Ice sheets and atmospheric drivers

CCI+ Phase 2 CMUG proposals: Ice sheets and atmospheric drivers

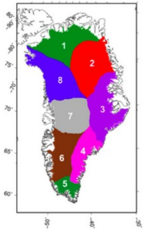
Scientific questions to be addressed:

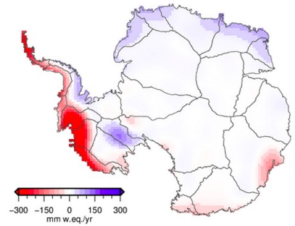
- Can regional/global climate models represent accurately the atmospheric and surface processes affecting the ice-sheets?
- Do the models capture the variability of the ECV’s and the albedo and emissivity feedbacks over the ice sheets?
- Where, when and why do the surface mass (energy) balance of the models processes perform least&most well?
- Which ECV’s show the most important biases affecting the surface mass budget estimates from regional/global climate models

Partners:

SMHI Ulrika Willén, Klaus Wyser

DMI Ruth Mottram, Shuting Yang





GMB_figure.png

Mottram et al 2019

Fig5a. Mass change time series for the entire GrIS generated by DTU (red) and TUDR (blue).

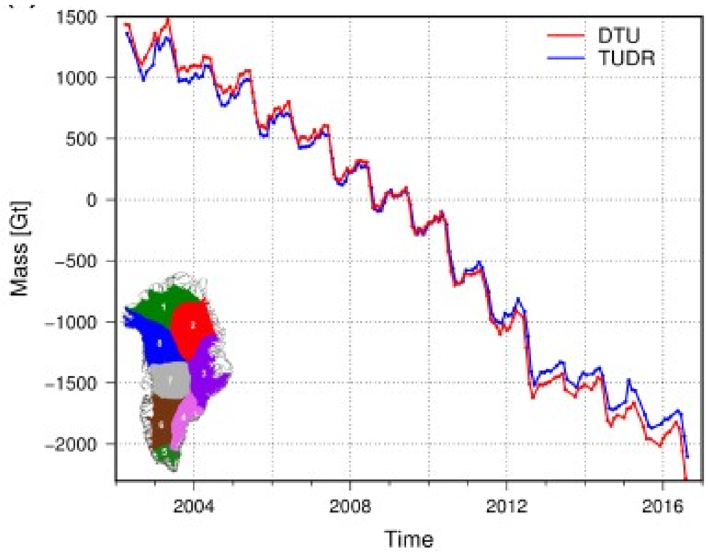
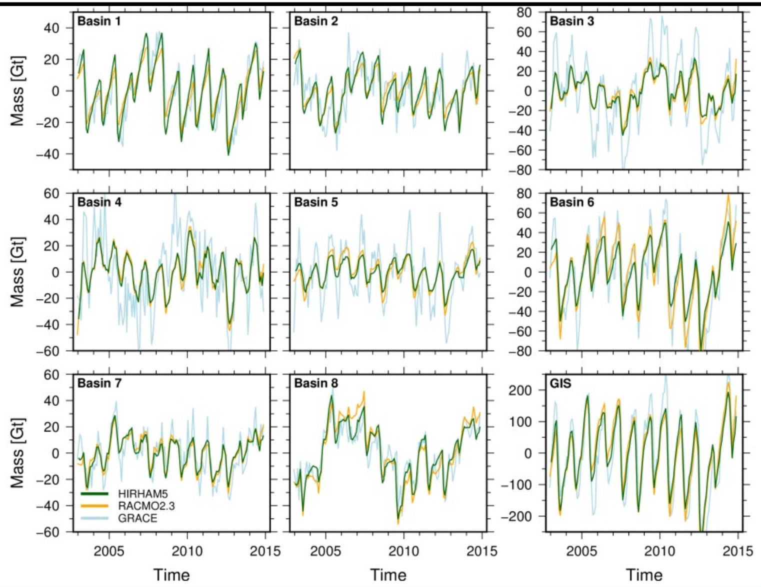


Fig8. Inter-comparison of mass changes from GRACE (GrIS CCI GMB product) and two regional climate models (HIRHAM5 and RACMO2.3) for different drainage basins and the entire GrIS. Mass changes are give w.r.t a linear and quadratic model.



