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NEAR REAL TIME APPLICATIONS FOR MARITIME SITUATIONAL AWARENESS

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Abstract

Maritime Situational Awareness is of global importance and satellite remote sensing technologies are well suited to derive maritime value added products. Processing systems to derive information about oil spill, ship or iceberg detection from spaceborne Synthetic Aperture Radar (SAR) image data are being developed and integrated at the Ground Station Neustrelitz, part of the German Remote Sensing Data Center (DFD). Shortly, products of meteo-marine parameters like wind and wave will complement the product portfolio. Research and development aim at the implementation of highly automated services for operational use. At this time SAR images are widely used because of the possibility to provide maritime products with high spatial resolution over wide swaths and under all weather conditions. In combination with other information sources like Automatic Identification System (AIS) data fusion products are available to support the Maritime Situational Awareness.

1. INTRODUCTION

1.1. Objective

The progression of maritime economic activities is based on a safe and secure environment. In response to the modern maritime risks and threats the first EU Maritime Security Strategy (EUMSS) and its Action Plan were adopted in 2014. 23 of the 28 EU Member States are coastal states, operating more than 8000 vessels, larger than 500 GT and more than 1200 commercial ports. Therefore there is a responsibility for safety and security in the global maritime domain. One primary goal is to achieve good environmental status (GES) for EU marine waters by 2020 [1], [2].

Remote sensing provides outstanding capabilities to monitor the large maritime domain in a minimum time frame. DLR and industrial partners launched in 2012 a major multi-annual research and development programme for “Maritime Safety and Security”. Within the DFD the activities target at the development and operation of Integrated Maritime Services. At this time DFD takes part in the national research project “Echtzeitdienste für die Maritime Sicherheit – Security” (EMSec) where the team takes over research and development tasks to achieve significant improvements of the availability and reliability of maritime value added products. Supplying timely information for the maritime domain is the main goal of the research and development for automated near real time (NRT) applications based on a remote sensing multi-sensor approach in a synergetic use with ground-based sensor data. Further main issues are data fusion and product development. The project aims to new funda-mentals for further development of operational systems, enabling support of service providers and Copernicus downstream services.

1.2. Background

The German Remote Sensing Data Center takes part in several national and European maritime projects. The European project Maritime Security Service (MARISS) was the first phase of a pan-European activity of ESA under Copernicus, previously known as “Global Monitoring for Environment and Security” (GMES). Within the different projects DFD’s department National Ground Segment in Neustrelitz, in the federal state of Mecklenburg - Western Pomerania, handles the reception, processing and distribution of data products for a multitude of satellite missions. Since 2008 the range of maritime activities was continuously expanded.

As Figure 1 shows, the acquisition circle of Neustrelitz (approximately by elevation of five degree) allows coverage from the North Atlantic to the Mediterranean Sea.

FIGURE 1. Ground Station Neustrelitz, acquisition circle for TerraSAR-X (white), Sentinel-1 (yellow) and Radarsat-2 (red); 5 degree elevation.

Covering the entire value chain from data reception to data processing and final distribution ensures that users can obtain high quality homogenized data products with high information content. The relevant experience covers all parts of the service cycle from interface definition and implementation, to data reception and operational near real time processing, product generation, analysis and dissemination to support services, particular in the maritime domain.

2. DATA AND METHODS

Image data, acquired from multiple Synthetic Aperture Radar (SAR) satellite missions and received directly in Neustrelitz, serve as primary input data to derive meteo-marine information. Figure 2 shows all steps from data acquisition up to the product dissemination.

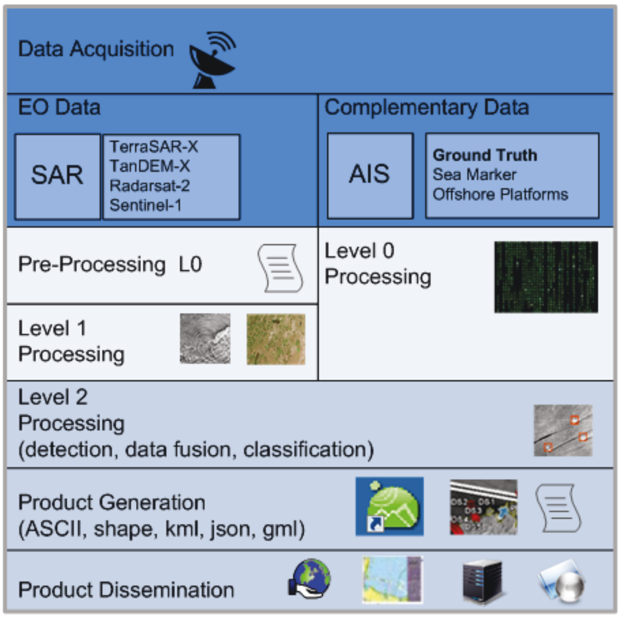

FIGURE 2. Workflow to supply satellite-based maritime information products (current status).

