Circulation Processes on Alaska's Shelf Seas

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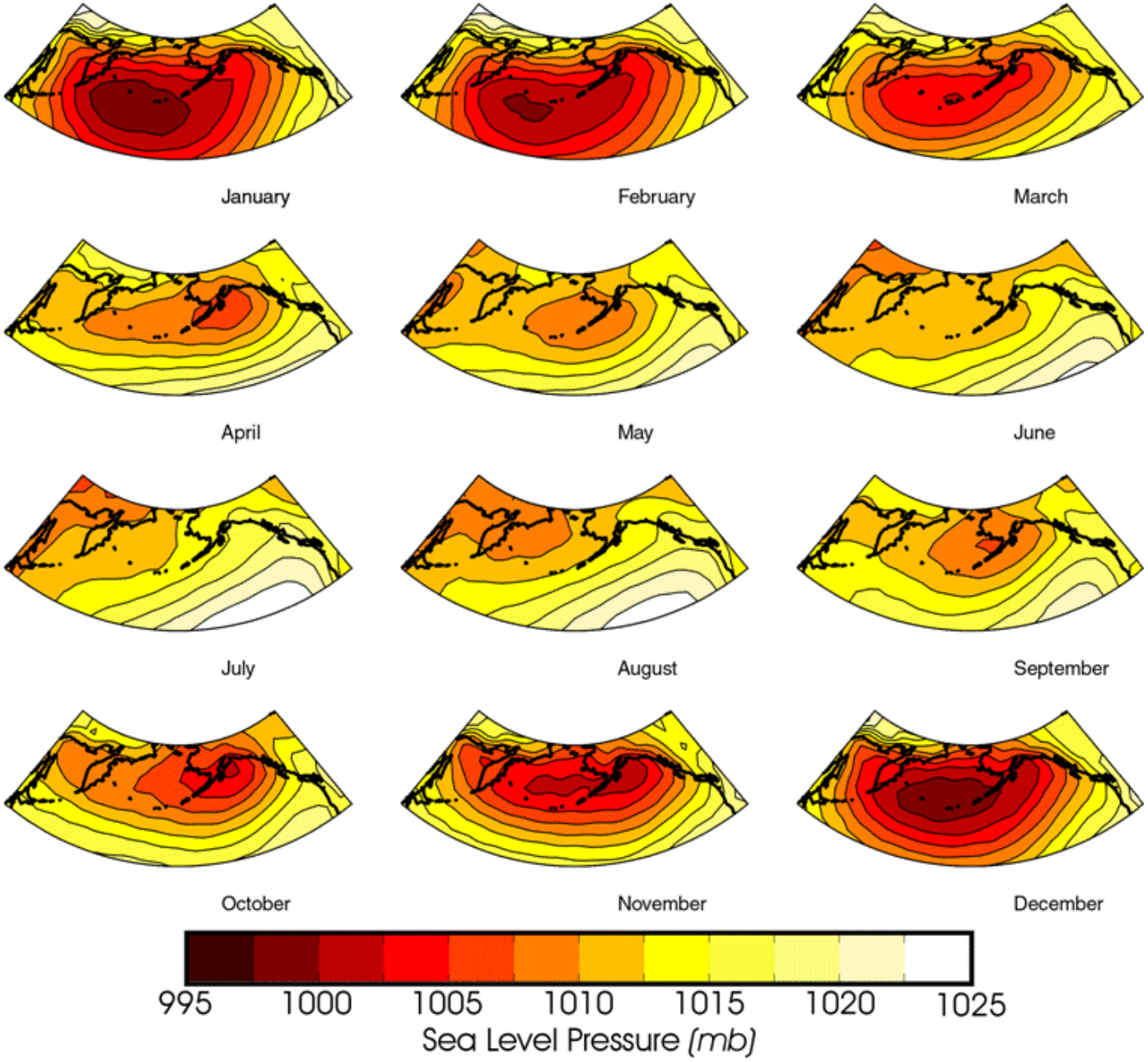
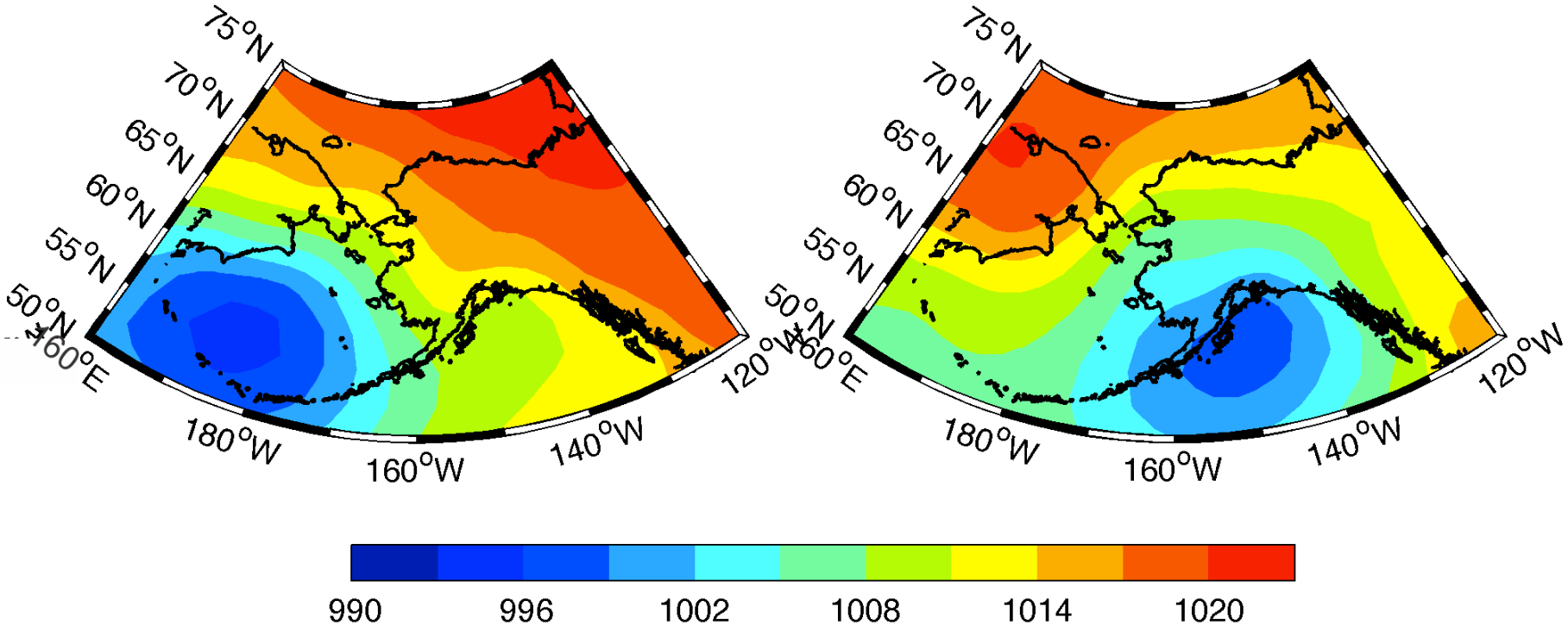
Gulf of Alaska
Bering Sea & Strait
Chukchi Sea
Beaufort Sea

Aleutian Low: the principal regional atmospheric driver

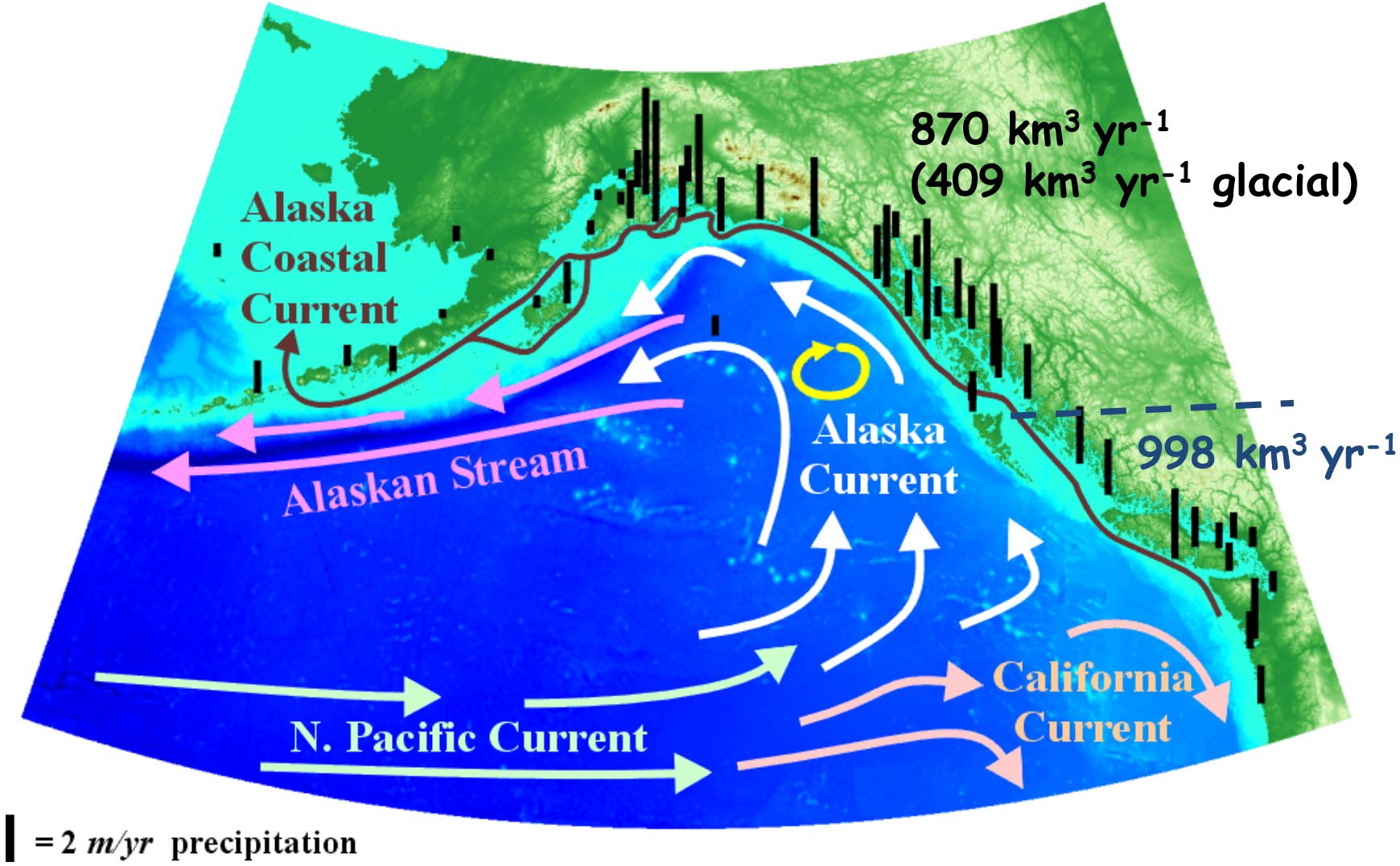


The Aleutian Low
Interannual variations in strength and position affect circulation, ice, water temperature/salinity



(Danielson et al., in review)

