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Frontal Processes in the Columbia River Plume Area

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RISE
River Influences on Shelf Ecosystems

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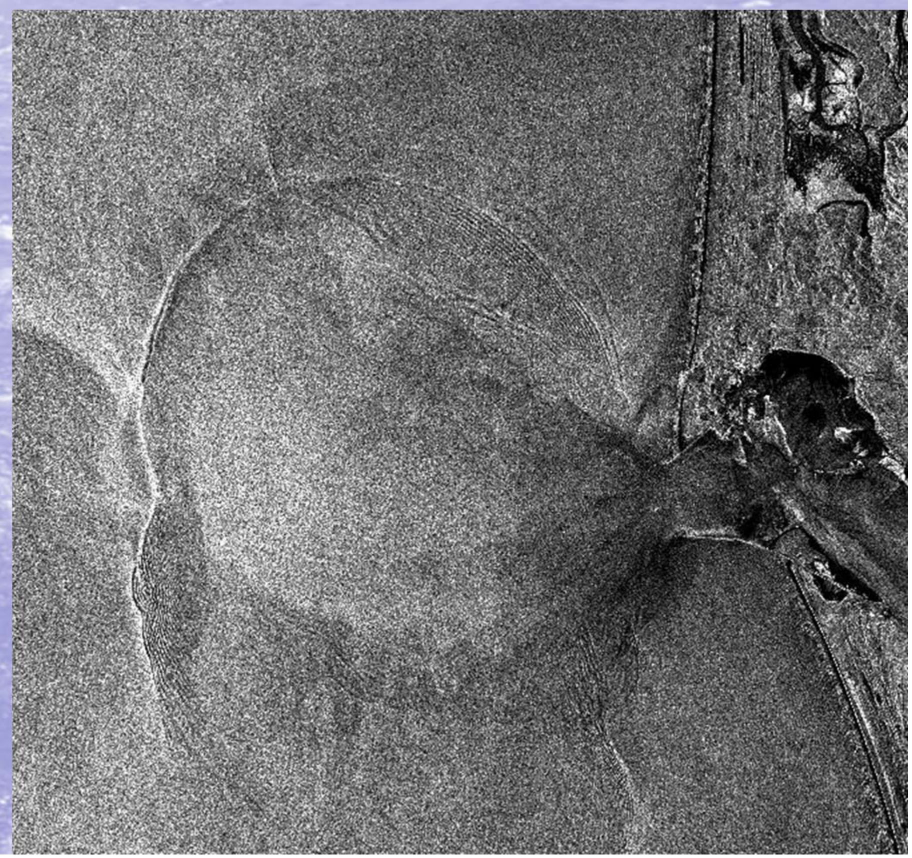

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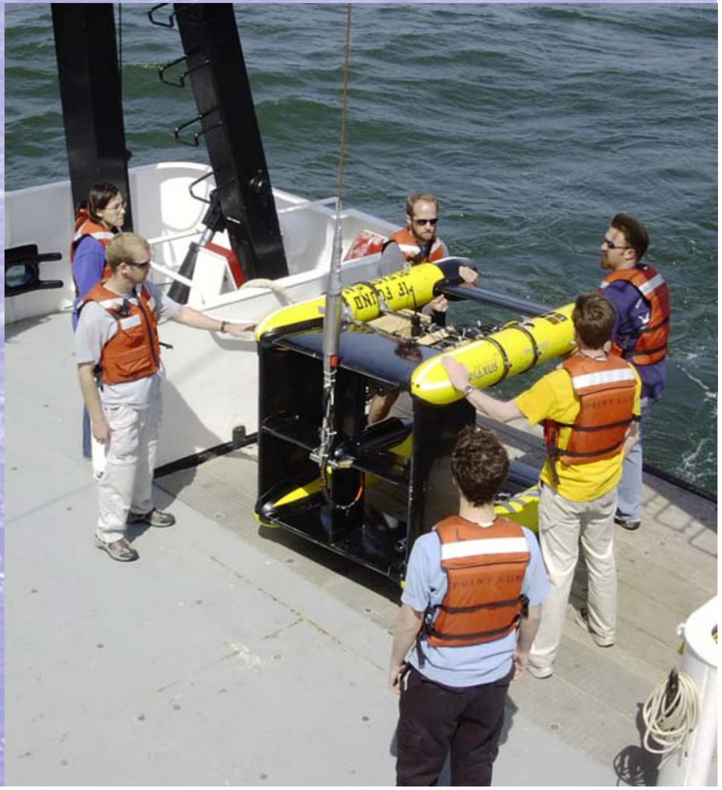
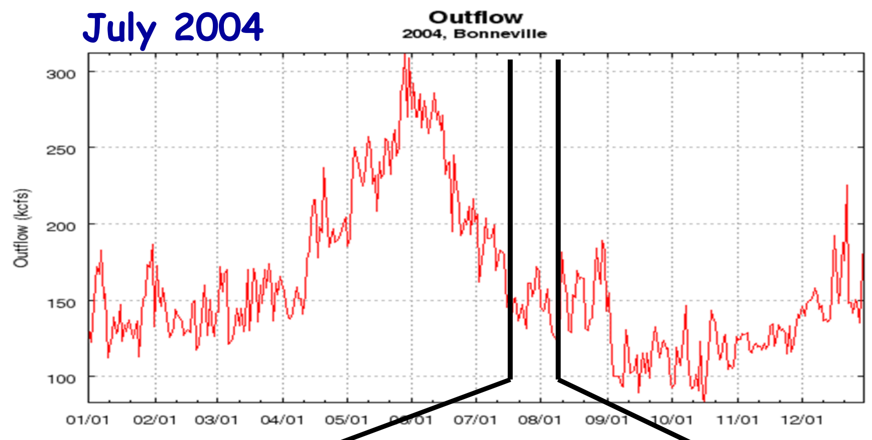
Phenomenology of CR Plume Fronts –

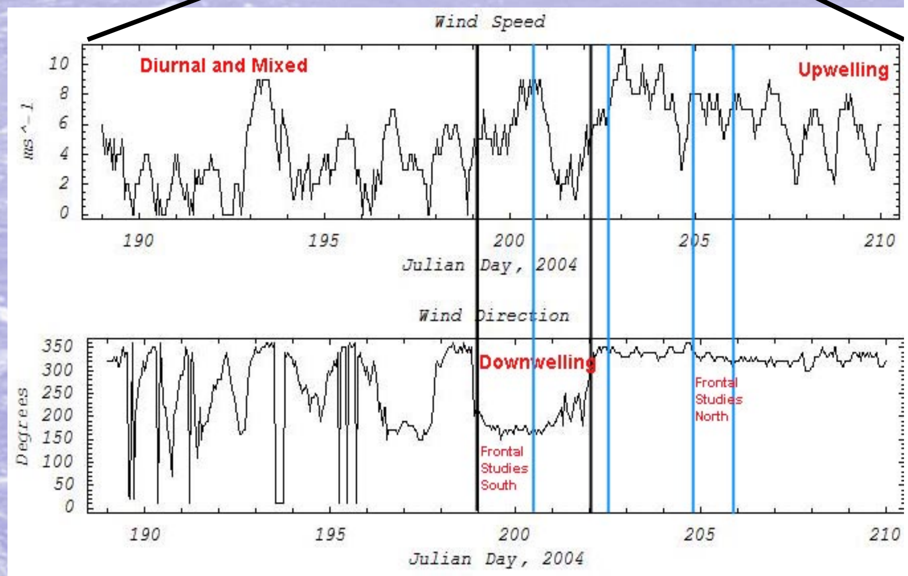
- A wide variety of fronts are seen in the plume area:
  - What are their characteristics?
  - How are they generated?
  - How much mixing do they cause?
- Fronts also generate internal waves (IW):
  - IW cause mixing and advect plume waters across fronts
  - See Pan and Jay poster for quantitative analysis
- What is the role of fronts and IW in plume-area productivity?
- Discussion here is based on:
  - SAR and ocean color images
  - TRIAXUS transects (multiple sensors), July 2004 and June 2005

