Home Page

70% of greenhouse gas emissions in 2016
(73%)
Source: Climate Watch, based on raw data from IEA (2018), CO2 Emissions from Fuel Combustion, www.iea.org/statistics; modified by WRI.
https://www.wri.org/blog/2020/02/greenhouse-gas-emissions-by-country-sector
(Accessed 22.6.20)

(65.3%) in 2010
Fossil fuel-related CO2 emissions reached 32 (±2.7) GtCO2/yr, in 2010, and grew further by about 3 % between 2010 and 2011 and by about 1–2 % between 2011 and 2012. Of the 49 (±4.5) GtCO2eq/yr in total anthropogenic GHG emissions in 2010, CO2 remains the major anthropogenic GHG accounting for 76 % (38±3.8 GtCO2eq/yr) of total anthropogenic GHG emissions in 2010.

IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

The Problem

Vostok/12C/180 ppm to 280-300 ppm

Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica
J. R. Petit, J. Jouzel, D. Raynaud, N. I. Barkov, J.-M. Barnola, I. Basile, M. Bender, J. Chappellaz
M. Davis, G. Delaygue, M. Delmotte, V. M. Kotlyakov, M. Legrand, V. Y. Lipenkov, C. Loris, L.PÉpin, C. Ritz, E. Saltzman & M. Stievenard

https://polar.ucsd.edu/wp-content/uploads/2020/02/sio115_week02_1999-petit-ice-cores.pdf (Accessed 24.7.20)

(Vostok)

800,000 years / 180 ppm (170 ppm) 300 ppm

EPICA Community Members, 2004. Eight glacial cycles from an Antarctic ice core. Nature 429: 623-628. Lüthi, D., M. Le Floch, B. Bereiter, T. Blunier, J.-M. Barnola, et al. 2008. High-resolution carbon dioxide concentration record 650,000-800,000 years before present. Nature 453: 379-382. dos 10.1038/nature06949.

(800,000 years)

pre-industrial /280ppm

https://www.esrl.noaa.gov/gmd/news/7074.html
https://cdiac.ess-dive.lbl.gov/trends/co2/modern_co2.html
(Accessed 22.6.20)

(a range of 275 to 285 ppm in the pre-industrial era (AD 1000–1750)) IPCC 2007
Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, 2007: Changes in Atmospheric Constituents and in Radiative Forcing. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

(280 ppm)

414 ppm (414 ppm July 2020)
https://www.esrl.noaa.gov/gmd/ccgg/trends/

(414 ppm)

180 to 300 ppm

(Vostok) as above

nearing 170 ppm

(800,000 years) as above

1000 ppm (750 - 1300 CO2 equivalent)

IPCC, 2014: Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Work- ing Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_summary-for-policymakers.pdf (Accessed 24.7.20)

> Without additional efforts to reduce GHG emissions beyond those in place today, emissions growth is expected to persist driven by growth in global population and economic activities. Baseline scenarios, those without additional mitigation, result in global mean surface temperature increases in 2100 from 3.7 °C to 4.8 °C compared to pre-industrial levels10 (range based on median climate response; the range is 2.5 °C to 7.8 °C when including climate uncertainty, see Table SPM.1)11 (high con dence). The emission scenarios collected for this assessment represent full radiative forcing including GHGs, tropospheric ozone, aerosols and albedo change. Baseline scenarios (scenarios without explicit additional efforts to constrain emissions) exceed 450 parts per million (ppm) CO2eq by 2030 and reach CO2eq concentration levels between 750 and more than 1300 ppm CO2eq by 2100. This is similar to the range in atmospheric concentration levels between the RCP 6.0 and RCP 8.5 pathways in 2100.12 For comparison, the CO2eq concentration in 2011 is estimated to be 430 ppm (uncertainty range 340–520 ppm).13 [6.3, Box TS.6; WGI Figure SPM.5, WGI 8.5, WGI 12.3]

(Mitigation 2014/IPCC)

World Bank WPS7477 Shock Waves: Managing the Impacts of Climate Change on Poverty Policy Research Working Paper 7477 Background Paper Climate Change Impacts and Mitigation in the Developing World An Integrated Assessment of the Agriculture and Forestry Sectors Petr Havlik, Hugo Valin, Mykola Gusti, Erwin Schmid, David Leciere, Nicklas Forsell, Mario Herrero Nikolay Khabarov, Aline Mosnier, Matthew Cantle, Michael Obersteiner Development Economics Climate Change Cross-Cutting Solutions Area November 2015

'This scenario can be seen as an extreme climate change situation; however the recent emission developments exceed even the RCP8.5 emission levels for the corresponding year (Peter et al, 2013)

Surprises
https://archive.ipcc.ch/ipccreports/tar/wg1/index.php?idp=504 (Accessed 24.7.20)

Our World

Rising Temperatures

1°C

A little more than 1°C (2° Fahrenheit) since 1880.
Nasa Earth Observatory
https://earthobservatory.nasa.gov/world-of-change/global-temperatures
(Accessed 22.6.20)

Southern California almost 2°C
(3.5°F)
https://www.epa.gov/sites/production/files/2016-09/documents/climate-change-ca.pdf
https://earthobservatory.nasa.gov/images/145534/rising-global-temperatures-influence-californias-fire-season
(Accessed 22.6.20)

West Africa, parts of Russia and Brazil 2.5°C
(between 1901 to 2012)

Fig SPM.1

SPM.IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Arctic temperatures have increased by 2° to 3°C

Arctic warming at twice the rate as the rest of the planet
https://www.upi.com/Science_News/2018/12/12/NOAA-Arctic-warming-at-twice-the-rate-of-the-rest-of-the-planet/5141544580754/ (Accessed 24.7.20)

Arctic up to 3°C warmer
(Dec to Feb)

