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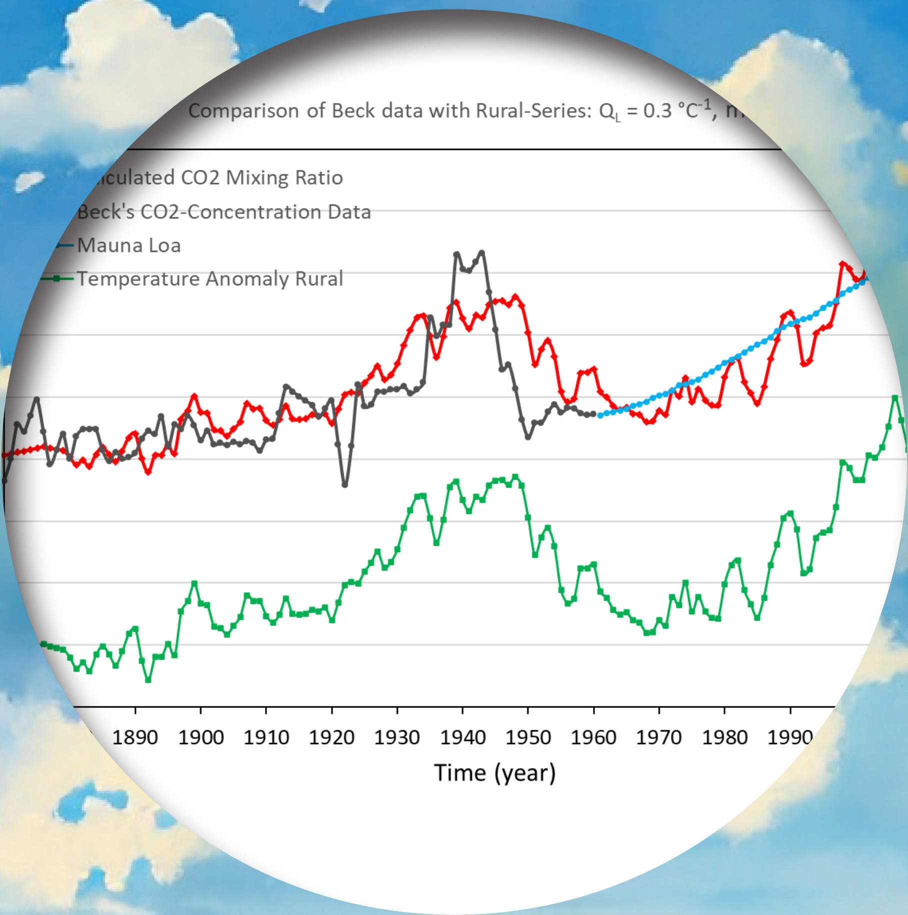

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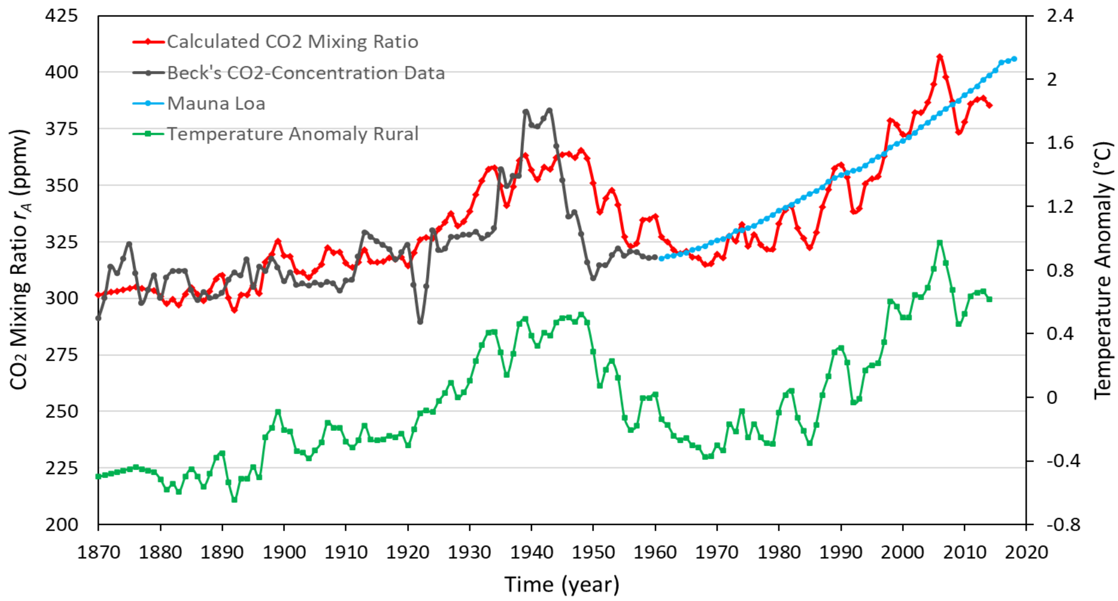

Comparison of historical CO_2 concentrations estimated by Ernst-Georg Beck (see SCC Vol 2.2 pages148-) (Dark Dots) with calculation (Red Diamonds) for m = 0.6 and Q_L = 30%/°C, based on Northern Hemisphere rural land air temperature data (Green Squares, Soon et al. 2015) over a period of 145 yrs. Q_L is the temperature sensitivity of soil respiration and m is the thermally-induced increase of atmospheric CO_2 from ocean and land. Additionally, this is compared with the Mauna Loa observations (Light Blue Dots, CDIAC 2017)

From an article by Hermann Harde: About Historical CO_2-Data Since 1826. *Explanation of the Peak around 1940*

Figure 1, page 214

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Editorial

In this issue we start with an essay by Richard Mackey on how the many observed oscillating atmospheric and oceanic systems are largely responsible for the Earth's weather and climate. The Earth's rotation forces the oscillations and is the primary reason for the climate change we observe. This is completely overlooked by IPCC:

Martin Hovland continues his series on the Holocene climate changes in southwestern Norway and discuss the findings related to the first human inhabitants. Two more installments are expected.

Then we have comments by Ferdinand Engelbeen on the article *Direct measurements of CO_2 near ground* by the late Ernst Georg Beck, which we published in Vol 2.2. Engelbeen claims that even if the measurements are fairly precise, many places were completely unsuitable for "background" CO_2 level measurements. Finally, he contested the huge CO_2 level observed around 1940. This article was posted for an Open Review, which attracted some comments. Some agreed partly with Engelbeen, but finally Hermann Harde demonstrated that the formula for release of CO_2 from ground and ocean due to higher temperatures (Salby and Harde 2022, SCC Vol2.3 p. 212-238) can explain the peak observed. The conclusion is that this shows that Beck's reconstruction and Harde's simple CO_2 release model don't support the ice core estimates of historic values of CO_2. Here is a clear need of better understanding of previous observations and the CO_2 estimates from ice-core measurements.

The debate on the reason for the observed increase of atmospheric CO_2 has now ended with two debate-papers by David Andrews and Edwin Berry, defending the human or natural cause of the increase, respectively. As usual, scientists don't agree. It is up to our readers to decide who has the best arguments.

We are pleased to realize one of our goals which is to provide a scientific debate. This is what brings science forward. We welcome contributors to a lively debate in future issues.

Good reading

Jan-Erik Solheim
Editor

A digital version of this volume can be found here: https://doi.org/10.53234/SCC202308/18

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pp. 119-172

The Earth's Decadal Rotation and Climate Dynamics

Richard Mackey

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Abstract

Several oscillating atmospheric/oceanic systems (e.g., the El Niño/Southern Oscillation, Quasi-Biennial Oscillation, Pacific Decadal Oscillation, and North Atlantic Oscillation) are largely responsible for the Earth's weather and climate. Two fluid structures (the oceans and atmosphere) envelope the solid Earth. A rotating fluid generates waves (inertial waves) that flow inside the fluid, not on the surface. The inertial (Rossby and Kelvin) waves in the atmosphere and oceans are largely responsible for the formation, intensity, and duration of the main atmospheric/oceanic oscillating systems. The Earth's rotation has a dominant role in climate dynamics because it causes the inertial waves. The Earth rotation rate is typically 86,400 seconds per day: the Length of Day (LoD). There are three well-established findings about the Earth's rotation:

- Every ten years or so the Earth's rotation rate increases or decreases significantly by between three and five milliseconds.
- When, on a decadal basis, the Earth's rotation rate increases, the Earth warms globally; when the rate decreases, the Earth cools globally.
- The cycles of global warming and cooling episodes repeat about every 60 years.

Overlaying these cycles are the impact of the

- Sun via radiation, matter, electromagnetic and gravitational fields, and their interaction effects;
- atmospheric/oceanic systems' interaction effects; and
- interaction effects of all processes.

The decadal rotational variations likely arise from gravitationally driven electromagnetic coupling between inner and outer cores and the mantle. Global temperature changes some eight years after the Earth's rotation rate changes. The Earth's rotation rate changes some eight years after the inner core's rotation rate changes. Recently, scientists found that the inner core's rotation rate began to slow around 2009. Global cooling is likely to set in around 2025. The Intergovernmental Panel on Climate Change does not mention any of the vast body of research published over the last 50 years on this subject. US and OECD scientific authorities consider that the deliberate omission of scientific results constitutes the falsification of science and is scientific misconduct.

Keywords: Greenhouse effect; radiative forcing; Earth rotation; Rossby wave; Kelvin wave; Lunar Nodal Cycle; complex systems; global warming; global cooling; core-mantle coupling; geodynamo; geomagnetic field; electromagnetic coupling; climate dynamics; Hurst-Kolmogorov dynamics; sensitive dependence; Liouville-Euler equations; Barents Sea ice-edge; Earth core; inner core; magnetopause; solar wind; solar system; falsification of science; scientific misconduct.

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Bertrand Russell

The concept of "truth" as something dependent upon facts largely outside human control has been one of the ways in which philosophy hitherto has inculcated the necessary element of humility. When this check upon pride is removed, a further step is taken on the road towards a certain kind of madness--the intoxication of power which invaded philosophy with Fichte, and to which modern men, whether philosophers or not, are prone. I *am persuaded that this intoxication is the greatest danger of our time, and that any philosophy which, however unintentionally, contributes to it is increasing the danger of vast social disaster.*[1]

1. Introduction *

A key finding of Geophysics is that every ten years or so the rate at which the Earth rotates increases or decreases significantly. The Earth typically spins at the rate of 86,400 seconds per day: this rate is known as the Length of Day (LoD). Every ten years or so, the rate of rotation speeds up or slows down more than the usual variations that occur in periods less than ten years. These decadal variations result in the LoD increasing or decreasing by between three and five milliseconds. Historically, the Earth's rotation was the absolute standard for time keeping in the 17th, 18th and 19th centuries. As a result, astronomers used the presumed fixed constant of the Earth's rotation to determine all astronomical attributes of the Sun and the solar system. The world's leading astronomers initially rejected the evidence emerging in the later part of the 19th Century that the Earth's rotation might be variable. An overview of the history of the recognition that the Earth's rotation was variable and not constant is at Attachment A.

Another key finding of Geophysics is that when, on a decadal basis, the rate of rotation of the Earth increases by the number of milliseconds mentioned above, the Earth warms globally[2]; when the rate decreases by a similar amount, the Earth cools globally. There is a time lag of about 8 years between LoD changes and global temperature changes. The most recent estimates of the temperature changes are ± 0.8°C.

In this paper Figure 1 (page 125) and Figure 7 (page 140), the two diagrams reproduced in Attachment B (Figures B1 and B2) and the discussion of them, shows the well-established relationship between the decadal changes in the Earth's rate of rotation and climate. The finding is not simply a correlation, but a detailed explanation of how changes in the Earth's rotation bring about changes in global temperatures.

These findings have been established by multiple teams of leading scientists working independently over the last half-century and published in the world's leading scientific journals.

The result was first reported in 1976 by Australia's distinguished Geophysicist, Emeritus Professor Kurt Lambeck AC, FRS, FAA, FRSN, Professor of Geophysics at the Australian National University, jointly with Dr Anny Cazenave of France.[3] Dr Cazenave has published additional results jointly with two distinguished French Geophysicists, Professor Vincent Courtillot, and Professor Jean-Louise Le Mouel.

Professor Nikolay S. Sidorenkov, the head of the Global Atmospheric Circulation Laboratory of the Russian Hydrometeorological Center, has published extensively on this topic (Sidorenkov (2009)).

Other teams include the distinguished American Physicist, the late Dr Jean O. Dickey (1945 - 2018);[4] Dr Leonid Zotov, Associate Professor at the Sternberg Astronomical Institute, Lomonosov Moscow State University; Dr Christian Bizouard, Director of the International Earth Rotation and Reference System Service (IERS) Earth Orientation Center and Director of the Earth Rotation and Space Geodesy team at Time-space Reference System (SYRTE) Observatoire de Paris; and Dr C.K. Shum, Professor and Distinguished University Scholar, Division of Geodetic Science, School of Earth Sciences, at The Ohio State University.[5]

In 1990, Professor Jean Pierre Rozelot published evidence of a strong relationship between the Earth's decadal changes in rotation and global temperatures.[6]

*Footnotes are placed at the end (pages 169-172)

Between 1984 and 2009, Professor Horst Jochmann and Dr Hans Greiner-Mai of the GeoForschungsZentrum (GFZ) (German Research Center for Geosciences at the Helmholtz Center Potsdam published over a two dozen papers that examined aspects of core-mantle coupling, Earth rotation and climate dynamics. The National Report of the Federal Republic of Germany about geodetic activities in the years 1995 to 1999 summarised much of their published research concluding that their work showed that the Earth's climate cycles are related more to core dynamics than to atmospheric circulation.

The following scientific journals published the findings referred to in the three preceding paragraphs:

- *Geophysical Journal of the Royal Astronomical Society*
- *Philosophic Transactions of the Royal Society of London*
- *Journal of Climate*
- *Nature*
- *Geophysical and Astrophysical Fluid Dynamics*
- *Astronomical Notes (Astronomische Nachrichten)*
- *Advances in Space Research*
- *Surveys in Geophysics*
- *Earth Interactions*
- *Physics of the Earth and Planetary Interiors*
- *Geodesy and Geodynamics*
- *Journal of Geodynamics*

as well as three significant monographs, namely Lambeck (1980), Sidorenkov (2009) an Kilifarska (2020).

These findings, stretching over almost fifty years, have not been contested by any scientist or scientific authority.

In two recently published, richly empirical papers, a team of scientists from Norway and Sweden showed that the Earth's rotation is an agent for forcing the Barents Sea ice-edge (BIE) (at least after 1800) to alternate between a southern and a northern position (Mörner, Solheim, Humlum, and Falk-Petersen (2020) and Solheim, Falk-Petersen, Humlum and Mörner (2021)). In order to understand how the BIE varied over time, the team analysed a 442-yearlong dataset of BIE variations. The data was collected from ship-logs, polar expeditions, and hunters in addition to airplanes and satellites in recent times. The authors explain that the database is the Arctic Climate System Study (ACSYS) Historical Ice Chart Archive, 1553-2002 compiled by Torgny Vinje (1929 – 2015)[7] of the Norwegian Polar Institute (NPI) over a period of some 50 years (Vinje 2001). The earliest chart on the database dates from 1553. The database is maintained and kept up-to-date; it is considered one of the NPI's significant scientific assets (Issaksson et al. 2016). The team found that the BIE position alternates between a southern and a northern position followed by Gulf Stream Beats (GSBs) at the occurrence of deep solar minima.

The team consisted of Jan-Erik Solheim, Professor Emeritus of The Arctic University, Ole Humlum, Professor Emeritus of Physical Geography at the University of Oslo, Department of Geosciences and adjunct Professor of Physical Geography at the University Centre in Svalbard, Stig Falk-Petersen, Senior Scientist at the Fram Centre, the High North Research Centre for Climate and the Environment, and the late Nils-Axel Mörner (1938 – 2020) formerly the Head of the Paleogeophysics and Geodynamics unit at Stockholm University until his retirement in 2005.

The authors report that the evidence indicates that the BIE is moving south this century, indicating Arctic cooling to come. If so, the effects of the BIE expanding south for the North Atlantic region, will be noticeable consequences for the ocean bio-production from about 2040, and presumably also for planned ocean transport across the Arctic Ocean.

Mazzarella and Scafetta (2018) examined links amongst the time series of LoD (1623–2016), the zonal index (ZI, 1873–2003), the NAO index 1659–2000) and the global sea surface temperature (SST, 1850–2016) to hindcast the severity of the global climate cooling during the Little Ice Age (LIA) of the seventeenth–eighteenth century. The authors' found that it was most likely that during the coolest period of the Little Ice Age (LIA), SST could have been about 1.0–1.5 °C cooler than the 1950–1980 period. According to the authors, this estimated LIA cooling is greater than what some multiproxy global climate reconstructions suggested, but it is in good agreement with other more recent climate reconstructions including those based on borehole temperature data.

2. Oscillating atmospheric/oceanic systems regulate climate

The Earth's atmosphere contains several major oscillating atmospheric/oceanic systems that are largely responsible for the regulation of the Earth's weather and climate. These oscillating systems include the El Niño/Southern Oscillation (ENSO); Quasi-Biennial Oscillation (QBO); the Pacific Decadal Oscillation (PDO); the Interdecadal Pacific Oscillation (IPO); the North Atlantic Oscillation (NAO); the Atlantic Multidecadal Oscillation (AMO); the Indian Ocean Dipole (IOD); Southern Annular Mode (SAM); the Madden–Julian Oscillation (MJO). the Arctic Oscillation (AO); the northern and southern polar vortices, which are two permanent cyclones at the poles; and Atmospheric Rivers. There are, as well, local systems specific for particular geographic areas of the world. For example, in Australia the Subtropical Ridge and the East-Coast Low Pressure System sometimes have a significant role in the regulation of Australia's weather and climate.

Two fluid structures envelope the solid Earth – the oceans and the atmosphere. A rotating fluid generates waves that flow through the interior of the fluid, not on the surface like the waves on the oceans. These waves are called inertial waves. They are caused by a restoring force, a force that acts to bring a body to its equilibrium position. This force is the Coriolis force which arises (along with the centrifugal force) in a rotating frame because the frame is always accelerating. The Coriolis force acts at a 90° angle to the direction of motion: its strength depends on the rotation rate of the fluid.

Inertial waves are perpendicular to the direction of wave travel, just like light waves. The phase velocity of inertial waves is the movement of the crests and troughs of the wave. It is perpendicular to their group velocity, a measure of the propagation of energy.

The inertial waves in the atmospheres and oceans of planets are known as Rossby waves. They are a key feature of large-scale ocean and atmospheric circulation.

Atmospheric Rossby waves are giant meanders in high-altitude winds that have a major influence on weather and climate. These waves are associated with pressure systems and the jet stream. Oceanic Rossby waves are huge, undulating movements of the ocean that stretch horizontally across the planet for hundreds of kilometres in a westward direction. They are so large and massive that they can change Earth's climate conditions. They move along the thermocline: the boundary between the warm upper layer and the cold deeper part of the ocean. They can be thousands of kilometres long, have amplitudes smaller than 10 cm and travel slowly, requiring years to decades to cross the Pacific Ocean. They do not show up clearly in ocean views provided by conventional measurements.

Since the rotation of the Earth causes Rossby waves, the rotation of the Earth has a dominant role in the dynamics of the atmosphere and oceans on time scales of a day or more.

If an inertial wave is trapped by a boundary, the fluid piles up and flows along the boundary. This phenomenon in planets' atmospheres and oceans of is known as Kelvin waves.

Atmospheric Kelvin waves play an important role in the adjustment of the tropical atmosphere to convective latent heat release, in the stratospheric quasibiennial oscillation, and in the generation and maintenance of the Madden–Julian Oscillation. The atmospheric equatorial Kelvin wave is one of the critical wave motions in the response of the tropical atmospheric circulation to a heat source.

Oceanic Kelvin waves play a critical role in tidal motion, in the adjustment of the tropical ocean to wind stress forcing, and in generating, sustaining, and terminating ENSO. Kelvin waves in the far-western Pacific initiate ENSO; whereas Kelvin waves from the western Pacific erode the thermocline structure in the central Pacific preventing further development of ENSO and ultimately terminating it.

In the atmosphere and the oceans, the Coriolis force vanishes at the equator. A consequence of this is that the equator forms a boundary against which the fluid piles up forming an equatorial Kelvin wave that flows eastward.

Rossby and Kelvin waves in the Atmosphere and the Oceans are largely responsible for the formation, intensity and duration of the seven atmospheric/oceanic oscillations – ENSO, QBO, PDO, IPO, IOD, SAM, and MJO that regulate global and regional climate.

Since the rotation of the Earth is responsible for the Rossby and Kelvin waves in the Atmosphere and the Oceans, the Earth's rotation has a dominant role in the dynamics of the Earth's atmosphere and oceans on time scales of a day or more. Therefore, changes in the Earth rotation rate are likely to affect the behaviour of Rossby and Kelvin waves. For example, in Australia there will be consequential effects of changes in the Earth's rotation on the atmospheric/oceanic oscillations, and therefore, on Australia's weather and climate and the risks of natural disasters.

According to Zotov et al. (2022), the Earth's rotation started to accelerate again after the strong El Nino in 2016 and in 2021 reached the maximal velocity observed almost since 1930s. Recently published evidence shows that the Earth's rotation would begin to slow down in 2024 and continue slowing down until at least 2032. As a result, the global warming observed from the beginning of the 20th century will most likely transition to a global cooling from the middle of the next decade.

3. Origin of decadal LoD variations

The development of knowledge about, and reasons for, the decadal variations in the Earth's rotation and the global warming/cooling that accompanies rotation variations is an active area of scientific inquiry. The major working hypothesis is about some form of coupling between inner core, the outer core, and the mantle. The preferred type of coupling is electromagnetic, but the precise form is the subject of intense investigation, as are the reasons for variations of LoD of between three and five milliseconds.

Strong evidence points to gravitational forces driving the electromagnetic coupling. There is also significant work-in-progress to explain the:

- global warming/cooling connected to Earth rotation variations;
- time lag of about eight years between changes in the Earth's rotational speed and surface temperature; and
- time lag of about eight years between the electromagnetic event that results in Earth rotation variations and the rotation variations happening.

It is to be noted that the Intergovernmental Panel on Climate Change (IPCC) does not mention in any of its many reports the vast body of research published over the last 50 years on this subject.

On 23 January 2023 Professor Xiaodong Song at the School of Earth and Space Sciences (SESS), Peking University, and Dr Yi Yang, an Associate Research Scientist in Professor Song's group reported substantial observational findings that inner-core rotation varies over multidecadal timescales and has slowed in recent years, probably from 2009 onwards (Yang, Y and Song, X D (2023)). This temporal variation in inner-core rotation is coupled to processes observed at the

Earth's surface, including the LoD and magnetic field variation. The authors used seismic observations to study the inner core. They analysed the difference in the waveform and travel time of seismic waves from near-identical earthquakes that have passed through the Earth's inner core along similar paths since the 1960s.

The analysis shows that the Earth's inner core oscillates with a period of approximately seven decades. See also Hawkins, Louise (2023).

Planet Earth, the diameter of which is 12,742 kms, consists of five major structures. The first is the crust –up to 70 kms thick – an oblate spheroid shell on which civilisation dwells. The second, the oblate spheroid shell immediately below the crust, is the mantle. It is solid and about 2,900 kms thick. The third oblate spheroid shell, which the mantle envelopes, is the super-heated outer core. It is a 2,300 kilometres wide roiling river of about 178 million cubic kilometres of super-heated liquid metal (mostly a mix of Iron and Nickle), the temperature of which is around 5,000º Centigrade. The viscosity of the liquid is like that of water; it sloshes about generating electromagnetic fields, which constitute the Earth's dynamo. The outer core envelopes the fourth structure, the inner core, a super-heated tangled bundle of structures, some solid, probably crystalline, some elastic, that sit within gooey Iron-Nickle mush, about 70% of the size of the Moon. The mush is known as a superionic fluid, a state more fluid than a solid, but not quite as fluid as a liquid. At the centre of the mosaic-like, malleable inner core is the fifth structure, a solid ball of metal 650 km in diameter. The pressure within the inner core is intense, about 3.6 million atmospheres. The irregular-shaped surface of the inner core is about 5,300 kms below the Earth's surface.

The gravitational and electromagnetic fields of the rest of planet Earth have countervailing impacts on the rate of rotation of the inner core, which floats in the low viscosity fluid of the outer core. This fluid does not restrain the inner core's motion; however, the gravitational and electromagnetic fields in which it is embedded and with which it interacts, do. In addition, since the inner core is pliable the impact of the countervailing forces can change the shape and orientation of the inner core not only its motion.

The magnitude and impact of the gravitational and electromagnetic fields interacting with the inner core, the nature of the interaction is a very active area of science, but at the time of writing this paper, there were not unambiguous findings. Mohazzabi and Skalbeck (2015) is a good example of work-in-progress.

In 1936 the Danish seismologist and geophysicist, Inge Lehmann (1888 – 1993) reported her discovery of the Earth's solid inner core inside the molten outer core. Prior to that, the scientific community believed Earth's core to be a single molten sphere. She discovered the inner core by a careful, rigorous examination of time travel curves generated by earthquakes.[8] Her discovery was corroborated by other scientists in the 1940s and 50s. In 1971, Dziewonski & Gilbert (1971) confirmed the hypothesis that the inner core was solid. According to Anderson (Anderson (2007))*, the inner core is isolated from the rest of the Earth by the low viscosity fluid outer core and it can rotate, nod, wobble, precess, oscillate, and even flip over, only loosely constrained by the surrounding shells. Among its anomalous characteristics are low rigidity and viscosity (compared to other solids), bulk attenuation, extreme anisotropy and super-rotation (or deformation).*[9]

In 2013 Professor Hrvoje Tkalcic and his team at the ANU College of Physical and Mathematical Sciences (Tkalcic et al. 2013) were the first to provide experimental evidence that the Earth's inner core has rotated at a variety of different speeds and at a different rate than the mantle. He found that the inner core's pattern of rotation over time is best described a pattern of *shuffling* rotation. The ANU team found that the inner core has a non-steady rotation with respect to the mantle on which are superimposed decadal fluctuations.

Professor Tkalcic and his team have corroborated findings of others that the inner core is distinctly heterogeneous consisting of a tangled mix of liquid, soft, elastic, hard and crystalline structures, in some parts mushy and squishy, having an irregular shape and lumpy surface (Tkalcic and Kennett 2008; Tkalcic 2015). Professor Tkalcic and his team, who have pioneered advanced mathematical methodologies to extract as much information as possible from seismic waves, have also corroborated the hypothesis that a solid metallic core is at the middle of the inner core (Phạm and Tkalcic 2023).

The Earth's climate system also exhibits multidecadal periodicity. The global mean sea level variation and global mean temperature variations are in phase with the magnetic field changes and the LoD variations, respectively. Thus, the Earth seems to behave as a resonating system that involves all the major layers of the solid Earth, from the surface to the inner core. The authors report that the multidecadal periodicity of the climate system might also originate from the oscillating core–mantle system, through the surface deformations and the exchange of angular momentum from the core and mantle to the surface. The authors state that their findings may imply dynamic interactions between the deepest and shallowest layers of the solid Earth system. Figure 1 illustrates the relationships between the geophysical and climate phenomena.

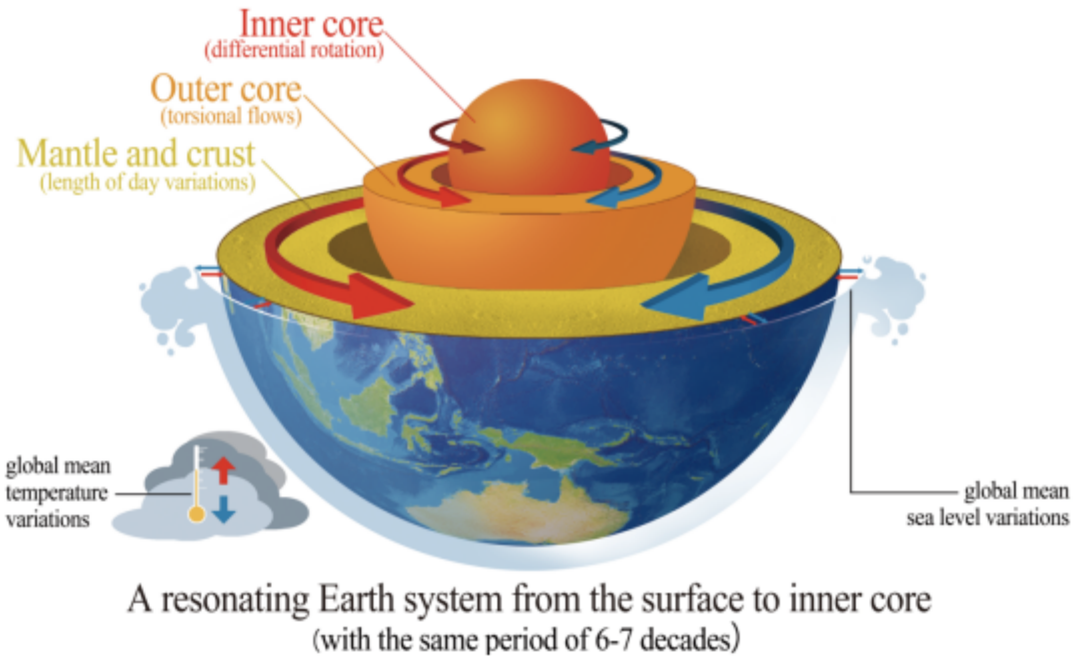

Figure 1. A possible resonating Earth system from the surface to the inner core. The system includes the inner core (from its differential rotation), the outer core (from the magnetic field changes), mantle and crust (from the LoD variations), and the surface (from the global mean sea level rise and temperature).From: [Chinese Scientists Found Rotation of the Inner Core Changes over Decades -Chinese Academy of Geological Sciences (cags.ac.cn)]

The findings of Professor Xiaodong Song and Dr Yi Yang (Yang and Song 2023), which built on the research of many scientists around the world and over the last two decades, were of such significance as to warrant a research note in *Nature Geoscience* (Hawkins 2023), which amongst other things, stated:

> *Seismic observations reveal that the Earth's inner core oscillates with a period of approximately seven decades. The multidecadal periodicity coincides with that of several other geophysical observations, particularly the variations in the length of day and the Earth's magnetic field, suggesting dynamic interactions between the major layers of the Earth.*
>
> *Similarly, the Earth's climate system also exhibits multidecadal periodicity. The global mean sea level variation and global mean temperature variations are in phase with the magnetic*

> *field changes and the LoD variations, respectively. Thus, the Earth seems to behave as a resonating system that involves all the major layers of the solid Earth, from the surface to the inner core.*
>
> *This study shows that inner-core rotation varies over multidecadal timescales and has slowed in recent years. This temporal variation in inner-core rotation appears to be coupled to processes we observe at the Earth's surface, including the length of day and magnetic field variation.*

Difficulties in measuring accurately the variable rate of rotation of the inner core in the 21st Century are analogous to the difficulties in measuring the variable rate of rotation of the Earth in the 19th Century (see Attachment A).

Hofmeister (Hofmeister et al. 2022), pointed out that basic principles of motion, discovered by Newton, require that lateral forces cause lateral motions. Their analysis, using Newtonian celestial mechanics, shows that the Moon is essential to Earth's long-lasting dynamics and unique tectonics, because its presence induces spatial and temporal variations in the positions of the barycenter and geocenter.

Their analysis shows that the unique dynamic geometry of the Earth-Moon-Sun system produces imbalanced forces and torques that drive Earth's tectonic plates and influences the activity of the other oblate spheroid shell structures of which the Earth is composed. The imbalance arises from the:

- shape of the Earth and its internal structures being oblate spheroids that are dynamic, not static;
- oscillating, off-center barycentre of the Earth-Moon system;
- imbalance between the Earth's tangential orbital acceleration and the Sun's gravitational field;
- cyclical stresses arising from this imbalance creates fractures in the Earth's structures, especially the cold, rigid and brittle lithosphere thereby adding further asymmetry to plate motions; and
- frictional heat created by the stress associated with the off-centre, shifting barycentre.

4. The 1970s findings of Lambeck and Cazenave

During the 1970s, Kurt Lambeck and Anny Cazenave published a series of papers reporting ground-breaking scientific observation and analysis showing that variations in the long-period (about 10 years) rotation of the Earth resulted in episodes of global warming and global cooling.[10] In these papers, Kurt Lambeck and Anny Cazenave drew on findings from Dr Cazenave's 1975 PhD thesis and prior work of Professor Lambeck and others about the Earth's rotation. They also reported considerable original work they undertook jointly during the 1970s.

In relation to decadal variations in the Earth's rotation, Lambeck and Cazeneve found that as the Earth rotates faster, (i.e. LoD shortens) the planet warms; in contrast, as the Earth rotates slower (i.e. LoD lengthens,) the planet cools. They found that not only did global temperature vary with these changes in the Earth's rotation, but other major climatic indices varied as well. These climatic indices included: changes in the atmospheric mass and pressure distribution; changes in the patterns of global wind circulation and velocity; variations in sea level; variations in the volumes of Arctic sea ice and snow accumulation at the South Pole; and variations of ice movements in the Weddell Sea. Lambeck and Cazeneve found that there is a time lag of between six and fifteen years between changes in the Earth's rotation and changes in the global temperature.

Lambeck and Cazenave (1976) found that:

> *The long-period (greater than about 10 yr) variations in the length-of-day (LoD) observed since 1820 show a marked similarity with variations observed in various climatic*

> *indices; periods of acceleration of the Earth corresponding to years of increasing intensity of the zonal circulation and to global-surface warming: periods of deceleration corresponding to years of decreasing zonal-circulation intensity and to a global decrease in surface temperatures. The long-period atmospheric excitation functions for near-surface geostrophic winds, for changes in the atmospheric mass distribution and for eustatic variations in sea level have been evaluated and correlate well with the observed changes in the LoD.*[11]

Lambeck and Cazenave (1976) argued that the cooling of the planet experienced in the 1960s and 1970s[12] arose from a slowing of the Earth's rotation in the 1950s. They wrote:

> *if the hypothesis* [that decadal rotation decrease (increase) results in planetary cooling (warming)] *is accepted, then the continuing deceleration of* [the rotating Earth] *for the last 10 yr suggests that the present period of decreasing average global temperature will continue for at least another 5-10 yr.*"[13] They added, *Perhaps a slight comfort in this gloomy trend is that in 1972 the LOD showed a sharp positive acceleration that has persisted until the present……*[14]

meaning that a period of global warming would begin around 1982/87.

A period of global warming began in the 1980s after a lengthy period of global cooling.

Lambeck and Cazenave (1976) comment further that:

> *Whatever mechanism is finally proposed it will have to explain the apparently significant lag that is found between the LoD and the various climatic indices, temperature and excitations. The interest of this lag suggests that the LoD observations can be used as an indicator of future climatic trends, in particular of the surface warmings.*[15]

Lambeck and Cazenave (1976) provided a broad overview of how decadal rotation variations over the period 1800 to 1950 changed ocean/atmospheric oscillations and thereby global and regional climates using results reported by Horace Lamb in his 1972 treatise, *Climate, present, past and future* (Lamb 1972). Lamb reported this pattern based on detailed observations of 150 years of climate data.

Lambeck and Cazenave (1976) summarised the patterns of global atmospheric circulation as follows:

> *Observations of climatic fluctuations during the last two centuries show two principal types of atmospheric circulation alternating typically every 20 - 40 years. The first type (type **I**) is characterized by an increasing intensity of the zonal circulation at all latitudes and with a poleward migration of the belts of maximum wind intensities. The circulation is accompanied by a decrease in the overall range of surface-air temperatures between the equator and the poles, and by an overall increase in the mean global surface-air temperatures. Ocean-surface temperatures also tend to increase at high latitudes. The type **II** circulation is characterized by a weakening of the zonal circulation, by a migration of the main streams to lower latitudes and by an overall decrease in temperature. For both types of circulation, the migration in latitude and the changing intensities are global phenomena, occurring at all longitudes and in the northern and southern hemispheres although the trends in different regions are not always in phase. Both easterly and westerly winds increase with the type **I** circulation, and both decrease during the type **II** circulation.*[16]

Lambeck and Cazenave (1976) explain how the decadal changes in the Earth's rotation (going faster/going slower) alter the Type I and II patterns of atmospheric circulation, resulting in periods of global warming and cooling. A central finding of Lambeck and Cazenave (1976) is that over a span of 150 years, when, on a decadal basis, the rotation of the Earth increased, then some 10 to 15 years later the planet warms; conversely, also on a decadal basis, when the rotation of the Earth decreased, some 10 to 15 years later the planet cools. They identify an interval of around

60 to 80 years between episodes of climate warming and cooling. That would suggest that the next episode of global cooling should begin around 2040/60.

In 1980, Cambridge University Press published Professor Lambeck's definitive treatise on the rotation of the Earth, *The Earth's Variable Rotation – Geophysical causes and consequences* (Lambeck 1980). This treatise is the standard text on this subject. On pages 275 to 285, Professor Lambeck summarises the findings and conclusions of his joint papers with Dr Cazenave. He included graphs of these findings, which are reproduced in Attachment B as Figures B1 and B2.

