Climate Dots That Don't Join Up

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The Intergovernmental Panel on Climate Change (IPCC) claims that since the beginning of the industrial revolution, mankind has emitted billions of tons of carbon dioxide into the earth's atmosphere, causing earth's temperature to rise by just over 1°C.
I will consider three components of this from a different perspective:

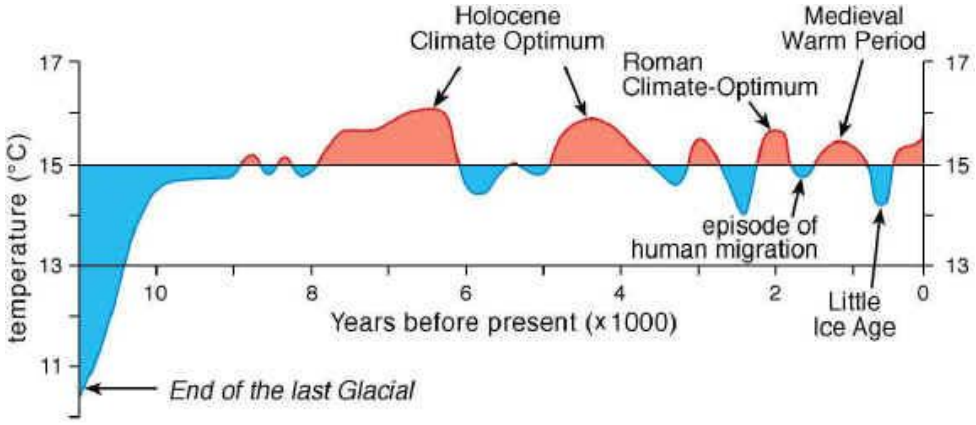
1) How does Earth's climate during the 17th century compare to now?
2) Is the current rising atmospheric CO_2 level caused by human emissions?
3) Is CO_2 in fact the main greenhouse gas?

I will demonstrate that there are several scientific flaws in the IPCC's claims, and then I will consider the link between atmospheric CO_2 and methane, and will show how this link undermines the IPCC's cause and effect theory.

1) How does Earth's climate during the 17th century compare to now?
The Industrial Revolution began at the end of a 400 year cold period known as The Little Ice Age. This culminated in a particularly cold period known as the Maunder Minimum at the end of the 1600s [1]. It was cold:

The Thames River was frozen over for 2 months every year – there were winter markets held on the river [2].
There was a worldwide glacial expansion known as the Grindelwald Fluctuation [3].
The Swedish army marched across the sea ice to invade Copenhagen [4].
There were widespread famines, and many populations were significantly reduced as crop production plummeted. People starved to death.
And so on…. It was cold, and miserable.

This was our pre-industrial age climate. The IPCC consider this the starting point from which human activity has warmed the climate and are attributing virtually all warming from this low point to human activity [5] .
This was the coldest period in the last 10,000 years – the current Holocene period. In the middle of the Holocene was a period that was considerably warmer than present temperature levels, and we are currently well within the temperature range of this Holocene period [6] From the climate described above to what we have now is the result of a 1.2°C temperature increase. Coming out of an ice age, one would expect glaciers to recede – this should be neither surprising, nor alarming.



Average near-surface temperatures of the northern hemispere during the past 11.000 years (after Dansgaard et al., 1969, and Schönwiese, 1995)

Figure 1

Solar irradiance increases when a sunspot is present. During the Mauder Minimum there was a period of about 75 years when there were virtually no sunspots, and this was followed by the Dalton Minimum in the early 19th century which was another period of low sunspot activity. It is clear from Figure 2 that there has been an overall increase in sunspot activity and therefore solar irradiance from the sun, since the Mauder Minimum – more irradiance equals more heat, resulting in a warming climate.

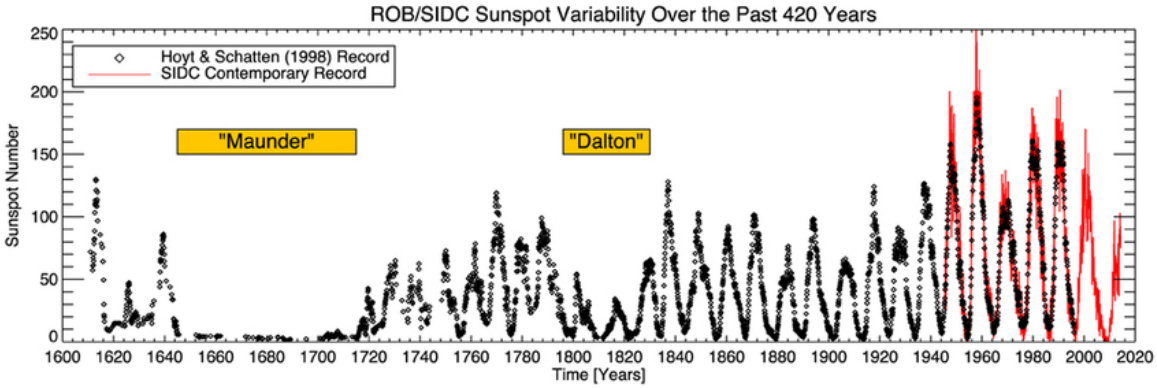


Fig 2

NASA has records showing the suns irradiance has been increasing for the last 120 years, and reconstructions show an increase of 1.25W/m^2 since the Mauder Minimum in the early 1700s [7].

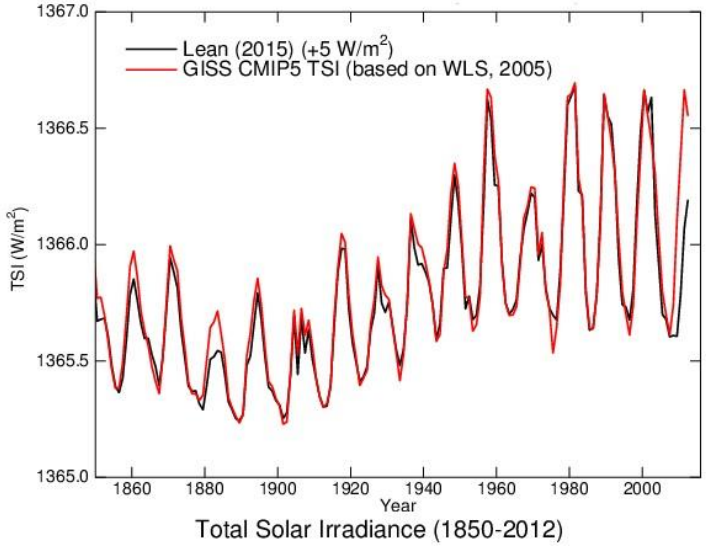


Figure 3.

