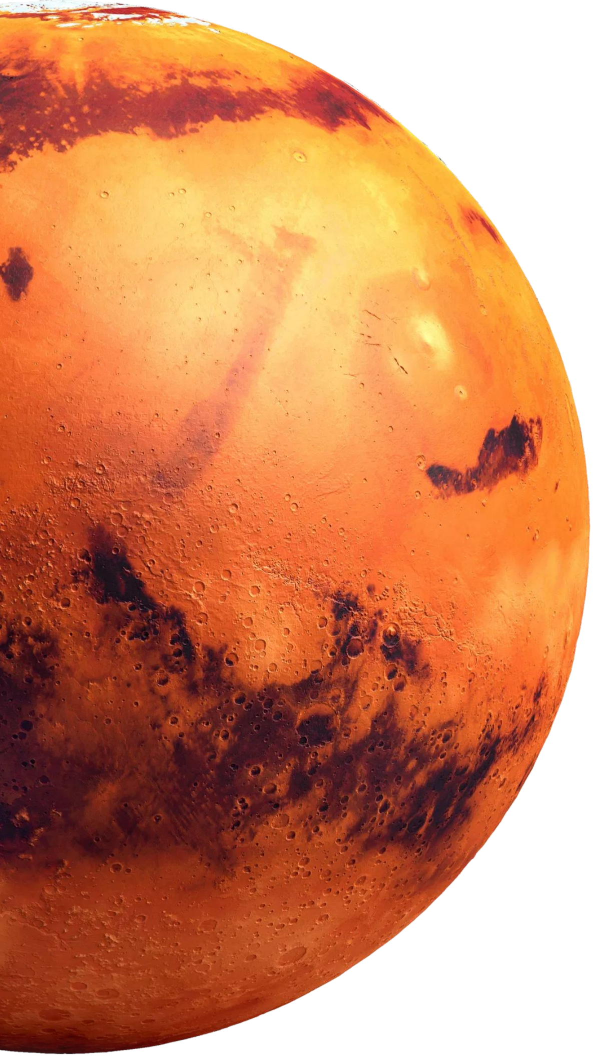

The past Martian climate may support present-day liquid water under the SPLD

Andres Castillo Llarena, Megan James, George Lu, Nanna Karlsson

Karthaus Summer School 2023

Geophysical Research Letters

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RESEARCH LETTER

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Water on Mars, With a Grain of Salt: Local Heat Anomalies Are Required for Basal Melting of Ice at the South Pole Today

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Both authors contributed equally to this work

Key Points:

- No amount of salt is sufficient to cause basal melting of south polar ice on Mars under typical conditions
- Under an ideal composition of an ice-perchlorate mixture, basal melting may occur if the geothermal heat flux is >72 mW m^{-2}
- A subsurface magma chamber may provide sufficient heat for local, transient melting of basal polar ice

Supporting Information:

- Supporting Information S1
- Table S1

Abstract Recent analysis of radar data from the Mars Express spacecraft has interpreted bright subsurface radar reflections as indicators of local liquid water at the base of the south polar layered deposits (SPLD). However, the physical and geological conditions required to produce melting at this location were not quantified. Here we use thermophysical models to constrain parameters necessary to generate liquid water beneath the SPLD. We show that no concentration of salt is sufficient to melt ice at the base of the SPLD in the present day under typical Martian conditions. Instead, a local enhancement in the geothermal heat flux of >72 mW/m^2 is required, even under the most favorable compositional considerations. This heat flow is most simply achieved via the presence of a subsurface magma chamber emplaced 100 s of kyr ago. Thus, if the liquid water interpretation of the observations is correct, magmatism on Mars may have been active extremely recently.

