# The Anthropocene Era

## Foreward

The study of the Anthropocene Era has become a major topic of interest to the scientific community (Crutzen & Stoermer, 2000; Steffen et al., 2007; Zalasiewicz et al., 2011)).

This short essay aims to offer a short description of the Anthropocene Era, its definition, starting point, how it is recognised and what its expected trajectories may be.

## Description and Definition

According to Lewis & Maslin (2015), “Recent global environmental changes suggest that Earth may have entered a new human-dominated geological epoch, the Anthropocene” and that “The impacts of human activity will probably be observable in the geological stratigraphic record for millions of years into the future, which suggests that a new epoch has begun” (p.171)

## The Timeframe

There are many good arguments about the approximate time when the currently recognised Holocene Era should be concluded and the Anthropocene Era should have been commenced (Lewis & Maslin, 2015; Davis, 2011). The Holocene Epoch (Era) is recognised as the latest geologic time covering the last 11,700 years of Earth’s history supported by many (Walker et al. 2018) but with no recognition at all of the Anthropocene as a separate Era in the International Chronostratigraphic Chart (Cohen et al., 2019)

However, in recent studies (Crutzen & Stoermer, 2000; Steffen, 2007; Lewis & Maslin, 2015) regarding what is now being recognised as the Anthropocene Era, there are several suggested starting points well tabled by Lewis & Maslin (2015, p. 175) as indicated below:

**Table 1 | Potential start dates for a formal Anthropocene Epoch**

| Event | Date | Geographical extent | Primary stratigraphic marker | Potential GSSP date* | Potential auxiliary stratotypes |
|---|---|---|---|---|---|
| Megafauna extinction | 50,000–10,000 yr BP | Near-global | Fossil megafauna | None, diachronous over ~40,000 yr | Charcoal in lacustrine deposits |
| Origin of farming | ~11,000 yr BP | Southwest Asia, becoming global | Fossil pollen or phytoliths | None, diachronous over ~5,000 yr | Fossil crop pollen, phytoliths, charcoal |
| Extensive farming | ~8,000 yr BP to present | Eurasian event, global impact | $CO_2$ inflection in glacier ice | None, inflection too diffuse | Fossil crop pollen, phytoliths, charcoal, ceramic minerals |
| Rice production | 6,500 yr BP to present | Southeast Asian event, global impact | $CH_4$ inflection in glacier ice | 5,020 yr BP $CH_4$ minima | Stone axes, fossil domesticated ruminant remains |
| Anthropogenic soils | ~3,000–500 yr BP | Local event, local impact, but widespread | Dark high organic matter soil | None, diachronous, not well preserved | Fossil crop pollen |
| New–Old World collision | 1492–1800 | Eurasian–Americas event, global impact | Low point of $CO_2$ in glacier ice | 1610 $CO_2$ minima | Fossil pollen, phytoliths, charcoal, $CH_4$, speleothem $\delta^{18}O$, tephra† |
| Industrial Revolution | 1760 to present | Northwest Europe event, local impact, becoming global | Fly ash from coal burning | ~1900 (ref. 94); diachronous over ~200 yr | $^{14}N$:$^{15}N$ ratio and diatom composition in lake sediments |
| Nuclear weapon detonation | 1945 to present | Local events, global impact | Radionuclides ($^{14}C$) in tree-rings | 1964 $^{14}C$ peak§ | $^{240}Pu$: $^{239}Pu$ ratio, compounds from cement, plastic, lead and other metals |
| Persistent industrial chemicals | ~1950 to present | Local events, global impact | For example, $SF_6$ peak in glacier ice | Peaks often very recent so difficult to accurately date§ | Compounds from cement, plastic, lead and other metals |

Table copied from Lewis & Maslin, 2015, p.175

From this table, consideration has been focused on the later commencement dates, ca1950. This represents the commencement date of “The Great Acceleration” (Lewis & Maslin, 2015; Steffen & McNeill, 2007; McNeill & Engelke, 2016)

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## The Great Acceleration, its recognition and trajectories.

The Great Acceleration is an expression relating directly to a more recent time frame indicating the commencement of greater non-linear change to many environmental issues related directly to human activities. The data acquired over this relatively short time frame has been graphed by Steffen et al. (2003, pp.254-255) over a range of issues.
12 issues are categorised into two broad areas of human activities and their environmental effects. These categories are Socioeconomic trends and Earth system trends.

All graphs trend in one direction only. All are related to human-related activities and indicate increasing consumption, loss and pollution among many issues.

### Conclusion

The indication or trajectory of any of these issues examined appears to be unstoppable. For a more positively foreseeable future, this data demands that however the Anthropocene Era is recognised (if at all by some), and regardless of the definition or timeframe dedicated to it, radical action must be taken to adapt and mitigate many existing human activities to slow down this worsening situation.

#### References

Cohen, K.M., Finney, S.C., Gibbard, P.L. & Fan, J.-X. (2013; updated) The ICS International Chronostratigraphic Chart. Episodes 36: 199-204.

Crutzen, Paul J. & Eugene F. Stoermer 2000. The “Anthropocene.” Global Change Newsletter vol.41, 17–18.

Crutzen, P.J., & Steffen, W. 2003. How Long Have We Been in the Anthropocene Era?. *Climatic Change* 61**,** 251–257.

Davis, R. V. Inventing the present: historical roots of the Anthropocene. *Earth Sci. Hist*. vol.30, 63–84 (2011).

Lewis, S., & Maslin, M. 2015. Defining the Anthropocene. *Nature* vol. 519, pp. 171–180.viewed 31 March 2020,