Fig 1.3

Allen, M.R., O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, J. Kala, N. Mahowald, Y. Mulugetta, R. Perez, M. Wairiu, and K. Zickfeld, 2018: Framing and Context. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

(1.5°C 2018 IPCC)

2016, 2019, 2015, 2017, 2018, 2014

'Global Climate Report' Jan 2020 NOAA.
https://www.ncdc.noaa.gov/sotc/global/202001/supplemental/page-1
(Accessed 22.6.20)

Since temperature records began over 150 years ago (since 1850 i.e. 170 years ago)

IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

(SPM Physical Science Basis 2007/IPCC)

By 2100 4°C to 5°C/up to almost 8°C
(3.7°C/ 7.8°C)

Without additional efforts to reduce GHG emissions beyond those in place today, emissions growth is expected to persist driven by growth in global population and economic activities. Baseline scenarios, those without additional mitigation, result in global mean surface temperature increases in 2100 from 3.7 °C to 4.8 °C compared to pre-industrial levels (range based on median climate response; the range is 2.5 °C to7.8 °C when including climate uncertainty, see Table SPM.1)11 (high confidence).

(Mitigation 2014/IPCC) above

2°C would decimate our planet/1.5°C

Hoegh-Guldberg, O., D. Jacob, M. Taylor, M. Bindi, S. Brown, I. Camilloni, A. Diedhiou, R. Djalante, K.L. Ebi, F. Engelbrecht, J. Guiot, Y. Hijioka, S. Mehrotra, A. Payne, S.I. Seneviratne, A. Thomas, R. Warren, and G. Zhou, 2018: Impacts of 1.5ºC Global Warming on Natural and Human Systems. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

(1.5°C 2018/IPCC.2)

IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.

(SPM 1.5°C 2018/IPCC.3)

The Earth's Ice Cover

Ice loss 6 fold increase
http://imbie.org/wp-content/uploads/2020/03/IMBIE_UoL_Press_Release-2020-FINAL.pdf
(Accessed 22.6.20)
(Ice loss increasing)

Arctic 2°C to 3°C
(1.5°C 2018 IPCC) above

Arctic up to 5°C warmer in some areas
In the Arctic, during the 20th century, air temperatures over extensive land areas increased by up to 5°C.

Anisimov, O.A., D.G. Vaughan, T.V. Callaghan, C. Furgal, H. Marchant, T.D. Prowse, H. Vilhjálmsson and J.E. Walsh, 2007: Polar regions (Arctic and Antarctic). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, 653-685. (p.656)

0.8°C (0.76°C)
The total temperature increase from 1850–1899 to 2001–2005 is 0.76°C [0.57°C to 0.95°C].

(SPM Physical Science Basis 2007/IPCC) above
(Impacts 2007/IPCC)

Almost 300 billion tonnes of ice (280 billion tonnes)
https://climate.nasa.gov/vital-signs/ice-sheets/ (Accessed 22.6.20)

(Ice sheets/NASA)

3 Niagaras

A gigatonne (Gt) is 1 billion tonnes

Niagara Falls: 3,160 tons of water flows over Niagara Falls every second
https://www.niagarafallsstatepark.com/niagara-falls-state-park/amazing-niagara-facts
(Accessed 22.6.20)

3160 x 60 seconds x 60 minutes = 11,376,000 per hr
11,376,000 x 24 hrs = 273,024,000 tons per day x365 days
Approx 99,653,760,000 tons a year = 90 billion tonnes

Greenland losing 280 billion tonnes a year = 90 x 3 = 270 billion tonnes =
More than 3 Niagara Falls worth of water pa

(Niagara)

2019 600 billion tonnes
https://climate.nasa.gov/news/2959/grace-grace-fo-satellite-data-track-ice-loss-at-the-poles/
(Accessed 22.6.20)

(Greenland 2019)

6 Niagaras

600 billion tonnes/90 billion tonnes = 6.66

(Niagara) above

90% of the surface melted /temperatures 22°C above normal

https://www.bbc.co.uk/news/world-europe-48674797 (Accessed 22.6.20)
http://nsidc.org/greenland-today/
http://nsidc.org/greenland-today/2019/11/large-ice-loss-on-the-greenland-ice-sheet-in-2019/ (Accessed 22.6.20)

Greenland 7m or 23 ft

The available evidence indicates that sustained global warming greater than a certain threshold above pre-industrial would lead to the near-complete loss of the Greenland ice sheet over a millennium or more, causing a global mean sea level rise of about 7 m.

Church, J.A., P.U. Clark, A. Cazenave, J.M. Gregory, S. Jevrejeva, A. Levermann, M.A. Merri eld, G.A. Milne, R.S. Nerem, P.D. Nunn, A.J. Payne, W.T. Pfeffer, D. Stammer and A.S. Unnikrishnan, 2013: Sea Level Change. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

(Sea Level/Physical Science 2013/IPCC)

40% less ice in the Arctic -

Arctic sea ice reaches second lowest minimum in satellite record Sept 23rd 2019
4.15 million sq km

National Snow and Ice Data Center
http://nsidc.org/arcticseaicenews/2019/09/arctic-sea-ice-reaches-second-lowest-minimum-in-satellite-record/
(Accessed 22.6.20)

1979 7.05 million km2 1980 7.67 million km2
1981 7.14 million km2 = use this as NASA dates its decline now from the 1981 - 2010 average

7.14 millions km2 in 1981 to 4.15 million km2 in 2019 =
Arctic Sea Ice Minimum 1979-2015 with Area Graph
https://svs.gsfc.nasa.gov/4435 (Accessed 24.5.20)

4.15/7.1 = 58 % of original 7.1 m sq km i.e.
41.55% loss
https://climate.nasa.gov/vital-signs/arctic-sea-ice/
(Accessed 22.6.20)

(Arctic/NASA)

