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# NAE TWIN OTTER OPERATIONS IN FIFE 1989

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# NAE TWIN OTTER OPERATIONS IN FIFE 1989

by

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NATIONAL AERONAUTICAL ESTABLISHMENT

## ABSTRACT

During the summer of 1989, the NAE Twin Otter Atmospheric Research Aircraft was flown in a special three-week extension the NASA-sponsored First ISLSCP[2] Field Experiment (FIFE-89). Airborne measurements of the fluxes of heat, momentum, water vapour and carbon dioxide were made during 16 low-altitude flights over the FIFE project area in central Kansas. This report documents the Twin Otter operations in FIFE and includes details on the instrumentation, software, flight procedures, atmospheric conditions and analysis methods. Run-average data are presented for all 285 flux runs flown by the Twin Otter in FIFE-89. This report is intended to serve as a working reference for scientists utilizing Twin Otter data either directly or through the FIFE data archive at the NASA Goddard Space Flight Center.


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[2] The International Satellite Land Surface Climatology Project

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### 1.0 INTRODUCTION

The First ISLSCP[1] Field Experiment (FIFE) was an international project designed to obtain the data necessary to relate satellite measurements to land surface/atmosphere interactions. The improved interpretation of satellite data is important to both short-term weather forecasts and long-term global monitoring for climate change. Most current global circulation models used for forecasting do not include terms to adequately account for the exchange of energy and mass between the atmosphere and the land surface, and in particular, the vegetation on the surface. FIFE was organized by the National Aeronautics and Space Administration (NASA) to study these processes over one type of vegetation, the tall-grass prairie of central Kansas, with plans to continue in future years to more complex biomes such as the wetlands and boreal forests.

Airborne measurements of the fluxes of heat, momentum, carbon dioxide and water vapour provide an essential link in relating small-scale ground-based measurements to the large scale estimates provided by satellites. With considerable experience in the airborne measurement of these fluxes, the NAE was one of the Canadian agencies that participated in FIFE in 1987, using the NAE Twin Otter atmospheric research aircraft. The Twin Otter also represented the only available system capable of making airborne measurements of the flux of carbon dioxide. This experiment presented an opportunity not only to contribute to the FIFE objectives, but also to continue flux studies in an area of uniform vegetation with enhanced surface and satellite observations. Some of the specific Canadian objectives in FIFE were:

- to compare the Twin Otter measured fluxes with those determined by several surface sites and other instrumented aircraft.

- to relate airborne flux estimates to run length, altitude, and environmental parameters such as vegetation type, temperature, wind speed, solar radiation, atmospheric stability and crop stress.

- to study the use of aircraft for regional observations of fluxes and relate these measurements to satellite radiance data.

- to attempt to infer vegetation growth rates from airborne $C0_2$ and water vapour flux measurements.

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[1] The International Satellite Land Surface Climatology Project

In 1987, the first year of FIFE, 150 scientists, six aircraft and five satellites were involved in the coordinated acquisition of radiometric, atmospheric and surface biophysical data sets over the 15 x 15 km test site near Manhattan, Kansas. A continuous year of monitoring observations (meteorological, satellite and surface measurements) was punctuated by four intensive field campaigns (IFC's), lasting a total of 57 days, during which most of the scientists and the aircraft were working at the site. The NAE Twin Otter participated in three of the IFC's, flying a total of 42 project flights to measure the fluxes of heat, momentum, water vapour and carbon dioxide. Twin Otter FIFE data have been digitally archived at the NASA Goddard Space Flight Center, and have been analyzed and presented in a number of reports and papers (References 1 to 12) .

Analysis of all FIFE results from the many data sources indicated some significant shortcomings in the data set. In particular, no transition from wet to dry soil conditions was observed during any of the IFC's, and no reliable data on the separate contributions to the *net* $C0_2$ flux were collected. As a result, it was decided that most participants would return to the FIFE site for one additional IFC in the summer of 1989. The field phase of FIFE-89 ran from July 24 to August 12, during which the NAE Twin Otter flew 16 project flights. Data from these flights have been processed by NAE and digitally archived at the NASA Goddard Space Flight Center.

The purpose of this report is to supplement the archive data by documenting the important details of the Twin Otter operations in FIFE-89, as was done in Reference 1 for the 1987 FIFE operations. This will include specific information on the instrumentation, software, recorded parameters, flight operations, analysis procedures and the format for the data archive. A description of each flight will be given which will include instrument status, meteorological conditions, tephigrams and flight track plots. *This report presents relatively more data than the 1987 report.* For example, a table is included which presents run average data, including fluxes, for all 285 data runs flown by the Twin Otter in FIFE-89.

## 2.0 CANADIAN PROGRAM

Reference 1 summarizes the history of the development of the NAE Twin Otter as a platform for gaseous flux measurement, and the steps leading up to participation in FIFE in 1987. The following organizations and scientists were directly involved in the Canadian Twin Otter operations in FIFE-89.

- NRC/NAE Flight Research Laboratory (J. I. MacPherson).
    - signed memorandum of Agreement with NASA and led Canadian team in participation in FIFE
    - own and operate Twin Otter aircraft
    - on-board scientist, technician and flight crew; data analysis

- Agriculture Canada, Land Resource Research Centre (R. Desjardins).
  - provide $C0_2/H_20$ analyzer; collaboration in analysis

- McGill University, MacDonald College Dept. of Renewable Resources (P. Schuepp).
  - on-board scientist; collaboration in analysis

In addition, the Atmospheric Environment Service (B. Goodison) provided the PRT-5 sensor for measuring ground surface temperature beneath the aircraft. The Canada Centre for Remote Sensing (J. Cihlar) will participate in some of the data analysis, in particular relating measured fluxes to satellite remote sensing data.

Funding for the direct operating costs of the Twin Otter aircraft and the associated travel costs of the support staff was provided by NASA.

## 3.0 INSTRUMENTATION

Figure 1 is a schematic diagram of the Twin Otter showing the mounting locations of the instruments flown in FIFE-89. Table 1 lists the sensors, type of output signal, and the label of the associated variables in the aircraft software.

An exhaustive description of the Twin Otter instrumentation will not be given here; this is available in References 13 to 15. Rather, the sections below will focus on *changes and improvements* to the instrumentation from the configuration used in the 1987 FIFE experiment, which was described in detail in Reference 1.

### 3.1 Air Motion

The Twin Otter is instrumented to measure the three orthogonal components of atmospheric motion over a frequency range of 0 to 5 Hz. The true air motion is derived in aircraft axes from the vector difference between the air velocity relative to the aircraft and the aircraft 'inertial' velocity relative to the ground (strictly speaking, the rotating earth is not an inertial frame of reference, but for ease of expression the term 'inertial' in this report will mean 'relative to the earth').

Air motion relative to the aircraft is measured by a nose-mounted gust boom incorporating a Rosemount 858 5-hole probe (Fig. 1). This device and the associated pressure transducers measure static pressure (altitude), dynamic pressure (airspeed) and the angles of attack and sideslip. A second altitude/air-speed system employs a separate set of pressure transducers connected to the fuselage-mounted pitot and static ports used for the flight instruments. The only change made to this system since 1987 was the application of slightly improved position error corrections, as detailed in Reference 15. These corrections are required for all aircraft to account for systematic pressure disturbances caused by the presence of the aircraft.

A major change has been made in the measurement of the inertial velocity of the aircraft. For the 1987 FIFE, this was measured using a complementary filtering technique, with the high-frequency contribution from integrated accelerometer and rate gyro signals, and the low-frequency contribution from a 3-axis Doppler radar. In 1989, an alternative inertial velocity was recorded from a Litton LTN-90/100 Inertial Reference System (IRS). Although this device was installed and evaluated in 1987, and discussed in Section 3.2 of Reference 1, it was *not* used in the 1987 FIFE data analysis. For the FIFE-89 data reported here, the IRS provided the inertial velocity for all the project flights, with the exception of the first.

Although the Litton IRS is now considered the primary instrument on the aircraft for the measurement of the inertial velocity, it was decided, for FIFE-89 at least, to retain the earlier complementary-filtered routine in the airborne software to serve as a back-up in case of IRS failure. Therefore, on the NAE Twin Otter, the on-board LSI-11/73 microprocessor currently computes *three* sets of winds, differing primarily in the means used to determine the inertial velocity. They are the following:

1) **NAE/DOP winds:** This uses a complementary filtering routine where the low frequency contribution to the inertial velocity is from a 3-axis Decca Doppler radar, and the high frequency components are from an NAE-assembled package of accelerometers and rate gyros. Winds are first computed in aircraft body-fixed axes, then resolved into earth axes (i.e., the locally level geographic frame of reference aligned with true north and east) using the signals from the aircraft attitude gyro and C-12 compass.

2) **Litton winds:** The true airspeed (TAS) vector is resolved into earth-fixed axes using the attitude angles and heading from the LTN-90 IRS. The 3-axis inertial velocities from the IRS are then subtracted from the TAS components to derive the 3-axis winds. This is the method used on most atmospheric research aircraft. It is subject to approximately 1 $ms^{-1}$ errors in the horizontal components due to IRS drift caused by the Schuler oscillation phenomenon (Reference 16).

3) **Lit/DOP winds:** This is similar to (1) above, except that the accelerometer, rate gyro, attitude and heading measurements all come from the LTN-90 IRS rather than the NAE package.

Further details on these wind computation methods are given in References 15 and 17. In summary, the method used for all but the first flight in FIFE-89 is that labelled above as **Litton winds.** For the first flight, the NAE/DOP winds were used, due to an IRS alignment error (thus effectively demonstrating the value of the back-up system).

### 3.2 Position

As in 1987, the Twin Otter carried an ARNAV Model R-40-AVA-100 Loran-C navigation system, which was used for flying specific tracks and for recording aircraft position. There were two sources of error in the position recorded from the Loran-C: (1) an offset in which the recorded position was about 0.5 nautical miles northeast of the actual position, and (2) a lag in which the recorded position trailed the actual position by about 0.27 nautical miles. These are discussed more fully in Section 3.3 of Reference 1.

In FIFE-89, aircraft position data were also available from the LTN-90 Inertial Reference System. This system is subject to the Schuler oscillation in which the indicated position can drift in error up to approximately one nautical mile per hour. For operations in a small area such as the FIFE site, this is a relatively large error. Consequently, the archive data and the flight track plots shown in Figure 8 are based on Loran-C position data, as in 1987.

### 3.3 Carbon Dioxide and Water Vapour

The fast-response concentration measurements required for the $C0_2$ and $H_20$ flux calculations were made by the ESRI infrared gas analyzer developed by the Agriculture Canada. The test section of the analyzer was mounted within a large duct that captured flow above the aircraft, entered the cabin through the roof, and passed through the rear of the cabin to exit through the floor (Figure 2). The system had a flow rate of approximately 300 litres/sec. The duct was also instrumented for the measurement of the airspeed, temperature and density of the sampled air, in order to calculate the $C0_2$ and $H_20$ mixing ratios. The ESRI analyzer had an effective frequency response of 15 Hz. Its operation in the 1987 FIFE project was discussed at length in Reference 1. Prior to FIFE-89, minor software and hardware changes were made to the analyzer to eliminate occasional dropouts in its digital output. Improvements were also made to the mounting structure of the analyzer test section, and the electronics were housed in a new rack (Figure 2).

Data from the ESRI analyzer are suitable for use with the vertical gust velocity and the eddy correlation technique to derive fluxes. However, it is not well suited to the measurement of absolute concentrations of $C0_2$ and water vapour, for its sensitivity can change a few percent during flight because of dirt accumulating on its mirrors. For this reason, a second, slower-response analyzer was installed in the Twin Otter for FIFE-89. This was a LI-COR LI-6251 $C0_2$

analyzer, which was mounted in the new rear rack (Figure 2), with its sample air drawn from the duct via a 3/8-inch plastic tube.

The LI-COR analyzer was also subject to sensitivity changes due primarily to pressure variations associated with altitude changes. Therefore, a system was designed and built to provide a self-calibration feature to be operated prior to most data runs. This was initiated by a button on the cockpit console, which activated a Campbell Scientific 21-X Data Logger that controlled a system of relays. These relays directed the flow of two reference gases to the LI-COR analyzer, first nitrogen (zero $C0_2$) for a timed period (usually about 10 seconds), followed by a second sample containing a ground-calibrated reference concentration of $C0_2$. A flag bit was also recorded on the NAE event marker which was used to identify this calibration sequence during data playback. Using the recorded LI-COR signals and the known reference gas concentrations, a subroutine in the playback program could then calculate a corrected sensitivity factor for the LI-COR data for the subsequent run.

During FIFE-89, this self-calibration sequence was initiated just prior to the start of most data runs, after the aircraft had been levelled at the correct altitude for the run. In the majority of cases, the system worked well, giving fairly consistent sensitivity changes, which were usually only about 1 to 3 percent. However, on a significant number of runs, the recorded signals associated with the calibration gases did not stabilize at the expected reference levels, so the sensitivity factors were considerably in error for these runs. It could not be determined what caused this, although pressure effects, back-flow and faulty relays were considered. Because the self-calibration technique did not reach the level of reliability desired, it was decided to *not* apply the sensitivity correction factors to the LI-COR data in the ground analysis of the FIFE-89 data. Further investigation of this self-calibration system will be undertaken when the aircraft is next configured for flux measurement.

### 3.4 Temperature and Dew Point

In the 1987 FIFE project, total temperature was measured by a Rosemount fast-response 102DJ1CG heated probe mounted on the port side of the aircraft nose (TTF, Table 1). In subsequent data analyses, it appeared that the aircraft-measured sensible heat fluxes were lower than expected, when compared with surface measurements. This was also the case for the other two flux measuring aircraft in the 1987 project. Aircraft to aircraft intercomparisons showed very good agreement (Section 8.3, Reference 1), indicating that the problem may be common to all aircraft, possibly as a result of flow distortion around the nose.

To investigate this possibility, a second identical temperature probe (TTNB) was mounted on the noseboom fairing, which was closer to the 858-probe location where the gust velocity was measured. For all FIFE-89 data runs, the sensible heat flux was computed using potential temperatures derived from both probes. Comparison of the results indicates that heat fluxes from the new probe were usually 5-10 percent *lower* than those from the fuselage-mounted probe. Mounting location does appear to make a difference in the fluxes, although not in the direction anticipated. Further investigation is required. The analyzed data archived for FIFE-89 use the sensible heat fluxes from the fuselage probe, as was done in 1987.

Dew point temperature was measured using an E, G and G Model 137 Cambridge dew point sensor mounted on the starboard side of the Twin Otter nose. As an experiment, it was decided to compute a second $H_20$ flux using dew point data for comparison with the flux measured by the ESRI fast-response gas analyzer. The equations used are detailed in Reference 15. Although the dew point analyzer has a time constant in excess of a second, for most FIFE-89 runs the computed flux was surprisingly close to that from the fast-response analyzer, i.e., usually within 10 percent. These results are only achieved, however, when the gust velocity is lagged by an appropriate number of data sampling time intervals (i.e., 20 which corresponds to 1.25 seconds), as explained in Section 4.2.2 below.

### 3.5 Radiometers

The same four radiation-measuring sensors used in 1987 (Section 3.7, Reference 1) were mounted on the Twin Otter for FIFE-89. There were no significant changes to either the downward Eppley-2 pyranometer, which measured reflected radiation, or the Skye Industries Vegetation Greenness Indicator.

The incident radiation was again measured with a Kipp and Zonen CM-11 pyranometer with a 305-2800 nm spectral range. The signal conditioning card for its input to the data recording system was not calibrated until July 29, 1989, that is, after Flight 03. As a result, the recorded signal was in error by about 5 percent for Flights 01-03. The playback software was modified to apply a correction for these flights, so that the analyzed data in the archive and listed below are not subject to the signal conditioning error.

For FIFE-89, a more accurate calibration of the PRT-5 infrared surface temperature radiometer was performed. A black metal cone was fabricated which was immersed in a well-mixed water bath and mounted under the PRT-5 sensor for calibration. This calibration was not done until after Flight 03, however, so software corrections were applied in the analysis program for Flights 01-03.

### 3.6 Event Marker

A multi-level event marker was recorded with a 16-bit word, which also incorporated the positions of eight function switches on the cockpit console. These were used to set flags in the airborne and playback software. Table 2 summarizes the event marker configuration for FIFE-89. There were only two changes from that used in 1987. Bit-5 (function switch #5) indicated which of the two temperature measurements (Section 3.4) was used in the true airspeed calculation. Bit-11 was the flag indicating that the LI-COR $C0_2$ analyzer was in its self-calibration cycle.

### 3.7 Microprocessor and Displays

The Twin Otter carries two microprocessors, an LSI-11/73 performing real-time computations of the wind, approximate fluxes, etc., and a DEC Falcon which manages the recording of the sensor outputs and the computed parameters. The two are connected by a Communication Interface Board (CIB). Full in-flight interaction with the main processor is provided by a console-mounted keyboard in the cockpit, with programs loaded from a dual floppy disk unit. Alpha-numeric data are presented on 12x40-character plasma display units in the cockpit and rear cabin. The LSI-11/73 replaces a slower LSI-11/23 which was used in 1987, thereby allowing the computation of the three separate winds (Section 3.1) and more accurate, real-time estimates of the fluxes (Section 4.1).

### 3.8 Data Recording System

The Twin Otter data acquisition system utilizes a CDC streamer tape drive, which has a capacity of 70 Mbytes on a 15x10 cm compact cartridge. The recording format is under computer control and is therefore very flexible. For FIFE-89, 64 parameters were written in 16-bit binary words at a rate of 16 samples per second. Data were written in 4096-word records, each representing 4 seconds of data. A header block at the start of each file provided flight information, a parameter identification list and scale factors with which to convert the recorded bit levels to engineering units.

All parameters which originate as analog signals (see Table 1) undergo anti-alias low-pass filtering on initial signal conditioning. Second order Butterworth filters are used with a breakpoint set to 5 Hz. At a true airspeed of 60 $ms^{-1}$, the minimum resolvable wavelength of the Twin Otter measurements is therefore about 12 m.

