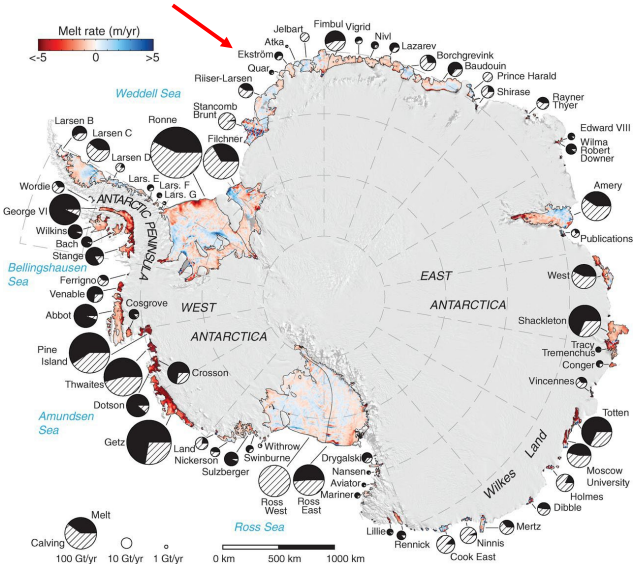
GFZ Helmholtz-Zentrum Potsdam

AWI

Universität zu Köln

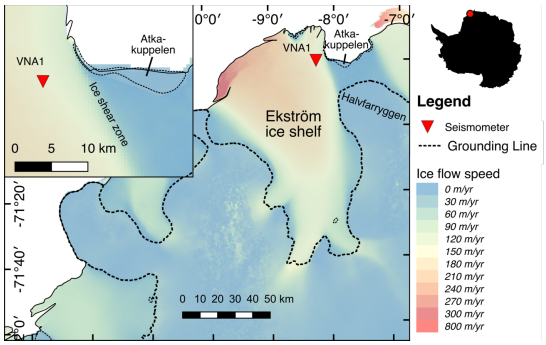
Basal melt rates of Antarctica's ice sheets

Circles are proportional in area to mass loss from each shelf in Gt/year (hatched: iceberg calving, black: basal melting)



Rignot et al. 2013, Science

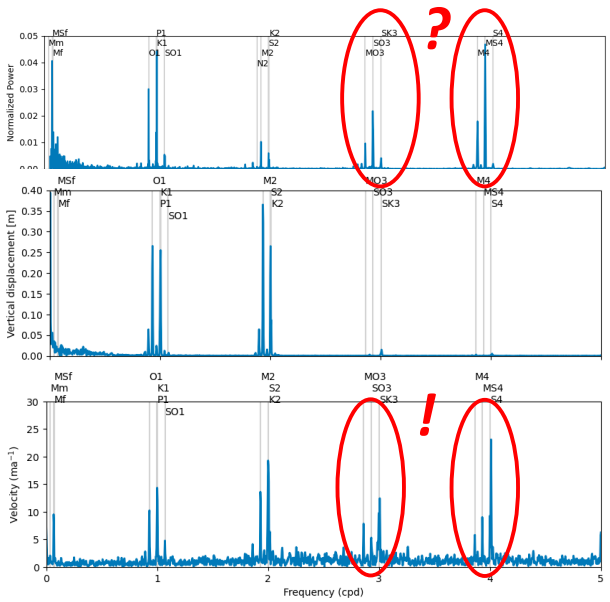
Ice flow of the Ekström ice shelf



Rignot et al. 2017

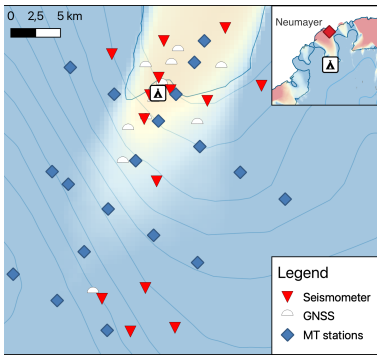
Tides affect ice sheet mass balance…

Motivation: Spectral analysis of seismic noise



- Seismic noise (near Neumayer Station)
  - Major tides
  - Large amplitudes HF tides (4 and 3cpd)
- GNSS
  - Major tides
  - Small amplitudes for 4 and 3cpd (1.6 and 2.2cm)
- Large amplitude in **horizontal motion of ice shelf**

