# AFI 10/04

# Orographic Flows and the Climate of the Antarctic Peninsula (OFCAP)

## Report on the 2010-11 Field Season

**Tom Lachlan-Cope and John King**

**July 2011**

## Introduction

The central aim of the OFCAP project is to determine how the surface climate over the Larsen Ice Shelf is affected by interaction of the circumpolar westerly winds with the mountains of the Antarctic Peninsula. In order to achieve this aim, a number of measurements were planned for the 2010-11 Antarctic field season. These included:

- Deployment of four automatic weather stations (AWSs) along a line across the Peninsula mountains at approximately 67$^{o}$S.
- Detailed measurements of the surface energy balance at a camp on the Larsen Ice Shelf.
- Airborne measurements of the flow across the Peninsula mountains and over the Larsen Ice Shelf using the MASIN instrumentation on BAS Twin Otter VP-FAZ.
- Radiosonde launches from Rothera and the Larsen Camp.

The OFCAP field season was scheduled to take place from late December 2010 to the end of January 2011. The original plan had been for four AWSs to be deployed by the end of December, with the other measurements starting in early January. Unfortunately delays at the start of the season meant that the initial input to Rothera was delayed and so the AWSs were not fully deployed until mid way through January. As a result, the airborne measurements were extended through to early February.

## Field Campaign Personnel

Tom Lachlan-Cope (BAS) – leading project at Rothera and in charge of aircraft measurements.

Russ Ladkin (BAS) – MASIN instrument engineer

Victoria Smith (Leeds) – In charge of WRF model runs and flight scientist

Andy Elvidge (UEA) – PhD student in charge of UK Met Office model output and flight scientist

Amélie Kirchgaessner (BAS) – AWS installation, flight scientist and Rothera radiosondes

Phil Anderson (BAS) – in charge of AWS installation.

Peter Kuipers Munneke (IMAU, University of Utrecht) – Larsen Camp scientist

Ian Hey (BAS) – Larsen Camp field assistant

## Personnel Movements

| | |
|---|---|
| 14 December 2010 | Phil Anderson and Amélie Kirchgaessner arrive Rothera |
| 19 December 2010 | Peter Kuipers Munneke arrives Rothera |

| | |
|---|---|
| 3 January 2011 | Peter Kuipers Munneke and Ian Hey input to Larsen Camp |
| 6 January 2011 | Tom Lachlan-Cope, Russ Ladkin, Andy Elvidge and Victoria Smith arrive Rothera |
| 27 January 2011 | Phil Anderson departs Rothera |
| 1 February 2011 | Peter Kuipers Munneke and Ian Hey uplifted from Larsen Camp |
| 4 February 2011 | Peter Kuipers Munneke departs Rothera |
| 9 February 2011 | Remaining OFCAP scientists depart Rothera |

**AWS deployments**

Four AWSs were constructed by BAS engineering section to a specification agreed by the OFCAP science team. Each station measures air pressure, wind speed and direction, air temperature and relative humidity. 10-minute mean data from these sensors are transmitted in real time by Iridium satellite link while high-frequency (10s) data are recorded on a memory card for retrieval when the AWSs will be recovered (planned for the 2011-12 field season). Due to delays in the construction of the AWSs, only a very short period of time was available to test the systems at Cambridge before they had to be shipped to the Antarctic. While this was not ideal, it did enable us to identify and correct some issues and it is a tribute to the care taken in design and construction that the AWSs performed well once deployed in the Antarctic.

