EC-ESA 2nd European Polar Science Week, Copenhagen, 3-6 Sep 2024

UKANET: a continuous GNSS network for solid-Earth and atmospheric geophysics in western Antarctica

Peter Clarke, Achraf Koulali, Pingping Huang (Newcastle University)

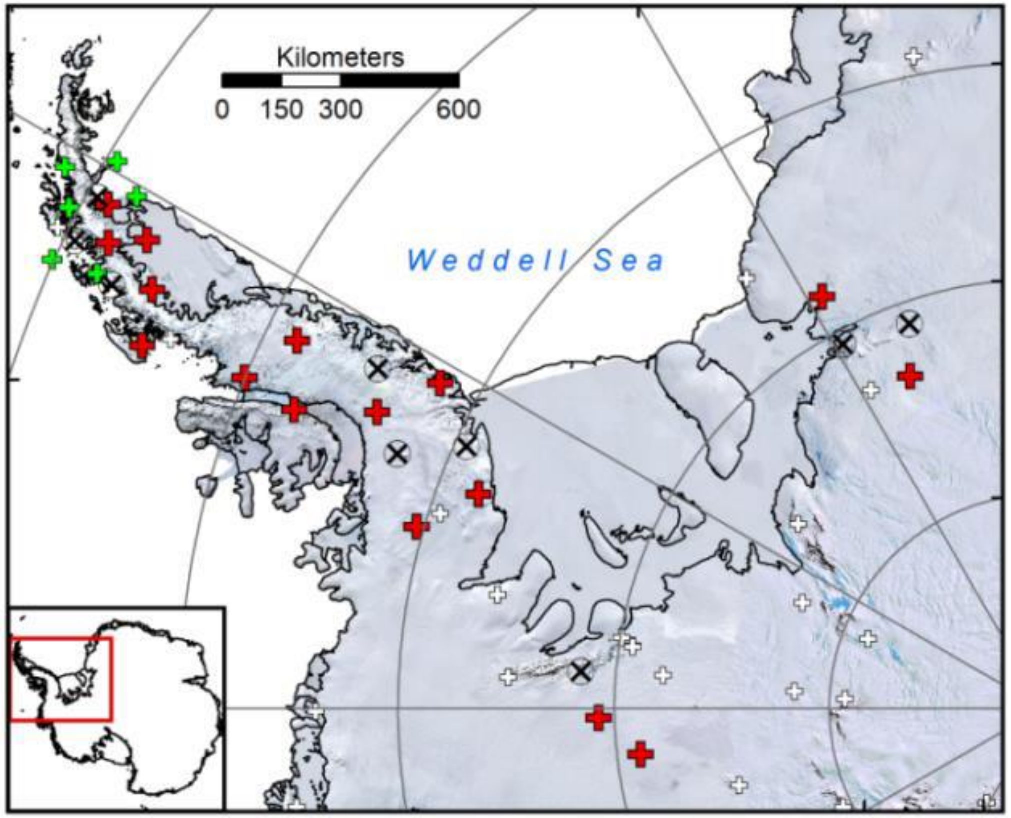
Mike Bentley, Grace Nield, Pippa Whitehouse (University of Durham)

Mervyn Freeman, David Maxfield, *et al.* (British Antarctic Survey)

with

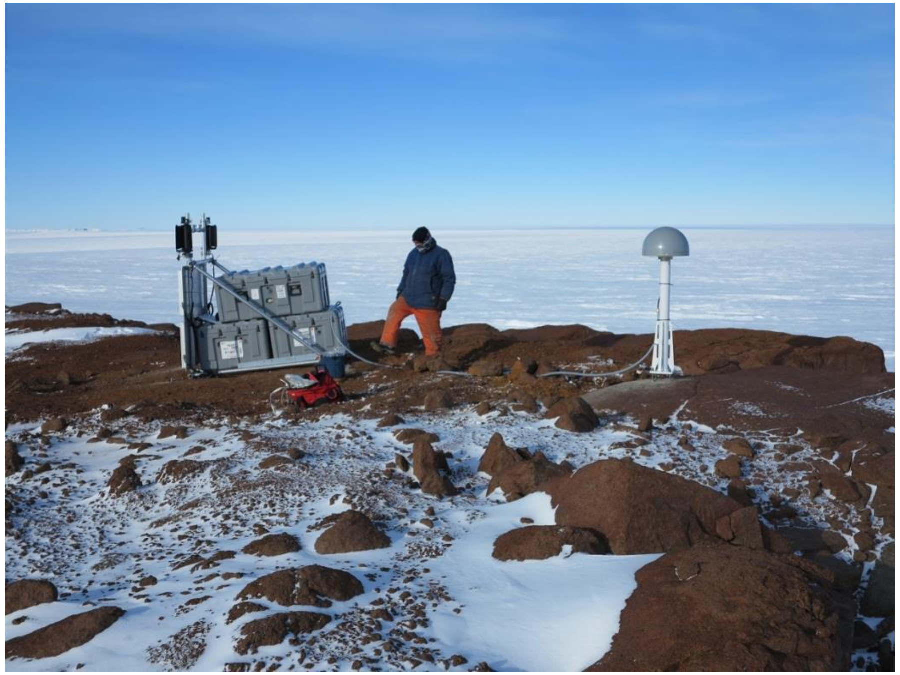
Terry Wilson, David Saddler, *et al.* (Ohio State University); **Matt King** (University of Tasmania); **Joe Pettit**, Nicolas Bayou, Erika Schreiber (EarthScope)

What is UKANET?



- Network of ~30 geodetic GNSS instruments deployed on bedrock across West Antarctica
- Continuous measurements of mm-precise 3D position, compared with records of snowfall and ice sheet change over decadal period

→ elastic and viscous properties of solid Earth



UKRI Natural Environment Research Council

Establishment: NERC grants NE/D009960/1, NE/F01466X/1 & NE/J005789/1, NE/K003674/1, NE/K004085/1.

Ongoing: NE/R002029/1, NE/Y006178/1.

