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# SWOT Cal/Val Campaign based on the SWALIS airborne sensor. Comparison of $\sigma_0$ from the Rhine River.

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**Abstract**—This paper introduces a quick comparison of backscattering coefficients,  $\sigma_0$ , between data gathered by the SWALIS (Still Water Low Incidence Scattering) airborne sensor and those from the SWOT (Surface Water and Ocean Topography) satellite mission. These comparisons were conducted over two distinct locations over the Rhine : Plobsheim and Gerstheim. SWALIS reveals fluctuations in these coefficients both in the open water areas and in areas adjacent to the banks over Plobsheim areas.

**Index Terms**—airborne radar, backscattering coefficient, SWOT mission, SWALIS sensor, water surfaces, darkwater

## I. INTRODUCTION

Spaceborne radar systems for oceanography and hydrology remote sensing utilize near-nadir incidence angles to enhance the backscattered signals, particularly at angles close to  $0^\circ$ . The SWOT (Surface Water Ocean Topography) mission, a collaboration between CNES and NASA, employs a Ka-band interferometric satellite synthetic aperture radar with incidence angles ranging from  $0.6^\circ$  to  $4.1^\circ$ . This mission aims to measure water levels across Earth's surfaces, including lakes, rivers, and oceans [1].

Within the scope of the SWOT mission, we developed an experimental airborne radar sensor named SWALIS (Still Water Low Incidence Scattering). SWALIS aims to evaluate the contrast between radar signals reflected from water and land surfaces, as well as to analyze the behavior of water surfaces and the associated  $\sigma_0$  values. Our experiments also investigate conditions resulting in low radar backscatter at very low incidence angles, ranging from  $0^\circ$  to  $5^\circ$ . Consequently, the SWALIS radar system serves as a calibration and validation tool for the SWOT mission [2]–[4].

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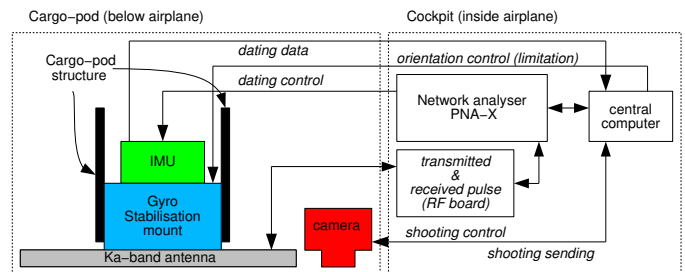


Fig. 1: Overview of the SWALIS system

This article presents a comparison of data obtained during measurement campaigns conducted in June 2023 over the Rhine. These data originate from both the SWOT satellite and the SWALIS airborne sensor. The first section provides a brief overview of the SWALIS airborne sensor, followed by an introduction to the SWOT calibration and validation campaigns and the corresponding SWALIS measurements over the Rhine river. Subsequently, we compare  $\sigma_0$  backscattering coefficients across predefined zones. In conclusion, we suggest future analyses and comparisons at other SWOT calibration and validation sites involving SWALIS.

## II. A BRIEF DESCRIPTION OF SWALIS SENSOR

The SWALIS system, as detailed in [2], consists of two main components: the first part is situated in the cargo-pod beneath the aircraft, while the second part is housed within the aircraft cabin. Fig. 1 illustrates all the components of the acquisition system and illustrates the connections between the segment installed in the cargo-pod and the segment installed in the aircraft cabin.

TABLE I: Day, time, tile and cycle corresponding to the studied SWOT paths.

Date	Time	Tiles	Cycles
June 13, 2023	12:21:58 UTC	003_240R	551
June 14, 2023	12:12:36 UTC	003_240R	552
June 15, 2023	12:03:13 UTC	003_240R	553

These distinct system segments are comprehensively discussed in [3]. Initial findings demonstrate the considerable potential of the SWALIS sensor for Ka-band airborne radar measurements. The sensor delivers power measurements that enable the derivation of radar equivalent area data normalized by the illuminated zone’s area, denoted as  $\sigma_0$  (Normalized Radar Cross Section - NRCS). This process is established through a calibration methodology outlined in [4].

### III. SWOT MISSION OVER THE RHINE/SWALIS FLIGHTS - JUNE 2023

The SWOT mission, discussed in [5], incorporates the KaRIn instrument, an interferometric synthetic aperture radar designed for continental hydrology and oceanography applications.

