2-1-2006

Frontal Processes in the Columbia River Plume Area

David A. Jay  
*Portland State University*

Jiayi Pan  
*Portland State University*

Philip M. Orton

Alexander R. Horner-Devine

Let us know how access to this document benefits you.

Follow this and additional works at: https://pdxscholar.library.pdx.edu/cengin_fac

Part of the Civil and Environmental Engineering Commons

Citation Details

https://pdxscholar.library.pdx.edu/cengin_fac/21

This Presentation is brought to you for free and open access. It has been accepted for inclusion in Civil and Environmental Engineering Faculty Publications and Presentations by an authorized administrator of PDXScholar. For more information, please contact pdxscholar@pdx.edu.
Frontal Processes in the Columbia River Plume Area

David A. Jay, Jiayi Pan
Department of Civil & Environmental Engineering
Portland State University

Alex Horner-Devine
Department of Civil Engineering,
University of Washington

Philip M. Orton
LDEO, Columbia University

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; $\Delta S > 10$; internal waves

Salinity and turbidity across a CR plume front

Along-frontal velocity:
- Plume moves onshore
- Offshore flow

Across-frontal velocity:
- Flow to north
- Frontal convergence
- Flow to south

Vertical velocity to $-0.3 \, \text{ms}^{-1}$!
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

July 20-21 Surface Salinity Map

20-21 July 2004 lines
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
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.