Shared frameworks for next-generation ice sheet modelling

Participants

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Introduction

Ice sheets respond to and influence the global climate on a variety of spatial and temporal scales. Their future evolution, especially the consequences for global sea level, is of great societal importance, and consequently numerical ice sheet models (ISMs) comprise a growing area of interest. The technical and scientific challenges inherent in ice sheet modelling are substantial, and are compounded by the need to couple ISMs to climate models in a physically-consistent and scientifically-useful way. In the UK, ISM development has, hitherto, been largely conducted by individuals or small groups, but these challenges require a coordinated, international approach, with a high degree of participation from the broader academic and stakeholder communities.

We propose to bolster UK leadership in this rapidly developing field. We will build upon an existing unfunded collaboration centred on an established ISM (Glimmer-CISM: see below). Our aim is to advance a sustainable technical framework and governance structure for Glimmer-CISM, with international collaboration and community participation at its core. Enhancing these fundamental aspects of model development will bring several high-value benefits: it will make new science possible through improved functionality, flexibility and documentation, it will allow the community to leverage other sources of funding to support code maintenance and development, and it will cement the model's reputation as a leading ISM internationally.

Background

Glimmer-CISM's origins lie in an ISM developed by Payne which was further developed as an open-source community model (Glimmer) in collaboration with Rutt, Hagdorn and Hulton[1]. Subsequently, Glimmer was adopted as the ice sheet model component of the Community Earth System Model (CESM, formerly CCSM[2]), and renamed Glimmer-CISM. Initially based on the Shallow Ice Approximation, Glimmer-CISM has recently gained a higher-order stress balance module developed by Price and Payne, as well as other enhancements. Development is conducted on a public-access website[3], and is coordinated by a steering committee comprising Rutt (chair), Hagdorn, Johnson, Lipscomb, Payne and Price.

Glimmer-CISM development was initially funded as part of GENIE (Payne, Rutt: NERC eScience ref. NER/T/S/2002/00221), and later though the National Centre for Earth Observation (NCEO), though with significant unfunded contributions from Hagdorn. US DOE support for implementing Glimmer-CISM in the Community Climate System Model (CCSM) began in 2006 and has led to development funding being substantially provided from US sources The first public release of CCSM was in June 2010, at which time the model was renamed the Community Earth System Model (CESM). While the US support has delivered significant benefits to the global ISM community, it is nevertheless understandably driven by the needs of CESM and US funders. At present, UK involvement in model development, and the provision of functionality and support for non-CESM users (e.g. the Met Office, University of Reading), is hampered by a lack of funds. There also is a substantial potential European user group coupling ISMs to GCMs in FP7 who currently use

the ISM, PISM, in part, because of concerns over Glimmer-CISM's coupling environment. This project aims to ensure that ongoing developments by the international partnership working on the code can continue to address UK climate science needs.

Project outline

There are three strands to the proposed project: software engineering, community participation, and governance development.

- **Software engineering**. Our ambition for Glimmer-CISM is that it should be a *modular, extensible framework for ice sheet modelling*. This allows different modules for solving the model equations (dynamical cores) to be developed and deployed in flexible combinations. To be of maximum benefit, the model also needs flexibility in the way it is coupled to climate models. Although Glimmer-CISM is a relatively well-engineered code, it will require substantial work to realise this ambition. This kind of work does not fit well into normal funding mechanisms because it is not targeted at specific science goals, but instead aims to build broad, long-lived capacity for science, that aligns with shared international goals. It is anticipated that the project will fund 2 yrs FTE to redesign the framework of GC with the aim of facilitating coupling to climate models and specialised 'plug and play' ice flow routines.
- **Community participation**. To build an effective, usable ISM framework, and to ensure it is used to its full capability, effective community participation is essential. We will work with a range of stakeholders from across the UK and international climate and cryospheric communities to ensure that engineering decisions reflect their fundamental, long-term needs. We will organise regular workshops for face-to-face discussion and training, as well as making extensive use of web-based tools for building engagement, and to grow the community of users which already exists around the model. It is particularly important that the international community working on the code develop a shared vision of the model architecture, and the way this can be employed across a wide spectrum of climate models.
- **Governance development**. The experience of the broader open source software (OSS) movement has been that effective community participation depends on transparent and accountable governance[4]. The need to deliver long-term, sustainable stewardship of an important component of the UK's climate modelling capability without recourse to substantial, long-term funding, means that a resilient international governance structure is needed. A key outcome of this reinvigorated structure will be our ability to lever non-NERC funding sources.

International Partners

The three named international partners are all members of the current Glimmer-CISM steering committee, and are also co-chairs of the CESM Land Ice Working group. As such, the PI and Co-Is of this proposal already collaborate with them on ISM topics. In-kind support provided by Lipscomb and Price at LANL will be in the form of:

(1) continued development of advanced dynamical cores and improved model physics, sponsored by DOE under the Scientific Discovery through Advanced Computing (SciDAC) project and by the Ice Sheet Initiative for Climate Extremes (ISICLES)

(2) dedicated software engineering support at NCAR, funded by NSF, for integrating ice sheets into CESM which could include the development of generic ice-sheet interfaces for climate models.

(3) twice-a-year meetings of the CESM Land Ice Working Group that bring together over 50 people in the North American land-ice modelling community and are of course open to the international community.

References

1 Rutt, I. C., M. Hagdorn, N. R. J. Hulton, and A. J. Payne (2009) The Glimmer community ice sheet model, *J. Geophys. Res.*, **114**: F02004.

2. http://www.cesm.ucar.edu/

3. http://developer.berlios.de/projects/glimmer-cism/

4. Bacon, J. (2009) The Art of Community: Building the New Age of Participation. O'Reilly Media.