Cross-shelf exchange by mesoscale eddies in the northeast Pacific Ocean

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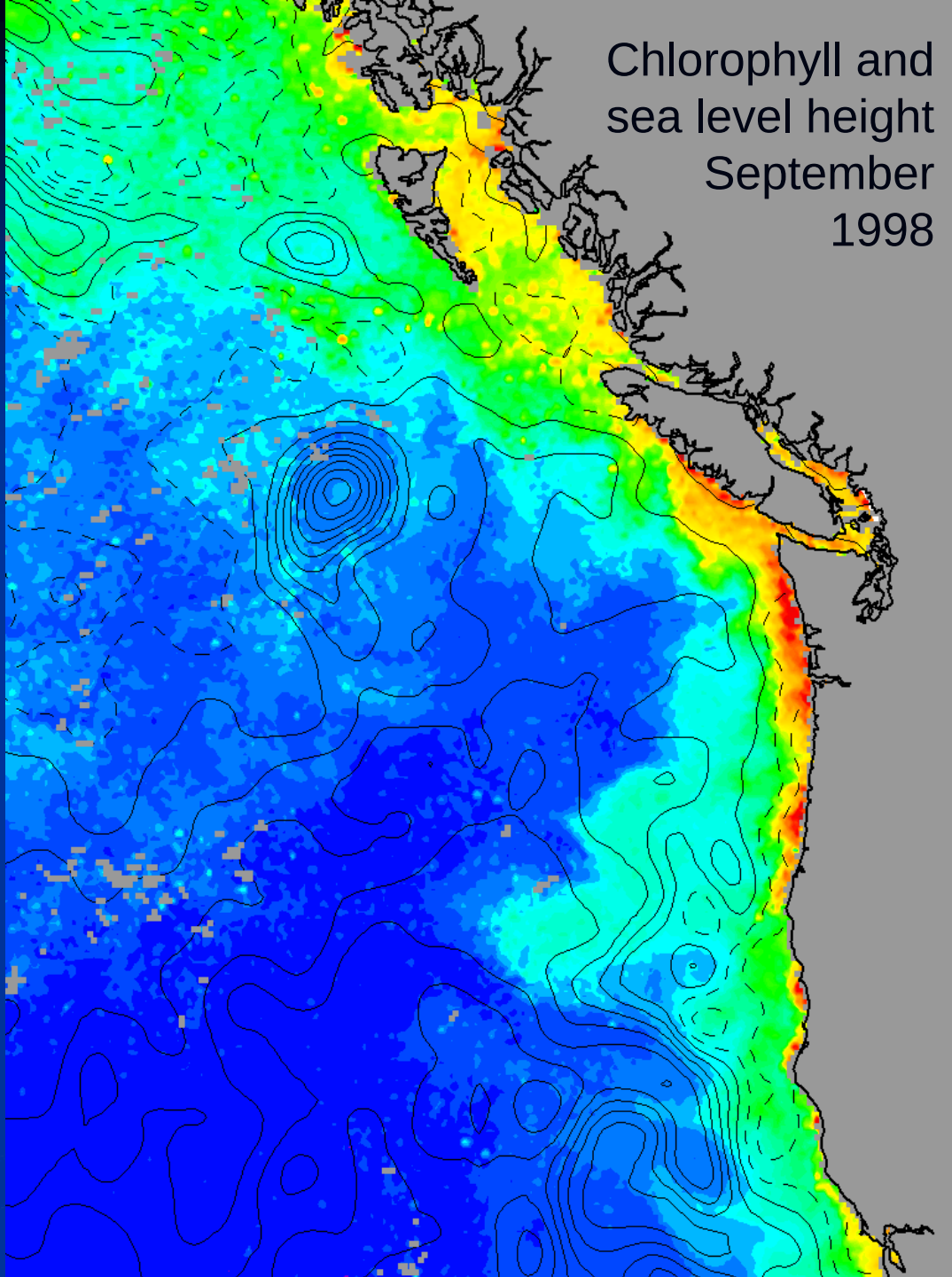


Outline of talk:

Sea level viewed from space:

- Eddies along the coast.
- Reference to flat surface.
- True images of sea surface height variability

Chlorophyll and sea level from space:

- Mesoscale eddies along the Pacific Coast
- Lack of eddies off southern Van Is.
- Impact of eddies in northern Gulf of Alaska
- Impact of eddies in Oregon and California

Sea level anomalies

Updated daily by Colorado Center for Astrodynamics Research, U. of Colorado

Plots sea level anomalies relative to a multi-year average sea level in satellite altimetry data, with high-pass temporal filters to remove annual cycle, and spatial filters to remove basin-scale signals.

Time series starts in Sept. 1992.

Fails to represent true sea surface slope due to persistent currents.

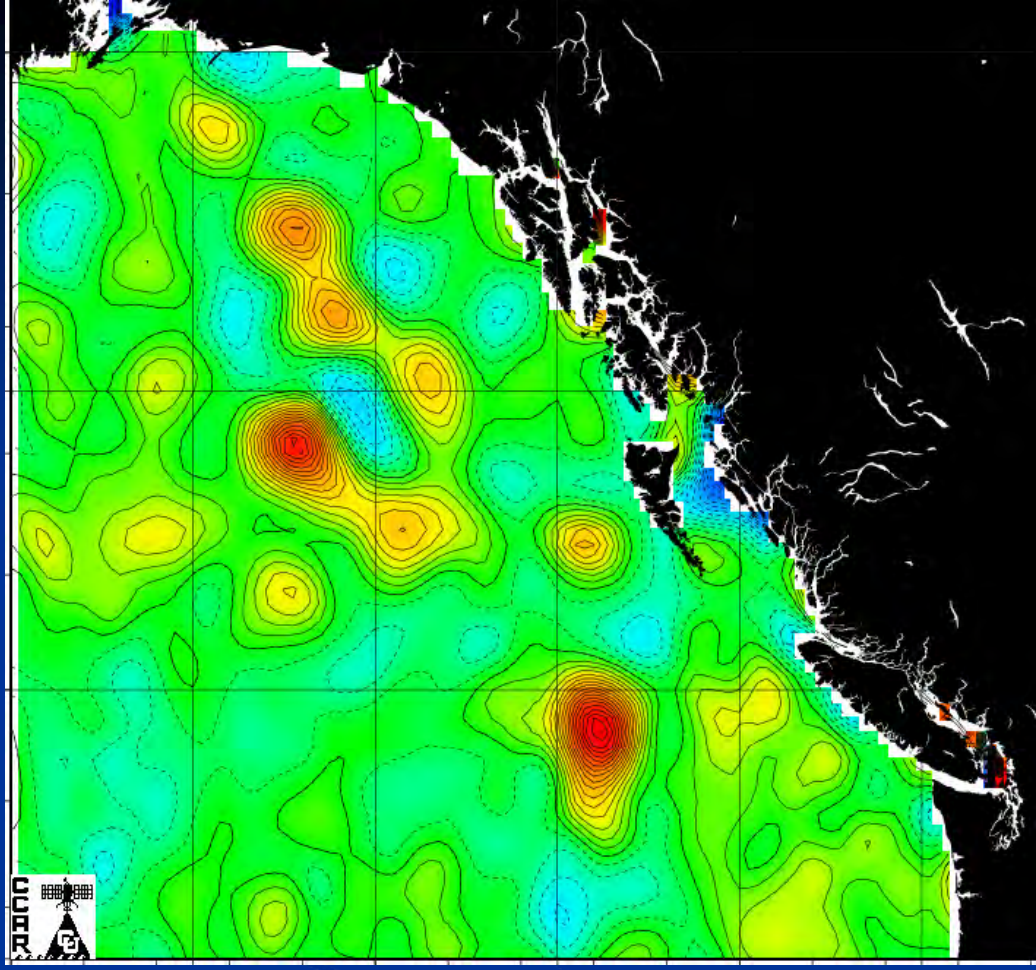


Image of 30 August 1998
Red = high sea level
Blue = low sea level

TOPEX/Poseidon, Jason-1 and 2, (~10 d) ERS-1 and 2, Envisat, (35 d) GFO (17 d)

Solution:
Find the true sea-surface height relative to the height measured by altimetry.

Foreman, M. G. G., W. R. Crawford, J. Y. Cherniawsky, and J. Galbraith, 2008: Dynamic ocean topography for the northeast Pacific and its continental margins, *Geophys. Res. Lett*., 35, L22606, doi:10.1029/2008GL035152.

•Determined average summer and winter baroclinic sea level height based on 100,000 historical temperature and salinity profiles in major archives.

•Fed into a finite element diagnostic model with ~100,000 nodes (tides, friction).

•Forced the model with average summer and winter winds.

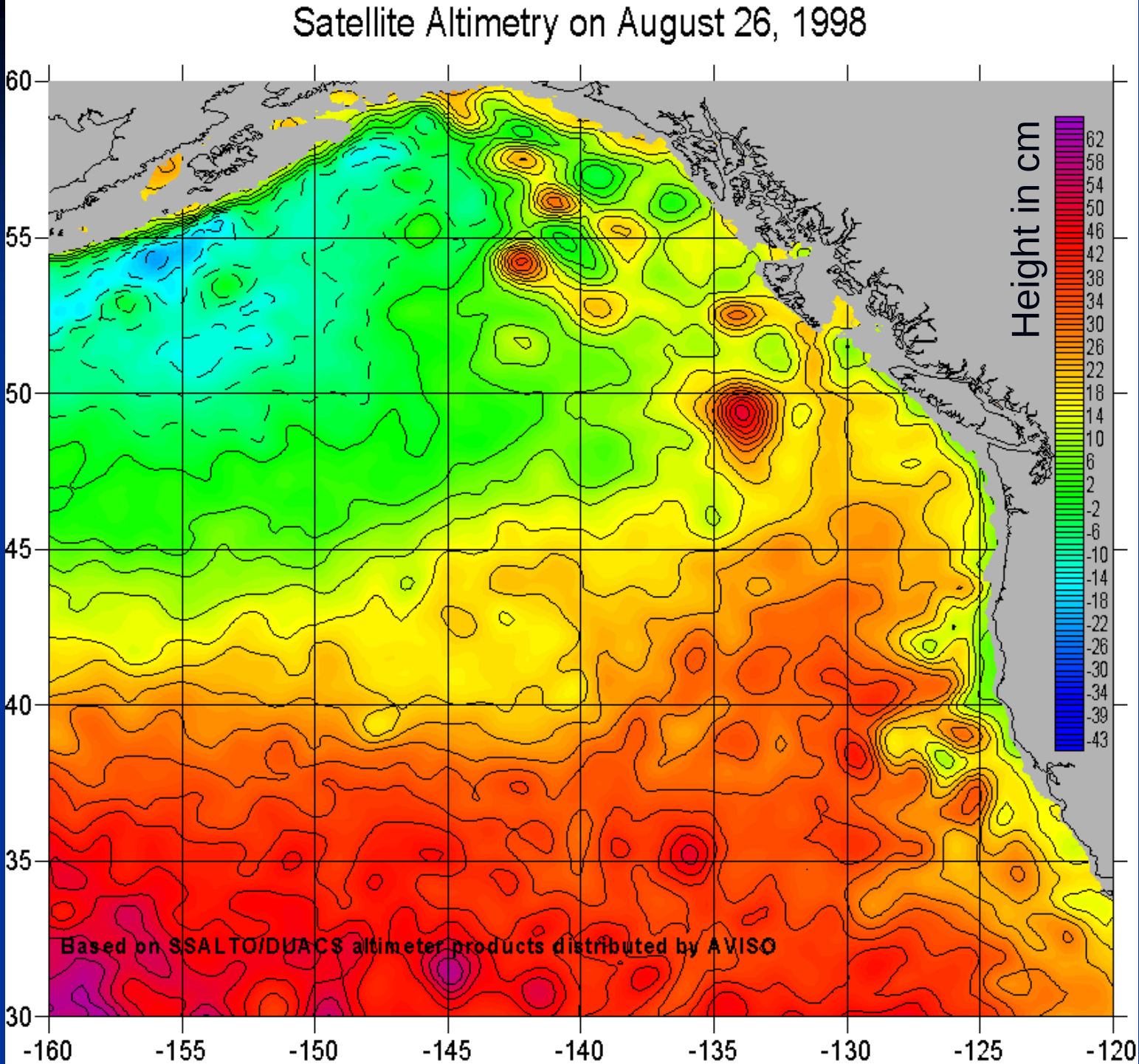
•Determined average summer and winter sea level at each node. These sea levels are the absolute heights of sea level above the geoid. Then Interpolated through the year by fitting to a sine wave to produce monthly average **(A)** .

