St3TART
FRM for Sentinel-3 Land Altimetry

Sentinel-3 Topography mission Assessment through Reference Techniques

St3TART project

Elodie Da Silva (NOVELTIS)

Nicolas Picot (CNES) – Jean-Christophe Poisson (vortex.IO)

Henriette Skourup (DTU) – Geir Moholdt (NPI) and much others :

St3TART project – Main objective

Prepare the ground to ensure an

« **operational provision of FRM (Fiducial Reference Measurement)** »

to support the S3 Land STM mission over :

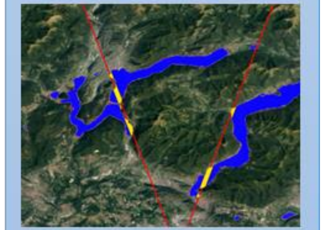
21 months project
From July 2021 to
April 2023

St3TART project – Detailed objectives

NOVELTIS

St3TART
FRM for Sentinel-3 Land Altimetry

	Land waters	Sea Ice	Land Ice	ScalSIT



Validation, FRM protocols & procedures

- Define and consolidate **methods and protocols for the validation** of the Sentinel-3 Altimetry Land products **with Fiducial Reference Measurements** (FRMs)

Roadmap for S3 STM Land FRM operational provision

- Identify existing networks and **assess the needs** for permanent sensors and campaigns.
- **Prepare a roadmap for the operational provision of FRM data to support the Sentinel-3 Altimetry Land validation**

FRM campaign preparation and execution

- **Deploy and operate** in-situ sensors, perform campaigns to collect FRM data
- **Provide FRM data** to the Copernicus Sentinel-3 STM validation teams

FRM Data Hub

- Web site, **for a centralized access** to FRM measurements
- Fully characterized and **documented FRM processing** and measurements

ScalSIT

- Super CAL/VAL site identifier tool for **inland waters**
- Determines the **intersections** between **Water mask** and **satellite orbits**
- Developped as a QGIS plugin

Towards a roadmap for FRM provisionning for S3

1

Correction	Average order of STD
Geoid height	Negligible impact if a sensor is +/- 1 km to the actual ground track
Pole tide, Solid Earth tide and Loading tide	Few milimeters
Orbit determination	< 1 cm
Ionosphere correction from models	< 1 cm
Dry tropospheric correction from models	< 1 cm
Wet tropospheric correction from models	~ 1.5 cm
Range estimation	Several cms or decimeters

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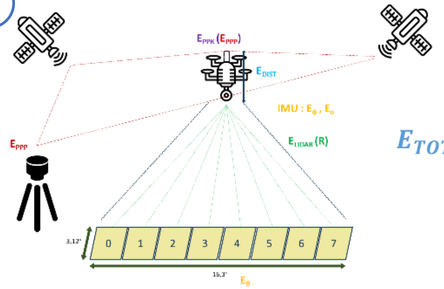


$$E_{TOT} = \sqrt{E_{PPK}^2 + E_{DIST}^2 + E_{AD_{TOT}}^2}$$

1 Identification of the measurand to focus on, reviewing altimetry measurement uncertainties

2 Review of in-situ sensors performance and adequacy to FRM needs

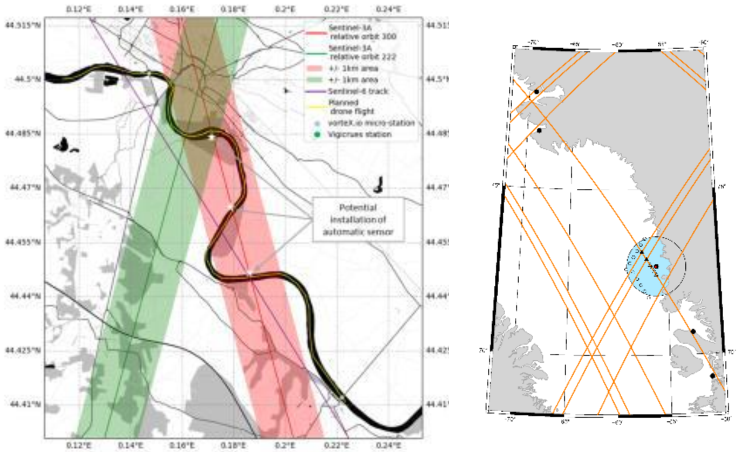
3 Identification of super sites to deploy sensors

