Modelling marine interactions and dynamic ice loss in Antarctica

PhD Student: Antonio Juárez Martínez

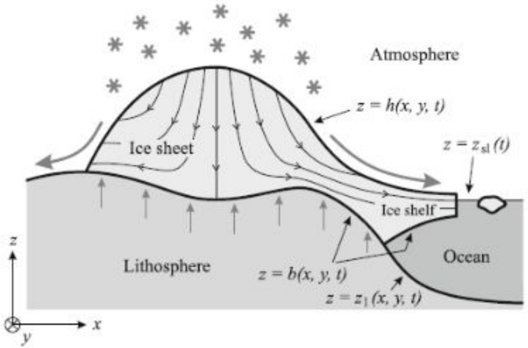
Supervisors: Marisa Montoya, Jorge Álvarez Solas and Alexander Robinson

Facultad de Ciencias Físicas. Jornadas de doctorandos 2022/2023.

Outline | Ice sheet modeling

Transantarctic Mountains at the edge of the Ross Ice Shelf. From: Bell and Seroussi (2020).

- Ice sheets ⇒ key role regulating the climate of the planet.
- Examples: effect on the ocean circulation through the storage and release of freshwater and high albedo.
- Conservation of mass (1), momentum (2) and energy (3), (Greve and Blatter, 2009).
- Model **Yelmo** (https://github.com/palma-ice/yelmo) ⇒ thermomechanical ice-sheet-shelf model written in Fortran. Robinson et al (2020).



Geometry of an ice-sheet. From: Greve and Blatter (2009).

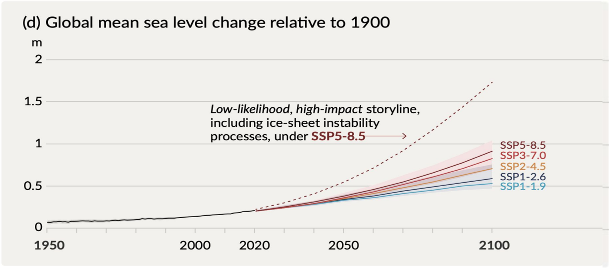
$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0 \quad (1)$$

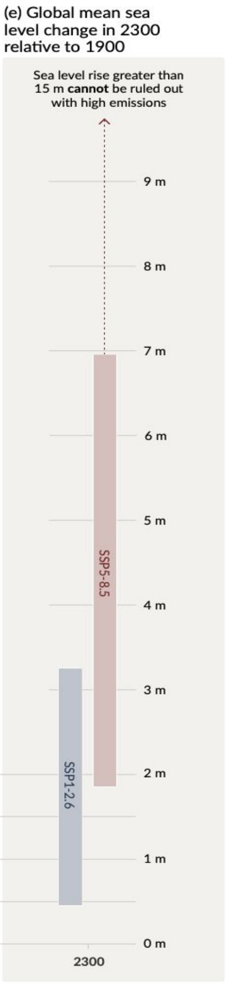
$$\rho \frac{d\mathbf{u}}{dt} = \mathbf{F} + \nabla \cdot \tau \quad (2)$$

$$\rho c_p \left(\frac{\partial T}{\partial t} + \mathbf{u} \cdot \nabla T \right) = Q_c + Q_d \quad (3)$$

Summary | Research

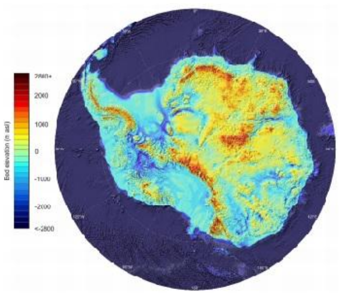
- Explore the future **evolution of Antarctica** and its associated **uncertainty** with the ice-sheet model **Yelmo**. Robinson et al (2020).
- Consider two periods: **2100** (comparison with ISMIP6; Seroussi et al, 2020) and **2500** (an extension). Starting from 2015.
- Now, ensemble simulations with new forcings until **2300.**
- Other physical processes producing uncertainty.
- Implementation of a submodule for **hydrology** in Yelmo. Brief introduction to the model and importance related to **dynamics**.