Neustrelitz is the main reception and processing facility for the TerraSAR-X mission. Both satellites serving these missions (TerraSAR-X and TanDEM-X) use active phased array SAR antennas (X-band) to acquire high resolution radar images of outstanding quality. The SAR instrument works independently of day time and weather conditions and is therefore well suited for target detection, oil spill detection as well as applications to derive wind and sea state information. Within the European project Support to Pre-Operational Validation of the High-Time Critical Components of CONOPS" (SAGRES) ship detection capabilities were expanded to include data from the CosmoSkyMed and Radarsat-2 missions as well.

The development of the collaborative ground segment for the Copernicus Mission Sentinel-1 will lead to further improvements in the spatial and temporal availability of maritime products from Neustrelitz. Furthermore the ground station is extended by a Radarsat-2 Regional Ground System (RGS) during the summer of 2015 and becomes part of the Radarsat-2 Ground Station Network, enabling real time access to Radarsat-2 data for scientific purposes.

2.1. Environment

To fulfil user requirements and achieve relevant processing times, i.e. product dissemination in less than 15 minutes after image acquisition, the efficient use of the processing hardware is mandatory. Within the EMSec project DFD focuses on the development of a new system approach based on the overall system virtualisation, taking into account that highly parallel processing is mandatory. Different shared file systems like Global File System 2 (GFS2) for Linux operating systems or the Quick File System (QFS) for Solaris are in use to support parallel processing. The storage behind this shared file system is partly built on solid-state disks (SSD), connected via fibre channel, to support fast data processing. The data on the SSD can be accessed almost promptly since there is no need to spin-up the drive platter as in the case of HDD drives. Due to the lack of these mechanical delays SSD technology enables a significant increase of read/write rates.

2.2. Framework Approach

While data from the ERS-2 and Envisat satellites were used in the past, TerraSAR-X is currently the main SAR data source for NRT applications due to its high spatial resolution. To overcome limitations of satellite access due to the geographic location of Neustrelitz, the Svalbard ground station, operated by Kongsberg Satellite Services (KSAT), is used complementary.

Figure 3 shows the principle workflow for NRT products including ship detection, one of the first value adding products implemented in the TerraSAR-X ground segment. For now ship detection order option is available for NRT future product orders and can be requested in addition to the standard Level 1b Multilook Ground Range Detected (MGD) product, for both StripMap and ScanSAR image mode. NRT processing is carried out at the Neustrelitz ground station while the downlink can be performed via the Neustrelitz as well as the Svalbard ground station.

The following chapter can be taken as one example, illustrating the value adding chain development carried out within the TerraSAR-X mission.

The production is embedded in the Data Information Management System (DIMS), using the Processing System Management (PSM) developed by DLR and Werum Software & Systems AG. The processing is performed on data take level. Screening (Level 0) and pre-processing (Level 1b) of SAR data are tasks of the TerraSAR Multi Mode SAR Processor (TMSP) [3]. Each unique data take represents one user order. To force fast data processing of a so called NRT future product order, PSM rules are implemented to fetch NRT flagged data takes first. After data decryption the data take is handed over to the NRT processing system where the data are mapped directly to the already scheduled processing request. In case of NRT future product orders, the processing starts immediately, using predicted orbit and attitude products which are already available before downlink.

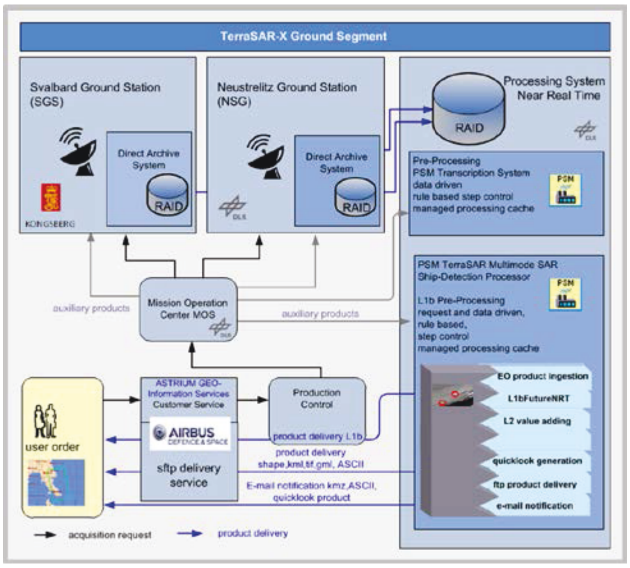

FIGURE 3. TerraSAR-X NRT ship detection product order and delivery chain.