In relation to the central finding of Lambeck and Cazenave (1976), Professor Lambeck reported:

> *Cause and effect cannot be distinguished from this observation alone and three alternative hypotheses are possible:*
>
> *a) the atmospheric circulation causes long-period changes in LoD, as it does for periods of less than 2-3 year;*
>
> *b) the fluctuations in LoD and climatic change are both consequences of a third phenomenon;*
>
> *c) or the fluctuation in LoD causes the observed variations in the circulation.*[17]

Professor Lambeck examined the likelihood of these three alternatives and concluded:

> *If the correlations of the indices and of the atmospheric-oceanic excitation functions with* m_3[18] *are real, the second hypothesis (b) is the most convincing even if little quantitative information appears to be available to substantive it.*[19]

Having concluded that variations in climate and LoD are the consequences of a third phenomenon, Professor Lambeck reviewed likely candidates and concluded:

> *electromagnetic coupling of the mantle to fluid motions in the core appears to be the most plausible explanation of the decade variations in the LoD.*[20]

In 1982, Dr Cazenave, jointly with three French scientists[21], (Courtillot, Le Mouel, Ducruix and Cazenave (1982), (1983)), published a paper in the journal *Nature* that reported a correlation between variations in the Earth's magnetic field, the Earth's rotation rate and some climatic indicators, thus suggesting a long-term influence of motions of the Earth's core on the Earth's climate dynamics. Dr Cazenave and her colleagues reported that a high correlation had been demonstrated between variations in the LoD with periods of about 10 years and trends in several climatic indices over the past 150 year. Dr Cazenave and colleagues reported that scientists had found a high (and significant) correlation between geomagnetic secular variations and decadal LoD fluctuations in the records of European observatories where the longest records are available: 1865-1975. The correlation coefficient was found to be about 0.8, with the geomagnetic variations leading LoD fluctuations by about 10 yr.

Courtillot, Le Mouel, Ducruix and Cazenave (1982), (1983) reported that

> *The clearly established 1970 secular acceleration, which has now been maintained for a decade, suggests a correlated positive acceleration in the immediate future and the beginning of a period of steady increase in average global temperature around 1990 (+ or - yr).*

The IPCC ignored this well-established explanation for the global warming that the IPCC attributed erroneously to Carbon Dioxide.

De Michelis, Tozzi, and Meloni, (2005) repeated this finding in a review article published in the *Memorie della Società Astronomica Italiana*. The IPCC ignored this, as well.

Mouel et al. (1981) in a paper published in *Nature* reported a good correlation between secular variations of the Earth's magnetic field and variations in the Earth's rate of rotation. They measured secular variations of the Earth's magnetic field using variations in the declination of the Earth's magnetic field.[22]

Given the high correlation between geomagnetic variations and decadal LoD variations on the one hand, and the high correlation between decadal LoD fluctuations and several climatic indices on the other, the authors point out that there is, most likely, a long-term influence of core motions on climate.

The authors report that there was a sudden and sharp acceleration of global extent in the geomagnetic field around 1970. This acceleration had been maintained (at the time of the publication of the authors' paper, 1982) for a decade. Since there is lead-time of about 10 years between geomagnetic variations and decadal LoD variations and about 8 years between LoD variations and climatic variations[23], the authors suggest that a period of global warming would begin in the 1990s and continue beyond. Dr Cazenave and her colleagues suggest that geomagnetic secular variation can be used to forecast a climatic change.

5. Corroboration of Lambeck and Cazenave's findings

Since the publication of Lambeck and Cazenave (1976), Lambeck (1980) and Cazenave et al. (1982) a substantial volume of peer reviewed scientific studies about the relationship between decadal changes in the Earth's rotation and climate dynamics has been published. The challenge of identifying the 'third phenomenon' has also been the subject of substantial investigation, which is summarised in below.

Dr Nikolay Sidorenkov of the Hydrometcentre of Russian Federation summarised a good portion of published research about the relationship between decadal changes in the Earth's rotation and climate dynamics in his recently published book *The Interaction Between Earth's Rotation and Geophysical Processes* (Sidorenkov 2009).

Amongst other things, he concludes:[24]

> *We have shown that there are strong correlations between the decadal variations in the length of day, variations in the rate of westward drift of the geomagnetic eccentric diapole, and variations in certain climate characteristics (the increments of the Antarctic and Greenland ice sheets, anomalies of the atmospheric circulation regimes, the hemisphere-averaged air temperature, the Pacific Decadal Oscillation, etc)*.

Sidorenkov (2009) concluded that because long-term variations in LoD can now be determined with great accuracy, the many-year findings he and others have documented show that the long-term variations in LoD present a unique, nature-born integral index of global climate changes.

In 1990, Professor Rozelot (Rozelot and Spaute (1990)) found a high and significant correlation between the LoD time series maintained by the Bureau International de I'Heure in Paris and 13 sets of climatological data from around the world containing measures of air temperature. These sets included three sets (Mexico, Lisbon and England) of 100 years length; one from Paris of 200 years length; one from Central England of 300 years length; and one from Shanghai of 500 years length.

Jochmann and Greiner-Mai (1996) (1997) found that

> *the variation of the geomagnetic field indicates the temporal behaviour of the core process which influences the Earth's rotation via core-mantle coupling and independently those processes which possibly cause climate variations. A direct influence of the magnetic field on climate could not be proved until now.*

And

> *Since the variation of the geomagnetic parameters precede that of the climate parameters, it may be supposed that geomagnetic variations could serve as indicators of natural climate change.*

And

> *So it can be concluded that the variation of the geomagnetic field indicates the temporal behaviour of the core process which influences the Earth's rotation via core-mantle coupling and independently those processes which possibly cause climate variations. A direct influence of the magnetic field on climate could not be proved until now.*

In 1999, the National Report of the Federal Republic of Germany about geodetic activities in the years 1995 to 1999 summarised much of the work of Professor Jochmann and Dr Greiner-Mai. The Report concluded that Jochmann and Greiner-Mai showed that the Earth's climate cycles are related more to core dynamics than to atmospheric circulation.[25]

In 2007, Professor Paul Roberts,[26] and colleagues (Roberts, et al. (2007)) established that there is 60-year period in the LoD, strong evidence for a very similar periodicity in the geomagnetic signal. They found that the geomagnetic change comes before the LoD variation by about 8 years.

In 2011, Dr Jean O Dickey[27] and colleagues published a paper in the *Journal of Climate* issued by the American Meteorological Society (Dickey et al. 2011) that confirmed the findings of Lambeck and Cazenave, Sidorenkov and Roberts. Dickey et al. (2011) analysed better quality global temperature time series and better-quality time series of the Earth rotation measures than those available to Lambeck and Cazenave in the 1970s.

The global surface temperature time series covered the period from 1850 to 2005; the Earth rotation time series covered the period from 1832 to 2004. Dickey et al. (2011) found that the global surface temperature increased following an increase in the rotational speed of the Earth; the global temperature decreased following a decrease in the speed of the Earth's rotation. Dickey et al. (2011) found that the time lag between changes in the Earth's rotational speed and surface temperature was 8 years rather than the 10 to 15 years reported by Lambeck and Cazenave or the 5 years reported by Dr Cazenave and her colleagues in 1982.

Dickey et al. (2011) reported extensive evidence that there is a period in the 60 to 80 year range between episodes of climate warming and cooling, corroborating the finding of Lambeck and Cazenave.

In 2016, three scientists (Zotov et al. (2016))[28] published a paper corroborating the findings of Dickey et al. (2011), Sidorenkov, Lambeck and Cazenave: that, on a decadal basis, as the Earth rotates faster, (i.e. LoD shortens) the planet warms; in contrast, as the Earth rotates slower (i.e. LoD lengthens,) the planet cools. The three scientists also confirmed the 60-year range between episodes of climate warming and cooling, but did not estimate the time lag between changes in the speed of rotation and changes in global temperature.

In 2016, Dr Steven Marcus, one of the co-authors of Dickey et al. (2011) repeated the analysis in Dickey et al. (2011) using more extensive data bases published by IPCC scientists and the UK Met Office Hadley Centre (Marcus 2016). Marcus (2016) found more evidence corroborating the theory of an Earth core-to-climate, one-way chain of causality. According to this theory - for which there is substantial evidence and analysis - multidecadal episodes of global warming and cooling arise from an internally generated, core-to-climate process imprinted on both the climate and Earth's rotational rate.

6. Earth's Decadal Rotation Variations driven by electromagnetic coupling of the mantle to fluid motions in the core

In his treatise, Lambeck (1980), Professor Lambeck concluded that the most plausible explanation of the decade variations in the Earth's rotation is electromagnetic coupling of the mantle to fluid motions in the core.[29]

Dickey et al. (2011) concluded that the same core processes that are known to affect Earth's rotation and magnetic field are likely to contribute to the excitation of the multidecadal climatic modes of global warming and cooling they document. Dickey et al. (2011) suggested that this could happen through geomagnetic modulation of near-Earth charged-particle fluxes that may influence cloud nucleation processes, and hence the planetary albedo, on regional as well as global scales.

Cazenave et al. (1982) noted that Professor Lambeck considered that the role of the Earth's core is central to a satisfactory explanation of the Earth's decadal rotation because it is the only sufficiently mobile part of the Earth with sufficient mass to modify the Earth's rotation by the observed amounts on that time scale. Furthermore, the authors explain, out of the range of mechanisms by which the required core-mantle coupling could occur, only electromagnetic core-mantle coupling survives the screening process despite severe uncertainties regarding the conductivity of the lower mantle and the core motions.

There is significant evidence that electromagnetic core-mantle coupling is the result of irregular magnetohydrodynamic[30] flow in the Earth's liquid metallic core. This irregular flow is a result of mechanical processes (such as tidal processes) and/or electromagnetic induction. As the electrically conducting metallic fluid core sloshes about, as it were, it interacts with the ambient magnetic field, generating additional electric currents and magnetic fields that in turn reinforce the ambient magnetic field.

Figure 2 is a cutaway diagram showing the layers of Earth from the crust to the inner core. The torsional waves (TW) in the core are shown in red.

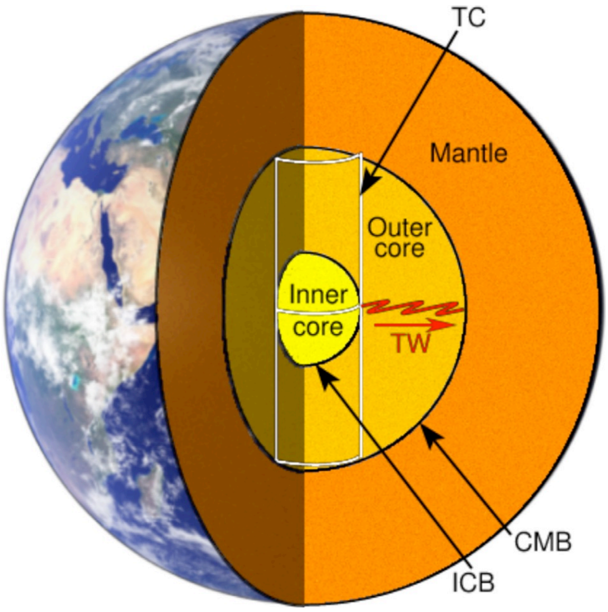

Figure 2. Schematic of torsional waves in the core. A cutaway diagram showing the layers of Earth from the crust to the inner core. Solid white lines show the location of the imaginary 'tangent cylinder' (TC), running vertically from pole-to-pole in the outer core and circumscribing the inner core. The red line indicates the possible trajectory of a torsional wave (TW) in the outer core from the inner core boundary (ICB) to the core–mantle boundary (CMB). The transverse torsional wave propagates radially from the TC to the CMB with its oscillations in the azimuthal direction. From Teed, et al. (2019)

In 1976, Professor Vincent Courtillot and Professor Jean-Louis Le Mouël, reported (Courtillot and Le Mouël 1976) that in 1969 there had been a sudden worldwide change in the dynamics of the Earth's magnetic field. These sudden changes are now referred to as geodynamic jerks. Geophysicists have established that these sudden changes occur roughly every ten years. There is considerable evidence that Alfvén torsional waves[31] are responsible for the geomagnetic jerks and the decade variations in the LoD (Jault 2003). There is also evidence (Lopes et al. 2021) that the aggregate joint gravitational forces of the Sun, Moon and planets regulate the Alfvén torsional waves, and, as a result, decadal variations in the LoD and the resultant episodes of global warming/global cooling. There are time lags between the principal events: some 8 years after the abrupt change to the Alfvén torsional waves, the Earth's decadal rotation changes – speeding up or slowing down; some 8 years after the change in LoD, the global temperature changes – if the Earth speeds up, the planet warms up, if the Earth slows down, the planet cools down. The cycles of global warming and cooling repeat every sixty years.

In 2019 Aleksander Tolstikov, Head of the measurement of time, frequency and determination of Earth rotation parameters, Federal State Unitary Enterprise All-Russian Research Institute of Metrology, and colleagues (Tolstikov et al. 2019) reported that in 2024 the Earth's rotation would go into a deceleration phase until 2032. As a result, the global climate warming observed from the beginning of the 20th century will most likely transition to a global climate cooling from the middle of the next decade.

In 2020 Leonid Zotov, Christian Bizouard, Nikolay Sidorenkov (Zotov et al. 2020) reported the same finding. In the near future, the Earth's rate of rotation will slow down and the LoD will lengthen. This means that the Earth will enter a period of global cooling.

The development of knowledge about reasons for the decadal variations in the Earth's rotation and the global warming/cooling that accompanies rotation variations is an active area of scientific inquiry. The major working hypothesis is about some form of coupling between inner core, the outer core and the mantle.

The preferred type of coupling is electromagnetic, but the precise form is the subject of intense investigation, as are the reasons for variations of LoD of between three and five milliseconds. Strong evidence points to gravitational forces driving the electromagnetic coupling.

5. Earth decadal rotation and seismic activity

Bostrom (2000)) points out that Sir George Darwin (1845 – 1912) in 1879, Professor Alfred Wegener (1880 – 1930) in 1915 and Professor John Joly (1857 – 1933) in 1925 had all proposed a connection between the Earth's rotation and displacements in the Earth's crust. However, Sir Harold Jeffreys (1881 – 1989) opposed it, just as he strongly and stubbornly opposed the theory of continental drift. Sir Harold Jeffreys' forceful opposition to a relationship between the Earth's rotation and crustal displacements dominated Geophysics throughout the first half of the 20th Century. According to Bostrom:

> *Perhaps more than most fields, research as to the relation between the Earth's deformation and its rotation has been characterised by dominant personalities. This may be because it is hard to explore such disparate areas as Astronomy and Geology.*[32]

In 1969, Dr. Nicolas Stoyko (1894 -1976) Chief Administrator, International Time Bureau, Paris Observatory (1942 -1969) and his wife Anna, also employed at the Bureau, reported a significant correlation between LoD variations and seismic activity (Stoyko, A and Stoyka, N (1969).

In 1974, the distinguished American Geologist, Professor Don Anderson (1933 – 2014) reported a striking correlation between the decadal variations in the Earth's rotation and global seismic and volcanic activity (Anderson 1974). Professor Anderson explained that since the Earth's crust and upper mantle stored a large amount of elastic energy because of rotational processes, a small perturbation in the rotational parameters is a probable trigger of global seismic activity.

Since Professor Anderson's finding, many scientists have reported the correlation, with more detailed explanations published in recent years. For example, in 1995, Da-Wei Zheng & Yong-Hong Zhou of the Shanghai Observatory, Chinese Academy of Sciences (Zheng and Zhou 1995) reported a correlation between decadal rotation variations and global seismic activity similar to that found by Professor Anderson. They explained the causative role of the decadal rotation variations in inducing seismic events that is similar to that of Professor Anderson. Gokhberga et al. (2016) reported findings that corroborate Zheng and Zhou (1995).

Scafetta and Mazzarella (2015) found that large earthquakes are highly likely to be triggered by crust deformations induced by, and/or linked to climatic and oceanic oscillations induced by astronomical forcings, which also regulate the LoD.

In 2017, Roger Bendick and Rebecca Bilham (Bendick and Bilham 2017) report that large earthquakes synchronize globally in the manner of integrate-and-fire oscillators most likely through a self-organizing process. They use the relatively new method of quantitative analysis known as topological data analysis to reveal the pattern of synchronisation. The elastic properties of the crust, asthenosphere and mantle provide the underlying mechanical coupling required for synchronization. Bilham and Bendick (2017) outline a way that decadal rotational fluctuations trigger the earthquakes that is similar to that suggested by Anderson in 1974. In particular, large earthquakes synchronize globally, and occur in groups in response to very low stress interactions such as that provided by abrupt changes in the Earth's decadal rotation. They found that earthquake activity clusters into peek activity approximately every 32 years. This peek happens five years after the Earth's decadal rotation variation reaches its slowest rate.

They wrote

> *On five occasions in the past century, a 25-30% increase in annual numbers of Mw≥7 earthquakes has coincided with a slowing in the mean rotation velocity of the Earth, with a corresponding decrease at times when the length-of-day (LoD) is short. The correlation between Earth's angular deceleration (d[LoD]/dt) and global seismic productivity is yet more striking and can be shown to precede seismicity by 5-6 years, permitting societies at risk from earthquakes an unexpected glimpse of future seismic hazard.*
>
> *The cause of Earth's variable rotation is the exchange of angular momentum between the solid and fluid Earth (atmospheres, oceans and outer core). Maximum LoD is preceded by an angular deceleration of the Earth by 6-8 years. We show delayed (increase in) global seismic productivity is most pronounced at equatorial latitudes 10°N-30°S.*
>
> *The observed relationship is unable to indicate precisely when and where these future earthquakes will occur, although we note that most of the additional Mw>7 earthquakes have historically occurred near the equator in the West and East Indies. A striking example is that since 1900 more than 80% of all M≥7 earthquakes on the eastern Caribbean plate boundary have occurred 5 years following a maximum deceleration (including the 2010 Haiti earthquake).*
>
> *The 5-6 year advanced warning of increased seismic hazards afforded by the first derivative of the LoD is fortuitous and has utility in disaster planning. The year 2017 marks six years following a deceleration episode that commenced in 2011, suggesting that the world has now entered a period of enhanced global seismic productivity with a duration of at least five years.*

Figure 3 below is Figure 4 in Bendick and Bilham (2017). It shows the relationship between changes in the Earth's rotation rate and the occurrence of large (Mw ≥ 7) earthquakes.

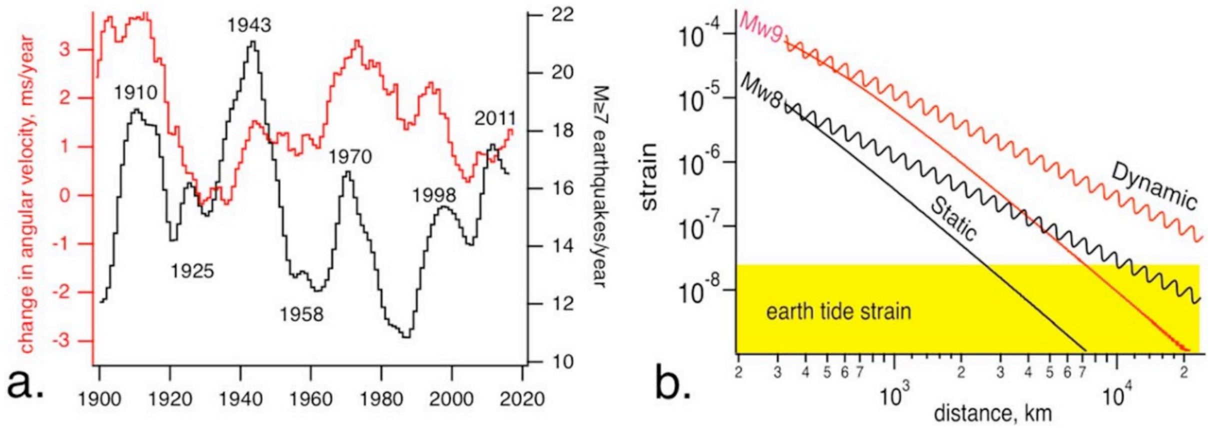

Figure 3. (a) Changes in the LoD (Gross et al., (2004)) correlate with decadal fluctuations in annual M ≥ 7 earthquakes (Anderson 1974; Shanker et al. 2001) (smoothed with 10 year running mean). Peak seismic activity and rotational acceleration occur at 15, 33, 60, and 88 years intervals. (b) Static (Press 1965) and dynamic (Agnew and Wyatt 2014) strain from distant Mw = 8 and Mw = 9 earthquakes exceed earth tide strain amplitudes at distances of 2500–30,000 km. Distances between plate boundaries are typically 1000–12,000 km; hence, the largest of Earth's earthquakes provides the weak force required for hemispheric synchronization. Source: Bendick and Bilham (2017).

In 2020, Alexey Lyubushin of the Institute of Physics of the Earth, Russian Academy of Sciences, Moscow, Russia, outlined a statistical methodology to construct 50 clusters of the world's seismic stations (Lyubushin 2020). He reported that a pattern is emerging that suggests that there will be in the near future, a small number of very large earthquakes, rather than a large number of small earthquakes. His analysis indicates that the next big earthquake will have a magnitude of 10 and occur in Nankai Trough south of Tokyo. He found that the decadal variations in the Earth rotation to be the determinant of this pattern and that an abrupt change in the rotation rate will induce the Earthquake.[33] According to conventional seismology, there is a 70-80% chance that a Nankai Trough megathrust earthquake will occur in the next 30 years.[34]

6. Measurement of global temperature

There are differences in the validity and reliability of the measures of temperature used in the three papers that establish the relationship between the changes in the Earth's decadal rate of rotation and climate dynamics. The examination of these differences will help establish the validity of the relationship.

Lambeck and Cazenave (1976) used actual measures of global temperature compiled by the National Center for Atmospheric Research (NCAR), Boulder, Colorado together with global temperature time series compiled by the American climatologist, J Murray Mitchell (1928 to 1990) (Mitchell 1970, 1961, 1953).

In the papers cited, Mitchell records the many shortcomings in the validity and reliability of the measures of temperature taken over the period he studied, 1860 to 1969. These included the use of different measuring instruments; instruments lacking standardised calibration; the encroachment of cities and airports; changes in the types of thermometers used; changes in the use and design of thermometer shelters; the accumulation of dirt on thermometers and their shelters; changes in methods of calibration; changes in the method of computing means; major changes in sites. Mitchell (and others) have pointed out that until the establishment of the Intergovernmental Panel for Climate Change (IPCC) all temperature-measuring methodologies were designed to measure temperature in relation to changes in the weather - not changes in the climate.

Lambeck and Cazenave (1976) were aware of the shortcomings of the temperature time-series. Nevertheless, the data they used was the best available. Even with its shortcomings, the analysis reported by Lambeck and Cazenave revealed a strong relationship between variations in the Earth's rate of rotation – on a decadal basis – and variations in global temperature over the period 1820 to 1970. They also predicted correctly that a period of global warming would begin in the early 1980s. Scientists who have examined this relationship independently of Lambeck and Cazenave have found the same relationship.

In contrast, Dickey et al. (2011) used the yearly mean values of the global average surface temperature, available from the Goddard Institute for Space Studies (GISS) temperature series since 1880 (known as GISTEMP) and from the Meteorological Office Hadley Centre–University of East Anglia Climatic Research Unit temperature series since 1850 (known as HadCRUT3).

The shortcomings of both sets of data (GISTEMP and HadCRUT3) have been documented extensively. For example, in 2010 Ross McKitrick, Professor of Economics, University of Guelph, Guelph Ontario Canada, published a critical review of global surface temperature data products on the Social Science Research Network (SSRN) (McKitrick 2010).

Professor McKitrick reported that

> *There are three main global temperature histories: the combined CRU-Hadley record (HADCRU), the NASA-GISS (GISTEMP) record, and the NOAA record. All three global averages depend on the same underlying land data archive, the Global Historical Climatology Network (GHCN). CRU and GISS supplement it with a small amount of additional data. Because of this reliance on GHCN, its quality deficiencies will constrain the quality of all derived products. The number of weather stations providing data to GHCN plunged in 1990 and again in 2005. The sample size has fallen by over 75% from its peak in the early 1970s and is now smaller than at any time since 1919. The collapse in sample size has not been spatially uniform. It has increased the relative fraction of data coming from airports to about 50 percent (up from about 30 percent in the 1970s). It has also reduced the average latitude of source data and removed relatively more high-altitude monitoring sites. GHCN applies adjustments to try and correct for sampling discontinuities. These have tended to increase the warming trend over the 20th century. After 1990, the magnitude of the adjustments (positive and negative) gets implausibly large. CRU has stated that about 98 percent of its input data are from GHCN. GISS also relies on GHCN with some additional US data from the USHCN network, and some additional Antarctic data sources. NOAA relies entirely on the GHCN network. …. The quality of data over land, namely the raw temperature data in GHCN, depends on the validity of adjustments for known problems due to urbanization and land-use change. The adequacy of these adjustments has been tested in three different ways, with two of the three finding evidence that they do not suffice to remove warming biases. The overall conclusion of this report is that there are serious quality problems in the surface temperature data sets that call into question whether the global temperature history, especially over land, can be considered both continuous and precise. Users should be aware of these limitations, especially in policy sensitive applications.*

Professor McKitrick found that

> *All three global products rely on sea surface temperature (SST) series derived from the archive of the International Comprehensive Ocean-Atmosphere Data Set (ICOADS, http://icoads.noaa.gov), though the Hadley Centre switched to a real time network source after 1998, which may have caused a jump in that series. Oceanic data are based on SST rather than marine air temperature (MAT). ICOADS observations were primarily obtained from ships that voluntarily monitored SST. Prior to the post-war era, coverage of the southern oceans and polar regions was very thin. Coverage has improved partly due to deployment of buoys, as well as use of satellites to support extrapolation. Ship-based readings changed over the 20th century from bucket-and-thermometer to engine-intake methods, leading to a warm bias as the new readings displaced the old. Until recently, it was assumed that bucket methods disappeared after 1941, but this is now believed not*

> *to be the case, which may necessitate a major revision to the 20th century ocean record. Adjustments for equipment changes, trends in ship height, etc., have been large and are subject to continuing uncertainties. Relatively few studies have compared SST and MAT in places where both are available. There is evidence that SST trends overstate nearby MAT trends. ICOADS draws upon a massive collection of input data, but it should be noted that there are serious problems arising from changes in spatial coverage, observational instruments and measurement times, ship size and speed, and so forth. ICOADS is, in effect, a very large collection of problematic data.*

As part of his PhD thesis at James Cook University, John McLean (2017) documented widespread shortcomings in HadCRUT4 (and HadCRUT3). McLean (2017) conducted the first publicly reported audit of the HadCRUT databases. He concluded, amongst other things, that

> *Data prior to 1950 suffers from poor coverage and very likely multiple incorrect adjustments of station data. Data since that year has better coverage but still has the problem of data adjustments and a host of other issues mentioned in the audit.The primary conclusion of the audit is however that the dataset shows exaggerated warming and that global averages are far less certain than have been claimed. Another implication is that the proposal that the Paris Climate Agreement adopt 1850-1899 averages as "indicative" of pre-industrial temperatures is fatally flawed. During that period global coverage is low – it averages 30% across that time – and many land-based temperatures are very likely to be excessively adjusted and therefore incorrect. A third implication is that even if the IPCC's claim that mankind has caused the majority of warming since 1950 is correct then the amount of such warming over what is almost 70 years could well be negligible. .... Ultimately it is the opinion of this author that the HadCRUT4 data, and any reports or claims based on it, do not form a credible basis for government policy on climate or for international agreements about supposed causes of climate change.*

McKitrick (2010) and McLean (2017) found a greater variety of data quality shortcomings, including more significant shortcomings, than those documented by Mitchell (1953) and Mitchell (1961). These findings mean that the shortcomings reported by Mitchell from 1953 onwards and by Willett (1950) had not been addressed by the relevant authorities.[35] McKitrick (2010) and McLean (2017) find that, amongst other things, the shortcomings in the HadCRUT and GISTEMP data result in both sets of data exaggerating any global warming. The IPCC's second, third, fourth and fifth assessment reports, published in 1995, 2001, 2007 and 2014 respectively, projected global temperature increases that greatly exceeded those that occurred from 1995 onwards.

Since the start of routine satellite temperature observations in 1979, there has been conflict between the temperature records compiled in HADCRUT and GISTEMP records on the one hand and the temperature record derived from the Microwave Sounding Units on satellites, on the other. Thorne et al. (2010) reviewed these controversies and produced a 'best estimate' of temperature trends from 1979 to 2009. Professor Peter Thorne is one of the lead authors of the IPCC's *Fifth Assessment Report*, published in 2014.

Figure 4 below shows the best estimate of temperature trends from 1979 to 2008 derived by Thorne et al. (2010):

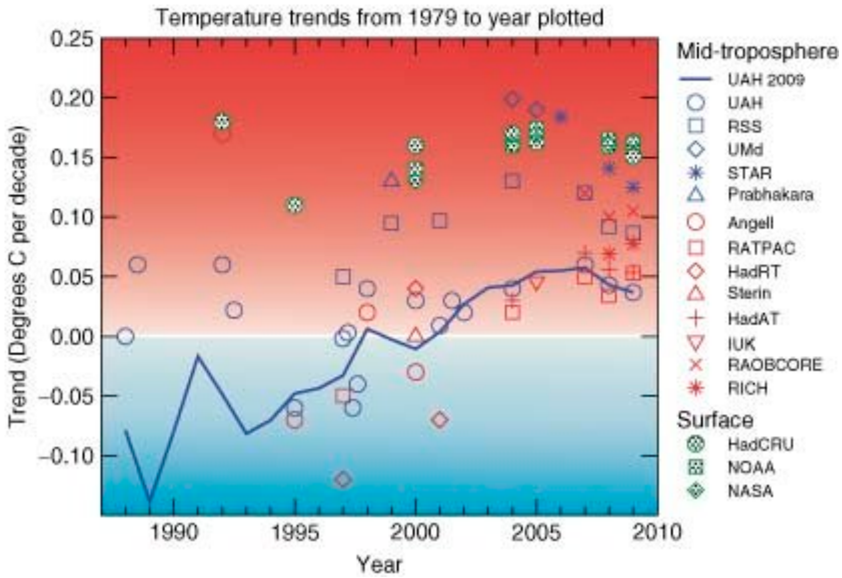

Figure 4. Evolution of estimates of observed trends in global-mean mid-troposphere and surface temperatures during the satellite era (since 1979), based on satellite (blue), radiosonde (red) and land/SST (green) observations. Symbols show trends for 1979 to the year plotted, as reported in the literature, except for 1979–2008 trends, which were calculated for Thorne et al. (2010). The acronyms listed on the right hand side are defined in Attachment C (page 156). Source: Thorne et al. (2010).

The blue line shows trends from the September 2009 version of University of Alabama in Huntsville (UAH) data for each year. Differences between this line and the UAH published estimates (blue circles) illustrate the degree of change in the different versions of this dataset.

Thorne et al. (2010) concluded that the satellite-based temperature published by University of Alabama in Huntsville has greater reliability and validity than the HADCRUT and GISTEMP records. That is to say, the blue line in the graph above is the most accurate record of global warming from 1990 to 2008. The most recent UAH Global Temperature Report April 2023 is:

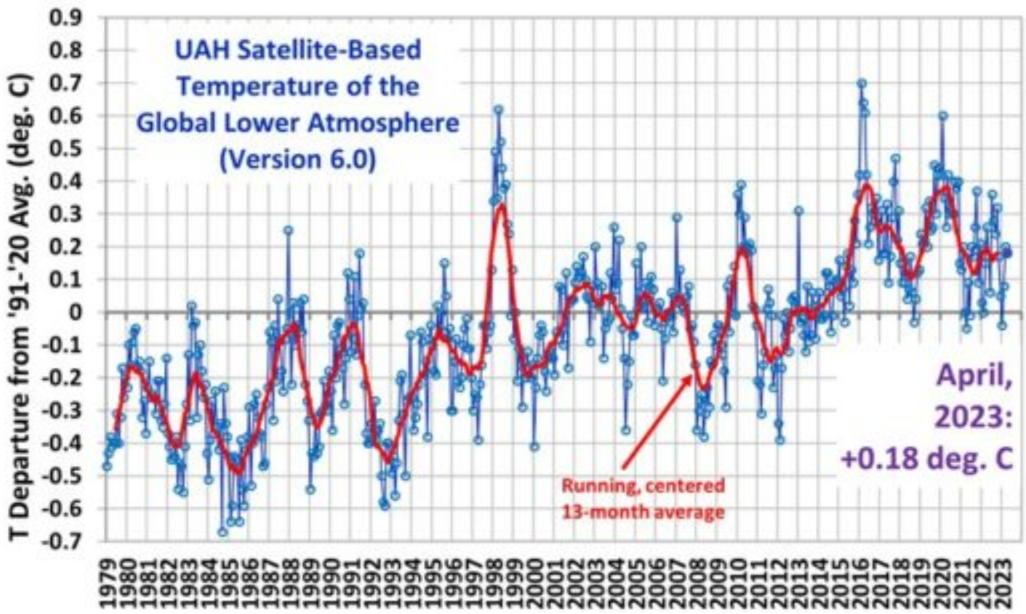

Figure 5. The linear warming trend since January 1979 remains at +0.13 C/decade (+0.11 C/decade over the global-averaged oceans, and +0.18 C/decade over global-averaged land. Source: UAH Global Temperature Report available here - [UAH Global Temperature Update for April, 2023: +0.18 deg. C - Roy Spencer, PhD. (drroyspencer.com)]

The following is drawn from Dr Spencer's website:

The global atmospheric temperature in April was very close to that of March, being only -0.02 °C cooler at +0.18°C (+0.32°F) above the 30-year average. The La Niña that has influenced global temperatures for almost three years has ended as the tropical atmospheric temperature shows a near zero departure from average (-0.03°C). Compared with March, the April NH temperatures cooled a bit and the SH temperatures warmed by almost the same amount, leaving the total global change, as noted, to be near zero. The atmosphere takes about 2 to 5 months to reflect major changes in the tropical sea water temperatures, so we can expect generally rising air temperature anomalies from now through the boreal winter in 2024 since the tropical Pacific sea water temperatures are warming rapidly. The sea is expected to warm as NOAA has declared an El Niño Watch, indicating high confidence that a warm phase tropical Pacific event is in the near future.

The planet's warmest spot in April occurred over western East Antarctica near the Princess Martha Coast with a departure from average of +4.4 °C (+7.9 °F). Warmer than average temperatures were felt from the North Pacific northwestward through eastern Russia, as well as a band from Quebec to Greenland to the Svalbard Islands then south through western Russia. Spain was warmer than average as was East Antarctica to New Zealand. With a reading of -3.2°C (-5.7°F) the coolest departure from average could be found over western Alaska near Kaltag. Another region of very cool air resided over central Russia, lying between warm areas to the east and west. North Africa eastward to India was cool as was the North Atlantic and central Europe. Much of the conterminous US was slightly below average giving a 48-state average of -0.38°C (-0.68°F). Alaska was even cooler than that, so with Alaska, the 49-state average fell to -0.66 °C (-1.19°F). Microsoft Word - GTR_202304APR_1.docx (uah.edu)

Attachment D is Dr Spencer's analysis of Australia's surface temperatures as recorded by Australia's Bureau of Meteorology (BoM) and compared to UAH Satellite data over the last 40 Years.

In contrast, the latest GISTEMP global average surface temperature graphs are:

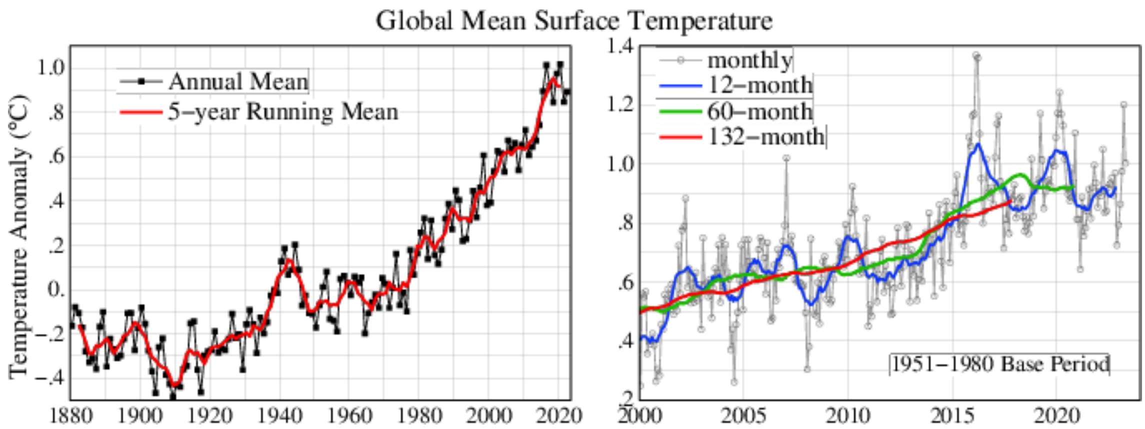

Figure 6. The latest GISTEMP global average surface temp graphs Global Temperature (columbia.edu)

Please note that there are crucial differences in the ordinate and abscissa scales used within Figure 6 and between Figures 5 and 4.

