Potential for the SWOT Mission to Advance Large-scale Hydrologic Modeling, Inland Bathymetry, and Fluvial Geomorphology: Exploring New Use Cases

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Introduction

CIRES is playing a substantial role in the upcoming Surface Water and Ocean Topography (SWOT) Mission, NASA's first solely-hydrology dedicated mission. A joint mission between NASA, CNES (FRA), CSA (CAN), and UKSA (UK), the SWOT Mission represents a leap forward in understanding of the global hydrologic cycle (Figs. 1, 2). Due to be launched November 17, 2022, the SWOT satellite contains a Ka-band interferometric SAR and Jason-class altimeter (Fig. 3), which will provide unique high spatial resolution data of simultaneous water-surface heights and inundation extents for near-global inland and ocean hydrology (Figs. 4, 5).

For inland hydrology, SWOT is a substantial improvement over existing satellite capabilities and allows the estimation of global river discharge as well as lake and wetland volumetric change. A very clear contribution of SWOT will be to provide information in global regions lacking publicly-available surface water data, and numerous techniques have been developed for these data-sparse regions. In regions with available in situ data, such as the CONUS, the contribution of SWOT has not been well developed. Several concepts to use SWOT data in these data-rich regions are presented here, including advancing hydrologic modeling, inland bathymetry, and fluvial geomorphology.

CIRES will play a substantial role in the upcoming SWOT Mission, serving as the primary SWOT Cal/Val hub and additional science derivatives (Fig. 8).

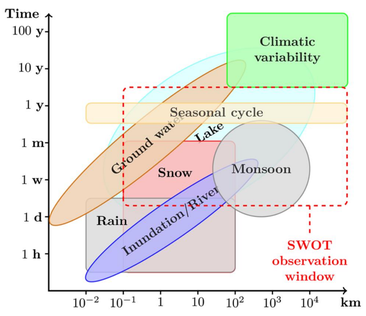

Figure 1. SWOT-targeted temporal and spatial scales of the global hydrologic cycle. *Biancamaria et al. 2016*

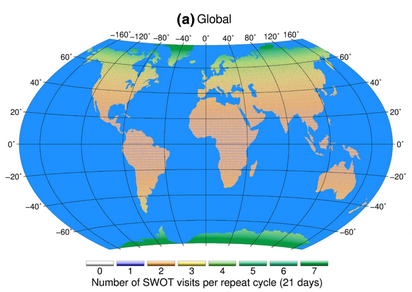

Figure 2. Map of number of SWOT visits per 21-day repeat cycle. *Biancamaria et al. 2016*

NASA SWOT Mission

- Satellite platform
- First hydrology-dedicated NASA satellite
- Near-global coverage every ~10 days
- Instruments: KaRIN, Jason-class altimeter, radiometer
- KaRIN: Ka-band radar (8.4mm), 120 km swath, decimeter vertical resolution

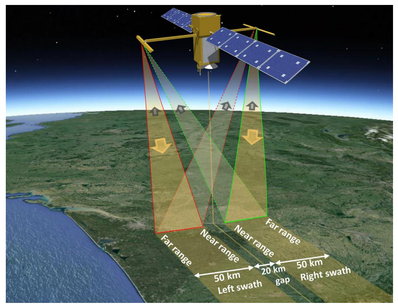

Figure 3. Illustration of SWOT satellite and nominal swath coverage. *Biancamaria et al. 2016*

SWOT Inland Hydrology Science Requirements:

1. **To provide a global inventory of all terrestrial surface water bodies whose surface area exceeds (250m)^2 (goal: (100m)^2, threshold: 1km^2) (lakes, reservoirs, wetlands) and rivers whose width exceeds 100m (goal: 50m, threshold: 170m).**
2. **To measure the global storage change in terrestrial surface water bodies at sub-monthly, seasonal, and annual time scales.**
3. **To estimate the global change in river discharge at sub-monthly, seasonal, and annual time scales.**