This equates to an increase of 150 trillion Watts globally – this is a huge amount of energy – it has caused the climate to warm.

2) Is the current rising atmospheric CO_2 level caused by human emissions?

We were in a mini ice age a few hundred years ago. When an ice age finishes, temperatures rise, (obviously, otherwise it hasn't finished) and the temperature of the oceans rise as well, slowly – this is what is happening now [8] . The amount of CO_2 in the atmosphere, and the CO_2 dissolved in the oceans, are in balance, and this balance is regulated by a gas physics law – Daltons Law of Partial Pressures [9]. This law dictates that the partial pressures of the two bodies **must** be in equilibrium – they naturally equalize [9a].
There is another gas physics law – Henry's Law [10] – that determines that as the temperature of the oceans rise, the partial pressure of the dissolved gases in them rises. This causes the oceans to expel more CO_2 into the atmosphere, resulting in the two bodies finding a new balance, or equilibrium. The everyday example of this is that if you leave an open soft drink in the fridge, it is still ok the next day, but if you leave it in the sun, it goes flat very quickly.

It takes hundreds, even thousands, of years for the ocean temperatures, and dissolved gases, to re-balance to a change in surface temperature [11]. This is what we are experiencing now. It would be defying basic physics laws if the atmospheric CO_2 levels were not increasing. There are many feedbacks that cause small changes in temperature to magnify into larger changes, and we do not understand how these all balance and interact with each other. One example of a feedback is rising temperatures raise atmospheric water vapour levels (humidity), which traps more infra-red heat.

Sixty years ago the atmosphere contained 300ppm (parts per million) of CO_2, which represented, and resulted from, an average partial pressure of 300µatm (micro bars) of CO_2 dissolved in the oceans. As a result of warming, the average ocean partial pressure has now increased to 420µatm. This has resulted in the oceans degassing CO_2 to the point at which the atmosphere is now in balance with it with 420ppm.

Human emissions will be contributing a minor portion of the rising CO_2 in our atmosphere, but they are not the primary cause of this. Rising ocean temperatures cause rising partial pressures of dissolved gases. This effect, combined with magnifying feedbacks, has resulted in the oceans de-gassing 200Gt (Giga tons) of CO_2 into the atmosphere, causing the rise of atmospheric CO_2 levels. They have risen together, and are in balance. There are 40,000Gt of carbon in the oceans – 50 times the amount stored in the atmosphere. Releasing 200Gt into the atmosphere is only 0.5% of this 'reserve' – a little burp as a result of a 1.2°C rise in temperature.

The IPCC claim the current atmospheric CO_2 levels are 'unprecedented' during the past 2M years [12]. They cannot possibly know this. Accurate atmospheric CO_2 levels were started in 1958. To directly compare these to ice core samples is very poor science, and anyone that does this does not understand the processes that air, trapped in snow, go through to become an ice core sample - they are just a low resolution proxy. We will have to wait at least a thousand years to get an ice core sample that represents our current period, and that sample will be contained in ice that is 3 - 5,000 years old [13]. The bubbles in glacial ice are being considered in the same way as a sample captured in a container and left on a shelf for 100,000 years. This is highly unlikely. When snow forms, water vapour transitions to ice without going through the liquid phase, so when it melts it has no dissolved gases in it, consequently the partial pressure difference between the air bubble, and any moisture in the firn, is huge. The IPCC assumes that none of the CO_2 has been removed during the process of compaction, through the firn phase, to glacial ice, while being exposed to raised pressures, sublimation and deposition [14]. They also choose to ignore the fact that these records are highly smoothed, eliminating peaks and troughs, as any sample will actually represent an average of about 1,000 years, i.e. a mix of the medieval warm period, the mini ice age, and the current warm period, all combined [15]. Ice core CO_2 measurements are just a highly smoothed proxy for atmospheric CO_2, and atmospheric CO_2 is just a proxy for temperature.

