Interannual and Decadal Variations in cross-shelf transport in the Gulf of Alaska

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Regional Ocean Modeling System
ROMS
Research Community

Motivations

- Region rich in zooplankton. HNLC region with iron limitation
- Evidence that eddies, generated at the coast, impact iron distribution
- The ecosystems have been noticed to respond to large-scale atmospheric variability
- On decadal time scales, the PDO is the leading mode of North Pacific variability, modulates coastal downwelling conditions. (stronger mesoscale eddy activity)

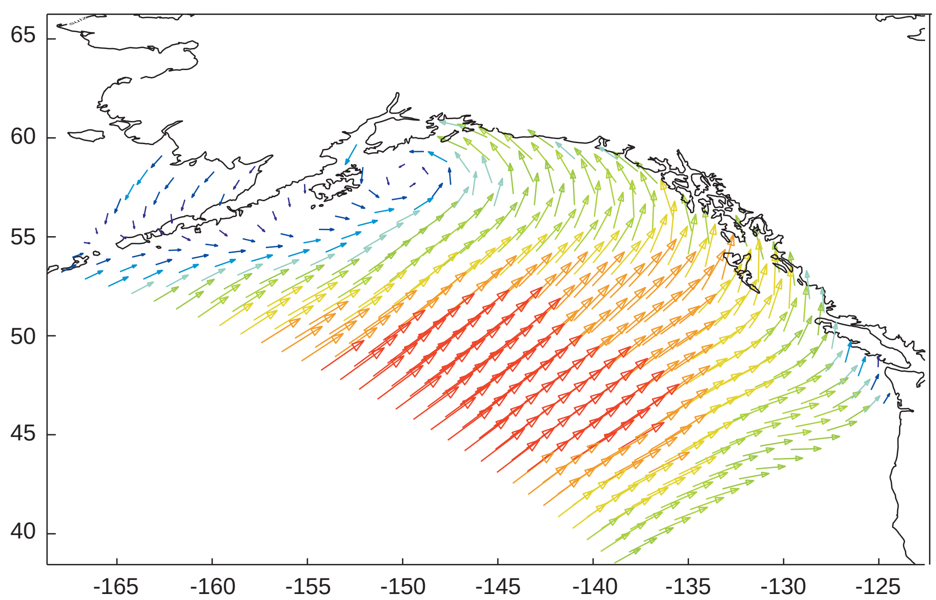
Goals

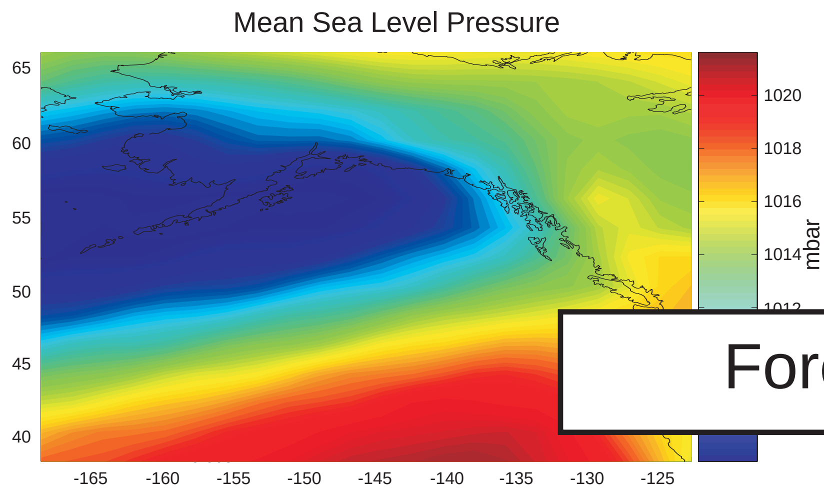
- This suggests that interannual and decadal modulations of the GOA open ocean ecosystems may be explained by exploring the statistics of eddy induced cross-shelf transport
- This study investigates the seasonal and interannual variations in cross-shelf transport in the GOA, by looking at the distribution and variability of a passive tracer injected at the coast.
- The goal of this study is to characterize the statistics of transport of the passive tracer and to understand how changes in atmospheric winds modify the distribution and transport of coastal water masses.

- **ROMS** (**R**egional **O**cean **M**odel **S**ystem)

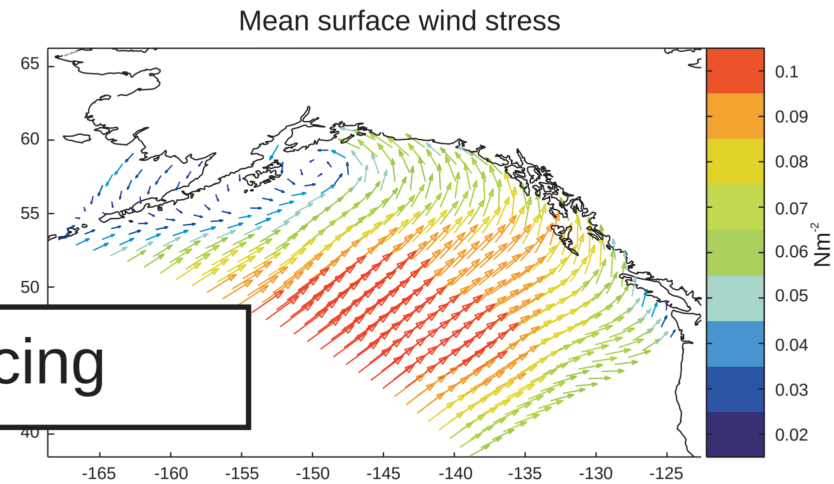
- **Grid**
  - Domain : see figure
  - Spatial resolution : ~11 km
  - Vertical : 42 vertical levels.
  - higher resolution in the upper layer