v/s

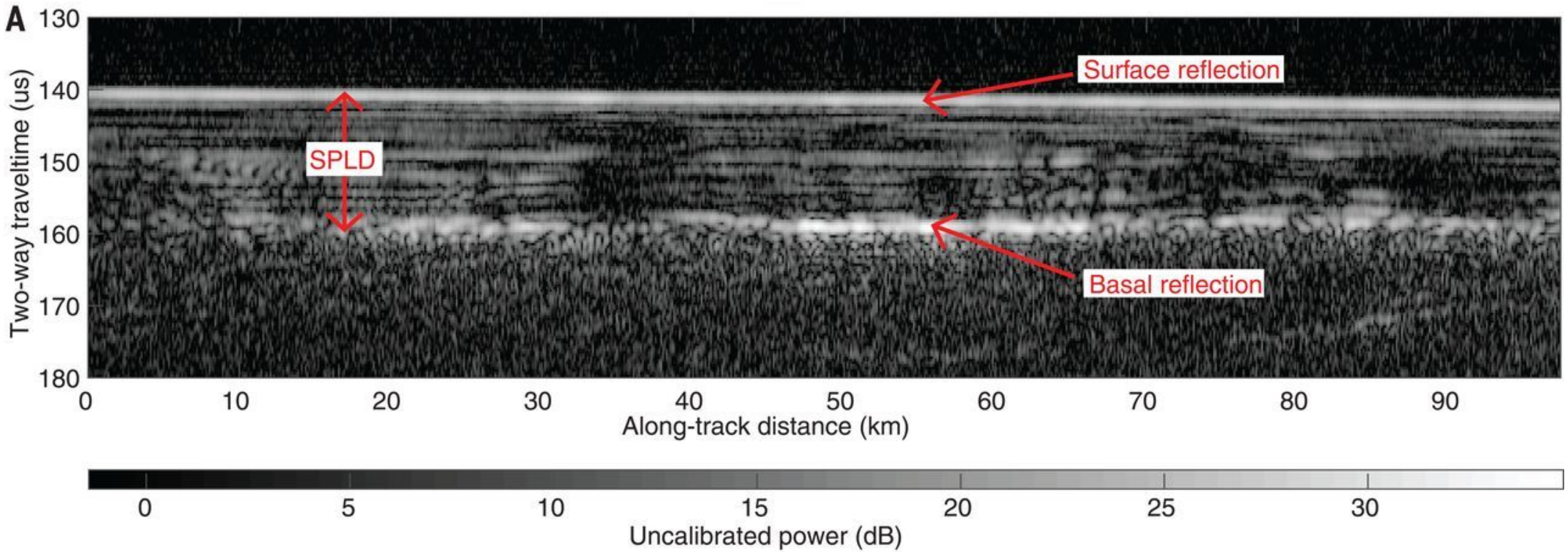
MARTIAN GEOLOGY

Radar evidence of subglacial liquid water on Mars

R. Orosei[1]*, S. E. Lauro[2], E. Pettinelli[2], A. Cicchetti[3], M. Coradini[4], B. Cosciotti[2], F. Di Paolo[1], E. Flamini[4], E. Mattei[3], M. Pajola[5], F. Soldovieri[6], M. Cartacci[3], F. Cassenti[7], A. Frigeri[3], S. Giuppi[3], R. Martufi[7], A. Masdea[8], G. Mitri[9], C. Nenna[10], R. Noschese[3], M. Restano[11], R. Seu[7]

The presence of liquid water at the base of the martian polar caps has long been suspected but not observed. We surveyed the Planum Australe region using the MARSIS (Mars Advanced Radar for Subsurface and Ionosphere Sounding) instrument, a low-frequency radar on the Mars Express spacecraft. Radar profiles collected between May 2012 and December 2015 contain evidence of liquid water trapped below the ice of the South Polar Layered Deposits. Anomalously bright subsurface reflections are evident within a well-defined, 20-kilometer-wide zone centered at 193°E, 81°S, which is surrounded by much less reflective areas. Quantitative analysis of the radar signals shows that this bright feature has high relative dielectric permittivity (>15), matching that of water-bearing materials. We interpret this feature as a stable body of liquid water on Mars.

Background



Orosei et al., 2018: Bright basal reflector from water! Possibly due to salts.

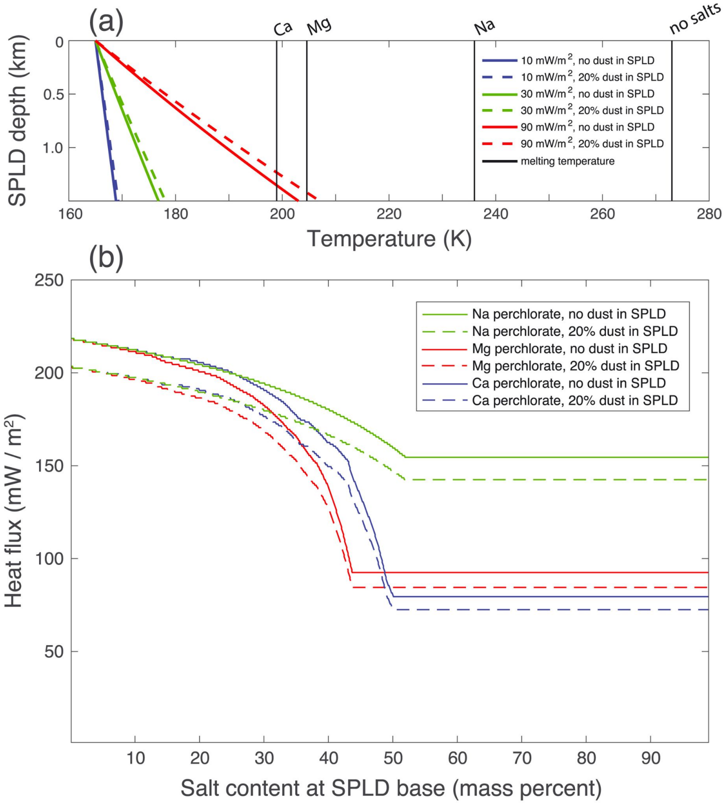
Background

Probably not salt

Requires very high geothermal heat flux (GHF).