US NSF / NASA support via OSU & EarthScope

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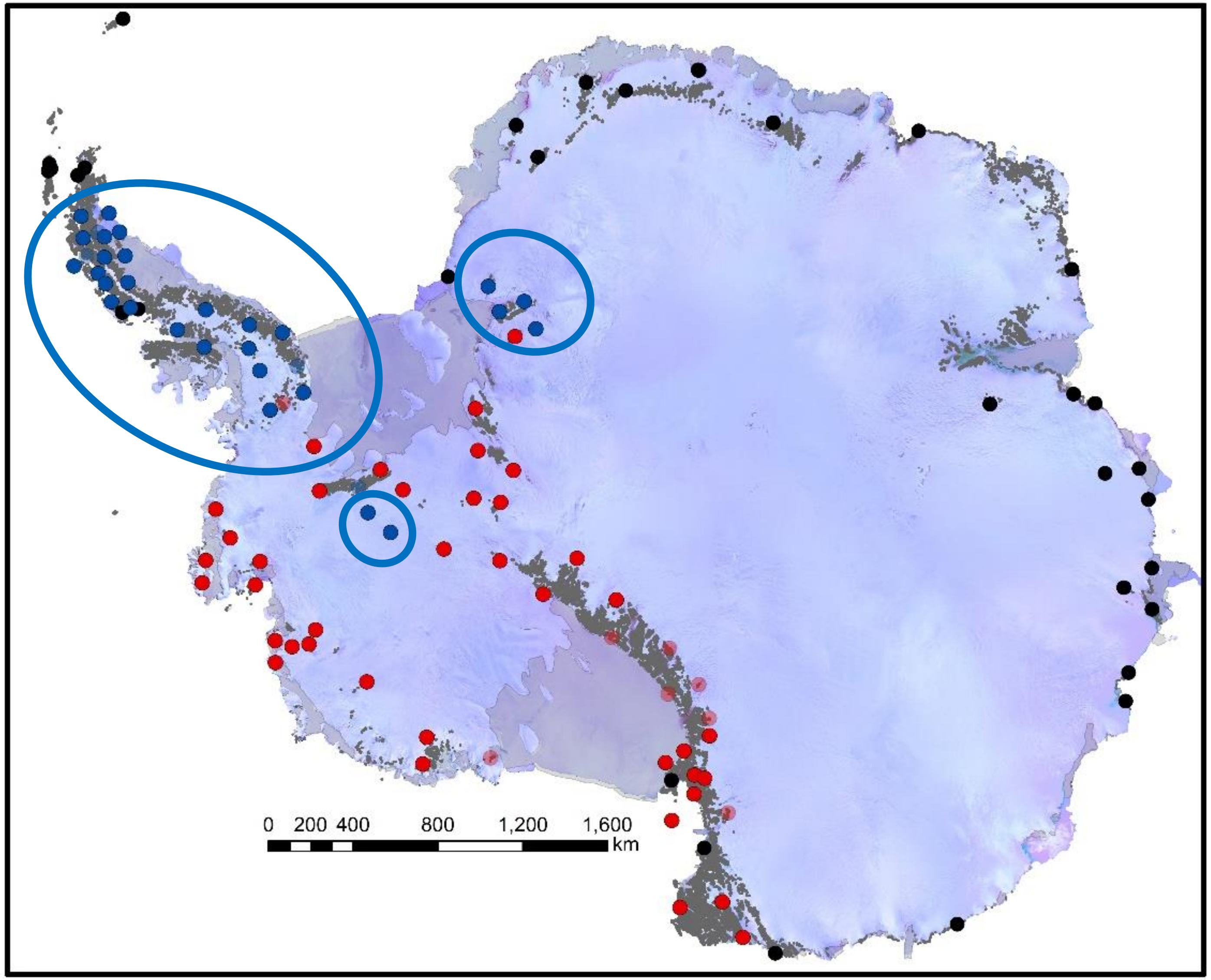
Where is UKANET?



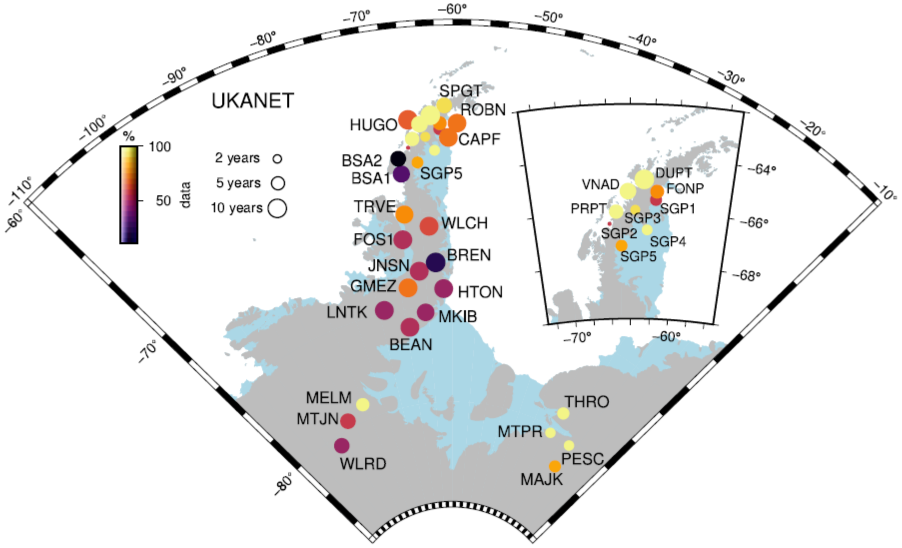
Antarctic GNSS networks

NB: several have co-located seismometers

Blue = UKANET
(amalgamated 2018 from various, mostly UK NERC, projects since ~2009)

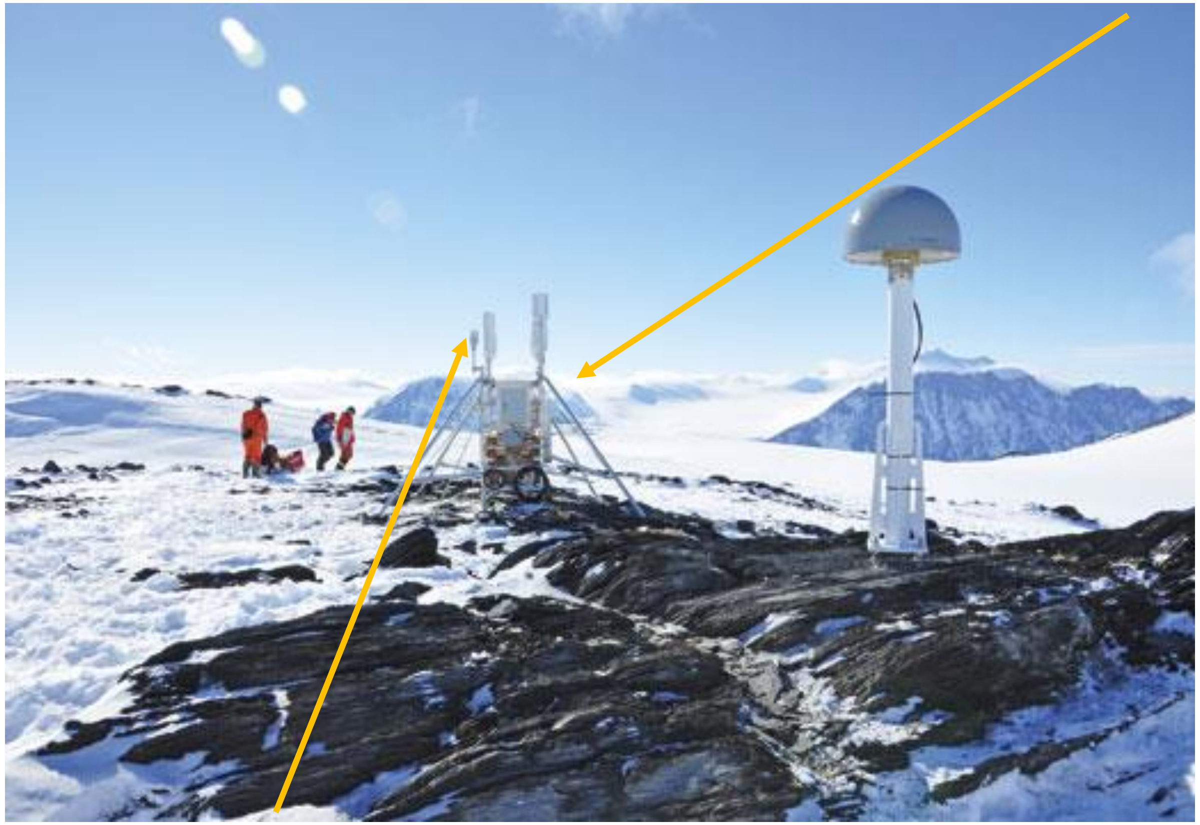
Red = US POLENET
(at end of its second tranche of ~10-year NSF funding since 2007)

