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Biophysical Variability in the Kuroshio Extension from Altimeter and SeaWiFS

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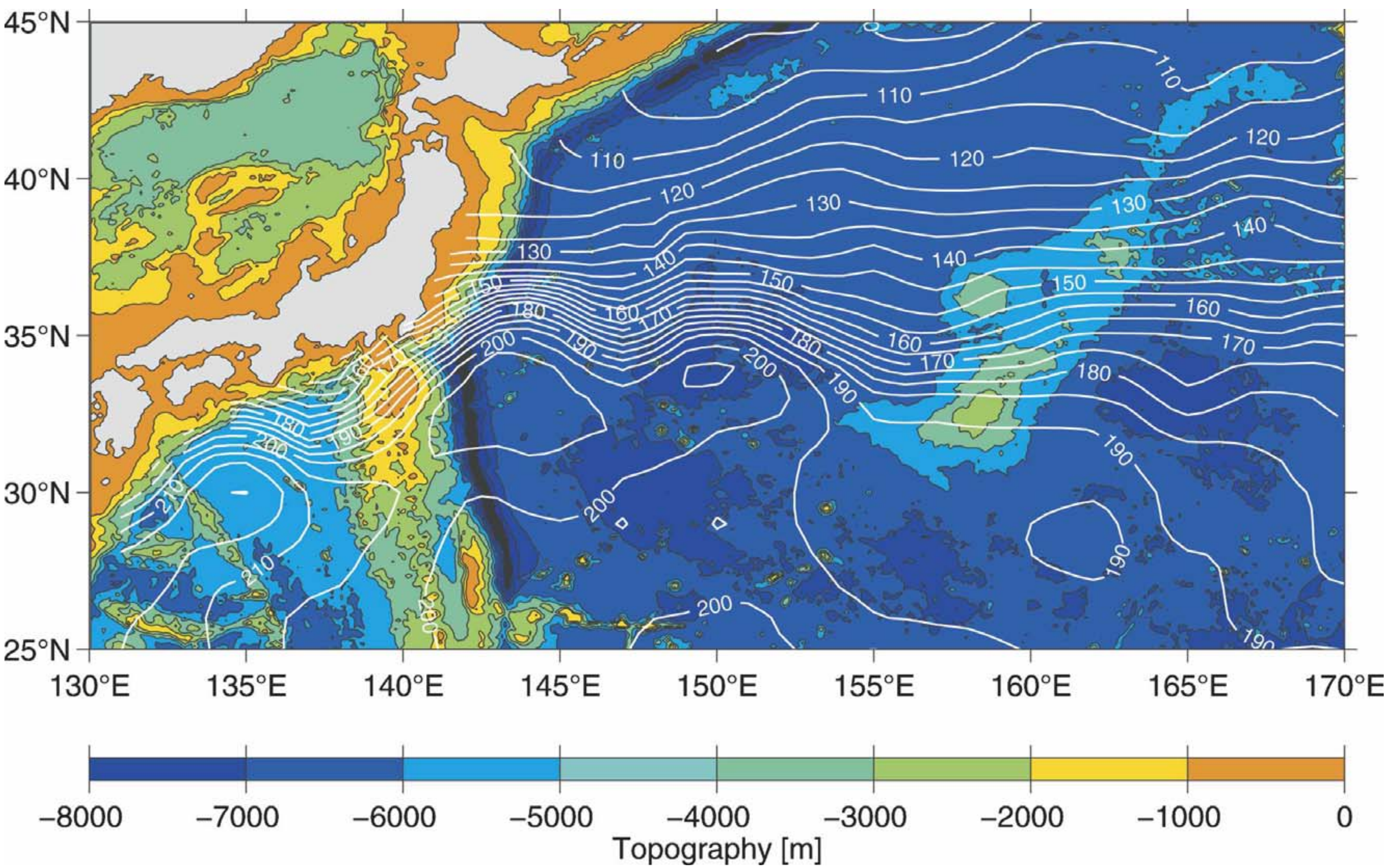
Mean Surface Dynamic Height
170 cm Contour → Kuroshio Extension (KE)
(Qiu & Chen 2005 JPO)



Theories

- (1) Primary productivity in the oceans is limited by the lack of nutrients in surface water.
- (2) These nutrients are mostly supplied from nutrient-rich subsurface waters through upwelling and vertical mixing (Barber 1992).
- (3) In ocean gyres upwelling and vertical mixing are not fully account for the observed productivity (Jenkins & Goldman 1985).
- (4) Upward pumping of nutrients is through action of meso-scale eddies (McGillicuddy et al. 1999, Segal et al. 1999).

Can we identify such a upward pumping mechanism in western Pacific (such as KE) using satellite data?

Purpose of the Study

- To examine the spatial and temporal variability of SeaWiFS chlorophyll-*a* (Chl-a) in the KE region in relation to eddy structure
- To identify the upward nutrient pumping mechanism
- To identify the Rossby wave propagation along the KE axis

Kuroshio Extension (KE)

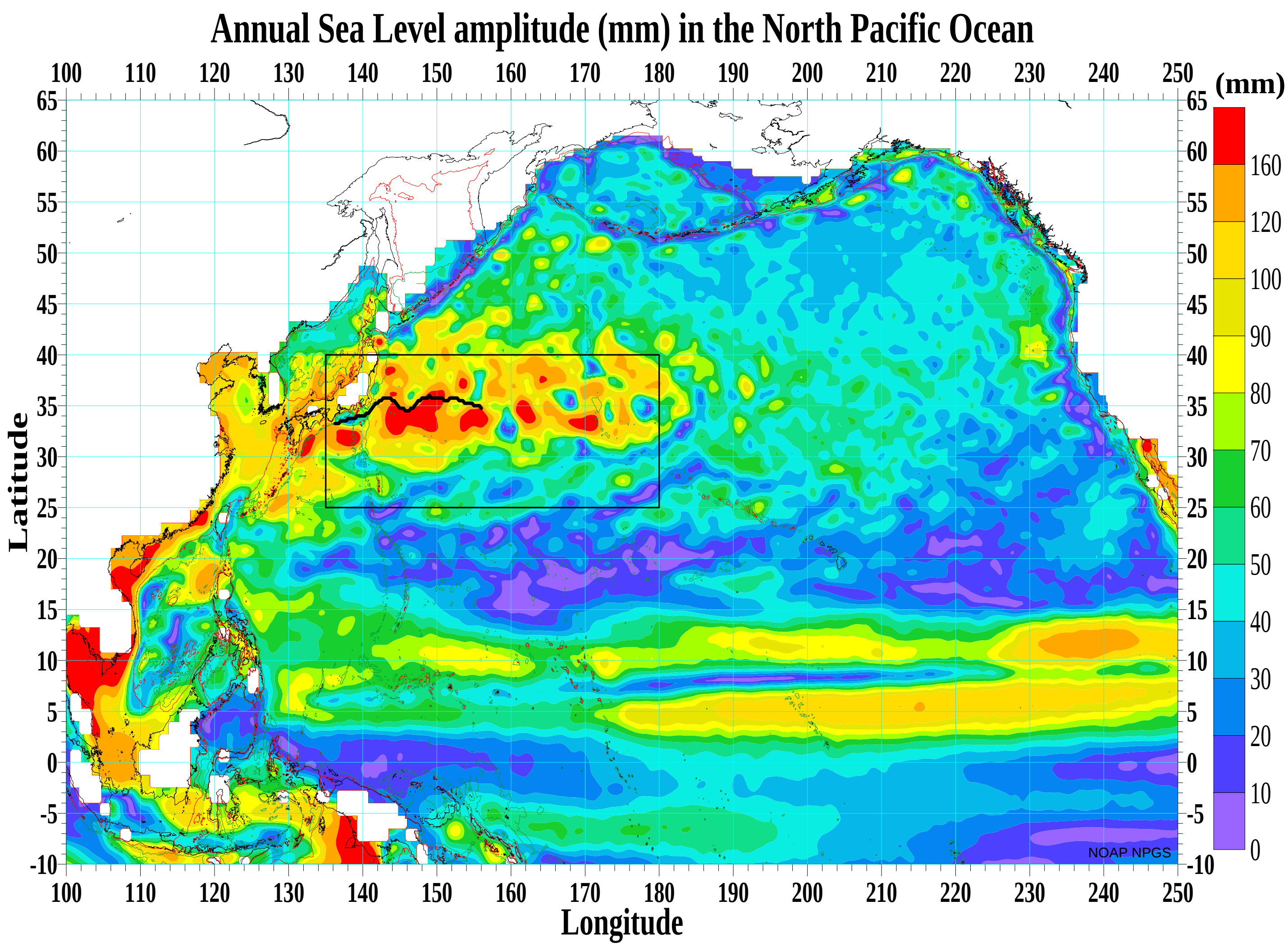
- To the east of Japan the Kuroshio swings eastward to form the Kuroshio Extension. The branching of this current in the region of 160° E results in the movement known as the North Pacific Current.