Until early July 2023, the SWOT satellite, launched on December 16, 2022, underwent its calibration and validation phase. During this period, specifically in the June 2023 campaign, we utilized the SWALIS sensor to synchronize its data with SWOT measurements. This synchronization process involves considering the passage times of SWOT, the designated areas of interest (AoI), and the corresponding incidence angles of these AoIs illuminated by SWOT.

We briefly outline the information pertaining to the SWOT mission and the operational framework for the SWALIS sensor in conjunction with SWOT.

#### A. SWOT : Calibration validation areas

During its calibration/validation phase, SWOT conducted flights over various calibration/validation sites worldwide. In France, the designated sites included Camargue, Garonne, Loire, Normandy, Pyrenees, and the Southern Rhine River. The areas of interest (AoIs) selected for simultaneous flights of the SWALIS sensor on the same track as SWOT were the Southern Rhine and Normandy (with a focus on Mont Saint-Michel).

The AoIs highlighted in this paper are the Southern Rhine River, where investigations into small wind phenomena are conducted. The orbital trajectory of SWOT over this area is at an upward angle of  $16^\circ$ , as depicted in Fig.2.

#### B. SWALIS and SWOT passages times

SWALIS flights over the Areas of Interest (AoIs) are coordinated with the passage times of SWOT, as outlined in Table I, along with the corresponding tile labels: June 13-15. Fig. 3 displays  $\sigma_0$  obtained from SWOT PIXC data over the Rhine, Plobsheim area in the north and the Gerstheim in south. Over these 3 days (June 13 to 15 -from the left to the right), we

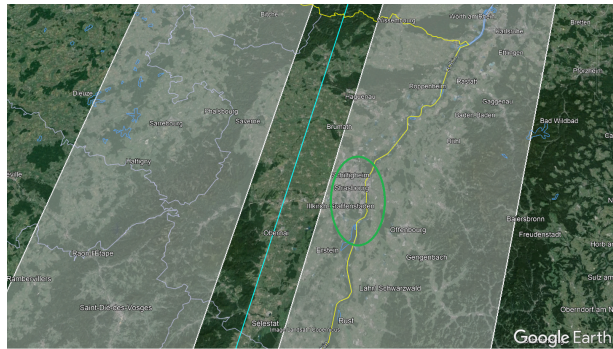


Fig. 2: SWOT’s Cal/Val orbit: ascending orbit over Strasbourg. In blue, the SWOT path. In gray, the KaRIN swath on either side of the track. In yellow, the Rhine river.

can note that the variation in  $\sigma_0$  is higher near the banks than anywhere else.

#### C. Configuring SWALIS parameters

The SWALIS measurement parameters used over the Rhine are described in table II. The height of the carrier, coupled with the half power bandwidth of the antenna in the cargo pod, gives a footprint close to that of SWOT. The mono-incidence

TABLE II: SWALIS : measurement parameters [3].

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

mode [2] at 33.63 GHz is used to achieve a steering angle of  $-0.14^\circ$ .

### IV. FIRST RESULTS FROM THE RHINE RIVER

The aim of this section is to compare the backscattering coefficient values of SWOT and SWALIS data. To this end, we start with SWOT’s PIXC data illustrated above (Fig. 3), from which we interpolate the  $\sigma_0$  information corresponding to a given angle class for each longitude and latitude.

In the South Rhine location, the angle of incidence for SWOT data is approximately  $1.3^\circ$ . Therefore, to ensure an adequate dataset for comparison, we choose SWALIS data within the  $[1^\circ-3^\circ]$  range for recordings that coincide with the satellite’s passage time (both before and after the pass). On June 14, Fig. 4 displays SWALIS received power data on Open Street Map (OSM) : record timely close to SWOT pass, before (right) and after (left). We observe similar patterns between SWOT and SWALIS in both the records depicted in Fig. 5 and Fig. 6, characterized by a nearly consistent bias. Specifically, the alternations between land and water are also prominently delineated in Fig. 5. The primary reason for the

