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Using Fuzzy Logic Approach on Evaporation Modeling

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Abstract

Due to chaotic behavior of weather, meteorological variables are controlled by many parameters which should be analyzed by nonlinear approaches. Thus, long-term prediction is almost impossible. In this study, it is aimed to simulate evaporation by using three different independent meteorological variables. In this context, daily data taken from Guzelyurt meteorological station in the Northern Cyprus is used. The measured data includes observations of temperature, relative humidity and atmospheric pressure. The observations are between the years of 2005 and 2014. Adaptive Neuro Fuzzy Inference System method is more useful for the abovementioned meteorological modeling structed in general stochastical ways in order to obtain a rule based evaporation model with membership functions. Fuzzy Logic model is structured with three inputs: temperature, relative humidity and atmospheric pressure and one output: evaporation. Three membership functions are defined for each input information, therefore we have 27 rules. These rules are defined to model the relations between the inputs and output. Here, Sugeno type Fuzzy Inference System is chosen for modeling the evaporation. Then, fuzzy based output are compared to real weather data and observations. The determination coefficient (R2) is obtained as 0.74, which is a statistically significant value. It will be planned to extend the study by considering other factors such as wind and solar radiation.

Keywords: Evaporation, Modeling, Fuzzy Logic, Northern Cyprus

INTRODUCTION

Water management is critical for the studies related to environmental subjects. Especially in recent years, climate change indications have pointed out the importance of water management. In this context, accurate determination of evaporation as one of the main components of water budget, is crucial for environment policies [1]. Fuzzy Logic gives a solution to this problem by representing the uncertainness. Fuzzy Logic uses expert opinion and its intuition to identify problems and structures. In this study, an independent variable (evaporation) is estimated by using three dependent meteorological variables (temperature, relative humidity and atmospheric pressure). It is clearly known that these dependent variables are not the only factors on modelling evaporation; therefore, a general mathematic equation can be written to identify evaporation. Fuzzy Logic model was structured with three inputs and one output. For every inputs, three membership functions were used and 3x3x3=27 rules were obtained. This rules were prepared to model the relations with the inputs and outputs.

DATA and METHODOLOGY

In the study; evaporation, atmospheric pressure, temperature and relative humidity data taken from Guzelyurt Meteorological Station which is located in Northern Cyprus were used. The observation period was taken to be 2005-2014 for all variables. Figure 1-4 show the time series of variables used in the study.

