

Pan-Antarctic Emperor Penguin Colony Dataset (2000, 2014, 2018)

Zhang, M.^{1, 2} Li, X. L.^{2*}

1. College of Global Change and Earth System Science, Beijing Normal University, Beijing 100875, China;
2. University Corporation for Polar Research, Beijing 100875, China

Abstract: The emperor penguin (*Aptenodytes forsteri*) is regarded as a “biological indicator” of Antarctic climate change. Precise colony location is used as the basis for analyzing the impact of climate change on emperor penguin population dynamics. Combined with historical high-resolution emperor penguin colony results, we used Landsat-7 ETM+ and Landsat-8 OLI to generate a dataset of pan-Antarctic emperor penguin colonies for 2000, 2014, and 2018, respectively. Visual interpretation methodology was used to identify areas covered by emperor penguin feces. The generated dataset includes location data for all emperor penguin colonies, archived in point and surface types, and the Landsat image names of the emperor penguin colonies, archived in .xlsx and .shp format.

Keywords: emperor penguin; Antarctica; Landsat; remote sensing; climate change

Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: <https://doi.org/10.3974/geodb.2020.05.06.V1>.

1 Introduction

Its unique geographical location means that the Antarctic region is relatively unaffected by human activities and has a simple ecological structure, which is extremely sensitive to global climate change^[1]. Seabirds are a reliable indicator of environmental change because they are sensitive to a variety of terrestrial and marine environmental factors^[2]. The pan-Antarctic emperor penguin (*Aptenodytes forsteri*) is regarded as a “biological indicator” of ecological environmental change in the Southern Ocean^[3–4]. However, identification of the exact location of emperor penguin colonies is required to estimate the population size and to provide basic data for studying the relationship between emigration in emperor penguin colonies and climate change.

Current data on emperor penguin colonies mainly include satellite, aerial, and field data^[5–8]. Fretwell and Trathan^[3] mapped pan-Antarctic emperor penguin colony locations for the year 2000 using Landsat ETM+, providing the first satellite-based mapping data, and

Received: 17-07-2020; **Accepted:** 15-09-2020; **Published:** 25-09-2020

Foundation: Ministry of Science and Technology of P. R. China (2018YFC1406906)

***Corresponding Author:** Li, X. L. AAT-9471-2020, Beijing Normal University, xianglanlicn@gmail.com

Data Citation: [1] Zhang, M., Li, X. L. Pan-Antarctic emperor penguin colony dataset t (2000, 2014, 2018) [J]. *Journal of Global Change Data & Discovery*, 2020, 4(3): 217–223. <https://doi.org/10.3974/geodp.2020.03.02>.

[2] Zhang, M., Li, X. L. Pan-Antarctic emperor penguin colony dataset (2000, 2014, 2018) [J/DB/OL].

Digital Journal of Global Change Data Repository, 2020. <https://doi.org/10.3974/geodb.2020.05.06.V1>.

discovered 38 emperor penguin colonies. Fretwell *et al.*^[9] then used high-resolution satellite images to identify the area occupied by emperor penguins, and established a regression relationship with the number of emperor penguins based on field observations. This first use of remote sensing data to estimate the number of emperor penguins around Antarctica provided an estimate of about 238,000 pairs. Aerial survey also has high resolution as a supplementary means of field investigation, and can identify some colonies covered by shelter whilst effectively avoiding human interference with the penguins. Schmidt and Ballard^[10] used aerial data to conduct long-term observations of the emperor penguin population at Cape Crozier. The results indicated that the fast ice at Cape Crozier broke ahead of time in 2018, leading to the disappearance of a large number of young emperor penguins.

Based on Landsat-7 and Landsat-8 images combined with historical emperor penguin colony locations, we mapped emperor penguin colony data for 2000, 2014, and 2018, respectively, to provide a database for Antarctic emperor penguin research.

2 Metadata of the Dataset

The metadata of the “Pan-Antarctic emperor penguin colony dataset”^[11] is summarized in Table 1. It includes the full name and short name of the dataset, the authors, spatial resolution, and the data format, size, files, publisher, and sharing policy, etc.