Figure 1 shows the sites planned for the AWSs and the actual locations of the deployments. Our aim was to deploy the four stations along a west-east transect of the Peninsula covering a representative “upwind” site (North Adelaide), the crest of the Peninsula (Avery Plateau), just “downwind” of the Peninsula mountains (Mill Inlet) and a site on the Larsen Ice Shelf (Larsen Camp). We knew that at two of these sites (Avery Plateau and North Adelaide), annual snow accumulation could be as high as 10m. As we wanted to obtain a full year’s data from all sites, we decided to deploy the AWS instruments at these two sites on 15m high tubular guyed masts. We recognised that we were taking a risk here as we had limited experience of the performance of such masts under Antarctic field conditions. The other two AWSs were to be deployed on 5m guyed scaffold pole masts which had performed well at other Antarctic locations. All AWSs were deployed by direct aircraft input and the time on the ground for deployment ranged from 2.5 hours for a 5m mast to 5 hours for a 15 m system.

The input of the AWS was coordinated by Phil Anderson and Amélie Kirchgaessner who arrived at Rothera station on the 14$^{th}$ December. Some preparatory work on the AWS systems had been carried out already by Russ Ladkin during his time at Rothera for the earlier IceBell campaign. There followed a period of training before the first AWS could be deployed. The first AWS was deployed on North Adelaide on Christmas Eve (see table 1) using a 15m mast.

This installation worked for five days, at which point the Iridium data indicated that the mast had collapsed. A site revisit confirmed this and the mast was replaced by a 5m mast as a temporary

measure, which in turn was replaced with a new 15m mast with improved guys. Unfortunately this mast only lasted a further three days before it too collapsed, although the high resolution data from this mast (downloaded from the onboard memory card) is available until 4 March when a fourth mast, this time 9m tall, was erected. It is believed that this mast lasted until early June when it in turn collapsed.

Given the uncertainty about the reliability of the 15m masts and the importance of a Peninsula crest deployment, a decision was made to deploy a 5m mast on the Avery Plateau. This was achieved on 9th January and, at the date of writing (July 2011) this station is still transmitting data. As the 5m system was likely to become buried by snow accumulation within a few months a 15m system was deployed on the Avery Plateau on 19 January as a backup. However, this station only lasted 3 days before the Iridium data indicated that the mast had collapsed. The collapsed system was recovered to Rothera by BAS personnel after the end of the OFCAP field season and was deployed near the skiway at Rothera to provide an additional source of "upwind" data.

Reconnaissance flights revealed that it was not safe to land an aircraft anywhere close to the site (Mill Inlet) chosen for the "downwind" station because of crevassing. Eventually, after much discussion of alternative sites, this station was deployed on 21 January at an altitude of around 400m on the Cole Peninsula, an eastward extension of the Peninsula mountains into the Larsen Ice Shelf. While not an ideal location for our purposes, the site has proved a good compromise and, at the time of writing (July 2011), is still providing data. For historical reasons we still refer to this station as "Mill Inlet".

At this stage in the field season we did not have an AWS available for deployment at the Larsen Camp site. We made a decision that the existing AWSs at this site (operated by BAS and IMAU) would provide sufficient data for the needs of the OFCAP project.

Detailed reports on each of these AWS deployments are available on request. An attempt will be made to recover all three AWSs during the 2011-12 field season, although this may prove impossible at the high-accumulation (North Adelaide and Avery Plateau) sites.

| Location | length of mast | input date | collapse date | end of Iridium data | high res data available until | Latitude | Longitude | Height asl |
|---|---|---|---|---|---|---|---|---|
| North Adelaide | 15m | 24.12.2010 | 29.12.2011 | sporadic until 09.01.2011 | 09.01.2011 | 66°38.87314' S | 67°43.7246' W | 225.86m |
| | 5m | 10.01.2011 | / | 18.01.2011 | 18.01.2011 | 66° 38.8925' S | 67° 43.6640' W | 227.83 m |
| | 15m | 18.01.2011 | 24.01.2011 04:15 | sporadic until 21.02.2011 | 04.03.2011 | 66° 38.8925' S | 67° 43.6640' W | 227.83 m |
| | 9m | 04.03.2011 | | ongoing | not yet available | 66° 38.8925' S | 67° 43.6640' W | 227.83 m |
| Avery Plateau | 15m | 19.01.2011 | 22.01.2011 14:29 | sporadic until 21.02.2011 | 21.02.2011 | 66° 55.6381' S | 65° 36.4801' W | 2068.65m |
| | 5m | 09.01.2011 | / | ongoing | not yet available | 66° 52.64012' S | 65° 27.3847' W | 1813.14 m |
| Mill Inlet | 5m | 21.01.2011 | / | ongoing | not yet available | 66° 51.7966' S | 63° 48.6636' W | 427.4 m |

