# Improving SAR Altimeter processing over the Coastal Zone - the ESA **HYDROCOASTAL** project **C**esa

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# The HYDROCOASTAL Project

HYDROCOASTAL is funded by the ESA Science for Society Programme, and is planned to run from Feb 2020 – April 2023, in 4 phases:

- 1. Scientific Review & Requirements Consolidation (Feb-July 2020)
  - State of the art review of SAR and SAR in altimeter data processing for coastal zone and inland waters.
- 2. Implementation and Validation (July 2020 May 2022)
  - Implement new SAR, SAR in altimeter processing algorithms to generate a test data set
  - Evaluate performance of the candidate algorithms
  - Generate "global" coastal zone and river discharge data sets
- 3. Impact Assessment (June 2022 December 2022)
  - Assessments of the global output products through a series of case studies
- 4. Outreach and Road Map (ends April 2023)

# Context

The junction between the coastal zone and inland waters is a boundary between

- Different science domains (hydrology, oceanography).
- Different satellite measurement regimes.
- Regions of high variability in small scales.

HYDROCOASTAL aims to enhance understanding of:

- interactions at this boundary,
- small-scale processes that these the govern interactions,
- exchanges with the ocean and the impact on regional sea-level changes.



Image courtesy of U Bonn: German Coast of the North Sea and the Elbe Estuary



# HYDROCOASTAL SAR Altimeter Test Data Set

The first test data set was produced to evaluate new L2 processing algorithms over the coastal zone and inland waters, and also processing to L3 (river/lake level time series) and L4 (river discharge)

We have selected 18 Regions of Interest to cover a wide range of inland water and coastal zone characteristics, on all continents (except Antarctica!). The data set includes 2 years data: 2018-2019

Input data products are CryoSat FBR baseline D SAR and SARin mode data, and Sentinel 3A and 3B SIRAL L1A data

Also enhanced Wet and Dry Troposphere Corrections have been produced by U Porto, and coastal tidal models assessed by Noveltis.

Documented descriptions of processing schemes and products available at www.satoc.eu/projects/hydrocoastal

## Target Type TDS1-01 River Rhine Germany River TDS1-02 Hungary, Serbia, Romania, River Danube River Bulgaria TDS1-03 River Amazon -Brazil River Solimoes TDS1-04 River Ob Russia River TDS1-05 River River Po Italy TDS1-06 River Yangtze China River, estuary TDS1-07 **River Mississippi** USA River TDS1-08 Nonacho Lake Canada Lake TDS1-09 River China, Mongolia, Russia River, wetland, Amur/Songhua estuarv Ionian / Aegean Greece Coastal /SARin TDS1-10 TDS1-11 Reindeer Lake Canada Lake TDS1-12 Zambezi River Zambia, Mozambique River TDS1-13 German Bight, Coastal Germany **Baltic Coast** TDS1-14 California Coast USA Coastal TDS1-15 Huelva and Spain Coastal, Estuary Bonanza TDS1-16 Elbe Estuary Germany Estuary TDS1-17 Coastal Tarifa Spain TDS1-18 Caspian Sea Russia Inland Sea









# **Processing to L1B**

isardSAT have generated Level 1B-S and Level 1B products as input to processing to L2.

- L1B-S: fully SAR-processed and calibrated SAR complex echoes arranged in stacks after slant range correction and before multi-looking.
- L1B : Geo-located and fully calibrated multi-looked SAR power echoes



*chain (credit: isardSAT)* 

# **Candidate L2 Algorithms**

Six candidate L2 processing algorithms are implemented. Their performance is being evaluated, and based on this, algorithms will be selected to generate global coastal zone and inland water products.

- 1. Two Step Analytical Processor coastal and inland: isardSAT
- 2. Specialised SARin coastal: Aresys
- 3. MWaPP Multiple Waveform Persistent Peak inland: DTU Space
- 4. ICC-ER (Isolate, Cleanse, Classify Empirical Retracker) inland: ATK
- 5. Statistical Re-tracker STARS type coastal: U Bonn
- 6. ALES+ for SAR coastal and inland: TU Munich

# 1<sup>st</sup> Data Set Coastal Zone Validation

The performance of the isardSAT, DTU, U Bonn and TU Munich processors over coastal regions has been evaluated through detailed studies and with a set of agreed metrics, as described in the *Product Validation Report* 



- German Bight /Baltic Sea (U Bonn)
- California Coast / Harvest (NOC)
- Southern Spain (U Cadiz)
- Land Proximity to Coast / Angle of Approach (SKYMAT)

## **Validation Results**

**Sea Surface Height (SSH):** SSH was by comparing Sea Level Anomaly to data from 15 tide gauges in 3 different regions. The standard deviation of differences (STDD) between TG and altimeter data was calculated and averaged from 2-20km from the coast.