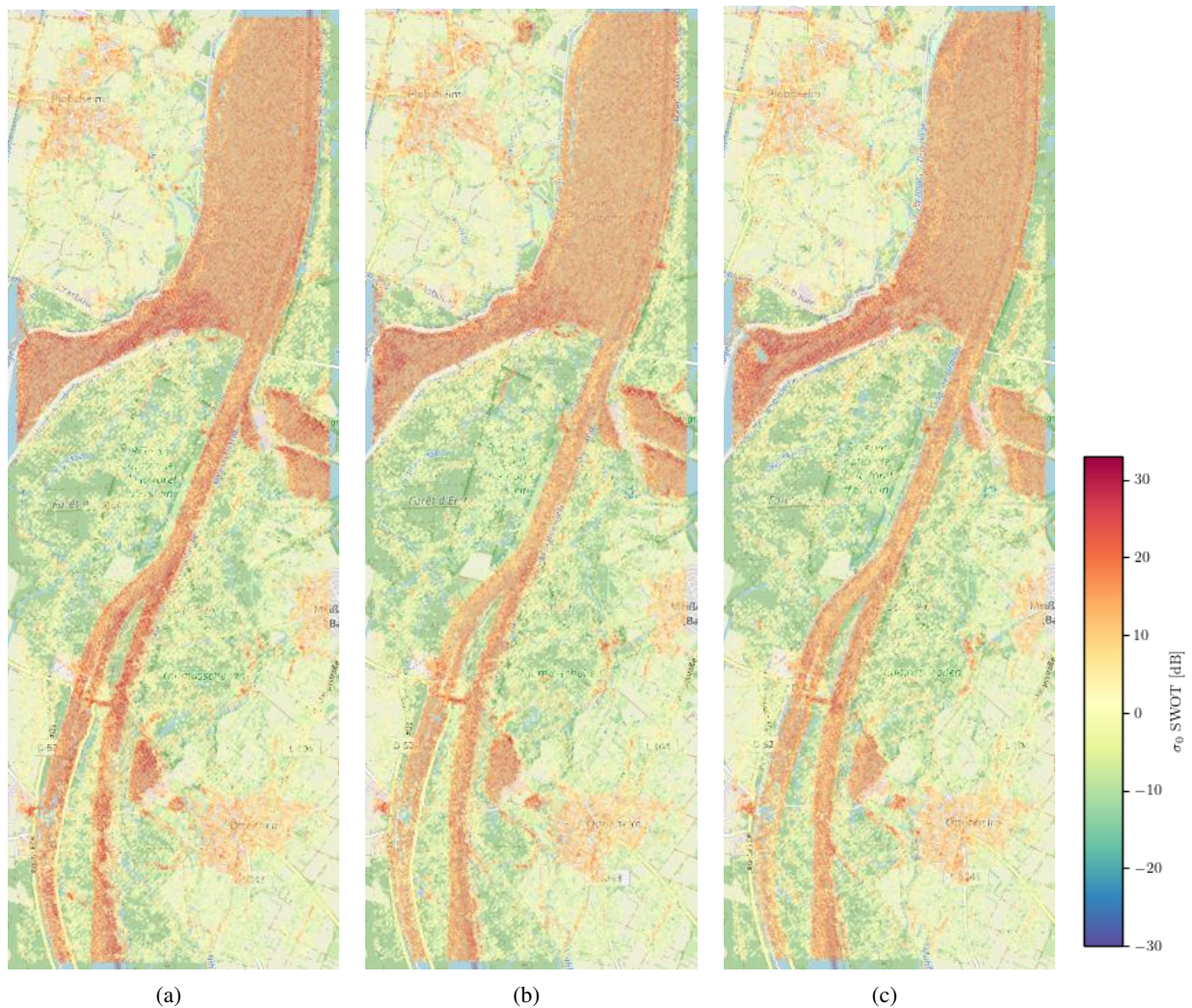


Fig. 3: SWOT PIXC data:  $\sigma_0$  plot over the Rhine for cycles 551 (3a) , 552 (3b) , 553 (3c).

peak at  $48.49^\circ$  latitude (Fig. 5) is the sparse distribution of SWOT's PIXC data over land. The comparison outcomes are similar over the area of Gerstheim.

## V. CONCLUSION

This article presents the initial comparisons of  $\sigma_0$  values derived from the SWALIS sensor with those from the SWOT mission over the Rhine river. While the  $\sigma_0$  patterns exhibit similarities, a residual bias persists.

The immediate next step involves refining the alignment of  $\sigma_0$  values between the SWALIS and SWOT datasets. Additionally, we will conduct a comprehensive analysis and comparison of radar measurements on a corner reflectors at SWOT calibration/validation sites where SWALIS measurements have been conducted.