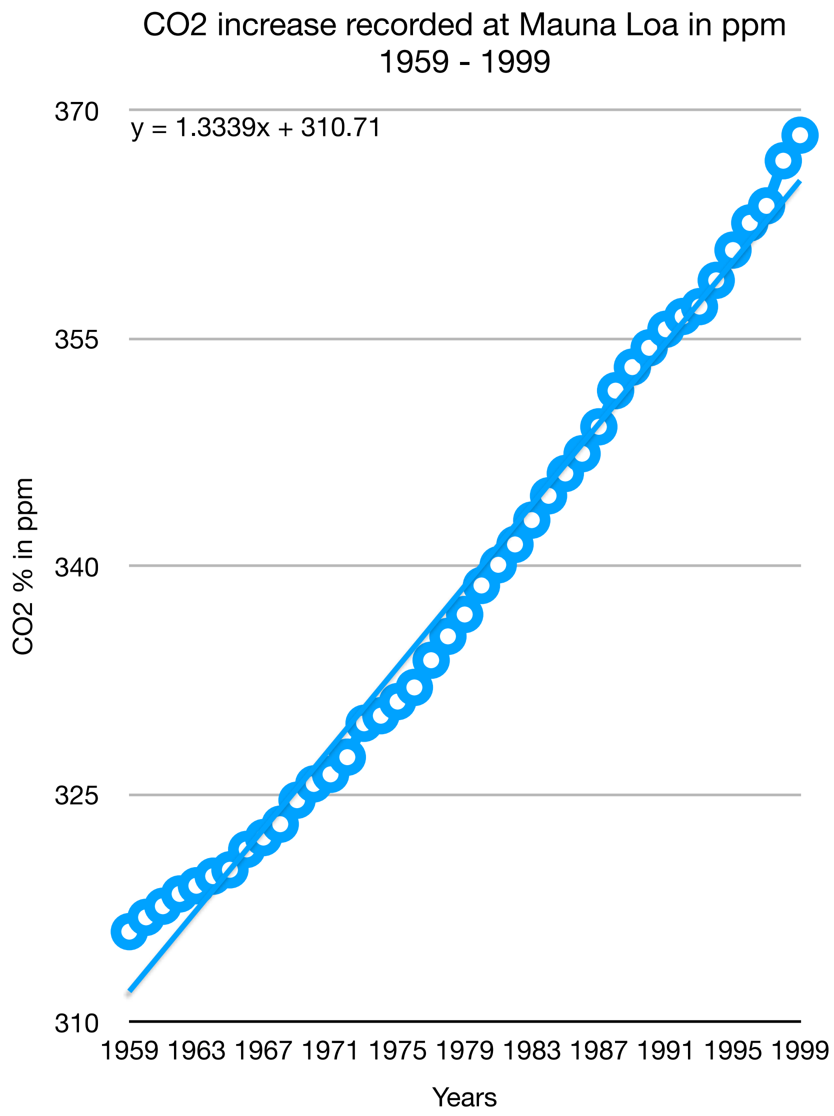
McNeill, J.R., and Engelke, P. 2016. The Great Acceleration: An Environmental History of the Anthropocene since 1945.Cambridge, Massachusetts.The Belknap Press of Harvard University Press.

Steffen, W., Crutzen, P. J. & McNeill, J. R. The Anthropocene: are humans now overwhelming the great forces of nature. *Ambio,* vol. 36, 614–621 (2007).

Zalasiewicz, J., Williams, M., Haywood, A. & Ellis, M. 2011.The Anthropocene: a new epoch of geological time? *Philosophical Transactions of the Royal Society*. London., vol. 369, 835–841.

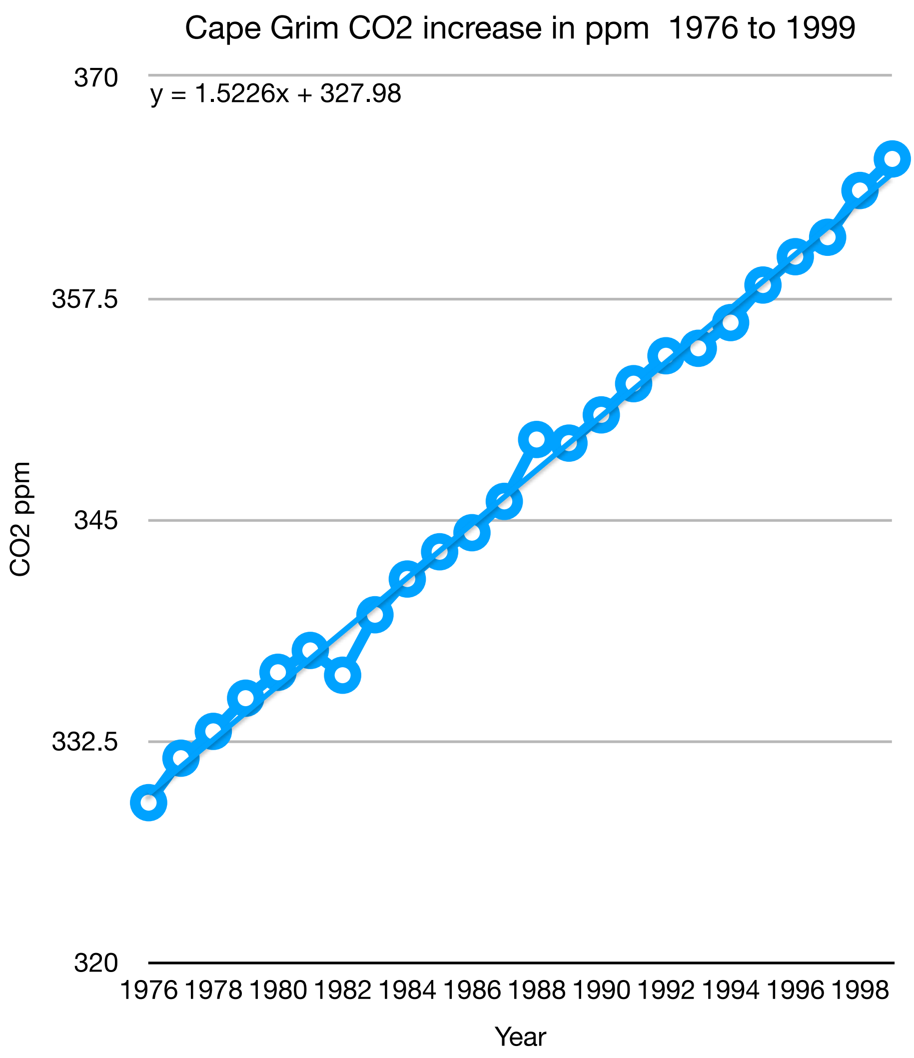
Walker, M., Head, M.J., Berkelhammer, M., Bjork, s., Cheng, H., Cwynar, L., Fisher, D., Gkinis, V., Long, A., Lowe, J., Newnham, R., Rasmussen, S.O., and Weiss, H. 2018. Formal ratification of the subdivision of the Holocene Series/Epoch (Quaternary System/Period): two new Global Boundary Stratotype Sections and Points (GSSPs) and three new stages/subseries: *International Union of Geological Sciences*. Viewed 31 March 2020,

## $CO_2$ concentrations comparisons: Mauna Loa (Hawaii - Northern Hemisphere) and Cape Grim (Tasmania - Southern Hemisphere)




The graph above has been produced from the Mauna Loa Carbon Dioxide observation site from data obtained from the years 1959 to 1999 (CDIAC, 2017, p.1). The straight trend line shows a clear and regular increase during those years with no indication of a reversal of values. The mathematical equation representing this current change of value as found at the top left-hand side of the graph, is $y=1.3339x + 310.71$.

A similar profile can also be produced by data obtained at Cape Grim on the northwest tip of Tasmania, as indicated below (CSIRO, 2020, p.1.)
The trend indicated here also shows no respite in $CO_2$ concentration levels.




**Conclusion**

The data, taken from two distinctly separate geographic locations, infers that the increasing $CO_2$ concentrations in the atmosphere are of global, not just localised, concern.

