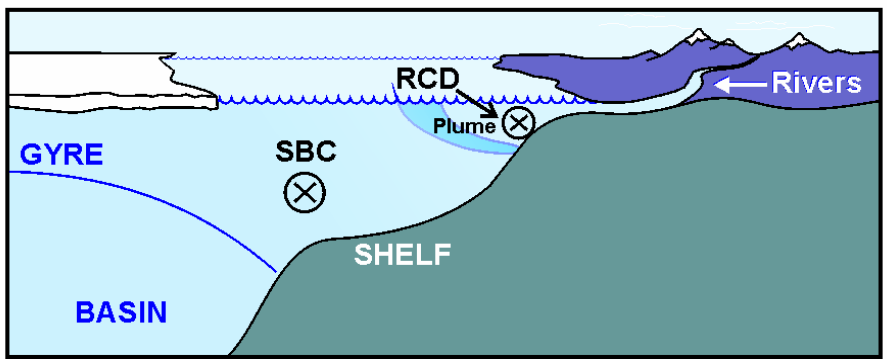
Dif Adv



…one foot in the grave?

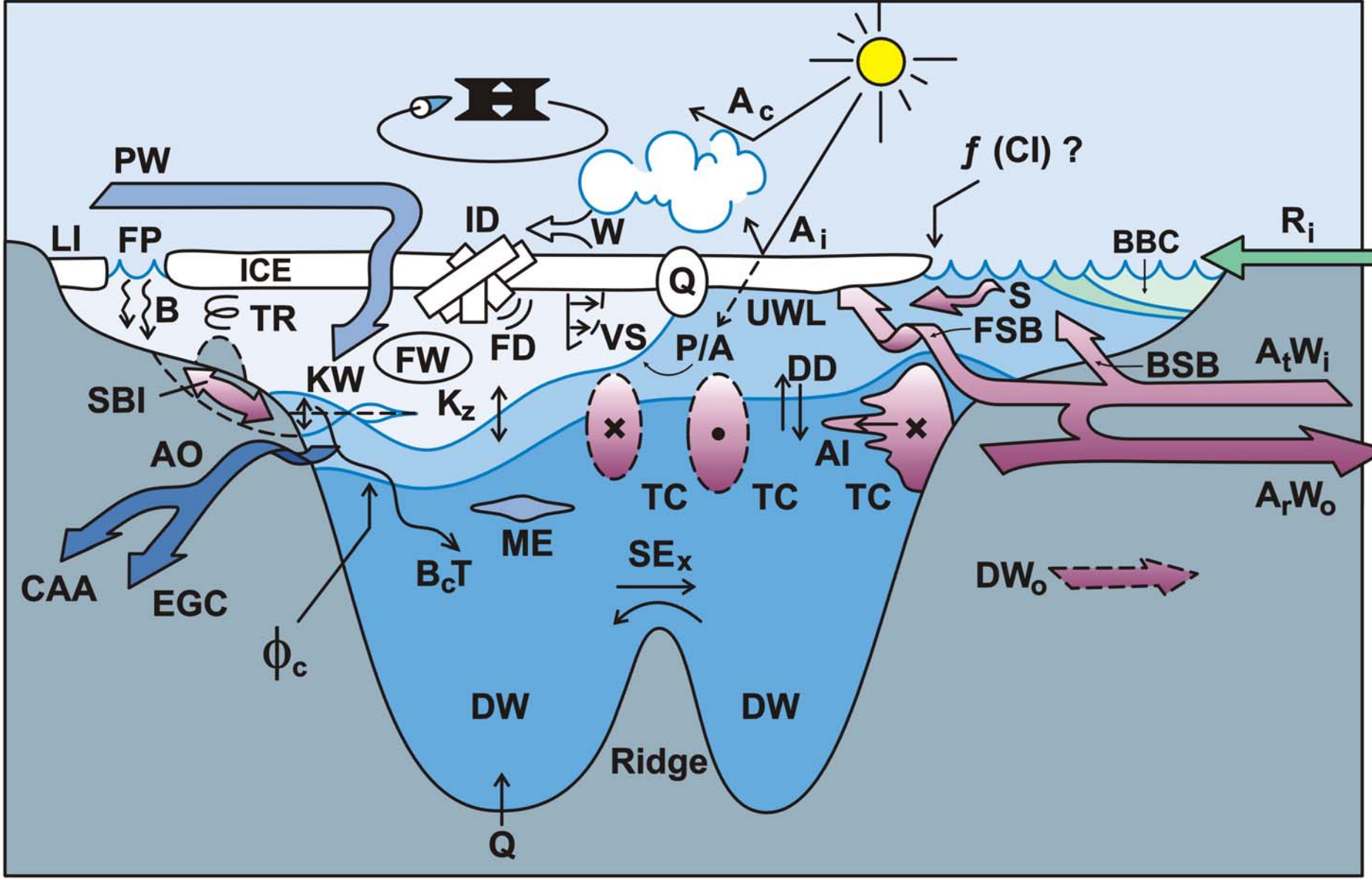
Nelson/Carmack/Jayme, in prep.

Riverine Coastal Domain
and Intercontinental Connections



Question: Is there a contiguous (e.g. a daisy chain) of gravity-driven flow that serves to transport freshwater in a clockwise direction around continents and islands in the Northern Hemisphere, and thus connect the Pacific, Arctic and Atlantic?

Structure; Processes Time scales; Variability???

