Numerical Simulations Reveal the Role of the Alaskan Stream in Modulating the Bering Sea Climate

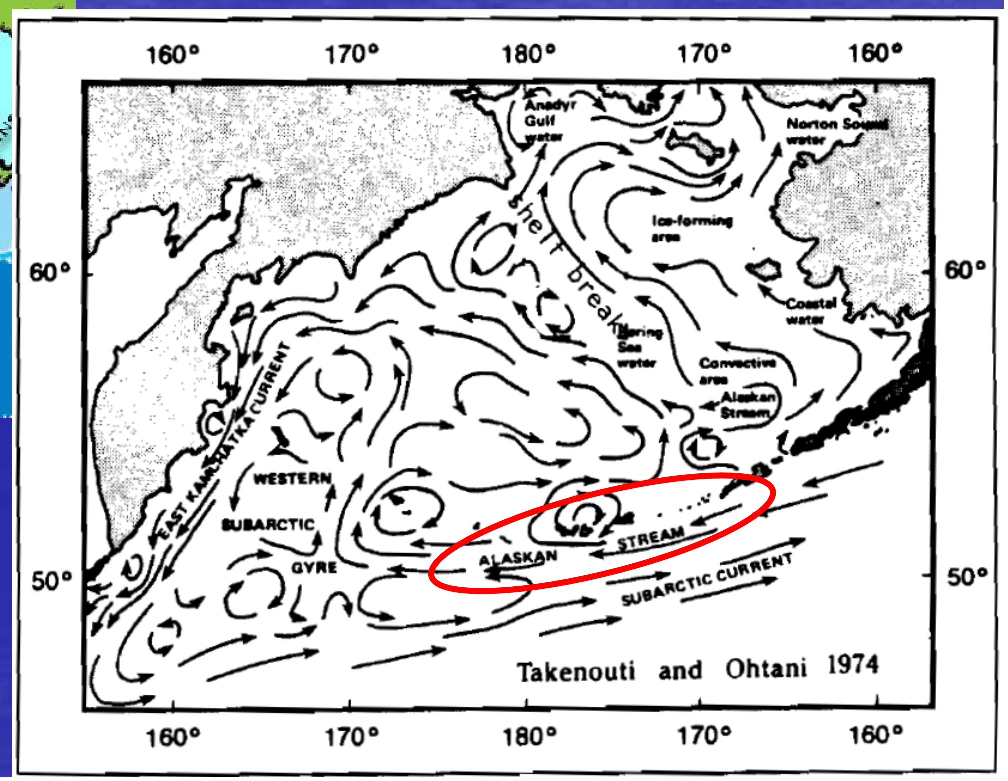
Tal Ezer
Center for Coastal Physical Oceanography
Old Dominion University

Lie-Yauw Oey
Program in Atmospheric & Oceanic Sciences
Princeton University

Support: NOAA Office of Climate Programs
(Project: “Modeling Sea Ice-Ocean-Ecosystem in the Bering-Chukchi-Beaufort Seas with Data Assimilation of RUSALCA Measurements”)

Study area- Bering Sea (BS):

- Important role in global ocean and Arctic circulation and climate change
- Local ecosystem sensitive to climatic changes
- Are Pacific climate variations affect the BS & Arctic? What is the mechanism?



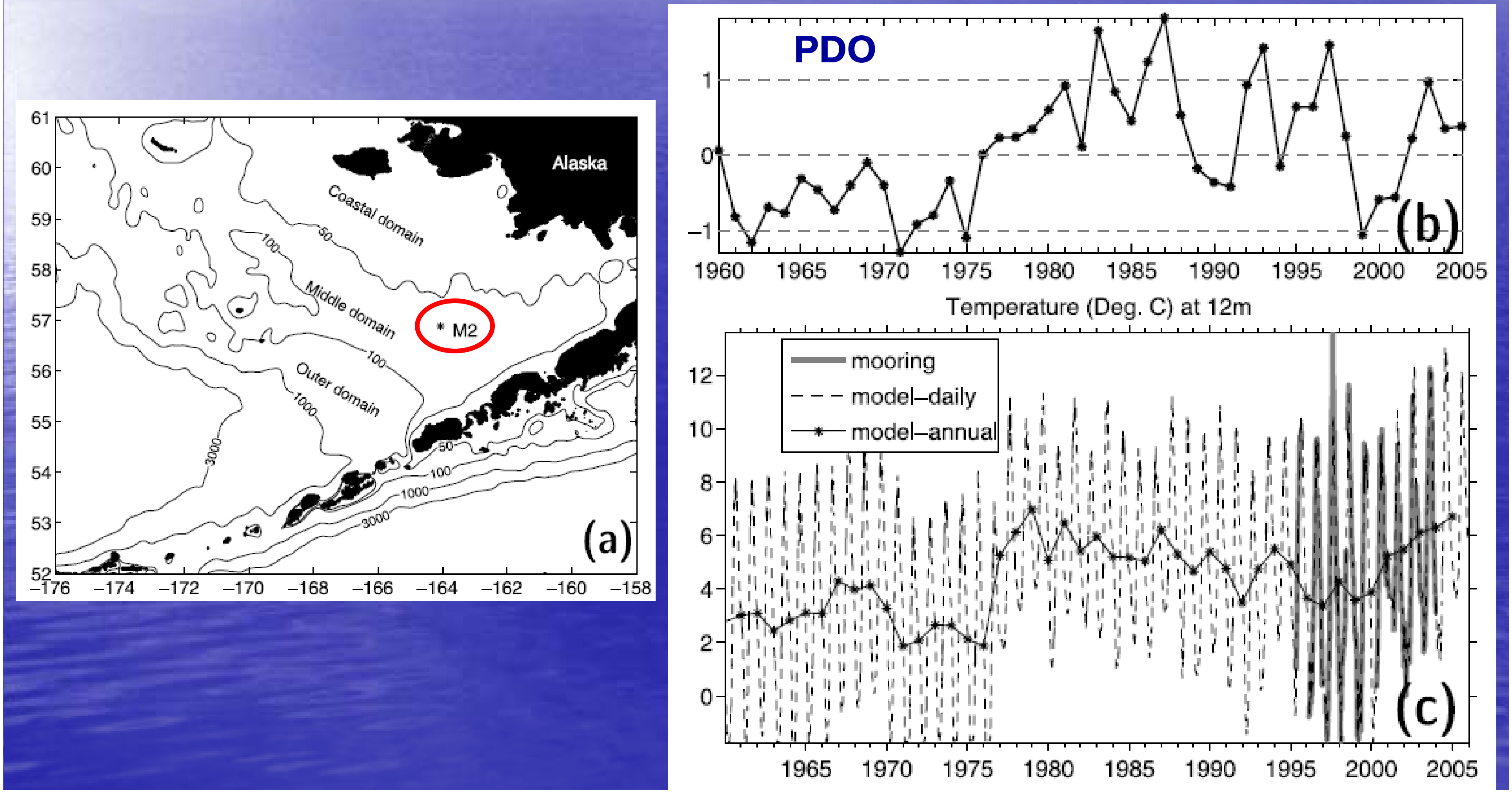
Of particular interest-
the role of the Alaskan Stream

Long-term ecosystem variations in the Bering Sea seem to relate to the Pacific Decadal Oscillations (PDO)

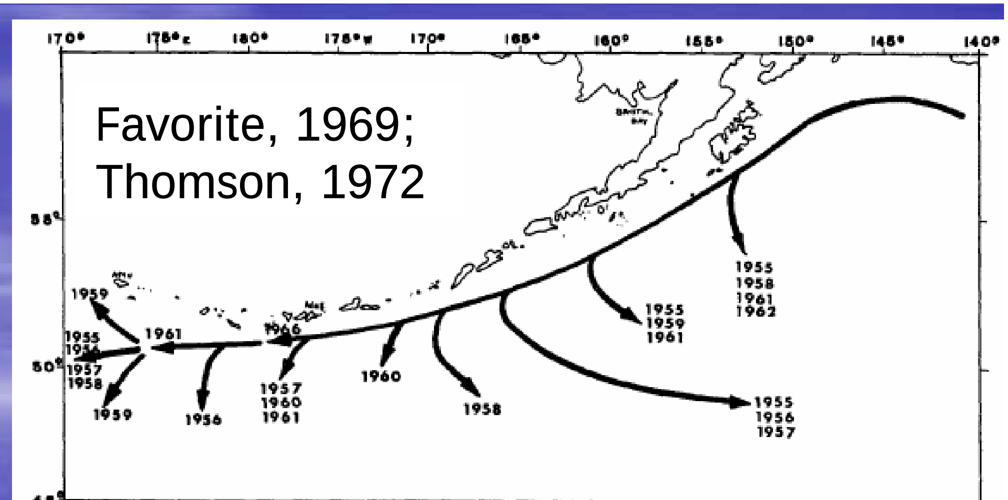
Response of lower trophic level production to long-term climate change in the southeastern Bering Sea

Meibing Jin,[1] Clara Deal,[1] Jia Wang,[2] and C. Peter McRoy[1]

JGR (2009)

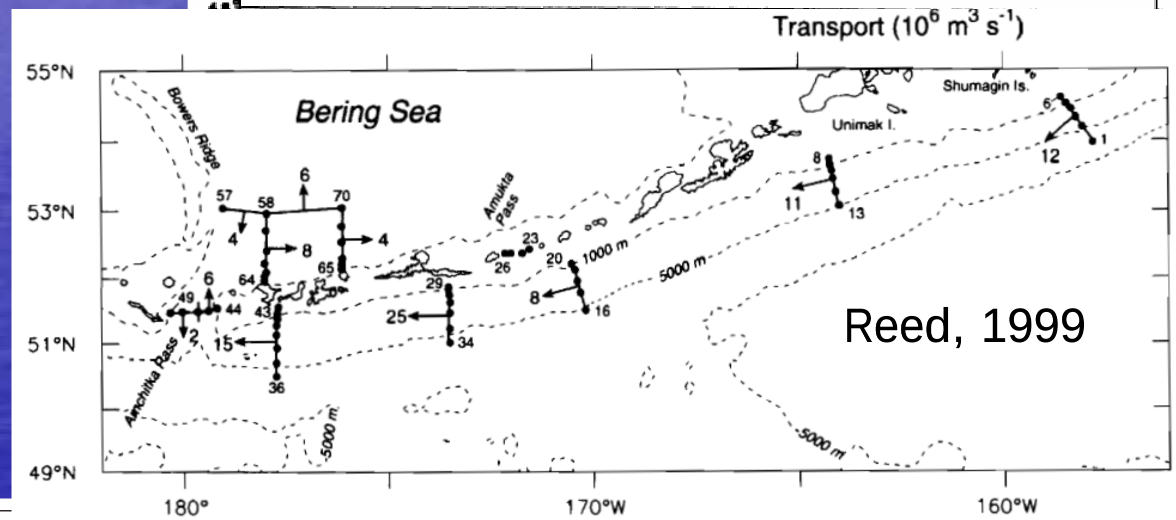


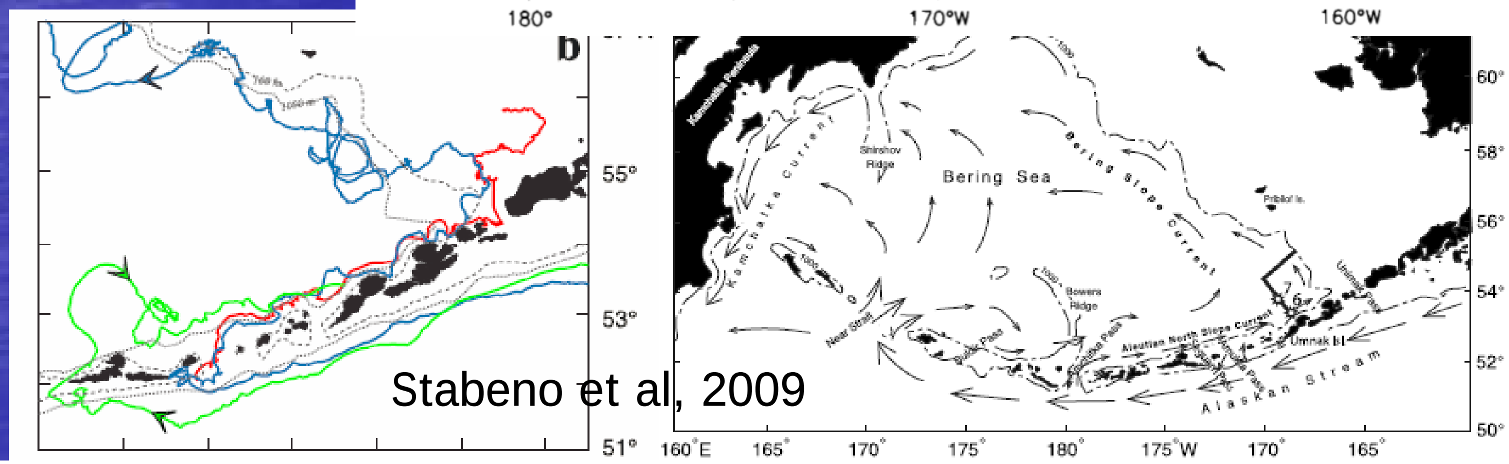
The Alaskan Stream



AS Transport:
Reed (1999): 8-25Sv
Maslowski (2008): 34-44Sv

- eddies
- seasonal Gulf of Alaska var.
- Pacific climate variations





Bering Sea (POM) Model:

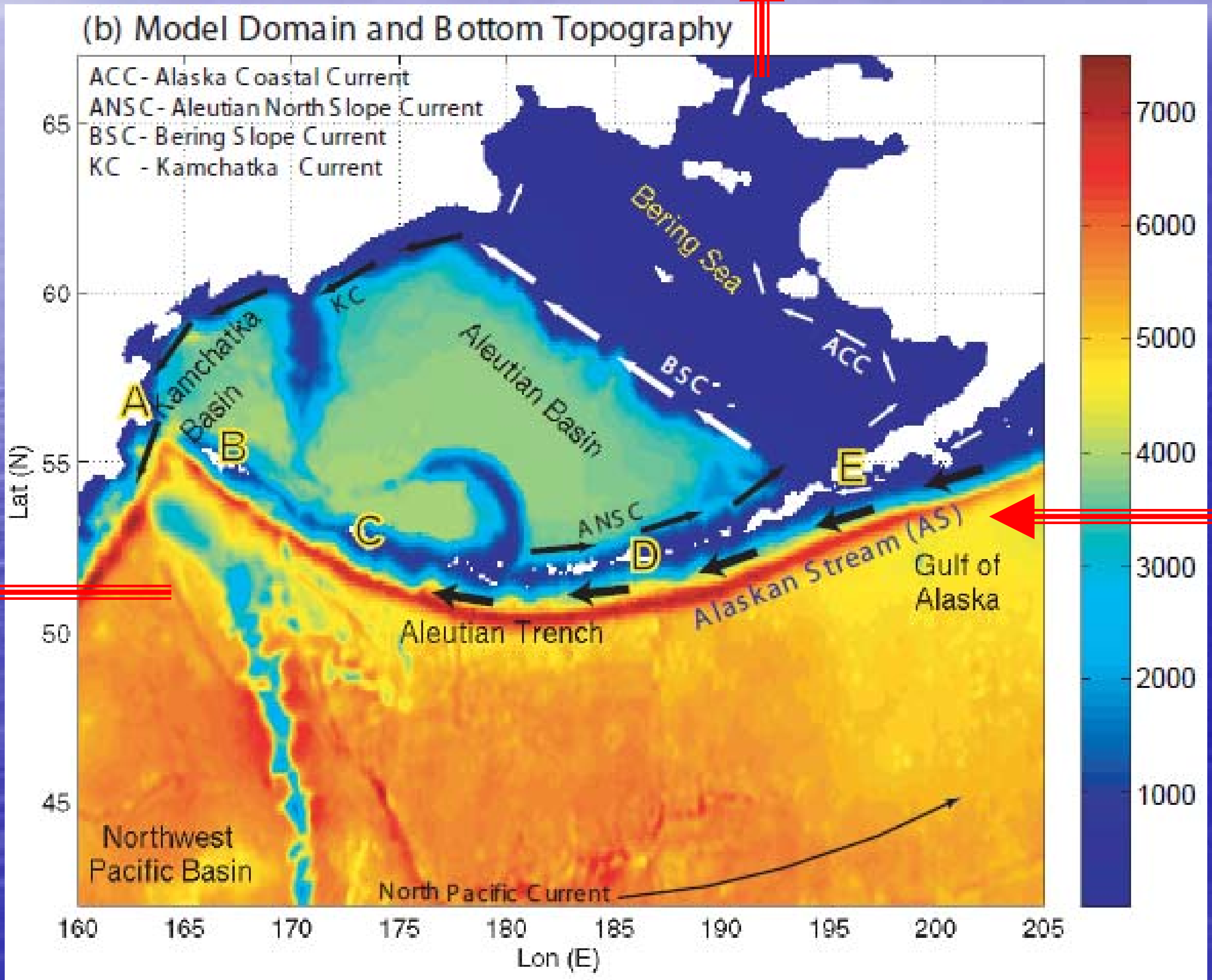
- Grid: dx ~ 5km, dy ~ 8km, 51 vertical levels; realistic topography
- Idealized case: -no data assimilation; -no wind; -no sea ice; -no rivers; -no surf. HF
- Only forcing: imposed boundary transports (no time-dependent forcing!)
- Purpose: **isolate the impact of the Alaskan Stream on the Bering Sea**

BS=0.5sv

9.5sv

24.5sv

39.5sv



3 experiments:

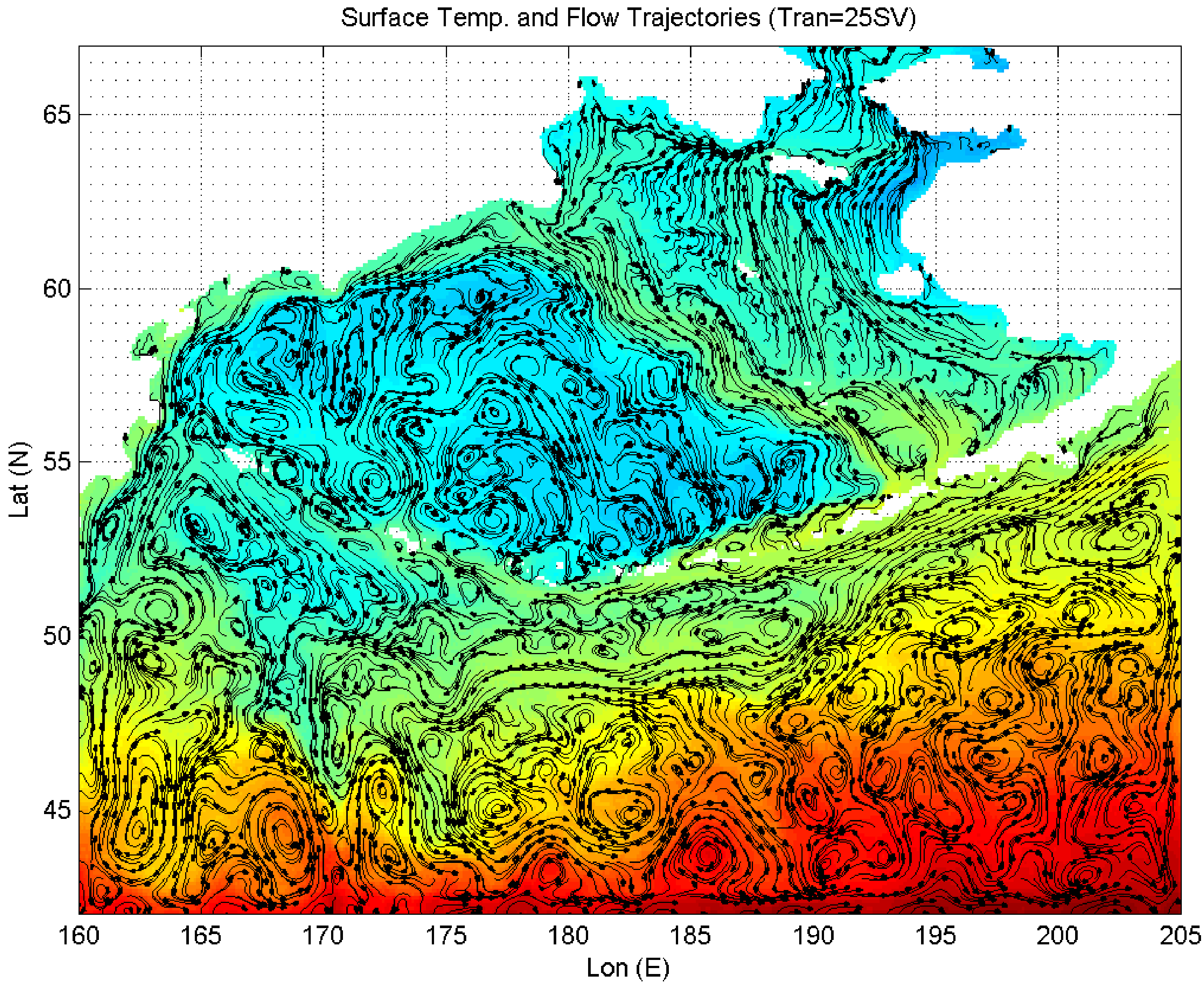
AS=10sv

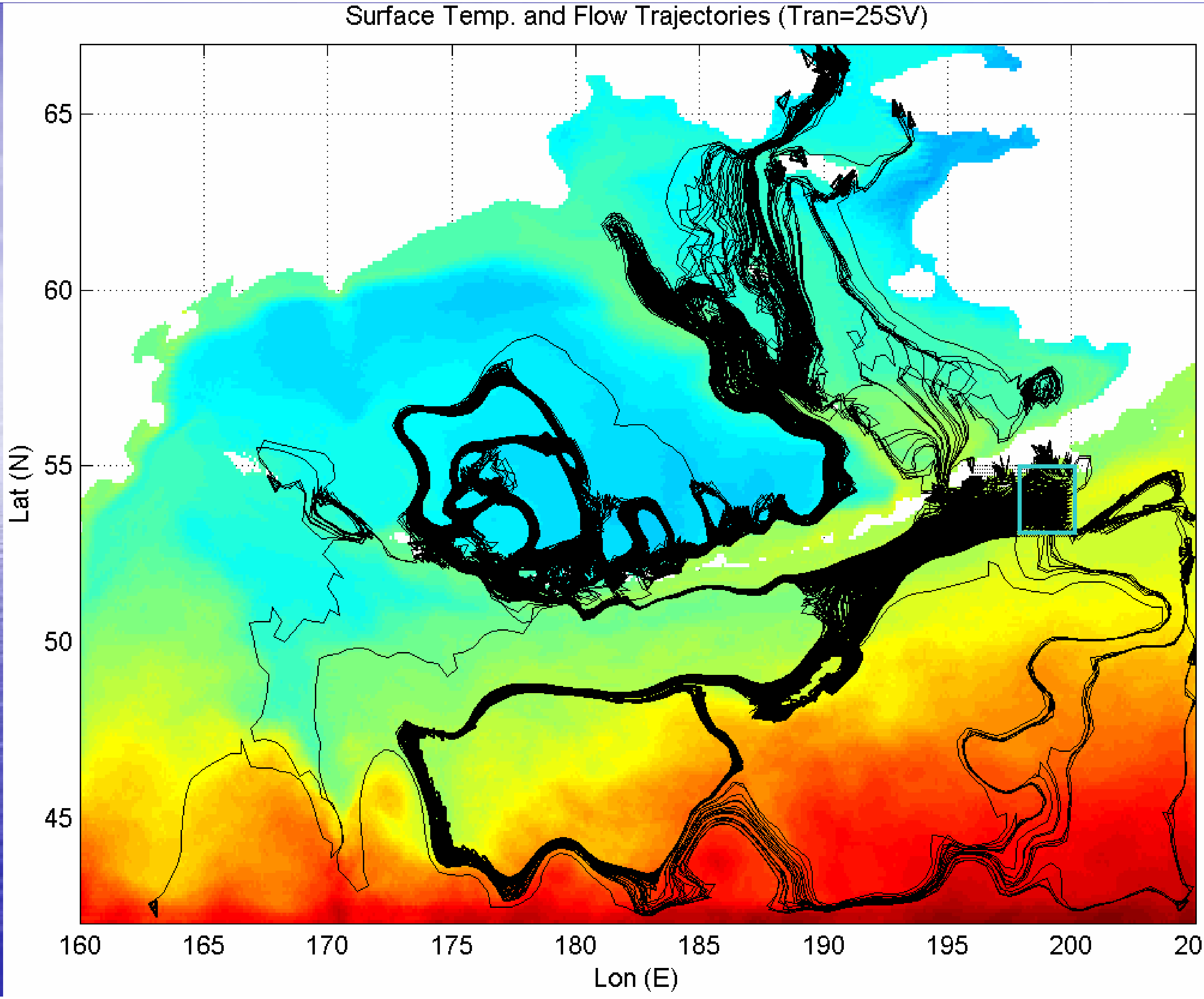
AS=25sv

AS=40sv

Each run:

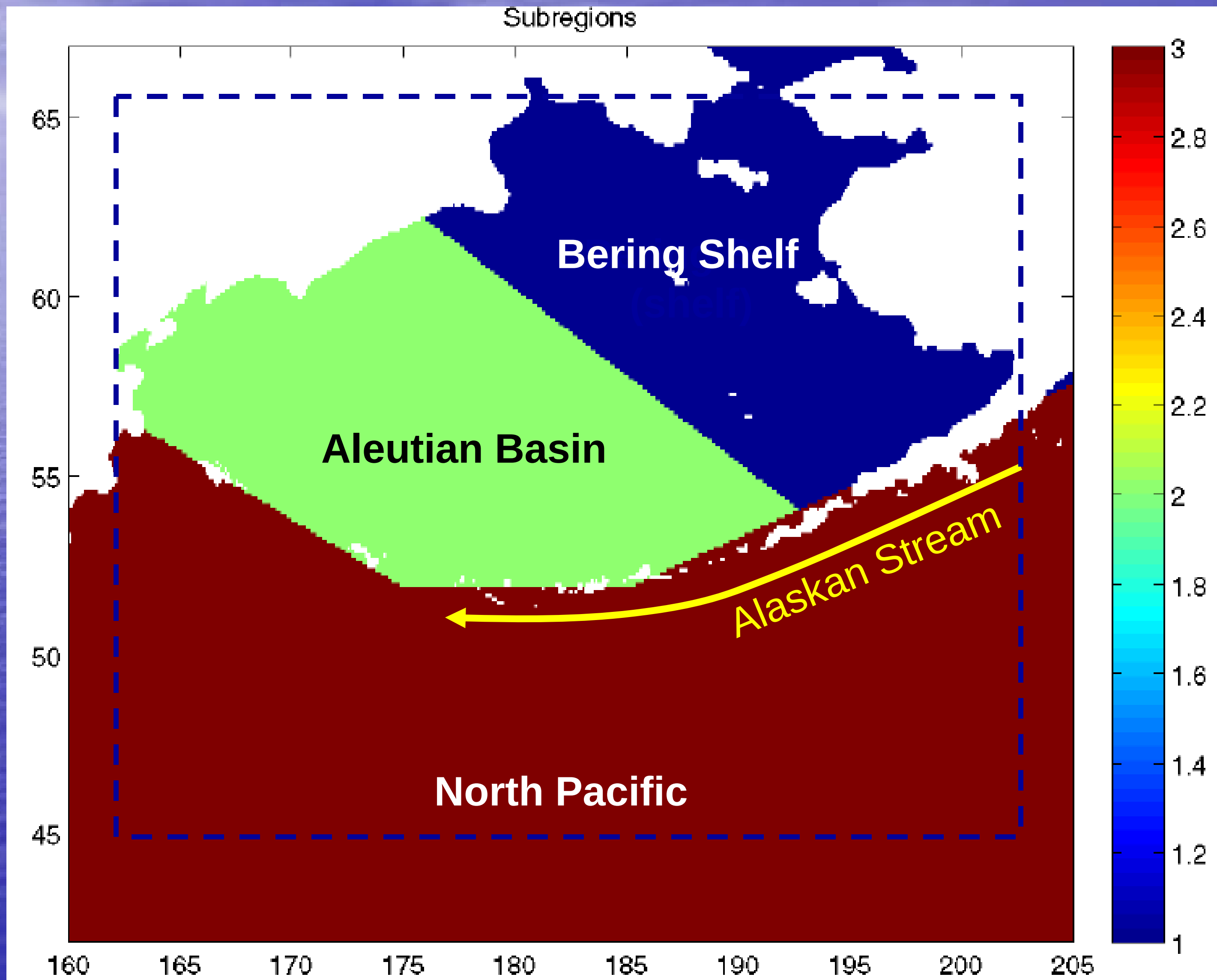
- 12y spinup
- 1y analysis


Surface Temp. and Flow Trajectories (Tran=25SV)
Lat (N)
65
60
55
50
45
160
165
170
175
180
185
190
195
200
205
Lon (E)



Surface Temp. and Flow Trajectories (Tran=25SV)
65
60
55
50
45
Lat (N)
160
165
170
175
180
185
190
195
200
205
Lon (E)

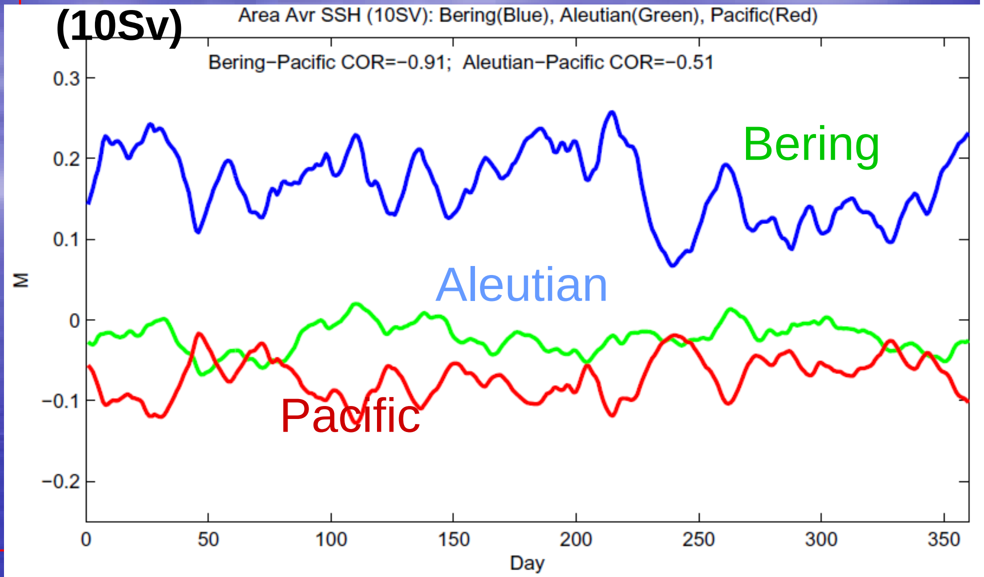
• Analysis of 3 sub-regions and the heat/momentum transport exchange between them

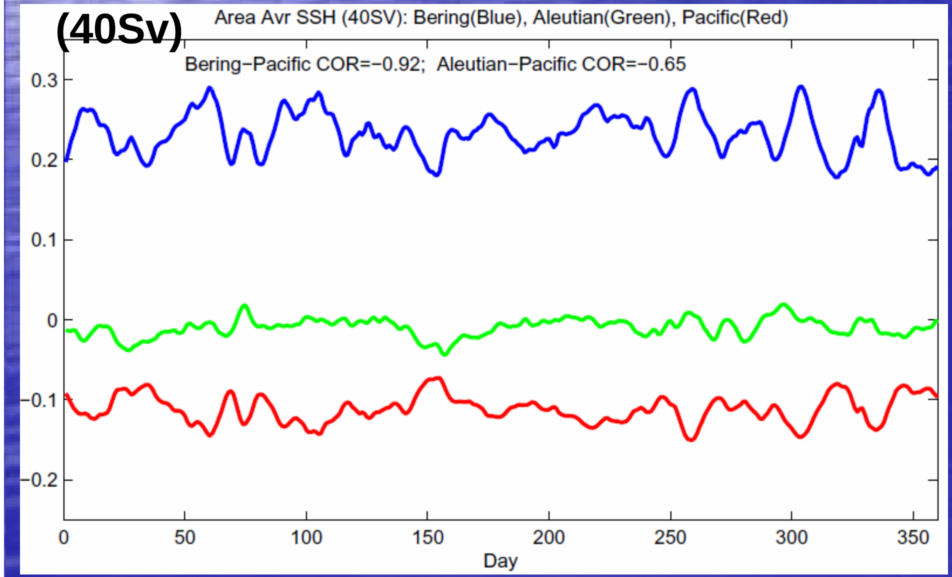


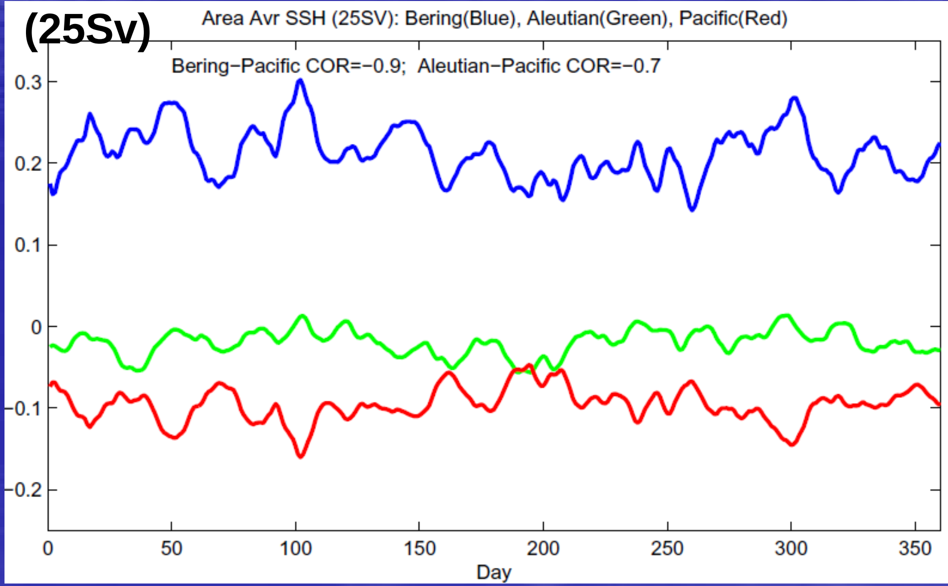
Changes of **area-averaged SSH** in sub-regions indicate mass transport exchange between regions.
Bering Shelf area: ~600,000 km^2 → 15cm/ 10 days ~ 0.1Sv net gain/loss

Pac-Ber Corr = **-0.9** (10, 25, 40 Sv)
Pac-Aleu Corr = -0.5,**-0.7,-0.65**

- Increase in AS transport → Bering SSH higher, Pacific SSH lower



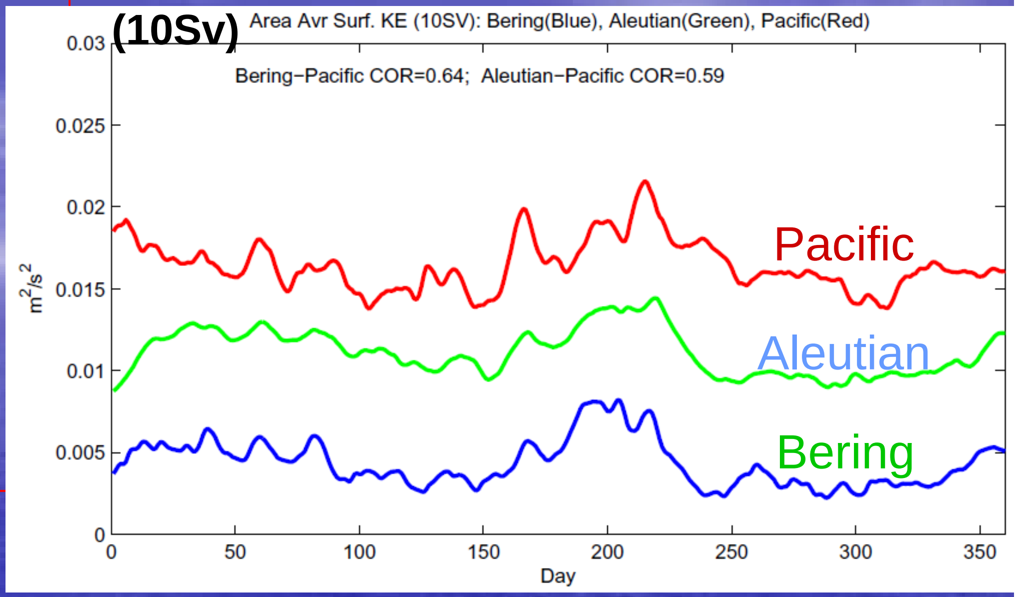


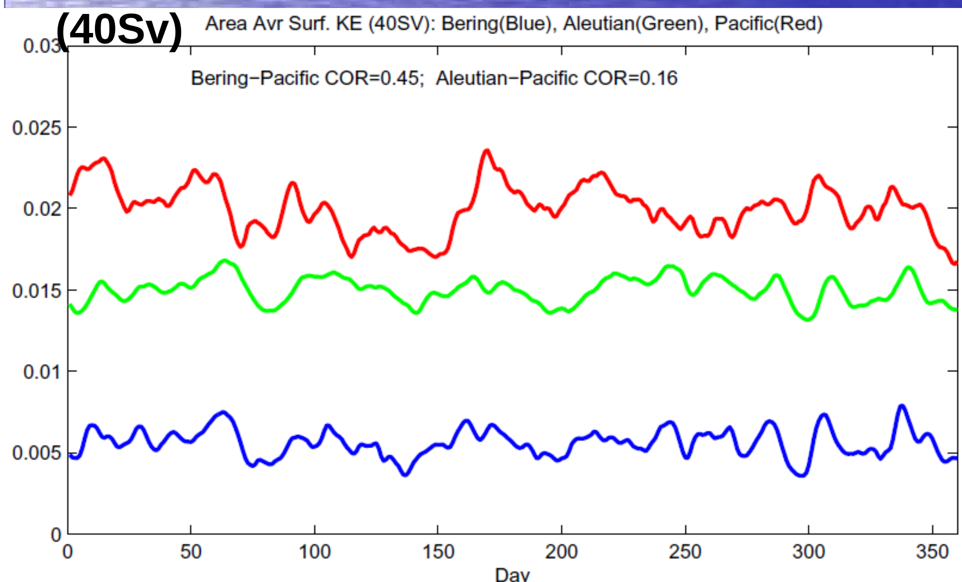


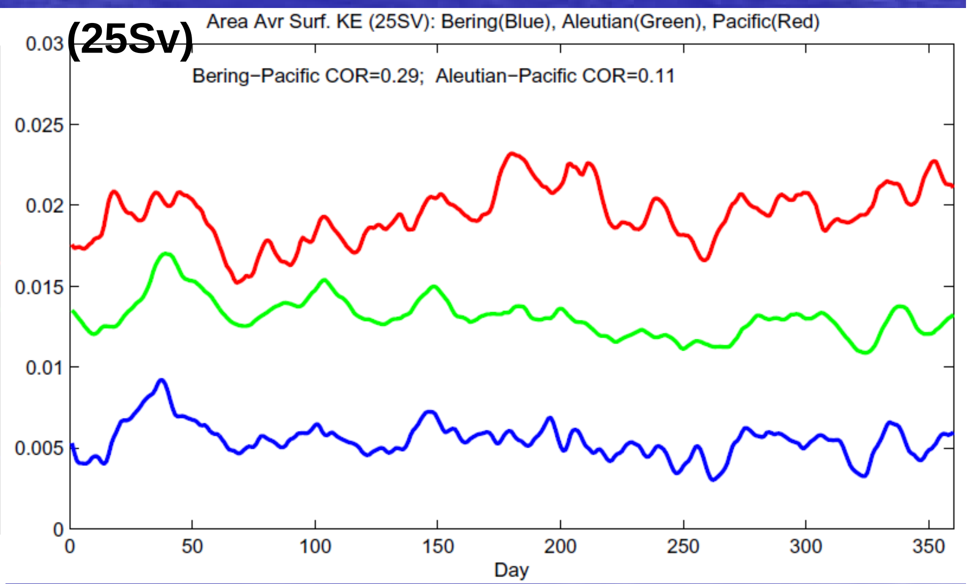
Area-averaged surface KE:

- weaker AS (10 Sv) → more impact on Bering Sea (larger Pacific-Bering correlations)

Pac-Ber Corr = **0.64**, 0.29, 0.45
(10Sv, 25Sv, 40Sv)



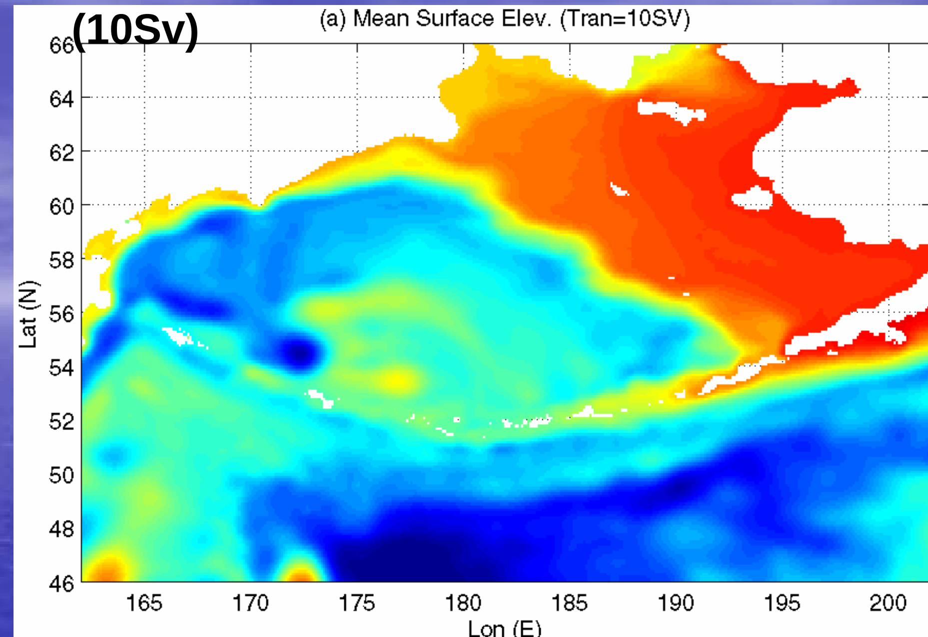


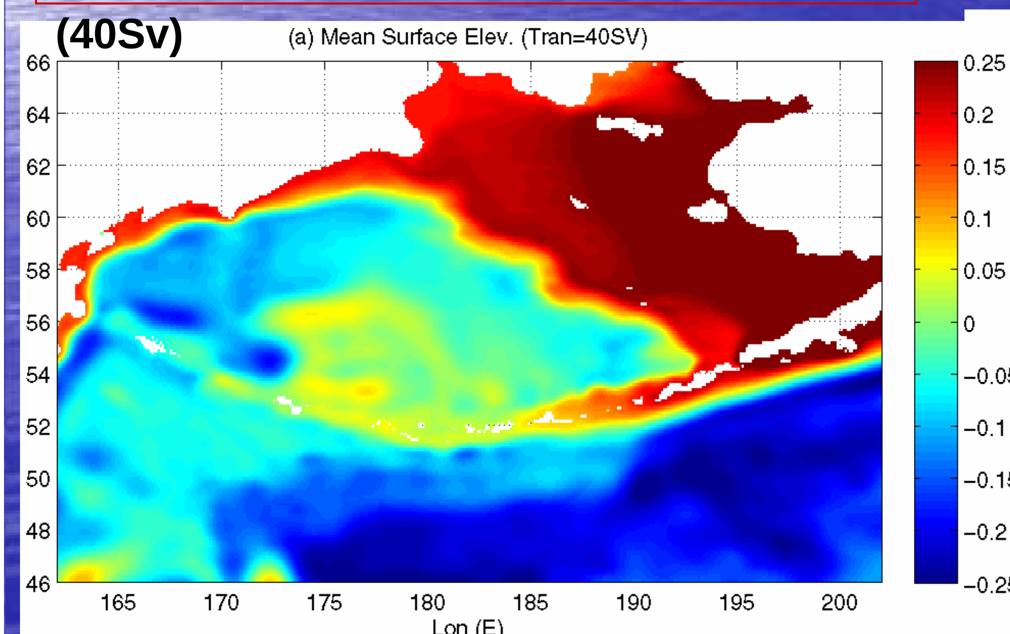


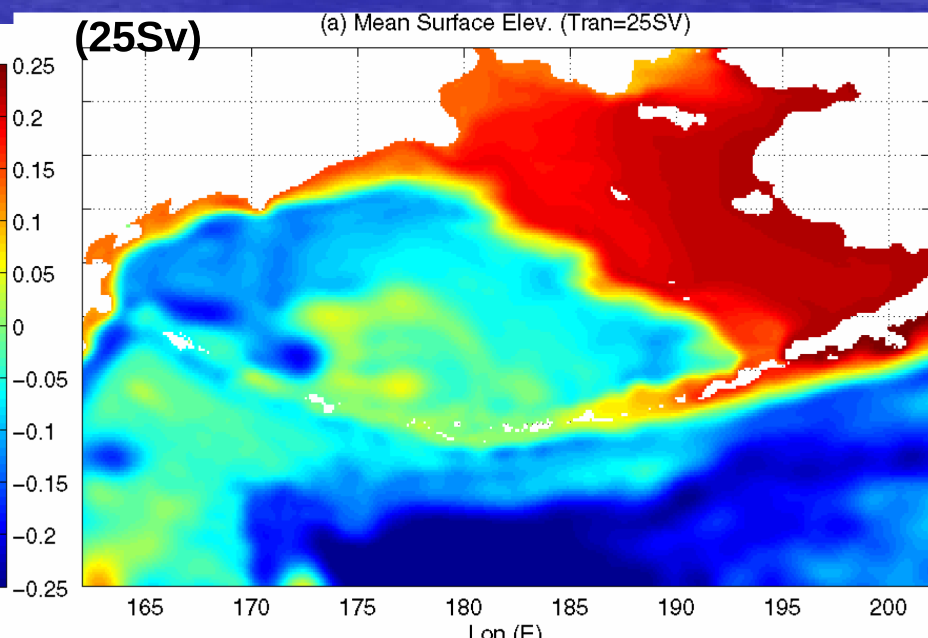
Annual Mean SSH

As the Alaskan Stream flow increases:

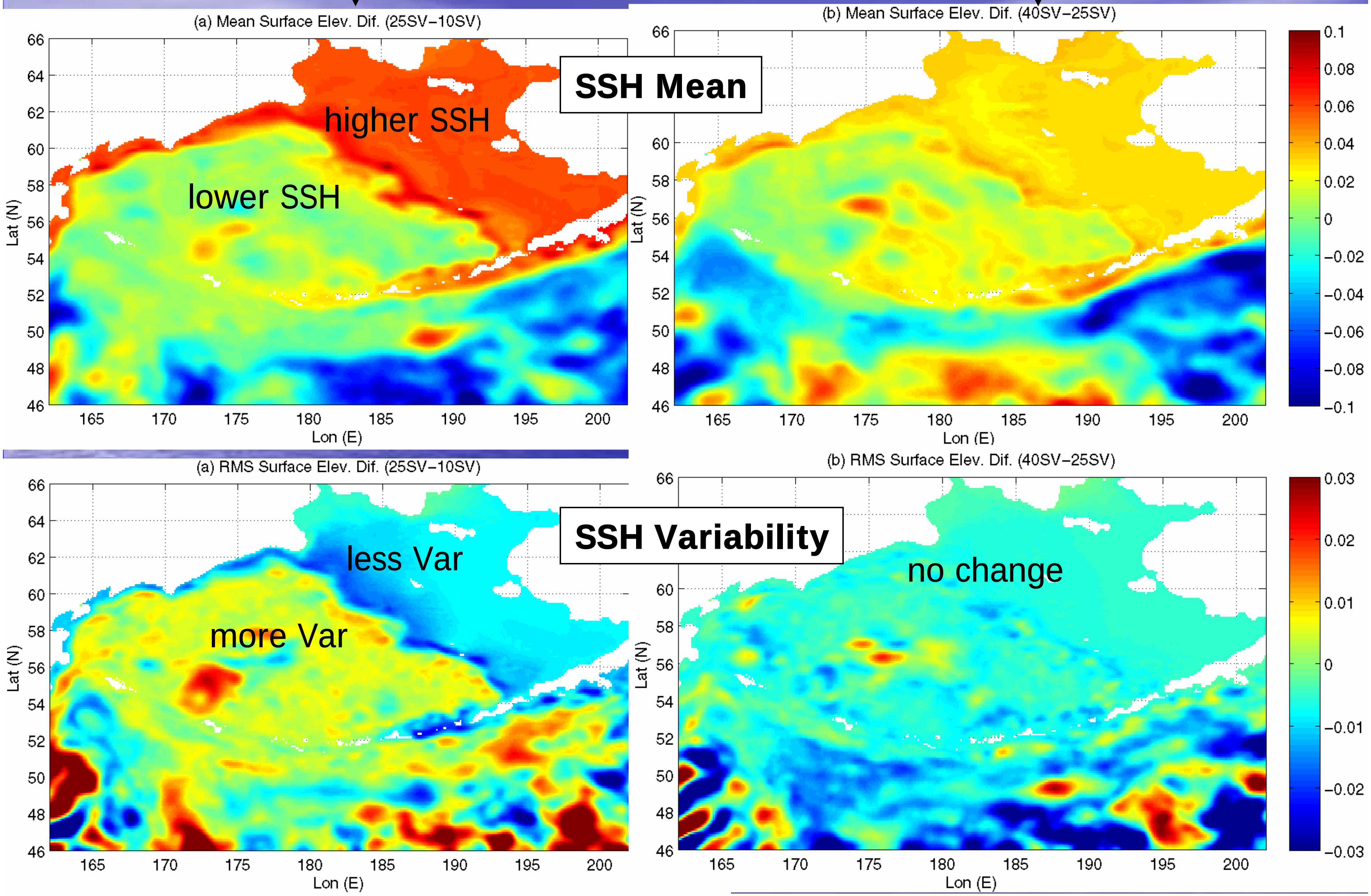
- the SSH in the Bering Sea increases→ stronger geostrophic shelf-break current?
- warmer Bering Sea?
- larger pressure-driven flow toward Arctic Ocean?





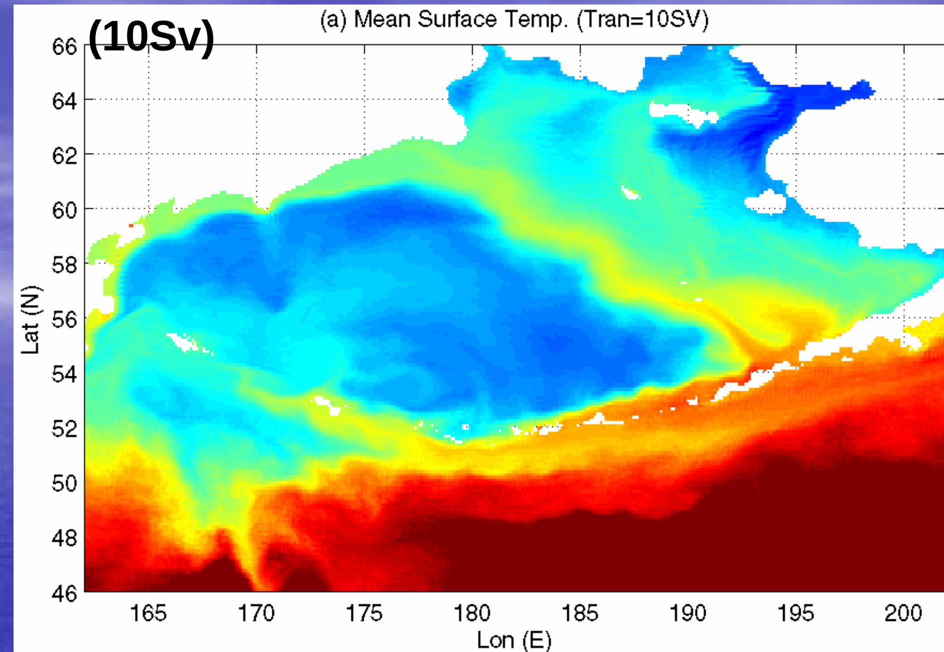


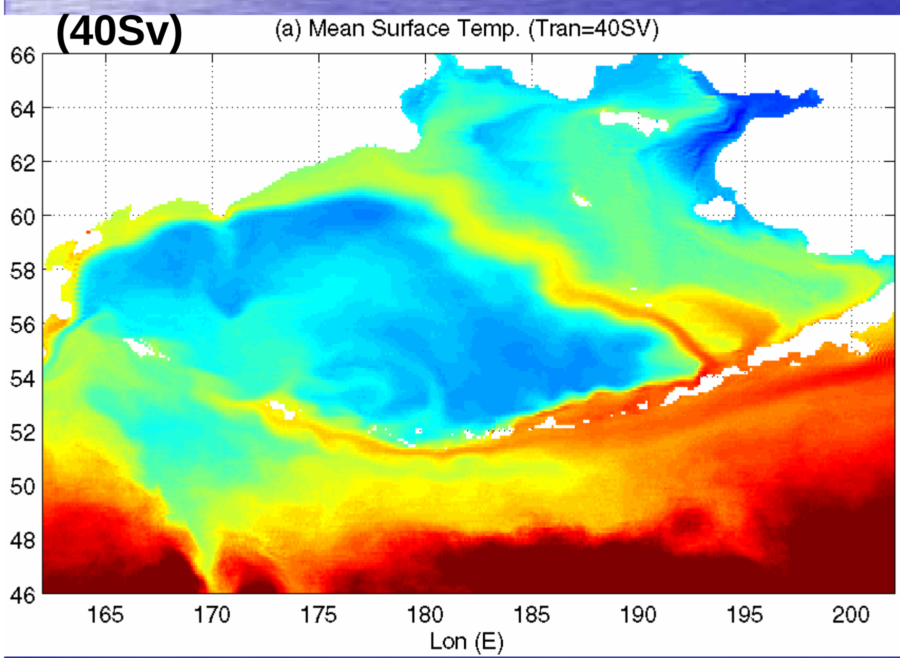
SSH changes: Most of the change in mean & var of SSH in the Bering Sea's shelf- when AS transp. **10→25sv**; smaller changes when AS transp. **25→40sv**.

