

Ship-of-opportunity observations of mesoscale eddies

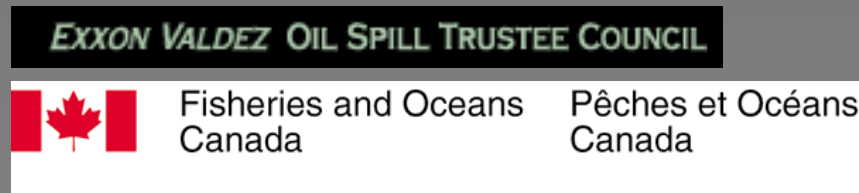
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¹Sir Alister Hardy Foundation for Ocean Science

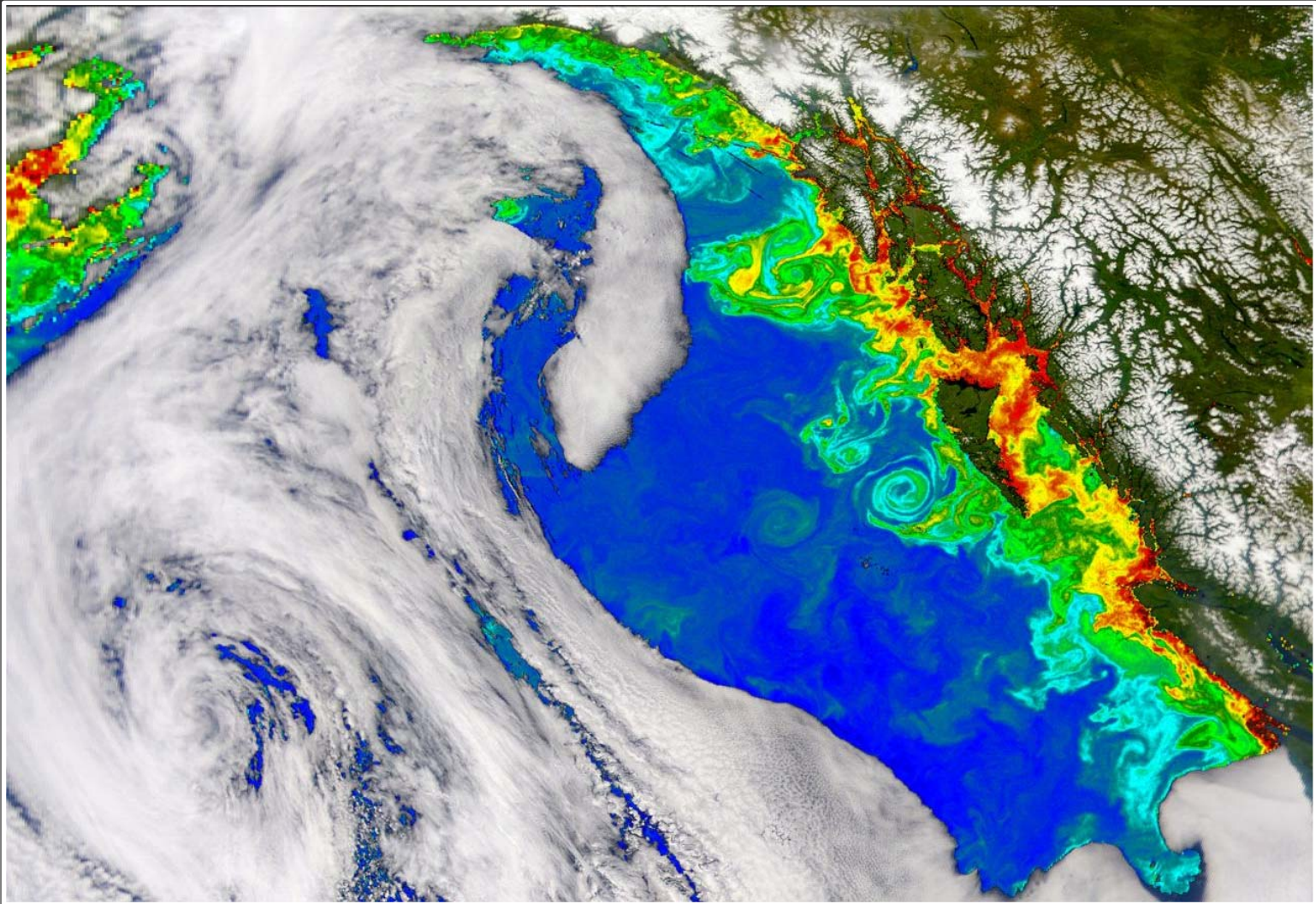
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³Hawaii Pacific University





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Mesoscale eddies form around the rim of the North Pacific
They influence plankton distributions and may act as a 'Hot-Spot' for upper trophic levels.

