“RINGS” kick-off meeting

RINGS: Collaborative international effort to map all Antarctic ice-sheet margins

International initiative “RINGS” aims to bridge the gap in disparate satellite observations and will help constrain societally-relevant Antarctic contributions to future sea-level rise.

House-keeping announcements

- 94 people registered for the meeting today.
- PLEASE
  - Mute yourself.
  - Communicate primarily using chat system.
  - Rise your hand in question/discussion sessions.
- We try to manage this meeting in one hour; if time is not sufficient, please post your feedback and comments in the survey form, which will be announced at the end of this meeting.
- This meeting is being recorded.

Agenda of the meeting

- Background and scientific rationales
- Lessons from prior surveys
  - NASA's Operation Ice Bridge
  - PolarGAP
- SCAR Action Group
  - Membership and links to other activities
  - Tasks and milestones
  - logo

RINGS: Collaborative international effort to map all Antarctic ice-sheet margins

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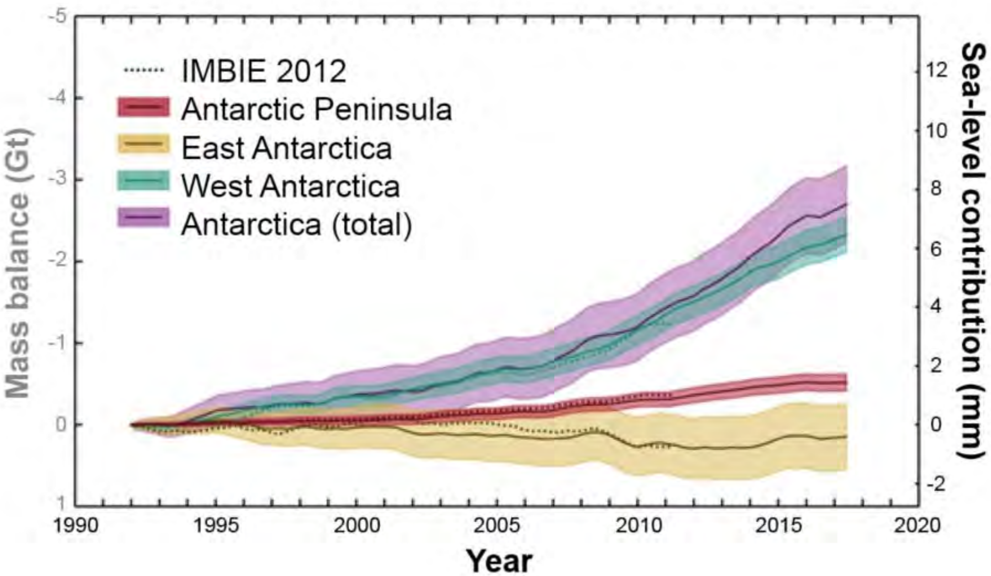
Satellite-based observations of recent Antarctic mass balance (or sea-level contribution)



The IMBIE team (2019, Nature)

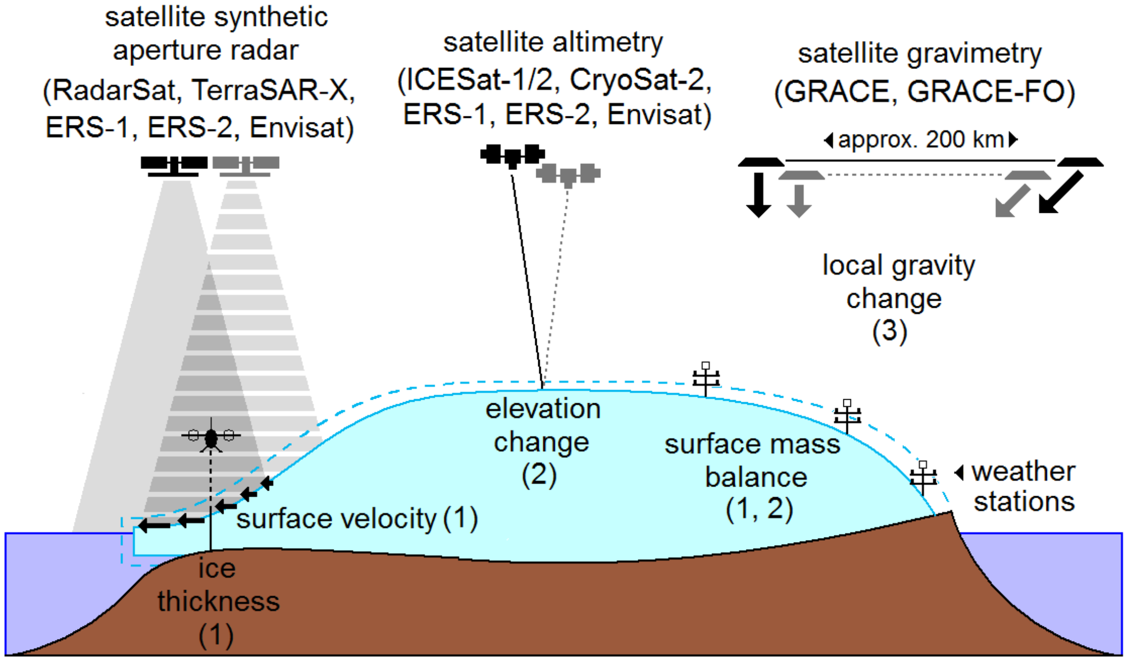
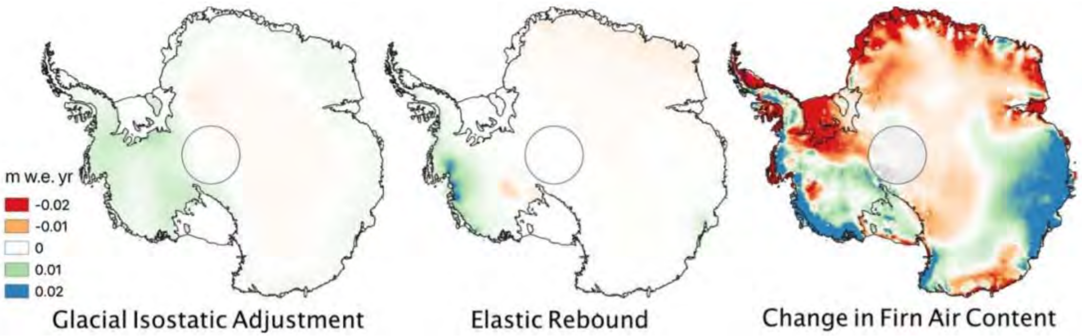
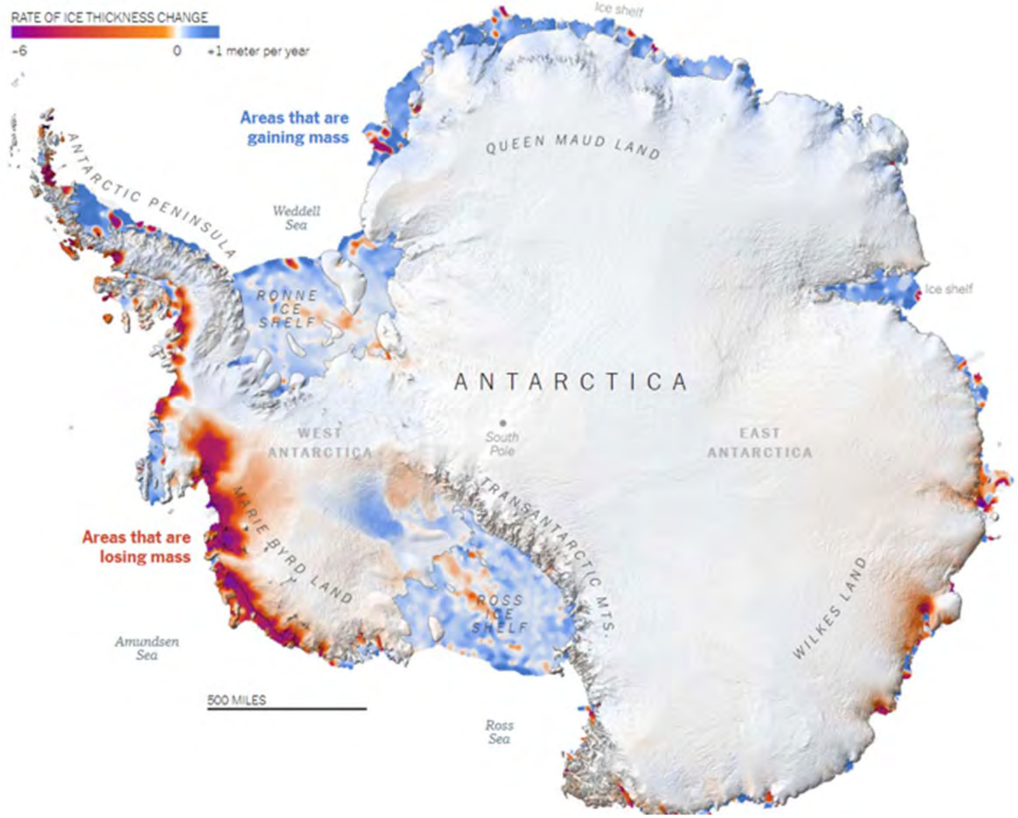


Image: @GlacierBytes

Monitoring of Antarctic mass balance using satellite remote sensing - altimetry monitoring -

- **Pros**
  - High-resolution in space and time
- **Cons**
  - Converting height changes to mass changes requires knowledge of snow density.

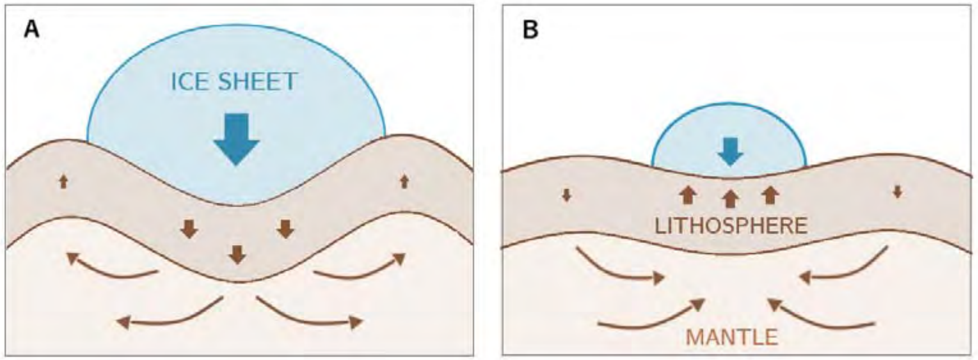


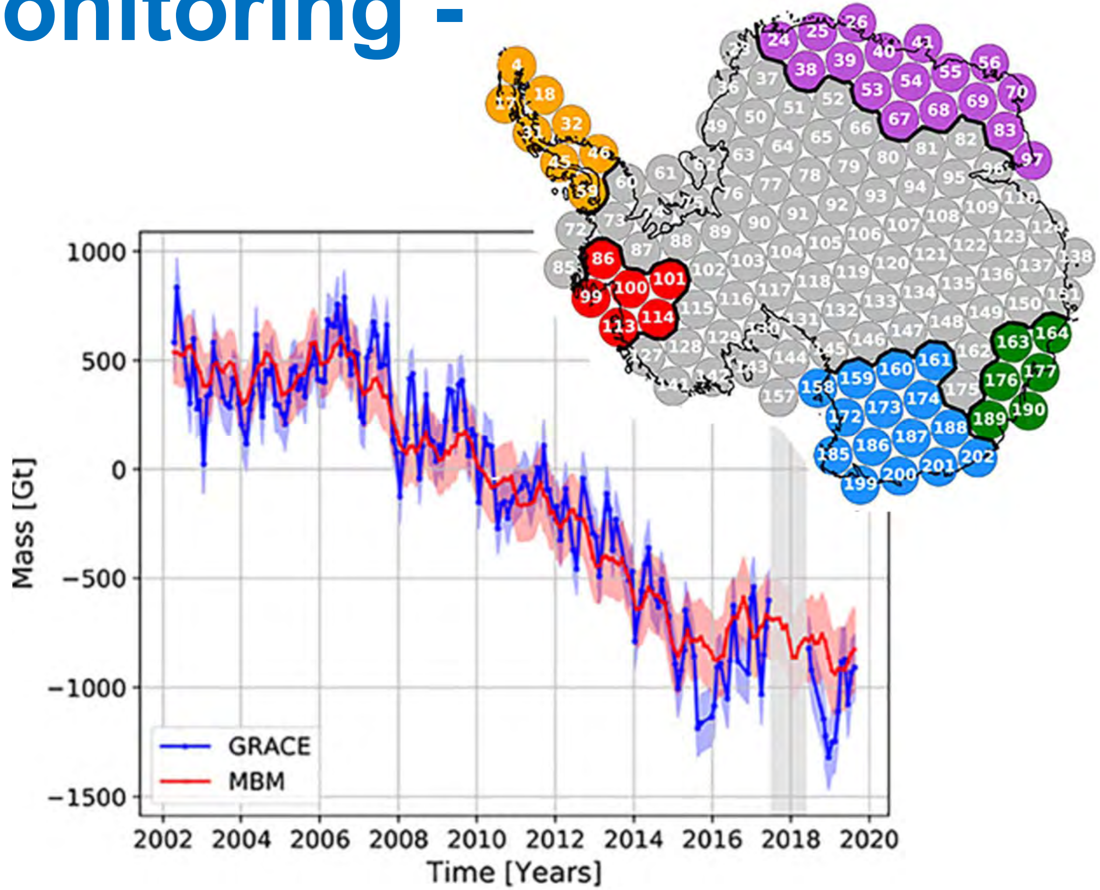


Smith et al. (2020, Science)

Monitoring of Antarctic mass balance using satellite remote sensing - gravity monitoring -

- **Pros**
  - Direct measurement of mass change
- **Cons**
  - Low spatial resolutions
  - Correction needed for bedrock uplift and mantle inflow caused by deglaciation since 20k years ago.



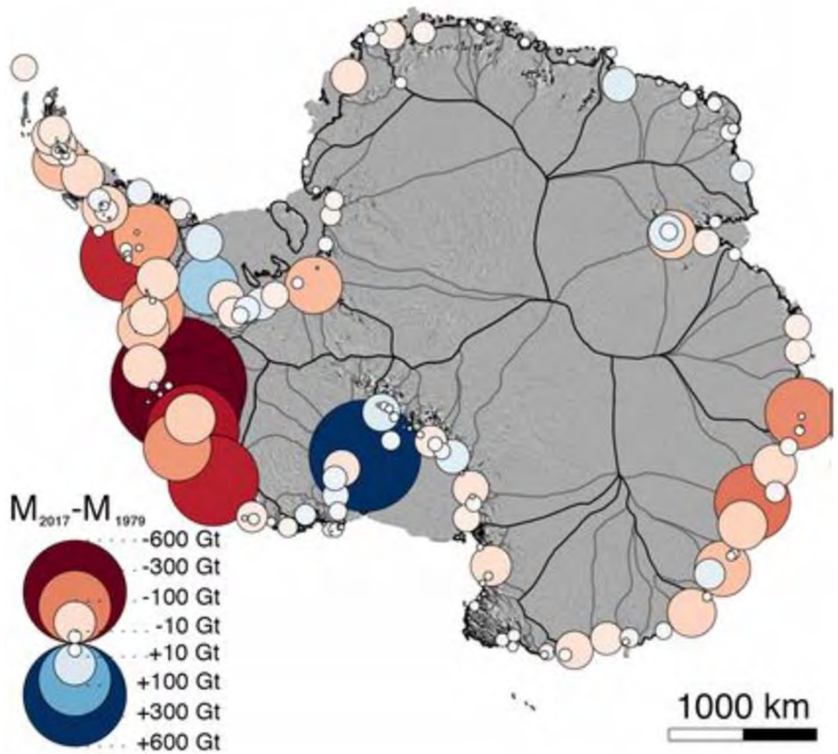


Velicogna et al. (2020, GRL)

Monitoring of Antarctic mass balance using satellite remote sensing - Input-output method -

(mass balance)
= (mass input) – (mass output)

- **Pros**
  - Process of loss/gain can be known.
- **Cons**
  - ….



