WORK PACKAGE 2

Work Package Summary

This report is for the period from start of project (1st March 2009) the end of the First Reporting Period (31st August 2010). Please describe all activity to this point.

Please add to the form boxes – they will expand as needed.

Work Package Leader: Frank PATTYN

Progress Summary (WP highlights):

1. Grounding line representation is successfully implemented in 3D higher-order and full Stokes models, and a series model intercomparison experiments for grounding line models is established. The experimental setup will be released in autumn. Modelling has shown that decrease of back stress imposed by ice shelves is the prevailing process responsible for inland dynamical thinning of the ice sheet.

2. Detailed measurements of melt and outlet flow are ongoing. A hot-water drilling was successfully carried out during summer 2010 at Russell Glacier (Greenland). Furthermore, continuous GPS data on Austfonna and Kronebreen (Svalbard) show a clear link between melt events and velocity.

3. Detailed observations of glacier calving, glacier speed-up and mass balance have been started on Svalbard target glaciers with clear signals during summer melt season. Data can be base for validation of a newly developed calving law in a flowline model that will be coupled to a 3D higher-order model (HOM). First steps of the coupling of an ice sheet (HOM) and ocean model for investigating the grounding line transition processes have been successfully accomplished.

Sub-Work Package Reports

Sub-Work Package Number: WP**2.1** Leader: Frank PATTYN
Title: MIGRATION OF GROUNDING LINES AND STRESS TRANSMISSION
Report:

A meeting of WP2.1 was held in Grenoble (October 2009) as ice2sea kick-off. During this meeting the different partners presented the current status of model performance with respect to grounding line migration. It was decided on the necessary steps to take to improve modelling of grounding lines. A model setup was defined for a new intercomparison exercise of 3D grounding line models, based on the previous MISMIP experience (MISMIP = Marine Ice Sheet Model Intercomparison Project). Models of different levels of complexity, capable of migrating the grounding line in a coherent way, and verified by the theoretical results of Schoof (2007), can participate. Experiments aim at investigating the response of grounding lines with repsect to buttressing, basal melting and subglacial trench geometry. Two WebEx meetings, following the Grenoble meeting, were organized to define the experimental setup.

At CNRS, the existing two-dimensional full-Stokes model for the grounding line dynamics has been moved to a first three-dimensional version. CNRS is now working on the implementation of a mesh displacement method for 3D geometries to keep the mesh refinement very small around the grounding line, even for large change in its position. CSC provided a solver for evaluating the distance in an unstructured mesh from the grounding line and support in the development of the mesh refinement method and parallelization of the whole model. Accounts for performing parallel computations for requested people from LGGE have been set up at CSC and charged with the agreed amount of CPU units. General support on these accounts as well as special support on technical issues connected to Elmer have been provided by CSC. Furthermore, a numerical mesh was also produced for the Pine Island region, which will form the basis for research that will be carried out in the second phase of this work package. Lionel Favier and Olivier Gagliardini have spend two weeks and 4 days, respectively, at CSC this spring for this purpose.

At ULB, a similar approach was taken with the 3D higher-order model, and grounding lines in the plane were included. A series of models were implemented, ranging from SIA, shelfy-stream (L1L2) to higher-order models (LMLa). They complement the suite of flowline models that are used in defining the grid resolution needed to represent grounding line migration in large-scale ice-sheet models. To optimize numerical stability, new sparse numerical solvers have been implemented in the Pattyn HOM (e.g. umfpack). An overview paper on numerical approaches to represent grounding line motion in large-scale ice sheet models is in preparation and will be submitted in autumn (Docquier, D., L. Perichon and F. Pattyn (in prep.) Marine ice sheet stability and the representation of grounding line dynamics in ice sheet models: Effect of grid resolution. to be submitted to Surveys in Geophysics).

BAS have been investigating the theoretical basis for grounding-line parameterisations with the aim of a properly derived sub-grid parameterisation for fixed grid models in 2D and 3D. The aim is to compare fixed and moving grid models. Moving grid models can reproduce expected behaviour.

Further improvements are being made with grounding line experiments in flowline models. A paper has been published in GRL (ice2sea paper number 004; collaboration between LGGE, BAS and CSC) regarding the coupling between basal melting and buttressing. It is shown that melting acts directly on the magnitude of the buttressing force by modifying both the area experiencing lateral friction and the ice-shelf velocity, indicating that the decrease of back stress imposed by the ice-shelf is the prevailing process responsible for inland dynamical thinning. Furthermore, feedbacks between melting and buttressing forces may lead to counter-intuitive results as an increase of the average melting rate may lead to inland ice thickening.

In order to prepare for a new MISMIP (Marine Ice Sheet Model Intercomparison Project) exercise in 3D, results from the first phase are being analysed by ULB and BAS (flowline experiments). It will enable us to identify types of numerical models that are capable of migrating the grounding line according to theoretical predictions. We also started a comparison of the effect of different approximations of the Stokes equations on grounding line migration to test the robustness of these approximations (see milestones).

