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Forecast of relationship between a relative humidity and a dew point temperature

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Abstract

Relative humidity is a sensitive parameter in the sciences. It impacts the physical performance of electrical devices, metals, agro-food and biological items to name just a few. There are numerous factors such as dew point temperature, ambient temperature and solar radiation that can combine to influence relative humidity. There have been a handful of studies conducted on forecasting variations in relative humidity in the city of Biskra, Algeria. One typically finds that the dew point temperature is involved in variants of relative humidity, so we have been trying to predict it and create a semi-empirical equation as a function of apparent solar time, influenced by maximum and minimum dew point temperature, rather than create a new correlation related with ambient temperature. This study aims to contribute relative humidity as a function of the dew point temperature and validate it with experimental measurements.

Keywords: relative humidity, environment, correlation, dew point temperature, semi-empirical, ambient temperature

1. Introduction

Most recent measurement systems have been employed primarily for weather forecasting purposes. Little thought has been given as to whether we can compare present observations to data from a century or even a decade previously. The result has been changes in instrumentation and practice which, whilst likely improving the absolute accuracy of the measurement, also compromise the historical continuity of the record for long-term climate monitoring purposes. To create a climate data record requires the identification and removal of as many such non-climatic influences as possible (homogenization) to yield an estimate of the true climate evolution.

The definition of dew point temperature is the temperature where water vapor in air condenses into liquid water at the same rate at which it evaporates. At temperatures below the dew point, water will leave the air [1].

Relative humidity is a measure of how much water vapor is in the air compared with the total amount of water vapor the air is capable of holding at a given temperature. If the relative humidity is 50% at room temperature then the air in the room is at half holding capacity. Relative humidity is the most common measurement given in weather reports.

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As regards evaluation of some uses and impacts in terms of humidity, there are some useful sources in the literature on relative humidity which we set out below.

Mateusz Wyrzykowski et al. [2] reported experimental measurements of RH changes in a low w/c mortar during uniaxial compressive loading. An instantaneous RH increase of almost 2% RH was observed inside sealed mortar samples in loading with a stress/strength ratio of 30%. The initial RH increase was recovered over time while the sample was under constant load.

Julian E. Castillo et al. [3] reported on an experimental study performed in a facility that allows visualization of the condensation process on a vertically oriented, hydrophobic surface at a controlled relative humidity and surface subcooling temperature. They related that the distribution and growth of water droplets was monitored across the surface at different relative humidity (45%, 50%, 55%, and 70%) at a constant surface sub-cooling temperature of 15°C below the ambient temperature (20°C).

Jiali An et al. [4] presented a novel relative humidity (RH) sensor based on single-mode–multimode–single-mode (SMS) fiber structure [5–7]. They showed the related numerical simulations of transmission spectra of SMS fiber structure with different surrounding refractive index. Sensitivity of the RH measurement of 0.09 nm/% RH in the range 30% to 80% RH was experimentally achieved. The intensity of wavelength at 1543 nm decreased as the humidity increased.

Dimas Firmanda Al Riza et al. [8] predicted hourly solar radiation using two methods. The first method used a decision matrix based on RH and ambient temperature data. The second method used an RH - clearness index, clearness index-beam atmospheric transmission and beam atmospheric transmission-RH correlation. The authors determined that the results show both methods perform satisfactorily.

Karthik Nadig et al. [9] This research improved the prediction accuracy of existing air and dew point temperature ANN models, by combining the two weather variables into a single ANN model for each prediction horizon. They reported a reduction in the mean absolute error (MAE) of prediction and in the number of prediction anomalies.

Sungwon Kim et al. [10] developed a soft computing model, including Generalized Regression Neural Networks (GRNN) and Multilayer Perceptron (MLP), for modeling daily dew point temperature. The results of GRNN and MLP performances are better than those of MLRM performance for the best input combinations at both stations.

F. Chabane et al. [11–22] present a study of heat transfer in a solar air heater by using a new design of solar collector. Collector efficiency in a single pass of a solar air heater both without and with fins attached under the absorbing plate was investigated experimentally. Maximum efficiency was obtained for 0.012 and 0.016 kg/s with, and without fins. In this case the paper finds that solar irradiation had a marked effect on air temperature and relative humidity.

2. Validation of measurement experiments:

Our validation is compared with experimental measurements to obtain the best approximation. Correction comes with real values, with data taken from a weather station in Biskra.

