SWOT Oceanography and Hydrology Data Product Simulators

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1. Introduction

The proposed Surface Water and Ocean Topography (SWOT) mission [1] would demonstrate a new measurement technique using radar interferometry to obtain wide-swath measurements of water elevation at high resolution over ocean and land, addressing the needs of both the hydrology and oceanography science communities. To accurately evaluate the performance of the proposed SWOT mission, we have developed several data product simulators at different levels of fidelity and complexity.

A point target simulator provides the highest level of fidelity by producing radar like echoes at the expense of computational complexity. A more efficient approach is to numerically integrate the interferometric response of the radar [2] at any given range bin r_0 and azimuth line as given by:

$$\langle v_1 v_2^* \rangle = \iint_{S(\vec{r})} A_{12}(r) G_1(\vec{r}) G_2^*(\vec{r}) \sigma_0(\vec{r}) \chi_r(r - r_0) \chi_{az}(\vec{r}) e^{-jk(r_1 - r_2)} dS \qquad \text{Eq. 1}$$

Here, A_{12} is a power factor related to radar parameters, k is the wave propagation constant, G_i are the antenna gains for each interferometric pair, σ_0 is the normalized backscatter cross-section, χ_r is the range interferometric point target response, and χ_{az} is the azimuth interferometric point target response. Since SWOT would perform on-board processing for the ocean products, the interferometric point target response would be different for ocean and hydrology products.

This interferometric simulator still requires significant computational resources and cannot be used as a global tool. Hence, a global simulator that uses parameterized and/or data driven models for the various instrument and media error sources has also been developed.

The following sections provide further examples of the various simulators, their validity and applicability.

2. Ocean interferometric simulator

Given the proposed wide swath and high resolution of SWOT's data, it would become prohibitive to downlink the raw radar echoes acquired by the interferometer globally over the ocean, and a sophisticated ocean processing algorithm has been implemented in an on-board processor (OBP) [3]. The OBP interferometric range and azimuth point target responses have been included in our interferometric simulator to accurately evaluate SWOT's projected ocean performance. This tool has been used to simulate realistic ocean scenes including the ocean waves and has allowed complete characterization of the so-called "Surf-board" wave effect [4], which is a type of oceanographic layover caused by the ocean waves. Figure 1 illustrates the height error as a function of cross track distance for a simulated 50km x 70km scene with a significant wave height of about 2 m.

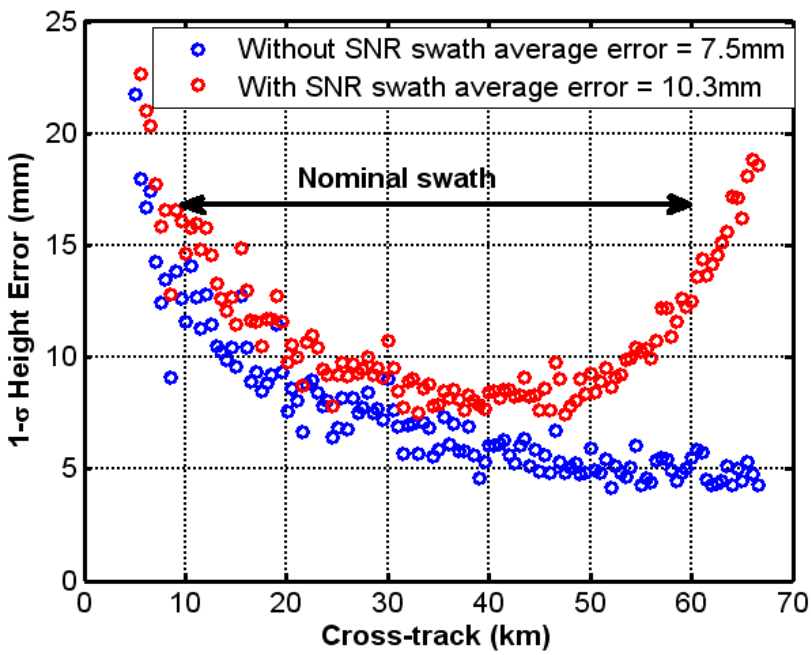

Figure 1. Simulated height error as a function of cross track distance with (red) and without (blue) thermal noise for a scene with SWH = 2m.

3. Hydrology interferometric and science data product simulator

Two separate simulators have been developed specifically for the hydrology data products. The SWOT Hydrology L1b Simulator produces L1b (interferogram) products using as inputs the orbit, radar parameters (e.g. power, bandwidth, baseline) and the digital elevation map (DEM) of

a scene. The SWOT Hydrology L2 Simulator uses the output of the L1b simulator to produce the final height and classification products. These simulators are not only used for system performance analysis and science studies, but also to develop processing algorithms such as classification, phase unwrapping, geolocation and science data product generation. Figure 2 exemplifies the output from the L1b simulator and how it can be used to identify regions contaminated by layover.

