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Report on the marine cores and on the analysis of the data; transmission of data to archives and to the General Portal.

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The high-resolution study, focused on the last two millennia and carried out on the SW104_C5-C5 core (Gulf of Gaeta, Central Tyrrhenian Sea), allowed us to identify and date six climatic oscillations: *Roman Period* (top interval ca. 530 AD), *Dark Age* (ca. 530 – ca. 840 AD), *Medieval Classic Anomaly* (ca. 840 – ca. 1240 AD), *Little Ice Age* (ca. 1240 – ca. 1850 AD), *Industrial Period* (ca. 1850 – ca. 1940 AD), *Modern Warm Period* (ca. 1940 AD). These past climatic oscillations have been recently documented also in the Gulf of Salerno (southern Tyrrhenian Sea) by Lirer et al. (2014).

These climatic oscillations, calibrated with a high-resolution age model, were identified by comparing the $\delta^{18}O$ *G. ruber* signal with the planktonic foraminiferal turnovers between carnivorous (*Globigerinoides ruber*, *G. quadrilobatus*, *Orbulina* spp., *Globigerinatella siphonifera*) and herbivorous-opportunistic species (*Turborotalita quinqueloba*, *Globigerinita glutinata*, *Globigerina bulloides*). The paleoclimatic reconstruction from the SW104_C5-C5 core (Fig. 1) allowed us to identify the following intervals:

1) The *Roman Period* is dominated by herbivorous-opportunistic planktonic foraminiferal species and it is characterised by two cold phases (Roman I and Roman III) interlayered by a warm phase. The climatic phases Roman I and Roman III are characterized by the presence of cool water species *G. scitula* and *N. pachyderma*. Conversely, between Roman I and Roman III, the $\delta^{18}O$ *G.ruber* signal shows a warming event marked by an increase of warm/wet species *G. siphonifera*, *Orbulina* spp. and *G. ruber.* At the top of this period, a first turnover from carnivorous to herbivorous-opportunistic planktonic foraminiferal species marks the *Roman Period-Dark Age* transition.
2) The *Dark Age* is characterised by a first warm phase followed by a cold one (Roman IV). The warm phase is documented by strong increase in abundance of planktonic warm water species (*G. quadrilobatus*, *G. sifoniphera* and *Orbulina* spp.). The cold and dry phase Roman IV is marked by maxima in cold water species (*G. scitula* and *N. pachyderma*) and by a decrease of the warm water species. The dryness characterizing the Dark Age is correlated with decreased humidity in the western Mediterranean (Nieto Moreno et al., 2011), evidenced by forest cover regression episodes (Jalut et al., 2000, 2009; Combourieu-Nebout et al., 2009), a decrease in river activity in southern Europe (Magny et al., 2002; Macklin et al., 2006), cooling events in the Balearic Basin (Frigola et al., 2007), and lower lake levels in southern Spain (Carrion, 2002).
3) The *Medieval Classic Anomaly* period is characterised by an overall stable climatic condition as testified by the coexistence of cold and warm water planktonic foraminiferal species. The $\delta^{18}O$ *G. ruber* signal documents a short time interval that could be associated with the Medieval Warm Period.
4) At ca. 1240 AD, a planktonic foraminiferal turnover documented the transition between the Medieval Classic Anomaly (MCA) and the subsequent colder conditions culminating in the Little Ice Age (LIA). The MCA–LIA transition is the last global-scale Rapid Climatic Change (RCC) event reported in the Holocene by Mayewski et al. (2004) and Lirer et al. (2014).
5) During the LIA, planktonic foraminiferal assemblages, associated with high fertility surface waters (maxima in *G. glutinata* + *T. quinqueloba*), document general cold-water conditions. Nieto Moreno et al. (2011) show an enhanced fresh water input, implying an establishment of wetter conditions in the western Mediterranean. Thus, increased fluvial input along with oceanographic oscillations may have promoted enhanced productivity, as suggested by larger TOC values and organometallic ligands (Nieto Moreno et al., 2011). The Maunder Minimum (MM, 1645–1715) represents the coldest period of the Little Ice Age (LIA, 1300–1900), an interval of reduced solar activity; within the MM, the Late Maunder Minimum