4 Deployment on the field (not over land ice)

5 Comparison of measures with S3 data (1st level of analysis) + analyse of uncertainties

6 Definition of the roadmap for FRM provisionning

3



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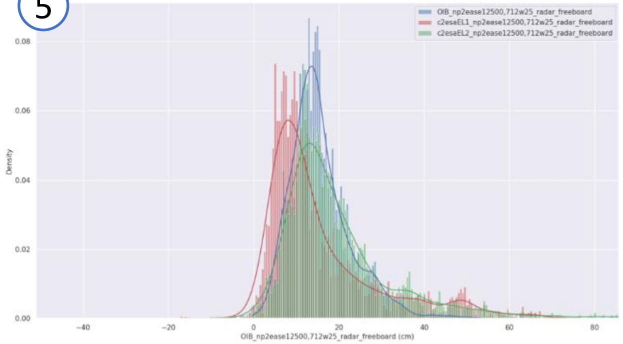
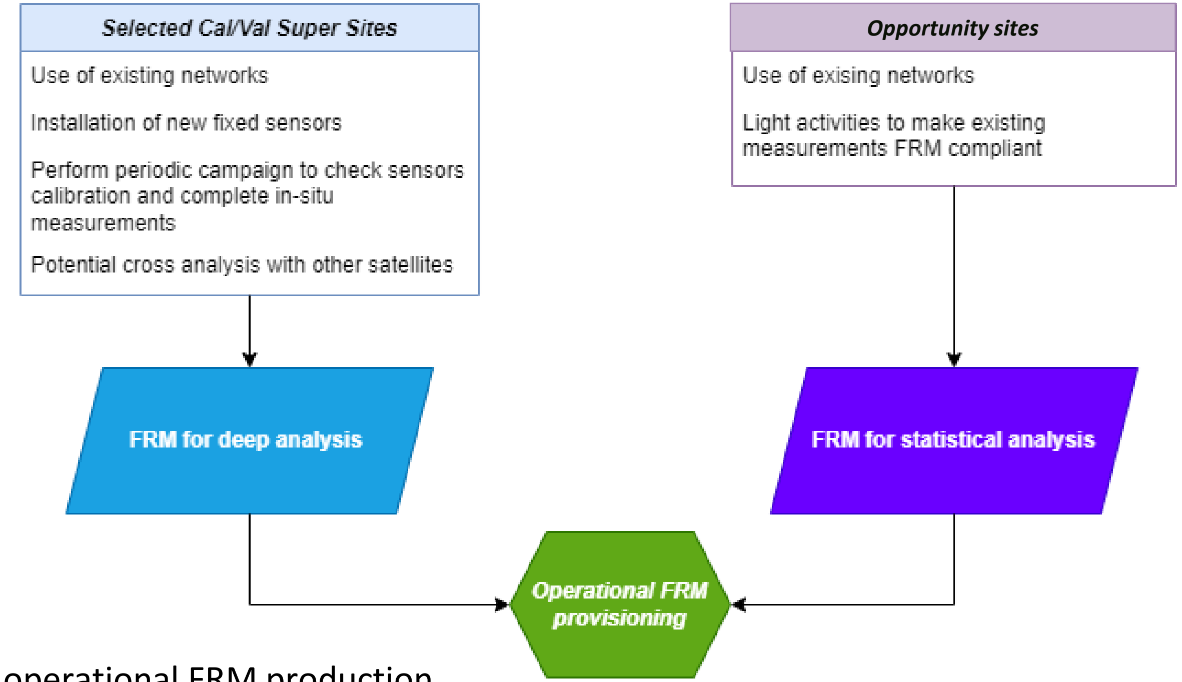


Inland waters – Strategy for FRM provisionning

Drivers:

- FRM quality
- Operational
- Affordable costs
- Federate international community
- Provide data within 28 days latency



Approach:

- Cal/Val super sites:
  - Site instrumented with all sensors and equipment needed to ensure operational FRM production
  - Demonstrators for future deployment of other Cal/Val super sites anywhere in the world, by any entity
  - Focused in Europe
  - List of selected super sites for this project: Garonne (France), Rhine (France and Germany), Po & Tibre (Italy), Maroni (French Guyana), Issykkul (Kirghizstan)

- Opportunity sites :
  - Taking advantage of existing in-situ sensors

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Inland Waters – Campaigns

- **18 vorteX.io micro-stations installed on super-sites over Rhine (FR), Pô (IT), Garonne (FR) and Canal du midi (FR), and more to come on Rhine (DE), Tibre (IT), Seine estuary (FR)**

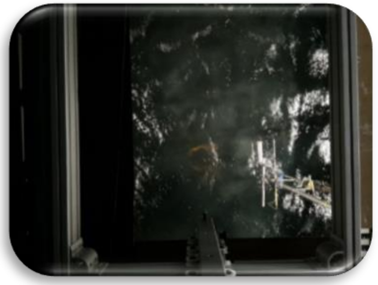
- **Drone campaigns over the same rivers to perform topography measurements**

- **Deployment of pressure sensors (solinst leveloger) where micro-stations can't be installed, under S3 track**

Deployment of leveloger in Marmande, under S3 track

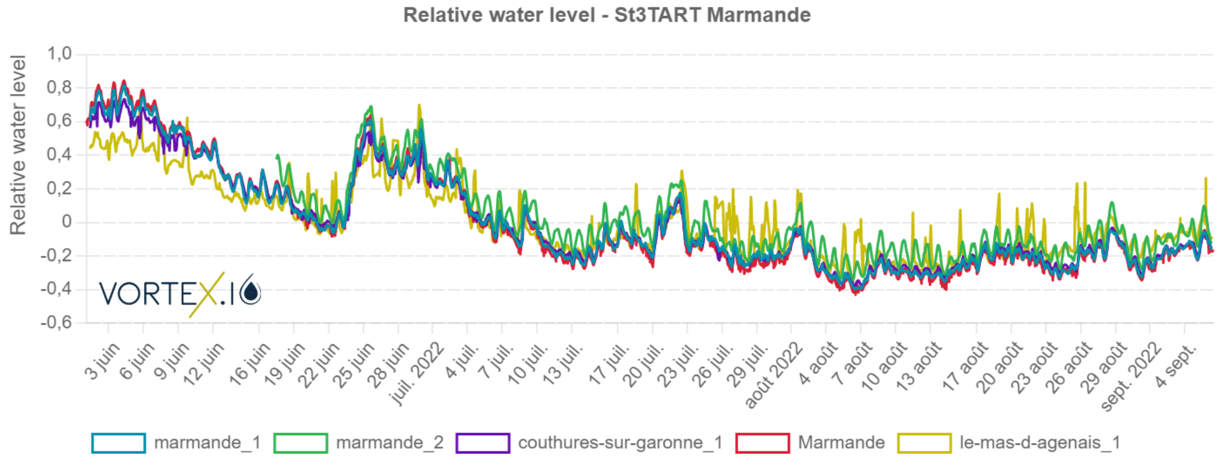
Deployment of leveloger in Maroni river (tropical river), under S3 track

