

# Ice Sheets in EC-Earth and AWI-ESM

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AWI, DMI, GEUS, GISS, KNMI, MPI-M, Uni-Bergen,  
Uni-Bremen, Uni-Fairbanks, Uni-Hamburg, ....

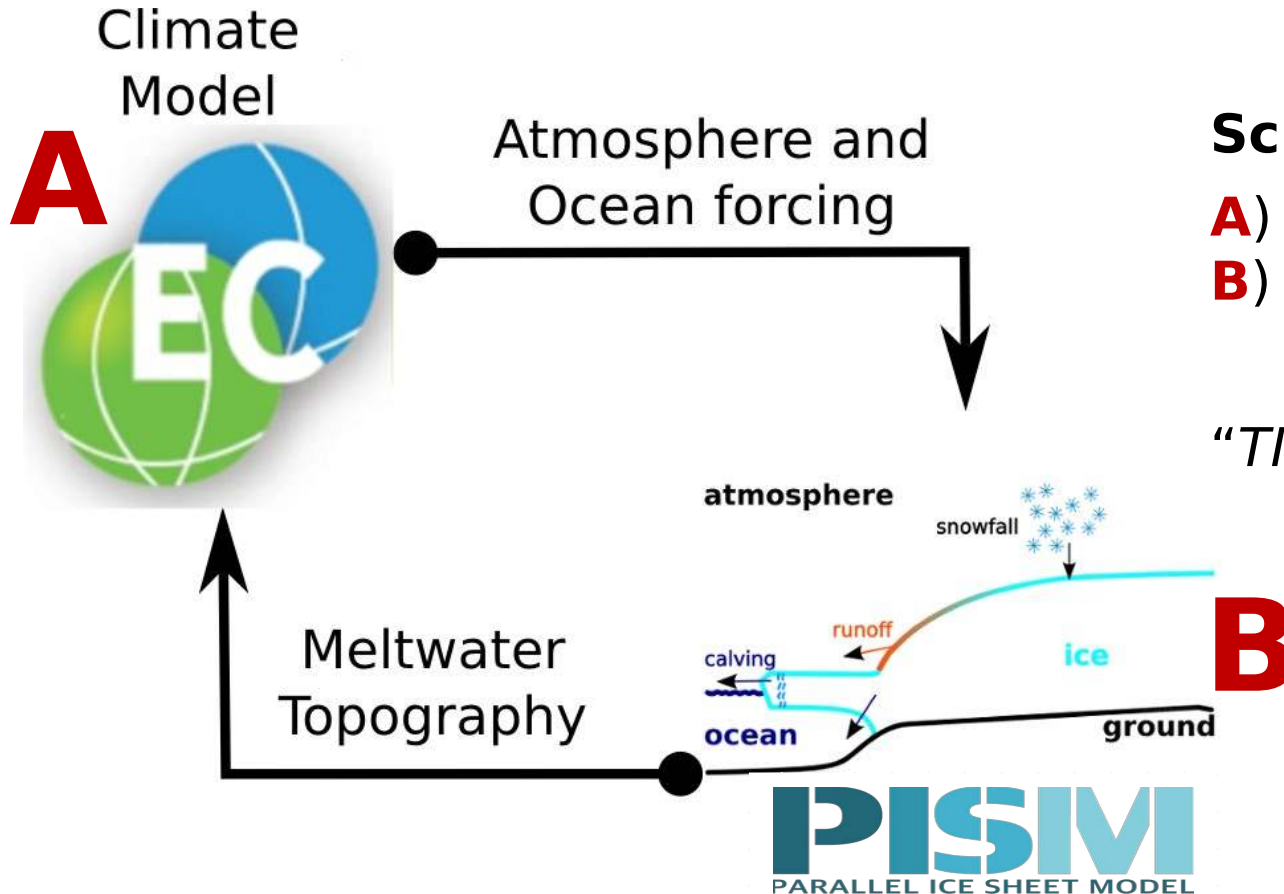
Christian Rodehacke<sup>1, 2</sup>, Shuting Yang,  
Andrea Giersch, Marianne S Madsen, Lars  
Ackermann, others

1) Danish Meteorological Institute (DMI)

2) Alfred Wegener Institute for Polar and Marine Reserach (AWI)  
2023-05-23 (Copenhagen)

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# Both Greenland and Antarctica (AIM)

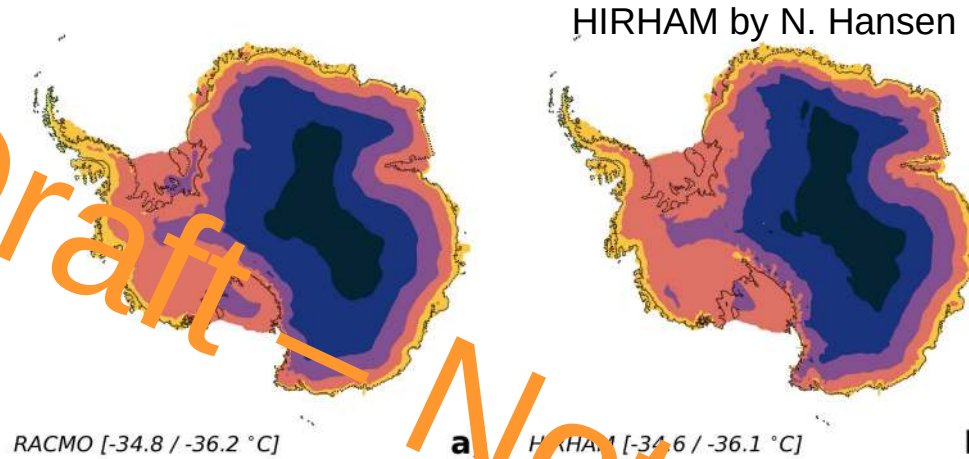
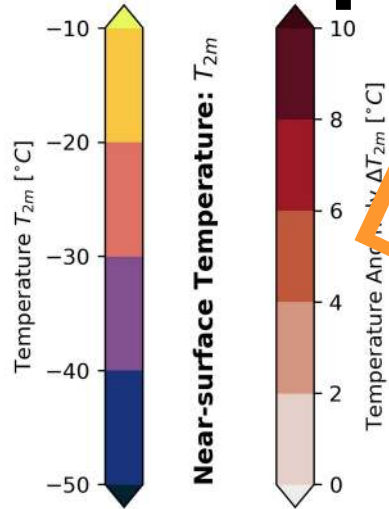