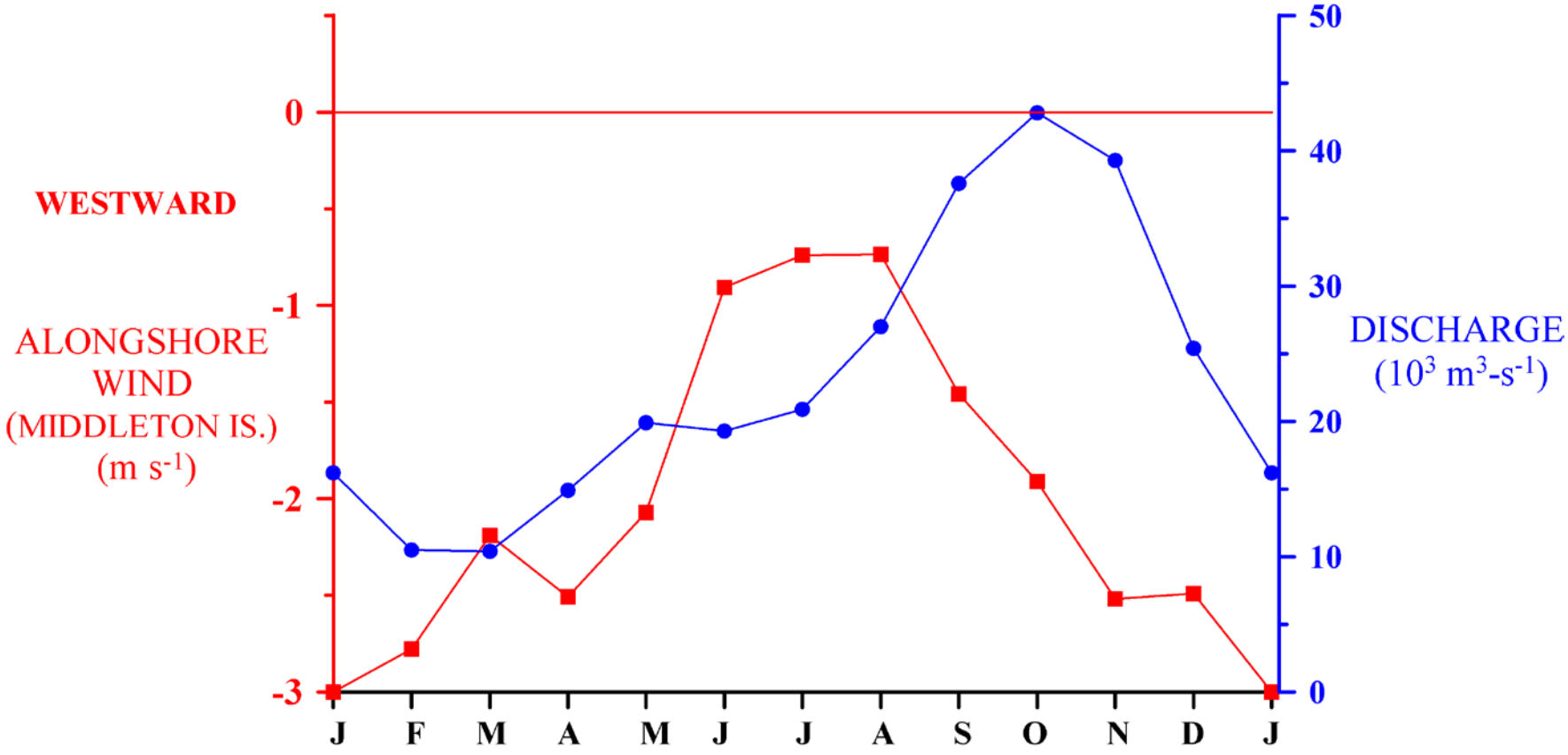
Gulf of Alaska



Neal et al., 2010

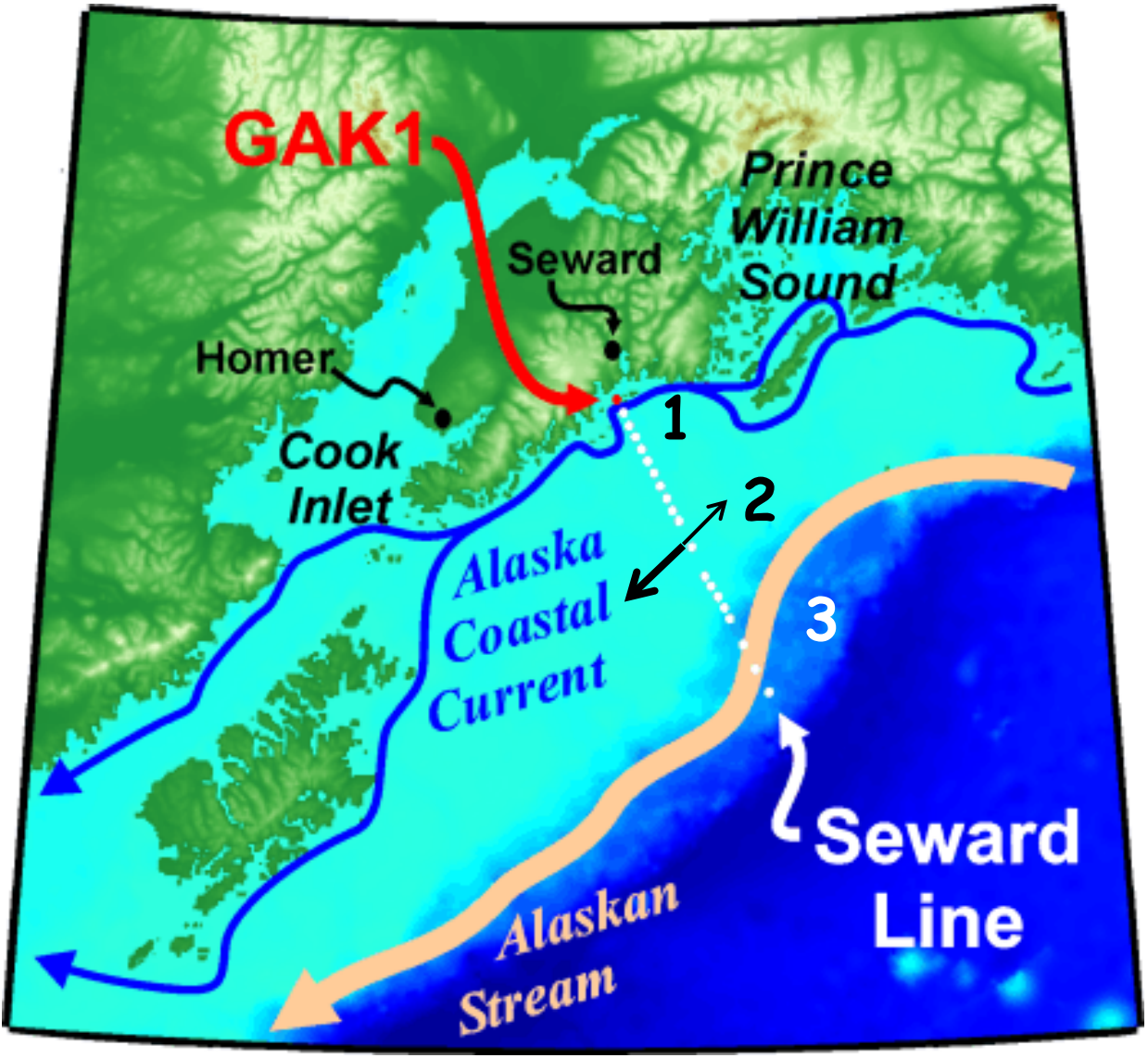
Morrison et al. 2012

Gulf of Alaska: Seasonal Winds & Coastal Discharge



Affects:

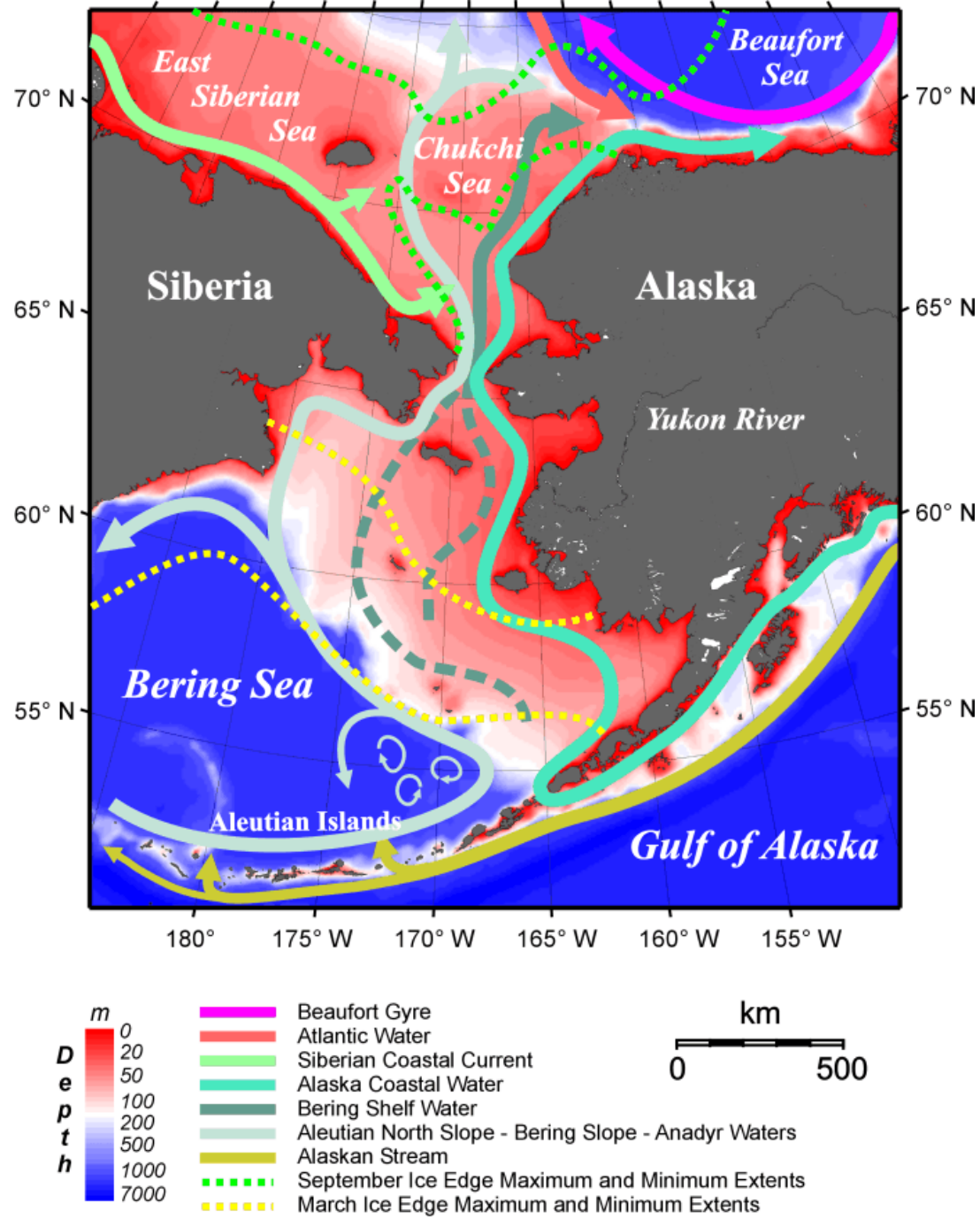
1. Water Density distributions:
   Vertically (stratification) and
   Horizontally (fronts): Winds trap runoff to the coast!
2. Current Strength and Structure



1. Alaska Coastal Current
   0.2 kts (summer)
   1 – 2 kts (fall – winter)
   20 – 40 km width

2. Mid-shelf flow
   Average westward,
   more variable & weaker
   than ACC.
   0.2 - 0.6 kts

3. Alaskan Stream
   Westward 1 – 3 kts
   Large (200 km) eddies
   Cause reversals



Bering Sea

Key features:

Smooth, gently sloping shelf

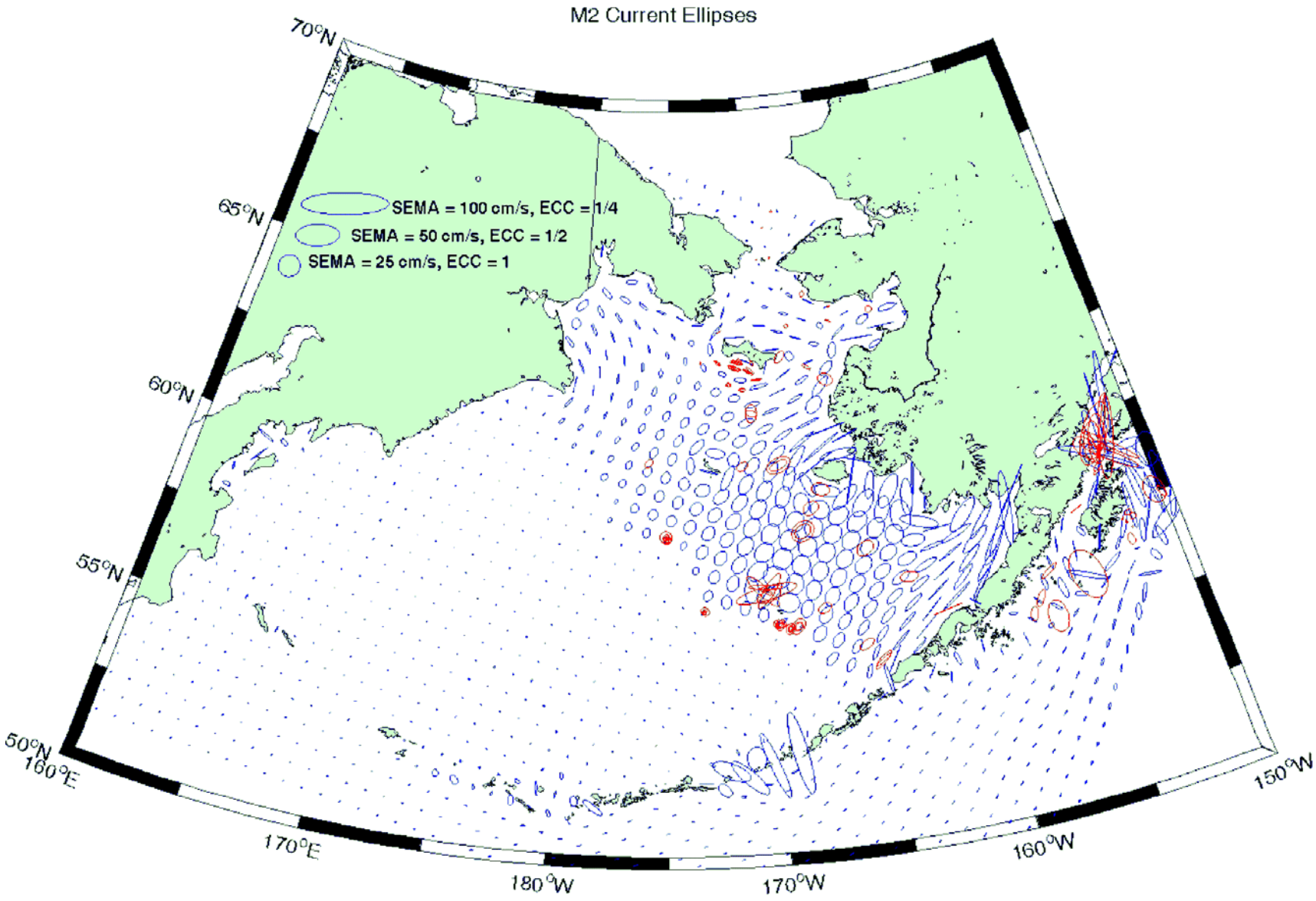
Winds & tides dominate circulation

Seasonality:

sea ice, river runoff

nearshore, shelfbreak exchange

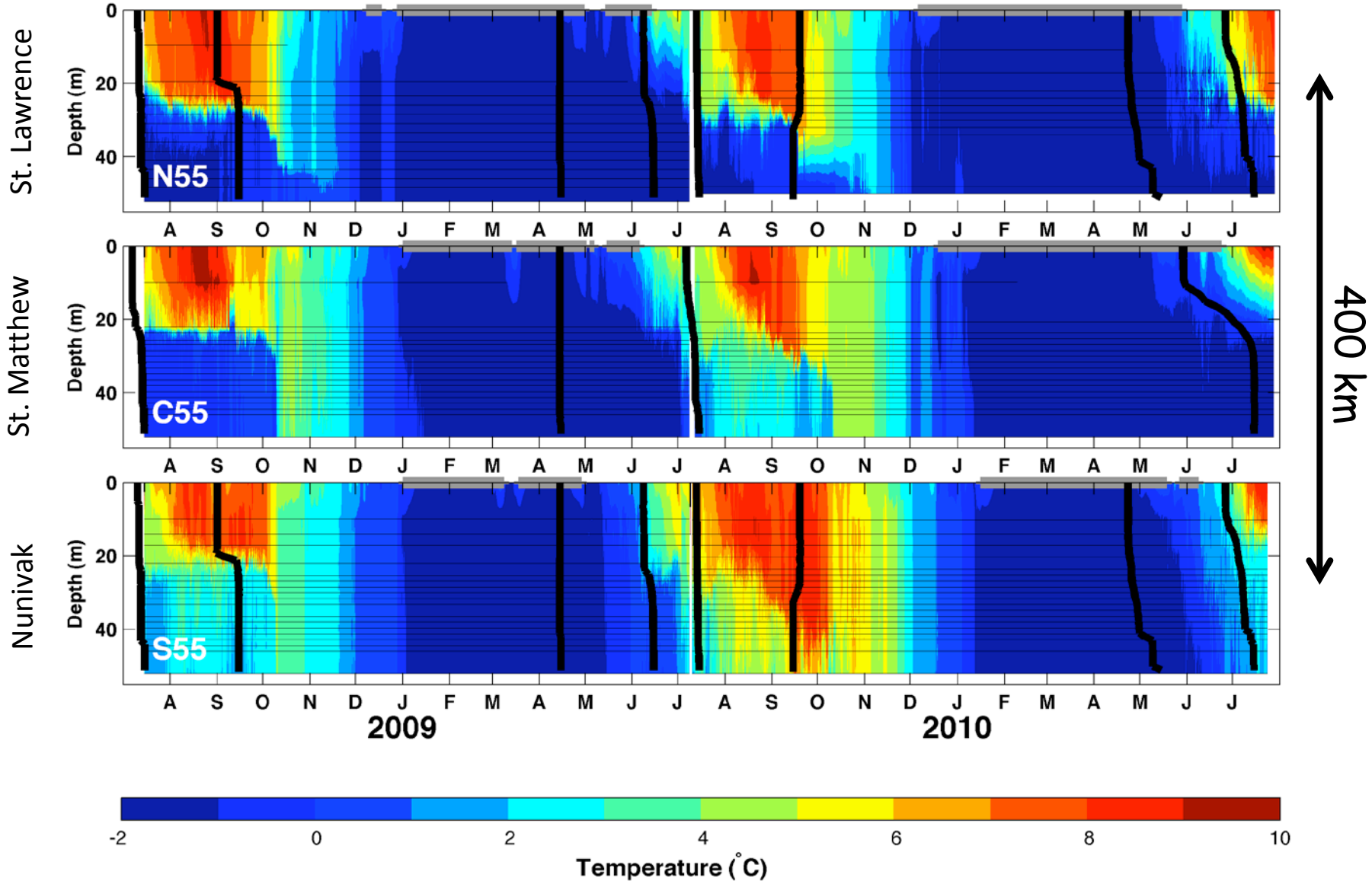
Mean flows are weak!!



Tidal magnitudes increase with decreasing bottom depth
(diurnal and semi-diurnal tides are important!)

Temperature and stratification (55m isobath) varies: spatially, seasonally, and interannually

Ice does not <u>form</u> until <u>water column</u> reaches freezing point!

