Application of GNSS meteorology for intense precipitation case studies in Bulgaria

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Abstract. One of the applications of the Global Navigation Satellite Systems (GNSS) Meteorology is to study intense precipitation events. Development of this applications is one of the tasks of working group two of the COST Action ES1206 Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate (GNSS4SWEC). This work is a contribution to the COST Action and targets the use of Integrated Water Vapour (IWV), derived with the GNSS Meteorology method, during convective events with heavy precipitation in Bulgaria. Two case studies were made for 2012. The first is on the 25 May 2012. Using two-dimensional maps of the IWV distribution the passage of a cold front can be timed. The IWV peak is between 06:00 UTC and 12:00 UTC before the passage of the cold front at 18:00 UTC. In the second case study on the 27 June 2012 a strong south north gradient of the water vapour is observed on the Balkan Peninsula before the intrusion of cold and dry air. This case study also demonstrates the synergy between GNSS meteorology and the use of Meteosat products.

1 Introduction

Extreme events play very important role in our daily life and are crucial in many aspects, as for example economics and healthcare. The extreme events are very diverse from very cold winters to very hot summers, and the latest tendency is that they are observed more frequently [1]. In this paper, the focus is on the heavy precipitation convection cases, which can lead to flash floods and large economic losses.

A number of recent publications discuss the application of GNSS meteorology for convection case studies. [2] make an observational study over the Bernese Alps in Switzerland. They investigate the orographic convection, using a range of independent observations, including GNSS meteorology. They present two case studies with isolated orographic convection over

the Alps in the afternoon and evening, producing thunderstorms. The results show that large transfer of water vapour occur from the Swiss plain to the mountains. Up to 50 % increase in IWV values are reported at individual Alpine stations, coincident with strong airflow convergence. [**?**] study the relationship between water vapour field evolution and the life cycle of precipitation systems during the intense observation campaign in the region of the Black Forest Mountains in summer 2007. They show that (1) frontal systems seem to develop preferentially where the largest amount of water vapour is available and (2) water vapour has predominant role as a precursor for initiation of local convection. Accumulation of water vapour on the crest of the orography leads to rich convection and its passing over the orography triggers lee-side convection. [4] use 2D GNSS water vapour maps to study two thunderstorms cases and shows the applicability of these maps for nowcasting applications. In the first one, the convergence of the 2D moisture field increased the activity of the thunderstorm. In the second case, the intense lightning of the thunderstorm occurred to the east of the water vapour maximum. With its development the thunderstorm overtakes the water vapour maximum and then weakens.
A long-term study for the period 2002-2010 in the city of Pamplona, located in the north of Spain, is conducted by [5]. They make an experimental analysis that establishes the relation between the variations of the GNSS IWV, surface pressure, and precipitation intensity.
In this paper two convection case studies with intense precipitation for 2012 in Bulgaria are presented. The work is contribution to working group two of the COST Action ES1206 Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate (GNSS4SWEC).

2 Methodology

The Sofia University Atmospheric Data Archive (SUADA) is developed to facilitate the use of vertically Integrated Water Vapour (IWV) data for meteorologic and climatic studies in Bulgaria/Southeast Europe. The SUADA database includes GNSS observations, from five different GNSS processing strategies. In this work we use data from ZenitGEO network. For the calculation of the IWV the GNSS meteorology method is used [6]. It is based on the fact, that the microwave signals sent from a sattelite are delayed when they travel through the atmosphere. Part of this delay is due to the water vapour and can be obatained by the following formula:

$$IWV = \int \frac{10^6}{(k_3/T_m + k_2')R_v}(ZTD - ZHD) \tag{1}$$

where k_2, k_3 and R_v are constant and T_m is the weighted mean atmospheric temperature, ZTD is zenith total delay and ZHD is zenith hydrostatic delay. [7] propose an altitude correction based on the exponential decrease of IWV observed by the Swiss GPS network :

$$IWV(0.5) = a \times IWV(h) \times exp\left[\frac{h-0.5}{H}\right] \tag{2}$$

where: IWV (0.5) is the IWV at 0.5 km, IWV(h) IWV at a given height h, and a is an empirical coefficient. Height is in km and IWV is in mm. The proposed by [7] correction is applied to 11 stations of the Zenit-geo GNSS network in Bulgaria (http://zenitgeo.com/) located at altitude between 36 and 542 m. After applying the altitude correction, 2D maps of IWV field for north Bulgaria are constructed.

3 Case studies

3.1 Frontal case study on 25 May 2012

During the period 22-29 May, several vortexes, part from a cyclone, move towards the Balkan peninsula. Heavy precipitation and thunderstorms are observed and it is relatively cool with maximum temperatures around 20 ° C. On May 25 cold front passes Bulgaria from north to south. The analysis of figure 3.1 shows a maximum of the IWV of 30 mm for the region of Sofia between 06:00 UTC and 12:00 UTC on 25 May 2012. This maximum precedes the passage of a cold front. The intrusion of a cold air mass can be seen in 15:00 UTC over North Bulgaria. The water vapour values decrease to 25 mm (figure 1) . The high amount of IWV coincides with the observed rainfall. A detailed study with higher temporal resolution of IWV field will be required to confirm the findings by [**?**] that water vapour starts to decrease before the precipitation onset.

