Use of GNSS water vapour for severe weather studies in Bulgaria: hail and heavy rain in 2012

Guergana Guerova[1], Martin Slavchev[2], Rumjana Mitzeva[1], Tsvetelina Dimitrova[3], and Tzvetan Simeonov[1]

[1] Sofia University, Physics Faculty, Department of Meteorology and Geophysics, 1164 Sofia, Bulgaria, e-mail: guerova@phys.uni-sofia.bg
[2] National Institute of Meteorology and Hydrology, Sofia, Bulgaria
[3] Hail Suppression Agency, 1606 Sofia, Bulgaria.

I. INTRODUCTION

Predicting the formation and development of vigorous thunderstorms producing heavy rain and hail is a complex process which among other environmental conditions depend on accurate estimation of water vapor distribution in space and time. Remote sensing of water vapour with GPS receivers has both temporal resolution and accuracy. Application of Global Navigation Satellite Systems (GNSS) in Meteorology is a well established research field in Europe and GNSS data from 1 800 stations are available for model validation and assimilation in the state-of-art models used for operational weather prediction by the National Meteorologic Services. Application of GNSS derived Integrated Water Vapour (IWV) to study cloud initiation is an emerging research topic.

Van Baelen et al. (2011) studied the relationship between the evolution of GNSS derived water vapour and the life cycle of precipitation systems and concluded 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. Graham et al. (2012) study two cases with isolated 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 with up to 50 % increase of IWV coincident with strong airflow convergence.

This work is focused on investigation of the GNSS derived IWV variations during formation and development of two vigorous multi-cell thunderstorms, producing hail and heavy rain over Bulgaria in 2012.

II. DATA

The GNSS-IWV is derived for 30 GNSS stations from the Zenitgeo permanent network in Bulgaria (http://www.zenitgeo.com/about-us.html) using the surface pressure and temperature from the Weather Research and Forecasting (WRF) model (http://www.wrf-model.org/index.php). Two dimensional IWV maps are produced via interpolation between the stations and the IWV is computed for altitude 500 m asl. The radar information is obtained by S-band Doppler radars of the Bulgaria Hail suppression agency. Radar reflectivity data are used for the analyses of cloud storm development.

III. RESULTS

Selected are two cases with intense precipitation including hail in central Bulgaria on 22 May and 5 June 2012. On 22 May the precipitation is associated with passage of a cold front at 18 UTC. On 5 June Bulgaria is under the influence of upper-level trough (500 hPa) and the jet streak passing over the country. Associated with the jet streak is increase of instability and development of multi-cell convective storms after 9 UTC.

III.A CASE STUDY 5 JUNE 2012

Severe hail stones (D up to 5-6 cm) were detected close to Plovdiv between 10:50 and 12 UTC. On figure 1 the multi-cell cloud cluster is well seen at 11 UTC on the the radar reflectivity plot (second plot at the top panel). The cluster moves eastward as seen at 12 UTC radar plot. Hail is detected (D < 2 cm) close to Sliven between 12:30 and 14:40 UTC. The 2D IWV field variation seen in bottom panel of figure 1 shows that both as Plovdiv and Sliven (marked with black stars) the IWV during the hail storms is above 35 mm. The diurnal cycle of IWV at Plovdiv on June 5 is presented in figure 2 (left plot). Before 7 UTC IWV increases with less that 1 mm/h. Between 7 and 11 UTC the IWV increases by 1.5 mm/h (i.e. 6 mm for 4 h). The maximum IWV values coincide with the timing of maximum extent of the thunderstorm development around Plovdiv. Studies by Done et al. 2005 and Graham et al. 2009 also find that the IWV maximum co-insides with the maximum extend of the thunderstorm development.

