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► **To cite this version:**

J.-C. K Koumi, S Méric, É Pottier, H Yésou, M Azzoni, et al.. SWOT CAL/VAL CAMPAIGN BASED ON THE SWALIS AIRBORNE SENSOR. COMPARAISON OF  $\sigma_0$  OVER THE MONT-SAINT MICHEL BAY AND OVER THE GONDREXANGE/STOKE PONDS. IGARSS, IEEE; IEEE GRSS, Jul 2024, Athènes, Greece. hal-04902179

**HAL Id: hal-04902179**

**<https://hal.science/hal-04902179v1>**

Submitted on 20 Jan 2025

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# SWOT CAL/VAL CAMPAIGN BASED ON THE SWALIS AIRBORNE SENSOR. COMPARAISON OF $\sigma_0$ OVER THE MONT-SAINT MICHEL BAY AND OVER THE GONDREXANGE/STOKE PONDS.

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## ABSTRACT

This paper presents the first comparisons of backscattering coefficients  $\sigma_0$  between acquisitions from the SWALIS (*Still Water Low Incidence Scattering*) airborne sensor and the space mission SWOT (*Surface Water and Ocean Topography*) over the Mont Saint-Michel (MSM) bay and over the Gondrexange and Stoke ponds. The MSM area is chosen both as a calibration/validation area for the SWOT mission and as a perfect area for analyzing the backscattering of specific sand areas.

**Index Terms**— airborne radar, backscattering, SWOT mission, SWALIS, wet and dry sands, darkwater

## 1. INTRODUCTION

Space radar for oceanography and hydrology remote sensing use the near-nadir incidence range so that the backscattered signals have a greater amplitude at incidence angles close to  $0^\circ$ . To this end, the SWOT (Surface Water Ocean Topography) mission, developed between CNES and NASA, is based on the use of a Ka-band interferometric satellite synthetic aperture radar with a range of incidence angles from  $0.6^\circ$  to  $4.1^\circ$ . The SWOT mission is responsible for measuring water levels at the earth's surface (lakes, rivers, oceans) [1].

As part of the SWOT mission, we develop an experimental airborne radar sensor called SWALIS (Still Water Low Incidence Scattering) to estimate the contrast between the radar signal backscattered both by water surfaces and land surfaces, and to characterize the behavior of water surfaces and the value of  $\sigma_0$ . Our experiments also characterize the conditions that induce low radar backscatter at very low incidence angles (from  $0^\circ$  to  $5^\circ$ ). The SWALIS radar system is therefore considered as a calibration and validation instrument for the SWOT mission [2, 3, 4].

This article compares data from part of the measurement campaigns carried out in June 2023 on the one hand over the Bay of Mont-Saint-Michel (MSM) and on the other hand over

the Gondrexange and Stoke ponds. These data are coming from the SWOT satellite and the SWALIS airborne sensor as well. The first section briefly describes the SWALIS airborne sensor. We then introduce the SWOT calibration and validation campaigns, followed by the associated SWALIS measurements. We then compare  $\sigma_0$  backscattering coefficients over predefined zones. In conclusion, we propose future analyses and comparisons over other SWOT calibration and validation sites where SWALIS is involved.

## 2. SWALIS SENSOR : A BRIEF DESCRIPTION

The SWALIS system described in [2] is subdivided into 2 parts: the first part is located in the cargo-pod under the plane and the second part is located in the aircraft cabin. In figure 1, we describe all the elements of the acquisition system and the links between the part installed in the cargo-pod and the part installed in the aircraft cabin. These different parts of the system are well addressed in [3]. First results show the high potential of the SWALIS sensor for Ka-band airborne radar measurements. The SWALIS sensor provides power measurements leading to radar equivalent area data normalized by the area of the illuminated zone  $\sigma_0$  and obtained by a calibration process developed in [4].

