

Transient Modeling of Borehole Temperature and Basal Melting in an Ice Sheet

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Goals

Develop an ice age model in Antarctica.

Use the model to find a site in Antarctica which would be ideal to find 1.5 Myr old ice.



<http://earthobservatory.nasa.gov>

Old ice - Motivation

- Old ice retrieval 1
- Model details
- Tests
- Corrections
- Old ice retrieval 2

Past environmental conditions and direct information on atmospheric composition.

Recover an 1.5 Myr old ice core would allow us :

- To extend our knowledge of past climate
- To understand ice sheet dynamics and anticipate climate changes



<http://www.npolar.no>

Dome Concordia Station

- Old ice retrieval 1
- Model details
- Tests
- Corrections
- Old ice retrieval 2

Oldest ice core existing :
800'000 yr

Google Earth



www.asoc.org

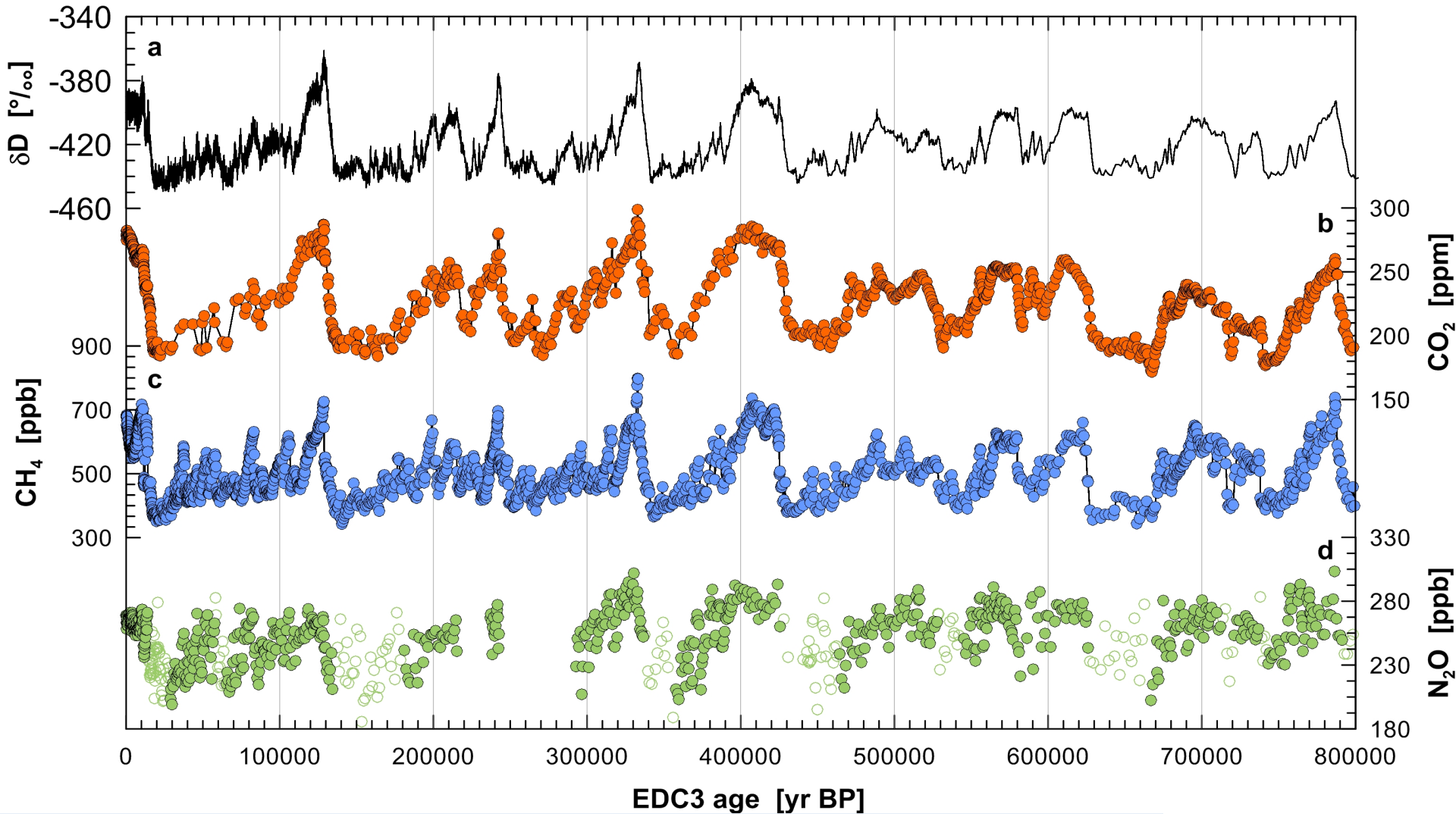


Dome C ice core

- Old ice retrieval 1
- Model details
- Tests
- Corrections
- Old ice retrieval 2

