Gaia—Guy Stewart Callendar: A Pioneer of Anthropogenic Climate Change Theory

The climate change hype in most public media in recent months takes three things for granted:

· that anthropogenic climate change is on its way,
· that attribution of climate change facets to causes is feasible and
· that political measures come anyway too late, at least with respect to the changes to occur over the coming few decades.

Only twelve years ago, in 1995, did the international scientific community agree on anthropogenic climate change detection by stating in the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC): "The balance of evidence suggests a discernible human influence on global climate".

But already about 70 years ago, exactly in 1938, a physicist in Great Britain, mainly working for an industrial association and the British army, has laid the physical foundation of anthropogenic climate change theory. It was Guy Stewart Callendar (1898 to 1964) who related changed atmospheric trace gas concentrations (mainly carbon dioxide [CO2]) to increased downward thermal infrared radiation fluxes in the atmosphere and these to higher near surface air temperature. His achievements as a scientist working in very different fields, namely steam tables but also fog dispersal on British airfields during World War II, have recently been summarised in a 176 pages book: The Callendar Effect, written by James R. Fleming and published by the American Meteorological Society.

Why was Callendar unsuccessful to spread his message about ongoing anthropogenic climate change across the full scientific community, not to speak about the public? – I give five reasons:

Firstly, because 70 years ago prominent meteorologists had no sufficient understanding of thermal infrared radiation (still in parts true today). Although Callendar had formulated the first full theory in his most famous scientific paper on The artificial production of carbon dioxide and its influence on temperature published in the Quarterly Journal of the Royal Meteorological Society in 1938, most of his established colleagues in meteorology criticised the paper. They mainly questioned his estimates of the CO2 concentration increase from "274 to 292" parts per million by volume (ppmv) in 1900 to "289 to 310" ppmv until 1938. We know now that his first estimates bracket the true values.

Secondly, Callendar failed because he was a newcomer in the field of meteorology and climatology. He was employed by the British Electrical and Allied Industries Research Association (BEAIRA) where his job was to improve steam tables showing saturation water vapour pressure as a function of temperature at very high temperatures. Callendar's tables are still important for conventional power plants and many industrial processes.

Thirdly, because World War II had set other priorities.

Fourthly, because global mean temperature did no longer rise from the late 1940s to the early 1970s. This stagnation of global mean temperature – as we know now – was also in parts due to an anthropogenic force, namely increased turbidity of air, which is also a consequence of fossil fuel combustion.

In 1939, Callendar published in the Meteorological Magazine another article on The composition of the atmosphere through the ages in which he stated: “As man is now changing the composition of the atmosphere at a rate which must be very exceptional on the geological time scale, it is natural to seek for the probable effects of such a change. From the best laboratory observations it appears that the principal result of increasing carbon dioxide (…) would be a gradual increase in the mean temperature of the colder regions of the earth”. He clearly captured the main reason for concern nowadays: the unprecedented climate change rate. Also the last half sentence shows his deep knowledge of infrared absorption by greenhouse gases, notably water vapour that masks increased downward thermal radiation at increasing CO2 concentrations nearly totally at high absolute humidity in low latitudes. But it also shows the neglect of a positive feedback by water vapour amplifying the warming caused by higher concentrations of long-lived greenhouse gases like CO2 and nitrous oxide.

Callendar’s Forerunners

Callendar was not an advocate of a climate change policy that would try to reduce emissions of greenhouse gases. The geographer Eduard Brückner, however, had stimulated an anthropogenic climate change debate about 50 years earlier than Callendar (see table). As he published his contributions in German, they were largely neglected in the English speaking world. He was also heavily criticised by his colleagues.

But Callendar was aware of the first pillars of a climate change theory published in English by John Tyndall. In 1863, Tyndall had clearly pointed to the greenhouse effect of the atmosphere: “The solar heat possesses the power of crossing an atmosphere, but, when the heat is absorbed by the planet, it is so changed in quality that the rays emanating from the planet cannot get with the same freedom back into space. Thus the atmosphere admits the entrance of the solar heat but checks its exit, and the result is a tendency to accumulate heat at the surface of the planet.”

