ECA&D and E-OBS: High-resolution datasets for monitoring climate change and effects on viticulture in Europe

Christiana Photiadou[1], *Natacha* Fontes[2], *Antonio* Rocha Graça[2], and *Gerard* van der Schrier[1,a]

[1] Royal Netherlands Meteorological Institute (KNMI), De Bilt, The Netherlands
[2] Investigação e Desenvolvimento Sogrape Vinhos, SA, Avintes, Portugal

Abstract. Climate change and climate variability profoundly affect the production of wine. When facing a changing climate, the characteristics of wine produced in each region will change while the natural year-to-year variations in climate will increase variability of income for wine businesses and therefore affect profitability and economic resilience. The challenge posed to the viticulture community is thus to closely monitor these changes to be able to adapt business practices. The European Climate Assessment and Dataset (ECA&D) and its gridded version E-OBS are tools to monitor the changing climatic conditions over Europe, with an emphasis on changes in extreme climatic conditions. In this paper, the potential of ECA&D and E-OBS for viticulture is demonstrated by a few examples. The examples include the changing areal suitable for Chardonnay cultivation, showing an expansion to areas which have been too cold only a few decades ago and retraction of optimal conditions from areas which have been suitable in the recent past. Other examples show the change in the diurnal temperature range in the latter stages of the ripening process of grapes and the variability in heavy precipitation events. Finally, first results of a new dataset for South America are presented.

1. Introduction

Climate is of paramount importance to the production of wine with critical moments during the growing season that the weather needs to be just right to attain a level of excellent quality. Climate is thus a driver of value for producers of both grapes and wines. High-quality grapes may be produced at a fairly narrow range of average air temperatures during the growing season, while regional differences in the diurnal temperature range, frost frequency in Spring, the duration of heat waves or cold snaps affect the production of quality compounds in grapes (sugars, acids, polyphenols, aroma precursors, etc.). Changes in the moisture regime and specifically on the timing of rains, the amount of moisture available from rains, and the atmospheric evaporative demand (atmospheric 'thirst'!), all influence grape composition in such a way that wine taste, colour and aroma is and will most likely will be impacted in the near future.

When facing a changing climate, with its persistent changes in temperature and precipitation patterns, the characteristics of wine produced in each region will change. These changes impact the quality of grapes and wines and may generate higher year-to-year variability in the production, which in return hamper the sustainability and economic resilience of wine businesses. Winegrowers face a big challenge in managing the increased variability between heavy rainfall on the one hand, and relatively high temperatures and drought on the other; a scenery that central Europe is becoming familiar with during summer seasons. Future business practise will require adaptation to overcome these changing and challenging conditions; a monitoring tool is thus essential to understand how these changing develop through time and how they are affecting viticulture and winemaking. The aim of this paper is to introduce an observation-based climate monitoring tool which specifically addresses variability and trends in wind and vine relevant indices.

The *European Climate Assessment and Dataset (ECA&D)* and its gridded version *E-OBS* are tools to monitor changing climatic conditions over Europe - the geographical area responsible for 45% of all wine-growing areas, 65% of global production and 70% of global exports of wine. ECA&D is a dataset with daily station data for over 10.000 stations in Europe, the Middle East and Northern Africa, which includes 12 elements – among them temperature, precipitation, and sunshine duration. The station data are provided by National Meteorological Services and other sources such as the climate-aware private company *Sogrape Vinhos, S.A*. Based on these station data, the high-resolution E-OBS maps of daily gridded data are made available for scientific research. *Climate Information Bulletins* are released once every year and provide a retrospective outlook of the past year with extreme events. In this study, we will discuss how E-OBS can be used as a monitoring tool in the grape and wine industry. Some limitations of E-OBS, which the user needs to be aware of are presented here as well.

