High-resolution modelling of the Greenland climate with the regional climate model COSMO-CLM

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Motivation

- PalMod: transient GCM simulation of last 120.000 years
- Not all parameters represented adequately in GCM, need of regionalisation
- Important e.g. for comparison with proxy data

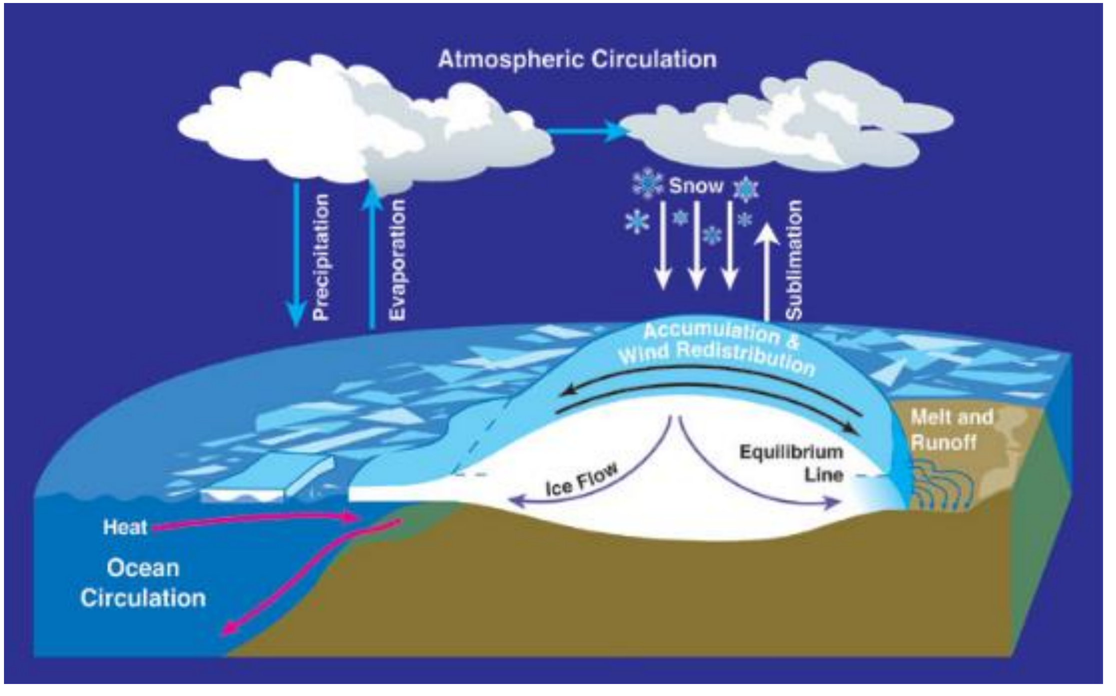
AIM:

- Set up COSMO-CLM for adequate simulations of the surface mass balance of the Greenland ice sheet
- Application for current and past climate conditions, e.g. Last glacial maximum (LGM)

Surface mass balance of ice sheet (SMB)

Three processes mainly determine whether the ice sheet grows or diminishes:

1. accumulation of snow
2. melt / sublimation
3. iceberg calving from glaciers



NASA: from Wikimedia Commons

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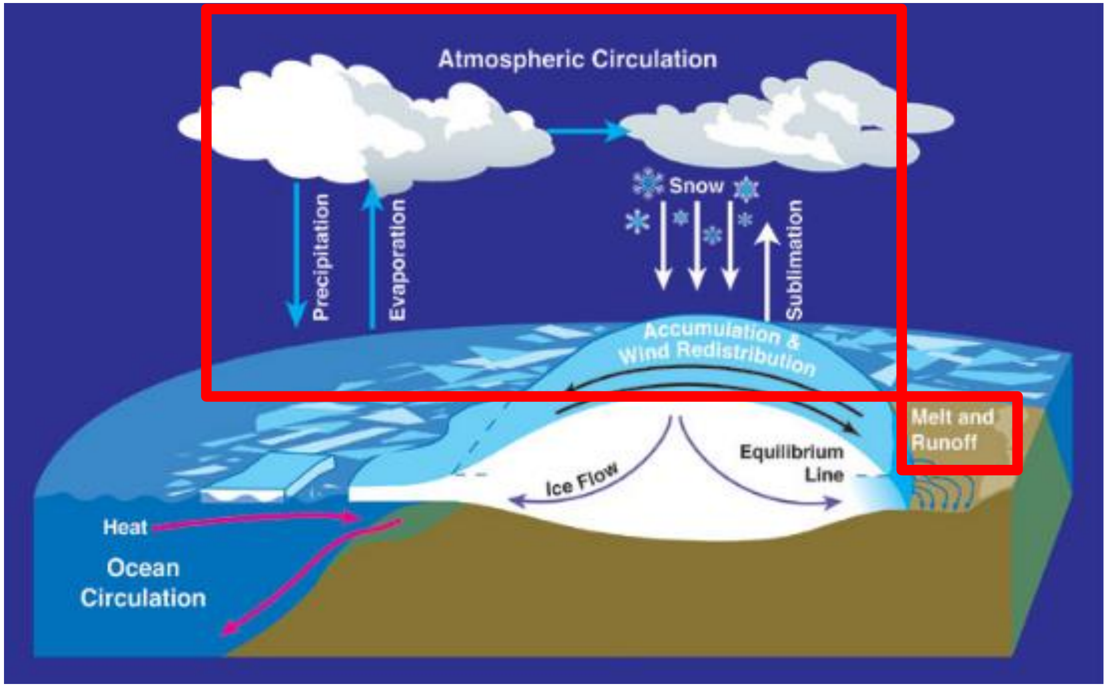
Focus only on SMB components affected by atmospheric conditions



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Sensitivity studies for model setup

- COSMO 5 CLM9, climate mode
- driving data: ERA-Interim, 6hourly, 1992-2015
- model resolution: 0.44°

