Reply to Response by Summerhayes *et al.* to Marks (2025): *Contemporary global warming versus climate change in the Holocene*

Leszek Marks[1]

A b s t r a c t. The natural input of solar energy is transformed by various external and internal factors to modulate climate on the Earth and there is a close relationship between insolation changes and long-term hydroclimate trends. Latitudinal insolation in the Holocene depended *on the Earth's orbital parameters (Milankovič cycles). A train of thought of Summerhayes* et al. *(2025) is charged with the concept of the dominant role in climate change of the antrhopogenic emission of greenhouse gases, mostly CO_2, and they reject the evidence on considerably higher temperatures than the current warming in the Early and Middle Holocene, Late and Middle Pleistocene interglacials and during the Early Pleistocene. Changes in incoming solar radiation during the Northern Hemisphere summers and a general weakening of summer monsoons in the Middle and Late Holocene resulted in a global disaster for ancient civilizations. Contrary to the hurray optimistic point of view of Summerhayes* et al. *(2025), much is to be done to understand the modern climate change, based on the multilateral analysis of geological proxies. It is a reasonable way not to promote the simplistic prognoses of climate change. The contribution of CO_2 to the modern warming is still an open question.*

Keywords: *climate change, solar radiation, greenhouse effect, Holocene, atmospheric CO_2, hockey stick, IPCC, Medieval Warm Period, Little Ice Age, Modern Warming*

A response of Summerhayes *et al.* (2025) to my review paper (Marks, 2025a) touches several important issues concerning the Holocene climate change and the supposed driving forces of the contemporaneous global warming. Summerhayes *et al.* (2025) start with a paradigm that the modern global warming is driven exclusively by the anthropogenic emissions of greenhouse gases, especially of CO_2. A research of the role of greenhouse gases and especially the atmospheric CO_2 has a long history as presented by my opponents. The Intergovernmental Panel on Climate Change (IPCC), established in 1988 under the aegis of the United Nations agency – the World Meteorological Organisation and the United Nations Environment Programme (UNEP), was the first one that forced the idea of the leading role of CO_2 in the modern warming. The IPCC has been entrusted with the task of proving the human impact on the climate as a result of increasing greenhouse gas emissions (mostly CO_2), mainly due to the combustion of fossil fuels. This idea played a dominant role in all reports of the IPCC, although no strong evidence has been provided to prove this hypothesis.

Already in the First Assessment Report (AR1), the focus was put on *…assessing the scientific information that is related to the various components of the climate change issue, such as emissions of major greenhouse gases and modification of the Earth's radiation balance resulting therefrom…* (IPCC, 1990). Such a restricted approach was continued by the IPCC (1995, 2001, 2007, 2013, 2021) in the five following assessment reports (AR 2–6). Many geoscientists disagree with this opinion (Easterbrook, 2011), but it is still very attractive, especially for non-geologists, politicians and researchers that are not involved in climate research. The IPCC has formulated guidelines for lead authors of the assessment reports to ensure a consistent treatment of uncertainties (Moss, Schneider, 2000; IPCC, 2005; Mastrandrea *et al.*, 2010), but the guidelines had no scientific foundations and were not supported by any statistical analysis. This IPCC's estimate of the likelihood was based largely on the agreement among the authors (Mastrandrea *et al.*, 2010) and it was a completely non-scientific approach. The AR4 (IPCC, 2007) was heavily criticized for the unsubstantiated statements, based among others on unreliable data used in climate change projections that, in fact, commonly presented a wishful thinking (expressed by Climategate, Glaciergate, Tempgate, Amazongate and other …gates), not supported by a proper scientific basis.

The criticism of Summerhayes *et al.* (2025) that I neglect the role of the orbital parameters (Milankovič cycles) in the Holocene climate is incorrect. This issue is presented in the chapter *Records of the Holocene climate change* (Marks, 2025a) and is based on Beer, Van Geel (2008) and Beer, Wanner (2012), who postulate a strongly increasing December insolation in the Northern Hemisphere and in the intertropical zone since the Middle Holocene (see also Polissar *et al*., 2013). The insolation trend in the Late Holocene results in a decreasing seasonality in the Northern Hemisphere and an increasing seasonality in the Southern Hemisphere. The climate prediction for the coming 3 kyr is after Beer, Van Geel (2008) and Beer, Wanner (2012), who based their proposal on changes in latitudinal insolation as a function of the Earth's orbital parameters (Milankovič cycles).

The term *pre-industrial* used by Summerhayes *et al.* (2025) is misleading as a benchmark for the modern warming. The invention of the steam engine by James Watts in 1784 did not immediately resulted in an explosion of industrial development. In fact, intensive industrialization began in the last decades of the 19th century. On the other hand, the minimum temperature occurred in the last decade of the 18th century and was associated with the final part of the Little Ice Age (LIA; 1300–1850 A.D.). In AR5 (IPCC,

[1] Polish Geological Institute – National Research Institute, Rakowiecka 4, 00–975, Warsaw, Poland; e-mail: leszek.marks@uw.edu.pl; ORCID ID: 0000-0002-4507-1828

2013), the pre-industrial period refers to the period before 1850 A.D. or exactly the 1850 A.D. values. For this reason, the use of the term pre-industrial for this period (created for the needs of the social and historical sciences, and the media) is a manipulation aimed at denying the natural climate change that started after the LIA and continues to this day. Climatostratigraphic units such as the Medieval Warm Period (MWP), LIA and Modern Warming are commonly used in the Quaternary stratigraphy, and their occurrence undermines the dogma of the responsibility of increasing content of greenhouse gases in the atmosphere (especially CO_2) for the modern global warming. It is debatable how much of the *1.5°C above pre-industrial levels*, as mentioned by Summerhayes *et al.* (2025), can be attributed to greenhouse gases (May, Crok, 2024).

It is a pity that the important chapter *Palaeoclimate*, which appeared in AR4 (IPCC, 2007), was considerably reduced in AR5 (IPCC, 2013) and disappeared completely in AR6 (IPCC, 2021). In AR6, only 2 pages and 2 figures (figs. 3.2 and 3.35) are devoted to the pre-1850 A.D. palaeoclimate, and this best illustrates the IPCC's respect for proxy data on past climates.

GREENHOUSE EFFECT

There is obviously a long history of research on the role of greenhouse gases in maintaining a higher temperature on Earth. Summerhayes *et al.* (2025) are right when they write that *Evidence from the geological past is vital to understanding the relationship between climate change and greenhouse gases*, and this statement is based on numerous scientific publications. On the other hand, the statement of Summerhayes *et al.* (2025) that *Contemporary global warming, driven by anthropogenic greenhouse gas emissions, began a substantial rise in the late 1970s and continues unrelentingly* repeats the IPCC dogma, but if correct, then the temperature rise from the *pre-industrial level* until the 1970s must have been forced by natural factors only. Looking at the curve of global mean annual temperature changes (https://data.giss.nasa.gov/gistemp/graphs_v4/), either there was no anthropogenic effect on temperature in 1945–1975, or it disguised a natural cooling. Anyway, there is no reasonable reason why the natural factors have not played any role in the temperature rise since 1970s.

It is also important to realize that the annual input of greenhouse gases into the atmosphere, especially of CO_2, is only slightly dependent on human activity (~4%), but mainly on temperature-dependent exchanges: atmosphere-/biosphere-soils (~52%) and atmosphere/oceans (44%).