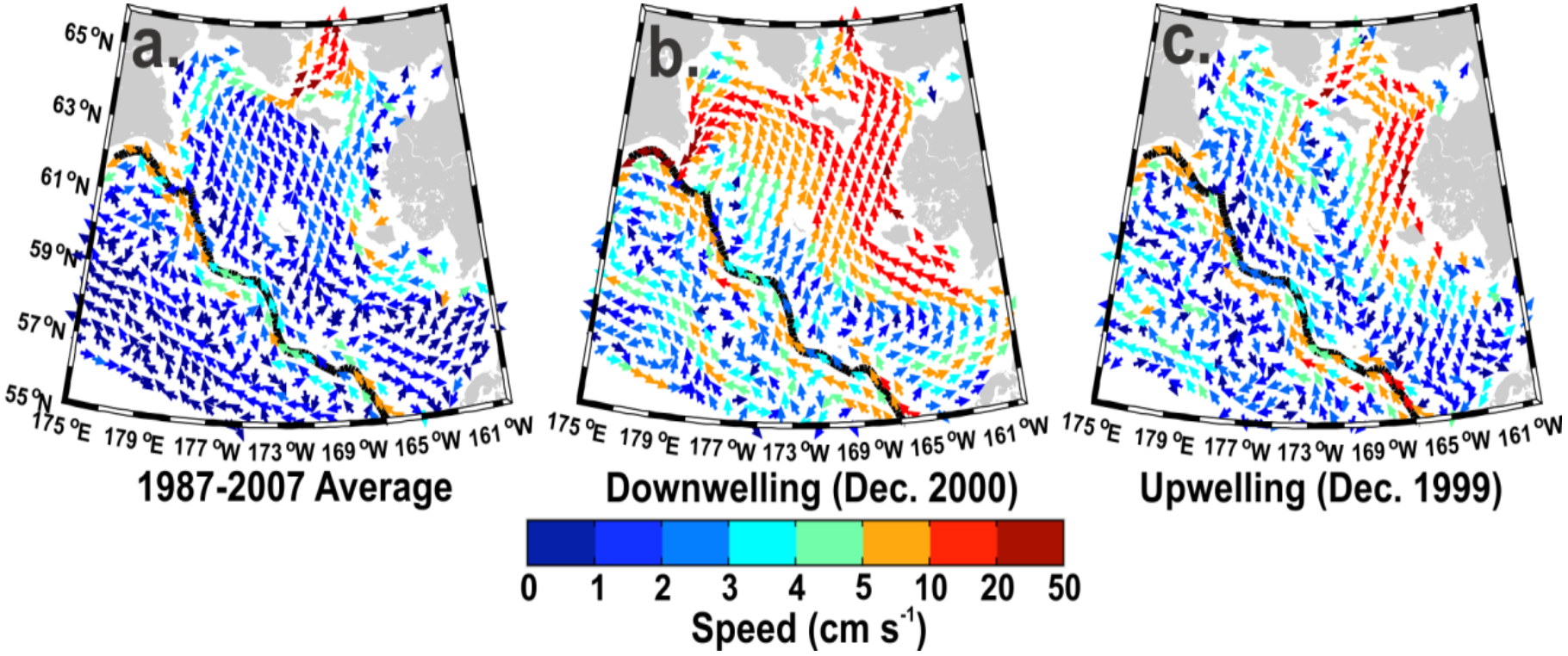


A numerical circulation model

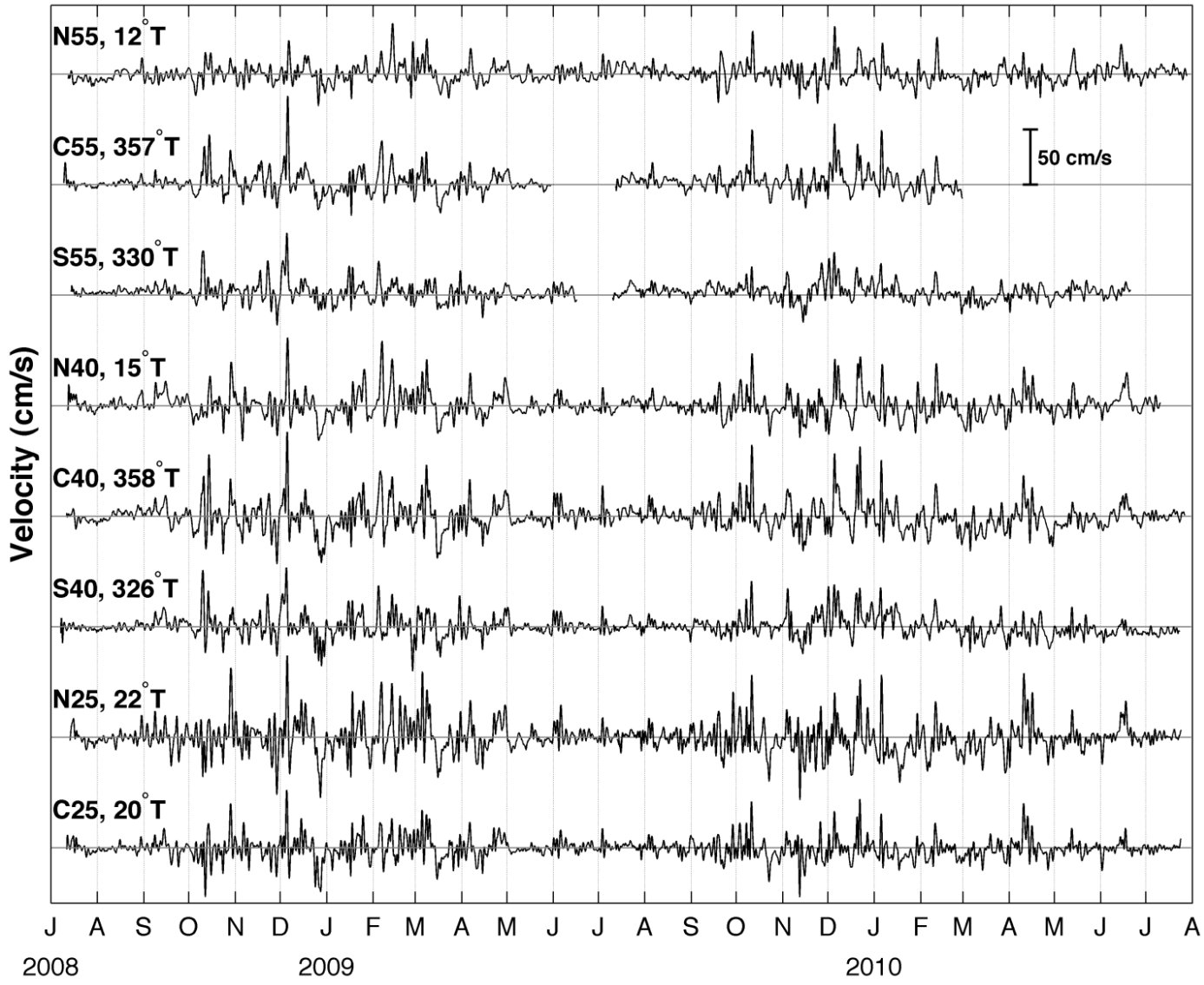
Mean

Northward Winds

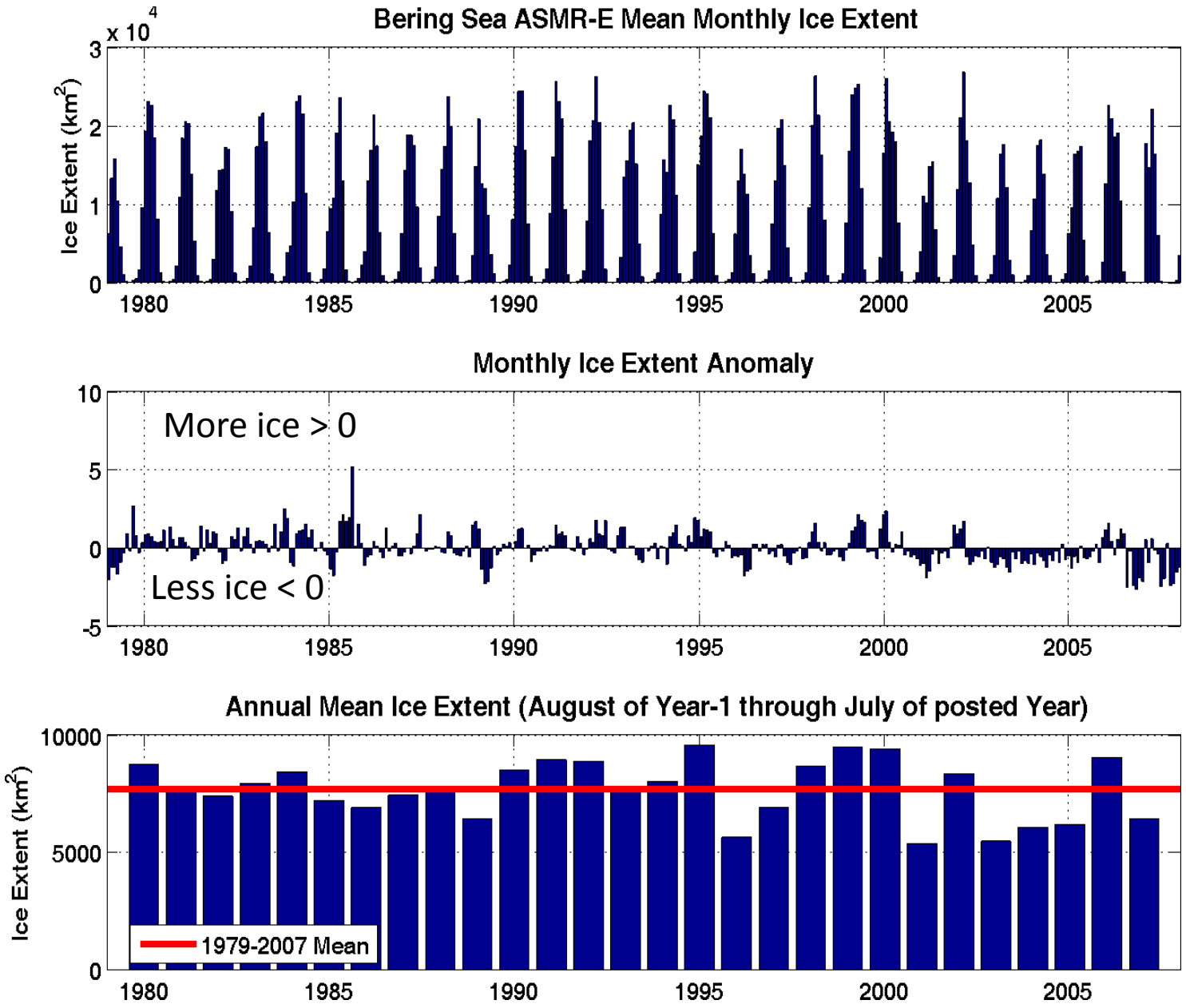
Southward winds



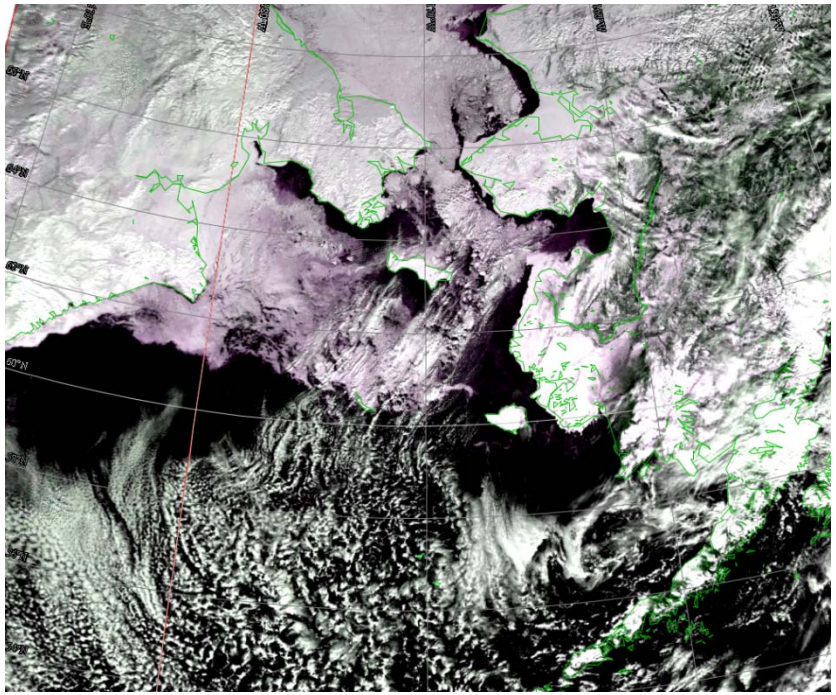
But large wind-driven variability
winter >> summer
small mean; large variance



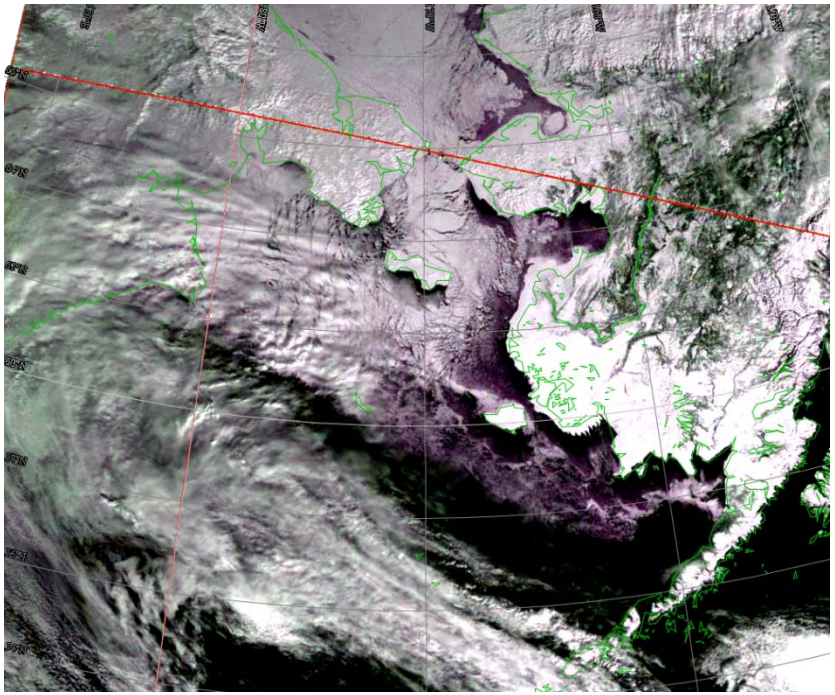
Interannual variations in ice extent are due to northerly winds



March 22, 2005

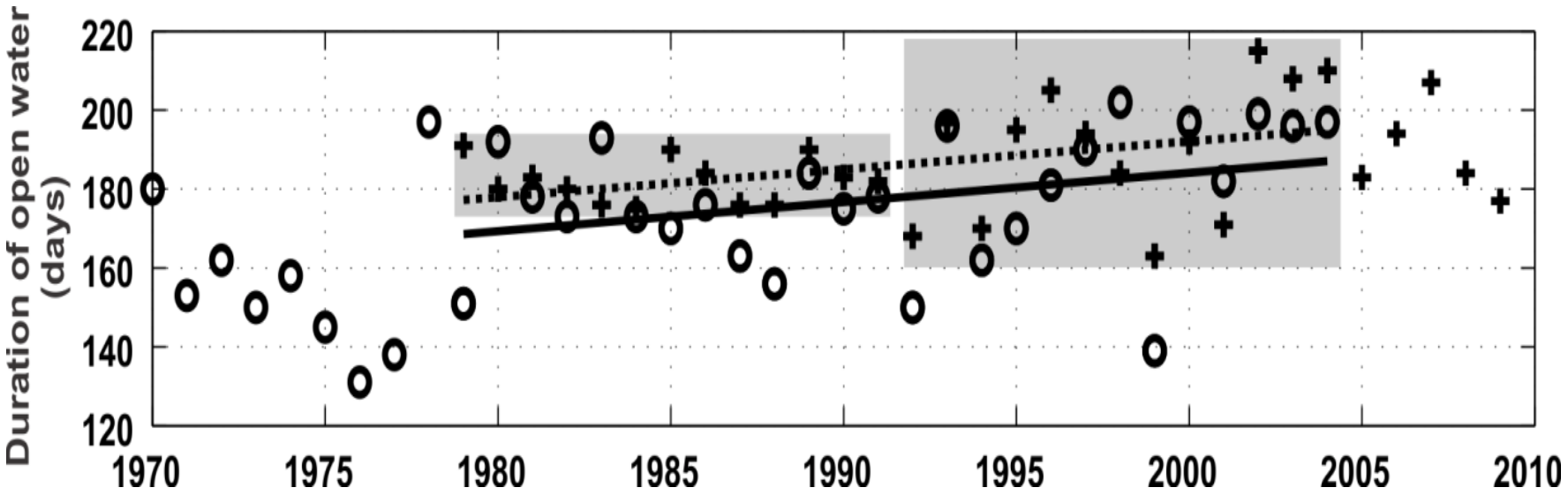


March 24, 2006



Ice extent affects:
Spring, summer, and fall bottom water temperatures and stratification

Annual number of ice-free days (1970 -2010)



