National Aeronautics and Space Administration

A Golden Era for Hydrology from Space

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Program: FY21 R&TD Strategic Initiative **Strategic Focus Area: A Golden Era for Hydrology from Space**

Objectives

The overarching goal of this initiative is to strengthen JPL's capabilities for scientific discovery and applied sciences in terrestrial hydrology / water resources in the upcoming golden era of hydrology to meet our strategic goals and to enhance our opportunities to capture new remote sensing business in these areas over the following decades. Specifically, the strategic objectives of this initiative are:

A. Ensure success of upcoming JPL hydro missions by confirming readiness, asserting scientific leadership, and fostering discoveries resulting from the Laboratory's engineering efforts. Science questions: what is the (pre-SWOT and pre-NISAR) state-of-knowledge for the spatiotemporal variability of Earth's lakes and reservoirs? What are the expected retrieval errors in SWOT-based river discharge algorithms as estimated from state-of-the-art uncertainty quantification methodology?

B. Strengthen JPL's response to the 2017 Decadal Survey (for both "Designated" and "Explorer" classes) by performing trade-space studies from a hydrology perspective in support of SDSWE, SBG, and/or MC. Science question: how can measurement requirements and measurement capabilities be best aligned for terrestrial water storage, evapotranspiration, and snow?

C. Remain at the forefront of the space-scape by ensuring capabilities for justifying transformative concepts for the next decadal survey. Science question: which hydrologic processes could be best captured by "small sat" capabilities?

Background

"Understanding our water cycle and monitoring our freshwater availability" is one of five Earth Science and Applications Strategic Themes in JPL's 2018 Strategic Implementation Plan, and therefore a critical priority for JPL's Earth Science and Technology Directorate.

A wealth of data is becoming available

Analysis
Interpretation
Synthesis

Transforming data into knowledge:
- How much water do we have?
- How is water availability changing?
- What new missions are needed?
- How is the water cycle influencing and interacting with the solid earth system and energy and carbon cycles?
- What new mission are needed to support terrestrial hydrology?

A dedicated effort is therefore necessary to further cement our scientific leadership in the remote sensing, modeling, and understanding of the terrestrial water cycle; both within NASA and across the numerous U.S. agencies mandated with water.

Approach and Results

We will build on our in-depth experience with hydrology-related missions and with geophysical model development to guarantee JPL's success in its ongoing and expected hydrologic remote sensing activities. Examples of the results obtained through our activities in the 2021 fiscal year:

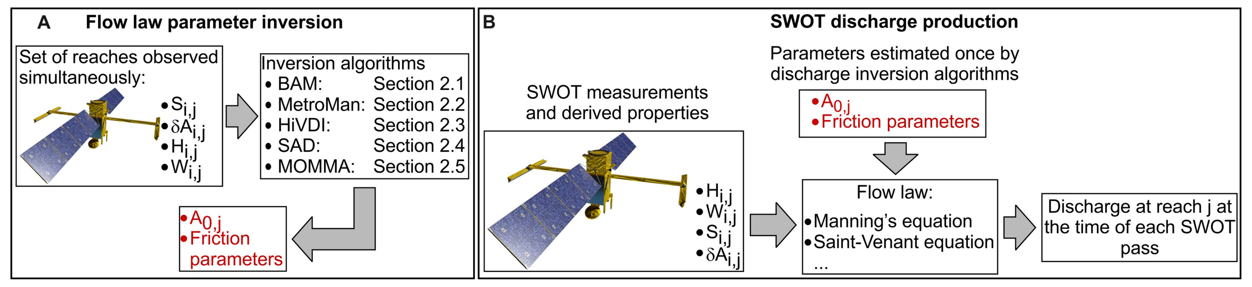

Figure 1. Schematic representation of how the SWOT mission will estimate discharge. Frasson et al. (2021) benchmarked five discharge inversion algorithms that will be used to estimate the unobservable parameters (reference cross-sectional area A_0 and friction parameters) and explored their sensitivity to temporal sampling, observation errors, a priori information, and the geometric characteristics of the inversion domain.