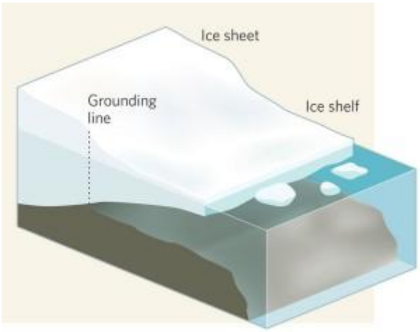


IPCC, AR6 (2021)

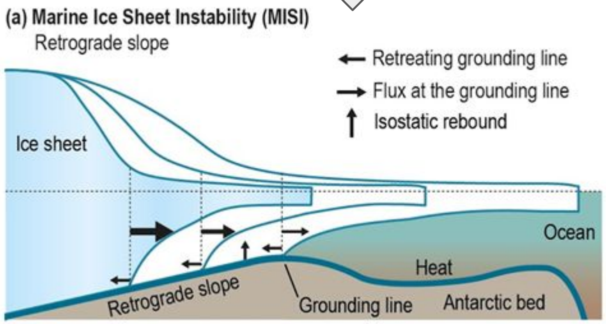
Motivation | Sea level contribution



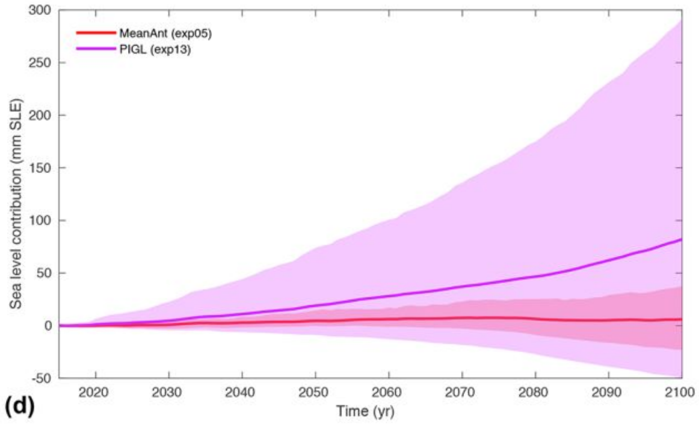
Bedrock elevation.
Fretwell et al. (2013)



Huybrechts 2009

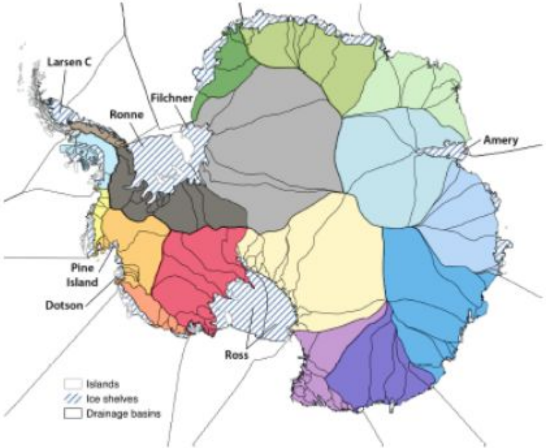


Meredith et al. (2019)



Sea level contribution and simulation spreads from Seroussi et al (2020).

Methodology | Basal melting



Basal melt parametrization

$$B_f(x,y) = \gamma_0 \times \left(\frac{\rho_{sw} c_{pw}}{\rho_i L_f}\right)^2 \times (\mathrm{TF}(x,y,z_{\mathrm{draft}}) + \delta T_{\mathrm{sector}}) \times |\langle \mathrm{TF} \rangle_{\mathrm{draft} \in \mathrm{sector}} + \delta T_{\mathrm{sector}}|$$

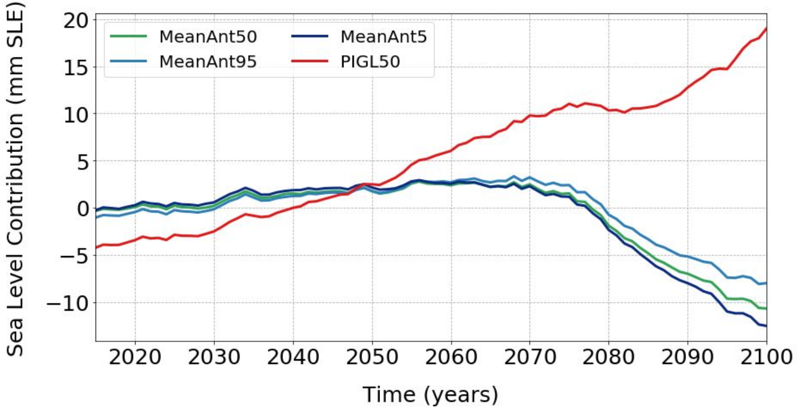
Jourdain et al (2020)