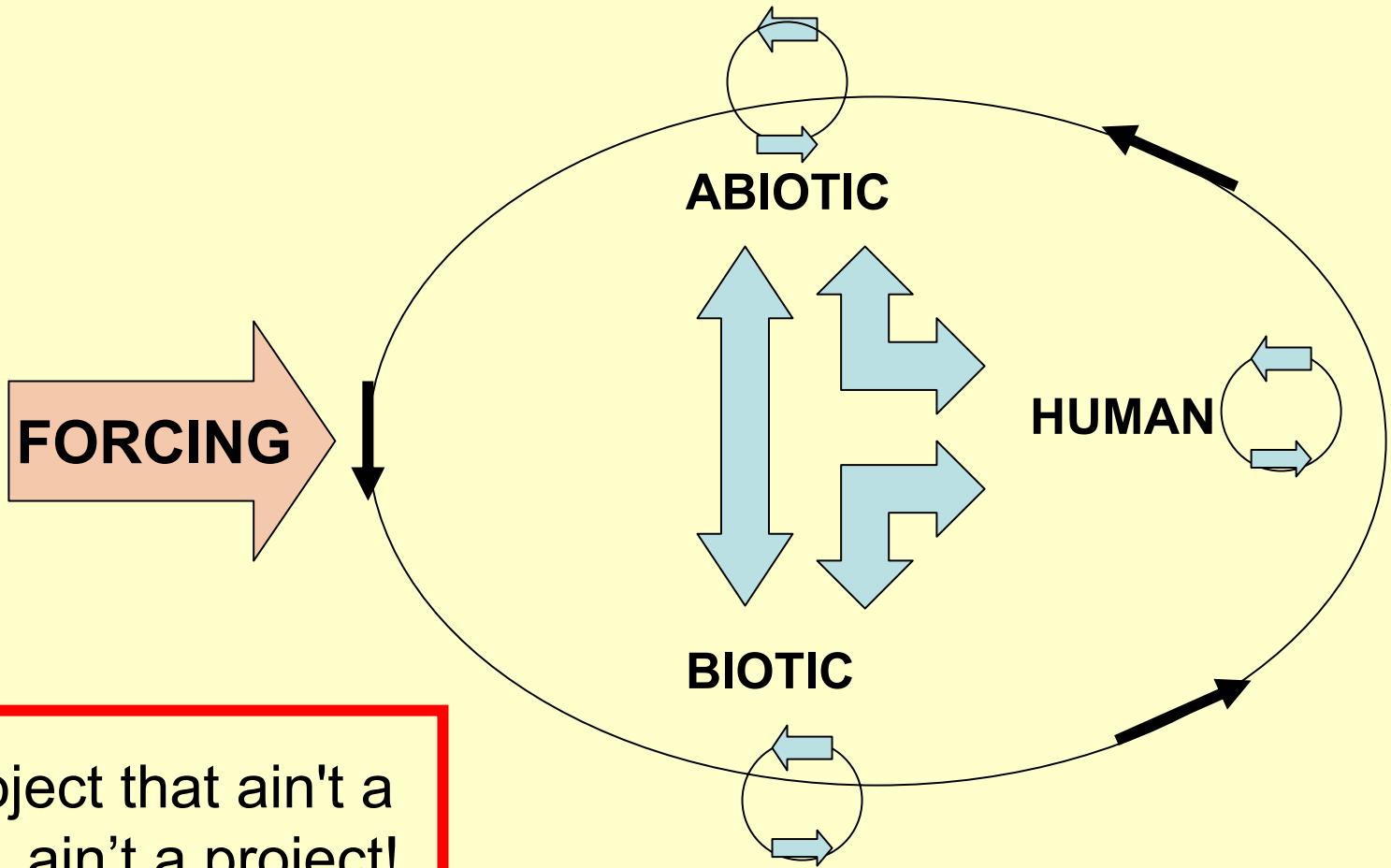


SYSTEM	CHALLENGES	BUDGETS	FEEDBACKS
sea ice	structures	sources	thermohaline
glacial ice	pathways	storage	albedo
permafrost	processes	export	frozen GHG

Three Good Things to Do

1. Provide basis to develop & verify models
2. Provide framework for palaeo interpretations
3. Define ‘tipping’ points prior to surprise