•Computed heights of average monthly sea level measured by altimetry (AVISO data), and adjusted these to match **(A).**

•Result: Absolute height of sea level relative to a gravitationally flat surface.

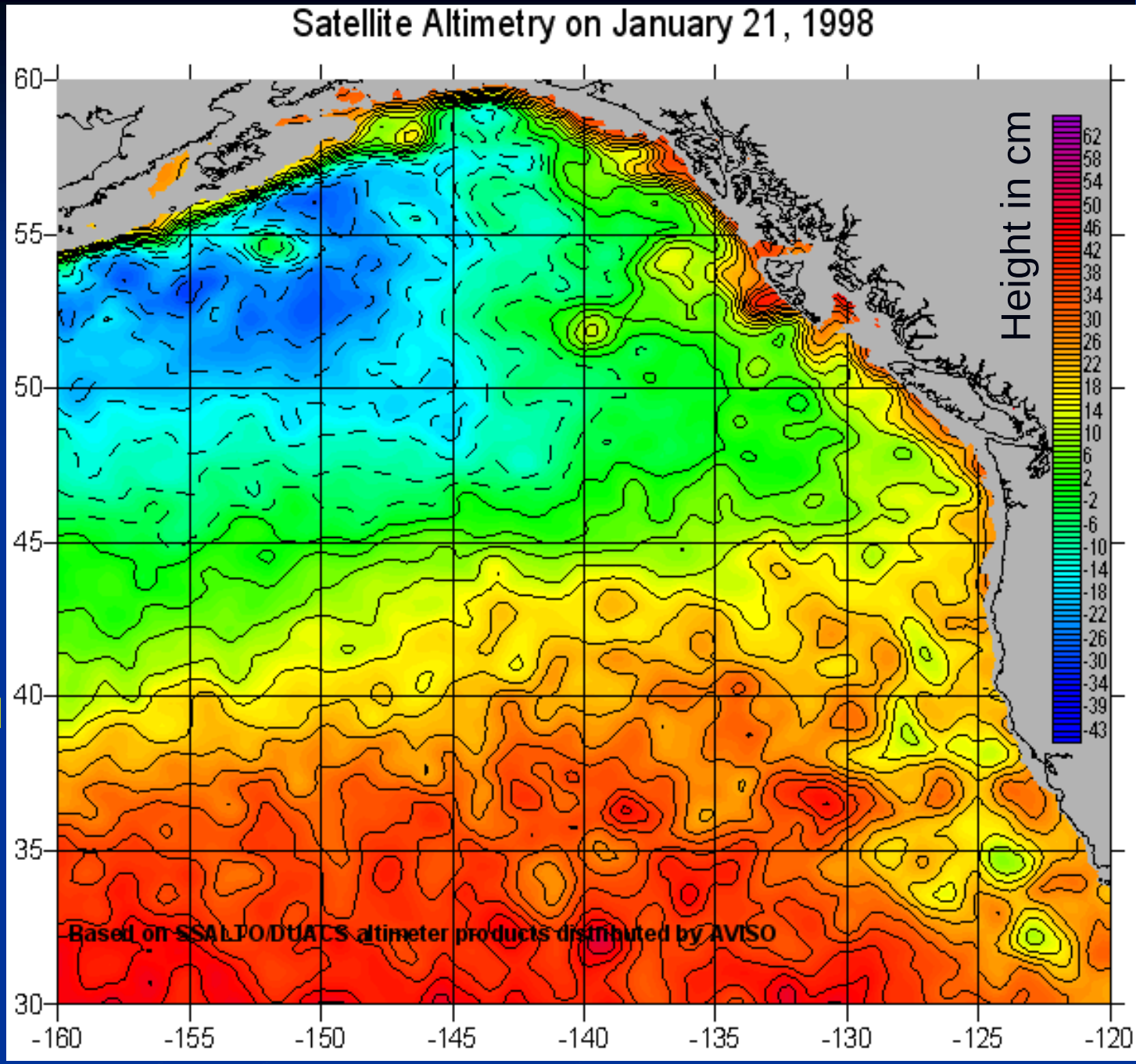
Summer Sea Surface Height

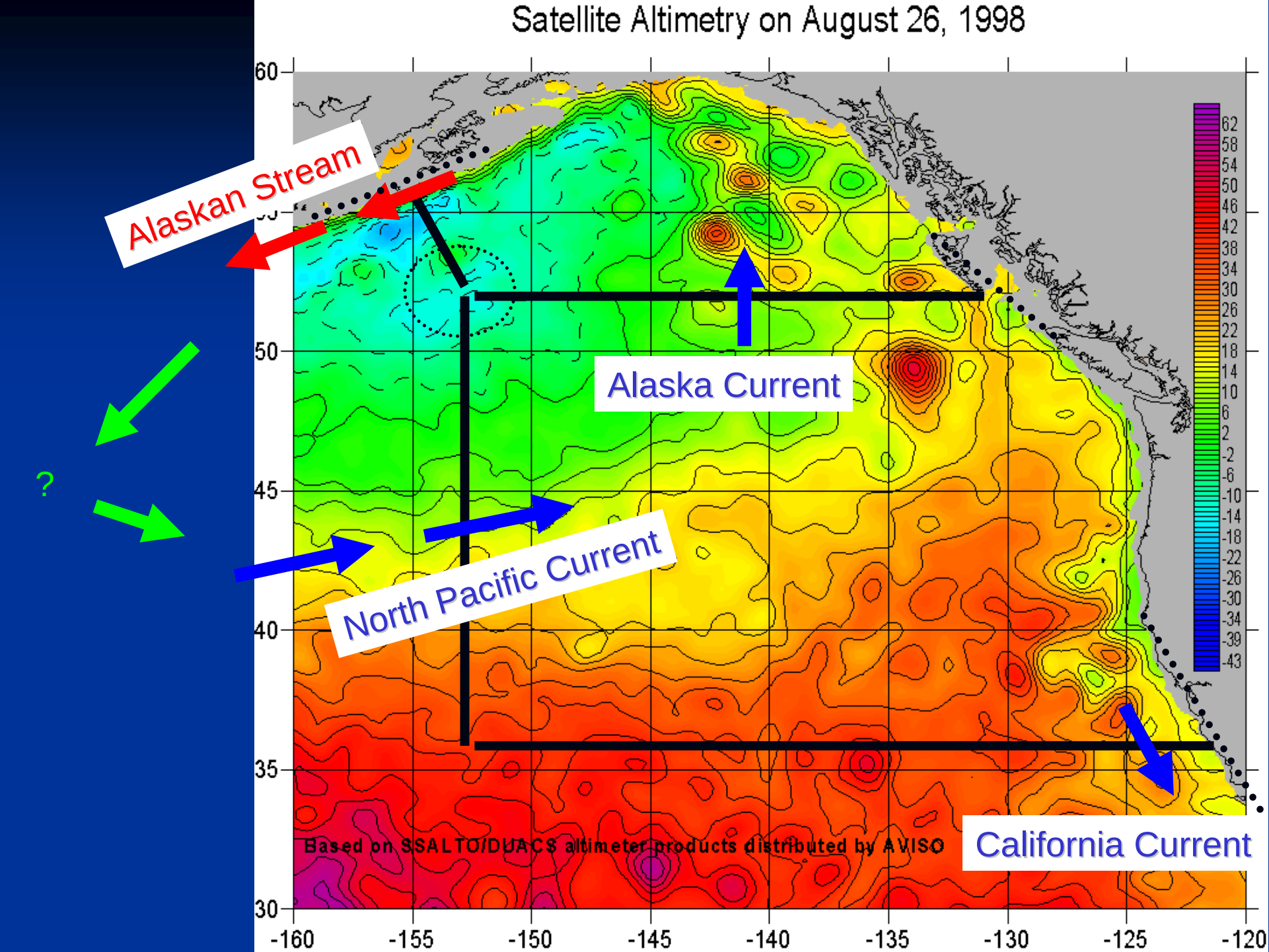
Digital files of sea surface heights at 0.25 deg.lat. & long. intervals, provided by AVISO, based on all available altimeters, updated every 3 days, referenced to Foreman et al. surface



Summer
Sea
Surface
Height
(80-cm drop)

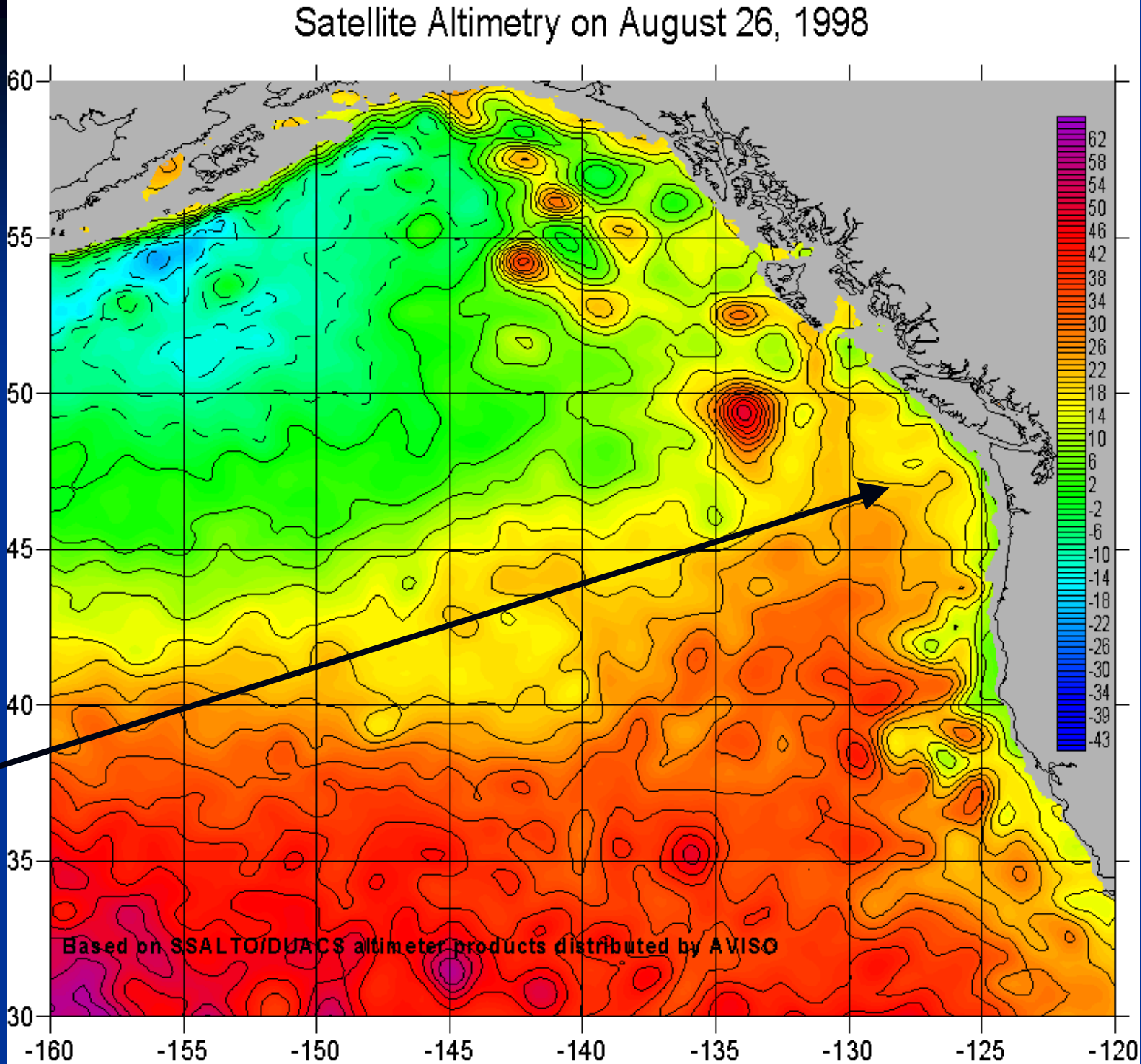
Digital files of sea surface heights at ¼ ° lat. & long. intervals, provided by AVISO, based on all available altimeters, updated every 3 days, referenced to Foreman et al. surface.