What We Can Learn from Callendar’s Bad Success

Is our behaviour to wait for the scientific proof before action adequate? The longer the lifetime of a phenomenon lasts, the less this behaviour is adequate. Would we wait until we know at which mean global temperature rise we trigger the melting of large parts of the Greenland ice sheet or the disintegration of the West Antarctic one, it is certainly too late to rescue many big cities in marshlands along coasts in centuries from now, because the turn-over time for these ice sheets is millennia. Presently, the temperature rise range estimated by scientists for this triggering lies between 1.5 and 3.0 degrees Celsius. As already 0.8 degrees Celsius have been observed since industrialisation began and since we are already committed to about the same even if no further greenhouse effect enhancement would occur, it may already be too late now to avoid a sea level rise of several metres over the coming centuries.

When Had the Time for Action to Curb Anthropogenic Climate Change Been Reached?

Let us first define different criteria that have to be fulfilled before action, starting with the most basic and ending with the most demanding one. In other words: Depending on the seriousness of the adoption of the precautionary principle for action with respect to global change issues less criteria have to be fulfilled.

Criterion #1: observation of mean global warming represented by long-term near surface air temperature (2m height) measurements.

Criterion #2: observation of an increase in long-lived greenhouse gas concentration in the atmosphere.

Criterion # 3: paleoclimate evidence of global warming caused by an enhanced greenhouse effect.

Criterion # 4: Detection of an anthropogenic contribution to a global mean warming using tested climate models and statistical fingerprint methods.

Criterion # 5: Attribution of climate change facets to causes, e. g. in the lowest stratosphere cooling is caused by ozone depletion rather than the anthropogenic greenhouse effect.

When Have these Criteria Been Accepted at a High Confidence Level by the Scientific Community?
For criterion # 1 the First Assessment Report of the IPCC, published 1990, was the decisive date.3 Criterion #2 became satisfied in the 1960s for CO2 only. For methane and nitrous oxide we also had to wait until the IPCC Report in 1990 gave rather accurate numbers. The halocarbons as artificial long-lived greenhouse gases became known a few years earlier in the Ozone Assessment Reports published by the World Meteorological Organization and NASA.

Criterion # 3 could also be called fulfilled with the same report when a high correlation between greenhouse gas concentration and temperatures at snow formation could be given for a 160 000 year long record of air bubbles in ice and ice itself in Antarctic ice cores.

Criterion # 4 has been summarised in the famous sentence “the balance of evidence suggests a discernible human influence on global climate” in the IPCC’s Second Assessment Report in December 1995.

Criterion # 5 has been accepted only very recently in the IPCC’s Third Assessment Report of 2000. The first attribution came for the cooling in the lower stratosphere caused mainly by depletion of ozone and not so much by the enhanced greenhouse effect. The Fourth Assessment Report names several new attributions, such as “sea level rise is largely a consequence of the warming of sea water in the upper ocean layers”.

Conclusions
What is now a hot political topic has developed in natural sciences over the last 185 years: the enhanced greenhouse effect of the atmosphere. The milestones in its understanding were nearly always connected with new observations. Firstly, observations of the height dependent temperature and pressure values in the atmosphere and the heating of a glass-covered box due to solar radiation by the French scientist Saussure led the Frenchman Fourier in 1827 to the argument that the atmosphere acts like a shield that is keeping heat in the system. In the mid-nineteenth century the Irishman John Tyndall gave the first description of the greenhouse effect of the atmosphere using his observations of trace gas absorption in the thermal infrared. But the Swede Arrhenius in 1896 put forward plausible reasons for a substantial warming, should the CO2 concentrations double, caused by the burning of coal in the coming centuries. His arguments were not so much based on new observations, but on the fast process of industrialisation in the late 19th century.

Looking back now equipped with massively developed monitoring of the earth system, one is tempted to ask: Why did the broader scientific community not ring the alarm bell earlier than in 1990?

The simple answer: The full story was not yet available. The full story is a clear link from measured trace gas changes originating from man's activities via tested radiation and transient climate models to observed and projected climate parameters. It became available in full for the IPCC's Second Assessment Report in December 1995: "The balance of evidence suggests a discernible human influence on global climate". In February 2007, the Fourth Assessment Report confirmed it by stating: "The understanding of anthropogenic warming and cooling influences improved (…) leading to very high confidence (emphasis added, H. G.) that the globally averaged net effect of human activities since 1750 has been one of warming".

Since then, there is no longer any excuse for inaction.