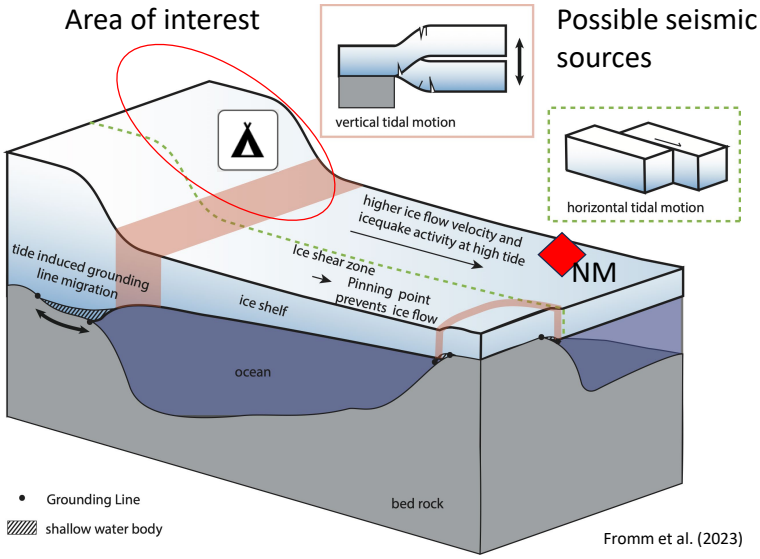
➢ seismic noise correlates with flow velocity ?!



Targets:

- Tidal variations
- Crustal structure

Hypothesis

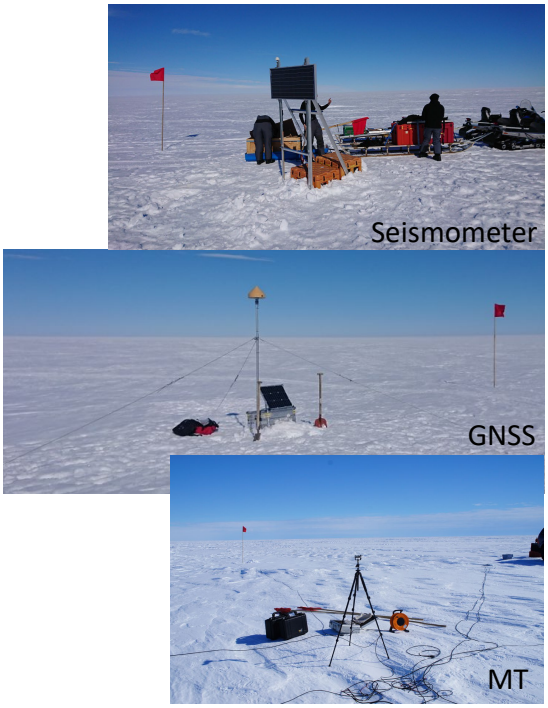


Fromm et al. (2023)

Data and methods

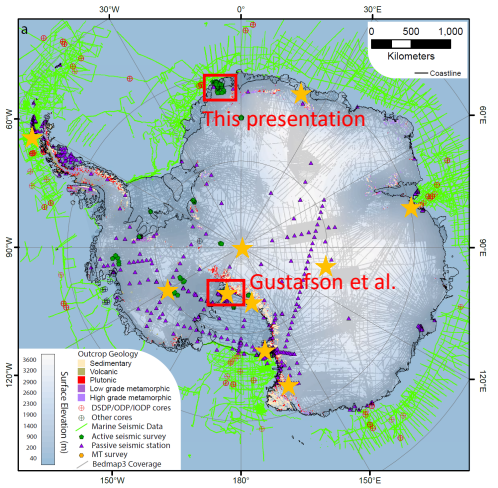
Expeditions in Jan 2022 and Feb 2023

- 15 Broadband seismometer
  - 75 – 355 days recorded @100Hz
  - spectral analysis of PPSDs
- 7 dual frequency GNSS
  - 76 – 122 days recorded @ 1Hz
  - Differential processing
  - Spectral analysis
- 22 Magnetotelluric stations
  - ~3days/station recorded
  - 2D/3D modelling of subsurface

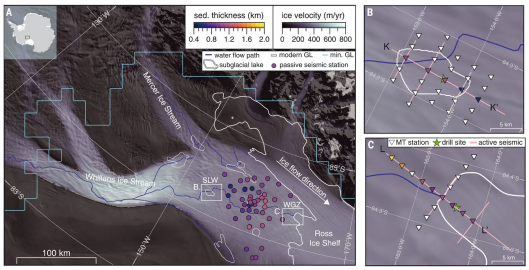


Geophysics in Antarctica

- Mostly seismic and airborne potential-field methods.
- Few published MT surveys (orange asterisks)



