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# The use of products from ground-based GNSS observations in meteorological nowcasting

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Heavy rainfall is often focalized in areas of moisture convergence. A close relationship between precipitation and fast variations of vertically-integrated water vapour (IWV) has been found in numerous cases. Furthermore, a latency of several tens of minutes of the precipitation relative to a rapid increase of the water vapour contents appears to be a common truth. Therefore, continuous monitoring of atmospheric humidity and its spatial distribution is crucial to the operational forecaster for a proper nowcasting of heavy rainfall events.

Radiosonde releases yield measurements of atmospheric humidity, but they are very sparse and present a limited time resolution of 6 to 12 hours. The microwave signals continuously broadcasted by the Global Navigation Satellite System (GNSS) satellites are influenced by the water vapour as they travel through the atmosphere to ground-based receivers. The total zenith delay (ZTD) of these signals, a by-product of the geodetic processing, is already operationally assimilated into numerical weather prediction (NWP) models and has positive impact on the prediction of precipitation events, as it has been reported after the analysis of parallel runs. Estimates of IWV retrieved from ground-based GNSS observations may also constitute a source of information on the horizontal distribution and the time evolution of atmospheric humidity that can be presented to the forecaster. Several advantages can be attributed to the ground-based GNSS as a meteorological observing system. First, receiving networks can be built and maintained at a relatively low cost, which it can, additionally, be shared among different users. Second, the quality of the processed observations is insensitive to the weather conditions and, third, the temporal resolution of its products is very high. On the other hand, the current latency of the data disposal, ranging between one and two hours, is acceptable for the NWP community, but appears to be excessive for nowcasting applications. Finally, it is not currently possible to obtain data from receivers set over sea, either on vessels or on buoys, because of the background motion, although there is ongoing work to process data recorded on offshore oil platforms.

At the Spanish Meteorological Agency (AEMET), the near-real-time map of IWV estimates retrieved from GNSS measurements in the west Mediterranean region is operationally built and presented to the operational forecaster. On average, nearly half of the atmospheric water is between sea level and a 1.5-km height. Therefore, the horizontal distribution of water vapour is strongly modulated by the topography. In the Iberian Peninsula, an area of complex orography, the penetration of shallow air masses of maritime origin through passes underneath mountain ranges is a common mechanism of moistening the air of inland regions. This fact makes difficult to build a realistic map of IWV without a high-resolution network of GNSS receivers. A method, based on the division of any IWV observation by a local statistical mean, is used to smooth the dependence on height of the magnitude to be interpolated. The new magnitude is contoured every 15 minutes following a 1DVAR assimilation scheme with the previous map as the background state and, finally, the IWV map is plotted after reversing the change of variable.

Several case studies are presented in order to illustrate the strengths and weaknesses of the product, to assess the potential benefit of using GNSS products in nowcasting and to define the steps to be done in order to make use of the full potential of the method: network densification, accuracy improvement –more frequent and precise determination of satellite orbits and clock offsets-, homogenization of data processing and faster disposition of products