The Alaskan current

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March 5, 2024

Numerical modeling

1 Introduction

This project consist in making a realistic simulation of the Alaskan current using the model CROCO. Alaska Current is part of the eastern limb of the Subarctic Gyre. This flow is characterized by a strong cyclonic flow which follows the west coast of North America. The Alaska coastal current starts approximately near the Vancouver Island to get stronger northward. This current brings relatively warm water to the North. In Winter, the region undergoes strong counterclockwise wind while in summer it transitions to a gentle clockwise circulation. Due to the earth rotation, in the winter, the central deep water masses are pushed toward the coast. This lead to convergence and downwelling. What sets this region apart is the significant level of precipitation it receives. Besides, there is a vast network of small rivers that distribute freshwater along the coast, reaching its peak during the spring season.

These two factors of wind and precipitation maintain a high contrast in density between the coast (with fresher and lower density water) and the offshore central area.

In Eastern Alaska, the current is approximately a hundred km wide, meandering eastward to the tip of the gulf through releasing mesoscale eddies into the ocean interior.

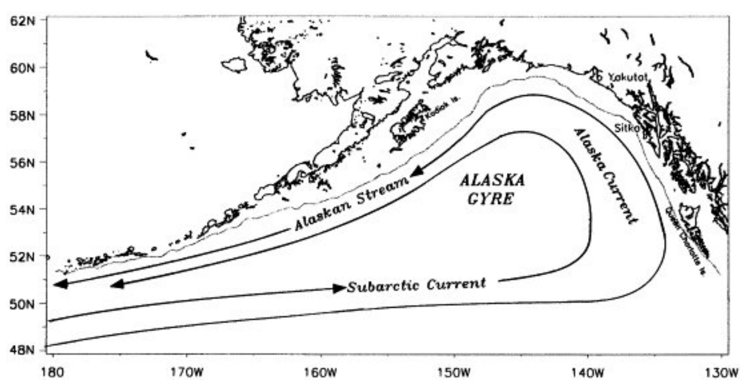
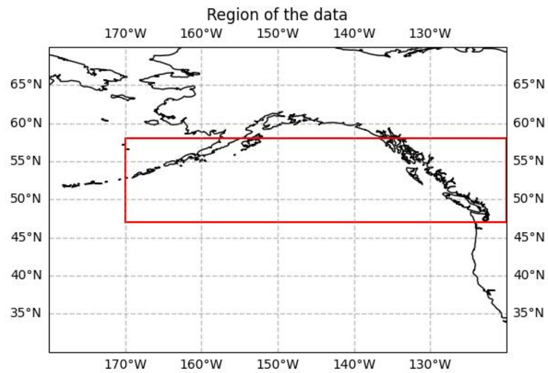


Figure 1: Caption

In the following report, we aim at analyzing different parameters of the simulation to find consistency with the characteristics of this current described by the literature.

2 Parameters of the simulation

The area of the simulation was between 170° and 120° W Longitude and between 47° and 58° N Latitude. The domain was divided into 139 ξ cells on the x-axis and 56 η cells on the y-axis. This represents a 1/3 ° resolution. The time step was chosen so to respect the stability constraints : $\frac{\Delta t}{\Delta x}\sqrt{gH} < 0.89$ We choose a time step $dt = 1800s$. The simulation ran for 2 years so 35040 time steps, starting the 1st of January. It was chosen to get the output every 10 days and averages every 30 days.



3 Analysis of the simulation

3.1 Kinetic energy

We plot the time evolution of the Kinetic energy for the last year of simulation. The kinetic energy is integrated over the domain at the surface.

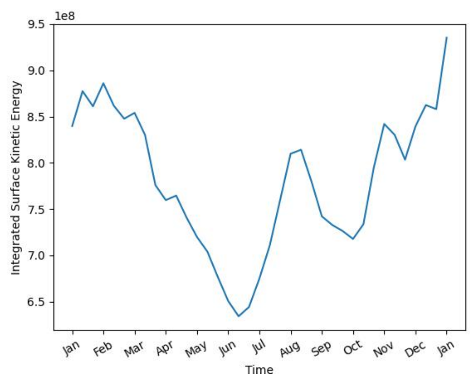


Figure 2: Global evolution of the surface kinetic energy

The Kinetic energy is maximum during January and February. Approximately, there is a difference of 2.5×10^8 between June and February. There is a strong seasonal variation in the area, with more mixing during winter time.

