An open access geospatial database for the sub-Antarctic Prince Edward Islands

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Researchers of projects at the sub-Antarctic Prince Edward Islands are increasingly considering geospatial data as an essential component in answering scientific questions. A need exists for high-resolution geospatial data in both multi- and transdisciplinary research to better analyse fine-scale biotic–abiotic interactions of the Islands' landscape and ecosystems within the context of climate change and the impacts of invasive species. However, much of the geospatial data that currently exist have limitations in spatial coverage and/or resolution, are outdated, or are not readily available. To address these issues, we present an online geospatial database for the Prince Edward Islands (both islands) produced from a high-resolution digital surface model and satellite imagery. This database contains vector files, raster data sets, and maps of topographical and hydrological parameters. It is freely available to download from Figshare – an open access data repository. We encourage the South African polar science community to make use of similar platforms for improved data sharing practices.

Significance:

- A topographical and hydrological geospatial database – produced from a 1 m x 1 m digital surface model of the Prince Edward Islands – is provided.
- These fine-scale geospatial data allow for a more comprehensive assessment of biotic–abiotic interactions at an island scale.
- Also included are locality maps specifying place names and established long-term marine mammal monitoring beaches and coastal zones for improved cross-referencing.
- The dataset is downloadable from an open access data repository and intended to promote open science and data sharing practices.

Introduction

The sub-Antarctic Prince Edward Islands (47°S 38°E) – consisting of Prince Edward Island and Marion Island – are sentinels for terrestrial and marine research in the southern Indian Ocean (Figure 1).[1] Located just north of the present-day Antarctic Polar Front and dominated by a hyper-maritime climate, the Islands provide a unique opportunity to study ecosystem responses to climate change.[2-7] The research projects conducted at the Prince Edward Islands cover a range of botanical, geological, geomorphological, and biological studies.[8,9] On the larger Marion Island, scientific research has been continuous for the last five decades, whereas on Prince Edward Island, access has been restricted to a single contingent of 10 people every four years[10] (Figure 1). Terrestrial science, therefore, occurs predominantly on Marion Island while at Prince Edward Island it is limited in scope with most progress in botanical and ornithological studies.[9] Geospatial information of Marion Island's topography has aided scientific investigations by not only providing the backdrop for site selection and planning of sampling strategies but also interpreting and modelling landscape and ecosystem evolution.[11-14] Since the introduction of handheld Global Positioning Systems (GPS) in early 2000s, terrestrial multi- and transdisciplinary research on Marion Island has increasingly started to include assessment of fine-scale interactions within the landscape to understand ecosystem responses to past and present climate change, as well as the impacts of invasive species.[15-18] Individual-based population studies focusing on various animal species have, by necessity, also been structured around specific geographical localities at the Islands to aid in experimental design.[19] Not only do scientific endeavours depend on accurate geospatial information[20], but conservation efforts, such as the planned mouse eradication programme on Marion Island[21], require precise geospatial data to support the planning phase of (if successful) the world's largest eradication programme of mice from an island. However, much of the geospatial information for the Prince Edward Islands was previously only available in hardcopy format[22,23] or, when such data have become available in digital format[24], they have typically had a limited spatial coverage and/or resolution, particularly for Marion Island's west coast[25]. Generally, such geospatial data are shared informally among the scientists who work on the Prince Edward Islands or are reproduced ad hoc from existing publications. Yet, the circulating data are rarely curated or updated, or are sometimes lost entirely as researchers retire or move on to other research sites. Some of the geospatial data needs have been addressed by the production of data on the Islands' geology[25], but fine-scale topographical and hydrological data are still outstanding. Furthermore, the naming process of the Prince Edward Islands' features remains unfinished.[26] Since the first attempt to register Prince Edward Islands place names with the South African Geographical Names Council (*Act 118 of 1998*) in 2001[27], only a select few features (e.g. Umkhombe, Mascarin and Resolution Peaks) have thus far been approved[26]. Most of Prince Edward Islands' place names are still considered 'provisional'[28] and are practically absent from the gazetteer of South African geographical names[26,29]. Nonetheless, these names are widely used in scientific spheres[9] and official policy documents[10]. However, these names are used piecemeal in subject-specific or region-specific works and there is, therefore, a need for a complete list of place names for the Prince Edward Islands, whether officially recognised, provisionally accepted, or colloquial, as these are currently not readily available in the public domain.

Data sharing issues are not unique to the South African National Antarctic Programme (SANAP) science community. Globally, the focus on data sharing practices or 'open science' is increasing[30,31] and has already transpired with specific African[32,33] and South(ern) African perspectives. The push from government (through the *South African Spatial Data Infrastructure Act, 54 of 2003*), funding agencies, publishers, and institutions and for improved data availability[33], have encouraged sharing practices by several scientific fields, amongst others, ecology[34,35], geomatics[36], and soil science[37]. Therefore, a geospatial database for both of the Prince Edward Islands is provided here, which includes topographical data (e.g. contour lines, aspect, slope, and hillshade raster), and hydrological data (e.g. streams and lakes) that were produced from a 1 m x 1 m digital surface model (DSM). In addition, topographical and locality maps of both Prince Edward and Marion Islands are provided in downloadable PDF format. We augment these contributions with marine mammal research-linked coastline codes/names that have been in long-term use for experimental design, and have consequently been adopted by the larger scientific community working at the Islands. Lastly, we provide a collated list of all the place names in use on Prince Edward and Marion Islands. The geospatial database, maps and the record of place names are available to download from Figshare (https://figshare.com/), an open access data repository.