Rignot et al. (2019, PNAS)

Input-output method for ice-sheet mass balance

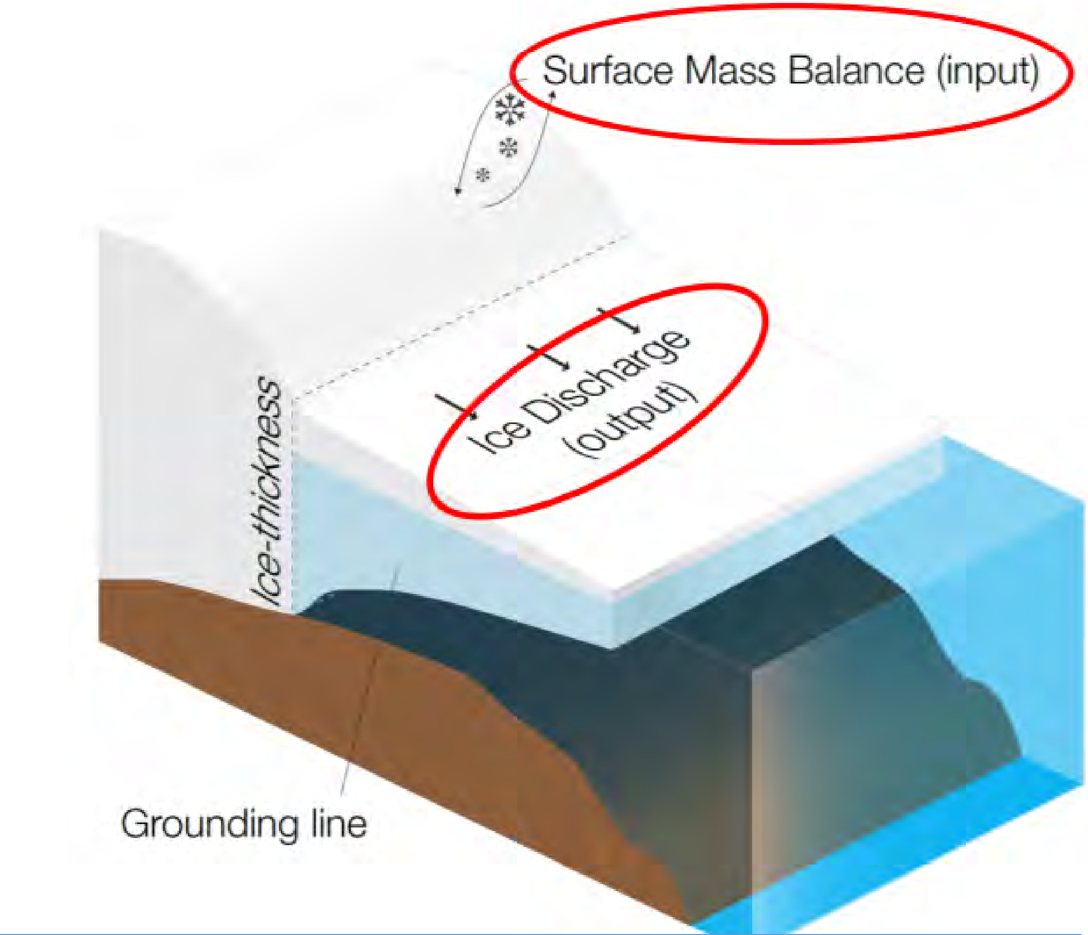


Illustration: Mouginot (UCI)

Input:

- surface mass balance (climate models)

Outputs:

- ice discharge through the ice-sheet margin
- surface/basal melting of grounded ice

(ice discharge)

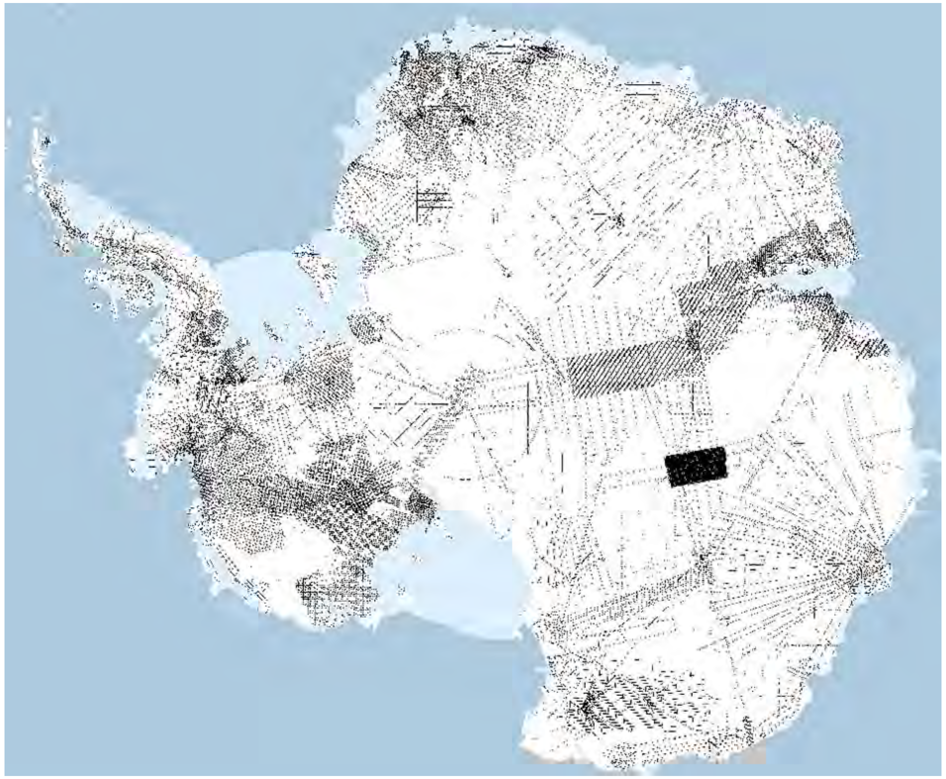
= (flow speed) x (ice thickness)

= (flow speed) x (ice elevation – bed elevation)

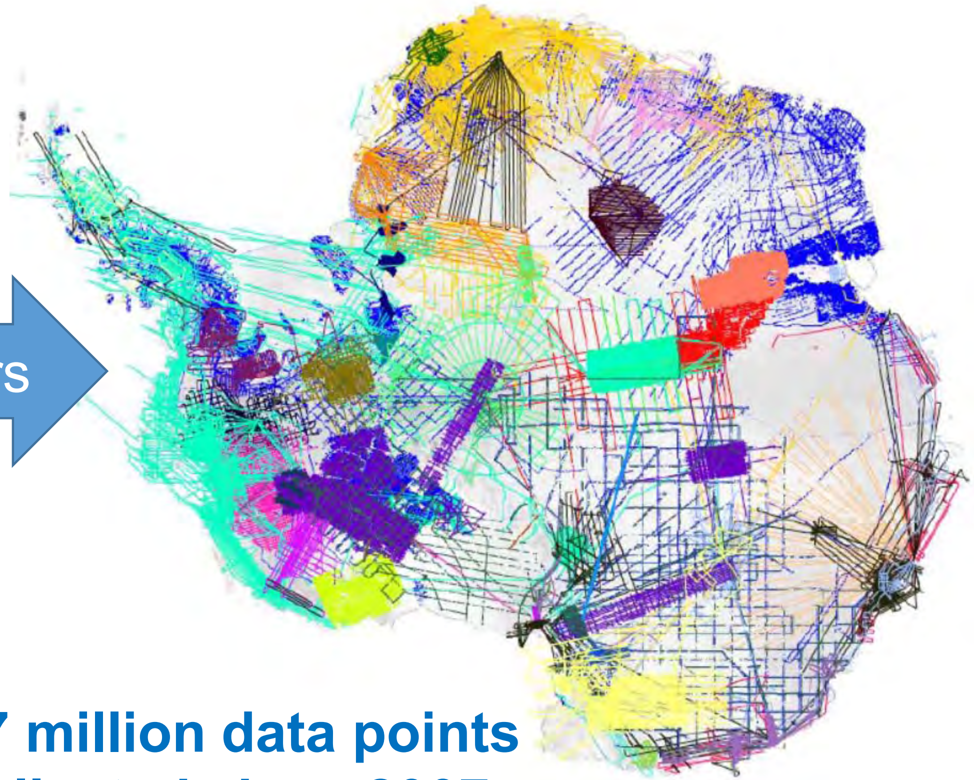
Monitorable by satellites (flow speed, ice elevation)

Need to know by airborne radar surveys (bed elevation)

Bed elevation data coverage is improving



~10 years

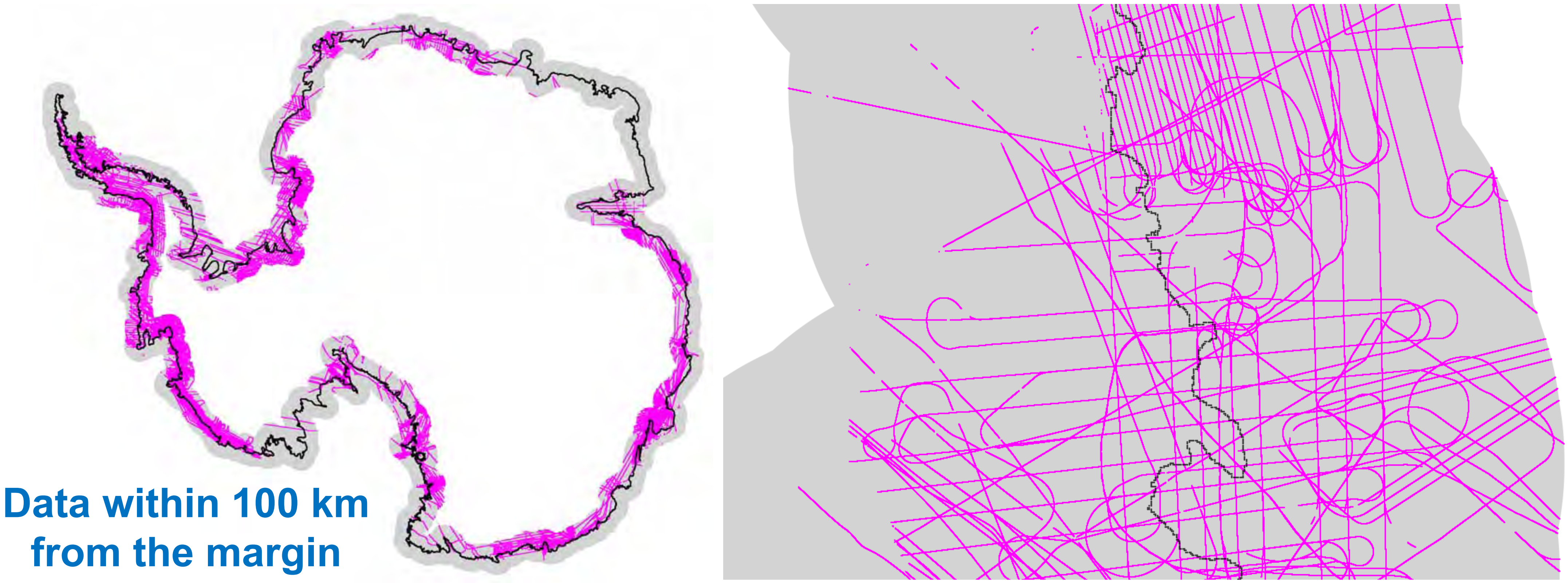


67 million data points collected since 2007

Fretwell et al. (2013, TC)

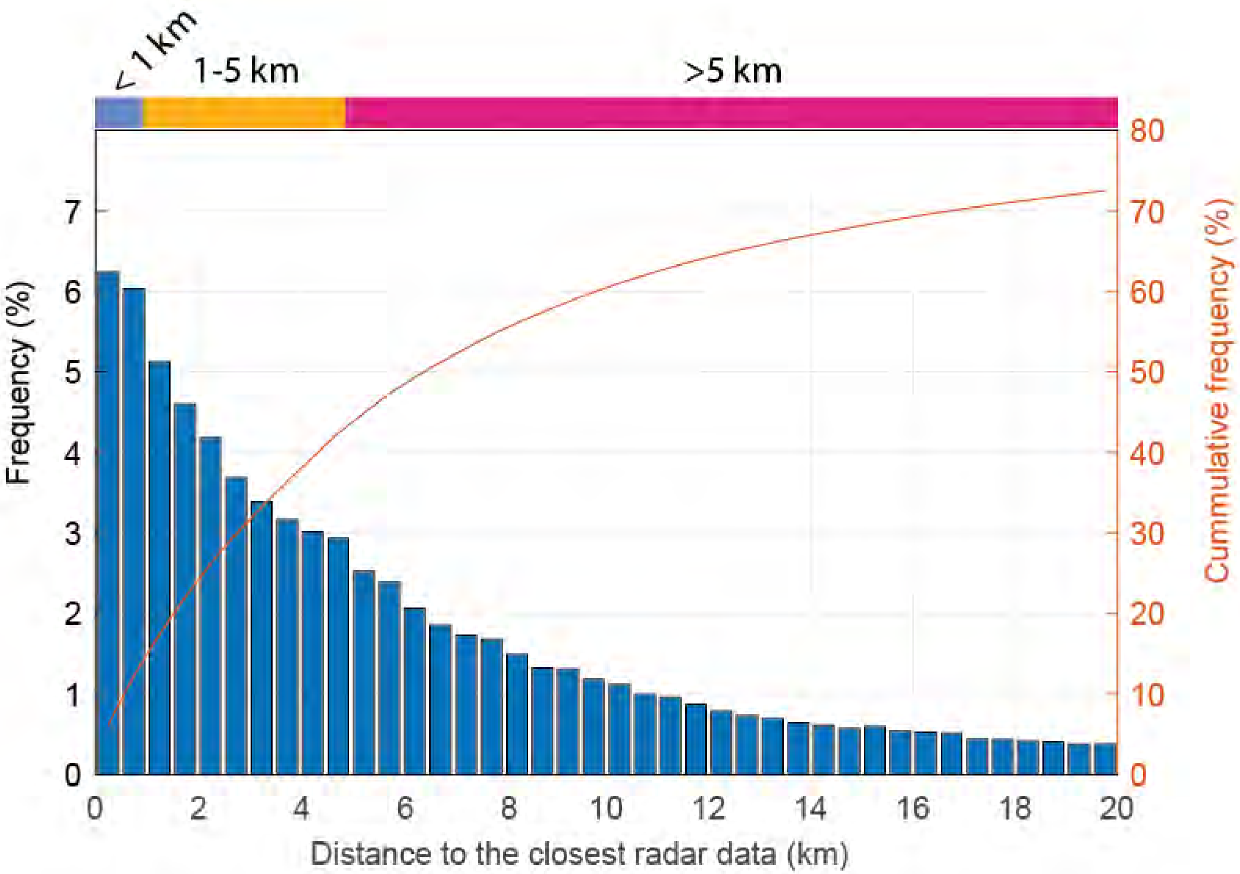
Morlighem et al. (2020, Nat. Geosci.)

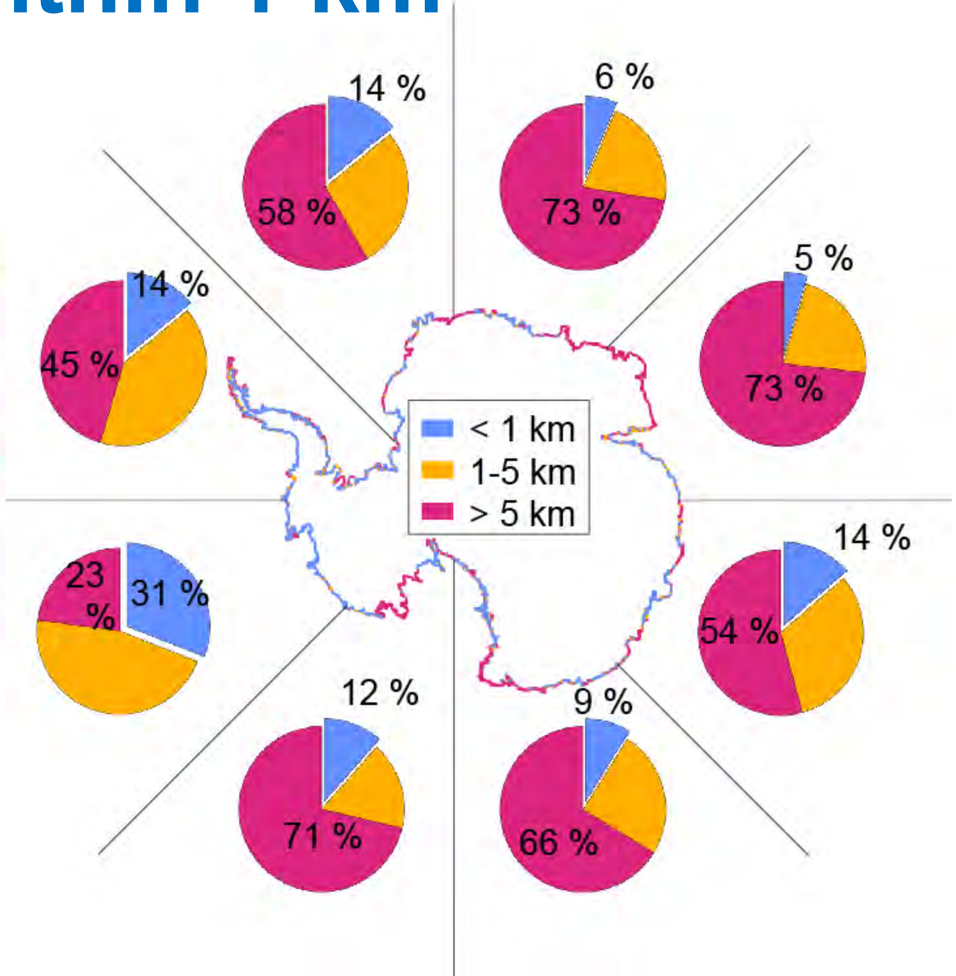
Compiling radar data collected for various purposes



Data source: Morlighem et al. (2020, Nat. Geosci.)

