GPS Monitoring of the Atmospheric Parameters

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Abstract

This paper concerns the determination of integrated water vapour (IWV) for several permanent GPS stations in Central and Eastern Europe. It also deals with application of the 1-hour GPS observations to the deriving atmospheric parameters. This research allowed us to investigate the atmosphere that the GPS signal cross over. Special strategy for this determination has been created in the Warsaw University of Technology EUREF Local Analysis Centre (WUT EUREF LAC). It is based on 1-hour GPS observations and consists of several stages described with full particulars in this paper. The comparison of the mean temperature obtained from radio soundings and related radiosonde-derived IWV to postprocessed solutions for two nearby GPS stations in Poland gave 0.98 correlation and 1 mm medium absolute error of the precipitable water. The GPS solutions have been also compared to the results of postprocessing of the data that came from Unified Model for Poland (UMPL). These analyses showed good consistency. The paper also presents the future plans for joint use of GPS and meteorological-derived data for the monitoring of the atmospheric parameters.

WUT Local Analysis Center

Permanent satellite observations in Astro-Geodetic Observatory at Jozefoslaw and routine activities of WUT EUREF Associated Local Analysis Center are performed in close connection with international services IGS and EUREF. Different procedures for GPS data processing of 30 station network both in daily and hourly mode are tested for optimal atmospheric parameters deriving. Figure 1 shows scheme of data flow and processing and figures 2,3 present some examples of results concerning Zenith Tropospheric Delay and TEC determination.

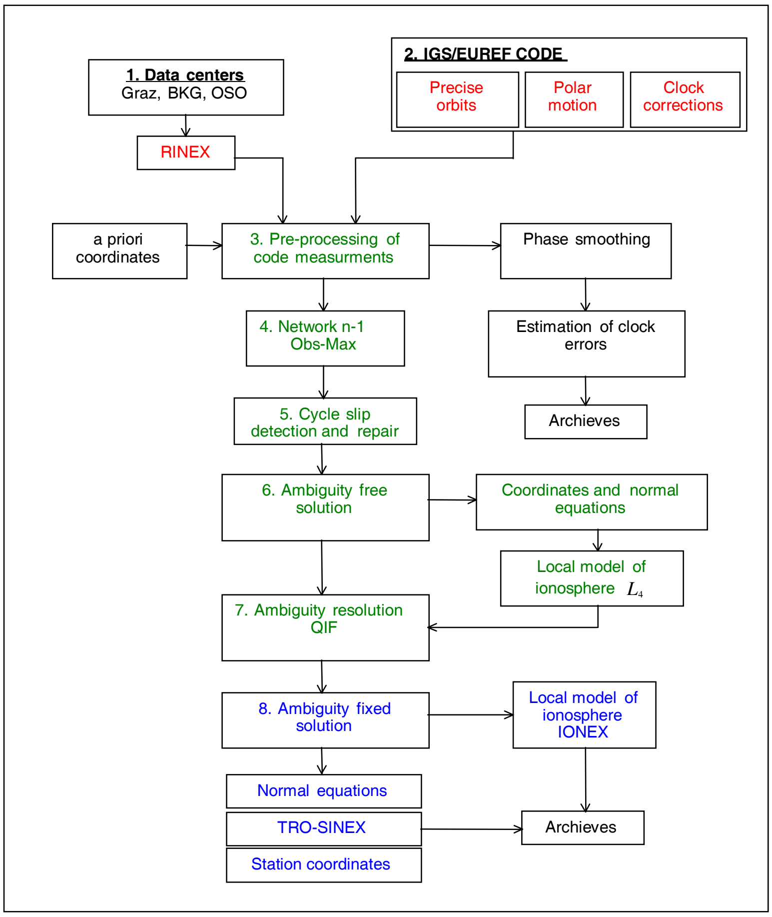

Fig.1 Scheme of GPS data processing performed in WUT LAC

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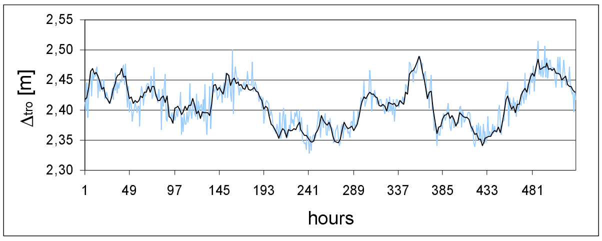

Fig. 2 Changes of the tropospheric zenith corrections at Jozefoslaw from 9-30 June 1997. Grey line: 1-hour solution, black line: 2-hours solution.