Black = Other

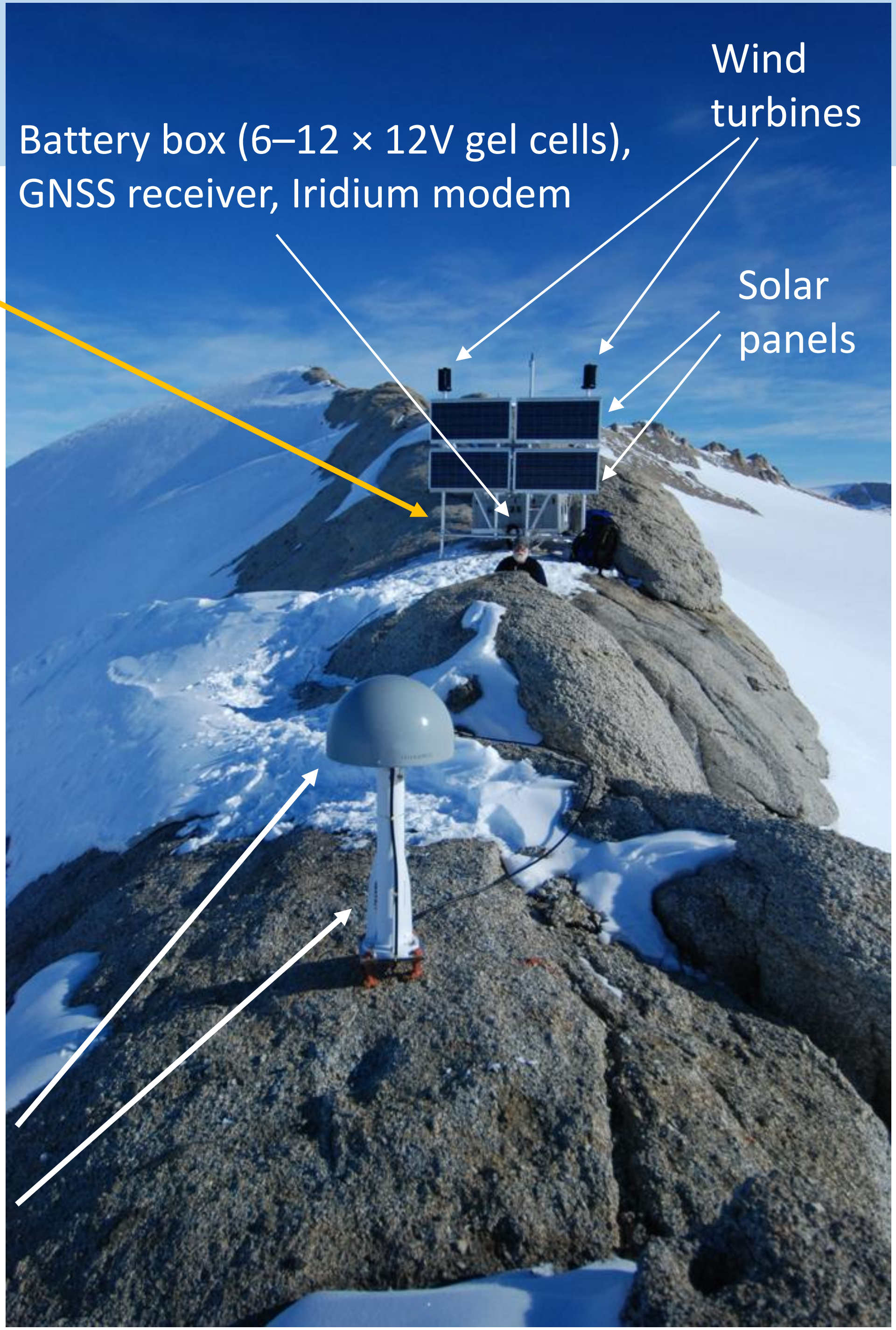


Typical UKANET site

Aluminium frame
(bolted down!)



Iridium antenna



GPS antenna in radome

Permanent steel monument
(bolted into bedrock)

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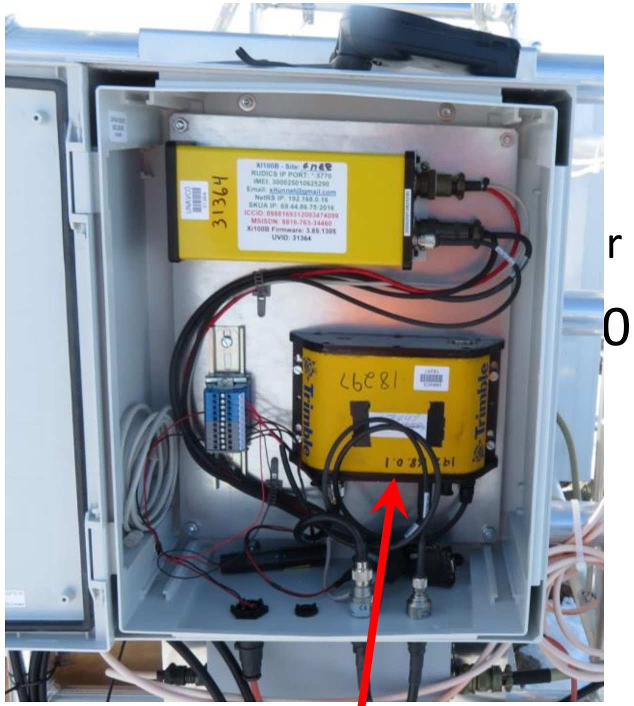
GNSS equipment