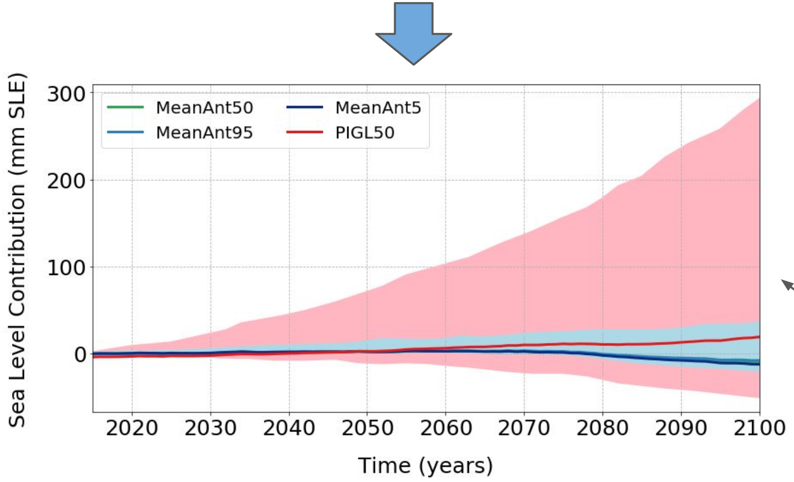
Experiments

Calibration method	Forcing	γ_0 (m/yr)
MeanAnt Medium	ctrl	14500
MeanAnt Medium	NorESM1-M (RCP8.5)	14500
MeanAnt High	NorESM1-M (RCP8.5)	21000
MeanAnt Low	NorESM1-M (RCP8.5)	9620
PIGL	NorESM1-M (RCP8.5)	159000

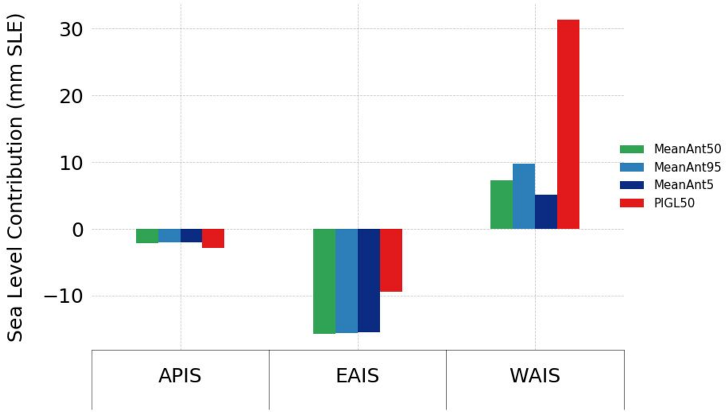
- MeanAnt (**Mean Ant**arctic observations)
- PIGL (**P**ine **I**sland **GL**acier observations)

