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Detecting water vapour from GNSS for Studying ERA 5 variability during heavy precipitation events: case study in the North of Italy

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Abstract

• One of the main factors influencing precipitation is the amount of water vapour in the atmosphere. Its distribution and evolution, which are ones of the key climate variables identified by the Global Climate Observing System, are essential to the functioning of hydrological processes.

• For studying climate change, a better understanding of the content and distribution of atmospheric water vapour is crucial, as water vapour is the main greenhouse gas, responsible for around 70% of the increase in global temperature.

• GNSS, which has more than 2000 stations around the world, has proved that it can now provide estimates of atmospheric delays in near-real time and convert them into quantities of precipitable water vapour.

• A network of several stations in Italy has been selected and processed by the goGPS processing software to estimate the water vapour at each station. The main objective is to see how water vapour varies over a summer period with respect to the precipitation falling. The results obtained are satisfactory and require the introduction of other parameters such as wind and weather radar images.

Methodology

1. From GNSS tropospheric delay to water vapour

$$\Delta L = 10^{-6}\int_S N ds \qquad N = 10^6(n-1)$$

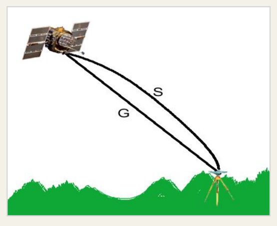
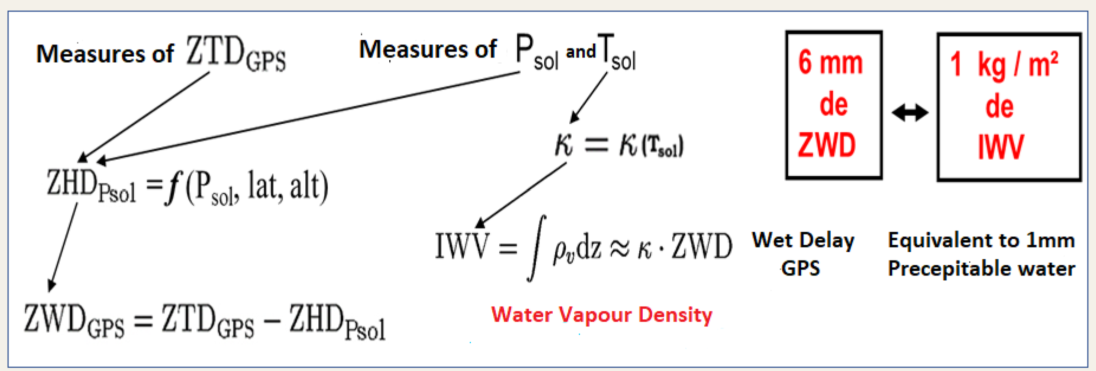


Figure 1: Tropospheric delay

The Zenith Total Delay (ZTD) of the neutral atmosphere can be devided in two parts: the Hydrostatic and the Wet delays.

• The Hydrostatic Delay (ZHD) is the delay due to the whole density of the neutral atmosphere and can be accurately estimated from the surface pressure P_{sol} and the variation of the gravity field (estimation with the fonction *f* which depends on P_{sol}, the latitude lat, and the height above the geoïd alt (in km); see **Saastamoinenn, 1972; Davis et al., 1985**).

• The Zenith Wet Delay (ZWD) represents the contribution of water vapour. Using a conversion factor κ applied on ZWD, the integrated water vapour content (IWV) can be estimated.



2. Evaluation of Water vapour GNSS from ERA5 reanalysis

ERA5 is the last generation of atmospheric reanalysis, which has just replaced ERA-Interim. ERA5 provides hourly atmospheric reanalysis data at 37 pressure levels from ~1000 to 1 hPa, with a horizontal spatial resolution of 0.25° × 0.25° .

A bilinear interpolation is necessary to obtain the vertical profiles on each station from ERA 5.

