REQUEST FOR A SPECIAL PROJECT 2026–2028

MEMBER STATE: The Netherlands

Principal Investigator[1]: Dr. Willem Jan van de Berg

Affiliation: Utrecht University
Institute for Marine and Atmospheric Research Utrecht (IMAU)

Address: Princetonplein 5
3584 CC, Utrecht
The Netherlands
+31 30 253 3273

Other researchers: Dr. Peter Kuipers Munneke, Dr. Carleen Reijmer, Dr. Maurice van Tiggelen, Dr. Elizabeth Case, Dr. Marte Hofsteenge, Thirza Feenstra MSc, Tesse van den Aker MSc (IMAU/UU), Dr. Erik van Meijgaard, Dr. Christiaan van Dalum (KNMI)

Project Title: Modelling the climate and firn state in Antarctica and Greenland

To make changes to an existing project please submit an amended version of the original form.)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SPNLBERG**	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2026	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for project year:		**2026**	**2027**	**2028**
High Performance Computing Facility	[SBU]	155.000.000		
Accumulated data storage (total archive volume)[2]	[GB]	400.000		

EWC resources required for project year:		**2026**	**2027**	**2028**
Number of vCPUs	[#]			
Total memory	[GB]			
Storage	[GB]			
Number of vGPUs[3]	[#]			

Continue overleaf.

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.
[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.
[3] The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

Principal Investigator: **Dr. Willem Jan van de Berg**

Project Title: **Modelling the climate and firn state in Antarctica and Greenland**

Extended abstract

Summary

The computer facilities requested in this proposal will enable us to continue our research into the interaction between the atmosphere and ice sheets, as well as the current and future climate and surface mass balance of these two ice sheets. For this research, we will use the polar-adapted regional climate model RACMO version 2.4p1 and the firn densification model IMAU-FDM. This proposal builds upon research previously supported by SPNLBERG grants. For 2026, we are requesting resources for the following projects:

1. Several short (single and 5-year) simulations to develop, test and evaluate RACMO2.4p2, the updated and retuned model version.
2. Renew our operational estimates of the climate, surface mass balance and firn state of the Antarctic (11 km resolution) and Greenland (5.5 km resolution) ice sheets covering 1940-2026 (Greenland) and 1975-2026 (Antarctica) using RACMO2.4p2 forced by the ERA5 reanalysis.
3. Generate a database of precipitation fields over the Greenland Ice Sheet with different geometries which serves as training data for neural network-based precipitation emulator.
4. High-resolution RACMO simulations for the Antarctic Peninsula
5. Development of the firn densification model and operational firn modelling work

The regional climate model RACMO (run at the Royal Netherlands Meteorological Institute (KNMI) and Utrecht University) is one of the two leading models, together with MAR (led by the University of Liège), for describing the near-surface climate and surface mass balance (SMB, i.e. net surface accumulation or ablation) of the Antarctic and Greenland ice sheets (Fettweis et al., 2020; Mottram et al., 2021; Otosaka et al., 2023). The resources requested here, summarised in Table 1, aim to further improve the model by using observational datasets, including the novel EarthCARE cloud observations (project #1), to derive a new operational dataset of the climate and SMB for Antarctica and Greenland (project #2). Key data from these simulations will be shared with the scientific community via Zenodo. Furthermore, we plan to train a neural network-based emulator to predict precipitation fields over the Greenland Ice Sheet (project #3). This emulator can quickly approximate the expected precipitation fields over a dynamic ice sheet in long-term numerical simulations, which are computationally impossible for RACMO. Project 4: Lastly, for project 5, we request a budget to improve and apply the firn model IMAU-FDM, which is specifically designed to provide the most detailed description possible of the evolution of the entire firn column of both ice sheets.

Table 1: Overview of requested resources.