The following account is derived from Data.GISS: GISTEMP HISTORY (nasa.gov) and the articles cited therein:

The two ordinates in Figure 6 are different. In the left-hand graph, the ordinate is a temperature anomaly in of 1.4° C ranging from -.4°C to 1.0°C, each ordinate grid being 0.1°C. The anomaly is calculated by a complicated statistical methodology developed in 1981, revised in 1987 and regularly ever since. The anomaly is a statistical construct formed by combining data from many data points for a designated area and constructing a single derived anomaly by reference to the base year 1880. In the right-hand graph the ordinate is a temperature anomaly in of 1.4°C ranging from 0.2°C to 1.4°C, each ordinate grid being 0.1°C. The anomaly in this graph is a derived construction similar to the anomaly in the right –hand graph except it is constructed by reference to temperatures constructed for base year period of 1951 to 1980. The derived constructions in the ordinates of Figure 6 are complex constructions which include several untested assumptions and data of questionable quality as revealed elsewhere in this paper. The two abscissae in Figure 6 are also different. In the left-hand graph the abscissa is the years 1880 to 2020, each abscissa grid being 10 years. In the left-hand graph the abscissa is the years 2000 to 2025, each abscissa grid being 5 years. Further detail about these methodologies may be found at Data.GISS: GISTEMP HISTORY (nasa.gov).

The following account is derived from Microsoft Word - GTR_202304APR_1.docx (uah.edu).

In Figure 5 the ordinate is a temperature anomaly in of 1.6ºC ranging from -0.7ºC to +0.9ºC each ordinate grid being 0.1ºC. The anomaly is a straightforward calculation of the difference between the average temperature of the years 1991 to 2000 and the temperature measured for a particular year from 1979 onwards. In Figure 5 the abscissa is the years 1979 to 2023 each abscissa grid being one year. Further detail about the methodologies may be found at Microsoft Word - GTR_202304APR_1.docx (uah.edu).

Since 2013 several prominent scientists, including several who have been prominent as lead authors of IPCC Assessment Reports, Methodology Reports, Special Reports, Technical Papers, and/or Working Group reports, have published papers reporting that over the period 1995 to 2014 the rate of global mean warming has been lower than the IPCC projected.

In other words, since 1995 the IPCC's climate models projected significantly more warming than has been observed.

For example, in 2013, Otto et al. (2013) reported:

> *The rate of global mean warming has been lower over the past decade than previously.*

Almost all of the 17 authors of this paper are prominent IPCC scientists; for example, 11 are lead authors of IPCC reports. Another co-author, Professor John Church, is a professor with the University of New South Wales' Climate Change Research Centre; was a project leader at CSIRO until 2016. Another co-author is Professor Friederike Otto, who in 2020, became one of 10 international climate scientists to join the core writing team of the IPCC *Synthesis Report of the Sixth Assessment Report* published in April 2022.

In 2014, Schmidt et al. (2014) reported:

> *Climate models projected stronger warming over the past 15 years than has been seen in observations.*

Dr Gavin Schmidt, the principal author, is the Director of the NASA Goddard Institute for Space Studies and a contributing author of the IPCC's *Fourth Assessment Report*. Professor Drew Shindell, one of the joint authors, was a lead author for one of the IPCC's reports.

In 2021, Po-Chedley et al. (2021) reported that climate models have, on average, simulated substantially more tropical tropospheric warming than satellite data, with few simulations matching observations.

Dr Ben Santer, the senior co-author of Po-Chedley et al. (2021), is a climate researcher at Lawrence Livermore National Laboratory and the convening lead author of Chapter 8 (*Detection of Climate Change and Attribution of Causes*) of the 1995 IPCC Working Group I Report *The Physical Science Basis*.

The papers cited above, and the many to which they refer, highlight the inadequacies of the IPCC's quantitative simulations of climate dynamics to portray climate dynamics with sufficient reliability and validity: the simulations exaggerate temperature increases.

The controversies reviewed highlight a central problem: the IPCC's quantitative simulations are not based on a sound theory of climate dynamics.[36]

A sound theory would examine all independent variables and delineate their relationships and dynamics over time with each other and with the dependent variable, the Earth's climate.

The IPCC's quantitative simulations are designed on the basis that the climate system is in a natural state of energy balance, and that there is no long-term climate change unless humans cause it by the emission of Carbon Dioxide. Climate scientists generally, in their published work, seem unable to explain climate dynamics independently of the IPCC's quantitative simulations.

In Dickey et al. (2011) the authors, using GISTEMP and HadCRUT time series, assumed that

> *in the last few decades, in particular, a robust global warming has been observed and is attributed to increasing anthropogenic greenhouse gases (Hansen et al. 1999).*
> and that *anthropogenic effects have significantly altered Earth's climate since the start of the industrial revolution (Solomon et al. 2007)* (i.e. the IPCC report, *Climate Change 2007: The Physical Science Basis)*.

As a result, they correct for these by removing estimated and hypothetical anthropogenic temperature change as specified by appropriately forced runs of coupled atmosphere–ocean general circulation models. Marcus (2016) does the same.

Figure 7 shows the graph of Hansen time series **(black line),** now known to be false.

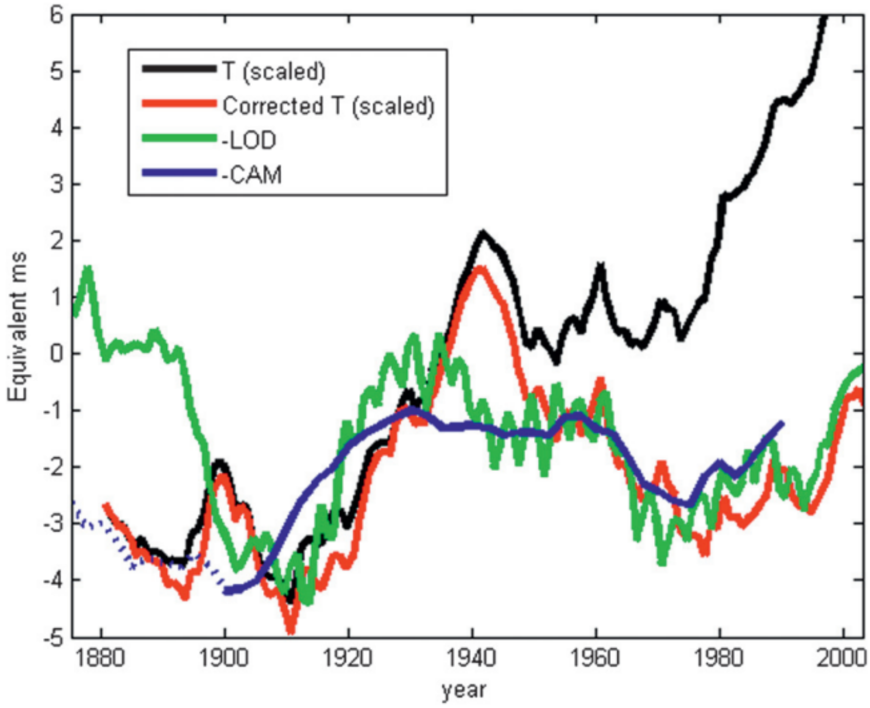

Figure 7. Time series of the surface air temperature, from Dickey et al. (2011). Note the two vertical axis: the left side is time in milliseconds; the right side is temperature; the unit is 0.1 degrees Celsius. Source: Dickey et al. (2011), page 570.

The **black line** is the global temperature estimates calculated by James Hanson in 2007 and used by the IPCC. The estimates are now known to be far too high. The temperature axis is the right-hand side vertical. The red line is the result of removing from the Hanson estimates the component estimated to be hypothetical warming arising from Carbon Dioxide. The red line therefore consists of estimates of the global temperature in the absence of any hypothetical Carbon Dioxide warming effect. The green line is the LoD and therefore a measure of the Earth's rotation. The blue line is the angular momentum of the Earth's core – that is, the rate at which the core spins around - in equivalent milliseconds.

Since it has been established that the global temperatures projected in Hansen et al. (2007) and in the IPCC reports, including Solomon et al. (2007), have been greatly exaggerated, it is not necessary to do the correction.

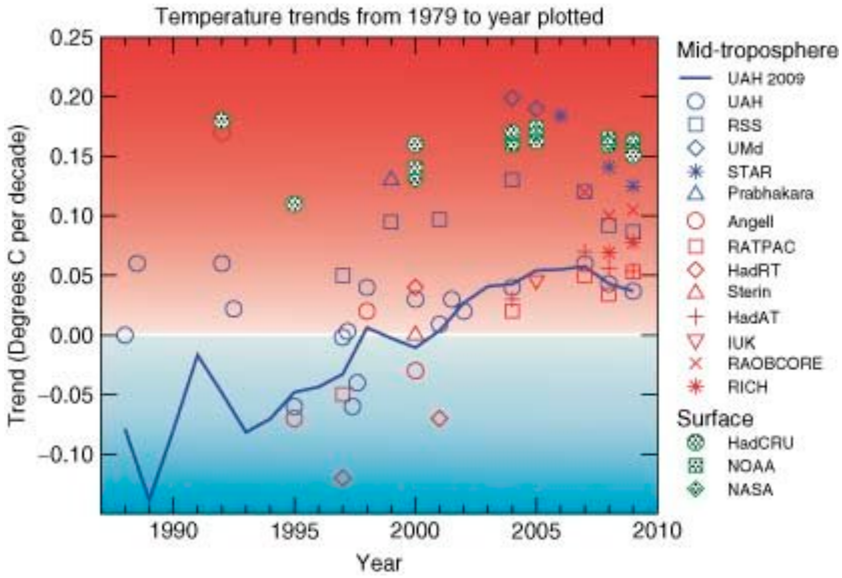

Figure 8. This is the same as Figure 4. It shows the best estimate of temperature trends from 1979 to 2008 derived by Professor Peter Thorne, a lead author of the IPCC's Fifth Assessment Report. The blue line in this Figure (Figure 8) relates to the red line in Figure 7: it is what the red line in Figure 7 should have been. The red line in Figure 7 is the Dickey graph of the 'corrected' Hansen et al. 2007 time series. The acronyms listed on the right hand side are defined in Attachment C (page 156). Source: Thorne et al. (2010).

Had Dickey et al. (2011) used the UAH 2009 time series – the blue line in Figure 8 – they would have concluded that almost all the global warming experienced by the Earth since the mid 1990s was a result of a decadal increase in the speed with which the Earth rotates. As will be explained further, there has been no global warming that could be attributed to Carbon Dioxide, once all other factors are considered.

Zotov et al. (2016) used three sets of data about the Earth's climate: (i) the global Earth temperature time series (land and sea surface) published by the Hadley Centre, HadCRUT4; (ii) A global mean sea level time series constructed by CSIRO for the period 1880 to 2009 (see Church and White (2008)); and (iii) another global mean sea level time series constructed by Jevrejeva et al. (2008) for the period 1700 to 2002. Zotov et al. (2016) refers to the CSIRO sea level time series as GMSL A (**G**lobal **M**ean **S**ea **L**evel) and the other as GMSL B.

Before applying a statistical methodology to the analysis of these time series to discover if there is evidence of an impact of the Earth's decadal rotation variations on the Earth's climate, Zotov et al. (2016) removed a hypothetical CO_2 warming trend from the HadCRUT4, GMSL A and GMSL B time series. The analysis applied to the use of HadCRUT and GISTEMP data by Dickey et al. (2011) applies, *mutatis mutandis*, to the use of HadCRUT4 data by Zotov et al. (2016). In relation to GMSL A and B, Baart et al. (2012a) and (2012b) found that there is no evidence of a CO_2 warming trend in global sea level time series. In addition, Watson (2020) found that there is no evidence of a CO_2 warming trend in Australia's sea level time series.

Had Zotov et al. (2016) used the UAH 2009 time series – the blue line in Figure 8– and had they not assumed – incorrectly – a hypothetical Carbon Dioxide warming trend in global sea level time series, they would have concluded that almost all the global warming experienced by the Earth since the mid 1990s was a result of a decadal increase in the speed with which the Earth rotates.

As explained below, there has been no global warming that could be attributed to Carbon Dioxide, once all other factors are considered.

There is also significant work-in-progress to explain the:

- global warming/cooling connected to Earth rotation variations and
- time lag of about eight years between changes in the Earth's rotational speed and surface temperature
- time lag of about eight years between the electromagnetic event that results in Earth rotation variations and the rotation variations happening.

7. Other determinants of climate dynamics

Over the last several decades, scientists from several disciplines have published in many of the world's leading scientific journals abundant evidence about the key determinants of climate dynamics. The most significant determinant is the Sun. The Sun influences climate dynamics in several ways, specifically the:

- Sun's:
    - output of radiation,
    - output of matter,
    - electromagnetic field,
    - gravitational fields,
    - shape; and
- topological structure of the heliosphere.

There are also significant effects from interactions between these.

The climate also depends on a number of subsystems of which the climate system is composed - principally the Earth's:

- atmospheric systems;
- ocean systems;
- coupled atmospheric-oceanic systems;
- clouds;
- Rossby and Kelvin waves;
- atmospheric angular momentum;
- rotation;
- dynamo;
- electromagnetic field;
- global electric circuit; and
- geomagnetic jerks.

Some of foregoing consist of further subsystems, for example:

> The Earth's atmosphere and ocean contain several major oscillating atmospheric/oceanic systems that have a key role in the regulation of the Earth's weather and climate. They include the Madden-Julian Oscillation (MJO); the El Niño/Southern Oscillation (ENSO); Quasi-Biennial Oscillation (QBO); the Pacific Decadal Oscillation (PDO); the Interdecadal Pacific Oscillation (IPO); the North Atlantic Oscillation (NAO); the Atlantic Multdecadal Oscillation (AMO); the Indian Ocean Dipole (IOD); the Sub-Tropical Ridge (STR); the Southern Annular Mode SAM) also known as the Arctic Oscillation (AO); East Coast Lows (ECLs); the Bruckner Cycle; Sudden Stratospheric Warming (SSW); and the Northern and Southern Polar Vortices, which are two permanent cyclones at the poles.[37]

There are significant interaction effects between these subsystems. Australia's situation illustrates this general point. Australia's climate is largely determined by the following atmospheric/oceanic systems and the interactions between them: Indian Ocean Dipole; El Nino Southern Oscillation; Inter-decadal Pacific Oscillation; The Southern Annular Mode; Madden Julian Oscillation; East Coast Lows; and Sub-Tropical Ridge; Sudden Stratospheric Warming; and the Southern Polar Vortex.

There is a substantial body of science about relationships between the solar wind, the global electric circuit and the Earth's climate dynamics. The solar wind is a stream of charged particles (electrons, protons and alpha particles and traces of heavy ions and atomic nuclei such as C, N, O, Ne, Mg, Si, S, and Fe) released from the Sun's corona (upper atmosphere). The solar wind is not constant; it is usually undulating and has discontinuities. These variations induce changes in the electric current flowing from the atmosphere to ground. This current is referred to as Jz.

Brian Tinsley, recently retired Professor of Physics at the University of Texas Dallas, is one of the world's leading researchers in this field. Professor Tinsley reported that research conducted jointly with Dr. Gary Burns of the Australian Antarctic Division, amongst others, found evidence supporting the theory that the solar wind can make global changes in Jz, which results in global changes in suitable types of clouds, which would result in changes in atmospheric dynamics, including changes in temperature, precipitation, storm invigoration, vorticity, and winter circulation. He found that about half of the global warming over the past century can be accounted for by changes in the Sun and the solar wind.

Professor Tinsley provides an overview of his (and others) research in this area on his website from which this statement is derived.[38]

7.1 Interaction effects

The interaction effects between all of the determinants listed above are considerable.

For example, it is well known that a sinusoidal force applied to any stable dynamic system induces sinusoidal periodicities in the system.[39] Accordingly, the Lunar Nodal Cycle (LNC) induces bi-stable sinusoidal periodicities[40] in the atmosphere (pressure, temperature and rainfall) and the ocean (temperature and sea level). The sinusoidal, highly stable 18.6 year LNC has a distinctive and significant effect on the Earth's climate dynamics. The LNC's elongated tidal bulge necessarily continues to be aligned with the Moon. The bulge moves to the northern (and southern) latitudes as the Moon moves northwards because of the LNC, being the furthest north it can get to at the 18.6 year point. This last happened on September 16, 2006. Even though the amplitude of the LNC is at most 5 cm, a small tide over a long period has great power.

Mazzarella and Palumbo (1994), in a deeply empirical study, found that in the Western Mediterranean area, the LNC is a significant determinant of a range of climate variable ((atmospheric pressure, rainfall, evaporation, river discharge, air temperature) and oceanic variables (sea surface temperature, mean sea level).

In a thoroughly empirical paper, which also reviews critically a large number of scientific reports published over 10 years, Cerveny and Shaffer (2001) report that the LNC is a major determinant of regional climates around the world.

The ocean currents generated by the northward movement of the tidal bulge, in conjunction with the rotation of the Earth through the bulges in the normal manner creating our experience of the tides, brings warmish equatorial water to the Arctic accelerating the warming that had being going on there because of other forms of solar activity and the Earth's variable rotation. The LNC has maximum effect at higher latitudes, resulting in higher sea levels at these latitudes. It creates tidal currents resulting in diapycnal mixing[41], bringing the warmer equatorial waters into the Arctic. The LNC is therefore a major determinant of Arctic climate dynamics, influencing long term fluctuations in Arctic ice. As a result, it is a key driver of European climate.

Professor Emeritus Harald Yndestad of the Norwegian University of Science and Technology has shown in more than one dozen major detailed observational reports enriched by sophisticated quantitative analysis that the LNC is a significant determinant of the northern hemisphere ecosystem. He demonstrated that the LNC brings cycles of warmth and cold. He showed how the shorter life cycles of biomass adapt to the longer LNC cycles resulting in periods of plenty and periods of scarcity. Professsor Yndestad's Climate Clock (https://www.climateclock.no) is an excellent guide to his work. Some of his key publications are: Yndestad (1999, 2002), 2003), 2006, 2008) and Yndestad et al. (2008).

He found that the LNC is transitioning to the phase, which results in a period of cooling.

Since the 1980s, a large number of high quality papers have been published, in addition to those already cited, which collectively show that the LNC has a major role in global climate dynamics over many hundreds of years.

For example:

- McKinnell and Crawford (2007) found that the LNC is a significant determinant of the climate dynamics of the entire Pacific Ocean.
- Yasuda (2009) found that the LNC drives the Pacific Decadal Oscillation. In addition, Yasuda (2009) noted that the deterministic role of the LNC means that climate predictability can be improved by use of the time-table from the astronomical tidal cycle.
- Saintilan et al. (2022) found that the LNC regulates the expansion and contraction of mangrove canopy cover over much of the Australian continent.

It is to be noted that the IPCC does not mention in any of its many reports the vast body of research published over the last 40 years about the dominant role of the LNC in the regulation of the Earth's climate.

Lopes et al. (2021) noted that in 1799, LaPlace derived the system of differential equations (now called Liouville-Euler) that fully describes the motions of the rotation axis of any celestial body. Laplace showed that only the gravitational forces and kinetic moments from other celestial bodies influence the rotation of any one of them.

Lopes et al. (2021) construct a 175-year long time series of the variations in the Earth's rotation axis under the influence of both gravitational potentials and kinetic moments. They take into consideration the involvement of the planets, the Sun and the Moon in accordance with Laplace's celestial mechanics, having regard to the Sun carrying more than 99% of the mass and the planets more than 99% of the total angular momentum of the solar system. They use singular spectral analysis to extract components of the time series. Their analysis shows that here are four causal processes that determine changes to the rate and inclination of the Earth's rotation in accordance with LaPlace's equations.

The first process is that of the planets, particularly the Jovian planets, acting on the Earth/Moon system. The second process is that of the Sun acting on the Earth/Moon system (and the rest of the solar system). The third process is that all the planets of the solar system act on the Sun. The fourth is that of the Sun, having been activated by the third process, proceeds to the second process.

The authors' quantitative analysis of solar system data confirms LaPlace's 1799 analysis that the motions of the rotation axis of the Earth is determined fully by both gravitational potentials and kinetic moments.

Mazzarella (2008) outlines a promising approach that has regard to interaction effects. Mazzarella (2008) noted the numerous failures of IPCC sponsored computer simulations of climate dynamics. He pointed out that the reductionist approach on which the simulations are based, blocks the best practice scientific evaluation of them, thereby rendering the simulations unscientific.

Mazzarella (2008) outlines a holistic approach, which complies with the canons of science. His approach is to analyze the Sun, atmospheric circulation, Earth's rotation and sea temperature as a single unit. He explained that the arrival on the Earth of fronts of hydrodynamic shock waves during epochs of strong ejection of particles from Sun gives rise to a squeezing of the Earth's magnetosphere and to a deceleration of zonal atmospheric circulation, which, like a torque, causes the Earth's rotation to decelerate which, in turn, causes a decrease in sea temperature.

Mazzarella (2008) showed that the integrated whole Earth-atmosphere-Sun system, incorporating the relevant independent variables, including turbulence of solar wind, atmospheric circulation and Earth's rotation, in an integrated way, explains most of global warming that has taken place since the 1980s. He found that the period of warming is about to conclude; it will be followed by a period of global cooling.

IPCC sponsored computer simulations of climate dynamics lack the capacity to portray and simulate successfully ENSO complexity. The simulations are not able to incorporate several important processes involving small scales. These processes have a significant role in the development of ENSO processes in a way analogous the well-known butterfly effect documented in 1963 by Professor Edward Norton Lorenz (1917 – 2008) (Lorenz 1963).[42] Noting this intrinsic failure of the IPCC sponsored computer simulations and having regard to ENSO's role as the Earth's strongest climate fluctuation, Mazzarella, Giuliacci and Scafetta (2012) adapted the concepts of Mazzarella (2008) to the analysis of ENSO. They confirmed the idea that the major local and global Earth-atmosphere system mechanisms are significantly coupled and synchronized to each other at multiple scales.

8. The inner core, the geodynamo, the geomagnetic field and climate dynamics

The turbulent convection of the liquid Iron/Nickle outer core interacting with the inner core sets up a process that converts convective kinetic energy to electrical and magnetic energy. The electrically conducting liquid outer core induces electric currents, which generate magnetic fields. The process creates Alfven waves and is self-sustaining so long as there is an energy source sufficient to maintain convection. Changes in the rate of rotation of the outer core, including any sudden jerks, will induce variations in the accompanying electromagnetic fields.

The Sun's outer atmosphere envelopes planet Earth and extends with diminishing density throughout the solar system. The Sun is more than 99 per cent of the mass of the solar system and more than one million times the size of the Earth. The source of all the Sun's energy is its core, an extremely dense, extremely hot (15 million ^{o}Celsius) sphere of continuous boiling thermonuclear fusion. The diameter of this sphere is approximately the distance from the Earth to the Moon. The nuclear fusion core contains about half the mass of the Sun; that is, about 50 per cent of the mass of the solar system. In contrast, the mass of the Earth is about 0.0003 per cent of the mass of the solar system.

The geomagnetic field generated by the outer core protects Earth from the destructive, lethal effects of the Sun, specifically the Sun's output of radiation and matter. The geomagnetic field creates the Earth's magnetosphere, the region of space surrounding the Earth in which charged particles are affected by the geomagnetic field. The magnetopause is the boundary between the magnetosphere and the Sun's extended atmosphere. It is the boundary between the geomagnetic field and the solar wind. The location of the magnetopause depends on the balance between the dynamic pressure of the geomagnetic field and the solar wind. As the solar wind pressure increases and decreases, the magnetopause moves inward and outward in response.

Figure 9 depicts complex, dynamic electromagnetic environment of the Earth.

The Sun-Earth system is electromagnetically, magneto-hydrodynamically, and gravitationally coupled, dominated by significant non-linear, non-stationary interactions, which vary over time and throughout the three-dimensional structure of the Earth, its atmosphere and oceans. The essential elements of the Sun-Earth system are the solar dynamo, the heliosphere, the lunisolar tides, the Earth's inner and outer cores, mantle, crust, magnetosphere, oceans and atmosphere. The Sun-Earth system is non-ergodic (i.e. characterised by continuous change, complexity, disorder, improbability, spontaneity, connectivity and the unexpected). Climate dynamics, therefore, are non-ergodic, with highly variable climatological features at any one time.

Ruzmaikin (2007) explained that linear and non-linear systems respond differently to external forces. The response of linear system is simply linearly proportional to the applied external force. Non-linear systems respond in a conceptually different way. Non-linear systems have internally defined preferred states known mathematically as attractors.

The response of non-linear systems to an external force is variable residency in the preferred states (i.e. the attractors) and changes in the transitions between them. The issue is not a magnitude of the response to an external force, as with the response of linear systems, but one or more of:

- a change of state;
- a change in the time spent in different states; and/or,
- the rate of oscillation between states.

Ruzmaikin (2007) considered that the impact of solar variability is to change the probability of the duration of particular climate patterns associated with cold conditions in some regions and warm conditions in other regions. These consequences are far more important, he argued, than changes to average global temperatures. Georgieva (2006)) established that the decadal changes in Earth's rotation rate depend on core-mantle coupling processes regulated by solar wind transferring solar magnetic fields and angular momentum modulated by planetary influences, and Kirov et al. (2002) demonstrated that the Earth's rotation rate depends on the magnetic polarity of the Sun. The Earth's rotation is systematically faster with a negative than with a positive polarity of the Sun. Kilfarska (2020) provides a detailed account of the many ways the geomagnetic field influences the Earth's climate.

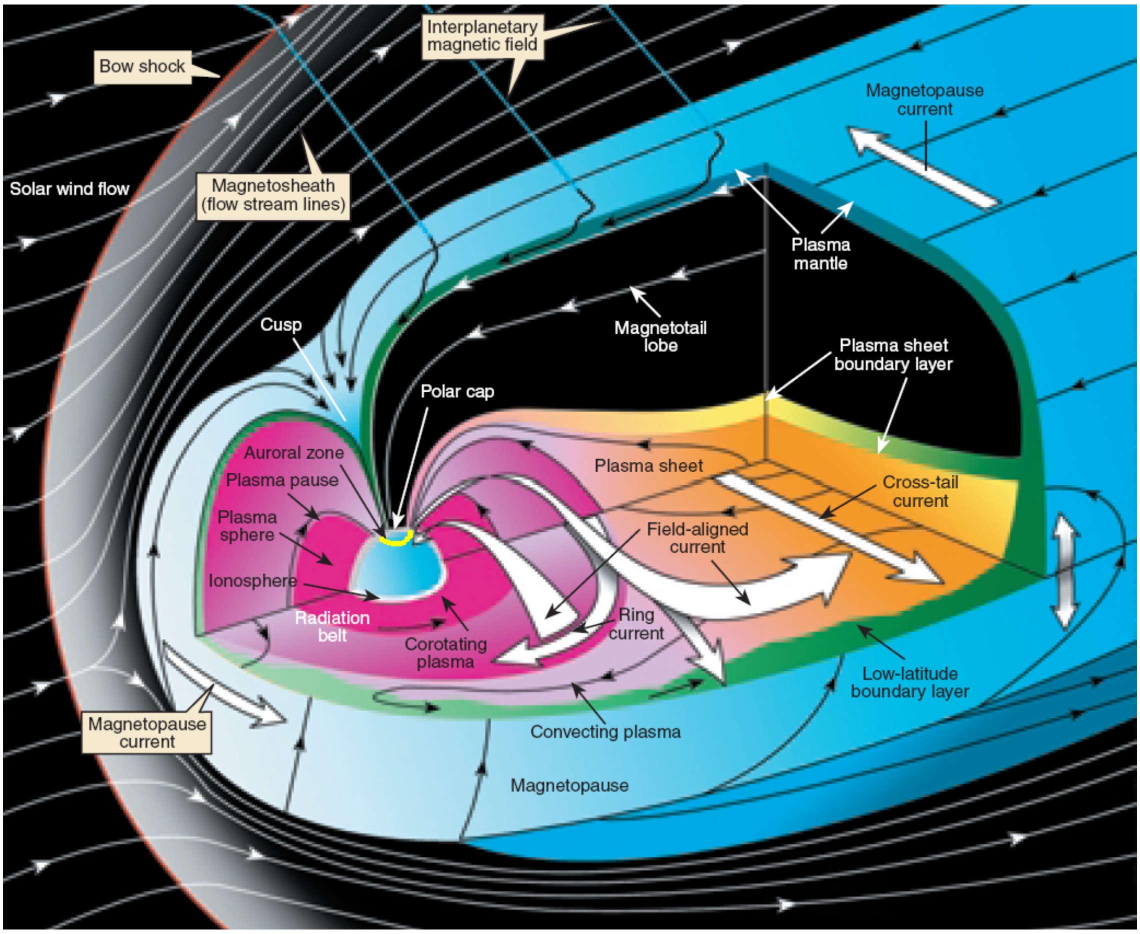

Figure 9. Schematic illustration of Earth's magnetosphere, illustrating major distinct regions and *electric current systems. (Source: [Magnetopause & Bow Shock (sepc.ac.cn)](sepc.ac.cn))*

The ring current (Figure 10) is one of the significant structures the Earth's electromagnetic environment. The ring current consists of those particles in the inner magnetosphere, which contribute substantially to the total current density and to the global geomagnetic disturbances on the Earth surface.

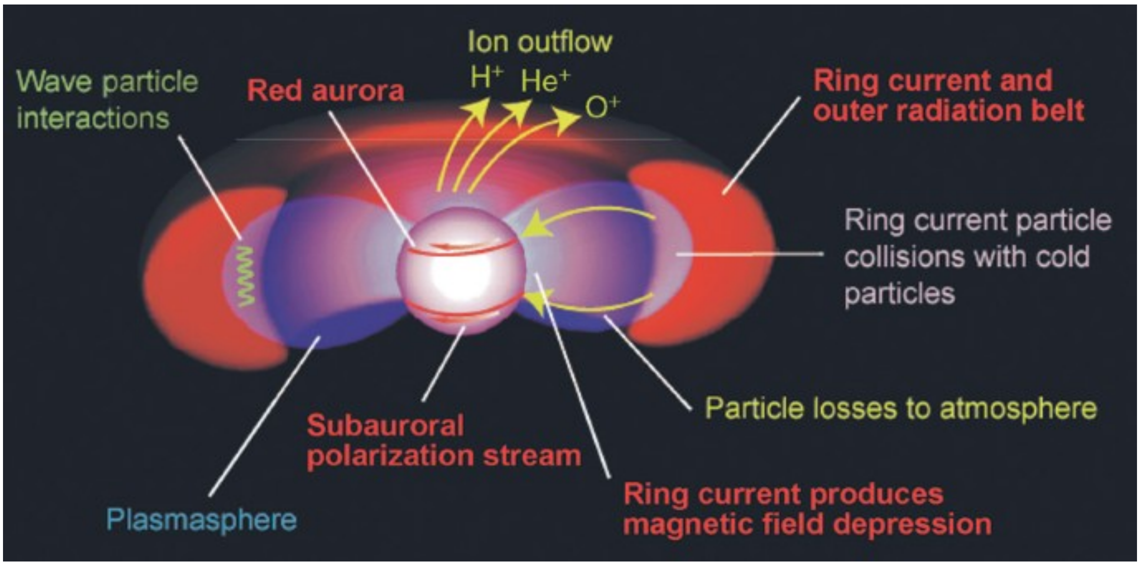

Figure 10 The Earth's ring current is shown as a red torus or donut-shaped region encircling the Earth near the equator at altitudes of-10,000-60,000 km.. Source: Moore (2007).

The ring current is an electric current of millions of Amperes encircling the Earth in space. It is a feature of the interaction between the magnetized conducting solar wind and the Earth, with its geomagnetic field and conducting ionosphere. Changes in the current are responsible for global decreases in the Earth's surface magnetic field. These changes are known as geomagnetic storms. Intense geomagnetic storms have severe effects on technological systems, such as disturbances or even permanent damage to telecommunication and navigation satellites, telecommunication cables, and power grids.

The ring current can be in two states: quiescent or storm.

The quiescent ring current is carried mainly by protons of predominantly solar wind origin

The storm ring current is the prime element of solar storms and is mostly terrestrial in origin. Just how solar storms influence the Earth's atmosphere to build up the high energy ions that characterise the storm ring current is an active area of inquiry.

Duhau and Martinez (1995) provide evidence for the theory that the storm ring current can increase length of day and geomagnetic variations on a decadal time scale via the exchange of angular momentum between the Earth's core and mantle. They found that there would be a 94 year lag between the sharp depression of the magnetic field that happens during a solar storm and the change in the LoD induced by that sharp depression.

Duhau and de Jager (2012) report that there are robust evidences that the semi-secular oscillations in LoD are the result of torsional oscillations in the liquid core that are excited 94 year before at the bottom of this layer by planetary motions. To fulfil the free fall motion principle (Shirley 2006), the total angular momentum of the Earth must be preserved. Therefore, as the motions in the liquid core are first excited at its boundary with the solid core, this last must undergoes a change of impulse of the opposite sign. The inner core motion is most likely to be activated first, because the differential action of the planetary system on the Earth's layers cause the periodic observed relative displacements and the relative turns between the inner core and the mantle (Bakin and Vilke 2004 and references therein).

Significant interactions could also be expected between the processes of the Earth-Moon-Sun geometry described earlier, the processes outlined by Lopes et al. (2021), the processes arising from the role of the Sun summarised above, the interactions between the oscillating atmospheric/oceanic systems outlined above and the Earth's dynamic electromagnetic environment.

For example, Wilson (2013) found that the LoD regulates the NAO and the PDO and that there is a remarkable correlation between the years where the phase of the PDO is most positive and the years where the deviation of the Earth's LoD from its long-term trend is greatest. Furthermore, he found a strong correlation between the times of maximum deviation of the Earth's LoD from its long-term trend and the times where there are abrupt asymmetries in the motion of the Sun about the Solar System barycentre. He claimed that significant synchronization between the orbital period of Jupiter and the rate of precession of the LNC is the reason for the strong correlation.

Scafetta and Willson (2013) report findings that support the hypothesis that the Sun, the heliosphere and the terrestrial magnetosphere are partially modulated by planetary gravitational and magnetic forces synchronized to planetary oscillations, as also found in other recent publications.

9. Scientific Misconduct

The IPCC does not mention in any of its many reports the vast body of research published over the last 50 years about the regulation of the Earth's climate by variations in decadal rotation of the Earth or the dominant role of the LNC in the regulation of the Earth's climate. The IPCC has deliberately omitted reporting these scientific results for over thirty years, since the publication of its *First Assessment Report* in 1990.

According to the U.S. Office of Science and Technology Policy (National Academy of Sciences (US), National Academy of Engineering (US) and Institute of Medicine (US) Committee on Science, Engineering, and Public Policy (2009)), and endorsed by the Organisation for Economic Co-operation and Development Global Science Forum,[43] not accurately representing in the research record by the deliberate omission of scientific results constitutes the falsification of science and is scientific misconduct.

Accordingly, the US and OECD scientific authorities would find the IPCC guilty of egregious scientific misconduct.

10. Elegant simplicity

This paper outlines a theory of elegant simplicity (in the sense of William of Occam) that explains the planet's climate dynamics in terms of variables that would apply to any planet of the solar system; indeed, to all planets of any solar system in the universe.

The key variables, the independent variables, are:

- The oblate, spheroid shells of which the planet is composed;
- The Earth-Moon-Sun system;
- The Sun;
- The solar system.

The planet's climate dynamics is the dependent variable.

11. Conclusion

a) In relation to the Earth's climate dynamics, there are six well-established findings from Geophysics:
   1. When, on a decadal basis, the rate of rotation of the Earth increases by between three and five milliseconds, the Earth warms globally[44]; when the rate decreases by a similar amount, the Earth cools globally.
   2. The behaviour of the Earth's core, particularly the inner core, is the key determinant of the Earth's decadal rotation variations.
   3. Although the dynamics of the core (the outer and inner cores) are not yet fully understood, it is clear that gravitational and electromagnetic couplings of the inner and outer cores to the mantle and crust have a dominant role.
   4. Quantitative analysis of solar system data confirms LaPlace's 1799 analysis that the motion of the rotation axis of the Earth is determined fully by both gravitational potentials and kinetic moments.
   5. There is time lag of about eight years between the electromagnetic event in the core that results in Earth rotation variations and the rotation variations happening.
   6. There is a time lag of about eight years between changes in the Earth's rotational speed and surface temperature.
   7.

b) On 23 January 2023 *Nature Geoscience* published findings of Professor Xiaodong Song at the School of Earth and Space Sciences (SESS), Peking University and Dr Yi Yang, an Associate Research Scientist in Professor Song's group, that the rotation of the Earth's inner core began to slow down from around 2009 onwards. According to the above-mentioned time lags, the Earth's global temperature should begin to decline from 2025 onwards, *ceteris paribus*.

c) Over the last several decades, scientists from several disciplines have published in many of the world's leading scientific journals abundant evidence about the key determinants of climate dynamics. The most significant determinant is the Sun. The Sun influences climate dynamics in several ways, including electromagnetic radiation, matter, gravitation, and interactions between these variables. The evidence is accumulating that if solar activity influences the Earth's climate dynamics, the climate will cool.

d) The Earth's climate dynamics also depends on a number of subsystems of which the climate system is composed. There are indications that the likely impact of these subsystems over the next few years will be mixed: some warming; some cooling.

e) There are, as well, significant interaction effects between all the variables that contribute to the Earth's climate dynamics, but these processes are not well understood.

f) The IPCC continues to ignore abundant evidence about the role of the Earth's rotation, the LNC, and most of the independent variables discussed in this paper, including interaction effects between the independent variables. The US and OECD scientific authorities would find the IPCC guilty of egregious scientific misconduct. Whereas observation has dominated the science of the Earth's and the inner core's variable rotation, the IPCC's approach to science is to make observation subordinate to computer simulations. This attitude is absent in every other branch of science, including those in which computer simulations have a significant role, such as Solar Physics.

g) As Bertrand Russell anticipated over 75 years ago, this has resulted in an intoxication contributing to a vast social disaster.

