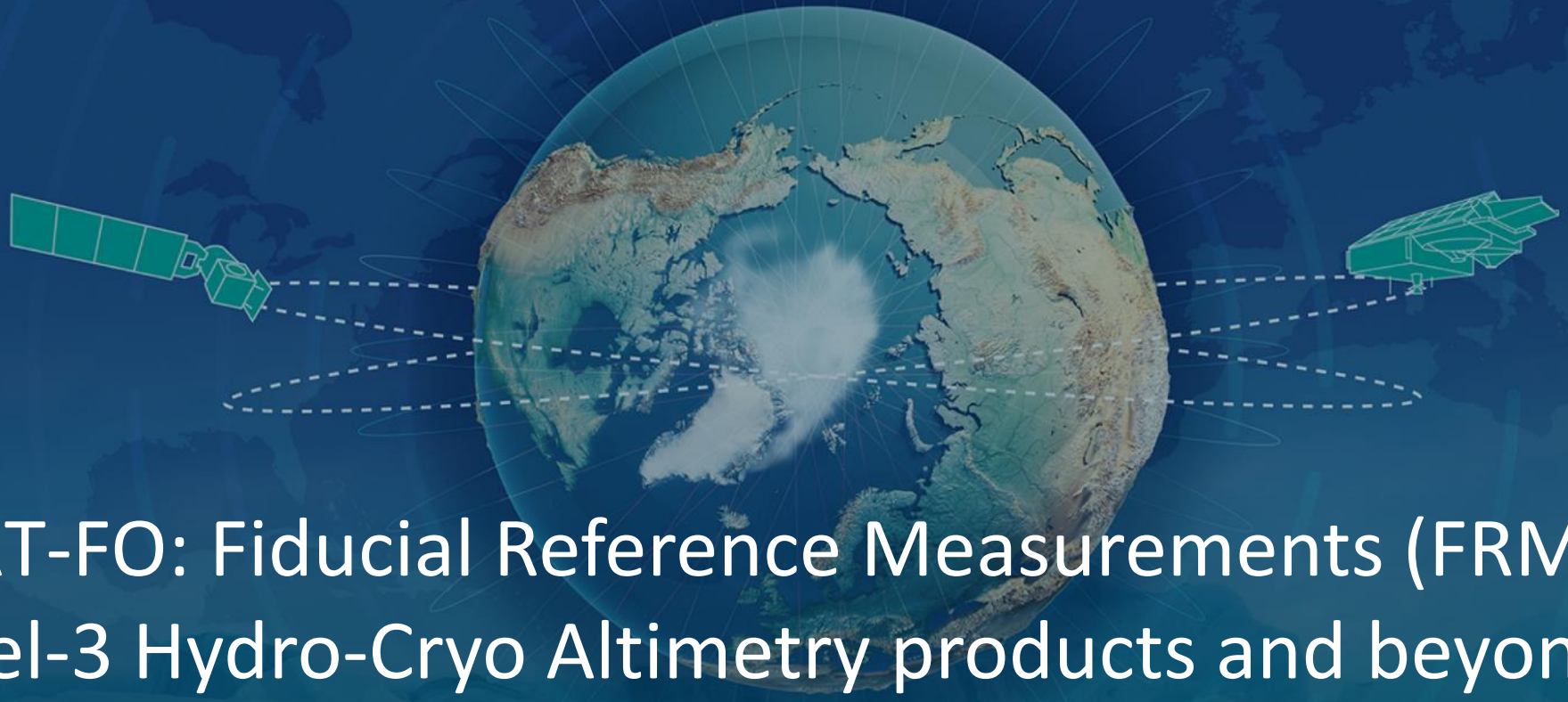


St3TART-FO: Fiducial Reference Measurements (FRM) for Sentinel-3 Hydro-Cryo Altimetry products and beyond

Claire Miller (NOVELTIS)

C. Miller, J-C. Poisson, N. Picot, H. Skourup, S. Fleury, V. Favier, G. Picard, G. Moholdt, E. Woolliams, S. Behnia, E. Le Merle, V. Boulenger, R. Ferrari, D. Segura, J. Sabalbal, M. Dechamp-Guillaume, V. Fouqueau, R. Lopez, C. Yanez, J. Lefebve, R. F. Hansen, S. Simonsen, S.Hvidegaard, L. Arnaud, E. Lemeur, C. Haas, T. Krumpen, N. Taburet, J. Renou, M. Chapellier, J. Aublanc, A. Tarpanelli , N. Sneeuw, M. Tourian, J. Foster, F. Vivier, A. Lourenco, R. Ricker, O.Rydeng Jenssen, H. Yésou , M. Azzoni, S. Amzil, T. Le Dauphin, P. Bonnefond, O. Laurain, M. El Hajj, F. Catapano, P. Féménias

St3TART-FO
FRM for Sentinel-3 Land Altimetry

- **Context & Objectives**

  - **St3TART-FO**'s core objective is to **operationally provide Fiducial Reference Measurements (FRM)** to support the validation activities of the Sentinel-3 SAR altimeter Hydro-Cryo Thematic data products, over **inland waters**, **sea ice**, and **land ice** areas.

  - Important activity for the **Copernicus Sentinel-3 mission**, a joint operation between ESA and EUMETSAT for which ESA oversees the S3 **Hydrology and Cryosphere** Ground Segment operations.

