Design and coordination of SWOT-related field campaigns

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1 Introduction & Objectives

Ocean dynamics at O(1-100) km scales (submesoscales to mesoscales) have significant global impacts on horizontal and vertical transfers of climate-relevant properties such as heat, momentum, carbon, and nutrients; air-sea interaction; and ecosystem structure. SWOT will allow us to observe, for the first time, the 2-D structure of sea surface height (SSH) on ∼15-120 km wavelength scales, and has the potential to transform our understanding of mesoscale ocean dynamics. Following its launch, SWOT will spend 90 days in a "fast-sampling phase", when it will cover a limited set of ground-tracks each day. At several dozen "crossover" locations, the satellite will cross over the same place twice per day (Fig. **??**). In situ observations will be highly complementary to the SWOT measurements made during the fast-sampling phase, and field campaigns during the time period have the potential to add enormous value to SWOT. A number of SWOT-related field campaigns are planned for the fast-sampling period, notably as part of the "Adopt-a-Crossover" (AdAC) effort that has been established to encourage international groups to make in situ measurements within the crossover regions (*d'Ovidio et al.*, 2019). The overarching aim of this project is to help make the AdAC field campaigns as valuable as possible for the SWOT mission in terms of quantifying oceanic variability on 10-150 km SWOT scales, providing SSH measurements for ground-truth, and characterizing the sea-state bias contribution to SWOT noise. To that end, we have two major objectives:

1. **Identify key measurements** that should be made as part of SWOT-related field campaigns.
2. **Facilitate communication and coordination** between groups planning SWOT-related field experiments, and provide a link between these groups and the SWOT Science Team.

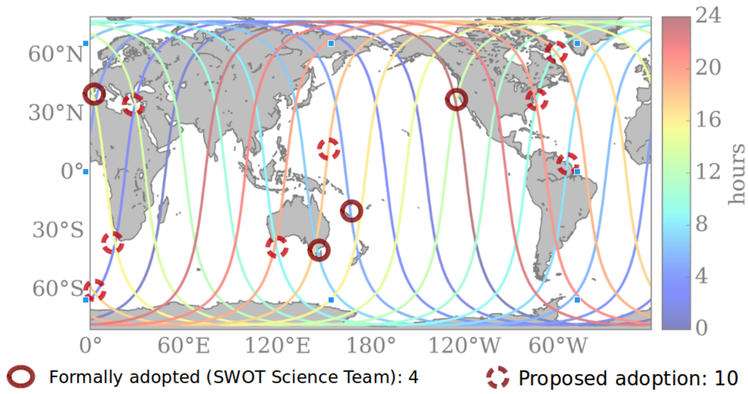

Figure 1: *SWOT orbit during the fast-sampling phase (colors represent the relative time of day, in hours, of each SWOT overpass). The circles represent the proposed Adopt-A-Crossover (AdAC) study regions: the solid circles indicate the four sites that have been formally adopted, and include the US CalVal site west of California; the French CalVal site in the western Mediterranean; a site near New Caledonia in the tropical west Pacific; and a site in Bass Strait. Proposed AdAC sites are shown as dashed circles. Updated from d'Ovidio et al. (2019).*

2 Approach

The first objective will be carried out by running Observing System Simulation Experiments (OSSEs), which use model output to test and evaluate different observing system designs. We will run OSSEs based on a set of existing and underway simulations, including the so-called MITgcm llc4320 simulation, which has already been extensively used for SWOT studies. We will develop a set of recommendations about which measurements, on which scales, from which platforms, would be the most complementary to the SWOT program.

For the second objective, our team will enable communication and coordination between groups planning fieldwork. We will work closely with collaborator Francesco d'Ovidio to facilitate the implementation of strategies developed in Objective 1, organize telecons and in-person meetings, help make resources and data consistent and accessible, and liaise with the greater SWOT Science Team.

