AltiHydroLab & SeaIceDataLab: Two initiatives from the young company ALONG-TRACK

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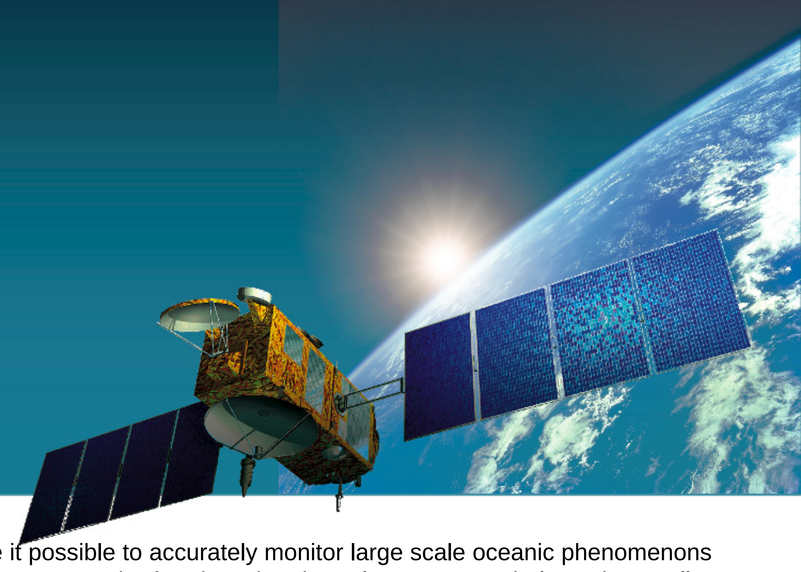

Radar altimetry has initially been designed to sense oceans with relaxed constrains on spatial resolution. Retracking algorithms based on the Brown's model made it possible to accurately monitor large scale oceanic phenomenons and model long term climate changes. Different evolutions of this type of retracker also permitted to measure water levels on large continental water bodies and to measure the free-board at the polynyas. Nevertheless, the smaller leads in sea-ice and smaller inland water bodies are still excluded while the climate change impacts are already threatening populations and the wild nature. In particular the semi-arid regions have to face droughts and famines. **It is now urgent to start monitoring in a systematic and automatized way, water bodies of all sizes, in all of the semi-arid regions and to compare the results to the climatologies derived from the reprocessing of more than 20 years of radar altimetry**. **The same applies to the mapping of sea-ice thickness/age for a better characterization of the climate change and to prevent major disasters with the increasing human activity at the poles.** In our view the customization of an ocean retracking scheme to hydrology and glaciology could only lead to a low spatial resolution and poor accuracy (averaging the high resolution content of the footprint). The failure in this approach pushed for a nice technological evolution of altimeters towards SAR mode ; the previous mode being renamed “Low Resolution Mode”. **Our team is actively involved in characterizing innovations such as SAR mode and the use of Ka Band. Nevertheless we believe that it is way too early to bury the LRM archive for hydrology and glaciology applications. We are working on a completely new retracking approach** to extract unrevealed and very valuable information from the 20 years of LRM data. Two labs are put in place with specific expertises, one being dedicated to Hydrology and the second to Sea-Ice. We give here a synthetic view of our roadmap and the ongoing researches in our labs as well as expected collaborations. **Our goal is to make it simpler to step ahead in environment and life protection applications.**

Key observations to revisit Altimetry over Land and Sea-Ice

Dominant echoes are often off-NADIR

In Hydrology and over Sea-Ice the dominant echoes mostly come from water surfaces, which may be off-nadir in contradiction to the homogeneous scene in the open ocean that favors the nadir direction. This was recently demonstrated (**Fig.A**) by a member of our team **[Bercher2013c]** thanks to the ESA level-2 SARin mode Cryosat data. Moreover this may be amplified by the fact that the topography and/or the presence of strong reflectors (calm water) may mislead the onboard tracker itself via off-nadir hookings phenomenons !