Table 3 presents the recorder buffer used in FIFE-89, which is considerably different from that used in 1987. It includes the parameter name used in the software, its position in the recorder buffer, its units and a brief description. Conversion of the recorded decimal bits to engineering units is accomplished by dividing by the indicated scale factor. The scale factor is essentially the inverse of the recording resolution.

# 4.0 SOFTWARE

## 4.1 Airborne

Several changes were made to the airborne software since 1987 to take advantage of the faster LSI-11/73 microprocessor. The first of these was the calculation of the *three* sets of wind measurements (Section 3.1) along with second-order corrections to velocity measurements to better account for the physical separation of the sensors on the aircraft. The equations used in the airborne software in FIFE-89 are detailed in Reference 15.

The second major change was the use of floating point arithmetic in the airborne calculation of flux estimates, rather than the previously used single precision integer arithmetic. This has greatly improved the accuracy and resolution of the real-time flux estimates presented on the plasma display units at the end of each flux-measuring run. Other refinements used in the ground playback program have also been incorporated in the airborne program. These include high-pass filtering of the signals contributing to the fluxes, and accounting for lags due to the physical separation of the $C0_2/H_20$ analyzer from the gust boom.

Figure 3 shows a comparison of the heat and $C0_2$ fluxes displayed in flight on the plasma units versus those subsequently computed on ground playback. Each symbol represents one 15-km run over the FIFE site, and all runs in Flights 04 to 06 are shown. The agreement is very good. Having these real-time estimates of fluxes during flight was of considerable assistance to the on-board scientists directing the flights. There is some scatter in Figure 3 because the real-time program still did not include all of the corrections used in the playback software. For example, the real-time $C0_2$ flux calculation does not include corrections for pressure broadening, nor does it use $C0_2$ converted to mixing ratio prior to flux calculation. Instead, the raw $C0_2$ concentration is used and the flux is corrected at the end of the run using the expressions developed by Webb *et al* in Reference 18. The differences in these methods are discussed further in Reference 15 and in Section 4.2.1 of Reference 1.

During FIFE-89, several versions of the airborne program were run. Table 4 lists the module used for each flight, along with the time period for which data were recorded. There were no significant differences among these modules that affected the recorded data. The differences had more to do with special tests to monitor the program in order to find the reason for occasional program halts due to a stack overflow. Also, because of a hardware failure on the event marker board, an alternate card (GNS) had to be used, which necessitated a change in the device address after July 28.

## 4.2 Playback

Post-flight analysis of the Twin Otter data is performed on a field data playback system comprised of a MicroVAX II processor and associated printer, plotter and tape drives. The principal analysis program, now called ARCFIFE-89, has grown considerably since 1987. It provides a greater number and variety of outputs, in order to more efficiently transfer data to other collaborating scientists. Output files stored on the MicroVAX disk can be transferred via Kermit software to PC-compatible floppy disks. The outputs available include:

- lineprinter listings of 1-second averages of key parameters, plus run-averages , standard deviations and computed fluxes.
- one-second averages of key parameters to floppy disk.
- photo summary file, with time, position, altitude and heading.
- averages over selected intervals of key parameters and the products of data contributing to the fluxes, eg., vertical gust times $C0_2$ fluctuations.
- summary file of run averages, unfiltered RMS values and fluxes.
- summary file of run averages, filtered RMS values and fluxes.
- filtered run averages for advection studies.
- linear trends of key parameters used in advection studies.
- archive data in the format specified for the FIFE Information System (FIS).

Several plotting routines used in the Twin Otter data playback are now grouped as options under a main driver called POKPLOTS. The plotting modules listed below accomplish the following tasks directly from the streamer tape:

- TRKDRW - Flight track plots from either Loran-C or IRS data.
- TEFDRW - Skew-T versus Log P plots and a wind hodograph for atmospheric profiling (soundings). Added in 1989 was a vector presentation of the winds.
- ANADRW - Analog plots of selected parameters.
- DPOSDT - Plots of differences in latitude and longitude between the Loran-C and IRS position measurements to document IRS Schuler drift. It also includes the difference in ground speeds measured by the IRS and Doppler radar.

Of major interest in flux measurement is a knowledge of the wavelengths of atmospheric motion contributing to the gas or energy transport. A program called COSPEC has been written to compute and plot the cospectra for the sensible and latent heat, momentum and $C0_2$ flux contributions versus wavenumber k (inverse wavelength). This program reads data directly from the streamer tape, producing one set of plots for each flux run, as designated by the event marker. The cospectral data are simultaneously written to a storage file. Another program called COMBINE can be used to retrieve selected cospectra files to compute and plot *average* cospectra for a set of runs (eg., Fig. 13). These are useful, for example, for comparing the cospectra of all runs at one height with all those at a second height, in order to examine the change with height in the size of the eddies responsible for the flux transport.

### 4.2.1. Flux Calculations

The fluxes of sensible and latent heat, momentum and $C0_2$ reported below and archived in the FIS have been computed by essentially the same equations as used in 1987. These were discussed in Section 4.2.1 of Reference 1, but are much more fully described in Reference 15 and will not be reproduced here. It must be emphasized that the method used to compute the $C0_2$ and water vapour flux (in both 1987 and 1989) was to convert the gas concentrations to mixing ratios (per kilogram of *dry* air) prior to their use in the eddy correlation equations.

The only difference in the flux calculations for FIFE-89 from the 1987 work is that the vertical gust velocity used is that derived from the Litton winds (WEP in Table 3) as opposed to that computed from the NAE/DOP winds (WGEI). The RMS values of WEP are generally a few percent higher than those of WGEI, suggesting that the use of WEP may produce slightly higher fluxes. This has *important ramifications* if 1987 and 1989 flux data are to be compared. This subject will be discussed below in Section 7.3 on data analysis and results.

### 4.2.2. Longitudinal Displacement of Sensors

On the Twin Otter, there is a physical displacement between the primary sensor for the vertical gust velocity at the tip of the noseboom, and the other sensors providing data for the flux calculations. In using the eddy correlation technique to compute fluxes, the data must be adjusted for the transport time for a parcel of air to pass from the noseboom to the other sensors. This adjustment is particularly important for runs at low altitude, where the spacing of the sensors can be a greater fraction of the typical turbulent eddy size.

The Rosemount temperature probe (TSF) and dew point sensor are on the sides of the fuselage nose about 4 m aft of the noseboom tip. The $C0_2/H_20$ analyzer is mounted in a duct through the rear of the cabin. The distance from the tip of the noseboom to the duct inlet is 9.9 m, and the analyzer is centred another 2.4 m from the duct inlet. Using the measured true airspeed of the aircraft, and the flow velocity in the duct, the theoretical time lags between the sensors can be easily calculated, as was done in Reference 1.

By means of an optional input in the playback software, the vertical gust velocity can be lagged a selectable number of sampling time periods prior to being multiplied by fluctuations in temperature, $C0_2$ and $H_20$ signals to derive the fluxes. To verify the predicted time lags, data from low-altitude runs can be analyzed with a range of lags. The resulting computed correlation coefficients are then plotted versus lag, with the maximum of the curve defining the appropriate lag for use in the subsequent data analyses. Another benefit of this technique is that the lag derived is a combination of delays resulting from both the physical separation of the sensors *and* the differences in the response times of sensors.

Figure 4 shows the plots of the correlation coefficients between the vertical gust velocity (WEP) and five other sensors. The temperature probe has a frequency response equal to that of the gust measurement, so its best lag of one time slice (1/16 sec) is due entirely to the physical displacement between the sensors. The same is true for the $C0_2$ and $H_20$ signals from the ESRI gas analyzer, but in this case the best lag to use is 5 time slices. For the dew point signal used in the calculation of an alternative water vapour flux, the peak correlation is given for a lag of 20 time slices (1.25 sec). The slow response of this sensor is responsible for the majority of the required lag. This is also the case for the LI-COR $C0_2$ analyzer, where a lag of 25 data points is required when used in the calculation of an alternative approximate $C0_2$ flux. These lags apply for flight at a true airspeed of 55-60 $ms^{-1}$, which is representative of the majority of the FIFE flux runs.

### 4.2.3 Corrections to Upward Radiometer

Software has been developed to continuously correct the upward radiometer reading for its mounting alignment and for variations in the pitch and roll attitude of the aircraft throughout each flight. The equations used are described in Reference 1. The procedure utilizes the following recorded data: GMT, pitch and roll attitude, heading, latitude and longitude. The only terminal input required is the sun declination angle from Table 169 of Reference 19.

### 4.2.4 High-pass Filtering

The analysis program, ARCFIFE89, computes the fluxes twice, using first unfiltered and then high-pass filtered data. The high-pass filtering is a convenient method to remove trends in the data at wavelengths longer than can be adequately sampled in the project runs. It is also used to permit comparison of data collected on runs of different lengths.

A third-order filter was used during the playback and archiving of the FIFE-89 data. The filter breakpoint was set to 0.012 Hz, which corresponds to a wavelength of approximately 5 km at the 60 $ms^{-1}$ typical true airspeed of the Twin Otter.

## 5.0 EXPERIMENTAL SITE AND FLIGHT PATTERNS

The Konza Prairie southeast of Manhattan, Kansas was again the focus of FIFE-89. The prairie itself, roughly 6 km on a side constituted the northwest portion of the 15x15 km study area. The Konza portion of the FIFE study area is a controlled experiment site 3487 hectares in area, consisting primarily of native tallgrass prairie vegetation, and is a long term ecological research site supported by the U.S. National Science Foundation. Controlled treatments on the Konza consist of grazed and ungrazed, burned and unburned areas in various annual rotations. The non-Konza part of the FIFE site is privately held and consists mainly of grazed and burned land. In FIFE-89, flight crews observed that the southeast quadrant appeared to be greener than the others, and also looked as if it had been seeded.

More complete descriptions of the FIFE site are available in References 1 and 20. The principal difference in the 1989 surface measurements was the concentration of most of the instrumentation in three 'supersites' known at Sites 906, 916 and 926 (Fig. 5). The University of Wisconsin LIDAR was again scanning the southwest quadrant from a location near the intersections of Highways I-70 and K-177.

Figures 5 to 7 show the tracks and navigational waypoints used in FIFE-89. In the flight and data summaries given below, the track flown on each run is identified using the waypoint labels shown in these figures. Figure 5 focuses on the tracks used on L- and T-shaped flight patterns, usually flown at several altitudes up to the top of the mixed layer in order to determine a flux profile. These were often done in coordination with the NCAR King Air. Figure 6 shows the tracks used on the grid flights, which were flown only by the Twin Otter, and at a single height of 1600 ft above sea level (approximately 100 m above ground). During some of the grid flights flown by the Twin Otter, the NCAR King Air made simultaneous profile measurements or flew the double-stack pattern (Ref. 11) for estimating advective contributions to the flux estimates.

As in 1987, the flux aircraft flew a so-called 'regional run' during transit to and from the base at Salina. These runs of about 75 km in length were always flown at 500 ft (150 m) above ground. The data from these runs are used to examine long wavelength contributions to the fluxes, to investigate the possibility of scaling-up flux estimates made on the shorter runs over the FIFE site to account for potential unmeasured longwave eddies. The regional run is flown over a greater variety of vegetation, from the Konza Prairie at the eastern end to mixed farmland and bare, ploughed fields at the west end. This variety makes the data useful for comparison with remote sensing images from satellite and the NASA C-130. The regional run for 1989 was changed from that flown in 1987, in order to have a better balance between Konza-type prairie grasses and the mixed farmland. The eastern end of the run was moved to the east edge of the FIFE site (Fig. 7), so about a fifth of the run was over the FIFE site itself, and about half the run was over similar vegetation. This improves the chances of using data from the regional run to correct FIFE-site flux estimates for long wavelength contributions. The track labelled 'B' in Figure 7 was flown only on Flight 01. All of the other regional runs were flown on track-C, which was displaced further south to avoid traffic conflicts at Fort Riley.

Other types of flight patterns were similar to those flown in 1987 and discussed in Reference 1. They included: (1) soundings over or near the FIFE site to document the thermal and dynamic structure of the atmosphere during each flight; (2) over-flight intercomparisons with the LIDAR; (3) wing-to-wing intercomparisons with the NCAR King Air, including 75 km of formation flight on the regional run; and (4) low-altitude runs over the Tuttle Creek Reservoir for verification of surface temperature measurements.

## 6.0 SUMMARY OF FLIGHT OPERATIONS

The Twin Otter arrived in Salina on July 21, 1989, and flight operations for FIFE-89 began on July 24. Sixteen project flights and several test flights were flown during the following three-week Intensive Field Campaign (IFC). The aircraft returned to its home base in Ottawa on August 14. Including transit and test flights, the Twin Otter was flown a total of 69.2 flying hours in FIFE-89.

Details of the Twin Otter flight operations and instrumentation status during FIFE-89 are presented in three tables, which should be *key references* for scientists working with Twin Otter data:

**Table 5: FIFE-89 Flight Summary:** This table lists *all* FIFE-related Twin Otter flights, including transit and test flights. It gives flight times (GMT), project flight number, and a brief description of the weather. It summarizes all of the measurement runs and the pressure altitudes flown (average terrain elevation of the FIFE site is about 1380 ft msl). Under "location", the waypoints given are those shown in Figures 5 to 7.

**Table 6: Types and Numbers of Runs:** This table lists the flights by type (project, transit and test) and gives the number of runs flown in the categories described in Section 5. These are grid lines, L- and T-shaped profiling runs, other linear runs, regional runs, aircraft-to-aircraft and aircraft-to-LIDAR intercomparisons, and soundings.

**Table 7: Instrumentation Problems:** This presents the instrumentation status for each of the 16 FIFE-89 project flights. In listing individual problems, parameter names correspond to those appearing in Tables 1 and 3.

Flight tracks for the 16 project flights are presented in Figures 8(a) to 8(d). Figures 9(a) to 9(c) show profiles of the measured wind, temperature and dew point for the soundings flown over or near the FIFE site. Winds are shown in both a hodograph and vector presentation. No soundings were flown on Flights 02, 05, 07 and 09.

## 7.0 DATA ANALYSIS AND RESULTS

Twin Otter data were analyzed using the procedures described above in Section 4.2 and the equations given in Reference 15. Copies of some of the various output files have been transferred to collaborating scientists at Agriculture Canada, the University of Wyoming and McGill University for further, specific analyses. Archive data has been sent via floppy disk to the FIFE Information System at the NASA Goddard Space Flight Center. The files consist of run-average meteorological and flux data, along with other parameters giving aircraft position and altitude and radiation measurements.

Table 8 lists the parameters archived for the flux aircraft, along with the units used and the digital formats. For each flight there is one data file named by the following convention: a two letter code for the aircraft (where the Twin Otter is NA), a 6-number date and a single letter extension indicating mission number of the day. An example for the Twin Otter for the second flight on August 4 is "NA890804.B".

Within each file there are eight lines of data for each flux run. The first line provides flight and run identification. Table 8 lists the data written in the other seven lines. It should be noted that for the FIS archive of the aircraft data, it was decided to use fluxes derived from high-pass filtered data. The wavelength for the filter was agreed to be 5 km, as previously described. Also, the sign convention adopted for the wind components was different from that usually used in the Twin Otter analysis routine. The north/south component (V) is considered positive from the south (-UGE), and the east/west component (U) is positive from the west (-VGE). This convention applies to the momentum fluxes as well. The more conventional momentum flux in wind axes is also archived. Because of this difference in the sign convention for the winds, care must be taken if the data from Table 9 of this report are compared with the archive data in the FIS.

### 7.1 Summary of Results

*Table 9 presents run-average data from all of the runs flown by the Twin Otter in FIFE 1989.* This is an important addition to this report that was not included in the parallel report (Ref. 1) for the 1987 FIFE project.

The RMS and flux data in Table 9 were computed from data that were high-pass filtered with a breakpoint set to 0.012 Hz, which corresponds to a wavelength of about 5 km at the speed of the Twin Otter. These data correspond to those archived in the FIFE Information System. The starting time of each run is shown as GMT (Central Daylight Time plus 5 hours). An explanation of the data appearing in each column is given at the start of the table.

Data from this table were extracted and plotted to try to determine any major trends in the fluxes and evidence of 'dry-down'. Only the runs flown at 1600 ft above sea level (about 100 m above ground) were used for this study. This includes *all* runs flown on the grid pattern, plus the lowest levels flown on the L- and T-shaped flight patterns. The results are plotted in Figure 10 versus the day of the year (Day 208 is July 27). Each symbol represents the average of 4 to 10 runs; the average from each 8-line grid is shown by the asterisk symbol. Although the data shown are for mostly sunny conditions, no attempt was made to distinguish between different wind conditions or atmospheric stabilities.

The ratio of sensible heat to latent heat flux (Bowen Ratio) depicted in the upper figure shows a decline until Day 216 (August 4), then an increase to near the end of the experimental period. This suggests a drying out of the Konza Prairie over the last half of the Intensive Field Campaign (IFC). These data will have to be compared with surface and satellite observations to confirm this. The mean $C0_2$ flux measured by the Twin Otter was relatively constant over the experimental period, averaging about 0.5 mg/m$^2$ per second (18 kg/hectare per hour). This falls about mid-way between the July 11 and August 15 data from the 1987 FIFE flights (Fig. 65, Ref. 1). The solid curve shown in Figure 10, representing a smooth fit through all the data points, shows a peak on day 219 (August 7). On this day, a T-shaped pattern was flown (Fig. 8(c)) in conditions of northeast winds. $C0_2$ fluxes were higher than average because the aircraft spent a greater proportion of its time downwind of the greener vegetation in the southeast quadrant of the FIFE area. The dotted line in Figure 10 shows trend data from only the grid runs, confirming a fairly constant $C0_2$ flux over the IFC.

