# The Flights of the ARA Cessna 404 '*Investigator 2*' during NAURU'99

# An Overview

**Jörg M. Hacker and David Pethick**

**October 1999**

**ARA Technical Report No. 9/1999**

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Cover photographs: Top: Nauru Island as seen from *Investigator 2*; Bottom: *Investigator 2* flypast of RV *Ronald H. Brown* and instrumented buoy

* Report available from: Dr. J.M. Hacker, ARA-Airborne Research Australia, Flinders University, PO Box 335, Salisbury South, 5106, Australia.

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# 1 Introduction

The field experiment NAURU'99 is part of the Atmospheric Radiation Measurement Program (ARM). ARM is a multi-laboratory, interagency program that was created in 1989 with funding from the U.S. Department of Energy (DOE) and is part of DOE's effort to resolve scientific uncertainties about global climate.

NAURU'99 was an Intensive Operational Period (IOP) conducted on and around the island of Nauru in the Tropical Western Pacific during the summer of 1999. During this international research campaign scientists gathered data on oceanic and atmospheric processes to better understand the influence of the tropics on planetary scale processes.

The primary research platforms in NAURU'99 were

- NOAA research vessel (RV *Ronald H Brown*)
- JAMSTEC research vessel (RV *Mirai*)
- ARA research aircraft Cessna 404 (*Investigator 2*)
- ARCS-2 installation on Nauru
- TAO buoy array

The ARM Program establishes and operates field research in several climatically significant locations. The Atmospheric Radiation and Clouds Station (ARCS), installed on Nauru in 1998, provides the long-term data used by scientists to study the effects and interactions of sunlight, radiant energy, and clouds on temperatures, weather, and climate in the Tropical Western Pacific (TWP).

The quality of this data must be accurately determined. This is one of the primary goals of the IOP. The ARCS program is confined to islands and is subject to criticism because of the known or suspected "island effects". To take full advantage of the island data, the degree of island contamination must be ascertained. Only then can the island data can be effectively extrapolated to represent over-the-ocean conditions. Nauru99 will provide a crucial data set for understanding island effects. The uncertainty of TAO buoy measurements will also be ascertained by field measurements.

The ARM Ocean Working Group (AOWG, 1996) developed six topics it considered critical to improving our understanding of the tropical ocean-atmosphere interaction:

- Spatial and temporal variability of radiation fluxes at the ocean surface.
- Island effect of the types described above.
- Atmospheric surface layer physics including diurnal variations in buoyancy flux and stability.
- Upper ocean mixed layer physics that effects the transmission and absorption of short-wave radiation.
- SST predictions from external factors such as cloudiness, rainfall, and mixing.
- Cycles of convection from small to large and the importance of convective size to the dynamics of the troposphere.

The research aircraft was used to measure turbulent and radiative fluxes in the boundary layer in conjunction with ship and island measurements. These observations will allow the investigate the 2-D variability of these fluxes in the oceanic environment and thereby supply information about the representative nature of the ship observations themselves.

Measurements of the modification of the boundary layer in the vicinity of the island will be useful in understanding the influence of the island on the ARCS measurements. Aircraft data provides high quality SST measurements ideal for the examination of spatial variability.

Finally, the availability of aircraft data allows for regular intercomparison of the data collected by the other measurement platforms. These "reference" measurements will prove invaluable in the detection of suspect data.

# 2 Aircraft and Instrumentation

The ARA research aircraft flown during NAURU'99 was the Cessna 404 VH-EOS using the call sign *Investigator 2.* A summary of its performance characteristics is given in Table 1.

| **Cessna 404 *'VH-EOS' Investigator 2*** | |
|---|---|
| number of engines | 2 |
| wing span | 11.8m |
| maximum scientific payload | 750 kg |
| endurance | 10 hours |
| range | 2,000 km |
| max. cruising altitude | 8,000 m |
| typical cruising speed | 165 kts / 300 km/h |
| speed range for measurements | 50-90 m/s |
| crew | 2-5 |

**Table 1: Basic characteristics of *Investigator 2***

The instrumentation installed on *Investigator 2* during NAURU'99 included fast temperature and humidity sensors for the determination of heat and moisture fluxes by the eddy-correlation method, and a 5-hole nosecone pressure port system enabling accurate measurement of the relative wind vector. The configuration of these instruments is displayed in Figure 1.

Data from these instruments is combined with accelerations and attitude angles from a ring laser Inertial Navigation System (*INS*) and latitude/longitude data from a Global Positioning System (*GPS*) receiver, in order to determine the 3-dimensional absolute wind vector to a high precision. An infrared radiometer was fitted for measurements of surface temperature. A full suite of radiometric instruments was flown to measure incoming and outgoing short- and longwave radiation. A liquid water sensor (King Probe) was also fitted. A Sony Hi8 video camera mounted forwards facing in the cockpit allowed continuous recording of time stamped visual data with time and position stamps.

A list of all sensors is given in Table 2.

In flight, data acquisition and real time data viewing was controlled by a *PC*-based data system. All analogue data was logged at 25Hz, INS data at 50Hz and GPS data at 10Hz.

More details about the aircraft and its instrumentation can be found on ARA's website at http://ara.es.flinders.edu.au.

| Parameter | Sensor(s) | Remarks |
|---|---|---|
| position, time, attitude, accelerations | Honeywell LaserNav Inertial Navigation System; Novatel 12-channel *GPS* | |
| turbulence, turbulent fluxes of sensible heat, water vapour and momentum | nose cone pressure port system with two Rosemount 1221VL differential pressure sensors for air angles | together with fast sensors for temperature and humidity |
| air temperature | modified *NCAR* k-probe (Pt100 sensor)<br>*FIAMS* reverse flow probe (Pt100 sensor)<br>modified Meteolab TP4S (thermocouple) | on nose cone<br>on nose cone<br>on nose cone |
| humidity | A.I.R. LA-1 Lyman-Alpha Hygrometer<br>Modified Meteolab TP4S dewpoint system | on nose cone<br>on nose cone |
| static and dynamic pressure | Rosemount 1281 pressure transducer | in aircraft pitot-static system |
| height above ground or water | King KRA-10A radar altimeter | 0-800m range |
| surface temperature | Heimann KT-15 infrared radiometer | 4° viewing angle, 8-14µm |
| solar and terrestrial radiation | Eppley PSP and PIR | |
| liquid water content | CSIRO King Probe | |
| video | Sony Hi8 Handicam | inside cabin |
| data system | ARA data system | data logging<br>real-time processing<br>64 analogue channels<br>(up to 100 Hz, 16 bit A/Ds)<br>RS232/422, ARINC419/429 I/O |

**Table 2: Sensors and systems on-board of *Investigator 2***

**Figure 1: ARA Cessna 404 *Investigator 2* with scientific nose cone**

# 3 Flight Summary

## 3.1 Overview

Between 22 June 1999 and 4 July 1999, a total of 12 flights were carried out by *Investigator 2*, of which nine flights were data gathering missions. Data was usually logged from just before take-off until shortly after landing. The data was recorded as binary files. A list of these files, flight times and a brief description of the patterns flown is given in Table 3. A more detailed breakdown of the daily aircraft activities is presented in Section 5. All flights commenced and terminated at Nauru Airport.

## 3.2 Flight Patterns

The following basic patterns were flown:

- **Large Triangle:** To study the variability of the atmospheric parameters between Nauru and the two research vessels, on 5 days a total of 9 Large Triangles were flown at 30m (100ft) above water along the route ARC Site – RV *Mirai* – RV *Ronald H. Brown* – ARC Site. On some occasions, ascents and descents were flown near the ships to altitudes of up to 3,000m. One circumnavigation of the Large Triangle took approximately 3 hours.
- **Stacks of Small Triangles:** After the two ships moved closer to the island, stacks of small triangles were flown between the ARC Site and the two vessels at various altitudes. Occasionally additional legs were flown to investigate in more detail the formation of a cloud street in the wake of the island. A total of 10 small triangle was flown on 2 July 1999. One circumnavigation of the Small Triangle took approximately 35 minutes.
- **Island traverses:** Various patterns were flown to study the island effect close to Nauru itself. These consisted of several circumnavigations of the island at various distances and altitudes, as well as traverses across the island at various altitudes and directions.
- **Fly-bys for intercomparison:** At the start and end of each Large Triangle, a close fly-by at the ARC Site was carried out. Additional fly-bys were carried out during the Small Triangles and the other patterns. The sections flown near the research vessels are also used for intercomparison.
- **Cloud penetration:** A series of dedicated could penetrations were carried out near the island with the aim to determine their liquid water content.
- **Others:** Some other patterns were flown for specific purposes, such as to determine the albedo of Nauru Island.

| SUMMARY OF FLIGHTS OF *INVESTIGATOR 2* DURING *NAURU'99* | | | |
|---|---|---|---|
| **Take-Off & Landing (LT 1999)** | **Take-Off & Landing (UTC 1999)** | **Description** | **Binary Data File(s)** |
| 22 Jun 10:37<br>22 Jun 11:20 | 21 Jun 22:37<br>21 Jun 23:20 | Instrumentation test flight | 990622_1037.v60 |
| 24 Jun 09:21<br>24 Jun 16:30 | 23 Jun 21:21<br>24 Jun 04:30 | Two Large Triangles with ascent/descent to 1,000m (3,000ft) AMSL during first triangle near *Mirai* | 990624_0921.v60<br>990624_0946.v60<br>990624_1140.v60<br>990624_1144.v60<br>990624_1247.v60<br>990624_1457.v60 |
| 25 Jun 09:38<br>25 Jun 16:50 | 24 Jun 21:38<br>25 Jun 04:50 | Two Large Triangles | 990625_0934.v60<br>990625_1001.v60<br>990625_1133.v60<br>990625_1326.v60<br>990625_1406.v60<br>990625_1521.v60 |
| 27 Jun 09:23<br>27 Jun 16:42 | 26 Jun 21:23<br>27 Jun 04:42 | Two Large Triangles with ascent/descents to 2,000m (6,000ft) AMSL during the second triangle near *Mirai* and *Ron Brown* | 990627_0920.v60<br>990627_0945.v60<br>990627_1115.v60<br>990627_1234.v60<br>990627_1359.v60 |
| 28 Jun 09:30<br>28 Jun 14:14 | 27 Jun 21:30<br>28 Jun 02:14 | One Large Triangle with ascent/descents to 3,000m (10,000ft) AMSL near *Mirai* and *Ron Brown* | 990628_0926.v60<br>990628_1226.v60 |
| 30 Jun 09:43<br>30 Jun 17:04 | 29 Jun 21:43<br>30 Jun 05:04 | Two Large Triangles with ascent/descent to 3,000m (10,000ft) AMSL during the second triangle near *Mirai* to 2,000m (6,000ft) near *Ron Brown* | 990630_0939.v60<br>990630_1142.v60<br>990630_1311.v60<br>990630_1405.v60<br>990630_1535.v60 |
| 02 Jul 09:15<br>02 Jul 16:37 | 01 Jul 21:15<br>02 Jul 04:37 | Ten Small Triangles at various altitudes; albedo grid over Nauru Island; and three orbits of the island | 990702_0911.v60<br>990702_1030.v60<br>990702_1156.v60<br>990702_1310.v60<br>990702_1413.v60<br>990702_1602.v60<br>990702_1608.v60 |
| 03 Jul 06:39<br>03 Jul 10:42 | 02 Jul 18:39<br>02 Jul 22:42 | Three stacks downwind of Nauru Island | 990703_0636.v60<br>990703_0824.v60<br>990703_0832.v60 |
| 04 Jul<br>04 Jul | | Multiple traverses across Nauru Island at various altitudes (degraded data set: no wind) | 990704_1026.v60<br>990704_1203.v60<br>990704_1335.v60 |

**Table 3: Flights of *Investigator 2* during NAURU'99**

# 4 Description of the Data Set

All data processing was carried out using ARA's data processing package ARAMF. The package itself, including extensive User Manual and source code, can be downloaded from ARA's web site at http://ara.es.flinders.edu.au.

## 4.1 Data sets

The following data from *Investigator 2* is (or will be) available from ARA

- CD-ROM with raw binary data (on special request only)
- CD-ROM with 1-second data (in ASCII-Format)
- Event files, other parameter files used during processing (also listed in Appendix XX)
- Spreadsheet with fluxes and other averages (shown as graphs in Appendix XX)
- Selection of plots (as Postscript files or pdf-files; some of the graphs shown in Appendix XX)
- Hi8 video tapes (time and position stamped); also available as time-lapse avi-files.

## 4.2 Derived Quantities from Initial Processing

Prior to the generation of this report, data from each of the runs was processed to first stage calibrated quantities. A set of derived quantities (as specific in Table 4) is available as 1-second averages in ASCII-Format on ARA's ftp-site. Higher resolution data is available on CD-ROM, by request.

