Near-term predictions

FACTSHEET

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Information on how the climate will evolve in the next decade is crucial to inform climate mitigation and adaptation policies. Near-term (or decadal) climate predictions, which fall between seasonal and multi-decadal timescales, can fill this gap and provide detailed climate information for the next 1-10 years.

In this factsheet, we explore near-term predictions, the information they can provide, and how it can be used by policymakers.

WHAT ARE NEAR-TERM PREDICTIONS?

Future climate can be predicted using climate models with a confidence that depends on the timescale covered by the forecast. At shorter timescales, **weather forecasts** predict the weather conditions at a given time and location for up to 15 days ahead, starting from the current observed state of the climate. At longer timescales, **climate projections** can provide information on how different climate variables (e.g. temperature) are expected to evolve in the long term, covering the next decades and centuries. These projections are based on scenarios of future greenhouse gas emissions and socio-economic development (also known as Shared Socioeconomic Pathways).

Climate predictions fall between these two timescales, providing information for the next weeks up to a decade. Among these are **near-term predictions** (also known as decadal predictions), which can cover any period from 1 to 10 years (Figure 1). Similar to weather forecasts, near-term predictions need observation-based data as a starting point but also external forcing information, such as greenhouse gas emissions, similar to those used in climate projections.

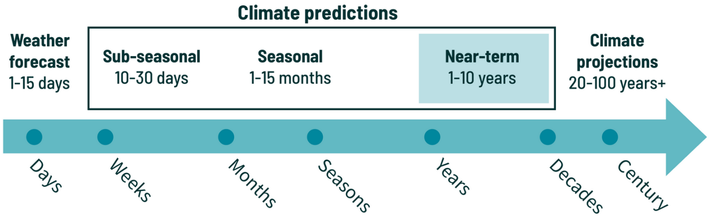

Figure 1. Different prediction timescales, marking near-term predictions. ©Image source: BSC-CNS

NEAR-TERM PREDICTIONS OF CO_2 CONCENTRATION

Besides climate variables, predicting atmospheric carbon dioxide (CO_2) evolution is also useful as this is the most important greenhouse gas driving climate change. This can be done using Earth System Models (ESMs), which include complete representations of the global biogeochemical cycles, i.e. how different chemical elements relevant to climate (such as carbon) move through the Earth system.

Although on timescales longer than a decade atmospheric CO_2 concentration is growing at a relatively stable pace due to emissions from human activities (e.g. fossil fuel burning and deforestation), the observed atmospheric CO_2 growth rate can vary widely from one year to the next. This is due to the natural variability of the global carbon cycle that is superimposed on the trend driven by emissions. For this reason, having a good estimate of future emissions is not enough to predict future near-term trends in atmospheric CO_2, and thus ESMs are used to predict the natural variability of the climate and the carbon cycle.

POTENTIAL APPLICATIONS OF NEAR-TERM PREDICTIONS

Near-term predictions of the carbon cycle are a relatively new and active field of research, and their potential applications have not been fully explored yet.

During the transition to net-zero emissions, near-term natural fluctuations of atmospheric CO_2 will become relatively more important with respect to the long-term trend. In this context, skillful predictions of these natural fluctuations will be useful to detect the change in atmospheric CO_2 growth rate and attribute it to ongoing efforts in emissions reduction (such as for verification of emission reductions), thus informing and supporting policymakers in adapting their strategies for the following years (Spring et al., 2020).

Due to the natural fluctuations in atmospheric CO_2 concentration, the drop in emissions expected from the implementation of the Paris Agreement will not be immediately detectable as a consequent drop in atmospheric CO_2.