  - The project's aim to ensure the successful operational provision of FRM ultimately contributes to the broader goals of S3 mission in providing **accurate** and **reliable Earth observation data**.

  - Will pave the way for other future altimetry missions such as **CRISTAL** and **S3 Next-Generation Topography**, as well as for potential synergies with the **Copernicus CIMR** expansion mission.

Context & Objectives

- St3TART-FO's core objective is to operationally provide Fiducial Reference Measurements (FRM) to su ucts, ov
- Im and EU s.
- Th s to the broader goals of S3 mission in providing accurate and reliable Earth observation data.
- Will pave the way for other future altimetry missions such as CRISTAL and S3 Next-Generation Topography, as well as for potential synergies with the Copernicus CIMR expansion mission.

> FRMs are a suite of "independent, fully characterised, and traceable measurements, tailored specifically to address the calibration/validation needs of a satellite borne sensor and that follow the guidelines outlined by the GEO/CEOS Quality Assurance framework for Earth Observation (QA4EO)"
> **Goryl et al., 2023**

- **Context & Objectives**

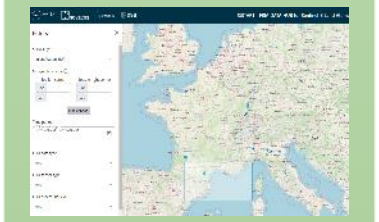
  - **St3TART-FO**'s core objective is to **operationally provide Fiducial Reference Measurements (FRM)** to support the validation activities of the Sentinel-3 SAR altimeter Hydro-Cryo Thematic data products, over **inland waters**, **sea ice**, and **land ice** areas.

  - Important activity for the **Copernicus Sentinel-3 mission**, a joint operation between ESA and EUMETSAT for which ESA oversees the S3 **Hydrology and Cryosphere** Ground Segment operations.

  - The project's aim to ensure the successful operational provision of FRM ultimately contributes to the broader goals of S3 mission in providing **accurate** and **reliable Earth observation data**.

  - Will pave the way for other future altimetry missions such as **CRISTAL** and **S3 Next-Generation Topography**, as well as for potential synergies with the **Copernicus CIMR** expansion mission.

Cryo2ice Symposium 2024

	Inland waters	Sea ice	Land ice	FRM Data Hub	Collaborative Campaigns
					
FRM sites identification and operational preparation	• **Identify** and **operate super sites** and **opportunity sites** for FRM operational provision • **Equip sites** with additional instrumentation and **prepare operational plans**				
FRM operational provision	• **Acquisition**, **processing** and **delivery** of FRM data • Ensure **good performance** of the FRM sensors and data processing • **Prepare roadmap for future** Altimetry missions beyond S3				
FRM data exploitation and uncertainty assessment	• Characterize the **uncertainties** associated to each FRM data product and measurand • **Exploitation** of **FRM data** for Cal/Val activities forS3				
Announcements of Opportunities	• **Complementary** to existing sites and activities • **Foster/contribute** to ongoing/planned **campaigns** for FRM provision to federate the community via **Announcement of Opportunity** (AO) calls				
				• Platform **for a centralized access** to FRM data • Fully characterized and **documented FRM** processing and measurements	• **Execute** the approved **AOs** • **Produce, process** and **deliver** FRM data

Cryo2ice Symposium 2024

May 2024 | December 2024 | February 2025 | June 2028

Set up phase → Rehearsal → Operational phase

Set up phase

- Station set-ups on sites
- Initiation of collaborations and campaigns
- Development of the FRM processing chain
- Set-up and finetuning of FRM Data Hub

Rehearsal

- Test of all the processing chains from data collection to FRM dissemination
- Demonstration of operational readiness

Operational phase

- Production of FRMs on all super sites and opportunity sites including campaigns
- Validation activities by all the scientific team
- Dissemination on FRM Data Hub
- Complementary to core activities, execution of selected AO proposals

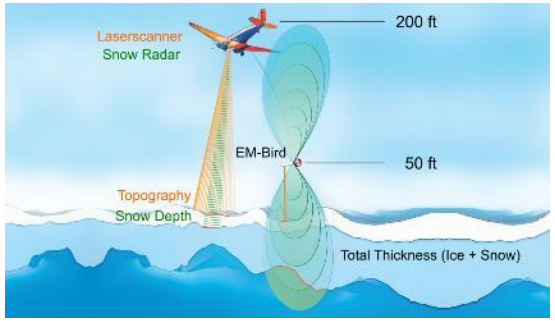
- **Sea ice – Approach**

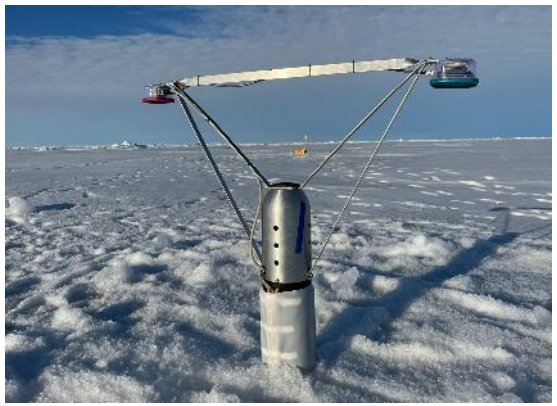
Total thickness, total freeboard, snow depth -> **AWI IceBird** (since 2019) - AWI