- **To meet FRM requirements : sensor performance analysis in a test basin, to evaluate the capability and absolute uncertainty of the sensors that are used in the project**

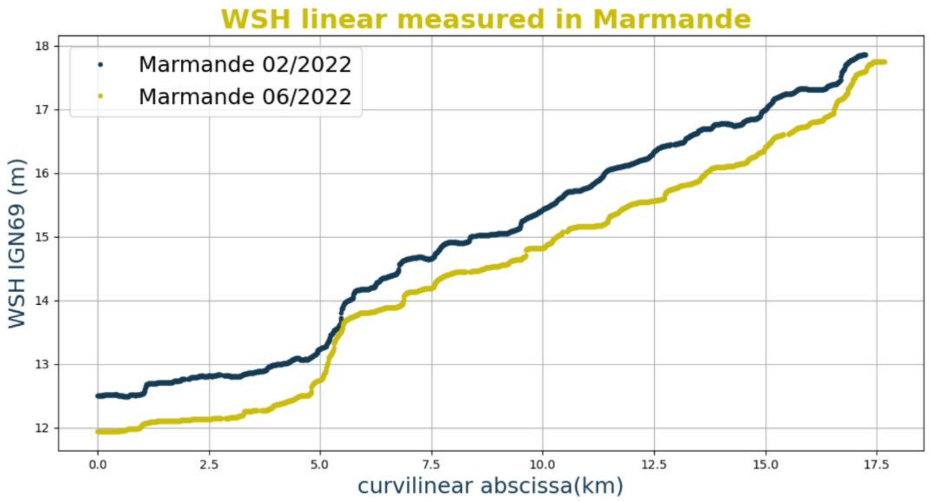


Inland Waters – Analysis of results

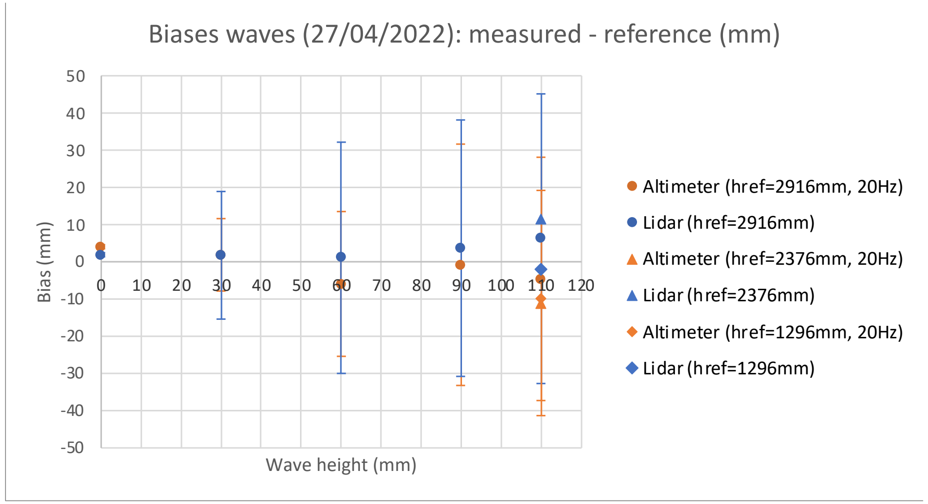
- **Comparison of the different vorteX.io micro stations measures along the Garonne**