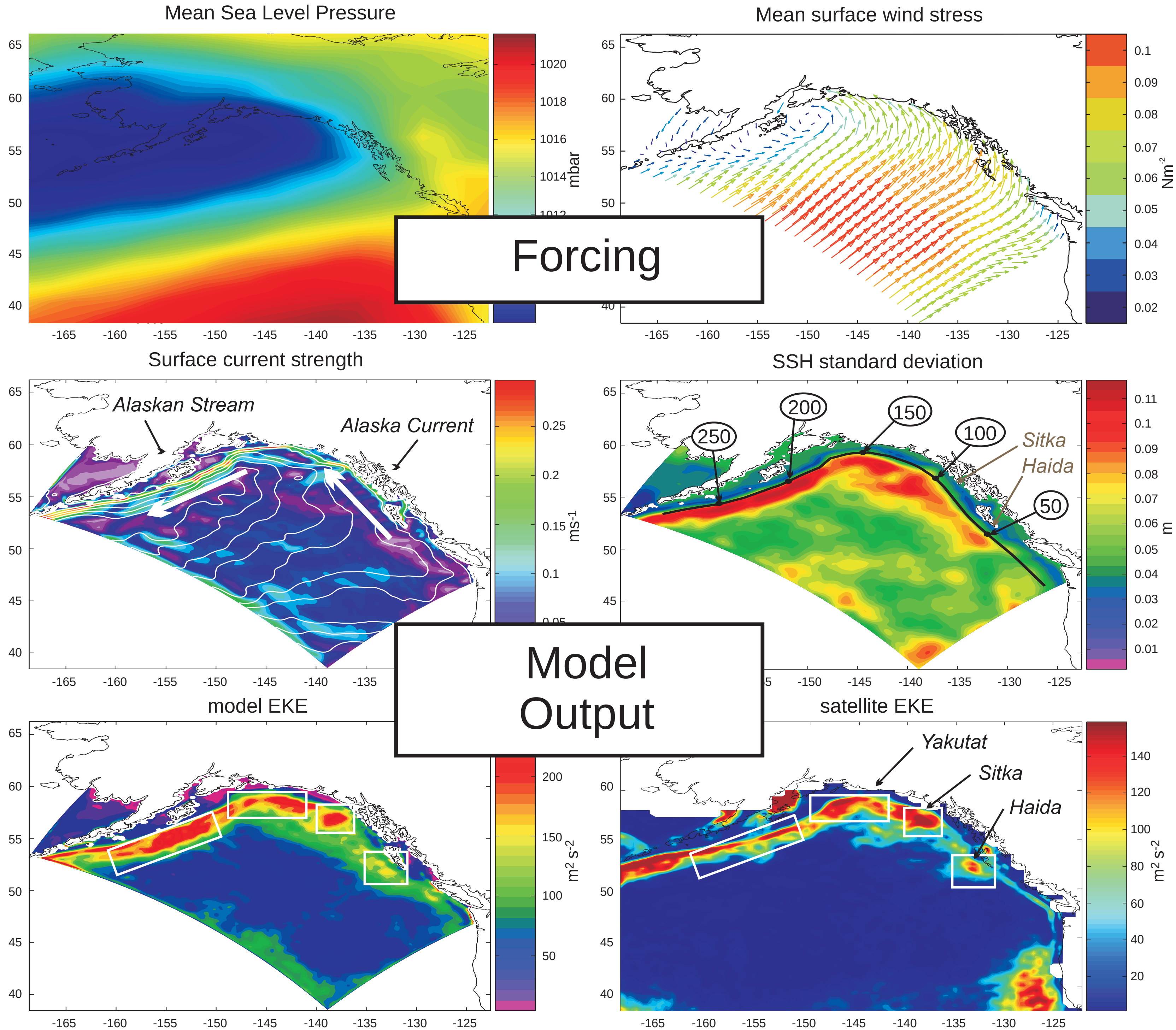
- **Experiments**
  - Nested grid
  - This outer grid uses boundary conditions from a hindcast simulation using the Community Climate System Model (CCSM) version of the Parallel Ocean Program (POP).
  - The surface forcing functions for the outer experiment (6 hourly forcing at 2º x 2º resolution) is obtained from the Common Ocean-Ice Reference Experiments (CORE) and the air sea fluxes are parameterized using bulk fluxes.




Mean Sea Level Pressure
65
60
55
50
45
40
-165 -160 -155 -150 -145 -140 -135 -130 -125
1020
1018
1016
1014
mbar

Forcing


Mean surface wind stress
65
60
55
50
-165 -160 -155 -150 -145 -140 -135 -130 -125
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
Nm^-2


Mean Sea Level Pressure
mbar
Mean surface wind stress
Nm-2
Forcing
Surface current strength
Alaskan Stream
Alaska Current
ms-1
SSH standard deviation
250
200
150
100
50
Sitka
Haida
m
Model
Output
model EKE
m2 s-2
satellite EKE
Yakutat
Sitka
Haida
m2 s-2

Passive tracer advection-diffusion equation, used in this study :

$$\frac{\partial P}{\partial t} + \underline{u}.\nabla P = A_H \nabla_H{}^2 P + \frac{\partial}{\partial z}\left(A_V \frac{\partial P}{\partial z}\right) - \frac{P}{\tau} + Q(x,y,z)$$

P =passive tracer concentration
A_H = 5 $m^2 s^{-1}$
A_V obtained by a KPP scheme
Q = source term
Thau = Decay time scale of 4 years

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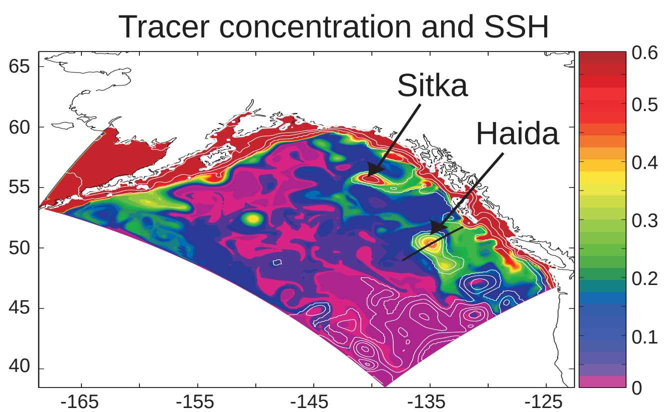

