

Airborne Remote Sensing In Australia Using Small, Modern, Highly Cost-Efficient Platforms - Capabilities And Examples

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Abstract - Airborne Research Australia (ARA) has pioneered the use of small, modern and highly cost-efficient platforms for a wide range of airborne remote and in-situ sensing.

The aircraft used are a purpose-built special-mission version of a motorglider with highly efficient aerodynamics combined with a quiet, minimum-pollution engine. Their flight characteristics and capabilities are very similar to those of typical mid-sized unmanned aerial vehicles (UAVs).

The aircraft and sensors have been used in a wide range of projects Australia-wide. Examples are the simultaneous use of full waveform resolving lidar, aerial imaging, hyperspectral, multispectral and microwave sensing on near 1,000km-long transects over Australia's savannah landscape; bathymetric studies using hyperspectral scanning over coastal waters in Victoria; and a survey of the topography of exposed reefs in the Kimberley region of Australia. Recently, an active airborne scatterometer was added to the sensor kit which has already produced first images.

Keywords: Small research aircraft; airborne lidar; airborne Hyperspectral; bathymetry; scatterometer.

1 Introduction

Over many years, Airborne Research Australia (ARA) has been a leader in using small and highly efficient airborne platform equipped with state-of-the-art remote and in-situ sensors for a wide range of environmental research. ARA is an integral, but externally funded part of the School of the Environment at Flinders University

ARA's airborne platforms are purpose-built special-mission versions of a popular motorized glider, making use of the latest developments in modern aerodynamics, airframe design and engine technology. These platforms are arguably the most efficient and environmentally friendly ones available worldwide today and are commonly designated as SERAs ("*Small Environmental Research Aircraft*").

ARA has been working in close cooperation with MetAir AG in Switzerland who also owns and operates an aircraft identical to the two ARA aircraft. An example of the scope of this collaboration is given in the examples below.

The ARA and MetAir SERAs are HK36TTC-ECO Dimonas, manufactured by Diamond Aircraft in Austria and Canada, as shown in Figure 1.



Figure 1: Top: One of ARA's ECO-Dimonas showing the two underwing pods carrying a lidar, a hyperspectral scanner, and aerial camera and some other sensors. Bottom: ECO-Dimona showing the four-pod configuration.

The ECO-Dimonas are capable of carrying up to a total of approximately 150kg of scientific payload in underwing and belly pods, and in the baggage area in the cockpit, together with a crew of two, usually a pilot/scientist and a scientist/systems operator. Typical cruising speed range is 20-50m/s at ranges of up to about 1,000km. Maximum endurance (depending on payload etc.) can be up to 7hrs. The aircraft have been operated for science tasks at flying altitudes between just a few metres above the ground (mainly for turbulent flux measurements) and up to 7km (as for instance during investigating the recent volcanic ash cloud in Europe).

The engine, a turbo-charged ROTAX 914F, uses premium unleaded petrol and delivers a near vibration-free environment for the sensors. The aircraft can operate without restrictions in all types of airspace, day and night, provided Visual Meteorological Conditions (VMC) are present.

Due to the nature of the aircraft, costing on the basis of flying hours is not very useful. Instead, they are normally included in science projects on an "operations day in the field" based cost model.

More information about the aircraft and projects is available on the ARA website www.airborneresearch.org and the MetAir website www.metair.ch. It may also be of interest to watch <http://www.vimeo.com/18974173> showing images taken from a wing-mounted camera during a recent ferry flight from Birdsville across the Simpson Desert to Lake Eyre.

In the following, some examples will be given from recent projects involving the ARA airborne toolkit. The locations of these projects are shown in **Figure 2** below.

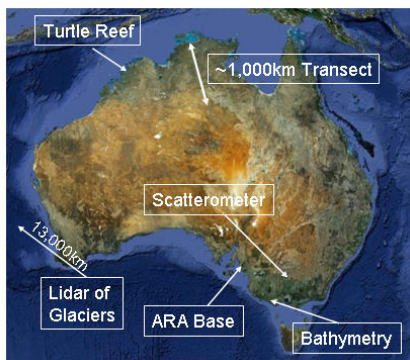


Figure 2: Geographical locations of projects and surveys described in this paper.