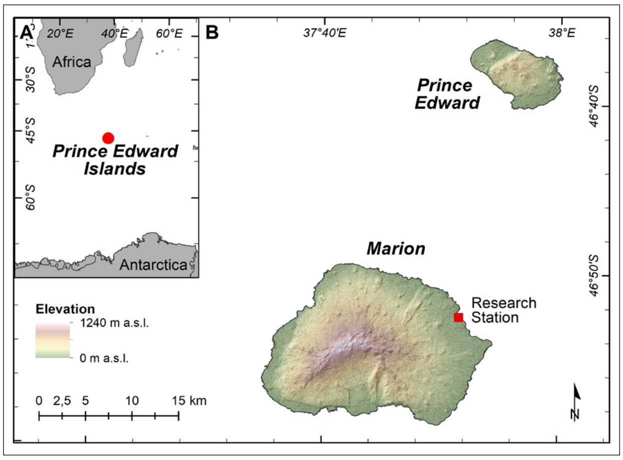

Figure 1: (A) The location of the Prince Edward Islands. (B) The location and size of Marion and Prince Edward Islands and their positions relative to one another. The South African National Antarctic Programme research station is situated on Marion Island. Maps similar to this figure are available for re-use through the online datasets.

Methods and results

All the geospatial data were generated in Esri® ArcGIS® Desktop 10.6 where the 'WGS 84 datum' and 'Transverse Mercator projection' with longitude 37°E as the central meridian (CM37E) were selected (Figure 2). The mapping process for both Prince Edward and Marion Islands was based on a DSM with a 1 m x 1 m cell size resolution and 0.7 m vertical accuracy as the primary data source (Figure 2A). This DSM was produced by the Chief Directorate: National Geospatial Information of the South African Department of Agriculture, Land Reform and Rural Development and completed in 2017 photogrammetrically using stereo Pléiades imagery and accurate ground control points captured in 2016. All the topographical data were generated directly from the DSM. A hillshade raster was generated from the DSM using the 'hillshade' tool (Figure 2D). Slope (in degrees) and aspect were calculated using ArcGIS® 'Slope' and 'Aspect' tools, respectively (Figure 2B and 2C). Contour lines were produced by first smoothing the DSM with the 'Focal Statistics' tool (statistic type = mean) and using a 10-m vertical and 20-m horizontal cell-size neighbourhood, following the proposed methods of Price[38]. The 'Contour' tool was used to generate 10-m contours from the smoothed DSM raster and the final layer was cleaned by deleting all contours below sea level and contour line segments less than 50 m in length, to overcome the potential interference of artefacts (Figure 2B and 2E). Drainage lines were generated using the Esri® 'Hydrology' toolset's 'Fill' (z-limit=unspecified), 'Flow direction' (method=D8) and 'Flow accumulation' functions, following the procedures of Jenson and Domingue[39]. A flow accumulation threshold of 50 000 was used to determine the final drainage density by using the 'con' (conditional) tool. This threshold was considered sufficient to capture all the drainage lines previously mapped for Marion Island[28], whereas a higher threshold would have produced excessive detail. The stream order of each drainage line was determined according to Strahler's classification, using the 'stream order' tool. The output raster was converted to a polyline feature (drainage lines) and smoothed at 30 m using a PEAK smoothing algorithm of the 'smooth line' tool (Figure 2D). The stream order, as well as the names of well-known[22,23,28] stream channels, are included in the attribute data of the final 'drainage line' dataset layer (Table 1).

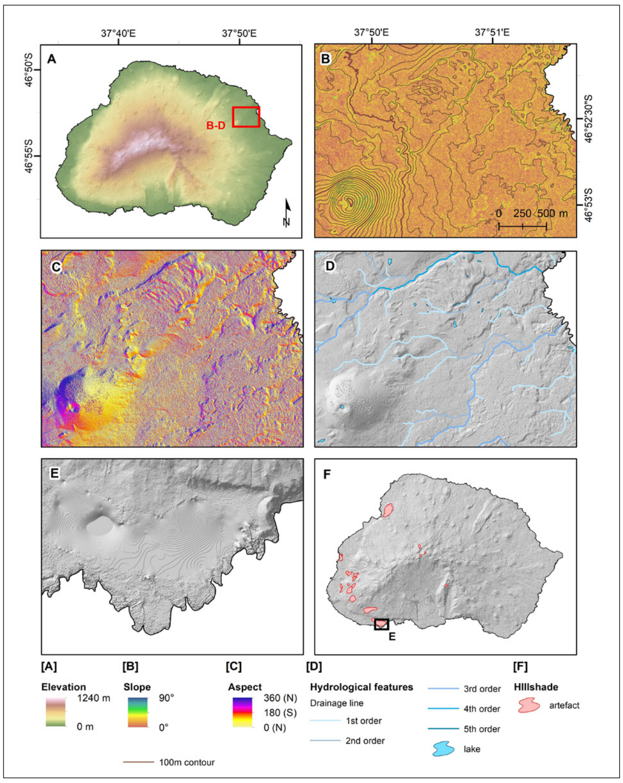

Figure 2: The datasets created in this study from the (A) digital surface model (DSM), using Marion Island's datasets as an example. (B) A slope raster and contour lines, (C) an aspect raster and (D) hydrological features such as drainage lines and lakes. The hillshade raster has (E) minor artefacts caused by interference in reflectance data by either cloud cover, scoria or snow. (F) Regions on Marion Island where artefacts in the DSM will affect the accuracy of derived geospatial data. Projection: Transverse Mercator CM37E.