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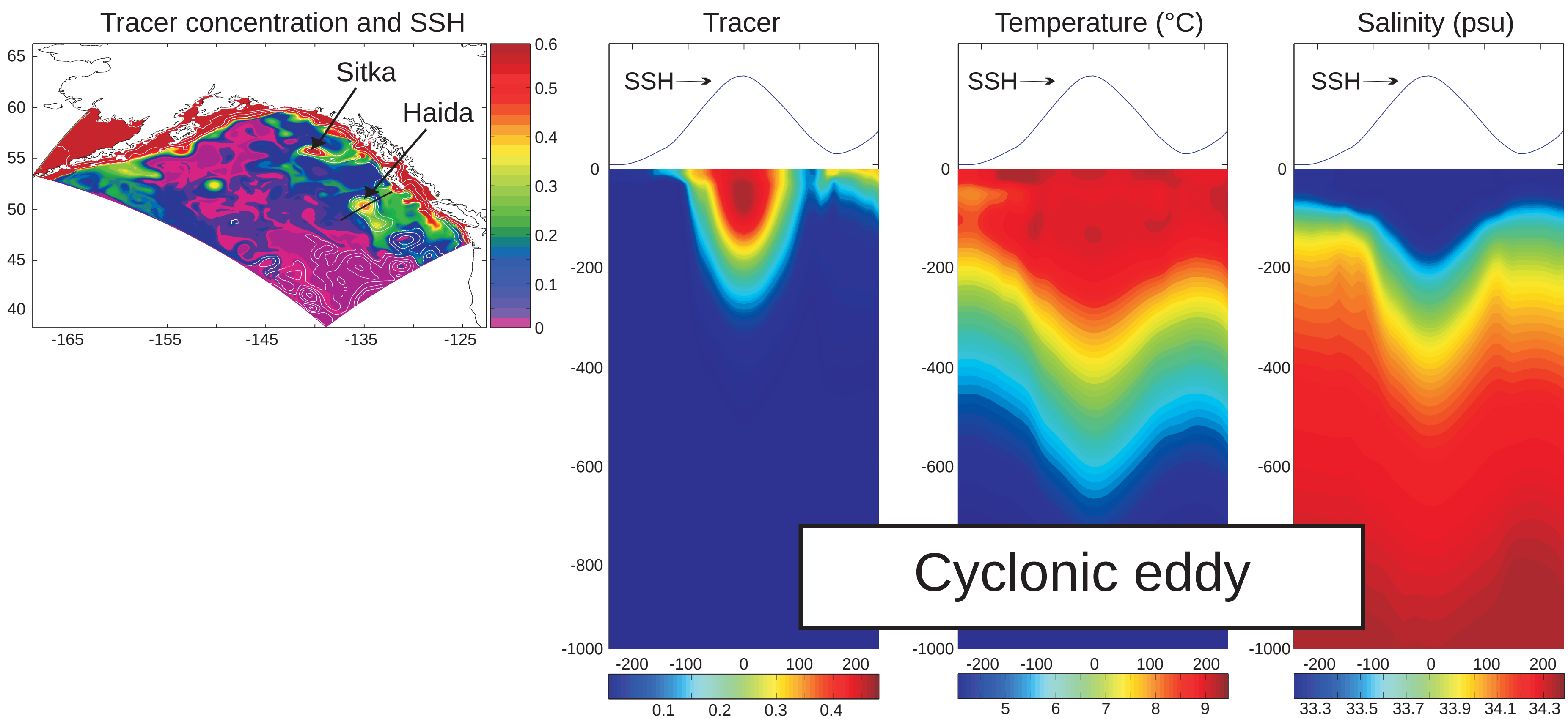
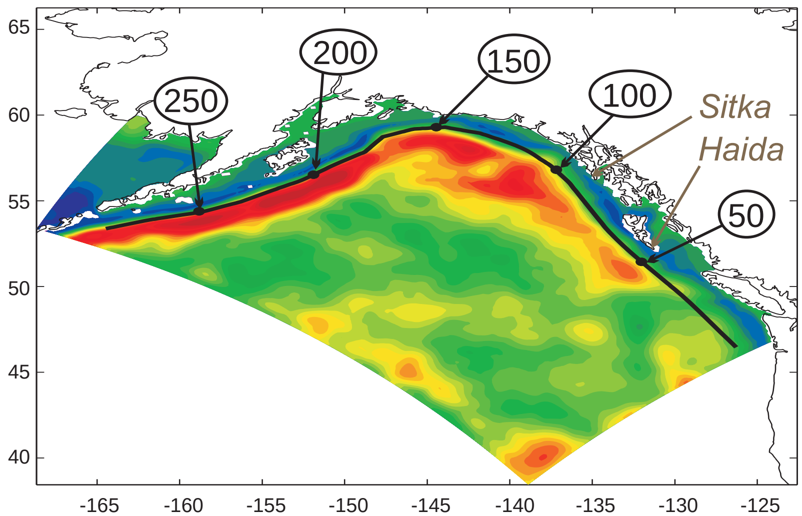