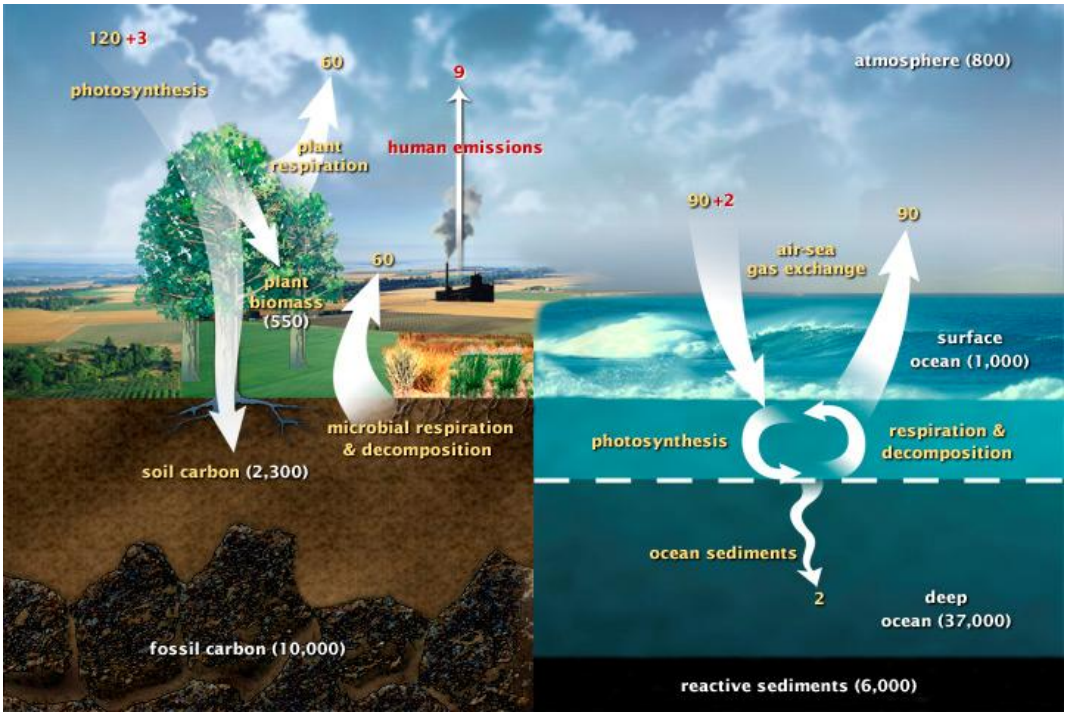


Figure 4. Carbon Cycle Diagram from NASA [16]

Mankind is adding about 9Gt of carbon to the atmosphere every year. The IPCC claim that about 50% of this is accumulating in the atmosphere, but as can be seen in the above carbon cycle, there are 90Gt of carbon being emitted from the ocean every year, plus another 120Gt added from the biosphere. This equals 210Gt of carbon being emitted into the atmosphere, naturally, every year, by these two cycling systems, within the carbon cycle. These systems effectively cycle human emissions directly into the ocean, where there are already 40,000Gt – of which mankind's contribution is tiny. It is a self-balancing, self-regulating system. The volume of CO_2 that is present in the atmosphere is determined by the partial pressure of the ocean - Dalton's Law regulates this. Every year about 90Gt of carbon are being emitted from the warm tropical waters, and a balancing volume is being sucked back into the cold polar waters, by a system known as the 'solubility pump'. The atmosphere is effectively acting as a conduit connecting, and distributing, carbon between the various sources and sinks.

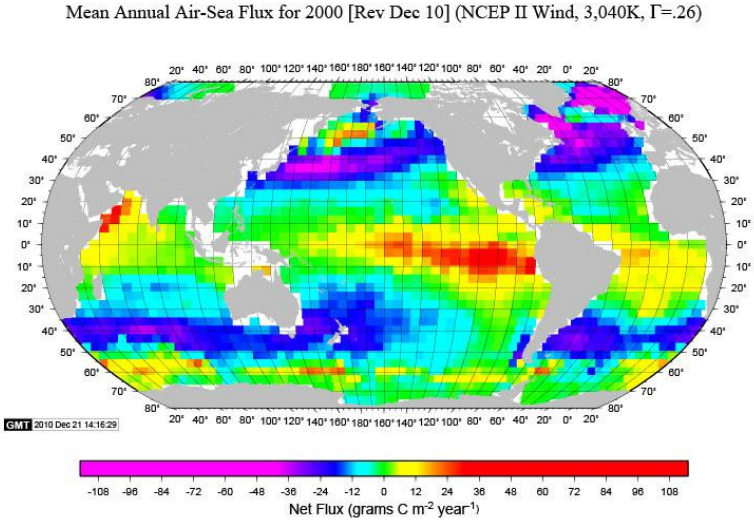


Figure 5. Taro Takahashi et al: [17]

Sixty years ago there were 90Gt of CO_2 going into the ocean, and 90Gt coming out of the ocean, when the atmosphere contained 300ppm. There are now 420ppm, and we still have 90Gt in and 90Gt out. If 90Gt can still be emitted every year, it proves this cycle is clearly in balance, and mankind's emissions are not accumulating in the atmosphere. If the carbon cycle diagrams are correct CO_2 cannot be accumulating in the atmosphere as this would contravene Dalton's and Henry's Laws of physics.

The Vostok ice core records below (left side), show that changes in temperature precede changes in CO_2 levels. This is stated in the scientific reports [18]. When temperatures rise, atmospheric CO_2 levels rise. When temperatures fall, CO_2 levels follow. Temperature change is the cause, CO_2 change is the effect, Henry's Law is the driver [19].
Anyone citing ice core samples should be looking at the bigger story they tell. Our current inter-glacial warm period is colder than the previous four, and we are far more likely to enter a proper ice age than spiral into uncontrolled warming.

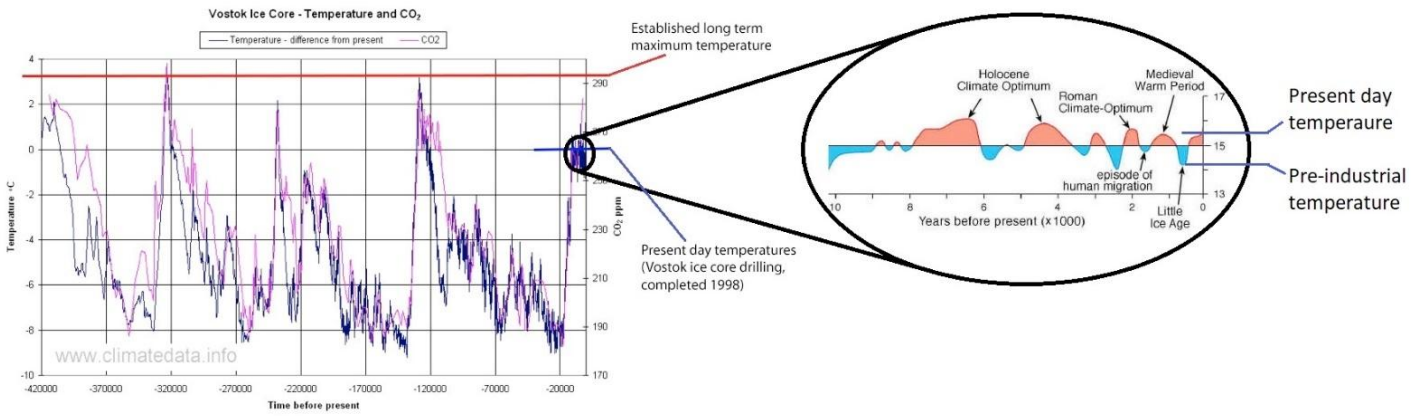


Figure 6.