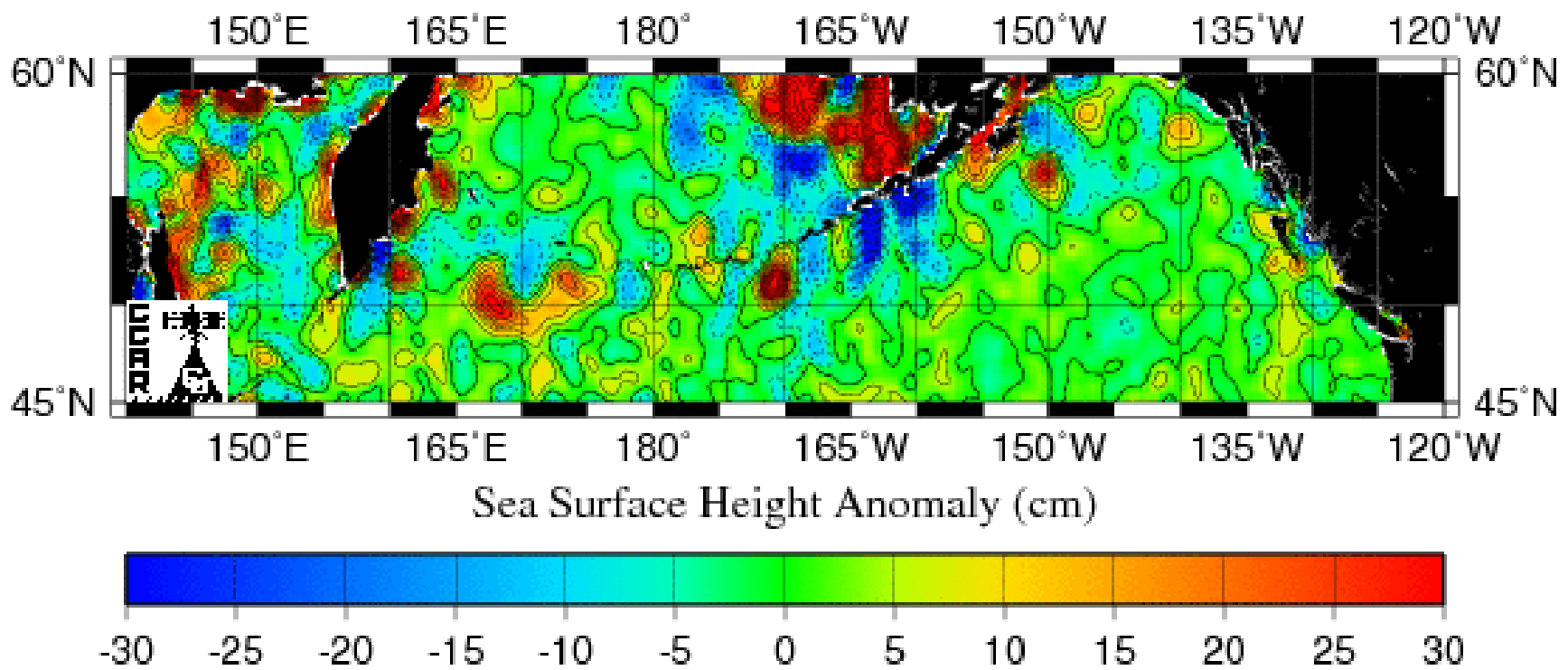


Eddies are thought to impact lower trophic levels by:

-  Advecting chlorophyll, nutrients and organisms from shelf to open ocean Brickley, P.J., & Thomas, A.C. (2004).
-  By supplying nutrients to the euphotic zone through vertical processes within the eddy Ladd, C., et al. (2005).
-  Colonisation by oceanic zooplankton and then aggregation and retention through vertical migration behaviour Mackas et al., (2005)
-  There is interannual variability in eddy strength and frequency with El Niño years producing larger, longer-lived eddies – climate change is likely to affect eddy frequency and intensity

Eddies are readily visible as sea surface height anomalies:

Real-Time Mesoscale Altimetry - Mar 24, 2007



<http://argo.colorado.edu/~realtime/welcome/>

The Continuous Plankton Recorder Survey uses ships-of-opportunity to sample the oceanic North Pacific on regular routes:

Plankton only



Plankton, some chl a, birds and mammals



Ship tracks often passed through eddies

Since the survey started in 2000, eddies have been sampled 47 times (whole N Pacific), 34 times in the Gulf of Alaska

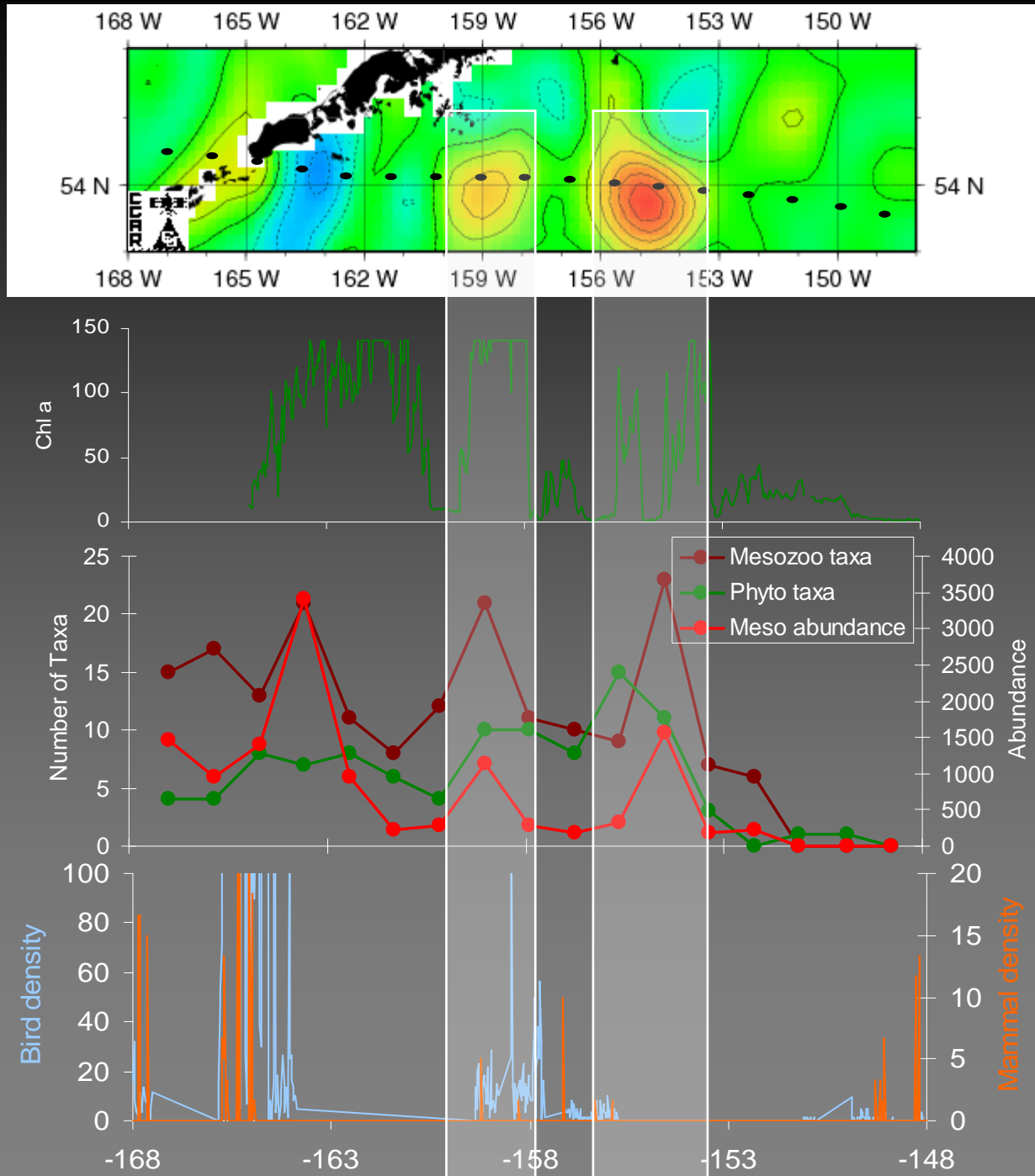
Variable	# sampled in GoA	# sampled in whole N. Pacific
Phyto- and zooplankton	34	46
Chlorophyll <i>a</i> (from CTD on CPR)	6	7
Bird and Mammal observations	5	14