- **Garonne topography at high/low level of water**

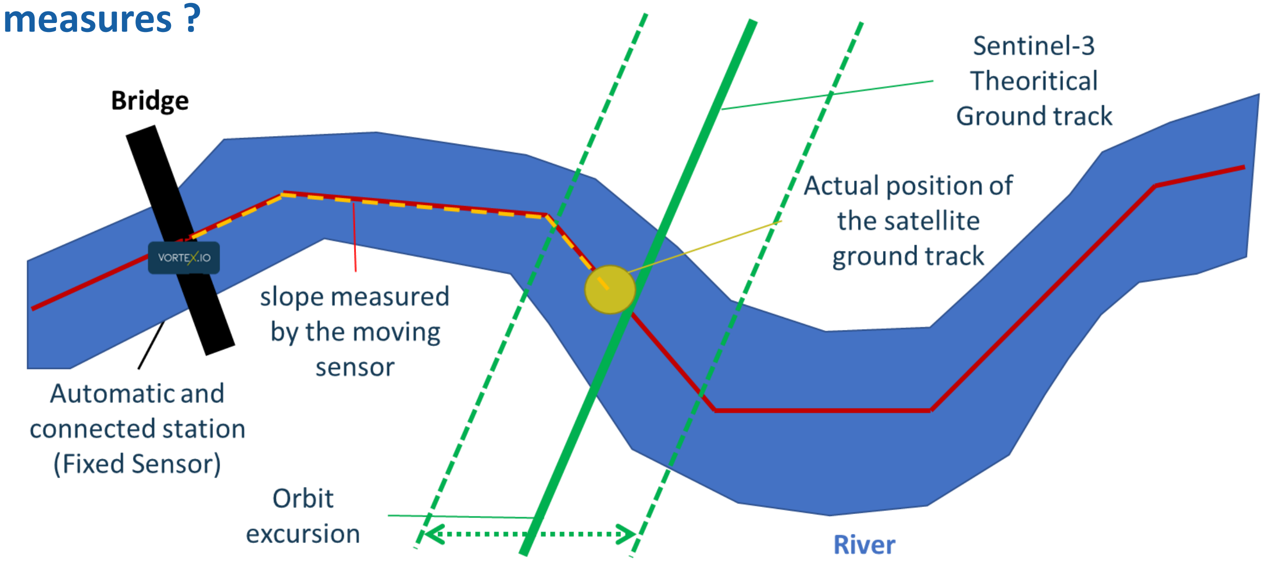


- **Example of results obtained during tests in basin**



Inland Waters – Provision of FRM

- **How to get FRM from measures ?**



$$WSH_{FRM}(t) = WSH_{FS}(t + \delta_{ts}) + \left(\Delta WSH_{slope} - Corr_{evo\_tempo}\right)$$

- δ_{ts} : propagation time of the river between the actual position of the satellite ground track and the fixed sensor => to measure the same « water drop » than the satellite
- $\Delta WSH_{slope} = WSH_{moving\_sensor\_at\_SGT} - WSH_{moving\_sensor\_at\_IS}$
  - $WSH_{moving\_sensor\_at\_IS}$: moving sensor measurement next to the in-situ sensor
  - $WSH_{moving\_sensor\_at\_SGT}$: moving sensor measurement at the actual position of the satellite ground track
- $Corr_{evo\_tempo}$: correction related to the water level evolution of the river during the campaign time.

Sea Ice – Work in progress

- **Selecting and evaluating FRM sensors**

Permanent	Semi-permanent	Campaigns
Upward looking sonar from moorings	Drifting buoys	Airborne, ice breaker, in situ, helicopter, drone
Continuous in time domain Longterm Fixed in space Point measurement	Continuous in time domain Longterm Moving Point measurement	Tend to be on the same season Short-term Moving Regional/local

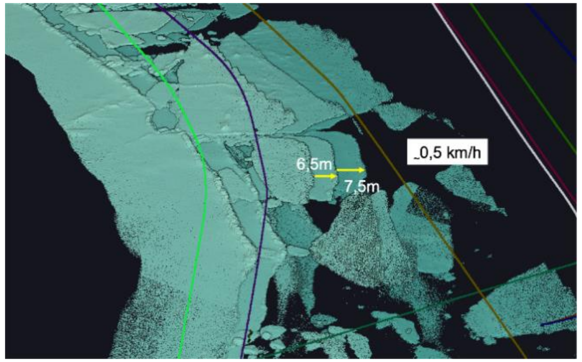
- **Construction of a FRM compliancy matrix, and ranking of sensors according to measurand, uncertainties of measurand, tracking of the uncertainties**

FRM compliancy	Ranking	Examples
High	3	Airborne radar altimeter ku-band, airborne lidar, geolocated visual images (e.g. geotiff), Upward Looking Sonar moorings
Readiness level low but good candidate	2	Drone technologies, snow radar from drifting buoys
Low	1	Upward looking sonar from AUV
Not compliant	0	Visual ship observations, visual images which are not geolocated

- **2 campaigns with two different objectives**
  - Baffin Bay campaign (Greenland) :
    - Near coincident observations with multiple sensors under S3 track from aircraft, drone and autonomous buoy
    - Test of new novel techniques together with proven sensors
    - Evaluation of the different sensors and their compatibility



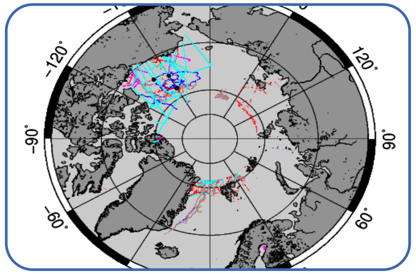
  - Drone Experiment for Sea Ice Retrieval (DESIR) campaign (ARICE H2020 project) :
    - Evaluate the difficulties to **deploy a drone from an ice-breaker**
    - Evaluate the **precise positioning without differential GPS** (PPP-AR Precise Point Positioning with Ambiguity Resolution) to support the drone observations



Sea Ice – Strategy for FRM provisionning

Specific difficulties:

- Sea ice environment is remote and harsh environment to work and operate in
- Need for coincident measurements of different geophysical parameters : freeboard, snow depth and ice thickness = > implies a combination of sensors and platforms
- Sites shall be located south of 81.5N limiting the site locations dramatically, especially for ice areas covered by multi-year ice (whose measure is more accurate than for first year ice)



Taking profit of all existing data / future campaigns

- Importance to maintain existing upward looking moorings
- Taking into account all in-situ measurements, not FRM compliant data is better than no data
- Cross calibration with other missions (CryoSat, ICESat-1, SARAL, SWOT, etc.)
- Importance to collaborate with other campaigns, to co-finance the different campaigns and get more data.

