Monitoring of periglacial surface processes on Deception Island, South Shetland Islands (Northern Antarctica Peninsula) using high resolution photogrammetric and Synthetic Aperture Radar data

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Introduction

Deception Island is one of the most active volcanoes in the Northern Antarctica Peninsula region. The island is characterised by the presence of periglacial processes (López-Martínez et al., 2011) that interact with the volcanic nature of the island (Smelli et al., 2002). In the current context of global climate change, Deception Island is experiencing progressive glacial retreat, which is affecting the surface hydrology and land surface morphology of the ice-free areas.

The aim is to determine periglacial surface features and processes of selected catchment basins at a high spatial resolution scale using drone images and monitor surface processes influenced by environmental variables on a large scale using satellite images (***Fig. 1***).

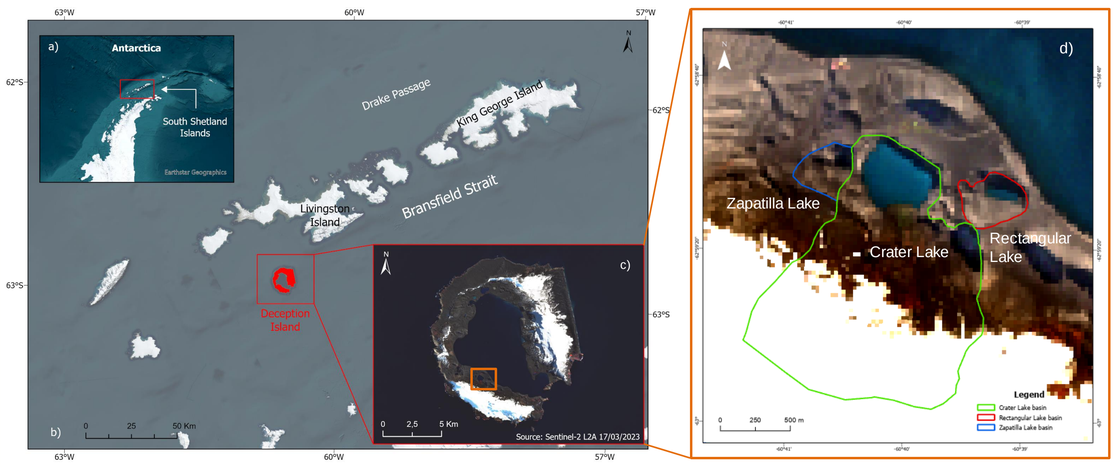

Fig. 1. Study area a) in Antarctica, b) within the South Shetland Islands, c) on Deception Island and d) in selected catchment areas.

Methodology

The methodology acoording to different data sources (***Fig. 2***):

- Unmanned Aerial Vehicle (UAV) photogrammetry in order to build RGB orthomosaics, Digital Elevation Model (DEM) and thermal acquired with DJI Mavic 3M and 3T drones and GPS Station Trimble R8S. The software used was ArcGIS Pro version 3.5.3 and Pix4D version 4.9.0.
- Field data acquired during the 2023-2024 and 2024-2025 Antarctic Campaigns in order to georeference the DEM and construct the bathymetry acquired with an echo sounder GARMIN ECHOMAP UHD60.
- Synthetic Aperture Radar (SAR) time series images (from 06-12-2023 until 30-11-2024) and continuous in situ temperature and tide data were used to apply a Principal Component Analysis (PCA) with Python version 3.11.

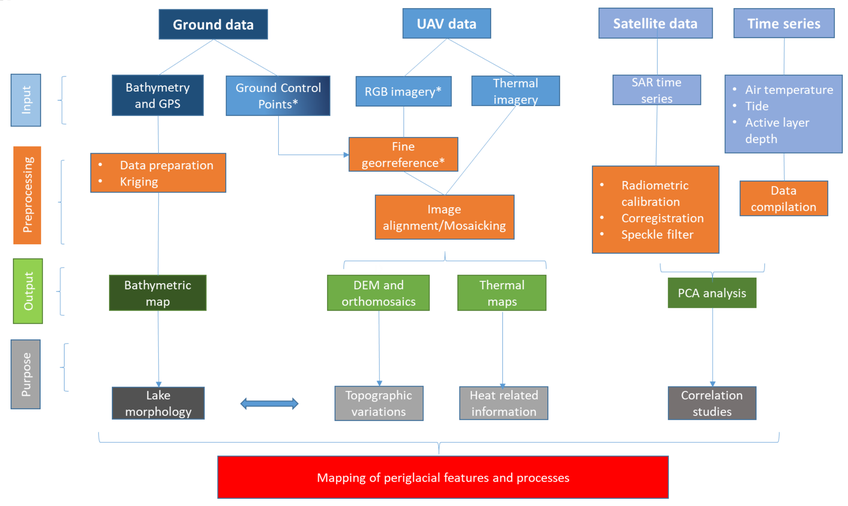

Fig. 2. Method workflow.