But only 5 eddies have all variables sampled

June 2nd 2005

Western GoA

All variables measured

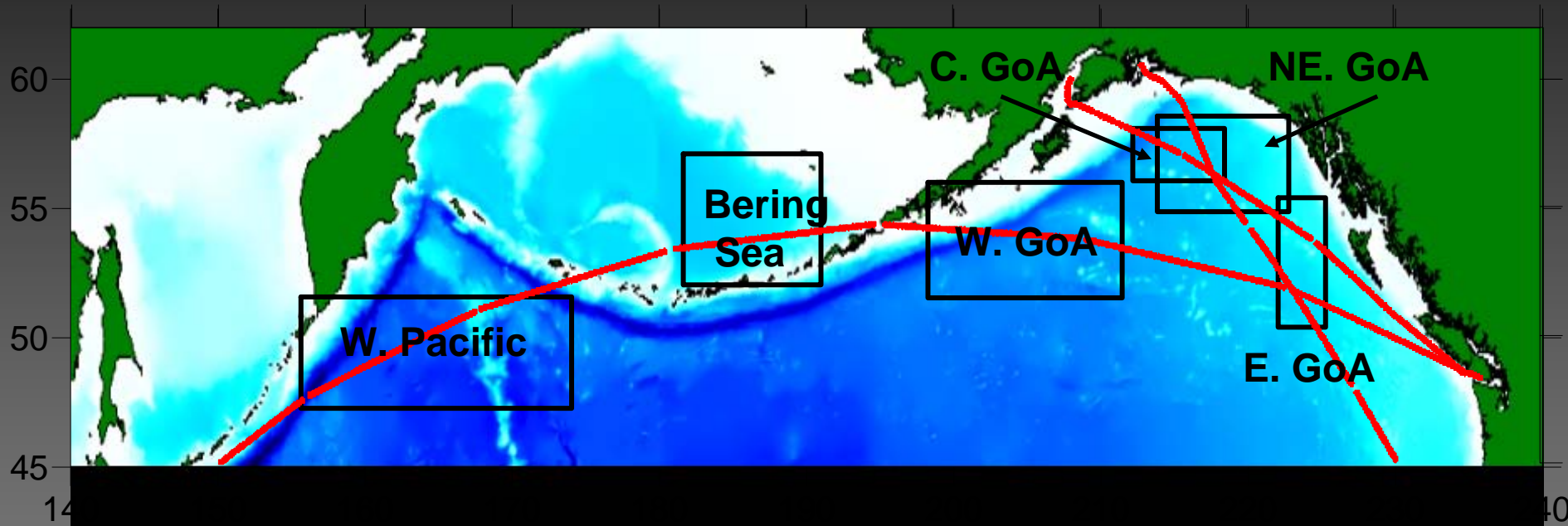


Two questions to examine:







1. Is there evidence that the eddies enhance the 'productivity' of the water within them with responses at multiple trophic levels, in all areas?
2. Do eddy properties visible from SSH anomaly images (size, age and intensity) determine biological properties?



6 regions where eddies were sampled by the ship transects:



Selected variables:

-  Number of phytoplankton taxa
-  Number of mesozooplankton taxa
-  Biomass of mesozooplankton
-  Number of bird species
-  Bird density
-  Mammal density

