

Beyond Climate Tipping Points: Greenhouse Gas Levels Exceed the Stability Limit of the Greenland and Antarctic Ice Sheets

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Theme: [Environment](#)

In-depth Report: [Climate Change](#)

The pace of global warming has been grossly underestimated. As the world keeps increasing its carbon emissions rising in 2018 to a record [33.1 billion ton](#) CO₂ per year, the atmospheric greenhouse gas level has now exceeded 560 ppm (parts per million) CO₂-equivalent, namely when methane and nitric oxide are included. This level surpasses the stability threshold of the Greenland and Antarctic ice sheets. The term “climate change” is thus no longer appropriate, since what is happening in the atmosphere-ocean system, accelerating over the last 70 years or so, is an abrupt calamity on a geological dimension threatening nature and civilization. Ignoring what the science says, the powers-that-be are presiding over the sixth mass extinction of species, including humanity.

As conveyed by leading scientists “Climate change is now reaching the end-game, where very soon humanity must choose between taking unprecedented action or accepting that it has been left too late and bear the consequences” ([Prof. Hans Joachim Schellnhuber](#))...

“We’ve reached a point where we have a crisis, an emergency, but people don’t know that ... There’s a big gap between what’s understood about global warming by the scientific community and what is known by the public and policymakers” [Prof. James Hansen](#).

Rising greenhouse gases and temperatures

By May 2019 the level of CO₂ (measured at Mouna Loa, Hawaii) has reached [414.66](#) ppm, growing at a rate of [3.42](#) ppm/year, well above the highest growth rate recorded for the [last 56 million years](#). The total of CO₂, methane (CH₄) and Nitric oxide (N₂O), expressed as CO₂-equivalents, has reached [at least](#) 563 ppm (Table 1) (depending on the greenhouse forcing value of methane), the highest concentration since 34 - 23 million years ago, when atmospheric CO₂ ranged between [300-530 ppm](#).

Table 1. Total atmospheric CO₂e from CO₂, CH₄ and N₂O

CO ₂	CO ₂ rate	CH ₄	CH ₄ rate	N ₂ O
414.66 ppm	3.42 ppm/year	1865.4 ppb	9.2 ppb/year	332ppb
<u>CO₂ ppm</u>	CO ₂ ppm rise/year	<u>CH₄ ppm</u> CH ₄ forcing <u>≥25CO₂e</u>	CH ₄ ppb rise/year	<u>N₂O ppm</u> N ₂ O forcing = 298CO ₂ e
CO ₂ ppm 414.7		CH ₄ ppm forcing 1.865x <u>≥25</u> ¹ ≥46.6 CO ₂ e (equivalent)		N ₂ O ppm forcing 0.332x298 = 99 ppm CO₂e