We plan to repeat this type of inter-comparison for SMB and for the observed Surface Elevation Changes (SEC) for the whole basin and the sub-basins, comparing the observed variability with the regional models Surface Energy Balance (SEB) and the individual components (SWN, LWN, LE and H) for Greenland and for Antarctica.

Ice sheets and atmospheric drivers

Motivation: Atmospheric rivers bring warm and humid air that affect the ice sheets...

Wille et al 2022: Intense atmospheric rivers can weaken ice shelf stability at the Antarctica Peninsula

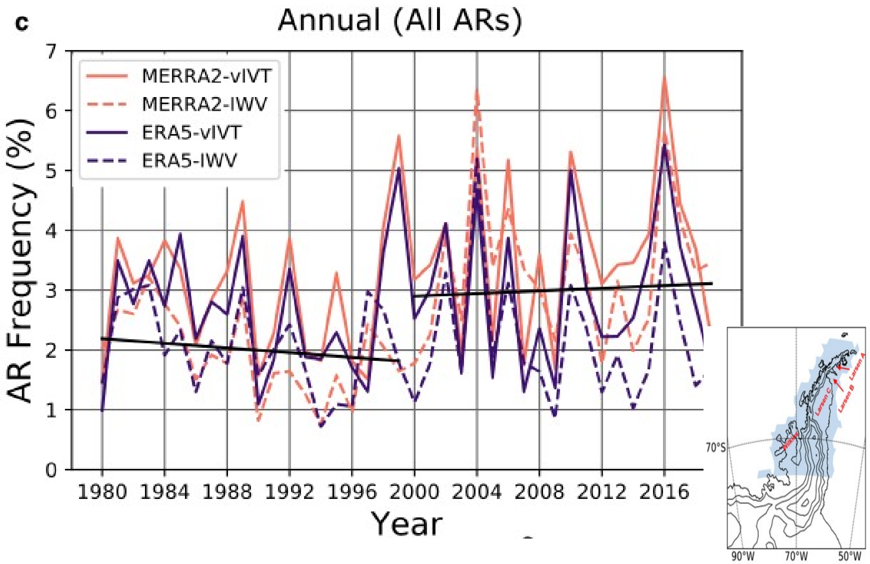


Fig1c. Frequency of annual AR landfalls on the Antarctica Peninsula according to the AR detection scheme applied to MERRA-2 and ERA5 reanalysis (AR landfall if AR shape touches the blue area)j

”the most intense atmospheric rivers induce extremes in temperature, surface melt, sea-ice disintegration, or large swells that destabilize the ice sheets with 40% probability. This was observed during the collapses of the Larsen A and B ice shelves during the summers of 1995 and 2002 respectively.

Overall 60% of calving events from 2000-2022 were triggered by atmospheric rivers.

The loss of the buttering effect from these ice shelves leads to further continental ice loss and subsequent sea-level-rise.

Under future warming projections the Larsen C ice shelf will be at risk from the same processes.”