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Conflicts of Interest

The Author declares he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Attachment A

Historical overview- the Earth's variable rotation

Prior to the recognition that the Earth's rotation was variable, the Earth's rotation was assumed constant and therefore the standard for time, thereby placing the rotation of the Earth as the standard clock in the same category as the physical standards for length and weight. As a result, astronomers used the presumed fixed constant of the Earth's rotation to determine all astronomical attributes of the Sun and the solar system.

When in 1870 in the distinguished American Astronomer, Professor Simon Newcomb (1835 - 1909), Director of the Nautical Almanac Office as well as Professor of mathematics and astronomy at Johns Hopkins University in Baltimore, found indications that the Earth's rotation was not constant, but he was reluctant accept this. Part of his concern was the inaccuracies in the relevant measures. The deviations were so small, he found it difficult to different between errors of observation and the real behaviour of the celestial objects (Newcomb 1874). He devoted considerable time and resources to trying to prove that the Earth's rotation was constant. In 1895, he was awarded the Astronomical Journal prize of $400 "For the most thorough discussion of the theory of the rotation of the Earth, with reference to the recently discovered variation of latitude."

In 1914, Dr A W Brown (1866 - 1938), Professor of Mathematics at Yale University, gave an address - as Vice-president of the British Association for the Advancement of Science - to the Association's Australasian meeting. His address, *Address on Cosmical Physics*, included a discussion of some irregularities in the Moon's motion (Brown 1914). At the time, Dr Brown was the world's expert about the behaviour of the Moon, having devoted his entire professional life to the study of the orbit of the Moon. In his address, he did not consider the idea that the Earth's variable rotation might be the cause of the Moon's irregularities.

In 1915, Sir Joseph Larmor (1857 – 1942), who held the Lucasian Chair of Mathematics at Cambridge University, wrote "The circumstance that there remains an outstanding irregularity in the orbital motion [of the Moon] … has been felt to create an intolerable discrepancy, which demands every effort of the gravitational astronomer to resolve"(Larmor 1915). He considered that the "outstanding irregularity" would most likely be attributed to irregular changes in the Earth's velocity of rotation on its axis. A change in the Earth's rotation rate causes a corresponding change in the unit of time. This shows up as an error in the position of any celestial body moving fast enough to show the effect. Graphs of the position of the celestial body in which one graph is of the body's theoretical position (assuming the Earth's rotation rate is constant) and the other the actual position will show the error. Sir Joseph Larmor argued that if the discrepancies cannot be explained by attributes of the celestial body or by errors of measurement, then the discrepancies provide convincing evidence for the only other factor, the Earth's variable rotation.

In the same year (1915) a 23 year post graduate student at Cambridge University working under the supervision of Sir Arthur Eddington (Plumian Professor of Astronomy and Experimental Philosophy and Director of the Cambridge Observatory), Hermann Glauert (1892 – 1934), who had a Isaac Newton Studentship in Astronomy and Physical Optics, reported his findings from his examination of the problem (Glauert 1915a, 1915b). He concluded, "…that the errors in longitude of the Moon and the three bodies considered in this paper [Sun, Venus and Mercury] may be accounted for by a rather irregular variation in the rate of rotation of the Earth, the change of momentum being partially or entirely compensated for by a corresponding change in the mean motion of the Moon". His papers include the detailed calculations and graphs of the results.

Sir Harold Spencer Jones (1890 – 1960), Astronomer Royal, confirmed that the Earth's rotation was variable, reporting his findings in 1926 and 1939 in the *Monthly Notices of the Royal Astronomical Society* (Spencer Jones 1926, 1939). Following this, various astrometric indices of the Sun and the planets of the solar system had to be recalibrated.

In 1928, the Canadian Astrophysicist, Joseph Pearce (1893 – 1988) reported that "during the last few years much evidence has been advanced which proves conclusively that the rotation of the Earth is variable; that sudden changes in the rate take place; and that these variations are of surprisingly large amounts, the Earth gaining or losing as much as 30 seconds in a period of 40 years" (Pearce 1928).

The next two challenges were (i) to explain why the Earth's rate of rotation was variable and (ii) to describe and explain any impact the Earth's variable rate of rotation might have on the other layers of the Earth, especially the asthenosphere, the lithosphere and the atmosphere.

As described in this report, several acclaimed scientists have independently of each other established a clear causative relationship between the Earth's decadal rotation variations and climate dynamics – as the rotation rate slows, the planet cools; as it speeds up, the planet warms. This pattern of slowing down, speeding up/cooling and warming repeats every 60 years. The scientists are Lambeck and Cazenave (1973, 1974, 1976, 1977), Sidorenkov (2009), Rozelot (1990), and Jochmann and Greiner-Mai (1996, 1997), amongst others.

In addition, Currie (1973) found evidence of a 60-year periodicity in the LoD time series; Currie (1980) found a relationship between the Earth's decadal rotation variations and the Sun's activity cycles. Mazzarella and Palumba (1988) found the same as Currie (1980). Mazzarella (2007) found that the turbulence of the solar wind, the Earth's rotation and atmospheric circulation explained a large proportion of global warming. Mazzarella (2007) concluded that changes in geomagnetic activity, and in the Earth's rotation, could be used as long- and short-term indicators, respectively, of future changes in global air temperature.

Mörner (1995) found that there is a strong linkage between the Earth's rate of rotation and the changes in ocean circulation. He established that there is a causal connection between the Earth's rotation, oceanic circulation (primarily the surface circulation; ocean/atmosphere heating, atmospheric (wind) heat transport and continental paleoclimatic changes.

Scientists discovered that the decadal variations in the Earth's rotation rate gave rise to variations of the geomagnetic field. Some of the key scientists were Emeritus Professor Takesi Yukutake of the University of Tokyo, the Russian scientist Dr S I Braginsky (Braginsky (1982)) and the French scientists, Professors Vincent Courtillot, Jean-Louise Le Mouel and Dominique Jault and Dr Camille Gire of the Institute of Globe Physics of Paris. Professor Yukutake worked at the Earthquake Research Institute, University of Tokyo, for over thirty years. His first significant paper linking the decadal variations of the Earth's rotation and the Earth's geomagnetic field was published in 1973. The French team published relevant papers from 1982 onwards. In 1976 the French team reported that that in 1969 there had been a sudden worldwide change in the dynamics of the Earth's magnetic field (geomagnetic jerks). They explained that the geomagnetic jerks are most likely to be a key determinant of the Earth's decadal rotational variations. Other scientists have independently corroborated this finding.

Several scientists have since established that variations in the Earth's geomagnetic field give rise to variations in the Earth's climate dynamics. Relevant findings have been published since 1956. Kilifarska et al. (2020) provides an overview of these findings.

There are other variables that give rise to the Earth's climate dynamics that take place concurrently with the changes to the Earth's climate dynamics arising from the decadal variations in the Earth's rotation. Over the last several decades, scientists from several disciplines have published in many of the world's leading scientific journals an abundance of evidence about the key determinants of climate dynamics.

The most significant determinant is the Sun. The Sun can affect the climate in several ways, specifically the Sun's:

- output of radiation,
- output of matter,
- electromagnetic field,
- gravitational fields,
- shape; and,

as well, the topological structure of the heliosphere.

There are also significant effects from interactions between these.

The main paper (of which this is an Attachment) summarises the findings as well as findings about the impact on the Earth's climate dynamics arising from the complex interactive dynamics of the many subsystems of which the climate system is composed.

Attachment B

On pages 275 to 285 of his treatise, *The Earth's Variable Rotation – Geophysical Causes and Consequences*, (Lambeck (1980)) Professor Lambeck summarises the findings and conclusions of his joint papers with Dr Cazenave. He included graphs of these findings, which are reproduced below.

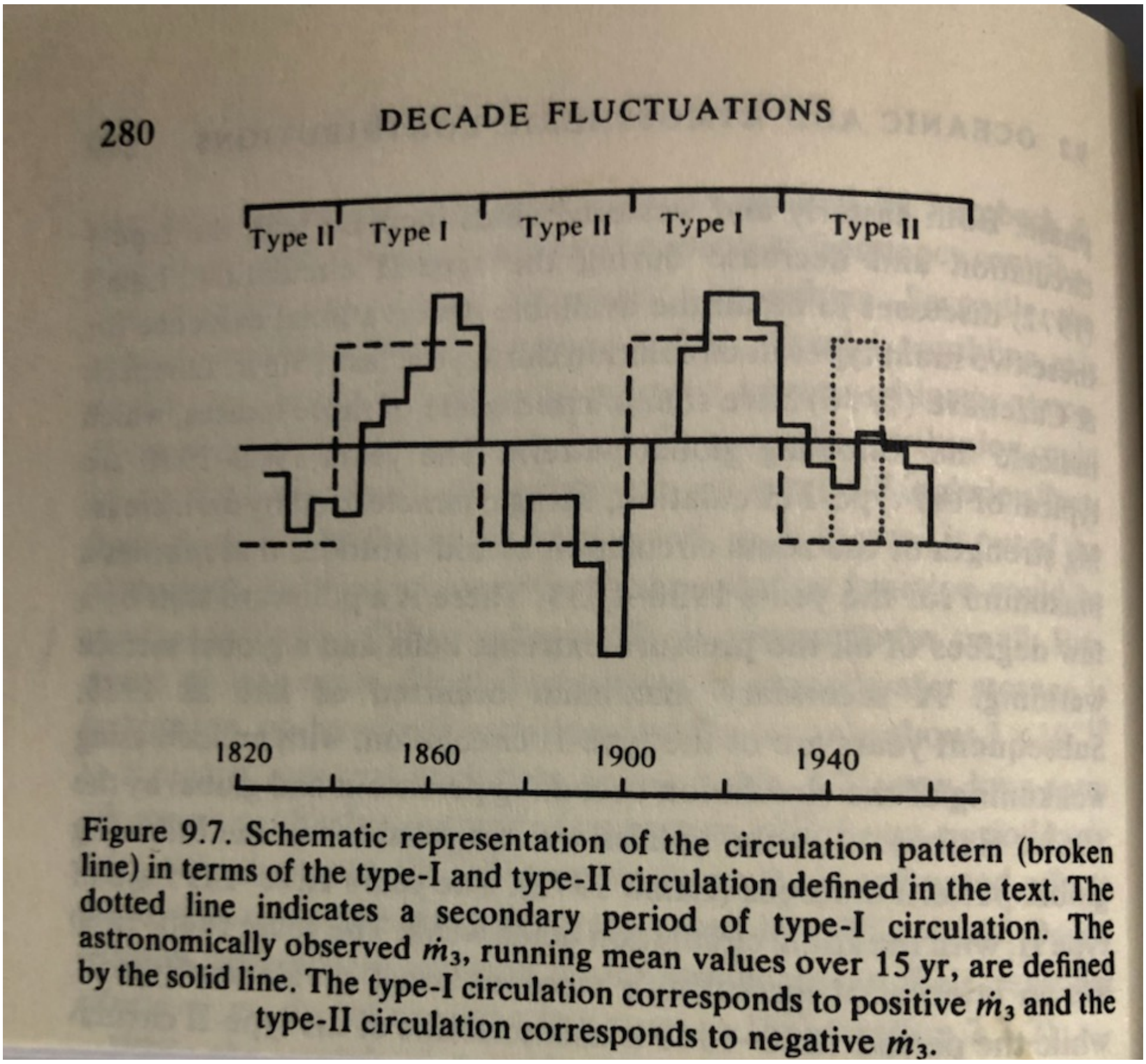
280 DECADE FLUCTUATIONS

Figure 9.7. Schematic representation of the circulation pattern (broken line) in terms of the type-I and type-II circulation defined in the text. The dotted line indicates a secondary period of type-I circulation. The astronomically observed $\dot{m}_3$, running mean values over 15 yr, are defined by the solid line. The type-I circulation corresponds to positive $\dot{m}_3$ and the type-II circulation corresponds to negative $\dot{m}_3$.

Figure B1. Relationship between variations in oceanic-atmospheric circulation patterns and variations in LoD (from Lambeck 1980).

On page 279 of Lambeck (1980), Professor Lambeck explains that this schematic diagram shows that a rotational acceleration is accompanied by periods of increasing strength of the zonal circulation while a rotational deceleration is accompanied by periods of decreasing circulation.

Note: The Earth's rotation rate, m_3, is directly proportional to changes in the LoD. $\dot{m}_3$ denotes the rate of change of the Earth's rotation. Therefore, a positive $\dot{m}_3$ means the Earth's rotation rate is increasing, whereas a negative $\dot{m}_3$ means the Earth's rotation rate is decreasing.

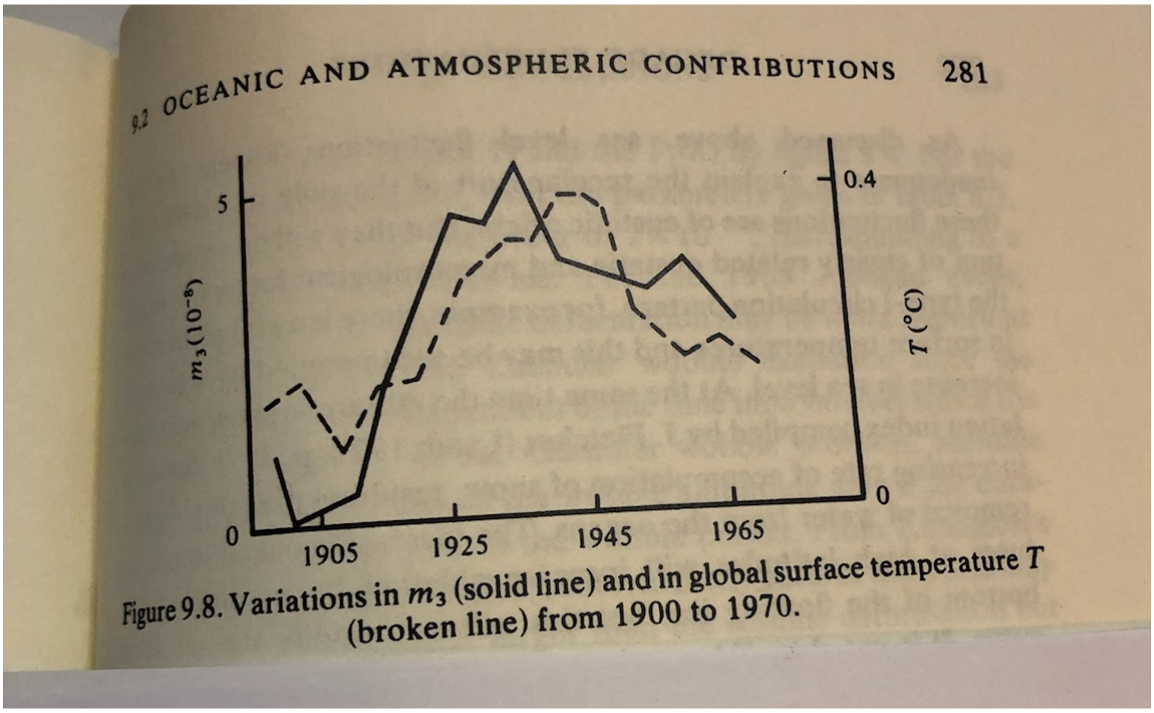

Figure B2. Relationship between variations in Earth rotation rate and variations in global surface temperature 1900 to 1970 (from Lambeck (1980)).

The left-hand side ordinate is the Earth's rotation rate, m_3, in milliseconds from 0 to 5; whereas the right hand side ordinate is the variation in global surface temperature in ºC from no variation at all (0) to a maximum of 0.4ºC.

Note: The Earth's rotation rate, m_3, is directly proportional to changes in the LoD.

Attachment C

Acronyms in Figures 4 and 8

This list explains the acronyms listed on the right-hand side in Figures 4 and 8. The explanations and definitions are from Thorne et al. (2010).

MSU—Microwave Sounding Unit

UAH—University of Alabama in Huntsville, developer of a version of MSU data products

RSS—Remote Sensing Systems, developer of a version of MSU data products

UMd—University of Maryland

STAR—The National Oceanic and Atmospheric Administration Center for Satellite Applications and Research

Prabhabara—Prabhabara (1999); Prabhakara C, Iacovazzi R, Yoo J-M, Dalu G (2000) and Prabhakara C, Iacovazzi R, Yoo J-M, Dalu G (1998)

Angell— Angell (2003)

RATPAC—Radiosonde Atmospheric Temperature Products for Climate, an adjusted radiosonde dataset

Sterin— Sterin AM, Eskridge RE (1997).

HadAT—Hadley Centre Atmospheric Temperatures, an adjusted radiosonde dataset

RAOBCORE—RAdiosonde OBservation COrrection using REanalyses, an adjusted radiosonde dataset

RICH—Radiosonde Innovation Composite Homogenization, an adjusted radiosonde dataset

HadCRUT3—Surface temperature dataset jointly prepared by the Hadley Centre and the Climatic Research Unit

NOAA—The National Oceanic and Atmospheric Administration

NASA—The National Aeronautics and Space Administration

Attachment D

Australia Surface Temperatures Compared to UAH Satellite Data Over the Last 40 Years

April 3rd, 2019 by Roy W. Spencer, Ph. D: *The monthly anomalies in Australia-average surface versus satellite deep-layer lower-tropospheric temperatures correlate at 0.70 (with a 0.57 deg. C standard deviation of their difference), increasing to 0.80 correlation (with a 0.48 deg. C standard deviation of their difference) after accounting for precipitation effects on the relationship. The 40-year trends (1979-2019) are similar for the raw anomalies (+0.21 C/decade for the observed temperature trend of the surface $T_{surface}$ (T_{sfc}), +0.18 deg. C for satellite), but if the satellite and rainfall data are used to estimate T_{sfc} through a regression relationship, the adjusted satellite data then has a reduced trend of +0.15 C/decade. Thus, those who compare the UAH monthly anomalies to the BoM surface temperature anomalies should expect routine disagreements of 0.5 deg. C or more, due to the inherently different nature of surface versus tropospheric temperature measurements*

1. Introduction.

I often receive questions from Australians about the UAH LT (lower troposphere) temperature anomalies over Australia, as they sometimes differ substantially from the surface temperature data compiled by BoM. As a result, I decided to do a quantitative comparison.
While we expect that the tropospheric and surface temperature variations should be somewhat correlated, there are reasons to expect the correlation to not be high. The surface-troposphere system is not regionally isolated over Australia, as the troposphere can be affected by distant processes. For example, subsidence warming over the continent can be caused by vigorous precipitation systems hundreds or thousands of miles away.

I use our monthly UAH LT anomalies for Australia (available here), and monthly anomalies in average (day+night) surface temperature and rainfall (available from BoM here). All monthly anomalies from BoM have been recomputed to be relative to the 1981-2010 base period to make them comparable to the UAH LT anomalies. The period analyzed here is January 1979 through March 2019.

2. Results before adjustments

A time series comparison between monthly T_{sfc} and LT anomalies shows warming in both, with a T_{sfc} warming trend of +0.21 C/decade, and a satellite LT trend of +0.18 C/decade:

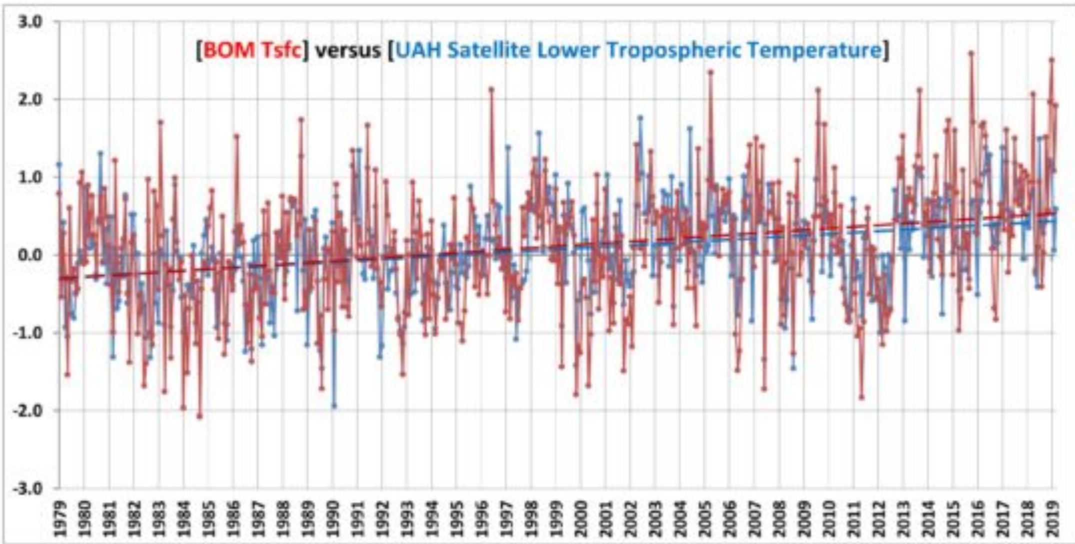

Figure D1. Australia average surface temperature (T_{sfc}) (red) and satellite lower tropospheric temperature (LT, blue) anomalies from January 1979 through March 2019.

The correlation between the two time-series is 0.70, indicating considerable — but not close — agreement between the two measures of temperature. The standard deviation of their difference is 0.57 deg. C, which means that people doing a comparison of UAH and BoM anomalies each month should not be surprised to see 0.6 deg. C differences (or more).

Part of the disagreement comes from rainfall conditions, which can affect the temperature lapse rate in the troposphere.

For reference, the following plot shows Australian precipitation anomalies for the same period:

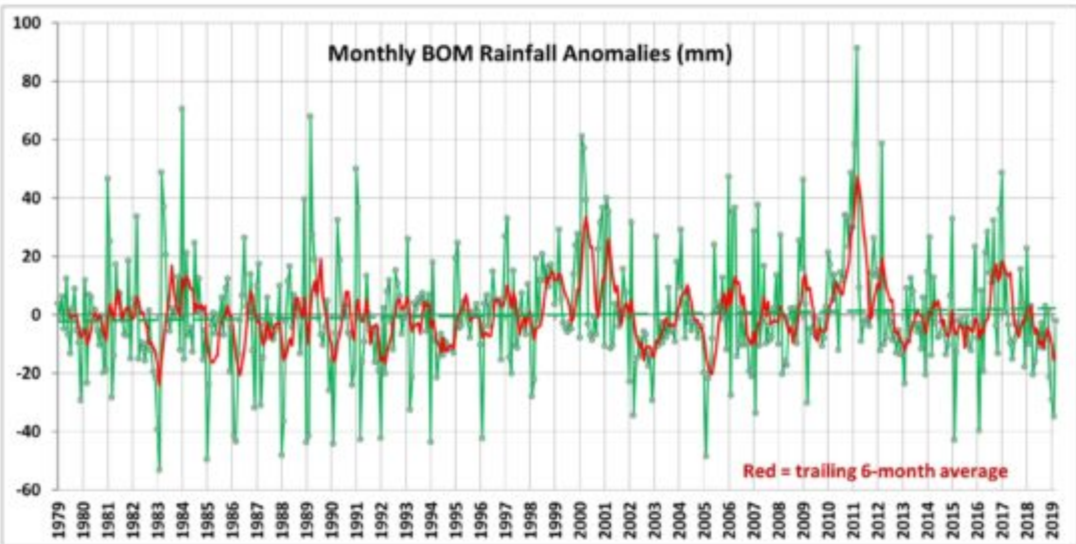

Figure D2. Australia precipitation anomalies from January 1979 through March 2019.

If we take the data in Figure D1 and create a scatter plot, but show the months with the 25% highest precipitation anomalies in green and the lowest 25% precipitation in red, we see that drought periods tend to have higher surface temperatures compared to tropospheric temperatures, while the wettest periods tend to have lower surface temperatures compared to the troposphere:

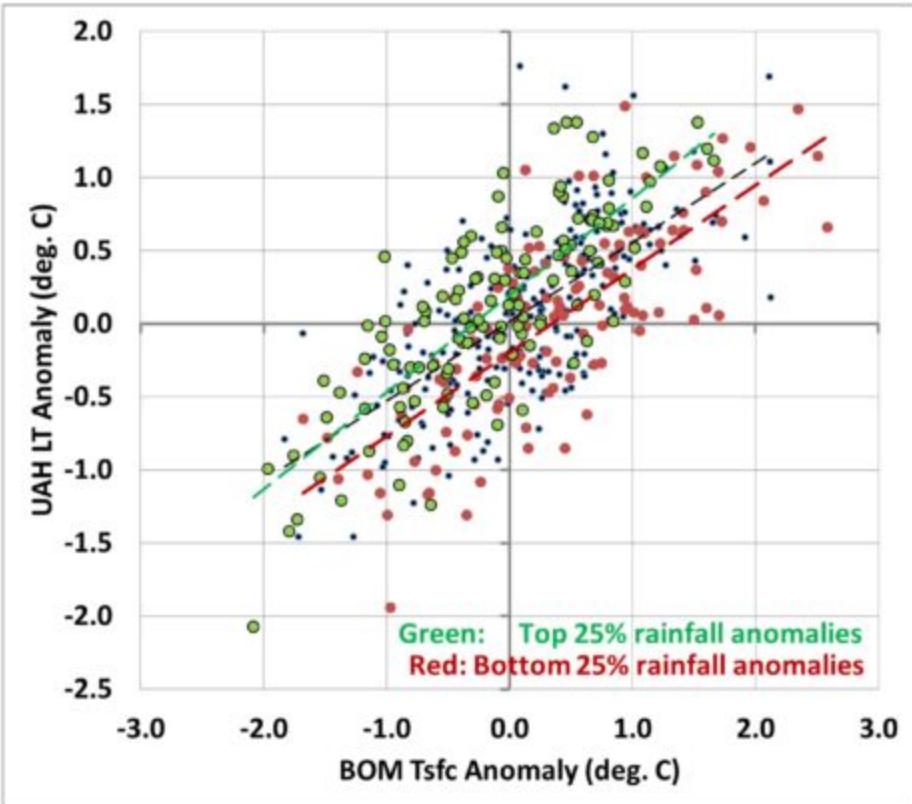

Figure D3. Scatterplot of the data in Figure D1, but with colour coding of those months with the 25% highest (green) and lowest (red) precipitation departures from average.

3. A more apples-to-apples Comparison

Comparing tropospheric and surface temperatures is a little like comparing apples and oranges. But one interesting thing we can do is to regress the surface temperature data against the tropospheric temperatures plus rainfall data to get equations that provide a "best estimate" of the surface temperatures from tropospheric temperatures and rainfall.

I did this for each of the 12 calendar months separately because it turned out that the precipitation relationship evident in Figure D3 was only a warm season phenomenon. During the winter months of June, July, and August, the relationship to precipitation had the opposite sign, with excessive precipitation being associated with warmer surface temperature versus the troposphere, and drought conditions associated with cooler surface temperatures than the troposphere (on average).

So, using a different regression relationship for each calendar month (each month having either 40 or 41 years represented), I computed a satellite+rainfall estimate of surface temperature. The resulting "satellite" time series then changes somewhat, and the correlation between them increases from 0.70 to 0.80 as shown in figure D4. Now the "satellite-based" trend is lowered to +0.15 C/decade, compared to the observed T_{sfc} trend of +0.21 C/decade. I will leave it to the reader to decide whether this is a significant difference or not.

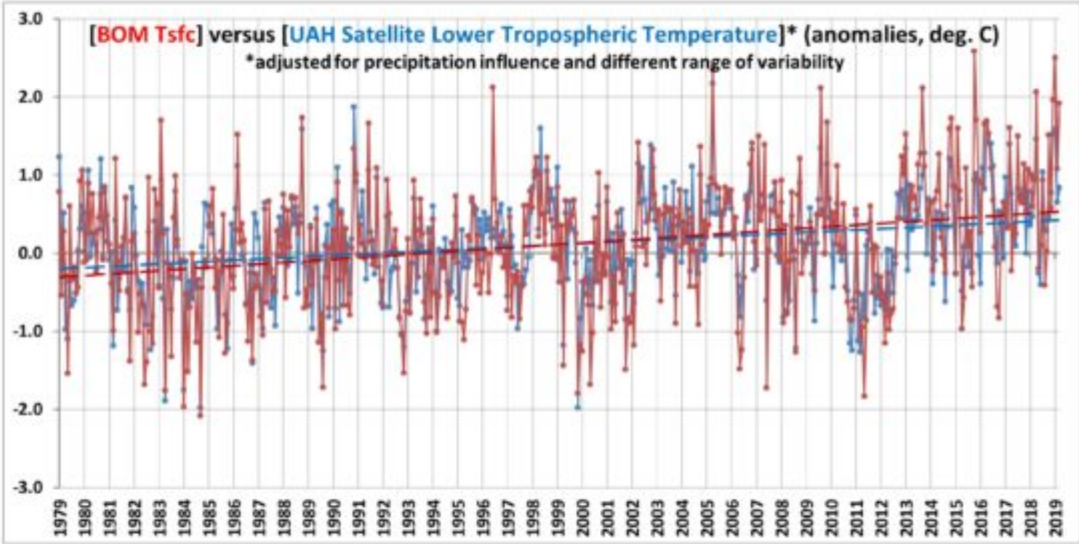

Figure D4. As in Figure D1, but now the satellite data are used along with precipitation data to provide a regression estimate of surface temperature.

To make the differences in Figure D4 a little easier to see, we can plot the difference time series between the two temperature measures as shown in the following Figure D5:

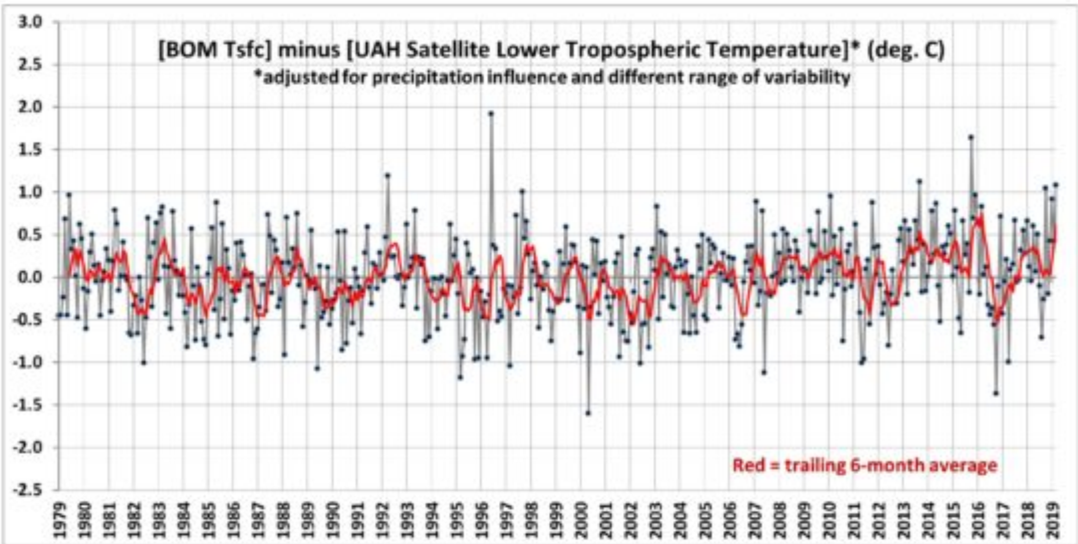

Figure D5. Difference between the two time-series shown in Figure D4.

Now we can see evidence of an enhanced warming trend in the T_{sfc} data versus the satellite over the most recent 20 years, which amounts to 0.40 deg. C during April 1999 – March 2019. I have no opinion on whether this is some natural fluctuation in the relationship between surface and tropospheric temperatures, problems in the surface data, problems in the satellite data, or some combination of all three.

4. Conclusions

The UAH tropospheric temperatures and BoM surface temperatures in Australia are correlated, with similar variability (0.70 correlation). Accounting for anomalous rainfall conditions increases the correlation to 0.80. The T_{sfc} trends have a slightly greater warming trend than the tropospheric temperatures, but the reasons for this are unclear. Users of the UAH data should expect monthly differences between the UAH and BoM data of 0.6 deg. C or so on a rather routine basis (after correcting for their different 30-year baselines used for anomalies: BoM uses 1961-1990 and UAH uses 1981-2010).

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Footnotes

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[1] Russell, Bertrand (1945) *History of Western Philosophy* New York: Simon and Schuster, page 828.

[2] Global warmimg and cooling in this context refers to average global atmospheric temperature. The relevant literature does not reference possible changes in the temperatures of the oceans.

[3] Dr Cazenave in a Foreign Member of the Royal Society, an Emeritus scientist, Centre National de la Recherche Scientifique of France, and was awarded the 2020 Vetlesen Prize. The Vetlesen Prize was designed to be the Nobel Prize of the Earth sciences.

[4] Jean O'Brien Dickey (1945–2018) - Eos

[5] Professor Shum is a Fellow of the American Association for the Advancement of Science and a Fellow of the International Association of Geodesy.

[6] Professor Rozelot is an eminent, now retired, French astronomer from the Université Nice Sophia Antipolis; Professor at the Université de la Côte d'Azur and formerly the deputy director of the Observatoire de la Côte d'Azur in Nice; a member of Gioenia Academy; formerly President of the National Council of Society of Engineers and Scientists of France (IESF) Côte d'Azur, and member of the National IESF Heritage Committee. He is the author of at least one dozen technical books on Solar Physics and approximately 350 papers published in international scientific journals.

[7] Torgny Vinje is regarded as one of the most important polar scientists in Norway during the modern polar era (Issaksson et al. (2016)).

[8] Inge Lehmann was a most impressive and innovative scientist. She stands out as a scientist dedicated to understanding correctly observations of the world. In her case, she showed a single-minded devotion to improving the quality and quantity of seismographic data. By hand, she constructed careful tabulations and graphs of seismic body-wave amplitudes and travel times. As a result of her single minded dedication to observational science, brought to bear her sharp observational insight into the seismic patterns she produced from data in which she had confidence. Her independence of mind and strength of character meant that she was not swayed by the authoritative males who dominated Geophysics at that time.

When presenting the American Geophysical Union's highest honour, the Bowie Medal, to Inge Lehmann in 1971, Professor Francis Birch, who was President of the AGU in 1964, stated *the Lehmann discontinuity was discovered through exacting scrutiny of seismic records by a master of a black art for which no amount of computerization is likely to be a complete substitute.* (Birch, Francis (1971))

Inge Lehmann's approach to the world was most likely shaped by her childhood. Her parents sent Inge, as a child, to an enlightened co-educational school run by Hannah Adler, an aunt of Niels Bohr. She learnt there that boys and girls could be treated alike for work and play. Later, she remarked: 'No difference between the intellect of boys and girls was recognized, a fact that brought some disappointments later in life when I had to recognize that this was not the general attitude.

After completing her studies and gaining a Master of Science in Geodesy from the University of Copenhagen, in 1928 she was appointed chief of the seismological department of the newly established Royal Danish Geodetic Institute, a post she held until her retirement in 1953. Between 1925 and 1936 she undertook the painstaking, meticulous data gathering, tabulation and graphing that enabled her to perceive the existence of the Earth's inner core. In her biographical notes she wrote:

The most important result arrived at was that the presence of a distinct inner core was required for the interpretation of some phases recorded at great epicentral distances.

Sources: Bolt, Bruce (1997) available here: Inge Lehmann. 13 May 1888-21 February 1993 (jstor.org);

Lehmann (1987); Rousseau, Christine (2013).

[9] Anderson, D L (2007) page 120.

[10] Lambeck, K. & Cazenave, A., (1973) (1974) (1976), (1977).

[11] Lambeck and Cazenave (1976) p555

[12] Peter Weart reported: *Through the 1960s and into the 1970s, the average global temperature remained relatively cool. Western Europe, in particular, suffered some of the coldest winters on record.* https://history.aip.org/climate/20ctrend.htm

[13] Lambeck and Cazenave (1976) p570

[14] Ibid., p570

[15] Ibid., p570

[16] Lambeck and Cazenave (1976), p 559.

[17] Ibid., p279.

[18] Note: m_3 describes variations in the rotation rate (directly proportional to changes in the LoD).

[19] Ibid., p279-280

[20] Ibid p283

[21] Professor Vincent Courtillot is a distinguished Geophysicist, Professor Jean-Louise Le Mouel, is also a distinguished Geophysicist, whose contributions to science have been widely recognized. He is a fellow of the American Geophysical Union (AGU) and the Royal Astronomical Society. He was president of the Geological Society of France, and is a Chevalier of the French Legion of Honor. In 1988, he was elected to the French Academy of Sciences. The AGU and the holders of the John Adam Fleming Medal are very pleased to welcome him as the newest Fleming Medalist. Dr Joel Ducruix (deceased) was a research mathematician in the Département des Sciences de la Terre, Université Paris VII and the Institut de Physique du Globe, Université Paris VI

[22] Declination is the angle showing how much magnetic north is different from true north.

