Validation of SWOT data using airborne LiDAR off the coasts of Normandy during the fast sampling orbit phase

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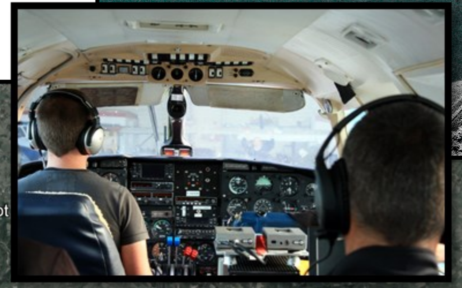
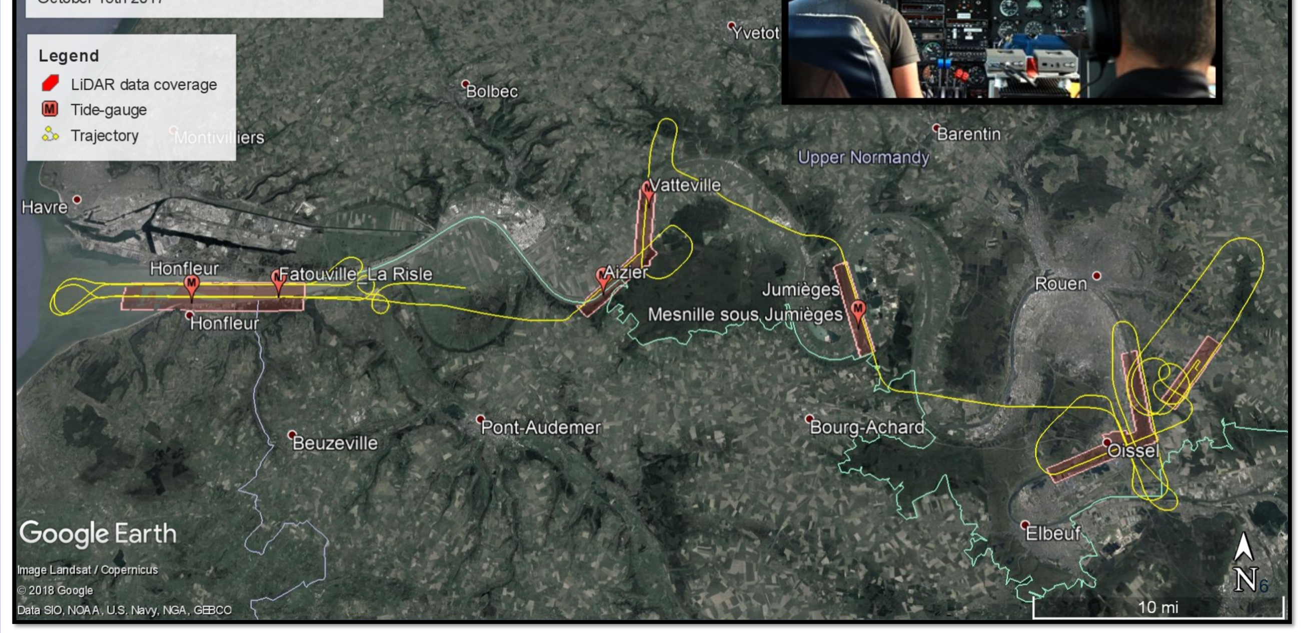
Pre-launch *2017 / 2022*

Accuracy assessment 1 - Water Measurement - Tide Gauge comparison

Comparing LiDAR and tide gauges on the **Seine River** indicates that the accuracy of the M2C lab airborne sensor, Leica ALS60, on water and on the ground are comparable with differences **range from 0 to 5 cm** with a **global mean of 2.44 cm**. This is valid on calm water with low river slope gradients.

A similar experiment on the **Gironde River** lead to similar results (*Paul Ternon, 2019*).





