Assimilation of satellite altimetry data in hydrological models for improved inland surface water information: Case studies from the "Sentinel-3 Hydrologic Altimetry Processor prototypE" project (SHAPE)

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SHAPE Project

The aim of this study is to give an introduction of the Sentinel-3 Hydrologic Altimetry Processor prototypE (SHAPE) project, with special focus on the components dealing with assimilation of satellite altimetry data in hydrological models. Preliminary results are presented from a case study on the Amazon River.

Outline

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

Objectives

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

Timeline

Kick-off (2015-09), Scientific&Req. Review (2016-02), Mid-Term Review (2016-12), Acceptance Review (2017-06), Final Review (2017-09).

Team

Along-Track : Prime, Alti-Hydro, Innovative Signal Proc., Production and use of Updated Water Masks, Retracking.

isardSAT : Innovative SAR Altimetry Chain, Retracking.

SMHI : Assimilation of AHP in Hydrological Models

University of Porto : Atmospheric and Geoid Corrections.

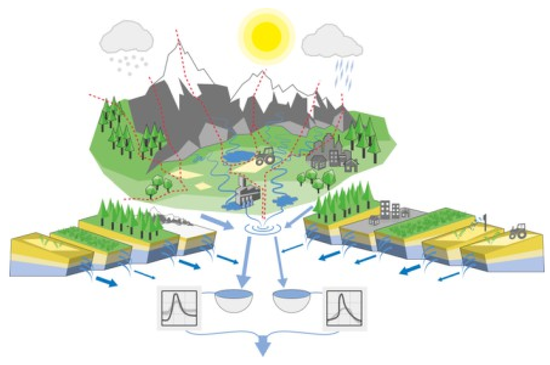
Regions and Periods of Interest

- Amazon: 2015-03→2016-02, Baseline C.
- Danube: 2015-03 → 2016-02, Baseline C.
- Brahmaputra: 2014-10 → 2015-09, Baseline C.
- Vänern lake: 2015-03 → 2016-02, Baseline C.
- Titicaca lake: 2015-03 → 2016-02, Baseline C.

Project Website

Documents & demo to be available
http://projects.along-track.com/shape/

Hydrological model and Alti-hydro data assimilation

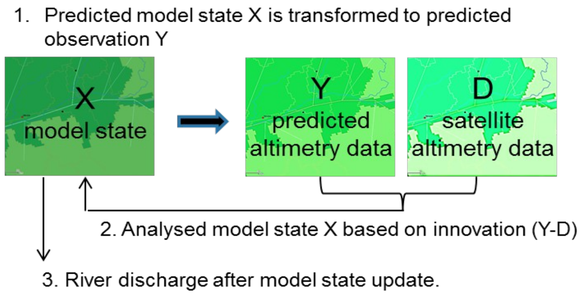


Visit http://hypeweb.smhi.se for more details.

The HYPE Model

The HYdrological Predictions for the Environment model (HYPE) is developed and used for research and operational purposes by SMHI:

- **A semi-distributed multi-basin** hydrological model, simulating water balance and ruoff from land, lakes, and rivers.
- **Runoff** (mm/day) from land/soil sub-classes is **Routed** through the lake and river network as defined by the sub-basin delineation and links:
  - **Lake water level** (m) is *directly* related to **lake outflow** (m^3/s) by water level-discharge relationships (rating curves).
  - **River discharge** (m^3/s) is based on **River stage** (m^3), and velocity dependent delay and damping of inflow – and is is only *in-directly* related to **River water level** (m) through a non-linear inflow-velocity response-function and river width.



