Application of GNSS tomography in 3D representation of atmospheric moisture during large scale intense precipitation events with Poland as an example

Marek Błaś[1], Witold Rohm[2], Mieczysław Sobik[1], Hugues Brenot[3], Estera Trzcina[2], Maciej Kryza[1], Hanna Ojrzyńska[1]

[1)] *Department of Climatology and Atmosphere Protection, University of Wrocław, Poland*

[2)] *Institute of Geodesy and Geoinformatics, Wroclaw University of Environmental and Life Sciences, Wrocław, Poland*

[3)] *Royal Belgian Institute for Space Aeronomy (BIRA), Atmospheric composition, Brussels, Belgium*

BACKGROUND

Some cyclones in Central Europe may cause extensive and prolonged rainfall events followed by large scale flooding. Such a low gains its energy from condensation of the atmospheric moisture transported from S through SE and E to NE sectors, which ascends over the cold air coming from the sector NW and N sectors. Monitoring of atmospheric water vapor distribution is essential in predicting the severity and lifecycle of heavy rain.

This work presents a study on the applicaion of tomographic solutions to investigate water vapor variations during heavy precipitation events. Using GPS observations, the wet reflectivity field was constructed for two cases occurring in Poland in 2014.

AIM:

1) evaluation of the meteorological correctness of the tomography retrieval;
2) whether the achieved temporal and spatial resolution of the troposphere Integrated Water Vapor (IWV) is able to provide new information about spatial distribution of precipitation enhancement mechanisms.

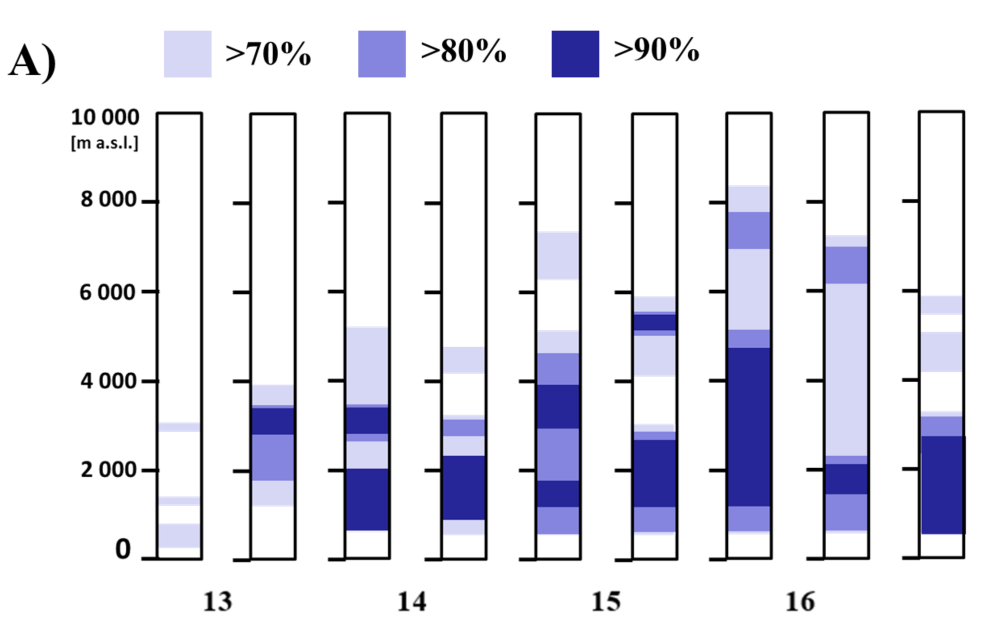
METHODS

GNSS tomography model TOMO2 was apply to resolve IWV before, during and after some intense precipitation events. The GNSS tomography is a technique that allows to reconstruct, from the GNSS satellite-receiver signal slant troposphere delay, a 3D pattern of water vapor content estimated with the spatial resolution of half the distance between the GNSS receivers and time resolution similar to the estimated troposphere delay. In the analysis, IWV at ten altitude layers was examined: <1000, 1000-1500, 1500-2000, 2000-2500, 2500-3000, 3000-4500, 4500-6000, 6000-7500, 7500-9000, as well as 9000-12500 m a.s.l. The applied technique allows to get full picture of tropospheric water vapor content at all locations covered by GNSS network.