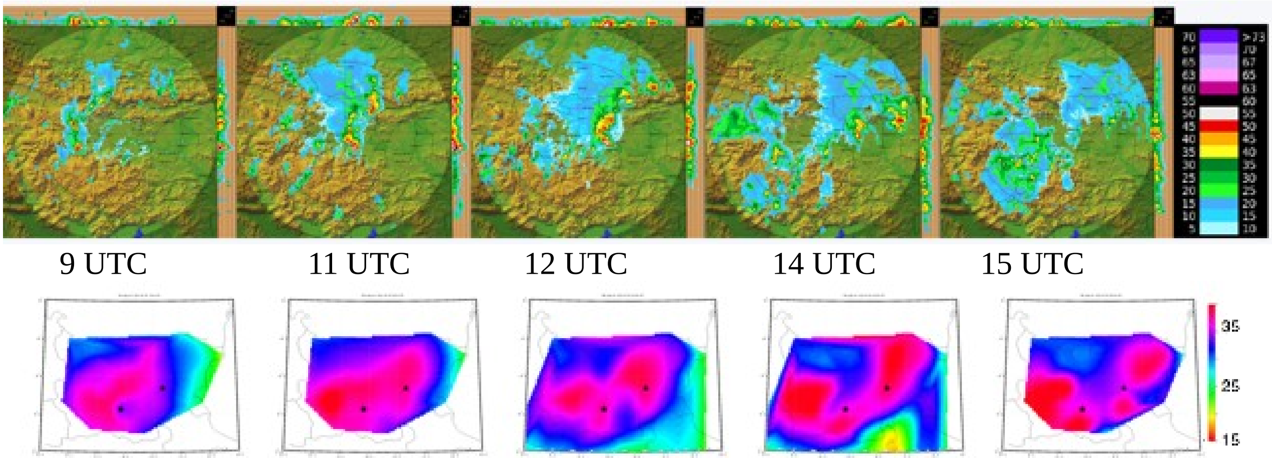

Figure 1: Maximum radar reflectivity [DBZ] (top panel) and 2D IWV (bottom panel) on 5 June 2012. Plovdiv and Sliven are marked with back stars on 2D IWV map.

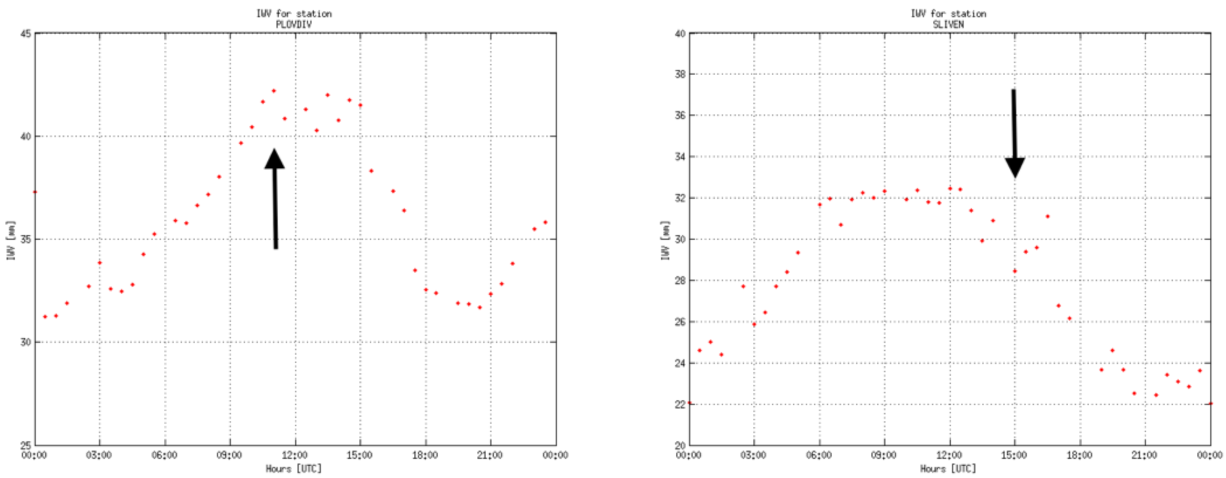

Figure 2: Diurnal cycle of IWV (bottom panel) on 5 June 2012 in Plovdiv (left) and 22 May 2012 in Sliven (right). With arrow is marked the start of the precipitation.

