

# Chapter 21

## Neural Models for Rainfall Forecasting

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### ABSTRACT

*This chapter is focused on obtaining an optimal forecast of one month lagged rainfall in Spain. It is assessed by analyzing 22 years of both satellite observations of vegetation activity (e.g. NDVI) and climatic data (precipitation, temperature). The specific influence of non-spatial climatic indices such as NAO and SOI is also addressed. The approaches considered for rainfall forecasting include classical Auto-Regressive Moving-Average with Exogenous Inputs (ARMAX) models and Artificial Neural Networks (ANN), the so-called Multilayer Perceptron (MLP), in particular. The use of neural models is proven to be an adequate mathematical prediction tool in this problem due the non-linearity of the problem. These models enable us to predict, with one month foresight, the general rainfall dynamics, with average errors of 44 mm (RMSE) in a test series of 4 years with a rainfall standard deviation equal to 73 mm. Also, the sensitivity analysis in the neural network models reveals that observations in the status of the vegetation cover in previous months have a predictive power greater than other considered variables. Linear models yield average results of 55 mm (RMSE) although they need a large number of error terms (12) to obtain acceptable models. Nevertheless, they provide means for assessing the seasonal influence of the precipitation regime with the aid of linear dummy regression parameters, thereby offering an immediate interpretation (e.g. coherent maps) of the causality between vegetation cover and rainfall.*

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## INTRODUCTION

Rainfall is a climatic phenomenon characterized by extremely irregular space-time distribution. Rainfall forecasting is a challenging task especially in the modern world where we are facing major environmental problems such as global warming. One of the most crucial issues of global climatic variability is its effect on water resources (Aida, 1996). Scenarios for rainfall forecasting are relevant for a wide range of Land Biosphere Applications, such as, agriculture and forestry, environmental management and land use, hydrology, natural hazards monitoring and management (e.g., river training works and flood warning systems), vegetation-soil dynamics monitoring, drought conditions and fire scar extent.

There are numerous factors that affect rainfall, such as terrain orography (in the particular case of Iberian Peninsula it is very complex and compartmentalized), land and sea surface temperature, soil moisture, vegetation, wind and pressure (Goosse, 2008; McGuffie & Henderson, 2005).

A brief of studies indicate that rainfall over the Iberian Peninsula is influenced by different modes of long term variability like the North Atlantic Oscillation (NAO) and El Niño South Oscillation (ENSO) (Rodó, 1997). The NAO index refers to a southern oscillation in atmospheric mass with centers of action near Iceland and over the subtropical Atlantic from the Azores across the Iberian Peninsula. The NAO controls the strength and direction of westerly winds and storm tracks across the North Atlantic (Parker & Folland, 1988). The SOI (Southern Oscillation Index) is an index used to quantify the strength of the coupled ocean-atmosphere phenomenon El Niño-Southern Oscillation (ENSO), by reflecting the fluctuations in the air pressure difference between Tahiti and Darwin, Australia.

Another important element affecting climate is vegetation cover. Far from being a passive component of the climate system, it acts on climate regulating exchanges of energy, mass, and

momentum between the surface and atmosphere. In a general way, there are two competing effects on local climate. First, vegetation modifies albedo, and it tends to cool down the surface because solar energy is reflected. Second, more leaves mean more surface area to evaporate water from, so decreasing them also decreases evaporation and, consequently, raise the local temperature. The balance between these two effects varies between different vegetation types (Adams, 2007; Bounoua, 2000; Schwartz & Karl, 1990). A wealth of studies indicates that land surface vegetation can considerably feedback on climate. Results obtained over the North American grasslands indicate that positive vegetation anomalies earlier in the growing season significantly “Granger cause” lower rainfall (and higher temperatures) later in summer (Wang, 2006). Recent observational works have also shown that there is a significant local impact of the vegetation state on monthly mean rainfall anomalies. At the same time, these studies have suggested that vegetation could have much higher impacts on rainfall at seasonal and longer time scales (Liu, 2006).

The global nature of precipitation regime is very complicated and requires sophisticated computer modeling and simulation to predict accurately. A variety of methods have been proposed for this purpose at different time scales. The classical approaches include conceptual (physical) and empirical (statistical) models. They attempt to model the fluid and thermal dynamic systems for gridpoint time series forecasting based on boundary meteorological data. These techniques often require intensive computations involving complex differential equations and computational algorithms (Beniston, 1998). In general, due to the complex nature of rainfall processes, the physical approaches are still unsatisfactory. Besides, the accuracy depends on certain constraints such as the adoption of incomplete boundary conditions, model assumptions and numerical instabilities.

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