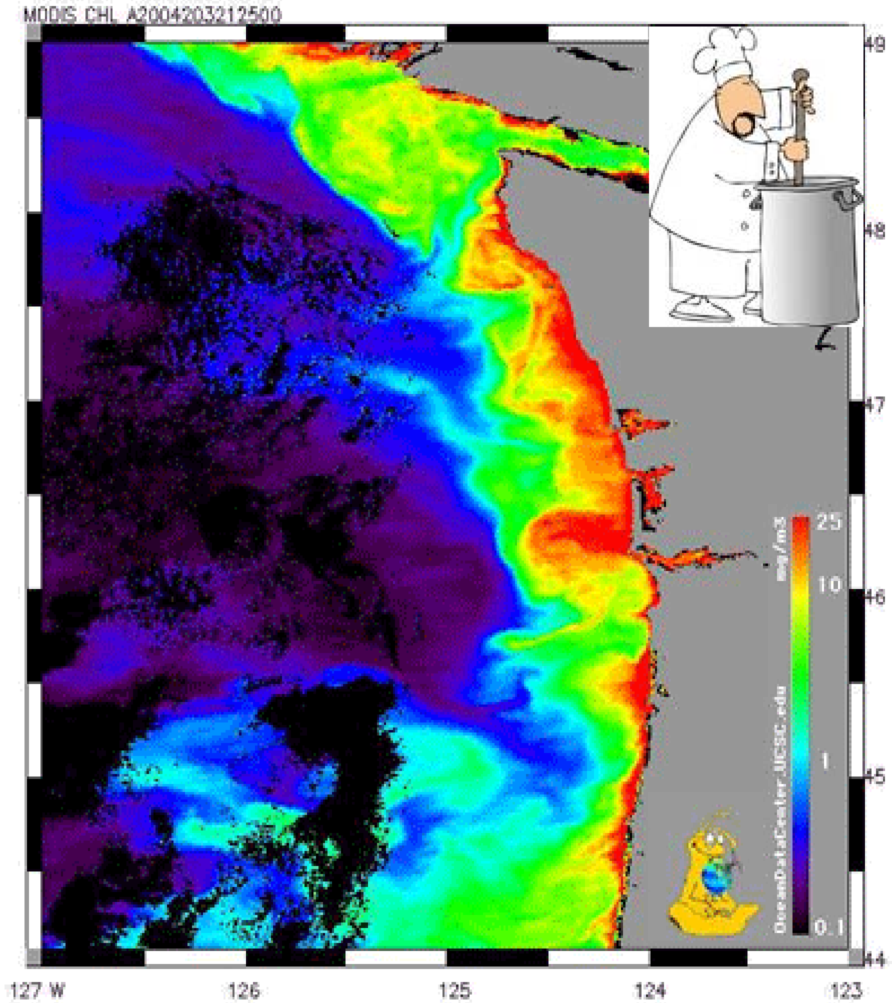
Plume soup: How a dash of river water affects Washington's coastal ecosystem

Alex Horner-Devine
UW Civil and Environmental Engineering

UW Water Center,

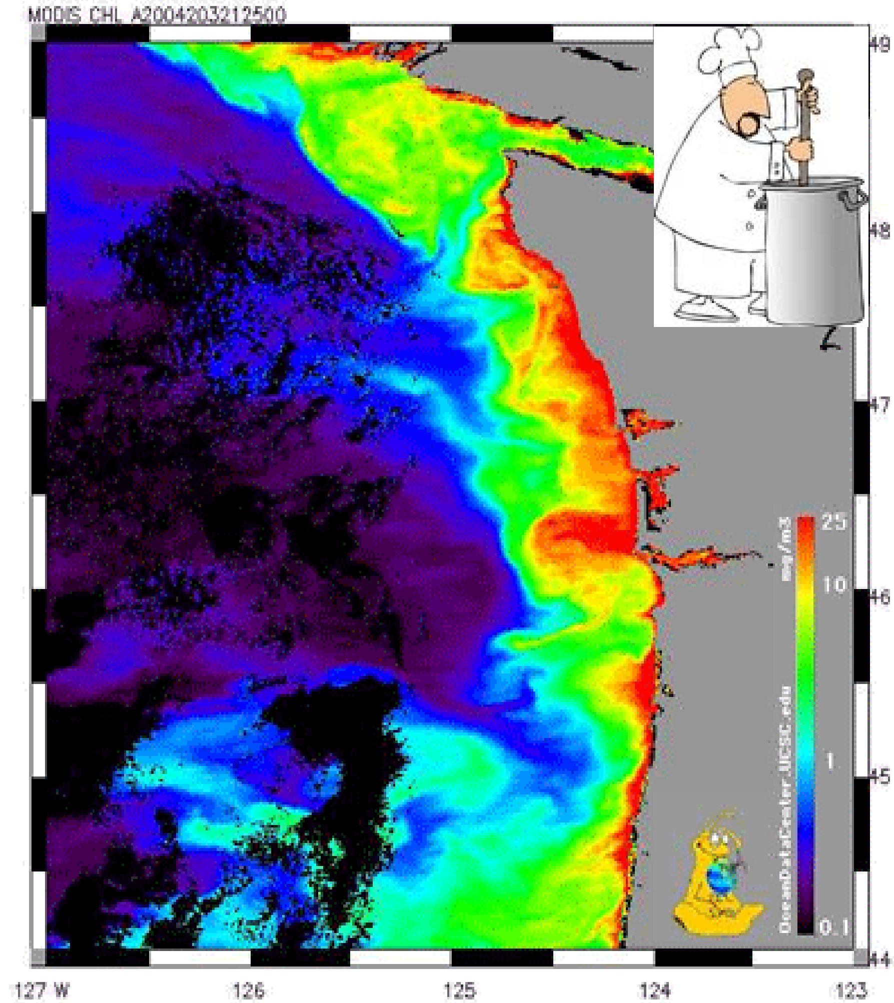
Annual Review of Research,

Feb. 14, 2008

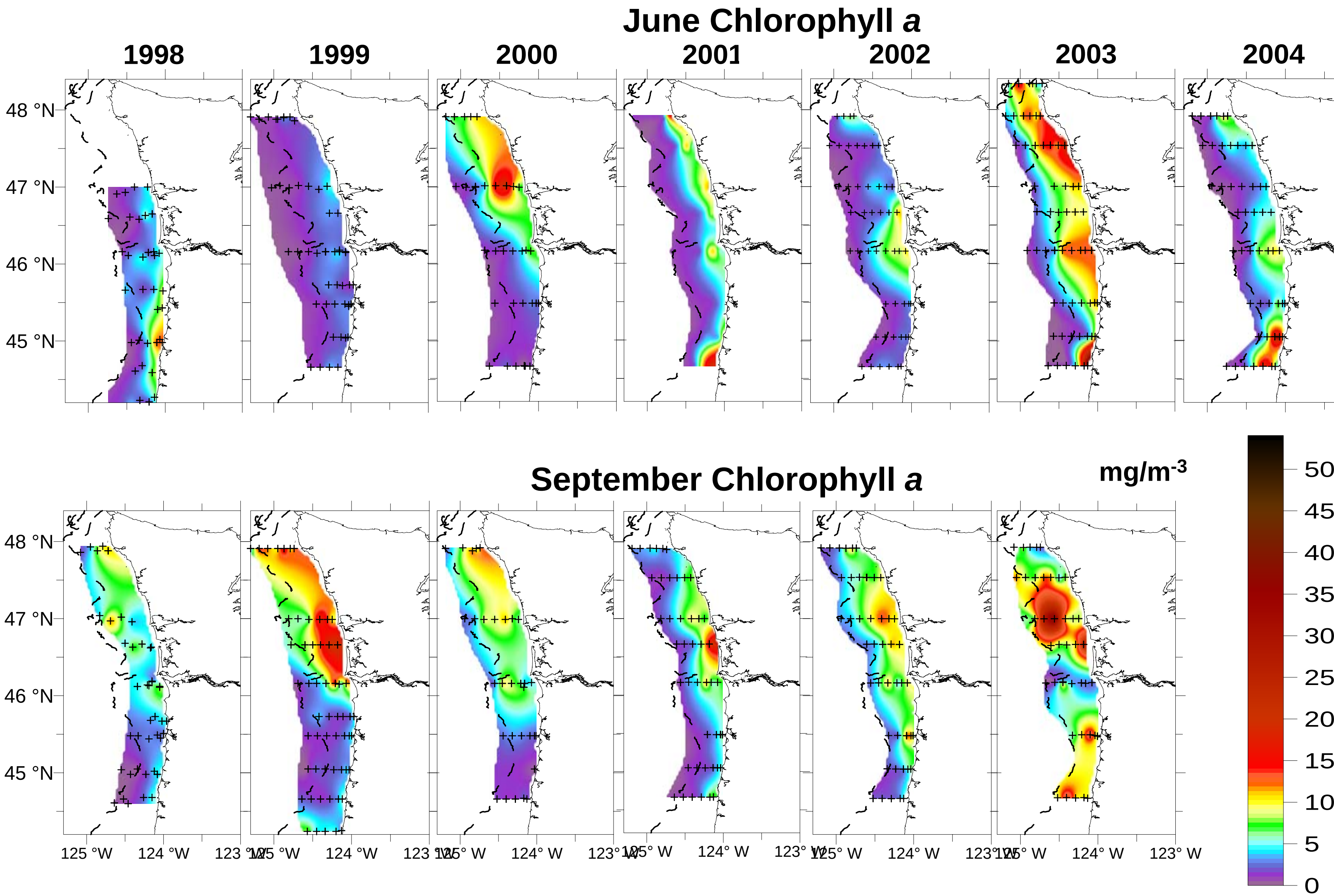


Collaborators: Stephen Monismith, Derek Fong, Tony Maxworthy, David Jay, Emily Spahn
Funding: National Science Foundation, Royalty Research Fund

<u>Paradox:</u> Along the WA-OR coast, where biological productivity has long been associated with upwelling strength, the productivity is highest to the north, where upwelling is weaker.

