Uta Krebs-Kanzow, Shan Xu, Paul Gierz and Gerrit Lohmann
Alfred-Wegener-Institut, Helmholtz Centre for Polar and Marine Research (AWI)

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

dEBM: A surface mass balance scheme including the diurnal cycle of solar radiation for ice sheet simulations on long time scales

Energy balance of a melting surface ($T_{surf}=T_{melt}$):

$T = T_{2m} - T_{melt}$: mean near surface temperature in °C
$(1\text{-}A)\ SW\downarrow$: short wave radiation (upwelling, diurnal variation)
$Lw_{net}\uparrow$: net long wave radiation (downwelling, $-c_1+c_2T$)
R_{turb} : turbulent heat fluxes (poorly constrained latent heat flux, sensible heat flux, function of T, different coefficients for clear sky or overcast?)

Approach: dEBM (diurnal energy balance model)

- Define the daily melt period by means of a minimum solar elevation angle Φ
- Φ := elevation angle for which $(1\text{-}A)\ SW\downarrow = Lw_{net}\uparrow$
- $(1\text{-}A)\ SW\downarrow$ can be integrated over melt period considering orbital parameters
- Nocturnal refreezing: (energy balance of a day) – (energy balance of the daily melt period)
- Distinguish clear sky and overcast conditions

➔ ***Krebs-Kanzow et al (2018)***[1] for melt scheme

Monthly mean forcing

- Solar radiation
- Near surface temperature

Optional:

- Downward long wave
- Cloud cover

$$\text{Melt} \sim c_1(1\text{-}A)\ SW\downarrow + c_2\,T - c_3$$
c_1, c_2, c_3 include diurnal cycle

