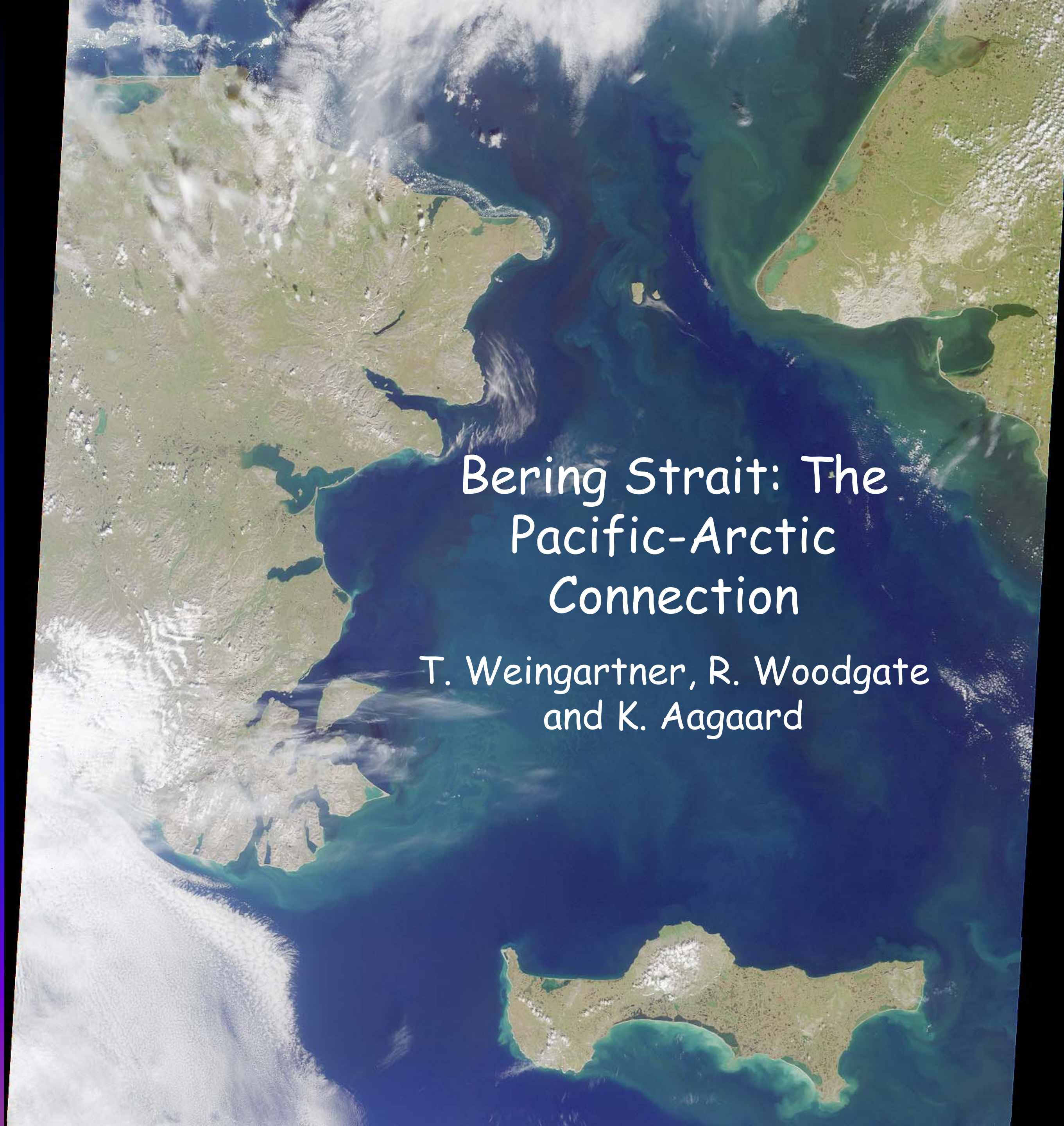


Bering Strait: The Pacific-Arctic Connection

T. Weingartner, R. Woodgate and K. Aagaard

Importance of Bering Strait

Recent History

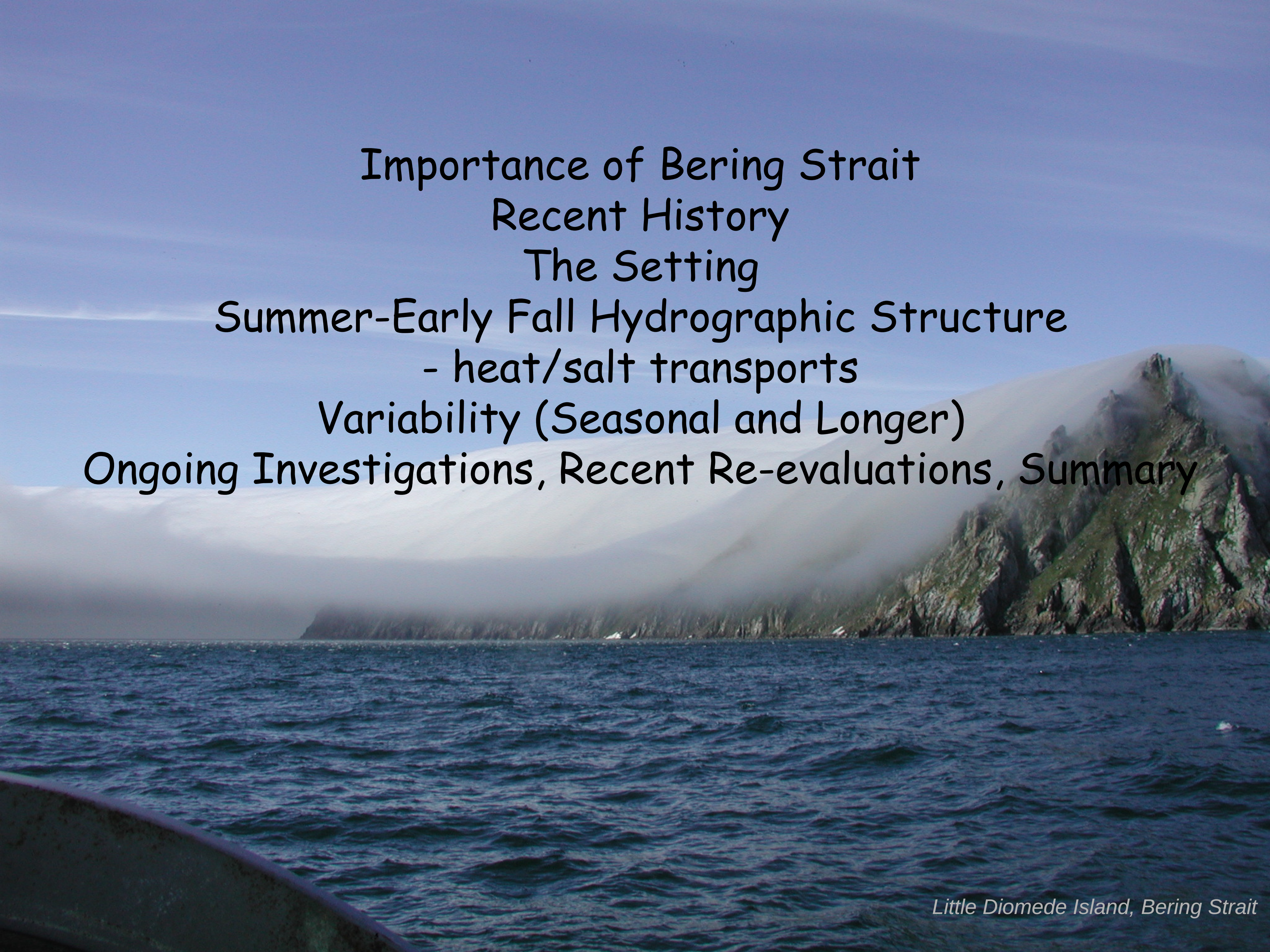
The Setting

Summer-Early Fall Hydrographic Structure

- heat/salt transports

Variability (Seasonal and Longer)

Ongoing Investigations, Recent Re-evaluations, Summary



Little Diomede Island, Bering Strait

Bering Strait – why care?

Bering Strait properties
-permeate the Chukchi Shelf & ventilate the Arctic Ocean
a carbon & nutrient source, stratification mechanism, sea ice control

The Bering Strait throughflow is
- a major part of the Arctic Freshwater budget *(Woodgate & Aagaard, 2005,)*
- an important part of global hydrologic cycle
- an integrated measure of change in the Bering Sea

Models: Bering Strait throughflow influences
- the stability of the Meridional Overturning Circulation
- Atlantic boundary currents

Little Diomede Island, Bering Strait

Bering Strait – who cares??

US FUNDED PROJECTS

Shelf Basin Interaction (SBI) of NSF (many projects)

Arctic Freshwater Initiative (FWI) of NSF (many projects)

Arctic Ocean Model Intercomparison Project (AOMIP) of NSF (Proshutinsky et al)

Beaufort Gyre Freshwater Study (NSF) (Proshutinsky et al)

Little Diomede Observatory (Cooper et al)

THEMATIC PROGRAMS

Arctic Subarctic Ocean Fluxes (ASOF)

Study of Environmental Arctic Change (SEARCH)

International Shelf Basin Interactions (SBE)

Community-wide Hydrologic Analysis and Monitoring Program (CHAMP)

Bering Sea Ecosystem Study (BEST)

International Polar Year (IPY)

Little Diomede Island, Bering Strait

Bering Strait History

Moored Measurements of T, S and Velocity

Pre-1990 Coachman and Aagaard

1990-2000
Knut Aagaard, Carol Pease, Tom Weingartner & ...
ONR, NSF, NOAA funding
Khromov, Surveyor, Alpha Helix, Laurier, ...

2000-2004
Knut Aagaard & Rebecca Woodgate
ONR funding
in support of NSF-SBI Program
Alpha Helix

Opportunistic use of moorings
T. Whitledge – Nut. Samplers & optics
Kelly Falkner (OSU)– Water Samplers
Dick Moritz (APL) – ULS (ice thickness)

CTD cruises

Pre-1990 Coachman and Aagaard

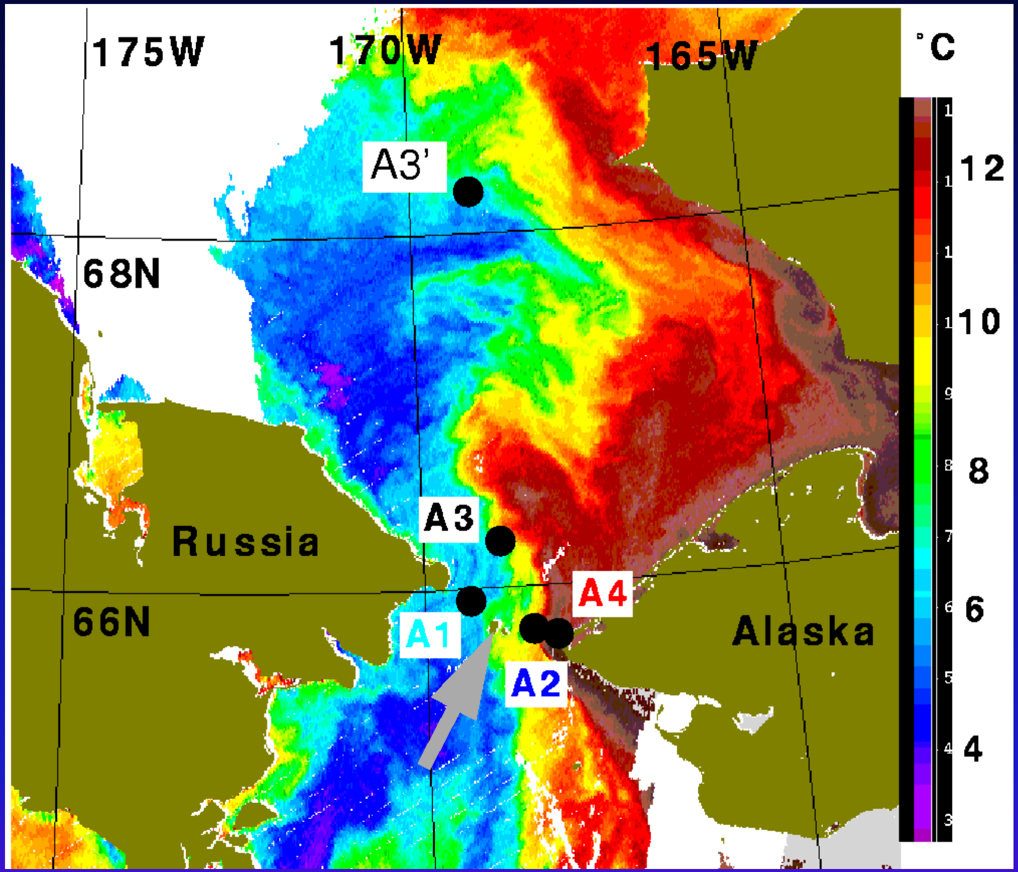
1990-2000
as per moorings

2000-2004
Knut Aagaard & Rebecca Woodgate
ONR funding
ship-time from NSF-SBI Program
Alpha Helix