- The Kuroshio Extension (KE) current carries warm water at nearly 140 million cubic meters per second (140 Sv) eastward into the North Pacific.

Sea Level Anomaly (SLA)

- SLA is measured by ERS 1/2 and TOPEX/Poseidon satellites from 1 January 1998 to 31 December 2007 at 7-day intervals.
- SLA has evident annual cycle and mesoscale structure dominated by eddy or Rossby waves.

Annual Sea Level amplitude (mm) in the North Pacific Ocean. The Kuroshio Extension route is associate with large annual amplitudes

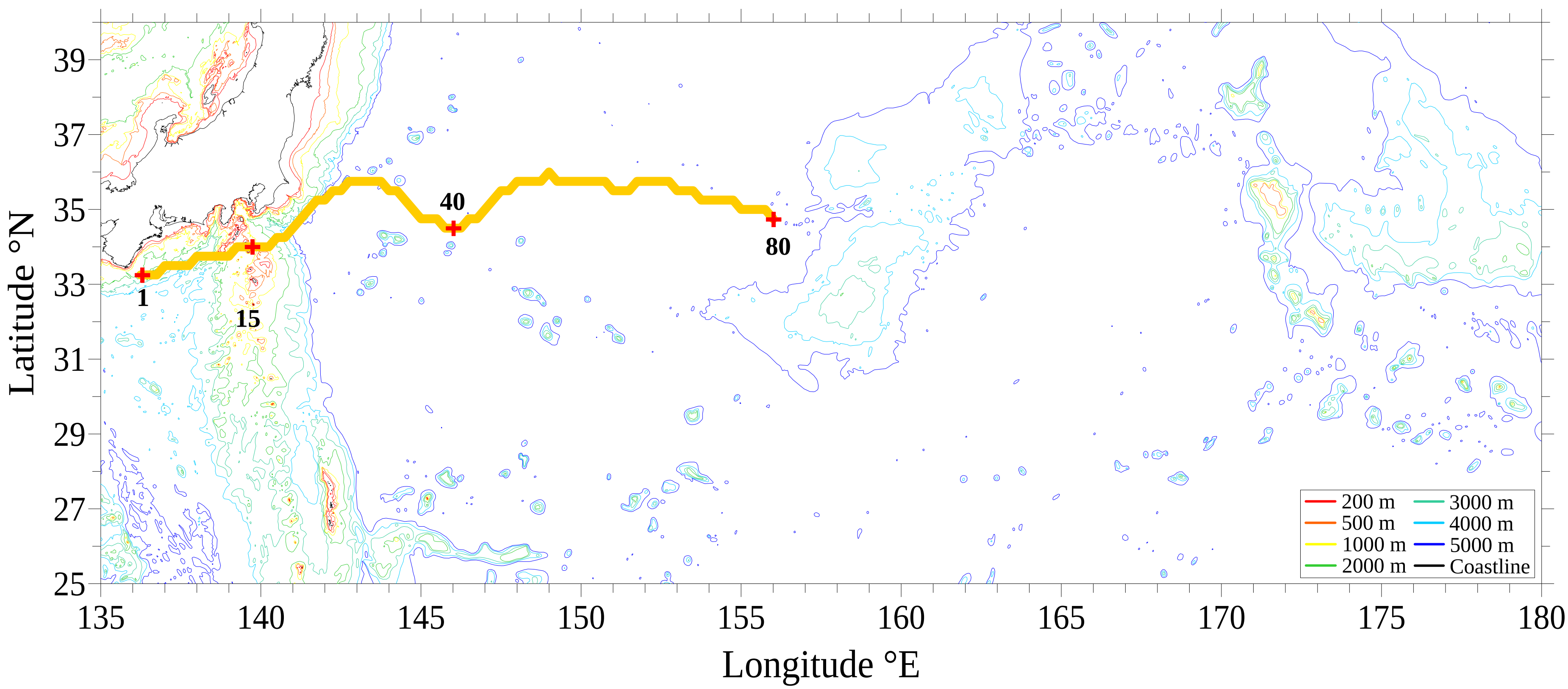


Annual Signal of SLA

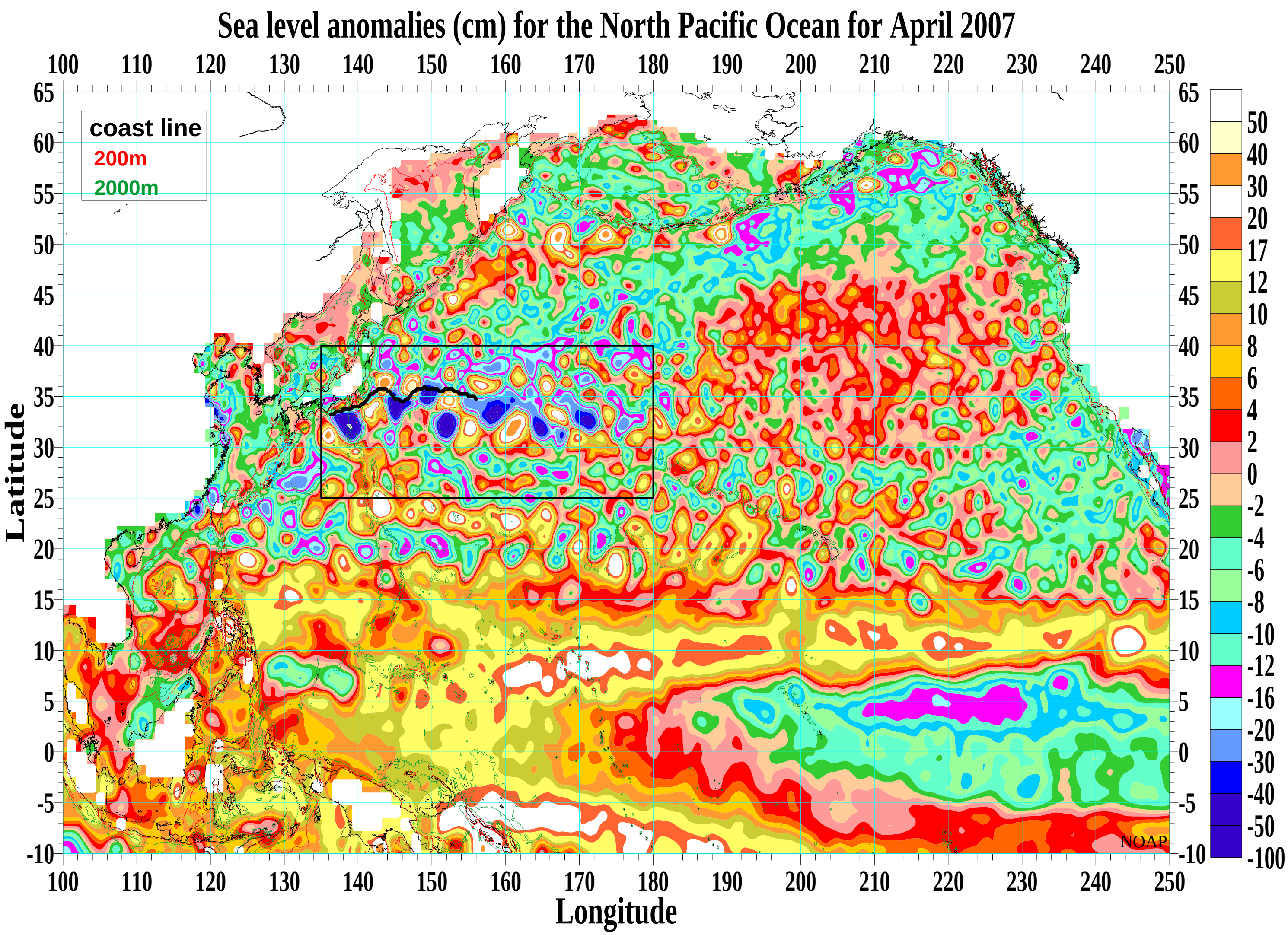
- (1) The annual signal is influenced partially by the ocean circulation and partially by the rise and fall of the sea surface that arises from the expansion and contraction of the ocean due to its heating and cooling with seasonal climatic change.