- Four modelling domains tested: ➔CORDEX-Arctic domain

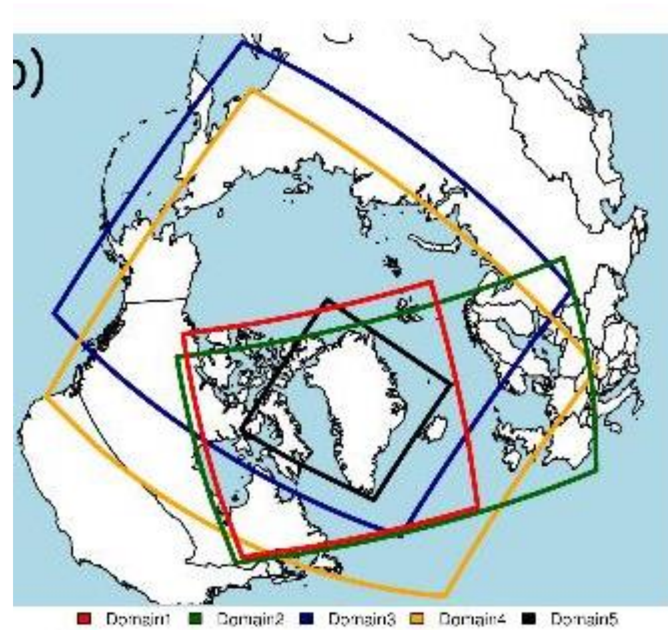
- Max. albedo: ➔ increase to 0.9

- Sea ice module: ➔Yes

- Time step (220s, 240s, 260s): ➔240s

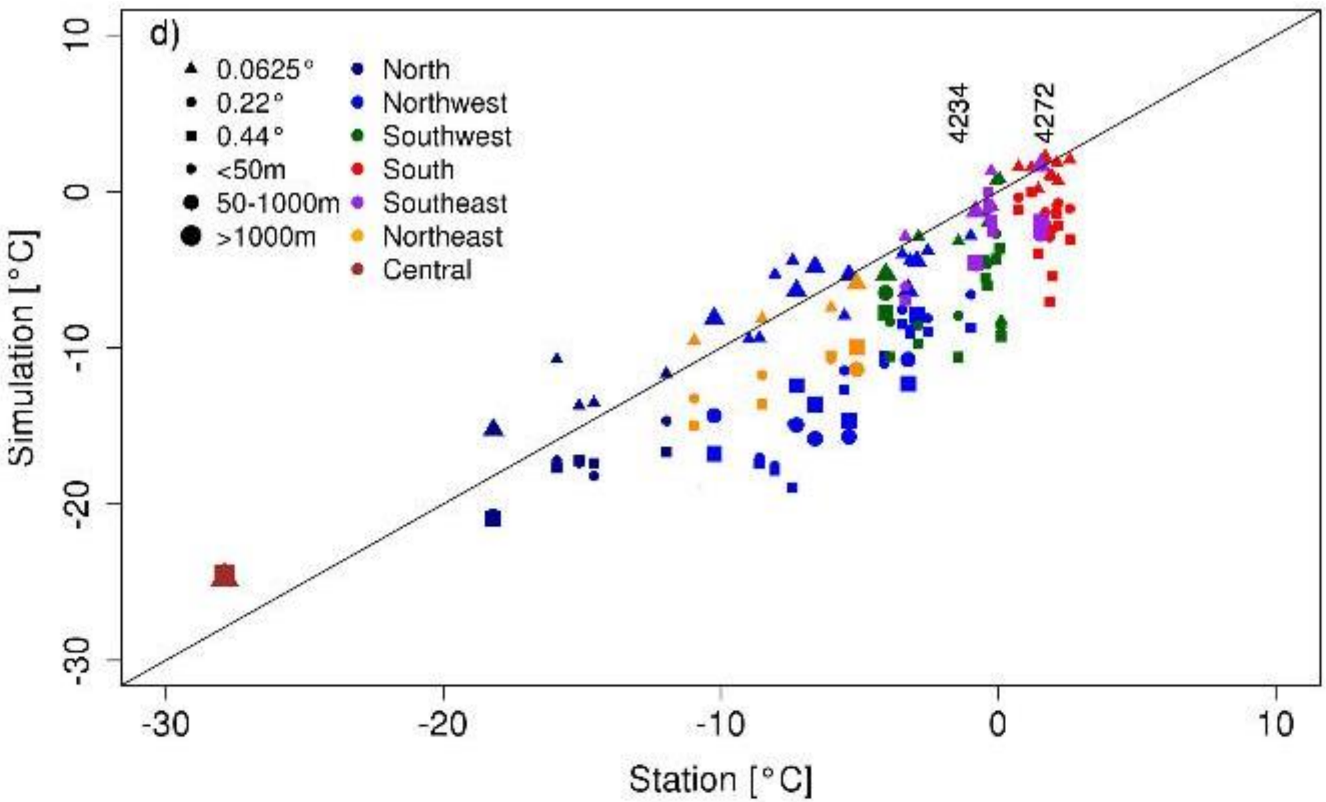
➔ Results for temperature, precipitation promising

➔ need: test higher resolution (0.22°, 0.0625°)



Blue: CORDEX-Arctic domain

Different resolutions: 1995-2015 mean temperature compared to DMI observations



positive skill:

- 92% for 7 km vs. 25 km
- 69% for 25 km vs. 50 km

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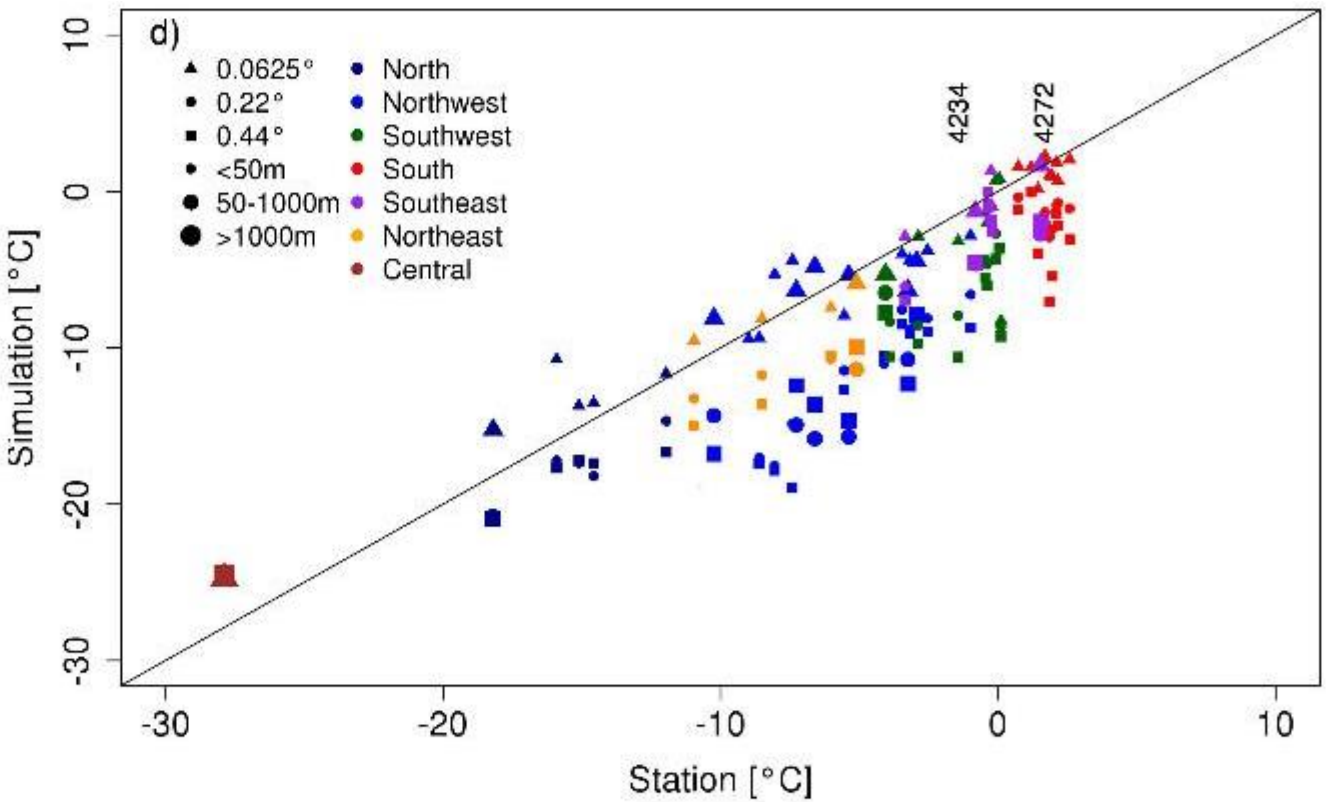

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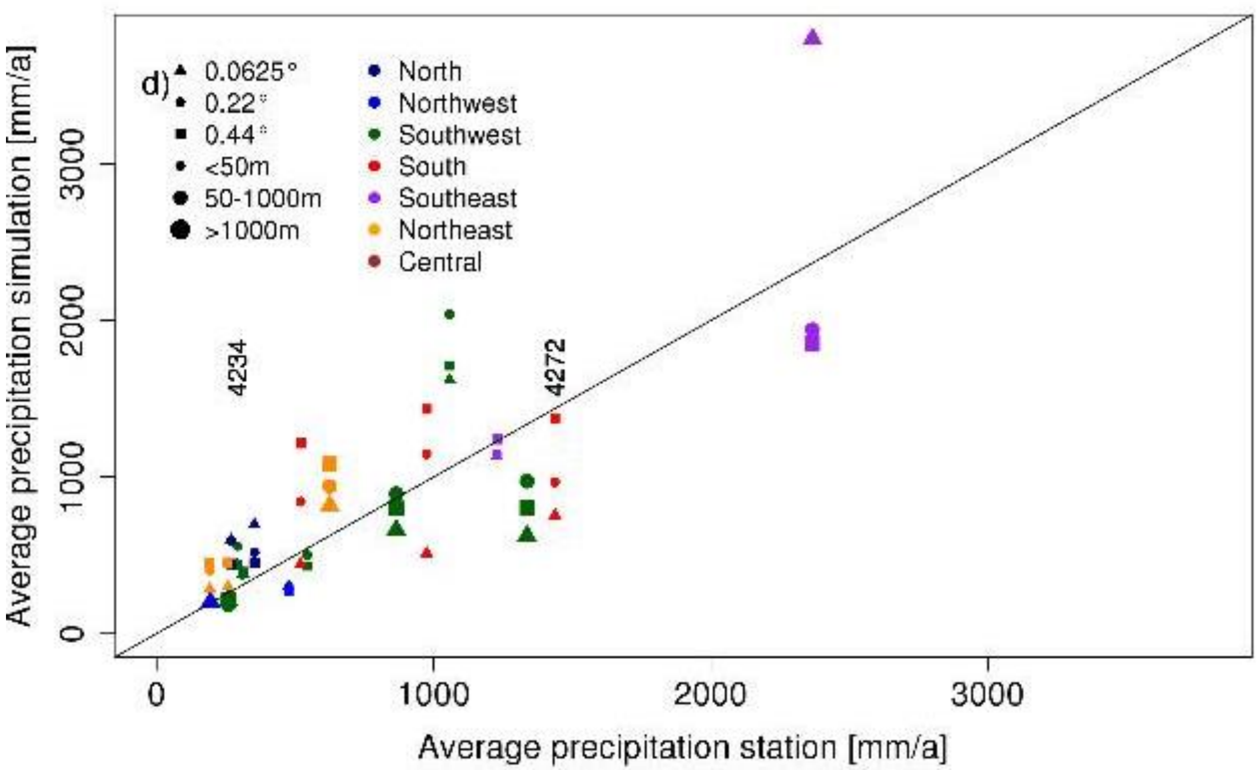
➔ added value of higher resolution

Different resolutions: 1995-2015 mean precipitation compared to DMI observations



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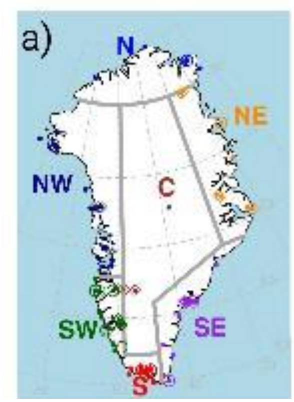