Based on (Jiang et al., 2016), the precipitable water (PW ≈ IWV), can be calculated using the specific humidity and air pressure from the reanalysis data set as followed

$$PW = \sum_{i}^{n-1}\frac{(q_i + q_{i+1}).(p_{i+1} - p_i)}{2\rho_w.g}$$

where n is the total number of layers, qi and pi are the specific humidity (unit: kg/kg) and air pressure (unit: Pa) at each layer, respectively; pw is the density of liquid water and defined as 1,000 kg/m³; g is the gravitational acceleration (unit: m/s²); see **Jiang et al., 2016**.

Study Area

The GNSS observation processing was carried out by means of the **goGPS** MATLAB which is an open source software (**Realini and Reguzzoni 2013; Herrera et al. 2016**).

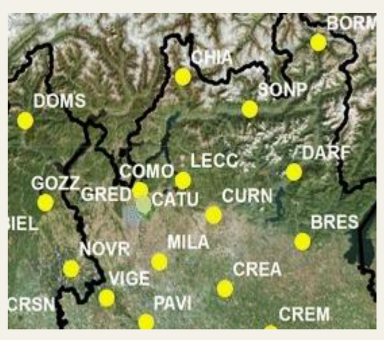


Figure 2 : GNSS Network, Italy

The study area was limited to a few stations in the Lombardy region (COMO CURN MILA CREM…) over a period of two month (June 1 - August 30) in 2017. Trimble low-cost receivers were used.

Pressure and Temperature parameters were interpolated from the Global GPT model every 30 seconds.

By exploiting the 30-s pressure time-series, ZHD were computed (**Saastamoinen 1973**) and subtracted from the estimated ZTD to obtain ZWD time-series. The ZWD time-series were then transformed into the final PWV 30-s time series (**Askne and Nordius 1987).**

Results and Analysis

- **Precipitable Water (PW) from ERA 5 reanalysis**

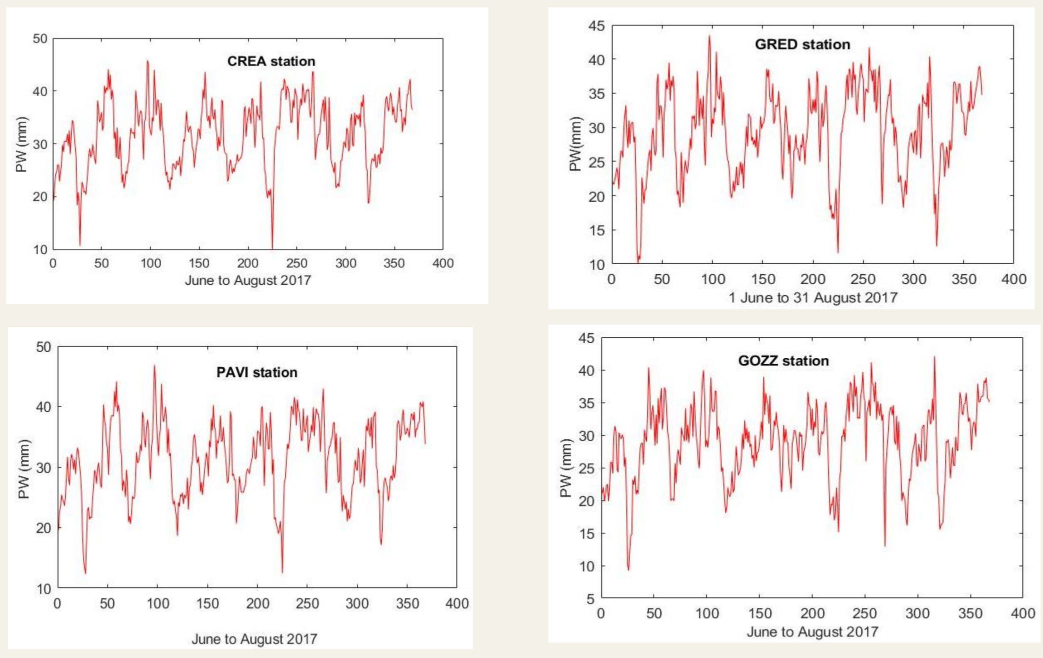


Figure 3: PW time-series from ERA5 reanalysis

The values have been calculated every six hours. We can notice strong behaviour variations from one station to another according to climatic/weather conditions (see Figure 3). Moreover, the maximum values were recorded at PAVI and CREM stations with 46.8 and 46.1 mm, respectively, and minimum values of 9 mm at GOZZ station.