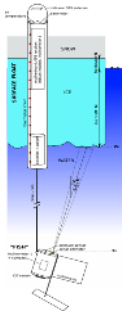
Total Freeboard or sea ice freeboard + snow depth -> **lidar + snow radar** -> **Drone** - NORCE + vorteX-io

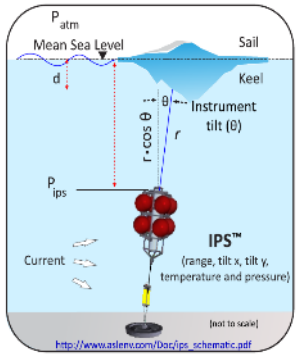
Sea ice thickness and snow depths (miniature radars) - > **Ice-T buoy** demonstrated in St3TART - LOCEAN

Sea ice draft -> addition of **IPS (Ice Profiling Sonar) on existing mooring** - LOCEAN

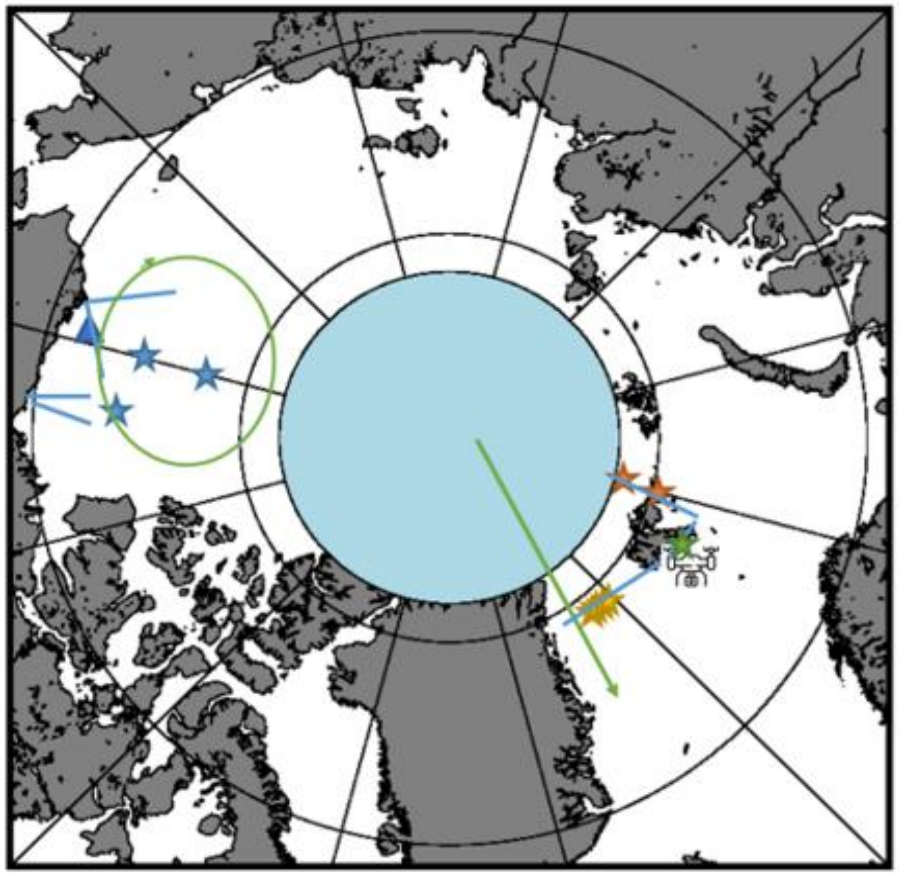








- **Sea ice – Opportunity sites**



Map of Sea Ice measurements considered in St3TART-FO

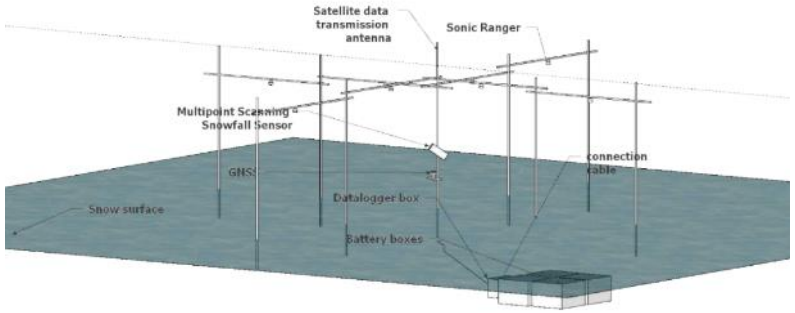
- **Sea ice – Future Campaigns**

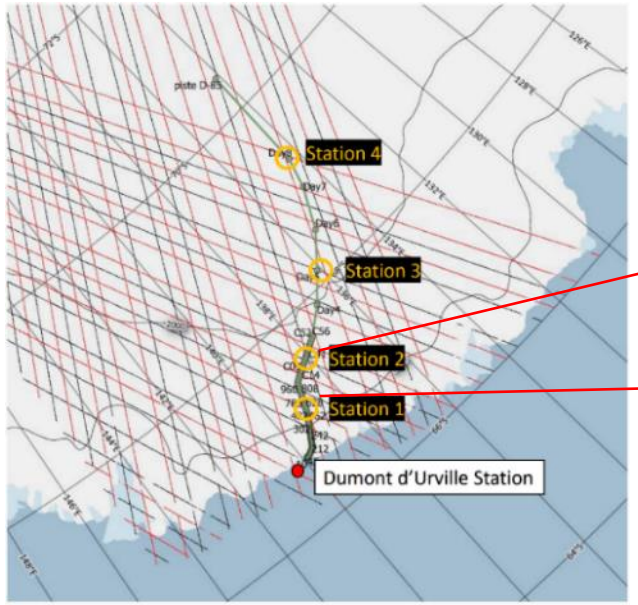
		Hist		2024	2025	2026	2027	2028
Svalbard/Fram Strait	Van Mijen, drone, snow radar		NORCE	X				
	Storfjorden, drone, snow radar + laser		NORCE, vorteX-io	X	X	X	AO	
	IPS on mooring in Storfjorden		LOCEAN		X*	X	X	