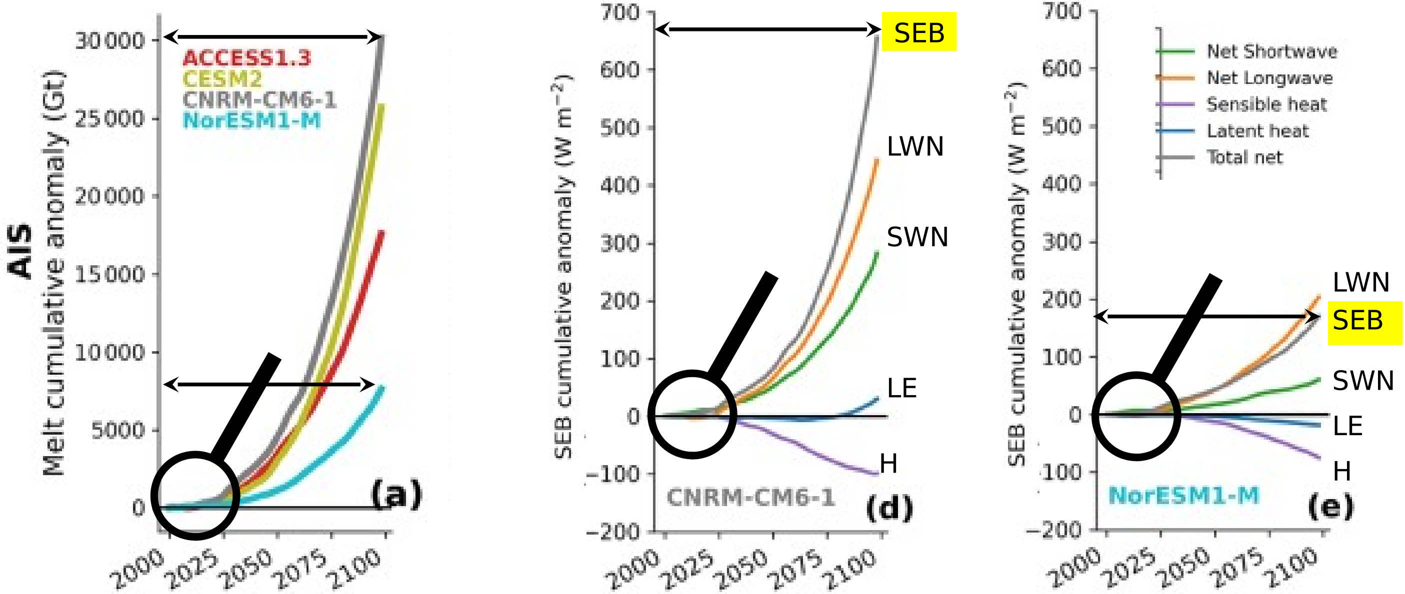
Ice sheets and atmospheric drivers

Kittel et al 2021: Clouds drive differences in future surface melt over the Antarctic ice shelves

”Clouds containing a larger amount of supercooled liquid water lead to stronger melt, subsequently favouring the absorption of solar radiation due to the snowmelt–albedo feedback.
As liquid-containing clouds are projected to increase the melt spread associated with a given warming rate, they could be a major source of uncertainties in projections of the future Antarctic contribution to sea level rise.”

Kittel down-scaled four CMIP5/6 models for Antarctica using MAR for the [1970-2000] and RCP8.5/ssp585 [2080-2100] periods

Fig1a,d,e. Differences fields for the AIS cumulative melt anomaly and the surface energy balance components



How well do the CMIP models represent the historical climate, e.g. present day cloud phase?

We need to scrutinize the CMIP models historical climate and regional models driven by reanalysis and by CMIP historical simulations, using observations.

Ice sheets and atmospheric drivers

Uncertainty in future ice sheet changes: choice of models

Barthel et al 2020: CMIP5 model selection for ISMIP6 ice sheet mode forcing: Greenland and Antarctica

They selected CMIP5 RCP8.5 models with small historical biases and large diversity in Climate Change signal for standalone ice sheet experiments to reflect plausible trajectories for climate projections.

