

**PASI Outline**  
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**Morning Lecture:**

Temporal Variability in Estuaries:

1. Internal tidal asymmetry: a simple theory of residual flow generation via internal asymmetry will be presented.
2. Neap-spring transitions: the processes and mechanisms of neap-spring transitions will be described.
3. Non-stationary tides in river-estuaries: the phenomenology of tidal-fluvial tides and the frictional interactions causing their non-stationarity will be described.

**Afternoon Lab:**

Approaches to Tidal Analysis:

Several variants of the t\_tide tidal analysis program will be employed to explore the ability of contemporary analysis programs to extract the tidal information content of weakly to severely non-stationary tides. The “standard” t\_tide program (as described (Pawlowicz et al., 2002) and at least two modifications of this program will be used:

- One modification abandons traditional least-squares (L2) error minimization in favor of a mixed L1/L2 norm, implemented via the “Robust fit” method of Huber (1996). This iterative method converges toward high frequency-resolution (L2) for low-noise data, but toward the stability of L1 for noisy data.
- The second modification constrains the total energy of the solution in an attempt to prevent over-fitting of short data sets. It can be implemented with either an L2 or L1/L2 norm.

Data from a series of stations in the Columbia River from km-30 to km-170 will be used for this exercise. These stations show varying degrees of disturbance of the astronomical tides by atmospheric and fluvial forcing. Overtides also grow substantially in the landward direction. Records of varying lengths will be used in an attempt to maximize the number of constituents resolved while preserving the ability to resolve non-stationary behavior.

Huber, P. J., 1996. *Robust statistical procedures*, 2nd Edition. No. 68 in CBMS-NSF Regional Conference Series in Applied Mathematics. Society of Industrial and Applied Mathematics.

Pawlowicz, R., B. Beardsley, and S. Lentz, 2002, Classical tidal harmonic analysis including error estimates in MATLAB using T\_TIDE, *Computers and Geosciences* 28, 929-937.