ANALYSIS OF CLIMATE SPATIO-TEMPORAL VARIABILITY IN THE CONEGLIANO-VALDOBBIADENE DOCG WINE DISTRICT

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ABSTRACT
Local climate characterization is fundamental in terroir description, yet global change perspectives raise questions about its feasibility, since temporal stability cannot be no more assumed for the forthcoming years.

The objective of this work was to gain a better understanding of the climatic spatio-temporal variability of a grapevine growing area, and how this has changed during recent times.

Using as a case-study the Conegliano-Valdobbiadene DOCG wine district in North-Eastern Italy, we developed a methodology to downscale daily mean air temperature from the European Climate Assessment gridded dataset (E-OBS), to derive daily temperature surfaces at 500m spatial resolution. This allowed to analyse how the spatio-temporal variability affected grapevine phenology in the last 60 years.

The main results showed that, respect to the 1950-1979 period, the average Winkler index between 1980 and 2008 showed a +184 °C increase, with little spatial variation, as well as for the estimated dates for the main phenological events, which showed a generalized anticipation of about 2 to 5 days. More pronounced changes were observed on the interannual variability, which showed increases in both the average values and pattern of distribution.

KEYWORDS
Grapevine, Climate Change, Temperature, Phenology, Downscaling, Spatial Interpolation

INTRODUCTION

Climate is one of the most important factor in the description of terroir, since the amount and temporal distribution of weather variables influences greatly wine production under both the quantitative and qualitative aspects (Jones and Davis, 2000). It is generally always possible to describe the principal traits of a local climate, provided that temporal stability and a relative spatial homogeneity can be assumed. These two conditions are implicit in the notion of terroir, which admits also the year to year climatic variability, which generates the vintage effect, as long as it can be considered a fluctuation within a stable range of variation.

The climate stability assumption is being challenged by the forthcoming global changes predicted by climatologists during the 21st century. Adaptation to these changes represent a major challenge for viticulturists worldwide, and among the various issues which need to be addressed, one is to understand to what extent the characterization of terroirs will remain feasible in a context of climatic changes.

In this work we have undertaken the task by studying the climatology of a wine production district in North-Eastern Italy, under both the spatial and temporal variability.

The analyses of trends in climate variability requires long-term weather observations taken at high temporal and spatial resolution. For the area under study, weather data were available only for a limited time extent, with wide gaps in the recording series. Global or continental climatic datasets which covers much longer time extents could be used, but they are typically elaborated at low spatial resolutions, which made them suitable only for large scale studies.

Part of the work was dedicated therefore to the development of a downscaling procedure for reconstruct local past weather from a European gridded dataset, and to interpolate it at a high spatial resolution. The result was the construction of complete daily weather database which allowed to analyse how grapevine phenology has changed within the area under study during the last sixty years, on both the spatial and time scale.

MATERIALS AND METHODS

Study site - The Conegliano-Valdobbiadene DOCG wine district is located in the Veneto region (45.95N, 12.17E). It is a prevailing hilly area which comprises 15 municipalities, extending for approximately 35 and 25 km in the East-West, and Norh-South directions respectively. Elevation ranges from 30 to 460m a.s.l., and 72.7% of the surface covered by vineyards varies between 100 and 300 m. The cultivated area is 8017 ha wide, and the principal production is the Prosecco di Conegliano-Valdobbiadene wine, obtained mainly from the native grape cultivar Glera (formerly “Prosecco”).

Weather data collection - Historical records of daily maximum and minimum temperature were obtained from ARPAV the regional agency for environmental prevention and protection, and from CODITV, the local provincial agency for crop protection. In total, data from 1989 to 2008 for 20 sites were available.

Another utilized source of data was the European Climate Assessment (ECA) dataset, developed as part of the European Union Framework 6 ENSEMBLES project, (Haylock et al. 2008, Klok & Klein Tank, 2009). This dataset has been elaborated into a gridded version, the E-OBS gridded dataset, which includes data at 0.25° spatial resolution for maximum, minimum and average daily air temperature, as well as rainfall. The whole gridded dataset was downloaded from the web site *http://eca.knmi.nl.*

E-OBS data were used to reconstruct local time series through a downscaling procedure, while locally measured data were used to calibrate and validate the procedure.

