SENTINEL-3 ALTIMETER PRODUCTS FOR COASTAL AND INLAND WATER APPLICATIONS

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http://www.esa.int/gmes

Background & Mission Objectives

The Sentinel-3 Mission (S-3) is part of the Global Monitoring for Environment and Security (GMES/Kopernikus) European initiative. S-3 is an operational mission in high-inclination, low-earth orbit designed to acquire global coverage microwave, optical and thermal data for operational oceanography and global land applications with near-real-time product delivery (< 3hrs). S-3 is an operational mission in high-inclination, low-earth orbit designed to acquire global coverage microwave, optical and thermal data for operational oceanography and global land applications with near-real-time product delivery (< 3hrs). For oceanic applications, the S-3 mission will deliver continuity to existing ones ESAs ERS and Envisat missions with ocean/land colour data, sea/land surface temperature estimates and sea surface and land ice topography at least at the level of corresponding Envisat instruments, the Medium Resolution Imaging Spectrometer (MERIS) and the Advanced Along-Track Scanning Radiometer (AATSR) and the Envisat Radar Altimeter (RA).

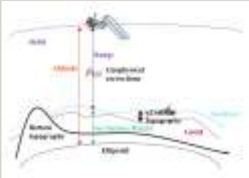
The nadir looking SAR altimeter concept has been studied in parallel in ESA and the US since the mid 1990s. This concept is now implemented in SIRAL instrument operating on board Cryosat-2 mission launched early 2010, and dedicated to ice topography observations. However, this novel altimeter concept can be very advantageous for observation of ocean surfaces, as it promises improved altimetric precision and better along-track resolution than conventional pulse-limited altimeters. This will allow to achieve high-resolution high-accuracy altimetric mapping of the ocean in regions of high mesoscale variability and in coastal areas. Several studies are ongoing to develop and test suitable processing algorithms for this new altimeter mode. This poster focus on the CNES studies.

Topography Mission

- **Observed surfaces**
  - Open ocean, coastal ocean
  - Ice sheets (interiors and margins)
  - Sea ice
  - In-land water (rivers & lakes)

Topography package:

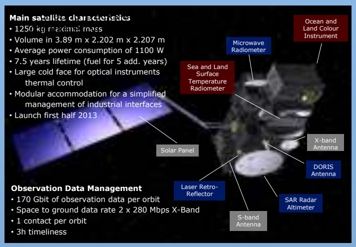
- **SRAL**
  Dual frequency Ku/C band Radar Altimeter, with SAR mode and open loop tracking (CryoSat/Jason heritage)
- **MWR**
  Dual channel microwave radiometer



- **Precise Orbit determination**
  - GPS receiver
  - Doris navigation receiver
  - Laser retroreflector

Revisit time and coverage

Topography Mission:
ground track repeatability,
dense spatial sampling



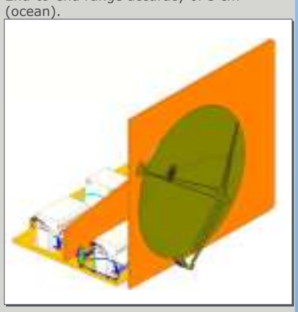
SRAL Overview

Dual frequency Ku/C band Radar Altimeter
- CryoSat and Jason heritage

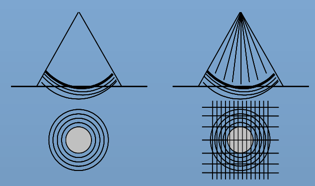
- **High horizontal resolution (SAR mode)**
- **SRAL Radar features:**
  - Ku-Band (13.575 GHz) : main frequency
  - C-Band (5.41 GHz) : ionosphere corrections
- **Open-loop tracking**
  - Used over rough surfaces
- **Fully redundant**
- **Measurement modes:**
  - 2 radar modes: Low Resolution Mode (LRM) and Nadir SAR mode
  - 2 tracking modes: Closed-loop and open-loop tracking modes
  - Any radar mode can be combined to any tracking mode

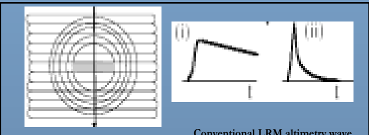
Objective

Retrieve orbit altitude information with an End-to-end range accuracy of 3 cm (ocean).



Conventional LRM altimetry resolution compared to Doppler one's.