Table 1 Metadata summary of the “Pan-Antarctic emperor penguin colony dataset (2000, 2014, 2018)”					
Items		Description			
Dataset full name		Pan-Antarctic emperor penguin colony dataset (2000, 2014, 2018)			
Dataset short name		PanAnta.PenguinColony			
Authors		Zhang, M. AAT-6690-2020, Beijing Normal University, zhmia06353@163.com Li, X. L. AAT-9471-2020, Beijing Normal University, xianglanlicn@gmail.com			
Geographical region		Pan-Antarctic			
Years		2000, 2014, 2018	Temporal resolution	16 days	Spatial resolution 15 m
Data format		.xlsx, .shp	Data size	142 KB (after compression)	
Data files		(1) E.Penguin_colony_shapefile, Emperor penguin colony location data, including all colony location data, including colony area and point data in 2000, 2014 and 2018; (2) Geolocation_E.PenguinColony tables in 2000, 2014 and 2018; (3) Landsat images' codes of emperor penguin colony in 2000, 2014 and 2018			
Foundation		Ministry of Science and Technology of P. R. China (2018YFC1406906)			
Computing environment		ENVI IDL, ArcGIS			
Data publisher		Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn			
Address		No. 11A, Datun Road, Chaoyang District, Beijing 100101, China			
Data sharing policy		Data from the Global Change Research Data Publishing & Repository includes metadata, datasets (in the <i>Digital Journal of Global Change Data Repository</i>), and publications (in the <i>Journal of Global Change Data & Discovery</i>). Data sharing policy includes: (1) Data are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use Data subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute Data subject to written permission from the GCdataPR Editorial Office and the issuance of a Data redistribution license; and (4) If Data are used to compile new datasets, the ‘ten per cent principal’ should be followed such that Data records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset ^[12]			
Communication and searchable system		DOI, DCI, CSCD, WDS/ISC, GEOSS, China GEOSS, Crossref			

3 Methods

Landsat-7 and Landsat-8 images were downloaded from the United States Geological Survey^[13] (Table 2). The product level was level 1 and the revisit cycle was 16 days. The multispectral band resolution was 30 m and the panchromatic band resolution was 15 m. There were not enough images for 2000, and we therefore used images downloaded from 1999 to 2003. For 2014 and 2018, we chose images for the breeding season from September to October. Emperor penguins return to the colony in March or April and leave the colony in November or December. Because they feed mainly on Antarctic krill, their feces are brown. The location of the colony can thus be located according to area of feces during the breeding season.

Table 2 Landsat data profiles

Time	Sensor	Resolution (m)	Bands	Image date
2000	ETM+	30/15	1, 2, 3	1999.9–2003.3
2014	OLI	30/15	2, 3, 4	2014.9–2014.10
2018	OLI	30/15	2, 3, 4	2018.9–2018.10

3.1 Algorithm Principle

Several months of accumulated emperor penguin feces appear brown on Landsat nature color images, in contrast to the main Antarctic features of water, snow, and ice. The most recent high-resolution pan-Antarctic emperor penguin colony locations were mapped in 2009, using high-resolution satellite data. However, some colony locations have since been updated and some new colonies discovered using aerial data and high-resolution satellite data. We therefore updated the pan-Antarctic emperor penguin colony locations using a combination of high-resolution colony location and visual interpretation.

3.2 Technical Route

The Landsat level 1 product was corrected by geometric and terrain correction. The difference in accessing times of the images led to differences in parameters such as sun-earth distance and solar elevation. We therefore transformed the original image from digital number to top of atmosphere reflectance (TOA), to effectively eliminate the error due to these factors in image analysis and to maintain good comparability among the various images. To achieve higher resolution data, we used Gram-Schmidt Spectral Sharpening to enhance the 30 m multispectral band with a 15 m panchromatic band. We identified emperor penguin feces by visual interpretation in nature color images and analyzed colonies based on high-resolution historical locations (Figure 1). Landsat image names corresponding to identify emperor penguin colonies were recorded, and corresponding vector maps were drawn for each colony.

4 Data Results and Validation

4.1 Data Composition

The dataset consists of three parts (Table 3):

- (1) emperor penguin colony location data in .shp files in 2000, 2014 and 2015 both in points and polygons, i.e., the area corresponding to emperor penguin feces in the breeding season;
- (2) places list of the emperor penguin colony in 2000, 2014 and 2018; and
- (3) Landsat images' codes corresponding to each emperor penguin colony in 2000, 2014 and 2018.