	HPCF (Million SBU)	Data storage (TB)
1) RACMO model development	25	25
2) Renewed operational RACMO estimates	55	100
3) RACMO simulations for neural network training	10	20
4) High-resolution RACMO simulations for the Antarctic Peninsula	35	50
5) Renewed operational projection simulations with IMAU-FDM	25	35
6) Unforeseen and data roll-over from 2025	5	170
Total	**155**	**400**

Project motivation

The aim of climate models is threefold: Firstly, to understand and represent the physical processes in the climate system. Secondly, to reconstruct the weather (and climate) as far back as possible. And thirdly, to project the climate given a shared socioeconomic pathway. As their name suggests, regional climate models focus on smaller regions spanning hundreds to thousands of kilometres, allowing for a higher spatial resolution than global models at similar or lower computational cost. However, their one-way coupling to global models prevents them from having a global impact due to their improved representation of the region of interest. On the other hand, this allows for the region's climate to be optimised specifically without the risk of inducing biases elsewhere.

At the Institute for Marine and Atmospheric research Utrecht (IMAU), which is part of Utrecht University, we have focused part of our atmospheric research on the polar regions, specifically on the interaction between the atmosphere and the surface over ice sheets. As well as aiming to understand, reconstruct and project the climate over ice sheets, we also aim to understand the surface mass balance (SMB) of ice sheets. The SMB is positive when the net annual gain of snowfall exceeds the mass lost through sublimation and meltwater runoff, and negative when a glaciated surface loses mass overall. The SMB includes processes in the firn layer — the layer of compacting multiyear snow up to 100 metres thick — as surface meltwater can be retained and refrozen in this layer. Therefore, the firn layer can prevent meltwater from running off the ice sheet and thus provide a positive contribution to the SMB. Along with ice discharge into the ocean, the SMB constitutes the mass balance of ice sheets and generally leads to ice sheet mass loss and, consequently, a rise in the global mean sea level (e.g., Mouginot et al., 2019; Otosaka et al., 2023; van den Broeke et al., 2016).

For this research into the climate over ice sheets, we will use the polar version of the regional climate model RACMO and the firn densification model IMAU-FDM. Technical details of both models are provided at the end of the proposal. In the polar version of RACMO, a special glacier tile represents glaciated surfaces (i.e. ice sheets, ice caps and glaciers). The glacier tile models a firn and ice column that is at least 30 metres thick and is typically represented by 30 to 50 Lagrangian layers. The layer thickness gradually increases from a few centimetres near the surface to several metres for the lowest layer. Using this tile, we can model the snow and ice albedo in detail for glaciated surfaces as a function of grain size, meltwater processes, surface roughness and snow drift. Consequently, we can accurately model the surface energy balance and SMB, including the aforementioned subsurface processes. However, this column model is not accurate enough to reliably model the evolution of the total firn air content and, consequently, the contribution of the firn layer to altimetric changes in ice sheets. Therefore, we also use the IMAU-FDM firn model, which represents firn columns with up to 1,000 layers and is thoroughly equilibrated before simulations.

Since the start of polar research with RACMO (van Lipzig et al., 2002), it has provided reliable estimates of the climate and SMB in Antarctica and Greenland (Ettema et al., 2009; Noël et al., 2018; van Dalum et al., 2025; e.g., van de Berg et al., 2006; van Wessem et al., 2018). RACMO simulations that estimate the current climate and SMB, driven by ECMWF reanalyses, are widely used in the scientific community, for example to drive ice sheet models (e.g., Berdahl et al., 2023; Schlegel et al., 2018), to estimate the freshwater flux from ice sheets (e.g., Bamber et al., 2018) and, most importantly, to estimate the mass balance of ice sheets (e.g., Otosaka et al., 2023; Rignot et al., 2008; Shepherd et al., 2018; 2020). Projections of the future climate and SMB (Noël et al., 2021; van Wessem et al., 2023) are also essential for community efforts to evaluate future SMB uncertainties (e.g., Glaude et al., 2024). In summary, approximately 40 to 45 peer-reviewed papers using RACMO data were published in 2024 alone, demonstrating the extensive use of RACMO data by the community.

Clearly, the representation of atmospheric and subsurface processes is imperfect in both RACMO and IMAU-FDM. Analysis of the results of RACMO version 2.4p1, the latest operational version, showed that it underestimates turbulent exchange near the surface in moderate and extreme flux conditions. Furthermore, we have been using EarthCARE data to evaluate the modelled cloud properties over Greenland and Antarctica since the first data became available, and this has shown an underestimation of cloud content for specific conditions. These issues lead to an underestimation of melt and ablation along the margins of the Greenland Ice Sheet. We plan to complete an updated polar version of RACMO (version 2.4p2) by mid-2026, after which we will renew our operational climate products in autumn 2026. An update to IMAU-FDM comprising a new firn densification parameterisation that is accurate and valid under climate change will be available in 2026. Therefore, we are also requesting resources to update our simulations using this new version of IMAU-FDM.

