

SCOOP: Evaluating the performance of Sentinel-3 SRAL SAR Altimetry in the Coastal and Open Ocean, and developing improved retrieval methods.

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**SAR Altimetry Workshop
La Rochelle 31 Oct 2016**

The SCOOP Project

- SCOOP (SAR Altimetry Coastal & Open Ocean Performance) project funded under the ESA SEOM (Scientific Exploitation of Operational Missions) Programme.
- Aim is to provide answers to the two questions:
 - *What level of performance can we expect from Sentinel-3 SRAL data over the open ocean and coastal zone?*
 - *Can we further enhance this performance with improvements to the processing schemes?*
- Two Year Project, October 2015 – October 2017
- 9 partners: SatOC (prime), CLS, isardSAT, National Oceanography Centre, Noveltis, Starlab, TU Delft, University of Bonn, and University of Porto.



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SCOOP Overview

1. State of the Art Review

- A thorough review of the current knowledge of SAR altimetry
- Recommendations regarding processing methods and algorithms.
- Summarise the latest evidence of performance of SAR Altimeter in the open ocean and coastal zone.

(refer to “A review of topical issues in SAR Altimetry,” Cipollini et al)

2. Phase 1

- Generate 1 year test data set applying SRAL baseline equivalent processing to CryoSat FBR data
- Evaluate expected performance of Sentinel-3 SRAL products over the open ocean and in the coastal zone

3. Phase 2

- Develop, implement and test modifications to the SRAL baseline processing algorithms
- Evaluate improvement in performance from modified processing

4. Scientific Road Map

- Recommendations for further developments, implementations and research for Sentinel-3 SRAL SAR

Delay Doppler Processing: L1A – L1B (isardSAT)

Key Steps

- Compute surface locations, datation, window delay -> beam angles
- Delay Doppler processing & stacking
- Geometry corrections
- Range compression, generate power waveforms
- Multi-looking

First Test Data Set: Processing Cryosat FBR “à la Sentinel-3”

- Cryosat calibrations applied according to Baseline-C
- No zero padding, no hamming windowing
- Stack masking designed for Sentinel-6 applied. Equivalent to Sentinel-3 approach, where geometry corrections are separated in fine and coarse shifts

Code is open source and available through
“DeDop” Project (www.dedop.org)

See Monica’s DeDop talk later, and Eduard’s presentation

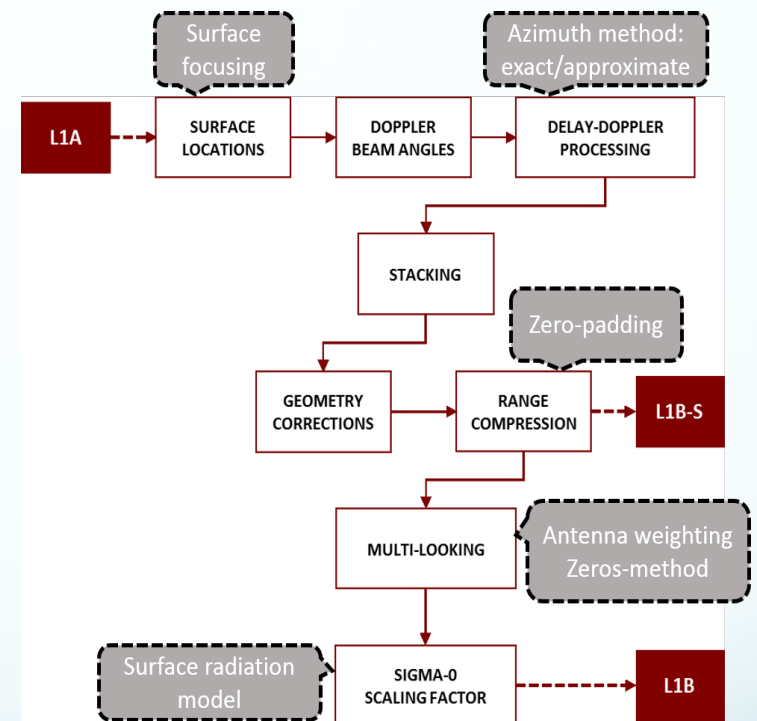


Image credits isardSAT

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Echo Modelling, Re-tracking: L1B to L2 (Starlab)

- First Test Data Set:

- Input isardSAT L1B produced from Cryosat FBR
- Implementation of SAMOSA-2 analytical waveform model.
- Application of a Look-Up Table (LUT) for the selection of a variable Point Target Response (PTR) width as a function of SWH.
- Improved thermal noise estimation.

