# Abkürzungen

AOGCMs Atmosphere–Ocean General Circulation Models
AOGCMs typically represent the physical behaviour of the atmosphere and oceans but atmospheric composition, such as the amount of CO2 in the atmosphere, is prescribed as an input to the model. This approach neglects the fact that changes in climate might affect the natural biogeochemical cycles, which control atmospheric composition, and so there is a need to represent these processes in climate projections.

$C^4$Models Coupled Climate / Carbon-Cycle models. At their core is the
- physical climate model,
- but additional components of land and ocean biogeochemistry respond to the changes in the climate conditions to influence in return the atmospheric CO2 concentration.

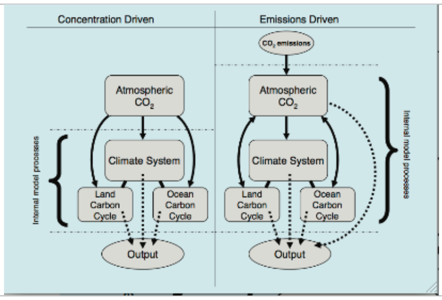
Input to the models comes in the form of anthropogenic CO2 emissions,
- which can increase the CO2 and
- then the natural carbon cycle exchanges CO2 between the atmosphere and land and ocean components.

These 'climate / carbon-cycle models' ('Earth System Models', ESMs) provide a predictive link between fossil fuel CO2 emissions and future CO2 concentrations and climate and are an important part of the CMIP5 experimental design.

$C^4$MIP Coupled Climate / Carbon-Cycle Intercomparison Project
CAM Community Atmosphere Model
CMIP5 Coupled Model Intercomparison Project Phase 5
Climate Models https://en.wikipedia.org/wiki/Climate_model
CLM Climate Limited-area Modelling
CWC (NCAR's) Cumulative Warming Committment
CESM Community Earth System Model
- CESM is a fully-coupled, community, global climate model that provides state-of-the-art computer simulations of the Earth's past, present, and future climate states.
- The CESM coupled model is based on a framework which divides the complete climate system into component models that are connected by a coupler component.
  - The coupler controls the execution and time evolution of the complete system by synchronizing and controlling the flow of data between the various components.
  - It also communicates interfacial states and fluxes between the various component models while ensuring the conservation of fluxed quantities.

Climate model A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for some of its known properties.
The climate system can be represented by models of varying complexity; that is, for any one component or combination of components a spectrum or hierarchy of models can be identified, differing in such aspects as
- the number of spatial dimensions,
- the extent to which physical, chemical or biological processes are explicitly represented, or
- the level at which empirical parametrizations are involved.

There is an evolution towards more complex models with interactive chemistry and biology.
Climate models are applied as a research tool to study and simulate the climate and for operational purposes, including monthly, seasonal and interannual climate predictions.




Box 6.4, Figure 1 | Schematic representation of carbon cycle numerical experimental design. Concentration-driven (left) and emissions-driven (right) simulation experiments make use of the same Earth System Models (ESMs), but configured differently.
- Concentration-driven simulations prescribe atmospheric CO2 as a pre- defined input to the climate and carbon cycle model components, but their output does not affect the CO2. Compatible emissions can be calculated from the output of the concentration-driven simulations.
- Emissions-driven simulations prescribe CO2 emissions as the input and atmospheric CO2 is an internally calculated element of the ESM.

CRF- Systematik. Hierbei erfolgt die Strukturierung in erster Linie nach Art der Emissionen (beispielsweise verbrennungsbedingt, flüchtig oder prozessbedingt). Eine Unterteilung nach Sektoren erfolgt in Unterkategorien (beispielsweise verbrennungsbedingte Emissionen der Industrie oder verbrennungsbedingte Emissionen der Haushalte). Diese Strukturierung ist unabdingbar, um den europäischen und internationalen Berichtspflichten nachzukommen und eine Vergleichbarkeit mit den Projektionen anderer Län- der sicherzustellen. Diese Strukturierung wurde in den bislang erstellten Projektionsberichten vorgenommen und ist so auch im Projektionsbericht 2019 maßgeblich.

