



WHEN THE EARTH SHAKES

A smarter Big Data process – monitoring geohazards from space

By Bernadette Jung

Global change is manifested in many ways and reveals itself in different areas of the living world. With a wide range of consequences for the environment, global change and its interactions are affecting humans in ways that can no longer be ignored. In recent decades, for example, the risk of being affected by natural disasters has increased. Firstly, climate change is resulting in more and more extreme weather events. Secondly, people around the world are increasingly living in urban areas, populating regions ever more densely and getting closer to the areas affected by volcanoes, tsunamis and powerful earthquakes. A single local event can also have immediate consequences in other parts of the world. The eruption of the Icelandic volcano Eyjafjallajökull in 2010 and the resulting flight ban over Europe demonstrated this in a dramatic way. In order to better predict and avoid geohazards, it is necessary to acquire a better understanding of their origins and the complex processes involved. Advanced remote sensing satellites and technologies are indispensable for this. Experts at the DLR Earth Observation Center (EOC) have thus set up a special data service, which is available via the Geohazards Exploitation Platform (GEP).

The Geohazards Exploitation Platform

GEP is a cloud-based web portal developed by Terradue Srl on behalf of the European Space Agency (ESA). The DLR Earth Observation Center (EOC) offers two services on the GEP web portal – up-to-date mapping of the world’s most dangerous earthquake zones and monitoring of 22 volcanoes. The first service, the Sentinel-1 Medium-Resolution InSAR Browse Service, operates with a resolution of 100 metres. Forty percent of Earth’s active seismic areas are under its constant observation. The analyses are freely accessible via the data portal. The second service observes the world’s most dangerous active volcanoes at a resolution of 50 metres. This Sentinel-1 High-Resolution InSAR Browse Service is also used for expert evaluations following the occurrence of major earthquakes.

Both services process radar data acquired by the Sentinel-1 mission. The Sentinel-1A and Sentinel-1B Earth-monitoring satellites have been in orbit since 2014 and 2016 respectively, and can generate images regardless of the weather conditions. They can detect the smallest ground movements, even from an altitude of 700 kilometres. Their radar signals can penetrate vegetation and detect surface elevation changes in the centimetre or even millimetre range. The Sentinel-1 satellites deliver images of Europe every six days, and images of the rest of the world every 12 days. “As soon as we receive the signals, our system automatically processes the Synthetic Aperture Radar (SAR) data from the satellites to derive various data products and uploads these directly to the cloud. These include amplitude images, interferograms and other radar images that make deformations of the Earth’s surface visible,” says Ramon Brcic, who works at the DLR Earth Observation Center in Oberpfaffenhofen and is Project Manager for the Sentinel-1 InSAR Browse Service on GEP.

The radar products allow geophysicists, volcanologists, seismologists and other experts to draw conclusions about changes to the Earth’s surface – from variations in height, ground conditions and topography,

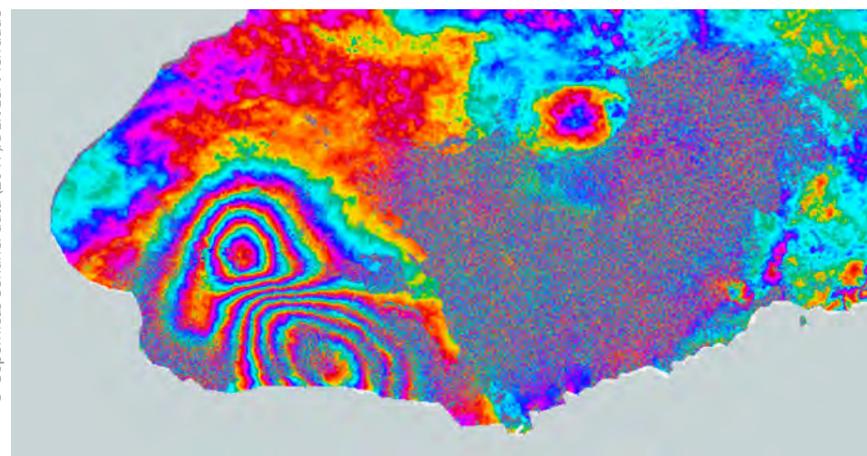


Ramon Brcic – an expert on the analysis of Earth observation data and Project Manager for the Sentinel-1 InSAR Browse Service on GEP.