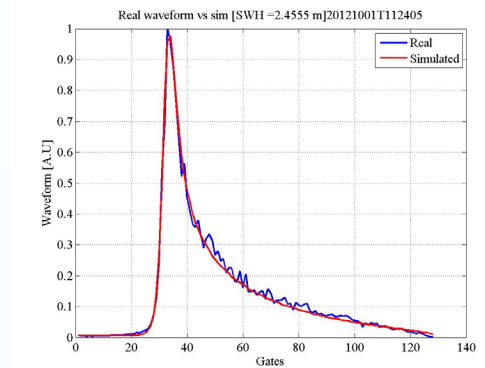
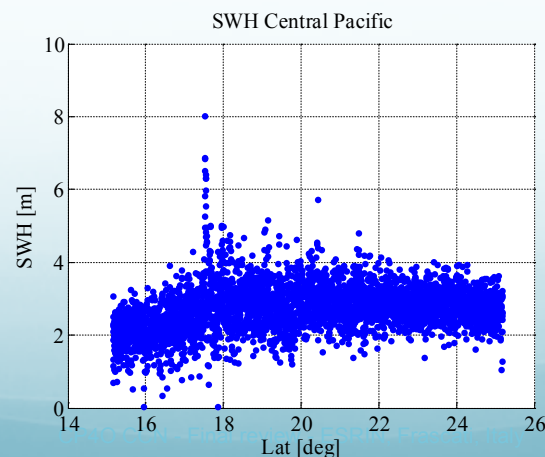
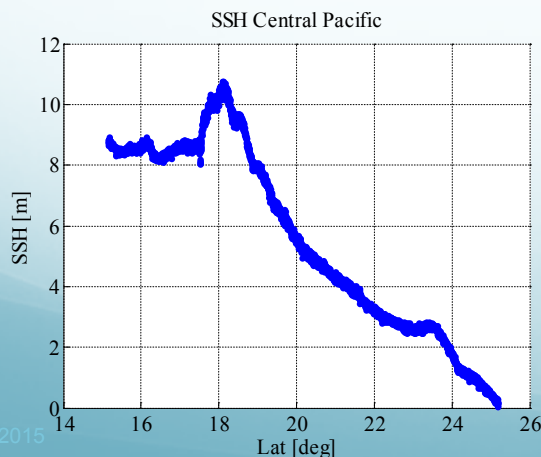
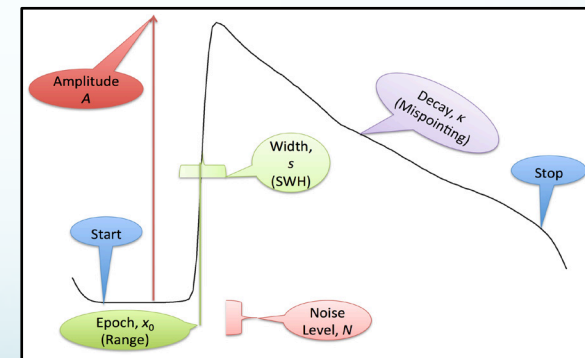


Image credits Starlab,
TU Delft



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RDSAR Processing (TU Delft)

- New code written for SCOOP to be equivalent to S-3 Processing
- Processing steps includes:
 - Gather 4 bursts of 64 echoes.
 - Adjust the Fine Range Word for each burst.
 - Align the echoes horizontally, then vertically (optional).
 - Correct echo amplitude and phase.
 - Zero-pad the echoes.
 - Perform a 1-dimensional FFT (Fast Fourier Transform), horizontally.
 - Incoherently average the individual waveforms.
 - Apply low-pass filter correction.
 - Rescale the waveform
- For Sentinel-3 (and CryoSat) PLRM product is/ will be “noisier” than existing LRM data sets, because of transmission sequence

