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
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Focus only on SMB components affected by atmospheric conditions.
Sensitivity studies for model setup

• COSMO 5 CLM9, climate mode
• driving data: ERA-Interim, 6-hourly, 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°)
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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→ added value of higher resolution
Different resolutions: 1995-2015 mean precipitation compared to DMI observations

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- added value for higher resolution, but smaller improvement than for temperature

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What about SMB?
Surface Mass Balance; ERA-Interim 2000-2014

SMB=Precipitation-(Melting+Evaporation)

COSMO-CLM

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SMB 2000-2014: 277 ± 101 GT (Mottram et al., 2017)
SMB 1980-1999: 480 ± 87 (Fettweise et al., 2017)
Surface Mass Balance; ERA-Interim 2000-2014

SMB = Precipitation - (Melting + Evaporation)

SMB too low!
⇒ Melting?

COSMO-CLM

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SMB 2000-2014: 277 ± 101 GT (Mottram et al., 2017)
SMB 1980-1999: 480 ± 87 (Fettweise et al., 2017)
Single components of SMB

mean melting: $727 \pm 457$ GT/a
mean melting 1991-2015: $363 \pm 102$ GT/a (van den Broeke et al., 2016)
1980-2015: $220 \pm 52$ GT/a (Fettweis et al., 2016)
Single components of SMB

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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

OLD

SMB 1980-1999:
480 ± 87 (Fettweise et al., 2017)
502 ± 74 (Box et al., 2013)

SMB: 564 ± 167 GT
Melting: 191 ± 47 GT

84 ± 253 GT
670 ± 188 GT

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Surface Mass Balance; ERA-Interim 1995-2000

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Results with new model setup more reasonable

Model can be used for other geological eras
Application to LGM data

- 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

LGM orography - present day orography
Preliminary results with LGM conditions: annual precipitation

COSMO-CLM, MPI-ESM 20ka BP

Thompson and Pollard, 20ka BP

[mm/a]

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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Mottram et al., 2017: Surface mass balance of the Greenland ice sheet in the regional climat model HIRHAM5, doi_10.14943


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