Results | Evolution until 2100



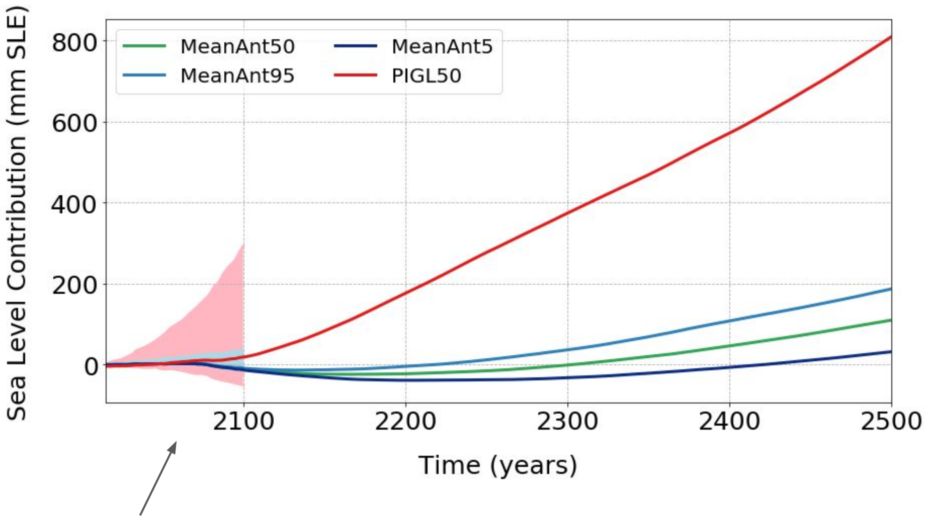


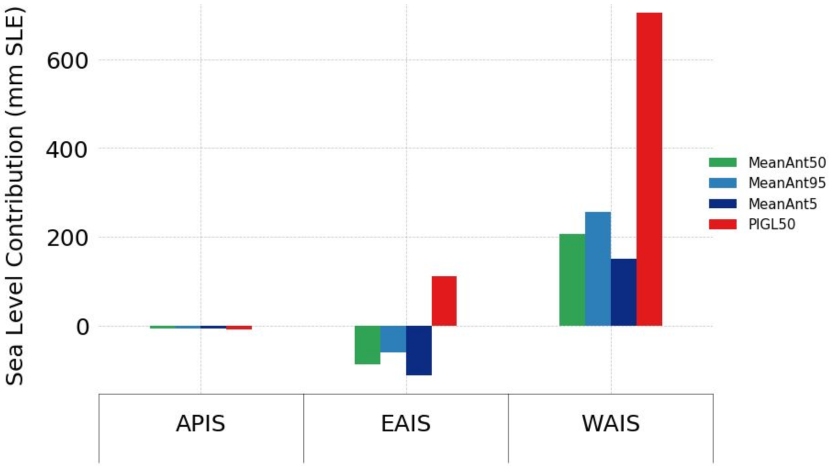
Shaded regions from Seroussi et al (2020)



The WAIS is the main contributor to sea level rise

Results | Evolution until 2500 (I)

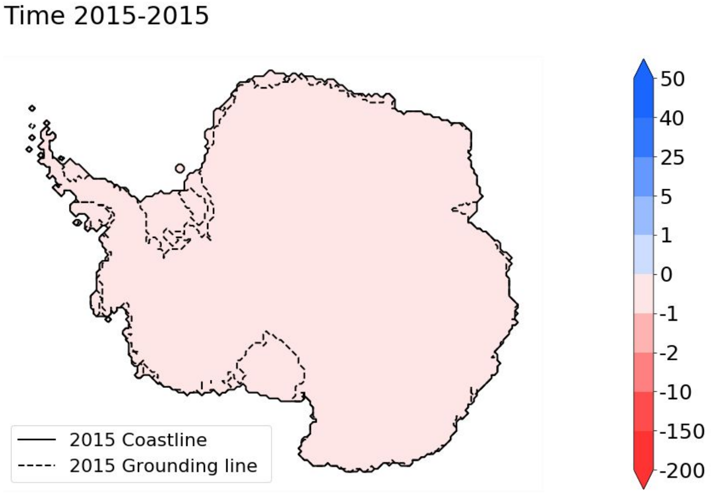




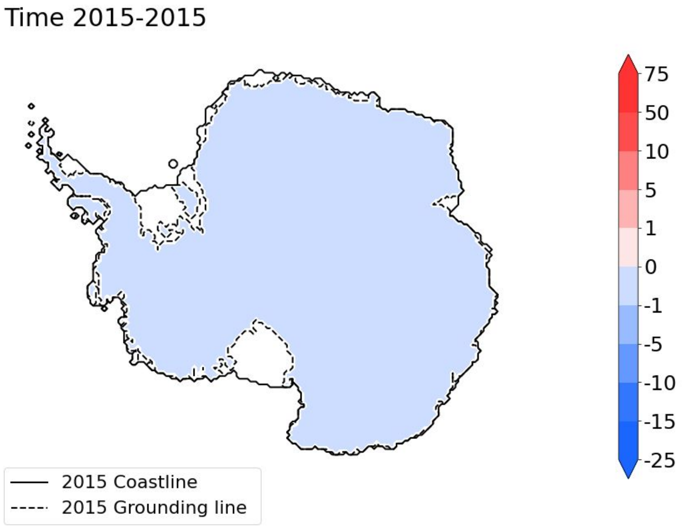
Shaded regions from
Seroussi et al (2020)