Both ECA&D and E-OBS enjoy strong support from the wider scientific community, with over 1250 citations to the E-OBS introducing study (status January 2017), and within the community focusing on viticulture to quantify climatic trends and climatic variability across Europe and in Europe's subregions (e.g., [1–4]). Following results of

[a] e-mail: schrier@knmi.nl

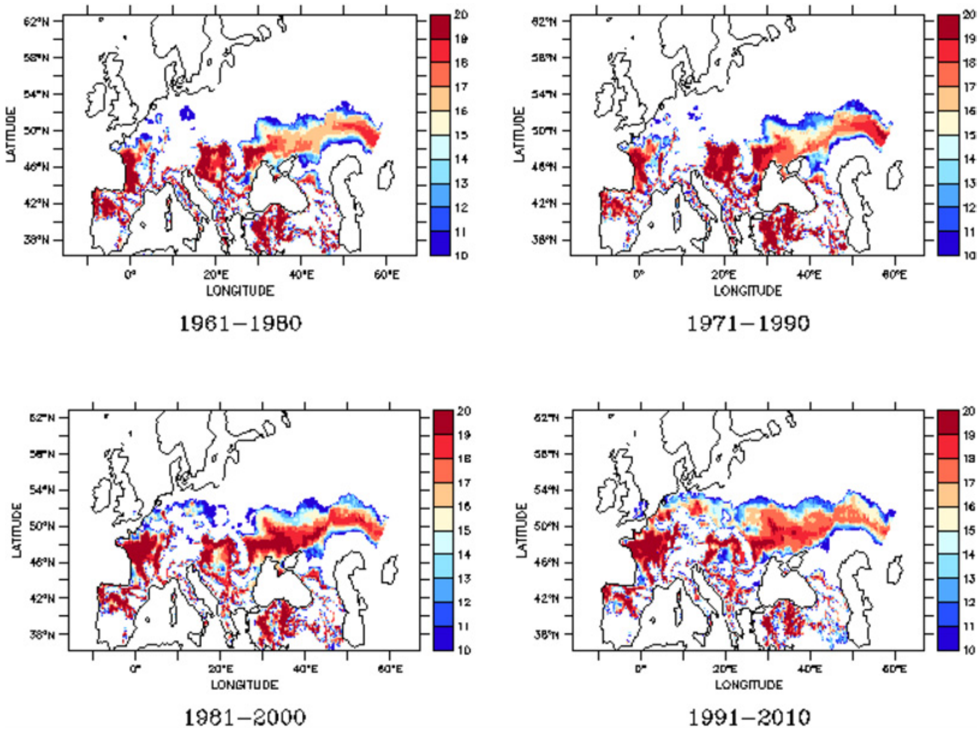

Figure 1. Number of seasons in 20-year overlapping periods which have optimal average temperatures for Chardonnay following the climate-maturity groupings [8].

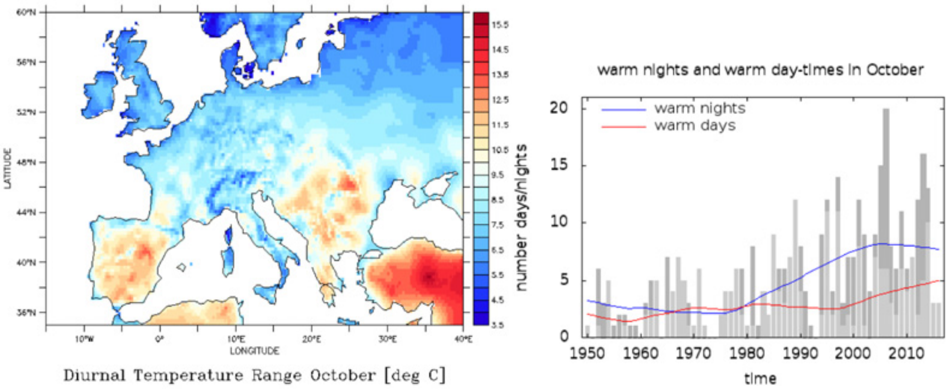

Figure 2. The 1981–2010 average Diurnal Temperature Range for October (left) and the evolution of the number of warm nights (blue) and day-times (red) in October for Bordeaux (France). The red and blue lines denote smoothed values; actual October values are given in the light and dark grey bars for warm day-times and warm nights respectively.

these earlier studies with some new analysis, the benefits of using E-OBS in understanding the nexus between climate, farming vineyards, wine quality, yields, and economics will be quantified. This will be done by discussing trends and variability in *Climate Impact Indicators* (CII, both on station and gridded data) which are widely used in the viticulture scientific community such as the Huglin Index and of more common descent, like the number of frost days in Spring, the number of rainy days and the number of warm days for specific seasons. Finally, an outlook will be provided to the LA-OBS dataset with daily temperature and precipitation focused on South America, using similar geostatistical techniques as its European counterpart. A similar tool is set to be made available for the benefit of South American wine regions, their grape-growers, winemakers, and local businesses, as well as national and regional regulatory bodies.

