# International collaboration is urgently needed for airborne surveys in Enderby Land to fill the largest RINGS data gap

**Australia**: Jason Roberts, Lenneke Jong, Robb Clifton (Australian Antarctic Division, AAD)
**Belgium**: Frank Pattyn (Universite Libre de Bruxelles, ULB) and Alain Hubert (International Polar Foundation, IPF)
**China**: Sun Bo and Cui Xiangbin (Polar Research Institute of China, PRIC)
**Germany**: Olaf Eisen, Daniel Steinhage and Graeme Eagles (Alfred Wegener Institute, AWI)
**India**: Yogesh Ray and Vikram Goel (National Center for Polar and Ocean Research, NCPOR)
**Japan**: Masahiro Minowa and Shin Sugiyama (Hokkaido University, HU), and Takeshi Tamura (National Institute of Polar Research, NIPR)
**Norway**: Kenichi Matsuoka, Geir Moholdt, Sven Lidstrom and John Guldahl (Norwegian Polar Institute, NPI)
**USA**: Jamin Greenbaum (Scripps Institution of Oceanography, University of California, SIO) and Duncan Young and Don Blankenship (University of Texas Institute of Geophysics, UTIG)

This is a preliminary planning and scoping paper that seeks to identify potential plans and solutions to support the RINGS[1] project in Enderby Land. It does not reflect any commitment or undertaking by National Programs or those named in the paper. More detailed planning and collaborative discussions will be needed to then seek agreement on resource allocations and contributions.

Ice discharge from the Antarctic Ice Sheet is one of the largest uncertainties affecting global sea-level rise estimates, both for today and over the coming centuries. The main source of this ice-discharge uncertainty is rooted in the poor knowledge of coastal bed topography (IPCC, 2019). For example, only 12% of the Antarctic grounding line have observed bed elevation data within 1 km, and 28% of the grounding line have no data points within 20 km (Matsuoka et al., 2022). To address this problem, SCAR established a new Action Group RINGS [1]. The primary objective of RINGS is to develop a comprehensive reference bed topography dataset around the entire Antarctic coast, and the secondary objective is to characterize the boundary conditions and processes responsible for varying mass balance around the Antarctic coast (RINGS Action Group, 2022).

## Urgent need for airborne geophysical surveys in Enderby Land

A recent analysis of existing radar-data coverage highlighted the neighboring eastern Dronning Maud Land (DML) and Enderby Land as the largest region of Antarctica with insufficient coastal bed elevation data (Matsuoka et al., 2022). Figure 1 plots the positions of radar profiles

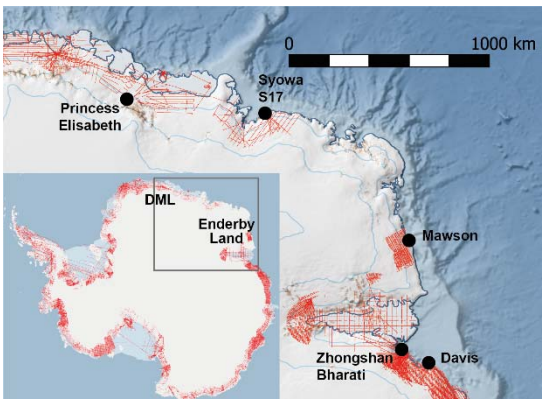


**Figure 1: Bed elevation data coverage collected by ice-penetrating radar in eastern Dronning Maud Land (DML) and Enderby Land. The inset map shows coastal pan-Antarctic data availability and the coverage of the main map. Black dots show logistical hubs of participating countries in this region.**

[1] "RINGS" refers the geometry of circum-Antarctic surveys (see logo top right of this page). It is not an acronym.

collected with modern GPS technology over grounded ice located within 100 km of the grounding line both for pan Antarctica and for Enderby Land. Previous surveys in Enderby Land were made in the vicinity of research stations, and over the Amery Ice Shelf. However, the regions between these data clusters remain completely absent of data, mainly due to their remoteness from established logistical hubs. Nearly 1000 km long coastline between S17 and Mawson is the longest data gap for RINGS. After the five-decade history of radar surveys in Antarctica, there is an urgent need for international coordination to fill this observational gap adequately. The RINGS Action Group is assessing the quantitative impact of future RINGS surveys on ice discharge estimate all around Antarctica, which will be presented in a group paper submitted to peer review in March, 2023. We will develop region-specific hypotheses and quantitative impact assessments based on them.

Considering the level of international collaboration required for this mission, the proposed effort, **Enderby Land RINGS**, can serve as an excellent template for subsequent efforts to develop comprehensive data coverage near the grounding line all around Antarctica. The initial Enderby Land RINGS survey will consist of three coast parallel rings, the primary ring at the grounding line and complementary landward and seaward rings

## Available capacities in Enderby Land

Critical capabilities needed to fill the coastal data gap in Enderby Land can be available through a new international collaboration between Australia, Belgium, China, Germany, India, Japan, Norway, and the USA under the RINGS Action Group. The scientific expertise and logistical capabilities of these nations would enable the needed geophysical surveys to subsequently assess the current and future mass balance and potential instabilities of the Antarctic Ice Sheet in Enderby Land. The necessary capacities are described below.

**Survey aircraft**: Australia (with USA instrumentation), China, and Germany each operate a long-range BT-67 Basler scientific aircraft and have extensive experience conducting large geophysical surveys. The Australian and Chinese aircrafts are often used for both scientific and logistical purposes; the German aircrafts are dedicated to scientific missions. The flight range of each platform varies depending on the instrument suite and crew requirements for a given campaign but typically falls within the range of 900 to 2000 km. It is preferable to have a longer-range aircraft for more efficient regional surveys, but the pool of these aircrafts enables the proposed missions.

