The Juan de Fuca Eddy – An initiation site for toxigenic *Pseudo-nitzschia* blooms impacting the Washington coast

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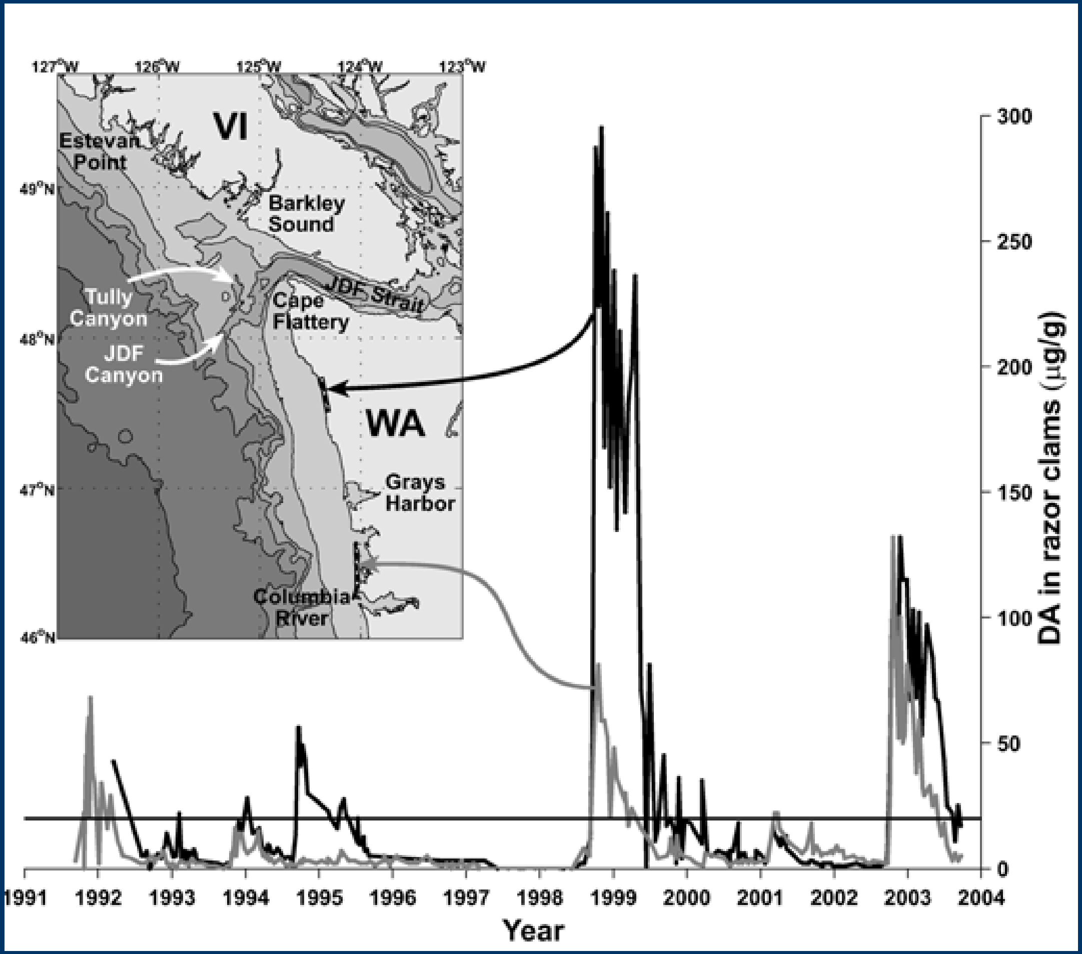
Background (1)

Domoic acid contamination closes WA state razor clam fishery

- domoic acid is a neurotoxin produced by *Pseudo-nitzschia*
- problem on US West Coast since 1991

Time series of DA in razor clams from northern (black) and southern (gray) WA state beaches

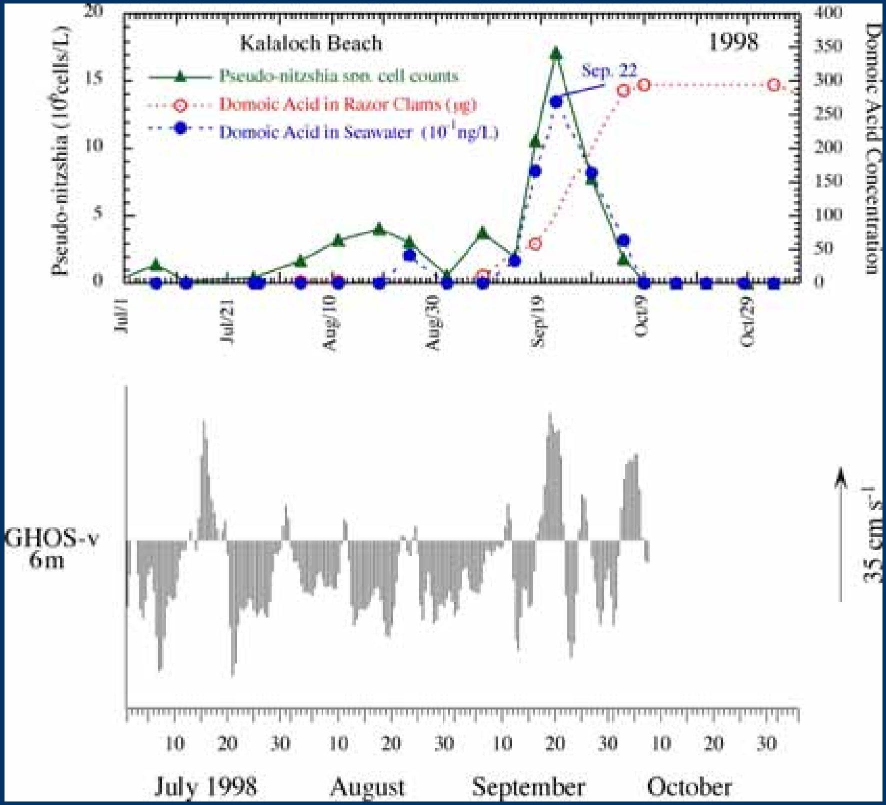


Data courtesy WA State Department of Health

Background (2)

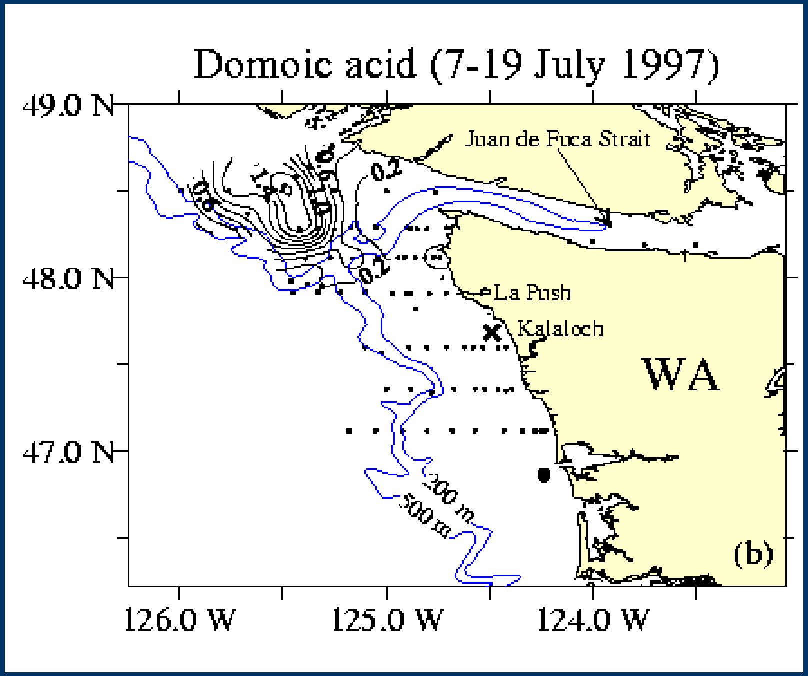
Offshore initiation and identification of a likely source region

