# What's new with the Bering Strait moorings?

Quick reminder of (physics) basics
RUSALCA 2010 cruise
The time-series so far
Stratification in TS and Vel
Where next?

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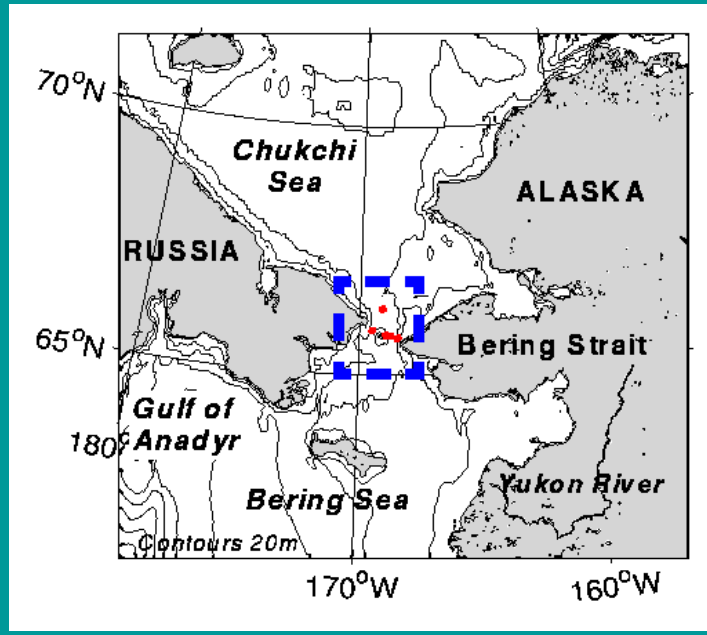
Elena Bondareva, Mikhail Kulakov, Valerian Golavsky (AARI)

*Funding from NOAA-RUSALCA and NSF-OPP (IPY and AON projects)*

*Thanks to Jim Johnson, David Leech, Seth Danielson, Wendy Ermold, Mike Schmidt and the crews of the Alpha Helix, Laurier, Sever, Lavrentiev and Khromov*

# Bering Strait: Pacific-Arctic Gateway




**~ 85 km wide**

**~ 50 m deep**

**-divided into 2 channels by the Diomede Islands**

**- split by the US-Russian border**

**-ice covered from ~ January to April**

**- annual mean northward flow ~0.8 Sv**

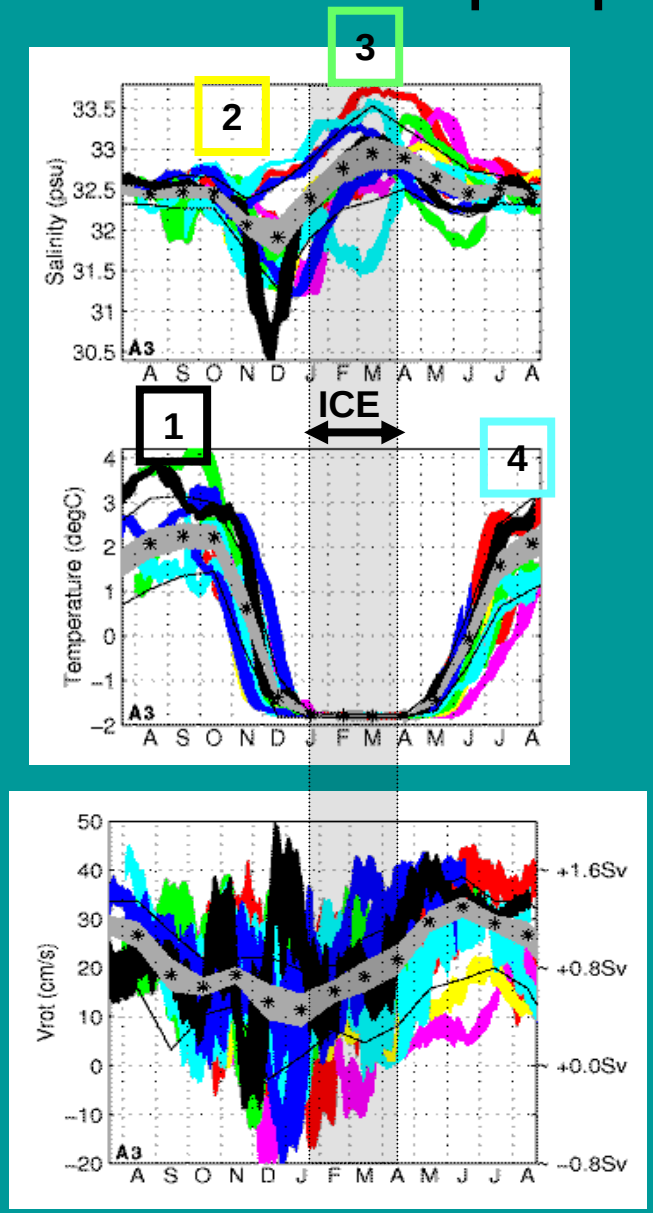
# Seasonal cycle in water properties (Woodgate et al, 2005)

**SALINITY**
31.9 to 33 psu

**TEMPERATURE**
-1.8 to 2.3 deg C

**TRANSPORT**
0.4 to 1.2 Sv

*(30 day means)*




**WHY CARE?**

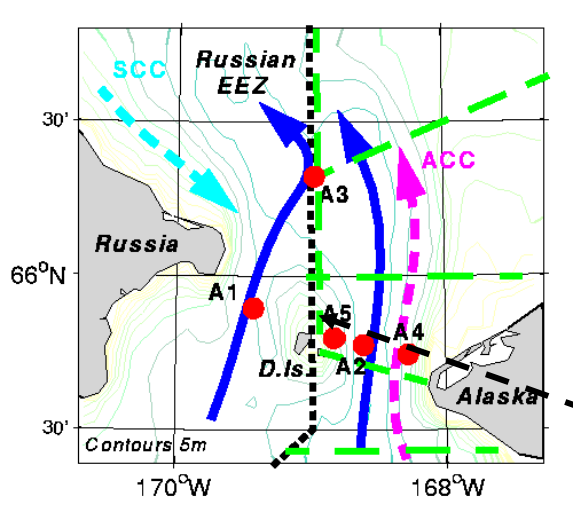
**Seasonally varying input to the Arctic Ocean**

- temperature
- salinity
-volume

- equilibrium depth (~50m in summer ~120m in winter)

-nutrient loading

# Bering Strait Basics




- annual mean ~0.8 Sv northwards
- monthly means ~ 0.3 to 1.3 Sv
- weekly means: -2 Sv to +3 Sv
- hourly flow up to 100 cm/s
- Alaskan Coastal Current 50-100 cm/s stronger
- rectilinear flow; weak tides

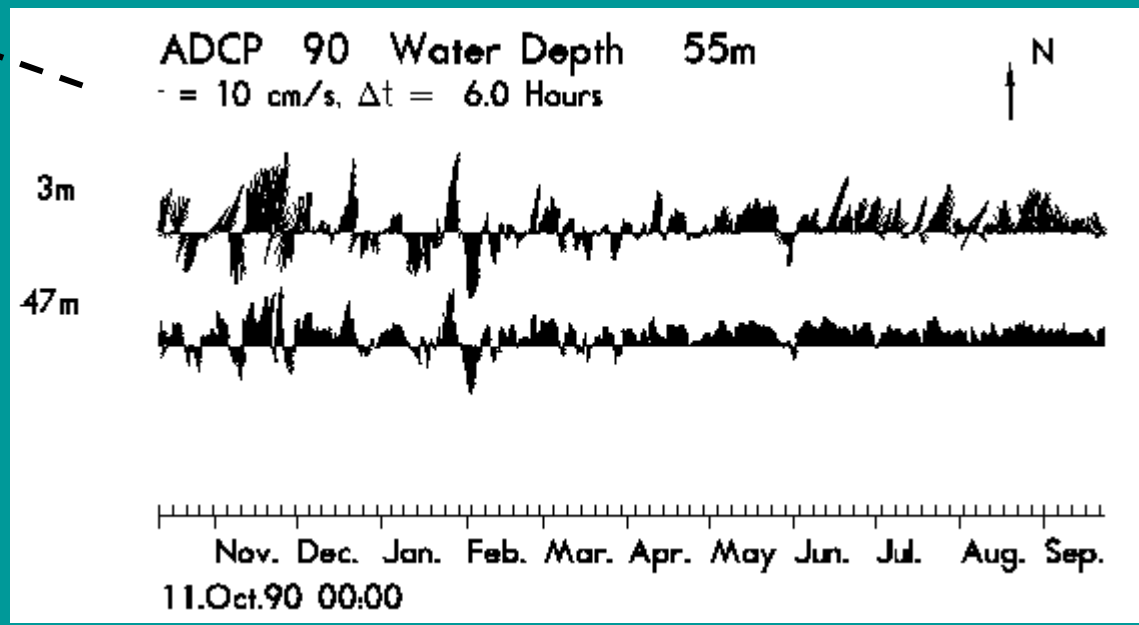
(Roach et al, 1995; Woodgate et al, 2005)

- away from boundarys, flow dominantly **barotropic**

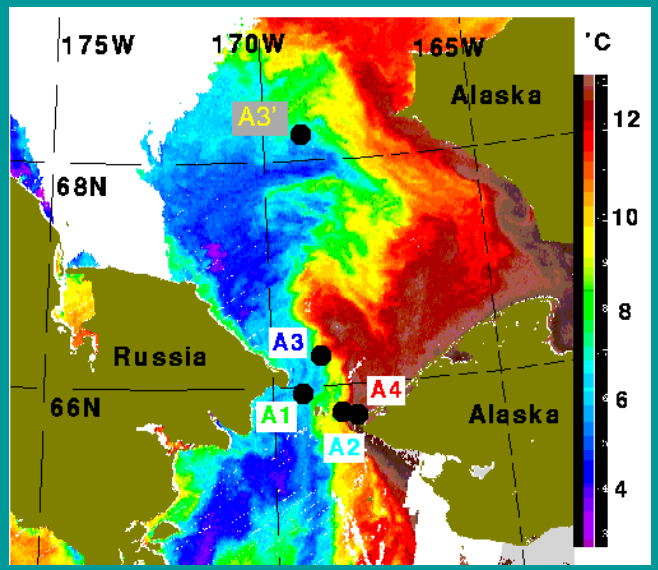
(Roach et al, 1995)

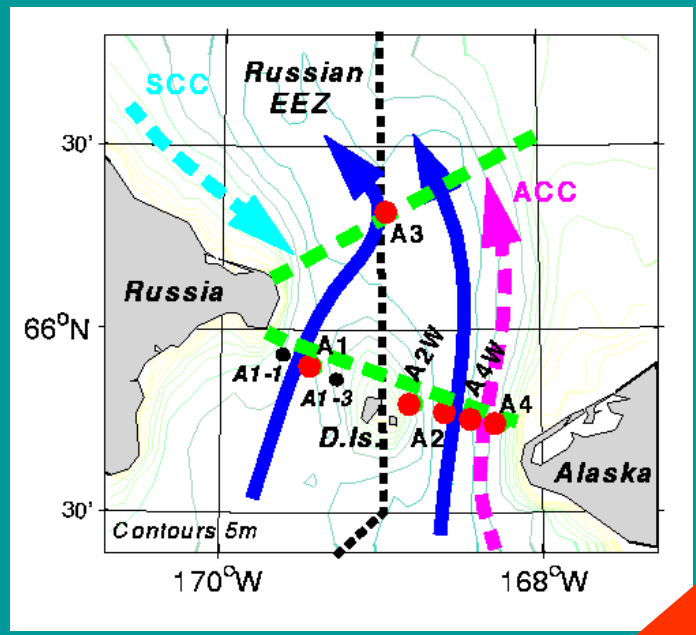
- flow in east and west channel **highly correlated**

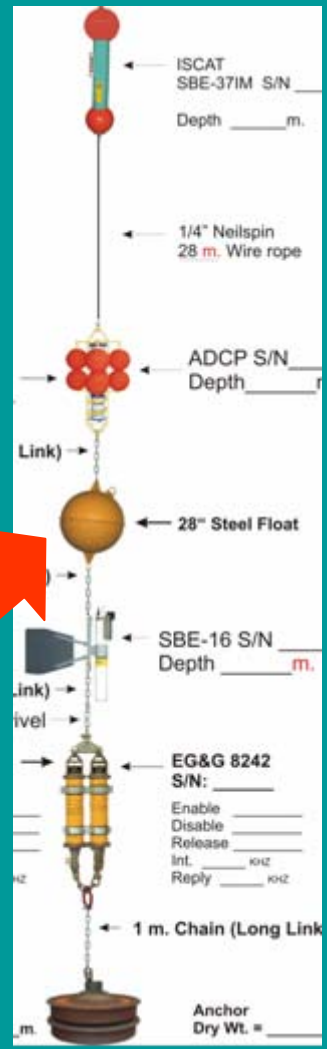
(0.95, Woodgate et al, 2005, DSR)