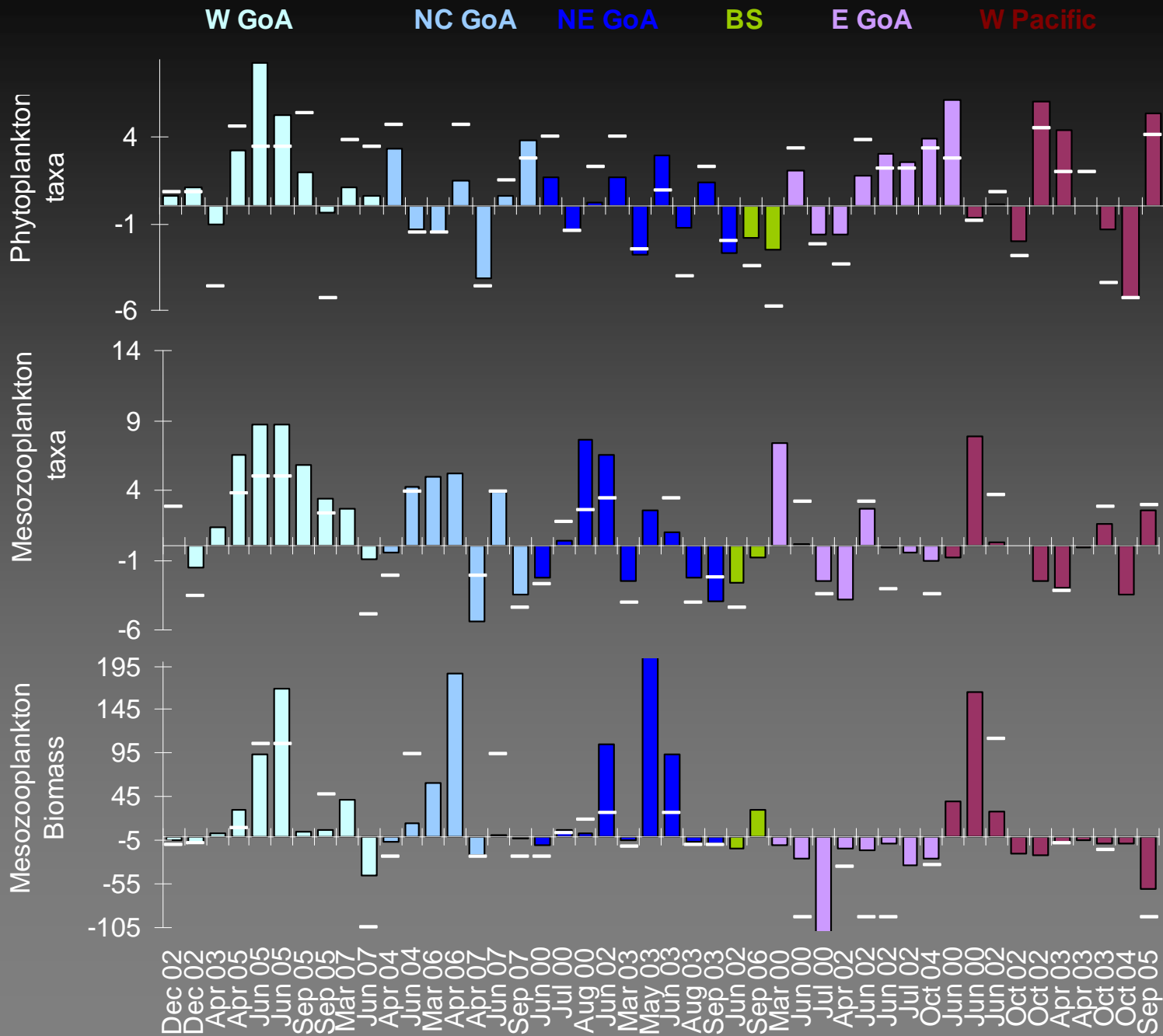
(chlorophyll a sampled too infrequently)

Calculated mean value of each variable within each eddy and monthly mean value for the region when eddies were not present

