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Estimation of the integrated water vapor above Maidanak observatory

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The molecules of water in the atmosphere absorb electromagnetic radiation in some spectral lines. They cause significant weakening of starlight intensity during the red and infrared-range astronomical observations. In spite of overall dry conditions of Maidanak, the night-time variations of the Integrated Water Vapor (IWV) are very important, because taking this effect of atmospheric extinction into account gives much benefit to precise photometry of celestial objects.

Integrated water vapor in the atmosphere is the same as Precipitable Water Vapor (PWV) which is the depth of water in a column of the atmosphere if all the water in that column were precipitated as rain. As a depth, both the integrated and precipitable water is measured in millimeters.

In November 2012, a new complex of hydro-meteorological and GPS stations (MADK) was installed at Maidanak observatory by GFZ (German Research Centre for Geosciences, Potsdam) in frame of the CAWa (Water in Central Asia) project [1].

The estimation of the IWV is based on determination of wet tropospheric delay of the signals coming from navigational satellites and received by the MADK GPS-receiver. The tropospheric delay can be separated into a hydrostatic (dry) and wet component:

$$ZTD = ZDD + ZWD$$

Zenith Dry Delay (ZDD) can be estimated by the Saastamoinen model [2] using the meteorological data of the station at the surface layer:

$$ZDD = \frac{0.002277 \cdot P}{1 - 0.00266 \cdot \cos(2 \cdot \varphi) - 2.8 \cdot 10^{-7} \cdot H},$$

where P is air pressure, φ is the latitude and H is the station height. Then ZDD subtracted out from the Zenith Total Delay (ZTD) of the signal in order to obtain Zenith Wet Delay (ZWD). A well-known coefficient [3] is used to transfer ZWD into IWV:

$$PWV = K * ZWD.$$

The Figure 1 shows an example of one-day IWV for January 9, 2013 above Maidanak observatory. In the first half of the day the surface relative humidity (RH) was more than 65%. It was close to 100% in the second half with some snow. Average value of IWV found to be 4.7 mm with the standard deviation of 0.6 mm.

Validation. Validation of the method and algorithm was performed in comparison to GFZ algorithm which is used for near-real time (NRT) GPS-meteorology [4, 5]. The Figure 2 shows a comparison of the estimations using the same data for the Potsdam station POTS. The figure shows that these two different algorithms give almost the same results with small systematical difference.

Seasonal variations are being studied as well as the correlation with the atmospheric extinction in R and I photometric bands of the spectrum. It is expected that above mentioned average value is not typical for the observatory because it is located in a semi-desert area. Another reason of low IWV values is a high altitude of the observatory which is more than 2500 m above sea level – higher than the essential water-containing boundary layer of the atmosphere.

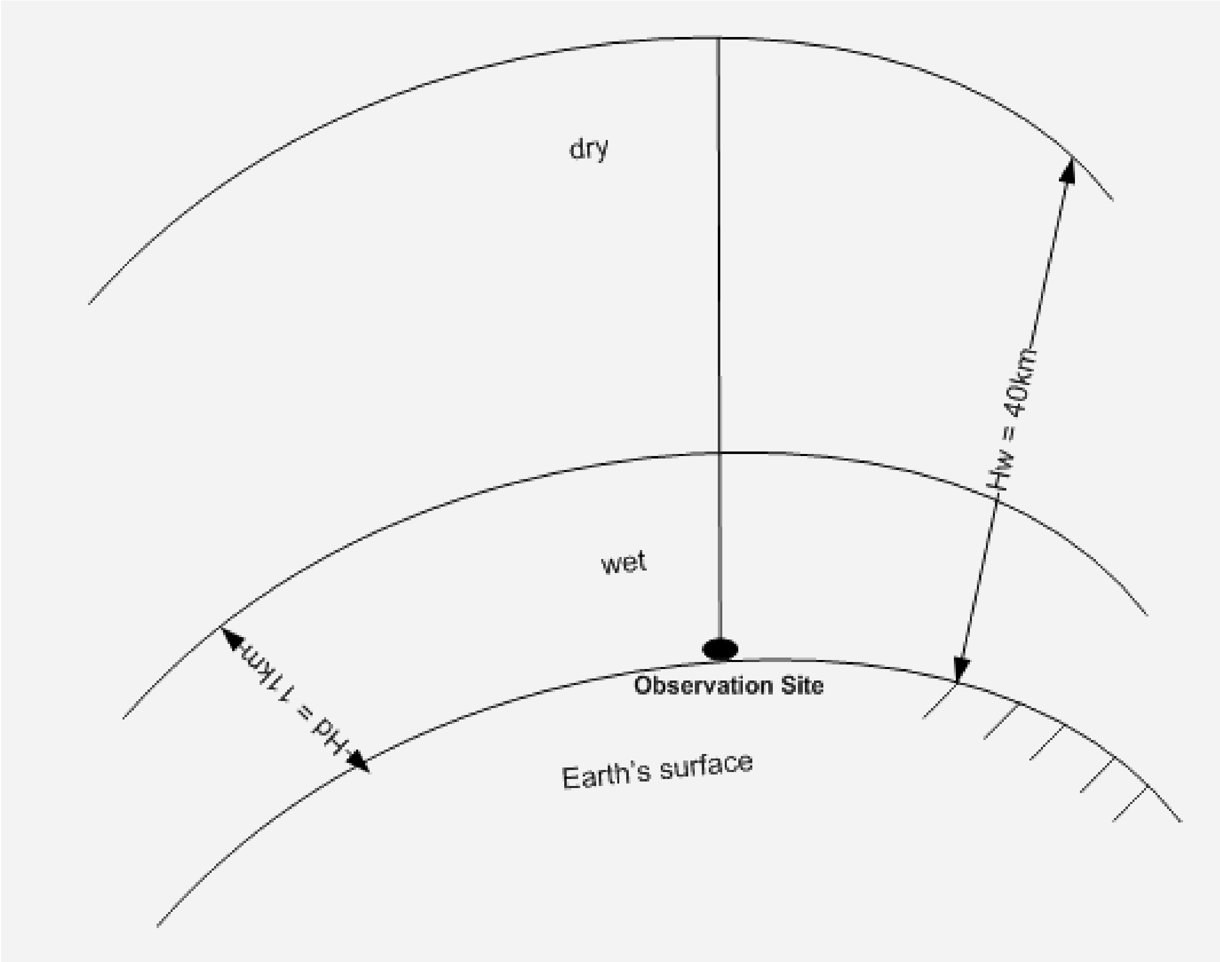
Summary. For the first time, the precipitable water vapor has been estimated above the Maidanak observatory. A comparison with GFZ algorithm showed that our algorithm estimates the IWV well enough. A comparison with a parallel spectral or water vapor radiometer (WVR) measurements should be performed in order to validate the results. A correlation with the atmospheric extinction is being studied.