## Script-based coupling

- A)** Earth system model
- B)** Icesheet model

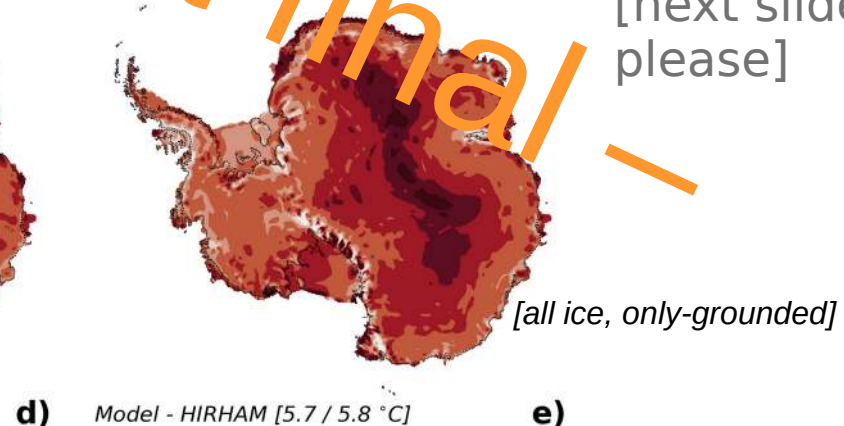
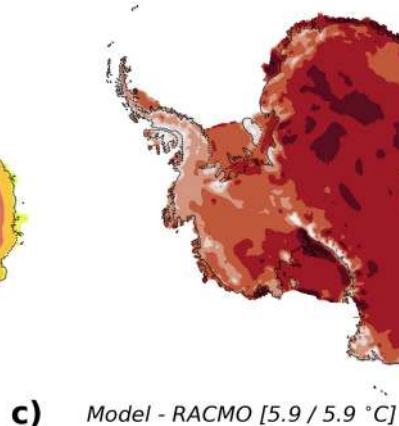
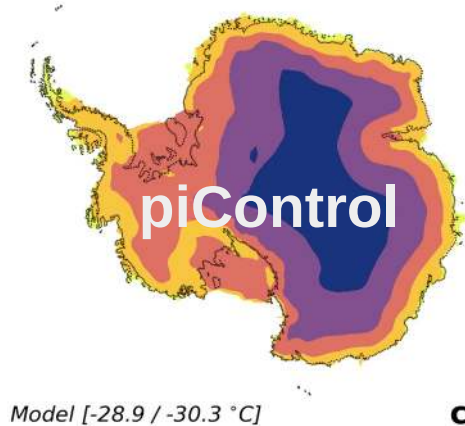
“TIC-TOC” approach

# Air temperature in Antarctica: EC-Earth

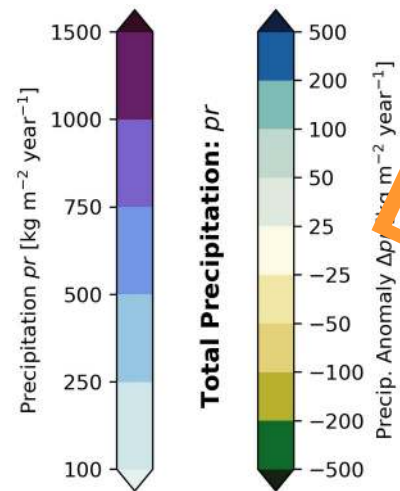


EC-Earth has a known warm bias in the atmosphere of the Southern Ocean. Side effects are ....

[next slide please]



# Snowfall Antarctica: EC-Earth



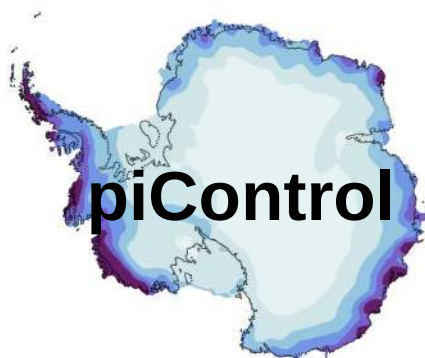
Draft - Not final -

Antarctica's equilibrium assumption: Precipitation fallen on Antarctica is rerouted into the ocean

RACMO [2550 / 2080 Gt year<sup>-1</sup>]

a) HIRHAM [2210 / 2370 Gt year<sup>-1</sup>]

b)



Model [3610 / 3010 Gt year<sup>-1</sup>]

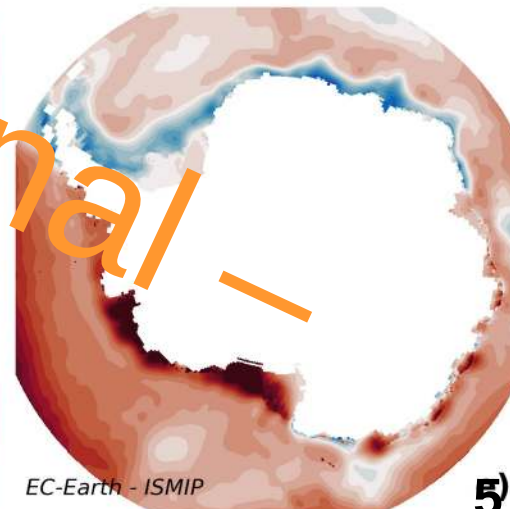
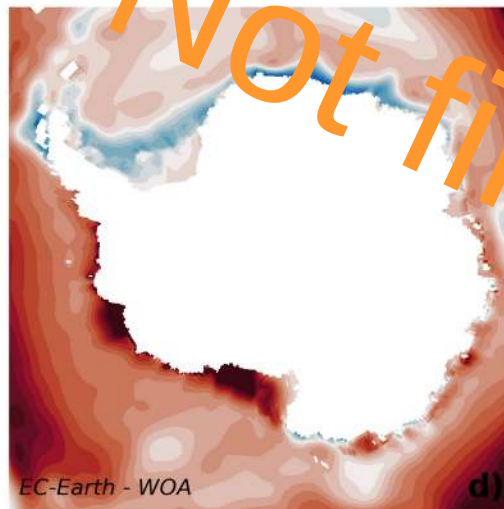
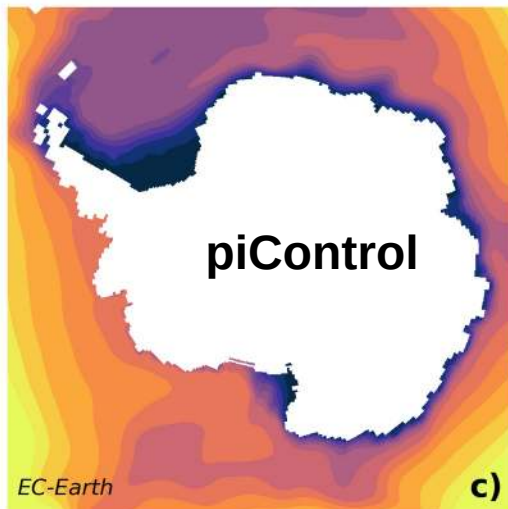
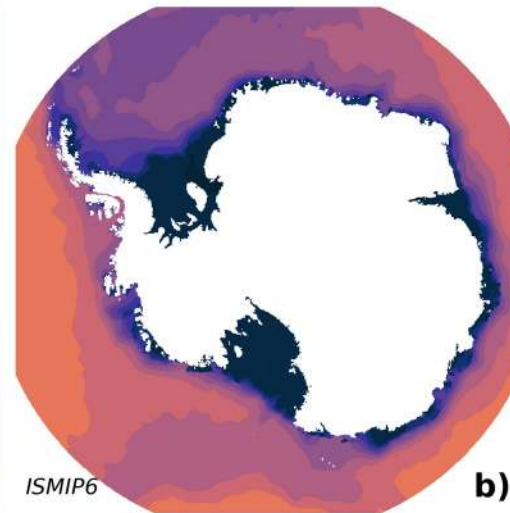
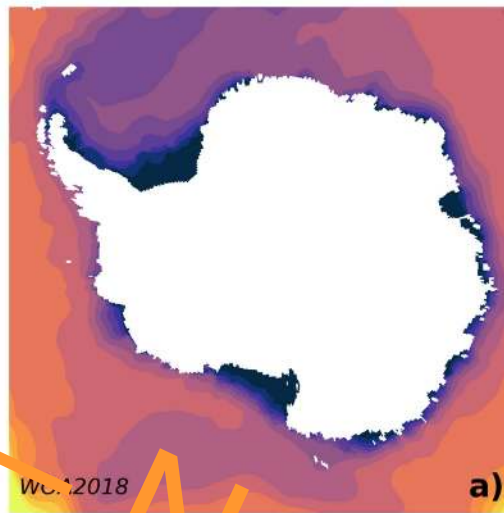
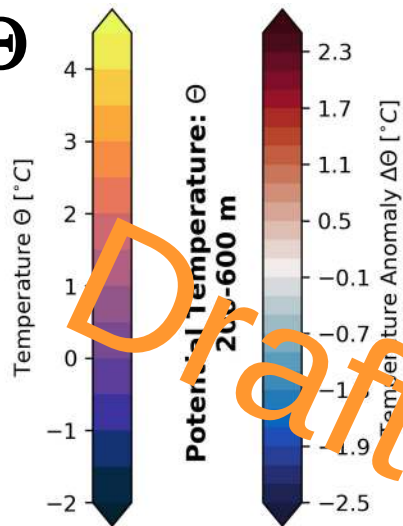
c) Model - RACMO [1060 / 930 Gt year<sup>-1</sup>]

