ANALYSIS OF THE DAILY MINIMUM TEMPERATURES VARIABILITY IN THE CASABLANCA VALLEY, CHILE

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ABSTRACT
The Casablanca Valley (CV) has a complex topography and is located near the Pacific Ocean. These factors generate important climatic differences in relation to other wine producing zones of Central Chile. The air temperature is one of the most important atmospheric variables in viticulture by its influence on the vine development and the quality of the grapes and wines. In this work, the minimum temperature has been studied using a set of meteorological stations to make a comparative climatology between the CV and surrounding viticultural zones, and also with data from an agrometeorological network inside the CV, to make a local comparison applying the Principal Component Analysis. The synoptic configurations were analyzed for the higher and lower minimum temperatures. The comparison with the surrounding zones shows that the CV has differences in the annual cycle of the minimum temperatures (amplitude and extremes values). Its minimum temperature anomalies are less correlated with the more continental stations, and the differences are statistically more marked and are increasing with growing season. The analysis inside de CV shows low differences, with a 93% of the variance explained by the first principal component, but some oceanic influence exists. The analysis shows that the valley has a well differentiated regime of minimum temperatures compared with other wine-producing zones, noticeable in the warm period. Inside the CV there is a low spatial variability, with an important synoptic control, and it is possible to describe some gradient along the ocean proximity.

KEYWORD
Minimum temperature temperature variability terroir viticultural zoning

INTRODUCTION
The optimal physiological behavior of grapevines requires certain weather conditions, and temperature is considered one of the main ones, given its role in the rate of maturation and harvest date of grapes, as well as its effect on grape composition and wine quality. In a daily scale, daytime temperatures are important for processes such as primary metabolism, while nighttime temperatures are important both as a risk factor (frosts) as well as its influence on processes like the secondary metabolism, responsible for the synthesis of compounds associated with wine quality (e.g. anthocyanins and tannins) (Jackson and Lombard, 1993). The importance of the minimum temperatures on wine production was the aim for doing the study of its variability in an important white wine-producing region of Chile. The study was performed in the Casablanca Valley, which corresponds to the main area of production of grape varieties for white wines, given its cold weather condition compared to other Chilean viticultural valleys. The valley has a complex topography, with higher altitudes reaching about 1000 m and lower points of about 100 m above sea level. Its area is close to 20 km NS

and 17 km EW, and has a distance of about 18 km from the Pacific Ocean. The main objective of this work is to characterize the minimum temperature variability in the Casablanca Valley and make a comparison with other regions of Central Chile.

MATERIALS AND METHODS

Daily minimum temperatures data of four weather stations were used for the period between January 2001 to December 2007, one located in the Casablanca Valley and three in surrounding zones outside the valley. These stations are: Casablanca (33.32S 71.44W), Santiago (33.43S 70.68W), La Platina (southern Santiago, 33.52S 70.62W) and Codigua (33.46S 71.20W) (Fig.1). Also data from an agrometeorological network of 9 stations at the Casablanca Valley were used for the period September 2006 to July 2008, showed in Fig.2. A non parametric statistical test and a Principal Components Analysis were performed for the time series comparison. The synoptic configurations were studied, using data of sea level pressure and wind vectors from the European Center of Medium-Range Weather Forecast reanalysis (Simmons and Gibson, 2000).

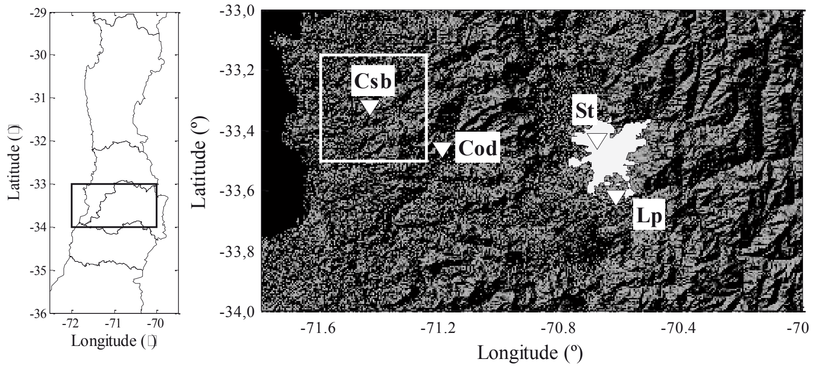

Figure 1. Position of the stations Casablanca (Csb), Codigua (Co), Santiago (St) and La Platina (Lp). The white square shows the location of the Casablanca Valley, and gray outline corresponds to the city of Santiago.