Total CO₂e: 414.7+46.6+99 = >560.3 ppm CO₂e

Plus: SF₆, CHF₃, CH₂F₂, CF₄, C₂F₆, C₃F₈, C₄F₁₀, C₄F₈, C₅F₁₂, C₆F₁₄

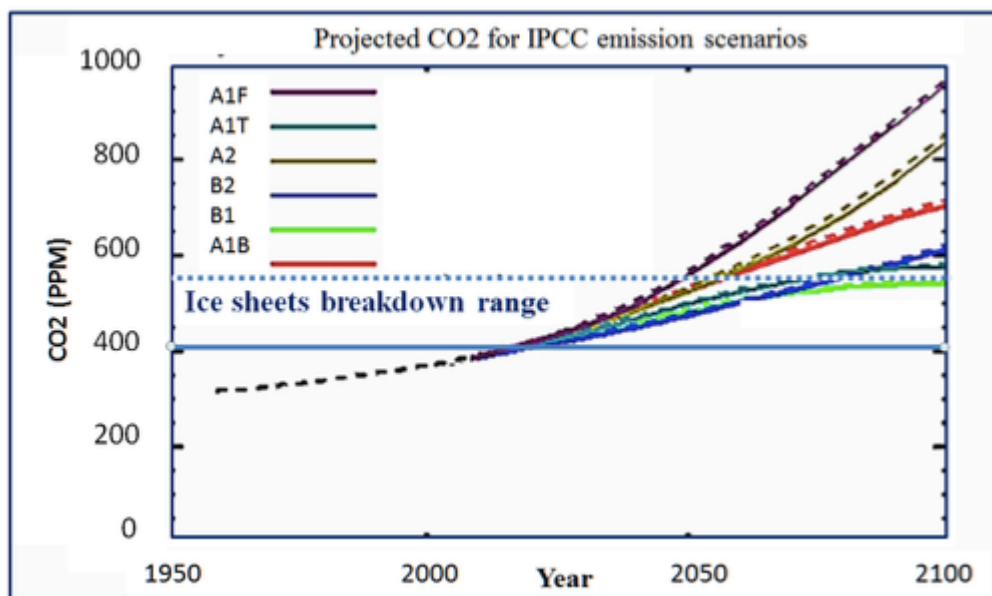


Figure 1. Projected CO₂ levels for [IPCC emission scenarios](#)

The current rise of the total greenhouse gas level to at least 560 ppm CO₂-equivalent, twice the pre-industrial level or 280 ppm, implies global warming has potentially reached +2°C to +3°C above pre-industrial temperature. Considering the mitigating albedo/reflection effects of atmospheric [aerosols](#), including [sulphur dioxide](#), dust, nitrate and organic carbon, [the mean rise of land temperature exceeds +1.5°C \(Berkeley Earth Institute\)](#).

The threshold of collapse of the Greenland ice sheet is estimated in the range of [400-560 ppm](#) CO₂ at approximately 2.0-2.5 degrees Celsius above pre-industrial temperatures, and is retarded by [hysteresis](#) (where a physical property lags behind changes in the effect causing it). The threshold for the breakdown of the West Antarctic ice sheet is similar. The greenhouse gas level and temperature conditions under which the East Antarctic ice sheet formed about 34 million years ago are estimated as [~800-2000 ppm](#) at 4 to 6 degrees

Celsius above pre-industrial values. Based mainly on satellite gravity data there is evidence the East Antarctic ice sheet is beginning to melt in places (Jones, 2019), with ice loss rates of approximately 40 Gt/y (Gigaton of ice per year) in 1979–1990 and up to 252 Gt/y in 2009–2017 (Rignot et al., 2019).

The cumulative contribution to sea-level rise from Antarctic ice melt was 14.0 ± 2.0 mm since 1979. This includes 6.9 ± 0.6 mm from West Antarctica, 4.4 ± 0.9 mm from East Antarctica, and 2.5 ± 0.4 mm from the Antarctic Peninsula (Rignot et al., 2019). Based on the above, the current CO₂-equivalent level of at least 560ppm closely correlates with the temperature peak at ~16 million years ago (Figures 2 and 5), when the Greenland ice sheet did not exist and large variations affected the Antarctic ice sheet (Gasson et al., 2016).