III.B CASE STUDY 22 MAY 2012

Severe hail and heavy rain (20 mm per 2 hours) were reported close to Sliven between 15 and 17 UTC. On 22 May 2012 the observed convective precipitation is associated with a well developed cyclones over Bulgaria both at surface and altitude. The multi-cell thunderstorm over Sliven is clearly seen at 15:37 and 16:23 UTC on figure 3 (third and forth plot on the top panel). After 17 UTC the cloud band is moving eastward. The 2D IWV is higher at 13 and 14 UTC and decreases afterwards (bottom panel in figure 3). Presented in figure 2 (right plot) is the diurnal cycle of IWV at Sliven. After 3 UTC IWV increases from 26 mm to 32 mm at 6 UTC. The IWV remains high between 6 and 12 UTC and start to decrease with the onset of cloud development and precipitation.

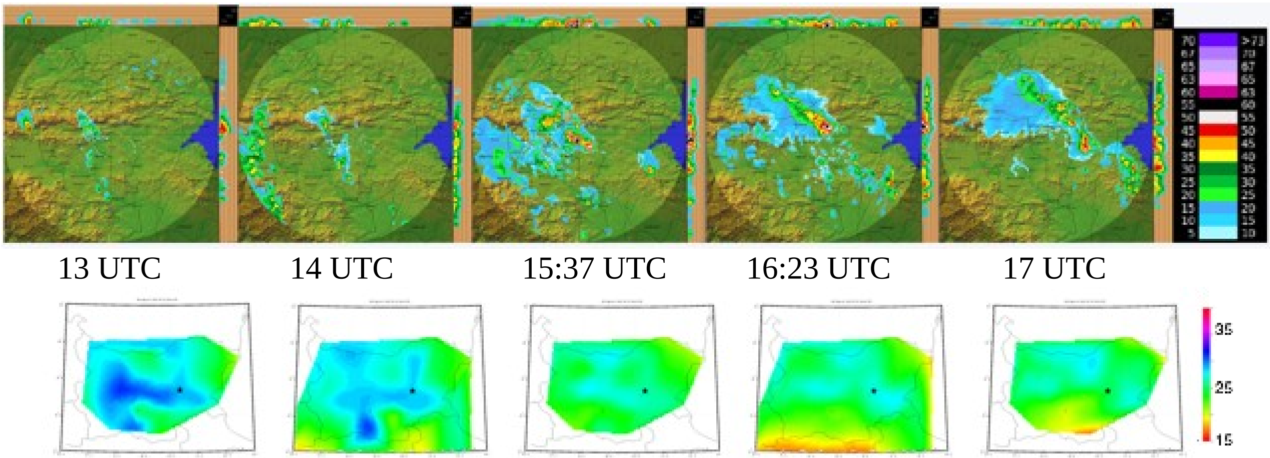

Figure 3: Maximum radar reflectivity [DBZ] (top panel) and 2D IWV (bottom panel) on 22 May 2012. Sliven is marked with back star on 2D IWV map.

IV. CONCLUSIONS

The study of two cases of multi-cell thunderstorms producing hail and intense precipitation using GNSS derived IWV and radar data gives promising first results. For the case on 5 June 2012 the maximum of IWV is during the maximum multi-cell development and the rate of IWV increase is 1.5 mm/h between 7 and 11 UTC. Important factor for the intensity of the developed cells is the increase of instability accounted with the passing jet streak. On 22 May the precipitation is ahead of a cold front. The diurnal cycle of IWV shows increase between 0 and 6 UTC then constant up to 12 UTC and high variability from 12 and 17 UTC. The two cases demonstrate that IWV behaviour highly depends on the synoptic scale processes and further studies using high temporal resolution IWV data will be required. The work will continue with in depth analysis of selected 20 cases in 2012.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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