Summerhayes *et al.* (2025) are right when they write that the climate signals from the Antarctic ice cores show that *CO_2 levels nonetheless rise during the initial increases in insolation just before an interglacial, released from the warming ocean surface*. Nevertheless, it means that the temperature rise was the driver and many publications support this opinion (e.g., Genthon *et al.*, 1987; Fischer *et al.*, 1999; Petit *et al.*, 1999; Caillon *et al.*, 2003). There are also papers, data and figures that contradict the conclusion of Summerhayes *et al.* (2025) that CO_2 was the first (e.g., Shakun *et al.*, 2012: fig. 5; Judd *et al.*, 2024: fig. 4). A rise in temperature is followed by a rise in atmospheric CO_2, also in modern times (Humlum *et al.*, 2012; Koutsoyiannis, Kundzewicz, 2020; Vinos, 2022; Koutsoyiannis *et al.*, 2023). An interesting analysis by AI concludes that the *anthropogenic CO_2-global warming hypothesis lacks empirical substantiation* and is *overshadowed by natural drivers such as temperature feedbacks and solar variability*, and it requires a fundamental revaluation of the current climate paradigms (Grok 3 beta *et al.*, 2025).

It is also true that *Feedback from water vapour evaporated from the warming ocean further amplifies the warming signal* (Summerhayes *et al.*, 2025). This warming of the ocean is due to a rise in temperature on the Earth, caused mainly by increased input of solar radiation. Thus, changes in atmospheric CO_2 are mostly a derivative of temperature.

I wonder why the retrospection of Summerhayes *et al.* (2025) – *Atmospheric CO_2 levels have now likely exceeded those at any other time in the past ~14 million years (Middle Miocene) including all Plio-Pleistocene peak interglacial CO_2 concentrations* – is so limited in time? Looking slightly further back in time, to the last 16 million years, the mean CO_2 level 14.5–14 million years ago was as high as it is today, and at the Miocene Climatic Optimum the CO_2 level was over 500 ppm (Hönisch *et al.*, 2023).

The modern greenhouse hypothesis focuses on the leading role of atmospheric CO_2 and its control of climate change, and is postulated in every IPCC report (1990, 1995, 2001, 2007, 2013, 2021). This approach follows closely and exclusively the views of three influential scientists: Svante Arrhenius, Guy Stewart Callendar and Charles David Keeling (cf. Beck, 2007). A respect of IPCC to their ideas ignores several hundred papers and the standard chemical methods used to analyse air gas data on the atmospheric CO_2 concentrations between 1800 and 1961. Without a thorough evaluation, Callendar (1938, 1940, 1958) and the IPCC (both cited by Summerhayes *et al.*, 2025), and Keeling (1960) discredited these techniques and data, rejecting most of them as flawed or highly inaccurate and favouring indirect measurements of air trapped in ice, because they were consistent with their hypothesis of an induced rise in CO_2 in the air caused by the burning of fossil fuels. According to these authors, the natural concentrations of atmospheric CO_2 were assumed *a priori* to have been in equilibrium until disturbed by mankind. Contrary to this unjustifiable view, thousands of accurate chemical analyses of atmospheric CO_2 since 1812 have revealed that varied concentration of atmospheric CO_2 track changes in temperature and also, there were three high level maxima of atmospheric CO_2 around 1825, 1857 and 1942 (the latter >400 ppm) in the Northern Hemisphere (Beck, 2007). Together with evidence from the much more distant geological past (Monnin *et al.*, 2004; Judd *et al.*, 2024; and others), these historical measurements make it obvious that climate change does not follow the dominant paradigm of a monotonically increasing CO_2 trend resulting from fossil fuel burning, as depicted in the post-1990 literature of the climate alarmists.

The magnitude of the inferred changes in CO_2 radiative forcing is similar to the variations attributed to other mechanisms, particularly solar irradiance and volcanic activity (Hoof *et al.*, 2008). This may therefore call into question the concept of the IPCC, which assumes an insignificant role of CO_2 as the preindustrial climate forcing

factor. In general, the role of greenhouse gases in rising global temperatures cannot be ignored, but it is incorrect to overlook the fact that greenhouse gases are not the only factor that steer the temperature at present. Based on evidence from the geological past, it is obvious that a rise in temperature preceded an increase in CO_2 content in the atmosphere (Genthon *et al.*, 1987; Fischer *et al*., 1999; Petit *et al.*, 1999; Caillon *et al.*, 2003).

Contrary to the opinion of Summerhayes *et al.* (2025), the role of CO_2 is not presented in figure TS.17 of IPCC (2021). Besides, water vapour is both of natural and anthropogenic origin, as higher temperature evolves more intense evaporation and subsequently more water vapour in the atmosphere. In no case, it is not the argument that the present-day slightly increased content of greenhouse gases in the atmosphere, especially CO2, is the main driver of modern temperature rise.

HOCKEY STICK

Summerhayes *et al.* (2025) are very gentle, writing that *while some of the statistics in the Mann et al. (1998) paper may have been weak, there really has been a sharp increase in temperature with time*. In fact, Mann *et al.* (1998) presented the temperature curve for the last 600 years, presumably to avoid the problem of the MWP. On the other hand, the curve for the last millennium by Mann *et al.* (1999) fully exposes that the hockey stick is false, because it completely ignores the presence of the MWP. The hockey stick of Mann *et al.* (1999) was constructed as a trick using tree-ring analysis, erasing thousands of publications with a solid background for the MWP (900–1300 A.D.) and the LIA as important climate changes in a global scale (Easterbrook, 2011). The hockey stick became the official position of the IPCC (2001), used to persuade the public and the politicians about the exclusive human influence on the modern warming, assigned arbitrarily to the increasing CO_2 emissions.

My adversaries (Summerhayes *et al.*, 2025) overlooked the papers cited in Marks (2025a), which are critical to the idea of the hockey stick, including McIntyre, McKitrick (2003, 2005), Montford (2010) and McShane, Wyner (2011). These pointed out not only major deficiencies of the method applied by Mann *et al.* (1999), but also unreliable palaeoclimatic proxies used, incorrect statistical processing, and likely political interference. Research based on thoroughly verified tree rings has proved that summer temperatures reached today's levels several times in the pre-industrial period (Büntgen *et al.*, 2020; Clintel Team, 2023). Tree-ring growth-climate relationships indicate that tree-ring formation does not depend on a single dominant factor, but on various combinations of summer precipitation and temperature (Seim *et al.*, 2012). Specifying the annual temperature sensitivity using tree rings is uncertain (Büntgen *et al.,* 2012; Seim *et al.,* 2012). However, even when using this method, a cooling trend is observed over the last 150 years instead of a warming trend (Clintel Team, 2023). Due to this inconvenience, Mann *et al.* (1999) replaced a cooling trend in their tree-ring temperature curve data for the last 150 years with observational (instrumental) temperature data. This approach is methodically incorrect because there is no proven tight coincidence between tree-ring and instrumental temperature data.

The hockey stick was partly albeit inconsequently corrected by Mann *et al.* (2008) who introduced a slightly warmer Medieval Warm Period (800–1200 A.D.) on their temperature curve, but depreciated its significance by naming this period the Medieval Climate Anomaly. The reconstructions of Ljungqvist (2010) and PAGES 2k Consortium (2013) have shown that the LIA was colder than suggested by Mann *et al.* (2008), whereas the MWP and parts of the first millennium CE were occasionally as warm as the present day. Thus, the temperature difference between MWP and LIA was found to be considerably larger, significantly deforming the shaft of the hockey stick shape and, in fact, completely eliminating it (Clintel Team, 2023).