**References**


Carbon Dioxide Information Analysis Center. 2017. *ESS-DIVE CDIAC Data Transition*, Viewed 31 March 2020, https://cdiac.ess-dive.lbl.gov.

CSIRO. 2020. *Latest Cape Grim greenhouse gas data,* Cape Grim_CO2_data_download, viewed 31 March 2020, https://www.csiro.au/en/Research/OandA/Areas/Assessing-our-climate/Latest-greenhouse-gas-data

## The World Ocean Circulation Experiment/ Graphics/Description

### Overview

The World Oceanic Circulation Experiment (WOCE), as stated in one publication of the Scripps Institution of Oceanography, was a “comprehensive global hydrographic survey of physical and chemical properties, of unprecedented scope and quality, and represents the "state of the oceans" during the 1990s (Orsi & Whitworth, 2005, pp 1-123).

This experiment produced a vast assay of data, including those related to the three major climate elements: salinity, temperature and density.

From these data, comparisons of changes over time can be made by reviewing graphics created indicating those respective changes. In this manner, assumptions can be made regarding their effect on both oceanic movement as exhibited by the thermohaline circulation and, as in later years later indicated, changes such as nutrient availability (Ribbe, 2004, p. 23) and marine life abundance (Hastings et al, 2020, pp 2-18).

### Graphics description and implication for global-scale ocean circulation

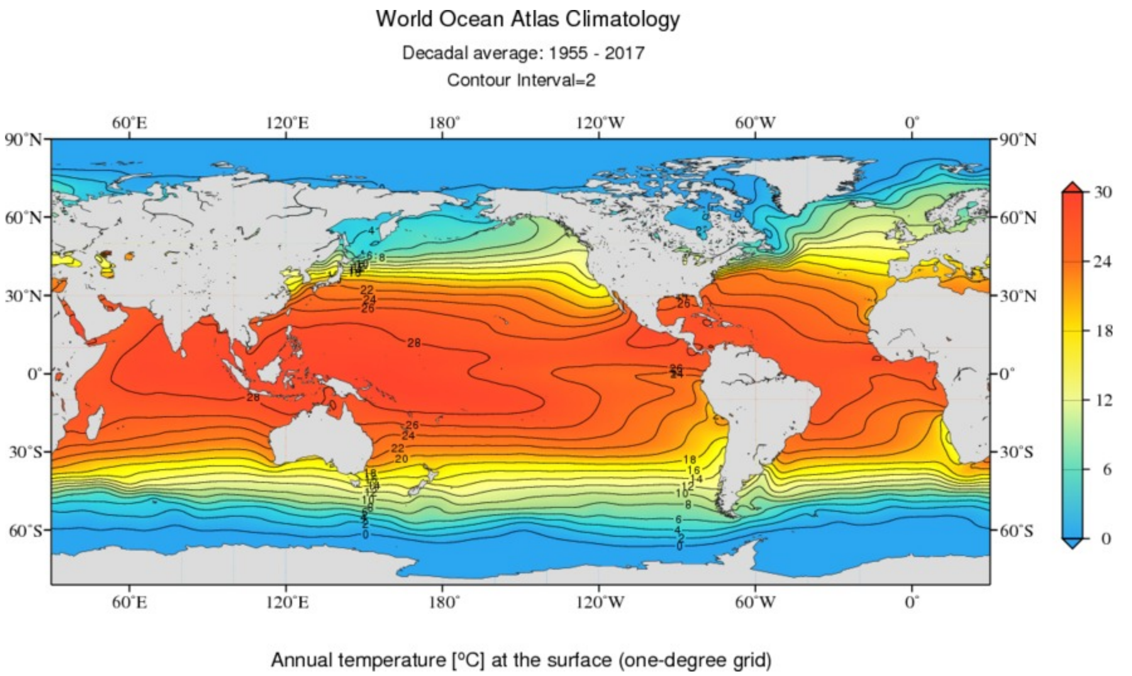
Examples of changes in Salinity and Temperature over time can be indicated by the below graphics taken from the National Centers for Environmental Information (NOAA, 2019, pp 1-2).

Both graphics shown below represent the decadal average of both temperature and salinity from 1955 to 2017 at the surface. The writer has arbitrarily chosen these graphics even though, from this website, many other graphical representations may be chosen to indicate data obtained during different periods and depths.

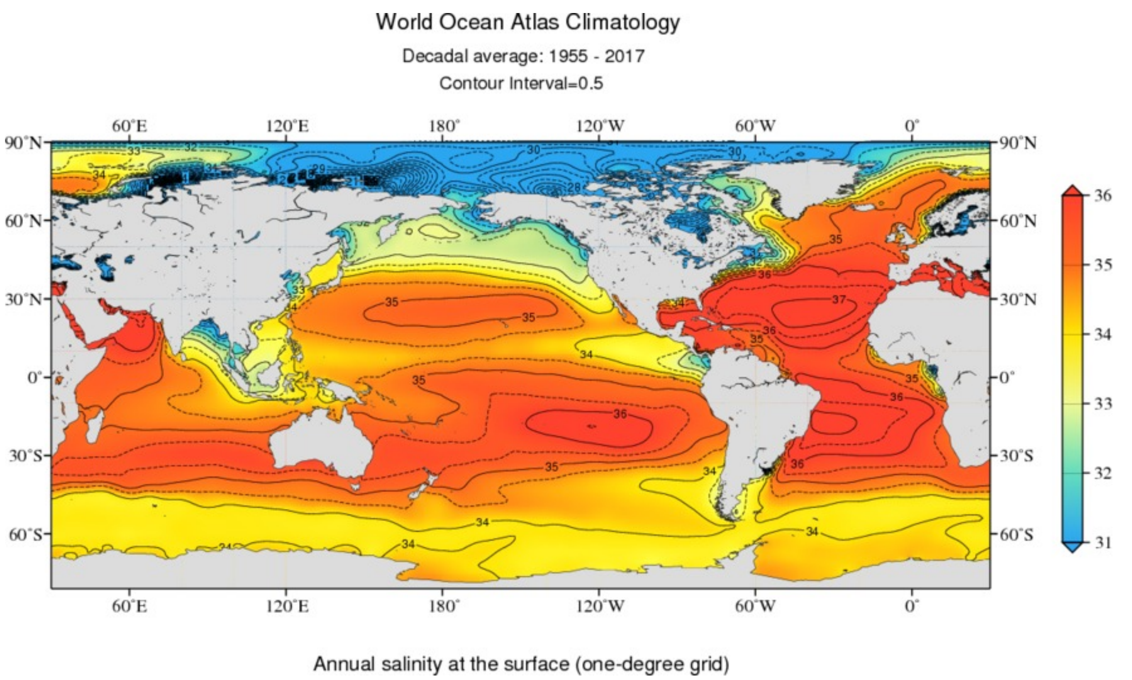
Each graphic is framed by points of longitude (meridians) and is represented in numerical form, indicating how far a location is east or west of a universal line called a Prime Meridian. This is numbered as 0 degrees, a longitudinal line running from the North Pole to the South Pole. Similarly, lines of latitude are those represented parallel to the equatorial line marked as 0 degrees. Lines of latitude are therefore given as degrees North or South. (Journey North, 2019, p.1).