Scheme is sensitive to monthly temperature, radiation, **latitude, and month**

Diurnal variations in Greenland`s ablation zones

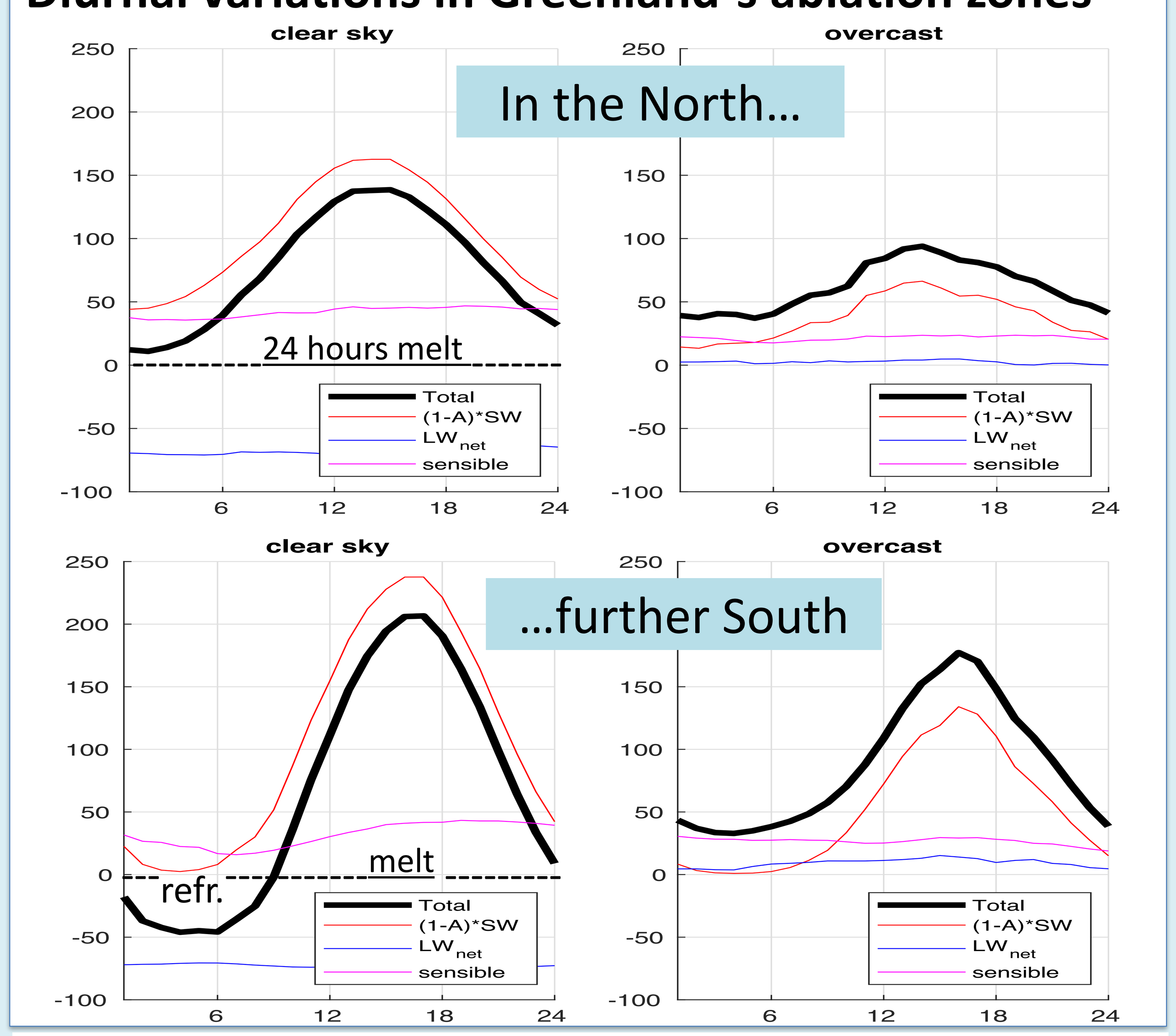

Fig.1 Latitudinal dependence of the diurnal cycle: *Mean July diurnal cycle of energy fluxes from weather stations in Northern (top row) and Western Greenland (bottom row) for clear sky and overcast conditions (PROMICE[2] stations KPC and KAN)*

1. Application to ERA-Interim[3] forcing

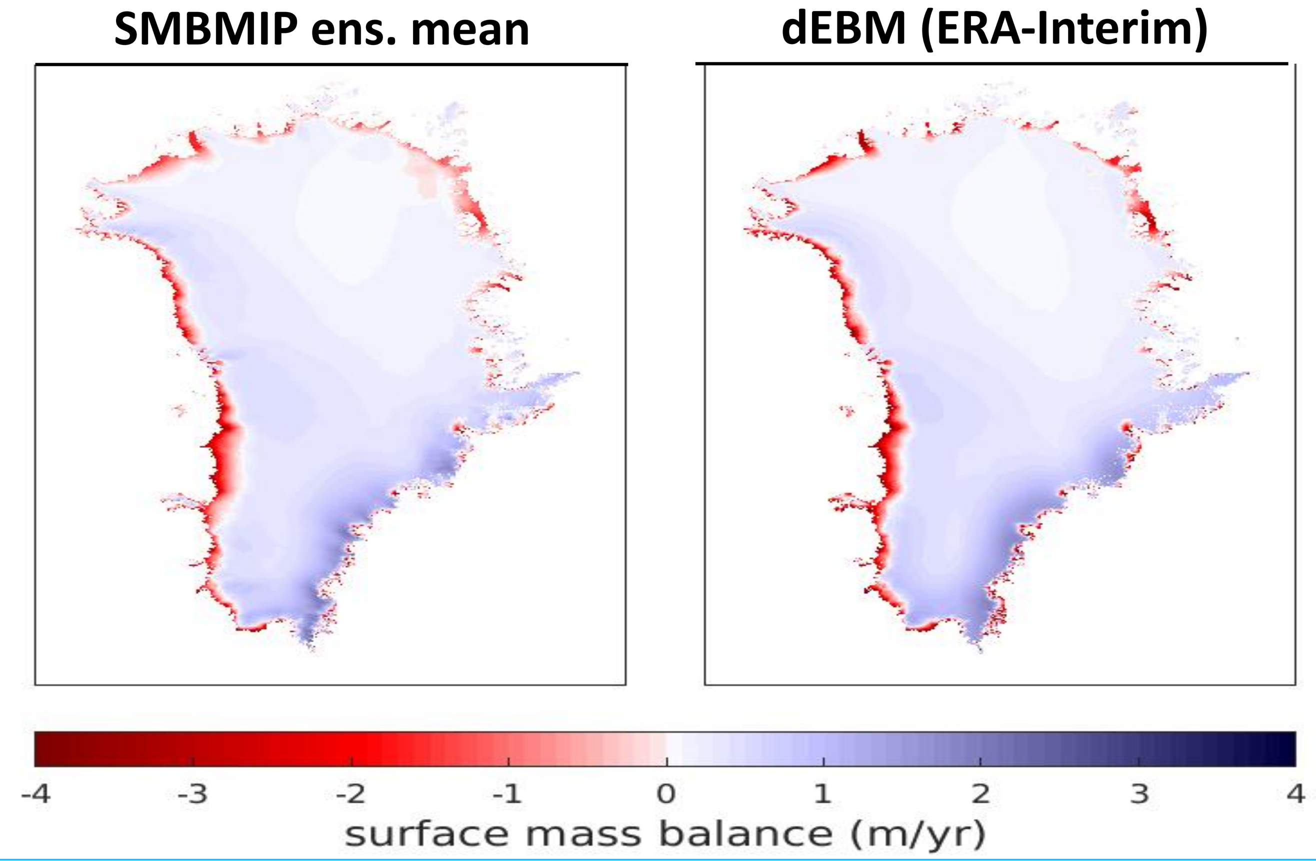

Fig.2, left: *Ensemble mean surface mass balance (SMB) for the 1980-2012 period from the surface mass balance model intercomparison project SMBMIP[4],* ***right:*** *mean 1980-2012 SMB from the dEBM scheme with ERA-Interim forcing downscaled to 1km resolution.*