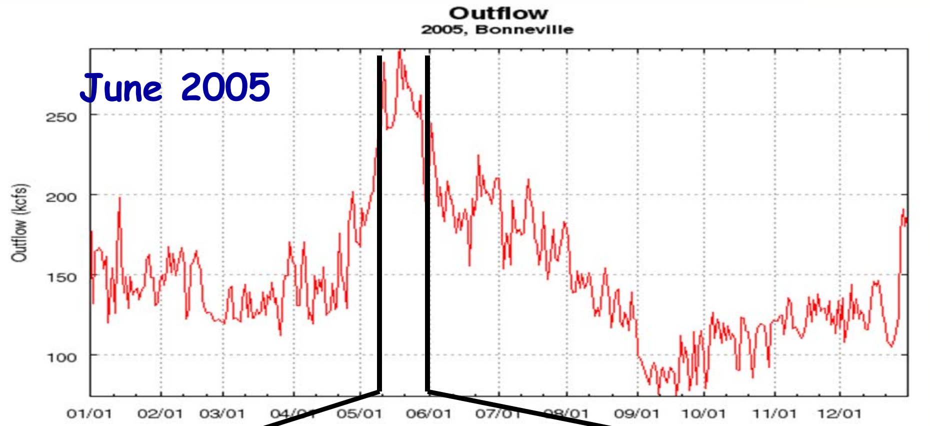


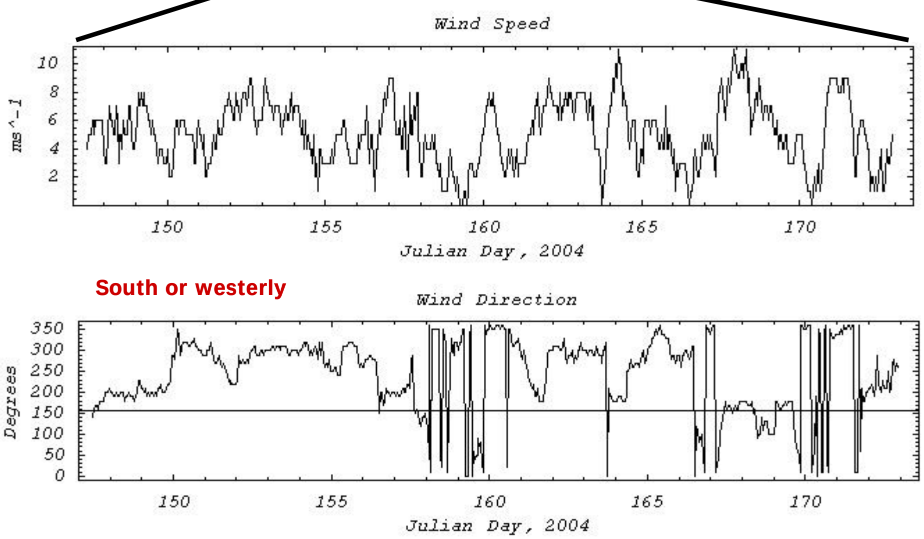
Climate Context –

- 2004: low-flow year, cruise 1 mo after freshet peak, some upwelling
- 2005: just after weak freshet, rainy May - extra nutrients from coastal streams; little or no upwelling at coast





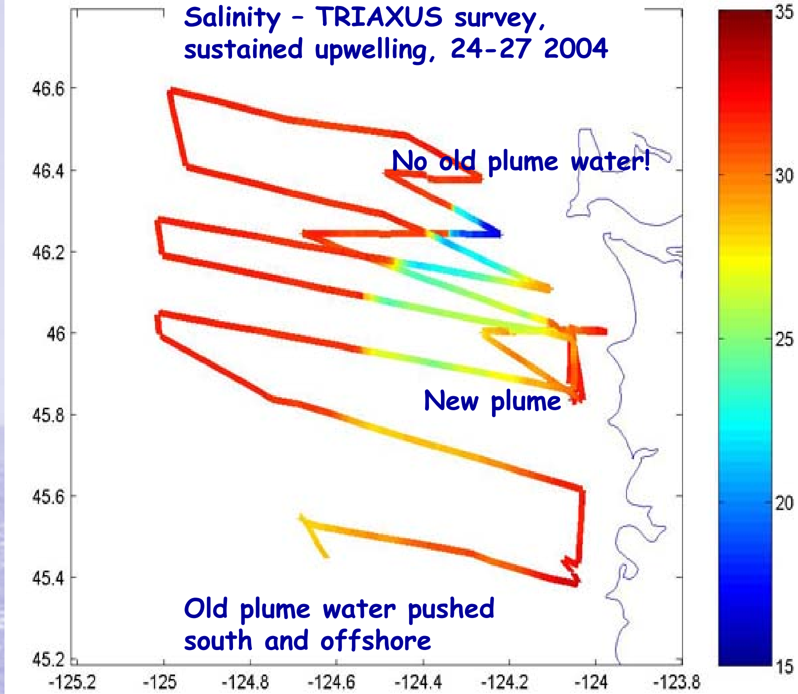


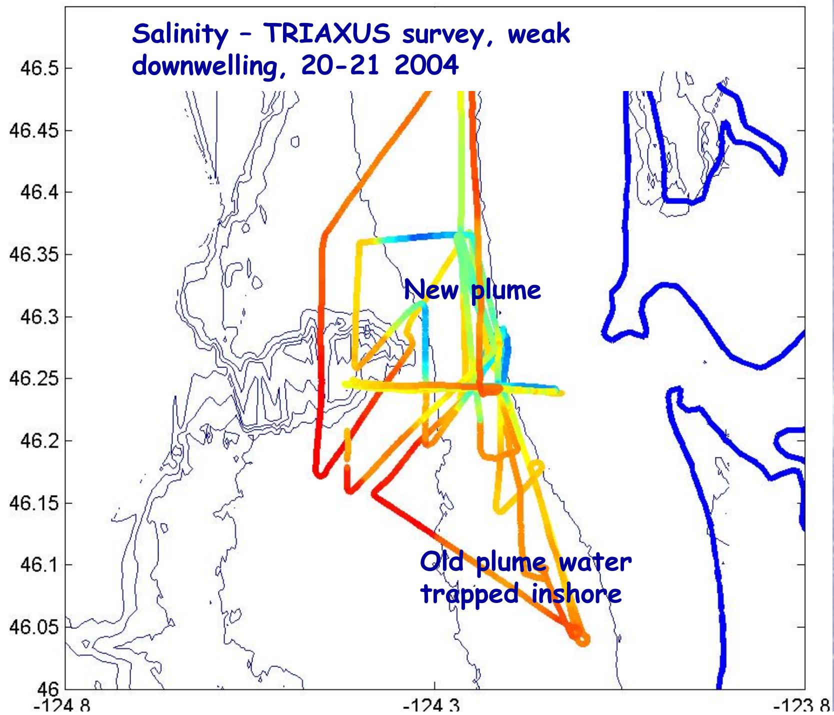


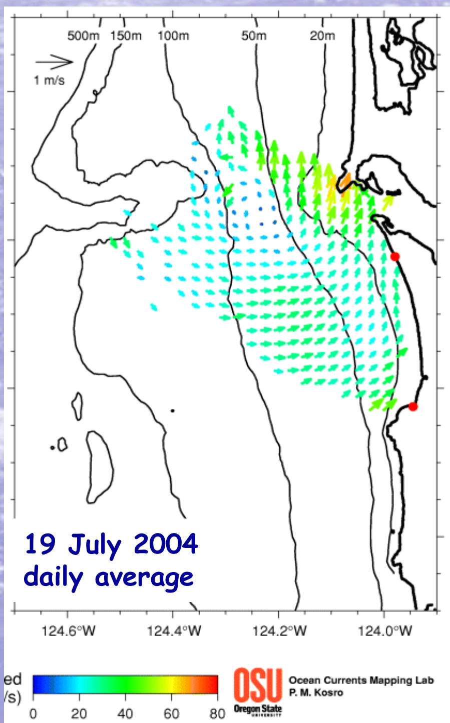
Plume Responses –

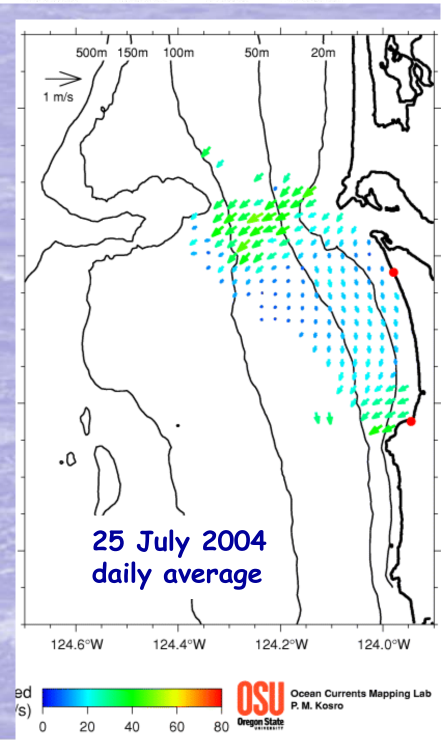
Contrasts between upwelling and downwelling

