Mapping geomorphological features in the Subantarctics

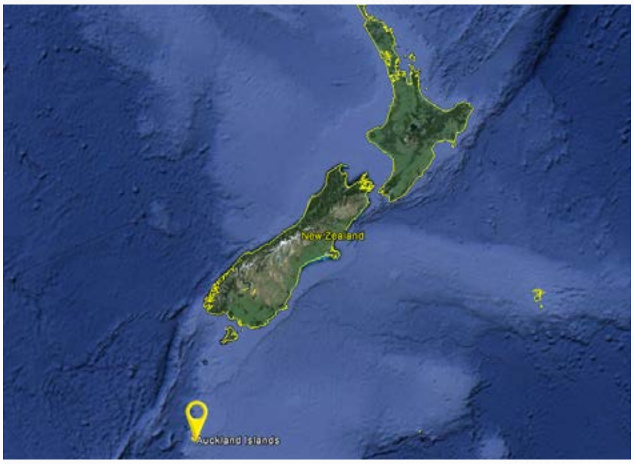
Landscape mapping with drones doesn't get more challenging than flying over remote, windy islands without disturbing the birds, as one team of climate change researchers discovered…

When trying to improve our understanding of climate change, one of the issues scientists face is that historical human observations don't reach back far enough in time to adequately test new climate models. One key to better understanding, then, is painting a more accurate picture of environmental conditions in the distant past.

A good place to measure environmental change over longer timescales is New Zealand's Subantarctic Islands, the country's five southernmost groups of outlying islands and a UNESCO World Heritage Site. It's here that natural archives—in the form of trees, peats and sediments—provide scientists with an opportunity to bridge the gap between modern observations and the geological past. In November 2014 a team of researchers led by Professor Chris Turney, a Professor of Climate Change and Earth Sciences at the University of New South Wales' Climate Change Research Centre, set out to do just that.

The main goal of their three-week expedition was to gather data on the climatic and environmental conditions on the Subantarctic islands in the distant and more recent past, for example by measuring the extent of past glaciation.

"These islands are an important location for recording changes in climate because of their exposed location in the Southern Ocean," explains Dr. Zoë Thomas, a research associate at the Climate Change Research Centre. "The islands can record shifts in the westerly wind belts that are linked to the Antarctic Circumpolar Current. These wind belts can have an enormous influence on the global climate through changes in upwelling and feedbacks with other oceanic currents. The Subantarctics also host a unique array of living organisms, containing a high level of species unique to each island. Although uninhabited today, human influence over the last few hundred years has had quite a profound effect on these islands."



New Zealand's Subantarctic islands are located in the latitudes of the so-called 'Furious Fifties,' known for their strong trade winds.

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Looking at landforms

At Musgrave Harbour, a beautiful valley fjord on the Auckland Islands archipelago, the team was looking to map the landscape's geomorphological features, because these provide evidence of past glaciation. By knowing the size, location and orientation of the site's moraines—large deposits of sediments and rocks carried, and subsequently deposited, by glaciers—the team could gain a better understanding of how different processes have shaped the landscape over time.

"Musgrave Harbour has a relatively complex geomorphology, so we wanted to map it, in high resolution, and create a 3D model that we could use to identify and quantify past glacial features," says Thomas. "By then taking sediment cores, we could also get an idea of what the past vegetation and environmental conditions were like. This data all feeds back to complex climate models. By comparing data from models simulating climate from thousands of years ago with past climate data, we can start to assess how good the models are, and identify gaps in our understanding of how the climate system works."

By creating an accurate 3D model and taking sediment cores (shown above), the team's aim was to determine the area's past vegetation and environmental conditions.

New Zealand Subantarctic Islands

The New Zealand Subantarctic Islands consist of five island groups (the Snares, Bounty Islands, Antipodes Islands, Auckland Islands and Campbell Island) in the Southern Ocean south-east of New Zealand. The islands, lying between the Antarctic and Subtropical Convergences and the seas, have a high level of productivity, biodiversity, wildlife population densities and endemism among birds, plants and invertebrates. They are particularly notable for the large number and diversity of pelagic seabirds and penguins that nest there. There are 126 bird species in total, including 40 seabirds, of which five breed nowhere else in the world. (Source: http://whc.unesco.org/en/list/877)

Drone decision

The reason why the team decided to employ a UAV is simple: no other method of data collection could provide the imagery required in the limited time available.

