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Research Paper

# Comparison of two fine scale spatial models for mapping temperatures inside winegrowing areas

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ABSTRACT

Climate change is a major issue for the wine industry. Climate and in particular temperature plays a key role in vine physiology and phenology. Temperatures can be highly variable inside a winegrowing region and they are strongly related to local environment (topography, water bodies, vegetation, urban areas...). General Circulation Models (GCM) and dynamical regional models can not take into account this local variability due to their low resolution. For fine scale modeling, a classic option is to create model based on Multiple Linear Regression (MLR) using temperature as dependant variable and local parameters as predictor variables. Though efficient, the non-linearity assumption is a strong constraint that limits performances of spatial models at the vineyard scale. In this study, we compared two fully automated methods which estimate daily temperature and temperature sums at a very fine scale, based on linear (MLR) and non-linear (Support Vector Regression: SVR) assumptions. Data were registered using a network of temperature data loggers installed in 2011 in renown sub-appellations of the Bordeaux area, including Saint-Emilion and Pomerol. Three growing seasons were studied 2012, 2013 and 2014. Model validation showed that SVR presented better results in each case thanks to the non linear component, for an equivalent computing time. Our study has highlighted that a high density network produces maps with a wider range of temperatures compared to medium to low density networks commonly used at a regional scale. In this article, a replicable and highly accurate model was created to produce fine scale temperature maps. Assessment of precise temperature variability at fine scale is essential to allow wine industry to adapt to climate change.

## 1. Introduction

Viticulture is an important agricultural sector around the world, being a key economic activity in a diverse range of countries. A surface area of 7.573 million hectares of arable land is occupied by vines internationally (OIV, 2015). These vines are very sensitive to environmental conditions, which influence yield, grape composition, wine quality and wine style (van Leeuwen and Seguin, 2006). The concept of *terroir* represents the combined effect of soil, climate and topography, and also includes the impact of human factors (e.g. viticultural management and choice of cultivar). Climate variability from year to year (the so-called vintage effect) is an accepted part of the *terroir*, but it is also acknowledged that there is a trend to warmer temperatures in vineyard regions associated with contemporary climate change effects: an increase of approximately 1 °C has been recorded over the past century (IPCC, 2013). Another increase of 1–3 °C is expected towards the end of the 21st century, of which the magnitude is dependent on the rate of greenhouse gas emissions. Hence, over the next few decades, wine-makers will face a modification in climate characteristics, which will result in a different expression of the *terroir* (Beltrando and Briche, 2010; Neethling et al., 2012). Among the diversity of climatic variable influencing grapevine physiology and phenology, temperature is often considered to be the most important (Gladstones, 1992; Jones and Alves, 2012; Mira de Orduña, 2010). Many studies have been dedicated to assessing this effect on vine behavior. Winegrowing areas have been classified by means of indices using accumulated heat or degree days (Amerine and Winkler 1944; Tonietto and Carbonneau, 2004). Other indices have been developed that relate grape sugar concentration with temperature (Huglin, 1978) or the occurrence of key phenological stages with temperature summations (Parker et al., 2013, 2011).

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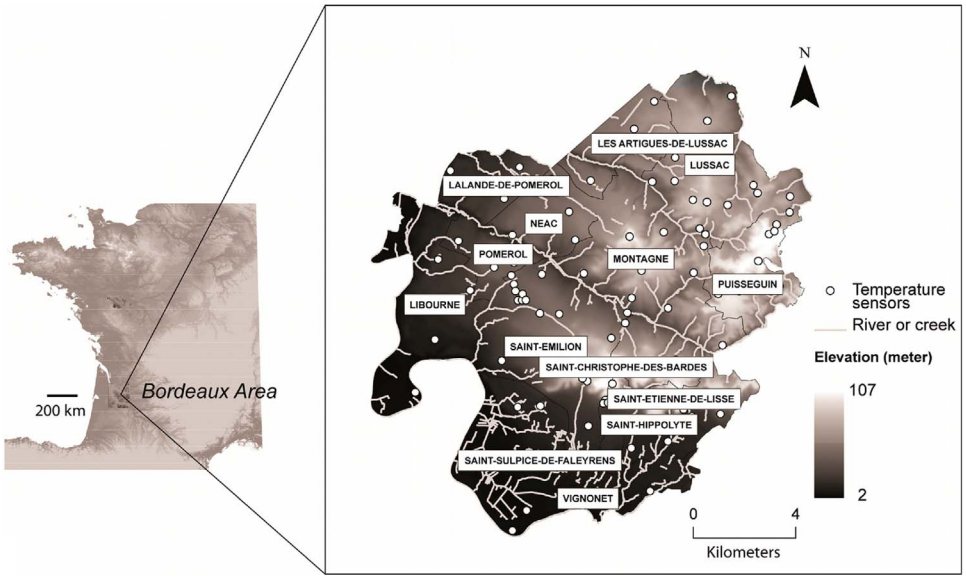


**Fig. 1.** Location and topographic map of the study site around the famous appellations of Saint-Emilion and Pomerol (Bordeaux, France). Data: IGN (94165, Saint-Mandé).