To continue this research in 2026, we request HPCF and storage facilities for the following 6 projects:

1) RACMO model development towards version 2.4p2

In 2024, we completed the development of RACMO, version 2.4p1. Version 2.4p1 includes a major update of the physics code, as described in detail in van Dalum et al. (2024). The modelled climate and SMB over Antarctica clearly improved compared to the preceding operational RACMO version, which was version 2.3p2 (van Dalum et al., 2025). For Greenland, the new version provided improved representation of the physical processes, but overall, the ablation is now underestimated compared to in situ observations, and consequently the modelled SMB of the Greenland Ice Sheet is higher than assessed to be correct.

Since mid-2024, we are evaluating the clouds modelled by RACMO against the novel observations of EarthCARE. This evaluation (see for example the SPNLBERG 2025 progress report) shows that RACMO, driven by ERA5 data, has generally a good representation of the observed cloud state, but that RACMO underestimates thin, upper-troposphere ice clouds, the liquid water presence in clouds, and peak hydrometeor concentrations during precipitating events. Tuning tests showed that these biases can be corrected by adjusting the microphysical parameters and atmospheric aerosol assumptions. These adjustments are expected to lead to more downwelling longwave radiation, which will enhance melting and ablation. Furthermore, we will further evaluate and adapt the near-surface turbulent exchange of heat and moisture for melting conditions as these fluxes are underestimated too.

To allow for thorough testing and model tuning, we request 25 million SBU and 25 TB of storage to run RACMO for both high-resolution domains (11 km over Antarctica, 5.5 km over Greenland) for 30 model years.

2) Renewed operational RACMO estimates for Greenland and Antarctica

Once this tuning is complete and RACMO2.4p2 has been finalised, we plan to update our operational RACMO simulations driven by ERA5 for the Greenland and Antarctic ice sheets. The Greenland simulation will use a resolution of 5.5 km and will start in 1940. The first five years will be run twice: the first time to allow the model to spin up. This 5-year spin-up period is required to allow the firn model in RACMO and the land soil properties to reach equilibrium. The Antarctic simulation, with a resolution of 11 km, will start in 1974 and the first five years will be discarded. Prior to 1979, ERA5 is not fed by satellite remote sensing data of atmospheric moisture, which leads to underestimated precipitation in East Antarctica and inaccurate RACMO simulations (see, for example, van Dalum et al., 2025, Figure 4).

We expect the computational costs of RACMO 2.4p2 to be similar to those of version 2.4p1; therefore, we request 55 million SBU and 100 TB of storage to complete and analyse these simulations.

3) RACMO simulations to train a neural network-based emulator of precipitation over Greenland

The SMB is the main driver of the evolution of the Greenland Ice Sheet (GrIS). For example, Feenstra et al. (2025), have shown that, during the 21st century, the dynamic changes to the geometry of the ice sheet are small compared to the projected changes to the SMB induced by climate change. However, over longer timescales, the impact of geometric changes on the SMB of the GrIS becomes considerable and must therefore be estimated in order to realistically model its evolution. This is particularly true for ice sheet model simulations covering one or more glacial cycles. Unsurprisingly, it is infeasible to run RACMO or any other regional climate model for such long periods or for many ice sheet realisations.

Therefore, the SMB is approximated in such studies. Despite the nonlinear processes driving it, ablation can still be reconstructed fairly well from one ice sheet geometry to another due to ablation's strong dependence on elevation through temperature. However, precipitation over the GrIS has a very irregular relationship with topography that cannot be approximated by linear regression models.

Therefore, our aim is to train a neural network emulator to estimate monthly precipitation fields using topographical data and information on large-scale circulation. However, emulators can only produce realistic results within the parameter space of their training data. Consequently, we intend to conduct numerous short simulations involving various GrIS geometries and climatic conditions. To ensure computational feasibility, we intend to use a model resolution of 11 km, which reduces the computational costs by at least a factor of seven compared to the default resolution of 5.5 km. We request 10 million SBU and 20 TB of storage for this project, which should allow for 200 years of model simulations.