"To map this complex area would have taken us weeks using traditional in-situ field surveys, if not been completely impossible due to the impenetrable density of the vegetation," Thomas explains. While other forms of remote sensing, such as aerial photographs and satellite data, are often used for geomorphological mapping, in areas as remote as the Subantarctics there is poor satellite coverage, often due to persistent cloud cover, and the available images that do exist are relatively low resolution.

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"The spatial resolution of the Landsat satellite imagery is 30 metres," Thomas states. "This is much lower than the 8.8 cm per pixel our eBee achieved, which enabled us to identify smaller scale features and finer spatial detail that we might otherwise have missed. The eBee's Postflight software also allows us to take accurate measurements of length, volume, height and area. We wouldn't have undertaken such a project any other way as it simply wouldn't have been feasible."

At such environmentally sensitive locations, the team's choice of drone also brought an additional benefit. "The eBee's low noise is important when working in protected areas that contain large bird populations. A larger drone with a higher noise level would not have been suitable," Thomas adds.

Windy work

Carrying out the drone flights themselves was not all plain sailing however, with the weather at this challenging, remote coastal location posing a real test.

"The Subantarctic islands are located in the latitudes of the 'Furious Fifties', known for their strong trade winds, so finding suitable windows of opportunity to fly the drone was always going to be a challenge," Thomas says. "The islands are also mountainous and very densely vegetated, making it difficult to find suitable landing locations — we had to find somewhere near the coast, for accessibility, but we also needed a large, flat area in which to land safely. This was not easy, but we managed to locate a select few areas that could work."

Still, the extreme location and conditions did somewhat restrict the scope of the team's aerial work, in that the researchers were not able to chart as large an area as they had hoped. "The conditions were far from ideal, with several factors meaning we could only perform short flights," Thomas explains. "First, we had winds gusting up to 12 metres a second. Second, our UAV had to climb at a high altitude due to the cliffs around us. And since there were few suitable landing spots, the eBee often had to travel quite a long way to get to where we wanted to map. This meant we covered an area of 1.5 square kilometres, whereas ideally we would have liked to cover double this."

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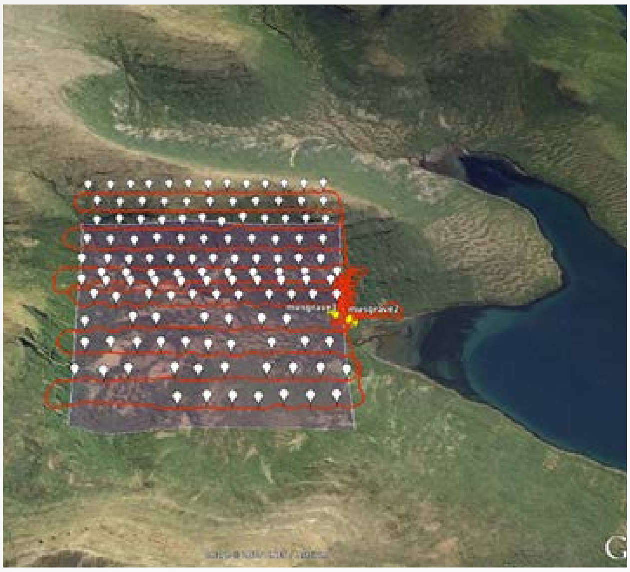
Flight methodology

When planning each flight in the drone's eMotion software, the team specified a desired ground resolution of 8.8 cm/pixel. This figure was the result of a carefully considered resolution-versus-altitude calculation.

"We chose this resolution in order to get the best detail possible, while still having the flight's altitude remain above the 250 metre height of the surrounding mountains," says Thomas. "We knew that eMotion could use digital elevation data to help fine-tune this flight planning and keep the drone's altitude consistent above the terrain, but we weren't confident that the existing elevation data for this area was accurate enough and since we knew there were steep cliffs we didn't want to risk any crashes by relying on data that we hadn't validated."

In terms of image overlap, the team chose 70% lateral and 75% longitudinal overlaps. Thomas notes that since the terrain was quite complex, a higher overlap, or using perpendicular flight lines, would have been preferable, but time constraints made re-flying the site impossible.



A Google Earth screenshot showing the eBee's flight lines (in red), its photograph capture points (white dots), and the mission's total coverage area (grey polygon).

