Ice sheets (glaciers) and atmospheric drivers

Partners SMHI Ulrika Willén, Klaus Wyser, DMI Ruth Mottram, Shuting Yang

Scientific questions to be addressed:

- Can regional (global) climate models represent accurately the atmospheric and surface processes affecting the Greenland and Antarctic ice-sheets?
- Where, when and why do the surface mass (energy) balance of the models processes perform least & most well?

WP 5.7 Regional PolarRes climate models for Greenland & Antarctica

Simulations are now available and analysis is ongoing at DMI.

Some preliminary results from Ruth Mottram et al will be shown here

OWP 5.7 Global climate models, EC-Earth and additional CMIP models

Will start soon...

Presented here some preliminary results from Shuting on the sensitivity of the global climate model EC-Earth to changes in albedo

Evaluating high resolution regional climate models with ESA CCI ice sheets data products

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With contributions from partners at:
Alfred Wegener Institute, Danish Meteorological Institute, Finnish Meteorological Institute, Institute Mathemathical Modelling in Ukraine, Norwegian Meteorological Institute, University of Helsinki, University of Utrecht, University of Liege, National Antarctic Science Centre of Ukraine, British Antarctic Survey

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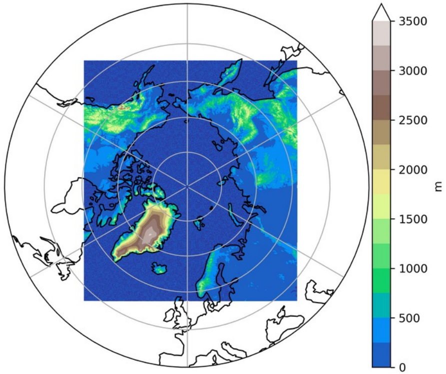
Introducing the new Polar RCM Ensemble:

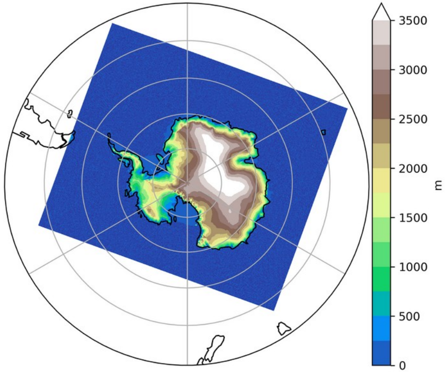
- Common domain
- Common grid
- Common Resolution
- Common experiments
- Follow CORDEX protocol

PolarRES

PolarRES models: ICON, MAR, RACMO, MetUM, WRF and HCLIM
Plus CARRA (Copernicus Arctic Regional Reanalysis) over Greenland
https://climate.copernicus.eu/copernicus-arctic-regional-reanalysis-service



Arctic domain:
709x629 grid points (10km?)



Antarctic domain:
739x637 grid points (10km?)

Copernicus Europe's eyes on Earth

CMUG/PolarRES case study: Ice Sheet SEC cf. with climate models

Important: Note that the **RCMs in this study do not include ice sheet dynamics**, they have fixed topography and SEC observational data will therefore not directly be comparable with especially fast flowing parts of Greenland (or areas where ice is slowing in Antarctica).

Surface Elevation Change (SEC) for 5 different timeperiods:
1992-1997, 1997-2002, 2002-2007, 2007-2012, 2012-2017