For value adding processing (Level 2) the following processors are currently integrated:

1) SAR AIS Integrated Toolbox (SAINT) for target detection [4], [5]
2) XMOD-2 to derive wind speed and direction [6]
3) XWAVE to derive wave height and wave length [7]
4) Oil spill classification processor [8]

The processor modules used to derive the information from the SAR image has been developed at the Maritime Safety and Security Lab in Bremen, part of DLR's Remote Sensing Technology Institute.

3. RESULTS

3.1. Target Detection

The target detection covers different requirements and is currently developed for vessel and iceberg detection. Outputs of the processing chain are value added products in different formats in addition to the standard L1b product, as specified within the ground segment. For all targets the generated products contain information about position and length. Width and heading are available for vessel detection only. Quality information is attached for each target representing the confidence level for detection.

In case of vessel detection ground truth information like terrestrial AIS data for North and Baltic Sea are acquired via network (also in real time) and merged to the SAR based intermediate product during post-processing before generating the final output.

The fusion with AIS data creates a more significant picture with additional information, e.g. ship name, ship class and destination. AIS messages are broadcasted and mandatory for all vessels larger than 300 GRT. If AIS information is available, the expected vessel position within the SAR image will be calculated based on this information. If there is a time delay between AIS message and the SAR image acquisition time, the vessel position will be predicted to the SAR image time, based on the latest AIS values. Correlation of SAR detections and AIS-messages is done based on the calculation of the SAR echo, taking into account the AIS information about heading and speed of the vessel. AIS point and track information are provided by additional layers to support backward and forward simulation for a configurable time frame.

Target detection products are available in different formats as described in chapter 3.5. As an example, figure 4 shows a kmz file, displayed in Google Earth, which can be attached to an e-mail notification, to inform the user that the product was delivered.

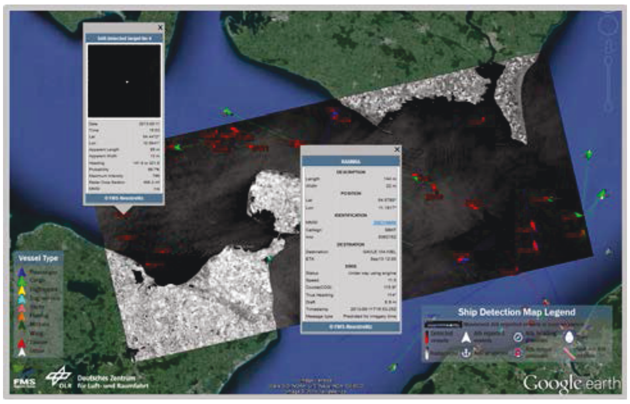

FIGURE 4. kmz output product extract; image data product TerraSAR-X merged with ground based AIS data; visualized in Google Earth.

3.2. SAR Wind Products

SAR derived wind field information will be generated fully automated during the level 2 processing.

For C-Band data the CMOD-5 algorithm was implemented while for X-Band SAR data the XMOD-2 core function is used [6]. Both algorithms derive wind fields from SAR images of sea surfaces by means of empirical geophysical model functions (GMF) with specifically adjusted coefficients. An autonomous processing rule is called by the PSM control system based on the additional value adding request parameter. Currently the processor is integrated as a second value adding step in parallel to the ship detection.

The fully automated derivation of wind direction from wind streaks on the ocean surface is a recent research issue. Therefore currently the wind field extraction needs estimated wind direction as additional input besides the SAR L1b image. Wind direction estimates are generated by means of the Weather Research and Forecasting (WRF) Model [8]. A single PSM application of the WRF model was implemented to provide the information The WRF model was chosen because it can generate globally wind direction in the desired spatial resolution. As a result a netCDF file is generated, containing wind direction and intensity (WD10). Similar to the product generation approach implemented for target detection, also wind products are available in different formats as described in chapter 3.5.

3.3. SAR Wave Products

Ongoing research at the Maritime Safety and Security Lab in Bremen is dedicated to the estimation of sea state conditions from SAR images. For X-Band data the XWAVE and for C-Band data the CWAVE algorithm is applied [6], [7]. Both algorithms analyse the modulation of backscatter intensities in a sub-scene using the Fast Fourier Transformation (FFT) and output significant wave height, peak period and peak wave length of sea state. The parameters of the XWAVE and CWAVE algorithms have been adjusted based on collocated measurement data of NOAA buoys in the open ocean and validated with an independent buoy dataset as well as model data from the DWD [7]. Figure 5 shows one example of a data fusion product provided by DWD. The DWD product in the background is overlayed by the DLR SAR wave product (rectangle) derived from the TerraSAR-X StripMap image.