Actual and well-documented pre-industrial warming and cooling events are a major challenge for the climate modellers, but their simulations lack any important natural forcings that could be responsible for temperature changes. Then there are climate models that are willingly used in the IPCC reports to make future temperature projections. These models are considerably deficient to reproduce a real climate system (see a detailed discussion in Clintel Team, 2023). The MWP and the LIA have been arbitrarily erased from the latest IPCC report (2021) and are treated as an inconvenient truth in the climate history of the last millennium (IPCC, 2021). In fact, the sentence of Summerhayes *et al.* (2025) that *IPCC (2021) did not reproduce or cite the original 'hockey stick' curve but did include graphs based on the latest available data and showing changes in global surface temperature for the past 2000 years* is not true (Fig. 1). A resurrection of the hockey stick in the AR6 (IPCC, 2021) proposes a sick idea that should never have been published in a peer-reviewed journal. If it happened, it should be quickly abandoned as a road to nowhere. Summing up, it is hardly understandable why Summerhayes *et al.* (2025) defend a lost cause of the hockey stick.

The belief of Summerhayes *et al.* (2025) in the wide use of past temperature reconstructions derived from palaeoclimate proxies to evaluate modelled past climate temperature change patterns, as mentioned in the IPCC (2021: section 3.3.1.1.1), is generally false. It was perfect that some comparisons of reconstructed temperatures, based on proxy data and modifications of the climate models, were considered, but figs. 3.2 and 3.4 in the IPCC (2021) prove that it is just a beginning of the road towards a highly reliable compatibility, even for the period 1850–2019. Taking an example, I could not find any reasonable explanation in the IPCC reports for the warming in 1930–1940s. This warming is very distinct in the official instrumental data (http://data.giss.nasa.gov/gistemp/graphs/). It was recognized even in the original paper on the 'hockey stick' by Mann *et al.* (1999) and in the IPCC reports (among others, see IPCC, 2013: fig. 10.6 and IPCC, 2021: fig. 3.9 and 3.41). In AR5 the presentation of natural, anthropogenic and global observational data from 1870 to 2010 (IPCC, 2013: FAQ 5.1, fig. 1) are presented in a completely unclear way to hide the reason for the warming of 1930–1940s, the occurrence of which could not be neglected. Figure 1 of Summerhayes *et al.* (2025) is a copy of fig. SPM.1 in IPCC (2021): this figure is almost the same as the 'hockey stick' of Mann (1999), so nothing has been really modified

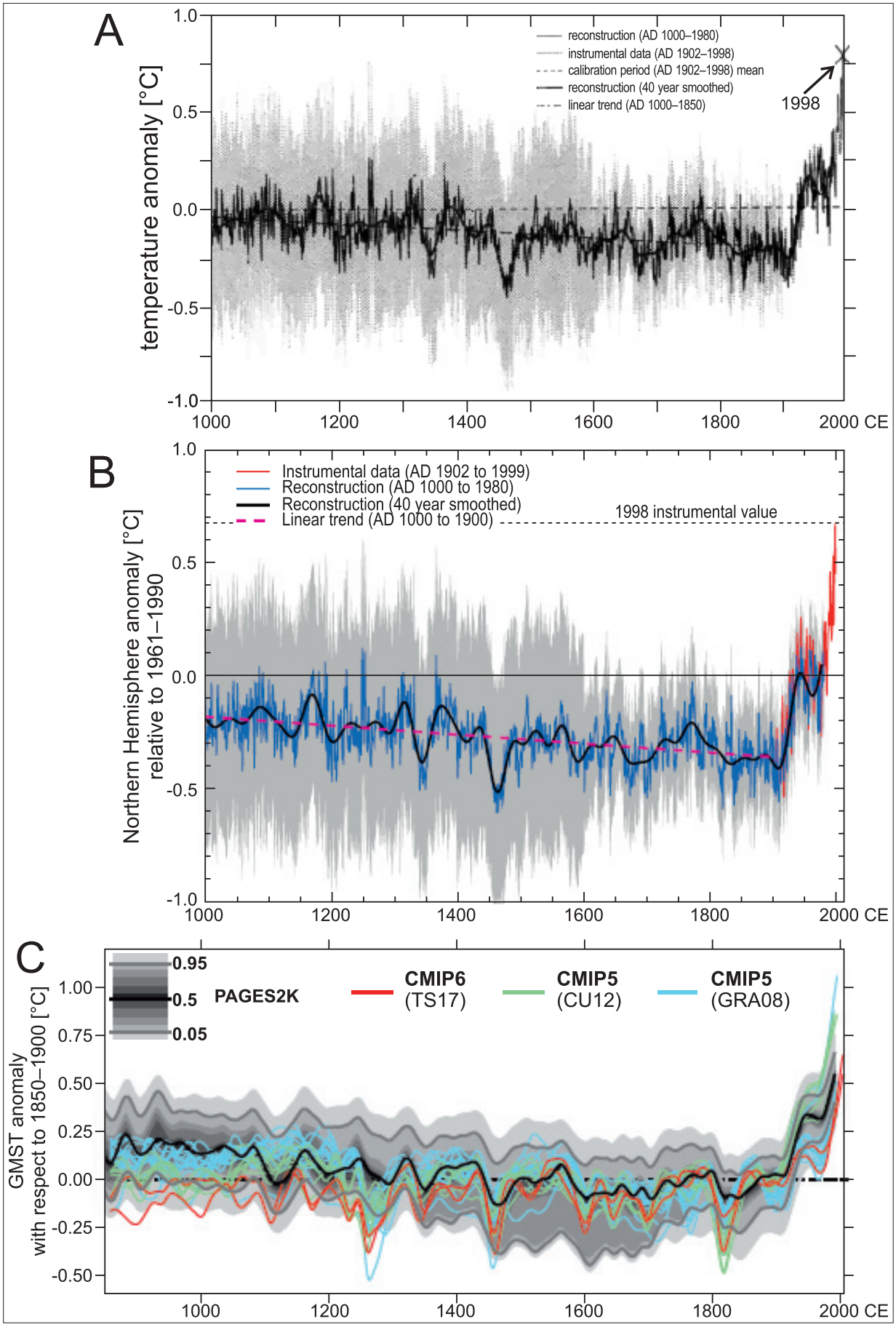

Fig. 1. Millennial temperature reconstruction: **A** – Northern Hemisphere temperature anomalies ('hockey stick' of Mann *et al.,* 1999), **B** – Northern Hemisphere temperature anomalies (IPCC, 2001), **C** – global mean surface temperature anomalies (resurrected hockey stick in IPCC, 2021) with simulations CMIP5, CMIP6 and PAGES 2k Consortium (2019); notice that the reference levels are not the same in B and C

since the AR3 (IPCC, 2001). The 1930–1940 warming is indicated by the observational data, but neither Mann nor any IPCC report has explained it and ascribed either to natural or human driving forces or both! The same figure (fig. SPM. 1 in IPCC, 2021) presents a reconstruction of global temperature during the last 2 millennia, but the well-known warmings of the MWP and the Roman Warm Period (250 B.C. to 350 A.D.), as well as the cooling of the Dark Ages Cool Period (440 to 900 A.D.), are not indicated (for details see: Moberg *et al.,* 2005; Loehle, 2007; Mann *et al.*, 2009). The MWP was much warmer than the modern warming in many regions in the world (e.g., d'Arrigo *et al.*, 2006; Newton *et al*., 2006; Drake, 2012).

