



# Cryosat-2 SAR Altimetry for Recovering Sea Surface Height Around and in Denmark – First Results from the LOTUS Project.



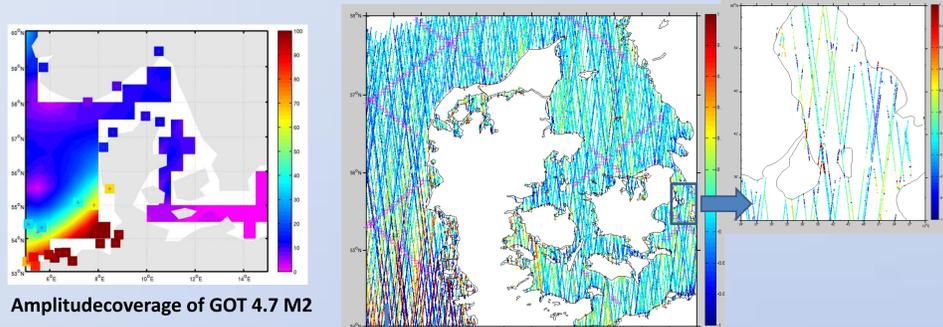
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The LOTUS project (preparing land and ocean take-up from Sentinel-3) is a recent funded EU project exploring the use of SAR altimetry in the coastal zone and on land. In the project sea level is pioneered using Cryosat-2 SAR altimetry for coastal and in-land studies to gain expertise and experience with SAR altimetry before the launch of Sentinel-3 which will likely work as an operational satellite in SAR mode (mode mask not fully confirm by ESA yet). The project is described in detail below.

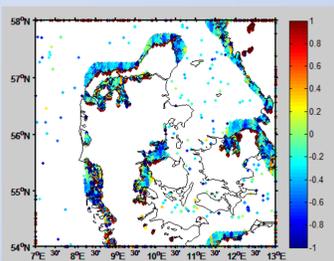
SAR altimetry from Cryosat-2 seems to be able to recover sea surface height nearly all the way to the coast with only minor degradation and the first results from sea surface recovery using Cryosat-2 SAR altimetry around and within Denmark has been performed. Focus on near-coastal sea surface height recovery is performed using SAR altimetry. A region in the northern part of Denmark contains both coastal and an inland fjord system called Limfjorden has been mapped with SAR altimetry from 2012 from Cryosat-2 Baseline B processed and processed using empirical retracers.

## Tides and annual variations:

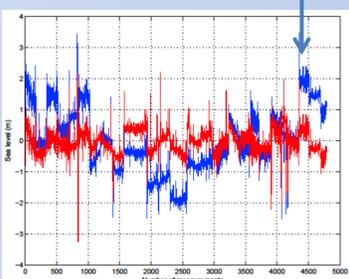
One of the default ocean tide models applied are the GOT 4.7/4.8. However for large part of the coast the model is not available As seen below. Data from Cryosat-2 also reveal that it is in error in some coastal regions like the German Bight where an analysis of residual tidal signal revealed more than 25 cm error in the tide model.



Amplitude coverage of GOT 4.7 M2

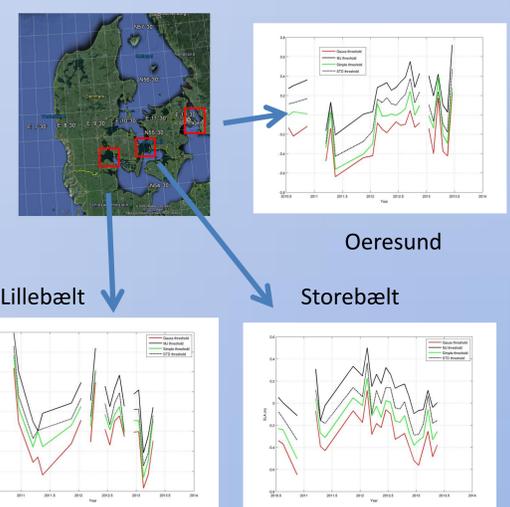


Cryosat-2 observations for 2012 with a tidal correction of zero.



Estimation of residual M2 from Cryosat-2 one year of C-2 observations. All C-2 in the 54-55N 6.5-7.5E box detided using GOT4.7 (blue) and a C-2 ocean tide model (red).