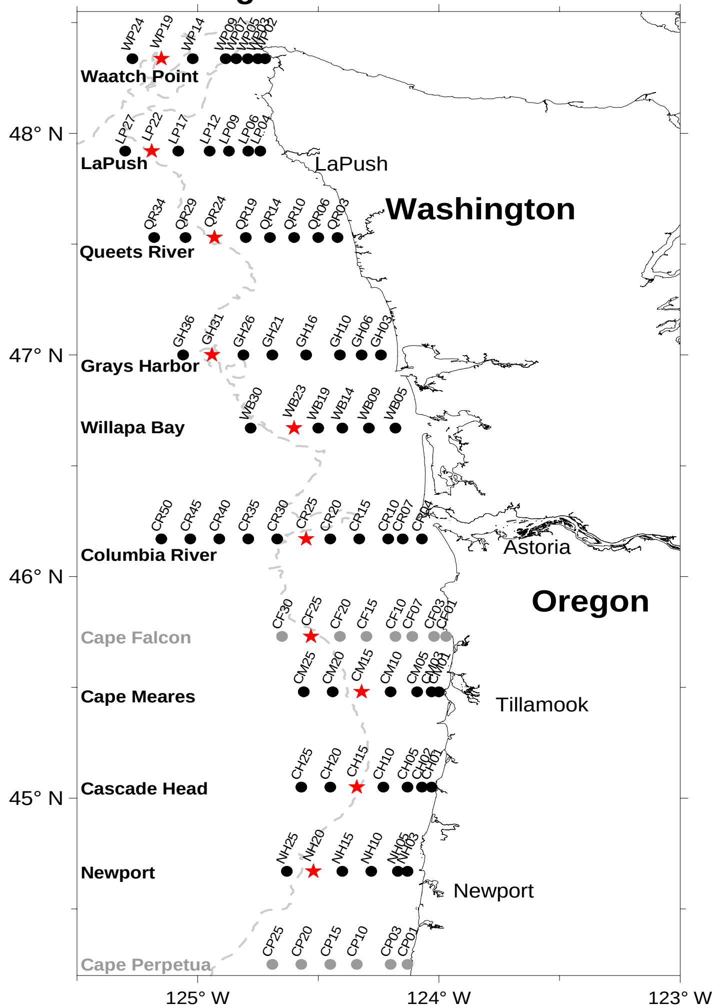


Chlorophyll



Juvenile salmonid study off WA and OR

BPA Plume Study
Target Station Locations

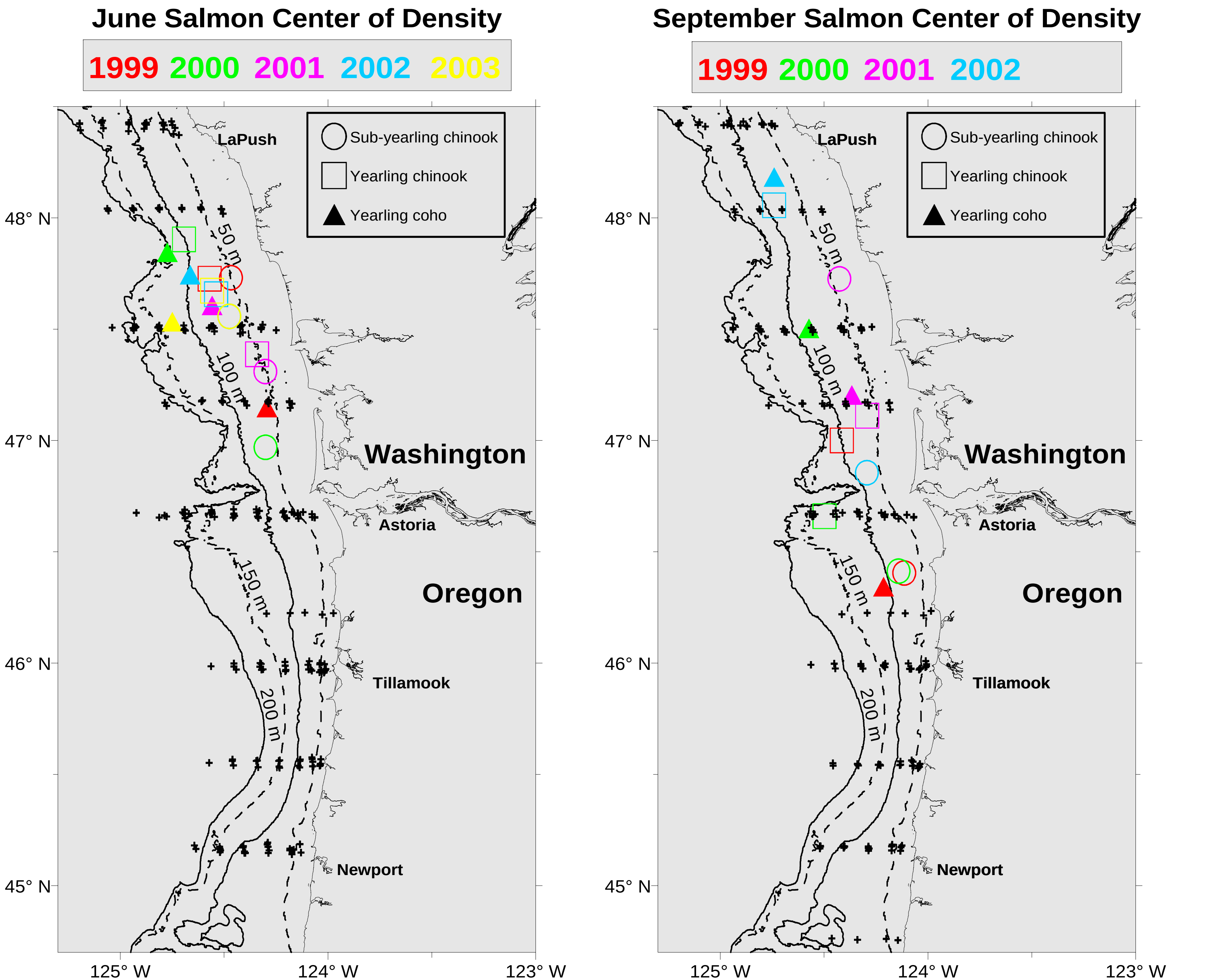


Cape Flattery to Newport; June and September 98-present (n = 6 yr).

8 transects sampled in June & September

2 transects sampled every 10 days April-July

CTD, nutrients, chl, zooplankton, and juv. fishes with pelagic trawl.



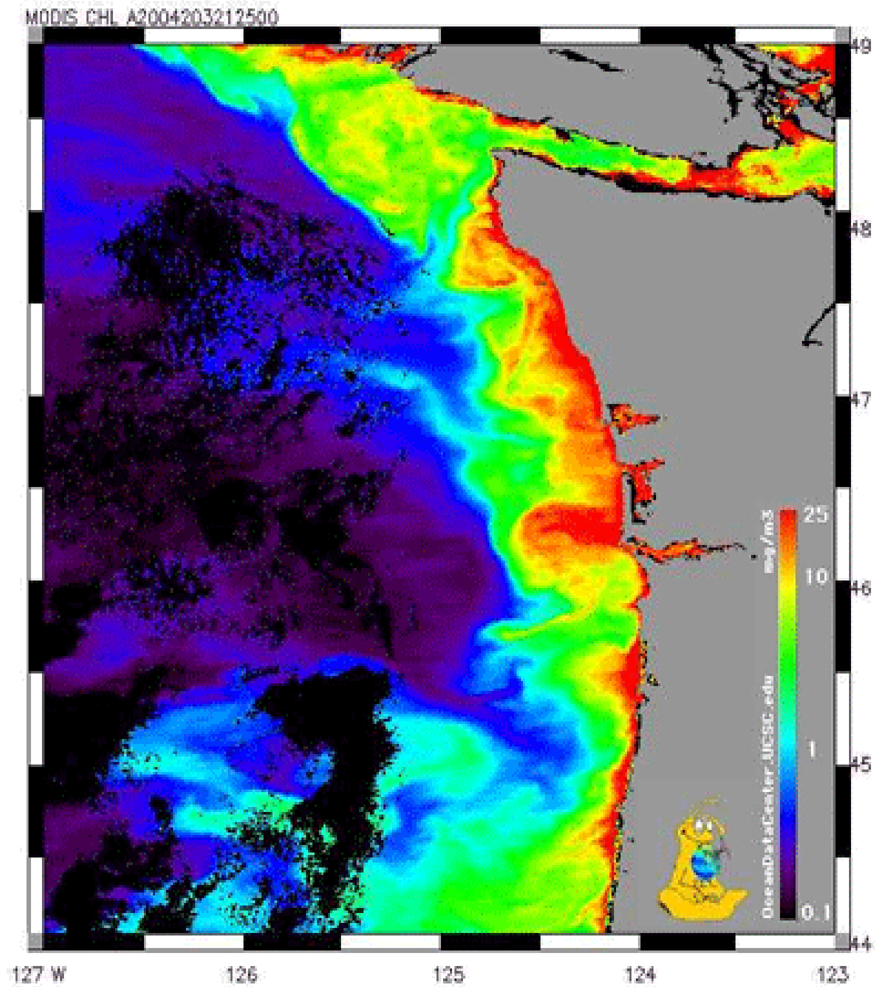
June Salmon Center of Density
1999 2000 2001 2002 2003
Sub-yearling chinook
Yearling chinook
Yearling coho
LaPush
Washington
Astoria
Oregon
Tillamook
Newport
50 m
100 m
150 m
200 m
48° N
47° N
46° N
45° N
125° W
124° W
123° W
September Salmon Center of Density
1999 2000 2001 2002
Sub-yearling chinook
Yearling chinook
Yearling coho
LaPush
Washington
Astoria
Oregon
Tillamook
Newport
50 m
100 m
150 m
200 m
48° N
47° N
46° N
45° N
125° W
124° W
123° W