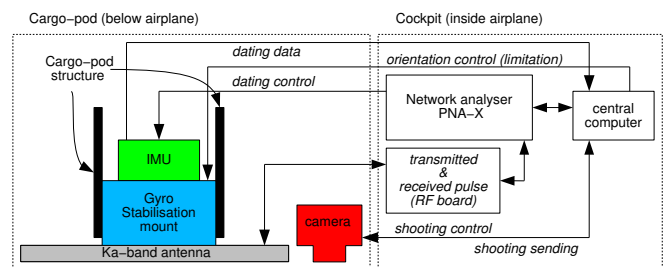
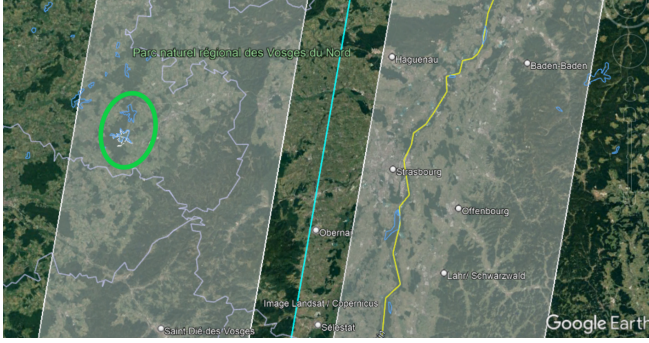


Fig. 1. General description of the SWALIS system



**Fig. 2.** SWOT’s Cal/Val orbit: ascending orbit over Strasbourg. In blue, the SWOT path. In gray, the KaRIN swath on either side of the track. In yellow, the Rhine river. Circled in green, the Gondrexange and Stoke ponds.

### 3. SWOT MISSION/SWALIS FLIGHTS - JUNE 2023

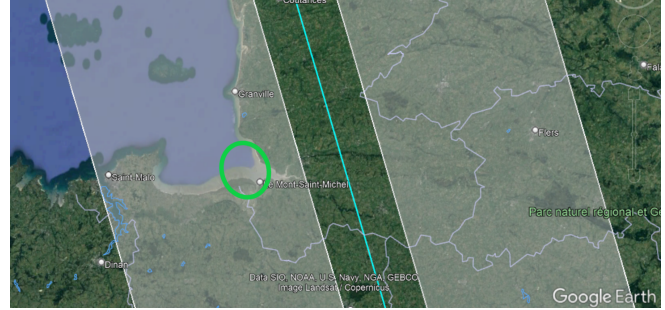
The SWOT mission, addressed in [5], carries the KaRIn instrument, an interferometric synthetic aperture radar for continental hydrology and oceanography.

Until early July 2023, the SWOT satellite, launched on December 16, 2022, was in its calibration and validation phase. We are using the SWALIS sensor during this period (June 2023 campaign) to synchronize SWALIS data with SWOT measurements. This synchronization is achieved by considering the SWOT passing hours, the selected areas of interest (AoI) and the incidence angle corresponding to the AoI illuminated by SWOT. We briefly present the information related to the SWOT mission and the intervention framework for the SWALIS sensor associated to SWOT.

#### 3.1. SWOT information

During its calibration/validation phase, SWOT flies over several calibration/validation sites around the world. In France, the selected sites are: Camargue, Garonne, Loire, Normandy, Pyrenees, Southern Rhine river). The AoI selected to fly the SWALIS sensor at the same time as SWOT are the Southern Rhine and Normandy (MSM mainly).

Over the Southern region, the AoIs shown in this paper are the ponds of Gondrexange and Stoke over which can be investigated dark water and small wind phenomena. The SWOT orbital trajectory over this area is upward at  $16^\circ$ , as shown in figure 2. For the Normandy site, we choose an area offering wet and dry sand backscattering phenomena: the bay of MSM. The SWOT orbital track over this area is downward at  $164^\circ$ , as shown in figure 3. The MSM bay is therefore on the right swath of the sensor (on the left of the image) at an incidence angle around  $3^\circ$ .



