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Neural network and fuzzy logic statistical downscaling of atmospheric circulation-type specific weather pattern for rainfall forecasting

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ABSTRACT

The weather natural disaster prevention for quantitative daily rainfall forecasting derived from the SACZ-ULCV weather pattern is proposed in this paper by using intertwined statistical downscaling (SD) and soft computing (SC) approaches. The fuzzy statistical downscaling (FSD) is first introduced and, then, employed for dealing with the SACZ-ULCV atmospheric circulation-type specific weather pattern for supporting daily precipitation (rainfall) forecasting. This paper also addresses the performance comparison of the FSD and the neural statistical downscaling (NSD) approaches when taking into account 12 major urban centers all over the state of São Paulo, Brazil, for the summer period. The SACZ-ULCV summer pattern is identified in meteorological satellite images when the cloudiness of the Brazilian Northeast upper level cyclonic vortices (ULCV) meets the South Atlantic convergence zone (SACZ). Increasing the convection and the cloudiness over the Southeast region of Brazil, the SACZ-ULCV causes severe rainfalls and thunderstorms with impact on the population. Finding a manner to anticipate these extreme rainfall events is of vital importance for minimizing or avoiding disasters, and saving lives. Daily rainfall forecasting had their performance improved either by using the proposed FSD or NSD in comparison to the Multilinear Regression ETA model. Results demonstrate the FSD and the NSD become feasible alternatives for achieving a correspondence from meteorological and thermo-dynamical variables to the daily rainfall variable.

1. Introduction

Natural disasters occur all over the world so far. Tsunamis, earthquakes, Vulcan eruptions, hurricanes, tornados, thunderstorms and severe rainfalls, only to mention few, are dangerous events for the civilization. They are examples of destruction and death that strike the civilization. Finding a manner to anticipate the impact concerning these natural phenomena is of vital importance for alerting, minimizing, or avoiding disasters and saving lives. This paper focus on extreme rainfall events due to its relevance for minimizing the impact on the population, by using fuzzy system or artificial neural network in synergy with statistical downscaling methods (SD).

Statistical downscaling methods are used by many numerical weather prediction centers (NWPC) for producing local or regional weather information, aiming at a better weather or climate prediction [21]. The SD encompasses both experimental observations, relative to a specific location, or simulations, computed either by a large scale general circulation model (GCM) or a regional circulation model (RCM), as shown in Fig. 1. Such an approach is, further, conceived to deal with either continuous or discrete time series. Discrete-time interval series can be associated, but not limited to, general periodic weather conditions such as seasonal periods, dry (rainy) periods.

Aiming at achieving more accurate weather forecasting, however, new approaches came out to use SD by taking into account more specific period of times within the discrete, periodic intervals. Such a shorter period of time is determined according to the interest in working with a *specific* weather pattern. After selecting a certain pattern within a time series, there is a discrete and periodic weather pattern, as illustrated in Fig. 2. One of the most known statistical downscaling approaches for specific weather pattern concerns

