Chapter 43
Simulation of Temperature and Precipitation under the Climate Change Scenarios:
Integration of a GCM and Machine Learning Approaches

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ABSTRACT

This study aims to discuss the potentials of machine learning methods such as artificial neural network (ANN), least squares support vector machine (LSSVM), and relevance vector machine (RVM) in downscaling of simulations of a general circulation model (GCM) for monthly temperature and precipitation of the Demirkopru Dam located in the Aegean region of Turkey. The predictors are obtained from ERA-Interim re-analysis data. The best performed downscaling model is integrated into European Centre Hamburg Model (ECHAM5) with A2 future scenario. The results are then discussed to assess the probable climate change effects on temperature and precipitation.

INTRODUCTION

Simulating precipitation and temperature, which are the main components of a hydrologic cycle, based on climate change scenarios is an important issue for water resources engineering. General circulation models (GCMs) are commonly used to predict the effect of climate change on precipitation and temperature. Since the resolutions of GCMs are generally coarse and GCMs are at large-scale, downscaling of large-scale GCM outputs to local scale is required. As a consequence of this requirement, several downscaling methods have been developed in the literature (Wilby et al., 1998).

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Among downscaling methods, the statistical downscaling methods use statistical relationships to convert global-scale outputs to local scale conditions and link the variations in global climate with those in local climate through transforming information from GCMs to the region via a series of equations. Linear regression models, nonlinear regression models, and artificial neural networks (ANNs) are used for identifying these relationships. Among the statistical downscaling methods, ANNs have been popular due to their capability to model relationships between large scale atmospheric variables (predictors) and predictands at local scale (e.g., Crane and Hewitson, 1998; Trigo and Palutikof, 1999; Fistikoglu and Okkan, 2011). In the literature, there exist important studies focusing on downscaling of precipitation and temperature via several ANN approaches. Hewitson and Crane (1992) investigated empirical relationships between sea level and 500 mb circulation fields, and the local precipitation in Chiapas, Mexico by using ANN method. Crane and Hewitson (1998) operated an ANN based downscaling procedure to derive daily subgrid-scale precipitation from general circulation model predictors for Susquehanna region of the Eastern USA. Cavazos (1999) presented a downscaling study to demonstrate the ability of nonlinear techniques, such as self-organizing maps and feed-forward artificial neural networks in producing realistic relationships between circulation–humidity fields and daily precipitation. Trigo and Palutikof (1999) simulate daily temperatures for climate change scenarios over Portugal via ANN approach. Schoof and Pryor (2001) carried out a precipitation downscaling study including both regression-based models and ANN. In their work, the downscaling techniques were discussed in terms of model performance, comparison of techniques and possible model improvements. Olsson et al. (2004) implemented a neural network modeling for 12-hour mean rainfall forecasting in the Chikugo River basin, Southern Japan considering atmospheric downscaling. Tatli et al. (2004) developed a statistical downscaling approach based on recurrent neural networks for monthly total precipitation over Turkey. Coulibaly et al. (2005) applied a time-lagged feed-forward neural network (TLFN) model to downscaling daily total precipitation series for the Serpent River watershed in Canada. Tolika et al. (2007) carried out a simulation of seasonal precipitation and raindays over Greece by using ANN. Cannon (2008) downscaled precipitation using an ANN to specify parameters of a mixed Bernoulli-gamma distribution. Ojha et al. (2010) presented a precipitation downscaling study for lake catchment in arid Region in India using multiple linear regression (MLR) and ANN. The ANN based model was found to be superior to MLR based model. Tomassetti et al. (2009) presented a neural network model, named NN5, for the downscaling of precipitation. The performance of their model was analyzed for several case studies, showing that the proposed technique could reproduce the spatial patterns of hourly precipitation as affected by complex topographical features. Mendes and Marengo (2010) presented a comparison between ANN and autocorrelation techniques over the Brazilian Amazon Basin. According to their study, ANN model significantly outperformed the other statistical models for the downscaling of daily precipitation variability. Cannon (2011) used quantile regression neural networks in precipitation downscaling. Okkan and Fistikoglu (2014) presented a study about downscaling of CGCM3 climate model outputs simulations to monthly precipitation and temperature of Tahtali watershed, in Turkey. Furthermore, Gardner and Dorling (1998) presented a review of ANN applications in the atmospheric sciences.

Although ANNs have a number of advantages, they have also some drawbacks including getting trapped in local minima and subjectivity in the determination of model structure and parameters (Suykens, 2001; Tripathi et al., 2006; Okkan and Serbes, 2012). In this sense, Vapnik (1995) and Suykens et al. (2002) have developed support vector machines (SVMs) and least squares support vector machines (LSSVMs), which provide solution to the problems appearing in ANN modeling. SVM and LSSVM methods have