Figure 6 above combines the ice core records from Vostok Antarctica with Figure 1 above, and shows our current Holocene has been an un-characteristically stable period when compared to the last 430,000 years. There is no reason to think it will last forever. We are currently only 75% up from the bottom to the top of the normal glacial/inter-glacial temperature range. The variation of climate conditions throughout the full range of this temperature spectrum is daunting to consider in the context of human civilization.

The IPCC is using ice core records to claim CO_2 levels are unprecedented in spite of the fact that the same records show the previous 4 interglacial periods were about 3°C warmer than we are currently experiencing [20].There is nothing unprecedented about higher temperatures, in fact our current interglacial is unprecedently cold - if earth's climate warmed another 3°C that would be perfectly normal, and, in fact, expected. The temperature signal in an ice core sample is so accurate that sometimes summer and winter seasons can be differentiated, but the CO_2 signal is highly smoothed, generally representing a period of a thousand years, or more, thus eliminating all shorter term peaks and troughs [21].

The following is the first line from one of the data sheets from Vostok:

Depth m	Ice Age years	Gas age years	CO2 ppmv value	minimum value	maximum value
124.6	4050	1700	274.5	279.5	269.5

If the IPCC's claim, that CO_2 levels determine temperature, is correct, and they claim that ice core CO_2 samples accurately represent atmospheric CO_2 levels, and they also claim that our current temperatures are the result of our current atmospheric CO_2 level of 420ppm, how do they explain the temperature during the previous interglacial, which was 3°C warmer than present, being derived from 280ppm of CO_2 [22]?

3) Is CO_2 in fact the main greenhouse gas?

Stop and ask the average person on the street "what is the main greenhouse gas?" and virtually everyone will say "carbon dioxide". Some will even say "methane". You suggest water vapour and they look blank. The general population is largely unaware of the fact that water vapour is a greenhouse gas – and, in fact, the main greenhouse gas. The importance of CO_2 as a greenhouse gas is being overstated to the public at large, while water vapour is completely ignored by the IPCC, as if it is irrelevant [22a].
The NASA website names water vapour as the most abundant greenhouse gas [23], yet the IPCC claims that water vapour is not a primary greenhouse gas, but instead only a secondary amplifying factor.
According to the Clausius-Clapeyron equation, the vapor pressure of water vapour increases by 7% for every 1°C increase in temperature [23a]. This is a powerful amplifying feedback.

We need to consider the infra-red absorption spectrum for the individual gases to help understand this….

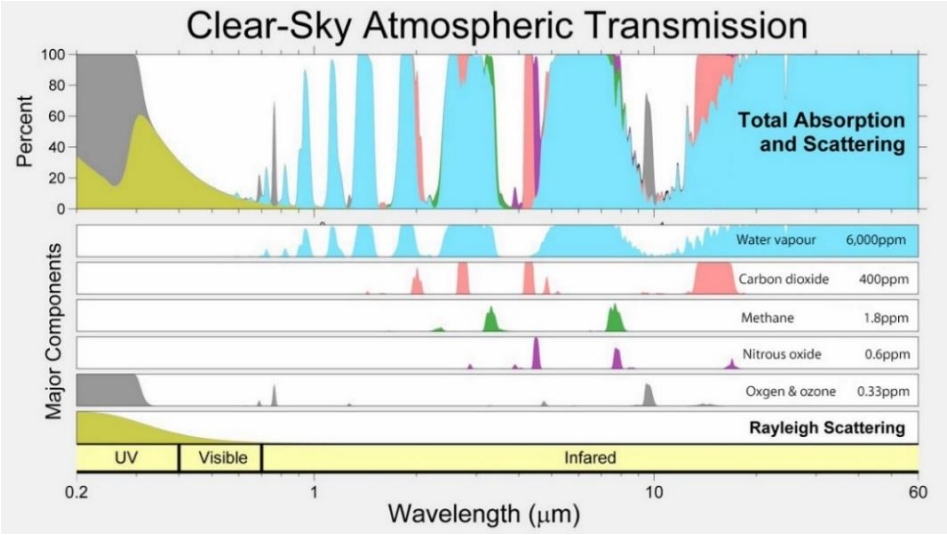


Figure 7.

Take particular attention to the amounts of each gas in ppm. It is clear that water vapour absorbs a far wider band of infra-red than any of the other gases, **and** there is 15 times as much water vapour as there is CO_2. Even if the volumes were equal, water vapour would totally dominate [24].

If there were no greenhouse gases Earth's average temperature (currently +15°C) would be about 33°C colder than it currently is (ie: -18°C) – this is the greenhouse gas effect [25]. Atmospheric CO_2 levels have increased from 300 to 420ppm since 1960 – about 40%, but temperatures have only increased by 0.5°C – about 1.5%. If CO_2 was as dominant as the IPCC claim, we should have seen a significantly larger temperature increase [26]. If there was no CO_2 earth's climate would be a bit cooler, but if there was no water vapor it would be an un-inhabitable frozen waste land [27]. Our concern is temperature, not CO_2. Atmospheric CO_2 is simply a proxy for temperature, and ice core CO_2 levels are a highly smoothed proxy for atmospheric CO_2 levels.

There is considerable debate about whether the wave bands for infra-red absorption of CO_2 are saturated, meaning that further increases of atmospheric CO_2 would not have any significant warming effect. The main warming effect from CO_2 comes from the 13 – 17 micrometre wavelength band and it can be seen, in Figure 7 above, that this is already fully saturated. Any further additions of CO_2 will produce only extremely limited warming, being derived from harmonics from this band, causing it to widen slightly.

One of the ways the IPCC is attempting to raise the relative importance of CO_2 is claiming that it stays in the atmosphere for a long time. It is now generally described as a long lived greenhouse gas that stays in the atmosphere for hundreds, even thousands of years [28]. There is nothing to support this claim. Basic analysis of any carbon cycle diagram shows there are 800Gt of carbon in the atmosphere. Every year 120Gt is sucked out of the atmosphere by the bio-sphere – mostly plants in the spring and summer – this is 15% of the total atmospheric carbon and creates a saw-tooth in the annual CO_2 graph. There are another 90Gt absorbed into the cold polar oceans every year – which is another 11% [29]. That's 26% of the total atmospheric volume being taken out of the atmosphere every year. This clearly means the average life expectancy for any CO_2 molecule in the atmosphere is about three years and eleven months.

