Can Tide/River-Flow Interactions in the Columbia River Estuary Be Observed in the Coastal Ocean?

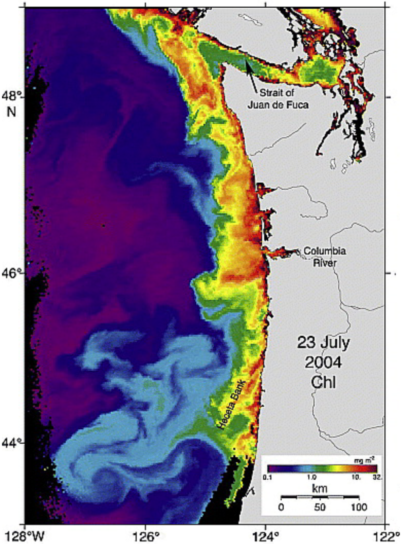
Edward D. Zaron,
Portland State University

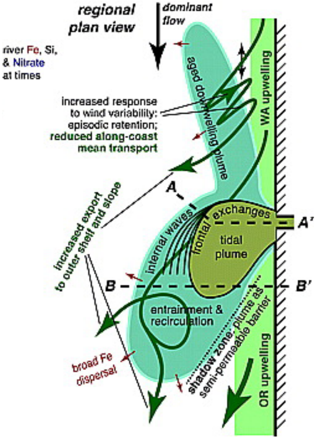
May 24–26, 2016
Columbia River Estuary Conference
Astoria, Oregon

Goals/Overview

- Can we detect feedbacks of estuarine processes on the nearby ocean?
- What are the smallest spatial scales of coastal tides observable with satellite altimetry?
- Eventual goal is to synthesize altimetry and tide gauges to develop a large-scale view of changing tides.

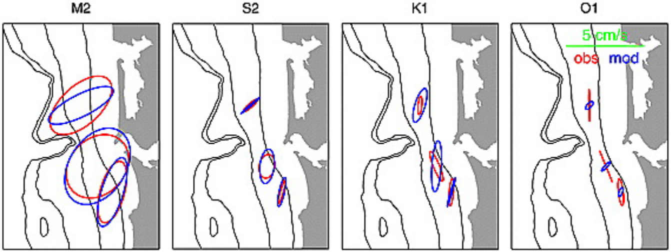
The Columbia River and the coastal ocean





Hickey et al (2010) 'RISE: Introduction and Synthesis', JGR, 115(C2).

Complex tides on the continental shelf



"Tidal circulation and water properties are best simulated in the estuary, ... In contrast, the worst model performance is for tidal properties on the shelf."

Liu et al (2009) 'Evaluation of a Coastal Ocean Circulation Model ...', JGR, 114(C2).

Plan of attack ...

1. Identify tidal properties unique to the Columbia River and Estuary.
   [Jay (1984); Kulkulka and Jay (2003); Matte et al (2013)]

2. See which of these properties, if any, can be identified with satellite altimetry.

3. Determine tide properties in the coastal ocean to compare with their estuarine counterparts.

Tidal Constituents

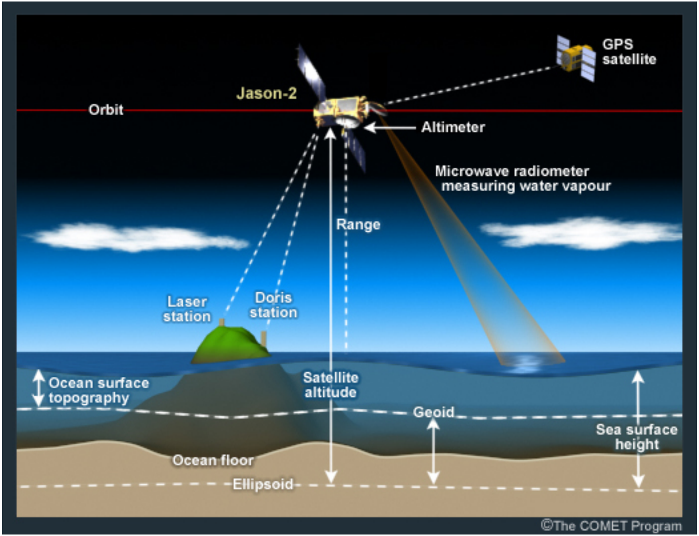
Linear Tides and Seasonal Modulates [Amp., mm]