4) High-resolution RACMO simulations for the Antarctic Peninsula

Many Antarctic ice shelves — the floating extensions of the grounded Antarctic Ice Sheet — have recently thinned, retreated or disintegrated. Since these ice shelves exert a buttressing effect on the grounded ice sheet, the removal of ice shelves reduces this effect and results in a loss of grounded ice and an increase in sea levels. Therefore, it is crucial to understand the viability of Antarctic ice shelves in a warmer future climate to better predict future sea level rise. The loss of AIS ice shelves may be caused by the atmosphere, the ocean, or both. A warming ocean thins the ice shelf from below, while a warming atmosphere increases surface melt, reducing the firn air content and ultimately leading to melt ponding. In both cases, the ice shelf's viability is compromised. For ice shelves in the coldest ocean waters, such as the Larsen C Ice Shelf (LCIS) in eastern Antarctica, atmospheric warming dominates, and the evolution of the firn layer is thus indicative of its viability.

In order to capture the climate and SMB, as well as the firn state, in sufficient spatial detail, we plan to carry out two RACMO2.4p1 simulations with a resolution of 5.5 km, covering the Antarctic Peninsula. The first simulation will cover the historical period (1979–2025) and will be driven by ERA5 data. The second simulation will be driven by CESM2 and cover the period 1980–2100, following the high-emission SSP3-7.0 scenario. A third RACMO simulation using the SSP1-2.6 scenario is planned for 2027. These simulations will subsequently drive IMAU-FDM to estimate the evolution of firn air content and assess when atmospheric warming begins to threaten the LCIS, as discussed below.

For the RACMO simulations, which span a total of 170 years, we request 35 million SBU and 50 TB of storage.

5) Renewed operational and firn air projection simulations with IMAU-FDM

As outlined in the 2025 progress report, the current year (2025) will be dedicated to updating the descriptions of firn densification and water percolation. In 2026, we plan to run the IMAU-FDM model on the Greenland Ice Sheet. These simulations will use the updated grain size physics and surface parameterisations. The first simulation is the operational simulation, which covers the present-day period from 1939 to 2025 and is forced by the ERA5-driven RACMO2.3p2 simulation. The second set of simulations are RACMO-CESM-driven historical and projection simulations under the SSP1-2.6 and SSP5-8.5 scenarios. These simulations will be analysed to improve our understanding of surface change, surface meltwater production, storage and runoff across the Greenland Ice Sheet. The final set of IMAU-FDM simulations will focus on the Larsen C Ice Shelf in Antarctica and will use historical and projected RACMO simulations derived in project #4.

The historic run for Greenland will require approximately 13 million SBU and 15 TB of storage. This simulation can be extended from restart files when new forcing data becomes available, which will lower our expected future computation costs. The future Greenland runs require approximately 7 million SBU and 10 TB of storage space. LCIS runs covering a smaller region require approximately 5 million SBU and 10 TB of storage.

Embedding of the projects

The proposed budget will support the research group working with RACMO and IMAU-FDM. A total of three PhD students and three postdocs will work on these projects, which will be supervised by four IMAU staff members. Furthermore, we will continue to collaborate with the RACMO experts at KNMI.

The proposed research is embedded in national and international collaborations, for example within the Dutch EMBRACER project, the EU-funded H2020 ICE:OCEAN project, the IMBIE initiative, and collaborations initiated within communities such as Polar CORDEX. Finally, key data from the proposed simulations will be made publicly available on Zenodo, while all other data will be available upon request.

Model descriptions

The regional atmospheric climate model RACMO.

RACMO was developed by the Royal Netherlands Meteorological Institute (KNMI), and our institute has employed a polar-adapted version of RACMO since 1998. Current operational versions 2.4p1 and 2.4p2 of the polar RACMO use the dynamical core of HIRLAM version 5.0.3 (Undén et al., 2002) and the physics of ECMWF IFS cycle 47r1 (ECMWF, 2020). The polar version of RACMO includes a dedicated tile for glaciated surfaces, as described above. A complete description of RACMO version 2.4p1 can be found in van Dalum et al. (2024). For some of the 2026 simulations, we will use RACMO version 2.3p2 (Noël et al., 2018) , which incorporates the ECMWF IFS physics from cycle 33r1. Version 2.3p2 of RACMO exhibits fewer biases over the ablation zone of Greenland and has therefore been retained alongside version 2.4p1.

