German Aerospace Center

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TanDEM-X and TerraSAR-X - imaging Etna while flying in formation

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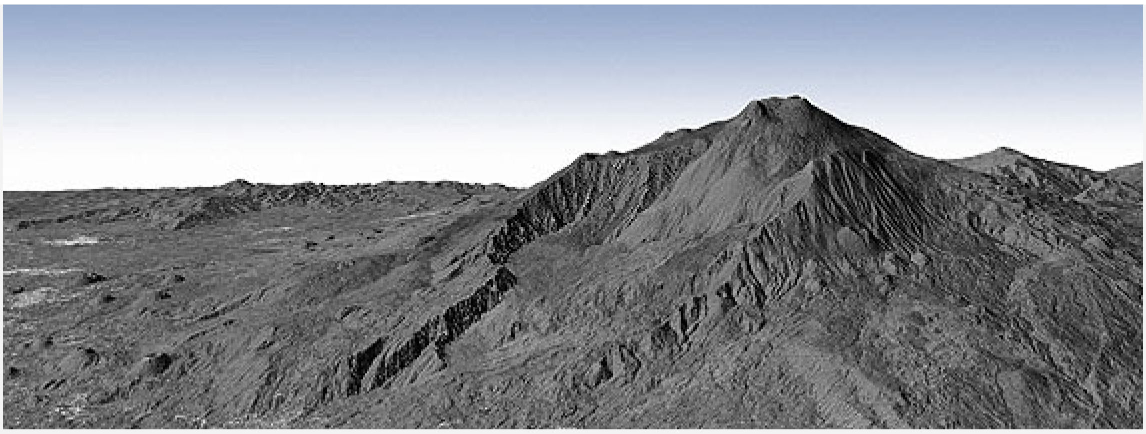
First synchronised elevation model for radar satellite pair

The TanDEM-X and TerraSAR-X satellite pair have acquired their first image of Earth's surface, synchronised to the microsecond, while flying over Mount Etna in Italy. Scientists at the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) have used the data to create a three-dimensional digital elevation model with an unprecedented elevation accuracy down to two metres. The image, taken while the satellites were flying just 350 metres apart, is the first in the world to be made by satellites flying in such a close formation.