Plume soup

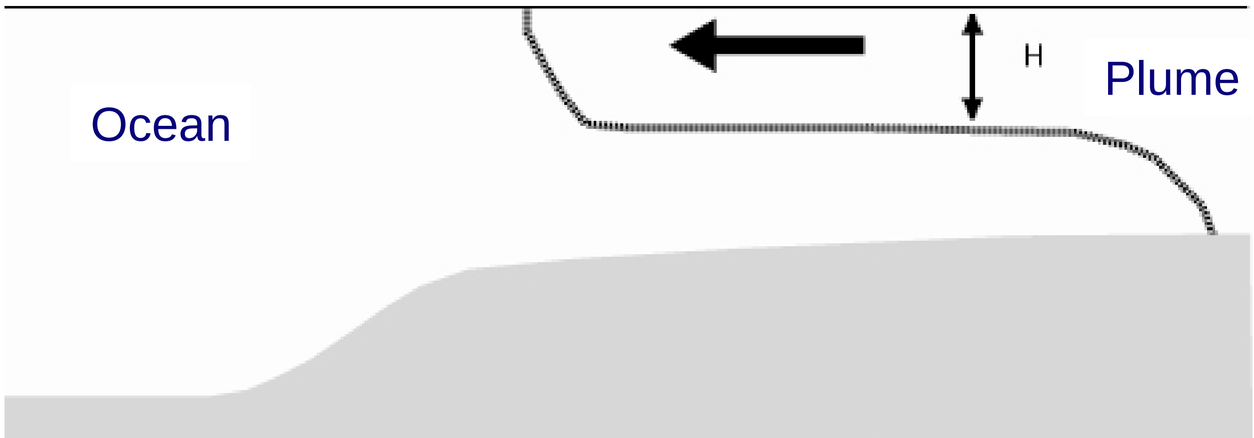
Average discharge = 7000 m^3/s

Approximate volume of shelf waters = 4×10^{12} m^3

Daily contribution from river =0.02%
= a dash

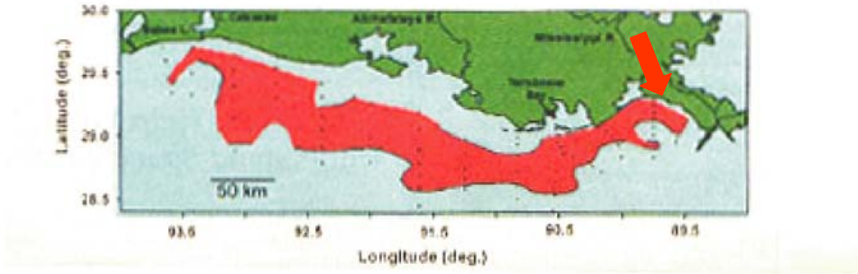


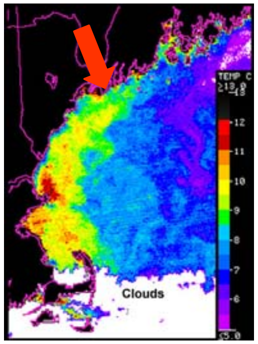
Plume Physics: Buoyancy

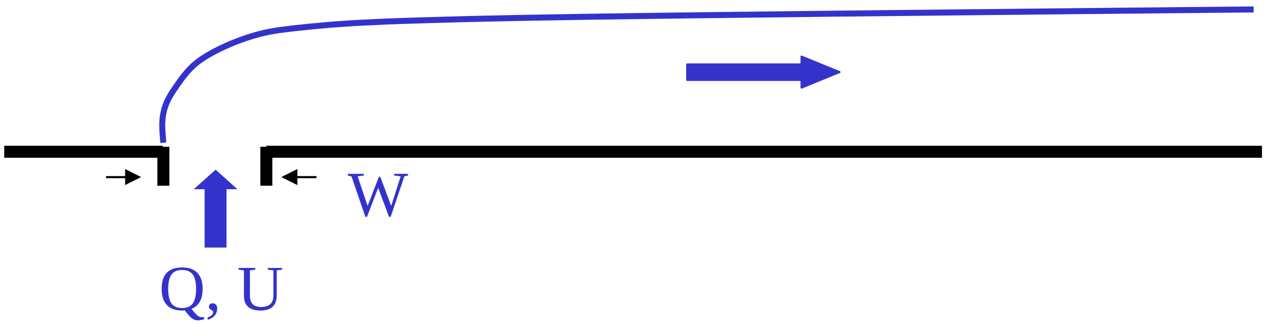


Density of river water is less than that of ocean water due to salt.