## 7.2 Night Flight

On of the unique features of the Twin Otter operations in FIFE-89 was the measurement of fluxes after dark on August 10 (Flight 14). The flight commenced near sundown in order to establish a safe flight pattern and altitude prior to the onset of darkness. Starting at 20:18 local time, a racetrack pattern was established with east/west runs over Site 916 and just south of Site 906 (Fig. 8(d)). The first pair of runs was flown at 1800 ft msl, and all subsequent runs were flown at the 1600 ft altitude (100 m above ground) common to the grid flights. Throughout the flight, the height of the mixed layer was monitored by an acoustic sounder at Site 906 and radioed to the flight crew.

Although the winds were perfect for the flight (south at 8 $ms^{-1}$), the sky cleared at sunset, causing the top of the mixed layer to fall more rapidly than desired. The sounder measured the height of the mixed layer at 150 m during the first run, falling to 90 m by the time of Run 10 and then rising to 120 m by the time of the last run at 02:37 GMT (21:37 local time). Therefore, the aircraft was near the top of the boundary layer for nearly all of the runs. Consequently, it was extremely smooth and measured fluxes were very low (Table 9(n)). Nevertheless, positive, or upward, $C0_2$ fluxes were measured, but the mean values were small (approximately 0.2 kg/hectare per hour). Unfortunately, there wasn't an opportunity to repeat this flight in the cloudy, windy conditions more suitable for estimating the respiration component of the $C0_2$ flux. However, the operational techniques developed for this flight proved that low-altitude flux measurements could be accomplished safely at night at flight altitudes with terrain clearance down to about 50 m.

### 7.3 The Effects of the Use of the Litton Winds in Fluxes

As discussed in Section 4.2.1 above, the only significant difference in the flux calculations for FIFE-89 was the use of the vertical gust velocity WEP from the Litton winds, rather than WGEI from the NAE/DOP winds as in 1987. To investigate the effects of this change, about 60 runs from flights on August 4 and August 10 were analyzed using both methods. Forty-five of these runs were flown on the grid pattern at an altitude of about 100 m agl. The remainder were flown at higher altitudes, usually near the top of the mixed layer, which broadens the range of flux values in this study. The results from a comparison of these data will be presented in this section.

Figure 11 shows plots of the run-mean fluxes using WEP versus those computed using WGEI. The dashed line represents the 1:1 correlation. The sensible heat, latent heat and $C0_2$ fluxes show a fairly consistent increase when WEP from the Litton winds is used as the vertical gust velocity. The increases are of the order of 10 to 20 percent. The momentum flux is an exception, primarily because different horizontal wind components are used in each case, that is, the Litton U-component is used with WEP and the NAE/DOP U-component is used with WGEI. Momentum flux is also a more difficult and variable flux to measure by aircraft. Although there is more scatter, it would appear that there is no consistent bias in the momentum flux that can be attributed to use of the Litton or NAE/DOP winds.

A closer look at the flux calculations has revealed that the larger fluxes are not just a result of the increased RMS vertical gust velocity when using WEP; there is also an improved correlation between the vertical gust and the concentration measurements, particularly for the water vapour. Figure 12 shows that the RMS WEP is consistently larger than that of WGEI, by an average of about 7 or 8 percent. The correlation coefficients from the $CO_2$ flux calculation show an average 3 or 4 percent improvement when WEP is used. This improved correlation is evidence that the vertical component WEP from the Litton winds is likely more accurate than the WGEI from the Doppler winds.

There is further evidence for this conclusion. In 1987, the Twin Otter flew wing-to-wing intercomparisons with both the NCAR and University of Wyoming King Air aircraft. The data showed excellent agreement in the RMS values of the horizontal components of the computed winds ($\sigma_u$ and $\sigma_v$ in Fig. 59 and Section 8.3, Reference 1). However, there was a discrepancy in the vertical component, $\sigma_w$, where the Twin Otter values were 10-15 percent less than those of the other aircraft. In 1987, the Twin Otter $\sigma_w$ was computed from the WGEI of the NAE/DOP winds. Inertial navigation systems were used in the calculations of the King Air winds, a method which is comparable to the 1989 WEP calculations for the Twin Otter. Twin Otter heat fluxes were also a few percent lower than those from the King Air aircraft (Fig. 61, Reference 1). In fact, the differences are very similar to those exhibited in Figure 11 of this report.

Since there are small but significant disparities in the computed fluxes associated with the use of either WEP or WGEI, the question arises as to the nature of these differences on the frequency plane. Do they occur at a preferred wavelength, or are the differences prevalent at the long or the short wavelengths? To investigate this, cospectra have been calculated for all sixteen runs flown in the grid pattern on Flight 06 on August 4, 1990, first using WEP and then using WGEI as the vertical gust velocity. The COMBINE routine was used to average and plot the mean cospectra from the WEP (solid line) and WGEI data (dashed line) in Figure 13. In order to observe possible differences over the largest possible wavelength range (i.e., up to the run length of 15 km), the data contributing to the fluxes had linear trends removed, but were *not* high-pass filtered.

Several observations can be made from these plots. First, the differences occur at the mid and low frequency end of the plot, that is, there is little difference in the cospectra at $k > 4 \times 10^{-3}$ $m^{-1}$ (wavelengths shorter than 250 m). This is not surprising, since the main difference in the methods is the use of the Doppler radar to provide the low frequency component of the inertial velocity used in the WGEI calculation. Also, at the higher frequencies, the response of the aircraft is damped by its own inertia, so the majority of the fluctuations in the gust measurement are from the noseboom airspeed and flow angle data, which are essentially the same in the calculation of both WEP and WGEI.

The differences shown in the integrated cospectra, i.e., the average fluxes shown in the legend above each plot, are consistent with the observations from Figure 11. The ratios of WEP/WGEI-derived fluxes is 1.23 for the sensible heat flux, 1.16 for latent heat flux and 1.09 for the $CO_2$ flux. The mean momentum flux is the same for both the NAE/DOP and Litton winds. Since the momentum flux involves *only* wind measurements, the agreement between the NAE/DOP and Litton estimates demonstrates an internal consistency and suggests that there are no problems due to axis misalignment or in the axis transformation software.

It can be concluded from this study that, if there are differences in fluxes computed from WGEI and WEP, the latter are probably the more accurate and will certainly be the more comparable with the other aircraft. It also suggests that some caution will have to be exercised when comparing Twin Otter fluxes from 1987 with those of FIFE-89. *It is possible that the 1987 sensible heat, latent heat and $C0_2$ fluxes are under-estimated by 10 to 20 percent.* This may also explain part of the under-estimation of the 1987 aircraft-measured sensible heat fluxes when extrapolated to the surface for comparison with data from ground-based systems (Reference 11).

## 7.4 Effects of Filtering and Run Length

For the Twin Otter data archived in the Fife Information System, the fluxes were computed using data that were high-pass filtered at 0.012 Hz, which corresponds to a wavelength of about 5 km at the typical flight speed. This wavelength represents about 1/3 of the run length over the FIFE site. The question arises as to how much the fluxes are under-estimated due to: (1) use of the high-pass filter, and (2) the inability to capture the long wavelength eddies due to the limited length of the runs themselves.

The first of these questions is the easier to answer. Figure 14 shows average cospectra for the 16 runs on the grid pattern during Flight 06. The fluxes were calculated using the vertical gust velocity WEP from the Litton winds, and linear trends were removed from the data prior to application of the eddy correlation technique to derive the fluxes. Cospectra using unfiltered data are represented by the solid line, while the dotted line shows those from the same runs using high-pass filtered data. The differences are small, with the unfiltered mean fluxes only 5-10 percent more than those derived from the filtered data. The average altitude for these runs was about 100 m. Of course, the effect of the filtering will increase with height where the eddy sizes are larger.

There has been some concern during the FIFE analysis period about the apparent underestimation of the sensible heat flux by all of the flux aircraft. Therefore, it was decided to look more closely at the effects of the high-pass filtering on the estimates of the heat flux from the Twin Otter. In Figure 15, the heat flux computed from unfiltered data is plotted versus that using data high-pass filtered at a wavelength of 5 km. Each dot represents one 15-km run over the FIFE site, while the crosses depict fluxes on a 37-km segment (i.e, half) of the regional run. All runs flown in 1989 below 300 m altitude above ground are shown, except for the night flight and a few cases in the last half of Flight 7 in which there was a large east/west trend in the potential temperature. The data contributing to both the filtered and unfiltered fluxes were not detrended prior to flux calculation.

Although there is a lot of scatter in the plots, the unfiltered flux is larger than the filtered estimate in the majority of the 15-km runs, and in *all* of the longer, more reliable regional runs. In the shorter runs over the FIFE site, the unfiltered flux is occasionally less than the filtered value. This is because negatively correlated, long wavelength components of the temperature and vertical wind signals can result in a negative contribution to the run-average flux. It is not always known whether these longwave components are real or false as a result of instrument drift. That is why the 5-km filter was adopted for the aircraft data in the first place. Nevertheless, Figure 15 suggests that a significant portion of the 'missing heat flux' is due to use of the high-pass filter and inadequate sampling of the long wavelength contributions to the flux.

The dashed line represents a linear fit to the data from the 15-km runs over the FIFE site, while the solid line depicts a 1:1 relationship. On average, the unfiltered fluxes are 15-20 percent greater than the filtered values. These differences are larger than those indicated in Figure 14 because this analysis includes runs at higher altitudes, where eddies are larger and proportionally more affected by the 5-km high-pass filter. The 15-20 percent difference represents about half of the discrepancy reported between the 1987 aircraft versus surface fluxes. Use of the Doppler rather than the Litton winds in 1987 (Section 7.3) could account for at least another 10 percent heat flux decrease, or a quarter of the discrepancy. Furthermore, it has also come to light at a recent workshop that overestimated net radiation measurements have led to a possible overestimation in the surface-measured heat flux values.

There is another interesting observation to be made from Figure 15. The dotted line depicts the linear fit to the data for the 37-km segments (i.e., half) of the regional run. It does not have as steep a slope as the dashed line for the 15-km runs, that is, the unfiltered/filtered ratio is greater on days with small fluxes than on large flux days. This suggests that, on low flux days, proportionally more of the flux contribution on the regional run is at long wavelengths. This effect is not seen for the 15-km runs, where the reduction by the filter appears to be about the same *percentage* on large and small flux days. This comparison implies that the difference is due to flux contributions at wavelengths longer than 15 km, which can be sampled on the regional run but not on the 15-km runs, and that these very long wavelength contributions are more prevalent on low flux days than on high flux days. Admittedly, these inferences are drawn from linear fits to data that have a lot of scatter, but they are consistent with the observation that aircraft-measured fluxes are lower than surface estimates. The subject deserves further investigation, possibly by comparing filtered and unfiltered fluxes from the entire 75-km regional run with averages from the same runs divided into 15-km segments.

Further to the question about underestimation caused by the limited run length, the unfiltered cospectra in Figure 14 show good closure at the long wavelength end, suggesting that there is little energy at wavelengths longer than 15 km. The flight altitude was only 100 m, however, and the data shown are from only one day; the results could conceivably change on another day with a different wind direction or atmospheric stability. This is discussed further in Reference 4, where filtered and unfiltered cospectra were calculated for some 75-km regional runs flown in 1987. A comparison of data from two days showed significant differences in the long wavelength contributions to the fluxes. It is hoped that such data from the regional runs can be used to normalize, or scale up, fluxes from the shorter runs over the FIFE site in order to account for the potentially missing long wavelength contributions.

## 8.0 CONCLUDING REMARKS

This report has documented the participation of the NAE Twin Otter atmospheric research aircraft in FIFE-89. It has provided the details of the instrumentation on the aircraft, real-time and playback software, and flight operations during the experiment. The various forms of data available to collaborating scientists have been listed, including the format of the data residing in the FIFE archive at the NASA Goddard Space Flight Center.

Also presented in this report were run-average meteorological, radiation and flux data for all 285 runs flown by the Twin Otter in FIFE-89.

FIFE-89 was the first flux-measuring project in which the alternative wind calculations have been available on the Twin Otter. The difference in the wind computation methods was primarily in the source of the aircraft inertial velocity measurement. Winds referred to as the NAE/DOP winds were used for the 1987 FIFE data, while those called the Litton winds have been used for archiving FIFE-89 data. Data for runs analyzed by both methods show flux increases of 10 to 20 percent when the Litton winds provide the vertical gust velocity used in the flux calculations. It is possible, therefore, that fluxes archived for FIFE in 1987 were under-estimated by that amount.

Analysis of FIFE-87 data has indicated that aircraft-measured sensible heat fluxes, when extrapolated to the surface, under-estimate surface-based flux measurements. Studies in this report suggest that at least half of this discrepancy is a result of the combined effects of a limited run length of 15 km, and the high-pass filtering of the aircraft data at a wavelength of 5 km.

FIFE-89 included the first attempt to make low-altitude flux measurements at night. Although the meteorological conditions were not ideal for this purpose, the operational techniques developed for this flight proved that low-altitude flux measurements could be accomplished safely at night at flight altitudes down to about 50 m.

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## TABLE 1: TWIN OTTER SENSORS FOR FIFE-89

| Category | Instrument | Type[1] Output | Parameter Labels | Description |
|---|---|---|---|---|
| Time | NAE Clock | D | HR, MINSEC | |
| Position | ARNAV Loran-C, R-40-AVA-100 | D | LTD, LTM<br>LGD, LGM | Latitude, degrees and minutes<br>Longitude, degrees and minutes |
| | Litton LTN-90-100 Inertial Reference System | D | LTML<br>LGML | Latitude, minutes<br>Longitude, minutes |
| Inertial Velocity | Litton LTN-90-100 Inertial Reference System | D | ULN,VLE,WZL<br>GSL | 3 Components of Velocity in Earth-axes<br>Total Ground Speed |
| | Decca Doppler Radar, Model 72 | D | VXM,VYM,VZM<br>VDTM | 3 Components of Velocity in Aircraft Axes<br>Total Ground Speed |
| Heading | Sperry C-12 Gyro Compass | S | HDGM<br>HDGT | Magnetic Heading<br>True Heading ( Uses Variation from Loran) |
| | Litton LTN-90-100 IRS | D | HDGTL | True Heading |
| Attitudes | Kearfott T2109 Gyro | S | THETA, PHI | Pitch and Roll Attitude |
| | Litton LTN-90-100 IRS | D | THETAL, PHIL | Pitch and Roll Attitude |
| Accelerations | Systron-Donner 4211 | A | AX,AY,AZ | Longitudinal, Lateral and Vertical Accelerations in Aircraft Axes |
| | Litton LTN-90-100 IRS | D | AXL,AYL,AZL | As above |
| Angular Rates | Smiths 402-RGA Rate Gyros | A | PRATE,QRATE<br>RRATE | Roll, Pitch and Yaw Rates in Aircraft Axes |
| | Litton LTN-90-100 IRS | D | PRATEL,QRATEL<br>RRATEL | As above |
| Altitude | Sperry AA-200 Radio Altimeter | A | RALT | Height Above Terrain, to 2500 ft |
| Temperatures | Rosemount 102DJ1CG | A | TTF | Fast Response Total Temp at Fuselage Nose |
| | Rosemount 102DJ1CG | A | TTNB | Fast Response Total Temp on Noseboom Fairing |
| | Rosemount 102DJ1CG | A | TTDUCT | Fast Response Total Temp in Duct |
| | Barnes PRT-5 | A | PRT5C | Surface Temperature |
| | E,G and G Model 137-S10 | A | DEWPTC | Dew Point Temperature |

[1] **D- Digital S- Synchro A- Analog**

## TABLE 1 (Cont): TWIN OTTER SENSORS FOR FIFE-89

| Category | Instrument | Type[2] Output | Parameter Labels | Description |
|---|---|---|---|---|
| **Temperatures (Cont)** | Paroscientific 215L-AW-012 | A | TSPARO | Temperature in Static Pressure Transducer |
| | Ag Canada | A | TSANAL | Temperature in $CO_2$/$H_2O$ Analyzer |
| | LICOR C02 Analyzer temp | A | LCTSC | Temperature in LICOR C02 Analyzer |
| **Pressures** | Paroscientific 215L-AW-012 Rosemount 858AJ28 Probe | D | PSNB | Noseboom Static Pressure, temperature compensated |
| | Rosemount 1221lV7A1B Rosemount 858AJ28 Probe | A | PDNB | Noseboom Dynamic Pressure |
| | Rosemount 12211F1VL5A1 Rosemount 858AJ28 Probe | A | PALPHA | Differential Pressure for Angle of Attack |
| | Rosemount 12211F1VL5A1 Rosemount 858AJ28 Probe | A | PBETA | Differential Pressure for Angle of Sideslip |
| | Rosemount 1201F1B4A1B | A | PSF | Alternate Static Pressure, Fuselage |
| | Rosemount 1201F2VL7A1A | A | PDF | Alternate Dynamic Pressure, Fuselage |
| | Rosemount 1221F2VL7A1A | A | PDDUCT | Dynamic Pressure in Duct |
| | A.I.R. AIR-DB-2C | A | PSDUCT | Static Pressure in Duct |
| **Analyzers** | Agriculture Canada ESRI Gas Analyzer | D | C02N02 H20 | Carbon Dioxide Concentration Water Vapour Concentration |
| | LICOR LI-6251 C02 Analyzer | A | LC02 | Carbon Dioxide Concentration |
| **Radiometers** | Kipp and Zonen CM-11 | A | RADUP | Incident Radiation, Top Fuselage |
| | Eppley Pyranometer | A | RADOWN | Reflected Radiation, Under Fuselage |
| | Skye Industries Greenness | A | GRN660 GRNRAT | Vegetation Greenness Index |

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[2] **D- Digital S- Synchro A- Analog**