Hydrographic CTD/ship's ADCP lines
(aided by Tom Weingartner)
Nutrient sampling – Terry Whitledge
O18 isotopes – Kelly Falkner, Lee Cooper (U. Tenn)
CDOM – Clara Deal (UAF)

Little Diomede Island, Bering Strait

Long-term moorings in Bering Strait



From 1990 to 2005

T, S and velocity
at 9m above bottom

A1 = western Channel
A2 = eastern Channel
A3 = combination of A1/2
A3' (up north)
A4 = Alaskan Coastal Current

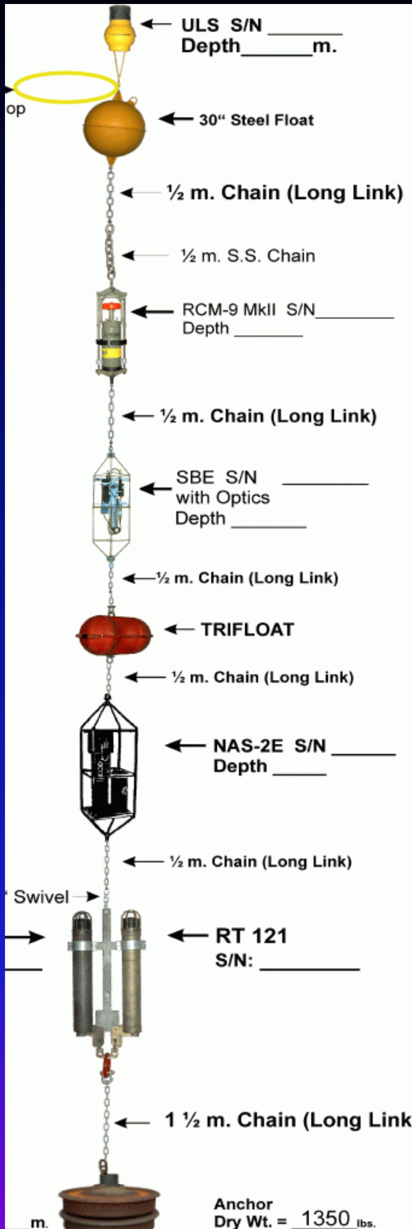
Not all moorings are deployed all years!

Sea Surface Temperature 26th August 2004, from MODIS/Aqua level 1

courtesy of Ocean Color Data Processing Archive, NASA/Goddard Space Flight Center, thanks to Mike Schmidt

Grey arrow marks the Diomede Islands (Little and Big Diomede). Russian EEZ line passes between the islands.

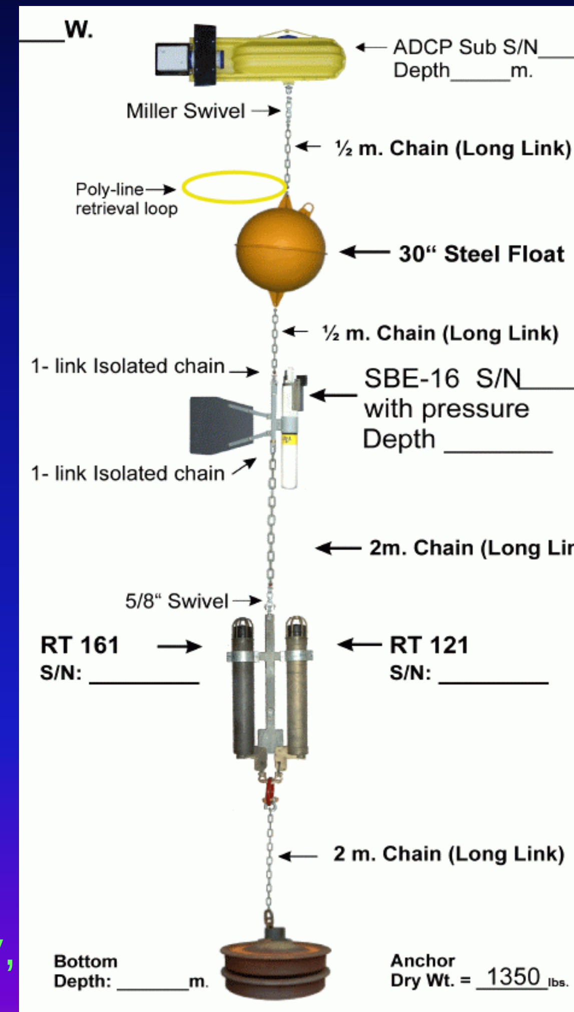
Moorings in Bering Strait



Short (~20m) long bottom moored
Top float at ~40m or deeper to
avoid ice keels and barges

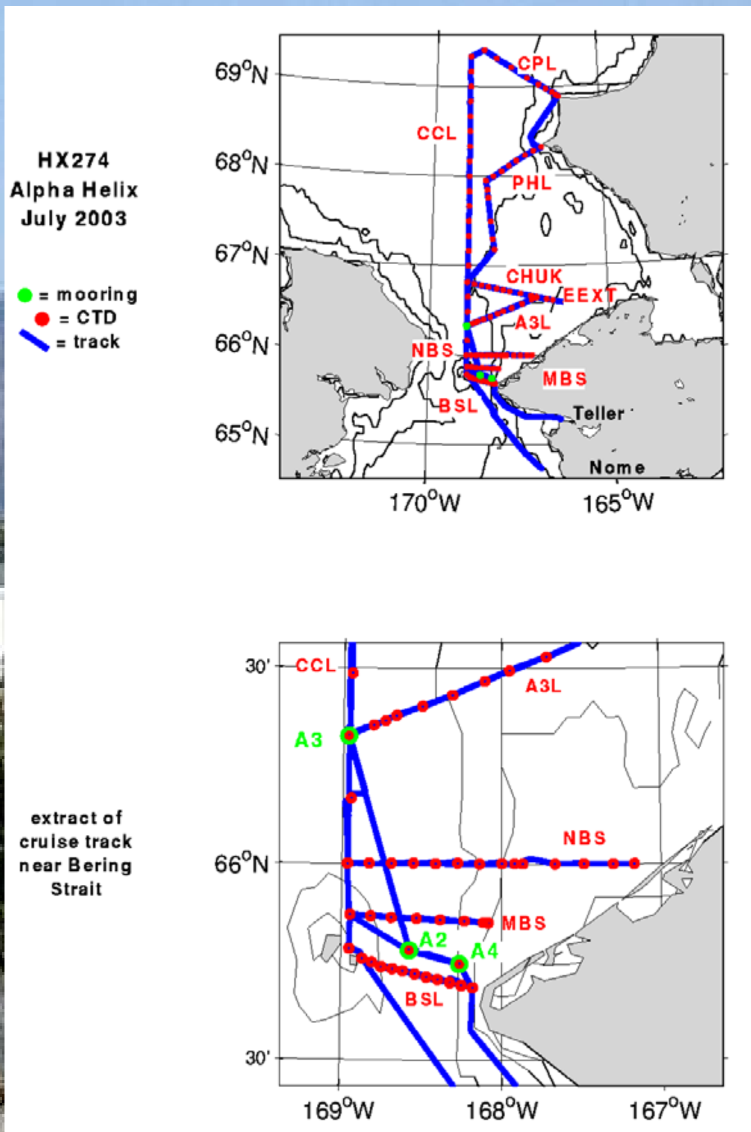
STANDARD MEASUREMENTS
= Temperature and salinity and velocity
at 9m above bottom
(SBE16, and Aanderaa RCM7 and
RCM9/11 due to biofouling)

EXTRA MEASUREMENTS
= ADCP - water velocity in 2m bins from
~15m above bottom to near surface
- ice motion and rough ice thickness
= ULS – upward looking sonars
(good ice thickness)
= NAS – Nutrient sampler
= SBE16+ - Fluorescence, transmissivity,
and PAR