Sub-Work Package Number: WP**2.2** Leader: Michiel VAN DEN BROEKE
Title: BASAL LUBRICATION BY SURFACE MELT
Report:

GREENLAND

In order to obtain a comprehensive set of data on ice velocities, subglacial water pressure and surface melt water, we planned to install simultaneous measurements of bore hole pressure, surface energy balance and GPS location during summer melt at Russell glacier, West-Greenland. In May 2010, AU (Aberystwyth University) performed a radar survey at 3 locations in the preferred area for drilling, about 8 km from the ice edge of Russell glacier. Ice thickness was found to be approximately 565 m and the location was approved for drilling. Aberystwyth University also set up 5 self sufficient geodetic GPS systems at and around this drilling location. In the first week of July 2010, AWI/IMAU successfully installed their hot water drill from AWI at this rough ice location and drilled 2 holes to the bedrock. In the first hole IMAU/AWI installed 1 pressure, 1 inclination and 25 wireless sensors. In the second hole one wired pressure/ temperature sensor and one wireless pressure sensor were installed. The wireless system is a new development (IMAU designed and manufactured) and proves to operate very well through 600 m thick ice. Once installed, the wireless system can in principle provide continuous subglacial measurements of pressure and temperature for several years in a row. IMAU also installed an automatic weather station (AWS) at the drill site to monitor the energy balance. In the second week of July all equipment was transported back to Kangerlussuaq. At the end of July 2010 Aberystwyth/Swansea University additionally performed a seismic survey at the drill site. In August 2010, IMAU dismantled the AWS and retrieved the first data set from the subglacial sensors showing a well operating system and a clear connection of the pressure sensors to the subglacial hydraulic system throughout a 2 month period (UU, AWI).

Fieldwork was also conducted on a number of calving outlet glaciers from the Greenland ice sheet in order to retrieve as many of the GPS-instruments deployed in 2009 as possible. In the Uummannaq region in northern West Greenland, three glaciers were visited: Store Bræ, Rink Glacier and Sermeq. On Store Bræ, one GPS was retrieved and replaced out of three deployed in 2009 and two new GPS-instruments were deployed of which one is designed to transmit data. At Rink Glacier, one out of two GPS' deployed in 2009 was retrieved and replaced, and two new GPS' were deployed of which one is designed to transmit data. In southern West Greenland, on the outlet glacier Kangiata Nunata Sermia in Godthaabsfjorden, two out of three GPS' deployed in 2009 were retrieved and replaced along with a new third GPS. In South Greenland, three out of three GPS' deployed in 2009 were retrieved and replaced. A visit to Upernavik Glacier in the southern part of Melville Bay, northern West Greenland, was planned and may still be effectuated, although poor weather may prevent this as was the case in the summer campaign. The GPS' at Upernavik Glacier will in that case be retrieved in summer 2011 instead. Data from the retrieved GPS-instruments are currently being extracted and processed. A full field season is planned for summer 2011 in order to extend the outlet glacier velocity record to at least two full years and may be complemented by velocity data from other outlet glaciers from the Greenland ice sheet, retrived in partnering projects at GEUS. With GPS-data retrieved in 2010 from almost every glacier that was visited in 2009, the fieldwork is considered highly successful, given the considerable risk of losing instruments on the frontal zone of fast-flowing outlet glaciers. The fieldwork benefitted from joining forces with a number of partnering projects and is therefore also considered a success for the collaborative aims of ice2sea (GEUS).

SVALBARD

HANSBREEN: Monitoring of melting of Hansbreen (Southern Spitsbergen) surface is continued using SR50 ultrasonic rangers in the middle part of ablation zone in summer 2010. Subglacial water outflows were identified on time lapse photographs of the terminus ice cliff. Water level and discharge in river flow from the neighbouring land-based Werenskiold Glacier has been recorded during the ablation period of 2010. Data from the gauge station will be collected and examinated after the end of the melt season. They will be interpreted together with meteorological data (cooperation with IGF partner) and subglacial water pressure sensors previously installed on Hansbreen (in cooperation with the University of British Columbia). Due to interruption of air traffic over Europe following the volcanic eruption in Iceland the delivery and installation of new subglacial water pressure sensors underneath Hansbreen was not possible in spring 2010. In April 2010, a new automatic weather station (with ultrasonic ranger SR50) has been installed on Hansbreen in the upper part of the ablation area (close to ablation stake T6). Data recorded by this AWS will give more information on snow/ice melting intensity near the ELA as contribution to calculations meltwater water supply to the glacier drainage system (US).

AUSTFONNA: Continuous GPS-receivers have been installed by UiO in spring 2009 on two fast-flowing outlets on Austfonna, Basin 3 in the south and Duvebreen in the north. In each of the two drainage basins five IMAU GPS-units were installed along the central flow line. The lower station is approximately 4km from the calving front and then each 4km upstream covering the lower 20 km of each basin. The continuous GPS data showed some very interesting results with a clear link between melt events and velocity. On the Austfonna outlets we could also see the summer season speed up in the beginning of the melt season with a slow deceleration over several months. The winter velocity in basin 3 decreases from about 300 m/a, 4km from the front, to 100 m/a, 20 km from the front. The summer speed up in the beginning of the summer is up to about 600 m/a in the lower point and up to 150 m/a 20 km upstream. In Basin 3 on Austfonna we could also observe a general increase of the summer velocity from 2008 to 2010 by about 50 % from about 200 m/a to about 300 m/a, 12 km from the front. These GPS data are now being analyzed in detail and a manuscript is under preparation for autumn 2010. Finally, mass balance (melt rate) is monitored by ablation stakes and AWS stations.

KRONEBREEN: The continuous GPS point on Kronebreen is now a detailed series running since May 2008. A clear link between melt event as well as rain events and surface velocity (sliding) can be observed. The velocity varies by a factor of 3, from about 0.2 m/day to 0.6 m/day in this part of the ice stream. Helicopter-based radar investigations for mapping bed topography were completed in spring 2009 by NPI on the lower, crevassed part of Kronebreen. A final bedmap is being prepared. Mass balance measurements for Kronebreen and its connected icefield Holtedahlfonna for the 2009-10 season were completed in Sept. There are now six years of mass balance data available for Kronebreen-Holtedahlfonna. Data were downloaded from two AWSs operating on Holtedahlfonna, and from an AWS operating in the fjord, very near the front of Kronebreen.