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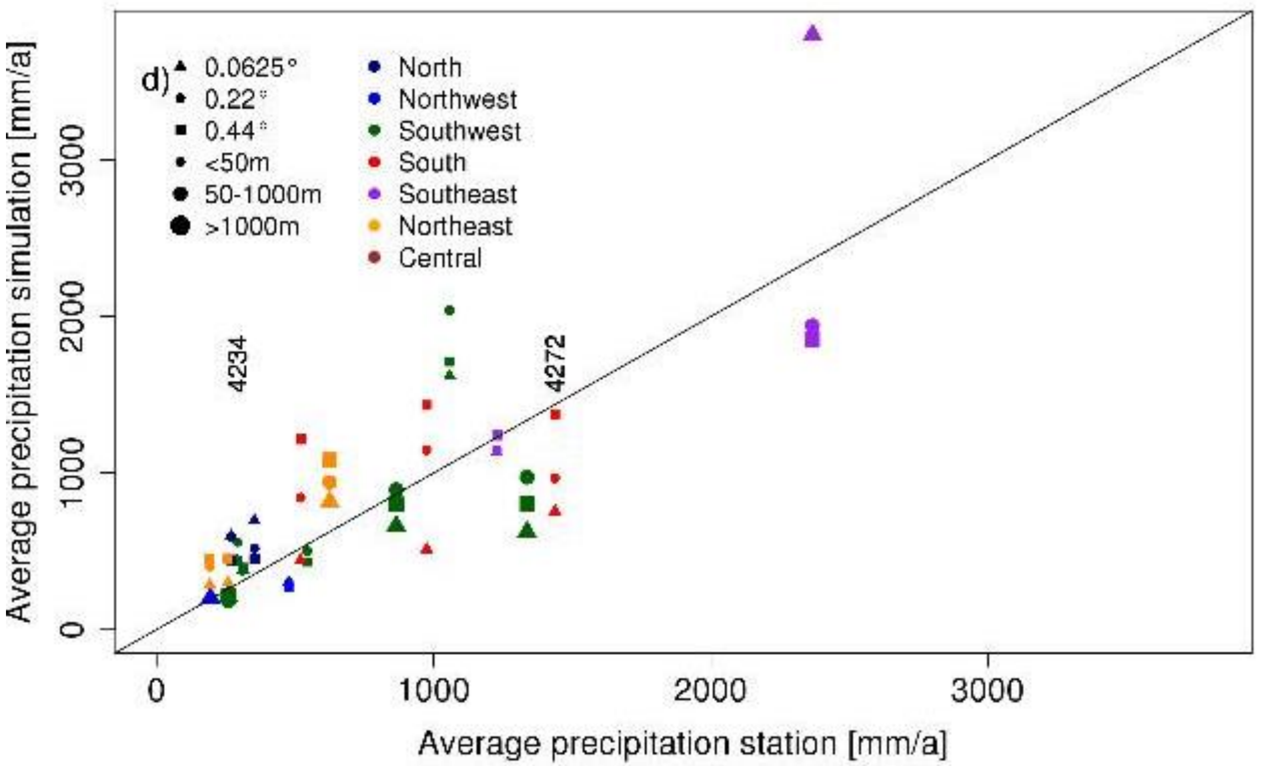

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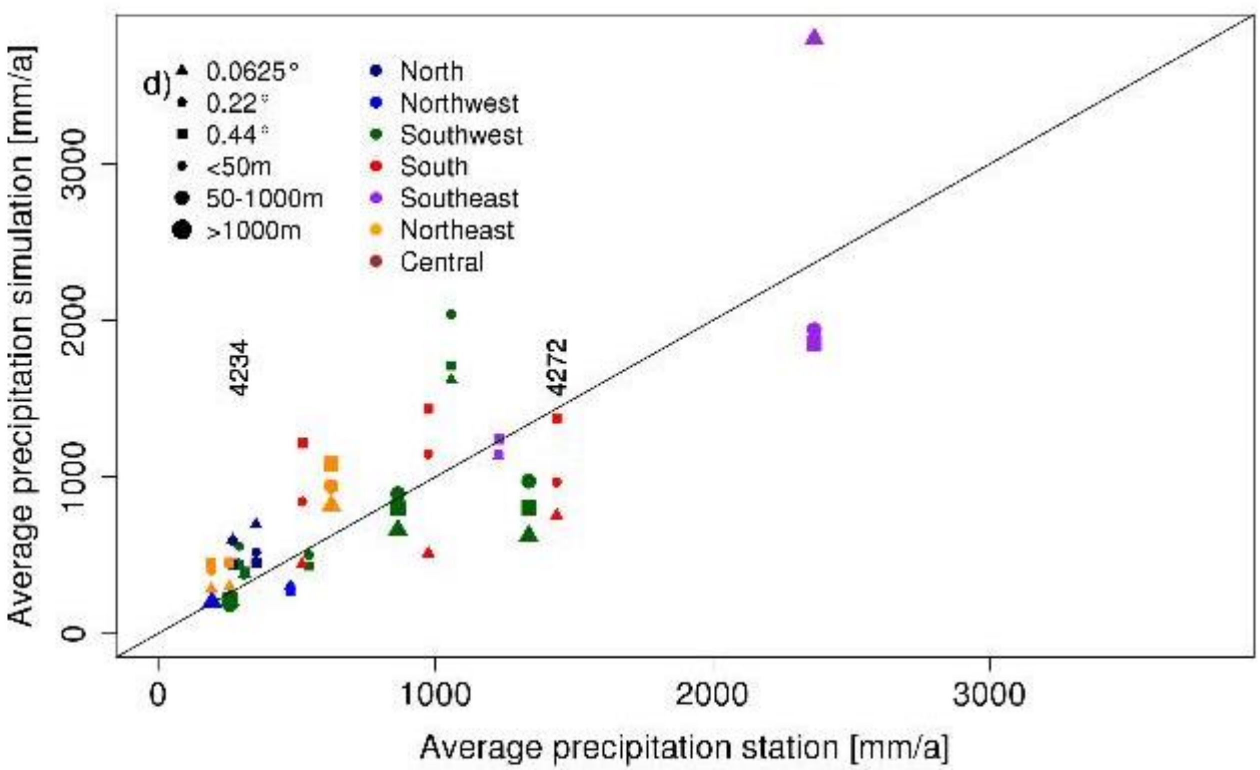

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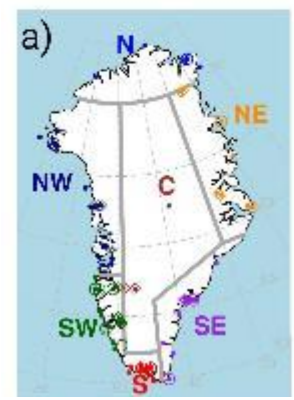