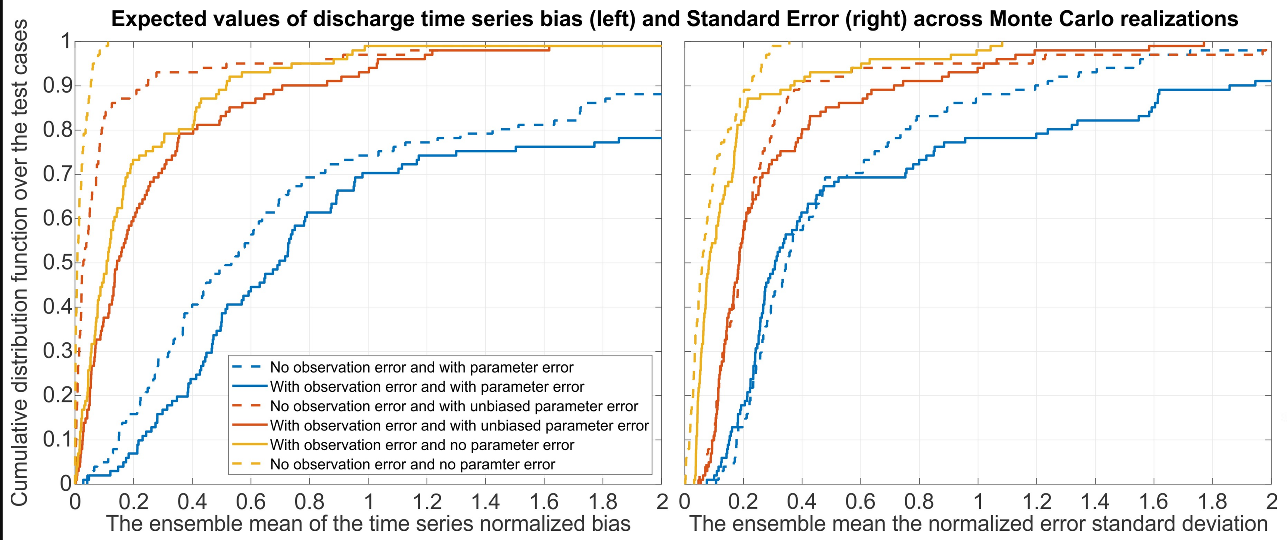

Figure 2. Evaluation of the relative importance of structural errors, SWOT observation errors, and discharge inversion (parameter) errors on the overall discharge error budget. The left panel shows the cumulative distribution functions of time series bias over 16 rivers, each containing 4 to 10 reaches computed using 6 sets of Monte Carlo simulations, with/without observation errors and with/without parameter errors (paper in preparation)