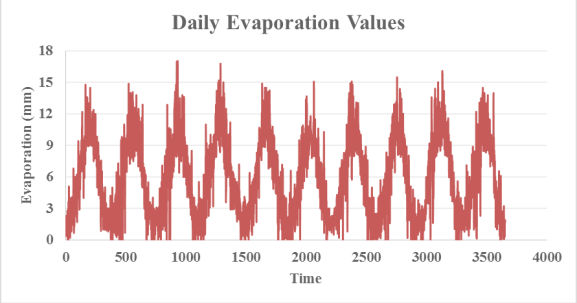

Figure 1. Time series of daily evaporation values

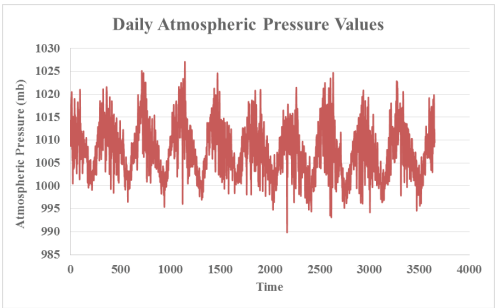

Figure 2. Time series of daily pressure values

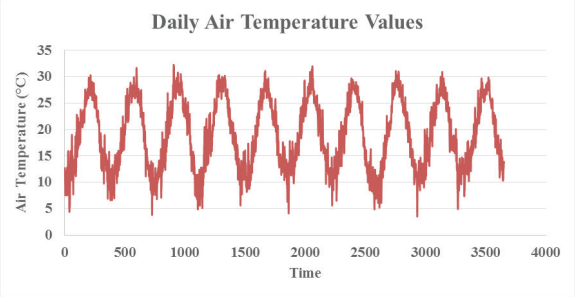

Figure 3. Time series of daily temperature values

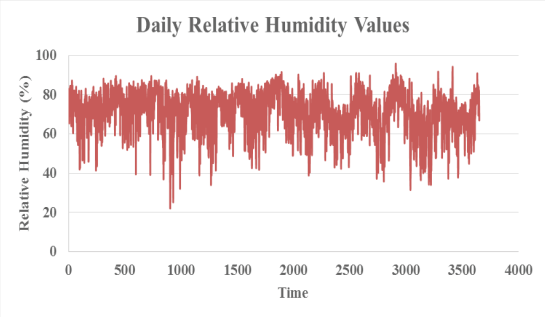

Figure 4. Time series of daily humidity values

One of the main points of fuzzy logic modelling is to choose Fuzzy Inference Method (FIS). There are some different FIS methods as Sugeno, Mamdani, Tsukamoto, Şen [2]. This methods contains advantages and disadvantages to each other's. Mamdani has an inference system like human behaviour and so it can be used to model very complicated nonlinear systems [3]. On the contrary, Sugeno have a constant output and so has less mathematical problem load. So, Sugeno is chosen for some problems and systems [4]. In this study, Sugeno Fuzzy Inference System are chosen to model evaporation.

After creating the Fuzzy Model the system are examined with a Simulink model. Fuzzy Logic Model block contains our fuzzy design. For fuzzy logic model, there are three inputs as pressure, temperature and humidity. And the block has an output as "Fuz_evaporation" (Figure 5).

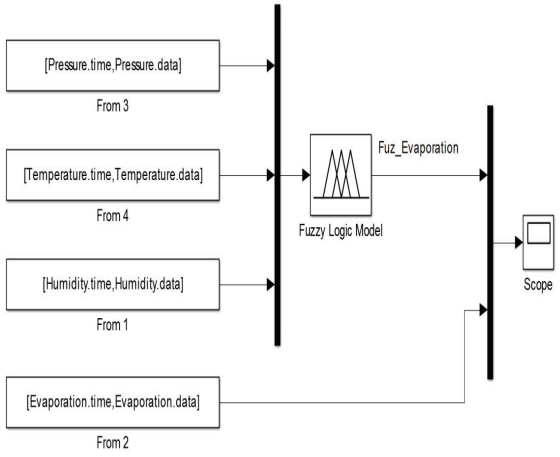

Figure 5. Fuzzy Logic Simulink Model

In Figure 6-8, 3-D surfaces of two inputs and output (evaporation) can be seen. It is clearly said that high evaporation values were related with low humidity and pressure values. On the other hand, when the temperature increases, higher evaporation is observed.