The Biskra weather station is a facility on land, with instruments and equipment for measuring atmospheric conditions to provide information for weather forecasts and to study the weather and climate. The measurements taken include temperature, barometric pressure, humidity, wind speed, wind direction and precipitation amounts. Wind measurements are taken with as little obstruction as possible, while temperature and humidity measurements are kept free from direct solar radiation or insolation. Manual remarks are taken at least once daily, while automated measurements are taken at least once an hour.

2.1. Instruments

The weather station helps us to measure and transmit data on wind speed, atmospheric pressure and air temperature.

Typical weather stations have the following instruments:

1. Thermometer for measuring air and sea surface temperature
2. Barometer for measuring atmospheric pressure
3. Hygrometer for measuring humidity.
4. Anemometer for measuring wind speed
5. Rain gauge for measuring liquid precipitation over a set period of time.

3. Numerical method:

3.1. Least squares

The method of least squares is a standard approach in regression analysis to find the approximate solution of over determined systems, i.e., sets of equations where there are more equations than unknowns. "Least squares" means that the overall solution minimizes the sum of the squares of the errors made in the results of every single equation.

3.2. Problem statement

The objective consists of adjusting the parameters of a model function to best fit a data set. A simple data set consists of n points (data pairs) (xi, yi), i = 1,..., and, where xi is an independent variable and yi is a dependent variable whose value is found by observation.

The model function has the form f(xi, β), where m adjustable parameters are held in the vector β. The goal is to find parameter values for the model which "better" fits the data. The least squares method finds its optimum when the sum, S, of squared residuals:

$$S = \sum_{i=1}^{n} r_i \tag{1}$$

is at a minimum. A residual is defined as the difference between the actual value of the dependent variable and the value predicted by the model.

$$r_i = y_i - f(x_i, \beta) \tag{2}$$

An example of a model is that of the straight line in two dimensions. Denoting the intercept as $\beta 0$ and the slope as $\beta 1$, the model function is given by f(xi, β)= $\beta 0 \ + \beta 1 x$. See linear least squares for a fully worked out example of this model.
A data point may consist of more than one independent variable. For example, when fitting a plane to a set of height measurements, the plane is a function of two independent variables. In the most general case there may be one or more independent variables and one or more dependent variables at each data point.

4. Dew point temperature

The dew point is the cooling temperature the air reaches for the current water vapor in the air to condense into liquid, thus forming dew, frost, collecting on surfaces, and forming clouds. The temperature at which the air becomes saturated with water vapor is the dew point.

Choosing the form of dew point temperature, estimating the new correlation

$$T_r = Y_0 + A \times \sin\left(\frac{\pi \times (ts - t_c)}{w}\right) \tag{3}$$

After modelling the relation we can capture the form of equations such as:

$$Y_0 \approx \left(\frac{T_{\max} + T_{\min}}{2}\right) \quad \& A \approx \left(\frac{T_{\max} - T_{\min}}{2}\right) \tag{4}$$

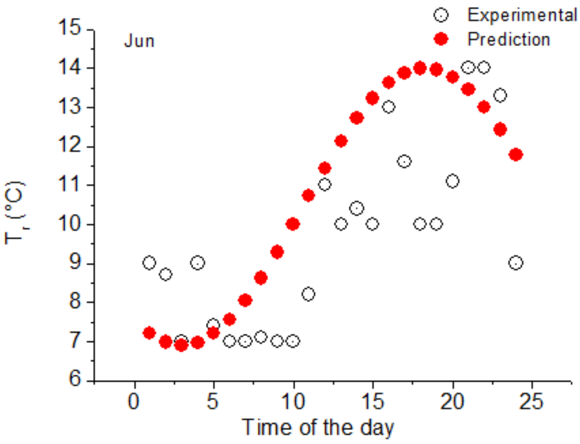

Figure 1: Variation of dew point temperature between experimental and semi-empirical data (April)