12 times the UK

UK 241,930 km2 x 10 = 2.42 million km2
Loss of Arctic sea ice 7.14 - 4.15 million km2 = approx loss of 3 million km2
= more than 12 times the UK

https://en.wikipedia.org/wiki/List_of_countries_and_dependencies_by_area
https://www.nationmaster.com/country-info/profiles/United-Kingdom
(Accessed 22.6.20)

over 12% per decade

(12.85% per decade)

(Arctic/NASA) above

Eagle Island
https://earthobservatory.nasa.gov/images/146322/antarctica-melts-under-its-hottest-days-on-record
(Accessed 24.7.20)

Antarctic vast (14,200,000 square kilometres =14.2m km2)
https://en.wikipedia.org/wiki/Antarctica (Accessed 24.7.20)

Size of US, India and Mexico combined
US 9.16m km2 India 2.97m km2 1.92m km2 = 14.05m km2
https://www.nationmaster.com/country-info/stats/Geography/Map-references (Accessed 24.7.20)

2226 m/4770m or up to 3 miles deep/90% of the world's ice

https://discoveringantarctica.org.uk/oceans-atmosphere-landscape/ice-land-and-sea/ice-sheets-and-glaciation/ (Accessed 22.6.20)

60% of the world's fresh water /60m rise in sea level
https://www.bas.ac.uk/about/antarctica/geography/ice/ (Accessed 22.6.20)

90% of world's ice (glacier ice) **2226 m** (EAIS nine times as big as WAIS)/**4770m** (4776 EAIS)
https://discoveringantarctica.org.uk/oceans-atmosphere-landscape/ice-land-and-sea/ice-sheets-and-glaciation/ (Accessed 24.5.20)

90% of world's freshwater
https://www.bas.ac.uk/science/science-and-society/education/antarctic-factsheet-geographical-statistics/
(Accessed 24.7.20)

70% fresh water
https://www.nasa.gov/home/hqnews/2007/feb/HQ_0742_antarctic_lakes.html (Accessed 24.7.20)

60 m/200 ft
https://nsidc.org/cryosphere/quickfacts/icesheets.html (Accessed 24.7.20)

Antarctic 150 billion tonnes

(147 billion tonnes pa since 2002)
(Ice sheets/NASA) above

Ice loss increasing

(Up to 265 billion tons of ice has been melting each year from 2009–2017.
A six-fold increase from the 1980's.)

The total mass loss increased from 40 ± 9 Gt/y in 1979–1990 to .....252 ± 26 Gt/y in 2009–2017. (so 45 Gt/y 1979-1990 to 265Gt/y 2009-17 265 divided by 45 = 5.88 increase - rounded to 6

Eric Rignot, Jérémie Mouginot, Bernd Scheuchl, Michiel van den Broeke, Melchior J.van Wessem, and Mathieu Morlighem. Four decades of Antarctic Ice Sheet mass balance from 1979–2017. PNAS, January 14, 2019 DOI: 10.1073/pnas.1812883116 https://www.pnas.org/content/116/4/1095 (Accessed 22.6.20)

'Mass balance of the Greenland Ice Sheet from 1992-2018' by the IMBIE Team, Nature 11th March 2020
https://www.nature.com/articles/s41586-019-1855-2
http://imbie.org/wp-content/uploads/2020/03/IMBIE_UoL_Press_Release-2020-FINAL.pdf
(Accessed 22.6.20)

https://www.theguardian.com/environment/2020/mar/11/polar-ice-caps-melting-six-times-faster-than-in-1990s
(Accessed 22.6.20)

(Ice loss increasing) above

Rift in Pine Island Glacier 2016

https://www.theverge.com/2016/11/29/13780410/antarctica-glacier-ice-sheet-melting-sea-level-rising
(Accessed 22.6.20)

Massive ice berg Feb 2020

Accelerated ice shelf rifting and retreat at Pine Island Glacier, West Antarctica
Seongsu Jeong Ian M. Howat Jeremy N. Bassis
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL071360 (Accessed 22.6.20)

Massive ice berg Feb 2020

300 km2/ 120 x 120 miles iceberg Feb 2020
https://www.nationalgeographic.com/science/2020/02/antarctica-pine-island-glacier/
(Accessed 22.6.20)

Pine Island

https://earthobservatory.nasa.gov/features/pine-island (Accessed 22.6.20)

Thwaites Glacier

https://earthobservatory.nasa.gov/images/146247/thwaites-glacier-transformed
(Accessed 22.6.20)

Every 4 to 6 years now annual event

https://www.livescience.com/pine-island-glacier-calving-retreat.html (Accessed 22.6.20)

1.2m / retreating rapidly

https://earthobservatory.nasa.gov/images/145032/two-decades-of-change-at-pine-island-glacier
(Accessed 22.6.20)

Other glaciers 250 billion tonnes pa

Ice melt from glaciers : Glaciers worldwide outside Greenland and Antarctica lost mass at an average rate of 220 ± 30 Gt yr–1 (equivalent to 0.61 ± 0.08 mm yr–1 sea level rise) in 2006–2015. {3.3.1, 4.2.3, Appendix 2.A, Figure SPM.1}

IPCC, 2019: Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.