Soil cover data - Information about soil cover was used to focus the analysis only on the surface actually covered by vineyards. The location of all vineyards plots was extracted from the 1:10000 soil cover map published in shapefile format by Veneto Region in the year 2009.

Downscaling approach - The spatial distribution of the surface air temperature at a given moment is determined by the interactions between the state of the atmosphere and the terrain features, e.g. elevation, slope or the presence of water bodies, whose effects changes depending on the type of weather conditions. As an example, the lapse rate induced by elevation gradients are known to vary throughout the year, following seasonal patterns. Since it is reasonable to think that similar weather conditions should correspond to similar patterns of atmosphere-terrain interaction, it was hypothesised that if a finite number of “weather types” could be defined according to some classification criterion, then each type should correspond to a specific pattern of atmosphere/terrain interaction, and ultimately to a specific pattern of temperature distribution. Furthermore, if for each weather type, a given site could be characterized by a quantitative relationship between its temperature, and the average zone temperature, then we would have a convenient method to estimate the site time-series of temperature from the knowledge of the weather type sequence and the time-series of the average zone temperature.

The idea was to use the E-OBS gridded dataset to individuate groups of days with similar meteorology. As a classification criterion we used the minimum and maximum E-OBS temperature values in the two grid-knots covering to the study area. These four daily temperature time-series were subjected to k-means cluster analysis. The optimal number of groups was searched in the interval 5-60. At the end, 45 groups gave the best results. For each group, the mean difference between the measured and the E-OBS values, was calculated for each measuring station in the interval where measurements were available. These differences were then used as correction factor to estimate the station mean temperature from E-OBS data in the periods where measurements were not available. The correction factors were calculated on half of the measures dataset (odd days), and validated on the other half (even days). The accuracy of estimation was assessed by calculating the Root Mean Square Error (RMSE) between estimates and measurements.

Spatial interpolation of the reconstructed weather data - Once the whole climatic series for the period 1950-2008 for each measuring station was reconstructed, daily mean temperature was spatially extrapolated for the whole vineyard-covered area, at a 500 m spatial resolution. Interpolation was carried out by multiple linear regression, using as predictors the elevation, latitude, longitude, average slope and aspect, derived from a digital terrain model with ordinary GIS procedures. The residuals between the estimates and the reconstructed data were then interpolated with Inverse Distance Weighting, and used to correct the estimates.

Phenology modelling - The estimated temperature were used to run a phenology model (Fila et al., 2010), predicting end of dormancy, bud break, flowering and veraison in the Glera cv. The model was an extension of the Unified Model developed by Chuine (2000), which was calibrated on 18 years of observations.

Analysis outline and statistical assessment - The interval from 1950 to 2008 was divided into two sub periods: from 1950 to 1979 (period 1), and from 1980 to 2008 (period 2). With respect to these two periods, the temperature variation in the vineyard-covered area was studied by analysing the Winkler index (WI), the sum of the active temperature from 1 April to 31 October ($\Sigma(T_{avg}-10)$) (Winkler, 1962). WI spatial variability was studied by calculating its distribution frequencies across the studied area, while the interannual variability was quantified by means of the Coefficient of Variation (CV), the ratio between standard deviation and the mean. The same evaluation scheme was applied to the estimated dates for the principal phenological events: end of dormancy, bud break, flowering and veraison.

RESULTS AND DISCUSSION

E-OBS data underwent a preliminary explorative analysis to outline the main variation trends (Fig.1). With respect to the average values calculated for the two sub periods, WI increased from 1485°C (period 1) to 1699°C (period 2).

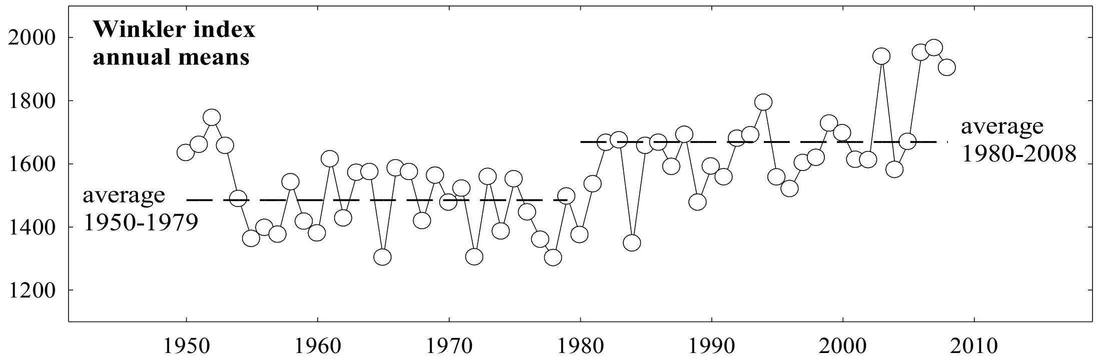

Figure 1 – Winkler index annual means, calculated from the E-OBS gridded dataset. The dashed horizontal lines represent the average for the two periods 1950-1979 and 1980-2008.