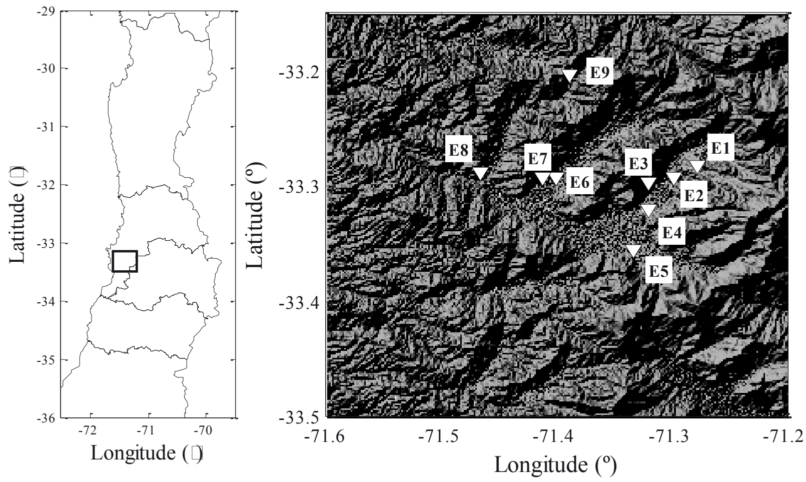

Figure 2. Position of the agrometeorological stations located in the Casablanca Valley.

RESULTS AND DISCUSSION

The first analysis was done for the minimum temperature series of the Casablanca Valley and the three weather stations in nearby areas (Fig.1). In Fig.3 the time series and the annual cycle obtained by fitting Fourier series are showed. In the curves it can be seen that, for the entire period, the Casablanca serie is the one with the lowest average values of minimum temperature, which rarely exceed the average of 10ºC, and the lower amplitude in the annual cycle. Such differences are more marked with the stations Santiago and La Platina, which are located in a more continental position, due to their higher distance from the Ocean and its influence. Taking the differences between the minimum temperature series of each station and their respective fitted Fourier series, the minimum temperature anomalies (MTa) were obtained. Having removed the annual cycle of the minimum temperature it is possible to do a correlation between them.

