The production of HR Water Masks with Sentinel-1, their verification with Sentinel-2 images and their use in Sentinel-3 Alti-Hydrology

SHAPE — Sentinel-3 Hydrologic Altimetry Processor prototypE

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The need of HR Water Masks in Alti-Hydrology

The ESA/SEOM funded SHAPE project deals with the design, the implementation and the testing of a processor prototype dedicated to the exploitation of Sentinel-3 (S3) altimetry data over the inland water domain.

The design of a precise and accurate **altimetry processor for hydrology** faces various **challenges** among which the **scene variability from pass to pass**. Indeed the water bodies contours and extents do strongly evolve under extreme events (droughts and floods) and/or seasonal effects. This together with orbital considerations do affect the location water (a strong reflector) within the altimeter footprints. In some cases the radar echoes strongly depart from their expected models at the retracking stage. This induces outliers and sample losses in the water height time series.

In the SHAPE project these pathological cases are being studied carefully in conjunction with Sentinel-1 (S1) derived High Resolution (HR) water masks. Indeed the concomitant S1 and S3 missions with a quasi systematic acquisition plan make it relatively easy to find closely-dated pairs.

Beyond this, HR water masks are also of great help at several stages of the SHAPE processing chain :

- to identify river / lake crossings : **vector water mask needed**,
- to better reject the potentially noisy signals (low water fraction in the instrument footprint),
- to append a water fraction field (**) to Sentinel-3 SRAL L2 products : **raster water mask needed**.

(*) S1 images offer night, day and all weather coverage at High Resolution and Wide Swath, permitting frequent updates of water masks .

(**) The need for a water fraction field was identified by the alti-hydrology community at the S34Science Workshop in Venice in 2015 and has been confirmed in the course of the SHAPE project.

Experiment Description

- Synergistic use of S2 and S1 data for water mapping with Machine Learning classifiers. The objective is to identify a method to produce and validate a large water masks data base and use them with S3 altimetry in hydrology.

- S2 L1C spectral bands are used for both the training of the classifier and the water masks quality control. Robustness, Accuracy and Computational Efficiency are seeked.

Machine Learning (Random Forest) Classification [R-1] and [R-2] of :

- Sentinel-1 IW-GRD-HR products : wide swath, 20m x 22m res. (rg x az).
- Two polarizations (VH and VV) tested independently and jointly.

Training Data Set (TDS) based on Sentinel-2 images (max 5% cloud)

- (S1,S2) co-located and closely dated pair (time delta : 19h).
- TDS / VDS selected on RGB image based on human expertise.
- good training dataset : S2 image <5% cloud cover.
- RGB image build from bands of water indexes (NDWI,MNDWI): B11, B8, B3.

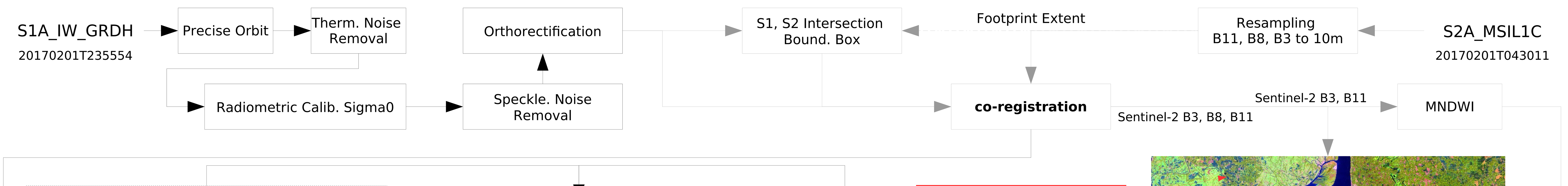
Validation Data Set (VDS) based on Sentinel-2 derived MNDWI mask

