2nd MAR workshop 13 – 15 September 2017

WEDNESDAY 13 September PM

- 14h00 – 15h00 MAR Development and Organization (Hubert Gallée, IGE – UGA)
- 15h00 – 15h30 Some well known biases in MAR and how they are compensated (Hubert Gallée, IGE – UGA, Xavier Fettweis, ULg)
- 15h30 – Pause
- 16h00 – 17h00 How to use MAR (Xavier Fettweis, ULg)

THURSDAY 14 September AM

Mountains and Glaciers

- 08h30 – 09h00 The 1980-2016 SMB evolution over all the small ice caps and ice sheet of the Arctic simulated by MAR at resolution of 7.5km (Xavier Fettweis, ULg)
  Simulations at very high resolution (7.5km) forced by ERA-Interim have been performed over Baffin, Ellesmere, Greenland, Iceland, Svalbard and the Russian islands. We will show here the first results of these new MARv3.7 simulations over never simulated small ice caps. Differences in interannual variability and SMB trend between the different areas will be discussed.

- 09h00 – 09h30 Importance of the Greenland ice sheet elevation melt feedback with the regional model MAR fully coupled with the ice sheet model GRISLI (Sebastien Le Clec'h, LSCE – IPSL)
  In the aim of evaluating the importance of the surface elevation feedback of the Greenland ice sheet (GrIS) between a regional atmospheric model (MAR) and Greenland ice sheet model (GRISLI), we used three methods to represent the interactions between both models under the RCP 8.5 scenario from 2020 to 2150. In the simple method, there is no coupling and MAR computes varying atmospheric conditions using the same present-day observed GrIS topography and extent. The second is an one-way coupling method which represents interactions by correcting MAR outputs (using fixed topography) to account for topography changes before their transfer to GRISLI. The third method is a fully two-way coupling changing the ice sheet topography and extent as seen by the atmospheric model at each ice sheet model time step. The 1-way and the fully 2-way methods amplify the decrease in surface mass balance for coastal regions in a warmer climate due to the surface elevation feedback. The no coupling method underestimates the projected total GrIS melting contribution to sea level rise (SLR) of respectively 7.6 % and 10.3 % in respect to the 1-way and the 2- way coupling method. Compared to the 1-way, the fully 2-way method tends to increase the spatial variability of the surface mass balance and surface temperature changes through time. Beyond century scale projections, a fully 2-way method becomes necessary in order to avoid underestimation of the ice sheet volume, topography and extent reduction by using a 1-way coupling. As the GrIS grid pixels becoming ice free are seen by the MAR, after 150 years, using the 2- Way method allow to compute a global anomaly SMB 135 Gt yr -1 lower than using NC or 1-Way coupling method. However, the 1-way method seems to be sufficient to represent the interactions between the atmosphere and the GrIS for projections till the end of this century using low resolution grid models.

- 09h30 – 10h00 Ice-flux and regional climate modeling to constrain the surface mass balance and ice discharge of San Rafael Glacier, northern Patagonia (Gabriella Collao, IGE – UGA)

  We simulate the ice dynamics of the San Rafael Glacier located in the Northern Patagonia Icefield (46.7oS/73.5oW). The glacier topography and ice thickness are obtained by high resolution airborne gravity and GPS measurements. The model is initialized using an inverse method to infer the basal friction coefficient from surface velocity estimations given by previous studies based on multiple synthetic aperture radar and optical satellite data collected between 1994 and 2014. Low values of basal shear stress (<100 kPa) are obtained at the front of the glacier and are in agreement with values from other ice streams. These values are reasonable considering the high surface velocities in this zone (up to 7.5 km/a). The modeled ice flow results suggest that the horizontal velocities are quasi-independent from depth in the lowest zone of the glacier. We force the 3D full-Stokes Elmer-Ice model based on a specific surface mass balance function for the San Rafael Glacier given by previous studies. We use geodetic elevation changes during the study period (2000-2012) and analyze the influence of different functions on the glacier dynamics, ice discharge and mass balance. The analysis suggests that the average SMB for the entire glacier is 0.08±0.06 Gt/a and that previous SMB estimations for San Rafael Glacier significantly overestimated the accumulation. The ice discharge is estimated at -0.83±0.08 Gt/a. In order to assess a more accurate SMB distribution at the glacier surface, we modeled the distributed surface mass balance over the last decade using the regional circulation model (MAR) forced with the Era-Interim reanalysis data. With these simulations, we aim to improve our understanding of the causes for the San Rafael Glacier's wastage.

