OCENA REANALIZE ERA5 VARIACIJE ATMOSFERSKE VODNE PARE V ALŽIRIJI

EVALUATION OF ERA5 REANALYSIS ATMOSPHERIC WATER VAPOR VARIATION IN ALGERIA

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IZVLEČEK

V kontekstu podnebnih sprememb je padavinska vodna para (PW) ključni parameter atmosferskih procesov in dinamike. Ker je izredno variabilna v prostoru in času, je njena natančnost bistvenega pomena za vsako geodetsko ali podnebno študijo.

Glavni cilj te študije je izračunati padavinsko vodno paro iz reanalize ERA5 za štiri postaje v Alžiriji, ki imajo različne vrste podnebja. Odločili smo se, da bomo uporabili metodo integracije za različne ravni tlaka z ERA5.

Vrednosti vodne pare primerjamo tudi z vmesno reanalizo ERA in profili radiosond. Rezultati dela kažejo dobro ujemanje z ERA5 in ERA interim s korelacijo, ki ni manjša od 0,95 in 0,70 v primerjavi s profili radiosond. Prvi rezultati so spodbudni, zlasti za meteorološke aplikacije, pri čemer se kažejo dobre možnosti za uvedbo še enega podatkovnega niza, na primer GNSS, za boljše razumevanje sprememb in obnašanja vodne pare v daljšem obdobju opazovanja.

ABSTRACT

In climate change context, the precipitable water vapour (PW) is key parameter of atmospheric process and dynamics and its variation is very high in space and time. It's accuracy is paramount for any geodetic or climatic study.

The main objective of this study is to compute precipitable water vapour from ERA5 reanalysis for 4 stations in Algeria which have different types of climate. We opt for using integration method for different level of pressure with ERA5.

The values of water vapour are also compared with radiosondes profiles. The results of this work shows good agreement with a correlation that is not less than not 0.95 and 0.70 compared as radiosondes profiles. The first results are encouraging, in particular for meteorological applications with good hope to introduce another dataset as GNSS to more understand the variation and behavior of water vapour over a long period of observation.

KLJUČNE BESEDE

vodna para, GNSS, Era Interim, Era 5

KEY WORDS

water vapour, GNSS, Era interim, Era 5

1 INTRODUCTION

Water vapor is a key parameter of the atmosphere with very high spatial and temporal variability (Trenberth et al., 1998). It contributes as a main source in the formation of clouds and precipitation, for this reason, this quantity must be known with precision to predict environmental and climatic processes.

This parameter is very difficult to estimate because it varies strongly in time and space. The use of different techniques makes it possible to estimate this quantity such as radiosoundings, lidars, radiometers but they cannot be operated only in certain weather conditions and sometimes prove to be very expensive to set up.

Satellite positioning systems are generally used for geodetic positioning and/or geodynamic deformation. Over the years, several GNSS (Global Navigation Satellite System) constellations have been created allowing the use of GNSS for meteorological purposes (Bevis et al, 1992).

Indeed, the water vapor present in the atmosphere is an essential element for the weather forecast.

The potential of GNSS was thus highlighted as a lower cost alternative and different studies was conducted in different regions of world to validate GNSS water vapour with radiosondes , MODIS , SSMI and other satellites (Torres et al., 2010; Van Malderen et al., 2014; Namaoui et al., 2017; Abdellaoui et al., 2019, Namaoui et al., 2021)

The variability of water vapour depends of many parameters like climate conditions, location of station, in a context of climate change, it is very important to follow the variations of trace gases in the atmosphere. To better understand all this change, it is necessary to improve the knowledge of water vapor; a homogeneous database must be established at the local or even regional scale with very reliable data.

The objective of our work is to calculate this quantity of water vapor from global climate model reanalysis dataset (ERA5) and see its variations in a region like Algeria where the climate is varied, because the country has a very large area with different topography regions (four times that of France): Algeria is located under a transitional climate, between the temperate zone and the tropical zone, this position puts it under the direct influence of the Mediterranean climate in the North and the desert climate in the South.

The reanalysis data are produced by combining measurements and observations from several sources (SYNOP station, radiosondes, satellites...), with simulation data to fill the existing gaps in the meteorological parameters, in order to obtain a regular and consistent representation of the state of the atmosphere.