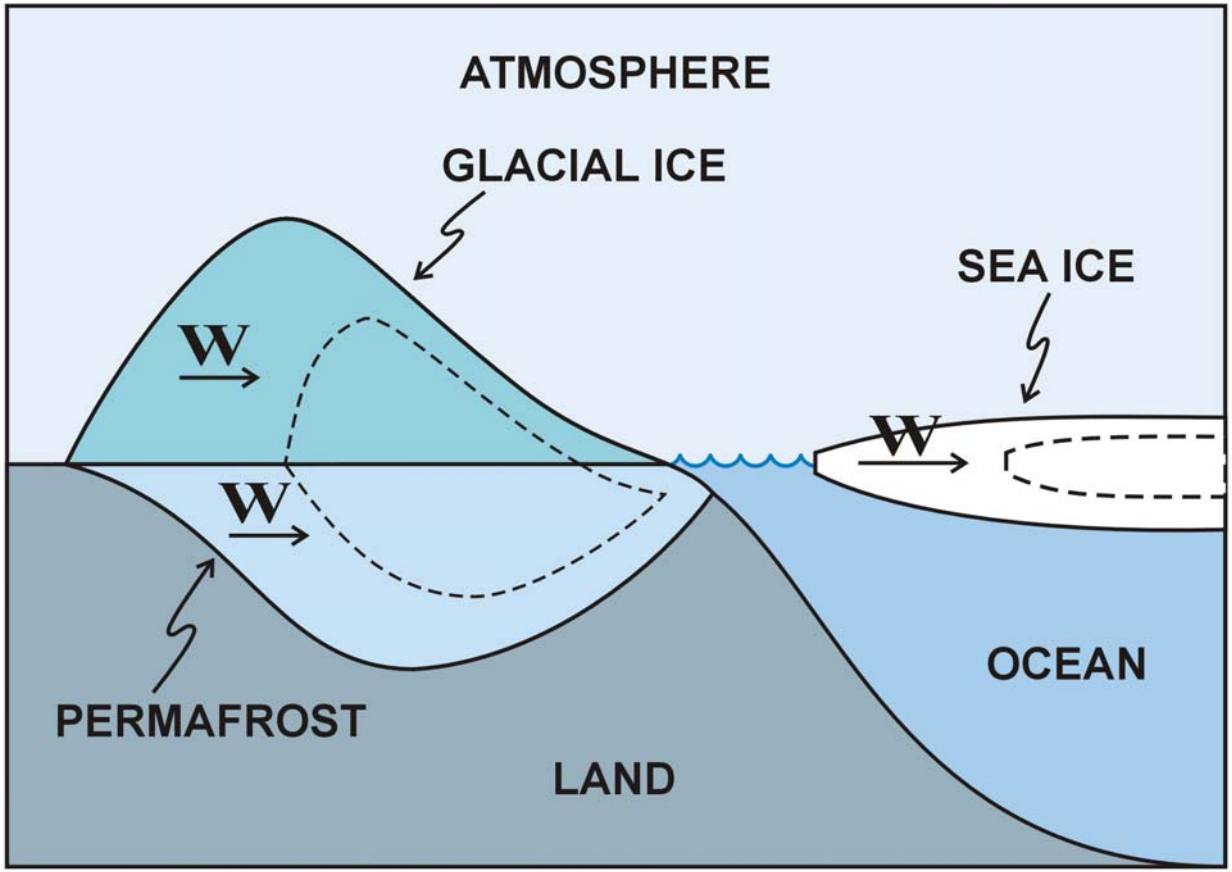
TRIADS



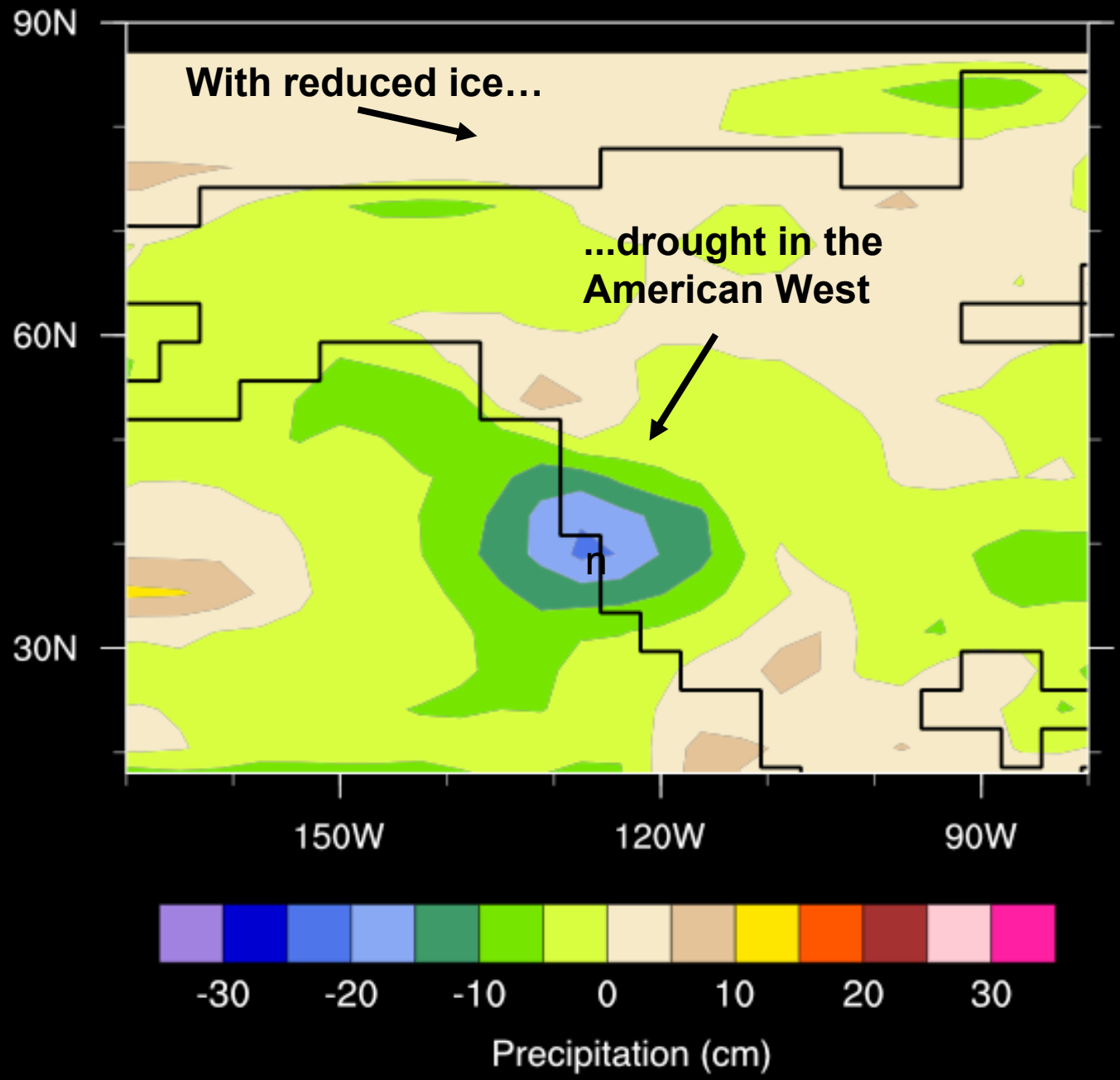
.. A project that ain't a triad … ain't a project!
Yogi Berra-ism

Any Questions?