Annual sea level variations in the straits of Denmark where no altimetry was previous available



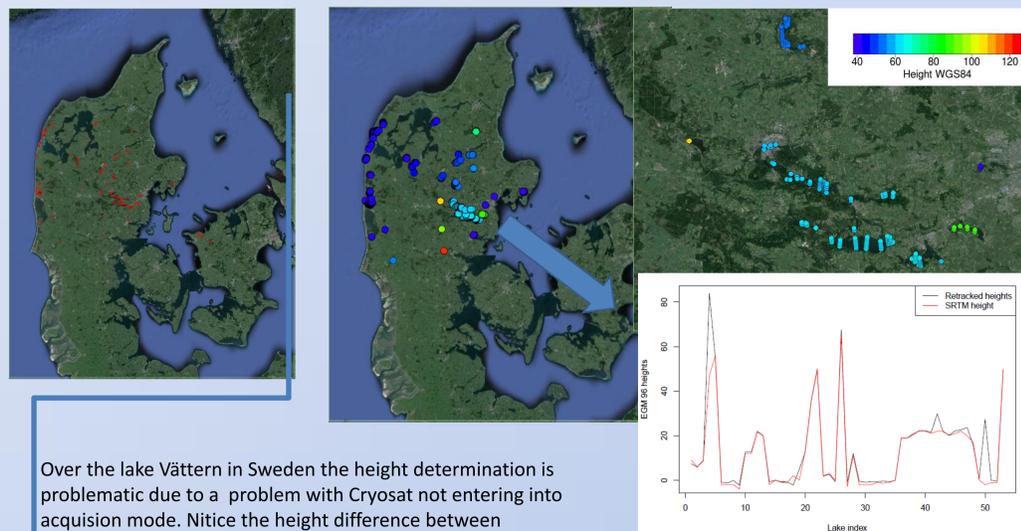
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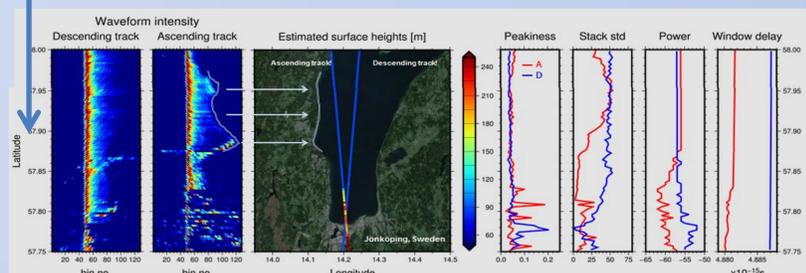
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## C2 Local and global Lake height retrieval

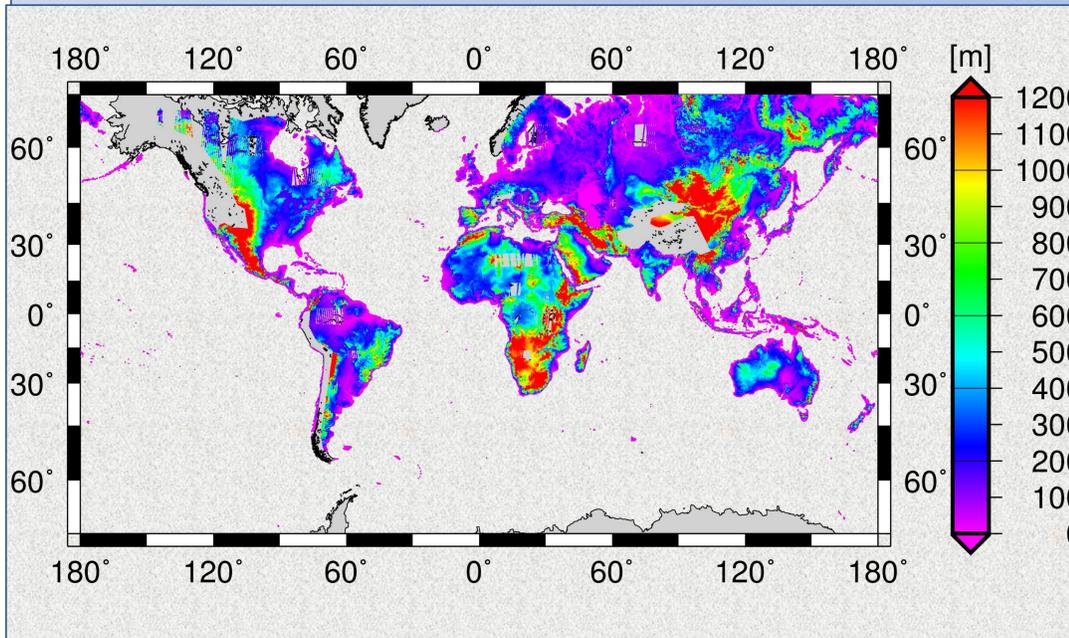
The ability of the SAR altimeter to measure over inland water is seen through an analysis of 55 lakes of the size ranging from 50 km<sup>2</sup> down to 5 km<sup>2</sup>.