Then for each eddy calculated the anomalies for each variable

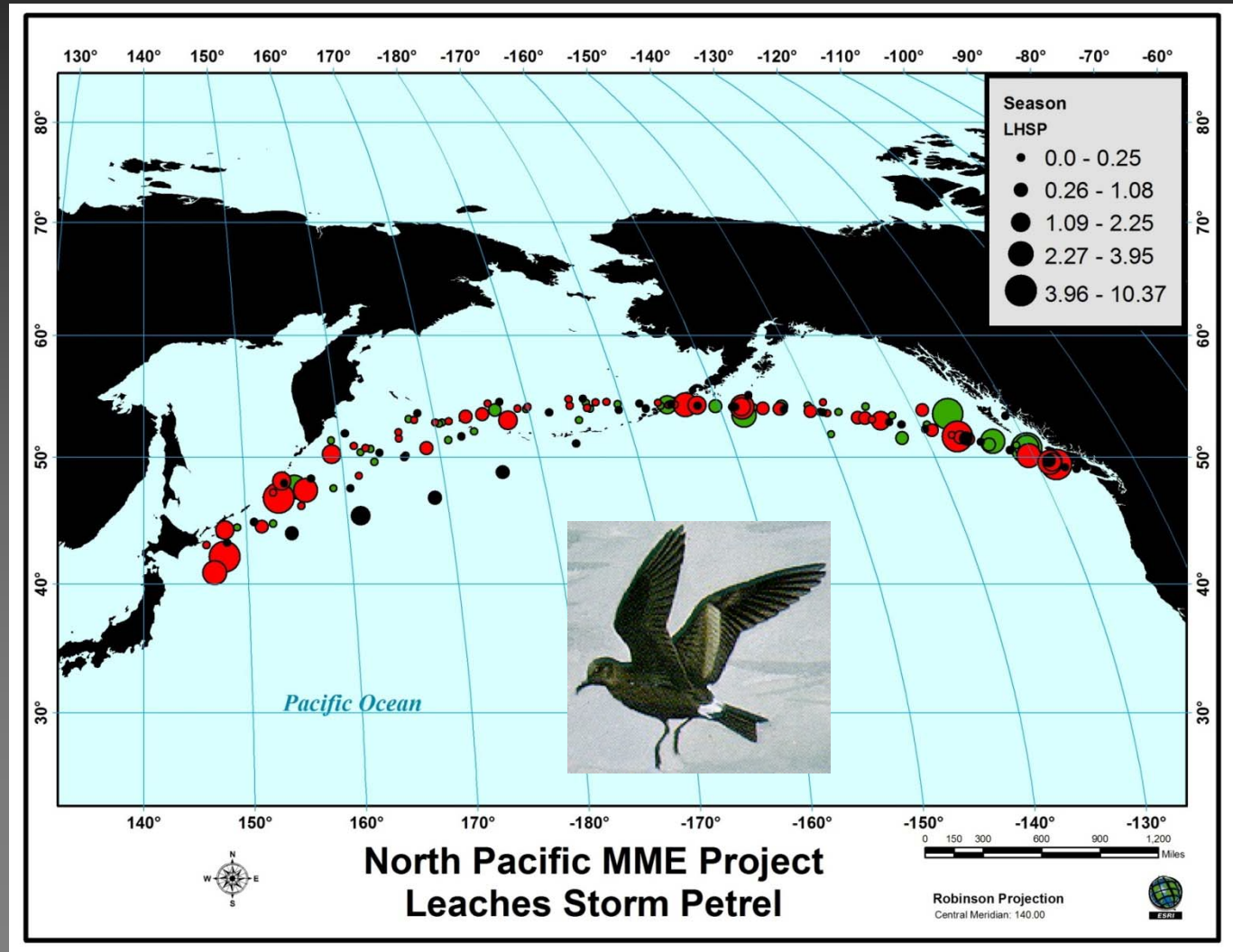
Lower trophic level anomalies

Columns show mean sample anomaly per eddy and white bars show one standard deviation of the monthly regional mean



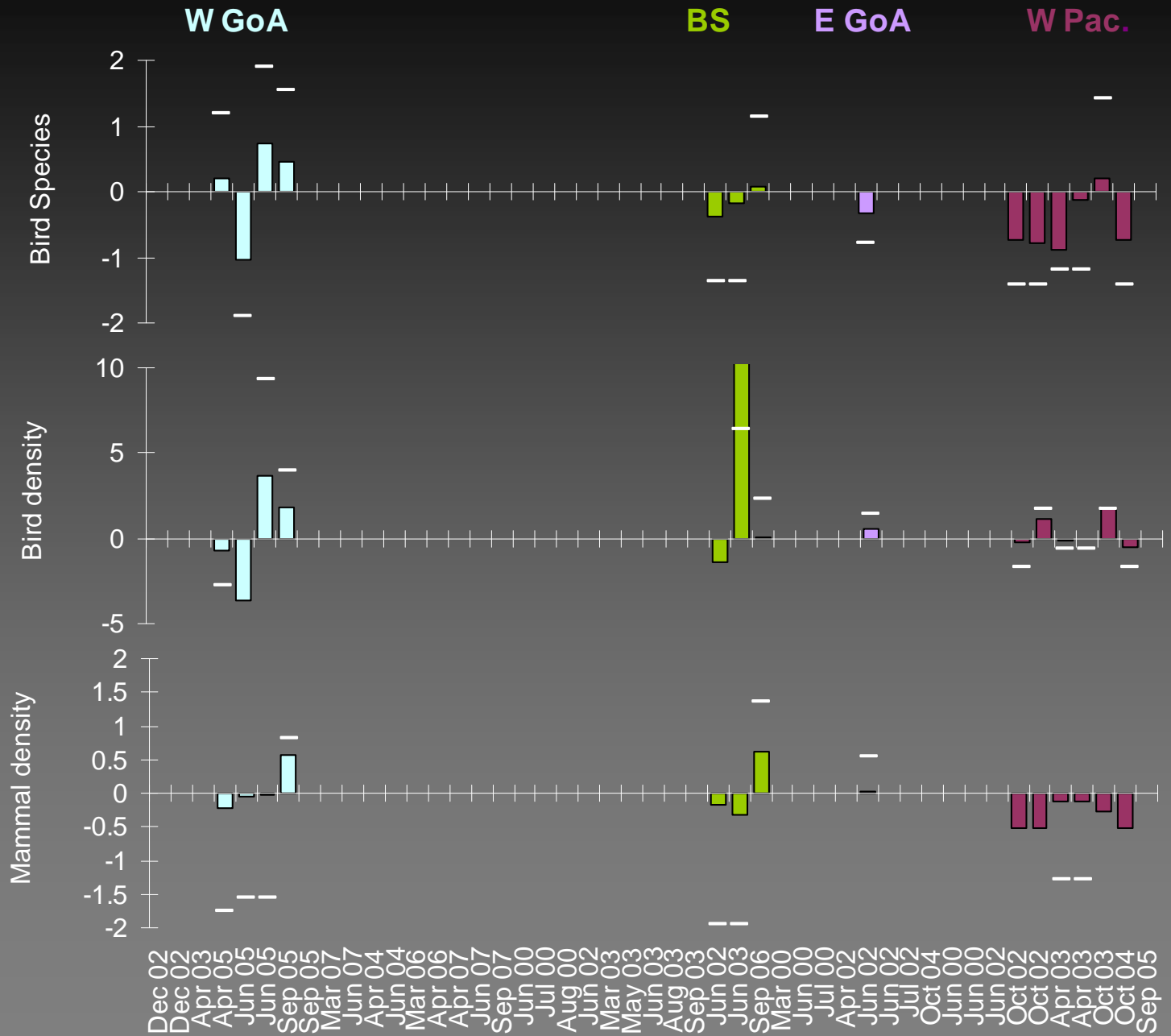
Focus on bird species that may be associated with eddies

Horned Puffin
Tufted Puffin
Parakeet Auklet
Black-footed Albatross
Leach's Storm Petrel
Mottled Petrel
Sooty Shearwater