3 Analysis and anticipated results

Objective 1

The SWOT fast-sampling phase is a unique opportunity to test the same hypotheses in a number of dynamically (and ecologically) different regimes, and a number of questions could potentially be addressed by combining in situ observations with synoptic SSH maps from SWOT. We will work to refine these questions and determine how best to address them through multi-site observations. This will be achieved by engaging with members of the scientific community, including the AdAC teams, SWOT Science and Mission Teams, and ocean modelers. The outcome will be a community white paper recommending a set of specific objectives that can be addressed through a combination of in situ and SWOT data during the fast-sampling phase in order to advance our understanding of SWOT-relevant science and interpretation of SWOT data.

The heart of the proposed work is to perform OSSEs with the MITgcm model output in order to determine optimal sampling strategies for making the measurements determined in the first part of the work. We will separately consider each region being proposed for AdAC experiments (currently around 14 regions; Fig. **??**). To do so, we will interact with each field team during the proposal and/or planning stage to understand their constraints and needs. We will first evaluate the ability of the MITgcm to produce variability on scales of interest in each AdAC region, focusing on comparisons of surface temperature, salinity, and density variance on 5 to 200 km horizontal scales. Then, OSSEs will be carried out by sampling the model as it would be sampled by different platforms (*Wang et al.*, 2018), focusing on the most widely available and practical options that can be used to estimate steric height from temperature and salinity and/or those that measure currents. These platforms include traditional and underway CTD casts; surface measurements made from ships; underwater gliders; moorings; and bottom pressure recorders. Additional platforms such as Wave Gliders and Saildrones may be considered if deemed valuable by the AdAC teams, in which case coordinated autonomous asset deployments will be explored (**?**). The metrics used to evaluate the sampling strategies we explore with the OSSEs will depend on the available platforms and the signal of interest (e.g., mesoscale or submesoscale dynamics, internal waves and tides, bio-physical interaction, SWOT ground-truth). In conjunction with the OSSE analysis, we will simulate SWOT measurements with the SWOT Simulator to determine how the in situ observations can most effectively complement SWOT measurements during the fast sampling phase.

The outcome of the OSSE analysis will be a set of specific recommendations tailored to the various AdAC groups, including recommendations for "core" measurements that are of primary importance as well as a set of "ancillary" measurements considered to be of secondary importance. The analysis