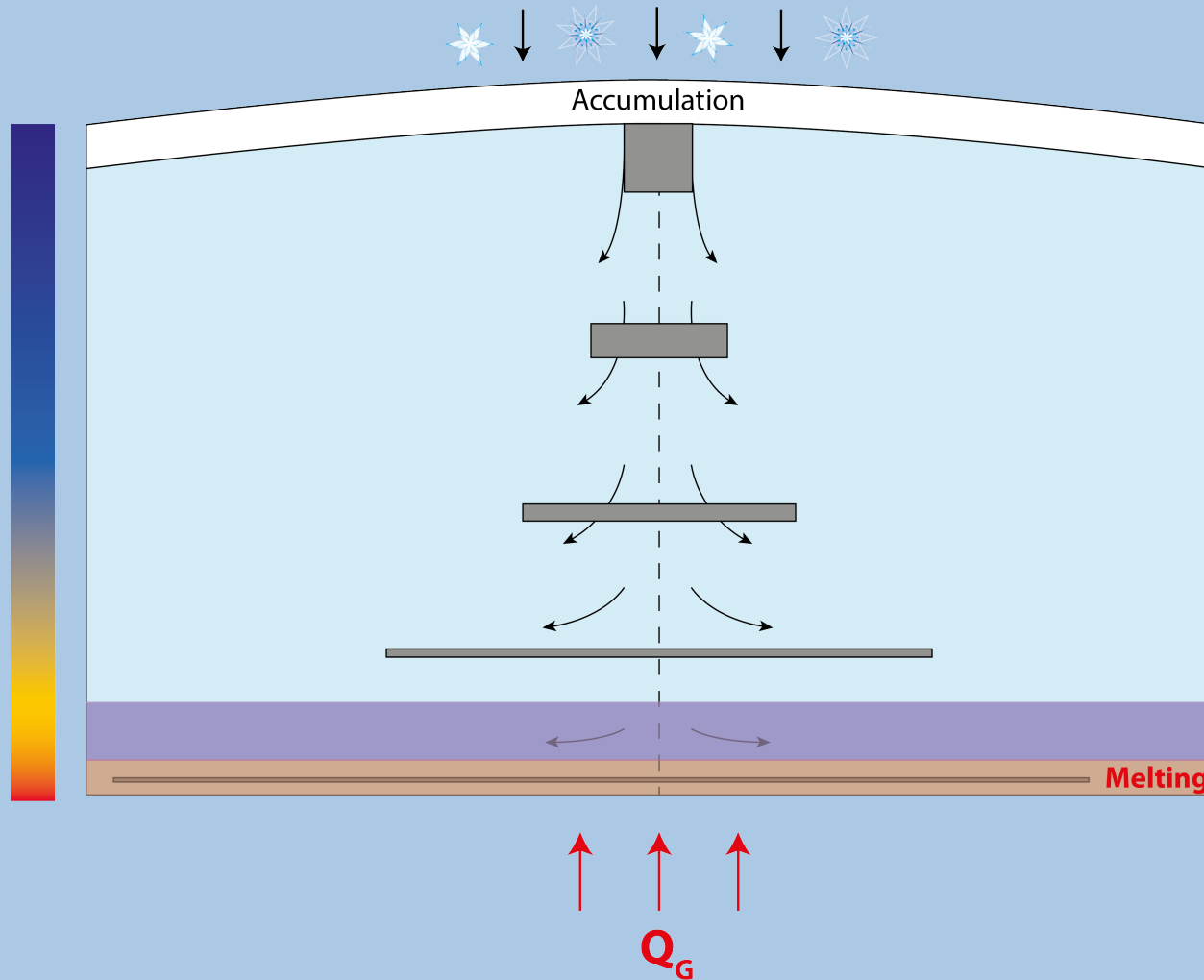
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Oldest ice - Requirements

- Old ice retrieval 1
- **Model details**
- Tests
- Corrections
- Old ice retrieval 2



- Old ice retrieval 1
- **Model details**
- Tests
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- Old ice retrieval 2

Model development

Requirements (physical-mathematical):

- Describe the snow and ice density
- Describe mechanical properties (ice compaction)
- Describe the heat diffusion
- Describe the basal melting
- Compute the age of the ice

$$\frac{\partial T(z, t)}{\partial t} = \frac{K(z, t)}{\rho(z, t)c(z, t)} \frac{\partial^2 T(z, t)}{\partial z^2} - w(z, t) \frac{\partial T(z, t)}{\partial z} + \frac{1}{\rho(z, t)c(z, t)} \frac{\partial K(z, t)}{\partial z} \frac{\partial T(z, t)}{\partial z} + \frac{\dot{E}_I(z, t)}{\rho(z, t)c(z, t)}$$

→ Develop a program solving all the equations

Boundary conditions

- Old ice retrieval 1
- **Model details**
- Tests
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- Old ice retrieval 2

Boundary conditions :

- Surface temperature
- Accumulation rate
- Ice thickness
- Ground heat flux

From today to 800'000 yr before present:

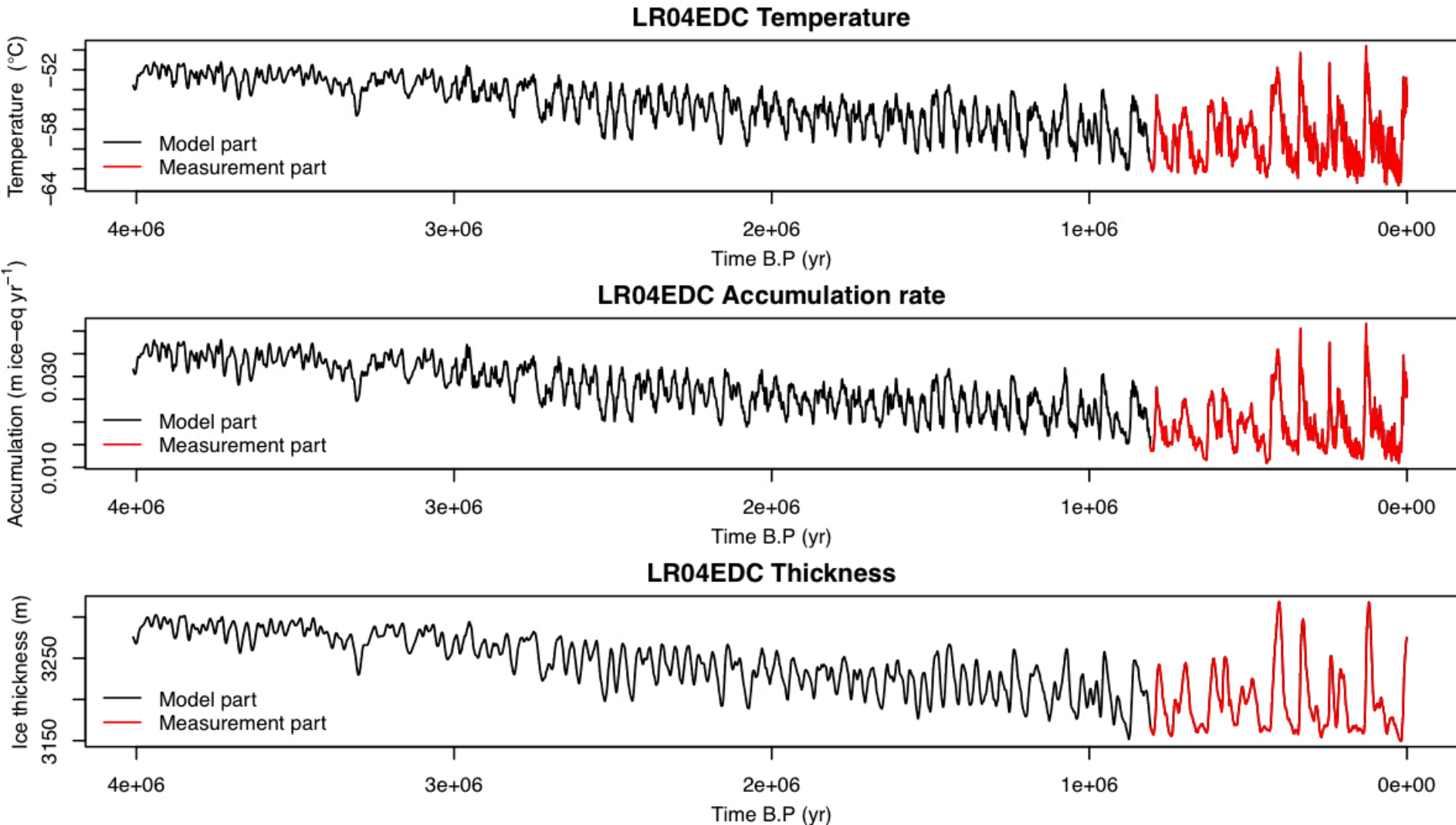
- Dome C time series

From 800'000 yr to 4Myr before present:

- Lisiecki and Raymo, 2005 $\delta^{18}\text{O}$ parameterization

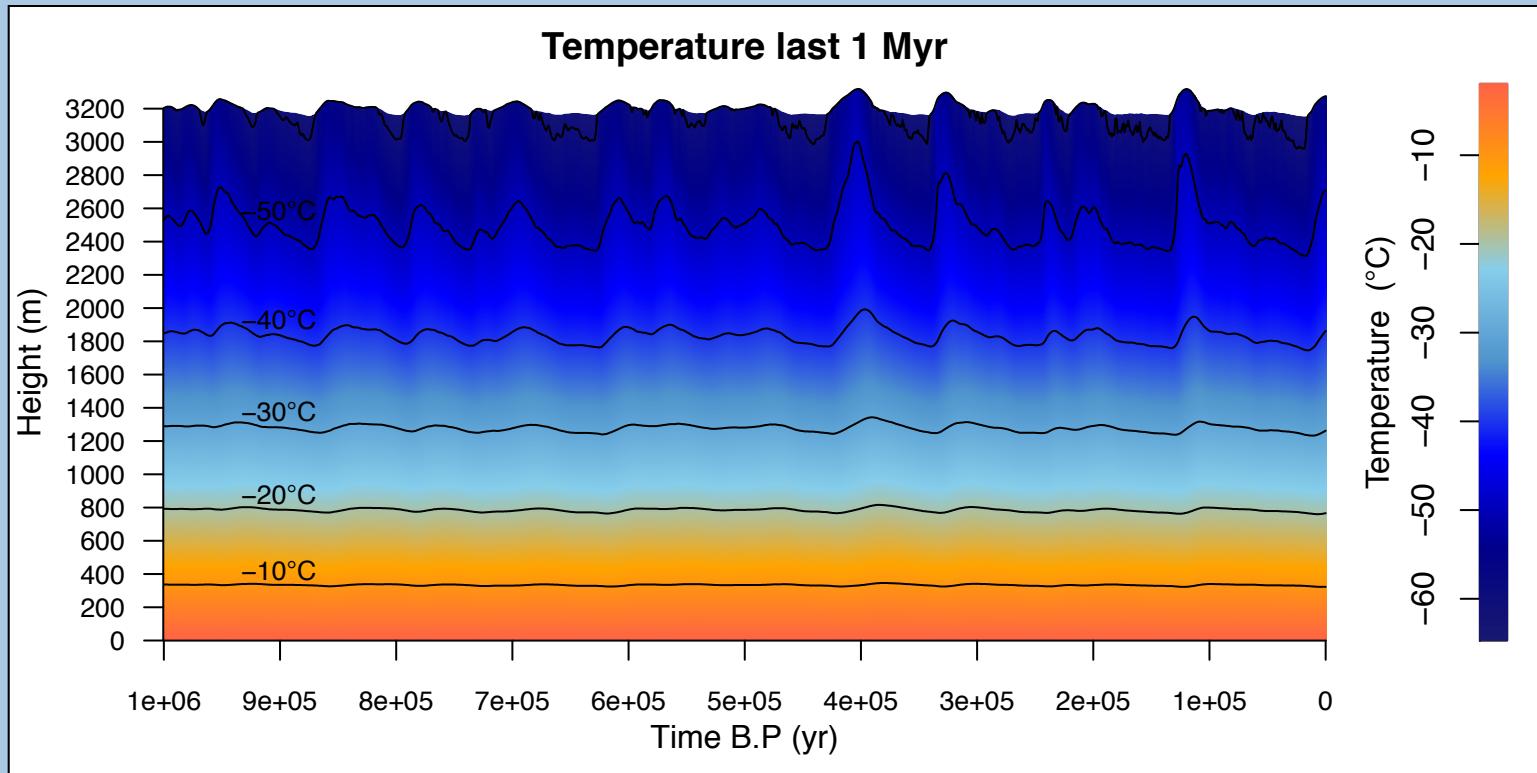
Boundary conditions

- Old ice retrieval 1
- Model details
- Tests
- Corrections
- Old ice retrieval 2



Model output

- Old ice retrieval 1
- Model details
- Tests
- Corrections
- Old ice retrieval 2

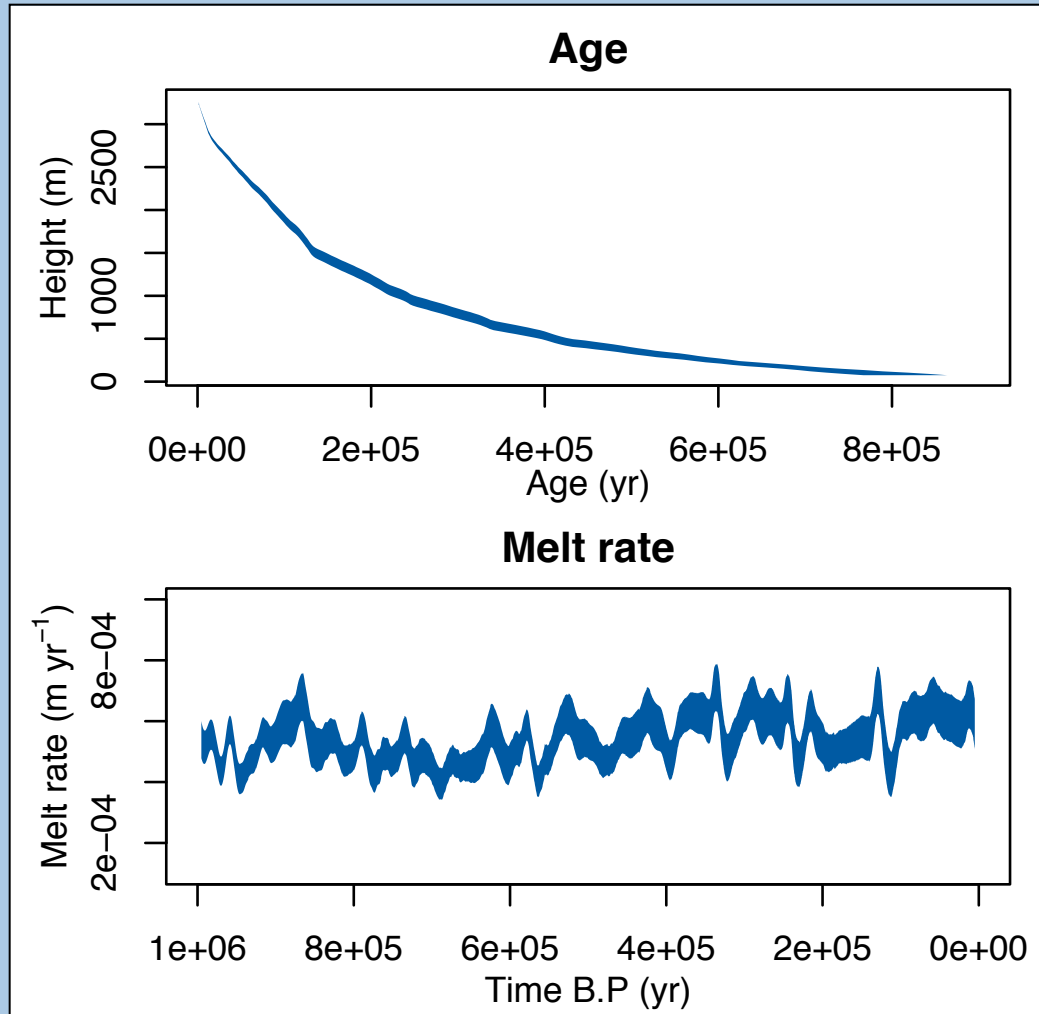


Model output

- Old ice retrieval 1
- **Model details**
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- Corrections
- Old ice retrieval 2

