Je-S form sections

# Objectives (4000 chars)

The overall objective of the project is to cement and strengthen UK leadership in the field of coupled ice-sheet-climate modelling, through the deepening of an existing, currently unfunded international collaboration, and by the development of an international network of model users and providers. In particular, we will work with the developers of the Community Earth System Model in the US (CESM), and with the Hadley Centre (UK). In addition, we will work with a broad spectrum of scientific stakeholders, and focus on the impact that the work will have among these parties. The work encompasses both ice sheet models (ISMs) and global climate models (GCMs). There are three broad aims:

1. Development and dissemination of a generic, sustainable technical and scientific framework for ISM-GCM coupling. This will define a standard Application Programming Interface (API) for ISMs and their coupling to climate models.

2. Implementation of the ISM part of the API within Glimmer-CISM, and the GCM part within the US Community Earth System Model (CESM) and the Hadley Centre climate models.

3. Enhancing access to and use of Glimmer-CISM by developing an API-compliant architecture for the model, and basing new documentation and training opportunities upon this.

Specific aims, in order of priority are:

1. Development of comprehensive ISM-GCM coupling API, based on experiences of Hadley Centre and CESM partners and on input from international ISM/GCM communities.

2. Implementation of API in Glimmer-CISM/CESM coupled model

3. Implementation of API in Glimmer-CISM/HadGEM3 coupled model

4. Widespread engagement of ISM/GCM communities in these issues

5. Successful training events drawing in modellers from across the international ISM/GCM communities

6. Improved Glimmer-CISM website incorporating training materials

7. New graphical user interface for Glimmer-CISM

# Summary (Non-specialist audience: 4000 chars)

The impact of climate change on the Greenland and Antarctic ice sheets is a problem of great importance to society. At the moment, we do not have very good estimates for the amount that these ice sheets will shrink during the coming century, and consequently it is difficult to predict how much sea level will change. Sea level rise is a concern because of the difficulties it would cause to the millions of people worldwide who live in low-lying areas.

Computer modelling of the climate is one of the most important ways we can attempt to predict the scale and rate of changes in the future. The climate system itself is made up of several components, and computer models of these are frequently developed separately from one another. Ice sheet models are a particular, very important model component, and for them to be used to predict sea level change, they need to be coupled with model components representing the atmosphere, ocean and land surface.

Coupled modelling is a technically and scientifically complex thing to do. It has been usual in the past to couple particular collections of models together in an ad-hoc way. However, it would be useful to be able to do this more flexibly, and to allow different ice sheet models, for example, to be exchanged for one another within the coupled model. This would allow us to discover whether different combinations of models give the same predictions. If they do, this strengthens our confidence in their predictions. However, it is quite likely that there would be differences between the predictions. Analysing these differences will increase our understanding of the climate system, and how the different parts affect one another. It would be very valuable for improving the models themselves, and hence the reliability of their results.

Another reason why flexible coupling is beneficial is that modelling techniques are always changing, and we need to be able to update our coupled models with the minimum of effort. At present, introducing a new component to a coupled model is a time-consuming and complex process. If we could somehow standardise things sufficiently, that process would be much easier.

This proposal will address these issues, and in so doing will strengthen the international community of scientists doing coupled ice sheet-climate modelling.

We will be working with an existing ice sheet model called Glimmer-CISM, which has been developed by scientists in the UK and US. We will also be working with climate models from the US and UK. By looking at these models, and by canvassing the views of scientists from around the world, we will develop a standard way of coupling ice sheet models to climate models. This will be published as a technical document for other scientists to adopt when developing new models, or adapting existing ones for coupling. We will also implement the coupling standard in the models we work with, to demonstrate its practicability and usefulness.

We will be running several events to engage with the climate and ice science communities. The most important of these are two workshops where we will discuss ice sheet-climate coupled modelling in detail. We will also run training events so that scientists will be informed about project outcomes, and have practical experience of working with the coupling design. We will also use the web to build up the community of users of the models, to enable it to be self-supporting.

Another part of the project is to provide an ice sheet model for teaching purposes – and for use by interested members of the public. This will be something with an easy-to-understand graphical interface which can be installed without difficulty on an ordinary computer.

All our work will be publicised and communicated with other scientists through conferences and publications.

# Academic Beneficiaries (4000 chars)

This project is specifically targeted to benefit a wide cohort of the academic community. The research aims to provide a better framework to permit the coupling of Ice Sheet Models (ISMs) and Global Climate Models (GCMs) and to implement this in a specific ISM (Glimmer-CISM) and counterpart GCMs. The framework will be of the form of a detailed and specific Application User Interface (API) that defines how the models are coupled to each other. This means that models that conform to the interface can be easily coupled to each other. Further, the project will enhance the accessibility and usability of Glimmer-CISM based around the API, together with training on how the API works, and how to use Glimmer-CSIM alongside GCMs.

The academic community will therefore benefit in a number of ways:

1. There is a focused cohort of Ice Sheet Model and GCM developers who will gain the opportunity to discuss and define the way the API should exist via a set of Workshops which lie at the heart of the project. This aims to ensure that the API specification is consensual across the community and that it is fit for purpose from the perspective of a number of developers. The definition of the API itself will provide a level of structure and clarity about the way such models are used together. As model developers go on to develop models into the future, it means they will have a framework around which to structure new developments. It means that their model codes can be more accessible and more easily interfaced with other codes. Overall, a key rationale for the project is thus to provide simpler, and more flexible interchange of model units. This will improve the way in which scientific questions can be asked, and model experiments performed.

2. Users of coupled ice sheet - climate models will be gain substantially from the project. We will specifically build improvements based around the API into Glimmer-CISM, the US Community Earth System Model (CESM) and Hadley Centre models. Further, we will enhance the documentation and accessibility of Glimmer-CISM and develop structured training materials based on these developments. We will hold a set of three training events for the benefit of the academic user community, particularly Postgraduate students. In sum our goal is to expand significantly the community of researchers who are able to use the codes, thereby increasing the value of the huge resource that has been committed to developing the code in the first place. The specification of the API as the vehicle for accessing and using the code means that we aim to future-proof these developments. Thus, even when (as we fully anticipate) Glimmer-CISM in its current form may evolve, anyone familiar with the API should be able to continue to use and implement code that adopts the API. The idea is that even when the inner workings of the code evolve, the interface, and thus access to the code will remain stable and consistent. So even though our training events will be delivered using Glimmer-CISM, they should have a longer-term impact based on the API. In sum, we hope there will be a far wider community of scientists who will be able to consider using Ice Sheet and Climate models in their research and linking them in to their own projects with far greater ease. 3. The broader climate science community also stands to gain from this proposal. We anticipate that the knock-on effect will be an upsurge in the research based around modelling experiments, which will be of wider interest to those interested in the operation of the climate system and of past and future climate change. These will increase knowledge of the climate system, and improve predictions of sea-level rise.

4. A further aim of the project is to establish a long-term network of Ice Sheet and Climate model developers who are interested in the API specification, with the aim that the API itself can continue to develop with the mutual agreement and participation of the user community.