[23] The 8 year lag between LoD variations and climatic variations rather than a 10 year lag estimated by Lambeck and Cazenave (1976) has been established by research published in 2006, 2011 and 2016. This research is reviewed in this paper.

[24] Sidorenkov, N. (2009) page 247.

[25] Professor Horst Jochmann, Doctor of Science (Engineering), is now retired and Dr Hans Greiner-Mai has died.

[26] Emeritus Professor of Mathematics and Distinguished Research Professor Mathematics Department, University of California Los Angeles (UCLA) and Emeritus Professor of Geophysical Sciences Institute of Geophysics and Planetary Physics, UCLA

[27] Dr Jean O Dickey (1945 -2018)

https://eos.org/articles/jean-obrien-dickey-1945-2018

[28] The three scientists are: Leonid Zotov, Associate Professor at the Sternberg Astronomical Institute, Lomonosov Moscow State University; Christian Bizouard, Director of the International Earth Rotation and Reference System Service (IERS) Earth Orientation Center and Director of the Earth Rotation and Space Geodesy team at Time-space Reference System (SYRTE) Observatoire de Paris; and C.K. Shum, Professor and Distinguished University Scholar, Division of Geodetic Science, School of Earth Sciences, at The Ohio State University.

[29] Lambeck, K (1980) op. cit. p283.

[30] The word magnetohydrodynamic (MHD) is derived from *magneto-* meaning magnetic field, *hydro-* meaning liquid, and *-dynamic* meaning movement. Professor Hannes Alfvén initiated the field of MHD in a letter to the journal, *Nature*, published in 1942. In 1970, he received the Nobel Prize in physics for this discovery. The fundamental concept behind MHD is that magnetic fields can induce currents in a moving conductive fluid, which in turn creates forces on the fluid and changes the magnetic field itself.

[31] An Alfvén wave is a wave that occurs in a conducting fluid as a result of the interaction of the magnetic fields and electric currents within it, causing an oscillation of the charged particles. The conducting fluid supports wave-like variation in the magnetic field. Alfvén waves are like the waves that occur on the stretched string of a guitar, the string representing a magnetic field line. When a small magnetic field disturbance takes place, the field is bent slightly, and the disturbance propagates in the direction of the magnetic field. Since any changing magnetic field creates an electric field, an electromagnetic wave, the Alfven wave, results. A torsional wave is a twisting wave. An Alfvén torsional wave is an electromagnetic wave that propagates radially from the inner core to the core–mantle boundary with its oscillations in the azimuthal (up and down) direction. See Figure 2.

[32] Bostrom (2000) p12.

[33] Aleksey Lyubushin — speaker of the global conference (creativesociety.com)

[34] Clarifying the Megathrust Earthquake Mechanism: Can Nankai Trough Earthquakes Be Forecasted? | Research at Kobe (kobe-u.ac.jp)

[35] The relevant authorities are: the Hadley Centre of the UK Met Office and the Climatic Research Unit (CRU) of the University of East Anglia for the HadCRUT data and the Goddard Institute for Space Studies for the GISTEMP data.

[36] Ball T (2014); Carter, R (2010); Carter, R and Spooner J (2013); Curry, J and Webster, P J (2011); Essex, C (1991), (2011); Essex, C and McKitrick, R (2002); Koonin, S (2021); Leroux, M (2005); Michaels, Patrick (1994).

Once again IPCC's math doesn't check out | Fraser Institute

The Hand of Government in the Intergovernmental Panel on Climate Change (fraserinstitute.org)

Independent summary for policymakers of the IPCC Fourth Assessment Report (fraserinstitute.org)

https://www.govinfo.gov/content/pkg/CHRG-115hhrg25098/html/CHRG-115hhrg25098.htm

https://judithcurry.com/2021/10/06/ipcc-ar6-breaking-the-hegemony-of-global-climate-models

Many climate change scientists do not agree that global warming is happening - PMC (nih.gov)

Climate Intelligence (CLINTEL) climate change and climate policy

[37] Note that Fagan (1999), (2000) and (2004) has shown how the climate changes rendered by these global atmospheric systems have resulted in major historic changes to cultures and societies throughout the world since the dawn of history.

[38] See http://www.utdallas.edu/physics/faculty/tinsley.html.

[39] Mazzarella and Palumbo (1994) pointed out that bistable modes of oscillation with respect to time are well known in physical and engineering systems and have been extensively studied. They can arise when a system is subjected to external systematic sinusoidal forcing which induces sinusoidal variations in coefficients of the equations of motion. For example, Magnus (1965) showed that „if the input function is sinusoidal, the output function — after the decay of certain transient vibrations — will also be a periodic function with the same frequency ω. In many cases it is, itself, sinusoidal, or at least so closely akin to sinusoidal that we can consider the sine curve to be a very serviceable approximation to it". See also pages 32 and 33 of *Newtonian Dynamics* by Richard Fitzpatrick, Professor of Physics at the University of Texas at Austin, available here: http://farside.ph.utexas.edu/teaching/336k/Newton.pdf. Note, hoever, if the system is unstable, the impact may be to induce some type of oscillatory behaviour or it may be to induce further instability; if the system is chaotic, the impact may result in a chaotic, oscillatory or stable system.

[40] 'Bistable sinusoidal periodicities' means that system can be in two stable, regular sinusoidal states.

[41] "diapycnal mixing" is the mixing of masses of water of different densities, which would remain in stratified layers except for the mixing.

[42] Lorenz (1963) showed that the climate system is a complex system characterised by sensitive dependence to initial conditions and perturbations. Such systems show extreme sensitivity to any slight change in the system's dynamics arising internally or from external impact, or perturbation, however slight. Very small uncertainties in initial conditions or very small disturbances to the processes as they develop will result in a wide spread of uncertainty about the state of the process at future points in time. In a review of the general circulation of the atmosphere, Lorenz (1967) emphasised the need to develop GCMs incorporating this sensitive dependence instead of relying on ad hoc changes to parameters to demonstrate the atmosphere must behave as it does. The computer simulations are only reliable to the extent that they represent correctly the physical processes they purport model, and to the extent that the simulations use correct boundary and initial conditions. The model's spatial resolution is a further major limitation, especially given the sensitivity of climate systems to initial conditions and perturbations. However, the computer simulations used by the IPCC rely excessively on the use of arbitrarily adjusted parameters. Furthermore, the computer simulations do not use the mathematics of complex systems, such as Hurst-Kolmogorov dynamics (Koutsoyiannis, 2011).

[43] 2a (oecd.org) (Organisation for Economic Co-operation and Development Global Science Forum - Best Practices for Ensuring Scientific Integrity and Preventing Misconduct).

[44] Global warmimg and cooling in this context refers to average global atmospheric temperature. The relevant literature concrning the Earth's rotation generally does not reference possible changes in the temperatures of the oceans.

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The Holocene Climate Change Story Part 4:
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Abstract

The first humans probably arrived at Sola in SW Norway just after the brutally cold Younger Dryas (YD) period, as the first neolithic tools found there are from around 11,500 years BP. This period is also called the Preboreal period, where the temperature trends upwards for over a thousand years, before suddenly plummeting again at around 8,200 years BP. In this Part 4, we discuss the reasons for such a transient temperature fall. Thereafter, the temperature increases in the Holocene thermal maximum period. The sea level at Sola reaches its highest Holocene level and is about 6 m higher than at present. Evidence of this transgression is archaeologically documented at sites in Sola, where human settlements by this time proliferate.

Keywords: Preboreal period, Holocene thermal maximum, human settlement at Sola, The Tapes transgression, The Storegga Tsunami

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1. Introduction

The municipality of Sola (58° 55' N, 5° 40' E; see Part 1, Fig. 1) located in Rogaland County, southwest coastal Norway, has a long and rich history of archaeological finds that date back to when Norway was first populated.

The first people to arrive at Sola after the Ice Age came from the south, possibly from Denmark or from Doggerland, during the early Mesolithic (the 'Early Stone Age'). The people in Denmark at this time belonged to the so-called Maglemose culture, and the first migrants who came to Sola approximately 11,500 years ago must then, according to Danish archaeological terminology, have belonged to "the Early Maglemosian era" (11,500 to 9,800 years BP).

These people were characterized as hunter-gatherer nomads who followed the wild-life associated with the northward migrating birch forest, which by 11,500 years BP had spread to the Sola environs (Damlien, 2016; Bang-Andersen, 2012. Huts made of bark have been preserved, in addition to tools made of flint, bone and horn. Characteristic artifacts of this culture are the sharply edged microliths of flintstone, used for spear and arrow heads. (Wikipedia).

The sea level in northern Europe at that time was still in the range of 5 – 8 m lower than at present and did not reach the current level until another ~2,000 years had passed. Climatically, we are still in the Preboral period (Fig.1).

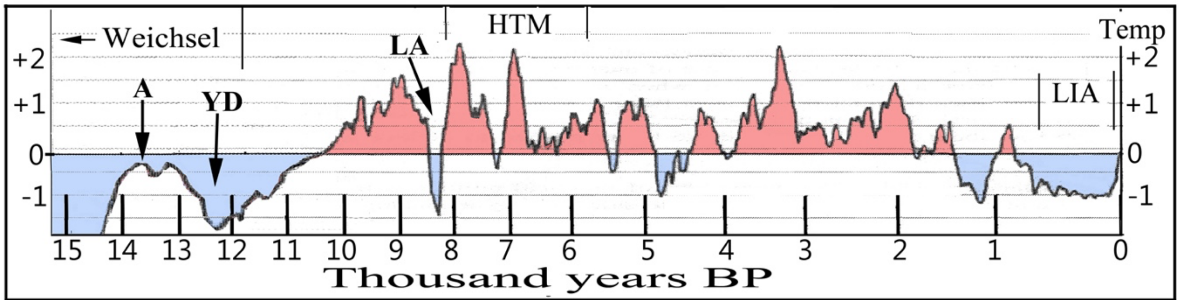

Figure 1: An approximated Weichsel glaciation to the Holocene interglacial temperature curve. It especially illustrates the Lake Agassiz (LA) cold period (also called 'the 8.2 ky event') and the 'Holocene thermal maximum' period (HTM) in relation to the other periods, mentioned earlier (A= Alleröd and YD=Younger Dryas) and the LIA=Little Ice Age, not treated yet. (Based on Gisp2, e.g., www.joannenova.com.au; https://climatechange.umaine.edu/gisp2/data/alley1.html; Wrightstone, 2017).

In the present Part 4 we will take a closer look at the climate and cultural development over the transition from Early Neolithic (Preboreal) to Late Neolithic (Boreal) and beyond, into the warmest Holocene thermal maximum period that lasted for 2,000 years and had a 6-7 m higher sea level than we have at present.

2. The period 11,500 to 9,000 years BP: -The Preboreal period with continued warming

At 11,500 years BP the global warming continued after the YD cold spell. There was relatively rapid melting of the enormous ice sheets covering Scandinavia and parts of North America. This gave room for trees to invade southern Fennoscandia. First came the birch, followed by the Boreal-forest trees, dominated by pine. Later came the deciduous broad-leafed / mixed oak forest, which occupied much of southern Scandinavia (Andersen and Borns, 1994). (Fig. 2).

The study of mountain glaciers in southern Norway, including the Folgefonna and Hardanger Jøkul (which are located 100 – 150 km northeast of Sola) also provide proxy temperature variations over time*: "Following a sudden cooling event from 8,200 to 8,000 years BP, these mountain glaciers receded and were either small or completely absent until 4,000 years BP. From then on, they have varied in size."* (Vorren et al., 2006).

According to Andersen and Borns (1994) (Fig. 2) most of the North Atlantic rapidly became ice free, after 10,000 years ago a Boreal marine fauna migrated into the North Sea and along the coasts of western and northern Norway. The sea transgressed southwards across some of the dry parts of the current North Sea floor. But the southern part remained dry land, as the marine connection through the English Channel was not established before about 8,500 to 8,000 years ago. Figures 2 and 3 from Andersen and Borns (1994) illustrate scenarios during the Preboreal and Boreal transition.

3. The Pioneers and their ancestors (11,500 – 9,700 years BP)

As we mentioned in Part 3, the Pioneers arrived from the south. According to Damlien, 2016*: "The first pioneers are suspected to have constituted small groups of very mobile hunters. After a few generations (100 – 300 years), we believe that family groups would have arrived, as the newcomers became familiar with the landscapes and biotopes. Their new knowledge made it possible to understand the landscape and more efficiently utilize the local resources. In their later period, we find evidence of seasonal usage of the inland and mountains. Thus, there are clear examples of* *seasonal dwelling complexes along the two lakes 'Store Flørlivatn' and 'Myvatn', in Gjesdal, to the east of Sola. These complexes are interpreted as remnants of coastal groups who visited the remote sites for hunting only."*

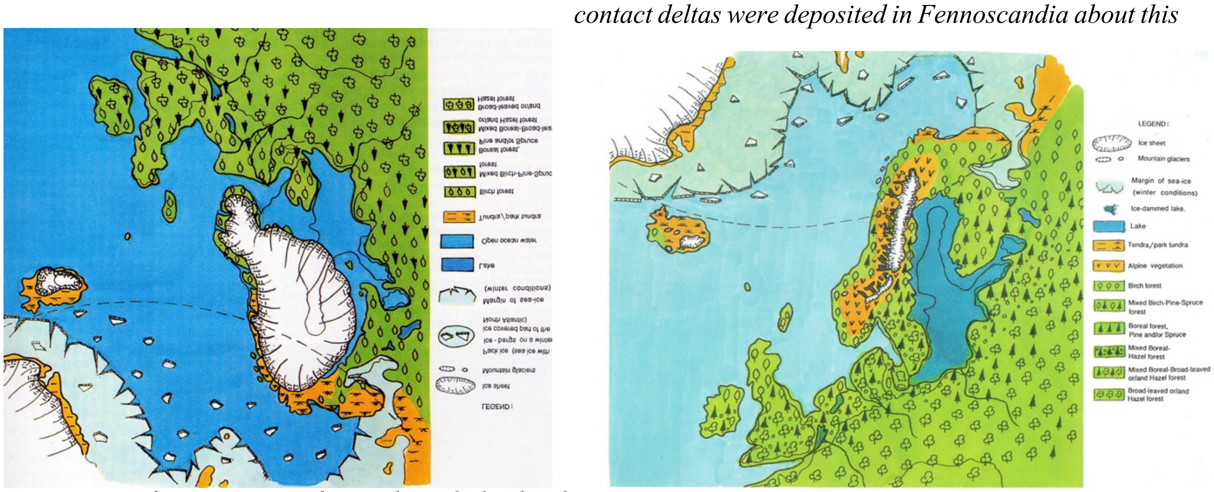

Figure 2: On the left: Northwestern Europe at ~9,500 yr BP, showing that the Baltic Sea experienced a temporary marine (salt-water) phase, the "Yoldia Sea". The youngest well-defined marginal moraines and ice-contact deltas were deposited in Fennoscandia about this time. Most of Europe was forested, and the birch forest has also spread to Sola, where the ice-cap has retracted far into the mountains in the north and east. Notice that Doggerland, in the North Sea is also partly forested with birch. (From Andersen and Borns, 1994). On the right: Northwestern Europe at ~9,000 – 8,500 yr BP: "This is an early part of the "Ancylus Lake" phase in the Baltic area. The lake drained by river through the Danish strait. There are still remnants of the North European Ice Sheet in the mountain valleys along the Scandinavian-mountain chain. This period was warm, and the ice remnants were generally stagnant. The ice dammed lakes in the upper parts of the normally east-draining mountain valleys. The Ancylus Lake is dammed in the south by land that has risen because of isostatic uplift as the ice-load has recently melted away. Notice that the southern part of the North Sea was still dry land, with one lake draining southwards through the English Channel Valley and another lake draining northwards to a bay at the mouth of the extended Elbe River Valley." (From Andersen and Borns, 1994).

4. The period 9,700 to 8,200 years BP: - Humans spread and settled at Sola

At Sola, one would expect that the hunter-gatherers behaved according to the Maglemose culture, and would have a favoured locality, which they roamed out from and returned to. From archaeological finds, it seems that the current Sola Centre, was one of these localities, where they had a certain set of activities.

According to Sørensen (2006), the roaming directions would be directed by the seasons. Thus, during winter months they would hunt for large game, including seals, that during January and February would have puppies to look after on and near the coast. During springtime, there would be plenty of birds migrating from the south to Sola and further north. During summer months they would be occupied by fishing, berry/nut-picking, and in autumn, they would again hunt migrating birds going south.

Around year 9,700 BP, (Fig. 2) the climate became warmer and drier, as the great glaciers over Southern Norway melted away. In Boreal (~8,000 y BP), only the largest mountain glaciers remained (such as the Jostedalsbreen and Folgefonna glaciers). During the same period, there was a dramatic sea-level rise (transgression), that drowned Doggerland and most of the previously dry land in the

North Sea. This, of course, opened up new possibilities for more human migration to and from Sola across the now ice-free mountains in the south-east.

According to Lillehammer (2003): *"Neither before, nor after the Weichsel glaciation has there ever been a better climate in the Rogaland district than during the 4 thousand years between 9,000 and 5,000 years ago. As the pine lived on, many more types of deciduous trees arrived, such as Ash, Elm, Oak, including Hazel in the lowlands of Sola. But even during this warm period hunters went to the mountains for hunting reindeer."*

Figure 3: A shelter build simply by leaning tree stems, branches, and sticks, like the one shown here, is called a 'gapahuk' in Norwegian (a 'lean-to shelter' in English). Such simple temporary shelters or dwellings do not leave any significant footprint for archaeologists to find, as they are liable to collapse into a heap of branches and stems. It is only artifacts left behind, for example bone and stone remnants that can document where humans occurred during the early stages, e.g., before ~9,000 years BP. Therefore, it is difficult to find how and where the pioneers lived, except for the obvious caves and rock shelters. (Photo: M. Hovland).

5. Early human activity-traces in Sola

Due to the building of a new 10 km long highway between Sola Center and the harbour township of Tananger there have recently been a series of remarkable archaeological finds in Sola. Thus, for example excavations in Sola Centre unearthed roasted hazel nutshells, dated to 8,500 years BP. This means that humans had settled nearby and were probably thriving there, during the early neolithic period. These finds were done near the top of a 7 m high rocky knoll surrounded by a lower grass- and wooded plain, near the current center of Sola municipality (Fig. 4).

In total, there were five surface layers showing human activity within the excavated area of approx. 200 m by 200 m (Fig 4). Four of these were on the protruding rocky knoll (Fig. 4) and the fifth is out on the plain. The three areas A1, A3, and C on the knoll were relatively undisturbed and may stem from different times of activity during the neolithic. On A1 a significant amount of quartz crystal chippings was found. A3 was the largest and most prolific surface of activity on the knoll. Several thousand flint chips were found from toolmaking. However, the most interesting discovery at this activity surface (A3) was a high number of scorched and burned hazel nutshells.

Wild hazel trees are also common at Sola in the Present, - which means that they have been around here for at least 8,500 years. *"The shells of hazel nuts have very good conservation properties. Datings made as early as 8,500 years BP is very rare to find in Rogaland. One of the reasons is that most dwelling areas were disturbed by alterations in sea level."* (Scheie Eilertsen and Redmont, 2019).

"The excavated archaeological remnants at this activity surface also contained simple flint- and rock-crystal (quartz) tools, and some rounded suspected cooking- and roasting-stones. On the nearby grassy plain there were clear remnants of a dwelling area. However, this had been partly destroyed by modern agricultural activity, which made dating impossible." (Scheie Eilertsen and Redmont, 2019). According to the archaeologists, this area is probably on the outskirts of a larger surface of activity, which had been used for some time.

Figure 4: On this rocky knoll, with pine trees, the archaeologists found several surfaces of former human activity. Apart from tools and tool-making flint and quartz chips, they also found roasted hazel nut shells. These were dated to about 8,500 y BP, which is quite exceptional and remarkable. The person standing in the field, in the front, is located at another work and dwelling surface, which had simultaneous activity. (Photo: K. Scheie Eilertsen).

Figure 5: Hazel nuts are common at Mesolithic sites like the one near Sola Centre. When roasted, the shells are long lasting. However, the dating at this site is much older than what is normally found. The reason is likely to be that these shells were found about 4 m above the sea level at that time. In lower lying locations the nut shells would likely have been washed away when the sea-level rose higher during the Holocene thermal maximum (HTM) period (7,000 – 5,000 y. BP). (Photo: M. Hovland).

6.   The 'Tjora 1' dwelling location

At Tjora, about 5 km northwest of Sola Center, there is another area that was excavated, measuring about 75 m^2 in area. Also here, the archaeologists made some unique discoveries. Two completely different dwelling surfaces were found and excavated, only 15 m apart, but with a time-difference of about 3,000 years. Whereas the youngest of these (Tjora 1) represented an early Mesolithic dwelling, the other one (Tjora 2) represented a sophisticated hut settlement.

The Tjora 1 site is from this same period as that on the knoll in Sola Centre, where the roasted hazel nuts were found, e.g., early neolithic (around 8,400 – 8,000 years BP). The settlement was found to be well protected against modern agriculture as it was partly covered by transgression material (pebbles, cobbles and a mixture of earth and sand). *"It was only when we were using an excavator truck to dig out the deepest hollow in the terrain, that we discovered that this was an early neolithic site. Not only was the deepest layer covered by aeolian sand. It was also covered by a heap of transgression material of cobbles, pebbles, earth and coarse gravel."* (Scheie Eilertsen, 2016). As we shall soon explain, there was a very cold spell starting around 8,200 yr BP, followed by a 3 – 4 m large tsunami-wave that hit the coastline of western Norway ~50 years later (e.g., around 8,150 years BP). The tsunami was caused by the large submarine landslide at Storegga (at the edge of the continental shelf) that took place at this time (see page 15 below). The mixed coarse material may well stem from this latter event, which means that the dwelling site is slightly older than this (8,150 yBP) and can well be contemporaneous with the Sola Center location (8,500 yBP).

Figure 6: Overview image of a partly excavated archaeological site at Tjora (Tjora 1), some 5 km north-west of Sola Centre. It is of early stone age and most probably before 8,150 yr BP. The red circles mark fireplaces (kirns) and the green circles are refuge hollows. From the stone remnants and many flint chips, the site was evidently also a workshop for making flint utensils, such as scrapes and arrow/spear heads. The site was probably contemporaneous with the Sola Centre location (e.g., from around 8,500 yr BP). This means that it was from the cool period and before the tsunami washed the shoreline of Sola. This location is only a few metres above the sea-level at 8,150 yr BP and must have been affected by the tsunami. The trench on the left has been cut though the heap of unsorted debris; rocks, sand, and mud that covered the whole site. This material is typical of sudden flooding and tsunami waves. (Photo: Scheie Eilertsen).

All in all, this probably means that there was a whole community of hunter gatherers at Sola, spread over many kilometres, with various specialities that probably lived in harmony at that time. During 8,500 BP, the sea level was at the same level as the Present, and the mean annual temperature was perhaps one or two degrees warmer than at present (e.g., around 8 – 9 degrees C, as Sola now has an annual mean temperature of ~ 7.8 C). (Andersen and Borns, 1994; Hovland, 1971).

However, this warm harmony and proliferation of humans in Sola, did not last very long. A rather sudden cooling set in around 8,200 years BP and lasted a couple of generations. This was the so-called '8.2 ky-cooling event' (Fig 1).

7. The 8.2 ky cooling-event

According to Ellison et al. (2006), the largest climatic perturbation in our present interglacial (e.g., Holocene), the 8,200-year event, is marked by two distinct ocean cooling events in the subpolar North Atlantic, at 8,490 and 8,290 years ago. The sequenced surface and ocean changes were forced by pulsed meltwater outbursts from a multistep final draining of the proglacial lakes associated with the decaying Laurentide Ice Sheet margins (Lakes Agassiz and Ojibway). This led to a summer sea surface temperature (SST) about 2 degrees C colder than at present. (Ellison et al., 2006).

The natural morainic dam that held the fresh meltwater in place, on the northern shores of the great Hudson Bay, Canada, collapsed (apparently in at least two main intervals), and enormous amounts of low-density water flooded through the Hudson Bay and into the Arctic North Atlantic, and disturbed the circulation of seawater in the whole North Atlantic Ocean. According to Ljungqvist (2017), the volume of freshwater was twice that of the Kaspian Sea.

The climatic effect was indeed felt throughout the world: *"It was changes in precipitation that probably was the most important factor for humans. During the 100 to 150 years, this cooling event lasted, it became wetter in Northern Europe and drier around the Mediterranean, Southern China, and Central America."* (Ljungqvist, 2017). To the inhabitants of Sola, the weather must have changed rather sharply from a pleasant mild climate to a cool, wet, and harsh climate, that lasted more than a generation or two.

Also, Kleiven et al. (2008) studied this event, and characterised it as follows*: "An outstanding climate anomaly 8,200 years before the present in the North Atlantic is postulated to be the result of weakened overturing circulation triggered by a freshwater outburst. It is the most prominent Holocene anomaly in bottom-water chemistry and flow speed in the deep limb of the Atlantic overturning circulation. It begins at 8,380 years BP and is coeval with the catastrophic drainage of Lake Agassiz".*

The final drainage of Lakes Agassiz and Ojibway has also been associated with an estimated 0.8 m rise in global sea level. These two lakes represented a huge glacier-dammed melt-water reservoir located inland, to the south of Hudson Bay, Canada. The discharge of Lake Agassiz and Ojibway had an estimated combined volume of 163,000 km^3 (or 5.2 x 10^6 m^3 s^{-1} (Sv) if released in one year). The lakes are the only identified potential freshwater sources of sufficient magnitude to explain the presence of the pronounced 8.2 ky cooling, that severely affected the North Atlantic region, and to some degree, the rest of the world also. (Ellison et al., 2006).

8. At 8,150 years BP: - A tsunami wave hits the coast

The 8.2 ky cooling event occurred not long after the hazel nuts were roasted in Sola (8,500 yr BP). But, if the people living along the coast of Sola managed to keep up their existence, during the cooler and wetter climate, they were soon to be affected by another of nature's most feared geohazards, namely a great tsunami wave generated by one of the world's largest known submarine slides, the so-called 'Storegga Slide', dated to 8,150 yr BP (Bondevik et al., 2003; Haflidason et al., 2005).

It occurred on the seafloor west of Trondheim, about 300 km north of Sola (Fig. 7), and it had a total run-out distance on the seafloor of ~800 km, with a vertical hight different of about 1.5 km. (Bugge, 1987; Bondevik et al., 2003). About 3,500 km^3 of muddy material slid out and generated a huge tsunami that impacted the Norwegian western coast, from Lofoten in the north to Lindesnes and Denmark in the south. It travelled along the whole western and southwestern coastline wreaking havoc all the way. Tsunami waves have extremely long wavelengths, which makes them travel at speeds of several hundred kilometres per hour and causing lethal high-energy destruction: *"Close to the present shore, the tsunami deposit is 30 to 40 cm thick and shows large rip-up clasts of peat embedded in the sand. Many of the clasts are 10-30 cm in diameter with sharp edges. Also, pieces of wood and trunks were found in the sand. The sand which is medium to very coarse, contains pebbles and cobbles; we even found a boulder as large as 25 cm in diameter."* (Bondevik et al., 2003).

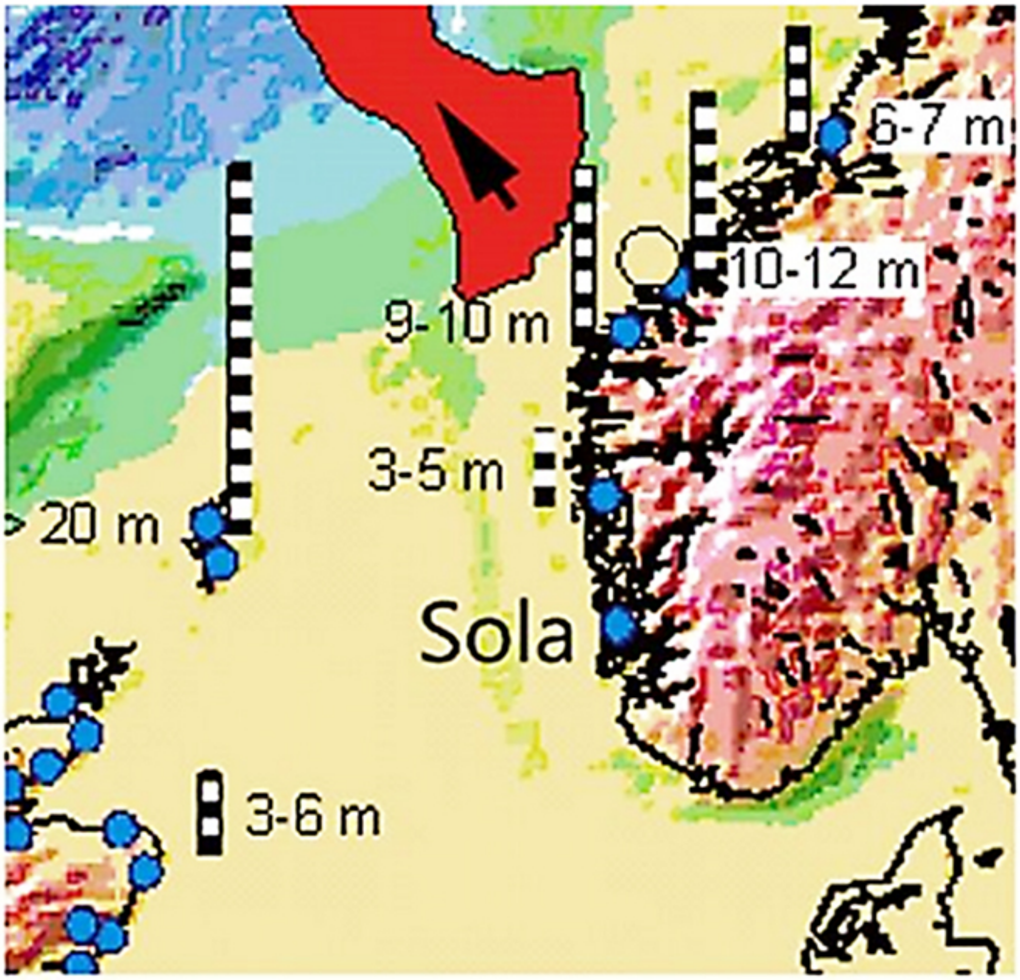

Figure 7: A map showing the situation after the Storegga submarine slide (red), one of the world's largest known submarine slides. Run-up heights of the tsunami wave are shown in metres. (Modified from Bondevik et al., 2003).

Archaeologists have speculated about this happening, and what it may have done to people along the Norwegian coastline. As the illustration shows, the total run-up of the tsunami wave around the North Atlantic basin was from 15 m on Shetland and 12 m in Trøndelag, Norway. At Sola, the run-up may have been around 3 – 4 m, which will have impacted the northern part of the Sola coastline most. This means that Tjora is one of the potential areas that would have been impacted.

At the University of Stavanger, there is now a research project underway, to investigate how life along the coast was disturbed by the Storegga tsunami event (dated at 8,150 yr BP). Is it possible to find any archaeological evidence that life changed dramatically after this traumatic event, where many people died, and dwellings were left in ruins? The project is led by Astrid Johanne Nyland, and has 9 researchers from Norway, Ireland, UK, and Denmark. The project is in its third year and will be completed in 2024. It will be interesting to see what they find out (Nyland, 2021).

9. A skeleton discovery at Vistehola cave

In Part 3, we mentioned that one of the dwelling locations near Sola, was the 'Vistehola' rock cave, in Randaberg municipality, 8 km WNW of Stavanger City. Excavations of 125 m^2 at Vistehola (also called the Svartehålå, 'The Black Cave') exposed a one-metre-thick culture layer, where the dweller's menu was documented. They had a healthy menu consisting of small land- and sea-mammals, many types of fish and birds. Small, fine tools were also found among the food remnants, such as fishhooks, net-sinkers, arrowheads, scrapers, and spearheads (Bang-Andersen, 1995). They even found a more-or-less intact human skeleton and that of a dog.

"The Viste skeleton is one of a small number in Norway, dated to the Mesolithic. The remains, identified as those of an adolescent male, were found during excavation in 1907 of a shellmidden within the Svartehålå (Brøgger, 1908). He was found with his back to the stone wall". (Schulting and Budd, 2016). So-called intrusive burials like this one, in early shellmiddens are not unknown, although they seem to be rare (Saville and Hallén, 1994). It was not until the publication of a direct radiocarbon dating of the skeleton, of 7,420 +/- 150 yr BP (Hufthammer & Meiklejohn, 1986), that its long-suspected Mesolithic attribution could be confirmed (Schulting and Budd, 2016).

The 'Viste-boy' skeleton was re-examined and re-analysed again in 2015, by Stavanger Museum, with emphasis on modern stable isotopes. A long bone sample was analysed for nitrogen $\delta^{15}N$. In addition, a new and adjusted modern carbon-14 dating was achieved and reported by Schulting and Budd (2016). The new dates of burial for the Viste-boy are now determined to be sometime between 8,255 and 8,025 yr BP, which is very interesting, for sure, as it is within the two natural events we have just mentioned: the 8.2 ky cooling and the Storegga Tsunami.

In addition, the following results came: *"The new $\delta^{13}C$ value of -14.7 permille indicates a considerably higher consumption of marine foods than the previously published measurement of – 17.1 permille, and so is rather more consistent with measurements on Danish Ertebølle coastal humans; however, it is now more at odds with the dominance of terrestrial fauna in the cave than initially thought….this discrepancy is probably more apparent than real, since given the early date of excavation (1907), it is unlikely that fish bones were adequately recovered by the archaeologists at that time."* (Schulting and Budd, 2016).

And furthermore: *"The Viste skeleton's $\delta^{15}N$-value of 18.4 permille is presently among the highest known in Europe, if not the highest (Schulting, 2015). This suggests that the Viste boy was consuming high-trophic-level, piscivorous fish and/or sea mammals. Thus, his diet was ~70 % fish. Sea mammals might be expected to have featured strongly, although cod – the remains of which were present at the site – also exhibit enriched ^{15}N".* (Schulting and Budd, 2016).

The new date and stable isotope data for the Viste skeleton highlights the importance of re-visiting and re-analysing earlier collections: *"This will considerably help refine the diet and dating of the Viste human (and dog!) remains and will also prove useful for palaeodietary research in western Norway and northwestern Europe". (*Schulting and Budd, 2016). Altogether 125 m^2 of the cave floor was excavated in 1907, then in 1939 and 1941. Aside from the bone tools, the archaeological material consists of a variety of lithic artefact types, such as ground and pecked greenstone 'chubby' adzes, cores, scrapers, burins, knives, microliths, and flakes of flint and other raw materials. In spite of coarse methods of excavation, the faunal data are rich in animal species, represented by terrestrial

Figure 8: Left image: At the Vistehola (also called the Svartehålå, 'The Black Cave') excavations in 1907 disclosed human ~15-year-old boy skeleton (The 'Viste boy'). He was buried at ~1.5 m depth in the shellmidden of the cave, together with a skeleton of a dog. They died in the period between 8,255 and 8,025 yr BP, where the temperatures had plummeted during the 8.2 ky cold spell, and thereafter there was a tsunami striking the coastline of SW Norway (dated to 8,150 y BP). (Photo: Kristian Jacobsen) Right image: The image of the boy on the right is based on the skull form and the sculpturer's idea of what he may have looked like (Olaussen, 2023; Photo: Jon Ingemundsen).

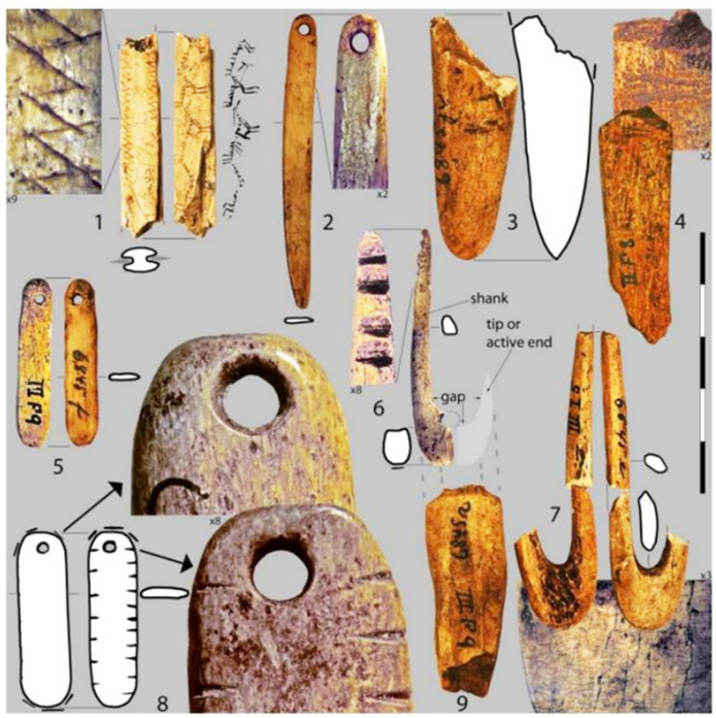

Figure 9. Viste bone and antler industry securely associated with stratum 1 (except number 3, on antler, they are all made of bone). 1: Fragment of an engraved bilateral slotted point; 2, 5 and 8: 'flutters'; 3: removed active end of a blade-axe; 4 and 9: waste debris cut by transverse sawing (all around) with a stone edge and flexion break; 6: fishhook roughout; 7: almost complete fishhook. (Scale subdivision in cm.) (Illustration by É. David).

and marine mammals (22), birds (37), and fish (11). The data indicate summer occupations and, possibly, also use during winter. The variety of the material together with the location and size of the site may indicate that it was used as a seasonal base camp during the relevant period (Mikkelsen, 1979). (Bergsvik and David, 2015).