SOLAR RADIATION

In their figure 2, Summerhayes *et al.* (2025) presented the solar variability for a very short period of the last 280 years and concluded that it *cannot be a significant factor in the sharp and continuing warming of the Earth in the late 20th and early 21st centuries*. The situation looks completely different when a longer timeframe is concerned (Wu *et al.*, 2018) and a rise in solar radiation during the last few decades does not appear as unprecedented as it seems (Fig. 2). The Earth's climate is dependent not only on sunspot cycles, but also by how much sunlight reaches the Earth' surface due to changes in the planet orbit and position in space relative to the Sun.

The solar input is the main driver of climate change on Earth because the greenhouse gases, no matter whether natural or anthropogenic, would play no role without a solar radiation. Grand minima and maxima are typical, yet rare and irregular solar phenomena. Solar activity was very high after the 1940s, but this prolonged grand maximum has returned to the normal, moderate level (Usoskin, 2023). Although sunspot cycles express the primary changes in solar activity, the solar radiation that reaches the Earth's surface is modified by several other factors (orbital parameters, cosmogenic radiation, clouds, greenhouse gases, atmospheric aerosols, etc.). Activity of the Sun is characteristic for an old star, which is not spot- but faculae-dominated, and is strongly dependent on the rotation period (for details see Cliver *et al*., 2022). The role of sunspot cycles and solar forcing in the Holocene is an important issue. The 11-year solar cycles represent the lowest (smallest) level of temperature changes triggered by solar radiation. These primary cycles are a part of many others, centennial- to millennial-scale cycles, induced by numerous other factors. Some of them occur in regular, but longer cycles. Summerhayes *et al.* (2025) focused on the short-term (elementary), 11-year sunspot cycles, minimizing or ignoring the long-term changes in solar radiation.

The statement of Summerhayes *et al.* (2025) that temperature rises depend on an increasing content of atmospheric CO_2 is unauthorized (Genthon *et al.*, 1987; Humlum *et al.*, 2012; Koutsoyiannis, Kundzewicz, 2020; Vinos, 2022; Koutsoyiannis *et al.*, 2023). For example, the global temperature increased in the Early and earliest Middle Holocene, while the amount of atmospheric CO_2 decreased from 10 to 7 ka BP (Fig. 3) and the CH_4 content dropped from 10 to 4 ka BP (Monnin *et al.*, 2004; Marcott *et al.*, 2013). The idea that changes in solar radiation are limited to the effects of single 11-year cycles may be incorrect, as the clustering of strong cycles over several decades can play a leading role in the solar forcing on the temperature on the Earth (Clette *et al.*, 2014). When looking for relations between temperature and atmospheric CO_2, it seems much more convincing to seek analogues in the geological past than to repeatedly reconsider climate change over the last few decades, as Summerhayes *et al.* (2025) did.

SEA LEVEL CHANGES

Contrary to the opinion of Summerhayes *et al.* (2025), the sea level in the Early and Middle Holocene was not stable. Observation data from areas in the Northern Hemisphere should be treated with caution due to the glacio-istostatic rebounds. The global mean sea level changes in the Holocene were much more complex than presented by Summerhayes *et al.* (2025). After 7.5 ka, it could exceed the early industrial level, reaching even 0.24 m above the present sea level by 3.2 ka and it presumably reflects after 7 ka the Antarctic ice sheet smaller than the present one (Creel *et al.*, 2024). There is no evidence for a significant acceleration in sea level rise during the past 200 years (Grinsted *et al.*, 2010; Fasullo *et al.*, 2016), as postulated many times, also in the AR5 (IPCC, 2021).

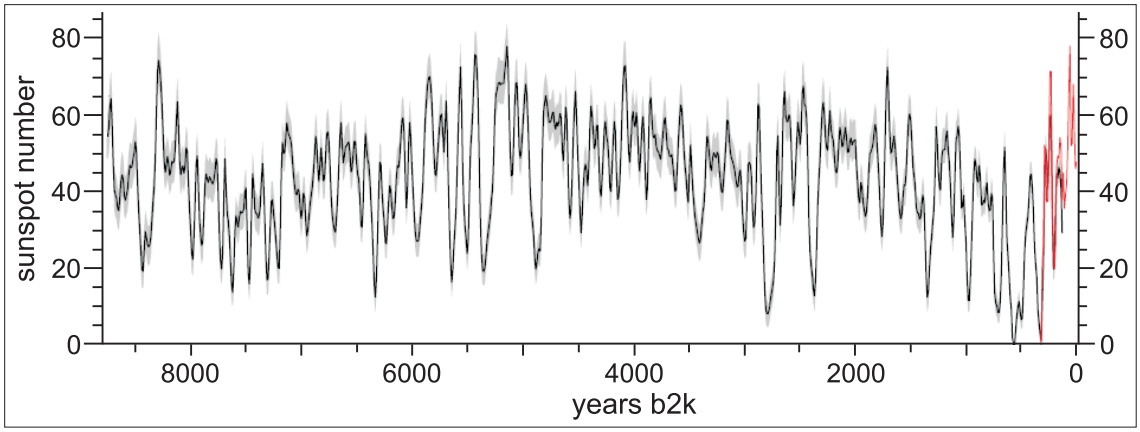

Fig. 2. Sunspot number reconstructed for the Mid-Late Holocene (grey shading indicates 68% confidence interval), the red line depicts the decadally resampled international sunspot number from Clette *et al.* (2014); after Wu *et al.* (2018), modified

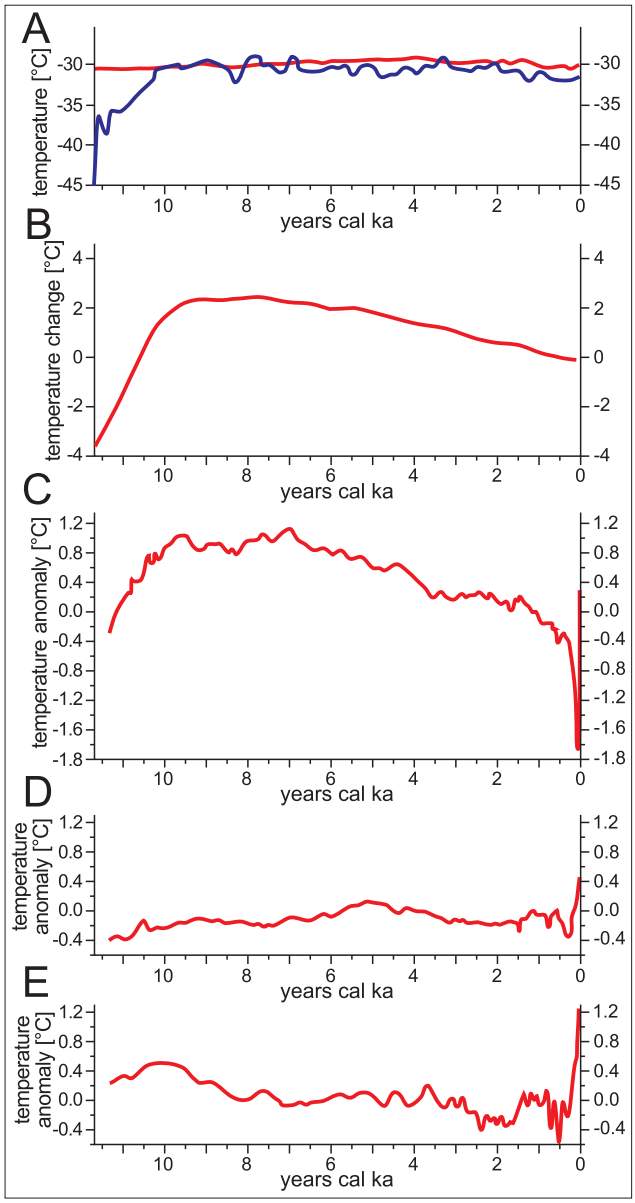

Fig. 3. Reconstructions of global and regional temperature in the Holocene: **A** – temperature history of West Antarctic Divide (**red**) and central Greenland (**blue**) after Cuffey *et al.* (2016); **B** – temperature change in Greenland after Vinther *et al.* (2009); zonal mean temperature reconstructions for latitude bands after Marcott *et al.* (2013): **C** – 90–30°N, **D** – 30°N–30°S and **E** – 30–90°S; all simplified and modified

