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First results of GPS water vapour and its comparison with radiosondes and ERA-Interim reanalysis in Algeria

Houaria Namaoui[1] , Salem Kahlouche[1], Ahmed Hafidh Belbachir[2], Roeland Van Malderen[3], Hugues Brenot[4], Eric Pottiaux[5]

[1]Division of Space Geodesy, Center of Space Techniques (CTS), Arzew, Algeria , [2]Department of Physical Engineering, University of Sciences and Technology of Oran (USTO), Oran, Algeria

[3]Royal Meteorological Institute of Belgium (RMIB), Uccle, Belgium ,[4] Royal Belgian Institute for Space Aeronomy (BISA), Uccle, Belgium , [5]Royal Observatory of Belgium (ROB), Uccle, Belgium

❑ Abstract

This study presents the estimation of precipitable water from GPS observations and meteorological data in Algeria, over three stations located at Algiers, Bechar and Tamanrasset. The objective of this study is to analyze the sensitivity of the GPS Precipitable Water (PW) estimates for the three sites mentioned above to the weighted mean temperature (T_m), either obtained from the Bevis et al. 1992 T_m-T_s regression, the Boutiouta & Lahcene (2013) T_m-T_s regression developed for Algeria, and calculated directly from ERA-Interim reanalysis. This study shows that the differences in T_m are of the order of 18 K producing differences of 1.8 mm in the final evaluation of PW. A good agreement is found between PW-GPS and PW calculated from radiosondes, with a small mean difference with Vaisala radiosondes (RS 92). A comparison with GPS and ERA-Interim shows a large difference of (4 mm) in the region of highlands. This difference is possibly due to the Earth's topography. These first results are encouraging, in particular for meteorological application in this region, with good hope to extend our dataset analysis to a more complete, global coverage over Algeria.

In this study we have tested different Tm formulations :

- $T_m = 0.72T_0 + 70.2$ ***Bevis et al. (1992)***
- $T_m = 0.96T_0 + 14.7$ ***Boutiouta et al.(2013)***
- ***Tm from ERA-Interim reanalysis***

❑ Determination of different Tm calculations

- T_m calculated by the regressions (**Bevis and Boutiouta**) have a more pronounced daily cycle than T_m calculated by ERA-Interim because the surface temperature varies with a larger amplitude during a day than a mean (integrated) temperature.
- The regression of Boutiouta, which is formulated for Algeria, shows worse agreement with T_m ERA-Interim than the regression of Bevis, which is based on radio soundings launched in the United States.

In this context , we have calculate *Tm* directly from radiosones data in Algeria at these stations as the reference, The comparison is plotted in Figure 3.

- For all stations, both in daytime and nighttime, a large bias between T_m of Boutiouta and the other T_m formulations, and in particular with the T_m calculated from radiosondes, exists.
- The best agreement with the T_m calculated from the radiosondes is with the T_m of ERA-Interim
- The distinct behavior of the T_m Boutiouta, might also be explained by the large geographical and climatology variety in Algeria, a country of the subtropical zone where the dominant climate is hot and dry. Therefore, it might be very difficult to find one T_m-T_s relationship that could be applied to whole the country.
- For Algeria, it seems that the parameterization of **Boutiouta & Lahcene (2013)** does not bring any added value related to geographical or climatological characteristics with respect to the Bevis T_m parameterization, even on the contrary

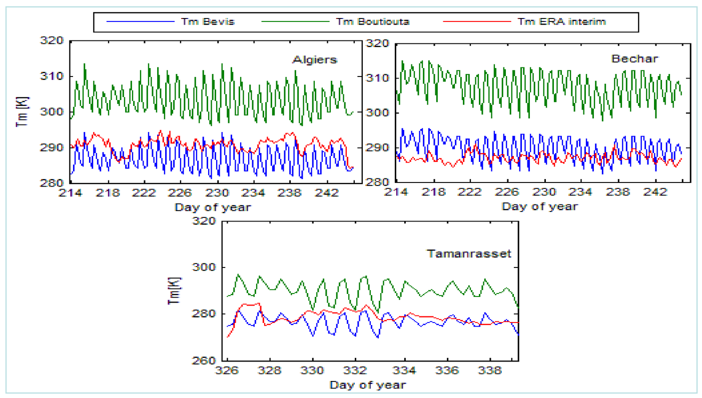

Fig .1:Time series of different T_m estimations for the 3 Algerian stations: Algiers, Bechar (both for August 2012) and Tamanrasset (21 Nov – 4 Dec 2012).