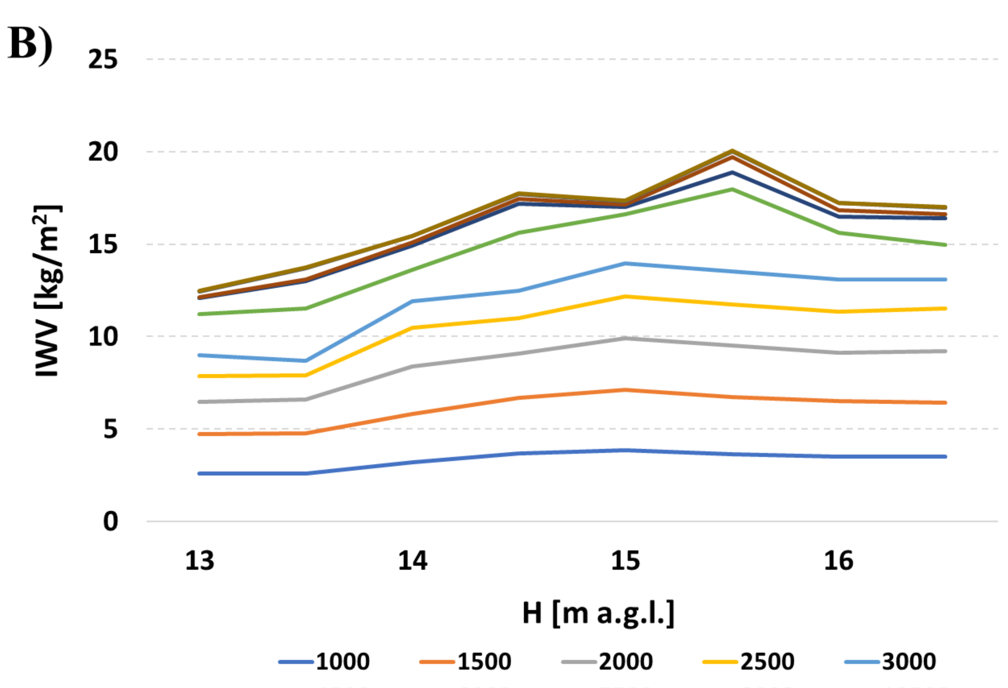
Two events were investigated: in May 2014 and in September 2014. The tomography retrievals have been compared with radiosonde profiles and numerical weather prediction (NWP) model.

RESULTS

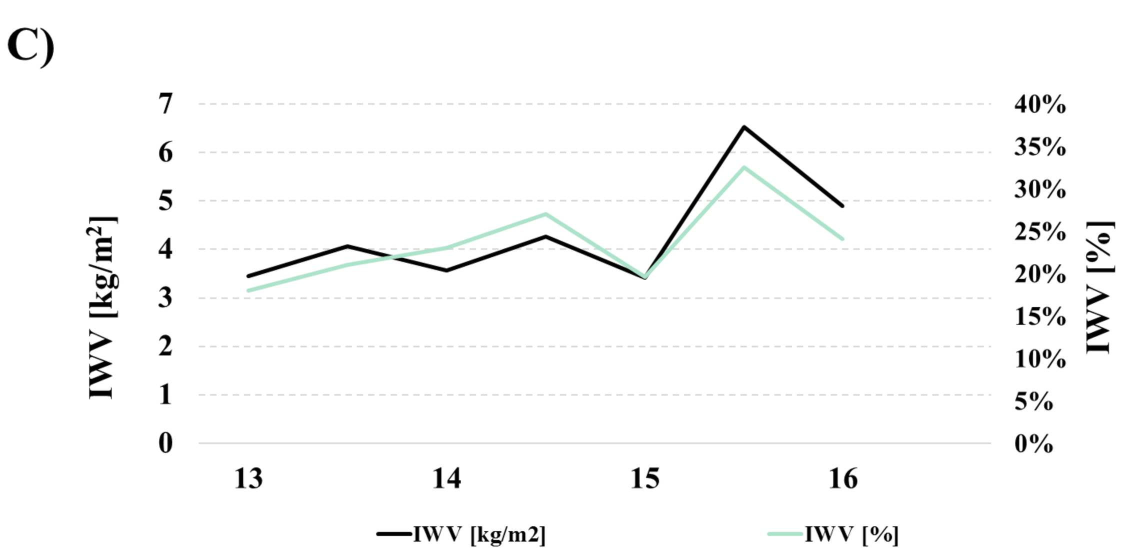
A)