"Altogether, 29 worked bone and antler artefacts have been analysed from the Mesolithic layers at Viste. The manufactured pieces represent six different tool categories, which make this series. relatively varied. Fishhooks of the so-called 'Viste type' are well represented. The hooks measure 2.6–6.9 cm in overall length. A majority of the hooks from Viste are broken, most often at the bow, probably during fishing." (Bergsvik and David, 2015).

10. The period 8,150 – 5,600 years BP: - The Holocene thermal maximum (HTM) and a unique hut construction

After the 8.2 ky event, the thawing of glaciers continued as the impact of the fresh water abated. The temperatures began to rise, and the North Atlantic Ocean settled down, with a viable Gulf stream, again.

"As a consequence of a warmer future climate is a rise in sea level that could cause a wide-spread transgression along many coastlines. The last time people in Scandinavia faced a transgression was in the Early to Mid-Holocene, in the Mesolithic. Settlements, cultural layers and remains of this age are found submerged and/or covered by beach sediments." (Fjellskaar and Bondevik, 2020).

In the Early and into the Late Mesolithicum (8,000 – 6,000 yr BP), the inhabitants of Sola were hunter gatherers, as no cultivation that we know of was being done. With a rising temperature, the sea level started rising and temperatures became more inviting as the growth season for trees and plants, lengthened. When the sea rises and floods the lowest-lying terrain, the coastline changes, with more islands and more inlets and straits forming. In Norway, this Mid-Holocene transgression is called the 'Tapes transgression', named after the warm-water edible mollusk *Tapes decussata*. (Bondevik et al., 2019).

On the island of Longva, near the west-coast city of Ålesund, Mid-Norway, Bondevik et al. (2019), observed that the Tapes beach ridge had been occupied by Mesolithic people. They wanted to know how they could have such an apparently precarious dwelling location, as beach ridges are prone to be overflooded by high waves during winter storms and apparently unsustainable for dwelling purposes. Their results are interesting and relevant also for the settlers in Sola.

Their archaeological excavations clearly showed that storms overtopped the beach ridge and deposited cobbles, gravel and sand on the settlements. Nevertheless, the beach ridge had been occupied for nearly two thousand years. They reckon that the beach ridge settlements must only have been used part-time: *"The settlements at Longva must have been part of a mobile settlement pattern. Families or groups moved to the Tapes beach ridge in the spring/summer to take part in fishing and hunt marine mammals and seabirds. As late autumn approached, they returned to their winter quarters. It is not yet known where these people spent the winter."* (Bondevik et al., 2019).

Radiocarbon dating of hazelnut shells and charcoal showed that the Tapes transgression maximum occurred between 7,600 and 5,600 yr BP at Longva. For this period of 2,000 years, the sea level had been stable at between 8.2 and 9.0 m above present day mean sea level for the Longva location. At Sola, where there has been very little, or no, isostatic vertical movement of the land, the sea level was about 6 - 7 m higher than at present.

11. Sola beach moves to Sola Centre

Because of the Tapes transgression, numerous archaeological sites in Sola of pre-Tapes age are found to be covered by eolian sand of up to two metres thickness. At most, the Sola beach, which at present is located to the west of the current Stavanger airport (Sola), moved 5 – 6 km inland, with typical beach sand dunes building up in the current Sola Centre, just about 500 m south of the rocky knoll mentioned earlier (Fig. 10 and 11). One of the sites that became covered by up to 15 cm of eolian sand is the Tjora 2 site.

Figure 10: The two photographs on the left were taken in the current centre of Sola, only 400 m from the location where the roasted hazel nutshells were found. The middle photo is a close-up of the photo on the left. It shows a sand dune of the same type as one now finds at Sola beach, about 5 kilometres to the west. The photograph on the right is taken at the current Sola beach. The elevation difference between the two images on the right is about 6 m. This is proof that the beach moved about 5 km in distance and 6 m in elevation as the sea level rose during the HTM period (also called the Tapes transgression). (photos: M. Hovland).

12. The 'Tjora 2' dwelling case

At the Tjora 2 location mentioned earlier, there are remnants of a unique hut foundation buried beneath eolian sand, transported by wind and waves a much younger and more advanced dwelling location than Tjora 1 (only 15 m away).

The Tjora 2 site is described as follows: The area is about 75 m^2 in size, where the thickness of the culture layer varies from a few centimetres to 30 centimetres. "Amongst the artefacts found here are two grinded chisles made of greenstone, several grinding plates and five scrapes. Numerous pieces of flint chips. Also, there were about 70 pieces of pumice stone, used for grinding and polishing of arrow-shafts. Up to 140 kernel stones and 35 stones for knocking flint. In other words, a place for producing arrows and other tools." (Scheie Eilertsen, 2016). It existed in the younger neolithic period (6,000 – 5,300 years BP), and the archaeologists found a distinct rectangular depression, measuring 5 m by 5 m where a hut had been constructed. The top of the depression was sealed by a layer of about 10 cm eolian quartz sand, similar to that existing on Sola beaches of today: "As we dug deeper into the depression, we became more and more aware of the fact that it's depth and shape was special and unusual. It proved that the structure represented a well-founded hut construction.

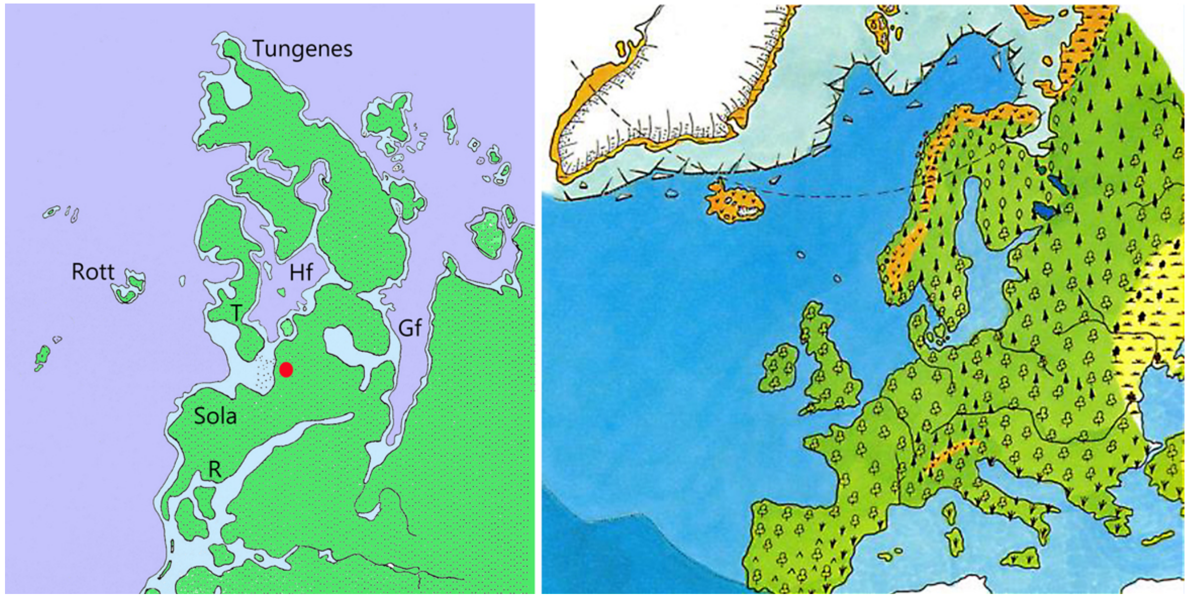

Figure 11: The map on the left shows the effect of the Tapes transgression during the HTM on the coastline of the Sola – Stavanger area. Dark blue shows the current coastline and, also that of around 8,000 years ago. The light blue shows land flooded by the maximum sea-level rise around 6,000 years ago. The red circle is Sola Centre. Legend: T= Tora; R=Ræge; Hf=Hafrsfjord; Gf=Gannsfjord. (Modified from Simonsen and Lye, 1978). The map on the right is from Andersen and Borns (1994), as they illustrate the situation during the HTM. Their figure caption reads: "Europe sbout 4,000 years ago. The presented vegetation pattern approximates the one which would prevail today if human activity had not influenced, and to some degree changed, the pattern. The ice cover on the northern part of the Atlantic Ocean represents winter ice-conditions."

The most unique aspect of this hut construction were the various types of peat blocks that had been used in the walls and beneath the walls were based on. Even though some of the wall peat blocks had collapsed into the center of the hut, it was obvious to us that this was a new and unknown way of building a sturdy hut". (Scheie Eilertsen, 2016).

In total, there were 962 other finds associated with this hut construction. These were all of the same period, 6,000 – 5,300 BP. The most significant remains are fireplaces, middens containing numerous waste flakes (flint) and lithic tools, including fish sinkers flint tools and fragments of tools, such as axes, arrowpoints, scrapes, etc. (Fig. 12).

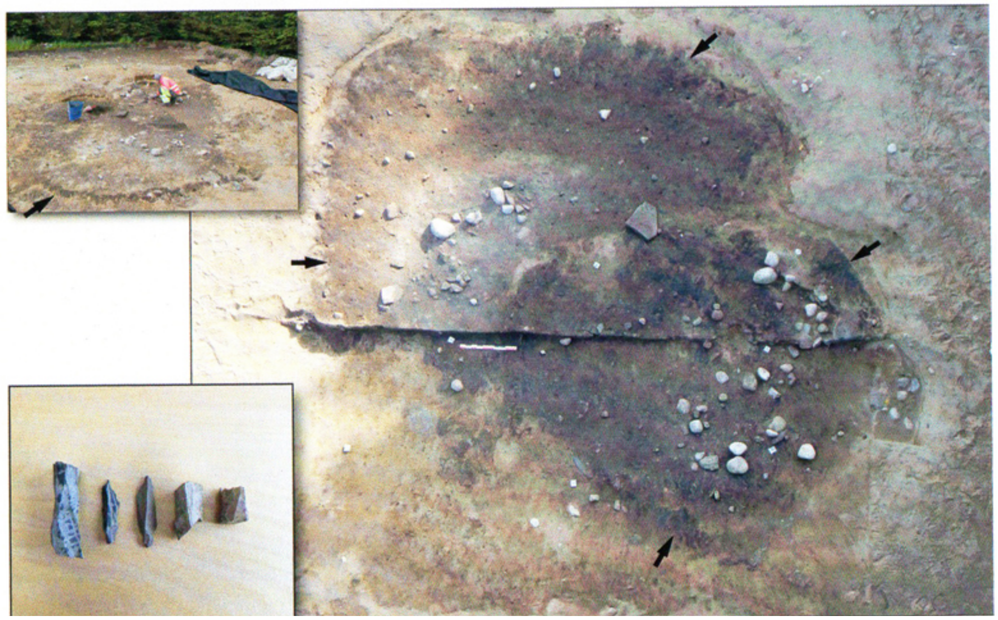

Figure 12: Overview of the two-phased hut basement, from Early Neolithicum, 6,000 – 5,300 yr BP. There is evidence of a lower wall of peat (darak stripes, marked with small arrows). Upper left: the hut during excavation. Lower left: cylindrical kernels in rhyolite and flint, arrowheads in rhyolite. (Illustration by Theo Gil). (Modified from Scheie Eilertsen, 2016).

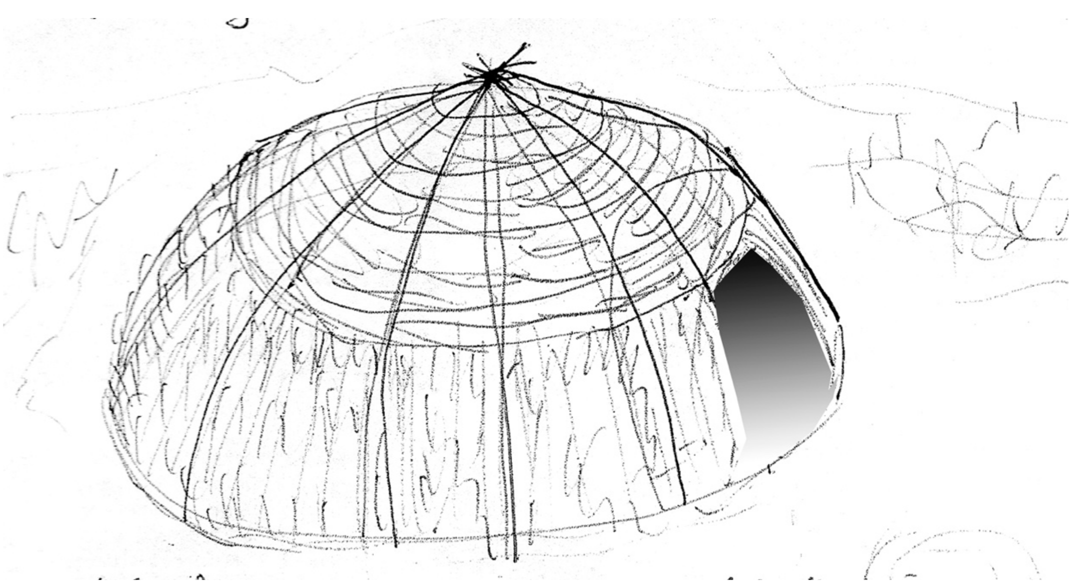

Figure 13: Artist's impression of how the sophisticated and sturdy hut may have appeared (M. Hovland).

It is rather remarkable that in horizontal separation, these two unique dwellings, are only 15 m from each other, whereas, in time, they are separated by about 3,000 years. It also seems that there were no dwellings here in that time span of ~3,000 years. Could it have something to do with a cooler climate?

In Part 5, we will cover the period from 5,300 to about 3,000 with climate cooling and the mysterious Bronze Age, where Sola has some unique archaeological finds.

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About Historical CO_2 Levels

Discussion of Direct Measurements near Ground since 1826 by E.-G. Beck

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Abstract

Several comments can be made on the reconstruction of the historical CO_2 data made by the late Ernst Beck (Beck, 2010, published in SCC 2022 [21]). While most chemical methods used were fairly accurate (+/- 10 ppmv), many places where was measured were completely unsuitable for "background" CO_2 levels and in many cases too few measurements were made at high wind speed to have a sufficient convergency of the data towards a "background" CO_2 level. Moreover, the late Ernst Beck made several mistakes in the interpretation of the available data. Finally, the possibility of huge CO_2 levels around 1940 is physically impossible and contradicted by several other proxy's and contradicted by CO_2 levels as measured in high resolution ice cores.

Keywords: Historical CO_2 levels

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1. Introduction

The following is the result of many years of direct discussions with the late Ernst Beck in the years 2000-2010, until his untimely death. I am very reluctant to give this critique, as he can't defend his work anymore, but when bad data are spread around, that is at the cost of the credibility of the community for other items where climate science is on shaky grounds.

Earlier discussions with the late Ernst Beck are reflected in a web page written in 2008 and with a last update in 2010 on my web site [1]. I was aware of his latest work but did not see it at that time, because it was never published. Until now, with the publication of his work in this journal.

2. The historical methods used

In general, the methods used were fairly accurate, with some exceptions.

E.g., the apparatus used at Barrow, Alaska [2] was only accurate to +/- 150 ppmv, which was accurate enough for the intended purpose: measuring CO_2 in exhaled air of the researchers at the near polar station of around 40,000 ppmv, but by far not accurate enough to measure CO_2 in ambient air to a few tens of ppmv.

Beck still included these inaccurate data in his latest work, pointing to an accuracy of 0.015% (+/- 5 ppmv at 300 ppmv) a factor of 30 smaller than reality, as the inventor of the apparatus Scholander [3] says that the accuracy of the method was +/- 0.015 *volume* percent, which is +/- 150 ppmv in 100% gas (CO_2 or O_2 or N_2 or a mix of them), not 0.015% of the measured data.

Other critiques about the accuracy of the chemical methods were expressed by peterd at the blog of Jennifer Marohasy [4], who looked at the historical methods in detail and found errors up to 50% overestimating the CO_2 levels for some methods that the late Ernst Beck assumed "accurate" to within 3% [4].

In fact a pity that the data of Barrow were not better, as at Barrow there is currently a "background" CO_2 measuring station from NOAA [5], so that a comparison of both datasets can be made. That will be done in chapter 8.3.

Several other misinterpretations of data and methods were encountered in our discussions.

3. The interpretation of some of the data.

It is difficult to know the criteria that Beck used to include or exclude certain historical series of data and how and why he "corrected" some of the data with tens of ppmv for seasonal or other reasons.

Besides several long series that make the bulk of the 1942 "peak", several other isolated measurements support his peak value. Unfortunately there are practically no measurements over the oceans or coastal with wind from the seaside in de period of his peak value where current "background" CO2 levels are found.

Several such measurements before and after the 1942 "peak" show background levels around the ice core 300 ppmv. That makes that Beck's remark under Figure 24 in his work (Beck 2022 [20]) can't be true and conflicts with what K. Buch (see Schneider ea. 2022 [6]) found during his investigations when exploring CO2 levels over the Northern Atlantic Ocean:

„It is most remarkable that literature reveals CO2 enriched air coming from the sea at several stations when sampling at the coast (Haldane North Sea, Buch 1932–1936 Barents Sea, Northern Atlantic) or over warmer ocean currents in the Northern Atlantic (Buch1932–1936). This suggests the Northern Atlantic Ocean as the source of the enhanced CO2 levels.

The work on K. Buch's life (Schneider ea. 2022 [6]) at page 41 says just the opposite:

„Low pCO_2 and uptake of atmospheric CO_2 were observed in different regions of the North Atlantic. As a consequence of plankton growth, the pCO_2 in June 1935 on the route between Copenhagen and Boston showed in general values below the atmospheric level. Extreme low pCO_2 were observed in arctic waters close to the ice boundary during measurements on a ferry along the route Narvik – Svalbard in August 1936 (BUCH, 1936).“

Based on the NH sea surface temperatures, according to HADSST3nh [7], in the period 1935-1945 the increase of the ocean surface water temperature was about 0.2 K. That gives a maximum increase in equilibrium pCO_2 between oceans surface waters and atmosphere of not more than 5 ppmv according to Henry's law. See the formula of Takahashi (2002 [9]). Even if the North Atlantic warmed twice as fast, 10 ppmv extra from the local oceans can't give a 60 ppmv peak globally as that is fast mixed with the bulk of CO_2 in the atmosphere over the oceans…

Several other (earlier) works mentioned in Buch's life, all point to a strong uptake of CO_2 in the Nordic Arctic oceans at very low pCO_2, not much different from current pCO_2 levels, which are extremely low in the North Atlantic waters: down to 150 µatm in equilibrium, with a global CO_2 level over 415 µatm in the atmosphere. That gives that the North Atlantic waters then and now have the highest CO_2 uptake in the world, directly into the deep oceans, with the sinking waters of the thermohaline circulation (THC).

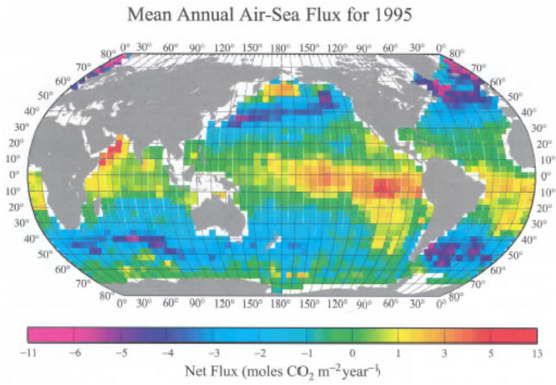

Figure 1: compilation of the releases and uptakes of CO_2 by the oceans. Source: Feely ea., 2001 [8].

Another misinterpretation is that Beck shows a "calculated" atmospheric CO_2 level from data by Wattenberg from the 1925-1927 scientific expedition by the research vessel "Meteor" of around 313 ppmv in Table 9 of his work (Beck, 2022 [21]).
Wattenberg did not measure any airborne CO_2 levels: all pCO_2 measurements were done on sea-water samples from different depths, including at 0-meter depth (surface water), which Beck interpretated as air samples. Which is impossible, as the same samples had also pH values measured.
While the original work of Wattenberg is not directly available on line, the methods used are available by Wattenberg (1925, page 67 [22]) and show following explanation:

"Die Kohlensäuredruckanalysen werden mit dem von A. Krogh beschriebenen Apparat ausgeführt, der hier an Bord ausgezeichnet funktioniert. Wenn genügend Wasser zur Verfügung steht, werden jetzt auf jeder Station 6 bis 8 Bestimmungen gemacht."

Free translation:

"The pCO_2 analyses were done with the apparatus as described by A. Krogh, which here on board functions perfectly well. When enough water is available, at every station some 6 to 8 measurements were done."

Water samples, not air samples… "Station" in this case is every place where the research vessel was halted to take lots of samples for many different analyses at many depths of the ocean.

I have no idea how Beck could calculate an average CO_2 level in the atmosphere from these water pCO_2 data.

4. The presented error range.

The "error range" (the grey area as given by Beck in Fig. 24 of his work [21]) is only about the error of the methods used *not* for the range of CO_2 values measured in any of the years. If one looks at the real range of all measurements worldwide in the same year, for most of the years the error range is from the bottom to far above the ceiling of the graph. Here a compilation of the same data as Beck from the same literature for the period of interest 1930-1950 from his earlier work:

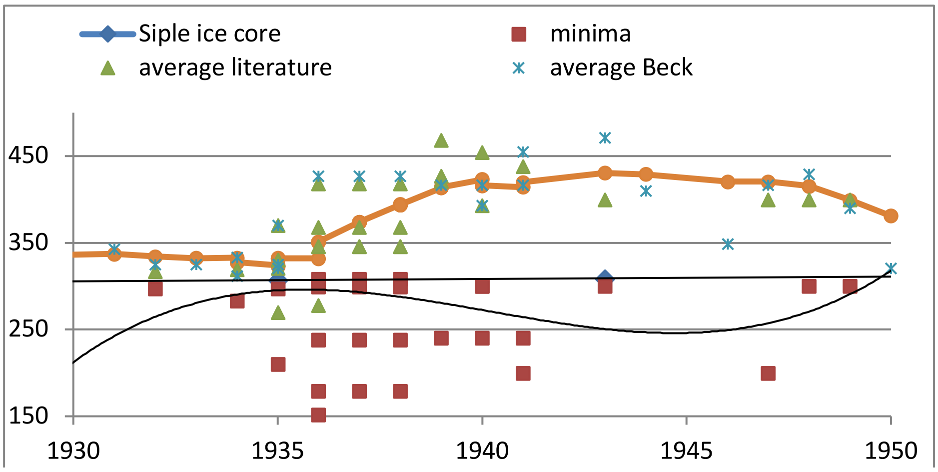

Figure 2: Minima and averages for all data of the years 1930-1950. Interesting: almost all minima are on or under the level of the Siple ice core CO_2 data, with only one exception in a series near Vienna where even the minima were above 500 ppmv.

This shows that the assumed error range of the methods had hardly any influence on the wide range caused by the CO_2 sinks and sources at the places where the measurements were done: the range of data was extremely wide, so that without further information, nobody can say what the real "background" CO_2 level in that period was, except for the data taken over the sea surface or coastal with wind from the seaside.

In most cases there were only short series or even single measurements at several places and thus no possible wind speed convergency towards an asymptote to have a clue of the real background CO_2 level.
Beck used part of the available data, based on criteria which are not very clear to give the average over the globe, but any connection with the real background CO_2 level is problematic:

The average of lots of non-background CO_2 data still is not the background CO_2 level!

Interesting point anyway is that all minima with one exception (taken in the morning at a sink of a mountain slope near Vienna) are on or below the Siple Dome ice core CO_2 levels. That means that ice core CO_2 data are within the extremely wide range of near all data over the period of interest.

5. The physical impossibility of a huge CO_2 peak around 1942.

If we take Beck's data for real, that implies that there was a 20% increase or 60 ppmv CO_2 or near 130 PgC in 15 years time from some source and that huge quantities of CO_2 were absorbed somewhere: about 50 ppmv CO_2 or 105 PgC in only 10 years time. The latter is 10.5 PgC/year or 5 ppmv/year uptake.

Compared to the total quantity of the above ground part of living biomass on land of around 500 PgC, that is about a quarter of all forests and other crops globally…
No such reduction or regrowth on such short period is known and doesn't show up in any other proxy or direct measurement. If real, that would give an enormous drop in the $^{13}C/^{12}C$ ratio together with the 1942 peak and an enormous increase in the same ratio after that. Which is totally absent in the data.

Theoretically there may have been a sudden acidification of the (deep) oceans by undersea volcanoes, but the opposite is simply not possible. There is no such a fast huge sink for CO_2 available that can absorb 105 PgC of CO_2 in only 10 years time out of the atmosphere, not in the oceans, not in vegetation and other possible sinks are even much slower.

The seasonal CO_2 fluxes are large enough, but these are driven by seasonal temperature changes: around 14 K difference between winter and summer in the NH and somewhat less in the SH, opposite to each other. That is good for appr. 50 PgC release/absorption of the oceans and 60 PgC absorption/release by vegetation, opposite of each other in spring/summer and reverse in fall/winter. The important point is that the end result of all seasonal fluxes is near zero at the end of a year. Temperature anyway can't be the driver for the 1942 peak, as the effect of 1 K global ocean surface temperature increase is only 12-16 ppmv/K according to Henry's law. See the formula of Takahashi (2002 [9]) which exactly calculates the influence of temperature on the pCO_2 of seawater.

Neither ocean fluctuations can be the cause of such a huge variability in such a short time span: while Yndestad [10] and Keeling [11] did find some correlation between the temperature variability and ocean lunar tides, the resulting variability in the Mauna Loa record is about tenths of a ppmv, not tens!

Currently there is slightly more natural uptake than release, directly in ratio to the extra 120 µatm (~ppmv) pressure of CO_2 in the atmosphere, above the current dynamic equilibrium per Henry's law (Takahashi, 2002 [9]) which is around 295 ppmv for the current average ocean surface temperature. That results in about 2.5 ppmv/year or 5 PgC/year net uptake by nature.
Still by far not enough to explain the drop of 50 ppmv in only 10 years, as the sink speed slows down with diminishing pCO_2 difference between atmosphere and ocean surface (and plant alveoli's). That also is clearly explained in Feely ea. (2001 [8]).

6. The conflict with other proxy's and measurements.

6.1 CO_2 in ice cores.

As seen before, the minima of the historical measurements are almost all on or below the ice core CO_2 data. That means that the ice core data are within the full range of measurements of all years that the historical data were taken.

Moreover, we have data from the high-resolution Law Dome ice cores with a resolution as narrow as 8 year and a repeatability of different samples at the same depth of 1.2 ppmv (1 sigma). The data even overlap with the direct measurements at the South Pole for a period of 20 years (1958-1978) (Etheridge ea., 1996 [12]):

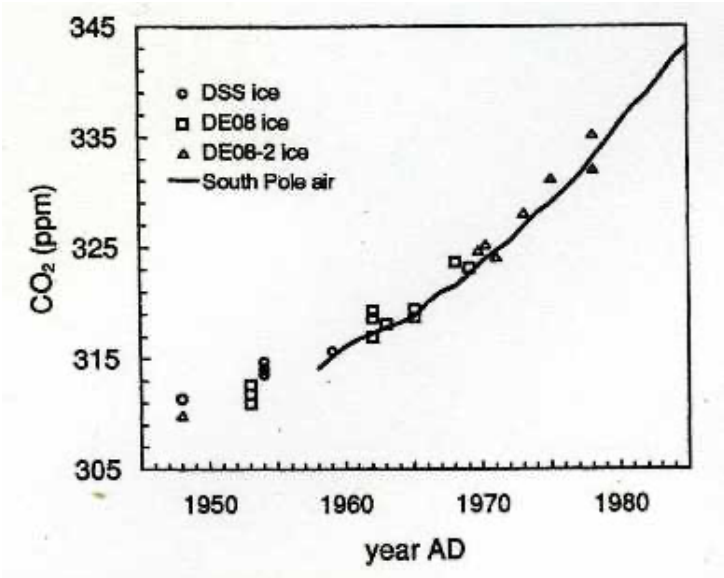

Figure 3: Overlapping of the Law Dome ice core CO_2 data with the direct CO_2 measurements at the South Pole. Source: Etheridge ea. 1996 [12].

The results of four ice cores, three at Law Dome and one at Siple Dome over the period 1900-1980 show nothing special in the period 1930-1950. Only slowly increasing CO_2 levels with even a small dip around 1942 for one the Law Dome ice cores (data from [13]):

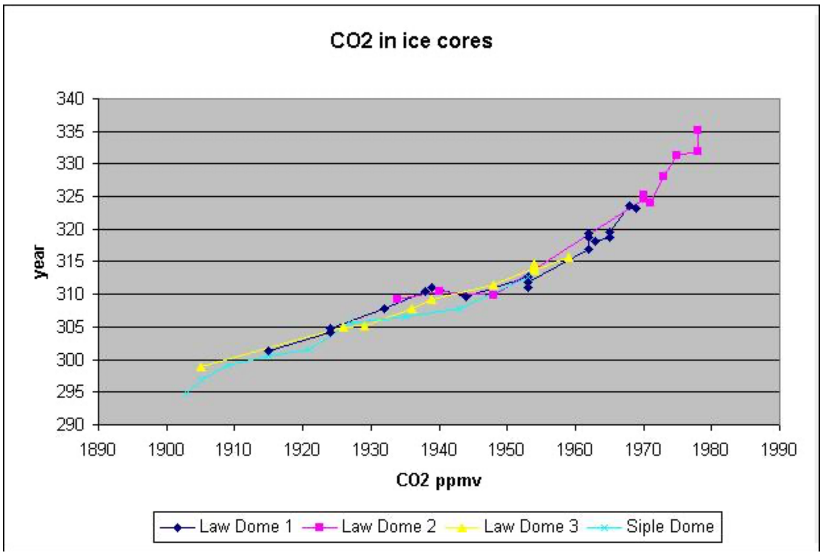

Figure 4: CO_2 levels in ice cores, Source: NOAA [13]

With a resolution of 8 years and a repeatability of 1.2 ppmv, two of the Law dome ice cores Law Dome ice cores (1 and 2) will detect a sudden 1-year wide “spike” of 20 ppmv, be it spread over 8 years or a sustained 2 ppmv increase over the full period of 8 years, thus certainly will detect a “peak” of 60 ppmv and back over a period of 25 years. They didn’t.

6.2 $^{13}CO_2$ in ice cores and air CO_2 and in coralline sponges.

The $^{13}CO_2$ level of CO_2 in ice cores (reflecting the $^{13}CO_2$ level in the atmosphere) and in coralline sponges (reflecting the $^{13}CO_2$ level in the ocean surface) show no change in the period 1930-1950, except for the fast decline in $^{13}CO_2$ level, caused by fossil fuel burning which has much lower $^{13}CO_2$ levels than the atmosphere or oceans.

If there was a huge increase in CO_2 from the deep oceans, the $^{13}CO_2$ level should go up (seawater CO_2 from the deep oceans have a higher $^{13}CO_2$ level at -6.4 per mil [1]) than the current atmosphere already below -8 per mil).
If there was a huge increase in CO2 from vegetation, the $^{13}CO_2$ level should go faster down than current, as burning or decaying vegetation has about the same low $^{13}CO_2$ level as fossil fuels. Nothing special can be seen in the $^{13}CO_2$ level decline over the period 1930-1950:

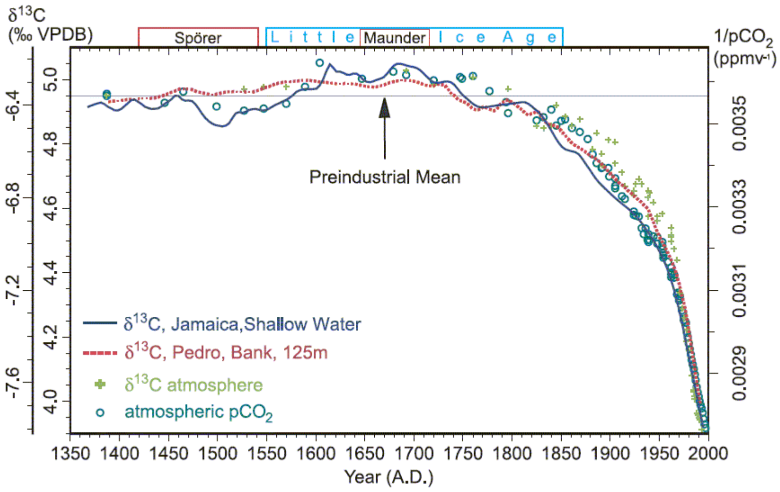

Figure 5: $^{13}CO_2$ decline in atmosphere and in coralline sponges. Source: Böhm ea., 2002 [14]

The resolution of the data in the coralline sponges is 2-4 years, the mixing ratio between ocean surface waters and the atmosphere is less than a year. Changes of 1 PgC CO_2 in the atmosphere by vegetation or 4 PgC from the deep oceans would be detected as a change in the $^{13}CO_2$ level of the coralline sponges. No changes caused by an over 100 PgC "peak" around 1942 can be found.

---

[1]) There is a huge discrimination in stable isotopes at the sea-air border and back. The net equilibrium between oceans (at zero per mil in the deep oceans, +1 to +5 per mil in the ocean surface) resulted in a relative stable level of -6.4 +/- 0.2 per mil in the atmosphere over the whole Holocene and started to drop from 1850 on down to below -8 per mil nowadays. See Böhm ea., 2002 [14].

6.3 Stomata data

Ernst Beck did mention stomata data as supporting his ideas, but as far as I can see, they don't. Stomata data are from plants growing on land and each place has its own (positive) CO_2 bias compared to global CO_2 levels. Therefore, they are calibrated against… ice cores and direct measurements over the past century.
The main advantage of stomata data is the high resolution over time, the drawback is that they mainly reflect local CO2 levels and local variability, depending of land use in the main wind direction, even the main wind direction may have changed over time (MWP vs. LIA).

Here the calibration of a series of European tree birch leaf stomata data in The Netherlands (Wagner ea., 2002 [15]):

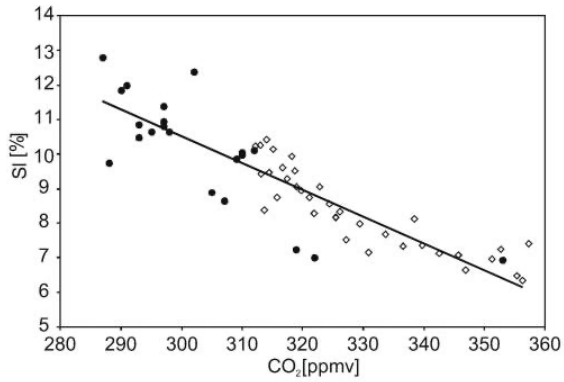

Figure 6: European tree birch leaf stomata index calibration data. Source: Wagner ea., 2002 [15]

According to high resolution ice cores, the CO_2 levels in 1942 were around 310 ppmv. If there was a real peak value of 370 ppmv in the same year as the 310 ppmv mark in the graph, according to Beck, the SI [%] would be near the bottom of the graph.

The same problem for the stomata data at Jay Bath (Kouwenberg ea., 2005 [16]) which are interpretated by Beck as high in the year 1950, but the authors didn't see anything special in that period. The error margin of the stomata CO_2 level estimates again includes the ice core CO_2 level.

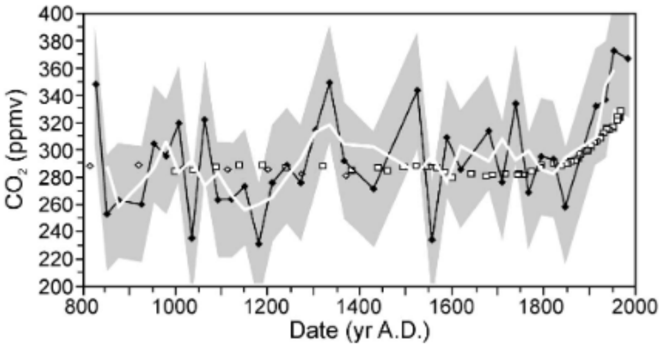

Figure 7. According to Ernst Beck, there was a high CO_2 value of 370 ppmv around 1950, but the wide error margins of the method includes the ice core results of around 310 ppmv in the same year. Kouwenberg ea., 2005 [16].

The authors of the reconstruction at Jay Bath even warn against the interpretation of the data:

"However, the large amplitude of the CO_2 signal in the Jay Bath record, compared to the ice cores and other stomatal reconstructions, may be influenced by the relatively low amount of needles in the low-CO_2 part of the calibration data set."

7. The influence of wind and rain on the CO_2 levels found.

7.1 The influence of wind speed.

Francis Massen has done a tremendous job by collecting and analysing a lot of meteorologic and other data, including CO_2 data, on top of a school building at Diekirch, Luxembourg.