Top

Backscatter Intensity view of a point cloud over Honfleur, Normandy with a tide-gauge (in red) and a view of the « Bridge of Normandy » in the back

Middle

View of the pilot and M2C LiDAR engineer before takeoff

Left

Plane trajectory and survey coverage over the tide gauges on the Seine River

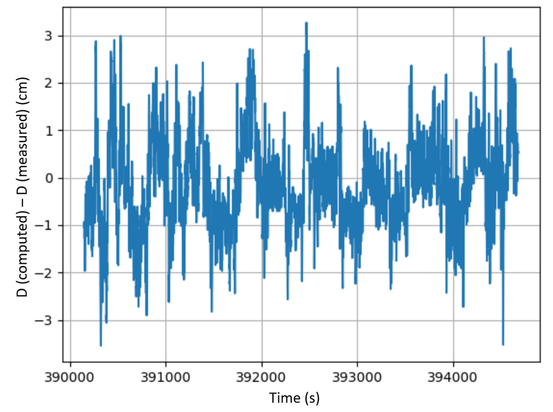
Accuracy assessment 2 - Plane Trajectory - GINS iPPP GNSS processing

Right

Distance measured between the 2 GNSS antennas and plot of the evolution of the computed distance during the entire acquisition

Bottom

Flight trajectory (in yellow) and data coverage (colored rectangles) over Rouen, Normandy along with the 2 permanent GNSS RGP ground stations



Trajectory processing

- DGPS using RGP permanent ground stations
- iPPP using GINS software (GRGS/CNES)

Distance Measured / GINS between the 2 antennas

mean = 7.2 mm σ = 4.8 mm

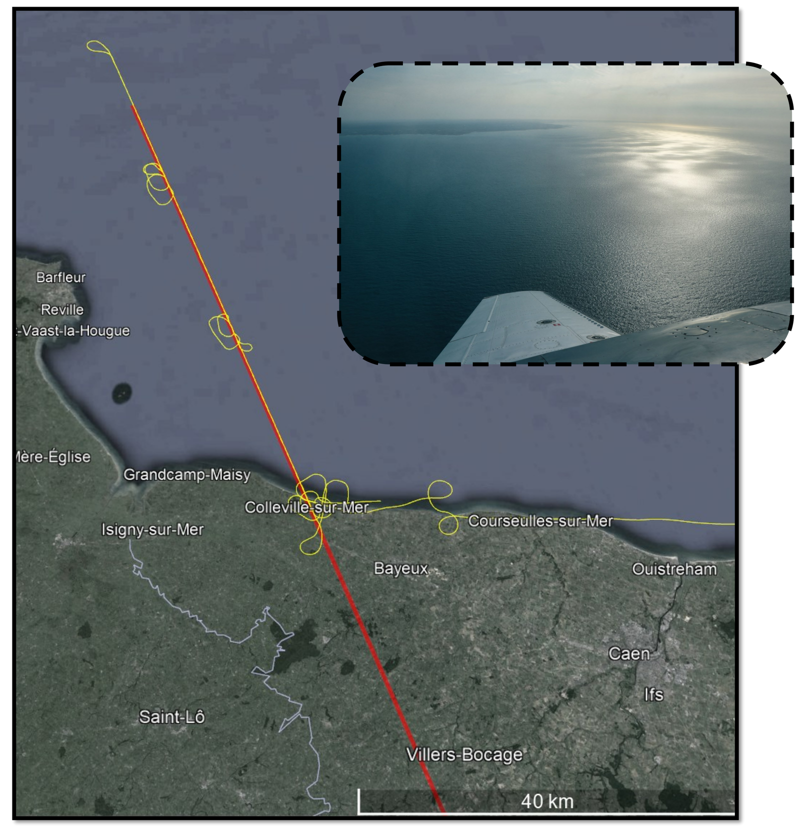
Ellipsoidal heights differences DGPS / iPPP

1st antenna mean = 3.70 cm σ = 1.20 cm

2nd antenna mean = 1.86 cm σ = 1.15 cm

Centimetric trajectory processing with GINS iPPP (*Laëtitia Roguet, 2022), (Romain Serthelon, 2020)*

