RISE 2004: Columbia River Plume
Physical Patterns during
a Period of Variable Forcing

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Laser Optical Plankton Counter results for 22 July, upwelling conditions. The LOPC captures particles from 0.1 to 35 mm

Image courtesy of Jay Peterson, NOAA-Fisheries
Project Title - Productivity, Biogeochemical Transformations and Cross-margin Transport in an Eastern Boundary Buoyant Plume Region

Target area - the Columbia River (CR) plume in a shelf setting extending from mid-Oregon to mid-Washington

Focus For today - compare broad patterns and frontal processes for upwelling and downwelling periods

Left: SeaWiFS 26 June 2000, Chl, mg m$^{-3}$
Note high Chl off WA

Right: CZ Color Scanner, from 24 May 1982
Note large plume area
Sampling and Cruises 2004 to 2006 -

- 3-week cruises in July 2004 (moderate flow), June 2005 and 2006 (high-flow), August 2006 (low-flow).
  - Most biogeochemistry on R/V Wecoma (moves slowly)
  - ADCP, Triaxus surveys, turbulent mixing, some biology on R/V Pt Sur
    - Jay OGI/OHSU: fronts, tides, MCR processes, Triaxus surveys
    - Nash/Moum COAS/OSU: turbulent mixing, small-scale processes
    - Peterson NOAA-Fisheries, zooplankton dynamics and distribution
- Three biophysical mooring with ADCP, CT, nutrients
- 1-km and 4-km coastal radars in plume area
- Along-shelf picture with COAST, OR and WA ECOHAB and BPA/NMFS
Sampling: Pt Sur Instrumentation -

- **Plume is hard to sample:**
  - Where is the plume today? (Use CORIE model)
    - Need to be highly mobile (use Triaxus towfish)
  - Scales are small and vertical mixing sporadically intense
    - Turbulence sampling (Chameleon profiler; Nash/Moum OSU)
  - Very shallow (2-10 m)
    - Towfish needs to sample outside of wake/propwash (3-D steerable)
    - Hard to sample with an ADCP

- **Strategy - two sampling modes:**
  - Turbulence sampling (Chameleon, Biosonics, ADCPs)
  - Triaxus surveys with CTDs, ADCP, LOPC Optical Plankton Counter, N sensor, LISST-25; towed downward ADCP

- **Downward pole mounted (300 kHz) for both modes**

_Triaxus on deck on the Pt Sur_
July 2004 Cruise: Plume Forcing -

- Below-average flow year. Flow declining, cruise a month after freshet peak
- Winds weak, variable for first 10 d. Then distinct downwelling and upwelling periods
- Frontal Triaxus data available only for downwelling
- Use upwelling frontal data from 2000
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 south, old plume caps sub-surface water S. of CR
Plume Fronts -
Upwelling Conditions:

- Sharp frontal convergence occurs on north (upstream) side of plume
- Coastal flow is offshore & around plume
- Bulk of plume moves S., offshore
- N. plume front moves N. against coastal flow
- Convergence in plume area, but averaging hides details
- Strong tidal variability!

24 July 2004
SAR 26 July 2004
25 July 2004 daily average
Upwelling Plume Fronts (Sept 2000) -

- Use ADCP data from fall 2001
- Plume moves south, offshore, but northern front moves to N.
- Layer Fr ~critical
- Sharp front! <200 m across
- Plume ~4 m deep, with definite plunge; S >10; internal waves
Fronts Under Summer Downwelling Conditions -

- Average shows an eddy and divergence in plume, not convergence
- Bulk plume to N. but S. front moves south against coastal flow
- Fronts are broad or weak again suggesting weak convergence

SAR with Triaxus Path 19-20 July 2004

Daily average currents, 7/19/2004

SAR 1428 GMT 19 July 2004
Plume Fronts: Summer Downwelling Conditions -

- Across frontal convergence weak on Line 5 (stronger on 4)
- Plume water moves offshore
- Ocean water moves onshore just below plume
- Layer Fr sub-critical
- Plume nose diffuse, ~2 m deep
- Frontal zone is ~6 km wide
Plume Fronts: Summer Downwelling Conditions –

- Triaxus gets to ~1 m from surface
- $S \approx 5-6$ on both lines
- Along-frontal $U \approx 0.3-0.6$ ms$^{-1}$
- Convergence weak, $\approx 0-0.2$ ms$^{-1}$
- Plume water moves offshore at front, but had to first turn left; different from upwelling

20-21 July lines
Ideas and Questions for Plume Fronts -

• Three differences between summer upwelling/downwelling fronts:
  – Weaker coastal flows, therefore less convergence during downwelling (not true in winter??)
  – Old plume water trapped inshore weakens density contrast for downwelling
  – Asymmetry in dynamics favors stronger fronts during upwelling
• Need to look at SAR data for winter - same patterns?
• Downwelling fronts may accomplish less vertical Nitrate mixing than upwelling fronts, because 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?
• What differences are seen in food web?
• Triaxus is a useful tool, but limited to > 60 m operating depth (excludes much of plume)
Ecosystem and Mgt Considerations -

- Crucial for plume-area primary production:
  - N mixed into plume from below
  - Fe and Si supplied by river
  - Mixing in plume interior and at fronts!

- Managers care about plume production, because juvenile salmon feed extensively in plume and at fronts

- Flow regulation may decrease plume frontal area and Fe supply

- Climate change reduces flow and changes seasonality - constrains future flow mgt options

- CR tides are increasing - does this imply reduced internal tidal energy on shelf?? (Seasonality important?)

- If Fe supply limits production - restoring Fe input trapped by dams may improve productivity.
Plume Fronts -

- SAR provides a means to extract plume front and internal wave patterns as a function of tides, flow and winds
- Can also look at spatial scales with 2D wavelets, estimate frontal convergence
- NESDIS images; thanks to Todd Sanders
• 7-25-2003

SAR 5 August 2003

SAR 25 July 2003
July 2004 Cruise -

- Triaxus and towed ADCP at left. Pt Sur at Right

Pt Sur photos courtesy of Aaron Raciot, CCALMR
Fronts Under Summer Downwelling Conditions -

- Flow is to north near CR, especially on 19-20 July

Daily average currents