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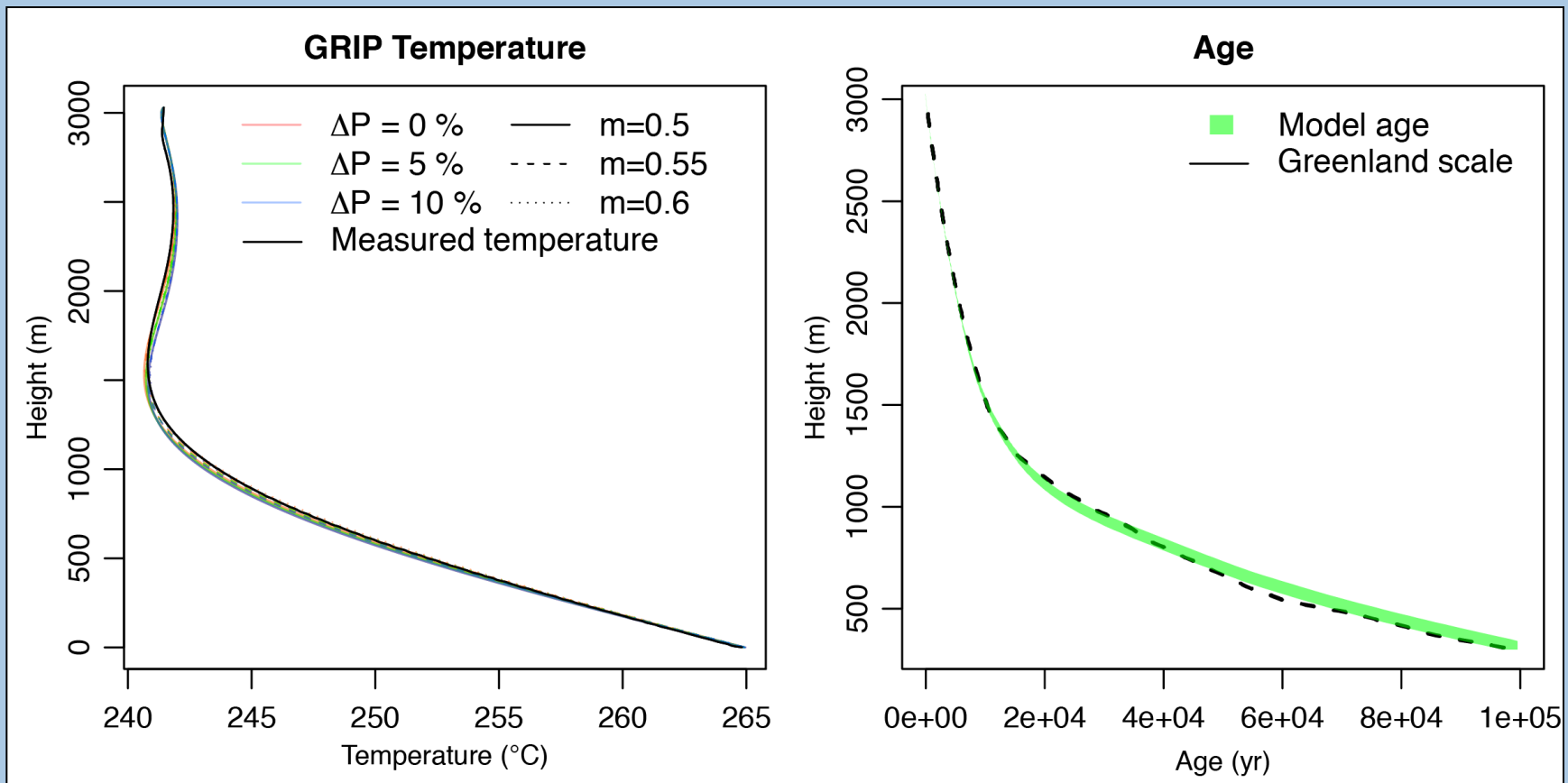
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Tests of the model

- Old ice retrieval 1
- Model details
- Tests
- Corrections
- Old ice retrieval 2