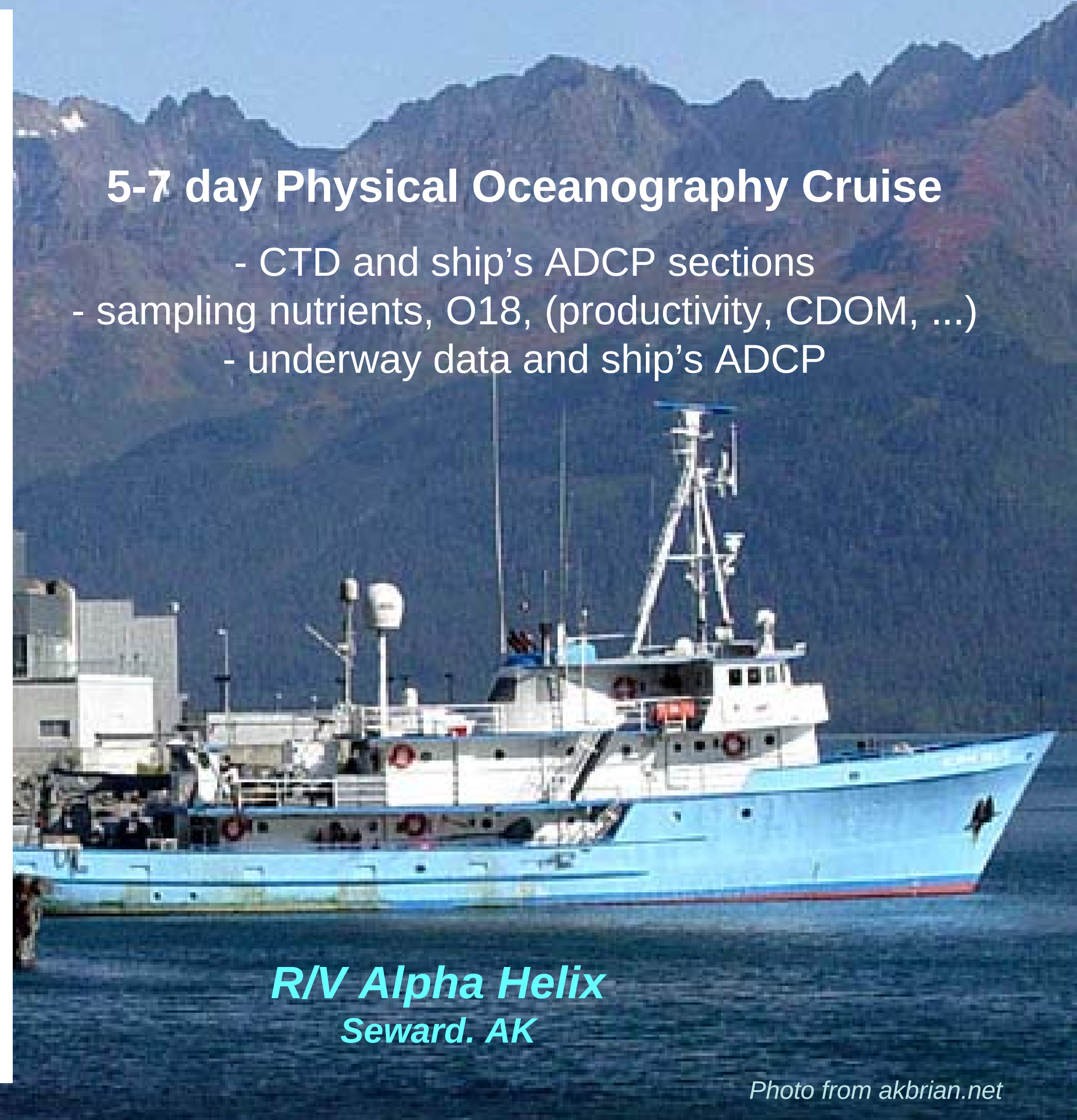
CTD cruises

e.g. Bering Strait & Chukchi Sea 2003



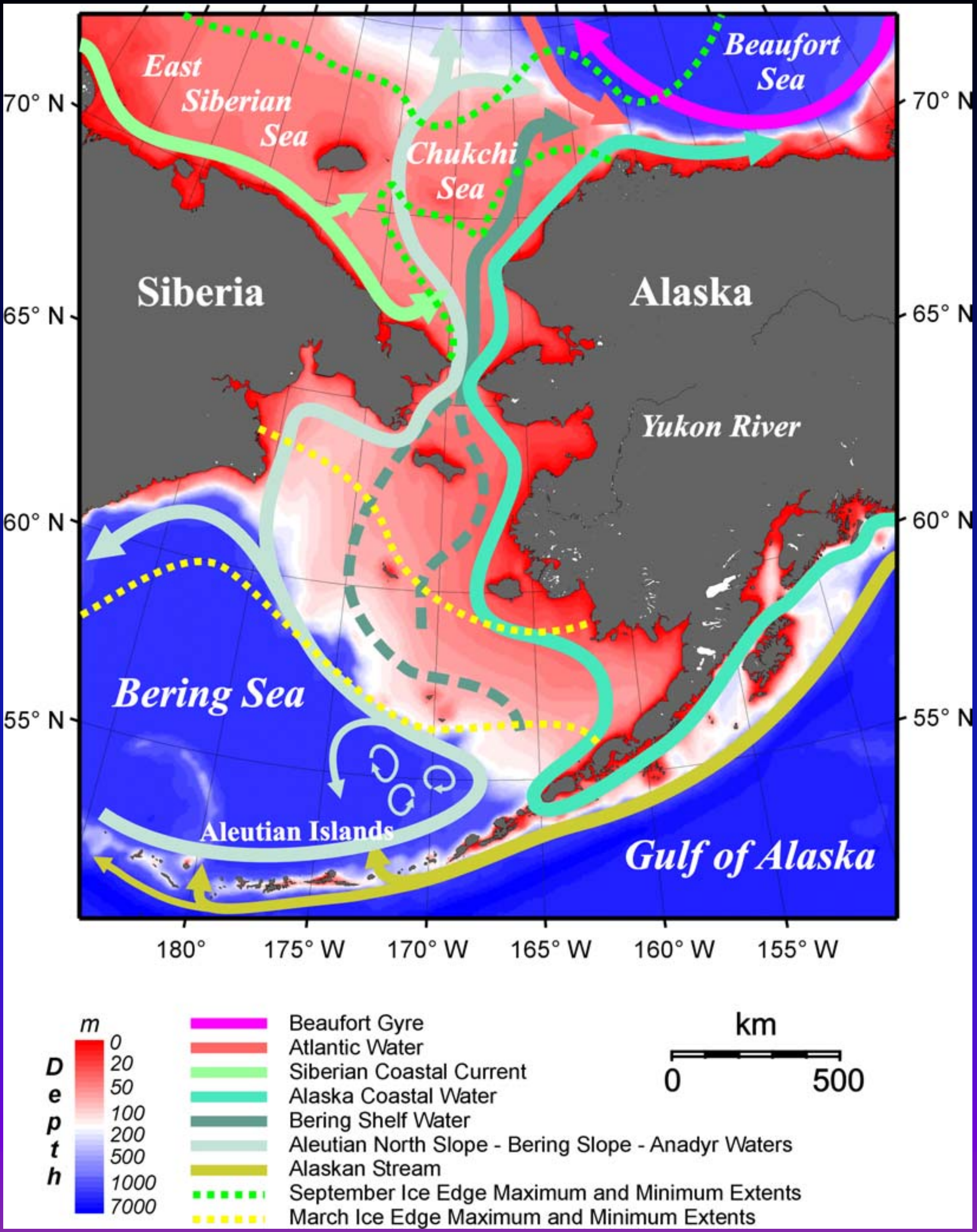
5-7 day Physical Oceanography Cruise

- CTD and ship's ADCP sections
- sampling nutrients, O18, (productivity, CDOM, ...)
- underway data and ship's ADCP

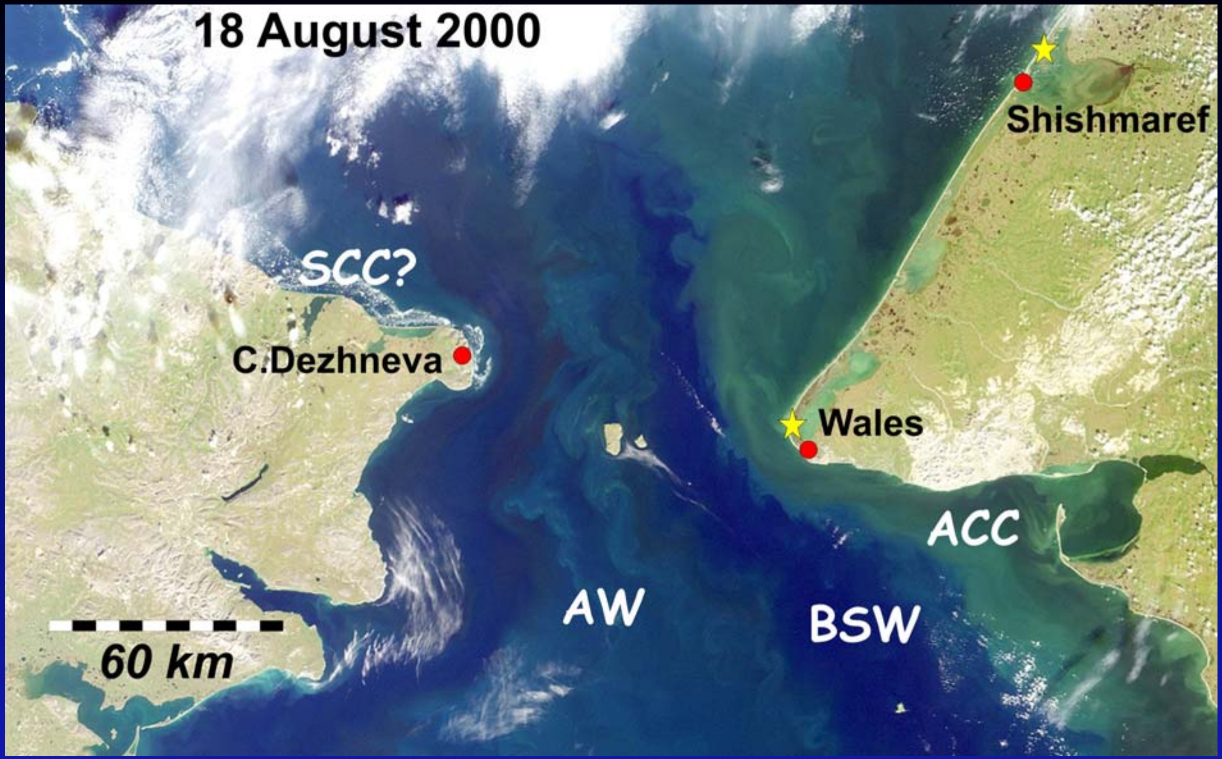


R/V Alpha Helix
Seward. AK

Photo from akbrian.net


East Siberian Sea
Chukchi Sea
Beaufort Sea
Siberia
Alaska
Yukon River
Bering Sea
Aleutian Islands
Gulf of Alaska
70° N
65° N
60° N
55° N
180°
175° W
170° W
165° W
160° W
155° W
m
Depth
0
20
50
100
200
500
1000
7000
Beaufort Gyre
Atlantic Water
Siberian Coastal Current
Alaska Coastal Water
Bering Shelf Water
Aleutian North Slope - Bering Slope - Anadyr Waters
Alaskan Stream
September Ice Edge Maximum and Minimum Extents
March Ice Edge Maximum and Minimum Extents
km
0
500

MODIS
IMAGE



Four water masses:

1.) Alaskan Coastal Current (ACC)*

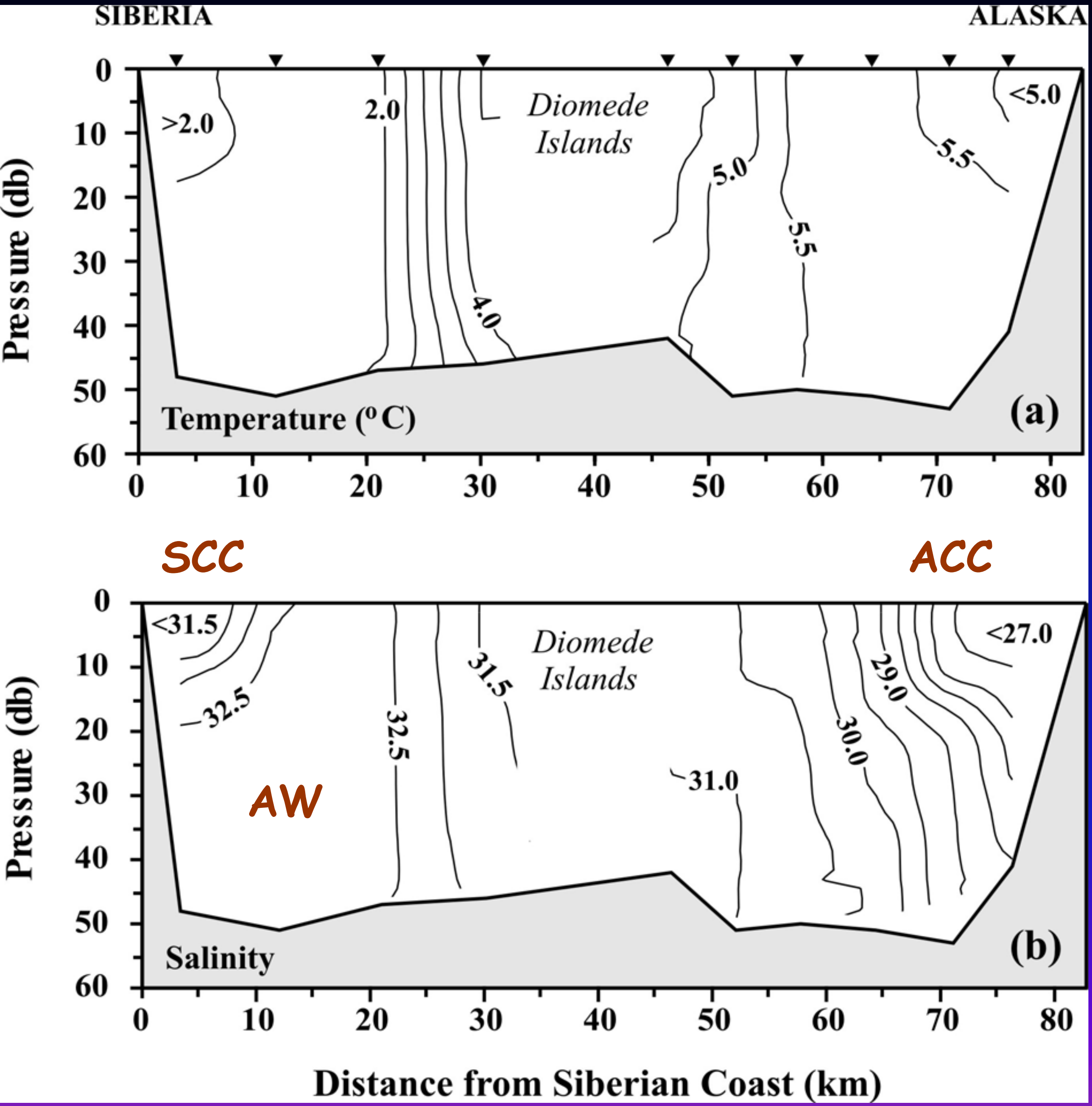
2) Bering Shelf Water (BSW)*

3) Anadyr Water (AW)*

4) Siberian Coastal Current (SCC) [East Siberian Sea]

*Properties established in Bering Sea and further south

AW and BSW mix north of the strait to form Bering Sea Water in the Chukchi



October 9, 1993

Northward flow

Coastal jets within 10km of the coast.