3.2 Vorticity

We will now turn to the analysis of the vorticty. Here we plot the vorticity normalized by the Coriolis Parameter $\frac{\zeta}{f}$. We started the plot the second year, after 10, 30, 90 and 360 days

<u>Vorticity at the surface:</u>

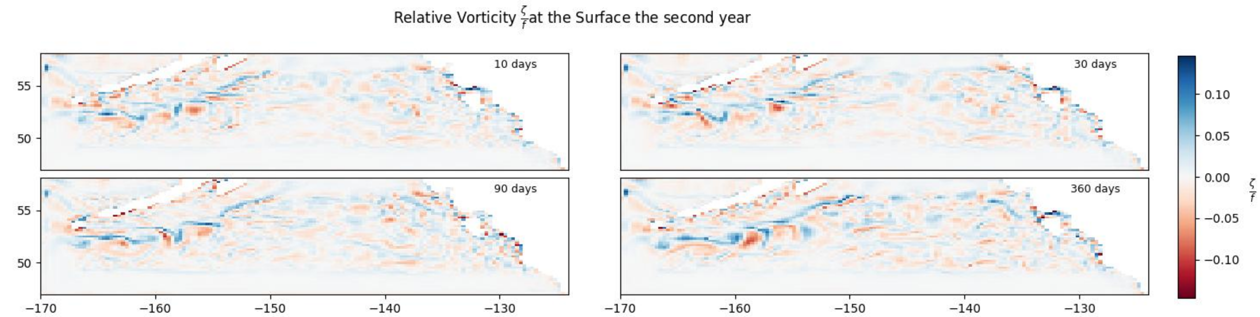


Figure 3: Normalized Vorticity at the surface for 10,30,90 and 360 days

The first striking pattern we observe is the presence of mesoscale eddies detaching along the west arm of the Gulf. The pattern seems stationary, we plot the mean vorticity averaged over the last year of simulation to check this trend:

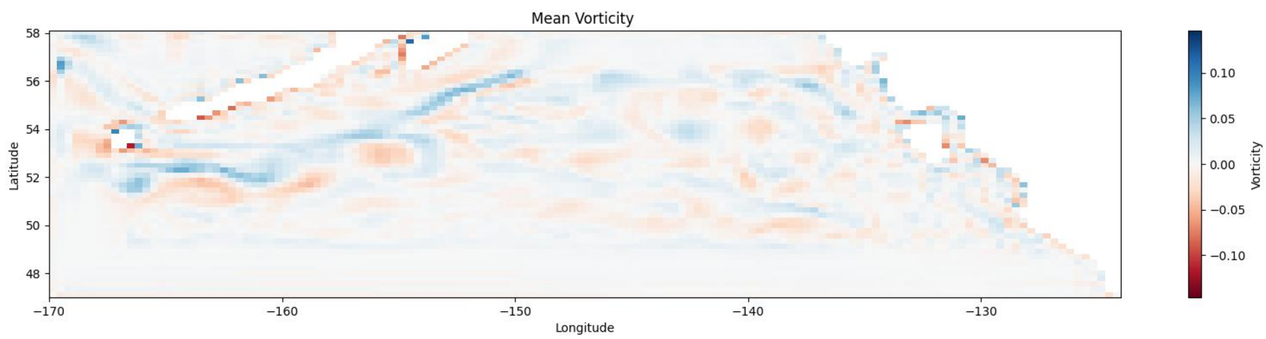


Figure 4: Mean normalized Vorticity at the surface

These eddies are characteristics of the region, they play an important role in the transport of heat, nutrients and biological populations into the water of the northeast Pacific Ocean. Eddies are mainly generated on the eastern side of the basin. Some will propagate westward, they are called the <u>Haida eddies</u>, while others along the western Gulf of Alaska shelf break (<u>The Alaskan Stream eddies</u>) Haida eddies are situated around the coordinates (-132,53), near the island next to to the coastline. They are mesoscale anti-cyclonic eddies characterized as relatively long-lived, transiting along the coast and possess a warm, less-saline core, relative to the surrounding waters. The vorticity here in the simulation seems

to remain constant over the year.