**TABLE 2**

**Event Marker Configuration for FIFE 1989**

| Bit | Decimal Count | Label on Printout | Indication |
|---|---|---|---|
| 15 | negative | - | No event |
| 14 | 16384 | E | Event Marker ON: Data run |
| 13 | 8192 | P | 35 mm photograph taken ( tied to camera sync pulse) |
| 12 | 4096 | N | Notepad cassette recorder being used for audio note taking |
| 11 | 2048 | C | LICOR $CO_2$ analyzer in self-calibration |
| 10 | 1024 | T | VHF radio transmission |
| 9 | 512 | M | Doppler radar in memory; velocities not useable |
| 8 | 256 | L | Loran-C data not available |
| 7 | 128 | - | F/S 7[1] - Navigation pointer routine running; used to return to same air parcel or cloud |
| 6 | 64 | S | F/S 6 - Doppler radar land or sea calibrations to be used |
| 5 | 32 | 5 | F/S 5 - OFF - TSNB used in TAS<br>- ON - TSF used in TAS, etc |
| 4 | 16 | 4 | F/S 4 - Position error adjustment subtracted from noseboom TAS |
| 3 | 8 | I | F/S 3 - Noseboom dynamic pressure port blocked; Alternative PDFNB used in flow angle calculation |
| 2 | 4 | F | F/S 2 - Fuselage true airspeed used in wind calculation instead of noseboom TAS |
| 1 | 2 | - | F/S 1 - Wind data displayed to crew in degrees magnetic or true |
| 0 | 1 | - | F/S 0 - Not used |

[1] F/S indicates function switch on console in cockpit. Status of the 8 function switches are recorded in the event word

**TABLE 3**

**TWIN OTTER RECORDER BUFFER IN FIFE-89**

**BUFFER A FIFE89 for use with Litton Running**
**Used for all FIFE-89 Flights**

| Word # | Name | Scale | Units | Description |
|---|---|---|---|---|
| 01 | FILEHR | 1 | - | File number; GMT hours (1) |
| 02 | MINSEC | 1 | - | GMT minutes; GMT seconds (2) |
| 03 | EVENT | 1 | - | Event marker |
| 04 | LTD | 1 | deg | Loran latitude, degrees |
| 05 | LTM | 100 | min | Loran latitude, minutes |
| 06 | LGD | 1 | deg | Loran longitude, degrees |
| 07 | LGM | 100 | min | Loran longitude, minutes |
| 08 | LTML | 100 | min | Litton latitude, minutes |
| 09 | LGML | 100 | min | Litton longitude, minutes |
| 10 | HDGT | 10 | deg | Magnetic compass true heading |
| 11 | HDGTLC | 10 | deg | Litton true heading |
| 12 | WDTI | 10 | deg | Dop/inertial true wind direction |
| 13 | WDTL | 10 | deg | Litton true wind direction |
| 14 | WSMI | 100 | m/s | Doppler/inertial wind speed |
| 15 | WSML | 100 | m/s | Litton wind speed |
| 16 | UGEI | 100 | m/s | North/south Dop/In wind component ( positive from north) |
| 17 | VGEI | 100 | m/s | East/west Dop/In wind component ( positive from east) |
| 18 | WGEI | 100 | m/s | Vertical Dop/In wind component ( positive up) |
| 19 | LWN | 100 | m/s | North/south Litton wind component |
| 20 | LWE | 100 | m/s | East/west Litton wind component |
| 21 | WEP | 100 | m/s | Vertical Litton wind component |
| 22 | TSNBC | 100 | deg C | Static temperature, noseboom fair'g |
| 23 | DEWPTC | 100 | deg C | Dew point temperature |
| 24 | TSDCTC | 100 | deg C | Duct static temperature, fast response R-102 probe |
| 25 | PRT5C | 100 | deg C | PRT-5 surface temperature |
| 26 | RADUP | 10 | $W/m^2$ | Incident radiation, upward facing |
| 27 | RADOWN | 10 | $W/m^2$ | Reflected radiation, downward " |
| 28 | C02N02 | 10 | $mg/m^3$ | $CO_2$ analyzer, duct, LP filtered |
| 29 | H20 | 100 | $g/m^3$ | $H_2O$ analyzer, duct, LP filtered |
| 30 | RALT | 10 | m | Radio altimeter height |
| 31 | TASFK | 100 | knots | True airspeed, fuselage |
| 32 | TASNBK | 100 | knots | True airspeed, noseboom |
| 33 | TASDCT | 100 | knots | True airspeed, duct |
| 34 | PSDUCT | 10 | mb | Static pressure, duct |
| 35 | PSNBC | 10 | mb | Static pressure, noseboom |
| 36 | TSFC | 100 | deg C | Static Temperature, fuselage |
| 37 | GRNRAT | 1000 | - | Greenness index |
| 38 | VDTM | 10 | m/s | Doppler ground speed |
| 39 | GSL | 10 | knots | Litton ground speed |
| 40 | LC02 | 1 | mv | Licor $CO_2$ analyzer, millivolts |

TABLE 3 (Cont)

| Word # | Name | Scale | Units | Description |
|---|---|---|---|---|
| 41 | LCTSC | 100 | deg C | Licor $CO_2$ analyzer temperature |
| 42 | UGEIL | 100 | mps | North/South Litton/Dop wind |
| 43 | VGEIL | 100 | mps | East/West Litton/Dop wind |
| 44 | WGEIL | 100 | mps | Vertical Litton/Dop wind |
| 45 | UC02N2 | 10 | $mg/m^3$ | $CO_2$ Analyzer, duct, unfiltered |
| 46 | $UH_2O$ | 100 | $g/m^3$ | $H_2O$ Analyzer, duct, unfiltered |
| 47 | TTF | 100 | deg K | Rosem't total temperature, fuselage |
| 48 | TTNB | 100 | deg K | Rosem't total temperature, noseboom |
| 49 | PSFC | 10 | mb | Fuselage static pressure |
| 50 | PDFC | 100 | mb | Fuselage dynamic pressure |
| 51 | PDNBC | 100 | mb | Noseboom dynamic pressure |
| 52 | AZL | 100 | $m/s^2$ | Vertical Acceleration, Litton, |
| 53 | PDDUCT | 100 | mb | Duct dynamic pressure |
| 54 | WGAI | 100 | m/s | Vertical Dop/Inertial wind component in aircraft axes |
| 55 | ALPHA | 100 | deg | Angle of attack, noseboom |
| 56 | BETA | 100 | deg | Sideslip angle, noseboom |
| 57 | THETAL | 100 | deg | Pitch attitude, positive nose up |
| 58 | PHIL | 100 | deg | Roll attitude, positive right wing down |
| 59 | VXMLTN | 128 | m/s | Doppler velocity along heading corrected to Litton location |
| 60 | VYMLTN | 256 | m/s | Doppler lateral velocity, positive to starboard |
| 61 | VZMLTN | 512 | m/s | Doppler vertical velocity, positive aircraft down |
| 62 | ULN | 100 | m/s | Litton north/south velocity, positive to north |
| 63 | VLE | 100 | m/s | Litton east/west velocity, positive to east |
| 64 | WZL | 100 | m/s | Litton vertical velocity, |

**Notes:** (1) first byte is tape file number, decimal
second byte is GMT hours, decimal

(2) eg., 2712 decimal is 27 minutes, 12 seconds GMT

## TABLE 4: AIRBORNE PROGRAMS AND RECORDED DATA

| Date | Flt # | Program | Version | File | Recorded GMT[1] |
|---|---|---|---|---|---|
| Jul 27 | 01 | PK9CF1 | Jul 26 | 1 | 1521-1525 |
| | - | " | " | 2 | 1532-1819 |
| " | 02 | PK9CH1 | Jul 26 | 1 | 1909-1950 |
| Jul 28 | 03 | PK9CF1 | Jul 26 | 1 | 1440-1804 |
| Aug 02 | 04 | POK9CI | Jul 29 | 1 | 1451-1825 |
| Aug 03 | 05 | " | " | 1 | 1714-1945 |
| Aug 04 | 06 | " | " | 1 | 1416-1724 |
| " | 07 | " | " | 1 | 1831-2126 |
| Aug 06 | 08 | " | " | 1 | 1459-1830 |
| " | 09 | " | " | 1 | 1928-2236 |
| Aug 07 | 10 | " | " | 1 | 1511-1529 |
| | | " | " | 2 | 1548-1838 |
| Aug 08 | 11 | POK9CJ | Aug 08 | 1 | 1511-1830 |
| " | 12 | " | " | 1 | 1940-2209 |
| Aug 10 | 13 | POK9CL | Aug 08 | 1 | 1557-1836 |
| " | 14 | " | " | 1 | 0051-0309[2] NF[3] |
| Aug 11 | 15 | " | " | 1 | 1619-2007 |
| Aug 12 | 16 | " | " | 1 | 1555-1958 |

[1] Greenwich Mean Time = Central Daylight Time plus 5 hours

[2] Evening flight August 10 (August 11 GMT)

[3] No end-of-file marker on tape

**TABLE 5: FIFE-89 FLIGHT SUMMARY - NAE TWIN OTTER**

| DATE | FLT # | GMT | HRS | WEATHER | RUNS FLOWN | LOCATION Waypoints |
|---|---|---|---|---|---|---|
| Jul 20 | - | 1406-1537 | 1.7 | Sunny | - Transit | Ottawa-Wiarton |
| | | 1716-1916 | 2.1 | Some cloud | - Transit | Wiarton-Milwalkee |
| | | 2052-2221 | 1.7 | Some cloud | - Transit | Milwalkee-Ottumwa |
| Jul 21 | - | 1455-1626 | 1.6 | Cloud, showers to sunny | - Transit | Ottumwa-Manhattan |
| | 00 | 1719-1816 | 1.1 | Mostly sunny, some cumulus; Winds NE at 10 mps | - Test run at 1900' msl<br>- Test run at 1900' msl<br>- Attempt new regional run, terminated about 10 miles east of west end | FNW-FNE<br>FN-FS<br>FE2-FWEST |
| Jul 24 | - | 2057-2128 | 0.6 | Towering cumulus, southeast winds | - Tests of event marker with various jumper combinations<br>- Licor tests at high and low speed , and during taxi | |
| Jul 25 | - | 1910-1950 | 0.6 | Cumulus | - Test of PK9CFX for event marker<br>- Several problems after 15 volt short | |
| Jul 26 | - | 2018-2044 | 0.6 | Cumulus, SSE winds | - 3 files using modules PK9CF1, PK9CE1 and PK9CH1<br>- Did pitches and several low level runs to test event and flux routines | |
| Jul 27 | 01 | 1522-1819 | 3.0 | Cumulus, Winds SSW 5-7 mps, Cloud Base: 4300' @ 1600Z, 4500' @ 1638Z, 5500' @ 1736Z, 5900' @ 1809Z, altimeter 30.20 | - Regional run B, 500' agl<br>- Sounding to 4800' msl<br>- Profile stack at 1600, 1900, 2600 and 4000' msl<br>- Profile stack at 4300, 2600, 1900, 1600, 1700, 1900, 2600 and 4300' msl<br>- Profile stack at 5200, 2700, 1900 and 1600' msl<br>- Sounding to 5900' msl | - FRW-FE2, Region B<br>-<br>- FNW3-FNE3<br>- FN2-FS2<br>- FNW3-FNE3 |
| Jul 27 | 02 | 1910-1951 | 0.8 | Cumulus, Winds south 5-7 mps | - Regional Run C at 500' agl | - FE2-FRW2, Region C |
| Jul 28 | 03 | 1440-1804 | 3.5 | Mostly clear, a few cumulus near end of flight, Winds south 5 mps, BL height 3700'msl at start, Altimeter 30.10 | - Control inputs, 9500'<br>- Descent sounding from 9500'<br>- 3 Lidar intercomparison runs, 1750, 2800 and 4000' msl<br>- 8-line grid working from south to north, 1600' msl<br>- 8-line grid working north to south, 1600' msl<br>- Regional run C, 500' agl | - 235 mag bearing over LIDAR site<br>- 8 east/west lines<br>- 8 east/west lines<br>- FRE-FRW2 |
| Jul 31 | - | 2030-2054 | 0.5 | Partially cloudy | - 4 test runs for new POK9CI | - Near Salina |

TABLE 5 (cont): FIFE-89 FLIGHT SUMMARY - NAE TWIN OTTER

| DATE | FLT # | GMT | HRS | WEATHER | RUNS FLOWN | LOCATION Waypoints |
|---|---|---|---|---|---|---|
| Aug 02 | 04 | 1452-1825 | 3.7 | Hazy and humid, approx 50% low cumulus, South winds 5-10 mps, Cloud base 2800' at start, rising to 3800' msl at end, Altimeter 30.00 | - Sounding from 9500'<br>- L-pattern, 1700 to 1600' msl<br>- L-pattern 2600' msl, 200' below cloud base<br>- L-pattern, 1600' msl<br>- L-pattern, 2600' msl<br>- L-pattern, 2800' msl<br>- L-pattern, 1600' msl<br>- L-pattern, 3000' msl<br>- L-pattern, 1600' msl<br>- One Lidar Intercomp, 205 magnetic, 3400' msl<br>- Regional run C, 500' agl | <br>- FS3-FN3, FNW-FNE<br>- FNE-FNW, FN3-FS3<br><br>- FS3-FN3, FNW-FNE<br>- FNE-FNW, FN3-FS3<br>- FS3-FN3, FNW-FNE<br>- FNE-FNW, FN3-FS3<br>- FS3-FN3, FNW-FNE<br>- FNE-FNW, FN3-FS3<br>- 205 bearing from over Lidar<br>- FRE-FRW2 |
| Aug 03 | 05 | 1715-1946 | 2.7 | Low cloud at start, 30 -40 % based at 2800' msl; reduced to about 20% and cloud base rose to 4100', Winds 220/10 mps, Altimeter 29.79 | - Regional run C, 500 agl<br>- 3 familiarization runs for new pilot, 1600' msl<br>- 4 Lidar intercomparison runs (first aborted about mid way) 2800, 2800, 1600 and 3900'msl<br>- Regional run C, 500' agl | - FRW2-FRE<br>- FNE-FNW, FW2-FE2, and FE6-FW6<br>- 235 bearing from Lidar<br><br>- FRE-FRW2 |
| Aug 04 | 06 | 1417-1724 | 3.3 | Clear, Winds 220/8 mps, Hot; PBL height: 2800' msl at 1440Z, 3500' at 1600Z, and 3200' at 1700Z, Altimeter 29.77 | - Descent sounding 9500-2500' msl<br>- Run along track-8 at 2500' msl<br>- Full 8-line grid at 1600' msl, working south to north<br>- Runs along track-1 at 3300 and 3100' msl<br>- Full 8-line grid at 1600' msl, working north to south<br>- Run along track-8 at 3100' msl | <br>- FW6-FE6<br>- 8 east/west lines (Fig. 6)<br>- FW0-FE0 & FE0-FW0<br><br>- 8 east/west lines (Fig. 6)<br>- FW6-FE6 |
| Aug 04 | 07 | 1832-2127 | 3.0 | Clear, Winds 190/7 mps, Hot; PBL height fairly constant at about 3100' msl, Altimeter 29.75 | - Full 8-line grid at 1600' msl, working north to south<br>- Runs on track-8 at 3100 and 2300' msl<br>- Full 8-line grid at 1600' msl, working south to north<br>- Run on track-1 at 3400' msl<br>- Regional Run C at 500' agl<br>- Control inputs at 95 knots, flaps 7 deg<br>- Pitching inputs, 110 knots, flaps up | - 8 east/west lines (Fig. 6)<br>- FW6-FE6, FE6-FW6<br><br>- 8 east/west lines (Fig. 6) KA 2032Z<br>- FW0-FE0<br><br>- FRE-FRW2 |
| Aug 06 | 08 | 1500-1831 | 3.7 | Clear, Winds 060/5 mps at start, backing to 010 by end; PBL top: 2250' msl at 1520Z, 3100' at 1926Z, 3500' at 1635Z, 4000' at 1800Z, Altimeter 30.08 | - Smooth runs and control inputs at 9500'<br>- Descent sounding to 2000' msl<br>- PBL runs along south edge, 2000'<br>- L-pattern at 1600' msl<br>- L-pattern at 2100'<br>- L-pattern at 1600'<br>- L-pattern at 2100'<br>- L-pattern at 3200/3100'<br>- L-pattern at 1600'<br>- L-pattern at 3100'<br>- L-pattern at 1600'<br>- L-pattern at 1600'<br>- L-pattern at 3500'<br>- 2 Intercomparison runs with KingAir, 1900 and 1600' msl | <br><br>- FW6-FE6<br>- FE5-FW5, FS3-FN3<br>- FN3-FS3, FW5-FE5<br>- FE5-FW5, FS3-FN3<br>- FN3-FS3, FW5-FE5<br>- FE5-FW5, FS3-FN3<br>- FN3-FS3, FW5-FE5<br>- FE5-FW5, FS3-FN3<br>- FN3-FS3, FW5-FE5<br>- FE5-FW5, FS3-FN3<br>- FN3-FS3, FW5-FE5<br>- FE5-FW5, FW5-FE5 |