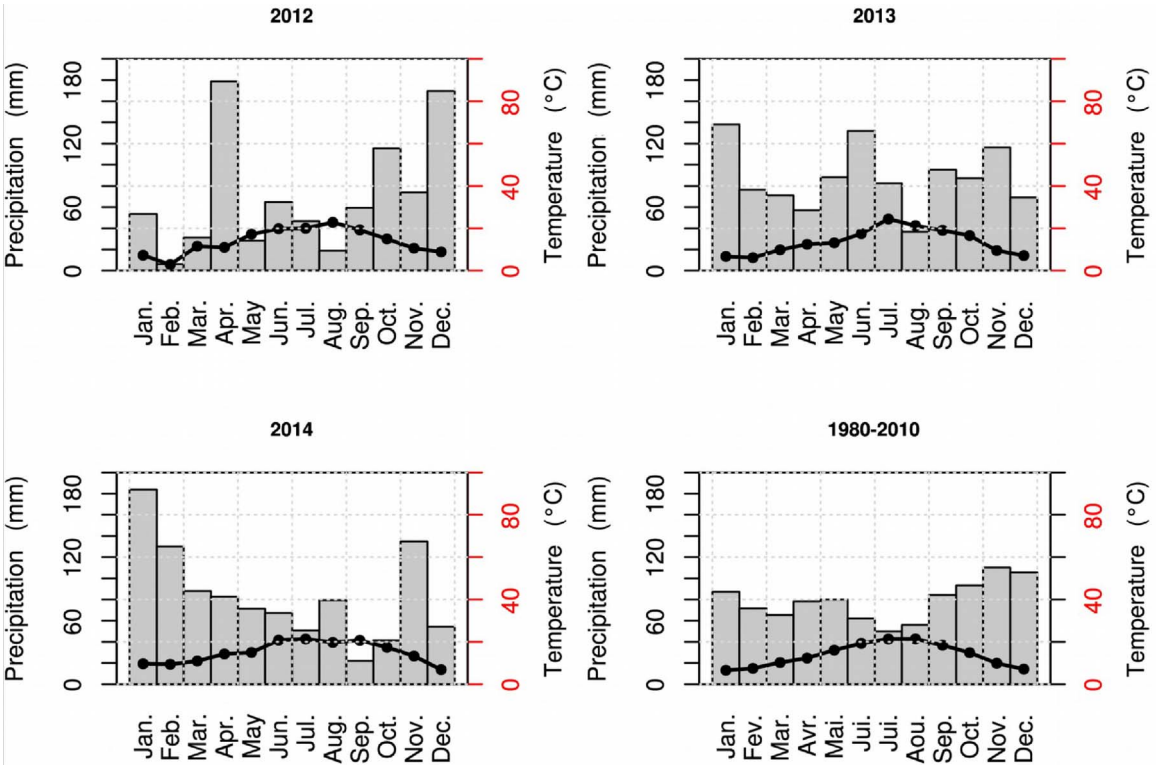


**Fig. 2.** Monthly precipitation and average temperature during the studied years (2012, 2013, and 2014) and for 1980–2010 at the Bordeaux-Mérignac station. Data: Météo France (94165, Saint-Mandé).

Relationships between these indices and vine behavior have been studied worldwide (Chuine et al., 2004; van Leeuwen et al., 2004; Garcia de Cortazar Atauri, 2006; Webb et al., 2007; Hall and Jones, 2009; Parker et al., 2013). In these studies, data from one climate station within each winegrowing region are often used, supposedly representing the whole area (Gladstones, 2011). This is not optimal since temperatures are likely to show large variability at fine scales (Scherrer and Körner, 2011; Ashcroft and Gollan, 2012). Quénol and Bonnardot (2014) have shown a difference of more than 2 °C over a vineyard area. Hence, improved knowledge of local climate variability is essential to better design and implement adaptation strategies in response to possible future climate changes.

Different types of model exist to represent climate on Earth at various scales. For global scales, the General Circulation Models (GCM) are mainly used for weather prediction but also to develop climate change *scenarii* and to estimate future climate parameters such as temperature, rainfall and wind globally, at a low spatial resolution (~300 km). Obviously, these kinds of model are not able to take into account temperature variability at local vineyard scales. Several studies have tried to improve the resolution of GCMs, leading to a number of different regional climate models, including the RAMS (Regional Atmospheric Modeling System) and WRF (Weather Research and Forecasting) models. In the context of climate variability in vineyards, RAMS has been used in the winegrowing region of the South African