THE ARCTIC SYSTEM

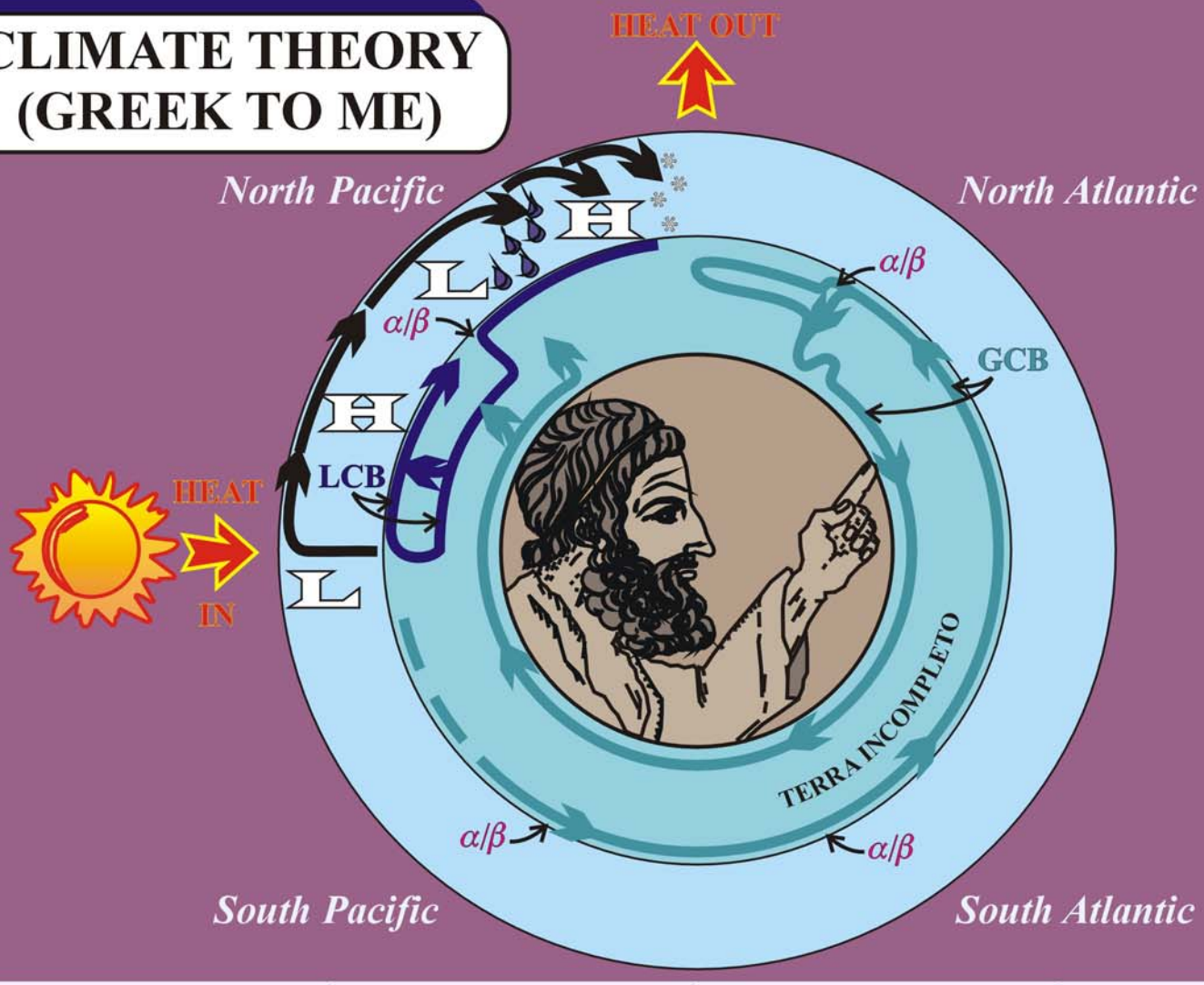


The current state of the Arctic System is defined by the presence of permanently frozen water in three forms: sea ice; glacial ice; and permafrost.