## TABLE 5 (cont): FIFE-89 FLIGHT SUMMARY - NAE TWIN OTTER

| DATE | FLT # | GMT | HRS | WEATHER | RUNS FLOWN | LOCATION Waypoints |
|---|---|---|---|---|---|---|
| Aug 06 | 09 | 1929-2237 | 3.3 | Mostly clear, a very few clouds, Winds N at 8-10 mps, becoming 020 at end of flight; PBL height: 5100' msl at 1935Z, 6000' at 2035, 5000' at 2200; Altimeter 30.10 | - Run at 4800', 300' below top of PBL<br>- Full 8-line grid, 1600' msl, working north to south<br>- Run at 5700', 300' below top of PBL (KingAir FE5-FW6 same time)<br>- Full 8-line grid, 1600' msl, working south to north<br>- Run at 4800', 200 ' below top of PBL<br>- Regional Run C at 500' agl | - FE0-FW0<br>- 8 east/west lines, (Fig. 6)<br>- FE6-FW6<br>- 8 east/west lines (Fig. 6)<br>- FW0-FE0<br>-FRE-FRW2 |
| Aug 07 | 10 | 1511-1848 | 3.8 | Mostly clear, a few thin clouds at 6000'decreasing; Cool; Winds NNE at 7 mps, PBL top almost constant at 6000'; Apparent longwave air motions, Altimeter 30.25. | - Regional Run C, (unuseable due to computer halts); attempted intercomp with NOAA Long-Easy<br>- Profile stack at 1600, 1900, 2900 and 5700' msl<br>- Profile stack at 5700, 2900, 1900, 1650, 1650, 1900, 2900 and 5700' msl<br>- Profile stack at 5700, 2900, 1900 and 1600' msl<br>- Sounding to 8000' msl<br>- Regional Run C at 500' agl (KingAir passes going other way) | - FRW2-FRE<br>- FE5-FW5<br>- FS2-FN2<br>- FE5-FW5<br>- FRE-FRW2 |
| Aug 08 | 11 | 1512-1830 | 3.5 | Clear to start, shallow clouds develop to 30%, Winds WNW and light: PBL height: 3100' at 1547Z, 4400' at 1608Z, 7000' at 1708Z, 7000' at 1746Z; Altimeter 30.15 | - Regional Run C, 500 agl with Long Easy in loose formation<br>- Run at 2900' msl<br>- 8-line grid at 1600' msl, working north to south<br>- Sounding climb to 7000'<br>- Run at 6500', below top of PBL<br>- 8-line grid at 1600' msl, working south to north<br>- Run at 7000' below top of PBL | - FRW2-FRE<br>- FW0-FE0<br>- 8 east/west lines (Fig. 6)<br>- FE6-FW6<br>- 8 east/west lines (Fig. 6)<br>- FW0-FE0 |
| Aug 08 | 12 | 1938-2209 | 2.7 | Shallow clouds based at 7900', reducing from about 30 to 5 % coverage, Winds light from the WNW; PBL height 7900' through flight, Altimeter 30.11 | - Run at 7500', below top of PBL<br>- 4-line minigrid, Tracks 2, 4, 6 and 8<br>- Climb sounding to 8600'<br>- Run at 7500', below top of PBL<br>- 4-line minigrid, Tracks 8,6,4, and 2<br>- Run at 7500', below top of PBL<br>- Regional Run C at 500' agl | - FNE-FNW<br>- 4 east/west lines (Fig. 6)<br>- FE6-FW6<br>- 4 east/west lines (Fig. 6)<br>- FNW-FNE<br>- FRE-FRW2 |
| Aug 10 | 13 | 1557-1938 | 3.8 | Variable cloud, including Cu at 6000', middle cloud and Ci; Winds south 7-8 mps; PBL height: 6000' at 1635Z, 6800' at 1850Z; Altimeter 30.13 | - Regional Run C at 500'<br>- Sounding to 7200' msl<br>- PBL run at 5700' msl<br>- 8-line grid, 1600' msl, working north to south<br>- PBL run at 6000' msl<br>- Second grid at 1600' msl working south to north- computer intermittent after 6 th line<br>- RTB | - FRW2-FRE<br>- FE0-FW0<br>- 8 east/west lines (Fig. 6)<br>- FE6-FW6<br>- 6 east/west lines (Fig. 6) |

**TABLE 5 (cont): FIFE-89 FLIGHT SUMMARY - NAE TWIN OTTER**

| DATE | FLT # | GMT | HRS | WEATHER | RUNS FLOWN | LOCATION Waypoints |
|---|---|---|---|---|---|---|
| Aug 10 | 14 | 0052-0310 (Aug 11) | 2.4 | Mostly clear, South winds 8 mps; Sodar PBL top: 150m agl at 0118Z, 125m agl at 0146Z, 90m agl at 0208Z and 120m at 0230Z; Altimeter 30.11 | - Night flight, descent soundng from 9500'<br>- Racetrack pattern, pair of runs at 1800' msl<br>- 5 pairs of runs at 1600' msl | <br>- FW2-FE2, FNE-FNW<br>- FW2-FE2, FNE-FNW |
| Aug 11 | 15 | 1619-2008 | 3.9 | Variable cloud, a few Cu based 6200-6500' msl, Upper thin layer at 8700'; PBL height; 5200' msl at 1708Z, 5900' at 1733Z, 6200' at 1920Z; Variable PBL height; Winds south 8-9 mps; Altimeter 30.18 | - Regional Run C at 500' agl in formation intercomparison with King Air<br>- Sounding from 7000'<br>- T-pattern; Profile stack at 1600, 1900, 2700 and 4800'msl<br>- Profile stack at 5000, 2800, 1900, 1650, 1650, 1900, 2800 and 5000' msl<br>- Profile stack at 5000, 2800, 1900 and 1600' msl<br>- Sounding climb to 9200' msl<br>- Regional Run C at 500' agl | - FRW2-FRE<br><br>- FNW-FNE<br>- FN2-FS2<br>-FNW-FNE<br>- Over FIFE site<br>- FRE-FRW2 |
| Aug 12 | 16 | 1556-1959 | 4.2 | Variable cloud, with Cu after 1700Z based at 6300' msl, PBL height: 4700' msl at 1643Z, 6300' at 1745Z, 6700' at 1900Z; Wind south 5 mps; Altimeter 30.13 | - Regional Run C in formation with King Air, 500' agl<br>- Sounding to 8000'msl<br>- PBL run at 4300' msl<br>- 8-line grid, 1600' msl, working north to south<br>- PBL run at 6000' msl<br>- 8-line grid , 1600' msl, working south to north<br>- PBL run at 6300' msl<br>- 2 Runs over Reservoir north of Manhattan, 200' agl<br>- Regional Run C at 500' agl | - FRW2-FRE<br><br>- FEO-FWO<br>- 8 east/west lines (Fig. 6)<br>- FE6-FW6<br>- 8 east/west lines (Fig. 6)<br>- FWO-FEO<br>- Reservoir<br>- FRE-FRW2 |
| Aug 14 | - | 1416-1655 | 2.7 | | - Transit, Salina-Peoria | |
| | | 1810-2058 | 2.8 | | - Transit, Peoria-London, Ont. | |
| | | 2206-2357 | 1.9 | | - Transit, London-Ottawa | |

**Total Flight Hours: 69.2**

## TABLE 6: TWIN OTTER FLIGHT SUMMARY TYPES AND NUMBERS OF RUNS

| Date | Flt | Hours | Flight Type | | | Number of Runs by Type[1] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Proj | Test | Tran | Grid | L/T | Line | Lid | Comp | Reg | Sound |
| Jul 20 | - | 5.5 | | | X | | | | | | | |
| 21 | 0 | 2.7 | | X | X | | 2 | | | | 1 | |
| 24 | - | 0.6 | | X | | | | | | | | |
| 25 | - | 0.6 | | X | | | | | | | | |
| 26 | - | 0.6 | | X | | | | | | | | |
| 27 | 01 | 3.0 | X | | | | 16 | | | | 1 | 2 |
| | 02 | 0.8 | X | | | | | | | | 1 | |
| 28 | 03 | 3.5 | X | | | 16 | | | 3 | | 1 | 1 |
| 31 | - | 0.5 | | X | | | | | | | | |
| Aug 02 | 04 | 3.7 | X | | | | 16 | | 1 | | 1 | 1 |
| 03 | 05 | 2.7 | X | | | | | 3 | 4 | | 2 | |
| 04 | 06 | 3.3 | X | | | 16 | | 3 | | | | 1 |
| | 07 | 3.0 | X | | | 16 | | 3 | | | 1 | |
| 06 | 08 | 3.7 | X | | | | 20 | 1 | | 2 | | 1 |
| | 09 | 3.3 | X | | | 16 | | 3 | | | 1 | |
| 07 | 10 | 3.8 | X | | | | 16 | | | | 2 | 1 |
| 08 | 11 | 3.5 | X | | | 16 | | 3 | | | 1 | 1 |
| | 12 | 2.7 | X | | | 8 | | 3 | | | 1 | 1 |
| 10 | 13 | 3.8 | X | | | 14 | | 2 | | | 1 | 1 |
| | 14 | 2.4 | X | | | | | 10 | | | | 1 |
| 11 | 15 | 3.9 | X | | | | 16 | | | 1 | 2 | 2 |
| 12 | 16 | 4.2 | X | | | 16 | | 5 | | 1 | 2 | 1 |
| 14 | - | 7.4 | | | X | | | | | | | |
| **Totals** | | **69.2** | **16** | | | **118** | **86** | **36** | **8** | **4** | **18** | **14** |

[1]**Types of Runs:**

- Grid — See Figure 4
- L/T — L or T shaped profiling runs at several altitudes
- Line — Other straight line runs, often to measure the top of the boundary layer
- Lidar — Intercomparison runs over LIDAR
- Comp — Intercomparison with NCAR King Air
- Reg — Regional run to/from Salina
- Sound — Sounding

TABLE 7 - INSTRUMENTATION PROBLEMS - TWIN OTTER - FIFE 1989

| Date | Flight | Description |
|---|---|---|
| Jul 21 | 00 | - Occasional event false event spike<br>- Radiometers and PRT-5 use 1987 calibration<br>- Licor self-calibration not correct on zero<br>- Spikes and 2 deg shifts on Noseboom total and static temperatures, also 2 deg shift s to the VHF transmissions |
| Jul 24 | - | - Event test; input induced event spikes, special jumper tests<br>- Licor self cal doesn't reach zero at 135 knots<br>- Spikes and steps on noseboom temperature, and affected by VHF transmissions |
| Jul 25 | - | - Event test using PK9CFX and event circuitry bypassed<br>- many serious problems after short of 15 volt power supply<br>- no Loran on tape<br>- HDGT is degrees magnetic<br>- TASNB U/S because of PDNB and problem with airspeed switch circuitry<br>- TTF and TTN purposely swapped at input to signal conditioning: proved that noise spikes on card, no probe: radio transmission problems on probe or installation<br>- Licor doesn't get proper zero consistently; better at low airspeeds |
| Jul 26 | - | - Noise spikes and steps on TTN and TSN; also 2 deg shifts with VHF transmissions<br>- File 1 uses PK9CF1, in which raw event buffer replaces Litton latitude mintes on Channel 8; other two files OK using PK9CE1 or PK9CH1<br>- Licor uses 30 seconds for each gas; doesn't always get proper zero |
| Jul 27 | 01 | - Litton winds and HDGTL not correct, possibly due to a wrong latitude on alignment; must use Doppler winds; WEP may be OK<br>- L event shows when E event on; Causes YLAT =0 and error in corrected radiation when event marker on for programs before Aug 5 (inclusive).<br>- Noise spikes and steps on TTN and TSN; also 2 deg shifts with radio transmissions<br>- PRT-5, upward and downward radiometers use 1987 calibration.<br>- Occasional spike on dew point<br>- Bursts of spikes on various other parameters, including TTF,TSF, PSF, Dew Point, PDNB, PDF, (indicate a return of the Moosonee problem)<br>- Licor fluxes don't agree well with ESRI. Pump may have started deterioration. |
| Jul 27 | 02 | - L event shows when E event on; Causes YLAT =0 and errors in corrected RADUP readings for programs before August 05 (inclusive).<br>- Noise spikes and steps on TTN and TSN; also 2 deg shifts with VHF transmissions<br>- PRT-5, upward and downward radiometers use 1987 calibration.<br>- Licor may not be reliable due to deteriorating pump |
| Jul 28 | 03 | - L event shows when E event on: Causes YLAT=0 and errors in corrected RADUP in programs before August 05 (inclusive)<br>- PRT-5, upward and downward radiometers use 1987 calibrations<br>- Licor pump has broken diaphram;, Licor not useable<br>- TTN and TSN has 2 deg shifts due to VHF transmissions |
| Jul 31 | - | - TTN and TSN spikes and steps for VHF transmission; Stepped off 1.5 deg for 8 minutes between two transmissions<br>- Licor self cal not always to zero |
| Aug 02 | 04 | - Licor self cal not always zero<br>- TTN and TSN has steps due to radio transmissions<br>- Probe heater switch off, TAS flashing at end run 02<br>- Haze lowers greenness index readings for higher altitude runs<br>- Bad block of data, approximately 1522Z<br>- Some spikes, evidence of the Moosonee problem |

**TABLE 7 (Cont)**

| | | |
|---|---|---|
| Aug 03 | 05 | - TTN and TSN have radio transmissio interference<br>- Probe heater switch cycling for about 2 minutes after takeoff<br>- Bad block of data about 1903Z |
| Aug 04 | 06 | - TTN and TSN have radio transmission interference<br>- Litton drifted 3 miles south<br>- Computer halt at location 027336 at 1454Z; Message about stack overflow. Repeated this run, which was the first of the morning grid |
| Aug 04 | 07 | - TTN and TSN have radio transmission interference<br>- TAS, PSF disturbances at 2116Z during inputs. May be Moosonee problem.<br>- LICOR U/S after 1919Z; tube from pump to analyzer disconnected<br>- ESRI $CO_2/H_2O$ analyzer nserviceable after 2105Z (last run)<br>- Insect remains on noseboom probe; Alpha and beta apear OK in control inputs |
| Aug 06 | 08 | - Computer halt at 162644Z<br>- TTN and TSN have radion transmission interference<br>- 2 mile Litton drift to south during flight |
| Aug 06 | 09 | - Computer halt at 212218Z<br>- TTN and TSN have radio transmission interference |
| Aug 07 | 10 | - Computer halt at 152913Z and at 162501Z<br>- Additional halt at about 1533 using older program PK9CF1<br>- TTN and TSN have radio transmission interference<br>- Doppler VY problem at 1735Z (Run 13): VY wrong sign |
| Aug 08 | 11 | - TTN and TSN radio interference<br>- Some evidence of the Moosonee problem, spikes on parameters handled by original D/A circuitry |
| Aug 08 | 12 | - Computer halt on taxi and just after takeoff; Recorder started at 1940Z, 2 minutes after takeoff<br>- Reload program at 2048Z; 2 minute gap in recorded data<br>- Doppler horizontal winds not correct on westerly headings: Doppler VY not going to negative readings when drift to left<br>- TASNB spikes from at least 2054-2114Z, especially Runs 07-09: Causes spikes in Alpha, winds<br>- Similar spikes in all parameters on original A/D; i.e, the Moosonee Problem |
| Aug 10 | 13 | - Computer halts several times after 1836Z- Abort rest of flight<br>- Moosonee spikes, possibly affecting computer<br>- TTN and TSN radio interference |
| Aug 10 | 14 | - TTN and TSN radio interference<br>- No EOF on tape |
| Aug 11 | 15 | - TTN and TSN radio interference<br>- Doppler VY problem on Run 14; Doppler and Lit/Dop winds inaccurate for this run |
| Aug 12 | 16 | - TTN and TSN radio interference<br>- Doppler VY problem ,intermittent; Affects Doppler windson several runs<br>- Licor self calibration not always to near zero<br>- Greenness Index unserviceable from 1628-1645Z, i.e. near end of second segment of first regional run |

## TABLE 8: FORMAT FOR DATA ARCHIVE - FIFE 89

Each file consists of 8 lines of data for each flux run. The first line gives flight and run identification. This is followed by seven data lines, which will be described below along with the formats used. Data from the three flux aircraft will be in this format. Unavailable data will be replaced by a string of 9's.

| LINE# | GROUP | PARAMETERS | UNITS | FORMAT | COMMENTS |
|---|---|---|---|---|---|
| 1 | IDENT | ' NAE' | - | A4 | -IDENTIFIES NAE TWIN OTTER |
| | | FLIGHT DATE, YYMMDD | - | 1X,A6 | - FLIGHT DATE |
| | | MISSION OF DAY, EG ' MISSION 1/2 | - | A12 | - FLIGHT OF THE DAY |
| | | RUN NUMBER | - | 1X,A6 | - NAE RUN NUMBER |
| 2 | TIME, LOCATION & RUN MEANS | RUN START TIME | CDT | 1X,6I1 | |
| | | " | GMT | 1X,6I1 | |
| | | STARTING LATITUDE | DEG,MIN | F7.1 | - EG,' 4357.2' |
| | | STARTING LONGITUDE | " | F7.1 | |
| | | RUN END TIME | CDT | 1X,6I1 | |
| | | ENDING LATITUDE | DEG, MIN | F7.1 | |
| | | ENDING LONGITUDE | " | F7.1 | |
| | | AIRCRAFT HEADING, TRUE | DEG TRUE | F5.0 | |
| | | MEAN PRESSURE ALTITUDE | M | F6.0 | - ADJUSTED FOR ALTIMETER SETTING |
| | | MEAN RADAR ALTITUDE | M | F6.0 | |
| | | MEAN TEMP | DEG C | F7.2 | - FROM TSC ( CH 36) |
| | | MEAN POTENTIAL TEMPERATURE | DEG K | F7.2 | - CALC FROM TSC AND PSNBC |
| | | MEAN MIXING RATIO | GM/KG | F6.2 | - CALC FROM DEW POINT, TSC & PSNBC GM OF H2O PER KG DRY AIR |
| | | MEAN NORTH/SOUTH WIND, + FROM SOUTH | M/S | F7.2 | - NEGATIVE OF UGE (CH 16 ABOVE) |
| | | MEAN EAST/WEST WIND, + FROM WEST | M/S | F7.2 | - NEGATIVE OF VGE (CH 17 ABOVE) |
| | | MEAN PRESSURE | MB | F7.1 | - PSNBC (CH 35) |
| | | MEAN PRT-5 SURFACE TEMP | DEG C | F5.1 | - CH 25 |
| | | MEAN DOWNWELLING RADIATION | W/M2 | F6.0 | - CH 26 ( INCIDENT) |
| | | MEAN UPWELLING RADIATION | W/M2 | F5.0 | - CH 27 ( REFLECTED) |
| | | MEAN GREENNESS INDEX | - | F5.2 | - CH 37 |
| 3 | RMS ASSOCIATED WITH ABOVE MEANS | RMS TEMPERATURE | DEG C | F5.2 | |
| | | RMS POTENTIAL TEMP | DEG K | F5.2 | |
| | | RMS MIXING RATIO | GM/KG | F5.2 | - FROM DEW POINT, TSC AND PSNBC |
| | | RMS NORTH/SOUTH WIND | M/S | F5.2 | |
| | | RMS EAST/WEST WIND | M/S | F5.2 | |
| | | RMS PRESSURE | MB | F4.1 | |
| | | RMS SURFACE TEMPERATURE | DEG C | F5.1 | |
| | | RMS DOWNWELLING RADIATION | W/M2 | F5.0 | |
| | | RMS UPWELLING RADIATION | W/M2 | F5.0 | |
| | | RMS GREENNESS INDEX | - | F5.2 | |