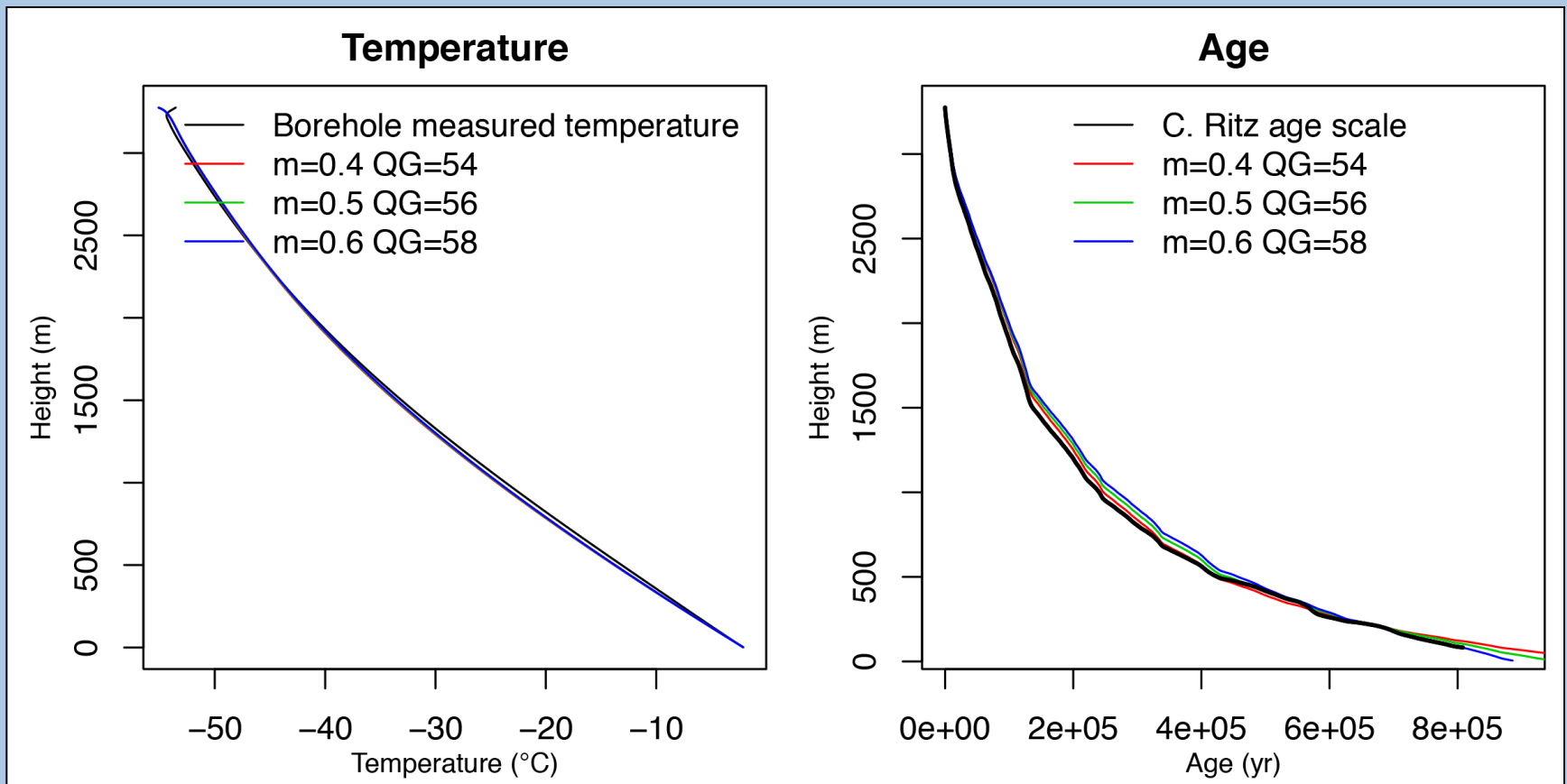
Greenland



Tests of the model

- Old ice retrieval 1
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- Old ice retrieval 2

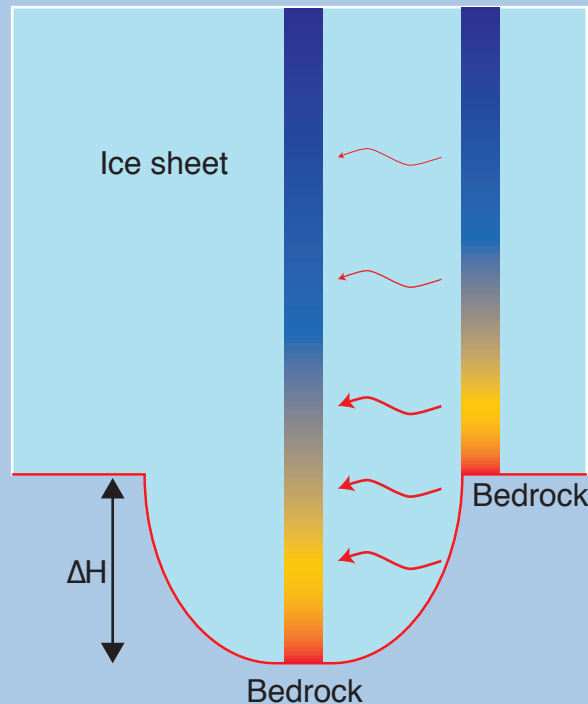
Antarctica



Correction of the model

- Old ice retrieval 1
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- Old ice retrieval 2

Topography



Valley ~100 m deep and ~5000 m wide at Dome C (Forieri et al., 2005)

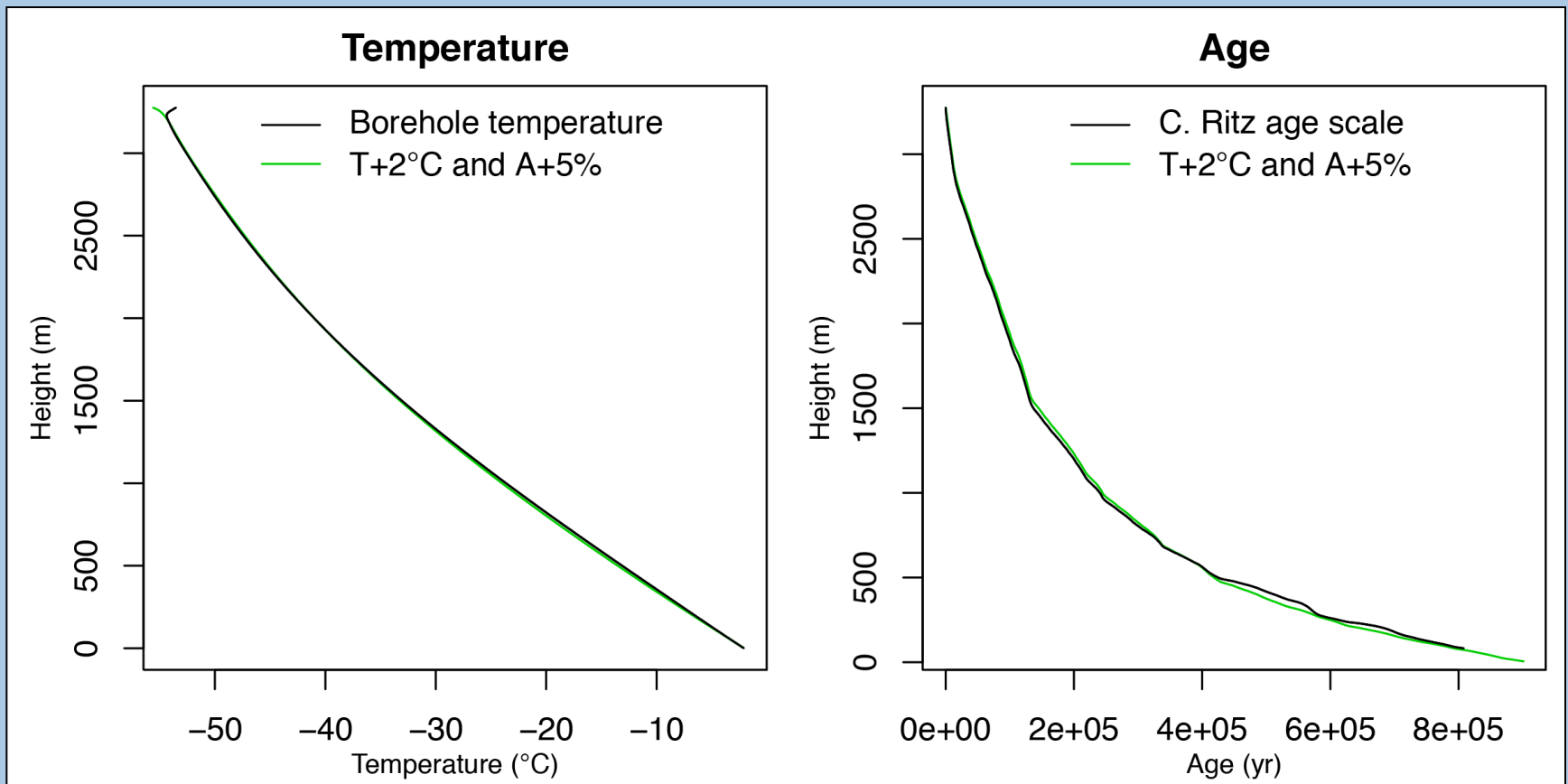
Can warm the profile up to ~0.2°C → Not enough but shows the importance of topography