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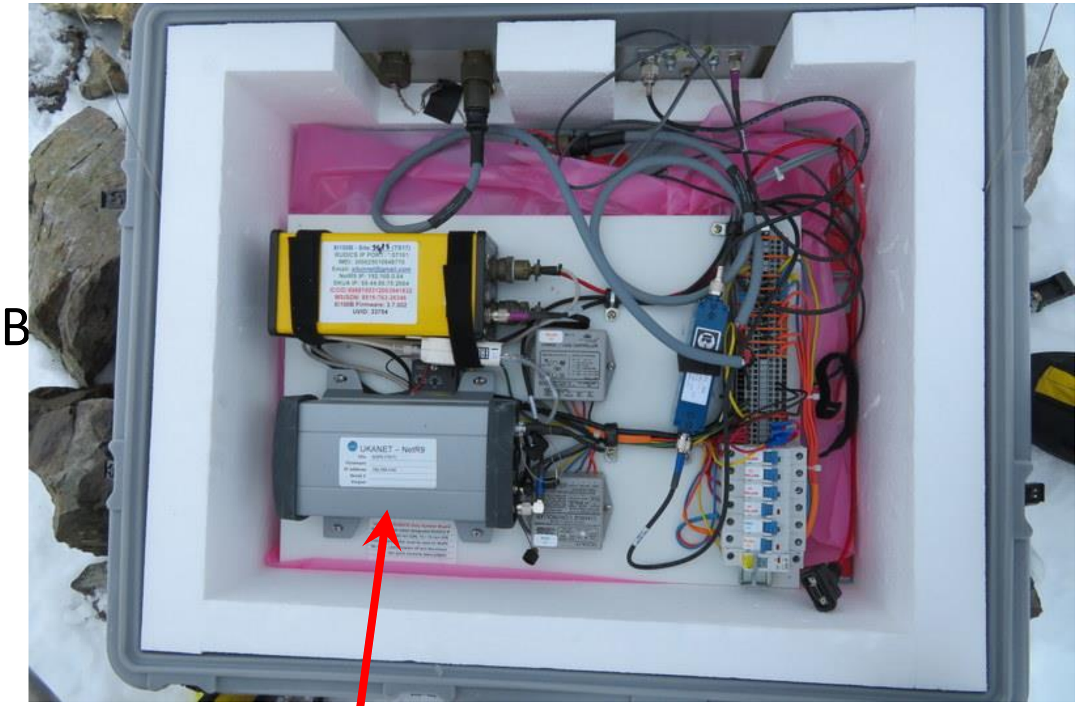
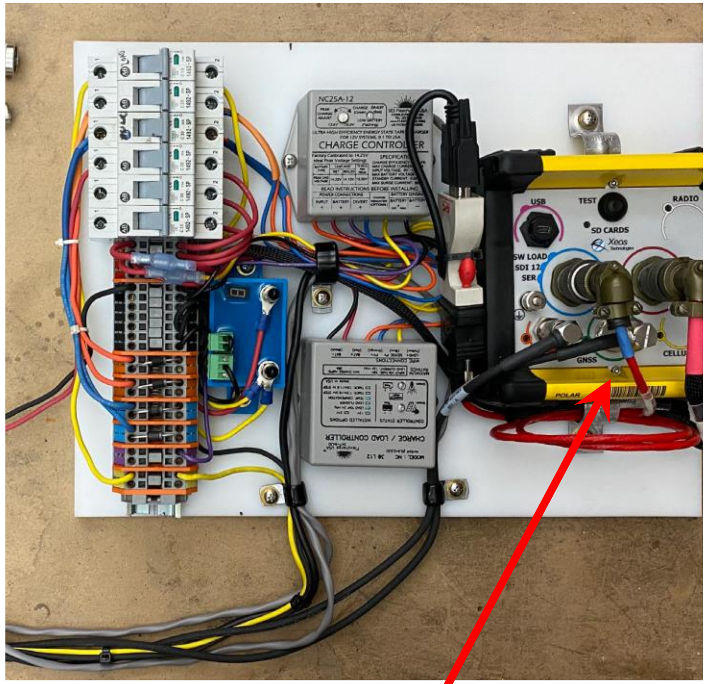


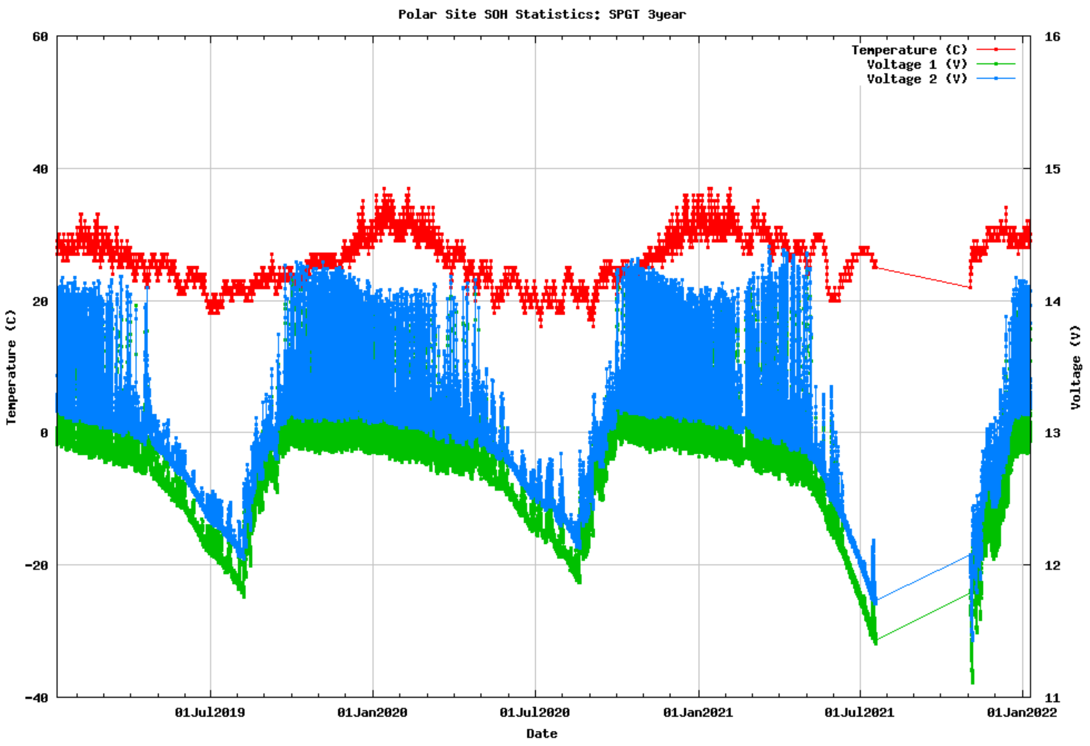


- Trimble NetRS
  - Ethernet adaptor
- Usually with XI100B Iridium modem

- Trimble NetR9
- Usually with XI100B Iridium modem
  - GPS + Iridium antennas
    (must be kept apart: notch filter [blue])

- AlertGeo Resolute
  - lower power
  - GPS+GLONASS
- Built-in Iridium modem

Recent improvements in power and autonomy



Significant improvements, leading to reduced logistic burden for BAS!
* a key part of this is access to US DoD Iridium data transfer *

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Data transmission and battery power

- GNSS consumes ~0.1 A / ~1.2 W year-round
  - sustainable for most sites on battery power
- Hourly data file ~120 KB (3 MB/day)
  - for "geodetic" 30 s sampling interval
  - requires ~5 min Iridium transmission window

Iridium data transfer cannot be sustained without solar power input!

- Iridium comms shutdown during winter
  - Mar-Jul until Oct, depending on latitude
  - daily wake-up opportunity
  - catch-up of data backlog in spring

Why is UKANET?

