Application for CMIP6-Endorsed MIPs

Please return to CMIP Panel Chair Veronika Eyring (email: Veronika.Eyring@dlr.de)

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The recently proposed, revised CMIP structure (see information on the CMIP Panel website at http://www.wcrp-climate.org/index.php/wgcm-cmip/about-cmip) provides for a small set of experiments to be routinely performed by modeling groups whenever they develop a new model version. The output from these so-called *ongoing CMIP Diagnostic, Evaluation and Characterization of Klima (DECK)* experiments will be distributed for community use via the ESGF infrastructure. Other Model Intercomparison Projects (MIPs) will build on the CMIP DECK experiments and augment them to address a broad range of scientific questions. Additionally proposed MIP experiments together with the CMIP DECK experiments will constitute the suite of simulations for the next phase of CMIP.

MIPs are now invited to request endorsement for the next phase of CMIP (i.e., CMIP6). Applications from MIPs requesting status as a CMIP6-Endorsed MIP should be sent to the CMIP Panel Chair. We would appreciate your application by mid-September 2014 in time for the next WGCM meeting, although applications will be considered after that point in time. A MIP may propose that a subset or even all of their experiments be included as part of the suite of simulations constituting CMIP6. The CMIP Panel will, together with the WGCM co-chairs, decide 1) whether a MIP meets the criteria for endorsement for CMIP6 and 2) which (if any) of its experiments will be included in CMIP6. Note that it is expected that all additional experiments proposed for CMIP6 will be scientifically analyzed and exploited by the MIP.

CMIP6-Endsored MIPs can make full use of the ESGF infrastructure. In order to minimize the burden imposed on modeling groups wishing to participate, the MIPs seeking to be part of CMIP Phase X must agree to comply with the CMIP standards in terms of experimental design, data format and documentation. In general the WGCM encourages adhering to the standards in place for CMIP.

The main criteria for MIPs to be endorsed for CMIP6 are

- The MIP addresses at least one of the key science questions of CMIP6;
- The MIP follows CMIP standards in terms of experimental design, data format and documentation;
- A sufficient number of modeling groups have agreed to participate in the MIP;
- The MIP builds on the shared *CMIP DECK* experiments;
- A commitment to contribute to the creation of the CMIP6 data request and to analyze the data;
- A commitment to identify observations needed for model evaluation and improved process understanding, and to contribute directly or indirectly to making such datasets available as part of obs4MIPs.

The additional criterion used to determine whether a particular MIP experiment should qualify for inclusion as part of the CMIP6 suite of simulations is:

- The proposed experiment is of central importance to CMIP6;
- The proposed experiment has been run at least by two modeling groups already;
- The proposed experiment is useful in a multi-model context and to a number of climate researchers.
- A commitment to scientifically analyze, evaluate and exploit the proposed experiment.

Note that the CMIP panel and WGCM co-chairs will attempt to decrease the total number of experiments included in CMIP6, compared with CMIP5. Thus, it is possible that not all or even none of the experiments proposed by a CMIP6-Endorsed MIP will be included.

Proposals from MIPs should include the following information:

** Preliminary information used to determine whether a MIP should be endorsed for CMIP6 or not.*

*** Information that must be provided later (and before the panel can determine which experiments, if any, will be incorporated in the official CMIP6 suite).*

- Name of MIP*

ISMIP6: Ice Sheet Model Intercomparison Project for CMIP6

- Co-chairs of MIP (including email-addresses)*

Eric Larour, NASA Jet Propulsion Laboratory, USA, eric.larour@jpl.nasa.gov
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Jonathan Gregory, University of Reading and Met Office Hadley Center, UK
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- Link to website (if available)*

- Goal of the MIP and a brief overview*

The primary goal of ISMIP6 is to improve projections of sea level rise via improved projections of the evolution of the Greenland and Antarctic ice sheets under a changing climate, along with a quantification of associated uncertainties (associated with both uncertainty in climate forcing and in the response of the ice sheets). This goal requires an evaluation of AOGCM climate over and surrounding the ice sheets; analysis of simulated ice-sheet response from standalone models forced “offline” with CMIP AOGCM outputs and, where possible, with coupled ice sheet-AOGCM models; and experiments with standalone ice sheet models targeted at exploring the uncertainty associated with ice sheets physics, dynamics and numerical implementation. A secondary goal is to investigate the role of feedbacks between ice sheets and climate in order to gain insight into the impact of increased mass loss from the ice sheets on regional and global sea level, and of the implied ocean freshening on the coupled ocean-atmosphere circulation.

