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Multi-scale approach to Euro-Atlantic climatic cycles based on phenological time series, air temperatures and circulation indexes

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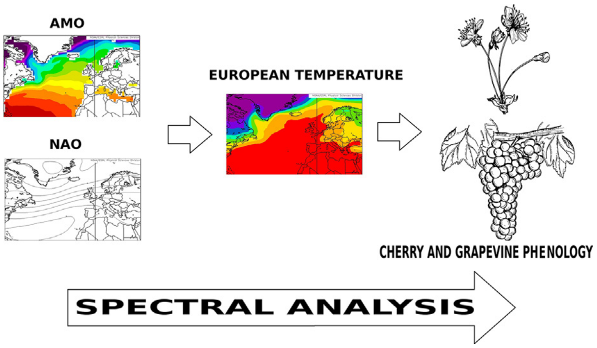
HIGHLIGHTS

- CIRCULATION(A) → TEMPERATURE(B) → PLANT PHENOLOGY(C) is the causal chain considered.
- Main aim was to analyze how spectral peaks of in A affects B, which in turn imprints C.
- Problem approached with suitable methods of spectral analysis
- Teleconnection with ENSO was also explored.
- Results highlights phenological peaks influenced by macroscale circulation indexes.

GRAPHICAL ABSTRACT



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ABSTRACT

The spectral periods in North Atlantic Oscillation (NAO), Atlantic Multidecadal Oscillation (AMO) and El Nino Southern Oscillation (ENSO) were analyzed and has been verified how they imprint a time series of European temperature anomalies (ETA), two European temperature time series and some phenological series (dates of cherry flowering and grapevine harvest). Such work had as reference scenario the linear causal chain MCTP (Macroscale Circulation → Temperature → Phenology of crops) that links oceanic and atmospheric circulation to surface air temperature which in its turn determines the earliness of appearance of phenological phases of plants.

Results show that in the three segments of the MCTP causal chain are present cycles with the following central period in years (the % of the 12 analyzed time series interested by these cycles are in brackets): 65 (58%), 24 (58%), 20.5 (58%), 13.5 (50%), 11.5 (58%), 7.7 (75%), 5.5 (58%), 4.1 (58%), 3 (50%), 2.4 (67%). A comparison with short term spectral peaks of the four El Niño regions (nino1 + 2, nino3, nino3.4 and nino4) show that 10 of the 12 series are imprinted by periods around 2.3–2.4 yr while 50–58% of the series are imprinted by El Niño periods of 4–4.2, 3.8–3.9, 3–3.1 years. The analysis highlights the links among physical and biological variables of the climate system at scales that range from macro to microscale whose knowledge is crucial to reach a suitable understanding of the ecosystem behavior.

The spectral analysis was also applied to a time series of spring – summer precipitation in order to evaluate the presence of peaks common with other 12 selected series with result substantially negative which brings us to rule out the existence of a linear causal chain MCPP (Macroscale Circulation → Precipitation → Phenology).

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1. Introduction

The midlatitudes of our planet are the theater of the peculiar causal chain MCTP that links macroscale atmospheric and oceanic circulation to surface air temperature which in its turn determines the timing of phenological phases of plants (Lieth, 1974). The global nature of the MCTP causal chain was recently stated by Reid et al. (2016) that working on time series of flowering dates of three cherry species in three remote locations of the North hemisphere (Japanese cherry - *Prunus jamasakura*, at Kyoto, Japan; cherry - *Prunus avium* - at Liestal, Switzerland; Yoshino cherry *Prunus x yedonensis* in the tidal basin, Washington D.C., US) detected the presence of the signature of the shift in surface air temperatures happened in the 80's of the XXth century and caused by an abrupt change in macroscale circulation (Mariani et al., 2009a). Moreover Zeng et al. (2014) stated the profound ecological consequences of the MCTP causal chain with reference to the increase of the seasonal amplitude of the CO_2 cycle.

More problematic is rather the analysis of the MCPP causal chain because it is remarkably weakened both by (i) the relevance of mesoscale processes in precipitation genesis (Barry and Carleton, 2001) and (ii) the effect of precipitation on plant phenology that is largely mediated by the soil water budget. On this latter aspect it should be noted that (a) soil water excess delays the spring heating of soils (Zhang and Zuo, 2011) with effects on timing of phenological phases, (b) soil water shortage affects the phenological timing of grapevine (Kuhn et al., 2014; Martínez-Lüscher et al., 2016) and (c) a quite different water content can derive from the same precipitation amount in function of the time distribution of the events (precipitation concentrated in a few events results in more relevant infiltration and runoff losses).

The present work focuses on meteorological data and geophysical or biological proxies in order to highlight climatic cycles whose existence will be corroborated by the detection of their presence in the three different segments of the MCTP causal chain. This exercise is referred to Europe, an ideal area because such historical records are among the longest of the world. In this general context, a preliminary comparison between our approach and that adopted by other authors (Tourre et al., 2011; Berger, 2008) was performed in order to verify the pros and cons with respect to an analysis based on the Multi Taper Method (hereafter MTM; Ghil et al., 2002). An attempt to highlight the signature of the causal chain MCPP in the selected time series was also made.