B)



C)



D)

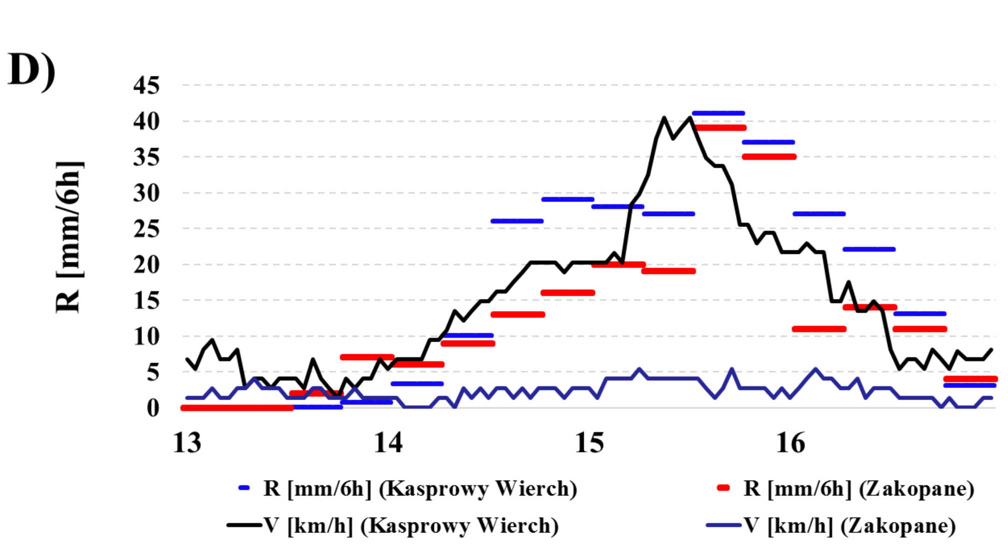


Fig. 3. Evolution of (A) relative humidity profiles above 70, 80 and 90% - radiosonde station Poprad; (B) IWV at ten layers every 6 hours – TOMO2 model; (C) absolute and relative contribution IWV above 3000 m a.s.l. – TOMO2 model; (D) gauged rainfall R and wind speed V (Kasprowy Wierch synoptic station – 1991 m a.s.l. and Zakopane synoptic station – 857 m a.s.l.) from 00:00 on 13 May 2014 to 23:00 on 16 May 2014 in a convergence zone;

THE SYNOPTIC SITUATION - HEAVY PRECIPITATION EPISODE (14-17 May 2014).

The steering pressure system for this event was a quasi-stationary low formed over SE Europe with its center oscillating between northern Serbia and southern Romania and central pressure slightly rising from less than 1000 hPa at the beginning to less than 1010 hPa at the end of the period. At the opposite part of Europe a strong high was formed extending over the British Isles, the Northern Sea and the Baltic Sea with atmospheric pressure higher than 1030. In such condition over the Southern Poland a moderate to strong north easterly atmospheric circulation prevailed.