## TABLE 8 (cont)

| | | | | |
|---|---|---|---|---|
| 4 LINEAR TRENDS | TREND IN TEMPERATURE | DEG C/M | , 1X,E10.3 | - TREND PER METER (GROUND SPEED) |
| | TREND IN POTENTIAL TEMP | DEG K/M | E10.3 | |
| | TREND IN MIXING RATIO | GM/KG/M | E10.3 | - DERIVED FROM DEW POINT |
| | TREND IN NORTH/SOUTH WIND | M/S/M | E10.3 | |
| | TREND IN EAST/WEST WIND | M/S/M | E10.3 | |
| | TREND IN PRESSURE | MB/M | E10.3 | |
| | TREND IN SURFACE TEMPERATURE | DEG C/M | E10.3 | |
| | TREND IN DOWNWELLING RADIATION | W/M2/M | E10.3 | |
| | TREND IN UPWELLING RADIATION | W/M2/M | E10.3 | |
| | TREND IN GREENNESS INDEX | 1/M | E10.3 | |
| 5 RMS TURBULENT *UNFILTERED* | RMS VERTICAL GUST VELOCITY | M/S | F5.2 | - WGE, DOPPLER/INERTIAL WIND |
| | RMS NORTH/SOUTH GUST VELOCITY | M/S | F5.2 | - UGE |
| | RMS EAST/WEST GUST VELOCITY | M/S | F5.2 | - VGE |
| | RMS ALONG-WIND COMPONENT | M/S | F5.2 | - ALONG RUN-MEAN WIND DIRECTION |
| | RMS ACROSS WIND COMPONENT | M/S | F5.2 | - ACROSS RUN-MEAN WIND DIRECTION |
| | RMS POTENTIAL TEMPERATURE | DEG K | F5.2 | |
| | RMS H2O MIXING RATIO (H2O ANALYZER) | GM/KG | F5.2 | - NOTE** FROM H2O ANALYZER IN DUCT DERIVED FROM CH 29, 34 AND 24 |
| | RMS CO2 MIXING RATIO (CO2 ANALYZER | MG/KG | F5.2 | - MG OF CO2 PER KG DRY AIR IN DUCT DERIVED FROM CH 28, 24, 34 AND 29 |
| 6 RMS TURBULENT * FILTERED* | SAME 8 PARAMETERS AS ABOVE, BUT HIGH PASS FILTERED AT 5 KM WAVELENGTH ( SEE NOTE 1) | | " | |
| 7 FLUXES *FILTERED* (NOTE 2) | NORTH/SOUTH MOMENTUM FLUX | N/M2 | F6.2 | - POSITIVE WIND FROM SOUTH |
| | EAST/WEST MOMENTUM FLUX | N/M2 | F6.2 | - POSITIVE WIND FROM WEST |
| | MOMENTUM FLUX ALONG MEAN WIND DIRECTION | N/M2 | F6.2 | - THE TRADITIONAL UW |
| | MOMENTUM FLUX ACROSS " " | N/M2 | F6.2 | - THE TRADITIONAL VW |
| | SENSIBLE HEAT FLUX | W/M2 | F6.0 | - FROM WGE & POTENTIAL TEMP |
| | LATENT HEAT FLUX | W/M2 | F6.0 | - FROM H2O ANALYZER |
| | CARBON DIOXIDE FLUX | KG/HA/H | F6.1 | - KILOGRAMS PER HECTARE PER HOUR |
| 8 CORRELATION | CORRELATION COEFFICIENTS FOR THE ABOVE 7 PARAMETERS | | ALL F6.2 | |
| | PLUS, CC FOR MIXING RATIO*POTENTIAL TEMP | | F6.2 | |

** NOTE : THE FLUXES WERE DERIVED FROM HIGH-PASS FILTERED DATA USING A BREAKPOINT OF 0.012 HZ, WHICH CORRESPONDS TO A WAVELENGTH OF APPROXIMATELY 5 KM.

# TABLE 9: TWIN OTTER DATA - FIFE-89

The data presented in each column of the following tables are described below:

| Column Heading | Units | Explanation |
|---|---|---|
| **Run Averages** | | |
| ST GMT | - | Greenwich Mean Time at the start of the run (Central Daylight Time plus 5 hours) |
| SEC | sec | Duration of the run |
| DIST | km | Length of the run (integrated ground speed) |
| PALT | m | Pressure altitude above sea level (has been corrected for altimeter setting) |
| RALT | m | Radio altimeter height above the ground |
| TEMP | deg C | Static temperature |
| DEWPT | deg C | Dew point temperature |
| PRT5 | deg C | Surface temperature |
| GRN | - | Greenness Index from Skye Industries sensor |
| RADUP | $W\ m^{-2}$ | Incident radiation from Kipp and Zonen CM-11, corrected for aircraft attitude angles |
| LICOR | $mg\ m^{-3}$ | $CO_2$ mean concentration from LI-COR slow-response analyzer, uncorrected |
| HDG<br>HDGL | deg T | Aircraft true heading from C-12 compass;<br>from Litton IRS |
| WIND,<br>WINDLD | deg T<br>$ms^{-1}$ | Mean wind direction and wind speed;<br>WINDLD from LIT/DOP winds |
| **RMS** | | **RMS of fluctuations in:** |
| UGE<br>UGEL | $ms^{-1}$ | North/south wind component,<br>UGE from NAE/DOP winds, UGEL from Litton Winds |
| VGE<br>VGEL | $ms^{-1}$ | East/west wind component,<br>VGE from NAE/DOP winds, VGEL from Litton Winds |
| WGE<br>WEP | $ms^{-1}$ | Vertical wind component; WGE from NAE/DOP winds, WEP from Litton winds |
| TS | deg C | Temperature |
| CO2 | $mg\ m^{-3}$ | $CO_2$ from fast-response ESRI Analyzer |
| H2O | $g\ m^{-3}$ | $H_2O$ from fast-response ESRI analyzer |
| **Fluxes** | | |
| WT | $W\ m^{-2}$ | Sensible heat flux |
| WC | kg/h•hr | $CO_2$ flux in kilograms per hectare per hour (36 times the flux in $mg \cdot m^{-2}$ per second) |
| WQ | $W\ m^{-2}$ | Latent heat flux (water vapour) |
| UW | $N\ m^{-2}$ | Momentum flux |
| Z/L | - | Stability parameter, height above ground divided by the Obhukov Scale Length |

NAE C-FPOK , FILE 2ARCFIFE89 (01 AUG 89), FLIGHT DAT 27-JUL-89 PRINT DATE 01-AUG-89 FIFE-01, 4TH PRINT, DOP WITH WEP,TSF

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200

| RUN AVERAGES | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP $W/m^2$ | LICOR $mg/m^3$ | HDG T | WIND T | WIND $ms^{-1}$ | UGE $ms^{-1}$ | VGE $ms^{-1}$ | WGE $ms^{-1}$ | TS degC | CO2 $mg/m^3$ | H2O $gm/m^3$ | WT $W/m^2$ | WC kg/hh | WQ $W/m^2$ | UW $N/m^2$ | Z/L |
| REGIONAL RUN B, 500 ' AGL | | | | | | | | | | | | | | | | | | | | | | | | |
| 153730. | 536. | 35.52 | 529. | 166. | 24.80 | 18.46 | 36.5 | 1.33 | 645. | 595.9 | 071 | 223 | 4.7 | 0.79 | 0.82 | 0.98 | 0.14 | 1.1 | 0.17 | 93. | -5.2 | 191. | -0.17 | -3.4 |
| 154633. | 543. | 37.56 | 550. | 163. | 25.16 | 18.44 | 33.4 | 1.78 | 608. | 588.8 | 074 | 235 | 5.5 | 0.90 | 0.88 | 0.95 | 0.18 | 1.3 | 0.14 | 97. | -12.9 | 160. | -0.26 | -1.9 |
| PROFILING STACKS, T-PATTERN | | | | | | | | | | | | | | | | | | | | | | | | |
| EAST/WEST FNW3-FNE3 | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 525. | 317. | 15.95 | 500. | 100. | 26.07 | 18.68 | 35.1 | 1.93 | 730. | 590.2 | 267 | 234 | 5.3 | 0.92 | 0.93 | 0.79 | 0.17 | 1.4 | 0.15 | 90. | -11.8 | 168. | -0.11 | -3.9 |
| 161254. | 273. | 15.95 | 586. | 194. | 25.26 | 18.30 | 35.3 | 1.87 | 769. | 583.4 | 095 | 234 | 6.3 | 0.83 | 0.87 | 0.85 | 0.12 | 1.1 | 0.14 | 63. | -10.4 | 87. | 0.03 | 37.3 |
| 1620 4. | 312. | 15.69 | 803. | 412. | 23.15 | 17.64 | 34.7 | 1.87 | 772. | 567.7 | 266 | 235 | 5.1 | 0.78 | 0.76 | 0.95 | 0.07 | 0.9 | 0.19 | 12. | -4.3 | 146. | 0.04 | 13.4 |
| 1628 8. | 261. | 15.85 | 1227. | 830. | 19.23 | 16.17 | 33.2 | 1.72 | 780. | 539.3 | 094 | 237 | 6.0 | 0.68 | 0.78 | 0.67 | 0.16 | 0.9 | 0.47 | -3. | 0.9 | 115. | -0.13 | -1.3 |
| 173929. | 278. | 15.35 | 1602. | 1205. | 16.69 | 14.79 | 35.2 | 1.68 | 785. | 513.8 | 268 | 218 | 4.2 | 0.73 | 0.92 | 0.70 | 0.16 | 0.6 | 0.23 | -9. | 0.2 | 57. | 0.06 | -3.9 |
| 174644. | 260. | 15.99 | 841. | 450. | 24.27 | 16.59 | 39.3 | 1.81 | 830. | 562.9 | 097 | 235 | 5.6 | 0.93 | 1.03 | 1.12 | 0.10 | 0.9 | 0.11 | 69. | -9.6 | 131. | 0.13 | 10.8 |
| 175320. | 295. | 15.75 | 599. | 197. | 26.84 | 16.99 | 37.9 | 1.85 | 696. | 579.5 | 269 | 225 | 4.4 | 0.97 | 0.83 | 0.97 | 0.13 | 1.1 | 0.12 | 90. | -11.3 | 105. | -0.10 | -8.1 |
| 18 016. | 254. | 15.48 | 508. | 105. | 27.88 | 17.18 | 39.2 | 1.89 | 788. | 585.8 | 096 | 230 | 5.0 | 0.98 | 0.86 | 0.82 | 0.19 | 1.2 | 0.15 | 104. | -10.6 | 132. | -0.10 | -4.9 |
| NORTH/SOUTH FN2-FS2 | | | | | | | | | | | | | | | | | | | | | | | | |
| 163852. | 307. | 16.70 | 1318. | 911. | 18.55 | 15.83 | 33.1 | 1.78 | 723. | 533.2 | 184 | 238 | 5.0 | 0.75 | 0.76 | 0.76 | 0.16 | 0.8 | 0.50 | -17. | 1.4 | 244. | -0.13 | -0.1 |
| 164614. | 290. | 17.22 | 802. | 402. | 23.76 | 17.28 | 36.2 | 1.88 | 760. | 567.1 | 000 | 230 | 5.2 | 0.74 | 0.94 | 1.13 | 0.11 | 1.1 | 0.19 | 72. | -11.0 | 226. | -0.15 | -8.2 |
| 1653 3. | 315. | 17.14 | 590. | 185. | 26.09 | 17.49 | 35.6 | 1.91 | 631. | 580.8 | 189 | 244 | 5.1 | 0.93 | 0.99 | 0.98 | 0.15 | 1.3 | 0.26 | 100. | -15.5 | 297. | -0.21 | -3.1 |
| 17 0 2. | 282. | 16.67 | 507. | 94. | 27.09 | 17.60 | 36.0 | 1.95 | 671. | 585.4 | 001 | 228 | 4.6 | 1.11 | 0.99 | 0.85 | 0.21 | 1.6 | 0.24 | 102. | -15.3 | 257. | -0.05 | -15.0 |
| 17 638. | 321. | 16.84 | 531. | 122. | 26.95 | 17.48 | 37.7 | 1.94 | 779. | 582.8 | 187 | 243 | 4.4 | 1.17 | 1.08 | 0.93 | 0.15 | 1.3 | 0.16 | 90. | -16.0 | 172. | -0.18 | -2.2 |
| 1714 8. | 278. | 16.25 | 587. | 177. | 26.48 | 17.19 | 37.1 | 1.97 | 700. | 578.4 | 000 | 231 | 5.1 | 1.17 | 0.88 | 1.00 | 0.16 | 1.3 | 0.20 | 118. | -18.7 | 241. | -0.11 | -8.6 |
| 172143. | 316. | 16.86 | 802. | 402. | 24.35 | 16.64 | 36.1 | 1.86 | 744. | 563.4 | 189 | 243 | 4.6 | 0.92 | 1.02 | 1.22 | 0.09 | 1.1 | 0.19 | 56. | -12.7 | 248. | -0.13 | -8.6 |
| 173028. | 275. | 16.48 | 1329. | 922. | 19.21 | 15.14 | 34.5 | 1.76 | 747. | 529.8 | 001 | 228 | 5.0 | 0.88 | 0.83 | 0.88 | 0.09 | 0.9 | 0.24 | -9. | 1.7 | 165. | 0.24 | 0.2 |

TABLE 9(a): TWIN OTTER DATA - FIFE89 FLIGHT 01 - 27 JULY, 1989

**NAE C-FPOK , FILE 1ARCFIFE89 (01 AUG 89), FLIGHT DAT 27-JUL-89 PRINT DATE 01-AUG-89 FIFE-02, PRINT 2, REGIONAL RUN C**

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200

| RUN AVERAGES | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP $W/m^2$ | LICOR $mg/m^3$ | HDGL T | WINDLD T | $ms^{-1}$ | UGEL $ms^{-1}$ | VGEL | WEP | TS degC | CO2 $mg/m^3$ | H2O $gm/m^3$ | WT $W/m^2$ | WC kg/hh | WQ $W/m^2$ | UW $N/m^2$ | Z/L |
| REGIONAL RUN C | | | | | | | | | | | | | | | | | | | | | | | | |
| 191823. | 657. | 40.08 | 575. | 163. | 28.09 | 16.73 | 42.8 | 1.66 | 721. | 581.4 | 235 | 200 | 5.5 | 1.04 | 1.11 | 1.10 | 0.21 | 1.1 | 0.14 | 163. | -7.3 | 117. | -0.14 | -7.0 |
| 192927. | 643. | 38.74 | 557. | 158. | 28.17 | 16.87 | 43.2 | 1.47 | 744. | 583.4 | 235 | 190 | 6.5 | 1.04 | 1.16 | 1.10 | 0.20 | 1.1 | 0.14 | 140. | -11.9 | 183. | -0.21 | -3.4 |