$$UP = \overline{U}\,\overline{P} + U'\overline{P} + \overline{U}P' + U'P'$$

Transect



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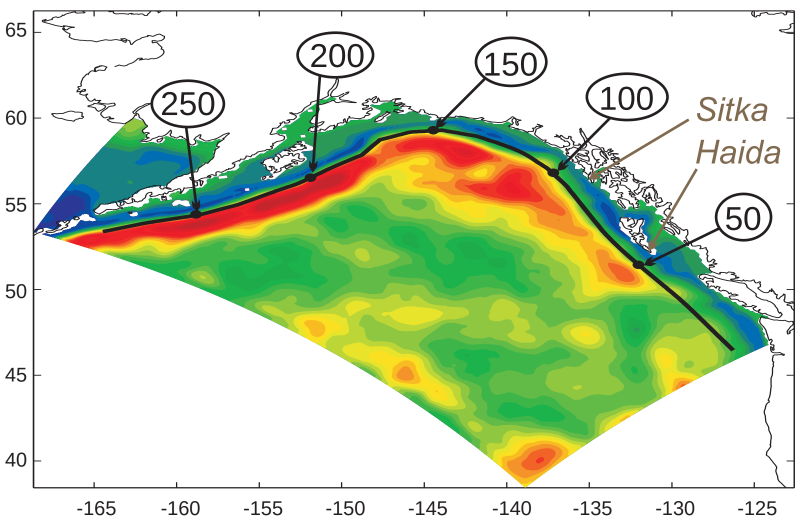
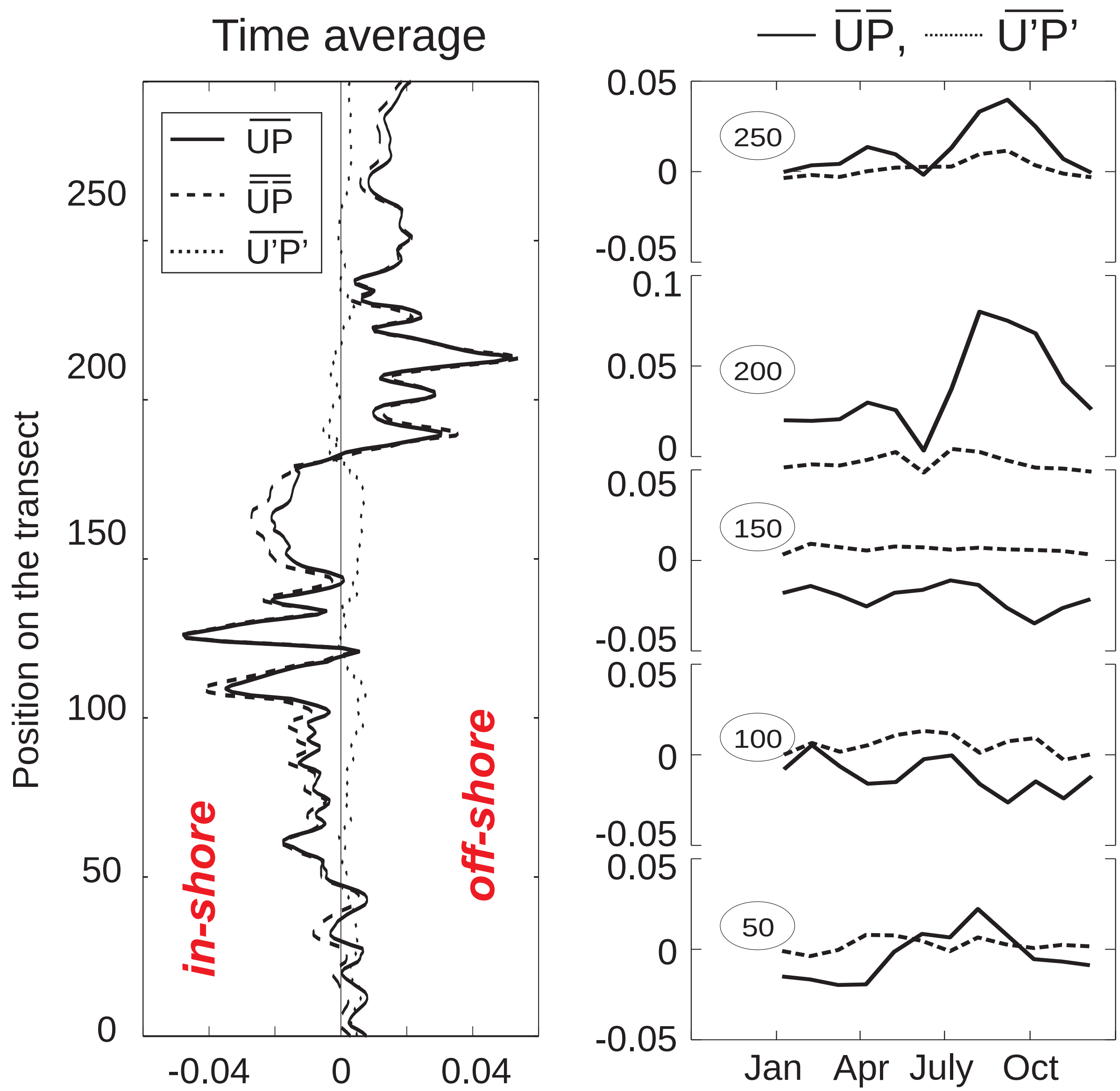
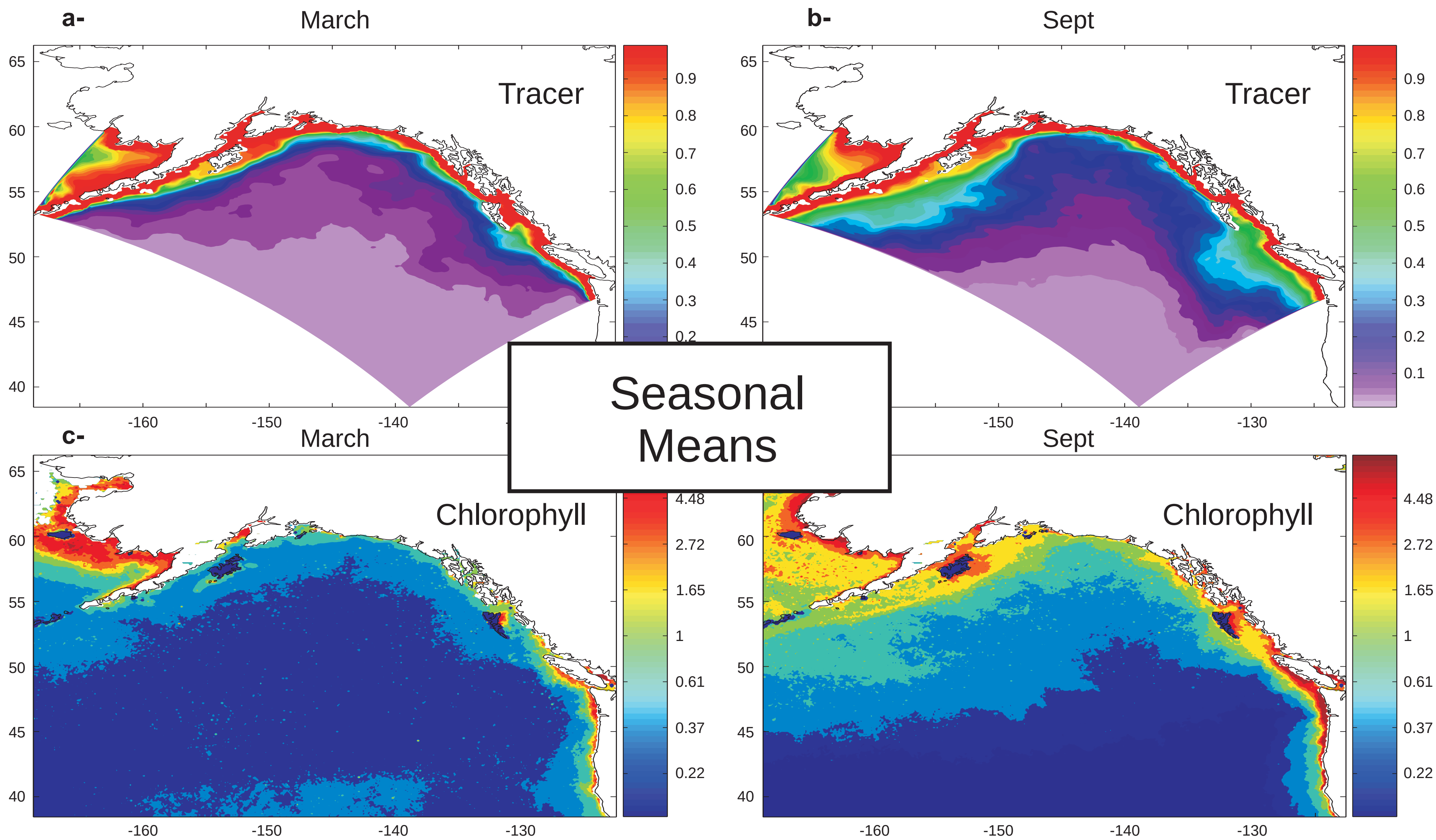
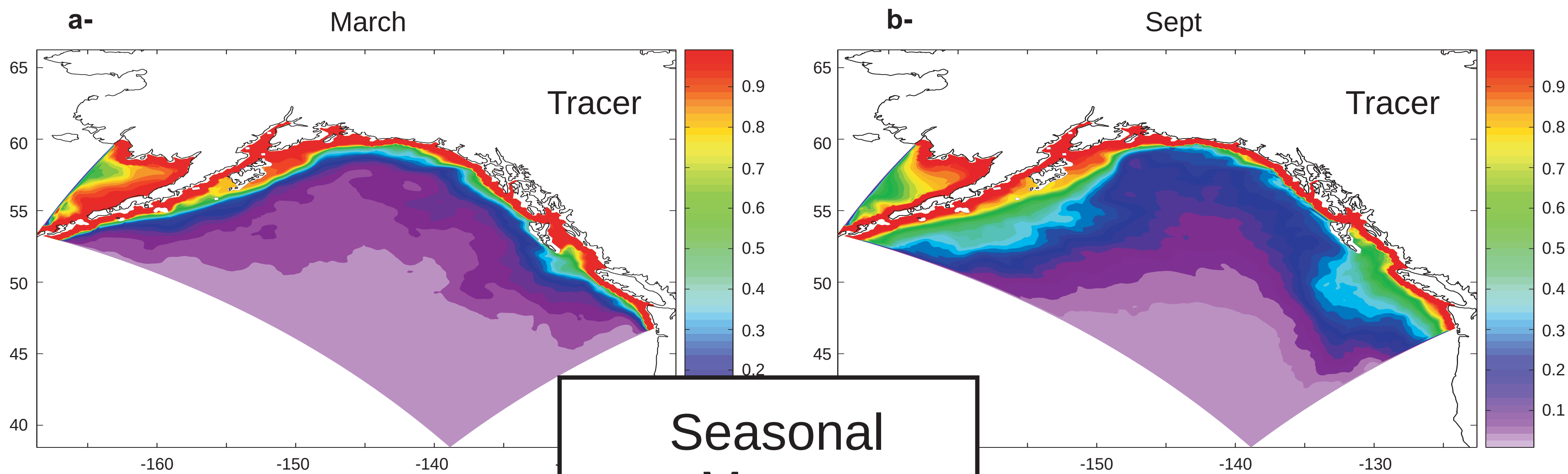
Transect