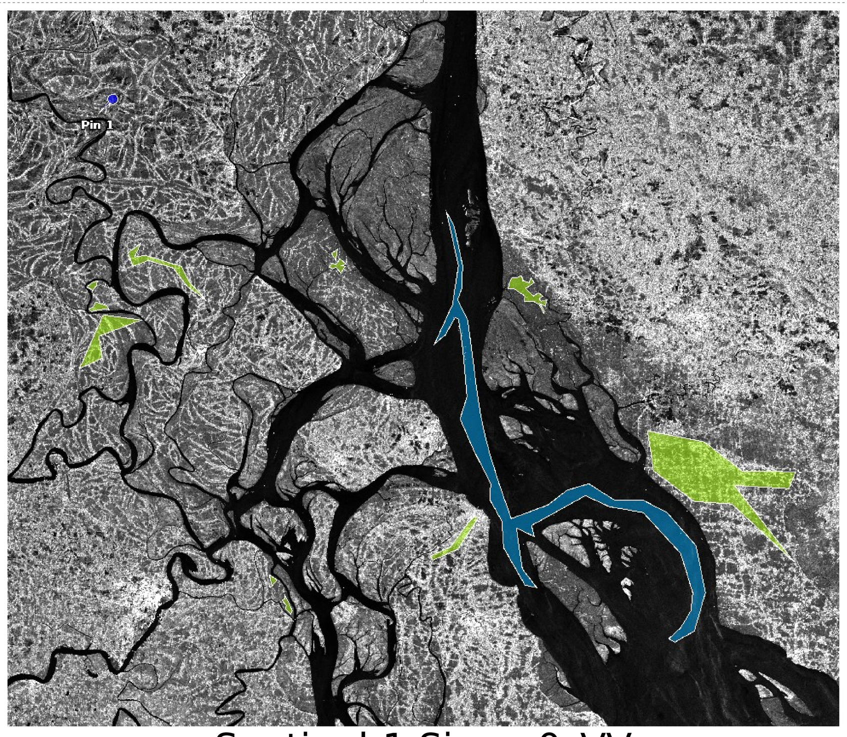
- MNDWI (Modified Normalized Difference Water Index) image computed as per [R-3] :

(B3 - B11_10m) / (B3 + B11_10m)