The STDD for Sentinel 3A / 3B data ranged from 3.4cm (California), to 17cm in the German Bight / Baltic. The STDD for Cryosat-2 data ranged from 6cm to 50cm. Different re-trackers performed best in different regions, and none was consistently better than the others.

Significant Wave Height (SWH), 10m ocean surface wind speed (SWH, **U10):** Only 2 retrackers (U Bonn and isardSAT) provided SWH and U10. In validation against data from 30 buoys, the U Bonn data were consistently found to perform better than the isardSAT data, showing higher correlation and lower standard deviations.

The validation team recommended selection of the U-Bonn re-tracker for coastal processing in the next stage of HYDROCOASTAL

# **HYDROCOASTAL Final Product**

From the evaluation of the first test data set, algorithms will be selected to generate a "global" coastal and river data set.

The global data set will comprise:

- Global L2 data sets for coastal zone and inland water
- Global L3 data sets (time series) for selected "large to medium" rivers
- Global L4 data sets (river discharge) for selected "large to medium" rivers
- Experimental data set for "small rivers and tributaries"

This "global" product will be made freely available.

# SWH, U10 Validation (NOC)

NOC compared altimeter SWH and U10 from the U Bonn and isardSAT retrackers against data from 21 buoys off the California coast



# **Final Product Coverage**

The final coverage of the output data set is to be finalised. The table opposite includes all areas required by the project impact assessment studies.

If external users would like to propose other areas for their own study, then please contact the project manager: d.cotton@satoc.eu

Target name	Country	Target type
Venice Lagoon	Italy	Coastal
Po	Italy	River
Ireland lakes	Ireland	Lakes
Yakutian alasses	Russia	Lakes
Kolyma R	Russia	River
Nadym R	Russia	River
Songhua/Amur	China/Russia	River/Estuary
Mackenzie	Canada	River
Amour	Russian part	River
Ebro Basin	Spain	River/Lakes/Coast al
Southern Baltic Sea	Germany	Coastal
German Bight	Germany	Coastal
Wadden Sea	Germany	Coastal/Estuary
River Rhine	Germany	River
Amazon basin	Brasil	River
Bristol Channel / Severn Estuary	UK	Coastal

# **SSH Validation (U Bonn)** Sea Level Anomaly v 9 Tide SSH "Noise" and no of valid Gauges records

# Impact Assessment Case Studies

A series of impact assessment studies will be carried out, to test and demonstrate the potential impact and benefits of the global dataset.

<ul> <li>Processing Case Studies</li> <li>Fully Focused SAR (Aresys, isardSAT)</li> <li>Attitude Errors (Aresys)</li> <li>Along and Across track slope (Aresys)</li> <li>Open Loop Tracking Study (NOVELTIS)</li> <li>Phase Unwrapping / Across Track Slope (DTU Space)</li> </ul>	<ul> <li>Coastal / Inland</li> <li>Severn Estuary (NOC)</li> <li>Baltic, German Bight, Elbe Estuary (U Bonn)</li> <li>Venice Lagoon (CNR)</li> <li>Thailand Coast (TU Delft)</li> <li>Ebro River and Delta (isardSAT)</li> <li>Wadden Sea (TU Delft)</li> </ul>
Elevation (m) - 300 -	

Andaman Sea	Thailand	Coastal	
Alps	Italy/ Switzerland	River/Lakes	



# **HYDROCOASTAL Outcomes**

The outcomes of HYDROCOASTAL will include:

- State of the Art Review on SAR Radar Altimetry.
- First SAR / SARin satellite altimeter L2, L3 and L4 Test data set over 18 Regions of Interest.
- Descriptions of processing algorithms and products.
- **Global Output Products**:
  - Global L2 coastal & inland water SAR altimeter data set.
  - Time series (L3) and river discharge (L4) data sets for medium to large rivers
- Scientific Road Map for further developments, implementations and research for SAR altimetry

# Interested? Please contact us to access the data and discuss possible applications and case studies www.satoc.eu/projects/hydrocoastal - https://eo4society.esa.int/projects/hydrocoastal