# POTENTIAL APPLICATIONS OF CLIMATE FORECAST TO WATER RESOURCES MANAGEMENT IN SOUTH AMERICA

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## Abstract

A series of climate outlook Fora for Southeast South America begun in Montevideo, Uruguay in December 1997, in the middle of the last strong El Niño 1997/98. Participation included specialists of the four countries of the Mercosur region, i.e. Argentina, Brazil, Paraguay and Uruguay. The motivation was the concern about the ongoing El Niño in mid 1997, the availability of experimental climate forecast, and the knowledge about the impact of past El Niño in the region. In three years, a total of 12 meetings were conducted in the region.

This chapter presents a preliminary evaluation of the first nine forecasts analyses using categorical agreement between precipitation forecasts and observations. It also shows an example of practical application of climate prediction to decision-making in water resources management in Argentina.

## 1. Introduction

A series of climate outlook Fora for Southeast South America begun in Montevideo, Uruguay in December 1997, in the middle of the last strong El Niño 1997/98. Participation included specialists of the four countries of the Mercosur region, i.e. Argentina, Brazil, Paraguay and Uruguay. The motivation was the concern about the ongoing El Niño in mid 1997, the availability of experimental climate forecast, and the knowledge about the impact of past El Niño in the region. In three years, a total of 12 meetings were conducted in the region.

Participation in the Fora included researchers in meteorology, agronomy, hydrology, oceanography, related environmental sciences, public health and social sciences, as well as users of agriculture, water resources management, hydroelectric generation, civil defense and emergencies. Sponsorship was received from different international organizations and research institutes in climate variability and short-term climate prediction, as well as universities, research institutes and research centers in the region, national weather services, water resources centers and hydropower plants, national and regional rural societies and other national and regional organizations.

The economic resources for the meetings were provided mostly by local and regional sources. The Fora produce seasonal forecasts of the averaged precipitation and temperature anomaly expected for the upcoming 3-month period.

The backbone of the regional climate assessment is the consensus agreement between coupled ocean-atmosphere model forecast, physically based statistical models, results of diagnosis analysis and published research on climate variability over the region and expert interpretation of this information in the context of the current situation. The region considered for the forecast includes continental areas bounded between 20°S to 40°S and to the east of the Andes Mountains.

Seasonal climate forecasts of precipitation are expressed in probabilistic terms. For this purpose, three categories are identified: *above-normal*, *normal*, and *below-normal,* which are associated to a tercile distribution of precipitation. Homogeneous regions are identified in each case and the seasonal climate forecast is presented as the probability of occurrence of each category during the upcoming 3-month period. The probabilities assigned to each category are determined by consensus agreement among the specialists.

## 2. Preliminary Evaluation of Southeast South America Climate Outlook Fora

A preliminary evaluation of the first 9 forecasts analyzes the categorical agreement between precipitation forecasts and observations (Berri and Hordij, 2000). Due to the limited number of cases to verify, the analysis considers that the forecast corresponds to the most likely category, i.e. the category having the highest probability.

Figure 1 presents a summary of results of the first 9 forecast. Regions with red shading represent 0 out of 9 categorical agreements, while regions with dark blue shading represent 9 out of 9 categorical agreements. Considering that a

3-category forecast has a one third chance to be correct (3 out of 9), only regions with at least 6 or more categorical agreements could be considered with a minimal degree of skill.