- (2) Maximum annual elevation change is about ±20 cm

Topography of the studied area and Kuroshio Extension axis (marked orange) adopted for the present study. Stations positions 1, 15, 40 and 80 are marked.



Satellite observed sea level anomaly (cm) in the North Pacific in April 2007



Chl-*a* Concentration

- Chl-*a* concentration is computed from the ratio of radiances measured in band-3 (480–500 nm) and band-5 (545–565 nm) according to the following NASA algorithm,
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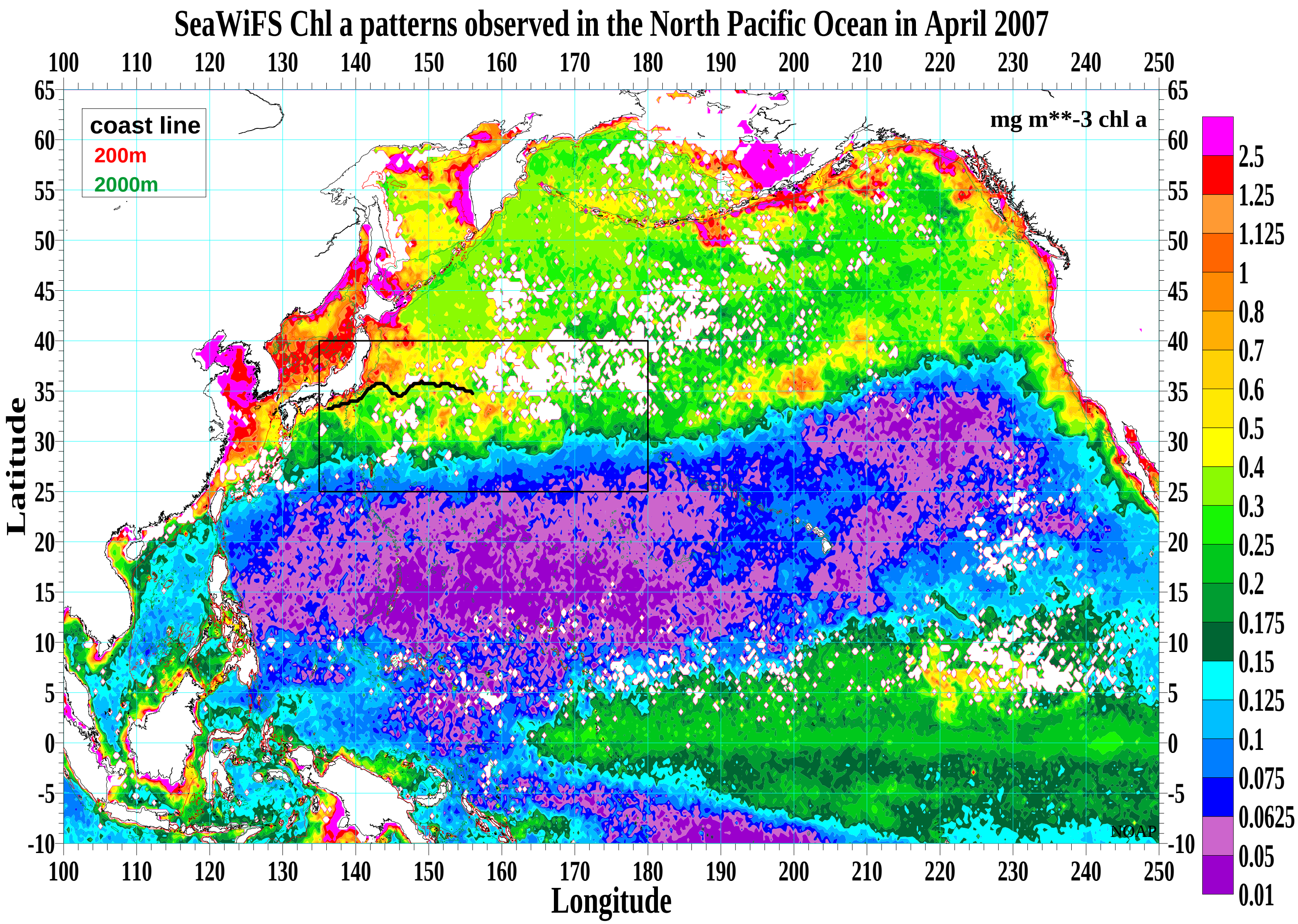
$$C_a = \exp\left[0.464 - 1.989 \mathrm{Ln}(L_{WM} 490 / L_{WM} 555\right]$$