Different spatial/temporal coverage example scenario

- Regional monthly repeat drone surveys at local scale
- Yearly deployment of Ice-T Buoys for continuous observation of snow depth and ice thickness
- Yearly deployment of ULS in areas not already covered to provide continuous measurement of sea ice thickness
- Yearly large airborne campaigns to tie regional studies from regional to larger scales

Focus on metrology – Analysis of uncertainties

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FRM for Sentinel-3 Land Altimetry

MEASURAND 01 – Define the measurand and measurement function

TRACEABILITY 02 – Establish the traceability with a diagram

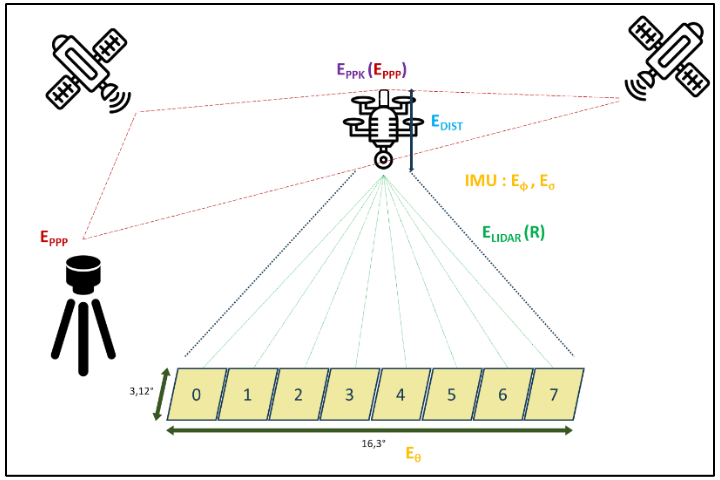
UNCERTAINTY 03 – Evaluate each source of uncertainty and fill out an effects table

HARMONISE 04 – If appropriate recalibrate / harmonise against a reference

CALCULATE 05 – Store relevant information in a Full FCDR for future users

LTDP STORE 06 – Store relevant information in a Full FCDR for future users

EASY VERSION 07 – Create a simplified version with summarised uncertainty information