In the end, the two flights eMotion predicted would last 30 minutes were each finished in 20-25 minutes. "This was because I simulated higher winds than there actually were at the time—it was a rare fine day with winds of approximately 5 m/s (but gusts of higher speeds)—so the eBee was able to complete the mission faster than expected," Thomas explains. The 152 images captured were then processed using the eBee's Postflight Terra 3D software the following day.

PROJECT WORKFLOW

01 Identify site of interest
(source: satellite imagery or areas mentioned in scientific papers)

02 Go to area on foot
(take sediment cores & examine terrain)

03 Identify suitable area for drone to map

04 Identify suitable take-off/landing locations

05 Wait for suitable weather conditions

06 Fly the drone

07 Process drone images & create 3D DSM

08 Analyse drone data
(e.g. identify position/size/volume/height of glacial features in conjunction with sediment core results & past glacier flow models)

In terms of optimising the positional accuracy of the outputs produced, using Ground Control Points was a non-starter. "Unfortunately the time constraints and difficult accessibility meant that placing GCPs wasn't feasible in the time we had available. However this wasn't considered a vital part of the project as we were mapping glacial moraines and their exact location in space is not essential knowledge," Thomas states.

Results

The team produced two final outputs: 152 high-resolution RGB images and the digital surface model the researchers needed to identify geomorphological features.

"The quality of the imagery we acquired was incredible. It allowed us to identify a moraine feature that we had not picked up at all on the lower resolution Landsat imagery," Thomas reports. "The ability to identify smaller scale features like this really helps us to improve our understanding of glacier flow lines. Very accurate measurements such as the height, length and volume of these moraine features are also useful metrics that help us to constrain reconstructions of past glaciation."

One of the images the eBee captured over Musgrave Harbour.

In addition, Thomas adds, mapping previously glaciated areas can also help identify locations where the best sediment record is likely to be found. "On foot, identifying where to take a sediment core can be quite challenging, but using the drone to pinpoint suitable locations is likely to become a very popular approach," she concludes. "This drone has such a wide range of potential applications that it could be a sound investment for many research departments."

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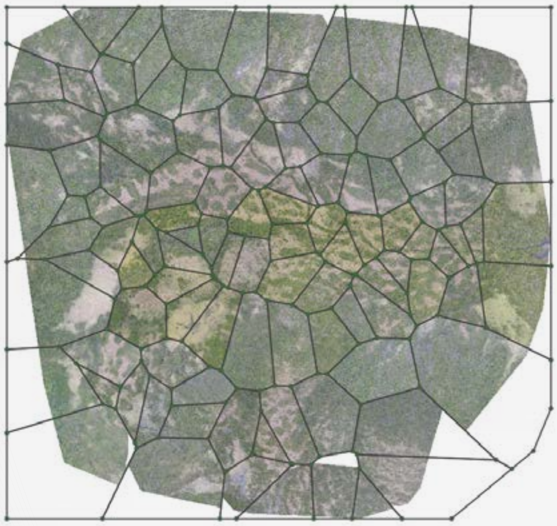
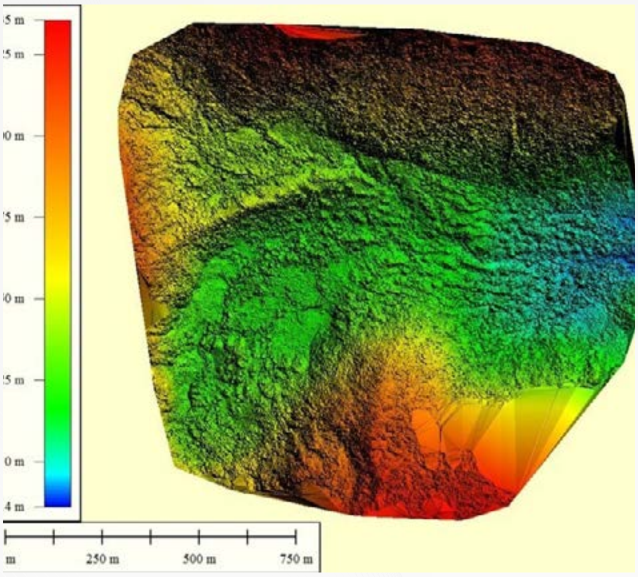
In terms of future projects, the team has fieldwork planned in Western Australia next, where there are huge seasonal lakes. Since different precipitation patterns in the past have created several relic shorelines, the team plans to use its eBee to map these in order to improve understanding of past lake levels and changes in precipitation patterns over time.