Maybe magma?

A steady state heat equation calculation has determined the GHF and the dust concentration required.



Sori and Bramson, 2019

Our Project

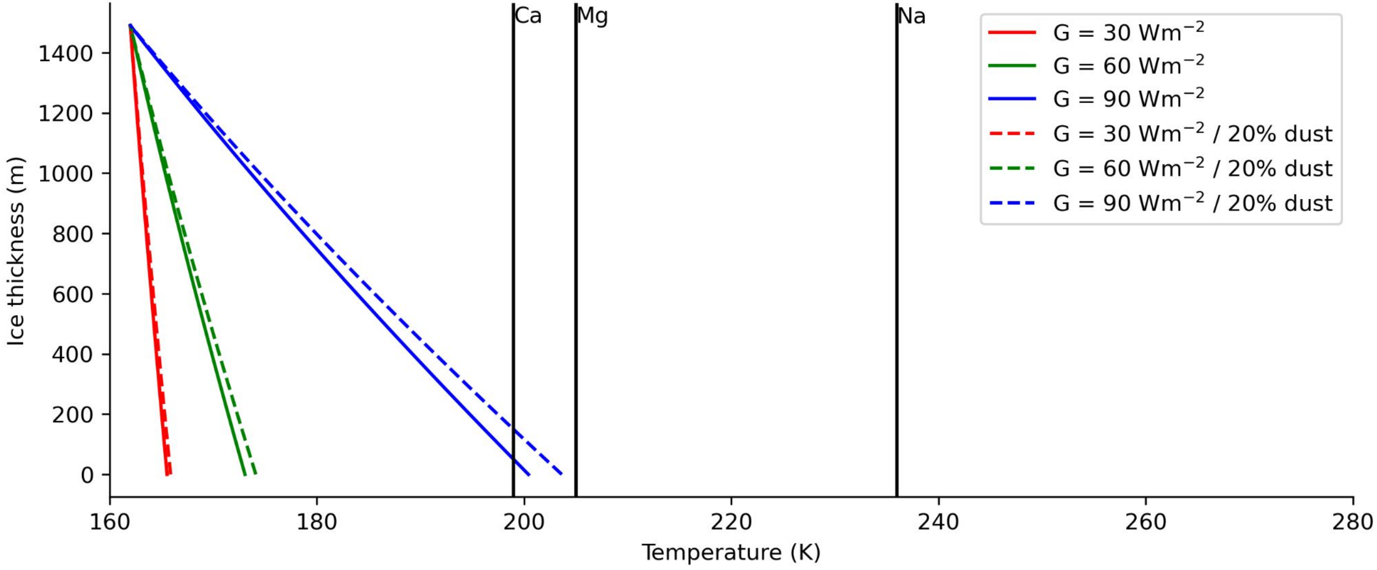
Mars insolation has significantly varied in response to the obliquity.

The temperature profile of the SPLD might have experience a transient response to the insolation.

Aims:

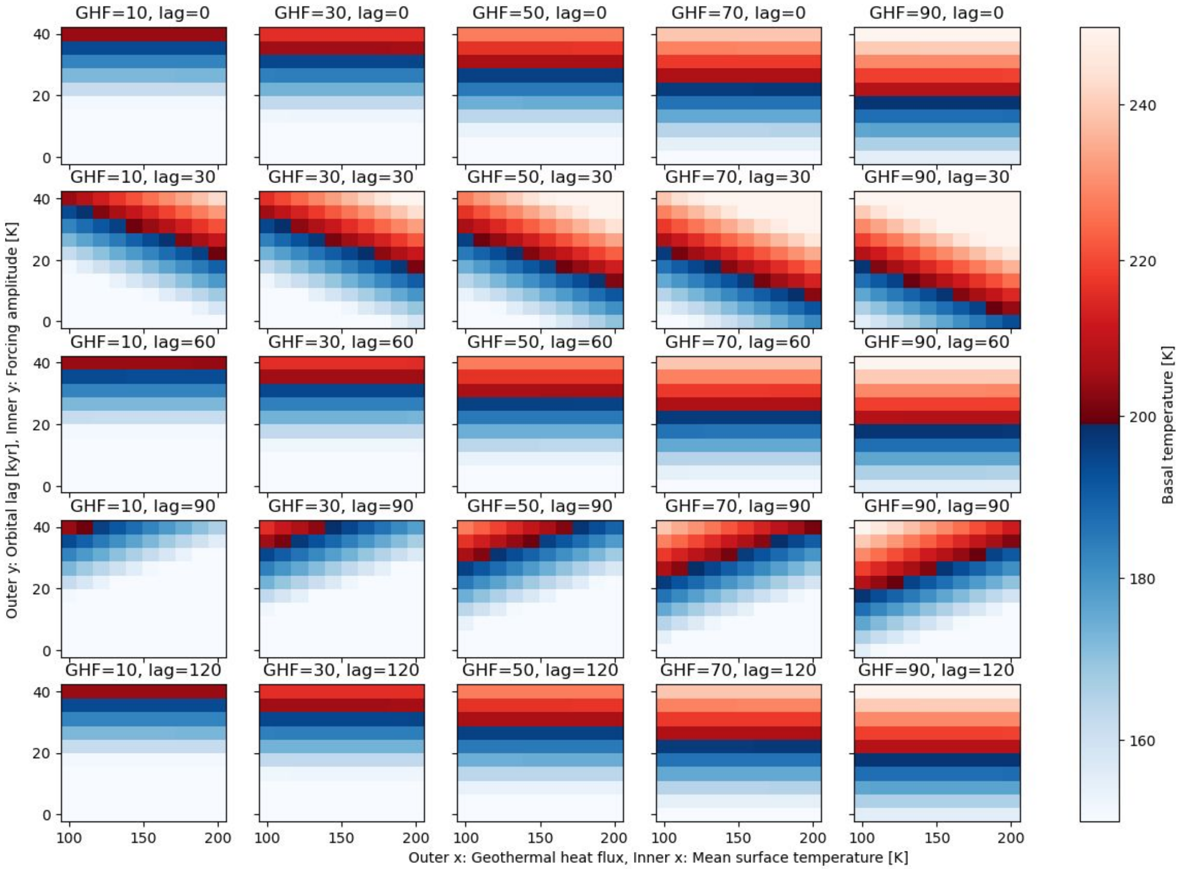
1. Reproducing results from Sori and Bramson (2019) with the time-varying heat equation
2. Looking at sensitivity to changes in forcing
3. Determining the time series for surface temperatures at SPLD
4. Finding liquid water scenarios with reconstructed surface temperatures