NUMERICAL MODELLING

Work on modelling the distribution of water at the base of glaciers, within the finite element and cellular automaton frameworks, is underway (UI). The first approach is to model a water sheet and (possibly) an underlying aquifer at the bed, similar to the formulation of Flowers and Clarke (2002). The next step will be to include a tunnel system, and one approach we are exploring involves a dynamic system that can adapt to changes in water flux, of course, and also change their position as the surface evolves. The results of the models, using different sliding laws, will be compared to measurements of ice velocity (GPS and satellite data). The water on the bed (most likely the pressure) will then be used as an input for the contribution of sliding to the glacier flow in the ice flow model. The ice flow model is based on the shallow ice approximation. Using Breidamerkurjökull as a natural laboratory, it is planned to investigate how calving and the grounding lines can be included within the framework of these models.

Using measurements of surface velocity (GPS and satellite data) and weather components (for water generation), UI plans to construct empirical (although based on theory) relations between input of surface melt-water and sliding velocity. These developments include using measurements on Icelandic glaciers and the Greenland ice sheet, to construct models that rely only on measurable variables. This is motivated by the fact that a lot of the modeling assumes basal conditions (e.g. sediments, topography, and tunnels) that are often unknown, and details that cannot be easily verified.

Sub-Work Package Number: WP**2.3** Leader: Klaus GROSFELD
Title: TIDEWATER GLACIER CALVING AND ICE-OCEAN INTERACTION
Report:

A new calving criterion has been developed and implemented in a higher-order flowline model. This new calving criterion is based on a physical model of calving processes, based on downward penetration of water-filled surface crevasses and upward propagation of basal crevasses. A calving event occurs when the depth of the surface crevasse (which increases as melting progresses through the summer) reaches the height of the basal crevasse (GEUS). In view of the sparsity of observations, the flowline calving model will be actively coupled to a three-dimensional higher-order model including grounding line motion. A new ice flux transfer algorithm is therefore being implemented (ULB).

UiO, NPI: Continuous GPS-receivers have been installed during field campaigns in April and August 2009, both on Kronebreen and on two fast-flowing outlets on Austfonna Ice Cap, Svalbard, in order to work on sampling field observations of velocity data. Time-lapse cameras are also installed on Kronebreen to monitor calving events. These measurements continued in 2010. As described in WP2.2, the continuous GPS data showed some very interesting results with a clear link between melt events and velocity. On the Austfonna outlets we could also see the summer season speed up in the beginning of the melt season with a slow deceleration over several months. In one of the two monitored drainage basins on Austfonna we could observe a general increase of the summer velocity from 2008 to 2010 by about 50% from about 200 m/a to about 300 m/a, 12 km upstream from the front. These data are now being analyzed in detail and a manuscript is under preparation during autumn 2010.

US: Monitoring of the Hansbreen lower reach in Southern Spitsbergen has been maintained by use of stereoscopic time lapse cameras (IQvision type) from 30 May to 24 September 2009. The laser scanning method was used as the reference data for examination of digital terrestrial time lapse photos and determination of glacier flow velocity and the terminus position changes in August and September 2009. Long range scanner Riegl LPM-321 enables acquisition of high resolution data from the range up to 6 km. Repeated terrestrial laser scanning enables to obtain data on the change of position of particular features on glacier surface (usually crevasses) for calculating glacier velocity field and tension rate in the badly crevassed area very close to the ice cliff (not accessible for GPS survey).

Additional instruments have been mounted to monitor the glacier calving cliff during dark winter as a part of the IPY Glaciodyn project (Polish segment), i.e. a laser distance meter to the calving cliff (Riegl FG21-LR laser distance ranger) and a new experiment with the Canon A530 camera for taking automatically pictures of the glacier front using only Moonlight illumination. Both instruments are working properly so far. An automatic tide gauge station has been established in September close to the Hansbreen calving front. Data collected in the Polish Polar Station are available for project partners and an online data exchange portal will be put in place. Available data are meteorological observations, ablation and accumulation data, and GPS measurements.

New, higher quality Canon EOS 1000D stereoscopic time lapse cameras in special housings have been mounted on permanent photogrammetric posts for continuation of monitoring of the frontal part of

Hansbreen, Svalbard in May 2010. Calibration of cameras was done before mounting. These replaced the IQvision cameras used previously. Operation of the Canon A530 camera used for pictures during polar night has been continued. Operation of the laser distance ranger Riegl FG21-LR to measure distance from solid land to the calving cliff has been continued after completion of the Polish segment of the IPY Glaciodyn project. It is used together with time lapse shots acquired every 12 hours of glacier cliff positions by a Garmin GMR 18HD panoramic radar mounted on the same point as the distance meter. All instruments provide data on dynamics of the lower reach of the glacier and the actively calving cliff. First results from winter and spring periods 2009/2010 show glacier flow velocity changes during winter related to episodes of higher temperatures (>0°C) and rainfall. The major finding from this unique series of time lapse pictures collected during winter and in spring time (until the last week of May 2010) is an almost complete absence of calving despite presence or absence of sea ice cover at the glacier terminus. Only 2-3 minor calving events were noted on the time lapse pictures during the cold period of the year. Winter advance of the glacier cliff reached 141 m at the point measured by the laser distance meter and 160 m (±10 m) on the centreline. Calving started in late May.

