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Preliminary studies on the integration of GPS and ECMWF to derive high spatial and temporal resolution water vapor maps

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The development of Global Navigation Satellite Systems (GNSS), since middle 1980s, has led to a significant change in the life of world’s community. One of their most important and known application for the mass market is navigation systems for automobiles but also for aircrafts and ships. They play an important role also in several technical and scientific activities such as surveying, mapping and geographic information systems (GIS). In geophysics, the high precision measurements of multiple stations can be used to find strain and ground movement. Actually the most common system, operational and globally available, is the US Global Positioning System (GPS).

Recently studies are in place to evaluate GPS application for meteorology. The atmosphere affects the GPS radio signals transmissions from space since the index of refraction is variable along the ray path. This index is a function of pressure, temperature, and moisture so GPS can be directly used for sensing properties of the atmosphere. Water vapor, located in the lowest layers of the atmosphere, significantly affects the GPS signal propagation velocity and, at the same time, plays an important role in atmospheric processes, from global climate change to micrometeorology. The information derived from GPS, which allows to quantify water vapor, is the Zenith Total Delay (ZTD) that summarizes the increase of the optical path length between GPS satellites and receiver. It has two components: the Zenith Hydrostatic Delay (ZHD), primarily affected by hydrostatic gasses, and the Zenith Wet Delay (ZWD), directly related to water vapor. While the ZHD can be modeled with high accuracy, the ZWD has a large temporal and spatial variability so it is rather difficult to model and predict.

The comparison between water vapor estimated from GPS ZTD and the results obtained from other well-known technics (radio-sounding with water vapor radiometers, ground or space-based, or Numerical Weather Models) has shown the reliability of GPS data for the estimation of this atmospheric parameter.

This work describes the results of preliminary studies on the integration between GPS and European Centre for Medium-Range Weather Forecasting (ECMWF) data to derive high spatial and temporal resolution water vapor maps. The data from ECMWF, characterized by high spatial resolution but low temporal resolution (3 hours), can be used to calculate the covariance function, which quantify their spatial variability. Knowing this function, ZTD values obtained from GPS, which have a low spatial resolution but high temporal resolution (15 minutes) could be regionalized and high resolution water vapor maps, almost in real time, could be obtained.

The work has been developed in the contest of a three year international program between Italy and Argentina (2011-2013). In the first two years, different analysis have been conducted, focused on the assessment of the capabilities of the SIRGAS permanent network, which is the densification of the International Reference Frame (ITRF) in South America and Antarctic continent. The ZTD derived by the SIRGAS permanent network has been compared with those obtained from the International GNSS Service (IGS) products and from the radiometer on Jason-1 altimeter satellite. The results showed the reliability of SIRGAS permanent network. The accuracy of SIRGAS ZTD values was analyzed also in terms of consistency with ZTD values obtained from the ECMWF ERA-Interim database. ERA-Interim is an “interim” reanalysis to the period 1979-present of all the data stored in the ECMWF database.

The work done consists in a detailed study of the consistence of the results (in terms of ZTD) obtained from ECMWF and GPS, considering two small areas of South America. The areas chosen were characterized by different features (e.g. orography) in order to better understand their influence on the spatial variation of ZTD. A procedure is also proposed to optimize the management of data.

Keywords: GPS meteorology, high resolution water vapor maps, ECMWF