The contours represented by solid or dotted lines are isothermal or isophthalic, that is, lines of equal temperature and salinity, respectively. These temperatures and salinities are also quantified by the legends on each graphic's right-hand side. Temperature is in degrees Celsius and Salinity by parts per thousand.

Both graphics indicate higher temperatures and salinities on the equatorial meridian's immediate northern and southern sides, with a distinctly further reach of increased salinity towards the prime meridian. This would indicate an area where the density of the water mass, as could be provided by a T-S diagram, implies an area of prime motivation for the thermohaline circulation; as the relatively high density of this water mass sinks, it would be replaced by less saline, hence less dense water mass. This, in turn, creates a convection current assisting in the production of global oceanic circulation.




Obtained from: NOAA National Centers for Environmental Information. 2019. Available at:




Obtained from: NOAA National Centers for Environmental Information. 2019. Available at:

## References

Hastings, R.A., Ritterford, L.A., Freer, J.J., Collins, R.A., Simpson, S.D., Genner, M.J. (2020). Climate Change Drives Poleward Increases and Equatorward Declines in Marine Species. *Current Biology,* vol.30, pp. 1-6, viewed 29 March 2020, ‘Understanding Latitude and Longitude’, *Journey North,1* viewed 29 March 2020,

NOAA National Centers for Environmental Information. 2019, viewed 29 March 2020,

Orsi, Alejandro H, Whitworth, Thomas, III. 2005. Scripps Institution of Oceanography. *Hydrographic Atlas of the World Ocean Circulation Experiment )WOCE) Volume 1: Southern Ocean,* viewed 29 March 2020,

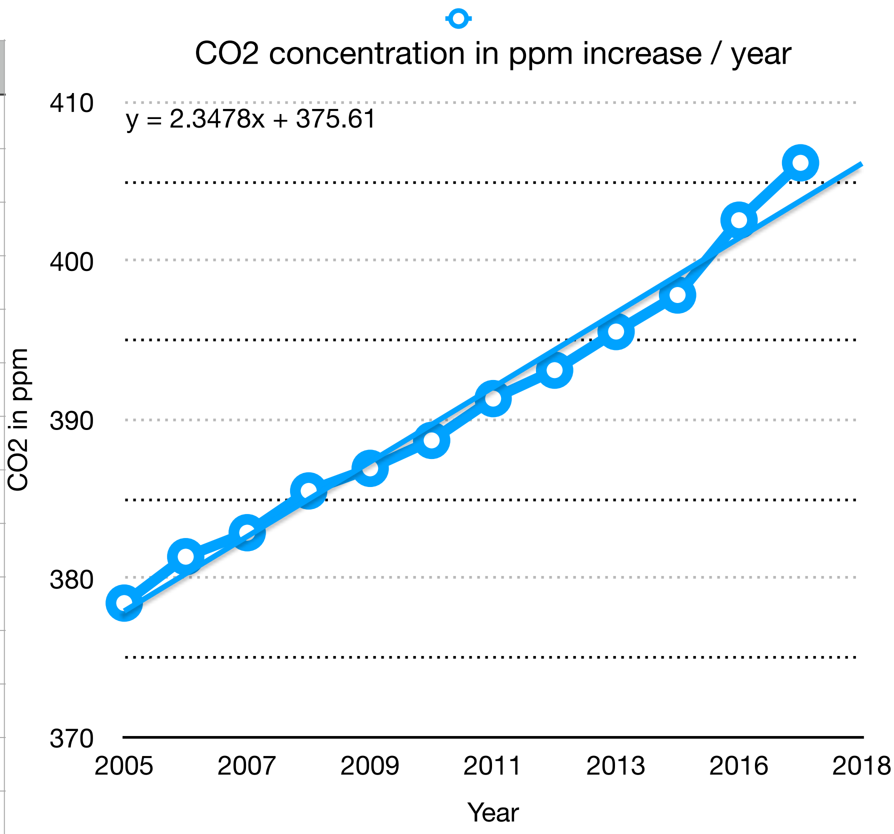
Ribbe, J., 2004, The southern supplier. Nature. 427, 23-24.

## Global Carbon Cycle

Annual change in the atmospheric concentration from 2005 to 2017 indicates a trend line showing that increase to follow the equation y = 2.3478x + 375.61

CO2 ppm change per year-1

| CO2 in ppm | |
|---|---|
| **2005** | 378.46 |
| **2006** | 381.38 |
| **2007** | 382.89 |
| **2008** | 385.52 |
| **2009** | 386.94 |
| **2010** | 388.7 |
| **2011** | 391.33 |
| **2012** | 393.12 |
| **2013** | 395.55 |
| **2015** | 397.85 |
| **2016** | 402.56 |
| **2017** | 406.17 |
| **2018** | 407.96 |
| **2019** | 410.83 |
| **2020** | 413.4 |




Data retrieved from the National Aeronautics and Space Administration

Global Climate Change - Carbon Dioxide. 2020, pp 7-13, viewed 29 March 2020, ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt.

This data set was using those indicated as observed in December of each of the years studied

**Reference**

National Aeronautics and Space Administration: *Global Climate Change - Carbon Dioxide*. 2020, viewed 29 March 2020, ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt.

