OROGRAPHIC INFLUENCE ON THE CENTRAL-NORTHERN ITALY CLIMATE FROM UNDERGROUND TEMPERATURES

V. Pasquale, M. Verdoya, P. Chiozzi

Dipartimento per lo Studio del Territorio e delle Sue Risorse, Università di Genova
Viale Benedetto XV 5, I-16132 Genoa, Italy
E-mail: *pasquale@dipteris.unige.it*

In last decades, new studies on palaeoclimate, improved analysis of data sets, with a more rigorous evaluation of their quality, and comparisons among data from different sources have led to a better understanding of climate changes. As temperature changes at the surface affect the temperature distribution in the subsurface, ground temperatures are one of the most important archives of the past climate signal. Within the framework of an international research project, we have been working at the inference of the ground surface temperature (GST) history in northern-central Italy (Fig. 1). Our goal is collection, analysis and interpretation of geothermal data, relevant to understanding the nature and causes of climate change over the past three centuries, mainly constituted by temperature logs in drill-holes and laboratory measurements of rock thermophysical properties.

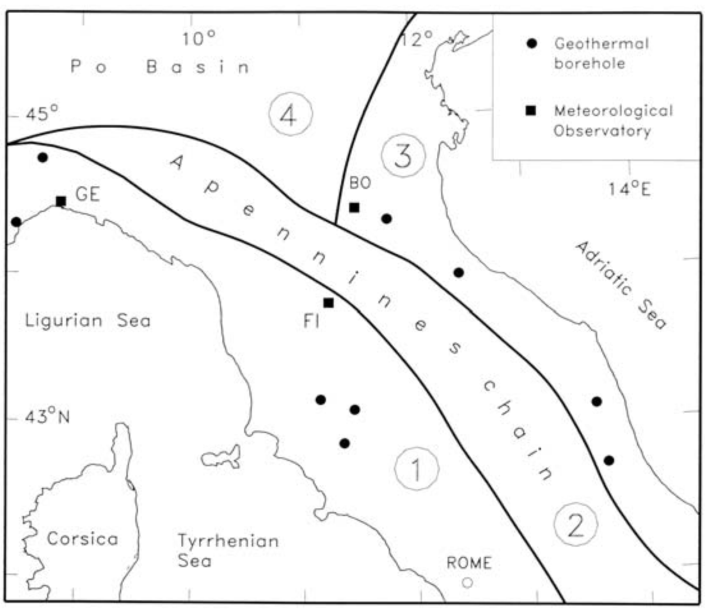
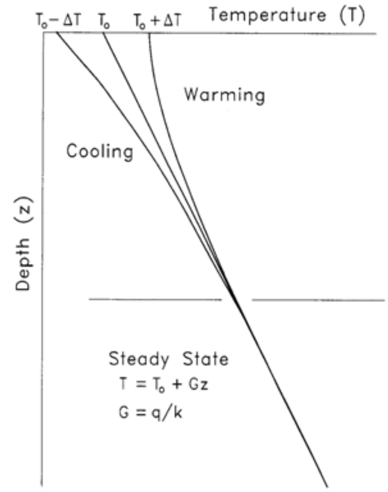


Figure 1. Location of the boreholes and meteorological observatories whose data were used for the climatic study. The main climatic regions are shown: Ligurian-Tyrrhenian (1), Apenninic (2), Adriatic (3), Po Basin (4).

The underground thermal conditions at shallow depths are controlled by the temperature at the surface and the heat flowing from the deeper parts. In an idealized homogeneous layer, if the surface temperature is steady (= T_o), the distribution of ground temperature is a linear function of depth z: $T=T_o+G \cdot z$, where G is the undisturbed geothermal gradient (Fig. 2). However, if the surface temperature changes with time, the underground temperature will depart from the linear distribution, which is governed by heat flux (q) and thermal conductivity (k). A progressive cooling at the surface will cool down the rocks near to the surface and increase the thermal gradient at shallow depths. A progressive warming, on the other hand, should be responsible for a temperature profile with smaller even negative thermal gradients at shallower depths. If the surface temperature oscillates with time, oscillations in the ground temperature will follow. The magnitude of the departure of ground temperature from its undisturbed steady state is related to the amplitude of the surface temperature variation, and the depth to which disturbances to the steady state temperature can be measured is related to the timing of the original temperature change at the surface. A ground surface temperature history is therefore recorded in the subsurface.