2. Materials and methods

2.1. Description of ECA&D dataset

The ECA&D data used in this study (`http://www.ecad.eu`) receives data from 68 participants from 64 countries, mainly National Meteorological and Hydrological Services (NMHSs). ECA&D is a collection of daily station observations of currently 12 elements, the Essential Climate Variables, from around 10500 stations throughout Europe and the Mediterranean. The daily station data are subject to data policy limitations of the NMHSs, some of which allow distribution of derived data (like averages or gridded data products) only.

Although most data provided to ECA&D is validated by the responsible NMHS, they first go through a series of basic quality checks to remove obvious problems and outliers. These tests are described elsewhere [5]. No attempt is made to correct data flagged as suspect and this data is not used in further analysis.

2.2. E-OBS dataset

Hofstra et al. [6] compared several interpolation methods for daily temperature and precipitation sums and concluded that the method which involves kriging using a geographically independent variogram is the most optimal interpolation method for the daily dataset. This method was described in detail by Haylock et al. [7], a brief summary is given here.

The gridding procedure adopts a three-step methodology of interpolating the daily data: interpolating the monthly mean using thin-plate splines to define the underlying spatial structure of the data; kriging the daily anomalies with regard to the monthly mean; and applying the interpolated daily anomaly to the interpolated monthly mean to create the final result. In such a large and complex region as Europe, thin-plate splines are a more appropriate method for trend estimation than other alternatives. For the gridding of the monthly mean temperature and monthly sums of precipitation, a three-dimensional spline is used, taking into account the station elevation.

The ECA&D station data are first gridded onto a high-resolution $0.1^\circ \times 0.1^\circ$ grid, followed by a regridding to a slightly coarser $0.25^\circ \times 0.25^\circ$ regular longitude-latitude grid. Other grids are produces as well for e.g., regional climate modelling applications. The motivation for the regridding is to provide area-averaged values of over the grid squares, which is of importance for precipitation given the low spatial coherency in precipitation.

2.3. Climate Impact Indicators

Climate Impact Indicators (CII) are currently widely used as tools to capture the extremes and the impact of climate change. The ECA&D, through a continuous collaboration with the World Meteorological Organisation (WMO) Expert Teams on Climate Change Detection and Indices (ETCCDI) and on Sector-specific Climate Indices (ET-SCI), provides CII based on station data and on E-OBS gridded data. The later provide an immediate visualization of the spatial variability throughout Europe and, for this occasion, in winemaking regions. ECA&D provides online around 70 CII for describing different regimes – from cold, drought, to extreme rain etc. Here we present a small sample of what is available and how the CII can be used in the viticulture management.

3. Results

3.1. Change in climate-maturity grouping for Chardonnay

The effect of the rise of temperatures on the viability of vineyards and the area where vine cultivation is possible, is illustrated by analysing the climate-maturity ripening potential for quality wine varieties. Figure 1 shows such an analysis for Chardonnay, using the climate maturity grouping based on [8] and for overlapping 20-year periods. In this figure, we show the number of growing seasons (defined as the April-October period) in this 20-year period for which the climate is suited to grow Chardonnay. The most optimal conditions are found in the areas where all growing seasons have temperatures in the optimal temperature range, whereas areas with only about half of the years with averaged temperatures in the optimal temperature range, are marginally suited. Figure 1 shows the gradual northward expansion of the area with suitable conditions to cultivate Chardonnay as time progresses, with south eastern England and Holland now marginally suited for this variety. The expansion of the area in France where climatic conditions are suitable for Chardonnay cultivation is interesting. The area centred around 20°E, 46°N, covering Hungary, northern Serbia and Croatia and Austria's Burgenland and Niederösterreich regions saw an initial improvement of conditions into the 1971–1990 period, followed by a deterioration in the following decades. The conditions to produce high-quality wines based on the Chardonnay grape in this area are deteriorating in the most recent period because of too high temperatures.