Field work in August/September 2010 has been devoted to maintaining the operation of all instruments and preparation of them for the next winter season. Ground control points for precise external orientation of time lapse cameras has been surveyed by precise GPS receivers. Traditional terrestrial photogrammetric pictures by Zeiss Photheo 1318 phototheodolite are planned to be taken for better calibration of the time lapse photos (if weather permits). Unfortunately, the automatic tide gauge station mounted in September 2009 close to the Hansbreen calving front has been lost (with logged data) during sea ice shelf removal by very strong winds at the beginning of summer. It will be replaced in spring 2011.

Progress has been made in examining and interpreting collected data in cooperation with IGF, maintaining AWS's and monitoring of Hansbreen flow velocity on the whole glacier by precise GPS receivers. Thanks to a new cooperation with the Institute of Oceanology of the Polish Academy of Sciences (within the framework of the AWAKE project), data on sea water temperature and salinity will be available for interpretation of results from glacier dynamics survey of the ice cliff.

IGF: Field work in 2009 and 2010 was concentrated on Hansbreen (SE Spitsbergen), located near the Polish Polar Station. Mass balance of Hansbreen was carried out. Snow pits in the accumulation, ablation and equilibrium zone were dug at the end of the accumulation season. Additionally, a control core drilling on the snow cover between snow pits was collected. Glacier motion monitoring in the central part of the ablation zone had been maintained the whole year by means of the precise time-lapse static sessions by the differential GPS station. Short speed up events has been noted during the ablation period with velocities up to 5 times higher than “background” sliding velocity between them. They appeared during / immediately after intense rainfalls or high melting periods. Four speeds up events have been noted in summer 2010 and 7 in summer 2009. Two automatic weather stations (AWS) in the ablation and accumulation zones had been maintained the whole year. Calibration of the sensors and statistical control of the measured elements was performed. An additional AWS was installed in the equilibrium zone of Hansbreen. All meteorological data are systematically available to all project partners as a meteorological bulletin (compiled data) or raw data (on request).

AWI: As for ice-ocean interaction, AWI is expanding the coupled Rimbay/Rombax model (coupled ice sheet - ocean circulation model) to apply it to a specific grounding line situation. To reach the goals of this sub-project a threefold approach is taken. First, a parametrized basal mass balance at the ice shelf base is applied to a 2D version of the ice model Rimbay (consistent with the MISMIP setup). This approach allows to investigate grounding line migration with respect to changing basal mass balance, which could occur due to ocean warming. For the MISMIP setup, the grounding line is nearly stable in position and ice thickness, regarding moderate basal melt rates. Second, for the application of a realistic geometry to a fully coupled ice sheet-ice shelf-ocean system, a full 3D ice model is essential. For these aims the coupled ice-sheet ice-shelf model Rimbay has been extended from the former 2D version towards a full 3D model. This model version will allow migrating ice divides, ice shelf front, and grounding line positions. Tests of this 3D version are currently underway. Third, the shallow-ice / shallow-shelf-approximation version currently applies the Schoof-Pollard algorithm for calculating the grounding line migration. This limitation will be overcome by a higher-order-model (HOM)-version. An ice-front boundary conditions for this setup is already implemented and to be testes, too. The interactive coupling of the Rimbay ice model to the Rombax ocean model has been tested succesfully and already applied to subglacial envionments, similar to the ice sheet-ice shelf transition.

Sub-Work Package Number: WP2.4 Leader: Christophe GENTHON
Title: SURFACE MASS BALANCE UNCERTAINTIES
Report:

Meteorological sensors, loggers, supporting structures and energy systems have been acquired by CNRS, pre-assembled and tested in France before deployment in Antarctica. Some tests have been run at the CEMAGREF test site in the Alps. Equipment was conditioned and shipped to Antarctica and installed during the 2009-10 field season. This includes a basic automatic weather station (AWS) with additional blowing snow sensors and snow gauge at D3 site near the coast; a basic AWS with additional blowing snow sensors, snow gauges and a 7m-mast to profile wind and blowing snow at D17, 12 km from the coast; a basic AWS with additional blowing snow sensors and snow gauge at D47, 100 km from the coast where katabatic winds originate and are the strongest. Calibration of the blowing snow sensors was carried out using manually-operated net systems.

A statistical study of Antarctic precipitation events in climate models has been carried out. It was found that the statistics of Antarctic precipitation events (number per year, fraction of total precipitation accounted by events of a given magnitude, etc.) significantly differ between models. A report is available at http://www-lgge.obs.ujf-grenoble.fr/~christo/calva/reports/barandun.pdf. While measuring precipitation rates in Antarctica is notoriously difficult, detecting precipitation events may be somewhat more accessible both on the field and by satellite (e.g. Bindschadler et al., 2005). This should contribute discriminating models ability to simulate and predict Antarctic precipitation. Based on data from a preliminary blowing snow monitoring system deployed during the 2008-09 Antarctic season, before the ice2sea program started but now integrated in the project, an evaluation of necessary corrections on instrument data have been produced. A report (in French) is available on line: http://www-lgge.obs.ujf-grenoble.fr/~christo/calva/reports/M2RTrouvilliez.pdf.

In December 2009, we had a visit by Japanese colleagues from Nagoya University, who recently developed new automatic and autonomous blowing snow sensors. They brought along one such sensor which we deployed at the CEMAGREF test site in the Alps to evaluate over the winter. Unfortunately the test was not fully satisfactory. Instead we continue to use the older system that it is not autonomous and can only be deployed at Dumont d'Urville were wintering staff is present.