CO2 ppm change per year

| CO2 in ppm | |
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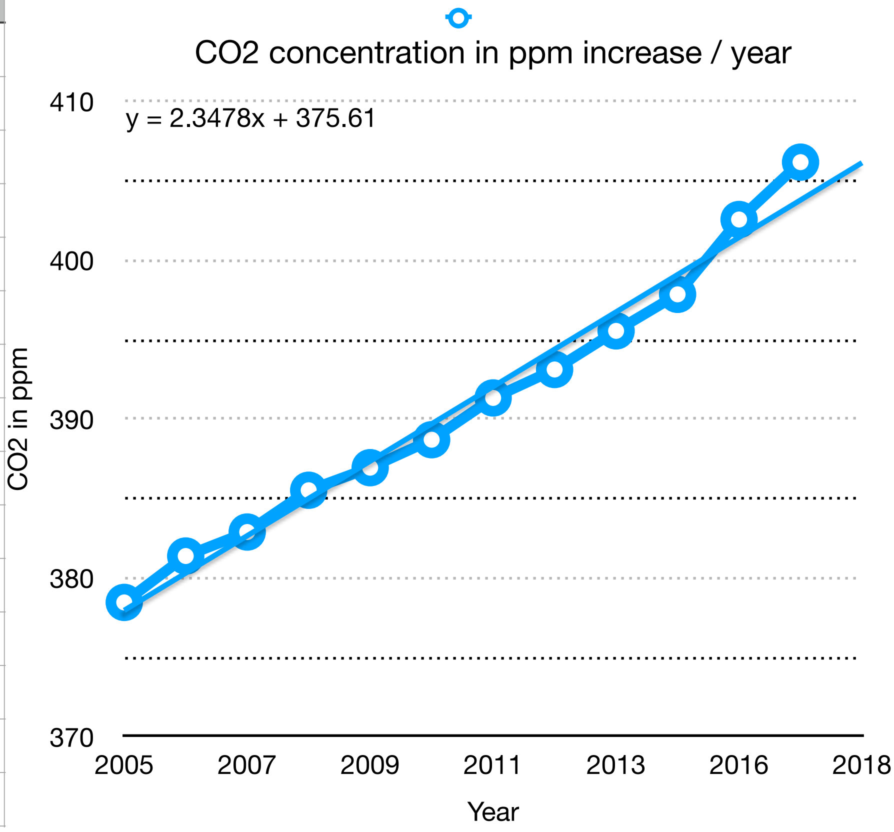
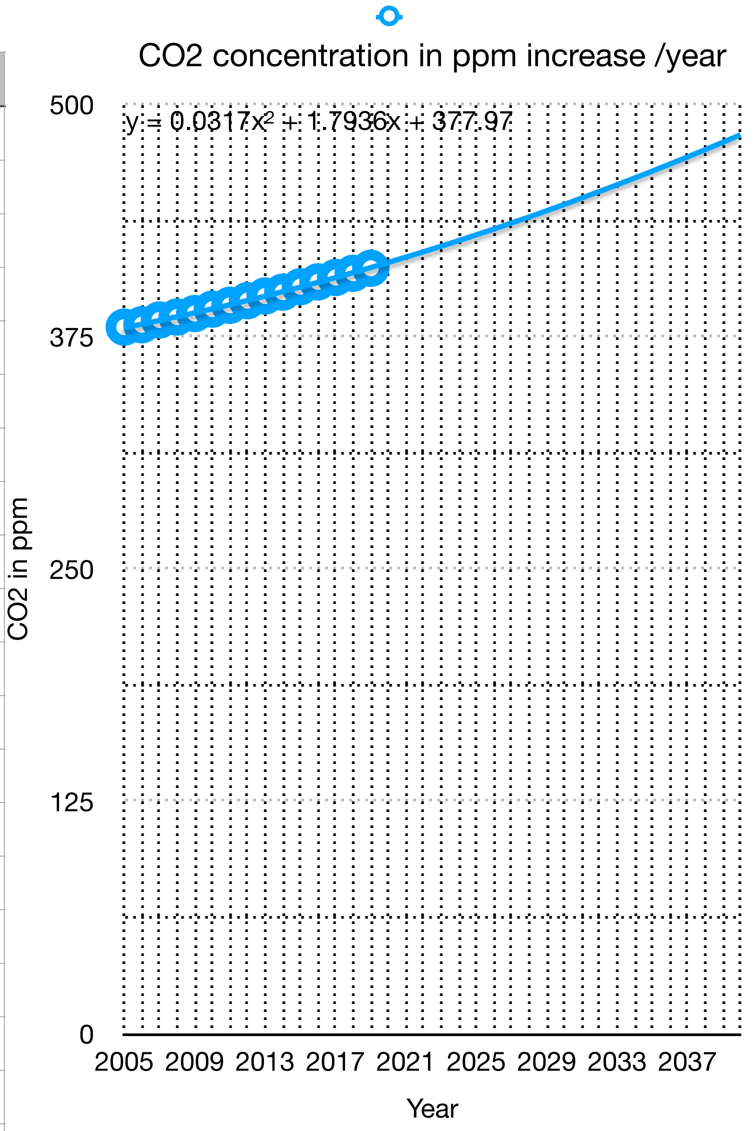



## Estimated CO2 values using an extended trend line to indicate future CO2 levels.

Using the formula automatically calculated by the MAC Numbers algorithm using polynomial expansion, the estimated values in the years 2025 and 2040 would be 426.52 and 479.58ppm respectively.

CO2 in ppm estimated increase 2005 - 2040

| Year | CO2 in ppm |
|---|---|
| **2005** | 380.11 |
| **2006** | 381.38 |
| **2007** | 383.94 |
| **2008** | 385.56 |
| **2009** | 387.42 |
| **2010** | 389.79 |
| **2011** | 391.86 |
| **2012** | 394.34 |
| **2013** | 396.84 |
| **2014** | 398.91 |
| **2015** | 401.85 |
| **2016** | 404.45 |
| **2017** | 406.81 |
| **2018** | 409.07 |
| **2019** | 411.76 |
| **2020** | |
| **2021** | |
| **2022** | |
| **2023** | |
| **2024** | |
| **2025** | 426.52 est. |
| **2026** | |
| **2027** | |
| **2028** | |
| **2029** | |
| **2030** | |
| **2031** | |
| **2032** | |
| **2033** | |
| **2034** | |
| **2035** | |
| **2036** | |
| **2037** | |
| **2038** | |
| **2039** | |
| **2040** | 479.58 |




Data obtained from National Aeronautics and Space Administration: Global Climate Change - Carbon Dioxide. 2020, viewed 29 March 2020, ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt

**Reference**

National Aeronautics and Space Administration: *Global Climate Change - Carbon Dioxide*. 2020, viewed on 29 March 2020, https://climate.nasa.gov/vital-signs/carbon-dioxide/

## The estimated residence time of current (existing) levels of carbon in the atmosphere.

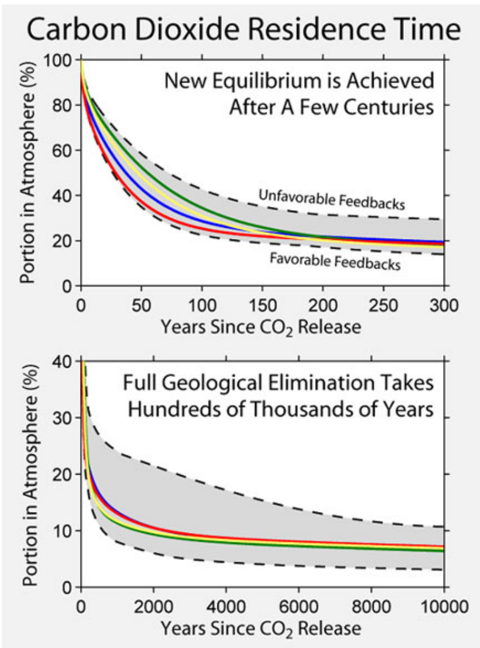
In the data obtained from Working Group 1: The Scientific Basis in 2019 from the Intergovernmental Panel on Climate Change (IPCC, p.1) they indicate that the concentration level of CO2 was 365ppm in 1998. At a rate of change of 1.5ppm/yr, the estimated lifetime is 5-200 years. This estimate given by the IPCC is given the caveat that “no single lifetime can be defined for CO2 because of the different rates of uptake by different removal processes” (p.1)