Fig 5c. Minimise Greenland ice sheet historical biases

700hPa Temp, Water vapour, Geopotential height 500hPa

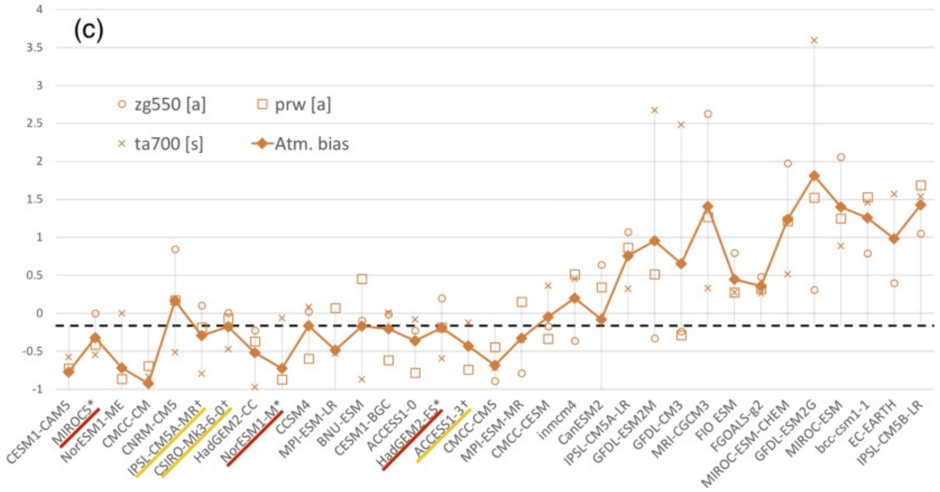
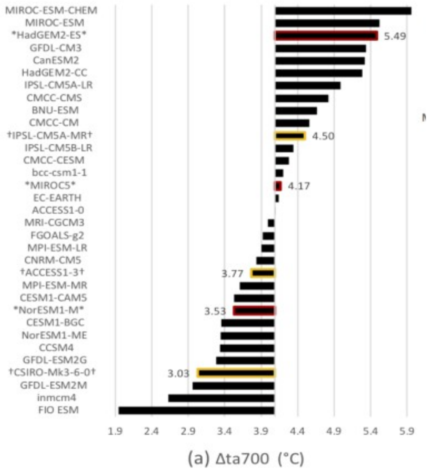


Fig 6a. Climate Change [2080-2100]-[1989-2009]

700hPa Temp (and Water vapour changes)



Can we find additional observational constraints?

From the variability, co-variability (trends) of individual ECV's and the SMB and SEB that affect the ice sheets on sub-basin scales

Ice sheets and atmospheric drivers

ECV's to be used

CCI ECV's:

Greenland and Antarctic Gravimetric Mass balance and Surface Elevation Change

- Land Surface temperature
- Total column Water vapour
- Cloud (fraction, ice and water path) and radiation fluxes (surface and TOA)
- *Snow on Greenland ice-free margins*

Other data sets:

- Melt extent and phases ESA 4D-Antarctica and 4D-Greenland
- CM-SAF Cloud, albedo, radiation and water vapour
- CloudSat Calipso cloud and radiation products
- CERES EBAF surface and TOA radiation fluxes
- ERA5 and CARRA (Copernicus Arctic Regional Reanalysis for Greenland, 2.5km)

Ice sheets and atmospheric drivers

Models to be used

Regional models driven by ERA5 and CARRA re-analysis (part 1)

- Greenland HIRHAM5, RACMO 2.3p2 (0.05deg resolution)
- Antarctic HIRHAM5 (0.11 and 0.44 deg resolution)
- Polar-CORDEX simulations to be made in Horizon EU project PolarRES with HCLIM; MAR, MetUW, RACMO (0.11 deg resolution) for both polar regions (if available in time)

Global models (part 2)

- EC-Earth3 AMIP ensemble sensitivity experiments using different albedo parameterisations
- EC-Earth3-GrIS coupled to the ice sheet model PISM for Greenland
- CMIP models coupled to ice sheet models and CMIP6 models used for regional downscaling and ice sheet model forcing experiments (ISMIP6)
- The coupled models present day climate will be evaluated in a statistical sense.