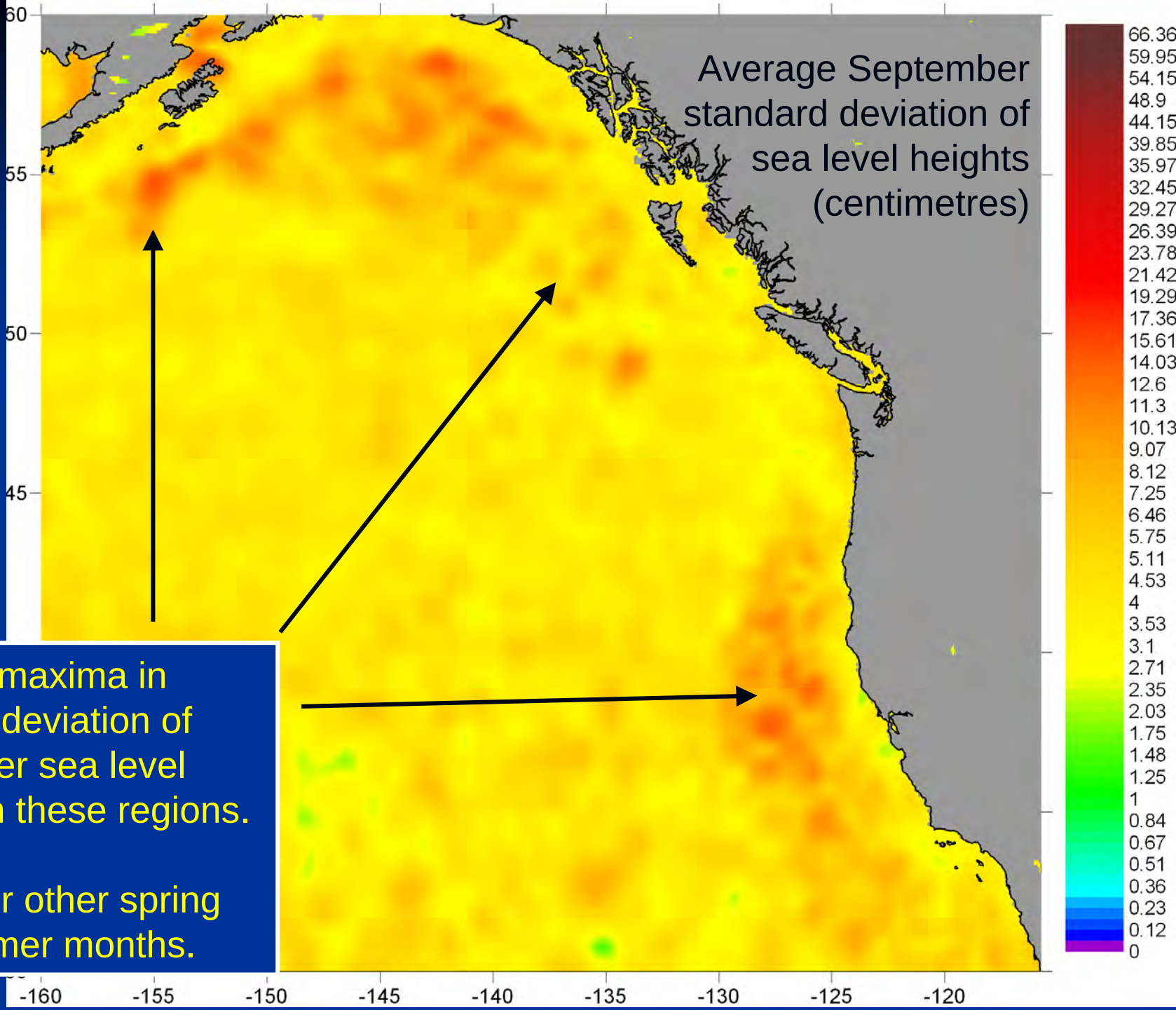



Satellite Altimetry on August 26, 1998
Alaskan Stream
Alaska Current
North Pacific Current
California Current
?
Based on SSALTO/DUACS altimeter products distributed by AVISO
60
50
45
40
35
30
-160
-155
-150
-145
-140
-135
-130
-125
-120
62
58
54
50
46
42
38
34
30
26
22
18
14
10
6
2
-2
-6
-10
-14
-18
-22
-26
-30
-34
-39
-43

Summer
Sea Surface Height

Note the penetration of high sea level waters toward the Vancouver Island & Washington State coast, and absence of eddies there.





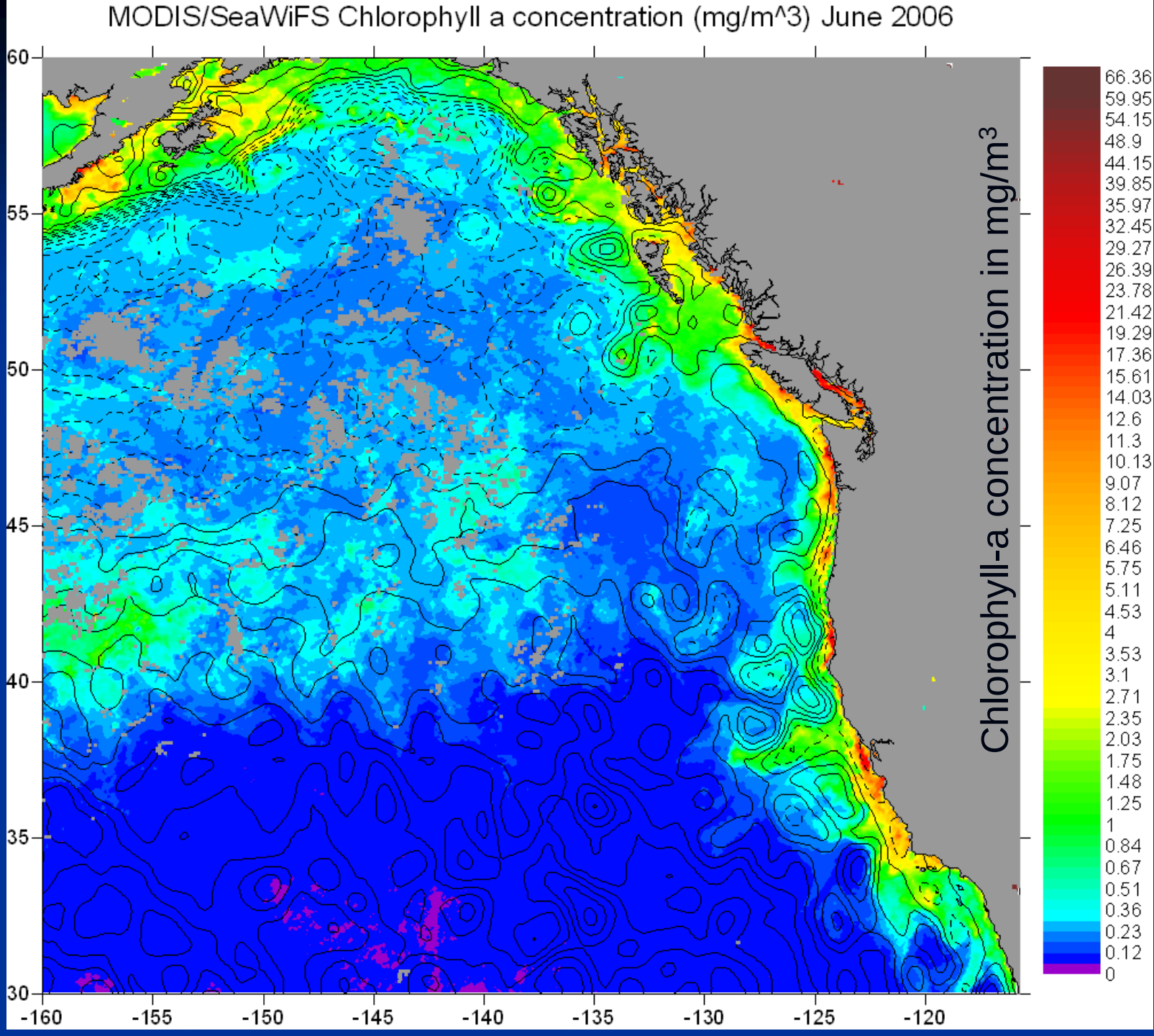
Note the maxima in standard deviation of September sea level heights in these regions.

Similar for other spring and summer months.

Plot ocean chlorophyll onto sea surface height contours.

Chlorophyll composite for June 2006 from SeaWiFS + MODIS, via NASA.

Altimeter data from AVISO for mid-June 2006.