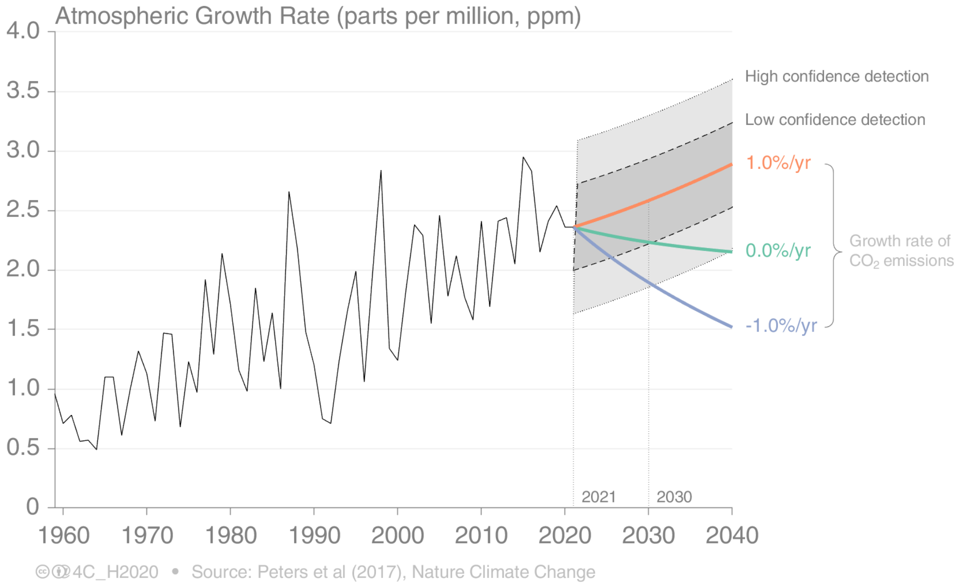

Figure 2. Growth rate of atmospheric CO_2 concentration in past decades and in the near term. An increasing trend is seen, but with large interannual variability (black line). The coloured lines correspond to different emission pathways, while the grey shaded areas indicate the range of the growth rate predictions and the confidence of the detection.

Figure 2 illustrates the uncertainty (shaded areas) in our current capability to detect changes in emissions.

Currently, CO_2 emissions are growing at roughly 1% per year. If growth stopped after the implementation of new policies (i.e. 0% annual growth), then it could take up to 10 years to confidently detect the change in observed atmospheric CO_2 due to both uncertainty in carbon cycle observations and natural variability (Peters et al., 2017). If CO_2 emissions declined at 1% per year, then that detection time could come down to about 5 years. By taking into account this natural variability, near-term predictions have the potential to reduce this window of detection.

Ongoing research efforts are expected to lead to improvements in the performance of near-term predictions by the time that the relevance of this information increases, potentially establishing these predictions as an independent means of verification of future policies.

Finally, near-term predictions also allow modellers to regularly assess their skill in modelling the climate and CO_2 variability, and thereby improve the representation of physical processes in their models.

WHICH ARE THE DRIVERS OF NATURAL VARIABILITY?

On average, about half of anthropogenic CO_2 emissions are absorbed in roughly equal parts by the ocean and land vegetation, while the other half stays in the atmosphere. These fractions have remained remarkably constant over the past few decades.

Apart from human emissions, a large amount of carbon is also emitted by natural sources and is continuously exchanged between the atmosphere, and the land and ocean. These exchanges can vary considerably from one year to the next, causing a large variability in the atmospheric CO_2 growth rate, which is driven by complex mechanisms and is challenging to predict. Major natural climate events, such as El Niño-Southern Oscillation (ENSO), La Niña and volcanic eruptions, can have a very large impact on the atmospheric CO_2 growth rate, and are referred to as natural variability.

As shown in Figure 3, while anthropogenic CO_2 emissions (represented by the thick lines) have been growing at a relatively stable pace over the past 60 years, the measured atmospheric CO_2 growth rate (represented by the bars) has varied considerably on an interannual basis. From the figure, it is immediately evident that years with dominant El Niño conditions tend to have higher atmospheric CO_2 growth rates than years with dominant La Niña conditions. This is mostly due to the impact of ENSO on rain patterns over South America and Indonesia, which host immense extensions of tropical forest that exchange large amounts of CO_2 with the atmosphere as the vegetation grows or decomposes. Under El Niño conditions, these regions receive on average less precipitation than under La Niña conditions, causing a negative anomaly in the amount of CO_2 absorbed and thus a positive anomaly in the