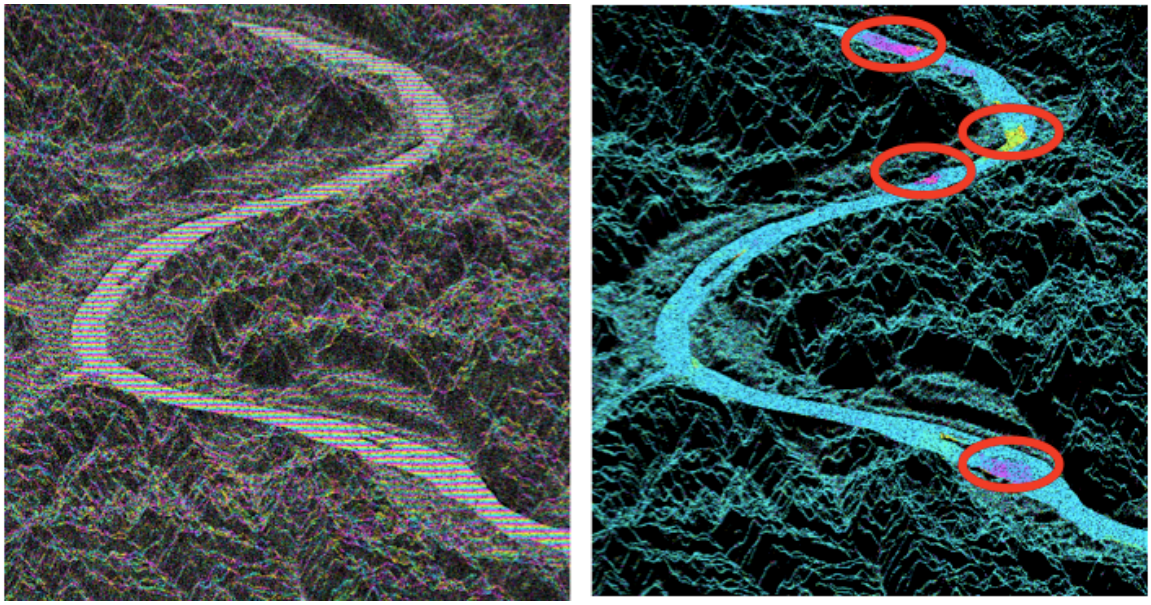

Figure 2. (left panel) Simulated interferogram of the Ohio River as if it had been observed by SWOT. Colors represent interferometric phase, which wraps between 0 and 2p, while intensity represents the returned power. (right panel) Interferometric phase after subtracting an interferogram containing no layover over water. The circled regions indicate locations where the interferometric phase is substantially affected by layover.

4. SWOT global science data product simulator

The simulators presented in sections 2 and 3 require significant computational resources and cannot be used for global studies. In order to address global performance, parameterized and/or data driven models have been used to simulate SWOT's projected instrument (thermal noise, phase and timing errors, mechanical deformations, attitude control and knowledge, POD) and media (wet and dry tropospheric correction, ionospheric correction, electromagnetic bias) errors at a global scale as well as the signal (sigma0, wind speed, ocean waves, tides, mean sea level,

sea level anomaly). SWOT's global simulator is developed as a fully modular tool such that various error sources can be isolated. The output format is equivalent to a possible SWOT's final L2 ocean data product. As an example, Figure 3 illustrates the swath average tropospheric error obtained for various radiometer configuration options obtained globally over a period of a year.

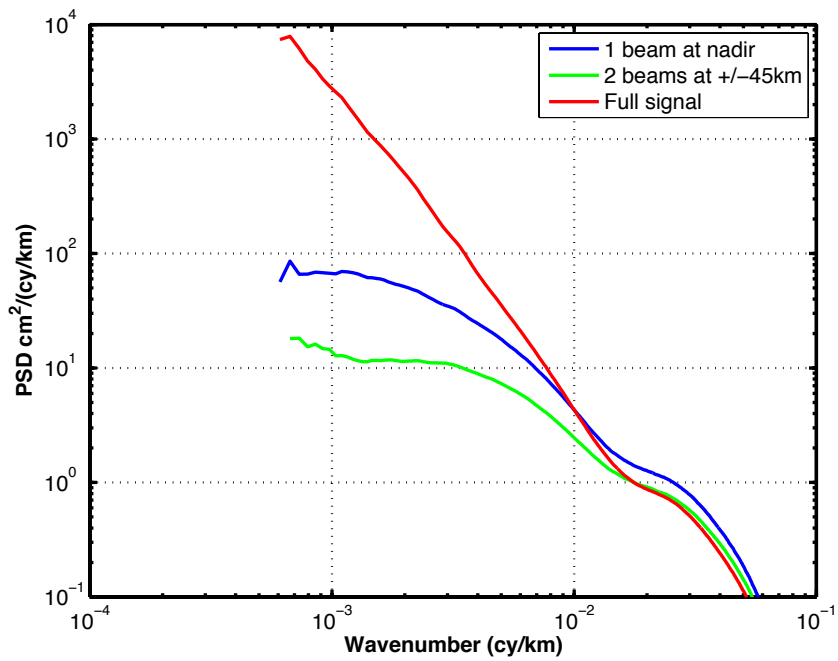

Figure 3. Swath average wet tropo correction error without including the instrument/retrieval error for various nadir and cross track radiometer options.

5. References

[1] "Surface water and ocean topography mission (SWOT): Science requirements document," available at http://swot.jpl.nasa.gov

[2] E. Rodriguez and J. Martin, "Theory and design of interferometric synthetic aperture radars," Radar and Signal Processing, IEE Proceedings, vol. 139, pp. 147 –159, Apr. 1992

[3] Eva Peral, Daniel Esteban Fernandez, Ernesto Rodriguez, Xiaoqing Wu "Surface Water and Ocean Topography Mission KaRIn: Ka-band Radar Interferometer On-Board Processor (OBP) Requirements and Algorithm Definition", *internal JPL memorandum*

[4] Eva Peral, Daniel Esteban Fernandez, Ernesto Rodriguez, "Impact of surface waves on projected SWOT ocean accuracy: the *Surf-board* wave effect", *internal JPL memorandum*