Boundary conditions (temperature and accumulation) correction

Tests of the model

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Antarctica



Oldest ice site

- Old ice retrieval 1
- Model details
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- Corrections
- Old ice retrieval 2

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Where will we find old ice ?

If the climatological conditions are the same than at Dome C,
we expect to find older ice where the ice sheet is thinner.

Because more ice → more pressure → more melting

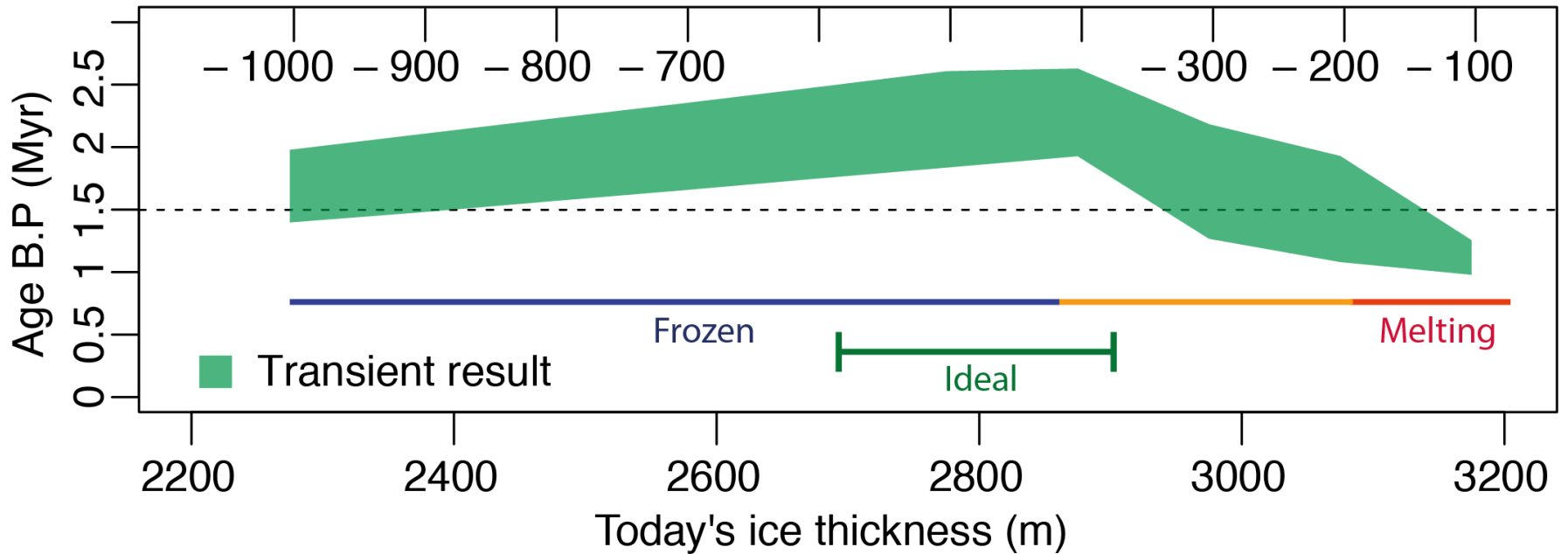
But too thin ice → too thin annual layers

→ We run the model with different ice sheet thicknesses

Oldest ice site

- Old ice retrieval 1
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- Old ice retrieval 2