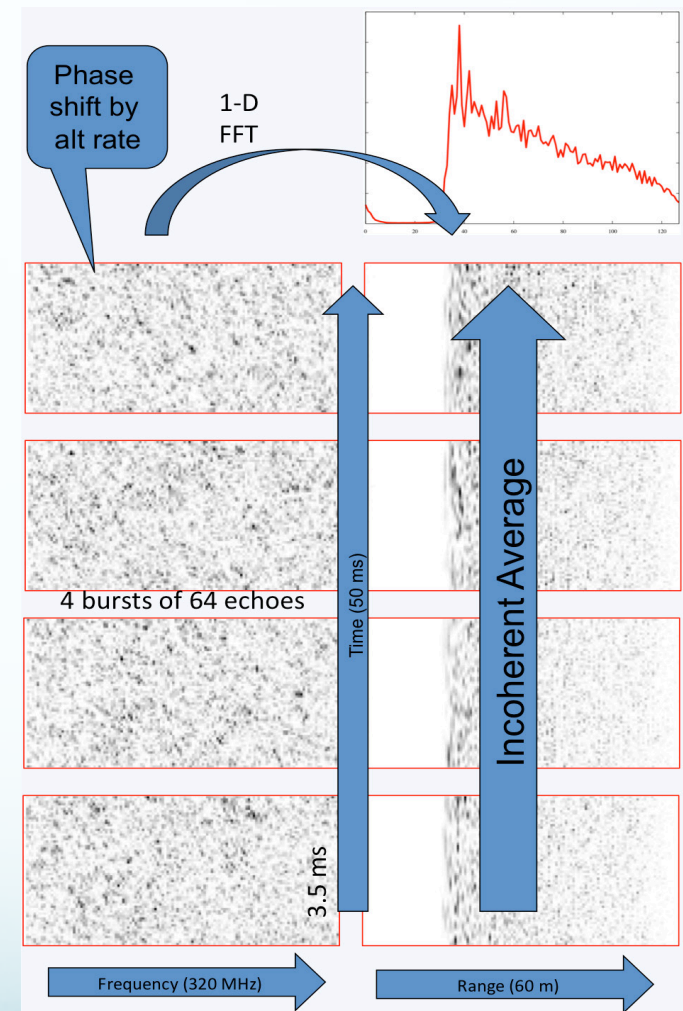


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SCOOP 1st Test Data Set

- 10 Regions of Interest:
 - West, Central and Eastern Pacific; NE Atlantic, N Sea, Agulhas, N Indian Ocean, Indonesia, *Cuba (SARin)*, Harvest (California)
- 2012-2013; 01/12/2105 onwards for Harvest
- CryoSat FBR baseline C data – reprocessed with Sentinel-3 SRAL baseline configuration. SAR L1B, SAR L2, RDSAR L2
 - Delay Doppler processing: FBR to L1B
 - SAR Echo Modelling /re-tracking: L1B to L2
 - RDSAR processing (underway): L2 PLRM
- Documented descriptions of processing schemes and products (<http://www.satoc.eu/projects/SCOOP/index>).html
- Available on request by email to ***scoop.info@esa.int***

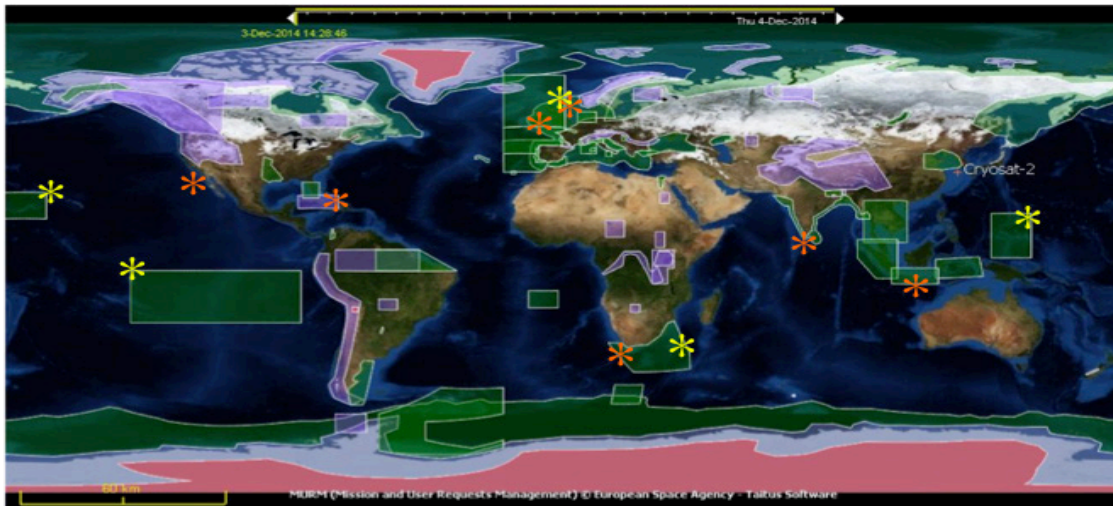


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Open Ocean Study (CLS, TU Delft, NOC)