The validation of Era reanalysis products (water vapour) with different techniques was effected in different regions in world [(Zhang et al., 2018), (Jie et al., 2021).] and the accuracy of results varies from region to region according to the climatic conditions and the terrain topography. (Rakhmatova et al, 2021).

2 DATA AND METHODS

2.1 ERA reanalysis

ERA-Interim is a global atmospheric reanalysis dataset from 1979 to the present, produced by a numerical weather prediction model run at ECMWF. (Dee et al, 2011).

The reanalysis has been widely applied in atmospheric science, particularly in operational meteorological centers to analyze the state of the climatological situation and to assess forecast error anomalies.

ERA5 is the last generation of atmospheric reanalysis, which has just been placed to replace ERA-Interim which was launched in the period 2006 to 2019. ERA5 provides hourly atmospheric reanalysis data at 37 pressure levels from 1,000 to 1 hPa, with a horizontal spatial resolution of 0.25° × 0.25°.

A bilinear interpolation is necessary to obtain the vertical profiles on each station from ERA5.

Based on (Jiang et al., 2016) , The PW can be calculated using the specific humidity and air pressure from the reanalysis data set as followed in equation 1

$$PW = \sum_{i}^{n-1} \frac{(q_i + q_{i+1}).(p_{i+1} - p_i)}{2\rho_w.g} \qquad (1)$$

$$g = 9.780325.\left[\frac{1+0.00193185.\sin(\varphi)^2}{1-0.00669435.\sin(\varphi)^2}\right]^{0.5} \qquad (2)$$

where n is the total number of layers, qi and pi are the specific humidity (unit: kg/kg) and air pressure (unit: Pa) at each layer, respectively; ρw is the density of liquid water and defined as 1,000 kg/m3; g is the gravitational acceleration (unit: m/s2) (Jiang et al., 2016).

2.2 Radiosondes

The radiosonde data, with a resolution of 12 h (at UTC 00:00 and 12:00), can be obtained in the websites of the University of Wyoming (http://weather.uwyo.edu/upperair/sounding.html).

In this study, we have used data from two out of three radiosondes stations in Algeria (Figure 1).

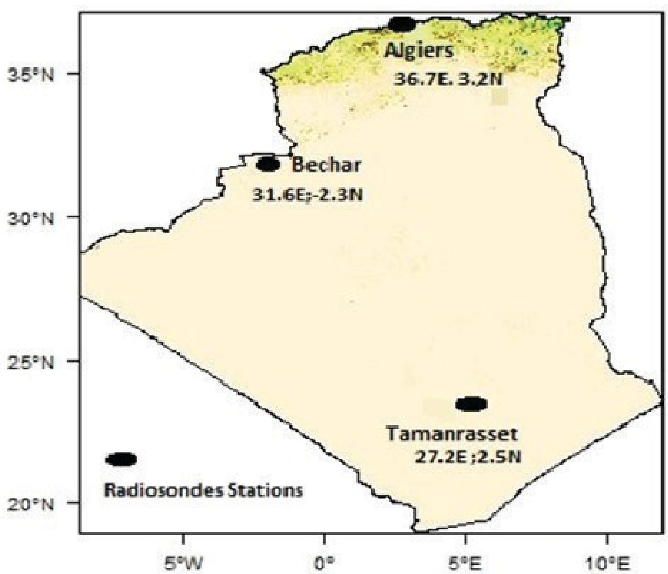

Figure 1: Location of radiosondes stations in Algeria.

Using equation (3), the Precipitable Water Vapour (PWV) content for each radiosonde profile can be calculated as (Realini et al, 2014):

$$PW = \int_{h_1}^{h_{21}} \rho_w dh = \sum_{i=1}^{n} \rho_{d,i} r_i \Delta h_i \tag{3}$$

$\rho_{d,i}$, r_i, Δh are respectively the dry air density, the mixing ratio, and the altitude step for layer where ρ_w the water vapour density, n is the total number of layers between h_1 and h_2. The dry air density ρ_d is expressed as

$$\rho_d = \frac{M_d}{R} \frac{P}{T} \tag{4}$$

with the molar mass of dry air M_d = 0.0289644 kg mol−1 and the universal gas constant for air R= 8.31432 J mol−1 K−1. T is the observed air temperature in Kelvin. The mixing ratio r is defined as the dimensionless ratio of the mass of water vapour to the mass of dry air

$$r = 0.622 \frac{e}{P} \tag{5}$$

where e is the partial pressure of water vapour and P is the air pressure.