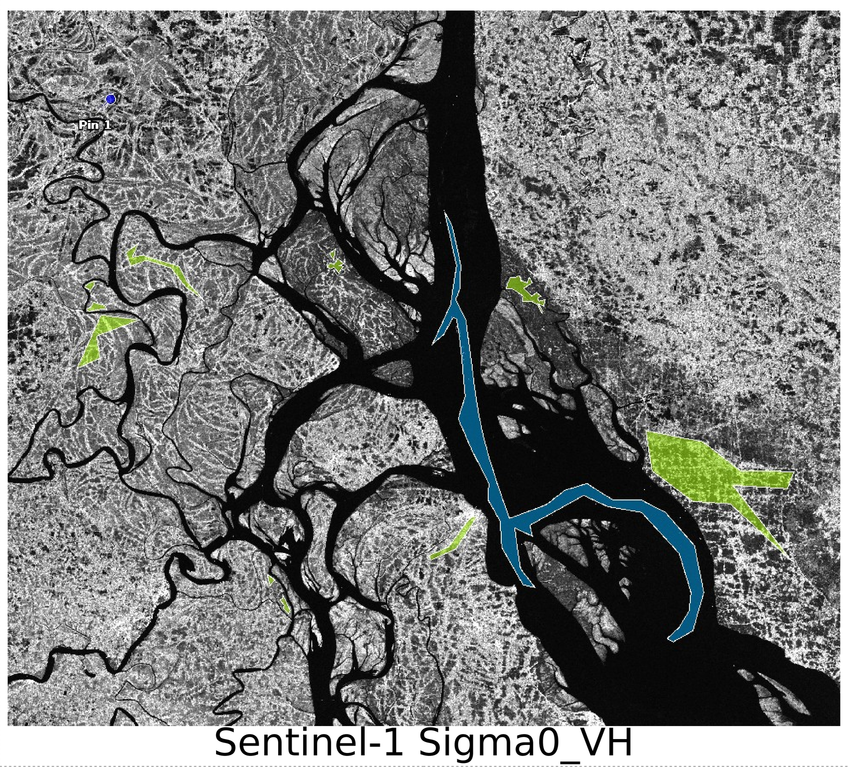
Test area : Ganges-Brahmaputra delta

Water Extraction & Validation Method

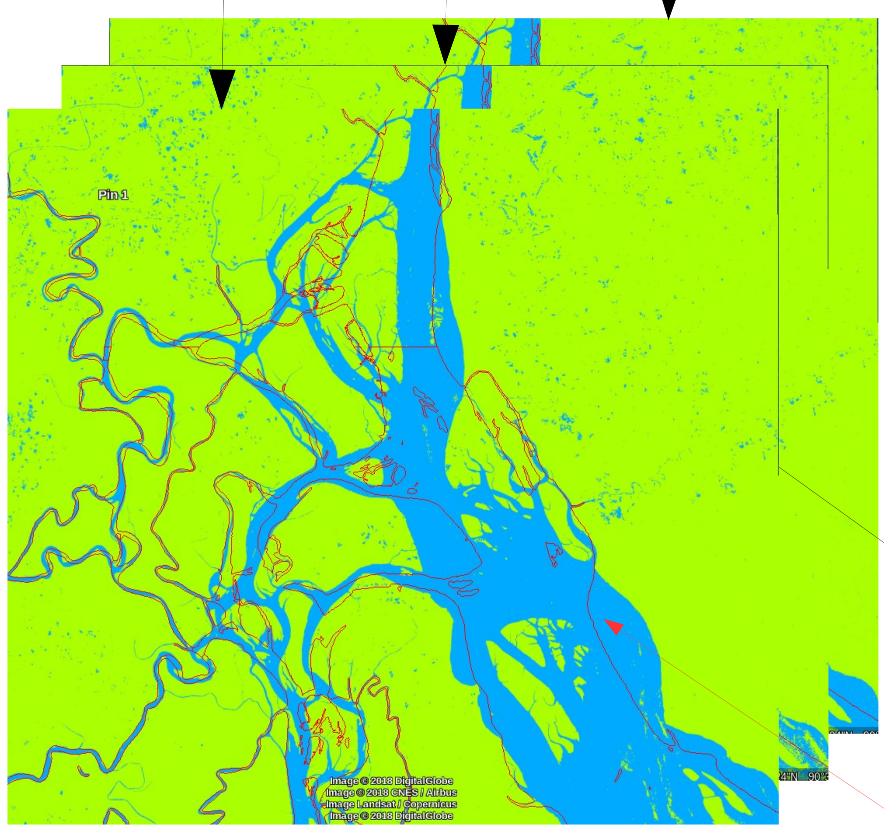




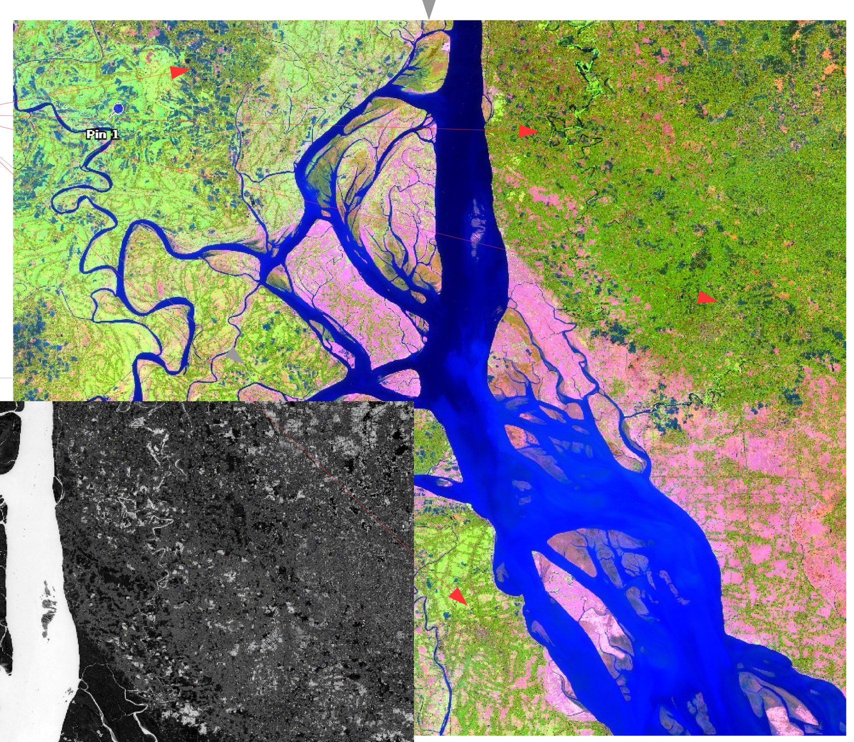
