Change detection and damage assessment based on the new generation radar satellites for G-MOSAIC pilot services

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1. Abstract

Within the GMES initiative, several projects focus on supporting the European Union Common Foreign and Security Policy (CFSP) and the Common Security and Defence Policy (CSDP). Two of them are GMOSS (2004-2008) and, addressed in this paper, G-MOSAIC (2009-2011). GMOSS was the predecessor of G-MOSAIC. An important issue in GMOSS was to connect the information needs following from the CFSP security priorities to Earth Observation (EO) technology [1]. The aim of G-MOSAIC is to go a step further and develop geospatial information products and pilot services for the EU external relations policies (CFSP/CSDP) and security end-users [2]. Pilot services to which TNO contributes, are developed in co-operation with DLR, e-GEOS, GMV, Infoterra, Joanneum Research, JRC, and others. Key technology that is discussed is radar change detection. Output products give information on vessel traffic, harbour activities, transhipment of goods, timber logging, earthquake damage, and reconstruction after crisis. Present radar EO systems turn out to be well suited to monitor different activities due to different scattering mechanisms, and irrespective of cloud cover.

2. Synthetic aperture radar

Since 2006 a new generation of radar satellites is operational, succeeding the successful generation of ERS, JERS, Envisat and Radarsat-1. Representatives of the new generation are TerraSAR-X, Cosmo-SkyMed, Radarsat-2, and ALOS PALSAR, see Table 1. Most important properties of these satellites are a higher resolution (1-10 m) combined with polarimetric imaging, and continued all-weather coverage, that make them pre-eminently suitable for security applications.

Synthetic Aperture Radar (SAR) is an active instrument, it transmits a signal to the earth and the returned scattering shows the characteristics of the illuminated surface. The radar wavelength determines the ability to penetrate vegetation and soils; the longer the wavelength, the deeper the penetration. The polarisation determines the observed scattering mechanism. In general there are three scattering mechanisms [3]:

- Double-bounce scattering from wall-ground or other orthogonal structures that function as an efficient radar reflector. Dependent on the size of such a structure, the backscatter can be quite strong. Double-bounce is visible in HH and VV.
- Rough-surface scattering. This type of scattering is diffuse and often weaker than double-bounce. Rough-surface scattering is visible in HH and VV.

- Volume or canopy scattering. This type of scattering occurs when the radar waves penetrate a medium such as vegetation canopies. The longer the wavelength, the deeper the penetration, and the stronger the radar return. Volume scattering is visible in all polarisations, but because double-bounce and rough-surface are not, HV and VH (referred to as cross polarisations) exclusively show volume scattering.

Table 1. Overview of past and present radar EO satellites.

Platform	**Launch**	**Band [1])**	**Polarisation [2])**	**Resolution**	**Status**
Seasat	1978	L	HH	25 m	Ended 1978
ERS 1	1991	C	VV	30 m	Ended 2000
JERS 1	1992	L	HH	18 m	Ended 1998
ERS 2	1995	C	VV	30 m	Operational
Radarsat 1	1995	C	HH	10 m	Operational
Envisat	2002	C	Dual pol	30 m	Operational
ALOS PALSAR	2006	L	Quad pol	10 m	Operational
Radarsat 2	2007	C	Quad pol	3 m	Operational
TerraSAR-X	2007	X	Dual pol	1 m	Operational
Cosmo-SkyMed	2007	X	Dual pol	1 m	Operational

[1]) L-band = 23 cm; C-band = 5 cm; X-band = 3 cm

[2]) Dual pol selectable from HH/VV, HH/HV, and VV/VH; Quad pol HH, HV, VH, VV

3. Methodology

3.1 Radar change detection

Radar change detection is a technology that detects the differences between two or more radar acquisitions of the same area, in time. First radar change detection studies, coherent and non-coherent, date back to the early nineties [4]-[6]. Coherent change detection takes into account the amplitude and phase of the radar image, while non-coherent change detection only considers the amplitude. For both, the imaging geometry of the acquisitions have to be the same, sometimes referred to as repeat-pass geometry. Because co-registration for coherent change detection is more demanding, chosen was to apply non-coherent change detection.

An important issue in non-coherent radar change detection has always been the reduction of speckle noise. Chosen is for the method described in [7], that showed good results applied to medium-resolution SAR imagery (ERS, Envisat, Radarsat-1) in the past [8]-[10]. Output is a vector change layer.

3.2 Radar damage assessment

Damage assessment can be considered as an application of change detection. A distinction can be made between detailed damage assessment that focuses on damages at building-level (e.g. applying the method chosen in Section 3.1), and grid-based damage assessment [1], [11]. The latter is based on the average difference or correlation per grid-cell, or a combination.