## TABLE 9(b): TWIN OTTER DATA - FIFE89 FLIGHT 02 - 27 JULY, 1989

NAE C-FPOK , FILE 1ARCFIFE89 (05 AUG 89), FLIGHT DAT 28-JUL-89 PRINT DATE 06-AUG-89 FIFE -03, PRINT 4

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200

| RUN AVERAGES | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP W/m² | LICOR mg/m³ | HDGL T | T | WINDLD ms⁻¹ | UGEL ms⁻¹ | VGEL | WEP | TS degC | CO2 mg/m³ | H2O gm/m³ | WT W/m² | WC kg/hh | WQ W/m² | UW N/m² | Z/L |
| CONTROL INPUTS, 9500' | | | | | | | | | | | | | | | | | | | | | | | | |
| 145453. | 23. | 1.57 | 2932. | * | 10.10 | -0.71 | 30.1 | 1.16 | 570. | * | 082 | 188 | 6.7 | 0.06 | 0.13 | 0.13 | 0.02 | 0.4 | 0.08 | -1. | 0.1 | -5. | 0.00 | -464.3 |
| 145523. | 18. | 1.24 | 2934. | * | 10.04 | -0.14 | 29.9 | 1.15 | 578. | * | 082 | 184 | 6.4 | 0.53 | 0.11 | 0.09 | 0.02 | 0.7 | 0.08 | 0. | -0.7 | -6. | 0.01 | -12.0 |
| 145546. | 17. | 1.16 | 2932. | * | 9.72 | 1.62 | 28.4 | 1.15 | 582. | * | 080 | 182 | 7.0 | 0.15 | 0.08 | 0.05 | 0.03 | 0.4 | 0.13 | 0. | -0.1 | 2. | 0.00 | 14.8 |
| LIDAR INTERCOMP, 235 MAG HEADING | | | | | | | | | | | | | | | | | | | | | | | | |
| 151210. | 300. | 18.16 | 544. | 160. | 25.61 | 18.28 | 34.0 | 1.84 | 618. | * | 234 | 198 | 4.2 | 0.83 | 0.73 | 0.85 | 0.12 | 1.1 | 0.21 | 71. | -6.3 | 232. | -0.11 | -5.3 |
| 152347. | 281. | 17.26 | 859. | 485. | 22.61 | 17.36 | 33.8 | 1.75 | 648. | * | 237 | 196 | 4.3 | 0.76 | 0.71 | 1.09 | 0.13 | 0.9 | 0.45 | 50. | -2.6 | 407. | -0.32 | -2.9 |
| 153511. | 274. | 17.38 | 1228. | 849. | 19.71 | 14.77 | 33.6 | 1.65 | 687. | * | 236 | 186 | 5.5 | 0.77 | 0.75 | 0.66 | 0.34 | 1.6 | 0.94 | -64. | 11.2 | 517. | -0.13 | 6.2 |
| GRID A, WORKING SOUTH TO NORTH, 1600' MSL | | | | | | | | | | | | | | | | | | | | | | | | |
| 154359. | 274. | 15.59 | 495. | 76. | 26.53 | 18.46 | 35.2 | 2.06 | 680. | * | 093 | 195 | 4.7 | 0.90 | 1.00 | 0.83 | 0.19 | 1.5 | 0.26 | 111. | -16.9 | 284. | -0.14 | -2.6 |
| 155024. | 296. | 16.42 | 495. | 79. | 26.63 | 18.39 | 35.2 | 2.12 | 698. | * | 264 | 184 | 4.3 | 0.90 | 1.01 | 0.81 | 0.17 | 1.7 | 0.29 | 101. | -17.4 | 251. | -0.21 | -1.3 |
| 155740. | 282. | 15.90 | 498. | 89. | 26.71 | 18.36 | 34.6 | 2.25 | 704. | * | 093 | 188 | 4.5 | 0.82 | 1.01 | 0.76 | 0.15 | 1.5 | 0.25 | 73. | -17.1 | 221. | -0.17 | -1.5 |
| 16 339. | 288. | 15.90 | 494. | 92. | 26.98 | 18.39 | 35.7 | 2.12 | 723. | * | 263 | 178 | 4.4 | 1.00 | 1.15 | 0.89 | 0.19 | 2.3 | 0.30 | 135. | -22.3 | 274. | -0.26 | -1.5 |
| 161034. | 289. | 15.95 | 493. | 85. | 27.10 | 18.38 | 37.2 | 1.84 | 730. | * | 094 | 183 | 5.1 | 0.94 | 1.00 | 0.87 | 0.19 | 1.7 | 0.28 | 120. | -22.5 | 271. | -0.15 | -2.8 |
| 161652. | 290. | 15.84 | 496. | 96. | 27.09 | 18.23 | 37.0 | 2.05 | 749. | * | 262 | 169 | 4.5 | 0.73 | 1.06 | 0.82 | 0.16 | 1.3 | 0.21 | 92. | -14.0 | 212. | -0.04 | -19.6 |
| 162326. | 293. | 15.81 | 496. | 104. | 27.23 | 18.17 | 38.5 | 1.93 | 755. | * | 093 | 181 | 4.9 | 0.82 | 0.98 | 0.84 | 0.17 | 1.2 | 0.19 | 96. | -14.9 | 179. | -0.07 | -7.7 |
| 162955. | 281. | 15.85 | 496. | 125. | 27.37 | 18.08 | 38.6 | 1.89 | 770. | * | 264 | 169 | 4.7 | 0.83 | 1.14 | 0.98 | 0.19 | 1.4 | 0.18 | 149. | -18.6 | 220. | -0.11 | -7.7 |
| GRID B, WORKING NORTH TO SOUTH, 1600' MSL | | | | | | | | | | | | | | | | | | | | | | | | |
| 163616. | 283. | 15.63 | 501. | 130. | 27.42 | 17.98 | 40.6 | 1.73 | 778. | * | 093 | 176 | 5.2 | 0.88 | 1.10 | 1.00 | 0.18 | 1.2 | 0.29 | 137. | -15.4 | 181. | -0.06 | -16.4 |
| 164251. | 280. | 15.63 | 505. | 103. | 27.32 | 18.15 | 39.1 | 1.93 | 794. | * | 262 | 168 | 5.2 | 0.85 | 1.07 | 0.88 | 0.19 | 1.2 | 0.19 | 115. | -14.1 | 155. | -0.10 | -5.7 |
| 164913. | 287. | 15.72 | 507. | 107. | 27.38 | 18.26 | 39.2 | 1.97 | 802. | * | 094 | 174 | 5.0 | 0.94 | 1.07 | 0.96 | 0.19 | 1.3 | 0.23 | 122. | -16.8 | 220. | -0.11 | -5.7 |
| 165525. | 278. | 15.61 | 508. | 100. | 27.31 | 18.14 | 39.4 | 1.83 | 759. | * | 262 | 168 | 4.8 | 0.93 | 1.05 | 0.87 | 0.16 | 1.4 | 0.21 | 105. | -19.0 | 241. | -0.24 | -1.4 |
| 17 142. | 275. | 15.06 | 505. | 91. | 27.38 | 18.23 | 39.1 | 2.01 | 835. | * | 092 | 171 | 5.0 | 1.00 | 1.07 | 0.90 | 0.17 | 1.6 | 0.21 | 95. | -20.5 | 255. | -0.11 | -3.9 |
| 17 8 6. | 290. | 16.09 | 507. | 92. | 27.49 | 18.31 | 39.7 | 2.19 | 844. | * | 264 | 163 | 4.4 | 0.94 | 1.20 | 0.88 | 0.20 | 1.5 | 0.22 | 122. | -18.1 | 204. | -0.17 | -2.4 |
| 171414. | 306. | 16.23 | 504. | 88. | 27.64 | 18.38 | 40.4 | 1.98 | 811. | * | 093 | 170 | 4.9 | 1.11 | 1.11 | 0.90 | 0.22 | 1.5 | 0.23 | 134. | -18.2 | 230. | -0.26 | -1.3 |
| 172110. | 273. | 15.15 | 508. | 83. | 27.57 | 18.30 | 40.8 | 2.00 | 828. | * | 264 | 162 | 5.0 | 0.85 | 1.09 | 0.94 | 0.21 | 1.4 | 0.28 | 124. | -13.3 | 213. | -0.13 | -3.6 |
| REGIONAL RUN C, 500' AGL | | | | | | | | | | | | | | | | | | | | | | | | |
| 173226. | 633. | 39.73 | 572. | 159. | 27.34 | 17.81 | 43.9 | 1.72 | 819. | * | 235 | 164 | 5.0 | 0.98 | 1.22 | 1.19 | 0.21 | 1.2 | 0.21 | 190. | -11.5 | 216. | -0.10 | -14.2 |
| 1743 9. | 633. | 39.00 | 560. | 164. | 27.32 | 18.32 | 43.9 | 1.52 | 802. | * | 235 | 171 | 5.6 | 1.03 | 1.26 | 1.17 | 0.19 | 1.1 | 0.20 | 169. | -12.2 | 247. | -0.19 | -4.8 |

TABLE 9(c): TWIN OTTER DATA - FIFE89 FLIGHT 03 - 28 JULY, 1989

NAE C-FPOK , FILE 1ARCFIFE89 (01 AUG 89), FLIGHT DAT 02-AUG-89 PRINT DATE 02-AUG-89 FIFE-04, L-PATTERN, LIDR, REG C

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200

| RUN AVERAGES | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP $W/m^2$ | LICOR $mg/m^3$ | HDGL T | WINDLD T | $ms^{-1}$ | UGEL $ms^{-1}$ | VGEL | WEP degC | TS | CO2 $mg/m^3$ | H2O $gm/m^3$ | WT $W/m^2$ | WC kg/hh | WQ $W/m^2$ | UW $N/m^2$ | Z/L |
| NORTH/SOUTH RUNS, FS3-FN3 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1600 ' MSL | | | | | | | | | | | | | | | | | | | | | | | | |
| 152631. | 203. | 12.74 | 531. | 146. | 24.31 | 20.66 | 30.2 | 1.63 | 577. | 597.1 | 000 | 168 | 8.3 | 1.41 | 0.55 | 0.65 | 0.08 | 1.0 | 0.11 | 33. | -6.8 | 82. | 0.12 | 1.8 |
| 155516. | 232. | 13.90 | 502. | 119. | 25.08 | 20.73 | 32.3 | 1.72 | 559. | 596.9 | 002 | 165 | 6.9 | 0.73 | 0.68 | 0.87 | 0.15 | 1.3 | 0.16 | 99. | -21.6 | 230. | -0.29 | -1.2 |
| 164416. | 309. | 15.30 | 506. | 125. | 25.96 | 20.78 | 32.8 | 1.67 | 487. | 592.4 | 176 | 159 | 6.1 | 0.90 | 1.11 | 0.91 | 0.18 | 1.5 | 0.17 | 117. | -17.9 | 169. | -0.16 | -3.3 |
| 171235. | 322. | 15.05 | 506. | 122. | 26.37 | 20.73 | 31.6 | 1.59 | 407. | 590.4 | 177 | 167 | 6.3 | 0.76 | 0.73 | 0.76 | 0.11 | 1.2 | 0.13 | 56. | -12.3 | 80. | -0.17 | -1.4 |
| 200 ' BELOW CLOUD BASE | | | | | | | | | | | | | | | | | | | | | | | | |
| 154640. | 294. | 14.46 | 802. | 425. | 21.92 | 20.08 | 30.5 | 1.55 | 538. | 577.0 | 182 | 172 | 6.3 | 0.63 | 0.74 | 0.82 | 0.10 | 0.8 | 0.18 | -2. | -2.0 | 120. | -0.02 | -15.1 |
| 161541. | 300. | 14.94 | 804. | 433. | 22.31 | 20.13 | 31.0 | 1.55 | 527. | 574.8 | 176 | 166 | 6.0 | 0.77 | 0.73 | 0.80 | 0.09 | 1.0 | 0.19 | 17. | -8.4 | 103. | -0.03 | -26.6 |
| 162352. | 226. | 13.86 | 864. | 490. | 21.98 | 19.85 | 32.5 | 1.55 | 748. | 570.4 | 003 | 167 | 7.2 | 0.77 | 0.75 | 0.77 | 0.12 | 0.9 | 0.24 | -4. | -5.1 | 161. | -0.07 | -2.5 |
| 165343. | 231. | 14.63 | 927. | 553. | 21.83 | 19.76 | 31.1 | 1.49 | 540. | 563.9 | 002 | 169 | 7.6 | 0.79 | 0.69 | 0.86 | 0.08 | 1.1 | 0.16 | 28. | -11.7 | 149. | -0.16 | -4.8 |
| EAST/WEST RUNS, FNW-FNE | | | | | | | | | | | | | | | | | | | | | | | | |
| 1600' MSL | | | | | | | | | | | | | | | | | | | | | | | | |
| 153158. | 299. | 15.44 | 504. | 118. | 24.76 | 20.93 | 27.5 | 1.90 | 355. | 596.2 | 097 | 176 | 7.4 | 0.76 | 1.53 | 0.73 | 0.12 | 1.5 | 0.16 | 66. | -17.6 | 151. | -0.24 | -1.0 |
| 16 051. | 303. | 15.49 | 505. | 117. | 24.79 | 20.96 | 30.5 | 1.98 | 613. | 596.7 | 095 | 168 | 6.5 | 0.75 | 0.86 | 0.78 | 0.16 | 1.6 | 0.13 | 96. | -22.2 | 150. | -0.25 | -1.4 |
| 163734. | 269. | 15.36 | 508. | 113. | 25.12 | 20.87 | 30.5 | 1.97 | 548. | 593.9 | 262 | 153 | 6.6 | 0.83 | 0.77 | 0.75 | 0.13 | 1.5 | 0.18 | 65. | -18.7 | 143. | -0.20 | -1.3 |
| 17 625. | 276. | 15.43 | 508. | 111. | 25.94 | 20.85 | 32.6 | 2.00 | 659. | 589.7 | 261 | 157 | 7.0 | 0.90 | 1.03 | 0.98 | 0.17 | 2.0 | 0.19 | 111. | -31.7 | 301. | -0.31 | -1.2 |
| 200' BELOW CLOUD BASE | | | | | | | | | | | | | | | | | | | | | | | | |
| 153955. | 281. | 15.30 | 802. | 419. | 21.75 | 20.08 | 27.2 | 1.70 | 423. | 575.9 | 260 | 169 | 7.0 | 0.50 | 0.58 | 0.64 | 0.11 | 0.8 | 0.22 | -15. | 1.3 | 139. | -0.03 | 4.6 |
| 16 9 8. | 283. | 15.62 | 804. | 420. | 21.85 | 20.13 | 28.4 | 1.72 | 459. | 576.0 | 262 | 165 | 6.6 | 0.68 | 0.74 | 0.78 | 0.09 | 1.0 | 0.20 | 7. | -6.9 | 140. | -0.11 | -2.8 |
| 162952. | 301. | 15.94 | 864. | 488. | 21.57 | 19.80 | 29.6 | 1.67 | 602. | 571.4 | 096 | 168 | 7.4 | 0.68 | 0.68 | 0.62 | 0.10 | 1.1 | 0.22 | -6. | -5.3 | 152. | -0.12 | -0.7 |
| 165953. | 276. | 15.16 | 921. | 548. | 21.67 | 19.60 | 31.3 | 1.74 | 727. | 563.1 | 096 | 172 | 7.7 | 1.12 | 0.76 | 0.72 | 0.12 | 1.4 | 0.29 | -12. | -12.2 | 175. | -0.36 | 0.0 |
| LIDAR RUN, 205 MAG, 3400' MSL | | | | | | | | | | | | | | | | | | | | | | | | |
| 173654. | 392. | 18.79 | 1053. | 665. | 21.40 | 18.84 | 32.3 | 1.64 | 710. | 552.9 | 204 | 170 | 8.9 | 0.74 | 0.74 | 0.68 | 0.12 | 1.4 | 0.31 | -10. | -2.6 | 47. | 0.06 | -4.7 |
| REGIONAL RUN C, 500' AGL | | | | | | | | | | | | | | | | | | | | | | | | |
| 175130. | 628. | 39.02 | 579. | 171. | 26.37 | 20.22 | 33.2 | 1.80 | 652. | 582.4 | 231 | 161 | 8.6 | 0.94 | 0.93 | 0.99 | 0.15 | 1.6 | 0.20 | 97. | -21.0 | 253. | -0.35 | -1.3 |
| 18 2 4. | 659. | 39.75 | 554. | 160. | 27.08 | 20.36 | 36.5 | 1.42 | 605. | 583.9 | 231 | 161 | 9.0 | 0.90 | 0.99 | 1.01 | 0.16 | 1.5 | 0.18 | 121. | -20.3 | 210. | -0.31 | -1.7 |

TABLE 9(d): TWIN OTTER DATA - FIFE89 FLIGHT 04 - 02 AUGUST, 1989

NAE C-FPOK , FILE 1ARCFIFE89 (01 AUG 89), FLIGHT DAT 03-AUG-89 PRINT DATE 03-AUG-89 FIFE-05, 2 REG, 4 LIDAR, 3 RUNS,

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200

| RUN AVERAGES | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP $W/m^2$ | LICOR $mg/m^3$ | HDGL T | T | WINDLD $ms^{-1}$ | UGEL $ms^{-1}$ | VGEL | WEP | TS degC | CO2 $mg/m^3$ | H2O $gm/m^3$ | WT $W/m^2$ | WC kg/hh | WQ $W/m^2$ | UW $N/m^2$ | Z/L |
| 3 FAMILIARIZATION RUNS, FNE-FNW, FW2-FE2 AND FE6-FW6 | | | | | | | | | | | | | | | | | | | | | | | | |
| 174931. | 314. | 15.55 | 492. | 103. | 25.89 | 21.01 | 28.4 | 2.03 | 523. | 597.6 | 259 | 208 | 9.7 | 1.00 | 0.90 | 0.82 | 0.10 | 1.5 | 0.21 | 49. | -13.3 | 184. | -0.31 | -0.5 |
| 175637. | 273. | 16.05 | 496. | 99. | 25.99 | 21.10 | 29.1 | 1.99 | 621. | 597.4 | 097 | 209 | 10.4 | 1.12 | 1.12 | 0.81 | 0.12 | 1.6 | 0.18 | 47. | -18.0 | 191. | -0.39 | -0.3 |
| 18 510. | 346. | 16.25 | 493. | 81. | 26.49 | 20.72 | 30.0 | 2.14 | 707. | 596.2 | 258 | 211 | 10.4 | 1.15 | 0.98 | 0.84 | 0.16 | 1.6 | 0.21 | 84. | -15.2 | 252. | -0.39 | -0.5 |
| LIDAR RUNS, 235 BEARING | | | | | | | | | | | | | | | | | | | | | | | | |
| 1817 7. | 226. | 10.23 | 856. | 490. | 23.00 | 19.77 | 30.0 | 1.77 | 825. | 571.8 | 233 | 213 | 10.6 | 0.77 | 0.81 | 0.87 | 0.08 | 0.9 | 0.23 | 8. | 0.8 | 230. | -0.30 | -1.0 |
| 182558. | 416. | 19.03 | 852. | 482. | 23.32 | 19.86 | 32.8 | 1.63 | 818. | 571.0 | 236 | 213 | 10.7 | 0.75 | 0.79 | 0.83 | 0.08 | 0.8 | 0.18 | 14. | -0.6 | 150. | -0.14 | -3.2 |
| 184038. | 410. | 18.83 | 500. | 117. | 27.23 | 20.76 | 35.6 | 1.74 | 856. | 593.9 | 234 | 208 | 10.0 | 1.03 | 0.92 | 0.88 | 0.16 | 1.3 | 0.16 | 94. | -10.9 | 197. | -0.40 | -0.7 |
| 185453. | 401. | 18.72 | 1198. | 825. | 20.61 | 18.69 | 32.5 | 1.52 | 828. | 546.6 | 237 | 217 | 9.6 | 0.64 | 0.70 | 0.58 | 0.26 | 1.4 | 0.47 | -10. | 0.9 | 137. | -0.03 | -0.1 |
| REGIONAL RUN C, WEST TO EAST, 500' AGL | | | | | | | | | | | | | | | | | | | | | | | | |
| 172519. | 541. | 39.27 | 540. | 161. | 25.72 | 19.82 | 36.0 | 1.42 | 752. | 600.1 | 064 | 209 | 11.0 | 1.02 | 0.96 | 1.07 | 0.16 | 1.3 | 0.15 | 112. | -13.4 | 209. | -0.33 | -1.5 |
| 173433. | 539. | 38.77 | 554. | 160. | 25.03 | 20.57 | 29.3 | 1.94 | 625. | 596.9 | 064 | 209 | 10.6 | 0.94 | 0.90 | 0.84 | 0.11 | 1.3 | 0.21 | 53. | -11.5 | 226. | -0.35 | -0.7 |
| REGIONAL RUN C, EAST TO WEST, 500' AGL | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 940. | 729. | 39.49 | 569. | 164. | 26.99 | 20.68 | 33.6 | 1.86 | 756. | 587.4 | 233 | 207 | 10.4 | 1.01 | 0.89 | 0.97 | 0.12 | 1.3 | 0.15 | 71. | -12.3 | 171. | -0.30 | -1.1 |
| 192159. | 732. | 40.11 | 547. | 158. | 27.53 | 20.91 | 39.9 | 1.44 | 753. | 588.4 | 233 | 199 | 10.6 | 1.14 | 1.17 | 1.14 | 0.17 | 1.4 | 0.15 | 141. | -13.6 | 205. | -0.41 | -1.3 |