(LMM, 1675–1715) was a period of persistent extremely cold winters in Europe (Barriopedro et al., 2008). The strong cooling recorded in the Northern Hemisphere during the Maunder Minimum was related by Barriopedro et al. (2008) to events of Atlantic blocking. During the Maunder event, the strong increase in *G. truncatulinoides* and *G. inflata* abundances suggest a deepening of the mixed layer during winter. Strong winds caused by Atlantic blocking may be responsible for mixing water, resulting in the rapid spread of these planktonic foraminiferal species.

6) The Industrial Period is characterized by an increase in abundance of *G. quadrilobatus* and *G. ruber*. Together with *G. ruber*, the abundance of *G. quadrilobatus* provides and estimate of the temperature of the mixed layer (Spooner et al., 2005). The dominance of herbivorous-opportunistic planktonic foraminiferal species and the $\delta^{18}O$ *G. ruber* signature document the occurrence of a humid climatic phase during the whole Industrial Period from approximately 1850 AD to 1940 AD (Nieto-Moreno, 2012).
7) The last planktonic foraminiferal turnover documented the onset of the Modern Warm Period. During this interval, the $\delta^{18}O$ *G. ruber* signal documents warming and more diluted seawater condition. In addition, from ca. 1950 AD onwards, the modern warm climatic phase and oligotrophic conditions are documented by a further strong increase in *G. ruber* pink and *G. quadrilobatus* abundances.

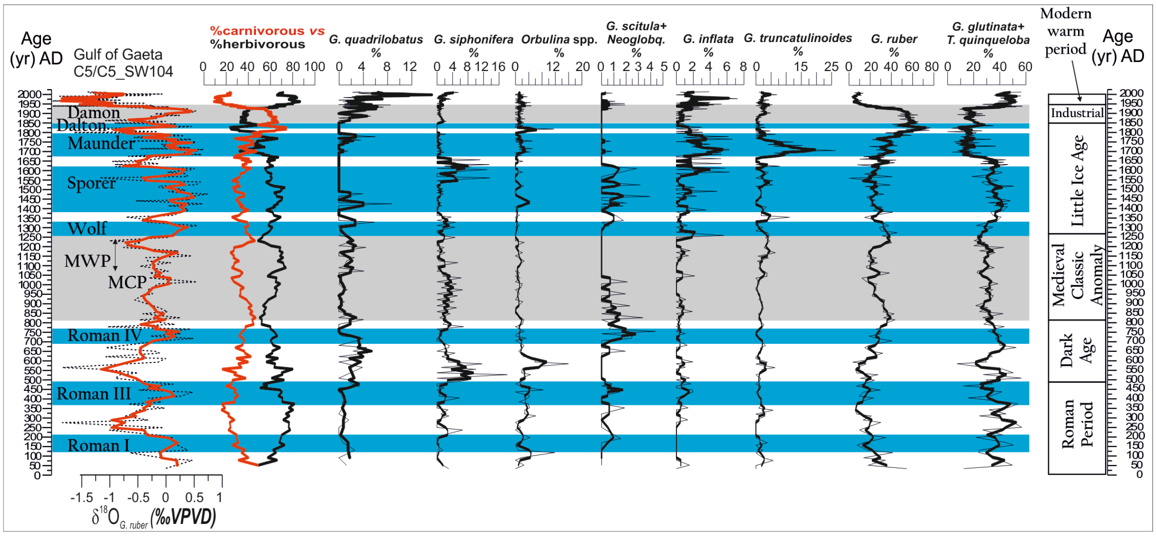

Fig. 1. Succession of climatic events identified during the last 2000 years in a marine sediment core from the Gulf of Gaeta (SW104_C5-C5 core). MWP: *Medieval Warm Period*; MCP: *Medieval Cold Period*.