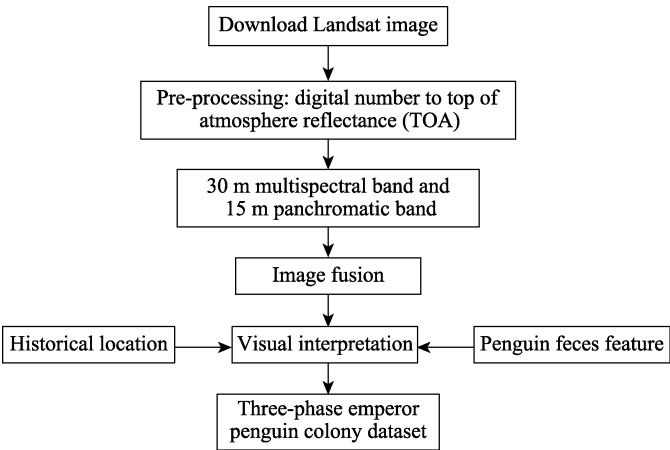


Figure 1 Workflow chart of data analysis

Table 3 Descriptions of the data composition of pan-Antarctic emperor penguin colonies

Dataset	Description
Vector data of the emperor penguin colony location	Emperor penguin colony location was the area corresponding to emperor penguin feces in the breeding season. The location was stored as a point and the area of the colony was stored as surface types (.shp)
Table of emperor penguin colony location	Places list of the emperor penguin colony in 2000, 2014 and 2018, including location names both in Chinese and English, as well as their geo-locations.
Landsat images using for the study	The variable Antarctic weather made it difficult to obtain high-quality images covering the emperor penguin colonies. The dataset selected relatively clear images as far as possible to allow users to analyze the original data. The dataset records (.xlsx) the image names selected for each colony

4.2 Data Results

We recorded 43, 49, and 42 colonies in 2000, 2014 (Table 4, Figure 2), and 2018, respectively.

Table 4 List of places of emperor penguin colony in 2014

Colony location	Colony location	Colony location
Astrid Coast	Dawson-Lambton Glacier	Ragnhild
Atka Bay	Dibble Glacier	Riiser Larsen
Auster Islands	Dolleman Island	Rothschild
Barrier Bay	Drescher Inlet	Rupert Coast
Bear Peninsula	Franklin Island	Sabrina Coast
Beaufort Island	Gould Bay	Sanae
Bowman Island	Gunnerus Bank	Shackleton Ice Shelf
Brownson Islands	Halley Bay	Smith Peninsula
Bryan Coast	Haswell Island	Smyley Island
Burton Ice Shelf	Lazarev Ice Shelf	Smyley Island2
Cape Colbeck	Ledda Bay	snow hill Island
Cape Crozier	Luitpold Coast	Stancomb Wills
Cape Darnley	Mertz Glacier East	Thurston Glacier
Cape Roget	Mertz Glacier West	Thurston Glacier2
Cape Washington	Noville Peninsula	Umbeashi Rock
Coulman Island	Peterson Bank	West Ice Shelf
Davis Bay		

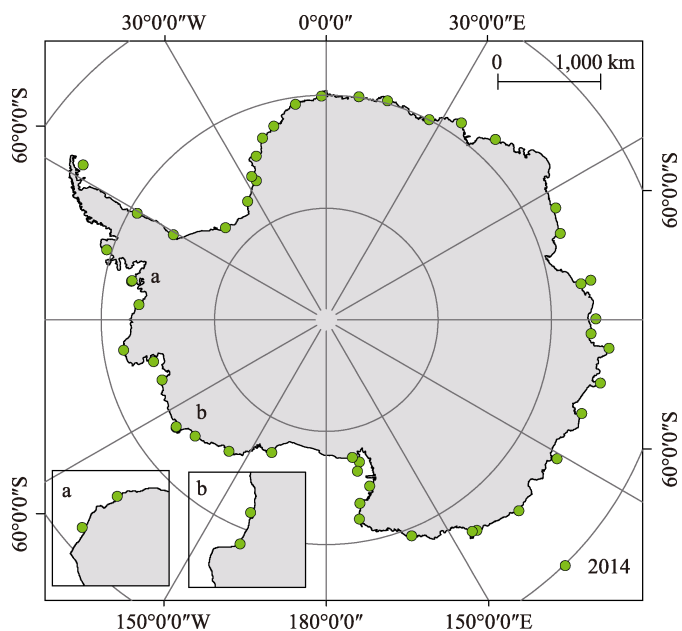


Figure 2 Pan-Antarctic emperor penguin colony locations in 2014, based on vector point file

The results showed that emperor penguin colonies were located all around Antarctica. Emperor penguins mainly breed on fast ice near islands, icebergs, or ice cliffs (Figure 3), which can act as a barrier to Antarctic winter snow and wind. Few emperor penguin colonies were located on ice shelf, such as the Shackleton Ice Shelf in 2018.