3 RESULTS AND ANALYSIS

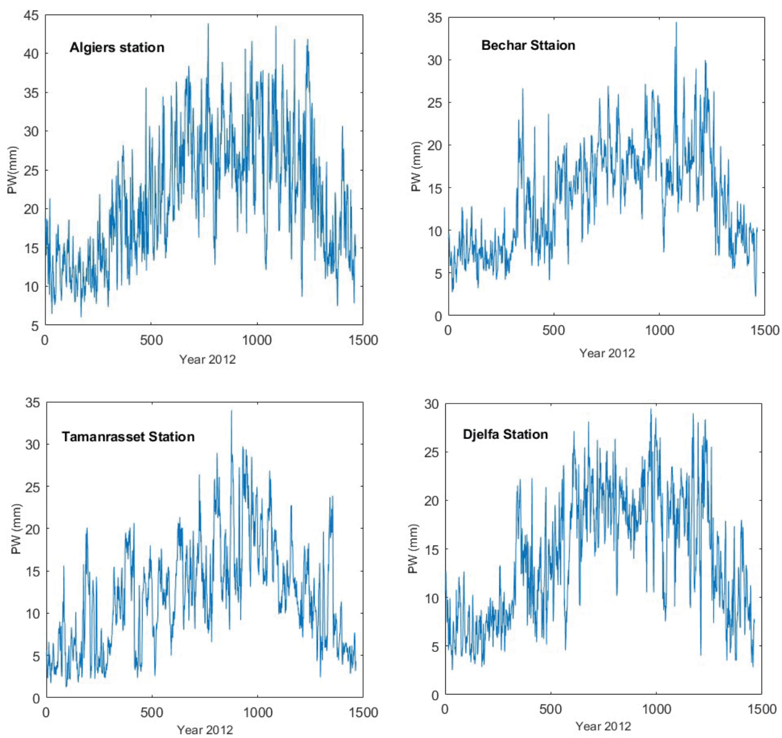

Figure 2: Time series of PW ERA5 reanalysis for Algiers, Bechar, Tamanrasset and Djelfa.

For year 2012, The time series of precipitable water from ERA5 at four stations (Algiers, Bechar, Djelfa and Tamanrasset) are plotted in Figure 2.

The values have been calculated every six hours, we notice very well that the behaviour varies from one station to another according to the climatic conditions of each one, moreover the station of Algiers is close to the sea or the peak it exceeds 45 mm since the humidity is very high.

However, the other stations Bechar, Tamanrasset and Djelfa the maximum was around 33, 32.5 and 36 respectively and the minimum was recorded at Tamanrasset with a value of 1.1 mm of precipitable water vapour. Tamanrasset is located in the extreme south of Algeria. The variation water vapour is very high in summer season compared with winter period generally, water vapour mixing ratio decreases with altitude in the troposphere.

The same behaviour was observed at Djelfa station with high values compared with Tamanrasset and Bechar station. The climate of Djelfa is of the semi-arid type with a nuance continental. The winters are cold and harsh and the summers hot and dry with the average humidity, varies between 35% and 79%.

The changes and distributions of atmospheric water vapour in different seasons are in accordance with the rule that the water vapour content is affected by the topographic dynamic lift effect (Hezhen et al., 2021). In figure 3, we can see clearly the seasonal variability in summer and winter. The mean value during winter is the order of 14 mm and the max is the order of 39 mm otherwise during the period of summer the values was higher than winter because during the warm months, the humidity of the air is also higher almost everywhere especially near the sea. (Lees et al.,2019).