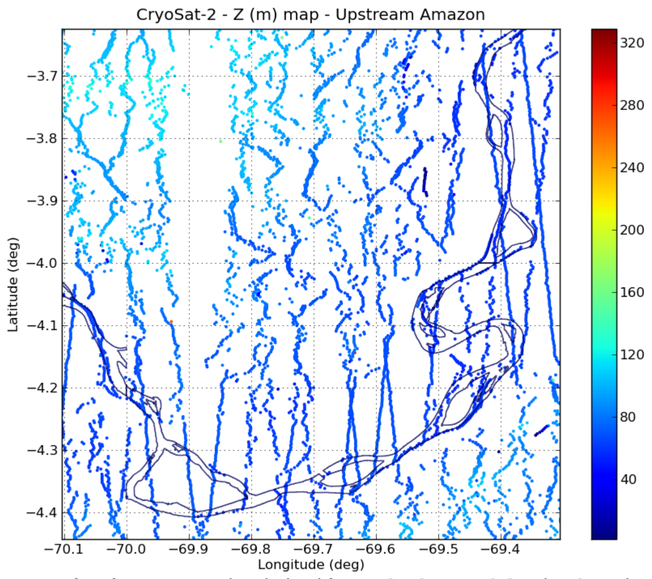

Fig. A. Map of surface topography, derived from ESA Cryosat-2 SARin L2 products over the Solimoes river (Brazil). A lot of the SARin measurements are focused on the river network.

Range-chronogram vs Individual Waveforms

In complex situations with multiple inland water bodies within the radar footprint, individual waveforms result from the weighted sum of the reflectors' echoes with a weight that evolves as the position of each reflector changes within the footprint. This leads to a difficult “out of model” waveform whereas the range chronogram (used by our retracker) gives the complete history of each reflector which is a lot more information as can be seen in **Fig. B** !

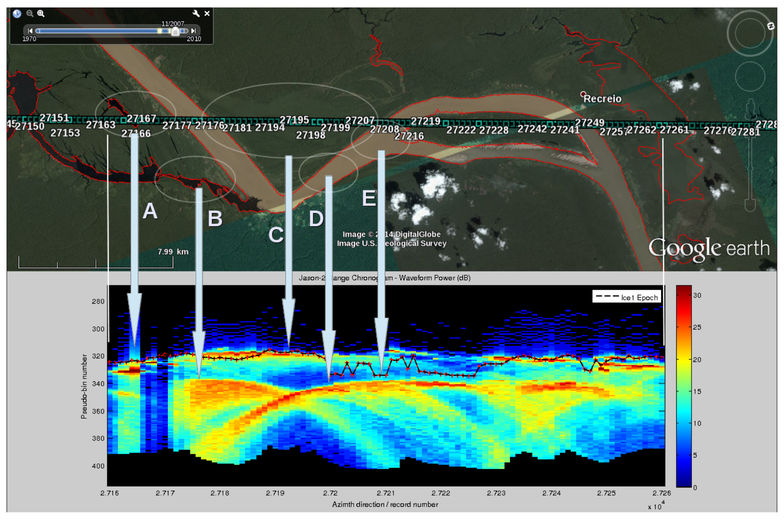

Fig. B. Jason-2 Range-Chronogram (SGDR products) over the Madeira river (Brazil). The ICE1 outputs are superimposed (red crosses linked by a black line). ICE1 provides the range in between two water bodies (B and C) while the Range-Chronogram shows the hyperbolic signatures of these two water bodies. The situation is even worse in more complex cases like in the vicinity of water bodies C, D and E. We are working on a new generation of retrackers that will exploit the conitnuity within the range-chronogram!

