2019 SWOT ROSES TOSCA (Oceanography)

The oceanography science goals of SWOT are to observe the sea surface height (SSH) in two dimensions at scales not resolved by conventional altimetry for studying the role of ocean circulation in exchange of heat and ocean properties between the upper and deep ocean. The SSH measurement is to be made by the technique of radar interferometry that is fundamentally different from conventional altimetry. The observations are also expected to advance the understanding of the processes of the coastal oceans and interactions with the estuaries.

The mission's science requirements were developed with the participation of the mission's Science Definition Team (2013-2016). As the thrust of SWOT is to make SSH observations at previously unresolved scales, the observational requirements were specified in terms of wavenumber spectrum. Based on the prediction of signal strength and measurement errors, the spatial along-track resolution of SWOT is estimated to be 15 km for 2 m significant wave height. However, both signal strength and measurement errors are dependent on seasonal conditions, the actual resolved wavelengths vary from 15 km in the tropics to 30-50 km at high latitudes with the largest values in the Southern Ocean (Wang et al., 2018).

The mission's Science Team (2016-2019) has continued preparing the algorithms for open ocean and coastal processing, and contributed to the scientific understanding of the SWOT ocean signal, errors and applications. The mission has two phases with a 1-day repeat Validation orbit, and a 21-day repeat Science orbit (see the AVISO website for precise orbit groundtracks : (https://www.aviso.altimetry.fr/en/missions/future-missions/swot/orbit.html).

To aid in the preparation of ocean science studies, a SWOT ocean simulator has been developed to simulate the realistic SWOT swath groundtrack and errors. The simulator can be applied to most high-resolution model formats, and is freely available (https://github.com/SWOTsimulator/swotsimulator/blob/master/doc/source/science.rst).

The upcoming Science Team (2020-2023) will participate in the final preparations of the mission, will be engaged in post-launch validation of the first SWOT measurements, and will continue working on the main ocean issues as detailed below.

Mesoscale ocean dynamics

The scales noted above belong to the short end of the oceanic mesoscale, which has not been adequately resolved by the conventional altimeters. After mapping to two-dimensional gridded fields, the resolution of conventional altimeters is about 150 km in wavelength with on-going improvement owing to the increased number of altimeters on orbit. SWOT will also carry a nadir-looking conventional altimeter. With the constellation of conventional altimeters providing the global mesoscale field down to 150 km, the new high-resolution observations of SWOT will provide opportunities to study the interaction of the mesoscale variability within its wide range of scales from hundreds to tens of kilometers. The fine-scale swath observations will allow a better characterization of the anisotropic structure of the mesoscale field, its strain and vorticity, and local 2D energy fluxes. Studies are encouraged that will further our understanding of these smaller mesoscale processes, and their observability with SWOT.

Synergistic applications with other observations capable of revealing mesoscale variability such as in-situ or airborne data, or satellite sea surface temperature and salinity, ocean color and SAR images, are also encouraged.

Tides and high-frequency motions

SWOT's orbits have been specifically designed to resolve the major tidal constituents during its lifetime. SWOT is expected to provide unprecedented observations of the barotropic tides, especially in the coastal and high-latitude regions where current tidal models have the largest errors. The development of high-resolution barotropic tide models will be a high priority for SWOT, and these should be progressively improved during the mission lifetime. Science studies addressing the barotropic tide, its modification due to the baroclinic tide, and improved tidal models will be encouraged.

Internal tides and low-mode internal gravity waves have SSH signals comparable to mesoscale geostrophic motions. How to separate them is a challenge of the SWOT mission. There is a high degree of geographic and seasonal dependence of the problem, which is more severe at low latitudes. Development of predictive models for the internal tides from existing altimetry data is of high priority for the mission. The swath observations of SWOT will provide new opportunities to validate and improve the internal tide models. Understanding and improving the non phase-locked, incoherent part of the internal tide is a challenge for SWOT, but also an important scientific opportunity to learn more on this pathway to ocean mixing and dissipation. It is anticipated that ultimate internal tidal models will be developed by incorporating the SWOT data.

Internal gravity waves are not deterministic processes amenable to prediction. Their potential presence in the SWOT observations presents an unprecedented challenge and an opportunity for studying the interaction of these waves with the mesoscale geostrophic motions.

Ocean fronts and air-sea interactions

Horizontal gradients in SWOT's 2D SSH data can reveal the larger ocean fronts, with scales of tens of kms. SWOT will also provide collocated SAR images at 250 m resolution including power and variance, as well as SAR Doppler Centroid products providing higher resolution observations of the surface roughness changes across fronts. Studies are encouraged that use the collocated SSH and SAR images and other data or models to investigate frontal dynamics and upper-ocean wind-wave interactions across ocean fronts.

Calibration and validation (CalVal)

The interferometry measurement of SSH is fundamentally different from conventional altimetry. The approach to CalVal requires innovation and planning. First, we need to validate the measurement in terms of wavenumber spectrum, as opposed to previous point-wise validation. This geodetic objective is to be accomplished by both airborne and in-situ observations, via lidar and arrays of moorings of geodetic and oceanographic sensors. Second, we need to validate the utility of the SSH observations to the study of ocean circulation to meet the science goals. Specifically, we need to have an observing system that is able to provide information of the 3D ocean circulation, such as its vorticity and vertical velocity that allows studies of the vertical transport of heat and biogeochemical properties. Regions with internal tide activity will also require specific in-situ sampling for SSH validation. The in-situ observations will be used to test the performance of the SWOT-measured SSH for achieving the science goals.

Geophysical Corrections and Algorithms

There are anticipated contributions from the Science Team to better understanding of the measurement physics and the mission's algorithm development. Particular challenges include the correction for the electromagnetic bias at the Ka band frequency and its spatial variability across the measurement swath; the estimation of wind speed and significant wave height across the swath; the use of radar imagery to estimate surface current features; the detection of land, ice, and rain contamination; and, finally, the removal of errors due to the presence of ocean waves.

Ocean state estimation

The challenge of the separation of tides/waves from geostrophic motions is exacerbated by the deficiency of temporal sampling by SWOT. Owing to the limitation of near-nadir look angles to minimize the measurement errors, the swath of the observation is only 120 km wide with a 20-km nadir gap. It will take 21 days to complete the coverage of the world's oceans. The bursts of repeat overflights at a given location are separate in time by 10 days at mid and low latitudes. Apart from high latitudes, the repeat observations are most likely incoherent, presenting a challenge for estimating the continuously evolving state of the ocean. It is anticipated this challenge will motivate the development of creative approach to the problem, including but not limited to the application of high-resolution assimilative models.

High-level data products

The number of observations at a given location in a repeat cycle ranges from two near the equator to more than ten at the highest latitudes. To reconstruct regular 2D SSH fields from the irregularly sampled observations with complex error characteristics will pose a significant challenge for advancing the study of ocean circulation from this new type of observation. Development of methodology for producing optimally estimated products on regular space and time grids on both global and regional basis will be an important activity of the Science Team. The capacity to calculate derivatives of the SWOT gridded data (reconstruction of vorticity, strain, vertical velocities, and detection of fronts and filaments) should also be addressed.