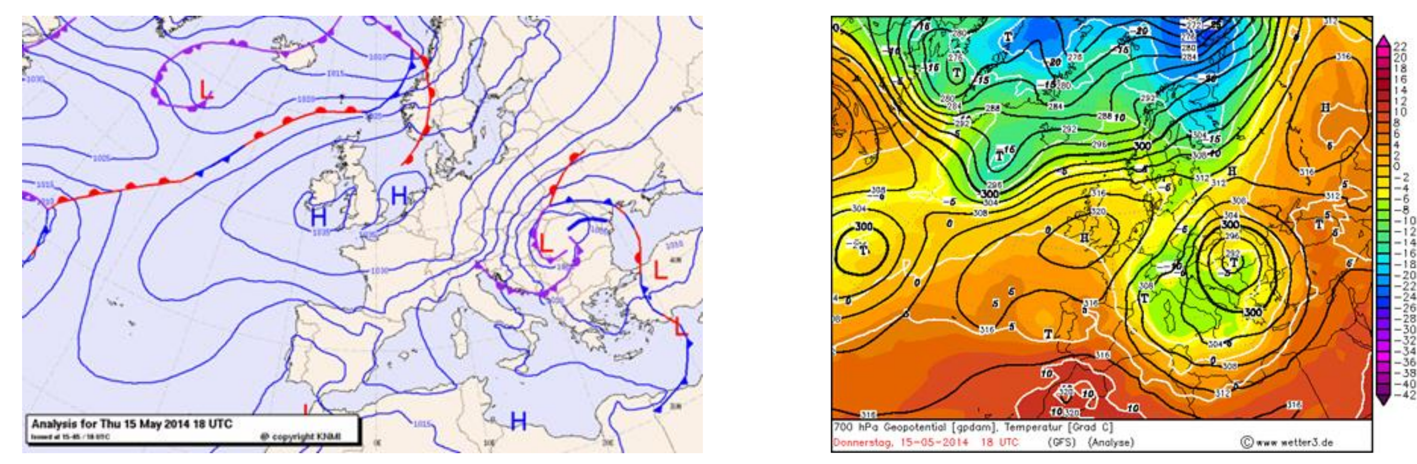
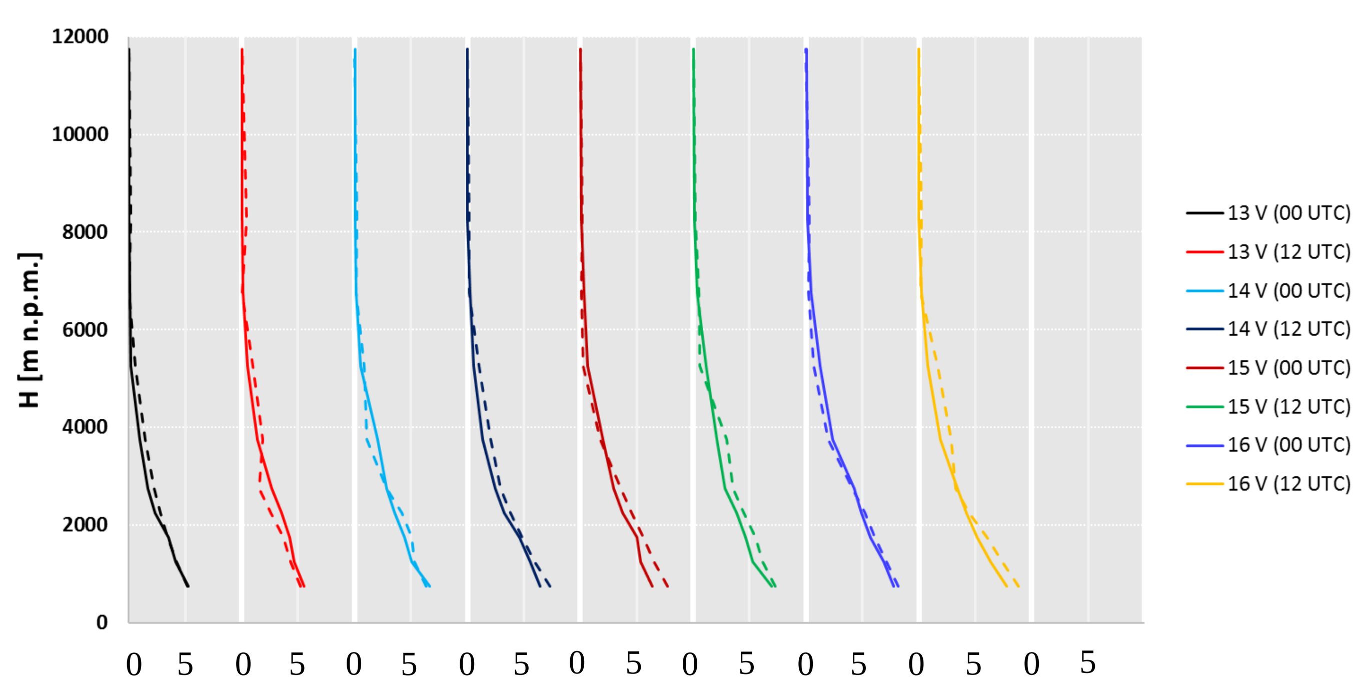


Fig. 1. The mean pressure at sea level (left) and geopotential height of the pressure level 700 hPa (right) in Europe– 15 May 2014 (18 UTC).