CO_2 is food for plants and NASA has identified a significant global increase in greening, resulting from the raised atmospheric CO_2 [30]. This is a significant natural sink which is absorbing a huge amount of CO_2.
If humans attempt to sequester CO_2 from the atmosphere, they will have to remove 2 billion tons to make just 1ppm difference. This is an incredible amount of carbon for no discernible gain, and the effort/investment will be in vain, because this removal would create a partial pressure difference that will immediately be compensated for within the ocean/atmosphere CO_2 cycle as Dalton's Law rebalances the two bodies pressures – ie: there will be an extra 2 billion tons of carbon emitted from the oceans to replace the removed carbon, and thereby rebalance the partial pressure of the atmosphere with the ocean.

Methane

As can be seen in Figure 7 above, methane (CH_4) has a very minor role as a greenhouse gas in our atmosphere. It is very effective at trapping radiation in a couple of narrow bands, but these are largely already covered by water vapor. However, CH_4 gets a lot of press, so it needs to be addressed.
All CH_4 cycle diagrams show CH_4 being produced by livestock emissions, the energy sector, landfill and wastewater treatment, and thawing permafrost in the Arctic, plus other sources and sinks. There is something missing though – CH_4 is being cycled in the ocean by a solubility pump, in exactly the same way that CO_2 is cycled – but there is no reference to this. CH_4 is water soluble, just as CO_2 is, and this means that it has a partial pressure in the oceans, and Dalton's Law of Partial Pressures determines that the ocean and atmosphere are in balance. Henry's Law means that the partial pressure is lower in the cold polar waters, where it is being absorbed, and higher in the warm tropical waters, where it is being expelled. In the same way that atmospheric CO_2 is determined and regulated by the ocean's partial pressure, so too is atmospheric CH_4. CH_4 cannot accumulate in the atmosphere – a rise in atmospheric CH_4 is caused by an increase in the average partial pressure of CH_4 in the oceans.

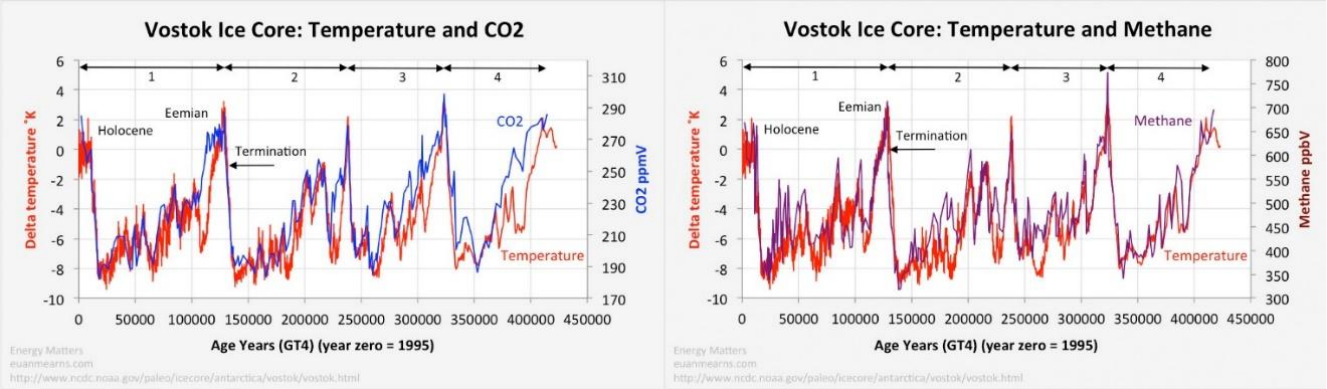


Figure 8. Compare temperature to CO_2 and CH_4. Note timelines - present time is at left hand side, not right.

Ice core records show that temperature, CO_2, and CH_4 fluctuate in phase [31]. The scientific report states that CH_4 follows temperature more closely than CO_2, which tends to lag, particularly at the termination of interglacials [32]. It is clear that the common denominator is temperature, and as stated earlier, changes in temperature precede changes in gases [18].

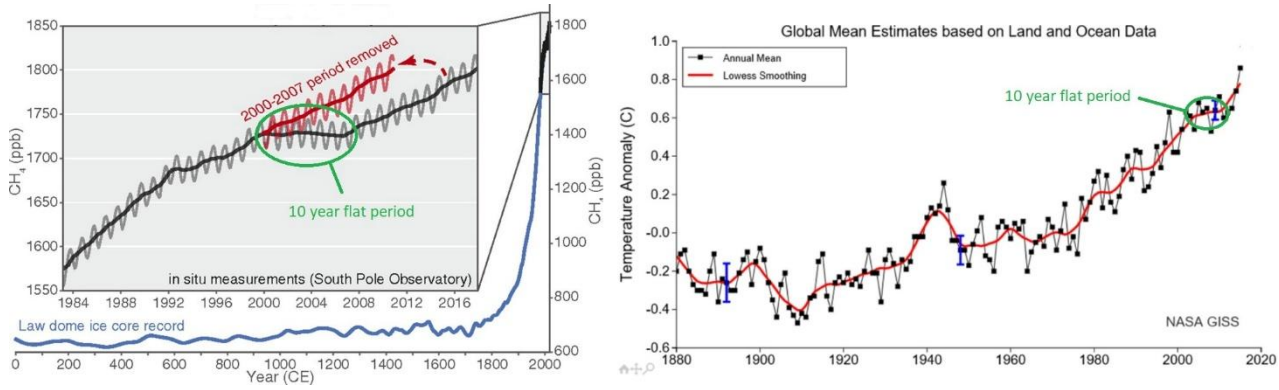


Figure 9.

In fact, CH_4 even followed the little pause when temperatures levelled between 1998 and 2008. During the 40 year period from 1980 to 2020, CO_2 increased 20% and CH_4 18.7%. If CH_4 hadn't been sensitive enough to follow the little temperature kink they would have both been 20%. This would be an incredible coincidence if they were not both driven by rising ocean partial pressures.