d) Model - HIRHAM [700 / 640 Gt year<sup>-1</sup>]

e)

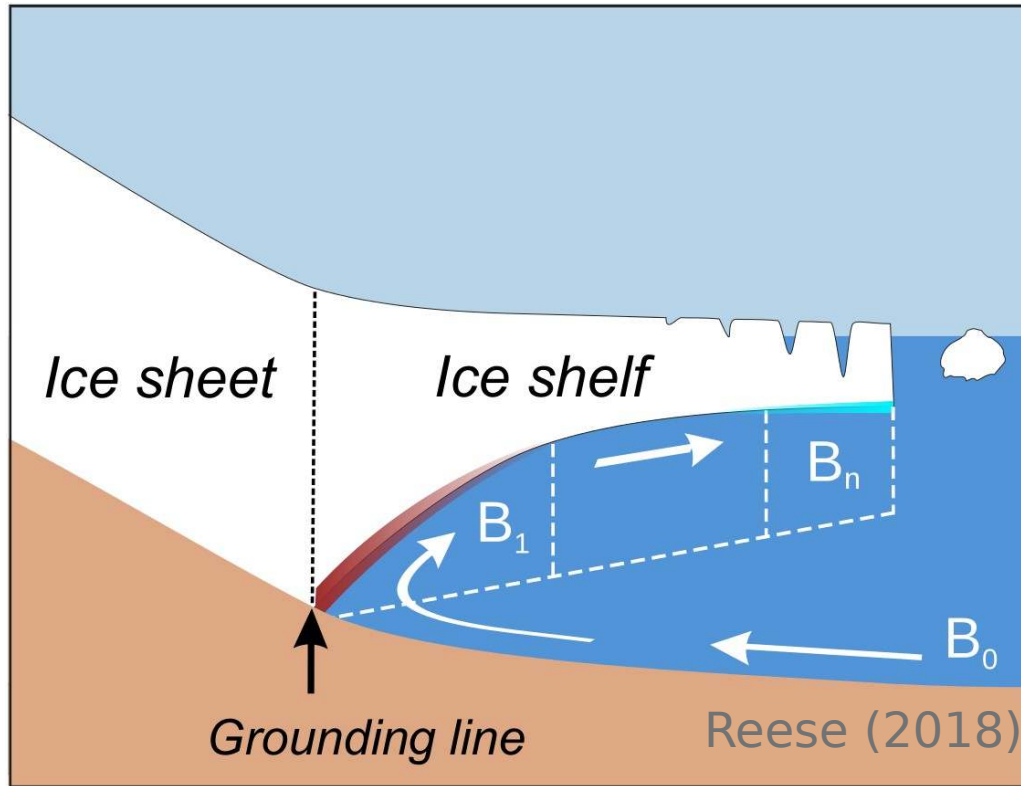
[all ice, only-grounded]