Transport

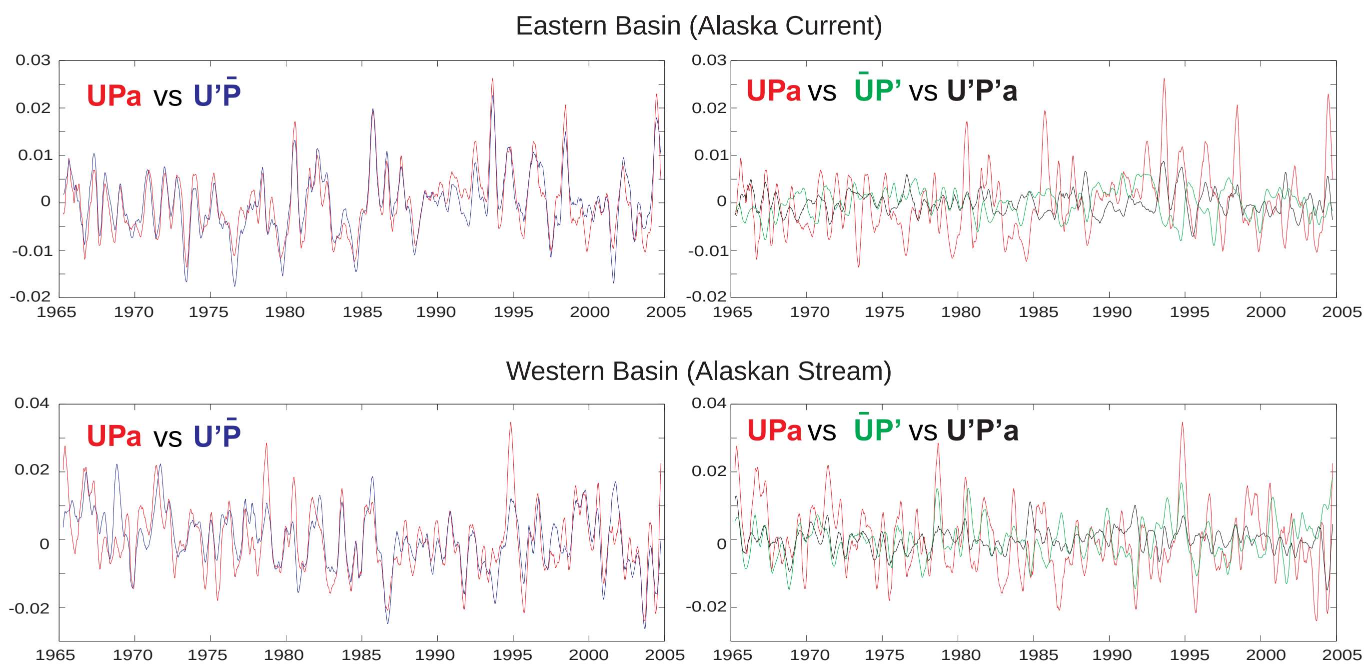



a-
March
Tracer
b-
Sept
Tracer
c-
March
Chlorophyll
Sept
Chlorophyll
Seasonal Means
65
60
55
50
45
40
-160
-150
-140
-130
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
4.48
2.72
1.65
1
0.61
0.37
0.22