The downscaling procedure allowed to produce estimates of mean daily temperature with an RMSE of 0.96 °C calculated on the validation subset. The 81.2 % of the residuals varied between ± 1°C and 92.5% between ± 1.5°C. This accuracy was considered sufficient to reconstruct the whole time series, and to interpolate them at the spatial resolution of 500 m.

The spatial distribution of the estimated WI across the cultivated area is reported in Figure 2. The index varied from 1100 to 2100 °C during period 1, and from about 1200 to 2200 °C in period 2. WI increased homogeneously in the whole cultivated area, without relevant changes in the shape of spatial distribution. The coefficient of variation, quantifying interannual variability, increased from 7.5% to 8.9%. In this case, a modification of the distribution curve is appreciable: in period 2 the mass of the distribution shifted towards the right, raising the curve skewness.

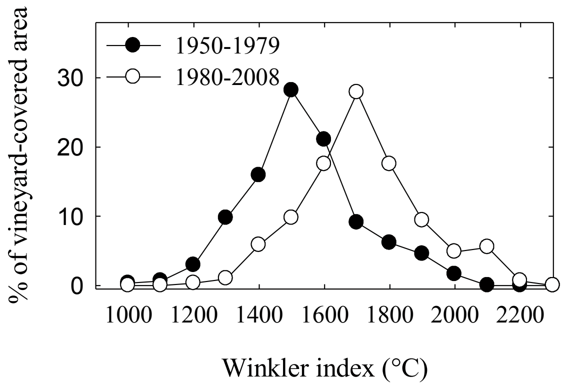

Figure 2 – Spatial distribution of the Winkler index in the vineyard-covered area. Closed symbols: 1950-1979 average; open symbols: 1980-2008 average.

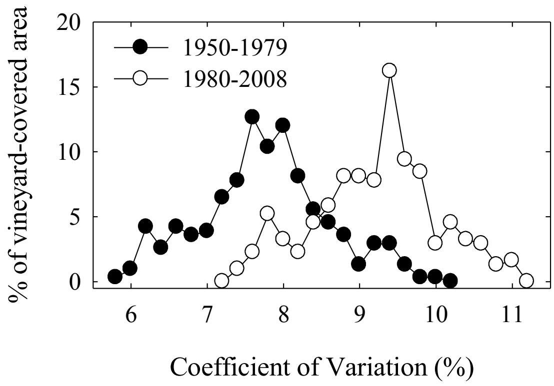

Figure 3 - Spatial distribution of the Coefficient of Variation, quantifying interannual variability of the Winkler index Closed and open symbols as in Fig. 2.

The generalized temperature increase had an impact on the estimated phenological behaviour. The dates for the end of dormancy and bud break showed very little changes in their spatial distribution and in their multi-year average. An anticipation of about 2 and 5 days was evident for the occurrence of flowering and veraison respectively, without changes in the shape of spatial distribution (Fig.4). It is interesting to note that the generalised temperature increase had a very low impact on the fulfilment of grapevine chilling requirement.