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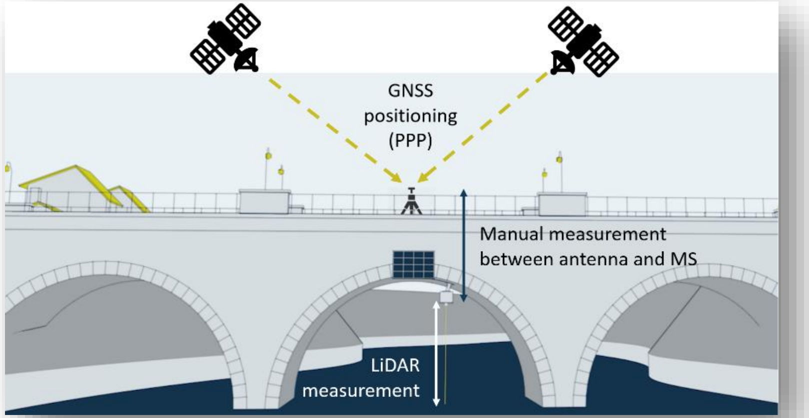
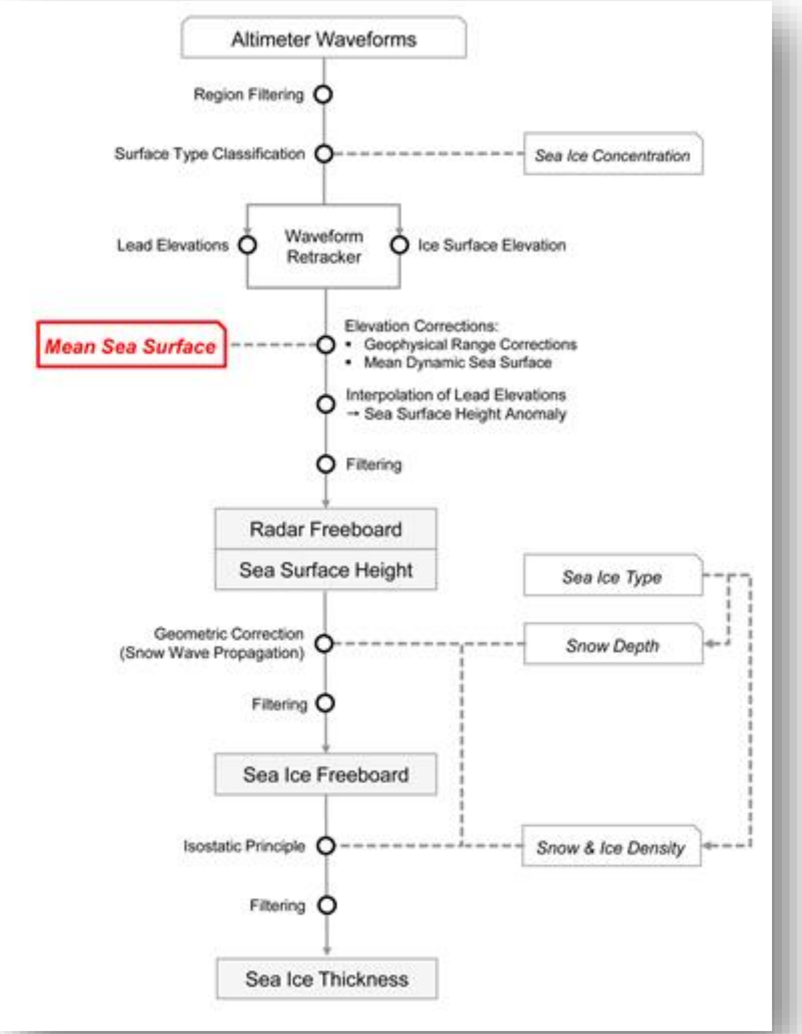
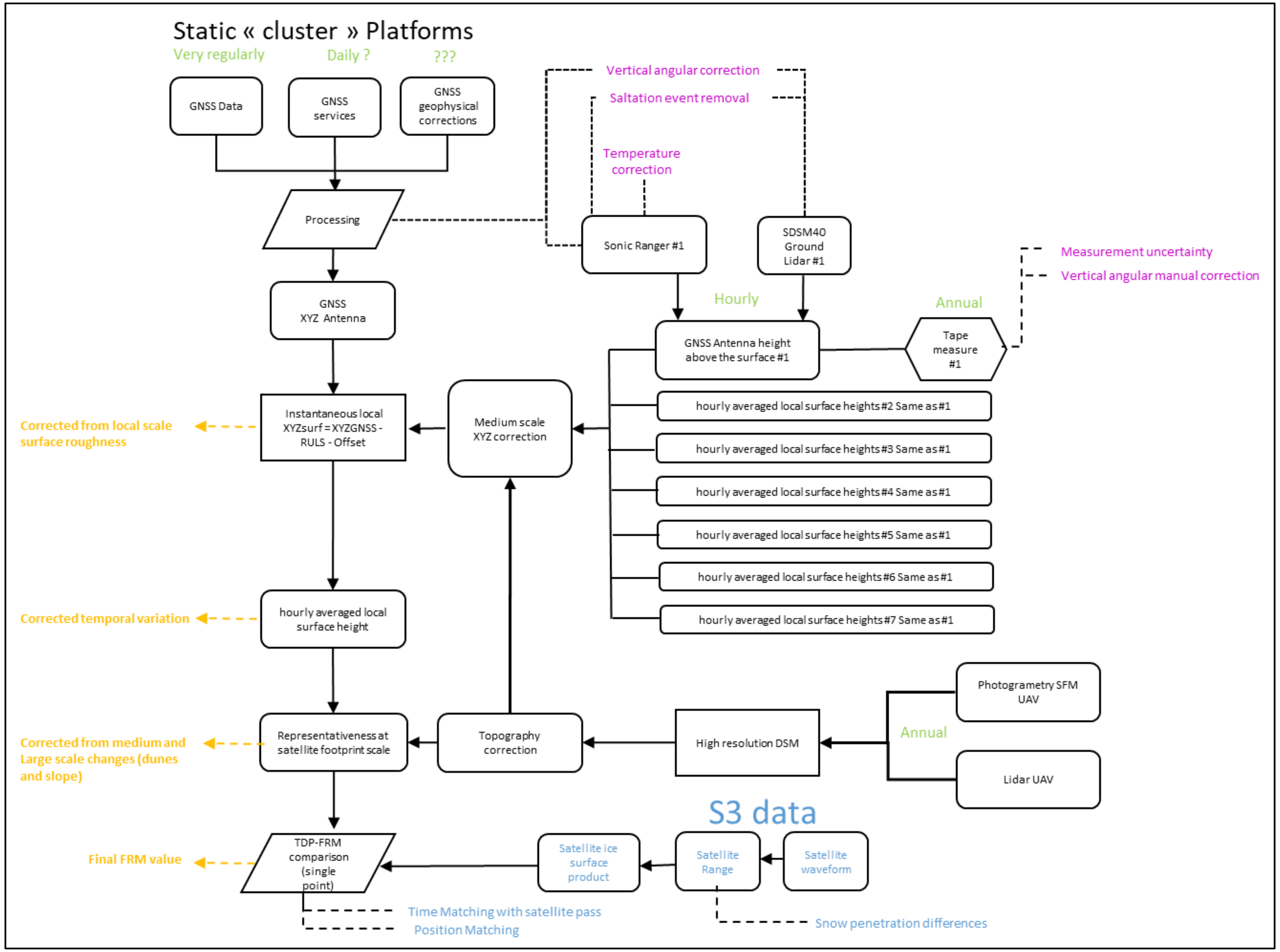