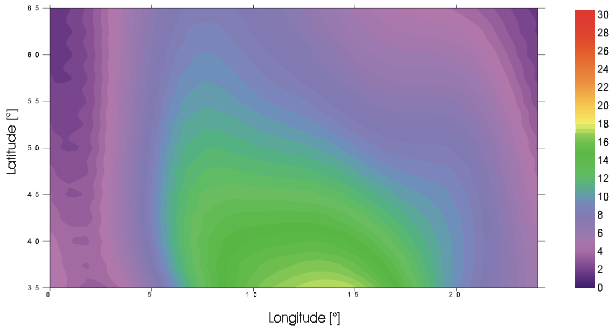

Fig.3 Map of the ionosphere from 159 day of 1997 obtained in WUT LAC

Tropospheric Data Analysis

Vertical profiles of temperature and humidity from two radio sounding points in Poland (Legionowo near Warsaw and Wroclaw) were used to calculate mean temperature and linear regression parameters relative to temperature on the surface. Mean temperature and regression coefficients show distinct time dependence.

We've obtained following relations for soundings during 1997-99:

Legionowo (2174 soundings)

$$T_m = (88.9 + 0.647 * T_s \pm 3.3)\mathrm{K}$$

Wroclaw (1996 soundings) – see Fig. 1

$$T_m = (91.6 + 0.638 * T_s \pm 3.8)\mathrm{K}$$

Integrated Precipitable Water Vapour data derived from radio sounding serve next to evaluate tropospheric estimates from GPS.

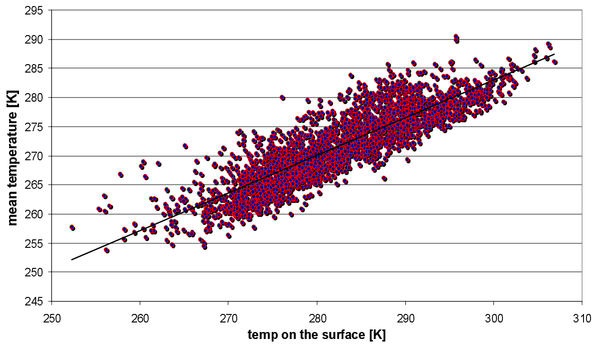

Fig. 4 Mean temperature from the radio sounding profiles plotted against the temperature on the Earth surface - Legionowo 1997-99

Thanks to surface pressure data we can extract wet delay component from the zenith tropospheric delay obtained in permanent GPS stations processing (CODE and WUT LAC daily solution product) and the formula for the mean temperature allows to calculate Integrated Water Vapour in vertical direction.

Now it is possible to compare IWV (or rather IPWV - Integrated Precipitable Water Vapour because we use mm in figures specification) with those directly integrated using radiosonde profiles both for daily and hourly solutions. In the vicinity of Warsaw we can use two permanent GPS stations BOGO and JOZE (at 10 and 30 km distance respectively to the radio sounding point.

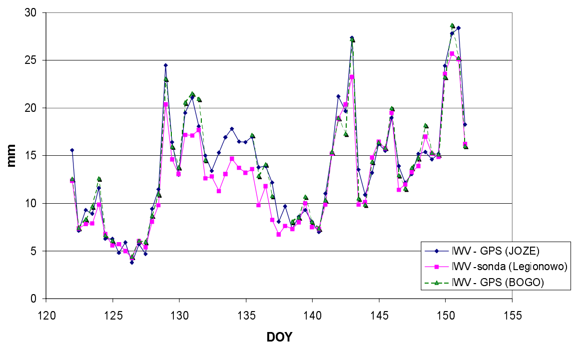

Fig. 5 IWV directly derived from radio sounding (Legionowo) & at two GPS sites in the vicinity (JOZE and BOGO)

Results with different models for wet delay separation were used (others factors e.g. gravitational correction term or integration details demonstrated little importance) are presented in the Tab.1.

