living planet symposium | MILAN 13–17 May 2019

Sentinel-3 Hydrologic Altimetry Processor prototypE (SHAPE): Project Achievements

2019-05-12 – Session: A.4.11

Bercher N.[1], Fabry P.[1], García-Mondéjar A.[2], Fernandes J.[3], Gustafsson D.[4], Ambrózio A.[5], Restano M.[6], Benveniste J.[7]

1 Along-Track, Plouzané, France ; 2 isardSAT UK, United Kingdom ; 3 Univ. Porto, Porto, Portugal ; 4 SMHI, Sweden ; 5 Serco, Frascati, Italy ; 6 Deimos, Frascati, Italy ; 7 ESA-ESRIN, Frascati, Italy

Introduction to SHAPE Project

SHAPE
Sentinel-3 Hydrologic Altimetry Processor prototypE

Stands for ***"Sentinel-3 Hydrologic Altimetry Processor prototypE"***

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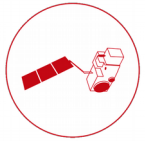
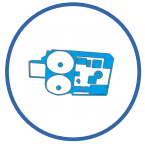


Objectives

- Inland Water domain: Characterize SARM performances for **water level** measurement, improvement **hydrological catchment modelling**, and river's **discharge** estimation using Sentinel-3 delay-Doppler processing applied to CryoSat-2 data (FBR)
- Implement SAR processing alternative & innovative techniques
- Propose & design new retrackers for SAR and RDSAR modes
- Improve Wet tropospheric correction over land and inland water



Introduction to SHAPE Project

Main Requirements

. Improve SARM Stack processing

. Implement new retrackers: 1 physical + 1 empirical

. Provide state of the art L2 Corrections & Geoid model

. Emulation of repeat orbit sampling pattern from CryoSat-2 geodesic orbit

. Produce L3 River & Lake Water Level (RWL, LWL)

. Produce L4 River Water Discharge (RWD)

. Assess impact of Altimetry data assimilation in River Discharge Models

. L3 & L4 validation

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Requirement Baseline v1.3

→ Available from SHAPE web site


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Sentinel-3 Hydrologic Altimetry Processor prototypE

– Requirements Baseline (RB) –

Sentinel-3 for Science – SAR Altimetry Studies
SEOM Study 3. Inland Water
Contract 4000115205/15/I-BG

Document reference : ISA_ESA_SHAPE_RB_2015_044
Issue : 1.3
Date : 2017-05-05

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Introduction to SHAPE Project

Consortium

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Prime Contractor, Management, contribs to L1BS → L2 processing, L3 processing (Water Level time series), Validation of L3

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L1A → L2 processing, Processor integration

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L2 Corrections

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Assimilation of Altimetry data in Hydrological Models (HYPE), L4 processing (River Discharge), Validation of L4

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ESRIN – Benveniste J., Restano M., Ambrózio A.

SHAPE Project Achievements

Regions of Interest

Outcome of detailed ROI assessment

(CryoSat-2 SAR/SIN & Sentinel-3A coverage, other altimetry, water masks & SAR imagery, auxiliary data for: L2 corrs & L3, Hydro. Models, in situ & fiducial data, etc.)

Rivers

Amazon (downstream)
CryoSat-2 SAR 2015-03 → 2016-02

Danube
CryoSat-2 SIN 2015-03 → 2016-02

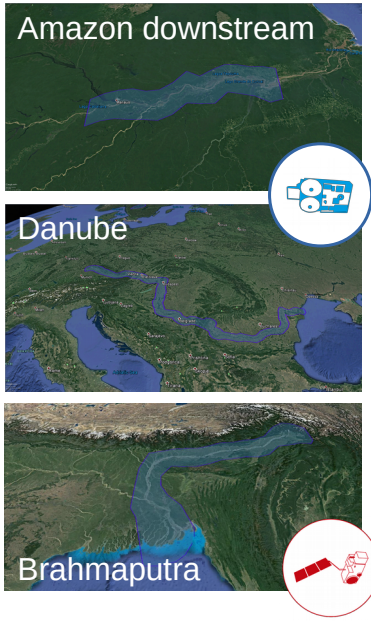
Brahmaputra
Sentinel-3A SAR 2016-06 → 2018-05

Lakes

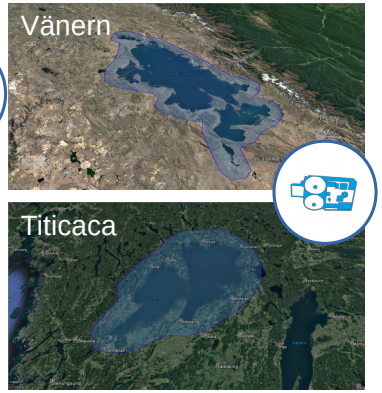
Vänern
CryoSat-2 SAR 2015-03 → 2016-02

Titicaca
CryoSat-2 SIN 2015-03 → 2016-02

Rivers



Lakes



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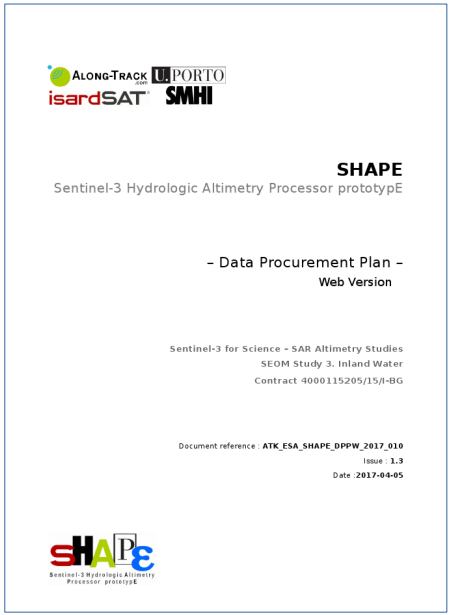
Data Procurement Plan v1.3.1

→ Available from SHAPE web site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– Data Procurement Plan –
Web Version

Sentinel-3 for Science – SAR Altimetry Studies
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Document reference : ATK_ESA_SHAPE_DPPW_2017_010
Issue : 1.3
Date :2017-04-05

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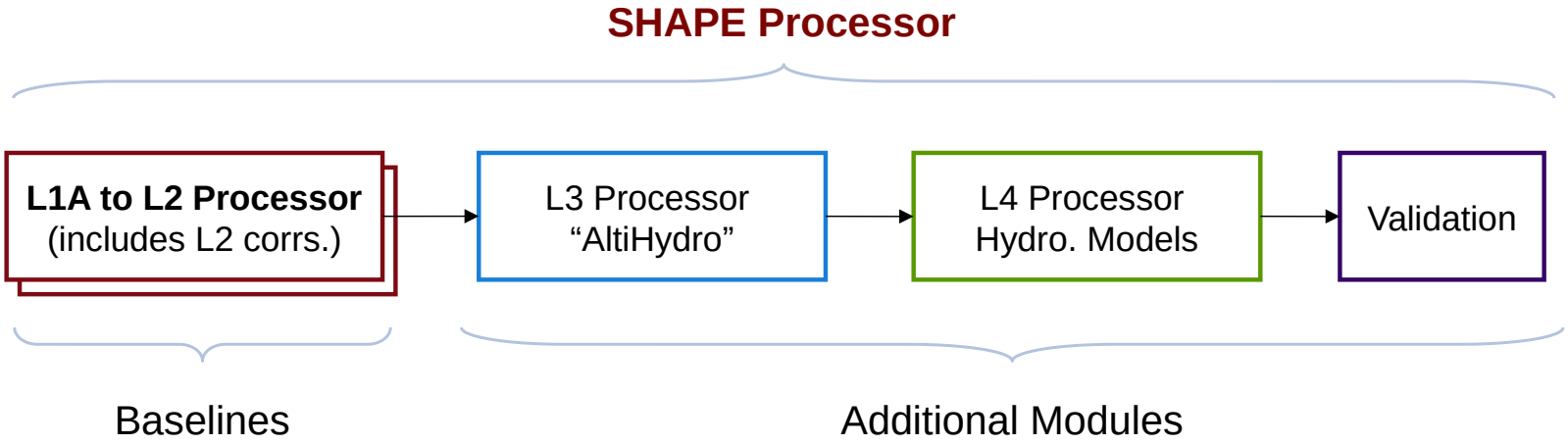
Sentinel-3 Hydrologic Altimetry Processor prototypE

SHAPE Project Achievements

SHAPE Processor : Overview



SHAPE is a configurable processor with two predefined baselines, namely:

- “s3like” : Mimic Sentinel-3 Processing baseline, 4 known retrackers
- “shape1” : Include all alternative & innovative algorithms, 2 new retrackers

SHAPE Project Achievements

SHAPE Processor

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Contribs to L1BS → L2 processing, L3 processing (Water Level time series), Validation of L3

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L1A → L2 processing, Processor integration

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L2 Corrections

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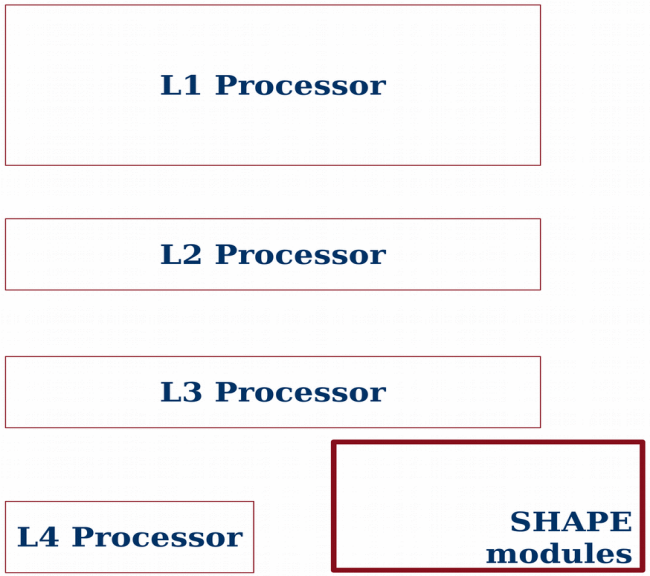
Assimilation of Altimetry data in Hydrological Models (HYPE), L4 processing (River Discharge), Validation of L4



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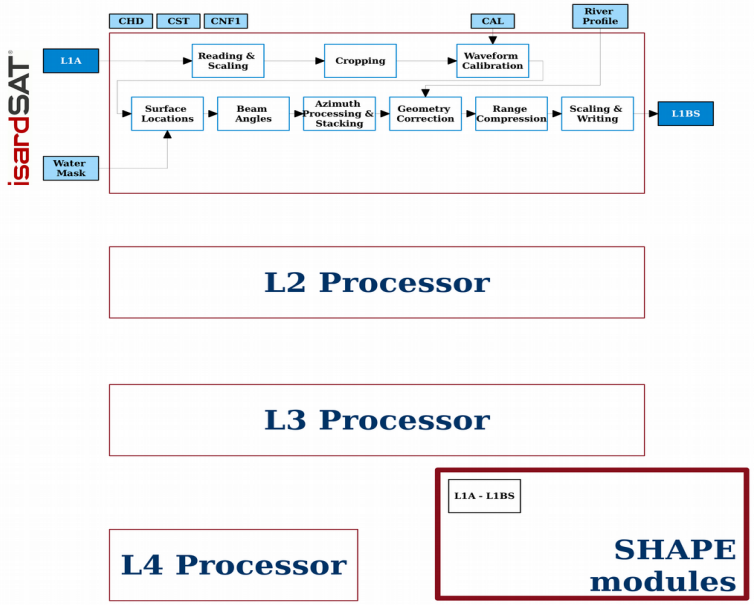

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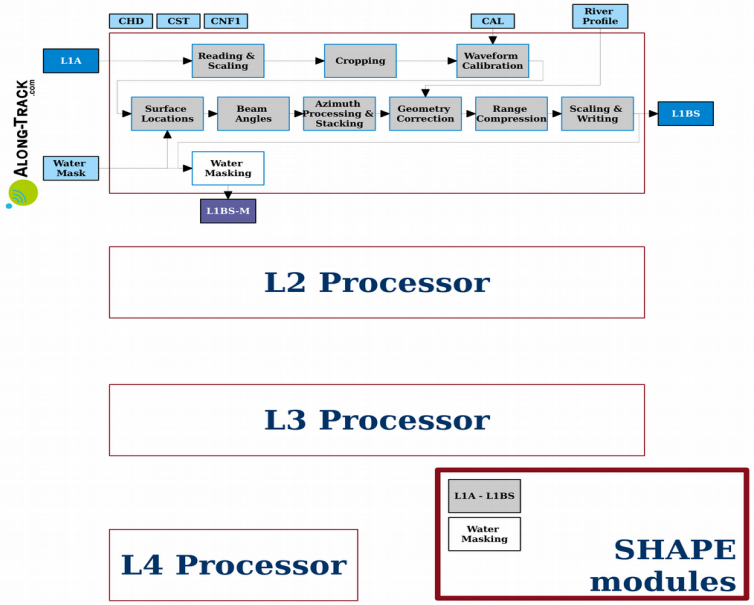

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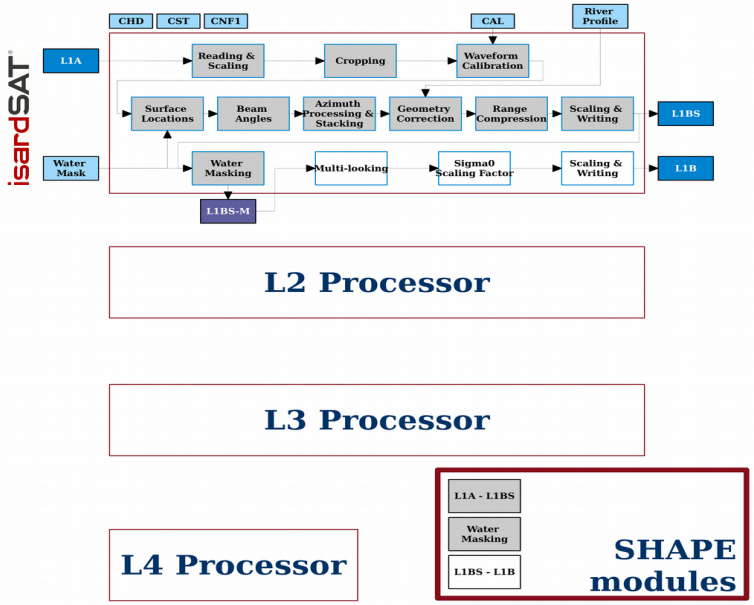

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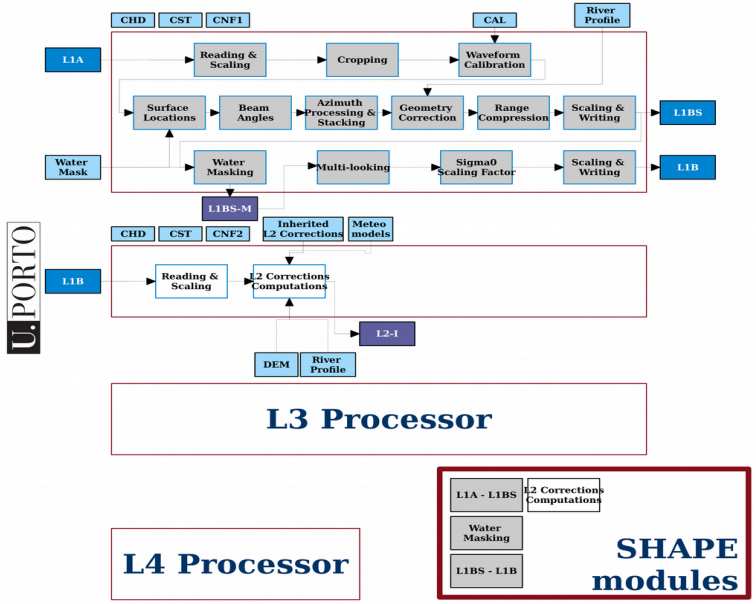

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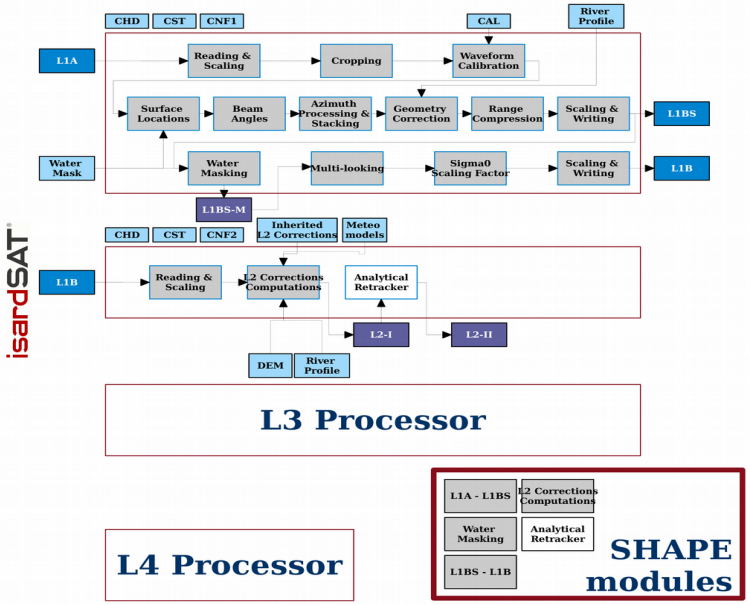