Orbital forcing, from the Milanovich Cycle of Eccentricity, drives our glacial/interglacial phases [33], and Henry's Law drives atmospheric gases into, and out of, the oceans as a response to the changes in temperature, and these changes are in turn amplified by feedbacks.

Conclusion

Central to the Intergovernmental Panel on Climate Change (IPCC) position is the claim that about 50% of anthropogenic CO_2 is being taken up by the oceans and biosphere, and that the balance is accumulating in the atmosphere [34]. Physics gas laws determine that an imbalance in the partial pressures of CO_2 between the atmosphere and the ocean will be equalised naturally, and immediately. The partial pressure of dissolved gases in the ocean determines the concentration of these gasses in the atmosphere. This means that human CO_2 emissions do not accumulate in the atmosphere – they cannot, and if anthropogenic CO_2 is not accumulating in the atmosphere, it cannot be driving climate change.

Considering the very real costs that are flowing through to, and distorting, industries such as farming, forestry, transport, and the energy sector, any government that implements policies based on IPCC reports should be able to show these industries that there is sound physical science to support that government's position before they impose costs – it is their responsibility to do so. There are several claims made by the IPCC that can be challenged scientifically, and entities within affected industries could call the government to identify policies that have been based on IPCC reports, and then mount a science based challenge against these policies.

References

[1 Miyahara, H., Tokanai, F., Moriya, T. *et al.* Gradual onset of the Maunder Minimum revealed by high-precision carbon-14 analyses. *Sci Rep* **11,** 5482 (2021). Introduction. Figure 3.
https://doi.org/10.1038/s41598-021-84830-5

] Rafferty, John P. and Jackson, Stephen T.. "Little Ice Age". *Encyclopedia Britannica*, 18 Mar. 2016, https://www.britannica.com/science/Little-Ice-Age Accessed 31 October 2021.

[2] Historic UK. https://www.historic-uk.com/HistoryUK/HistoryofEngland/The-Thames-Frost-Fairs/

[3] Evan T. Jones,Rose Hewlett,Anson W. Mackay,
First published: 01 February 2021 https://doi.org/10.1002/wea.3846

[4] en-academic.com https://en-academic.com/dic.nsf/enwiki/5076517

[5] NASA. Climate Change: How Do We Know? Evidence | Facts – Climate Change: Vital Signs of the Planet (nasa.gov)

[6] Greenland GISP2 ice core data.
Alley, R.B.. 2004.
GISP2 Ice Core Temperature and Accumulation Data.
IGBP PAGES/World Data Center for Paleoclimatology
Data Contribution Series #2004-013.
NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.
ORIGINAL REFERENCE: Alley, R.B. 2000.
The Younger Dryas cold interval as viewed from central Greenland.
Quaternary Science Reviews 19:213-226.
ADDITIONAL REFERENCE:
Cuffey, K.M., and G.D. Clow. 1997. Temperature, accumulation, and ice sheet
elevation in central Greenland through the last deglacial transition.
Journal of Geophysical Research 102:26383-26396.
https://www.ncei.noaa.gov/pub/data/paleo/icecore/greenland/summit/gisp2/isotopes/gisp2_temp_accum_alley2000.txt

Climate Data Information, Figure 5, & fig 7.
http://www.climatedata.info/proxies/ice-cores/

Antarctica – Vostok ice core data.
Jouzel, J., C. Lorius, J.R. Petit, C. Genthon, N.I. Barkov,
V.M. Kotlyakov, and V.M. Petrov. 1987. Vostok ice core: a continuous
isotope temperature record over the last climatic cycle (160,000
years). Nature 329:403-8.

Jouzel, J., N.I. Barkov, J.M. Barnola, M. Bender, J. Chappellaz,
C. Genthon, V.M. Kotlyakov, V. Lipenkov, C. Lorius, J.R. Petit,
D. Raynaud, G. Raisbeck, C. Ritz, T. Sowers, M. Stievenard, F. Yiou,
and P. Yiou. 1993. Extending the Vostok ice-core record of
palaeoclimate to the penultimate glacial period. Nature 364:407-12.

Jouzel, J., C. Waelbroeck, B. Malaize, M. Bender, J.R. Petit,
M. Stievenard, N.I. Barkov, J.M. Barnola, T. King, V.M. Kotlyakov,
V. Lipenkov, C. Lorius, D. Raynaud, C. Ritz, and T. Sowers. 1996.
Climatic interpretation of the recently extended Vostok ice records.
Climate Dynamics 12:513-521.

Petit, J.R., J. Jouzel, D. Raynaud, N.I. Barkov, J.-M. Barnola,
I. Basile, M. Bender, J. Chappellaz, M. Davis, G. Delayque,
M. Delmotte, V.M. Kotlyakov, M. Legrand, V.Y. Lipenkov, C. Lorius,
L. Pepin, C. Ritz, E. Saltzman, and M. Stievenard. 1999.
Climate and atmospheric history of the past 420,000 years from the
Vostok ice core, Antarctica. Nature 399: 429-436. January 2000
https://cdiac.ess-dive.lbl.gov/ftp/trends/temp/vostok/vostok.1999.temp.dat;

[7] NASA, Forcings in GISS Climate Model: Solar Irradiance. https://data.giss.nasa.gov/modelforce/solar.irradiance/

Krivova, N. A., L. E. A. Vieira, and S. K. Solanki (2010), Reconstruction of solar spectral irradiance since the Maunder minimum, J. Geophys. Res., 115, A12112, doi:10.1029/2010JA015431. Reconstruction of solar spectral irradiance since the Maunder minimum. Page 1.
https://agupubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1029/2010JA015431

[8] US Environmental Protection Agency. Climate Change Indicators. Why Does It Matter? https://www.epa.gov/climate-indicators/oceans

National Oceanic and Atmospheric Administration: Climate at a Glance | National Centers for Environmental Information (NCEI) (noaa.gov)

[9] Britannica, The Editors of Encyclopaedia. "Dalton's law". Encyclopedia Britannica, 1 Jun. 2017, https://www.britannica.com/science/Daltons-law . Accessed 31 October 2021.