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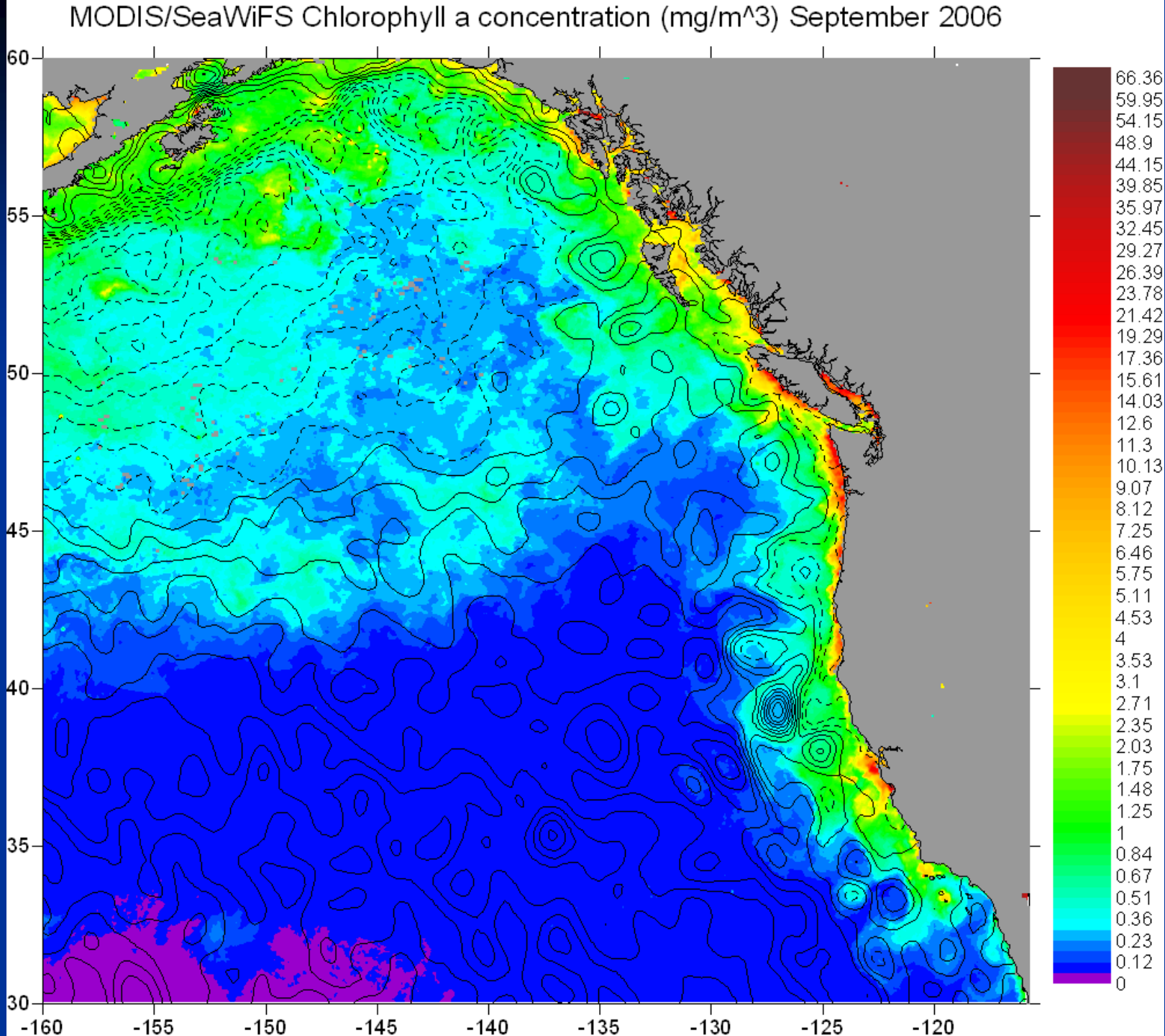

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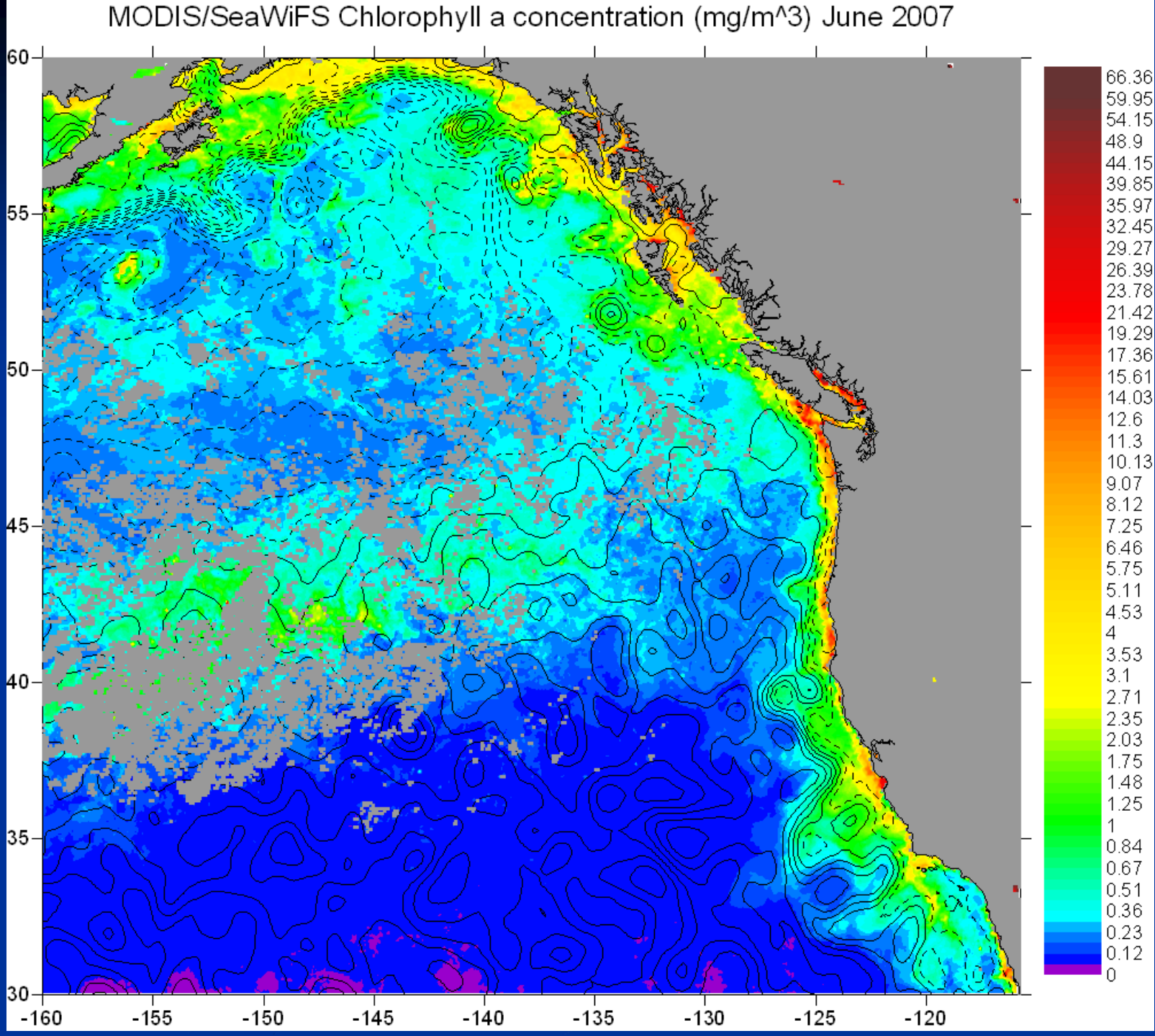

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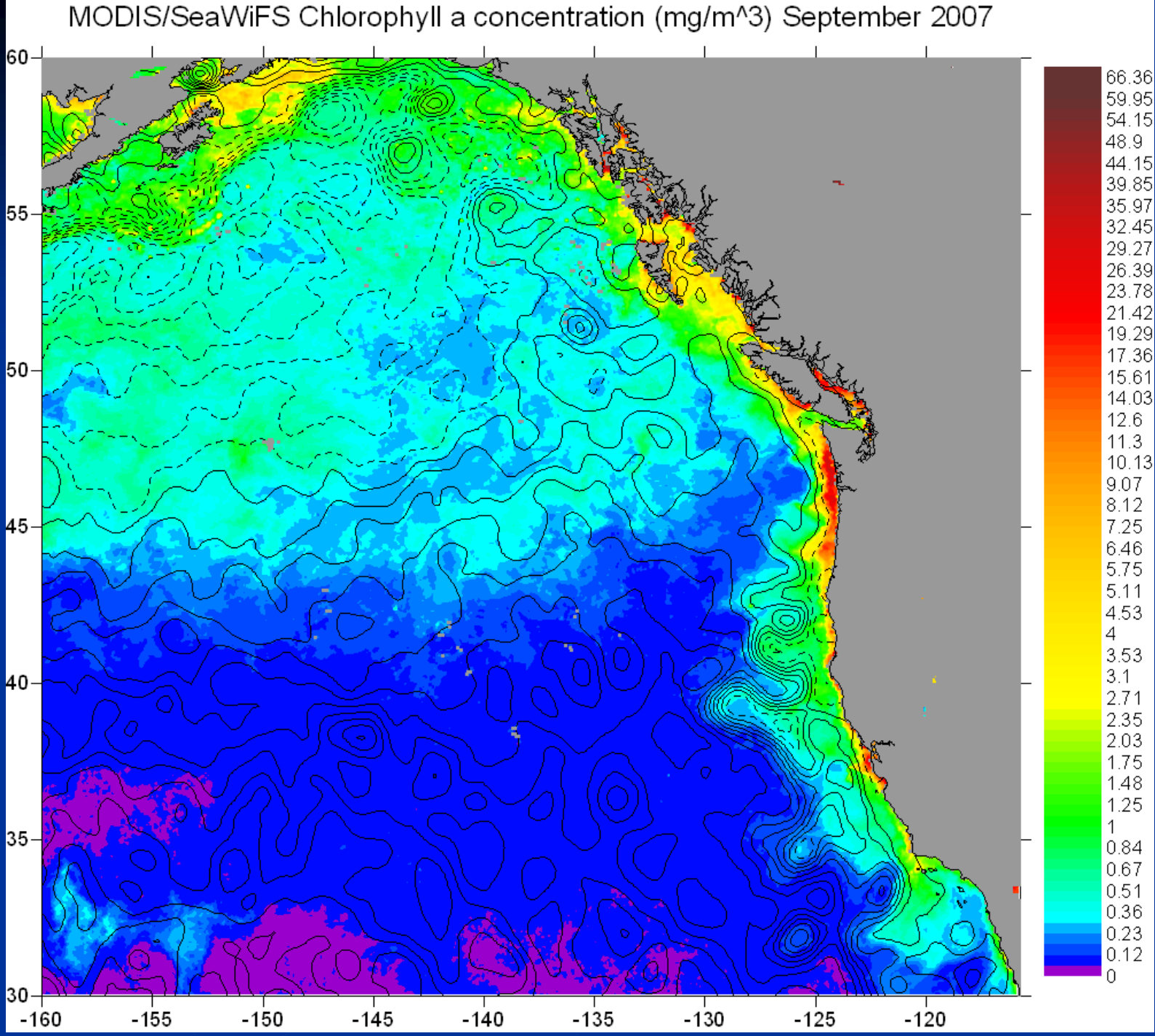
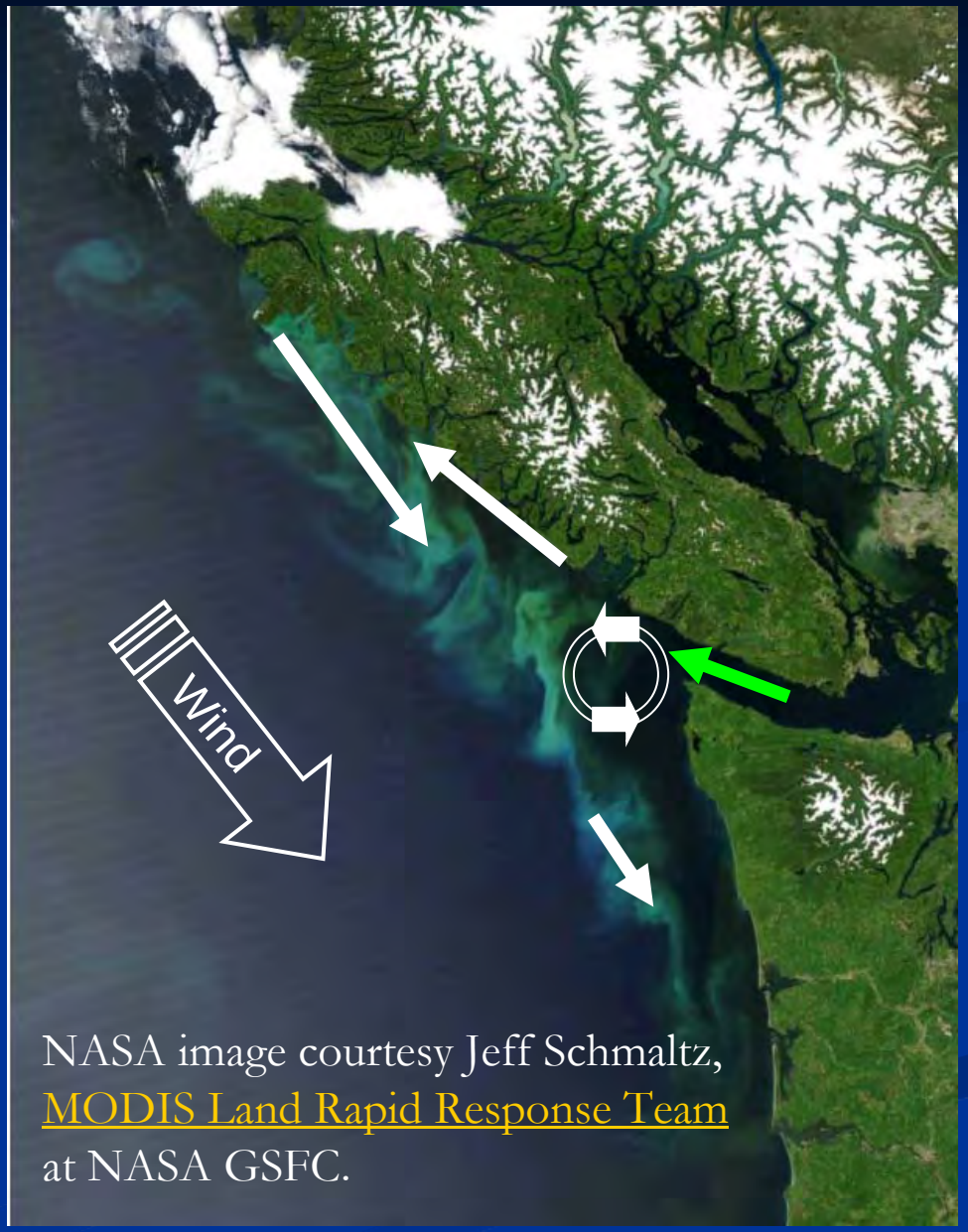