“With our InSAR service on GEP, experts can decide immediately which datasets need to be examined more closely. Once they have performed a detailed analysis, they can make statements about the risk of further earthquakes and their expected strength.”

Ramon Brcic

through to the smallest movements. This is important for making predictions and mapping risks. For example, time series analyses of hundreds of images over several years can be used to determine exactly where deformations are occurring at tectonic plate boundaries and how fast the plates are moving. It also allows natural events such as earthquakes, volcanic eruptions and flooding to be assessed faster and more effectively. Research centres, measurement stations and monitoring services therefore use the data service provided by scientists at the DLR site in Oberpfaffenhofen. “With our InSAR service on GEP, experts can decide immediately which datasets need to be examined more closely. Once they have performed a detailed analysis, they can make statements about the risk of further earthquakes and their expected strength,” Brcic explains. “Normally, these kinds of ground movements have to be surveyed with GPS sensors on site. Thanks to radar interferometry, we can map large areas in detail with a single overflight.”



GEP view of the Cerro Azul volcano on the Galapagos island Isabela (Ecuador) at high resolution (50 metres) from the InSAR Browse Service. The interferometric phase shows the ground movement caused by a magma intrusion during the period from 8 to 20 March 2017. The coloured fringes show a drop of 11 centimetres at the summit and a 14-centimetre rise on the southeast flank.

Status at a click

The Sentinel mission is part of the European Earth observation programme Copernicus, so the satellite data are made freely available. Private individuals, researchers and service providers alike can use the raw data to obtain information, conduct research or develop new applications. But before this can happen, enormous amounts of data are accumulated and need to be analysed. Where should we be looking? What information can be derived from the data? Which datasets need to be examined more closely?

“ESA has defined seven subject areas, which effectively act as initial filters so that the various users can access the Sentinel data quickly and in a targeted way. Each topic has its own data portal – the coastal environment, forestry, hydrology, polar regions, the urban environment, food security, and geohazards – for which we at EOC are responsible,” Brcic says. As a specialist in SAR signal processing, he knows just how difficult searching for suitable datasets can be.