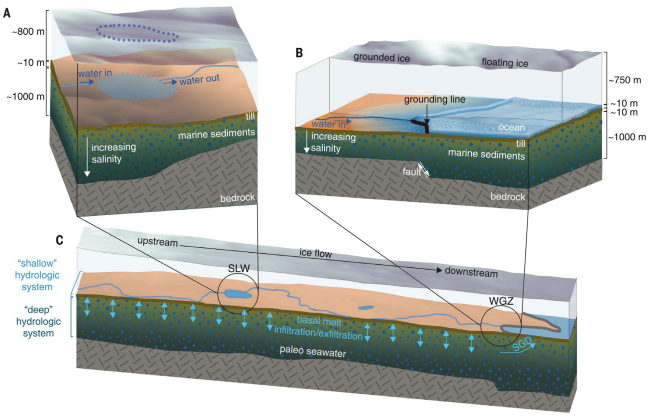
Investigating subglacial groundwater systems



MT imaged:

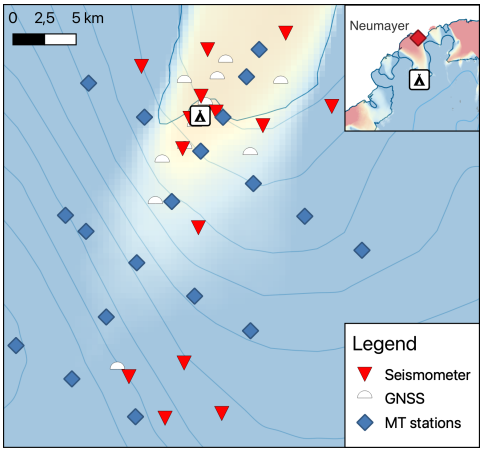
- Resistive bedrock
- Conductive laterally-varying sedimentary layer
- Increasing conductivity in sediments -> interpreted as increasing salinity with depth
- Mixing between the fresh basalt meltwater and more saline deeper groundwater.
- Implications for unmonitored loss of basal meltwater and transport of hotter groundwater to ice base.

Gustafson+ 2022, **Science**, "*A dynamic saline groundwater system mapped beneath an Antarctic ice stream*"

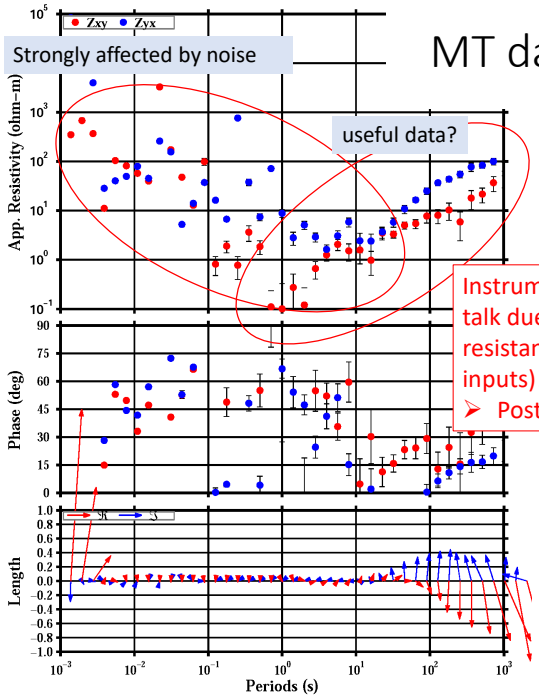


MT data set from Ekström Ice Shelf

- 19 broadband MT stations deployed by GFZ and AWI during the 2022/2023 field seasons.
- Earlier MT work near Neumayer station was unsuccessful...