Table 1. Details of the AWS deployments

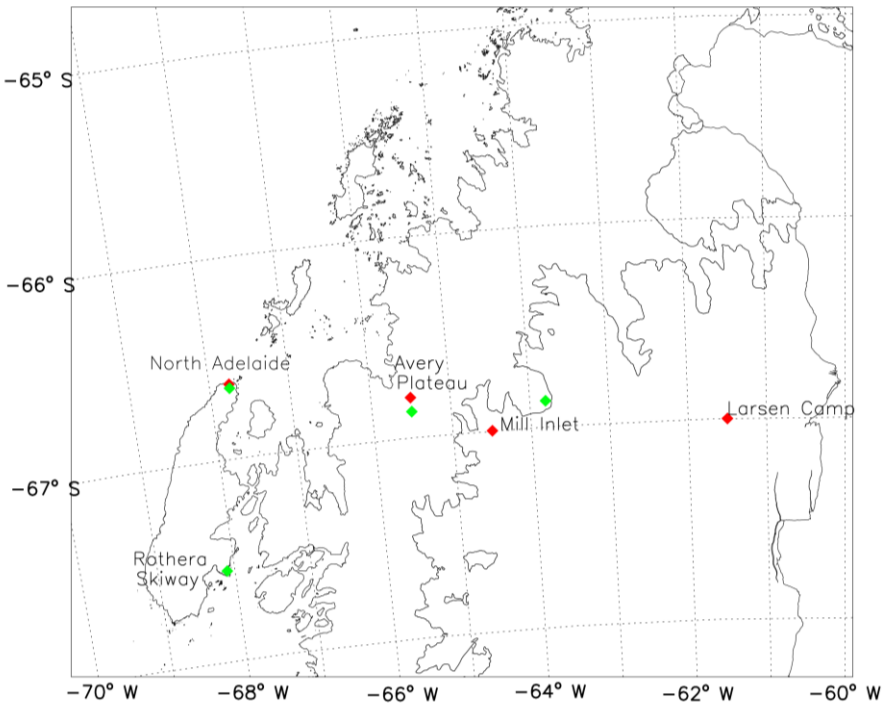


Figure 1. Planned (red) and actual (green) locations of the AWSs

Figure 2. North Adelaide AWS

**Larsen Camp**

A manned camp was maintained on the Larsen Ice Shelf (67°01'S 61°29'W) from 3rd January to the 1st February 2011. The camp was manned by Peter Kuipers Munneke (from the Institute for Marine and Atmospheric Research Utrecht) and Ian Hey (Field Assistant) and a separate detailed field report for this part of the project is available. At the camp a wide range of measurements were made including radiation, turbulent surface heat fluxes, snow properties and atmospheric profiles with radiosondes. Further details of these measurements can be found in the separate field report.

**Radiosondes**

Atmospheric soundings were made using Vaisala RS92 radiosondes at both Rothera and the Larsen Camp. At Rothera, these soundings were made using equipment permanently installed at the station and supplemented the operational programme of 4 soundings per week operated by the BAS Meteorological and Ozone Monitoring Unit. At Larsen Camp, balloons were filled from helium cylinders and were launched from a portable launcher system. As supplies of helium, balloons and sondes were limited at this location, soundings were only made during periods of particular interest to the OFCAP project, generally at times when the winds over the Peninsula were from the west and MASIN flights were taking place. A total of 52 sondes were launched from Rothera while 24 were launched from Larsen Camp.