"We also plan to use the drone's near-infrared camera option to differentiate between tree species," Thomas says. "On the west coast of New Zealand native tree species are currently being threatened by invasive species. Mapping the affected areas will enable us to quantify the spread of these."



The project's final orthomosaic shown in Postflight Terra 3D.



The team's digital surface model of Musgrave Harbour, featuring a small-scale moraine feature in the centre-left.

The same digital surface model shown in 3D.

About the CCRC

The Climate Change Research Centre (http://www.ccrc.unsw.edu.au/) at the University of New South Wales is a multi-disciplinary research centre comprising one of the largest university research facilities of its kind in Australia, administered within the School of BEES in the Faculty of Science. CCRC houses research expertise in the key areas of Earth's climate: atmospheric, oceanic and terrestrial processes, applying basic scientific principles to pressing questions on climate dynamics, global climate change, and extremes of weather and climate.

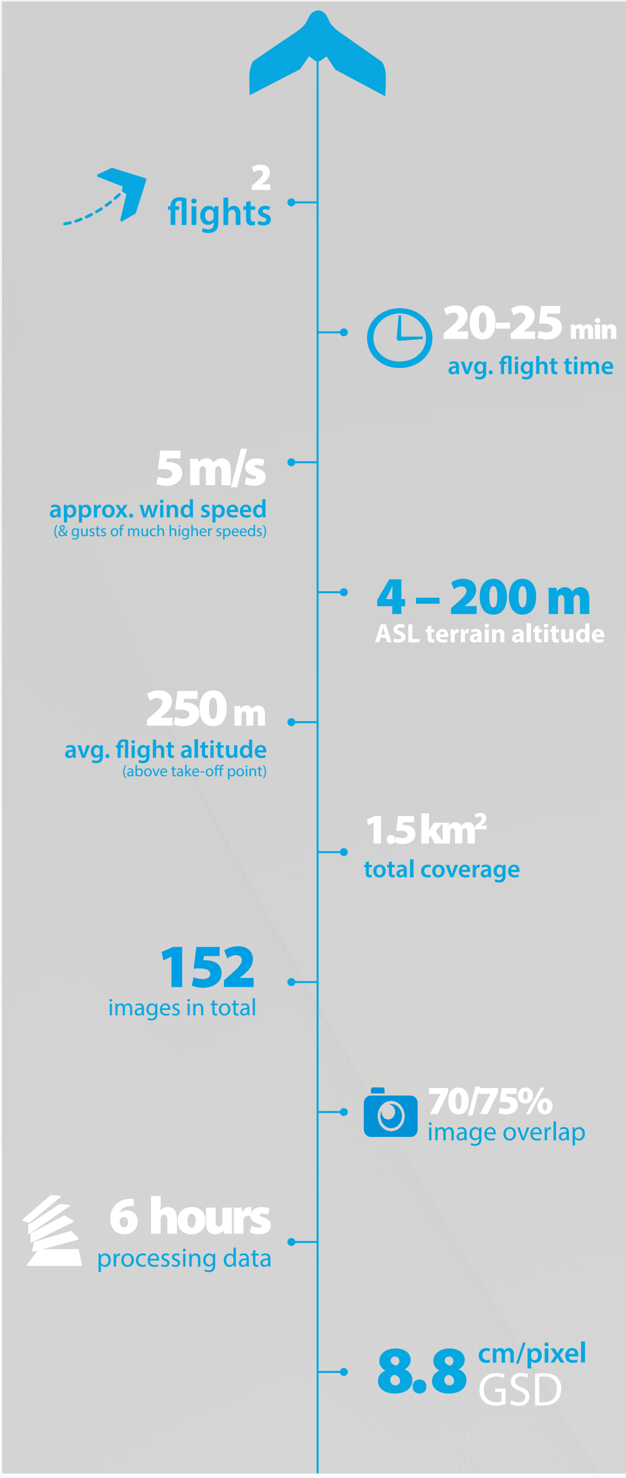
Visit the Climate Change Research Centre

Watch Dr. Thomas' eBee launch video

Watch the full expedition video

Visit Professor Turney's popular science website

PROJECT STATISTICS



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