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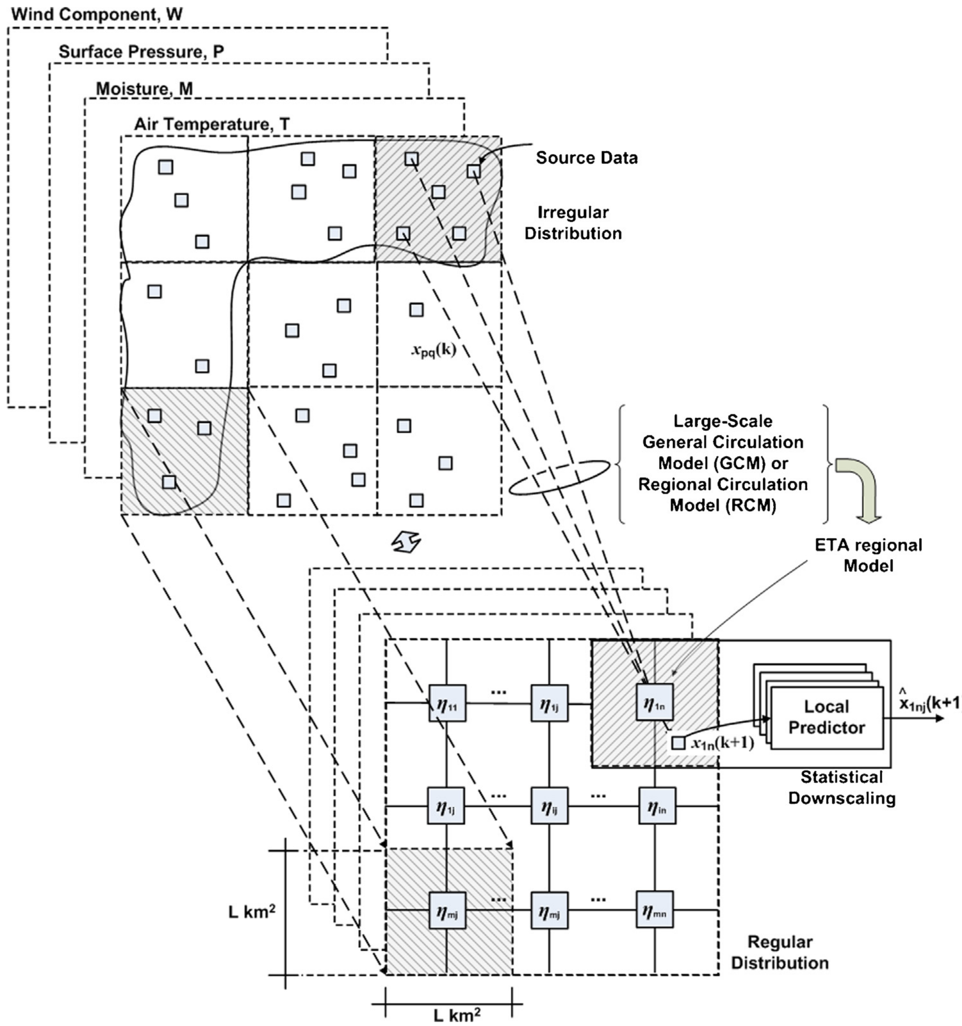

Fig. 1. A statistical downscaling method when using a $L\,\text{km} \times L\,\text{km}$ large-scale general circulation model (GCM) – or regional circulation model (RCM) – for spatial scale reduction to a local point, $x_{in}(k+1)$, by ETA Regional Models, η_{ij}, to predict a meteorological or climate state, $\hat{x}_{in}(k+1)$.

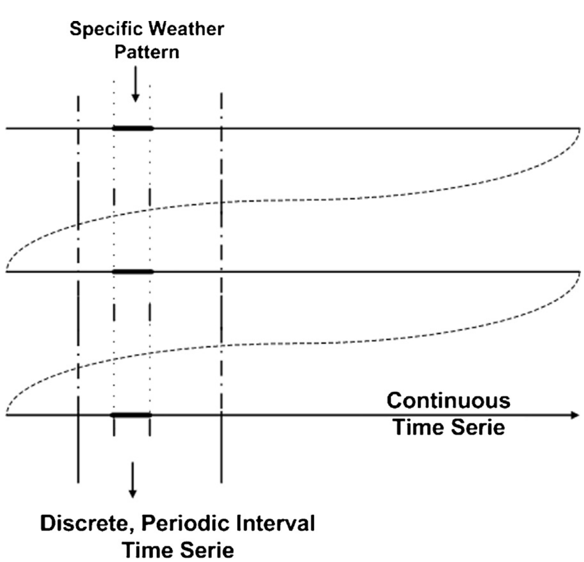

Fig. 2. Specific weather pattern: continuous and discrete, periodic interval time series.

weather pattern methods (WPM) [51]. The WPM associates a given weather pattern classification to an observational station data. Such an observational weather pattern classification can be *subjective* when concerning synoptic, qualitative information, based on expertise and heuristic [37], or *objective* when related to quantitative data, automatically obtained by using, for instance, clustering and/or classification algorithms [7,10,39]. A WPM-SD approach which relates weather cold front frequencies, a sort of atmospheric circulation-type specific weather pattern, and the rainfall forecasting is found in [50]. Such a relationship is carried out by stratifying daily rainfall occurrences according to the presence or absence of weather front systems. The importance of frontal information in statistical downscaling models concerns the improvement of rainfall predictions.

Regardless the sort of the time series employed, the weather conditions are influenced by the variability in the dynamics of time and space scales. The inherent complex, nonlinear behavior and the high variability on space and time of any weather pattern characterizes, however, such a forecasting activity as a hard task [35]. The estimation of future dynamical behavior for systems that are usually nonlinear mostly requires nonlinear identification methods [5]. Nonlinear models derived of the field of soft computing area (SC) emerge as alternative approaches.

The artificial neural network, for short neural network (NN), is one of the most prominent approaches for meteorological signal