Common Reporting Format-Systematik (Quellgruppen des Treibhausgasinventars). Diese unterscheidet nach dem Quellenprinzip folgende Sektoren:
a) Energie
   - sowohl verbrennungsbedingte, darunter
     - Energiewirtschaft,
     - Industrie,
     - Verkehr,
     - Haushalte und Gewerbe,
     - Handel und Dienstleistungen
   - als auch diffuse Emissionen
b) Industrieprozesse und Produktverwendung
c) Landwirtschaft
d) Landnutzung, Landnutzungsänderung und Forstwirtschaft
e) Abfallwirtschaft und Abwasser
f) Sonstige

Die Sektoren sind hierarchisch weiter in Teilsektoren bzw. Quellgruppen unterteilt, wobei eine alphanummerische Systematik zur weiteren Unterteilung verwendet wird. Dabei können aus einer Anlage Emissionen in mehreren Quellgruppen entstehen.
Beispielsweise wird
- der energetische Teil der Emissionen aus der Zementherstellung in der Quellgruppe 1.A.2.f bilanziert,
- der auf die chemische Reaktion entfallende prozessbedingte Anteil in der Quellgruppe 2.A.1.

Die Anwendung des Quellprinzips führt ... dazu, dass im Projektionsbericht keine vollständigen Life-Cycle-Minderungen von Maßnahmen berechnet werden können. Die Effekte einer Maßnahme können in mehreren Sektoren auftreten
- z.B. Elektromobilität führt zu
  - höheren Stromemissionen, ggf.
  - höheren flüchtigen Emissionen von Kohle/Gas, und
  - zu geringeren Umwandlungsemissionen (Raffinerien)).
- Direkt sichtbar an den Verkehrsemissionen ist in der Quell-Methodik aber nur die Kraftstoffeinsparung.

CRF UNFCCC National Inventory Submissions Common Reporting Format Tables (CRF)

ECS Equilibrium Climate Sensititvity (DT2x = about 2.8 degrees Celsius, for more details see below)
Estimates of the **equilibrium climate sensitivity** (ECS) based on
- observed climate change
- climate models and feedback analysis, as well as
- paleoclimate evidence

indicate that ECS is likely in the range
- 1.5°C to 4.5°C with high confidence,
- extremely unlikely less than 1°C (high confidence) and
- very unlikely greater than 6°C (medium confidence).
- The **transient climate response** (TCR) is likely in the range 1°C to 2.5°C and extremely unlikely greater than 3°C, based on observed climate change and climate models.(Quelle: Ch 12, page 1033, WG1AR5_all_final),

EMIC Earth System Model with Intermediate Complexity
ERF Effective Radiative Forcing
ESM Earth System Model also called climate / carbon-cycle models
A coupled atmosphere–ocean general circulation model in which a representation of the carbon cycle is included, allowing for interactive calculation of atmospheric CO2 or compatible emissions. Additional components (e.g., atmospheric chemistry, ice sheets, dynamic vegetation, nitrogen cycle, but also urban or crop models) may be included. See also Climate model.

The ESMs are made up of many 'components', corresponding to different processes or aspects of the system. To understand their behaviour, techniques have been applied to assess different aspects of the models' sensitivities (Friedlingstein et al., 2003, 2006; Arora et al., 2013). The two dominant emerging interactions are the sensitivity of the carbon cycle
- to changes in CO2 and its sensitivity
- to changes in climate.

Bildungsserver: Zwar werden Kohlendioxid, Aerosole, Ozon und Vegetation auch in den gekoppelten Atmosphäre-Ozean-Modellen berücksichtig, aber ohne interaktive Rückkopplungen mit dem physikalischen Klimasystem (d.h. man gibt z.B. CO2-Konzentrationen vor). Gerade die Einbeziehung dieser Rückkopplungen in die Klimasimulation macht den Unterschied zwischen einem physikalischen Klimamodell und einem Erdsystemmodell aus.
... In früheren Modellen wurde das CO2 hauptsächlich als externer Antrieb für Klimaänderungen berücksichtigt. Das durch menschliche Tätigkeiten emittierte Kohlendioxid geht in der Natur jedoch in einen Kreislauf ein, der auf das physikalische Klimasystem zurückwirkt. Ozean und Landvegetation spielen dabei eine zentrale Rolle, indem sie etwa die Hälfte des anthropogenen CO2 als Netto-Senken aus der Atmosphäre aufnehmen. Ihre Aufnahmekapazität verändert sich jedoch unter dem Einfluss des durch das CO2 hervorgerufenen Klimawandels.
- Das in der **Atmosphäre** verbleibende CO2
  - erhöht die Temperatur
    - der Atmosphäre und als Folge auch
    - des Ozeans,
  - verändert den Niederschlag und
  - fördert die Photosynthese der Pflanzen, wodurch die Senken-Funktion von Landvegetation und Ozean erheblich beeinflusst wird.
- Ein wärmerer **Ozean** kann weniger CO2 aufnehmen.