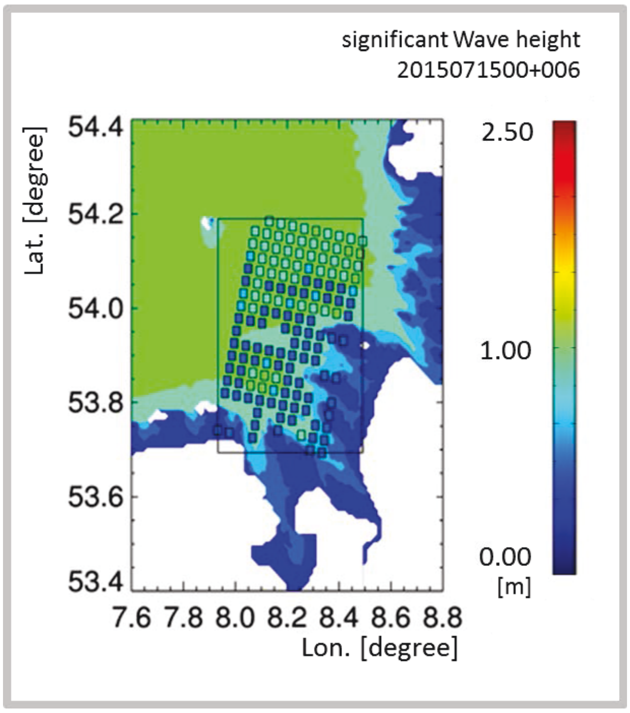

FIGURE 5. Example of a data fusion product, provided by the DWD (slightly modified).

The processing chain is currently implemented in a single solution, running the Level 2 wave detection in a stand-alone PSM environment. Concerning the TerraSAR-X mission, it is planned to integrate the whole processing rule in parallel to the wind detection. As described for the wind estimation in the previous chapter, an autonomous processing rule is called by the PSM control system based on the specified value adding request parameter. Following the product generation approach implemented for wind detection the same product types will be available for dissemination via delivery server or Web GIS server.

3.4. Oil Detection

Supported by the national project “Real-time Services for Maritime Security” (EMS) a prototype application for semi-automated oil spill detection based on the TerraSAR-X StripMap and ScanSAR modes was developed.

The application supports stand-alone processing as well as integration in the already existing NRT workflow based on the MGD Level 1b product. All processing steps are triggered by the oil detection processing rule, added to the PSM control system which is calling a sequence of additional processing steps. Main element of the workflow is the classification processor, based on a trained neural network [9]. Virtual Network Computing (VNC) is implemented to enable remote operator interaction, needed to select a region of interest (ROI) containing an oil spill or ‘look-alike’ candidates. The software supports multiple choices in case that more than one ROI has to be analysed. Only the selected ROI’s are the input for the classification processor. As a result from the classification, possible oil spills are highlighted. Before the processors for product generation and dissemination are executed the classification result has to be confirmed by the operator.

3.5. Product Formats and Dissemination

After product generation different product formats are available in addition to the NRT L1b product. Currently the product generation processor supports the following product formats:

- Geography Markup Language (GML) format, compliant to the EMSA CSN Standard5
- Keyhole Markup Language (KML) with embedded quicklook images in Portable Network Graphics (png) format
- ESRI shape file format (shape)
- Geo-referencing information, embedded within a TIFF (GeoTIFF)
- JavaScript Object Notation (json) for target detection only
- Portable Document Format (PDF), for oil spill detection only
- Joint Photographic Experts Group (jpeg)

Different dissemination options are available like ftp/ sftp via delivery server at DLR or directly on user site. Delivery via e-mail (e.g., jpeg, kml or shape and ASCII files) as well as via Web Mapping Server (e.g. tiff and ESRI shape file layer) is also supported.

4. CONCLUSION AND OUTLOOK

There is a wide range of remote sensing capabilities based on SAR images to support maritime surveillance. Some algorithms for value adding services in the maritime domain are already available for operational use. Near real time performance is, amongst others, the main requirement for such services.

New satellite systems like the Copernicus mission Sentinel-1 will increase the availability of image data. Further research and development are needed for the usage of the new image modes, e.g. Sentinel-1 TOPS mode. The integration of further data streams, not only from radar but also from optical sensors, as well as satellite based AIS, will increase the reliability of the services.

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