Sensing the Earth's Third Dimension

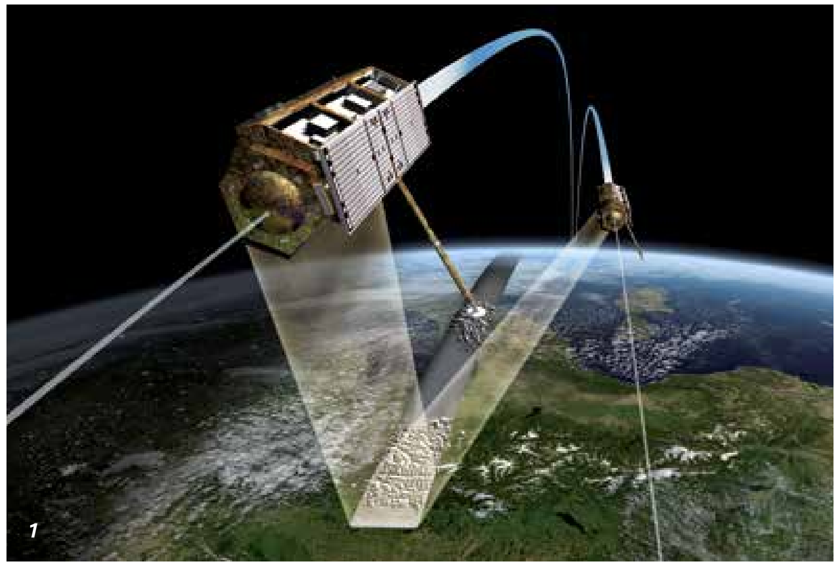
Interferometric Processing of TanDEM-X Data: Multi-Baseline Phase Unwrapping

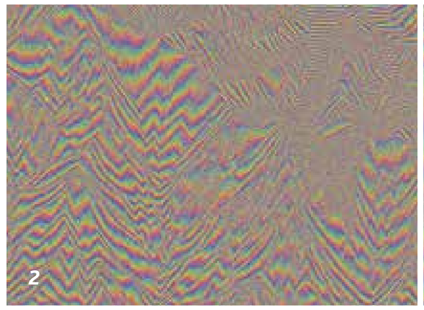
Germany's radar satellite project TanDEM-X is supposed to provide Interferometric Synthetic Aperture Radar (InSAR) data of the Earth's surface with unique precision and global coverage (Fig. 1). Generated by coherently combining two simultaneously acquired SAR images, the interferogram contains information about the third dimension of the imaged scene in its complex values. The height information, however, cannot be gained directly, due to the following problem: The interferometric phase can only be measured within a range of 360 degrees, and thus is ambiguous (Fig. 2, 3). An additional phase unwrapping step is required to obtain the unambiguous values. This procedure is considered as the most challenging link in the interferometric processing chain.

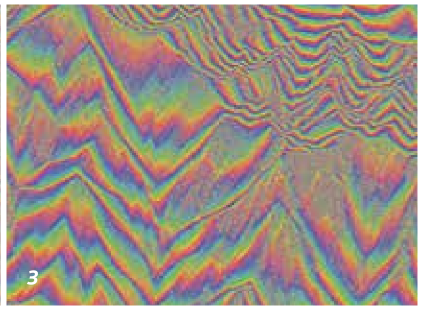
The research on Interferometric SAR and InSAR phase unwrapping started at ZESS in the mid nineties with contributions to the Shuttle Radar Topography Mission (SRTM) and the development of phase unwrapping algorithms using Kalman filtering techniques. The Kalman filter interprets the real and imaginary parts of the interferogram's pixel values as non-linear observations of the true, unambiguous phase (and terrain height) and fuses this information with information about the phase slope gained by frequency domain techniques.

This interpretation can be extended to multiple baseline interferometric sets (as provided by the TanDEM-X mission); in that way each interferogram adds two further observations per pixel. As a result, not only the range of ambiguity will be extended, but also the phase error noise will be reduced—the contradicting features of large and small baseline interferograms will be combined in an optimal way: Large baseline interferograms (Fig. 2) are characterized by a high fringe density and fine height sensitivity. They, however, show a reduced height of ambiguity, which makes phase unwrapping more difficult or even impossible in regions of steep terrain slopes. To increase the ambiguity height, the baseline length has to be shortened—at the cost of height sensitivity (Fig. 3). By fusing the information of two or more interferograms with different baselines, the requirements on height sensitivity can be fulfilled with the phase unwrapping robustness being preserved.

To further improve the phase unwrapping performance, the Kalman filter approach is able to process additional information like water maps and digital height models (Fig. 4).







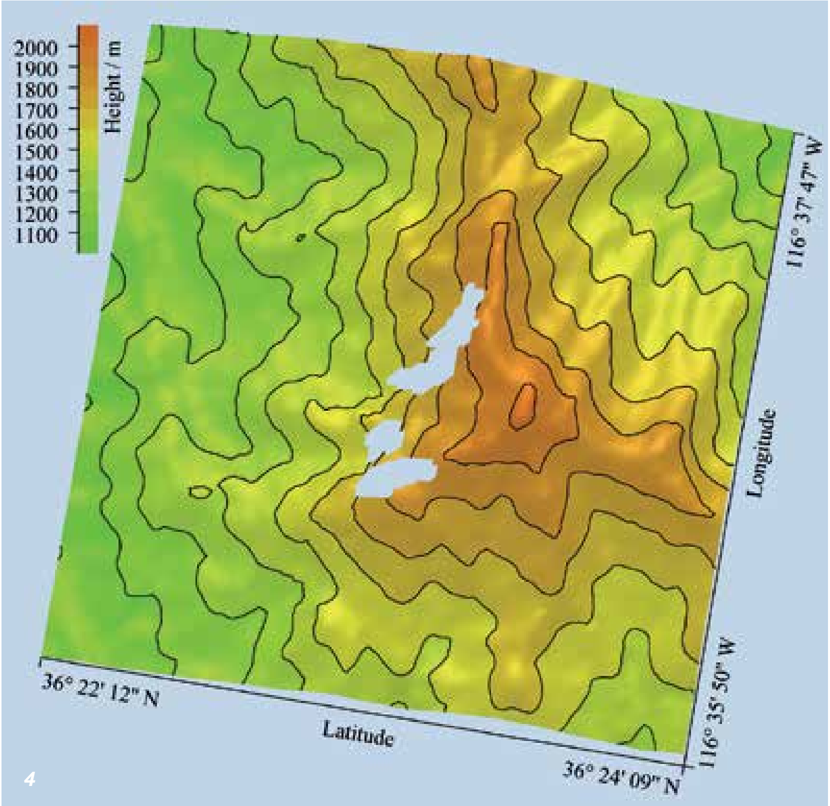


Fig. 1. TanDEM-X configuration. The radar satellites TerraSAR-X and TanDEM-X are flying in a close formation. In the standard bistatic mode, one satellite illuminates the scene while both satellites receive the radar echoes. Image: DLR, CC-BY 3.0

Fig. 2, 3. Interferometric phase of a scene located in Death Valley, U.S.A. The larger baseline of the left interferogram results in a higher fringe density with an improved height resolution at the cost of a smaller ambiguity height compared with Fig. 3. Data: © DLR.

Fig. 4. Digital Elevation Model (DEM) of the imaged scene. The elevation data provided by the Shuttle Radar Topography Mission (SRTM) are used as reference and potentially as additional information to be processed by the Kalman filter.

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