Real life test - flight under the radar altimeter Sentinel 3A



Top - *Flight plan (in Yellow) and Sentinel 3A ground track (in red) in Normandy, Novembre 2019*

Top Right - *View of the Pixair Survey Navajo PA-31 of the English Channel during the LiDAR acquisition Flight*

Sentinel 3A

3 data sources: CNES, CTOH, Eumetsat / 13 different processings

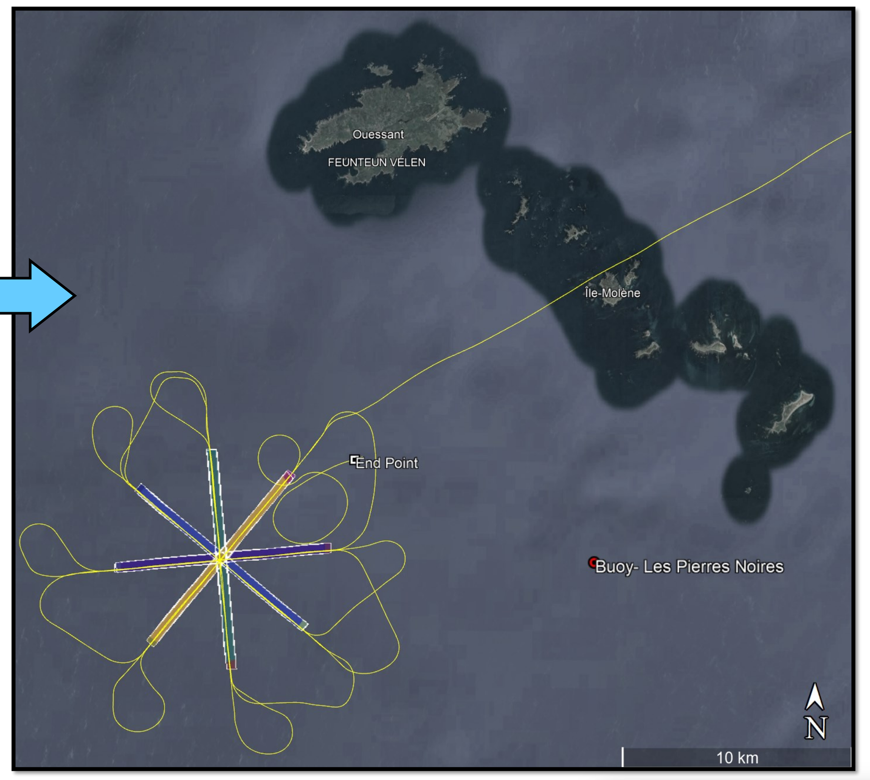
Comparison LiDAR / CNES LR-RMC with the tropospheric delay from ECMWF lead to best results:

Mean = -0.87 cm σ = 4.90 cm

Line	Axis	Mean (cm)	StdDev (cm)
1	1	19.86	12.82
2	2	10.95	3.65
3	3	10.02	4.33
4 *	**3**	**- 0.87**	**4.90**
5	2	-1.48	4.08
6	2	-13.84	4.03
7	2	-5.53	4.00
8	1	-2.49	25

Flight composed of 8 lines over 3 axes, comparison with other lines are given on the table on the right (L. Roguet, 2022)