Plume Physics: Rotation

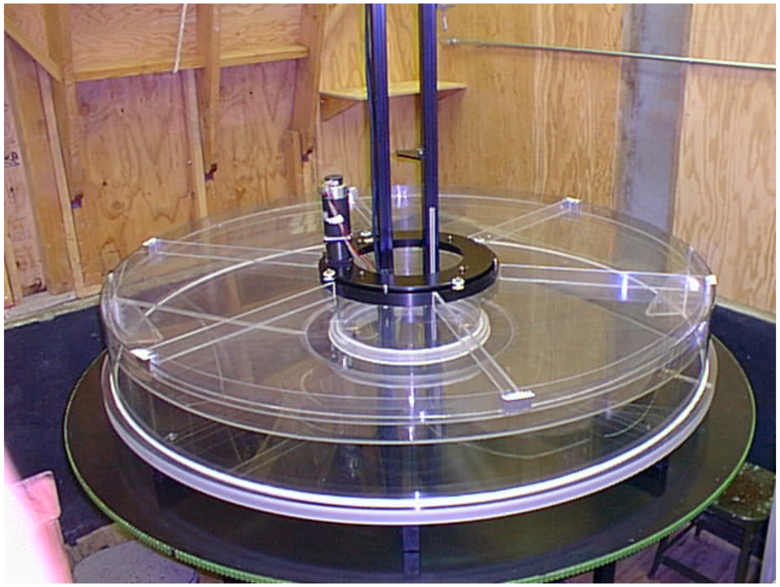


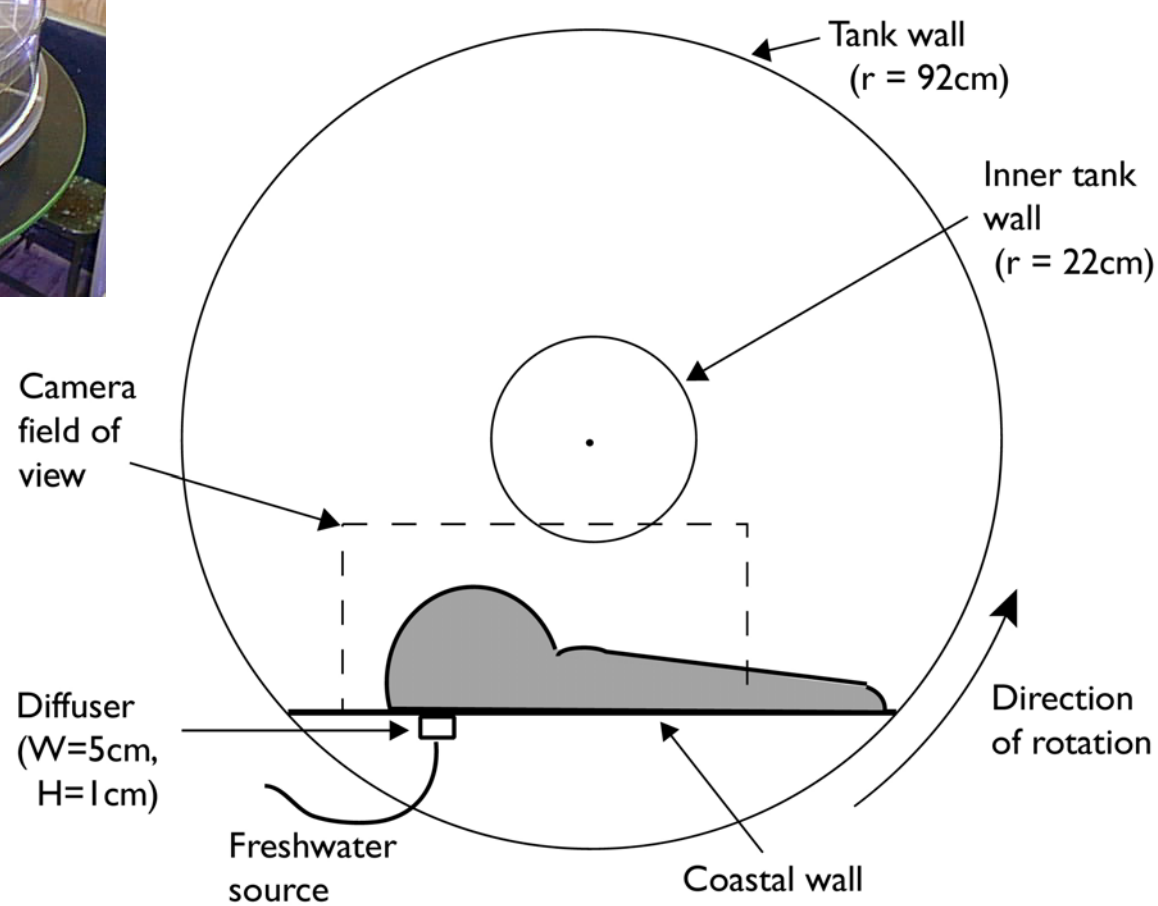




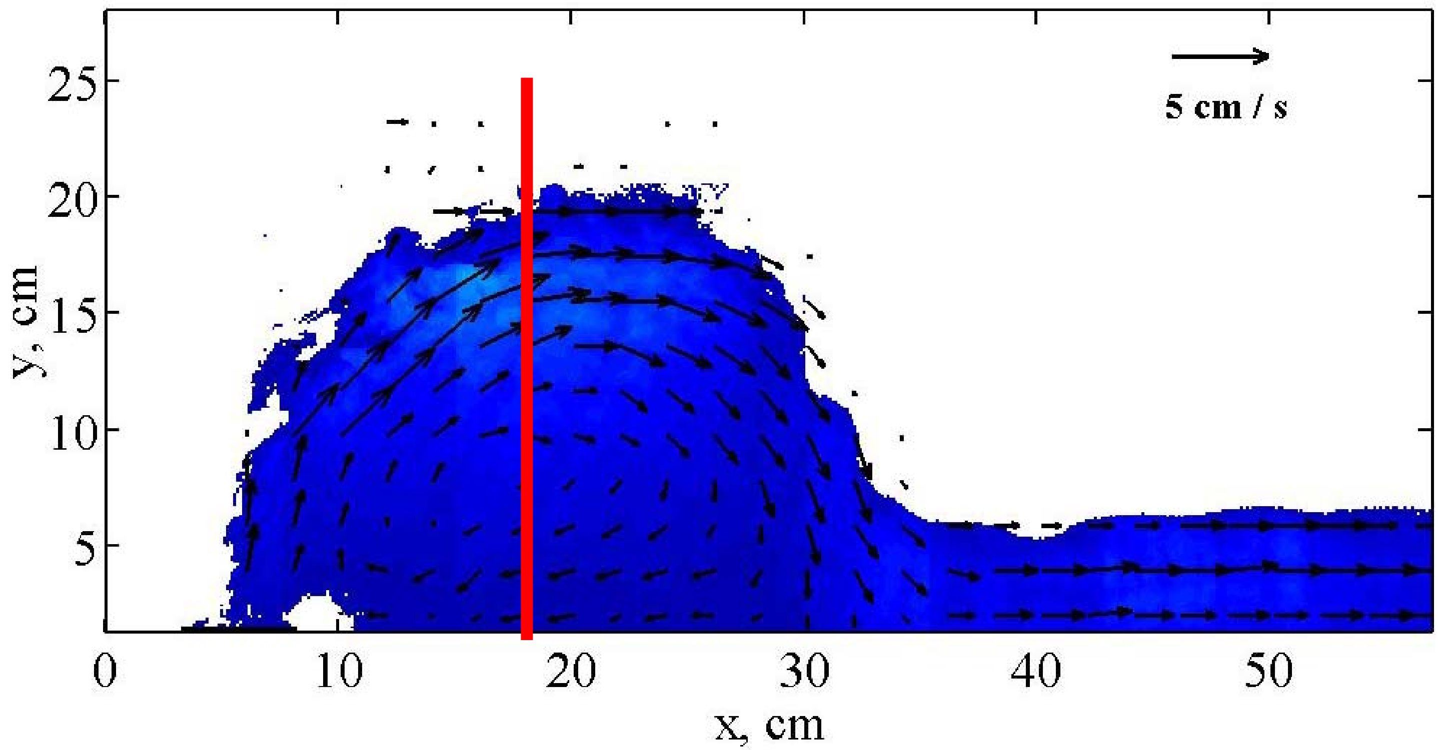
Earth's rotation causes flow in the northern hemisphere to be deflected to the right.

