Analysis of Airborne SAR and InSAR Data for Coastal Monitoring

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Abstract: The German Wadden Sea is a very fragile ecosystem listed as UNESCO World Heritage Site and therefore closely monitored. This monitoring includes but is not limited to the waterways, the erosion of the islands causes by tides and storms, the condition of coastal protection buildings and the land cover and use. The goal of the project called GeoWAM is to investigate whether or not it is possible to replace airborne Laser scanning, which is the state of the art for this task, by airborne Synthetic Aperture Radar. As part of the project consortium, the Karlsruhe Institute for Technology and the University of Stuttgart are investigating new methods for the automatic evaluation of radar data. In this paper we describe the efforts on the subject of classification, georeferencing and the extraction of 3D structures.

1. Motivation

In order to be able to respond to urgent issues of water science, water management and ecology with regard to coastal protection, high-resolution and accurate geodata of coastal areas and water bodies are required. Today and in the future, we will be facing an increasing demand for geo basic products, especially in the form of digital terrain and surface models. These can be used to ensure the traffic safety of seafaring roads and support various federal and state authorities and NGOs in the implementation of their work on traffic safety and services of general interest in the coastal region. Nowadays, usually airborne laser scanning (ALS) is applied to derive demanded geodata products. With regard to the modelling of coastal areas, data collection on dry fallen mudflats and foreshore area is of particular interest. Hence, only extremely short time windows are available for the acquisition of the corresponding data, due to changing water levels and weather conditions. This is bottleneck for ALS, which suffers from clouds and fog and is usually bound to stripe width of some 500 m only. For this reason, remote sensing methods are desirable that allow a higher degree of flexibility. Current developments in airborne Interferometric Synthetic Aperture Radar (InSAR) technology lead us to expect new technical and economic advantages over operational technologies, such as ALS. These advantages are based in particular on the up to five times higher area coverage performance and the weather independence of the InSAR technology. However, for corresponding operational applications and application-related product provision, intensive research activities are still required with regard to data acquisition, data processing, user-oriented data analysis and product development. Therefore, we are investigating how to improve the entire development chain starting from more efficient capturing of airborne SAR and InSAR

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data up to the deployment of ready-to-use coastal-relevant geodata products. The individual steps of this development chain are presented in Fig. 1.
In this paper, we focus in particular on the step of SAR analysis and interpretation. This includes the investigation and evaluation of the data acquired via airborne SAR with regard to user requirements for the purpose of water management in tidal affected areas. This includes questions such as the separation of soil and non-soil points and a further subdivision of the land cover into classes relevant for coastal areas, the optimization of georeferencing to geocode the results at the best possible rate as well as the extraction of structural edges within the dry fallen mudflats.

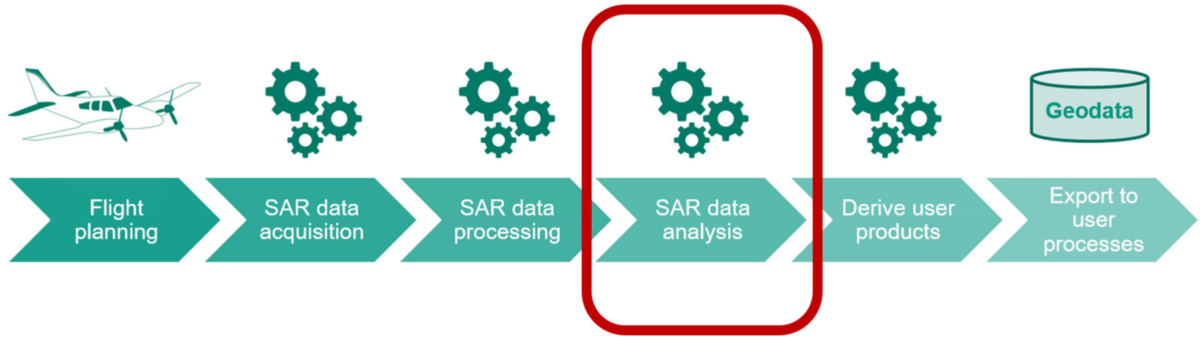

Fig. 1: Development chain, including flight planning, data acquisition, processing and analysing as well as generating and providing geodata products.

2. Data acquisition

As part of our project, we planned three flights for the data acquisition, whereof two have already taken place so far. We have chosen the coastal region near Spiekeroog and the Elbe estuary near Brunsbüttel as representative test areas. For the timing of the flight, a low tide level is of great importance, because the analysis of dry fallen mudflats is of particular interest. In addition, the measurement campaigns are arranged in such a way that two different vegetation conditions can be observed.
The airborne SAR system F-SAR of the German Aerospace Centre (Deutsches Zentrum der Luft- und Raumfahrt; DLR) (HORN et al. 2017) is used for data acquisition. It is capable to record simultaneously data at different wavelengths and polarizations in very high resolution. For our measurements, we used the X- and S-band antennas. To enable interferometry on the one hand a repeat-pass mode was used, additionally the configuration of the X- and S-band antennas allows single-pass interferometry. Amplitudes images, single look complex data, and interferometric intermediate products such as phase- and coherence images are generated by DLR based on the recorded raw data obtained during the flights. These data provide the basis for further analysis and interpretation and the generation of high-resolution geodata products.

