FORMATION FLYING FOR ALONG-TRACK INTERFEROMETRIC OCEANOGRAPHY – FIRST IN-FLIGHT DEMONSTRATION WITH TANDEM-X

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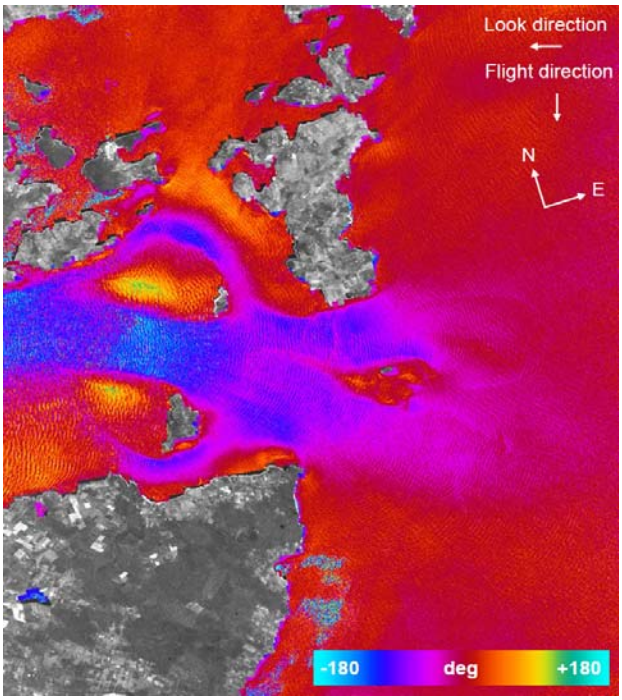
ABSTRACT

The TerraSAR-X mission (TSX, launched on 15 June 2007, operated in 505 km, sun-synchronous, low Earth orbit) provides high-resolution Synthetic Aperture Radar (SAR) data to both science and commercial users. At 21 June 2010 an almost identical satellite, TanDEM-X (TDX), was launched in order to form the first configurable SAR interferometer employing formation flying with TSX. The main objective of the common TanDEM-X (TerraSAR-X add-on for Digital Elevation Measurement) mission is to generate a global digital elevation model (DEM) with unprecedented accuracy as the basis for a wide range of scientific research as well as for commercial DEM production. In order to collect sufficient measurements for a global DEM, three years of formation flying are foreseen with flexible across-track baselines ranging from 150 m to few kilometers.

Beyond that primary mission objective, TanDEM X provides a configurable SAR interferometry test bed for demonstrating new SAR techniques and applications. In particular, TanDEM-X offers a unique chance to measure very slowly moving sea ice as well as ocean currents by means of Along-Track Interferometry (ATI). But, due to limited acquisition capacity the secondary mission objectives cannot be realized before the completion of global DEM acquisition. Instead, the third or fourth year of formation flying will be dedicated to a variety of scientific interferometric experiments.

Because of the fact that space-borne SAR ATI with along-track baselines in the order of 50 m has not been demonstrated yet, there is a strong interest in preliminary ATI experiments with TanDEM-X to validate the methods foreseen for both SAR acquisition and processing. In order to demonstrate the possibilities and limits of the ATI method for ocean current measurements a first set of ATI experiments was performed in February and March 2012 in the background of the on-going TerraSAR-X and TanDEM-X missions. At that time the ground-controlled formation geometry comprised of minimum satellite distances of 150 m in the plane perpendicular to flight direction and favorable along-track separation of 10 to 80 m in the latitude regions of interest.

The first section of the paper recalls the formation flying concept (i.e. the relative eccentricity / inclination vector separation method) and the guidance, navigation and control approach implemented for TanDEM-X. It further elaborates on the constraints imposed by across-track interferometric radar operation and safety measures, and the formation control requirements imposed by along-track oceanography interferometry are derived. In contrast to the coarse 200 m along-track accuracy required for routine across-track interferometric global DEM acquisition, the along-track control window desired for ATI oceanography is only ± 10 m. This is quite challenging for ground-based control with typically 30 m RMS along-track control accuracy and maximum 100 m control error. Flight results of the first ATI campaign for ocean surface current measurement at the Orkney Islands are presented, demonstrating the high potential of TanDEM-X for mapping water surface currents, which has applications in the field of renewable energy and climate research.



Color-coded interferometric phase of a TanDEM-X acquisition (Feb. 26th, 2012 6:41 UTC) of the "Pentland Firth" tidal current between Scotland and the Orkney Islands. The main surface movement is in westward direction. Land areas have been masked with the grey-scale SAR image. The phase can directly be converted into surface velocity component (perpendicular to flight-direction) yielding a maximum velocity of 3 m/s.

TanDEM-X ATI campaigns will become more flexible at the time when global DEM acquisition is finalized and formation geometries can be adjusted to the needs of oceanography and other secondary mission objectives. Instead of daily ATI acquisitions several scenes per orbit will then be acquired demanding for more frequent formation control that can not be achieved with sufficient accuracy from ground. Employing the TanDEM-X Autonomous Formation Flying (TAFF) experiment, the formation control cycle will be reduced from 24 to 8 hours. TAFF makes use of nearly permanent onboard availability of real-time GPS-based relative navigation and autonomously plans and executes in-plane formation keeping maneuvers. It has successfully been validated in March 2011 and the next TAFF experiment is foreseen for May/June 2012. Based on the achieved TAFF in-orbit characterization a typical ATI scenario software simulation will be presented in the second part of the paper.

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