	ICE-T, NP -> Fram Strait		LOCEAN	X	X		X	
	Dedicated airborne campaign Svalbard	X	DTU			AO		
	Fram Strait Moorings	X	NPI	X	X	X	X	X
	Barents Sea moorings			X	X	X	X	X
Beaufort Gyre	IceBird airborne campaign		AWI	X	X	X	AO	
	Drone snow radar/lidar from ice camp		NORCE			AO		AO
	BGEP moorings	X	Woods Hole	X	X	X	X	X
	CRREL IMB	X	CRELL	X	X	X	X	X
	ICE-T		INT		X		X	
	SIMS		TBD	Summer	Summer	Summer	Summer	Summer
Antarctic/Weddell Sea	Airborne Antarctic RINGS		DTU/ESA	X				

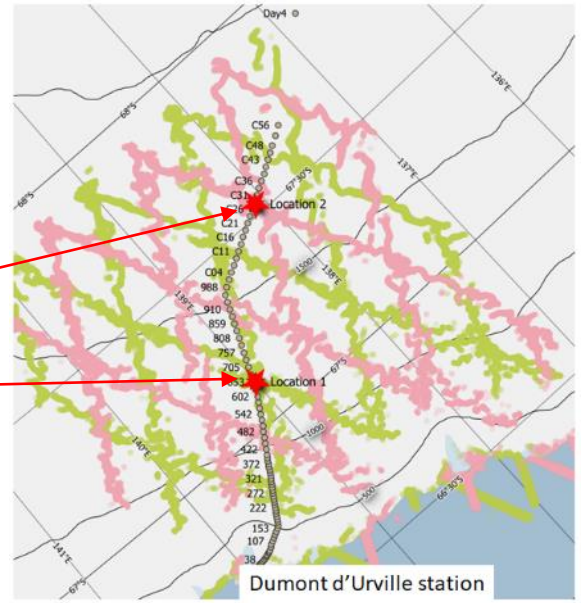
- **Land ice - Fixed Stations**

Test in the Alps
2024

Deployment in Antarctica
2025

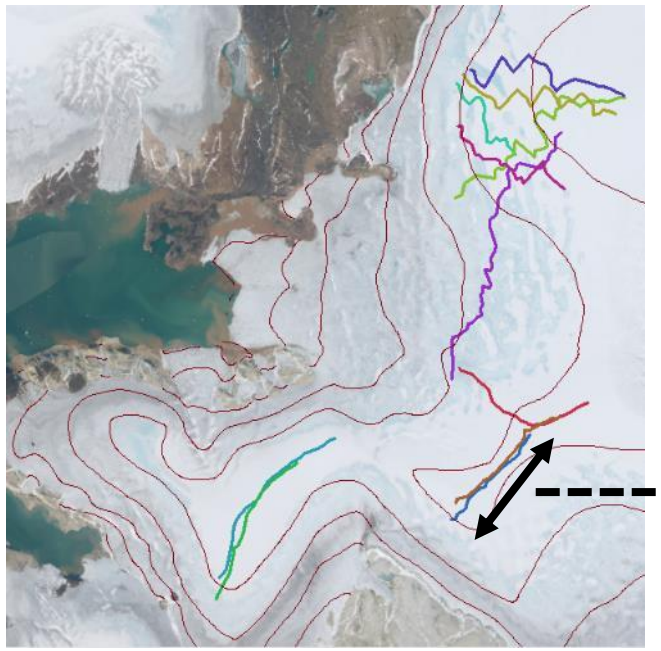






Map of Adélie Land with orbits and station sites identified

- **Land ice – Campaigns**
  - **Kinematic GNSS campaigns in Svalbard** for direct validation of Sentinel-3:
    - The 2024 campaign: successfully completed and in processing.