At certain times during the flights, data from individual sensors should be treated with special care, or be discarded all together. During the generation of the data set containing the 1sec averages, channels were set to *invalid*, indicated by a numeric value of 999999. More comments about individual channels are given below.

## 4.3 Special Aspects of the Derived Quantities

A number of points need be made regarding the currently data available, and some considerations prior to further processing.

### *4.3.1 The effect of aircraft maneuvers on the wind measurements*

Aircraft maneuvering degrades the accuracy of the 3D-wind measurements. Horizontal wind measurements for sections other than straight flight paths should therefore either be removed, or interpreted with caution. Vertical wind measurements should be interpreted with caution for sections other than straight and level flight. In the 1 second averages, the wind components were set to *invalid* for times when the roll angle of the aircraft was more than 20° to either side.

### *4.3.2 Radar altitude vs. pressure altitude*

In the dataset, two altitudes are available, radar altitude (zRAD) and pressure altitude (PA). Radar altitude is the flying altitude as derived from the aircraft's radar altimeter. This instrument can be used from approximately 5m of altitude to a maximum of 700m over land or water. Values outside of this range have been set to *invalid* in the 1 second averages.

Pressure altitude is the altitude computed using static pressure and the conversion to metric altitude according to the ICAO Standard Atmosphere (ISA). As the ambient conditions for the ISA are fixed, PA computed in this manner does not normally give the true geometric altitude, but rather the geometric altitude above the

1013.25hPA level using the vertical lapse rate as defined by the ISA. This means, for instance, that PA can be negative for low altitudes at times when the surface ambient pressures was higher than 1013.25hPa, or the surface temperature was different from 15°C.

### *4.3.3 Soundings*

The quicklook plots in Appendix XX show 1 second averaged data from the ascents and descent carried out during the *Big Triangles* close to the research vessels. The sometimes large differences between ascent and descent are caused by a variety of effects, amongst them the penetration of cloud and different rates of climb and descent. Before using this data in detailed studies, ARA should be contacted for advise on how to interpret this data.

### *4.3.4 Temperature sensors*

All temperature measurements are taken from the direct-flow sensor described in Section 2.

### *4.3.5 The effects of rain and cloud liquid water*

Occasionally during sampling runs, the aircraft passed through showers of rain or through cumulus cloud. Liquid water affects many of the aircraft sensors, such as temperature sensors, humidity sensors and radiometers. Therefore, such flight sections should be interpreted with care. An attempt was made to automatically detect periods of rain by comparing the measurements from the direct- and reverse-flow temperature sensors. The occurrence of rain was also marked in the files by using event "r". The presence of cloud liquid water was measured by the CSIRO King Probe as listed in Section 2. The parameter *clouds* as listed in Table 4 does not indicate cloud penetrations, but rather the presence of cloud *above* the aircraft as derived from the level of shortwave downwelling radiation. Before a detailed interpretation of flight sections affected by rain or cloud liquid water is made, ARA should be contacted for advice.

### *4.3.6 Radiometric measurements*

The radiation quality indicator *radQI* indicates the size of the correction required by the downward facing Eppley PIR (longwave radiation) to compensate for temperature inhomogeneity between the instrument dome and body.

r*adQI* is given by the formula

$$radQI = K * SB * \left( dome^4 - body^4 \right)$$

where K = dome constant, estimated to be 3.5
SB = Stefan-Boltzmann Constant ($5.67*10^{-8}$)
Dome = dome temperature (°K)
Body = body temperature (°K)

The correction is used in the calculation of the net LW radiation at the surface of the thermopile, and appears to provide a good correction (particularly when the correction is less than 20 $Wm^{-2}$). This correction is calculated independently for the instrument measuring downwelling LW radiation.

*radQI* can also be used as an indicator as to the quality of both the upwelling and downwelling shortwave radiation data, as measured by the Eppley PSP's mounted on the roof and in the bomb-bay of the Cessna 404. These instruments do not have their own thermistors, so it is necessary to estimate the temperature of the shortwave instruments using the measurements from the adjacent longwave instruments.

The time-series shown in Figure 2 shows *radQI* and all four radiation fluxes measured by the aircraft. The prefix *dn* or *up* refers to downwelling or upwelling radiation. For example *SWdn* is the downwelling (ie

incoming) shortwave radiation. This data is taken during straight and level flight at approximately 30m altitude. It follows a fast descent from 1,000m. It is clearly visible that the radiometers are still adjusting to the warmer ambient temperature.

There are two measurements that should be almost constant during this measurement pattern, *SWup* and *LWup*. This is because the temperature and reflectivity of the sea surface should not change over a short period of time/distance.

As can be seen, both these values are correlated to *radQI*. When *radQI* is rapidly decreasing *LWup* is exhibiting similar behaviour. *SWup* is rapidly increasing. As *radQI* reaches a constant value, so do both radiation measurements. The error in *LWup* is small, as this correction is taken into account during the calculation of *LWup*. The error in *SWup* however, is very large. Shortwave radiation readings should be considered unreliable during periods when *radQI* is greater than $\pm 5$ W/m$^2$.

Note that *radQI* is often slightly negative. This is because the dome of the instrument is slightly cooler than the body of the instrument. It is most likely that this is due to a small calibration error.

It is recommended that shortwave radiation measurements taken when *radQI* is greater than $\pm 5$W/m$^2$ be treated with caution. Shortwave radiation measurements are unreliable when *radQI* is greater than $\pm 10$W/m$^2$. In the latter case, shortwave values have been set to *invalid* in the 1second averages.

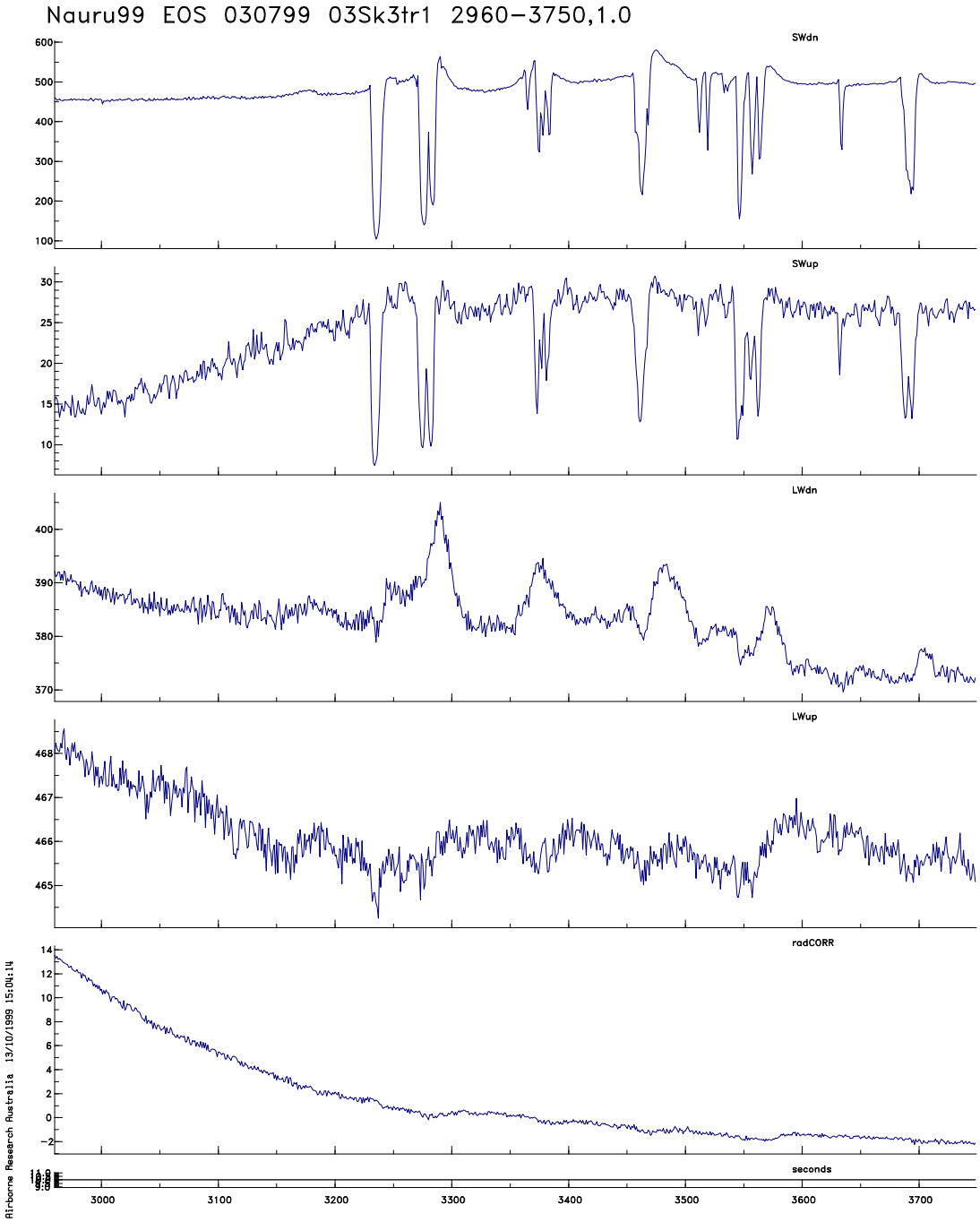


**Figure 2: Explanation of parameter *radQI*. For further details, see text.**

| Parameter | Units | Description/Comments |
|---|---|---|
| NPhhmmss | HHMMSS | Local time of sample as derived from GPS |
| NPsec | sec | GPS seconds (as broadcast from the GPS satellites [*]) |
| Nlat | º | Latitude (positive north) derived from GPS |
| Nlon | º | Longitude (positive east) derived from GPS |
| zRAD | m | Height above terrain/water, from radar altimeter (valid below 700m only) |
| zPS | m | Pressure altitude using ICAO Standard Atmosphere) |
| ps | hPa | Static pressure |
| TAS | m/s | True Airspeed |
| GS | m/s | Ground speed |
| Ipch | º | Aircraft Pitch Angle, from INS |
| Irll | º | Aircraft Roll Angle (bank), from INS |
| Ithdg | º | Aircraft True Heading, from INS |
| tsKT | ºC | Surface Temperature, from Heimann KT15 radiometer |
| trec | ºC | Corrected air temperature, from direct flow sensor |
| theta | ºC | Potential temperature, from direct flow sensor |
| tdML | ºC | Dew Point Temperature, from Meteolabor TP4 sensor |
| q | g/kg | Specific Humidity |
| uair | m/s | East-West (U) component of 3-D wind vector |
| vair | m/s | North-South (V) component of 3-D wind vector |
| wair | m/s | Vertical (W) component of 3-D wind vector |
| sIN | $W/m^2$ | Short-wave incoming radiation |
| sOUT | $W/m^2$ | Short-wave outgoing radiation |
| lIN | $W/m^2$ | Long-wave incoming radiation |
| lOUT | $W/m^2$ | Long-wave outgoing radiation |
| RNet | $W/m^2$ | Net radiation |
| albedo | 1 | Albedo |
| lwCSIRO | $g/m^3$ | Liquid water content from CSIRO King probe |
| clouds | | Cloud indicator |
| rain | | Rain Indicator |
| tsEP1 | ºC | IR surface temperature from downwards facing Eppley PIR |
| tsEP2 | ºC | IR surface temperature from downwards facing Eppley PIR, corrected using Chris Fairall's TOGA-COARE algorithm |
| radQI | $W/m^2$ | see Section 4.3.6 |

**Table 4: Derived quantities available as 1 second averages**

[*] Resets to zero at midnight UTC each Sunday morning

# 5 Day-by-Day Description of Flights

## 5.1 Nomenclature

In the following tables, each flight has been split into a number of segments. A brief description of each run is given, along with relevant comments.

The following nomenclature has been adopted to identify specific flight sections:

| Sections | Naming Convention | | |
|---|---|---|---|
| Straight and level sections of the triangles | ddTnLnx | where | dd = calendar day (24, 25, …)<br>Tn = number of triangle (T1, T2, …)<br>Ln = number of leg (L1, L2, …)<br>x = subsection* of leg of triangle (a,b,…) |
| Ascents | ddAnll | where | dd = calendar day (24, 25, …)<br>An = number of ascent (A1, A2, …)<br>ll = location (MI, RB, ST; where<br>MI = RV 'Mirai'<br>RB = RV 'Ronald H Brown'<br>ST = ARM Site Nauru |
| Descents | ddDnll | where | dd = calendar day (24, 25, …)<br>Dn = number of ascent (D1, D2, …)<br>ll = location (MI, RB, ST) |
| Fly-bys | ddllnx | where | dd = calendar day (24, 25, …)<br>ll = location (MI, RB, ST)<br>n = number of triangle (1, 2, …)<br>x = fly-by (a, b, …) |

It was necessary to define subsections for some of the flight patterns, because the data system in the aircraft stopped logging occasionally for an unknown reason. When this happened, the system was re-started immediately leading to gaps in the data of normally no more than a few seconds or, for the worst case, up to two minutes.

