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EDITORIAL

As climate changes, everything changes

Christian Bernhofer[1]

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What happened in the journal?

Theoretical and Applied Climatology (TAAC) has recently undergone a few changes. These include the editorial management system SNAPP (https://www.springernature.com/gp/snapp) and an enlarged Editorial Board (https://www.springer.com/journal/704). As the new managing editor, I would like to address these changes and set them in perspective to the developments in climate research and in the related publishing sector.

TAAC is continuing a Central European tradition of scientific journals on climate, dating back to the very beginning of modern meteorology mid of the nineteenth century, but more clearly related to the "Archive der Meteorologie, Serie B" published in Vienna (a journal replacing the "Meteorologische Zeitschrift" after the 2nd World War). Its typical manuscript density is around 1000 manuscripts per year, of which approximately one third is published. For the past 35 years, the journal has concentrated on climate issues across scales including results from monitoring or theoretical considerations. Prof. Hartmut Graßl (HG), Director of the World Climate Research Programme at WMO in Geneva (1994–1999), Director of the Max-Planck-Institute for Meteorology MPI in Hamburg (1988–1994, 1999–2005), and Professor at the University Hamburg (1988–2005), was managing editor from 1995 to 2021. He accompanied the establishment of the journal as a globally recognized trademark in climate sciences. During this period, climate change became an important topic and the numbers of articles submitted almost exploded to the current number.

In 2021, Christian Bernhofer (C. B.) followed as managing editor, while H. G. continued as Honorary Editor. With his new responsibility, C. B. intends to broaden the focus of the journal to embrace even more topics. All topics are welcome, as long as they strongly relate to climate or have a large climatological relevance, even when they are topics of a neighboring scientific field.

This should help to address the full community of researchers in **climate system science**, including experts not only in the central discipline of meteorology, but also in oceanography, hydrology, ecology, geology, chemistry, and in others. For methodologies, climate system science relies on modeling and data analysis, but is somewhat special in the vast combination of methods from a multitude of disciplines, from numerical mathematics for the best algorithms, statistics for a reliable parameterization of climate processes and their careful validation, and geo-informatics for the necessary spatial reference to computer science for the best computing architecture to ensure high speed and reliability. This has led to a remarkable progress in understanding and projecting the Earth's climate, but the related impact of both climate variability and climate change (CC) is often hard to assess. Thus, TAAC will also invite articles addressing climate services, i.e., CC adaptation and CC mitigation.

We want to attract excellent manuscripts, which address aspects of the climate system or the climate system itself, as long as the topic relates directly to the **climate system** (for reference, please see Fig. 1 in Baede et al. (2001)). This includes the **components** of the climate system (atmosphere, hydrosphere, cryosphere, biosphere), and **processes** linking the components with each other (like evapotranspiration, ET, and carbon fluxes at the soil–vegetation–atmosphere interface), thereby changing the **composition** of the atmosphere.

Here, the atmospheric concentrations of H_2O and CO_2 are the two major drivers of the natural greenhouse effect (GHE), with a preindustrial GHE equivalent to a surface temperature increase of around 33 K. For the past 200 years, the concentration of CO_2 has increased from about 280 to about 420 ppm in 2022. In Fig. 1, the CO_2 record at Mauna Loa shows the recent acceleration of this increase. The so-called "Keeling plot" (named after C. David Keeling, who started the measurements in March of 1958) is the single most cited reference among all scientific citations. This is already an indicator of the more recent appreciation of climate sciences. The