4.3 Data Validation

Fretwell and Trathan^[3] identified 38 penguin colonies in 2000. Five of these 38 known sites were thought to be still extant, because they were confirmed in report^[14]. The current dataset confirmed 43 emperor penguin colonies in 2000. 32 of the 38 colonies identified by Fretwell and Trathan^[3] were identified, but the Amundsen Bay colony was not determined. We identified a further 11 emperor penguin colonies combined with historical locations, including two colonies not identified by Fretwell and Trathan^[3] through satellite images, at Cape Crozier and Auster Islands. We identified 49 emperor penguin colony locations in 2014.

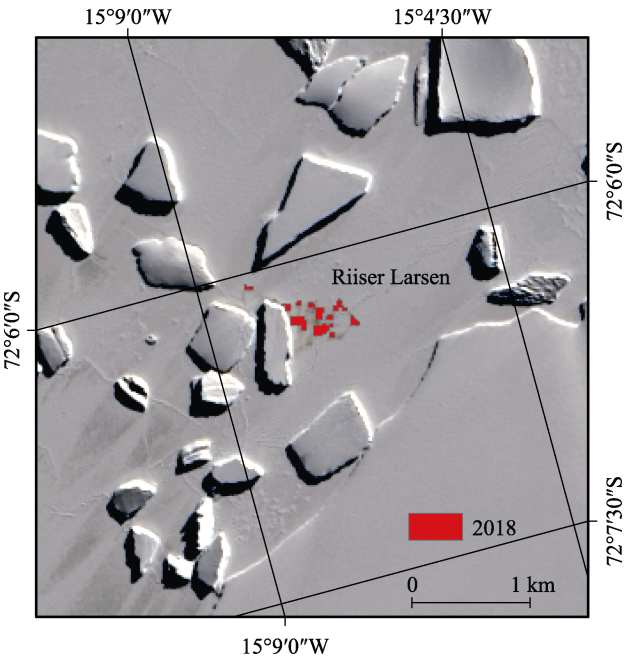


Figure 3 Riiser Larsen colony in 2018 (red area presents emperor penguin colony)

Compared with the historical high-resolution results, seven colonies were not confirmed^[15]. However, we identified two new colony locations, at Smyley Island2 and Thurston Glacier2, close to the Smyley Island and Thurston Glacier colonies, respectively. Due to their close proximities, Smyley Island and Smyley Island2, and Thurston Glacier and Thurston Glacier2, might both comprise single large colonies, respectively. We identified 42 emperor penguin colony locations in 2018, 12 colonies of which were not confirmed compared with the historical high-resolution results.

5 Discussion and Conclusion

The current dataset includes the locations of emperor penguin colonies in three different years. The dataset also analyzed the emperor penguin colonies recorded in 2000 in light of the identification of new colonies in recent years^[16–17]. Information on the historical location of emperor penguin colonies is needed to analyze their emigration, and the 2000 dataset thus supplies a historical basis against which to analyze the locations of newly discovered colonies. High-resolution data previously identified 54 emperor penguin colonies^[15]; however, a lack of long-term observations of emperor penguin colonies has led to insufficient data to support the analysis of any changes. The remote sensing identification of pan-Antarctic emperor penguin colonies is mainly limited by image resolution and weather factors (cloud and snow cover), and selecting clear images covering penguin colonies is therefore necessary. Results from 2014 and 2018 were used to update the historical emperor penguin colony locations. Snow cover will also tend to mask the appearance of penguin feces, thus affecting colony identification, while sheltering features around the colony may mean that some are missed by satellite data observations^[17]. The current dataset indicates that most emperor penguin colony locations remained stable over a period of nearly 20 years, though some colony locations changed due to environmental changes, such as ice shelf collapse.