Cross-channel T & S and nutrient differences can be large in summer, but small in winter.

Property fluxes require measurements in both channels and in boundary flows.

Most moorings in channel center

(Weingartner et al., 1999)

Bering Strait and Chukchi Sea 2003

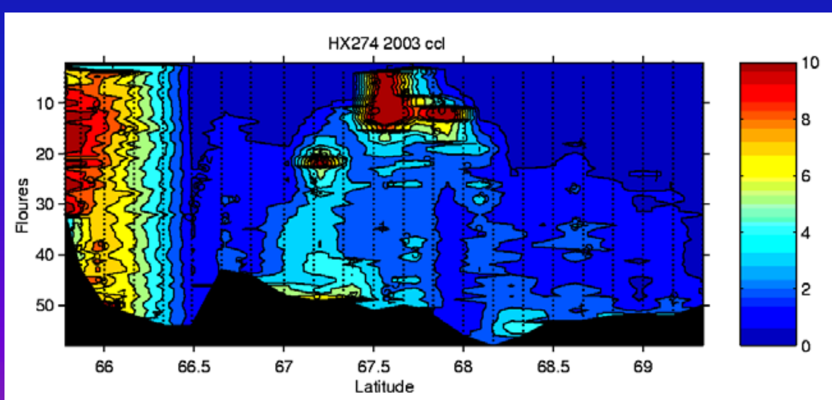
Chl_a (mg-m^{-3})

June 23, 2003

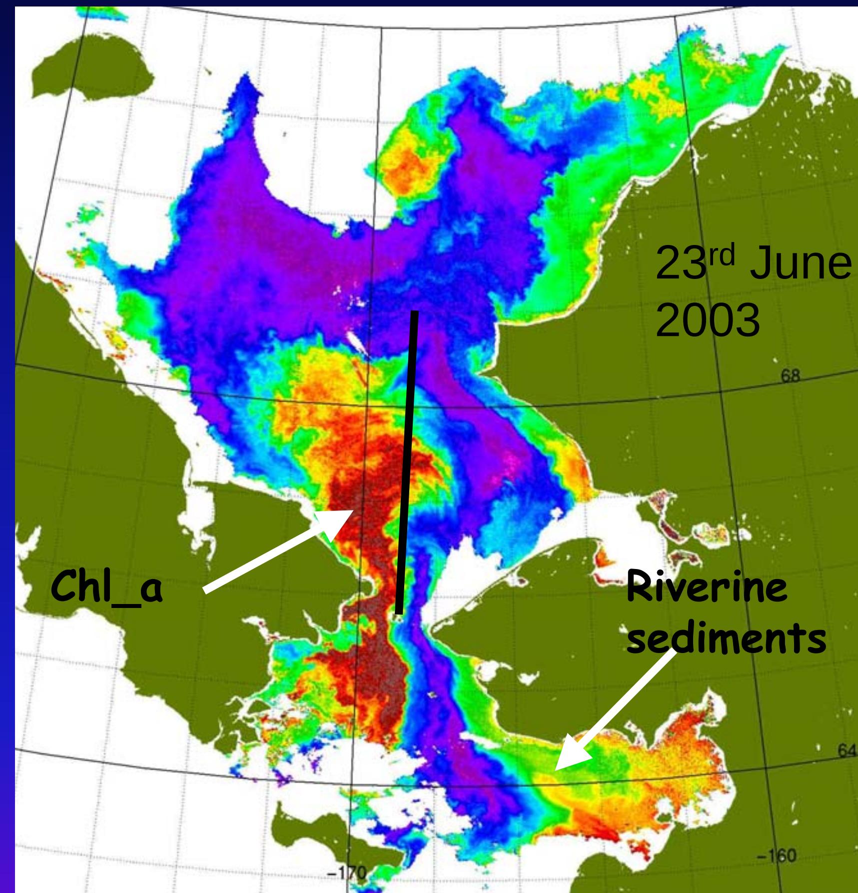
High Biomass/Production in AW

Carbon deposition zone in southern Hope Valley

Convention line Fluorescence



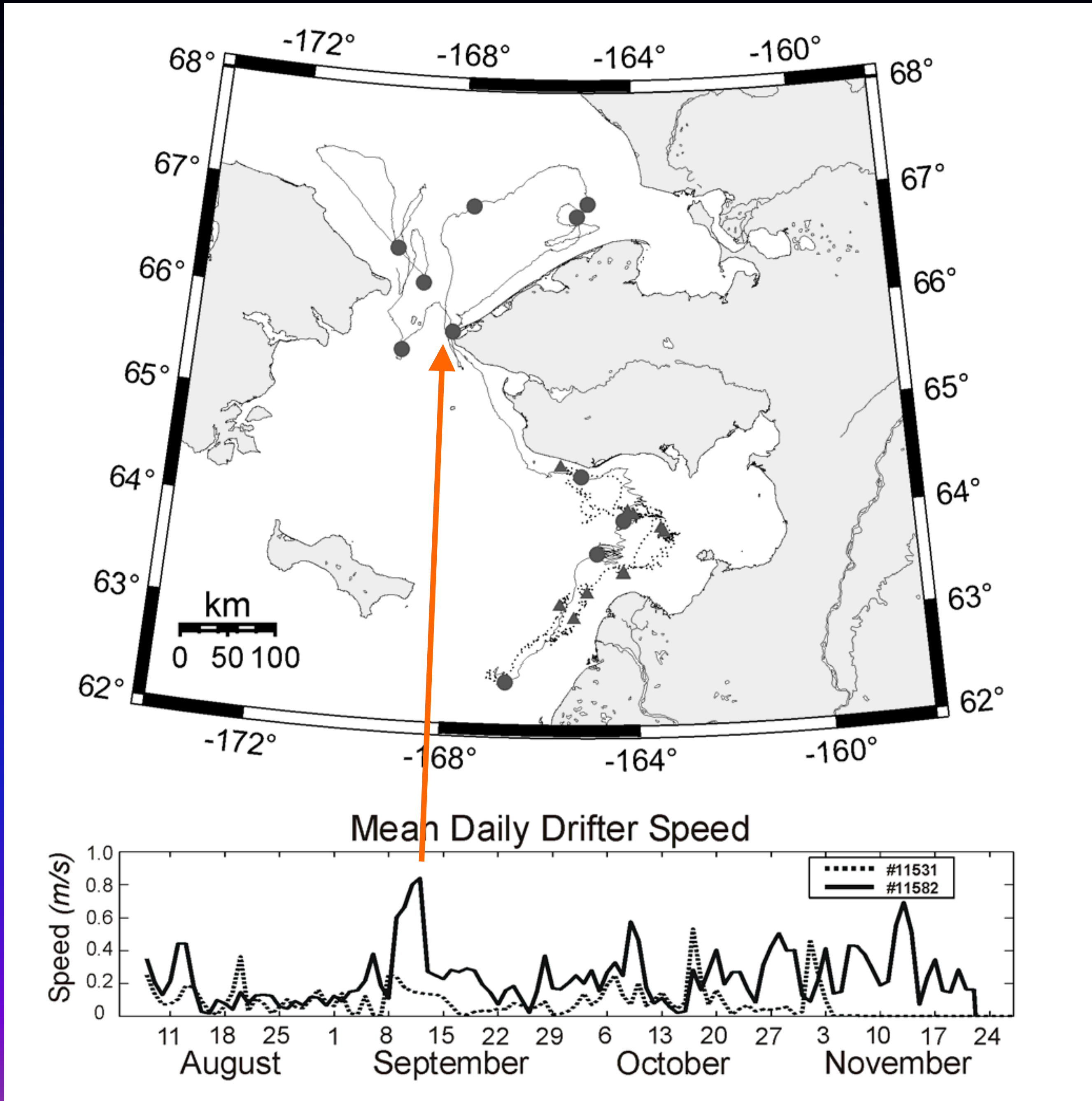
5th – 7th July 2003



Chlorophyll from SeaWifs Satellite

from NASA/Goddard Space Flight Center and Orbimage

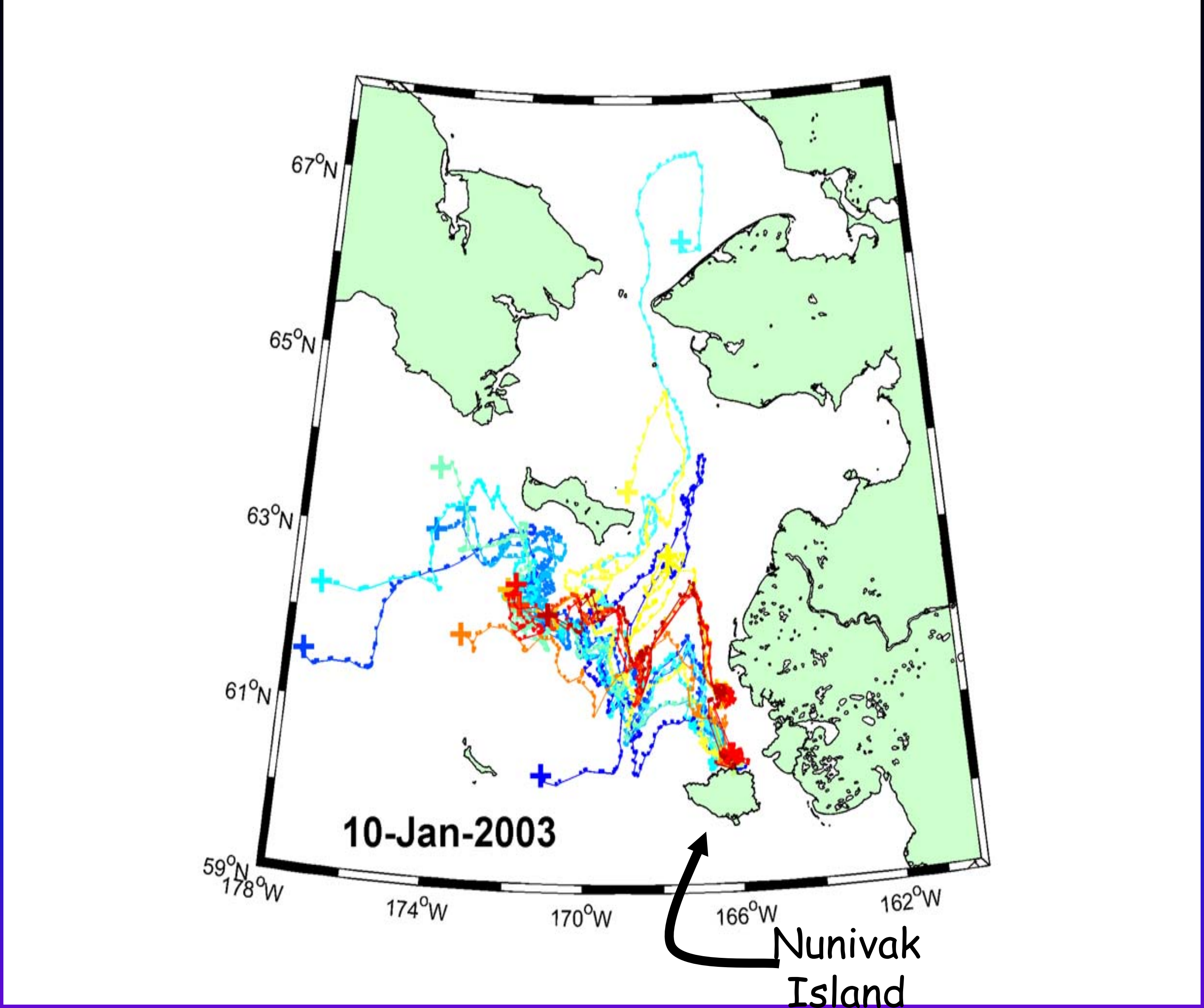
One oceanographer's meat is another oceanographer's poison



