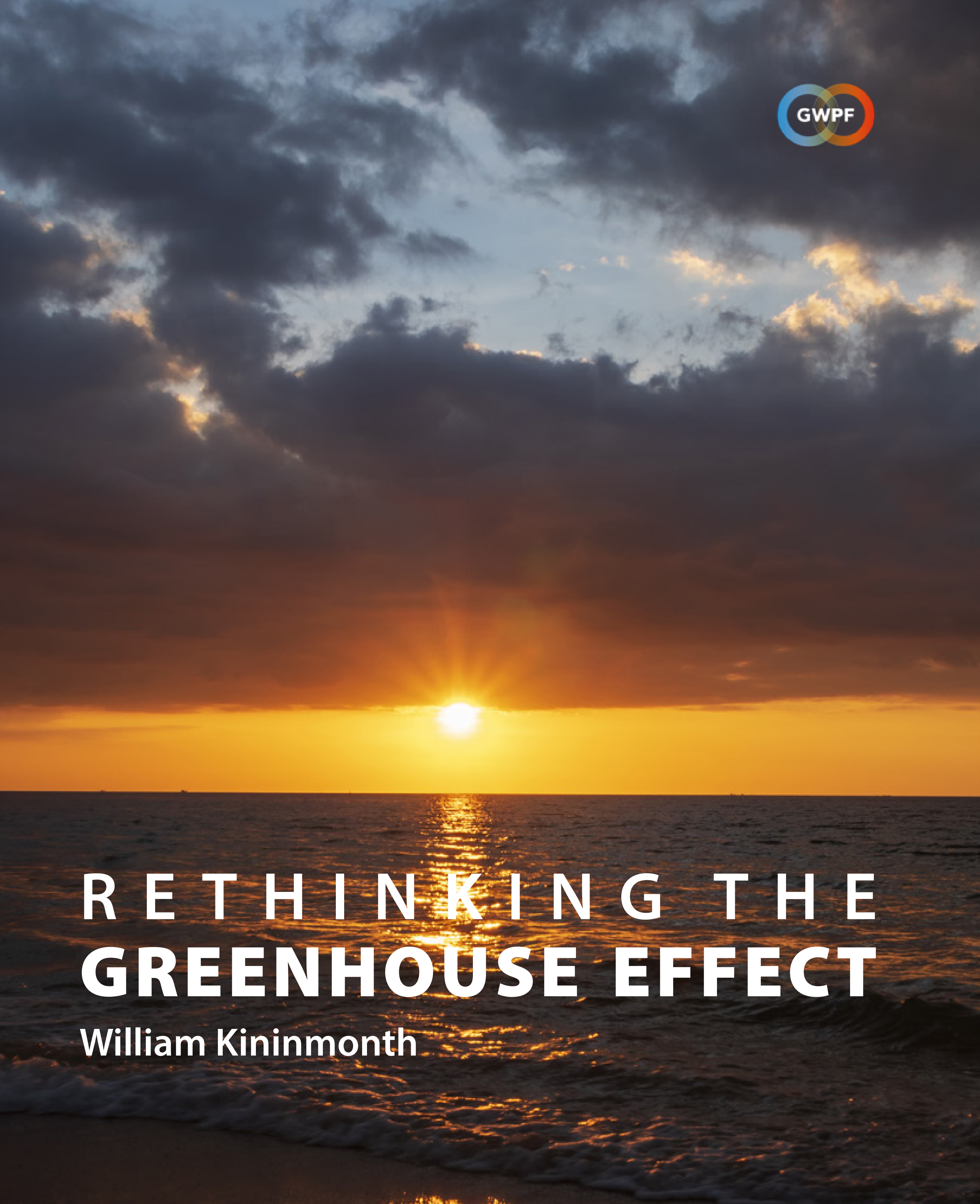

RETHINKING THE GREENHOUSE EFFECT

William Kininmonth

The Global Warming Policy Foundation
Note 34

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About the author

William Kininmonth joined the Australian Bureau of Meteorology in 1960, and retired in 1998 as head of the National Climate Centre. He was a consultant to the World Meteorological Organization's Commission for Climatology and participated in regional coordination and training programs. William Kininmonth is author of *Climate Change: A Natural Hazard* (2004, Multi-Science Publishing).