1.1. Some insights on the MCTP causal chain

The time variability of macroscale circulation for the Euro-Atlantic area is often analyzed by means of NAO, AMO and ENSO.

AMO describes the temperature of the North Atlantic surface (Kilbourne, 2014) and its presence, documented since 1857 by direct measurements is also testified for the last 8000 years by means of a multiproxy approach (Knudsen et al., 2011). As implied by the term “Oscillation”, AMO is subject to characteristic cycles that have a relevant effect on the European thermal and pluviometric regime (Sutton and Dong, 2012).

The NAO index is based on the difference of the normalized sea level pressure between two stations in the North Atlantic, one in the far North (typically in Iceland) and another more to the south (typically in the Azores islands or in the Iberian Peninsula). The winter NAO (NAOI, from December to March) is the most effective on European climate because the thermal contrast between the Atlantic Ocean and the Eurasia is stronger than in summer. More specifically a positive NAOI gives advection towards Europe of mild and moist maritime air masses from the Atlantic while advection of polar continental air from the Siberia, very cold and dry, is observed with a negative NAO (Hurrell, 1995).

A possible link between AMO and NAOI was proposed by McCarthy et al. (2015) which hypothesized that the long persistence of NAOI on positive values triggers the transition of AMO from negative to positive, as for example happened with the 1994 transition, triggered by a long positive phase of NAOI that begun in 1988. In this context the positive NAOI determined the phase change of European temperatures from negative to positive anomaly whose persistence over time was then guaranteed by the positive AMO.

ENSO is the most important coupled ocean–atmosphere phenomenon that causes global climate variability on seasonal to interannual time scales (Wolter and Timlin, 2011).

Europe offers the longest world instrumental records of surface weather variables because first meteorological instruments (thermometer, pluviometer, barometer and evaporimeter) were invented by the Galilean school, an highly original scientific forum that conceived the idea of first regular meteorological measurements within the Tuscany network, active from 1655 (Camuffo and Bartolin, 2012) and at the same time spread meteorological instruments at the European level to promote an observing network that would operate in a coordinated manner (Camuffo and Jones, 2002). The availability of very long time series is quite interesting for historical and climatological purposes although the homogeneity of such series is negatively affected by problems like changes in urban heat island effect, measurement units, observational standards (e.g.: time of observation) and location of instruments.

Climatic reconstructions before the beginning of the instrumental period are carried out with proxy data, such as the time series of ^{18}O in marine sediments that enabled Cesare Emiliani to show the occurrence of a sequence of ice ages during the Pleistocene (Berger, 2013), gases and dust embedded in the Greenland and Antarctic ice sheets useful to rebuild global temperatures, wind and other atmospheric features (Jouzel, 2013) and the tree growth rings of *Pinus aristata* Engelm, in USA, useful to rebuild temperature and precipitation or a very long period (Carrara and McGeehin, 2015).

Agriculture is a relevant source of secular proxy data because this revolutionary technology was discovered at the end of the last ice age and was initially based on the domestication of herbaceous species (wheat, rice, corn, sorghum, etc.) while the domestication of woody plants like grapevine (*Vitis vinifera* L.), apple (*Malus communis* L.), peach (*Prunus persica* L.), cherry (*Prunus avium* L.) and black cherry (*Prunus cerasus* L.) happened later. About grapevine it can be considered that the first wine was produced about 8000 years ago in Georgia (McGovern, 2003) and the vine has been cultivated for at least 6000 years between the Caucasus and the Zagros (Zohary et al., 2012). After the domestication, grapevine migrated first to Europe and then to other continents. From this long history follows that grapevine phenological time series are an important source of data for paleoclimate reconstructions. While they are not the only type of available phenological data for grapevine (Parisi et al., 2014), grapevine harvest dates (GHD) are by far the predominant phenological information on this crop which in plains or low hills of the Euro-Mediterranean areas with Koeppen climate Csa, Cfa or Cfb is harvested from midsummer to late autumn (July for earliest varieties, November for latest ones). GHD are registered since the Middle age by the municipalities of a wide area involving France, Switzerland, Austria and Northern Italy that established the official date of the beginning of the harvest in order to protect the wine quality and prevent the grapes theft. The gathering of these time series was started by the physicist Louis Dufour (1870) for Swiss and the climatologist Alfred Angot (1885) for France while more recent contributions came for example from the historians Le Roy Ladurie (1976) and Labbé and Gaveau (2013).

GHD are mainly determined by temperatures (more daily maximum than minimum) of the spring period before grapevine flowering (April, May and June). More in detail, mild temperatures during spring give an early flowering that is generally followed by an early harvest. On this causal scheme is founded the reconstruction of spring temperatures of the past on the base of GHD dates carried out for example in Switzerland (Meier et al., 2007), Italy (Mariani et al., 2009b), Austria (Maurer et al., 2011) and France (Chuine et al., 2004).