With the data collected, he could show that with high wind speed, the wide spread of the collected data was narrowing into an asymptote that resembles the background CO_2 levels of the same period in time. That is reflected in the work he made together with Ernst Beck and presented these results at the online KLIMA2009 conference of the University of Hamburg (Massen and Beck, 2009 [17]).

The results for Diekirch are plotted here:

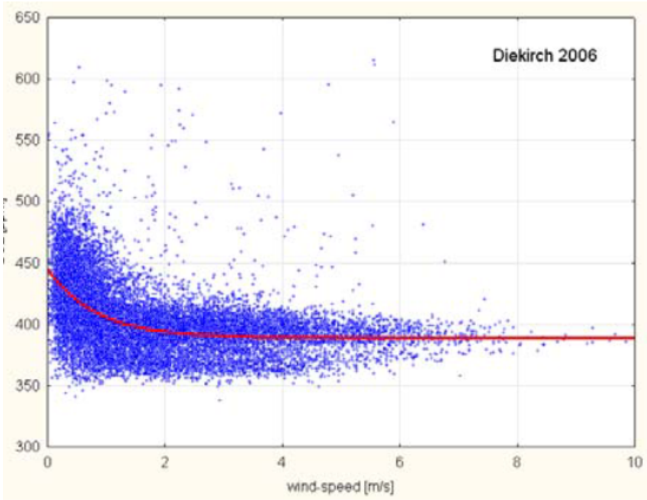

Figure 8: Asymptote caused by wind speed vs. CO_2 levels. Source: Massen and Beck, 2009 [17]

There is a clear influence of wind speed on the measurements and with higher wind speeds, the measurements approach the real "background" CO_2 levels as measured at Mauna Loa and other baseline stations.

An important point is that one need many data at high wind speed to get the best performance of the algorithm. In this case, the bulk of all data is between 350 and 500 ppmv at near zero wind, but rapidly goes down to 350-420 ppmv already at 2 m/s wind speed and results in around 390 ppmv for the asymptote. The asymptote lays at around 25% of the original range with near zero wind.

Ernst Beck used this method to look at the historical data of Giessen (Germany). We will come back on that point when we discuss the data as interpretated by Beck in chapter 8.2.

7.2 The influence of rain.

In his latest work, Beck also used precipitation as a tool to estimate the real background CO_2 levels. In fact, rain itself has not much influence on CO_2 levels, as fresh water doesn't dissolve much CO_2.

Where the rain drops are formed (out of several m^3 air for one litre rain), the drop in CO_2 level in the surrounding air is not even measurable: its solubility is only 3.4 g CO_2 in one litre fresh water of 0°C at a pressure of 1 bar of 100% CO_2 [18]. At 0.0004 bar only 1.3 mg/l CO_2 is dissolved in rainwater.

My impression is that the results of more rain have more to do with the turbulence of the air masses that are moving together with (heavy) rain, not with the precipitation itself.
It can be a useful tool if rain data are available and wind data are not available and enough data with heavy rain are available.

Anyway, in most cases there are too few historical datapoints on precipitation from the same site to give a good impression of the performance of rain on the CO_2 data to give the background CO2 level.

8. The interpretation of the data from longer series

The whole "peak" value around 1942 by Ernst Beck is mainly based on two longer series of data: Poona, India and Giessen, Germany.

8.1 The CO_2 series of Poona, India.

The station at Poona, India did collect only a few ambient air CO_2 measurements. Most measurements done were under, in between, and just above growing crops, as that was the purpose of the measurements: following the CO_2 use by growing crops.
Thus, completely out of order to know anything about "background" CO_2 levels.
Here the plot of all the measurements:

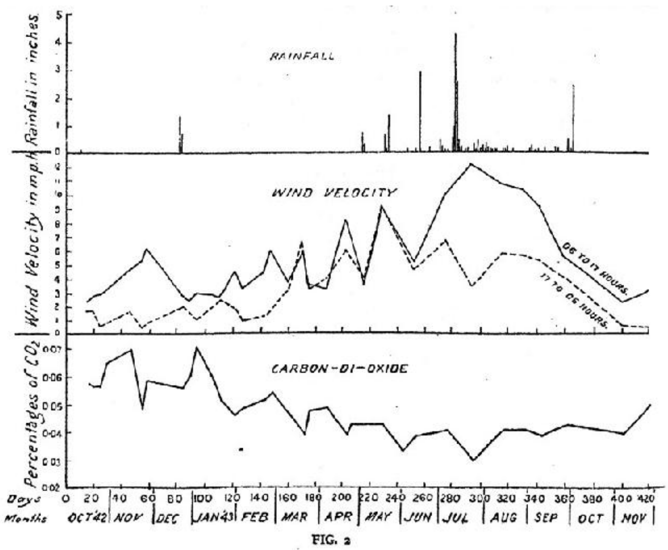

Figure 9: CO_2 measurements (1-2 per month) at Poona, India (Misra, 1942-1943 [19]).

There are far too few datapoints available and most of them were around crop leaves, to get even a clue of the real background CO_2 levels of that time… The range from 300 to 700 ppmv within a year shows that one can obtain about any level one (doesn't) want from following crops on land.

8.2 The CO_2 data from Giessen, Germany.

The second and most important place where a long series of CO2 data was taken was in Giessen, mid-west Germany. Here the "finger plot" of the historical data as calculated by Massen and Beck [17]:

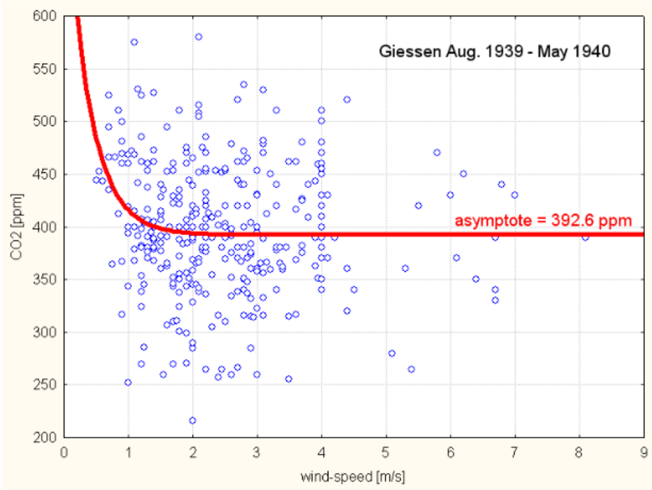

Fig.10 The CO_2 versus wind speed plot of the Giessen measurements by W. Kreutz (average = 398, stdev = 62)

Figure 10: finger plot of the historical CO_2 data from Giessen, Massen and Beck, 2009 [17].

The "finger plot" of the data is rather questionable, as there are only some 20 datapoints at wind speeds over 4 m/s, compared to the hundreds of data points at Diekirch in Figure 8 or the modern data from the modern station at Linden/Giessen (see Figure 11).
Moreover, there is a huge spread from 250 to 530 ppmv for the bulk of the data up to 2 m/s and even over 4 m/s, the spread still is from 270 to 470 ppmv.

The interesting point is that there is a modern CO_2 measuring station, at a few km from the site of the historical station, which takes air samples every half hour over a GC for CO_2 and other ambient gases of interest. Linden/Giessen still is rural in modern times, thus some comparison is possible.

From the modern station, here the "finger plot" of a lot of CO_2 data collected by HLNUG [20]:

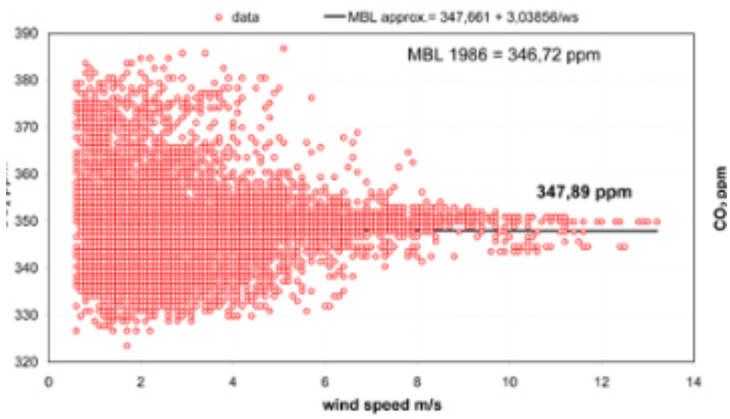

Figure 11: finger plot of the modern CO_2 monitoring station at Linden/Giessen [21]

Compared to the historical data, the bulk of the modern data have a much smaller range of measurements: about 330-380 ppmv, while 250-530 ppmv for the historical data. That is a difference in range of over five times in width. That doesn't give much confidence in the historical measurements, as one can expect more disturbances from traffic in modern times than around 1939-1941. Moreover, there is a clear finger plot for values at wind speed above 6 m/s, which is questionable for the historical data by lack of sufficient observations at high wind speed.

To show the problems which the historical measurements, here a plot of the modern station CO_2 data of Linden/Giessen over a few days with little wind and a strong inversion layer:

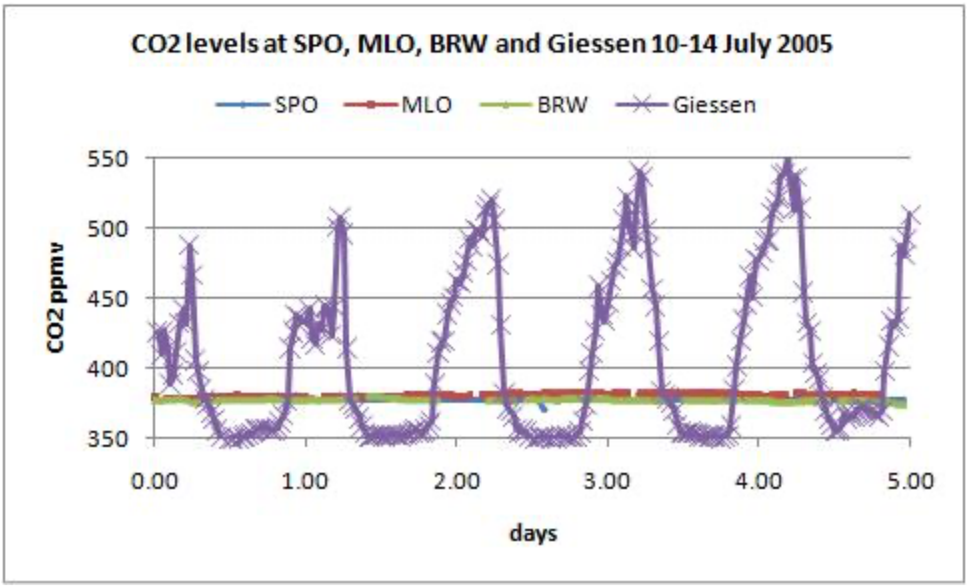

Figure 12: CO_2 data from the South Pole (SPO), Mauna Loa (MLO), Barrow (BRW) and Giessen Data from the period 10-14 July 2005. All data are raw(half) hourly measurements and include outliers. Data from Giessen from [20] other station data from NOAA [23].

The historical measurements at Giessen were taken three times a day at 7 A.M., 2 P.M. and 9 P.M. That makes that one measurement was below "background" (due to photosynthesis) and two were at the flanks of the decreasing and rising CO_2 levels under inversion. Over a full year of data, that gives already in average a local bias of around 40 ppmv in the modern station data, compared to Mauna Loa.

As an aside, Beck in his latest work says that the samples were taken every 90 minutes, but that was only during an extra campaign over 5 days, not over the full period:

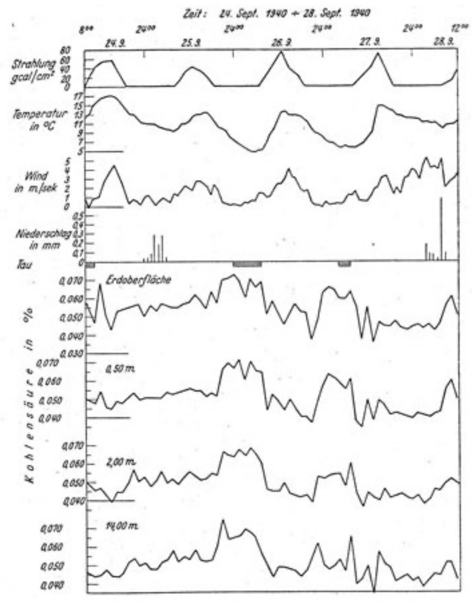

Abb. 1. Tagesverlauf der Kohlensäure und Witterungsfaktoren.

Figure 13: CO_2 samples taken every 90 minutes in the period 24-28 September 1940 (Kreutz, 1941 [24])

Another strange mistake in Beck's text is that he says that the standard deviation of the historical measurements was +/- 6.47 ppm, while the table from Kreutz shows a sigma between 61.1 and 65.9 ppmv, as at that time everything was expressed in tenths of a percent in air. Also clear is that only three samples per day were taken at different heights over the full period, except the above 5 days:

Tabelle 1 a und b.
Mittlere CO_2-Werte.
a) vom 1. August 1939 bis 31. Januar 1941.

	0 m	0,5 m	2,0 m	14,0 m	Mittel
Vormittag	42,8	41,7	40,5	43,2	42,1
Nachmittag . . .	52,9	45,0	43,0	46,4	46,8
Abend	42,5	42,5	41,6	44,0	42,7
Tagesmittel . . .	46,1	43,1	41,7	44,4	43,85

b) für das Jahr 1940

	0 m	0,5 m	2,0 m	14,0 m
Mittel	46,8	45,1	43,4	46,2
Maximum	64	62	62	68
Minimum	27	28	24	24
Streuung σ (abs.) .	± 6,42	± 6,11	± 6,12	± 6,59
Streuung σ (%) . .	13,7	13,6	14,1	14,3

Figure 14: Averages and standard deviations of samples at different heights over time in Giessen (Kreutz 1941 [24]). Vormittag = morning, Nachmittag = afternoon, Abend = evening. Streuung = standard deviation

In comparison, the full chart of all measurements can be shown:

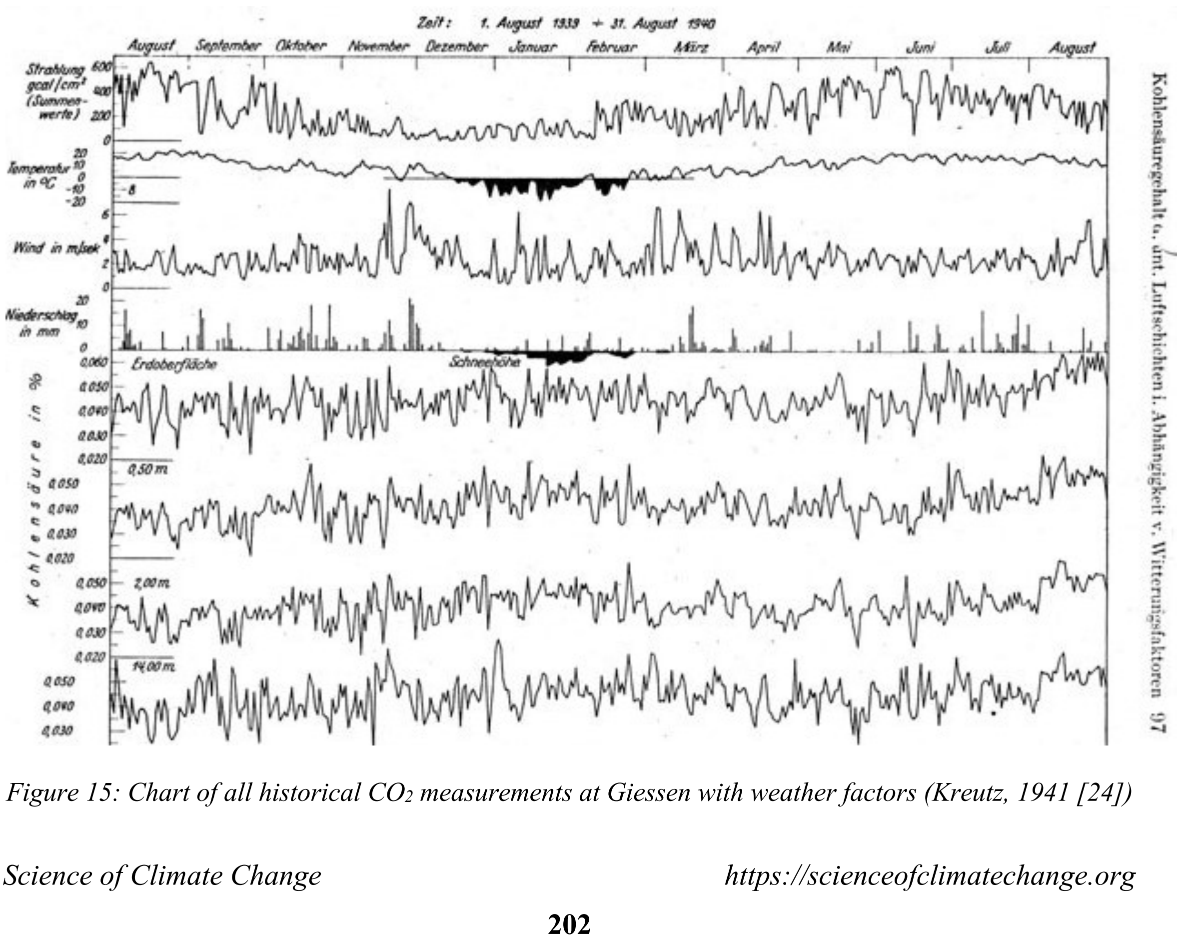

Figure 15: Chart of all historical CO_2 measurements at Giessen with weather factors (Kreutz, 1941 [24])

8.3 The CO_2 data from Point Barrow, Alaska, USA.

The difference between the historical and modern data is striking:

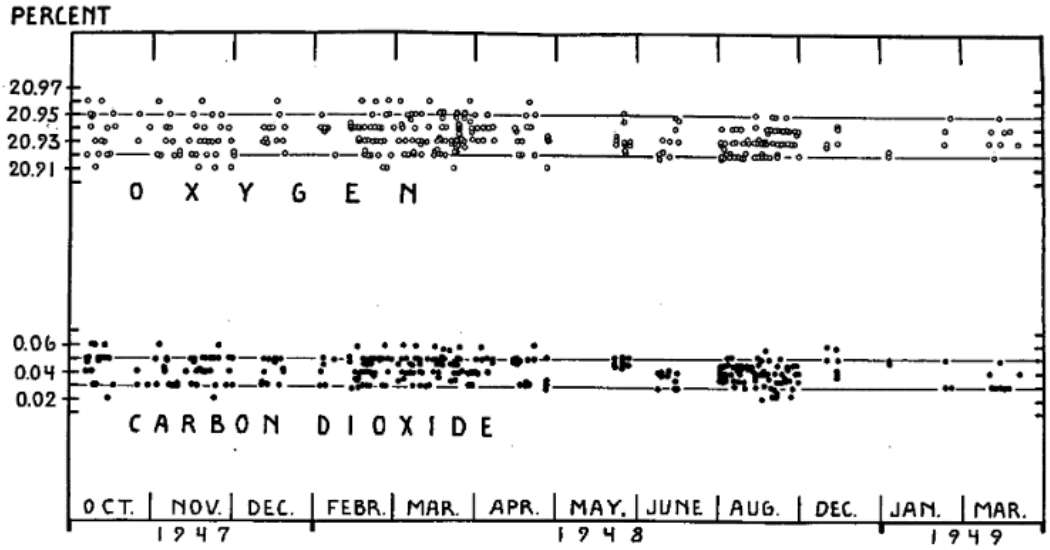

Figure 16: historical CO_2 measurements taken at Point Barrow, range: 200-600 ppmv [2].

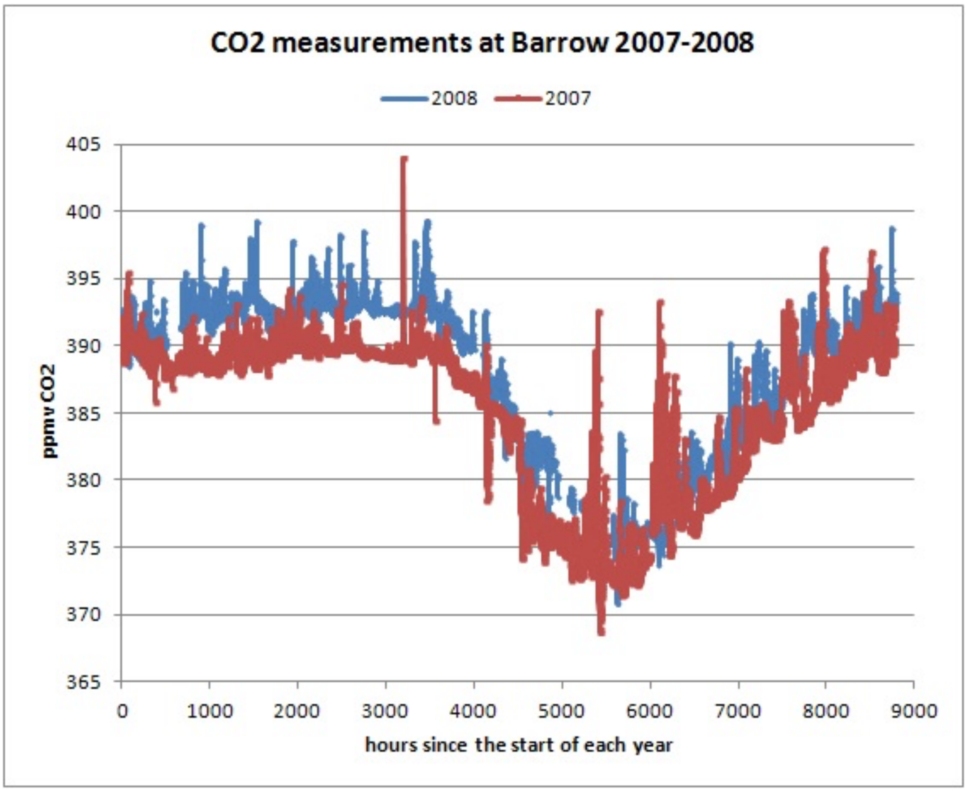

Figure 17: Modern hourly averaged CO_2 measurements at Point Barrow, range: 370-405 ppmv, including all local outliers and a 18 ppmv seasonal amplitude (NOAA [23])

Not only is there a 100 ppmv bias in the historical data, which the authors accept as acceptable for the accuracy of the apparatus that was used, but the spread of the data is also enormous:

between 200 and 600 ppmv for the historical data compared to 370-400 ppmv (with 2 outliers on 17,500 hourly datapoints) for the modern station, including a seasonal amplitude of 18 ppmv. A difference of 13 times in range… For still a very pristine area…

9. The inclusion and exclusion of series

Beck was not the first to make a compilation of the available CO_2 measurements in certain periods of the past. Callendar did that already in the 1930's [25], based on very stringent a-priori criteria. One can agree or disagree about the criteria used by Callendar, but I still have the impression that Beck didn't use any criteria at all and just lumped everything together: the good, the bad and the ugly…

One of the criteria by Callendar was to exclude series that were taken for agricultural purposes, which would have excluded the series of Poona, India by Misra. Which is fully warranted as such data have not the slightest resemblance of background CO_2 data of that time…

Even so, there are strange omissions in his choice to include some series and exclude others.

If one looks at the description of the data collected at Point Barrow [2], several other investigations were mentioned by the researchers that may be of interest. Only one is retained by Beck for his compilation: the Scholander tests of the new equipment that was intended to measure CO_2 in exhaled air [3]. Here the full list of investigations that were mentioned by the researchers at Point Barrow:

Author	Year	CO_2 ppmv	O_2 %	Technique
Nansen and Petter-son	1880	300-320		
Krogh	1904	250-700	20.92-21.02	Haldane
Benedict	1912	300	20.95	
Krogh	1919	300	20.95	
Fieser	1924	300	20.94	different absorber
Müller	1928	240-300		
Peters and Van Slyke	1932		20.93	Haldane
Haldane and Graham	1935		20.93	Haldane
Carpenter	1937	310	20.94	
Lockhart and Court	1942	300-1700	20.48-20.76	Haldane
Scholander	1947	330	20.94	for exhaled air
Hock ea.	1952	400	20.94	same as Scholander 1947

Table 1: list of different CO_2 and O_2 measurements mentioned by the Point Barrow researchers [2].

Hock ea. (1952 [2]) of the Barrow test accepted the around 300 ppmv CO2 levels as the "background" data of that time and their 400 ppmv average as within the margins of the method used…

Of particular interest is the Carpenter investigation (1937 [26]), also mentioned by Callendar (1928 [25]):
It is the first and only one that I know which mentioned the use of a "calibration gas" to test the CO_2 measuring device before using it for its real purpose (physiological tests in different research facilities).
The calibration gas was a simple cylinder with compressed air that was used to test the apparatus and check if it did show the same values over the full period of use.

After that check, CO_2 and O_2 in ambient air were measured at the three locations where the research was established.

The results are very interesting:
With only one outlier (at 600 ppmv) on 1266 samples, the three locations did show an average of 310 ppmv CO_2 in ambient air with a standard deviation of only 15-17 ppmv, method and results together.
Compare that to the figures of Giessen a few years later that show an average of 417-461 ppmv and a standard deviation of 61.1-65.9 ppmv, causing the "peak" in Beck's compilation.
Carpenter's data and several other series were not included in Beck's work.

In his latest work, Beck (2022, [21]), the SI shows 875 stations with data, but in his text, he mentions that only 87 data series were used in his compilation. I didn't find which stations exactly were retained and which not, neither the criteria he used for inclusion of exclusion, except a vague sentence that:

"The selection process was characterized by using only data sampled by known methods and from locations which allow a validation of local influences and air masses"

Allow me to have some doubts that anyone can know the local influences at the historical places and air masses (like the influence of all the land use changes in the main wind direction).

Conclusion

While I admire the enormous amount of work that the late Ernst Beck has done in recovering lots of historical CO_2 measurements, his estimation of the accuracy of these measurements seems very optimistic and the problems with the local contamination of the data seems highly underestimated. The criteria he used to exclude or include certain series are far from clear.
Moreover, the historical "peak" around 1942 is physically impossible and conflicts with other proxies over the same period and with CO_2 data from high resolution ice cores.

Still, it was a monumental work that he has done, to support the words of Jan-Erik Solheim. Together with Francis Massen I can only hope that others will recover even more historical data and give them back to the scientific world.

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Acknowledgements:

The author wishes to thank Francis Massen for the many positive remarks to clarify several of the items as given here.

Also several anonymous reviewers for their critique who forced me to rethink what I wrote and defend or rework my words.

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About Historical CO_2 Levels

Discussion of Direct Measurements near Ground since 1826 by G. E. Beck

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Keywords: CO2 background history; CO2 estimate variations, CO2 signature variations.

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1. Data for background CO_2 level

Ernst Georg Beck estimated a CO_2 background time-series from 1826 to 1960. In a discussion from Ferdinand Engelbeen, he has a comment ha many of them are unsuited for background CO_2-levels. The huge CO_2 level around 1940 is physical impossible and contradicts other proxy´s. (Englebeen 2023).

Beck collected approximately 100.000 data series from approximately 900 stations. He estimated 20-50 % variations in the period 1826-1855, 2.6-10 % variations from 1855-1865, and 3 % variations from 1865-1960. The computed 3 % variations from mean values confirm the estimated CO_2 background level for the period 1850 to 1960 (Beck 2022).

The huge CO_2 level was close to 370 ppm in 1940. The CO_2 level at Mauna Loa was approximately 370 ppm in 2000. The global sea surface sea temperature in 1940 had a coincidence to global sea surface temperature in 1980. This coincidence supports a possible relation between global sea temperature variation and a CO_2 background level variation.

2. The CO2 background signature

The historical CO2 time-series from 1826-1960 represents a mean CO_2 background level from all sources. The most dominant source is revealed by computing the time-series signature (period and phase relations). A signature analysis of the time-series (Yndestad 22a; Yndestad 22b) reveals that:

The CO_2 signature from 1850-1960 coincides with the Mauna Loa atmospheric CO_2 growth variability signature, the global sea surface temperature variability signature, and the lunar nodal tide variability signature. This is strong evidence of a lunar forced global sea temperature variation and the historical atmospheric CO_2 background level.

Atmospheric CO_2 variations have a maximum growth rate when global sea surface temperature variations have a maximum state. The $\pi/2$ (rad) phase lag between global sea temperature variations and atmospheric CO_2 variations, reveals that atmospheric CO_2 variations are controlled by global sea temperature variations.

The historical CO_2 level time-series from 1826 to 1960, and the Mauna Loa CO2 timer-series cover a total period of 200 years. The long historical time-series, and better analysis methods, have opened a new perspective on climate science.

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About Historical CO_2-Data since 1826:

Explanation of the Peak around 1940

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Abstract

Recently a compilation of almost 100.000 historical data about chemical CO_2 concentration measurements between 1826 and 1960 has been published as post mortem memorial edition of the late Ernst-Georg Beck. This compilation can give important insight in understanding natural CO_2 emission processes, but it has been criticized, in particular a documented significant increase of the atmospheric CO_2 concentration around 1940. In this contribution we do not respond to any criticism of more or less suitable places for sampling or the interpretation of respective data, but concentrate on the CO_2 data around 1940 and the variations over the last century. We show that the observed concentration changes not only correlate with observed temperatures, but can also quantitatively be explained, mainly in terms of the temperature dependent soil respiration.

Keywords: CO_2 mixing ratio; direct chemical measurement; natural CO_2 emission, soil respiration; oceanic CO_2 emissions

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1. Introduction

Our knowledge about paleoclimatic variations of CO_2 concentration in the atmosphere is exclusively based on proxy data. But such indirect measurements from ice cores, tree rings, stalactites or stomata suffer from higher time resolution, sensitivity and accurate calibration of the data. Therefore, before the implementation of infrared spectroscopy analyses in 1958 for atmospheric CO_2 concentration measurements, with the development of chemical techniques in the early 19th century it was a great progress to have a direct method available for the detection of the CO_2 level. But unfortunately, these data were not systematically prepared or compiled, and instead, paleoclimatic research was only concentrating on the less accurate proxy data.

Luckily, with a more than 12 years delayed publication of a monumental data set of the late Ernst-Georg Beck (Beck 2022), new insight into variations of the CO_2 concentration over the 19th century and the first half of the 20th century can be derived. Special thanks to H. Yndestad (2022), and J.-E Solheim as Chief-Editor of this journal for making available this publication. Beck found more than 200,000 single samples of air analyzed with chemical methods, showing daily, yearly and seasonal variations, which were published in 979 technical papers. He selected almost 100,000 samples associated with documented meteorological conditions between CO_2, wind speed, precipitation, day time and year. This gave the opportunity to determine atmospheric CO_2 concentrations with an accuracy, at least an order of magnitude better than from proxy data, and he concluded that there are repeated fluctuations in concert with the surface temperature variations of the sea.

In an actual article (Engelbeen 2023) the historical data were criticized that many places were completely unsuitable for "background" CO_2 level measurements and that Beck made several mistakes in the interpretation of the available data. Particularly, the huge CO_2 levels around 1940 would be physically impossible and contradict several other proxies as measured in high resolution ice cores.

While it is out of the scope of this contribution to comment on the unsuitability of places, the number of measurements at higher wind speed (to have a sufficient convergence of data) or on any mistakes in the interpretation, we look closer to the measured CO_2 levels around 1940.

In Section 2 we briefly review the temperature sensitivity of oceanic and land emissions with their expected contributions to the atmospheric CO_2 mixing ratio (for further details see: Salby & Harde 2022). Simulations with a land-air temperature series (Soon et al. 2015) alone or in combination with sea surface data (HadSST4, Kennedy et al. 2019) can well reproduce an increased concentration over the 30s to 50s and the further evolution over the last century. Particularly soil respiration in the tropics and mid-latitudes can be identified as the main natural source. Different to a pure correlation of time series, our studies give a clear physical explanation with a quantitative reproduction of the observed data.

2. Relationship of Temperature and Atmospheric CO_2-Concentration

Beck's historical data compilation consists of 97,404 samples of atmospheric CO_2 mixing ratios, which were derived from 901 stations and cover a period from 1826 to 2008. The data show a pronounced maximum between 1939 and 1943 with a concentration up to 383 ppm, this in contrast to the monotonically rising CO_2-levels reconstructed from ice cores. Alone the data around this maximum from 1930 to 1950 represent about 60,000 samples and are based on the work of more than 25 different authors and locations.

The time resolution and accuracy of this data series is much better compared to reconstructions from ice core data and even from stomata. Therefore, for serious climate studies it is of fundamental importance and interest to better understand possible forcings that can explain strongly varying CO_2 levels, particularly over periods, for which more reliable meteorological and astrophysical data are available than this is the case for paleontological times. At the same time, stronger anthropogenic impacts over this period can be largely excluded. So, it sounds pretty inconvincible, when Engelbeen (2023) comments that "*the possibility of huge CO_2 levels around 1940 is physically impossible and contradicted by several other proxy's and contradicted by CO_2 levels as measured in high resolution ice cores*.

Beck already found a high correlation of the CO_2 level data to the global Sea Surface Temperature (SST) series of the Royal Netherlands Meteorological Institute (Kaplan, KNMI). Supported by different observations of CO_2 enriched air at the coast (North Sea, Barents Sea, Northern Atlantic) he suggested that warmer ocean currents over the Northern Atlantic are the sources of the enhanced CO_2-levels.

Different studies confirm outgazing of warmer oceans, particularly the tropical oceans, as sources of CO_2. But they also show that the oceanic CO_2 emission E_O as flux F_O, weighted by its fractional surface area S_O as

$$E_O = S_O F_O \cong S_O B(v) \Delta r \tag{1a}$$

depends primarily upon wind speed v and the atmosphere-ocean contrast $\Delta r = r_O - r_A$ (Wanninkhof 2014) with r_O as the CO_2 mixing ratio of the ocean and r_A as mixing ratio of the atmosphere. The temperature sensitivity to oceanic emission

$$Q_O = \frac{1}{E_O}\frac{dE_O}{dT_O} \cong 3\,\%/°C \tag{1b}$$

with T_O as the mean ocean temperature is relatively small (Salby & Harde 2022, eq. (20)).

Different to the oceans, CO_2 emission E_L over land with the flux F_L and fractional area weighting S_L follows from soil respiration R

$$E_L = S_L F_L \cong S_L R(T_L, m_L), \tag{2a}$$

which depends upon soil temperature T_L and moisture m_L (see: Salby & Harde 2022, eqs (6.1) and (6.2)). Soil respiration R derives from microbial activity and upward diffusion of the produced CO_2 (cf. Maier et al. 2020). It is noteworthy that the partial pressure of CO_2 in soil and its mixing ratio r_L with 500 - 20,000 ppmv vastly exceeds the atmospheric mixing ratio r_A.

For a uniform perturbation of surface conditions, the enormous partial pressures of CO_2, found just a few tens of cm beneath the surface, makes emission from land determinative in re-establishing equilibrium between the atmosphere and the Earth's surface.

Although R is influenced by soil moisture, it is controlled chiefly by surface temperature (Wood et al. 2013; Zhou et al. 2013), which is determined by air temperature, i.e., $F_L \cong R(T_L)$. The temperature sensitivity of soil respiration,

$$Q_L = \frac{1}{R}\frac{dR}{dT_L} = \frac{1}{E_L}\frac{dE_L}{dT_L} \tag{2b}$$

is observed in the range 10%/°C - 25%/°C at temperate and polar latitudes (Raich & Schlesinger 1992; Lloyd and Taylor 1994). In tropical forest, however, copious precipitation and sunlight magnify active biomass, which supports soil respiration. There, the observed sensitivity to temperature is greatest (ibid; Brechet et al. 2018), 30%/°C and higher (Wood et al. 2013; Nottingham et al. 2018). This is roughly about one order of magnitude larger than the oceanic sensitivity Q_O with ≈ 3%/°C. Therefore, despite the smaller land surface area, soil respiration can well be considered as comparable or even as the dominating temperature dependent source of CO_2.

2.1 Relative Contributions of Ocean and Land

The fractional perturbation of atmospheric CO_2, $\delta r_A/r_A$ equals the fractional perturbation of total emission, $\delta E_T/E_T$, independently of effective absorption (see: Salby & Harde 2022, eq. (26)):

$$\frac{\delta r_A}{r_A} = \frac{\delta E_O + \delta E_L}{E_O + E_L} \tag{3}$$

According to marine observations of Δr (Takahashi 1997; Feely et al. 2001) and satellite observations of CO_2, particularly over tropical land (Palmer et al. 2019), emission from tropical ocean and land surface lie in the range

$$0.63 E_O < E_L < 4.57 E_O. \tag{4a}$$

With (3) it follows (see: Salby & Harde 2022, Appendix A) that the fractional increase of atmospheric CO_2 must lie in the range:

$$0.39 \cdot Q_L \cdot \delta T_L < \frac{\delta r_A}{r_A} < 0.02 + 0.82 \cdot Q_L \cdot \delta T_L\,, \tag{4b}$$

with a medium value $m \approx 0.6$ for the thermally-induced increase of atmospheric CO_2, collectively from ocean and land

$$\frac{\delta r_A}{r_A} \approx m \cdot Q_L \cdot \delta T_L\,. \tag{4c}$$

Integration of (4c) gives the atmospheric mixing ratio as a function of the land air temperature:

$$r_A(\delta T_L) \approx r_A(0) \cdot e^{m \cdot Q_L \cdot \delta T_L}\,, \tag{5a}$$

with $r_A(0)$ as mixing ratio at preindustrial times.