- **Estimation of GNSS PW from goGPS**

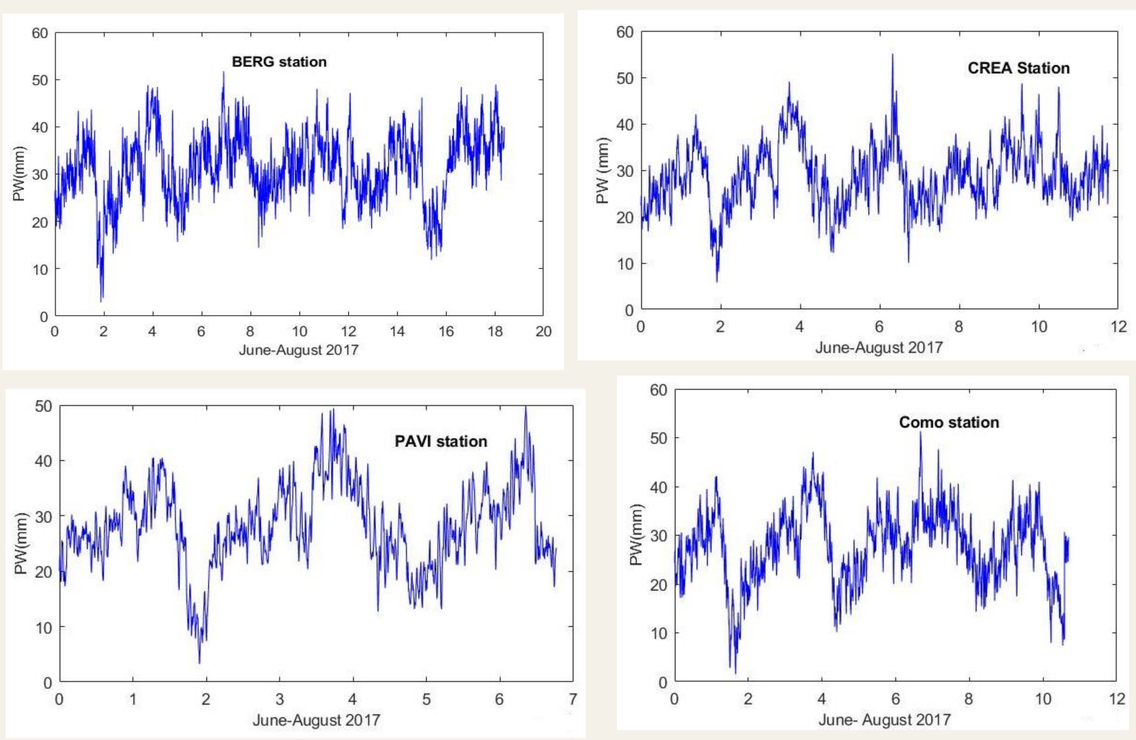


Figure 4: GNSS PW from goGPS software

The variation of GNSS water vapour is very highly in this period of summer because some stations near the lack (COMO) where the evaporation is higher. The maximum of PW was unregistered at GRTR with 53mm.

GNSS water vapour and ERA5

• The evaluation was based on statistical parameters MBE (mean bias error) and RMSE (root-mean-square error) to analyse and evaluate the retrieved PWV precision based on different types of measurements.

• A lower RMSE indicates a smaller discrepancy between the ERA5 and GNSS PW. **(Shuaimin et al. 2020)**

The statistic results are illustrated in the table below. The mean bias does not exceed 1.5 mm.