Observations - wave spectrum flight off the coast of Ouessant, in the Iroise Sea

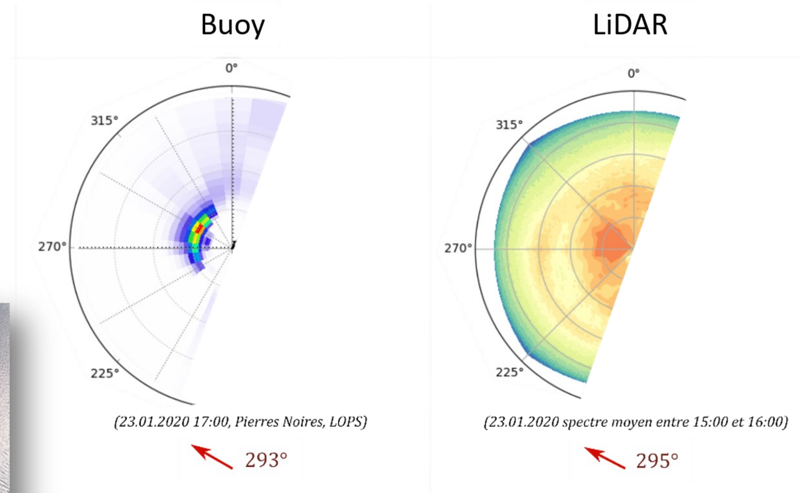


Top - *« Star-like » flight plan (in Yellow) and LiDAR coverage (colored) near Ouessant island*

Right - *View of the wave field during the acquisition*

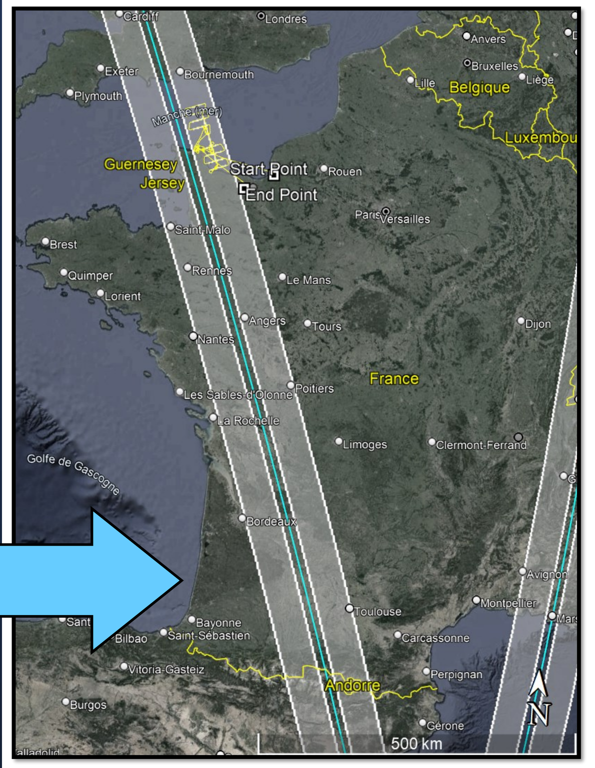
A preparatory flight was conducted off the coast of Ouessant dedicated to wave field observation with a special « star-like » flight plan pattern to maximize the direction angles of the observable waves.

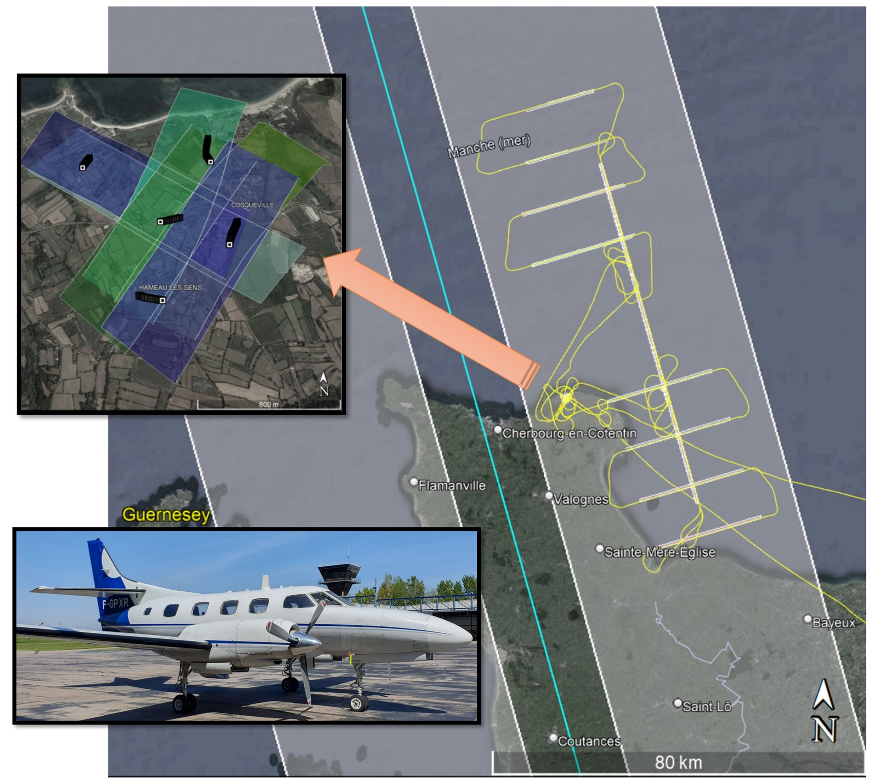
Wave spectrum computation by Hugo Kersimon (2023) showed good consistency with the local buoy « Les Pierres noires » in the Iroise Sea.