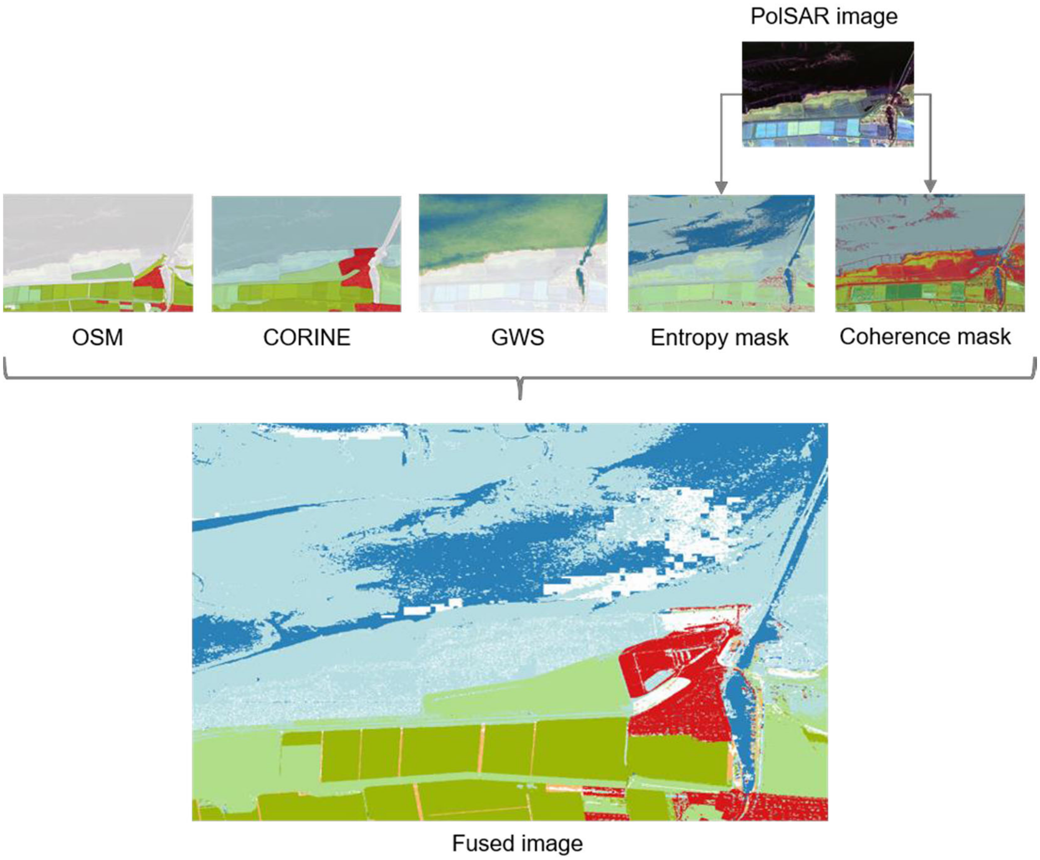

Fig: 2: Fused reference map, used for data labelling

3. SAR data analysis

3.1 Land use land cover classification

In order to interpret the processed SAR images, suitable algorithms can be applied to derive statements about soil properties and thus about land use and land cover. Another aim is to distinguish between water areas, wetland areas, meadows, shrubs, forests and human made infrastructure. This shall be achieved by novel classification algorithms based on supervised learning strategies to be developed in the framework of this project. For this purpose, a part of the acquired SAR- data needs to be annotated. In order to accomplish this task in an efficient manner, we fused information given by available land use land cover products and information derived from a previous unsupervised classification of our collected data (Fig. 2). We use the automatically labelled data to train a Random Forest, which assign the desired classes by evaluating various SAR-features. The chosen features are extracted using Eigenvalue decomposition (CLOUDE & POTTIER 1996) as well as the model based Freeman-Durden decomposition (FREEMAN & DURDEN 1993). The resulting pixel-wise classification needs to be post-processed and generalized in order to obtain the desired user-oriented products, such as coastal lines or hydraulic constructions.