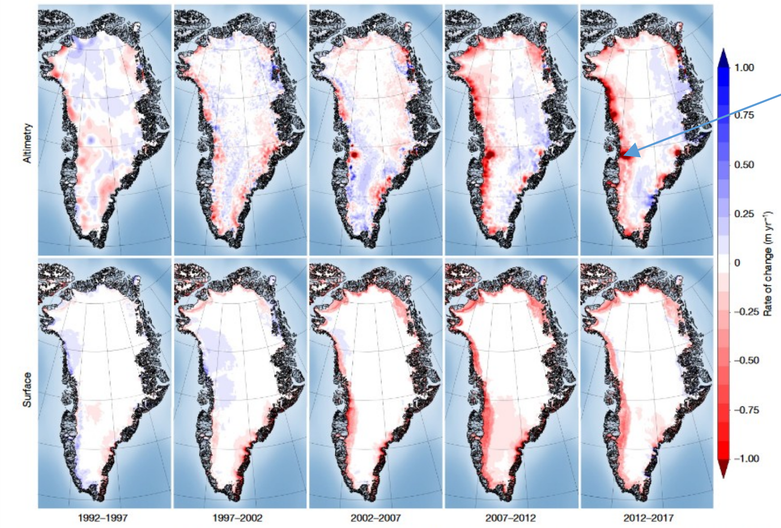


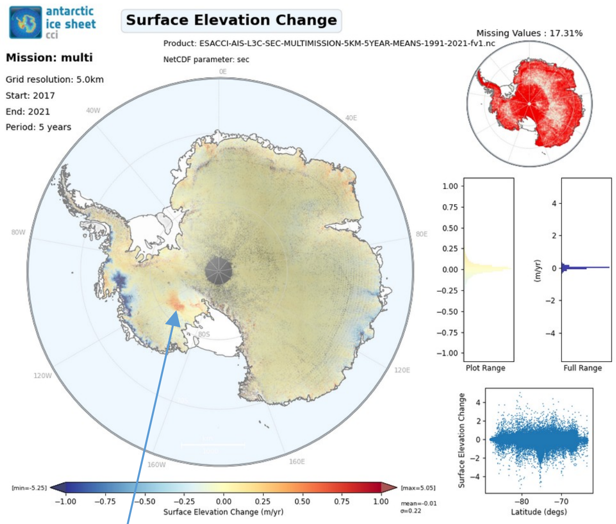
Fig. 1 | Greenland Ice Sheet elevation change. Rate of elevation change of the Greenland Ice Sheet determined from ERS, ENVISAT and CryoSat-2 satellite radar altimetry (top row) and from the HIRHAM5 SMB model (ice equivalent; bottom row) over successive 5-yr epochs. Data from ref. [29].

Shepherd et al., 2019

SEC from ESA CCI

Ice sheet dynamics cause ice sheet thinning

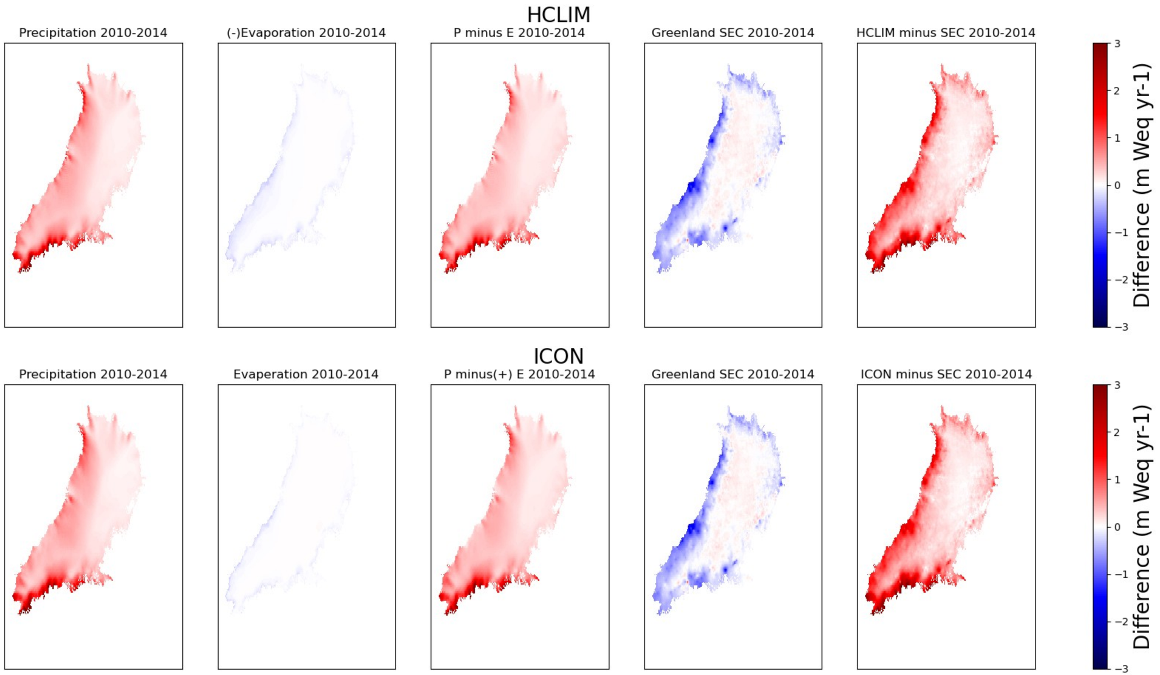
SMB from HIRHAM5 RCM



Ice dynamics cause thickening (slowdown of ice stream)