- 10h00 – Pause

Mountains and Glaciers

- 10h30 – 10h45 The Himalayan Snow Cover in MAR (Martin Menegoz, BSC)

- 10h45 – 11h00 Trajectories Project (Bruno Wilhelm, IGE – UGA)

- 11h00 – 11h30 The MAR model : a useful tool to study floods generated by rainfalls and snow melting (Coraline Wyard, ULg)

  As a consequence of climate change, several studies concluded that winter floods occurrence could increase in the future in many rivers of northern and western Europe in response to an increase in extreme precipitation events. This study aims to determine if trends in extreme hydroclimatic events generating floods can already be detected over the last century. In particular, we focus on the Ourthe River (southeast of Belgium) which is one of the main tributaries of the Meuse River with a catchment area of 3500 km². In this river, most of the floods occur in winter and about 50 % of them are due to rainfall events associated with the melting of the snow which covers the Ardennes in winter.

  In this study, hydroclimatic conditions favorable to flooding were reconstructed over 1959-2010 using MAR forced by the following reanalysis : ERA-interim completed by ERA40, ERA-20C and NCEP/NCAR v1. The use of the MAR model allows to compute precipitation, snow depth and run-off resulting from precipitation events and snow melting in any part of the Ourthe river catchment area. Therefore, extreme hydroclimatic events, namely extreme run-off events, which could potentially generate floods can be reconstructed using the MAR model. As validation, the MAR results were compared to weather station-based data. A trends analysis was then performed in order to study the evolution of conditions favorable to flooding in the

Ourthe River catchment.
The results show that the MAR model allows the detection of more than 95% of the hydroclimatic conditions which effectively generated observed floods in the Ourthe river over 1974-2010. Conditions favourable to floods in the Ourthe River catchment present negative trend over the period 1959-2010 as a result of a decrease in snow accumulation and a shortening of the snow season. This trend is expected to accelerate in a warmer climate. However, regarding the impact of the extreme precipitation events evolution on conditions favouring floods, the signal is less clear since the trends depend on the reanalysis used to force the MAR model.

- 11h30 – 12h00 Discussion: Atmosphere – Hydrology Coupling (animation: Gaël Durand)

- 12h00 – 13h30 Lunch Break

THURSDAY 14 September PM

Antarctic

- 13h30 – 14h00 Antarctica : where are we going ? (Cécile Agosta, ULg)
  In Antarctica, few atmospheric models have succeeded in modelling the surface climate over the entire ice-sheet, and even atmospheric reanalyses are subject to large uncertainties. The main difficulty is to develop specific parametrisations with few observational datasets.

  Here we present the last results of MARv3 for the end of the 20th century (1980-2010), over the whole ice-sheet, at a resolution of 35km. We chose this intermediate resolution in order to be able to use multiple forcings.

  We forced MAR with 6 different reanalyses, which allow to determine the uncertainty in the surface climate inherited from the reanalyses uncertainties. We add a comparison with RACMO which show large differences with MAR in the spacial pattern, whereas temporal variability at the basin scale is mainly driven by the forcing reanalysis.

  Continuation of this work will be to force MAR with multiple global climate models over the 21st century to assess the future evolution of the Antarctic surface climate together with the associated uncertainty estimates.

- 14h00 – 14h30 Climate change in Antarctica : On the contribution of Global Climate Model with a high regional resolution (Julien Beaumet, IGE – UGA)
  Downscalling of future climate scenarios with the help of a Regional Climate Model (RCM) such as MAR often depends, for oceanic as well as for atmospheric lateral boundary forcings, on climate scenarios from coupled Atmosphere-Ocean General Circulation Model (AOGCM) with a coarse horizontal resolution such as those from the CMIP5 experiment. However, most of these models fail in representing mean state and variability of the Antarctic climate. In this study, we present methods that allow to bias-correct errors on oceanic forcings and systematic errors on atmospheric general circulation.
  Despite recent improvements, atmosphere only GCM such as ARPEGE and LMDZ remain considerably less skilled for the modelling of surface climate and ice-sheet surface

mass balance of polar regions than polar-oriented RCMs such as MAR. In this study, we also assess the ability of LMDZ and ARPEGE to represent Antarctic surface climate and surface mass balance through model intercomparisons with an ERA-Interim driven MAR simulation at 35 kilometers horizontal resolution and through validation with observational data sets (READER, SAMBA...).

