Assessing the impacts of surface waves on SWOT measurements

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Introduction

This project is focused on understanding and refining the effect of waves on ocean measurements collected by the new type of satellite ocean radar interferometer to be flown on SWOT. Ocean surface waves of all flavors including swell, chop, surf, and even small wind-generated ripples can strongly influence the quality of satellite ocean surface topography measurements collected by any radar or lidar system. This is because the wavy surface alters the expected range-to-earth measurement that would occur for a smooth surface and because ocean waves are highly variable and unpredictable. The SWOT science team anticipates that in order to accurately measure the ocean height variations across short horizontal spatial scales of 5-120 km, there will be a need to make wave-related radar measurement adjustments. These will help to compensate for within-swath changes in near-surface winds and longer-scale waves (e.g. swell or seas).

While baseline SWOT ocean data correction methods are already in place (Esteban-Fernandez et al., 2017), this project will evaluate and refine these methods using early mission SWOT data. We also believe pre-launch refinements can be proposed by using relevant wave-related data from existing ocean radar satellites that share useful similarities with the new SWOT KaRIN radar. These systems include SARAL/AltiKa, the Global Precipitation Mission (GPM), Sentinel-1 SAR and S-3 Delay/Doppler Altimeters, and CFOSAT SWIM. Finally, we intend to employ an ocean simulator that addresses wave-impacted radar interferometer measurements as one tool to evaluate the effectiveness of the onboard SWOT approach to wave impact mitigation.

Broad project objectives are to :

1. address pre- and post-launch issues related to the SWOT radar cross-swath measurements that include models for surface wind speed, significant wave height (SWH), and the sea state bias (SSB) range correction by combining existing global numerical wave prediction products with satellite data from conventional altimeter near-nadir radar satellite datasets (GPM and CFOSAT) at Ku- and Ka-band.

2. perform a detailed assessment of wave impacts on SWOT ocean range measurement characteristics during the early 90-day phase of the mission. High-rate ocean data will only be

available during this phase and will be used to assess and validate the performance of SWOT's operational on-board data compression approach.

Our team, approach, and specific objectives:

This team of researchers has been active in the study of ocean radar backscatter, wind-wave modeling, and oceanographic remote sensing topics as they pertain to many past NASA missions including the development of the long-term ocean sea level data record using conventional radar altimeters and more recent efforts to exploit ocean surface Doppler measurement capabilities (Chapron et al., 2005; Egido and Smith, 2017) to expand NASA's capabilities. We will use expertise gained from working with Ka-band radar measurements from aircraft and spacecraft (Vandemark et al., 2005, 2016, Nouguier et al., 2017) to anticipate and quickly develop new SWOT capabilities for mapping ocean surface roughness features at a scale of 500 m along the 120 km swath of ocean that will be continuously measured using the KaRIN radar (Dubois and Chapron, 2018).

To provide a flavor of the expected small spatial changes in wave-impacted roughness that the SWOT radar will be able to map, we the examples shown in Figures 1 and 2. The first is given

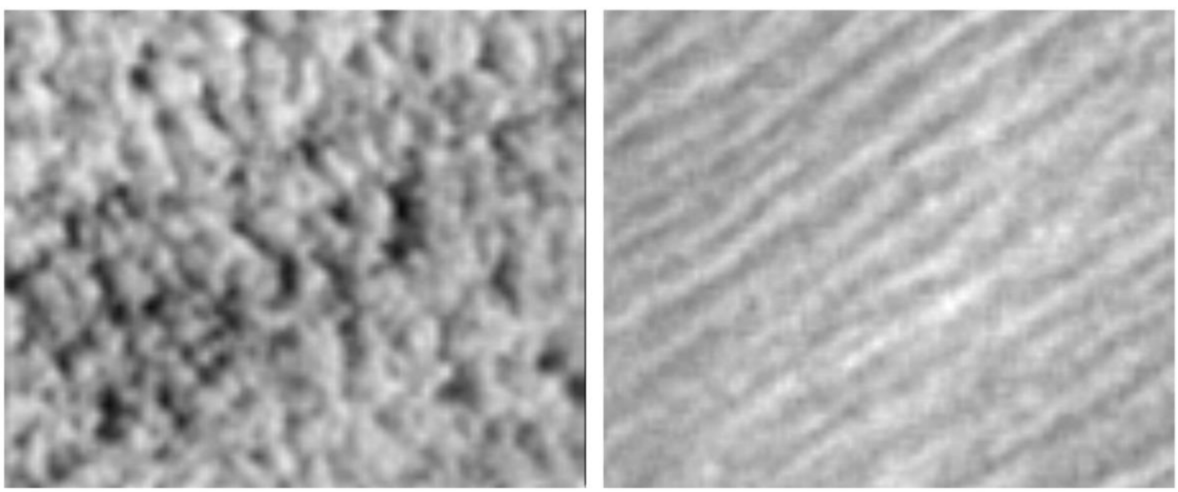

Fig. 1 Two example SWOT ocean radar backscatter simulations (in this case each are 20 x 20 km) showing expected surface wind-wave variations at the base of the atmospheric boundary layer (ABL). These images were made using Sentinel-1A SAR radar backscatter images smoothed to the 500 m pixel scale expected for SWOT Level 2 sigma0 data. The example at left shows a case of thermally-driven ABL microscale convection, at right are the impacts of 1-2 km scale ABL roll vortices aligned with the wind direction.