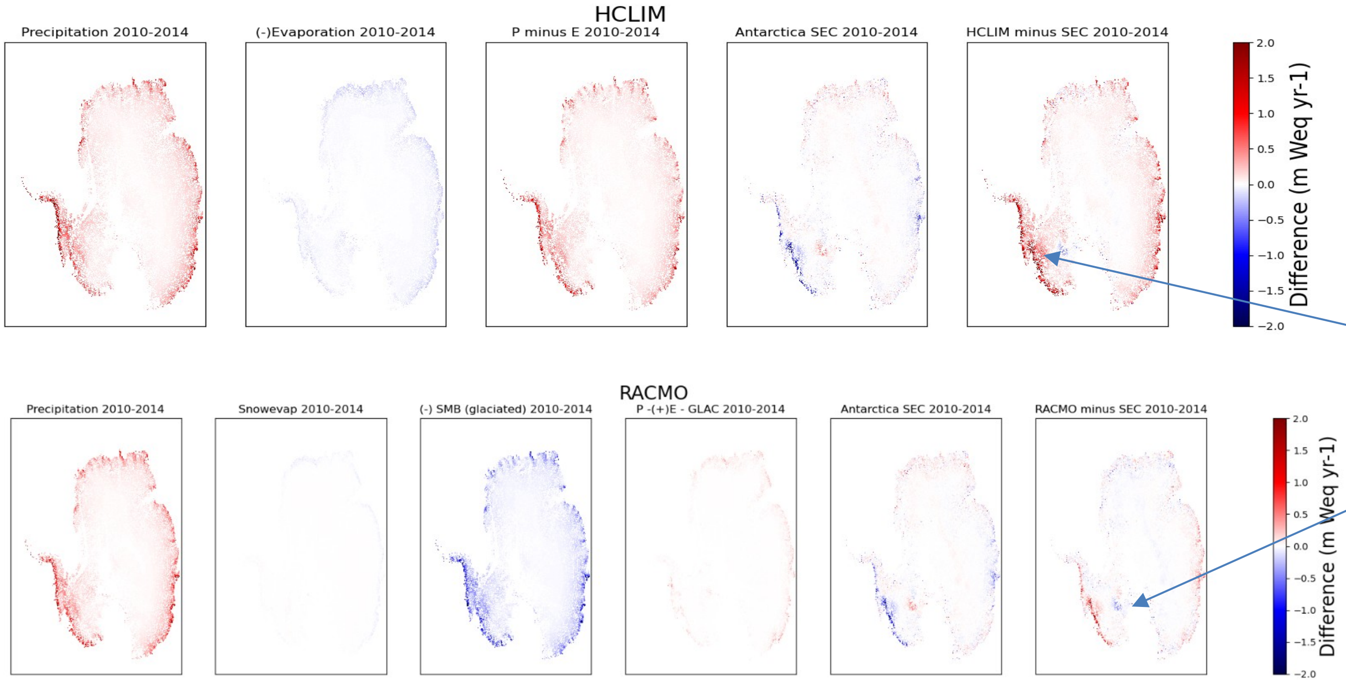
Hot off the press: RCM(P-E) – ESA(SEC) right column

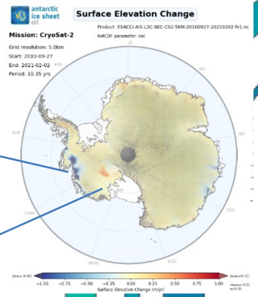
Please don't share – we're still checking these results…!