Higher trophic level anomalies

Bird density is only those species thought to be associated with eddies



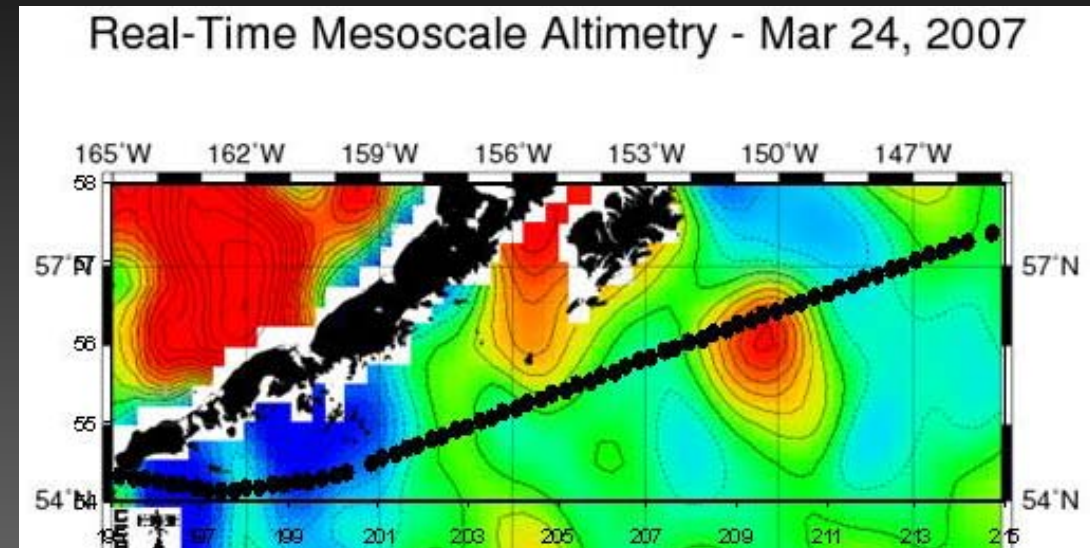
Percentage of anomalies that are positive, positive by > 1 st dev or negative by > 1 st dev

	W GoA	NC GoA	NE GoA	E GoA	Bering Sea	W. Pacific
Phyto taxa	80, 30 0	57, 14 0	56, 0 22	75, 50 0	0, 0 0	60, 33 11
Zoo taxa	78, 57 0	57, 20 20	56, 25 13	38, 0 0	0, 0 0	50, 0 0
Zoo biomass	70, 29 0	57, 0 0	56, 25 0	0, 0 0	50, 0 0	30, 0 0
Bird taxa	75, 0 0			0, 0 0	33, 0 0	17, 0 0
Bird density	50, 0 0			100, 0 0	67, 33 0	33, 17 0
Mammal density	25, 0 0			100, 0 0	33, 0 0	0, 0 0

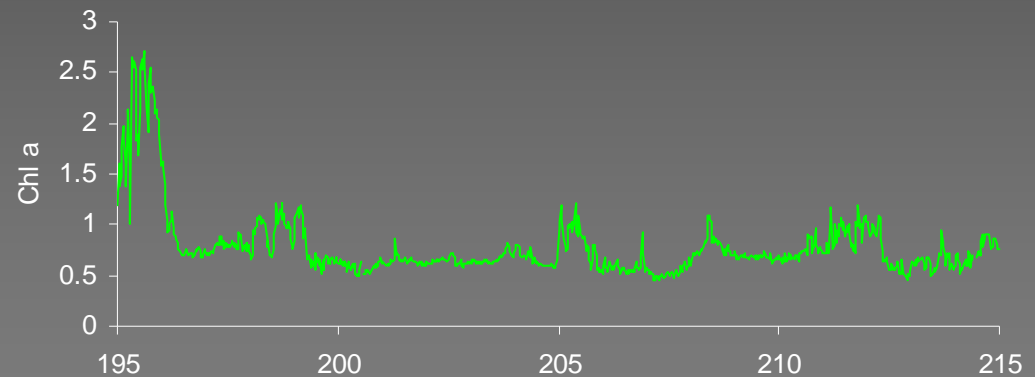
Only 1 eddy

Not all eddies enhance productivity....