However, from the most recent data available through the IPCC, we now know that the current concentration level is estimated at 415.68 ppm. This would then expand the estimated lifetime to 5-275 years (CO2.earth, p. 1)

Hausfather (2010, p.5) of Yale Climate Connections suggests a similar time frame and states that:

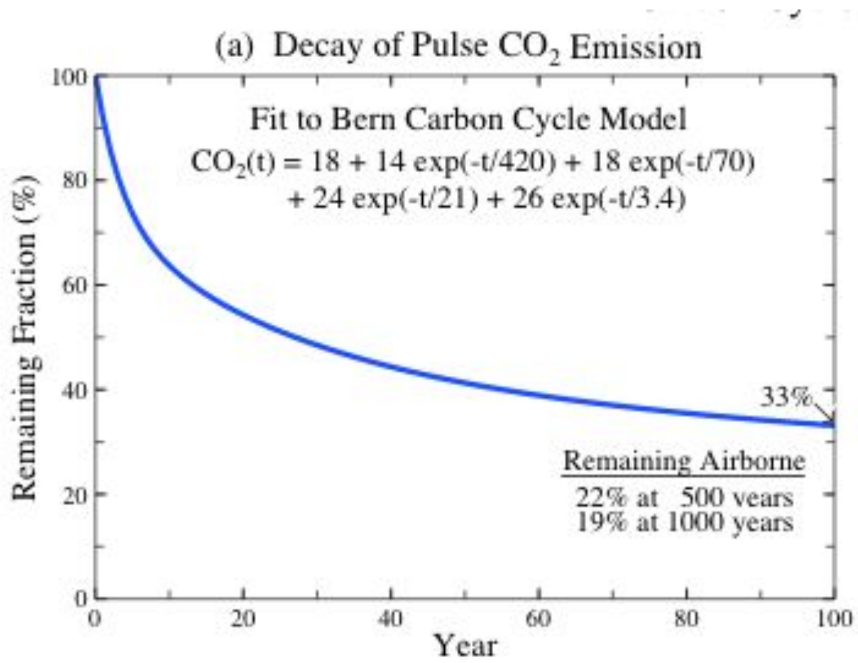
> *Using a combination of various methods, researchers have estimated that about 50 per cent of the net anthropogenic pulse would be absorbed in the first 50 years and about 70 per cent in the first 100 years. Absorption by sinks slows dramatically after that, with an additional 10 per cent or so being removed after 300 years and the remaining 20 per cent lasting tens if not hundreds of thousands of years before being removed.*

This statement is followed up graphically as represented below:




From: Yale Climate Connections. Viewed 29 March 2020, https://www.yaleclimateconnections.org/2010/12/common-climate-misconceptions-atmospheric-carbon-dioxide/[

A further extension of this time frame is found in the Bern carbon cycle model which indicates residual CO2 at 1000 years.




*Sourced from Hansen J. et al. Dangerous human-made interference with climate: a GISS modelE study: Atmospheric Chemistry and Physics, viewed 29 March 2020, http://www.acamedia.info/sciences/sciliterature/globalw/residence.htm.*

**Conclusion**

Whatever the time frame settled on is, it would appear that the existing concentration of CO2 in the atmosphere is both increasing and creating a situation where residence time and its related disturbance to future climatic conditions will also be increasing.

Unless CO2 production can be reduced by greater effort placed on mitigation policies.

**References**


CO2 Earth. 2020. *Latest Daily CO2,* viewed 31 march 2020, https://www.co2.earth/daily-co2

Working Group 1: The Scientific Basis: *Intergovernmental Panel on Climate Change.* 2020, viewed 29 March 2020,

Hansen, J.et al. 2007. Dangerous human-made interference with climate: a GISS modelE study: *Atmospheric Chemistry and Physics*, viewed 29 March 2020, http://www.acamedia.info/sciences/sciliterature/globalw/residence.htm

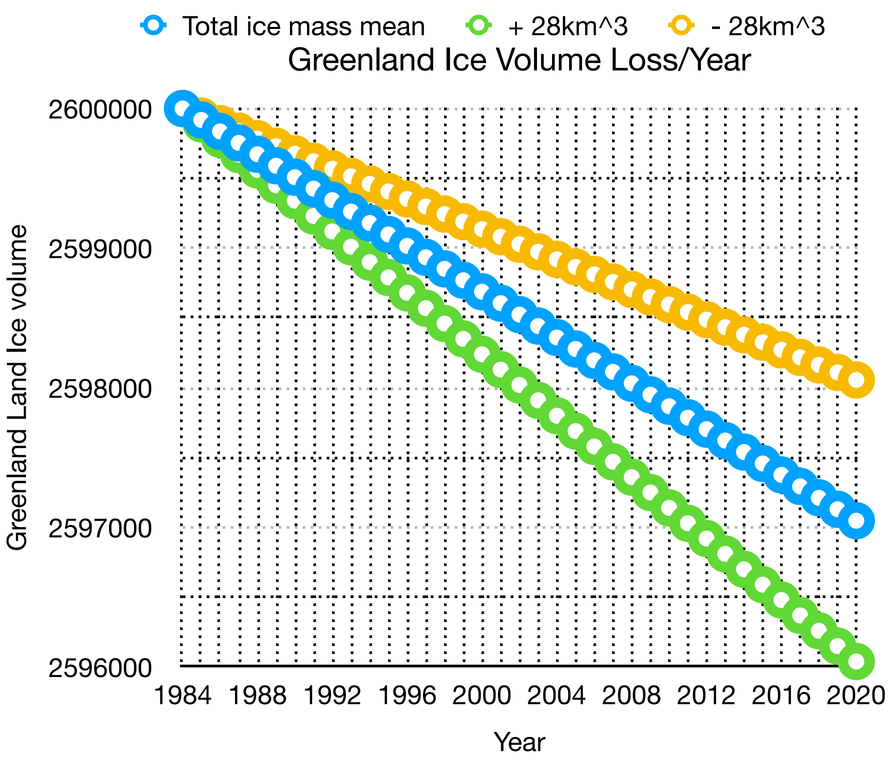
Hausfather, Z. 2010. Common Climate Misconceptions: Atmospheric Carbon Dioxide. *Yale Climate Connections,* viewed 29 March 2020, https://www.yaleclimateconnections.org/2010/12/common-climate-misconceptions-atmospheric-carbon-dioxide