Using time-dependent heat equation

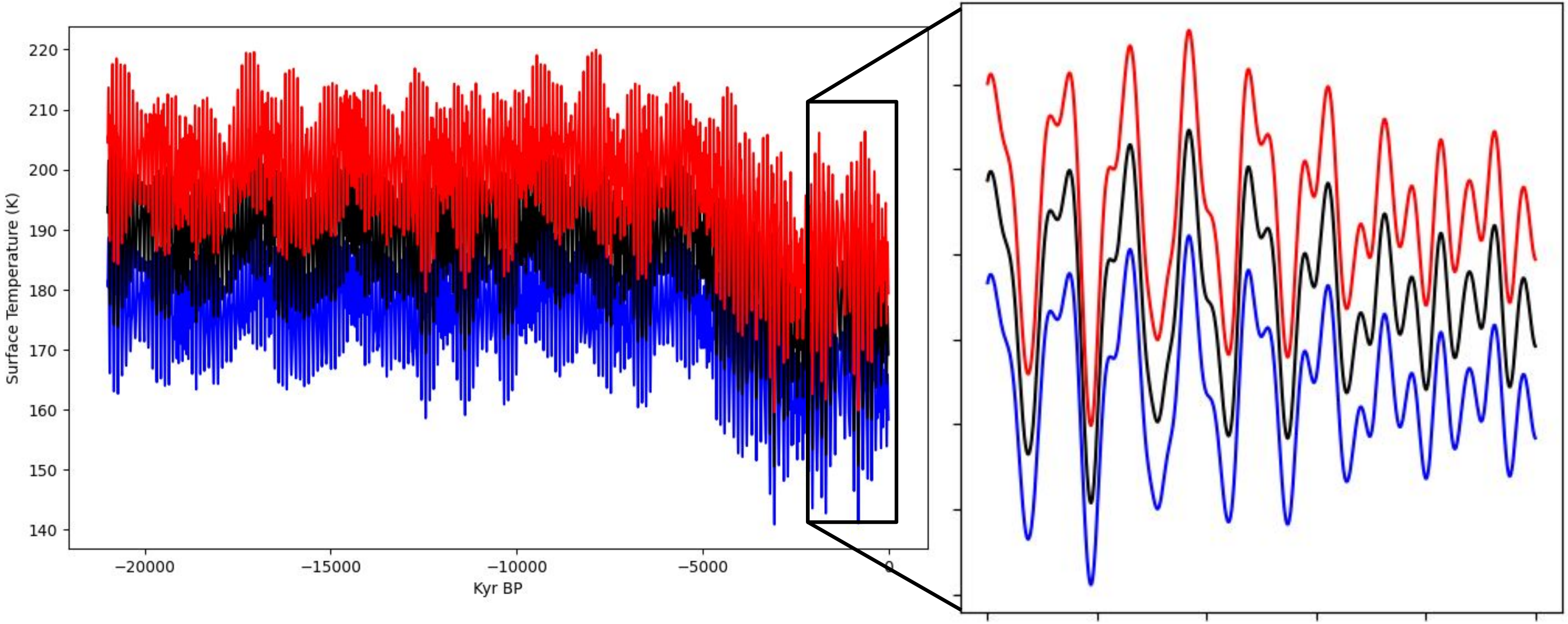


Karlsson N., (Pers communication)