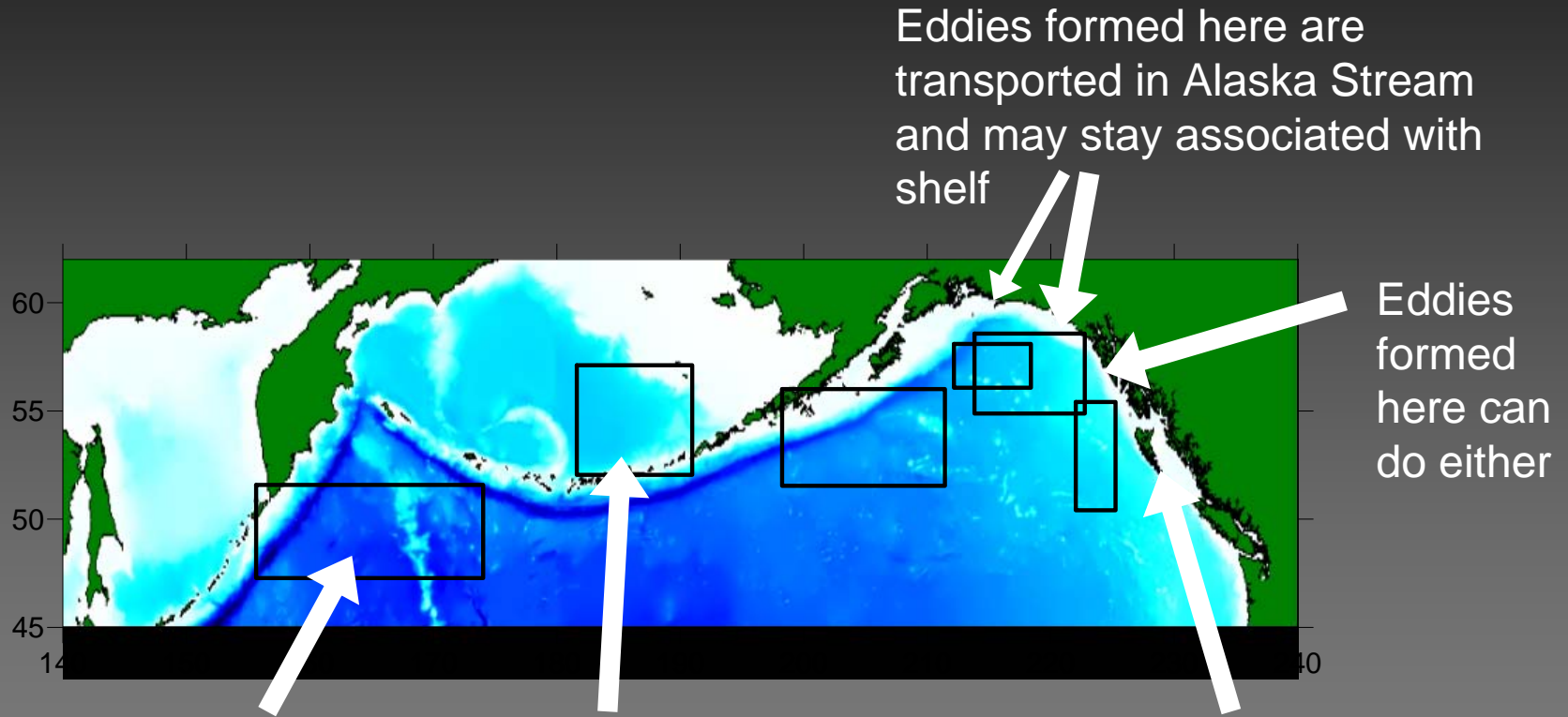
“in August 2007 ...a chlorophyll desert in the centre of a Haida Eddy in the eastern GoA” Bill Crawford pers. com.



.....but some regions consistently do (W GoA) or sometimes do (E GoA)



Formation regions, formation conditions, time of year, eddy track will all affect the biology



Eddies formed here are transported in Alaska Stream and may stay associated with shelf

Eddies formed here can do either

Eddies here may be from oligotrophic Kuroshio

Bering Sea is already productive and not Fe limited. Eddy structure may inhibit horizontal advection

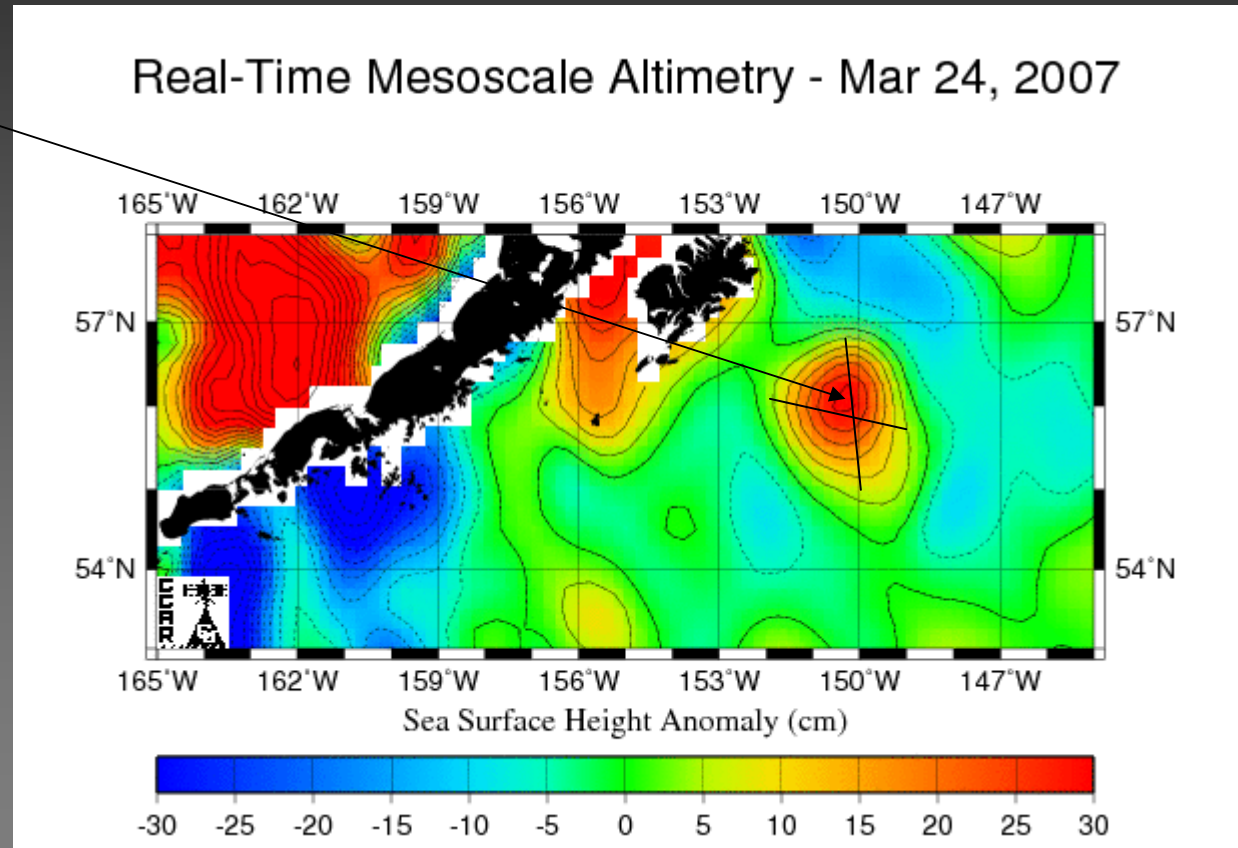
Eddies formed here move westwards into open ocean

Do eddy properties visible from SSH anomaly images affect biological properties?

