Estimating depth from SWOT measurements: A case study from the Rio Grande river

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Funding: Physical Oceanography
Progress in estimating discharge

- LeFavour and Alsdorf, GRL, 2005
- Andreadis et al., GRL, 2007
- Durand et al., GRL, 2008
- Biancamaria et al., IEEE JSTARS, 2010
- Durand et al., IEEE JSTARS, 2010
- Biancamaria et al., RSE, 2010 (in press; Friday talk)
- Andreadis et al., in prep. (Friday talk)
- Clark et al., in prep. (See posters)
- Wilson et al., in prep. (See posters)
- Yoon et al., in prep. (See posters)
- Jasinski et al. (See posters)
- Carlo et al. (See posters)
\[ Q = \frac{1}{n} wz^{5/3} \left( \frac{\partial h}{\partial x} \right)^{1/2} \]

Le Favour & Alsdorf, GRL, 2005
Progress: Effect of height errors

\[
\left( \frac{\sigma_Q}{Q} \right)^2 = \eta^2 + \left( b \frac{\sigma_{H_{SWOT}}}{H_{SWOT}} \right)^2
\]

Height errors will not be a controlling factor in discharge estimates

Rivers deeper than $\sim 1.5$ m, uncertainty less than 25%

Biancamaria et al., JSTARS, 2010
Progress: Effect of depth errors

Durand et al, JSTARS, 2010
Progress: Effect of depth errors

Depth errors
Depth estimated by least-square continuity algorithm

Includes errors due to SWOT height, baseflow depth, and temporal sampling

Durand et al, JSTARS, 2010
The depth problem: Another look

SWOT does not observe depth below the lowest height measurement
Hydraulic depth: Definition

Goal: Estimate hydraulic depth from SWOT observations

\[ D = \frac{A}{T} \]

\[ A = \int_{x_{min}}^{x_{max}} y(x) \, dx \]
A new project: Two approaches to depth

Hydraulic Geometry

Data Assimilation

For more: See Larry Smith’s talk tomorrow
A new dataset: Rio Grande river
Data assimilation: Background

1) Propagate forward in time
   Need state model

2) Update with new measurement \( z_{i+1} \)
   Need measurement model to relate measurement to states
Trading time for space with SWOT

Durand et al, JSTARS, 2010
Hydraulics: Gradually-varied flow

\[ \frac{\partial h}{\partial x} = \frac{S_0 - S_f}{1 - Fr^2} - S_0 \]
Spatial ensemble Kalman filter

1) Propagate forward in space
   Need state model

2) Update with new measurement \( z_{i+1} \)
   Need measurement model to relate measurement to states

\[ y_j(t_{i+1} | Z_{i+1}) \]

\[ y_j(t_{i+1} | Z_i) \]

\[ s_i \] (Downstream) \hspace{1cm} \[ s_{i+1} \] (Upstream)

Space
Parameterizing unseen bathymetry

Goal: Estimate the optimal minimum depth

**Downstream**

**Upstream**

2004 Survey Section MD-53 in MCH

Estimated MCH Geometry, Overbanks from DTM
Results at a single cross-section

Downstream

Upstream

Graphs showing elevation and distance for both downstream and upstream locations.
Results at a single cross-section

Downstream

Upstream

Observation
Hydraulic reasons for the correlation

Shallower bathymetry leads to lower height upstream
Estimating bathymetry from SWOT

Use the EnKF analysis equation:

$$z_k^+ = z_k^- + C_{zh} (C_{hh} + C_v)^{-1} (h_{obs} - h_k^-)$$
The correct hydraulic depth is obtained. 

True depth = 1.03 m
Rio Grande hydraulic depth

Bias Error
Prior: 58 cm
Posterior: 22 cm
Future and ongoing work

- Use spatial height sequence to update farther upstream
- Use sequence of height measurements (from high to low water) simultaneously to update bathymetry
- Sensitivity to measurement errors
- Application in 2-D (couple to instrument simulator)
- Introduce errors in discharge
Another approach to depth

Courtesy: Yeosang Yoon, see posters
Estimating bathymetry and depth

Results from a combined state-parameter EnKF

Courtesy: Yeosang Yoon, see posters
Are there any questions?