Only 12% of the Antarctic ice-sheet margin has radar data within 1 km



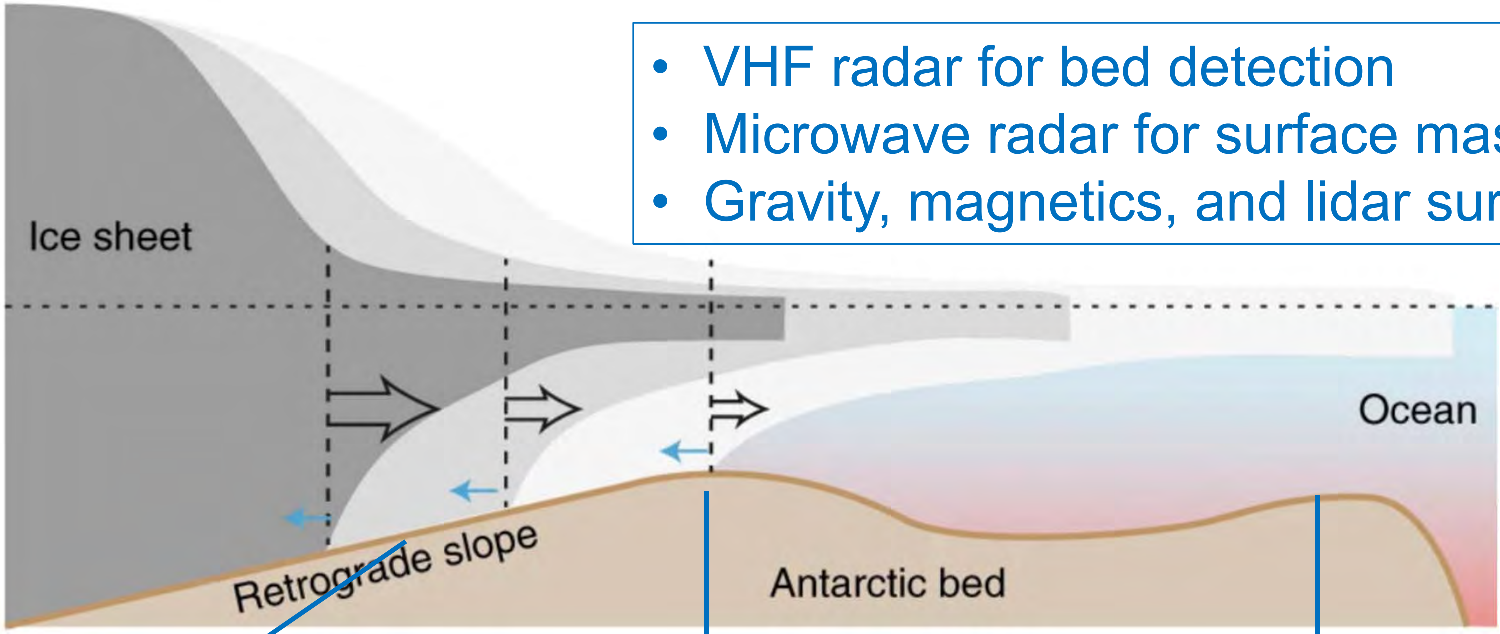


Data source: Morlighem et al. (2020, Nat. Geosci.)

“RINGS” in brief

- ✓ **Interdisciplinary, coordinated airborne missions**
- ✓ **Primary target = bed topography at the margin**
  - ✓ Complete reference bed topography data for robust assessments of ice discharge from all around Antarctica.
- ✓ **Primary RING + seaward + landward RINGS**
  - ✓ Prediction of future retreat of the margin
  - ✓ Sub-ice-shelf bathymetry and quantification of ice-ocean interactions
  - ✓ Geology and subglacial hydrology

RINGS's ultimate goals: accurate monitoring and future predictions



- VHF radar for bed detection
- Microwave radar for surface mass balance
- Gravity, magnetics, and lidar surveys

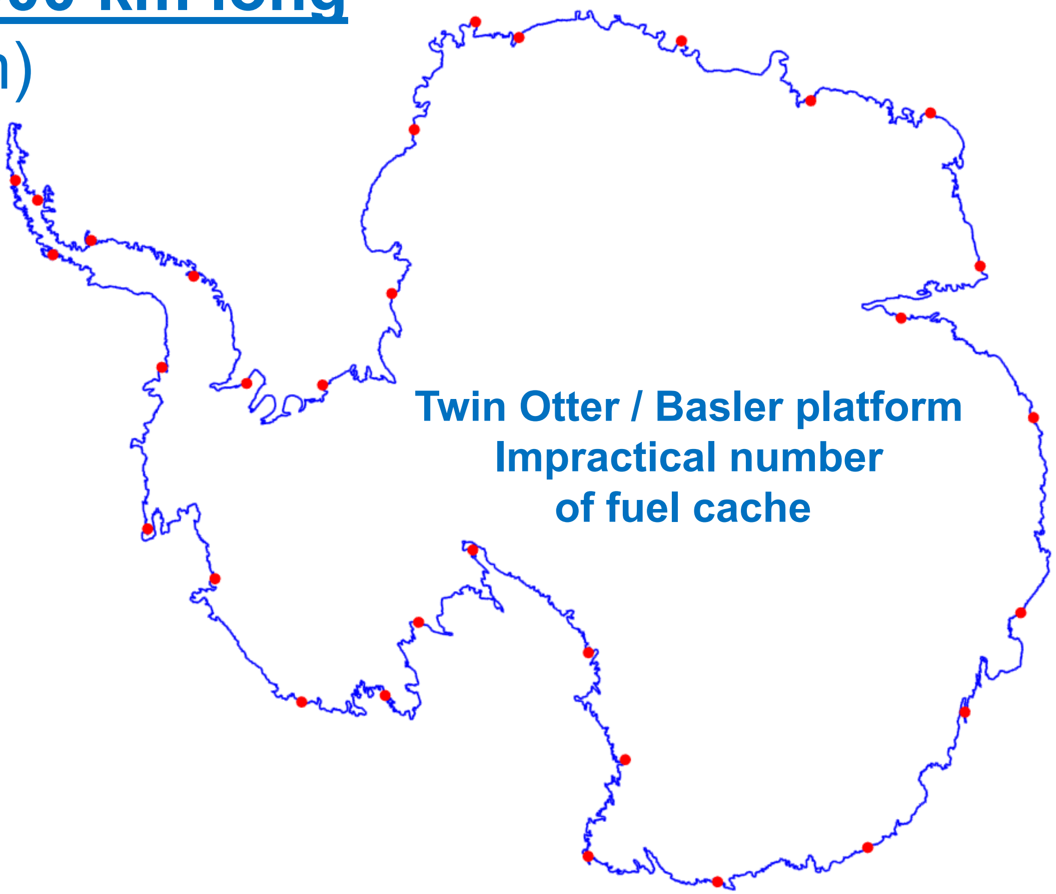
Landward RING
(future ice-sheet retreat)
(subglacial hydrology)

Primary RING
(ice discharge)

Seaward RING
(basal melting)
(bathymetry under ocean)

How to make pan-Antarctic surveys?

Antarctic ice-sheet margin: 62,000 km long
(Earth's circumference: 40,000 km)



- Reconnaissance, pan-Antarctic surveys
  - Long-range airplane to seamlessly cover the all ice-sheet margins
- Targeted regional surveys
  - Twin-Otter or Basler to make comprehensive surveys including RINGS.
  - Drone

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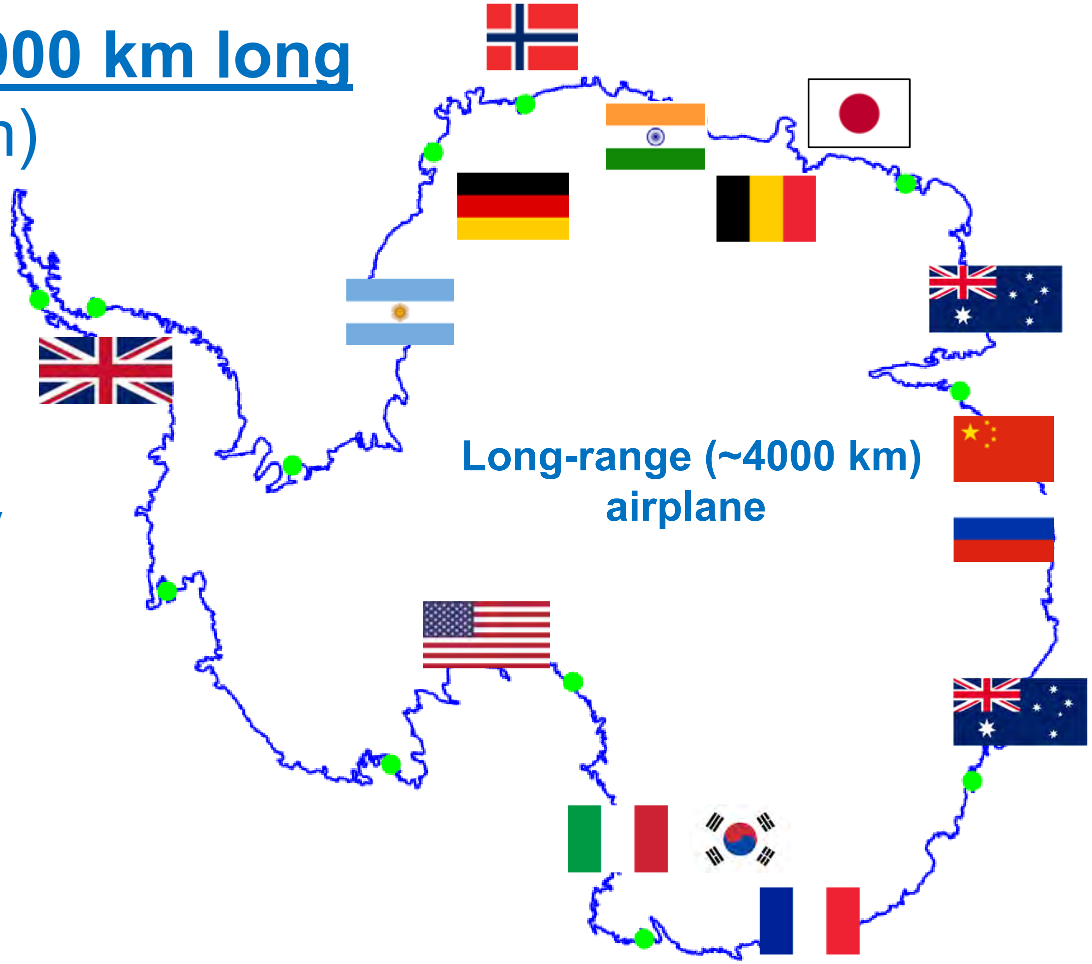
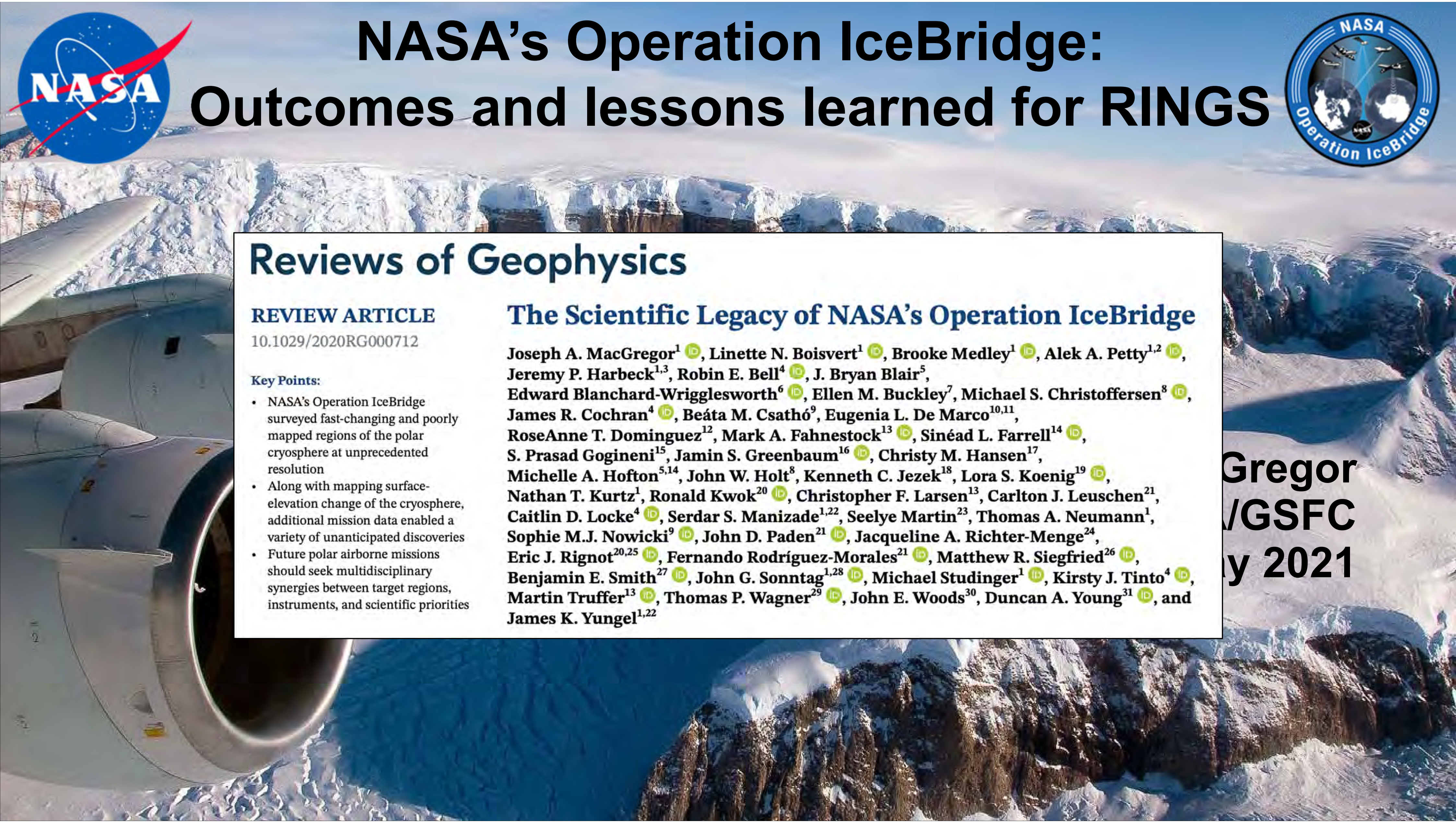


Lessons from prior airborne surveys

- NASA’s Operation Ice Bridge
  - Joe MacGregor

- DTU-BAS-NPI PolarGAP
  - Rene Forsberg

NASA's Operation IceBridge: Outcomes and lessons learned for RINGS



Reviews of Geophysics

REVIEW ARTICLE
10.1029/2020RG000712

Key Points:

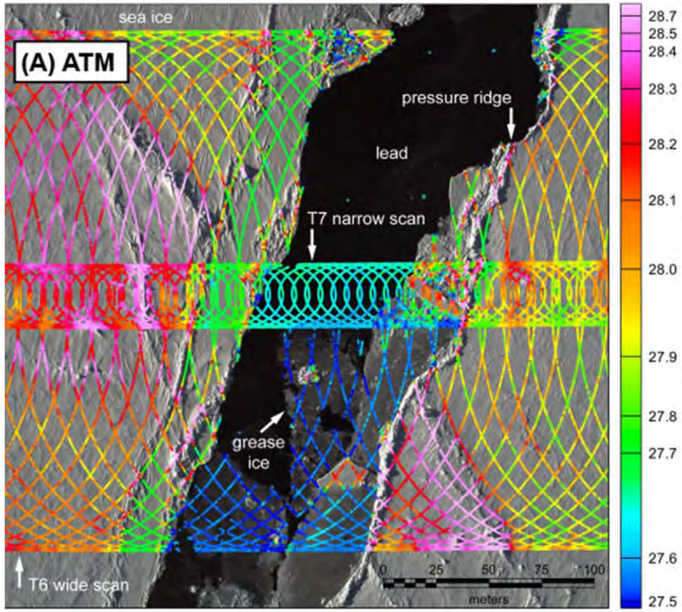
- NASA's Operation IceBridge surveyed fast-changing and poorly mapped regions of the polar cryosphere at unprecedented resolution
- Along with mapping surface-elevation change of the cryosphere, additional mission data enabled a variety of unanticipated discoveries
- Future polar airborne missions should seek multidisciplinary synergies between target regions, instruments, and scientific priorities

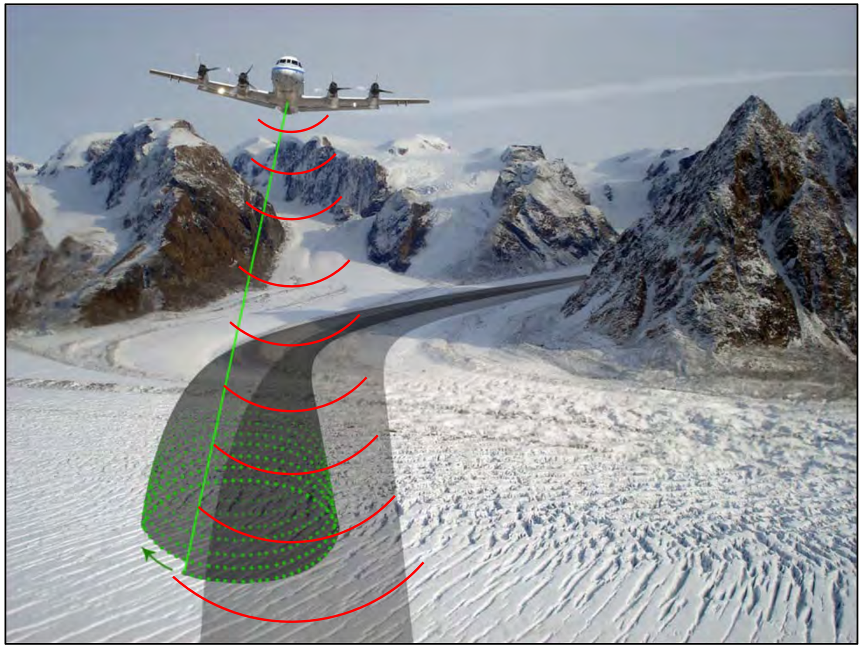
The Scientific Legacy of NASA's Operation IceBridge

Joseph A. MacGregor[1], Linette N. Boisvert[1], Brooke Medley[1], Alek A. Petty[1,2], Jeremy P. Harbeck[1,3], Robin E. Bell[4], J. Bryan Blair[5], Edward Blanchard-Wrigglesworth[6], Ellen M. Buckley[7], Michael S. Christoffersen[8], James R. Cochran[4], Beáta M. Csathó[9], Eugenia L. De Marco[10,11], RoseAnne T. Dominguez[12], Mark A. Fahnestock[13], Sinéad L. Farrell[14], S. Prasad Gogineni[15], Jamin S. Greenbaum[16], Christy M. Hansen[17], Michelle A. Hofton[5,14], John W. Holt[8], Kenneth C. Jezek[18], Lora S. Koenig[19], Nathan T. Kurtz[1], Ronald Kwok[20], Christopher F. Larsen[13], Carlton J. Leuschen[21], Caitlin D. Locke[4], Serdar S. Manizade[1,22], Seelye Martin[23], Thomas A. Neumann[1], Sophie M.J. Nowicki[9], John D. Paden[21], Jacqueline A. Richter-Menge[24], Eric J. Rignot[20,25], Fernando Rodríguez-Morales[21], Matthew R. Siegfried[26], Benjamin E. Smith[27], John G. Sonntag[1,28], Michael Studinger[1], Kirsty J. Tinto[4], Martin Truffer[13], Thomas P. Wagner[29], John E. Woods[30], Duncan A. Young[31], and James K. Yungel[1,22]

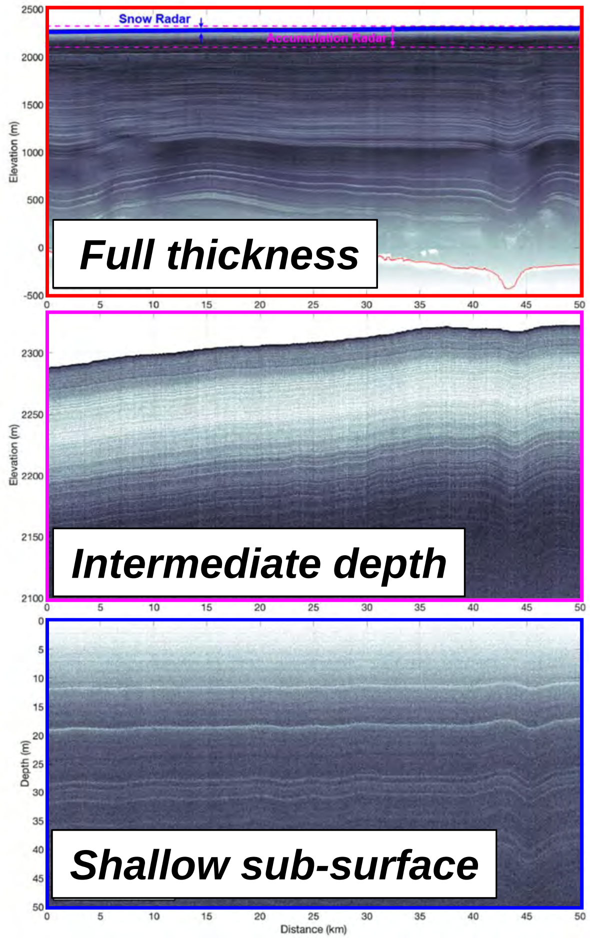
Multi-instrument strategy to address multiple science requirements

Multiple laser altimeters and cameras mapped the ice surface.



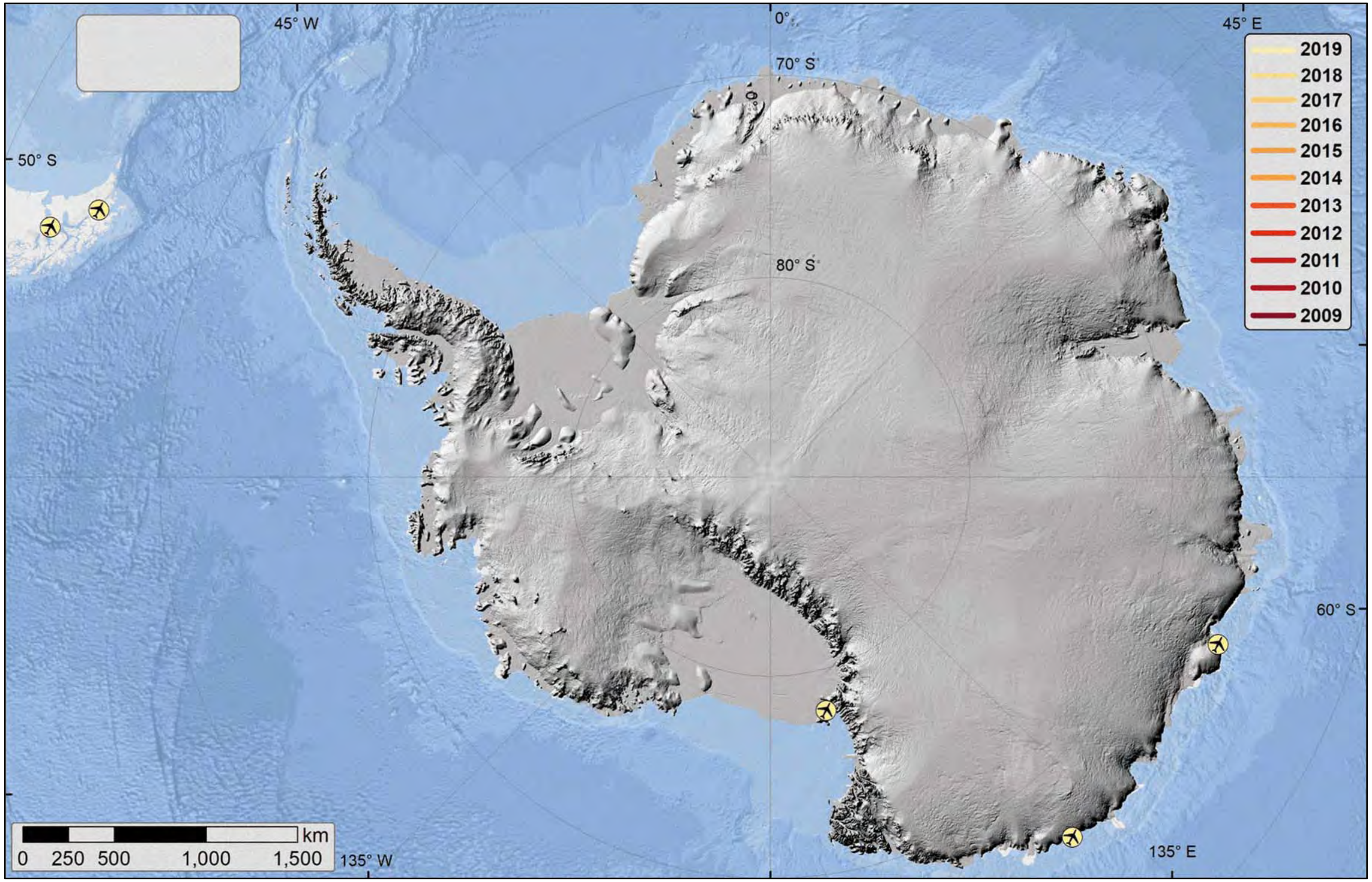


Multiple radar sounders mapped layers at various depths and ice thickness.



Gravimeters and magnetometers provided bathymetry and geologic context, respectively.

2009–2019 Antarctic survey extent



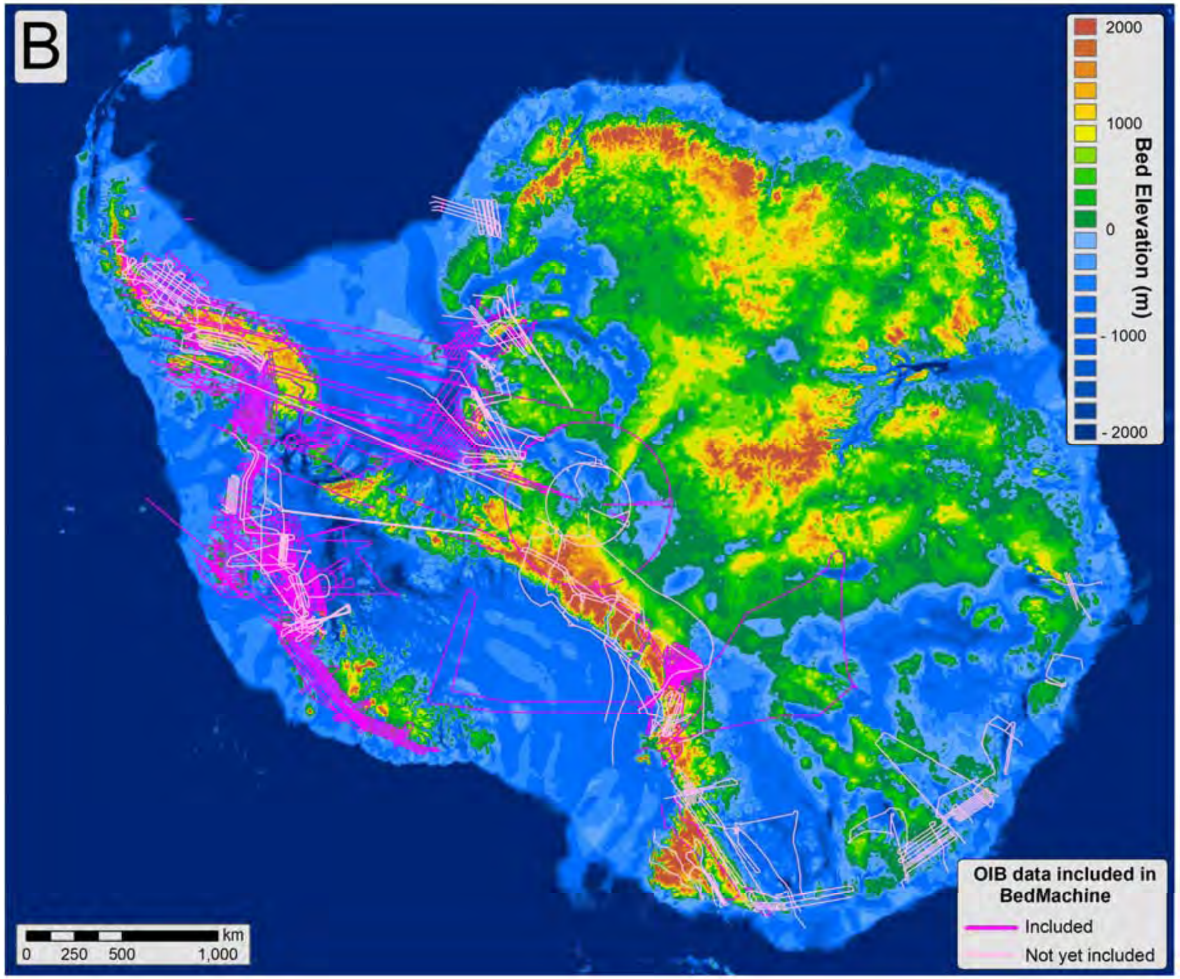
Deployed aircraft

OIB deployed 12 different aircraft types and 15 different aircraft.