# Bering Strait Moorings




**Your instrument here!!!!**

**Since 1990**

**1-4 near–bottom moorings**

**Since 2007**

***(International Polar Year)***

**8 moorings with upper and lower sensors**

**Now also with**

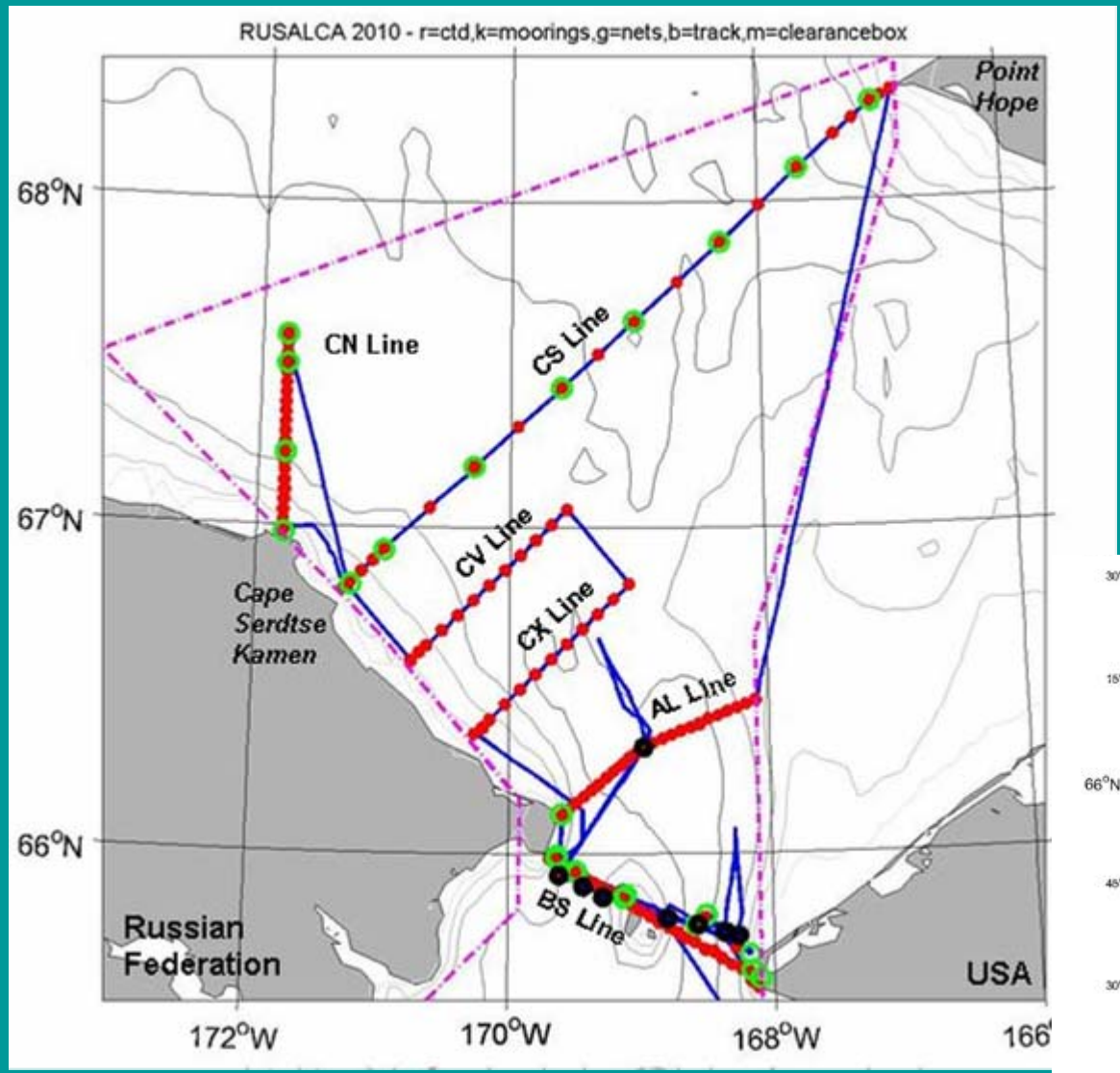
**- Whale Recorders – Kate Stafford and Carter Esch**

**- pH and pCO2 sensors – coming 2011, Kelly Falkner**

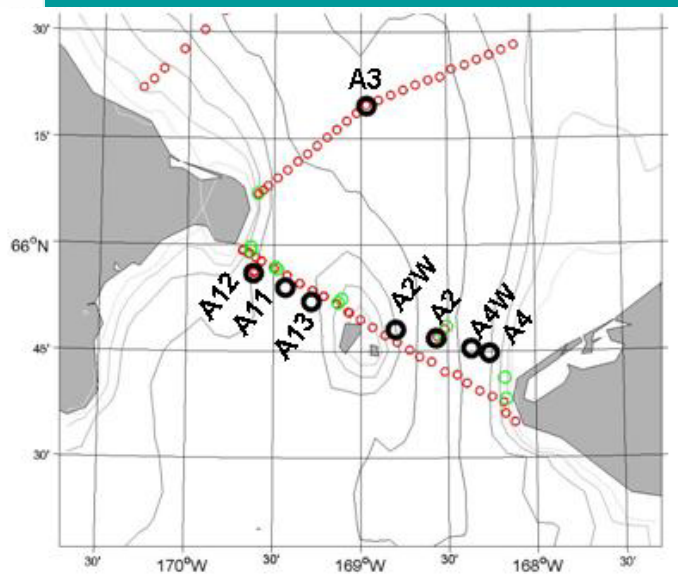
**Annual CTD sections**

# RUSALCA 2010 Khromov Cruise

**31st July – 11th Aug 2010**
**Nome to Nome**

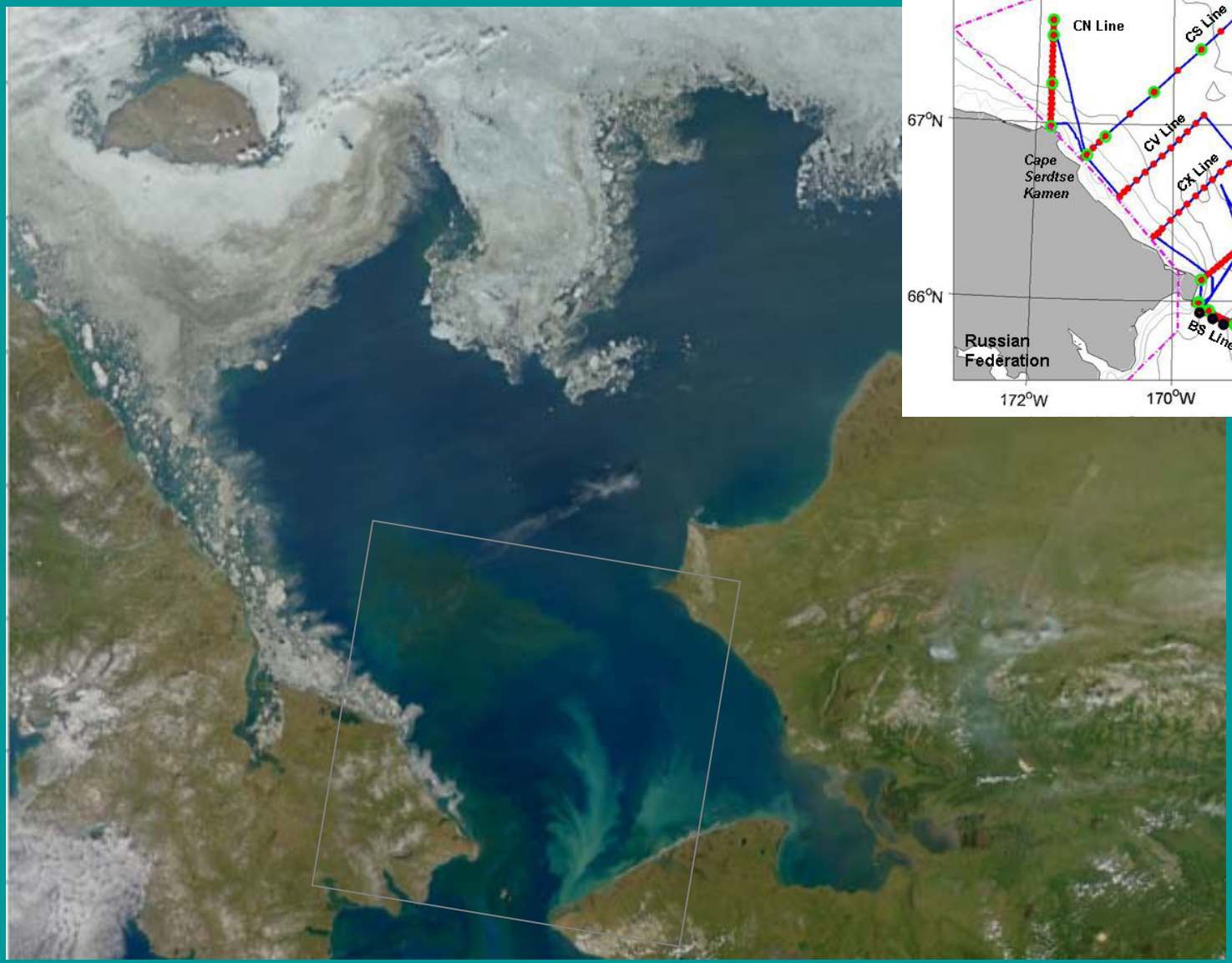


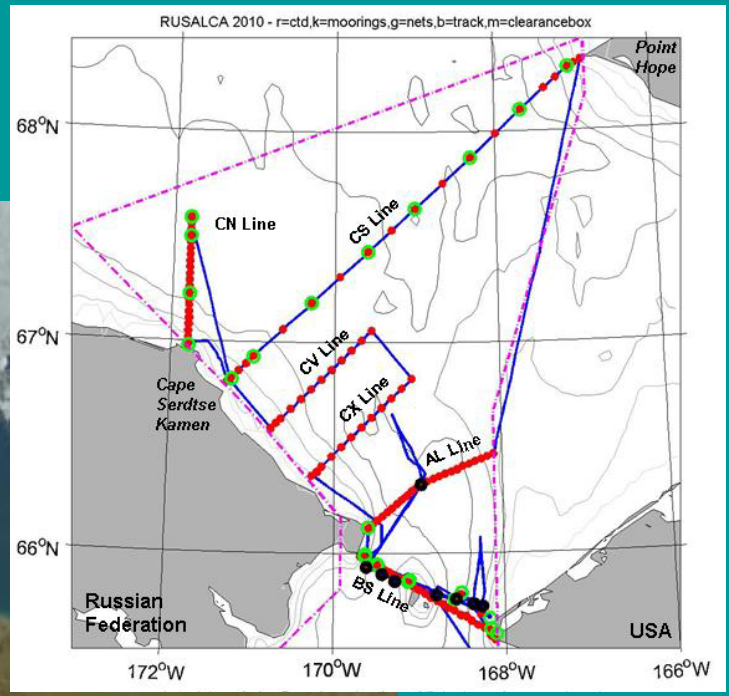

*Mauve = clearance box*
*Blue = ship track*
*Black dots = moorings*
*Red dots = CTDS*
*Green dots = nets*
*+ 4 Primary productivity stations*



# 8th July 2010 Ocean Color Image

(http://oceancolor.gsfc.nasa.gov)
(found by Bill Crawford)

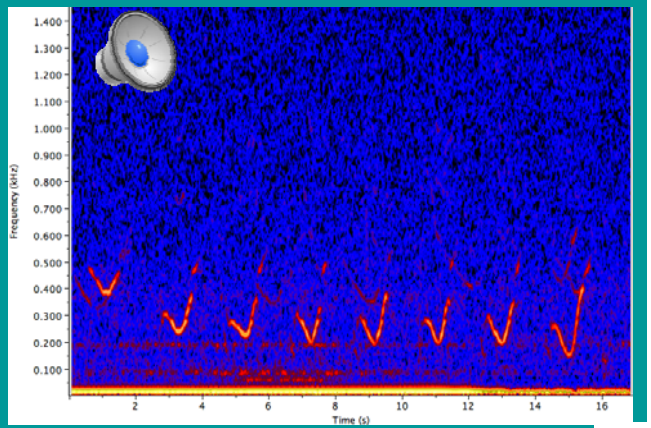





**RUSALCA 2010**
**31st July**
**– 11th Aug 2010**

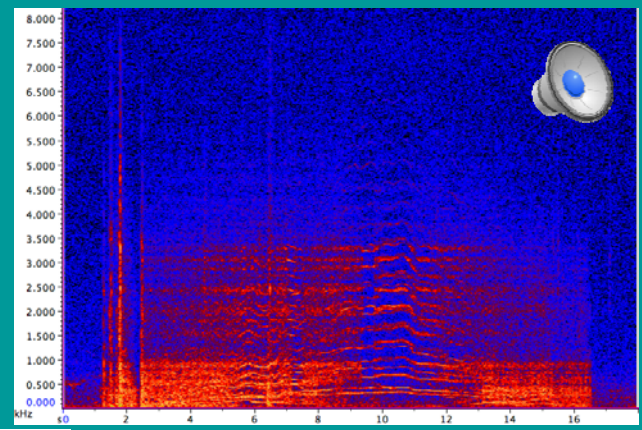
# Marine Mammal Observations

Kate Stafford (University of Washington)
Carter Esch (WHOI, PhD Student)




**Moored Hydrophones at mid-strait moorings**

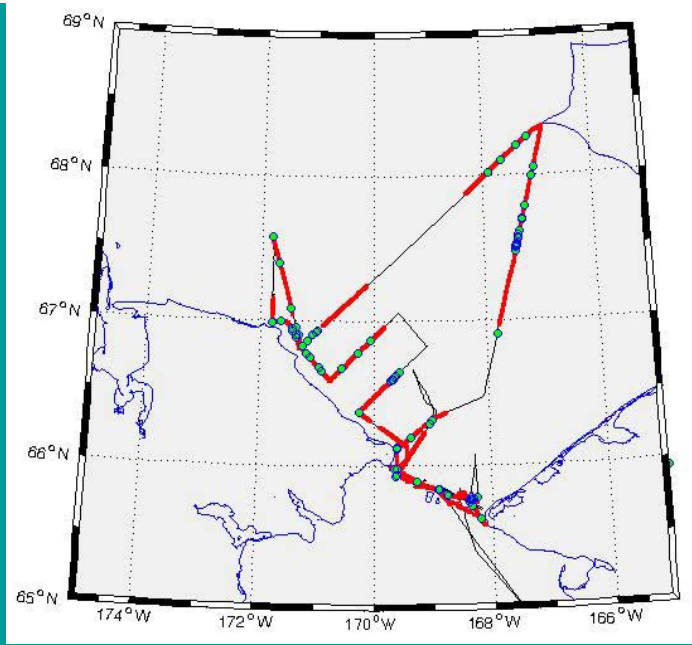
- spectrograms of bowheads (left) and ice noise (right)
- to be analyzed with mooring data




**Bridge Observations**

- to be analyzed with CTD data

black= track,
red=observation period
*=sighting

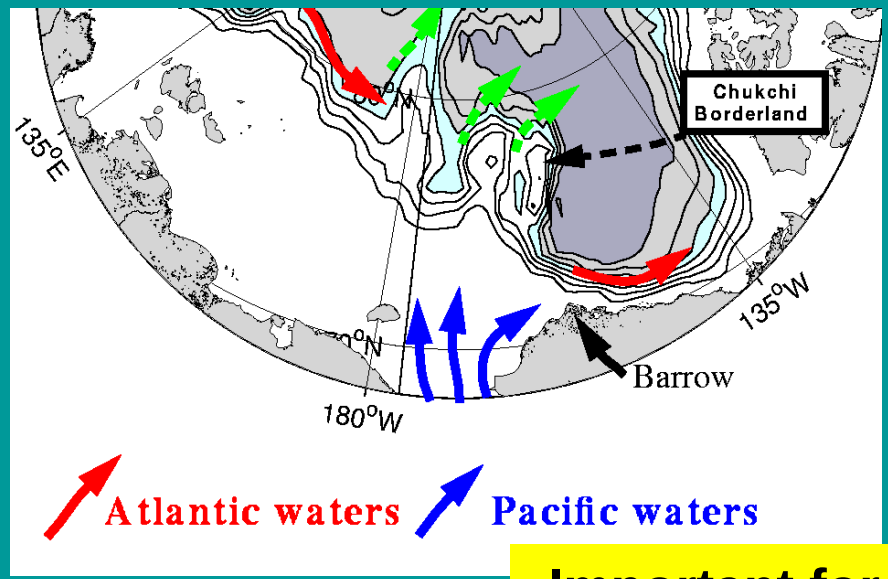



**Greater density of species and animals seen in Western Bering Strait**

Greater productivity of Anadyr water = more marine mammals?
→Consider passive acoustic monitoring here in the future?