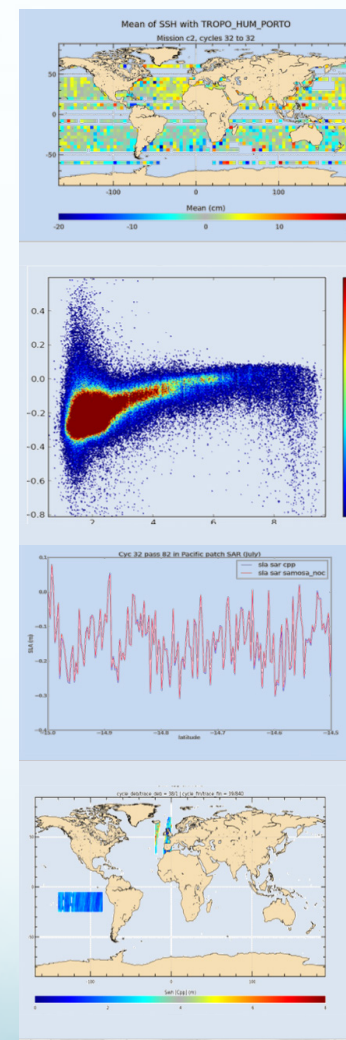
The open ocean study is led by CLS, objectives are:

- **Characterise the expected performance** on Sentinel-3 SRAL data in the **open ocean**
- **Develop, test and implement modifications** to the processing of the L1B-S product (e.g. zero-padding, multi-looking, antenna pattern compensation, stack beam weighting), and improvements to the implementation of the model in the re-tracking of the SAR echo to generate the L2 product.
- **Evaluate the performance of products** generated by this modified processing chain and **make recommendations**.
- Carry out a study into the **dependency of SAR altimeter data on swell** (amplitude, direction and wavelength).
- To propose a solution for a **SAR mode Sea State Bias** correction for the open ocean, building on findings from a study being funded by EUMETSAT (EUMITS ITT No.14/209556 "Jason-CS SAR Mode Sea State Bias Study")

(See next talk: "Results from observations to detect sea state bias from SAR mode altimetry.", Bellingham et al)

Open Ocean Study – Evaluation Approach (CLS)

Technique	Parameter(s)
Residuals between model and data	waveforms
misfit against wave height misfit	misfit, SWH
Histograms	SLA, SWH, Sigma0
Parameter profiles as a function of time	SLA, SWH, Sigma0
Cartography	SLA, SWH, Sigma0, radial velocity, mispointing, rejected data
Noise against wave height	SLA, SWH, Sigma0
wavenumber spectra	SLA, SWH, Sigma0
Cross over C2/C2	SLA, SWH, Sigma0
Cross over C2/J2	SLA, SWH, Sigma0
Along track differences (mean and standard deviation), as a function of latitude and coastal difference	WTC
Along track gain of variance, as a function of latitude and coastal difference	SLA
Cross over difference, gain of variance as a function of latitude and coastal difference	SSH
Along track analysis	SLA



Images
credit CLS

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Coastal Zone Study (NOC, Noveltis, U Bonn)

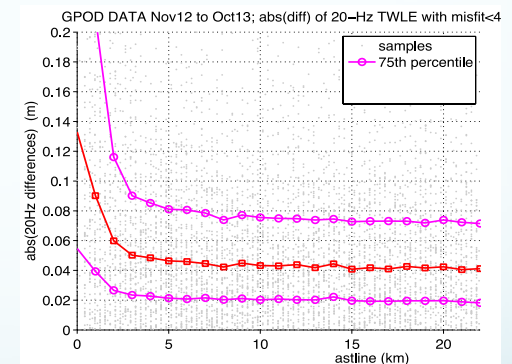
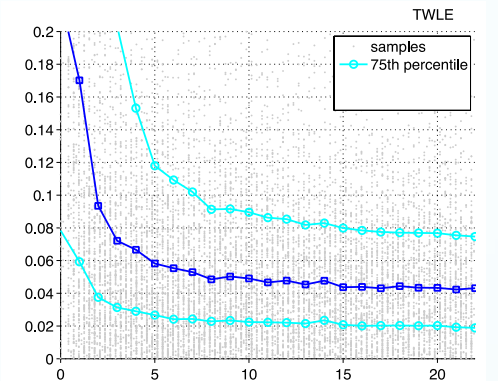
The aims of the coastal zone study are to:

- **Characterise the expected performance** on Sentinel-3 SRAL data in the **coastal zone**, including a specific regional study in the **German Bight** and a study of the impact of **swell** on the **US West Coast** .
- **Develop, test and implement modifications to the processing of the L1B-S** product (e.g. zero-padding, burst weighting window, higher posting rate).
- **Evaluate the performance of products** generated by this modified processing chain and make recommendations.
- Improve performance close to the coastline by developing techniques to **identify and discriminate against the impact of land contamination** of the nadir ocean echo.
- Develop, test & implement **coastal re-trackers** for S-3 SAR and RDSAR data
- Investigate how the **orientation of the ground track** with respect to the coastline, and the **proximity of the land**, affect the performance

Coastal Zone Validation Metrics (NOC)

SSH1	Metric: Zero-lag correlation of time series w.r.t. Tide Gauges: values of r. Expected outcomes: r does not decrease; r increases in points in close proximity to coast	SSH
SSH2	Metric: Zero-lag correlation of time series w.r.t. Tide Gauges: position of maximum r. Expected outcome: Location of max r remains at same distance from coast or moves closer	SSH
SSH3	Metric: RMS of residuals w.r.t. Tide Gauges. Expected outcomes: RMS does not increase; RMS decreases in points in close proximity to coast; RMS within acceptable threshold for assimilation in models or other specific application (may be application-dependent); RMS within requirement S3- MR-210	SSH
SWH1	Metric: Zero-lag correlation of time series w.r.t. wave buoy (and/or wave model) data: values of r. Expected outcomes: r does not decrease; r increases in points in close proximity to coast	SWH
SWH2	Metric: RMS of residuals w.r.t wave buoy (and/or wave model) data. Expected outcomes: RMS decreases in points in close proximity to coast; RMS within acceptable threshold for assimilation in models or other specific application (may be application-dependent); RMS within requirement S3- MR-320	SWH
WIN1	Metric: Cross-correlation of time series w.r.t. in situ wind measurements: values of r. Expected outcomes: r does not decrease; r increases in points in close proximity to coast	Surface wind speed
WIN2	Metric: RMS of residuals w.r.t. in situ wind measurements. Expected outcomes: RMS decreases in points in close proximity to coast; RMS within acceptable threshold for assimilation in models or other specific application (may be application-dependent); RMS within requirement S3-MR-330	Surface wind speed

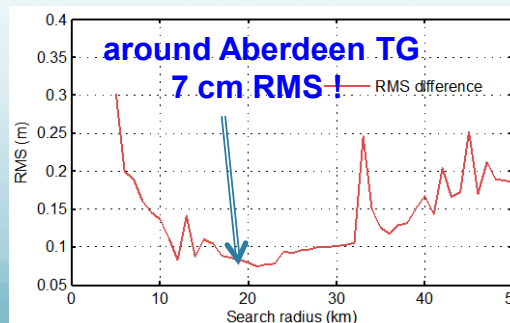
CryoSat-2 SAR



Data processed by GPOD @ ESRIN

Cipollini et al

Images
credit NOC



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Coastal Zone: Noveltis: Harvest Study