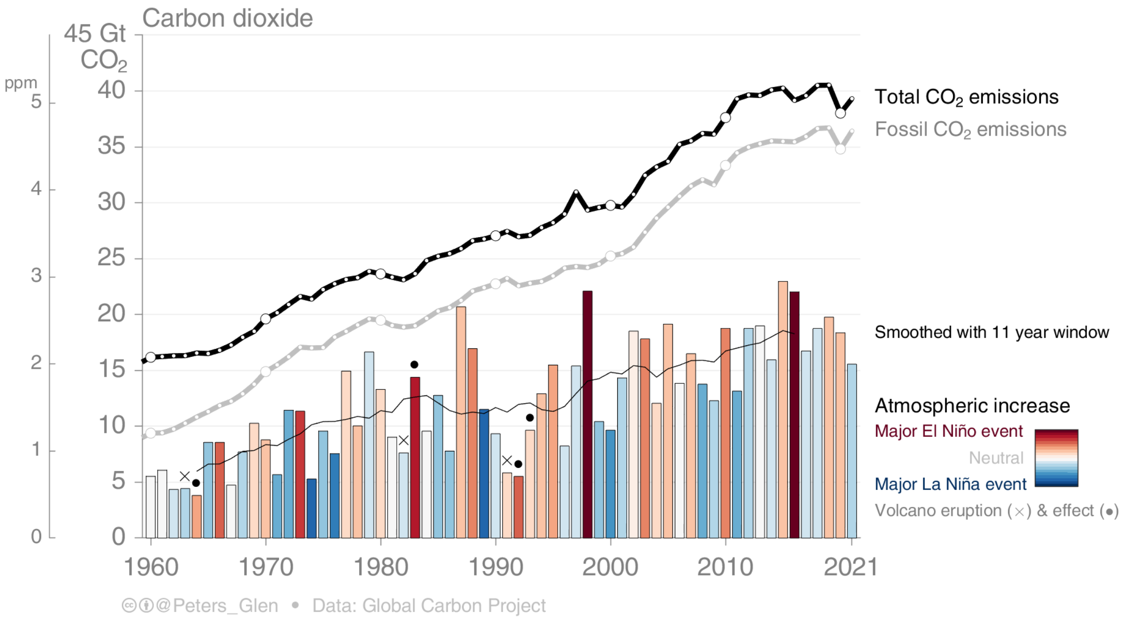

Figure 3. Total and fossil CO_2 emissions (lines, measured in $GtCO_2$) have risen steadily over recent decades, while the growth in atmospheric CO_2 (bars, measured in ppm) exhibits large variability. The variability is significantly affected by El Niño and La Niña events, with the strength shown by the red and blue shading. Major volcanic eruptions (marked with x) can have effects on the carbon cycle for 1-2 years after the volcano (shown as black dots). Note that total emissions include fossil fuels and other human activities, e.g. cement production, land-use change.

atmospheric CO_2 growth rate. At the same time, the ocean partly compensates for this anomaly by responding in the opposite direction. In fact, under El Niño conditions, westward winds over the tropical Pacific are anomalously weak, causing a reduction in the upwelling of carbon-rich deep water to the surface, while the opposite happens during La Niña conditions.

Another natural cause for atmospheric CO_2 variability is major volcanic eruptions, and three such events are reported in Figure 3. Volcanic eruptions cause a decrease in global surface temperature by injecting into the atmosphere small dust particles and gases that reflect incoming solar radiation. Their effect is usually confined to the hemisphere where the eruption took place and can last for several years. The overall effect on the global carbon cycle is uncertain as the colder temperature tends to increase ocean carbon solubility and reduce soil microbial activity.

Both of these effects result in lower atmospheric CO_2 growth, but at the same time, the reduced incoming solar radiation decreases plant growth, causing higher atmospheric CO_2.

4C IS WORKING TO IMPROVE NEAR-TERM PREDICTIONS

In 4C, we are working to improve three European predictive systems, which are based on three Earth system models, namely EC-Earth3-CC, MPI-ESM-LR and IPSL-CM6A-CO2-LR. Research strives to continuously develop and improve these models and the procedures adopted to generate the initial conditions from which the predictions are initialised. New observational products are integrated as they become available, while actual future predictions are performed alongside retrospective near-term predictions and more idealised process-oriented studies with the objective of understanding the current predictive capability of these systems, their limitations and the potential pathways toward their improvement.

References

Spring A. et al. (2020). Environ. Res. Lett. 15: 114058. https://doi.org/10.1088/1748-9326/abc443

Peters G.P. et al. (2017). Nature Clim Change 7: 848-850. https://doi.org/10.1038/s41558-017-0013-9

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