<u>Vorticity at 400m depth:</u>

The vertical axis is in sigma coordinates, we had to interpolate the velocity field at 400m before computing the vorticity. By the end of the year, there seem to be more vortices. The region is known for having a the great interannual variability. We observe more distinct vortices by the end of the year. Eddy variability is non Deterministic in this area [5], it's thus hard to conclude big trends. Overall, Alaska Current eddies generally move westward away from the eastern boundary, it's been shown that there is a corelation with the speed of propagation of Rossby wave[5].

According to [3] In general, Alaskan Stream eddies are more numerous, larger and more intense than Haida eddies. Periods of increased eddy activity do not necessarily correspond to El Niño events, but are associated with anomalous downwelling wind conditions along the continental margin.

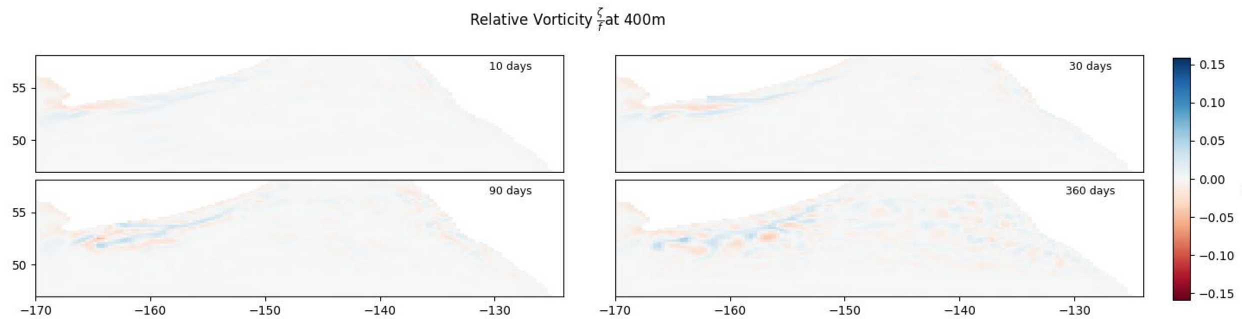


Figure 5: Normalized Vorticity at 400m depth for 10,30,90 and 360 days

3.3 Temperature

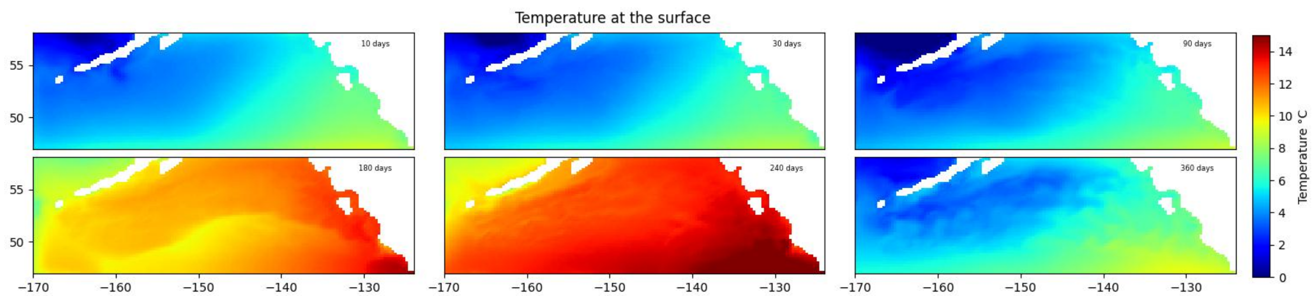


Figure 6: Snapshots of the Temperature at the surface

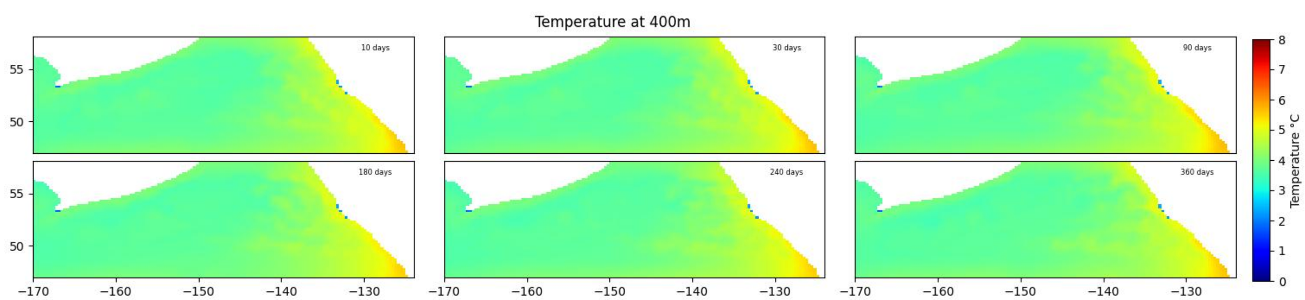


Figure 7: Snapshots of the temperature at 400m depth