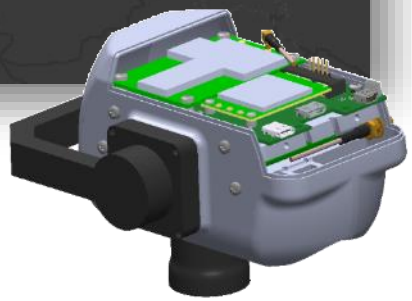


A selection of POCA tracks from AMPLI (CLS/Aublanc et al.) suitable for repeat-pass GNSS survey on Austfonna ice cap

  - Potential **joint campaigns** with sea ice team

- **Inland waters**

vorteX-io
Micro-station V2.1



Lightweighted altimeter

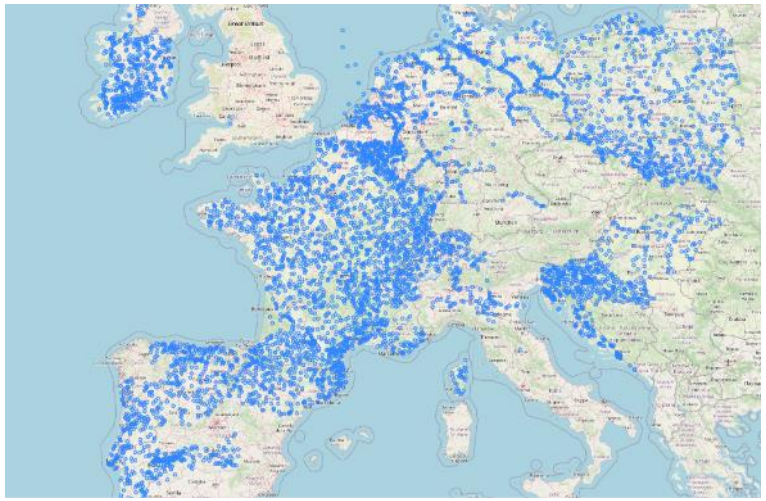
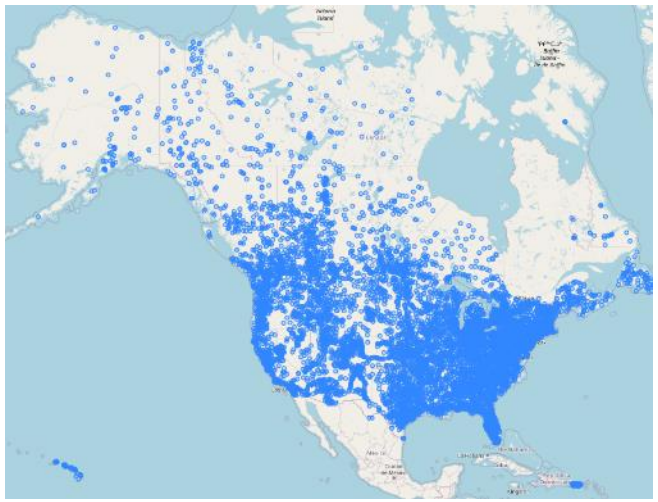
Super sites: installation of new micro-stations & planification of drone campaigns

8 super sites for a total of 25 micro stations

- "Le Canal du Midi" in Trèbes
- The Garonne River in Marmande
- French part of the Rhine River
- Seine estuary in Honfleur
- Issykkul Lake in Kirgizstan
- Tiber River near Perugia
- Po River
- German basin of the Rhine River