MT data from 2017

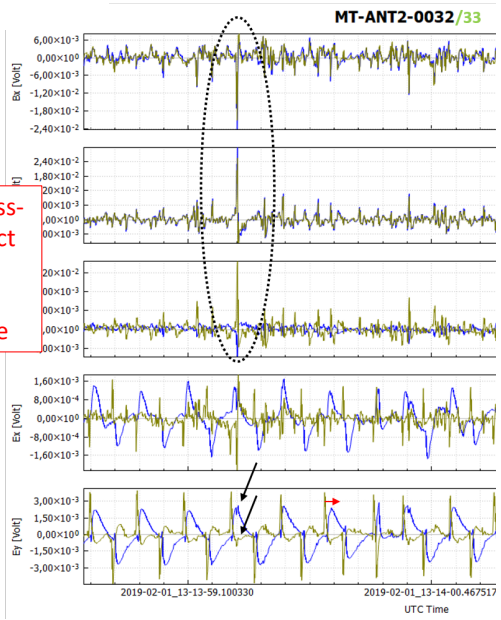


B-fields are perfectly in sync between sites

Instrumentation noise: cross-talk due to very high contact resistances (almost open inputs)!

➢ Poster from Tobias Reise

Noise in E has different shape, same periodicity but is out of sync



Physics of the Earth and Planetary Interiors, 60 (1990) 89–99
Elsevier Science Publishers B.V., Amsterdam – Printed in The Netherlands

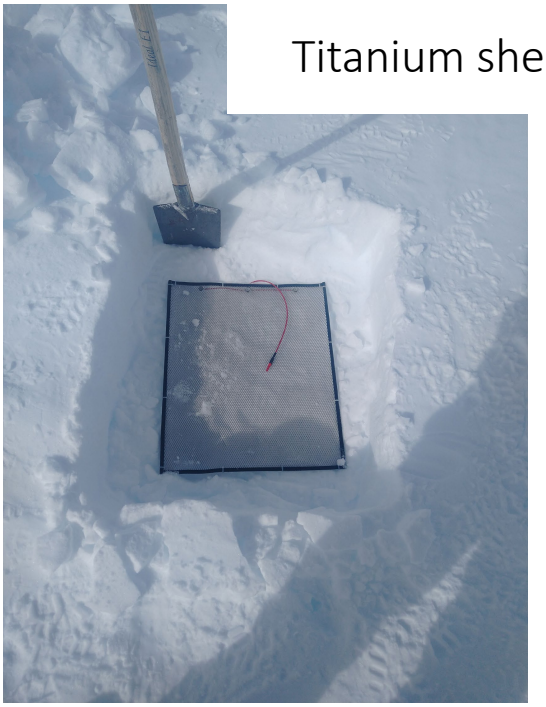
Magnetotelluric measurements in Antarctica

