A new map of Earth – in 3D and extremely precise

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DLR provides initial data for scientific use

This ambitious project started on 21 June 2010, when the radar satellite TanDEM-X set off into space to join its twin satellite, TerraSAR-X. Since then, these two German satellites have been orbiting Earth in an intricate formation and mapping its surface. Now, the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) is making the first elevation models of a new global topography for scientific use. Canyons in Australia's Flinders Ranges National Park, Canadian islands and the rugged volcanic landscape of Russia's Kamchatka Peninsula are revealed at a level of detail 30 times greater than anything seen to date. Over 800 scientists from 31 countries have already registered to work with these highly accurate elevation models. The complete and uniform terrain model is scheduled for completion by the end of 2015.

Precise measurement of Earth from orbit

Together with TerraSAR-X, TanDEM-X has already travelled 800 million kilometres at an altitude of 514 kilometres, scanning Earth's entire land surface more than twice. The satellites move around one another in a helical pattern, at times imaging Earth while separated by only 120 metres. This first formation flight by two satellites broke new ground. The researchers have to determine the distance between the satellites with a precision of just a few millimetres to permit the exact measurement of the height of points spread across the 150 million square kilometres of land surface on Earth. The clocks on board the satellites, designed to deliver precise measurements of how long it takes the radar signals to travel down to Earth and back again, are synchronised to within one billionth of a second. "Due to the significant improvements in accuracy, I am convinced that the elevation model delivered by TanDEM-X will represent a new reference for a variety of applications," explains Alberto Moreira, Director of the DLR Microwaves and Radar Institute and scientific head of the mission.

Elevation models for the 'simpler' regions are the first to have been calculated based on the data from TanDEM-X. These are regions that require data from no more than two measurement passes to compute the final elevation models, among them large expanses of Australia, North and South America, Russia and Africa. Then there are the "difficult, demanding areas with steep mountains, such as the Alps and the Himalayas, or rugged volcanic landscapes," says Moreira. In summer 2013, the DLR experts in the project team altered the trajectories of the two satellites, putting them in a clockwise orbit around one another. This changed the viewing direction from which the satellites observe Earth. The final data required for the new global elevation model will now be collected during the third and fourth observation cycles.

Mapping the Earth, piece by piece

Even while the satellites continued to scan Earth with their radar signals, an almost fully automated process took the images to create initial, small Digital Elevation Models (DEM) of regions measuring 30 by 50 kilometres. Even this preliminary work, which comprises over 350,000 DEM datasets, presents Earth in a precision down to two metres. A final stage of processing, ongoing since the end of 2013, involves taking these models and joining them to produce larger mosaics, generating not just 2500 terabytes of data, but creating a final model of over one fifth of Earth's land surface. "This is gradually creating a new topography of Earth," says Alberto Moreira. Radar technology offers a crucial advantage; the satellites are able to scan Earth largely independent of the weather conditions, and at any time – day or night.

There is no shortage of applications for the satellite images. For instance, the images can be used for hydrological runoff models and maps of potential flood areas, to reveal changes following volcanic eruptions and earthquakes and also to track the melting of glaciers and polar ice caps. The radar images are also important for mission teams operating on the ground following catastrophes, for instance to analyse flood zones or the destruction of infrastructure and buildings. When the global elevation model is complete, TanDEM-X will be used to demonstrate new technologies such as the detection of ocean currents or vegetation structures.

In total, four DLR institutes are involved in the mission: the Microwaves and Radar Institute directs and plans the mission; the Remote Sensing Technology Institute developed the fully automatic data processing system; the German Remote Sensing Data Center (DFD) takes care of the reception, processing and archiving of the measurement data, also mosaic production of the elevation models; and the German Space Operations Center (GSOC) controls and monitors the satellites themselves.