Tab. 1: Radiosonde – GPS data difference; models of the hydrostatic delay: S - Saastamoinen, H- Hopfield

year [mm]	JOZE S	JOZE H	BOGO S	BOGO H
1997 average difference	2,9	2,1		
mean absolute difference	3	2,2		
1998 average difference	2,7	1,8	2,5	1,6
mean absolute difference	2,7	2	2,7	2,1
1999 average difference	2,4	1,5	2	1,2
mean absolute difference	2,5	1,8	2,1	1,4

It's worth noting that dry Hopfield model and results from station closer to the radio sounding point have given smaller but still positive bias (GPS IWV greater), rms of order 2 mm. Radiosonde data may be used also to evaluate wet delay models based on surface meteorological data.

Some trails has been made to set in motion hourly data processing for near real-time tropospheric data estimations which can be applied in WUT LAC operation and utilised by meteorologists and in numerical weather prediction. Table 2 includes standard deviations between tropospheric parameters stemming from 24- hour standard daily solution with troposphere parameters estimated as a corrections to Saastamoinen model from 1-hour sessions.

Tab. 2: Daily – hourly ZTD RMS

Station	σ [m]
Borowa Gora	0,0096
Borowiec	0,0088
Jozefoslaw	0,0105
Lamkowko	0,0103
Wroclaw	0,0094

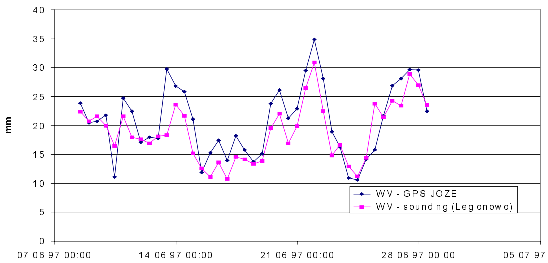

Fig. 6: Comparison of IWV gained in hourly solution and integrated from IMGW sounding in Legionowo (twice a day)

For further analysis we used UMPL numerical weather prediction model (version of British Meteo Office Unified Model maintained by Interdisciplinary Centre for Mathematical and Computational Modelling, Warsaw) as a source of 3-met surface data for most of EUREF and IGS stations in the area covered by model. Now we can create IWV map that demonstrates in near synoptic scale, spatial distribution of IWV. Also we used model derived T=0 prognosis step vertical data (13 levels) for IWV calculation in order to compare with analysis centres products- see figure 7. We get mostly negative biases, average absolute difference depends upon solution quality (both EUREF & IGS stations smaller then merely EUREF), season and station height. Correlation as a conformity indicator was also analysed; all minutes are included in table 3.

Tab.3 Comparison of all results.

		correlation	difference RMS [mm]
IWV – GPS (CODE)	IWV – GPS (WUT – LAC)	0.99	0.7-0.9
IWV – radiosonde (Legionowo)	IWV – GPS (BOGO)	0.985	2
IWV – radiosonde (Legionowo)	IWV – GPS (JOZE)	0.985	2.1
IWV – NWP UMPL	IWV – GPS	0.96-0.67	1.5
IWV – local meteo data	IWV – met from NWP model	0.98	0.5-1.0
IWV - GPS	IWV – *a priori* ZWD model	0.9-0.91	

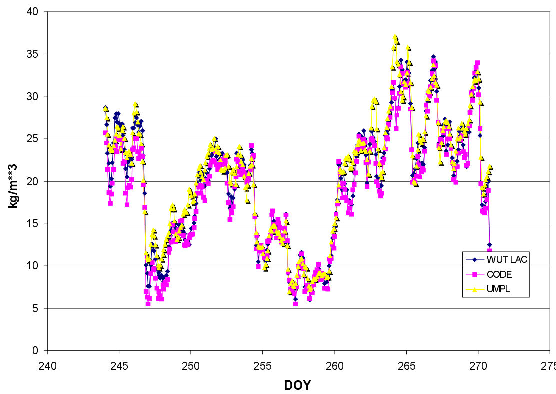

Fig. 7 IWV from GPS solutions (WUT and CODE) and UMPL NWP model vertical profiles

Conclusions

GPS is valuable tool for monitoring atmospheric parameters especially water vapour content in troposphere. Empirical determination of local parameters using aerological measurements makes possible achieving 1-mm accuracy. Independent IWV information (radio sounding) improves deterministic models, supports precise post-processing strategies and makes possible near real time sensing of atmospheric water vapour for meteorology and numerical weather prediction.