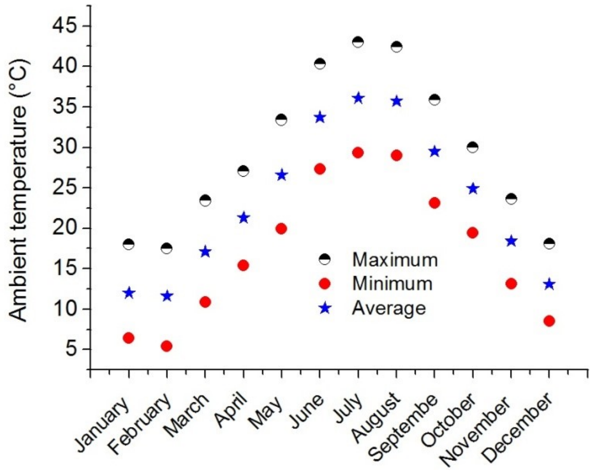

Figure 2: Ambient temperature profile as a function of months

4.1. Modelling ambient temperature

In most cases, the ambient temperature is taken as the average value. Its evolution from sunrise to sunset is marked by minimum values at sunrise and sunset and a maximum value in the middle of the day. These are the only values given by weather stations. Modelling the temperature of the air is generally used, as heat transfer fluid in solar collectors is of paramount importance.

4.2. Proposed semi-empirical correlation:

A relationship was modelled between the ambient temperature and temperature minimum and maximum corresponding to all hours of day, no forget duration of the day and time of the day with real times, and we can propose the semi-empirical correlation by:

$$T_{am} = Y_1 + A_1 \times \exp\left(-2 \times \left(\frac{(AST - X_c)}{w}\right)^2\right) \quad (5)$$

$$A_1 = \frac{\overline{A}}{w\sqrt{\frac{\pi}{2}}}$$

4.3. Relative humidity

Humidity describes the quantity of water vapor in a gas such as air. There are many different ways to express humidity, e.g., relative humidity, absolute humidity, dew point temperature and mixing ratio. In the following, the origin of water vapor in the air is discussed and the most frequently used definitions for humidity are described.

$$RH = A \times \cos\left(\frac{B}{\pi} \times (ts - C)\right) + D \quad (6)$$

5. Results and discussion

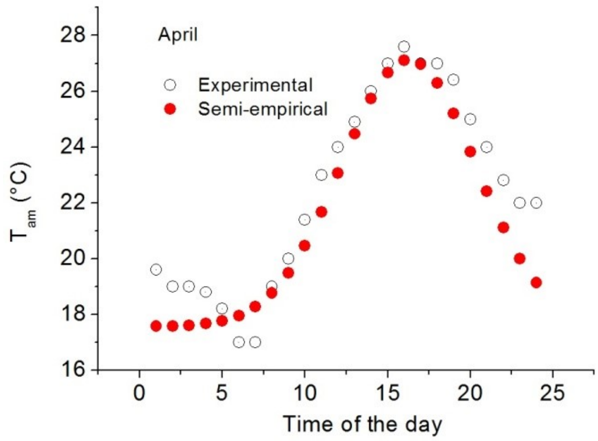

Figure 3: Variation of ambient temperature between experimental and semi-empirical data (April)

Fig. 1 shows the variation of dew point temperature measured experimentally in Biskra, Algeria; the tests were carried out in a period from January through December 2014. These tests were conducted at the University of Biskra (34.8°N, 5.73° E). This region is characterized by a dry climate in summer. The tests were performed for clear days, free of disturbances (clouds).

These data measured in Biskra, Algeria show that the region is characterized by high temperatures with strong seasonal variations in July and January Fig. 2.

Fig. 4 shows the variation of relative humidity in Biskra, corresponding to the new correlation relationship. Relative humidity started with maximum values and fell when the ambient temperature was at maximum values.

Table 1: Data showing the constants of correlation of dew point temperature

Month	Y_0	A	w	t_c	T_{max}	T_{min}	$\frac{(T_{\max}-T_{\min})}{2}$	$\frac{T_{\max}+T_{\min}}{2}$	R^2
January	5.596	1.751	10.383	9.054	7	4.5	1.25	5.75	0.6077
February	7.037	2.147	8.873	7.997	9.5	3.5	3	6.5	0.7763
March	7.563	2.450	17.647	-4.13	10	4	3	7	0.7714
April	9.593	1.637	11.924	2.531	12	7	2.5	9.5	0.6415
May	8.761	5.550	12.349	2.57	12	4.3	3.85	8.15	0.6728
Jun	9.7212	2.515	13.64	13.32	14	6.9	3.55	10.45	0.6471
July	14.79	3.291	9.924	9.170	20	10.5	4.75	15.25	0.8012
August	24.48	5.291	14.784	-4.20	30	19	5.5	24.5	0.7161
September	13.615	1.506	8.404	7.627	15.2	11	2.1	13.1	0.7233
October	10.013	1.198	17.719	15.491	11.7	7.4	2.15	9.55	0.8206
November	8.890	2.059	14.585	-3.418	12	6.4	2.8	9.2	0.6706
December	4.094	1.772	12.913	4.628	6	2	2	4	0.8531