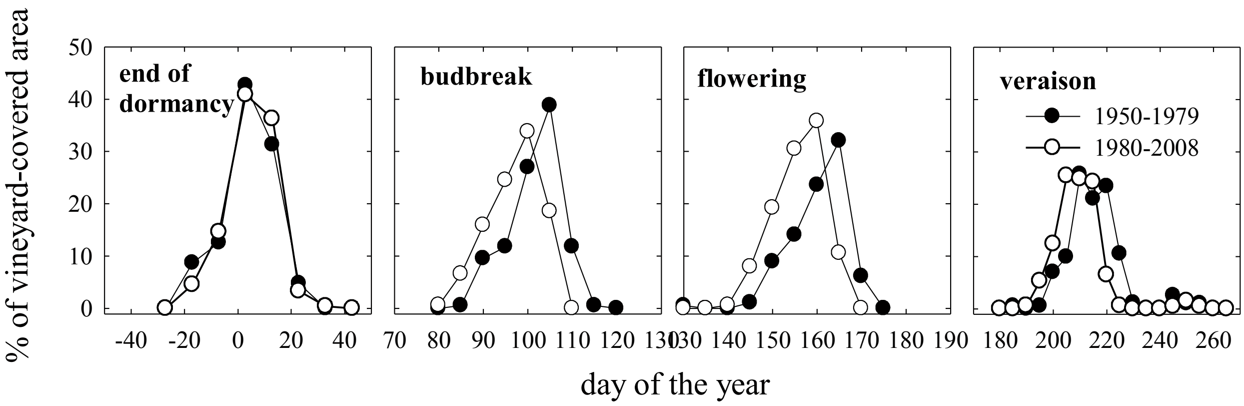

Figure 4 – Spatial distribution of the estimated dates for the main phenological events. Closed and open symbols as in Fig. 2.

The interannual variability showed more evident changes in both averages and spatial distributions (Fig. 5). All phenological events showed an increase in the average CV from period 1 to period 2, except for the end of dormancy, where it decreased from 7.8 to 7.5 %, due to a higher concentration of areas around the distribution peak. Bud break showed an average increase of the CV, but the area maintained a variability range between 4 and 10%. Flowering and veraison showed the least interannual variation, which was associated to a very little spatial variation.

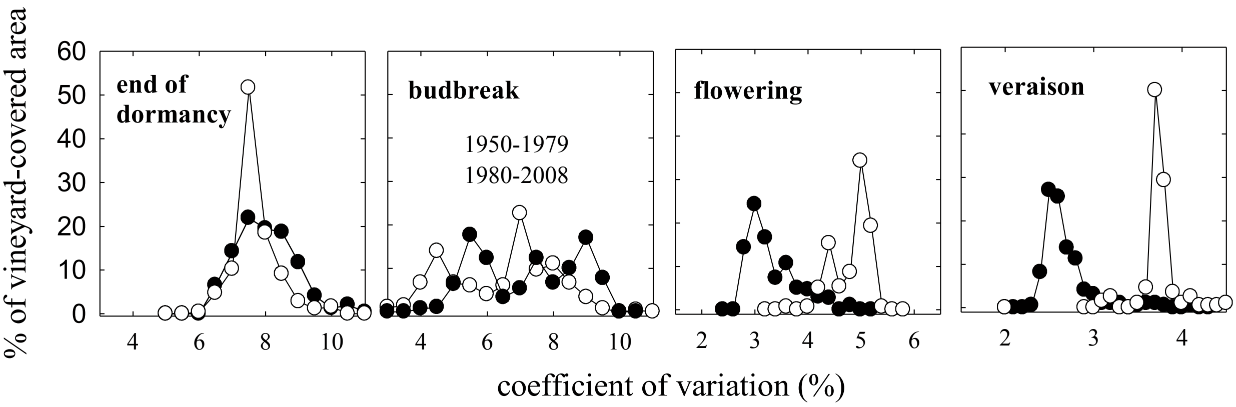

Figure 5 – Spatial distribution of the coefficient of variation for the estimated dates for the main phenological events. Closed and open symbols are as in Fig. 2.

CONCLUSIONS

An analysis of the spatio-temporal variation of daily temperature in a wine producing zone was carried out by combining a downscaling and a spatial interpolation procedure to an European gridded dataset. The spatial variation was analysed with reference to the periods 1950-1979 and 1980-2008. In general, the second period was characterized by an increase in the average temperature and in the interannual variability.

The climatic change had little effects on the end of dormancy and bud break, while it induced an anticipation of flowering and veraison.

More important changes were observed in the interannual variability, which were also associated with variation in the spatial distribution across the vineyards.

In the time interval studied, the temperature changes do not seem to have relevance in the zoning of the district. The increased interannual variability on the other hand, is more likely to have an impact on the operational standpoint, making necessary to adjust the organization of vineyard management.

ACKNOWLEDGEMENTS

We acknowledge the E-OBS dataset from the EU-FP6 project ENSEMBLES (http://ensembles-eu.metoffice.com) and the data providers in the ECA&D project (http://eca.knmi.nl).

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