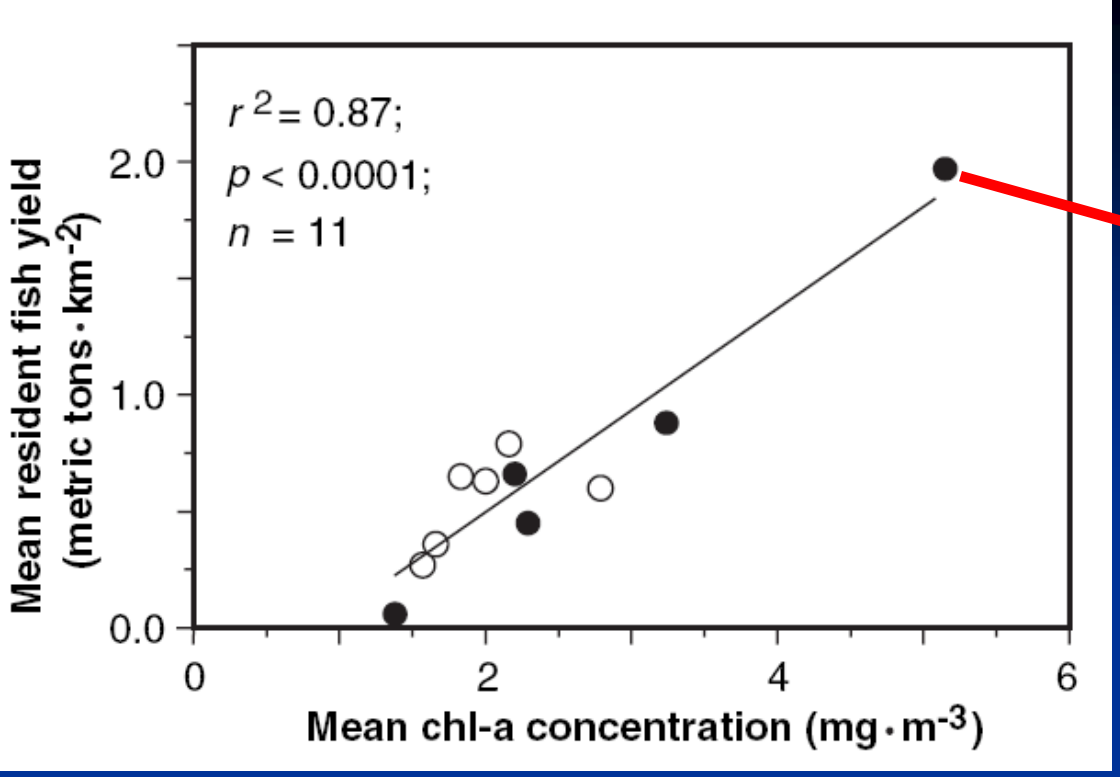
The image at rights reveals an intense bloom of coccolithophores in June 2006 along the continental shelf break.

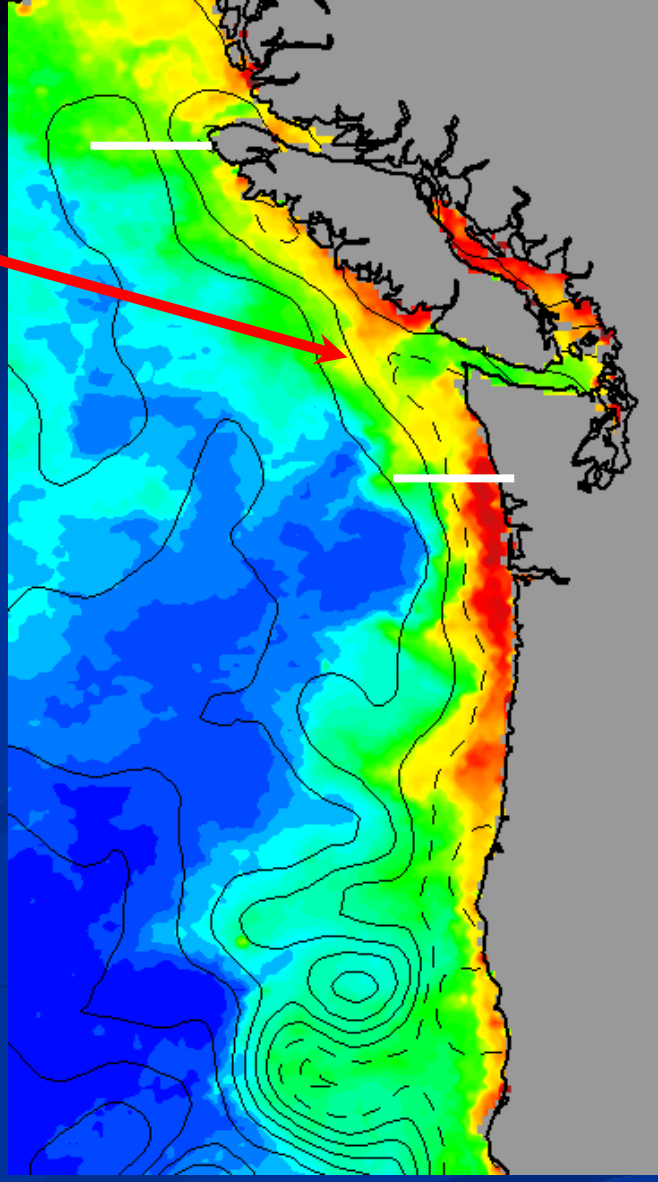
Note that few portions of this bloom extend far into deep-sea waters, despite the strong upwelling winds from the northwest.

This bloom defines the most productive waters of the Pacific Coast of USA and Canada.



