EUCLIPSE

EU Cloud Intercomparison, Process Study & Evaluation Project

Grant agreement no. 244067

Deliverable D0.14:	Vision paper on future research issues in relation to climate change.
Delivery date:	54 months
Responsible partner:	KNMI

SEVENTH FRAMEWORK PROGRAMME

Vision Paper on future research issues in relation to climate change

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EUCLIPSE Deliverable 0.14

Abstract: This vision paper summarizes the proposed research initiatives on climate change of the World Climate Research Programme's Grand Challenge on Clouds, Circulation and Climate Sensitivity that germinated from the EUCLIPSE project and relates this to the vision and proposed research initiatives by the European Climate Observations, Modelling and Services (ECOMS) board for the European Horizon 2020 programme

1. Background

Equilibrium climate sensitivity (ECS) is still one of the most vital research themes in climate science. Many global and regional aspects of the climate system appear to be directly proportional to the equilibrium climate sensitivity. Hence narrowing climate sensitivity remains the single most important goal in climate science, as it conditions so many aspects of climate change.

Therefore, one main theme of EUCLIPSE has been to study the role of low clouds in a warming climate because the response of these clouds is considered to be the largest contributor to the uncertainty in climate sensitivity. One of the most important results of EUCLIPSE is that new ideas and hypotheses of low cloud feedback have been put forward and tested. These ideas have been proven powerful in understanding the response in climate models to forcing, and helped to break a long-standing deadlock in our understanding of the climate system, namely whether or not low clouds are contributing to or mitigating against forced changes in the climate system. Because of the work in EUCLIPSE it is now thought that low clouds act to amplify warming, although to what degree remains open.

A second main theme of EUCLIPSE has been the influence of clouds and convection on the large scale circulation and its associated precipitation patterns. Climate models exhibit great difficulties in predicting the regional distribution of (especially) tropical rainfall, mainly because they fail to correctly represent the large-scale circulation. EUCLIPSE helped understanding why this is so and has been able to attribute these biases to how cloud-radiative and cloud-convective processes couple to the large-scale circulation

Although these results should be considered as only first steps toward progress in the areas of climate sensitivity and future precipitation changes, it is a clear demonstration that progress is very well possible in areas that have been considered as main barriers for many decades. A couple of reasons can be given for this breakthrough. First, EUCLIPSE advanced the integration of existing frameworks and the development of new frameworks to study climate change. The use of a hierarchy of models, from single column models, to high-resolution process models, to short time integrations of advanced climate models EUCLIPSE has shown how this hierarchy of models must be used in combination to solve important problems in climate science. EUCLIPSE advanced the use of new diagnostic techniques to better link observations to modelling, both through the development of simulators that are now routinely imbedded in climate models, but also through the development of high frequency grid-point output for comparison with ground stations. Finally EUCLIPSE advanced the model hierarchy by showing the power of new idealizations, ranging from three dimensional calculations of radiative convective equilibrium using Earth System Models, to the applicability of reduced frameworks like aqua planets for studying climate change.

The prospects that progress is likely to be made for these crucial and important themes in the coming 5 to 10 years has motivated the World Climate Research Programme (WCRP) to launch ***Clouds, Circulation and Climate Sensitivity*** as one of their six Grand Science Challenges, a theme that germinated directly from the EUCLIPSE project. The two lead coordinators of this Grand Challenge, which are EUCLIPSE Workpackage leaders have drafted a White Paper on this theme addressing the question *"How the interactions between clouds, greenhouse gases and aerosols will affect temperature and precipitation"* (Bony and Stevens 2012). Subsequently a process of broad community consultation gave rise to the idea of shaping the grand challenge around the articulation of a handful of scientific questions. The process of identifying these questions culminated in a workshop dedicated to this purpose and are summarized in a WCRP report (Stevens et al. 2014). The vision on future research issues related to climate change arising from the EUCLIPSE project is well articulated in these two documents. The purpose of the present document is merely a short summary of this vision and to relate these to the proposed initiatives for the European Horizon 2020 programme For a more detailed description of the Grand Science Challenge on clouds, circulation and climate sensitivity (in short GSC-clouds) the reader is invited to access the above mentioned white paper and the WCRP report.

2. Clouds, Circulation and Climate Sensitivity

The expectation of the GSC-clouds is that it will overcome three main barriers in the coming 5 to 10 years that have prevented progress in assessing climate sensitivity and future precipitation changes: i) Inability to constrain the effects of clouds on climate sensitivity estimates, ii) Lack of understanding of regional circulation and precipitation changes, especially over land and iii) Unreliable representation of the coupling between cloud-processes and large-scale dynamics. EUCLIPSE has already demonstrated that, provided that sufficient capacity building will take place, these barriers can be lifted and significant progress can be achieved in a ten-year timeframe. This framework encouraged the structuring of the GCS-clouds around five targeted research initiatives, which all tend to be rooted in a particular scientific culture but which all will bring together expertise from theory, modelling and observation. These initiatives are as follows:

1. **Climate and Hydrological Sensitivity:** This initiative focuses on narrowing uncertainty in estimates of different measures of climate sensitivity, including the hydrological sensitivity.

