Internal Circulation in Tidal Channels and Straits: a Comparison of Observed and Numerical Turbulence Estimates (AASERT)

David A. Jay
Department of Environmental Science and Engineering
Oregon Graduate Institute
20000 NW Walker Road
Beaverton, OR 97006-8921
Phone: 1-503-748-1372 Fax: 1-503-748-1273 e-mail: djay@ese.ogi.edu

António M. Baptista
Center for Coastal and Land-Margin Research
Oregon Graduate Institute
20000 NW Walker Road
Beaverton, OR 97006-8921
Phone: 1-503-748-1247 Fax: 1-503-748-1273 e-mail: baptista@ccalmr.ogi.edu

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http://www.ese.ogi.edu/~djay

LONG TERM GOALS

The principal long-term goals of this project are to provide:

- In concert with related projects, an improved understanding of vertical turbulent mixing and it consequences in stratified estuarine flows.

- Improved methods for determination of the suspended particulate matter (SPM) concentration and transport fields from acoustic and optical backscatter measurements.

OBJECTIVES

The past year's work focused on the second goal, finding improved methods for determination of the SPM concentration and transport fields from acoustic and optical backscatter measurements, given appropriate calibration data. As a part of this effort, we have used continuous wavelet transform methods to determine the importance of tidal and non-tidal mechanisms in horizontal SPM transport.

APPROACH

In coordination with the parent grant of this AASERT, we have developed single and multiple-frequency inverse analysis methods for SPM determination. The student supported by this AASERT for 1999-2000, Annika M. V. Fain, focused on the single frequency inverse techniques. A single-frequency inverse analysis uses dynamical information present in SPM profiles. Profiles ("basis functions") are defined for each time each of a small number of size or W_s classes. The contribution of each basis function to the observed profile at a given time is determined by an inverse analysis (via non-

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negative least-squares or NNLS). Results depend, however, on the assumed SPM dynamic balance used to form the basis functions. Previous analyses have used a balance in the vertical between turbulent SPM flux and particle settling. Fain (2000) and Fain and Jay (2000) also use a modified Rouse balance approach, but have improved upon previous single-sensor analyses in several respects. First, the presence of aggregates of unknown density means that scattering behavior and settling velocity (W_s) are not simple, known functions of particle size. When aggregates are present, we formulated the analysis around settling velocity (W_s) classes rather than size classes. Second, the non-negative least squares (NNLS) inverse technique used is quite sensitive to mismatch between the assumed and actual settling velocity distribution. We have, therefore, used known W_s spectra. Finally, our inverse technique is based on a broader dynamical analysis that defines estuarine SPM dynamics in terms of five non-dimensional numbers. The parameters are the Rouse number P, an advection number A (a non-dimensional height of maximum SPM concentration above the bed), a trapping efficiency E (measuring the efficiency of retention of material in the system), a trapping potential T_P (ratio of stratification-induced shear to shear velocity), and a Supply Number S_R (S_R is a measure of the strength of the fluvial or marine SPM supply to the system). These parameters have been chosen both for dynamical relevance, and because they are relatively robust against calibration difficulties.

WORK COMPLETED

The single-frequency code has been developed, tested and used in analyses of the SPM dynamics of the Columbia River estuary. This work forms the basis of Annika Fain's M.S. thesis and related publications (Fain, 2000, Fain et al., 2000, Jay et al., 2000). The single-frequency code is also used in the multi-frequency inverse analysis described in the report for the parent grant of this AASERT.

RESULTS

Analysis of four 7-8 mo. ADCP records (from the ONR-supported CORIE system) has allowed for exploration of the above parameter space (Fain, 2000; Fain et al., 2000, Jay et al., 2000). This data set is favorable for a test of the inverse method, because a very large calibration data set is available, and interference from zooplankton in the acoustic signal was small. An important result is the dependence of trapping efficiency E on river flow (Figure 1). E in the Columbia River estuary is shown as a function of the seasonal trajectory of Supply Number S_R for the Columbia River for May to December 1997. This period encompassed the strongest freshet since 1974, and 1997 had the highest total annual flow of any year in the 20th century. Also shown is E for the Fraser River estuary under extreme freshet conditions in July 1999, during one of the strongest freshets of the 20th century. Results suggest that the moderate flows after the spring freshet resulted in the most efficient trapping in the Columbia. E was very low in the Fraser, because of the high flow. These results conform to intuitive understanding. If the river flow is too high, trapping of SPM in the estuary will be small (low E) despite a very high supply, because the estuary is so short that all salt (and SPM retained in the salt wedge salinity intrusion) will be removed on each greater ebb. If the flow is too low, the estuary is very large, but upstream bottom currents are weak and may not retain SPM effectively (low E again). Also, the limited SPM supply is diluted in a very large estuarine water mass. E is then maximized at intermediate flow levels where upstream bottom flows are robust, but salt is not removed on every ebb. It appears that the 1997 data set encompassed the period of maximum E for the Columbia. The residence time of river water and SPM in the Fraser was so small in July 1999 that SPM was exported over the top of the salt wedge before it could settle into the lower layer, yielding $E \ll 1$. There is one other important influence not considered in the two-dimensional (x and z) dynamics encompassed by the parameter space described here – SPM can be stored in peripheral areas during freshets and supplied to the main body of the estuary