Greenland Ice Volume Loss

| Year | Total ice mass mean | + 28km^3 | - 28km^3 |
|---|---|---|---|
| 1984 | 2600000 | 2600000 | 2600000 |
| 1985 | 2599918 | 2599670 | 2599946 |
| 1986 | 2599836 | 2599780 | 2599892 |
| 1987 | 2599754 | | 2599838 |
| 1988 | 2599672 | 2599560 | 2599784 |
| 1989 | 2599590 | 2599450 | 2599730 |
| 1990 | 2599508 | 2599340 | 2599676 |
| 1991 | 2599426 | 2599230 | 2599622 |
| 1992 | 2599344 | 2599120 | 2599568 |
| 1993 | 2599262 | 2599010 | 2599514 |
| 1994 | 2599180 | 2598900 | 2599460 |
| 1995 | 2599098 | 2598790 | 2599406 |
| 1996 | 2599016 | 2598680 | 2599352 |
| 1997 | 2598934 | 2598570 | 2599298 |
| 1998 | 2598852 | 2598460 | 2599244 |
| 1999 | 2598770 | 2598350 | 2599190 |
| 2000 | 2598688 | 2598240 | 2599136 |
| 2001 | 2598606 | 2598130 | 2599082 |
| 2002 | 2598524 | 2598020 | 2599028 |
| 2003 | 2598442 | 2597910 | 2598974 |
| 2004 | 2598360 | 2597800 | 2598920 |
| 2005 | 2598278 | 2597690 | 2598866 |
| 2006 | 2598196 | 2597580 | 2598812 |
| 2007 | 2598114 | 2597470 | 2598758 |
| 2008 | 2598032 | 2597360 | 2598704 |
| 2009 | 2597950 | 2597250 | 2598650 |
| 2010 | 2597868 | 2597140 | 2598596 |
| 2011 | 2597786 | 2597030 | 2598542 |
| 2012 | 2597704 | 2596920 | 2598488 |
| 2013 | 2597622 | 2596810 | 2598434 |
| 2014 | 2597540 | 2596700 | 2598380 |
| 2015 | 2597458 | 2596590 | 2598326 |
| 2016 | 2597376 | 2596480 | 2598272 |
| 2017 | 2597294 | 2596370 | 2598218 |
| 2018 | 2597212 | 2596260 | 2598164 |
| 2019 | 2597130 | 2596150 | 2598110 |

## Greenland Ice depletion

The estimated volume of Greenland's Land Ice in 1984 (Untersteiner, 1984, p. 122) was 2.6.10^6 km^3. At a linear downward (loss) trend of 82+/- 28km^3 of ice per year (Velicogna & Wahr, 2005), the results could be extrapolated from the below graph, but as the estimated progression is linear, the time to completely melt using the above values would be 23,634, 31,707 and 48,148 years respectively.



But from more recent data from *The Greenland Ice Sheet,* p.24 derived from Ringot and Kanagaratnam (2006, p.988), a different construction can be made. It would appear that ice loss is not moving with linear velocity but accelerating. Even so, the trend line from these data can also be viewed as a linear progression as estimated by the MAC algorithm with the formula y=83.873x - 18.4

Greenland ice mass-balance data
(Ringot and Kanagaratnam, 2006, p.988)

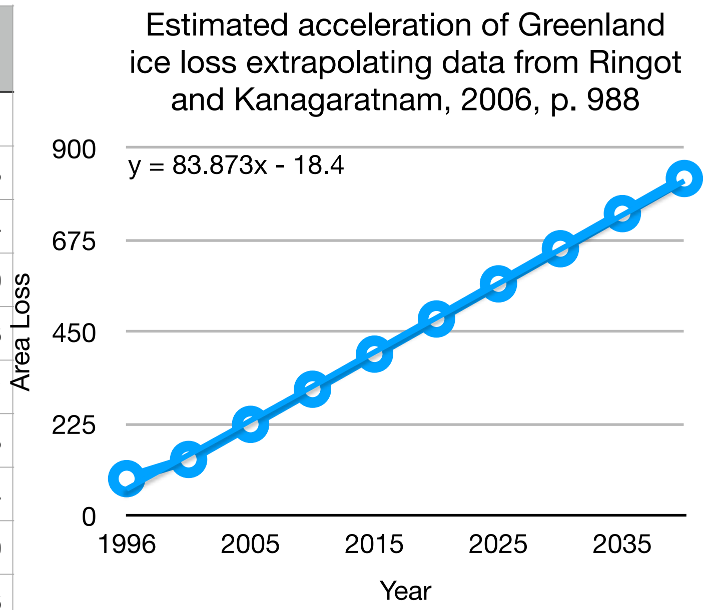
| | | Volume of ice lost/year ($km^3$) | | |
|---|---|---|---|---|
| Region | area ($km^3$) | 1996 | 2000 | 2005 |
| North | 464,876 | 2.4 | 0.7 | 2.3 |
| East | 223057 | 32 | 51 | 118 |
| West | 521350 | 22 | 41 | 47 |
| Total | 1209280 | 56 | 92 | 167 |
| Total corrected | | 91 (±31) | 138 (±31) | 224 (±41) |

From: The Greenland Ice Sheet. Available at: https://web.viu.ca/earle/geol305/The%20Greenland%20Ice%20Sheet.pdf.[Accessed 31 March 2020]

This would alter loss values as outlined below and reduce the ultimate time of complete depletion to 14,417 years using the mean values given by Ringot and Kanagaratnam, 2006, p.988.

[y = 1209280, then x = (1209280 -18.4)/83.873 = 14,417 years]

| Year | Mean estimated loss value in km^3 |
|---|---|
| 1996 | 91 |
| 2000 | 138 |
| 2005 | 224 |
| 2010 | 310 |
| 2015 | 396 |
| 2020 | 482 |
| 2025 | 568 |
| 2030 | 654 |
| 2035 | 740 |
| 2040 | 826 |



**References**

Rignot, E. & Kanagaratnam, P. 2006. Changes in the Velocity Structure of the Greenland Ice Sheet: *Science,* vol. 31, Issue 5763, pp. 986-990.

Untersteiner, N.1984. The cryosphere: *Global Climate*. Ed Houghton, J.T. Cambridge University Press.

Vancouver Island University. *The Greenland Ice Sheet.* Available at:https://web.viu.ca/earle/geol305/The%20Greenland%20Ice%20Sheet.pdf. [Accessed 30 March 2020]

Velicogna, I. & Wahr, J., 2005. Greenland Mass Balance from Grace. *Geophysical Research Letters*, vol.32, 18505-18505.