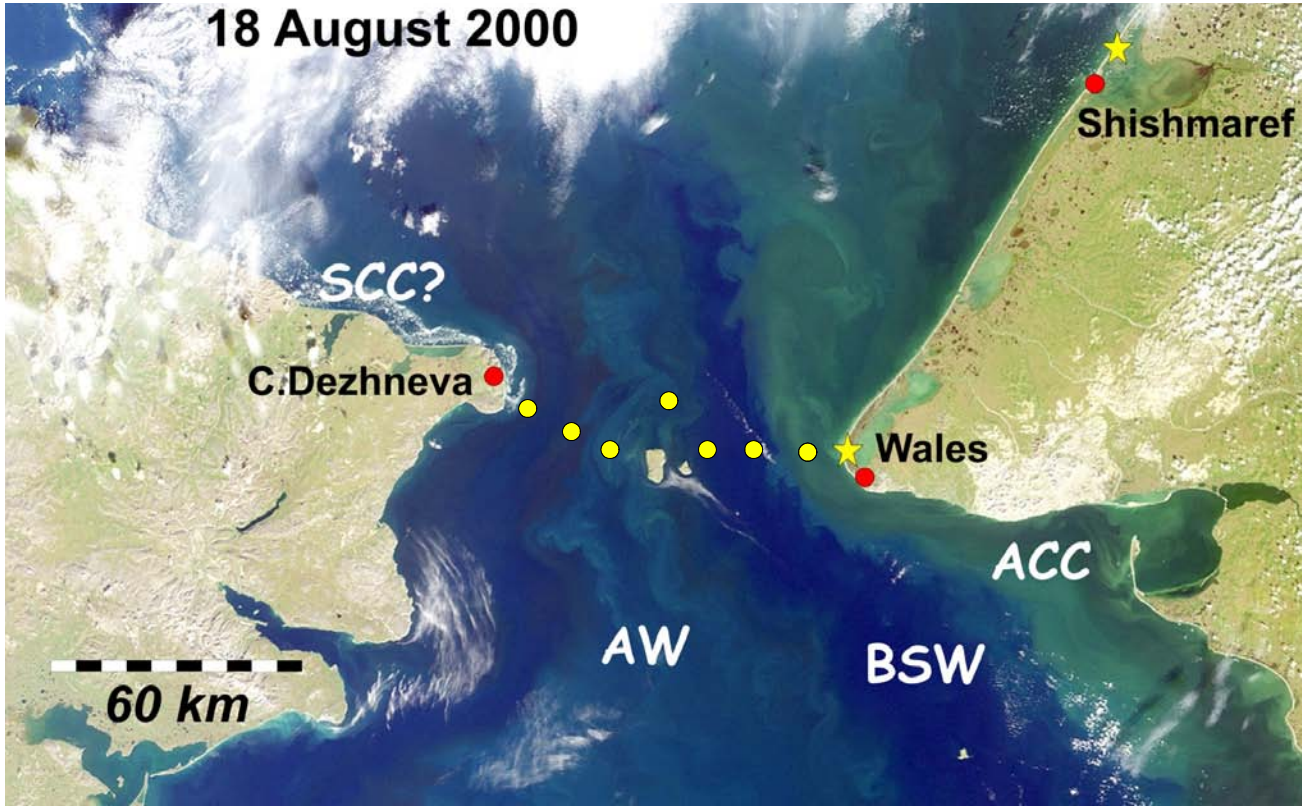
Least squares best fit linear trend

Observations +

Model o

Models do reasonably well in predicting ice cover in the Bering Sea

Bering Strait

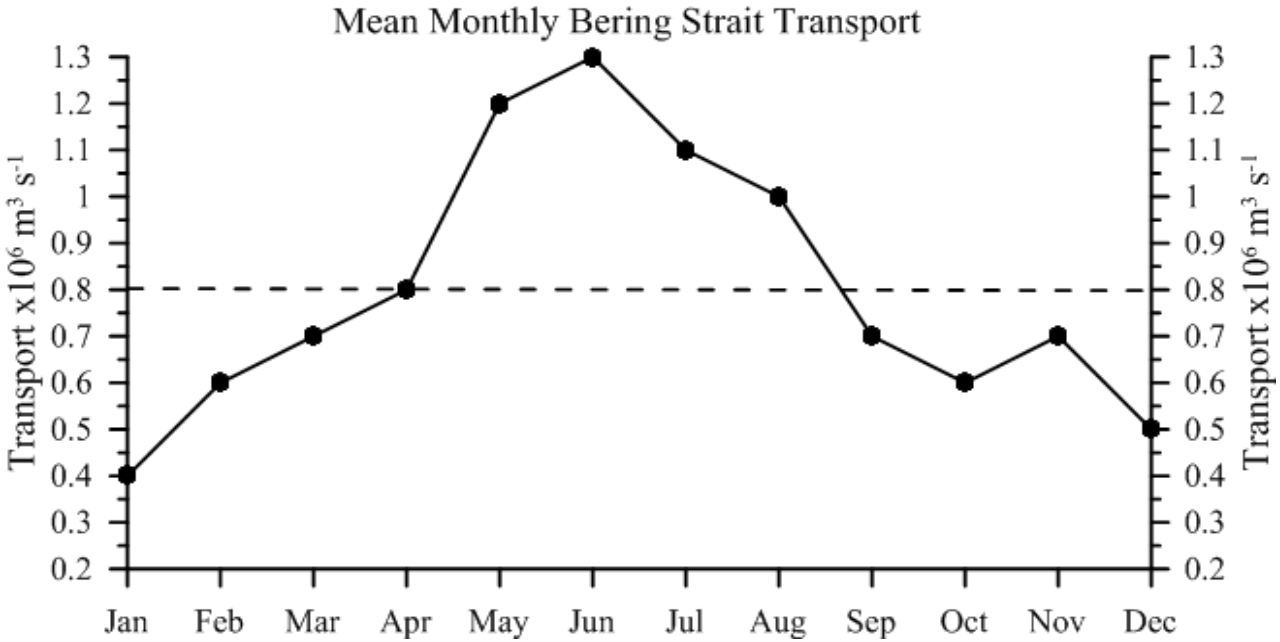


1.) Alaskan Coastal Current (ACC): a major Freshwater and Heat source

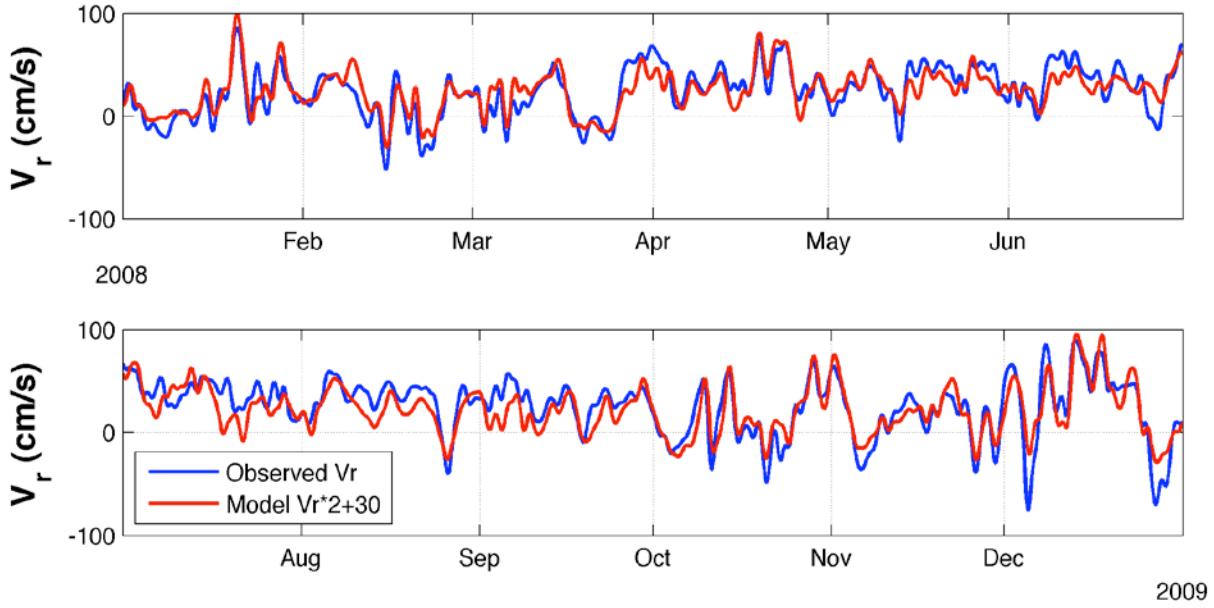
2) Bering Shelf Water (BSW): a mid-shelf source (moderate properties)

3) Anadyr Water (AW): Bering Sea Basin source (cold, salty)

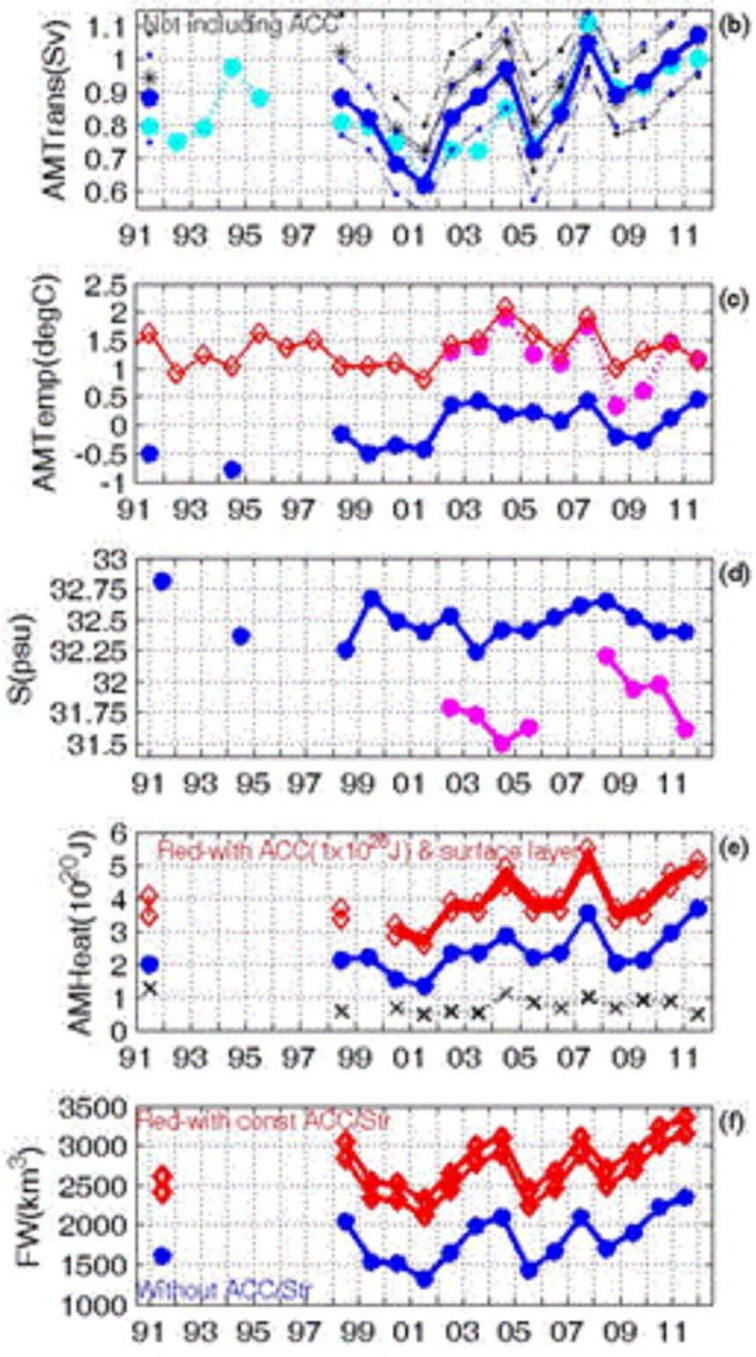
*Properties established in Bering Sea and further south
*All transported northward



Northward
(global processes)



Model Predictability
Good for transport based on winds:
-local
-remote
(Bering shelf, Chukchi shelf, East Siberian Sea)



Interannual Variability is LARGE

TRANSPORT

Mean annual transports and heat fluxes show **<u>increase from</u>**:

2008 (0.9 Sv; 2 x 10^{20} J)
to:
2011 (1.1 Sv; 5 x 10^{20} J)

2007 (1.1 Sv; 5 x 10^{20} J)

HEAT FLUX

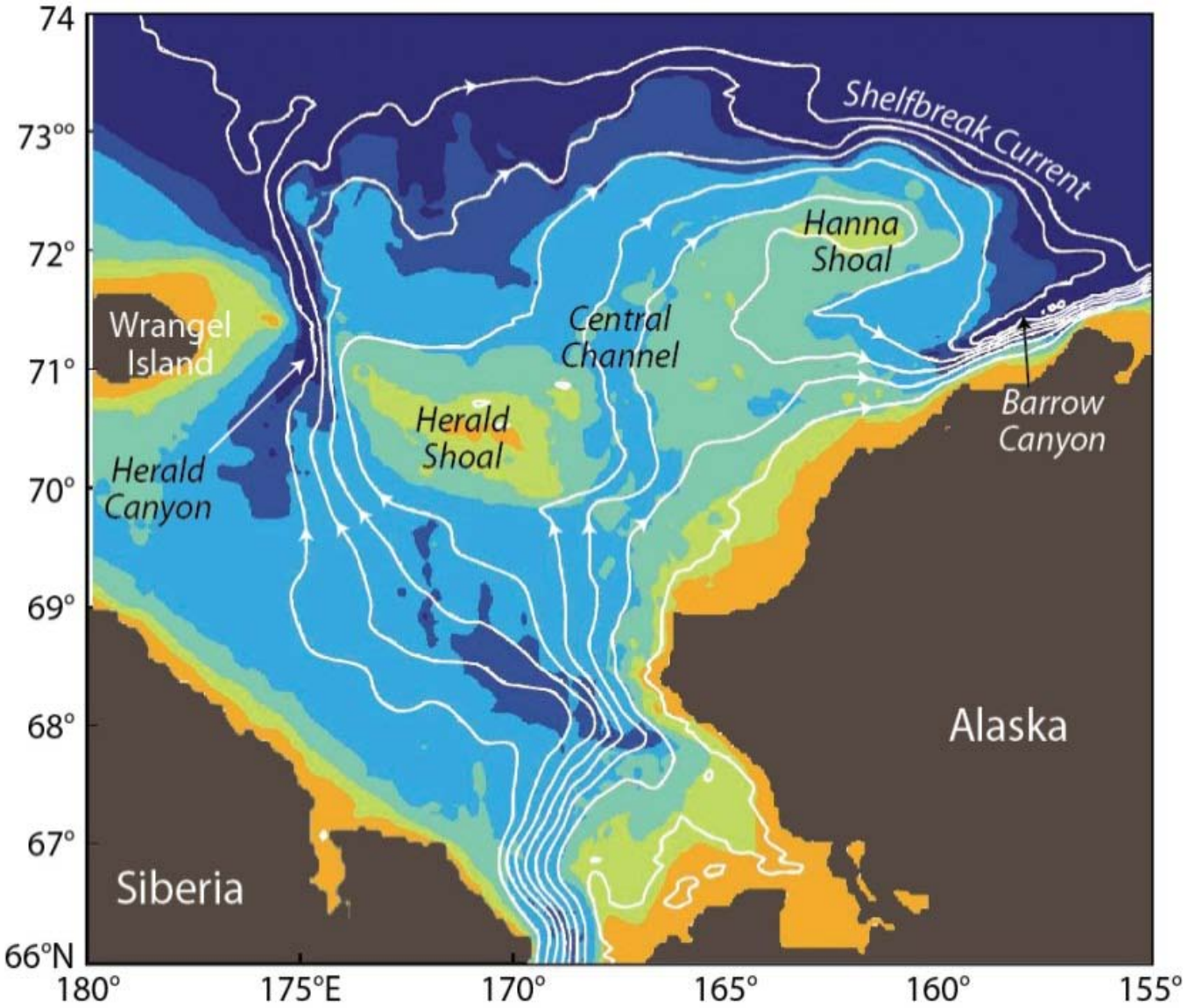
SALT FLUX

Critical to Chukchi Ice processes

Woodgate, Weingartner, and Lindsay (2013)