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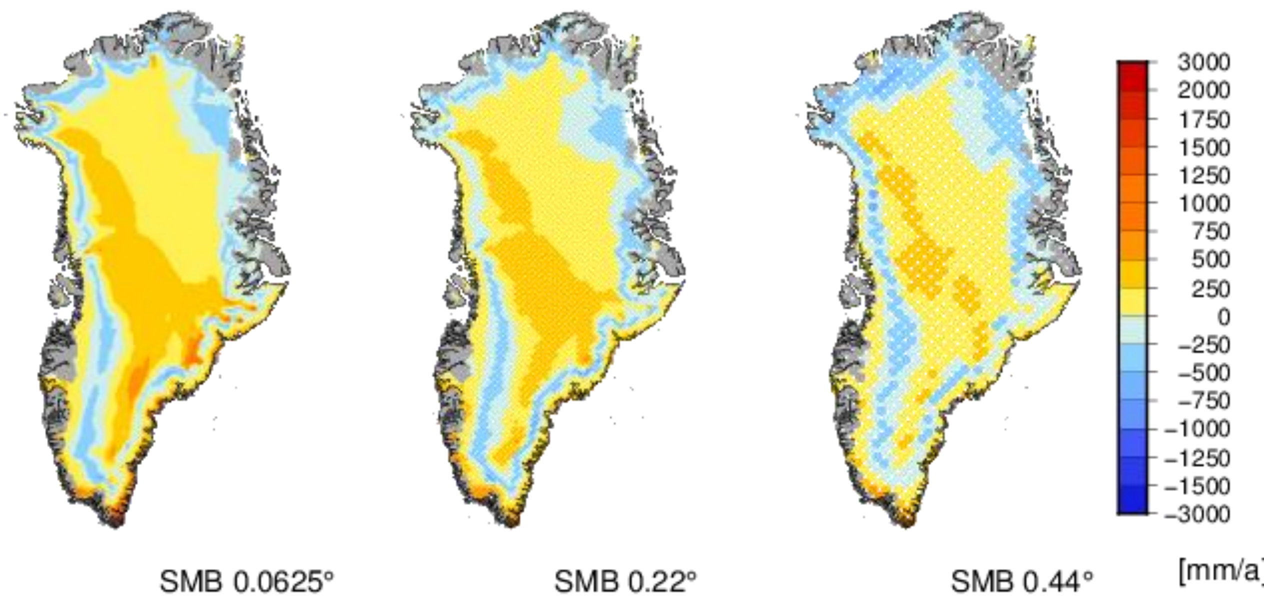
What about SMB?

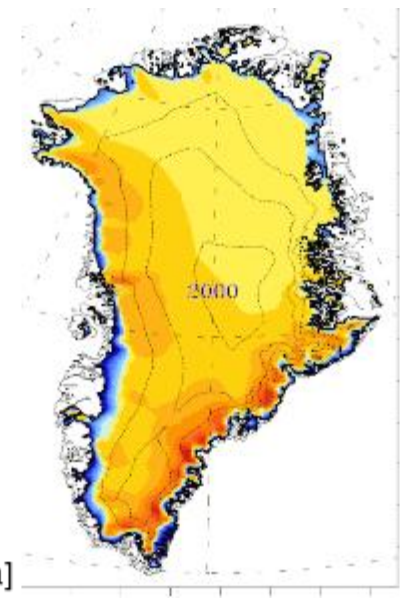
Surface Mass Balance; ERA-Interim 2000-2014

SMB=Precipitation-(Melting+Evaporation)

COSMO-CLM

MAR





14,1 GT

18,5 GT

8,2 GT

SMB 2000-2014: 277±101 GT (Mottram et al., 2017)

SMB 1980-1999: 480±87 (Fettweise et al., 2017)

Climato.be

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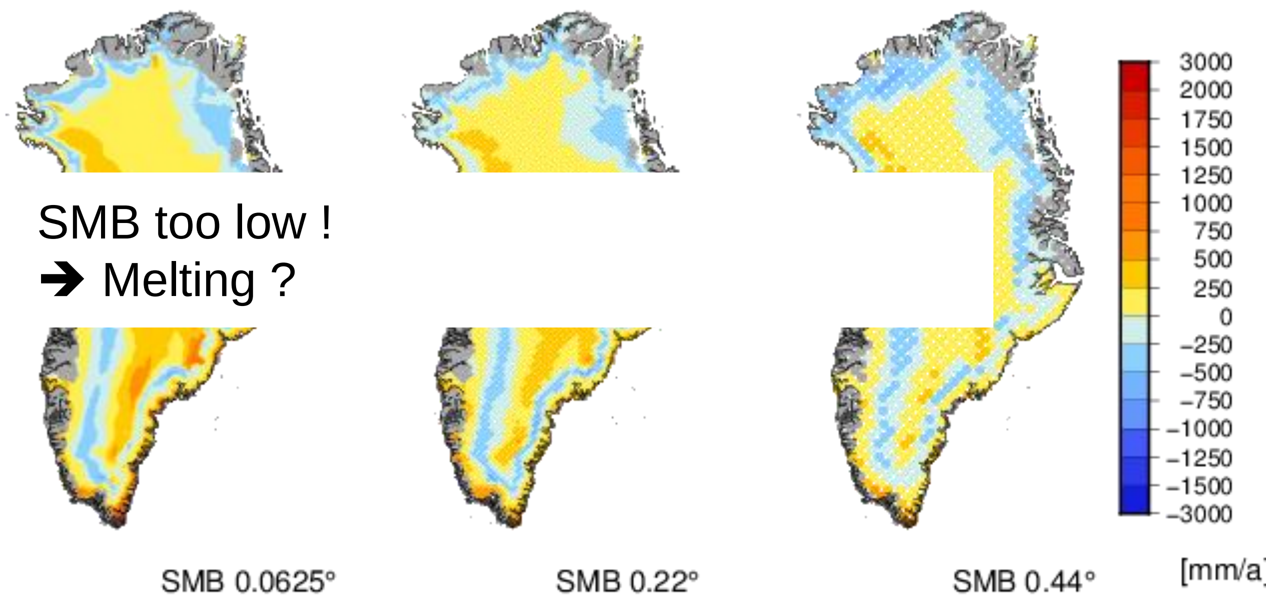
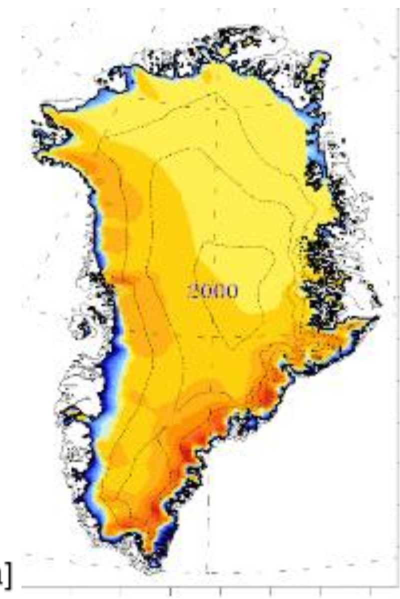


SMB too low !
➔ Melting ?