Over the lake Vättern in Sweden the height determination is problematic due to a problem with Cryosat not entering into acquisition mode. Notice the height difference between ascending and descending tracks in the south part.



The Global threshold retracking of Cryosat-2 LRM and SAR inland altimetry is shown below.



## LOTUS - FP7-SPACE-2012-1 Collaborative project.

The objective of the LOTUS project is to support the development of Copernicus (previously known as GMES) by developing applications of Sentinel-3 to complete the space observation infrastructure that are designed for land and ocean monitoring for Copernicus. Duration: 1 Jan 2013 – 31 Dec 2015

Partners: DTU Space, Starlab, CLS, University of Newcastle, DHI

The SRAL instrument onboard Sentinel-3 is a new generation of radar altimeter featuring a SAR mode.

The SAR capability is a new feature and no data products based on this SAR mode data are provided or used operationally.

Therefore, new methodologies, data processing, and applications need to be developed to prepare the take-up of the Copernicus Sentinel-3 data.

### Objective 1: Processing of SRAL SAR mode waveforms over ocean.

The objective of the LOTUS project is to

- develop processing scheme for extracting high-resolution sea surface heights, wave heights and wind speeds from SAR mode data, and to
- apply the RDSAR technique to convert SAR mode data into LRM data to complement the open ocean LRM data sets in the coastal areas and secure seamless transitions between converted SAR mode and open ocean LRM products.

### Objective 2: Processing of SRAL SAR mode waveforms over land.

The objective of the LOTUS project is to develop processing scheme for extracting high-resolution river and lake heights, soil moisture, and snow water equivalents.

### Objective 3: Definition of new data products and processing chains.

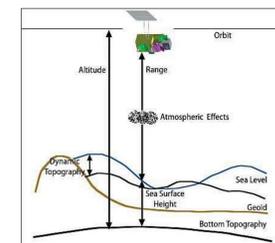
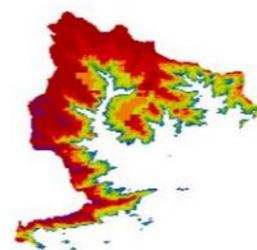
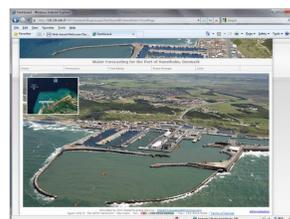
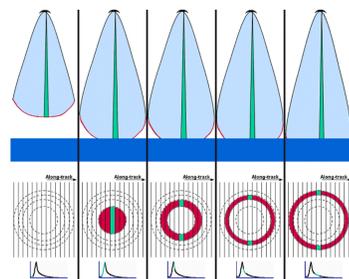
The objective is to design processing chains, simplified, easy-to-use or higher-level products. The processing chains will be specified in close relationship with the relevant Copernicus services and downstream applications.

Several kinds of data products and processing chains will be defined and designed, both new Level-2 data products and higher level data products, addressed to the different surface targets.

### Objective 4: Production of demo data and assessment.

The objective of the LOTUS project is to prepare prototype Sentinel-3 data sets to support the development of new value-adding applications for ocean and land services, respectively. Cryosat-2 SAR data and available Sentinel-3 data will be processed in specific targeted test areas to prepare prototype data sets of:

- Sea surface heights, wave heights and wind speeds,
- River and lake levels,
- Soil moisture, and
- Snow water equivalent.



### Objective 5: Applications of new Copernicus data:

The objective of the LOTUS project is to develop new and improved coastal oceanographic services by utilizing the data features emerging with Sentinel-3. The services will primarily utilize the increased resolution of the SRAL SAR and place emphasis on value adding integration with complementary data such as ocean modelling, in-situ data and multiple sensors. The services are developed to have a global applicability.

### Objective 6: Applications of new Copernicus data in value-adding land services.

The objective of the LOTUS project is to develop new and improved land services by utilizing the data features emerging with Sentinel-3. The services will be developed to have a global applicability and will be demonstrated in selected case study regions and targeting the following applications:

- Monitoring of River and lake levels,
- Monitoring Soil moisture,
- Monitoring of Snow Water Equivalent, and
- Contributions to climate monitoring.

### Objective 7: Dissemination and exploitation.

The LOTUS project will disseminate the results obtained in the project on the use of Sentinel-3 SRAL SAR mode data as well as derived new products for Copernicus land and marine services.

Effective dissemination actions are directed towards European SMEs to facilitate the exploitation of the new products in value adding applications for both ocean and land.

Furthermore, this project will disseminate the results to European services and projects contributing to the climate and climate change monitoring as well as to Copernicus services for security and emergency management.