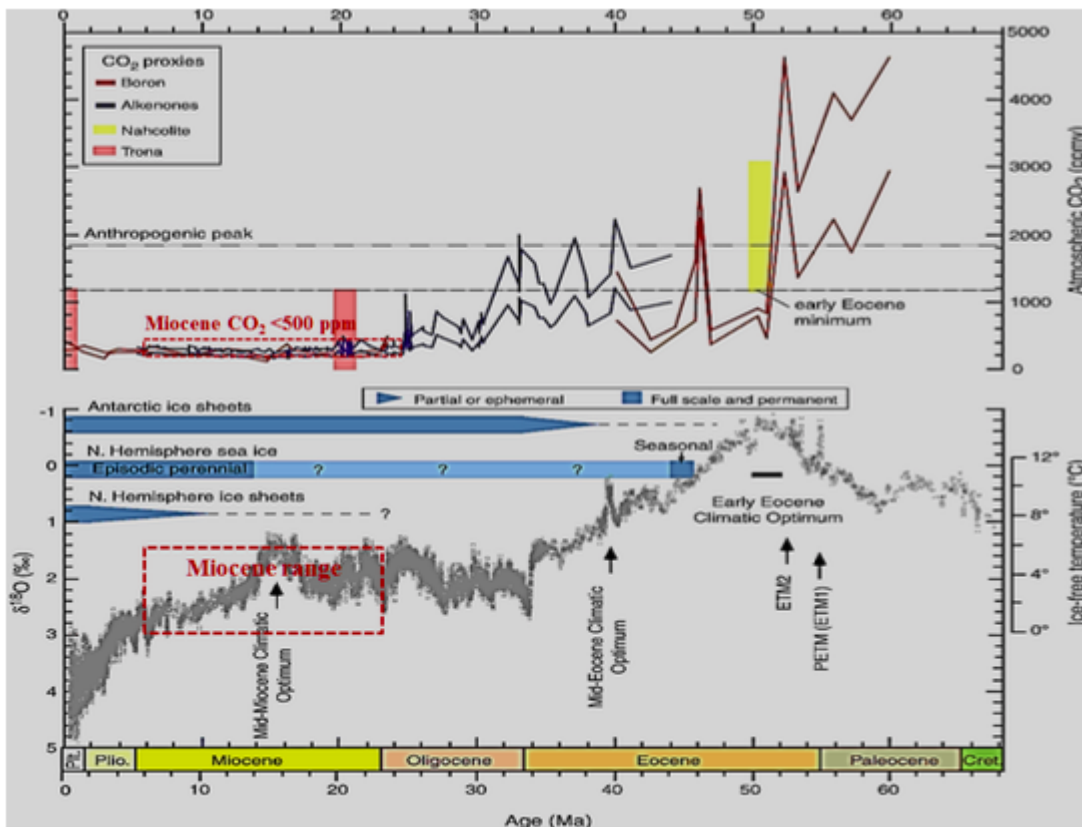


Figure 2. Updated Cenozoic pCO₂ and stacked deep-sea benthic foraminifer oxygen isotope curve for 0 to 65 Ma (Zachos et al., 2008) converted to the Gradstein timescale (Gradstein et al., 2004). ETM2 = Eocene Thermal Maximum 2, PETM = Paleocene/Eocene Thermal Maximum.

Transient melt events

As the glacial sheets disintegrate, cold ice-melt water flowing into the ocean ensue in large cold water [pools](#), a pattern recorded through the glacial-interglacial cycles of the [last 450,000 years](#), manifested by the growth of cold regions in north Atlantic Ocean [south of Greenland](#) and in the Southern Ocean fringing Antarctica (Figures 3 and 4). The warming of the Arctic is driven by the ice-water [albedo flip](#) (where dark sea-water absorbing solar energy alternate with high-albedo ice and snow) and by the weakening of the [polar boundary and jet stream](#). Penetration of Arctic-derived cold air masses through the weakened boundary results in extreme weather events in North America, Europe and northern Asia, such as the recent "[Beast from the East](#)" event.

Warming of +3°C to +4°C above pre-industrial levels, leading to enhanced ice-sheet melt, would raise sea levels by at least [2 to 5 meters](#) toward the end of the century, and likely by 25 meters in the longer term. [Golledge et al. \(2019\)](#) show meltwater from Greenland will lead to substantial slowing of the Atlantic overturning circulation, while meltwater from Antarctica will trap warm water below the sea surface, increasing Antarctic ice loss. The effects of ice sheet-melt waters on the oceans were hardly included in IPCC models. Depending on [amplifying feedbacks](#), prolonged Greenland and Antarctic melting (Figures 3 and 4) and a consequent freeze event may ensue, lasting perhaps as long as two to three centuries.