(SPM Cryosphere 2019/IPCC)

Muir Glacier

12km/7miles 800m/2600 ft
(2625 ft)
National Snow and Ice Data Centre
https://nsidc.org/cryosphere/glaciers/questions/move.html
https://climate.nasa.gov/climate_resources/4/graphic-dramatic-glacier-melt/
(Accessed 22.6.20)

7 Niagara Falls/ 11 Niagara Falls

(Ice sheets/NASA) above 280 billion tonnes pa See (Ice Sheets/NASA) above 147 billion tonnes pa See (SPM Cryosphere 2019/IPCC) above 250 billion tonnes pa = Total 677 billion tonnes

(Niagara) above = 90 billion tonnes pa. So 677/90 = over 7 Niagara Falls

2019 Greenland 600 bn tonnes (Greenland 2019) above Antarctica 147 bn tonnes (Ice sheets/NASA) above World's glaciers 250 billion tonnes (SPM Cryosphere 2019/IPCC) = 997 billion tonnes 997/90 = 11 Niagaras

Antarctic 18.3°C

https://earthobservatory.nasa.gov/images/146322/antarctica-melts-under-its-hottest-days-on-record
(Accessed 22.6.20)

Ice Sheets are Dangerously/Professor Eric Rignot

Declaration of Eric Rignot PH D in support of Plaintiffs Urgent Motion Under
Circuit Rule 27-3(b) for Preliminary Injunction in Juliana, et al. v. United States of America, et al.

https://static1.squarespace.com/static/571d109b04426270152febe0/t/
5cae37ee9b747a781fadfcf5/1554921459623/DktEntry+21-13+Rignot+Dec+ISO+Urgent+Motion+for
+Preliminary+Injunction.pdf (Accessed 22.6.20)

Sea Level Rise

20 cm

Over the period 1901 to 2010, global mean sea level rose by 0.19 (0.17–0.21) m (high confidence) (Church et al., 201398; Table SM1.1).

Abram, N., J.-P. Gattuso, A. Prakash, L. Cheng, M.P. Chidichimo, S. Crate, H. Enomoto, M. Garschagen, N. Gruber, S. Harper, E. Holland, R.M. Kudela, J. Rice, K. Steffen, and K. von Schuckmann, 2019: Framing and Context of the Report. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.

Rate of sea level rise is accelerating - rising twice as fast as it was last century

GMSL from tide gauges and altimetry observations increased from 1.4 mm yr–1 over the period 1901–1990 to 2.1 mm yr–1 over the period 1970–2015 to 3.2 mm yr–1 over the period 1993–2015 to 3.6 mm yr–1 over the period 2006–2015 (high confidence).

So 1.4 increasing to 3.6 mm yr-1 = more than twice as fast

Oppenheimer, M., B.C. Glavovic , J. Hinkel, R. van de Wal, A.K. Magnan, A. Abd-Elgawad, R. Cai, M. Cifuentes-Jara, R.M. DeConto, T. Ghosh, J. Hay, F. Isla, B. Marzeion, B. Meyssignac, and Z. Sebesvari, 2019: Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.

(Sea Level Rise/Cryosphere 2019 IPCC)

Tuvalu /1997 lost first island
(Tepuka Savilivili)
https://www.theguardian.com/environment/2002/feb/16/weekendmagazine.globalwarming
(Accessed 22.6.20)

11,500
(11,508 in 2018)
https://data.worldbank.org/indicator/SP.POP.TOTL?locations=TV
(Accessed 22.6.20)

Some islanders left

https://borgenproject.org/facts-about-tuvalu-refugees/ (Accessed 22.6.20)
http://www.moyak.com/papers/tuvalu-climate-change.html (Accessed 22.6.20)

Under water in coming decades

https://www.rnz.co.nz/news/political/308703/pacific-atolls-could-be-underwater-by-2050
(Accessed 22.6.20)

30 - 60 cm / 1m

GMSL is projected to rise between 0.43 m (0.29–0.59 m, likely range) under RCP 2.6 and 0.84 m (0.61–1.10 m, likely range) under RCP 8.5 by 2100 (Figure 4.3) (relative to1986–2005)

Risen 20 cm from 1901 to 2010 - plus 30-60cm relative to 1986 -2005 - slight cross over

(Sea Level Rise/Cryosphere 2019 IPCC) above

80% of the Maldives 1200 islands less than 1 metre above sea level

http://news.bbc.co.uk/1/hi/world/south_asia/3930765.stm (Accessed 22.6.20)

Sea level was 6 to 9m higher in the past when temperatures same as today

GMSL was considerably higher than today during past climate states that were warmer than pre-industrial, including the Last Interglacial (LIG; 129–116 ka), when global mean surface temperature was 0.5ºC–1.0ºC warmer, and the mid-Pliocene Warm Period (mPWP; ~3.3 to 3.0 million years ago), 2ºC–4ºC warmer. Despite the modest global warmth of the Last Interglacial, GMSL was likely 6–9 m higher, mainly due to contributions from the Greenland and Antarctic ice sheets (GIS and AIS, respectively), and unlikely more than 10m higher (medium confidence).

IPCC, 2019: Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O.Pörtner,D.C.Roberts,V.Masson-Delmotte,P.Zhai,M.Tignor,E.Poloczanska,K.Mintenbeck,A.Alegría,M.Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.

(SPM Cryosphere 2019/IPCC)

680 million/ Up to one billion people

The low-lying coastal zone is currently home to around 680 million people (nearly 10% of the 2010 global population), projected to reach more than one billion by 2050.

(SPM Cryosphere 2019/IPCC) above

2018 1.56 metre

https://www.theguardian.com/world/2018/oct/29/venice-experiences-worst-flooding-since-2008 (Accessed 22.6.20)

2019 1.87m

https://www.bbc.co.uk/news/world-europe-50401308 (Accessed 22.6.20)

Jakarta, Kolkata (Calcutta), New Orleans, Miami already flooded /
Mumbai, Shanghai, Tokyo, New York are all also threatened /
US$ 3 trillion /US$35 trillion or almost 10% (9%) **of global GDP**

New York (Newark)

Ranking of the World's Cities most exposed to coastal flooding today and in the future' ,
OECD, RMS, Uni of Southampton, C.I.R.E.D, Tyndall Centre, Meteo France
Executive Summary

https://climate-adapt.eea.europa.eu/metadata/publications/ranking-of-the-worlds-cities-to-coastal-flooding/11240357 (Accessed 22.6.20)

(Cities/Coastal flooding)

Ice sheets will keep melting and sea level will keep rising for centuries

(SPM Cryosphere 2019/IPCC) as above

Distribution Frequency and Intensity of Rainfall

Changing distribution of rainfall/more extreme longer droughts

Seneviratne, S.I., N. Nicholls, D. Easterling, C.M. Goodess, S. Kanae, J. Kossin, Y. Luo, J. Marengo, K. McInnes, M. Rahimi,M. Reichstein, A. Sorteberg, C. Vera, and X. Zhang, 2012: Changes in climate extremes and their impacts on the natural physical environment. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen,M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 109-230.