- References (if available)*

ISMIP6 is based on a long history of Ice Sheet Model Intercomparison Projects (ISMIP http://homepages.vub.ac.be/~phuybrec/ismip.html), in particular the more recent Sea level Response to Ice Sheet Evolution (SeaRISE http://websrv.cs.umt.edu/isis/index.php/SeaRISE_Assessment), ice2sea (www.ice2sea.eu) and COMBINE (https://www.combine-project.eu/) efforts. ISMIP6 brings together for the first time a consortium of international ice sheet models and coupled ice sheet-climate models to fully explore the sea level rise contribution from the Greenland and Antarctic ice sheets. Papers generated by these recent activities, that involved the ice-sheet modeling community, include:

- Bindschadler, R. et al. (2013) Ice-Sheet Model Sensitivity to Environmental Forcing and Their Use in Projecting Future Sea levels (The SeaRISE Project). Journal of Glaciology, 59 (214), 195-224.

- Edwards, T.L., et al. (2014) Effect of uncertainty in surface mass balance elevation feedback on projections of the future sea level contribution of the Greenland ice sheet. The Cryosphere 8(1), 195-208.
- Favier, L., et al. (2014) Retreat of Pine Island Glacier controlled by marine ice-sheet instability. Nature Clim. Change 4(2), 117-121.
- Nowicki et al. (2013) Insights into spatial sensitivities of ice mass response to envirnmental change from the SeaRISE ice sheet modeling project I: Antarctica. Journal of Geophysical Research- Earth Surface, 118 (2), 1002-1024.
- Nowicki et al. (2013) Insights into spatial sensitivities of ice mass response to environmental change from the SeaRISE ice sheet modeling project II: Greenland. Journal of Geophysical Research- Earth Surface, 118(2), 1025-1044.
- Pattyn, F., et al. (2013) Grounding-line migration in plan-view marine ice-sheet models: results of the ice2sea MISMIP3d intercomparison. Journal of Glaciology 59(215), 410-422.
- Rae, J., et al. (2012) Greenland ice sheet surface mass balance: evaluating simulations and making projections with regional climate models. The Cryosphere 9(6), 1275-1294.
- Shannon, S.R., et al. (2013) Enhanced basal lubrication and the contribution of the Greenland ice sheet to future sea level rise. Proceedings of the National Academy of Sciences 110(35), 14156-14161.
- Shepherd, A., et al. (2012) A Reconciled Estimate of Ice-Sheet Mass Balance. Science 338(6111), 1183-1189.

➢ An overview of the proposed experiments*

The overall framework for ISMIP6 is designed to deliver projections of the ice sheet contribution to sea level rise. Together with the proposed glacier CliC (Climate and Cryosphere) targeted activity and projections of thermal expansion (that already sit within the CMIP framework), this will allow sea level to become part of the family of variables for which CMIP can provide routine IPCC-style projections. The proposal will both use and augment the CMIP-DECK experiments, as summarized in Table 1. ISMIP6 will use the shared standard CMIP DECK experiments for analysis of the climate over and surrounding the ice sheets, and as forcing for the standalone ice sheet models (ISM) projections. Additional sensitivity experiments will be performed with the ISM to investigate the uncertainty associated with these projections arising from ice sheet models. The key output will be an ensemble of historical and future estimates of ice sheet contribution to sea level. To address the feedbacks introduced by interactive ice sheets, we propose that a small number of selected DECK experiments are repeated with coupled AOGCM-ISM, where the ice sheet is an interactive component of the AOGCM. Our assessment of the state of existing AOGCMs is that coupled models including an interactive Greenland ice sheet can realistically be expected for CMIP6, however it is unlikely that such models will include the Antarctic ice sheet (because of the greater complexity of its response to climate forcing, and the issues associated with simulations of the Southern Ocean).

