NUVEM - New methods to Use GNSS Vapor Estimates for Meteorology of Portugal

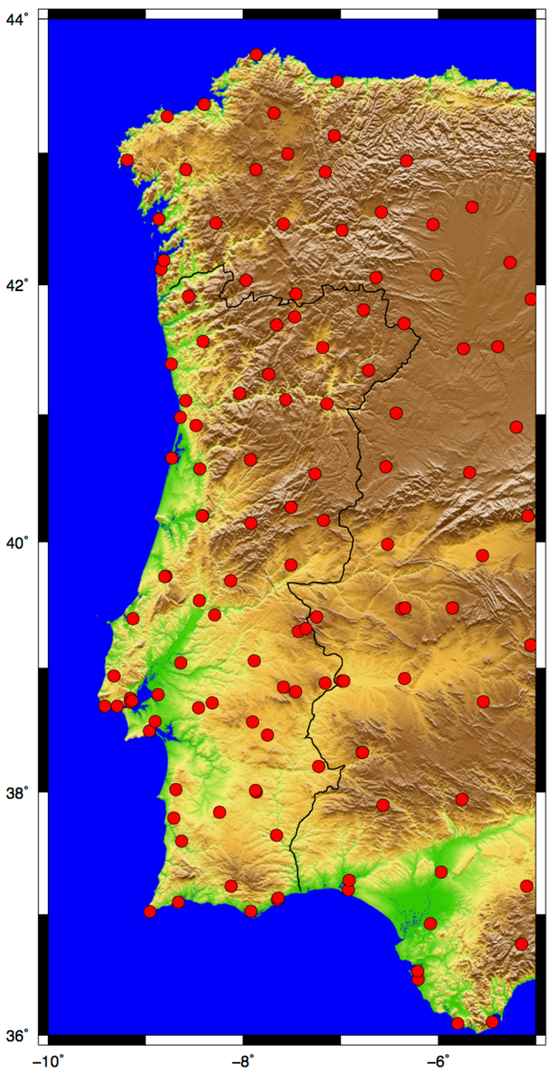
Hugo Valentim[1]
[(1)]SEGAL (Univ. Beira Interior/IDL), Covilhã, Portugal
email: hugo.valentim@segal.ubi.pt

ABSTRACT

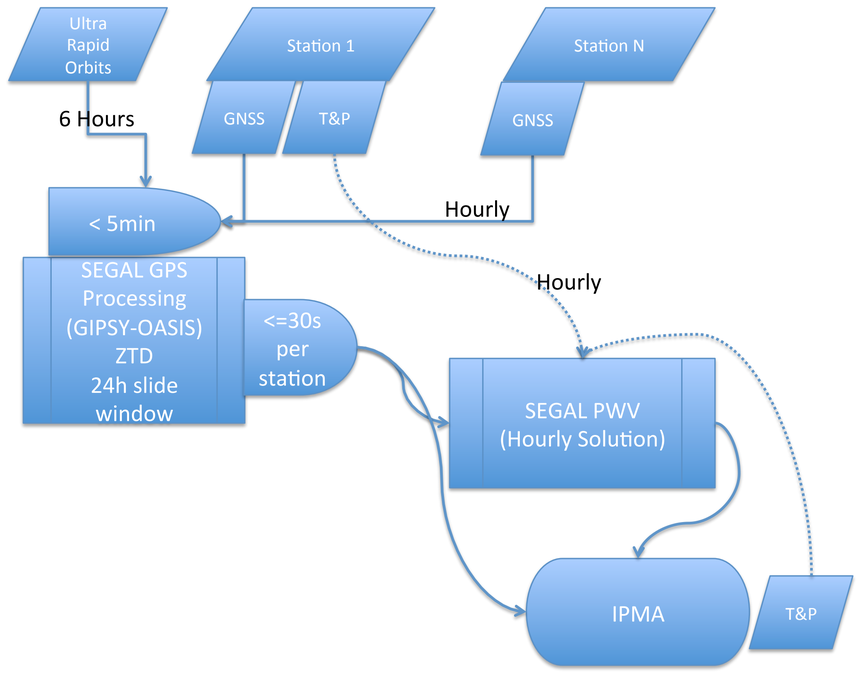
Measuring the quantity and distribution of water vapour is a difficult task but of great importance for accurate weather prediction and climate studies. The amount of water vapour can change rapidly on very short time-scales and is often associated with extreme weather, such as thunderstorms. Extreme weather events are typically difficult to predict and track with current operational meteorological systems but have the potential to cause great humanitarian and economic damage to the public. Water vapour influences the signal from GNSS (Global Navigation Satellite Systems) satellites. This property enables us to use GNSS observations to estimate the amount of water vapour that is present in the atmosphere. This observation technique for use in very short range weather forecasting (nowcasting) has improved considerably in the last few years due to:
a) increased frequency by which raw GNSS data are provided (hourly uploads and/or real-time data streaming);
b) increased number of ground-based stations of the GNSS networks in the last 5 years improving the coverage globally, including Portugal;
However, in the country GNSS data are currently not yet used for operational meteorology. The objective of this project is to include GNSS-PWV estimates in the weather forecast of Portugal, especially in the decision process of warning dissemination of severe weather situations. To achieve such objective, the NUVEM project is divided in two major components:
a) development and implementation of methods to compute accurate estimates of ZTD (Zenith Total Delay) and derived PWV (Perceptible Water Vapour) in near real time.
b) integration of these estimations in the now casting operations done at IPMA (Portuguese Meteorological Service). The NUVEM team at SEGAL (University of Beira Interior) is already computing ZTD using daily files. These are computed with a delay of about two weeks in order that precise satellite orbits can be used in the computations and are converted into PWV on an operational basis. The goal of this project is to develop and optimize the procedures already implemented in order to obtain reliable PWV estimates