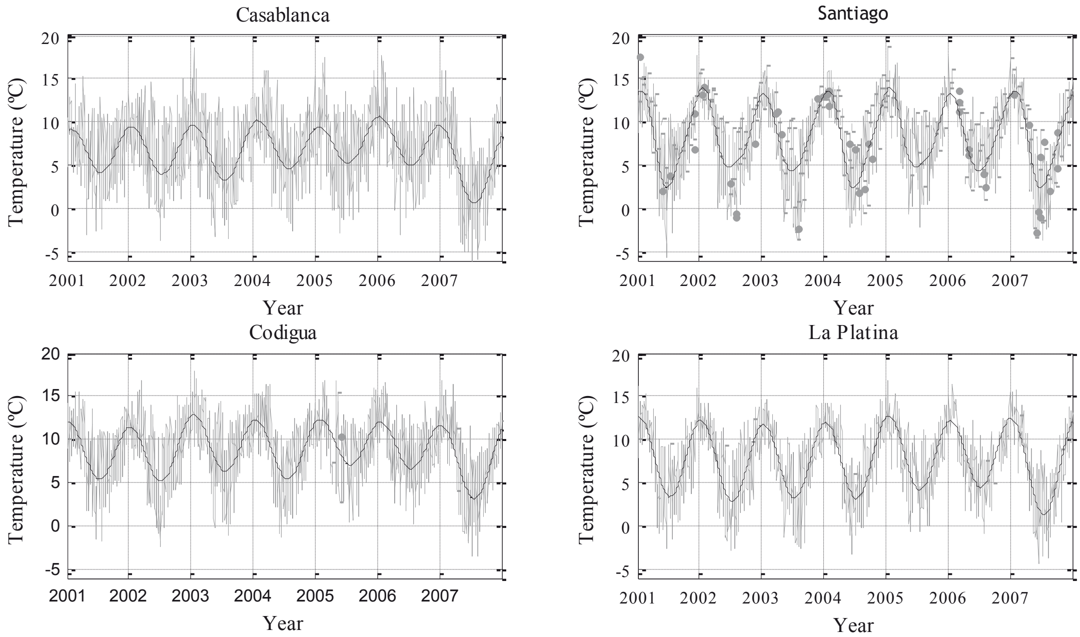

Figure 3. Minimum temperature series (gray) for Casablanca, Codigua, Santiago and La Platina. The black curve represents the annual cycle obtained by fitting Fourier series.

The Pearson correlation coefficient between the MTa of Casablanca and Santiago (0.57), and between Casablanca and La Platina (0.55) is nearly the same. The correlation between the MTa of Casablanca and Codigua is higher (0.76), which shows the difference between zones near the coastline and inland, and the different thermal regulation in the basin of Santiago and the zones near the ocean, which also can be seen in the high correlation between Santiago and La Platina (0.81) and between Casablanca and Codigua (0.76). It is likely that the spatial and temporal patterns are both strongly influenced by the synoptic conditions, observable in the high correlation between the MTa of the nearest stations, as the influence of local factors like the proximity to the ocean from each geographical area.

Given the different importance of minimum temperatures in the annual cycle in viticulture, a comparative analysis in different periods was done. The annual average series of minimum temperatures from 2001 to 2007 were calculated (Fig.4). Casablanca and Codigua have an average difference of nearly 2.5°C throughout the year, while between Casablanca and La Platina-Santiago the main differences are extended to the warm season. From the point of view of wine production, these differences indicate a condition of grapes growing at Casablanca which can take a maturation process under nighttime temperatures described as favorable for the optimal quality factors expression (Jackson and Lombard, 1993). This highlights the difference with the Central Valley area of Chile, but it also indicates that during the winter months the chill accumulation, needed for breaking dormancy, can be met in both areas. It is likely that the geographical position of Codigua station, which is located near the mouth of the Maipo River, gets more direct influence of air from the Pacific Ocean, which would result in higher minimum temperatures.

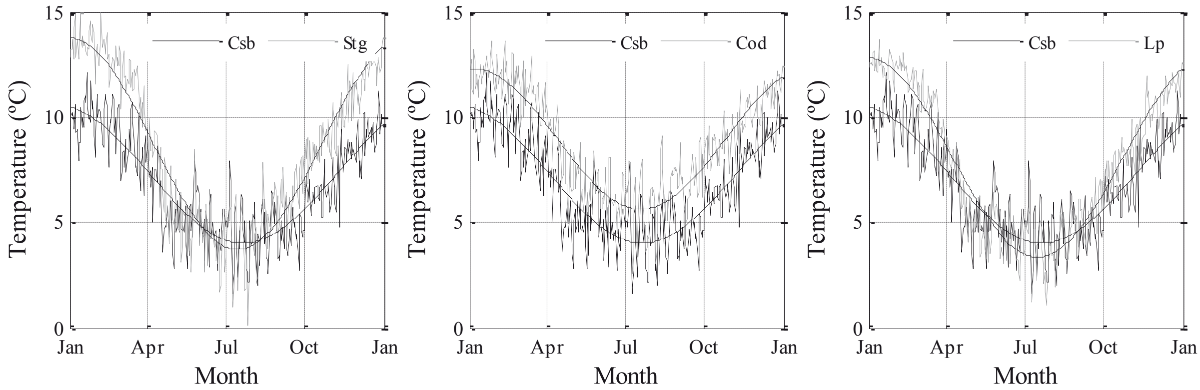

Figure 4. Average annual series of minimum temperature and Fourier fitting. Csb: Casablanca, Stg: Santiago; Cod: Codigua; Lp: La Platina.

