**Uncertainty in climate sensitivity due to clouds**

This programme brings together world-leading UK communities to use existing and new studies of clouds which, together with new capacity in climate modelling, will enable a better understanding of how clouds are affected by climate warming.

Cloud feedbacks are a fundamental and persistent problem in climate science and are the dominant uncertainty in assessing global and regional climate sensitivity. To address the issue, the Uncertainty in Climate Sensitivity due to Clouds programme aims to bring together world-leading UK communities across cloud physics, atmospheric measurements, remote sensing and climate science.

The programme will exploit existing and new observations, together with new capacity in climate modelling, to enable a step change in quantifying and reducing uncertainty in cloud feedbacks under climate change.

The Uncertainty in Climate Sensitivity due to Clouds programme has been developed by the Natural Environment Research Council (NERC) via the [strategic programme areas](https://www.ukri.org/councils/nerc/guidance-for-applicants/types-of-funding-we-offer/strategic-research/nerc-strategic-programme-areas/) ideas generation process.

The main objective of this programme is to use the combined expertise of climate modellers, cloud physicists and remote sensing experts to stimulate the scientific advances needed for a reduction in uncertainty in climate sensitivity due to clouds. To achieve this, progress is needed in three key areas:

* improvement in our quantitative physical understanding of cloud responses to warming
* translation of new understanding into more realistic high-resolution cloud models that can inform and underpin development of robust and verifiable model parameterisations at the global scale
* exploitation of new and existing observations to test and refine model processes, leading to more tightly constrained values of cloud feedback and climate sensitivity.

As greenhouse gas concentrations rise steadily owing to human activities, putting accurate bounds on future climate change is an urgent research problem. Quantifying the likely impacts of climate change remains a challenge, however, largely due to uncertainties in climate model projections.

Climate model projections are the basis for the policy decisions that are needed to minimise the economic and societal impacts of climate change. As such, accurate climate change projections are of tremendous global and national economic significance: the value of reducing uncertainties in climate projections has recently been estimated at trillions of dollars if accomplished in the next decade. Climate models are continually subject to improvement and extension to include more process-level detail, but we are at a strategic juncture promising a step change with respect to modelling of cloud effects on climate sensitivity.

The large uncertainty range in climate sensitivity means we cannot accurately estimate the maximum carbon dioxide (CO2) concentrations which would be allowable to achieve the Paris Agreement ambitions. Current estimates for the 2°C target range from 470 to 600 parts per million. Narrowing the uncertainty range for climate sensitivity is therefore directly relevant to policymaking on emissions pathways. Conversely, there is great uncertainty in the climate change projected for any given future trajectory of concentrations, for example, a range for likely global warming of 2.6°C to 4.8°C during the 21st century under the RCP8.5 scenario.

Uncertainties at the regional scale are even larger with, for example, ambiguity over even the sign of average precipitation change in key vulnerable regions. Global projections result from the combined effects of regional feedbacks, many of which involve interactions between clouds, surface processes, radiation and the large-scale dynamics. Therefore it is not currently possible to estimate the severity of the impacts (such as economic, ecological and societal) or to make definite plans for resilience and adaptation.

The ‘likely’ range for equilibrium climate sensitivity (the global-mean temperature increase in response to a doubling of CO2 concentration since the pre-industrial period) is 1.5°C to 4.5°C (Intergovernmental Panel on Climate Change report, 2014). This broad uncertainty range has not narrowed over several decades, despite substantial investment in observation systems and model development, but the consequences and societal impacts of climate change are very different between the high and low extremes of this range. The climate sensitivity value also defines the prospects for achievability of the United Nations Framework Convention on Climate Change Paris Agreement to keep global temperature rise to well below 2°C above pre-industrial levels, and to aim to limit the increase to 1.5°C. Since Earth has already warmed by 1°C since pre-industrial times, urgent action is required to determine whether this policy goal can be met.

The way in which clouds respond to warming (the cloud feedback) is the dominant source of uncertainty in climate sensitivity estimates. Among the set of models used for climate projections, clouds are projected to change in different ways, resulting in very different amplification or damping of warming regionally and globally. Reduction of this uncertainty will require a better understanding of the key processes of change and a substantial improvement in the way they are represented in climate models.

Our understanding of cloud feedbacks has advanced substantially in recent years, so a clear research path can now be defined. Previously the translation of limited knowledge into climate sensitivity estimates was very slow. In particular, we now know from modelling and satellite data analysis that specific cloud types (or regimes) are critical to cloud feedbacks, and qualitatively how the important cloud types respond. We know that quantifying cloud feedbacks requires an understanding and parameterization of processes at scales even smaller than the few kilometres that will be achieved by climate models over the next few decades, so a dedicated effort to bridge these scales is needed.

Through exploiting our current knowledge of cloud physics, together with a targeted programme of new observations, we can now tackle the more challenging problem of how clouds change over decadal timescales.