2. Application to last glacial maximum (LGM) forcing

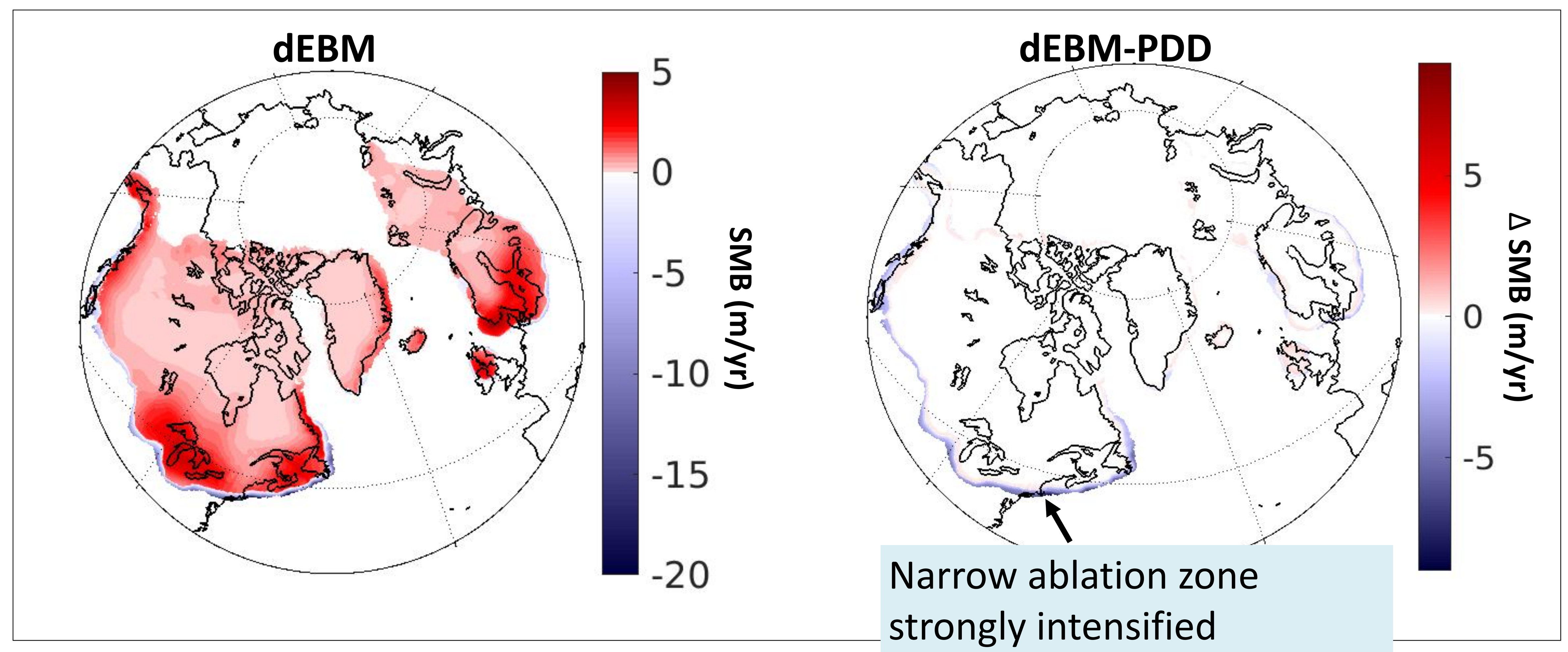

Fig.3, left: *dEBM surface mass balance (SMB) with atmospheric forcing from a last glacial maximum (LGM) simulation with the climate model AWI-CM[5];* ***right:*** *bias of the dEBM SMB versus the positive degree day scheme[6] implemented in PISM.*

References

(1) Krebs-Kanzow, U., Gierz, P. and Lohmann, G. (2018). Brief communications: Ice surface melt scheme including the diurnal cycle, The Cryosphere, https://doi.org/10.5194/tc-12-3923-2018
(2) Sørensen, L. S., Simonsen, S. B., Forsberg, R., Stenseng, L., Skourup, H., Kristensen, S. S., & Colgan, W. (2019). Programme for monitoring of the Greenland ice sheet (PROMICE): Airborne survey. Dataset published via Geological Survey of Denmark and Greenland and DTU-Space. https://doi.org/10.22008/promice/data/airbornesurvey.
(3) ERA-Interim: https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era-interim
(4) SMBMIP: http://climato.be/cms/index.php?climato=SMBMIP
(5) Sidorenko, D., Rackow, T., Jung, T., Semmler, T., Barbi ,D., Danilov, S., Dethloff ,K., Dorn, W., Fieg, K., Goessling, H. F., Handorf, D., Harig, S., Hiller, W., Juricke, S., Losch, M., Schröter, J., Sein, D. V., Wang, Q. 2015. Towards multi-resolution global climate modeling with ECHAM6–FESOM. Part I: model formulation and mean climate. *Climate Dynamics*, *44*(3-4), pp.757-780.
(6) Krebs-Kanzow, U., Gierz, P. and Lohmann, G. (2018). Estimating Greenland surface melt is hampered by melt induced dampening of temperature variability. Journal of Glaciology, doi:10.1017/jog.2018.10