All these geospatial layers were clipped to coastline polygons, sourced from National Geospatial Information in 2019. Waterbodies or 'lakes' were mapped with the combined use of the hillshade raster and satellite imagery from Earth Observing 1 – Advanced Land Imager (EO1-ALI), QuickBird (QB), WorldView 1 (WV1) and WorldView 2 (WV2). The EO1-ALI has a 10-m cell-size resolution, was captured on 5 May 2009, and is orthorectified and georeferenced. The resolutions, production dates and limitations to the spatial coverage of the imagery sets from QB, WV1 and WV2 have already been covered by Rudolph et al.[25,40] The QB, WV1 and WV2 imagery sets are not orthorectified but are rather only georeferenced. The outline of waterbodies were digitised at a scale of 1:1000 using the QB, WV1 and WV2 images, and then repositioned spatially using the EO1-ALI and hillshade raster as reference. Minor artefacts exist in the reflectance data of DSM in regions typically associated with cloud cover, scoria substrate or snow cover (Figure 2E). These interferences invariably effect the accuracy of the hillshade raster in, for example, Marion Island's Central Highland or on the west coastal plains where such surfaces are widespread and cloud cover is common (Figure 2F). In such cases, verification was done using available satellite imagery, existing maps[22,23,28] and over two decades' of field observations[8,19] which allowed for some lakes to be mapped for the first time. Alternative data validation is not possible at this time, as the reference data used in this study form the most complete, up-to-date and highest-resolution spatial dataset that is currently available. Still, geospatial data from these regions should be used with some caution. The attributes and use limitations of the final raster and vector layers are presented in

Table 1. Vector data can be downloaded as Esri® shapefiles or OGC® GeoPackages (https://www.geopackage.org/). Complete metadata for each of the geospatial layers were captured according to the built-in ISO 19139 metadata standards of Esri® ArcCatalog™ and can be viewed as a stand-alone text file in the database.

A list of all the documented place names for the Prince Edward Islands was compiled by first referring to the original surveys[41-43] and topographical maps[22,23], and then updating the list from newer maps of Marion Island[24,28] and lastly cross-checking this list with the Prince Edward Islands Management Plan[10]. Names not initially included in this compilation but that are in common use, specifically on Marion Island, were added to the list as an 'alias'. Where applicable, the older/previous name is also included under 'alias'. Coordinates are provided for the features, as determined using satellite imagery and the hillshade raster. For peaks, the coordinate indicates the highest point; for lakes, ridges or streams etc., a coordinate is given for a point within the feature. The collated place name lists for Marion and Prince Edward Islands are given in the online resource as geospatial datasets and as Supplementary tables 1 and 2, respectively. Lastly, a summary of marine mammal monitoring beaches and coastal zones visited by research programmes on Marion (e.g. Marion Island Marine Mammal Programme[19]) and Prince Edward Islands, and their code identifiers are included in the supplementary tables, the geospatial database and as annotated maps. Their long-term (over four decades) use has additionally benefitted use in consistency across different research programmes. A list of the names, coordinates, and their descriptions (where applicable) of marine mammal monitoring beaches at Marion Island and monitoring coastal zones at Prince Edward Island are provided in Supplementary tables 3 and 4, respectively. Sets of downloadable maps were constructed for both Marion and Prince Edward Islands, each one showing their respective topographical and hydrological features, and another depicting the location of marine mammal monitoring beaches and coastal zones. Previews of these maps can be seen in Figures 3–5 and their specifications can be seen in Table 1.

Figure 3: A preview of the topographical and hydrological data of (A) Marion Island and (B) Prince Edward Island which have been used to construct download maps of each (see Table 1). Refer to Supplementary tables 1 and 2 for the coordinates of these feature points. Projection: Transverse Mercator CM37E.

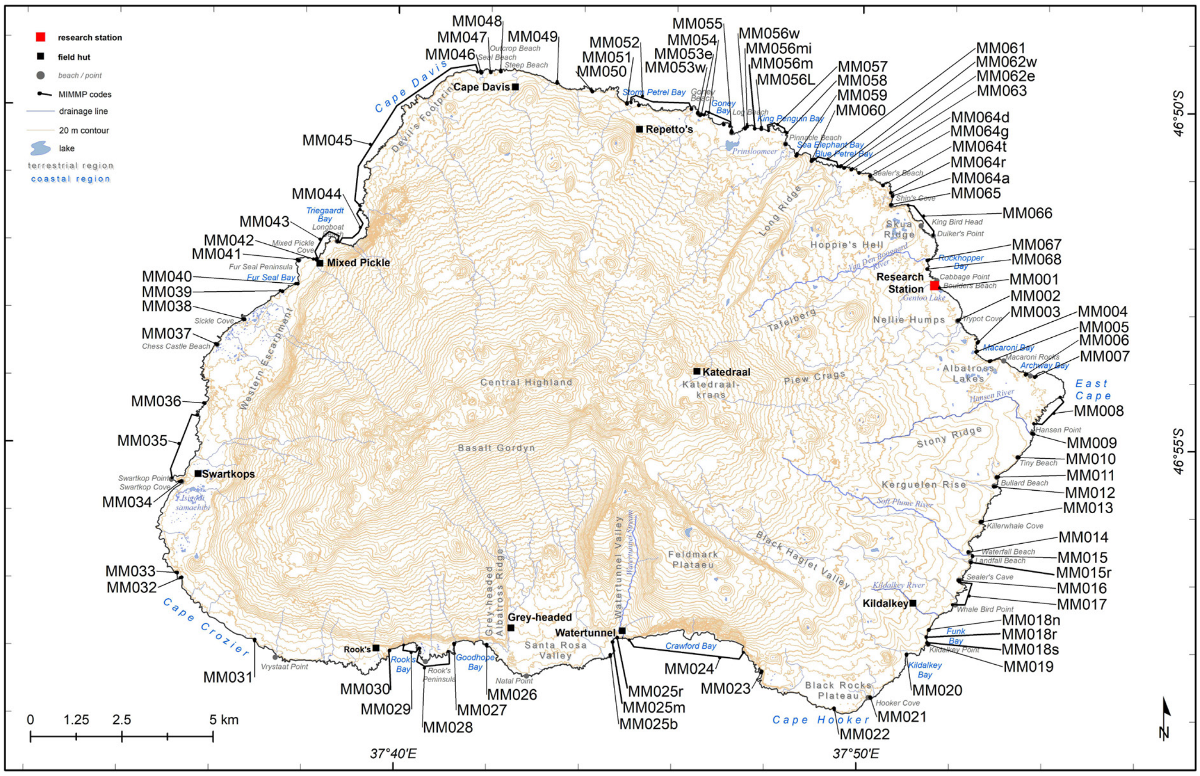

Figure 4: A preview of the map indicating names and codes of beaches and zones used in marine mammal monitoring research programmes at Marion Island. Detailed descriptions and coordinates can be found in Supplementary table 3 and the map is available to download from the open access dataset (see Table 1). Projection: Transverse Mercator CM37E.