The final elevation models will be created and delivered in the form of 'tiles', each representing an area of approximately 100 by 100 kilometres or one degree of geographic latitude and longitude. Two of these tiles – Flinders Ranges in Australia and Badlands National Park in the United States – are now available as examples on the TanDEM-X science server.

Tandem-L – the next generation

Another radar mission is currently the subject of a feasibility study. The Tandem L mission would use two satellites equipped with digital antennas and deployable reflectors to orbit Earth and record its entire land surface twice a week – 100 times faster than TerraSAR-X and TanDEM-X. "This mission, which could feasibly start in 2020, will put us in a position to record the dynamic processes unfolding across Earth far quicker than we can at the moment, hence making an essential contribution to environmental and climate research," says Alberto Moreira. "The data provided as part of this radar mission will help us acquire a much greater understanding of our planet and its dynamic processes."

The mission

TanDEM-X is being implemented on behalf of DLR with funding provided by the Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie; BMWi) in the form of a public-private partnership (PPP) with Airbus Defence and Space. DLR is responsible for the scientific use of the TanDEM-X data, planning and implementing the mission, controlling the two satellites and for creating the digital elevation models. Airbus Defence and Space built the satellites and contributes to the costs of their development and use. A division of Airbus Defence and Space (formerly Infoterra GmbH) is responsible for the commercial marketing of TanDEM-X data.

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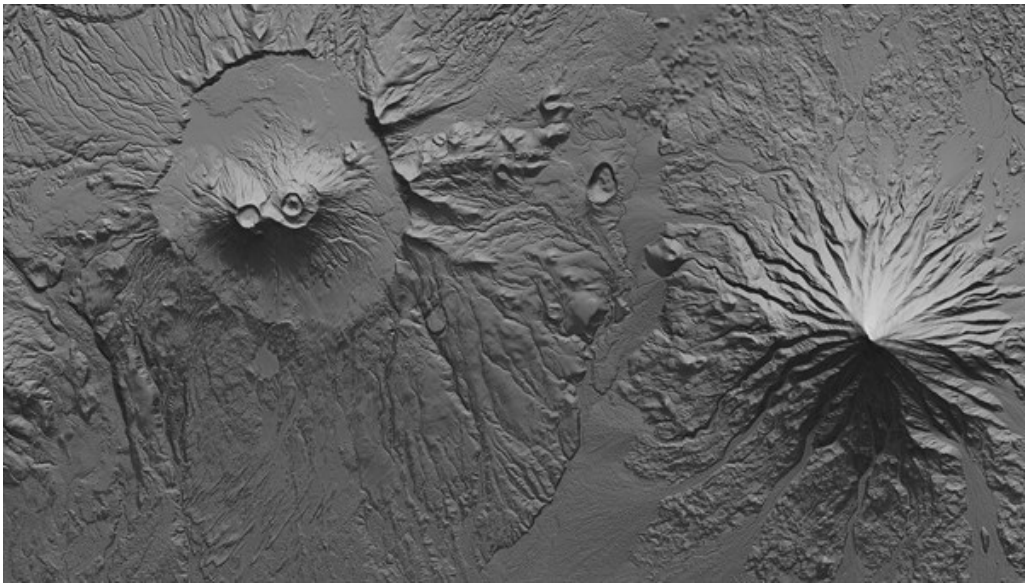
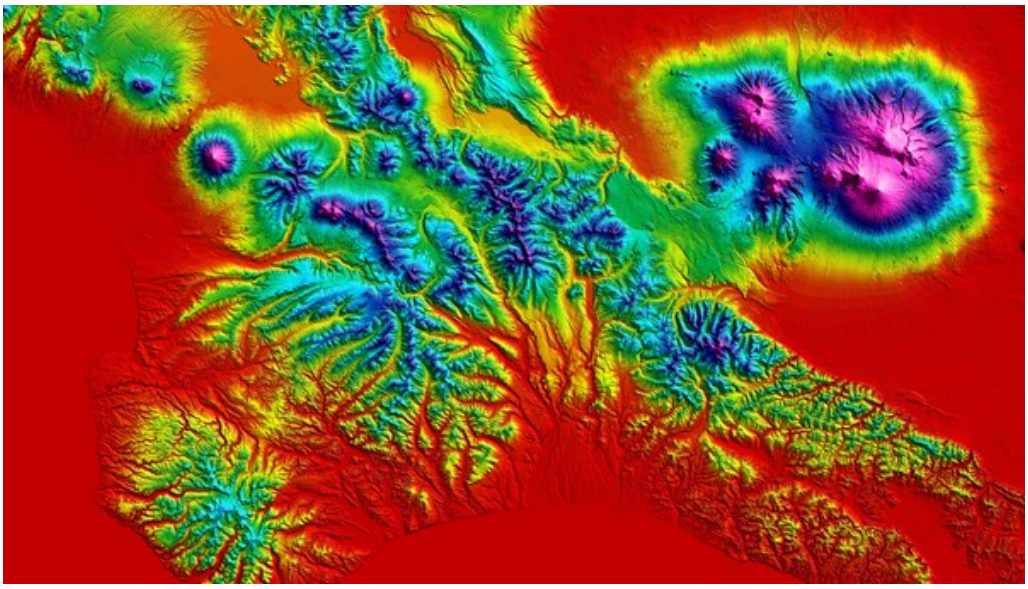
Elevation models of the volcanoes on the Russian Kamchatka Peninsula