Introduction

The widely held belief that humans are causing a climate emergency has its origins in the claim that greenhouse gases keep the planet warm by absorbing Earth's radiation,[1] preventing it escaping to space. From this understanding, it would naturally follow that releasing more greenhouse gases, specifically carbon dioxide from industrial emissions, will lead to more warming. The claim is an extension of a theory proposed in the 1820s by French mathematician Joseph Fourier, which was later used by Swedish chemist Svante Arrhenius in his 1896 hypothesis for the cause of ice ages.

The Intergovernmental Panel on Climate Change (IPCC) is the body created by the United Nations to advise governments on the potential impacts of carbon dioxide on future climate. Its explanation for anthropogenic global warming assumes that Earth was in radiation balance prior to industrialisation; that is, the planet's temperature was stable because, at the top of the atmosphere, incoming solar radiation[2] was offset by an equal magnitude of longwave radiation emission to space.

Burning of fossil fuels has undoubtedly increased the carbon dioxide concentration of the atmosphere. In the IPCC's explanation, as the concentration has increased, there has been a reduction in the intensity of radiation emitted to space. This so-called 'radiation forcing' heats the atmosphere.

The reality of the greenhouse effect is, however, much more complex than just the absorption of Earth's radiation by greenhouse gases[3] and the balance of radiation at the top of the atmosphere. It has been understood for more than 60 years that greenhouse gases emit more radiation – to space and back to Earth – than they absorb. The atmosphere is only prevented from cooling by a constant flow of heat and latent energy (the evaporation of water vapour) from the Earth's surface. It is impossible to properly understand what is going on without considering these enormous flows of energy.

The IPCC's construct also overlooks the fact that Earth is a sphere, and what happens at different latitudes is very different: most absorption of solar radiation takes place over the tropics, while there is excess emission of longwave radiation to space over higher latitudes.[4] Nowhere is there local radiation balance. The ocean currents and winds of the atmosphere are constantly transporting excess heat from the tropics to higher latitudes as the dynamics of the climate system strive to achieve global radiation balance. However, any balance is only transitory because of the different rates of transport by the oceans and atmosphere and the seasonally changing pattern of solar heating.

The absence of global radiation balance is exemplified by the fact that Earth's average surface temperature is not constant; it has an annual range exceeding 2.5°C. This shows that the global emission of longwave radiation to space must vary through the year. This can only mean that the amount of heat radiated to space is a function of Earth's changing temperature, which in turn means radiation to space cannot in any way be defining Earth's temperature, either locally or globally.

An alternative approach to explaining why Earth's temperature is changing is to follow the course of energy as it traverses the climate system, from absorption over the tropics, transport poleward by the atmospheric and oceanic currents, to emission to space over higher latitudes. In this way, it is possible to see:

- how the surface energy budget defines Earth's greenhouse effect;
- that solar radiation absorbed over the tropical oceans forms a surface layer heat reservoir, which in turn regulates heat exchange to the atmosphere;
- how temperatures over high northern latitudes respond as the winds transport heat from the tropics.

The conclusion to be drawn is that changing atmospheric carbon dioxide has minimal impact on Earth's temperature and climate. In fact, the temperature changes observed over the recent four decades are consistent with a slowing of poleward transport of heat by the ocean currents.

The greenhouse effect

The temperature at any given point on the Earth's surface is regulated by energy-exchange processes. The surface:

- gains energy through absorption of solar energy and absorption of longwave radiation emitted downward by the greenhouse gases of the atmosphere
- loses energy through emission of longwave radiation, and flow of heat and latent energy to the atmosphere.

That is true on average for the Earth's surface, but at any particular point, the situation might be slightly more complicated. As we will see, in the warm tropical oceans, there is another energy outflow due to heat transport by the ocean currents.

Apart from absorption of solar radiation (which is essentially constant), the magnitude of each of the energy surface processes is governed by physical laws. The rate of energy flow in each process varies with surface temperature, but each according to a different relationship. The Earth's equilibrium global average surface temperature is achieved when the processes come into long-term balance; in other words, when the absorption of solar radiation is offset by the other energy exchange processes: emission of longwave radiation, the flow of heat and latent energy to the atmosphere, and the absorption of longwave radiation from the atmosphere.