Once the mechanism by which surface thermal variations propagate downwards leaving traces of past climates is understood, recovering the climate history from borehole temperature logs can be approached as an inverse problem. Figure 1 shows the location of the selected 200-350 m deep boreholes used in our studies, together with the meteorological observatories at which surface air temperature time series were available. The climate history of the Ligurian Tyrrhenian side can be outlined from the surface air temperature change as inferred from the Genoa University and Florence Ximeniano observatories data, expressed as a departure from the average value over the period 1833-1994 (Fig. 3). The trends of the Genoa and Florence series are similar and can be regarded as representative of the regional temperatures at least for a 200 km long band on the Tyrrhenian side. The curve which better fits both series shows increased temperature values at the present-day. The curve fitting the mean departures over the period 1814-1982 of the Bologna University Observatory data shows a minimum value of 0.5 K centred in 1860 and a maximum of about 0.25 K in 1945. A comparison of this series with dendroclimatological temperature estimates also shows significant coincidence, implying that the meteorological series of Bologna may be representative of a wide sector of the Po Basin and the northern Adriatic side.

Figure 2. Effects on underground temperature distribution due to surface warming (*ΔT*) and cooling (-*ΔT*).

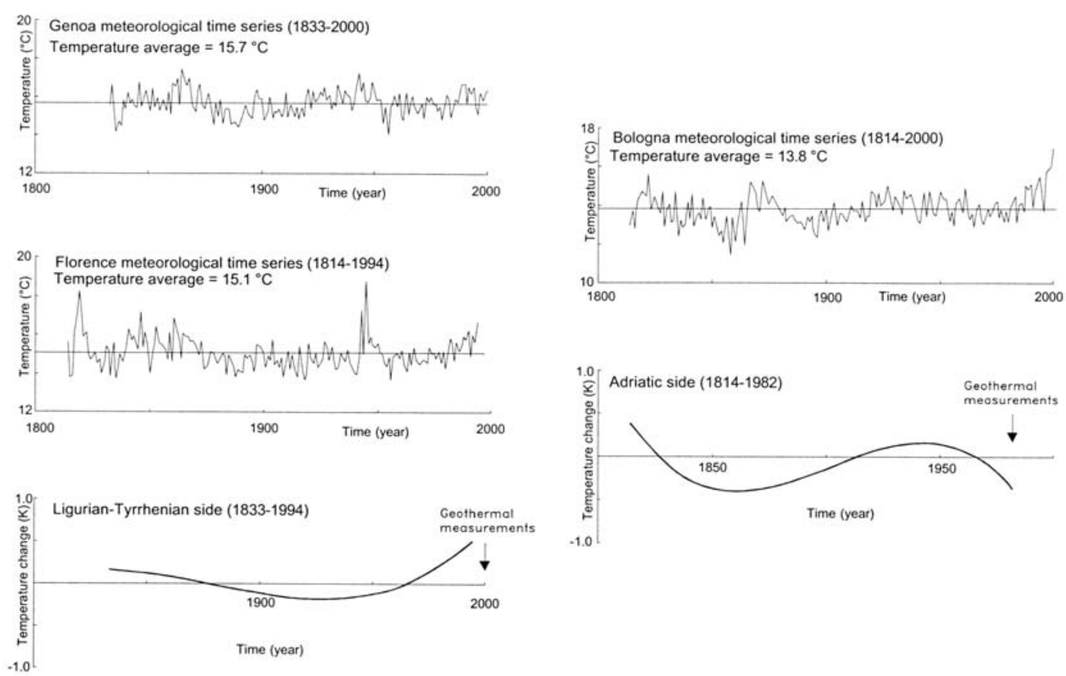


Figure 3. Annual surface air temperature during the 19th and 20th centuries recorded at meteorological observations and temperature changes for the Ligurian-Tyrrhenian and Adriatic sides. The curves of temperature change (polynomial of degree 3) is the best estimate to the average value calculated from Genoa and Florence records for the Ligurian-Tyrrhenian side and from Bologna data for the Adriatic side. The arrows indicate the date of the underground temperature logs.

