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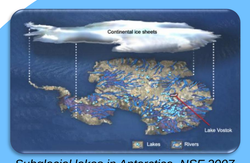
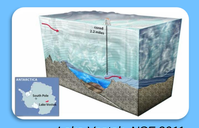
Ice streams and subglacial lakes

the crucial impact of basal hydrology on ice sheet modeling

Is there water under the Antarctic ice sheet?

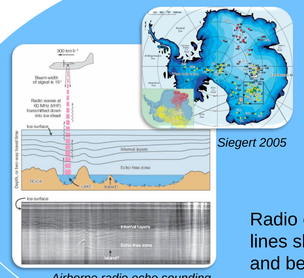


Subglacial lakes in Antarctica, NSF 2007


Lake Vostok, NSF 2011

More then 300 discovered subglacial lakes which are connected by subglacial rivers form a widespread hydrological network.

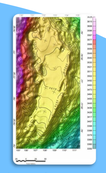
How do we know that?



Siegert 2005

Airborne radio echo sounding

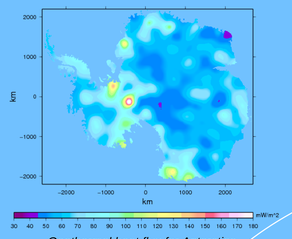
Lakes can be identified by unusual flat ice sheet surface areas on satellite images.


Ice surface over Lake Vostok, Studinger 2003

Radio echo sounding (RES) flight lines show radar profiles of ice sheet and bedrock. Basal water is identified by bright reflections and flat surfaces at the ice bottom.

Where does the basal water comes from?

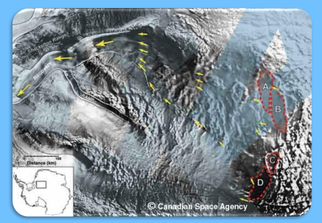
Despite the cold surface with temperatures around -50C, large areas of the bed of the ice sheet are at the pressure melting point and actively melting through the combined influence of the insulating cover of ice and the flow of geothermal heat into the base of the ice sheet.



Geothermal heat flux for Antarctica, Fox Maule 2005

Why incorporate basal hydrology in ice sheet modeling?

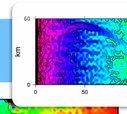
Basal rivers are supposed to reduce the basal friction of the ice sheet and thus considerably raise the ice velocity, ice streams evolve.



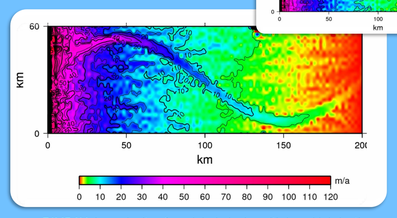
Recovery Lakes (red) at the onset of the Recovery Ice Streams (yellow)

Subglacial lakes are often situated at the onset of ice streams and act as water reservoirs for upstream catchment areas.

Ice stream



RIMBAY: ice velocity without basal lubrication

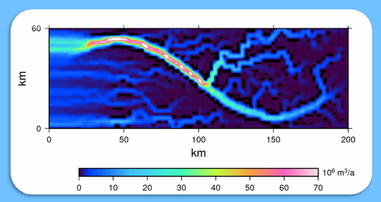


RIMBAY: ice velocity of modeled glacier with basal lubrication

Basal water flux lubricates the ice base and an ice stream develops.

Multi-physics
3D ice-sheet model
RIMBAY

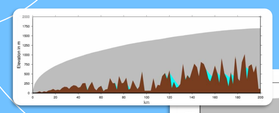
Basal water flux

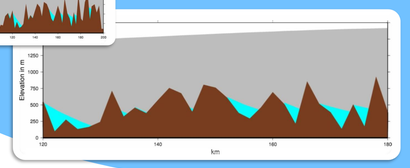


RIMBAY: basal water volume flux

Basal meltwater runoff forms a subglacial river system.

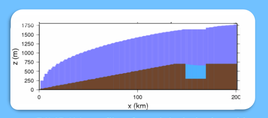
Subglacial lakes


RIMBAY: profile of modeled glacier with bedrock, subglacial lakes and ice sheet



Sinks are filled up by meltwater and subglacial lakes evolve.

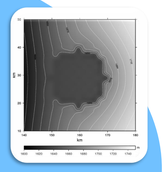
Model a single subglacial lake

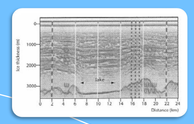


RIMBAY: profile of modeled glacier with bedrock, subglacial lake and ice sheet

Ice model RIMBAY

- Shallow ice approximation (SIA) for grounded ice sheet
- Shallow shelf approximation (SSA) for ‚floating' ice over the lake

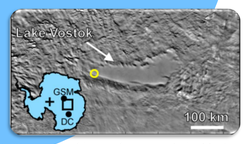

RIMBAY: flat ice sheet surface over a subglacial lake



Radar profile with subglacial lake

Model results indicate all characteristics of real lakes

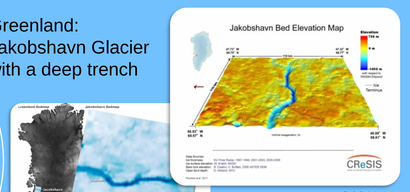
- flat ice sheet surface over subglacial lake
- inclined lake surface



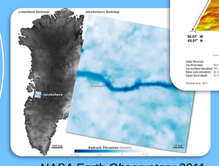
Satellite image of ice surface over Lake Vostok

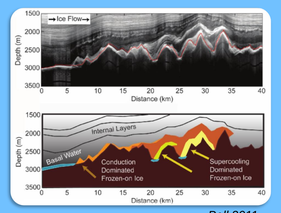
How does the subglacial bedrock typically looks like?

Greenland:
Jakobshavn Glacier
with a deep trench

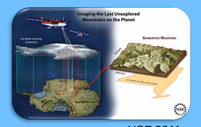


Herzfeld 2011


NASA Earth Observatory 2011



Bell 2011

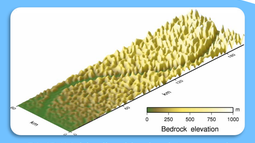


NSF 2011

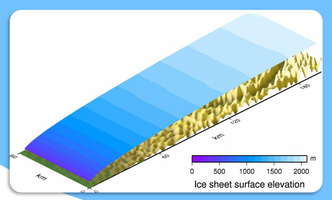
Antarctica:
Gamburtsev Mountains
with a very mountainous bedrock topography

Idealized model geometry

Mountainous bedrock topography with a sine-shaped trench.



RIMBAY: idealized bedrock topography



RIMBAY: ice sheet in equilibrium after 10,000 years

After 10,000 years of accumulation a stable ice sheet builds up.

HELMHOLTZ GEMEINSCHAFT