PALAEOCLIMATE MODELS

As listed by Summerhayes *et al.* (2025), the IPCC projections of global temperature incorporate the effects of CO_2, other greenhouse gases, aerosols and changing land use. The IPCC completely ignores the natural forcing of modern warming and underestimates the role of non-greenhouse agents that have been important amplifiers of temperature rise since the 1980s (e.g., a decreasing anthropogenic emission of sulphur compounds). Summerhayes *et al.* (2025) rightly noted *an observed narrowing of tropical cloud belts, decreasing the Earth's ability to reflect sunlight: an unanticipated positive feedback on an overall warming world*, but neglect the fact that the total cloudiness has been decreasing since the end of the 1980s, more markedly over land than over water areas (Pokrovsky, 2019) and occurred also in the intertropical zone (Archibald, 2010). It is puzzling that the cloud cover decreases in *an overall warming world* of Summerhayes *et al.* (2025), although evaporation of the warmer surface waters emanates more water vapour to the atmosphere.

The global carbon cycle was not in a steady state during the Early Holocene and was divergent from changes in atmospheric CO_2 (Jessen *et al.*, 2007). Depletion and restoration of atmospheric CO_2 in A.D. 1000–1500 was driven mainly by short-term perturbations of sea-surface temperature and/or salinity (Wagner *et al.*, 1999). The changing atmospheric circulation, associated with the positive phase of North Atlantic Thermohaline Circulation, transformed presumably the weather structure in subtropical and temperate zones (Marsz, 2023). The share of *low-pressure weathers* with extensive layered cloud fields continued to decrease, and the share of *high-pressure weathers* with limited cloudiness and/or cloudless weather was increasing. It was the reason for the increase in insolation, and thanks to it, without changing the amount of solar radiation, more solar energy could reach the Earth's surface and be converted into heat to warm the troposphere. Therefore, a strong temperature increase occurred due to the contribution of residual ocean heat, as well as heat from increased insolation due to reduced cloud cover. When the temperature rises, the oceans absorb most of the extra heat retained by the Earth, and at the same time the warmer surface waters of the oceans release a huge volume of CO_2.

I do not know why Summerhayes *et al.* (2025) see underestimates in the IPCC projections of global temperatures when compared with the observational data. Figure 4 in Marks (2025a) shows that also the last projection of temperature (IPCC, 2021) starts well above the observational data. On the other hand, a reasonable temperature forecast for the coming 3 ka was presented by Beer, Van Geel (2008), based on changes in latitudinal insolation as a function of the Milankovič cycles.

FINAL REMARKS

The natural input of solar energy is transformed by various external and internal factors to modulate climate on the Earth. Latitudinal insolation in the Holocene depended on the Earth's orbital parameters (Milankovič cycles). Their analysis shows that in comparison, compared to the present values, summer temperatures in the Northern Hemisphere were higher in the Early and Middle Holocene (Beer, Van Geel, 2008; Beer, Wanner, 2012). Winter temperatures in the Southern Hemisphere were higher in the Middle Holocene, followed by higher temperatures in the Northern Hemisphere in the Late Holocene. In Europe, tree-ring stable isotopes suggest that the climate was wetter and summers were warmer during most of the Holocene, with the upper treeline position about 200 m higher than during the *industrial time* (Arosio *et al.*, 2025). It implies a close relationship between insolation changes and long-term hydroclimate trends. In the coming 3 ka, lower temperatures are possible everywhere, except for the intertropical zone where higher winter temperatures are expected (Marks, 2016).

A train of thought of Summerhayes *et al*. (2025) is charged with the concept of anthropogenic emission of greenhouse gases, mostly CO_2, and considerably higher temperatures in the Early and Middle Holocene seem to them to be completely unacceptable. The Middle Holocene climate was warm and stable, with air temperatures 1.0–3.5°C higher than today (Fig. 3; Renssen *et al.*, 2012; Kaufmann *et al.*, 2020). Changes in incoming solar radiation during the Northern Hemisphere summers in the Holocene first led to large-scale expansion, followed by the subsequent collapse of the African monsoon, which was a crucial demand for Pharaonic Egypt (Bell, 1971; Butzer, 1976, 2001, 2012; Welc, Marks, 2014). A general weakening of summer monsoons in the Middle and Late Holocene resulted in a global disaster for ancient civilizations (Weiss *et al.*, 1993; Cullen *et al.*, 2000; deMenocal *et al.,* 2000; Madella, Fuller, 2006; Schwartz, 2007; MacDonald, 2011; Hamzeh *et al.*, 2016; and others).

Summerhayes *et al.* (2025) use the term *Anthropocene epoch* and it is misleading, both for geological and non-geological communities. Most of the authors of the response prepared by Summerhayes *et al.* (2025) were deeply involved in preparing the proposal to establish the Anthropocene as a geological epoch. They perfectly know that their Anthropocene proposal was definitely rejected by the International Commission on Stratigraphy and International Union of Geological Sciences. It means that the statement of Summerhayes *et al.* (2025) *we have left the Holocene and entered an Anthropocene epoch* is incorrect. We are still in the Holocene, the modern interglacial that began 11.7 kcal BP (http://quaternary.stratigraphy.org/working-groups/anthropocene/; https://stratigraphy.org/news/152; Marks, 2025b).

The statement of Summerhayes *et al.* (2025) *there is a serious risk of long-term warming that would bring Earth's climate close to temperatures typical of the early Late Pliocene about 3 million years ago, when Greenland lost its ice sheet, the West Antarctic Ice sheet disappeared and the East Antarctic Ice Sheet contracted* is completely wrong. The episodes warmer than the current warming occurred in the Holocene Thermal Optimum, in the Pleistocene interglacials (e.g., Eemian and Holsteinian) and also during the Early Pleistocene. We should be aware that *substantial greenhouse gas emissions from deep Arctic lake sediments*, as suggested by Summerhayes *et al.* (2025), may not occur, just as they did not occur during all these warm periods in the Quaternary when there was much less atmospheric CO_2 than in the Pliocene. It is another good evidence that CO_2 is not the main steering force of the temperature changes on the Earth.

Contrary to the optimistic point of view of Summerhayes *et al.* (2025), much is to be done to understand the modern climate change, considering also the multilateral analysis of the geological proxies, e.g. showing the changes of the Atlantic Multidecadal Oscillation (Moore *et al.*, 2017). Interpretation and modelling of the Earth's climate should be supported by the real palaeoclimatic proxies and should not be based on imagination and wishful thinking. Proxies first, then interpretation and modelling will favour moving forward our understanding of the driving forces of the Earth's climate.

In general, we should take care of the environment on the Earth. Burning of fossil fuels is certainly not the best way to use them. But the IPCC and the climate alarmists are not authorized to demand from the governments and societies to spend billions of dollars/euros for the political undertakings that are not supported by the current state of knowledge and are unlikely to deliver the expected results.