In the absence of greenhouse gases (including water vapour; in other words we are assuming Earth to be a waterless planet), no longwave radiation is emitted from the atmosphere to be absorbed at the surface, nor is there any net flow of sensible and latent heat from the surface. Under these conditions, the equilibrium surface temperature is reached when the absorption of solar radiation is equal to the surface emission of longwave radiation. Without greenhouse gases the surface temperature would be about −19°C.

However, Earth is of course a water planet, with the oceans making up 70% of the surface area and evaporation from the surface providing a steady flow of latent energy – in the form of water vapour – to the atmosphere. Water vapour is the predominant greenhouse gas in the atmosphere and the primary source of longwave radiation absorbed at the surface. The absorption of longwave emission from the greenhouse gases has supplemented solar radiation, raising the global average surface temperature such that the energy exchange processes are in balance at an equable surface temperature of about 15°C, about 34°C warmer than in the absence of water.

The importance of water vapour in regulating the greenhouse effect is evident from Table 1, which shows the changing absorption of longwave radiation at the surface from the emissions by the greenhouse gases. In each column of the table, the atmospheric water vapour is the same and represents the average tropical value. It is the carbon dioxide concentration that increases from left to right, from no carbon dioxide, through values typical of the last glacial maximum (200 ppm), pre-industrial levels (300 ppm), contemporary levels (400 ppm), and finally to values consistent with future unconstrained industrial emissions (600 ppm).

The approximately 7 W/m^2 contribution to surface absorption by bring carbon dioxide up to pre-industrial levels represents only 2% of the greenhouse effect. Increasing it to the 600 parts per million (ppm) level expected with unabated emissions only increases the latter figure by about 0.2%, from 369 W/m^2 to 370 W/m^2.

Climate history also points to the limited effect of carbon dioxide on Earth's temperature. At the time of the last glacial maximum, 20,000 years ago, great ice sheets covered much of North America and northwest Europe; sea level was about 130 metres lower than today. Over the next 10,000 years atmospheric

Table 1: Carbon dioxide's minimal contribution to the greenhouse effect

Carbon dioxide (ppm)	0	200	300	400	600
Radiation emitted by the greenhouse gases and absorbed at the surface					
Surface radiation (W/m^2)	361.40	368.01	368.64	369.26	370.21
Increase (W/m^2)	—	6.61	0.63	0.62	0.95
Cumulative increase (W/m^2)	—	6.61	7.24	7.86	8.81

Atmospheric water vapour levels are assumed constant at a level consistent with the tropics. Data from MODTRANS (MODTRAN Infrared Light in the Atmosphere (uchicago.edu)).

carbon dioxide concentration increased from about 200 ppm to 300 ppm, and there were clearly large changes in temperature over the same period – the great ice sheets largely melted, and the sea surface rose to near its present level. However, the associated changes in radiation absorbed at the surface were rather small (Table 1). Then, over the recent century of industrialisation, carbon dioxide increased to more than 400 ppm, again with a small associated increase in radiation absorbed at the surface. However, the associated changes in global temperature have been difficult to detect. This all suggests that carbon dioxide has only minimal climate impact and was not the cause of Earth's deglaciation.

Equatorial ocean and lower atmosphere temperature

As noted above, most solar radiation hits the Earth in the tropics. It passes through the atmosphere and is absorbed at the surface. The solar radiation is absorbed into, and mixed through, the surface layer of the oceans, which cover most of the Earth's surface. The result is a lens of warm water near the surface, a tropical ocean heat reservoir often reaching more than 100 metres in depth (Figure 1).

The temperature of the warm ocean lens is affected by four energy flows:

- absorption of shortwave radiation direct from the sun
- absorption of longwave radiation from greenhouse gases in the atmosphere
- loss of heat and latent energy to the atmosphere
- loss of heat via ocean currents.