The present pan-Antarctic emperor penguin colony locations were mapped based on high-resolution satellite images taken in 2009; however, future, high-resolution results can also be compared with the dataset. The number of Antarctic emperor penguin colony locations is thus still uncertain. The study of emperor penguin colony locations is focus on two field: (1) the identification of new colony locations; and (2) the emigration of already known colonies. The current study used free Landsat data; however, this has relatively low resolution, while high-resolution data from abroad is expensive to obtain. Emperor penguins breed in the Antarctic winter, leading to difficulties in field investigations during the breeding season. It is hoped that relevant domestic polar satellites can be used to promote research on Antarctic penguins in the future.

Author Contributions

Zhang, M. and Li, X. L. designed the dataset processing; Zhang, M. collected and processed the images; Zhang, M. designed the model and algorithm; Zhang, M. validated the dataset; Zhang, M. wrote the paper.

References

- [1] He, H., Li, X. L., Cheng, X., *et al.* Aerial photography based estimation of greenhouse gas emissions from penguins in Victoria Land, Antarctica [J]. *Chinese Science Bulletin*, 2016, 61: 3268–3277.
- [2] Che-Castaldo, C., Jenouvrier, S., Youngflesh, C., *et al.* Pan-Antarctic analysis aggregating spatial estimates of Adélie penguin abundance reveals robust dynamics despite stochastic noise [J]. *Nature Communication*, 2017, 8(1): 832.
- [3] Fretwell, P. T., Trathan, P. N. Penguins from space: faecal stains reveal the location of emperor penguin colonies [J]. *Biogeography*, 2009, 18(5): 543–552.
- [4] Ji, M., Zhang, B. G., Zhang, Y. Y., *et al.* Sizing and trend analysis of penguin numbers in Antarctic from high resolution photography by unmanned aerial veilles [J]. *Journal of Beijing Normal University (Natural Science)*, 2019, 55(1): 25–35.
- [5] Schiel, R., GüPner, F., Spitzenberger, H. J. Population size and condition of the Emperor Penguin *Aptenodytes forsteri* colony of Snow Hill Island, Weddell Sea, Antarctica: observations from 29 December 2018 [J]. *Marine Ornithology*, 2019, 47: 189–192.
- [6] Fretwell, P. T., Trathan, P. N. Emperors on thin ice: three years of breeding failure at Halley Bay [J]. *Antarctic Science*, 2019, 31: 133–138.
- [7] Kooyman, G., Ponganis, P. J. Rise and fall of Ross Sea emperor penguin colony populations: 2000 to 2012 [J]. *Antarctic Science*, 2017, 29(3): 201–208.
- [8] Todd, F. S., Adie, S., Splettstoesser, J. F. First ground visit to the emperor penguin *Aptenodytes forsteri* colony at Snow Hill Island, Weddell Sea, Antarctica [J]. *Marine Ornithology*, 2004, 32: 193–194.
- [9] Fretwell, P. T., Larue, M. A., MORIN, P., *et al.* An emperor penguin population estimate: the first global, synoptic survey of a species from space [J]. *PLoS One*, 2012, 7(4): e33751.
- [10] Schmidt, A. E., Ballard, G. Significant chick loss after early fast ice breakup at a high-latitude emperor penguin colony [J]. *Antarctic Science*, 2020, 32(3):180-185.
- [11] Zhang, M., Li, X. L. Pan-Antarctic emperor penguin colony dataset (2000, 2014, 2018) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2020. <https://doi.org/10.3974/geodb.2020.05.06.V1>.
- [12] GCdataPR Editorial Office. GCdataPR data sharing policy [OL]. <https://doi.org/10.3974/dp.policy.2014.05> (Updated in 2017).
- [13] United States Geological Survey (USGS) [DB/OL]. <https://earthexplorer.usgs.gov/>.
- [14] Wienecke, B. Emperor penguin colonies in the Australian Antarctic Territory: how many are there? [J]. *Polar Record*, 2009, 45(235): 304–312.
- [15] Ancel, A., Cristofari, R., Trathan, P. N., *et al.* Looking for new emperor penguin colonies? Filling the gaps [J]. *Global Ecology and Conservation*, 2017, 9: 171–179.
- [16] Larue, M. A., Kooyman, G., Lynch, H. J., *et al.* Emigration in emperor penguins: implications for interpretation of long-term studies [J]. *Ecography*, 2015, 38(2): 114–120.
- [17] Ancel, A., Cristofari, R., Fretwell, P. T., *et al.* Emperors in hiding: when ice-breakers and satellites complement each other in Antarctic exploration [J]. *PLoS One*, 2014, 9(6): e100404.