# The role of Pacific waters in the Arctic

**Important for Marine Life**
*most nutrient-rich waters entering the Arctic*
*(Walsh et al, 1989)*



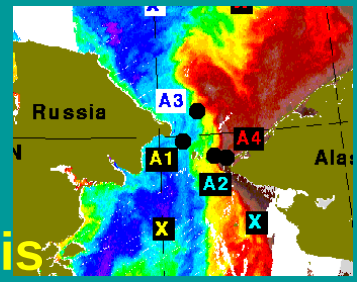

**Significant part of Arctic Freshwater Budget**
*~ 1/3rd of Arctic freshwater input*
*(Wijffels et al, 1992; Aagaard & Carmack, 1989; Woodgate & Aagaard, 2005)*

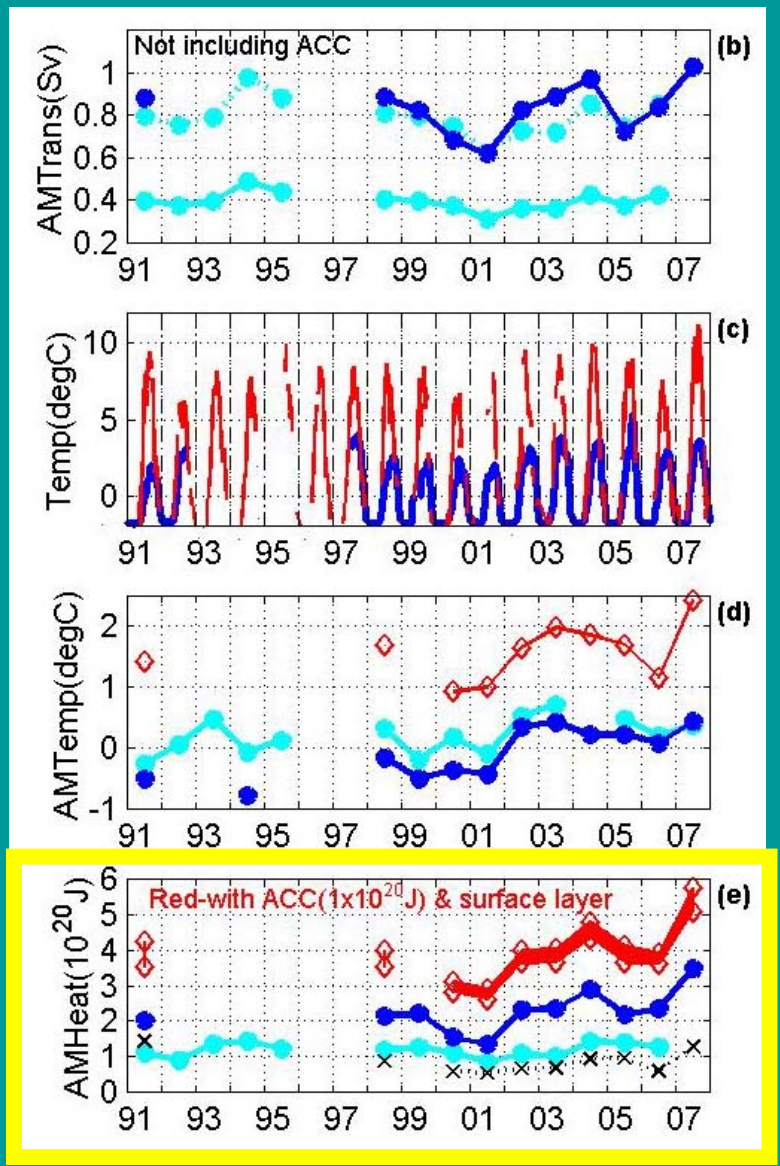
**Implicated in the seasonal melt-back of ice**
*In summer, source of near-surface heat to the Arctic*
*(Paquette & Bourke, 1981; Ahlnäs & Garrison, 1984)*

**Important for Arctic Stratification**
*In winter, form a cold (halocline) layer, which insulating ice from warm Atlantic waters beneath*
*(Shimada et al, 2001, Steele et al, 2004)*

# Estimating Heat Flux

*Woodgate et al, 2010*




*Heat flux relative to -1.9deg C, Errors ~ 0.1 Sv, $10^{20}$J*

**2007 Bering Strait Heat is**
**5-6 x $10^{20}$ J/yr (20 TW)**
**which is:**

**- 2 x the 2001 Bering Strait heat**

**- could melt 2 x $10^6$ km$^2$ (2 MSK)**
**of 1m thick ice**
winter extent ~ 10 MSK
2006 Sept min ~ 6 MSK
2007 Sept min ~ 4 MSK

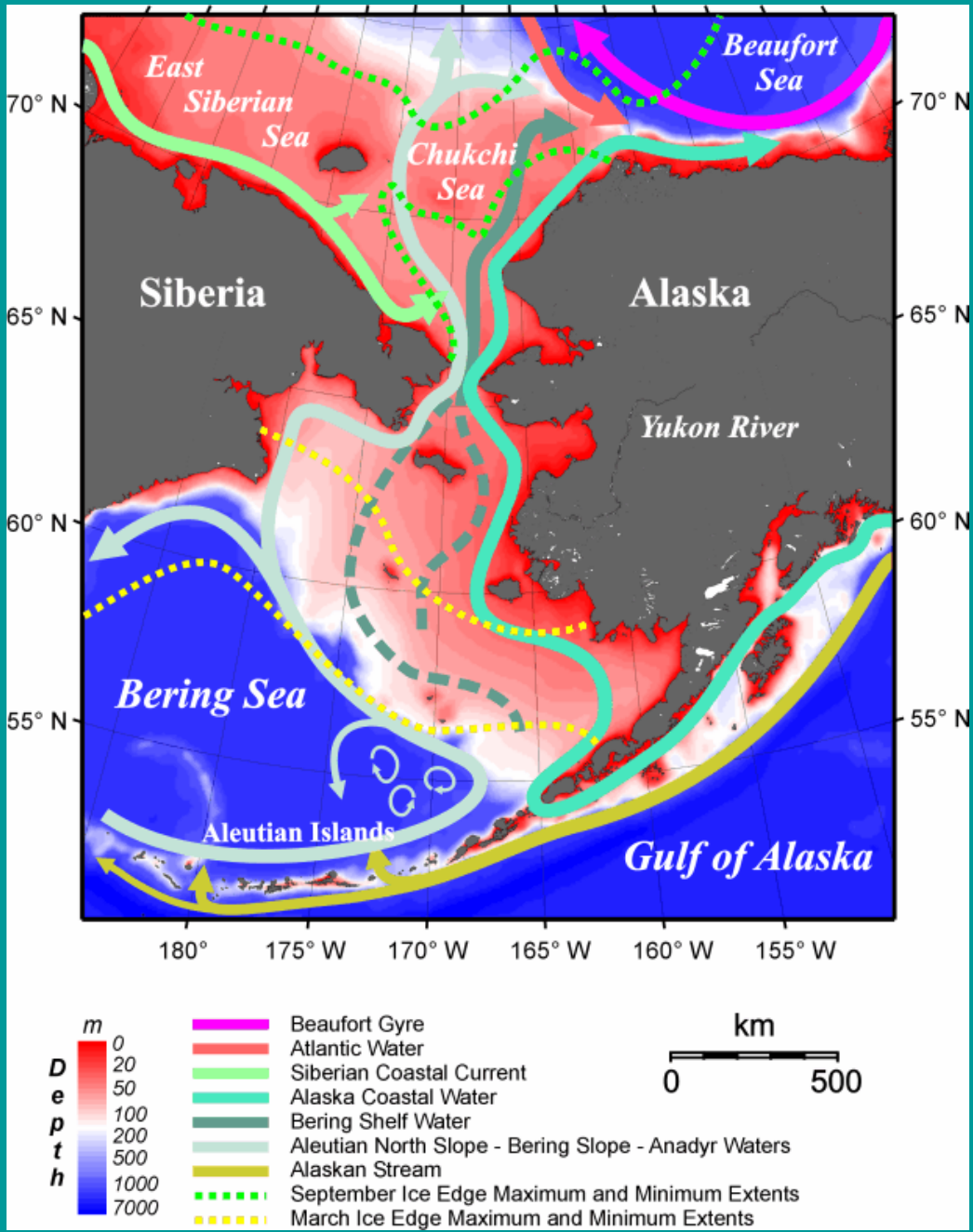
**- 4 W/m$^2$ over ½ the Arctic**
(ERA-40 -2 to + 10 W/m$^2$ *Serreze et al, 2007*)

**- greater than incoming solar into Chukchi**
~ 3 to 4.5 x $10^{20}$ J/yr (*data, B.Light*)

**- ~ 1/3$^{rd}$ of Fram Strait Heat**
~30-50TW net, (*Schauer et al, 2008*)

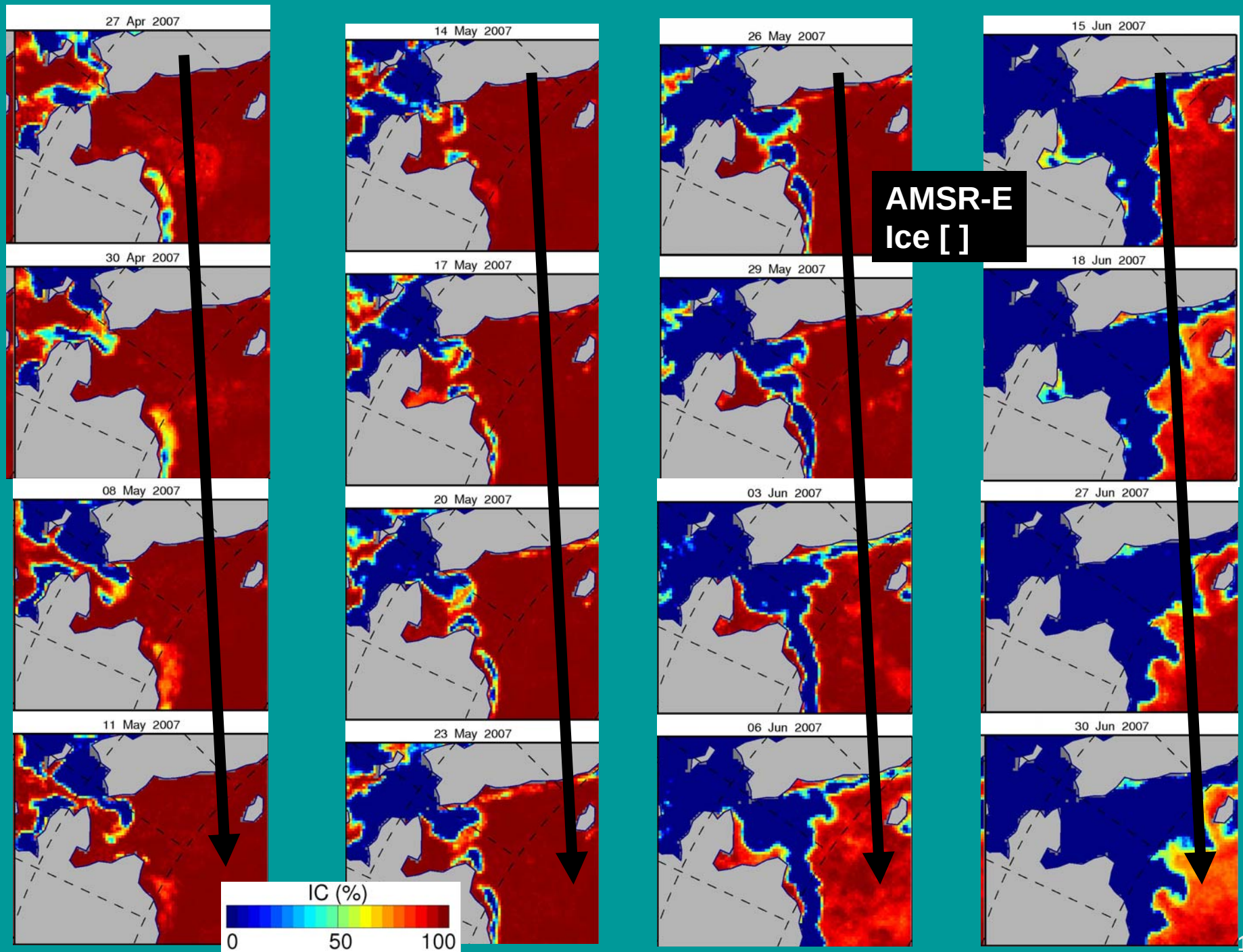
# Where does this heat go?

**3 topographically steered outflows from the Chukchi**
**- Barrow Canyon**
**- Central Channel**
**- Herald Valley**



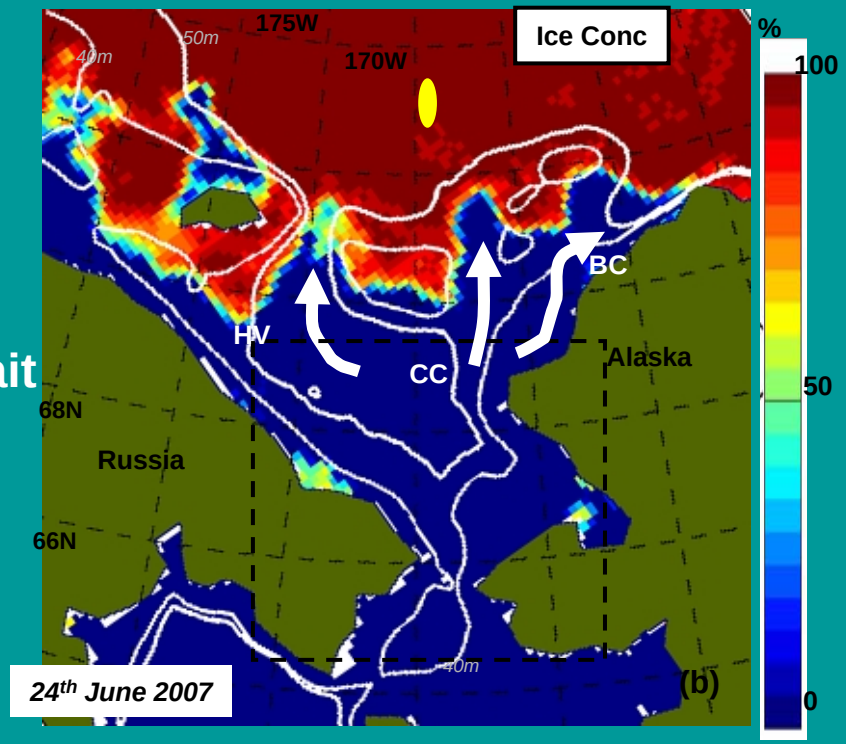


Weingartner and Danielson


27 Apr 2007
14 May 2007
26 May 2007
15 Jun 2007
30 Apr 2007
17 May 2007
29 May 2007
18 Jun 2007
08 May 2007
20 May 2007
03 Jun 2007
27 Jun 2007
11 May 2007
23 May 2007
06 Jun 2007
30 Jun 2007
AMSR-E
Ice [ ]
IC (%)
0
50
100