All versions of RACMO are fully parallelised using MPI, have separate I/O and scale well on ATOS. Depending on the domain size, we will run RACMO on between 256 and 1024 cores.

The firn densification model IMAU-FDM

IMAU-FDM is a 1D Lagrangian column model that represents the entire firn column with full vertical detail (Brils et al., 2022; Veldhuijsen et al., 2023). Compared to the firn model in RACMO, it features updated parameterisations for heat transfer and densification and uses high vertical resolution (3–15 cm) throughout the firn column. Furthermore, due to its stand-alone nature and lower computational costs than RACMO, it can be run to equilibrium prior to simulations. Equilibration takes only a century at high accumulation sites, but over 1000 years at the cold, dry interior of Antarctica. This vertical resolution and equilibration are required to derive consistent and precise estimates of firn air evolution throughout the column. This is necessary, for example, to distinguish between local elevation changes in an ice sheet and changes induced by accumulation, changes in firn air content, and changes due to changes in ice flow.

IMAU-FDM is a single-core model. To run IMAU-FDM efficiently on ATOS nodes, a distributor system has been designed to manage the many single-core runs within one np job, taking into account the expected wall time of the individual simulations and the np job's overall remaining wall time.

References

Bamber, J. L., Tedstone, A. J., King, M. D., Howat, I. M., Enderlin, E. M., van den Broeke, M. R., & Noel, B. (2018). Land Ice Freshwater Budget of the Arctic and North Atlantic Oceans: 1. Data, Methods, and Results. *Journal of Geophysical Research: Oceans*, *123*(3), 1827-1837. https://doi.org/https://doi.org/10.1002/2017JC013605

Berdahl, M., Leguy, G., Lipscomb, W. H., Urban, N. M., & Hoffman, M. J. (2023). Exploring ice sheet model sensitivity to ocean thermal forcing and basal sliding using the Community Ice Sheet Model (CISM). *The Cryosphere*, *17*(4), 1513-1543.

Brils, M., Kuipers Munneke, P., van de Berg, W. J., & van den Broeke, M. (2022). Improved representation of the contemporary Greenland ice sheet firn layer by IMAU-FDM v1.2G. *Geosci. Model Dev.*, *15*(18), 7121-7138. https://doi.org/10.5194/gmd-15-7121-2022

ECMWF. (2020). *IFS Documentation CY47R1 - Part IV: Physical Processes*. ECMWF. https://doi.org/10.21957/cpmkqvhja

Ettema, J., van den Broeke, M. R., van Meijgaard, E., van de Berg, W. J., Bamber, J. L., Box, J. E., & Bales, R. C. (2009). Higher surface mass balance of the Greenland ice sheet revealed by high-resolution climate modeling. *Geophysical Research Letters*, *36*(12). https://doi.org/https://doi.org/10.1029/2009GL038110

Feenstra, T., Vizcaino, M., Wouters, B., Petrini, M., Sellevold, R., & Thayer-Calder, K. (2025). Role of elevation feedbacks and ice sheet–climate interactions on future Greenland ice sheet melt. *The Cryosphere*, *19*(6), 2289-2314. https://doi.org/10.5194/tc-19-2289-2025

Fettweis, X., Hofer, S., Krebs-Kanzow, U., Amory, C., Aoki, T., Berends, C. J., Born, A., Box, J. E., Delhasse, A., Fujita, K., Gierz, P., Goelzer, H., Hanna, E., Hashimoto, A., Huybrechts, P., Kapsch, M. L., King, M. D., Kittel, C., Lang, C., . . . Zolles, T. (2020). GrSMBMIP: intercomparison of the modelled 1980–2012 surface mass balance over the Greenland Ice Sheet. *The Cryosphere*, *14*(11), 3935-3958. https://doi.org/10.5194/tc-14-3935-2020