- Disciplines using Antarctic GNSS:
  - mantle and solid Earth geophysics
    - ice sheet mass balance (gravimetry) and modelling
  - plate tectonics / plate motion and earthquake geophysics
  - ionospheric physics and radio science (space weather)

  - fundamental geodesy and gravimetry
    - support for ice flow and other in situ measurements
  - geomorphology (landscape evolution)
  - sea level and tidal science (admittedly mostly at coastal locations!)
  - atmospheric science (e.g. retrieving water vapour variability)

Postglacial rebound (Glacial Isostatic Adjustment)

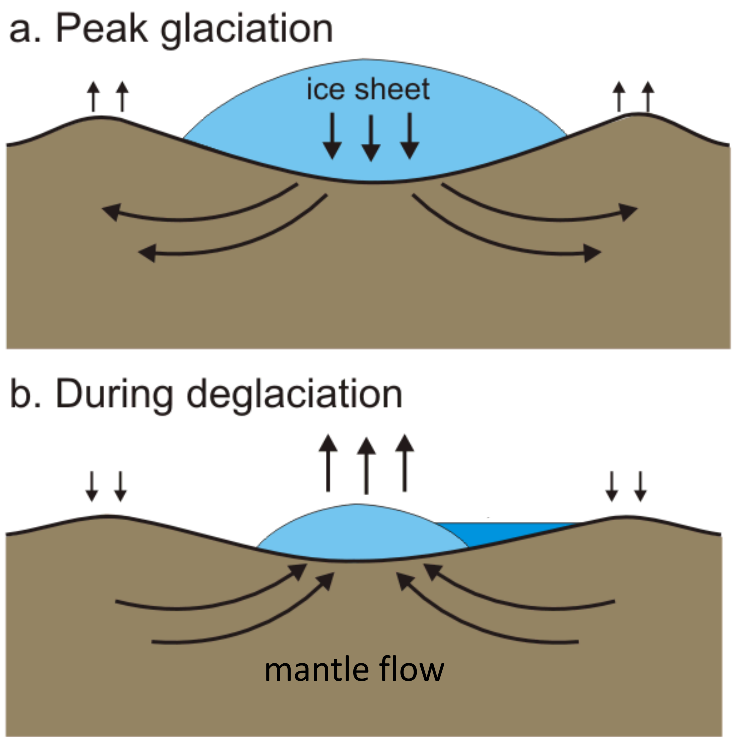
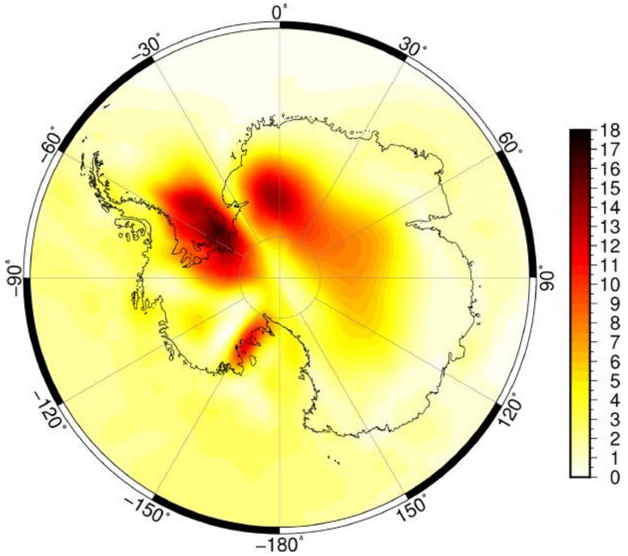
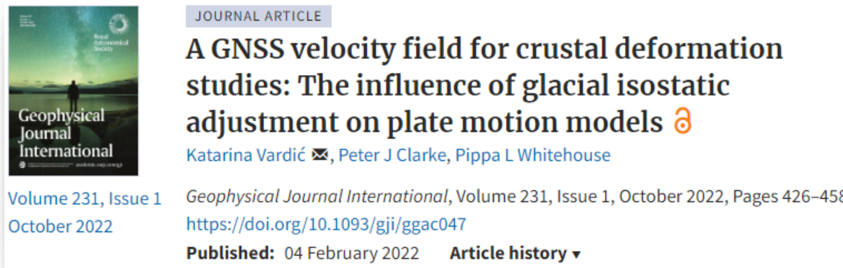


image credit: Natural Resources Canada

Not to scale vertically!

- The solid Earth subsides in response to ice sheet growth … and rebounds after the ice melts
- Subsidence and rebound continue for decades to millennia because the interior of the Earth is *viscous*
- Ongoing rebound due to past ice melt complicates attempts (using GRACE gravimetry) to quantify present ice melt
- We try to *model* the signal due to past ice melt, and remove it from the gravity observations … but models must be validated!





JOURNAL ARTICLE

A GNSS velocity field for crustal deformation studies: The influence of glacial isostatic adjustment on plate motion models

Katarina Vardić, Peter J Clarke, Pippa L Whitehouse

Volume 231, Issue 1
October 2022

Geophysical Journal International, Volume 231, Issue 1, October 2022, Pages 426–458, https://doi.org/10.1093/gji/ggac047

Published: 04 February 2022 **Article history ▾**

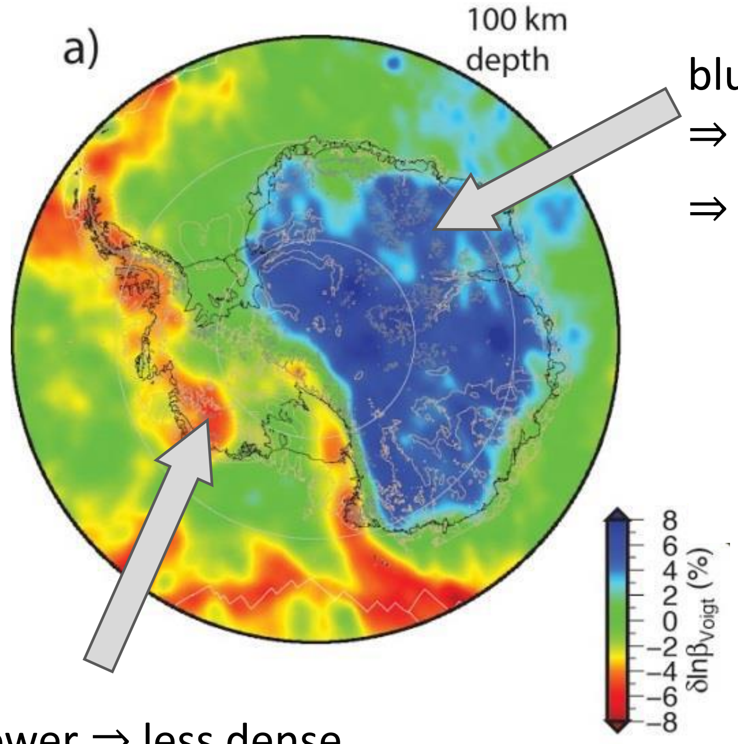
mm/yr EWH uncertainty due to GIA models *(Vardić et al., 2022, GJI)* – ~25 Gt/yr range

Mantle viscosity (1)

- Global average mantle viscosity 10^{20}-10^{21} Pa s
  ⇒ relaxation times of several thousand years

- Evidence suggests mantle viscosity much lower across West Antarctica and Antarctic Peninsula:

  1) Seismic velocities



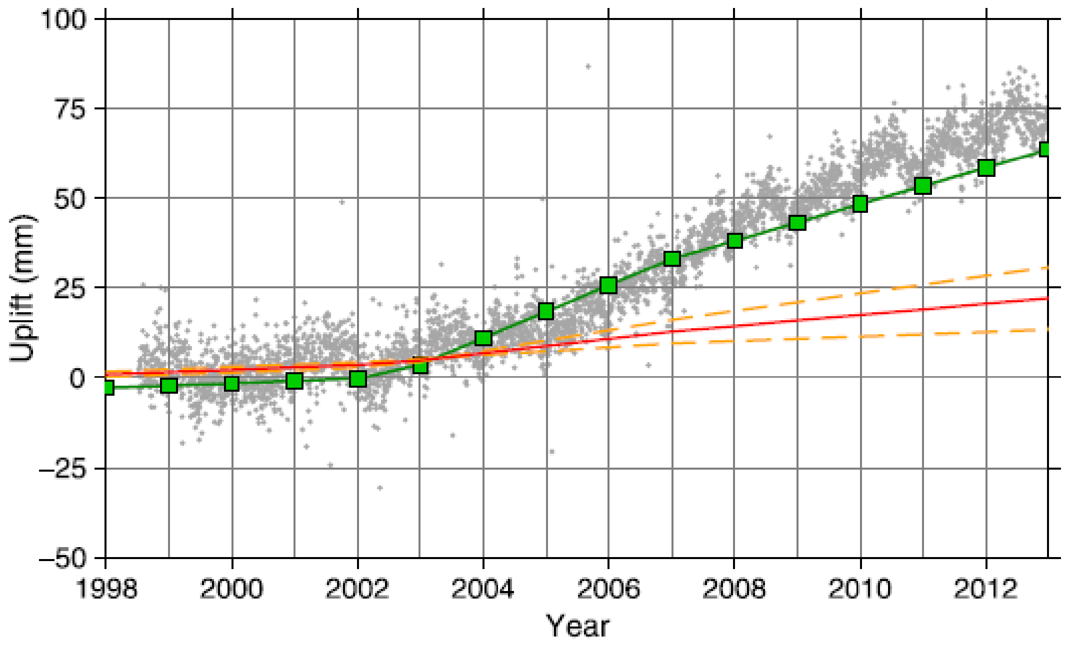
blue = faster
⇒ denser ⇒ colder
⇒ higher viscosity

red = slower ⇒ less dense
⇒ hotter ⇒ lower viscosity

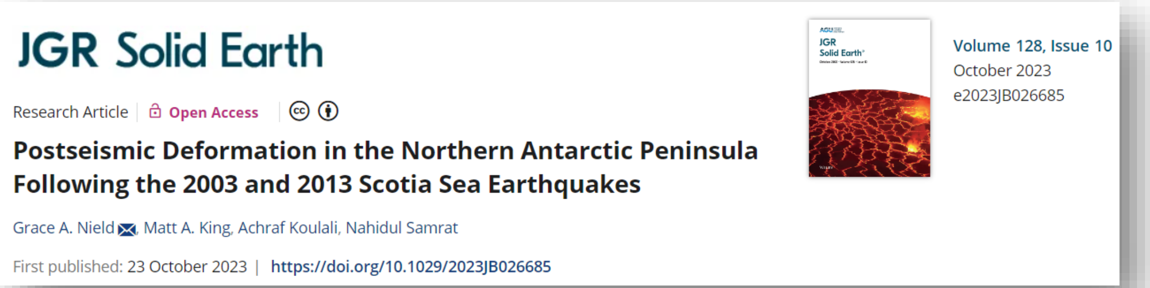
(image: Lloyd et al., 2020, JGR)

Mantle viscosity (2)

- Global average mantle viscosity 10^{20}-10^{21} Pa s ⇒ relaxation times of several thousand years
- Evidence suggests mantle viscosity much lower across West Antarctica and Antarctic Peninsula:
  1) Seismic velocities
  2) GNSS time series



GPS time series from northern Antarctic Peninsula *(Nield et al., 2014, EPSL)*


JGR Solid Earth

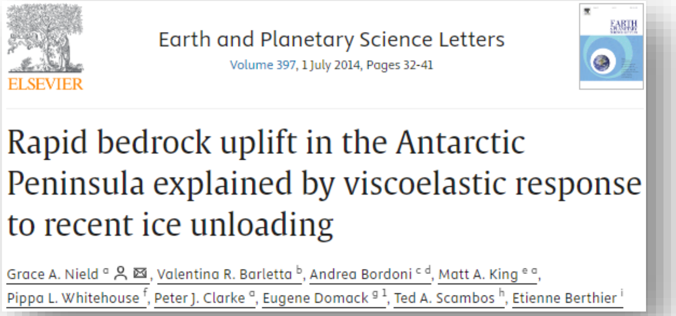
Volume 128, Issue 10
October 2023
e2023JB026685

Research Article | Open Access

Postseismic Deformation in the Northern Antarctic Peninsula Following the 2003 and 2013 Scotia Sea Earthquakes

Grace A. Nield, Matt A. King, Achraf Koulali, Nahidul Samrat

First published: 23 October 2023 | https://doi.org/10.1029/2023JB026685


ELSEVIER

Earth and Planetary Science Letters
Volume 397, 1 July 2014, Pages 32-41

Rapid bedrock uplift in the Antarctic Peninsula explained by viscoelastic response to recent ice unloading

Grace A. Nield [a], Valentina R. Barletta [b], Andrea Bordoni [c d], Matt A. King [e a], Pippa L. Whitehouse [f], Peter J. Clarke [a], Eugene Domack [g 1], Ted A. Scambos [h], Etienne Berthier [i]

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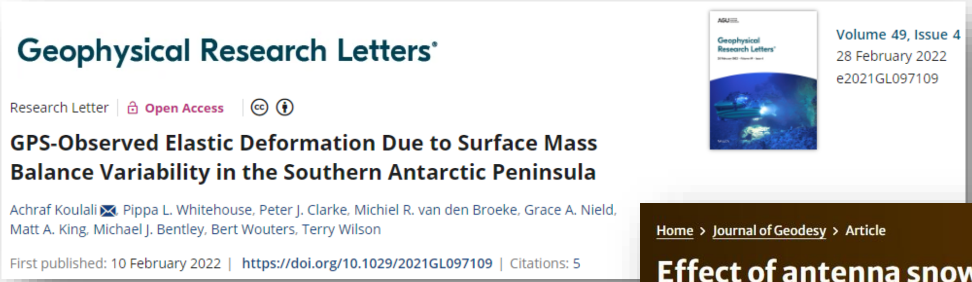
Present-day elastic effects

- Year-to-year surface mass balance (snow accumulation / redistribution / melt) causes fluctuations in bedrock site position
- High-resolution meteorological models needed to account for this … but imperfect
- Effects are small but significant – vital to minimise other disturbances to site and equipment (especially GNSS antenna)
- Important to correct time series, not derived velocities


Geophysical Research Letters

Volume 49, Issue 4
28 February 2022
e2021GL097109

Research Letter | Open Access

GPS-Observed Elastic Deformation Due to Surface Mass Balance Variability in the Southern Antarctic Peninsula

Achraf Koulali, Pippa L. Whitehouse, Peter J. Clarke, Michiel R. van den Broeke, Grace A. Nield, Matt A. King, Michael J. Bentley, Bert Wouters, Terry Wilson

First published: 10 February 2022 | https://doi.org/10.1029/2021GL097109 | Citations: 5