# Ice Edge reflects flow Pathways

**Flow carries**
**- ice?**
**- heat from the Strait**
**- local heat**




*Woodgate et al, 2010*

**TRIGGER for sea-ice retreat**

Also:

**1) can't hide mass**

*.. strong Bering Strait flow*
*= strong outflow to Arctic proper*

**2) Time to Transit Chukchi**

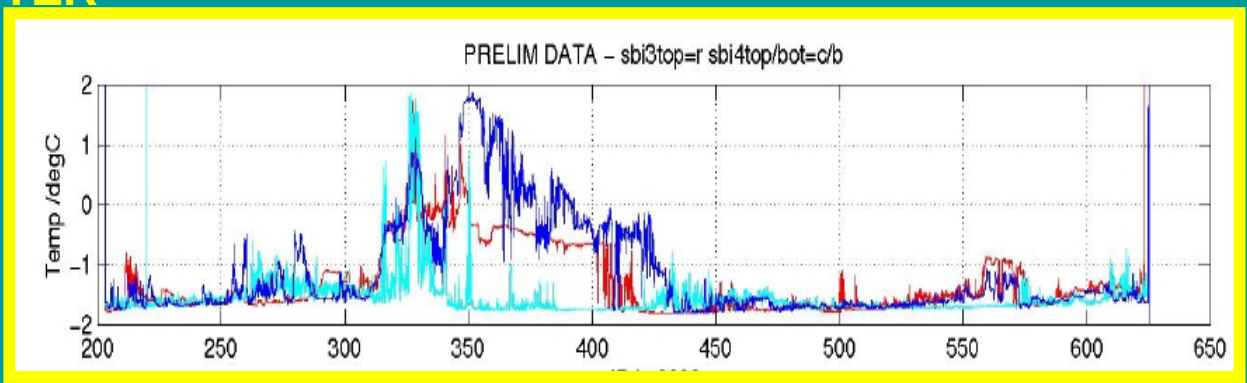
*... many months, and changes*
*... (0.6 Sv ~ 9 months; 1 Sv ~ 5.5 months)*

**3) Supply to Arctic in WINTER**

*..BStrait ~ May to Dec*
*...Chukchi N ~ Dec to Feb*

73 20N
- red 60m/70m water

73 37N
- cyan 60m/110m water
- navy 100m/110m water

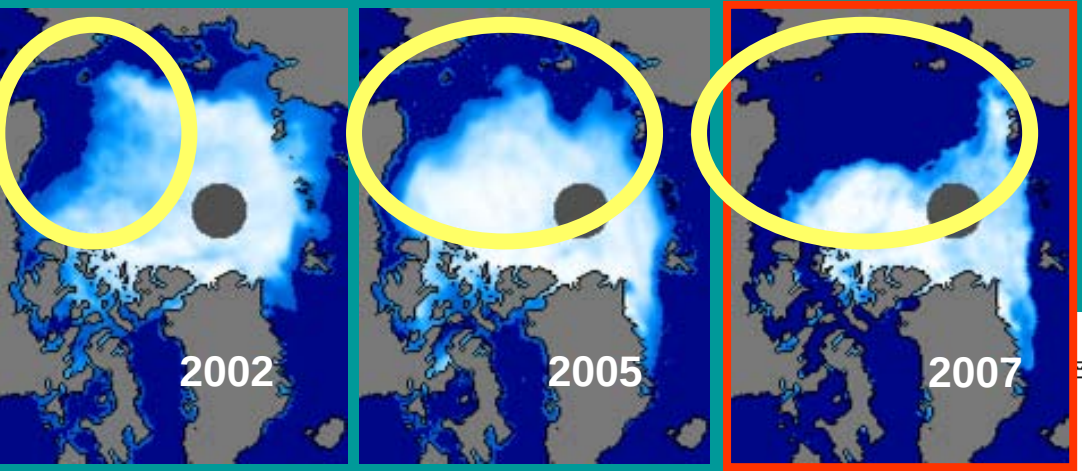


***Meltback in area of Pacific Water influence***

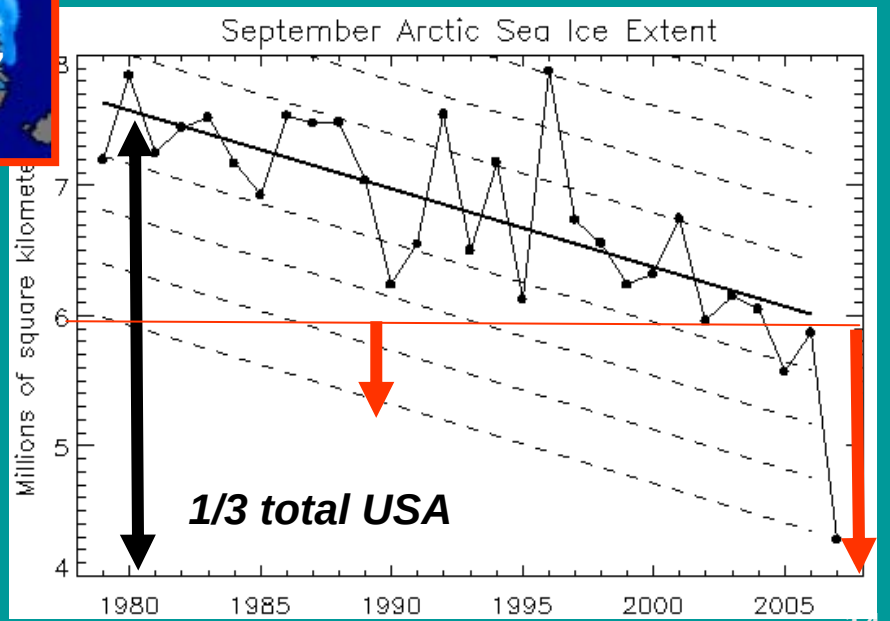
**Roles of Bering Strait in sea-ice retreat:**
- **triggers** the melt (then ice-albedo feedback)
- gives **freshwater stratification** to keep solar heat shallow
- **winter** source of subsurface heat

**2007 Ice retreat AMSR movie**
*Chapman et al, UIUC, Illinois*

**Bering Strait**
**~ 2-6 x $10^{20}$ J/Y**




**could melt**
**0.6- 2 million square km**
**of 1m thick ice**



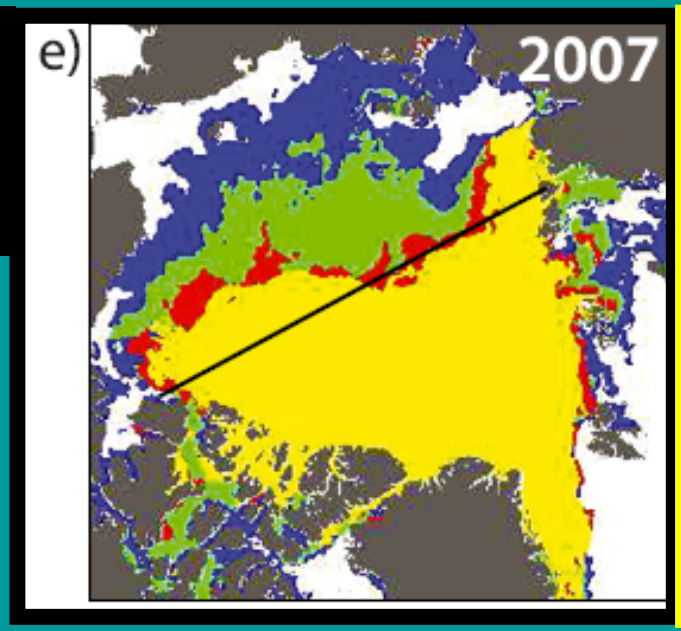

# Minimum (Sept) Sea-ice extent

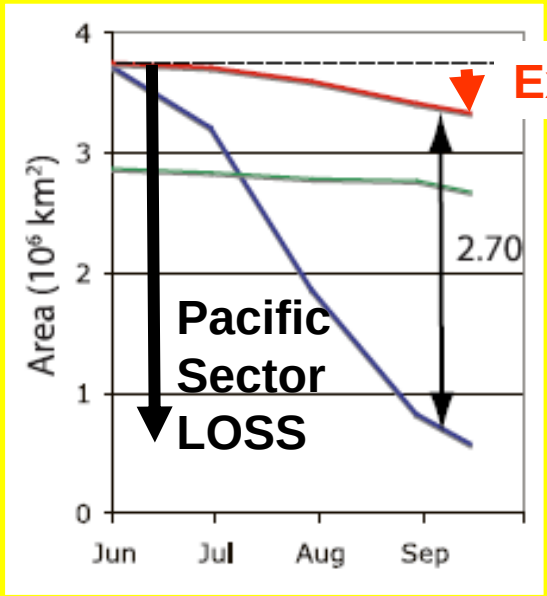
*Stern, UW, Data NASA*

# 2007 Ice Advection

*Kwok et al, GRL, 2008*

June
July
Aug
Min




Pacific Area
Atlantic Area
Advection

**2007 Ice export only**
**~ 15% of 2007 retreat**
*(also Ogi et al, 2008)*

***(?? ridging??, unseen??)***

**Fram Strait sea ice flux**

2005 ~ 0.25 x $10^6$ km$^2$
2006 ~ 0.16 x $10^6$ km$^2$
2007 ~ 0.28 x $10^6$ km$^2$

***2007 was about MELT***

**Figure 3.** Maps of the Arctic ice extent at the end of June (blue), July (green), August (red), and the summer minimum (yellow) for the five summers. Line plots show the ice area in the two sectors (Pacific, blue; Atlantic, green) and the contribution of ice advection (in red) across the flux gate (defined above) to the summer retreat of sea ice in the Pacific: (a) 2003, (b) 2004, (c) 2005, (d) 2006 and (e) 2007. The flux gate, the bounds of the Arctic Ocean, and the two sectors (P-Pacific, A-Atlantic) are identified in Figure 3a.

# Bottom versus Top Melt

*Perovich et al, GRL, 2008*

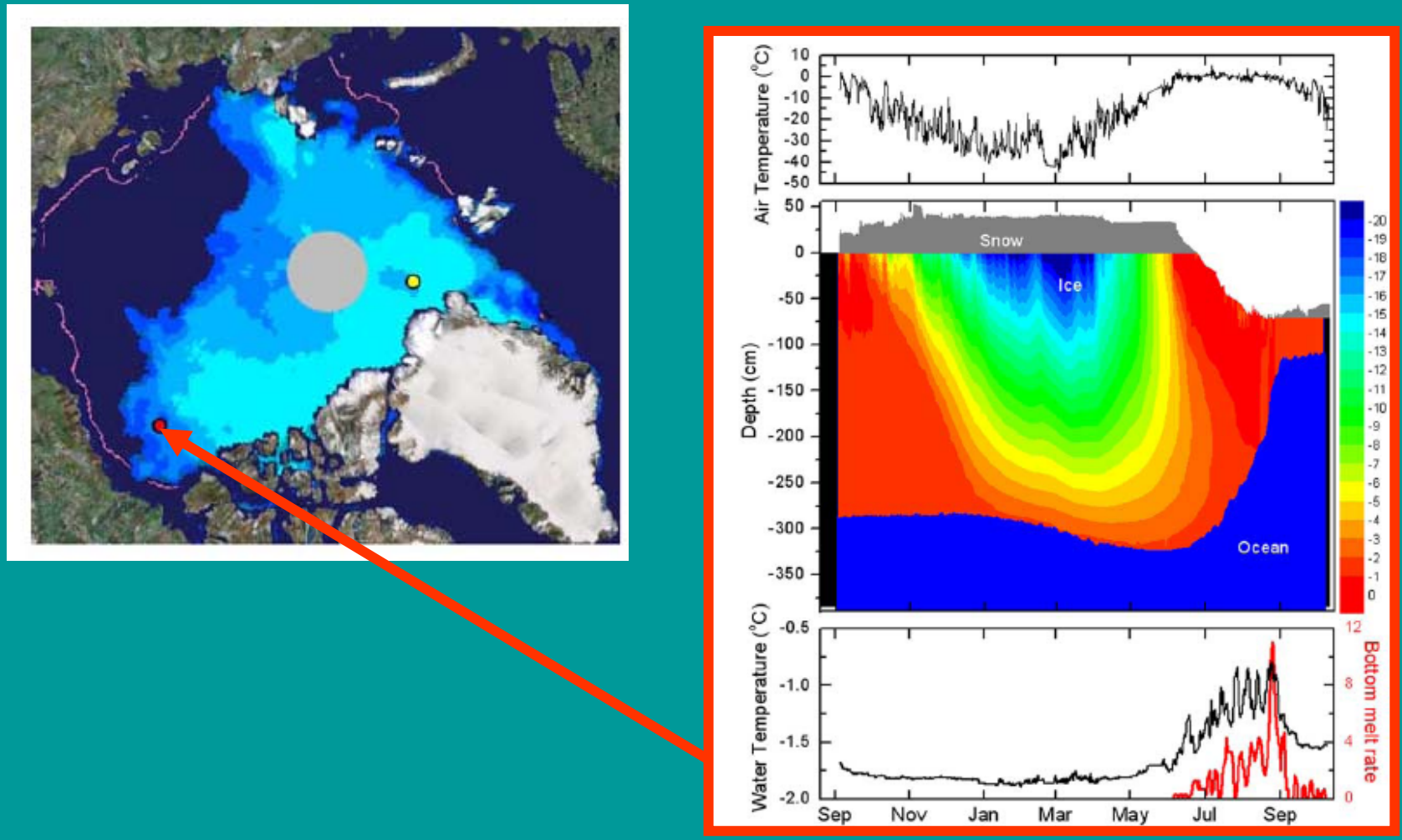
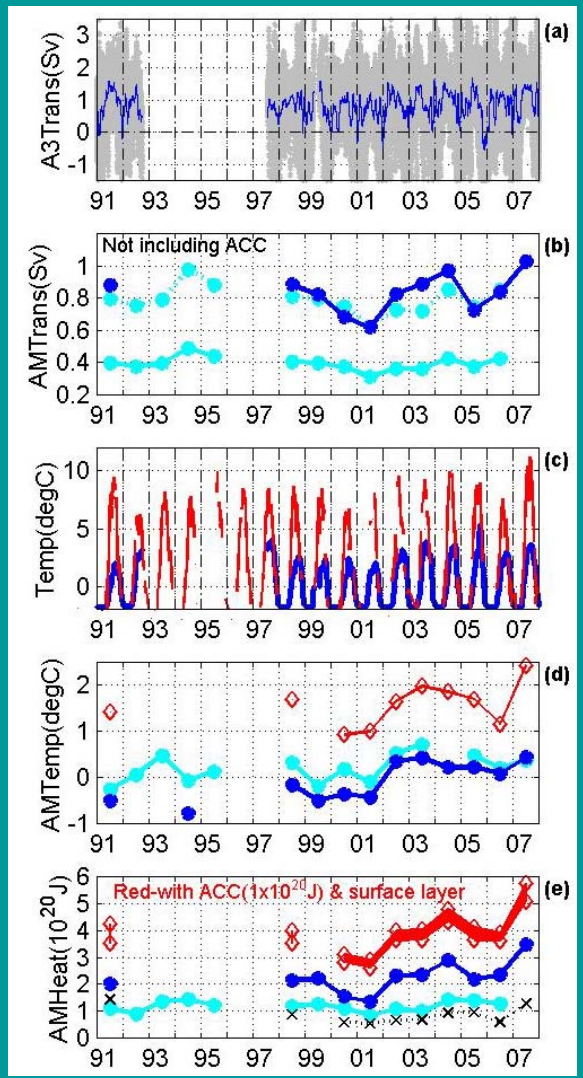
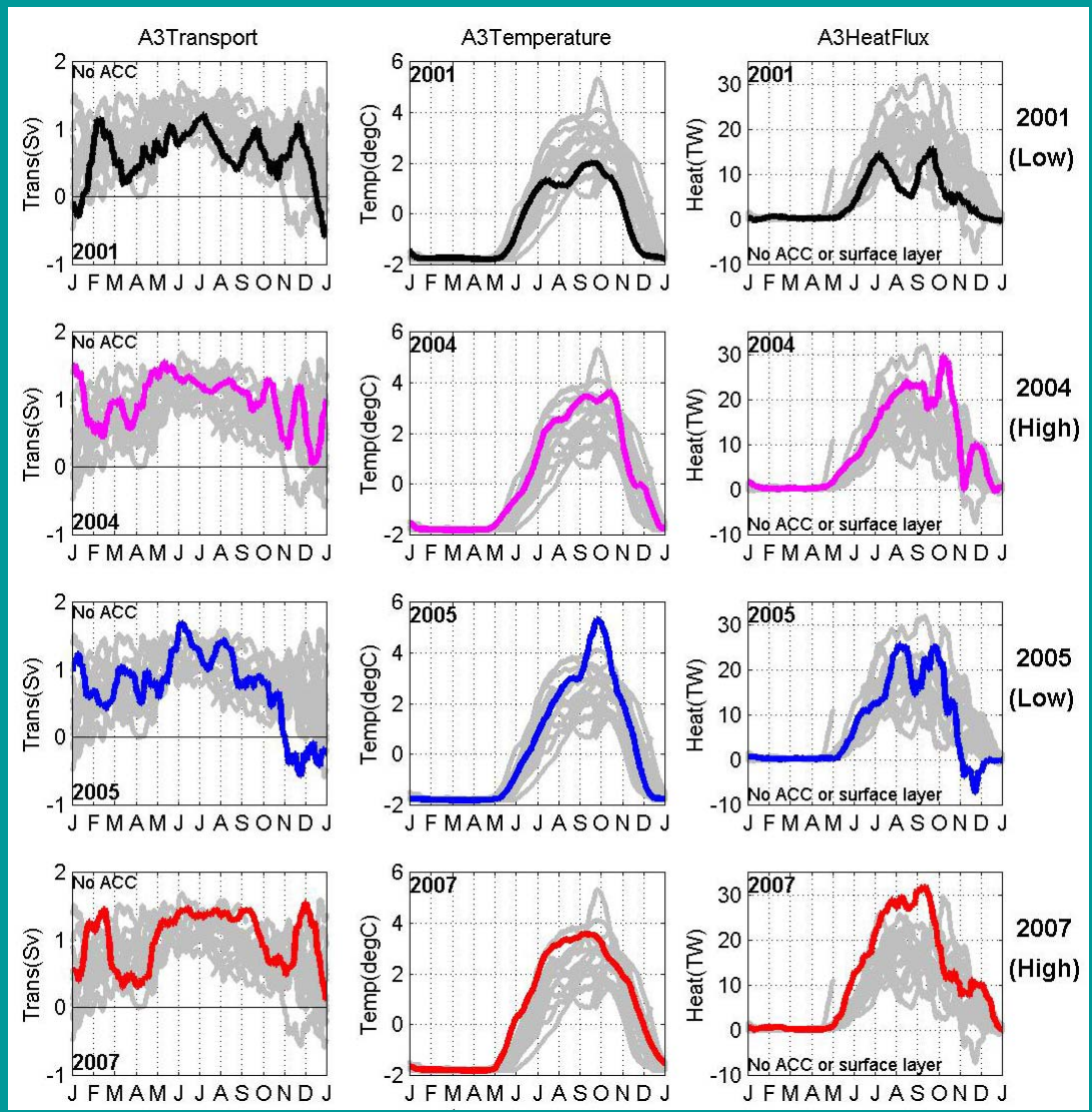