Site	M_2	$M_{2a}+M_{2b}$	$M_{2c}+M_{2d}$	O_1	$O_{1a}+O_{1b}$	$O_{1c}+O_{1d}$
Astoria	952	19.7	12.8	240	5.1	21.0
Cape D.	851	-	-	256	-	-
Newport	891	4.5	0.9	259	3.1	2.8

Overtides and Seasonal Modulates [Amp., mm]

Site	M_4	$M_{4a}+M_{4b}$	$M_{4c}+M_{4d}$	M_6
Astoria	8.0	8.7	5.6	12.0
Cape D.	25.0	-	-	3.0
Newport	12.8	2.9	1.9	8.0

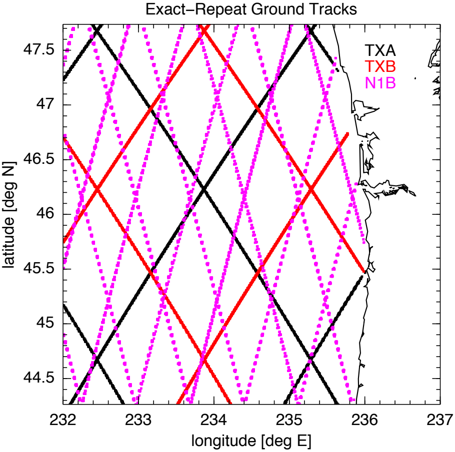
Satellite altimetry



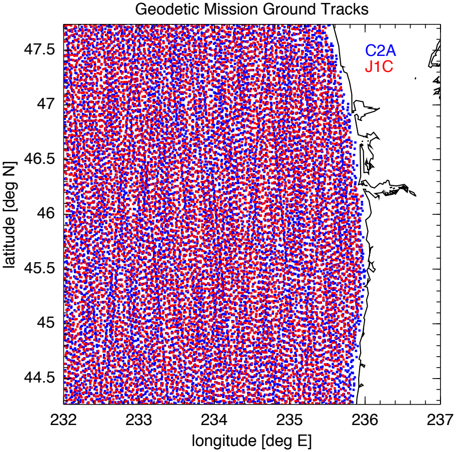
Altimeter missions, past and present

Mission	Dates	Repeat Period	Track Spacing	Geodetic Phase?
Geosat	1985-1989	17 days	163 km	yes
GFO	2000-2008			
ERS-1/2	1991-2010	35 days	77 km	yes
EnviSat-1	2002-2012			
Saral/AltiKa	2013-			
TOPEX/Poseidon	1992-2005	10 days	315 km	
Jason-1/2/3	2002-			yes
CryoSat-2	2010-	369 days	8 km	yes

Ground tracks



ERM: 1992–2016



GM: 2010–2016

Analysis method

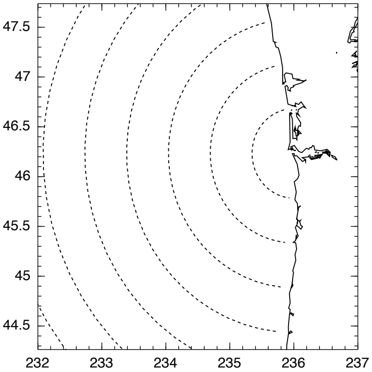
$$h(x,t) = \sum_{j}^{\text{space}} \sum_{i}^{\text{tide}} \Big(A_{ij}\cos(\omega_i t) + B_{ij}\sin(\omega_i t) \Big)\, \Phi_j(x) \qquad (1)$$

- A_{ij} and B_{ij} are in-phase and quadrature harmonic constants.
- Specify $\Phi_j(x)$ spatial basis functions *a priori*.
- Coordinate $x = (\theta, \lambda)$, latitude and longitude.
- Solve for A_{ij} and B_{ij} by least-squares fitting to observed data, $d_k = h(x_k, t_k)$.