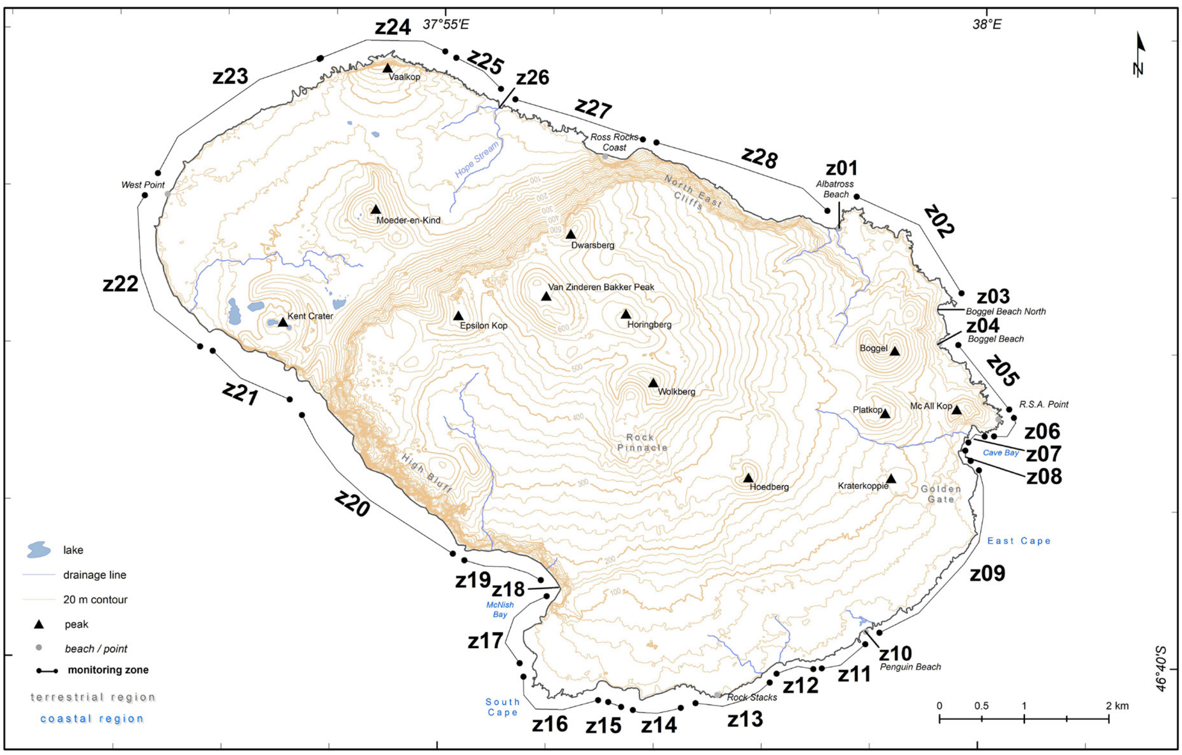

Figure 5: A preview of the map indicating codes of marine mammal monitoring beaches and zones used in research programmes at Prince Edward Island. The detailed code descriptions and coordinates can be found in Supplementary table 4 and the map is available to download from the open access dataset (see Table 1). Projection: Transverse Mercator CM37E.

Table 1: A summary of the geospatial data and downloadable maps which can be accessed through the open access dataset. The attributes and limitations of the different data layers are indicated. A list of the place names and their coordinates is included in Supplementary tables 1–4.

Data type		Attributes	Limitations / comment	Format
Raster	Hillshade raster	1 m x 1 m cell size	Some regions with surface snow cover, scoria or cloud cover are not interpolated accurately due to artefacts in reflectance data of the DSM[a]	TIFF image (.tif)
	Slope	0–90° slope angle	1 m x 1 m cell size	TIFF image (.tif)
	Aspect	0–360° range aspect, flat = -1	1 m x 1 m cell size	TIFF image (.tif)
Vector	Contour lines	10 m vertical intervals, averaged over 20 m horizontal resolution	Topographical irregularities smaller than 20 m in vertical and horizontal scale are omitted, nodes of <50 m in length have been removed. Coastline contour (0 m) does not distinguish between rocky outcrops at sea level or sheer cliff faces. Have not been cleaned manually for other artefacts.	Esri® shapefile and OGC® GeoPackage (.gpkg)
	Drainage lines	Stream order, length	Only represents drainage lines based on topographical depressions, does not necessarily indicate true surface run-off	Esri® shapefile and OGC® GeoPackage (.gpkg)
	Lakes	Latitude and longitude of lake centroid, area in square metres	Lake size changes annually, current layers reflect the prominent water bodies visible on satellite imagery obtained in 2009 (EO1-ALI[b] and QB[c]), 2011 (WV1[d]) and 2012 (WV2[e])	Esri ® shapefile and OGC® GeoPackage (.gpkg)
Vector and datasheet	Place names	Feature type (terrestrial or, coastal features), alias (previous/alternative name), MIMMP[e] beach code, latitude, longitude	Not all names are officially recognised by the South African Geographical Names Council but are in common use by researchers	Esri® shapefile, OGC® GeoPackage (.gpkg) and MS Excel worksheet tables (.xlsx)
	Marine mammal monitoring beaches/zones			
Ready-made maps	Topographical and hydrological maps	For Marion and Prince Edward Islands showing contour lines, peaks, terrestrial (ridges, valleys) and coastal (beaches, points, coves) features, field huts, drainage lines, lakes		Designed for paper size A2, in .jpg and .pdf format
	Maps indicating marine mammal monitoring beaches and coastal zones	Beach codes used on Marion Island primarily by MIMMP[f] and coastal zones used on Prince Edward Island: including contour lines, peaks, coastal features (beaches, points, coves), field huts, drainage lines, lakes, beach codes		Designed for paper size A2, in .jpg and .pdf format
	Locality maps	Maps with varied detail showing the Islands' situational location within a global, Southern Ocean / sub-Antarctic context		Various sizes, in .jpg format