<table>
<tr><th>Existing CMIP-DECK exp. used by ISMIP6 (AOGCM only)</th><th>Standalone ISMIP6 ice sheet model exp.* (ISM only)</th></tr>
<tr><td>- AMIP simulation (amip)
- Pre-Industrial Control (piControl)
- 1% yr CO2 to quadrupling CO2 (1pctCo2)
- RCP8.5 up to year 2300 (rcp85)</td><td rowspan="3">- ISM control (controlism)
- ISM for last few decades forced by amip (amipism)
- ISM forced by 1pctCo2 (1pctCo2ism) for quantification of feedback
- ISM for 21st century and up to 2300 sea level forced by rcp85 (rcp85ism)
- Other ISMIP6 specific experiments to explore uncertainty due to ISM</td></tr>
<tr><td>New ISMIP6 CMIP6 exp.** (Coupled AOGCM-ISM)</td></tr>
<tr><td>- Pre-Industrial Control (ismPiControl)
- 1% yr CO2 to quadrupling CO2 (ism1pctCo2)
- RCP8.5 up to year 2300 (ismRcp85)</td></tr>
</table>

Table 1: Overview of experimental framework for ISMIP6 (further details on experimental design and motivation are explained in later sections). Name of experiments are indicated in italic. *These types of standalone ensemble ISM experiments were implemented in the European ice2sea and SeaRISE efforts for IPCC-AR5, but using forcing derived from AR4 (See www.ice2sea.eu and http://websrv.cs.umt.edu/isis/index.php/SeaRISE_Assessment) **These types

of experiments, where the ice sheet is an interactive component of the AOGCM, have been recently run as part as the European COMBINE effort (https://www.combine-project.eu/) by three modeling groups: IPSL, MIP-I, and DMI.

- An overview of the proposed evaluation/analysis of the CMIP DECK and CMIP6 experiments*

The primary goal of ISMIP6 is an analysis of the historical and future estimates of ice sheet contribution to sea level via evaluation of the ensemble simulations.

This goal therefore also requires that three components of the Earth system are evaluated and analyzed by comparing to in situ, airborne and satellite observations:

1) The ice dynamics (surface elevation and mass changes, ice flow changes, ice mass flux through gateways, grounding line and ice front locations)
2) The atmosphere over the ice sheets (surface radiative and turbulent fluxes, temperature, surface mass balance (SMB), albedo)
3) The ocean surrounding the ice sheets (sea surface height, sea surface temperature, wind stress, hydrographic properties at the margins of the ice sheets to the extent available, sea-ice cover)

Observations over the ice sheets that are required for a more in depth analysis will be suggested for inclusions in the Obs4MIPs archive. For the atmospheric and oceanic variables, additional comparisons with reanalysis are suggested as a quality test. For evaluating the feedbacks introduced by coupling dynamic ice sheets to AOGCM, we will compare the results of simulations of AOGCM with and without dynamic ice sheet models.

- Proposed timing*

The analysis of atmospheric and oceanic climate over and surrounding the ice sheets from the CMIP5 archive will begin immediately in order to assess the quality and implied change in surface mass balance. Analysis of the CMIP6 data would be ongoing and follow the simulation phase of CMIP6.

ISMIP6 started the design of the standalone ice sheet experiments during a workshop in July 2014, therefore further refining these experiments and data preparation would be completed by mid 2015. The sea level projections based on the selected CMIP5 experiment would begin mid 2015, and continue in tandem with CMIP6. Analysis of the projection simulations and sensitivity experiments would be ongoing in order to identify the dominant sources of uncertainty.

The runs for the AOGCM-ISM simulations would occur towards the beginning or middle of the CMIP6 cycle, so that the knowledge gained from the effect of dynamic ice sheets and associated feedback can be incorporated in other MIPs.

- For each proposed experiment to be included in CMIP6**
    - the experimental design;
    - the science question and/or gap being addressed with this experiment;
    - possible synergies with other MIPs;
    - potential benefits of the experiment to (A) climate modeling community, (B) Integrated Assessment Modelling (IAM) community, (C) Impacts Adaptation and Vulnerability (IAV) community, and (D) policy makers.

As summarized in Table 1, the experimental design for ISMIP6, consist of three different types of modeling efforts: standard DECK experiments, simulations with standalone ice sheet models, and simulations with coupled AOGCM-ISMs when possible.

