



GCOS STEERING COMMITTEE

THIRTIETH SESSION

GCOS SC-30, 7–8 December 2022

Virtual Session

GCOS Climate Indicators

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The Steering committee is invited to consider the existing climate indicators identified by GCOS to see if they need to be augmented by additional indicators. Areas for consideration include covering changes to the biosphere, indicators of extremes and climate cycle indicators.

DRAFT DECISION (4)

The Steering Committee decides that

1. GCOS Secretariat works with WMO/Climate Services to explore the adoption of additional climate indicators, such as the earth energy imbalance or covering new domains (e.g. biosphere).
2. GCOS Secretariat organizes a workshop on Earth Cycles jointly with WCRP and asks Han Dolman, Karina von Schuckmann and Wouter Dorigo to develop the aims and objectives of this workshop from a GCOS perspective.
3. The workshop on Earth Cycles should consider how the current set of Climate Indicators reflect the changing earth cycles and whether any additional indicators are needed.

Summary:

- 1) The Global Climate Indicators are a set of parameters (Figure 1) that describe the changing climate without reducing climate change to only temperature. They comprise key information for the most relevant domains of climate change: temperature and energy, atmospheric composition, ocean and water as well as the cryosphere.

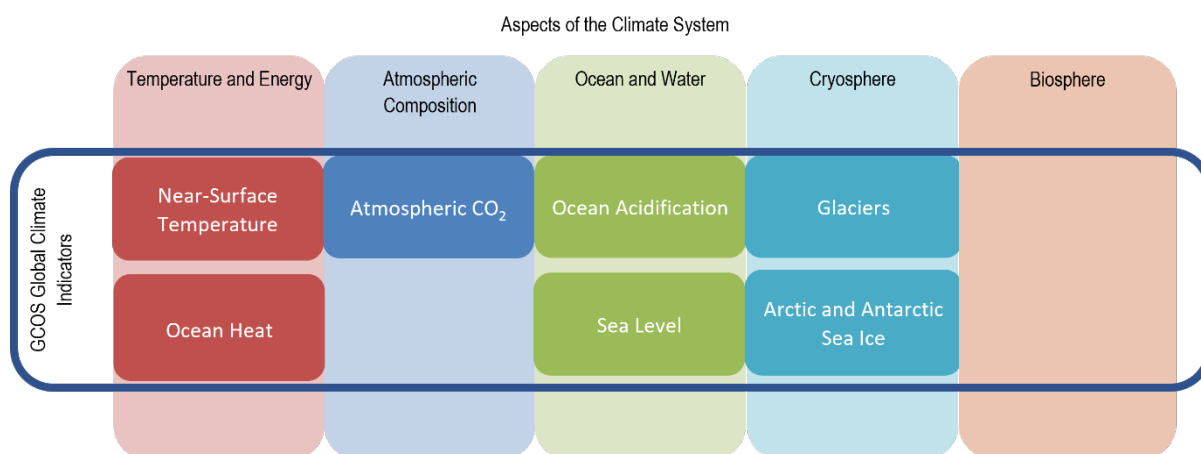


Figure 1. GCOS Climate Indicators

- 2) These Global Climate Indicators have been identified by scientists and communication specialists in a discursive process led by GCOS during workshops and scientific panel meetings and have been finally endorsed by WMO. They form the basis of the annual [WMO Statement of the State of the Global Climate](#), which is submitted to the Conference of Parties of the [United Nations Framework Convention on Climate Change \(UNFCCC\)](#). In addition, the Copernicus Climate Change Service (C3S) of the European Commission uses the GCOS indicators for their annual "[European State of the Climate](#)".
- 3) These seven headline indicators are complemented by a set of subsidiary indicators that provide additional information and allow a more detailed picture of the changes in the respective domain. It is important to note, that the Global Climate Indicators are not limited to specific datasets or certain storylines.
- 4) GCOS held a meeting at WMO in February 2017 to discuss Global Climate Indicators with participants from UNFCCC, ECMWF, C3S¹, ESA Climate Office, IOC, ISC, UNEP, GEO, IPCC, WCRP as well as various WMO branches GAW, CLPA, OBS. This meeting agreed that:

the need is to identify a small set of essential climate indicators for the purpose of communication of climate change to date. Surface temperature is not the best indicator of climate change as it is a poor overall thermodynamic descriptor of the Earth's energy balance. A broader set of indicators would better describe and communicate the full range of physical climate change over the last 150 years...
- 5) It was also agreed that these indicators should meet the following criteria:
 - **Relevance:** each should be a clear, understandable indicator of global climate change, which has broad impact for a range of audiences. Some indicators will also have national and regional values;

¹ Copernicus Climate Change Service

- **Representativeness:** indicators as a package should provide a representative picture of changes to the Earth system related to climate change;
- **Traceability:** should be calculated using an internationally agreed (and published) method;
- **Timeliness:** should be calculated regularly (at least annually) with a short lag between the end of the period and publishing the data;
- **Limited number:** to allow clear, concise, communication the number of indicators should be limited to less than 10.

6) The Subsidiary Body for Scientific and Technological Advice (SBSTA) of the UNFCCC stated in its 47th session in 2017:

Paragraph 5) The SBSTA noted the efforts undertaken by GCOS and the wider science community on the development of climate indicators, including global surface temperature, global atmospheric carbon dioxide and glacier change, and by WMO on the categorization of extreme events. The SBSTA invited GCOS and WMO to report to it on progress, as appropriate, and noted the relevance of their work in the context of decision 4/CP.22, paragraph 4(c)...