to highlight and all-new surface wind variation SWOT mapping capability at global scale. The second uses altimeter data to show global hot-spots that will likely be problematic for SWOT range corrections due to unresolved sea state variations - one focus area in the proposed work.

Specific research objectives will be to investigate the variability across SWOT measurement swaths in terms of electromagnetic bias at the Ka-band frequency, wind speed and significant wave height. We will also focus on how variations in the ocean wave field impact SWOT range performance at the swath scale.

Before the SWOT launch, we propose to:

- Develop a new Ka-band radar wind speed model for application to SWOT that addresses expected within-swath variability of radar backscatter and wind
- Produce a study of 5-50 km scale sea state variability and expected relationships to SWOT-observed gradients using existing altimeter data
- Provide a refined Ka-band sea state bias model for SWOT
- Build a new data platform for assessment of ocean wave impacts on SWOT range error and bias at crossovers, making use of existing CFOSAT near-nadir real aperture radar observations as a pathfinder dataset. This work will combine numerical ocean surface and radar scattering simulations associated with both satellites.

After launch, we will focus on the SWOT 90-day fast-phase mission data to:

- Investigate cross-swath SWOT range measurements under variable sea state conditions using both high and low-rate ocean data at dedicated crossover sites. This will entail highest resolution range noise and bias studies related to predicted SAR interferometer volumetric, layover, wave aliasing, and tilt/bunching effects. Lessons and approaches gained from numerical simulations will be applied. Effects of the OBP will be documented.
- Evaluate proposed SSB, wind, and SWH algorithms and investigate characteristics at scales of 1-100 km using the SWOT altimeter combined with the interferometer – this in tandem with in-depth range noise and bias studies at focus SWOT crossover nodes

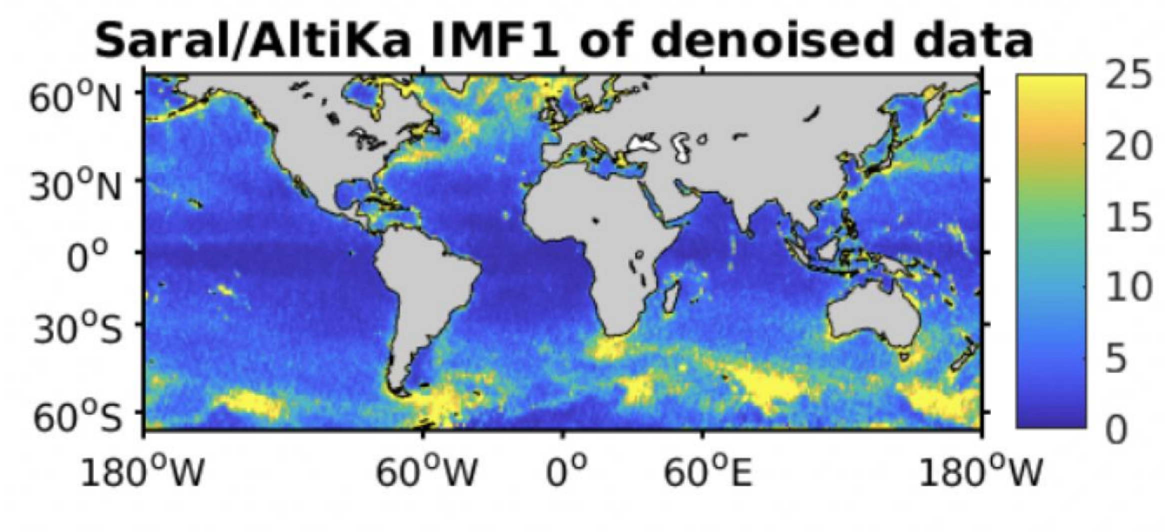

Fig. 2 A global mapping of persistent regions with strong SWH gradients at scales between 30 and 100 km over 1 year produced using SARAL/AltiKa satellite altimeter data. The color scale is variance (cm^2). Here along-track SWH data have been denoised using a new scale-dependent filtering to improve isolation of SWH gradients that SWOT is likely to encounter. Figure is taken from Quilfen and Chapron (2019).

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