The link between surface temperature variation and underground temperature can however give more reliable inferences about past temperature variations than the meteorological series alone and help to distinguish whether the recently observed warming represents a natural climatic variation or an induced anthropogenic change of climate. The ground surface temperature history was derived at each borehole by means of standardized inversion procedures operating on the temperature logs by removing the steady-state component in the deeper part of the *T-z* profiles. The inferred history can be regarded as the long-term trend during the past two-three centuries and thus is complementary to high resolution proxies such as tree rings, ice cores, corals and lake sediments. The analysis put into evidence that the trend of the temperature change in the western side of the Apennines differs from that of the eastern side (Fig. 4).

In the Ligurian-Tyrrhenian side, all the investigated boreholes show the same trend. The temperature has been always lower than that of the 1990s, with minimum values of -0.6 K from 1930 to 1960. This cold period was preceded by a slow decrease of temperature since 1800 and it has been followed by a warming phase at a high rate up to now. On the Adriatic side, the magnitude of the inferred climatic change differs from that of the western side of the Apennines chain. Our results indicate that ground surface temperature has always been higher than that of the 1980s. After a warmer period ended in 1940, there has been cooling until the time of the temperature measurements (1982). During the latter phase, the temperature has decreased at an average rate of -0.03 K/yr.

Even if processing of data from more boreholes would be recommendable for reaching definitive conclusions, the available data hints that observed difference in the course of the climatic history may have been caused by local climatic changes in the Adriatic side. The existence of such additional climatic changes, which cannot be attributed to the change of climate represented by the meteorological observations, deserves certain explanation.

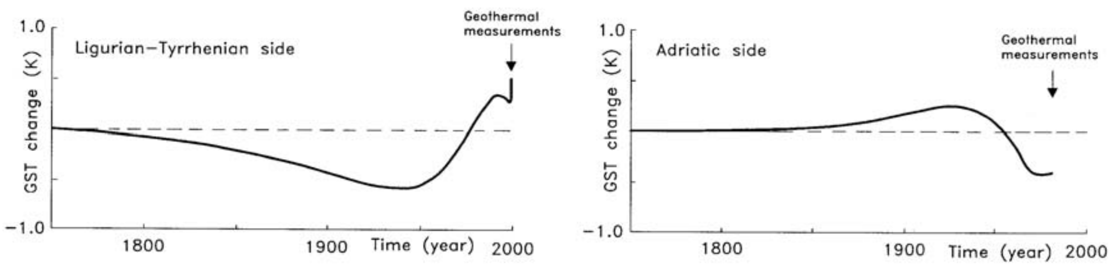


Figure 4. Ground surface temperature (GST) change from inversion of temperature-depth data in the boreholes of the Ligurian-Tyrrhenian and Adriatic sides.

The major geographical factors influencing the climate in the central-northern Italy are the barrier effect of the Apennines, especially in connection with the cold air from the northeast, and the unstabilizing effect of the Mediterranean Sea which tends to facilitate cyclogenesis in the vicinity of the peninsula. Winter on the Tyrrhenian coast is warmer than on the Adriatic cost at the same latitude. Then, for its particular geographical position, this area presents different climate types, which range from Mediterranean to transitional continental and altitude. The Mediterranean climate of the Ligurian-Tyrrhenian side is particularly mild also for the presence of the mountains which protect the region from the northern winds. The Apennines separate the Ligurian-Tyrrhenian side from the less mild Adriatic sector and have a climate of altitude. Within the Apenninic area, the western and eastern sides show seasonal trend of temperature and precipitation like that of the Ligurian-Tyrrhenian side and of Adriatic sector, respectively.