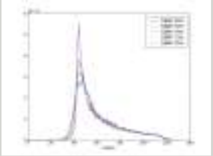


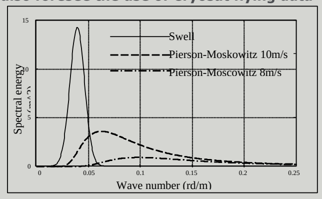
Conventional LRM altimetry cells compared to Doppler one's.

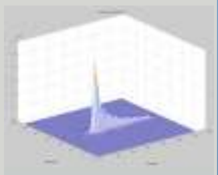
Conventional LRM altimetry wave form (pulse limited) compared to Doppler one's. (beam limited)

CNES simulator

- **CNES has contracted CLS to develop a simulator including the SAR simulation capability.**
- **Surface modelization is based on the use of Pierson-Moskowitz model and the swell is derived from Durden et Vesecky model.**
- **This simulator has been widely validated in 2009 and will be used as part of the SAR processing analysis.**
- **We also foresee the use of Cryosat flying data**







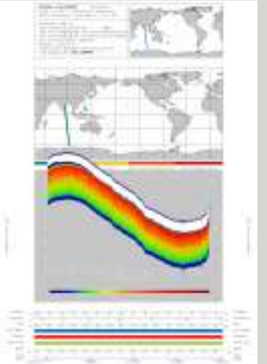
CNES SAR processing study

- **CNES is about to start a dedicated study to work on the processing of SAR echoes. Today, no analytical model is available, we will so work with numerical solutions (neural network, numerical derivatives, ….).**
- **The continuity between LRM and SAR estimates will be deeply analysed. To do so we will use our simulator and the CryoSat flying data.**
- **Based on the simulator : the same scene will be used to generate LRM and SAR echoes. MLE3/4 LRM estimates will be compared to the SAR estimates. In particular, the impact of the swell (wave number equivalent to the along track resolution) will be widely assessed.**
- **Based on CryoSat flying data provided by the project :**
  1. 'LRM' like echoes will be reconstructed on ground with the raw SAR data. MLE3/4 LRM estimates will be compared to the SAR estimates.

  2. SAR estimates will be widely compared to ocean conditions derived from DUACS maps.

Analysis of CryoSat data

- **2 SAR acquisition sequences were performed by CryoSat project to support to analysis conducted for S3 project.**
- **Those data have been analysed and we have started the development of a processing module (LRM Cryosat Processing Chain : LRM CPC) to analyse the possibility to rebuilt LRM like echoes with SAR data.**
- **The LRM CPC processing chain starts from Level-0 TM files and performs the following steps of processing:**
  - Level-1: Decommutation, time-tagging and localization of measurements
  - Level-1b: Calculation of instrumental corrections and geophysical/meteorological corrections
  - Level-2: MLE4 waveforms Retracking and calculation of Sea Surface Height Anomaly
- **The LRM processing chain can process either LRM data from ECHO files or tracking SAR data from TRK and SAR files.**



Analysis of CryoSat data CPC Processing steps

- **Processing Steps C-P-C processor computes SSHA values for each altimeter measurements (20Hz). For each measurement, the following steps are performed.**
- **Level-1 processing step: The Level-1 processing step consists in:**
  - ***extracting altimeter parameters from TM files***
  - ***time-tagging altimeter measurements:*** Altimeter time-tag are computed taking into account CRYOSAT altimeter characteristics (NIMP, PRF) and altimeter fine datation parameter. Then, the time-tag is referred to the sea surface taking into account altitude of the satellite.
  - *calculating altimeter altitude, velocity and position :* Altimeter altitude, radial velocity and positions are computed by interpolating SSALTO CRYOAT MOE (medium ephemerid) with Everett method.
- **Level-1b processing step: The Level-1b processing step consists in:**
  - ***calculating the corrected altimeter tracker range:*** Altimeter tracker range is computed taking into account CRYOSAT altimeter characteristics (tracker range resolution, COR2 values). The tracker range is corrected from USO frequency shift, Doppler effect, internal path delay, and the CoG position. USO correction is computed from SSALTO USO file. Doppler effect is calculated with the radial velocity relationship. To finish the IPD and CoG corrections are set to constant value (given by ESA team).
  - ***Calculating LPF filter values:*** The Low Pass Filter is computed from CAL2 TM file.
  - ***Calculating all geophysical and meteorological corrections:*** The following list of geophysical and meteorological corrections are calculated: Wet tropospheric path delay, Ionospheric corrections, Dry troposheric corrections, Pole tide corrections, Ocean tide correction, Solid tide correction, Inverted barometer