Bold: Deployed in/over Antarctica. ***Green: Most relevant to RINGS.***

Aircraft	Organization	Flights (#)	Med./max. time aloft (hr)	Med./max. range (km)	Personnel (#)
AS350-B3	CAS (Heli-Greenland)	8	N/A	N/A	8
B-200	LaRC	18	5.0 (6.1)	2194 (4147)	4–6
B-200T	CAS (Dynamic Aviation)	15	5.1 (7.8)	2144 (3060)	4–6
C-130H	WFF	42	8.0 (9.2)	3700 (4139)	20
Cessna-206	CAS (Keller Aviation)	13	5.0 (6.5)	900 (1200)	2
DC-3T	**CAS (Airtec)**	**16**	**6.4 (8.2)**	**2010 (2575)**	**6–10**
DC-3T	**CAS (Kenn Borek)**	**109**	**6 (7)**	**1950 (2100)**	**8–9**
DC-8	**AFRC**	**155**	**11.1 (12.5)**	**7547 (9779)**	**>40**
DHC-3T	CAS (Ultima Thule)	161	4.5 (6.0)	700 (1000)	4
G-V	**JSC**	**30**	**10.0 (10.6)**	**7068 (8278)**	**20**
G-V	**NCAR**	**27**	**10.6 (11.8)**	**8334 (9310)**	**15**
HU-25C	LaRC	33	3.7 (4.1)	2567 (2784)	10
HU-25A	LaRC	29	3.6 (4.0)	2154 (2682)	10
P-3	**WFF**	**286**	**7.8 (10.1)**	**3661 (5330)**	**20–25**
WP-3D	NOAA	16	7.8 (8.8)	3675 (4100)	25

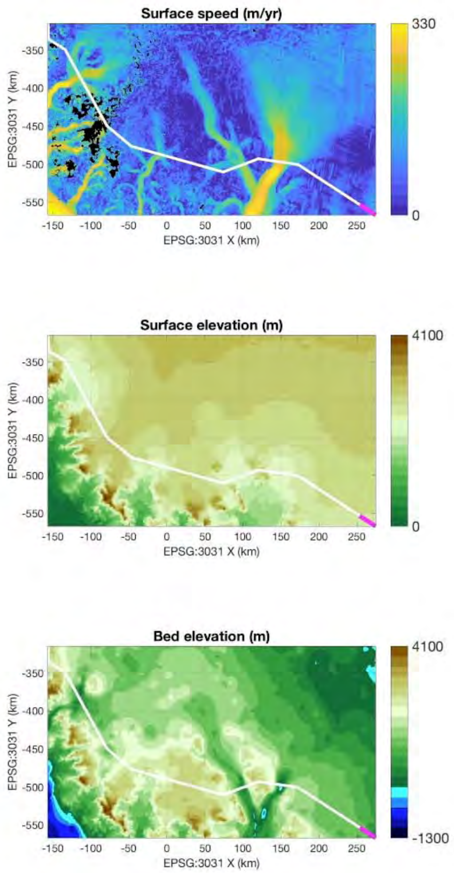
Existing and future contributions to bed topography syntheses

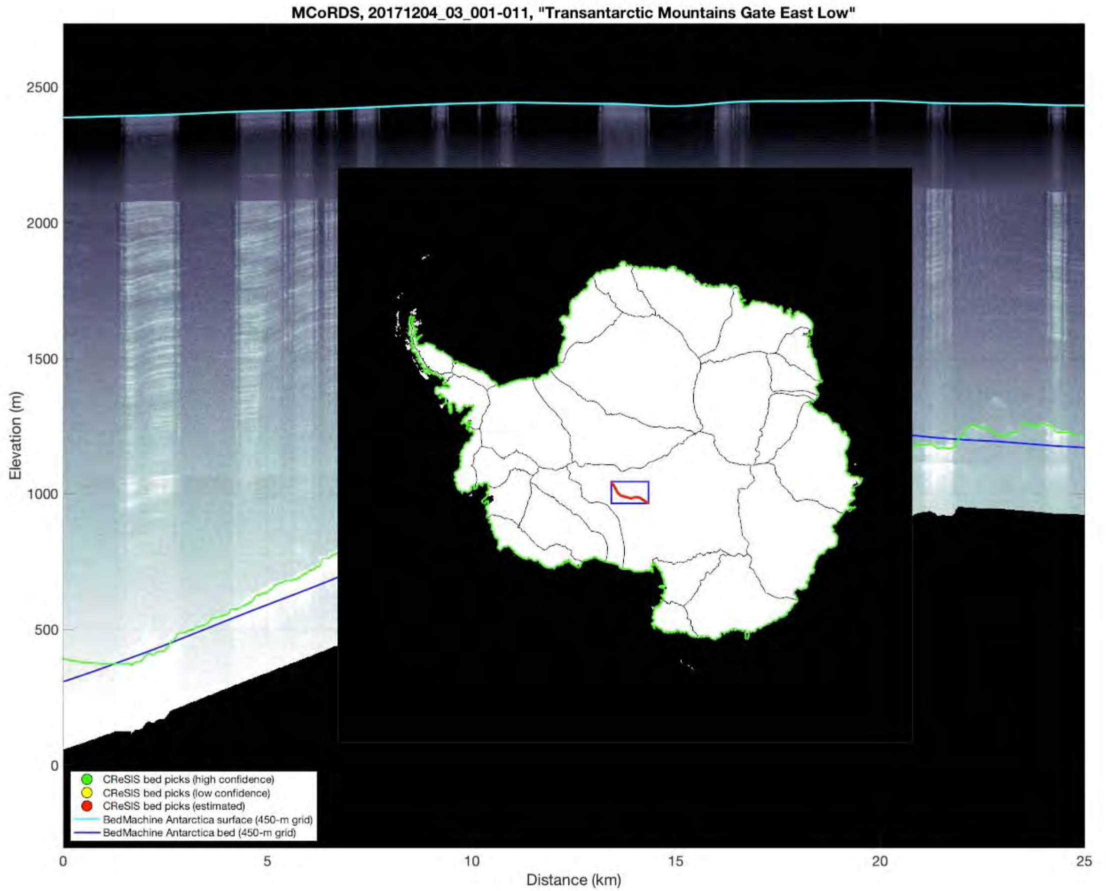


Deployed radar sounders

Instrument	Description	Lead	# campaigns
Multi-channel Coherent Radar Depth Sounder (MCoRDS)	**Primary multi-element VHF system to sound thick polar ice and detect internal layering**	**CReSIS**	**22**
Snow Radar	**Two-element SHF system to detect annual snow layering on ice sheets and sea ice**	**CReSIS**	**23**
Accumulation Radar	Multi-element UHF/SHF system to detect internal layering in the firn column of ice sheets	CReSIS	9
Arizona Radio Echo Sounder (ARES)	**Low-frequency, single-element towed system to sound thick temperate ice**	**UA**	**7**
UAF HF Radar Sounder	Low-frequency, single-element towed system to sound thick temperate ice	UAF	5
High-Capability Radar Sounder (HiCARS)	**Two-element low-VHF system to sound polar ice and detect internal layering**	**UTIG**	**4**
Warm Ice Sounding Explorer (WISE)	Low-frequency, single-element towed system to sound thick temperate ice	JPL	2
Pathfinder Advanced Radar Ice Sounder (PARIS)	Dual-element VHF system to sound polar ice at high altitude	APL	1

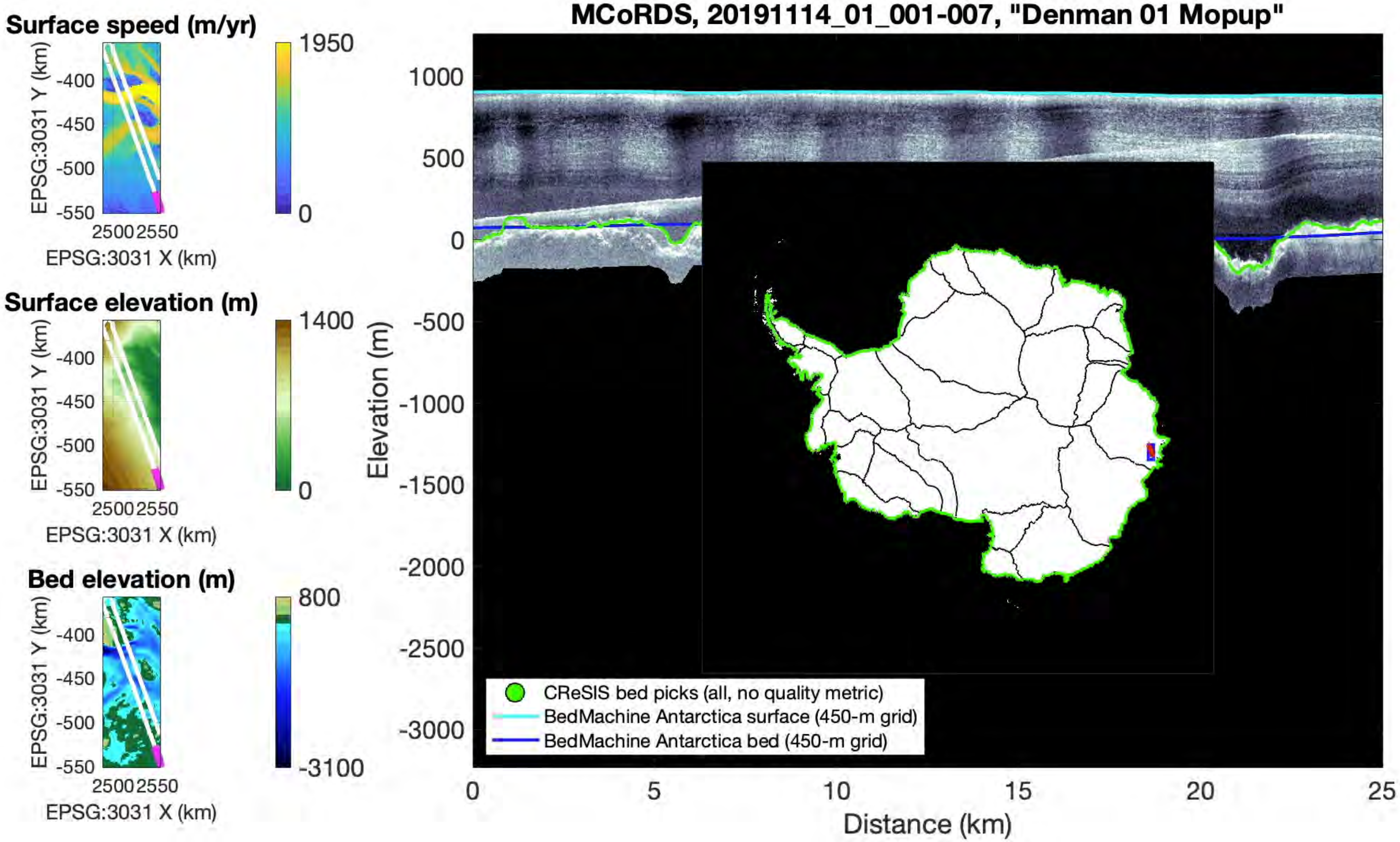
Example RINGS-like radargrams: MCoRDS on DC-3T Basler (2017)





8 elements; 150–450 MHz; belly array only version of MCoRDS on Polar6

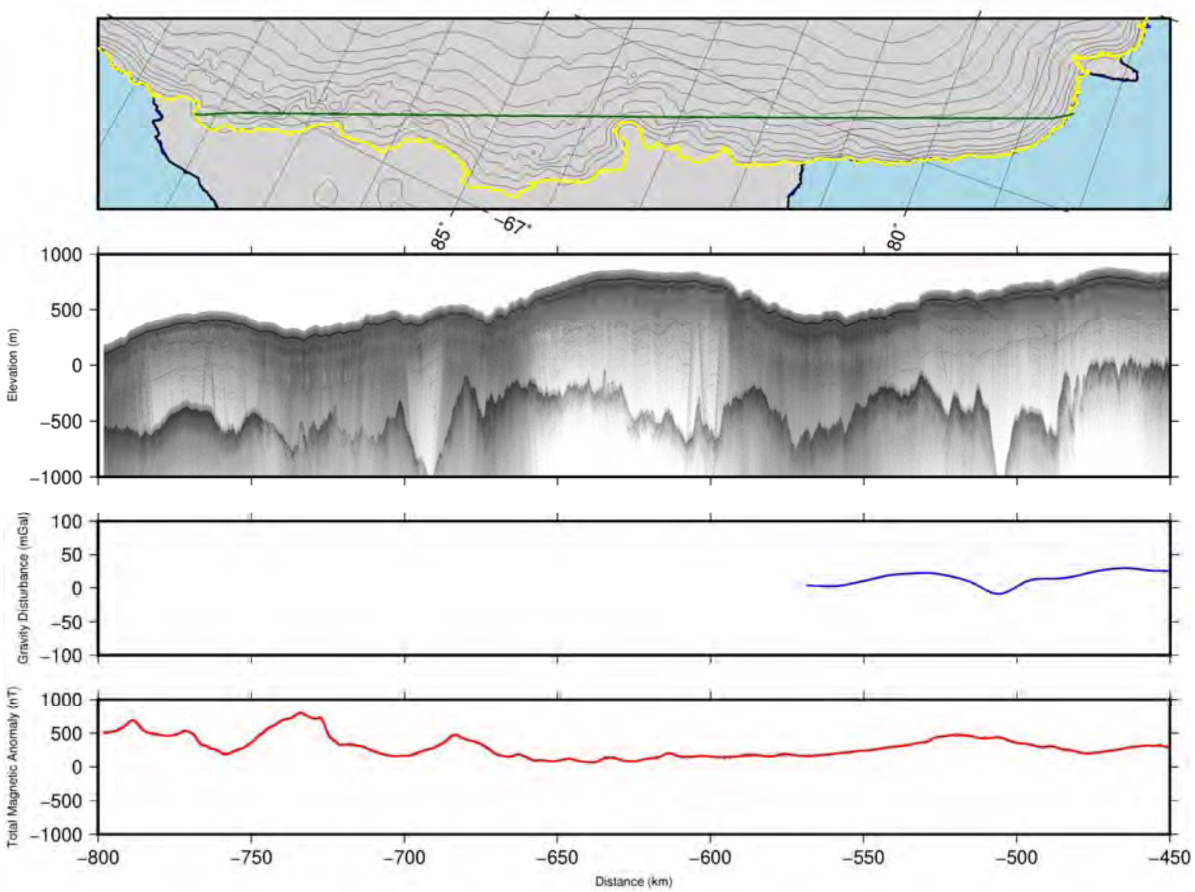
Example RINGS-like radargrams: MCoRDS on G-V (2019)



4 elements; 236–254 MHz; quick-turnaround design + build

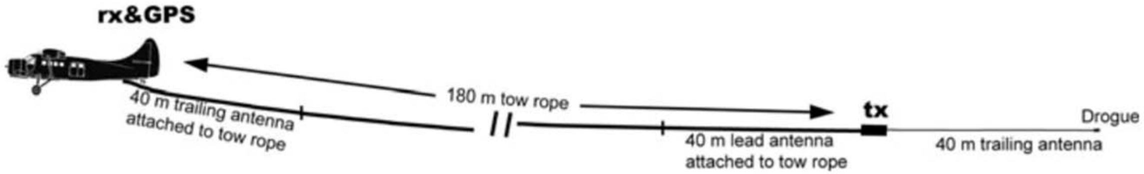
Example RINGS-like surveys UTIG/HiCARS at West Ice Shelf

PEL/JKB2h/Y16a (pik1)



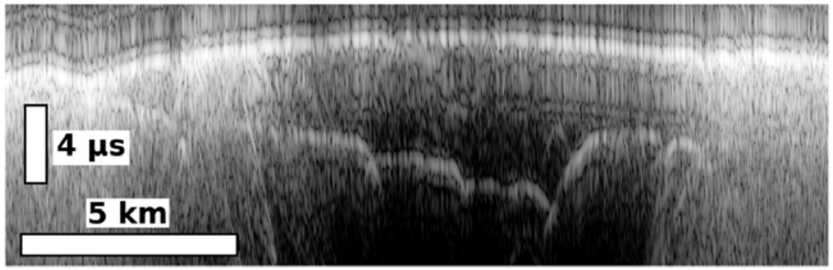
60 MHz center frequency, 15 MHz bandwidth

Arizona Radio Echo Sounder (ARES)



Conway et al. (2009)

2.5 or 5 MHz; trailing drogue deployment



Malaspina Glacier

Deployed gravimeters and magnetometers

Instrument	Description	Lead	# campaigns
Airborne Inertially Referenced Gravimeter (AIRGrav)	Fine-resolution system to measure gravity at excellent accuracy (≤ 1 mGal) and high speed amid turbulence	LDEO	14
BGM-3, ZLS and GT-1A	Fine-resolution systems to measure gravity at good accuracy (≤ 4 mGal) and high speed amid turbulence	UTIG	4
iMAR/DgS	Fine-resolution hybrid system to measure gravity at high accuracy (< 2 mGal) and high speed amid turbulence	LDEO	2
Geometrics 823A	Fine-resolution system to measure magnetic field	UTIG	4
Scintrex CS-3	Fine-resolution system to measure magnetic field	LDEO	4

AIRGrav onboard DC-8

Lessons learned relevant to RINGS

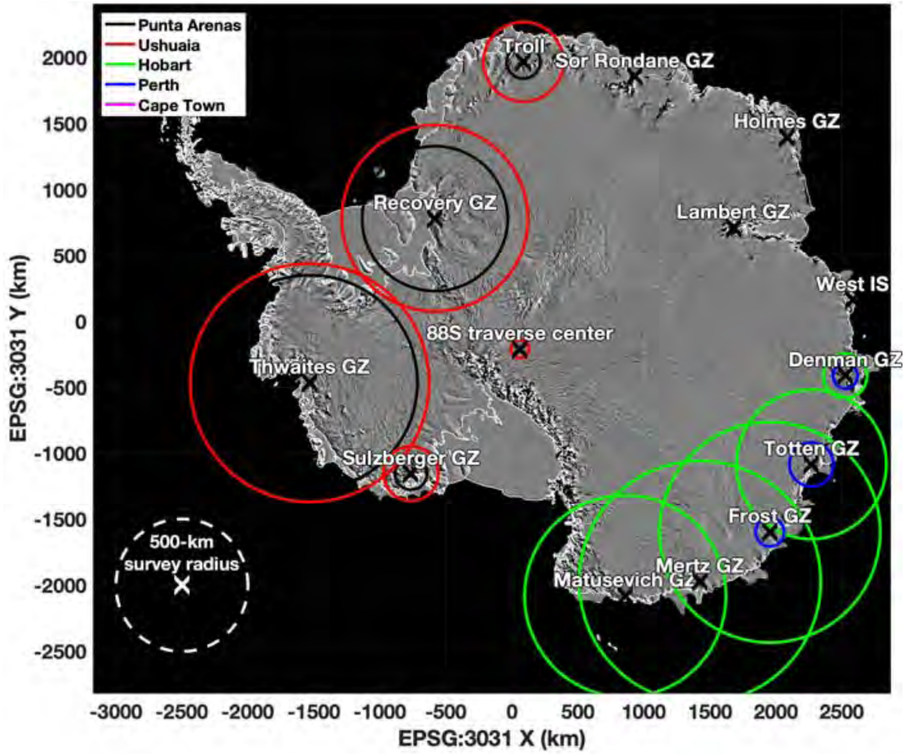
- Off-continent basing for valuable surveying at scale is possible, but OIB got to many of the "easy" targets. G-V with improved MCoRDS could aid with gap-filling for circumnavigation.