2001 Drifters (Aug. – Nov.)

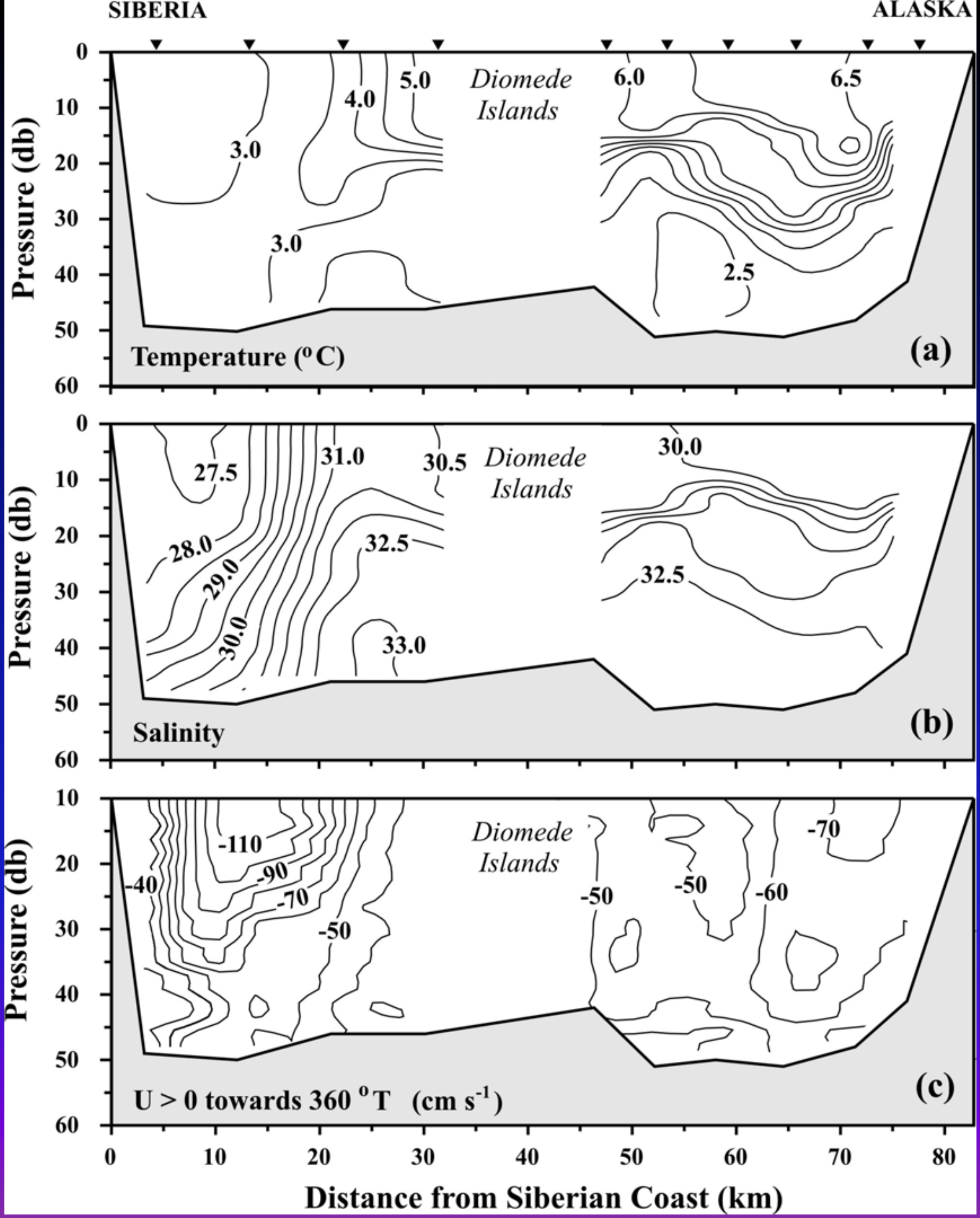
1. Runoff advected northward in the coastal current in summer/early fall.

2. reversals and mixing in the northern Bering/southern Chukchi in fall.



2002 Drifters (Sept – Nov.)

1. Cross-shore spreading on central shelf in fall.
2. Possibly mixes with Anadyr inflow to dilute the western channel?
3. Sets BSW properties

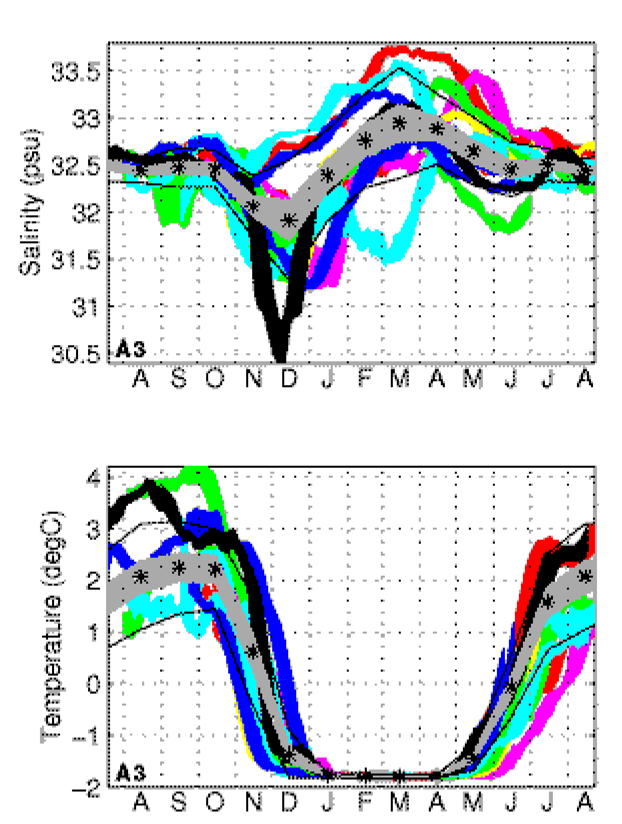


September 21, 1993.

What is probably atypical, but most likely to occur in fall through early winter under northerly winds.

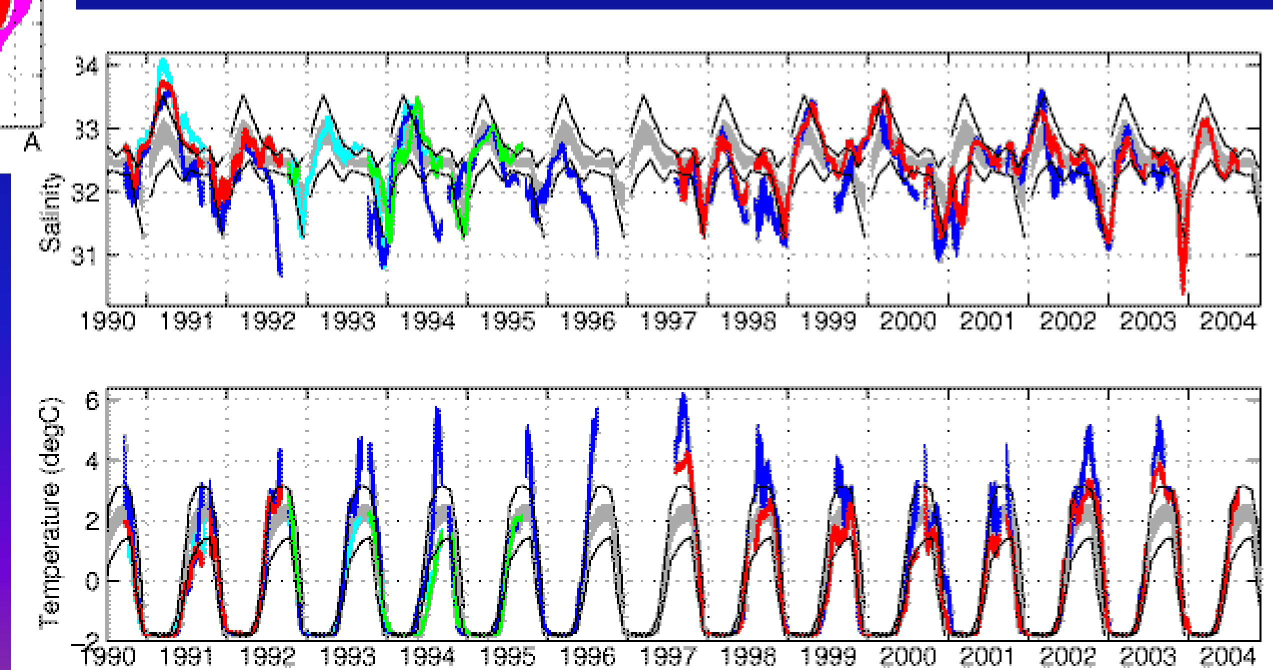
"Downwelling" response in western channel & "upwelling" response in eastern channel.