[a]Digital surface model; [b]Earth Observing 1 – Advanced Land Imager; [c]QuickBird; [d]WorldView 1; [e]WorldView 2; [f]Marion Island Marine Mammal Programme

Location maps of the Island group were also created and have been made available for general use (Table 1). The final geospatial database and series of maps can be downloaded from Figshare (https://doi.org/10.6084/m9.figshare.19248626) as either vector or raster data, and in PDF or TIFF format (Table 1).

The maximum elevation and calculated surface area of the Prince Edward Islands have changed little since the first estimations were performed using the data collected during the island surveys of Langenegger and Verwoerd[43]. The first measurement of the elevation of the highest point on Marion Island was done by Captain Nares on the HMS *Challenger* in 1873.[43] He determined the maximum elevation to be 1280 m above mean sea level (a.m.s.l.). Later, Langenegger and Verwoerd[43] stated that the maximum elevation of Marion Island is 1230 m a.m.s.l., whereas Prince Edward Island is considerably lower at 672 m a.m.s.l. The map released for Marion Island in 2002[24] set the maximum contour line at 1240 m a.m.s.l. The most recent data for the Prince Edward Islands set the maximum elevation for Marion Island at 1248 m a.m.s.l. and 669 m a.m.s.l. for Prince Edward Island. However, these values should be verified in the field using a differential GPS. In addition, Verwoerd[44] stated that the calculated surface areas of Marion Island and Prince Edward Island were 290 km^2 and 44 km^2, respectively. Using the first digital topographical data of Marion Island[24], Meiklejohn and Smith[45] calculated the projected surface area and actual surface area, using the raster-based method of Jenness[46], as 290.33 km^2 and 300.42 km^2, respectively. Using the 'Add Surface Information' tool in ArcGIS® Desktop 10.6 on the 2019 DSM from National Geospatial Information, the 2D and 3D surface areas of Marion Island are calculated as 293.23 km^2 and 346.65 km^2, respectively. Using the same method, the 2D and 3D surface areas for Prince Edward Island are 45.09 km^2 and 56.16 km^2, respectively. Owing to the volcanic origin of the islands, their subaerial extent may change following any future volcanic eruptions and lava outflows.

Discussion

The geospatial database we have produced provides a valuable online resource for researchers working on the Prince Edward Islands. Prior to this database, geospatial data of the Prince Edward Islands existed either exclusively in hardcopy form[22-24], had limited spatial resolution or were not readily available[28]. A digital dataset such as this, that provides fine-resolution geospatial data of both islands, will facilitate multi- and transdisciplinary research and allow for a more comprehensive assessment of biotic–abiotic interactions on an island scale, as well as improve modelling capabilities. More specifically, scientific investigations, which consider slope, aspect or elevation as key variables in their studies, can assess these relationships at a finer scale, using the topographical data provided here. For example, our understanding of the development of geomorphic features through aeolian[47], soil frost[4] and freeze-thaw[7,48] or mass movement processes[49], has been limited to point or site-specific datasets. Similarly, studies that focus on indigenous or invasive species can now investigate the potential control of topographical and/or hydrological factors on their distribution at a larger scale. This can be applied to, for example, burrow-nesting bird species[13], microorganisms[12,14] or plant communities. The effect of these topographic controls on variations in microclimate – such as wind stress[16], temperature[15] or precipitation[6] – can also be explored at a higher resolution. Furthermore, long-term landscape development such as the islands' geological and geomorphological evolution[44], deglaciation[11] and island responses to climate change[50,51] rely heavily on the knowledge of topographical controls, which can be readily achieved by (accurate) mapping[25,40,50,52]. In addition, as the dataset also incorporates Prince Edward Island at the same spatial resolution as that for Marion Island, it provides a unique opportunity to model and predict processes (e.g. geomorphic) or ecosystem interactions (e.g. vegetation assemblages, species population distribution) for the less frequented Prince Edward Island. The combined use of satellite imagery and the DSM allowed for the mapping of numerous waterbodies (lakes), including some along Marion Island's west and southwest coasts which have never been mapped before. In addition, a compilation of commonly used (official, provisional and colloquial) place names for both Prince Edward Islands and their feature descriptions are presented here. This record provides a much-needed summary or baseline of current 'local knowledge' and can facilitate the process of presenting these names, or alternatives, to the South African Geographical Names Council to ratify their use.