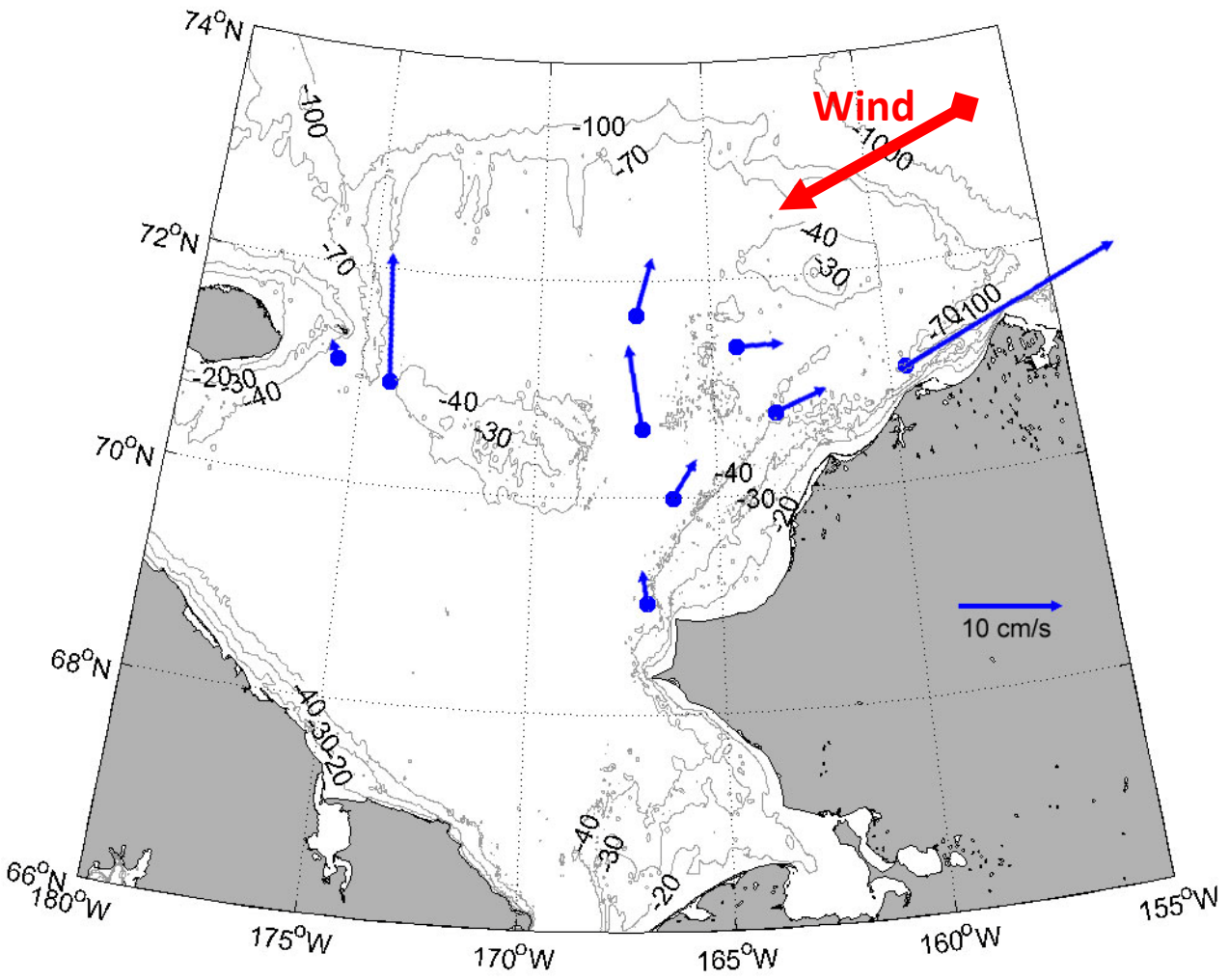
The Chukchi Shelf

Mean Flow: Bering Strait only (no winds)

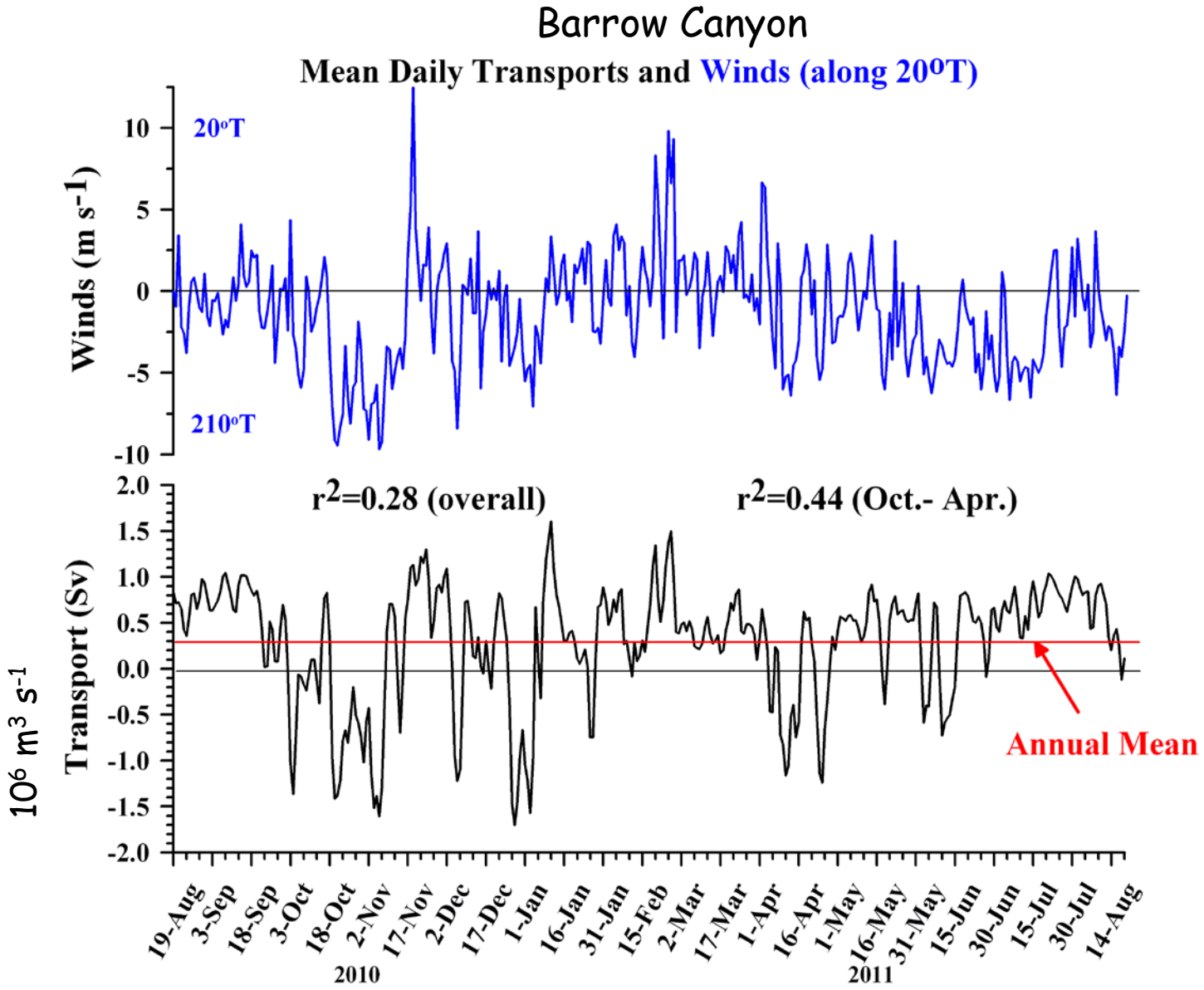


Spall (2007)

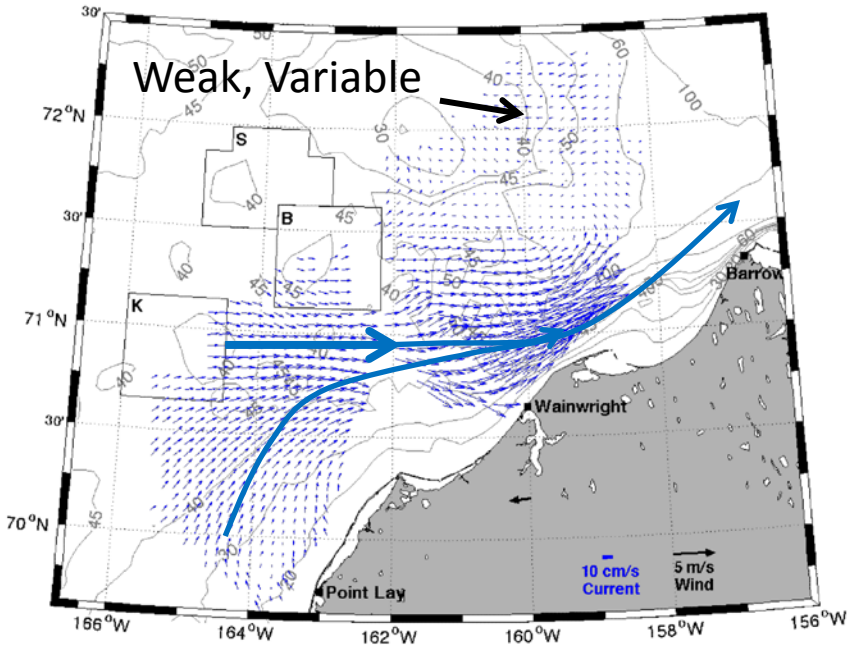
Sub-Surface Currents



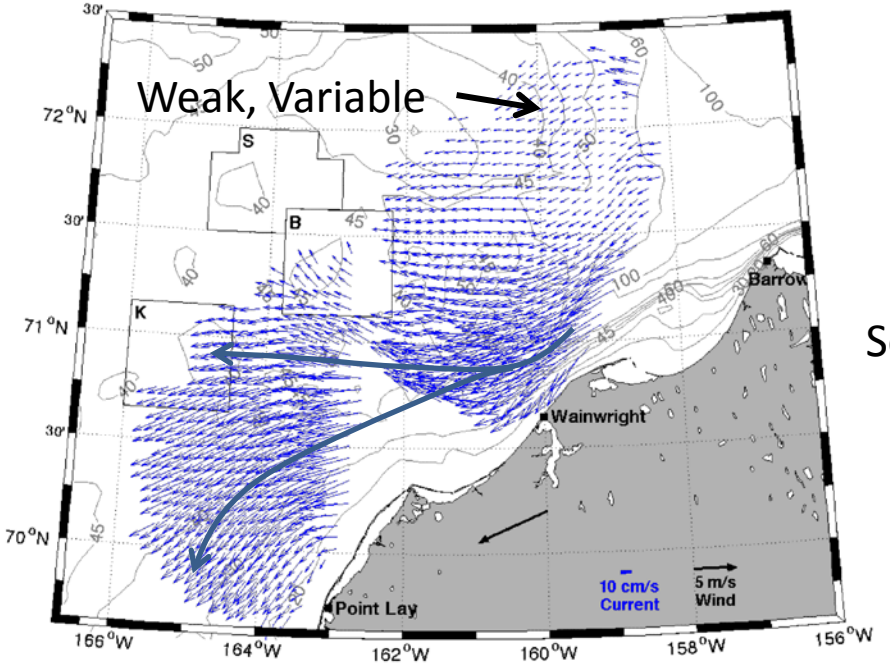
- Historical mooring data support the model
- Oppose mean winds
- Swiftest in canyons/channels and weakest in shallow regions
- Strongest in summer and weakest in winter



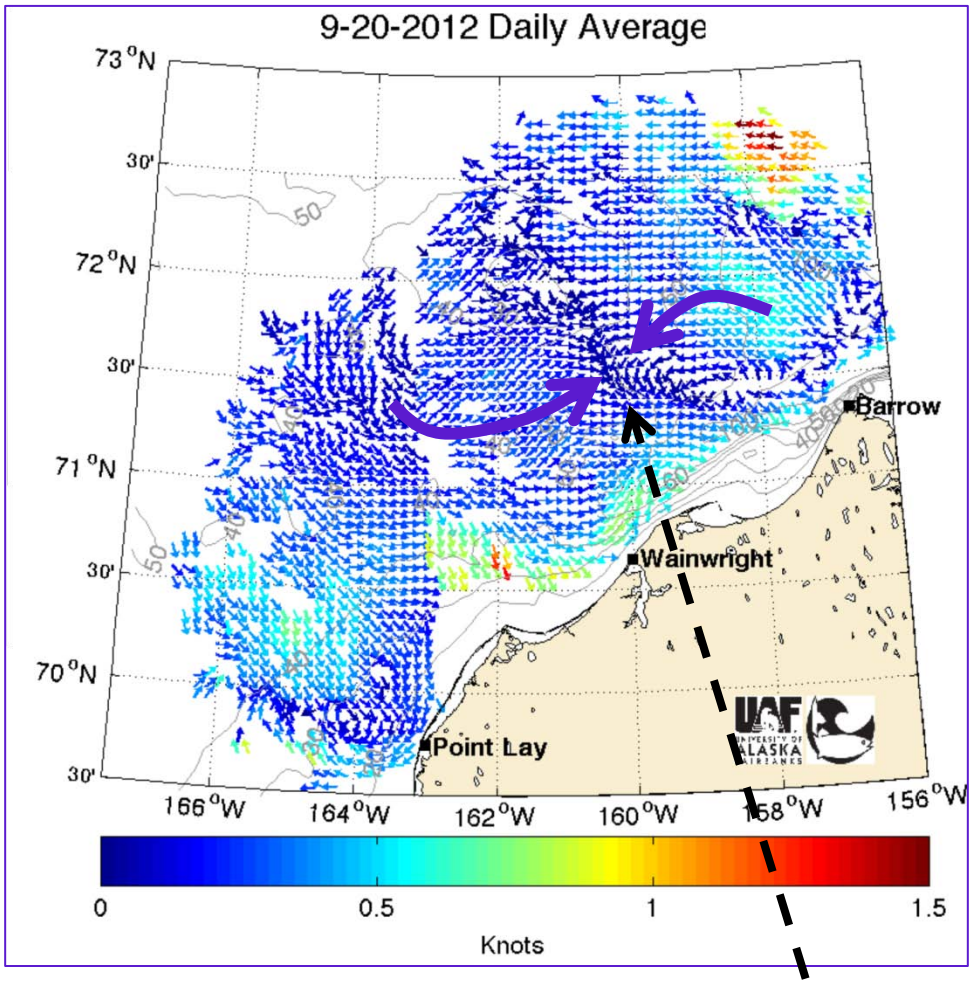
Wind-current correlation increases when Bering Shelf winds are included



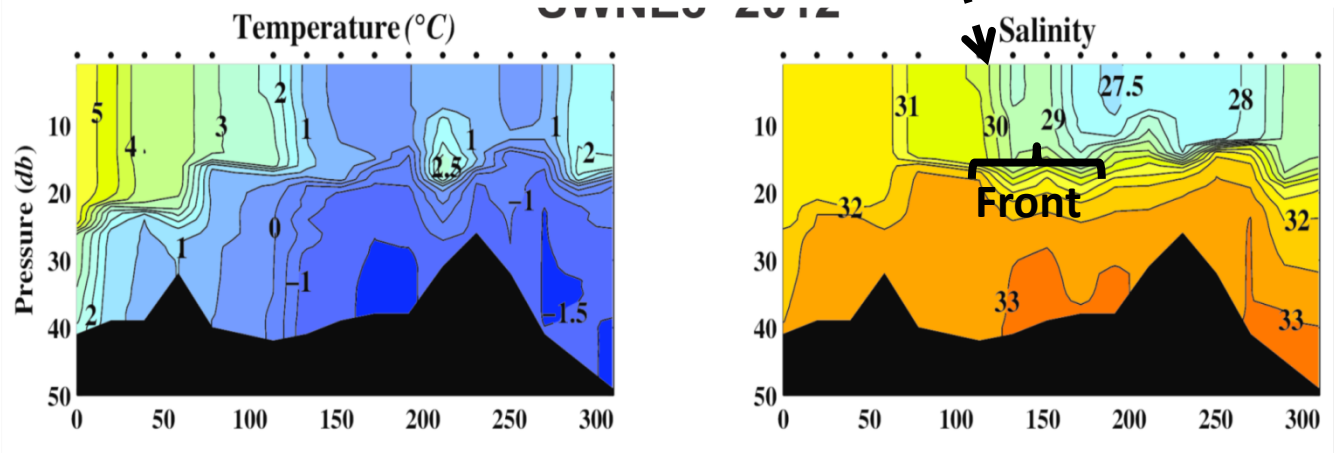
Northeastward flow through Barrow Canyon