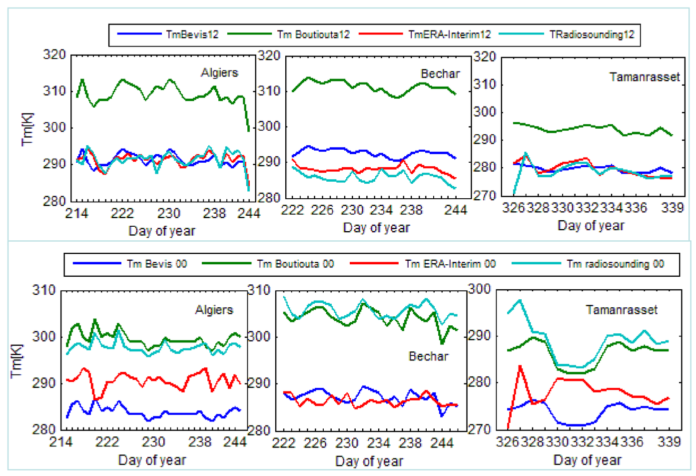

Fig .2:Comparison of different T_m parameterizations at daytime (12h) and nighttime (00h).

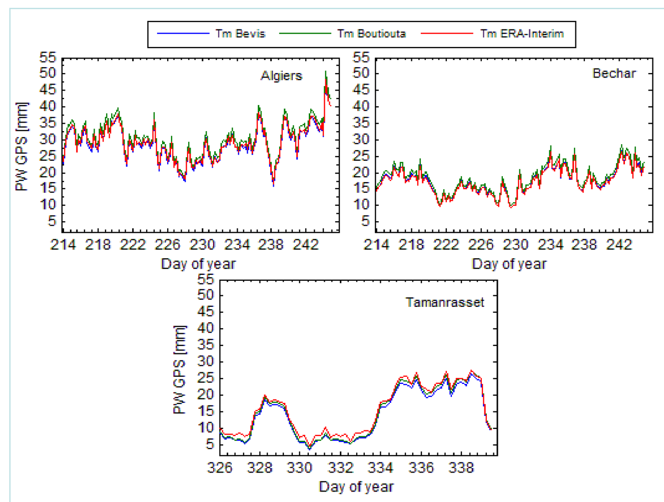

Fig .3 : Time series of precipitable water from different T_m parameterizations of different T_m parameterizations at daytime (12h) and nighttime (00h).

❑ Comparison of the different PW GPS

The different time series of water vapour are presented in Figure 3.

- The values of water vapour vary with the location of the station
- The maximum value of 51 mm was reached in August at the Algiers station, which is close to the sea, and the minimum value (of the order of 3.7 mm) was observed for the Tamanrasset station in November.
- For the Bechar station, the mean values of water vapour are in the order of 18 mm, so in between the Algiers and Tamanrasset ranges.
- The uncertainty of Tm in GPS PW was calculated from the formula (1) and we have find , the difference of 18 K produce a small difference in GPS PW (2mm), This study is agree with **Fernández et al., (2010)** were difference of 15 K produce a small difference in GPS PW.

The effect of the uncertainties in T_m values on GPS-PW estimations is given by the following equation **(Sappuci 2014):**

$$\sigma_{pw}^2 = \left[10^6.ZWD.R_w.\frac{k_3}{\left(R_w k_3 + R_w k_2' T_m\right)^2}\right].\sigma_{T_m}^2$$

$k_2' = (0.2213 \pm 0.0225)\ K/Pa$

$k_3 = (373900 \pm 1200)\ K^2/Pa$

❑ Validation of PW GPS with radiosondes and ERA-Interim

1. PW GPS and radiosondes

we compare the PW GPS retrievals with the PW calculated from the integration of the vertical profiles measured with radio soundings (PW RS).

- A Good agreement can be observed between the PW RS and PW GPS over all stations, except for the Algiers station, where the correlation coefficient is only around 0.60. This station has a strong outlier with a too low PW value of around 5 mm measured by the radiosonde.
- This GPS station is also characterized by a large daytime dry bias of around 5 mm, compared to the RS observations.