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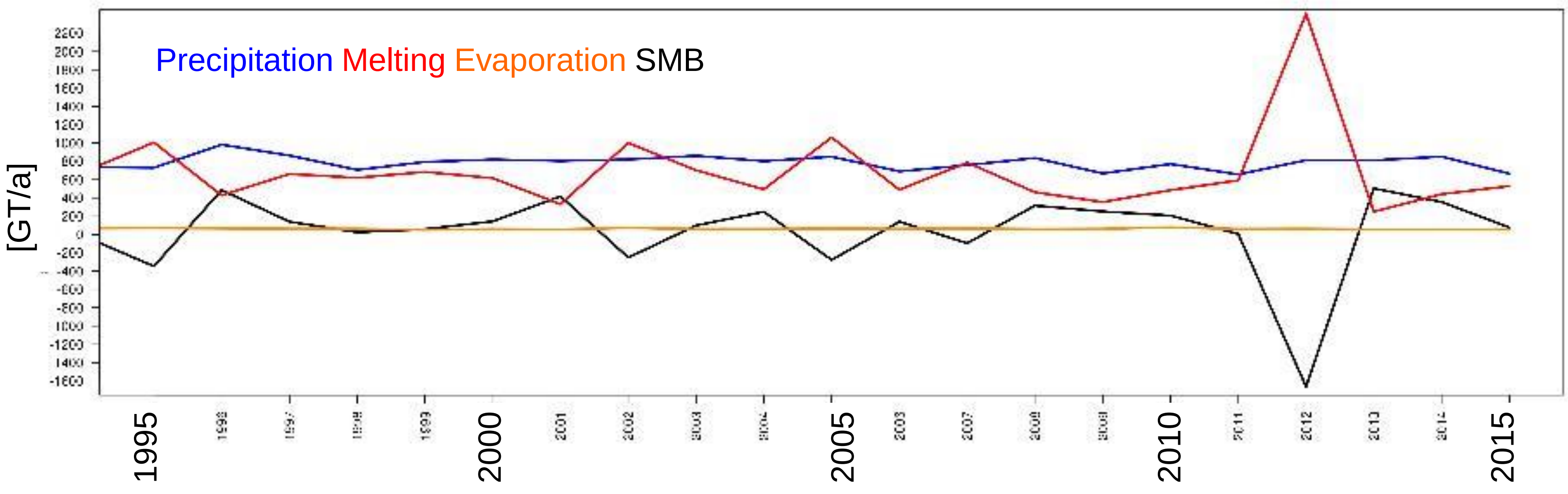
Single components of SMB



mean melting: 727±457 GT/a
mean melting 1991-2015: 363±102 GT/a (van den Broeke et al., 2016)
1980-2015: 220±52 GT/a (Fettweis et al., 2016)

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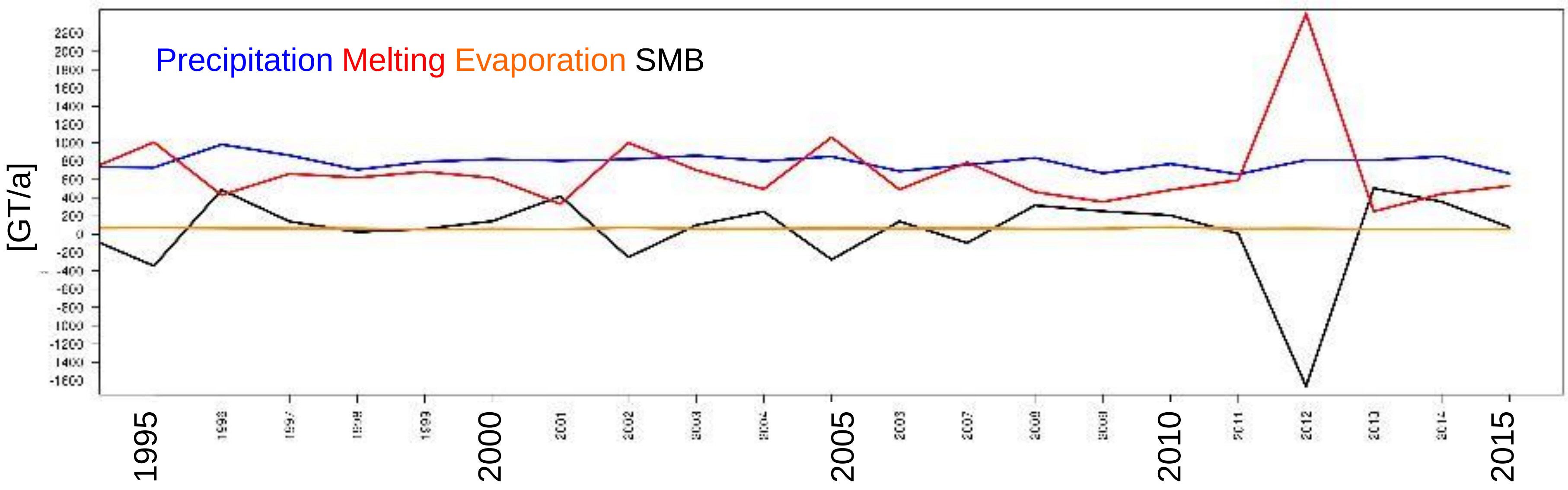

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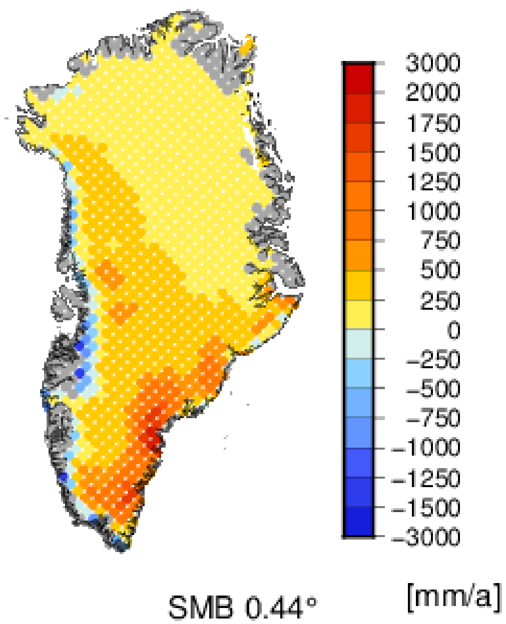
➔ further changes in model setup