✉ Christian Bernhofer
christian.bernhofer@tu-dresden.de

[1] Theoretical and Applied Climatology, TU Dresden, Tharandt, Germany

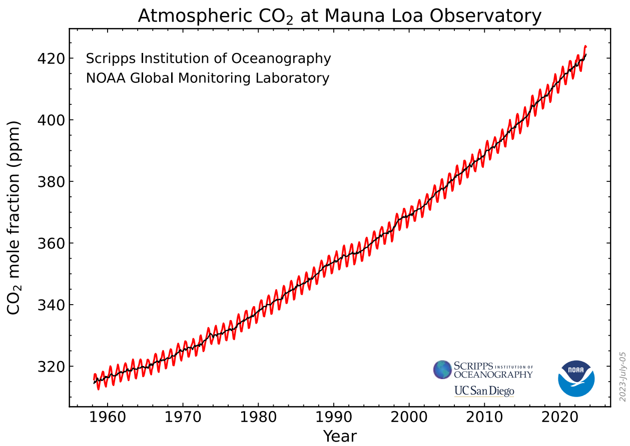

Fig. 1 Longest record of direct measurements of CO_2 concentration in the atmosphere at Mauna Loa Observatory, Hawaii (NOAA Global Monitoring Laboratory, Scripps Institute of Oceanography at the University of California San Diego) (https://gml.noaa.gov/webdata/ccgg/trends/co2_data_mlo.png; retrieved 20230606). Used with permission of NOAA under the Fair Use Doctrine of US Copyright law

obvious reason of the CO_2 increase by 50% from the preindustrial level of about 280 ppm to the current level of about 420 ppm is human activity, mainly fossil fuel combustion and deforestation. At the same time, we have increased other greenhouse gases (GHG) like methane (CH_4) or nitrous oxide (N_2O) as well. Because of the associated "direct" global warming, evapo(transpi)ration ET increases, leading to an increase of water vapor, the most powerful GHG of the Earth's atmosphere and responsible for the additional "indirect" global warming.

This already led to a global temperature increase indicative of human influence by the late 1990s (for an update, see Schönwiese et al. 2010). The human impact on the climate system became so important that Paul Crutzen introduced the term "Anthropocene" in 2000 (Crutzen and Stoermer 2000; see Steffen 2021), addressing the recent past as a geological period dominated by humankind. A major characteristic of the Anthropocene is climate change, with a global warming signal of additional 1.2 K in 2022.

1 Background

In the 70 years since the launch of the predecessor of TAAC, climatology has made considerable contributions to our understanding of the biogeophysics of planet Earth. Despite the lack of academic degrees (to study climate for a university degree, the best choice is meteorology), climatology has already become a science of its own. Traditionally concerned with the statistical analysis of data from meteorological measurements, the development of models capable of simulating the general circulation in the troposphere created a new view on climatology. The basic equations in numerical modeling are similar in meteorology and climatology. However, climate model output does not depend on initial conditions. Instead, it should reveal the adjustment of the atmosphere to boundary conditions, like the distribution of continents, GHG and aerosol concentrations, or surface cover by vegetation and ice. Climate modeling and geological evidence suggest that global temperatures were always between 10 and 30 °C for the past 500 million years. Probably biotic (photosynthesis effecting CO_2 concentration) and abiotic (sea floor spreading and weathering of high mountain ranges) contributed to self-regulation (homeostasis) of Earth's climate (Ruddiman 2008).

Fifty years ago, there was the common understanding that the limited length of climate records is the main reason for excursions from the statistical expectation. This paradigm of a "constant" climate with defined limits of variability is still reflected in up-to-date definition of WMO for climate (https://public.wmo.int/en/about-us/frequently-asked-questions/climate; retrieved 20220811):

Climate, sometimes understood as the "average weather," is defined as the measurement of the mean and variability of relevant quantities of certain variables (such as temperature, precipitation, or wind) over a period of time, ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). Climate in a wider sense is the state, including a statistical description, of the climate system.

A shorter definition, but with the same intentions, might be, "Climate is the average state of the atmosphere including typical deviations." When distinguishing climate and weather, NOAA uses "Weather reflects short-term conditions of the atmosphere while climate is the average daily weather for an extended period of time at a certain location" (https://oceanservice.noaa.gov/facts/weather_climate.html; retrieved 20230523). A famous saying puts this as, "Climate is what you expect, weather is what you get," often attributed to Mark Twain, but could be traced back to the geographer Andrew John Herbertson (1901; according to https://quoteinvestigator.com/2012/06/24/climate-vs-weather/; retrieved 20230523).