The results of pollen analysis (extended back to 2000 years BC) of the SW104_C5-C5 core are presented in a synthetic percentage diagram, which brings together the percentages of individual taxa in the main ecological categories. The diagram (Fig. 2) shows significant changes in the forest cover, in terms of vegetation structure and floristic composition, which can be outlined as follows:

• 1600 BC - 900 BC: a forested landscape, with prevalence of evergreen oak-dominated forests, suggests a warm and humid climatic phase. Deciduous trees, including oaks, *Ostrya* and *Fagus*, are also represented in significant amounts. Open environments are characterized by grasses belonging to the *Asteraceae* and *Chenopodiaceae* families. Among the indicators of human impact, there is the presence of *Olea* and *Vitis*, which may be partly related to the management and exploitation of natural populations by humans during the Bronze and Iron Ages.

• 900 BC - 100 AD: this phase shows an opening of the forest cover, possibly linked to a climate change towards more arid conditions, as suggested by an appreciable increase of *Artemisia* and other herbaceous taxa. The indicators of human impact decreased in the range between 900 and 200 BC, and then increased dramatically from 200 BC onward, indicating a significant increase in the pressure of human activities on the natural systems during the Roman domination.

• 100-800 AD (*Roman Period-Dark Age* interval): the pollen record shows a new general development of forest cover, due to a considerable percentage increase in arboreal taxa, mainly conifers, especially between 100 and 400 AD (*Roman Period*). Tree populations may have benefited from a warm and humid climate, as it is documented in the literature. In the middle of the range considered, between 400 and 600 AD, a further decline in the pollens from many tree species suggests a reduction of forest cover. This event was associated with a rapid decrease in both evergreen and deciduous broadleaved taxa, as well in conifers, although the expansion of *Castanea*, among anthropogenic indicators, contributed to keep the tree percentage values high. This complex forest dynamics may be explained by the influence of a phase with cooler climate (cf. *Dark Ages Cold Period*), which may have resulted in a significant impact on the development of the natural populations of trees, already cleared by man in order to favour chestnut forestry. Between 600 and 800 AD, an increase of tree percentages suggests a new growth of natural forest communities, presumably following the onset of a cooler and wetter climate.

• 800 - 1150 AD (*Medieval Classic Anomaly*): there is rapid and significant opening of the landscape vegetation, characterized by a rapid decrease in the deciduous trees and a parallel considerable increase in herbaceous taxa. The expansion of herbaceous plant communities, dominated by *Cichorioideae*, *Asteroideae*, *Gramineae* and *Artemisia*, may have been favoured by an oscillation toward a more arid climate.

• 1150 - 1500 AD (lower and middle part of *Little Ice Age*): the landscape was dominated by open vegetation, although a new development of tree populations, both deciduous and evergreen, occurred possibly in relation to a phase with milder climatic conditions and increased rainfall, chronologically corresponding to the Medieval Climate Anomaly.

• 1500 - 1870 AD (middle and late part of *Little Ice Age*): the pollen record shows a new significant decrease in the forest cover. This process seems to have particularly affected the broadleaved tree taxa, whose curves show the lowest percentage values of the entire sequence between 1650 and 1750 AD, in correspondence with the Maunder Minimum. The cool climate associated with this minimum of solar activity may have affected the development of populations of many arboreal taxa, except conifers that show a moderate increase. High values of fragments of fungal hyphae of the genus *Glomus* suggest an increase of terrigenous sediments, plausibly related to the reduction of forest cover and a simultaneous increase of runoff.

• 1870 - 2000 AD (*Industrial-Modern Warm Period*): the pollen record ends with a recovery of the arboreal vegetation, dominated by *Pinus*, which may reflect extensive plantation of pine forests in the coastal areas of the Gulf of Gaeta, especially during the last centuries. Moreover, the recent impact of human activities is well documented by an increase in anthropogenic pollen indicators, suggesting that the nearby territory was increasingly occupied by cultivations of *Olea*, *Vitis*, cereals and hemp.