few minutes after each hour when the GNSS data becomes available for all continuous GNSS stations in Portugal and some in Spain (around 140 stations in total, cf. Figure 1). In this respect, methodologies will be optimized to obtain the GNSS data directly from the providers. The solutions will be validated using internal and external values and the computed solutions will be transferred in a timely manner to IPMA Operational Center. The validation of the derived estimations using robust statistics is an important component of the project. Noise models and outlier detections will be implemented and solutions provided by other sensors (like radio-sondes) will be used to have external validations. At IPMA, the goal is to implement the operational use of GNSS-PWV to assist weather nowcasting in Portugal. Maps of GNSS-PWV will be automatically created and made available to the forecasters, in order to assess their value when compared to other sources of meteorological information. Nowcasting relies on the timely availability of reliable observations; when they differ from the latest of meteorological information. Nowcasting relies on the timely availability of reliable observations; when they differ from the latest available forecasts they provide important new information to correct the forecast outlook. In addition, a regular comparison with available forecast model results will be collected to build statistics of observation minus model departures. This will be the first step towards the assimilation of GNSS-PWV estimates at IPMA numerical weather prediction (NWP) models. Finally, SEGAL's archive will be used to select a few recent cases of severe weather (e.g., 18-19 January 2013), where GNSS-PWV will be compared with NWP model results.
The collaboration with the UK Met Office where such operations are being implemented and coming close to operational level is also an additional guarantee this project will reach the proposed goals.
The NUVEM project will also contribute for the active participation of Portugal at the COST Action ES1206 - Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate (GNSS4SWEC) where the Principal Investigator is the Portuguese Representative and several members of the NUVEM research team are participating. In this respect, the NUVEM project will also evaluate the possibility that Portugal become a node in the European operational network of GNSS-PWV providers.