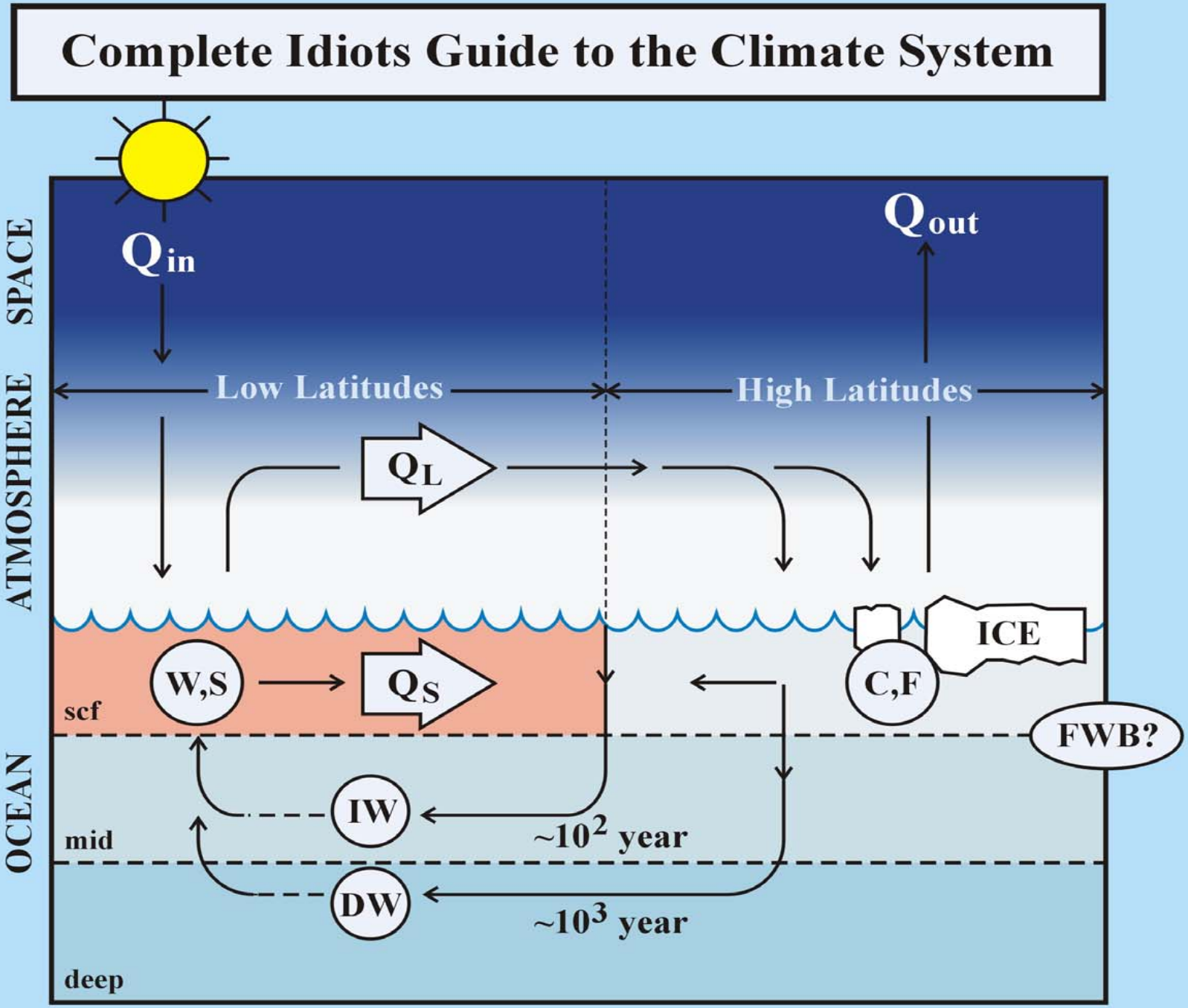


Sewall and Sloan, 2004

CLIMATE THEORY (GREEK TO ME)



FIRE	EARTH	AIR	WATER
The Sun: → Main Supply of Energy	Supplies Basics → Gravity → Orbit → Rotation → Primordial Stuff	Carries ~50% of excess heat poleward (but mostly by H_2O vapor)	→ Oceans carry remaining excess heat via the Great & Lesser Conveyor Belts → Salt is a Worry (α/β)!


Complete Idiots Guide to the Climate System
SPACE
ATMOSPHERE
OCEAN
Qin
Qout
Low Latitudes
High Latitudes
QL
W,S
QS
ICE
C,F
scf
FWB?
IW
~10^2 year
mid
DW
~10^3 year
deep