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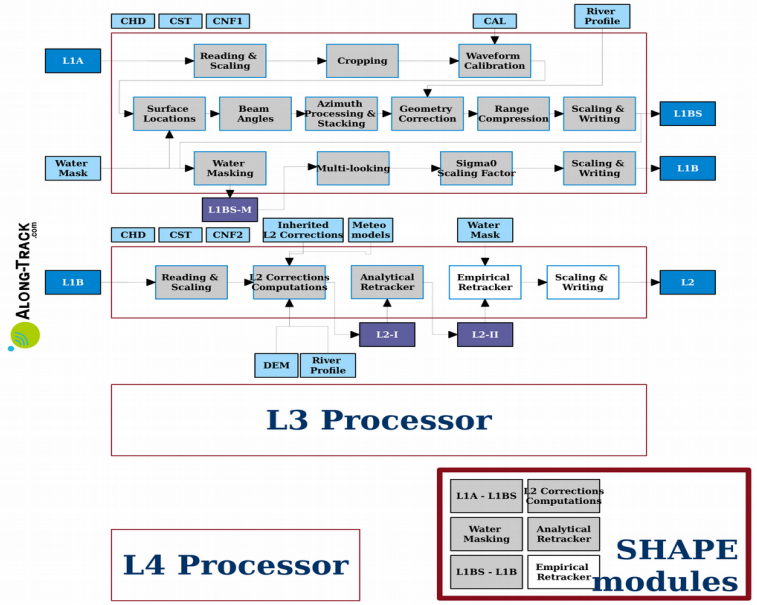

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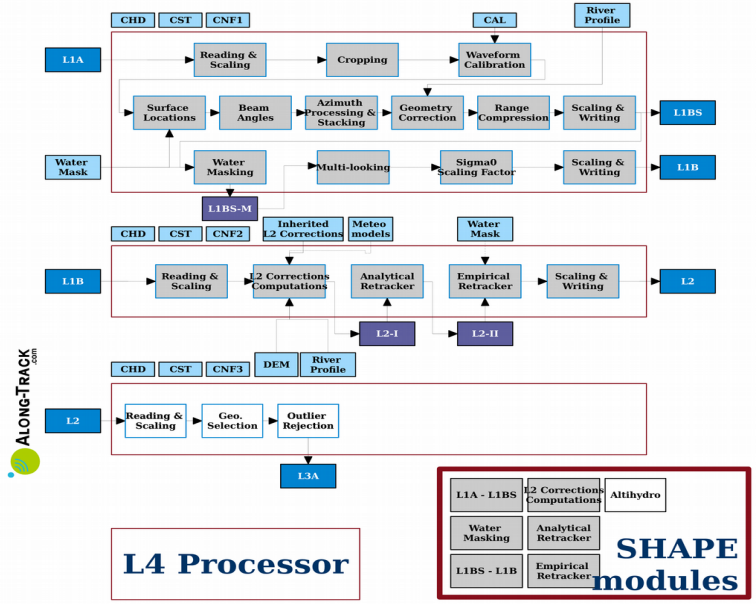

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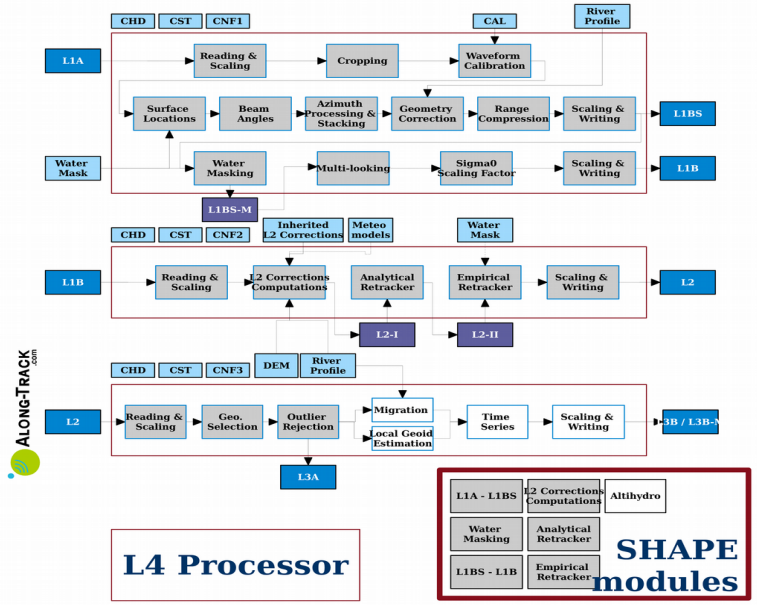

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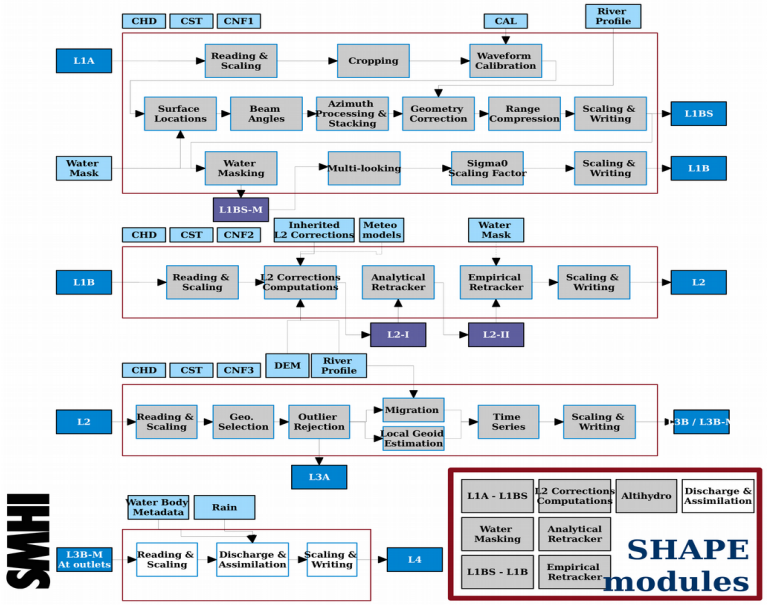

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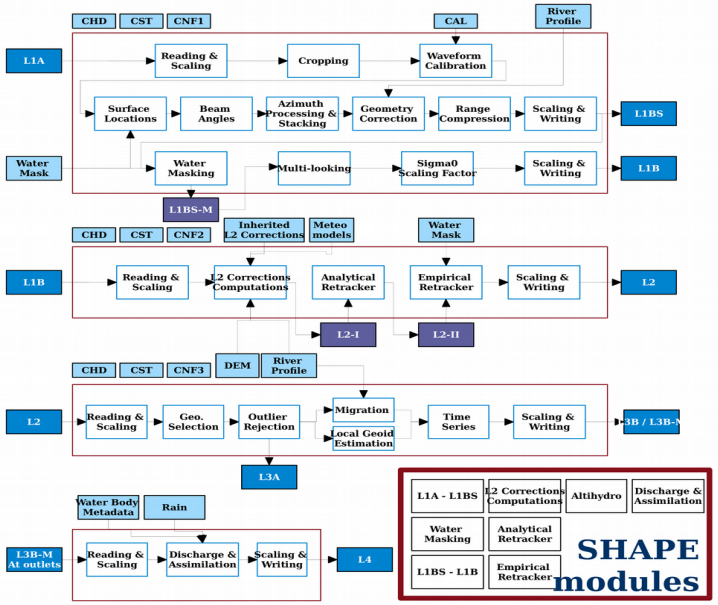