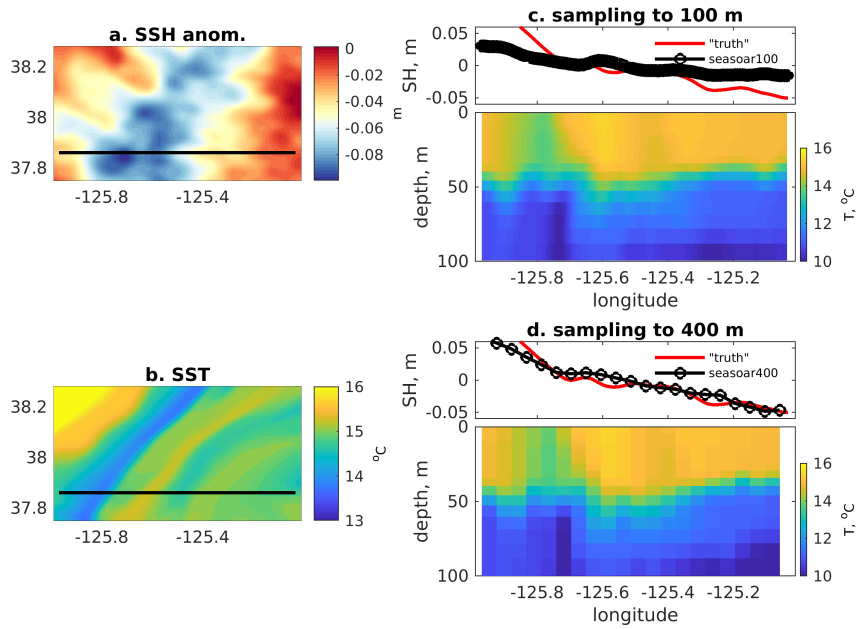

Figure 2: *Example of an OSSE based on output from the llc4320 simulation. (a) SSH anomaly, showing a small mesoscale feature; (b) SST, showing strong submesoscale fronts associated with the mesoscale eddy. The horizontal black line in (a) and (b) represents a theoretical 80-km long ship transect across the feature. Two different sampling strategies with a SeaSoar (undulating CTD) are tested: (c) rapid shallow profiles to 100 m depth, and (d) profiles to 400 m depth, which results in wider spacing between profiles. For each case, the steric height anomalies that would be estimated from the SeaSoar profiles are shown (black lines with the "true" steric height from the model (red lines), and the temperature section that would be measured from the SeaSoar is shown in color. A comparison illustrates that the faster, shallower sampling (c) captures the submesoscale fronts better whereas the deeper sampling (d) is better able to capture the steric height signal.*

code used for the OSSES will be developed to be readily adapted to different regions and will be made publicly available.

Objective 2

Our second objective is to facilitate communication between the field campaign groups, and between these observers and the broader SWOT Science Team, and to help coordinate the field campaigns. This will be done through the following activities: (a) Develop and recommend data policies to ensure that the measurements collected from the diverse AdAC groups are easily read, shared, and compared. (b) Telecons: throughout the project lifetime, we will organize and run bi-monthly telecons to keep the AdAC groups informed of each others' plans and progress. (c) Workshops: during each annual SWOT Science Team meeting, we will hold a 1-day workshop for the AdAC groups to interact with the SWOT Science Team and CalVal team. (d) AdAC website: We will help create and maintain an AdAC website that will serve as the main portal by which AdAC groups can easily obtain and share information.

This objective will be carried out in close collaboration with Francesco d'Ovidio, and will result in a high level of organization and communication between AdAC groups and the SWOT Science Team, particularly regarding data sharing and best practices.

4 Milestones

Year 1 (2020-2021)

Engage with the SWOT Science Team, SWOT Mission Team, AdAC groups, and ocean modelers to refine science questions and hypothesis to be tested with multi-site AdAC field campaigns. Extract MITgcm in regions of interest and perform comparisons to in situ observations.

Year 2 (2021-2022)

Write community white paper on recommendations for AdAC observations. Perform OSSE analysis to determine sampling strategies in the AdAC regions. Work with AdAC Consortium to develop and promote measurement protocols and best practices for sharing data.

Year 3 (2022-2023)

SWOT fast-sampling phase and AdAC experiments: continue providing coordination between AdAC experiment teams, including OSSE analyses as requested, guidelines for measurement protocols, etc. Write paper on OSSE analysis. Analysis of model output to investigate extracting submesoscale fronts and information about internal tides from SWOT measurements combined with in situ data in AdAC regions.

Year 4 (2023-2024)

Following AdAC field campaigns, work with AdAC teams to produce data sets that are consistent and openly available. Write paper on MITgcm-based analysis of (sub)mesoscale dynamics in AdAC regions.

References

d'Ovidio, F., A. Pascual, J. Wang, A. Doglioli, Z. Jing, S. Moreau, G. Grégori, S. Swart, S. Speich, F. Cyr, et al. (2019), Frontiers in Fine-Scale in situ Studies: Opportunities During the SWOT Fast Sampling Phase, *Frontiers in Marine Science*, *6*, 168.

Wang, J., L.-L. Fu, B. Qiu, D. Menemenlis, J. T. Farrar, Y. Chao, A. F. Thompson, and M. M. Flexas (2018), An observing system simulation experiment for the calibration and validation of the surface water ocean topography sea surface height measurement using in situ platforms, *Journal of Atmospheric and Oceanic Technology*, *35*(2), 281–297.