AWS/blowing snow sensors (Larsen Glacier, Talos Dome) and stake farms (Midpoint, Talos Dome, Sitry, High Priestley, Larsen Glacier) in Terra Nova Bay area and Dome C/Talos Dome drainage area have been maintained and measured during present Antarctic season (Nov-Dec 09). Blowing snow transport observations from instruments (deployed during previous Antarctic seasons) and satellite images were acquired at the wind convergence zone of Terra Nova Bay (East Antarctica) throughout 2006 and 2009. These measurements are integrated to make a first-order quantitative estimation of blown snow exported to the atmosphere and ocean in a slope/coastal katabatic wind convergence area during 2006-2007 (this research started before the ice2sea program, but is now integrated in the project, Scarchilli et al, 2010 http://www.springerlink.com/content/99m763l4q872q015/?p=0d97c4355ba74bd4b4608049060a47c0&pi=0).

Following the observation conducted at Terra Nova Bay, blowing snow at the regional scale is surveyed on East Antarctica katabatic wind confluence area using daily MODIS TERRA and AQUA satellite images in true-colour along with infrared images, with 250 m of pixel size. Snow transport features (billows and waves) are very well recognised on satellite images of Wilkes Land, megadune area, Lambert Glacier, Dronning Maud Land. Snow transport features are always associated with the extensive presence of wind crust and blue ice area. Analysis of image clearly shows the minimum observation of snow transport over the summer period (from mid-November to January), while the phenomenon occurs very frequently during the spring and fall months, with maximum values in April and September. Due to an absence of illumination southern of 66°S during the Antarctic winter, satellite images are only available from mid August to the end of April.

A combination of remote sensing and field data (snow radar) is used to identify regions of wind crust and blue ice surface in the Dome C drainage area. Wind crust and blue ice areas are characterised by surface mass balance from slightly positive or nil (10 kg m-2 yr-1 > wind crust > -20 kg m-2 yr-1) to strong negative (-50 kg m-2 yr-1 > blue ice area > -500 kg m-2 yr-1). Wind crust and blue ice area exhibit lower albedo detectable by visible and near infrared satellite sensors (MODIS and Landsat ETM+). We determined that wind crust covers approximately 10 to 20%, while blue ice covers about 2% of the NE Dome C drainage area. Since these areas are much lower in accumulation than current compilations of surface mass balance based on interpolation of measurements (e.g., Arthern et al., 2006) or climate-model determinations of net accumulation (e.g., van de Berg et al., 2006), the presence of extensive wind crust implies that surface mass balance is overestimated at present.

A study of the origin, the spatial gradient and the dynamic conditions that forced precipitation events over the East Antarctic Ice Sheet were analysed, combining a Lagrangian model (Hybrid Single-Particle Lagrangian Integrated Trajectory) output and the European Re-Analysis ERA40 (from 1980 to 2000) data (Uppala et al. 2005) obtained from the European Centre for Medium Range Weather Forecast (ECMWF). The study has improved our understanding of the role of atmospheric geopotential anomalies (low- and high-frequency planetary waves and blocking highs) in poleward moisture transport (Scarchilli et al., submitted to Climate Dynamics).

Staffing

Partner	Research	Name	Start date	F/M
ULB	Tidewater calving and grounding line migration	Faezeh M. NICK	01/10/2009	F
ULB	Grounding line migration	Laura PERICHON	01/01/2010	F

CNRS	Grounding line migration	Lionel Favier	28/09/2009	M
GEUS	Tidewater glacier calving	Andreas AHLSTROM	31/07/2010	M
GEUS	Tidewater glacier calving	Dirk VAN AS	01/03/2009	M
GEUS	Tidewater glacier calving	Faezeh M. NICK	01/03/2009	F
GEUS	Tidewater glacier calving	Robert SCHJOTT	31/07/2010	M
GEUS	Tidewater glacier calving	Soren NIELSEN	31/07/2010	M
GEUS	Tidewater glacier calving	Jens BISGAARD	31/07/2010	M
IGF	Tidewater glacier calving	Agnieszka PIETRZAK	01/05/2010	F
IGF	Tidewater glacier calving	Dariusz PUCZKO	01/04/2009	M
CNRS	Blowing snow	Luc PIARD	01/04/2009	M
AWI	Ice sheet - ice shelf coupling	Silvia MASSMAN	01/12/2009	F
UI	Modelling basal lubrication	Throstur THORSTEINSSON	01/10/2009	M
CSC	Mesh refinements in grounding line models	Thomas ZWINGER	01/10/2009	M
CNRS	Grounding line modelling	Emmanuel LE MEUR	01/03/2009	M
CNRS	Grounding line modelling	Gaël DURAND	01/03/2009	M
CNRS	Grounding line modelling	Olivier GAGLIARDINI	01/03/2009	M
CNRS	Grounding line modelling	Basile DE FLEURIAN	01/03/2009	M

Deliverables

Internal Deliverables: ***Please comment on all deliverables for your Work Package that are due in the First Reporting Period. See the Description of Work for details.***

Deliverable Number: 2.3-2
Deliverable Name: Estimate of future mass loss from improved 3D ice sheet model
Status: delayed
Report: The coupled 3D ice sheet / 2D calving flux model will be developed at ULB. It will be used by GEUS and applied to a number of selected calving glaciers in Greenland. There is no longer a plan to estimate future calving fluxes because of the lack of sufficient coherent observations at this point to transform them

into an empirical calving law. Furthermore, estimating the future mass balance is within the scope of W5 with their access to climate prediction input.

There will be a delay of 19 months. This is partially a mistake in the original date. Also, the deliverable contains more than initially - now it is a combined effort of modelling and calving flux estimates instead of calving fluxes derived from observations and statistical analysis – hence this takes longer to deliver. The reason this is possible is that these calving estimates will not be delivered to WP4 or 5 as was the original intention, so the analysis can be performed more thoroughly without these time constraints. Due to this delay and the change of focus of the deliverable (essentially focussed now on physical model development and improvement instead of empirical model formulation), WP5 will perform their analysis with mass balance datasets from WP4 in combination with parameterized calving fluxes.