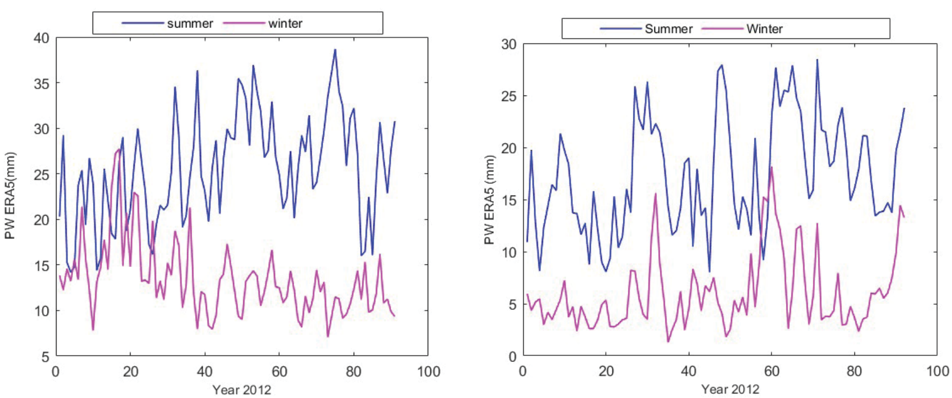

Figure 3: Seasonal variability of water vapour at Tamanrasset (left) and Algiers (right) stations.

4 COMPARISON WITH ERA INTERIM AND RADIOSONDES PROFILES

The evaluation was based on statistical parameters MBE (mean bias error) and RMSE (root-mean-square error) to analyse and evaluate the retrieved PWV precision based on different types of measurements.

A lower RMSE indicates a smaller discrepancy between the Era5 and Era interim PWV. The following formulas were applied in our statistical analysis (Shuaimin et al. 2020):

$$MBE = \frac{\sum_{i=1}^{N} (PW_{ERA5} - PW_{ERA\text{int}}}{N} \qquad (6)$$

$$MBE = \sqrt{\frac{\sum_{i=1}^{N} (PW_{ERA5} - PW_{ERA\text{int}}}{N}} \qquad (7)$$

where N is the number of PW pairs, PWE_{RAint} is PW value of ERA interim PW_{ERA5} is PW value of ERA5.

The ERA5 PW dataset was compared to PW ERA-Interim dataset based on some commonly used statistical indicators such as correlation coefficient, bias, and RMSE. Generally, the correlation coefficient (R) is mostly used to assess the degree of consistency instead of absolute agreement, and a positive (negative) bias indicates an overestimation (underestimation) of PWV.

The scatter plots for all observations of PW ERA5 against PW ERA interim can be found in figure 2, together with the fitted linear regressions.

A fairly good agreement can be observed between two sources of ERA reanalysis over all stations with mean bias error do not exceeds 0.7 mm and withcorrelation coefficient at least 0.96.