**Figure 2.** Time series from August 2006 to October 2007 from the Beaufort Sea ice mass balance buoy. (top) Air temperature. (middle) Internal ice temperature using color contours, with blue being cold and red warm. The gray shaded area represents snow, the black areas represent missing data, and the dark blue represents the ocean. (bottom) Upper ocean temperature near the bottom of the ice (black) and the bottom melt rate (red) in cm per day. Bottom melt rates were smoothed using a three-day running mean.

# What drives the change?

***Colours now indicate year***

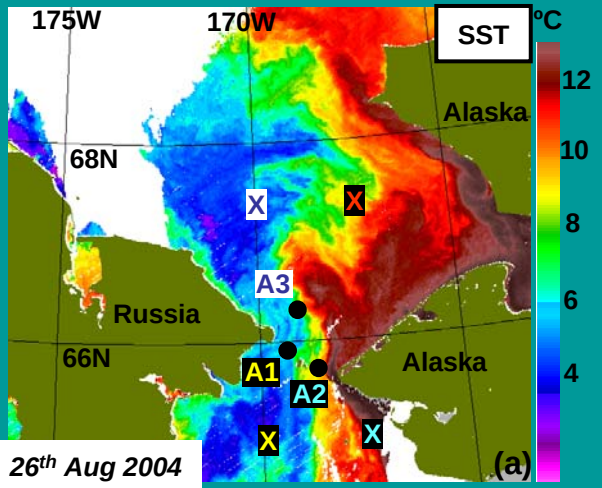


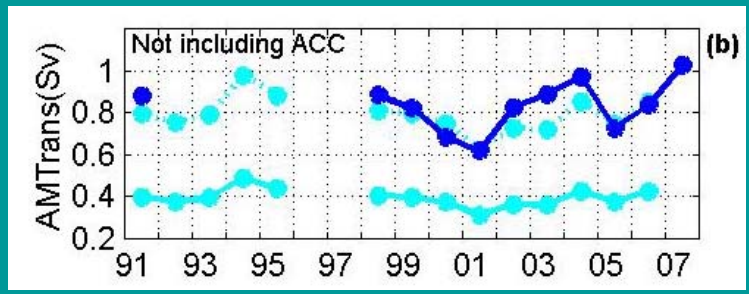




**Heat flux increase due to changes in both flow and temperature**

*Woodgate et al, 2010*

# What is changing the flow?



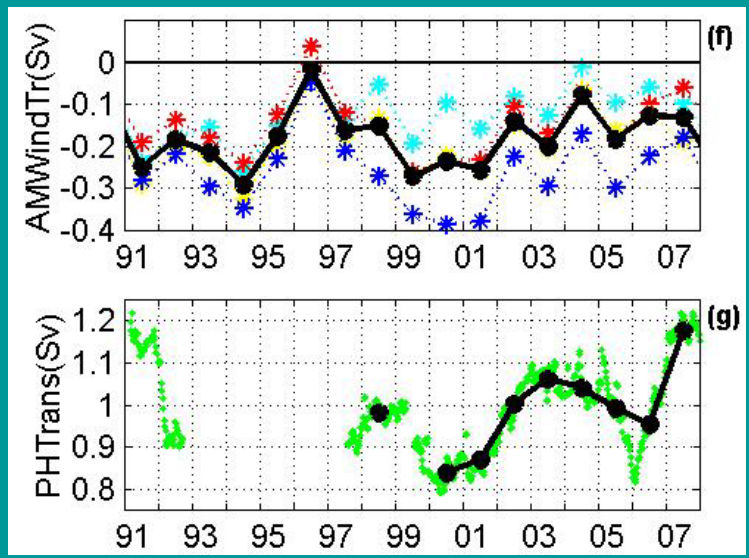

**Flow =**

**Const x WIND**

**+ Pressure Head**
*(often assumed constant)*

**Wind Term**

**Pressure Head Term**

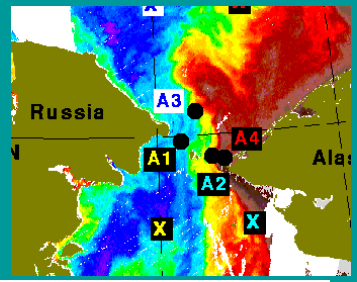


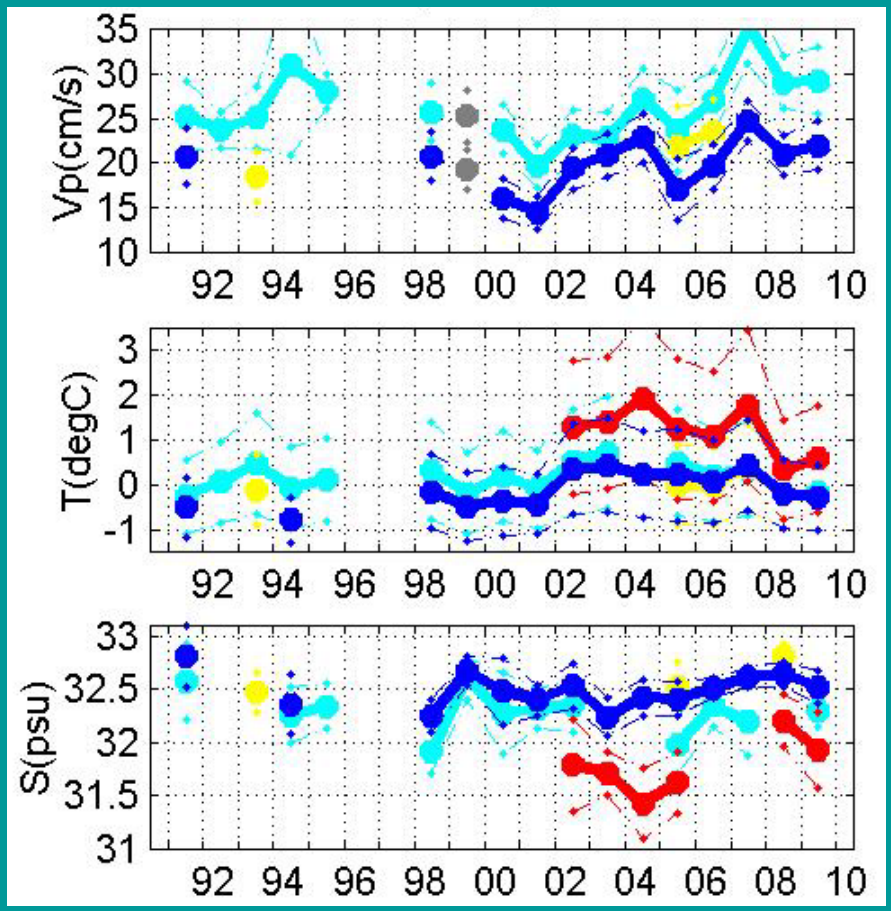

**Look at least squares fit to 1 year chunks of data**

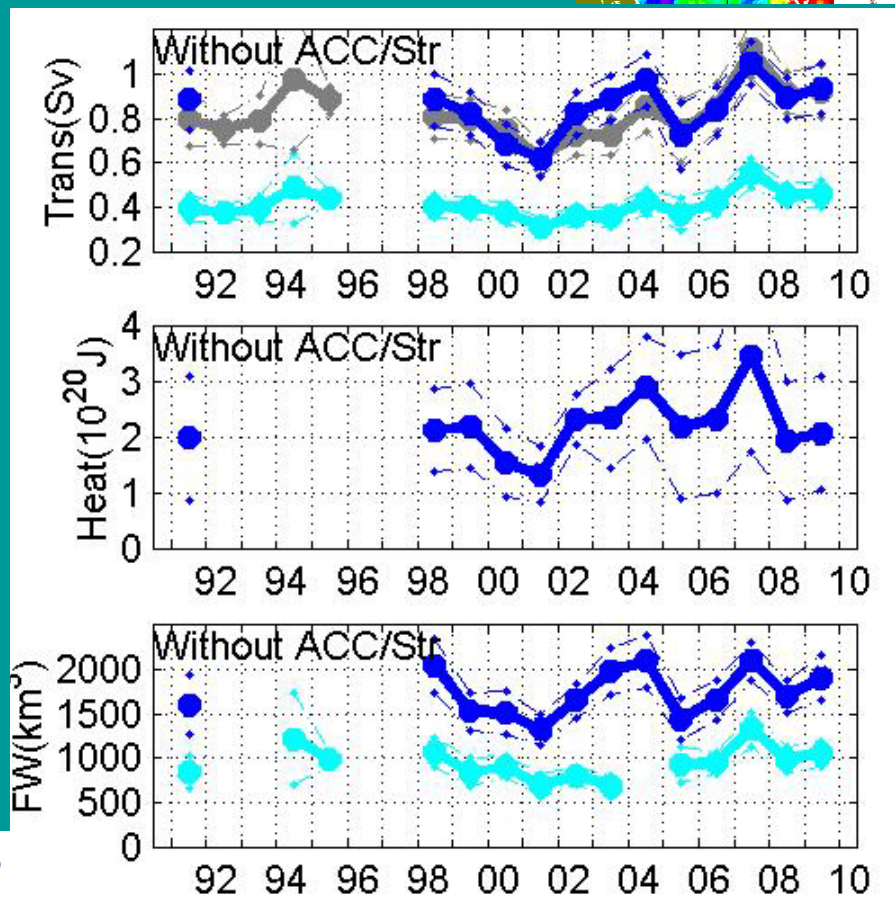
**Significant changes in the Pressure Head, i.e. far field forcing of the flow**

# Bering Strait Annual Fluxes

## - 2009 Update




**Transport still high** *?instrument change?*

**Temperatures recently fallen**

**- also heat flux fallen**

**Variability in Freshwater Transport**

Colours give mooring location (red=ACC)

# The role of Pacific waters in th[illegible]tic

**ARCTIC FRESHWATER FLUXES**

Bering Strait ~ 2500 $km^3/yr$
(0.08 Sv)

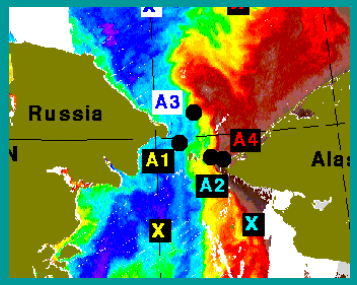
Arctic Rivers ~ 3300 $km^3/yr$
P-E ~ 900 $km^3/yr$