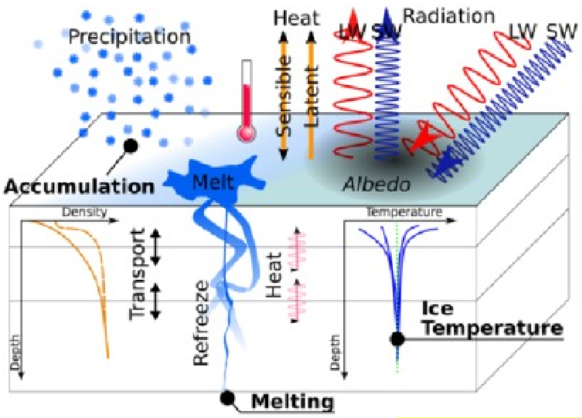
Surface mass balance in EC-Earth3-GrIS

A: Direct coupling

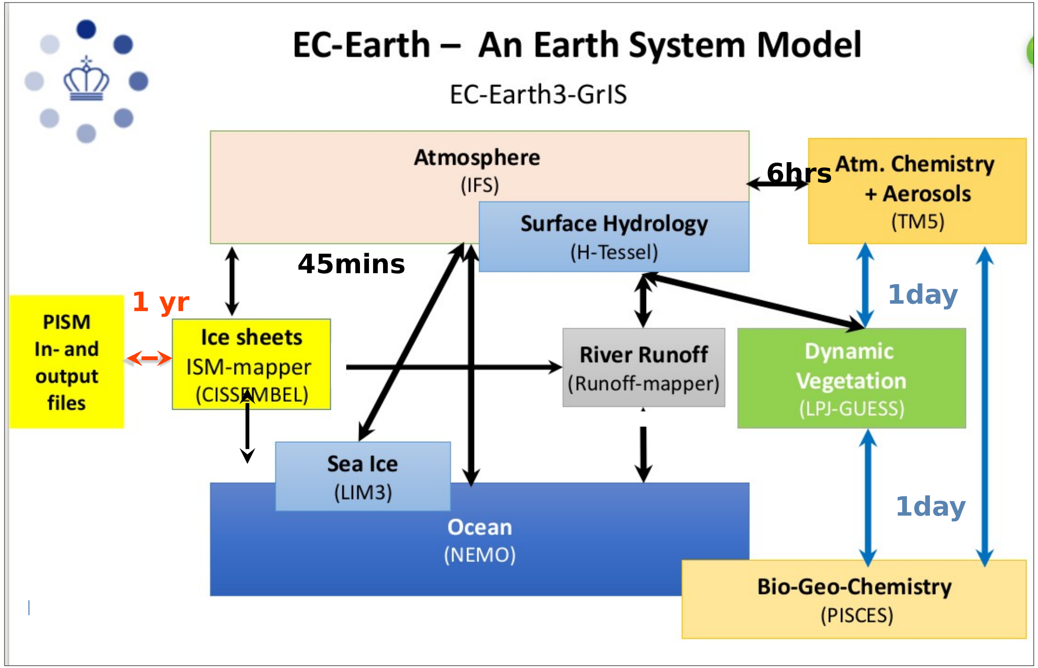
- SMB calculated in EC-Earth (~80 km)

B: Coupling using the CISSEMBEL EBM

- SMB is calculated at the resolution of the ice sheet model (5 km)



Rodehacke DMI



Marianne Madsen DMI

Ice sheets and atmospheric drivers

Scientific questions

Scientific questions to be addressed:

- Can regional/global climate models represent accurately the atmospheric and surface processes affecting the ice-sheets?
- Do the models capture the variability of the ECV’s and the albedo and emissivity feedbacks over the ice sheets?
- Where, when and why do the surface mass (energy) balance of the models processes perform least&most well?
- Which ECV’s show the most important biases affecting the surface mass budget estimates from regional/global climate models?

- Can the metrics be used for observational based model selection to reduce the spread of the ice sheet contributions to the future sea level rise...?

