# Policy Brief

November 2023

## Science needs to help reduce persistent uncertainties in climate projections

*This Policy Brief provides an overview of the key policy recommendations from the European project 4C.*

## SCIENCE POLICY RECOMMENDATIONS

The uncertainties in the carbon cycle are hard to constrain, due to sparse observations and insufficient models. The 4C project aimed to reduce these uncertainties. As a scientific project, the policy recommendations shown below are aimed at supporting scientific needs in the years ahead, to help further constrain the uncertainties in models of the carbon cycle. These recommendations represent broad areas that should be addressed in future funding calls.

1

**Improving carbon cycle monitoring**

Scaling up monitoring of the carbon cycle will ensure sufficient observations to correctly calibrate models. Better observations reduce the uncertainty of future projections of climate-carbon cycle interactions. A major knowledge gap is how the carbon cycle and climate system respond to rapidly declining emissions, something that is yet to occur and therefore outside of our observations.

2

**Improving carbon cycle metrics**

There remain large uncertainties in the near-term evolution of the climate system, indicated by the uncertain remaining carbon budget to stay below 1.5°C. New or improved metrics of the carbon cycle are needed to help track progress to ambitious targets, new modelling tools that respond to updated observations of progress are needed, and more nuanced ways to frame the climate challenge that go beyond targets and deadlines are needed.

3

**Supporting scientific knowledge**

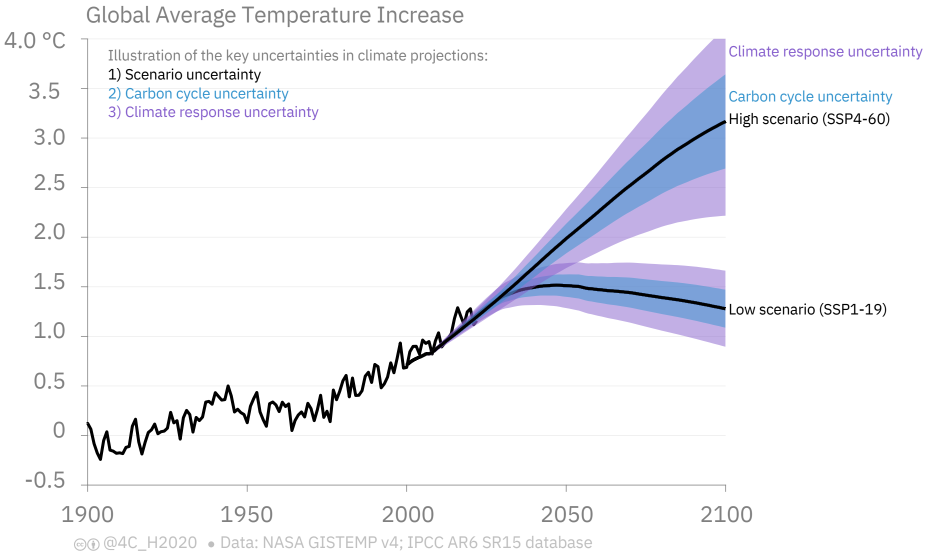
Support the annual publication of synthesis products like the Global Carbon Budget. These products provide continuity and a constant evolution in the knowledge about the carbon cycle, something that cannot be sufficiently achieved through the 5-7 year IPCC cycle. It is critical to have synthesis products to assess the regular and continuous monitoring of the carbon cycle, to help verify emissions, detect early changes in the natural carbon sinks, and ensure progress is being made to meet the objectives of the Paris Agreement and national legislation.

# CLIMATE-CARBON INTERACTIONS IN THE CURRENT CENTURY (4C)

Observations and models of the Earth system provide a coherent view of the evolution of human-caused climate change, explaining the evolution of global warming in the past decade, and providing coherent trajectories of future warming for a given evolution of the world's greenhouse gas emissions. Nevertheless uncertainties persist, related to:

1. how society will evolve over the next decades and the associated future emissions,
2. how much these emissions will change the composition of the atmosphere, and
3. how the Earth system will respond to a change in atmosphere composition, warming, and associated climate change.