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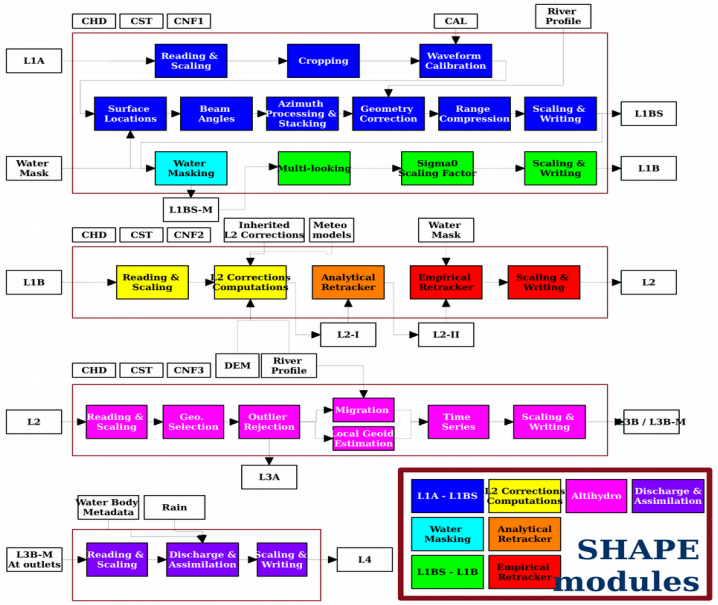

SHAPE Project Achievements

SHAPE Processor Status

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L1A → L2 processing, Processor integration

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L2 Corrections

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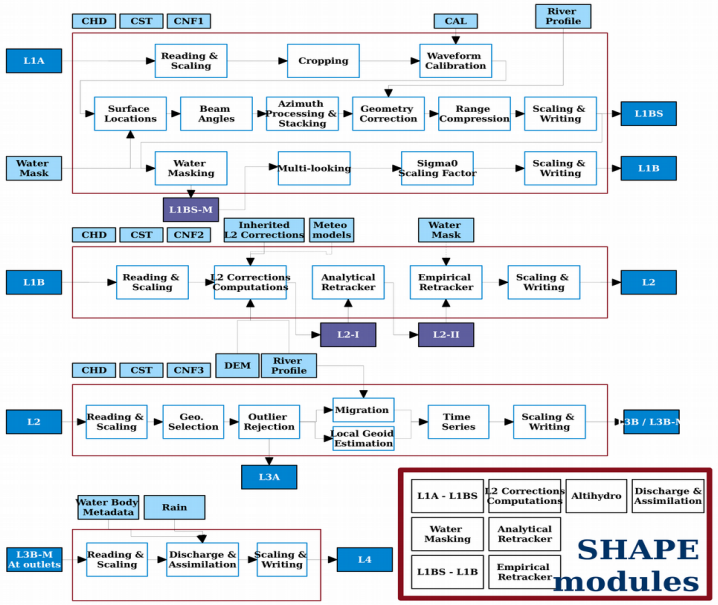
Assimilation of Altimetry data in Hydrological Models (HYPE), L4 processing (River Discharge)

Validation of L4

LEGEND: To be done – In progress – Done



SHAPE Project Achievements

Selected Algorithms – L1B 2-steps Analytical SARM Retracker

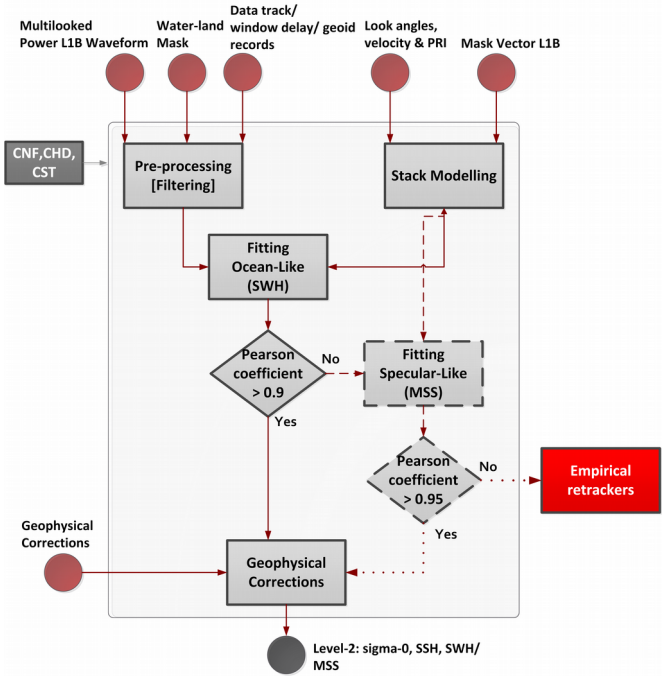
Main processing algorithms:

Pre-processing (filtering)

- Stack modeling
- Fitting procedure
- Geophysical corrections

Two-step fitting procedure

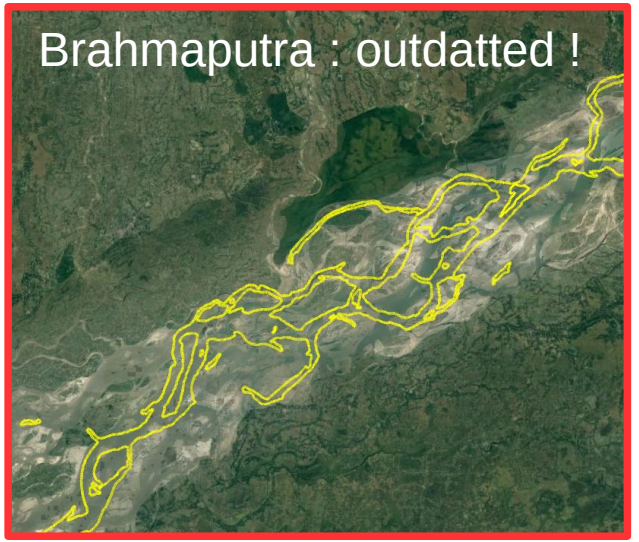
- 1st Ocean-like fitting is performed
- If correlation below a given threshold → 2nd fitting for more specular returns based on roughness parameter
- If correlation not enough an empirical retracker should be used



SHAPE Project Achievements

Selected Algorithms – L1/L3 Updated High Resolution Water Mask (WM)

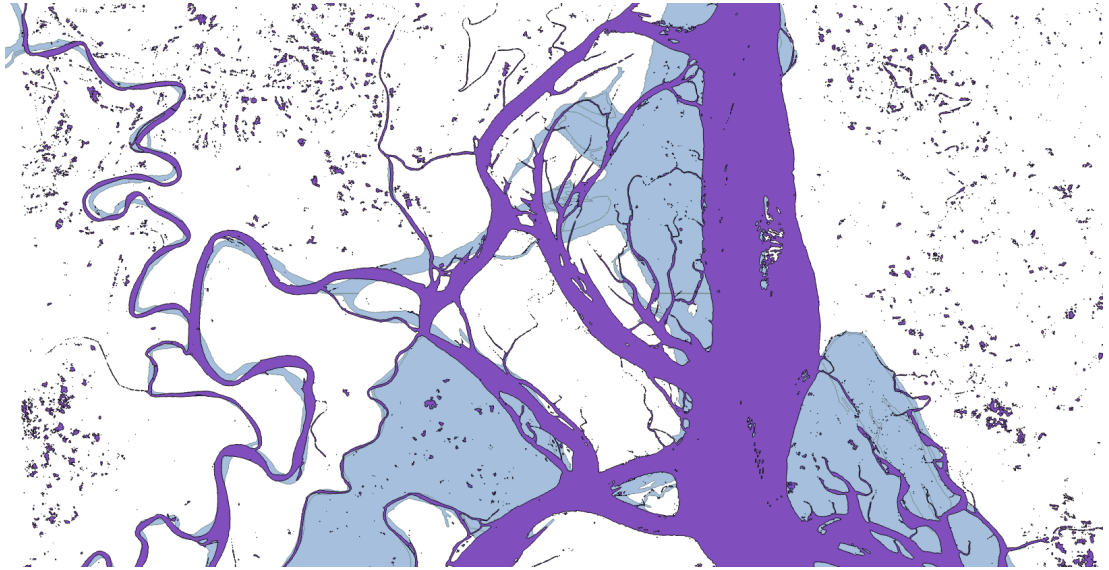
SHAPE uses SRTM/SWBD Global Water Mask, but...