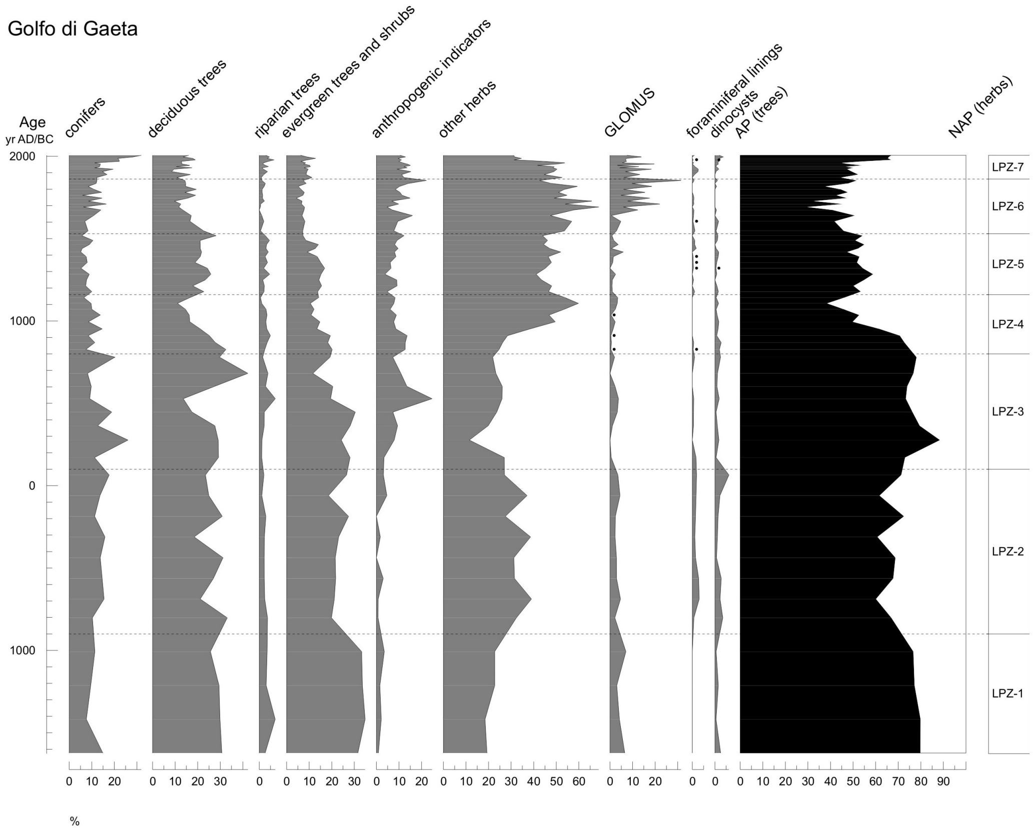

Fig. 2. Synthetic pollen percentage diagram from the Gulf of Gaeta (core SW104_C5-C5).

The comparison between the SST reconstructed from $\delta^{18}O$ *G. ruber* signals from Gulf of Gaeta (central Tyrrhenian Sea, NextData Project), Gulf of Salerno (Lirer et al., 2014, south Tyrrhenian Sea), Gulf of Taranto (Grauel et al., 2013) and Menorca Basin (Moreno et al., 2012) shows a good correlation in trends and values (Fig. 3). This parallel behavior is also visible in the comparison with continental data from the Alps (Wirth et al., 2013), caves in Turkey (Gokturk et al., 2001) and caves in Austria (Mangini et al., 2005), suggesting a climate connection between different environments. In addition, the flood events for the central/southern Tyrrhenian Sea (NextDdata Project) reported in historical documents fit rather well with flood reconstructions from continental records in the Alps (Wirth et al., 2013).