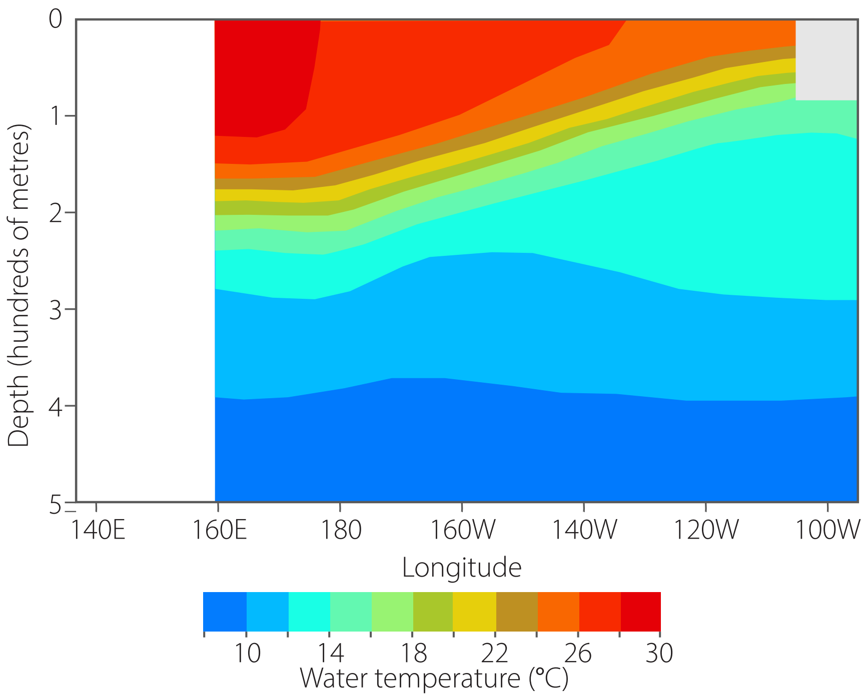

Figure 1: The heat reservoir of the tropical ocean surface layer

Temperature across a depth section of the equatorial Pacific Ocean. (Papua New Guinea to the left, South America to the right.) Source: US NOAA Pacific Marine Environment Laboratory.

The surface waters are warmed by solar radiation, and temperatures vary with ocean circulations. The cooler waters over the eastern equatorial Pacific Ocean are due to the ascending cold interior waters associated with the global Thermohaline Circulation.

Over the last 40 years, the ocean surface has warmed by about 0.4°C, implying that the balance of energy flows has changed. But by which process? The flow of energy from the sun is essentially constant, so that is quickly eliminated. However, after that opinions differ. The IPCC claims that the atmosphere, warmed by increasing carbon dioxide concentrations, has heated the oceans below. However, this cannot be true, because, in the tropics at least, the atmosphere is cooler than the ocean.

Varying carbon dioxide concentrations do have an influence; as they increase, the emission of radiation to the surface increases, warming the ocean surface. However, as noted in Table 1, the effect over the tropics is small. In fact, it is possible to calculate that the increase in carbon dioxide concentration, from 337 ppm to 411 ppm, only results in an increased energy flow of 0.3 W/m^2. That is far too little to explain an increased ocean temperature of 0.4°C, because the increased temperature in turn increases the flow of energy to the atmosphere by about 3.5 W/m^2.

In other words, while a small amount of extra energy has gone into the tropical ocean surface as a result of increased carbon dioxide concentrations, eight times as much has been escaping to the atmosphere. The absorption of additional radiation energy from the change in carbon dioxide concentration is insufficient to support the rise in latent heat loss from the increase in surface temperature.

This leaves changes in ocean currents as the only plausible explanation for the warming of the tropical reservoir. Importantly, this idea is supported by real-world evidence, such as the observed slowing of the Gulf Stream.

The tropical atmosphere

The above explanation for the warming of the tropical heat reservoir is consistent with other observed changes in the climate, notably atmospheric temperatures in the tropics and in the Arctic.

As noted previously, the greenhouse gases of the atmosphere emit more radiation than they absorb. This energy loss is offset by a flow of heat and latent energy from the surface. The tropical ocean heat reservoir is the primary source of this energy, and the rate at which heat flows is regulated by the ocean surface temperature.

Over the tropics, the heat and latent energy from the ocean surface remains in the lowest layer of the atmosphere below the clouds, and the trade winds draw it into the Equatorial Trough – a narrow band of latitudes close to the equator (the Doldrums, in common parlance). As the heat builds up in this region, deep convection clouds form,[5] and it is these that transport heat upwards into higher layers of the atmosphere, where the winds distribute the heat poleward.

The transport of heat upwards through this deep convection process creates a tight link between the temperature of the tropical atmosphere and that of the ocean surface below. Figure 2 shows the coherence of the atmosphere and ocean surface temperatures. The correlation between the detrended records is 0.86, albeit with a one- to two-month delay in the atmosphere's response.