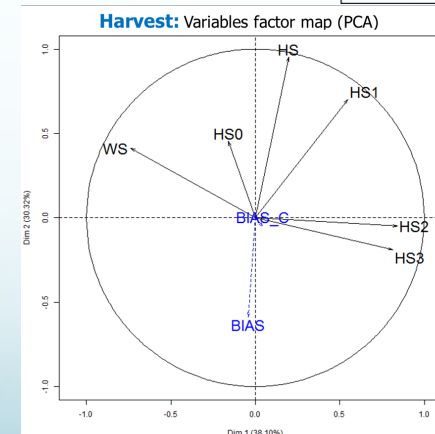
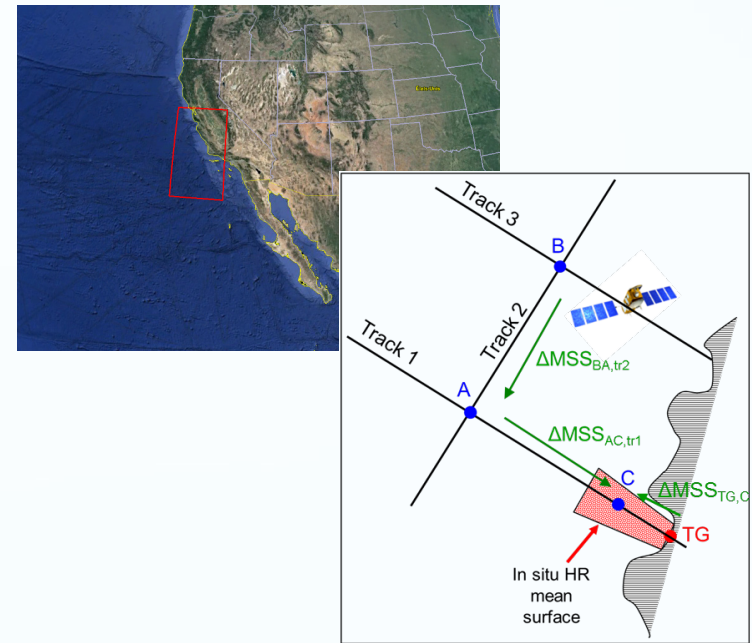
1. Stability of the altimeter SSH

→ Altimeter absolute bias, drifts, geographically correlated errors, local coastal performances

- Verification of the SSH stability at the coast in SAR mode for CryoSat-2: [implementation at Harvest](#)
- Evaluation of the [wet tropospheric correction\(s\)](#)
- ➔ **New SAR-mode zone at Harvest for CS2**

2. Sea state impact on the altimeter SSH

- ➔ Sensitivity of the altimeter SSH bias to the major sea state components
- ➔ [Harvest](#) mainly governed by swell
- [Statistical analysis](#): Correlations, Principal Components Analyses (PCA),...
- Evaluation of the [Sea State Bias correction\(s\)](#)
 - Altimeter SSH bias
 - Sea state parameters: HS (*SWH*), HS0, HS1, HS2, HS3, wave direction, skewness, period...
 - Wind speed



Images credit
Noveltis

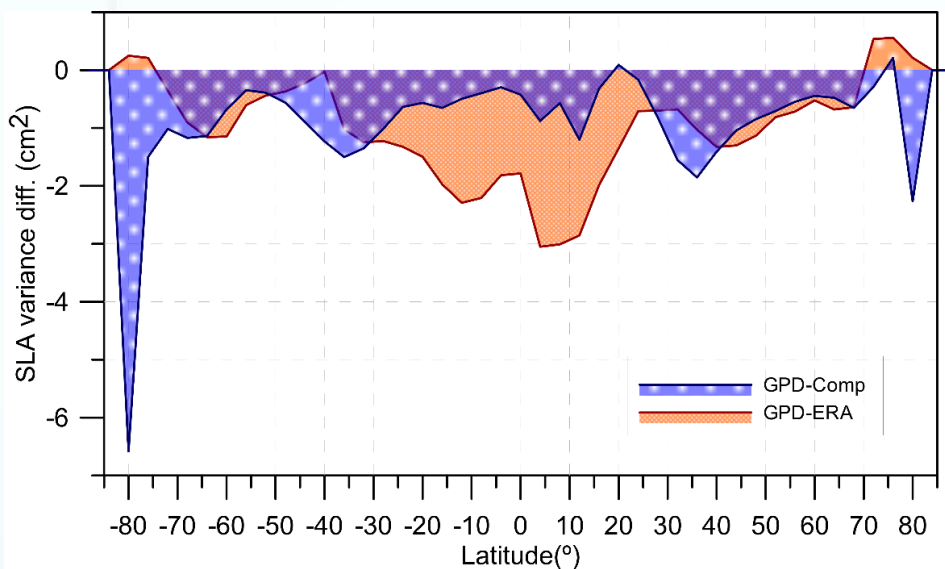
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Wet Troposphere Modelling