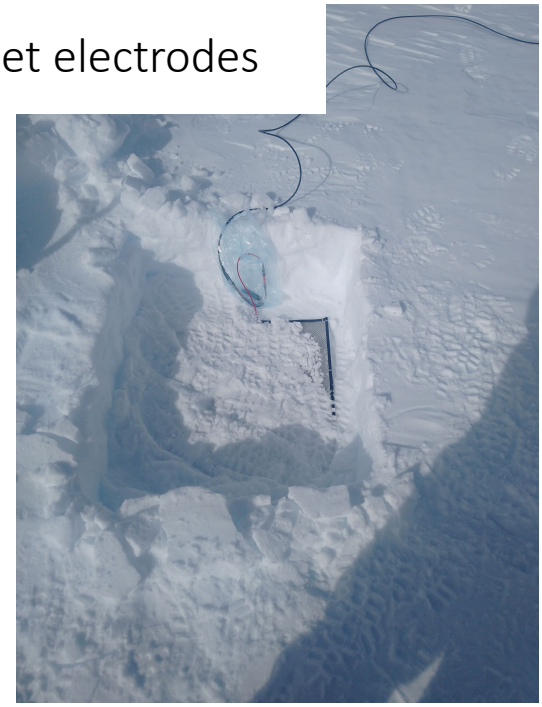
Königstein im Taunus, 1.-3.3.1988

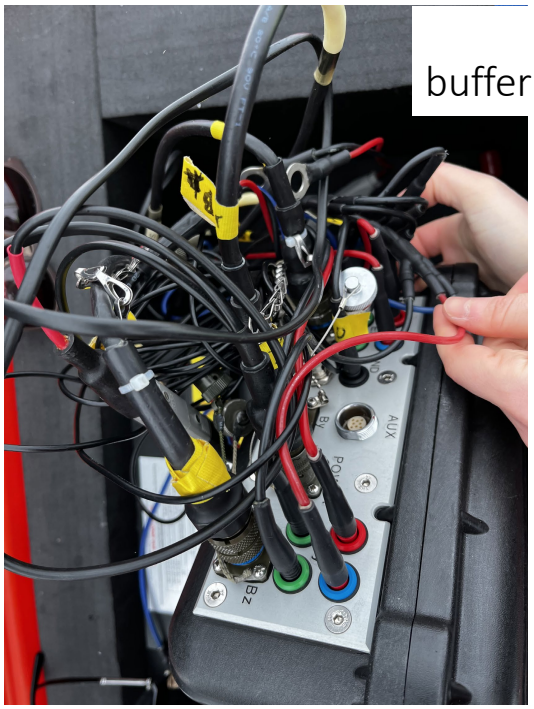
Inhaltsverzeichnis

During austral summer 1984–1985 magnetotelluric measurements were carried out in North Victoria Land, Antarctica. The magnetic field was measured by a three-component fluxgate magnetometer. Copper screens (50 cm × 50 cm) were used as electrodes for recording the electric field, connected to a two channel electrograph with an input impedance of 10^{12} Ω. Analogue data are digitized with 12 bit resolution by a data acquisition system. 1 Mb of solid state CMOS-RAM memory was used to store the data in the field until it could be played back onto 3.5 inch floppy discs during station control. All equipment is designed for low power consumption. In the field it is supplied by a battery, which is charged by solar panels. Time series of measured data are presented. The influence of the polar electrojet (PEJ) on the source fields is clearly seen by comparing 24-h time series with the position of the auroral oval at different times of the day. Despite the clear effect of the PEJ in the data, the calculated apparent resistivity and phase curves seem to be rather uninfluenced. Initial interpretations have led to a typical continental resistivity distribution, showing decreasing resistivity with increasing depth.

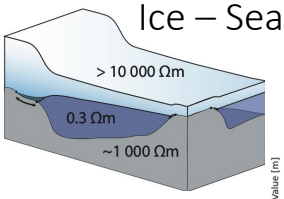
Titanium sheet electrodes

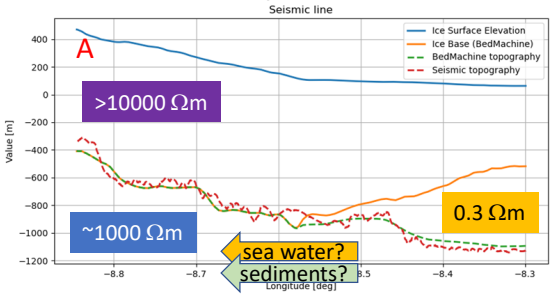


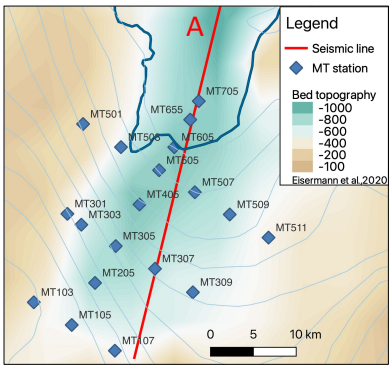



ELMAR &
buffer amplifiers (Stodt)
AUX
OUTPUT

Ice – Sea – Bedrock: Major constituents for MT modelling





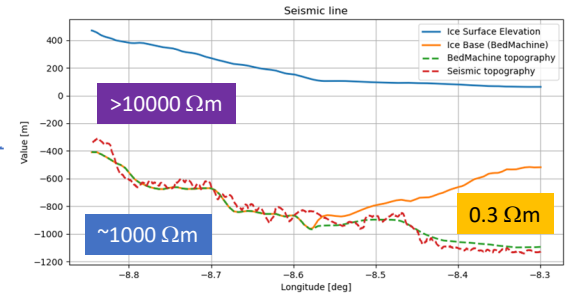


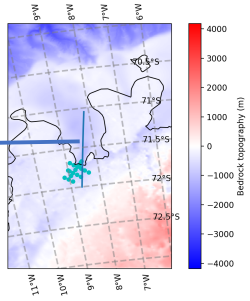
- Extreme resistivity contrasts
- Highly 3-D structures

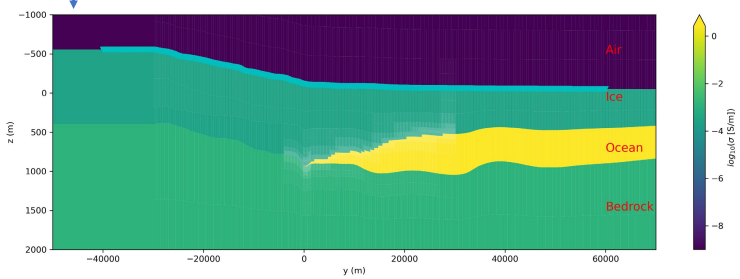
Smith et al. 2020, GRL; Morlighem et al. 2020, Nat. Geo.; Eisermann et al. 2020, GRL