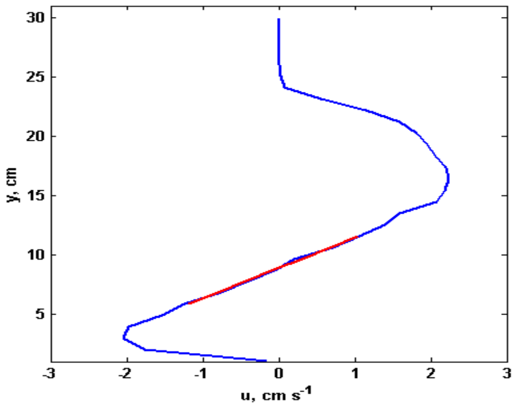
Laboratory modeling of river plumes





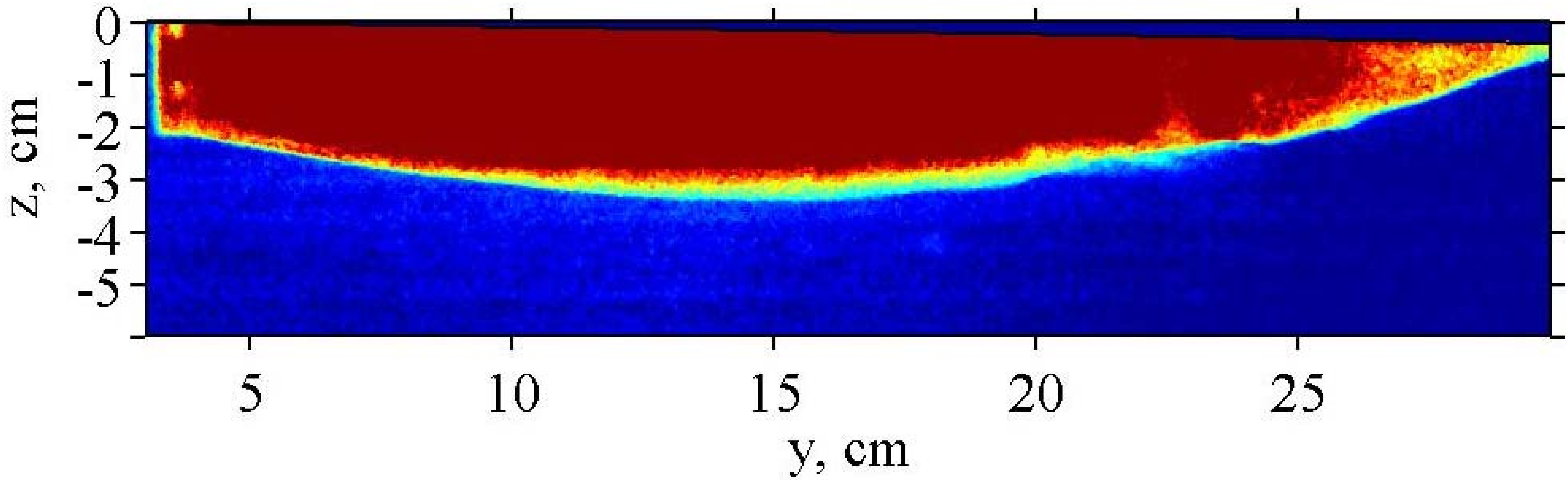
Laboratory plume



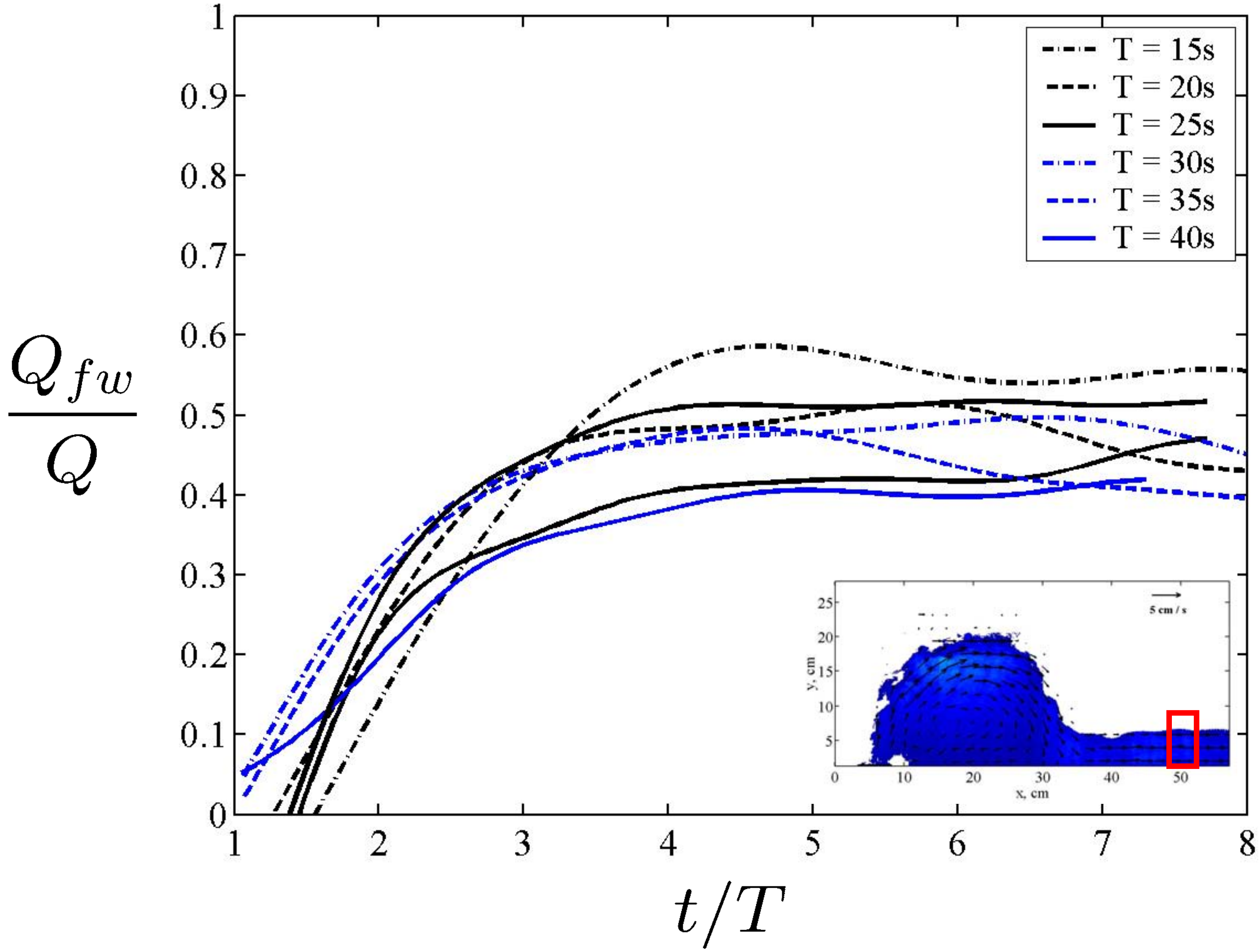


Velocity profile shows re-circulation

Depth

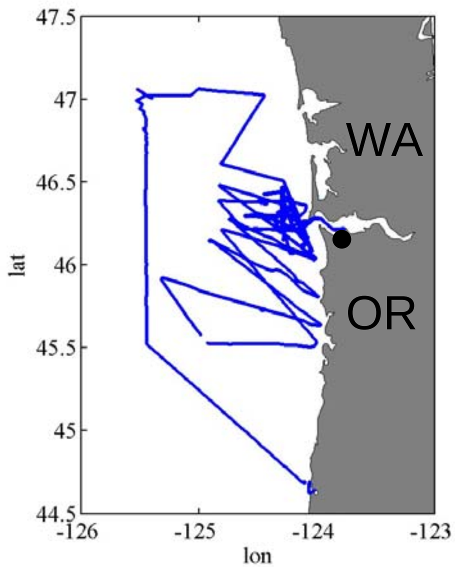


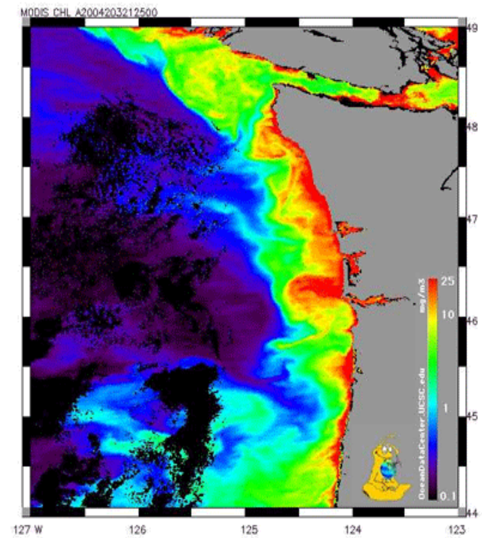
Approximately 50% of river discharge accumulates in an eddy near the mouth, referred to as "the bulge"



RISE

River Influences on Shelf Ecosystems

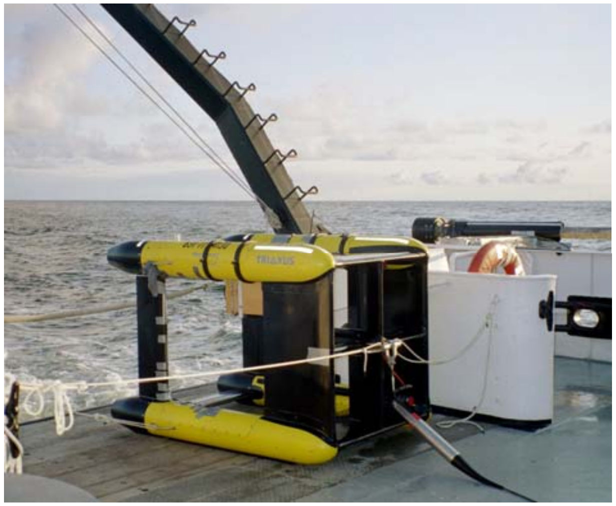


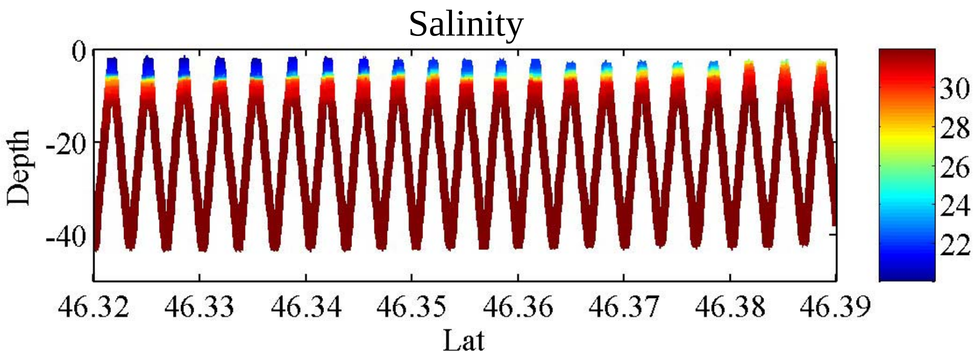


Courtesy of Raphael Kudela

Four cruises: July 2004, June 2005, August 2005, June 2006
Two vessels: R/V Pt. Sur (physical), R/V Wecoma (biological, geochemical)

Sampling configuration





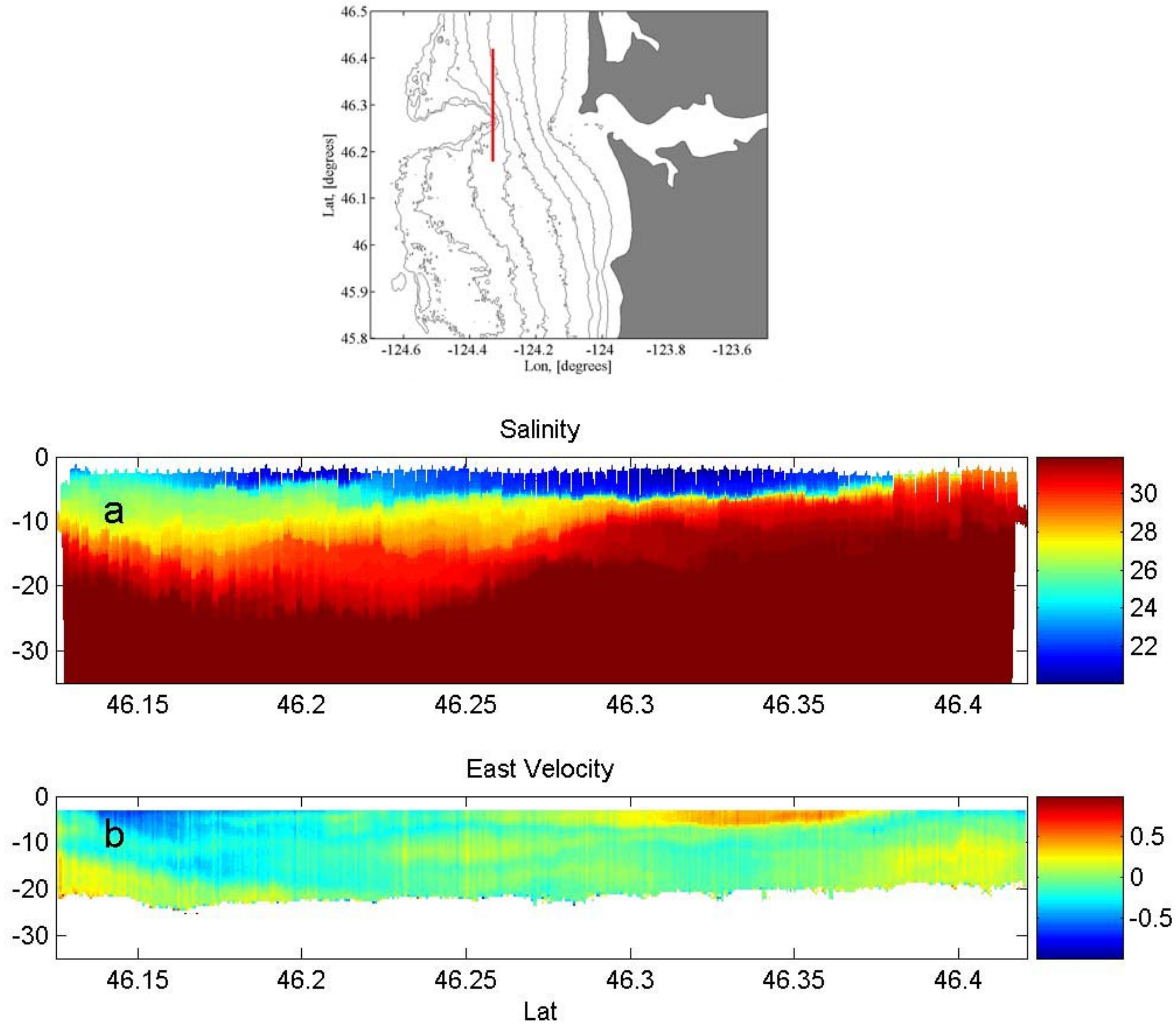
Triaxus tow-fish:

- CTD sampling between -60m and -1m depth
- ~1 minute repeat time
- 7 knots boat speed
- an uneasy relationship with crab pots