The following experimental design is proposed:

1) Analysis of standard AMIP and RCP8.5 DECK experiments over ice sheets (for all models including those without interactive ice sheets):
   - AMIP: Allows the evaluation of AGCM climate over ice sheets, in particular surface mass balance (SMB: the combination of precipitation, evaporation and surface runoff).
   - RCP8.5: continued to year 2300 if possible. The experiment would assess projected changes in SMB with fixed ice sheet extent and topography.

   Note: we would start with the existing CMIP5 output and repeat the analysis when CMIP6 output is available. The output from these experiments will be used to assess the uncertainty in sea level arising from climate forcing and to drive the standalone ice sheet models.
2) Standalone ice sheet models experiments:
   - ISM control: Constant forcing, needed to evaluate model drift.
   - ISM AMIP: simulation for the last few decades to understand the well observed record of ice sheet changes. ISM would be driven by SMB anomalies obtained from the standard AMIP DECK simulations, and ice shelf basal melting or temperature anomalies from ocean models.
   - ISM 1% yr CO2 to quadrupling C02: for comparison with the AOGCM-ISM experiment in order to evaluate ice sheet feedback.
   - ISM RCP8.5: simulation for the 21st century (and maybe up to the 23rd century depending on DECK) for the most realistic ice sheet contribution to sea level projections. ISM would be driven by SMB anomalies (with adjustments for ice sheet elevation change) and ice shelf mass balance or temperatures anomalies derived from the standard RCP8.5 DECK simulation.
   - Additional ISM experiments would be designed to assess the uncertainty in sea level projections due to ice sheet models. These experiments would explore the uncertainties identified in the ice2sea and SeaRISE efforts, which include ice sheet initialization, poorly known basal conditions and subgrid-scale processes. In addition, ISMIP6 would investigate questions such as “How much excess oceanic heat flux is required to trigger marine ice sheet instability?” to shed light on the potential collapse of the Antarctic ice sheet.

   Note: Following the approach taken in the ice2sea and SeaRISE efforts, the anomalies derived from the DECK experiments would be added to the forcing used in the ISM control runs. Modeling groups could decide to carry out the experiments for both the Greenland and Antarctic ice sheets, or to focus on one ice sheet.
3) Coupled AOGCM-ISMs experiments (same set up as DECK experiment but with evolving ice sheets)
   - Pre-industrial control: the aim is to produce a realistic non-drifting coupled state.
   - 1% yr CO2 to quadrupling CO2 and kept constant at 4xCO2: for analysis of coupled ice sheet-climate system. Experiment would be compared to the standard DECK without ice sheets and to the standalone ISM forced by the standard DECK, in order to diagnose the strength of ice sheet-climate feedback.
   - RCP8.5: for analysis of coupled system and sea level projections from a coupled framework, which can be compared to the standalone ice sheet model projection. Experiment would cover the 21st century and preferably run out to the 23rd century.

   Note: We suggest that the experiment 1% yr CO2 to quadrupling CO2 is performed first, followed by RCP8.5. Modeling groups could decide to carry out the experiments for both the Greenland and Antarctic ice sheets, or to focus on one ice sheet. Feedbacks that we propose to explore include albedo-melt feedback, elevation-SMB feedback, precipitation-sea ice feedback, fresh water (runoff and icebergs calving and submarine melting)- ocean feedback , atmospheric circulation – ocean heat flux feedback (e.g. tip-jets, katabatic winds). This type of coupled experiments have been carried out by 3 modeling centers (IPSL, MPI-M, DMI) and soon MeteoFrance as part of the European COMBINE project. These coupled models (**IPSL**: IPSL – GRISLI; **MPI-M**: MPI-ESM – PISM and MPI-ESM – SICOPOLIS; **DMI**: EC-Earth – PISM, and soon CNRM-GRISLI) were described and evaluated in the COMBINE reports 'Assessment of performance of AOGCMs coupled to Greenland and Antarctic models' (http://www.combine-project.eu/fileadmin/user_upload/combine/dels/D4.3.pdf) and 'Feedbacks of individual components: Cryosphere' (http://www.combine-project.eu/fileadmin/user_upload/combine/dels/D7.7_v2.pdf, in the second part: 'Impacts of including an interactive Greenland ice sheet in ESM). Efforts of including dynamic ice sheets into AOGCMs are also occurring with CESM, GEOS5 and ModelE for example, so it is expected that about 8-10 groups will be in a position to run such experiments for CMIP6.