RCMs have slightly more accumulation in the centre of the ice sheet than SEC (note this is senstivie to density assumptions) and, as expected, underestimate surface lowering around the margins because no melt or runoff included

In Antarctica we can assume P-E is closer to SMB (right column





But RACMO’s SMB still gives a better result than HCLIM’s P-E although the two models have similar atmospheres, so we need to use SMB + firn densification for all RCMs in this project…

There are also ice dynamic effects visible in the SEC anomalies

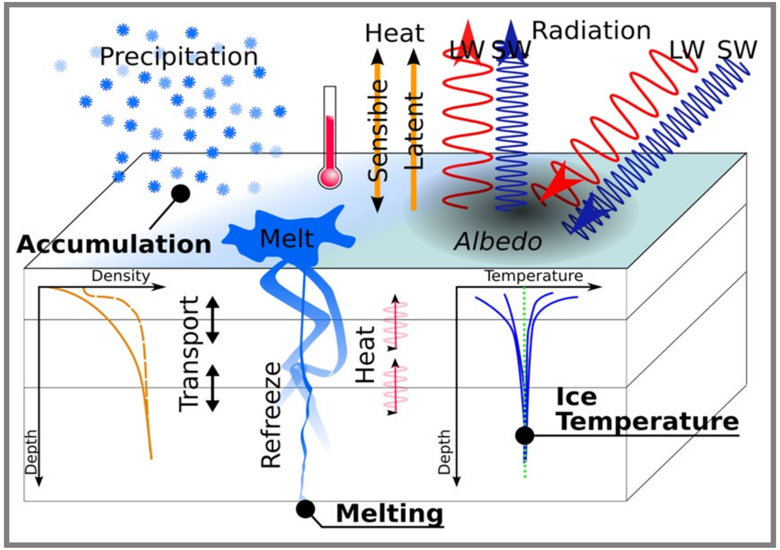
But P-E is not SEC, we need to factor in compaction, melt, retention, runoff and densification processes: Surface mass budget

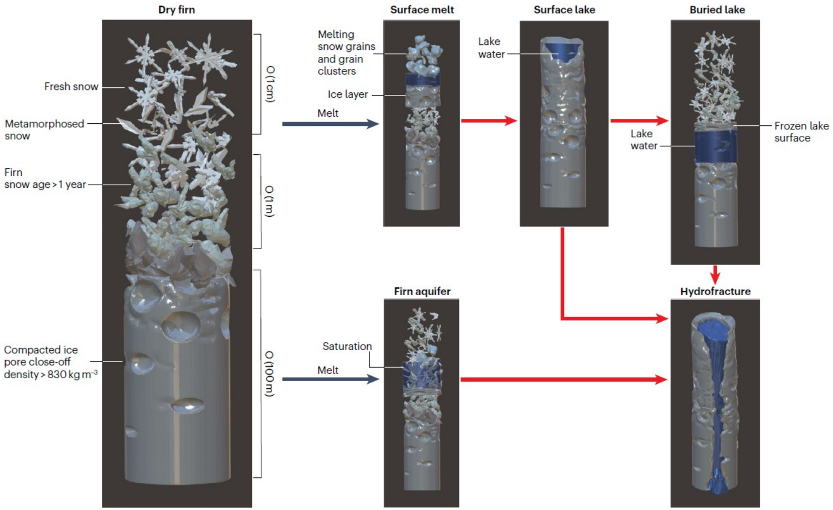
Not all PolarRES models have SMB and firn processes over the ice sheet inside the RCM.