Sentinel-1 Sigma0_VV



Sentinel-1 Sigma0_VH

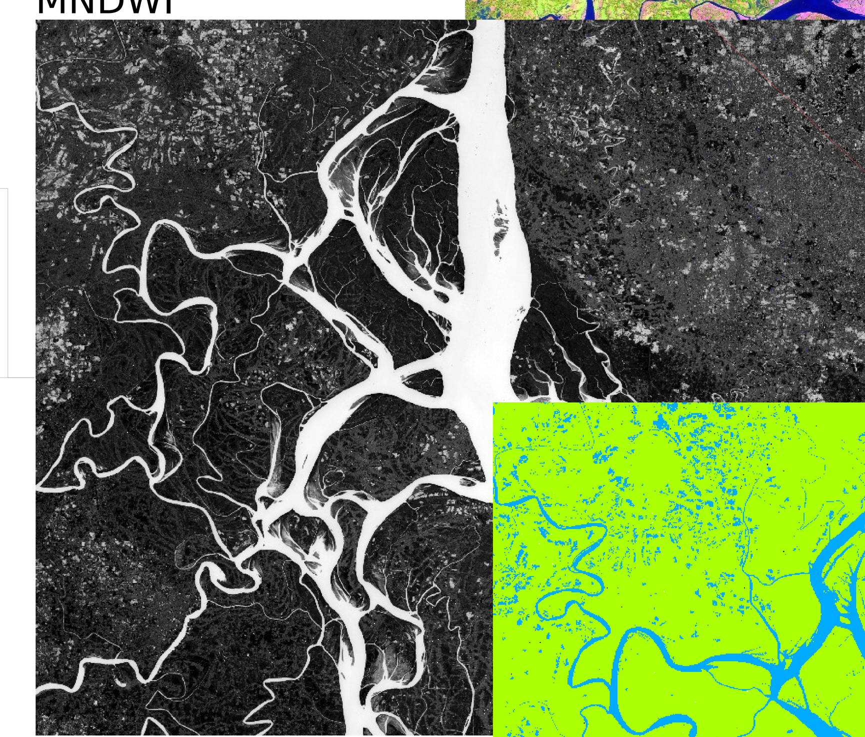


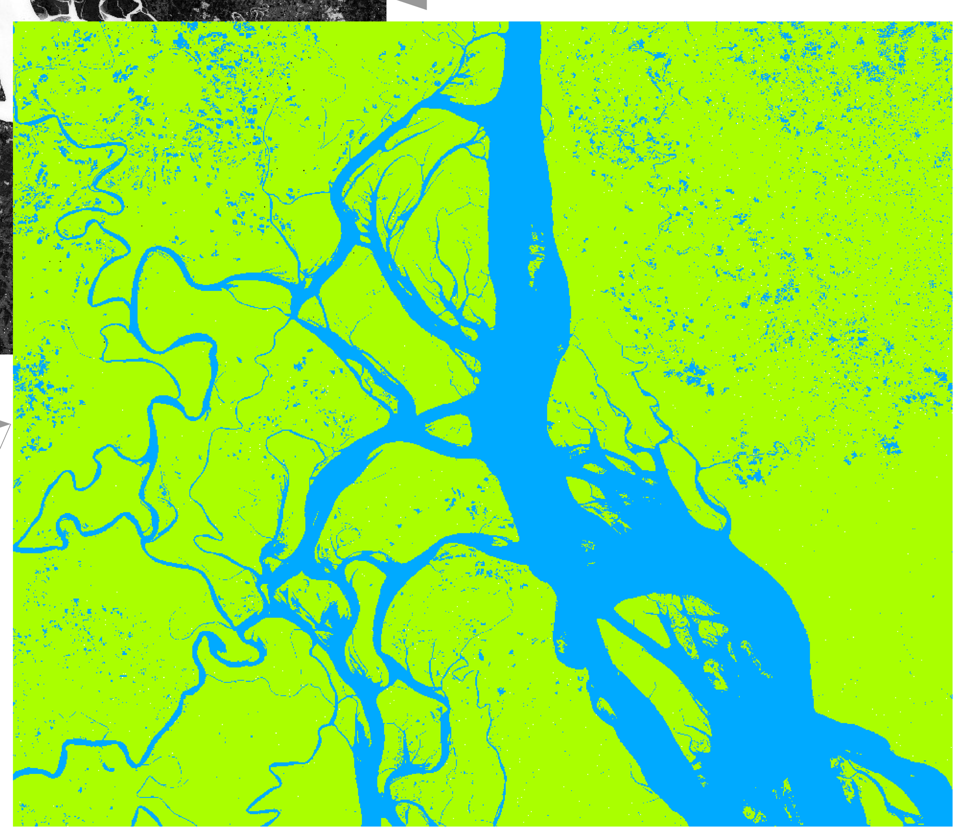
New Raster Water Mask from S1 (VV,VH)