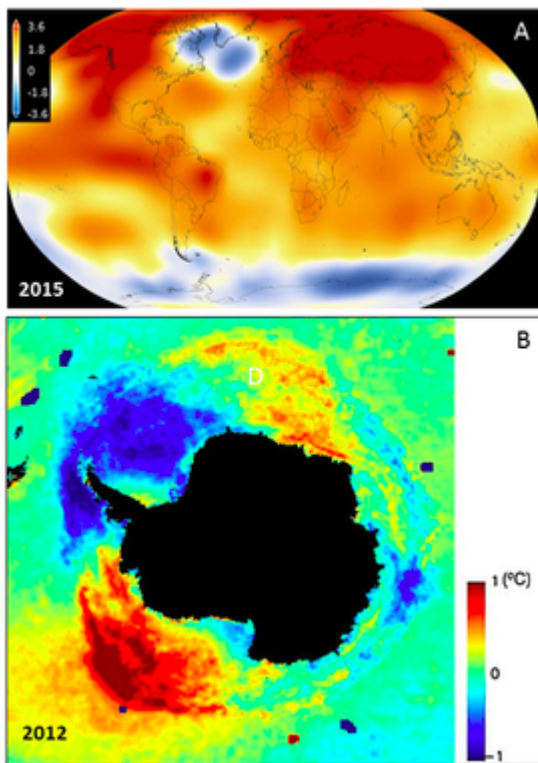


Figure 3.(A) Global warming map ([NASA 2018](#)). Note the cool ocean regions south of Greenland and along the Antarctic. Credits: Scientific Visualization Studio/Goddard Space Flight Center; (B) 2012 Ocean temperatures around Antarctica, ([NASA 2012](#)).

21st-23rd centuries' uncharted climate territory

Modelling of climate trends for 2100-2300 by the IPCC [AR5 Synthesis Report, 2014](#) portrays predominantly linear models of greenhouse gas rise, global temperatures and sea levels. These models however appear to take little account of [amplifying feedbacks](#) from land and ocean and of the effects of cold ice-melt on the oceans. According to Steffen et al. (2018) *“self-reinforcing feedbacks could push the Earth System toward a planetary threshold”* and *“would lead to a much higher global average temperature than any interglacial in the past 1.2 million years and to sea levels significantly higher than at any time in the Holocene”*.

Amplifying feedbacks of global warming include:

- A. The [albedo-flip](#) of melting sea ice and ice sheets and the increase of the water surface area and thereby sequestration of CO₂. [Hudson \(2011\)](#) estimates a rise in radiative forcing due to removal of Arctic summer sea ice as 0.7

Watt/m², a value close to the total of methane release since 1750.

B. Reduced [ocean CO₂ intake](#) due to lesser solubility of the gas with higher temperatures.

C. Vegetation desiccation and loss in some regions, and thereby reduced evaporation with its cooling effect. This factor and the increase of precipitation in other regions lead to differential feedbacks from vegetation as the globe warms ([Notaro et al. 2007](#)).

D. An increase in [wildfires](#), releasing greenhouse gases.

E. Release of [methane](#) from permafrost, bogs and sediments and other factors.

Linear temperature models do not appear to take into account the effects on the [oceans](#) of ice melt water derived from the large ice sheets, including the possibility of a major [stadial event](#) such as already started in oceanic tracts fringing Greenland and Antarctica (Figure 3). In the shorter term sea level rises include the Greenland ice sheet (6-7 meter sea level rise) and West Antarctic ice sheet melt (4.8 meter sea level rise). Referring to major past stadial events, including the [8200 years-old Laurentian melt](#) event and the [12.7-11.9 younger dryas](#) event, a prolonged breakdown of parts of the Antarctic ice sheet could result in major sea level rise and extensive cooling of northern and southern latitudes, parallel with warming of tropical and mid-latitudes (Figure 4) ([Hansen et al.. 2016](#)). The clashes between polar-derived cold weather fronts and tropical air masses are bound to lead to extreme weather events, echoed in *Storms my grandchildren* ([Hansen, 2010](#)).