The primary goal of these experiments is to improve sea level projections due to changes in the ice sheets, and assessing the uncertainty in these projections due to climate forcing versus that arising from ice sheet models. The secondary goal is to understand how ice sheets affect and are affected by climate. These experiments will thus shed light on the key science questions considered by CMIP6: "How does the Earth system respond to forcing?", "What are the origin and consequences of systematic model biases", and "How can we assess future climate change given uncertainty in scenarios?". These goals directly contribute to the Cryosphere Grand Challenge and the Sea level Rise Grand Challenge of the Climate and Cryosphere (CliC) project and the World Climate Research Program. Finally, the ISMIP6 sea level projections will be relevant to the Impacts Adaptation and Vulnerability (IAV) community and policy makers.

Possible synergies with other MIPs include:

- Coordinated Regional Climate Downscaling Experiment (CORDEX). We might use the downscaling for RCP8.5 from CORDEX to drive ice sheet models "offline" as an additional sensitivity experiment.
- Southern Ocean MIP, since we would be providing freshwater input in the form of surface runoff and iceberg flux. We would also benefit from their assessment of ocean hydrographic properties, which could be used to derive oceanic forcing for standalone ice sheet simulations.
- Snow Models Intercomparison Project (SnowMIP). This might help improving the snow models used in AOGCMs.
- Observations for Model Intercomparison (Obs4MIP). We would use the observations available on the current database to test how the inclusion of dynamic ice sheets affects the simulations. We would also suggest additional datasets that are pertinent to ice sheets and surface mass balance.
- Reanalysis for Model Intercomparison (Ana4MIP). We would use reanalysis in the assessment of the surface mass balance from AOGCM, and potentially as contemporary forcing for the ice sheets.
- Paleoclimate Modelling Intercomparison Project (PMIP). If PMIP considers the Last Glacial Maximum, we would propose to coordinate an effort with coupled ice sheets. Other simulation of interest would be paleoclimate forcing that we could use to drive ice sheets to the present day.

These synergies with other MIPs illustrate potential collaborations within the climate community. It is hoped that other MIPs would be interested in investigating how changes in the ice sheets affect the component of the climate that is their expertise.

➢ If possible, a prioritization of the suggested experiments, including any rationale**

For the coupled AOGCM-ISM, we suggest that the experiment 1% yr CO2 to quadrupling CO2 is performed first, followed by RCP8.5. The former will allow for an easier evaluation of ice-climate feedback, but the later is more relevant to our goal of sea-level rise projections. In the event that the RCP8.5 scenario is replaced in the DECK by a different future climate scenario, we will simply use the new scenario instead in our framework in order to avoid making projections of future sea level that are out of sink with the CMIP6 experiments.

- All model output archived by CMIP6-Endorsed MIPs is expected to be made available under the same terms as CMIP output. Most modeling groups currently release their CMIP data for unrestricted use. If you object to open access to the output from your experiments, please explain the rationale.**

No objections.

- List of output and process diagnostics for the CMIP DECK/CMIP6 data request**
    - whether the variable should be collected for all CMIP6 experiments, or only some specified subset and whether the output is needed from the entire length of each experiment or some shorter period or periods;
    - whether the output might only be relevant if certain components or diagnostic tools are used interactively (e.g. interactive carbon cycle or atmospheric chemistry, or only if the COSP simulator has been installed);
    - whether this variable is of interest to downstream users (such as impacts researchers, WG2 users) or whether its principal purpose is for understanding and analysis of the climate system itself. Be as specific as possible in identifying why the variable is needed.
    - whether the variables can be regridded to a common grid, or whether there is essential information that would be compromised by doing this;
    - the relative importance of the various variables requested (indicated by a tiered listing) is required if the data request is large.