**Fig. 3.** SWOT Cal/Val orbit: descending orbit over the MSM bay. In blue, the SWOT path. In gray, the KaRIN swath on either side of the trajectory.

Date	Time	Tiles	Cycles
June 20, 2023	11:16:21 UTC	003_240L	558
June 21, 2023	11:06:59 UTC	003_240L	559
June 22, 2023	10:57:36 UTC	003_240L	560
June 27, 2023	20:46:34 UTC	016_069R	565
June 28, 2023	20:37:11 UTC	016_069R	566
June 29, 2023	20:27:49 UTC	016_069R	567

**Table 1.** Day, time, tile and cycle corresponding to the studied SWOT paths.

#### 3.2. SWALIS and SWOT paths

The SWALIS flights over the AoIs are synchronized with the SWOT path times which are described in table 1 and the corresponding tile labels as well: June 20-22 over Gondrexange and Stoke ponds and June 27-29 over the bay of MSM. For each day, figures 4 and 5 exhibit the MSM and Gondrexange-Stokes ponds SWOT radar images respectively. For the MSM bay, the SWALIS flew over the area around 1 hour before SWOT due to specific constraints of the PIMA airborne (the last flights took place 30 minutes before SWOT path).

#### 3.3. Set up of SWALIS parameters

The SWALIS measurement parameters which are common to both campaigns are described in table 2. Scanning mode

Parameters	Values
Transmitted power	-8 dBm
Pulse width $\tau$	$1 \mu s$
PRF	4 kHz
IF filter	15 MHz
Sampling frequency	20 MHz
Carrier height	500 m
Number of samples per pulse	100
Number of pulses per burst	50

**Table 2.** SWALIS : measurement parameters [3].

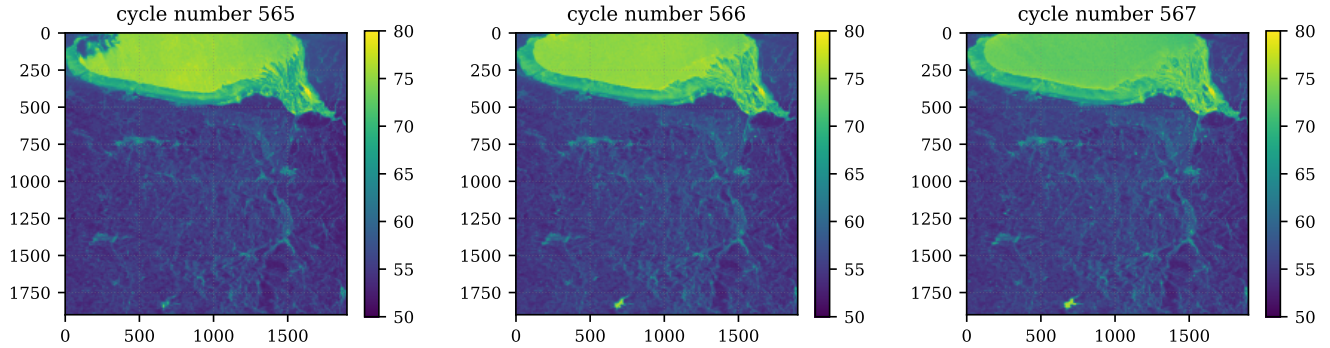


Fig. 4. MSM bay: extracts from the coherent power SWOT radar images.