3.2 Optimization of georeferencing

The usability of such classification products is also depending on the quality of its geocoding. Hence, the optimization of the georeferencing step is one of the main project challenges, since this step specifies the geopostion accuracy of all other products. To realize the optimization of geocoding, we plan to conceive, analyse and evaluate different strategies in terms of resource effort and improvement level. The following options are feasible:

- Usage of corner reflectors, transponders or InSAR DSM control areas,
- Usage of image-to-image matching by integration of UAV data or SAR satellite data, or
- Generation of control points by using radargrammetric image pairs.

First, we will focus on the integration of SAR satellite data to make use of their high precision orbit information. For this purpose, TerraSAR-X data were ordered in parallel to the airborne data acquisition time. Since the satellite passes the area of interest only twice the day at fixed times, the tide height cannot be taken into account as opposed to the airborne data acquisition. Nevertheless, the good match between airborne and spaceborne SAR data shown in Fig. 3 gives reason to hope.

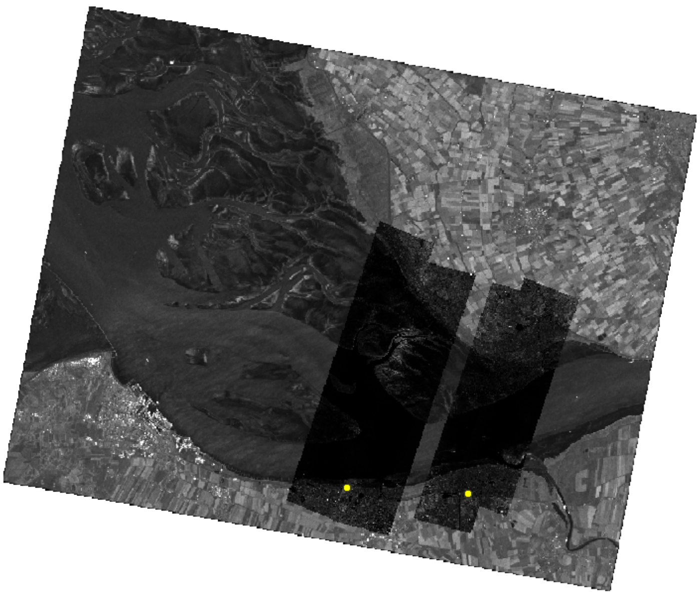

Fig. 3 TerraSAR-X image overlaid by F-SAR data strips and marked reflector positions

3.3 Structural edge detection

Besides the classification of land cover, the extraction of 3D structures becomes important for coastal protection. With every ebb and flood, the silt is exposed to high currents and thus moved. The position of tidal creaks with its breaking edges is monitored to observe wide area changes in the mud flat over time. To identify the tidal creaks its breaking edges have to be detected automatically in the SAR data.

In the project, we will develop different approaches to extract those breaking edges. First, we transfer state of the art algorithms (e.g. MANDLBURGER et al. 2016) developed to extract breaking edges from ALS DEMs to InSAR DEMs. Since the generation of InSAR DEMs is a computationally intensive process, we further examine methods based solely on single look complex data. For this task, SAR specific edge detectors like CFAR need to be integrated. Another attempt is based on applying a SAR specific Canny-like algorithm that is used to extract edges on a single SAR image. A result of this approach is shown in Fig. 4. As additional option, the use of polarimetric features to detect structure lines is planned.

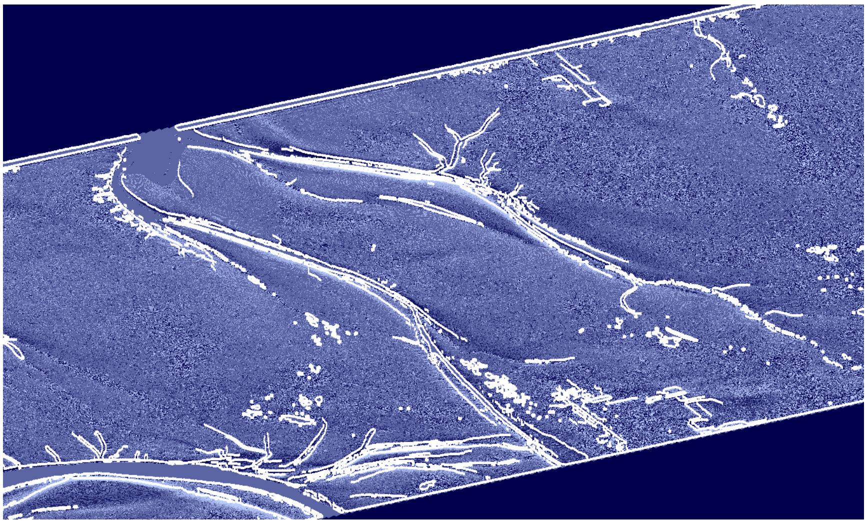

Fig. 4: InSAR DEM overlaid with result of the SAR adopted Canny algorithm

4. Acknowledgement

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5. Literature

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