Results and discussion

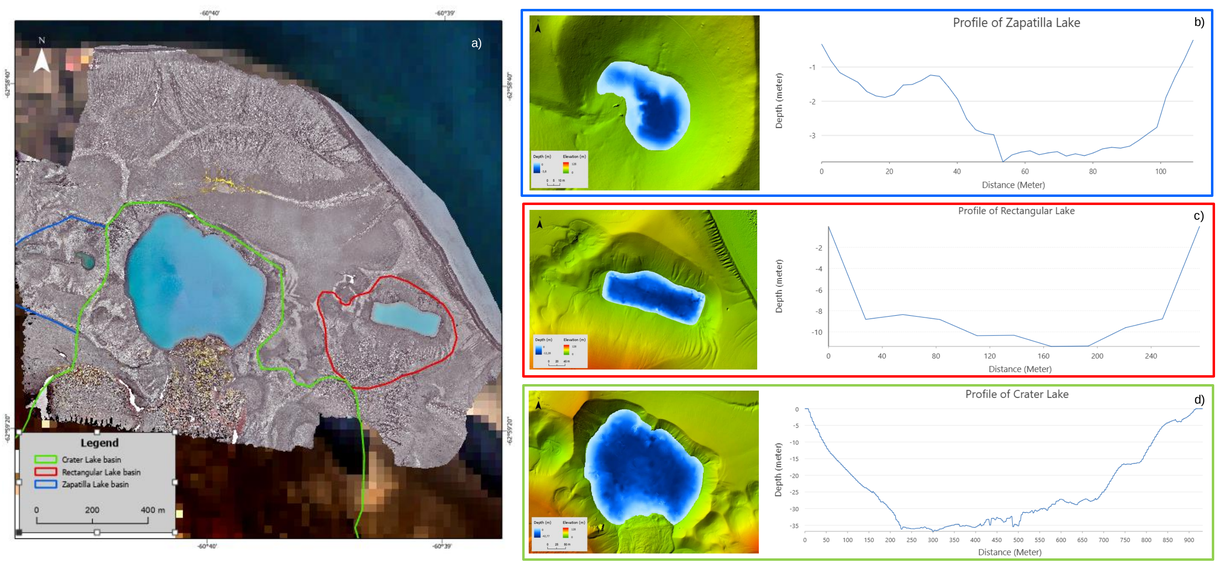

Fig. 3. a) High resolution RGB mosaic 2024, b) Zapatilla Lake, c) Rectangular Lake, and d) Crater Lake with their corresponding DEM, bathymetry and lake profile.

~~A~~ high-resolution RGB mosaic was obtained for several catchment areas (***Fig. 3a***). Furthermore, a DEM and corresponding bathymetry of each lake with a basin profile were determined (***Fig 3 b, c, d***). Crater Lake has an extension of 18.05 ha, its deepest point is -42.77 m with a median of -24.18 m. Rectangular Lake has 2.09 ha, its deepest point is -12.28 m with a median of -6.94 m. Zapatilla Lake has 0.32 ha, its deepest point is -3.8 m with a median of -1.01 m. The preliminary thermal mosaic of the study area represented by Digital Numbers (DN) showing the relative behavior in terms of heat related information for the different surfaces (***Fig 4***). Waterbodies and glacial surfaces present the lowest values, whereas higher values show exposed volcanic deposits. PCA analysis of SAR images was defined as the lowest X and as the highest Y values of temperature and tide, respectively. The PCA reveals in the case of temperature is strongly related with the topography and in the case of tide seems to affect the hydrogeology where water bodies are distributed within the ice-free areas (***Fig 5***).

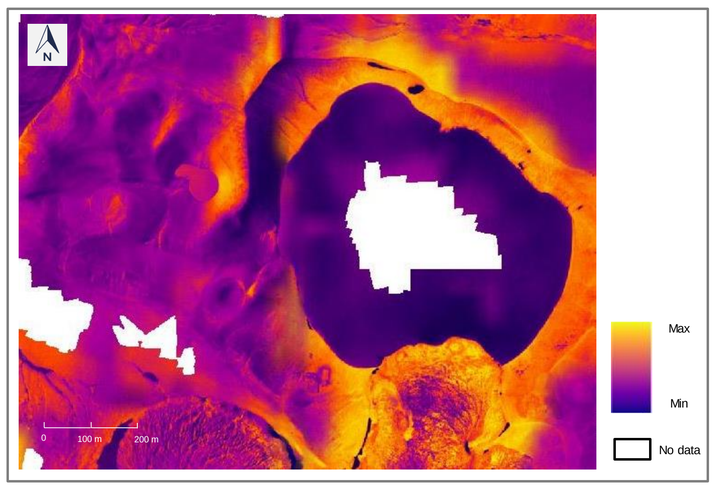

Fig. 4. Preliminary mosaic of heat related information of Crater Lake and Zapatilla Lake.

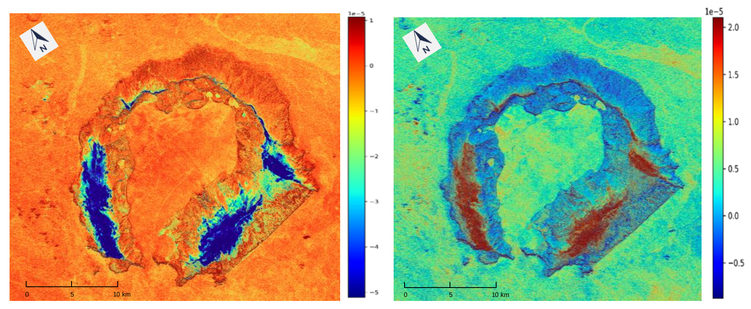

Fig. 5. PCA analysis showing the a) mean differences between the highest and lowest mean temperature and b) mean differences between the highest and lowest mean tide level.

Conclusions

- A high resolution orthomosaic and DEM together with the lake morphology was obtained with UAV imagery and field data from the 2024 Antarctic Campaign.
- The preliminary thermal map shows the distribution of the heat-related information and the next step is to adapt the programming code to obtain a temperature map.
- A correlation was found between SAR imagery and selected environmental variables, however to improve the results, a longer data time series analysis (4 years) will be used to improve the correlation and masking out the sea and the glacier areas.
- Ongoing work is being carry out to interpret periglacial features and processes and determine areas with erosion and accumulation within the ice-free areas.

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