Deliverable Number: 2.3-3
Deliverable Name: Sensitivity estimates of ice sheet – deliver W5.2
Status: delayed
Report: The deliverable D2.3-3 due in April 2010 is not possibly not be ready by then, since the project position at the AWI could not be filled until 1 December 2009. Accordingly, the AWI project activities in WP2.3 are delayed by about 9 months. During this period, the coupled Rimbay/Rombax model (coupled ice sheet - ocean circulation model) is applied it to a specific grounding line situation, based on a modified MISMIP setup, similar to the one that will be used in the grounding-line intercomparison (WP2.1). This approach allows to investigate grounding line migration with respect to changing basal mass balance, which could occur due to ocean warming.

Milestones

Internal Milestones: ***Please comment on all milestones for your Work Package that are due in the First Reporting Period. See the Description of Work for details.***

Milestone Number: M2.1-1
Milestone Name: Hierarchy of models including longitudinal stress-gradients
Status: partially completed
Report: A vast number of numerical ice sheet models that treat grounding line migration according to different approximations of the Stokes equations for ice flow have been developed by the partners within WP2.1. Flowline versions of these models have all participated in the MSIMIP intercomparison project and are currently analysed. A publication on these results is currently in preparation. Similary, the 3D models are currently testing the 3D MISMIP variant that will be lanched in autumn. Results of this test phase in combination with the original MISMIP analysis will lead to a hierarchy of models that cope with grounding line migration in terms of computation time and accuracy/precision.

Milestone Number: M2.2-1
Milestone Name: Decide locations for hot-water drilling
Status: complete, on time
Report: In May 2010 (Aberystwyth University) performed a radar survey at 3 locations in the preferred area for drilling, about 8 km from the ice edge of Russell glacier. The ice thickness was found to be approximately 565 m and the location was approved for drilling. Aberystwyth University also set up 5 self

sufficient geodetic GPS systems at and around this drilling location. In July 2010, drilling was carried out in this spot.

Milestone Number: M2.2-2
Milestone Name: Preliminary model version test
Status: partially completed
Report: Work on modelling the distribution of water at the base of glaciers, within the finite element and cellular automaton frameworks, is underway. The first approach is to model a water sheet and (possibly) an underlying aquifer at the bed, similar to the formulation of Flowers and Clarke (2002). The ice flow model is based on the shallow ice approximation.

Milestone Number: M2.2-3
Milestone Name: Installation of water pressure sensor and termistor strings
Status: complete, on time
Report: Two holes were drilled to the bedrock (or in sediment) about 600 m deep. In one hole a wireless pressure sensor, 1 inclination and 25 wireless temperature sensors were installed and in the other hole we installed one wired pressure/temperature sensor and one wireless pressure sensor. The wireless system proves to operate very well through 600 m thick ice. At two other locations between 1000 and 1500 m height 15 m long thermistor strings were installed.

Milestone Number: M2.2-4
Milestone Name: End of primary target glacier fieldwork
Status: complete, on time
Report: A number of target glaciers in Greenland and on Svalbard were chosen and a complete monitoring program has started, as described in the report of WP2.2.

Milestone Number: M2.2-5
Milestone Name: Collection of GPS data
Status: complete, on time
Report: In Greenland, GPS-instruments deployed in 2009 were retrieved from 5 out of 6 possible outlet glaciers from the Greenland ice sheet. The 6th glacier will be visited no later than summer 2011, along with visits to the other 5 outlet glaciers.

Milestone Number: M2.3-1
Status: complete, on time
Milestone Title: Field studies and data acquisitions: Radar profiling on Hans Glacier
Report: Location: Polish Polar Station, Hornsund, Spitsbergen. Radar profiling were made on Hansbreen for mass balance and thermal structure of glacier.

Milestone Number: M2.3-1
Milestone Title: Field studies and data acquisitions: Scanning of Hans Glacier calving front and automatical photos.
Status: complete, on time
Report: Location: Polish Polar Station, Hornsund, Spitsbergen. Velocity of glacier surface were recorded by sets of automatically cameras from slopes of Fugleberget. New techniques for recording of changing on calving front by mobile laser scanning were tested.

Milestone Number: M2.3-1
Milestone Title: Field studies and data acquisitions: Continuous observation of the flow velocity of outlet glaciers
Status: partially completed
Report: Location: Kronebreen and two fast-flowing outlets on Austfonna Ice Cap, Svalbard. Continuous GPS-measurements in five locations in each drainage basin. In addition the time-lapse cameras will continue on Kronebreen.

Milestone Number: MM2.3-2
Milestone Name: Setting up the models for idealized geometries
Status: partially completed
Report: A coupled ice sheet - ice shelf version for investigating the sensitivity of grounding line position to basal ice shelf melting has been set up in 2D and 3D. Expansion of the 2D to a full 3D version has been numerically completed. Test on performnce are under process.

Milestone Number: MM2.4-1
Milestone Name: Field campaign jointy undertaken with GLACIOCLIM-SAMBA / PNRA
Status: complete, on time
Report: Succesful collaborative field work was carried out during the 2009-2010 austral summer in Antarctica. More details are found in the WP2.4 report.

Additional Work

Please add details of any work undertaken for ice2sea that was not part of the deliverables as in the Description of Work.