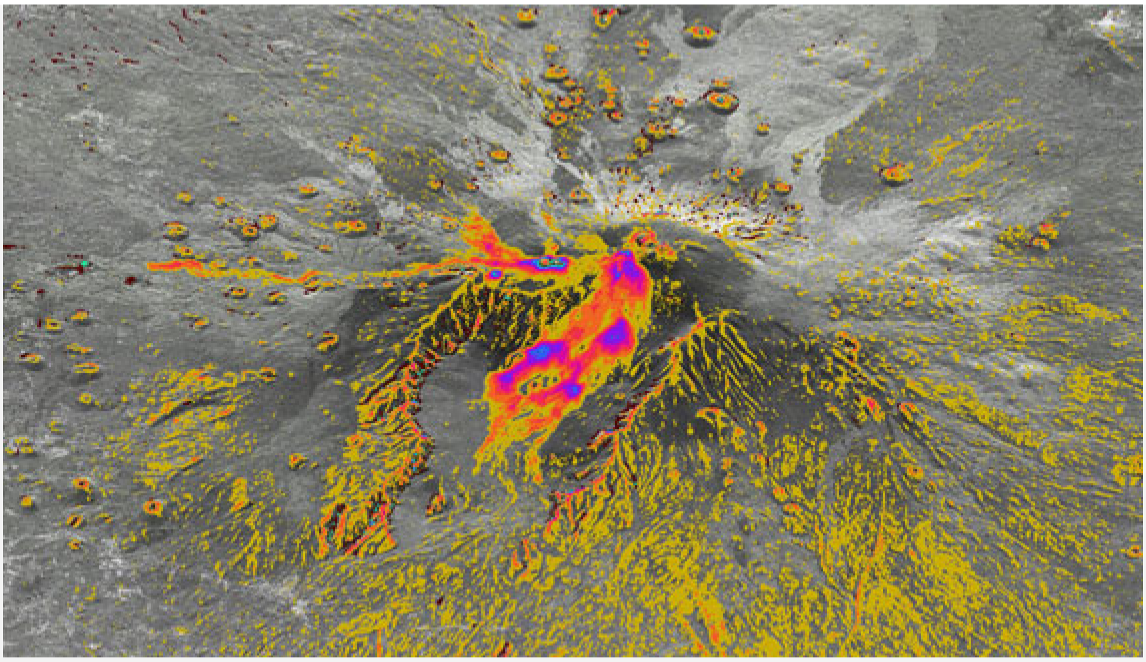


Mount Etna in three dimensions

The image shows Mount Etna on the east coast of Sicily. On the left of the image, in the foothills of the volcano, the city of Catania is visible as a collection of white points. This three-dimensional view of the volcano was generated from data recorded by TanDEM-X and TerraSAR-X. This was acquired using bistatic radar, where one of the satellites transmits a radar signal to Earth and the two satellites receive the reflection of this signal simultaneously. In this way, a highly accurate three-dimensional terrain model is created on a 12-metre grid. A similar recording technique was used in the Shuttle Radar Topography Mission (SRTM) in February 2000. However, in this case only 60 percent of Earth's surface was imaged, and at a coarser grid spacing of 30 to 90 metres.

Satellite pair captures detail from space

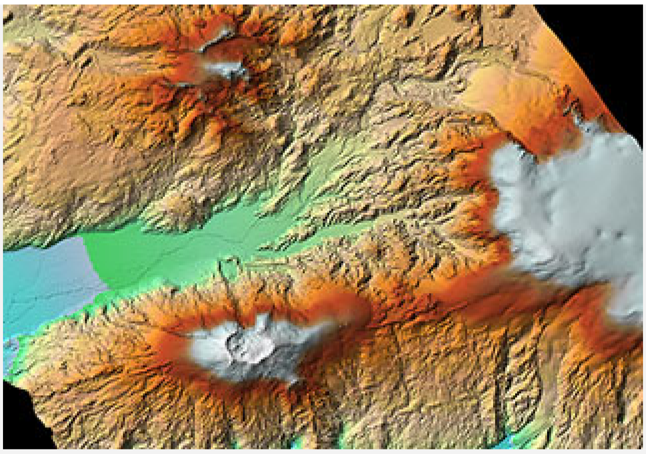
Comparison of the TanDEM-X elevation model with data acquired ten years previously by SRTM demonstrates the improvement in precision; the difference between the elevations measured today and the SRTM elevation data is represented in colour on a TanDEM-X radar image of the area surrounding Mount Etna. In the area of the actual crater especially and along the flanks of the volcano there are differences of up to 30 metres.



Data from TanDEM-X and SRTM compared

This is partly down to the greater accuracy of the elevations measured by TanDEM-X and TerraSAR-X; as they flew over at an altitude of over 500 kilometres, the two radar satellites were able to detect detail on Etna that SRTM could not resolve. The other reason is that the volcano and its environs have changed over the course of the years; for example, to the south (left in the image) a lava flow from 2001 can be seen. The modern images use a finer measurement grid and enable geodynamic processes to be monitored. To create the three-dimensional elevation model of the entire land surface of Earth, the two satellites will fly over and image every area multiple times.