The IPCC Working Groups reports are a valuable source of data, but their use requires a critical approach, as much has been left out due to the political incorrectness of the IPCC-promoted mainstream in the modern climate change. The selection of data is particularly susceptible to criticism, and it questions the scientific neutrality of the IPCC, suggesting a dominant political impact on the presented conclusions (e.g., Cabbolet, 2025). The contribution of CO_2 levels to the modern warming is still an open question, despite the conclusions of the IPCC reports (Vinos, 2022). Finally and luckily enough, it seems optimistic that humans do not have enough power (except for a catastrophic nuclear war) to transform substantially the Earth's climate and environment.

I am grateful to the editors Ewa Dąbrowska-Jędrusik and Magdalena Mizerska (both Polish Geological Institute – National Research Institute) for their constructive comments on the primary draft of the manuscript.

REFERENCES

ARCHIBALD D. 2010 – The past and future of climate, why the world is cooling and why carbon dioxide won't make a detectable difference. Westways Colorgrafix.

AROSIO T., LEUENBERGER M., NICOLUSSI K., ESPER J., KRUSIC P.J., BEBCHUK T., TEGEL W., HAFNER A., KIRDYANOV A., SCHLÜCHTER CH., REINIG F., MUSCHITIELLO F., BÜNTGEN U. 2025 – Tree-ring stable isotopes-European Alps reveal long-term summer drying over the Holocene. Science Advance, 11, eadr4161

BECK E-G. 2007 – 180 years of atmospheric CO_2 gas analysis by chemical methods. Energy & Environment, 18 (2): 259–282; https://doi.org/10.1177/0958305X0701800206

BEER J., VAN GEEL B. 2008 – Holocene climate change and the evidence for solar and other forcings. [In:] Battarbee R.W., Binney H.A. (eds.), Natural climate variability and global warming: a Holocene perspective. Wiley-Blackwell, Oxford: 138–162.

BEER J., WANNER H. 2012 – Corrigendum to "Mid- to late Holocene climate change: an overview". Quaternary Science Reviews, 51: 93–94.

BELL B. 1971 – The Dark Ages in ancient history: the First Dark Age in Egypt. American Journal of Archaeology, 75: 1–26.

BÜNTGEN U., FRANK D., NEUENSCHWANDER T., ESPER J. 2012 – Fading temperature sensitivity of Alpine tree growth at its Mediterranean margin and associated effects on large-scale climate reconstructions. Climatic Change, 114 (3): 651–666.

BÜNTGEN U., ARSENEAULT D., BOUCHER É., CHURAKOVA O.V., GENNARETTI F., CRIVELLARO A., HUGHES M.K., KIRDYANOV A.V., KLIPPEL L., KRUSIC P.J., LINDERHOLM H.W., LJUNGQVIST F.C., LUDESCHER J., MCCORMICK M., MYGLAN V.S., NICOLUSSI K., PIERMATTEI A., OPPENHEIMER C., REINIG F., SIGL M., VAGANOV E.A., ESPER J. 2020 – Prominent role of volcanism in Common Era climate variability and human history. Dendrochronologia, 64, 125757.

BUTZER K.W. 1976 – Early hydraulic civilisation in Egypt, a study in cultural ecology. The University of Chicago Press, Chicago.

BUTZER K.W. 2001 – When the desert was in flood. Environmental history of the Giza Plateau. Newsletter of the Ancient Egypt Research Associates, 5 (1): 3–5.

BUTZER K.W. 2012 – Collapse, environment and society. Proceedings of the National Academy of Sciences of the United States of America, 109 (10): 3632–3639.

CABBOLET M.J.T.F. 2025 – To all who believe in science as an open discussion of new ideas: a call for reforms to reverse the politicization of science. Journal of Academic Ethics; doi.org/10.1007/s10805-025-09646-8