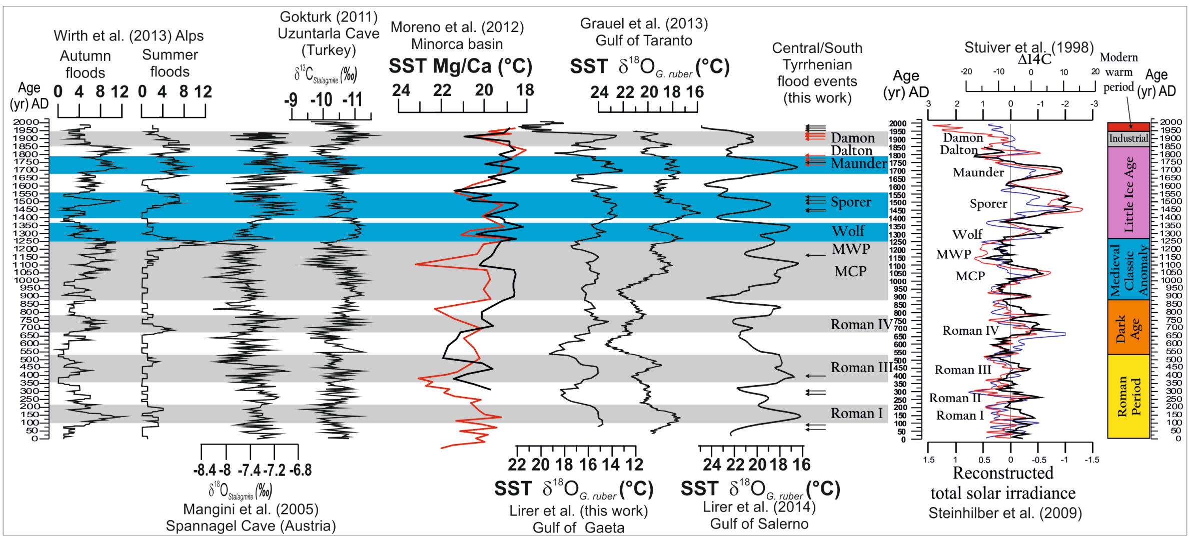

Fig. 3. Sea Surface Temperature (SST) reconstruction of marine records (central and southern Tyrrhenian Sea, Gulf of Taranto and Minorca basin) compared with continental data for the last 2000 years.

Spectral and wavelet analysis of the signal of reworked coccoliths from the uppermost part of the SW104_C5-C5 core (last 350 years, Gulf of Gaeta) and the Atlantic Multidecadal Oscillation (AMO) index reveal a distinct peak at about 80 years. The comparison of filtered signals at the 80 years frequency band (Fig. 4) revealed a good correlation between the Volturno river runoff (reworked coccoliths index) and the AMO index during the last 350 years. This feature support the hypothesis that the reworked coccoliths can be used to reconstruct past runoff oscillations.

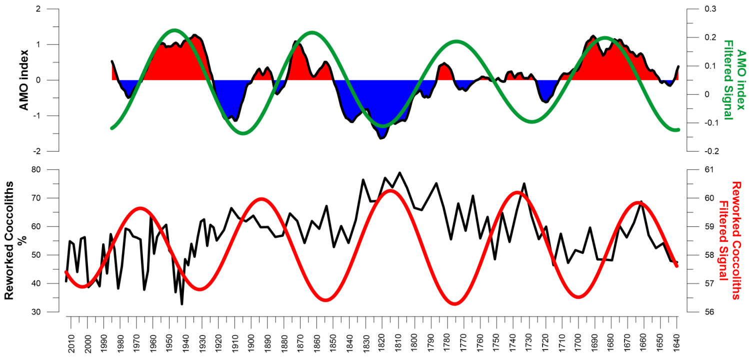

Fig. 4. AMO index and reworked coccoliths signal (black curves) and corresponding filtered signals at the 80 yr frequency band (green and red curves).