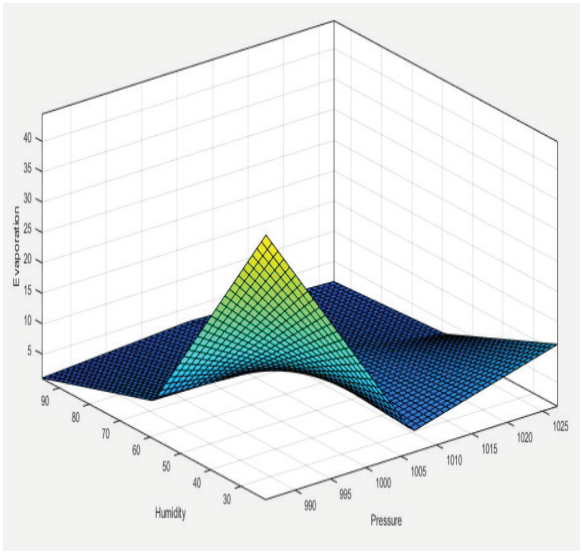

Figure 6. Pressure-Humidity-Evaporation Surface

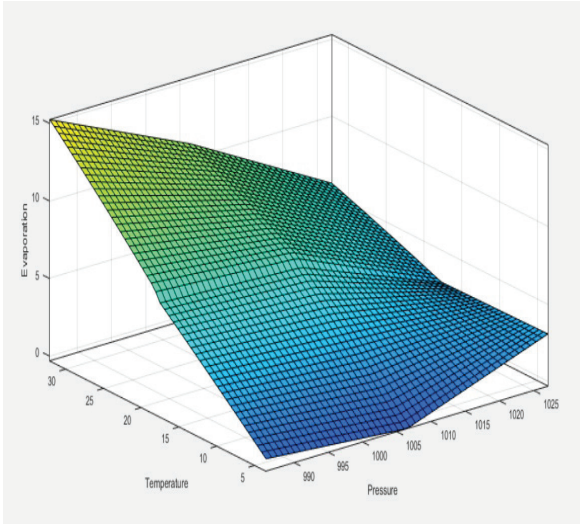

Figure 7. Pressure-Temperature-Evaporation Surface

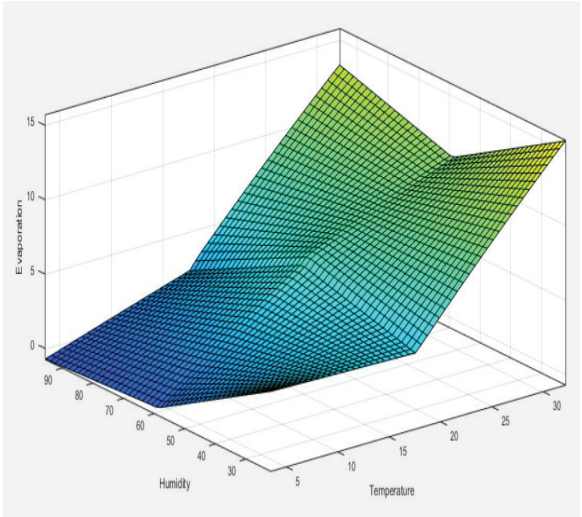

Figure 8. Temperature-Humidity-Evaporation Surface

APPLICATION and RESULTS

Figure 9 and Figure 10 show the prediction results of Fuzzy model. It is easily seen that, Fuzzy model can predict the behaviour of evaporation. On the other hand, it is a fact that model is insufficient on higher evaporation values. This situation can be seen by looking at Figure 10.

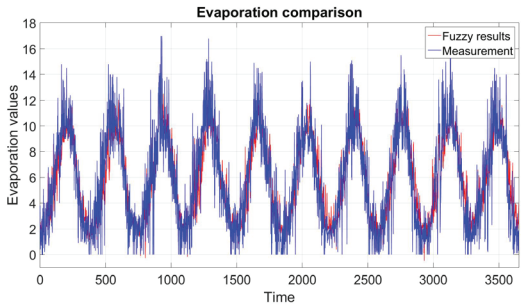

Figure 9. Fuzzy Logic Model results

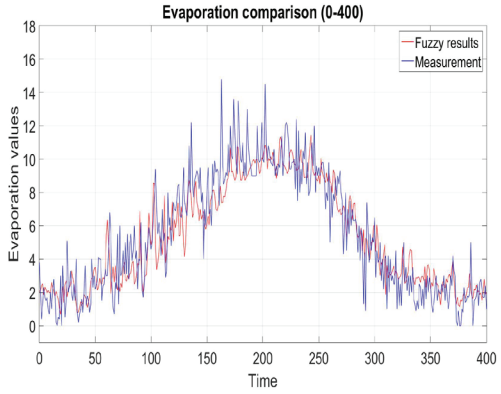

Figure 10. Fuzzy Logic Model results (first 400 values)

Figure 11 shows the scatterplot between observations and predictions. It is obvious that bigger fluctuations from fitted line are observed in higher evaporation values. This result is agreeable with abovementioned results. The determination coefficient (R2) is obtained as 0.74, which is a statistically significant value.

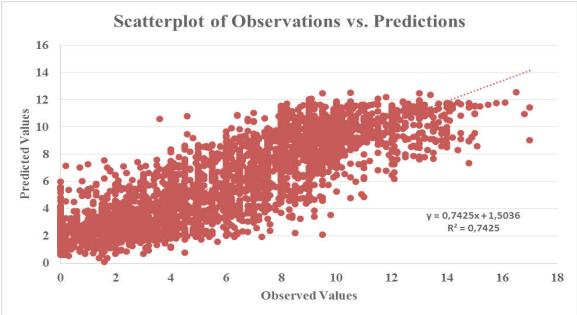

Figure 11. Scatterplot of observations and predictions

As a conclusion, the recent study needs to be extended in the near future in order to obtain more consistent results by considering other factors such as wind and solar radiation.

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