$$SMB = RF + SF - RU - SU + DE$$

$$Runoff = Melt + Rainfall + Condensation - Retention - Refreeze$$

$$SEB = SWD - SWU + LWD - LWU + SHF + LHF + GHF$$

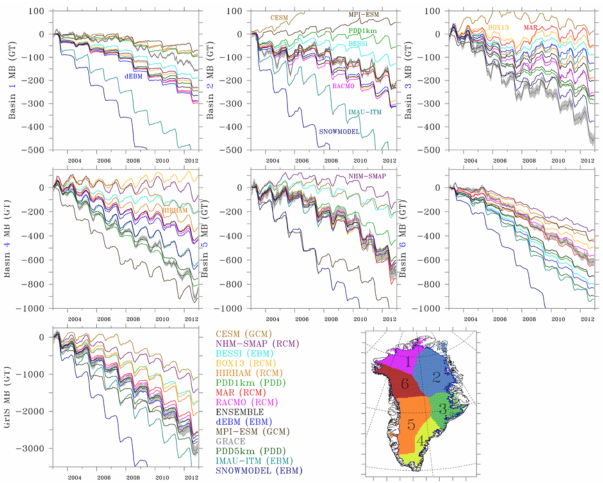




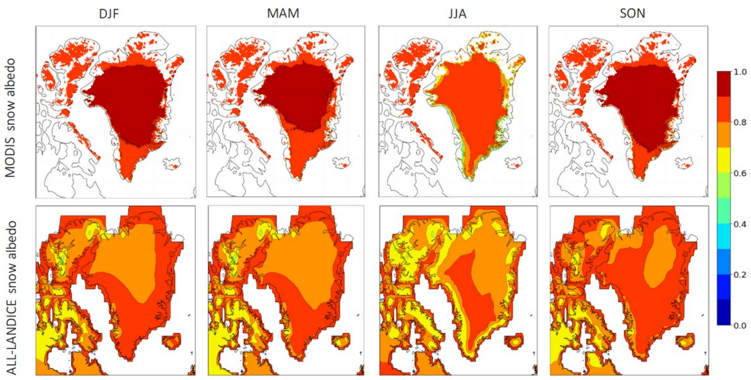
Firn Symposium team, NREE, 2024

Next Steps..

- Run SMB for all models that don't output it (HCLIM, MetUM, ICON) + gather SMB/firn air content where possible.
- Subtract the ice dynamics signal using ice velocity changes (?)
- GMB and MFID – compare SMB + Discharge with GRACE (as in Fettweis et al., 2020)
- Contribution to ISMIP7 for CMIP7 -> a new SMBMIP to include also deep learning and statistical approaches to SMB as well as PolarRES RCMs
- Assess how GCM driven simulations perform against similar time periods.

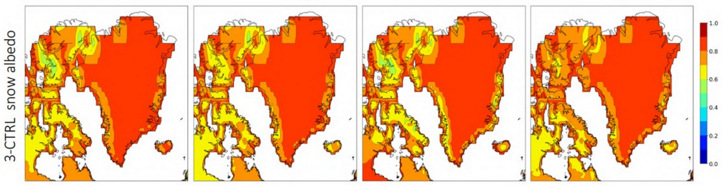


DMI evaluation of changes in snow albedo over Greenland for EC-Earth



Modis snow albedo

Standard EC-Earth3 CTRL exp: $\alpha = 0.8$



$$\alpha_{sn}^{t+1} = \begin{cases} (\alpha_{sn}^{t} - \alpha_{firn}) \exp\left(-\frac{\Delta t}{\tau_{firn}}\right) + \alpha_{firn} & M_{sn} = 0 \\ \alpha_{min} & M_{sn} > 0 \end{cases}$$

$\alpha_{firn} = 0.75 \mid \alpha_{min} = 0.60 \mid \tau_{firn} = 30\ days$

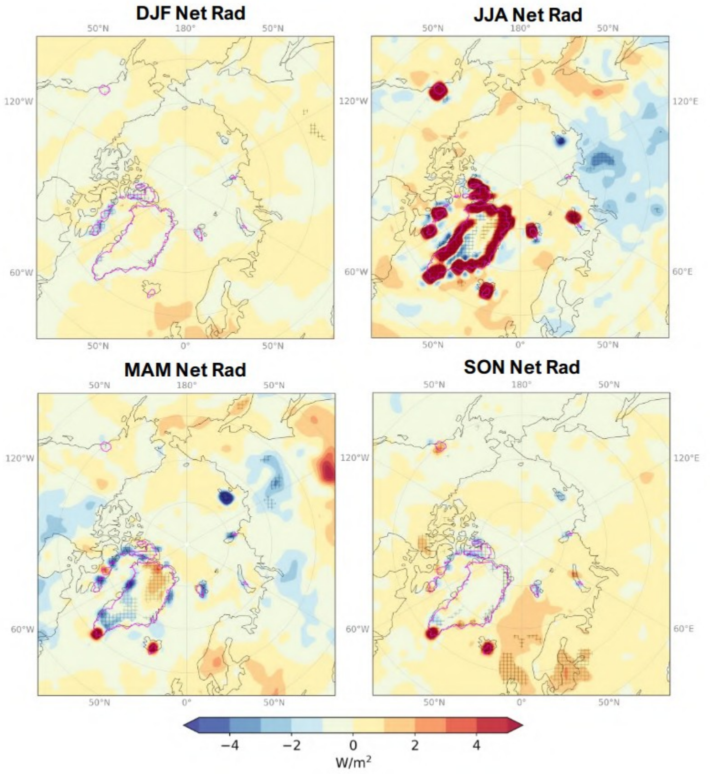
$\alpha_{refrozen} = 0.65$

Ensemble AMIP experiments (3 members) 1979-2018
With new snow albedo accounting for snow aging and snow melt/ refreezing over land ice