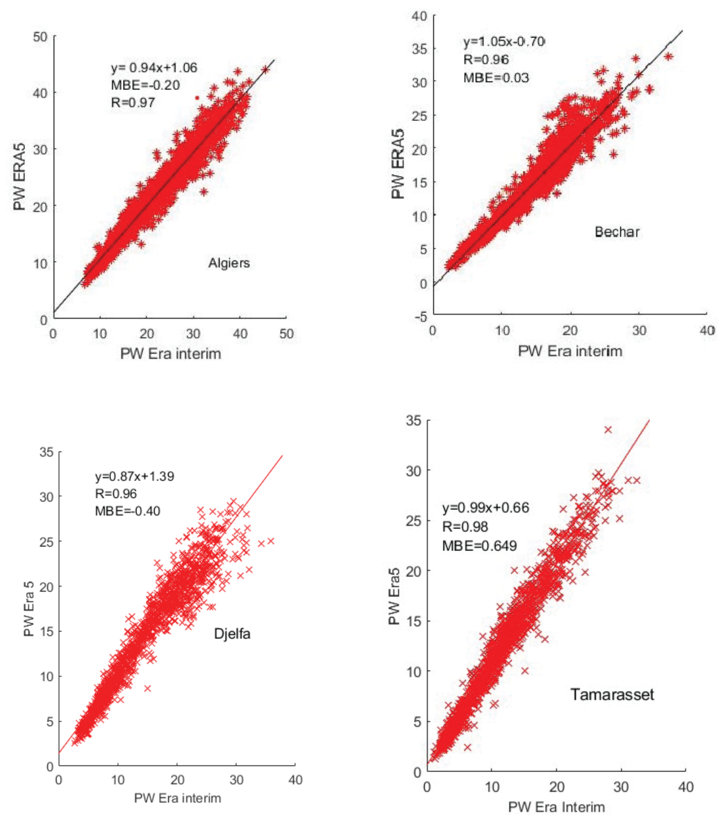

Figure 4: Scatter plots of PW ERA5 and PW ERA interim at Algiers, Bechar, Tamanrasset and Djelfa.

Tamanrasset and Djelfa stations are located at altitude where depasses 1400m and with lower values of water vapour. The mean bias of these stations is slightly higher compared as Algiers. Where model of reanalysis affects topography.

In the absence of availability of GNSS data in Algeria, we have compared the values of ERA5 reanalysis with two radiosondes profiles available in Algeria (Algiers and Tamanrasset). The comparison was made with ERA5 at the same lunch of radiosondes (12 UTC).

The figure 5 shows time series of PW ERA5 and radiosondes at Algiers and Tamanrasset Station

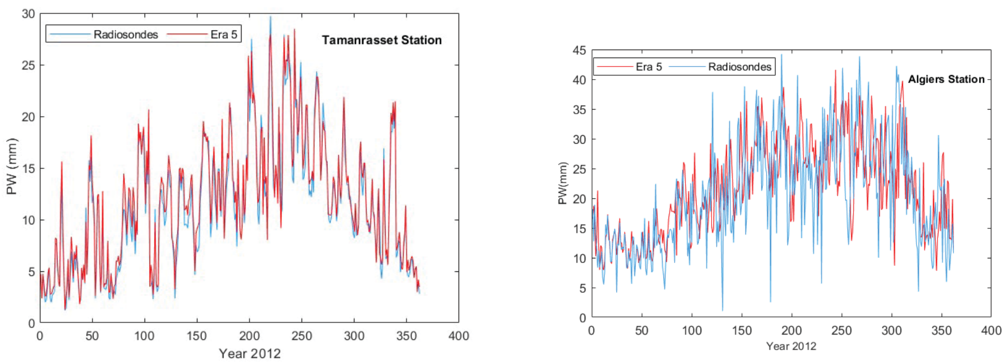

Figure 5: Time series of Precipitable water vapour from Radiosondes and ERA5.

Correlation coefficient of 0.65 and 0.77 at Algiers and Tamanrasset respectively with the mean bias, which not exceeds 1 mm. The results of PW radiosondes and ERA5 are plotted in figure 5 and statistical parameters are summarized in table 2.

Table 2: Statistical comparison between PW ERA5 and PW radiosondes. The MBE is the mean PW difference taken as RS minus ERA5.

Stations	MBE [mm]	RMS [mm]	R
Algiers	0..98	4.5	0.65
Tamanrasset	-0.73	3.5	0.76

5 CONCLUSION

The objective of this study is to derive the water vapour from ERA reanalysis and see the performance of two sources data over a different stations and different climate s in Algeria.

The seasonal variation of water vapour depends on location and climate indices as precipitations and topography of region, the maximum was observed at Algiers station with 44 mm and minimum of 1.26 mm at Tamanrasset station where the climate of the Sahara, hot, sunny and arid, is characteristic of that of a hot desert, located on both sides of a tropic.

The results show a good agreement between precipitable water vapour ERA5 and ERA interim at different locations with mean bias which not exceeds 0.6 5 mm and correlation coefficient higher than 0.90.

The water vapour from reanalysis was also compared with 2 profiles radiosondes in Algeria and the statistical results show an agreement between ERA5 reanalysis and radiosonde profile especially in region with a complex topography as Algeria.

The Tamanrasset station show a negative bias between PW Radiosondes and ERA5 reanalysis. We also test the impact of outliers on our comparison. The correlation coefficent increases from 0.65 to 0.70 at Algiers Station.

The models of ERA reanalysis can be useful in applications of GNSS meteorology in the absence of meteorological stations.

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