- Upwelling: plume to south, high salinity water onshore. Old plume is south and offshore of new plume
- Downwelling: new plume to north and offshore, old plume caps sub-surface water south of CR



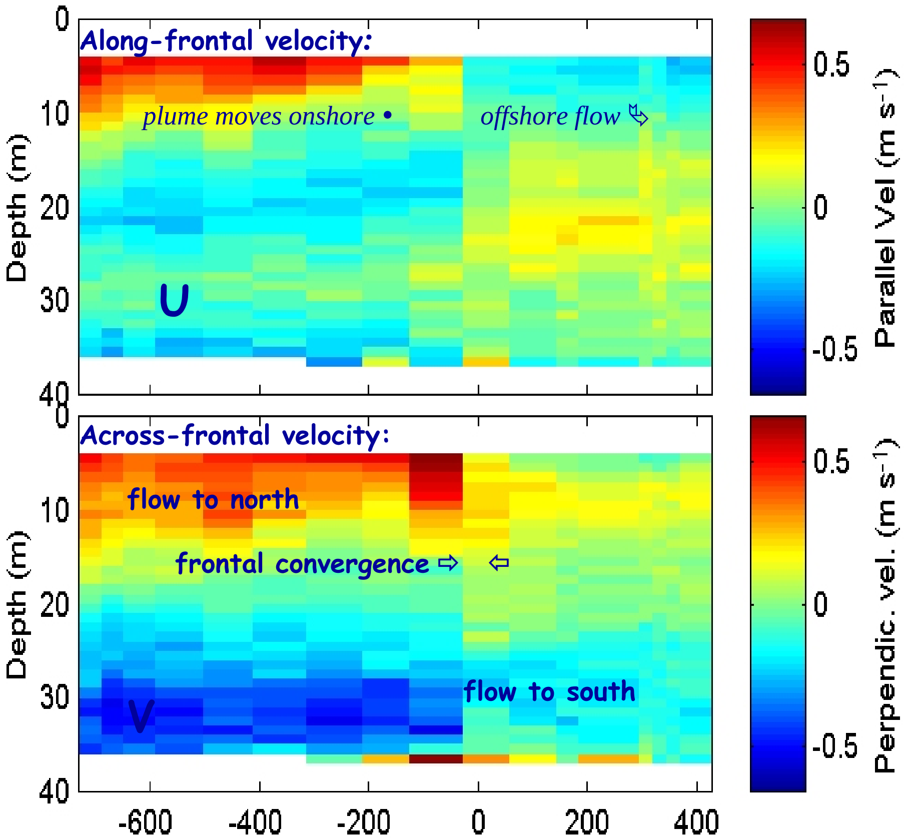




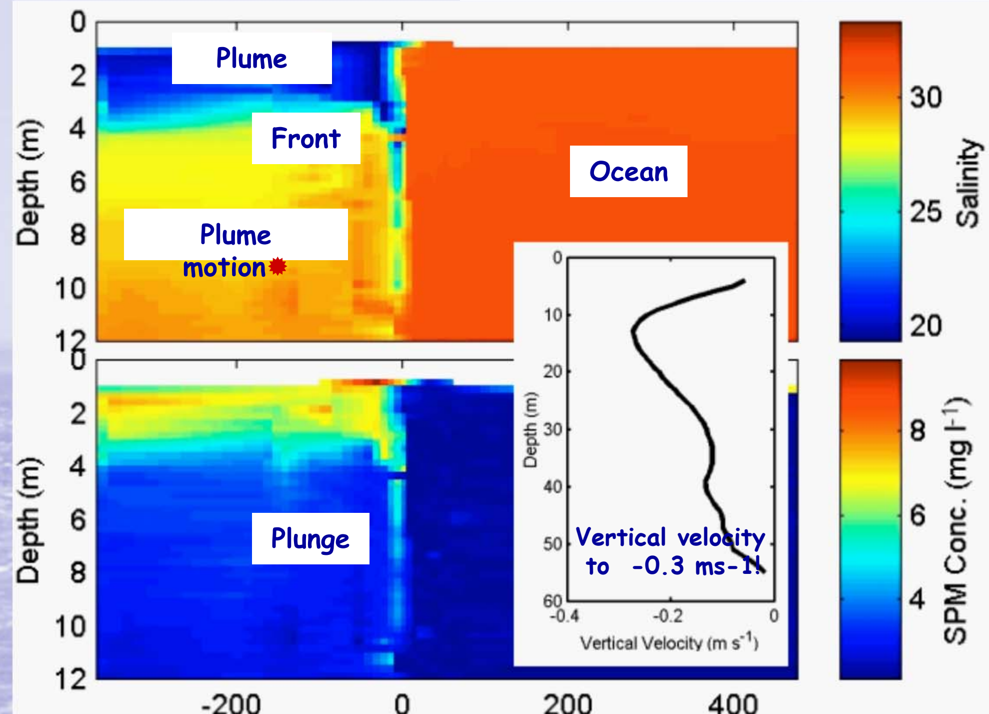


Upwelling Plume Fronts -

- Plume moves south, offshore, but northern front moves to N.
- Layer Fr is super-critical
- Sharp front and convergence! <200 m across
- Plume ~4 m deep, with definite plunge; 👎S >10; internal waves

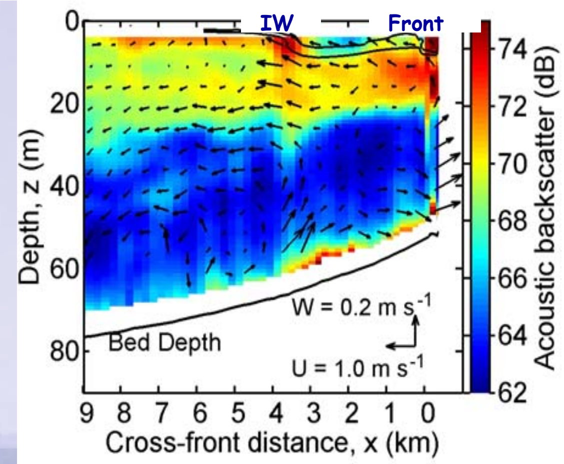


Salinity and turbidity across a CR plume front



Upwelling Fronts & Internal Waves: the “Zipper” –

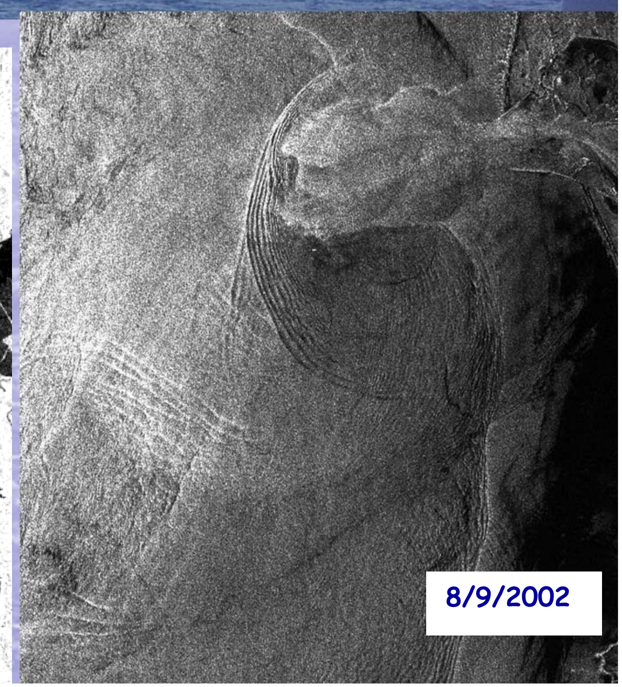
- IW first seen on south side, front “un-zips”
- Regularly occur under upwelling conditions
- Long-shore flow creates an asymmetry in Froude #
- IW are ubiquitous in plume far-field and interact with plume-front solitons
- IW cause resuspensions