As mentioned, the differences described above are clear for spring-summer time, but during autumn-winter such differences tend to decrease. To estimate the time when the temperatures are statistically different or not, the Wilcoxon-Mann-Whitney nonparametric test (Wilks, 1995) was performed for a comparison of a 30-day mobile period for each station and Casablanca. Thus, the period 1 to 30 January, 2 to 31 January, 3 January to 1 February, and so on was compared successively. Fig.5 shows the temporal change of the *p* value, which indicates the statistical significance of the differences between the ranges of 30 days being compared, in addition to the limit of $p = 0.05$ used as criteria for statistical significance. There is a clear difference between the three comparisons. So between Casablanca and Codigua the minimum temperatures are statistically different in the entire year, except for a short period in autumn when the *p* value exceeds 0.05. The minimum temperatures between Casablanca and the Santiago-La Platina stations remain statistically different for the whole period of spring and summer ($p<0.05$), but for a long period in autumn-winter they are not statistically different except for a short period, which could respond to the greater synoptic scale variability induced by the passage of frontal systems in central Chile, which are more active during the winter months, and increases the variability of this time scale (Falvey and Garreaud, 2007).

A local comparison was done throughout the Principal Component Analysis (PCA) and the associated Empirical Orthogonal Functions (EOF) (Wilks, 1995), using the minimum temperatures anomalies for the data from the agrometeorological network inside the Casablanca Valley (Fig.2). For the temporal variability, the first mode explains a 93.4% of the total variance with a large decrease for the subsequent modes. The high variance explained by the first PC could be related to the proximity of each station and to the topographical configuration of the valley, which allows a common synoptic control that regulates temperature behavior. The EOF's associated with each PC show some spatial structure of the main modes of variation. In Table 1 the values of the EOF1 and EOF2 are presented. The structure of the EOF1 shows differences between the stations located near the coast and the others, except station E1, which has a different behavior. These results show that, despite the low temporal variability that exists in the valley, there is a spatial pattern of the MTa that varies with the sea proximity. The EOF2 has a different pattern that could respond to some influence of other physical factors, since the pattern is reversed, but with a low explained variance (3.7%).

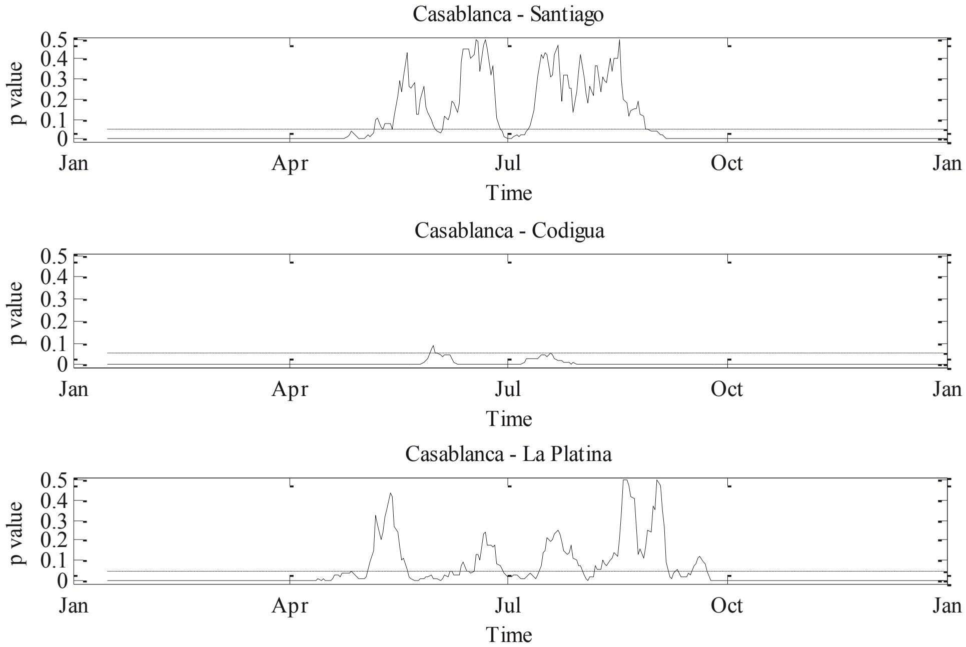

Figure 5. Temporal change of the *p* value of the Wilcoxon-Mann-Whitney test. The dotted line shows the limit of p=0.05 for statistically significant differences.

Table 1. Empirical Orthogonal Functions associated to the Principal Component 1 and 2.