The current CMIP5 CMOR tables Amon (Monthly Mean Atmopsheric Fields), Omon (Monthly Mean Ocean Fields), LImon (Monthly Mean Land Cryosphere Fields), and OImon (Monthly Mean Ocean Cryosphere Fields) already contains many of the output required to diagnose and intercompare the climate over glaciated land/ice sheets and to derive forcing for the ice sheets. However a few additional variables may be needed to properly derive the forcings for ice sheets and to record outputs from the evolving ice sheets in the coupled AOGCM-ISMs experiments (such as ice elevation change). Table 2 list our initial assessment of the Amon and LImon variables that we plan to use in ISMIP6, or that are missing. Unless otherwise stated, these variables would be on the atmosphere grid and contain monthly output. As one of our first task is to evaluate the existing CMIP5 models output for the DECK experiments that we will be using, we will revisit Table 2 during this effort, and include the oceanic variables.

Variable	Units	Existing CMOR variable name or comment if new variable
Near Air Temperature	K	tas in Amon
Snow area fraction	%	snc in LImon
Surface Snow and Ice Sublimation Flux	$kg\ m^{-2}\ s^{-1}$	sbl in LImon
Surface Rainfall rate	$kg\ m^{-2}\ s^{-1}$	pr in Amon
Surface snowfall rate	$kg\ m^{-2}\ s^{-1}$	prsn in Amon
Snow Melt rate	$kg\ m^{-2}\ s^{-1}$	snm in LImon or snm in Amon
Latent Heat flux	$W\ m^{-2}$	hfls in Amon

Sensible Heat flux	W m^{-2}	hfss in Amon
Downwelling Shortwave over ice sheet	W m^{-2}	rsds in Amon
Upward Shortwave over ice sheet	W m^{-2}	rsus in Amon
Downwelling Longwave over ice sheet	W m^{-2}	rlds in Amon
Upward Longwave over ice sheet	W m^{-2}	rlus in Amon
Calving Flux	kg m^{-2} s^{-1}	The loss of ice sheet due to iceberg calving. Exist in Omon as ficeberg, would be on Omon grid
NEW VARIABLES THAT ARE CURRENTLY NOT EXISTING IN THE CMIP5 CMOR TABLES, these quantities would origin from the ice sheet grid but be remapped to the ocean or atmosphere grids		
Ice sheet area fraction	%	Fraction of grid cell covered by ice sheets or glaciated land (similar to sci in OImon)
Ice Sheet Altitude	m	The altitude or surface elevation of the ice sheet in the atmosphere portion of the grid cell.
Surface Temperature of Ice Sheet	K	Similar to tsice in Olmon but over glaciated land
Temperature at the interface between ice sheet and snow	K	Similar to tsnint in Olmon but over glaciated land
Rate of Melt at upper surface of ice sheet or ice shelf	kg m^{-2} s^{-1}	Similar to tmelt in Olmon but over glaciated land or ice shelf
Rate of Melt at lower surface of ice sheet or ice shelf	kg m^{-2} s^{-1}	Similar to bmelt in Olmon but under glaciated land or ice shelf

Table 2: Data to be saved on the atmosphere grid (monthly) to capture the glaciated/ice sheet surface realm. Most of these variables already exist in the CMIP5 tables.

For diagnosis and intercomparison of the dynamical ice sheet models within AOGCM (the coupled AOGCM-ISM), the variables in Table 3 would be saved on the dynamical ice sheet native grid or on a regular (5x5km) grid designed for the ice sheets (such as done in the SeaRISE effort). These variables would be recorded for the entire length of the experiments involving ice sheets.

Variable	units	comment
Ice Sheet Altitude	m	The altitude or surface elevation of the ice sheet
Ice Sheet Thickness	m	The mean thickness of ice sheet
Bedrock Altitude	m	The bedrock topography.

Calving Flux	kg m^{-2} s^{-1}	The loss of ice sheet due to iceberg calving (solid ice discharge).
Individual components of Upper Surface Mass Balance	kg m^{-2} s^{-1}	
Individual components of Surface Mass Balance beneath ice sheet and ice shelf	kg m^{-2} s^{-1}	
Column mean ice velocity	m/yr	
Magnitude of ice velocity at the upper surface	m/yr	
Magnitude of ice velocity at the lower surface	m/yr	
Magnitude of basal shear stress	Pa	
Basal Water Content	m	The effective thickness of water beneath the grounded ice sheet
Surface Temperature of Ice Sheet	K	
Basal Temperature of Ice Sheet	K	
Mask	1	Grounded ice sheet, floating ice shelf, ice free land

Table 3: Example of data to be saved on the ice sheet grid (monthly or yearly) to capture the dynamical ice sheet model realm.