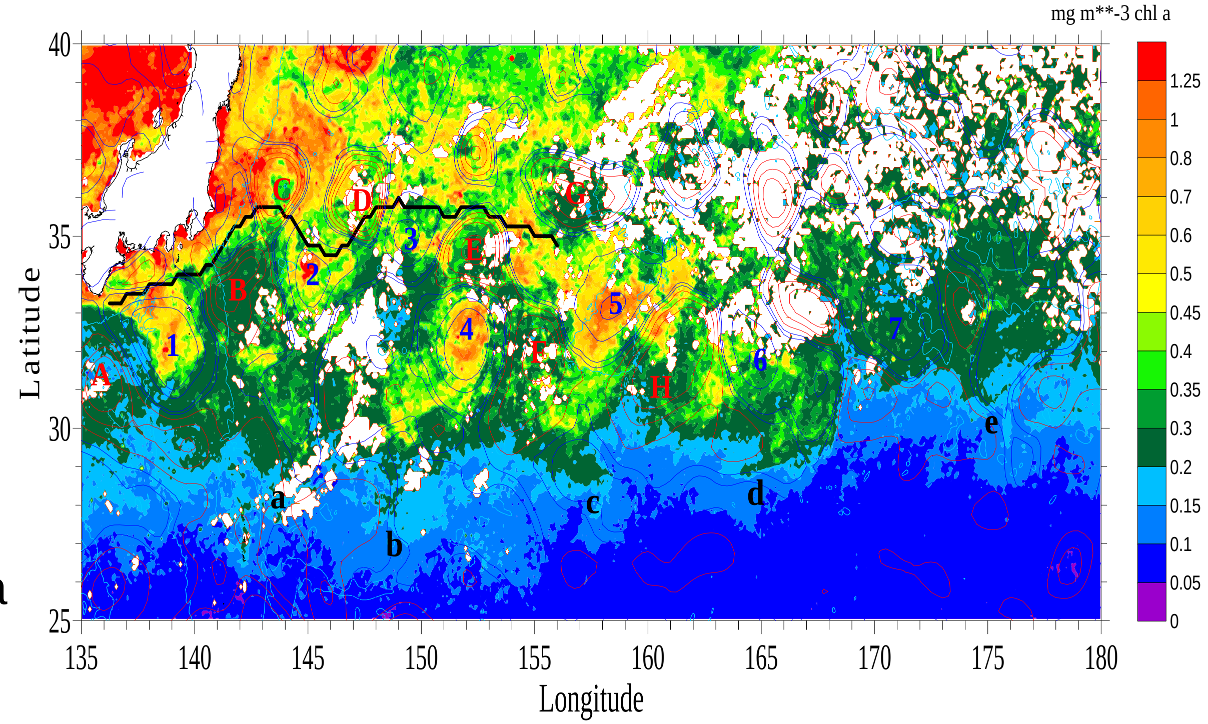
Satellite observed Chl-*a* concentration (mg/m^3) in the North Pacific in April 2007.



Chl-*a* concentration

Cyclonic eddy ←→ High Chl-a

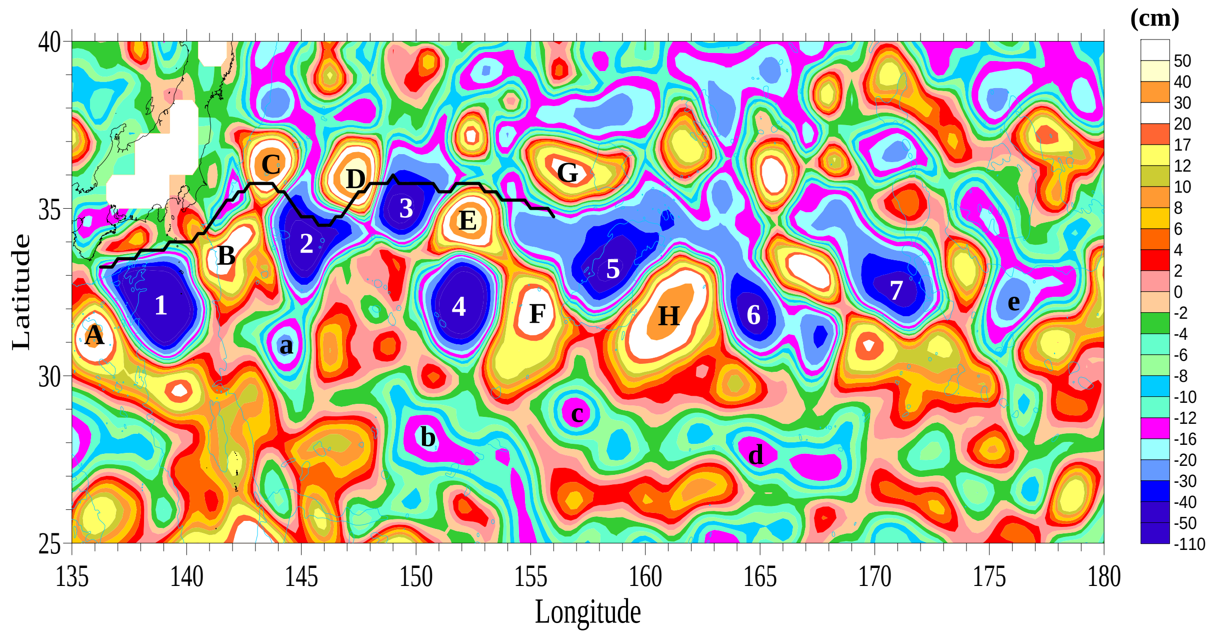
Anticyclonic eddy ←→ Low Chl-a



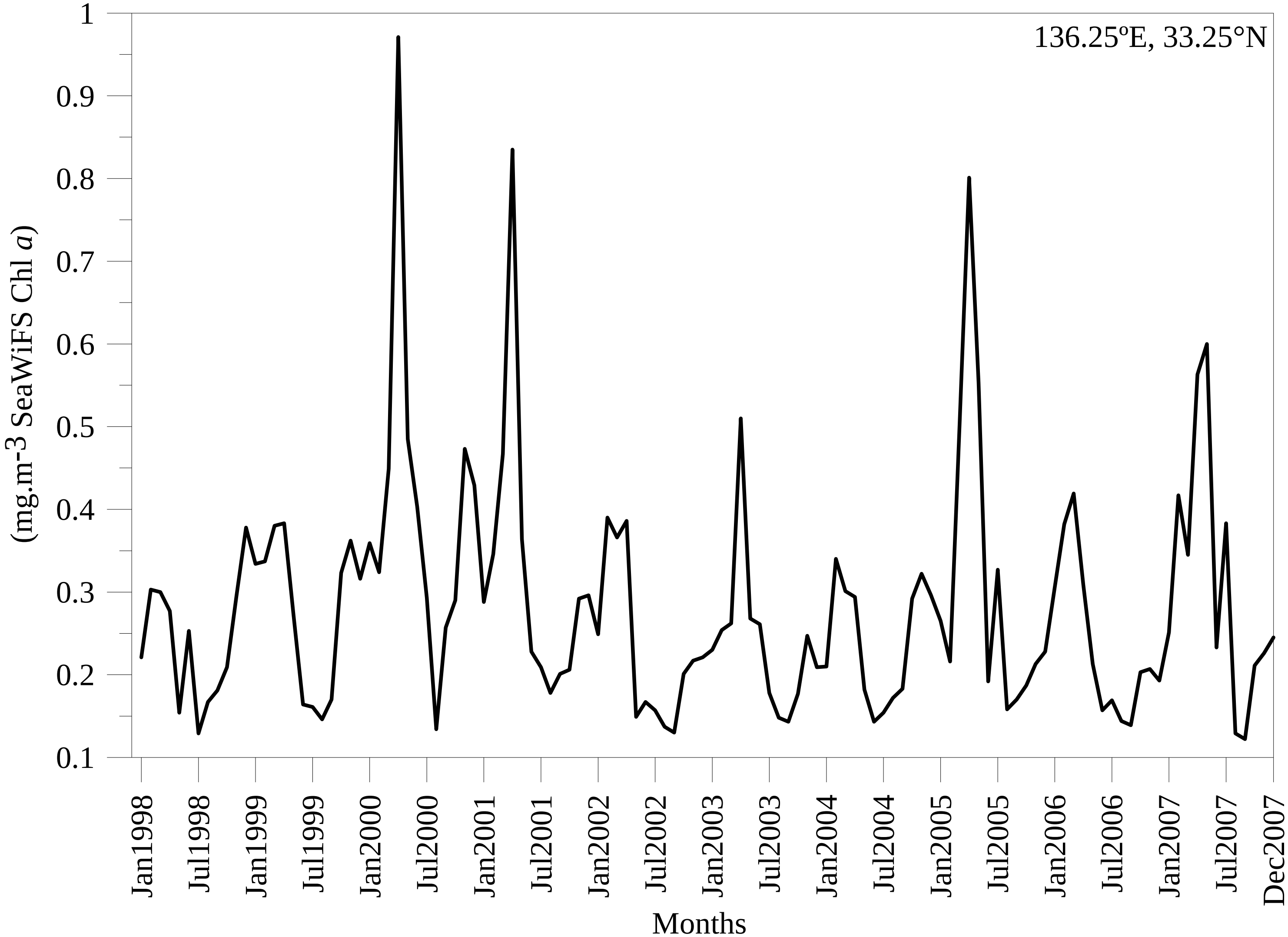
SLA (mm)