[9a] Ocean Acidification: The Other CO2 problem.
Scott C. Doney,1 Victoria J. Fabry,2 Richard A. Feely,3 and Joan A. Kleypas 4. – Ocean Carbonate System.
Ocean Acidification: The Other CO2 Problem (washington.edu)

[10] Chandan G, Cascella M. Gas Laws and Clinical Application. [Updated 2021 Sep 2]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK546592/

[11] Migdat Hodzic and Ivan Kennedy (January 4th 2021). Kalman Filter Harmonic Bank for Vostok Ice Core Data Analysis and Climate Predictions, Glaciers and the Polar Environment, Masaki Kanao, Danilo Godone and Niccolò Dematteis, IntechOpen, DOI: 10.5772/intechopen.94263. Many references throughout. Available from: https://www.intechopen.com/chapters/73751

[12] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani,
S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3–32, doi:10.1017/9781009157896.001.
Page 8, A.2.1 Summary for Policymakers (ipcc.ch)

[13] Bernhard Stauffer, Jacqueline Flückiger, Eric Wolff and Piers Barnes
Cambridge University Press. The EPICA deep ice cores: first results and perspectives.
Reconnaissance and Top Part of the two Ice Cores – last paragraph.
The EPICA deep ice cores: first results and perspectives | Annals of Glaciology | Cambridge Core

Historical CO2 Record from the Vostok Ice Core
Source: J.M. Barnola
D. Raynaud
C. Lorius
Laboratoire de Glaciologie et de Geophysique de l'Environnement
38402 Saint Martin d'Heres Cedex, France
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Beringa Street 38
St. Petersburg 199226, Russia
January 2003
https://cdiac.ess-dive.lbl.gov/ftp/trends/co2/vostok.icecore.co2

C. Buizert, in Encyclopedia of Quaternary Science (Second Edition), 2013. Ice Core methods, Studies of Firn Air. Introduction.
https://www.sciencedirect.com/topics/earth-and-planetary-sciences/firn

[14] NASA. Graphic: The Relentless Rise of Carbon Dioxide: Graphic: The relentless rise of carbon dioxide – Climate Change: Vital Signs of the Planet (nasa.gov)

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IPCC Fifth Assessment Report, Carbon and Other Biogeochemical Cycles, Page 467, The Human-Caused Perturbation in the Industrial Era.
https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter06_FINAL.pdf

[15] University of Copenhagen. Center for Ice and Climate. The Firn Zone: Transforming Snow to Ice.
https://www.iceandclimate.nbi.ku.dk/research/drill_analysing/cutting_and_analysing_ice_cores/analysing_gasses/firn_zone/

Bethan Davies. AntarcticGlaciers.Org. From Snow, to Firn, to Glacier ice.
http://www.antarcticglaciers.org/glacier-processes/from-snow-to-glacier-ice/

C. Buizert, in Encyclopedia of Quaternary Science (Second Edition), 2013. Antarctic air bubbles and the long-term ice core record of CO2 and other greenhouse gases☆
Dominique Raynaud, ... Jinhwa Shin, in Past Antarctica, 2020
https://www.sciencedirect.com/topics/earth-and-planetary-sciences/firn

[16] NASA. Earth Observatory. The Carbon Cycle. https://earthobservatory.nasa.gov/features/CarbonCycle

[17] **Taro Takahashia**,*, Stewart C. Sutherlanda , Colm Sweeneya , Alain Poissonb , Nicolas Metzlb , Bronte Tilbrookc , Nicolas Batesd , Rik Wanninkhofe , RichardA. Feelyf , Christopher Sabinef , Jon Olafssong , Yukihiro Nojirih aLamont-Doherty Earth Observatory of Columbia University, Palisades, NY 10964, USA bLaboratoire de Biogeochimie et Chimie Marines, Universite Pierre et Marie Curie, Case 134 4 place Jussieu, ! 75252 Paris Cedex 05, France c Antarctic CRC and CSIRO Marine Research, Hobart, Tasmania 7001, Australia dBermuda Biological Station for Research, Ferry Reach GE 01, Bermuda e AOML, National Oceanographic and Atmospheric Administration, 4301 Rickenbacker Causeway, Miami, FL 33149, USA f PMEL, National Oceanographic and Atmospheric Administration, 7600 Sand Point Way, NE, Seattle, WA 98115, USA gUniversity of Iceland and Marine Research Institute, Skulagata 4, 121, Reykjavik, Iceland hGlobal Warming Mechanism Laboratory, National Institute for Environmental Studies, Tsukuba, Ibaraki 305-0053, Japan
Global sea-air CO2 flux based on climatological surface ocean pCO2, and seasonal biological and temperature effects.
https://www.researchgate.net/publication/230891072_Global_sea-air_CO2_flux_based_on_climatological_surface_ocean_pCO2_and_seasonal_biological_and_temperature_effects

[18] Migdat Hodzic and Ivan Kennedy (January 4th 2021). Kalman Filter Harmonic Bank for Vostok Ice Core Data Analysis and Climate Predictions, Glaciers and the Polar Environment, Masaki Kanao, Danilo Godone and Niccolò Dematteis, IntechOpen, DOI: 10.5772/intechopen.94263. Abstract, and several other references throughout. Available from: https://www.intechopen.com/chapters/73751

Climate Data Information. Antarctica. Figure 5: Vostok Ice Cores – Temperature and CO2.
Ice Core Data for Antarctic and Arctic (climatedata.info)

[19] Migdat Hodzic and Ivan Kennedy (January 4th 2021). Kalman Filter Harmonic Bank for Vostok Ice Core Data Analysis and Climate Predictions, Glaciers and the Polar Environment, Masaki Kanao, Danilo Godone and Niccolò Dematteis, IntechOpen, DOI: 10.5772/intechopen.94263. No.9: Further Considerations. Available from: https://www.intechopen.com/chapters/73751

[20] Climate Data Information. Figure 5, and 6. Ice Core Data for Antarctic and Arctic (climatedata.info)

