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Modelling net radiation at surface using "*in situ*" netpyrradiometer measurements with artificial neural networks ☆

Antonio Geraldo-Ferreira [a,b], Emilio Soria-Olivas [c], Juan Gómez-Sanchis [c,*], Antonio José Serrano-López [c], Almudena Velázquez-Blazquez [d], Ernesto López-Baeza [b]

[a] *Fundação Cearense de Meteorologia e Recursos Hídricos, Fortaleza, Ceará, Brazil*
[b] *Climatology from Satellites Group, Department of Physics of the Earth and Thermodynamics,University of Valencia, Spain*
[c] *Electronic Engineering Department, E.T.S.E, University of Valencia, C/ Dr Moliner 50, 46100 Burjassot, Valencia, Spain*
[d] *Royal Meteorological Institute of Belgium, Bruxelles, Belgium*

A R T I C L E I N F O

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A B S T R A C T

The knowledge of net radiation at the surface is of fundamental importance because it defines the total amount of energy available for the physical and biological processes such as evapotranspiration, air and soil warming. It is measured with net radiometers, but, the radiometers are expensive sensors, difficult to handle, that require constant care and also involve periodic calibration. This paper presents a methodology based on neural networks in order to replace the use of net radiometers (expensive tools) by modeling the relationships between the net radiation and meteorological variables measured in meteorological stations. Two different data sets (acquired at different locations) have been used in order to train and validate the developed artificial neural model. The statistical results (low root mean square errors and mean absolute error) show that the proposed methodology is suitable to estimate net radiation at surface from common meteorological variables, therefore, can be used as a substitute for net radiometers.

1. Introduction

Net radiation is a fundamental parameter that governs the climate of the lower layers of the atmosphere and it depends critically on the structure and composition of the atmosphere and the presence of clouds, in addition to surface features such as albedo, emissivity, temperature, humidity and thermal properties of the underlying soil. Thus net radiation is a fundamental quantity for analyzing the evolution of climate, from both local and global perspective. It is the driving force of physical and biological processes such as evapotranspiration, the latter being used to optimize the quality and yield of crops, water resources planning, weather forecasting, etc. (Bennie, Wiltshire, Hill, & Baxter, 2008; Ji, Kang, Zhao, Zhang, & Jin, 2009; Li et al., 2009). Despite its importance, the net radiation is measured only in a very few number of standard weather stations because net radiometers are expensive instruments and require constant care in the field, so that the net radiation measurements can be reliable. Hence, this quantity is difficult to obtain due to the cost of net pyrradiometers. This paper presents a methodology for modeling net radiation using artificial neural networks. After an initial period collecting data in order to train the network with real samples, the neural network model can be used as an estimator of net radiation samples for a given area without using net radiometers at all times. The strategy here is to train the neural network model using the net radiation collected "in situ" over a representative period and then use that model and not the net radiometer. There are a large number of linear and nonlinear models who perform modeling of the net radiation at surface but using as input the incoming solar radiation or the net radiation components separately (downwelling shortwave radiation, reflected shortwave radiation, downwelling and upwelling longwave radiation). But the root of the problem remains; radiometers are needed to obtain these input variables to the model (Alados, Foyo-Moreno, Olmo, & Alados-Arboledas, 2003; Daughtry et al., 1990; Kohsiek et al., 2007). This problem can be avoided by using as input parameters, in the neural networks developed to model the net radiation at surface, the most common meteorolog-

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* Corresponding author.
E-mail address: juan.gomez-sanchis@uv.es (J. Gómez-Sanchis).

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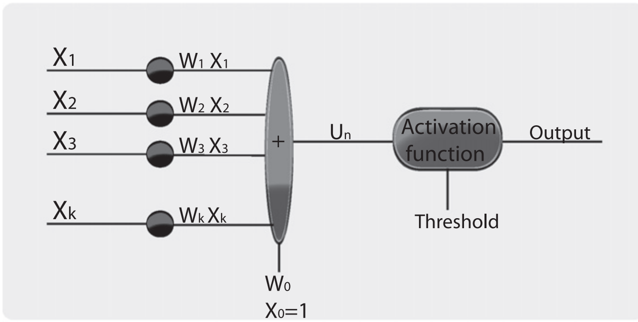

Fig. 1. Scheme of a neuron.