Trainer, Hickey and Horner (2002)



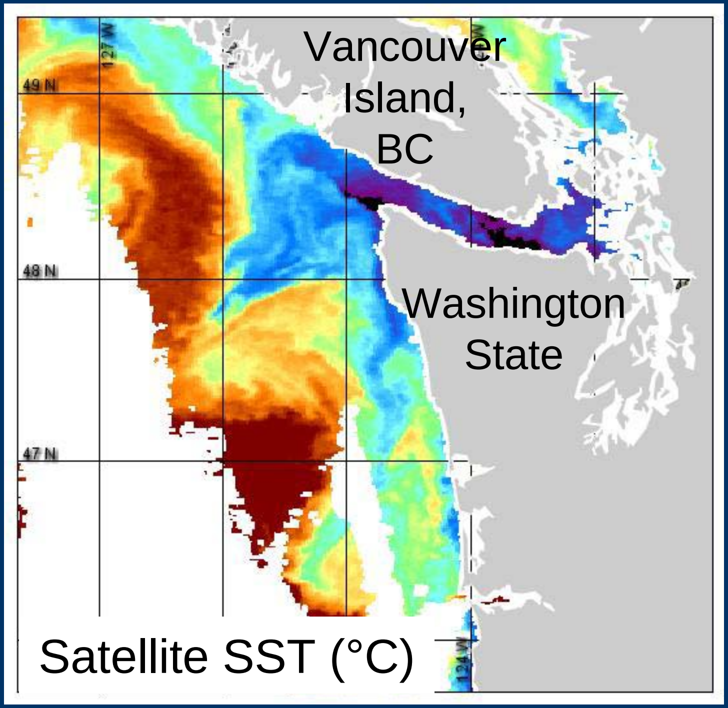
1998 fishery closure preceded by northward wind event (onshore advection of surface waters)

Survey data indicated *Pseudo-nitzschia* in JDF eddy region are more likely to be associated with toxin than those in coastal upwelling region



ECOHAB Pacific Northwest

www.ecohabpnw.org



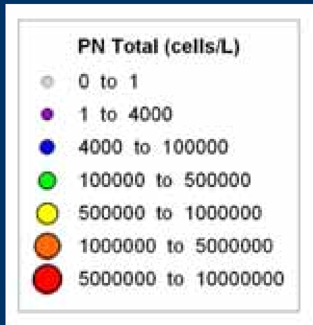
- identification as potential source region for toxic *Pseudo-nitzschia* blooms led to renewed interest in Juan de Fuca eddy
- ECOHAB PNW began in 2002 as a 5-year multi-disciplinary project studying the physiology, toxicology, ecology and oceanography of toxic *Pseudo-nitzschia* species off the Pacific Northwest coast

HYPOTHESIS:

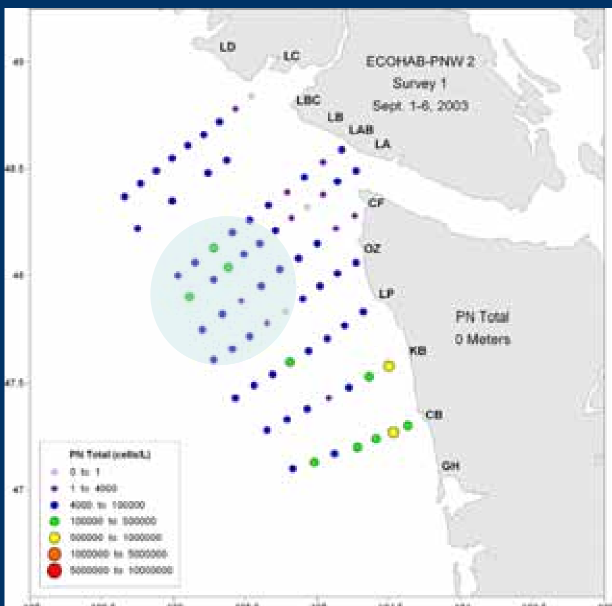
- seasonal eddy is initiation site for toxic PN impacting WA coast and that coastal upwelling sites are less likely to develop toxicity

APPROACH:

- bio-physical modeling component (Foreman, Peña talks this session!)
- four years of regional multi-disciplinary field studies



Pseudo-nitzschia distributions September 2003-2005



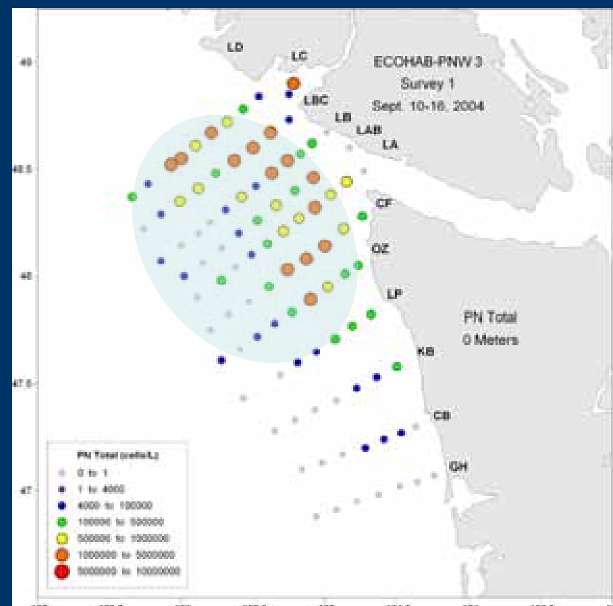
Sept 2003

68,000 cells/L

2.5 nM pDA

cf. *P. pseudodeli, deli, aus, heimii*

860,000 cells/L 14.1 nM



Sept 2004

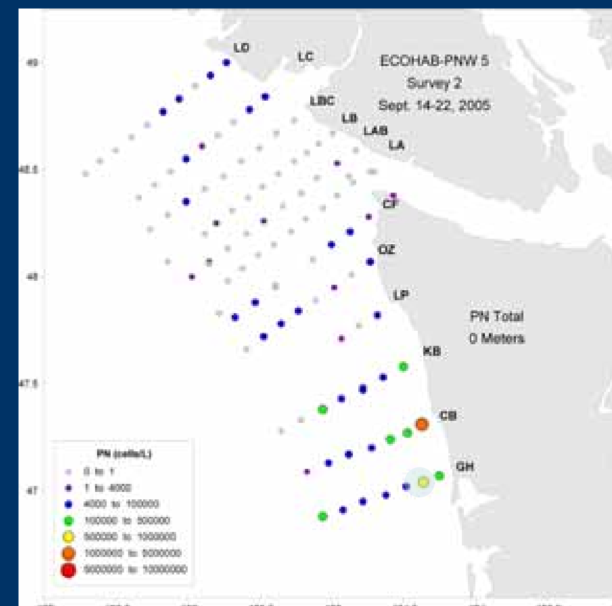
3,280,000 cells/L

43.3 nM pDA

P. cuspidata

EXTREME event!