On the eastern side of the Carpathian mountain range, the total area suitable for Chardonnay cultivation has generally increased over time, but areas can be distinguished where the climate has become too hot in the most recent period for optimal ripening conditions.

3.2. Warm nights

The climatic influences on wine production are complex, but in an ideal situation, the grower would like to have in the period from *veraison* to harvest little to no rainfall with the vines ripening into the early fall and a large Diurnal Temperature Range (DTR) [8]. The climate change signal can be detected in the DTR as well, especially in the balance between the number of warm day-times and the number of warm nights. The former is based on the daily maximum temperature where a warm day-time is defined as a day with the temperature above the 90^{th} percentile (based in its turn on the 1961–1990 period). The latter is based on the daily minimum temperature using a threshold based on the 90^{th} percentile of daily minimum temperatures. Figure 2 shows a map with the 1981–2010 mean DTR for October and a graph showing the evolution of the number of warm day-times and warm nights in that month for Bordeaux (France). October is chosen to focus on the period around harvest. The graph shows a steep increase in the number of warm nights from the late 1970s onwards which is not present in the number of warm day-times. The latter increases since the late 1990s. Averaged over October, the trend in DTR is slightly negative but Fig. 2 shows that changes in the extremes in day-time and night temperatures can be more pronounced.

3.3. Extreme precipitation indicators

Apart from warmer conditions over the growing seasons, climate change also brings changes to the hydrologic cycle. While the Mediterranean region sees generally drier conditions in the summer half year, areas in Europe further north are seeing generally wetter conditions. Nevertheless, an increase in more extreme precipitation is generally observed over all of Europe. The implications of more frequent and severe downpours are that organic vineyards run a larger risk of crop damage or crop loss. Organic farmers are limited to use non-synthetic chemicals to fight