The German Aerospace Center (DLR) is delivering the first final digital elevation models from the TanDEM-X mission for scientific use. Here, a detailed view around the Krasheninnikov Caldera and Kronotsky Volcano is presented as a shaded relief map. Maps of this kind using TanDEM-X data permit analyses of possible lava flow, used to determine endangered areas.

Credit: DLR.

TanDEM-X elevation model of the Kamchatka Peninsula



A digital elevation model from the TanDEM-X mission showing an area on the Kamchatka Peninsula in the northeast of Russia. Wide expanses of the Pacific plate press against the Eurasian plate, causing unique volcanic activity with an very high density of volcanoes. Of the over 160 volcanoes, 29 are currently active and six of them erupt on average each year. Kamchatka is known as the ‘Land of Ice and Fire’ due to its combination of snow and ice and its high level of volcanic activity. Its highest peak is the 4835-metre Kliuchevskoi. The simultaneous eruption of four volcanoes (Shiveluch, Bezymianny, Tolbachik and Kizimen) in January 2013 catapulted the region into the headlines. UNESCO declared the volcanic region of Kamchatka a Natural World Heritage Site in 1996.

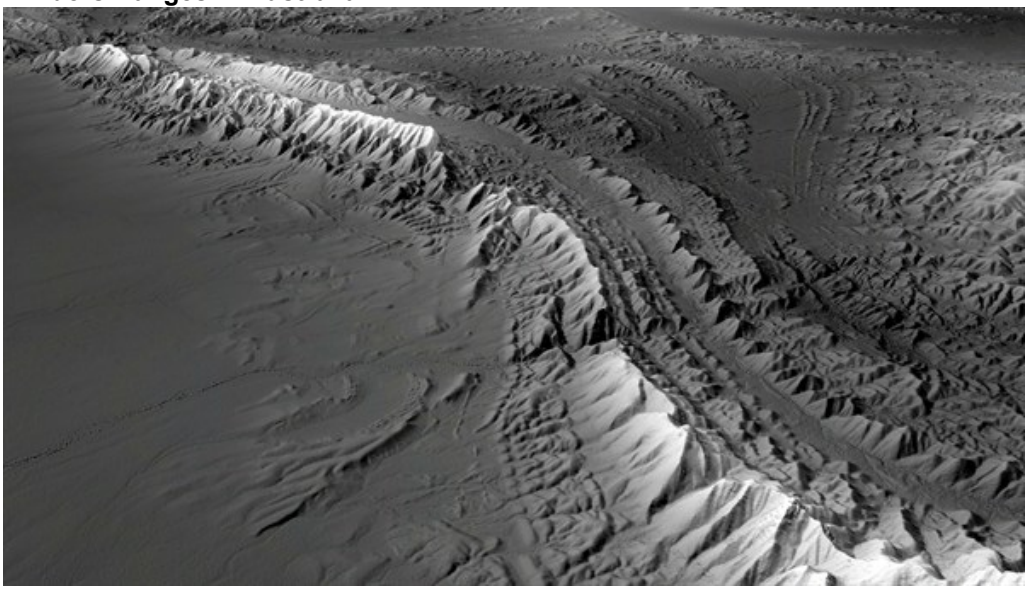
Credit: DLR.