[Red:B11, Green:B8, Blue:B3]

MNDWI





MNDWI derived Reference Water Mask

error_rate = error_pixels / (all_pixels)

Training + Classification	Error Rate
Sigma0_VV only	0.05566585
Sigma0_VH only	0.042460684
(Sigma0_VV, Sigma0_VH)	0.038577792

Outdated SRTM SWBD water mask still in use.

Conclusions

Conclusion

The Random Forest algorithm performs well on S1 images. In this experiment a 7792 x 6679 pixels, say **a 52MPixel image is processed in 75s which is a very good performance with a laptop** (intel i7 7th generation dual core processor, 32GB SDRAM4). Among the 3 test cases the **training with both VV and VH polarizations exhibits the best result**. Our experimental protocol is not rigorous since we did not remove the training samples from the test dataset. Nevertheless it is a small training dataset. The resulting Water Mask is in excellent agreement with the human interpretation of the images and with the MNWDI index. It is also clear that **the old SWBD mask (red contours) cannot be used anymore** in a delta.

The build of a Sentinel-2 RGB image from the 3 bands that are used in water indexes has been a great choice. It revealed the shallow water areas. These areas need to be avoided when selecting the water class ; indeed deltas are subject to tides and S1 IW GRDH images have a coarser resolution then S2 images. The RGB image also revealed a high density of rice fields that may have been interpreted as forest (land class) if the land training was selected on a S1 image. The RGB image served to manually delineate the geolocation polygons from which are extracted the S1 land and water training pixels. The radiometry of these S1 reference pixels will remain valid for future runs of the classifier (with other images) but the polygons that define training classes are not reusable at any date.

Running the trained classifier on other images will allow a statistical quality control. If the results keep as good we will start producing a Water Fractions field for the Sentinel-3 or cryoSat-2 SAR altimetry data. **This work not only highlights the great synergy potential of the Sentinel-1, 2 but it also opens up new possibilities in the synergistic use of these two missions and the Sentinel-3 mission.** We believe that the systematic use of updated water masks in alti-hydrology processing chains could make sense. **Last but not least the huge archive of Sentinel-2 images with less than 5% cloud cover can immediately be used to produce a series of Very High Resolution Water Masks of Reference (10m)** through classification of MNDWI. Along-Track can deliver these masks.

References

[R-1] Breiman, L. 2001. Random forests. Machine Learning 45: 5-32.

[R-2] Breiman, L., Cutler, A., Liaw, A. and Wiener, M. 2006. Breiman and Cutler's Random forests for classification and regression.

[R-3] Yun Du, Yihang Zhang, Feng Ling, Qunming Wang, Wenbo Li and Xiaodong Li. 2016. Water Bodies' Mapping from Sentinel-2 Imagery with Modified Normalized Difference Water Index at 10-m Spatial Resolution Produced by Sharpening the SWIR Band.

Acknowledgments

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Sentinel-1 and -2 data are from https://scihub.copernicus.eu/

Project Website

Documents & demo products to be available at

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

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