Sub-Work Package associated: 2.1
Work undertaken: Flowline studies of grounding line sensitivity
Details: At LGGE, two more studies will be carried out using a full Stokes flow line model. Their purpose is to investigate (i) at which resolution the bed rock topography has to be known and where is it important to have high resolution in bedrock datasets of the Antarctic and Greenland ice sheet, and (ii) how wrong the Schoof relation for the grounding line position is in the case of a non-steady configurations (rapid changes). The deadline for these two items should be beginning of 2011.

Sub-Work Package associated: 2.1
Milestone Title: Radar profiling across the grounding line and GPS measurements
Report: In the framework of the French DACOTA project (ANR and IPEV fundings), extensive airborne radar profiles have been measured during austral field season 2009-2010 on the Astrolabe Glacier, East Antarctica. The whole drainage basin of the Astrolabe has been surveyed, and the raw dataset should allow to produce an accurate DEM (<5 km resolution) of the bed elevation. GPS stations have been temporarily set up on the Astrolabe coastal region in order to accurately locate the grounding line. A strain network (12 permanent GPS stations, partly paid by ice2sea) will be installed in February 2010 across the grounding line and should record surface deformation for the coming austral winter.

Sub-Work Package associated: 2.1
Fieldwork Location: Dronning Maud Land, Antarctica
Work undertaken: Radar profiling across the grounding line
Report: Several radar profiles (>200km) have been collected on an ice rise in the Roi Baudouin Ice Shelf (Dronning Maud Land) across the grounding line. Internal reflectors/layers are identified to depths of 400m below the surface, which in view of the local accumulation rates should reveal the accumulation history of the last 1000 years. The internal layers have been digitized and are currently modelled with different low and higher-order ice sheet models to reconstruct isochrones. The analysis is carried out autside ice2sea, but results are beneficial to the ice2sea project as they aim at validating ice flow models across the grounding line. Results demonstrate the existence of subglacial melting underneath the ice shelf at the grounding line, pointing to a thermohaline circulation under the ice shelf in an area where bathymetry is relatively shallow.

Sub-Work Package associated: 2.2
Work undertaken: Additional measurements performed at the drill site at Russel glacier consisting of a radar and seismic survey, operation of an automatic weather station, installation of 5 self sufficient geodetic GPS systems. A wireless subglacial measurement system was developed.
Details: Aberystwyth University performed a radar survey at 3 locations in the preferred area for drilling to obtain ice thickness information, about 8 kms from the ice edge of Russell glacier. The ice thickness was found to be approximately 565 m and the location was approved for drilling. Additionally, 5 self sufficient geodetic GPS systems were set up by Aberystwyth University at and around the drilling location. Aberystwyth/Swansea University also performed a seismic survey at the drill site. An automatic weather station (AWS) from the IMAU was operational during July and August at the drill site to monitor the energy balance. A wireless subglacial measuring system was newly development at the IMAU and proves to operate very well through 600 m thick ice. Once installed the wireless system in principle provides continuous subglacial measurements of pressure and temperature for several years in a row.

Sub-Work Package associated: 2.2; 2.3
Work undertaken: Collecting information from archives in Scott Polar Research Institute, University of Cambridge.
Details: US collected information from archives in SPRI concerning GPR measurements, calving, thermal and hydrological regime of Spitsbergen's Glaciers which will be used for work out of data and papers.

Sub-Work Package associated: 2.2;2.3
Fieldwork Location: Upernavik Glacier, Rink Glacier, Store Glacier, Sermeq Avangnardleq, Kangiata nunata sermia (West Greenland) and Sermilik Brae (South Greenland)
Work undertaken: GPS measurement along the flowline and observing calving front with time-lapse camera
Report: In August 2009, 17 GPS units (L1/L2) have been deployed along the flowline of the above glaciers (10-30 km from the calving front). They will measure the ice movement for a period of at least one year. This work has been done in collaboration with Roderik van der wal (Utrecht University), Alun Hubbard (Aberystwyth University). A time-lapse camera was installed at the front of Sermilik Brae to observe the calving events and frontal movement in collaboration with Jason Box (Ohio State University). We are planning to collect most of the GPS units in summer 2010.

Sub-Work Package associated: 2.3
Work undertaken: Comparative studies on use of stereoscopic time lapse cameras for monitoring of flow velocity and calving rate of Alaskan and Svalbard glaciers.

Report: Comparison of monitoring systems of Columbia Glacier, Alaska and Hansbreen, Svalbard have been done for improvement of methodology and better understanding of calving mechanism based on direct observations and photographic record. Cooperation with Prof. Tad Pfeffer, University of Colorado (Boulder) has been undertaken. An attempt to develop of a software for automatic photogrammetric analysis of large number of time lapse photos has been started. Participation in field work on Columbia Glacier in August 2010 made possible to compare details of time lapse survey system deployed there with this used for Hansbreen in Svalbard.

Sub-Work Package associated: 2.4
Fieldwork Location: Adélie Land, from the coast to 100 km inland; Terra Nova Bay drainage basin area
Work undertaken: Download data, maintain existing systems, deploy automatic monitoring systems for precipitation, winds and turbulence resulting in blowing snow, and blowing snow itself, to validate and refine modelling
Report: Two people on the field in Adélie Land, from Dec. 15 2009 to Feb. 15 2010, to deploy: A basic automatic weather station (AWS), plus blowing snow sensors and snow gauge, at D3 site near the coast; A basic AWS, plus blowing snow sensors, snow gauges and a 7-mast to profile wind and blowing snow, at D17 12 km from the coast; A basic AWS plus blowing snow sensors and snow gauge at D47 100 km from the coast. All instruments are up and running at time of writing this report. Instruments closest to the coast (D3) will be visited during the winter by winter-over staff at Dumont d'Urville, data will be downloaded and mailed to LGGE.