N**orthern England and southern Scotland flood levels increased 11% per decade** .

'Changing climate both increases and decreases European river floods'.
Blöschl G[1], Hall J[1], Viglione A[1], Perdigão RAP[1], Parajka J[1], Merz B[2], Lun D[1], Arheimer B[3], Aronica GT[4], Bilibashi A[5], Boháč M[6], Bonacci O[7], Borga M[8], Čanjevac I[9], Castellarin A[10], Chirico GB[11], Claps P[12], Frolova N[13], Ganora D[12], Gorbachova L[14] ... [Show all 47] ... Živković N[35]
Author information
Nature, 28 Aug 2019, 573(7772):108-111
DOI: 10.1038/s41586-019-1495-6 PMID: 31462777

https://www.nature.com/articles/s41586-019-1495-6
https://www.ceh.ac.uk/press/changing-climate-linked-major-changes-flooding
(Accessed 22.6.20)

The number of floods increased by over 1/3 / 2.3 billion people to be flooded since1995 alone /2 billion from Asia

over 1/3 : 171 2005-2014 , 127 floods previous decade
95% of those affected by floods live in Asia i.e. 95% of 2.3 billion = over 2 billion

The Human Cost of Weather Related Disasters 1995-2015
Centre for Research on the Epidemiology of Disasters CRED /UNISDR

The number of floods per year rose to an average of 171 in the period 2005-2014, up from an annual average of 127 in the previous decade.
171/127 = 1.35 = 35%

https://www.unisdr.org/files/46796_cop21weatherdisastersreport2015.pdf (Accessed 22.6.20)

23 million people were inundated by floods in Kerala, India, in 2018/ 500 died

(Image taken from Bangladesh as not able to find Kerala such image of people neck deep in water)

India: Kerala Floods DREF n° MDRIN020 Emergency Plan of Action Final Report
Source IFRC Published 1 May 2019 Origin View original
https://reliefweb.int/report/india/india-kerala-floods-dref-n-mdrin020-emergency-plan-action-final-report
(Accessd 22.6.20)

Drought-stricken Areas

Dry areas in the world have more than doubled since the 1970's !!

Globally, very dry areas, (Palmer Drought Severity Index PDSI ≤ -3) have more than doubled since the 1970's due to a combination of ENSO events and surface warming ..p.90:

IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.

Water in Niger, Lake Chad and Senegal has decreased by 40–60% .

United Nations Fact Sheet on Climate Change Africa is particularly vulnerable to the expected impacts of global warming https://unfccc.int/files/press/backgrounders/application/pdf/factsheet_africa.pdf
(Accessed 24.7.20)

The 2003 and 2004 South African drought affected a total of 27 million people / Ethiopia's 2015 drought

2003 and 2004 South African drought (15 million & 12.6 million people affected respectively), 2015 Ethiopian drought (10.2 million people affected),

Disasters in Africa: 20 Year Review (2000-2019*) https://www.emdat.be/publications (Accessed 24.7.20)

Southern Africa reduction in water/400 million

From 200 million (2007 report) to 600 million in 2050 :

Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo and P.Yanda,

2007: Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II

to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F.

Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge

UK, 433-467.

(Africa)

2010-12 Somalian drought almost 260,000 deaths/half children under 5.

258,000 people and 133,000 children

Famine Early Warning Systems Network

https://fews.net/east-africa/somalia/special-report/may-2013 (Accessed 22.6.20)

Dada

https://www.unhcr.org/ke/dadaab-refugee-complex (Accessed 22.6.20)

Africa 1.3 billion people today/2.5 billion 2050
https://www.bbc.co.uk/news/world-africa-35038878 (Accessed 22.6.20)
(1.3349 bn+)/ (2,489,275,458 by 2050)
(www.Worldometers.info) (Accessed 22.6.20)

United Nations, World Population Prospects 2019/

https://qz.com/africa/1099546/population-growth-africans-will-be-a-third-of-all-people-on-earth-by-2100/ (Accessed 22.6.20)

Somalia 2017 Estimated 9 million livestock
(estimated half of 18 million livestock)

https://www.theguardian.com/global-development/2017/may/24/somaliland-hunger-crisis-world-doesnt-respond-until-children-are-dying-foreign-minister-saad-ali-shire (Accessed 22.6.20)

Mother-of-three, Nimo Mohamed Abdi,Awdal, Horn of Africa

https://www.islamic-relief.org/famine-fears-severe-drought-east-africa/ (Accessed 22.6.20)

Drought stricken land areas 1% to 30%

p.782 in the A2 scenario (Burke et al., 2006).
Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver and Z.-C. Zhao, 2007: Global Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

<u>Hurricanes</u>

Warmer waters more powerful storms

https://oceanexplorer.noaa.gov/facts/hurricanes.html (Accessed 22.6.20)

Doubling of Cat 4 and 5

With thanks to Steve Bowen and his team, Director & Meteorologist,Head of Catastrophe Insight Impact Forecasting Aon Email 14th March 2020 with the information

Cat 5 3 fold increase

https://en.wikipedia.org/wiki/List_of_Category_5_Atlantic_hurricanes

https://en.wikipedia.org/wiki/List_of_Category_5_Pacific_hurricanes (Accessed 22.6.20)