6/13/2005 looking seaward across IW train

6/3/2005

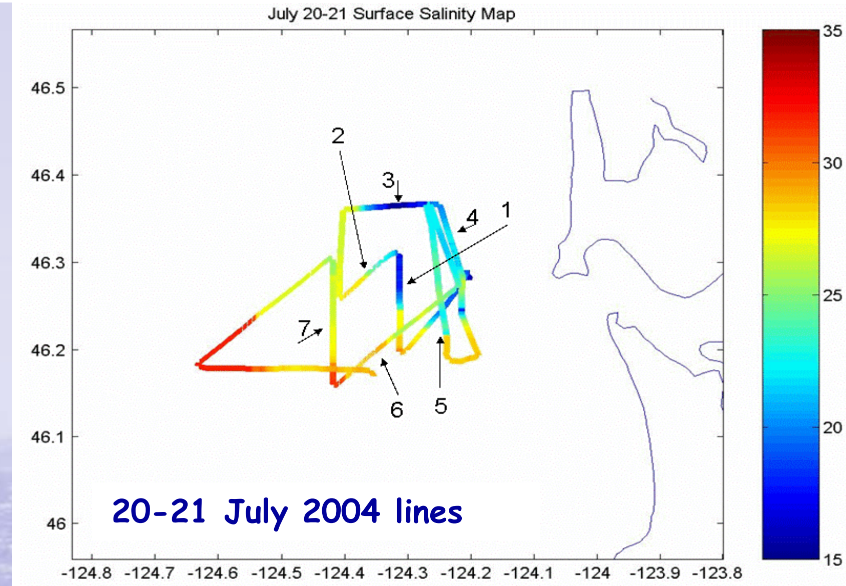
6/24/2004

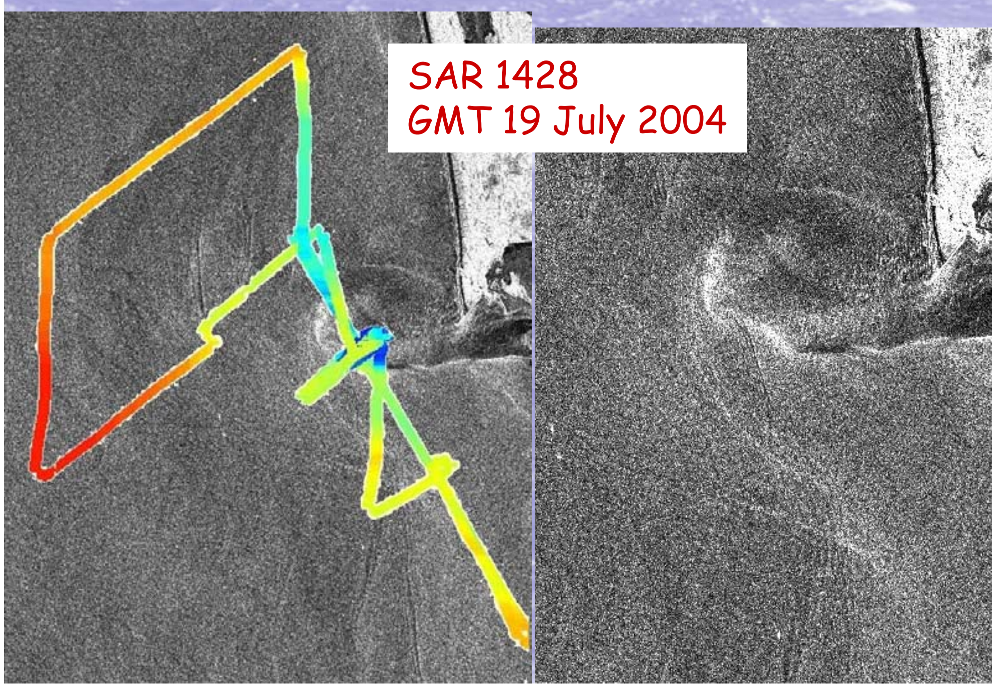


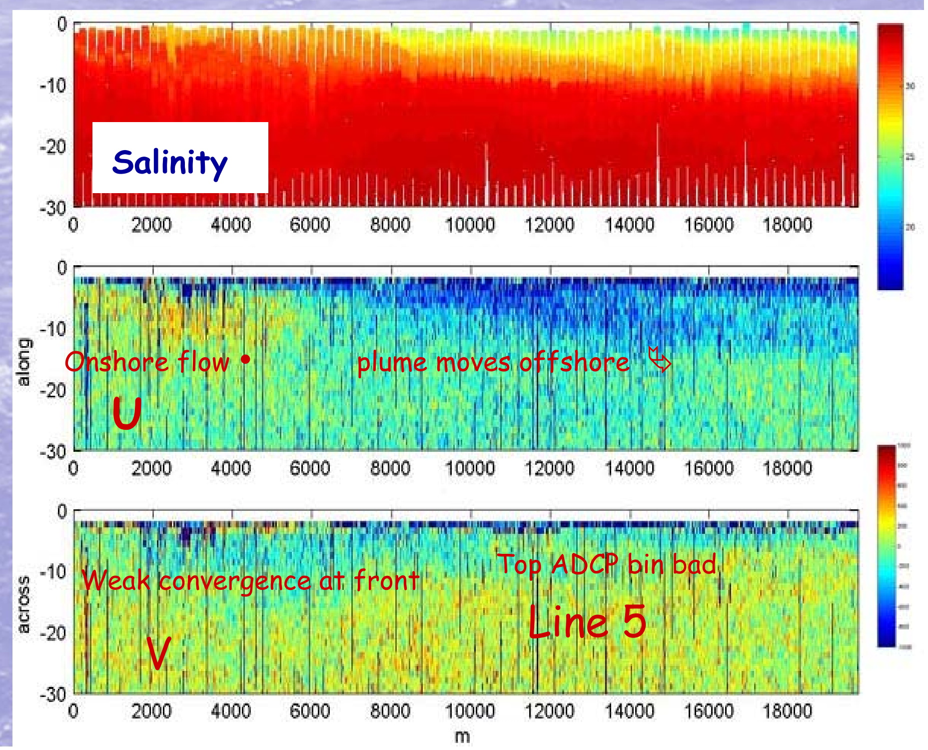
8/9/2002

Plume Fronts: Summer Downwelling Conditions –

- Convergence weak; fronts diffuse
- Plume water moves offshore
- Ocean water moves onshore just below plume
- Plume Fr number sub-critical
- Plume nose diffuse, ~2 m deep
- Frontal zone is ~6 km wide