The Holocene (last 11ka) pollen maps of Italy have been produced in cooperation with the Laboratory of Palynology and Palaeoecology (CNR) of Milan. The aim of the work was to review the available pollen data from the Italian territory considering the complex physiographic, edaphic, climatic and vegetational features of this region. This ecogeographic diversity favours a considerable biodiversity, further increased by the long-term persistence of plant taxa across the Quaternary, and by the strategic location of Italy, placed between Europe and Africa and between the eastern and western Mediterranean Basin. A database of hundred pollen records was plotted at time intervals of 500 years for the last 11000 years. Although there is a prevalence of sites in northern Italy with respect to the southern regions and some areas are not well known yet (e.g. Po Plain, central Apennines, Sardinia), there is a good distribution of sites thanks also to the large number of new records studied in the last few years. We screened the published pollen records from Italy to exclude the records with uncertain chronological setting. When available, the original counts were considered. In the other cases, we digitized the percentage data from the published diagrams. To detect the local presence of a taxon in the study area, we used threshold values as suggested in the literature, ranging from 0.5 to 5% depending on the taxon.
The pollen maps were also compared with the modern distribution of the corresponding taxa. This was a difficult task as the detailed distribution of tree taxa is not properly mapped in Italy and is not available in a national homogeneized database. Therefore, we used the tree distribution maps obtained from the Vegetation Database of Sapienza University in Rome, which is still being built.
We produced the pollen maps of several tree taxa, including *Picea, Abies, Betula, Fagus, Carpinus betulus, Corylus*, deciduous and evergreen *Quercus*, and *Olea*. In addition, the pollen maps of arboreal vegetation have been plotted (Fig. 5). Overall, a progress of knowledge on the past vegetational features of Italy has been attained as well as a better understanding of the modern vegetation, which often shows complex patterns that can be traced back in time over several thousands of years. Although the available distribution maps for modern tree taxa in Italy need to be refined and pollen data are still missing from large areas of Italy, complex patterns and discontinuous ranges of modern tree taxa can be traced back in time over several thousands of years. Water availability appears to be a major factor influencing not only the modern distribution of trees, but also their history. The tree cover was generally

higher in the regions with higher orographic precipitation with respect to dry areas. This is not always depending on their latitudinal location. For example, it appears that the rainy mountains of Calabria in southern Italy have been more forested than some relatively dry sites in the Aosta Valley in NW Italy through the whole Holocene. This complexity urges not to simply frame the vegetation history in standard schemes of North-South differences of vegetation, often based on the comparison of pairs of selected sites, but to consider all the available records to reconstruct complex vegetational patterns.

