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Local ionospheric corrections derived from GNSS - A case study with TerraSAR-X

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Germany's synthetic aperture radar (SAR) satellites TerraSAR-X and TanDEM-X belong to the latest generation of radar satellites which have moved radar remote sensing to a new level. Besides being an all weather and all day imaging system, radar remote sensing offers various advanced methods like SAR interferometry or persistent scatterer interferometry that exploit magnitude and phase information of the radar signal. In order to achieve centimeter to millimeter accuracy with these advanced methods, all occurring error contributions (internal signal delay, orbit, troposphere, ionosphere, solid earth tides, loading effects, ...) have to be taken into account by applying appropriate corrections.

Within the project DLR@Uni funded by the German Helmholtz Association HGF, an experimental framework at Wettzell station has been set up to perform a detailed analysis of all the corrections required for high resolution radar satellites and to achieve the goal of a 1cm precision level for absolute radar coordinates. This framework involves a 1.5 meter corner reflector (CR), a 1.5 year series of data takes from TerraSAR-X, and it makes use of the multi-sensor environment of Wettzell station. Besides Satellite Laser Ranging (SLR) for orbit assessment and the local geodetic network to control the CR reference coordinates, the Wettzell GNSS receivers are used for generating tropospheric and ionospheric corrections. By comparing the reference radar times (range and azimuth) available from geodetic survey with those from the TerraSAR-X data takes, the quality of the corrections can be investigated.

Although often being considered negligible for X-band observations, the conducted experiment has clearly shown the necessity for ionospheric corrections, if the capabilities of current SAR satellites are to be fully exploited. For every TerraSAR-X data take, the ionospheric impact was derived from the geometry-free linear combination of the GNSS measurements and modeled in terms of vertical Total Electron Content (vTEC). By mapping this locally observed ionosphere to the TerraSAR-X range geometry and performing this procedure for each pass, a significant improvement in the comparison of the ranging times was achieved. In particular the 30 seconds temporal sampling of the regional vTEC modeling gives an advantage over the GNSS based global vTEC maps issued by the Center for Orbit Determination in Europe (CODE), which are sampled by 2 hours.

Another important element regarding ionospheric corrections is the vertical extent of the ionosphere. Like many other low earth orbiting satellites, TerraSAR-X orbits are still within the ionosphere, and thus a separation into top-side and bottom-side ionosphere is required. For doing so, an approach for estimating the top-side vTEC from the TerraSAR-X dual-frequency GPS receiver data was implemented. As a result, the procedure yields top-side reduction values for the total ionospheric corrections obtained from ground-based GNSS. Although being still experimental, this concept already indicates its usefulness during times of increased ionospheric activity.

After considering the ionosphere by the outlined methods and taking into a account all the other contributions for the TerraSAR-X SAR system, a range measurement accuracy of 1 cm was achieved for the CR in Wettzell.