New albedo scheme is more responsive, but still underestimate the albedo over dry northern areas and along the coasts

Snow albedo feedbacks: Radiative response

Net surface radiation (SW-LW) LANDICE - CTRL

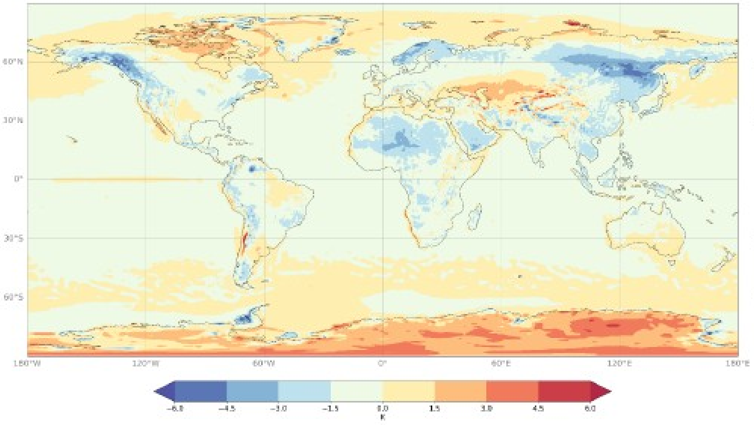


- Strong heating in the ablation regions in melt season
- Better representation of albedo – melt feedback

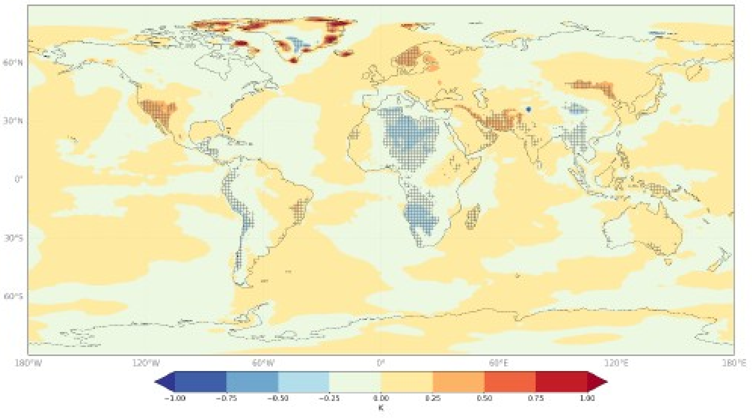
Snow albedo feedbacks:
Local and Remote responses

Surface Air Temperature bias and response

ALL-CTRL – ERA5



ALL-LANDICE – ALL-CTRL



- Better representation of surface temperature in the ablation zone over the ice sheet
- Some indications of reduced cold biases over high latitude Eurasia
- Signals of remote response are not clear due to large internal variability (needs for large ensemble!)

DMI Plans for OWP 5.7 analysis

- Evaluation of the EC-Earth3-ESM with an interactive ice sheet model (PISM) for Greenland
  - Focus on Greenland
  - Simulated SMB and ice surface temperature, compared with ERA5/CARRA/RCM (WP5.7)
  - Simulated Greenland ice sheet characteristics in comparison with CCI ECV, e.g., Gravimetric mass balance, surface elevation changes, ice surface velocity

  - Evaluation of SMB on Antarctic if resource allows

SMHI Plans for WP 5.7 and OWP 5.7 analysis

- ECV’s: ESA-CCI LST, TCWV, Clouds (radiation fluxes) and glaciers.
- Interact with the ECV teams on which data sets to use e.g. LST AQUA MODIS that is stable (Good et al 2022) and on how to use the uncertainties (possibly build on ESMValTool study for LST)
- Evaluate regional models (PolarRES, CORDEX) and global (EC-Earth, CMIP) climate models w.r.t the representation of the variables mean (bias), variability and extremes for Greenland and Antarctica
- Focus on cloud and water vapor radiation feedback at the surface and the TOA
- Include areas with (large) glaciers in the evaluations of the models - interact with Frank Paul