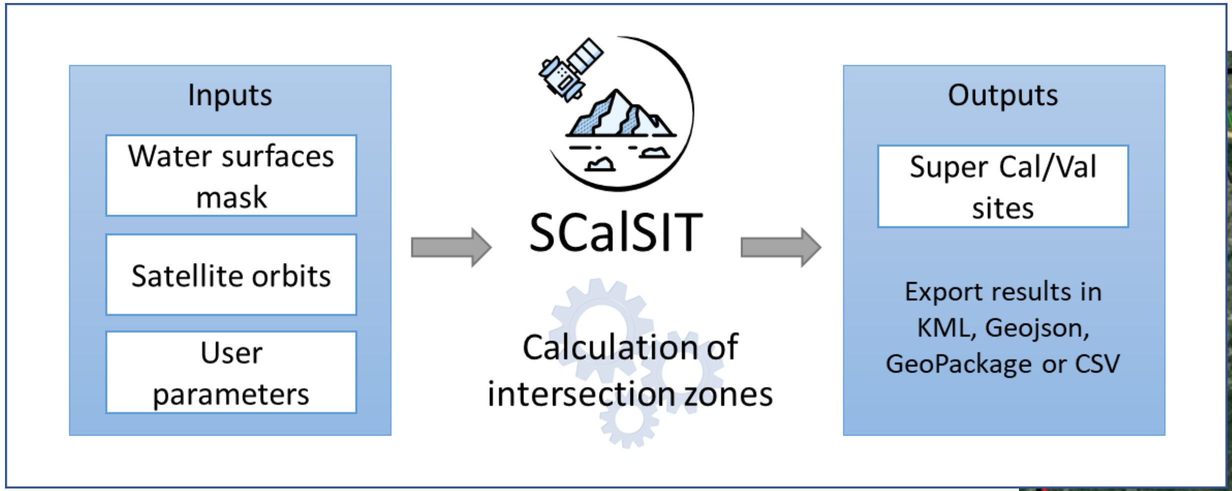
$$E_{TOT} = \sqrt{E_{PPP}^2 + E_{DIST}^2 + E_{AD}^2}$$

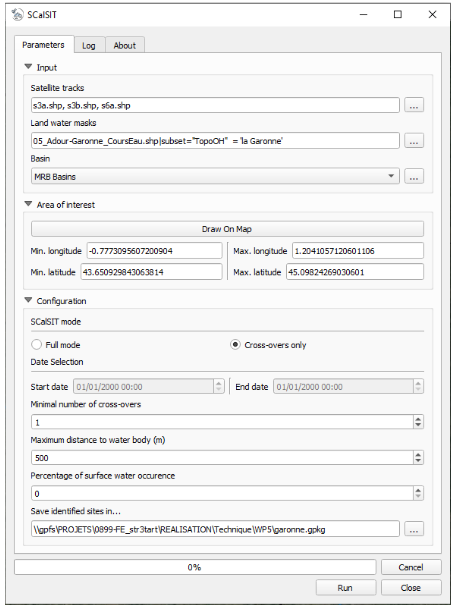


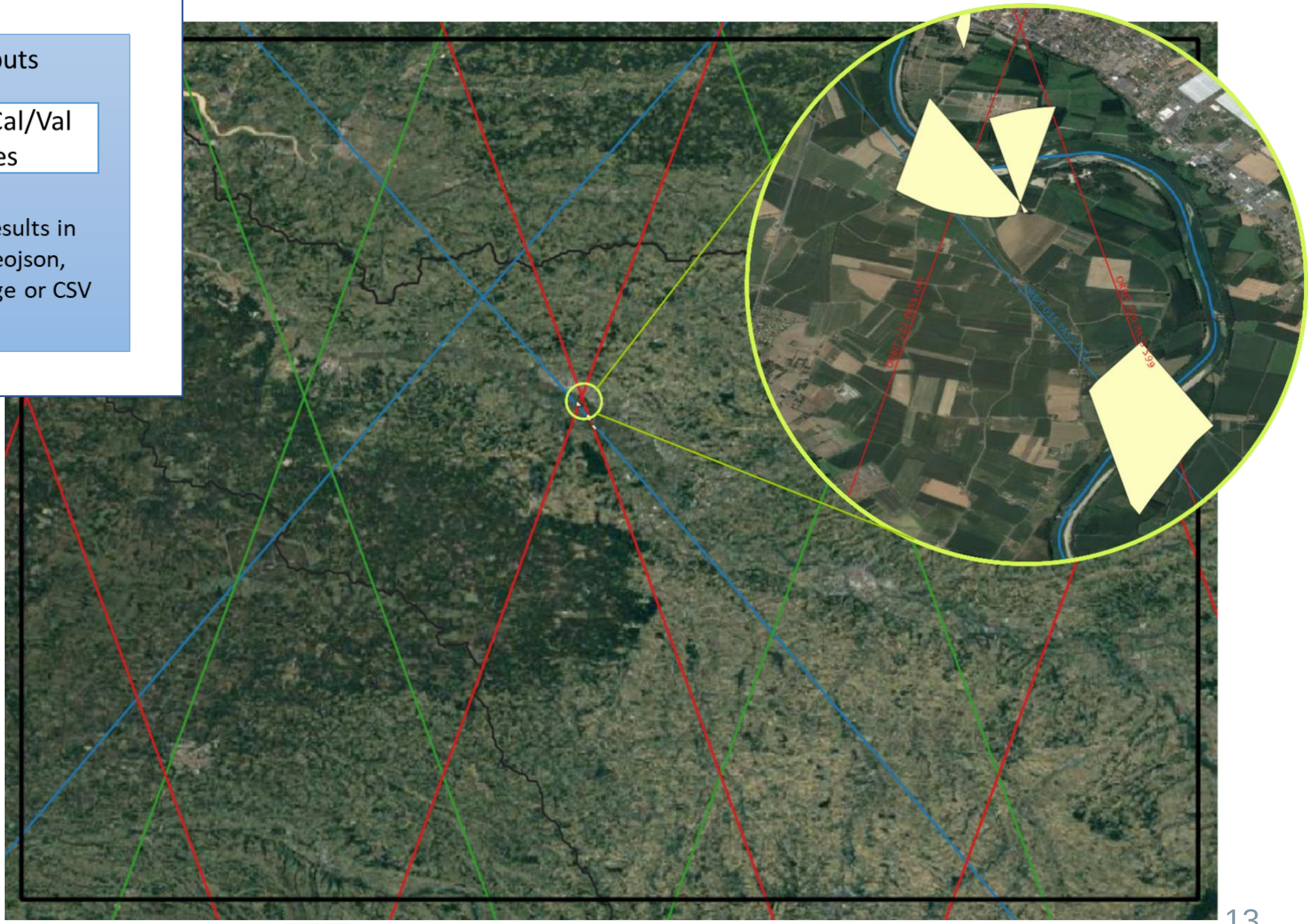
Focus on metrology – Analysis of uncertainties