MODIS image “true colour” for 25 June 2006





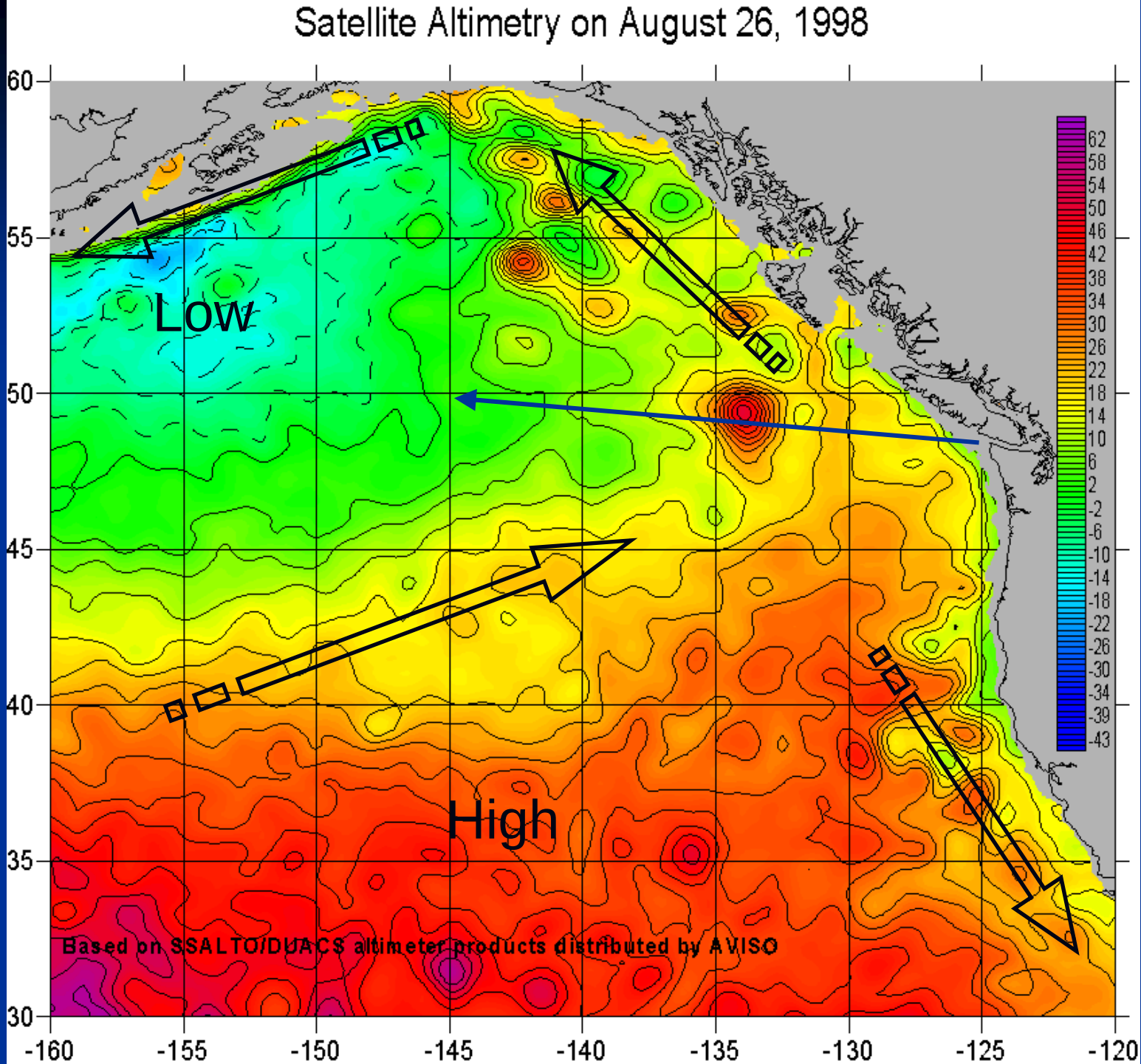
September 2007

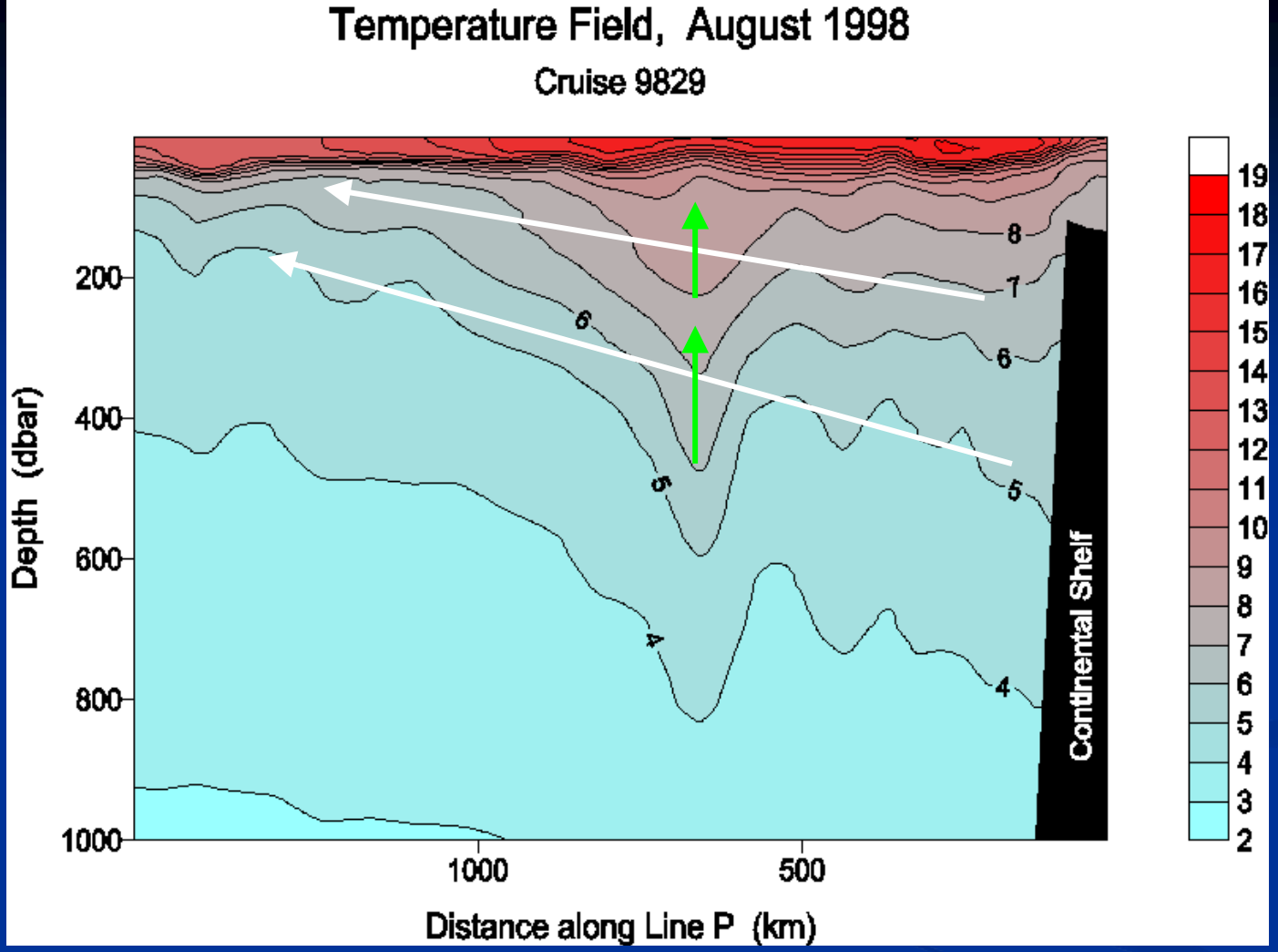
Large-scale trophic linkage between the annual mean chl-a concentration (NWLR-Off) and the long-term annual yield of resident fish for each of the 11 NPAFC regions from San Diego to the Aleutian Islands.

Solid circles denote upwelling regimes; open circles, downwelling regimes.

Source:
Ware and Thomson, 2005, Science 308, p1280-1284.

Summer
Sea
Surface
Height





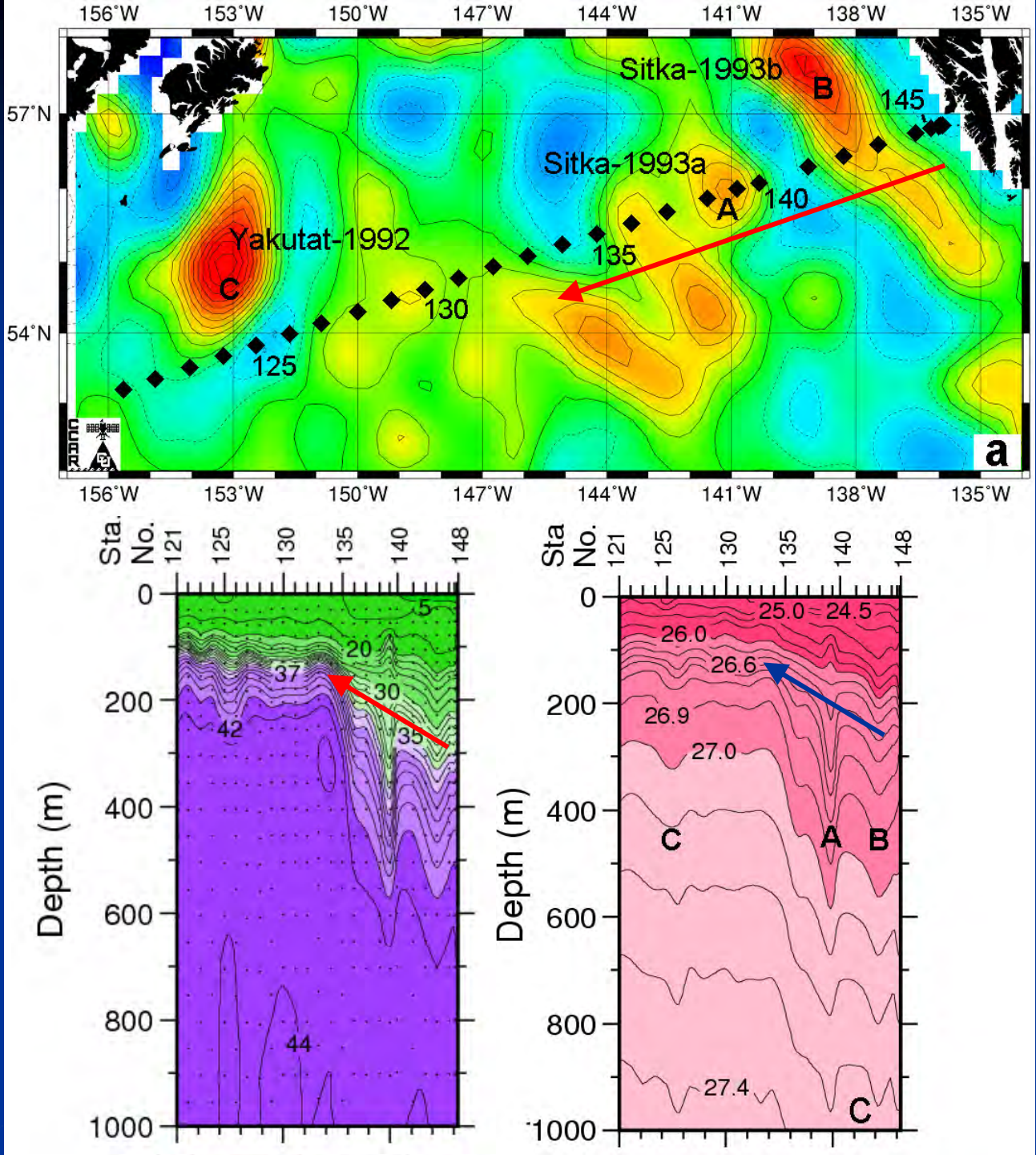
Waters in anticyclonic mesoscale eddies will rise as the eddies decay.

These waters will also rise to seek waters of the same density as they propagate westward .

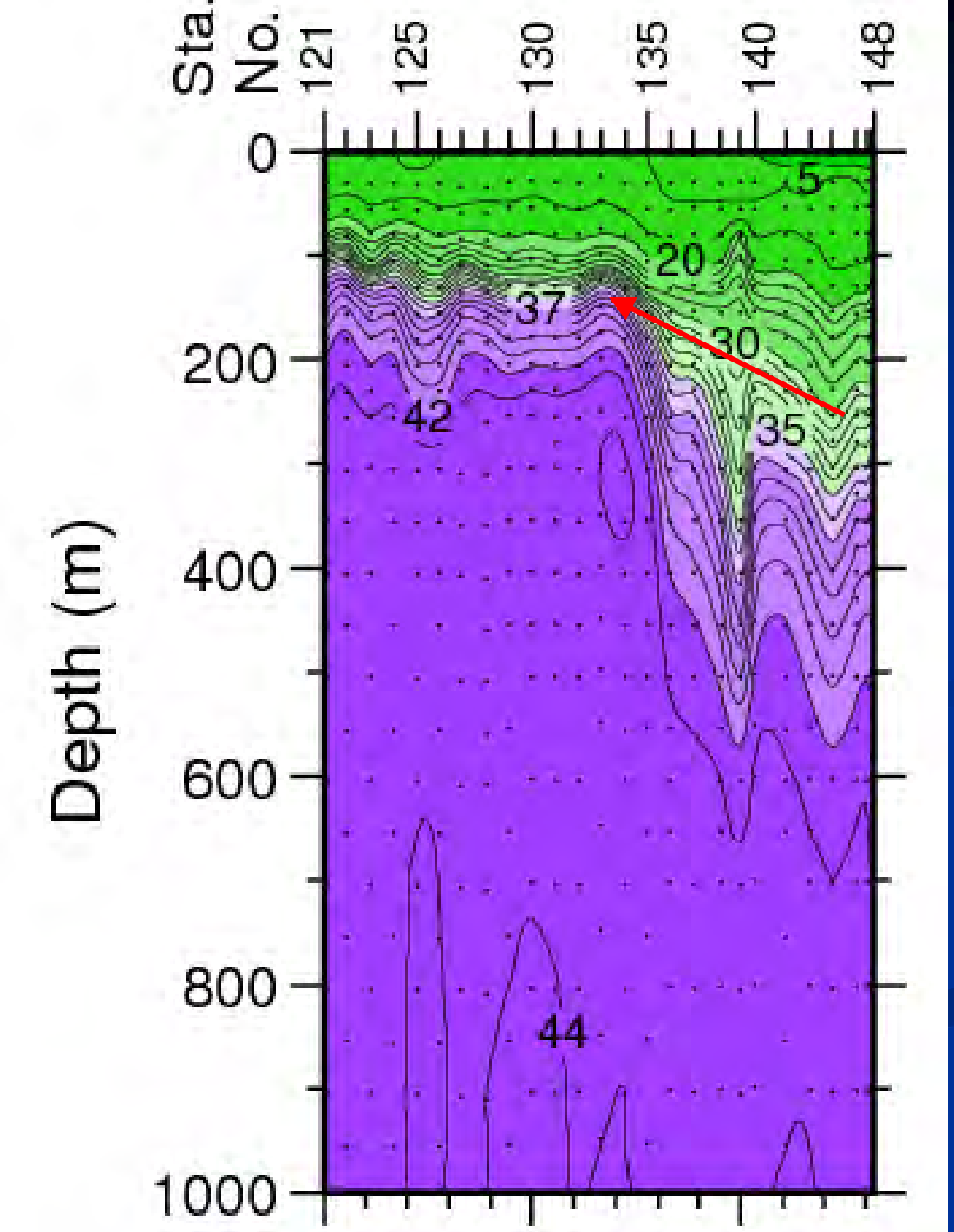
WOCE Section
P17NE
Musgrave 1993
Colour denotes height.
Numbers denote st'n. #