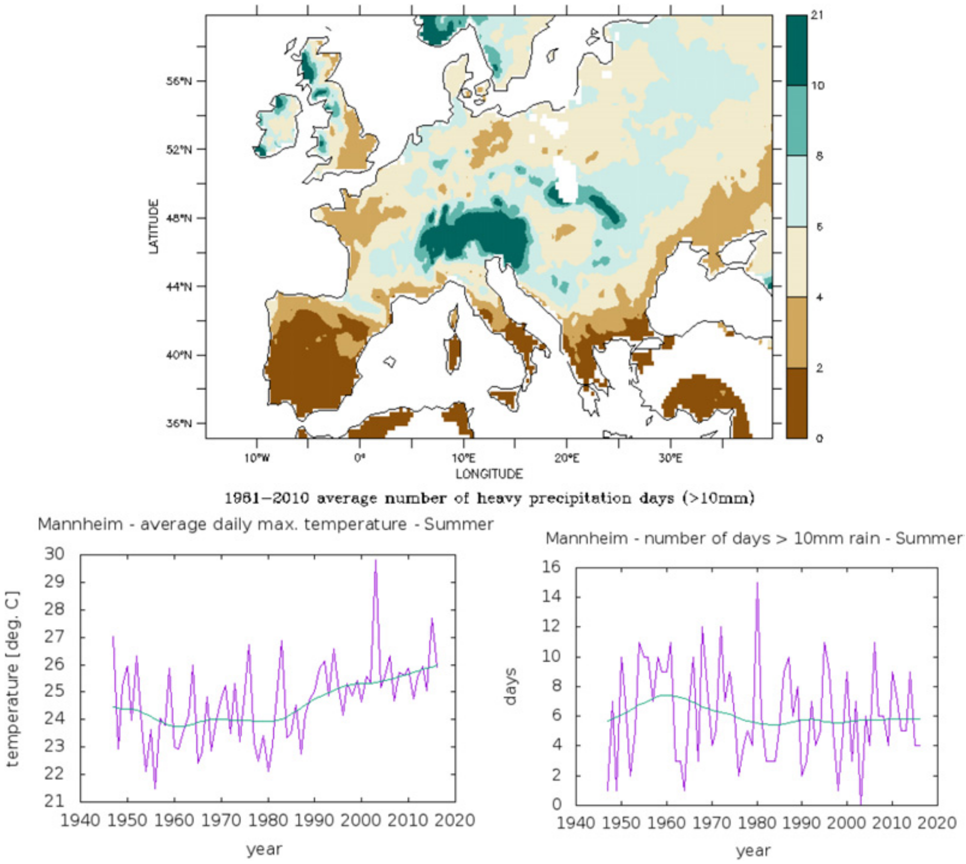

Figure 3. The average number of days with heavy precipitation (> 10 mm/day) in summer for the 1981–2010 period in Europe (top panel). The bottom panels show the change in time of the average daily maximum temperature in summer for Mannheim, in the German Rhine valley (left). The bottom right panel shows the number of days in summer with heavy precipitation (>10 mm/day) for Mannheim.

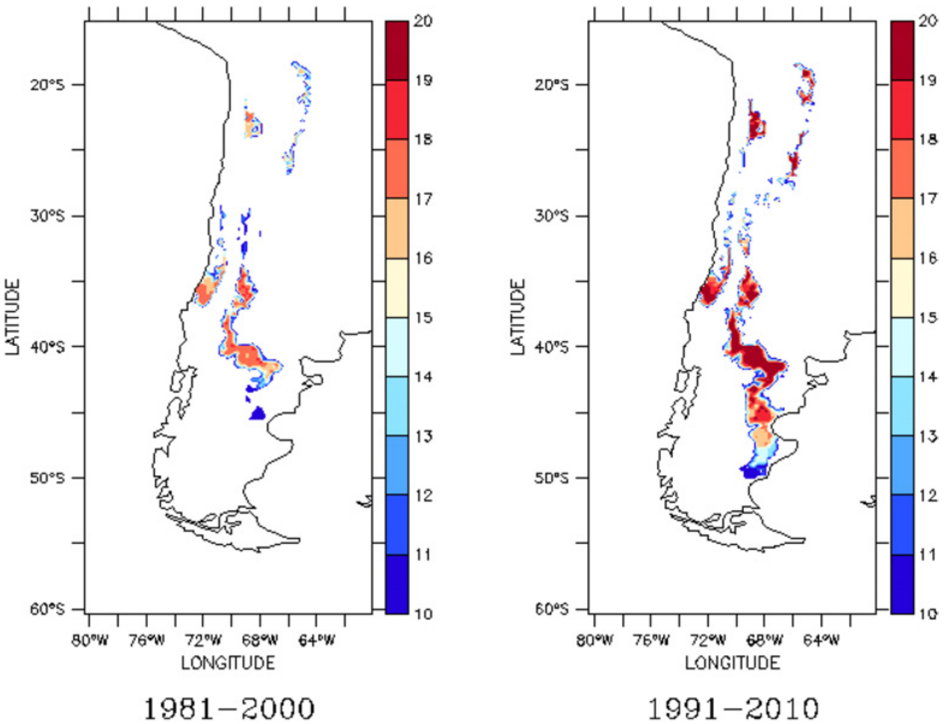

Figure 4. Number of seasons in 20-year overlapping periods which have optimal average temperatures for Chardonnay following the climate-maturity groupings (Jones, 2007).

DOI: 10.1051/bioconf/20170901002

fungal infections like downy mildew. Heavy rains wash the anti-fungal solution off the vines' leaves while warm conditions fuel the growth of the mildew.

Figure 3 shows a map with the climatological mean value of the number of days in summer with heavy precipitation (> 10 mm/day) and two graphs for Mannheim with the change over time for the summer daily maximum temperature and the number of days with heavy precipitation. Mannheim is in the German Rhine valley, north in the Baden wine district. The graphs show a distinct trend towards higher day-time temperatures (with a peak for the 2003 heat wave). For the days with heavy precipitation, a trend cannot be clearly distinguished for this station. Nevertheless, the large year-to-year variability of the number of days with downpours, which can be observed from the graph, makes it clear that one harvest may be more affected than others.

