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Climate Warming: Evidence Monitored in the Subsurface

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ABSTRACT. Two experimental shallow boreholes at two different environments were drilled to monitor the depth-response of the underground temperature field to changes on the Earth's surface. The several-year-long temperature records from the depth of approx. 40 metres provided a direct evidence of the decadal-scale ground surface temperature (GST) warming which can be related to the present-day climate change. Greater warming rate of 0.025–0.03 K/yr was found at the large urban environment of Praha-Spořilov compared with lower value of 0.018 K/yr typical for rather agricultural environment at Kocelovice in southern Bohemia. This difference may indicate certain regional environmental component of the present climate warming. While meteorological long-term air temperature series can reveal any warming rate only after many years of registration, underground monitoring can provide this information quite reliably and in a much shorter time.

KEY WORDS: climate warming, anthropogenic component of subsurface temperatures, borehole data.

Introduction

The present global climate is characterised by a general warming. Even when the causes of the pronounced increase in the mean surface air temperature (SAT) in the last few decades all over the world are not clear, the crucial problem is to assess the warming rate and to distinguish between the role of the natural climate variability and the potential man-made contribution. At any location year-to-year variations in mean annual temperature are large, but only analyses of meteorological time series and other data over periods of decades and more can provide evidence of long-term systematic changes. Changes in the mean annual temperature produce corresponding variations in the ground surface conditions, these variations then propagate downward into the rocks beneath the surface and modify the ambient underground thermal regime. Due to low thermal diffusivity of the rocks the penetration is slow, the subsurface response is progressively delayed with increasing depth. Shorter period oscillations, such as daily and seasonal/annual changes attenuate rapidly and the Earth's surface selectively filters out high frequency oscillations. It can be shown that for typical rock diffusivity of 1×10^{-6} m/s the annual ground surface variations with typical amplitude of 20–30 degree C practically diminish below approx. 15–20 m depth. It is the depth range of 30 to 50 m from where the evidence about the climate change of the last few decades can be extracted. In the present paper we summarise and discuss the results of 6 year monitoring temperature in one hole and 1 year monitoring in another experimental 40-m deep borehole, both deliberately drilled for this purpose.

Boreholes

The first 40-m deep borehole was drilled in October 1992 at the campus of the Geophysical Institute in Prague-Spořilov (50°02'27"N, 14°28'39"E, 275 m a.s.l.). Upper few meters present soil and loose material of low thermal conductivity (1.7 to 2.7 W/mK), underlain by Ordovician silt to clayey shale of gradually increasing thermal conductivity. Similar observational site, but located away from the potential urban effect, was selected at Kocelovice (49°28'2.2"N, 13°50'18.7"E, 519 m a.s.l.) in south central Bohemia. at a distance of about 70 km SSW of Prague. The hole was drilled in 1997, penetrated compact granite body of mean conductivity of 3.1 ± 0.1 W/mK, covered by about 1–2 m soil layer.

Both holes were equipped with a measuring chain of temperature sensors spaced at selected depth levels covering all 0–40 m depth interval, progressively denser near the surface. Air temperature is being monitored at three elevations of 0, 1, 2 meters.

Six-year (1994–1999) record of temperature at 38.3-m depth in the Spořilov hole (Fig. 1) clearly demonstrates the gradual year-to-year increase of temperature within the range 0.025 to 0.30 K/yr with a mean value of 0.0264 K/yr characteristic for

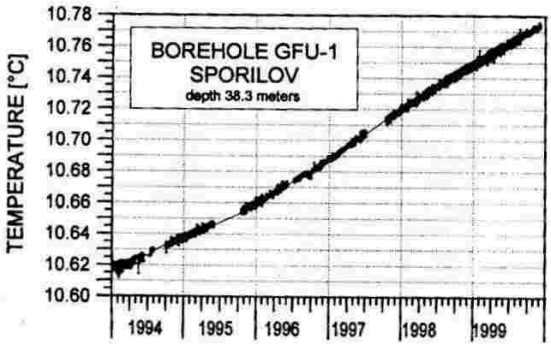

Fig. 1. Six year temperature monitoring at 38.3 m depth (Spořilov borehole).

the last six years. Similar but shorter one-year record from Kocelovice hole revealed warming rate of 0.0176 K/yr.

Interpretation

In an attempt to use the older temperature logs done for heat flow studies (Bodri and Čermák, 1997) almost one hundred temperature-depth T(z) profiles were inverted to assess the ground surface temperature (GST) history on the territory of the Czech Republic. The results were used to project a regional GST warming pattern which was then compared with a similar pattern constructed for long-term SAT series (1961–1996) from 30 local meteorological stations. Both patterns revealed certain similarities suggesting higher warming rates characteristic for areas generally more densely populated and with higher concentration of industry while lower warming rates correspond to generally farming land (Bodri and Čermák, 1999). Both present values found at Prague-Spořilov and at Kocelovice sites are in good agreement with pattern obtained from meteorological SAT series. The difference between the observed higher warming rate at Spořilov compared with information from Kocelovice confirms the assumption of the regional character of the present warming rate reflecting certain potential anthropogenic contribution in large urban conglomeration.

Concluding remarks

The experiment proved that the magnitude of the present-day warming corresponding to the last one to several decades is reasonably well extractable by precise temperature monitoring at shallow boreholes below the depth of the penetration of the annual variations. So far data sets from only two experimental boreholes (one of them being only one year long) are preliminary, but well confirmed the applicability of the method.

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Extraterrestrial Influences on Meteorological Parameters

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ABSTRACT. We studied the long-term trends of meteorological time series and their relations on extraterrestrial factors. All our series were processed by integral curve method consisting in addition of deviations of the parameter of interest. We can conclude that the 90–100 year solar cycle plays the first rate role in the forming of these trends and in this way it influences the climate changes too. In Bohemia, the temperature and solar activity have their trends parallel and precipitation opposite. After the year 1989 the long term trend of solar activity began to decrease. According to the searched relations we can expect colder and wetter epoch in this region in next years until the green-house effect forcing prevails these extraterrestrial factors. The tropical cyclone occurrence in North Atlantic and solar activity are parallel. It means in average an occurrence decrease of tropical cyclone in further development. The courses of the position of planetary height-level frontal zone and solar activity are parallel. It means shift of this zone southward and so the cooling on the Northern Hemisphere in the future.

KEY WORDS: solar activity, meteorological series, climate changes.

Introduction

We searched relations between extraterrestrial factors and secular meteorological series to improve our long-range weather forecasts.

Methods and material studied

We used the integral curve method to diescover the long-term trends in time series. This method consists in addition of deviations of element of interest. The examined time series were the mean annual temperature in Prague-Klementinum 1771–1999, annual precipitation totals in Bohemia 1876–1999, the German synoptical pattern classification "Grosswetterlagen" 1881–1999, the mean annual Wolf's numbers of solar activity, the mean annual geomagnetic indices Cip 1884–1999, the tropical cyclone annual totals in the North Atlantic area 1871–1994, mean annual position of planetary height-level zone 1967–1998. Some parameters were studied in their monthly values too.