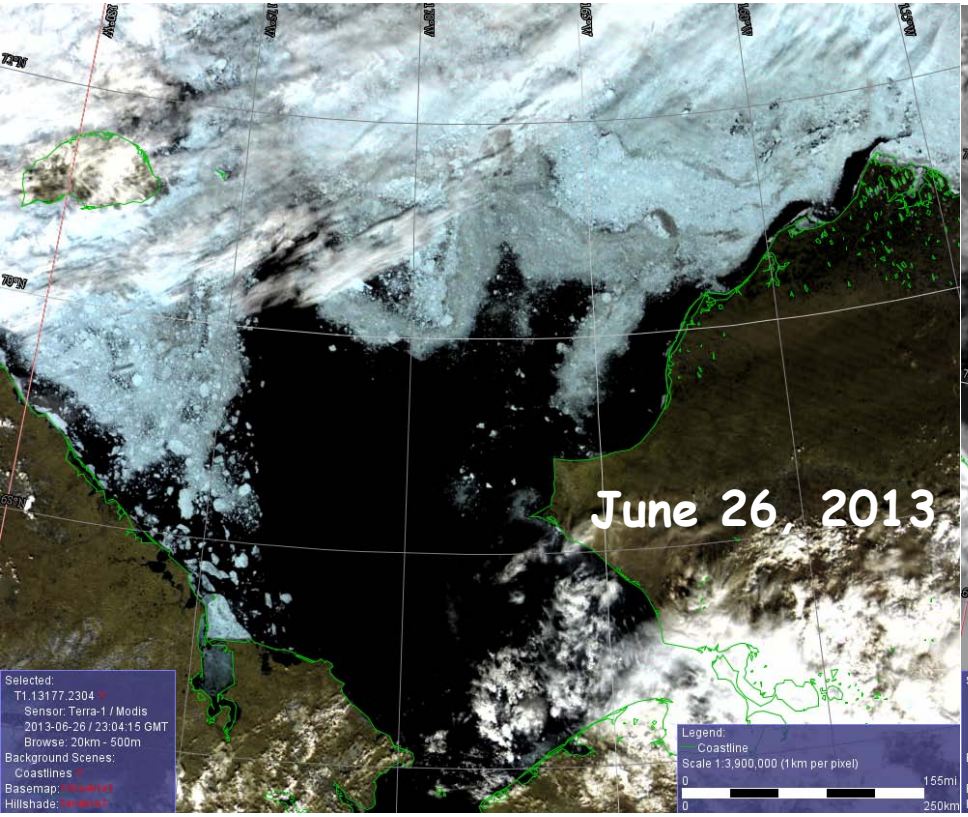
Southwestward flow through Barrow Canyon
(Winds from northeast > 11 knots)

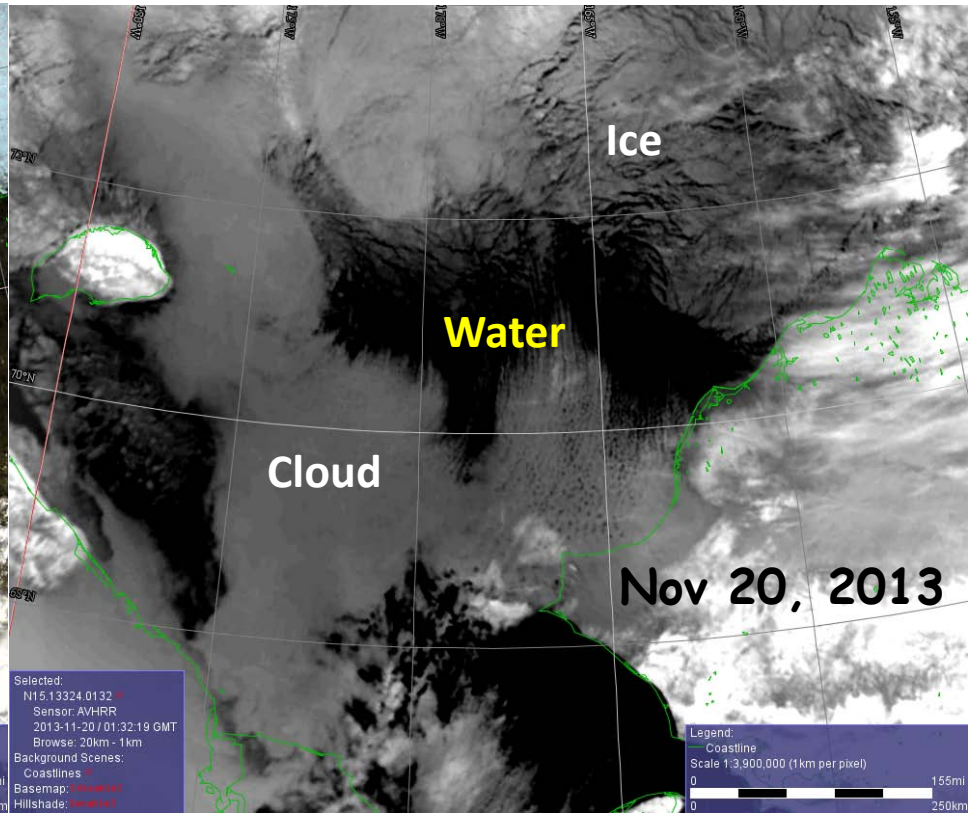


Small scale variability:
ubiquitous,
frontal convergence

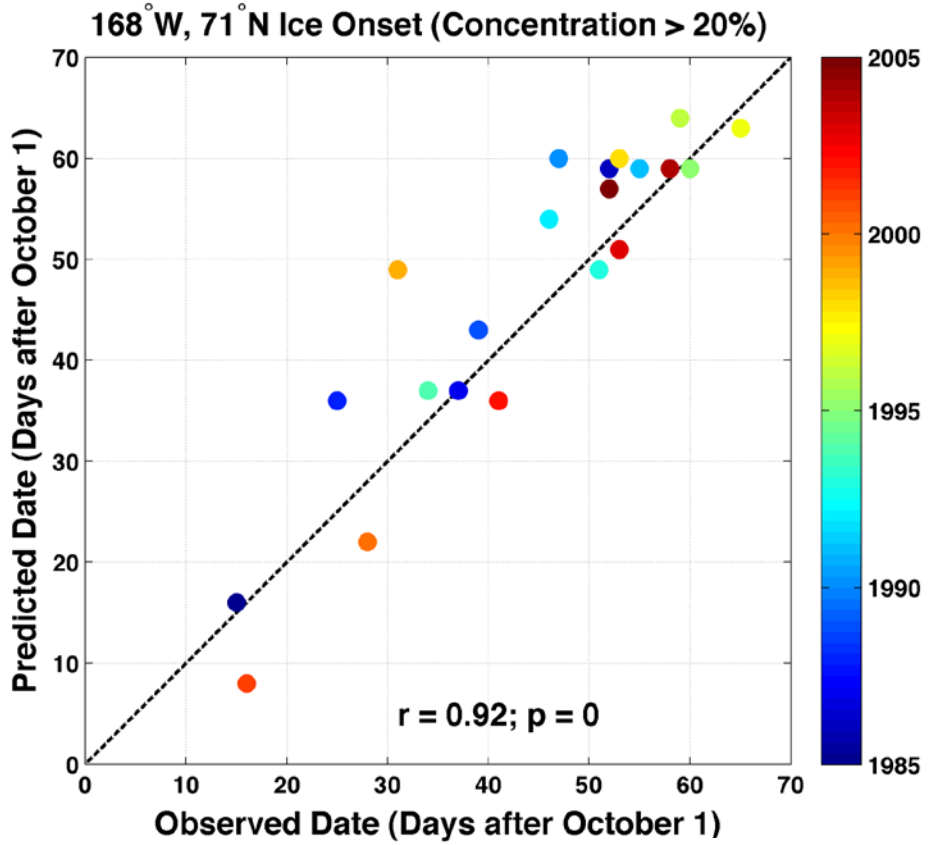


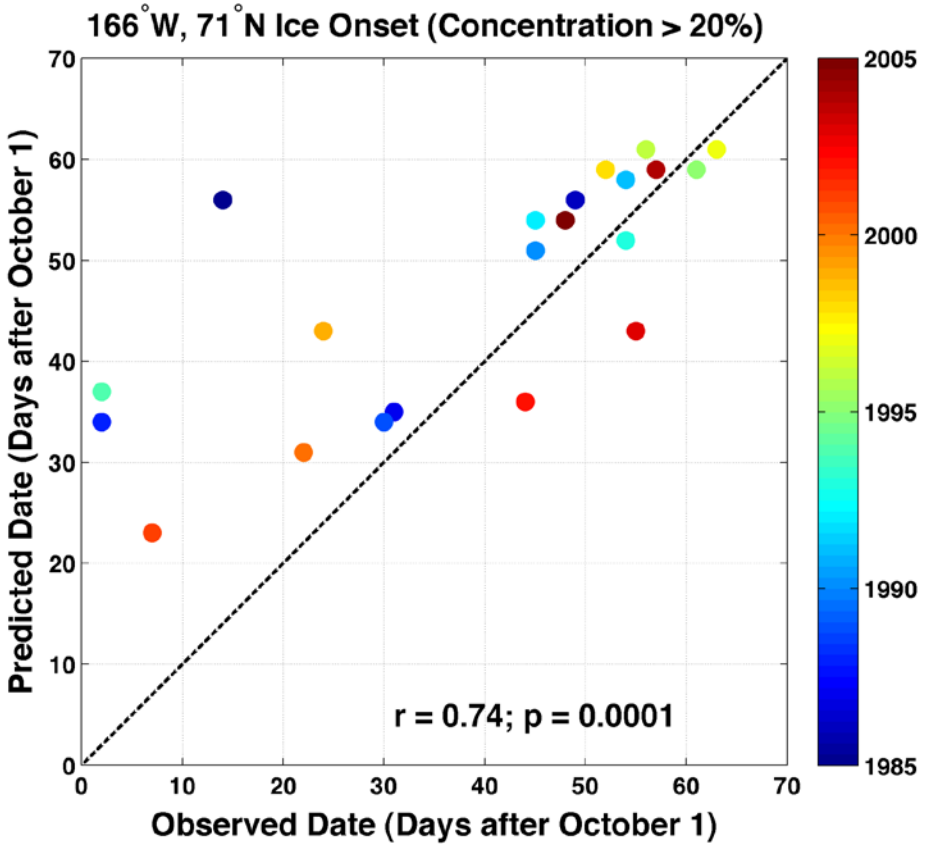
Bering Strait Heat Flux and the Chukchi Ice Cover: Accelerates Spring Retreat and Retards Fall Advance





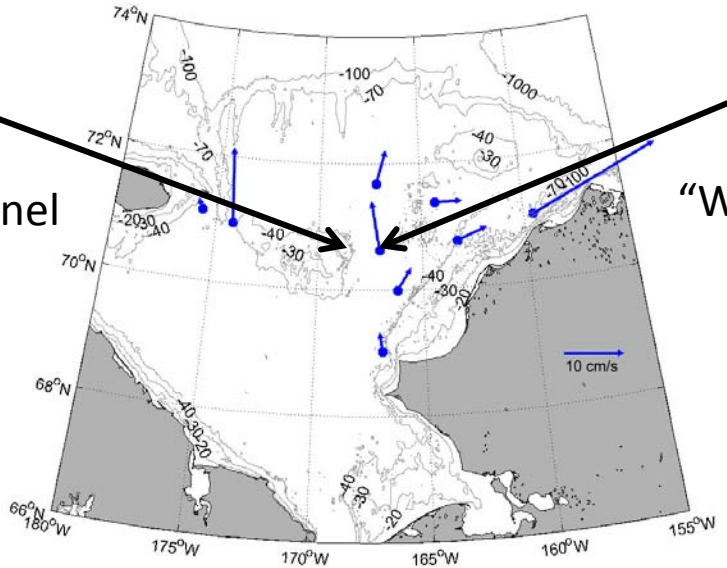
But . . . temperature and transport are not enough
we must also know the salinity distribution!!