Stations	EOF 1	EOF 2
E1	0.886	0.426
E2	0.985	0.089
E3	0.986	0.055
E4	0.985	0.054
E5	0.984	0.002
E6	0.978	-0.175
E7	0.972	-0.204
E8	0.956	-0.255
E9	0.957	0.040

To explore the synoptic configurations associated with the extreme minimum temperature at the valley, the anomalies of sea level pressure (SLP) and wind vectors corresponding to days of the 10% upper and lower limit of the PC1 were taken. The days with lower minimum temperatures (Fig.6a) are associated with a regional positive SLP anomaly in the Pacific Ocean, which allows a greater surface cooling, and with a negative anomaly in the Atlantic region, with a wind field that allows a cold air intrusion from the polar regions as a geostrophic response, what has been described in a generalized way (Garreaud, 2000). The days with upper minimum temperatures are associated with a weakening of the dominant anticyclonic activity (Fig.6b), with a negative SLP anomaly next to the Chilean coasts, and a wind field with an important meridional component that allows the arrival of equatorial air. This analysis allows to infer an important regional synoptic influence that regulates the minimum temperatures variability in a scale of the whole valley, given the weakening or the intensification of the SLP and the advection of cooler or warmer air than Casablanca.

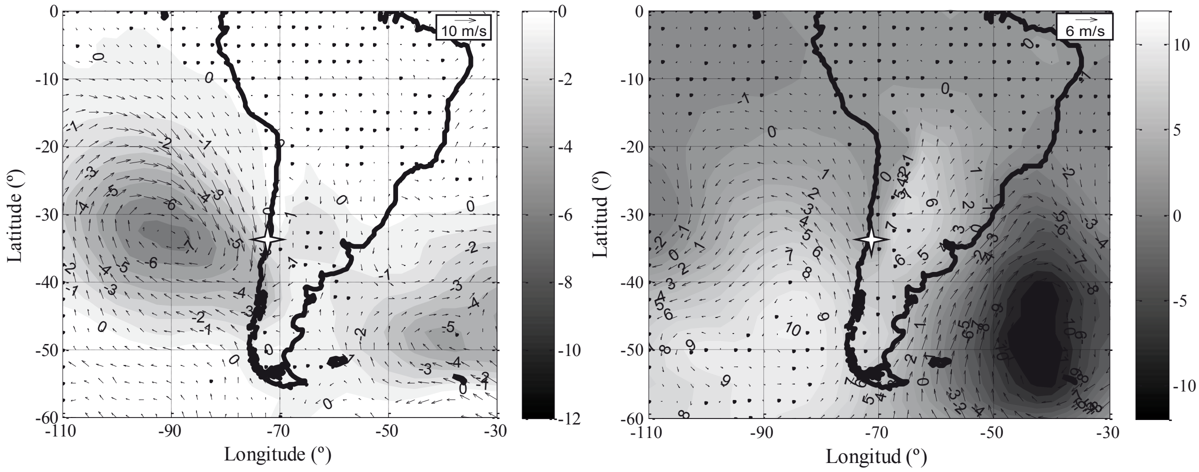

Figure 6. Composites of sea level pressure (hPa) and wind vectors (m/s) anomalies for: a) lower and b) upper limit of the 10% in the PC1. White star shows the Casablanca Valley location.

CONCLUSIONS

The variability of the minimum temperatures in the Casablanca Valley was analyzed. The comparison shows important differences with the more continental zones, in a regional scale, with differences in the annual cycle that are marked mainly in the growing season and not in winter and autumn time. This is significant from the point of view of the occurrence of sprimg frosts, which are more frequent in the Casablanca Valley, and for the lowest temperatures at which the plants are exposed during the growing season. The local comparison shows a low temporal variability, with minimum temperature anomalies that don't change significatively at one point or another. The associated EOF shows that, despite the low temporal variability, there is a spatial pattern that shows a sea proximity orientation. The synoptic patterns associated with the extreme minimum temperature anomalies shows an average pressure and wind field associated to the cold or warm air advection and the surface process that can induce a reinforced nocturnal cooling.

ACKNOWLEDGMENTS

The author gratefully acknowledges the Asociación de Empresarios Vitivinícolas del Valle de Casablanca and the Dirección Meteorológica de Chile for the meteorological data.

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