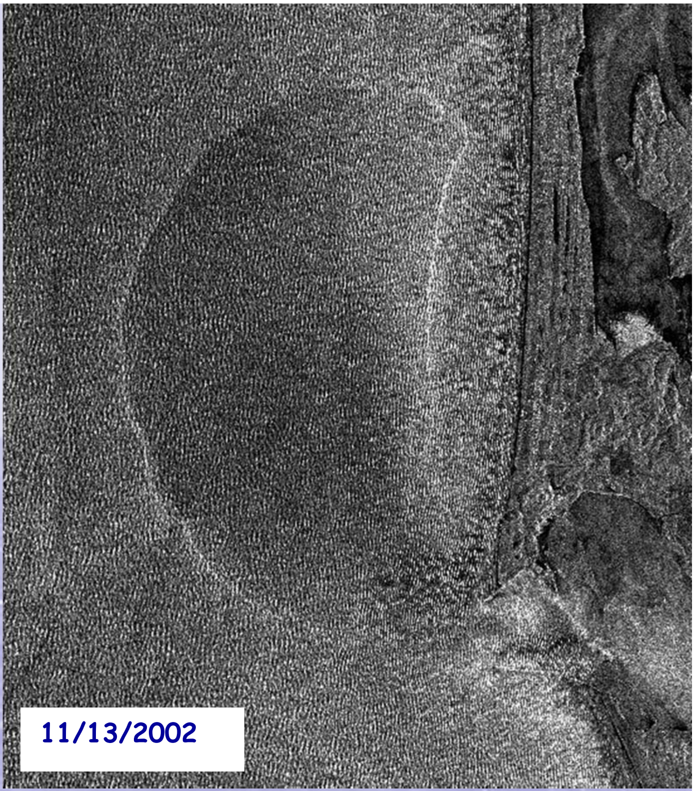






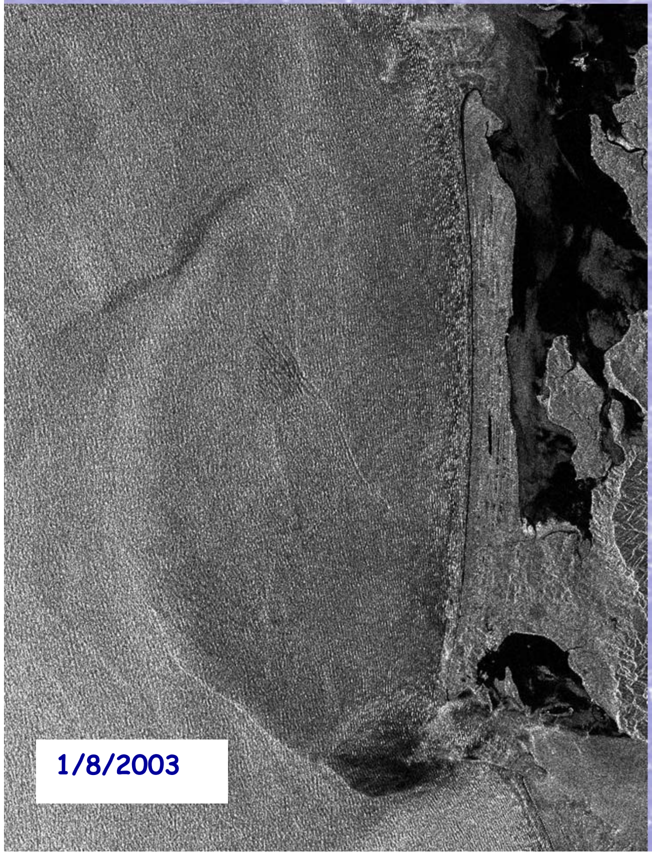
Downwelling Fronts –

- Downwelling plume fronts are sometimes strong, but rarely in summer
- Less evidence of IW:
  - more wind mixing of old plume water
  - old plume water has moved out of the plume area
  - Zipper uncommon; doesn't change direction
- Landward front can generate IW



11/13/2002

5/26/2002

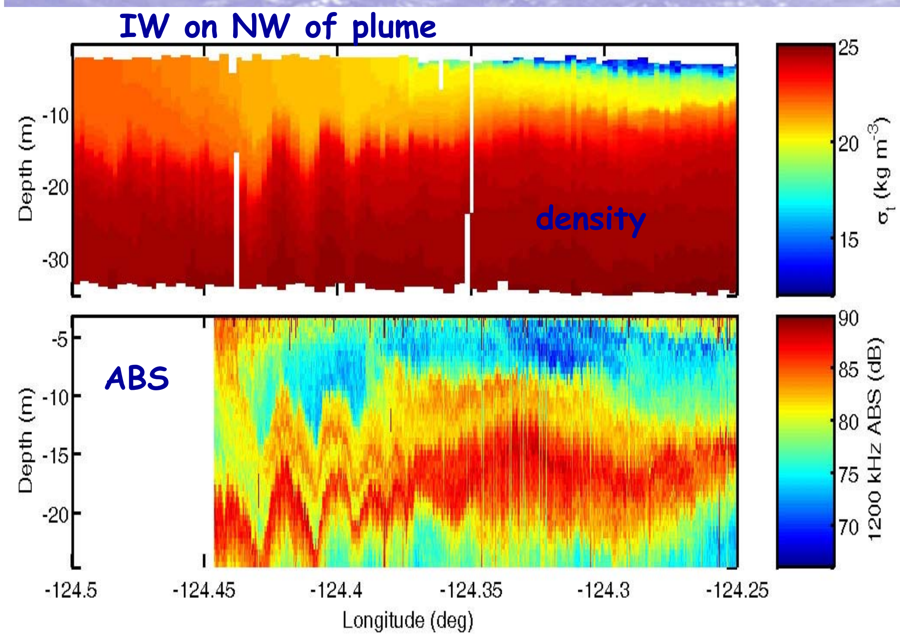


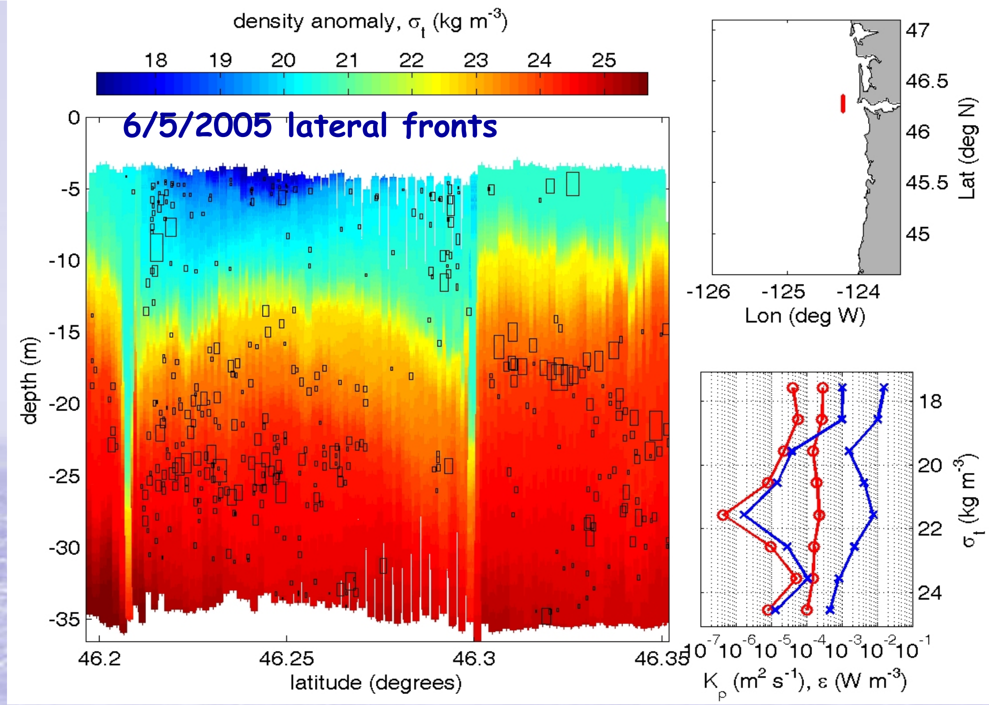
1/8/2003

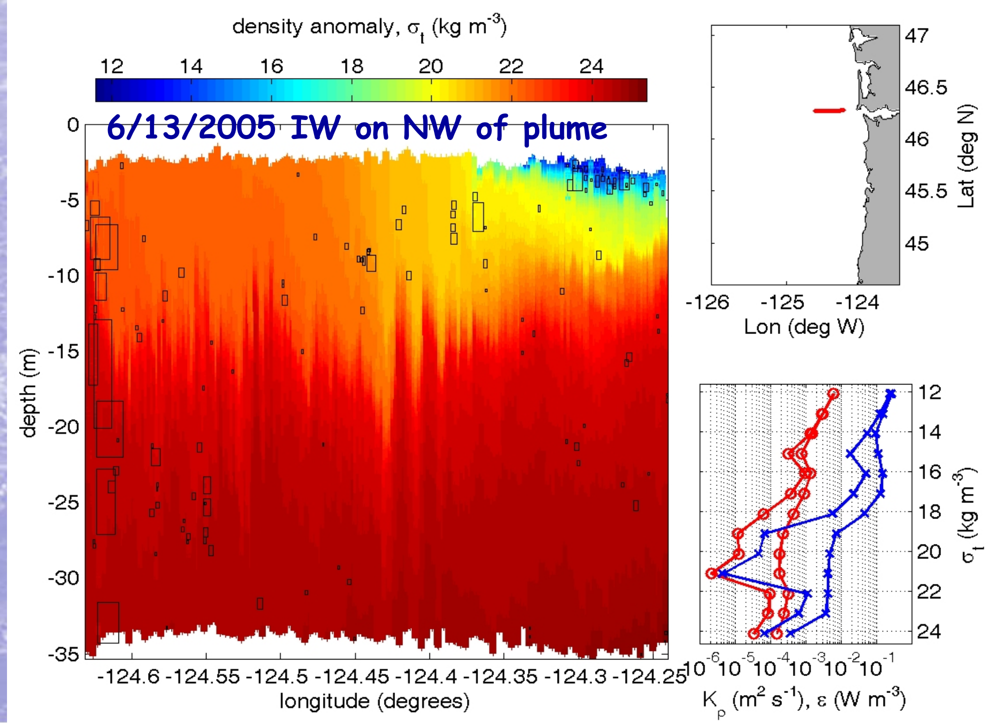
5/29/2002

Plume Fronts, IW and Mixing:

- Mixing determined from fine structure by "Thorpe Sort":
  - Captures larger overturns
  - Rectangle height = ht of overturn
  - Rectange width = Thorpe scale
  - Very strong mixing at fronts, but this can't be measured by Thorpe sort because isopycnals slope
- Fronts cause local mixing, IW cause remote mixing and export of water from plume

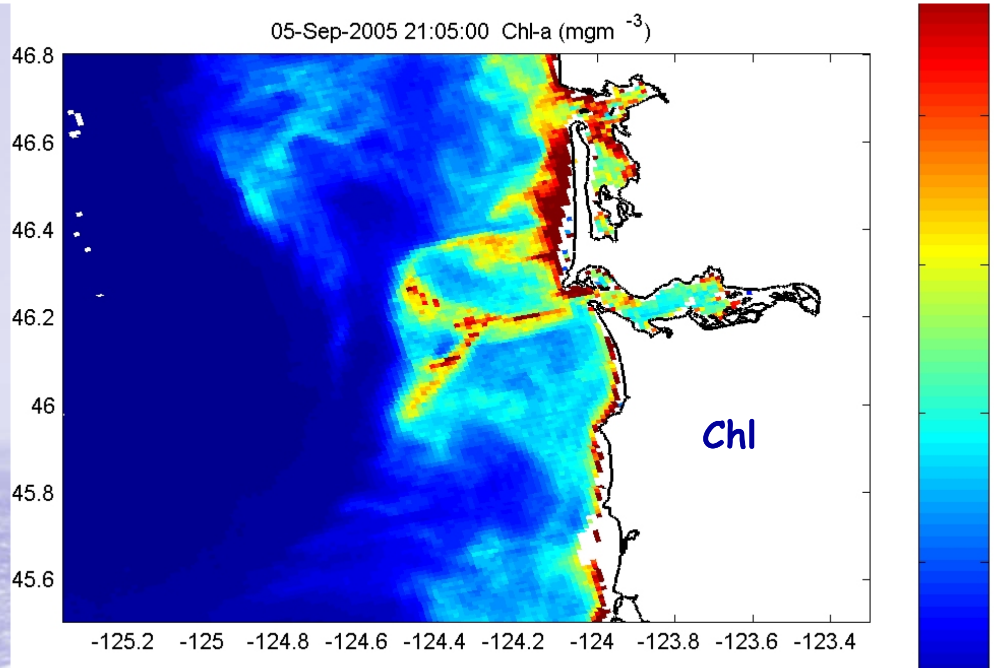


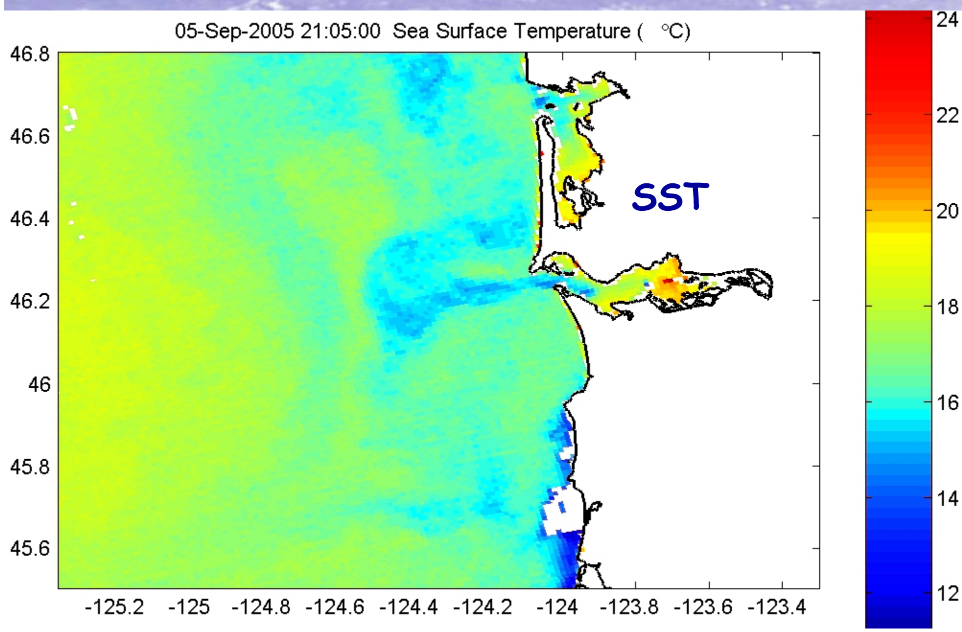


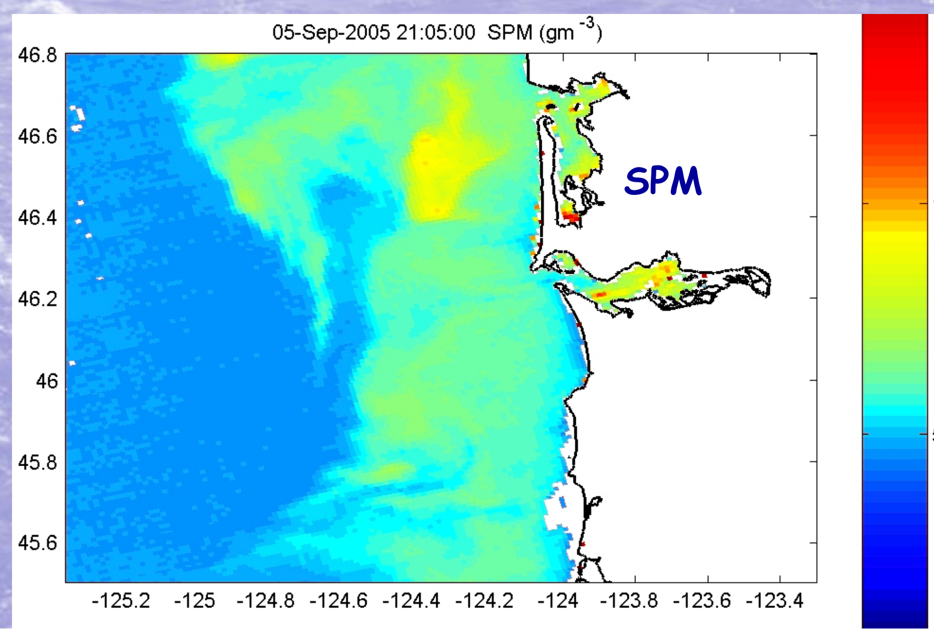


Plume Fronts, IW and Primary Production –

- 5 September 2005, upwelling conditions
- Mixing is occurring around the margins of the plume, allowing production
- Note cooler water inside estuary mouth – aspirated at lift-off point