- **Inland waters**

Opportunity sites: increased data volume and geographic coverage

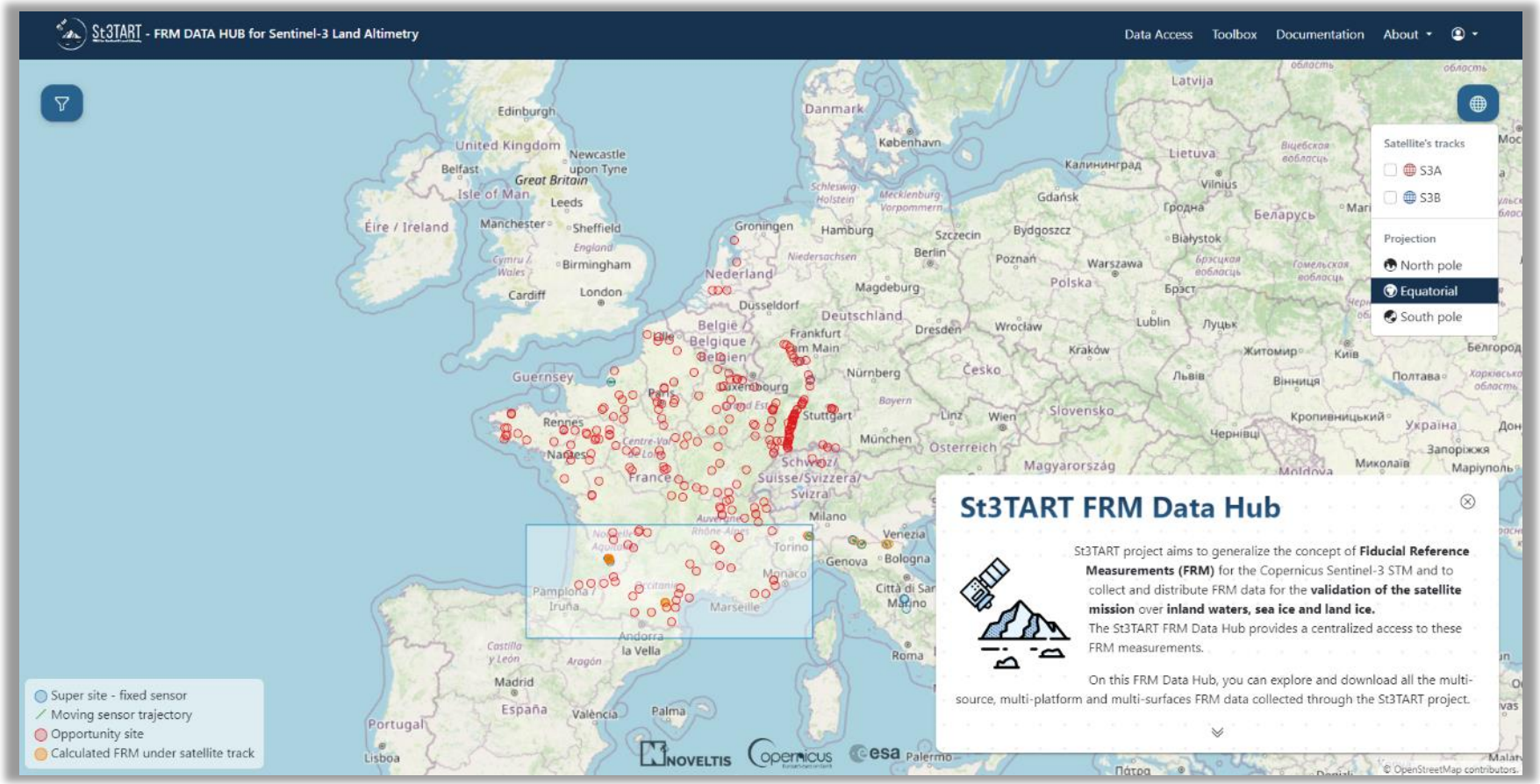




9 public networks were identified in St3TART

Today, data collected from **18 public national networks** for a total of **23 106 stations**

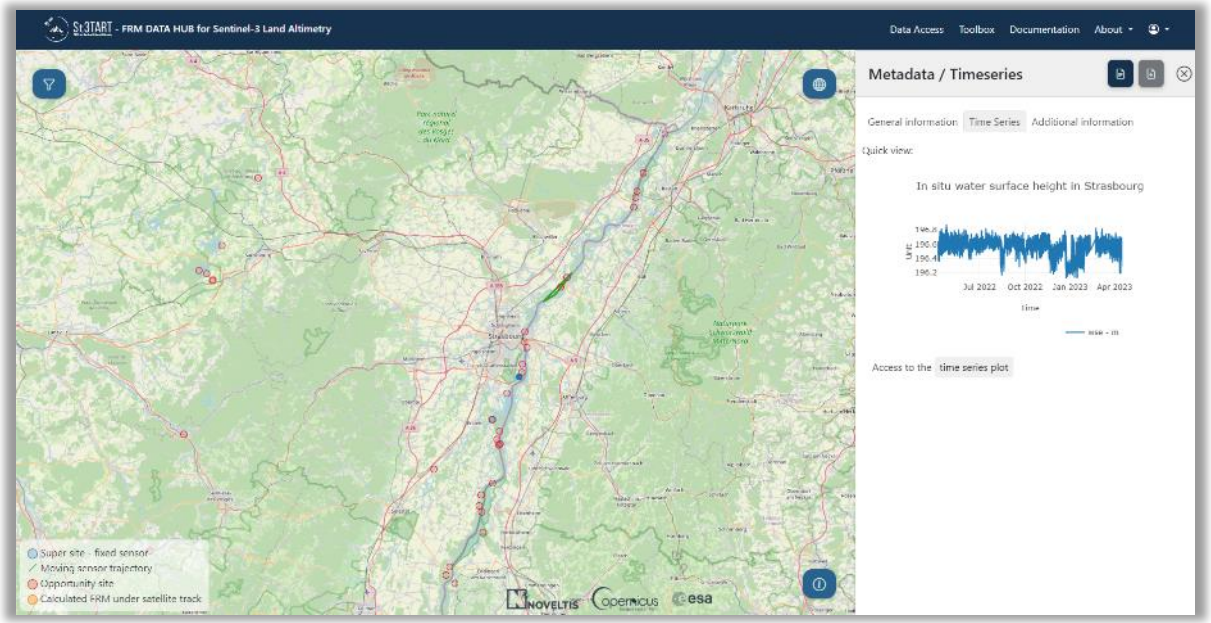
Final number of opportunity sites targeted for November 2024