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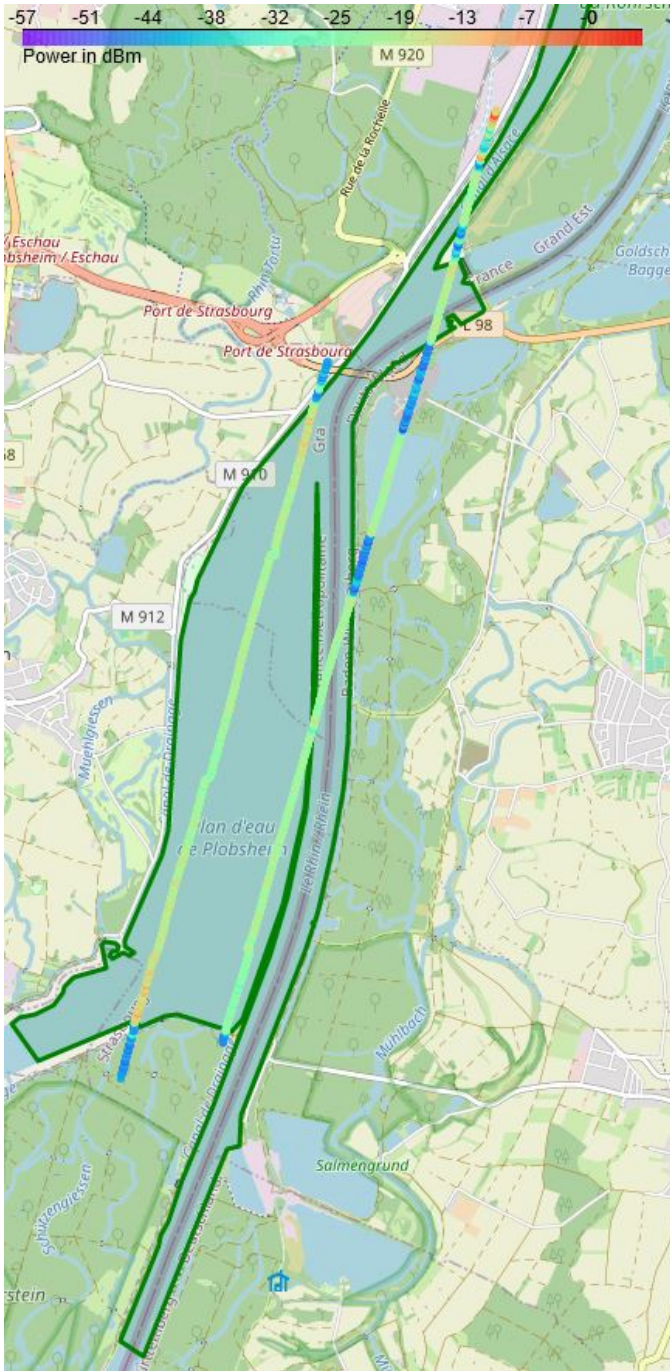


Fig. 4: SWALIS data on OSM - June 14: record close to SWOT path, before (right) and after (left).

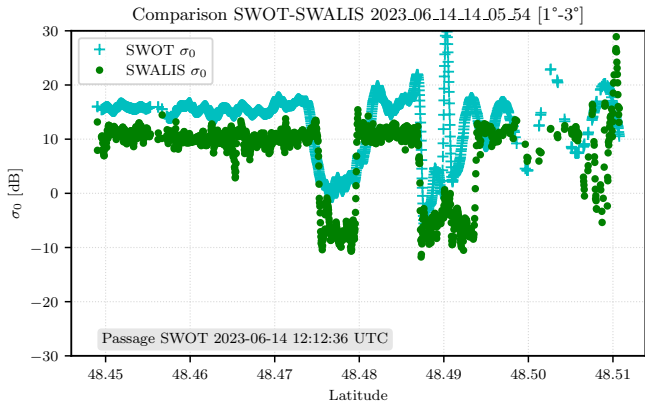


Fig. 5: Comparison of  $\sigma_0$ : closest record before SWOT passage, June 14.

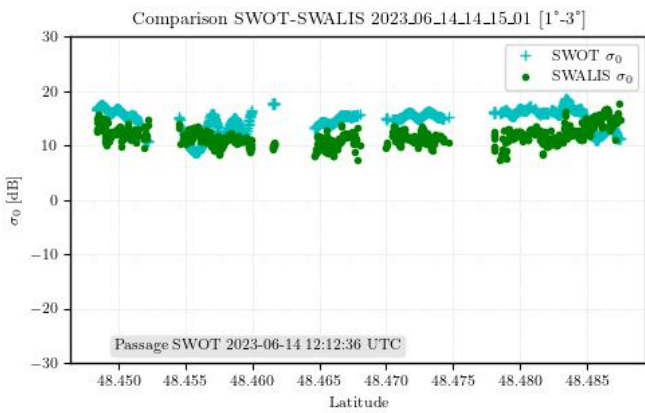


Fig. 6: Comparison of  $\sigma_0$ : closest record after SWOT passage, June 14.