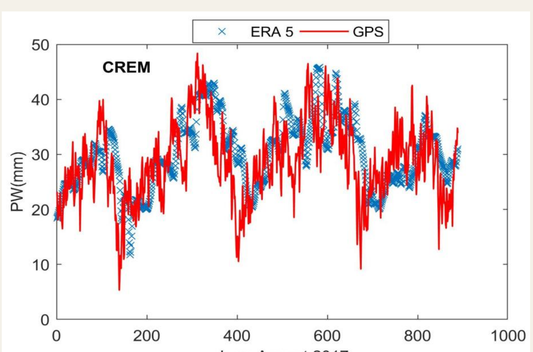


Fig 5: Time series of GNSS water vapour and ERA 5 reanalysis

Stat	Min(mm)	max(mm)	bias(mm)
COMO	13.2	51.2	1.56
CREM	15.1	51.8	1.35
PAVI	21.2	53.2	1.09

Statistical parameter PW GNSS AND ERA5

GNSS water vapour with precipitations

As part of this work, a reanalysis of MERRA2 was implemented to investigate the conditions brought on by the heavy rainfall that felt on Lombardy.

We selected a few stations, determined which had the highest values during this period in June, and observed the behaviour of these values during days with heavy rains (15, 25 and 28 June 2017).

We discovered that at some stations (COMO, CREA, GRED, etc.), values up to 50 mm were associated with rainy days.

Figures 6 and 7 show peak water vapour levels at the COMO and CREM stations a precipitation and pressure throughout June 2017.

However, the correlation is linear at some stations, and not for others, which requires additional modelling.

GNSS water vapour with precipitations

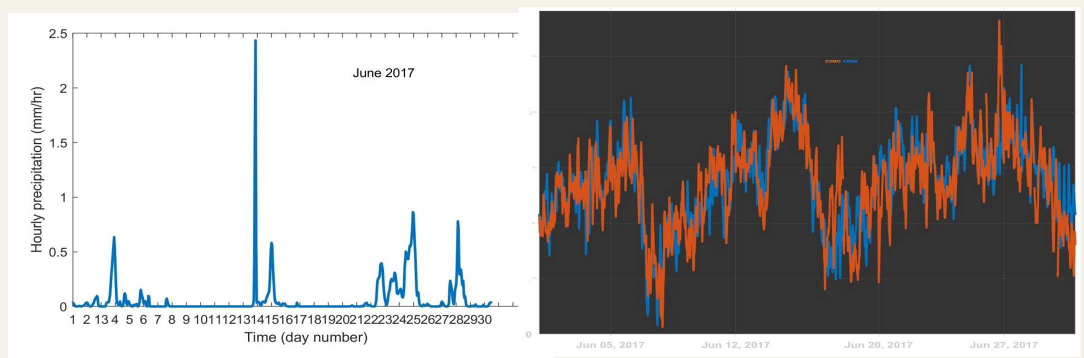


Figure 6 Time series of GNSS water vapour and precepitations from MERRA2

Precipitation was calculated by MERRA2 for the whole of June with a time resolution of 1 hour.

We can clearly see that towards the end of the day on the 14th, it was raining, which was confirmed by the Italian weather station.

The peak on the 13th is an outlier that exceeds the average of ordinary rainfall values.

The same thing was observed at the start of the day on the 25th (between 6am and 7am), and the meteorological information (archive data and TRMM) was confirmed.

