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

The aim of this study is to give an introduction of the Sentinel-3 Hydrological 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.

SHAPE Project

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 simulating repeat with Alti-Hydro Products (AHP).
- Analyze weaknesses of Sentinel-3 IPF at all levels.
- Assess the benefits of assimilating SARR/SAR derived AHP into hydrological models.
- Design innovative techniques to build and to refine the LIB-S and assess their impact onto LIB and AHP.
- Improve SARR/SAR retracking over river and lakes.
- Provide improved L2 Corrections (topographic, 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


Team

- ALONG-TRACK: Prime, Alti-Hydro, Innovative Signal Proc, Production and use of Updated Water Masks, Retracking. \(\text{SHAPE} \rightarrow \text{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.
- Titicaca lake: 2015-03 → 2016-02, Baseline C.
- Vänern lake: 2015-03 → 2016-02, Baseline C.
- Amazon: 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

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 Hydro1K), 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.

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 runoff 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), and velocity dependent delay and damping of inflows – and is only in-directly related to River water level (m) through a non-linear inflow-velocity response-function and river width.

Assimilation of Alti-Hydro 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.

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.

Model results and evaluation

The assimilation of Alti-hydro water levels is dependent on a correct relation between River discharge (m$^3$/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.