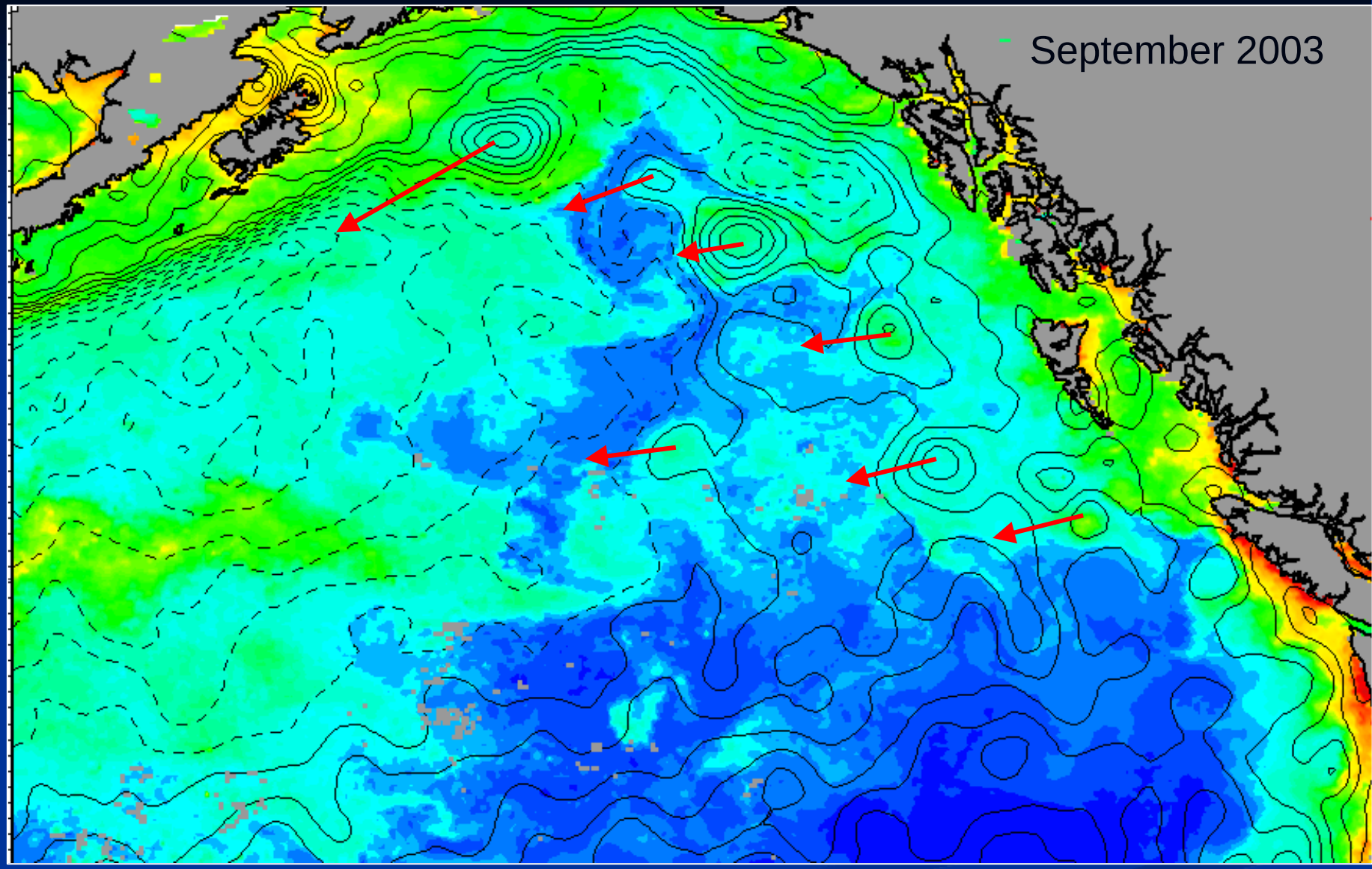
Left: Nitrate

Right: Sigma-Theta

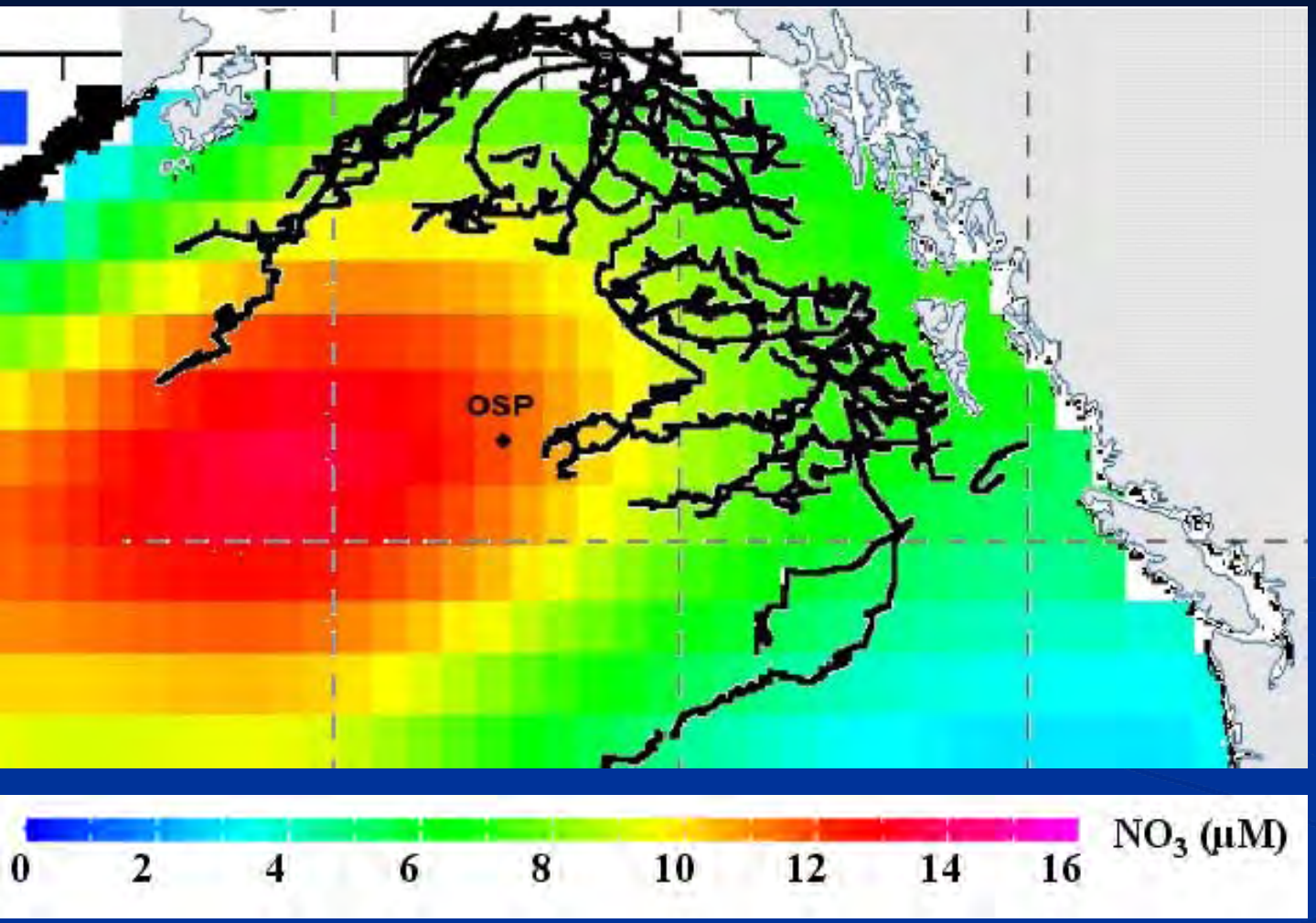


Nitrate concentration





Altimeter (black contours) + Chlorophyll (Colours)



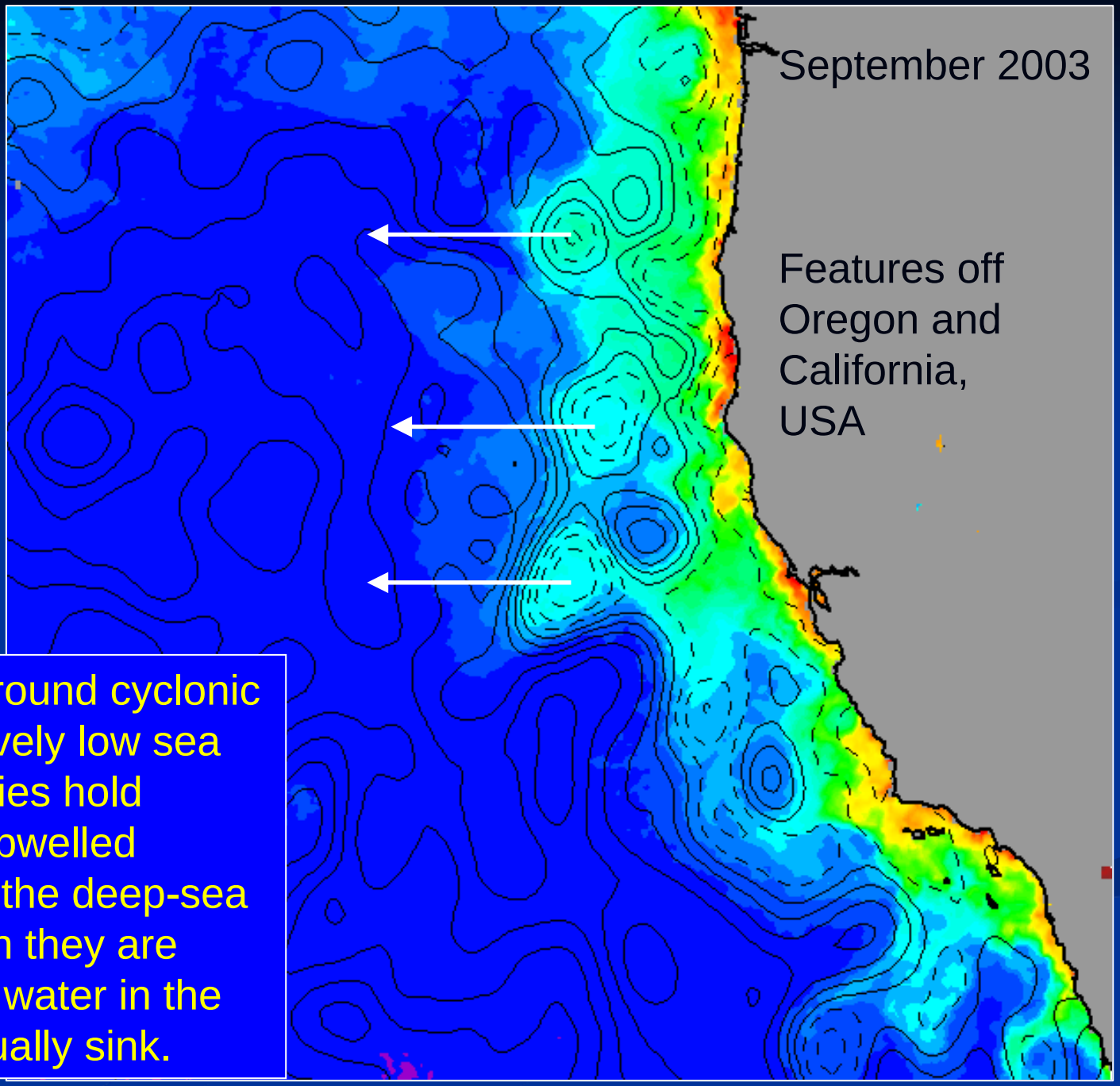
Annual average NO3 concentration in surface waters. (based on Levitus 1994).

This image suggests that the northeast limit of HNLC waters is determined by trajectories of large Haida and Sitka Eddies.
These eddies are rich in iron and silicate, as well as nitrate.