**Survey instruments**: China, Germany, and the USA (on Australian aircraft) operate ice-penetrating radar systems capable of meeting the requirements of the proposed missions. China and the USA both operate a type of radar system that has been used extensively in nearly all sectors of Antarctica; the system is relatively lightweight and enables longer flights than many other installations. Germany operates a state-of-the-art ultra-wide-band (UWB) radar capable of deep sounding without compromising range resolution, as well as a microwave radar for shallow sounding that can be operated alongside the UWB system. Despite its advantages, the UWB system is heavy, thus limited range, so Germany also operates a lighter radar sounder (EMR) that is less capable than the UWB but enables longer flights. China, Germany, and the USA all operate gravimeters and magnetometers which can provide insights into the subglacial geological context, as well as optical cameras and laser altimeters that provide opportunities for visual context and calibration and validation of orbital altimeter data.

**Runways and logistic supports**: There are runway for ski-equipped aircrafts ("skiways") at Princess Elisabeth (23.5°E), S17 (40°E), Mawson (63°E), Bharati (76.2°E), Zhongshan (76.4°E) and Davis (78°E) Stations operational throughout the Austral summer field seasons; locations

of these stations are shown in Fig. 1. Sea ice runways at Syowa and Davis Stations are also operational at the beginning of the field seasons.

**Scientific expertise**: This partnership of nations together has cutting-edge expertise in airborne geophysics, radio glaciology, satellite remote sensing, and ice-flow modeling. This international partnership ideally suited to carry out these surveys, to analyze and publicly release the resulting datasets, and to use the data to provide an updated assessment of mass balance and potential instabilities of the Antarctic Ice Sheet in Enderby Land.

## Possible survey plans

We propose to carry out the Enderby Land surveys in two separate missions. **The first mission** is intended to provide the first coverage of coastal Enderby Land using a few reconnaissance flights between Japan's S17 facility and Australia's Davis and China's Zhongshan Stations during **the 2023-24 field season**. It will be coordinated with planned DML RINGS surveys further west in the same field season. **The second mission** is intended to increase data density in the region, with coverage guided by the results of the reconnaissance flights. Considering the time needed for analysis of the 23-24 field data and subsequent planning, **the 2026-27 season** is perhaps the earliest possible opportunity for the second mission. Detailed plans will be further discussed and developed through the RINGS Action Group. The plans will also consider the necessity to further develop a continuous, gapless coverage towards Wilkes Land.

The flight plans for the 2023-24 season will be discussed further based on the initial plan outlined below. At this stage, no national programs have formally committed their resources for this mission, but key players in each nation share the same interest and desire to integrate the plans into complementary work so that a first coordinated Enderby Land RINGS survey can be attempted during the 2023-24 season. Required fuel for each option is approximate, as the RINGS Survey requirements are being discussed and will be finalized in the second quarter of 2023. Each flight team is composed of 5 - 8 personnel, including two pilots and one aircraft maintenance engineer.

- **Reconnaissance 1 (Australian plane)**: Depart Davis Station (need for Jet A1 fuel: approx. 20 drums), refuel at Mawson Station (4 drums), survey for the primary ring, and overnight at S17 (20 drums).
- **Reconnaissance 2 (Chinese plane)**: Depart Zhongshan Station (20 drums), refuel at Mawson Station (4 drums), survey along the coast, and overnight at Princess Elisabeth Station (20 drums)
- **Reconnaissance 3 (German plane, in conjunction with DML RINGS)**: Depart Princess Elisabeth Station (20 drums), survey along the coast towards east and back, and overnight at S17 (10 drums).
- **Reconnaissance 4 (Australian plane)**: Depart S17, survey along the coast, refuel at Mawson Station (10 drums), and overnight at Davis Station.
- **Reconnaissance 5 (Chinese plane)**: Depart Princess Elisabeth Station, survey along the coast, refuel at Mawson Station (10 drums), and overnight at Zhongshan Station.
- **Reconnaissance 6 (German plane)**: Depart S17, fly the vicinity of Lützow-Holm Bay, and overnight at Princess Elisabeth Station.

Approximate amount of fuel needed for these missions is:

- Davis Station: 20 drums
- Mawson Station: 28 drums
- Zhongshan Station: 20 drums

- S17: 30 drums
- Princess Elisabeth Station: 40 drums

## Data sharing and planned publications

The data collected with these surveys will be available as agreed within the RINGS Action Group and as guided by the SCAR data policy (SCAR, 2022). Before the public release of the data, this international group will make a joint effort to process and analyze the collected data and develop the first assessment of Antarctic Ice Sheet mass balance in Enderby Land using the newly collected data. All participating institutions and involved scientists will have representation on the first publication.

## References

IPCC. (2019). IPCC Special Report on the Ocean and Cryosphere in a Changing Climate.

Matsuoka, K., R. Forsberg, F. Ferraccioli, G. Moholdt, and M. Morlighem (2022), Circling Antarctica to unveil the bed below its icy edge, *Eos, 103,* https://doi.org/10.1029/2022EO220276.

RINGS Action Group (2022), RINGS: Collaborative international effort to map all Antarctic ice-sheet margins, Scientific Committee on Antarctic Research, https://doi.org/10.5281/zenodo.6638327.

Scientific Committee on Antarctic Research (2022), SCAR Data Policy (2022), SCAR report No. 42, ISSN 1998-0337.