2-1-2006

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Frontal Processes in the Columbia River Plume Area

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Research sponsored by the National Science Foundation (Co-OP) and NOAA-Fisheries
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

Northern front, with plume to right
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
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

SAR 1428
GMT 19 July 2004

20-21 July 2004 lines

Salinity
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
Plume Fronts, IW and Mixing:

- Mixing determined from fine structure by “Thorpe Sort”:
  - Captures larger overturns
  - Rectangle height = ht of overturn
  - Rectangle 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

6/5/2005 lateral fronts
6/13/2005 IW on NW of 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.