# Ocean $\Theta$

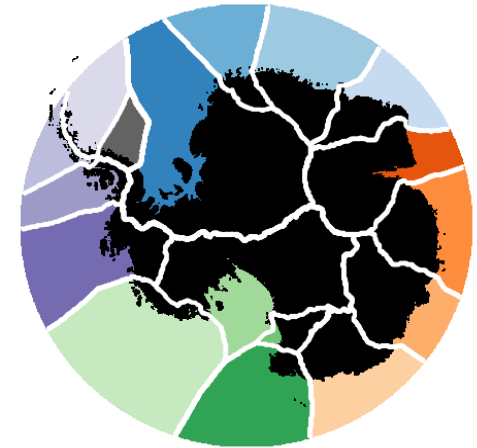


Draft - Not final -

# PICO Model: Basal ice shelf melting



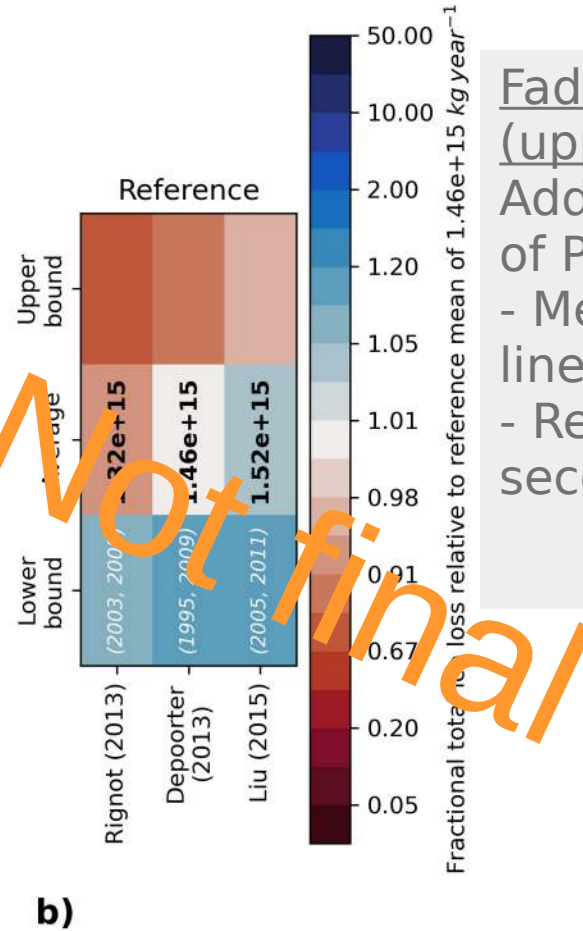
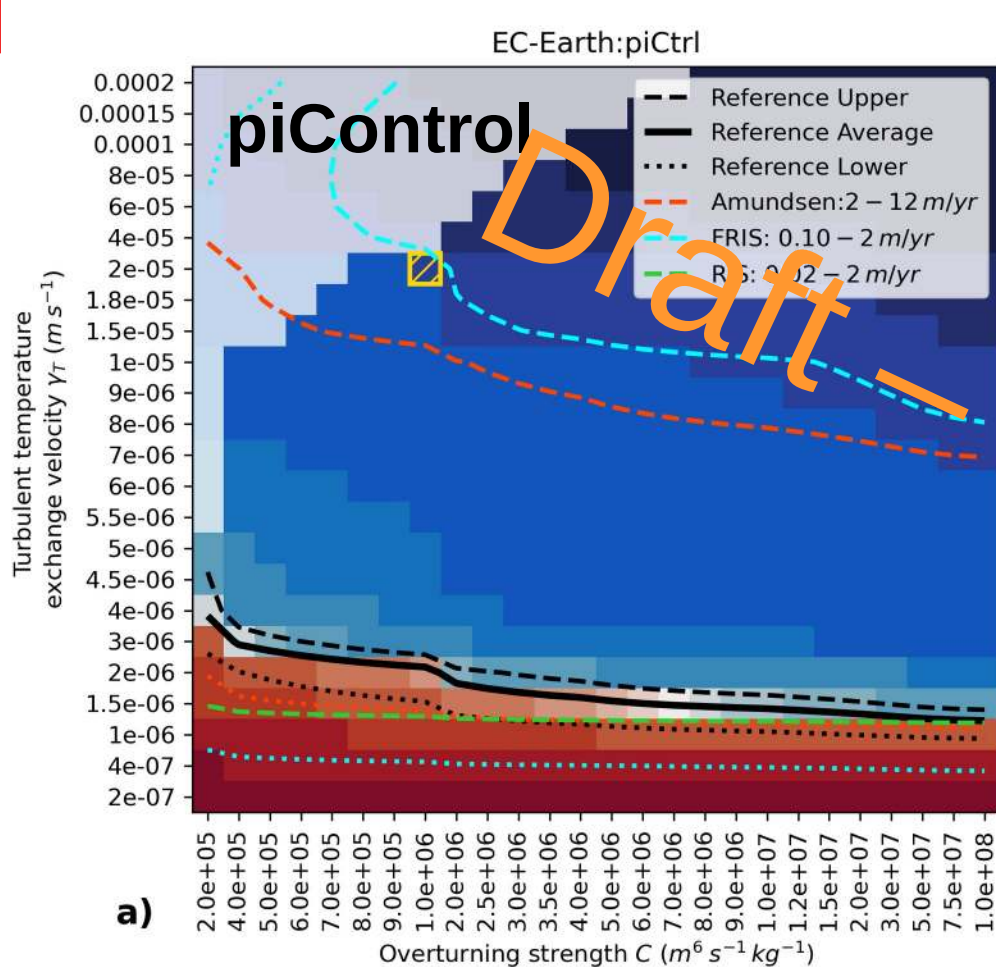
Basins



## Conditions

- Melting (1<sup>st</sup> row)  $> 0$
- Melting (2<sup>nd</sup> row)  $<$  Melting (1<sup>st</sup> row)

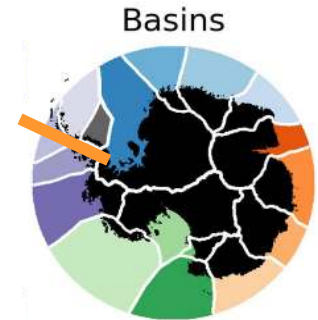
# PICO Parameters



Faded areas  
(upper left)

Additional constrain  
of PICO are violated

- Melting at grounding line
- Reduced melting in second row

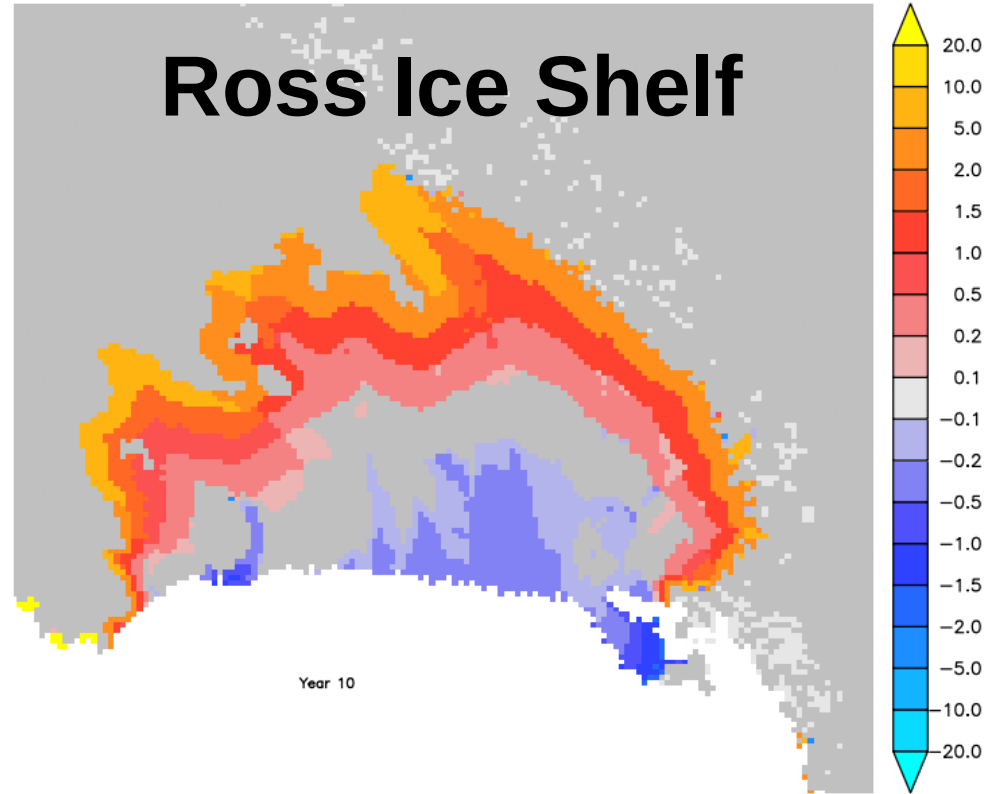
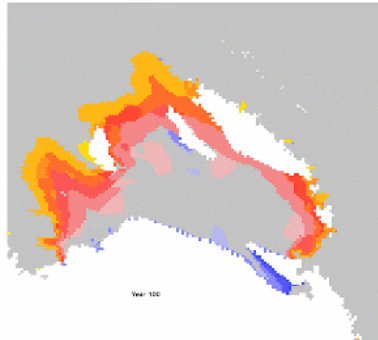
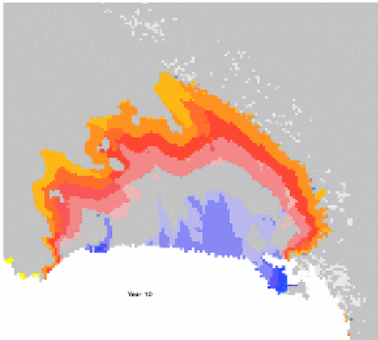


# Give it a try!

## Antarctica Simulation

- Parallel Ice Sheet Model
- Ocean via PICO
- 8 km
- EC-Earth piControl

Light gray ice-free ground  
Gray grounded ice  
Color Ross Ice Shelf:  
Basal Melting Rate (m/yr)



ice basal melt rate from energy conservation and subshelf melt, in ice thickness per time (m year<sup>-1</sup>)