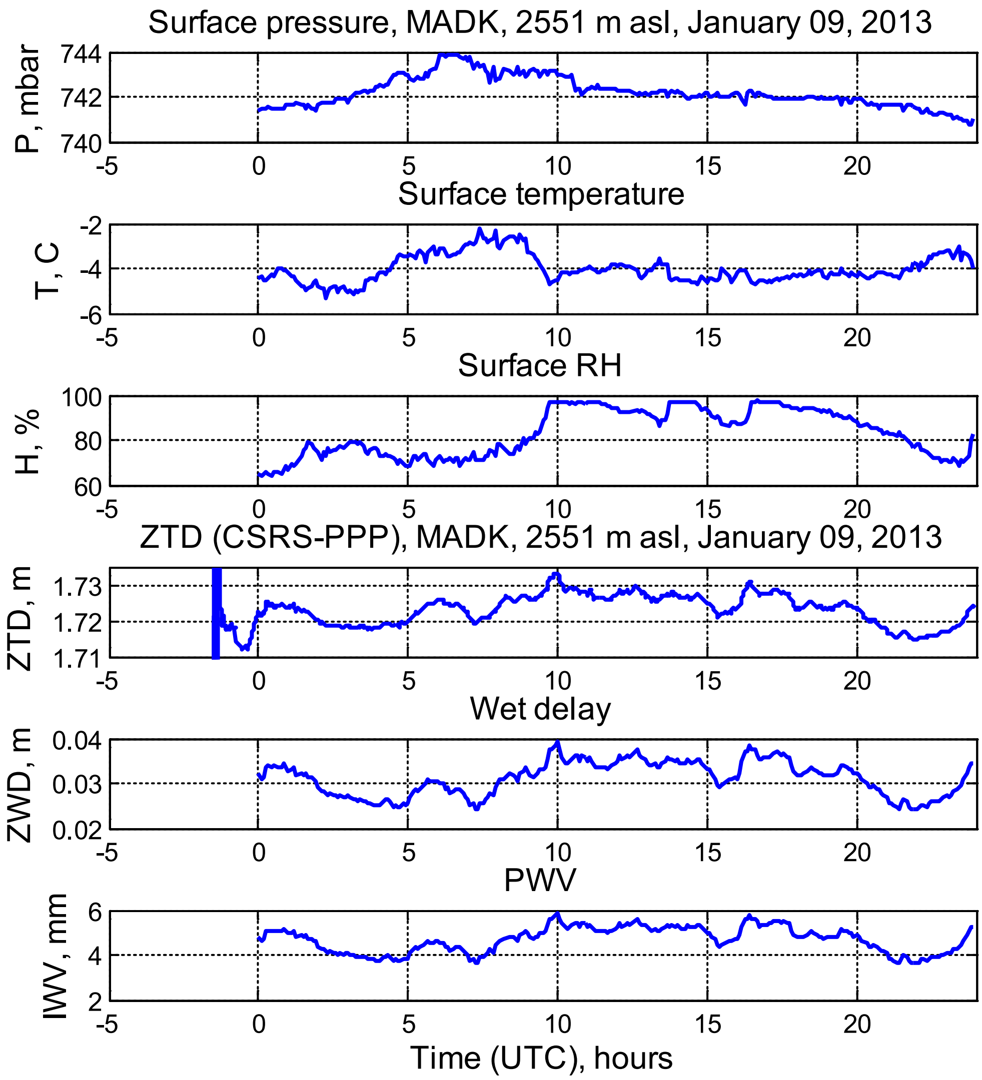
References:

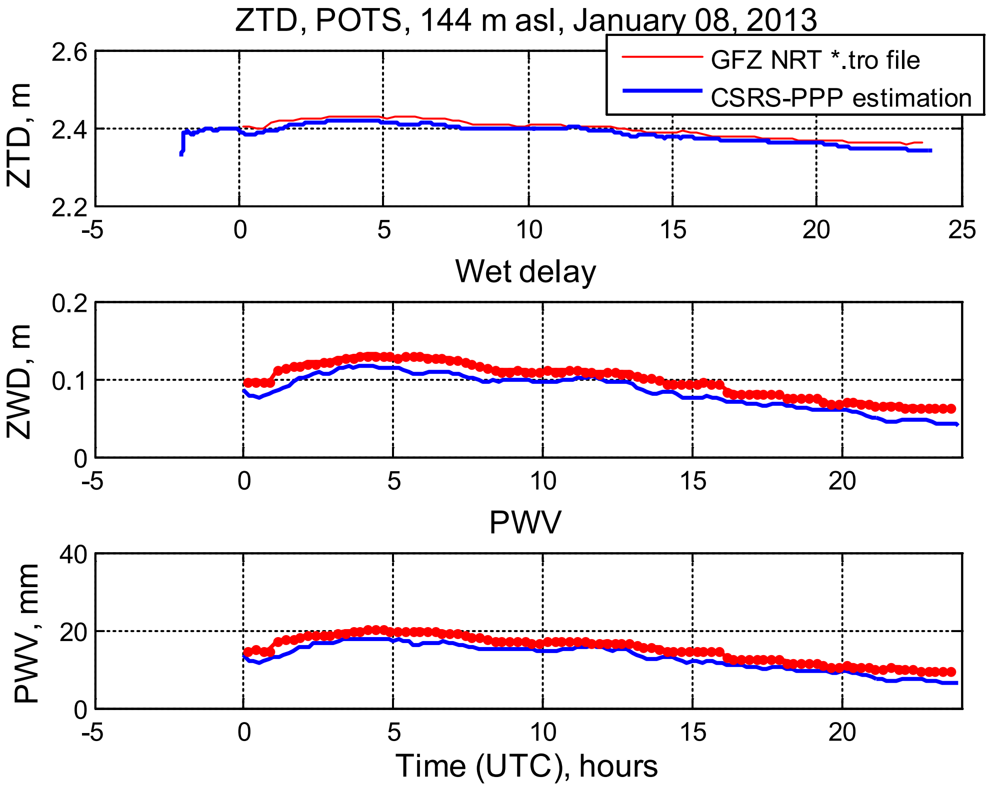
1. http://www.cawa-project.net/
2. Saastamoinen J. (1972), Atmospheric correction for the troposphere and stratosphere in radio ranging of satellites. In “The use of artificial satellites for geodesy”, Geophys. Monogr. Ser., 15, 247–251.
3. Bevis et al. (1994), GPS meteorology: Mapping zenith wet delays onto precipitable water, Journal of Applied Meteorology, 33, 379–386.
4. Dick, G., Gendt, G., Reigber, C. (2001): First experience with near real-time water vapor estimation in a German GPS network. - Journal of Atmospheric and Solar-Terrestrial Physics, 63, 12, 1295-1304.
5. Gendt, G., Dick, G., Reigber, C., Tomassini, M., Liu, Y. Z., Ramatschi, M. (2004): Near Real Time GPS Water Vapor Monitoring for Numerical Weather Prediction in Germany. - Journal of the Meteorological Society of Japan, 82, No. 1B, 361-370.

$$ZDD = \frac{0.002277}{\cos z}\left[P + \left(\frac{1255}{T} + 0.05\right)e - \tan^2 z\right]$$

$(1-0.00266\cdot\cos(2\varphi)-2.8\cdot 10^{-7}\cdot H)$


dry
Hw = 40km
wet
Hd = 11km
Observation Site
Earth's surface


Surface pressure, MADK, 2551 m asl, January 09, 2013
P, mbar
744
742
740
Surface temperature
T, C
-2
-4
-6
Surface RH
H, %
100
80
60
ZTD (CSRS-PPP), MADK, 2551 m asl, January 09, 2013
ZTD, m
1.73
1.72
1.71
Wet delay
ZWD, m
0.04
0.03
0.02
PWV
IWV, mm
6
4
2
-5
0
5
10
15
20
Time (UTC), hours


ZTD, POTS, 144 m asl, January 08, 2013
GFZ NRT *.tro file
CSRS-PPP estimation
ZTD, m
2.6
2.4
2.2
-5
0
5
10
15
20
25
Wet delay
ZWD, m
0.2
0.1
0
PWV
PWV, mm
40
20
0
Time (UTC), hours