A person at Zucchelli Station from October 9, 2009 to December 4 to download data and maintenance of two AWS/blowing snow stations and 5 stake networks.

Impediments to Progress

If applicable, explain the reasons for failing to achieve critical objectives and/or not being on schedule and explain the impact on other tasks as well as on available resources and planning:

The deliverable D2.3-3 due in April 2010 is not possibly not be ready by then, since the project position at the AWI could not be filled until 1 December 2009. Accordingly, the AWI project activities in WP2.3 are delayed by about 9 months. Unfortunately, the staff member left the AWI for a permanent position. From 1 October 2010, the position will be filled again.

Outlook

Please outline the future for the Work Package activities, in particular affects of deviations to plans to future deadlines (milestones and deliverables):

GROUNDING LINES: A first set of deliverables is due at the beginning of 2011 (recommendations on mesh sizes for processes within ice streams and at the contact with the ocean, and a suite of planview models to be incorporated in large-scale ice sheet models).

BASAL LUBRICATION: In August 2011 UU will have a short fieldwork campaign at the edge of Russell glacier (West-Greenland) and collect new data from the subglacial instruments, automatic weather stations and geodetic GPS systems at the drilling location. A publication presenting the dataset and its interpretation and a note on the performance of the wireless sensor system from the UU is prepared.

CALVING (US): Automatically cameras will run on by US at spring 2010 for recording of surface and calving front of Hans Glacier. Field work with long range scanner Riegl LPM-321 are arrangement for autumn 2010. First results will be presented in next report.

CALVING (UiO, NPI): The measurements of flow velocity on Kronebreen and Austfonna Ice Cap outlet glaciers will continue in 2011. Analysis of GPS-data of the speed-up of glaciers during summer melting period will be done during 2010/2011.

AWI: Incorporation of grounding-line migration schemes and ice front conditions in the Rimbay/Rombax model will be expanded. In specific model setups the ice sheet/ice shelf - ocean interaction is investigated by giving sensitivity estimates of varying boundary conditions on selected model fields.

MASS BALANCE UNCERTAINTIES

Until the end of the Reporting Period 1 (August 31, 2010), we will process the data acquired on the field, work-out pre-calibration of the automatic instruments, and run the MAR model over the available period of observation. The data are those acquired during the 2009-2010 summer campaign, and those to be downloaded and sent out by the winter-over staff as they can access the observation sites. Reports from the winter-over parties will also be used to prepare the next field season to maintain and improve the systems deploy during the 2009-10 season. We will also prepare for the deployment of the new Japanese automatic blowing snow sensor and of a new precipitation sensor.

Resources

Provide a **statement on the use of resources**, in particular highlighting and explaining deviations between actual and planned person-months per work package and per beneficiary in Annex 1 (Description of Work).

At this stage, there has been overall understaffing compared to the planned person-months per workpackage, due to the later start of the project. Since the project start date (March 2009) is earlier than the official signature by the different partners, some institutes could not hire personnel from the starting date onward. In order to comply with the strict deadlines of deliverables, partner institutes managed to do the work using other resources, which leads to an ice2sea benefit at this point (this is especially true for those partners that are carrying out field work). However, the later 'official' start date lead to a number of delays, especially with respect to the modelling efforts, as explained in the sections on 'deliverables' and 'impediments'.

WP2.1: Two part-time persons were hired at ULB (one post-doc and one researcher), as well as one full-time post-doc at LGGE. No staff is yet appointed at BAS (May 2011 anticipated start-date). At CSC, T. Zwinger committed himself part time to the project (according to the DOW).

WP2.2: UI hired personnel on the project according to the DOW; UU will use the assigned man months later in the project, as the person doing the work until now (Paul Smeets) has been funded from other sources; UiO has planned to engage personnel, but so far no one has been employed and the work (essentially field work) was carried out using other availbale resources. HI hired personnel according to the DOW.

WP2.3: AWI, GEUS and IGF hired personnel for the project according to the DOW. UiO has planned to engage personnel, but so far no one has been employed and the work (essentially field work) was carried out using other availbale resources.

WP2.4: CNRS hired personnel for the project according to the DOW. ENEA did not employ personnel so far and the work (essentially field work) was carried out using other availbale resources.

Other Comments

Please add anything further here. If applicable, propose corrective actions.

Publication list

Please list all publications for this Work Package. Start with ice2sea manuscript number. Add links to files if possible.

004: Gagliardini O., G. Durand, T. Zwinger, R. Hindmarsh and E. Le Meur, 2010. Coupling of ice-shelf melting and buttressing is a key process in ice-sheets dynamics, Geophys. Res. Lett., 37, L14501, doi:10.1029/2010GL043334. (http://www-lgge.obs.ujf-grenoble.fr/~gagliardini/publis/Download_GRL2010.html)

006: de Fleurian B., O. Gagliardini, T. Zwinger, E. Le Meur, and G. Durand. A coupled hydro-glaciological model to explain post-jökulhlaups dynamics, in revision of a new submission to Journal of Geophysical Research

007: F.M. Nick, C.J. van der Veen, A. Vieli and D. Benn. (2010) A physically based calving model applied to marine outlet glaciers and implications for their dynamics, accepted for Journal of Glaciology.

015: Scarchilli C., Frezzotti M. and Ruti P.M. (submitted) Snow precipitation at four ice core sites in East Antarctica: provenance, seasonality and blocking factors. Climate Dynamics

016: Bellot H., Naaim-Bouvet F., Trouvilliez A., Genthon C., Present weather sensors tests for measuring drifting snow, Annals of Glaciology, submitted