Assuming a constant climate, you would only need a sufficiently long data record, which comprises the almost complete weather statistics, which in turn is the climate. Today, we are aware of several deviations of a constant climate, like the El Niño–Southern Oscillation phenomenon with two "quasi-stable" states of the tropical circulation in the Pacific or the Younger Dryas event, when a sudden spread of cold surface waters from melting glaciers caused a 1000-year cold anomaly in the region of the northern Atlantic around 10,000 years ago.

2 A personal view on current research challenges in climatology

As climate data from traditional standardized measurements are the typical input to impact models and often the only legal background for climate change adaptation (CCA), we need to bridge the gap between climate model output and the needs for CCA without simplifying the climate system too much. At the same time, traditional time series of station data remain the backbone for assessing climate variability. Therefore, TAAC will always be open for manuscripts related to “traditional” climatology.

The border between the methods (especially in modeling and observations) is no longer clearly defined. The classical differentiation between meteorology (weather) and climatology (climate) becomes “blurred.” This makes it hard to define the focus of any climate journal. Maybe, for TAAC it helps authors and editors to check whether a manuscript is more suitable to the sister journal, Meteorology and Atmospheric Physics (MAP). However, many aspects deserve special attention, sometimes both in weather and climate related research. Whether to publish in TAAC or MAP is therefore primarily a decision of the author(s). In case of potential conflicts, the handling editor will inform the author(s). In terms of applied climatology, we can easily distinguish based on the time scale. Analysis of observations and CC related model output rely always also on statistics.

The following research topics are a personal choice of CB and by far not exclusive.

2.1 Seamless nesting

General coupled atmosphere/ocean circulation models (GCMs, also used for the abbreviation of Global Climate Models) have been the standard for the recent IPCC reports, with an always better resolution arriving at approximately 100-km grid size for the Sixth Assessment Report (AR6; IPCC 2023). As this is way above of the necessary resolution to include realistic orography or surface patterns, nesting steps are used with a smaller domain and better spatial resolution (down to 10 km or even less to about 1 km). However, there is an obvious parametrization problem related to scaling, for example, whether you are able to create the correct precipitation statistics without including some of the features causing this statistics. As limits in computing power will probably not allow a drastic reduction in grid size within a decent time span, new methods are needed to integrate sub-grid scale effects or to allow a bi-directional information transfer between outputs of different nesting levels.

2.2 Surface boundary conditions (terrestrial and aquatic)

The earth’s surface and the adjacent atmospheric boundary layer is regulating important exchanges of radiation, heat, water, a long list of trace gases (CO_2, CH_4, N_2O, O_3, etc.), and a similarly long list of aerosols (like VOCs and SO_4), while both groups also interact with each other. This holds for aquatic and terrestrial surfaces, which indicates that this is a field of intensive cooperation with atmospheric chemists, oceanographers, and ecologists. Surface boundary conditions are relevant for many aspects of climate modeling: surface albedo, surface roughness, energy partitioning between latent and sensible heat, carbon fixation and release, emission and uptake of other gases, and the fraction of precipitation reaching the soil surface.

2.3 Convection

Precipitation due to moist convection is often much localized, different to frontal or orographic precipitation. Even at a resolution of 3 km, a sub-grid effect needs to be parameterized. This leads to a potential bias in output. The problem is similar to precipitation forecast in numerical weather prediction (NWP), but as the coupling to the surface is only of minor importance in NWP, their convection schemes are difficult to transfer to climate modeling, as other parameterizations (e.g., land or earth surface schemes) are needed. Mesoscale convective systems might be included at the earliest nesting steps, while the chance to integrate cloud microphysics directly is practically zero with existing techniques. Therefore, the need continues for appropriate parametrizations. We expect that a better convection treatment will also help to improve radiation transfer in climate models.