Anticyclonic eddies → A, B, C, …

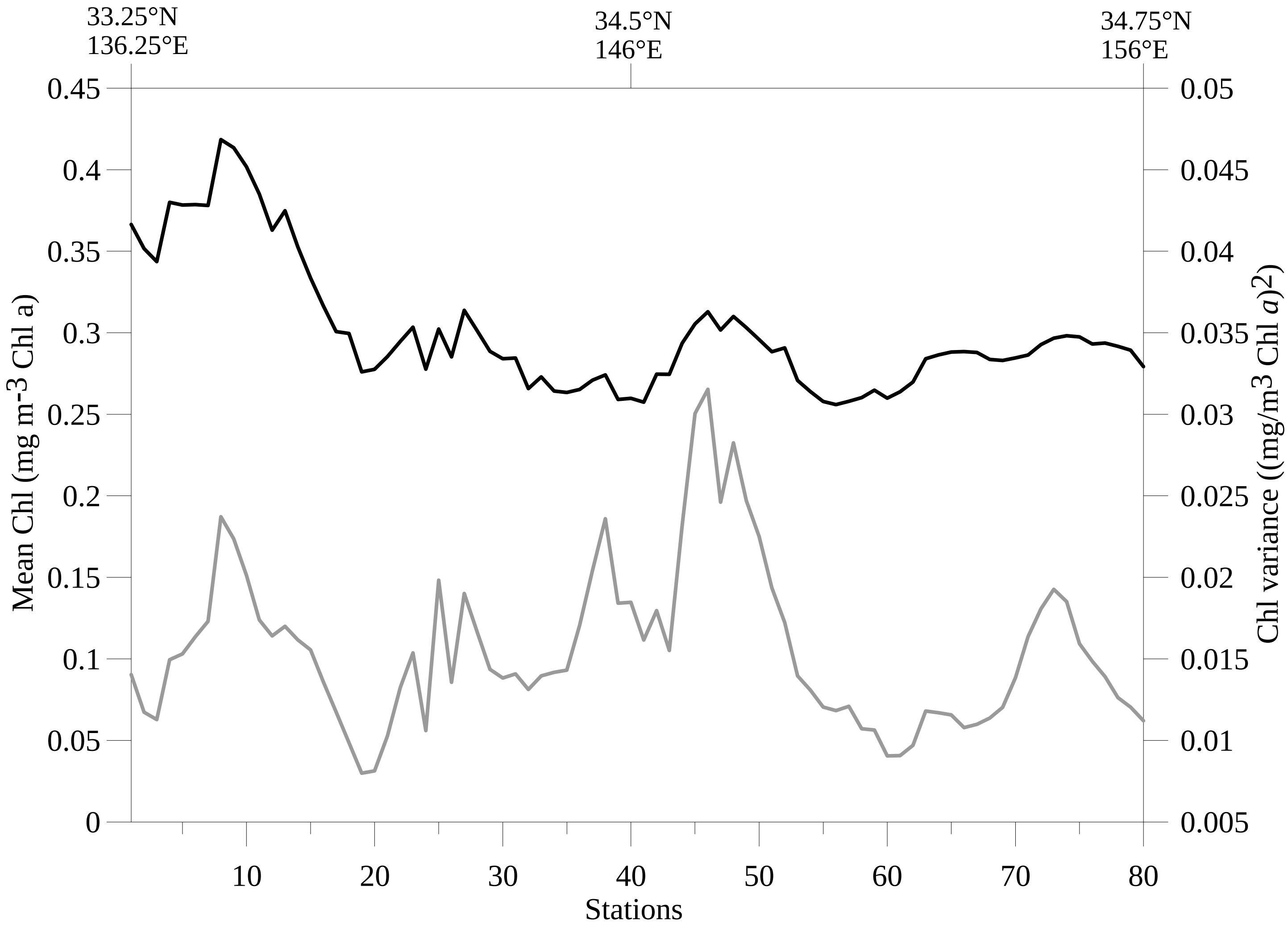
Cyclonic eddies → 1,2, …



Temporal variation of Chl-*a* concentration (mg m^{-3} Chl *a*) at Stn-1 (136.25E, 33.25N)



Mean of Chl-*a* (mg m^{-3} Chl-*a*; black curve) and variance (seasonal cycle removed) of Chl-*a* ([mg m^{-3} Chl *a*]^2; grey curve) along the route of the Kuroshio Extension for a 10 years period (1998-2007)