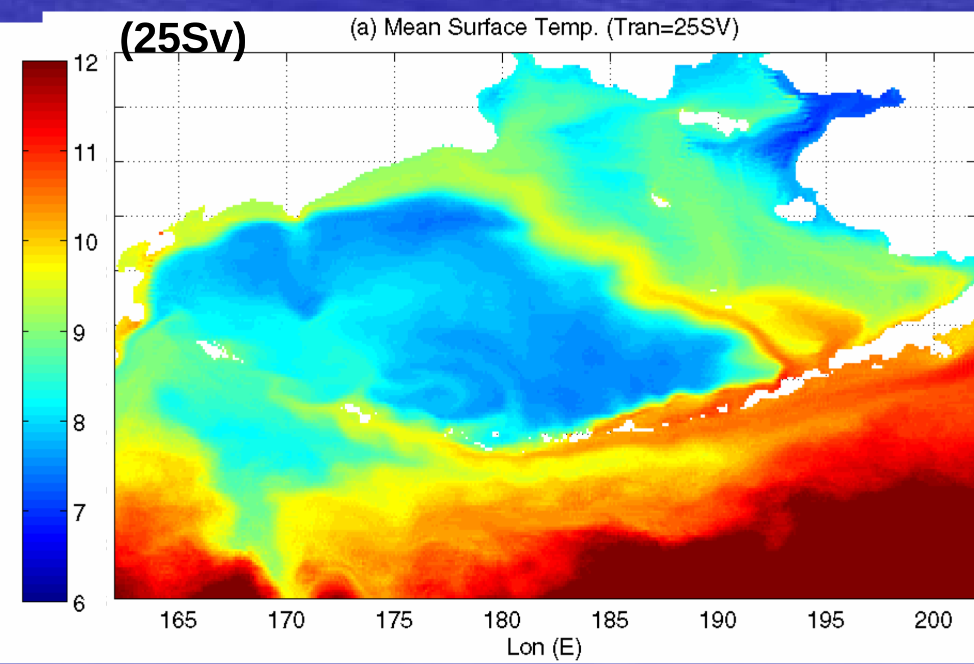


Annual Mean SST

As the Alaskan Stream flow increases, the penetration of Pacific waters into the Bering Sea shelf increase.

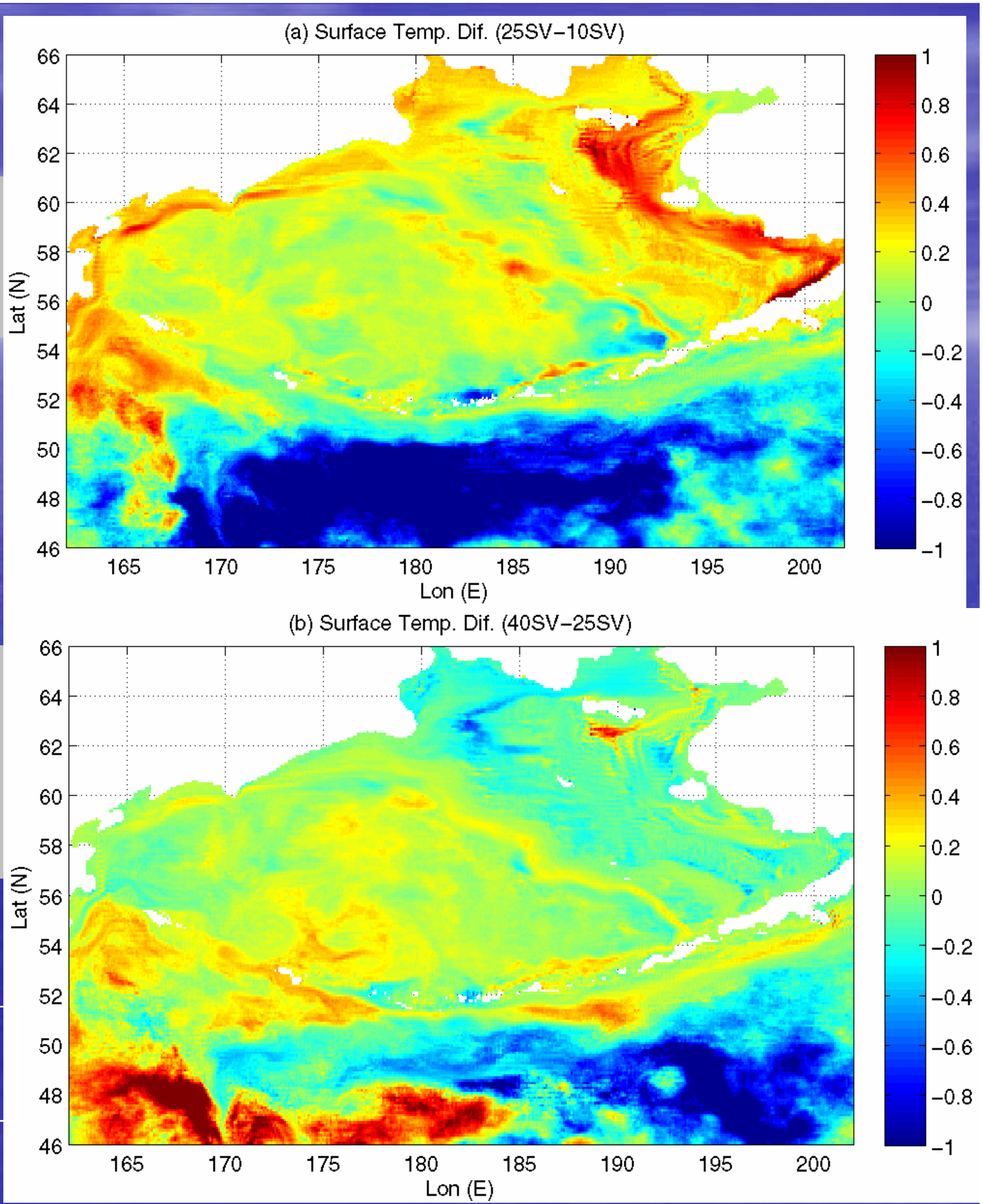






Surface temperature changes:

Bering Sea gets **WARMER** when AS transport increases from 10sv to 25sv



Northern Bering Sea shelf gets **COLDER** when AS transport increases from 25sv to 40sv.

Northwest Pacific get **WARMER**

Change in circulation is non-linear wrt AS transport!

