Abstract

The Global Navigation Satellite System (GNSS) has revolutionized positioning, navigation and timing, becoming a fundamental infrastructure in everyday life and being even more relevant in the future due to the GNSS market (GNSS-enabled smartphones, personal navigation devices, precise farming, GNSS-guided autonomous robots, self driving cars, etc.). Aside from well-known civilian and commercial applications, in the recent years, the GNSS, in particular Global Positioning System (GPS) has proved its capacity to monitor atmospheric water vapour, one of the major meteorological parameters, with an accuracy that is comparable to the measurements of other conventional meteorological sensors.

Water vapour plays a crucial role in most atmospheric processes, however, it is not currently observed by the meteorological sensors with desirable spatial resolution, which is a knowledge gap and important source of errors in numerical weather forecast models, particularly related to severe weather phenomena. Regarding this aspect, GNSS as some advantages in comparison to conventional meteorological sensors: low maintenance costs, continuous operating system, high sampling, near-real time response and continuously increasing spatial coverage.

The establishment of GNSS meteorology as an operational atmospheric sounding technique has been a focus of a number of major European Projects and nowadays the provision of GNSS tropospheric products was established as a standard sounding technique. Despite this outstanding achievement, the accuracy of near real-time products based on ultra-rapid GPS orbits aimed at contributing for now-casting and the derivation of 3D (or 4D considering the temporal dimension) water vapor distribution through tomographic techniques still remains a challenging task.

The main objective of this work was to improve current tomographic analysis methods based on GPS observations, using parallelized Algebraic Reconstruction Techniques (ART) to estimate the 3D field of tropospheric water vapor in a region, in order to evaluate its high spatial-temporal variability in a 4D reference (spatial 3D plus time). The methodology to perform the GNSS tomography was developed from scratch at Space and Earth Geodetic Analysis Laboratory (SEGAL) a polo of Dom Luiz Geophysical Institute (IDL) at University of Beira Interior (UBI). Specifically, a software package, SEGAL GNSS Water Vapor Reconstruction Image Software (SWART) was developed and applied to a set of case studies.

Based on GPS observations from a network of GPS receivers, the 3D and 4D water vapor distribution within the troposphere can be determined by tomographic techniques (inversion techniques). This inversion is a typical ill-posed problem, which in general does not have a stable solution. The quality of the GPS tomography is affected by a number of factors such as the spatio-temporal distributions of the observations, the reconstruction method, the initial field, terrain morphology, etc. Independent observations can help to constrain the a priori GNSS tomographic field. Radiosonde data, which provides information on the vertical distribution of moisture in the troposphere, are often used for that purpose.

This work focuses on the contribution of GNSS dense networks as an efficient tool for Water Vapor Tomography. The main goals are to improve the use of GNSS tomography in real-time applications, where the performance of the SWART and the availability of real and near real-time products are crucial, and to improve the use of GNSS in high resolution numerical weather prediction models. These improvements will lead to the integration of these data into numerical prediction models in a routine procedure.

Keywords

GNSS, Tomography, Water Vapor, Meteorology and Real-time.