1200 kHz ADCP

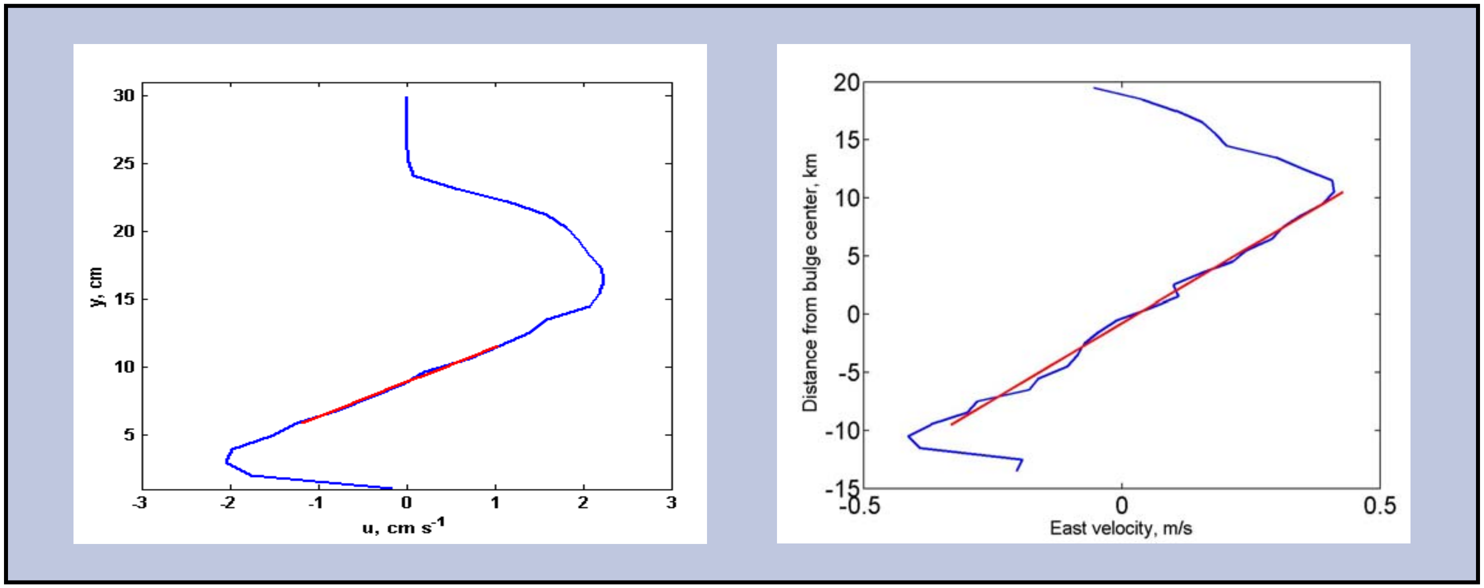
- Vessel mounted

NS transect



46.5
46.4
46.3
46.2
46.1
46
45.9
45.8
Lat, [degrees]
-124.6
-124.4
-124.2
-124
-123.8
-123.6
Lon, [degrees]
Salinity
a
0
-10
-20
-30
46.15
46.2
46.25
46.3
46.35
46.4
30
28
26
24
22
East Velocity
b
0
-10
-20
-30
46.15
46.2
46.25
46.3
46.35
46.4
Lat
0.5
0
-0.5

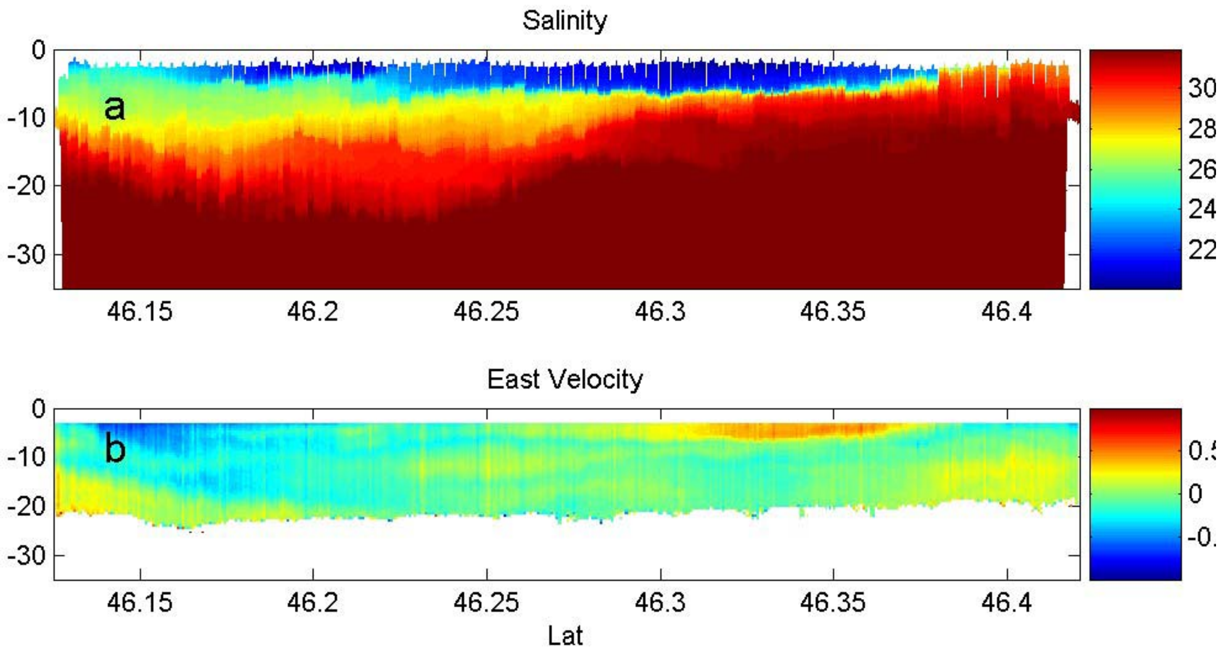
25cm plume predicts 35km plume!

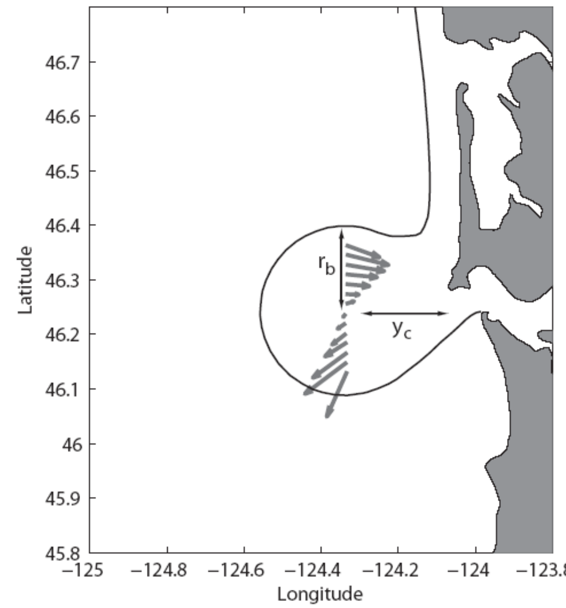


Laboratory plume

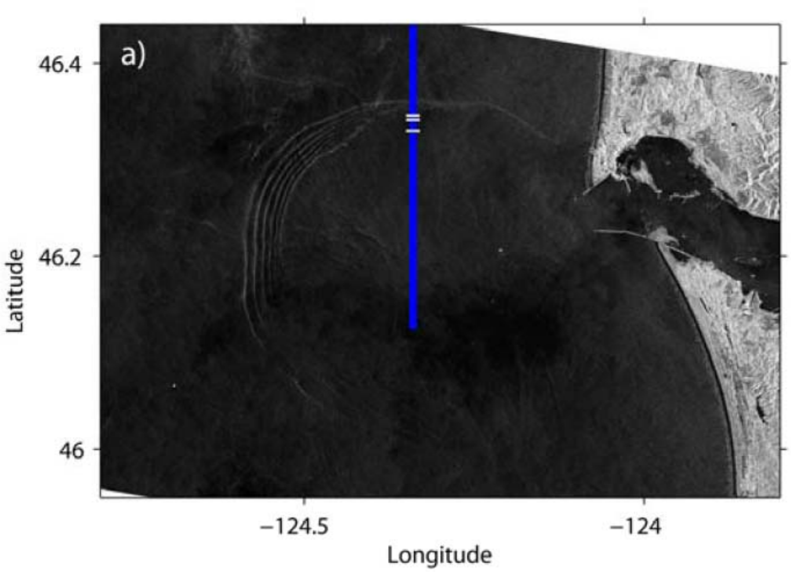
Columbia River plume

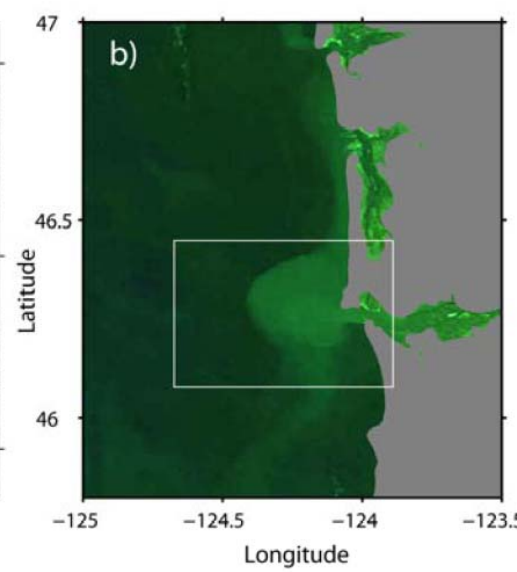
NS transect





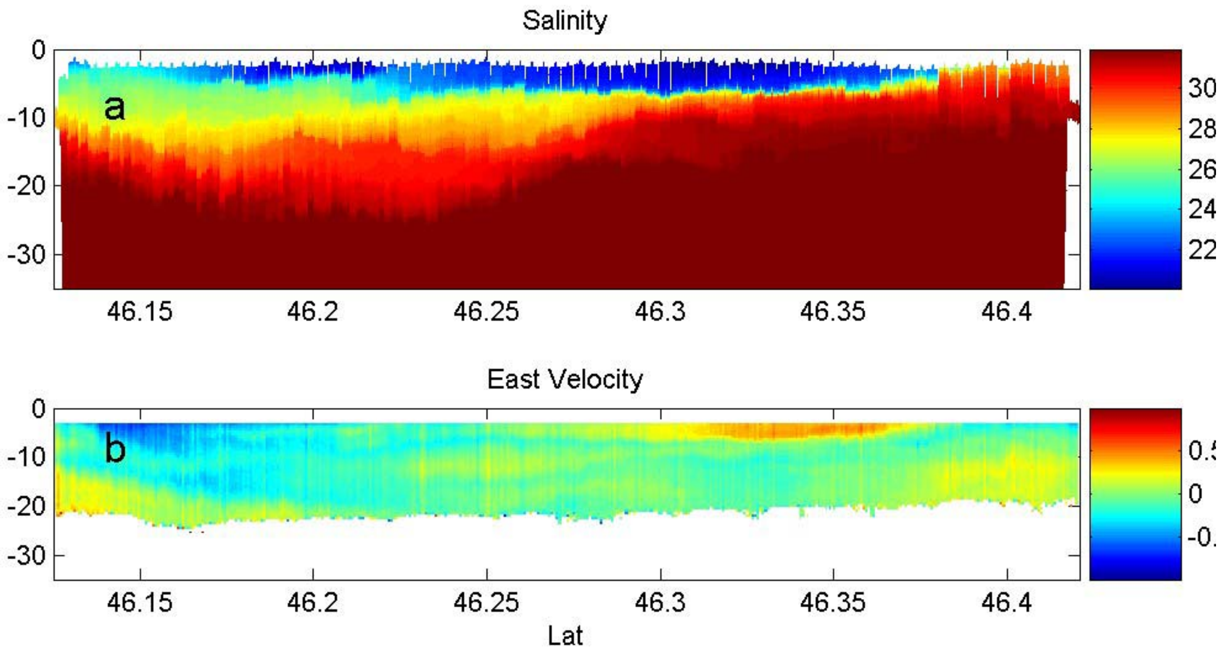
SAR Image
Thanks to
Jiayi Pan
(PSU)