Suppose Warming results in …

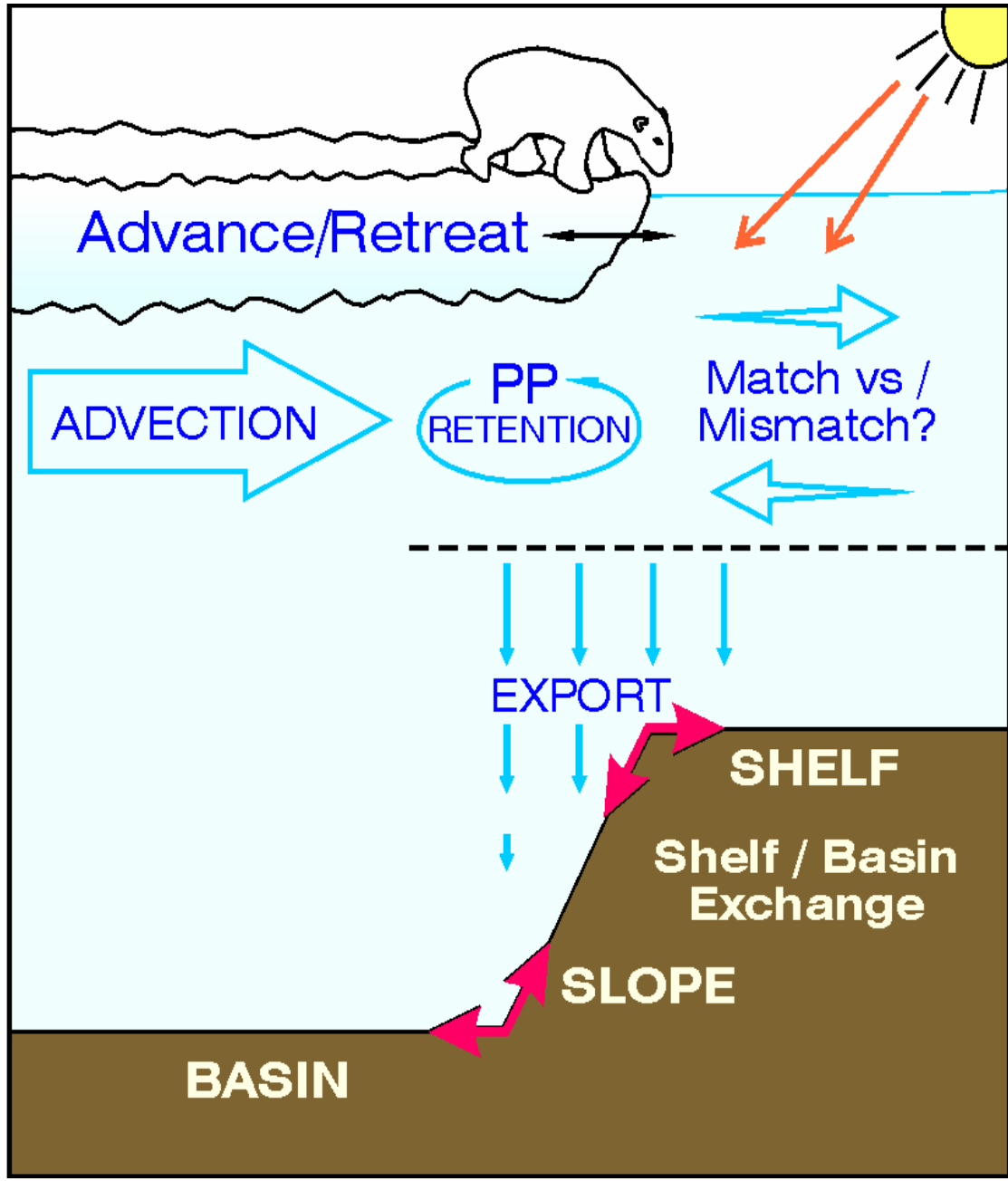
Retreat of Seasonal Ice Margin

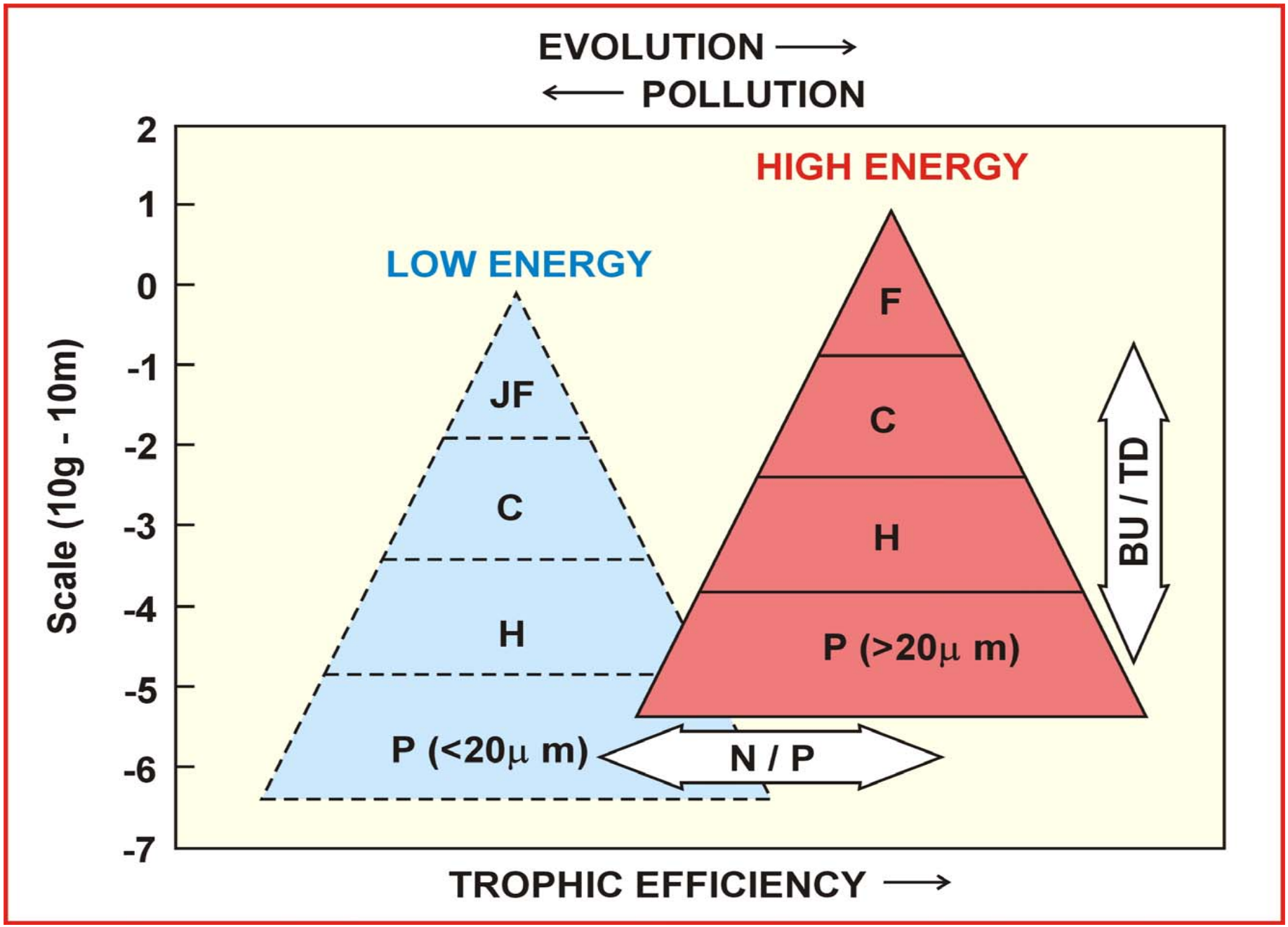
Bottom-up
- Increased underwater light
- Increased upwelling/nutrients
- Altered advection of resources

Top-down
- Loss of ice algae?
- Loss of top predators?
- Altered advection of predators?

So – what is net affect on:

- Primary production?
- Match vs. mismatch?
- Retention vs. Export?
- Pelagic Benthic coupling?