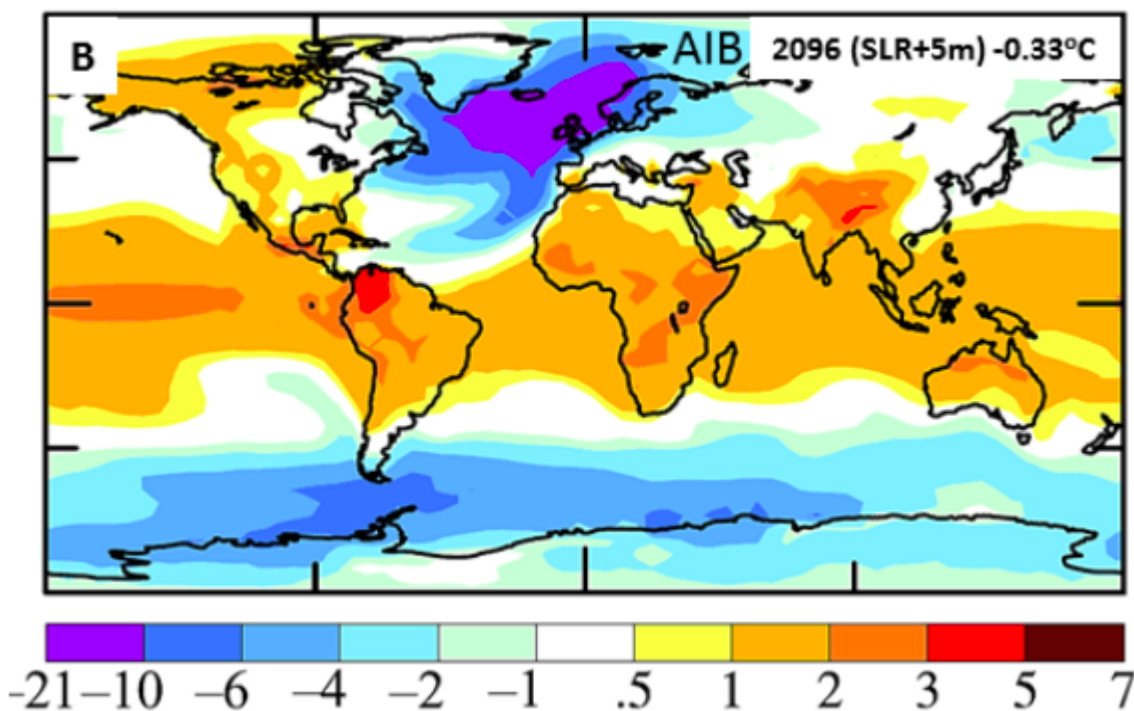


Figure 4. Model Surface-air temperature (°C) for 2096 relative to 1880-1920. [Hansen et al 2016](#). The projection betrays major cooling of the North Atlantic Ocean, cooling of the circum-Antarctic Ocean and further warming in the tropics, subtropics and the interior of continents, including Siberia and Canada.

Summary and conclusions

- A. Global greenhouse gases have reached a level exceeding the stability threshold of the Greenland and Antarctic ice sheets, melting at an [accelerated rate](#).
- B. The current growth rate of atmospheric greenhouse gas of 3.42 ppm CO₂/year is the fastest recorded for the last [55 million years](#).
- C. Allowing for the transient albedo enhancing effects of sulphur dioxide and other aerosols, mean global temperature has reached about 2 degrees Celsius above per-industrial temperatures.
- D. Due to [hysteresis](#) the large ice sheets outlast their melting temperatures.
- E. Cold ice melt water flowing from the ice sheets at an [accelerated rate](#) will reduce the temperature of large ocean tracts in the North Atlantic and circum-Antarctic. Strong temperature [contrasts](#) between cold polar-derived air and water masses and tropical air and water masses, ensuing in extreme weather events, would result in extreme weather events, retarding agriculture in large parts of the world.
- F. Humans will survive in relatively favorable parts of Earth, such as sub-polar regions and sheltered mountain valleys, where hunting of surviving fauna may be possible,
- G. In the wake of partial melting of the large ice sheets, the Earth climate would shift to polarized conditions including reduced polar ice sheets and tropical to super-tropical regions such as existed in the Miocene ([5.3 - 23 million years ago](#)) (Figure 5).