**The data Velicogna and Wahr used** in their June 2005 paper titled "*Greenland mass balance from GRACE"* was by using "22 monthly GRACE (Gravity Recovery and Climate Experiment) gravity fields to estimate the linear trend in Greenland ice mass during 2002–2004. We recover a decrease in total ice mass of 82 ± 28 km^3 of ice per year, consistent with estimates from other techniques." (2005, p.1)

GRACE estimates use sophisticated mathematical techniques to give monthly mass estimates and incorporate further techniques attempting to minimise leakage from short-term mass variabilities encountered by precipitation, runoff (meltwater) and discharging flows of ice. These issues of eliminating possible errors in the GRACE data obtained are detailed by Velicogna et al (2005, pp. 3-4) in their paper on *Short term mass variability in Greenland, from GRACE.*

This also refers to those errors attributable to PG: the viscoelastic response of the solid earth to glacial unloading (Velicogna and Wahr, 2005) and how these may affect final assumptions.

**References**

Velicogna, I., and Wahr, J., 2005, Greenland Mass Balance from GRACE. *Geophysical Research Letters*, vol.32, 18505-18505.

Velicogna, I., J. Wahr, E. Hanna, and P. Huybrechts. 2005. Short-term mass variability in Greenland, from GRACE, *Geophysical Research Letters*, vol. 32, L05501. Available at:https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2004GL021948. {Accessed 30 March 2020]

## Estimated time for Ice sheet disappearance

From the 8204 Global Environmental Systems Course Notes, Module 5 The Cryosphere (p.5), the following Table indicates total land and ice areas and volumes from the Antarctic to the Arctic Ocean.

Interestingly, the latest data from the NSIDC (Quick Facts on Ice Sheets, p.1) mirrors the above data for the areas and volumes for both the Antarctic and Greenland.

Table 5.1: Estimated inventory of land and sea ice. Reproduced from Hartmann (1994) using Untersteiner (1984) data.

| | | | Area [km$^2$] | Volume [km$^3$] | [%] of total land ice |
|---|---|---|---|---|---|
| Land Ice | Antarctic | | $13.9 \cdot 10^6$ | $30.1 \cdot 10^6$ | 89.3 |
| | Greenland | | $1.7 \cdot 10^6$ | $2.6 \cdot 10^6$ | 8.6 |
| | Mountain | | $0.5 \cdot 10^6$ | $0.3 \cdot 10^6$ | 0.76 |
| | Permafrost | Continuous | $8 \cdot 10^6$ | | |
| | | | | | |
| | | Discontinuous | $17 \cdot 10^6$ | | |
| | Seasonal Snow | Eurasia | $30 \cdot 10^6$ | | |
| | | | | $2\text{-}3 \cdot 10^3$ | |
| | | America | $17 \cdot 10^6$ | | |
| Sea Ice | Southern Ocean | Min | $3 \cdot 10^6$ | $6 \cdot 10^3$ | |
| | | Max | $18 \cdot 10^6$ | $2 \cdot 10^4$ | |
| | Arctic Ocean | Min | $8 \cdot 10^6$ | $2 \cdot 10^4$ | |
| | | Max | $15 \cdot 10^6$ | $4 \cdot 10^4$ | |

Even so, working with these data, It appears that the total ice volume in Antarctica and Greenland is 32.7.10^6 km^3. Converting this to approximate weight in Gt, we can then utilise the data presented by Rignot et al.(2011, p.1) to estimate possible ice sheet disappearance.

As I Gt is approximately equivalent to 1.00km^3 of ice, the mass of both ice sheets will be 30.1.10^6 and 2.6. 10^6 respectively.

At a rate of change of approximately 145 Gt/year and 281.00Gt/year (NASA, 2020, p.1) for the Antarctic and Greenland masses, respectively, we can then make reasonable estimates as to the total depletion of ice in both regions if ice mass depletion was linear. This would give the following:

Antarctica = 30.1.10^6/145 =  20756 years
Greenland = 2.6.10^6/ 281 = 9252 years

**References**

University of Southern Queensland.2020. *8204 Global Environmental Systems: Module 5 The Cryosphere,* viewed 31 March 2020, https://usqstudydesk.usq.edu.au/m2/course/view.php?id=18280

National Aeronautics and Space Administration: *GlobalClimate Change - Ice Sheets*.2020. Available at: /.{Accessed 30 March 2020]

National Snow and Ice Data Centre (NSIDC). 2020. *Quick Facts on Ice Sheets*. Available at: .{Accessed 30 March 2020]

Rignot, E., Velicogna, I., van den Broeke, M. R., Monaghan, A. & Lenaerts, J., 2011, Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea-level rise. *Geophysical Research Letters*, vol. 38, L05503.

## The estimated rise in global sea level

According to Rignot et al. (2011, p.1) "*In 2006, the Greenland and Antarctic ice sheets experienced a combined mass loss of 475 ± 158 Gt/yr, equivalent to 1.3 ± 0.4 mm/yr sea-level rise.*"

Using the data contained in the chart from the previous question, at this rate, and given that 1km^3 of ice is approximately equal to 1Gt, and using the mean value of 475 GT/yr giving a 1.3mm rise in sea level, we can estimate the following:

32.7.10^6 Gt = total mass
475 Gt loss = 1.3mm rise in sea level

The total mass of ice is divided by the annual loss of mass and then multiplied by the rise in sea level measured in metres.

∴ Total loss = [32.7.10^6/475]. 0.0013m = 89.49m

Or:

The total ice mass is 32.7 million cubic metres spread over the total global ocean area of 361.106 million square kilometres.

∴ 32.7.10^6km^3/361.106.10^6km^2 (NOAA, 2010, p.1) = 0.09056km = 90.56m

Using the estimated length of time for the complete melt of the two regions as calculated in 5.1 (a) and relating to the eventual rise in sea level calculated above, the sea level rise to 2100, 80 years hence, would indicate:

≈ 90(80/14417) ≈ 0.5 (0.4994) metres

This appears to be similar to the projections considered by Lindsay (2019, p.8), who states:

*Both the low-end and "worst-case" possibilities were revised upward in 2017 following a review by the U.S. Interagency Sea Level Rise Taskforce. Based on their new scenarios, the global sea level is very likely to rise at least 12 inches (0.3 meters) above 2000 levels by 2100 even on a low-emissions pathway. On future pathways with the highest greenhouse gas emissions, sea-level rise could be as high as 8.2 feet (2.5 meters) above 2000 levels by 2100. (Emphasis mine)*

**References**


Eakins, B.W. and G.F. Sharman. 2010. Volumes of the World's Oceans from ETOPO1, NOAA National Geophysical Data Center, Boulder, CO.

Lindsay, R. 2019. Climate Change: *Global Sea Level*. NOAA National Geophysical Data Center, viewed 30 March 2020, https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level

Rignot, E., Velicogna, I., van den Broeke, M. R., Monaghan, A. & Lenaerts, J., 2011, Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea-level rise. *Geophysical Research Letters*, vol. 38, L05503.