Paragraph 6) The SBSTA noted the importance of ocean-related climate indicators, including ocean heat content, ocean acidification, sea level rise, and Arctic and Antarctic sea ice extent, for informing on the state of the global climate. It encouraged Parties to sustain observations underpinning these indicators...

7) Since the original list was agreed, a number of additional climate indicators have been proposed including:

- **Biosphere Change.** TOPC has spent some time considering options for this indicator. Initially the focus was on forests, or deforestation, as an indicator. However, while this does relate to emissions of CO₂, it is not an impact of climate change on the biosphere. Subsequently, TOPC has been considering other potential indicators listed below.
 - **Carbon storage in terrestrial systems.** Aboveground biomass is increasingly measurable globally and could show both changes due to human activities and responses to climate change (e.g. carbon fertilisation).
 - **Carbon fluxes from terrestrial ecosystems.** This does respond to changes in the climate system, especially if focussed on areas where disturbance is minimal. Improved results are becoming available.
 - **Changes in phenology in temperate and boreal regions** are a potentially a good indicator which does respond to a climate signal. Potentially observable by satellites. Global Greening (and browning) has been used by the IPCC to show the large-scale changes taking place. Again, it is difficult to distinguish between the climate and anthropogenic signals and it does not relate directly to an ECV but is easy to explain to the public.
- **Extremes**
 - **Heat waves.** These are an increasing and major impact of climate change, especially on human mortality and morbidity, as well as other biological systems. While it was agreed this would be useful as an indicator, WMO has 27 indices of extremes and was unable to recommend two for this purpose. Preferably, a debate on the selection of these indicators is needed: which is most appropriate for an indicator of climate change, and which best relates to human health impacts Ideally, they should be aggregable at the global level and show how extreme events are increasing.

- **Droughts.** Another important impact of climate change, but work would be needed to determine how drought data can be aggregated to provide a global indicator.
 - **Storm activity.** While this has been proposed it is unclear how to precisely define it. The IPCC, in AR 6, has said that it expects an increase in the strength of tropical cyclone but not their number.
 - **Ocean Heat Waves.** Again, these are an important impact of climate change with potentially severe impacts on marine life (e.g. coral reefs). It is unclear how this could be aggregated to a global level.
- **Hydrology**
 - **Total Water Storage.** This has recently been added as an ECV and it is the aggregate of all water stored on land including, snow, reservoirs and lakes, rivers and groundwater. Changes in this reflect human impacts and climate change. It does give a clear signal on perturbations in the water cycle.

8) In addition, a number of parameters were defined as subsidiary indicators – they provide useful information but do not provide a significantly different signal or are not sufficiently important to be full indicators. They include **Methane, Fluorinated GHG, Nitrous Oxide and Snow Extent.**

Climate Cycles

- 9) A proposal has been made to have indicators for the Earth's climate cycles. Table 1 provides an initial assessment of the current situation and possible additions. This identifies indicators that, arguably, are linked to the overall cycle. For example, sea level is linked to changes in the water cycle and temperature changes in the ocean and so is not a good indicator of either, while changes in atmospheric CO₂ or total water storage largely reflect changes in the carbon and water cycles respectively.
- 10) The **Earth's Energy Imbalance** is clearly this is an important measure of climate change and drives increases in energy stored in the Earth system. A suggestion has been made by Karina von Schuckmann for this to be an additional indicator (see Information Document INF. 2.3). However, over 90% of the energy is stored in the ocean as ocean heat (already an indicator) and, as these are for general public consumption and are not a scientific exercise, it is not clear that this is sufficiently different to warrant being a separate indicator.
- 11) **Atmospheric fraction of CO₂.** The atmospheric fractions (the amount of the anthropogenic CO₂ emission remaining in the atmosphere) has been remarkably constant since 1959. It indicates that oceanic and land sinks are increasing with the emissions. If the atmospheric fraction increase, it would indicate a destabilizing of those sinks and the carbon cycle.

Table 1. An initial assessment of Indicators of the climate cycles

Existing Indicators		Potential New Indicators
Energy Balance	Ocean Heat Content	The Earth's Energy Imbalance (closely related to the Ocean Heat Content) is a more accurate description of the Energy Cycle but is nearly the same numerically as changes in ocean heat content. As indicators are for general use, not scientific analysis, and as Ocean Heat Content is used and adopted by

		many organisations including UNFCCC, WMO, it is not clear this should be changed
Carbon Cycle	Atmospheric CO ₂	Emissions of CO ₂ to the atmosphere might be added if the fraction of emissions retained in the atmosphere changes significantly.
Water Cycle		Total Water Storage

Potential Next Steps

- 12) Noting that the overall aim of the indicators to have as small a list of indicators as possible, and not cover every possible impact of climate change, it is proposed that:
- a. Changes to the Biosphere are not included in these indicators. TOPC should be asked to define a suitable indicator for presentation to the Joint Panel Meeting in June 2023 and final decision by the Steering Committee.
 - b. A more detailed consideration of how to deal with extremes is needed. Extremes are one of the most immediate phenomena impacting humans, infrastructure and ecosystems. This may be an area where collaboration with WMO is appropriate. The issues to be addressed are:
 - i. Which extremes should be considered;
 - ii. What parameter related to the magnitude of the event is most appropriate and can be aggregated to a global indicator?
 - c. Currently there is no indicator that covers hydrology (though there are ones for the cryosphere). Total Water Storage could fill this gap if it can be aggregated in a meaningful way at the global level. TOPC should be asked to attempt this.
 - d. GCOS should consider if all the climate cycles are adequately covered. This consideration should be performed by the Task Team on Climate Cycles when it is established.
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