Sensitivity to temporally varying surface temperatures

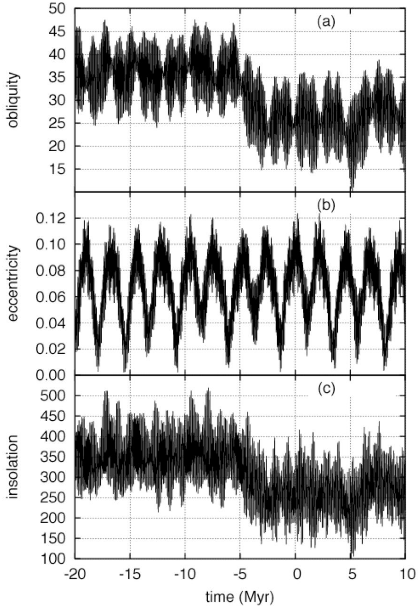


Insolation-based surface temperature reconstruction

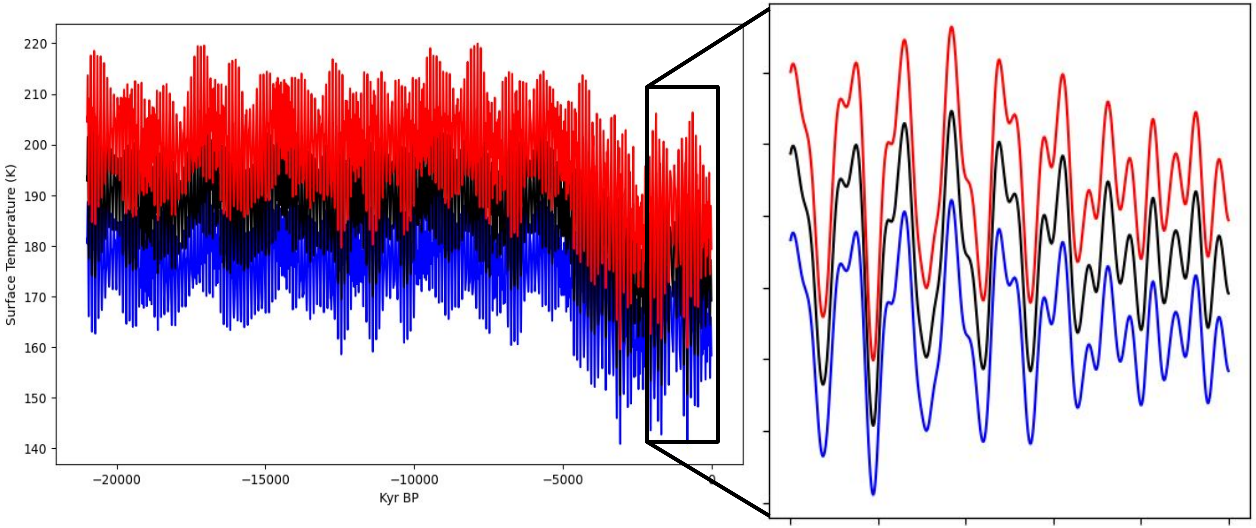


Insolation-based surface temperature reconstruction

Orbital parameters change over time.