Surface Mass Balance; ERA-Interim 1995-2000

NEW: reduced min. heat diffusion coefficient for turbulence: 0,1



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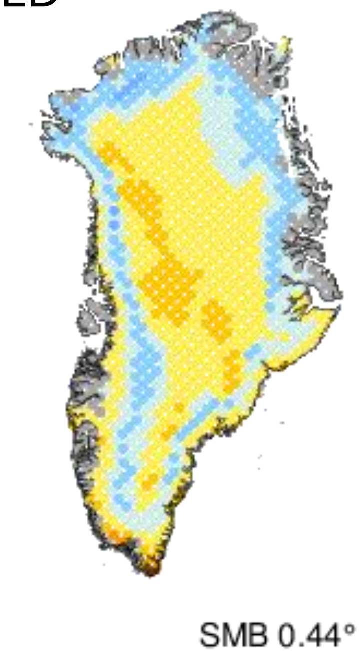

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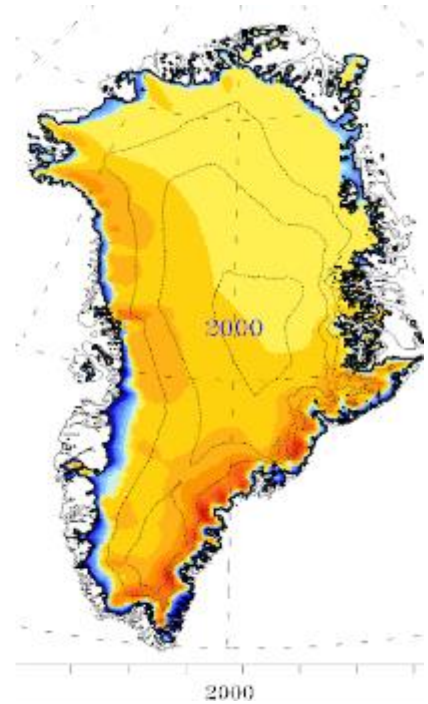

SMB: 564±167 GT
Melting: 191±47 GT

84±253 GT
670±188 GT

SMB 1980-1999:
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502±74 (Box et al., 2013)

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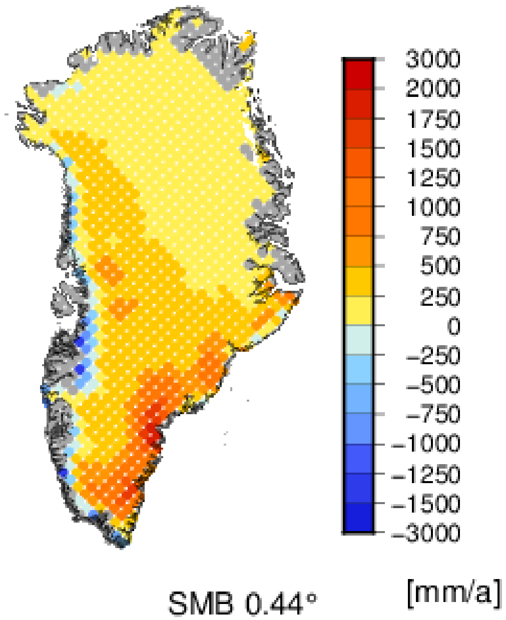

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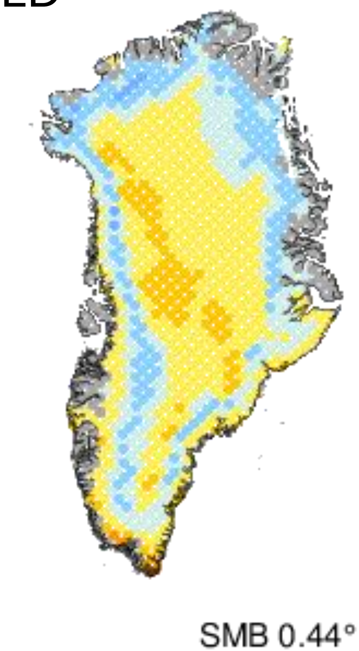

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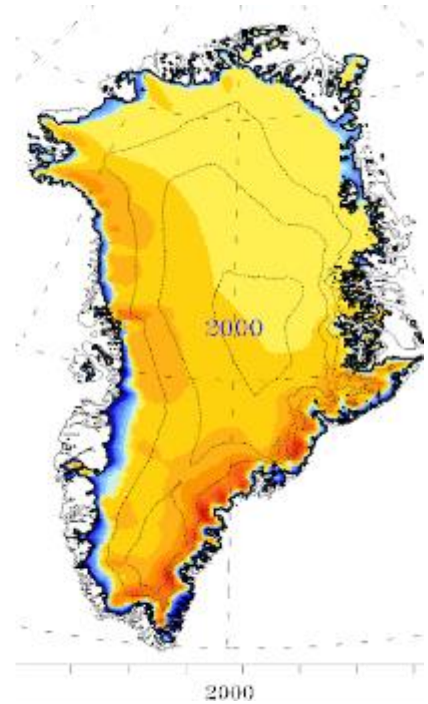

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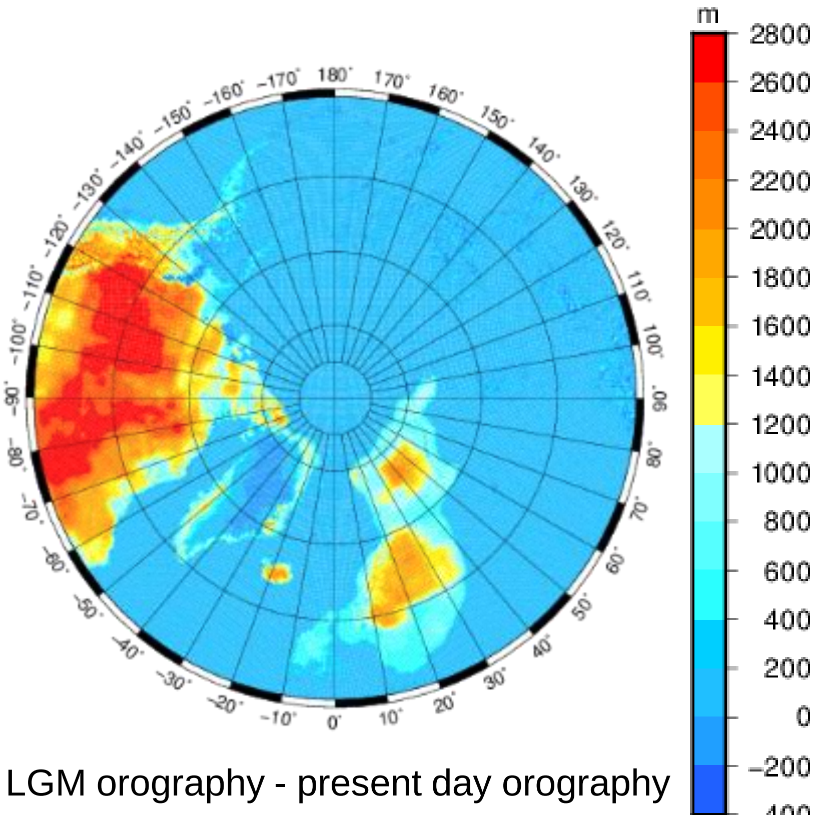
➔ Results with new model setup more resonable
➔ Model can be used for other geological eras