*Fram Strait water ~ 820 $km^3/yr$*
*Fram Strait ice ~ 2790 $km^3/yr$*
*Canadian Archipelago ~ 920 $km^3/yr$*

**Largest Interannual Variability??**

**Significant part of Arctic Freshwater Budget**
*Bering Strait throughflow*
*~ 1/3rd of Arctic Freshwater*
*(Wijffels et al, 1992; Aagaard & Carmack, 1989; Woodgate & Aagaard, 2005; Serreze et al., 2006)*

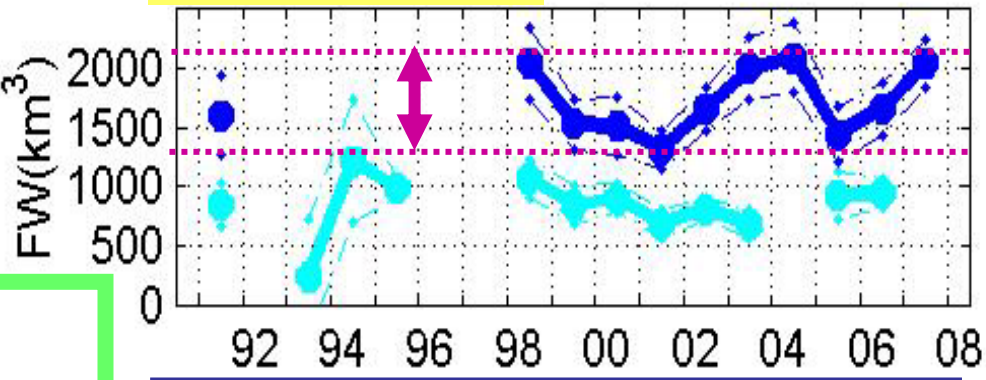
# Freshwater variability




**600 km3/yr**

## Bering Strait

+ 800 for stratification




## P-E

SERREZE ET AL.: FRESHWATER CYCLE OF THE ARCTIC

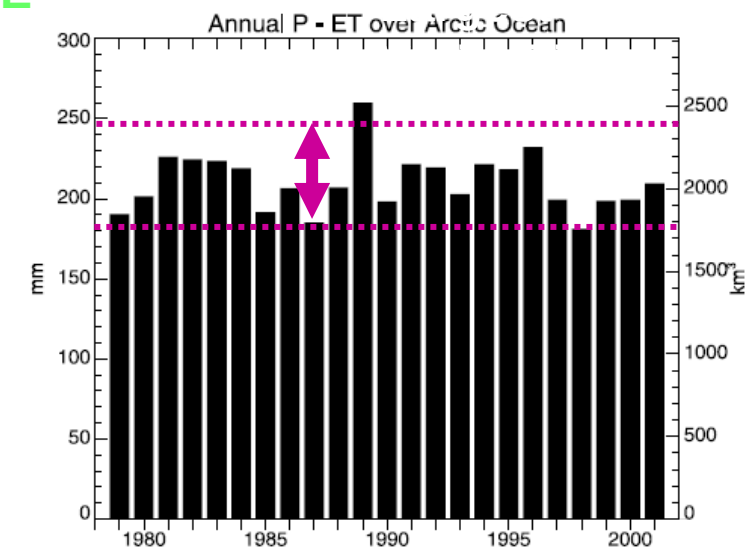
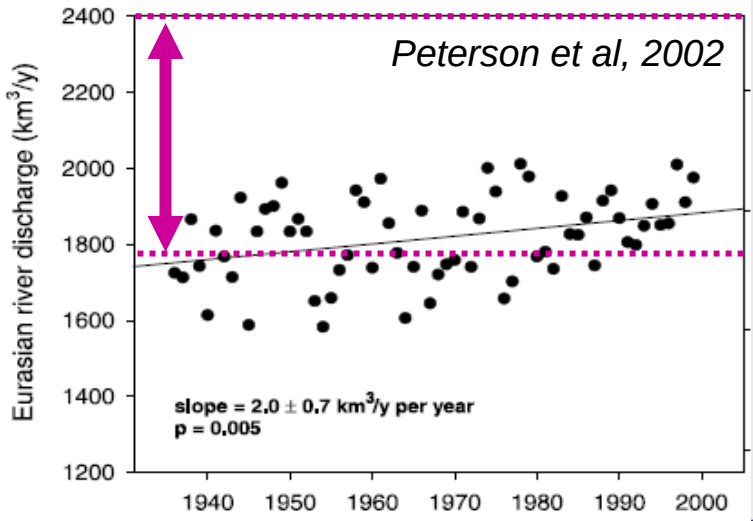


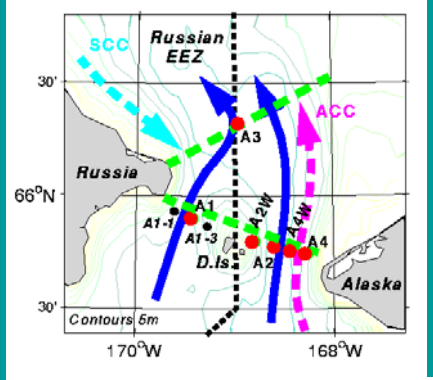

Figure 12. Annual time series of aerological P-ET from ERA-40 for the ocean domain.