Lists of all event marks and other relevant parameters, as well as a list of the video tapes is given in Appendix XX.

In Sections 5.2 to 5.9, details of flight patterns together with significant events are given for each day. Also shown are the day's flight track with positions and times marked, as well as flight altitudes. x- and y-distances shown in these diagrams are distances from the ARC-Site. Times are Local Time along the flight track and on the abscissa of the time series.

### 5.2 24 June 1999

| Run | Start End (LT) | Height (m) | Description | Comments |
|---|---|---|---|---|
| Take-Off | 09:21 | | Nauru Airport | QNH 1012hPa |
| 24ST1A | 09:31 | 30 | Fly-by ARC Site | |
| 24T1L1A | 09:31 09:46 | 30 | ARC Site to *Mirai* (partly) | INS Error caused restart of logger |
| 24T1L1B | 09:47 10:26 | 30 | ARC Site to *Mirai* (cont'd) | |
| 24MI1A | 10:26 | 30 | Fly-by *Mirai* | |
| 24A1MI | 10:27 10:36 | 30-1000 | Ascent near *Mirai* | Cloud was observed to occur between 2000ft and 3000ft [1] |
| 24D1MI | 10:36 10:45 | 1000-30 | Descent near *Mirai* | |
| 24MI1B | 10:46 | 30 | Fly-by *Mirai* | |
| 24T1L2A | 10:47 11:41 | 30 | *Mirai* to *Ron Brown* | An "i" event was used to mark an unexplained increase in the downward facing pyranometer signal |
| 24RB1A | 11:41 | 30 | Fly-by *Ron Brown* | |
| 24RB1B | 11:43 | 30 | Fly-by *Ron Brown* | |
| 24T1L3A | 11:44 | 30 | *Ron Brown* to ARC Site | Shortly after commencing the leg the downward facing Eppley Pyranometer (#28874f3) failed [2] Logger restarted |
| 24T1L3B | 11:45 12:48 | 30 | *Ron Brown* to ARC Site (cont'd) | INS Error caused restart of logger |
| 24T1L3C | 12:48 13:03 | 30 | *Ron Brown* to ARC Site (cont'd) | |
| 24ST1B | 13:08 | 30 | Fly-by ARC Site | |
| 24T2L1A | 13:10 14:00 | 30 | ARC Site – *Mirai* | |
| 24MI2A | 14:00 | 30 | Fly-by *Mirai* | |
| 24MI2B | 14:03 | 30 | Fly-by *Mirai* | |
| 24T2L2A | 14:04 14:58 | 30 | *Mirai* to *Ron Brown* | Event "r" at end of the leg is the overpass of the *Ron Brown* – NOT rain. |
| 24RB2A | 14:57 | 30 | Fly-by *Ron Brown* | |
| 24RB2B | 15:00 | 30 | Fly-by *Ron Brown* | |
| 24T2L3A | 15:03 15:58 | 30 | *Ron Brown* to ARC Site (partly) | First "i" event indicates the time when all downward facing Eppley channels were temporarily disconnected from the data system..<br>Second "i" event indicated the time when a quick detour was made from the track to check on a sighting in the water. The sighting was confirmed as a buoy and fishing net. |
| 24T2L3B | 16:01 16:18 | 30 | *Ron Brown* to ARC Site (cont'd) | |
| Landing | 16:27 | | Nauru Airport | QNH 1009hPa |

**Notes:**

[1] The Lyman-Alpha humidiometer appeared to be contaminated by liquid water during the ascent/descent through cloud near the *Mirai.* The contamination appeared to no longer exist by the time the descent was completed and the next leg was begun.

[2] Attempts to rectify this problem included unplugging the instruments (all downward facing Eppley instruments) from the power supply and data system. Finally, the logger was restarted, but the problem could not be rectified. The problem in #28874f3 was later attributed to water found IN the instrument, which appears to have caused a short circuit in the internal amplification circuit. For the remainder of the experiment the spare Eppley PSP (#29712f3) was used for downward facing solar radiation measurements. The amplifier on this instrument has been set to 500 times to improve accuracy of measurements.

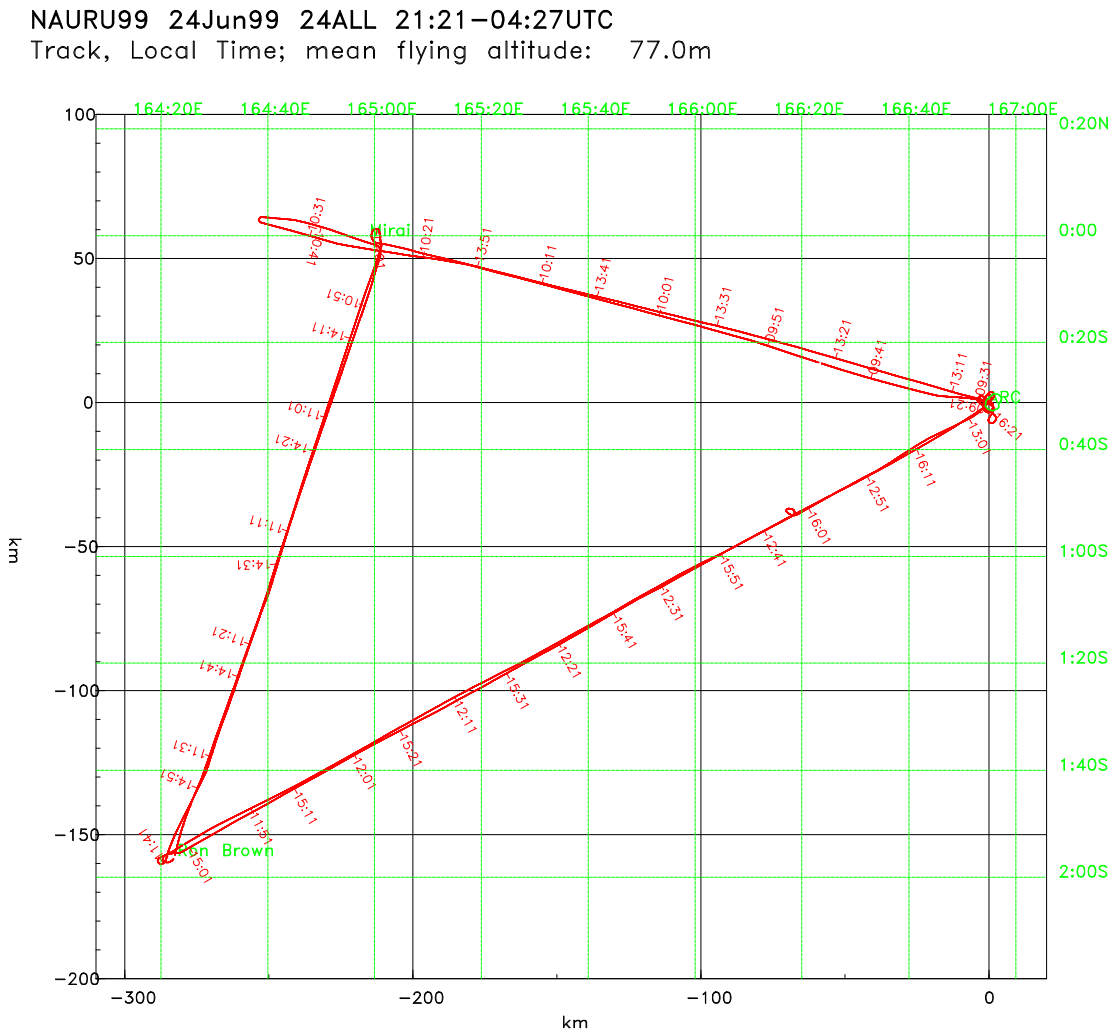


**Figure 3: Flight track of 24 June 1999**

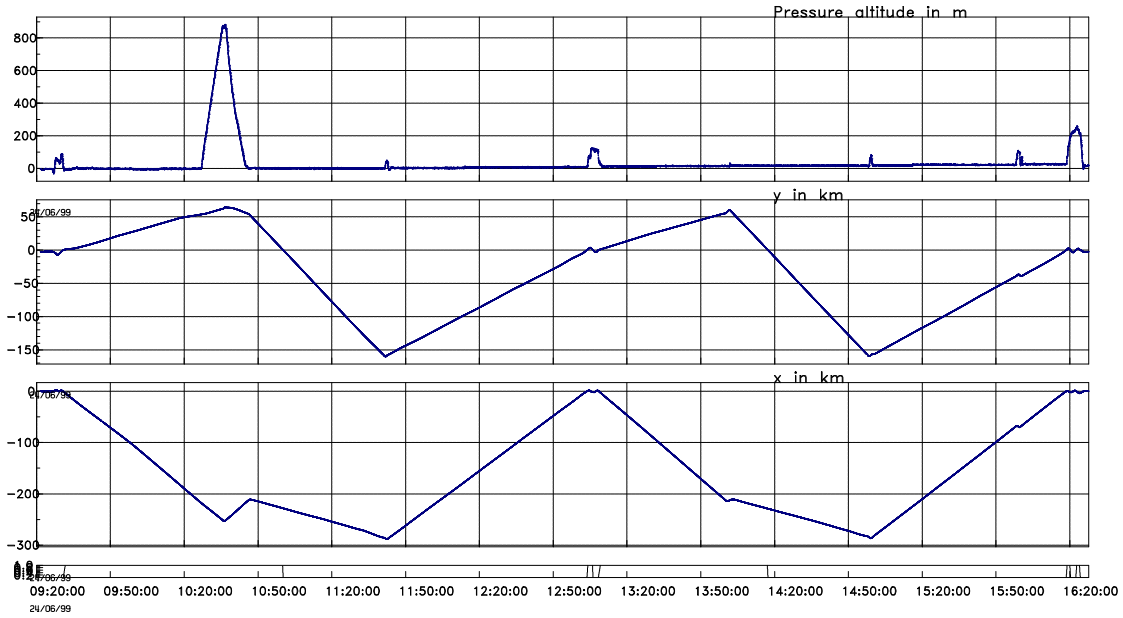


**Figure 4: x- and y-distances from the ARC-Site and flight altitudes (PA) for the flight on 24 June 1999**

### 5.3 25 June 1999

| Run | Start End (LT) | Height (m) | Description | Comments |
|---|---|---|---|---|
| Take-Off | 09:34 | | Nauru Airport | QNH 1012hPa |
| 25ST1A | 09:44 | 30 | Fly-by ARC Site | |
| 25T1L1A | 09:44<br>09:56 | 30 | ARC Site to *Mirai* (partly) | During this leg the logger was restarted several times to attempt to remove the noise seen in some signals coming from the nose. This problem has since been tracked down to the KT-15, causing a new plug configuration to be used from flight 3 onwards. |
| 25T1L1B | 10:02<br>10:35 | 30 | ARC Site to *Mirai* (cont'd) | |
| 25MI1B | 10:38 | 30 | Fly-by *Mirai* | The cloud base height was approximated at 2100ft. |
| 25T1L2A | 10:38<br>11:32 | 30 | *Mirai* to *Ron Brown* | |
| 25RB1A | 11:32 | 30 | Fly-by *Ron Brown* | |
| 25RB1B | 11:35 | 30 | Fly-by *Ron Brown* | |
| 25T1L3A | 11:37<br>12:57 | 30 | *Ron Brown* to ARC Site | The "i" marker (approximately 2 minutes after the event) indicates an interesting cloud bank to be investigated for mesoscale activity.<br><br>At the end of this leg a landing was made at Nauru for approximately 15 minutes. During this time the configuration of the analogue input signals was re-arranged. |
| 25ST1B | 12:59 | 30 | Fly-by ARC Site | |
| 25ST2A | 13:34 | 30 | Fly-by ARC Site | |
| 25T2L1A | 13:35<br>14:05 | 30 | ARC Site – *Mirai* (partly) | Several restarts of the logger required after the plug to the nose power distribution box was accidentally disconnected from the scientific power supply box.<br><br>Due to failure to reopen the bomb-bay doors after the second takeoff, no downward facing Eppley measurements (lDN or sDN) are available for this leg. |
| 25T2L1B | 14:07<br>14:23 | 30 | ARC Site – *Mirai* (cont'd) | |
| 25MI2A | 14:23 | 30 | Fly-by *Mirai* | |
| 25MI2B | 14:27 | 30 | Fly-by *Mirai* | |
| 25T2L2A | 14:28<br>15:19 | 30 | *Mirai* to *Ron Brown* | |
| 25RB2A | 15:19 | 30 | Fly-by *Ron Brown* | |
| 25RB2B | 15:22 | 30 | Fly-by *Ron Brown* | |
| 25T2L3A | 15:23<br>16:43 | 30 | *Ron Brown* to ARC Site | The aircraft passed underneath a large cloud band approximately 60NM from Nauru. May be of interest for temperature and radiation data. |
| 25ST2B | | 30 | Fly-by ARC Site | |
| Landing | 16:51 | | Nauru Airport | |

