Snow Accumulation, Melt Rates and Glacier Mass Balance Measured by TanDEM-X

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Glacier mass balance, apart from being a sensitive climate indicator, is an important input for glaciological models. Defined as the mass difference of snow accumulation during winter and the amount of melted snow and ice during summer, measured as mass change per time, it indicates directly advance or retreat of a glacier.

Traditional methods to determine the mass balance are based on snow depth measurements by means of probing and snow pits together with measuring the ablation rate derived from the exposed length of a stake which was drilled deep enough into the ice before melting [1]. Covering large glacier areas by such kind of point measurements is a tremendous amount of work, therefore new methods based on GPS measurements, Lidar-scans, optical stereography and comparison of digital elevations models (DEM) are used as a complementary source of data [2]. The DEM-based methods are challenging as typically the accuracy of DEMs is in the same order of magnitude as accumulation and ablation rates. The TanDEM-X satellite mission [3, 4], build to create a globe-spanning digital elevation model based on single- pass SAR-Interferometry provides a spatial resolution on the meter scale and a relative vertical resolution of about 1 meter, depending on system configuration. The height-sensitivity can be further increased to the submeter scale by measuring the height difference between two TanDEM-X acquisitions from the same orbit which is enough to be sensitive the snow accumulation.

The satellite formation TanDEM-X uses an X-band SAR system with a frequency of 9.65 GHz to avoid too much penetration into the underlying ground. The penetration into snow is a crucial parameter and can reach a couple of meters for very dry and cold snow [5]. However, it quickly changes as soon as the moisture content within the snow volume increases above a fraction of a percent [6] where the penetration depth is not more than few cm. Here, I will present results from a TanDEM-X based study of the Great Aletsch Glacier. Multiple digital elevations models obtained by single-pass SAR-Interferometry (InSAR) have been calibrated by a large number of reference points to get a vertical resolution on the sub-meter scale. A time-series of the derived DEMs between April 22, 2011 and May 31, 2013 show not only the volume change of snow and ice between spring and autumn, but can also be used as a proxy to estimate the penetration depth into cold winter snow at high altitude. As the spatial resolution of the TanDEM-X system is exceptionally high, high-resolution snow accumulation maps can be derived across all important glaciers of the Aletsch Area.