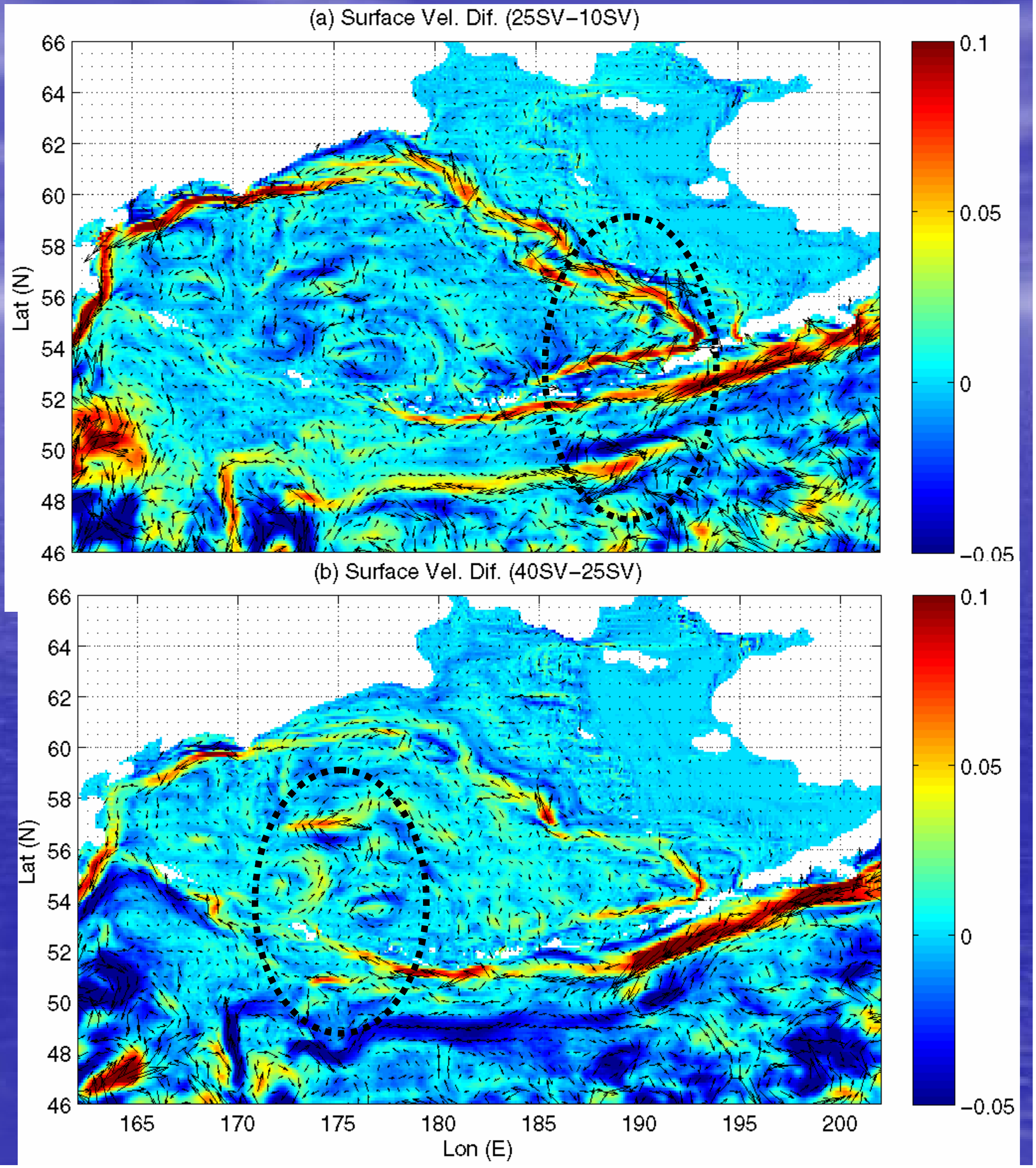
Surface velocity changes

AS: 10 Sv → 25 Sv

Increase flow into Bering Sea shelf and earlier southward separation of AS

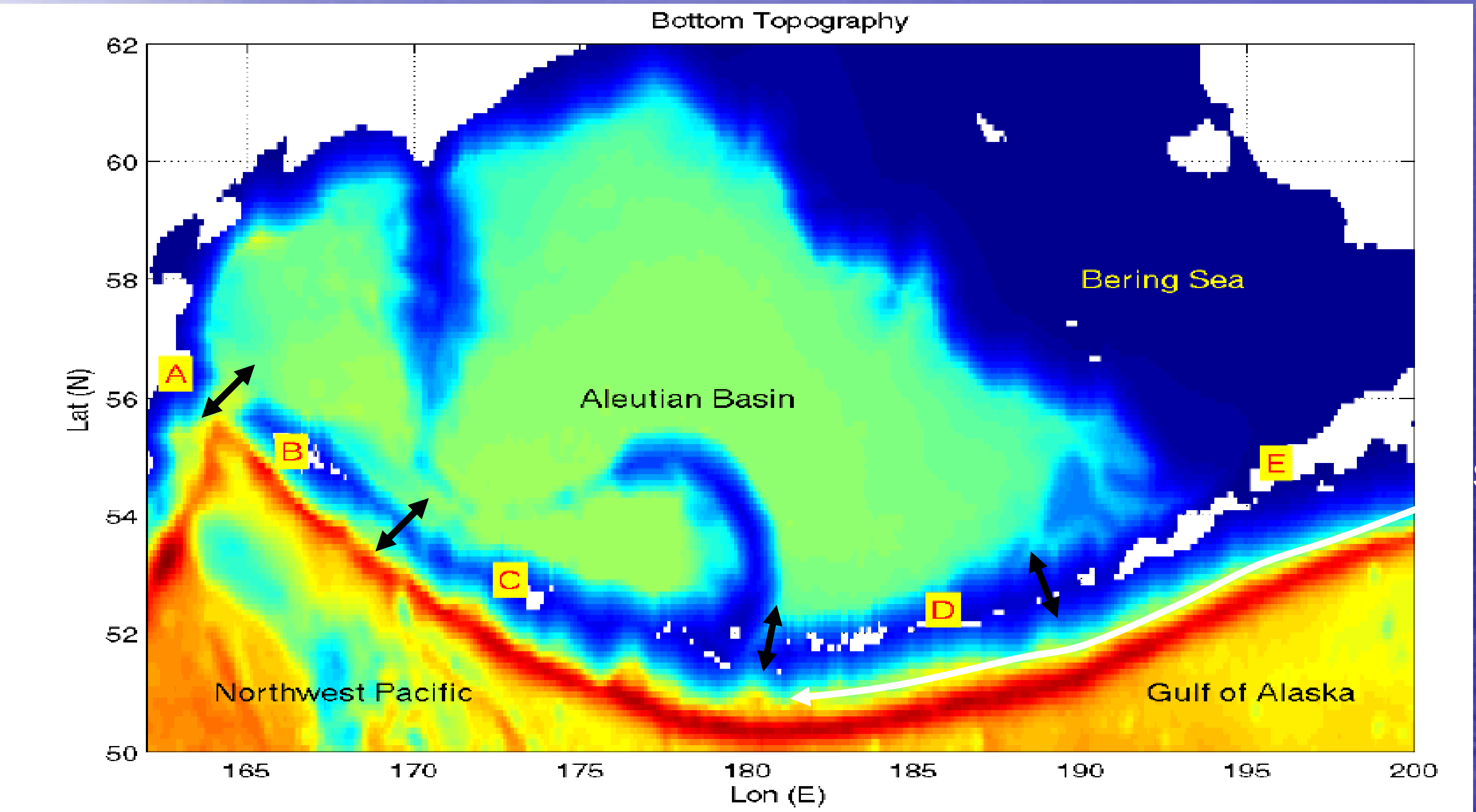
AS: 25 Sv → 40 Sv

Increase flow into Aleutian Basin and separation of AS farther west

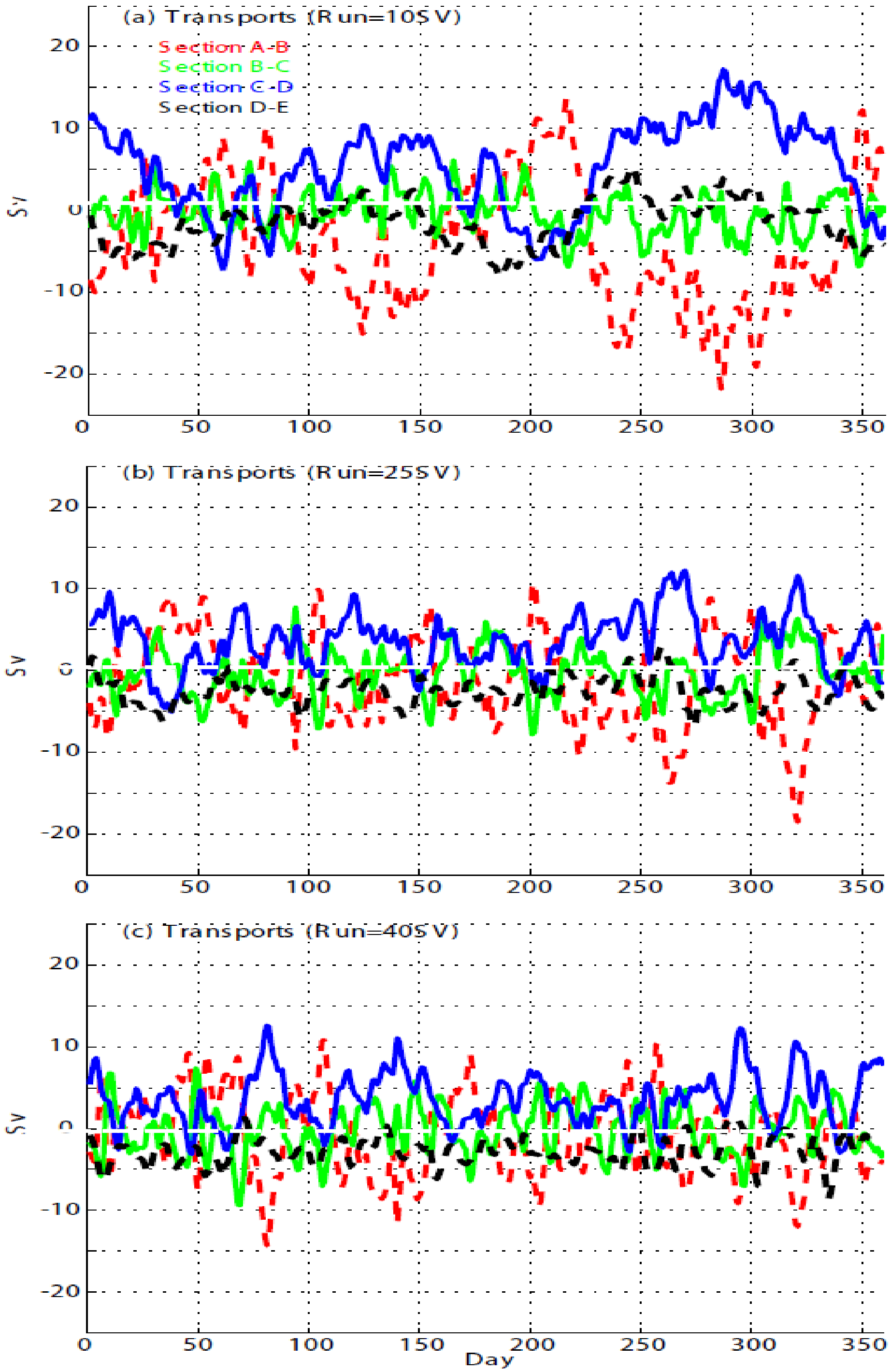


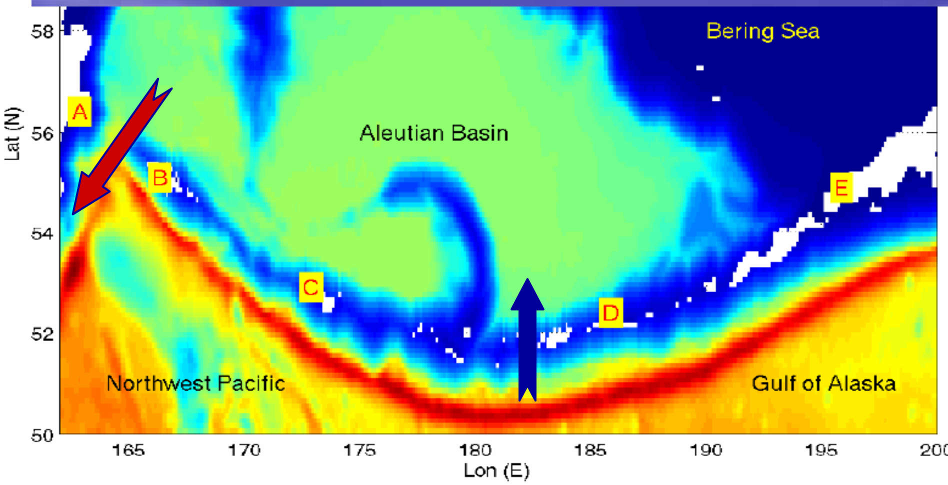
Transport exchange between the Pacific and the Bering Sea across the Aleutian Islands.

Are they affected by the Alaskan Stream transport?



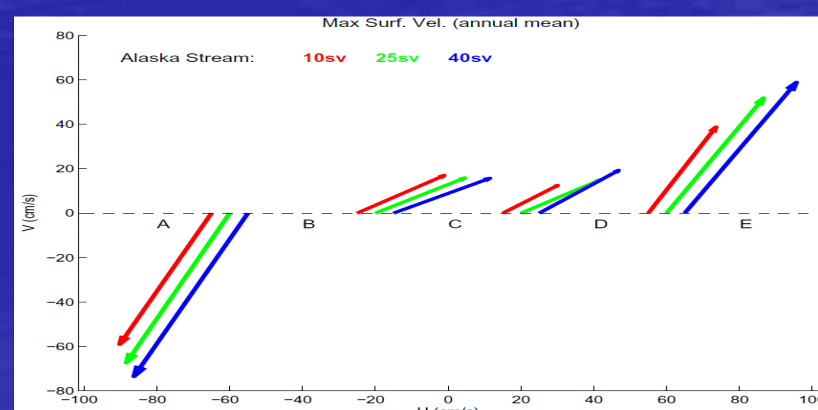
s



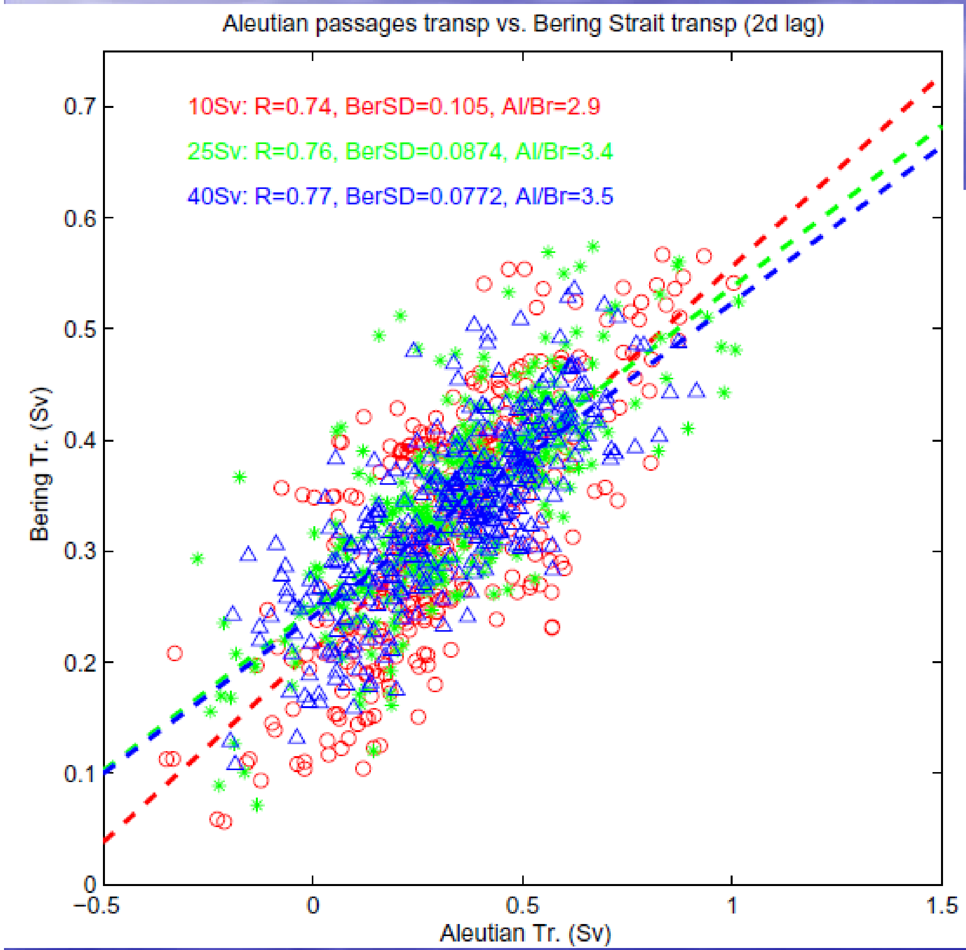


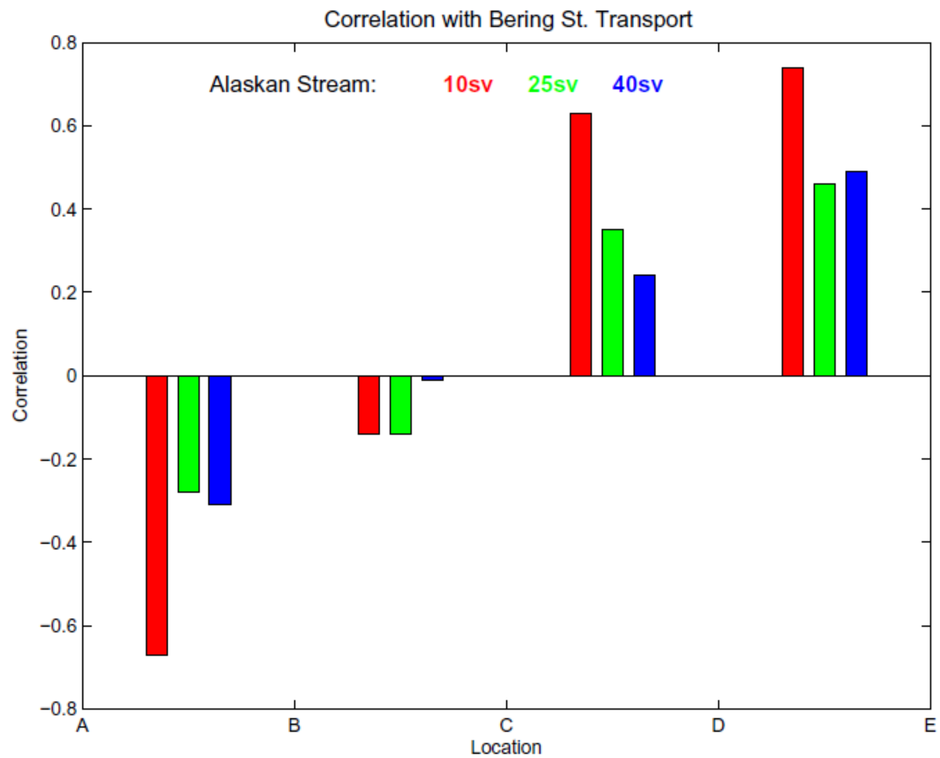
• Net transport from the North Pacific into the Aleutian basin is balanced by outflow along the Asian coast (East Kamchatka Current)

• Increase in Alaskan Stream transport decreases transport variability across the passages



Question: are variations in the in/out transports through the Aleutian passages exactly balanced? If not- are they affecting the Arctic Ocean variability?