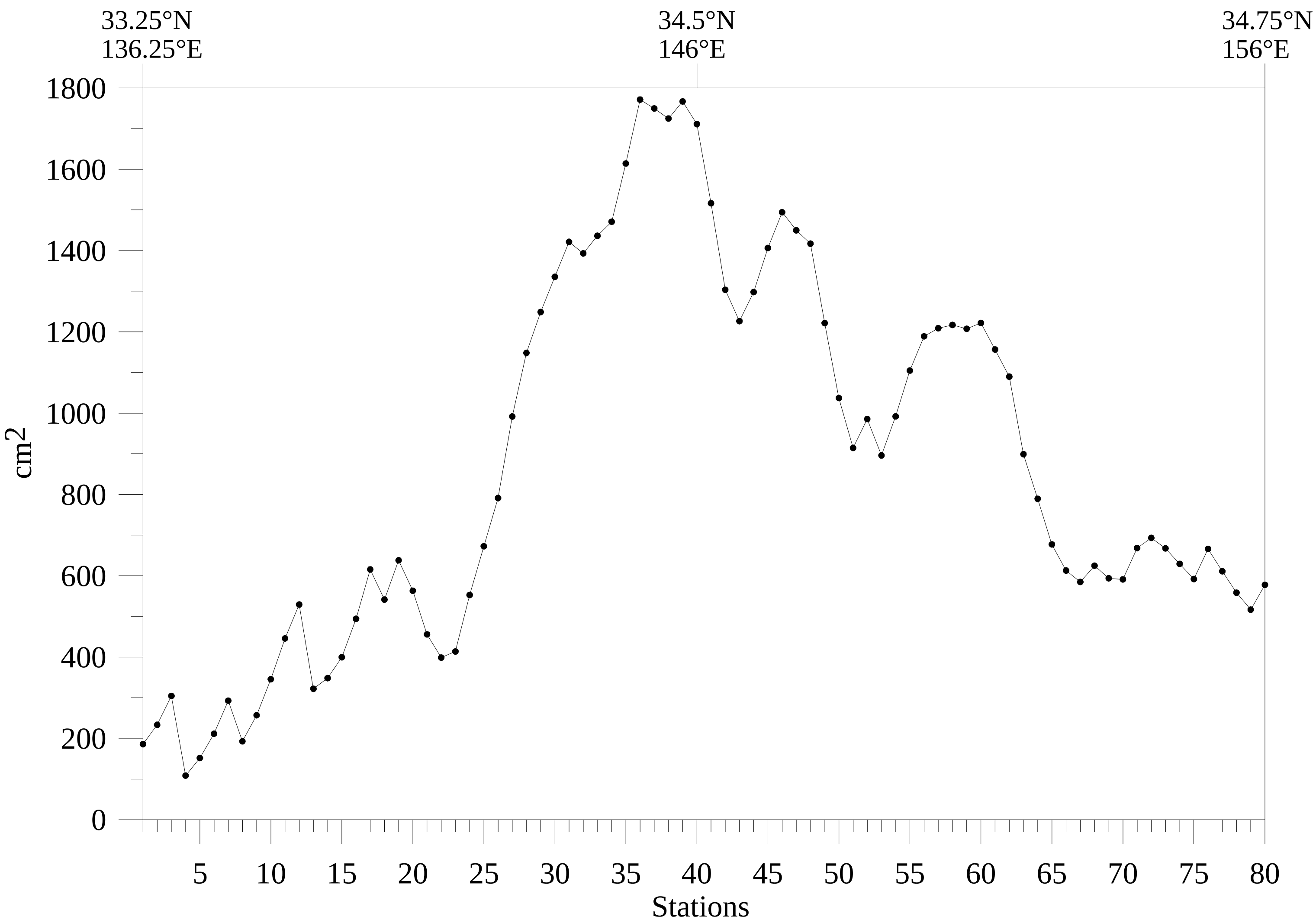


Mean Chl-a concentration in western (stns 1-15) and eastern (stns 16-80) KE

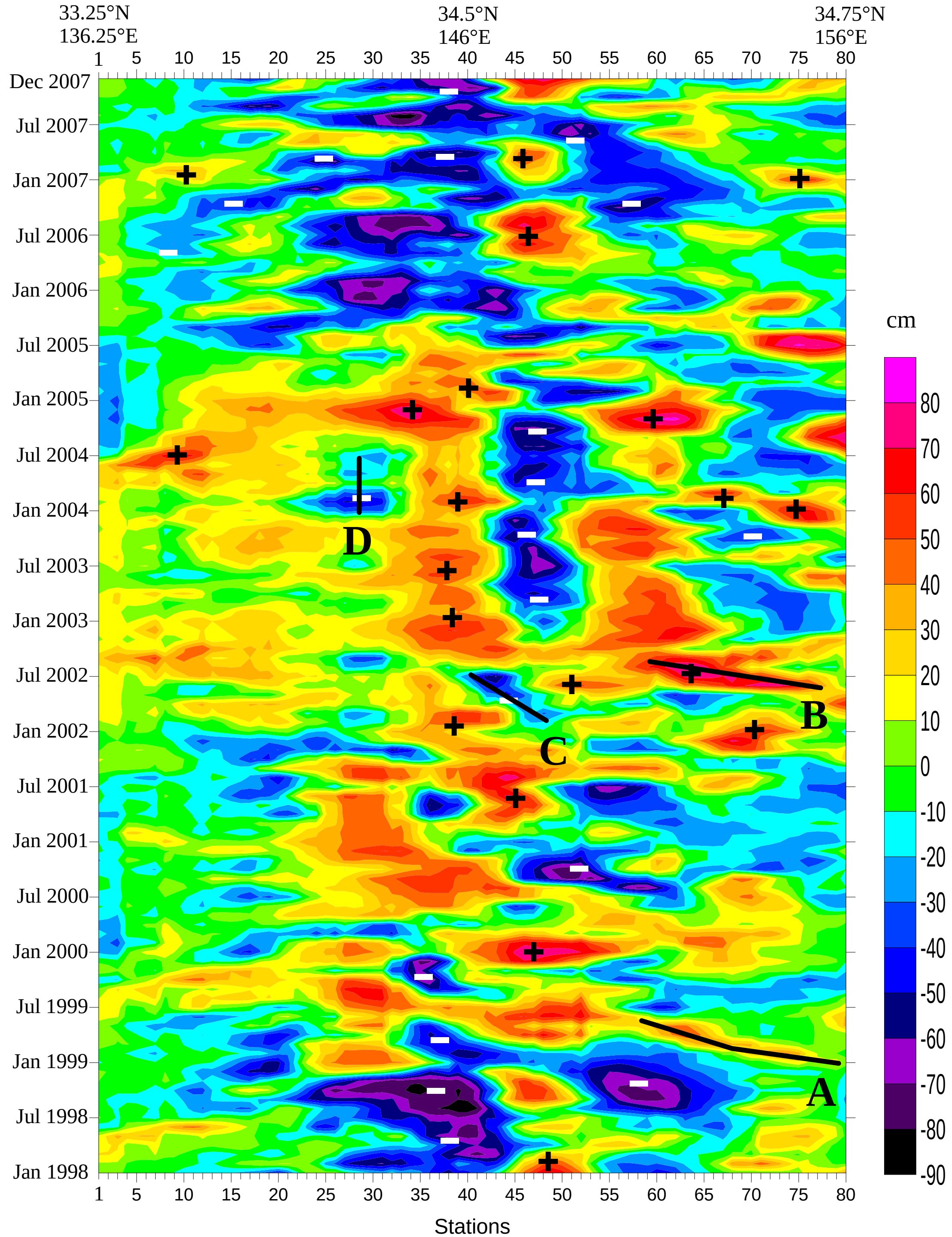
Western → $$\overline{x}_{Chla} \pm \sigma = 0.37 \pm 0.02 \text{ mg m}^{-3}$$

Eastern → $$\overline{x}_{Chla} \pm \sigma = 0.28 \pm 0.02 \text{ mg m}^{-3}$$

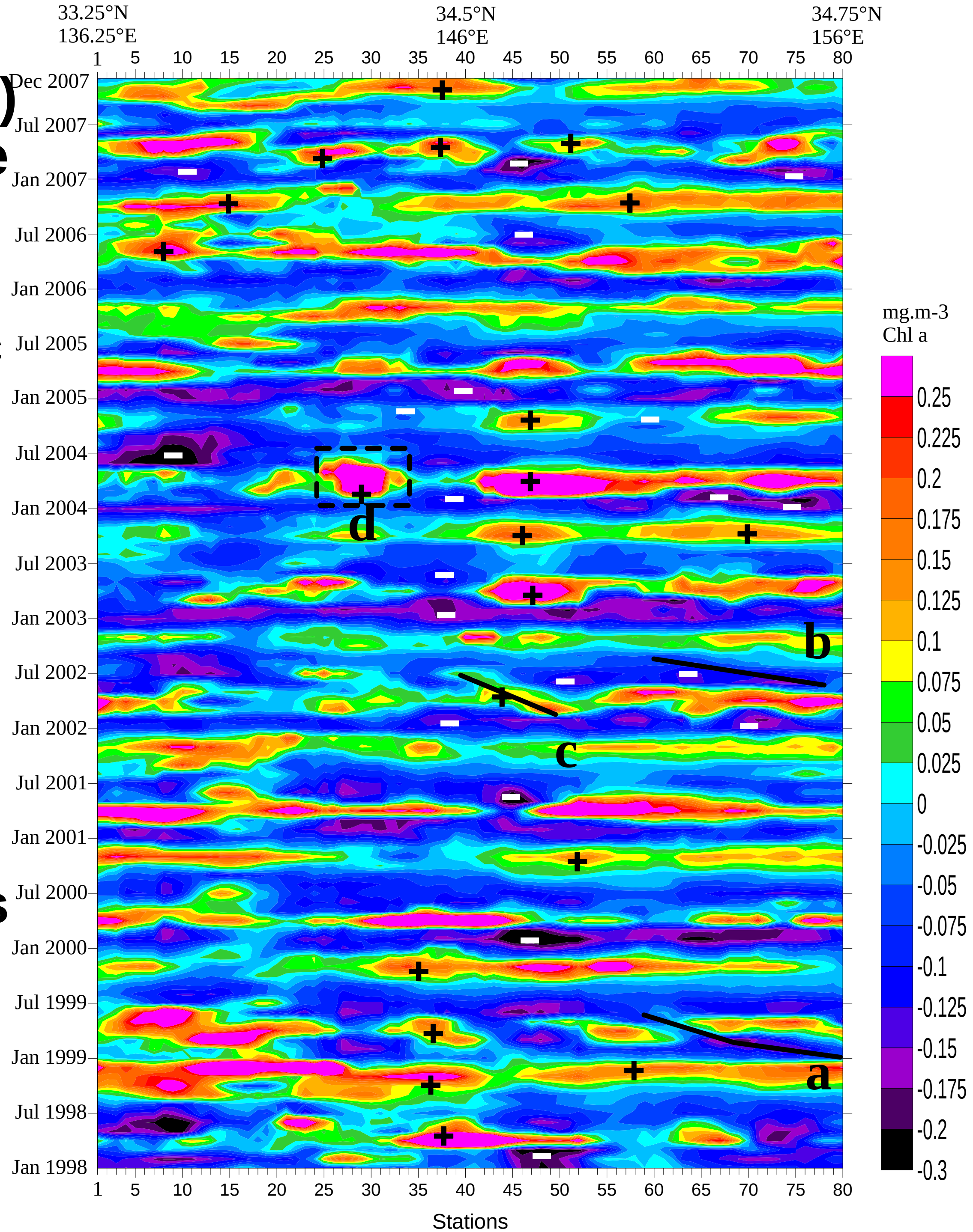
Variance (annual component removed) of sea level anomalies (cm^2) along the route of the Kuroshio Extension for a 10 years period.