(Weingartner et al., 1999)

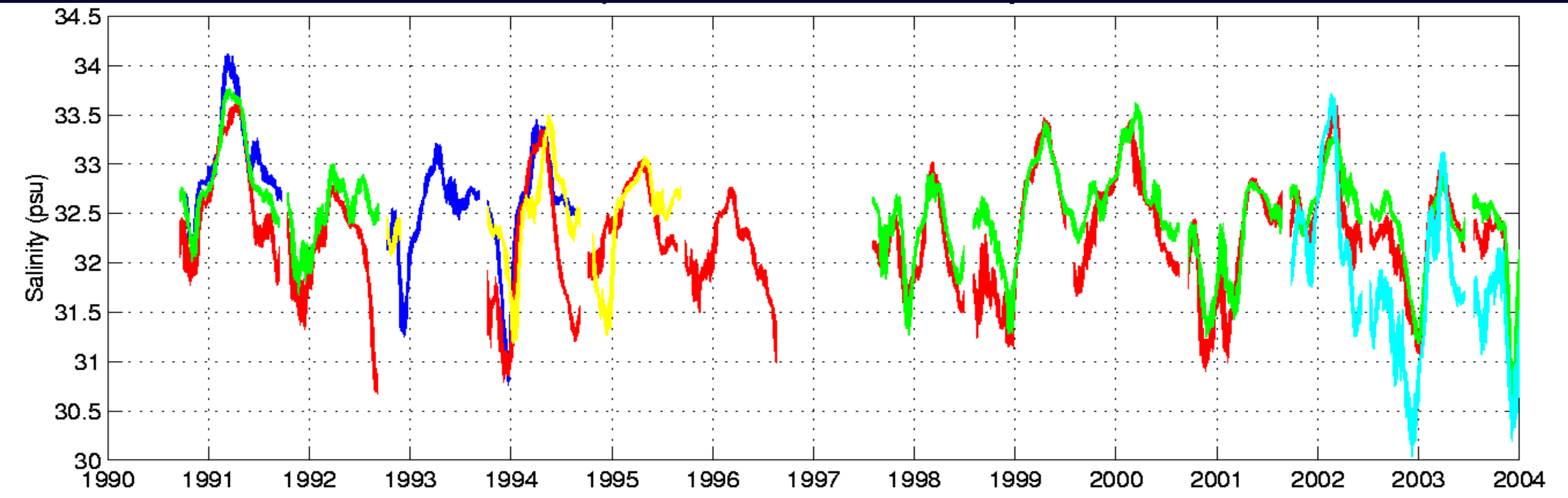


A monthly temperature-salinity climatology for Bering Strait

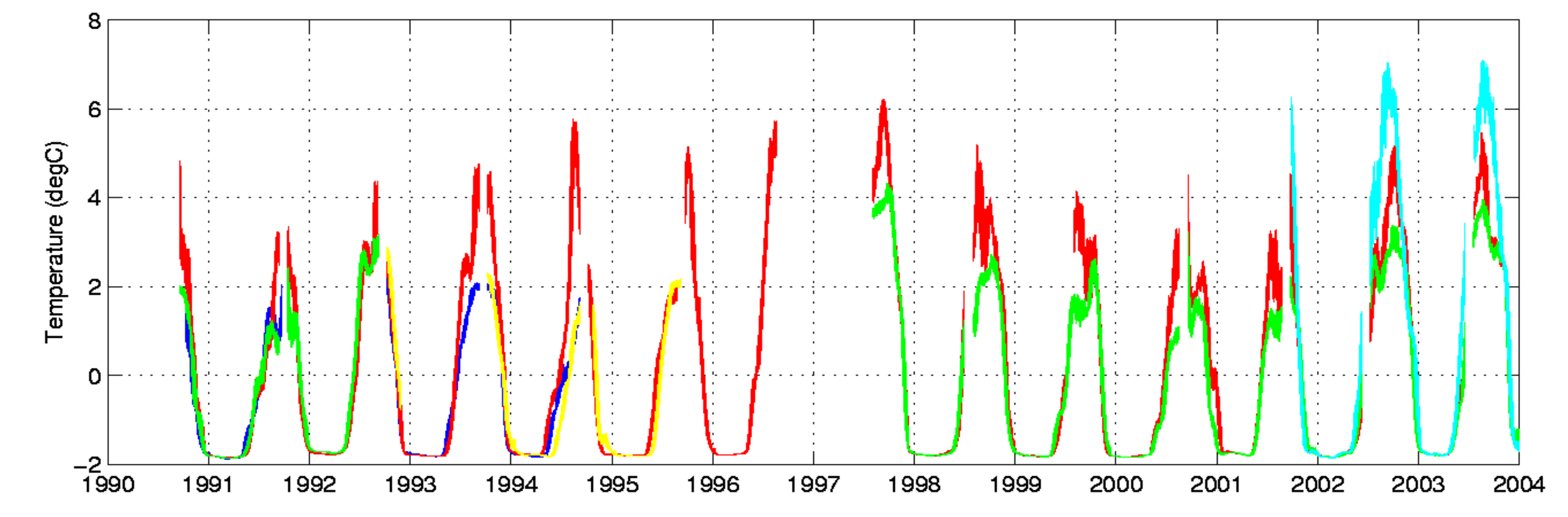
(Woodgate et al., 2005)