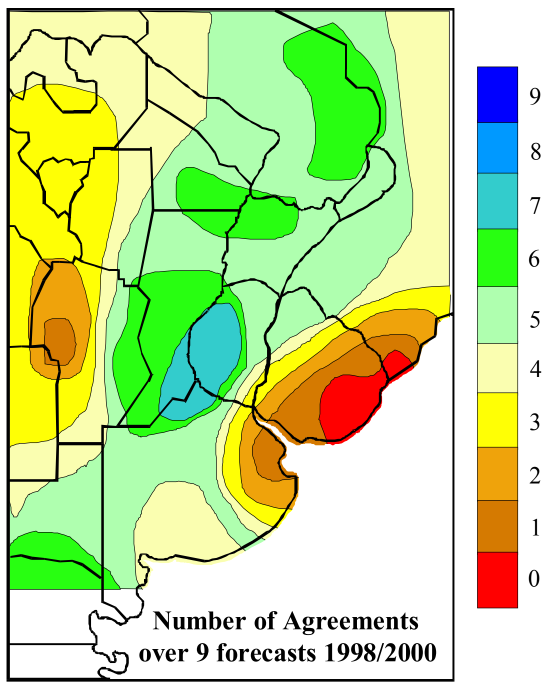


Figure 1

Figure 1 shows that the central part of the analyzed region would satisfy that condition, which includes a smaller region with 7 out of 9 agreements. These areas are located over Northeastern Argentina, within the region where statistically significant correlation between ENSO and precipitation has been reported by different authors. It should be stressed that during the analyzed period, 1998 until mid 2000, there was a very strong El Niño at the beginning, followed immediately by a strong La Niña event. Both situations provided good grounds for the skill obtained. On the other hand, the areas where there was disagreement do not show such strong association with ENSO.

Moreover, these areas are affected by local factors such as the vicinity to the Atlantic Ocean, for example in the case of eastern Uruguay where 9 out of 9 categorical disagreements are found. Orographic effects and different degrees of seasonal feedback between the atmosphere and the underlying surface affect some regions as for example Central-Western Argentina. Also, the rapid change of ENSO phase in early 1998 from El Niño to La Niña contributed to the uncertainty of the climate community as to whether classifying that year as a late El Niño or early La Niña part of the cycle. This situation conspired against a proper utilization of the results obtained in climate diagnostic studies based on ENSO ensembles.

## 3. An example of practical application of climate prediction to decision-making in water resources management in Argentina

### 3.1 The Diamante River case

The Diamante River, located in western Argentina approximately between 34°S-35°S and 69°W-70°W, has its source in the high ranges of the central Andes Mountains. The hydrological regime, measured at the flowgauge station La Jaula (34°40’S, 69°19’W), during the period 1946-1994, presents a well-defined spring and summer maximum, when the melting of the snow accumulated during wintertime takes place. A simple calculation concludes that the period October-March accounts for 70% of the annual water volume. The total drainage area upstream the flowgauge station is 2,750 $km^2$.

Downstream the station are located the Agua del Toro and Los Reyunos hydropower plants, with a combined power of 500 Mw. Important irrigation areas totaling 800 $km^2$ are located downstream these water reservoirs, which are dedicated to vegetables crops, grapes and other fruits that represent an important economic activity in the region.

For the purpose of hydroelectricity management, it is convenient to define the accumulated water volume flowing during the period October-March, which it is referred to as the seasonal volume. At the end of the winter, in September, an estimate of the snow volume in the catchment is made and the first seasonal volume prediction is issued. The snowpack thickness model in use by the water resources operator converts the snow volume into an equivalent water volume that will flow during the period October-March. The power utility company uses this prediction to produce future electricity generation estimates.

## 3.2 Relationship between Diamante River streamflows and sea surface temperatures of the Pacific Ocean

The relationship between the Diamante River streamflows and the sea surface temperatures (SST) of the equatorial Pacific Ocean is studied by means of a linear correlation analysis between the seasonal volume, and monthly mean simultaneous SST and lagged SST up to 9 months. In order to make comparable the variability of such different numerical values as seasonal water volume (of the order of $10^9$ $m^3$), and SST (of the order of $10^1$ °C), normalized anomalies are calculated. Subtracting the mean value of the period and dividing by the standard deviation, normalized the original 1949-1994 seasonal volume time series. Similarly, the original monthly SST time series are normalized by subtracting the monthly mean value and dividing by the monthly standard deviation. Hereafter, the term seasonal volume and SST will refer to normalized anomalies.

### 3.3 A simple regression model for seasonal volume forecast

A statistically significant relationship is found between seasonal volume October(*t*)-March(*t*+1) in the Diamante River and SST anomalies observed in the equatorial Pacific Ocean, where *t* identifies a calendar year and *t*+1 the following one. The relationship peaks during March(*t*)-April(*t*) and November(*t*)-December(*t*), when considering the region known as Niño3 (5°S-5°N, 90°W-150°W). The relationship is such that Niño3 SST anomalies are positively correlated with seasonal volume anomalies.