- Appeal to multiple scientific communities: include gravimeter and snow radar whenever possible. Similarly, you can't innovate enough in reaching the scientific community for flight design input.

- Embargos on data distribution are a structural disadvantage. Free the data quickly!

- Fickle polar weather could lock OIB out of target regions for weeks at a time. Better to survey something rather than nothing. Over-plan options to remain productive.

Range-at-target circles for G-V with OIB payload based on 2019 Antarctic campaign



DTU Space
National Space Institute

DTU Technical University of Denmark

www.space.dtu.dk

IceGrav, PolarGap and RINGS

.. a case story on how to set up large projects on a shoestring by strong international cooperation

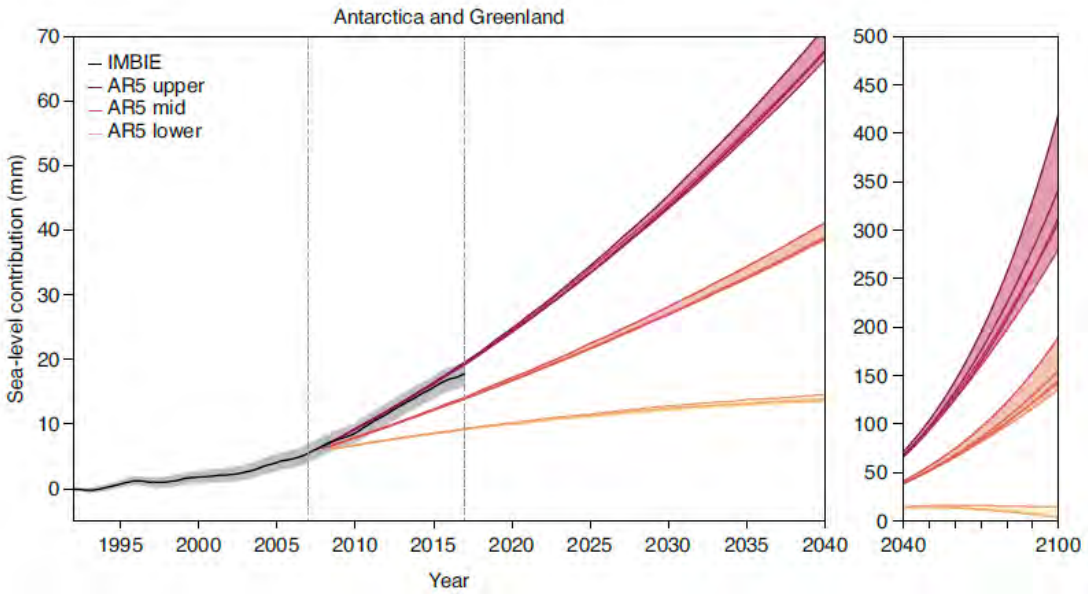
René Forsberg, DTU Space, Denmark

Basler/DC3 at Rothera, IceGRAV 2011

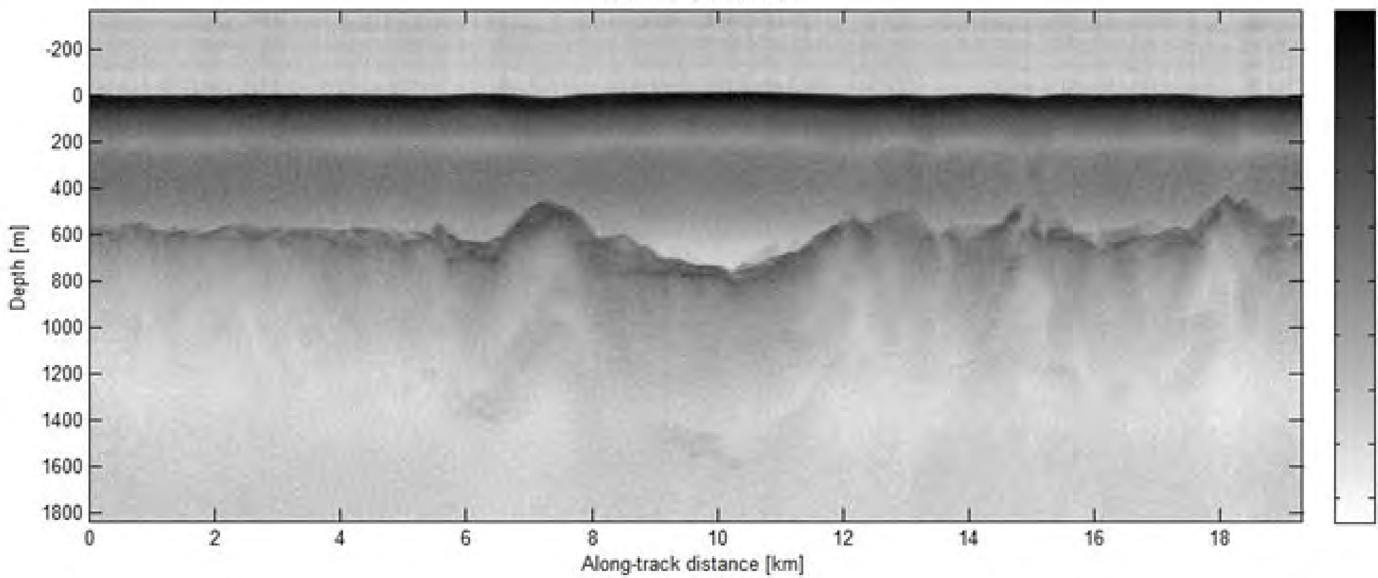
Basler/DC3 at Station Nord, LomGRAV 2009

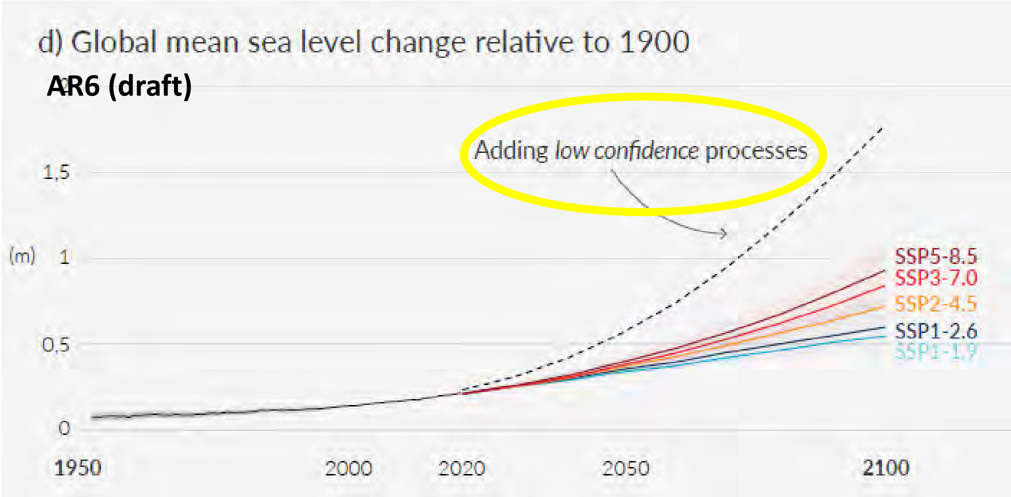
Why RINGS ?

Mass balance – of course - but also subglacial geophysics around ice streams, ice shelves and grounding lines ..



Jotulstraumen, DTU/NPI 2011

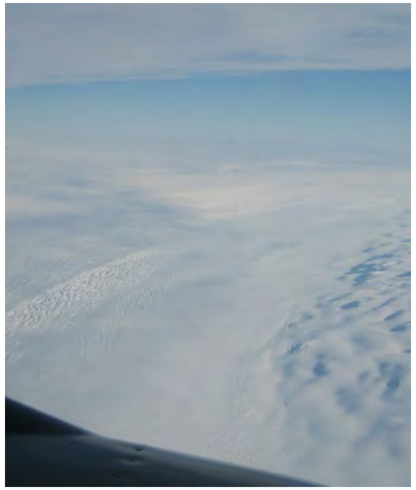




EU Copernicus Polar Observing System report (2021):

Mass loss of ice sheets from primarily Input-Output methods ..

(not GRACE/GRACE-FO /NGGM)

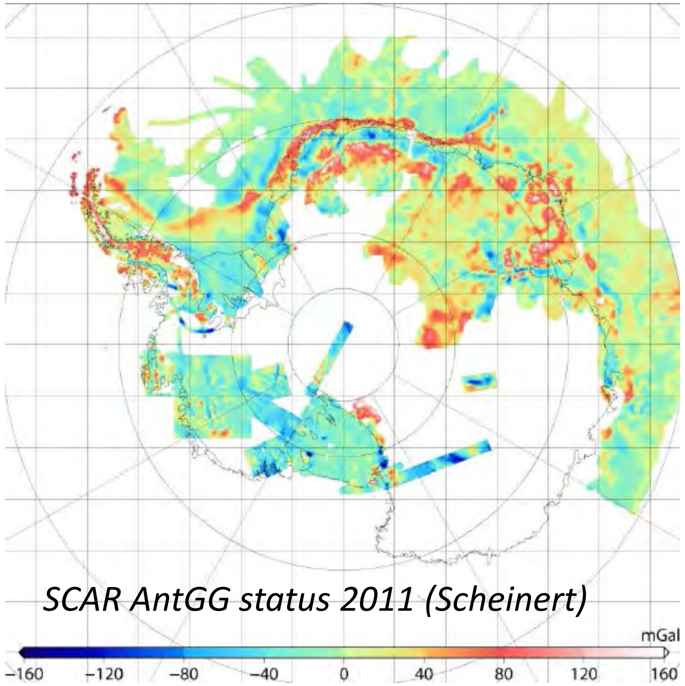


Why Geophysics? IceGRAV and PolarGAP background ..

Gravity and magnetic fields need complete global high-resolution coverage

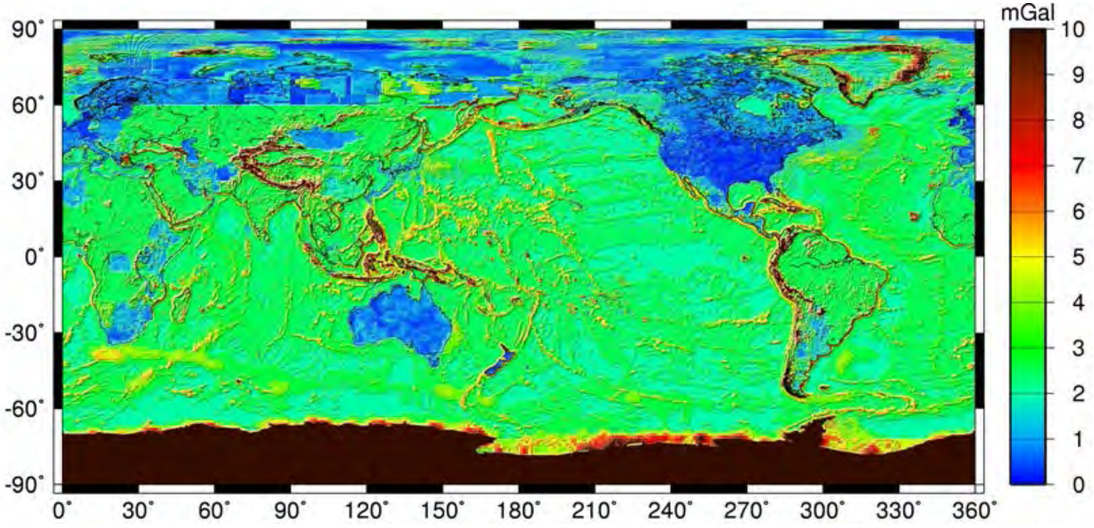
Satellites can not do it with sufficient details .. GOCE orbit left polar gap S of 83°

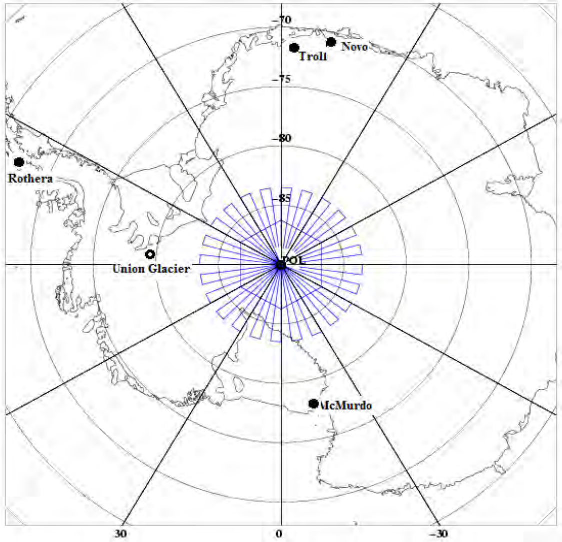
Denmark/DTU got involved after 2009 succesful Arctic long-range airborne survey and internationally coordinated mapping .. 2009 phone call



SCAR AntGG status 2011 (Scheinert)