# Diagnostic EC-Earth Antarctica

## 25 Ensemble members

Variation of the **two** parameters describing ocean-driven basal ice shelf melting in PICO

**Ocean forcing**  
EC-Earth piControl

**Model year 3000**

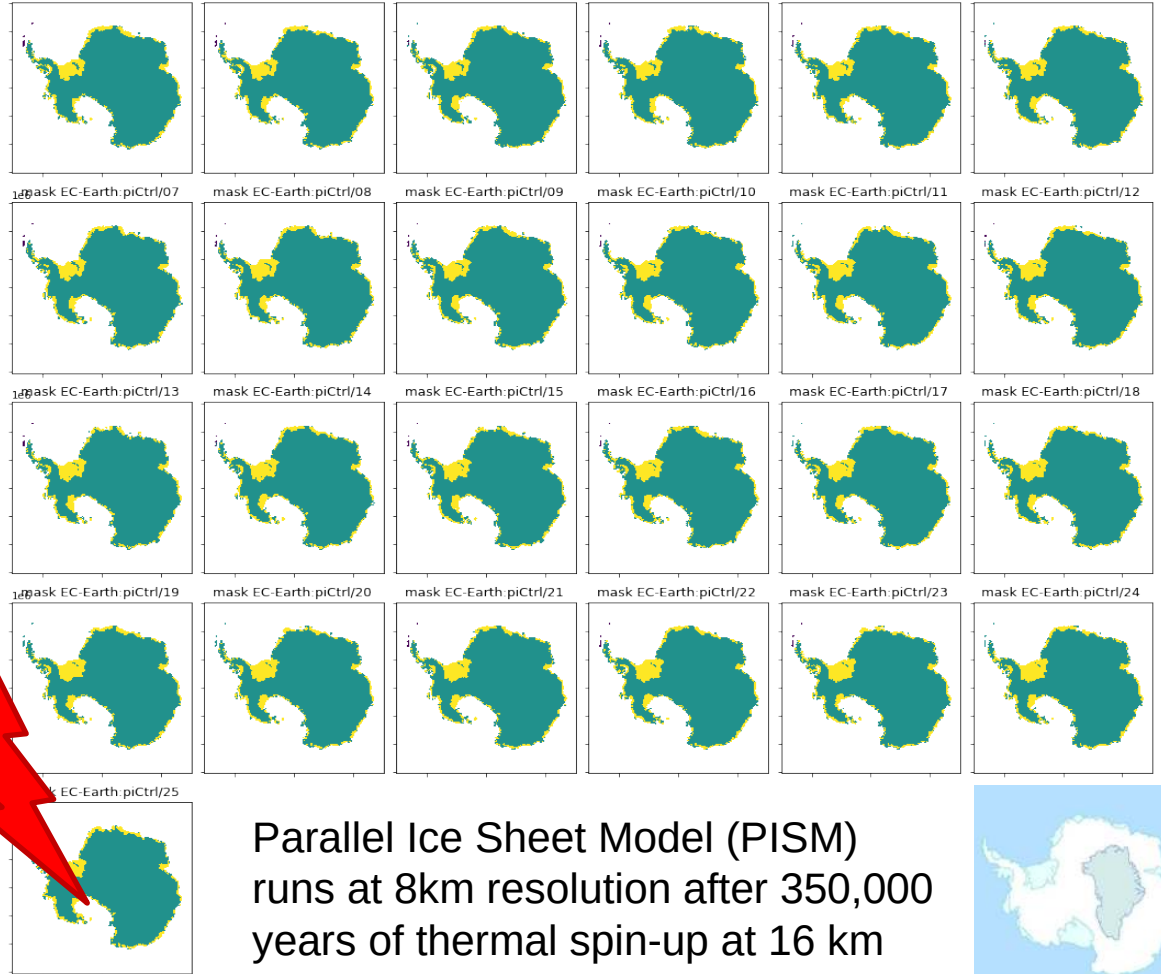
## West Antarctica collapses

Ongoing downward trend. No hope for healing in longer simulations

Ice-free ground

Grounded ice

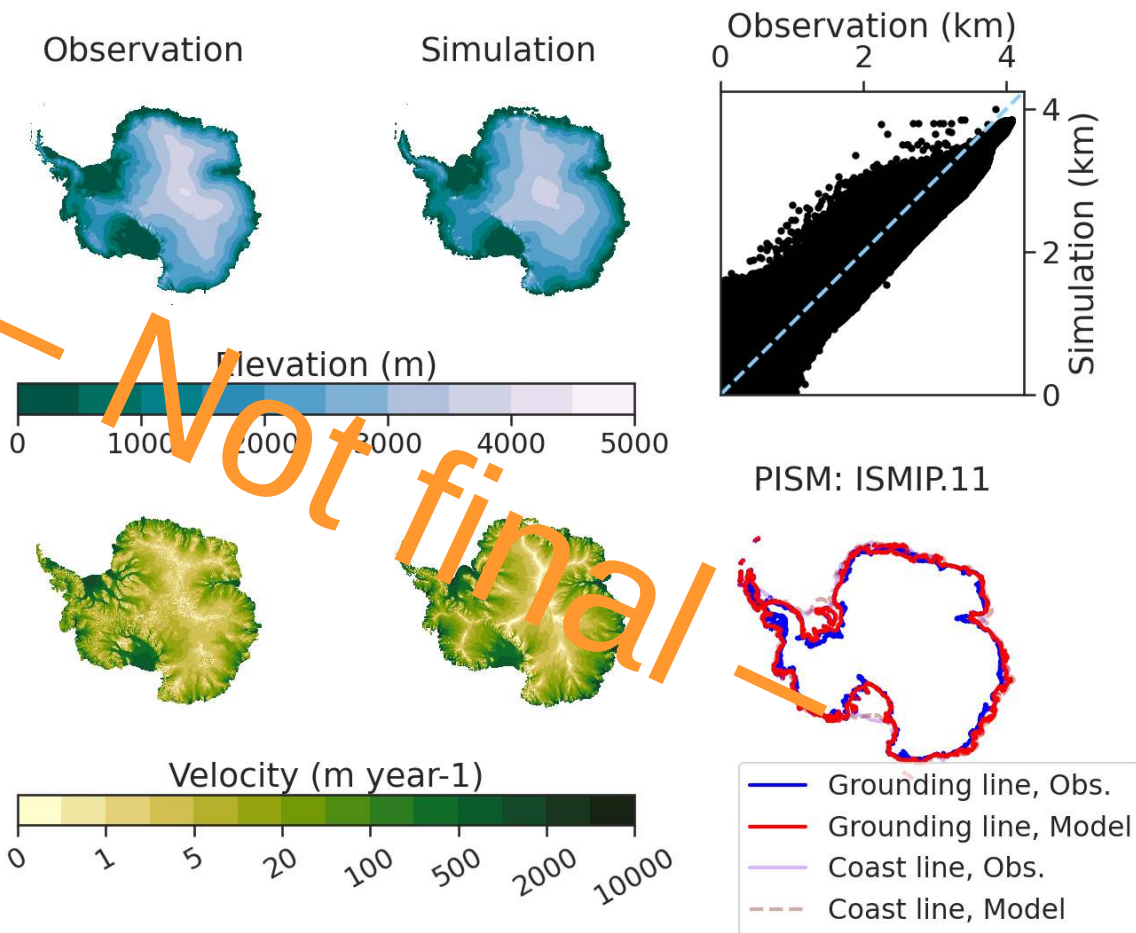
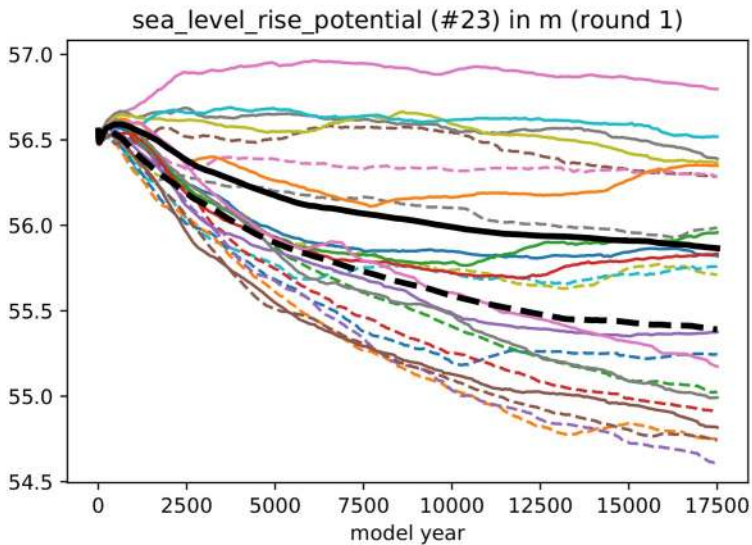
Floating Ice shelf