1. Intensity (cm)

2. Size (km²)

3. Age (months)



Multiple Linear Regression results – all areas combined

	Phyto taxa	Zoo taxa	Zoo Biomass	Bird taxa	Bird density	Mam. density
Intensity				-		-
Area			+			+
Age	+		+			+
Phyto taxa		+				
Zoo taxa				+		
Zoo Biomass						

	Phyto taxa	Zoo taxa	Zoo Biomass	Bird taxa	Bird density	Mammal density
Intensity				-		-
Area			+			+
Age	+		+			+
Phyto taxa		+				
Zoo taxa				+		
Zoo Biomass						


Species richness is positively correlated with species richness of the trophic level below

Mammals are possibly influenced by eddy characteristics


By area (lower trophic levels and physical variables only)


	Phytoplankton taxa	Zooplankton taxa	Zooplankton Biomass
W GoA			
C GoA			+Size -Intensity
NE GoA	+Intensity		
E GoA		-Size	
W Pacific		+Size	+Age +Size


Summary

 Eddies influence the biology of the ocean, though not all eddies enhance productivity

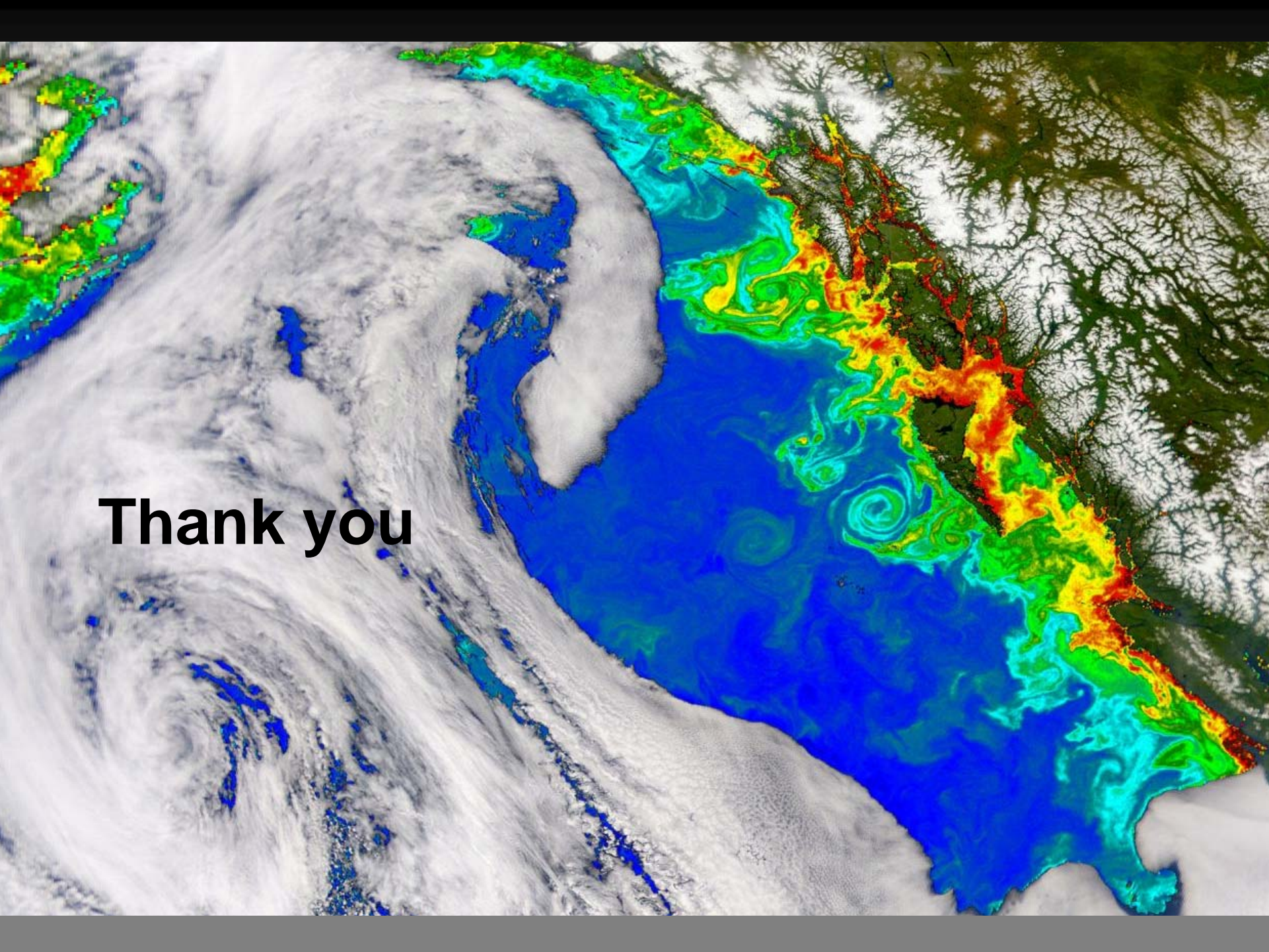
 Diversity is most influenced

 Regional variations in biological enhancement dependent on formation region and to some extent physical properties

 There are trophic linkages within the eddies, especially diversity

 Measuring some physical properties is possible from satellites and Argo floats (Ueno et al., in prep) but biological and chemical properties require being in the water.

 FUTURE needs to account for these mesoscale features



Thank you