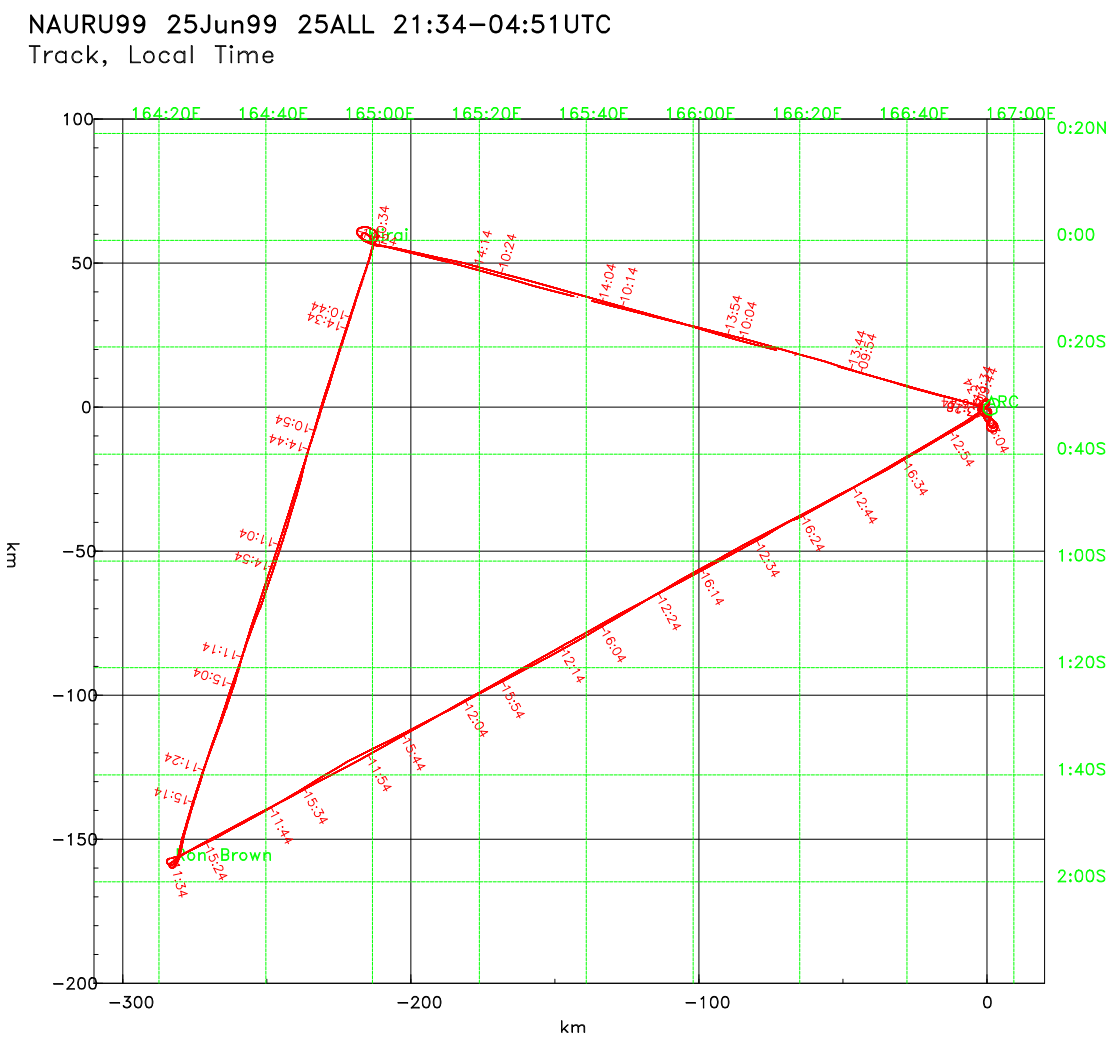


**Figure 5: Flight track of 25 June 1999**

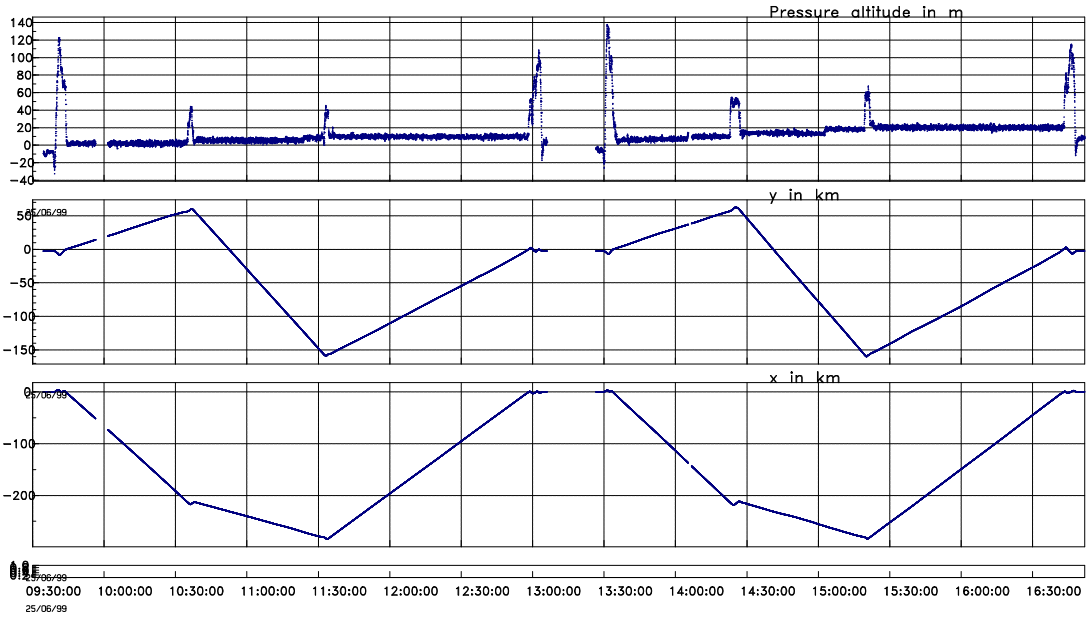


**Figure 6: x- and y-distances from the ARC-Site and flight altitudes (PA) for the flight on 25 June 1999**

### 5.4 27 June 1999

| Run | Start End (LT) | Height (m) | Description | Comments |
|---|---|---|---|---|
| Take-Off | 09:23 | | Nauru Airport | QNH 1012hPa |
| 27T1L1A | 09:31 09:45 | 30 | ARC Site to *Mirai* (partly) | The INS interface error required the logger to be restarted during this run. |
| 27T1L1B | 09:46 10:17 | 30 | ARC Site to *Mirai* (cont'd) | |
| 27MI1A | 10:17 | 30 | Fly-by *Mirai* | |
| 27MI1B | 10:20 | 30 | Fly-by *Mirai* | |
| 27T1L2A | 10:20 11:13 | 30 | *Mirai* to *Ron Brown* | |
| 27RB1A | 11:13 | 30 | Fly-by *Ron Brown* | |
| 27RB1B | 11:16 | 30 | Fly-by *Ron Brown* | |
| 27T1L3A | 11:16 12:34 | 30 | *Ron Brown* to ARC Site (partly) | "r" marks a shower to starboard approximately 1 mile from the aircraft. A few drops fell on the aircraft as well.<br><br>The INS interface error required the logger to be restarted during this run. |
| 27T1L3B | 12:35 12:41 | 30 | *Ron Brown* to ARC Site (cont'd) | |
| 27ST1B | 12:42 | 30 | Fly-by ARC Site | |
| 27ST2A | 12:46 | 30 | Fly-by ARC Site | |
| 27T2L1A | 12:47 13:34 | 30 | ARC Site – *Mirai* | |
| 27MI2A | 13:33 | 30 | Fly-by *Mirai* | |
| 27A2MI | 13:36 13:47 | 30-2000 | Ascent near *Mirai* | "i" marks the cloud base. Some sampling of the cloud base occurred during this ascent. Highest cloud tops were noted at 5000ft, with the majority of cloud tops at 3500ft. |
| 27D2MI | 13:47 13:58 | 2000-30 | Descent near *Mirai* | |
| 27MI2B | 13:57 | 30 | Fly-by *Mirai* | |
| 27T2L2A | 14:02 14:53 | 30 | *Mirai* to *Ron Brown* | Some showers to starboard – 1 mile, marked with "r"<br><br>During the ascent of the Ron Brown very interesting cloud patterns were noted. Cloud bases were at approximately 2300ft. During the second part of the ascent a very large cumulus was alongside the aircraft (port side). See photos taken by JMH. During the descent this same cloud was passed to starboard. The cumulus cloud top was estimated at 8000ft. |
| 27RB2A | 14:53 | 30 | Fly-by *Ron Brown* | |
| 27A2RB | 14:55 15:06 | 30-2000 | Ascent near *Ron Brown* | |
| 27D2RB | 15:07 15:16 | 2000-30 | Descent near *Ron Brown* | |
| 27RB2B | 14:55 | 30 | Fly-by *Ron Brown* | |
| 27RB2C | 15:16 | 30 | Fly-by *Ron Brown* | |
| 27T2L3A | 15:17 16:37 | 30 | *Ron Brown* to ARC Site | Some showers observed approximately half a mile to port early in the run. Marked with "r". Close |

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|---|---|---|---|---|
| | | | | examination of taDF and/or lwc sensor records to identify exact times when the aircraft entered showers.<br><br>Event “r” is heavy rain on the port side of the aircraft, approximately 2 miles away.<br><br>Rain and showers at various points along the run during the last 80NM to Nauru. At times the aircraft heading was changed to avoid the heaviest rain. “i” marks the resumption of track. JMH commented on a good example of a temperature front associated with this particular heavy shower. |
| 27ST2B | 16:38 | 30 | Fly-by ARC Site | |
| Landing | 16:42 | | Nauru Airport | |