        - D.h. mehr Kohlendioxid verbleibt in der Atmosphäre, die dadurch wärmer wird,
        - was wiederum die Temperatur des Ozeans erhöht,
        - der dadurch noch weniger Kohlendioxid aufnehmen kann usw.

    ein positiver Rückkopplungsprozess.

- **Pflanzen** werden durch mehr $CO_2$ in ihrem Wachstum zwar gefördert und können dadurch mehr Photosynthese betreiben.
    - Gleichzeitig können verringerte Niederschläge in bestimmten Regionen der Erde das Pflanzenwachstum einschränken, wodurch weniger $CO_2$ aufgenommen wird.
    - Und die höheren Temperaturen führen zu einer Verstärkung der Zersetzung von organischem Material und damit zu einer höheren $CO_2$-Freisetzung.

Diese Rückkopplungsmechanismen in ein Modell einzubeziehen und in Projektionen zur zukünftigen Klimaentwicklung zu integrieren macht die besondere Qualität von **Erdsystemmodellen** gegenüber früheren **Ozean-Atmosphäre-Modellen** aus.

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GCM — General Circulation Model

GMST — global mean surface temperature

HadCM3 — Hadley Centre coupled ocean-atmosphere model,

HadOCC — ocean carbon-cycle model. It accounts for
- the atmosphere - ocean exchange of $CO_2$, and
- the transfer of $CO_2$ to depth through both
    - the solubility pump and
    - the biological pump

HadSCCCM1 — Hadley Centre Simple Climate / Carbon-Cycle Model

IPCC — Intergovernmental Panel on Climate Change - made up of over 2000 scientific and technical experts from around the world

MAGICC — Model for the Assessment of **Greenhouse**-gas Induced Climate Change. This is a reduced-complexity carbon cycle, atmospheric composition and climate model (more)

MME — Multi-Model Ensembles

NCAR — National Center for Atmospheric Research

NDC — The Paris Agreement (Article 4, paragraph 2) requires each Party to prepare, communicate and maintain successive nationally determined contributions (NDCs) that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions.

OAGCMs — ocean–atmosphere general circulation models

Parametrizing — expressing in relatively simple terms

Parameterization of structural uncertainties. One advantage of simple models is that they can be used to span structural uncertainties across more complex models.
- Structural uncertainties in AOGCMs arise from the way certain processes or components (such as clouds) are "parameterized" or expressed in relatively simple terms
    - these parameterizations are *structural components* of the model.
    - Within these parameterizations there may be a number of parameters, and *parametric uncertainties* arise from the uncertain values of these parameters.
- Thus, two models can differ in their aggregated response characteristics
    - because they have different structures (including aspects commonly referred as "parameterizations"), or
    - because, within common structures, they use different parameter values.
- This distinguishes between structural and parametric sources of uncertainty. In fact, we take advantage of this in the present study (MAGICC) by "parameterizing" the structural uncertainty range of more complex models (cf. O'Neill and Melnikov, 2008) by estimating the parametric values within the more flexible MAGICC structure that fits the AOGCM results. This approach is distinct from perturbed physics studies with intermediate complexity models or AOGCMs (Murphy et al., 2004), which often concentrate on assessing parametric uncertainties within a fixed and comparatively more rigid model structure.

PPE — Perturbed Physics Ensembles

quartile — Quartile isind Werte, die eine Stichprobe von Daten in vier gleiche Teile teilen. Mit diesen können Sie die Streubreite und die Zentraltendenz eines Datensatzes schnell bestimmen; dies sind wichtige Schritte, mit denen Sie erste Erkenntnisse über die Daten gewinnen.

1. Quartil (Q1) — 25 % der Daten sind kleiner oder gleich diesem Wert.

2. Quartil (Q2) — Der Median. 50 % der Daten sind kleiner oder gleich diesem Wert.

3. Quartil (Q3) — 75 % der Daten sind kleiner oder gleich diesem Wert.

Interquartil — Der Abstand zwischen dem ersten und dem dritten Quartil (Q3–Q1); damit umfasst dies die mittleren 50 % der Daten.