Post-launch *May / June 2023*

Flight campaign CalVal SWOT



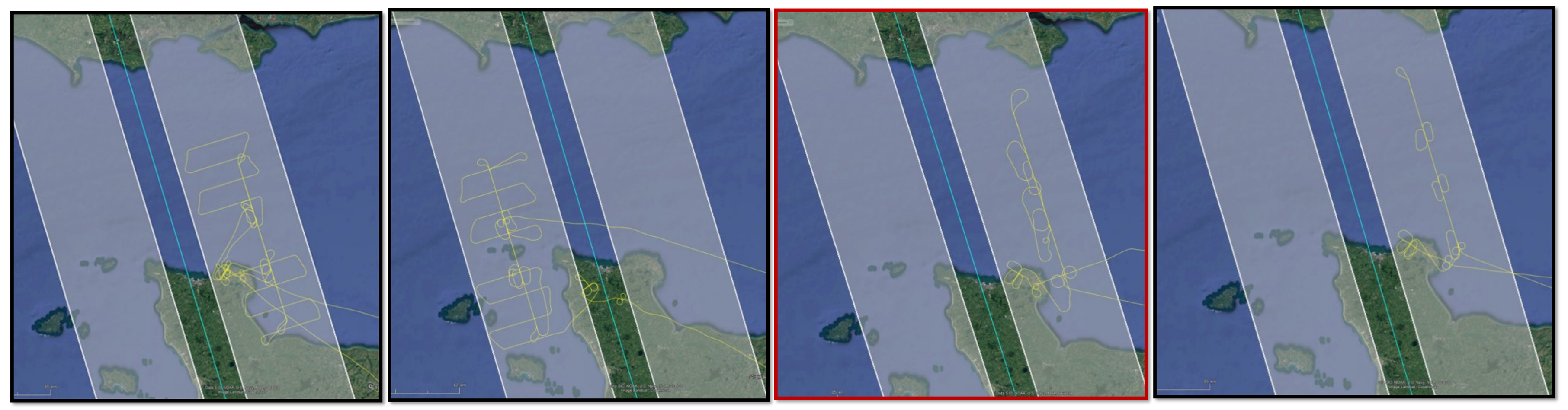


In 2023, during the CalVal phase, 4 airborne LiDAR flights under the SWOT ground track were conducted by the M2C lab using 2 different planes from Pixair Survey:

- SWOT1, May 25th (Piper Navajo)
- SWOT2, May 26th (Piper Navajo)
- SWOT3, June 15th (Swearingen Fairchild Merlin)
- SWOT4, June 16th (Swearingen Fairchild Merlin)