At the surface, we clearly observe the variation of temperature between summer and winter. The coast is on average warmer than the center of the basin. West Alaskan stream eddies are visible in the cold season, they contribute to convey the energy. When comparing with observation data [4] our model sea surface temperature are slightly warmer than the observation in October 1996
There is a clear front of cold water, splitting the map into two distinct areas of cold and warm water. The southeast side is characterized by warm waters coming partly from the Californian current, following the coast. At 400m depth, there isn't much variation along the year, the basin is around 4°C.

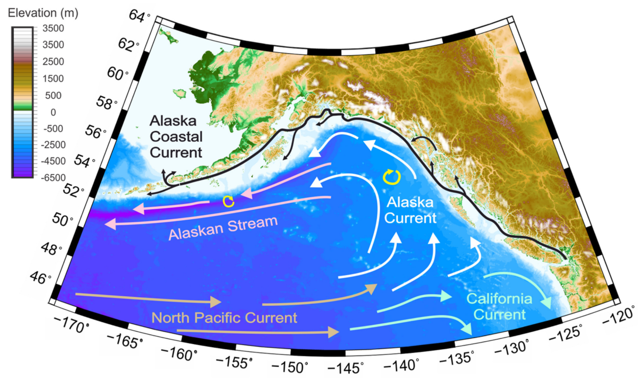


Figure 8: Ocean Circulation in the Gulf of Alaska

3.4 Zonal Section in the Kodiak Archipelago (57.590°N, 153.496°W)

We choose to plot a zonal section at N57° of latitude. Alaska Current turns southwestward and get stronger near Kodiak Island, turning into the Alaskan Stream. This section crosses the Kodiak Archipelago which is famous for having a rich biodiversity due to strong vertical mixing [7].

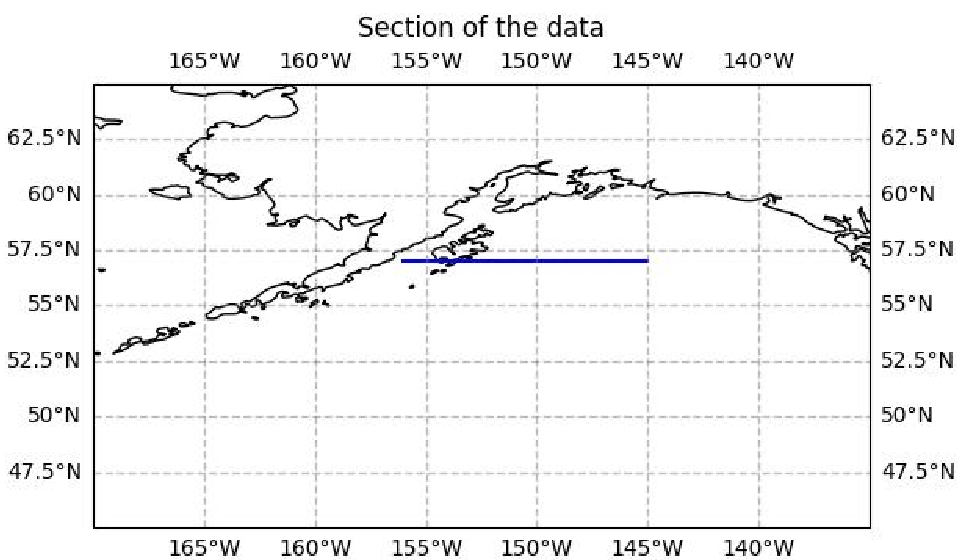


Figure 9: Section crossing the Kodiak Island

This is the place where the Alaskan stream eddies can form. They strongly influence nutrient concentrations, notably iron and dissolved inorganic materials, as well as chlorophyll concentrations and zooplankton.

Density section and temperature :
Here we plot the density of the section.