4. A new dataset with daily temperature and precipitation data for South America

Using a similar set-up as in the ECA&D, a station-based dataset for daily temperature and precipitation has been developed in collaboration with National Meteorological and Hydrological Services of South America. This activity is hosted by the CIIFEN institute in Ecuador and is coined the *Latin American Climate Assessment and Dataset (LACA&D)*[†].

Based on the station dataset, a preliminary gridded dataset with daily temporal resolution and a spatial resolution of 0.25° has been developed [9] and will be made available for scientific research under the name LA-OBS. Currently, this dataset spans the period 1981/01/01 to 2014/12/31. Based on the LA-OBS dataset, a similar exercise as for Fig. 1 is done for the wine producing regions in Chili and Argentina. Figure 4 shows the number of growing seasons (defined as the October – April period) in overlapping 20-year periods where climatic conditions are optimal to grow Chardonnay. Figure 4 shows that the area where climatic conditions are optimal for this variety has increased, and it shows that the areas which were already well suited to grow Chardonnay have become excellent areas in the more recent period.

5. Conclusion

The quality and quantity of wine produced in each region is affected by climate change, with its gradual and persistent change in climatic zones and precipitation patterns. The more random natural year-to-year variability profoundly affects viticulture management and general profitability of vineyard and winery operations as well. In this paper, a tool to monitor climate change and climate variability is presented by showing a few basic examples. It is shown, using simple indices relevant for the climate maturity grouping of Chardonnay, that the area where cultivation is adequate for quality wine spreads northward and eastward. It is also shown that some areas already became too hot to produce high-quality wines on every growing season. This observation is under the reservation that the use of hard-limit thresholds will insufficiently reflect the ability of the grapes to grow under stressed conditions. Ancient grapevine varieties such as Chardonnay have a high-level of intra-varietal genetic diversity allowing for high adaptive potential, if vineyards are not planted eugenic, i.e., using a single clone (plants multiplied from a single original mother-plant).

In conclusion, while the station-based dataset ECA&D and its gridded counterpart E-OBS can be used to monitor changes in climate, some caution is required in interpreting trend analysis. Although data have been quality checked, there are issues with the homogeneity of some of the series. When a meteorological station is moved from one place to the other (because of e.g., an expanding city), a discontinuity in the temperature and/or precipitation will be introduced in the series. A simple trend analysis will then confuse this discontinuity with climate change. It is ongoing work to adjust the series for these discontinuities which are still present in the current version of E-OBS.

References

[1] Martínez-Lüscher, J., Sánchez-Díaz, M., Delrot, S., Aguirreolea, J., Pascual, I., & Gomès, E. Australian journal of grape and wine research **22**, 87–95 (2016)
[2] Fraga, H., Malheiro, A. C., Moutinho-Pereira, J., Jones, G. V., Alves, F., Pinto, J. G., & Santos, J. A. Regional Environmental Change **14**, 295–306 (2014)
[3] Fraga, H., Malheiro, A. C., Moutinho-Pereira, J., & Santos, J. A. International Journal of Biometeorology **57**, 909–925 (2013)
[4] Malheiro, A. C., Santos, J. A., Pinto, J. G., & Jones, G. V. Bulletin de l'OIV **85**, 973 (2012)
[5] ECA&D Team. European Climate Assessment & Dataset Algorithm Theoretical Basis Document (ATBD). Royal Netherlands Meteorological Institute KNMI, De Bilt, NL, version 10.5 (2012)
[6] Hofstra, N., Haylock, M. R., New, M., Jones, P. D. & Frei, C. Journal of Geophysical Research: Atmospheres, 113: D22220, doi:10.1029/2008JD010100 (2008)
[7] Haylock, M. R., Hofstra, N., Klein Tank, A. M. G., Klok, E. J., Jones, P. D., & New, M. (2008). Journal of Geophysical Research: Atmospheres **113**(D20) (2008)
[8] Jones, G. V. Proceedings of the Thirteenth Australian Wine Industry Technical Conference, The Australian Wine Research Institute (2007)
[9] Cornes, R. van den Besselaar, E. J. M., van der Schrier, G. Klein Tank, A. M. G. (in preparation) (2017)

[†] `http://lacad.ciifen.org/`