Age 25 m a. bedrock



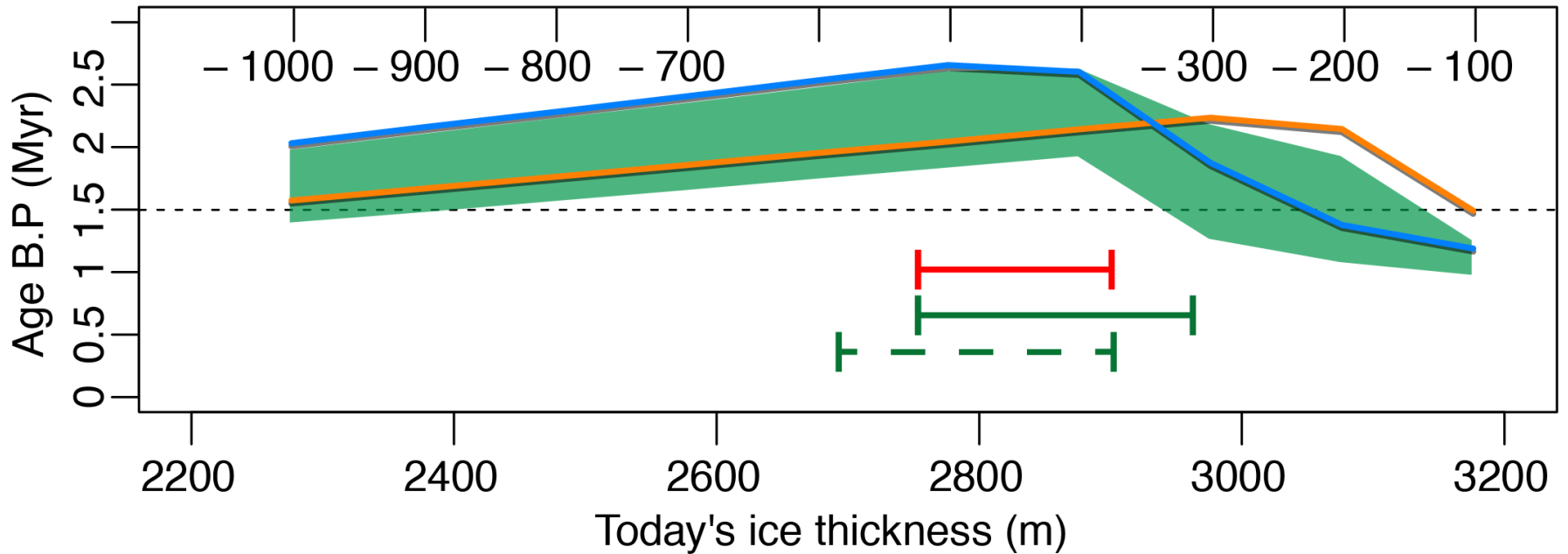
Oldest ice site

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Age 25 m a. bedrock



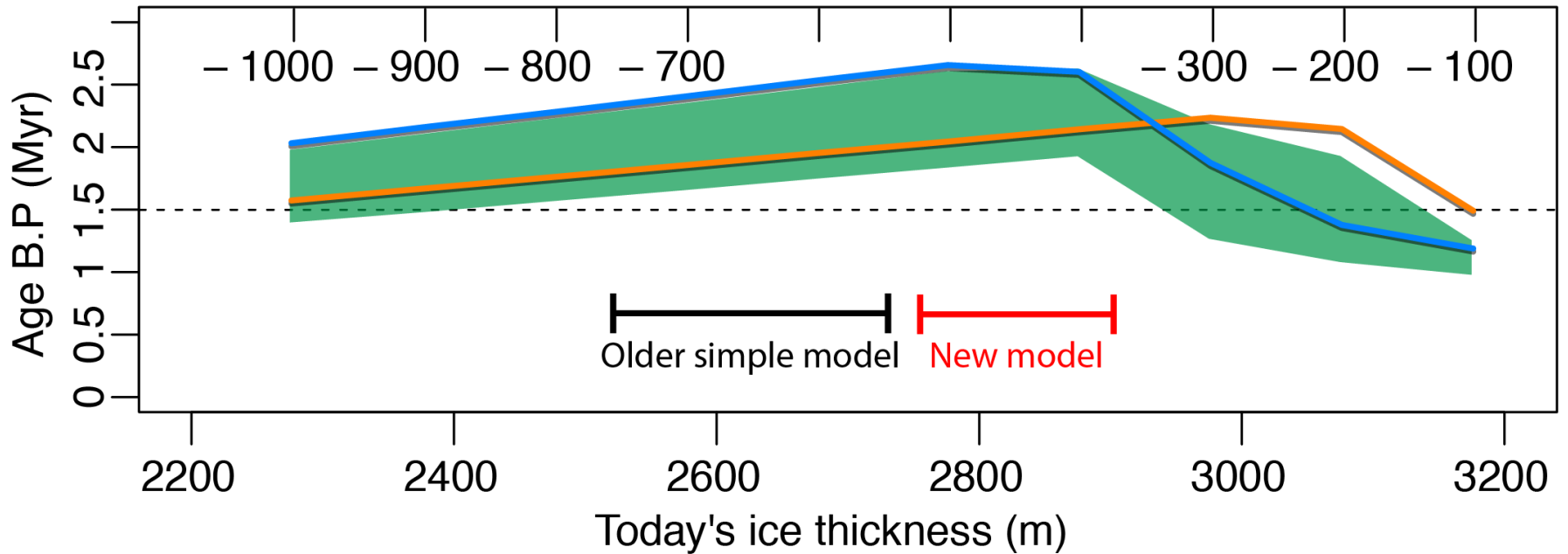
Oldest ice site

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Age 25 m a. bedrock



Summary

Model in agreement with literature and measurements in Greenl.

Model not able to reproduce temperature measured at Dome C

Corrections needed in boundary condition

1.5 Myr old ice very likely exists at 25 meters above bedrock

Ideal ice thickness is between 2750 and 2900 meters

Transient model is an improvement with respect to steady state model

Thank you for your attention