11,220,000 cells/L 94.6 nM



Sept 2005

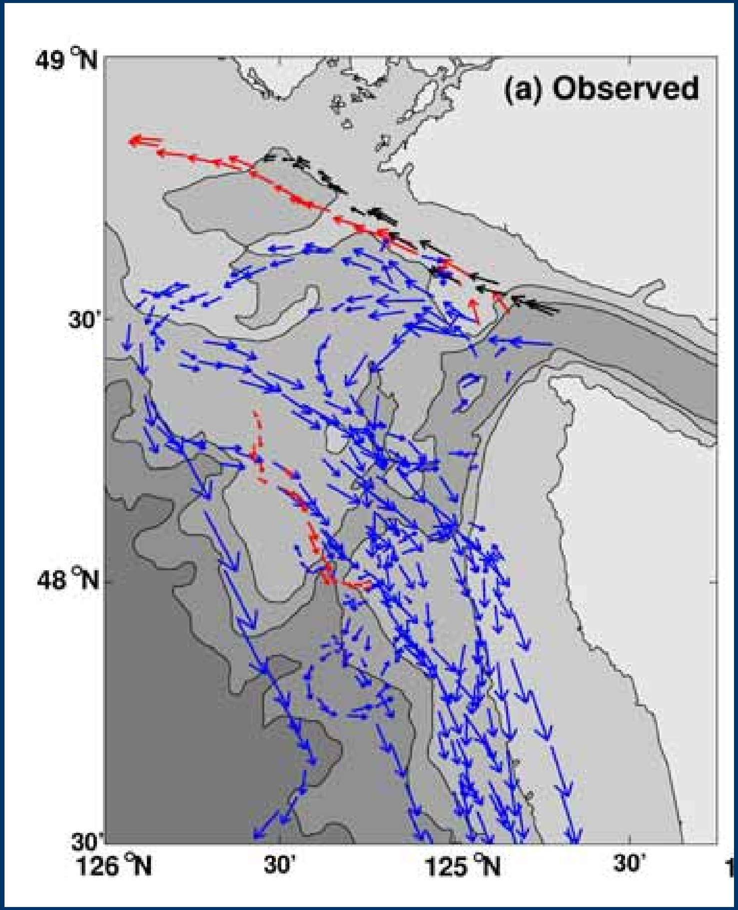
1,130,000 cells/L

6.7 nM pDA

P. cuspidata, aus

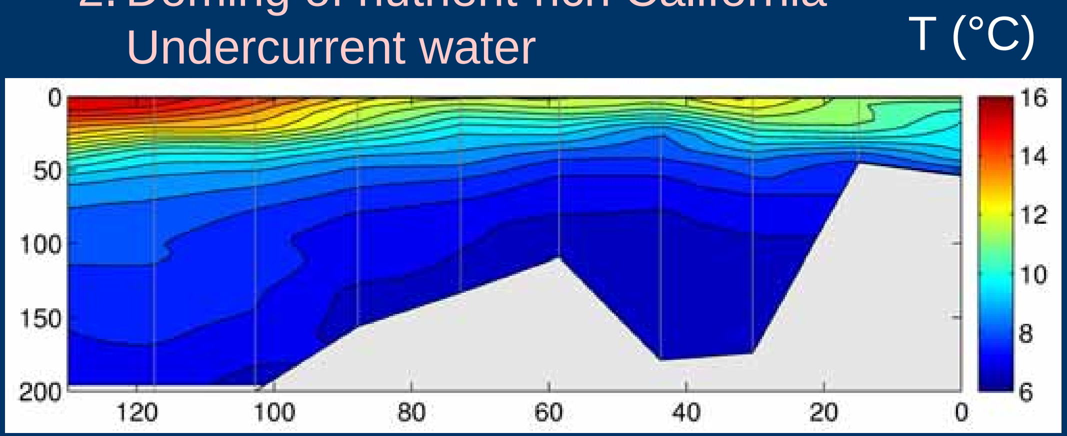
Important characteristics of the Juan de Fuca Eddy

1. Cyclonic circulation pattern

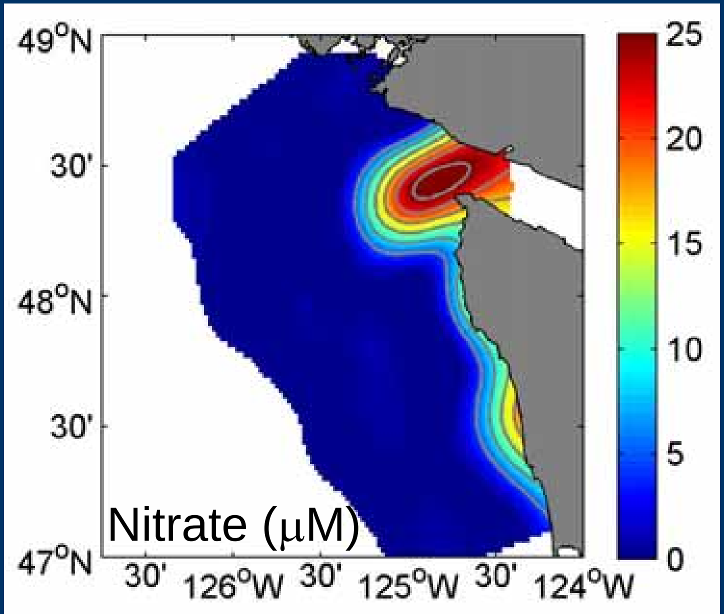


MacFadyen et al., *Cont. Shelf Res.*, 2005

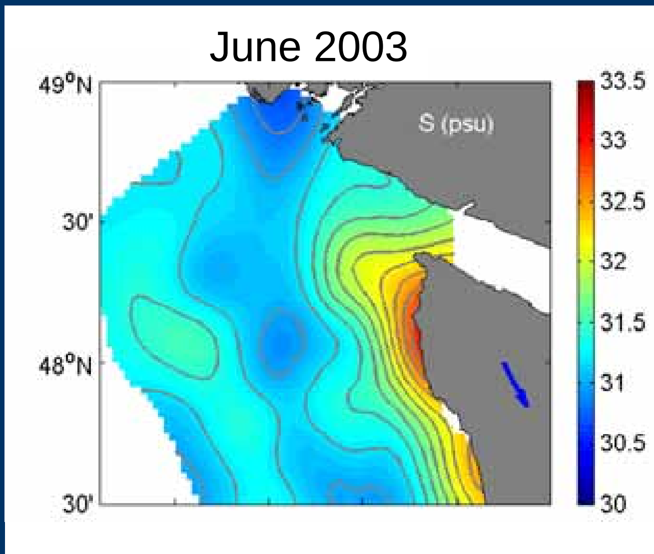
2. Doming of nutrient-rich California Undercurrent water