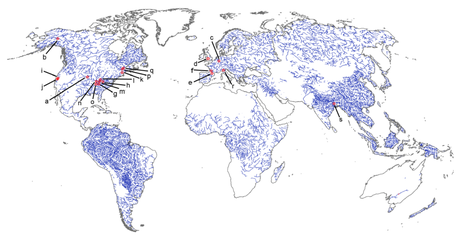

Figure 4. SWOT observable rivers. *Durand et al. 2017*

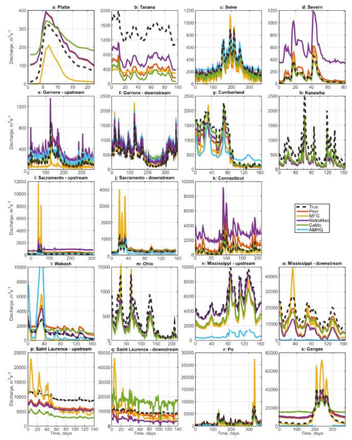

Figure 5. Example of SWOT discharge algorithm development, the 'Pepsi blind taste test' experiment, tested five main algorithms at 19 sites with SWOT simulator data. *Durand et al. 2017*

New Use Case: Hydrologic Modeling

- Currently, it is very difficult to parameterize lake spill, temporal storage change, and channel characteristics for large-scale hydrologic modeling.
- SWOT data will provide these data (Fig. 6) for orders of magnitude more lakes, rivers, and wetlands.
- For example, there are ~1,600 lakes and reservoirs assimilated into the NOAA National Water Model, whereas SWOT will provide data for ~2 million in the same region.

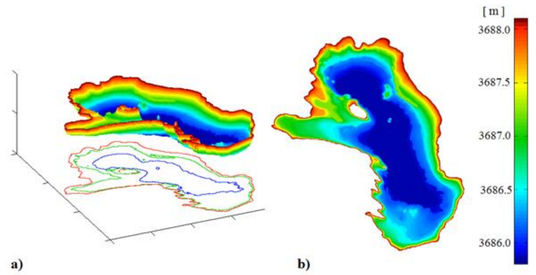

Figure 6. Lake Poopo: Example of lake volume inferred from repeat passes of SWOT simulator. (Courtesy of JF Cretaux)

New Use Case: Inland Bathymetry

- Currently, fewer than 5% of inland waterways have measured bathymetry.
- SWOT data will provide reach-scale depth estimates for larger rivers and the range of all water surface elevation data, the 'bathtub ring' (Fig. 7).
- Combined with discharge data from gages, SWOT inland bathymetry retrievals for large rivers is comparable to measured depths (Fig. 7).

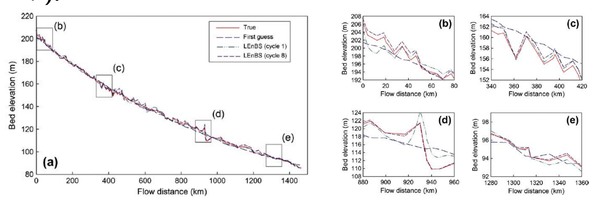

Figure 7. SWOT simulated depth retrieval compared to measured bathymetry. *Yoon et al. 2012*

New Use Case: Fluvial Geomorphology

- Currently, the field of fluvial geomorphology relies upon field or aerial methods to determine primary driving forces, such as depth-slope product or shear-velocity (u_*).
- SWOT data will provide these data from direct measurements.
- Large potential for SWOT to encourage the start of a new sub-field, 'Global Geomorphology'

$$u_*^2 \equiv \frac{\tau_b}{\rho}$$

$$u_* = \sqrt{g\overline{HS}}$$

measured by SWOT

Shear velocity (u_*) has a first-order effect on nearly all fluvial geomorphology processes, including: sediment transport (bedload and suspended load), bank erosion, lateral migration, bar migration, and bedrock erosion.

CIRES Science

- CIRES to be a hub for Cal/Val
- Cal/Val Tier 1 and Tier 2 sites
- Science development:
  - River slopes and extrapolation from gages
  - Discharge inversion algorithms, discharge estimation
  - Automated reach definition
  - Lake volume

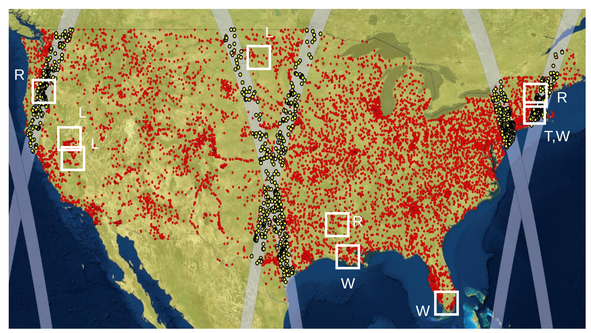

Figure 8. Map of US project Cal/Val Tier 1 sites. 'L, R, W, T' refer to lake, river, wetland, or tidal Cal/Val sites.

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