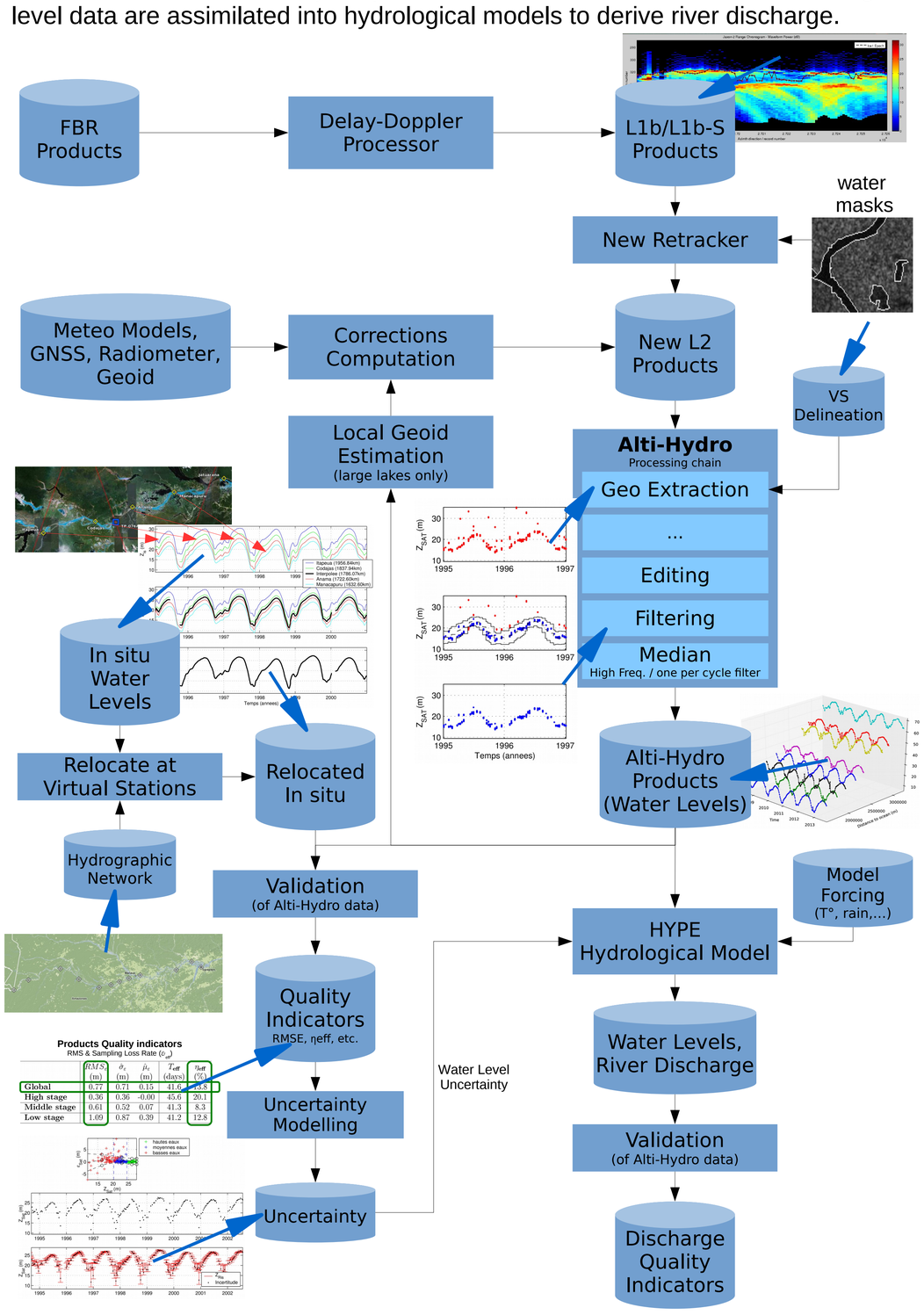
Assimilation of Altimetry data

Assimilation into hydrological models provides a way of utilizing the full potential of the satellite altimetry data for transformation into lakes and rivers discharge, avoiding the need for co-located in-situ data and rating curve establishment and frequent revisits at fixed locations:

- Altimetry data is assimilated into HYPE to correct the simulated water level and provide updated discharge calculations.
- Ensemble Kalman filters and/or Particle filters will be used as data assimilation techniques.
- Migration of the Altimetry water levels along the river, from the crossing of the satellite track to the sub-basin outlets of the hydrological model (or vice versa as an 'observation operator') is the most crucial step to bridge the gap between model and satellite data.

SHAPE Processor Overview

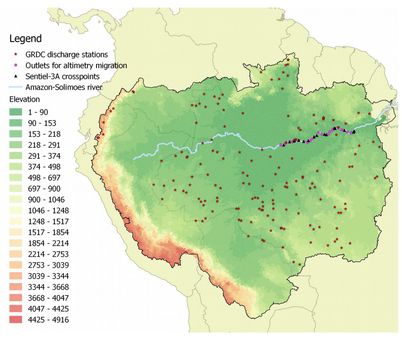
The SHAPE Processor implements all of the steps necessary to derive rivers and lakes water levels and discharge from Delay-Doppler Altimetry and perform their validation against in situ data. The processor uses FBR CryoSat-2 data as input (and will switch to Sentinel-3A data whenever possible) and various ancillary data (proc. param., water masks, L2 corrections, etc.), to produce surface water levels. At a later stage, water level data are assimilated into hydrological models to derive river discharge.