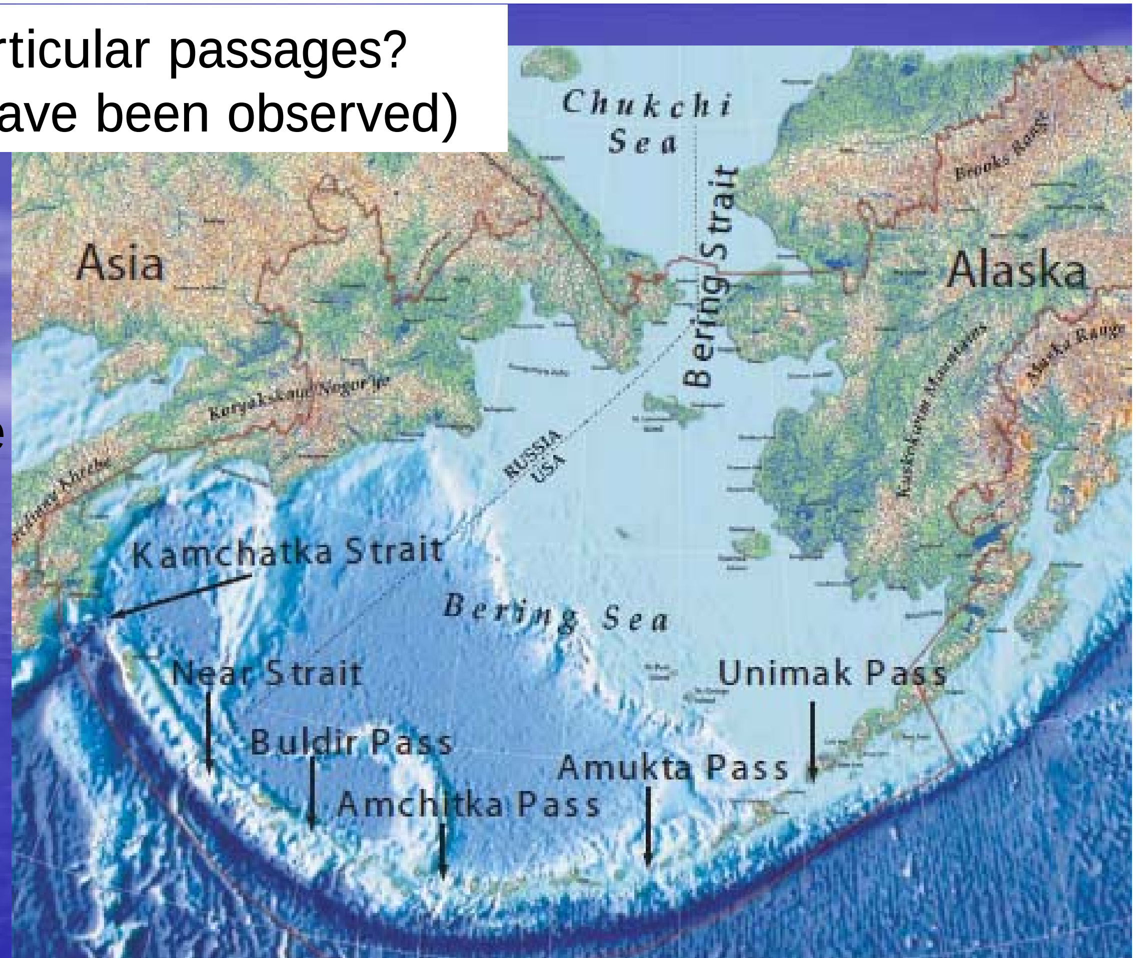




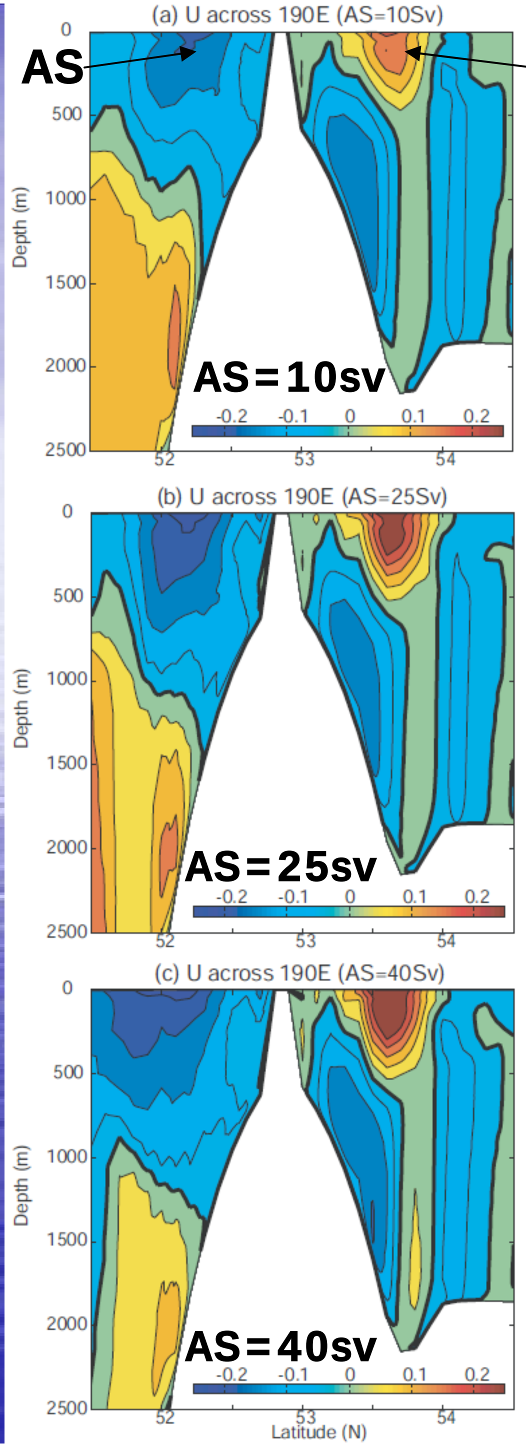
Answer: the net transport from the Pacific to the Bering Sea is highly correlated with the Bering Strait transport toward the Arctic!

What about the flow through particular passages?
(of the ~30 passages only few have been observed)

- Large discrepancy between the model and observations...
- But also between different observations taken by different people at different times...
- Reasons: eddies; climate variations; no deep observations

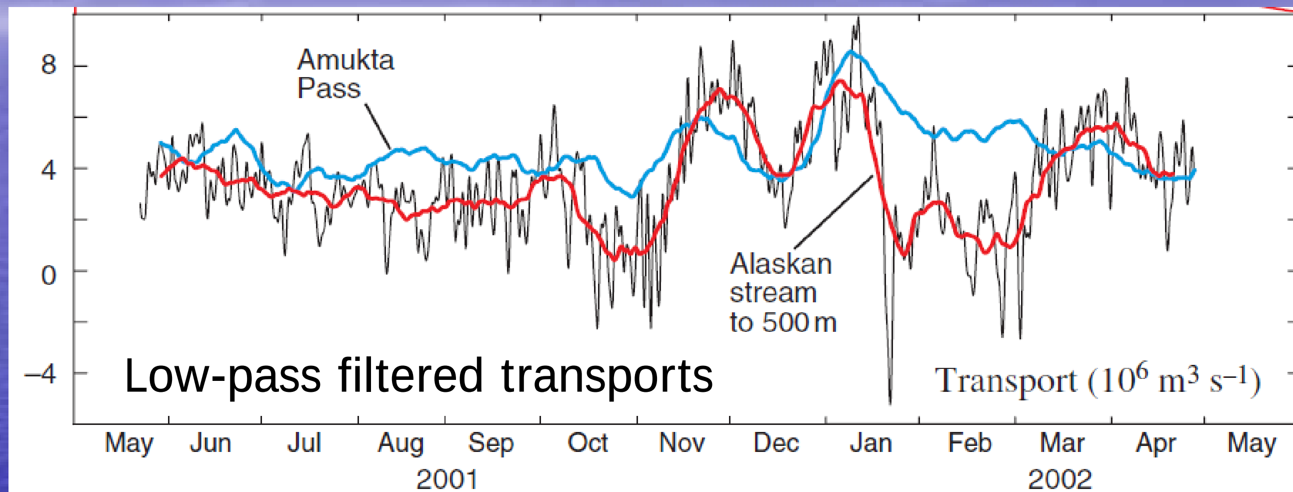


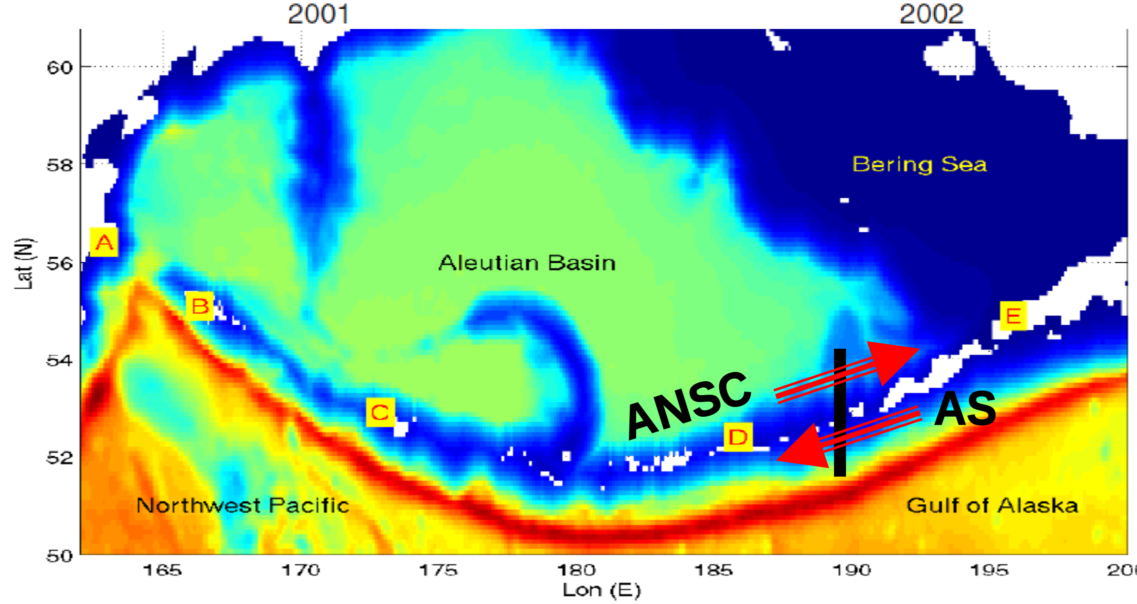
Location and Depth (m)	Model Run (AS =) 10 Sv	25 Sv	40 Sv	Observations
Unimak Pass (~100)	0.37 (0.19)	0.47 (0.21)	0.48 (0.22)	0.23[b] 0.4[c](0.1–0.5)[b]
Amukta Pass (~400)	1.1 (1.4)	1.2 (0.69)	1.4 (0.7)	0.6,[b] 4,[d] 4.7[c](−0.1–1.4)[b]
Amchitka Pass (~1500)	−3.4 (1.0)	−3.2 (0.78)	−3.3 (0.75)	−4,[e] −2.8,[f] 0.3,[b] 2–5[g,h](−2.8–2.8)[b]
Buldir Pass (~1000)	3.8 (1.9)	4.1 (1.2)	4.8 (1.4)	~1[b](unknown)[b]
Near Strait (~2500)	2.94 (2.9)	2.64 (3.2)	2.74 (3.6)	~3,[b,f] 5,[i] 10[g](6–12)[b]
Kamchatka Strait (~4500)	2.7 (7.6)	−0.01 (5.5)	−0.7 (4.9)	−6,[j] −7,[i] −12,[b] −24[k](−5 to −15)[b]
Bering Strait (~50)	0.32 (0.11)	0.35 (0.09)	0.34 (0.08)	0.6,[l] 0.8[m,n](0.3–1.4)[b]