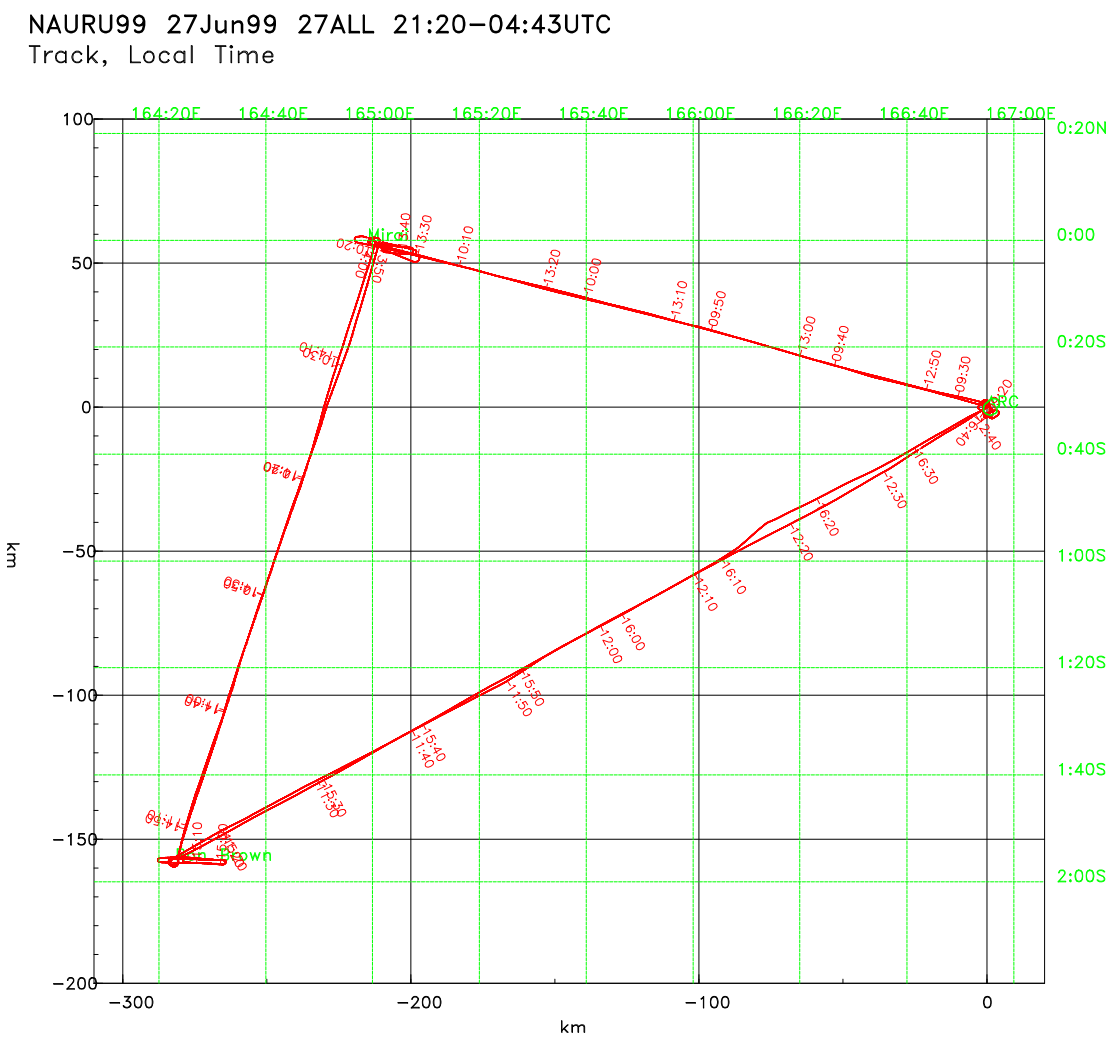


**Figure 7: Flight track of 27 June 1999**

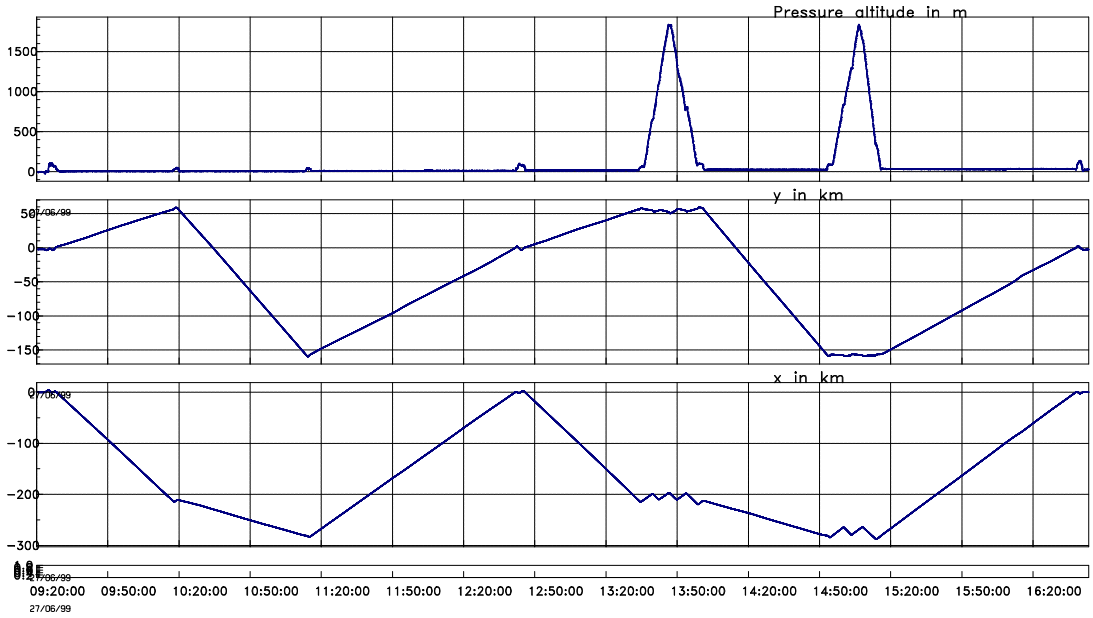


**Figure 8: x- and y-distances from the ARC-Site and flight altitudes (PA) for the flight on 27 June 1999**

### 5.5 28 June 1999

| Run | Start<br>End<br>(LT) | Height (m) | Description | Comments |
|---|---|---|---|---|
| Take-Off | 09:30 | | Nauru Airport | QNH 1013hPa |
| 28ST1A | 09:35 | 30 | Fly-by ARC Site | |
| 28T1L1A | 09:36<br>10:23 | 30 | ARC Site to *Mirai* | No downward facing Eppley measurements (lDN and sDN) during this leg as the bomb-bay was used to drop off a package to the Mirai at the end of the leg.<br><br>Increasing winds noted today (as they have been for every flight day since flight 1), and for the first time large patches of Cirrus cloud were observed. It will be interesting to examine to what extent the Cirrus cloud affects to radiation measurements. |
| 28MI1A | 10:22 | 30 | Fly-by *Mirai* | Cable dropped successfully to the Mirai. Event marker for opening the door a few minutes late. |
| 28A1MI | 10:28<br>10:56 | 30-3000 | Ascent near *Mirai* | Small clouds appeared at 2700ft (tops at 3000ft). We were informed that a radiosonde launch would take place approximately 20 minutes after the aircraft reached the top of ascent. This would be excellent comparison data for our profile. |
| 28D1MI | 10:58<br>11:13 | 3000-30 | Descent near *Mirai* | |
| 28T1L2A | 11:17<br>12:07 | 30 | *Mirai* to *Ron Brown* | Heavy rain was observed during this leg approximately 1nm to port. This was marked with an "r". Some rain was observed on the windscreen of the aircraft.<br><br>Towards the end of the leg some interference from the Ron Brown radar was clearly heard through our headphones. Examine whether there is any signal interference. The noise had a frequency of approximately 1Hz. |
| 28RB1A | 12:07 | 30 | Fly-by *Ron Brown* | |
| 28A1RB | 12:09<br>12:27 | 30-3000 | Ascent near *Ron Brown* | Cloud bases were observed at 1400ft and 1900ft. |
| 28D1RB | 12:27<br>12:40 | 3000-30 | Descent near *Ron Brown* | |
| 28RB1B | 12:41 | 30 | Fly-by *Ron Brown* | |
| 28T1L3A | 12:43<br>14:07 | 30 | *Ron Brown* to ARC Site | |
| 28ST1B | 14:08 | 30 | Fly-by ARC Site | |
| Landing | 14:14 | | Nauru Airport | QNH 1011hPa |

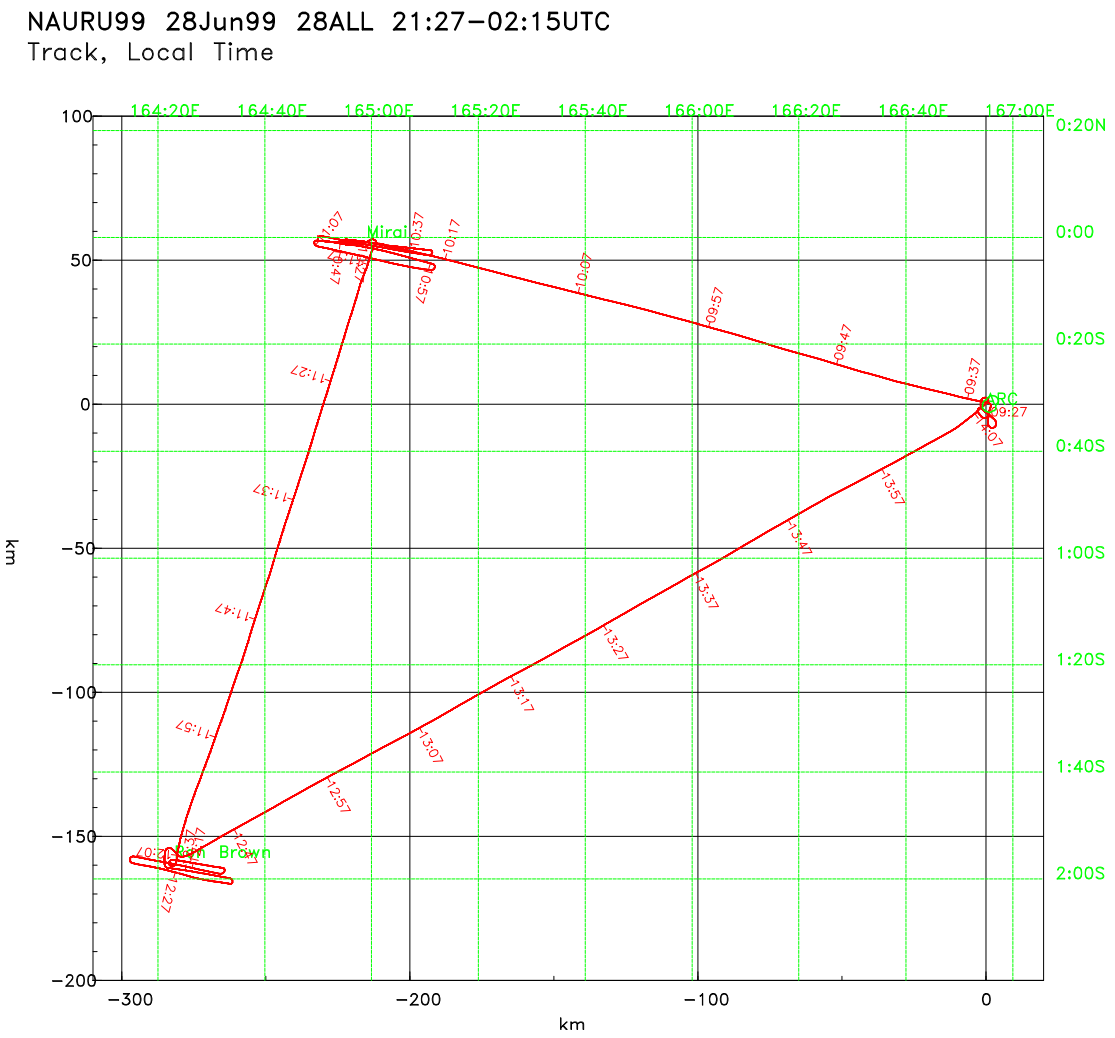


**Figure 9: Flight track of 28 June 1999**

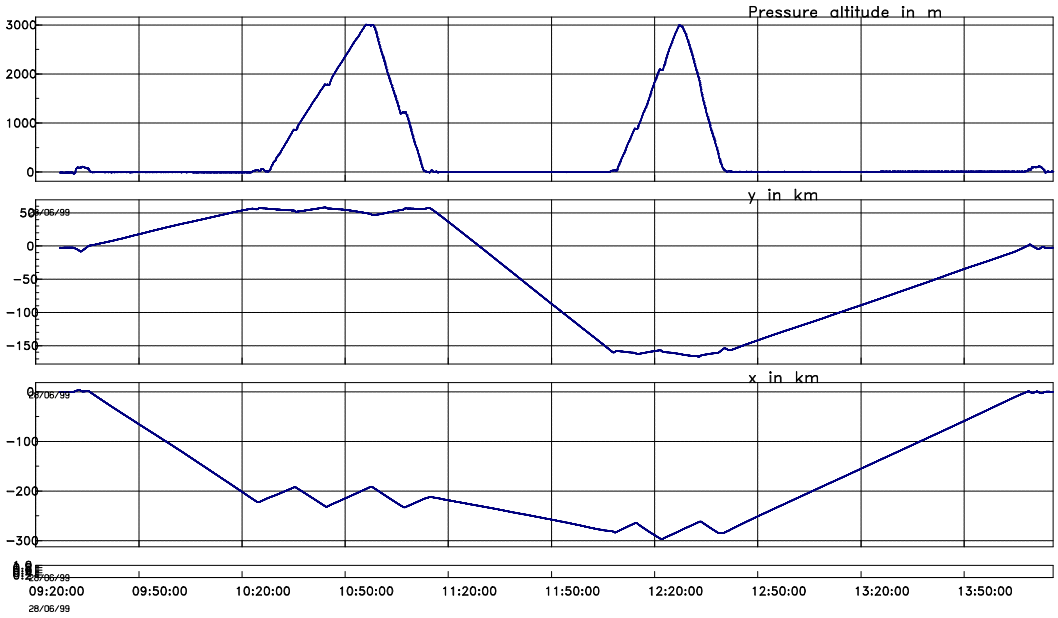


**Figure 10: x- and y-distances from the ARC-Site and flight altitudes (PA) for the flight on 28 June 1999**

### 5.6 30 June 1999

| Run | Start End (LT) | Height (m) | Description | Comments |
|---|---|---|---|---|
| Take-Off | 09:43 | | Nauru Airport | |
| 30ST1A | 09:49 | 30 | Fly-by ARC Site | |
| 30T1L1A | 09:56<br>10:45 | 30 | ARC Site to *Mirai* | It was noted that rain overnight and during the early morning may affect island conditions. Some scattered altostratus and cumulus clouds at various points along the leg.<br><br>A rain event was noted 1nm off the starboard wing. Marked with an "r". |
| 30MI1A | 10:45 | 30 | Fly-by *Mirai* | |
| 30MI1B | 10:47 | 30 | Fly-by *Mirai* | |
| 30T1L2A | 10:48<br>11:40 | 30 | *Mirai* to *Ron Brown* | Light rain showers were noted near the start of this run, and were marked with an "r" at start of the event.<br><br>Substantial rain was noted at 01:16:00 (from 990633_0939) . Rain events show up clearly on the liquid water content sensors. |
| 30RB1A | 11:40 | 30 | Fly-by *Ron Brown* | Sea Surface Temperature (from 3m under the surface) was reported by Ron Brown as being 29.1°C. |
| 30RB1B | 11:43 | 30 | Fly-by *Ron Brown* | |
| 30T1L3A | 11:44<br>13:04 | 30 | *Ron Brown* to ARC Site | |
| 30ST1B | 09:55 | 30 | Fly-by ARC Site | |
| 30ST2A | 13:04 | 30 | Fly-by ARC Site | Before starting this leg an overfly of one of the Nauru towers was made and marked with a "t". |
| 30ST2B | 13:08 | 30 | Fly-by ARC Site | |
| 30T2L1A | 13:08<br>13:12 | 30 | ARC Site – *Mirai* (partly) | The logger was restarted near the start of this run due to an INS interface error. |
| 30T2L1B | 13:12<br>13:56 | 30 | ARC Site – *Mirai* (cont'd) | |
| 30MI2A | 13:56 | 30 | Fly-by *Mirai* | |
| 30A1AMI | 13:58<br>14:06 | 30-3000 | Ascent near *Mirai* (partly) | The cloud base of the ascent over the Mirai was estimated at 1800±200ft. A very small amount of rain during the ascent was noted. Cloud tops were observed at 4200ft and approximately 11000ft.<br><br>The logger was restarted during the ascent to 10000ft due to INS interface error. No descent events were marked during this leg. |
| 30A1BMI | 14:06<br>14:14 | 30-3000 | Ascent near *Mirai* (cont'd) | |
| 30D1MI | 14:14 | 3000-30 | Descent near *Mirai* | |
| 30MI2B | 14:26 | 30 | Fly-by *Mirai* | The SST estimate from the Mirai was 29.0°C. It was not made clear from which instrument this estimate was made. |
| 30T2L2A | 14:26 | 30 | *Mirai* to *Ron* | Problem noted during the ascent to 6000ft with the |