The availability of published data (or lack thereof), and particularly *spatial* data, is an issue not unique to the Prince Edward Islands' scientific community, but one that exists in general scientific practice.[30,31,53] The South African government rightly recognises the need to encourage better data sharing practices through ratification of the *South African Spatial Data Infrastructure Act* (*Act 54 of 2003*). There are numerous advantages of data sharing[33,53] and successful practices have been realised by several scientific disciplines[34-36,54]. The increasing demand for data sharing has sparked the emergence of numerous online data repositories such as Figshare[55], Mendeley Data[56,57], and Zenodo[58]. A Registry of Research Data Repositories (https://www.re3data.org/) makes it possible to find a digital repository to suit the specific needs of a research lab or project. Most of these repositories enable the user to publish data under a Creative Commons Attribution Licence, which allows for the data to be used, shared and/or adapted, as long as proper credit is given. In other words, authors retain copyright of the dataset. This practice is further supported by sharing platforms through assigning digital object identifiers (DOIs) to datasets, making them fully citable. Alternatively, dedicated universal data hosting infrastructures such as the Group on Earth Observations e.g. ArfiGEOSS[59], and the South African Earth Observation Network (SAEON) also provide the opportunity for earth science data to be curated. Martínez-López et al.[60] provide an overview of some of these platforms and we encourage scientists to explore and make use of these to improve access and curation of geospatial data. We further recommend that such practices form an integral part of the SANAP scientific community's mandate to foster open science.

Conclusion

Geospatial information provides the necessary geographical data for terrestrial scientific investigations. We provide here a topographical and hydrological geospatial database, produced from a 1 m x 1 m DSM of the Prince Edward Islands. These geospatial data will facilitate the consideration of finer-scale spatial variables in terrestrial scientific investigations at the Prince Edward Islands, and especially on Marion Island, from data collection to analysis and modelling phases of scientific investigations. Updated topographical maps of both islands are also available for download, along with locality maps, and lists inclusive of the Islands' place names and their localities are also provided. The geospatial database is downloadable from an open access data repository and the file formats ensure wide use across platforms. A more comprehensive integrated terrestrial and marine geospatial dataset is still needed to effectively monitor climate change impacts at the Prince Edward Islands and for the successful management of the Islands as a Marine Protected Area. For example, high-resolution bathymetry data of the ocean floor will facilitate an integration of terrestrial and oceanic studies to better understand the ocean–land interactions. We encourage research endeavours in the wider South African scientific community to support open science practices and make similar geospatial data readily available through open access data repositories, as has been done here.

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Data availability

Datasets and maps used in this paper are available in the supplementary tables and as an open dataset to download from Figshare (https://doi.org/10.6084/m9.figshare.19248626). The dataset is licenced under a Creative Commons Attribution 4.0 International Licence.

Competing interests

We have no competing interests to declare.

Authors' contributions

E.M.R.: Conceptualisation; methodology; data analysis; validation; data curation; writing – the initial draft. D.W.H.: Conceptualisation; data analysis; validation; writing – revisions; project management; funding acquisition. P.J.N.d.B.: Validation; data curation; writing – revisions. W.N.: Conceptualisation; validation; writing – revisions; project leadership; funding acquisition. All approved the final version of the manuscript.

References

1. Ansorge IJ, Skelton P, Bekker A, De Bruyn PJN, Butterworth D, Cilliers P, et al. Exploring South Africa's southern frontier: A 20-year vision for polar research through the South African national antarctic programme. S Afr J Sci. 2017;113(5/6), Art. #a0205. https://doi.org/10.17159/sajs.2017/a0205

2. Rouault M, Mélice JL, Reason CJC, Lutjeharms JRE. Climate variability at Marion Island, Southern Ocean, since 1960. J Geophys Res C Ocean. 2005;110(5):1–9. https://doi.org/10.1029/2004JC002492

3. Smith VR. Climate change in the sub-Antarctic: An illustration from Marion Island. Clim Change. 2002;52:345–357. https://dx.doi.org/10.1023/A:1013718617277

4. Nel W. A preliminary synoptic assessment of soil frost on Marion Island and the possible consequences of climate change in a maritime sub-Antarctic environment. Polar Res. 2012;31(1), Art. #17626. https://doi.org/10.3402/polar.v31i0.17626

5. Le Roux PC. Climate and climate change. In: Chown SL, Froneman PW, editors. The Prince Edward Islands: Land-sea interactions in a changing ecosystem. Stellenbosch: SUN Press; 2008. p. 39–64. https://doi.org/10.18820/9781928314219/03

6. Hedding DW, Greve M. Decreases in precipitation on sub-Antarctic Marion Island: Implications for ecological and geomorphological processes. Weather. 2018;73(6):203. https://doi.org/10.1002/wea.3245

7. Boelhouwers J, Holness S, Sumner P. The maritime Subantarctic: A distinct periglacial environment. Geomorphology. 2003;52(1–2):39–55. https://doi.org/10.1016/s0169-555x(02)00247-7

8. Nel W, Boelhouwers JC, Borg C-J, Cotrina JH, Hansen CD, Haussmann NS, et al. Earth science research on Marion Island (1996–2020): A synthesis and new findings. S Afr Geogr J. 2021;103(1):22–42. https://doi.org/10.1080/03736245.2020.1786445

9. Chown SL, Froneman PW. The Prince Edward Islands: Land-sea interactions in a changing ecosystem. Stellenbosch: SUN Press; 2008. https://doi.org/10.18820/9781928357063/01

10. DST-NRF Centre of Excellence for Invasion Biology. Prince Edward Islands Management Plan. Stellenbosch: DST-NRF Centre of Excellence for Invasion Biology; 2010.