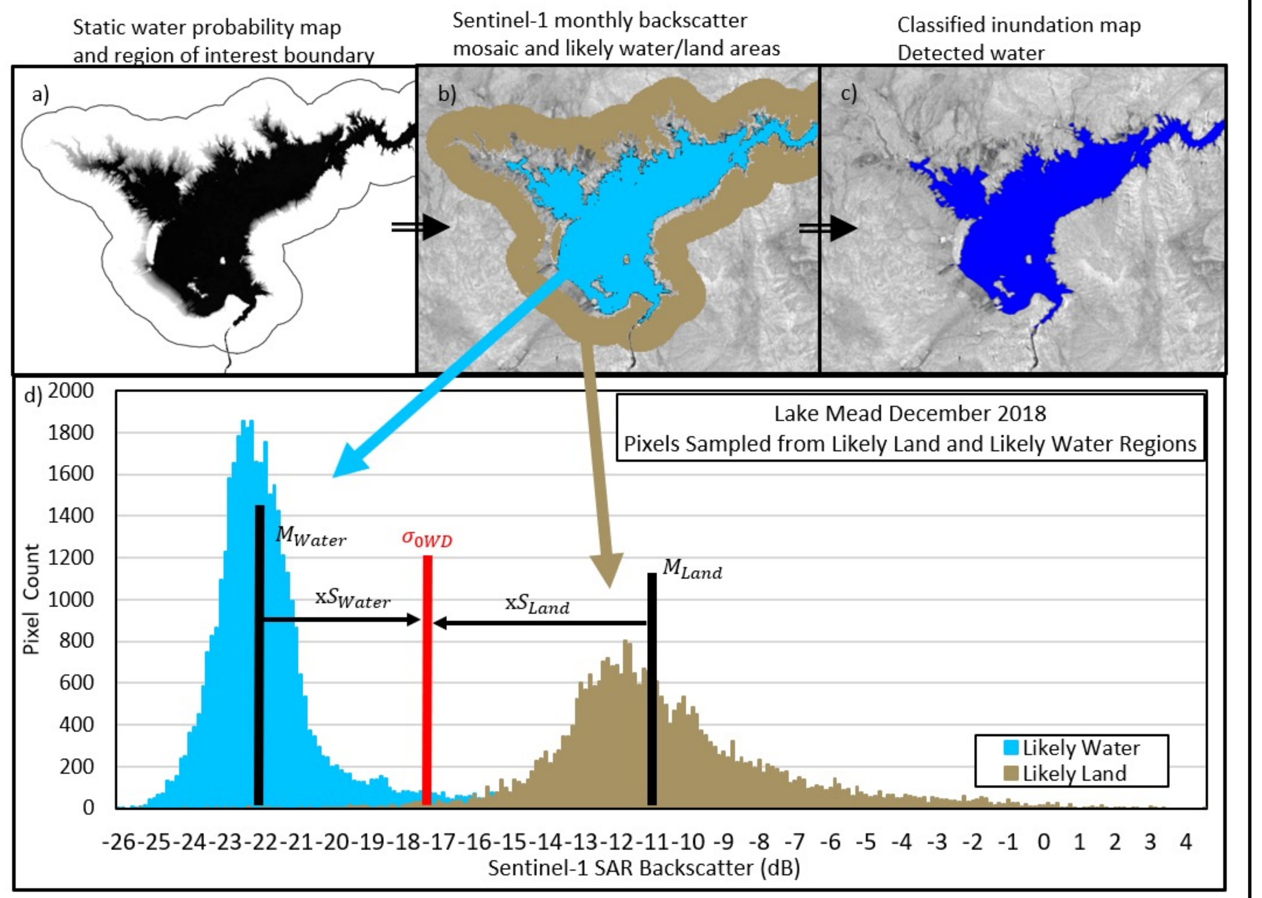

Figure 3. Schematic representation of the water detection algorithm developed by Matthew Bonnema to be applied to Sentinel 1 (From Bonnema et al., submitted). Panel a shows the probability of inundation based on a Landsat-derived dataset. This probability is used to construct two areas: one where we are certain to see water and a second where we know it to be land. Sentinel backscatter in each of the areas is used to construct the histograms shown in panel d, which are used to derive the water detection threshold σ_{0WD} that is unique for each image. The σ_{0WD} derived for a particular image is used to classify that image and produce an inundation map such as the one shown in panel c.

Significance/Benefits to JPL and NASA

The core of our activities in the first two years (FY20 and FY21) has focused on hiring efforts, and this second year (FY21) has also included research advancements.

- Renato Frasson was hired in FY20 and started at JPL on June 01 2020. Madeleine Pascolini-Campbell accepted our offer of employment on September 08 2021 and is expected to start on October 25 2021.
- Our hiring of Renato Frasson has already further asserted JPL's leadership in SWOT hydrology. Renato Frasson has been partially supported by this Strategic R&TD and by the SWOT flight project Algorithm Definition Team. He is also serving as Co-I on two NASA ROSES 2019 SWOT Science Team projects. Since starting at JPL, Renato Frasson has already published a critical paper (Frasson et al., 2021, Figure 1) focusing on the evaluation of SWOT's river discharge algorithms. He has been participating in dedicated weekly research meetings focusing on uncertainty quantification in the context of SWOT discharge (Figure 2). Renato Frasson is also advising one postdoctoral researcher (Matthew Bonnema) evaluating inundated area variability in Earth's natural lakes and artificial reservoirs which led to the recent submission of a manuscript (Bonnema et al., submitted, Figure 3) and just recruited a second.

Publications

- Bonnema, M., David, C. H., Frasson, R. P. de M., Yun, S.-H., & Oaida, C. M. (202x). The Global Surface Area Variations of Large Lakes and Reservoirs. Geophysical Research Letters, Submitted.
- Frasson, R. P. de M., Durand, M. T., Larnier, K., Gleason, C., Andreadis, K. M., Hagemann, M., et al. (2021). Exploring the Factors Controlling the Error Characteristics of the Surface Water and Ocean Topography Mission Discharge Estimates. Water Resources Research, 57(6), e2020WR028519. https://doi.org/10.1029/2020WR028519

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