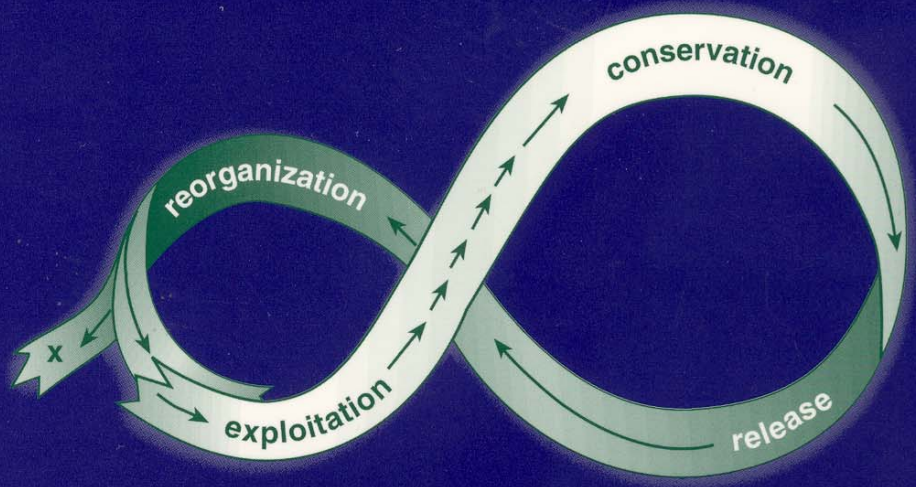




Parsons, pers. Comm.

Panarchy

UNDERSTANDING TRANSFORMATIONS IN HUMAN AND NATURAL SYSTEMS



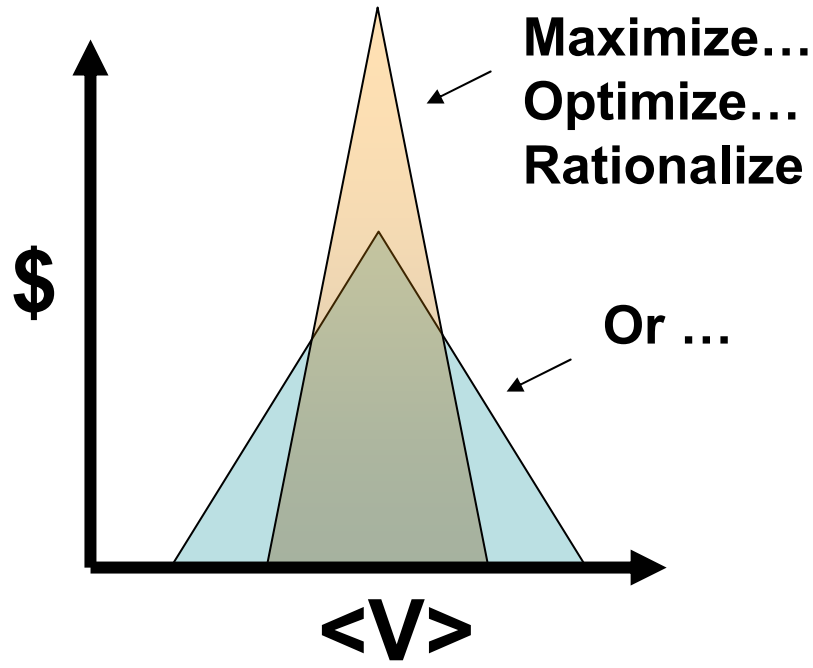
EDITED BY

Lance H. Gunderson

C. S. Holling

Remember Sisimuit?

Resilience
Resilience
Resilience



From $N^2 = N_T^2 + N_S^2$

where

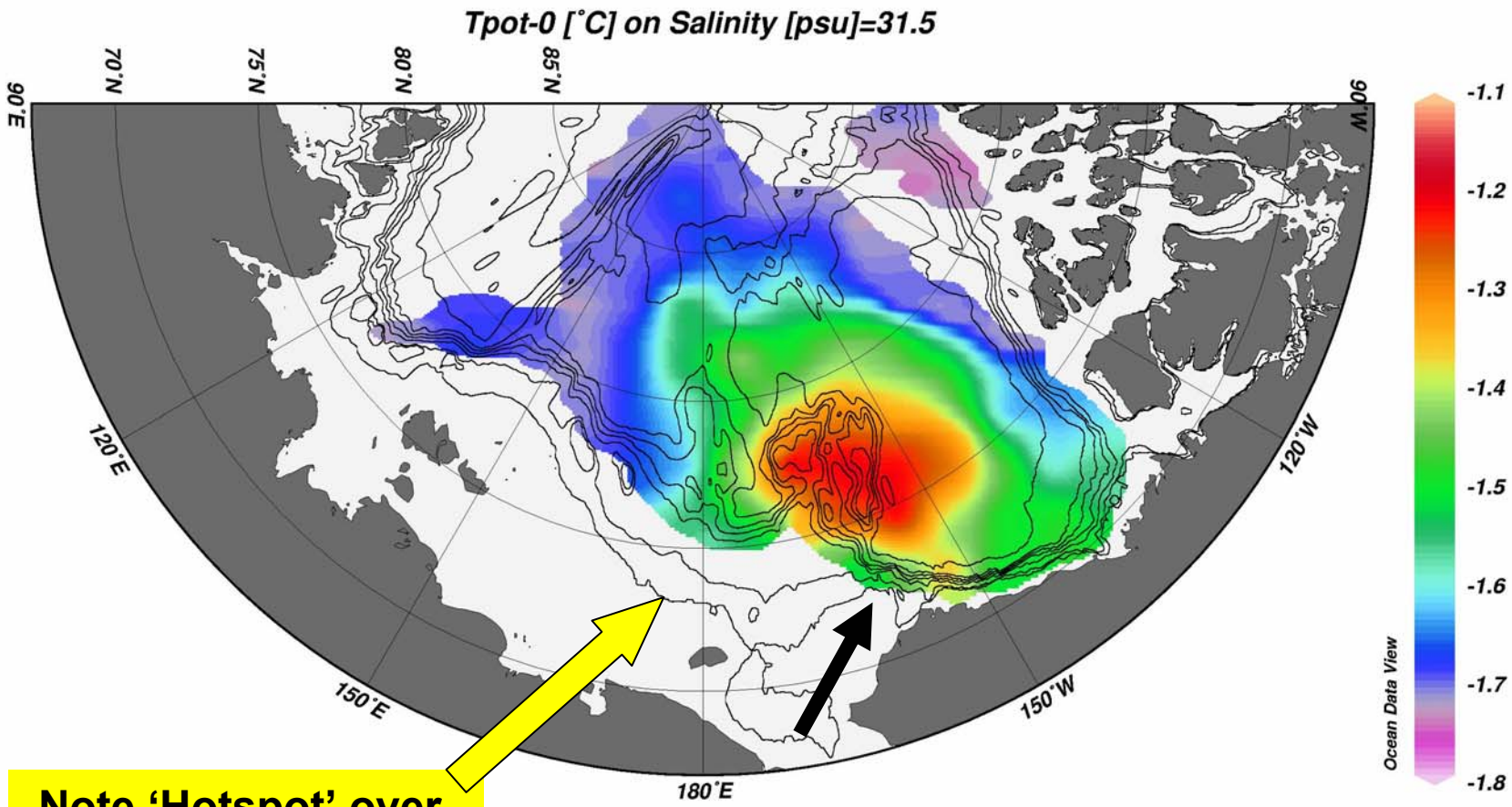
($N_T^2 = \alpha g dT/dz$ & $N_S^2 = \beta g dS/z$)