Including also anthropogenic emissions δE_A over the Industrial Era, (3) expands by this additional term δE_A in the numerator, while the total emission E_T in the denominator stays unchanged. Thus, (4c) expands by the additional term $\delta E_A/E_T$, which at equilibrium and due to the conservation law with $r_A = E_T \cdot \tau_{eff}$ and τ_{eff} as the effective absorption time converts (5a) to:

$$r_A(\delta T_L) \approx r_A(0) \cdot e^{m \cdot Q_L \cdot \delta T_L} + \delta E_A \cdot \tau_{eff}. \qquad (5b)$$

In Fig. 1 is plotted the rural-only land air temperature anomaly of the Northern Hemisphere (Green Squares) over the period 1870 to 2014 (see: Soon et al. 2015). The number of stations used for each year over the relevant interval 1930 to 1950 is typically 300. The data represent an average over 3 years. This series was chosen, as it represents most directly any variations of the land emissions E_L with temperature.

The calculated CO_2 mixing ratio as a function of the rural land air temperature anomaly δT_L and the anthropogenic emissions δE_A is plotted as Red Diamonds for $m = 0.6$ and a temperature sensitivity $Q_L = 30\%/°C$, as expected for soil respiration in the tropics to mid-latitudes. For the fossil fuel emissions and land use changes we refer to the CDIAC data (2017), and for the effective absorption or residence time we use $\tau_{eff} \approx 3.5$ yrs in agreement with IPCC (AR5 2013, Fig. 6.1; AR6 2021, Fig. 5.12; Harde 2017; Harde & Salby 2021). Comparison with the historical CO_2 data (Dark Dots) shows that the calculation confirms an increased emission and mixing ratio over the 30s to 50s, only with a broader and reduced maximum than the CO_2 observations. Also the observed increasing concentration over the Mauna Loa Era (Light Blue Dots) can well be reproduced by the thermally induced emissions, while the anthropogenic emissions over this period will not contribute more than $\delta r_{A,ant} = \delta E_{A,max} \cdot \tau_{eff} \approx 12$ ppmv (assuming equilibrium).

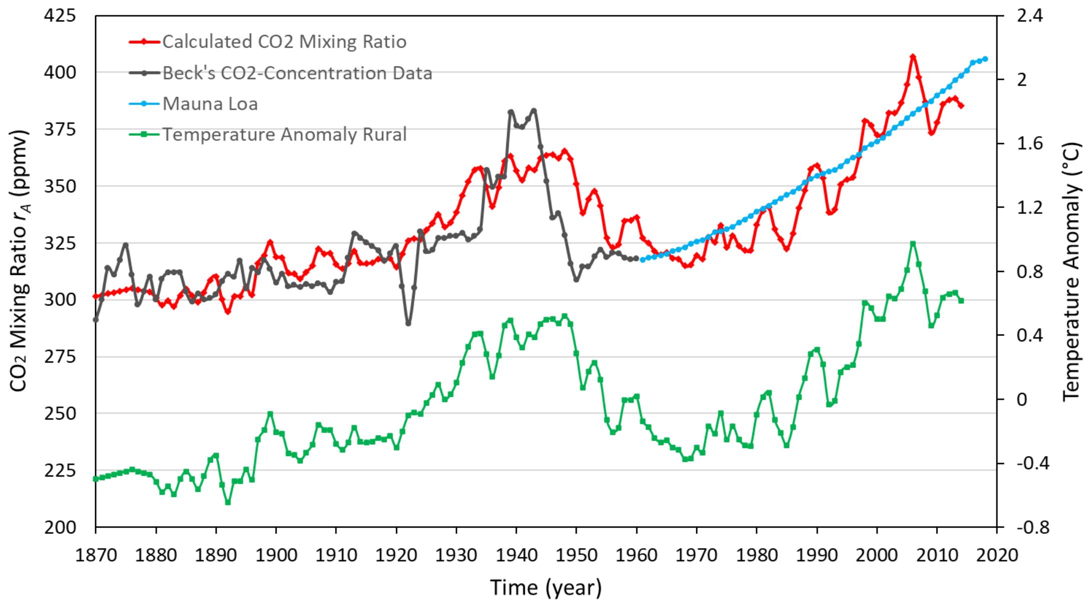

Fig. 1: Comparison of Beck's historical CO_2 concentration (Dark Dots) with calculation (Red Diamonds) for $m = 0.6$ and $Q_L = 30\%/°C$, based on Northern Hemisphere rural land air temperature data (Green Squares, Soon et al. 2015) over a period of 145 yrs. Additionally this is compared with the Mauna Loa observations (Light Blue Dots, CDIAC 2017).

2.2 Alternative Consideration of Oceanic and Land Emission

A slightly different derivative for the contributions of ocean and land starts again from (3), including the anthropogenic emissions δE_A. Integration of (1b) and (2b) gives:

$$\delta E_k = E_k\left(e^{Q_k \delta T_k} - 1\right), \quad k = O, L\,. \qquad (6a)$$

With a relative weighting $w = E_L/E_O$ and $E_T = E_O + E_L$, together with (3), including human emissions, the fractional perturbation $\delta r_A/r_A$ then can be written as:

$$\frac{\delta r_A}{r_A} = \frac{1}{E_T}\left\{\frac{E_T}{1+w}\left(e^{Q_O \cdot \delta T_O} - 1\right) + \frac{w \cdot E_T}{1+w}\left(e^{Q_L \cdot \delta T_L} - 1\right) + \delta E_A\right\}, \qquad (6b)$$

and together with $r_A = E_T \cdot \tau_{eff}$, the atmospheric mixing ratio as a function of the temperature anomalies δT_L and δT_O and also the anthropogenic emissions δE_A then becomes:

$$r_A(\delta T_L, \delta T_O) \approx r_A(0) \frac{e^{Q_O \cdot \delta T_O} + w e^{Q_L \cdot \delta T_L}}{1+w} + \delta E_A \cdot \tau_{eff}. \qquad (6c)$$

Fig. 2 displays the respective calculation with this modified derivation of combined emissions for a weighting $w = 2$, i.e., with land emissions E_L twice the oceanic emissions E_O (Red Diamonds). The respiration was again calculated for $Q_L = 30\%/°C$ and using the Northern Hemisphere rural-only temperature anomaly (Green Squares, Soon et al. 2015). The oceanic emissions were calculated with a temperature sensitivity $Q_O = 3\%/°C$ and applying the sea surface temperature anomaly HadSST4 of the Met Office Hadley Centre (Blue Triangles, Kennedy et al. 2019). Anthropogenic emissions are the same as in Subsection 2.1.

This simulation is quite similar to Fig. 1, as it is clearly dominated by the strongly temperature dependent respiration, while the oceanic emissions, mainly controlled by the atmosphere-ocean contrast and wind speed (see eq. (1)), only supply an almost constant background of one third to the total emissions. In comparison to the historical observations (Dark Dots) the maximum around 1940 can well be reproduced with an assumed weighting of two, only the CO_2 measurements indicate a faster decay over the 40s, before the mixing ratio is again increasing with temperature. A smaller weighting w slightly reduces the maximum around the 40s and the consecutive increase.

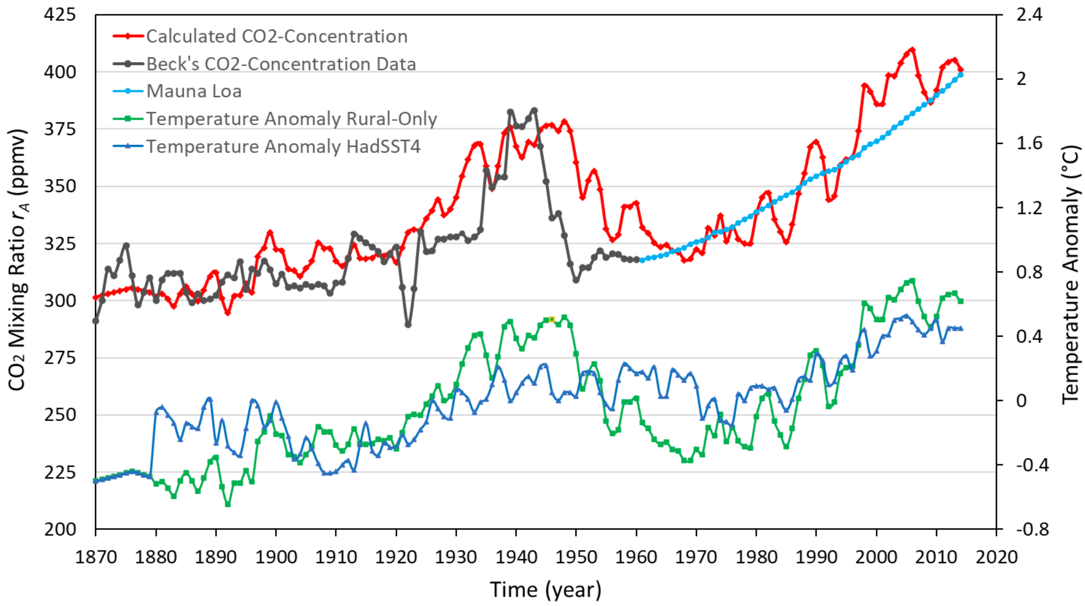

Fig. 2: Comparison of Beck's historical CO_2 data (Dark Dots) with calculation (Red Diamonds) for $Q_L = 30\%/°C$ and $Q_O = 3\%/°C$. The land emission E_L is assumed to be twice the oceanic emission E_O. Mauna Loa observations (Light Blue Dots, CDIAC 2017), Northern Hemisphere rural land air temperature (Green Squares), global Sea Surface Anomaly HadSST4 (Blue Triangles).

3. Conclusion

An extensive compilation of almost 100.000 historical data about CO_2 concentration measurements between 1826 and 1960 has been published as post mortem memorial edition of the late Ernst-Georg Beck (Beck 2022). Different to the widely used interpretation of proxy data, Beck's compilation contains direct measurements of chemically analysed air samples with much higher accuracy and time resolution than available from ice core or tree ring data.

At the same time this compilation covers a period, which is of fundamental importance to understand climatic processes from the Little Ice Age up to the implementation of infrared spectroscopy analyses in 1958. Particularly shorter variations over the 19th and 20th century and a documented significant increase of the atmospheric CO_2 concentration around 1940 allows to study how far, above all, natural processes have to be made responsible for these perturbations.

In this contribution we compare the temperature sensitivity of oceanic and land emissions and their expected contributions to the atmospheric CO_2 mixing ratio. Our simulations with a land-air temperature series (Soon et al. 2015) alone, or in combination with sea surface data (HadSST4, Kennedy et al. 2019) can well reproduce the increased mixing ratio over the 30s to 40s, the consecutive decline over the 50s and the additional rise up to 2010. This stronger variation cannot be explained only by fossil fuel emissions, which show a monotonic increase over the Industrial Era.

Particularly soil respiration in the tropics and mid-latitudes can be identified as the main natural source of CO_2 emissions. Smaller deviations in the maximum and width between observation and calculation of the mixing ratio around 1940 may be explained by some local impacts of the historic CO_2 concentration data (mostly covering the coast of the North Sea, Barents Sea and Northern Atlantic), they may also result from a smaller mismatch between the main emission areas and the covered temperature data (Northern Hemisphere), and also the time constants, before quasi equilibrium can be established in temperature and concentration, can cause some deviations. For direct comparison of the data, we avoided averaging over longer periods.

But most important, our studies not only show a high correlation of observation and calculation, but also give a clear physical explanation with a quantitative reproduction of the observed data, based on independent measurements of the temperature sensitivity of oceanic and land emission.

Anyone who has doubts about the historical CO_2-data and relies on indirect proxy data, must also have doubts about the temperature trends, not only over the 30s to 50s, but up to the presence.

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Guest-Editor: Prof. Jan-Erik Solheim; Reviewers are anonymous.

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More Comments to Engelbeen's Discussion Paper

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Abstract

The late Ernst-Georg Beck wrote a monumental article titled *"Reconstruction of Atmospheric CO_2 Background Levels since 1826 from Direct Measurements near Ground* ", published in this journal in 2022 (Beck, 2022).

Beck's results are controversial, especially because his reconstruction showed a pronounced peak in atmospheric CO_2 around 1940, which is contrary to the common understanding of the CO_2 history based on ice-core measurements. Beck's paper was commented by Ferdinand Engelbeen (Engelbeen 2023), and thereafter, the editor invited to an Open Review process of Engelbeens article. The result of the Open Review process is summarized in this paper, with contributions from three named contributors and one unidentified blogger.

Keywords: Historic CO_2 levels, Ground observations of CO_2.

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1. Introduction

The late Ernst-Georg Beck wrote a monumental article titled *"Reconstruction of Atmospheric CO_2 Background Levels since 1826 from Direct Measurements near Ground* ", published in this journal in 2022 (Beck 2022).

Beck's results are highly controversial, especially so because of data that showed a pronounced peak in atmospheric CO_2 around 1940, which is contrary to the common understanding of the CO_2 history based on ice-core observations.

A critique of Beck's article, by Ferdinand Engelbeen (Engelbeen, 2023) was posted on the SCC website with an invitation to an Open Review process, in addition to a few invited reviewers. However, mostly because our journal is not widely known, we got only one unexpected reply, from an unidentified blogger.

It may also interest our readers that Hermann Harde (Harde 2023) has shown that the observed CO_2 concentration changes during 1940 – 50 not only correlate with observed temperatures, but can also quantitatively be explained, mainly in terms of the temperature dependent soil respiration and release from the sea (Henry's law).

2. Francis Massen[1]

Ferdinand Engelbeen (FE) makes a well-documented critique of Beck's paper, and I accept many

[1] Luxenbourg. He also gave a longer review, sent to Engelbeen.

of his points. Most importantly, I agree that the famous 1942 peak in Beck's reconstruction is probably an artefact. When I wrote the Klima 2009 paper with Beck (Massen and Beck 2011), I was uneasy seeing the "fingerprint" plot of the Giessen data: as FE writes, there really are too few (CO_2, wind-speed) pairs with high wind velocities, so that even if the fitting gives a result close to 392 ppmv, the paucity of high wind data points makes this at least questionable.

But there remain at least some points that do not invalidate a priori Beck's estimation of higher CO_2 background values than those commonly considered at a certain time. The stomata proxy curve (Fig. 7 in FE's discussion) shows high ~370 ppmv in 1950; now this peak value and the ice-core data (310 ppmv) lie within the error margin of the stomata based reconstruction. So, does this mean that 370 ppmv is a priori impossible? I would say no, as the error range is the domain of all possible values.

A second point for attention is FE's Table 1, which resumes the investigations (of the scientific literature of historic CO_2 measurements) by the Barrow Point researchers. It is interesting to compare the data to the ice-core data curve from the 10 reports given by Engelbeen (2023): 4 give results that deviate distinctly from the usually lower ice core data, given in brackets:

Nansen & Petterson (1880):	300 - 320	[291]
Müller (1928):	240 - 300	[306]
Lockart & Court (1942):	300 - 1700!	[310]
Hock (1952):	400	[312]

I do not understand how FE's comment on the 400 ppmv value as being "within the margins of the method used" does rule out that value as impossible.

Conclusion

As many authors before him, Beck certainly has made errors, and many points are not defined clearly enough. What remains is that no other work of such a wide span has been made by others after his death. I am waiting with impatience for a fresh group of researchers to take up the problem and re-investigate the historic CO_2 measurements, using possible new selection criteria, new data evaluation techniques and so on.

Meanwhile Beck's work, with all its critical points, remains what J-E. Solheim correctly calls a "monumental" work.

3. Ove Huus[2]

Becks extensive work with direct measurements of atmospheric CO_2 is of great importance and could have added valuable and significant early knowledge and critique to the correctness of the so-called hockey stick development curve supplied by IPCC to politicians via Callendar and Keeling.

Historic CO_2 proxy values from ice core pores have in general proven to be too low and stable compared with proxies from Stomata and direct measurements.

The process of creating ice from snow via firn depends on location and seems not well understood and documented. The process itself takes place under significantly different climate circumstances in the Antarctic and Arctic - which will influence the results and make direct comparison questionable. Drilling, collecting and transferring ice cores for analyzing data also depends on methods and skills and seems to lack stringent standards and procedures.

[2] Norway

How the IPCC have transferred and connected their proxy ice core CO_2 data from Antarctica to the Mauna Loa direct measured CO_2 data - seems also highly questionable. These facts have been disclosed, criticized and published by several scientists i.e. Ernst-Georg Beck (Beck 2007), Zbig-niew Jaworowski (Jaworowski 2007) and recently by David Dilley (Dilley 2023).

In SCC Volume 2.3, Harald Yndestad (Yndestad 2022) reveals and explains the vital dynamic connection between Atlantic Sea Surface temperatures and Beck´s atmospheric CO_2 data. The role of ocean latent energy and atmospheric CO_2 forcing from changing tide and the moon plays here a vital part.

The reason for the high CO_2 atmospheric content around 1945 seems well documented through various temperature records – specifically across the US by the HadCRUT4 series – just prior to 1945.

4. Victor M. Velasco[3]

One of the major challenges in reconstructing any variable is calibrating historical data that was gathered using different methodologies and instruments.

The untimely death of Ernst-Georg Beck(†) is a significant obstacle as he is the author who could have addressed Ferdinand Engelbeen's critiques. However, I have not seen any quantification from Engelbeen that demonstrates potential errors in CO_2 reconstructions by Beck†. Moreover, H. Yndestad's wavelet spectral analysis does not seem to be contested.

All reconstructions of any variable have inherent precision and uncertainty. For instance, there are at least two Total Solar Irradiance (TSI) reconstructions: one by the ACRIM missions and the other by PMOD. To date, no reconciliation exists between these two reconstructions, and it is unknown which one is accurate. Both reconstructions have supporters and critics, and each of the authors defend their work. However, discrediting colleagues' work without mathematical proof seems unethical in scientific research, as qualitative comparisons can be subjective.

Prior to the industrial revolution, there was limited discussion about the significant European for-est fires that polluted the air and the global environment. Therefore, the quantity of CO_2 released into the atmosphere is substantial, as seen in Ernst-Georg Beck's reconstruction and Ferdinand Engelbeen's Figure 3. Historical drought indices can provide additional information about atmos-pheric CO_2, as forests, after oceans, are major CO_2 sinks.

5. Unknown

Ferdinand Engelbeen has a comment that many of the observations are unsuited for background CO_2- levels. "The huge CO_2 level around 1940 is physically impossible and contradicts other proxies (Englebeen 2023)." He also questions the validity of the "new" method with windspeed at Giessen in 1940 to measure the background-level for CO_2. Too few and too much spread he writes for this site. But Kauko et al. (1935) measurements from airplanes over Helsinki shows 361-375 ppm CO_2. The data from the windspeed method etc. at Giessen from 1940, may still be close to the real background, since Kauko et al. (1935) also indicates higher levels.

From Becks article:

"This indicates that in 1935 Kauko had measured the real background CO_2 in the air over Helsinki (lat 60.1 long 25E) of 361 ppm ±0.33 % in Dec. 7th and 375 ppm ±0.33 % at 1000 m in Feb. 20th over the clouds. For an estimation of the CO_2 background average for 1935 the modern seasonal averages listed in Globalview CO_2 at similar latitudes of Pallas Finland, lat 68N, Baltic Sea lat 55N, Zotino lat 60N and Shetland lat 60.1N from Globalview-CO_2 are helpful. Globalview MBL

[3] Mexico

CO_2 data since 1980 are comparable to historic times because they exhibit about the same high atmospheric CO_2 range of about 360–380 ppm as the historic data to be evaluated"

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Guest Editor

Stein Storlie Bergsmark

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The Root Cause of Atmospheric CO_2 Rise

More Clear Thinking

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Abstract

This paper continues the debate sponsored by Science of Climate Change on the root causes of atmospheric CO_2 rise during the last century. A little progress has been made in finding common ground, but not very much. A suggestion is made to make the discussion more productive.

Keywords: Carbon cycle, radiocarbon, net global uptake, isofluxes

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1. Introduction and a Proposal

In an earlier paper (Andrews 2023), three primary points were made:

(1) Data show that land and sea reservoirs have been net sinks, not sources, of carbon from the atmosphere during the Industrial Age.

(2) Mixing of carbon between reservoirs, which happens on a time scale of about one decade, precludes making inferences on the cause of atmospheric carbon increases from the present composition of the atmosphere.

(3) The attempt of (Harde and Salby 2021) to reconcile their model with correctly interpreted radiocarbon data was unsuccessful (despite their claim to the contrary) as it required postulating unrealistically large new sources of ^{14}C.

(Harde 2023a) and (Berry 2023) contested these points, while (Engelbeen 2023) supported and elaborated on the first two. Now (Harde 2023b) in a response to Engelbeen, has agreed that the basic argument in support of point (1) is correct, though he continues to dispute the consequences.

Often “responses” by author A to author B’s “comments” have been restatements of author A’s previous articulated positions, without addressing in any meaningful way concerns raised by author B’s comments. Further productive discussion is difficult if arguments perceived by author B to be critical have been ignored. Author B’s only recourse is to find another way to make his point which likely includes yelling a little louder the second time. (Harde 2023b) is an exception, since with his Equation (1) and (2) he endorsed the concept of “Net Global Uptake”, the concept that carbon conservation can be used to infer trends in land/sea reservoirs, though he did not concede the full consequences laid out in (Engelbeen 2023).

In an in-person debate, Author B could cross examine Author A to ensure his concern was considered. As our remote debate format does not allow this, this note will conclude with two focused questions each for Berry and Harde. The questions will underscore this author’s opinion of the most critical flaws in each of their analyses. They can choose to answer them or not. But if they ignore them, their evasion will be obvious. Of course, Harde and Berry can choose to respond with one or two focused questions of their own but should expect answers only if they have been responsive to questions to them. Let us stop talking past each other.

2. Net Global Natural Emissions

Equation 2 in (Harde 2023b) describing the rate of change of atmospheric CO_2 concentration is one all now accept. It is based simply on carbon conservation and the absence of significant anthropogenic absorption processes. Other than that, it is model independent with the two emission and one absorption variables independent and unconstrained. It treats natural and anthropogenic emissions on an equal footing. There is not a shred of circular reasoning in its derivation. We reproduce it here:

$$\frac{\delta c_{CO_2}}{\delta t} - e_A = e_N - a_N \qquad (1)$$

As Harde notes, the quantities on the left-hand side (average rate of change in atmospheric carbon in a year, average anthropogenic emission rates) are well measured. Those on the right-hand side (absorption and emission rates of carbon to and from natural land/sea reservoirs) are poorly known. But this equation allows the *difference* between emissions and absorption ("Net Global Natural Emissions") to be known with some precision. (Andrews 2023) discussed the negative analogue of this quantity for carbon rather than CO_2, called "Net Global Uptake" by (Ballantyne 2012) who found it to be +192 ± 29 PgC. for the period 1960 to 2010, making Net Global Natural Carbon Emissions -192 ± 29 PgC . We are on the same page except for sign conventions and whether we are tracking CO_2 or carbon. Note that ALL natural sources of carbon emissions are included in e_N including volcanoes, outgassing freshwater ponds, etc., or else the logic of its derivation would be violated. As we said, e_N itself is poorly known.

After noting Engelbeen's conclusions from this equation, (Harde 2023b) criticizes three models for allegedly making further unwarranted assumptions about, for example, the constancy of e_N. He accuses *those models* of circular reasoning. We will not pursue that accusation but note only that Harde does not apply his claim of circular reasoning to his own Equation 2. He continues to dispute some of Engelbeen's inferences, but significantly (Harde 2023b) no longer disputes that land/sea reservoirs are sinks, not sources, as he had in (Harde 2023a).

(Harde and Salby 2021) modeled the relationship between absorption and atmospheric concentration. (The supposed confirmation of this model with ^{14}C data is not credible, but we defer that discussion.) This allows (Harde 2023b) to determine a value of a_N from data, and then use it to get an e_N . Unsurprisingly this is higher than e_A by about a factor of six from his calculation. The two-way natural exchanges have always been described as larger than the one-way anthropogenic one. So we have the situation that while the natural reservoirs are undoubtedly net sinks, the gross emissions from them are higher than anthropogenic emissions. $a_N > e_N > e_A$. The disagreement between camps boils down to arguing about which inequality is more important: is it $a_N > e_N$ making natural reservoirs sinks, or $e_N > e_A$ making natural emissions dominate anthropogenic ones? The standard argument of course is that a pre-Industrial Age balance when $a_N = e_N$ was upset by the addition of e_A,. Plots in (Ballantyne 2012) of the changing Net Global Uptake support this, as does Figure 1. Perhaps the question *"do natural sources contribute anything at all to the CO_2 rise?"* is not the right one to ask. In Ballantyne's analysis, temporarily reduced (but still positive) Net Global Uptake during the 1990's is attributed to a volcanic eruption. Should that count as a contribution to the rise? But claiming that natural processes dominate the rise in CO_2, just because gross natural emission rates exceed anthropogenic ones, when Net Global Natural Emissions are negative is untenable. .

The history of atmospheric CO_2 concentration over the last 800,000 years per the UN EPA is shown in Figure 1. We can also read it as a history of Net Global Uptake since anthropogenic emissions were 0 except at the very end of the plot. During eras in the geological past when natural emissions exceeded natural absorption, dC/dt was positive making Net Global Uptake negative. Whenever Net Global Uptake was positive, that meant that dC/dt was negative. But in the present era, Net Global Uptake is positive, *yet dC/dt has never been more positive*. The current excursion in atmospheric CO_2 concentration is not like previous ones.

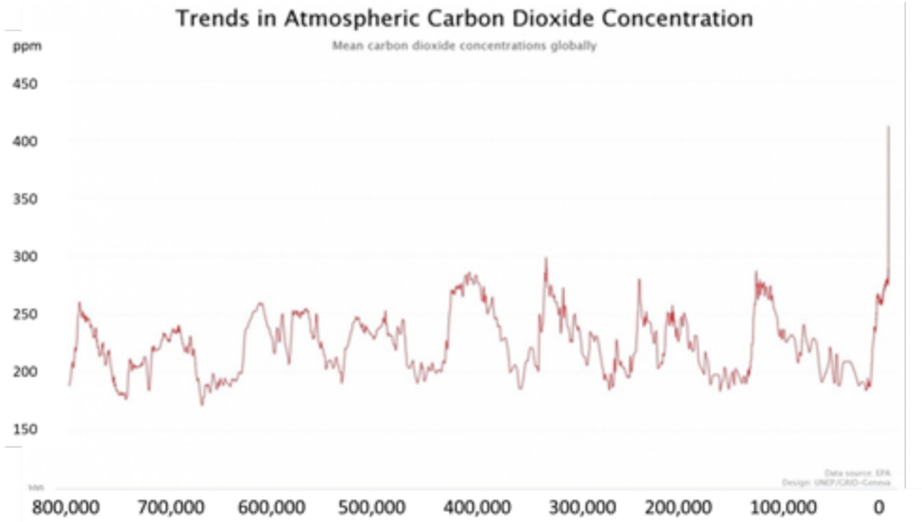

Figure 1 Atmospheric CO_2 concentration for the last 800,000 years. Only on the far right of this graph have Net Global Uptake and dC_{CO2}/dt been positive at the same time.

2. Two questions for Berry

2.1 You have argued in (Berry 2023) without giving detail that analyses using data and carbon conservation to show that natural reservoirs have been net sinks throughout the last century used circular reasoning. Do you still believe that, and if so can you elaborate?

2.2 (Berry 2023) reiterates your model of the human carbon cycle. (Andrews 2023) argued that you have been calculating an unimportant quantity: the amount of carbon in the present atmosphere that was once contained in a fossil fuel. Because of mixing on a decade time scale the statement *"Human carbon in the present atmosphere is only 30% of the Industrial Age increase"* is not the same as *"Human emissions caused only 30% of the increase."* Let us assume your calculation of human carbon in the present atmosphere is correct. How can you justify making inferences about the cause of CO_2 rise from it, given the mixing?

3. Two questions for Harde

3.1 In (Harde and Salby 2021) you set out to establish your model of carbon exchanges by fitting atmospheric ^{14}C concentration curves which, since about 2000, have shown steady increases. Your model required them to decrease exponentially. You therefore made a fit with a growing background, and published the parameters of that fit, ascribing the background to new nuclear power plants, nuclear testing, and increases in cosmic ray flux. Figure 3 in (Andrews 2023) used your parameters and argued they were unreasonably high. You say in (Harde 2023a) *"the artificially constructed background in Andrews' Fig 3 has nothing to do with our calculation and explanation, which unambiguously confirms our previous conclusion"*. Have you reconciled the parameters you found from the fit to other estimates of ^{14}C sources, or found an error in Andrews' use of your parameters and produced another plot to correct it?

3.2 In (Harde 2023a) you write *"Radiocarbon is an ideal tracer, which obeys the same rules as the other isotopologus, and thus can be well used to study temporal carbon mixing and exchange processes."* You didn't like the alcohol water mixing analogy, but no doubt can see that balanced mixing between two carbon reservoirs with initially different isotopic composition can lead to equilibration in the isotopic composition of each without changes in the total carbon content. That means that total carbon flows do NOT necessarily follow ^{14}C flows. While you dismissed isofluxes, might they help you understand the rise in ^{14}C this century?

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Nature Controls the CO_2 Increase II

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Abstract

This paper continues the debate sponsored by Science of Climate Change on the role of human emissions in the CO_2 increas since 1750.

Keywords: CO_2; carbon cycle; climate change; climate emergency; climate alarmism; climate fraud; climate crisis; human emissions.

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1. Introduction

The *Intergovernmental Panel on Climate Change* (IPCC, 2013, p. 467, Executive Summary, selected paragraphs) say incorrectly and without scientific basis,

> The Human-Caused Perturbation in the Industrial Era CO_2 increased by 40% from 278 ppm about 1750 to 390.5 ppm in 2011.
>
> The removal of human-emitted CO_2 from the atmosphere by natural processes will take a few hundred thousand years (high confidence).
>
> This very-long time required by sinks to remove anthropogenic CO_2 makes climate change caused by elevated CO_2 irreversible on a human time scale.
>
> By contrast, since the beginning of the Industrial Era, fossil fuel extraction from geological reservoirs, and their combustion, has resulted in the transfer of significant amount of fossil carbon from the slow domain into the fast domain, thus causing an unprecedented, major human-induced perturbation in the carbon cycle.

The IPCC assumes the natural CO_2 level remained at about 280 ppm since 1750.

Berry (2019, 2021, 2023) made the following points:

1. The bomb-caused increase in $\delta^{14}C$ before 1970 has returned to its original balance level of zero with an e-time (level/outflow) of 16.5 years, and this is significant.
2. IPCC's (2007, 2013) natural carbon cycle data can be replicated by a simple four-reservoir "physics" carbon cycle model that uses only one hypothesis, namely, that Outflow equals Level divided by an e-time.
3. This simple, IPCC-approved hypothesis allows us to calculate the human and natural carbon cycles separately.
4. Inserting IPCC's own data into the physics carbon cycle model calculates IPCC's true human carbon cycle.
5. This true IPCC human carbon cycle shows the human addition to atmospheric CO_2 as of 2020 was about 33 ppm.
6. This means natural carbon emissions have increased since 1750 to add about 100 ppm to the 1750 280 ppm CO_2 level as of 2020.
7. This means the fundamental claim of the IPCC that human emissions have caused all the CO_2 increase above 280 ppm is a fraud of global proportions.

8. The e-times of human and natural CO_2 are identical because their molecules are identical.
9. This means IPCC's claim that human CO_2 has an e-time of thousands of years while natural CO_2 has an e-time of 3.5 years is not just wrong but a fraud.
10. This means IPCC's claim that human emissions caused all the CO_2 increase is also a fraud.
11. The percentages of carbon in each reservoir in IPCC's natural carbon cycle represents the natural equilibrium percentages.
12. The human carbon cycle at equilibrium will have these same percentages.
13. Since total human carbon emissions are only one percent of natural carbon in the carbon cycle, the present equilibrium level of human CO_2 is only 4 ppm.
14. This 4 ppm contradicts IPCC's claim that human emissions have caused an unprecedented, major perturbation in the carbon cycle.
15. The return of $\delta^{14}C$ to its original balance level of zero indicates that natural processes cause the $\delta^{14}C$ balance level to remain at zero.
16. This explains the $^{14}CO_2$ increase to be a result of the $^{12}CO_2$ increase while the $\delta^{14}C$ balance level to remain at zero.
17. The return of $\delta^{14}C$ to its balance level of zero, and not to a lower balance level, shows human emissions have not significantly increased the CO_2 level.

Andrews (2023a, 2023b) contests some of the above points made by Berry.

2. Andrews makes a basic physics error

Andrews (2023b) begins with his equation (1), shown here with e_H on the right side:

$$dL / dt = e_N - a_N + e_H \quad (1)$$

where

L = carbon level (PgC)

t = time (years)

dL / dt = rate of change of L (PgC / year)

e_N = natural carbon inflow (PgC / year)

e_H = human carbon inflow (PgC / year)

a_N = natural carbon outflow (PgC / year)

a_H = human carbon outflow (PgC / year)

Andrews writes we "all now accept" his (1) and.

> "It is based simply on carbon conservation and **the absence of significant anthropogenic absorption processes**. Other than that, it is model independent with the two emission and one absorption variables independent and unconstrained. It treats natural and anthropogenic emissions on an equal footing. **There is not a shred of circular reasoning in its derivation.**" (My bolding.)

However, we do not accept (1) because it is missing a way for human carbon to flow out of the atmosphere. We must correct Andrews (1) by subtracting a_H to get (2):

$$dL / dt = (e_N - a_N) + (e_H - a_H) \quad (2)$$

Andrews incorrectly assumes human carbon outflow is insignificant and he omits this outflow in his equation (1). His omission assumes human carbon causes all the CO_2 increase, which is what he claims he proved. This is the circular reasoning that he claims does not exist in (1).

Since Andrews (1) is wrong, all his conclusions are incorrect.

3. Correct physics

Berry's (2021, 2023) equation (1) is a correct formulation as follows:

$$dL / dt = Inflow - Outflow \tag{3}$$

Equation (1) applies independently and in total to N for natural carbon and H for human carbon:

$$dL_N / dt = I_N - O_N \tag{4}$$

$$dL_H / dt = I_H - O_H \tag{5}$$

$$dL / dt = I_N - O_N + I_H - O_H \tag{6}$$

Added together, where L is the sum of human and natural carbon, (6) is the same as (2)

To solve (4), (5), or (6), to find human carbon added to the atmosphere, we need more data.

Berry (2021, 2023) used IPCC's own data to calculate that human carbon emissions have added 33 ppm of CO_2 and natural carbon 100 ppm to the 280-ppm level as of 2020.

4. Andrews first two primary points are wrong.

Andrews (2023b) includes "three primary points" in his Introduction.

- Point (1) is invalid because it omits the term for human carbon emissions.
- Point (2) is invalid because it ignores Berry's calculations of IPCC's true human and natural carbon cycles.

5. Berry's reply to Andrews' two questions

Andrews' (2023b) definition of net sink is based on his equation (1) that omits human carbon outflow. Equation (2) shows why Andrews' claim that nature is a net absorber is wrong.

Berry's calculation of the human carbon cycle shows how human carbon flows from the atmosphere to the land, surface ocean, and deep ocean reservoirs, according to IPCC's data.

6. Berry's questions for Andrews

6.1 Use of ice-core data to reconstruct CO_2 *data*

How do you justify (in your Figure 1) your comparison of CO_2 levels derived from ice-core proxy data before 1900 with CO_2 levels derived from in-situ data after 1960 when you consider the following?

- Segalstad (1998) shows why ice core reconstructions of CO_2 levels are not reliable.
- Jaworowski (2007) shows ice cores underestimate CO_2 levels.
- Salby (2012, pp. 21, 66) shows ice-core reconstructions of CO_2 levels do not accurately measure historical CO_2 levels.
- There is no published confirmation that the proxy data agree with the in-situ data.

6.2 Best explanation for the ^{14}C *increase after 1960.*

- Do you agree the $\delta^{14}C$ balance level has returned to its original balance level of near zero (Berry, 2023, Figure 13)?
- Do you understand Berry's hypothesis that accurately predicts the ^{14}C increase?
- Do you agree that Berry's hypothesis is the simplest Occam's Razor hypothesis?

6.3 Cawley's analogy.

- Do you admit Cawley's (2011) analogy supports Berry's physics model?

6.4 Calculating human and natural carbon cycles independently.

- Do you agree we should calculate the human and natural carbon cycles independently?

6.5 How human CO_2 *remaining in the atmosphere equals the human* CO_2 *added.*

- Do you agree Berry's calculated human carbon level is the same as the amount of human CO_2 added to the atmosphere?

6.6 How $\delta^{14}C$ *measures the human* CO_2 *added.*

- Do you agree the $\delta^{14}C$ balance level near zero means the human-caused increase in the CO_2 level is also near zero?

7. Conclusions

Andrews (1) omits the term to calculate human carbon outflow. So, his argument is circular.

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Conflicts of Interest

The Author declares he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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