REFERENCES

(Publications of the Genoa University Research Group related to climatic reconstruction)

Pasquale V., G. Flocchini, G. Russo, 1992: Surface temperature field trend along an European traverse. *Proceeding 22th Conférence Internationale de Météorologie Alpine (CIMA),* Toulose (France), 345–349.

Pasquale V., G. Russo, A. Sacchini, M. Verdoya, 1994: Precipitation rate as a possible signal of recent climatic variations. *Annalen der Meteorologie,* **30**, 278–281.

Pasquale V., M. Verdoya, P. Chiozzi, 1996: Climatic signal from underground temperatures. *Proceeding 24th International Conference on Alpine Meteorology,* Hydrometeorological Inst. of Slovenia, Bled (Slovenia), 201–208.

Verdoya M., 1996: Climatic change inferred from borehole temperatures, climatic change modelling with accurate temporal resolution in the last centuries*. Rapp. Workshop Comm. It. IGBP, C.N.R. Progr. Intern. Geosfera e Biosfera*, Roma, marzo 1996, 311–313.

Chiozzi P., V. Pasquale, M. Verdoya, 1997: Surface temperature history from borehole logs. *Atti 15 Convegno del Gruppo Nazionale di Geofisica della Terra Solida*, Roma, 95–96.

Pasquale V., M. Verdoya, P. Chiozzi, 1998. Climate change from meteorological observations and underground temperatures in northern Italy. *Studia Geoph. et Geod.*, **42**, 30–40.

Pasquale V., M. Verdoya, P. Chiozzi, 1998: Recent climatic warming seen in subsurface temperatures. *Proceeding of the 25th International Conference on Alpine Meteorology,* Torino (Italy), settembre 1998, 96–100.

Pasquale V., M. Verdoya, P. Chiozzi, 1998: Character of climate in northern Italy during the last two centuries inferred from combined analysis of meteorological data and underground temperatures. *Proceeding of the International Conference on "The Impacts of Climate Change on the Mediterranean Countries",* University of Ioannina, Metsovo (Greece), September 1998, 1–15.

Pasquale V., M. Verdoya, P. Chiozzi, J. Safanda, 1999: Climate change in the western Alps during the last three centuries. *Workshop on "Past Climate Change Inferred from the Analyses of the Underground Temperature Field" (IGCP Project No. 428), Romanian Journal of Geophys.,* Sinaia (Romania) March 14-17, 1999, 11.

Pasquale V., M. Verdoya, P. Chiozzi, J. Safanda, 2000: Evidence of climate warming from underground temperatures in NW Italy. *Global and Planetary Change*, **25**, 215–222.

Chiozzi P., V. Pasquale, M. Verdoya, S. Bellani, 2000: Climate reconstruction in central northern Italy from underground and air temperatures. *International conference "Geothermics at the turn of the century",* Evora (Portugal), 3–7 April 2000, 33.

Pasquale V., M. Verdoya, P. Chiozzi, S. Bellani, 2001: Temperature signal in the underground for climate history reconstruction in Italy. *Intern. Workshop on "Heat flow and the Structure of the Lithosphere",* Kostelech, Czech Rep., 9-15 June 2001, 56.

Pasquale V., M. Verdoya, P. Chiozzi, 2002: Underground temperature logs for a picture of the climate changes. *27th General Assembly of the European Geophysical Society, Geophysical Research Abstracts,* **Vol. 4** Nice (France), April, 2002.

Pasquale V., M. Verdoya, P. Chiozzi, L. Bodri, 2003: Climatic differentiation from inversion of geothermal data. *28th General Assembly of the European Geophysical Society, Geophysical Research Abstracts,* **Vol. 5** Nice (France), April, 2003, 02138.

Bodri L., P. Chiozzi, V. Pasquale, M. Verdoya, 2003: Last 1000 years climate reconstruction inferred from geothermal measurements in Italy. *Proceeding of the 2nd Internat. Conf. European Society Environ. History*, Prague 2003, 16–22.

Pasquale V., M. Verdoya, P. Chiozzi, L. Bodri, S. Bellani, 2005: Temperature signal in the underground for climate history reconstruction in Italy. *Global and Planetary Change* (in press).