SHAPE Project Achievements

Selected Algorithms – L1/L3 Updated High Resolution Water Mask (WM)

SWBD water mask (blue) and Updated Water Mask (purple)

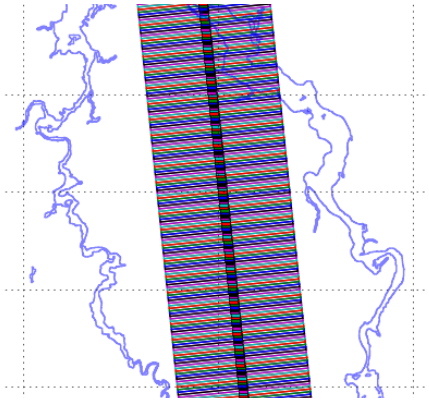


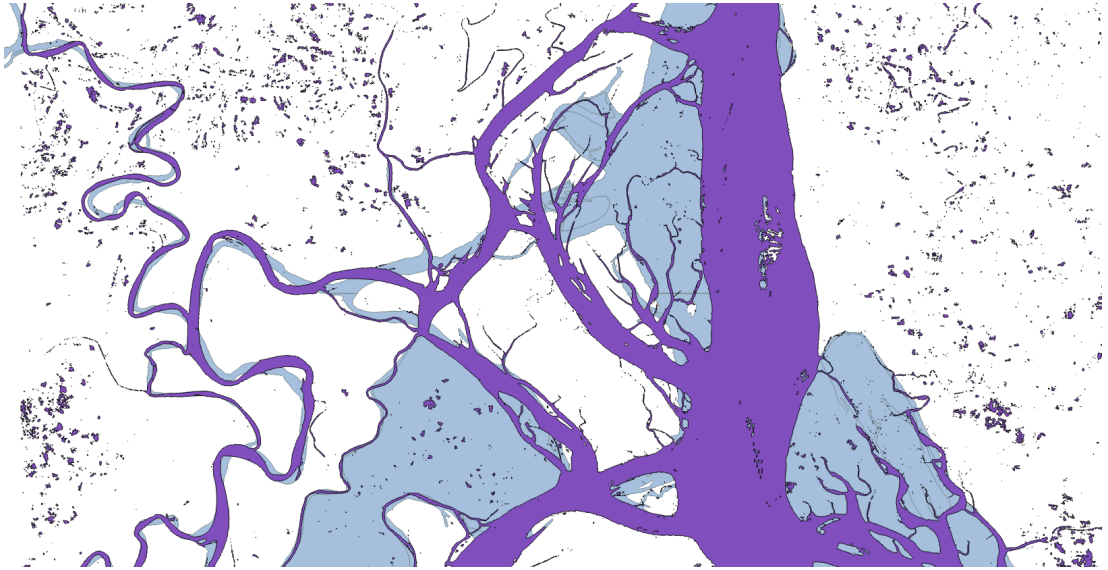
SHAPE Project Achievements

Selected Algorithms – L1/L3 Updated High Resolution Water Mask (WM)

SWBD water mask (blue) and Updated Water Mask (purple)

Application: Compute Water Content Fraction in SARM footprints!

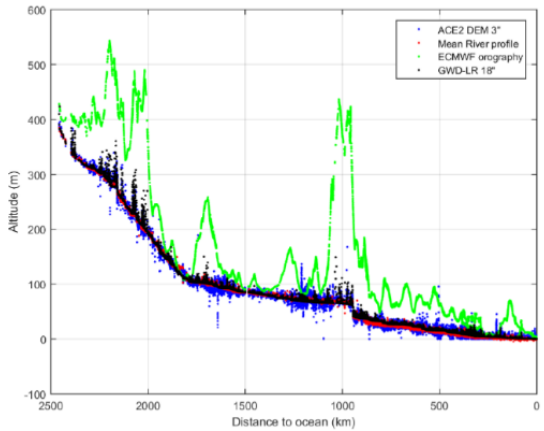




SHAPE Project Achievements

Selected Algorithms – L2 Wet/Dry Corrections

Reference Height for `Alt-Height` computation



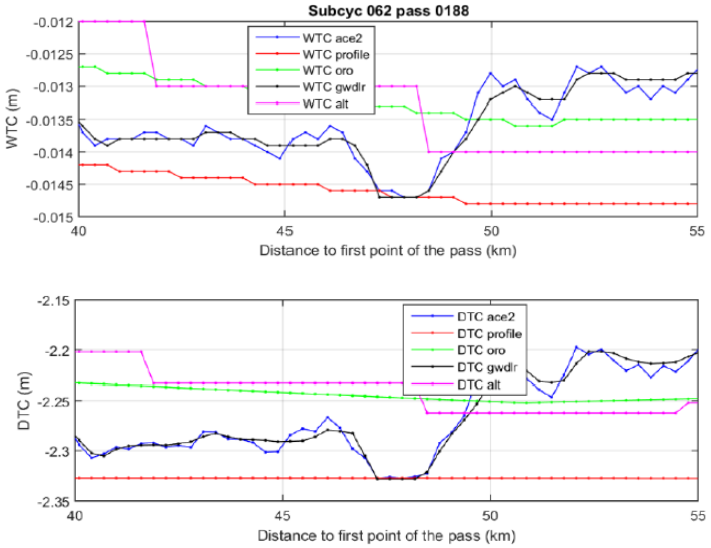
Altitudes above geoid along the Danube river mean profile – ACE2, Mean profile, ECMWF, GWD-LR

Wet

Dry

Sensibility to reference height

Mean River Profile = best reference

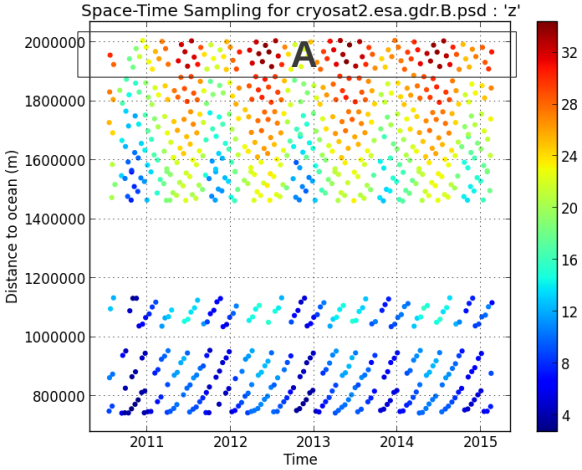


SHAPE Project Achievements

Selected Algorithms – L3 Migration of RWL meas. along River Path

Space-Time representation (Hövmoller diagram) of L3/RWL data (Amazon example)

1. Collect data in A space interval, any time

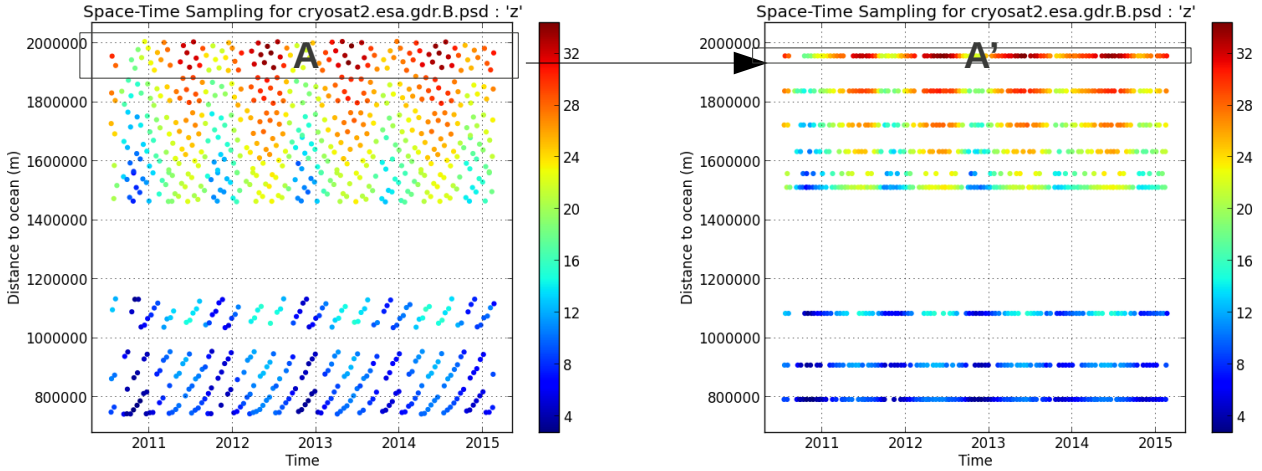


SHAPE Project Achievements

Selected Algorithms – L3 Migration of RWL meas. along River Path

Space-Time representation (Hövmoller diagram) of L3/RWL data (Amazon example)