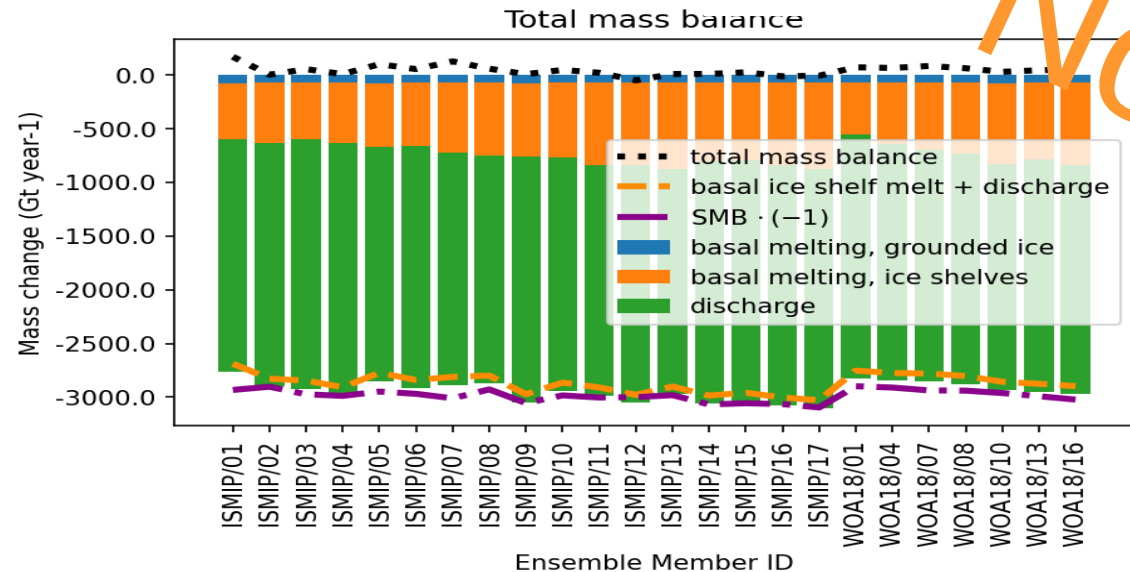
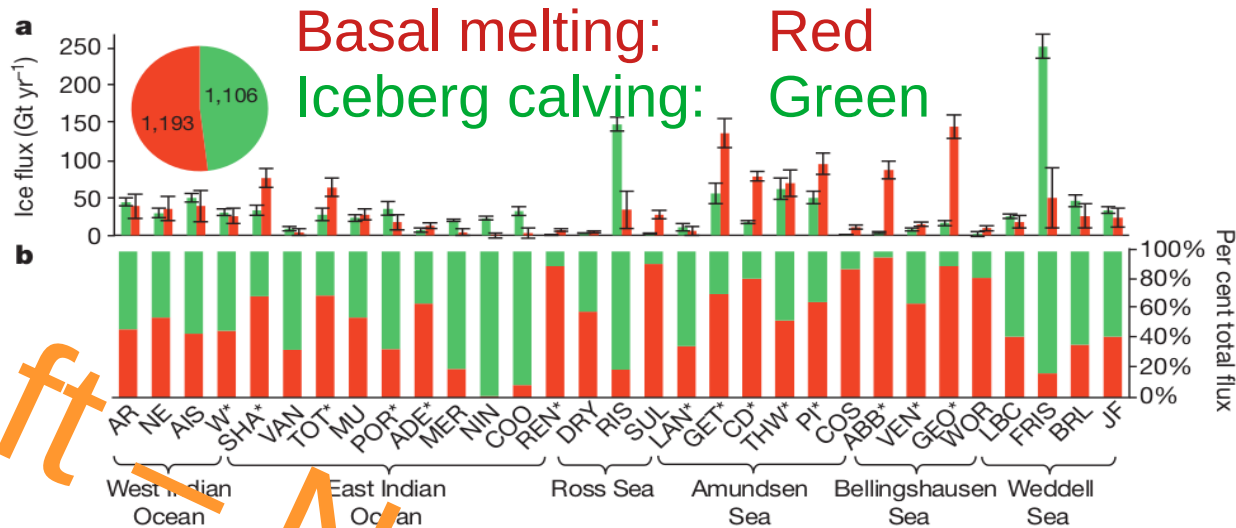
# Diagnostic EC-Earth Antarctica: Anomaly