Analysis method

$$h(x,t) = \sum_{j}^{\text{space}} \sum_{i}^{\text{tide}} \left(A_{ij}\cos(\omega_i t) + B_{ij}\sin(\omega_i t) \right) \Phi_j(x)$$

Each Φ_j is spatially constant within an annulus:

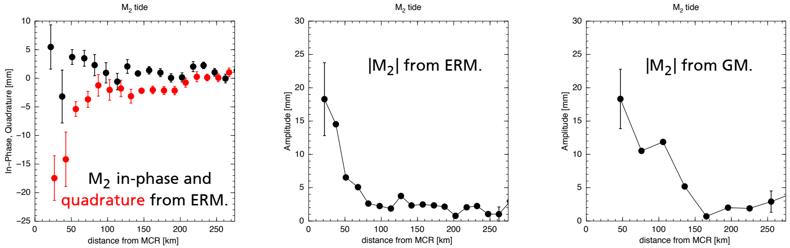


Analysis method: omitted details

1. Altimeter path delay corrections.
2. Constituent selection:
   - Good: M_2, M_{2c}, O_{1c}, O_{1d}, M_{4d}, M_6
   - Bad: M_{2a}, M_{2b}; K_1, P_1; M_3, MK_3, ...
3. Data selection and screening.
4. Other choices for Φ_j.

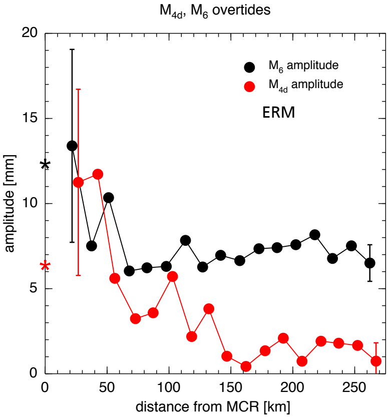
Results: M_2

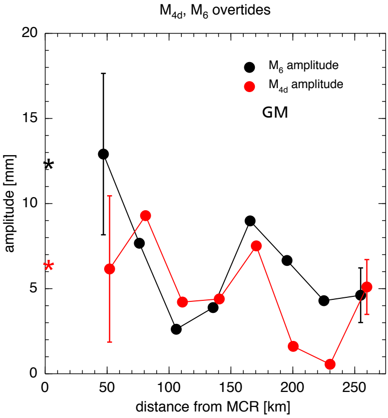
Amplitude of M_2 is about 2 cm approaching shore (anomaly from barotropic TPXO model).



Nearshore response is likely a result of other processes (e.g., internal tides) rather than estuary feedbacks.

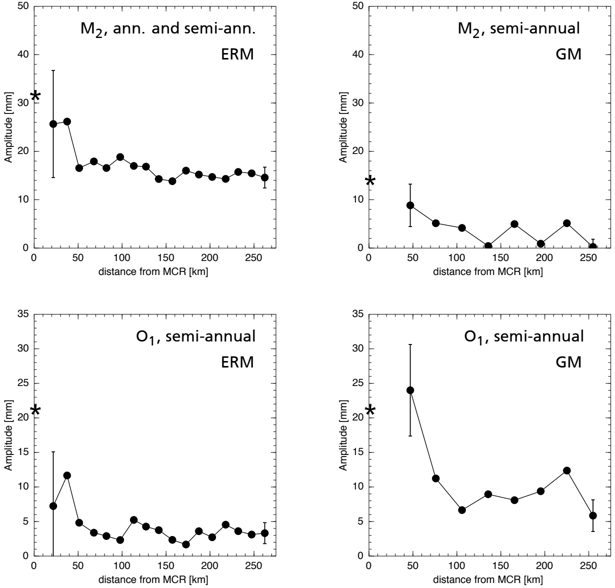
Results: Nonlinear overtides, M_6 and M_{4d}





Values at Astoria shown by * and * at x=0 km.

Results: Seasonal modulates of M_2 and O_1



Summary

- Nearshore structure of M_2 tide is identified from both ERM and GM altimetry. The 1–2 cm amplitude is consistent with a baroclinic tide on the continental shelf.
- The M_{4d} and M_6 overtide amplitudes are plausible, but noisy close to shore.
- The M_2 and O_1 annual and semi-annual modulates are also plausible, but too noisy to be conclusive.
- Apparent back effects diminish within 100 km of MCR.