2.4 Treatment of the water cycle in monitoring and modeling

The water cycle is the single most important negative feedback process after the Stefan-Boltzmann law stabilizing the climate. ET consumes 2.5 MJ kg^{-1}, an enormous energy source — if made available during condensation — for higher latitudes and the upper part of the troposphere. Water vapor triggers cloud formation, influencing the energy budget of the atmosphere. Surface runoff is generated from excess precipitation (residual after subtracting ET and infiltration from precipitation). From a climate perspective, the sum of surface runoff is identical to the atmospheric transport from the oceans to the land area. At longer time scales, groundwater formation depends on the infiltration of surface waters. River systems are sensitive to height changes, causing new routing or even the change of flow direction in geological times.

The special role of the cryosphere is evident from current climate change (see, e.g., melting of Alpine glaciers), but also from the time lag between the change in northern hemisphere solar radiation and the temperature changes involving ice sheet formation and decay, which are associated with the Milankovitch cycles of the Earth's orbital parameters and the ice ages.

2.5 Carbon cycle and other greenhouse gases

For most of the almost 4 billion years of life on Earth, the climate has been surprisingly stable. According to current understanding, this is due to the carbon cycle (CO_2 and methane CH_4), plate tectonics, and the existence of life (Ruddiman 2008). A complex interplay of weathering, volcanism, and biological activity in the oceans and later on land regulated the concentration of CO_2 favorably for life to continue. Therefore, climate models need to include the carbon cycle for modeling the past and the future climate.

2.6 Statistical methods — Artificial Intelligence and machine learning

Without speculations on the introduction of quantum computers, new non-linear statistics like Artificial Neural Networks or in general terms Artificial Intelligence (AI) already became a very popular tool in Applied Climatology. These machine learning techniques offer "instant solutions" and are developed by many for the use of many. The appropriate analysis and interpretation methods still need to be developed. Expert knowledge and process understanding remain a prerequisite for a decent use of AI in climatology.

2.7 Measurements — a global network under pressure

Over almost two centuries, the ever-increasing network of weather and climate stations has been the backbone of weather forecasts and climate analyses. All kinds of "volunteer" weather stations (from private weather services, but also from citizen scientists) become more and more available, even challenging some of the (inter)national observational networks. New precipitation data are collected via RADAR or from the mobile phone network. LIDARs start to become part of standard probing of the troposphere. All these new observation instruments and methods need to be incorporated in the data stream for the starting fields (initial conditions) of weather forecast. Weather forecasts are not the typical concern of TAAC. However, new data differ typically in standards from the existing data and later they will become a subject of climatology. Therefore, some methodological developments like data fusion should be reflected in contributions to the journal.

2.8 Measurements — integrating remote sensing and model output

During the last 50 years, the number of ground stations and regular soundings of the atmosphere by weather balloons reached a plateau, after which it started to strongly decline. Remote sensing could replace many aspects of these expensive ground-based measurements; for example, the impressive improvements made in NWP are due to the frequent updates by satellite measurements of EUMETSAT or NASA/NOAA. Nevertheless, the application of remote sensing approaches is often limited by scarcely available ground truth. This is not only true for the Global South, as economic constraints led to a reduction of manually serviced stations almost everywhere. The use of mesoscale climate-model output, the use specialized satellite data (e.g., from the COPERNICUS program), or the use of reanalysis data might be a solution.

2.9 Measurements — new observations become available

New research observation networks like FLUXNET (Pastorello et al. 2020) provide unprecedented information on the status of the surface fluxes and the concentration of atmospheric constituents. Fluxes of CO_2, water vapor, energy, and momentum are continuously observed at about 500 sites globally. ICOS (https://www.icos-cp.eu/) or NEON (https://www.neonscience.org/) contribute by protocols and data facilities, not only for the dominantly terrestrial FLUXNET sites, but also for the oceans and for the atmosphere via a network of tall towers. This will probably be the future monitoring standard for fluxes and trace gas concentrations, allowing to study the effects of CC and management on the green carbon sink of the planet.