Tropical Cyclones and Climate Change Assessment: Part I: Detection and Attribution
Thomas Knutson
NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey

II) "Tropical Cyclones and Climate Change Assessment: Part II. Projected Response to Anthropogenic Warming"
Main report .pdf file for Part II.
Supplemental material for Part II: 1) Supplemental text; 2) Model projections tables; and 3) Author elicitation responses.)

https://www.gfdl.noaa.gov/global-warming-and-hurricanes/ (Accessed 22.6.20)

Hurricane Katrina storm surge 9 m almost 30 ft
(9.1m)
https://www.nps.gov/articles/storm-surge.htm (Accessed 22.6.20)

Over 1800 people, 80% of the city, 6m
https://www.weather.gov/jetstream/katrina (Accessed 22.6.20)

us$125 billion
National Hurricane Center NOAA
Costliest U.S. tropical cyclones tables updated
https://www.nhc.noaa.gov/news/UpdatedCostliest.pdf (Accessed 22.6.20)

2017 Hurricane Harvey, Maria and Irma damages of over US$300 billion (US$130 bn, US$93 bn, US $78bn = US$301 bn) **/10 hurricanes /us$700 billion (US$693.3 billion }**

Costliest

Hurricane Harvey	2017	US$130 bn	(1)
Hurricane Katrina	2005	US125 bn	(2)
Hurricane Maria	2017	US$ 93 bn	(1)
Hurricane Andrew	1992	US$87 bn	(3)
Hurricane Sandy	2012	US$ 85 bn	(1)
Hurricane Irma	2017	US$ 78 bn	(1)
Hurricane Ike	2008	US$30 bn	(2)
Hurricane Wilma	2005	US$29.0 bn	(4)
Hurricane Ivan	2004	US$20.5 bn	(2)
Hurricane Charley	2004	US$ 16 bn	(2)
		US$693.3 bn	

(1) Weather Climate Catastrophe Insight 2019 Annual Report
Aon
https://www.aon.com/unitedkingdom/insights/Weather-Climate-Catastrophe-Insight-2019-Report.jsp
(Accessed 22.6.20)

(2)
National Hurricane Center NOAA
Costliest U.S. tropical cyclones tables updated
https://www.nhc.noaa.gov/news/UpdatedCostliest.pdf

(3) A hurricane is approaching. Are you ready or not?
Munich Re Melanie Instead
https://www.munichre.com/topics-online/en/climate-change-and-natural-disasters/natural-disasters/storms/hurricane-florence.html (Accessed 22.6.20)

(4) Hurricanes, Science and Society
http://www.hurricanescience.org/history/storms/2000s/wilma/ (Accessed 22.6.20)

Economic losses US$96 billion to US$442 billion/ Insured losses US$20 billion to US$171 billion

With thanks to Steve Bowen and his team, Director & Meteorologist,Head of Catastrophe Insight Impact Forecasting Aon Email 14th March 2020 with the information

Bahamas 24 hours with 185 mphr/ 7m waves /70 people

https://en.wikipedia.org/wiki/Hurricane_Dorian (Accessed 22.6.20)
Waves : https://public.wmo.int/en/media/news/hurricane-dorian-causes-devastation-bahamas (Accessed 22.6.20)

Heatwaves

2019 UK 38.7C Germany 42.6°C and France 46°C !

https://public.wmo.int/en/media/news/july-matched-and-maybe-broke-record-hottest-month-analysis-began (Accessed 22.6.20)

India 48°C

https://www.bbc.co.uk/news/world-asia-india-32872846 (Accessed 22.6.20)

2,500 deaths

https://www.britannica.com/event/India-Pakistan-heat-wave-of-2015 (Accessed 22.6.20)

Russia 2010 56,000

https://www.reuters.com/article/us-russia-heat-deaths-idUSTRE69O4LB20101025 (Accessed 22.6.20)

Russia 44°C

https://www.metoffice.gov.uk/weather/learn-about/weather/case-studies/russian-heatwave (Accessed 22.6.20)

European Heatwave 2003 /approx 70,000 deaths

Report on excess mortality in Europe during summer 2003 (EU Community Action Programme for Public Health, Grant Agreement 2005114)
by JM Robine, SL Cheung, S Le Roy, H Van Oyen et F R Herrmann
https://ec.europa.eu/health/ph_projects/2005/action1/docs/action1_2005_a2_15_en.pdf
(Accessed 22.6.20)

European Heatwave 2003 temperatures 38-47.4°C

47.4°C in Portugal
https://www.severe-weather.eu/event-analysis/max-temperatures-ever-recorded-in-portugal/ (Accessed 22.6.20)
https://en.wikipedia.org/wiki/2003_European_heat_wave (Accessed 22.6.20)

2016 51°C in India (Phalodi) , Almost 54°C (53.9°C) **in Iraq (Basra),**

Provisional WMO Statement on the Status of the Global Climate in 2016
https://public.wmo.int/en/media/press-release/provisional-wmo-statement-status-of-global-climate-2016 (Accessed 22.6.20)

Kuwait (Mitribah) 54°C in 2016.
https://www.climatecentre.org/news/758/wmo-will-research-whether-reported-54-c-in-kuwait-heatwave-sets-official-all-time-eastern-hemisphere-record (Accessed 22.6.20)

2017 Iran (Ahwaz) 53.7°C / Pakistan (Turbat) 54°C

State of the Global Climate 2017
https://www.un.org/sustainabledevelopment/blog/2017/11/wmo-statement-on-state-of-climate-in-2017/ (Accessed 22.6.20)

IPCC Globes

Figure 12.11 from Collins, M., R. Knutti, J. Arblaster, J.-L. Dufresne, T. Fichefet, P. Friedlingstein, X. Gao, W.J. Gutowski, T. Johns, G. Krinner, M. Shongwe, C. Tebaldi, A.J. Weaver and M. Wehner, 2013: Long-term

Climate Change: Projections, Commitments and Irreversibility. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. (https://www.ipcc.ch/report/ar5/wg1/)

0.6°C

(0.61°C ± 0.06°C)

The observed warming to the 1986–2005 reference period (see Section 2.4.3) is 0.61°C ± 0.06°C (1850–1900), 0.30°C ± 0.03°C (1961–1990), 0.11°C ± 0.02°C (1980–1999).

