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Analyzing Dynamic Characteristics of Internal Solitons Generated at the Columbia River Plume Front with SAR Images

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1. Introduction

The Columbia River plume transports dissolved and particulate load, phyto- and zooplankton, and larvae across the shelf. It also facilitates primary production and influences food-web structure through its supply of silicate and nutrients. Small-scale phenomena such as plume fronts and internal waves generated by the plume can greatly affect vertical mixing between the plume and ocean waters. Internal waves that are generated at the front of the river plume and propagate offshore (Nash and Moum 2005; Orton and Jay 2005) both cause mixing and transport plume water into the adjacent coastal ocean. We use Synthetic Aperture Radar (SAR) images and vessel data to obtain the dynamic parameters of the internal waves generated at the Columbia River plume front, analyze effects of the internal waves on the vertical mixing, and estimate horizontal transport in the plume water layer.

RISE (River Influences on Shelf Ecosystem) project studies the effects of the Columbia River plume on the ecosystem of the North American coast. The first and second cruises were carried out in July, 2004 and June 2005. Using the in-situ data, we derived the upper and lower layer densities and depths in the areas where the internal waves were observed.

3. Theoretical analyses

The above soliton have the following properties:

- Amplitude: $A = \frac{1}{\sqrt{1 + \xi}}$
- Plane Speed: $V = \frac{1}{\sqrt{1 + \xi}}$
- Upper Layer Vel: $u = \frac{1}{\sqrt{1 + \xi}}
- Lower Layer Vel: $v = -\frac{1}{\sqrt{1 + \xi}}$

Where $H$ is the water depth, $h$ is the upper layer depth, $\rho$ is the density, and $\xi$ is the wavenumber.

4. Effects of the internal solitons on vertical mixing

The turbulent vertical mixing can be described by the gradient Richardson number $R_i$. Vertical turbulent mixing develops when $R_i < 0.25$ (turbulent critical value). Internal solitons can increase the vertical velocity shear, and decrease the $R_i$, allowing vertical turbulent mixing to occur.

- Shear increase:
  - Velocity Shear caused by an internal soliton
  - The background Richardson number (in absence of internal waves) in the SA1 case $R_{i0} = \frac{g h}{\nu^2} = 2.98$
  - Under soliton SA1 influence $R_i = \frac{g h}{\nu^2} = 0.3$.

Thus, the internal soliton caused the turbulent mixing.

5. The horizontal transport in upper layer (plume layer) induced by internal solitons

This net horizontal transport results from the non-linearity of the internal soliton. For a linear internal wave, the velocity field is harmonic, and no net transport is expected. The net horizontal transport can help to spread the plume water out.

6. An internal soliton packet captured in RISE 2005 cruise

TRIAXUS observations allow us to define model parameters and understand soliton properties. The current direction within the solitons is to the northwest, suggesting that the observed solitons are traveling offshore. The echo intensity, and CTD S and T shows that the amplitude of leading soliton is about 15 m, and the low salinity is deeper on the right side than the left side, reflecting that under the influence of the solitons the surface plume water with low salinity can be mixed into a lower level, and also the horizontal transport of the plume water by the internal solitons strengthens this process.

7. Conclusions

1) We have derived dynamic parameters of internal solitons with SAR image based on the backscatter cross section model of internal solitons developed in this study.
2) Using the derived dynamic parameters, we find that vertical turbulent mixing is facilitated by the influence of the internal soliton SA1.
3) The internal solitons, generated at plume front, cause a horizontal transport in the upper layer, which carry plume water beyond plume area, resulting the horizontal mixing.

References