3. Proximity to JDF Strait

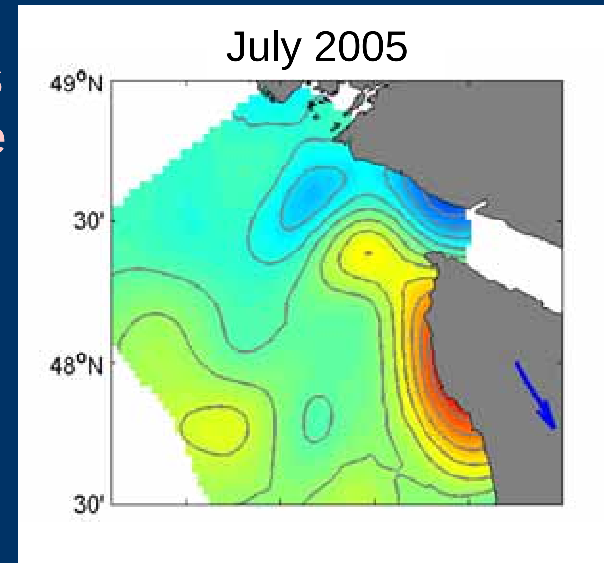


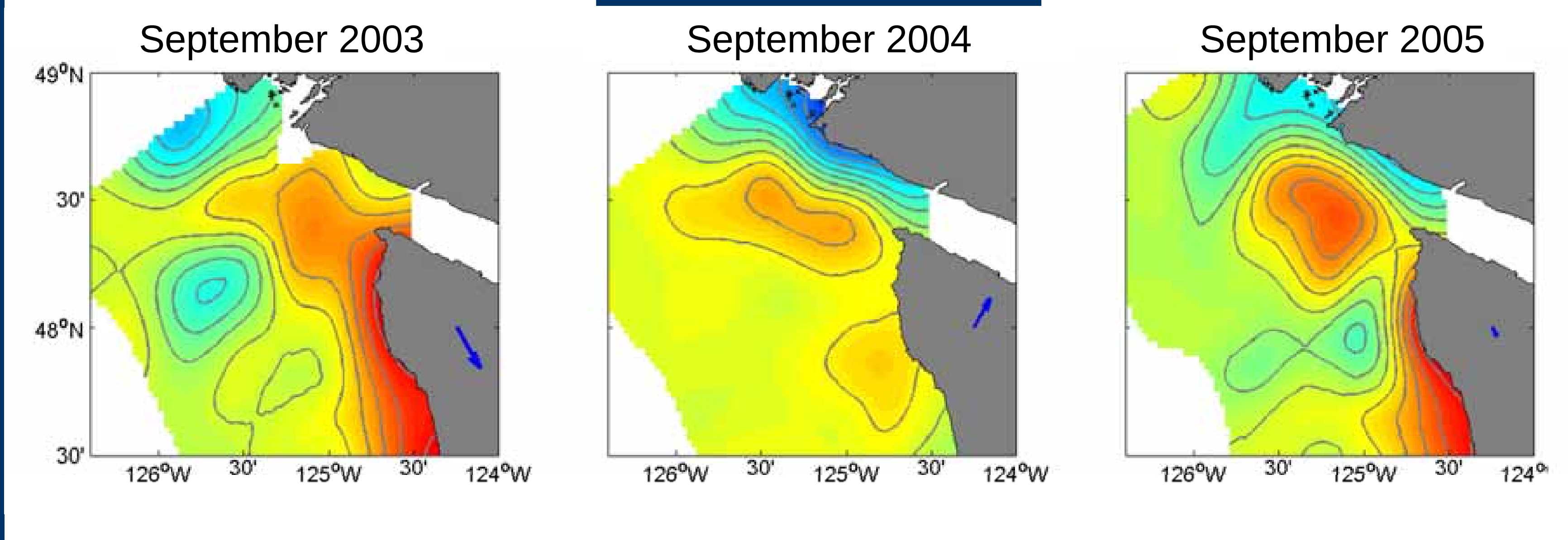
Patterns in near-surface salinity



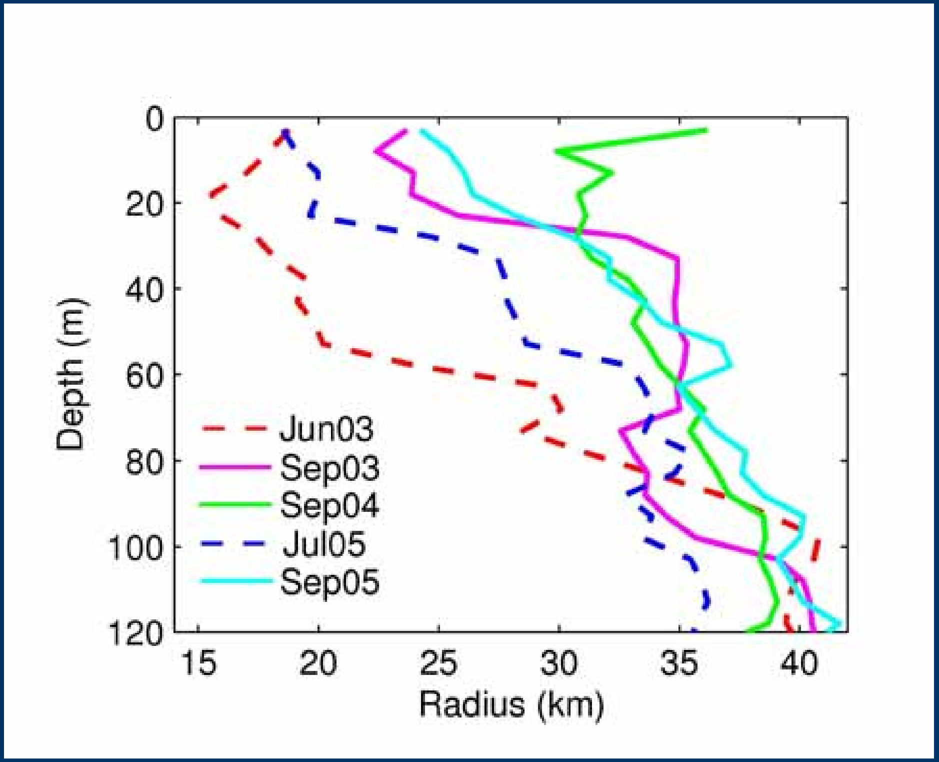
June/July surveys
-upwelling favorable conditions