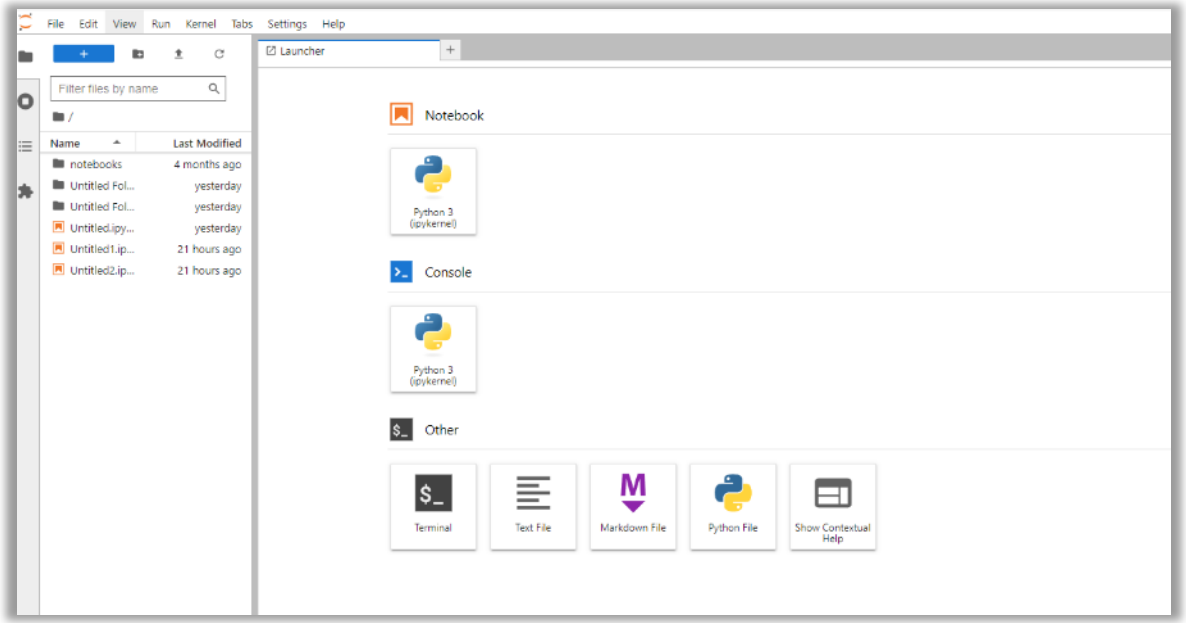
- **FRM Data Hub**



- Central repository for FRM measurements
- Aim to federate the Cal/Val community
- Free and openly accessible starting from Feb. 2025
- Unified data format: NetCDF with specific attributes

- **FRM Data Hub – Advanced features**





Visualisation & Download

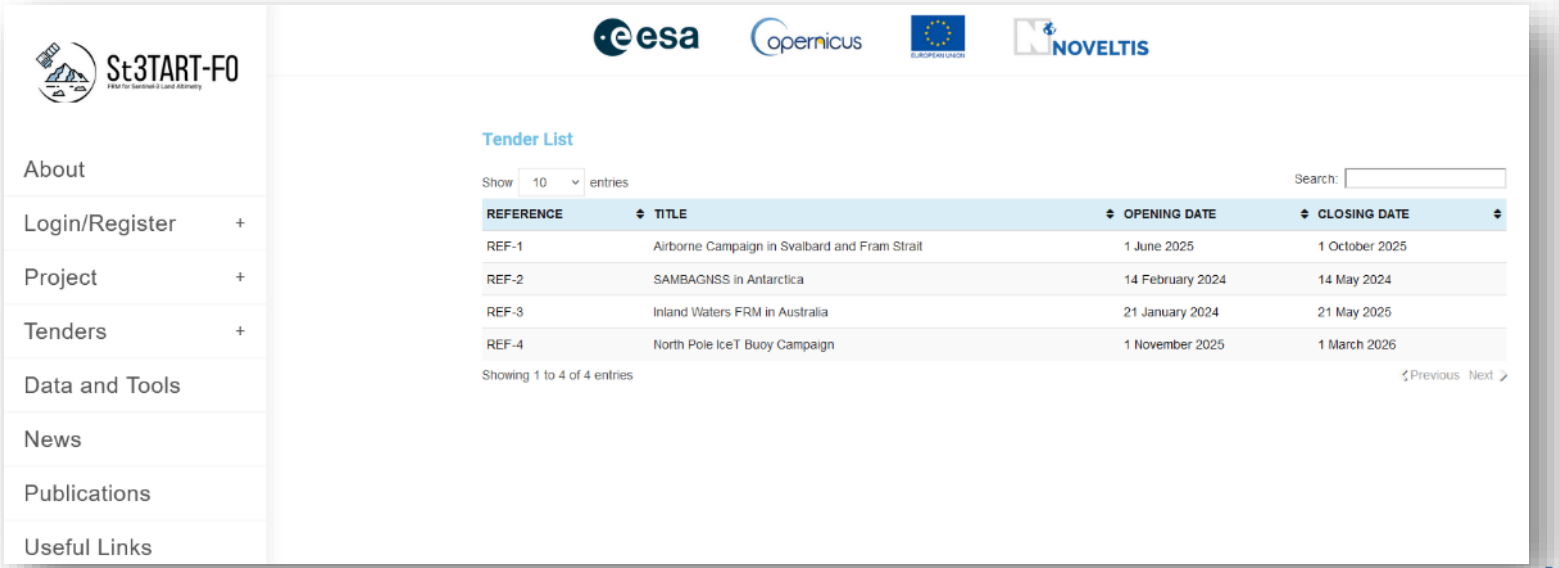
- Interactive time series plots
- Maturity matrix display
- Metadata