Nevertheless, future bias-corrected climate scenario using atmosphere-only GCM such as LMDZ and ARPEGE at a high horizontal resolution are expected to provide future climate scenarios with added value and reduced uncertainties with respect to those coming from CMIP5 or CMIP6 experiments, potentially providing better forcings for other downscalling experiments using RCM such as MAR.

- 14h30 – 15h00 Sensitivity of the Antarctic surface mass balance to oceanic perturbations (Christoph Kittel, ULg)

  Regional climate models (RCMs) are suitable numerical tools to study the surface mass balance (SMB) of the wide polar ice sheets due to their high spatial resolution and polar-adapted physics. Nonetheless, RCMs are driven at their boundaries and over the ocean by reanalysis or global climate model (GCM) products and are thus influenced by potential biases in these large-scale fields. These biases can be significant for both the atmosphere and the sea surface conditions (i.e. sea ice concentration and sea surface temperature). With the RCM MAR, a set of sensitivity experiments has been realized to assess the direct response of the SMB of the Antarctic ice sheet to oceanic perturbations. MAR is forced by ERA-Interim and anomalies based on mean GCM biases are introduced in sea surface conditions. Results show significant increases (decreases) of liquid and solid precipitation due to biases related to warm (cold) oceans. As precipitation is mainly caused by low-pressure systems that intrude into the continent and do not penetrate far inland, coastal areas are more sensitive than inland regions. Furthermore, warm ocean representative biases lead to anomalies as large as anomalies simulated by other RCMs or GCMs for the end of the 21st century.

- 15h00 – 15h30 MAR over the Southern Ocean: scientific questions and perspectives (animation: Nicolas Jourdain, IGE – UGA)

- 15h30 – Pause

- 16h00 – 16h30 Blowing snow in MAR. Sensitivity Tests (Hubert Gallée, IGE – UGA)

  The parameterization of blowing snow in MAR depends on parameters such as surface roughness length and air density profile in the boundary layer. Surface roughness increases due to the building of sastrugis and air density near the surface increases because of the weight of blowing snow particles and the cooling due to their sublimation. In turn turbulence intensity and downslope pressure gradient force are respectively weakened and strengthened by an increase of air density near the surface, while an increase of roughness length due to snow erosion is responsible for an increased turbulence and a slowing down of the wind speed near the surface. Finally the relative humidity increases due to the sublimation of blown snow particles.

  The model is set-up over Adélie Land, Antarctica, with a fine horizontal resolution (5 km) and an improved vertical resolution near the surface (lowest level is situated 0.7 m above the surface). The domain of the model covers the steepest slopes of Adélie Land, on an area of 500 times 500 km^2. Simulations last 2 summer months (December 2010 and January 2011). A significant sensitivity of MAR is found to the the parameterization of the roughness length, justifying the need to observe the evolution of the roughness in Antarctica

- 16h30 – 17h00 Observations and modeling of drifting snow occurrences in coastal East Antarctica (Charles Amory, ULg)
  Drifting snow is an important component of the Antarctic near-surface climate, particularly pronounced in windy coastal regions of the ice sheet. However, drifting snow measurements suffer from a high scarcity, to the extent that long-term datasets that constitute essential development and evaluation bases for parameterization schemes barely exist. As a result, drifting snow is poorly or more generally not represented in polar atmospheric models. The goal of this study is to describe the main features of drifting snow events at two coastal locations, D17 and D47, respectively 10 and 110 km inland of Adelie Land (East Antarctica) and assess the ability of the regional climate model MAR run at a fine spatial (10 km horizontal and 1 m vertical) resolution to reproduce the occurrence of these events. Measurements performed with acoustic snowdrift sensors show high drifting snow frequency values of 63% at D17 (2010-2016) and 85% at D47 (2010-2012) with a strong seasonal cycle but a low inter-annual variability. Model results are evaluated at a half-hourly time step and compare favorably with observations for both the frequency of occurrence and horizontal snow mass transport close to the surface.