CAILLON N., SEVERINGHAUS J.P., JOUZEL J., BARNOLA J.-M., KANG J., LIPENKOV V.Y. 2003 – Timing of atmospheric CO_2 and Antarctic temperature changes across Termination III. Science, 299: 1728–1731.
CALLENDAR G.S. 1938 – The artificial production of carbon dioxide and its influence on temperature. Quarterly Journal of the Royal Meteorological Society, 64 (275): 223–240; https://doi.org/10.1002-/qj.49706427503
CALLENDAR G.S. 1940 – Variations of the amount of carbon dioxide in different air currents. Quarterly Journal of the Royal Meteorological Society, 66 (287): 395–400; https://doi.org/10.1002/qj.49706628705
CALLENDAR G.S. 1958 – On the amount of carbon dioxide in the atmosphere. Tellus, 10 (2): 243–248; https://doi.org/10.1111-/j.2153-3490.1958.tb02009.x
CLETTE F., SVALGAARD L., VAQUERO J.M., CLIVER E.W. 2014 – Revisiting the sunspot number, a 400-year perspective on the solar cycle. Space Science Reviews, 186: 35–103; doi 10.1007/s11214-014-0074-2
CLINTEL TEAM 2023 – The resurrection of the hockey stick. [In:] Crok M., May A. (eds), The frozen climate views of the IPCC, an analysis of AR6. clintel.org
CLIVER E.W., SCHRIJVER C.J., SHIBATA K., USOSKIN I.G. 2022 – Extreme solar events. Living Reviews in Solar Physics, 19, 2; https://doi.org-/10.1007/s41116-022-00033-8
CREEL R.C., AUSTERMANN J., KOPP R.E., KHAN N.S., ALBRECHT T., KINGSLAKE J. 2024 – Global mean sea level likely higher than present during the Holocene. Nature Communications, 1 (5), 10731; https://doi.org/10.1038/s41467-024-54535-0
CUFFEY K.M., CLOW G.D., STEIG E.J., BUIZERT C., FUDGE T.J., KOUTNIK M., WADDINGTON E.D., ALLEY R.B., SEVERINGHAUS J.P. 2016 – Deglacial temperature history of West Antarctica. PNAS, 113 (50): 14249–14254.
CULLEN H.M., DEMENOCAL P.B., HEMMING S., HEMMING G., BROWN F.H., GUILDERSON T., SIROCKO F. 2000 – Climate change and the collapse of the Akkadian empire: evidence from the deep sea. Geology, 28 (4): 379–382.
D'ARRIGO R., WILSON R., JACOBY G. 2006 – On the long–term context for late twentieth century warming. Journal of Geophysical Research, 111, D03103; https://doi.org/1010.1029/2005JD0063
DeMENOCAL P., ORTIZ J., GUILDERSON T., ADKINS J., SARNTHEIN M., BAKER L., YARUSINSKY M. 2000 – Abrupt onset and termination of the African Humid Period: rapid responses to gradual insolation forcing. Quaternary Science Reviews, 19: 347–361.
DRAKE B.L. 2012 – The influence of climatic change on the Late Bronze Age Collapse and the Greek Dark Ages. Journal of Archaeological Science, 39: 1862–1870.
EASTERBROOK D.J. 2011 – Geologic evidence of recurring climate cycles and their implications for the cause of global climate changes – the past is the key to the future. [In:] Easterbrook D.J. (ed.), Evidence-based climate science: data opposing CO_2 emissions as the primary source of global warming. Elsevier: 3–51, https://doi.org/10.1016-/B978-0-12-385956-3.10001-4
FASULLO J.T., NEREM R.S., HAMLINGTON B. 2016 – Is the detection of accelerated sea level rise imminent? Scientific Reports, 6, 31245.
FISCHER H., WAHLEN M., SMITH J., MASTROIANNI D., DECK B. 1999 – Ice core records of atmospheric CO_2 around the last three glacial terminations. Science, 283: 1712–1714.
GENTHON C., BARNOLA J.M., RAYNAUD D., LORIUS C., JOUZEL J., BARKOV N.J., KOROTKEVICH Y.S., KOTLYAKOV V.M. 1987 – Vostok ice core: climatic response to CO_2 and orbital forcing changes over the last climatic cycle. Nature, 329: 414–418.
GRINSTED A., MOORE J.C., JEVREJEVA S. 2010 – Reconstructing sea level from paleo and projected temperatures 200 to 2100 AD. Climate Dynamics, 34 (4): 461–472; https://doi:10.1007/s00382-008-0507-2
GROK 3 BETA, COHLER J., LEGATES D., SOON F., SOON W. 2025 – A critical reassessment of the anthropogenic CO_2-global warming hypothesis. Science of Climate Change, 5.1: 1–16; https://doi.org-/10.53234/SCC202501/06
HAMZEH M.A., MAHMUDY-GHARAIE M.H., ALIZADEH-LAHIJANI H., MOUSSAVI-HARAMI R., DJAMALI M., NADERI-BENI A. 2016 – Paleolimnology of Lake Hamoun (E Iran): implication for past climate changes and possible impacts on human settlements. Palaios, 31: 616–629.
HOOF T.B. VAN, WAGNER-CREMER F., KÜRSCHNER W.M., VISSCHER H. 2008 – A role for atmospheric CO_2 in preindustrial climate forcing. PNAS, 105 (41): 15815–15818; doi/10.1073/pnas.0807624105
HÖNISCH B. et The CenCO2PP Consortium 2023 – Toward a Cenozoic history of atmospheric CO_2. Science, 382 (6675), eadi5177; https://doi.org-/10.1126/science.adi5177
https://data.giss.nasa.gov/gistemp/graphs_v4/
http://quaternary.stratigraphy.org/working-groups/anthropocene/
https://stratigraphy.org/news/152
HUMLUM O., STORDAHL J., SOLHEIM J. 2012 – The phase relation between atmospheric carbon dioxide and global temperature. Global Planetary Change, 100: 51–69.
IPCC 1990 – First Assessment Report (FAR), Working Group I: Scientific Assessment of Climate Change; https://www.ipcc.ch
IPCC 1995 – Second Assessment Report (SAR), Working Group I: The Science of Climate Change; https://www.ipcc.ch/
IPCC 2001 – The Third Assessment Report (TAR), Working Group I: The Scientific Basis; https://www.ipcc.ch/
IPCC 2005 – Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties. Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland.
IPCC 2007 – The Fourth Assessment Report (AR4), Climate Change: The Physical Science Basis; https://www.ipcc.ch/
IPCC 2013 – The Fifth Assessment Report (AR5): the Physical Science Basis; https://www.ipcc.ch/report/ar5/wg1/
IPCC 2021 – The Sixth Assessment Report (AR6), Climate Change: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA; https://doi.org/10.1017/9781009157896
JESSEN C.A., RUNDGREN M., BJÖRCK S., MUSCHELER R. 2007 – Climate forced CO_2 variability in the early Holocene: a stomatal frequency reconstruction. Global Planetary Change, 57: 247–260.
JUDD E.J., TIERNEY J.E., LUNT D.J., MONTANEZ I.P., HUBER B.T., WING S.L., VALDES P.J. 2024 – A 485-million-year history of Earth's surface temperature. Science, 385, eadk3705; https://doi.org/10.1126-/science.adk3705
KAUFMAN D., MCKAY N., ROUTSON C., ERB M., DÄTWYLER C., SOMMER P.S., HEIRI O., DAVIS B. 2020 – Holocene global mean surface temperature, a multi-method reconstruction approach. Scientific Data, 7 (1), 201; https://doi.org/10.1038/s41597-020-0530-7.
KEELING C.D. 1960 – The concentration and isotopic abundance of carbon dioxide in the atmosphere. Tellus, 12 (2): 200–203.
KOUTSOYIANNIS D., KUNDZEWICZ Z.W. 2020 – Atmospheric temperature and CO_2: hen-or-egg causality? Science, 2, 83; https://doi.org-/10.3390/sci2040083
KOUTSOYIANNIS D., ONOF C., KUNDZEWICZ Z.W., CHRISTOFIDES A. 2023 – On hens, eggs, temperatures and CO_2: causal links in Earth's atmosphere. Science, 5 (35), 35; https://doi.org/10.3390-/sci5030035
LJUNGQVIST F.C. 2010 – A new reconstruction of temperature variability in the extra-tropical Northern Hemisphere during the last two millennia. Geografiska Annaler, A92 (3): 339–351.
LOEHLE C. 2007 – A 2000-year global temperature reconstruction based on non-tree-ring proxies. Energy and Environment, 18: 1049–1058.
MACDONALD G. 2011 – Potential influence of the Pacific Ocean on the Indian summer monsoon and Harappan decline. Quaternary International, 229: 140–148.
MADELLA M., FULLER D.Q. 2006 – Paleoecology and the Harappan Civilisation of South Asia: a reconsideration. Quaternary Science Reviews, 25: 1283–1301.
MANN M.E., BRADLEY R.S., HUGHES M.K. 1998 – Global-scale temperature patterns and climate forcing over the past six centuries. Nature, 392: 779–787.
MANN M.E., BRADLEY R.S., HUGHES M.K. 1999 – Northern Hemisphere temperatures during the past millennium: Inferences, uncertainties, and limitations. Geophysical Research Letters, 26: 759–762.
MANN M.E., ZHANG Z., HUGHES M.K., BRADLEY R.S., MILLER S.K., RUTHERFORD S., NI F. 2008 – Proxy-based reconstructions of hemispheric and global surface temperature variations over the past two millennia. PNAS, 105 (36): 13252–13257.
MANN M.E., ZHANG Z., RUTHERFORD S., BRADLEY R.S., HUGHES M.K., SHINDELL, D., AMMANN C., FALUVEGI G., NI F. 2009 – Global signatures and dynamical origins of the Little Ice Age and Medieval Climate Anomaly. Science, 326: 1256–1260.
MARCOTT S.A., SHAKUN J.D., CLARK P.U., MIX A.C. 2013 – A reconstruction of regional and global temperature for the past 11,300 years. Science, 339 (6124): 1198–1201.
MARKS L. 2016 – Climate change in the Holocene (in Polish with English summary). Przegląd Geologiczny, 64 (1): 59–65.
MARKS L. 2025a – Contemporary global warming versus climate change in the Holocene. Przegląd Geologiczny, 73 (2): 170–176; http://doi.org/10.7306/2025.15
MARKS L. 2025b – Stratigraphic setting of the Anthropocene in the Quaternary (in Polish with English summary). Przegląd Geologiczny, 73 (1): 11–17; https://doi.org/10.7306/2025.2