3.2 Isolated convective cells on 27 June 2012

For the period 24-27 June the weather is dynamic, changeable with unstable air mass, cumulonimbus clouds development and precipitation with different range and intensity. On 26 June a cold air associated with atmospheric front passage from north-west can be seen at 12:00 UTC (figure 2). It is to be noted that the cold and dry air first covers the Danubian plain and then crosses the Balkan mountain in the middle of Bulgaria. After the front passage on 27 of June the air mass remains unstable with high relative humidity at level 700 hPa and warming at high altitudes (200hPa). These conditions lead to isolated convective cells development

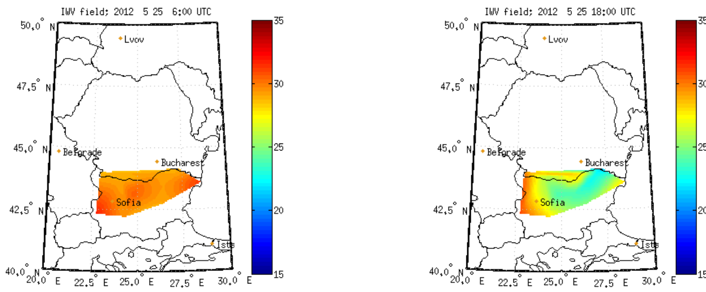

Figure 1. IWV 2D map for 25 May 2012 in 06:00 UTC (left panel) and 18:00 UTC(right panel)

with thunderstorms and intense precipitation reaching 74 mm in north-east Bulgaria.

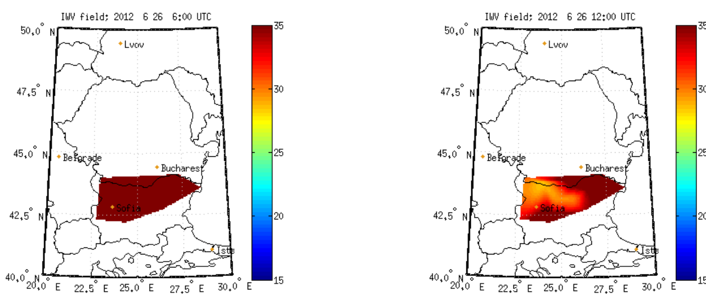

Figure 2. IWV 2D map for 26 June 2012 in 06:00 UTC (left panel) and 12:00 UTC (right panel).

In figure 3 2D maps of the IWV distribution obtained by GNSS meteorology (left panel) method and from Meteosat satellite water vapour channel 6.7 μm (right panel) are displayed. It must be noted, that on the GNSS, the maximum value of the water vapour is displayed in red and the minimum in blue. On the Meteosat maps the colours are reversed. The two methods display the strong south - north gradient of the IWV - its amount is almost double in south.

4 Discussion

In this paper the method suggested by [7] for the altitude correction is applied for the GNSS tropospheric products for 11 stations of the Zenit-geo network in Bulgaria. Using 2D water vapour maps, two convective cloud

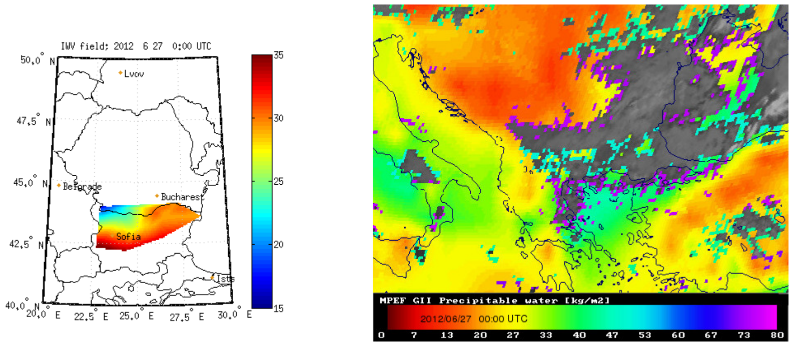

Figure 3. IWV 2D field on 27 June 2012 (00:00 UTC top left panel and 18:00 UTC bottom left pannel), Meteosat satellite water vapour image (00:00 UTC top right panel and 18:00 UTC bottom right pannel).

cases in 2012 were studied. The first one is on the 25 May 2012 when the passage of a cold front is well timed with advection of cold and relatively dry air. For the second case study on the 27 June 2012 2D IWV maps from both GNSS and Meteosat confirm strong north-south gradient. The analysis show, that on the previous day the humid air mass in north Bulgaria was replaced by cold and dry air, advected from north-west covering first the Danubian plain and then crossing the Balkan mountain. The presented in this paper case studies demonstrate the synergy between GNSS and Meteosat water vapour maps. Future work will be derailed analysis and comparison of 20 convective situations with numerical weather prediction model.

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