- 17h00 – 17h30 Drifting snow in Adélie Land: a modeling study (Charles Amory, ULg)
  The drifting snow climate of Adélie Land as represented by the regional climate model MAR is evaluated for the period December 2012 – December 2013. The evaluation data include meteorological observations collected at one location and annual surface mass balance (SMB) values obtained from stake measurements over a 150-km transect. The model is run at a high spatial (10 km horizontal and 1 m vertical) resolution and evaluated at a half-hourly time step. Two simulations are performed, one with drifting snow activated, and one with drifting snow switched off. The comparison shows that the model is well able to simulate the near-surface conditions. Accounting for drifting snow significantly improves the representation of relative humidity, while wind speed, air temperature and friction velocity are affected less importantly. MAR also succeeds in reproducing the drifting snow frequency and drifting snow flux at the monthly scale, resulting in a better representation of the SMB when drifting snow is activated. Neglecting drifting snow leads to an overestimation of the SMB by 50% on average over the transect.

FRIDAY 15 September AM

- 08h30 – 09h00 How to give accurate SMB forcing to ice dynamic model for the 21st century projections? (Vincent Favier, IGE – UGA)
  Significant changes in atmospheric circulation occurred around Antarctica, due to the exceptional positive trend in the Southern Annular Mode and to the climate variability observed in the tropical pacific at the end of the 20th century. Even though climate over the East Antarctic Ice-Sheet (EAIS) remained quite stable, a warming and precipitation increase was observed over the West Antarctic Ice-Sheet (WAIS) and over the West Antarctic Peninsula (AP) during the 20th century. Nevertheless, the high regional climate variability still overwhelm climate changes associated to drivers of global temperature changes, as reflected by recent cooling of the Antarctic Peninsula. Climate and SMB models still fail to accurately reproduce these temporal SMB trends at a regional scale, mainly because complex processes are still insufficiently considered, such as: 1) atmospheric circulation changes related to complex

ocean/ice/atmosphere interactions, 2) specific polar atmospheric features (cloud microphysics, wind scouring and impact on stable surface boundary layers), 3) surface firn physics involved in surface drag variations, or in firn air depletion and albedo feedbacks. As a consequence, reducing the uncertainty in projection of the future SMB of Antarctica will depend on our capability to remove biases in the future sea surface conditions and atmospheric general circulations proposed by the Atmosphere-Ocean General Circulation Models (AOGCM) and in considering specific Antarctic surface / atmosphere interactions.
Here, we account for this diagnosis and propose an approach based on 1) bias corrections of future sea surface conditions coming from AOGCM scenarios from CMIP5/CMIP6 models. These corrections are then used as boundary conditions for a modeling with a stretched grid atmospheric GCM (LMDZ4), whose systematic errors in atmospheric circulation are corrected using tendency errors from nudged simulations. These outputs are then used to force the regional atmospheric model (MAR) to assess future regional scale SMB variations in Antarctica. Here, the MAR is adapted to account for interactions between drifting snow and surface drag over sastrugi fields by introducing a specific formulation for the roughness length. This formulation accounts for the relationship existing between snow-surface temperature and microrelief erodibility caused by the sintering of surface crystals. This adaptation is necessary to reproduce the seasonal variations in drifting snow frequency and horizontal snow mass transport as evidenced from observations.

- 09h00 – 09h30 Antarctic Humidity and Clouds. APRES3 Project (Christophe Genthon and Hubert Gallée, IGE – UGA)

- 09h30 – 10h00 MAR at the Cryosphere Processes Laboratory: a perspective on 10 years of results and achievements (Patrick Alexander, CCNW)
  Over the past 10 years our group has been working with MAR outputs and its code to study the surface energy balance and mass balance of the Greenland and Antarctica ice sheets, and, recently, of Himalaya as well. MAR has been crucial in most, if not all, our scientific research. We combined MAR with remote sensing observations and in-situ measurements for our analysis. In this regard, MAR has been a tool that allowed us to understanding processes and drivers modulating the spatio-temporal variability of surface quantities over the ice and snow regions. In this brief talk, I will highlight few of the many achievements (publications, presentations or funded activities) that were obtained over the past 10 years at our laboratory thanks to MAR and its synergy with remote sensing and in-situ observations and the profound impact that MAR has had on the US scientific community focusing on both Greenland and Antarctica.

- 10h30 – 11h00 Pause

- 11h00 – 11h30 Discussion: Influence of impurities in ice and snow on surface albedo (animation: Xavier Fettweis, ULg)

- 11h30 – 12h00 MAR Website (Amine Drira, IGE – UGA)

- 12h00 – Lunch