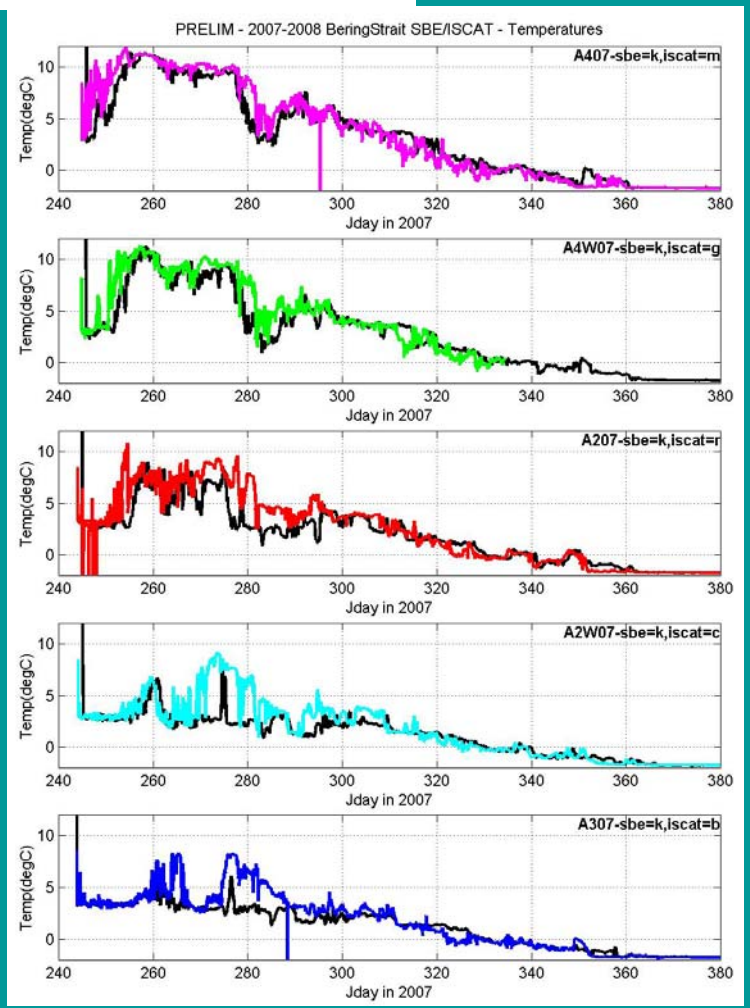
*Serreze et al., 2006*

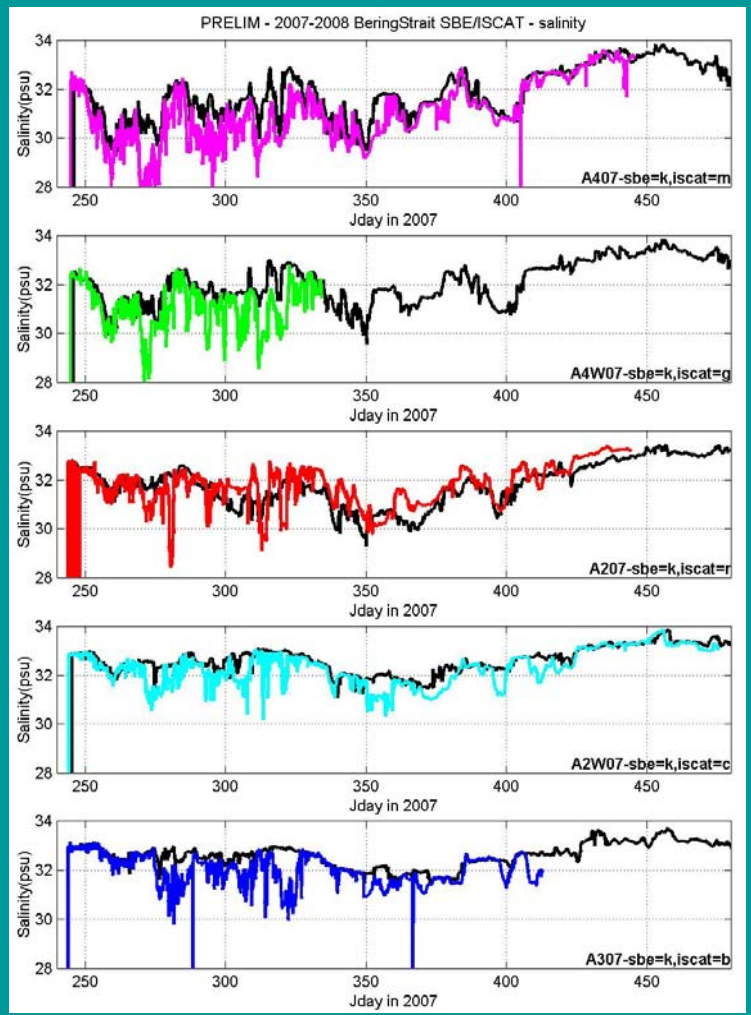
## Rivers

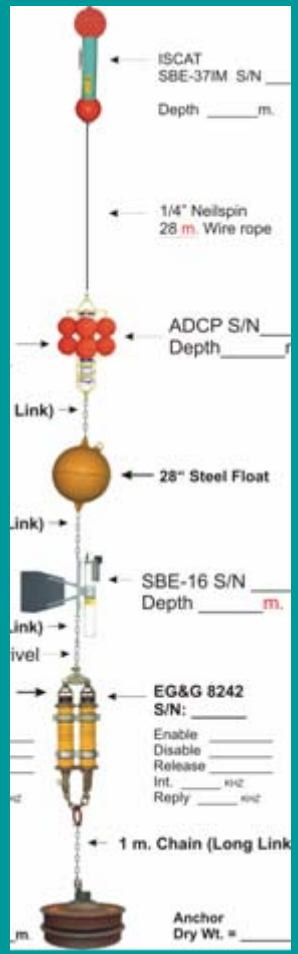


# First Look at Stratification



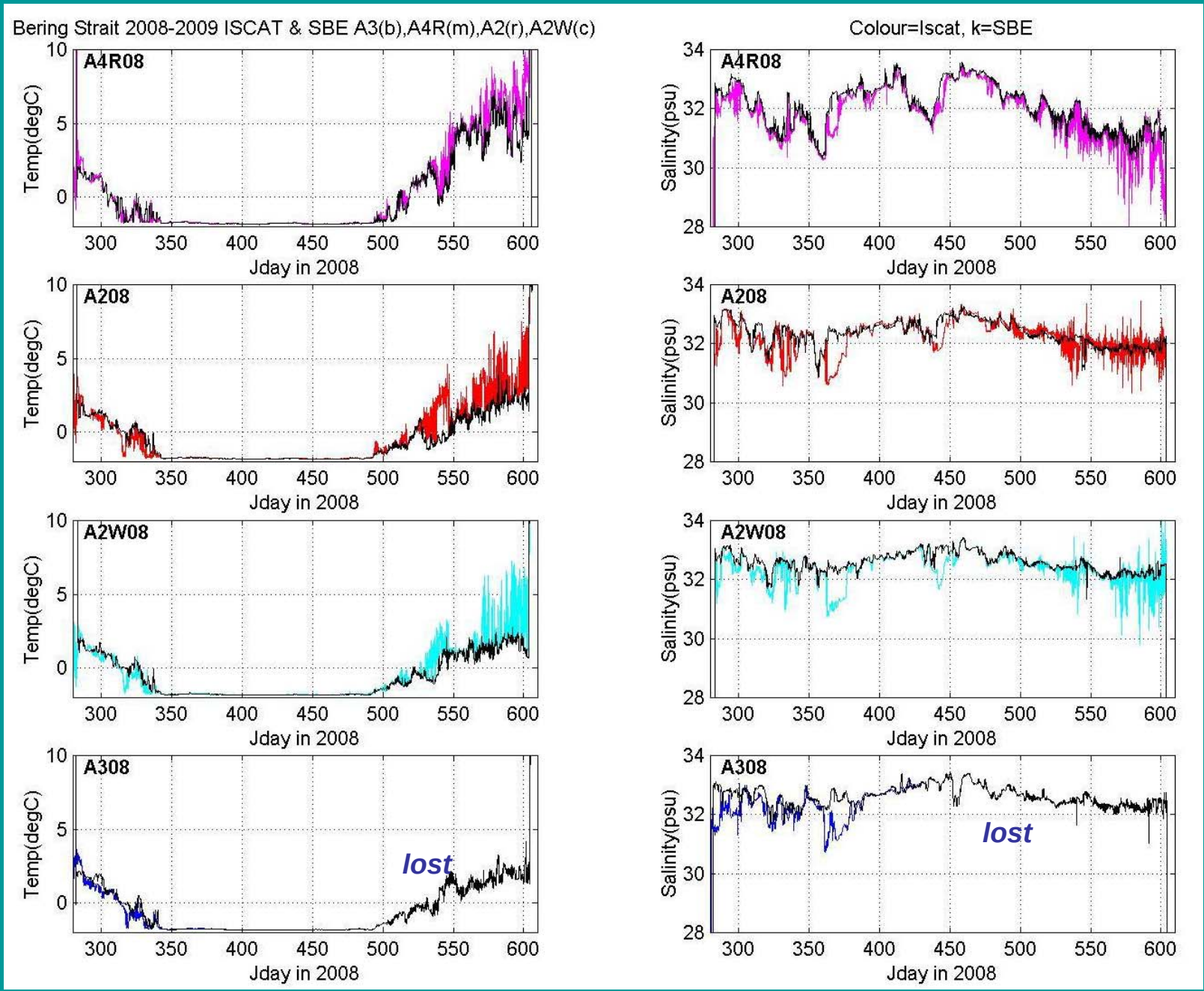



**EAST**
**(US side)**

**MIDDLE**



# Top to Bottom Temperature Profile

**Red= Satellite sea surface temperature**

**Cyan = iscat**

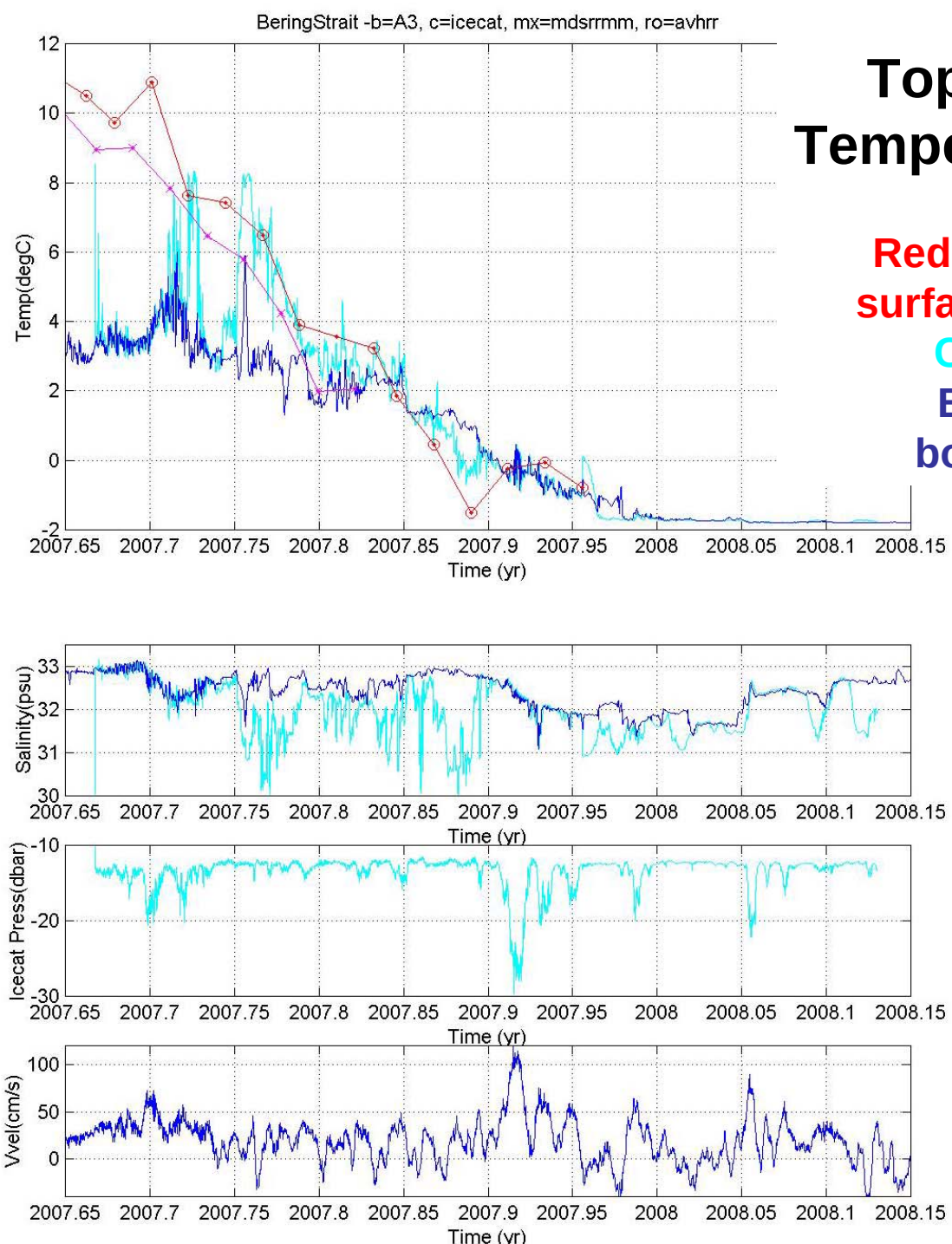
**Blue = near bottom seacat**

**Temp (deg C)**

**Salinity (psu)**

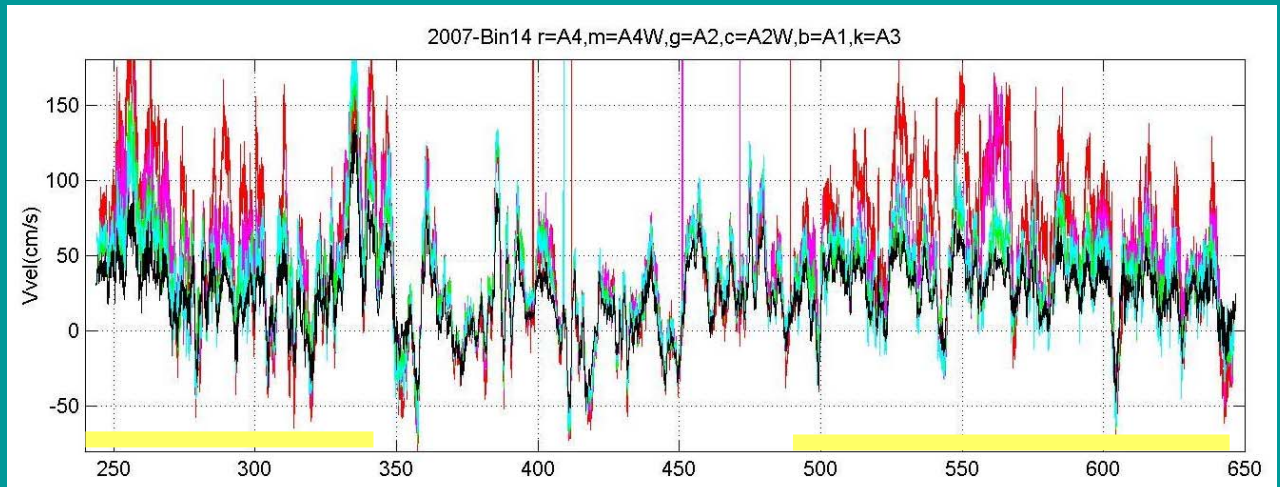
**Iscat Pressure (db)**

**Northward Velocity (cm/s)**

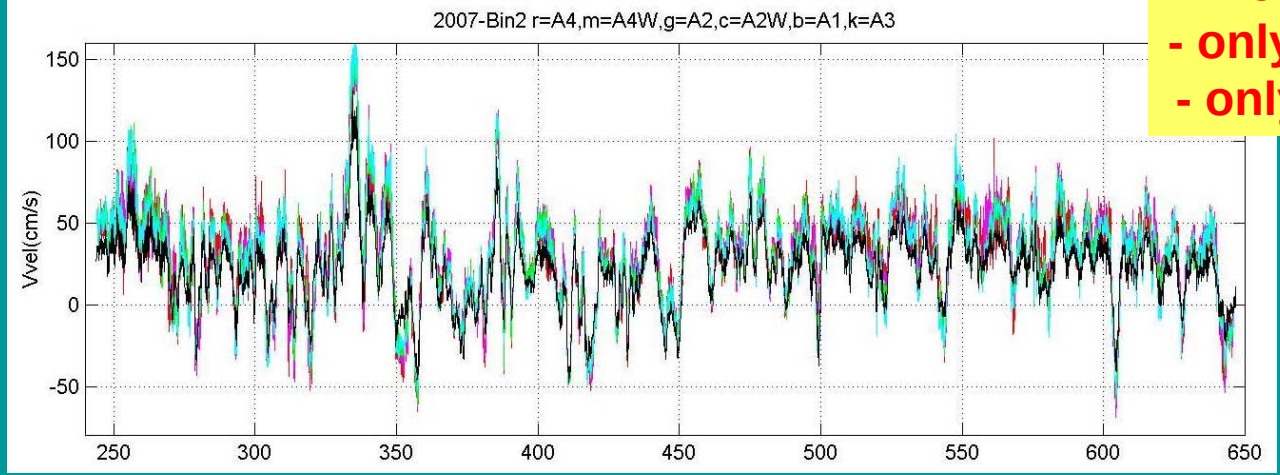


# Northward Velocity coherent at all sites

~ 15m depth




~ 40m depth




**Velocity Shear**
**- only near surface**
**- only summer/fall**

**Julian Day in 2007**

**Colours mark moorings**

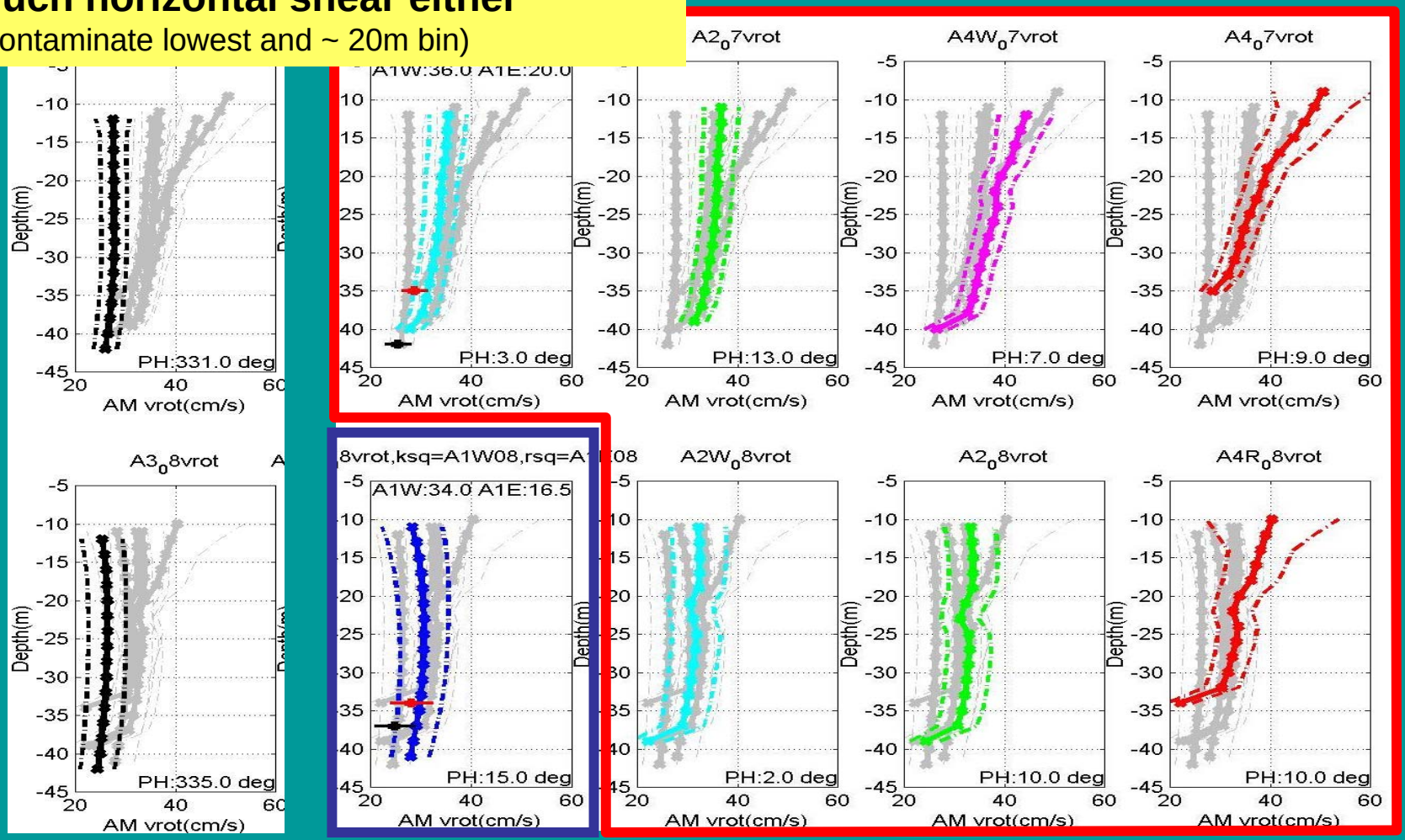
**A3**
**A1** ***xxDIxx*** **A2W** **A2** **A4W** **A4**

# ength Mean Velocity

**IN RECORD-LENGTH MEAN (~ 1 year)**
**- Away from ACC, not much vertical shear**
**- Not much horizontal shear either**
- (Iscats contaminate lowest and ~ 20m bin)