1. Collect data in A space interval, any time
2. Remove spatial variability
   (=Mean River Profile)

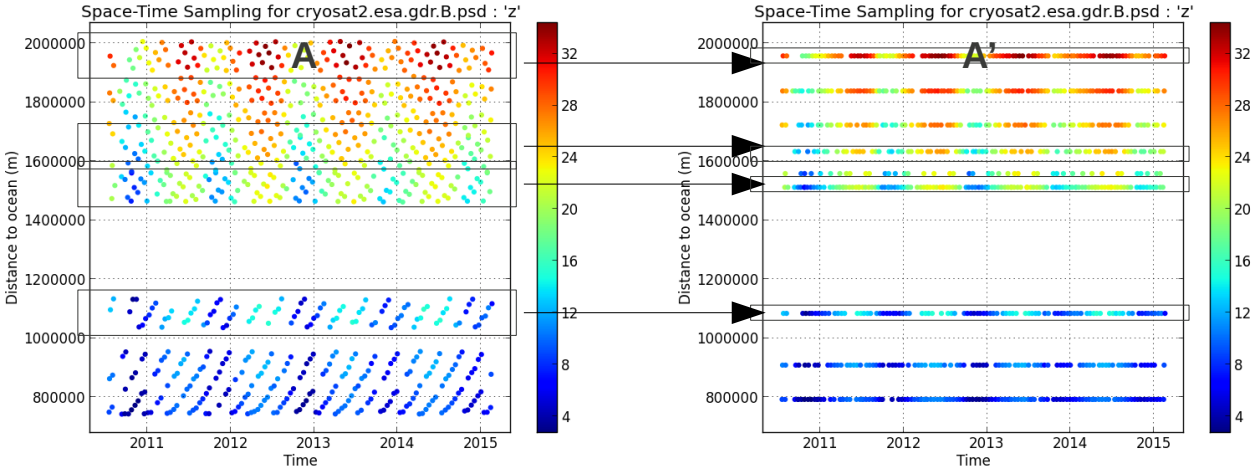


SHAPE Project Achievements

Selected Algorithms – L3 Migration of RWL meas. along River Path

Space-Time representation (Hövmoller diagram) of L3/RWL data (Amazon example)

1. Collect data in A space interval, any time
2. Remove spatial variability
   (=Mean River Profile)
3. Change coordinates



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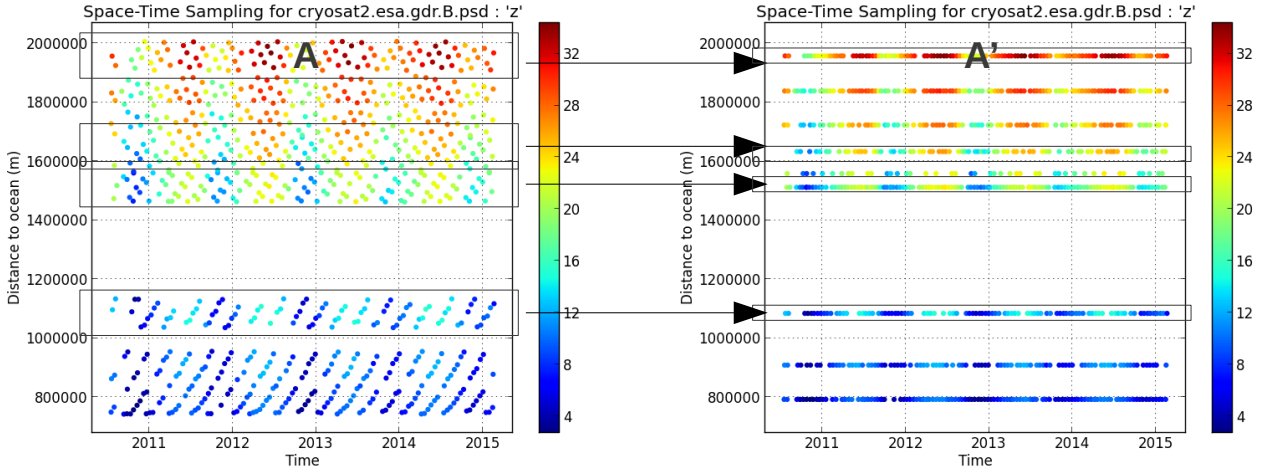
Selected Algorithms – L3 Migration of RWL meas. along River Path

Space-Time representation (Hövmoller diagram) of L3/RWL data (Amazon example)

1. Collect data in A space interval, any time
2. Remove spatial variability
   (=Mean River Profile)
3. Change coordinates

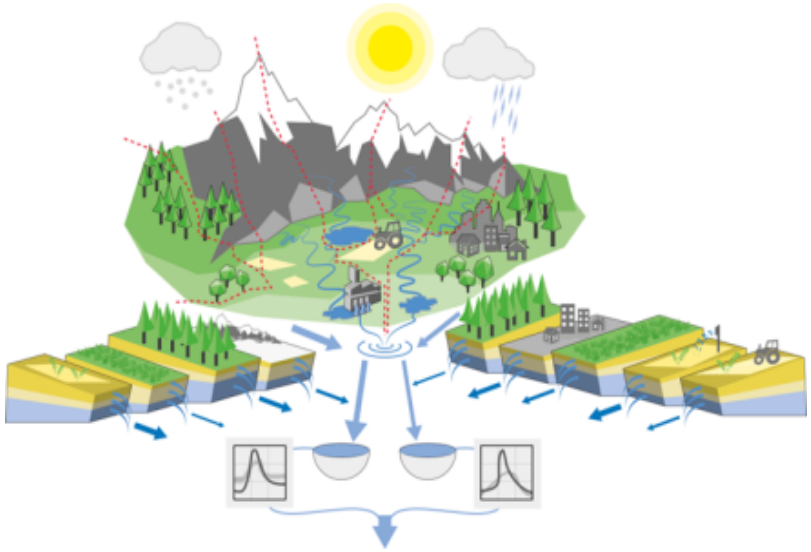
<u>Then A is migrated to A’</u>

Do the same for all other locations to be migrated



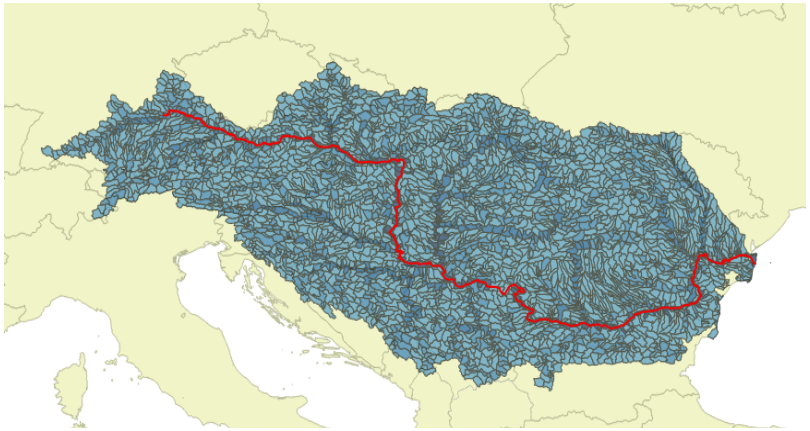
SHAPE Project Achievements

Selected Algorithms – **L4 Assimilation of L3/RWL in Hydrological Models**



HYPE – Semi-distributed catchment based hydrological model (Lindström et al, 2010)