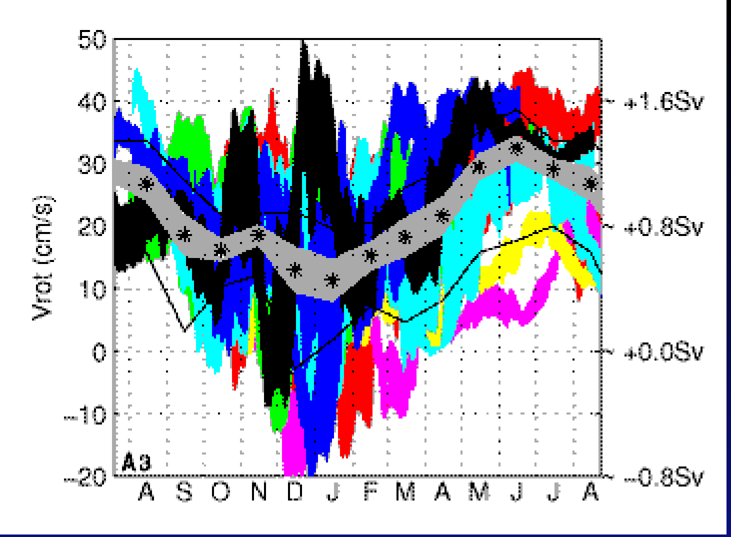


Salinity and Temperature from the Bering Strait



Western Ch (A1) **North BS (A3 A3')** **Eastern Ch (A2)** **Alaskan Coast (A4)**

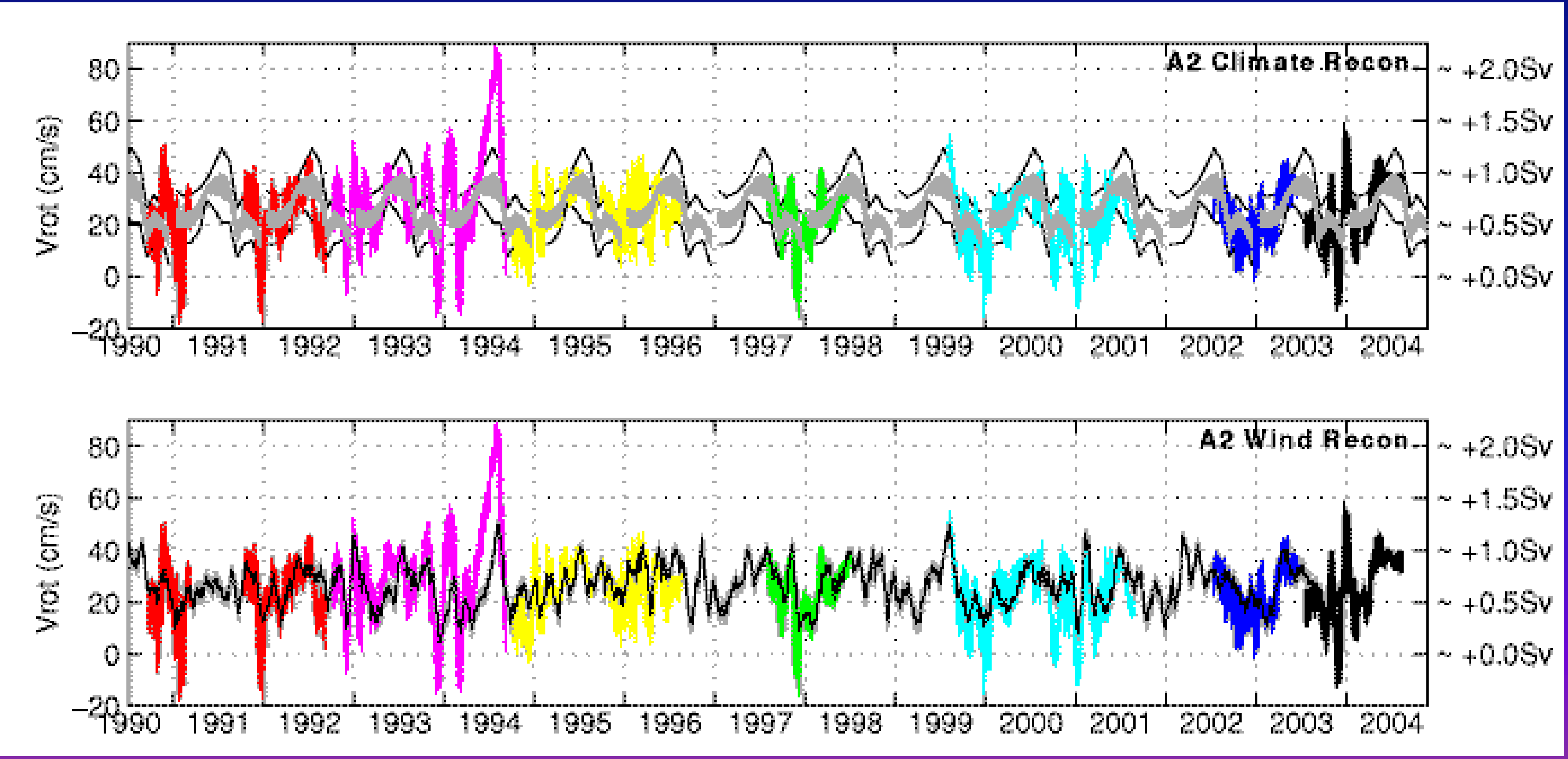


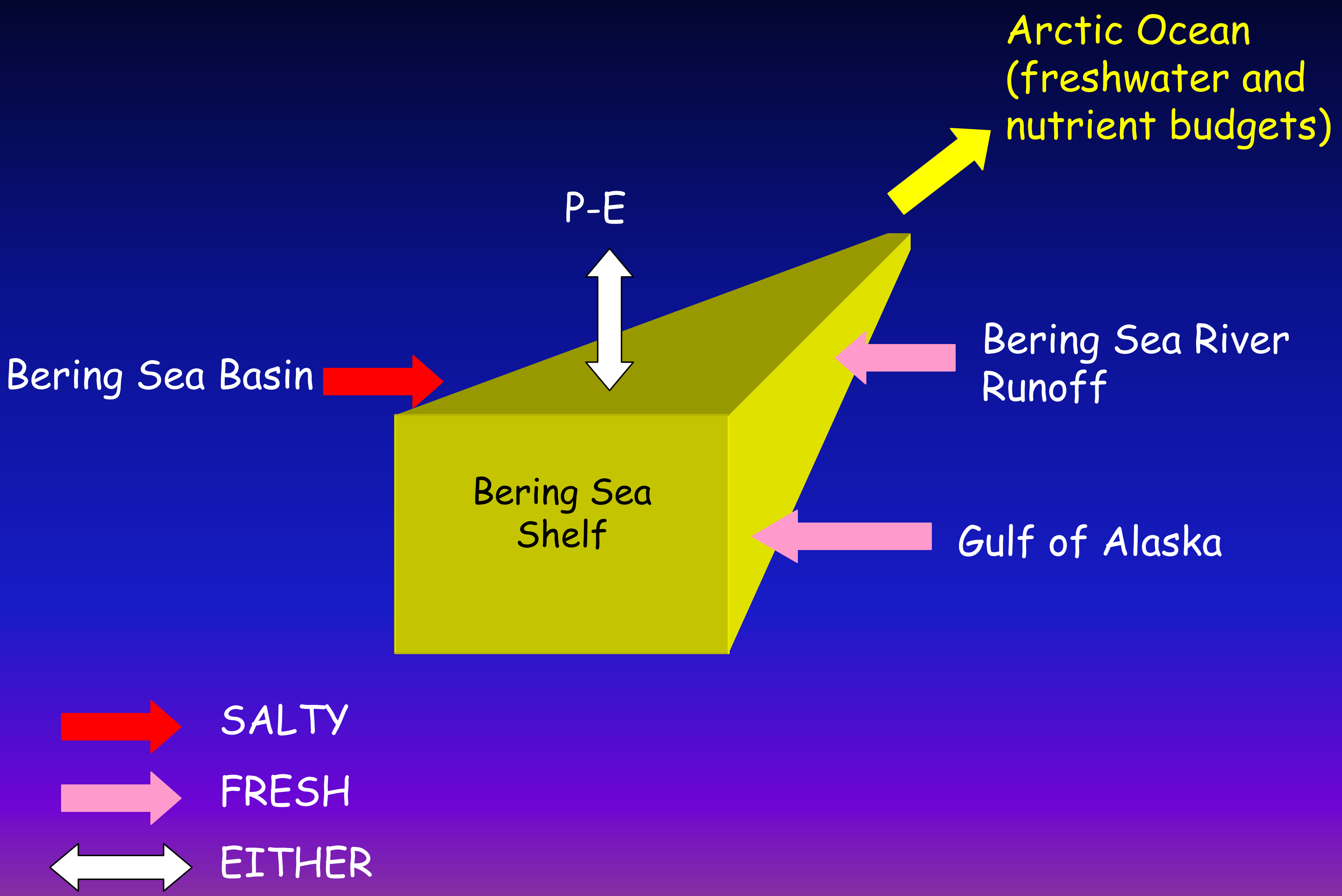


Reconstructing the velocity field

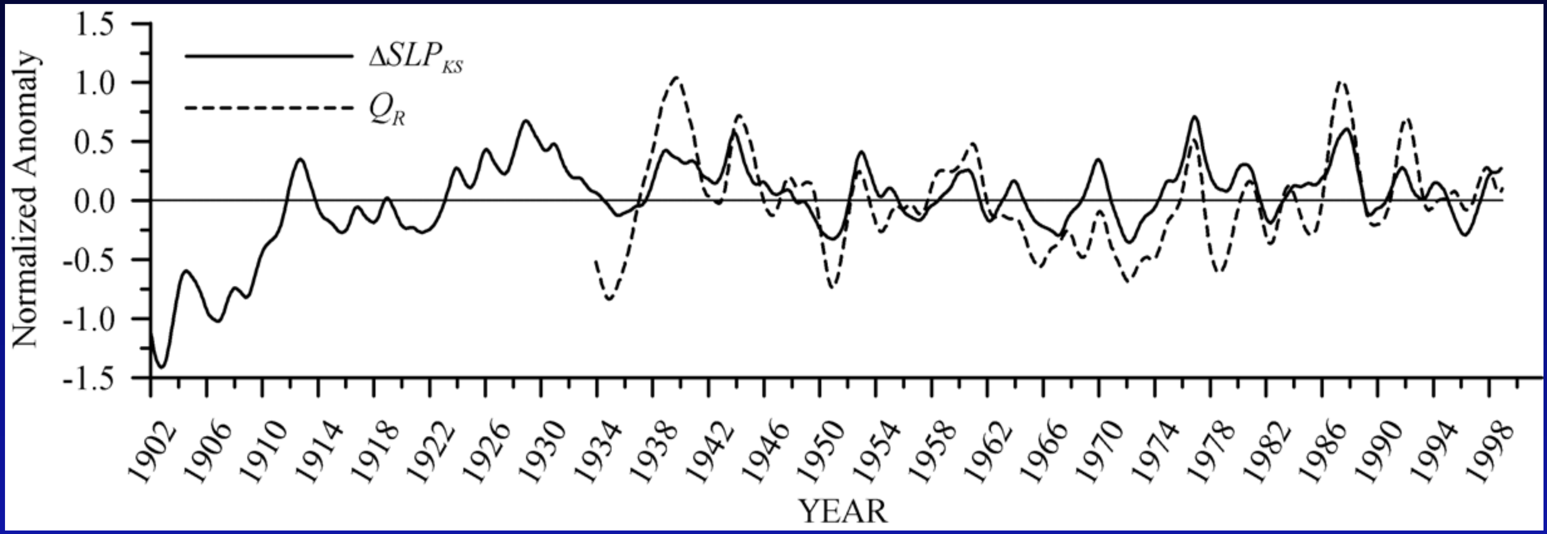
(Woodgate et al., 2005)

NCEP WINDS ARE REASONABLE PROXY FOR VELOCITY – WITH EXCEPTIONS




Arctic Ocean
(freshwater and
nutrient budgets)
P-E
Bering Sea Basin
Bering Sea River
Runoff
Bering Sea
Shelf
Gulf of Alaska
SALTY
FRESH
EITHER

A Proxy for Freshwater Transport Anomalies from the Gulf of Alaska shelf

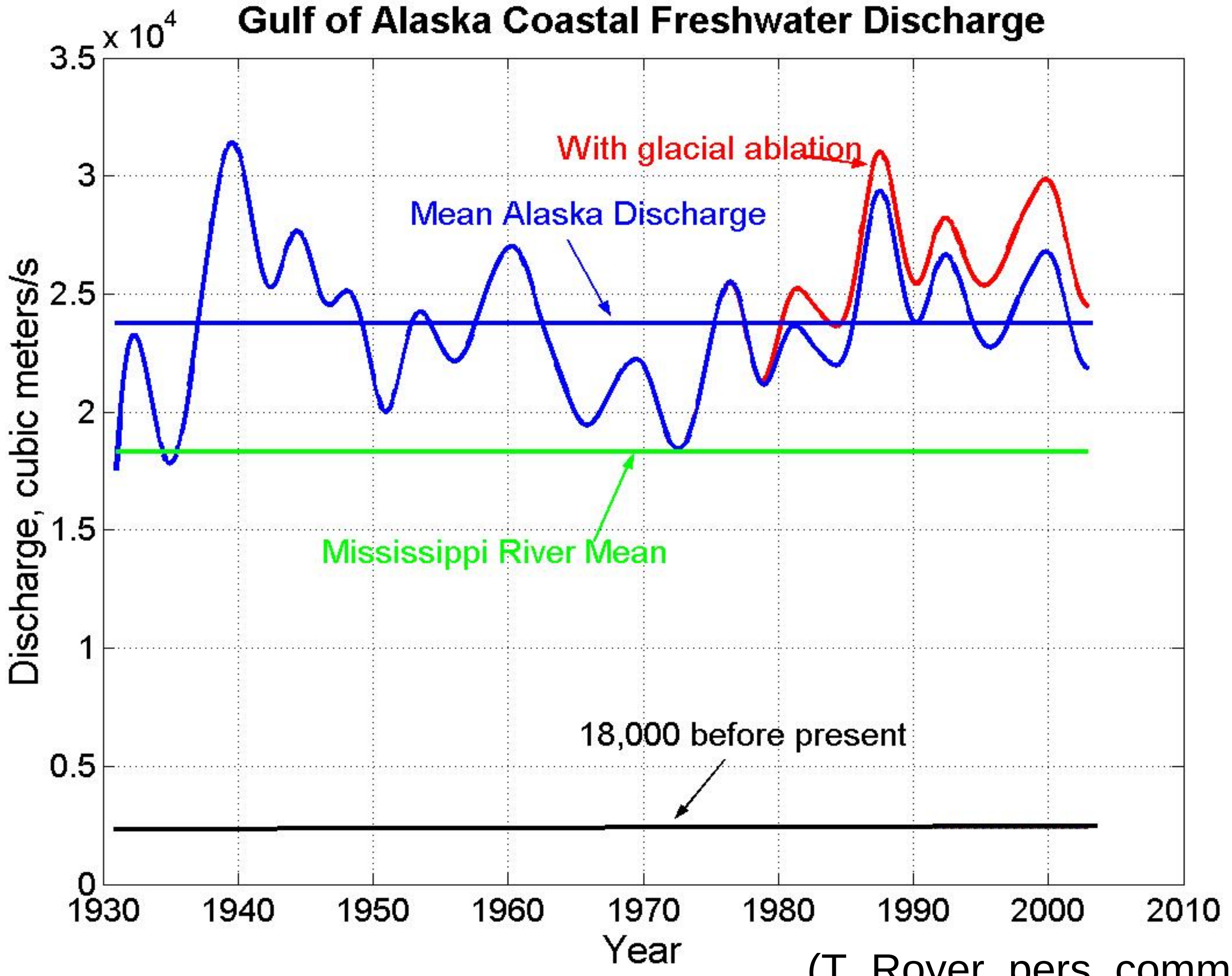


Normalized anomalies of Gulf of Alaska runoff (Q_R 1930 – 2000; dashed line) and the sea level pressure difference between Ketchikan and Seward *(ΔSLP_{KS}; solid line*).

Q_R correlated with ACC mass and freshwater transports and freshwater content. Most of this runoff likely enters the Bering Sea (Weingartner et al., 2005).

PDO explains ~<15% of variance.

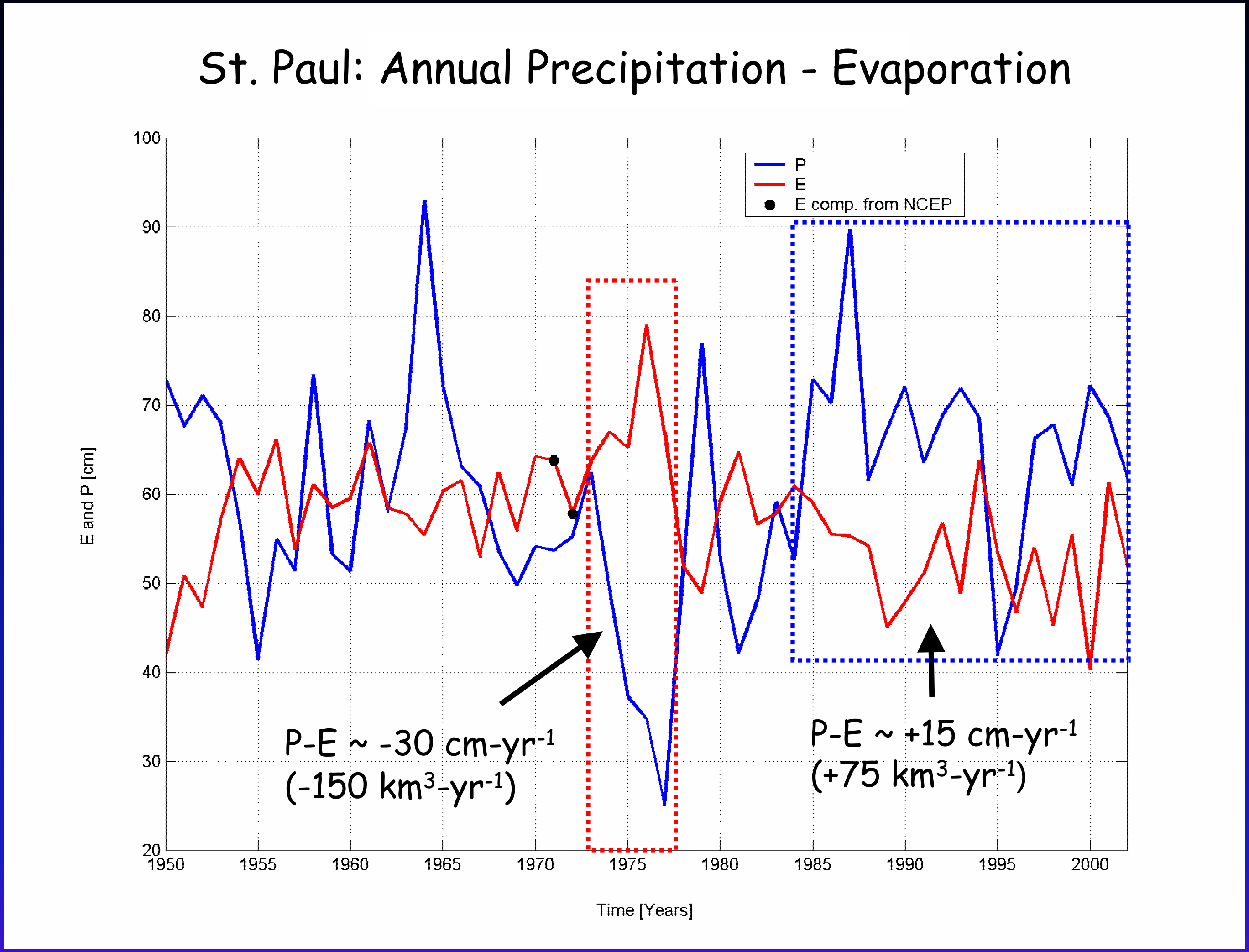
1970s – low runoff, increasing since and through 2004 + increased glacial runoff.