Reasonable patterns for climatology-driven simulations, e.g., ISMIP or WOA18

Model year 17500  
Calving thickness 75 m  
**Still small drift**

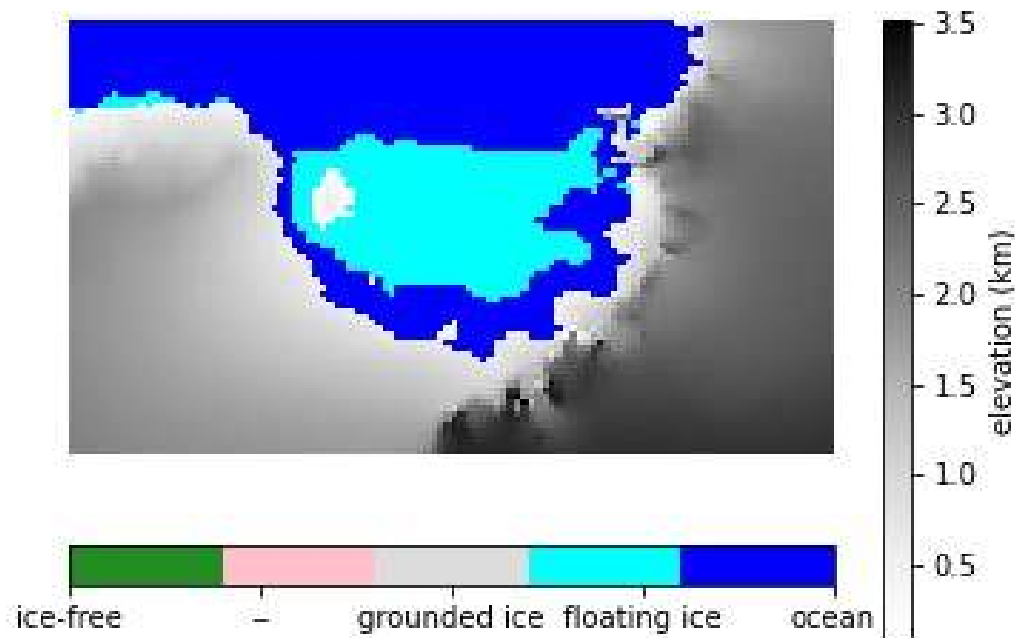


# Partitioning losses



**Simulations**  
Iceberg calving dominates over basal ice shelf melting

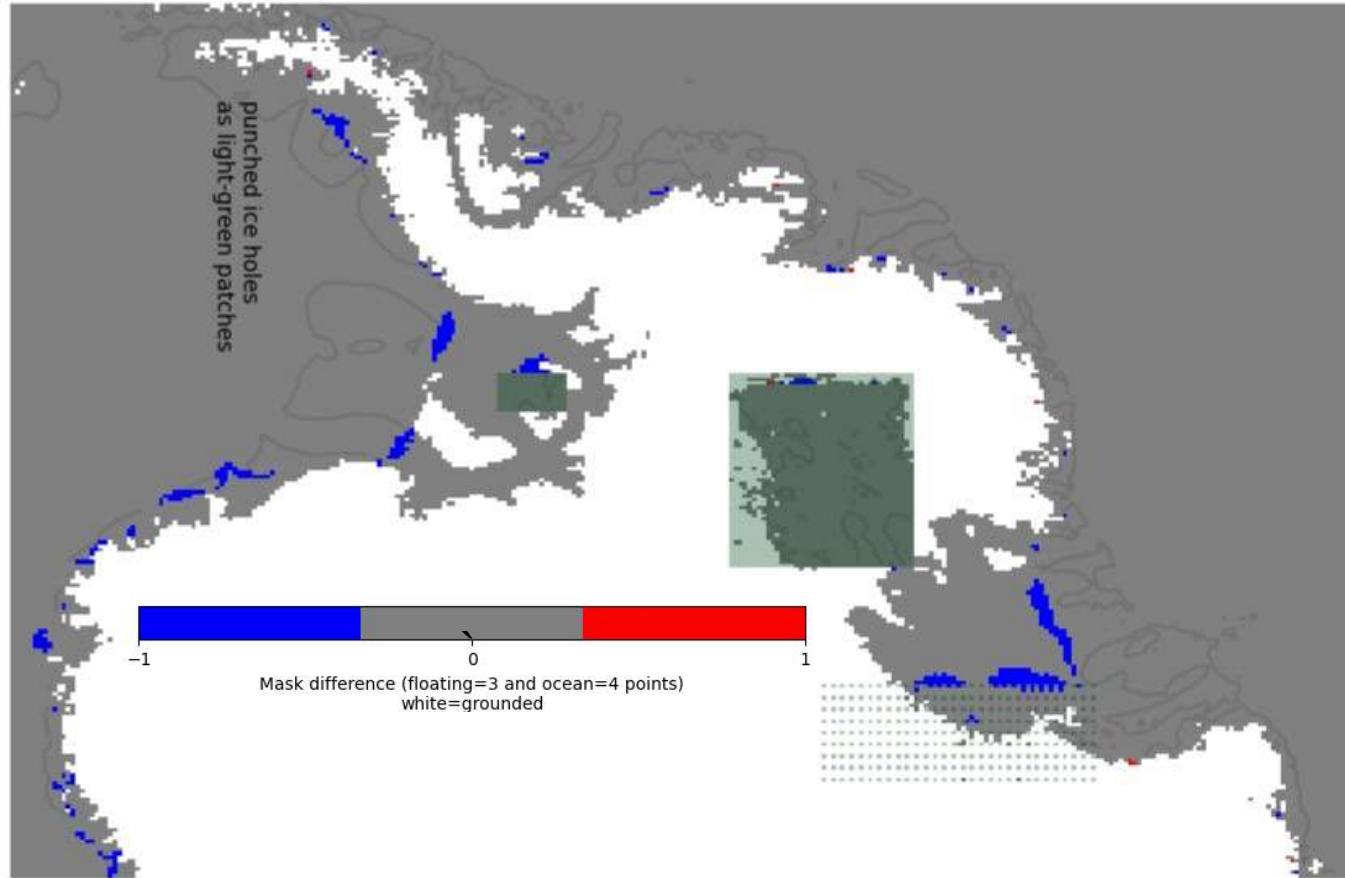
# Run a coupled simulation ... (bahh)



## AWI-ESM + PISM-Antarctica

- Black-hole calving again
- Anomaly (flux correction) coupling
  - Atmosphere
  - Ocean
- Only the island holds the ice shelf patch
- .....

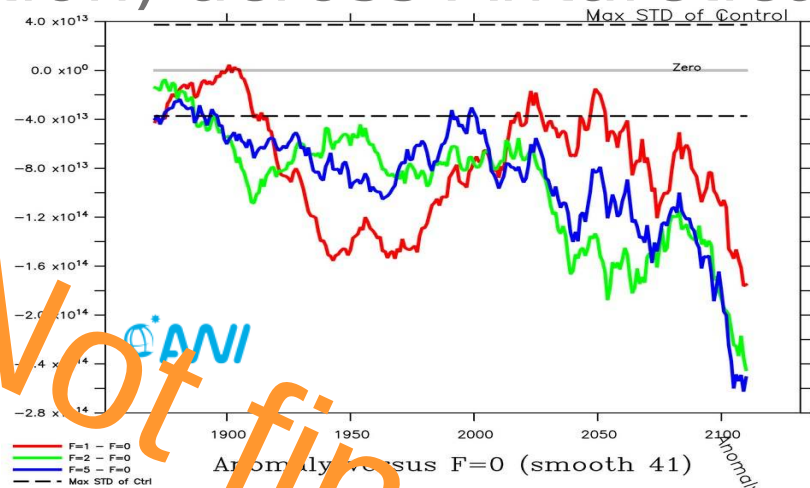
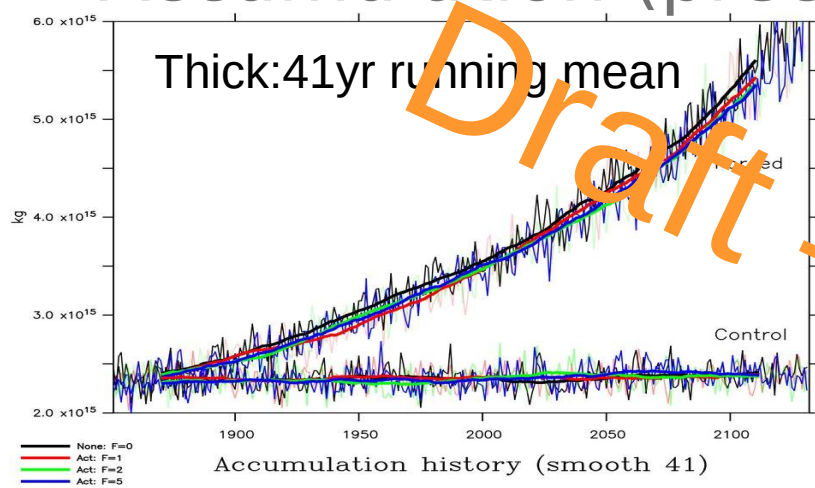
# Suppression of black hole calving