2.10 Impact of CC and social sciences?

The impact of CC leads to concerns and actions. This refers to adaptation to CC and also to CC mitigation. We all agree that adaptation is, for good reason, regarded as a necessity; where and when and how to adapt still remains often an unsolved question of research. Meanwhile, CC mitigation is seen similarly as a necessity. However, only global efforts within a concerted action have the chance to succeed. The Paris Treaty of 2015 set the 1.5 °C or at least 2 °C target for global warming, a benchmark which can only be reached if we start seriously in the 2020s. The obvious gap between the promises of many countries and the global status underlines that peripheral topics are and will become even more important for climatology, social sciences, and climate change communication.

2.11 Interactions and climate system sciences

There is growing awareness that processes, budgets, and concentrations related to planet earth are all interlinked in a complex time–space "matrix" or "web." To give an example, the groundwater reserves reflect past climate for 10 to 10,000 years, but soil moisture only up to 10 years. Likewise, the combination of variable storage within the global carbon budgets and the related atmospheric concentration introduced a kind of a thermostat in the Earth-atmosphere feedback. The biosphere probably contributed significantly via photosynthesis and respiration. According to the understanding of paleoclimatologists, these feedbacks helped to overcome locked-up situations like snowball earth (Hoffman and Schrag 2000) or even avoided them after the strong increase of the terrestrial biomass about half a billion years ago. A more recent example is the relationship between the albedo of plant canopies to the carbon sequestration potential (the potential of trees being higher than that of herbaceous plants). The heating potential of trees by a lower albedo is typically compensated by a higher carbon sink. The related CC mitigation becomes larger with higher temperature and with increases in duration of the vegetative active period and thus the carbon sequestration.

In fact, this might not only support the classical GAIA hypothesis, "mother Earth helps to establish homeostasis relative to the global temperature" by albedo changes and C sequestration changes in a window small enough to allow continuous development of life, very close to Lovelock's "Daisy World" (Lovelock and Watson 1982). It also shows that the combination of physical parameters for planet Earth is rather unique, reducing the chance to find another inhabited planet with a similar civilization at the same time. This includes a stable position of the Earth's orbit around the sun, a solar system with enough element input from no longer existing stars, and a certain position in our galaxy (Lenton et al. 2020).

3 Aims and scope of the journal in 2023

Theoretical and Applied Climatology is dedicated to form an open and interdisciplinary forum that allows for the scientific exchange between climate related disciplines and climatology as part of atmospheric sciences, as well as between climate related spatial and temporal characteristics, like regional climates or boundary layer climates, from all over the globe.

Research papers and reviews on issues relevant to the climate system are published, covering the following topics:

- Climate modeling with all trace constituents of the atmosphere and associated feedbacks, climatic change and climate projections, and methods of climate related modeling including artificial intelligence (deep learning, machine learning)
- Micro, meso, and global climate; climate services; communication; adaptation and mitigation of climate change; applied meteorology; biometeorology; building meteorology; and technical meteorology.
- Eco-climatology with its complex interactions with ecosystems, including aspects of self-organization, stability, and ecosystem services, like carbon sequestration or agricultural and forestry products.
- Meteorological measurements, including techniques of remote sensing, network analysis, and geo-statistics of climate data.

We want to highlight that this topic list is open for extension, as a rapidly changing science might develop new fields of interest or application. As a scientific community, researchers will expand or change climate science. TAAC wants to provide the stage for these developments.

The **editorial board** of TAAC has been diversified to reflect the shift in scope as well as to adjust the handling of manuscripts in order to provide expert knowledge in the board in this wide range of climate system sciences. Simultaneously, we want to speed up the reviewing process. This will help the authors with their obligations to present valid evidence of their research. A shorter handling time will help the journal in the growing jungle of journals to become even better. Meanwhile, this should help to support the international climate research community by interesting and relevant insights into local, regional, and global climate. Still, we are looking for new members of the editorial board for an even better coverage of climate system sciences (interest can be expressed to the managing editor).

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