1.1 ~1,000km Transects

In the context of the SPECIAL project (“Savanna Patterns of Energy and Carbon Integrated Across the Landscape”), comprehensive airborne surveys were flown by both ARA ECO-Dimonas in September 2008 under by the acronym “TIPPEX”, relating to the aircraft team being based at Tipperary Station in the Northern Territory. The complete airborne toolkit available at ARA at the time was deployed and flown along the nearly 1,000km-long North Australian Tropical Transect (NATT) as shown in **Figure 3**. An overview paper has just been submitted (Beringer et al, 2011).

The toolkit consisted of:

- full waveform resolving lidar (Riegl Q560)
- Hyperspectral scanner (SPECIM EAGLE)
- Hi-res aerial camera (Canon EOS 1Ds)
- ARA/AWI Tri-Spectral scanner (for ndvi)
- PLMR - L-Band radiometer (for soil moisture)
- Turbulent flux instrumentation (H, LE, Cm)

Examples of results are shown in **Figure 3**, **Figure 4** and **Figure 5**.

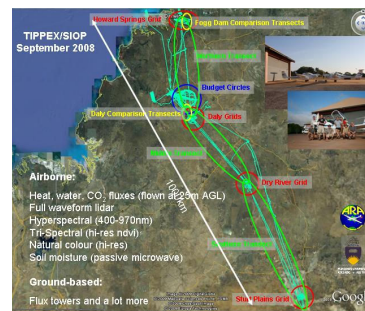


Figure 3: Flights along the NATT and other features of the TIPPEX sub-campaign of SPECIAL.

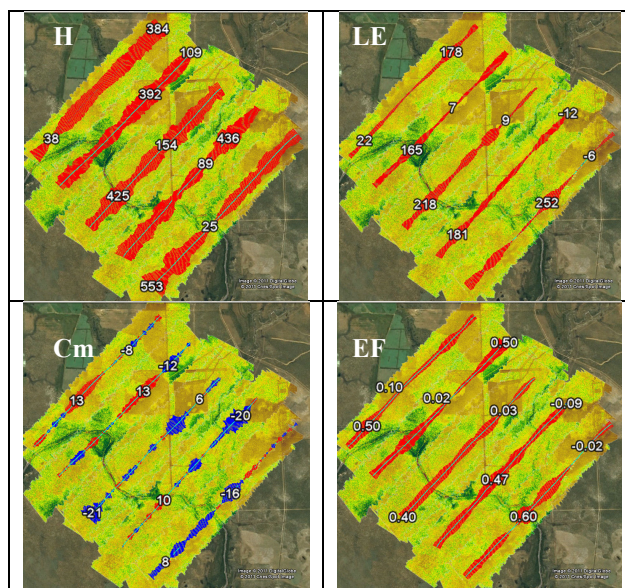


Figure 4: Aircraft flux grids (~20km) over the Daly River site (see Figure 3). For visualization, the fluxes were spatially averaged over 800m, their magnitude is illustrated by the length of the coloured whiskers (red: upward fluxes, blue: downward fluxes). Minimum and maximum flux values are shown for each transect. H is sensible heat flux (W/m^2), LE is latent heat flux (W/m^2), Cm is flux of CO_2 ($\mu mol CO_2 / m^2 / s$), EF is evaporative fraction ($LE/H+LE$). The image beneath the fluxes is aircraft-derived NDVI using data from the ARA/AWI Tri-Spectral Scanner.

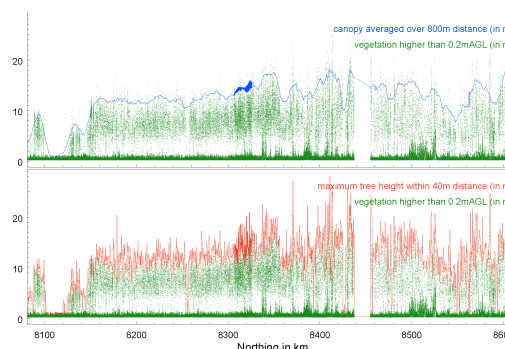


Figure 5: Canopy structure measured along the NATT using the lidar flown in the ECO-Dimonas.

1.2 Bathymetry from Hyperspectral Measurements

Hyperspectral measurements in the VNIR spectral range can be used to derive bathymetric measurements in reasonably clear water. This feature was used to derive the topography of the ocean floor in a coastal area near Warrnambool, Vic. The SPECIM Eagle II sensor (400nm – 970nm wavelength range, see www.specim.fi) was used together with the DALEC3 spectrometer, both mounted to the wing of one of the ECO-Dimonas.