Preliminary 2D Modelling of major features

Discrete FE grid

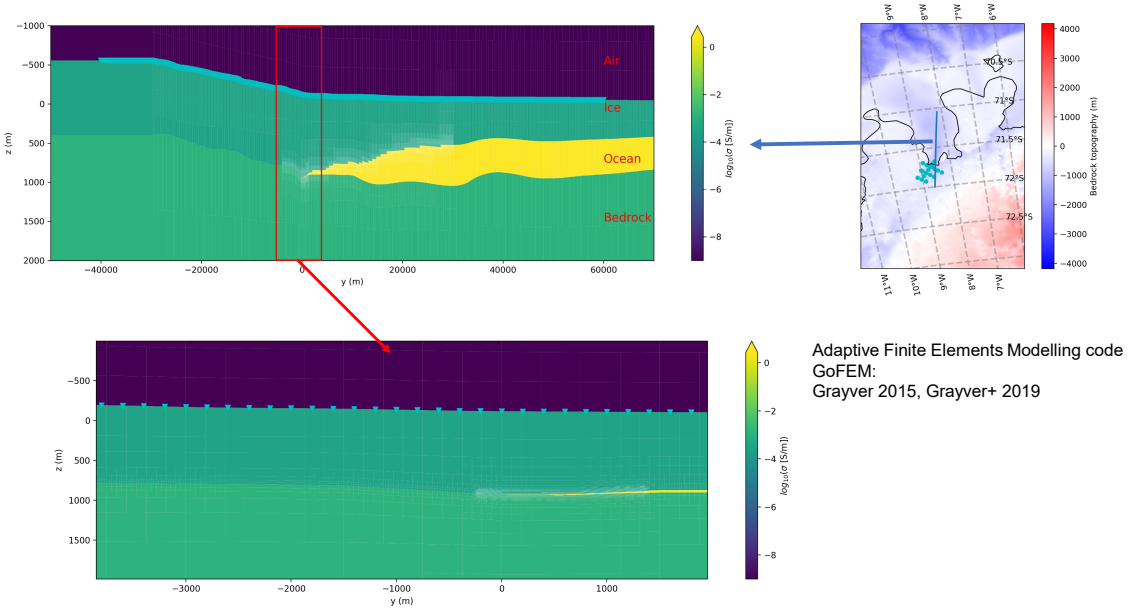






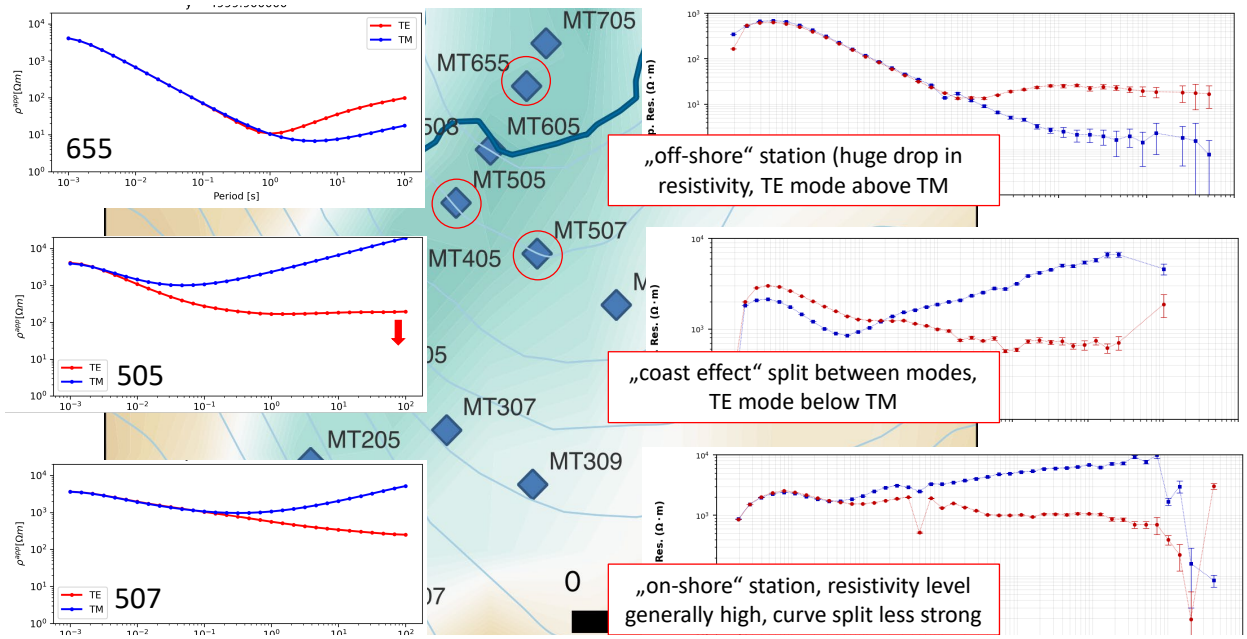
Adaptive Finite Elements code GoFEM
Grayver 2015, Grayver+ 2019