**2007-2008**

**2008-2009**

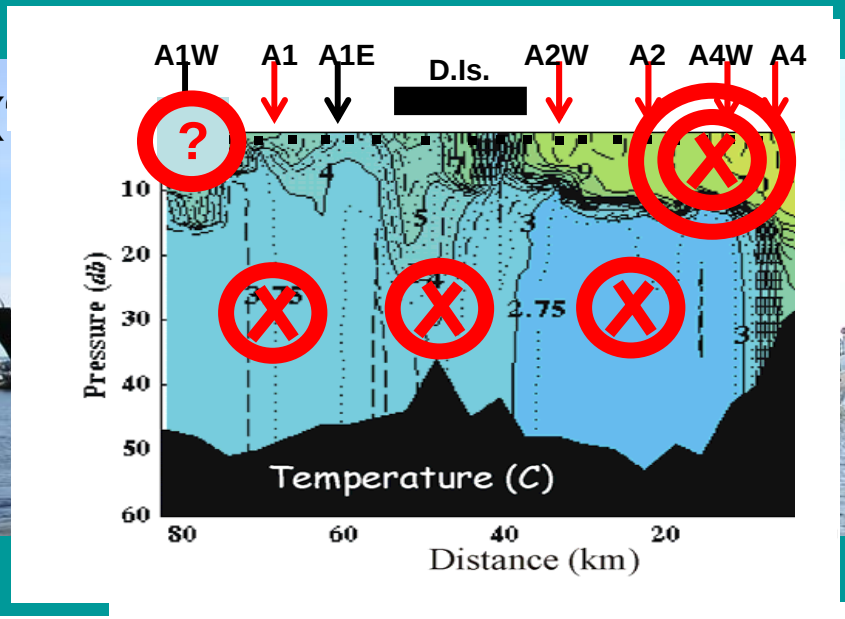


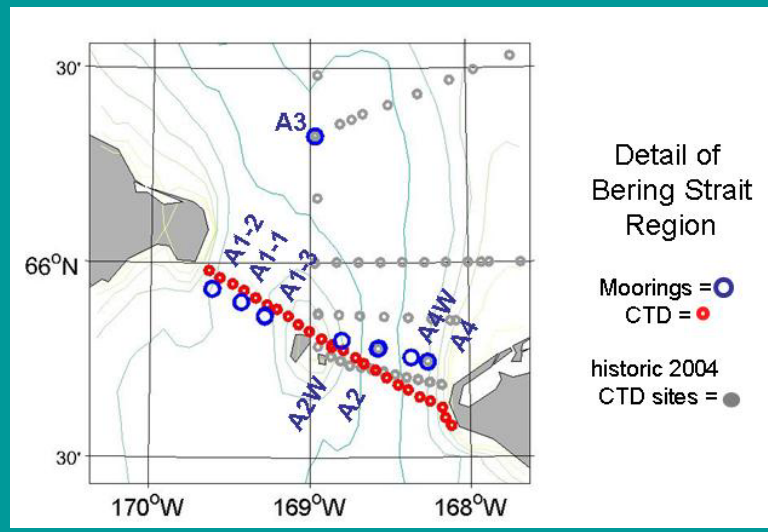

**A3 – north of Strait**

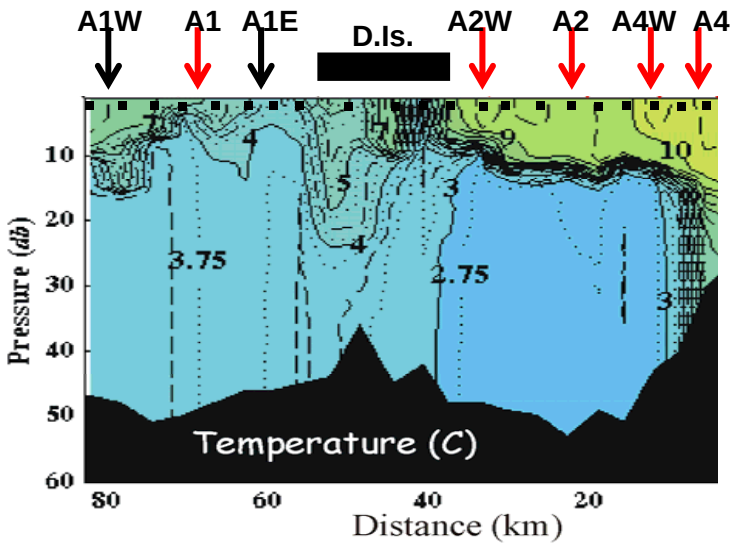
**A1 – west channel (Russian)**

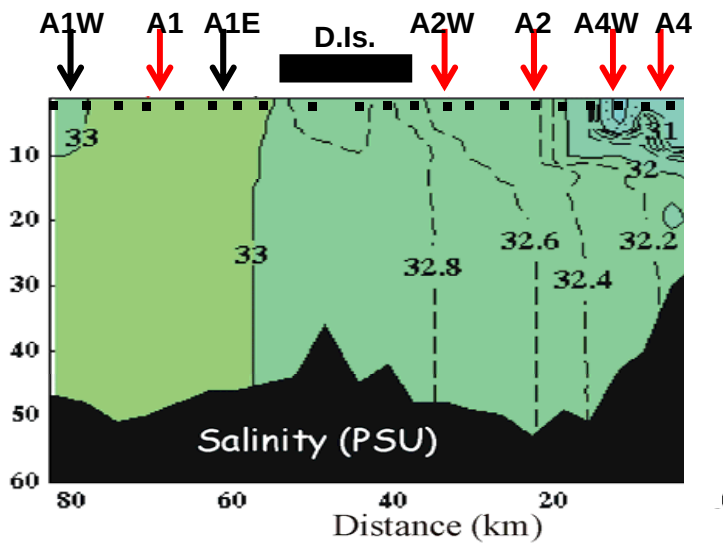
**A2W A2 A4W A4 - east channel c(USA)**

# 2007 IPY “CEBEP” RUSALCA cruise



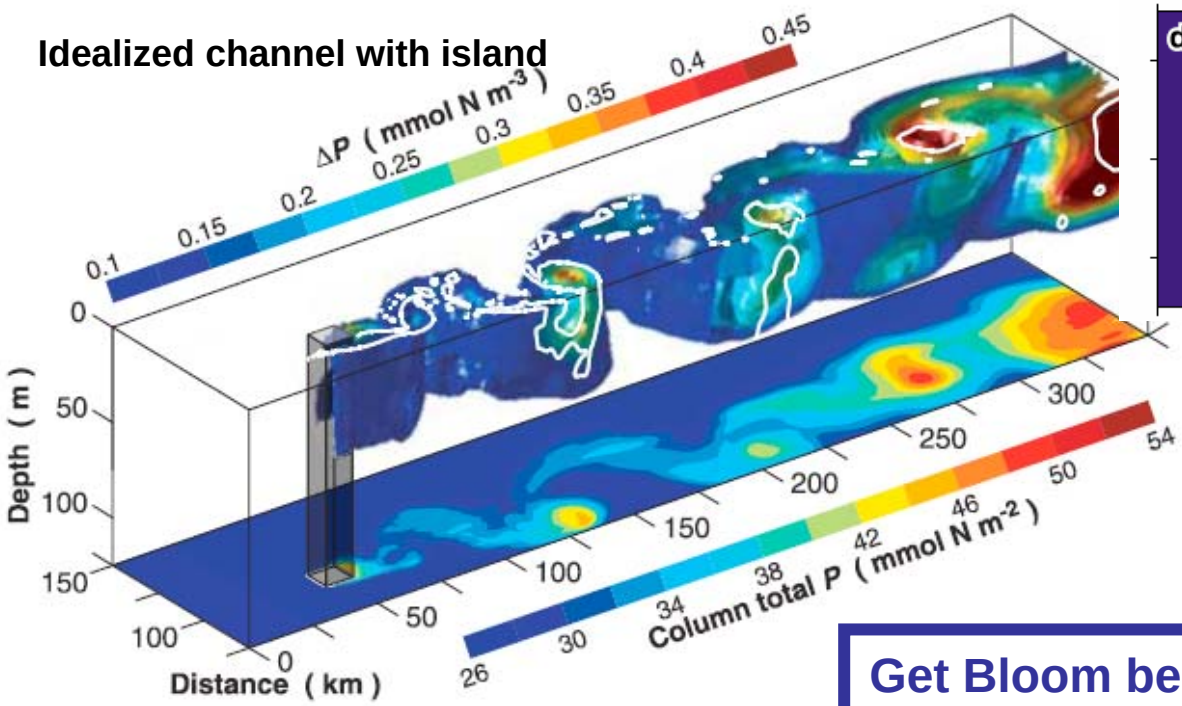



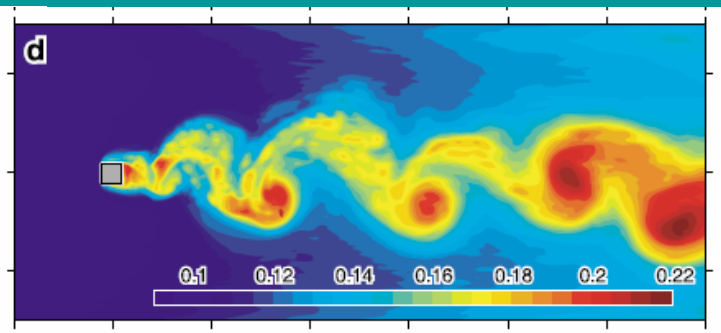
# How islands cause phytoplankton to bloom in their wakes

D. Hasegawa,[1] M. R. Lewis,[1] and A. Gangopadhyay[2]

**GRL, 2009**

**Idealized channel with island**



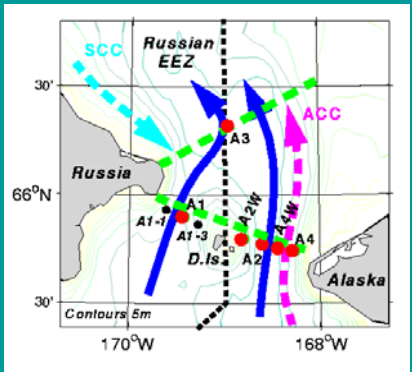

Surface Concentration of initially subsurface tracer after 75 days

**Figure 3.** A 3D view of increased phytoplankton concentration as a result of local growth ($\Delta P \equiv P - C$) within the euphotic layer on day 75 and the column integrated phytoplankton concentration. Solid white lines are normalized vorticity contours enclosing regions larger than +1. The temporal dynamics of the process can be seen in Animation S1.

**Get Bloom because of:**
- **passive upwelling of subsurface bloom**
- **nutrient upwelling by island**
- **nutrient upwelling in eddies in wake**

**For Bering Strait**
- **also oscillating flow**
- **supply Fe/nutrients from island?**

# What's new in the Bering Strait?



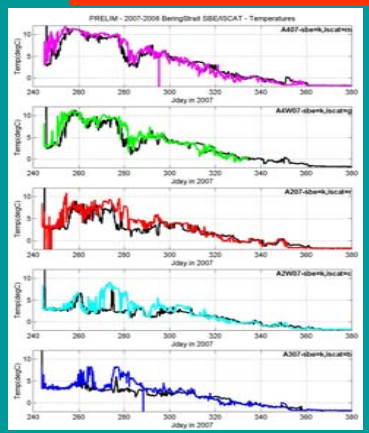

**8 Mooring Array from 2007- 2013**

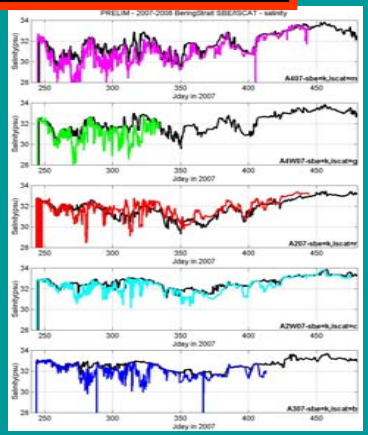
Whale recorders pH and pCO2

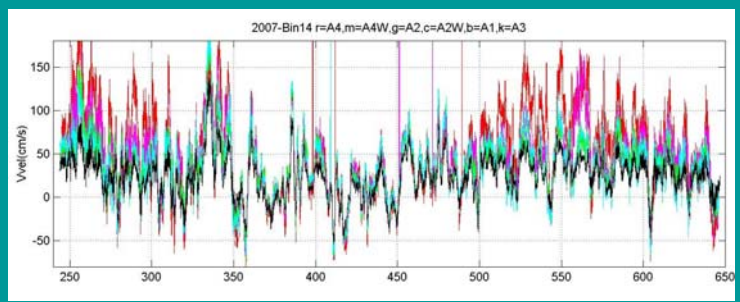
**Heat Flux as a trigger of sea ice melt (esp 2007)**

**Largest Interannual FW variability?**

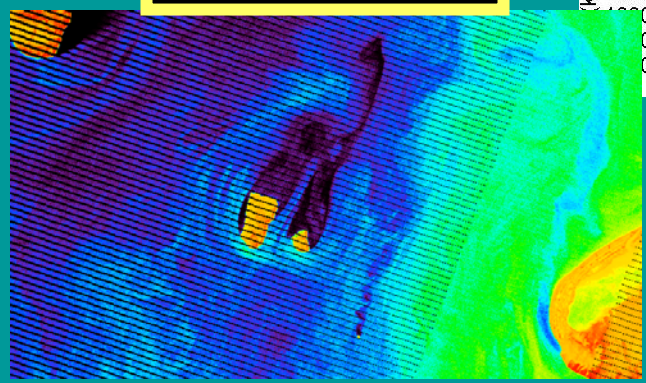
**TS and Vel stratification**

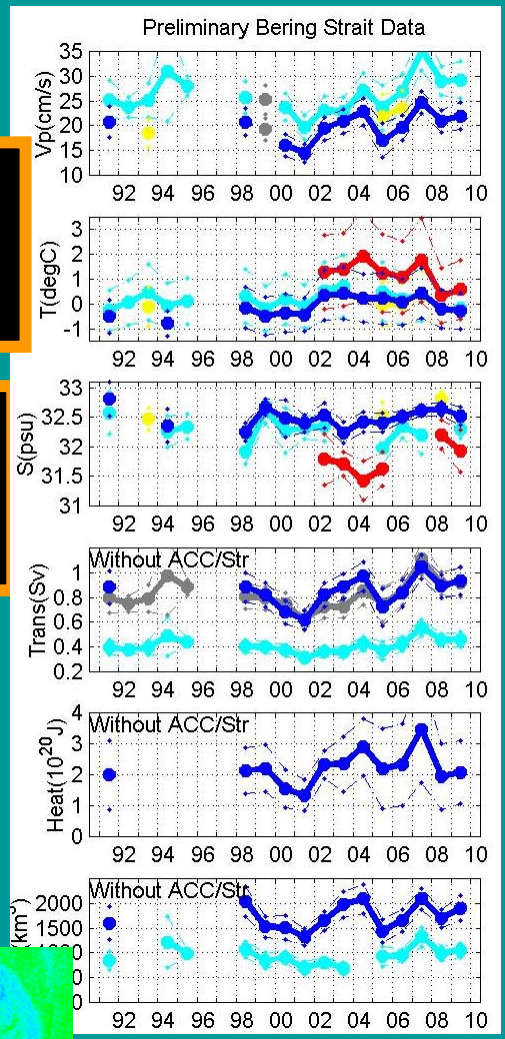







**Next**
- quantification
- physics
- modelling?






*psc.apl.washington.edu/BeringStrait.html*

Bering Strait: Pacific Gateway to the Arctic - Mozilla Firefox

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http://psc.apl.washington.edu/BeringStrait.html

Bering Strait

Getting Started Latest Headlines

*Little Diomede Island, middle of the Bering Strait*

# BERING STRAIT: Pacific Gateway to the Arctic


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*University of Washington, USA*
***Tom Weingartner, Terry Whitledge***
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*Arctic and Antarctic Research Institute, Russia*
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ONR High Latitude

NSF-Polar Program

NOAA Arctic Resear

RUSALCA

Back to High Latitude Dy

## BERING STRAIT BASICS

**Bering Strait Basic Facts**

**- *WHY* is the Bering Strait throughflow important?**
**- *WHAT* are we doing?**
**- *WHAT* are we learning?**

**A Decade in the Bering Strait**
**Bering Strait Ice Flux**

**Other Publications**

## RECENT PAPERS

The 2007 Bering Strait Oceanic Heat Flux and anomalous Arctic Sea-ice Retreat Woodgate et al, GRL, 2010

Interannual changes in the Bering Strait Fluxes of Volume, Heat and Freshwater between 1991 and 2004 Woodgate, et al, GRL, 2006

Some Controls on Flow and Salinity in Bering Strait Aagaard, et al, GRL, 2006

Monthly Temperature, Salinity and Transport Variability of the Bering Strait Throughflow. Woodgate, et al, GRL, 2005

Revising the Bering Strait Freshwater Flux to the Arctic Ocean. Woodgate & Aagaard, GRL, 2005

***Technical Report*** - Using A3 as a climate station for the Bering Strait Throughflow, Woodgate et al, August 2007

## RESEARCH EXPEDITIONS

Khromov 2010 (July/August)
Khromov 2009 (Aug/Sept)
Lavrentiev 2008 (Oct)
Sever 2007 (Aug/Sept)
Sir Wilfrid Laurier 2006 (July)
Sir Wilfrid Laurier 2005 (July)
Alpha Helix 2004 (Aug/Sept)
Alpha Helix 2003 (July)
Alpha Helix 2002 (June)
Alpha Helix 2001 (Sept)
Alpha Helix 2000 (Aug/Sept)

## DATA ACCESS

***GOTO DATA ARCHIVE***

## BERING STRAIT BASICS

- The only ocean gateway between the Pacific and Arctic, and ~85km wide,