A multiple linear regression model is developed, employing Niño3 SST anomalies during March(*t*)-April(*t*) and November(*t*)-December(*t*) and two auto-regressive components, i.e. seasonal volume observed 1 and 2 years before. The model produces 3-category forecast (above normal, normal and below normal), of the October(*t*)-March(*t*+1) seasonal volume anomalies. A cross-validation analysis carried on comparing model predictions with observations for the period 1951-1994, achieve statistically significant correlations.

The result of the cross-validation analysis is shown in the figure 2, where the thick line represents the standardized anomalies of October(*t*)-March(*t*+1) seasonal volume observed in the Diamante River basin, and the thin line represents the calculated standardized anomalies with the regression model.

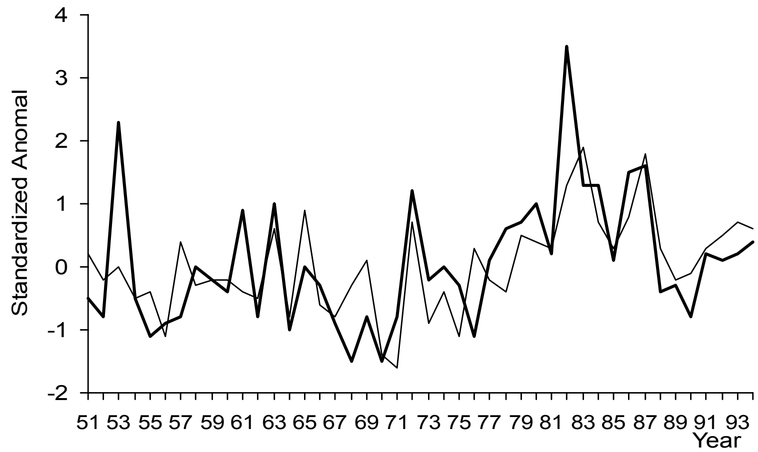


Figure 2.

Since November(*t*)-December(*t*) Niño3 SST anomalies are input to the model, they are replaced with 6-month Cane and Zebiak model predictions (Chen et al., 1995), performed in May(*t*). A cross-validation analysis of the SST model predictions for the period 1980-1994, achieves a categorical skill of 73 %, equal to that of the snowpack model during the same period. The following table shows the result of the contingency analysis.

| | | Predicted | | |
|---|---|---|---|---|
| | | Below | Normal | Above |
| | Below | 3 | 2 | 0 |
| | | 2 | 3 | 0 |
| Observed | Normal | 0 | 0 | 5 |
| | Above | | | |

## 3.4 Practical use of the model

The advantage of the SST model resides in the ability to produce a forecast in May, before the main snowfalls, with a similar result to that obtained with the snowpack model. The snowpack model can only be applied in October when the maximum snow cover is reached. On the other hand, the snow volume deposited in the catchment is estimated from few point measurements and, therefore, it represents an approximation. The SST model is able to provide the water resources operator information about the amount of water available in the system during the following summer, even before the wintertime snowfalls that feed the system.

The availability of the forecast in May can be of utility to the water resources operator for a better planning of the system. For example, irrigation downstream the dam begins in July and it is operated without any knowledge of the water replacement in the system. Advance knowledge of the surpluses or shortages that the system might experience during the following season, could certainly help a better planning of the water resources.

Another example is related to the value of the hydroelectricity generated by the power plants in the system. In August, representatives of all sectors involved in generation and distribution of electricity in the interconnected system in Argentina, discuss the price of the kilowatt to be delivered by each plant during the following 12-month period. Normally, the price is agreed considering mean seasonal offer and demand patterns. Thus, advance knowledge of water availability in the dam could help the local operation to discuss a fairer price.

Obviously, a sample of 15 seasonal predictions (1980-1994) is not large enough to draw definitive conclusions about the SST model ability. Nevertheless, the results can be considered sufficiently positive to continue the investigation in order to improve the skill of the methodology.

## References

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