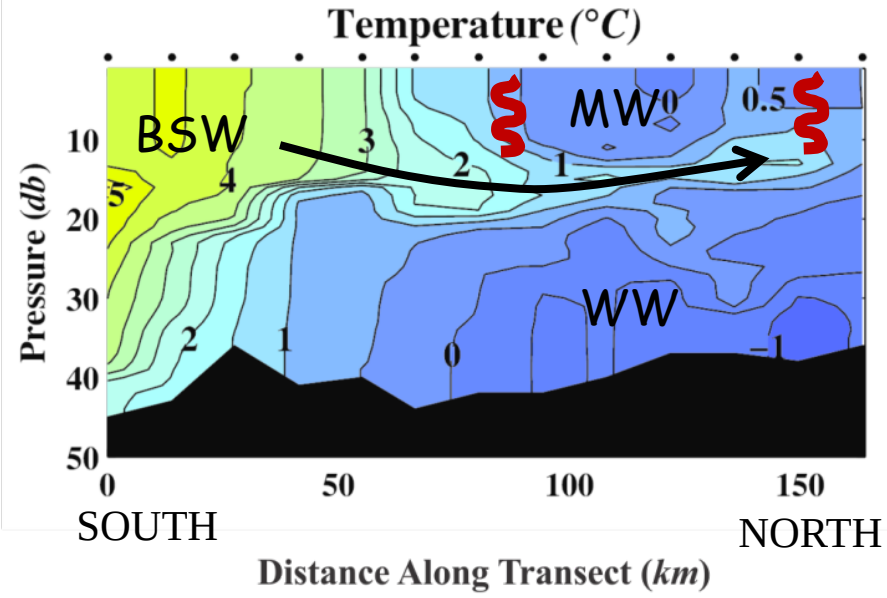


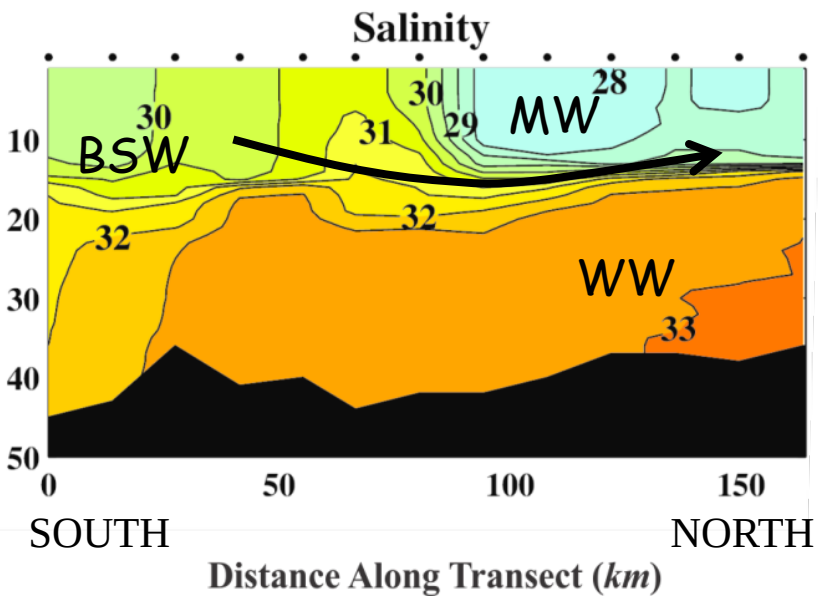
"Cold side" of Central Channel

"Warm side" of Central Channel



August 2012: South of Hanna Shoal



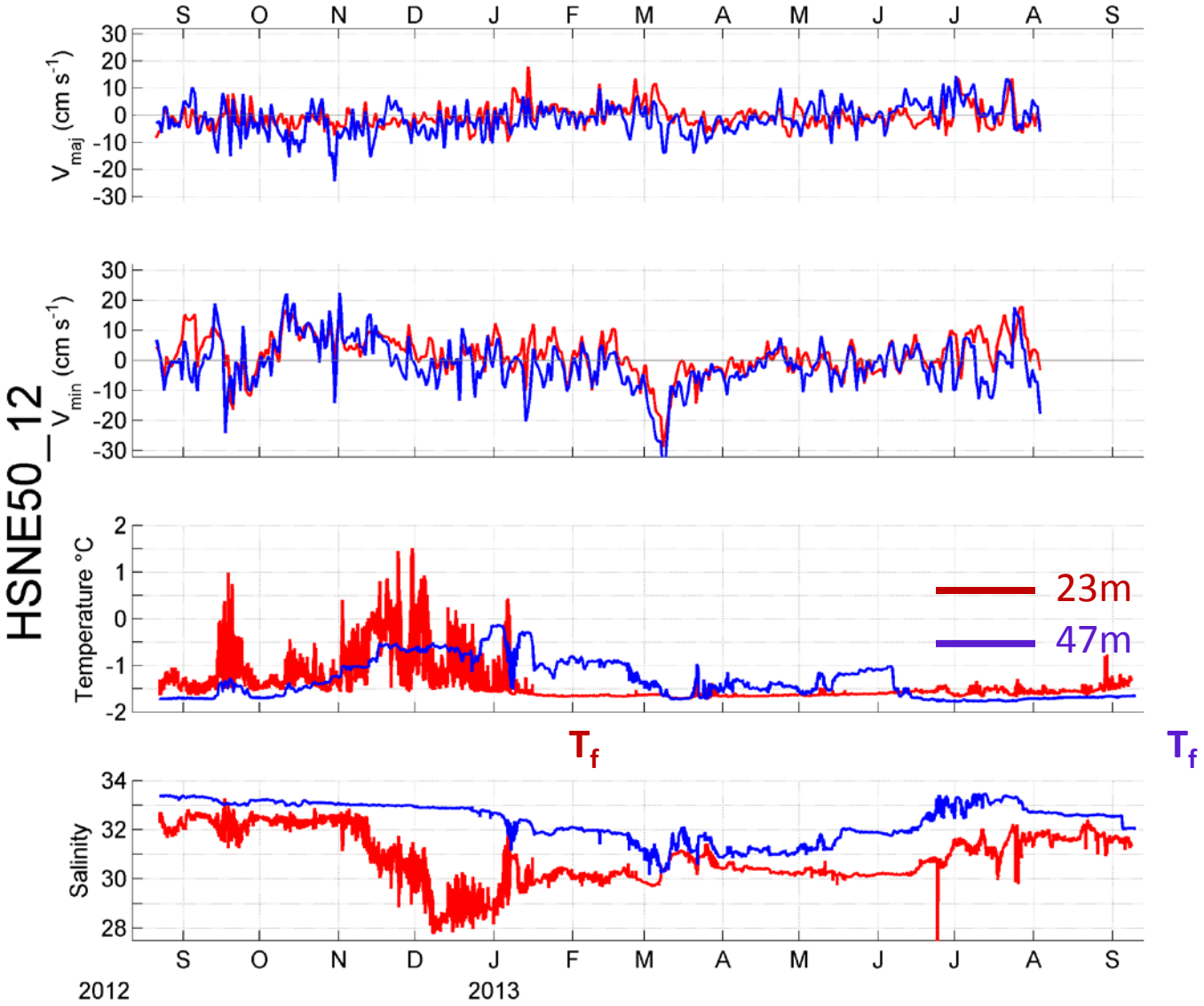


Subducting BSW plumes are a heat source for the surface (ice)

This process is salinity dependent!!!

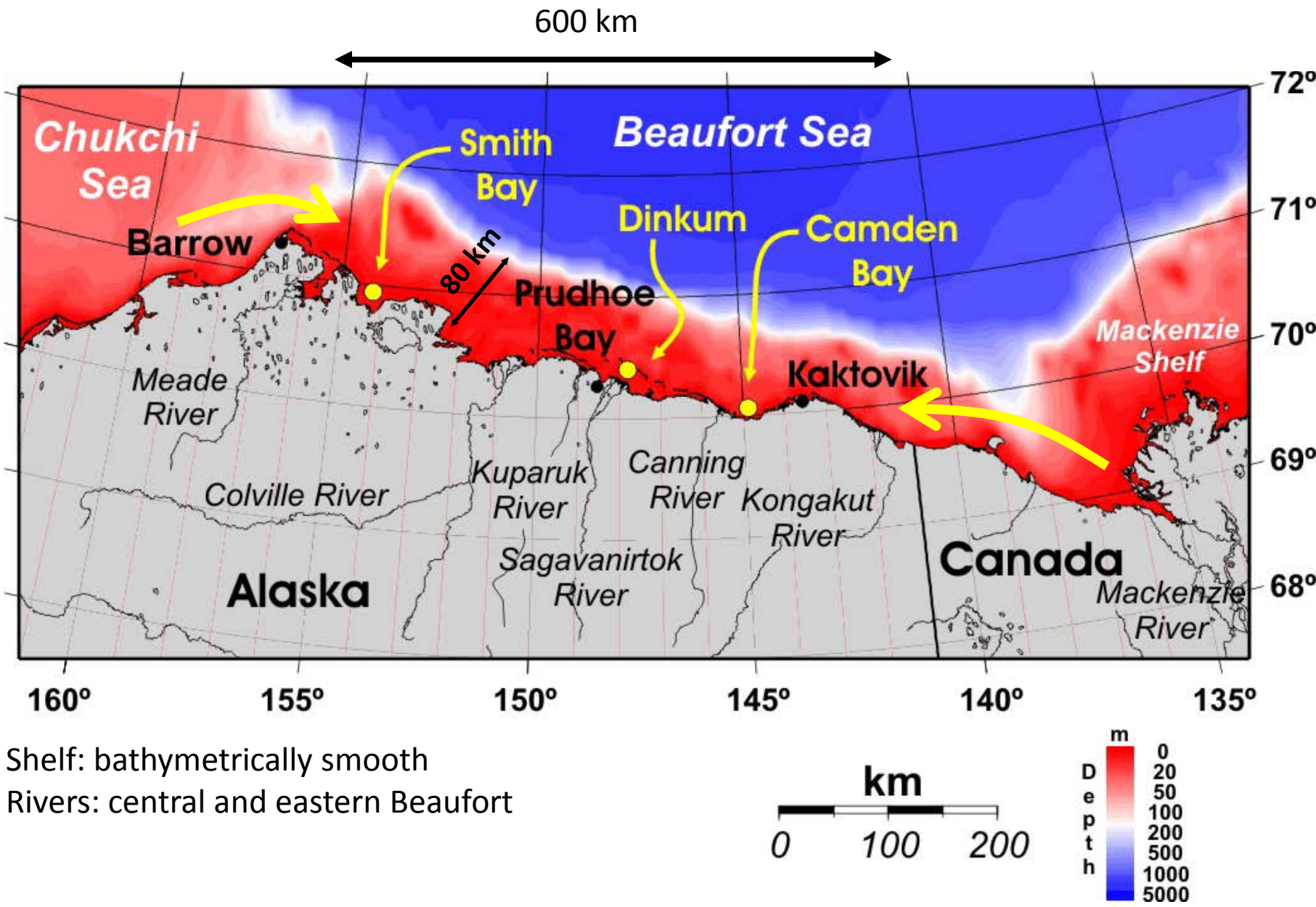
Chukchi Sea Ice Cover:
A complex result of ocean and atmospheric heat fluxes, and winds

NE Hanna Shoal – a very different "shelf"!!



NOT LIKE THE BERING SEA SHELF!!

The Alaskan Beaufort Shelf (ABS)

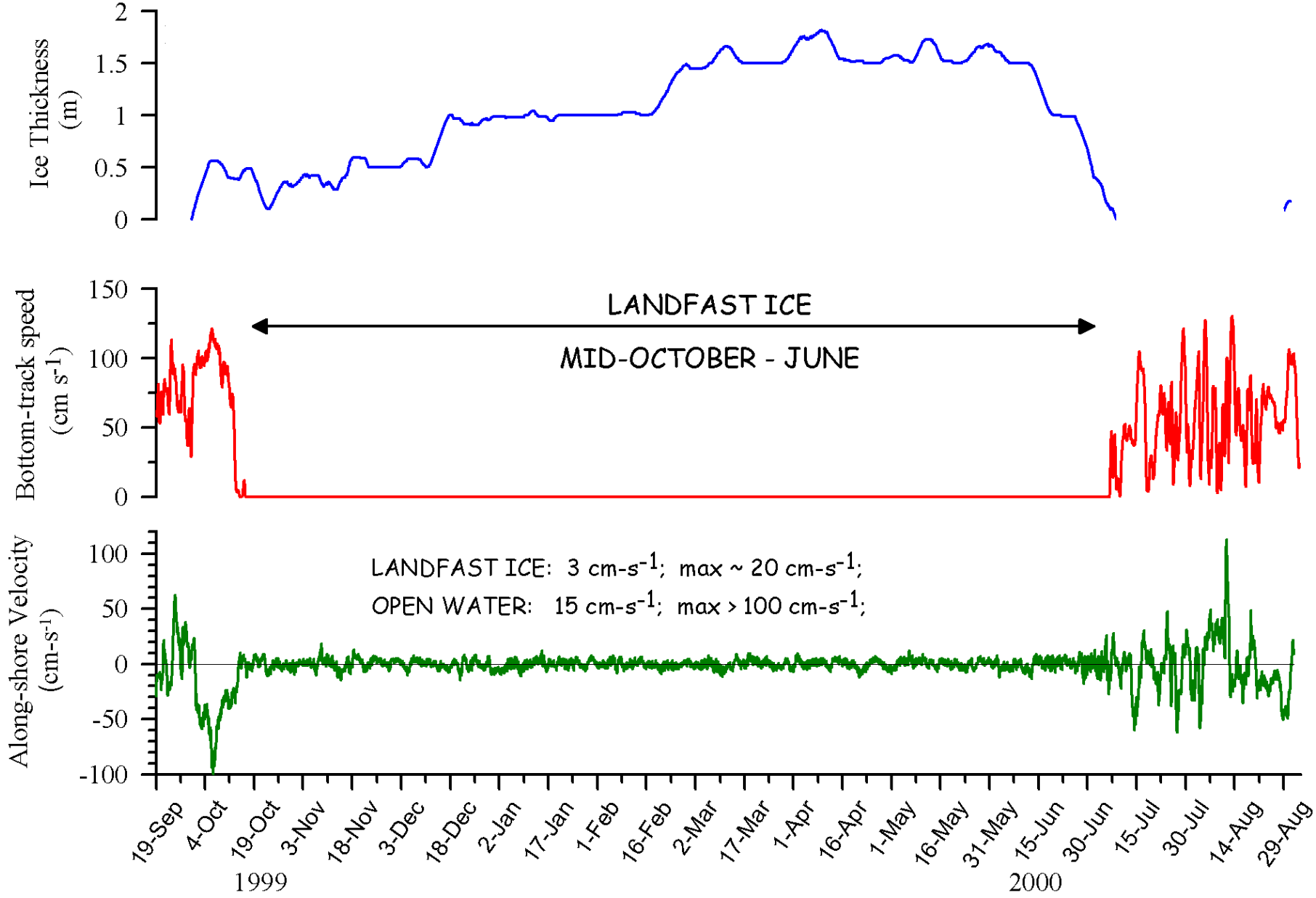


Shelf: bathymetrically smooth

Rivers: central and eastern Beaufort

The Annual Cycle: Ice Thickness, Ice Set-up & Alongshore Currents

(Within 30 km of the coast)