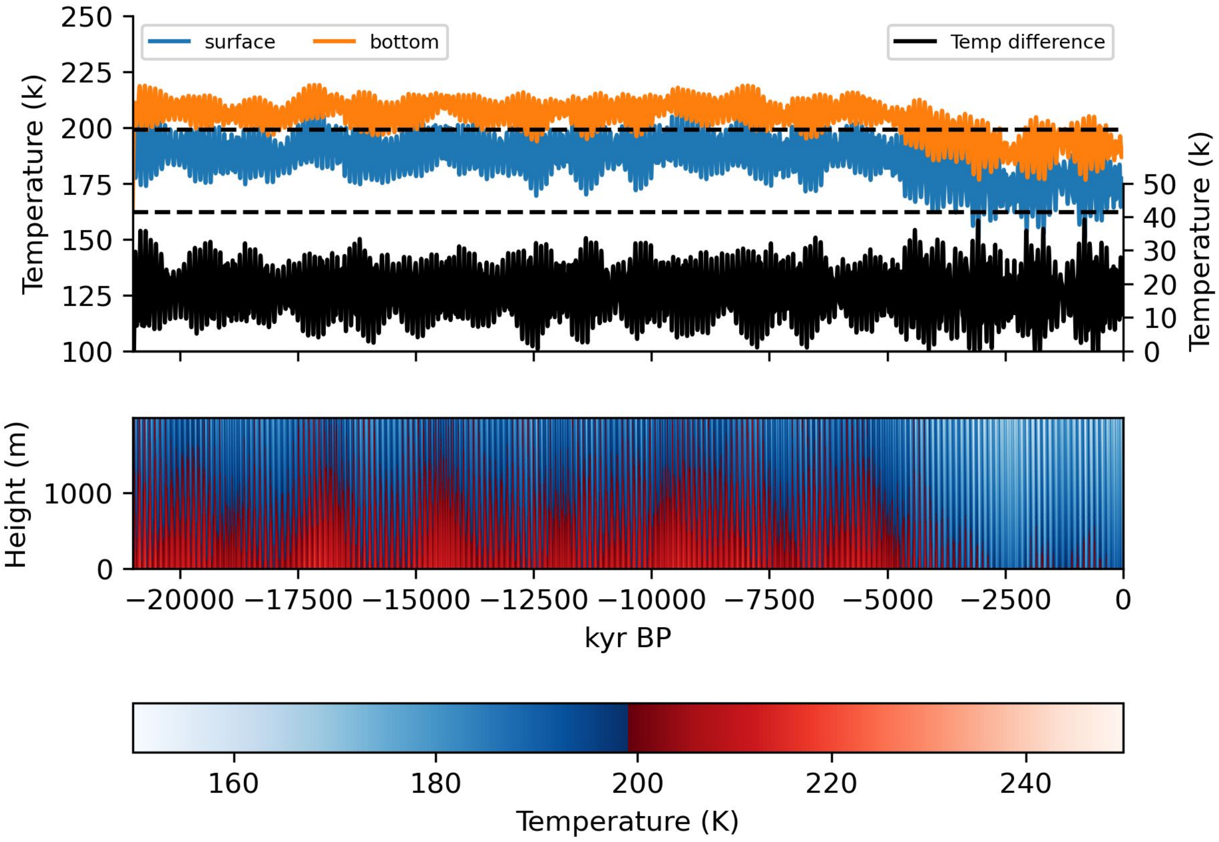


(Laskar and others, 2002, 2004)



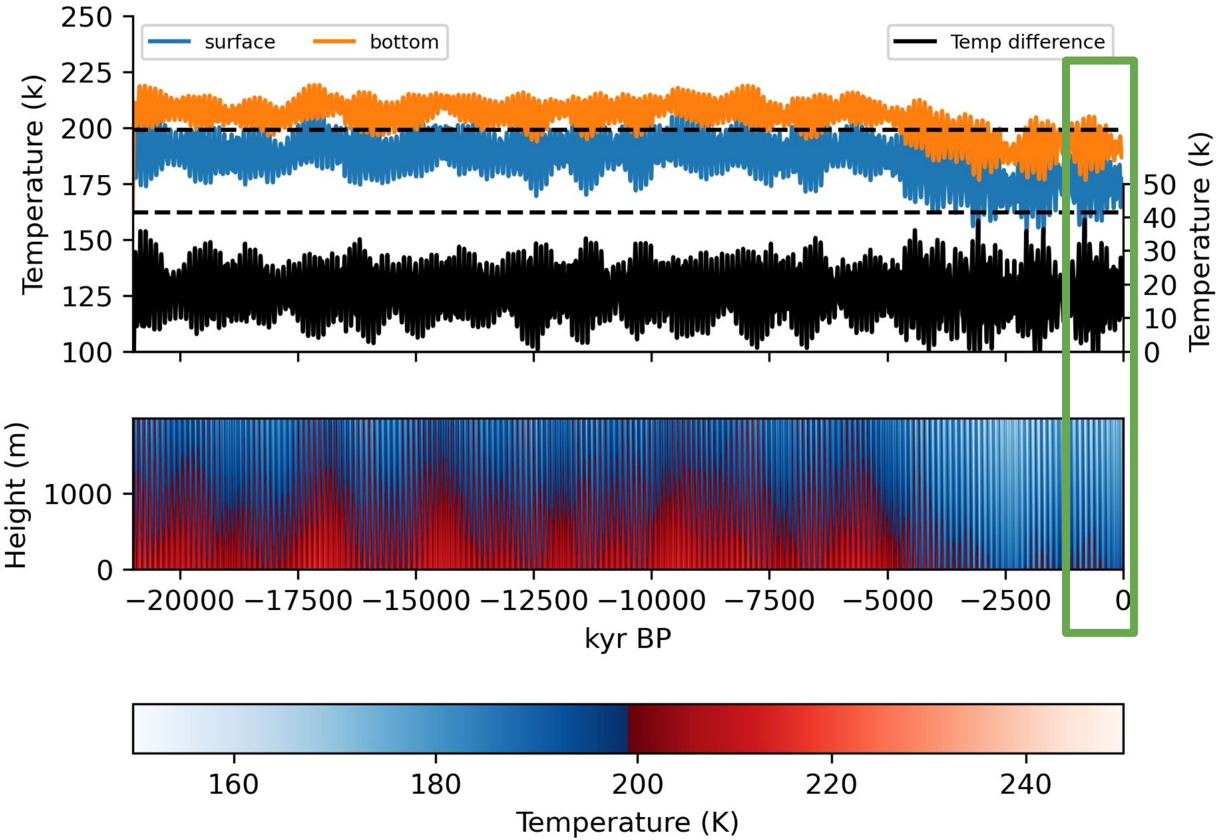
Karlsson N, (Karthaus 2023)