MARSZ A.A. 2023 – Wewnątrzsystemowe mechanizmy zmienności i zmian klimatu. Stowarzyszenie Klimatologów Polskich, Reda-Warszawa.
MASTRANDREA M.D., FIELD C.B., STOCKER T.F., EDENHOFER O., EBI K.L., FRAME D.J., HELD H., KRIEGLER E., MACH K.J., MATSCHOSS P.R., PLATTNER G-K., YOHE G.W., ZWIERS F.W. 2010 – Guidance note for lead authors of the IPCC Fifth Assessment Report on consistent treatment of uncertainties. Intergovernmental Panel on Climate Change (IPCC). Available at <http://www.ipcc.ch>
MAY A., CROK M. 2024 – Carbon dioxide and a warming climate are not problems. The American Journal of Economics and Sociology, 84 (1): 43–57; https://doi.org/10.1111/ajes.12579
MCINTYRE S., MCKITRICK R. 2003 – Corrections to the Mann *et al.* (1988) proxy data base and northern hemispheric average temperature series. Energy & Environment, 14 (6): 751–771.
MCINTYRE S., MCKITRICK R. 2005 – Hockey sticks, principal components, and spurious significance. Geophysical Research Letters, 32, L03710; https://doi.org/10.1029/2004GL021750
MCSHANE B.B., WYNER A.J. 2011 – A statistical analysis of multiple temperature proxies: are reconstructions of surface temperatures over the last 1000 years reliable? Annals of Applied Statistics, 5 (1): 5–44.
MOBERG A., SONECHKIN D.M., HOLMGREN K., DATSENKO N.M., KARLEN W. 2005 – Highly variable Northern Hemisphere temperatures reconstructed from low- and high-resolution proxy data. Nature, 433: 613–617.
MONNIN E., STEIG E.J., SIEGENTHALER U., KAWAMURA K., SCHWANDER J., STAUFFER B., STOCKER T.F., MORSE D.L., BARNOLA J-M., BELLIERD B., RAYNAUD D., FISCHER H. 2004 – Evidence for substantial accumulation rate variability in Antarctica during the Holocene, through synchronization of CO_2 in the Taylor Dome, Dome C and DML ice cores. Earth and Planetary Science Letters, 224: 45–54.
MONTFORD A.W. 2010 – The hockey stick illusion, Stacey International, London.
MOORE G.W.K., HALFAR J., MAJEED H., ADEY W., KRONZ A. 2017 – Amplification of the Atlantic Multidecadal Oscillation associated with the onset of the industrial-era warming. Scientific Reports, 7, 40861; https://doi.org/10.1038/srep40861
MOSS R., SCHNEIDER S. 2000 – Uncertainties. [In:] Pachauri R., Taniguchi T. and Tanaka K. (eds.), Guidance Papers on the Cross Cutting Issues of the Third Assessment Report of the IPCC. Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland.
NEWTON A., THUNELL R., STOTT L. 2006 – Climate and hydrographic variability in the Indo-Pacific Warm Pool during the last millennium. Geophysical Research Letters, 33, L19710; https://doi.org/10.1029/2006GL027234
PAGES 2k Consortium 2013 – Continental-scale temperature variability during the past two millennia. Nature Geoscience, 6 (5): 339–346; https://doi.org/10.1038/ngeo1834
PAGES 2k Consortium 2019 – Consistent multidecadal variability in global temperature reconstructions and simulations over the Common Era. Nature Geoscience, 12 (8): 643–649; https://doi.org/10.1038/s41561-019-0400-0
PETIT J.R., JOUZEL J., RAYNAUD D., BARKOV N.I., BARNOLA J-M., BASILE I., BENDER M., CHAPPELLAZ J., DAVISK M., DELAYGUE G., DELMOTTE M., KOTLYAKOV V.M., LEGRAND M., LIPENKOV V.Y., LORIUS, C., PEPIN L., RITZ C., SALTZMANK E., STIEVENARD M. 1999 – Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. Nature, 399 (6735): 429–436; https://doi.org/10.1038/20859
POKROVSKY O.M. 2019 – Cloud changes in the period of global warming: the results of the International Satellite Project. Atmospheric and Oceanic Physics, 55 (9): 1189–1197; https://doi.org/10.1134/S0001433819090366
POLISSAR P.J., ABBOTT M.B., WOLFE A.P., VUILLED M., BEZADA M. 2013 – Synchronous interhemispheric Holocene climate trends in the tropical Andes. Proceedings of the National Academy of Sciences, 110 (36): 14551–14556.
RENSSEN H., SEPPÄ H., CROSTA X., GOOSSE H., ROCHE D.M. 2012 – Global characterization of the Holocene thermal maximum. Quaternary Science Reviews, 48: 7–19; http://doi.org/10.1016/j.quascirev.2012.05.022
SCHWARTZ G. 2007 – Taking the long view on collapse: A Syrian perspective. [In:] Kuzucuoglu C., Marro C. (eds.), Sociétés humaines et changement climatique a la fin du Troisieme Millénaire: une crise a-t-elle eu lieu en Haute Mésopotamie? Varia Anatolica, 19: 45–68.
SEIM A., BÜNTGEN U., FONTI P., HASKA H., HERZIG F., TEGEL W., TROUET V., TREYDTE K. 2012 – Climate sensitivity of a millennium-long pine chronology from Albania. Climate Research, 51 (3): 217–228.
SHAKUN J.D., CLARK P.U., HE F., MARCOTT S.A., MIX A.C., LIU Z., OTTO-BLIESNER B., SCHMITTNER A., BARD E. 2012 – Global warming preceded by increasing carbon dioxide concentrations during the last deglaciation. Nature, 484: 49–54; https://doi.org/10.1038/nature10915
SUMMERHAYES C., HEAD M.J., GAŁUSZKA A., FIAŁKIEWICZ-KOZIEŁ B., WATERS C.N., ROBIN L., SÖRLIN S., CEARRETA A., WALLENHORST N., ZALASIEWICZ J. 2025 – Response to Marks (2025): Contemporary global warming versus climate change in the Holocene. Przegląd Geologiczny, 73 (5): 469–476.
USOSKIN I.G. 2023 – A history of solar activity over millennia. Living Reviews in Solar Physics, 20, 2; https://doi.org/10.1007/s41116-023-00036-z
VINÓS J. 2022 – Climate of the past, present and future, a scientific debate. 2nd ed, Critical Science Press, Madrid.
VINTHER B.M., BUCHARDT S.L., CLAUSEN H.B., DAHL-JENSEN D., JOHNSEN S.J., FISHER D.A., KOERNER R.M., RAYNAUD D., LIPENKOV V., ANDERSEN K.K., BLUNIER T., RASMUSSEN S.O., STEFFENSEN J.P., SVENSSON A.M. 2009 – Holocene thinning of the Greenland ice sheet. Nature, 461: 385–388; https://doi.org/10.1038/nature08355
WAGNER F., BOHNCKE S.J.P., DILCHER D.L., KÜRSCHNER W.M., GEEL B. VAN, VISSCHER H. 1999 – Century-scale shifts in Early Holocene CO_2 concentration. Science, 284: 1971–1973.
WEISS H., COURTY M-A., WETTERSTROM W., GUICHARD F., SENIOR L., MEADOW R., CURNOW A. 1993 – The genesis and collapse of third millennium North Mesopotamian civilization. Science, 261: 995–1004; https://doi.org/10.1126/science.261.5124.995
WELC F., MARKS L. 2014 – Climate change at the end of the Old Kingdom in Egypt around 4200 BP: new geoarcheological evidence. Quaternary International, 324 (4): 124–133; http://dx.doi.org/10.1016/j.quaint.2013.07.035
WU C.J., USOSKIN I.G., KRIVOVA N., KOVALTSOV G.A., BARONI M., BARD E., SOLANKI S.K. 2018 – Solar activity over nine millennia: a consistent multi-proxy reconstruction. Astronomy & Astrophysics, 615, A93; https://doi.org/10.1051/0004-6361/201731892

The work was received by the editorial office on 19.05.2025
Accepted for printing on 20.05.2025