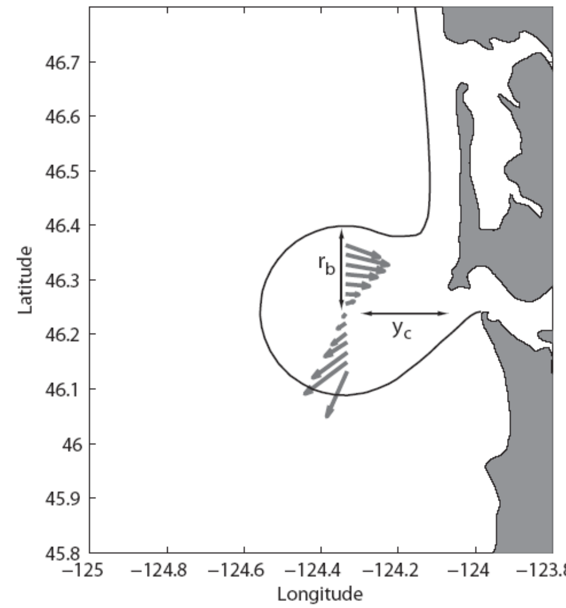




MODIS Image
Thanks to
Raphael Kudela
(UCSC)

NS transect



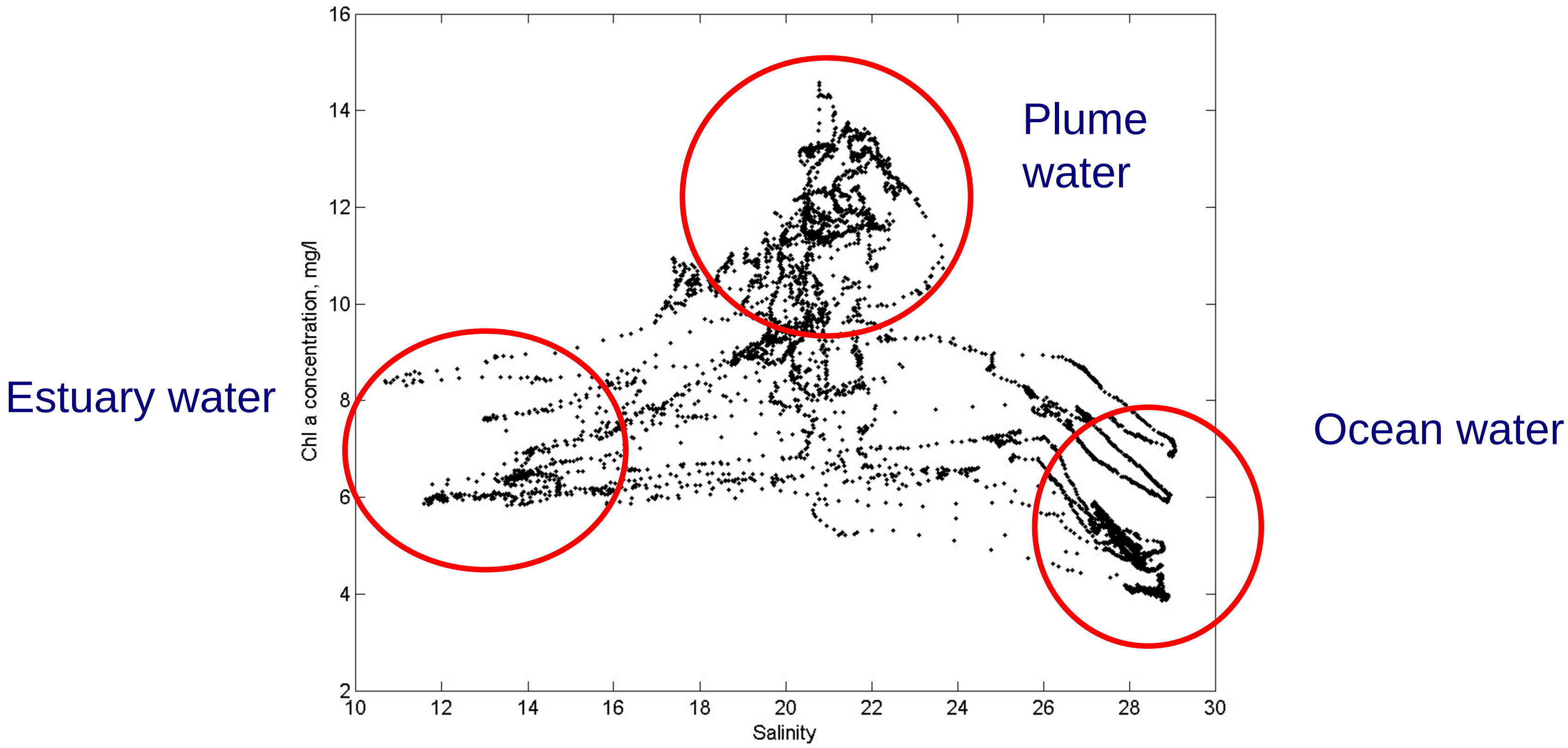


Volume of freshwater

$$V_{fw} = \int_0^{\pi} \int_0^{-H} \int_0^{R} \frac{\Delta S}{S_o} dr dz d\theta.$$