GNSS time series from Southern Antarctic Peninsula *(Koulali et al., 2021, GRL)*


Home > Journal of Geodesy > Article

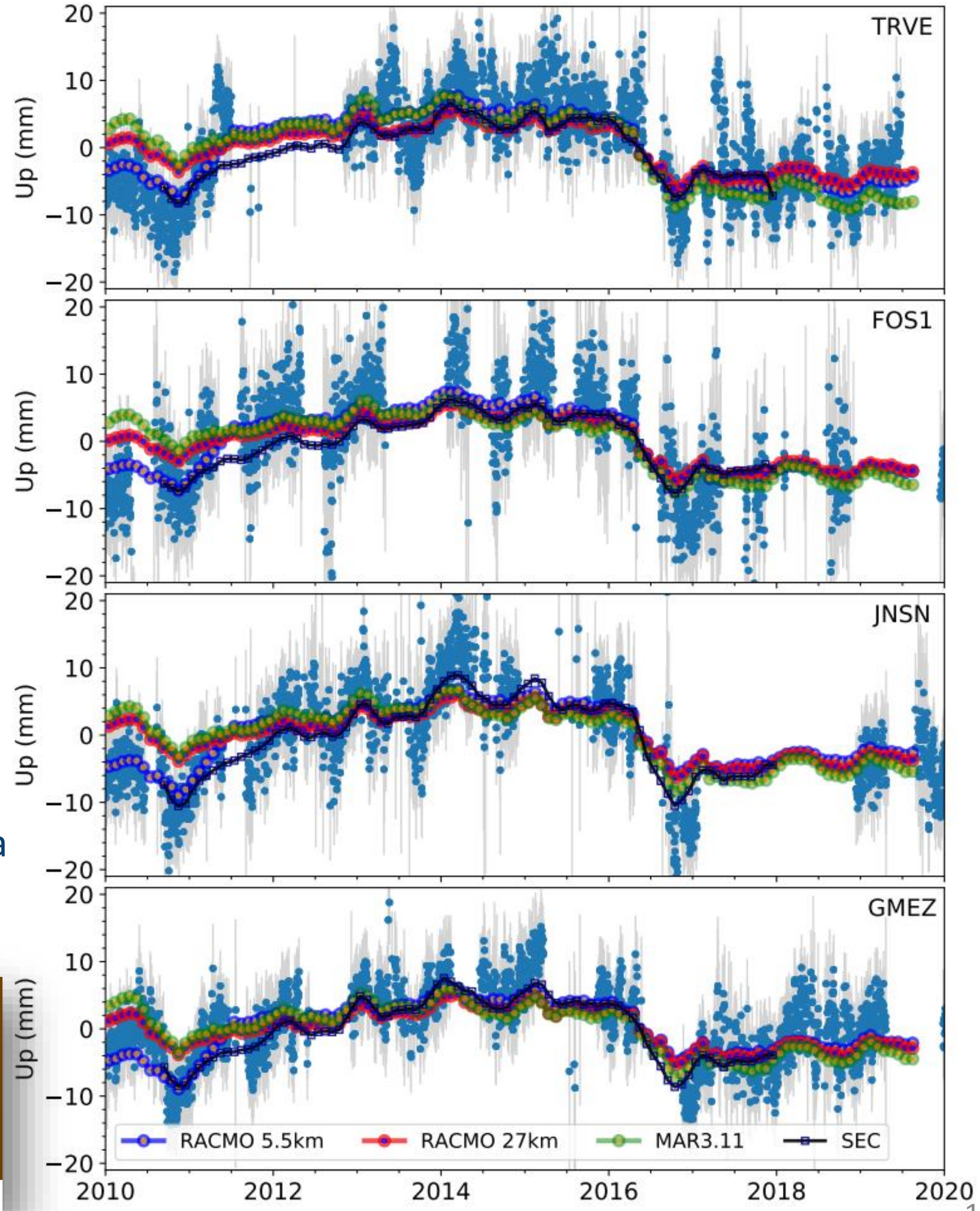
Effect of antenna snow intrusion on vertical GPS position time series in Antarctica

Original Article | Open access | Published: 12 October 2020

Volume 94, article number 101, (2020) Cite this article

Journal of Geodesy

A. Koulali & P. J. Clarke



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TEC and space weather

- Interaction of the solar wind and geomagnetic field affects ionospheric Total Electron Content
  - implications for global telecoms, power grids, etc
- Observations near N & S magnetic poles are particularly useful for monitoring
  - southern hemisphere is under-sampled
  - in recent decades, movement of magnetic poles places UKANET sites conjugate to N American observatories
- Possibility of high-rate observations in short term
  - e.g. first interhemispheric multi-point study of south polar total eclipse, in December 2021

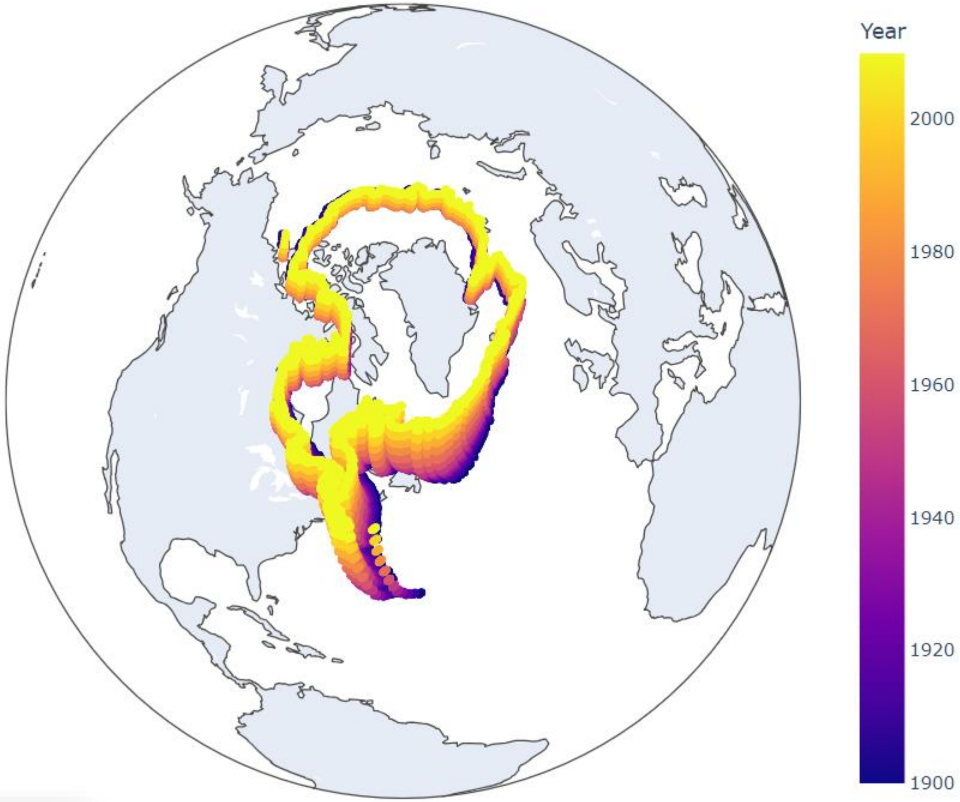

image credit: Kristina Collins, UCLA

JGR Space Physics

Volume 128, Issue 3
March 2023
e2022JA031142

Research Article | Open Access

The 2021 Antarctic Total Eclipse: Ground Magnetometer and GNSS Wave Observations From the 40 Degree Magnetic Meridian