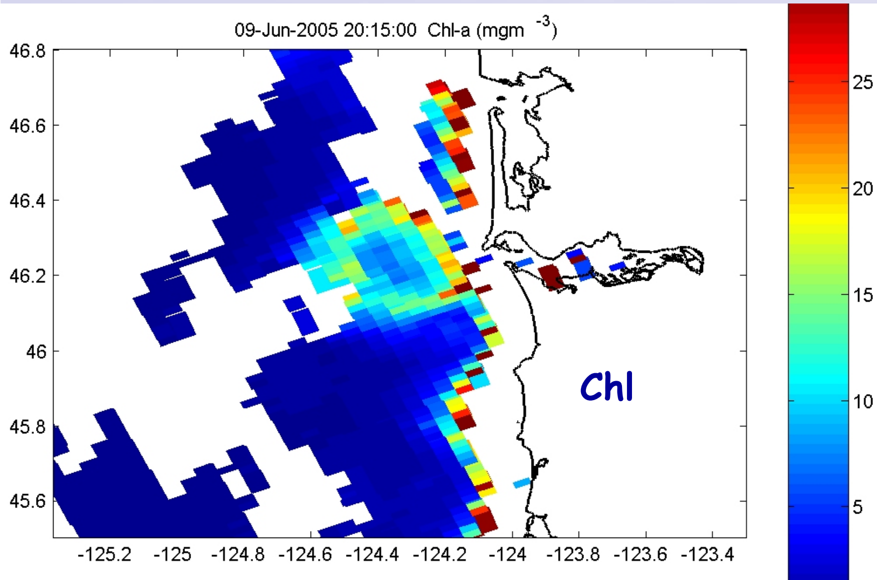


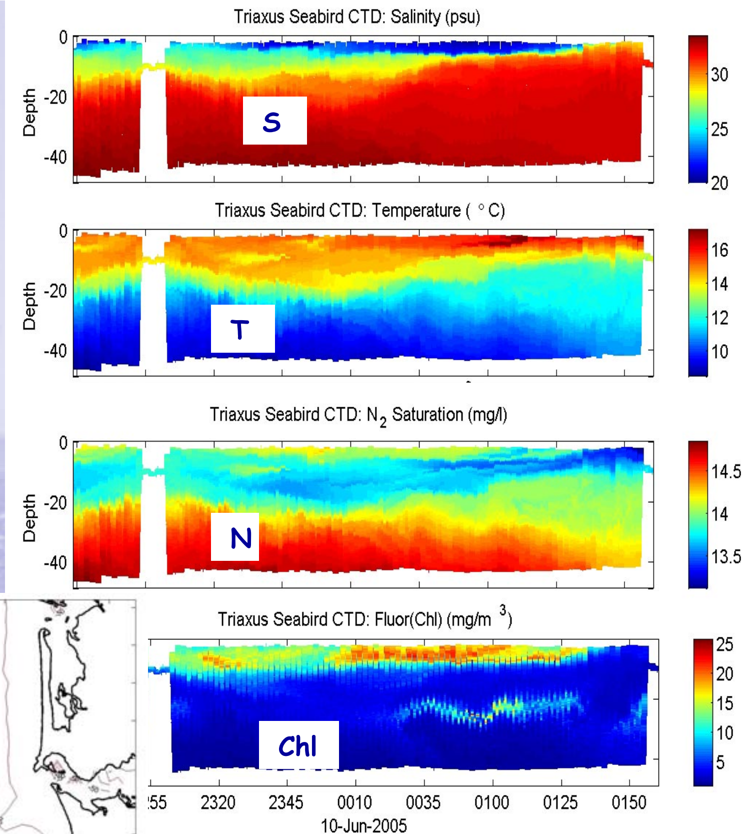


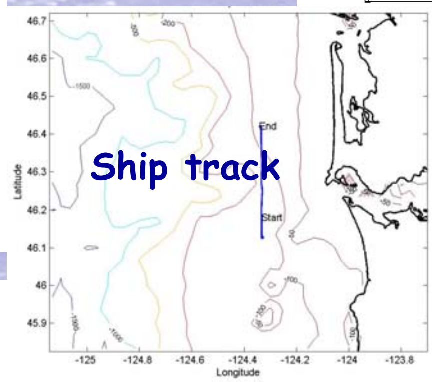


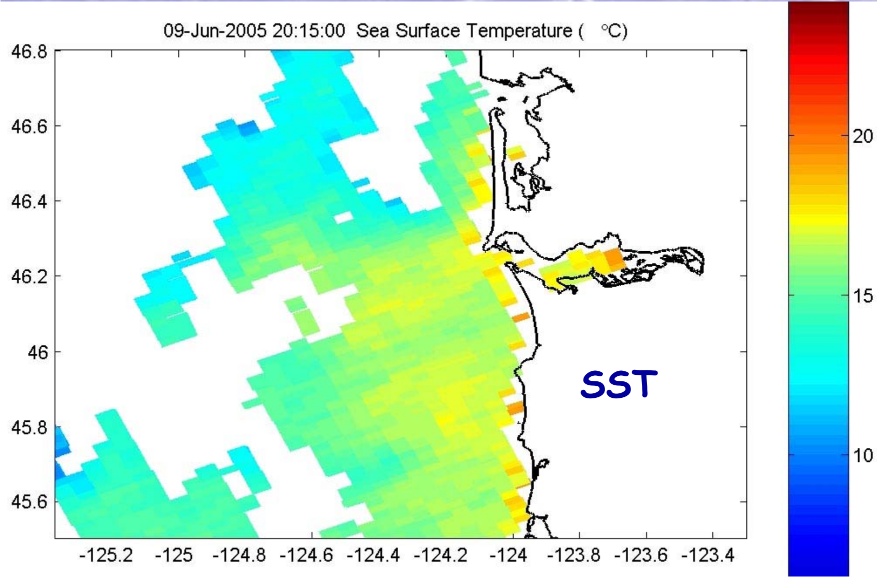
Fronts, IW and Primary Production –

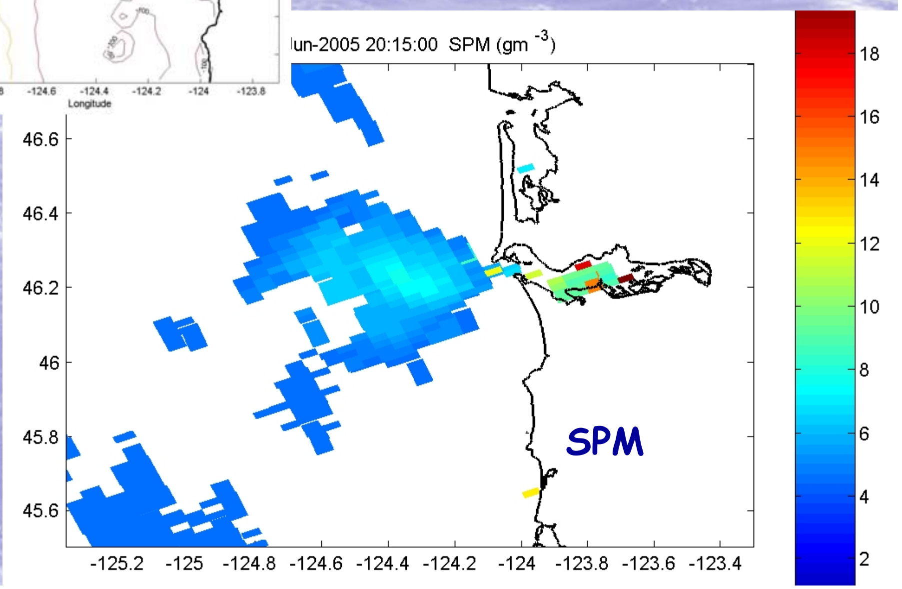
- 9 June 2005 – neutral conditions
- productivity in/around plume