Sept surveys
-upwelling, downwelling, relaxation

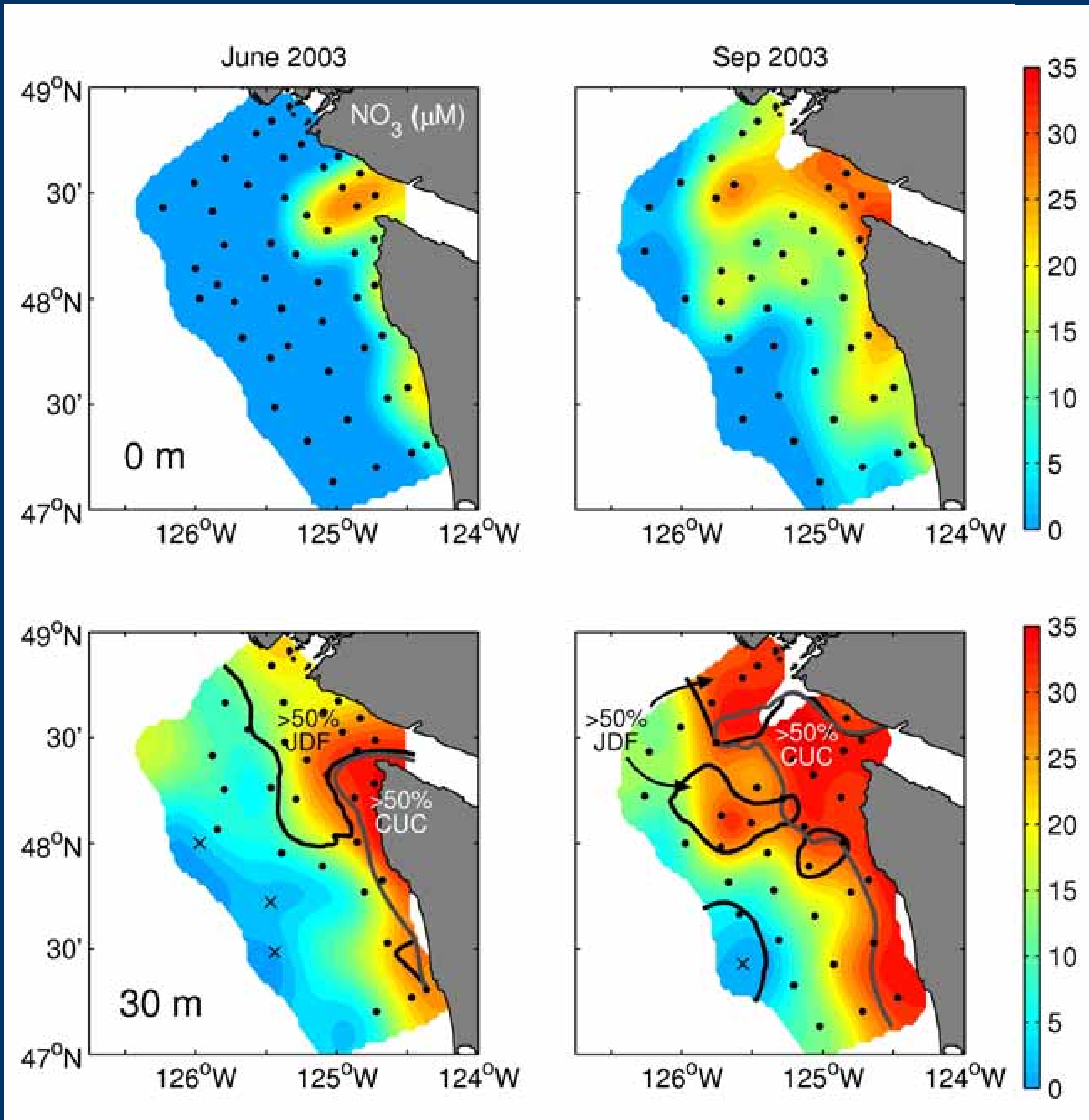




Seasonal development



- use extent of positive salinity anomaly to calculate an eddy “radius” (km) as a function of depth
- seasonal increase in spatial extent above 100 m



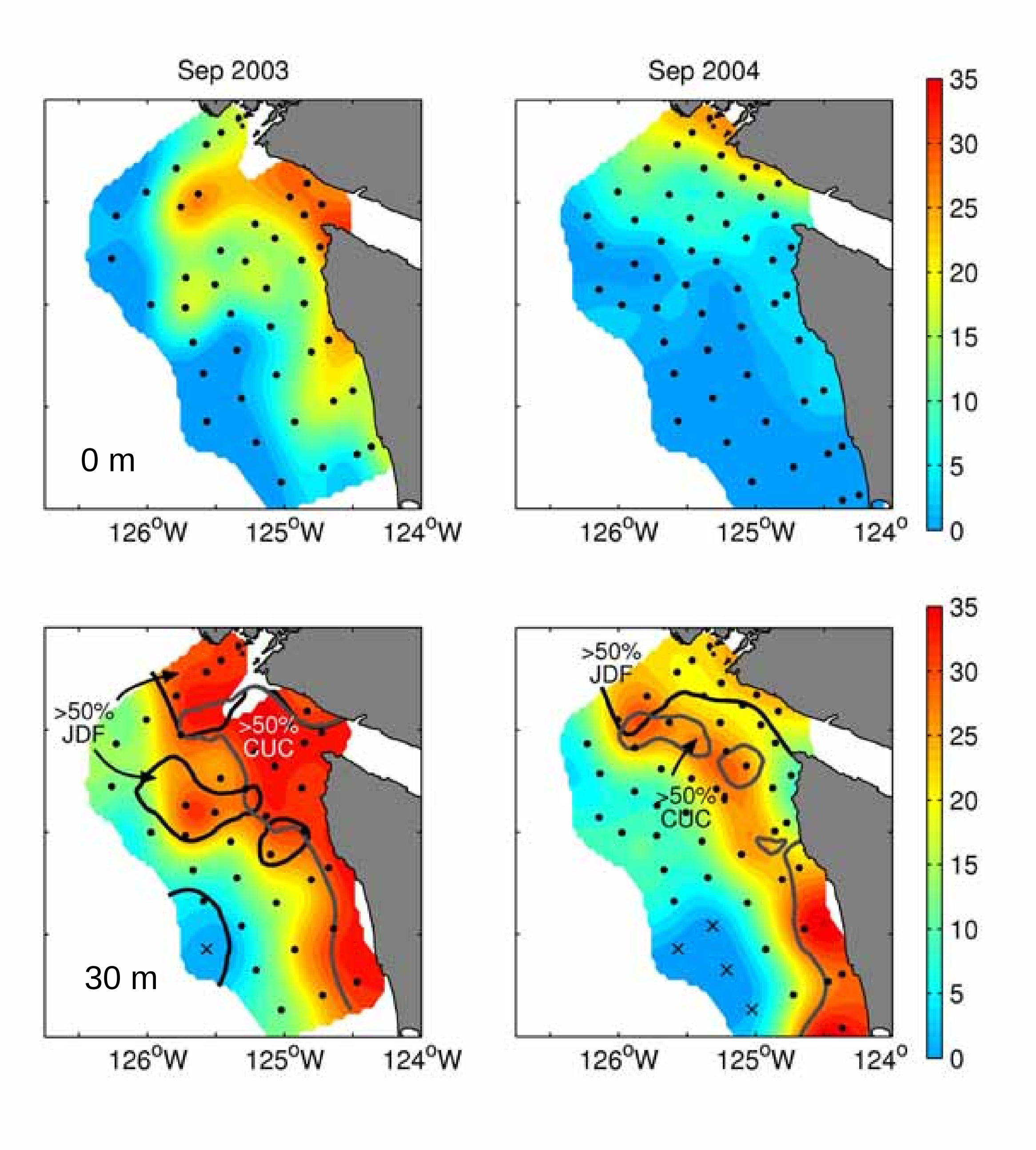
Early summer

Late summer

Effect on nutrient distributions

-- seasonal development --

- broad region of elevated nitrate off JDF strait – 100 km offshore in September
- least-squares fit water mass analysis
- combination of upwelling from below within eddy center and cross-shelf advection of strait outflow