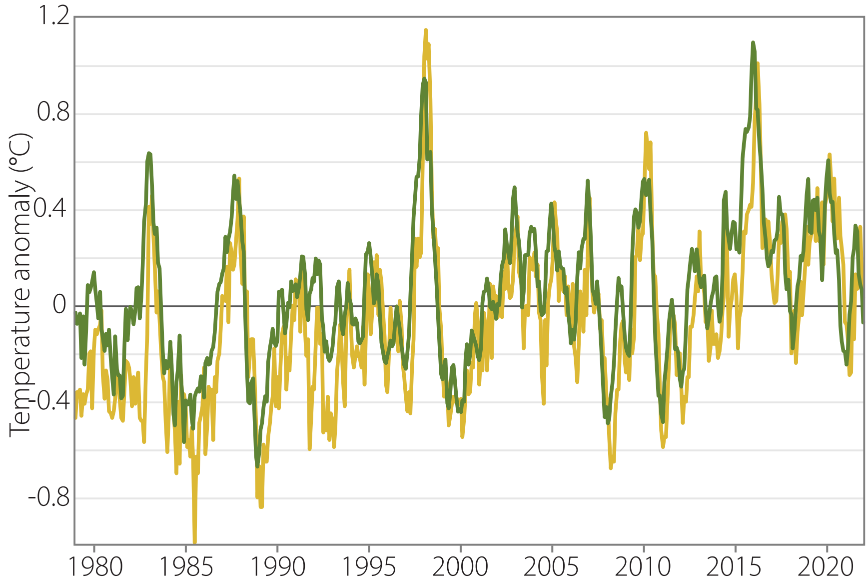

Figure 2: Equatorial temperatures: ocean surface and lower atmosphere.

Monthly temperature anomaly for the equatorial ocean surface (Lat. 10°S to 10°N) and lower atmosphere of the tropics (Lat. 20°S to 20°N). Data: ocean temperature from the US NOAA NCEP/DOE R2 data set; lower atmosphere from University of Alabama, Huntsville satellite soundings.

— Ocean
— Lower atmosphere

The temperatures in both records change markedly from year to year – at times by up to 1°C. These changes are associated with changes in the ocean circulation associated with the El Niño and La Niña events. Superimposed on this short-term variability, there have been long-term warming trends of about 0.1°C per decade in both records. The effect of the warming is two-fold:

- the increased warmth in the tropical atmosphere is a source of additional energy, and increases the rate of heat transport to higher latitudes;
- the warmer oceans increase the flow of latent energy to the atmosphere.

The latent energy is not immediately apparent, but will be seen in the warming at higher latitudes.

Arctic warming

Over middle and high latitudes, the emission of radiation to space exceeds the absorption of solar radiation. However, temperatures over these higher latitudes are sustained by the input of heat transported from the tropics in the atmospheric circulation. This process is at a maximum during the winter months, when radiation loss to space is at its greatest, polar temperatures are coldest, and the circulation is strongest.

Systematic monitoring of Earth's temperature over the last 40 years has revealed regional and seasonal features associated with warming. At equatorial latitudes, ocean surface and atmospheric temperatures have been warming at a rate of around 0.1°C per decade. Over the same period, surface temperatures in middle and high latitudes of the northern hemisphere have increased at higher rates, averaging about 0.7°C per decade over the Arctic.

Warming is greater over the Arctic than over the tropics because the additional latent energy exchanged from the tropical oceans is transformed to heat over middle and high latitudes. Moreover, the Arctic warming varies throughout the year, from about 0.4°C per decade in summer to 1.2°C per decade in colder months (Figure 3). The fact that the warming has occurred predominantly during the cold winter half of the year, when the polar surface is largely in darkness, implies that it can only be the result of heat transport from warmer latitudes.