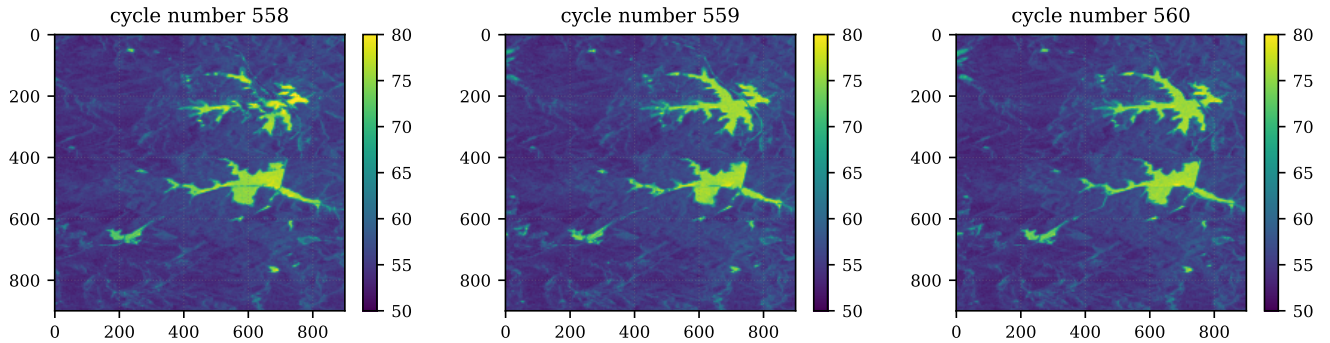


Fig. 5. Gondrexange and Stoke ponds: extracts from the coherent power SWOT radar images.

is used through using 3 input frequencies that makes possible to reach 3 different steering angles [2]:  $-0.14^\circ$ ,  $1.83^\circ$  and  $3.06^\circ$  during the MSM campaign. For the measurements over Stoke and Gondrexange only one frequency is used in order to achieve a steering of  $3.06^\circ$ .

#### 4. FIRST RESULTS

Our first aim is to rely the physical measurement conditions with both SWOT and SWALIS radar measurements. On the one hand, the SWALIS sensor provides geo-referenced optical images of the illuminated scene. Mosaicking these images enables rapid qualitative analysis of the areas overflowed by the sensor.

##### 4.1. The MSM bay

We then can define 3 areas over which we are carrying out a more in-depth analysis by comparing the  $\sigma_0$  while superposing SWALIS data and SWOT PICX data as illustrated in figure 6. A wet sand area (green rectangle), a little hill of sand thus less humid (blue rectangle) and an area close to and including the sea (red rectangle) can be discriminated. On the other hand, the SWOT  $\sigma_0$  data are extracted by applying an interpolation procedure in longitude and latitude along the SWALIS trace to the SWOT PIXC image. We obtain the  $\sigma_0$  values from SWOT to make a comparison (figure 7) at the

same incidence angles (between  $1.5^\circ$  and  $2.5^\circ$  incidence angle) with the  $\sigma_0$  data from SWALIS.

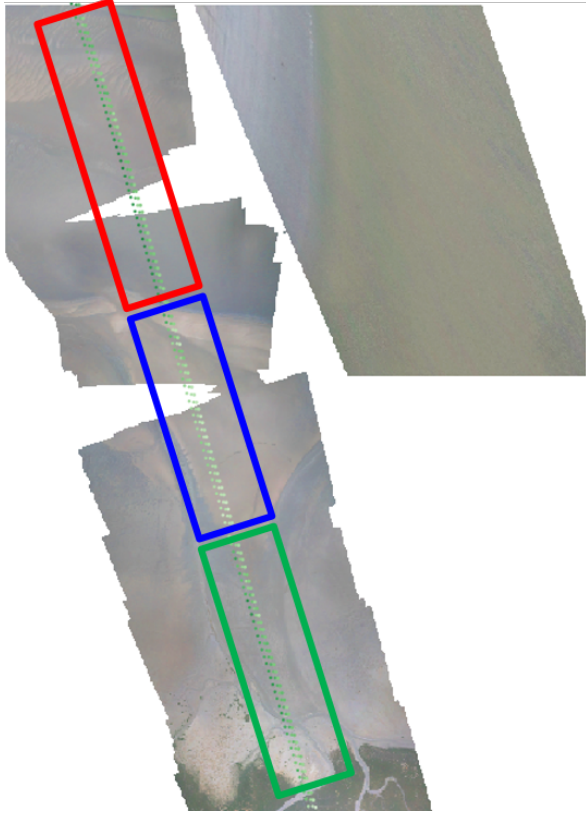
Timely speaking, this SWALIS path is the closest to the SWOT one. The hill of sand (blue zone) shows less backscattered signal than the wet sand area (green zone). Moreover, the  $\sigma_0$  values remain constant over the sea area (red zone). Another comment is about the  $\sigma_0$  values evolution which is comparable between SWALIS and SWOT. Nevertheless, the absolute amplitudes are comparatively different. We have 2 hypothesis for explaining this issue. Firstly, the SWOT sensor is currently awaiting correction of the calibration coefficient for the  $\sigma_0$  value. Secondly, measurements are planned to refine the calibration coefficients for the SWALIS sensor [4]. These points are currently under investigations.