SCOOP includes an activity to develop an improved WTC for Sentinel-3

- For the first test data set SCOOP is using CryoSat data but, unlike S3, CryoSat does not have an on-board microwave radiometer (MWR). Thus, while S3 data are not available, the study is being conducted both for CryoSat and Envisat, since Envisat and S3 radiometers are similar (2-band).
- The WTC are based on the GNSS-derived Path Delay Plus (GPD+) algorithm developed by U Porto
- The GPD+ WTC are computed by space-time objective analysis using all available data types (valid on-board MWR values, GNSS data at coastal and island stations and data from scanning imaging MWR (SI-MWR) on board ~20 different satellites).
- Results for S3 are expected to be similar to those obtained for Envisat. For CryoSat slightly worse results are obtained due to the absence of on-board MWR

GPD+ WTC Performance for Envisat



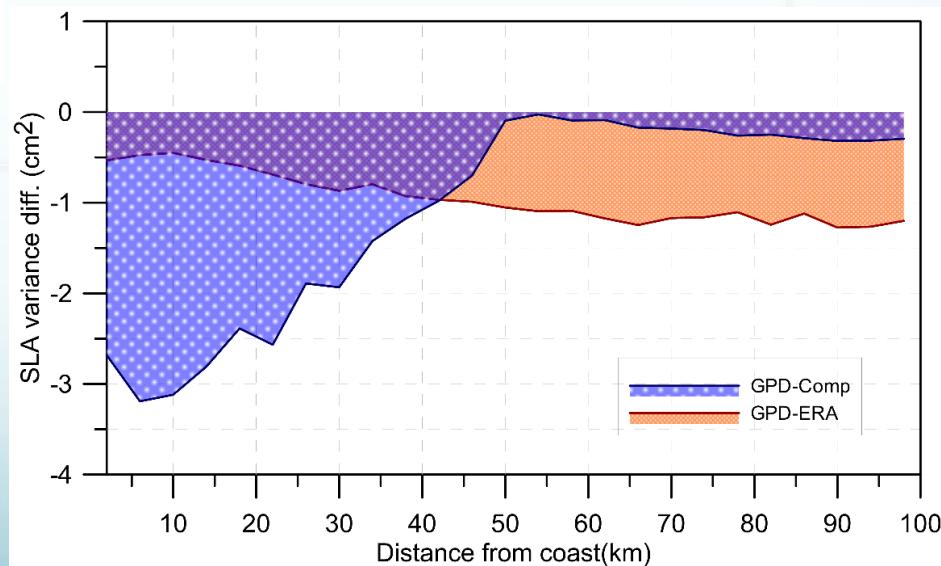
Variance difference between GPD+ and Composite WTC (blue) and ERA (orange), function of distance from coast, for Envisat cycles 06 to 93.

Results for CryoSat-2 are slightly worse due to the absence of on-board radiometer.



Variance difference between GPD+ and AVISO Composite WTC (blue) and the ERA Interim model (orange), function of latitude, for Envisat cycles 06 to 93.

Results for CryoSat-2 are slightly worse due to the absence of on-board radiometer.



SCOOP Status

- First Test Data Set largely complete (Cryosat FBR data processed à la Sentinel 3 to SAR L1B, SAR L2, *RDSAR L2*)
- Available via ftp on request
- GPD+ WTC correction produced
- Open Ocean and Coastal Zone assessment just starting
- Phase 2 in 2017, apply and evaluate processing modifications
 - To include (TBD) zero padding, hamming (and other) windowing), stack masking, surface focussing, new approaches to stack processing
 - Coastal re-trackers (ALES, L1B stack geo-referencing); stack data exploitation.
- ***2nd Test Data set will also be made available, expected late spring 2017***
- Project ends late 2017

SCOOP Outcomes

The outcomes of the SCOOP project will include:

- Characterization of the expected performance of Sentinel-3 SRAL SAR mode altimeter products, in the coastal zone and open-ocean.
- An evaluation, and clear description, of enhancements to the Sentinel-3 SRAL processing in terms of their ability to provide improved measurements over the open ocean and in the coastal zone.
- The provision of clear technical information of Sentinel-3 SRAL SAR products and their processing, supporting correct interpretation and application of these data by the user community.
- A Scientific Road Map including recommendations for further developments, implementations and research for Sentinel-3 SRAL SAR data

Thank You

www.satoc.eu/projects/SCOOP