Table 2: Data showing the constants of correlation of relative humidity

Month	A	B	C	D	H_{max}	H_{min}	$\frac{(H_{\max}-H_{\min})}{2}$	$\frac{(H_{\max}+H_{\min})}{2}$	R^2
January	7.242	0.811	2.962	61.637	69	52	8.5	60.5	0.7493
February	-17.73	0.852	-51.972	50.329	70	32	19	51	0.9156
March	18.274	0.667	1.8378	60.819	79	43	18	61	0.9353
April	4.8369	2.311	12.448	45.452	64	36	14	50	0.1716
May	9.3061	0.937	5.7039	39.011	49	21	14	35	0.4883
Jun	15.249	0.763	4.4378	29.982	46	16	15	31	0.9843
July	-15.455	0.939	-1.9486	31.420	52	18	17	35	0.9367
August	31.333	0.783	27.7533	50.599	79	31	24	55	0.7520
September	8.4399	0.917	5.2065	29.718	36	24	6	30	0.9208
October	-4.8621	1.934	26.237	47.987	63	28	17.5	45.5	0.8088
November	13.477	0.896	4.0081	50.099	64	33	15.5	48.5	0.8603
December	14.817	0.865	4.3673	62.697	78	45	16.5	61.5	0.8444

Table 3: Data showing the constants of correlation of relative humidity

Month	Y_0	A	w	X_c	T_{max}	T_{min}	$(T_{\max}-T_{\min})$	$\frac{T_{\max}+T_{\min}}{2}$	Adj. R-Square
January	9.86	82.38	7.68	15.45	17.5	6.5	11	12	0.9730
February	13.57	103.75	7.076	15.74	17	5	12	11	0.8974
March	13.25	73.79	14.94	14.94	22.5	10	12.5	16.25	0.9510
April	18.29	102.9	8.87	16.77	27	15	12	21	0.9419
May	19.45	85.88	8.06	17.66	32.5	16.5	16	24.5	0.9196
Jun	24.86	137.66	9.26	16.58	40	27.5	12.5	33.75	0.8419
July	30.44	98.94	7.42	18.13	43	29	14	36	0.8584
August	31.82	62.07	6.93	17.12	42.5	28.5	14	35.5	0.7597
September	29.68	90.35	7.025	15.5	35	22.5	12.5	28.75	0.7597
October	18.39	77.69	6.85	17.33	30	20	10	25	0.8983
November	13.72	142.38	9.93	16.32	24	13	11	18.5	0.9144
December	6.88	109.51	7.39	14.93	17.5	7.5	10	12.5	0.9645

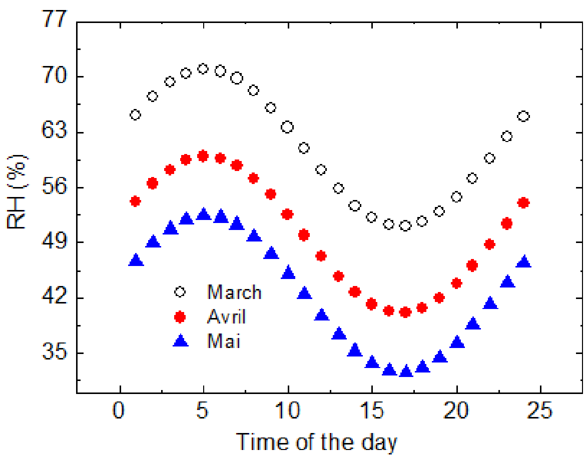

Figure 4: Variation of relative humidity of the semi-empirical data (April)

6. Conclusion

In our study, we predicted ambient temperature, dew point temperature and relative humidity through modelling by numerical methods and validated the results with experimental results.

The data gained from the experimental and theoretical study were used to develop a mathematical model. From the results obtained we note that the ambient temperature profile achieved by the proposed semi-empirical model is the nearest fit to that provided by the experimental data.

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