(T. Royer, pers. comm.)

Recent increases in glacial ablation (Arendt, et al. 2002) have decreased the salinity, increased the transports, and temperatures.

0 – 75 dbar Salinity Change: -0.03/decade ~-0.1 in 35 years.



Mean Annual P-E ~50 km^3 yr^{-1} (A freshwater source)

River Inflows + P-E:

Yukon: ~200 $km^3\ yr^{-1}$

Other Alaskan: ~90 $km^3\ yr^{-1}$

Anadyr: ~41 $km^3\ yr^{-1}$

P-E: ~50 $km^3\ yr^{-1}$

Total ~330 $km^3\ yr^{-1}$

No Long-term Trends Apparent in river discharge (but gappy time series).

Gulf of Alaska

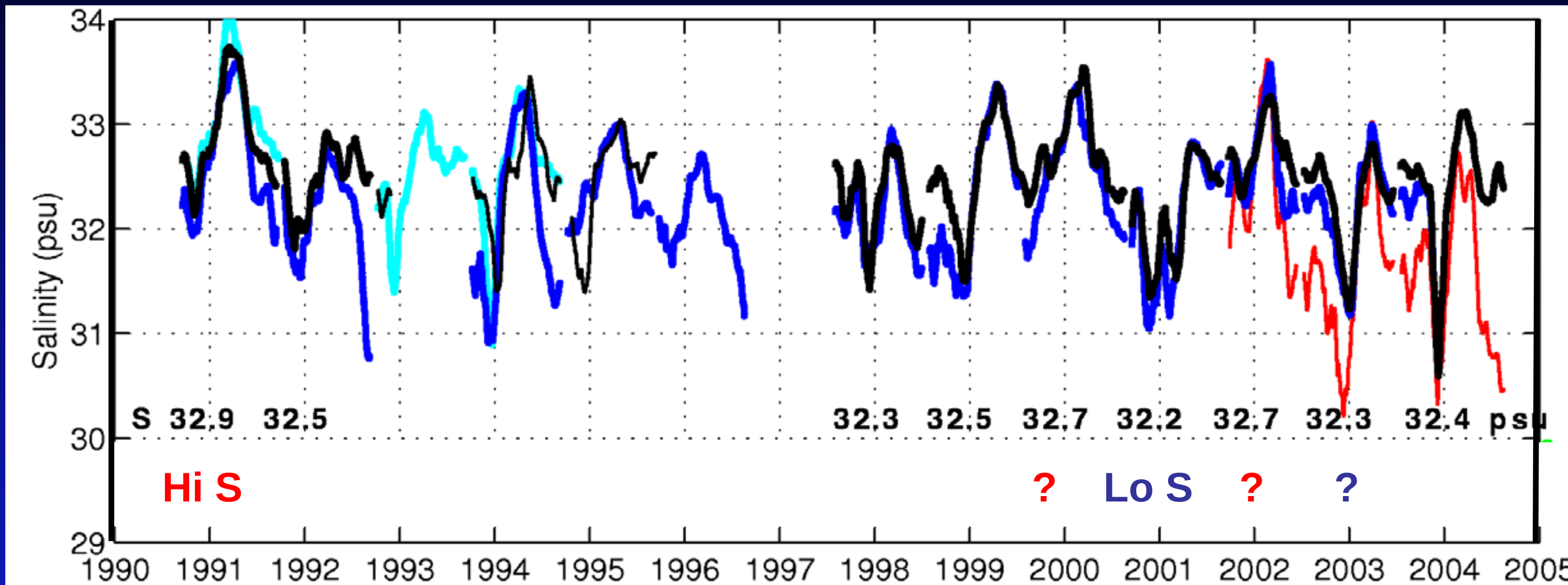
Mean annual integrated discharge: >1000 $km^3\ yr^{-1}$ with most entering the Bering Sea shelf.

Assume 330 & 500 $km^3\ yr^{-1}$.

Salinity of the Bering Sea onshelf flux is 33.4 – 33.7

(upwelling depths: from 120 – 220 m)

A 14-year mean from the moorings?



14–year mean salinity 32.5 ± 0.3 psu (AC89=32.5psu!!)

30 day smoothed salinity
9m above bottom at
A1= West Channel
A2=East Channel
A3= North Bering Strait
(combination of A1&A2)
A4=Alaskan Coastal Current

BUT this is near-bottom, central strait

What about
- the Alaskan Coastal Current??
- stratification of the water column??
- ice??

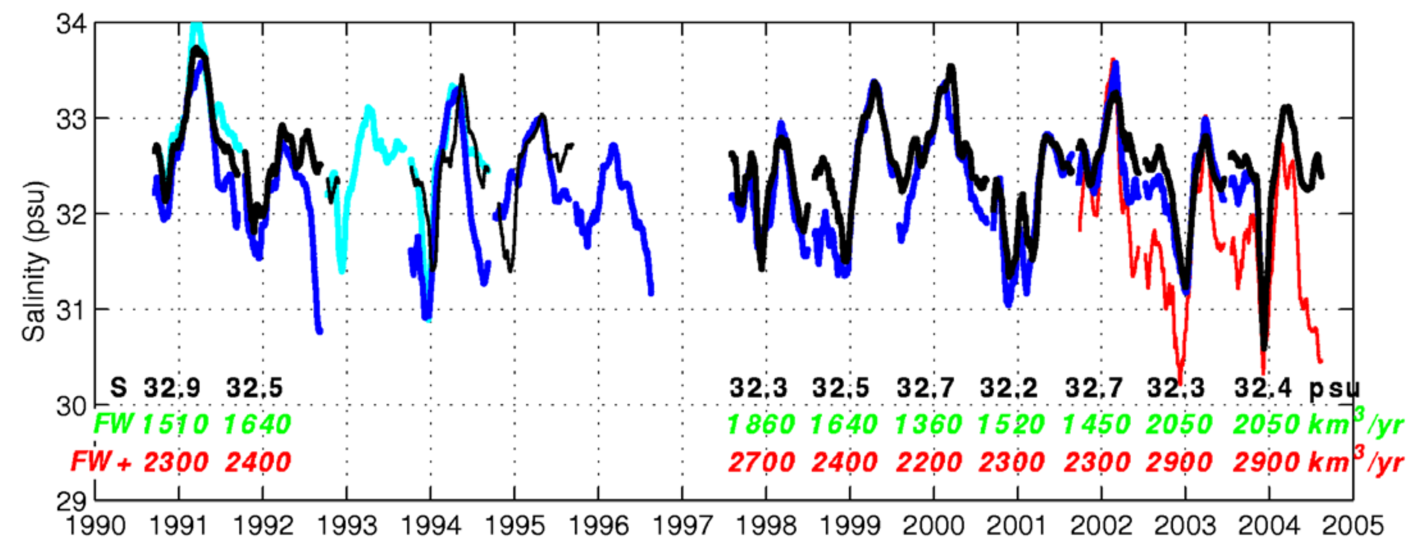
The Bering Strait Freshwater Flux

(Woodgate and Aagaard, 2005)

S = near bottom annual mean salinity

FW = freshwater flux assuming no horizontal or vertical stratification

FW+ = revised flux, including estimate of Alaskan Coastal Current and seasonal stratification



Annual Mean Freshwater Flux
~ 2500 ± 300 km3/yr
including
~ 400 km³/yr (Alaskan Coastal Current)
~ 400 km³/yr (stratification and ice)

Interannual variability (from near bottom measurements) smaller than errors, although possible freshening since 2003-2004

Why does the Bering Strait Matter?

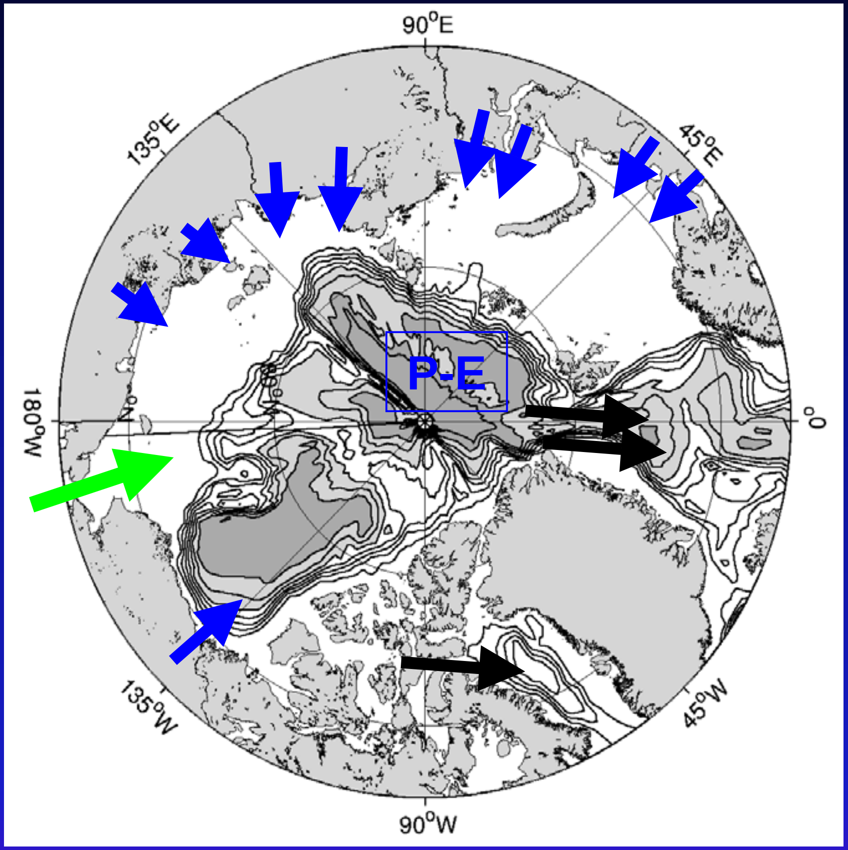
Aagaard & Carmack, 1989 (AC89)

BERING STRAIT
~ 0.8 Sv
(moorings)

~32.5 psu
(summer 1960s/70s)

Freshwater Flux relative to 34.8 psu ~ 1670 km³/yr

Woodgate & Aagaard (2005): ~ 2500 ± 300 km³/yr



OTHER INPUTS
Runoff = 3300 km³/yr
P-E = 900 km³/yr
+ ...

OTHER OUTPUTS
Fram Strait water = 820 km³/yr
Fram Strait ice = 2790 km³/yr
Canadian Archipelago = 920 km³/yr
+ ...

For the future

What is the variability in the mass, salt and heat fluxes in the western channel? (RUSALCA EFFORT)

What are the contributions of the boundary currents to Bering Strait mass and freshwater transport variations?

Since 1990 we have not seen the decadal scale salinity variations likely to occur in Bering Strait.


The End


~~The End~~
The Dawn