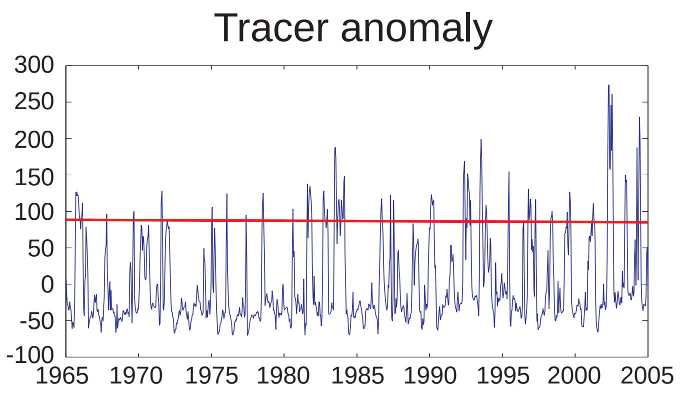


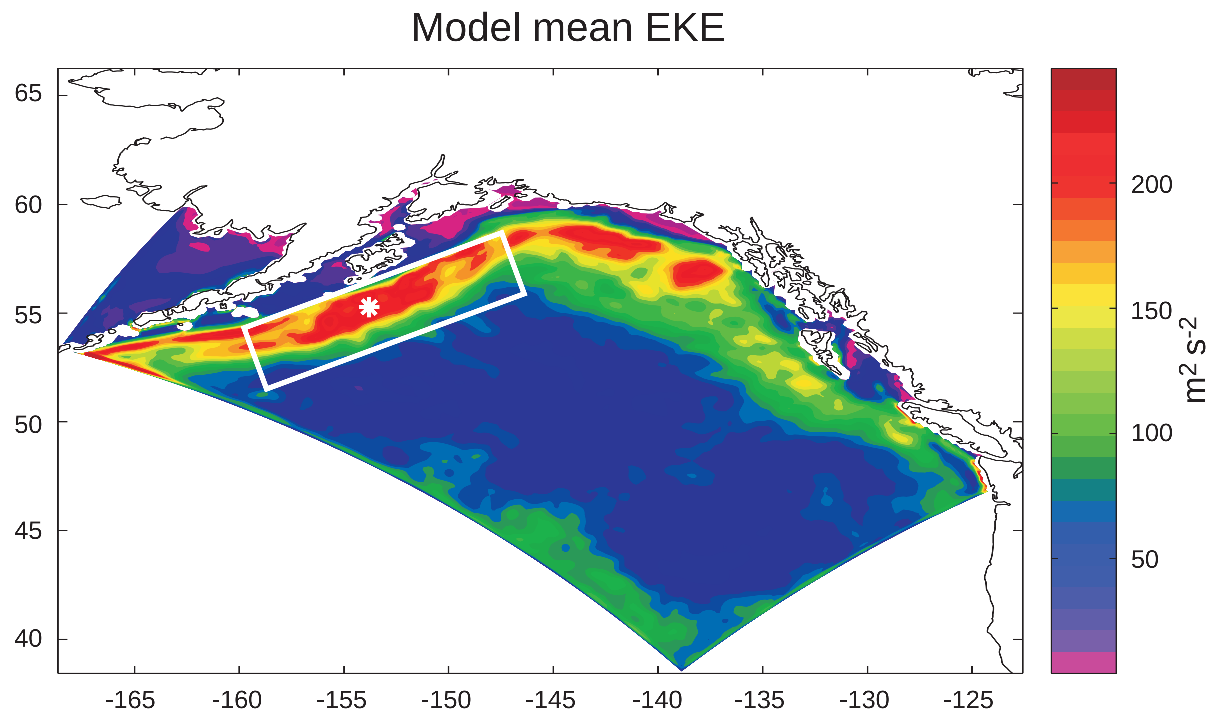
Seasonal Means

$$(UP)_{anomaly} = U'\bar{P} + \bar{U}P' + (U'P')_{anomaly}$$



WESTern basin





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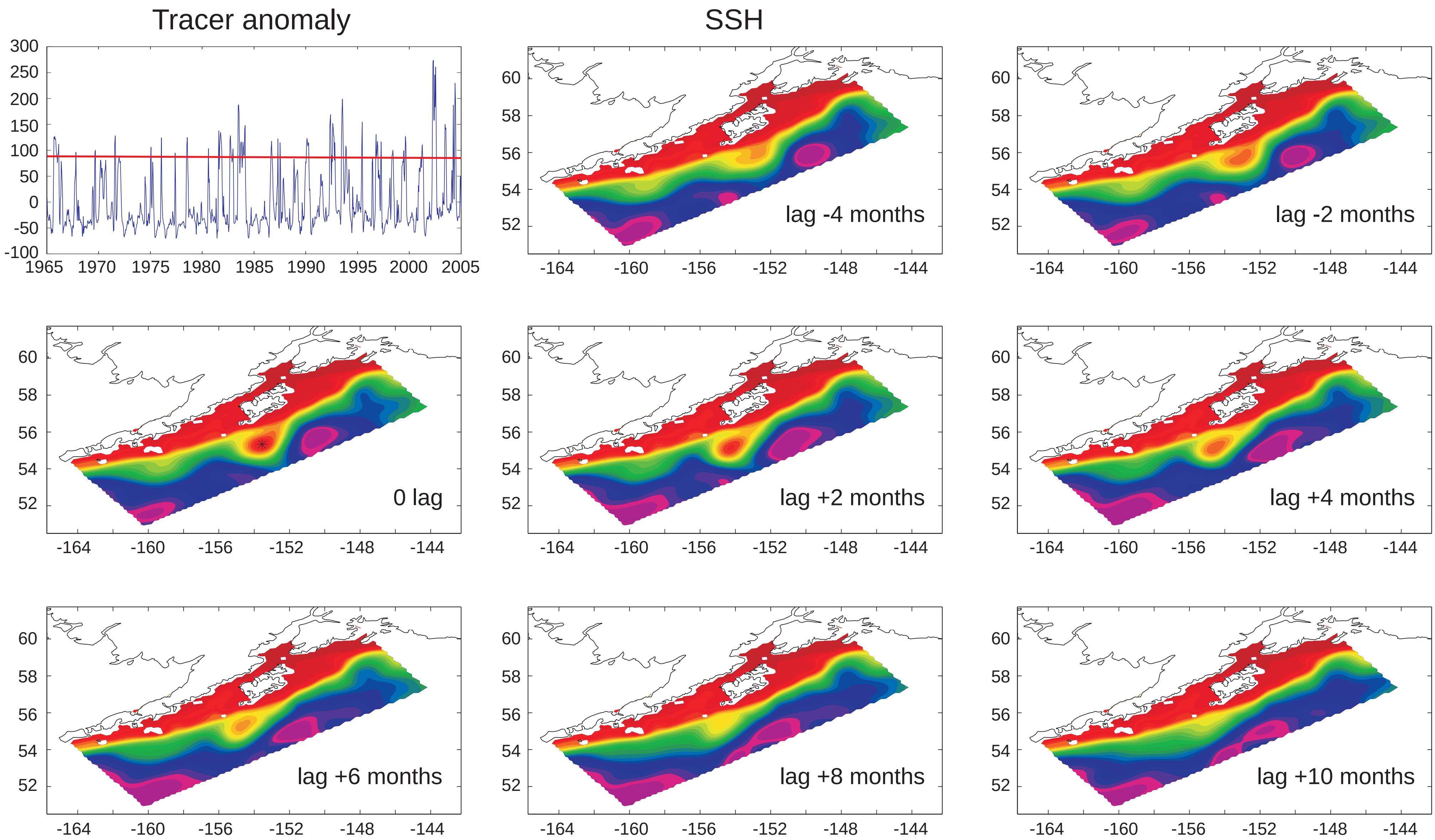
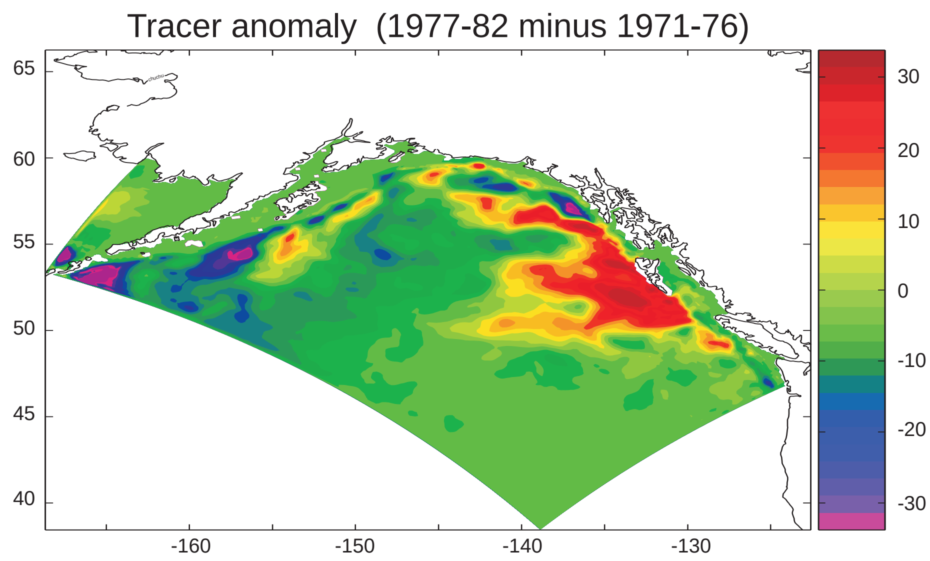


imply that high anomalous coastal passive tracer found along the western basin is mainly associated with eddy variability