Define α & β Oceans

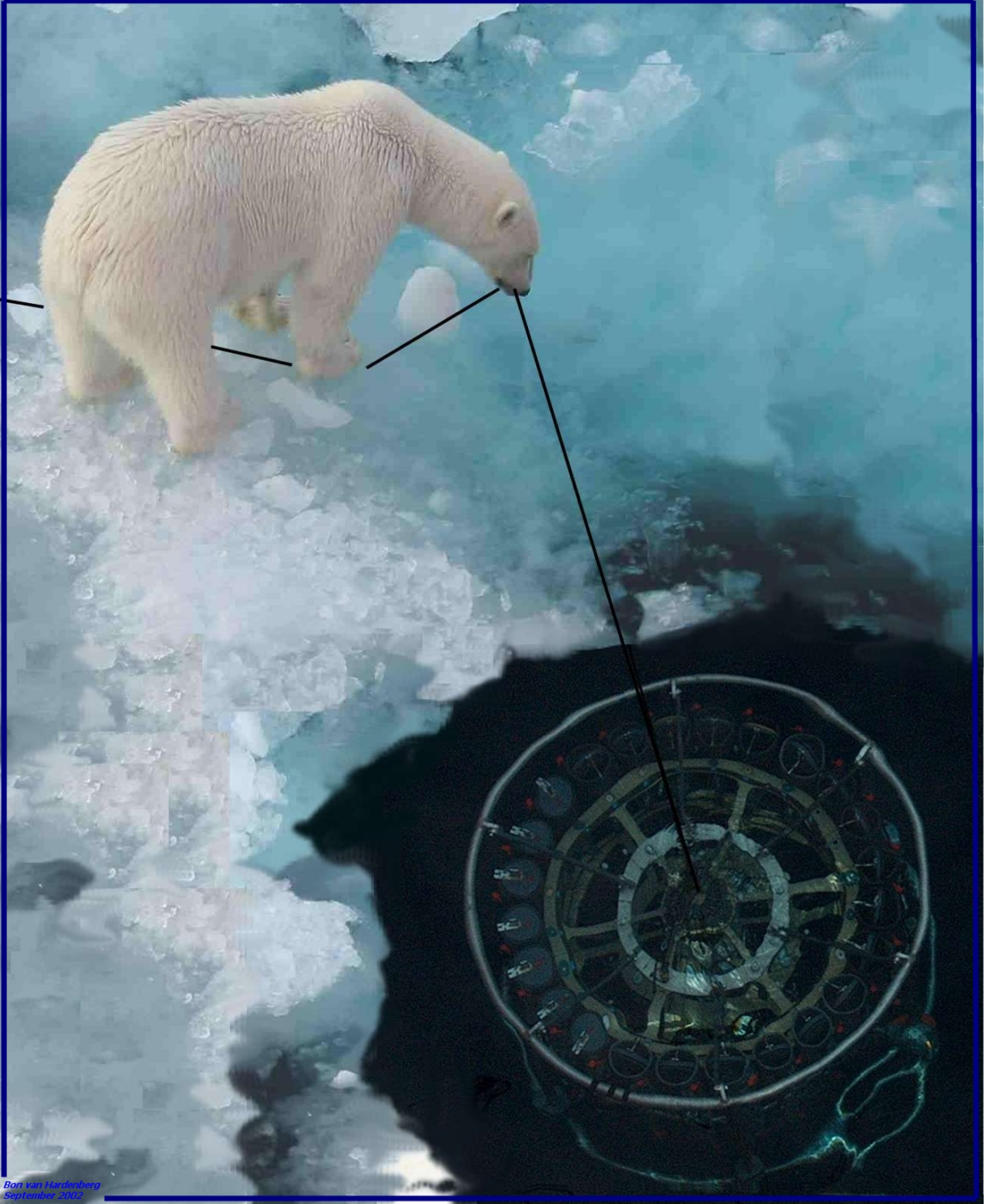
(Note: Canada has a β-Ocean)

The upper layers of subtropical seas are basically stratified by temperature ($N_T^2 = g\alpha(dT/dp) > 0$; the *alpha oceans*), while the upper layers of high-latitude seas are basically stratified by salinity ($N_S^2 = g\beta(dS/dp) > 0$); the *beta oceans.*

Inflow Shelf: Example from the Bering/Chukchi



Note ‘Hotspot’ over The Northwind Ridge



Ice Drift