Very high dynamics over polynyas

Due to its high inclination, the SARAL mission is well suited to sense the cryosphere. Together with our colleague Sara Fleury from CTOH/LEGOS, we recently observed that **the AltiKa waveforms are very peaky over polynyas and exhibit a very high dynamic range up to 20dB** as show in **Fig. C** where the AltiKa acquisition is collocated in time and space with a LANDSAT8 image. **In some case the Automatic Gain Control system reaches its own limits and the waveforms are saturated. The altimeters' AGC shall be monitored over the cryosphere.**

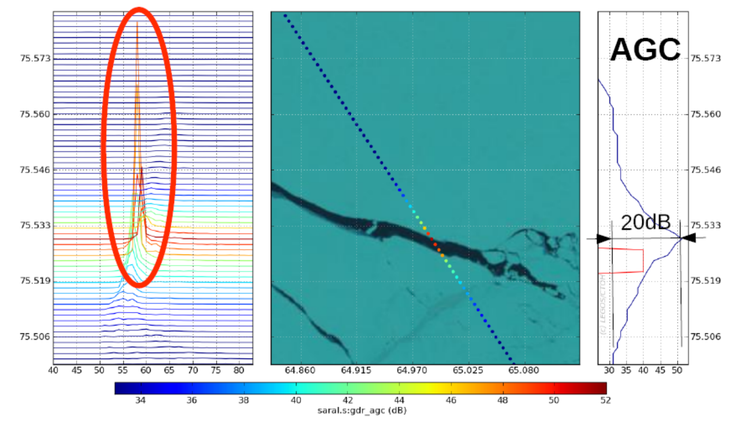

Fig. C. SARAL/AltiKa Range-Chronogram (left) obtained from the succession of waveforms along the track that is itself superimposed to the collocated Landsat8 image (middle). The waveforms have been amplitude-corrected with the AGC gains depicted on the (right) but not aligned via the onboard tracker window (the hyperbolic range signature is hidden). The scene corresponds to the flight over a large polynya in Arctica. Peaky waveforms and high dynamics of the AGC can be observed and may cause troubles to standard retrackers.

AltiHydroLab

The main objectives

- **To revisit LRM altimetry in Hydrology** via the use of relevant hypotheses (see above) leading to the development of the 2D-retracker (see below) that will improve both measurement accuracy and spatial resolution.

- **To support SAR and SARin altimetry for Hydrology**. Due to its very promising potential, SAR is the measurement mode of the forthcoming Sentinel-3 and Jason-CS satellites. SARin, exclusive to Cryosat-2, gives a unique opportunity to study swath processing before the launch of the SWOT mission. The team intends to apply its experience in SAR imaging processing to the tuning of SAR processing chains in altimetry (Doppler beam steering, multi-look matrices, etc.).

- **To finely characterize Ka band altimetry over land**, including EM interactions and waveforms characterization by context.

- **Together with partners, contribute to improve operational Inland Water Level Data Bases, before the launch of SWOT** in geographical areas of interest (semi-dry regions, the Amazon…). The idea is to take benefits from the latest improvements in retracking in order to provide a 30 years long time series which begins to have a significant meaning regarding climate change.

Work Plan & Collaborations

- To complete our **2D-retracker for hydrology**, that takes profit of the water body signatures continuity within the range-chronogram.

- To validate the 2D-retracker by :

  • a case by case study based on collocated imagery

  • comparison to in situ data

  • reprocessing long term water level times series over the study areas.

  • developing quality assessment and validation methods to perform the real-time (and off-line) monitoring of satellite measurements consistency.

- To develop **automated processing methods to build high-quality, multi-mission, river water level time series derived from satellite altimetry** (LRM, SAR, SARin), for both repetitive and drifting orbit mission phases and Ku and Ka bands.

SealceDataLab

The main objectives

- **To revisit LRM altimetry in Glaciology** via the use of relevant hypotheses (see above) into a 2D-retracker (*AltiHydrolab*) that will improve both measurement accuracy and spatial resolution. Indeed leads/ice transitions are quite similar to the rivers/banks transitions.

- **To support SAR and SARin altimetry for sea-ice applications**.

- **To finely characterize Ka band altimetry over sea-ice**, including EM interactions and waveforms characterization by context.