New images of the Eyjafjalla volcano



Eyjafjalla volcano in Iceland

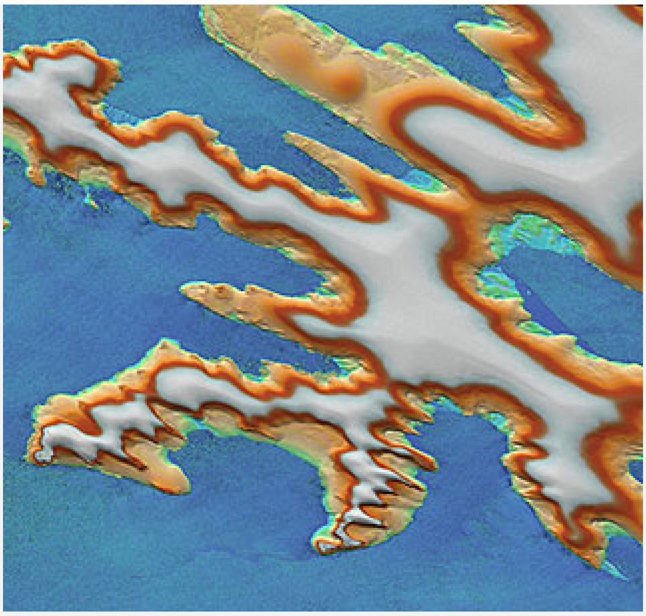
Changes to Icelandic volcano Eyjafjalla are also visible in the two satellites' new elevation model. As they flew overhead, TanDEM-X and TerraSAR-X got sight of the volcano – whose ash cloud caused flight bans across Europe in spring 2010 – and took precise measurements of the rugged landscape of rock and ice. The colours indicate the height of the terrain; the peaks of the volcanoes are shown in white, while the lowlands where the melt water flows in spring are shown in green. The volcano's crater, which was exposed from beneath the ice by its activity, is easily recognisable. To the right, another volcano, Katla, is 'slumbering' beneath a massive ice cap. The indentations visible in the ice indicate that this volcano is also active and that its ice cap is melting and collapsing as a result. Areas such as Iceland are being mapped in elevation for the first time by the radar satellites flying in formation, as the elevation model created by SRTM only reached 60 degrees latitude.

Patented discoveries

In creating three-dimensional digital elevation models with this level of accuracy, the German Aerospace Centre and Astrium GmbH have broken new ground: among other things they have patented processes used by the satellites to exchange data for the synchronisation of their radar pulse. These ensure that TanDEM-X and TerraSAR-X are precisely synchronised to the microsecond as they record the same areas.

Until now, DLR researchers had been letting the two satellites look at the Earth asynchronously, while they were still flying 20 kilometres from each other. In this way they created around 2000 elevation models of different regions. The elevation models being produced now, however, have been processed using data captured synchronously by the satellites. To automatically calculate the 3D elevation models, DLR has developed algorithms specifically for the mission. "Processing the bistatic pairs of data is a big challenge. Everything must match up exactly in order to reach this level of precision. All sorts of data can affect the algorithms, from synchronisation signals to millimetre-accurate orbital calculations," says DLR processing engineer Thomas Fritz. "All the systems involved, from calculating and planning the imaging to processing the elevation data have worked perfectly," confirms Birgit Schättler, who is responsible for commissioning the ground segment.

Future applications



A snapshot of land and water – Franz Josef Land in the Arctic Ocean

The adjustable flight formation and bistatic technique used by the two radar satellites make it possible for the data acquired to be analysed for a wide range of research on Earth. For example, bodies of water can be imaged without a problem for the first time. This involves the satellites synchronously generating an image of the area. In an initial successful test, DLR researchers observed the islands of Franz Josef Land in the Arctic Ocean. As if frozen in time, even the wave pattern of the sea can be recognised in the elevation model of the island group. Oceanography or climate researchers can also use such images to precisely analyse ocean currents, for example. In this image the highest areas are coloured white – the colour scheme thus roughly corresponds to the formation of ice on the islands.

Milestone on the way to a 3D elevation model of the Earth

The first images taken in close flying formation form the foundation of the mission objective; from 2011 the two satellites will spend three years systematically measuring the entire surface of Earth multiple times with great precision. The radar satellites can observe the 150 million square kilometres of Earth's surface around the clock, without interruption from the weather and clouds. The data acquired can be used for mapping the landscape, city planning and navigation, as well as for mission planning in disaster areas. It can also be used for scientific research in glacial, earthquake or volcanic regions.

Public-private partnership

The DLR is responsible for the scientific use of the TanDEM-X data, planning and executing the mission, controlling the two satellites and generating the digital elevation model. Astrium built the satellites and contributed to the cost of their development and deployment. As with TerraSAR-X, Infoterra GmbH, a subsidiary of Astrium, is responsible for the commercial marketing of the TanDEM-X data.

The TanDEM-X mission is being operated by the German Aerospace centre (DLR) with funding from the German Federal Ministry for Economics and Technology (Bundesministerium für Wirtschaft und Technologie; BMWi), in the form of a public-private partnership with Astrium GmbH.

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