11. Rudolph EM, Hedding DW, Fabel D, Hodgson DA, Gheorghiu DM, Shanks R, et al. Early glacial maximum and deglaciation at sub-Antarctic Marion Island from cosmogenic 36Cl exposure dating. Quat Sci Rev. 2020;231, Art. #106208. https://doi.org/10.1016/j.quascirev.2020.106208

12. Chau JH, Born C, McGeoch MA, Bergstrom D, Shaw J, Terauds A, et al. The influence of landscape, climate and history on spatial genetic patterns in keystone plants (*Azorella*) on sub-Antarctic islands. Mol Ecol. 2019;28(14):3291–3305. https://doi.org/10.1111/mec.15147

13. Dilley BJ, Hedding DW, Henry DAW, Rexer-Huber K, Parker GC, Schoombie S, et al. Clustered or dispersed: Testing the effect of sampling strategy to census burrow-nesting petrels with varied distributions at sub-Antarctic Marion Island. Antarct Sci. 2019;31(5):231–242. https://doi.org/10.1017/S0954102019000300

14. Mortimer E, Jansen van Vuuren B, Meiklejohn KI, Chown SL. Phylogeography of a mite, Halozetes fulvus, reflects the landscape history of a young volcanic island in the sub-Antarctic. Biol J Linn Soc. 2012;105:131–145. https://doi.org/10.1111/j.1095-8312.2011.01770.x

15. Ripley BS, Edwardes A, Rossouw MW, Smith VR, Midgley GF. Invasive grasses of sub-Antarctic Marion Island respond to increasing temperatures at the expense of chilling tolerance. Ann Bot. 2020;125(5):765–773. https://doi.org/10.1093/aob/mcz156

16. Momberg M, Hedding DW, Luoto M, Le Roux PC. Exposing wind stress as a driver of fine-scale variation in plant communities. J Ecol. 2021;109(5):2121–2136. https://doi.org/10.1111/1365-2745.13625

17. Hugo-Coetzee EA, Le Roux PC. Distribution of microarthropods across altitude and aspect in the sub-antarctic: Climate change implications for an isolated Oceanic Island. Acarologia. 2018;58:43–60. https://doi.org/10.24349/acarologia/20184278

18. Greve M, Mathakutha R, Steyn C, Chown SL. Terrestrial invasions on sub-Antarctic Marion and Prince Edwards Islands. Bothalia. 2017;47(2), Art. #2143. https://doi.org/10.4102/abc. v47i2.2143

19. Bester MN, De Bruyn PJN, Oosthuizen WC, Tosh CA, McIntyre T, Reisinger RR, et al. The Marine Mammal Programme at the Prince Edward Islands: 38 years of research. Afr J Mar Sci. 2011;33(3):511–521. https://doi.org/10.2989/1814232X.2011.637356

20. Hedding DW. Comment on "Clinopyroxene megacrysts from Marion Island, Antarctic Ocean: Evidence for a late stage shallow origin" (2019) by R. J. Roberts, K. D. Lehong, A. E. J. Botha, G. Costin, F. C. De Beer, W. J. Hoffman and C. J. Hetherington. Mineral Petrol. 2020;114(4):357–359. https://doi.org/10.1007/s00710-020-00713-z

21. Preston GR, Dilley BJ, Cooper J, Beaumont J, Chauke LF, Chown SL, et al. South Africa works towards eradicating introduced house mice from sub-Antarctic Marion Island: The largest island yet attempted for mice. In: Veitch C, Clout M, Martin A, Russell J, West C, editors. Island invasives: Scaling up to meet the challenge. Gland: IUCN; 2019. p. 40–46. https://portals.iucn.org/library/node/48358

22. Langenegger O, Verwoerd WJ. Topographic map of Prince Edward Island. Pretoria: Geological Survey; 1968.

23. Langenegger O, Verwoerd WJ. Topographic map of Marion Island. Pretoria: Geological Survey; 1968.

24. Chief Directorate: Surveys and Mapping. Marion Island Provisional Map 1:25 000. Cape Town: Department of Environmental Affairs & Tourism; 2002.

25. Rudolph EM, Hedding DW, Nel W. The surface geology of the Prince Edward Islands: Refined spatial data and call for geoconservation. S Afr J Geol. 2021;124(3):627–638. https://doi.org/10.25131/sajg.124.0014

26. Jenkins E. The naming of uninhabited islands: Jules Verne's The Mysterious Island and Marion Island. S Afr Geogr J. 2017;99:184–195. https://doi.org/10.1080/03736245.2016.1211032

27. South African Geographical Names Council. Meeting Minutes. 2001; November.

28. National Geospatial Information. Marion Island Provisional Map 1:25 000. Cape Town: Department of Agriculture, Land Reform and Rural Development; 2005.

29. South African Geographical Names Council. Gazetteer of geographical names approved, 2000–2014. Pretoria: Department of Arts and Culture; 2014.

30. Chawinga WD, Zinn S. Global perspectives of research data sharing: A systematic literature review. Libr Inf Sci Res. 2019;41(2):109–122. https://doi.org/10.1016/j.lisr.2019.04.004

31. Klump J. Long-term availability of geoscience data. In: Geoinformatics 2008 – data to knowledge. Reston, VA: US Geological Survey; 2008. p. 55–58.

32. Chiware ERT. Open research data in African academic and research libraries: A literature analysis. Libr Manag. 2020;41(6/7):383–399. https://doi.org/10.1108/LM-02-2020-0027

33. Abebe R, Aruleba K, Birhane A, Kingsley S, Obaido G, Remy SL, et al. Narratives and counternarratives on data sharing in Africa. In: Conference on Fairness, Accountability, and Transparency (FAccT '21); 2021 Mar 3–10; virtual event. New York: Association for Computing Machinery; 2021. p. 329–341. https://doi.org/10.1145/3442188.3445897

34. Rutherford MC, Mucina L, Powrie LW. The South African National Vegetation Database: History, development, applications, problems and future. S Afr J Sci. 2012;108(1/2), Art. #629. https://doi.org/10.4102/sajs.v108i1/2.629

35. Coetzer W, Hamer M. Managing South African biodiversity research data: Meeting the challenges of rapidly developing information technology. S Afr J Sci. 2019;115(3/4), Art. #5482. https://doi.org/10.17159/sajs.2019/5482

36. Sebake MD, Coetzee S. Results of three case studies for assessing motivators and barriers to address data sharing in South Africa. S Afr J Geomatics. 2012;1(1):32–43.