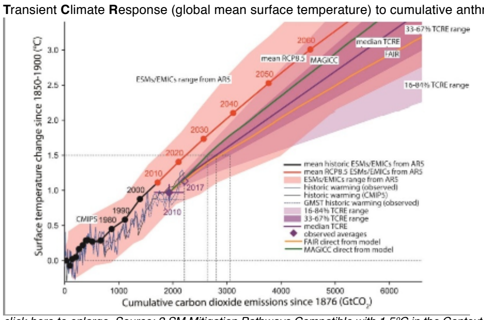
RNCTC — The reference non-$CO_2$ temperature contribution (RNCTC) is defined as the median future warming due to non-$CO_2$ radiative forcing until the time of net zero $CO_2$ emissions

SRES — Special Report on Emission Scenarios (IPCC AR4)

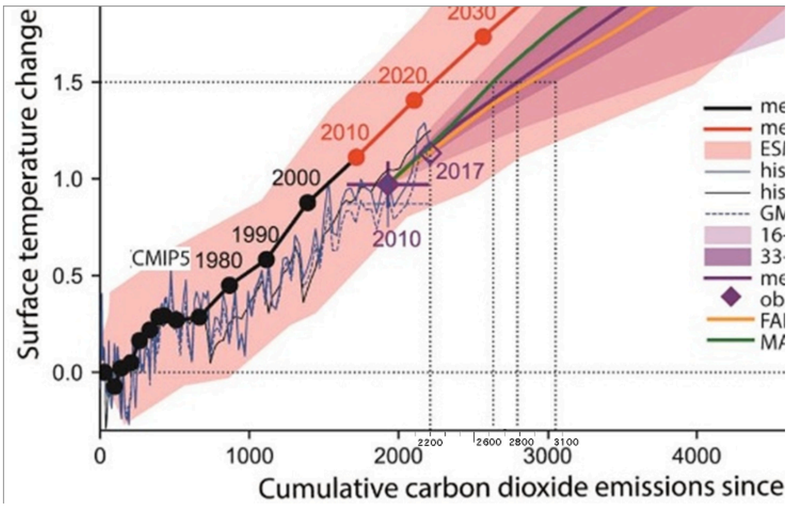
SST — surface sea temperature

SVAT — Soil Vegetation Atmosphere Transfer Scheme (in CLIMBER)

TCRE — **T**ransient **C**limate **R**esponse (global mean surface temperature) to cumulative anthropogenic $CO_2$ **E**missions (usually 1000 GtC, WGI AR5_all_final, TFE.8, Figure 1)




*click here to enlarge. Source: 2.SM Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development – Supplementary Material*




*Source of the following TCRE: page 103, WGI AR5_all_final*

TCRE is model dependent, as it is a function of
- the cumulative $CO_2$ [only, no other GHGs] airborne fraction and
- the transient climate response,

both quantities varying significantly across models.

Taking into account the available information from multiple lines of evidence,
- observations,
- models and
- process understanding,

the near linear relationship between cumulative $CO_2$ emissions and peak global mean temperature
- is well established in the literature and robust for cumulative total $CO_2$ emissions up to about 2000 GtC [7000 $GtCO_2$].

- It is consistent with the relationship inferred from past cumulative CO2 emissions and observed warming,
- is supported by process understanding of the carbon cycle and global energy balance, and
- emerges as a robust result from the entire hierarchy of models.

Expert judgment based on the available evidence suggests that TCRE is likely between 0.8°C and 2.5°C per 1000 GtC for cumulative emissions less than about 2000 GtC [7000 GtCO2] until the time at which temperature peaks (TFE.8, Figure 1a). {6.4.3, 12.5.4; Box 12.2}

When accounting for the non-CO2 forcings as in the RCP scenarios, compatible carbon emissions since 1870 are reduced to about
- 900 GtC, 820 GtC and 790 GtC to limit warming to less than 2°C since the period 1861–1880 with a probability of
- >33%, >50%, and >66%,

respectively.

*Source of the following paragraph: 2.SM Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development – Supplementary Material, page 2SM-5 (im Cache)*
TCRE is diagnosed from integrations of climate models forced with CO2 emissions only. However, the influence of other climate forcers on global temperatures should also be taken into account (see Figure 3 in Knutti and Rogelj (2015). The reference non-CO2 temperature contribution (RNCTC) is defined as the median future warming due to non-CO2 radiative forcing until the time of net zero CO2 emissions. The RNCTC is then removed from predefined levels of future peak warming (DeltaTpeak) between 0.3°C to 1.2°C. The CO2-only carbon budget is subsequently computed for this revised set of warming levels (DeltaTpeak – RNCTC).