RADIOSONDE DATA VS GNSS IWV



R^2	0,862
BIAS	-0,223
MSE	0,247
RMSE	0,497

Fig. 2. Absolute humidity vertical profile [g/m³] above the Poprad aerological station 13-16 May 2014 - comparison between radiosonde data (solid line) and GNNS data (dashed line).

VERTICAL TRANSPORT OF HUMID AIR AS A REASON OF HEAVY RAINFALL

Relative humidity (RH) combined with the air temperature is a good indicator of the amount of water vapor in air. In the conditions of intense cyclogenesis, the air aloft at higher levels has relatively high RH (Figure 3A), approaching to saturation. In the convergence zone, during the heaviest rainfall intensity (16 May 2014), the layer with high RH (>70%) extended up to 8000 m a.s.l. (about 4000 m is normal for a typical low moving from the western sector). In addition, the remarkable water vapor fluctuations (Figure 3B and 3C) in the altitude layers above 3000 m can be seen as precursors to heavy precipitations. Water vapor continued to accumulate above 3000 m and its contribution to the total tropospheric IWV varied from 20% (between 13-15 May) to above 30% on 16 May when the most intense rainfall occurred.

OROGRAPHIC EFFECT

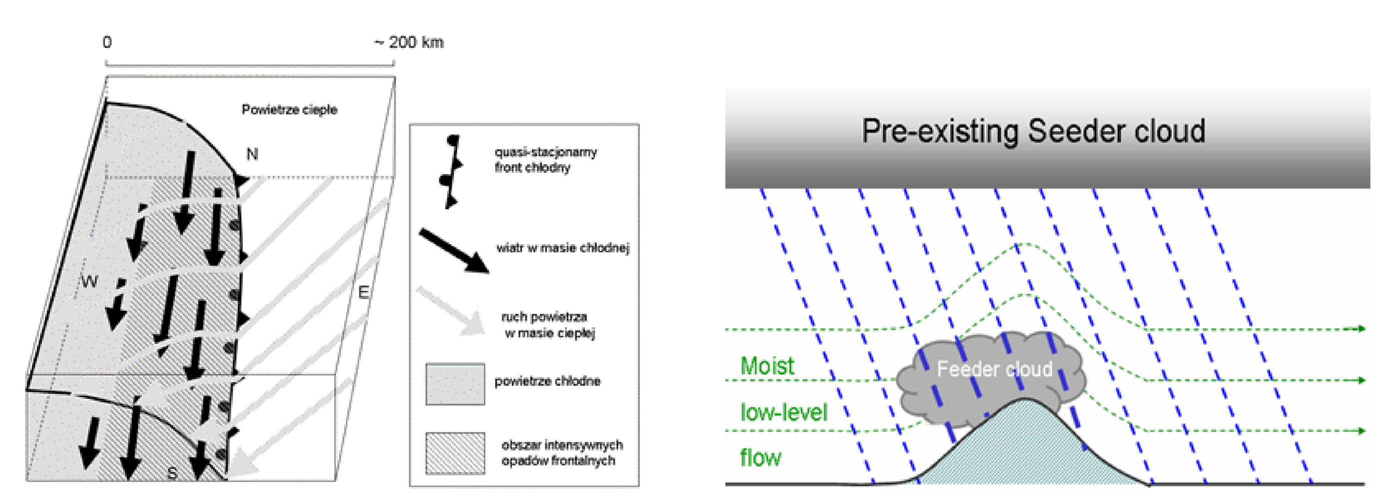


Fig. 4. Formation mechanism of intense precipitation caused by the macroscale convergence (left side) and mechanism of the „seeder-feeder effect" (right side).

Largest precipitation totals are observed mainly in the upper parts of mountain catchments where they are typically 2 times higher than in the foreland of the mountains. During orographic uplift over mountains (Figure 3D), additional condensation takes place that significantly increases the precipitation intensity (Fig. 4). Enriched with water, lower clouds are still washed by the rain drops from a higher level.

CONCLUSIONS

1. **We show a good agreement of GNSS IWV data with radiosonde.**
2. **The use of GNSS IWV data significantly improves both spatial and temporal resolution of atmospheric moisture field representation over the area of Poland during the evolution of heavy precipitation events.**
3. **Further studies of the atmospheric moisture field with the use of GNSS data may potentially improve the precipitation forecast skill.**