4. Results

Pilot services that make use of radar change detection technology and that are addressed here, are coastal and harbour surveillance, illegal timber logging, damage assessment, and reconstruction monitoring. Up to now several geospatial information products were produced to evaluate the pilot services.

One product shows the activities that take place in the harbour of Burgas, Bulgaria, based on detailed change detection applied to TerraSAR-X images. Visible are relocated ships, cranes, trains, sea-containers, and goods, see Figure 1 (left).

Another product shows vessel movements in Radarsat-2 images, in and outside the port of Rotterdam, The Netherlands. The image is enriched with data from AIS transponders (Automatic Identification System) mounted on the larger ships, to give an overview of the vessel traffic. Correlation of non-stationary objects in radar and AIS has to be compensated for an azimuth shift caused by the Doppler processing of SAR images.

A third product shows areas of timber logging in the Democratic Republic of the Congo (DRC) based on change detection applied to ALOS PALSAR images. Comparing these loggings with the concession areas will show if these loggings are legal or not. Especially in this product the volume-scattering properties of long-wavelength cross polarisations are used, see Figure 1 (middle).

A fourth product is a damage assessment of Port-au-Prince, Haiti, after the earthquake on 12 January 2011, based on TerraSAR-X and Cosmo-SkyMed images. Two assessments were done, one grid-based with cells of 200 m, and one detailed assessment at building level. Results were compared with the Post Disaster Needs Assessment (PDNA) of UNITAR/UNOSAT, JRC, and the World Bank. The grid-based damage assessment shows the best results, mainly in the more regular structured areas such as the city centre, that return more double-bounce scattering. Damage in the shanty areas is less visible, see Figure 1 (right).

A fifth product shows reconstruction activities in Banda Aceh, on Sumatra, Indonesia, after the tsunami on 26 December 2004, based on TerraSAR-X images.

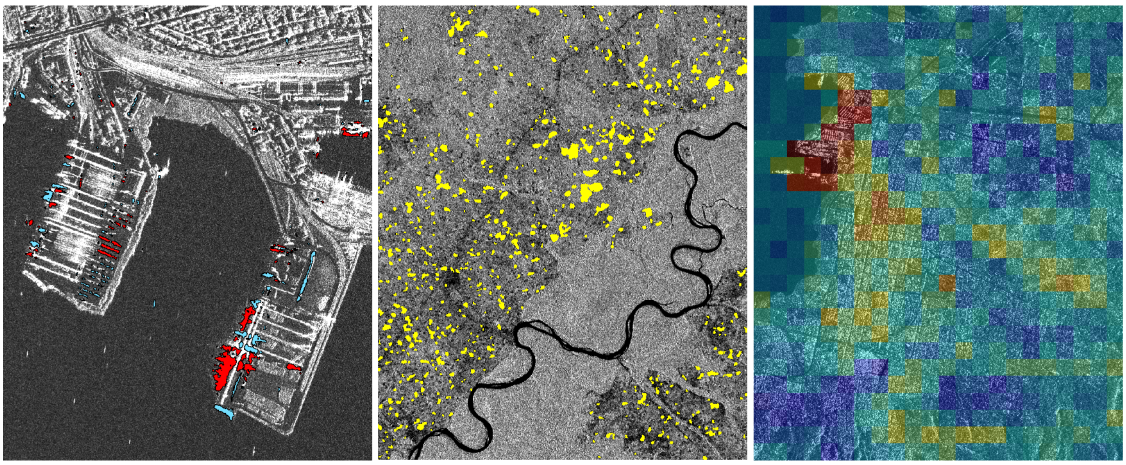

Figure 1. Harbour activities in Burgas, Bulgaria (left), timber logging in DRC (middle), and grid-based damage assessment in Port-au-Prince, Haiti (right). © Infoterra GmbH. © JAXA/METI. Data were provided by the European Space Agency.

5. Conclusions

In this paper the high-resolution radar and change detection technology that is used in several G-MOSAIC pilot services is discussed. With these pilot services different information products were generated for intelligence and crisis management. The products give information on vessel traffic, harbour activities, transhipment of goods, timber logging, earthquake damage, and reconstruction after crisis. Present radar EO systems turn out to be well suited to monitor different activities due to different scattering mechanisms, and irrespective of cloud cover. Correlation of non-stationary objects in radar and other data has to be compensated for an azimuth shift caused by the Doppler processing of SAR images. Due to the scatter mechanisms in urban areas, damage in the shanty areas is less visible than in the more regular structured areas such as the city centre.

6. References

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