Figure 3 Preparing a radiosonde for launch at the Larsen Camp

**Aircraft measurements**

The MASIN Twin Otter aircraft (VP-FAZ) fitted with atmospheric instruments flew 22 flights, lasting in total around 78 hours, in support of the OFCAP project (see table 2). During the intensive observing period from the 11th January to 5th February two strong westerly events took place (26-28th January and 4-5th February). Six flights were flown during the earlier event and five in the second. Easterly winds were experienced more often than westerlies and the remaining OFCAP flight were used to observe easterly flow events.

The flights normally consisted of an ascent on the west of the Peninsula, a transit across Peninsula at around 3000m altitude(often close to 67°S – the line of AWSs but sometimes at 68°S) and then a descent to the surface on the eastern side. In westerly events the aircraft would sample the detailed structure of the wind and temperature on the east of the Peninsula, while for easterly events more measurements were made on the west. The flight tracks for the OFCAP flights are shown in figure 4.

| Flight | Date | Duration | Location | Who | Purpose | Comments |
|---|---|---|---|---|---|---|
| 178 | 05-Feb-11 | 04:00 | Cross Peninsula/Larsen | Tor, Tom, Andy | OFCAP | Broken Floor PIR |
| 177 | 05-Feb-11 | 04:10 | Cross Peninsula/Larsen | Tor, Tom | OFCAP | Broke floor PIR on landing |
| 176 | 05-Feb-11 | 04:00 | Cross Peninsula/Larsen | Andy, Russ, Nick A | OFCAP | |
| 175 | 04-Feb-11 | 04:00 | Cross Peninsula/Larsen | Andy, Tom | OFCAP | |
| 174 | 04-Feb-11 | 03:30 | Cross Peninsula/Larsen | Tor, Tom, Tamsin | OFCAP | |
| 173 | 03-Feb-11 | 04:30 | Cross Peninsula | Tor, Andy, Russ | OFCAP 68S | No CAPS |
| 171 | 02-Feb-11 | 03:15 | Cross Peninsula | Andy, Tom, Amelie | OFCAP Easterly flow | 68 S crossing |
| 169 | 01-Feb-11 | 04:00 | Cross Peninsula/Larsen | Tor, Russ | OFCAP slight westerly | Northern Box |
| 167 | 30-Jan-11 | 03:00 | Marguerite Bay | Tom, Russ | OFCAP Tor windy valleys | |
| 166 | 30-Jan-11 | 04:15 | Peninsula Cross / Larsen | Tor, Tom, Amelie | OFCAP easterly flow | 68S crossing, computer restarts |
| 165 | 28-Jan-11 | 02:15 | Larsen to Rothera | Andy, Russ | OFCAP westerly flow | |
| 164 | 28-Jan-11 | 02:00 | Rothera to Larsen | Andy, Russ | OFCAP westerly flow | |
| 163 | 27-Jan-11 | 04:00 | Peninsula Cross / Larsen | Tor, Tom | OFCAP westerly flow | Vorticity streamer flight |
| 162 | 27-Jan-11 | 04:10 | Peninsula Cross / Larsen | Andy, Russ | OFCAP westerly flow | repeat of 160-1 |
| 161 | 26-Jan-11 | 02:15 | Larsen to Rothera | Tor, Tom, Amelie | OFCAP westerly flow | Larsen N-S and 68 S line |
| 160 | 26-Jan-11 | 02:10 | Rothera to Larsen | Tor, Tom, Amelie | OFCAP westerly flow | 67 S line |
| 158 | 24-Jan-11 | 03:00 | Marguerite Bay | Tor, Amelie, Tom | Jets/clouds | Overfly North Adelaide AWS |
| 157 | 23-Jan-11 | 03:30 | NE of Adelaide Island | Tom, Amelie, Andy | OFCAP Barrier flow / clouds | |
| 156 | 22-Jan-11 | 05:00 | Cross Peninsula and Marguerite Bay | Tor, Andy, Russ | OFCAP Peninsula flow and fjord jets | |
| 149 | 13-Jan-11 | 04:15 | Cross Peninsula | Tom,Russ, Tor | OFCAP Foehn Wind Easterly flow | |
| 148 | 12-Jan-11 | 04:00 | Cross Peninsula | Tom, Russ, Amelie | OFCAP Foehn Wind Easterly flow | FPH problem at very low DPs. |
| 147 | 11-Jan-11 | 03:00 | Cross Peninsula | Tom, Russ, Tor | OFCAP East Peninsula Barrier Wind | |
| Total | | 78:15 | | | | |

