Large-scale estimation of river discharge from SWOT satellite observations through data assimilation

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Motivation

- SWOT *direct* observations will include **water surface elevations**, **widths** and **slopes**
- Discharge is very important for hydrology
- Direct estimation of discharge through Manning's equation can be difficult
- Models can predict discharge, but impeded by significant errors
  - Forcings (e.g. precipitation, boundary inflows)
  - Model parameters (e.g. channel characteristics)

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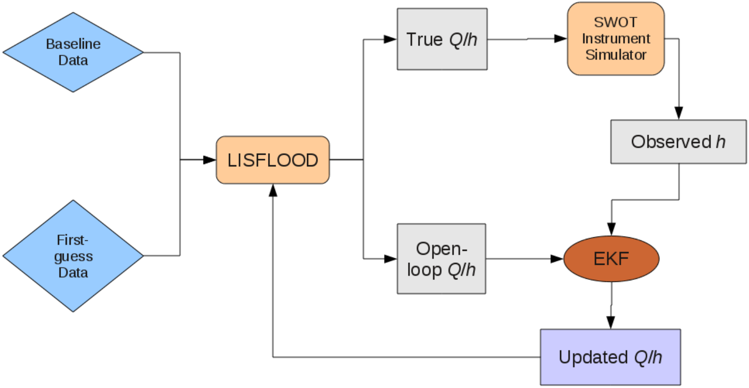
- Merging SWOT observations with modeling predictions via data assimilation
- Developing and testing of SWOT assimilation framework for discharge estimation

Experimental design

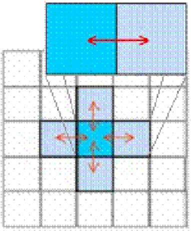
- "Virtual" SWOT observations
- Synthetic data assimilation experiment

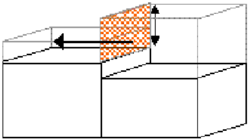


Models

- LISFLOOD-FP raster-based hydrodynamics model
- 1-D solver for channel flow
- 2-D flood spreading model for floodplain flow
- Kinematic, Diffusive and Inertial formulations
- Requires information on topography, river channel characteristics and boundary inflows

- Assumption of rectangular channel
- Has been successfully applied in a number of river systems (mostly smaller scale)



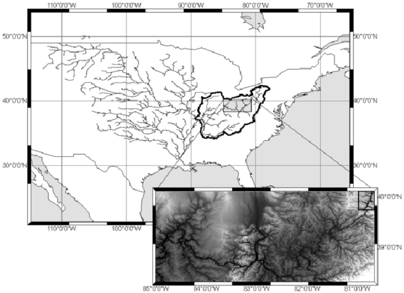


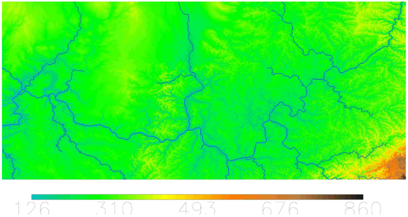
Data assimilation

- A number of assimilation techniques available
- Extended Kalman filter (EKF)
  - Requires explicit modeling of model error covariance, and tangent linear models
- Ensemble Kalman filter (EnKF)
  - Requires ensemble of model states
- EKF is used, estimating the model error covariances using the NMC method
  - assumes error correlations are similar to correlations of differences between successive forecasts
- Every SWOT pass is assimilated separately (filtering)
  - Smoothing could be done by assimilating observations for every orbit cycle

Study area

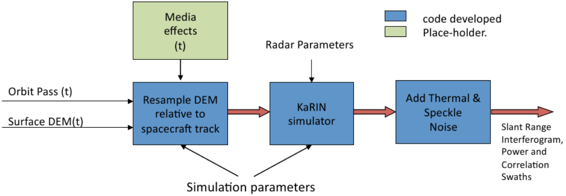
- ∼1000 km reach of the Ohio River basin
- Drains an area of ∼220,000 km^2
- Topography from National Elevation Dataset (30 m)
- River topology from HydroSHEDS
- Channel width and depth from developed power-law relationships
- Modeled main stem with inflows from tributaries

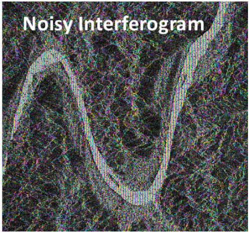


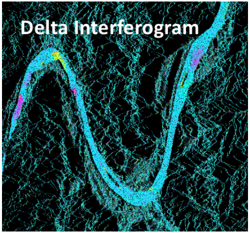


Simulating SWOT observations

- Synthetic observations from the SWOT instrument simulator
- Produces data with correct SNR, geometric and noise characteristics
- Example interferograms and processing chain