2. **Coupling Clouds to Circulation:** This initiative encapsulates the parameterization problem as it pertains to diabatic processes in the atmosphere, but will do so by thinking of it in the context of circulations.

3. **Changing Patterns:** This initiative is designed to link understanding of circulations and factors causing changes in circulations, to regional responses, thereby giving more of a dynamic impetus to the Grand Challenge

4. **Leveraging the Past Record:** This initiative targets the exploitation of observations of the recent past, or proxies for changes over the more distant past, to improve understanding and assessment of climate sensitivity and precipitation projections.

5. **Toward more reliable models**: This initiative aims at improving models used for projecting future climate change

A further process of broad community consultation gave rise to the idea of shaping the grand challenge around the articulation of four scientific questions (Stevens et al 2014):

1. How will storm tracks change in a future climate?

2. What controls the position and strength of tropical convergence zones?

3. Is convective aggregation important for climate?

4. Does convection determine the strength of cloud feedbacks?

By focusing on these *Four Questions*, each intellectually compelling in its own right, the community would be better placed to attract the brightest young minds to work on important problems, which, together with more focus and coordination, would lead to substantial progress in key areas of climate science over the coming decade.

3. Research needs for climate modelling within the European Horizon 2020 programme

A recent document (Hewitt et al 2013), published by European experts in the field represented by the European Climate Observations, Modelling and Services (ECOMS) board has provided a vision and motivation for research and development over the coming decade for climate observations, modelling and services. The proposed initiatives are suitable for forming the Horizon 2020 programme under Challenge 5: Climate Action, Resource Efficiency and Raw Materials.

The vision expressed in this document is *"a European society capable of properly managing the risks and opportunities arising from climate variability and change"*.

To achieve his vision coordinated development of climate modelling is required to support decision-making in Europe. In order for climate model output to be confidently used by decision-makers, work is required to improve trust in our simulations of the climate, and to ensure that Europe is developing leading capability for the next generation of models of the Earth system through improved resolution, initialisation of the predictions, process representation and model architecture.

There are significant challenges associated with making predictions of the Earth system. There are scientific challenges to develop sufficiently complex, realistic and efficient models. There are technological challenges associated with managing huge and complex datasets (from observations and model simulations), and having sufficient computing capability and capacity to develop and use the models. To address these challenges three consecutive initiatives have been identified:

1. European Union Climate Projections 2020, EUCP20: Development of a climate prediction system for the EU region based on the **current generation** of climate models. Focussing on high-resolution climate projections, covering timescales from seasons to decades. This activity also takes into account initialisation of the predictions and evaluation of the models

2. Developing trust in climate models: this will include the development of better observational systems; use of multi-model ensembles; more comprehensive Earth system modelling; better treatment of uncertainty, all leading to improved estimates of climate sensitivity

3. European Union Climate Projections 2030, EUCP30 : Develop modelling capabilities for

the **next generation** of climate prediction system, including higher-resolution modelling, earth system modelling, process representation, prediction initialisation, high performance computing and computational efficiency capabilities.

4. Synthesis

The Grand Science Challenge on Clouds & Circulation and Climate Sensitivity has close links with the climate modelling initiatives proposed by the ECOMS board for the Horizon 2020 programme. In particular the initiatives of the GC-clouds will strengthen the science that is required to make the next generation of climate models in a number of ways:

i) Through *narrowing the uncertainty climate sensitivity* it will contribute to developing trust in climate models by reducing uncertainties in many aspects of climate projections.

ii) The Grand Challenge initiatives related to the *coupling of clouds to circulation* and to *the changing patterns* will provide information on which shifts in the large scale circulation such as for instance in the storm tracks and the Hadley Circulation are robust and which are the associated expected changes in precipitation patterns. At present climate models show large differences in changing precipitation patterns for future climate, making it difficult to decide which changes in precipitation patterns are credible

iii) The *levering the past record* initiative will provide constraints on the radiative forcing due to aerosols in the 20th century. This will disentangle uncertainties due to radiative forcing and due to the climate response and thereby allow for making more precise estimates of climate sensitivity based on the past climate

iv) and finally the cross-cutting initiative *"toward more reliable models"* is an absolute imperative for developing trust in climate models. It is aimed at improving parameterized processes that are responsible for long-standing biases, like the double ITCZ problem.

All these GC-initiatives and the related four science questions will contribute to research needs in the Horizon 2020 program as it will provide more credible information on changes in future temperatures, circulation and precipitation Therefore European scientists can and should maintain their leading position on the area of understanding and developing the physical climate system, supported by the Horizon 2020 programme, thereby contributing to having the best climate modelling systems in the world, in support of climate services for the European society.

References

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