| | | | | |
|---|---|---|---|---|
| | 15:18 | | *Brown* | aircraft's starboard alternator. Further investigation on the ground indicated a fault in the alternator. |
| 30RB2A | 15:18 | 30 | Fly-by *Ron Brown* | |
| 30A2RB | 15:18<br>15:27 | 30-2000 | Ascent near *Ron Brown* | |
| 30D2RB | 15:28<br>15:36 | 2000-30 | Descent near *Ron Brown* | |
| 30RB2B | 15:36 | 30 | Fly-by *Ron Brown* | |
| 30T2L3A | 15:38<br>16:54 | 30 | *Ron Brown* to ARC Site | Some interesting showers and associated wind and temperature fields noted approximately 20nm from Nauru. These were marked with an "i". |
| 30ST2C | 16:55 | 30 | Fly-by ARC Site | |
| 30ST2D | 16:58 | 30 | Fly-by ARC Site | |
| Landing | 17:04 | | Nauru Airport | QNH 1009hPa |

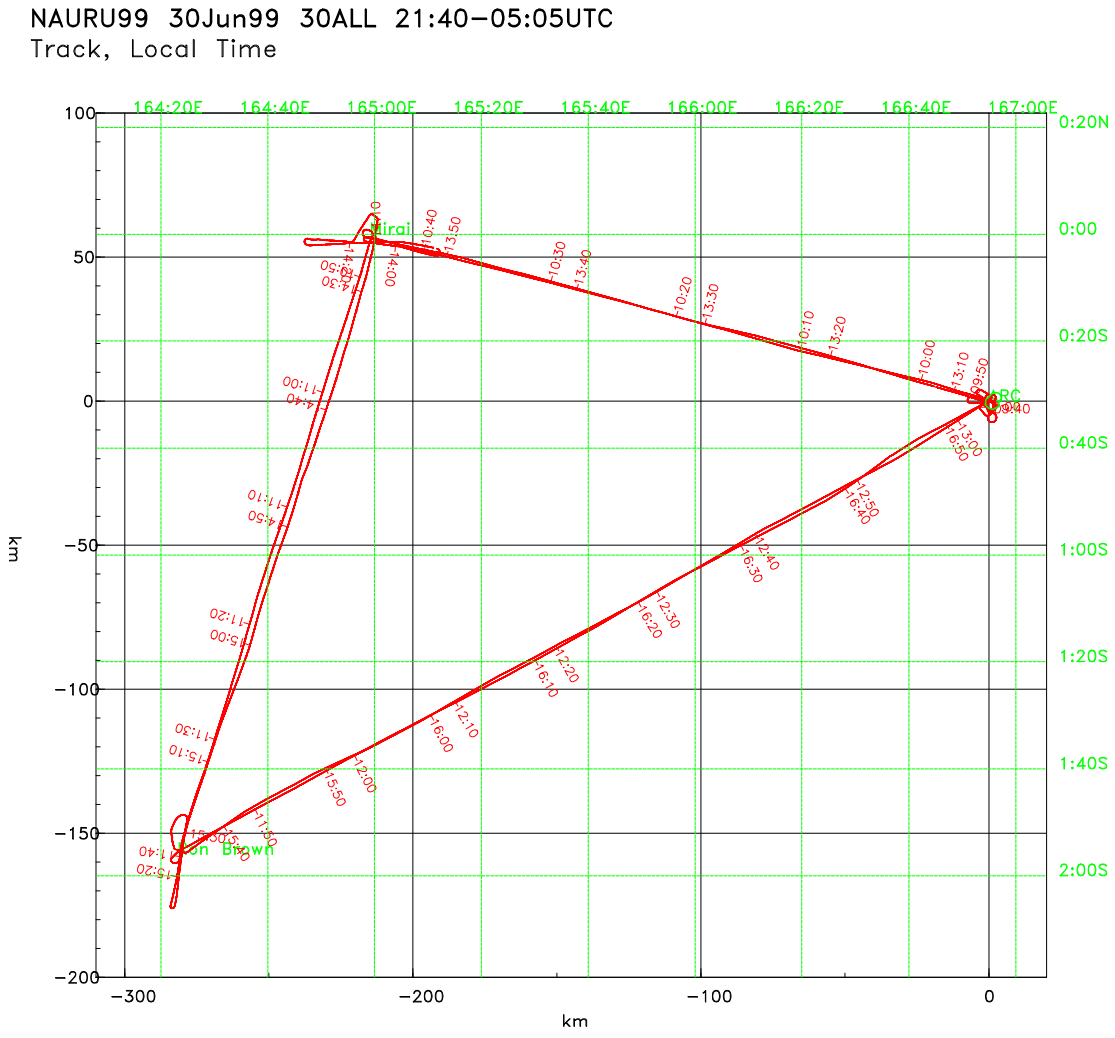


**Figure 11: Flight track of 30 June 1999**

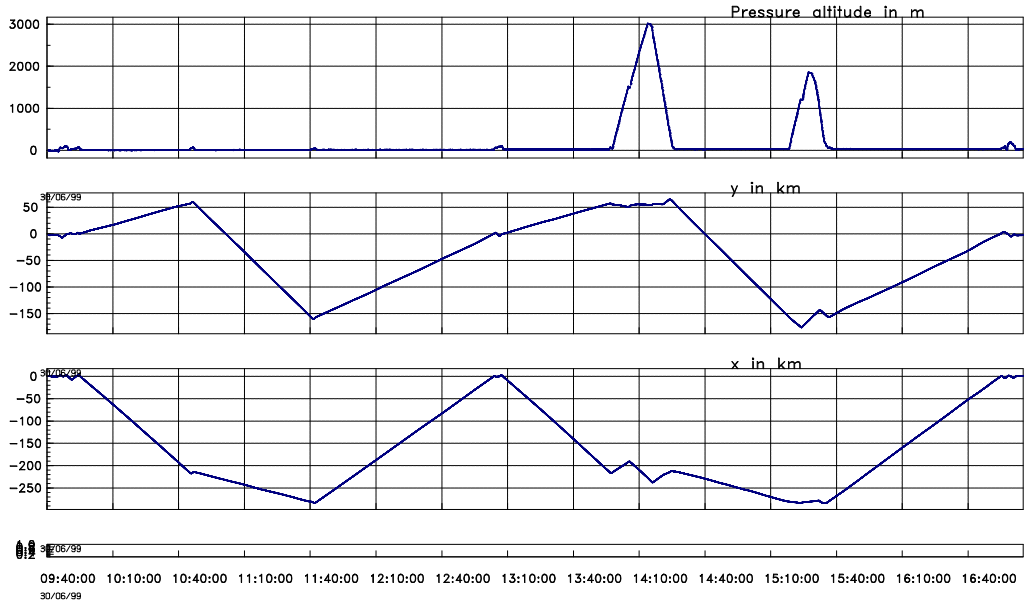


**Figure 12: x- and y-distances from the ARC-Site and flight altitudes (PA) for the flight on 30 June 1999**

### 5.7 2 July 1999

| Run | Start End (LT) | Height (m) | Description | Comments |
|---|---|---|---|---|
| Take-Off | 09:15 | | Nauru Airport | QNH 1011hPa |
| 02ST1A | 09:21 | 30 | Fly-by ARC Site | |
| 02T1L1A | 09:23 09:33 | 30 | ARC Site to *Mirai* | |
| 02MI1A | 09:33 | 30 | Fly-by *Mirai* | |
| 02MI1B | 09:34 | 30 | Fly-by *Mirai* | |
| 02T1L2A | 09:35 09:44 | 30 | *Mirai* to *Ron Brown* | |
| 02RB1A | 09:43 | 30 | Fly-by *Ron Brown* | |
| 02RB1B | 09:46 | 30 | Fly-by *Ron Brown* | |
| 02T1L3A | 09:47 09:52 | 30 | *Ron Brown* to ARC Site | |
| 02ST1B | 09:52 | 30 | Fly-by ARC Site | |
| 02ST2A | 09:57 09:59 | 400 | Fly-by ARC Site | |
| 02T2L1A | 09:57 10:07 | 400 | ARC Site to *Mirai* | Started with a “2” instead of a “1” |
| 02MI2A | 10:07 | 400 | Fly-by *Mirai* | |
| 02MI2B | 10:08 | 400 | Fly-by *Mirai* | |
| 02T2L2A | 10:08 10:17 | 400 | *Mirai* to *Ron Brown* | |
| 02RB2A | 10:17 | 400 | Fly-by *Ron Brown* | |
| 02RB2B | 10:19 | 400 | Fly-by *Ron Brown* | |
| 02T2L3A | 10:20 10:26 | 400 | *Ron Brown* to ARC Site | |
| 02ST2B | 10:25 10:27 | 400 | Fly-by ARC Site | Ascent after the end of run. |
| 02ST3A | 10:33 10:35 | 1200 | Fly-by ARC Site | |
| 02T3L1A | 10:33 10:41 | 1200 | ARC Site to *Mirai* | Passed through a few clouds. Overfly marked a bit late (10 seconds) 2nd time past ship. |
| 02MI3A | 10:41 | 1200 | Fly-by *Mirai* | |
| 02MI3B | 10:43 | 1200 | Fly-by *Mirai* | |
| 02T3L2A | 10:44 10:52 | 1200 | *Mirai* to *Ron Brown* | It was noted that it took a long time before lUP reached a steady level. Required further investigation. |
| 02RB3A | 10:51 | 1200 | Fly-by *Ron Brown* | |
| 02RB3B | 10:54 | 1200 | Fly-by *Ron Brown* | |
| 02T3L3A | 10:54 11:00 | 1200 | *Ron Brown* to ARC Site | After the end of leg, “i” marks the beginning of the descent. |
| 02ST3B | 10:59 11:02 | 1200 | Fly-by ARC Site | |
| 02ALB1 | 11:11 11:14 | 150 | Albedo run over island | First albedo run over island. Done with the zRAD set at 500ft, but zRAD did not appear to be functioning properly. Will thus require correction for island altitude. |
| 02ALB2 | 11:15 11:18 | 150 | Albedo run over island | |
| 02ALB3 | 11:21 11:23 | 150 | Albedo run over island | |