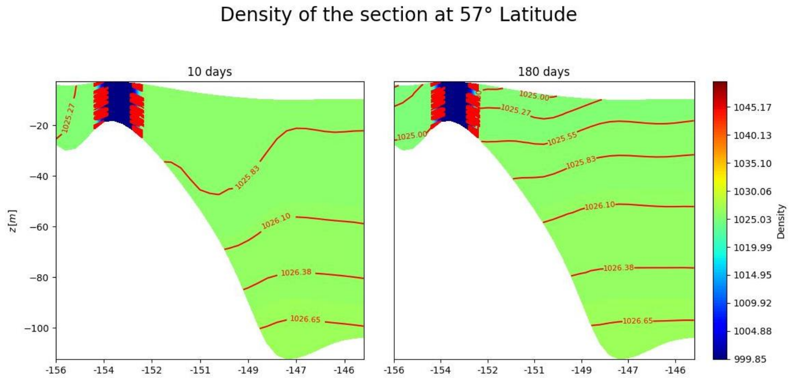


Figure 10: Zonal section at 57°N showing the density in January and in June

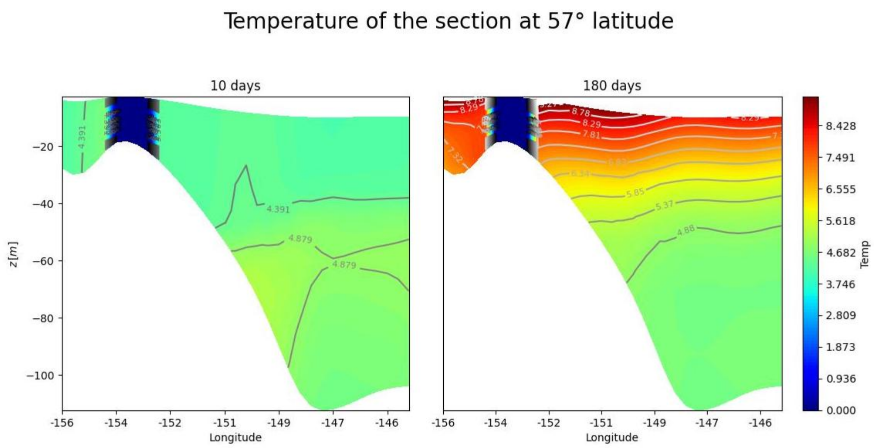


Figure 11: Zonal section at 57°N showing the temperature in January and in June

The winter salinity gradient is less important than in summer. [8] There is a strong slope of density in January. Emphasizing a strong baroclinic winter current in this region. The density on the eastern side of the island is lower than on the west. The water flowing near the coast is warmer and less salty than the mid-water. (due to fresh water inpout form rivers) The model seems to lack this information.

Velocity of the section

We realize a section showing the velocity at the chosen section. In January, there is a "fast" current east to the Island reaching 0.10m/s. This corresponds to the Alaskan coastal current, composed of warmer water. There is a second area with higher speed which correspond to the Alaskan stream. We notice a strong variation between winter and summer.

On the eastern side of the island, and particularly in June the speed increases significantly due to the narrowness of the passage. The current is baroclinic, it would be closer to the coast in summer than in winter however none of the available data provides convincing evidence of a significant seasonal cycle in baroclinic transport of the Alaskan Stream [6]

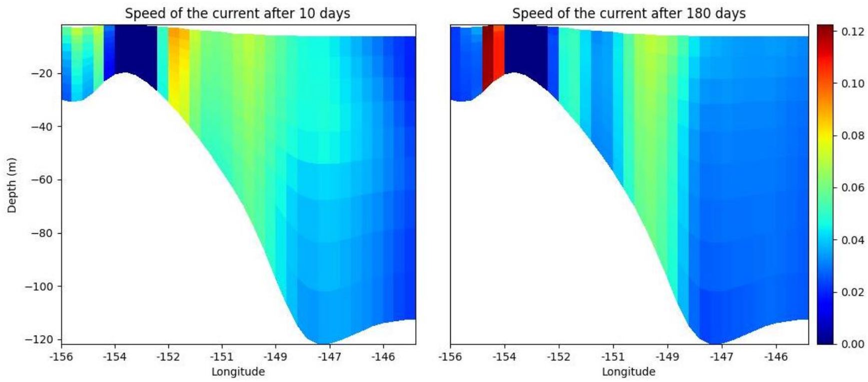


Figure 12: Velocity section in January (left) and in June (right)

3.5 Mean surface velocity

We see the coastal current heading west and returning south by the end of the western Alaskan Arm. The current makes big meanders (100kms), with the highest velocity near the Kodiak Island and south of the tip of the Gulf. Some modeling results indicate that meanders and eddies in the Gulf of Alaska are a result of baroclinic instability of the Alaska Current [2].