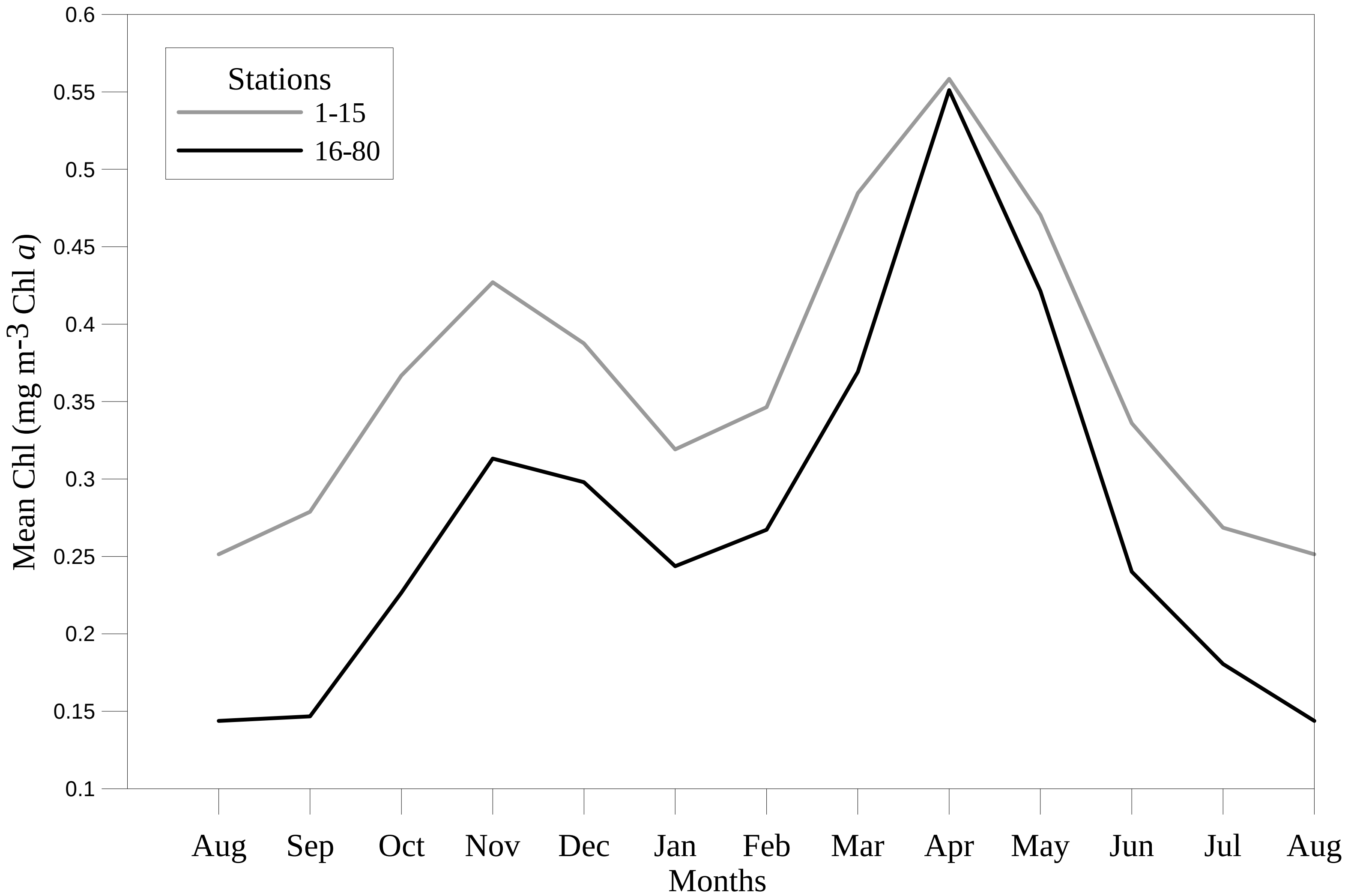
- **The altimeter signal is the SLA (cm) with the annual signal removed.**
- **Anticyclonic (A, B) and cyclonic (C, D) eddies have been followed in time and space.**
- **Negative sign indicates position of a low SLA associated with elevated Chl-*a* anomaly**
- **Positive sign indicates position of a high SLA associated with lower Chl-a anomaly**