Bulge volume = 4-8 days worth of discharge

Consequences

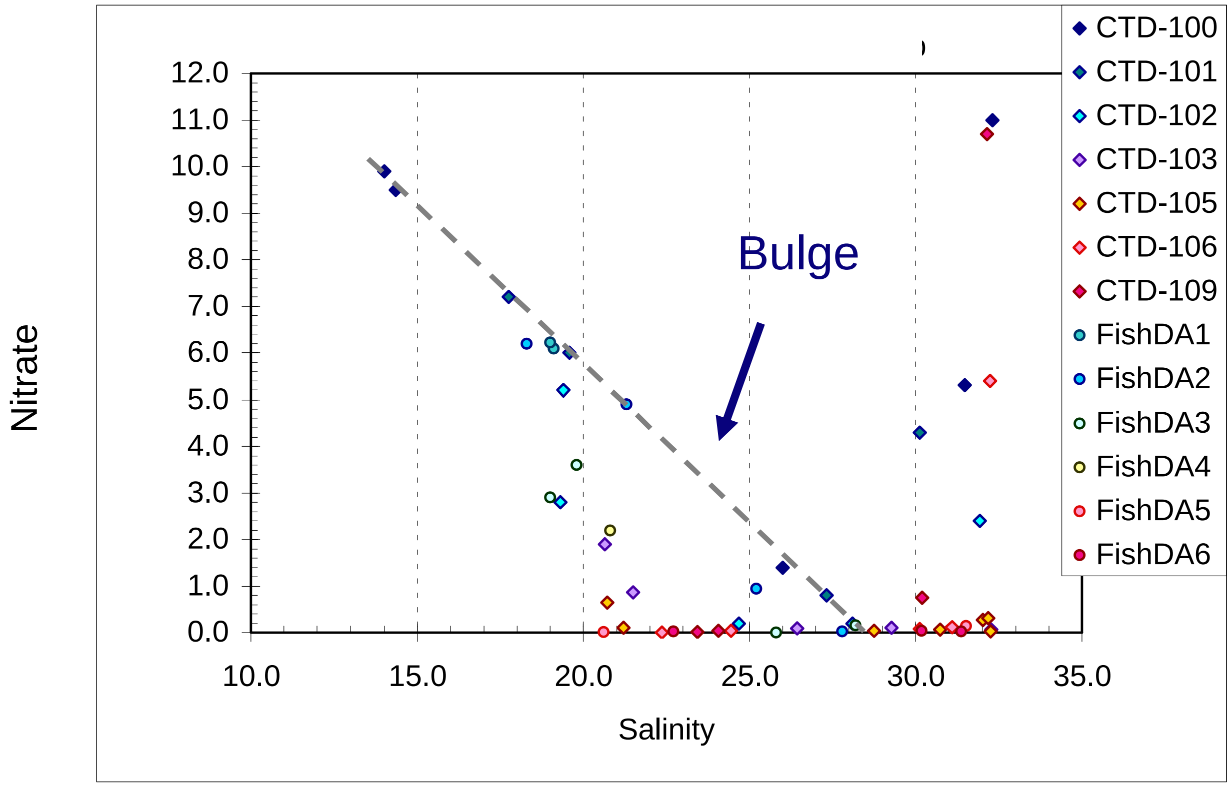


Timescale for plankton growth ~ 4-5 days

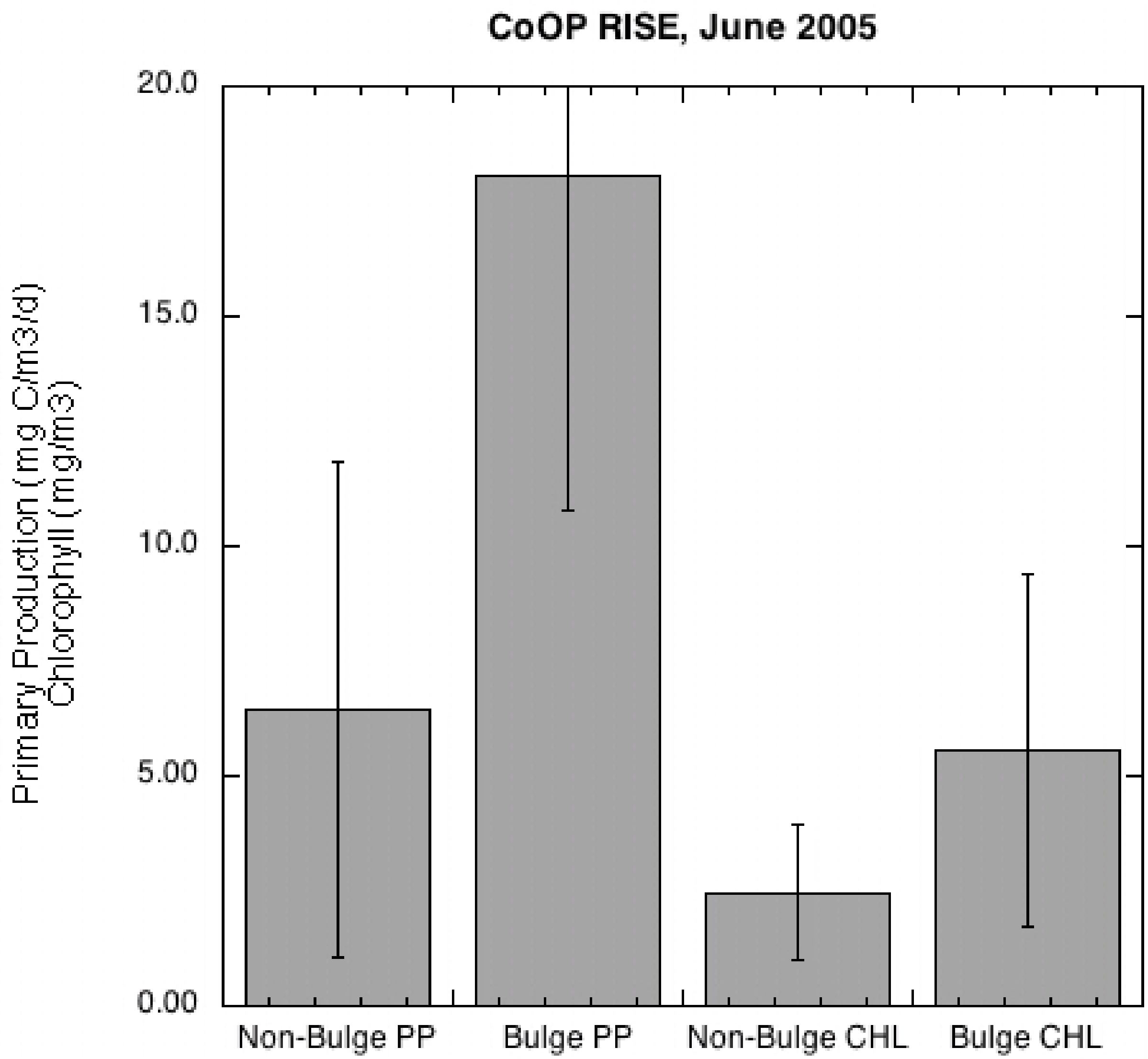
Bulge retention time ~ 4-8 days

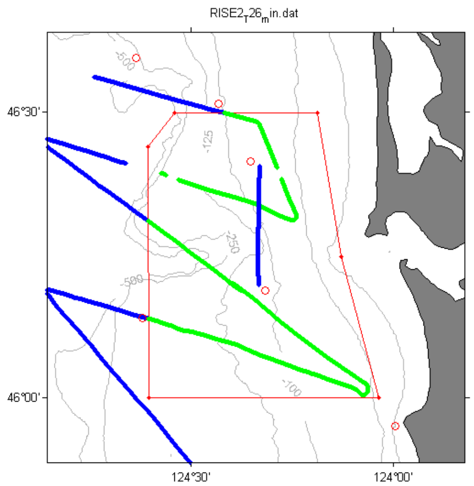
Horner-Devine *et al.*, accepted J. Mar. Sys.

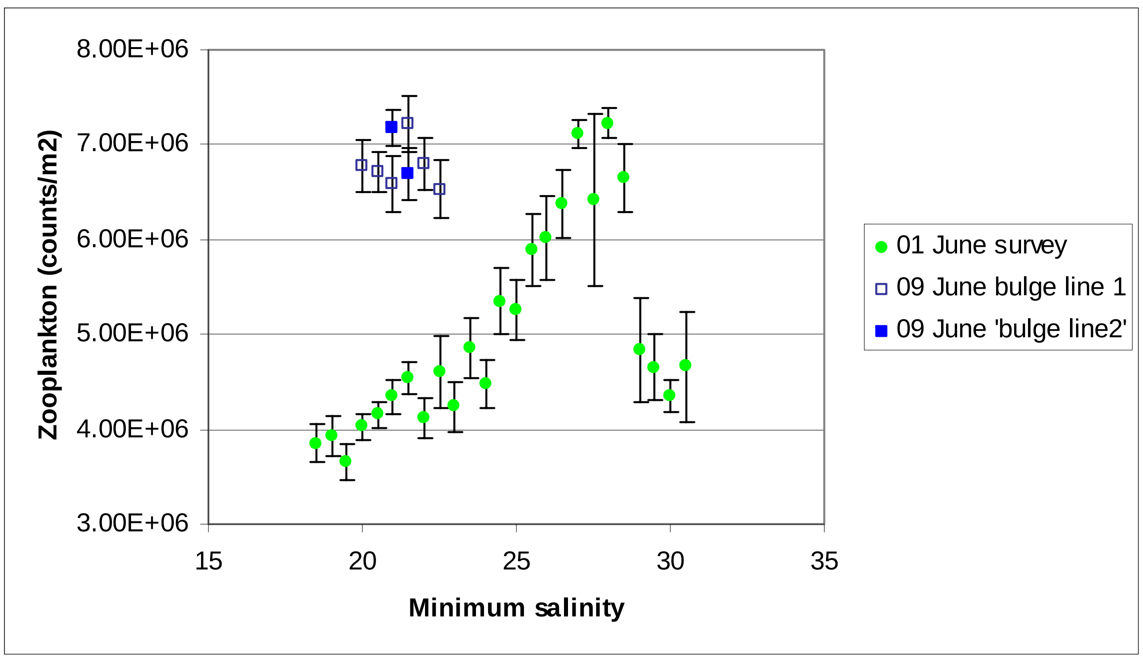
Draw-down of nitrate, silicate and iron



Plume productivity







The average abundance of zooplankton-sized particles in the vicinity of the bulge was higher than other regions of similar surface salinity

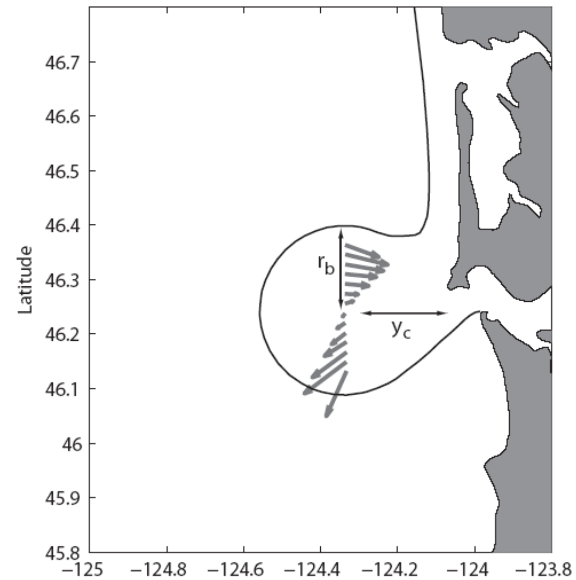
The Columbia Plume

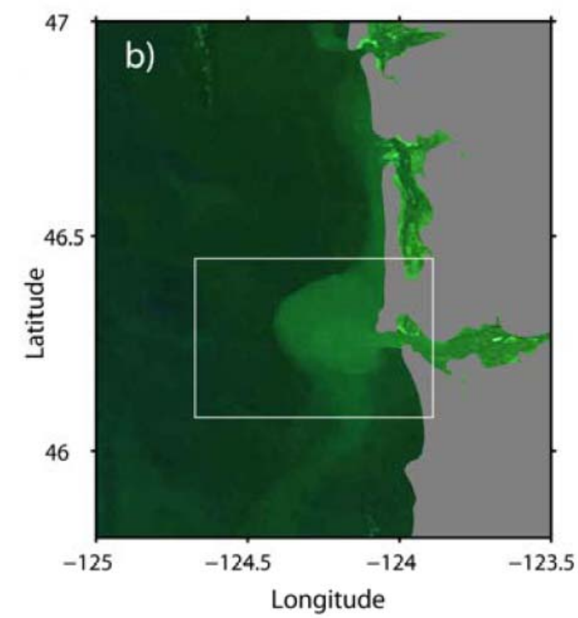
•mixes upwelling-derived nutrients with nutrients from the river

•provides long residence times (under certain conditions) in near-surface waters, which make for optimal growth conditions

•has significantly enhanced rates of primary productivity compared with local waters

•supports enhanced productivity up the food chain





Thanks