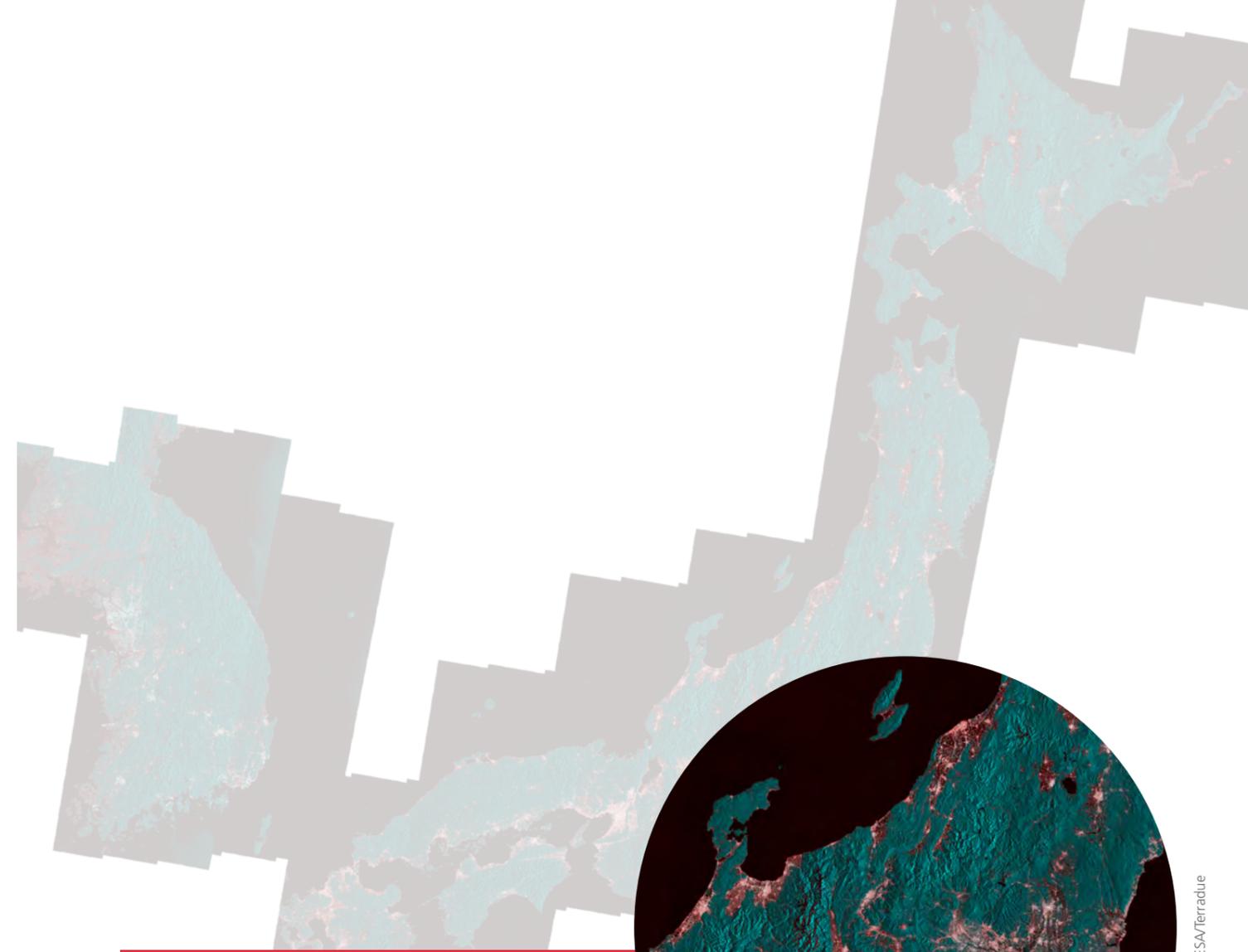
The special feature of GEP is its fully automated processing chain. User-specific data products are made available there, ready for use. Through a search mask, visitors to the web portal can have an immediate overview of all major volcanic and earthquake regions. If required, the pre-defined search area can be adjusted manually. “If I need data about a particular earthquake, all I have to do in GEP is check whether the event was recorded by the satellites and whether an interferogram is available. I can see this immediately and decide whether it makes sense to process the data further. Usually, there are several interferograms of an earthquake from different imaging directions, acquired at different times, so I can select the one best suited to my analysis,” Brcic says, describing the advantages of this approach. “I do not have to do anything else – the images are right in front of me.”

Automated data processing

The ‘Integrated Wide Area Processor’ (IWAP) software is used to process the radar data and generate the images for GEP. IWAP can ingest data from sensors on several radar satellites using various software modules. The system was developed by researchers at the DLR Remote Sensing Technology Institute around 15 years ago. It is constantly being further developed and adapted to meet new requirements. Brcic’s team has integrated the proven DLR processor into ESA’s portal system for the systematic monitoring of geohazards. IWAP obtains the Sentinel-1 satellites’ raw data directly from the Copernicus Open Access Hub – the central data archive of the European Earth observation programme. The processor generates six end products from each image pair. The resulting radar images are made available on GEP at the end of this interferometric processing chain.

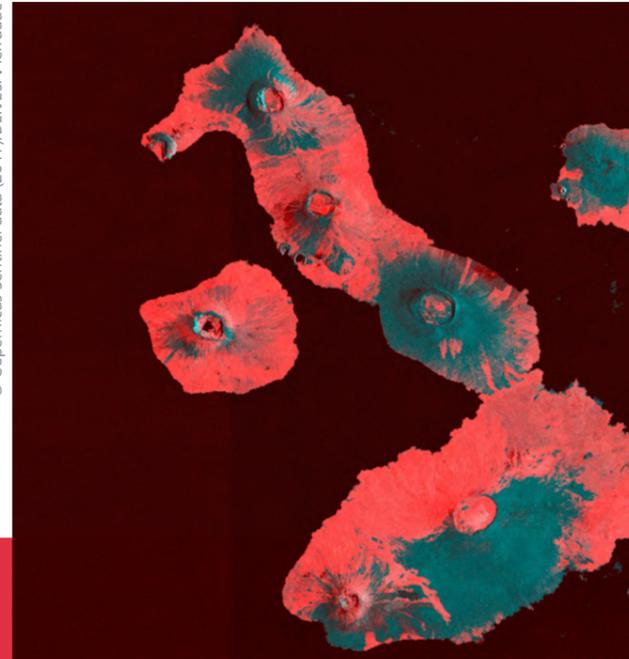
Only a few interferograms per day are required for the high-resolution observation of the 22 volcanoes. In contrast, the medium-resolution service for seismic areas covers a total of 15 percent of Earth’s land surface. During 2017 and 2018, the system reached peak performance, converting one terabyte of raw data into more than 100 interferograms per day or one interferogram every 15 minutes. Since then, all of them have been available to scientists and other users.