St3TART tools : SCalSIT

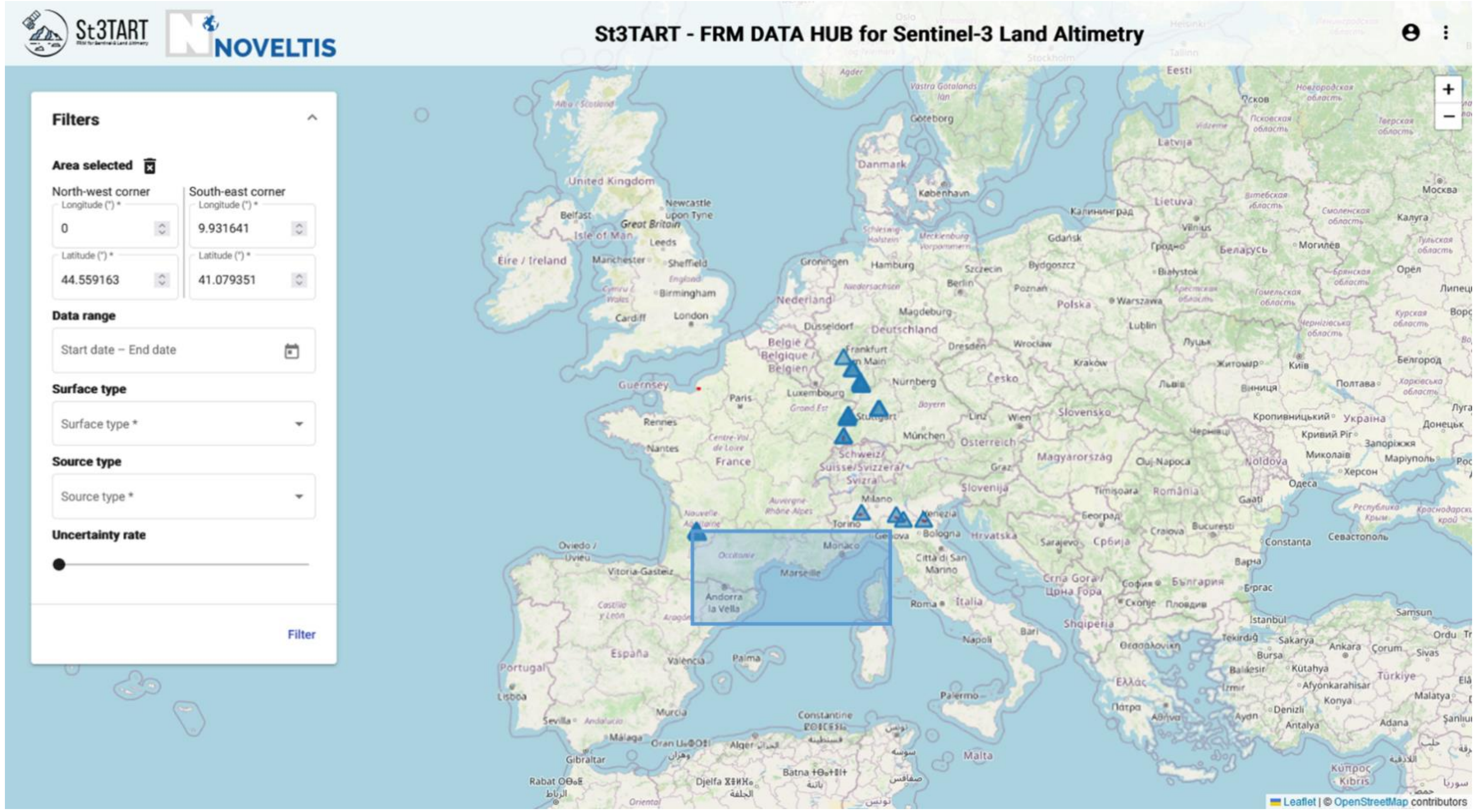






St3TART tools : FRM Data Hub

Centralized access to FRM measurements, the FRM Data Hub aims to federate the Cal/Val community to share FRM measurements in a free and accessible manner with fully characterized and documented FRM processing and measurements.



- Unified data format: NetCDF with specific attributes
- Filename convention

- **First step**: data from St3TART FRM campaigns
- **Next step** : any FRM measurements

Thanks for your attention !

https://sentinel3-st3tart.noveltis.fr/

Contact: eda-silva@noveltis.fr