The Horizon 2020 research project Climate-Carbon Interactions in the Current Century (4C) addresses the crucial knowledge gap on how much the atmosphere composition will change and how the carbon cycle within the Earth system will respond under different emission scenarios.




## UNDERSTANDING CARBON-CLIMATE INTERACTIONS, THE EASY WAY

### *Key policy-relevant resources in 4C*

4C placed a large effort on communicating the science in a format digestible for policy makers. 4C also published a large number of open-access scientific papers, datasets, and public deliverables, and had dozens of media interactions. These products ensure the project objectives on Knowledge Transfer are met.

**Factsheets**

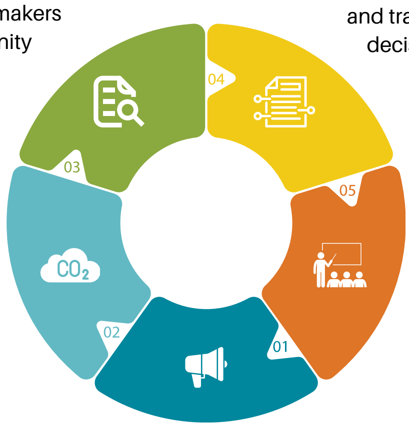
Presenting the main concepts behind 4C science, targeting policymakers and the scientific community

- *Near-term predictions*
- *Emergent Constraints*
- *Carbon Budget*

**Science summaries**

Highlighting relevant results and translating them for use by decision and policymakers

- *Effect of COVID-19 on $CO_2$ emissions*
- *Increase in $CO_2$-induced global warming will only stop when emissions stop*
- *Overview of project findings (coming soon)*




**Carbon Outlooks**

Publishing key 4C outcomes, in partnership with the annual Global Carbon Budget

*2020*
*2021*
*2022*

**Climate Classrooms**

Providing an easy-to-understand explanation of the main scientific concepts behind the 4C project, targeting a general audience

- *Drivers of $CO_2$ concentrations*
- *Global carbon cycle*
- *Shared Socioeconomic Pathways*

**Outreach material**

Including: Infographic, Explorable Explanation, Interviews with partners etc.

# New knowledge developed during the 4C project

## Understanding the contemporary carbon cycle

- Increased understanding of the 'Budget Imbalance': the difference between independent estimates of components of the global carbon budget
- Identified missing demography and age processes in modeling the northern extra tropics land sink
- Satellite observation gave a deeper understanding of the shortcoming of land models (e.g., disturbance, climate mortality, turnover)
- Step change in the quantification of the ocean carbon sink and its variability with new data products and systematic comparisons of independent observations and constraints
- Used the Atmospheric Potential Oxygen (APO) as an independent constraint on the global carbon budget

## Reducing uncertainties in climate projections over the 21st century

- Made progress understanding how several key metrics of the carbon cycle are interconnected: Transient Climate Response to cumulative carbon Emissions (TCRE), Zero Emission Commitment (ZEC), and the Remaining Carbon Budget (RCB)
- Improved estimates of permafrost carbon emissions on the remaining carbon budget
- New adaptive scenario methodology to meet climate stabilisation targets, with novel inclusion of non-$CO_2$ emissions
- A machine learning weighting method developed and together with two other weighting methods implemented into ESMValTool

## Near-term prediction of the climate and carbon cycle

- Developed new Earth System Models with interactive carbon cycle using data assimilation, which now provide independent estimates of atmospheric $CO_2$ and sinks for the Global Carbon Budget synthesis
- Provided a new reconstruction of the global carbon budget with improved representation of natural variability of the carbon cycle
- Established predictive skills for atmospheric $CO_2$ and carbon sinks
- Determined the mechanisms that provide predictability of the terrestrial carbon sink

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