Current greenhouse gas forcing and global mean temperature are approaching Miocene Optimum-like composition, bar the hysteresis effects of reduced ice sheets (Figure 5). Strong temperature polarities are suggested by the contrasts between reduced Antarctic ice sheet and super-tropical conditions in low to mid-latitudes. Land areas would be markedly reduced due to a sea level rise of approximately [40 ± 15 meters](#)

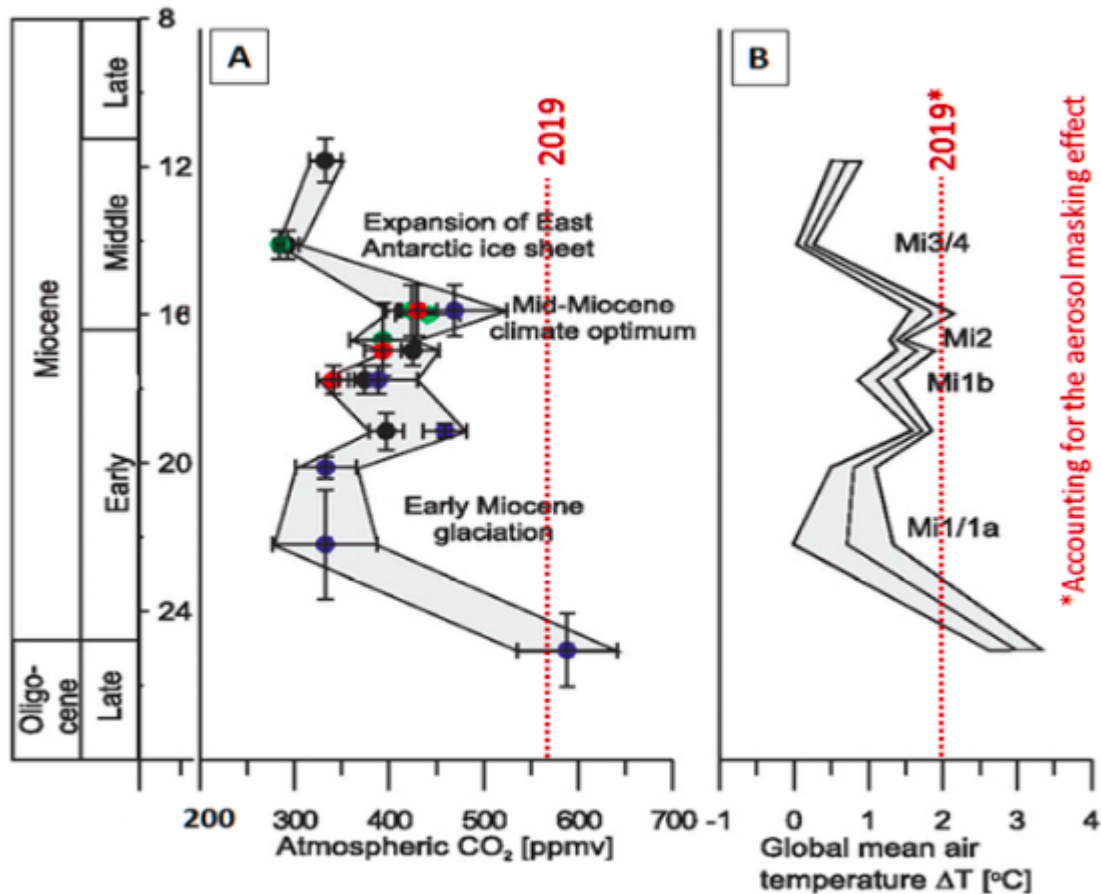


Figure 5. Late Oligocene–Miocene inferred atmospheric CO₂ fluctuations and effects on global temperature based on Stomata index (SI) of [25 and 12 Ma](#) (late Oligocene to late middle Miocene) fossil leaf remains; (A) Reconstructed late [Oligocene–middle Miocene CO₂ levels](#) based on individual independently calibrated tree species; (B) Modeled temperature departure of global mean surface temperature from present day, calculated from mean CO₂ estimates by using a CO₂–temperature sensitivity study. Red discontinuous lines: 2019 CO₂-e levels and 2019 temperatures (discounting the aerosol masking effects).

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Note

[1] A methane forcing value of 25 XCO₂ is a conservative long-term value. Shorter term forcing values are [significantly higher](#)

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