Flight Conditions SWOT 1 & 2 - 150 kt / 800 m

SWOT 3 & 4 - 200 kt / 600 and 800 m

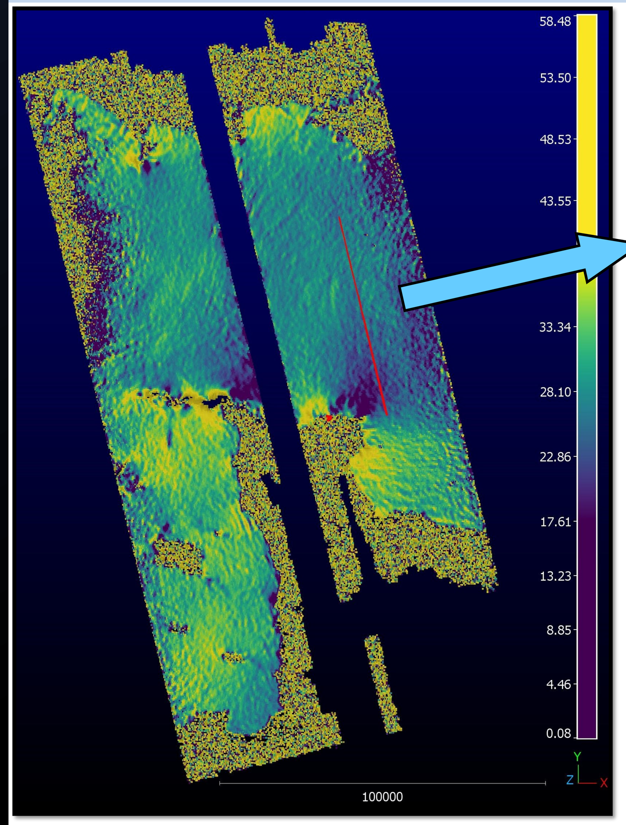


Top - SWOT 1-day fast sampling orbit along with the location of the LiDAR flight in Normandy, France

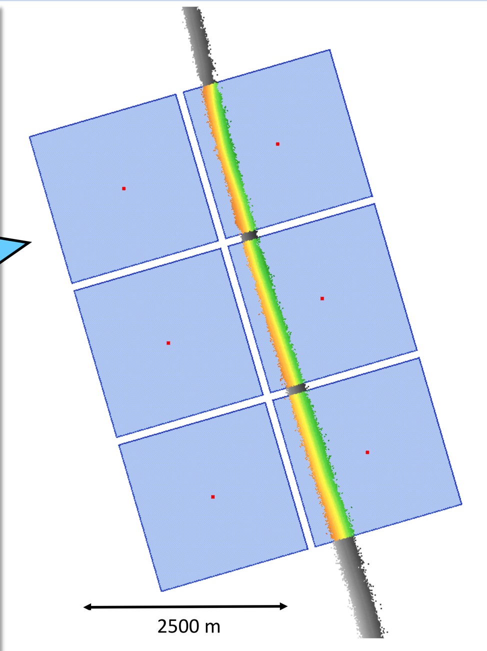
Top Right - LiDAR calibration site, 227 Ground Control Points close to Cherbourg

Right - Flight plans of the 4 LiDAR acquisition flights performed during the CalVal phase

LiDAR / SWOT Sea Surface Height (SSH) comparisons



SSH SWOT L2 LR Unsmoothed pre-cal (Point Cloud Normals Inclinaison in degrees, neighborhood of 1.5 km) and **LiDAR data** (in red)



For each SWOT centroid, LiDAR data in the corresponding grid is averaged and then compared along the flight axis

- LiDAR coverage (colored)
- SWOT SSH grid (in blue)
- SWOT L2 centroid (in red)

Line	Axis	SWOT Basic[1]		SWOT Unsmoothed[2]	
		Mean (m)	StdDev (cm)	Mean (m)	StdDev (cm)
1	1	0.27	2.13	1.94	2.86
2*	**2**	**0.12**	**1.47**	**1.79**	**3.40**
3	3	0.09	3.00	1.77	6.94
4	3	0.02	3.10	1.70	5.22
5	2	-0.12	3.89	1.56	5.74
6	1	-0.37	7.07	1.31	6.83

Comparison between SWOT and LiDAR data for flight SWOT 3, composed of 3 axes flown twice each (UTM30)

[1]**SWOT Basic**

SWOT L2 LR, 2 km grid, SSH + Xover + SSB

[2]**SWOT Unsmoothed**

SWOT L2 LR unsmoothed, 250 m grid, SSH with no Xover correction and no SSB correction

(M. Thomasson, 2024)

References

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