Figure 6:
DALEC3
wing mount

The DALEC3 was developed by Curtin University and In-situ Marine Optics and features three optical channels (2x radiance, 1x irradiance) with a FOV of 5° for the wavelength range 350nm - 1050nm at a resolution of 3.3nm. The DALEC3 was flown close to the water surface to derive the most accurate spectral characteristics of the water.

Figure 7 shows a 3D-image of the bathymetry of the coastal waters.

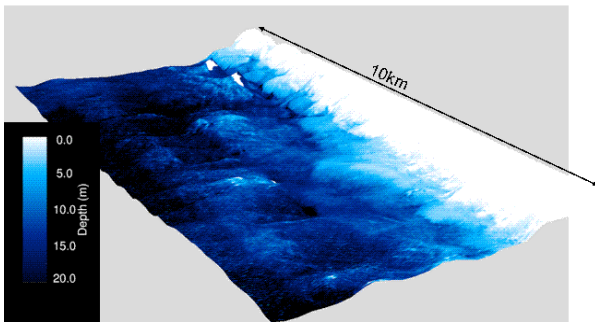


Figure 7: Bathymetry of coastal waters near Warrnambool, Vic as derived from a combination of the SPECIM Eagle Hyperspectral scanner and the DALEC3 spectrometer. Courtesy of W. Klonowski, In Situ Ocean Optics.

1.3 Turtle Reef, Kimberley Region, WA

In collaboration with WAMSI (“West Australian Marine Sciences Institute www.wamsi.org.au), ARA used one of its ECO-Dimonas to carry out a lidar, hyperspectral, tri-spectral and photographic survey of the Turtle Reef within Talbot Bay in the Kimberley Region of Western Australia. The survey was flown during very low tidal conditions which gave the unique opportunity to determine in great detail the shapes, elevations and features of the large areas of the exposed coral reef.

Due to the extreme remoteness and environmentally sensitive nature of the area, the ECO-Dimona was an ideal platform for this survey. Aerial and ground views of the area and the exposed coral are shown in Figure 8. Examples of results are shown in Figure 9 and Figure 10.



Figure 8: Aerial and ground view of the Turtle Reef area and the coral features. Some photos are courtesy of S Blake of WAMSI.

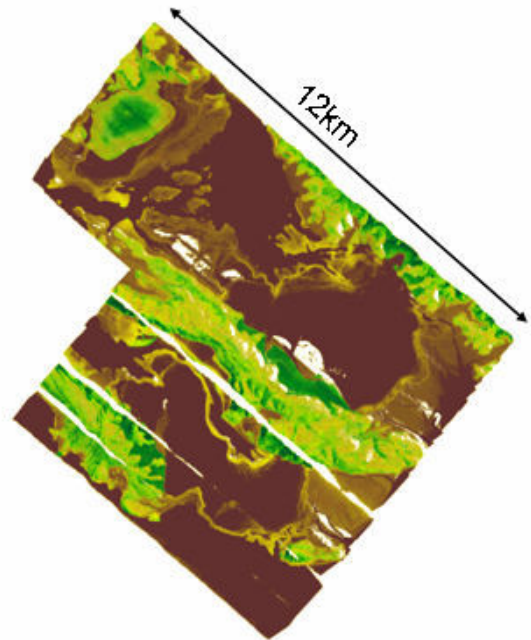


Figure 9: Turtle Reef and part of Talbot Bay as seen by the ARA/AWI-Tri-Spectral Scanner. Shown is ndvi in shades yellow and green, with brown areas indicating open water.

A video rendering of the aerial photographs can be viewed on <http://www.vimeo.com/19011651>

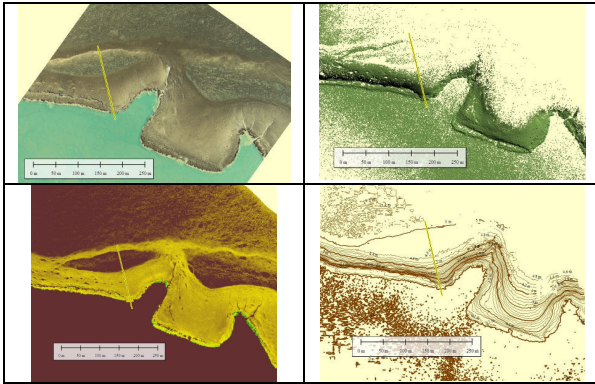


Figure 10: Various parameters of an edge of Turtle Reef. Top left: Aerial image; top right: Lidar returns (note that the lidar does not normally get returns from open smooth water surfaces; bottom left: ndvi (brown represents open water surfaces; bottom right: elevation contours derived from the lidar.