- **To exploit the synergies of Altimetry with imagery (SAR, radiometry)**:

  • Validate the 2D-retracker for sea-ice applications

  • Collocate SAR images with Altimeter acquisitions

  • Exploit the improved freeboard measurements as an input to improve the classification of the regions after an image segmentation step.

Work Plan & Collaborations

- To complete our 2D-retracker for sea-ice and to validate it on a case by case study based on collocated imagery

- To go on prototyping an automated Synthetic Aperture Radar Image Segmentation-Classification tool that will generate high resolution sea-ice maps after a learning stage based on the collocated altimetry measurements from our 2D-retracker.

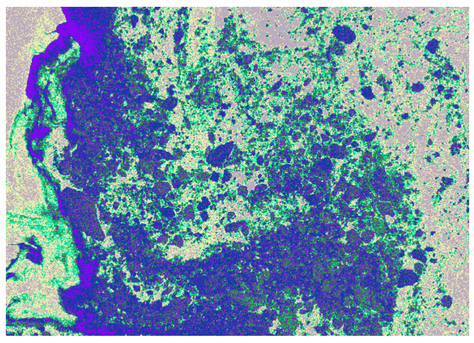

Fig. D. Output of a pixel-wise clusterization technique (based on the Maximization Expectation technique).

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Our objectives and motivations

- The main motivation of this young company is to boost the use of satellite remote sensing data into environment protection, humanitarian and security oriented applications and services. We are too small to run these services by ourselves but we intend to ease their development in collaboration with partners.

- We are mainly focused on two applications of remote sensing :

  • **Hydrology** (***AltiHydroLab***) for the monitoring of inland water resources and their evolution over the three last decades

  • **Sea-Ice** (***SealceDataLab***) for both climate monitoring and safe navigation near the poles.

- A strong objective is to assist the space agencies and their contractors by contributing to breakthroughs in remote sensing algorithmic as well as the cross-validation of high level products derived from multiple missions.

Our activities / expertises

- The team has a strong, 10 years old, background related to validation exercises **[Bercher2010], [Bercher2012a]** and to the assessment and improvement of innovative products (PISTACH, CPPv13, CNES/retracking, River and Lake, HydroWeb, etc.), Signal and Images processsing.

- A core element of our activities is the **design of innovative algorithms and methods that break the technological locks**: as mentioned in the *AltiHydroLab* section we are currently working on a new generation of retrackers that exploits the range chronogram. As part of the *SeaIceDataLab* we are bringing new methods and ideas in the combination of Synthetic Aperture Radar / Radiometry Images together with Altimetry in order to generate high resolution sea-ice maps.

- We are very motivated to participate again to **technical feasibility studies for new instrument concepts and/or processing schemes** in altimetry, imagery and scatterometry **[Fabry2013].**

- We also offer software development services related to **automated processings, chains prototyping, traceability and archiving**.

Conclusion & perspectives

We are a young team with fresh ideas and solid expertise. **Our major goal is to boost the use of satellite remote sensing data for environment protection, humanitarian and security oriented applications and services**.

It is time to **make the technological breakthroughs** that will make altimetry and remote sensing in general into operational applications for Hydrology and Sea-Ice !

Do not hesitate to contact us for any feedback or to express your interest in collaborating with us !

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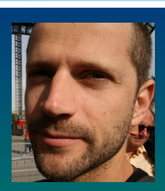
Nicolas Bercher – Space Hydrology & Validation (PhD), graduated in eletronics, signal processing, remote sensing. 10 years of experience as a *research engineer* in Tétis (Irstéa, 7 years) and LEGOS (CNRS, 3 years) laboratories.

Past & present collaborations: CNES, ESA, SALP, CLS, River & Lake, HydroWeb ....



Pierre Fabry – Radar Signal & Image Proc. (SAR imaging, Doppler scaterrometry, Radar Image Segmentation) and multi-dimensional signal processing (PhD). Experience includes *research engineer* positions at CLS (4 years) and Technical Officer at ESA/ESTEC (7 years).

Past & present collaborations : ARESYS, IRD, NERSC, KNMI, LEGOS ...

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