Example of Danube river's sub basins



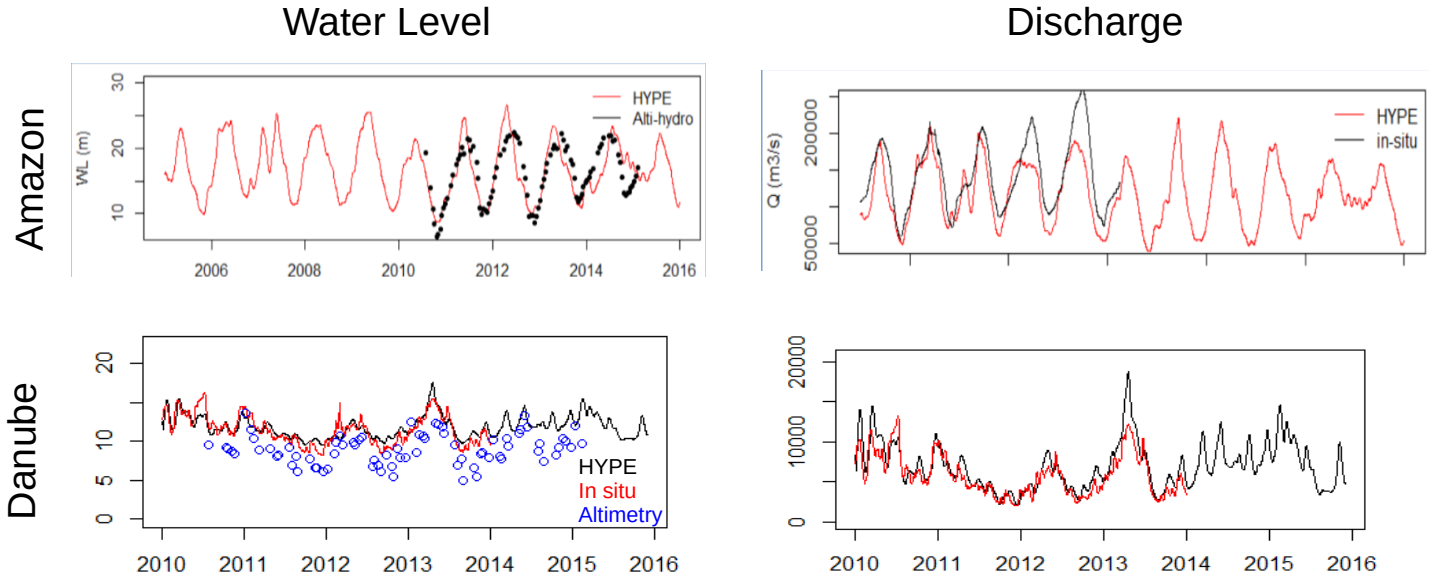
SHAPE Project Achievements

Selected Algorithms – L4 Assimilation of L3/RWL in Hydrological Models

Preliminary work: This is on-going work based on non-SHAPE L3/RWL products!

Next steps

Models Calibration,
Assimilation experiments with
SHAPE L3/RWL



SHAPE Project Achievements

SHAPE Data Products Format Definition

Products format have been defined, all in netCDF:

L1BS – Complex Stack data

L1B – Waveform data (module only)

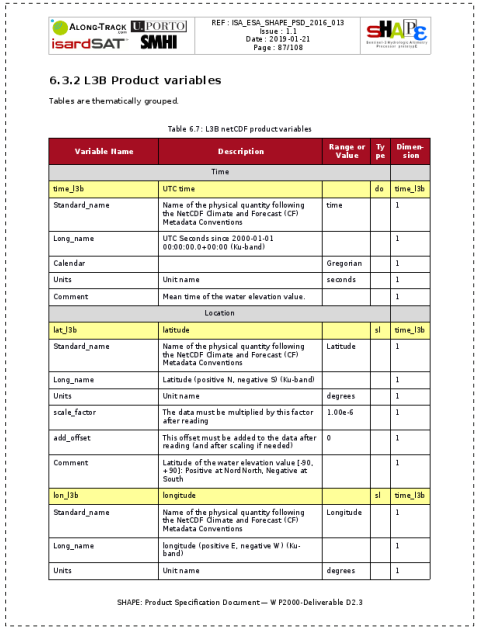
L2 – Retracked Range data & corrections

L3 – River & Lake Water Level time series

- **L3A** = L2 subset within the water mask + boolean variables resulting from outliers rejection routines → users able to run their own routines without complete L2 data
- **L3B** = Water Level time series
- **L3BM** = Migrated L3B to locations along the river path: Validation: @gauging stations | Assimilation: @model's outlets

L4 – River Discharge

Product Specification Document v1.1



ALONG-TRACK | isardSAT | U.PORTO | SMHI

REF : ISA_ESA_SHAPE_PSD_2016_013
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SHAPE

6.3.2 L3B Product variables

Tables are thematically grouped.

Table 6.7: L3B netCDF product variables

Variable Name	Description	Range or Value	Type	Dimension
Time				
time_l3b	UTC time		do	time_l3b
Standard_name	Name of the physical quantity following the NetCDF Climate and Forecast (CF) Metadata Conventions	time		1
Long_name	UTC Seconds since 2000-01-01 00:00:00.0+00:00 (ku-band)			1
Calendar		Gregorian		1
Units	Unit name	seconds		1
Comment	Mean time of the water elevation value.			1
Location				
lat_l3b	latitude		sl	time_l3b
Standard_name	Name of the physical quantity following the NetCDF Climate and Forecast (CF) Metadata Conventions	Latitude		1
Long_name	Latitude (positive N, negative S) (ku-band)			1
Units	Unit name	degrees		1
scale_factor	The data must be multiplied by this factor after reading	1.00e-6		1
add_offset	This offset must be added to the data after reading (and after scaling if needed)	0		1
Comment	Latitude of the water elevation value [-90, +90]: Positive at Nord North, Negative at South			1
lon_l3b	longitude		sl	time_l3b
Standard_name	Name of the physical quantity following the NetCDF Climate and Forecast (CF) Metadata Conventions	Longitude		1
Long_name	longitude (positive E, negative W) (ku-band)			1
Units	Unit name	degrees		1

SHAPE: Product Specification Document — WP2000-Deliverable D2.3

SHAPE Project Achievements

SHAPE Data Products Status

Products in testing versions for processor development, all from CryoSat-2/FBR for the moment:

	Amazon	Danube	Brahmaputra	Vänern	Titicaca
s3like	L1BS L1B L2 v1.05	L1BS L1B L2 v1.06	L1BS L1B v1.04	L1BS L1B L2 v1.05	L1BS L1B L2 v1.05
shape1	-	-	-	-	-

SHAPE Project Achievements

Validation & Verification of SHAPE Data Products

Validation against in situ data

IMPORTANT: Validation here is not data dispersion

Verification against fiducial data

E.g., third party Altimetry.

SHAPE Project Achievements

Validation & Verification of SHAPE Data Products

Validation against in situ data

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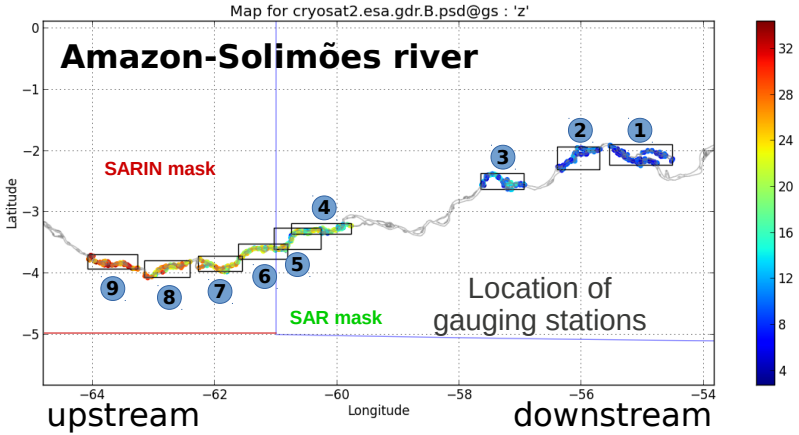
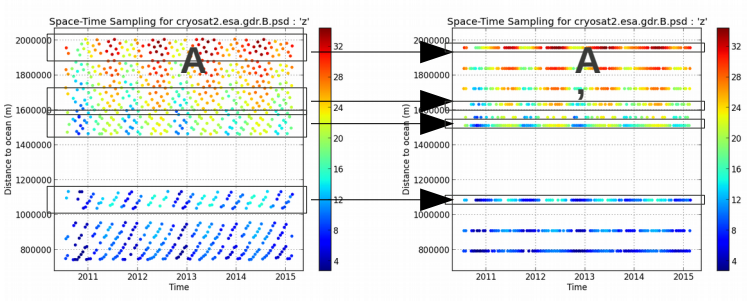
E.g., third party Altimetry.