- Any proposed contributions and recommendations for**
    - model diagnostics and performance metrics for model evaluation;
    - observations/reanalysis data products that could be used to evaluate the proposed experiments. Indicate whether these are available in the obs4MIPs/ana4MIPs database or if there are plans to include them;
    - tools, code or scripts for model benchmarking and evaluation in open source languages (e.g., python, NCL, R).

Model evaluation over the ice sheets will include in situ, airborne, satellite data and reanalysis. Most of these cryospheric data products are not currently available in the obs4MIPs database and we will work closely with obs4MIPs to rectify this. The process is complicated by the need to evaluate both climate forcing over and around the ice sheets (i.e., AOGCM model output) and ice-sheet model response. The current proposed evaluation is described below, and we plan to have a workshop with data providers and modelers in 2015 to finalize the evaluation plan. The recent IMBIE project (Shepherd et al 2013) provides an excellent example of the ice-sheet observational community work together to provide a reconciled product suitable for testing ice-sheet models.

The components of the system that would be evaluated and analyzed include:

1) The ice sheet dynamics (surface elevation and mass changes, ice flow changes, ice mass flux through gateways, grounding line and ice front locations)

2) The atmosphere over the ice sheets (surface radiative and turbulent fluxes, temperature, surface mass balance (SMB), albedo). This component can be divided into two parts: climate forcing that would be generated by an AOGCM and processes at the ice sheet surface (that may or may not be captured within an AOGCM but will also be included in standalone ice-sheet models, such as SMB and albedo evolution).
3) The ocean around the ice sheets (sea surface height, sea surface temperature, wind stress, hydrographic properties at the margins of the ice sheets to the extent available, sea-ice cover). This component can similarly be divided into two parts: ocean forcing that would be generated by an AOGCM and processes at the ice sheet boundary (that may or may not be captured within an AOGCM but will also be included in standalone ice-sheet models, such as ice-shelf melt). A key concern will be the validation of ocean thermal forcing of the ice sheets, which is likely to focus on evolving temperature at depth and, in particular, AOGCM simulation of the Southern Ocean.

To evaluate the ice dynamics, flux gates will be defined at the coast (along grounding lines) and the mass flux through each gate estimated and compared to the flux calculated from observed surface velocities. This will create the total contribution of the ice sheet to sea level rise and for the period of GRACE data [2003- present] that the time series will be evaluated against. In addition, we will use measurements of ice sheet elevation change from ERS-1 and ERS-2 [1992-present] and ICESat [2003-2009], along with ice sheet velocities, grounding line and ice front locations.

To evaluate the climate over the ice sheets, we suggest that the variability and monthly means of measured radiation (short wave and long wave), temperature and ablation measured at Automatic Weather Stations (AWS) will be compared to model output. For the Greenland ice sheet for example, data from GC-net, PROMICE and DMI coastal stations will be used. Some kind of standardization in the processing should be made, so that each model uses the same data sets. The modeled accumulation will be evaluated by comparison with radar data sets collected as part of NASA's Operation IceBridge and accumulation measured in shallow ice cores. Ablation measurements at K-transect will be used to evaluate the melt on the west coast of Greenland. A comparison with output from RCM downscaling of reanalysis (ERA-Interim or others) would be suggested as a quality test for the SMB. We would also evaluate albedo and polar surface temperature from AVHRR [1982-present] , or MODIS [2000-present]. Location of surface melt can be estimated from the brightness temperature from passive microwave sensors [1979-present].

The inclusion of dynamic ice sheets is likely to affect the basic climatology of temperature, winds, surface flux, sea surface temperature, sea ice and clouds, for which observations are already in the obs4MIPs data base.

- Any proposed changes from CMIP5 in NetCDF metadata (controlled vocabularies), file names, and data archive (ESGF) search terms.**

- Explanation of any proposed changes (relative to CMIP5) that will be required in CF, CMOR, and/or ESGF.**

Some new standard CF names will be needed for ice sheet quantities, and there may be a need for ice sheet-grids to be handled, perhaps by CMOR.