Station	T_m	RMSE	MBE	R²	RMSE	MBE	R²
		12h00			00h00		
Algiers	ERA-Interim	3.24	4.49-	0.77	3.91	2.09	0.62
	Bevis	3.16	44.5-	0.77	3.84	1.48	0.63
	Boutiouta	3.34	5.40-	0.77	4.07	-2.95	0.63
Bechar	ERA-Interim	1.54	2.27-	0.89	1.35	0.89-	0.95
	Bevis	1.90	0.94	0.88	1.95	-2.92	0.92
	Boutiouta	1.92	- 0.53	0.86	2.06	1.89	0.92
Tamanrasset	ERA-Interim	0.92	-0.68	0.99	2.90	-0.29	0.92
	Bevis	0.98	- 0.74	0.99	2.92	- 0.15	0.92
	Boutiouta	1.03	-1.43	0.99	3.06	- 0.76	0.92

- The origin of these large mean differences might be related to the PW GPS (multipath near the GPS antenna and minor quality of the radiosonde type MODEM M2K2-DC at this station.).
- **(Nash et al., 2011)**, (WMO) RS intercomparison campaign , the systematic bias estimates showed that MODEM night-time relative humidity measurements had large positive bias greater than 10 per cent for much of the time in the lower and middle troposphere,
- Comparisons of M2K2DC measurements to GPS IWV performed at Nîmes and Ajaccio, France, showed also a moist bias at night, typically of 5 to 10 % **(Bock et al., 2013).**
- For the Bechar and Tamanrasset stations, the correlation coefficients are higher (around 0.88 for all observations, but even between 0.92 and 0.99 if we separate the daytime and nighttime observations), the RMSE ranges between 1 to 3 mm, and GPS PW biases are mostly dry and below 2 mm. For Bechar station, the biases vary significantly among the different T_m parameterizations and between daytime and nighttime.

2. PW GPS and ERA-Interim reanalysis

- The results are hardly affected by the used T_m parameterization, and the differences are especially in the regression slopes and biases.
- The daytime observations at the Algiers and Tamanrasset stations show a better agreement (lower RMSE, higher correlation coefficients), but with larger dry biases than the nighttime measurements.

Station	T_m	RMSE	MBE	R²	RMSE	MBE	R²
		12h00			00h00		
Algiers	ERA-Interim	2.87	-1.75	0.75	3.08	1.12	0.72
	Bevis	2.879	-1.77	0.75	3.12	1.73	0.72
	Boutiouta	2.88	-3.63	0.75	3.12	0.26	0.72
Bechar	ERA-Interim	2.34	4.23	0.81	1.98	4.03	0.92
	Bevis	2.33	3.85	0.81	1.94	3.94	0.91
	Boutiouta	2.33	3.85	0.81	1.94	3.94	0.92
Tamanrasset	ERA-Interim	1.39	-1.03	0.97	2.01	-0.59	0.95

- For the Algiers station, the PW GPS compares better with PW ERA-Interim for all statistical parameters and at both timestamps, whereas exactly the opposite is true at Bechar. This can probably be explained by the model sensitivity to topography. Bechar is surrounded by a mountain range that has three summits on the top of the Saoura valley at altitudes varying between 1200 and 1900 m

- For Tamanrasset, the PW GPS agrees best with PW RS for the daytime observations, whereas for the nighttime measurements, the agreement is better with the PW ERA-Interim, except for the biases. This station has also a distinct geography, being surrounded by several streambeds (these remaining dry except during the rainy season), so called Oueds (in our case the Oueds of Tamanrasset, Sersouf and Tahaggart).

❑ Conclusions

- This study gives some first results of comparing different precipitable water data sources for three stations in Algeria (Algiers, Bechar and Tamarasset). In particular, we analyzed the impact of the weighted mean temperature T_m on the retrieved PW GPS by comparing three different T_m parameterizations (the T_m-T_s linear regression of Bevis et al. (1992), the T_m-T_s linear regression for Algeria from Boutiouta & Lahcene (2013), and T_m calculated from ERA-Interim).
- The results indicate that the differences in T_m are of the order of 18 Kelvin, producing differences of 1.8 mm in the final evaluation of PW.
- A good agreement between GPS and radiosondes has been evaluated with mean differences less than 2 mm, except at the Algiers station (MODEM M2K2-DC) radiosonde launches.
- The comparison between PW ERA-Interim and PW GPS shows differences in the magnitude and the sign of the bias that vary from station to station .
- The T_m of ERA-Interim has been closest to the reference (T_m calculated directly from the radiosondes). However we suggest to use the T_m of ERA-Interim for all applications of GNSS and meteorology in Algeria, given the lack of radiosondes stations in the north of Algeria and of the weak correlation between surface temperature and mean temperature in a large area of countries like Algeria, as was illustrated by the poor performance of the T_m-T_s linear regression of Boutiouta in comparison with the other T_m estimations.

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