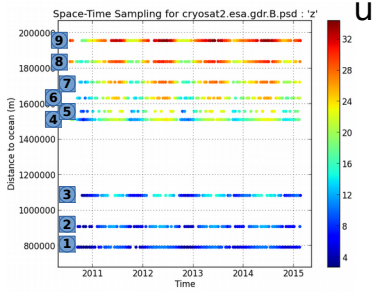
Validation example



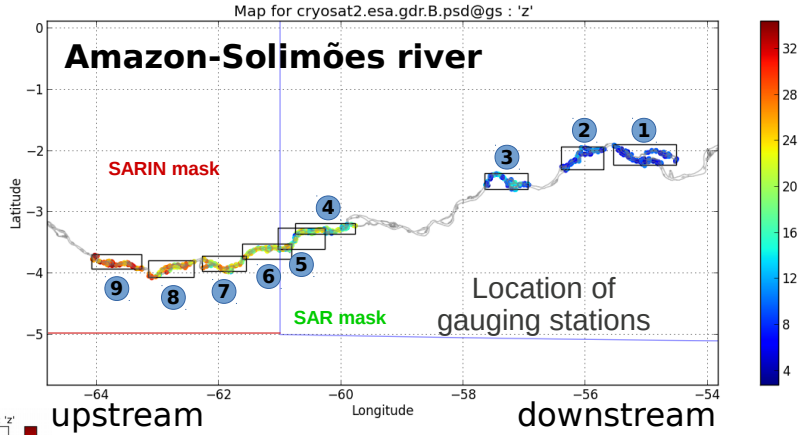
SHAPE Project Achievements

Validation & Verification of SHAPE Data Products





Validation example



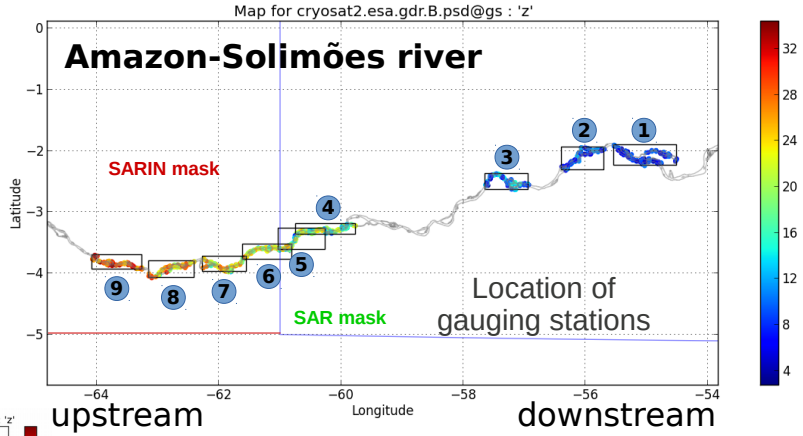
SHAPE Project Achievements

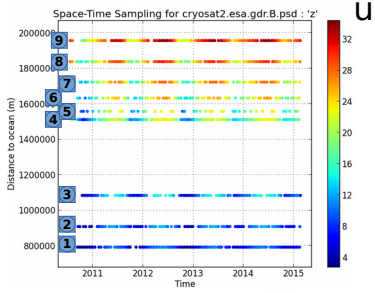
Validation & Verification of SHAPE Data Products

Period		Gauging Station	Virtual Station dist. (km)	Mode	Nb meas.	RMS (m)	Mean (m)	STD (m)	MAD (m)	Teff (days)
2012 – 2015 / 2010 – 2012	1	Santarem	793	SAR	61	0.48	0.42	0.23	0.17	13.9
				SARIN	56	0.86	0.77	0.36	0.24	13.9
	2	Obidos	909	SAR	45	1.19	1.09	0.49	0.18	17.7
				SARIN	41	1.41	1.31	0.52	0.22	19
	3	Parintins	1084	SAR	48	1.04	0.91	0.50	0.19	17.7
				SARIN	38	1.24	1.15	0.46	0.20	20.5
	4	Jatuarana	1512	SAR	53	1.49	1.38	0.57	0.24	15.8
				SARIN	57	1.71	1.59	0.63	0.24	13.7
	5	Manaus	1558	SAR	34	2.06	1.98	0.57	0.18	17.9
				SARIN	49	2.27	2.20	0.55	0.25	24.6
	6	Manacapuru	1633	SAR	13	1.51	1.37	0.63	0.11	63.2
				SARIN	89	2.07	1.97	0.61	0.18	18
2010 – 2015	7	Anama	1723	SARIN	84	2.23	2.19	0.44	0.25	19.6
	8	Codajas	1838	SARIN	50	2.09	2.06	0.34	0.14	32.5
	9	Itapeua	1957	SARIN	103	2.44	2.42	0.36	0.21	15.9

Table of Quality Indicators

Validation example





Project Planning

Past events

2015-09 Kick-off (KO)

2016-02 Scientific Review & Requirements (SR)

2016-06 Progress Meeting 1 (PM1)

2016-12 Progress Meeting 2 (PM2)

2017-05 Mid Term Review (MTR)

2017-12 Progress Meeting 3 (PM3)

2018-12 Mid Term Review Closure (MTR-2)

Events for 2019

Progress Meeting 4 (PM4)

Acceptance Review (AR)

Final Review (FR)

+ Dissemination Activities

+ Project Brochure

Conclusion & Perspectives

SHAPE Highlights

SHAPE is an ESA(*) Project!

(*) "Extremely Super Ambitious", you didn't know? ;-)

L1A inputs for CryoSat-2 or Sentinel-3A missions

SHAPE Processor : from L1A to L2-L3-L4, configurable, two predefined baselines

Two new retrackers: Physical & Empirical

State of the Art L2 corrections : Wet/Dry tropo + EIGEN6C4 Geoid

L3 Processor : mimics repeat orbit from geodesic CryoSat-2 orbit

Data assimilation in Hydrological HYPE models → L4/RWD

Validation against in situ data / Verification against fiducial data

Conclusion & Perspectives

On-going tasks

Final Prototype Processor Integration

Completion of L3/RWL products

Completion of L4/RWD products

Remaining tasks

Validation of L3 & L4 data

Roadmap

Data Dissemination & Outreach items (project brochure)

Project Closure by 2019

Consortium: Great team to work with!!!

Thank you!

NEWS

Release of the Requirements Baseline (RB) document
2017/05/05
Release of the Data Procurement Plan (Web Version) document
2017/05/04
Release of the Work Breakdown Structure (WBS) document
2016/12/14
GGHS 2016 SHAPE Poster available online!
2016/09/19
SHAPE project at GGHS 2016
2016/09/19

OUTLINE

The SHAPE project is funded by ESA through the Scientific Exploitation of Operational Missions (SEOM) Programme Element to prepare for the exploitation of Sentinel-3 data over the inland water domain (water heights and discharge).

OBJECTIVES

- Characterise CryoSat-2 SAR data over inland water.
- Assess the performances, in Hydrology, of applying the Sentinel-3 IPF to CryoSat-2 data and emulating repeat-orbit Alti-Hydro Products (AHP).
- Analyse weaknesses of the Sentinel-3 IPF at all levels.
- Assess the benefits of assimilating the SAR/RDSAR derived AHP into hydrological models.
- Design innovative techniques to build and refine the L1B-S and assess their impact onto L1B and AHP.
- Improve SAR/RDSAR retracking over river and lakes.
- Provide improved L2 Correction (troposhpheric, geoid) for Sentinel-3 over land and inland water.
- Specify, prototype, test and validate the Sentinel-3 Innovative SAR Processing Chain for Inland Water.

REGIONS OF INTEREST

The project seletected five regions of interest to develop and to test the SHAPE prototype:

- The Amazon river (downstream from Manaus to mouth)
- The Danube River
- The Brahmaputra river
- The Vänern lake
- The Titicaca lake

Please refer to the Data Procurement Plan "Web Version" (DPPW) document available for download from the Documents page.

https://projects.along-track.com/shape/

Abstract

Abstract

The SHAPE project is part of SEOM, Scientific Exploitation of Operational Missions, an ESA program element which aims at expanding the international research community, strengthening the leadership of the European EO research community and addressing new scientific researches.

This Research and Development intends to make the best use of SAR (delay-Doppler) altimetry data for applications in hydrology. The study focuses on three main variables of interest: river water level (RWL), river discharge (RWD) and lake water level (LWL), RWD and LWL being part of the Terrestrial Essential Climate Variables (TECV) defined by GCOS.

The project embraces data processing from L1A altimetry products up to L2 (geophysical products), L3 (water level time series) and L4 (River discharge). It started with CryoSat-2 data (before the launch of Sentinel-3A) and is integrating Sentinel-3A as another input for the SHAPE processor.

The project has developed its own modular and configurable altimetric processor comprising a delay-Doppler processor (from L1A to L1b), a L2 processor including state-of-the-art geophysical corrections and new SARM retrackers. On top of this, the SHAPE project also implements its own L3 processor (from L2 to RWL and LWL) and L4 processors (from RWL to RWD) and a validation and verification framework. With the confidence brought by the validation and verification steps, the project implements hydrological dynamic and semi-distributed models of river catchments able to assimilate RWL measurements in order to estimate RWD.

The high level of configuration of the processor allows to work in parallel on two different baselines. The first one is dedicated to mimic as much as possible the real Sentinel-3 baseline and the second a baseline optimised for hydrology, at all processing levels.

The project focuses on 3 rivers (Amazon, Danube and Brahmaputra) and 2 lakes (Vänern and Titicaca). Sentinel-3A L1A data is considered to be used on the Brahmaputra river while CryoSat-2 L1A data is used on the other water bodies.

In this communication, we report both on the achievements made by the project as well as providing results, we also report about its status and planning.