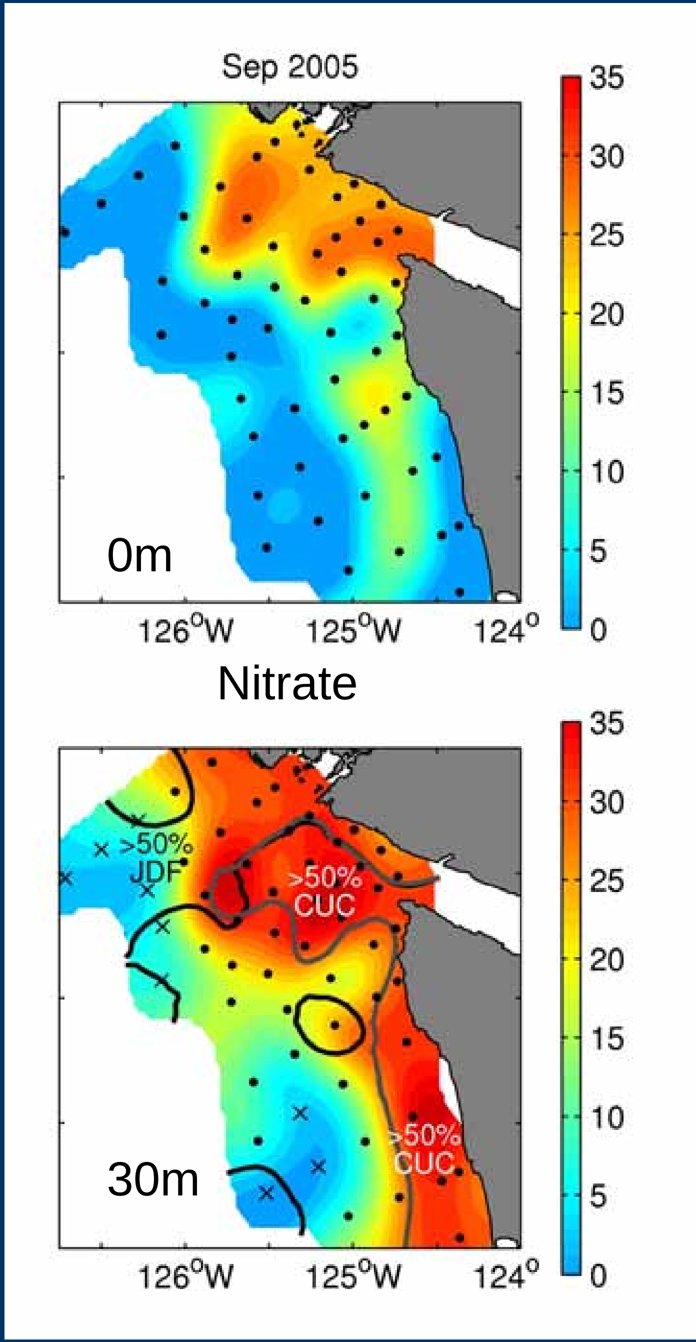
Upwelling

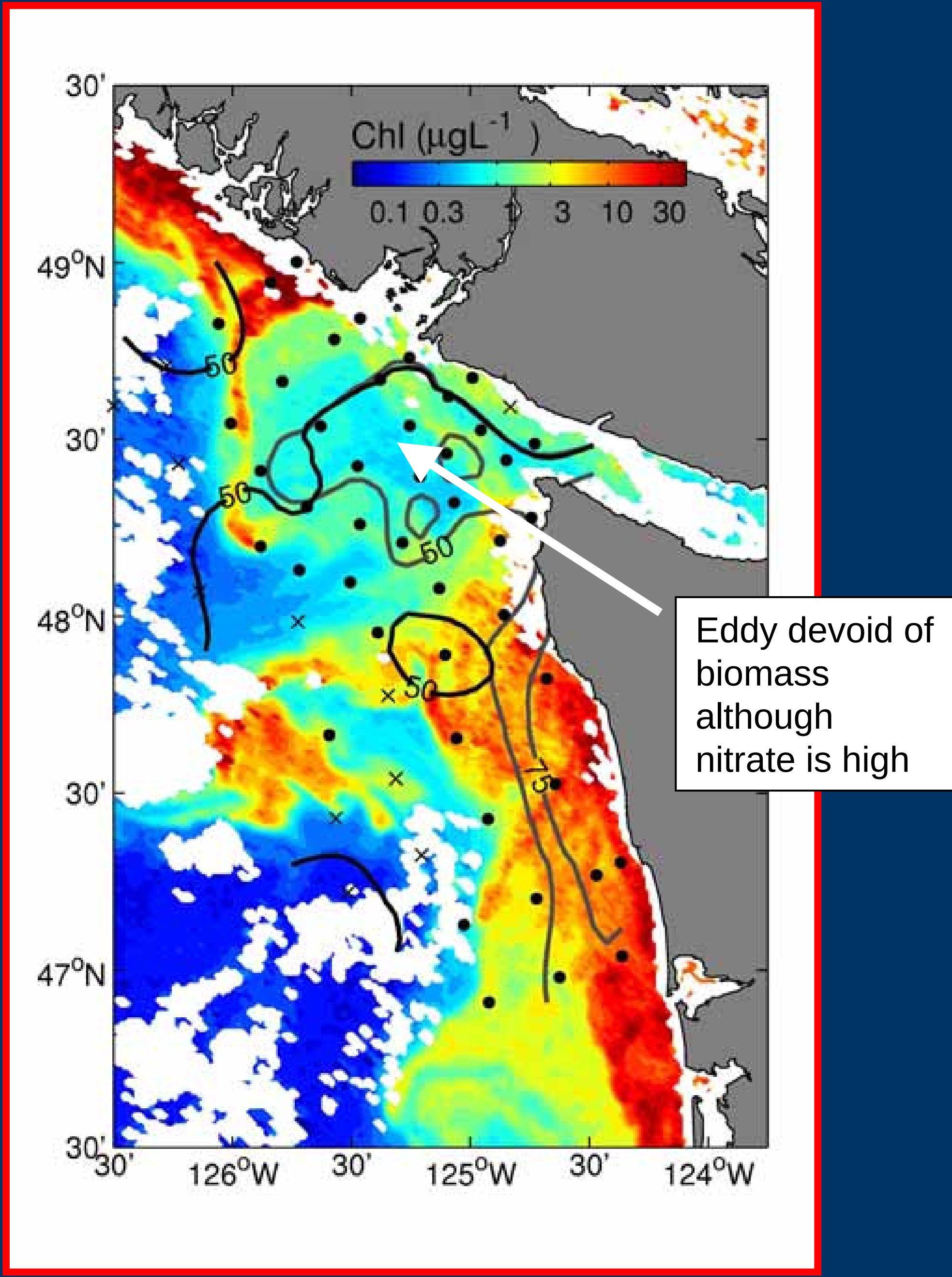
Storm

Effect on nutrient distributions

--- upwelling vs. downwelling—

- surface nitrate concentrations within eddy still exceed 5 μM during Sep 2004 survey
- maximum nitrate concentrations (at 30 m) associated with CUC water


Sep 2005
35
30
25
20
15
10
5
0
0m
126°W
125°W
124°
Nitrate
30m
>50%
JDF
>50%
CUC
>50%
CUC