EASTern basin

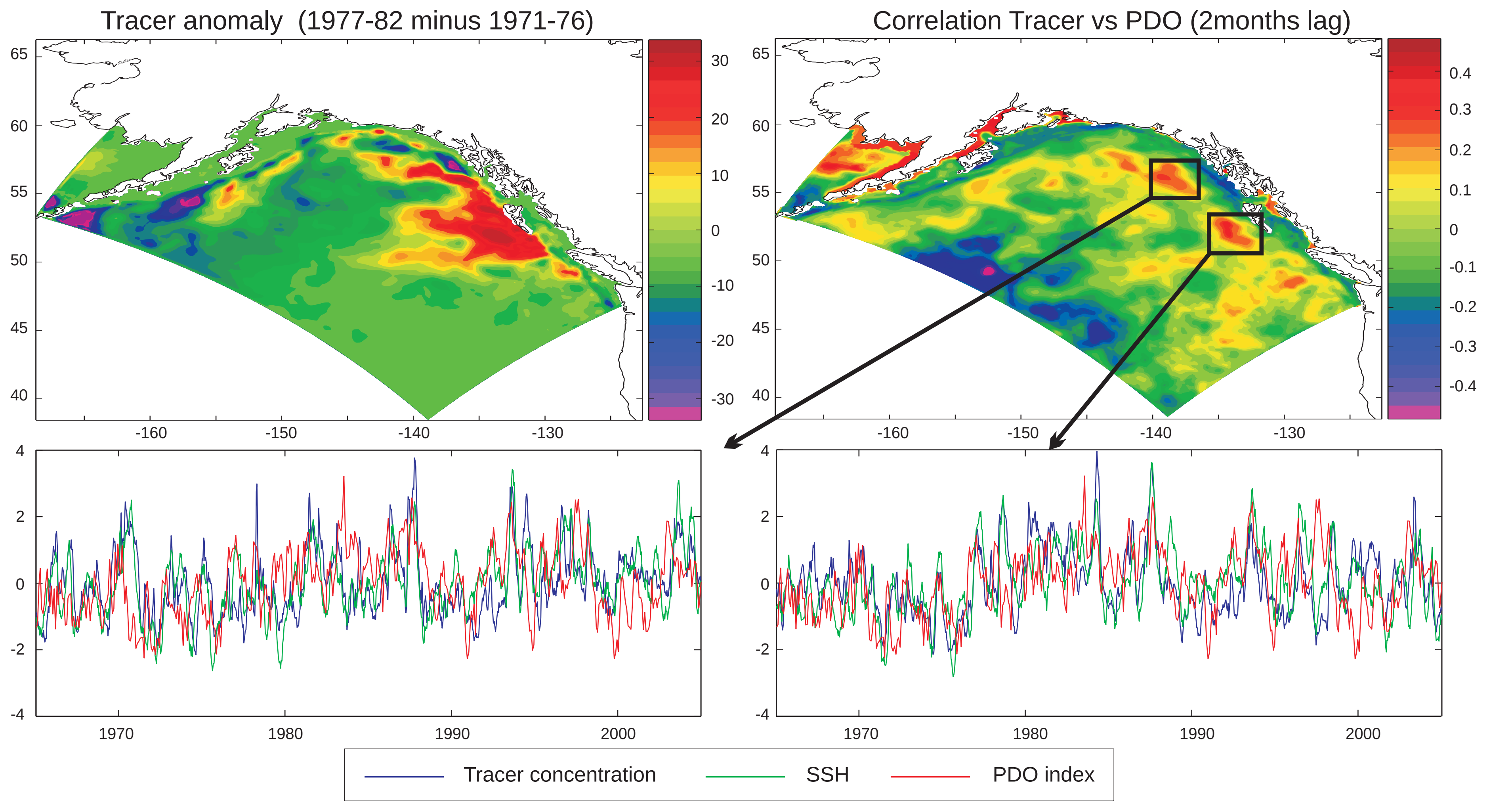


On a decadal time scale, along the Alaska Current, changes in wind stress are associated with changes in the PDO index.

The eastern GOA shows a significant change in tracer distribution following the 76-77 climate shift

The advection is more pronounced west of the Sitka region and west of the Queen Charlotte Island, where Sitka and Haida eddies are generated.

EASTern basin



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- The passive tracer simulation, analyzed in this study, provide a method to explore the evolution and distribution of coastal water masses into the gyre interior.

- We find presence of passive tracer within the core of the anticyclonic eddies confirms that eddies advect coastal waters into the gyre interior and implies that, in addition to warm and fresh water, eddies also transport oxygen-poor water and important biochemical quantities

- Along the eastern side, on average that while the advection of tracers by the average flow at the surface is directed towards the coast consistent with the dominant downwelling regime of the GOA, it is the mean eddy fluxes that contribute to offshore advection into the gyre interior.
  In the western basin, both the advection of tracers by the average flow and the mean eddy fluxes contribute to the mean offshore advection.

- On interannual timescales, the cross-shelf transport in the western region is mainly associated with intrinsic eddy variability. In contrast along the eastern boundary, stronger offshore transport of the passive tracer coincide with periods of stronger downwelling conditions, which trigger the development of stronger eddies.

- For instance, after the 1976-77 climate-shift when the Aleutian low pressure intensifies and stronger coastal downwelling conditions become predominant throughout the GOA, stronger advection of coastal passive tracer is found in the eastern basin, in particular in the path of coastal eastern eddies, such as Haida and Sitka eddies.