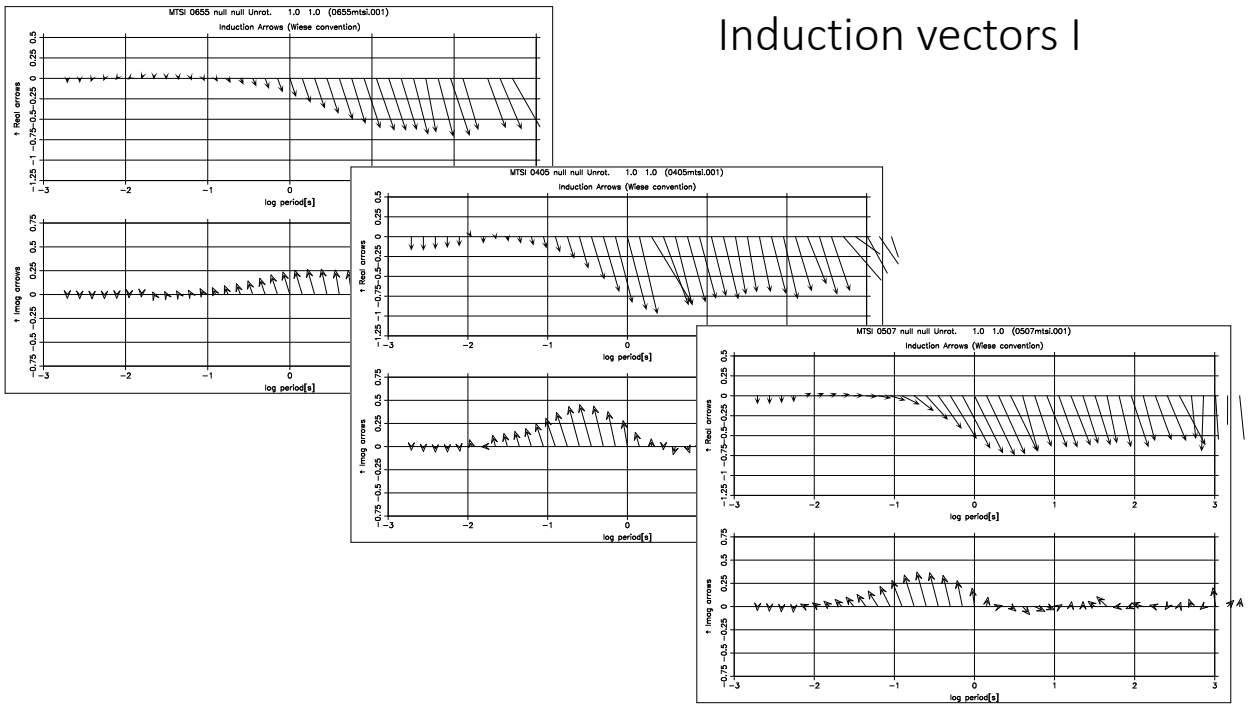
2D MT Modelling

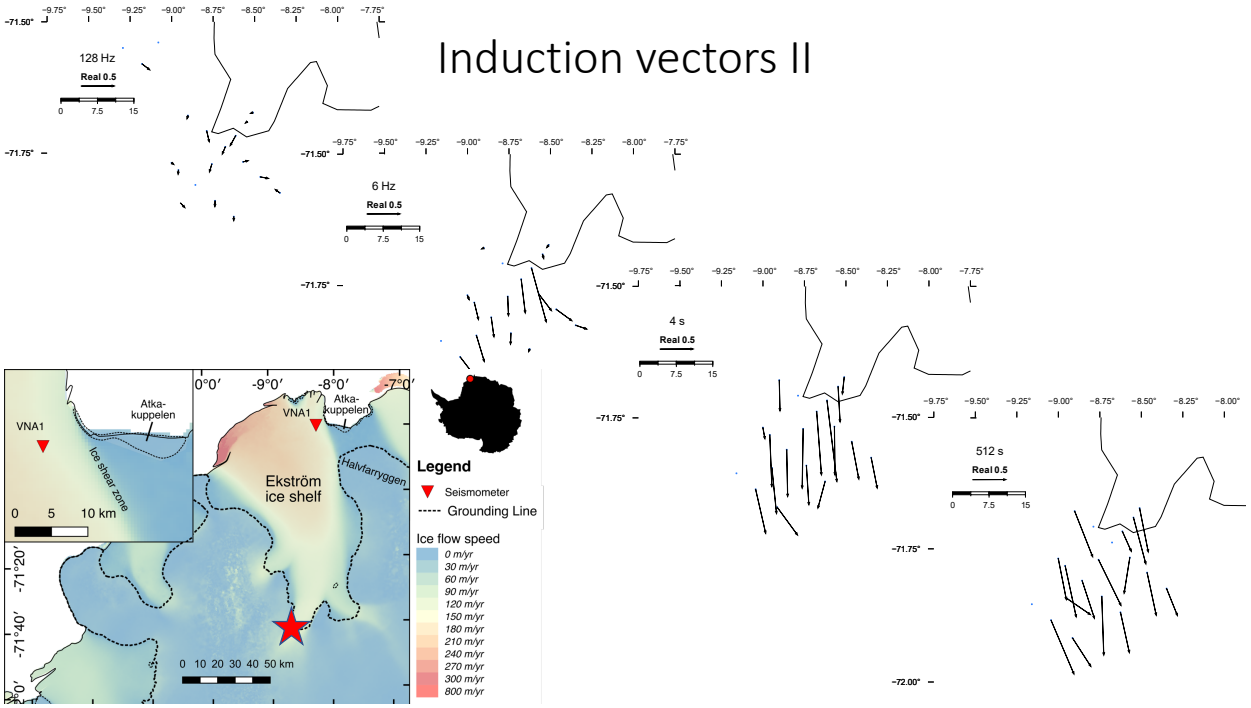


Adaptive Finite Elements Modelling code
GoFEM:
Grayver 2015, Grayver+ 2019

Preliminary 2D modelling vs measured data




Induction vectors I
MTSI 0655 null null Unrot. 1.0 1.0 (0655mtsi.001)
Induction Arrows (Wiese convention)
MTSI 0405 null null Unrot. 1.0 1.0 (0405mtsi.001)
Induction Arrows (Wiese convention)
MTSI 0507 null null Unrot. 1.0 1.0 (0507mtsi.001)
Induction Arrows (Wiese convention)
↑ Real arrows
↑ Imag arrows
log period[s]


Induction vectors II
128 Hz
Real 0.5
6 Hz
Real 0.5
4 s
Real 0.5
512 s
Real 0.5
Atka-kuppelen
VNA1
Ice shear zone
Ekström ice shelf
Halvfarryggen
0 5 10 km
0 10 20 30 40 50 km
Legend
Seismometer
Grounding Line
Ice flow speed
0 m/yr
30 m/yr
60 m/yr
90 m/yr
120 m/yr
150 m/yr
180 m/yr
210 m/yr
240 m/yr
270 m/yr
300 m/yr
800 m/yr

Summary and outlook

- New instrumentation available for MT in polar regions
- MT data consistent with first order features (e.g. land-ocean transition)
- Full 3D inversion modelling necessary
- First conductivity model of the Ekström Ice Shelf region
- Integration with collocated seismic and GNSS data
  - Correlation of HF tides in seismic noise exists only on the ice shelf, **no** corresponding displacements in GNSS data near the grounding zone.

In the longer term…

- Building expertise and know-how at national and European levels for large-scale non-seismic geophysical imaging in polar and other cold regions

Acknowledgements

- We are grateful to a number of people who helped us in the field and with logistics, in particular the geophysics Üwis (2022/23) Alicia Rohnacher and Benita Wagner, the GIPP-MT team from GFZ, and Jölund Asseng from AWI.