S. E. Coyle, M. D. Hartinger, C. R. Clauer, J. B. H. Baker, I. Cnossen, M. P. Freeman, J. M. Weygand

First published: 16 February 2023 | https://doi.org/10.1029/2022JA031142 | Citations: 2

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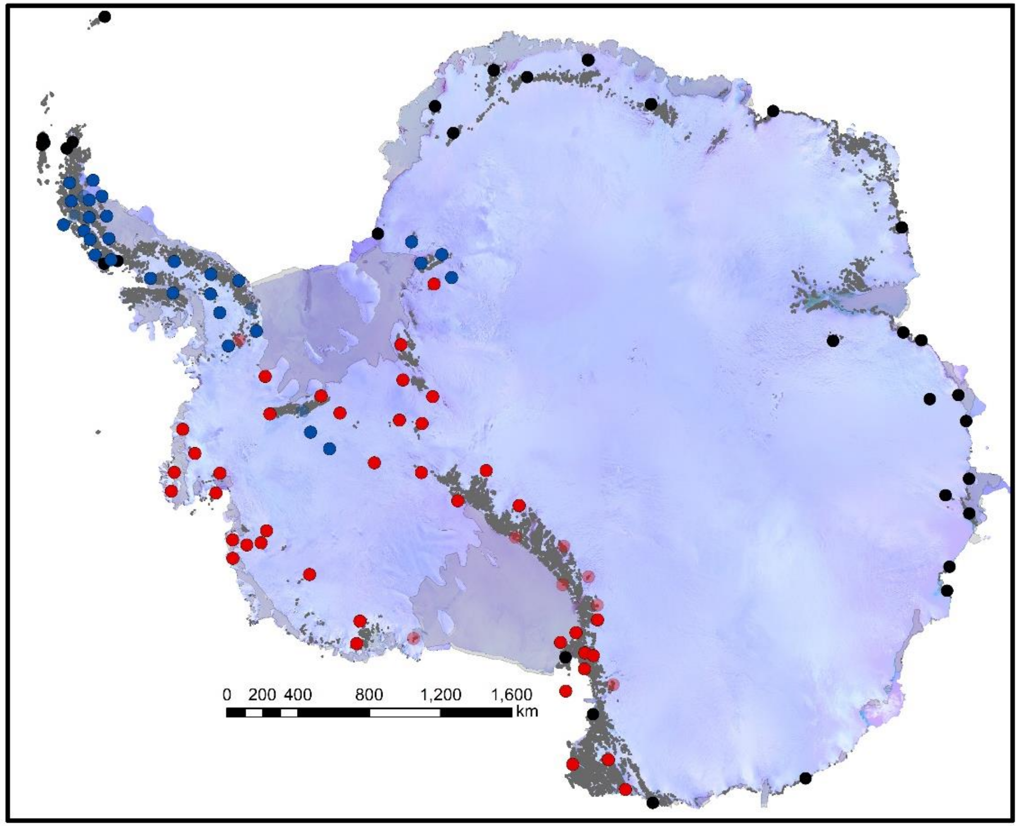
Whither UKANET – and Antarctic GNSS in general?

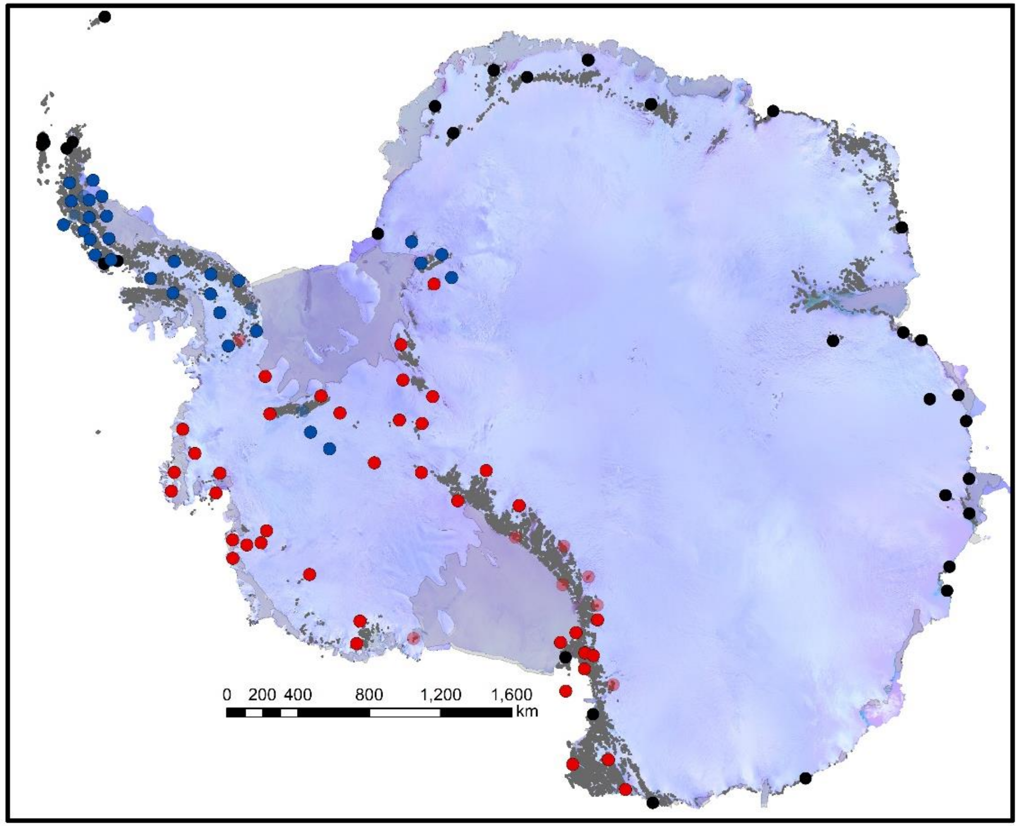
- UKANET (and POLENET) delivers scientific GNSS data to a number of international communities (via GAGE https://www.unavco.org/data/)
    - also quality-controlled data products via e.g. GIANT-REGAIN
- A (slightly reduced) UKANET is supported in the medium term with BAS National Capability funding
    - monumentation left in place at decommissioned sites

… what about POLENET?



Take-home messages

- Establishing and maintaining geodetic networks in interior Antarctica is hard!
  - high CO_2/$$$ installation and decommissioning costs
  - high ongoing power/comms requirements
- Variety of scientific communities can benefit from access to GNSS data and products
  - enables continued evolution of science goals
- FAIR data access is great, but to justify continued support for data collection, users <u>must</u> credit original sources
  - also use curated / quality-controlled derived datasets →



ESSD-2024-355 | Data description paper

Received: 16 Aug 2024

Advancing geodynamic research in Antarctica: Reprocessing GNSS data to infer consistent coordinate time series (GIANT-REGAIN)

Eric Buchta, Mirko Scheinert, Matt A. King, Terry Wilson, Achraf Koulali, Peter J. Clarke, Demián Gómez, Eric Kendrick, Christoph Knöfel, and Peter Busch