Glaude, Q., Noel, B., Olesen, M., Van den Broeke, M., van de Berg, W. J., Mottram, R., Hansen, N., Delhasse, A., Amory, C., Kittel, C., Goelzer, H., & Fettweis, X. (2024). A Factor Two Difference in 21st-Century Greenland Ice Sheet Surface Mass Balance Projections From Three Regional Climate Models Under a Strong Warming Scenario (SSP5-8.5). *Geophysical Research Letters*, *51*(22), e2024GL111902. https://doi.org/https://doi.org/10.1029/2024GL111902

Mottram, R., Hansen, N., Kittel, C., van Wessem, J. M., Agosta, C., Amory, C., Boberg, F., van de Berg, W. J., Fettweis, X., Gossart, A., van Lipzig, N. P. M., van Meijgaard, E., Orr, A., Phillips, T., Webster, S., Simonsen, S. B., & Souverijns, N. (2021). What is the surface mass balance of Antarctica? An intercomparison of regional climate model estimates. *The Cryosphere*, *15*(8), 3751-3784. https://doi.org/10.5194/tc-15-3751-2021

Mouginot, J., Rignot, E., Bjørk, A. A., van den Broeke, M., Millan, R., Morlighem, M., Noël, B., Scheuchl, B., & Wood, M. (2019). Forty-six years of Greenland Ice Sheet mass balance from 1972 to 2018. *Proceedings of the National Academy of Sciences*, *116*(19), 9239-9244. https://doi.org/doi:10.1073/pnas.1904242116

Noël, B., van de Berg, W. J., van Wessem, J. M., van Meijgaard, E., van As, D., Lenaerts, J. T. M., Lhermitte, S., Kuipers Munneke, P., Smeets, C. J. P. P., van Ulft, L. H., van de Wal, R. S. W., & van den Broeke, M. R. (2018). Modelling the climate and surface mass balance of polar ice sheets using RACMO2 – Part 1: Greenland (1958–2016). *The Cryosphere*, *12*(3), 811-831. https://doi.org/10.5194/tc-12-811-2018

Noël, B., van Kampenhout, L., Lenaerts, J. T. M., van de Berg, W. J., & van den Broeke, M. R. (2021). A 21st Century Warming Threshold for Sustained Greenland Ice Sheet Mass Loss. *Geophysical Research Letters*, *48*(5), e2020GL090471. https://doi.org/https://doi.org/10.1029/2020GL090471

Otosaka, I. N., Shepherd, A., Ivins, E. R., Schlegel, N. J., Amory, C., van den Broeke, M. R., Horwath, M., Joughin, I., King, M. D., Krinner, G., Nowicki, S., Payne, A. J., Rignot, E., Scambos, T., Simon, K. M., Smith, B. E., Sørensen, L. S., Velicogna, I., Whitehouse, P. L., . . . Wouters, B. (2023). Mass balance of the Greenland and Antarctic ice sheets from 1992 to 2020. *Earth Syst. Sci. Data*, *15*(4), 1597-1616. https://doi.org/10.5194/essd-15-1597-2023

Rignot, E., Bamber, J. L., van den Broeke, M. R., Davis, C., Li, Y., van de Berg, W. J., & van Meijgaard, E. (2008). Recent Antarctic ice mass loss from radar interferometry and regional climate modelling. *Nature Geoscience*, *1*(2), 106-110. https://doi.org/10.1038/ngeo102

Schlegel, N. J., Seroussi, H., Schodlok, M. P., Larour, E. Y., Boening, C., Limonadi, D., Watkins, M. M., Morlighem, M., & van den Broeke, M. R. (2018). Exploration of Antarctic Ice Sheet 100-year contribution to sea level rise and associated model uncertainties using the ISSM framework. *The Cryosphere*, *12*(11), 3511-3534. https://doi.org/10.5194/tc-12-3511-2018

Shepherd, A., Ivins, E., Rignot, E., Smith, B., van den Broeke, M., Velicogna, I., Whitehouse, P., Briggs, K., Joughin, I., Krinner, G., Nowicki, S., Payne, T., Scambos, T., Schlegel, N., A, G., Agosta, C., Ahlstrøm, A., Babonis, G., Barletta, V., . . . The, I. t. (2018). Mass balance of the Antarctic Ice Sheet from 1992 to 2017. *Nature*, *558*(7709), 219-222. https://doi.org/10.1038/s41586-018-0179-y