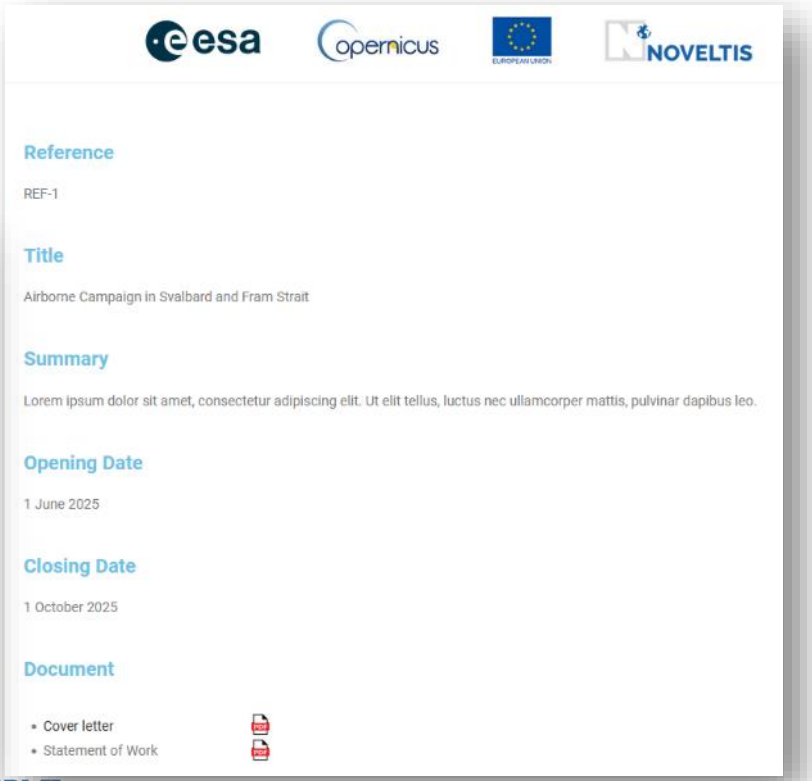
Deployment of Jupyter Hub

- Working area hosting data analysis scripts (open source)
- Jupyter Notebooks…

- **FRM Collaborative Campaigns**
  - Connect with external partners for additional field campaigns and leverage diverse expertise and resources: **inland waters**, **sea ice**, and **land ice**.
  - Execution of activities submitted and approved with ESA through **Announcement of Opportunities** (AOs)
  - **Dedicated budget available for the AOs**
  - First AOs to open early 2025 on project website: https://sentinel3-st3tart.noveltis.fr/tender-list/

Interested in St3TART-FO activities? Please let us know and stay tuned for AO calls!

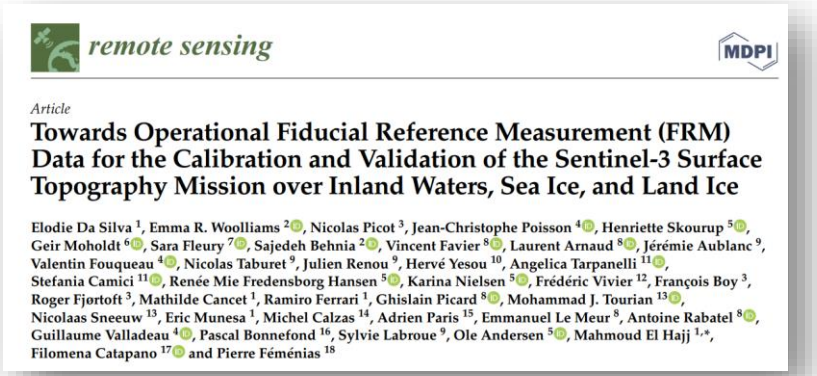




For more information about St3TART-FO…

- Please visit our **project website**: https://sentinel3-st3tart.noveltis.fr/
- Stay connected for our upcoming **workshops**: Q1 2026 and Q3 2027
- Our St3TART **paper** available on our website

St3TART-FO website


remote sensing

MDPI

Article

Towards Operational Fiducial Reference Measurement (FRM) Data for the Calibration and Validation of the Sentinel-3 Surface Topography Mission over Inland Waters, Sea Ice, and Land Ice

Elodie Da Silva [1], Emma R. Woolliams [2], Nicolas Picot [3], Jean-Christophe Poisson [4], Henriette Skourup [5], Geir Moholdt [6], Sara Fleury [7], Sajedeh Behnia [2], Vincent Favier [8], Laurent Arnaud [8], Jérémie Aublanc [9], Valentin Fouqueau [4], Nicolas Taburet [9], Julien Renou [9], Hervé Yesou [10], Angelica Tarpanelli [11], Stefania Camici [11], Renée Mie Fredensborg Hansen [5], Karina Nielsen [5], Frédéric Vivier [12], François Boy [3], Roger Fjørtoft [3], Mathilde Cancet [1], Ramiro Ferrari [1], Ghislain Picard [8], Mohammad J. Tourian [13], Nicolaas Sneeuw [13], Eric Munesa [1], Michel Calzas [14], Adrien Paris [15], Emmanuel Le Meur [8], Antoine Rabatel [8], Guillaume Valladeau [4], Pascal Bonnefond [16], Sylvie Labroue [9], Ole Andersen [5], Mahmoud El Hajj [1,*], Filomena Catapano [17] and Pierre Féménias [18]

- Check out our sea ice **poster**:
  - Poster 41: "**Operational Fiducial Reference Measurements over Sea Ice in support of Sentinel-3 validation (ESA St3TART-FO project)**", Skourup et al.

Cryo2ice Symposium 2024

Thank you on behalf of the **St3TART-FO** team!

Contact: st3tart@noveltis.fr

Programme of the

Implemented by