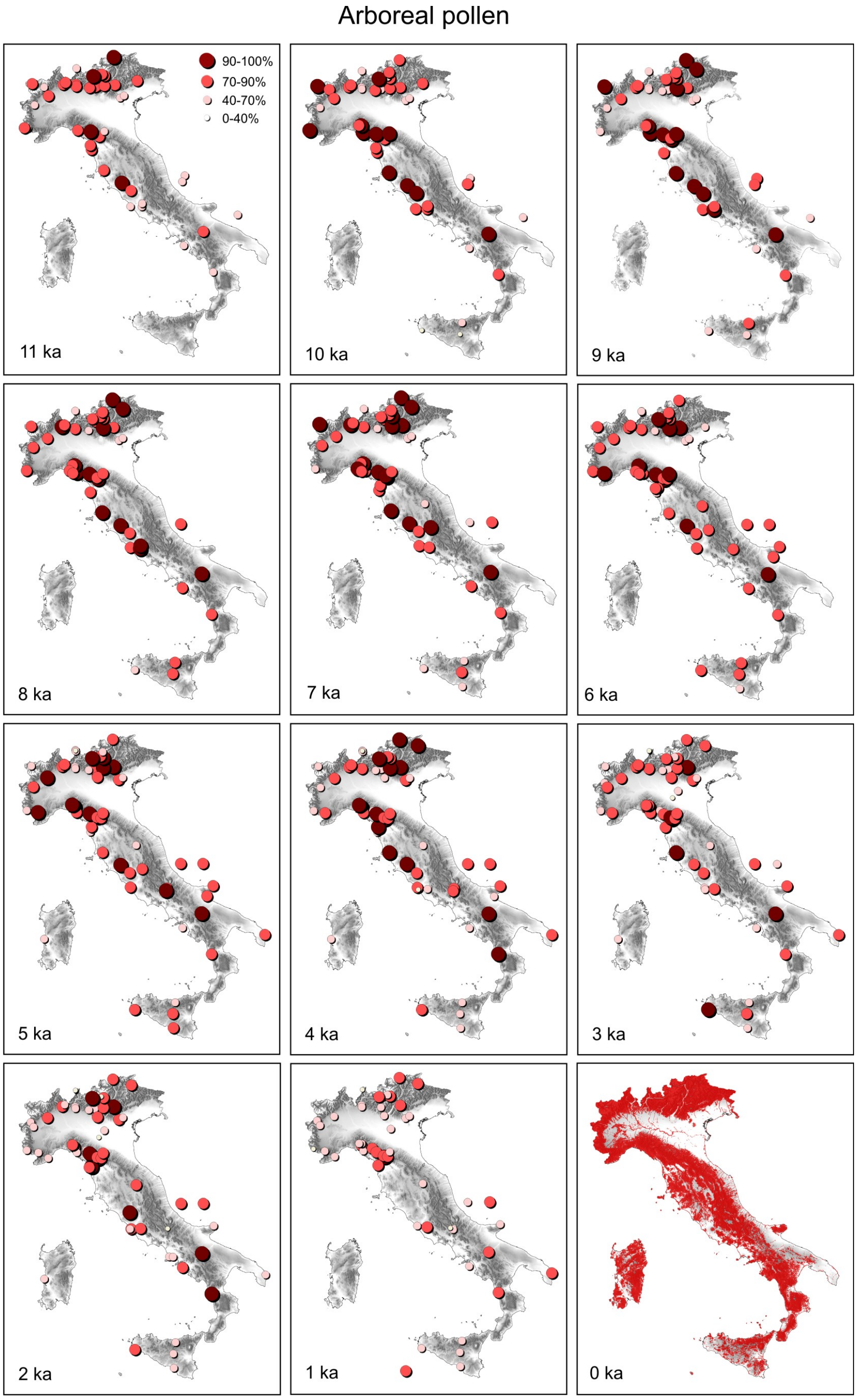

Fig.. 5. Abundance of Arboreal Pollen in Holocene records and modern national forest cover (ISPRA, 2010) in Italy. Ages are expressed as ka (thousands of years) BP.

Transmission of data to the archives and General Portal.

The numerical data transferred to the NextData archives are as follows:

- Planktonic foraminiferal quantitative data of cores: core ND14O_SW104 (Gulf of Taranto), core ND14Q_SW104 (south Adriatic Sea) and core ND11_SW104 (Sicily Channel);
- Calcareous nannofossils quantitative data of cores: core ND11_SW104 and ND2_SW104 (Sicily Channel);
- $\delta^{18}O$ e $\delta^{13}C$ data from planktonic foraminifer *Globigerinoides ruber* of core ND11_SW104 (Sicily Channel);
- Pollens quantitative data of core SW104_C5-C5 (Gulf of Gaeta, central Tyrrhenian Sea);
- Magnetic susceptibility data of cores recovered in the Adriatic Sea in July 2014: (GIOVE_4, GIOVE_5, ND_14M_bis, ND_14O, ND_14Q, ND_14R, ND_14S, ND_14T, ND_14U, ND_14V, ND8_2014, ND11_2014).