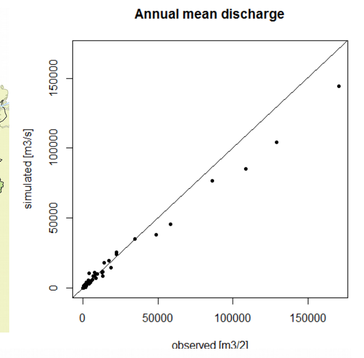


Amazon River Case Study

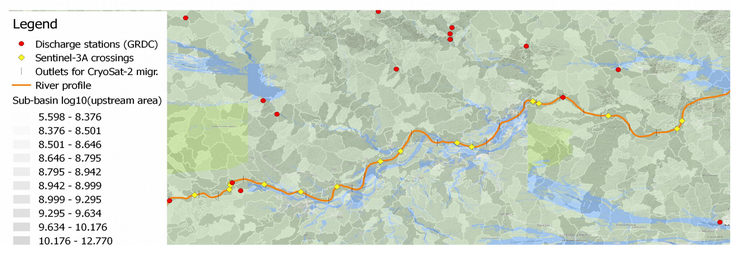
Amazon-HYPE model application

A HYPE model application was developed for the 5.9 Million km^2 Amazon River basin including ~11000 sub-basins with an average size of 530 km^2. The model is based on open data sets for hydrography (USGS HydroSHEDS), land cover (ESA CCI), soil (HWSD), lakes (GLWD), river width (GWD-LR) and discharge (GRDC).



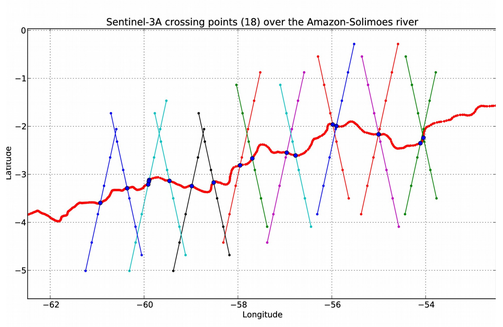


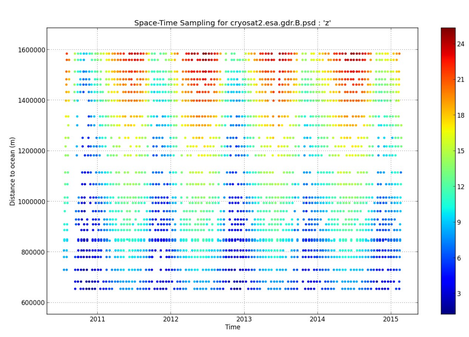
The river routing was especially adopted for the case study area covering about 1000 km of the lower Amazon-Solimoes river using the same river profile as used for the Alti-hydro data processing.



Alti-Hydro Processing

To mimic the use of Sentinel-3A data, CryoSat-2 water level measurements 2010-2015 where first migrated along the river path to Sentinel-3A tracks crossing, and secondly migrated to the selected Amazon-HYPE sub-basin river outlets.



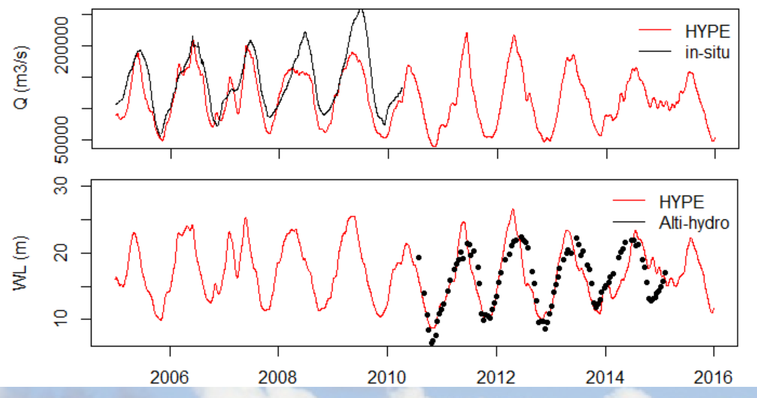


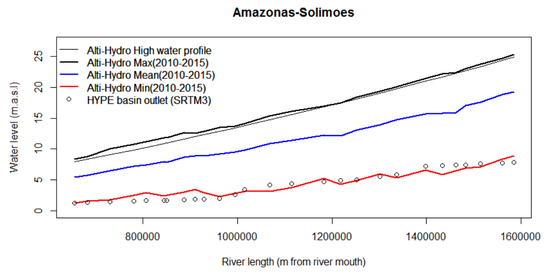
Space-Time migrated Alti-hydro data, that can be used for:

1) model calibration/evaluation
2) assimilation for improved modelled discharge, or
3) direct discharge estimation (empirical rating curves or hydraulic modelling).

Model results and evaluation

The assimilation of Alit-hydro water levels is dependent on a correct relation between River discharge (m3/s) and Water level (m) in the model. This relation was much improved by estimating the river area at low flow and high flow situations by projecting the minimum and maximum levels in the Alti-hydro data time series on the underlying DEM data:





The overall water balance and river velocity response was roughly calibrated with discharge data in upstream areas.

Systematic deviations from observations of discharge (in situ) and water level (Alti-hydro) is still seen in the lower Amazon, most likely due to missing floodplain dynamics and overestimated river velocity.

The improvement of further model development versus assimilation of the altimetry data will be evaluated in the next phase of the project.

This project is funded by ESA