Results | Evolution until 2500 (II) with PIGL

<u>Ice Thickness Anomalies (m)</u>

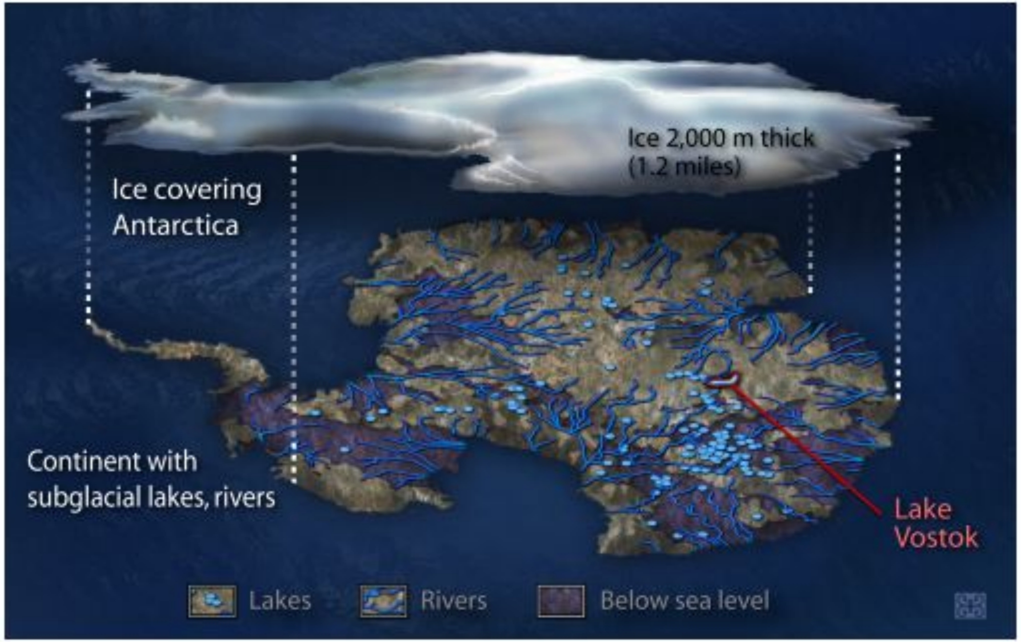


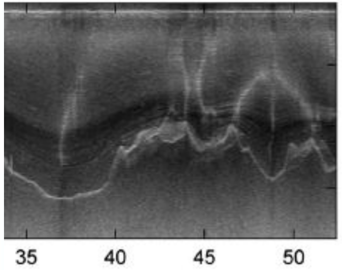
<u>Surface Velocity Anomalies (m/yr)</u>



Other physical processes | Subglacial hydrology

The ’Labyrinth’ in the Dry Valleys (East
Bingham (2014).



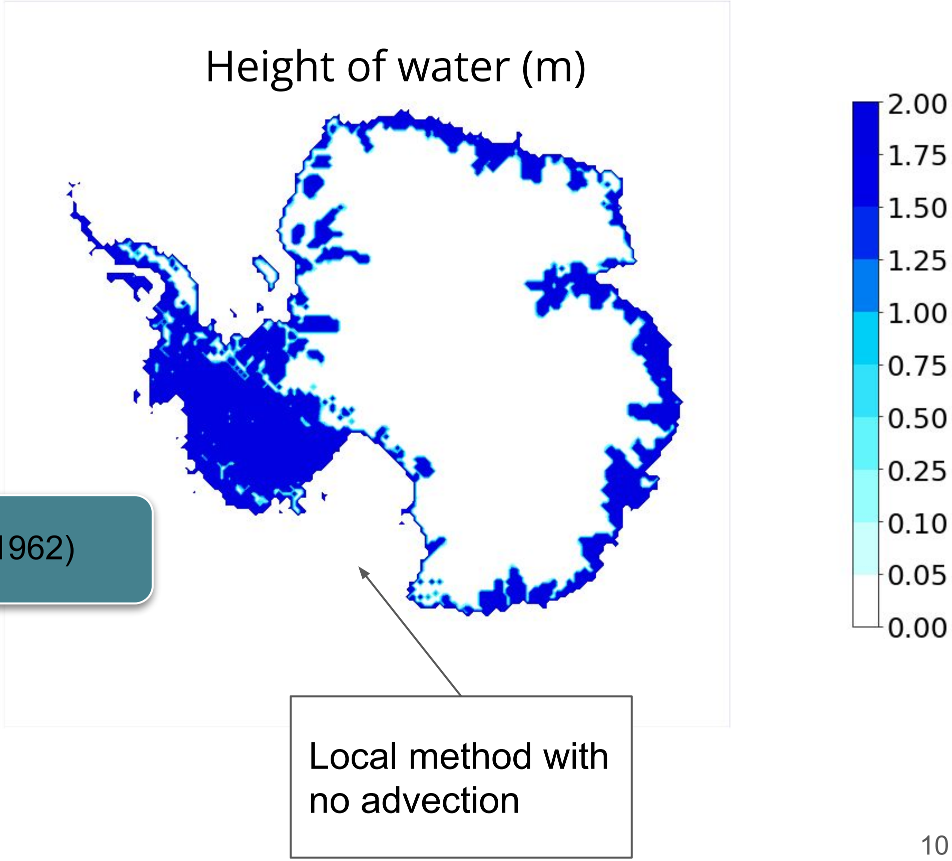


and Bingham (2014).