Collins, M., R. Knutti, J. Arblaster, J.-L. Dufresne, T. Fichefet, P. Friedlingstein, X. Gao, W.J. Gutowski, T. Johns, G. Krinner, M. Shongwe, C. Tebaldi, A.J. Weaver and M. Wehner, 2013: Long-term Climate Change: Projections, Com- mitments and Irreversibility. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter12_FINAL.pdf

(note that to translate the anomalies in Figure 12.5 into anomalies with respect to that period, an assumed 0.61°C of observed warming since 1850–1900, as discussed in Section 2.4.3, should be added) p.1054 Chap 12 WGI 2013 .

2100 heatwaves threaten the majority of Mankind

48% threatened with drastic reductions of greenhouse gas emissions and 74% threatened under a scenario of growing emissions.
Mora, C., Dousset, B., Caldwell, I. et al. Global risk of deadly heat. Nature Clim Change 7, 501–506 (2017). https://doi.org/10.1038/nclimate3322 (Accessed 22.6.20)

Wildfires

Supersize wildfires

How Megafires Are Remaking American Forests
BY LAURA PARKER, NATIONAL GEOGRAPHIC
https://www.nationalgeographic.com/news/2015/08/150809-wildfires-forest-fires-climate-change-science/ (Accessed 22.6.20)
https://www.theguardian.com/environment/2019/dec/20/scientists-fear-surge-in-supersized-bushfires-that-create-their-own-violent-thunderstorms (Accessed 22.6.20)

2019 Australia's hottest driest year

Annual Climate Statement 2019
Bureau of Meteorology
http://www.bom.gov.au/climate/current/annual/aus/ (Accessed 22.6.20)

49.9°C
(in Nullarbor)
Australia heatwave: All-time temperature record broken again
https://www.bbc.co.uk/news/world-australia-50837025 (Accessed 22.6.20)

18 million hectares = 180,000 km2

https://www.unenvironment.org/news-and-stories/story/ten-impacts-australian-bushfires
(Accessed 22.6.20)

Area larger than the state of Florida 170,311 km2

https://www.britannica.com/place/Florida (Accessed 22.6.20)

Fires Amazon Africa Alaska

https://www.nytimes.com/2019/08/28/climate/fire-amazon-africa-siberia-worldwide.html
(Accessed 22.6.20)

California 2019

https://www.fire.ca.gov/incidents/2019/ (Accessed 22.6.20)

1 billion creatures died

More than one billion animals killed in Australian bushfires
The figure includes mammals (excluding bats), birds and reptiles and does not include frogs, insects or other invertebrates. NSW's wildlife is seriously threatened and under increasing pressure from a range of threats, including land clearing, exotic pests and climate change.
https://sydney.edu.au/news-opinion/news/2020/01/08/australian-bushfires-more-than-one-billion-animals-impacted.html (Accessed 22.6.20)

70m flames

NSW bushfires: 60 - 70 m flames confront firefighters in the Blue Mountains - video
https://www.theguardian.com/global/video/2019/dec/16/nsw-bushfires-60-70m-flames-confront-firefighters-in-the-blue-mountains-video (Accessed 22.6.20)

Why Australia's 2019 - 2020 bushfire season was not normal, in three graphs

https://www.unenvironment.org/news-and-stories/story/why-australias-2019-2020-bushfire-season-was-not-normal-three-graphs (Accessed 22.6.20)

Species

1°C severe impact

https://www.iucn.org/resources/issues-briefs/species-and-climate-change (Accessed 22.6.20)

1°-2°C causes bleaching

Coral Reefs and Climate Change
A spike of 1°–2°C in ocean temperatures sustained over several weeks can lead to bleaching, turning corals white. If corals are bleached for prolonged periods, they eventually die.
https://www.iucn.org/resources/issues-briefs/coral-reefs-and-climate-change
(Accessed 22.6.20)

25- 50% corals destroyed

UNEP estimates that about 25 to 50% per cent of the world's coral reefs have been destroyed
https://www.unenvironment.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/coral-reefs
(Accessed 22.6.20)

85% coral reefs gone / all lost

(25 out of 29 World Heritage Reefs) :
Impacts of Climate Change on World Heritage Coral Reefs A First Global Scientific Assessment
United Nations Educational, Scientific and Cultural Organisation / World Heritage Convention
http://whc.unesco.org/en/news/1676 (Accessed 22.6.20)
https://www.unenvironment.org/news-and-stories/story/perfect-storm-when-climate-change-stokes-wildfires-marine-heatwaves-and

A quarter all fish marine species
(4000 coral reef fish species)
[1] Spalding MD, Ravilious C, Green EP (2001) World Atlas of Coral Reefs. United Nations Environment Programme, World Conservation Monitoring Centre. University of California Press: Berkeley. 416pp. https://archive.org/details/worldatlasofcora01spal/page/26/mode/2up?q=quarter+of+all+marine+species
(Accessed 22.6.20)

Arctic Polar bears are starving/ Female bear 420 miles (426) **20%** (22%)

Polar Bears Really Are Starving Because of Global Warming, Study Shows Stephen Leahy https://www.nationalgeographic.com/news/2018/02/polar-bears-starve-melting-sea-ice-global-warming-study-beaufort-sea-environment/ (Accessed 22.6.20)