*Hot of the press*

# Cpl. Atm-Oce+ice shelves: ECHAM-FESOM-1.4

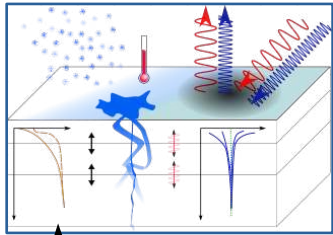
## Accumulation (precipitation) across Antarctica



### Active static ice shelves: Less precipitation across Antarctica under warming?

- 800 years spin-up, Scenarios 1850 - 2129
  - Control run (piControl): pre-industrial climate
  - Forced run (1pct4CO2): 1% CO2 increase until 4-times CO2
  - Basal ice shelf melting rates are multiplied by a factor of **0, 1, 2, 5**.
  - Antarctica's precipitation equals basal melting and coastal fresh water release

# External SMB on-the-fly (FUTURE)



Elevation, precipitation, air temperature, dew point temperature short/longwave radiation (down), Wind velocity, surface pressure, (cloud cover)

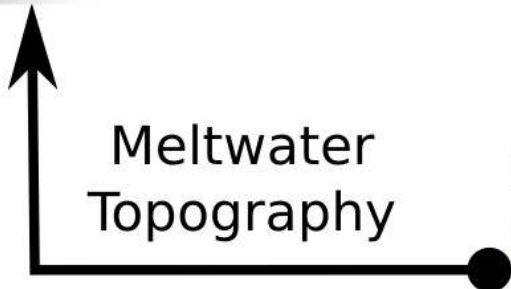
**A**



Atmosphere and Ocean forcing



Meltwater Topography



atmosphere

snowfall

runoff

calving

ocean

ice **B**

**PISM**  
PARALLEL ICE SHEET MODEL

*Running prototype*

## Script-based coupling

**A)** EC-Earth-[OASIS]-CISSEMBEL

**B)** Icesheet model

## CISSEMBEL

Runs on the finer PISM grid

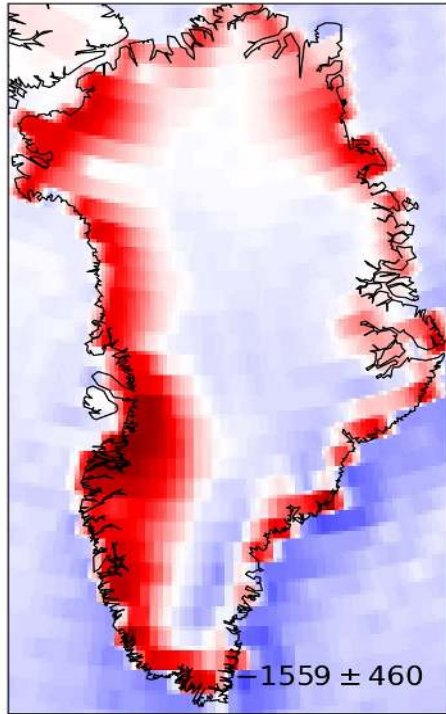
Modells narrow ablation zones

One-way: Forcing for PISM

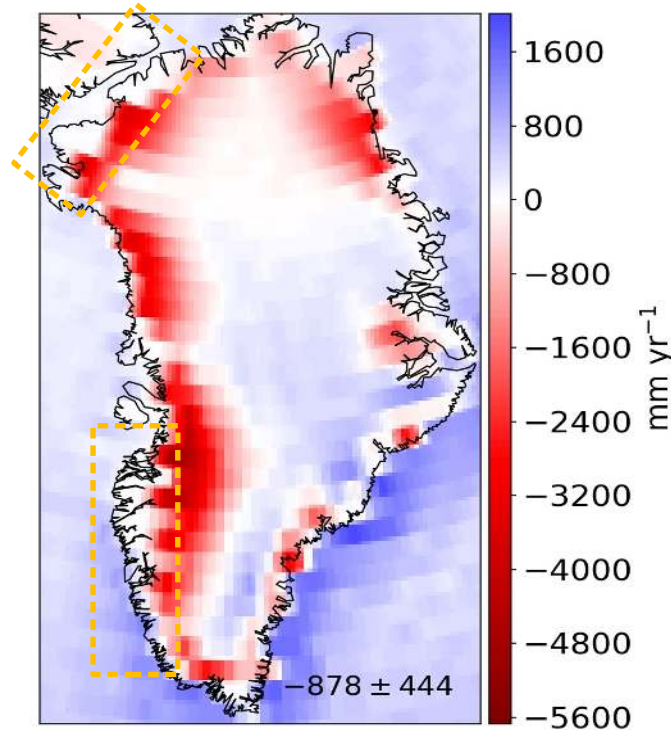
Two-way: Plus Feedback to \*IFS

# Improved Greenland

EC-Earth - PISM



EC-Earth-  
CISSEMBEL-PISM



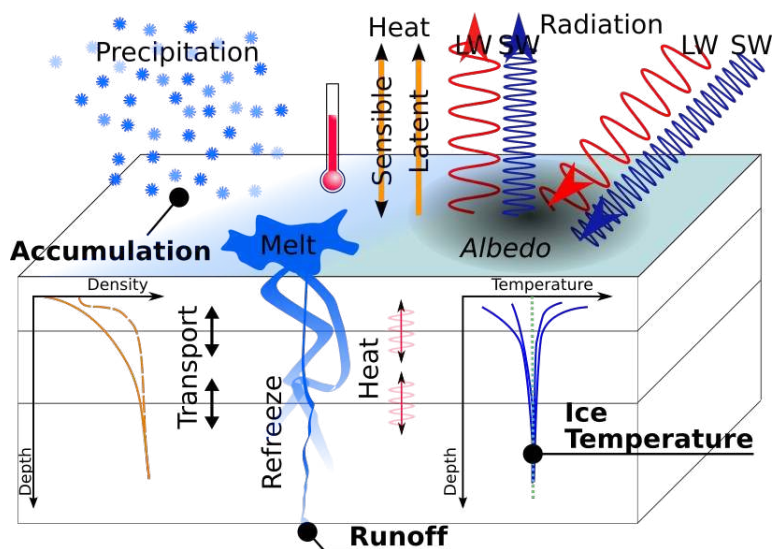
**Coupled  
EC-Earth+CISSEMBEL -  
Ice Sheet Model PISM**

Prototype: one-way coupling from atmosphere (*IFS*) to the surface mass balance model *CISSEMBEL* via *OASIS*.

*CISSEMBEL* resolves narrow ablation zones, represent better snow processes, and downscale atmospheric forcing.



# Conclusion



## CISSEMBEL

Copenhagen Ice Snow Surface  
Energy and Mass Balance model

- Spin-up is only the first step
- Too thin ice shelves deemed to be acceptable
- Much more calving than basal melting
- Biases in climate model: Anomaly coupling
- Calving and its details can be challenging
- Dedicated SMB model as a coming feature