References

Mottram et al 2019: An Integrated View of Greenland Ice Sheet Mass changes based on Models and Satellite Observations. https://www.mdpi.com/2072-4292/11/12/1407

Wille et al 2022: Intense atmospheric rivers can weaken ice shelf stability at the Antarctica Peninsula. https://www.nature.com/articles/s43247-022-00422-9

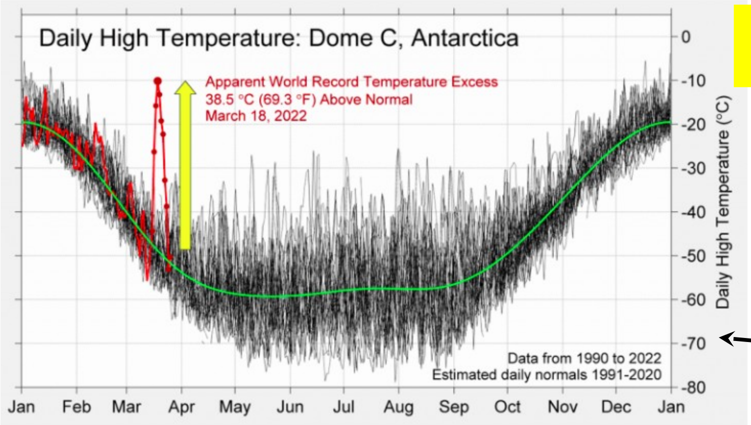
Kittel et al 2021: Clouds drive differences in future surface melt over the Antarctic ice shelves. https://tc.copernicus.org/articles/16/2655/2022/

Barthel et al 2020: CMIP5 model selection for ISMIP6 ice sheet model forcing: Greenland and Antarctic. https://tc.copernicus.org/articles/14/855/2020/

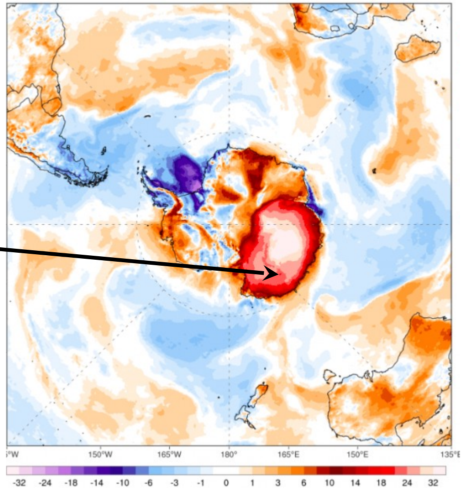
Ice sheets and atmospheric drivers

Extra: Atmospheric Rivers bringing warm air and water vapor to Antarctica and Greenland…

18th March 2022: Concordia-Dome C
-11.2°C +38.5°C (1991-2020)

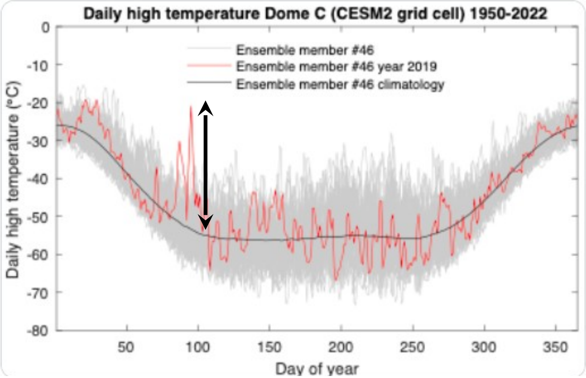


CFC/CFSR Forecast for 18th March
>+32°C (1979-2000)



Scale: -34°C to 34°C

CESM2 March Dome C Grid cell 1°x1°
-20°C +30° (1950-2022)
Ensemble member 46/50,
Initial analysis by Flavio Lehner



https://berkeleyearth.org/antarctic-heatwave-rapid-attribution-review-dome-c-record/