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TRIfFFID dynamic global vegetation model. It models the state of the biosphere in terms of
- the soil carbon, and
- the structure and
- coverage of 5 functional types of plant within each model gridbox
  - broadleaf tree,
  - needleleaf tree,
  - C3 grass,
  - C4 grass and
  - shrub

UNEP United Nations Environment Program
WMO World Meterological Organization

1 Pg 1 Gt

TCRE **T**ransient **C**limate **R**esponse to cumulative CO2 **E**missions (TCRE)
The transient global average surface temperature change per unit cumulative CO2 emissions, usually 1000 GtC.
TCRE combines both information
- on the airborne fraction of cumulative CO2 emissions (the fraction of the total CO2 emitted that remains in the atmosphere, which is determined by carbon cycle processes) and
- on the transient climate response (TCR).

See also Transient climate response (under Climate sensitivity).

| | |
|---|---|
| *Climate sensitivity* | Climate sensitivity refers to the change in the annual global mean surface temperature in response to a change in the atmospheric CO2 concentration or other radiative forcing. |
| *Equilibrium climate sensitivity (ECS)* | Refers to the equilibrium (steady state) change in the annual global mean surface temperature following a *doubling of the atmospheric carbon dioxide (CO2) concentration.* As a true equilibrium is challenging to define in climate models with dynamic oceans, the equilibrium climate sensitivity is often estimated through experiments in AOGCMs where CO2 levels are either quadrupled or doubled from pre-industrial levels and which are integrated for 100-200 years.<br><br>The climate sensitivity parameter (units: °C (W m–2)–1) refers to the equilibrium change in the annual global mean surface temperature following a unit change in radiative forcing. |
| *Effective climate sensitivity* | An estimate of the global mean surface temperature response to a doubling of the atmospheric carbon dioxide (CO2) concentration that is evaluated<br>- from model output or<br>- observations<br>for evolving non-equilibrium conditions.<br><br>It is a measure of the strengths of the climate feedbacks at a particular time and may vary with<br>- forcing history and<br>- climate state, and<br>therefore may differ from equilibrium climate sensitivity. |
| *Transient climate response (TCR)* | The change in the global mean surface temperature, averaged over a 20-year period, centered at the time of atmospheric CO2 doubling, in a climate model simulation in which CO2 increases at 1% yr-1 from pre-industrial. It is a measure of the strength of climate feedbacks and the timescale of ocean heat uptake. |

Likelihood Each finding is grounded in an evaluation of underlying *evidence* and *agreement.*
- A level of *confidence* is expressed using five qualifiers:
  - very low,
  - low,
  - medium,
  - high and
  - very high, and typeset in italics, for example, medium confidence.

- The following terms have been used to indicate the assessed likelihood [probability] of an outcome or a result (consistent with AR5):
  - virtually certain 99–100% *probability*,
  - very likely 90–100%,
  - likely 66–100%,
  - about as likely as not 33–66%,
  - unlikely 0–33%,
  - very unlikely 0–10%,
  - exceptionally unlikely 0–1%.

- Additional terms may also be used when appropriate:
  - (extremely likely 95–100%,
  - more likely than not >50–100%,
  - more unlikely than likely 0–<50%,
  - extremely unlikely 0–5%) Assessed likelihood is typeset in italics, for example, *very likely.*

probabilities
- The probability assessment used in the scenario classification [of Special Report SR15] is based on simulations using two reduced-complexity carbon cycle, atmospheric composition, and climate models:
  - the 'Model for the Assessment of Greenhouse Gas-Induced Climate Change' (*MAGICC*) (Meinshausen et al., 2011a), and
  - the 'Finite Amplitude Impulse Response' (*FAIR* v1.3) model (Smith et al., 2018).
- For the purpose of this report, and to facilitate comparison with AR5, the range of the *key carbon cycle and climate parameters* for MAGICC and its setup are identical to those used in AR5 WGIII (Clarke et al., 2014).
- For each mitigation pathway, MAGICC and FAIR simulations provide probabilistic estimates of atmospheric concentrations, radiative forcing and global temperature outcomes until 2100.
- However, the classification uses MAGICC probabilities directly for traceability with AR5 and because this model is more established in the literature.
- Nevertheless, the overall uncertainty assessment is based on results from both models, which are considered in the context of the latest radiative forcing estimates and observed temperatures.