At this time, we roughly apply the same data processing to the Gondrexange pond area and we compare the  $\sigma_0$  of SWOT to the  $\sigma_0$  measurements of SWALIS. We see the same trend as illustrated by figure 8.

#### 5. CONCLUSION

In this article, we describe the first comparisons of  $\sigma_0$  values obtained by the SWALIS sensor with  $\sigma_0$  from the SWOT mission over 2 calibration/validation areas. The  $\sigma_0$  patterns are similar but a bias value remains.

The first next step is to adjust the  $\sigma_0$  values between



**Fig. 6.** Mosaic of SWALIS optical images with the SWALIS airborne path (small green stickers).

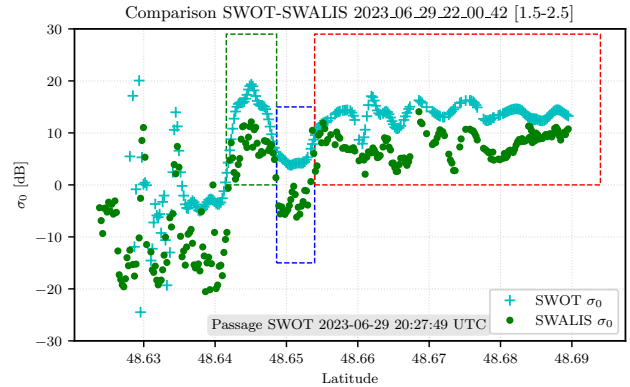
the SWALIS and SWOT data. Furthermore, we will analyze and compare radar measurements at the other SWOT calibration/validation sites where we carried out SWALIS measurements, i.e. the Southern Rhine areas.

## 6. ACKNOWLEDGMENT

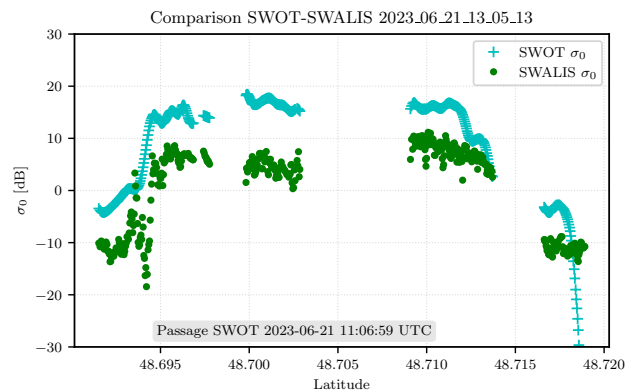
We would like to thank G. Grunfelder and G. Picoult for their huge contributions to the measurement campaigns. We would also thank all the CNES members involved in the SWALIS sensor conception.

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**Fig. 7.** Comparison of  $\sigma_0$  over the MSM bay



**Fig. 8.** Comparison of  $\sigma_0$  over the Gondrexange pond

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