Yau AM, Bender ML, Robinson A, Brook EJ. Reconstructing the last interglacial at Summit, Greenland: Insights from GISP2. *Proc Natl Acad Sci U S A*. 2016;113(35):9710-9715. doi:10.1073/pnas.1524766113. Abstract and again in Conclusions.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5024603/#

[21] Temperature signal resolution:
Dating of the GV7 East Antarctic ice core by high-resolution chemical records and focus on the accumulation rate variability in the last millennium
Raffaello Nardin[1], Mirko Severi[1,2], Alessandra Amore[1], Silvia Becagli[1,2], Francois Burgay[3,4], Laura Caiazzo[5], Virginia Ciardini[6], Giuliano Dreossi[2,3], Massimo Frezzotti[7], Sang-Bum Hong[8], Ishaq Khan[3], Bianca Maria Narcisi[6], Marco Proposito[6], Claudio Scarchilli[6], Enricomaria Selmo[9], Andrea Spolaor[2,3], Barbara Stenni[2,3], and Rita Traversi[1,2]
Introduction. https://cp.copernicus.org/articles/17/2073/2021/

CO2 signal resolution:
Petit, J., Jouzel, J., Raynaud, D. *et al.* Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* **399,** 429–436 (1999). Page 431, Climate and atmospheric trends, figure 3 description.
http://large.stanford.edu/publications/coal/references/docs/1999.pdf

[22] Climate Data Information. Figure 5. Ice Core Data for Antarctic and Arctic (climatedata.info)

[22a] IPCC AR6, Technical Summary, Page 90, Diagram (e) Radiative Forcing Components. Page 92, Diagrams (A) and (B).
IPCC_AR6_WGII_TechnicalSummary.pdf

[23] NASA. Global Climate Change. The Causes of Climate Change. https://climate.nasa.gov/causes/

[23a] Online water vapour pressure calculator. Difference between 14°C and 15°C is slightly over 7%.
Vapor Pressure of Water Calculator -- EndMemo

[24] NASA. Climate and Earth's Energy Budget. Climate Forcings and Global Warming. Climate and Earth's Energy Budget (nasa.gov)

Not a reference, but a good, easy to understand presentation applying the laws of physics comparing the effects of atmospheric CO2 with water vapour. Michel van Biezen, Physicist, online tutorials. Astronomy - Ch. 9.1: Earth's Atmosphere (17 of 61) How Does CO2 Keep Us Warm? - YouTube Videos 17-21, & 39-41, & 51 & 52.

[25] NASA. Global Climate Change, What is the Greenhouse Effect? What is the greenhouse effect? – Climate Change: Vital Signs of the Planet (nasa.gov)

[26] Not a reference, but a good, easy to understand presentation applying the laws of physics to the effects of increasing atmospheric CO2. Michel van Biezen, Physicist, online tutorials. Astronomy - Ch. 9.1:Earth's Atmosphere (53 of 61) What is the Doubling Effect with Different Models? - YouTube

[27] Not a reference, but a good, easy to understand presentation applying the laws of physics to the effect of atmospheric CO2 relative to water vapour. Michel van Biezen, Physicist, online tutorials. Astronomy - Ch. 9.1: Earth's Atmosphere(52 of 61) What is the G.H. Effect Contribution of CO2?(100m) - YouTube

[28] Coordinating Lead Authors: Philippe Ciais (France), Christopher Sabine (USA) Lead Authors: Govindasamy Bala (India), Laurent Bopp (France), Victor Brovkin (Germany/Russian Federation), Josep Canadell (Australia), Abha Chhabra (India), Ruth DeFries (USA), James Galloway (USA), Martin Heimann (Germany), Christopher Jones (UK), Corinne Le Quéré (UK), Ranga B. Myneni (USA), Shilong Piao (China), Peter Thornton (USA);
IPCC Fifth Assessment Report, Carbon and Other Biogeochemical Cycles, Page 469, Irreversible Long-Term Impacts of Human-Caused Emissions. The removal of human-emitted CO2 from the atmosphere by natural processes will take a few hundred thousand years (high confidence).
And page 472, Box 6.1, Multiple Residence Times for an Excess of Carbon Dioxide Emitted in the Atmosphere.
https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter06_FINAL.pdf

EPA. Understanding Global Warming Potentials: Understanding Global Warming Potentials | US EPA

[29] NASA, Earth Observatory, The Carbon Cycle. https://earthobservatory.nasa.gov/features/CarbonCycle

[30] NASA. Carbon Dioxide Fertilization Greening Earth, Study Finds. Carbon Dioxide Fertilization Greening Earth, Study Finds | NASA

Characteristics, drivers and feedbacks of global greening.
Shilong Piao, Xuhui Wang, Taejin Park, Chi Chen, Xu Lian, Yue He, Jarle W. Bjerke, Anping Chen, Philippe Ciais, Hans Tommervik, Ramakrishna R. Nemani and Ranga B. Myneni.
Greenness changes.
(PDF) Characteristics, drivers and feedbacks of global greening (researchgate.net)

[31] Petit, J., Jouzel, J., Raynaud, D. *et al.* Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* **399,** 429–436 (1999). The Ice Record 430, First sentence on page.
http://large.stanford.edu/publications/coal/references/docs/1999.pdf

[32] Petit, J., Jouzel, J., Raynaud, D. *et al.* Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* **399,** 429–436 (1999). Page 433, Greenhouse Gases. http://large.stanford.edu/publications/coal/references/docs/1999.pdf

[33] Petit, J., Jouzel, J., Raynaud, D. *et al.* Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* **399,** 429–436 (1999). Page 431, Climate and atmospheric trends, figure 3 description.
http://large.stanford.edu/publications/coal/references/docs/1999.pdf

[33] Petit, J., Jouzel, J., Raynaud, D. *et al.* Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* **399,** 429–436 (1999). Page 435. New constraints on past climate change. 100-kye cycle.
http://large.stanford.edu/publications/coal/references/docs/1999.pdf

[34] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani,
S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3−32, doi:10.1017/9781009157896.001. Introduction, A: The Current State of the Climate, A.1.1.
IPCC 6th Ass Summary fro policy makers.pdf