GEP has been online since mid-2016 and has now successfully completed its trial phase. With the processing of Big Data on an operational platform, the SAR team from Oberpfaffenhofen has been able to demonstrate the full capability of its system to striking effect. But the technological possibilities do not end there. In the future, yet another IWAP processor function could be integrated into the data service. For example, the Persistent Scatterer Interferometry

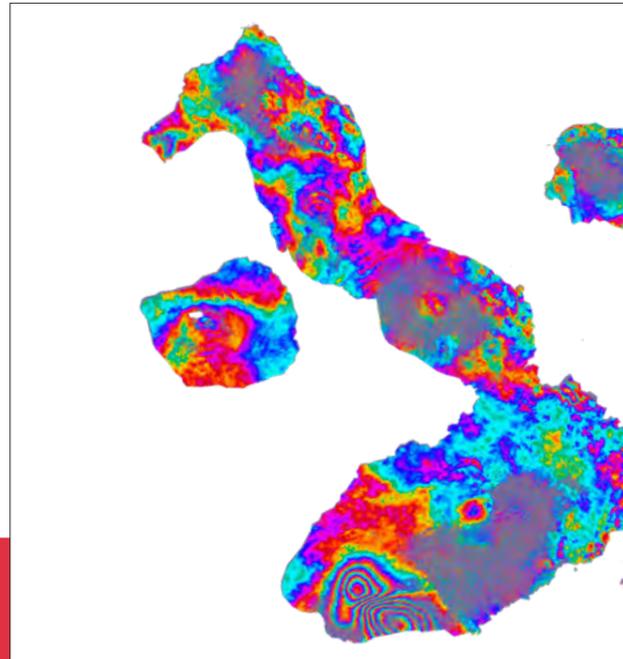


GEP view of Japan and Korea at medium resolution (100 metres) from the InSAR Browse Service covering the period May to June 2017. Each of the 33 images used here is a compilation of different results – here amplitude and coherence – to reveal certain details. Urban areas appear in white, heavily overgrown areas in cyan, and areas with little or no vegetation reddish. An interferogram and four other specialised views are also available on GEP.

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Galapagos Islands – this GEP product combines two different aspects of an image pair, amplitude and coherence, and highlights these properties using false colours. Bare or only lightly vegetated regions (red) can be distinguished from more heavily vegetated regions (cyan) at a glance (High-Resolution InSAR Browse Service, March 8-20, 2017).



Galapagos Islands – this interferogram shows how the ground rises and falls due to volcanic activity. Each coloured fringe represents a change of 2.8 centimetres (High-Resolution InSAR-Browse Service, 8-20 March 2017).

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(PSI) processing chain takes hundreds of images of an area acquired over a period of years and automatically generates ground deformation velocity maps with an accuracy reaching one millimetre per year. The process is already being used and further developed outside of GEP for earthquake risk assessment.

The necessary technologies and expertise for additional applications and services are certainly available. “If more services are needed, then it is computing power that is important,” says Brcic. “One way of saving on computing power and using it even more efficiently is to process the data in a more targeted way. This means that the service only creates an interferogram of an area when a request is

made.” At present, the team is working on converting the system to an event-driven service. In the future, GEP will automatically search for and process the appropriate Sentinel-1 data in the event of an earthquake or volcanic eruption. The remote sensing experts at the EOC will also continue to develop practical methods and find smart Big Data solutions to protect people from geohazards.

Bernadette Jung is an editor at the DLR site in Oberpfaffenhofen.

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