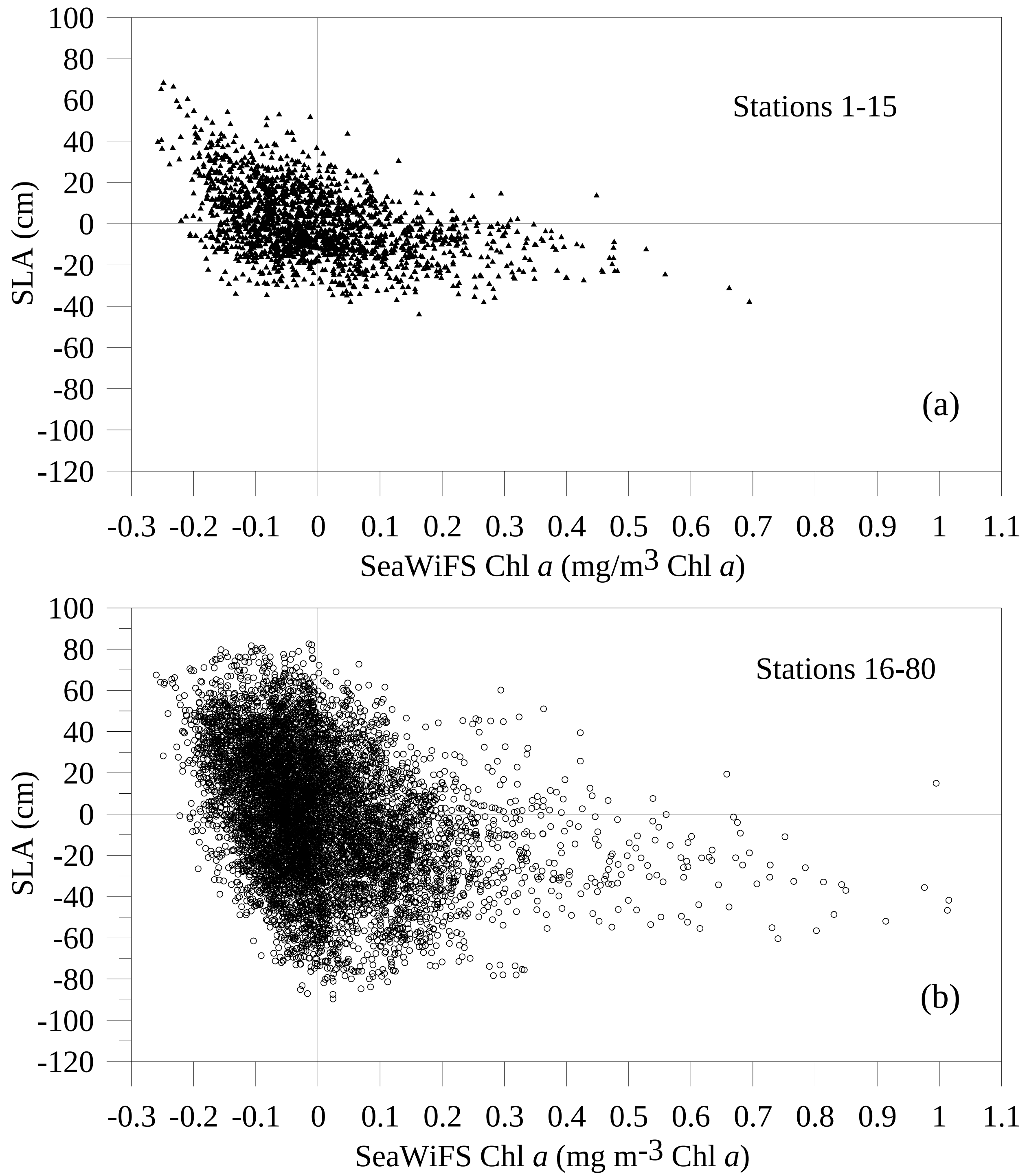
- **The Chl-*a* signal is the SeaWiFS Chl-*a* (mg m^{-3}) with the seasonal cycle removed.**
- **The high Chl-*a* (c, d) correspond to cyclonic eddies (C, D) and the low Chl-*a* (a, b) correspond to anticyclonic eddies (A, B).**
- **Positive sign indicates position of elevated Chl-*a* anomaly**
- **Negative sign indicates position of lower Chl-*a* anomaly associated with high SLA**



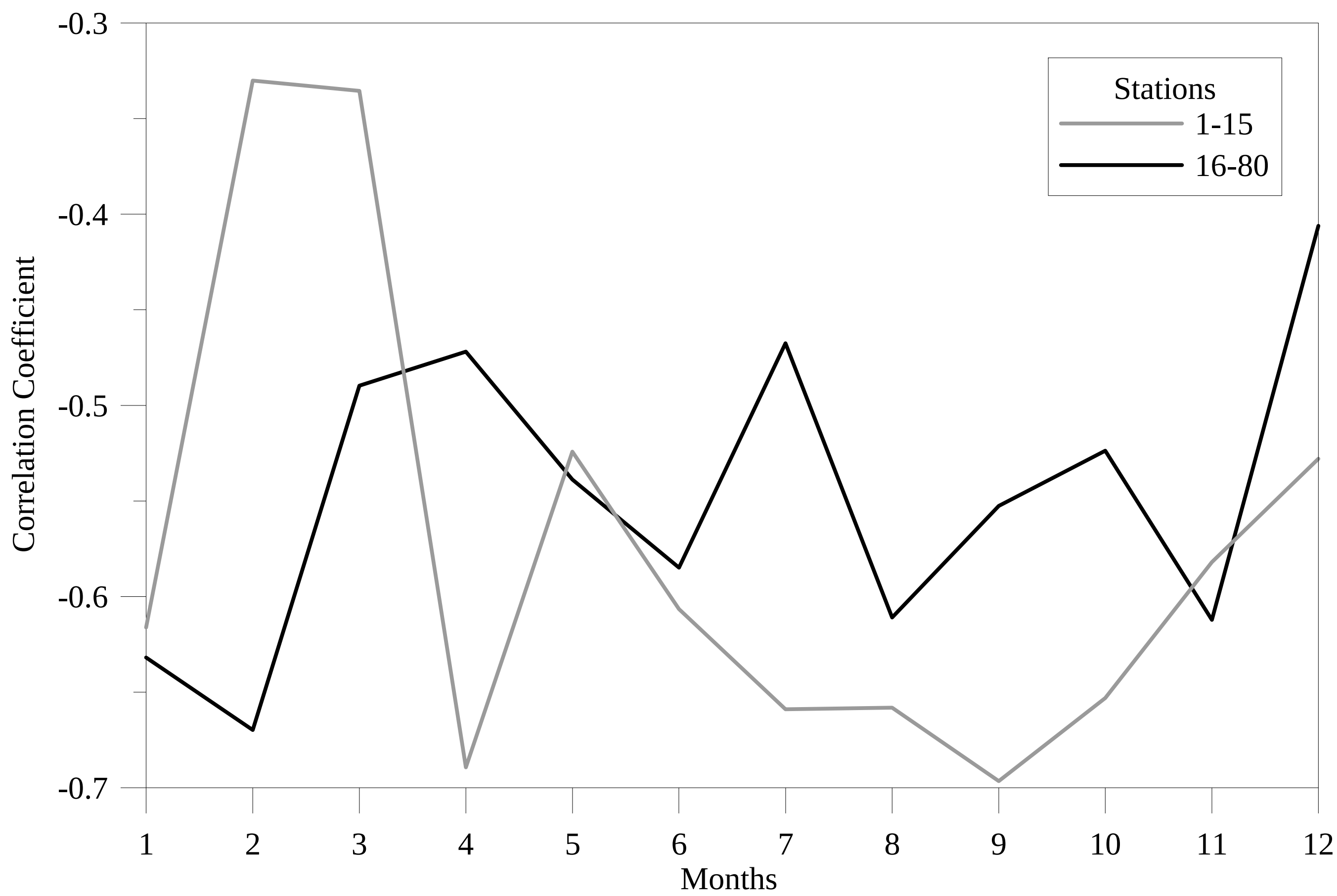
Chl-*a* (mg m^{-3} Chl *a*) seasonal cycle along the route of the Kuroshio Extension. The results for station 1-15 are in grey and for station 16-80 in black



Correlation between Chl-*a* and SLA residuals along the route of the Kuroshio Extension for (a) stations 1-15 and (b) stations 16-80.



Monthly correlation coefficient between Chl-*a* anomalies and SLA residuals for stations 1-15 are in grey and in black for stations 16-80
Low correlation in Feb - March



Conclusions

- (1) Upward pumping of nutrients by meso-scale eddies in the KE region was identified.
- (2) Rossby wave propagation along the KE axis was detected.
- (3) SeaWiFS chlorophyll-*a* concentrations are redistributed at the eddy scale by the eddy surface swirl currents.
- (4) The zonal scale for chlorophyll perturbations was determined at ~ 460 km