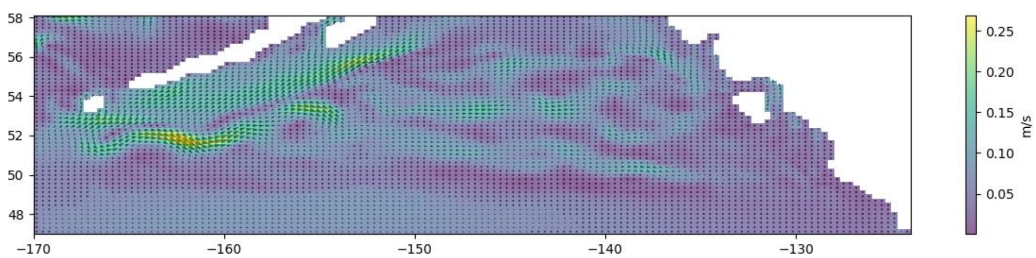


Figure 13: Mean surface velocity averaged over 1 year

3.6 Sea surface height variance

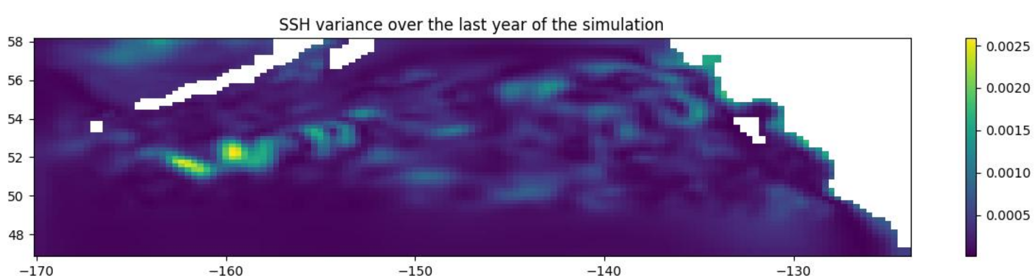


Figure 14:

3.7 Surface eddy kinetic energy

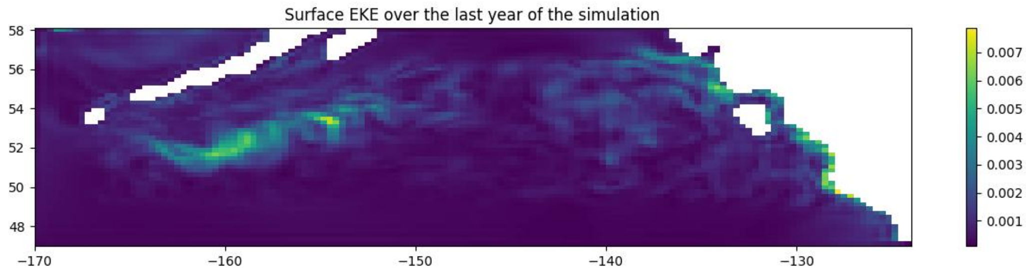


Figure 15:

The plot confirm the presence of energetic eddies on the side of the basin. Eddies generally form in winter and get detached from the continental margin by the end of mars[1]. The eddies on the westest part are called the Yakutat Eddies. They are believed to form in instabilities of flow along the continental slope. These eddies have the big responsibility of transporting warm and salty water into the deep sea region.
The Haida Eddies are on the eastern side of the Gulf. They transport nutrient rich Coastal Waters into the center of the Gulf.

4 Conclusion

To conclude, the Gulf of Alaska region is characterized by turbulent waters. We noticed the presence of numerous eddies traveling across the region. They carry warm water from the coast offshore. The area also experiences significant seasonal changes in temperature and density. The density distribution leads to baroclinic instabilities which then change the flow. The literature advocate also a string link with El Nino oscillation but the origin of lots of phenomenons born in this region are also badly understood. I could have run the model at a higher resolution, (1/8 degrees) for a better study of the eddies and the Kodiak Island region.

References

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