Application to LGM data

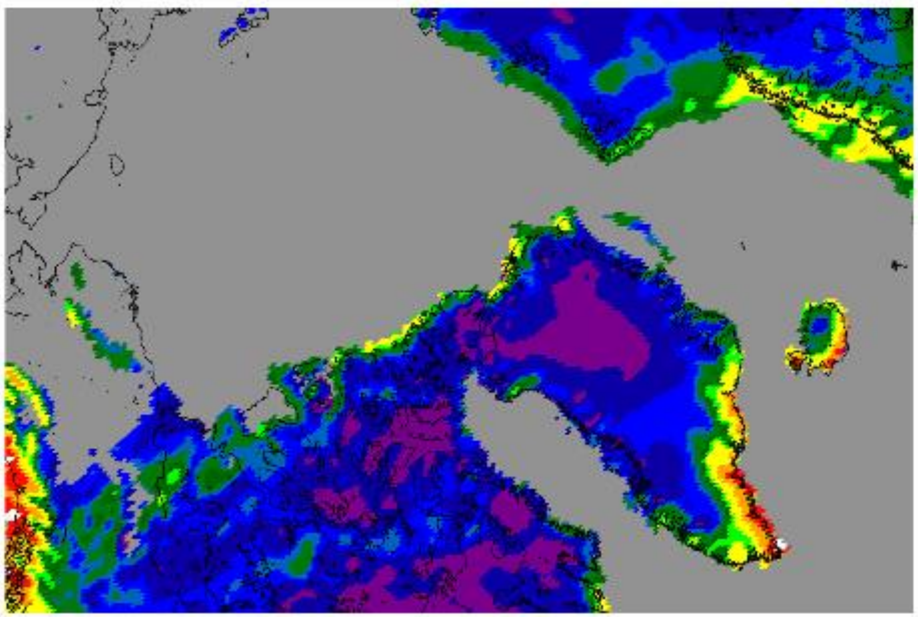


LGM orography - present day orography

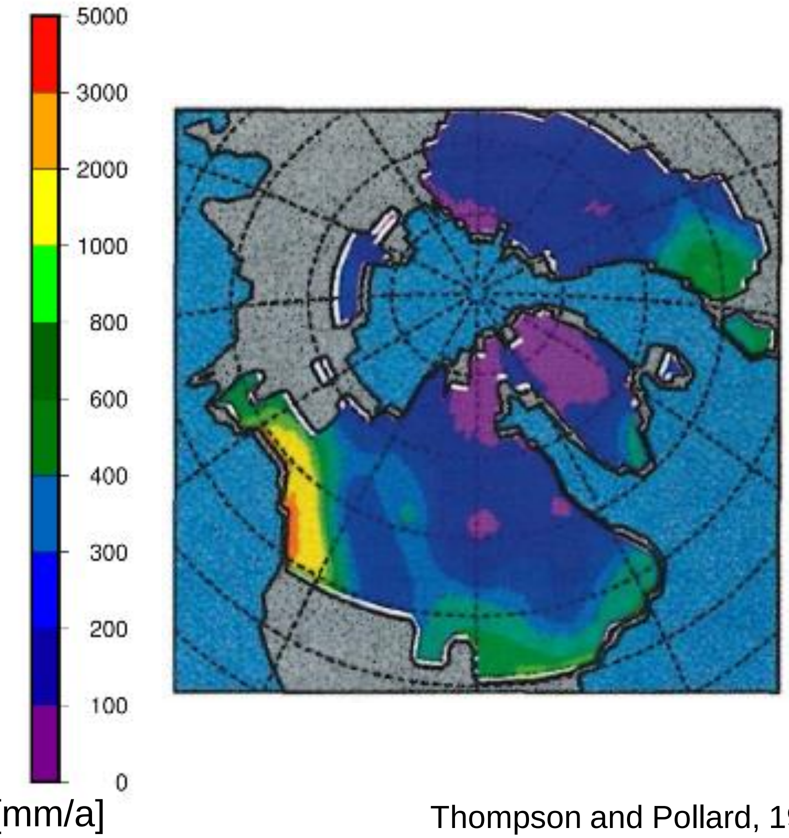
- Changes in ice sheet, orography, land-sea mask, solar constant, orbital parameters, CO2-concentration
- Following changes in PMIP project:
  - Ice sheet data for 20ka on 0.16° resolution
  - LGM CO2-concentration: 119 ppm
  - Eccentricity: 0.018994
  - Obliquity: 22.949°
  - Perihelion: 294.42

Preliminary results with LGM conditions: annual precipitation

COSMO-CLM, MPI-ESM 20ka BP



Thompson and Pollard, 20ka BP



Thompson and Pollard, 1997

Conclusions and ongoing work:

Model set up:

- COSMO5 CLM9; CORDEX-Arctic region
- Sea ice; Increase max. albedo to 0.9
- Decrease minimum heat capacity for turbulence to 0.1

Results:

- Simulations generally better for temperature than for precipitation and SMB
- Quality of simulations depends on region and resolution
- Preliminary simulations with MPI-LGM data (20ka) promising

Future work:

- Finalise / analyse long-term regional paleoclimate simulations driven with MPI-ESM
- Quantify added value of dynamical downscaling of paleo GCM data

Thank you!!!

https://nsidc.org/cryosphere/quickfacts/icesheets.html

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Van de Broeke et al., 2016: On the recent contribution of the Greenland ice sheet to sea level change, The Cryosphere, 10, 1933-1946