37. Paterson G, Turner D, Wiese L, Van Zijl G, Clarke C, Van Tol J. Spatial soil information in South Africa: Situational analysis, limitations and challenges. S Afr J Sci. 2015;111(5/6), Art. #2014-0178. https://doi.org/10.17159/sajs.2015/20140178

38. Price M. Creating cool contours. Modeling glacial terrain with ArcGIS. ArcUser. 2006:48–51. Available from: https://www.esri.com/news/arcuser/0506/files/coolglaciers.pdf

39. Jenson SK, Domingue JO. Extracting topographic structure from digital elevation data for geographic information system analysis. Photogramm Eng Rem Sens. 1988;54(11):1593–1600.

40. Rudolph EM, Hedding DW, Nel W. The glacial geomorphology of sub-Antarctic Marion Island. J Maps. 2021;17(2):313–324. https://doi.org/10.1080/17445647.2021.1931970

41. Verwoerd WJ. Kommentaar op 'n artikel onder die opskrif 'Place Names of Prince Edward Islands,' deur Sylvester L. Crozet [Commentary on an article entitled 'Place Names of Prince Edward Islands,' by Sylvester L. Crozet]. Antarct Bull. 1969;Jun:56. Afrikaans.

42. Crozet SL. Place names of the Prince Edward Islands. Antarct Bull. 1968:32–33.

43. Langenegger O, Verwoerd WJ. Topographic survey. In: Van Zinderen Bakker Sr. EM, Winterbottom JM, Dyer RA, editors. Marion and Prince Edward Islands: Report on the South African biological and geological research expedition 1965–1966. Cape Town: A.A. Balkema; 1971. p. 32–39. https://doi.org/10.1126/science.176.4035.662

44. Verwoerd WJ. Geology. In: Van Zinderen Bakker Sr. EM, Winterbottom JM, Dyer RA, editors. Marion and Prince Edward Islands: Report on the South African biological and geological research expedition 1965–1966. Cape Town: A.A. Balkema; 1971. p. 40–62. https://doi.org/10.1126/science.176.4035.662

45. Meiklejohn KI, Smith VR. Surface areas of altitudinal zones on sub-Antarctic Marion Island. Polar Biol. 2008;31(2):259–261. https://doi.org/10.1007/s00300-007-0389-5

46. Jenness J. Calculating landscape surface area from digital elevation models. Wildl Soc Bull. 2004;32:829–839. https://doi.org/10.2193/0091-7648(2004)032[0829:CLSAFD]2.0.CO;2

47. Hedding DW, Nel W, Anderson RL. Aeolian processes and landforms in the sub-Antarctic: Preliminary observations from Marion Island. Polar Res. 2015;34(1), Art. #26365. https://doi.org/10.3402/polar.v34.26365

48. Hansen CD. On high-altitude and high-latitude diurnal frost environments [PhD thesis]. Grahamstown: Rhodes University; 2018.

49. Nel W, Holness S, Meiklejohn KI. Observations on rapid mass movement and screes on Sub-Antarctic Marion Island. S Afr J Sci. 2003;99(3/4):177–181.

50. Hedding DW. Spatial inventory of landforms in the recently exposed central highland of Sub-Antarctic Marion Island. S Afr Geogr J. 2008;90(1):11–21. https://doi.org/10.1080/03736245.2008.9725307

51. Sumner PD, Meiklejohn KI, Boelhouwers JC, Hedding DW. Climate change melts Marion Island's snow and ice. S Afr J Sci. 2004;100(7):395–398.

52. Nel W. A spatial inventory of glacial, periglacial and rapid mass movement forms on part of Marion Island: Implications for Quaternary environmental change [MSc dissertation]. Pretoria: University of Pretoria; 2001.

53. Bangani S, Moyo M. Data sharing practices among researchers at South African universities. Data Sci J. 2019;18(1):1–14. https://doi.org/10.5334/dsj-2019-028

54. Koopman MM, De Jager K. Archiving South African digital research data: How ready are we? S Afr J Sci. 2016;112(7/8), Art. #2015-0316. https://doi.org/10.17159/sajs.2016/20150316

55. Thelwall M, Kousha K. Figshare: A universal repository for academic resource sharing? Online Inf Rev. 2016;40(3):333–346. https://doi.org/10.1108/OIR-06-2015-0190

56. Bhoi NK, Centre B. Mendeley Data Repository as a platform for research data management. In: Rautaray B, Swain D, Swain C, editors. Marching beyond libraries: Managerial skills and technological competencies. Bhubaneswar: Overseas Press India Pvt. Ltd; 2018. p. 481–487.

57. Swab M. Mendeley data. J Can Heal Libr Assoc l'Association des bibliothèques la santé du Canada. 2016;37(3):121–123. https://doi.org/10.5596/c16-022

58. Salvador S, Sicilia M, Garc E. Community curation in open dataset repositories : Insights from Zenodo. Procedia Comput Sci. 2017;106:54–60. https://doi.org/10.1016/j.procs.2017.03.009

59. Group on Earth Observations (GEO). Strengthening the use of Earth Observations and bringing GEOSS to Africa. Geneva: GEO; 2017. Available from: https://www.earthobservations.org/documents/publications/201705_AfriGEOSS_brochure.pdf

60. Martínez-López JI, Barrón-González S, Martínez López A. Which are the tools available for scholars? A review of assisting software for authors during peer reviewing process. Publications. 2019;7(3):59. https://doi.org/doi:10.3390/publications7030059