Introducing realistic forcing: The long term oscillation



Parameter		
Dust	20	%
Accumulation	0.01	M y-1
Geo. Heat Flux	0.03	W m-2
Ice thickness	1500	m

Introducing realistic forcing: The long term oscillation



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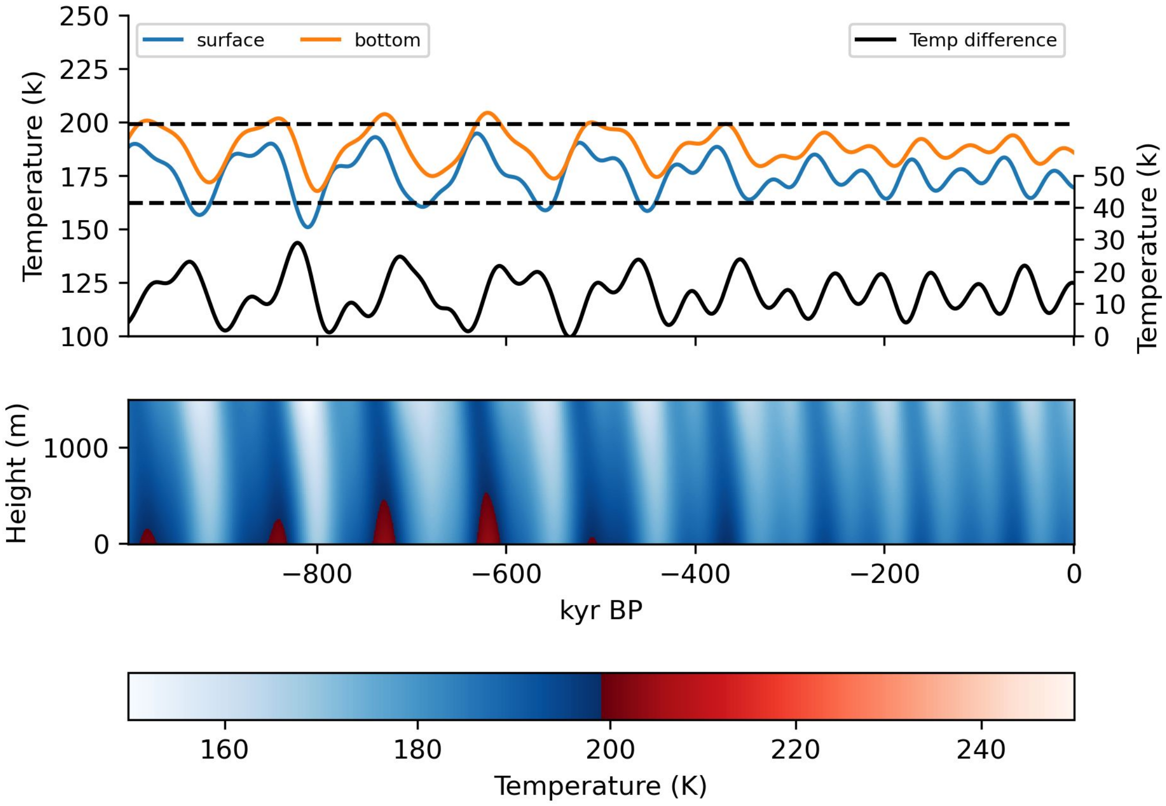
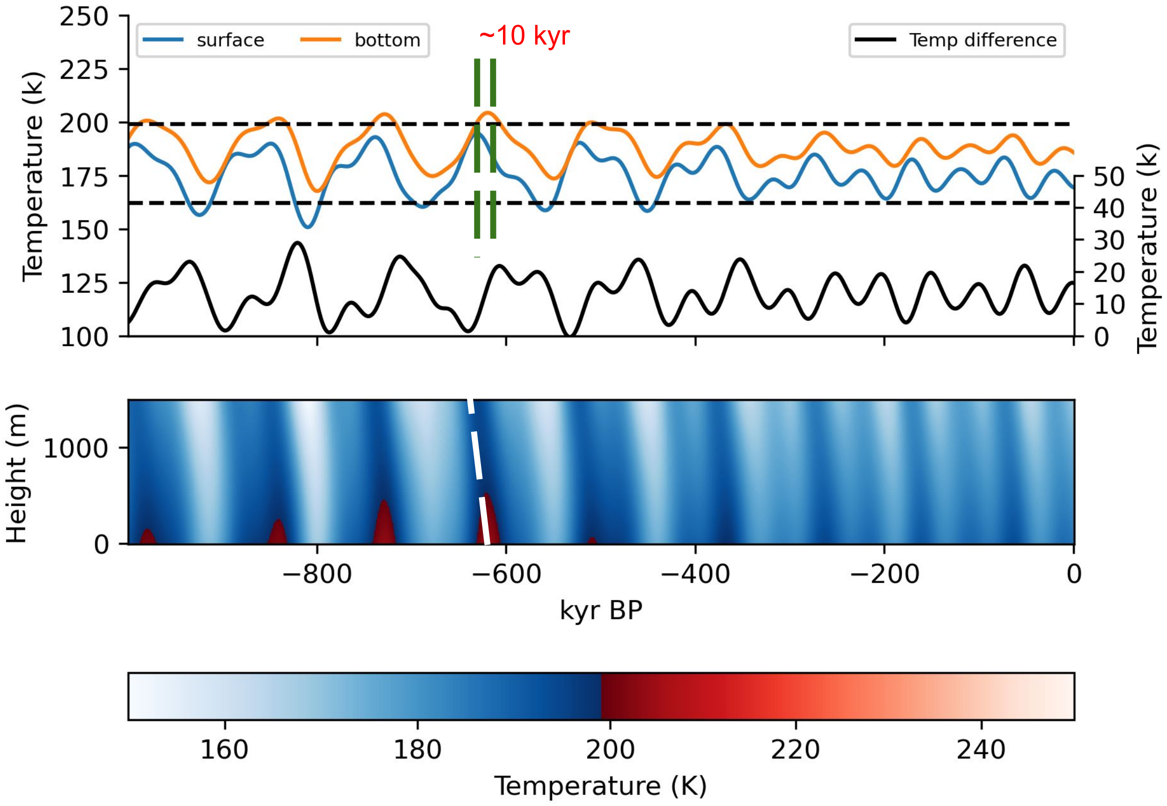
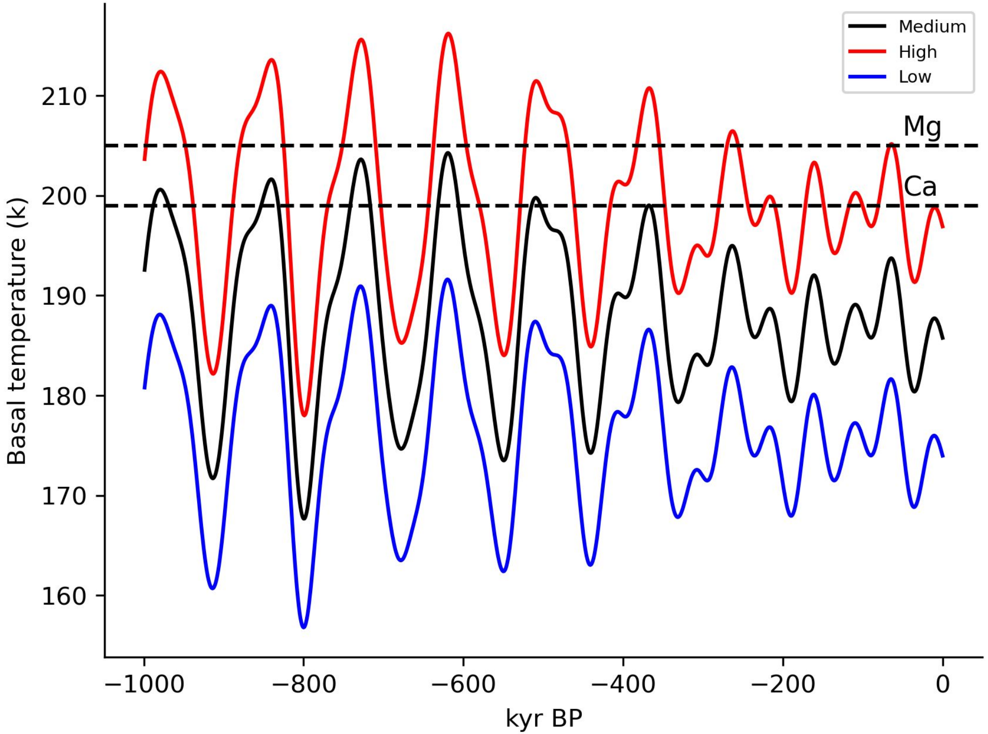
Zoom into the last million years



Zoom into the last million years



Basal temperatures under different forcing scenarios



Take home message

- We have used the transient heat equation to show that meltwater can likely exist under the SPDL
- In our transient simulations, temperatures at base stay past the melting point even when the surface temperatures drop
- The lag in time (~10k kyr) is not enough to account for the basal temperatures to remain above melting (using realistic GHFs)
- What remains to be investigated is how long liquid water can remain liquid even if temperatures are below freezing
- Additional sensitivities could be investigated as well

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Larsen, J., & Dahl-Jensen, D. (2000). Interior temperatures of the Northern Polar Cap on Mars. Icarus, 144(2), 456–462. DOI: 0.1006/icar.1999.6296

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