| | | | | |
|---|---|---|---|---|
| 02ST4A | 11:25<br>11:27 | 30 | Fly-by ARC Site | |
| 02T4L1A | 11:25<br>11:34 | 30 | ARC Site to *Mirai* | |
| 02MI4A | 11:34 | 30 | Fly-by *Mirai* | |
| 02MI4B | 11:35 | 30 | Fly-by *Mirai* | |
| 02T4L2A | 11:36<br>11:45 | 30 | *Mirai* to *Ron Brown* | |
| 02RB4A | 11:44 | 30 | Fly-by *Ron Brown* | |
| 02RB4B | 11:47 | 30 | Fly-by *Ron Brown* | |
| 02T4L3A | 11:47<br>11:52 | 30 | *Ron Brown* to ARC Site | |
| 02ST4B | 11:53<br>11:55 | 30 | Fly-by ARC Site | |
| 02ST5A | 11:57<br>12:00 | 400 | Fly-by ARC Site | |
| 02T5L1A | 11:58<br>12:07 | 400 | ARC Site to *Mirai* | Events marking overfly of leg and overfly of station were late. Used a "2" to end this leg instead of a "1". |
| 02MI5A | 12:06 | 400 | Fly-by *Mirai* | |
| 02MI5B | 12:08 | 400 | Fly-by *Mirai* | |
| 02T5L2A | 12:08<br>12:17 | 400 | *Mirai* to *Ron Brown* | |
| 02RB5A | 12:17 | 400 | Fly-by *Ron Brown* | |
| 02RB5B | 12:19 | 400 | Fly-by *Ron Brown* | |
| 02T5L3A | 12:19<br>12:25 | 400 | *Ron Brown* to ARC Site | |
| 02ST5B | 12:24<br>12:27 | 400 | Fly-by ARC Site | |
| 02ST6A | | 1200 | Fly-by ARC Site | |
| 02T6L1A | 12:33<br>12:41 | 1200 | ARC Site to *Mirai* | Several cloud samples during ascent to 4000ft before start of run and after the start of this leg. Slow temperature response of LW instruments noted again. |
| 02MI6A | 12:40 | 1200 | Fly-by *Mirai* | |
| 02MI6B | 12:43 | 1200 | Fly-by *Mirai* | |
| 02T6L2A | 12:43<br>12:50 | 1200 | *Mirai* to *Ron Brown* | Ron Brown marked with a "j" instead of an "n". |
| 02RB6A | 12:50 | 1200 | Fly-by *Ron Brown* | |
| 02RB6B | 12:52 | 1200 | Fly-by *Ron Brown* | |
| 02T6L3A | 12:52<br>12:58 | 1200 | *Ron Brown* to ARC Site | A few cloud strikes during this leg. Most near the top of cloud. |
| 02ST6B | 12:58<br>13:00 | 1200 | Fly-by ARC Site | |
| 02ST7A | | 3000 | Fly-by ARC Site | |
| 02T7L1A | 13:15<br>13:23 | 3000 | ARC Site to *Mirai* | Not flown straight from island to Mirai – see track plot. The run began to the west of the island. |
| 02MI7A | 13:23 | 3000 | Fly-by *Mirai* | |
| 02MI7B | 13:25 | 3000 | Fly-by *Mirai* | |
| 02T7L2A | 13:26<br>13:33 | 3000 | *Mirai* to *Ron Brown* | Video restarted twice – 2nd marker at correct time |
| 02RB7A | 13:33 | 3000 | Fly-by *Ron Brown* | |
| 02RB7B | 13:36 | 3000 | Fly-by *Ron Brown* | |
| 02T7L3A | 13:36<br>13:42 | 3000 | *Ron Brown* to ARC Site | "d" marks descent from 10,000ft to 100ft. Cloud apparent during descent that appears to be an |

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| | | | | island effect. Referred to as a cloud street from now on. |
| 02ST7B | 13:42<br>13:45 | 3000 | Fly-by ARC Site | |
| 02ORBIT | 13:54<br>14:12 | 30 | 3 orbits around the perimeter of the island | 3 Orbits of the island approximately 1km from shore. The beginning and end of the three orbits in indicated by an “o” event. New logger file started at the end of this leg. |
| 02ST8A | | 30 | Fly-by ARC Site | |
| 02T8L1A | | 30 | ARC Site to *Mirai* | Marked the end of this leg with a “2” instead of a “1” (also a bit early). |
| 02MI8A | | 30 | Fly-by *Mirai* | |
| 02MI8B | | 30 | Fly-by *Mirai* | |
| 02T8L2A | | 30 | *Mirai* to *Ron Brown* | This leg was extended to examine the “cloud street” mentioned earlier. The cloud street clearly developed as it extended outwards from the island, culminating in a large cumulus cloud before slowly dissipating. See photos by JMH. Gaps clearly appeared between each individual cloud cell, although all are part of the same airstream. When the aircraft was directly below the cloud street it was marked with an “i”. |
| 02RB8A | | 30 | Fly-by *Ron Brown* | |
| 02RB8B | | 30 | Fly-by *Ron Brown* | |
| 02T8L3A | | 30 | *Ron Brown* to ARC Site | |
| 02ST8B | | 30 | Fly-by ARC Site | |
| 02ST9A | | 400 | Fly-by ARC Site | |
| 02T9L1A | | 400 | ARC Site to *Mirai* | |
| 02MI9A | | 400 | Fly-by *Mirai* | |
| 02MI9B | | 400 | Fly-by *Mirai* | |
| 02T9L2A | | 400 | *Mirai* to *Ron Brown* | Flew underneath the cloud street again, extending this leg beyond the Ron Brown. |
| 02RB9A | | 400 | Fly-by *Ron Brown* | |
| 02RB9B | | 400 | Fly-by *Ron Brown* | |
| 02T9L3A | | 400 | *Ron Brown* to ARC Site | |
| 02ST9B | | 400 | Fly-by ARC Site | |
| 02ST10A | | 1200 | Fly-by ARC Site | |
| 02T10L1A | | 1200 | ARC Site to *Mirai* | |
| 02MI10A | | 1200 | Fly-by *Mirai* | |
| 02MI10B | | 1200 | Fly-by *Mirai* | |
| 02T10L2A | | 1200 | *Mirai* to *Ron Brown* | From above the cloud street it is apparent that either side of the “street” the sky is clear of cloud for approximately 2nm. The street also appears to have shifted slightly north of its previous position. |
| 02RB10A | | 1200 | Fly-by *Ron Brown* | |
| 02RB10B | | 1200 | Fly-by *Ron Brown* | |
| 02T10L3A | | 1200 | *Ron Brown* to ARC Site | |
| 02ST10B | | 1200 | Fly-by ARC Site | |
| 02CS1 | | | Along cloud street | Run flown through the cloud street through the middle of the clouds. Logger had to be restarted during this leg. |
| 02CS2 | | | Back along cloud | |

| | | | | |
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| | | | street | |
| Landing | 16:37 | | Nauru Airport | Run toward Nauru near base of cloud. End of this run marked a little early. Video finished a few minutes before end of leg. |

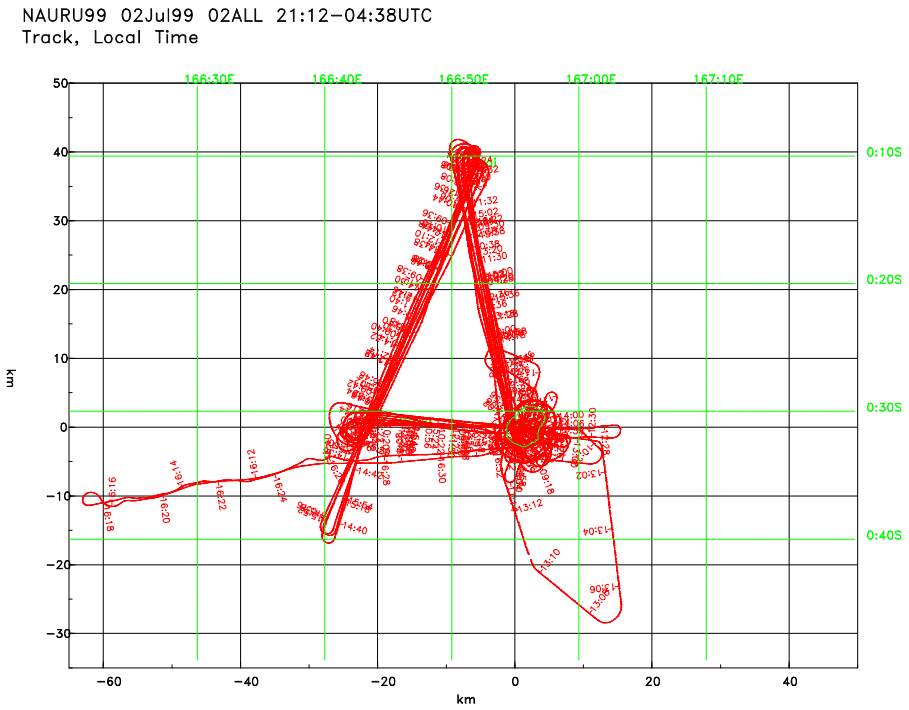


**Figure 13: Flight track of 2 July 1999**

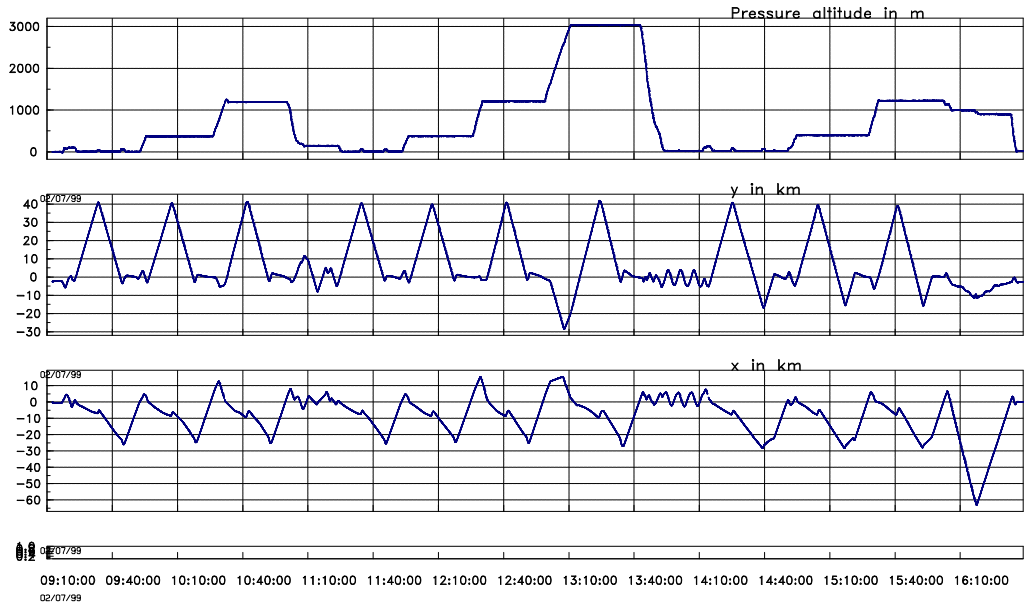


**Figure 14: x- and y-distances from the ARC-Site and flight altitudes (PA) for the flight on 2 July 1999**

## 5.8 3 July 1999

| Run | Start End (LT) | Height (m) | Description | Comments |
|---|---|---|---|---|
| Take-Off | 06:39 | | Nauru Airport | QNH 1010hPa |
| 03L1A | | 30 | | Immediately after takeoff flew away from Nauru to establish the mean wind condition (approximated at 090°). Also flew over the centre of the island to establish its position on the GPS.<br><br>Upward facing Eppley SW less than zero due to very low sun angle. |
| 03L2A | | 30 | | Run to 15NM downwind of island from upwind point. Right hand turn from centre of Stack Run 1 to northern point of Stack Run 1. |
| 03S1L1A | | 30 | | First Stack run from north end to south end. |
| 03S1L2A | | 450 | | Second Stack run, from southern to northern end of stack. |
| 03S1L3A | | 1050 | | Third stack run, from northern to southern end. Event markers for stacks placed when the aircraft is on the right heading, but may still be ascending to the correct height. HF radio call during this leg. |
| 03D1A | | 1050 - 30 | | After completing the first stack run, aircraft descended from 3500ft to 100ft (end of descent marked). It then flew to the northern end of stack 2, located a further 15NM away from Nauru. |
| 03S2L1A | | 30 | | First Stack run from north end to south end. Logger restarted during this leg. |
| 03S2L2A | | 450 | | Second Stack run, from southern to northern end of stack. |
| 03S2L3A | | 1050 | | Third stack run, from northern to southern end. Event markers for stacks placed when the aircraft is on the right heading, but may still be ascending to the correct height. Track deviated slightly early in this leg to run through a thick cloud. Marked with a "c". |
| 03D2A | | 1050 - 30 | | After completion of this stack the aircraft descended to 100ft. The start and end of this descent was marked with a "d". During this descent there was some HF radio chatter. JMH also noted at this time that there appeared to be some enhanced convection along the wind line. The end of travel to the northern start point of the final stack (repeat of the 15NM stack) was marked with a "2". |
| 03S3L1A | | 30 | | First Stack run from north end to south end. New video during this leg. |
| 03S3L2A | | 450 | | Second Stack run, from southern to northern end of stack. |
| 03S3L3A | | 1050 | | Third stack run, from northern to southern end. Event markers for stacks placed when the aircraft is on the right heading, but may still be ascending to the correct height. |
| 03D3A | | 1050 - 30 | | At this time the flight was abandoned for the day, as the two ships were moving into a side by side |

| | | | | |
|---|---|---|---|---|
| | | | | configuration and there was no apparent development in the conditions. Several photos of the island and site were taken before entering the landing pattern. |
| | | | | |
| Landing | 10:42 | | Nauru Airport | |

**Notes:**

Downwind of Nauru, three stacks were flown. The first was 15NM downwind of the island, the second 30NM downwind of the island and the third was a repeat of the first .