More than 30% of the polar bear population could be lost by 2060
(over next 3 generations 35 to 41 years i.e. by 2060)
Wiig, Ø., Amstrup, S., Atwood, T., Laidre, K., Lunn, N., Obbard, M., Regehr, E. & Thiemann, G. 2015. Ursus maritimus . The IUCN Red List of Threatened Species 2015: e.T22823A14871490.
https://www.iucnredlist.org/species/22823/14871490
https://royalsocietypublishing.org/doi/10.1098/rsbl.2016.0556 (Accessed 22.6.20)

I million animal and plant species face extinction
The IPBES Global Assessment Report on Biodiversity and Ecosystem Services (2019)
https://ipbes.net/global-assessment (Accessed 22.6.20)

Surprises

Permafrost is thawing

The permafrost region represents a large, climate sensitive reservoir of organic carbon with the potential for some of this pool to be rapidly decayed and transferred to the atmosphere as CO2 and methane as permafrost thaws in a warming climate, thus accelerating the pace of climate change .
Schuur, E., McGuire, A., Schädel, C. et al. Climate change and the permafrost carbon feedback. Nature 520, 171–179 (2015). https://doi.org/10.1038/nature14338 (Accessed 22.6.20)

Permafrost contains almost twice the amount of carbon as exists in Earth's atmosphere -
(1700 Pg)
Tarnocai, C. et al. Soil organic carbon pools in the northern circumpolar permafrost region. Glob. Biogeochem. Cycles 23, GB2023 (2009)
MacDougall, A., Avis, C. & Weaver, A. Significant contribution to climate warming from the permafrost carbon feedback. Nature Geosci 5, 719–721 (2012).
https://www.nature.com/articles/ngeo1573?draft=marketing (Accessed 22.6.20)

68 and 508 Pg carbon by 2100
Methane Lakes
https://earthdata.nasa.gov/learn/sensing-our-planet/leaking-lakes (Accessed 22.6.20)

25% of the land in the northern hemisphere has permafrost.
International Permafrost Association
https://ipa.arcticportal.org/publications/occasional-publications/what-is-permafrost (Accessed 22.6.20)

Methane over 30 times as powerful
https://blogs.princeton.edu/research/2014/03/26/a-more-potent-greenhouse-gas-than-co2-methane-emissions-will-leap-as-earth-warms-nature/ (Accessed 24.7.20)

Permafrost could release up to 175 Gigatons this century
(up to 174 Pg with high emissions)

21st-century modeled permafrost carbon emissions accelerated by abrupt thaw beneath lakes

Katey Walter Anthony, Thomas Schneider von Deimling, Ingmar Nitze, Steve Frolking, Abraham Emond, Ronald Daanen, Peter Anthony, Prajna Lindgren, Benjamin Jones & Guido Grosse
https://www.nature.com/articles/s41467-018-05738-9#change-history (Accessed 24.7.20)

Climate Change and the Permafrost Carbon Feedback
E A G Schuur 1 , A D McGuire 2 , C Schädel 1 , G Grosse 3 , J W Harden 4 , D J Hayes 5 , G Hugelius 6 , C D Koven 7 , P Kuhry 6 , D M Lawrence 8 , S M Natali 9 , D Olefeldt 10 , V E Romanovsky 11 , K Schaefer 12 , M R Turetsky 13 , C C Treat 14 , J E Vonk
The new northern permafrost zone carbon inventory reports the surface permafrost carbon pool (0–3m) to be 1,0356150Pg carbon (mean6 95% confidence interval, CI)[12,20] (where 1Pg51billion tons) (Fig. 1a). Model scenarios show potential carbon release from the permafrost zone in the range 37–174 Pg carbon by 2100

under the current climate warming trajectory (Representative Concentration Pathway RCP8.5), with an average across models of 92 6 17 Pg carbon (mean 6 s.e.) (Fig. 3)[45–5]

130-150 GtC https://www.bbc.com/future/article/20190612-the-poisons-released-by-melting-arctic-ice (Accessed 22.6.20)

2019 Arctic report card

Thawing permafrost throughout the Arctic could be releasing an estimated 300-600 million tons of net carbon per year to the atmosphere.
https://arctic.noaa.gov/Report-Card (Accessed 22.6.20)

That's about 18 years worth of current global emissions !

gigaton = 1 billion metric tons x 0.907185 tonnes

36 billion tonnes of CO2 pa x 0.27 = 9.72 billion tonnes carbon
174 bn ton x 0.907185 = divided by 9.72 = 16.24 to 17.9 years worth
https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions (Accessed 22.6.20)

Siberia 30°C hotter May 2020

https://phys.org/news/2020-06-warmest-siberia-10c-hotter.html
https://www.theguardian.com/environment/2020/jun/17/climate-crisis-alarm-at-record-breaking-heatwave-in-siberia
https://www.cnbc.com/2020/05/29/heat-wave-scorches-us-india-siberia-experiences-record-highs.html
(Accessed 22.6.20)

Rapid warming of Greenland 10°C

https://www.ncdc.noaa.gov/abrupt-climate-change/The%20Younger%20Dryas (Accessed 22.6.20)
The Younger Dryas cold interval as viewed from central Greenland
January 2000Quaternary Science Reviews 19(1):213-226 DOI: 10.1016/S0277-3791(99)00062-1
Richard B. Alley

White surface of ice
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Time Lag

Time Lag 20-50 yrs

20 years
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25- 50 years to reach 60% of its equilibrium response :

Earth's Energy Imbalance: Confirmation and Implications
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https://earthjustice.org/sites/default/files/black-carbon/hansen-et-al-2005-earths-energy-imbalance.pdf
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30-50%
The Economics of Climate Change' (2006) The Stern Review Report c Crown Copyrght p.3&16

Act Now

1.5°C/45%/net zero 2050/six-fold

IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.

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