1.4 Scatterometer / SAR

The latest addition to the airborne toolkit available at ARA is the PLIS, the “Polarimetric L-Band Imaging Scatterometer”, a 1.26GHz L-Band radar. It allows monitoring environmental variables such as soil moisture, vegetation and salinity, and additionally terrain height when used as an Interferometric SAR (InSAR). The unit was designed and manufactured by ProSensing, USA for a consortium of several universities in Australia. To carry the PLIS antennas on ARA’s Dimonas, it was necessary to design, manufacture and certify two additional wing pylons, a task that was accomplished from start to finish in less than 3 months.



Figure 11: PLIS antenna pylon on the ECO-Dimona wing.

In late 2010, first test flights with the PLIS were carried out near Narrandera, NSW (SMAPex campaign) and near Adelaide, SA. Figure 12 shows an example of early

results of PLIS data from the SMAPex campaign. With spatial resolution between 1 and 2m, it shows L-band reflectivity in different transmit/receive polarisations, different polarisation combinations being represented as different colour channels. This means that scattering structures with polarisation-dependent reflectivity properties show up with different colours, structures without significant polarisation dependence show up as white. Crops with lots of vertical physical structure (stalks), and land surfaces with horizontal physical structure (tilled with straight, parallel grooves) are likely to have strong polarisation dependence in different directions. Linear metal structures such as powerlines and irrigation equipment are also clearly visible in this representation. Open water yields a specular reflection

with relatively low (dark) returned power; the shorelines appear outlined in blue in this representation.

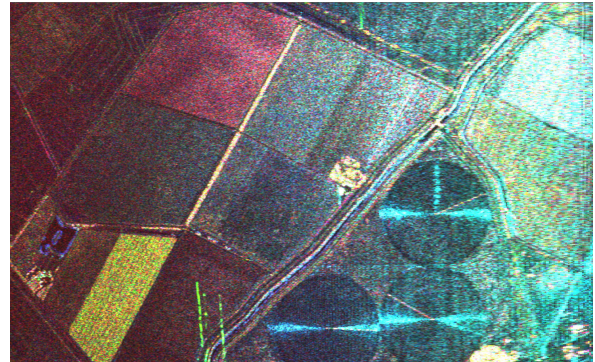


Figure 12: First results from the PLIS scatterometer. For explanations, see text.

1.5 Exchange of Lidar Pod

In August 2008, the ARA Lidar underwing pod was shipped to Switzerland and fitted to the MetAir ECO-Dimona. Airborne lidar measurements commenced just 2 days after the arrival of the pod in Switzerland from Australia, illustrating the advantage of the “pod”-



approach. Lidar surveys were then carried out over glaciers in the Austrian and Swiss Alps, as well as over agricultural and natural surfaces in Germany. Only two weeks later, the Lidar pod arrived back in Australia to be deployed at the SPECIAL/TIPPEX campaign

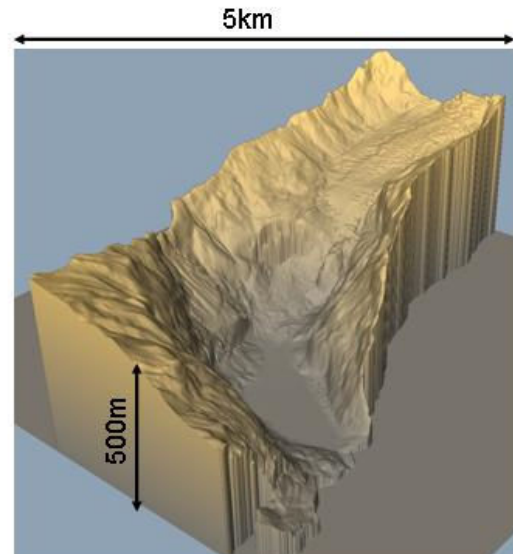


Figure 13: Glacier in the Maderanertal in Switzerland as seen by the ARA airborne lidar flown on the MetAir ECO-Dimona.