PLAN & METHODS

Three tasks covers all activities planned in the framework of the NUVEM project in order to reach the ultimate goal of this project: develop the capabilities in Portugal to operationalize the use of GNSS-PWV estimates for weather nowcasting (and prepare future assimilation for regional models). Such capabilities are at this moment completely lacking in Portugal. Task 1 will be focused on the optimization of the computation of hourly estimates of ZTD (and derived PWV) to be submitted to IPMA where, in the framework of Task 2, they will be used to support the weather nowcasting for the territory of Portuguese Mainland. Finally, Task 3 will focus on summarizing and on the dissemination of the conclusions of the project towards the automatic operationalization of the entire process (from data collection to the use of the solutions by IPMA).
This poster focuses on the Task 1 activities.

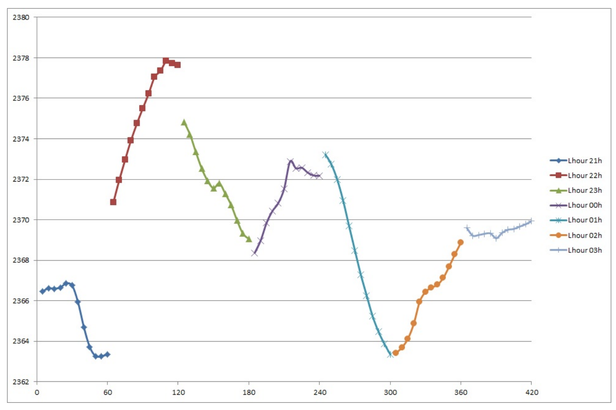


SEGAL is already routinely computing, using the GIPSY-OASIS software package, daily estimates of PWV for around 700 stations globally distributed (around 200 in Iberia) in the framework of several projects, see for example Adams et al. [2011]. Such estimates are obtained as a parallel product of the accurate computation of the station coordinates with respect to the global reference frame (currently ITRF2008), which is done with an average delay of two weeks (after the precise orbits provided by IGS – International GNSS Service become available). SEGAL is making full use of the resources available at Department of Computer Sciences of UBI by distributing the processing of the GNSS observations by a pool of 30 computers, which is managed centrally by one dedicated server. Additionally, one computer is reserved for the dedicated processing of GNSS data for tomographic studies in the framework of the PhD programme of André Sá (member of the NUVEM team). In the framework of Task 1, the objective of NUVEM project is to adapt and develop the current configuration in order that ZTD (and PWV) estimates will be computed in NRT (Near Real Time), i.e., few minutes after each hour for all available stations in
Portugal:
RENEP [http://www.dgterritorio.pt/cartografia_e_geodesia/geodesia/redes_geodesicas/renep/],
SERVIR [http://www.igeoe.pt/servir/servir.asp];
and neighboring networks in Spain:
IGN [http://www.fomento.es],
Galicia [http://www.cartogalicia.com/],
Castilla and Leon [http://gnss.itacyl.es],
Extremadura [http://194.224.247.162:8080/WebExtremadura/],
Andalucia [http://www.juntadeandalucia.es/obraspublicasytransportes/redandaluzadeposicionamiento/rap/].



For this project, the collecting and processing will be changed into an hourly routine. Sometimes the data will be incomplete due to failures of the internet connection or due to instrument failure at the GNSS station. Automated scripts need to be written that can decide if there is enough data to include for the station. Besides the GNSS data collected at the stations, it is necessary to use the Ultra-Rapid orbits provided by the International GNSS Service which are given every six hours and the surface pressure and temperature at site location. The flowchart of the processing is shown in Figure above.
Although the estimation of ZTD from GNSS has already been studied by various research groups, the optimal analysis strategy is still an open question. The Ultra Rapid orbits are released every six hours implying that for our processing we are using orbits that are predicted 3 up to 8 hours in the future. To obtain the best results, not only the last hour, but the last 24 hours are analysed. The accuracy of the estimated ZTD will deteriorate when the orbits are increasingly based on prediction. In post-processing mode we can reprocess the data using the precise IGS orbits and investigate the sensitivity of Ultra Rapid orbits on the final results.
We will also include the atmospheric tides S1 and S2 in the GIPSY-OASIS analysis. These has a period of 24 and 12 hour and in Portugal an amplitude of around 0.5 mm. Although small, their period coincides with the temporal variations in water vapour and therefore they should be removed to avoid that they contaminate the ZTD estimation.
To convert the ZTD values into PWV estimates, one needs surface pressure and surface temperature values. Unfortunately, these are only available at a few GNSS stations in Portugal. Therefore IPMA will provide these meteorological values from their atmospheric model and send them to SEGAL.
The output of this task is a hourly list of ZTD and PWV estimates in World Meteorological Organisation accepted BUFR format and in simple ASCII format (SINEX).
To ensure that the collection and processing of GNSS data occurs in an operational manner, all steps will be fully documented in order that future improvements and adaptations to changing circumstances can be performed in a quality controlled manner. The objective is that the GNSS analyses can continue after this project has finished with the minimum amount of human intervention.
Related to the operationalization of the GNSS analysis process, automated scripts that check the availability and correctness of the data will be produced. Besides the aforementioned check about the quantity of data, it will be checked if the noise levels are within acceptable levels, if there are offsets and if there our outliers that need to be removed. These statistical tests will be performed using appropriate noise models that take into account the temporal correlation that exist in the data. It is envisaged that the process can start to run in operational mode in the last two months of the project, which will allow fine tuning of the scripts.
At SEGAL, all GNSS data for Portugal are being archived. The data of 18 and 19 January, when Portuguese Mainland was hit by a severe storm, will be reprocessed and the ZTD, converted into PWV values, will be analyzed by the NUVEM team as a special case study of the benefits to have GNSS-derived tropospheric products in extreme weather situations.

Besides the GNSS data, the processing requires the regular download of the Ultra-Rapid Orbits provided by IGS [http://www.igs.org], which are the most consistent satellite ephemerides available (the PPP strategy requires that satellite orbits and clocks will be kept fixed during the processing). They are uploaded 4 times per day (03hUTC, 09hUTC, 15hUTC, 21hUTC) and they contain 48h worthwhile of orbits (24h estimated based on observations before the central time, which are 00hUTC, 06hUTC, 12hUTC, 18hUTC, respectively, and 24h of predicted orbits). Therefore, when processing the 24h windows, the part of the orbits that have been predicted varies between 3h and 8h, which covers always the last hour, which is the one that we are interested in.
We will investigate how we can constrain the estimated solutions in order to minimize the jumps that we obtain when we are using the 24h-sliding window to extract the last hour. Figure (right) shows an example (using precise orbits) of estimated hourly solutions using a 24h-sliding window. Although the jumps are not very large: the daily variation for that particular day is 120mm whereas the major jump is 8mm, such jumps should be minimized (preferably eliminated) in order to have continuity on the delivered solutions.



GNSS4SWEC 2014 Summer School, Varna, Bulgaria, September 2014

This work is being carried out in the framework of the NUVEM(EXPL/GEO-MET/0413/2013) and SMOG (PTDC/CTE-ATM/119922/2010) projects, funded by the Portuguese National Science Foundation (FCT).