even during periods of low river flow. This factor likely influences the value of S_R that shows maximal E in Figure 1. The asymptotic low and high S_R behaviors posited are, however, likely robust.
The single-sensor inverse approach described here has the advantage of dynamical and numerical simplicity, but there are two primary weaknesses: a) neglect of horizontal advection of SPM, and b) the fact that a bulk SPM calibration is employed, whereas backscatter strength depends on particle size. The method is, then, best suited to circumstances where the range of sizes present is not too large. The presence of aggregates (the dominant material found in the Columbia River estuary) is, however, not an obstacle.

IMPACTS/APPLICATIONS

Application of this technique should allow the routine interpretation of acoustic backscatter (e.g., from acoustic Doppler current profiles) in terms of SPM properties, provided that: a) the backscatter field is dominated by SPM not zooplankton, and b) adequate calibration data are available.

TRANSITIONS

Two continuous wavelet transform tidal analysis programs with sample data sets illustrating their use have been placed on the PI's web page (see CWT software library sub-heading under http://www.ese.ogi.edu/~djay). Dr. R. Signell of the US Geological Survey has also set up a link to these programs on his Sea-Mat web site (http://crusty.er.usgs.gov/sea-mat). These programs and related codes have been used in the analysis of the SPM data derived from inverse analyses.

RELATED PROJECTS

Work for the Tidal Channels AASERT project has been coordinated with the National Science Foundation Columbia River Land-Margin Ecosystem Research (LMER) Program and with the Oceanographic and Environmental Characterization of Coastal Regions (OECCR) funded by ONR.

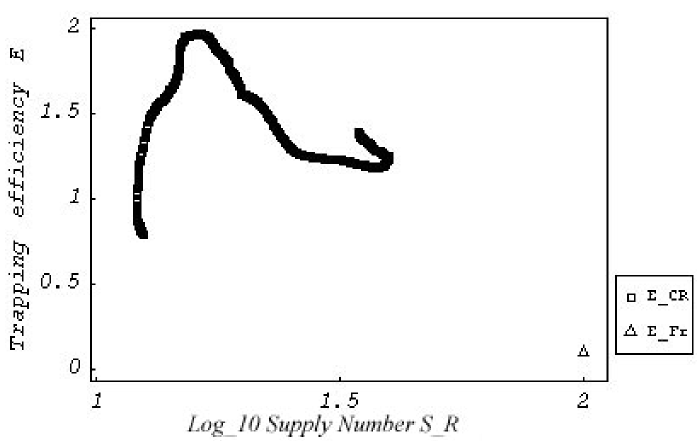

Figure 1: The May-December seasonal trajectory in the Columbia River (CR) estuary of SPM particle trapping (Trapping Efficiency E) as a function of SPM supply (Supply Number S_R). A point for the Fraser River (FR) is added to demonstrate the high river-flow asymptote.

REFERENCES

Fain, A.M.V., 2000, Suspended particulate dynamics in the Columbia River Estuary, MS thesis, Department of Environmental Science and Engineering, Oregon Graduate Institute, 97 pp.

Fain, A.M.V., D. A. Jay, D. J. Wilson, P. M. Orton, and A. M. Baptista, 2000, Seasonal, monthly and tidal patterns of particulate matter dynamics in a stratified estuary, submitted to *Estuaries*.

Jay, D. A., A. M. V. Fain, P. M. Orton, J. McGinity, D. J. Wilson, W. R. Geyer and D. McDonald, 2000, Particle Trapping in Stratified Estuaries -- Explorations of a Parameter Space, in preparation for *Contin. Shelf Res*.

PUBLICATIONS

Fain, A.M.V., 2000, Suspended particulate dynamics in the Columbia River Estuary, MS thesis, Department of Environmental Science and Engineering, Oregon Graduate Institute, 97 pp.

Fain, A.M.V., D. A. Jay, D. J. Wilson, P. M. Orton, and A. M. Baptista, 2000, Seasonal, monthly and tidal patterns of particulate matter dynamics in a stratified estuary, submitted to *Estuaries*.

Jay, D. A., P. Orton, D. J. Kay, A. Fain, and A. M. Baptista, 1999, Acoustic determination of sediment concentrations, settling velocities, horizontal transports and vertical fluxes in estuaries, in *Proceedings of the IEEE Sixth Working Conference on Current Measurement*, S. P. Anderson, E. A. Terray, J. A. Rizzoli White, and A. J. Williams, III, eds, pp. 258-263.

Kay D. J. and D. A. Jay, 1999, Interfacial mixing in a highly stratified estuary. 1. Characteristics of mixing, submitted to *J. Geophys. Res*.

Kay D. J. and D. A. Jay, 1999, Interfacial mixing in a highly stratified estuary. 2: Momentum balance and mixing budget, submitted to *J. Geophys. Res*.

PATENTS

None.