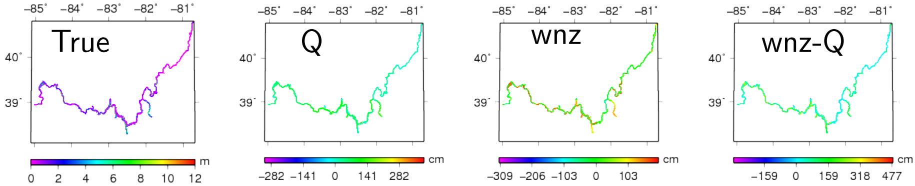




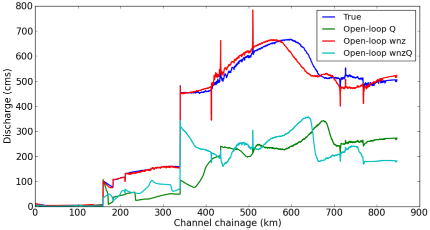


Open-loop simulations

- True water depth and differences of three open-loop simulations from truth



- Channel discharge for one time step
- Inflow error dominates simulated discharge
- Errors in channel characteristics play a less significant role

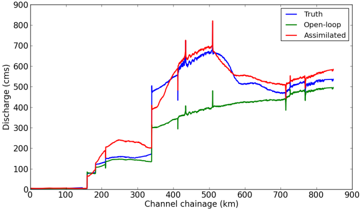


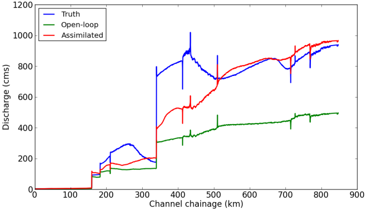
River discharge

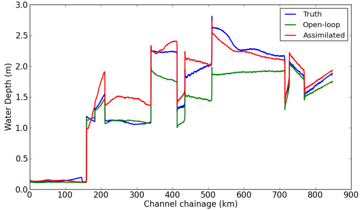
- Errors in inflows as well as channel characteristics
- Ingesting SWOT observed WSE results in improved discharge estimates

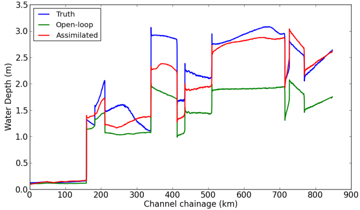
March 30, 2010

April 19, 2010



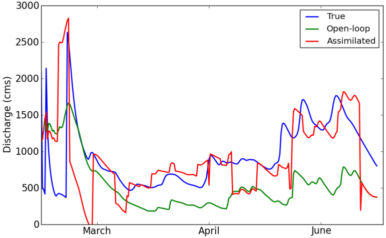




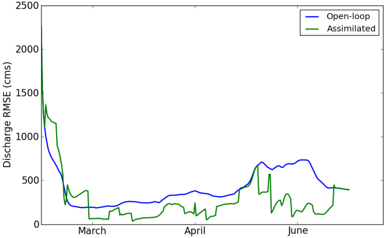


Discharge errors

- Comparison of predicted discharge at study basin outlet
- Spatially averaged error along the river channel
- Assimilated discharge estimates are clearly better
- Issue with temporal persistence, related to inflow errors



Downstream discharge

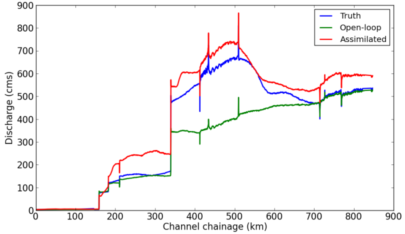


Discharge RMSE

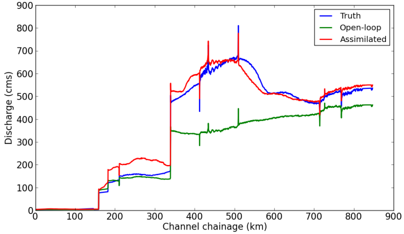
Impact of different model errors

- Synthetic data assimilation framework allows exploring impact of different model errors to discharge estimate
- Examples of assimilation with errors only in boundary inflows, and channel characteristics

Q errors

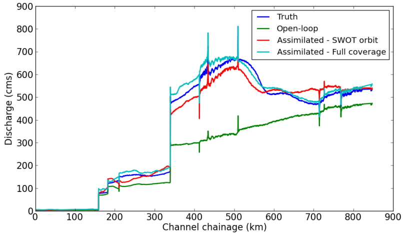


w-n-z errors

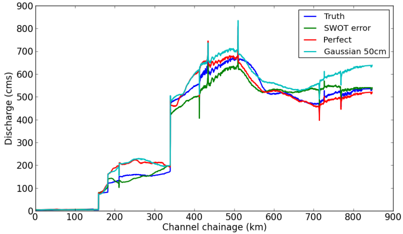


Sensitivity to coverage and observation errors

- How much is the skill decreased when compared to observing the entire domain in one pass?



- SWOT observations will have uncertainty estimate associated
- Impact of assumption about observation error



Future research

- Explicitly model tributaries
- Massively parallel computing towards global applications
- Evaluate different assimilation techniques and error covariance modeling approaches
- Assimilate additional SWOT observables (top width, slopes)
- Evaluate information content of SWOT observations
  - Estimate river channel bathymetry
  - Calibrate hydrodynamic and hydrologic models