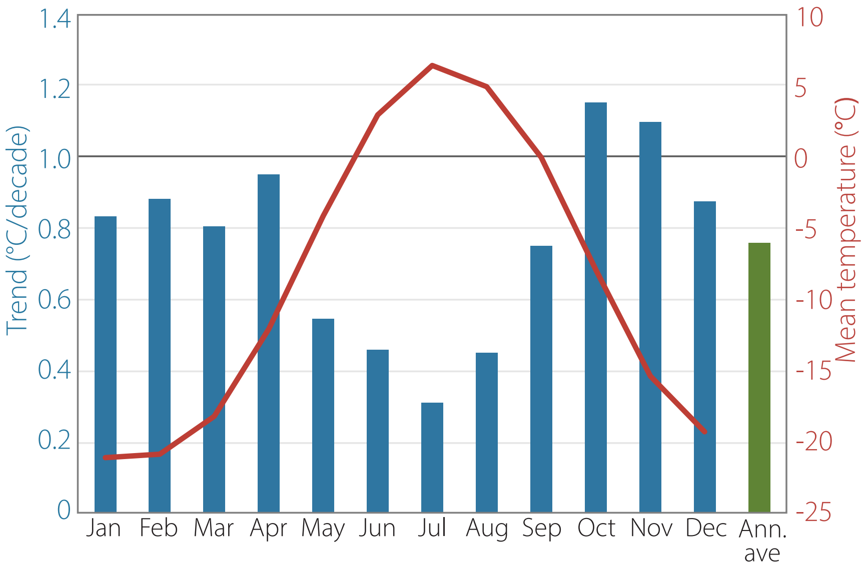

Figure 3: Polar temperatures respond to the seasonally changing atmospheric circulation and heat transport.
Data: US NOAA NCEP/DOE R2 dataset.

The warming spring and autumn months have extended the summer snow melt period and the length of the growing season, the latter contributing to the greening of the planet observed by satellite.

Summary

The characteristics of recent climate change and its cause are clear. The tropical oceans have warmed, not as a result of additional atmospheric carbon dioxide but most likely because of a reduction in the transport of heat, as ocean currents slow. The warmer tropical oceans have raised the temperature of the tropical atmosphere in turn, in particular through the medium of deep equatorial convection clouds. Additional energy flowing from the warmer tropical oceans has been transported by the winds to enhance polar warming, especially in the winter months.

Put another way, recent warming is probably simply the result of a fluctuation in the ever-changing ocean circulation; carbon dioxide must be recognised as a very minor contributor to the observed warming and one that is unlikely to prolong the warming trend beyond the peak generated by the natural oceanic oscillations.

There has been much speculation that the recent warming trend will generate extreme weather events dangerous to humankind. The evidence is not compelling. The greatest warming has been over high northern latitudes, when temperatures are well below freezing. It will therefore be unlikely to have any appreciable impact on flora or fauna. Notwithstanding this, the impacts of both short- and medium-term shifts in natural oscillations, such as El Niño and the Atlantic Multidecadal Oscillation, will continue, and adequate preparedness remain essential.

The pattern of recent global warming underscores the validity of what meteorologists widely recognise: the oceans are the vital inertial and thermal flywheels of the climate system. The corollary is, if one wants to control climate, it will be necessary to control the oceans. Efforts to decarbonise in the hope of affecting global temperatures will be in vain.

GWPF invited the Royal Society and the Met Office to review this paper, and to submit a response to be published as an appendix to it. No reply was received.

Notes

1. Earth's radiation is radiant energy emitted by substances at temperatures typically found on Earth. Earth radiation is also referred to as longwave radiation.

2. Solar radiation is energy emitted by the high temperatures of the Sun that reaches Earth. Solar radiation is also known as shortwave radiation.

3. 'Greenhouse gases' are those gases of the atmosphere (especially water vapour and carbon dioxide) that absorb and emit longwave radiation.

4. Although the amount of emission at high latitudes is lower than in the tropics.

5. Within the deep convection clouds the warm moist air from near the surface is lifted buoyantly into the high atmosphere. As the air rises, it cools and the heat and latent energy are transformed to potential energy. As the air in the high atmosphere is taken poleward in the winds it subsides and the potential energy is transformed to heat. It is this heat that is available to offset the radiation energy loss of the atmosphere.

About the Global Warming Policy Foundation

People are naturally concerned about the environment, and want to see policies that protect it, while enhancing human wellbeing; policies that don't hurt, but help.

The Global Warming Policy Foundation (GWPF) is committed to the search for practical policies. Our aim is to raise standards in learning and understanding through rigorous research and analysis, to help inform a balanced debate amongst the interested public and decision-makers. We aim to create an educational platform on which common ground can be established, helping to overcome polarisation and partisanship. We aim to promote a culture of debate, respect, and a hunger for knowledge.

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