Altimeter
(black contours)

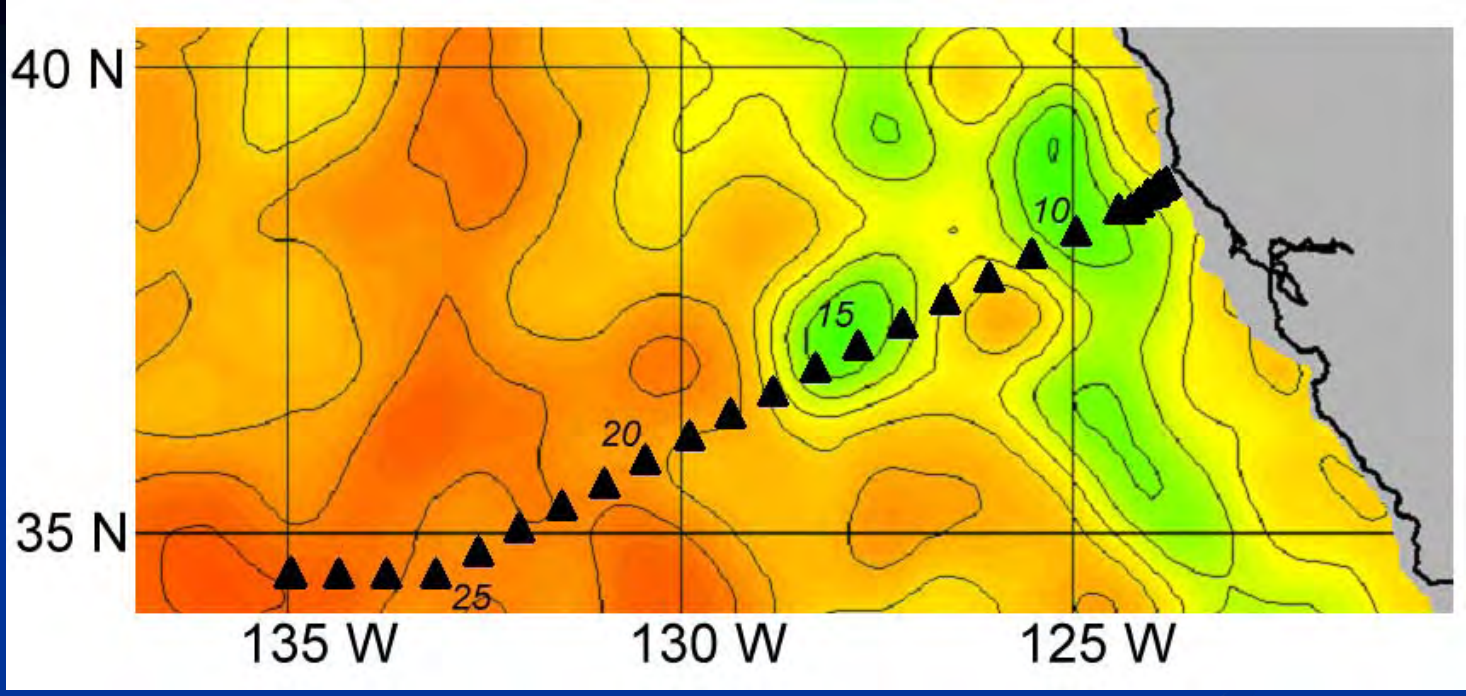
+

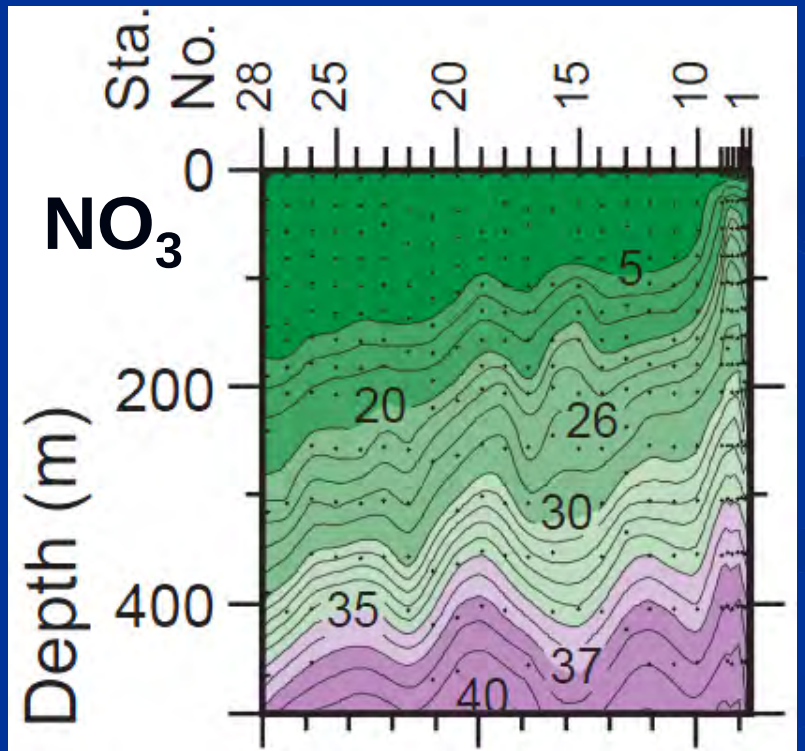
Chlorophyll
(Colours)

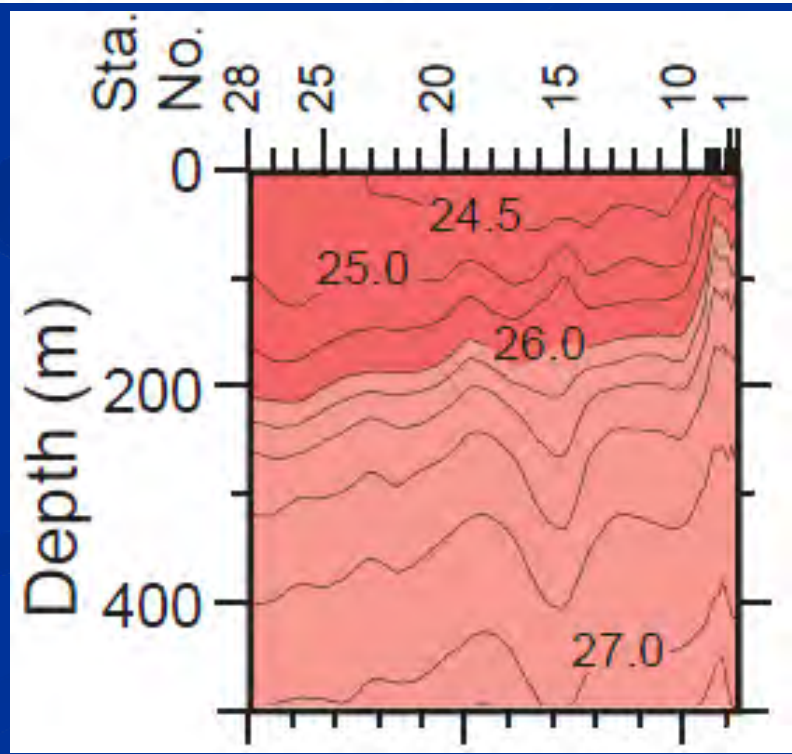


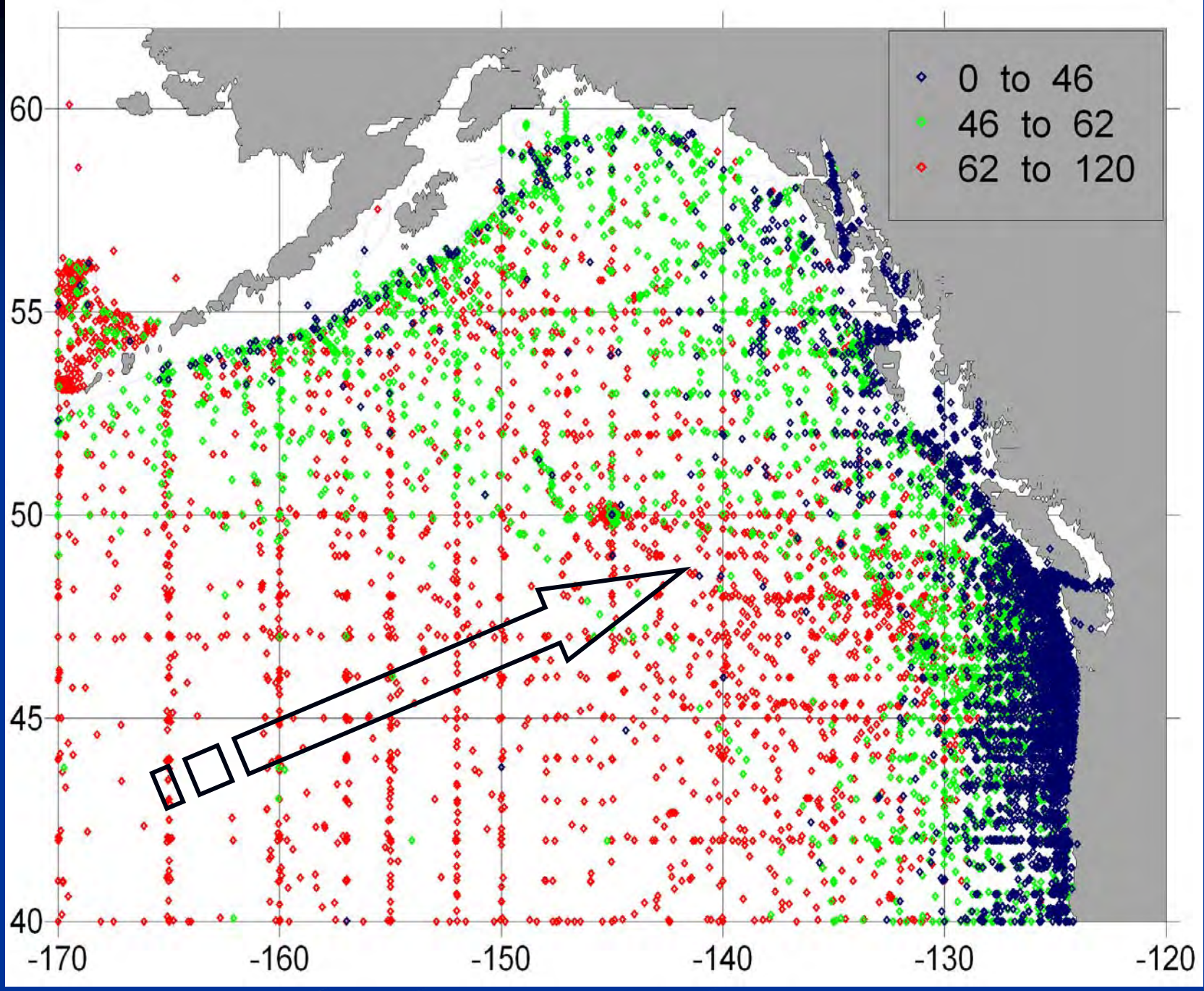
Dashed lines surround cyclonic eddies with relatively low sea level. These eddies hold denser water (+upwelled nutrients) than in the deep-sea regions into which they are propagating, and water in the eddies will eventually sink.

WOCE Section P17CA
Musgrave 1993
Colour denotes Height. Numbers denote st'n. #









Percent Oxygen saturation on the 26.5 sigma-theta surface.

- Conclusions:

- Coastally generated mesoscale eddies impact the productivity of the coastal regions where they form, and the deep-sea regions into which they propagate.

- Anticyclonic eddies propagating into major anticyclonic gyres likely have a greater impact on deep sea life.

- Cyclonic eddies propagating into major anticyclonic gyres likely sequester more carbon.