Perspective view of the volcanic landscape in Kamchatka

Perspective view of the Krasheninnikov Caldera (in the foreground) and the 3528-metre Kronotsky Volcano, towering up as an almost perfect cone. On the left horizon, the Kliuchevskoi Volcano is visible; at 4835 metres, it is the highest elevation in Kamchatka. This view was computed using data from the German Aerospace Center (DLR) TanDEM-X satellite mission.

Credit: DLR.

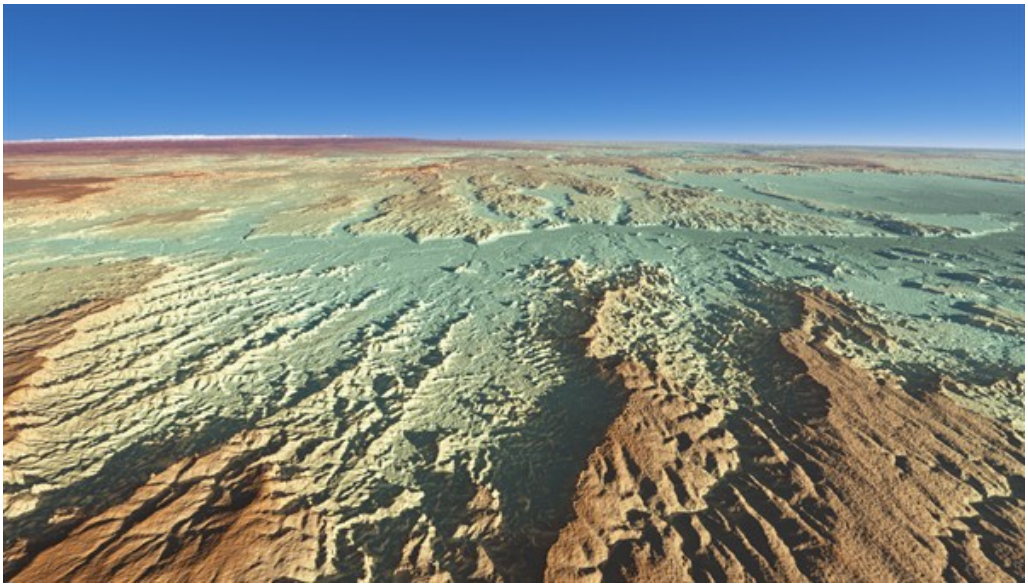
Flinders Ranges in Australia



This TanDEM-X elevation model by the German Aerospace Center (DLR) shows a mountain chain in South Australia with a height of roughly 1000 metres. It consists of rocks dating back up to two billion years. Rugged highland ridges, deep gorges and sunburned valley plains dominate this landscape.

Credit: DLR.

Badlands National Park in the USA



This three-dimensional elevation model, created using data acquired by the TanDEM-X radar satellite mission, shows the Badlands National Park in the south-west of South Dakota, a weather-beaten landscape whose complete lack of suitability for agricultural purposes earned it the name Badlands. The 1990 film Dances with Wolves with Kevin Costner in the leading role was largely shot in the National Park and surrounding areas.

Credit: DLR.

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