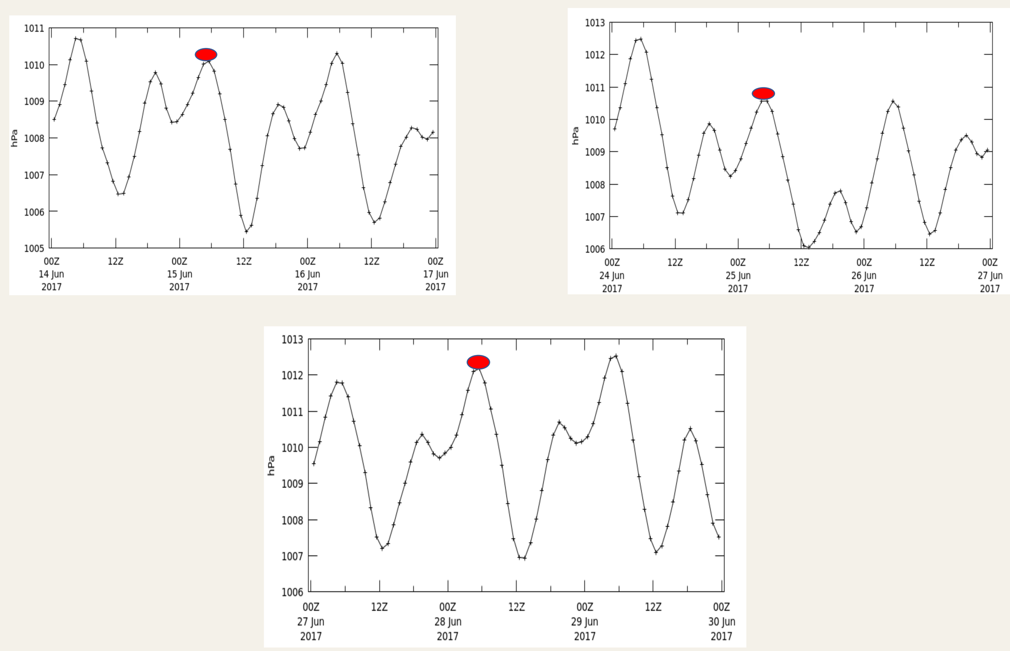


Figure 7 : variation of pressure values from MERRA2, Lombardy region (COMO)

We analyzed the pressure values during the three rainy periods in June, when there was a lot of precipitation, with a total of 220mm over the month and an average of 7.33mm per day.

We noticed that the values decrease just after the hours of rain, for example on June 15, a few hours after the rains, there is a remarkable drop in the variation of pressure.

On the 25th, when the downpour affected the whole of Lombardy early in the day at around 07:00, the pressure dropped during these hours.

Conclusion

- Temporal variations of the order of millimeters per hour were marked at all stations (Up to 53 mm).
- In a summer period with temperatures of 35 degrees Celsius, the peak variation exceeded 53 mm.
- Some stations showed a correlation between water vapour peaks (as seen in the PW peaks) and MERRA2 model-induced precipitation, with an order of correlation greater than 0.60.
- Pressure values decay with the timing of precipitation on certain stations,
- It is necessary to model the relationship between PW peaks and the time of rainfall events in depth by introducing wind speed.
- Long-term GNSS observations (at least 10 years) would be useful to detect the variability of this parameter and opt for other methods such as neural networks.

References

- **Askne J**, Nordius H (1987) Estimation of tropospheric delay for microwaves from surface weather data. Radio Sci 22(03):379–386.
- **Herrera AM,** Suhandri HF, Realini E, Reguzzoni M, de Lacy MC (2016) goGPS: open-source MATLAB software. GPS Solut 20(3):595–603.
- **Realini E, Reguzzoni M** (2013) goGPS: open source software for enhancing the accuracy of low-cost receivers by single-frequency relative kinematic positioning. Meas Sci Technol 24(11):115010.
- **Saastamoinen J** (1973) Contributions to the theory of atmospheric refraction. Bull Géod 107(1):13–3.
- **Shuaimin**, W., Tianhe, X., Wenfeng, N., Chunhua, J., Yuguo, Y., Zhenlong, F., Mowen,L. & Zhen, Z. (2020). Evaluation of Precipitable Water Vapour from Five Reanalysis Products with Ground-Based GNSS Observations', Remote Sensing,12(11): 1817 (2020).