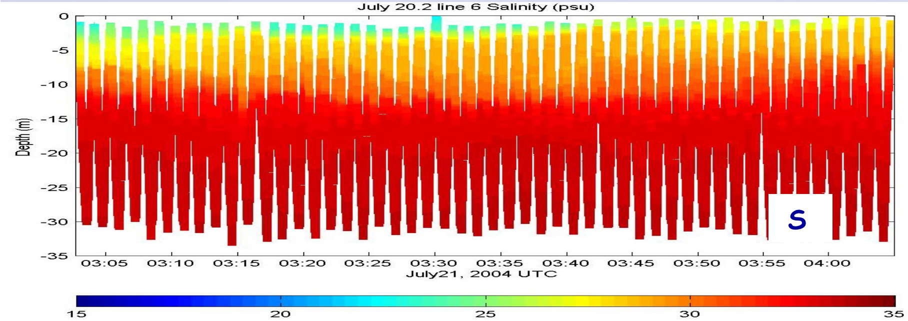


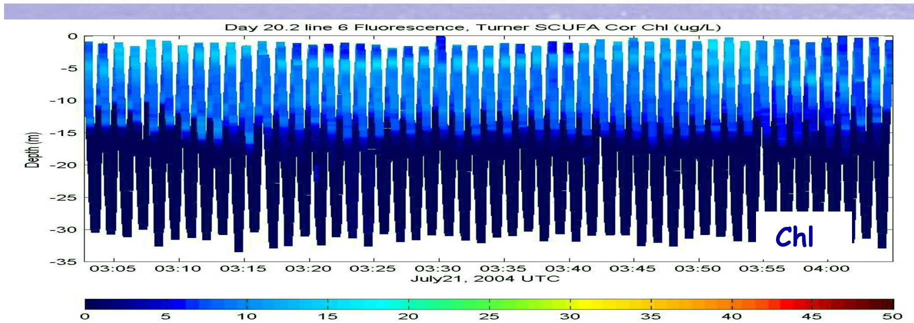


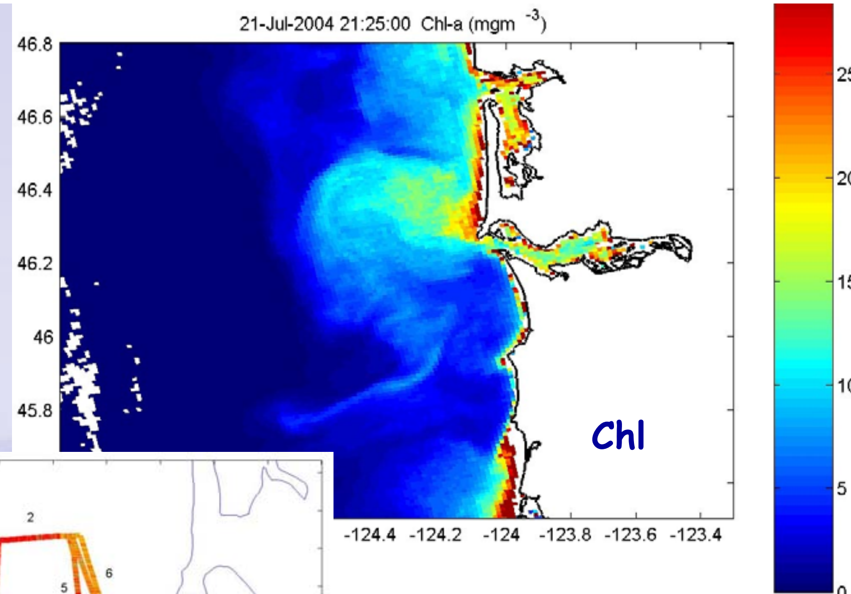


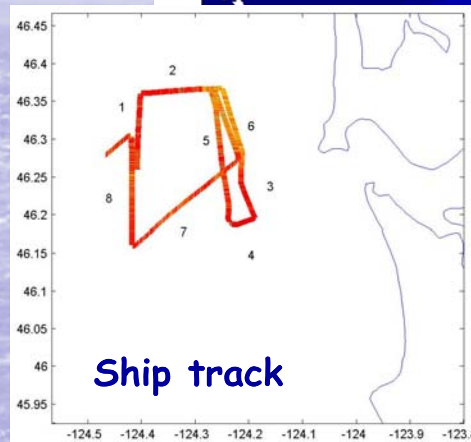
Fronts, IW and Primary Production –

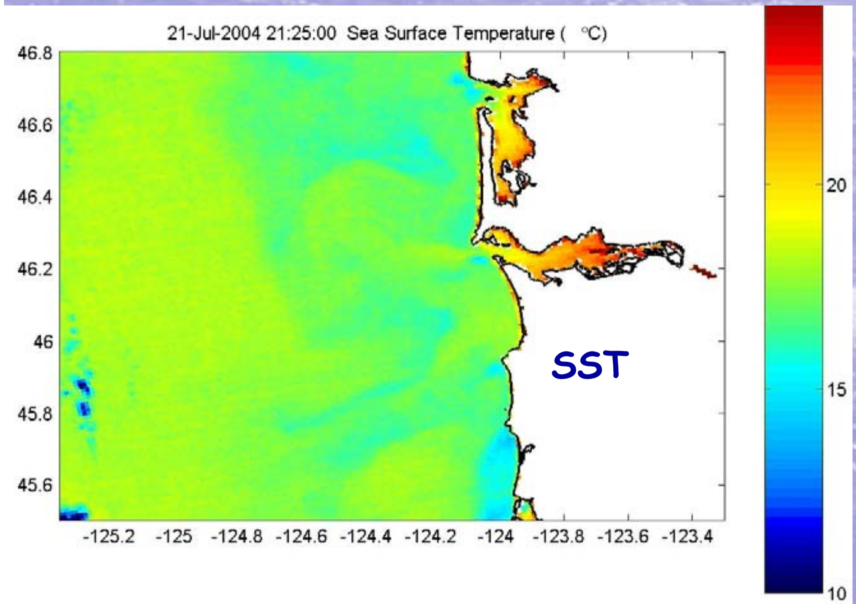
- 21 July 2004 – onset of upwelling

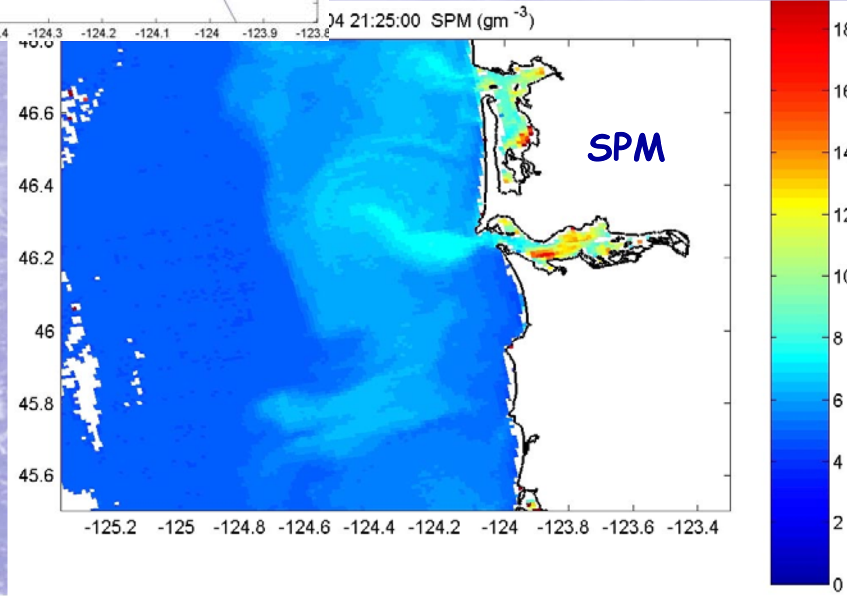












Conclusions and Questions –

- Upstream front is usually sharper under upwelling conditions than during downwelling; three differences:
  - Weaker coastal flows, therefore less convergence during downwelling (winter??)
  - Old plume water trapped inshore weakens density contrast in downwelling
  - Coriolis favors stronger fronts during upwelling
- Both fronts and plume-generated IW contribute to mixing
- Strong fronts mix water column to bed to ~60 m; re-suspend SPM
- Downwelling fronts accomplish less vertical N mixing than upwelling fronts, because high N, high salinity water is deeper
- Are internal waves/tides at plume base relatively more important to vertical mixing in the downwelling case, because fronts weaker?
- Need to evaluate mixing due to internal tides
- TRIAXUS is a useful tool, but limited to > 50 m operating depth (excludes much of plume)
- SAR and ocean color help fill in the missing pieces of the picture

Ecosystem and Mgt Considerations –

- Interaction of plume and upwelling is crucial for plume-area primary production:
  - N and P mixed into plume from below
  - Fe and Si supplied by river
- Managers care about plume production, because juvenile salmon feed extensively in plume and at fronts
- Columbia River flow regulation decreases plume area, plume frontal length, and Fe supply. Effect on mixing ambiguous.
- Climate change reduces flow and changes seasonality –
  - constrains future flow mgt options
  - Upwelling and peak flow coincide less well in time than historically
- If Fe supply limits production – restoring Fe input trapped by dams may improve productivity.