Global gravity field model EGM2008 - errors

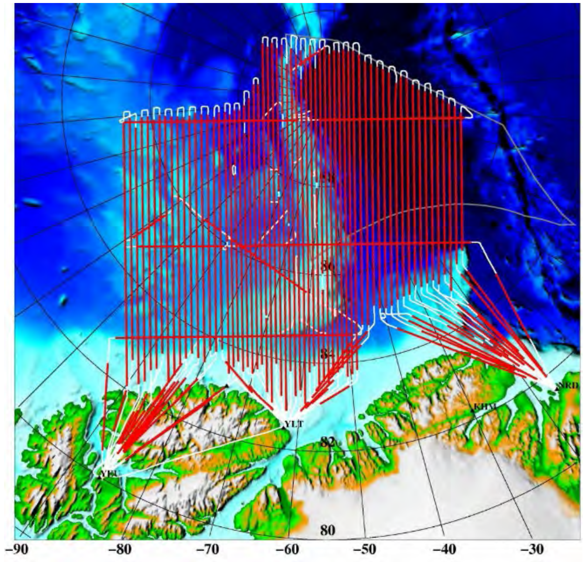


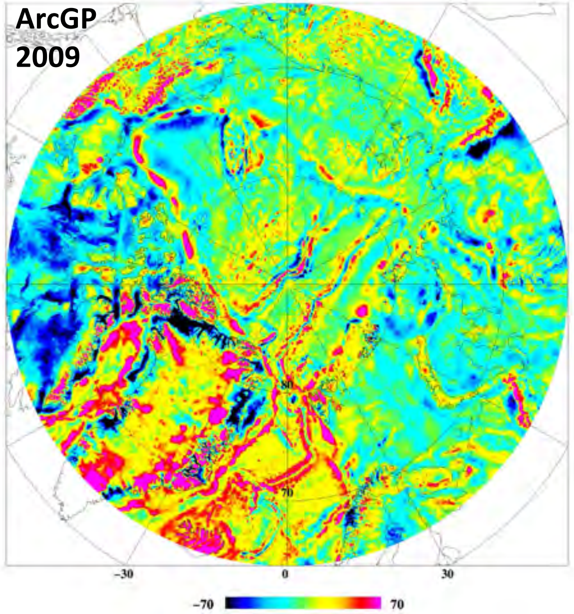


ESA PolarGap proposal 2015/16 –
DTU Space, BAS, NPI

Arctic 2009

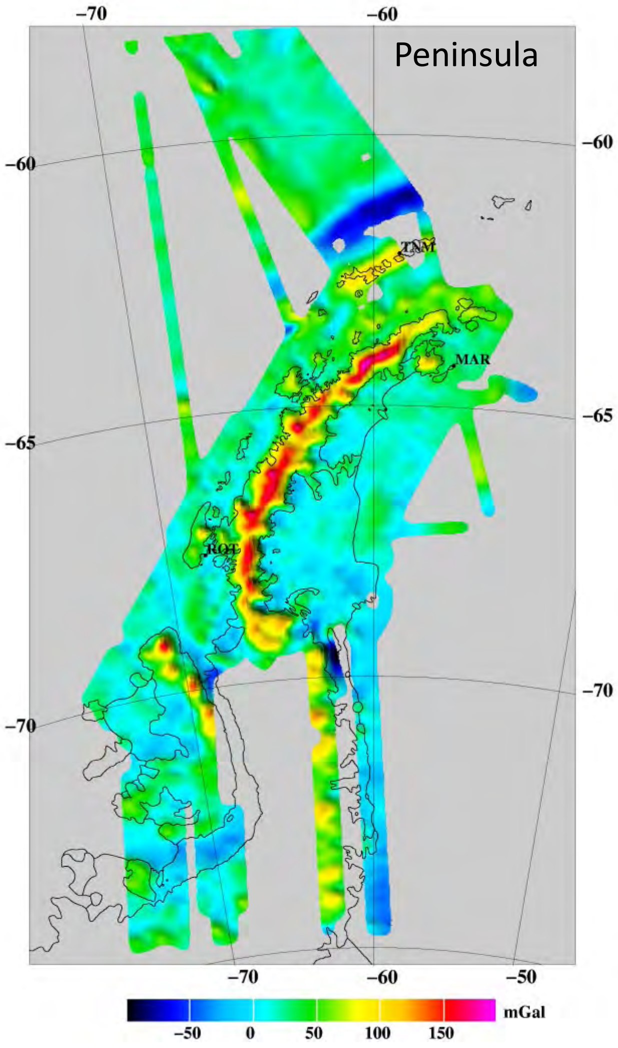
LOMGRAV-2009 Denmark/Canada

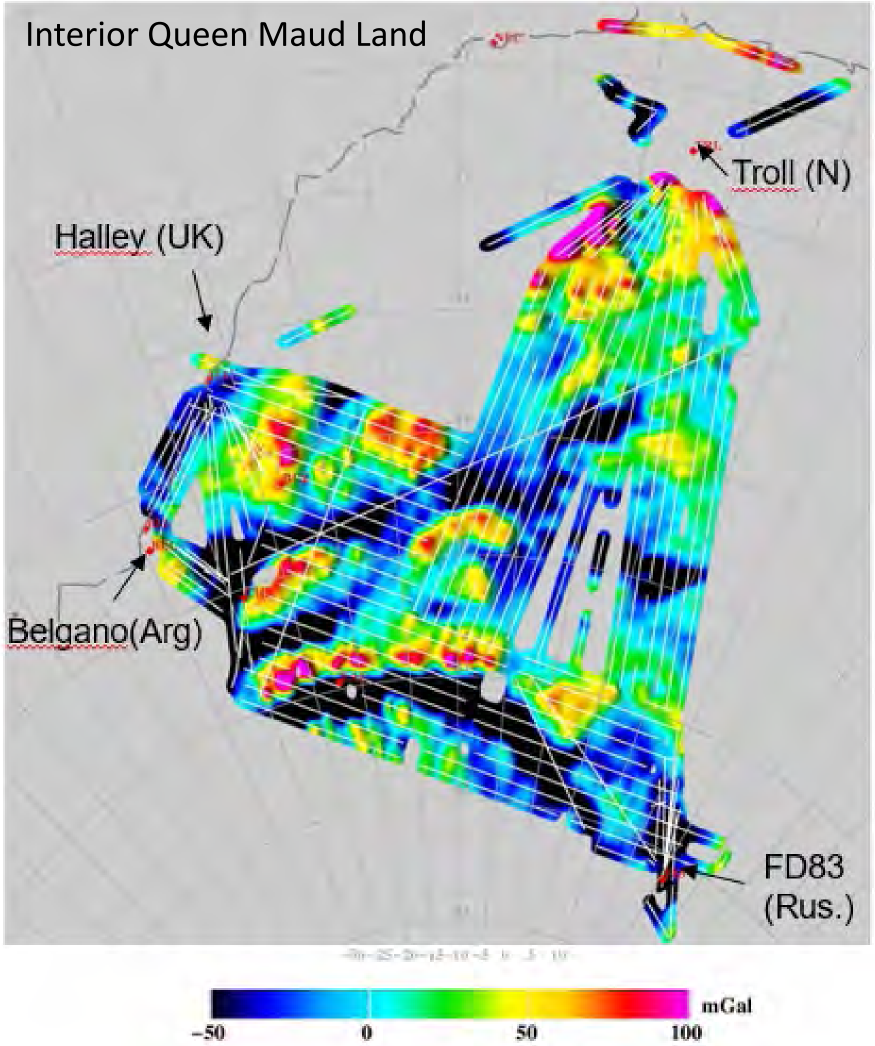




Antarctic 2009-11

IceGRAV (grav, mag, radar, laser)





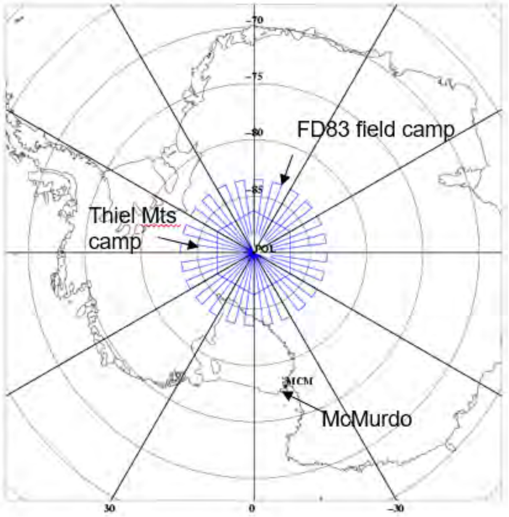
Joint project with Argentina, Univ of Texas, NPI, BAS

PolarGap 2015/16

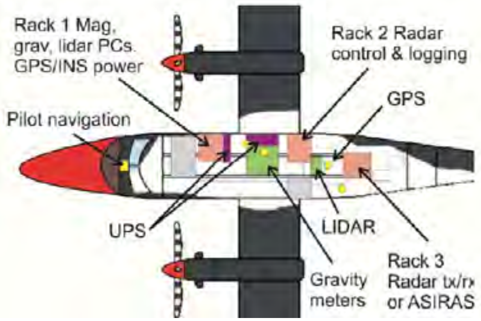
ESA-GOCE fill-in campaign

+ ASIRAS Ku-band radar from pole
(radar/lidar CryoSat validation)

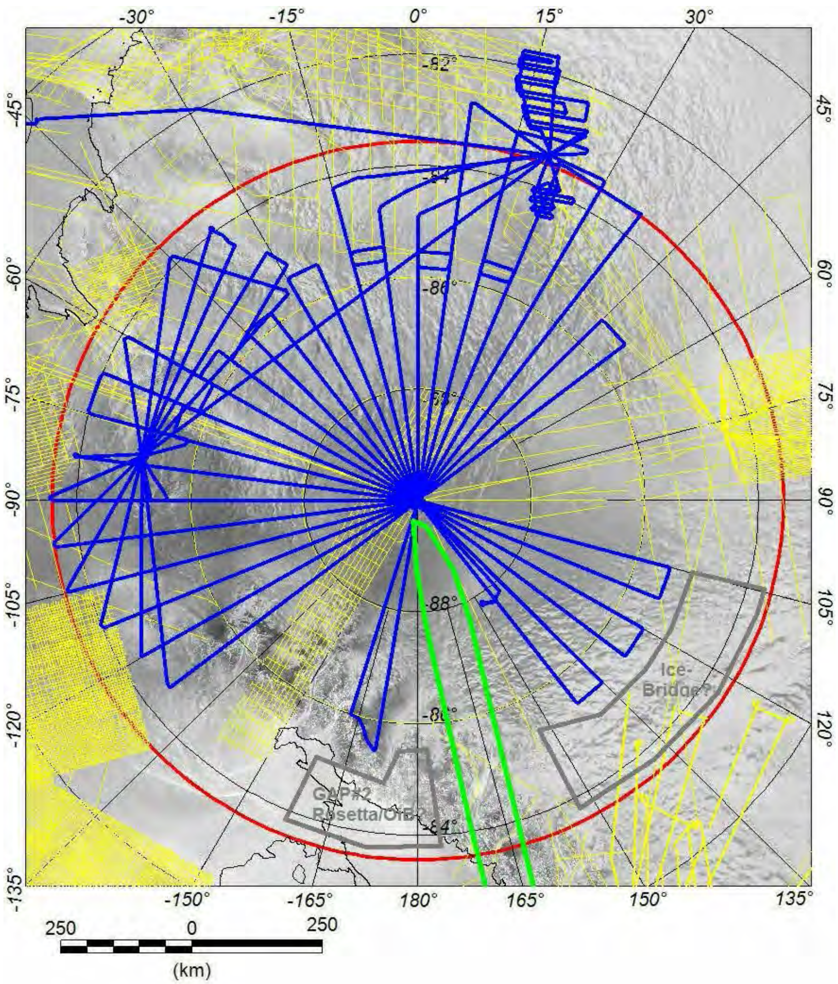
Theory



Grav-mag-radar-lidar,
~5 week airborne survey,
135 flt-hrs, 26000 km survey lines

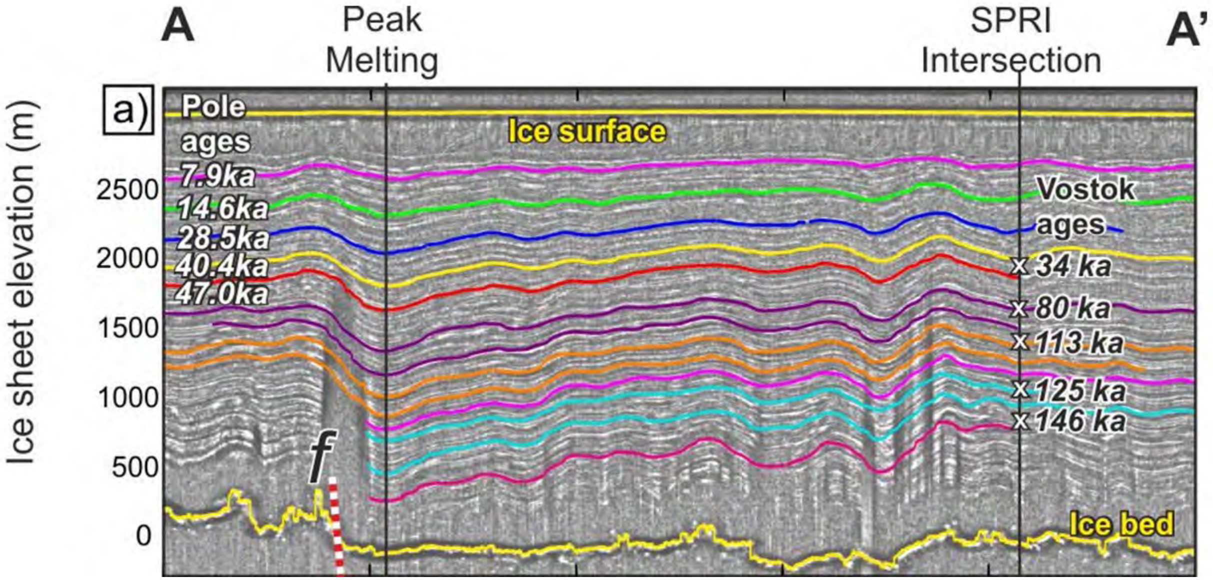


Practice



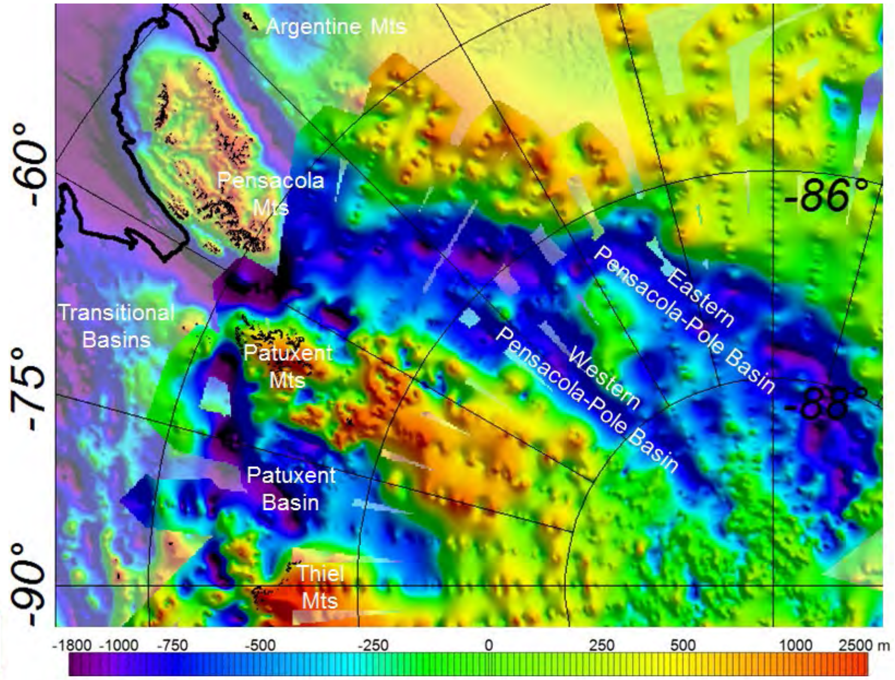
Spin-off science/ exploration PolarGap 2015/16

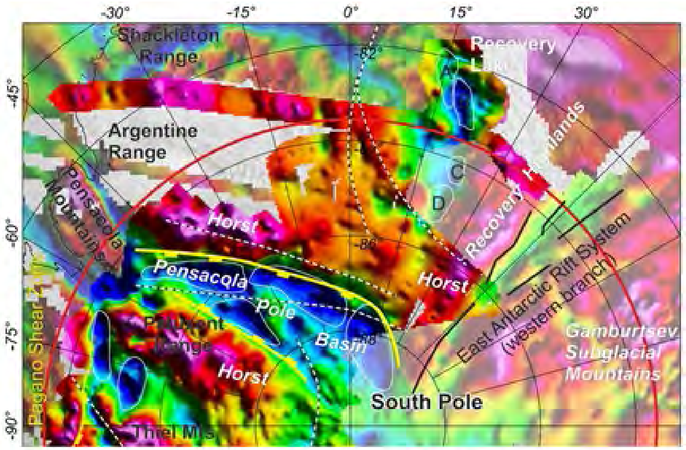
Many joint papers ..