Shepherd, A., Ivins, E., Rignot, E., Smith, B., van den Broeke, M., Velicogna, I., Whitehouse, P., Briggs, K., Joughin, I., Krinner, G., Nowicki, S., Payne, T., Scambos, T., Schlegel, N., A, G., Agosta, C., Ahlstrøm, A., Babonis, G., Barletta, V. R., . . . The, I. T. (2020). Mass balance of the Greenland Ice Sheet from 1992 to 2018. *Nature*, *579*(7798), 233-239. https://doi.org/10.1038/s41586-019-1855-2

Undén, P., Rontu, L., Järvinen, H., Lynch, P., Calvo-Sanchez, J., Cats, G., Cuxart, J., Eerola, K., Fortelius, C., García-Moya, J., Jones, C., Lenderlink, G., McDonald, A., McGrath, R., Navascués, B., Nielsen, N., Ødegaard, V., Rodriguez-Camino, E., Rummukainen, M., . . . Tijm, A. (2002). *HIRLAM-5 scientific documentation*.

van Dalum, C. T., van de Berg, W. J., Gadde, S. N., van Tiggelen, M., van der Drift, T., van Meijgaard, E., van Ulft, L. H., & van den Broeke, M. R. (2024). First results of the polar regional climate model RACMO2.4. *The Cryosphere*, *18*(9), 4065-4088. https://doi.org/10.5194/tc-18-4065-2024

van Dalum, C. T., van de Berg, W. J., van den Broeke, M. R., & van Tiggelen, M. (2025). The surface mass balance and near-surface climate of the Antarctic ice sheet in RACMO2.4p1. *EGUsphere*, *2025*, 1-40. https://doi.org/10.5194/egusphere-2024-3728

van de Berg, W. J., van den Broeke, M. R., Reijmer, C. H., & van Meijgaard, E. (2006). Reassessment of the Antarctic surface mass balance using calibrated output of a regional atmospheric climate model. *Journal of Geophysical Research: Atmospheres*, *111*(D11). https://doi.org/https://doi.org/10.1029/2005JD006495

van den Broeke, M. R., Enderlin, E. M., Howat, I. M., Kuipers Munneke, P., Noël, B. P. Y., van de Berg, W. J., van Meijgaard, E., & Wouters, B. (2016). On the recent contribution of the Greenland ice sheet to sea level change. *The Cryosphere*, *10*(5), 1933-1946. https://doi.org/10.5194/tc-10-1933-2016

van Lipzig, N. P., Meijgaard, E. v., & Oerlemans, J. (2002). The spatial and temporal variability of the surface mass balance in Antarctica: results from a regional atmospheric climate model. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, *22*(10), 1197-1217.

van Wessem, J. M., van de Berg, W. J., Noël, B. P. Y., van Meijgaard, E., Amory, C., Birnbaum, G., Jakobs, C. L., Krüger, K., Lenaerts, J. T. M., Lhermitte, S., Ligtenberg, S. R. M., Medley, B., Reijmer, C. H., van Tricht, K., Trusel, L. D., van Ulft, L. H., Wouters, B., Wuite, J., & van den Broeke, M. R. (2018). Modelling the climate and surface mass balance of polar ice sheets using RACMO2 – Part 2: Antarctica (1979–2016). *The Cryosphere*, *12*(4), 1479-1498. https://doi.org/10.5194/tc-12-1479-2018

van Wessem, J. M., van den Broeke, M. R., Wouters, B., & Lhermitte, S. (2023). Variable temperature thresholds of melt pond formation on Antarctic ice shelves. *Nature Climate Change*, *13*(2), 161-166. https://doi.org/10.1038/s41558-022-01577-1

Veldhuijsen, S. B. M., van de Berg, W. J., Brils, M., Kuipers Munneke, P., & van den Broeke, M. R. (2023). Characteristics of the 1979–2020 Antarctic firn layer simulated with IMAU-FDM v1.2A. *The Cryosphere*, *17*(4), 1675-1696. https://doi.org/10.5194/tc-17-1675-2023