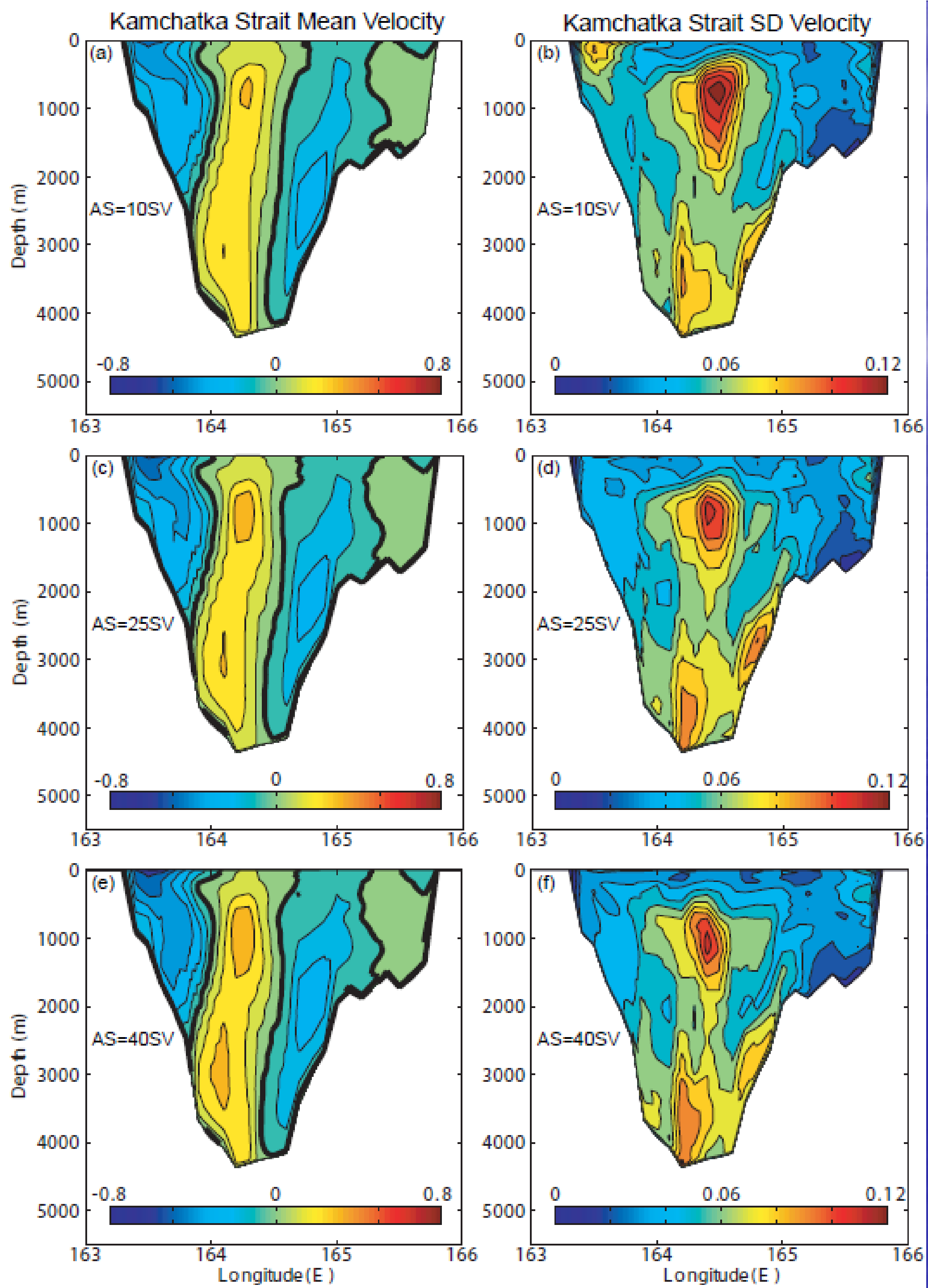


Stabeno et al. (2005)

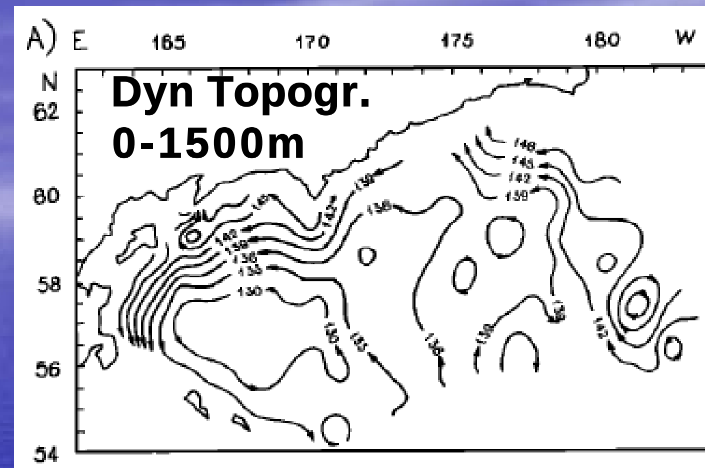
transport in Amukta Pass, calculated from current meters, was approximately five times as large as previously estimated from hydrographic surveys. At monthly and longer periods, the variability in transport in Amukta Pass was related to the position and strength of the Alaskan Stream southeast of the pass. Vertical mixing







Kamchatka Strait flow from hydrographic observations (Verkhunov & Tkachenko, 1992)



Assume level of no motion at 1500m! Is this realistic?

- The model shows deep flows that have not been observed (no data)....
- Deep observations are needed to verify if the model is correct or not...

Maul et al., 1985

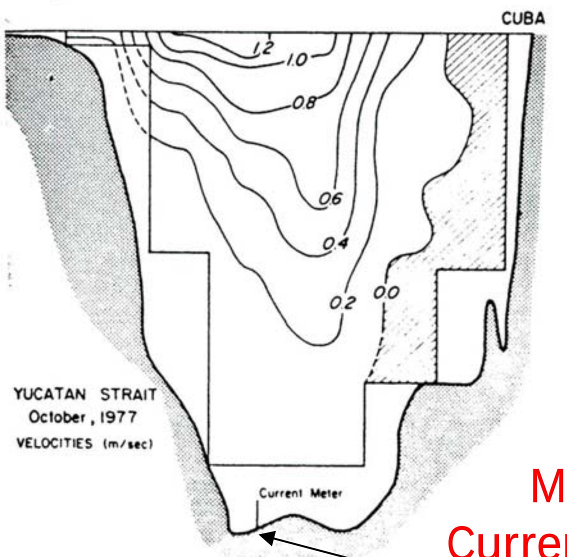
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 90, NO. C5, PAGES 9089–9096, SEPTEMBER 20, 1985

Comparisons Between a Continuous 3-Year Current-Meter Observation at the Sill of the Yucatan Strait, Satellite Measurements of Gulf Loop Current Area, and Regional Sea Level

George A. Maul, Dennis A. Mayer, and Stephen R. Baig

National Oceanic and Atmospheric Administration, Miami, Florida

From October 1977 through November 1980 a current-meter mooring was maintained in the Yucatan Strait. The meter was moored halfway between Mexico and Cuba, 145 m above the sill or in 1895 m of water. Motions of low frequency ($<14^{-1}$ cycles/day) are oriented approximately parallel to the isobaths, 021°–030° true. Net drift for 3 years is to the SSW at an average velocity of 1.8 cm/s. Sustained southward flows at intervals of 8 months, which persisted for several months each, have average velocities of 5 cm/s, with randomly spaced bursts as high as 15 cm/s. Energy in subtidal frequency bands has significant peaks near 38^{-1} and 19^{-1} cycles/day, with a broad band of energy between 300^{-1} and 200^{-1} cycles/day. The latter peak is consistent with the approximately 8-month interval between the southward flow events. Comparison with weekly areal coverage of the Gulf Loop Current from Geostationary Operational Environmental Satellite infrared observations shows little covariation, except that 8 months is typical of some anticyclonic eddy generation. There is little coherence of sill depth velocities with Naples sea level at subtidal frequencies, but with Miami there is coherence at several frequencies, notably 38^{-1} and 19^{-1} cycles/day. In the higher frequencies, the principal tidal motions are diurnal and are oriented somewhat across the isobaths toward the northwest, 346°–349° true, with counterrotating O_1 and K_1 constituents. No semidiurnal, inertial, or fortnightly energy is observed above the background continuum.

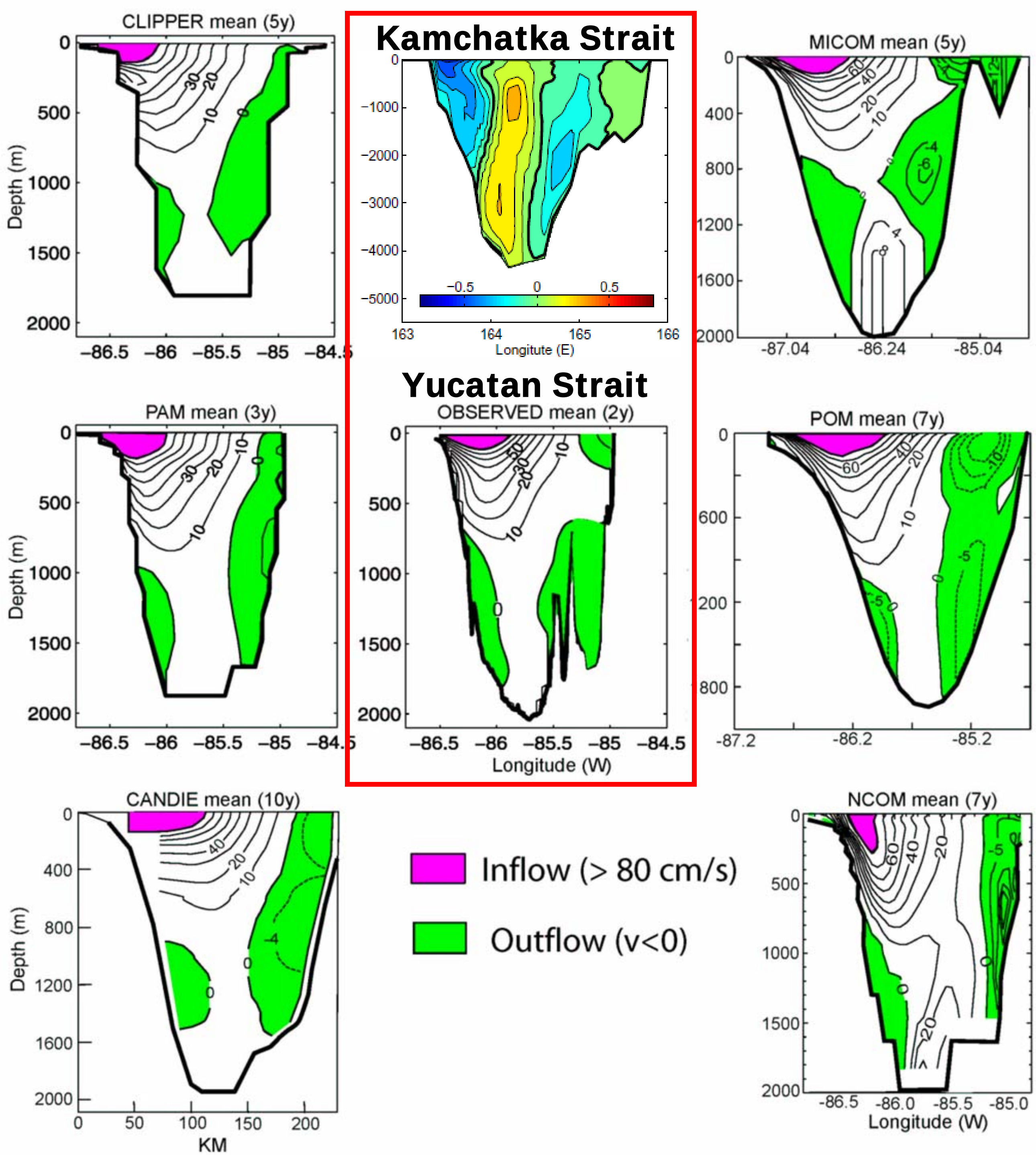


Maul's
Current meter

Is it possible that the model is "more correct" than the flow derived from observations?....

This happened before in another strait:

The Yucatan Channel



The flow through the Yucatan Channel is simulated quite well by different models (see rev. of models by *Oey, Ezer & Lee, 2005*)

Models:

Candela et al. (2003)

Ezer et al. (2003)

Morey et al. (2003)

Romanou et al. (2004)

Sheng & Tang (2003)

Oey et al. (2003)

Conclusions

- Idealized model simulations were able to isolate the role of the Alaska Stream on the Bering Sea climate and variability
- The unexpected response was non-linear whereas a small/large increase in AS transport resulted in BS warming/cooling
- Increase in AS transport shift the inflows toward western passages and reduced the variability in the BS
- As much as ~0.5sv of the variability in the Bering Strait flow toward the Arctic Ocean can be attributed to meso-scale variations in the AS (compared with observed Bering Strait mean of ~0.8sv and interannual variability of ~0.5).
- Idealized process studies are important components in support of realistic ocean-ice-ecosystem realistic models now under development.
- For more details see: *Ezer and Oey (JGR, Apr. 2010)*

THANK YOU