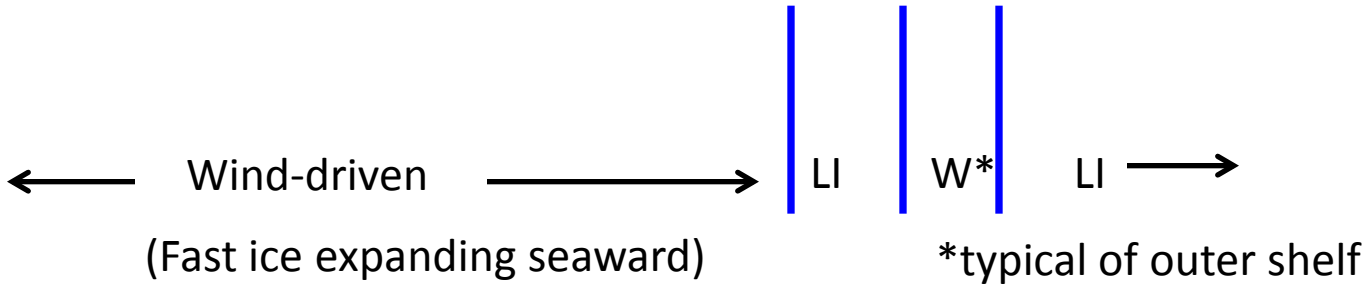


eastward

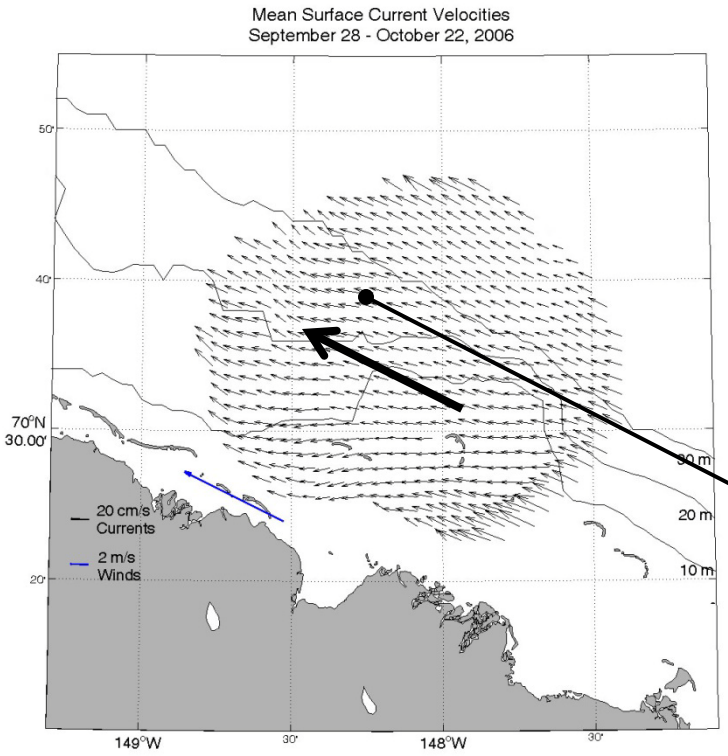
westward

eastward

westward



Wind season (Sep – Oct): Strong winds, well-mixed(?) conditions



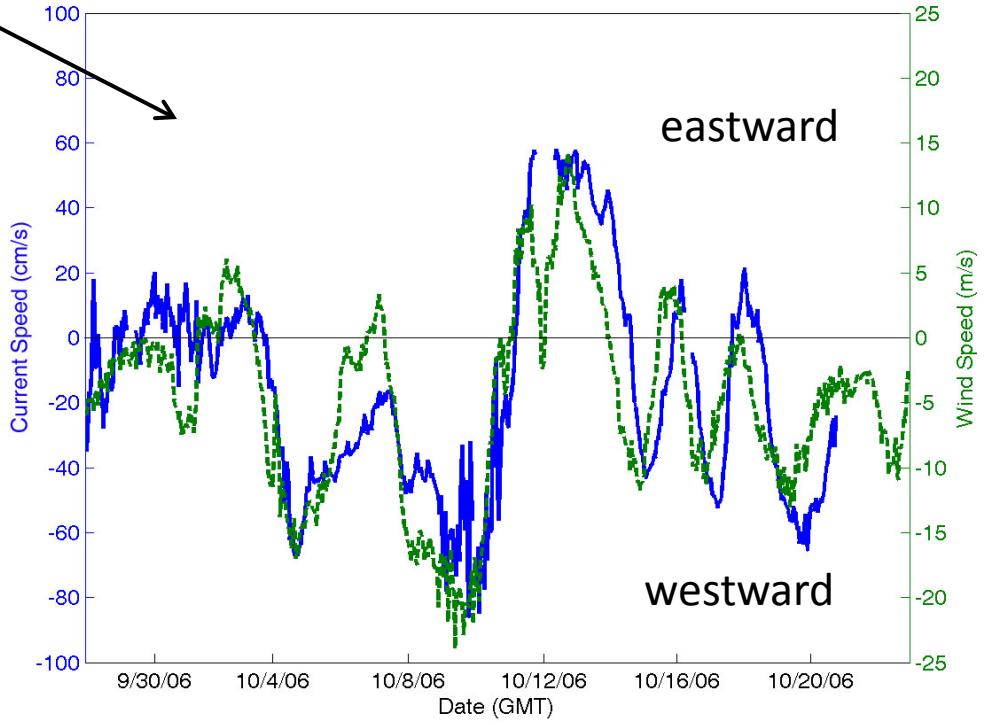
12 MHz HF radar

October 2006

Mean winds: 10 m/s westward

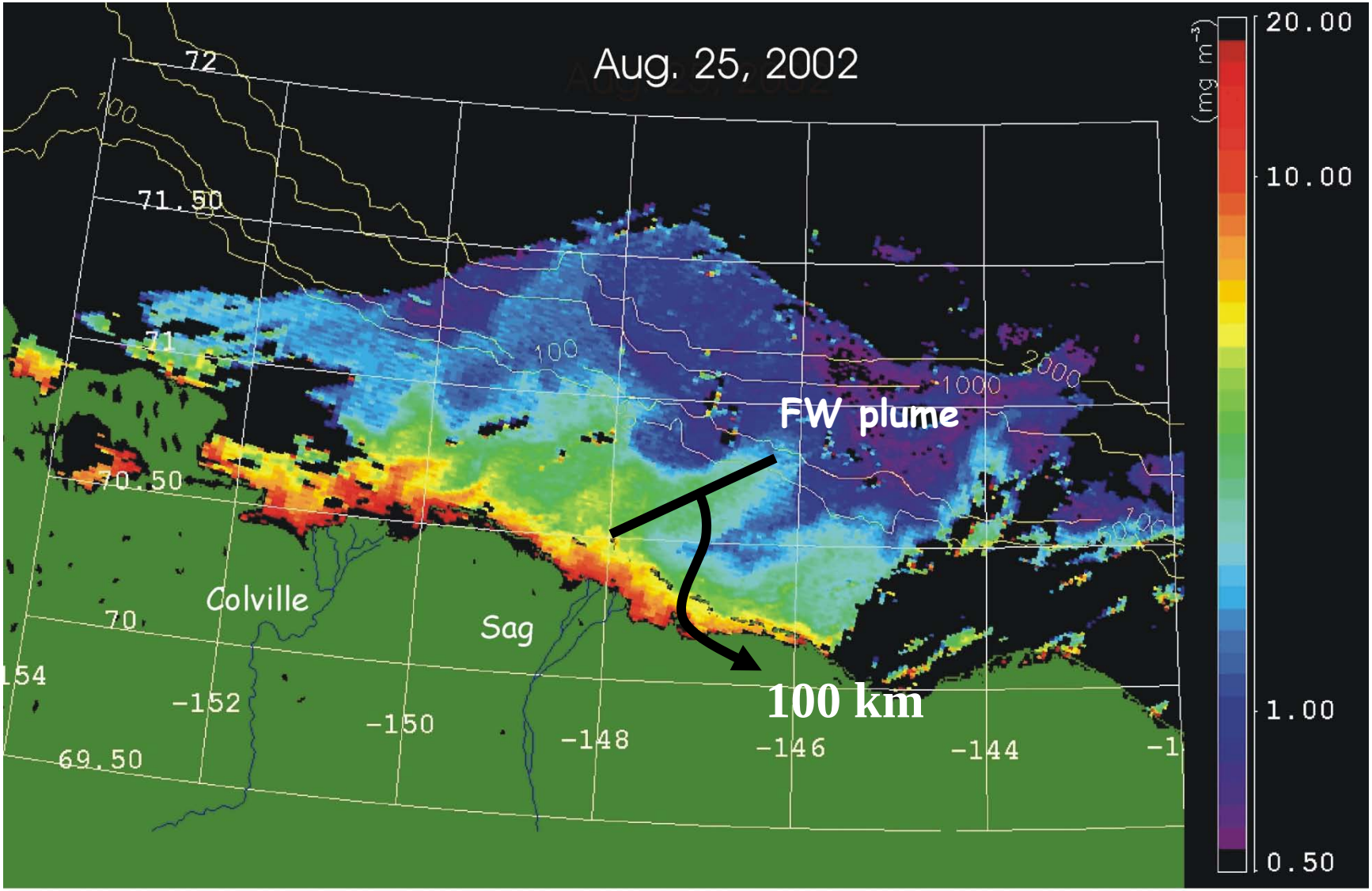
Mean Along-shelf Flow: 0.5 kts

Inner shelf volume replaced in 45 days!



Impacts winter shelf properties

Runoff can modify the wind-driven (Jul-Sep) circulation – but to what extent?



Winds (preceding 7 days): Variable 5 - 10 m/s

Summary

1. Aleutian Low: position and strength impacts circulation
   time scales: daily – interannually
2. Gulf of Alaska: winds & runoff
3. Bering Sea: winds and tides
4. Bering Strait: Global processes and winds
5. Chukchi Sea: Bering connection and winds
6. Beaufort: Winds, runoff; spatially modulated by landfast/pack ice

The broad scale circulation connects Alaska's shelves to each other

Thoughts on sea-ice predictability

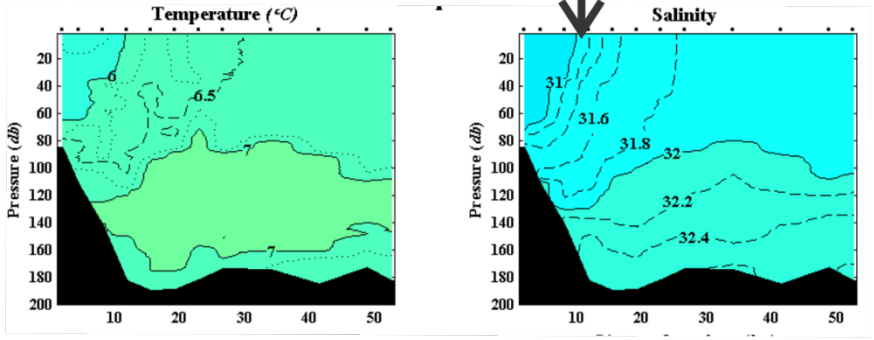
1. Bering: relatively simple (air-sea heat exchange and winds)

2. Chukchi: complicated, ocean circulation is likely a major player

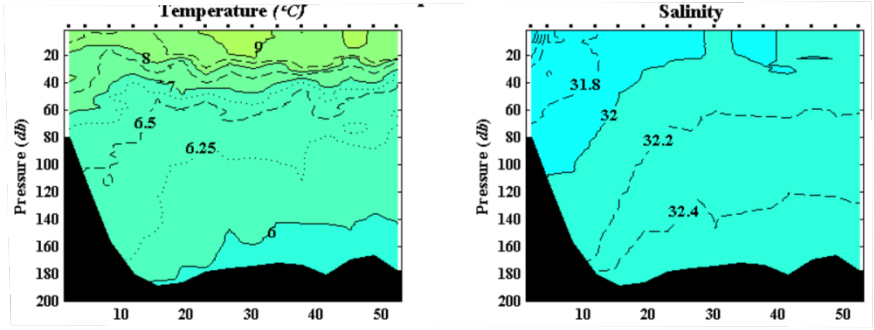
3. Beaufort: maybe simple/maybe difficult
   - lack oceanographic understanding
   - predicting the landfast/pack ice distribution is a challenge!

4. It may be simpler to obtain in-situ & real-time data to forecast ice formation for operational purposes!!

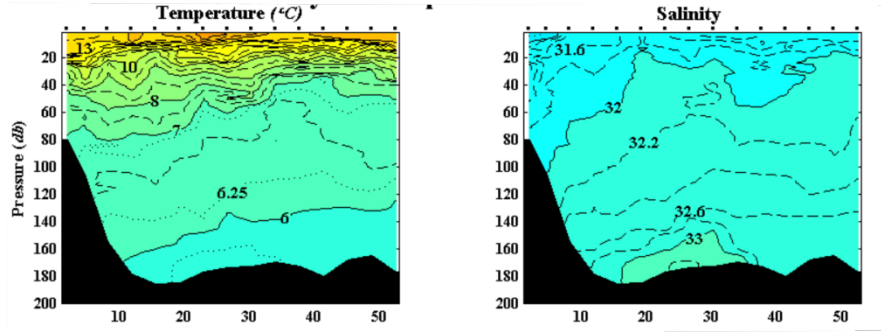

Thank you !



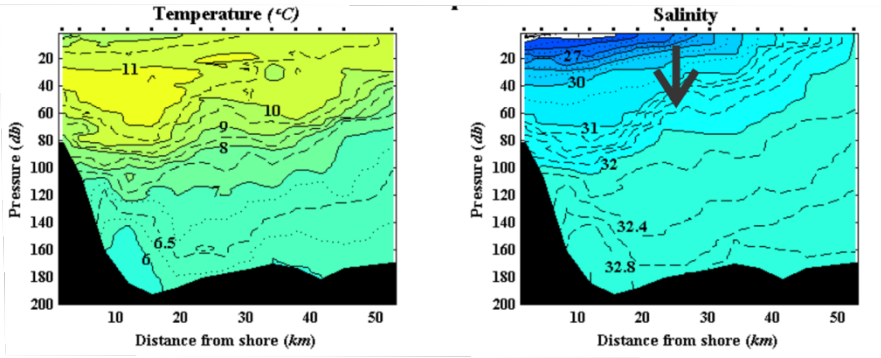
March
well-mixed
moderate flow &front



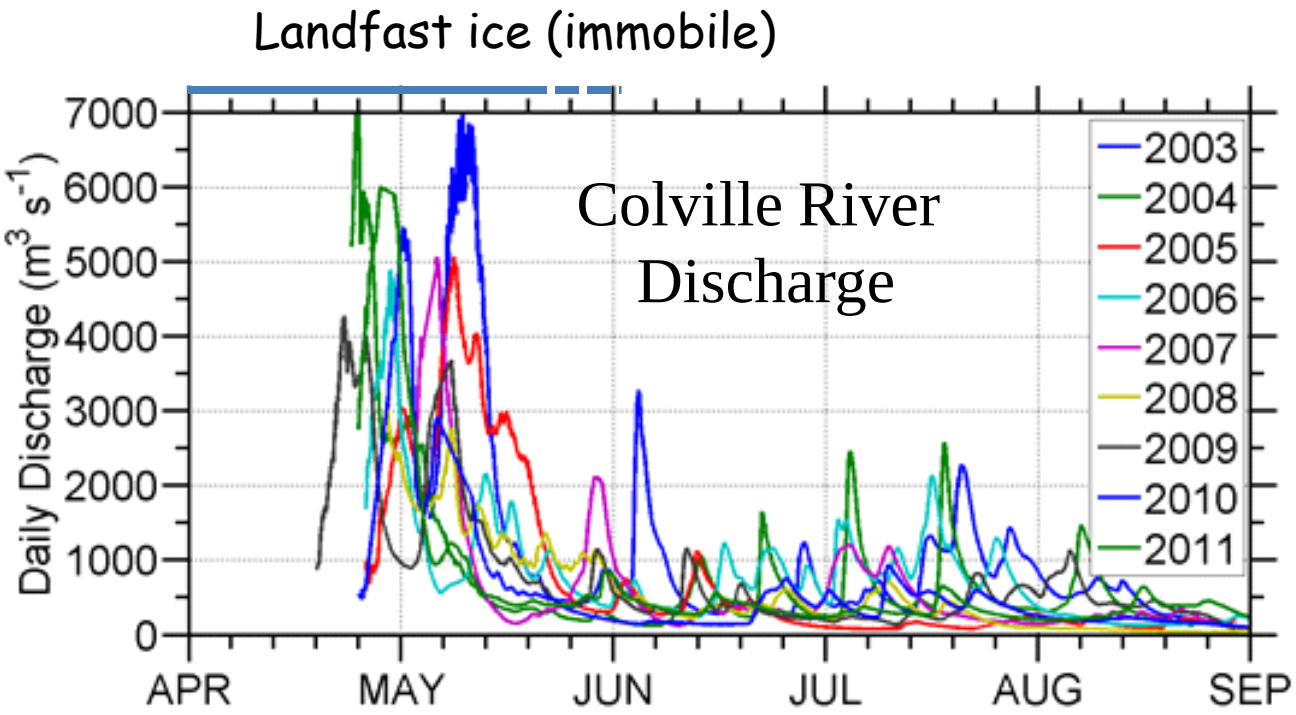
May
increasing stratification
weak flow & front



July
increasing stratification
weak flow & front



October
maximum stratification
maximum flow & strong front

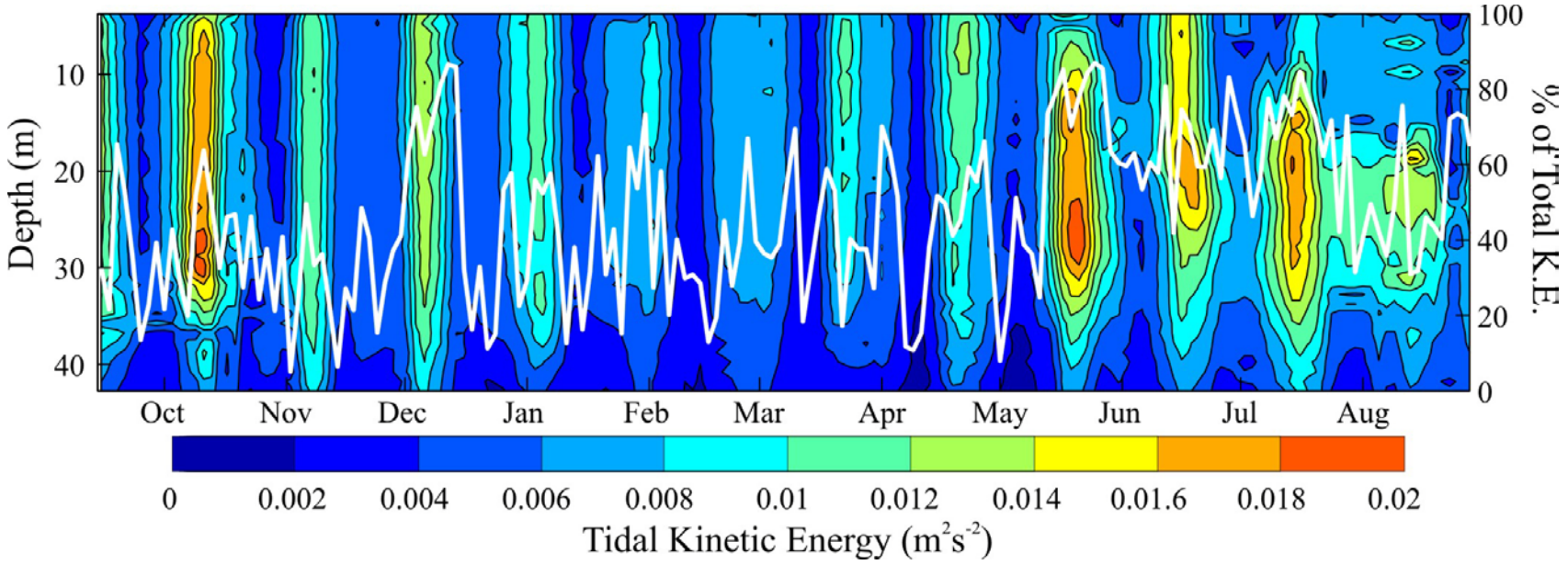


The 2 week spring freshet carries:
80 - 90% of annual discharge
Most of the TSS, metals, POC, DOC (pers. comm. J. Trefry)

Processing depends upon landfast ice!

Tidal kinetic energy near St. Lawrence Island

Mixing varies seasonally, monthly, diurnally



Bering Sea Shelf Summer/Fall Frontal Structure