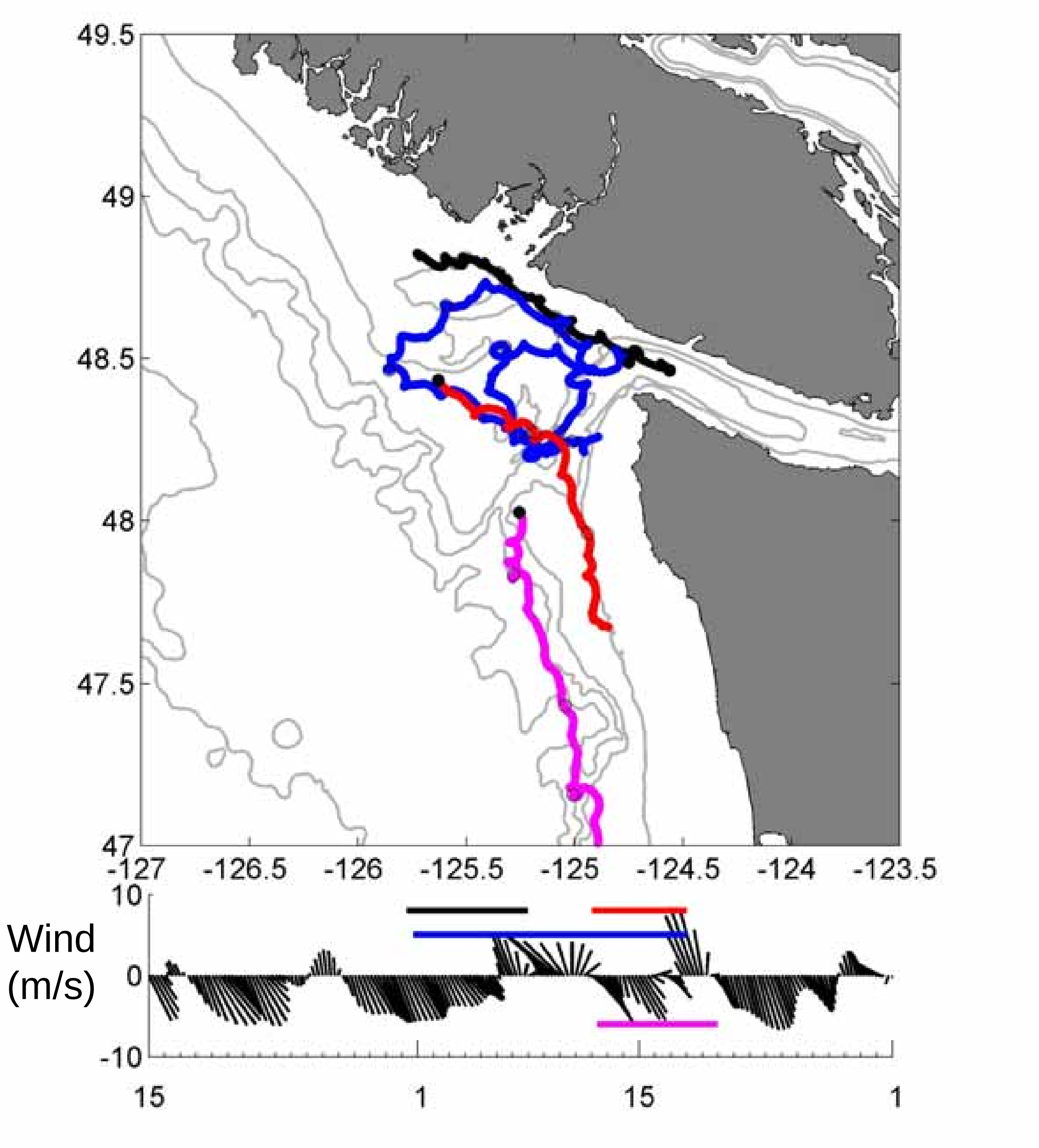

Chl (μgL-1)
0.1 0.3 1 3 10 30
30'
49°N
30'
48°N
30'
47°N
30'
30'
126°W
30'
125°W
30'
124°W
50
50
50
50
75
Eddy devoid of biomass although nitrate is high

Wind-driven variability in circulation

- surface GPS drifters deployed in eddy
- demonstrate retention and escape from eddy under varying wind conditions
- onshore movement associated with storms

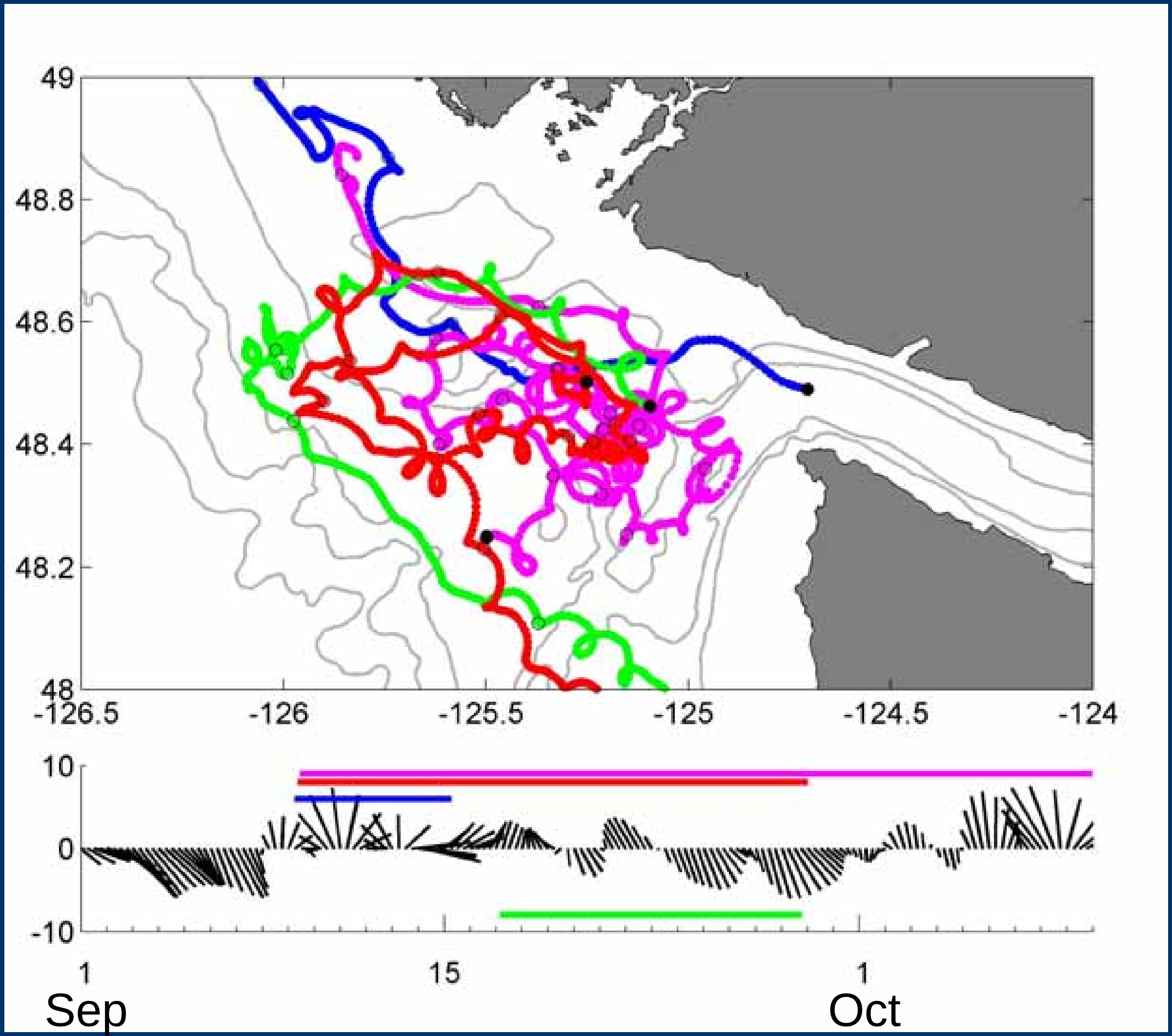
1. September 2003
--RETENTION and ESCAPE--

- drifters approaching southern perimeter of eddy either escape if winds are southward (red trajectory) or remain in the eddy if winds are northward (blue drifter)