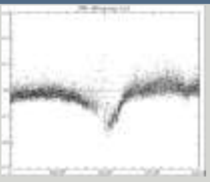
Analysis of CryoSat data CPC Processing steps

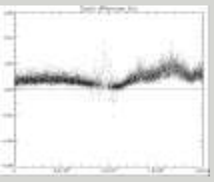
- **Level-2 processing step: The Level-2 processing step consists in:**
  - ***Correcting the waveform from the LPF filter***
  - ***Performing the MLE4 retracking of the waveform:*** MLE4 retracking has been developed following the Jason-2 method. However, It has to be noted that the CPC retracking does not used a MQE threshold to determine the solution convergence. The algorithm stopped when 10 iterations have been performed. Usually, over ocean, 6 iterations are necessary to get the solution. Moreover, in the CPC retracking the skewness is not taken into account. Epoch, SWH, Power, thermal noise and mean quadratic error and mispointing values are estimated by the retracking algorithm.
  - ***Calculating the look-up table corrections:*** Jason-2 MLE4 Look-up table have been reused to compute the correction to apply to epoch and SWH solutions.
  - ***Calculating Sea State Bias:*** The Jason-2 Sea State Bias table have been reused to compute the correction to apply to epoch. As the wind speed is not computed in CPC chain, a default value is used to get the SSB correction (wind = 7m/s).
  - ***Calculating Mean Sea Surface Height:*** The MSS-CLS01 file have been used to interpolated the MSS height at the altimeter location.
  - ***Calculating SSHA:*** The Sea Surface Height anomaly is computed as following:
    ssha = orb_alt – range - iono_cor_alt_ku - model_dry_tropo_corr - rad_wet_tropo_corr - solid_earth_tide - ocean_tide_sol1 - pole_tide - hf_fluct - mss - ssb)

CPC Validation procedure Use of Jason-2 data

- **The CPC validation process consisted in adapting the processing chain to be able to process Jason-2 data. In that way, with a direct comparison between CPC output products and SSALTO-SIGDR products, we can assess the CPC outputs quality. For the comparison, measurements over ocean have been selected. CPC retracking algorithm has performances very close to SSALTO algorithm. Introducing MQE convergence criteria would improve CPC retracking of degraded WVF.**

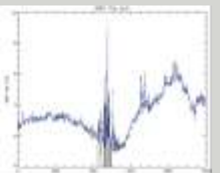
Parameter	Differences / Comparison	Comments
SWH	less than 5 cm	up to 10cm during sigma0 bloom. CPC retracking performs only 10 iterations whereas SSALTO retracking waits for the MQE convergence. Over cell rain, more than 10 iterations are required (see number of iteration plot).
Epoch	less than 2 cm	differences are SWH dependant. Could be related to the skewness parameter which is not taken into account in CPC whereas skewness is set to -0.1 in SSALTO.
Power	less than 8 U_fft	higher differences during sigma0 bloom.
Number of iterations	CPC = 10 SSALTO around 6	SSALTO retracking needs more than 10 iterations to process WVF with sigma0 bloom.
MQE	Both method have MQE less than 0.01.	-
Number of valid points	Most of time, both method retrieve 20 valid points	CPC rejects more points during sigma0 bloom.
RMS	Both method have 5 to 10 cm RMS	CPC seems to be slightly better.

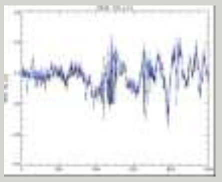




CPC Validation procedure Use of Jason-2 data

- **Then the compression to 1Hz standard data rate was implemented (linear regression method). The following list of parameters have no differences:**
  - Altitude, localisation, altitude rate
  - Tracker range
  - Met/Geo corrections
  - SSB, MSS values
- **SSHA and SWH comparisons:**
  - SWH and SSHA differences with respect to SALTO-SIGDR have centimetres range. Those differences are directly linked to the retracking results and are acceptable in the frame of this study.
  - This is explained by the lack of MQE threshold in the iterative process and skewness parameter in the CPC retracking model.





CPC Validation procedure Use of CryoSat SAR and LRM data

- **We used CRyoSat SAR data dated June, 8th to reconstruct on ground the LRM like echoes. SSHA derived from LRM MLE4 estimates was compared to the DUACS values. A remarkable agreement was obtained on this short data set.**
- **Finally we used 7 days of CryoSat LRM data and compared the SSHA with the equivalent DUACS values. Again a remarkable agreement was obtained.**