Table 2. MASIN flight details

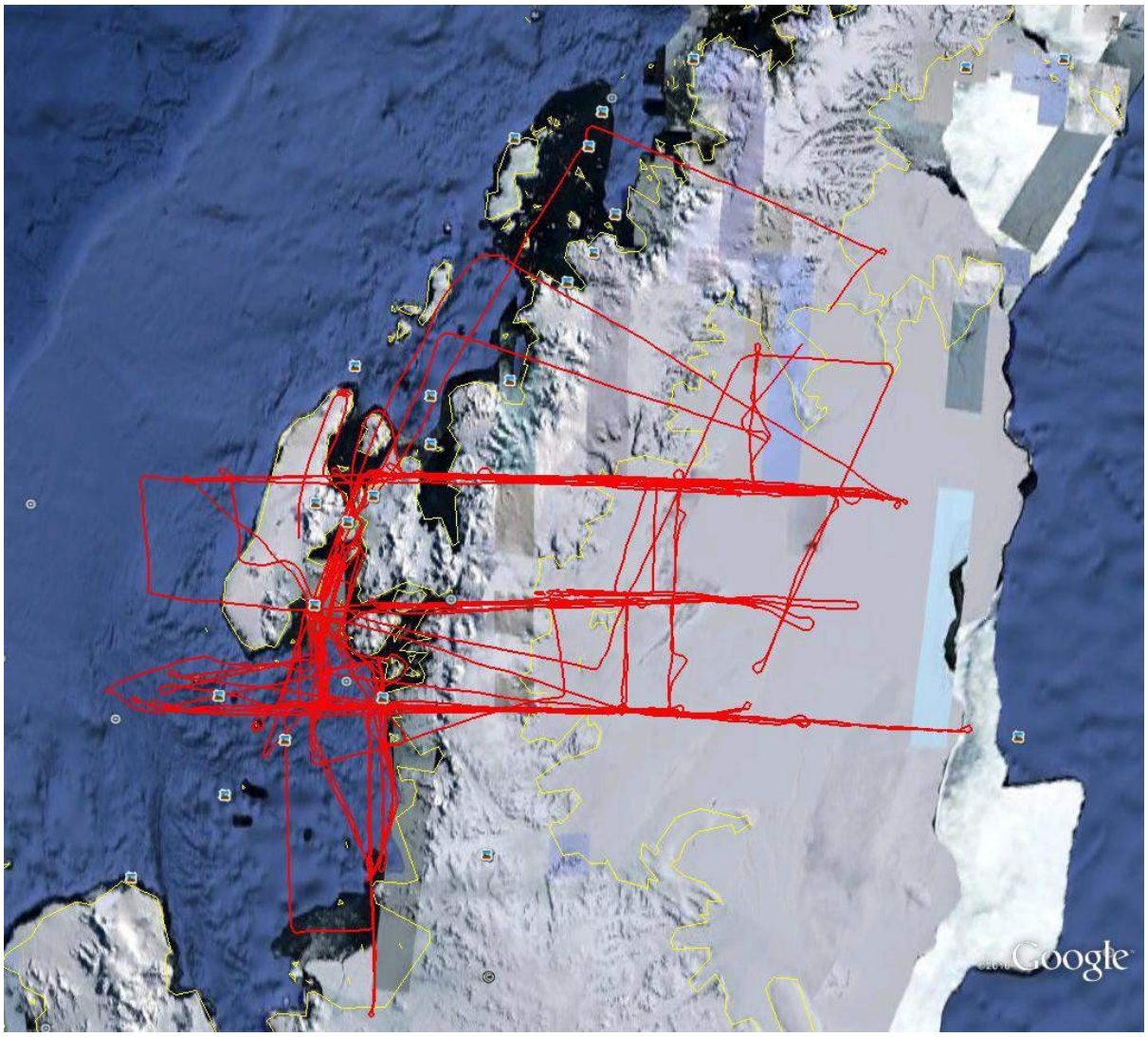


Figure 4. MASIN flight tracks for OFCAP

**Forecasting for campaign**

Detailed forecast were required for the intensive observing period so that best use could be made of the aircraft and no westerly wind events were missed. Leeds University ran the WRF forecast model at 1.5km resolution and made the output available in near real time to the team in the Antarctic. Victoria Smith was responsible for the running of the model and provided briefings every morning to the OFCAP team. The UK Met Office also ran a limited area model at a resolution of 4km for most of the period although for the last two days model output was available at 1.5km. The UK Met Office model was presented at the briefings by Andy Elvidge.

These high resolution models and the briefings given by Andy and Victoria made a big impact on the project as a whole. The briefing for the OFCAP project was normally held in briefing room at Rothera after the main operational brief had been held in the morning although occasionally it had to be postponed for a while time for the data to arrive at Rothera.

The impact these forecasts had on the project was huge as it enabled westerly events to be identified before they started so all phases of their development could be investigated. Also the high resolution modelling meant that the fine scale structure was observed and it meant that the flight plans could be adjusted to fly through interesting features.

**Summary and recommendations**

Overall, the OFCAP field season was very successful. Although westerly winds across the Peninsula (our prime focus of interest) occurred frustratingly infrequently during our one-month field campaign, we did manage to observe two such episodes and gathered high-quality airborne and ground-based data during each. Analysis of these data, and the ongoing data from the AWSs that are still operating, is currently being undertaken.