September 2004

--RETENTION IN THE EDDY--

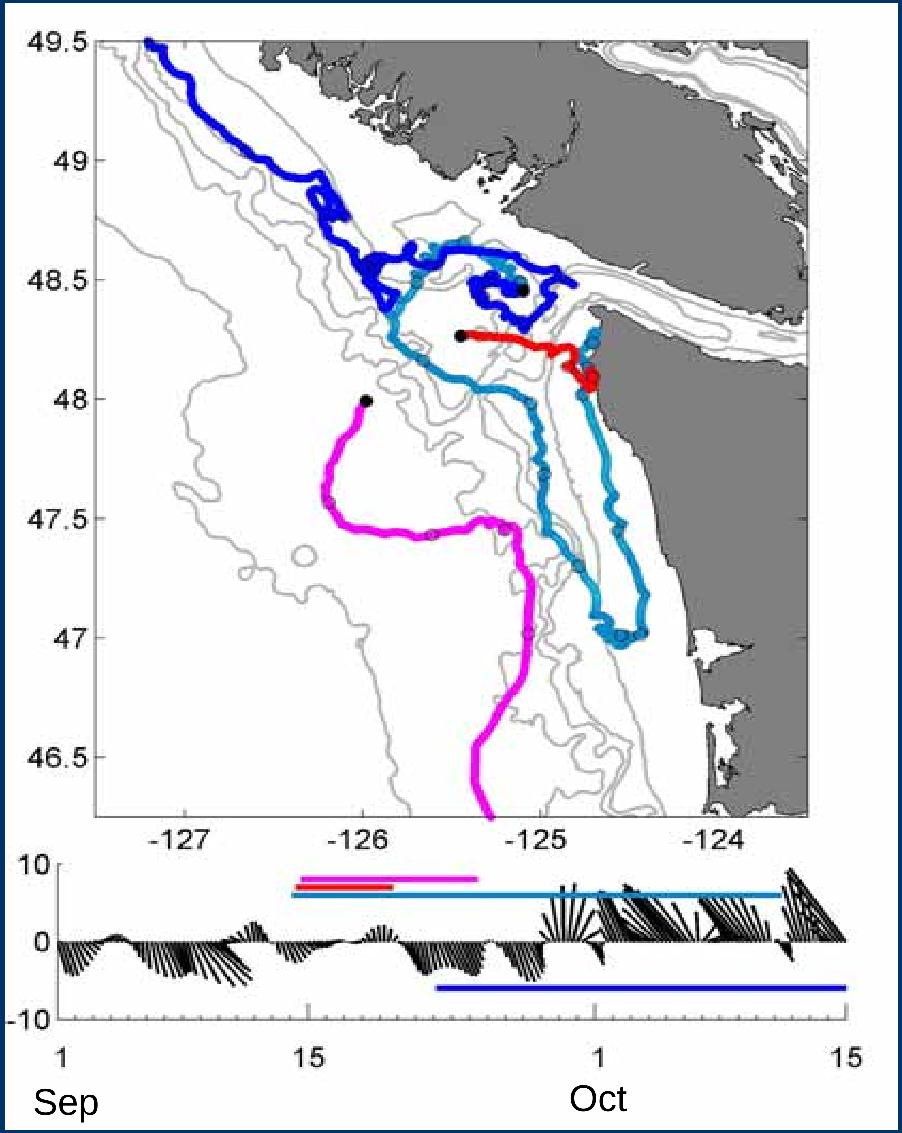


- under variable wind conditions surface particles may be retained in the eddy for long periods (pink drifter, >30 days before exiting to north)

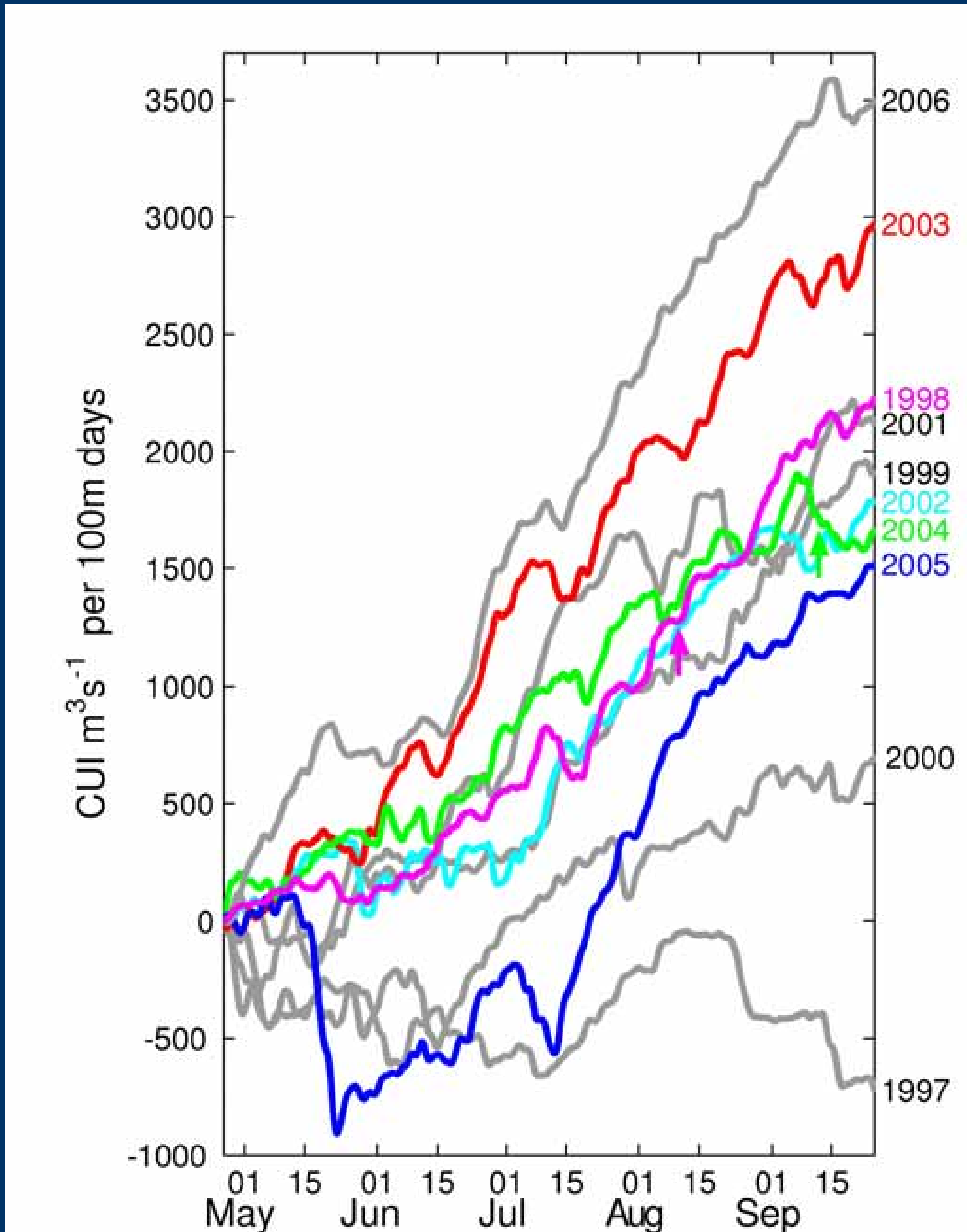
September 2005

--FALL STORM BRINGS DRIFTERS ONSHORE--

- after escaping the eddy to the south during upwelling favorable winds (light blue track), particles may be advected shoreward by subsequent fall storms



Cumulative upwelling index (1997-2006)



Implications for *PN* bloom development and export

- September 2004 – highest concentrations of *PN* and domoic acid in eddy
- 2004 CUI near seasonal mean
- in these years, predominantly upwelling-favorable wind conditions are interrupted by frequent short northward wind reversals
- under these conditions, eddy is very retentive to surface particles – retaining blooms in region of persistent nutrient supply

Summary and conclusions

- toxin is more consistently associated with *Pseudo-nitzschia* in the Juan de Fuca Eddy than in coastal upwelling zone
- retentive circulation patterns and persistent nutrient supply may favor the development of blooms in this region
- eddy increases in spatial extent from early to late-summer
  - more PN and toxin observed in eddy in late summer cruises
  - shellfish closures at coastal sites occur mostly in the fall
- eddy is very retentive to surface particles when summer upwelling-favorable winds are interrupted by frequent reversals to northward winds – "average" summer upwelling index
  - circulation in eddy in September 2004 was much more retentive than during surveys conducted during upwelling – intermittent upwelling/downwelling may maintain blooms in region of moderate nutrients
- ultimately, once blooms develop in the eddy, precise sequence of wind conditions determine if toxic *Pseudo-nitzschia* impact WA state coastal shellfish sites

Acknowledgments

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