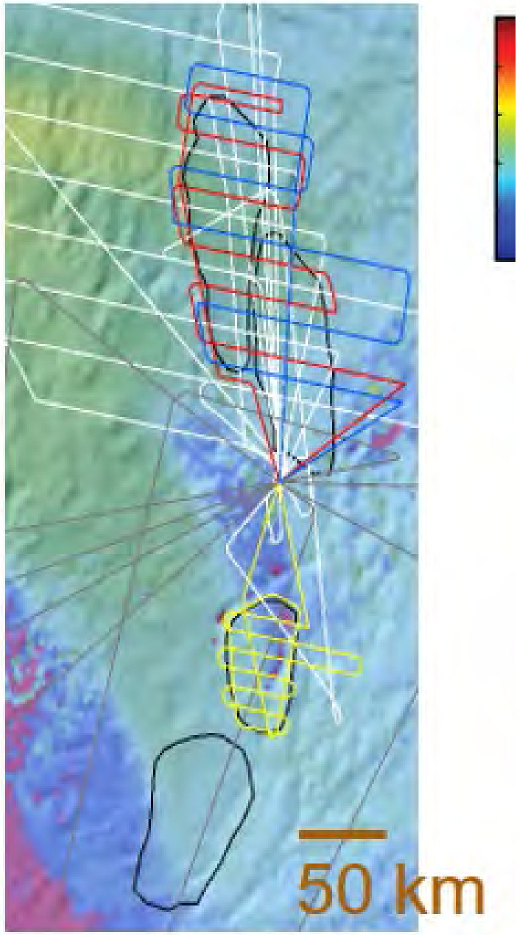
Huge subglacial valley (Pensacola-Pole basin)

Ice melt from below near South Pole (unknown subglacial heat flow anomaly)





Gravity and magnetic fields for geology/tectonics



Subglacial laks details (Recovery Lakes A-D)

- **IceGrav/PolarGap experience shows that large areas can be covered in short time and with limited funds** (< 3 M€) **provided close international logistics and science cooperation …** *model for RINGS?*
- **Even with narrow primary focus (**gravimetry**) a lot of add-on science has been done or pending ..**
- *Antarctic airborne campaigns don't need to be excessively expensive and planned years ahead (more DTU/BAS ESA CryoSat campaigns 2016/17 + 2022)*

IceGrav/PolarGap thanks to:
IAA-Argentina
Danish Embassy, Buenos Aires
Argentinean Navy and Air Force
INACH/University of Valdivia
University of Texas at Austin
British Antarctic Survey
Norwegian Polar Institute
NSF logistics
South Pole Station crew
Kenn Borek and BAS pilots
ALCI South Africa/Russia
National Geospatial-Int. Agency
European Space Agency
+ many, many scientists ..

Thanks for your attention

Action Group "RINGS"

- Approved by national delegates in a digital meeting late March.
- Located under Physical Science Group and Geo Science Group.

Lead proponents

- Kenny Matsuoka (Norway)
- Rene Forsberg (Denmark)
- Fausto Ferraccioli (Italy)
- Tom Jordan (UK)
- Kirsty Tinto (USA)
- Geir Moholdt (Norway)






SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH*

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* SCAR is a Thematic Organisation of the International Science Council (ISC)

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9296 Tromsø
Norway

8 April 2021

Dear Dr Matsuoka,

I am writing to confirm officially that RINGS has been approved as an Action Group under the Physical Sciences and Geosciences Groups of the Scientific Committee on Antarctic Research. The formation of the group was approved by the SCAR Delegates at their meeting on 24 March 2021.

The topography of the ice sheet margin is currently very poorly mapped. The aim of the group in setting up coordinated, airborne measurements to map the topography is crucial to our understanding of processes at the ice sheet margin. This will enable a robust assessment of ice discharge from all around Antarctica and therefore its contribution to sea level rise.

If there is anything that we can do to help as the group gets started as an Action Group, please do not hesitate to contact the SCAR Secretariat (info@scar.org).

Sincerely yours,

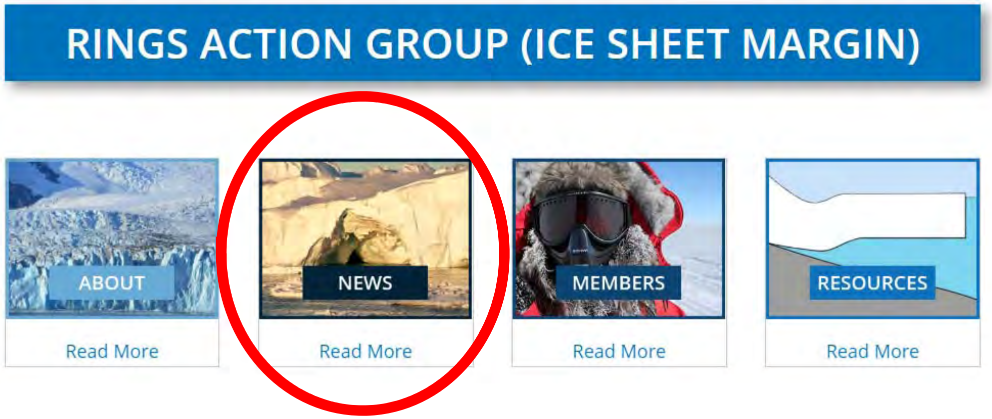
Dr Yeadong Kim
SCAR President

Action Group membership

- Current membership (27 members)

Jason Robert (AAD), Olaf Eisen (AWI), Tom Jordan and Peter Fretwell (BAS), Carl Leuschen (CReSIS), Kirsty Tinto and Robin Bell (LDEO), Won Sang Lee (KOPRI), Joe MacGregor and Michael Studinger (NASA), Alex Gardner (NASA JPL), Kenny Matsuoka and Geir Moholdt (NPI), Sergey Popov (PMGE), Sun Bo and Xueyuan Tang (PRIC), Rene Forsberg (Tech. Univ. Denmark), Mirko Scheinert (Tech. Univ. Dresden), Mathieu Morlighem (Univ. California Irvine), Jamin Greenbaum (Univ. California San Diego), Manu Le Meur and Catherine Ritz and (Univ. Grenoble), Andrew Shepherd (Univ. Leeds), Frank Pattyn (Univ. Libre de Bruxelles), Duncan Young and Don Blankenship (Univ. Texas), Fausto Ferraccioli (OGS)

- Open to all who are directly working on this topic.
- Information is more widely shared through “News” under RINGS web page at SCAR.



Need to develop strong links to relevant activities

- SCAR SRP INSTANT and its sub committees.
- SCAR Action/Expert Groups
  - BEDMAP
  - IBCSO
  - ISMIP
  - ISMASS
  - AntArchitecture
- Others
  - IMBIE
  - BedMachine
  - COMNAP

Help us to make this list comprehensive!

(use “chat” system)

Whitepaper
(soon to be available at the web site)

RINGS: Collaborative international effort to map all Antarctic ice-sheet margins

International initiative "RINGS" aims to bridge the gap in disparate satellite observations and will help constrain societally-relevant Antarctic contributions to future sea-level rise.

IPCC's recent Special Report on Ocean and Cryosphere in a Changing Climate (SROCC) addresses rapidly increasing sea-level contribution from the Antarctic Ice Sheet. The lack of ice thickness data at the margin of the ice sheet (grounding zone) is pointed out as one of the main sources of uncertainty for accurate estimation of Antarctic ice discharge, and adds to discrepancies with other satellite-based mass change estimates. It is also the location where the bed topography matters the most as it controls the stability of the grounding zone. There is therefore an urgent need to carry out airborne surveys around the entire Antarctic Ice Sheet margin.

The ice discharge of the Antarctic Ice Sheet to the ocean can be calculated by a combination of ice thickness data and satellite-measured ice flow speed near the grounding zone. While satellites such as Sentinel-1 and Landsat-8 can routinely measure ice-flow speed, **limited knowledge of ice thickness leads to large uncertainties in ice discharge and eventually in overall assessments of Antarctic mass balance**, estimated as the difference between ice discharge at the grounding zone and mass input (snowfall) to the entire ice sheet. Mass balance estimated in this way currently has large discrepancies to other estimates based on gravity changes detected by GRACE/GRACE-FO satellites or ice-elevation changes detected by the CryoSat-2 and ICESat-2 satellites.

Ice thickness changes with time. However, once bed topography is measured using ice-penetrating radar with high precision and positioning control, ice thickness in the future can be monitored using ice sheet's surface elevations measured with satellite altimetry missions such as CryoSat-2 and ICESat-2. The existing BEDMAP and BedMachine compilations provide pan-Antarctic baselines for bed topography. While BEDMAP3 is being developed by a new SCAR Action Group, BedMachine version 2, released in 2020, is the most recent bed topography map, including nearly 67 million radar data points collected since 2007. According to the locations of post-2007 radar data used for BedMachine, 12% of the Antarctic margin has at least one radar data point within 1 km from the margin, and 30% has a data point within 1-5 km (Fig. 1). Therefore, the bed topography is relatively well known for about one third of the Antarctic margin. However, 58% of the margin has no data within 5 km, and 28% has no data within 20 km. Thus, **ice thickness for more than half of the Antarctic margin remains inadequately known for estimating ice discharge.**

Availability of bed topography data is not uniform around Antarctica (Fig. 2). For example, the Amundsen Sea sector has the best data coverage, though still one quarter of the margin has no data within 5 km. In contrast, nearly three quarters of the margin has no data within 5 km in Enderby Land and eastern Dronning Maud Land. Looking more locally, fast-flowing glaciers have better data coverage than slowly moving ice in many regions, but even for glaciers that are well studied, data are not always available continuously along the margin. This is because radar data are often collected along the ice flowline, rather than across the glacier. Compiling individual datasets collected for different purposes with different standards is a pragmatic, but not an ideal solution. **Systematic collection of new radar data in the vicinity of the margin specifically aiming for ice-discharge estimates is a crucial step to monitor the current status, and predict the future, of the Antarctic Ice Sheet.**

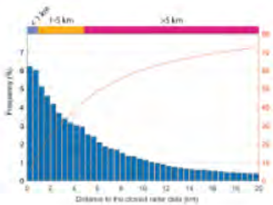


Fig. 1: Histogram showing the radar data availability in the vicinity of the ice-sheet margin. Bins are each 0.5 km, and about 28% of the margin has no radar data within 20 km.

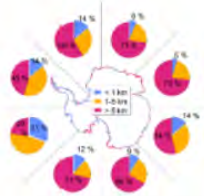


Fig. 2: Availability of radar data within < 1 km, 1-5 km and > 5 km from the ice-sheet margin. The pie charts show the fraction of these availabilities in each region around Antarctica.

To fill this major knowledge gap across all the margins of Antarctica for the first time, we propose **Antarctic RINGS** as an ambitious and challenging initiative in a truly international cooperation. **The primary objective** of RINGS is to provide more accurate and complete reference data for robust assessments of ice discharge from all around Antarctica. This dataset will also tremendously improve the accuracy of ice-sheet models by providing a better mapping of the grounding zone. When this dataset is combined with satellite altimetry data over the entire ice sheet, it can also be used to constrain mass input from snowfall to Antarctica, which is currently estimated with regional climate models but hardly validated over a large region. **The secondary objectives** of RINGS are (1) to better constrain the likelihood and rates of predicted future retreat of the ice-sheet margin by determining basal boundary conditions in adjacent inland areas, (2) to better quantify ice-ocean interactions by providing novel knowledge of the bathymetry of the cavity beneath adjacent ice shelves, and (3) to perceive subglacial hydrology for constraining basal mass balance of the ice sheet and subglacial geology particularly relevant to sediments and heat flow. To reach these objectives, it is necessary to complete not only the primary ring at the margin, but also a seaward ice-shelf ring and a landward ring, using radar, gravity, magnetics and lidar instruments altogether.

RINGS builds upon and will compliment highly successful international efforts such as **BEDMAP, BedMachine, IBCSO** to characterize bed topography of the Antarctic continent, the **IMBIE team** and **ISMASS** to quantify recent ice sheet change, and **ISMIP** to model Antarctic ice sheet evolution in the future and predict its effects on future global sea-level rise. It is essential to coordinate RINGS with **SCAR's** new scientific research program **INSTANT** (Instabilities and Thresholds in Antarctica). Marginal zones of the ice sheet have multiple tipping elements, which can potentially make abrupt and dramatic changes of the Antarctic Ice Sheet and Southern Ocean. Deepened understanding of these tipping elements requires interdisciplinary efforts between the glaciological, oceanographic and geophysical communities. RINGS will generate novel synergies between disciplines, and directly contribute to future **IPCC** assessments of Antarctic contributions to global sea-level rise.

The RINGS initiative will require substantial **international pooling of logistic and scientific resources** and capabilities in different geographic sectors of Antarctica, to achieve systematic coverage of ~62,000-km long Antarctic margin, which is a quarter longer than Earth's circumference. This is a challenging task, especially given the poorer weather along the coastal regions. The RINGS missions could be split into various national campaigns, provided common protocols are strictly followed by these surveys. Considering the limited range of current ski-equipped aircraft, such as a Twin-Otter (~1100 km) and Basler (~2000 km), **long-range aircrafts** with extended ranges up to ~4000 km would be an important asset. A long-range aircraft would also have the important environmental advantage of reducing the need for fuel caches at remote locations. Such a long-range aircraft could also give more opportunities for additional reconnaissance geophysical data. Unmanned Aerial Vehicles (UAV) are an emerging platform particularly suited for follow-on high-resolution surveys, targeted on sectors that are either under ongoing rapid change or exhibit significant potential for future change.

The first step of RINGS is to clarify the current knowledge gap to a greater extent and assess impacts of new data that fill these knowledge gaps at different levels. This work can be done using location data of BedMachine's input radar data and soon-to-be-available BEDMAP3 open-data depositary. **The second step of RINGS** is to develop a set of protocols to systematically collect, analyze, and share comprehensive airborne geophysical datasets collected by individual regional efforts. The second step can be efficiently done at a workshop including major aircraft operators and radar survey groups. **The new SCAR's action group RINGS** will be an ideal platform to complete these tasks and generate large momentum of the international Antarctic community to carry out this ambitious project that is crucial to precisely estimate the future sea-level contribution from Antarctica.

<u>RINGS Action Group membership as of 27 May, 2021 (alphabetical order of institutions)</u>:

Jason Robert (Australian Antarctic Division), Olaf Eisen (Alfred Wegener Institute), Tom Jordan and Peter Fretwell (British Antarctic Survey), Carl Leuschen (CReSIS, UNiv. Kansas), Kirsty Tinto and Robin Bell (Lamont-Doherty Earth Obs.), Won Sang Lee (Korea Polar Inst.), Joe MacGregor and Michael Studinger (NASA), Alex Gardner (NASA JPL), Kenny Matsuoka and Geir Moholdt (Norwegian Polar Inst.), Sergey Popov (Polar Marine Geosurvey Expedition), Sun Bo and Xueyuan Tang (Polar Research Inst. China), Rene Forsberg (Tech. Univ. Denmark), Mirko Scheinert (Tech. Univ. Dresden), Mathieu Morlighem (Univ. California Irvine), Jamin Greenbaum (Univ. California San Diego), Manu Le Meur and Catherine Ritz and (Univ. Grenoble), Andrew Shepherd (Univ. Leeds), Frank Pattyn (Univ. Libre de Bruxelles), Duncan Young and Don Blankenship (Univ. Texas), Fausto Ferraccioli (National Inst. Oceanography and Applied Geophysics)

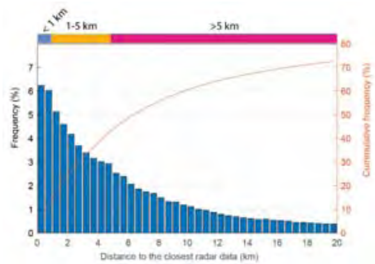
Terms of Reference

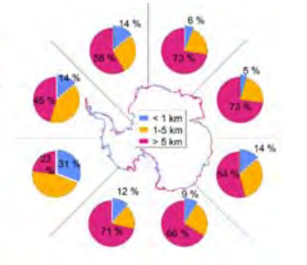
The RINGS Action Group will work for **two years** to facilitate community efforts to fill critical knowledge gaps in the Antarctic Ice Sheet margins to monitor and predict the future of the Antarctic Ice Sheet. As a SCAR Action Group, RINGS aims to:

- Define knowledge gaps of geophysical datasets in the ice-sheet margins.
- Assess impacts of efforts to fill these knowledge gaps at different levels on estimates of ice discharge from Antarctica and on predicting the future of the ice sheet.
- Develop feasible plans to fill these knowledge gaps by generating interdisciplinary, and international synergies.

Tasks and milestones

M1	4th quarter (Q4), 2021	Completion of ongoing analysis to define knowledge gaps
M2	Q1, 2022 (depending on pandemic)	International Workshop (Tromsø, Norway)
M3	Q3, 2022 (SCAR OSC in India)	Action Group Meeting
M4	Q4, 2022	Submission of a peer-reviewed article (action-group deliverable)





Action Group logo design

- We need a distinct logo that represents our interdisciplinary group.
- Our logo will be often presented together with the SCAR logo, as well as with logos of institutions and national Antarctic programs.
- We wish this logo (or its variant) will be used in future survey missions as well.

Rank these candidates and provide your feedback
(survey is now closed)

Logo design work is supported by Norwegian Polar Institute's Antarctic Program

Please turn on your camera for a group photo

Thanks

- Visit
  (survey is now closed)
  - to provide your feedback on the logo and more generally on this meeting and the Action Group.

- Keep updated! SCAR tweets when a new item is posted on our web site.
  - Follow @SCAR_Tweets