As a result of our experiences during the field campaign, we make the following recommendations:

1.) More engineering effort is required to solve the problem of how to deploy a long-term AWS in a high snow accumulation region. Our chosen solution (15 m guyed tubular masts) proved not fit for purpose despite investing considerable effort in the design of these masts and development of safe procedures for erecting them. Ideally, we would have liked a "test" season to develop a solution, but this is almost impossible within the constraints of a 3-year grant.

2.) Having high-resolution forecast model data available at Rothera, together with project staff who were able to devote time to interpreting this model output, proved to be of immense value to our project. We recommend that any atmospheric science project where measurements are strongly dependent on prevailing atmospheric conditions (as they were for OFCAP) should consider adopting a similar approach.

**Acknowledgements**

The success of the OFCAP field season reflects the excellent professional support that we received from BAS Field Operations. We thank Mike Dinn and Rothera field operations managers Andy Barker and Rod Strachan for ensuring that the required logistics were in place, and the BAS Air Unit, particularly pilots Alan Meredith, Al Howland and Doug Cochrane, together with Clem Collins and the air mechs, for getting us into the field and supporting the MASIN flying. Ian Hey gets our thanks for his support of the Larsen Camp and AWS deployments. We also thank the Met team at Rothera, particularly Tamsin Gray, for their support. Steven Pickering, Dureid El-Moghraby and Mark Dixon (University of Leeds) helped set up the advanced reservation facility on the Leeds Supercomputer and made sure that the WRF simulations could take place each night. Finally, we thank the Met Office, particularly Clive Wilson and Mark Weeks, for setting up and delivering a high-resolution forecast system to support the project at very short notice.