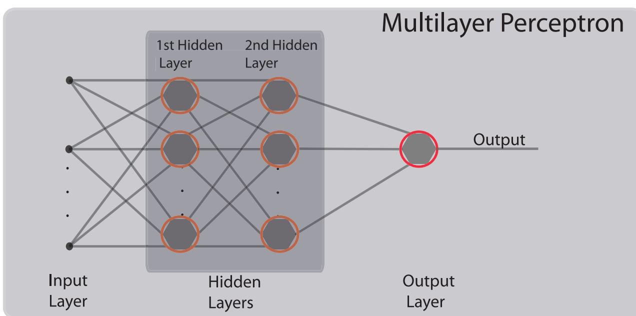

Fig. 2. Multilayer perceptron scheme. Dotted lines show the feedback in the model; in this paper this type of connections was not used.

ical variables collected in the majority of weather stations, around the word, including those that send, daily, information to the *Global Telecommunication System (GTS)*. The GTS is defining as: *The co-ordinated global system of telecommunication facilities and arrangements for the rapid collection, exchange and distribution of observations and processed information within the framework of the World Weather Watch* citegts. These variables are: wind speed, air temperature, atmospheric pressure and humidity.

The following sections describe the neural model used, the multilayer perceptron. After this, the datasets and the variables involved in the problem will be presented. Finally, we will present the results and conclusions obtained in the study.

2. Multilayer perceptron

The multilayer percepron (MLP) has been the neural network model used in this study. It consists of some individual process elements called neurons, which are arranged in a series of layers. Fig. 1 shows the structure of these neurons.

This neuron is constituted, in its first part, by a multiplier, which multiplies the inputs by a series of coefficients called synaptic weights. The objective of learning algorithm is to obtain the optimum values for the synaptic weights (Haykin, 2009). In the next part of the neuron we will find the activation function that gives nonlinear behavior to the neural network model. Fig. 2 shows the scheme of a MLP.

The number of neurons in the input and output layers is defined by the problem addressed. The user is responsible for choosing the number of hidden layers and neurons. There are many demonstrations of the fact that the multilayer perceptron with a hidden layer is an universal modelization tool of continuous functions. In the case of discontinuous functions two hidden layers are required (Reed & Marks, 1999). It is important to highlight that there are rules that guide to designer on the number of hidden neurons in each layer, however there is not work to set this number accurately. In a large number of applications a "trial and error" strategy is used in order to obtain the number of neurons in the hidden layer (Haykin, 2009).

The operation of the neural network is given by the values of synaptic weights. The learning algorithm is the procedure by which the neural model obtain the optimal parameters for solve the problem. There are many learning algorithms but, when choosing a particular one of them is necessary to consider the following features that any learning algorithm should fulfill (Bishop, 1995): Effectiveness, robustness, independence from initial conditions, high generalization ability, low computational cost and simplicity. The aim of any learning algorithm is to obtain as an error (defined

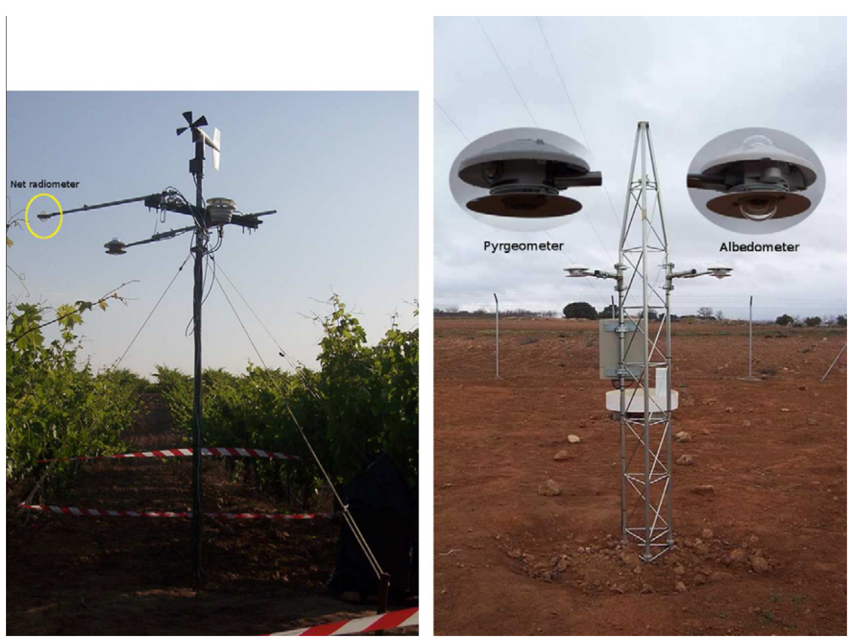

Fig. 3. (left) Net radiometer used to measure net radiation at surface in the FESEBAV experiment and (right) radiometer used at VAS that measure net radiation components separately (downwelling and reflected shortwave radiation, downwelling and upwelling longwave radiation).