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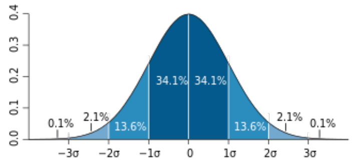
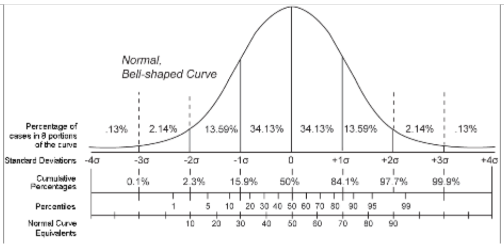
## Standard deviation and percentile

**Standard deviation**
The formula for the sample standard deviation is

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2},$$

where $x_i$ are the observed values of the sample items, $\bar{x}$ is the mean value of these observations, and N is the number of observations in the sample.




Quelle: https://en.wikipedia.org/wiki/File:Standard_deviation_diagram.svg

https://upload.wikimedia.org/wikipedia/commons/5/5c/PR_and_NCE.gif

When $x_i$ are normally distributed and i is infinite, s = σ

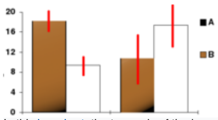
**Percentiles** represent the area CDF under the **normal curve (pdf)**, increasing from left to right. Each **standard deviation** σ **represents a fixed percentile**. Thus, rounding to two decimal places,

- −3 σ is the 0.13th percentile = 0.0013 quartile,
- −2 σ is the 2.28th percentile,
- −1 σ is the 15.87th percentile,
- 0 σ is the 50th percentile = 0.5 quartile,
- +1 σ is the 84.13th percentile,
- +2 σ is the 97.72nd percentile, and
- +3 σ is the 99.87th percentile.
- for conversion from standard deviations to percentiles see here (https://www.dummies.com/education/math/statistics/figuring-out-percentiles-for-a-normal-distribution/) (in cache)
  - the numbers in this table give cdf[z] = quartile[z] for sigma = 1, mu = 0
    - quartile[z = 1.64 sigma] = 0.9495

| z | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.6 | .9452 | .9463 | .9474 | .9484 | .9495 | .9505 | .9515 | .9525 | .9535 | .9545 |

interquartile range: Bereich, in dem 50% der Elemente liegt.

**90% confidence interval** (Wikipedia)




In this bar chart, the top ends of the brown bars indicate observed means and the red line segments ("error bars") represent the confidence intervals around them. Although the error bars are shown as symmetric around the means, that is not always the case.
It is also important that in most graphs, the error bars do not represent confidence intervals (e.g., they often represent standard errors or standard deviations)

The explanation of a confidence interval can amount to something like:

- "*The confidence interval represents values for the population parameter for which*
  - *the difference between the parameter and the observed estimate is not statistically significant at the 10% level*".[5]
- In fact, this relates to one particular way in which a confidence interval may be constructed.

If the true value of the parameter lies outside the 90% confidence interval, then a sampling event has occurred (namely, obtaining a point estimate of the parameter at least this far from the true parameter value) which had a probability of 10% (or less) of happening by chance.

**Units Conversion**

| Unit 1 | Unit 2 | Conversion | Source |
|---|---|---|---|
| GtC (gigatonnes of carbon) | ppm (parts per million)[a] | 2.124[b] | Ballantyne et al. (2012) |
| GtC (gigatonnes of carbon) | PgC (petagrams of carbon) | 1 | SI unit conversion |
| $GtCO_2$ (gigatonnes of carbon dioxide) | GtC (gigatonnes of carbon) | 3.664 | 44.01/12.011 in mass equivalent |
| GtC (gigatonnes of carbon) | MtC (megatonnes of carbon) | 1000 | SI unit conversion |

**Table 1** Factors used to convert carbon in various units (by convention, Unit 1 = Unit 2 conversion).

[a] Measurements of atmospheric $CO_2$ concentration have units of dry-air mole fraction. "ppm" is an abbreviation for micromole $mol^{-1}$, dry air. [b] The use of a factor of 2.124 assumes that all the atmosphere is well mixed within 1 year. In reality, only the troposphere is well mixed and the growth rate of $CO_2$ concentration in the less well-mixed stratosphere is not measured by sites from the NOAA network. Using a factor of 2.124 makes the approximation that the growth rate of $CO_2$ concentration in the stratosphere equals that of the troposphere on a yearly basis.

Source: https://www.earth-syst-sci-data.net/10/2141/2018/#top&gid=1&pid=1
C. Le Quere, Global Carbon Budget 2018, Earth Syst. Sci. Data, 10, 2141–2194, 2018,
https://www.earth-syst-sci-data.net/10/2141/2018/#top
https://doi.org/10.5194/essd-10-2141-2018,

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