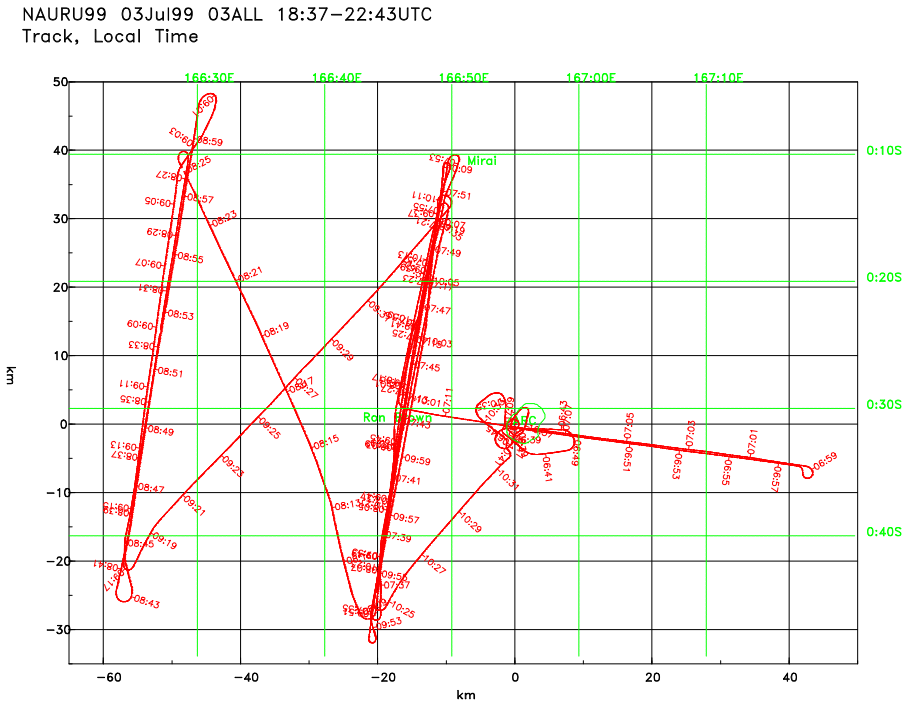


**Figure 15: Flight track of 3 July 1999**

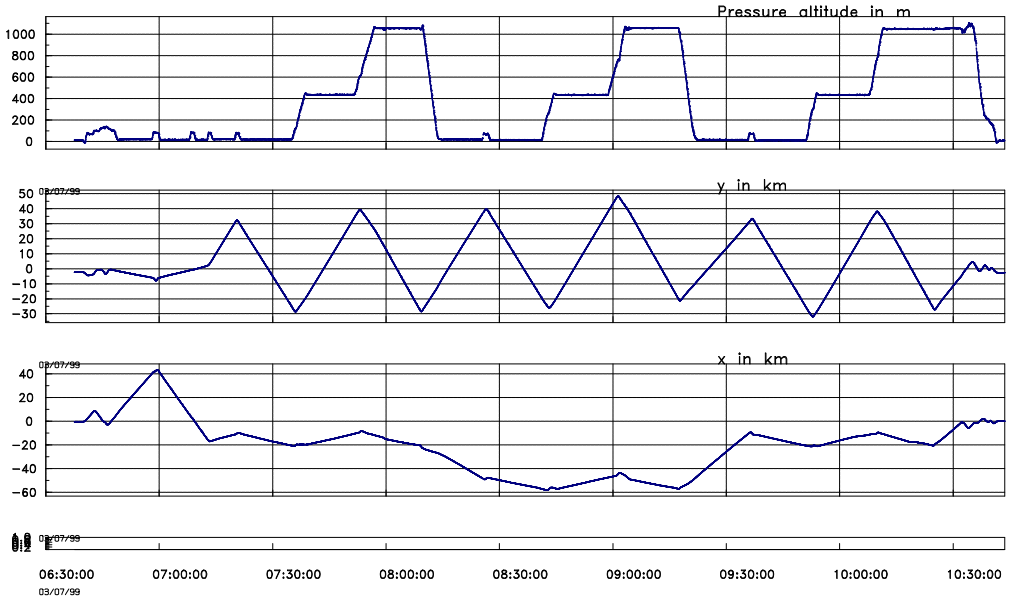


**Figure 16: x- and y-distances from the ARC-Site and flight altitudes (PA) for the flight on 3 July 1999**

### 5.9 4 July 1999

| Run | Start End (LT) | Height (m) | Description | Comments |
|---|---|---|---|---|
| Take-Off | | | Nauru Airport | QNH 1011hPa |
| Landing | | | Nauru Airport | |

**Notes:**

INS Errors (failing to initialise correctly) before logger was started. This problem was not resolved despite several attempts during the flight.

Leg 1
Flown from the centrepoint of the island to 20nm downwind of island while ascending. Cloud bases were noted at approximately 2400ft.

Leg 2
Flown at a variable height above the cloud tops. The leg was flown to 10nm upwind of the island before beginning descent (marked with "D").

Leg 3
Flown at approximately 1500ft. The start marker for this leg was very late. The leg starts at the end of the descent.

Leg 4
Descent to 100ft, marked with "D" for start and end of descent. During the descent the start of leg marker ("4" in this case) marks the time when the aircraft is on the correct heading, but is not necessarily at the correct height.

Leg 5
Ascent towards the centre of the island, then turn to 360 (ie north) and continue ascending until the aircraft was at cloud top height (approx. 3300ft). In order of appearance the "5" event markers are the – start of leg, start of turn, end of turn and end of leg.

Leg 6
Run South at approx. 3300ft from 10nm north to 10nm south of the island. A small kink in this leg due to failure to follow GPS track correctly.

Leg 7
Descending initially to 1500ft, heading north to 10nm north of the island centre. At the end of this leg descent started. A HF radio call was made during this descent.

Leg 8
Descending initially to 100ft, heading south to 10nm south of island centre. At the end of this leg the logger was restarted to minimise logger file sizes.

Leg Z
Aircraft returned to the centre of the island while ascending then made several series of cloud penetrations. Please note the King 1 was not functioning during this flight, thus lwc1 and lwc2 are not valid. Please use lwc3 for liquid water content measurements during this flight.

The first series of cloud penetrations were made near cloud base. The end of this series was marked with a "1".

The second series of cloud penetrations (through same clouds where possible) were made approximately 300ft higher. Ended with a "2".

The third series of cloud penetrations were made a further 300ft higher, near cloud top. Ended with a "3".

After the completion of this leg, a second series of profiles were flown cross-wind.

Leg 1
Tracking east from the station at approximately 3500ft to less than 10nm from station. Marked with a "1" at beginning and end of leg.

Leg 2
Tracking west at approximately 3500ft. Marked with a "2" at start and end of leg. A couple of cloud penetrations (through top) during this leg. Run extended to approximately 12nm from Nauru Ops station.

Leg 3
Descending back towards Nauru Ops. Descent stopped at 2400ft, just below cloud base. Continued in straight line over ARCS site to sample air upwind of site.

Leg 4
Descending to 1200ft. First "4" is too early, second "4" is start of leg.

Leg 5
Flown at 600ft. Descent at the end of this leg. Flown over Nauru Ops station.

Leg 6
During descent to 300ft a HF radio call was made. Event "4" was an accident – please ignore.
Leg 7
Flown to the centrepoint of the run, then turned 90° and continued a further 5nm. Stacks were then repeated perpendicular to the mean wind, 6nm either side of the centrepoint of the island.

Leg 8
Flown at 100ft. At the end of this leg the aircraft ascended to 3500ft. A new logger file was started before beginning the ascent.

Legs 1-5
Flown at approximately 3600ft, 2400ft, 1200ft, 600ft and 300ft respectively. No other points of interest during this stack.

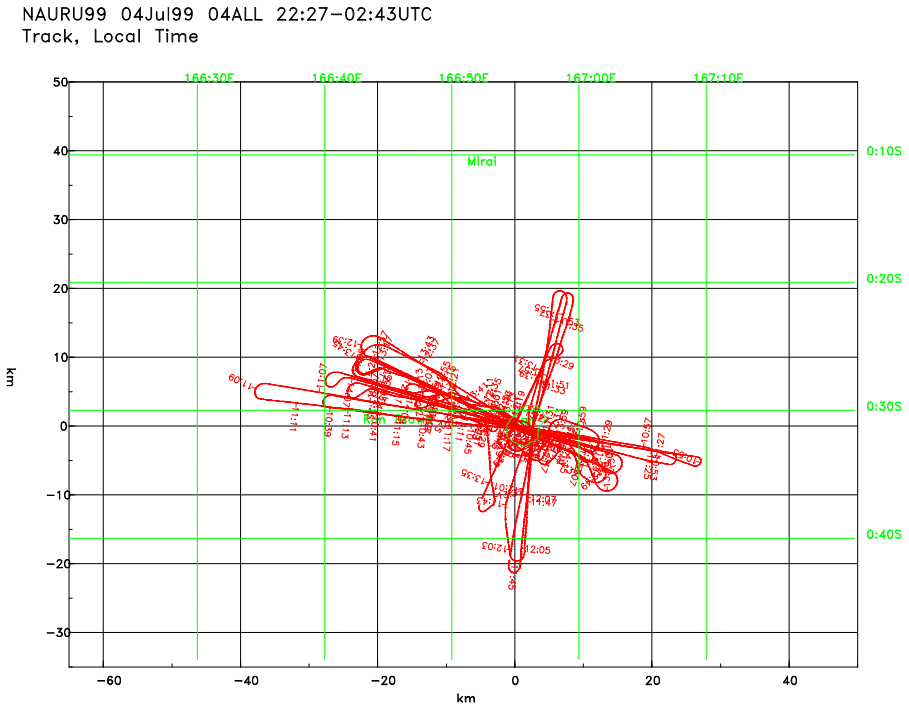


**Figure 17: Flight track of 4 July 1999**

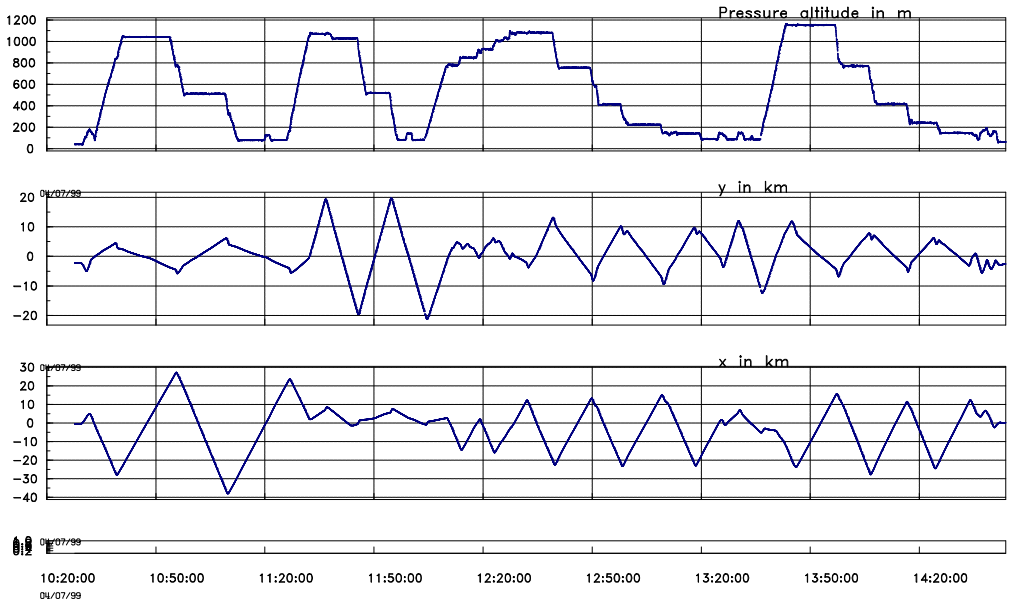


**Figure 18: x- and y-distances from the ARC-Site and flight altitudes (PA) for the flight on 4 July 1999**

# 6 List of Appendices

The following Appendices to this Report are available:

Appendix 1: Quicklook Plots for 1 Second Averages

Appendix 2: Fluxes, SST, Winds, Clouds and Rain

Appendix 3: Fluxes and Fluctuations for Individual Flight Legs

Appendix 4: Listings of Parameter and Command Files used during Processing

# 7 Acknowledgements

This aircraft, ARA's Cessna 404 VH-EOS *Investigator 2* and its instrumentation was partially funded by grants from the Australian Research Council, the Sir Ross and Sir Keith Smith Fund and a grant from the Major National Research Facilities Program (MNRF) of the Commonwealth of Australia, as well as generous support from Dr. and Ms. Schultz of Glen Osmond/South Australia.

*Investigator 2* was skillfully piloted by Capt. Noel Roediger.

We also wish to thank the Government of Nauru for their friendly cooperation in operational matters, as well as Air Nauru for access to their facilities at Nauru Airport.