Other physical processes | Subglacial hydrology

- ❖ From the physics, water could evolve.
- ❖ This evolution could affect ice-sheet dynamics.

How a water layer at the base impacts sliding? (Weertman,1962)



Construction of the model

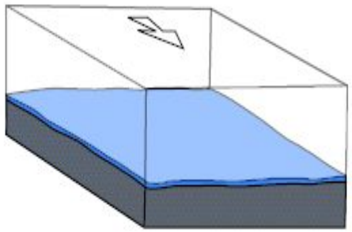
Physical principles:

1. Water is conserved.

2. Water flows from high to low values in a hydraulic potential:

    a. Pressure

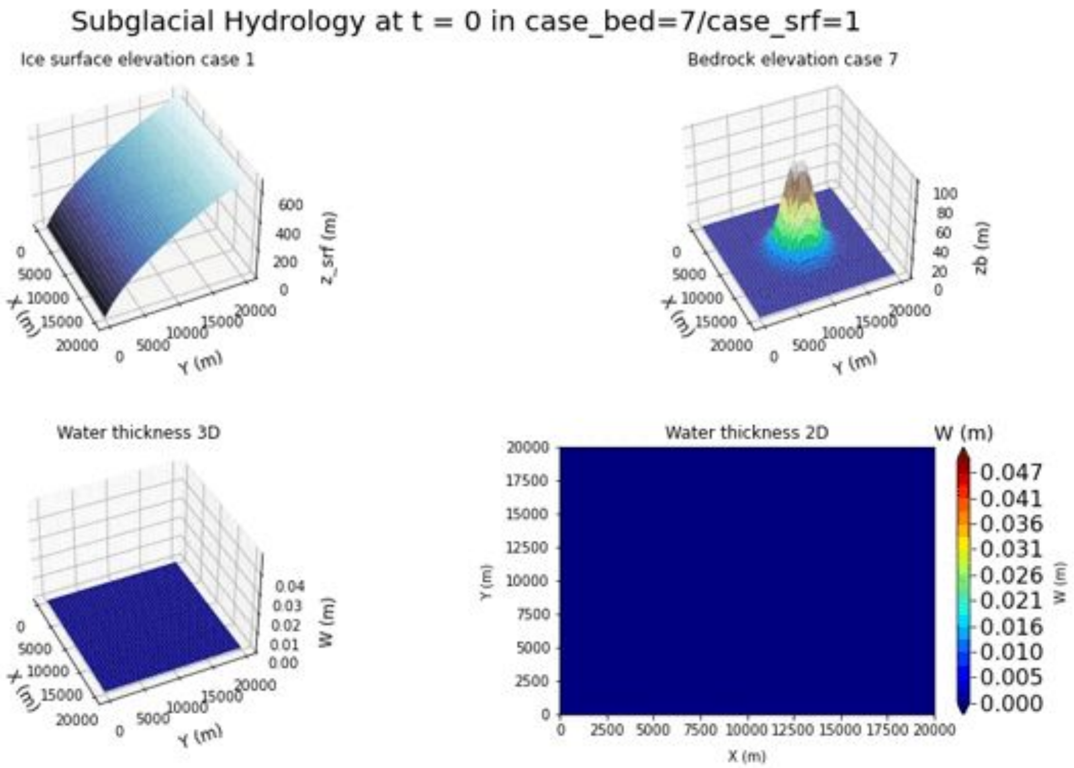
    b. Elevation



Hewitt notes (Karthaus)

Two state variables: W (height of water) and P (pressure of the water)

Results | First test



Conclusions

- ❖ Strong dependency in the calibration of basal melting → uncertainty
- ❖ In the range of the results achieved by Seroussi et al (2020) for ISMIP6.
- ❖ In 2100, sea level rise between -12.5 mm and 19 mm. In 2500, sea level could surpass 80 cm.
- ❖ WAIS the main contributor. EAIS counterbalance effect.
- ❖ Simulations with new forcings and other GCM models until 2300.
- ❖ Subglacial hydrology is important in relation with basal sliding and dynamics.
- ❖ When fully implemented in Yelmo, we will try to assess these effects on Antarctica.


Thank you!!