TABLE 9(e): TWIN OTTER DATA - FIFE89 FLIGHT 05 - 03 AUGUST, 1989

NAE C-FPOK , FILE 1ARCFIFE89 (01 AUG 89), FLIGHT DAT 04-AUG-89 PRINT DATE 04-AUG-89 FIFE 89-06, CLEAR, GRID

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200

| RUN AVERAGES | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP $W/m^2$ | LICOR $mg/m^3$ | HDGL T | T | WINDLD $ms^{-1}$ | UGEL | VGEL $ms^{-1}$ | WEP | TS degC | CO2 $mg/m^3$ | H2O $gm/m^3$ | WT $W/m^2$ | WC kg/hh | WQ $W/m^2$ | UW $N/m^2$ | Z/L |
| UPPER RUN , TRACK-8, 2500' | | | | | | | | | | | | | | | | | | | | | | | | |
| 1443 0. | 251. | 15.56 | 778. | 375. | 23.75 | 18.08 | 27.5 | 2.09 | 513. | 575.4 | 098 | 228 | 10.3 | 0.69 | 0.90 | 0.48 | 0.20 | 0.8 | 0.27 | -18. | 0.3 | 50. | -0.10 | 2.2 |
| FULL 8-LINE GRID, 1600' MSL, WORKING SOUTH TO NORTH | | | | | | | | | | | | | | | | | | | | | | | | |
| 145822. | 267. | 15.60 | 504. | 87. | 26.61 | 19.14 | 29.0 | 2.27 | 544. | 591.3 | 096 | 219 | 8.7 | 0.81 | 0.84 | 0.79 | 0.13 | 1.4 | 0.16 | 65. | -19.5 | 201. | -0.34 | -0.5 |
| 15 435. | 328. | 15.97 | 504. | 90. | 26.69 | 19.15 | 29.0 | 2.33 | 571. | 590.7 | 263 | 219 | 7.8 | 0.90 | 0.76 | 0.72 | 0.10 | 1.4 | 0.15 | 39. | -12.2 | 142. | -0.25 | -0.5 |
| 151136. | 265. | 15.63 | 505. | 100. | 26.77 | 19.19 | 29.0 | 2.46 | 578. | 589.6 | 095 | 223 | 8.2 | 0.87 | 0.90 | 0.70 | 0.11 | 1.5 | 0.17 | 33. | -15.6 | 151. | -0.26 | -0.4 |
| 151819. | 340. | 16.56 | 504. | 101. | 26.92 | 19.28 | 29.5 | 2.34 | 605. | 588.7 | 263 | 223 | 7.2 | 0.86 | 0.80 | 0.73 | 0.11 | 1.8 | 0.19 | 45. | -19.9 | 202. | -0.21 | -0.8 |
| 152560. | 290. | 16.11 | 504. | 99. | 27.04 | 19.35 | 30.8 | 2.08 | 615. | 588.2 | 096 | 221 | 8.0 | 0.82 | 0.73 | 0.73 | 0.11 | 1.5 | 0.29 | 51. | -16.8 | 157. | -0.29 | -0.5 |
| 153324. | 323. | 15.77 | 506. | 107. | 27.13 | 19.42 | 31.2 | 2.24 | 641. | 587.5 | 264 | 218 | 7.4 | 0.77 | 0.82 | 0.75 | 0.13 | 1.3 | 0.14 | 54. | -10.1 | 143. | -0.20 | -1.1 |
| 154029. | 268. | 15.49 | 506. | 119. | 27.29 | 19.47 | 31.9 | 2.08 | 651. | 587.0 | 096 | 218 | 8.3 | 0.79 | 0.84 | 0.83 | 0.14 | 1.2 | 0.13 | 68. | -14.0 | 158. | -0.17 | -1.9 |
| 154649. | 330. | 15.86 | 505. | 141. | 27.41 | 19.44 | 33.8 | 1.99 | 672. | 586.9 | 263 | 219 | 7.4 | 0.87 | 0.78 | 0.82 | 0.14 | 1.1 | 0.13 | 70. | -12.6 | 158. | -0.24 | -1.3 |
| UPPER LEVEL RUNS, TRACK-1, 3300 AND 3100' | | | | | | | | | | | | | | | | | | | | | | | | |
| 155858. | 253. | 15.48 | 1025. | 680. | 24.71 | 17.24 | 33.2 | 1.65 | 718. | 554.7 | 089 | 273 | 5.9 | 0.82 | 0.60 | 0.60 | 0.52 | 4.0 | 0.24 | 36. | 4.1 | -1. | -0.06 | -21.5 |
| 16 547. | 365. | 17.94 | 959. | 613. | 24.09 | 18.03 | 33.7 | 1.78 | 734. | 558.3 | 268 | 252 | 6.0 | 0.94 | 0.61 | 0.53 | 0.29 | 1.0 | 0.26 | -39. | -0.6 | 59. | -0.02 | 102.7 |
| FULL 8-LINE GRID, 1600' MSL, WORKING NORTH TO SOUTH | | | | | | | | | | | | | | | | | | | | | | | | |
| 161449. | 283. | 16.14 | 506. | 141. | 28.10 | 19.65 | 36.9 | 1.75 | 735. | 585.7 | 096 | 216 | 7.6 | 0.75 | 1.00 | 0.93 | 0.18 | 1.4 | 0.15 | 95. | -20.7 | 231. | -0.22 | -2.0 |
| 1621 2. | 315. | 15.49 | 505. | 108. | 28.16 | 19.75 | 35.0 | 2.07 | 746. | 584.9 | 261 | 212 | 6.9 | 0.78 | 0.74 | 0.77 | 0.16 | 1.5 | 0.18 | 68. | -15.8 | 193. | -0.13 | -2.6 |
| 162737. | 264. | 15.23 | 509. | 112. | 28.28 | 19.73 | 34.9 | 2.10 | 756. | 584.5 | 096 | 216 | 7.7 | 0.80 | 0.91 | 0.78 | 0.13 | 1.6 | 0.16 | 43. | -14.2 | 145. | -0.24 | -0.7 |
| 163341. | 328. | 15.91 | 508. | 101. | 28.44 | 19.80 | 35.2 | 2.07 | 767. | 583.6 | 262 | 214 | 6.9 | 0.81 | 0.86 | 0.78 | 0.16 | 1.8 | 0.20 | 64. | -25.1 | 242. | -0.22 | -1.1 |
| 164034. | 281. | 16.12 | 511. | 109. | 28.67 | 19.89 | 34.3 | 2.22 | 777. | 582.6 | 096 | 216 | 7.2 | 0.91 | 0.83 | 0.80 | 0.14 | 1.8 | 0.19 | 44. | -22.0 | 213. | -0.31 | -0.5 |
| 164648. | 343. | 16.69 | 511. | 102. | 28.90 | 19.83 | 34.1 | 2.47 | 787. | 582.9 | 262 | 215 | 6.4 | 0.86 | 0.80 | 0.77 | 0.14 | 1.8 | 0.22 | 49. | -22.8 | 258. | -0.21 | -1.0 |
| 165359. | 274. | 15.73 | 510. | 99. | 29.15 | 19.88 | 35.8 | 2.19 | 798. | 582.4 | 095 | 216 | 7.0 | 0.81 | 0.80 | 0.75 | 0.15 | 1.5 | 0.18 | 29. | -16.3 | 175. | -0.18 | -0.7 |
| 17 0 4. | 315. | 15.48 | 507. | 89. | 29.43 | 19.85 | 36.0 | 2.23 | 807. | 582.3 | 262 | 214 | 6.2 | 0.89 | 0.76 | 0.77 | 0.17 | 1.7 | 0.21 | 58. | -19.8 | 242. | -0.19 | -1.1 |
| UPPER LEVEL RUN, 3100' MSL, TRACK-8 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1710 1. | 280. | 16.19 | 961. | 566. | 25.62 | 18.82 | 35.2 | 1.95 | 839. | 552.2 | 093 | 219 | 4.9 | 0.83 | 0.77 | 0.55 | 0.47 | 1.5 | 0.47 | -37. | -2.9 | 110. | -0.02 | 79.1 |

TABLE 9(f): TWIN OTTER DATA - FIFE89 FLIGHT 06 - 04 AUGUST, 1989

NAE C-FPOK , FILE 1ARCFIFE89 (01 AUG 89), FLIGHT DAT 04-AUG-89 PRINT DATE 04-AUG-89 FIFE 07, FULL GRID, CLEAR, S WIND,

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200

| RUN AVERAGES | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP $W/m^2$ | LICOR $mg/m^3$ | HDGL T | WINDLD T | $ms^{-1}$ | UGEL $ms^{-1}$ | VGEL | WEP | TS degC | CO2 $mg/m^3$ | H2O $gm/m^3$ | WT $W/m^2$ | WC kg/hh | WQ $W/m^2$ | UW $N/m^2$ | Z/L |
| 8- LINE GRID, 1600' MSL WORKING NORTH TO SOUTH | | | | | | | | | | | | | | | | | | | | | | | | |
| 1838 1. | 291. | 15.95 | 503. | 139. | 31.77 | 20.70 | 44.6 | 1.74 | 858. | 581.2 | 095 | 200 | 6.3 | 0.83 | 1.01 | 0.96 | 0.18 | 1.1 | 0.20 | 115. | -8.8 | 220. | -0.25 | -2.0 |
| 184437. | 302. | 15.52 | 499. | 101. | 31.89 | 20.87 | 42.2 | 1.96 | 862. | 579.3 | 261 | 193 | 5.8 | 0.78 | 0.97 | 0.88 | 0.16 | 1.3 | 0.24 | 91. | -11.5 | 278. | -0.25 | -1.2 |
| 185056. | 278. | 15.49 | 503. | 104. | 31.99 | 20.84 | 41.7 | 2.09 | 857. | 577.7 | 095 | 193 | 6.5 | 0.79 | 1.06 | 0.83 | 0.16 | 1.3 | 0.26 | 82. | -13.6 | 277. | -0.24 | -1.2 |
| 185648. | 284. | 15.34 | 504. | 95. | 32.15 | 20.73 | 41.0 | 1.98 | 860. | 577.1 | 261 | 189 | 5.7 | 0.81 | 0.90 | 0.80 | 0.14 | 1.9 | 0.34 | 72. | -21.5 | 371. | -0.19 | -1.4 |
| 19 3 6. | 298. | 16.16 | 502. | 95. | 32.31 | 20.71 | 40.0 | 2.22 | 853. | 576.6 | 094 | 189 | 6.0 | 0.79 | 0.92 | 0.78 | 0.13 | 1.7 | 0.32 | 50. | -19.3 | 321. | -0.25 | -0.7 |
| 19 931. | 304. | 16.34 | 503. | 94. | 32.37 | 20.79 | 39.0 | 2.38 | 852. | 575.9 | 261 | 185 | 5.8 | 0.75 | 1.01 | 0.76 | 0.12 | 1.7 | 0.33 | 45. | -15.0 | 256. | -0.11 | -2.0 |
| 1916 6. | 300. | 16.48 | 504. | 91. | 32.45 | 21.03 | 40.5 | 2.22 | 845. | 581.0 | 094 | 183 | 6.2 | 0.81 | 1.10 | 0.77 | 0.15 | 1.8 | 0.33 | 61. | -19.7 | 321. | -0.16 | -1.6 |
| 192253. | 275. | 15.14 | 505. | 83. | 32.40 | 21.20 | 39.6 | 2.17 | 843. | * | 261 | 180 | 6.1 | 0.86 | 1.05 | 0.74 | 0.13 | 1.6 | 0.28 | 51. | -13.5 | 230. | -0.21 | -0.8 |
| RUN NEAR TOP OF PBL AT 3100', TRACK-8, SOUTH EDGE AND ONE AT 2300 ' | | | | | | | | | | | | | | | | | | | | | | | | |
| 193028. | 310. | 17.27 | 958. | 567. | 27.93 | 19.78 | 39.2 | 1.96 | 849. | * | 096 | 200 | 7.1 | 0.72 | 0.81 | 0.80 | 0.15 | 1.1 | 0.27 | 6. | -4.3 | 218. | -0.09 | -5.5 |
| 193819. | 302. | 16.14 | 718. | 315. | 30.15 | 20.84 | 39.3 | 2.02 | 838. | * | 261 | 185 | 6.6 | 0.81 | 0.83 | 0.90 | 0.13 | 1.0 | 0.24 | -3. | -7.8 | 230. | -0.06 | -3.5 |
| 8-LINE GRID, 1600' MSL, WORKING SOUTH TO NORTH | | | | | | | | | | | | | | | | | | | | | | | | |
| 194629. | 292. | 15.55 | 510. | 91. | 32.49 | 21.44 | 40.9 | 2.12 | 818. | * | 097 | 177 | 6.9 | 0.83 | 0.91 | 0.83 | 0.19 | 1.7 | 0.26 | 59. | -18.9 | 304. | -0.22 | -0.9 |
| 195320. | 301. | 16.39 | 510. | 95. | 32.55 | 21.55 | 39.2 | 2.18 | 810. | * | 262 | 174 | 6.7 | 0.76 | 1.07 | 0.76 | 0.17 | 2.9 | 0.47 | 29. | -17.9 | 279. | -0.17 | -0.9 |
| 195943. | 303. | 16.21 | 508. | 99. | 32.66 | 21.62 | 39.3 | 2.42 | 798. | * | 096 | 176 | 7.5 | 0.86 | 0.98 | 0.81 | 0.17 | 1.9 | 0.35 | 31. | -22.7 | 371. | -0.32 | -0.4 |
| 20 6 9. | 295. | 16.41 | 511. | 105. | 32.65 | 21.75 | 39.3 | 2.14 | 790. | * | 260 | 171 | 7.4 | 0.90 | 0.92 | 0.79 | 0.15 | 1.7 | 0.33 | 20. | -15.6 | 265. | -0.18 | -0.7 |
| 201229. | 314. | 16.38 | 510. | 103. | 32.72 | 21.71 | 40.8 | 2.02 | 779. | * | 098 | 175 | 8.3 | 0.86 | 0.86 | 0.83 | 0.18 | 1.9 | 0.31 | 45. | -14.8 | 215. | -0.21 | -0.9 |
| 201910. | 289. | 16.13 | 511. | 109. | 32.65 | 21.99 | 41.0 | 2.01 | 771. | * | 259 | 169 | 8.1 | 0.85 | 0.98 | 0.76 | 0.17 | 2.5 | 0.46 | 37. | -11.6 | 249. | -0.21 | -0.8 |
| 202541. | 306. | 15.98 | 509. | 114. | 32.80 | 21.84 | 41.8 | 2.05 | 758. | * | 098 | 175 | 8.9 | 0.83 | 0.90 | 0.80 | 0.18 | 1.8 | 0.33 | 42. | -14.2 | 329. | -0.23 | -0.9 |
| 203226. | 293. | 16.44 | 512. | 139. | 32.67 | 22.09 | 42.7 | 1.78 | 746. | * | 259 | 168 | 8.8 | 0.96 | 0.88 | 0.80 | 0.17 | 1.6 | 0.27 | 51. | -11.5 | 274. | -0.22 | -1.3 |
| RUN NEAR TOP OF PBL, NORTH EDGE, 3400' MSL | | | | | | | | | | | | | | | | | | | | | | | | |
| 204046. | 288. | 16.86 | 1062. | 730. | 28.20 | 19.16 | 41.5 | 1.63 | 749. | * | 098 | 205 | 8.6 | 0.53 | 0.63 | 0.60 | 0.20 | 0.7 | 0.42 | -15. | -0.1 | 136. | 0.03 | -8.6 |
| REGIONAL RUN C, 500' AGL (CO2/H2O GOES U/S) | | | | | | | | | | | | | | | | | | | | | | | | |
| 204847. | 658. | 38.83 | 571. | 159. | 32.30 | 21.20 | 40.1 | 1.90 | 715. | * | 233 | 179 | 8.7 | 0.94 | 0.92 | 0.92 | 0.13 | 1.5 | 0.29 | 62. | -12.0 | 271. | -0.30 | -1.0 |
| 205952. | 710. | 40.35 | 552. | 158. | 33.46 | 20.46 | 46.1 | 1.47 | 692. | * | 232 | 184 | 9.3 | 0.85 | 1.09 | 0.94 | 0.17 | * | * | 101. | * | * | -0.17 | -3.0 |

TABLE 9(g): TWIN OTTER DATA - FIFE89 FLIGHT 07 - 04 AUGUST, 1989

NAE C-FPOK , FILE 1ARCFIFE89 (05 AUG 89), FLIGHT DAT 06-AUG-89 PRINT DATE 06-AUG-89 FIFE 08, INPUT, L-PATTERN, INTERCOMP

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200

| RUN AVERAGES | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP W/m$^2$ | LICOR mg/m$^3$ | HDGL T | WINDLD T | ms$^{-1}$ | UGEL ms$^{-1}$ | VGEL | WEP | TS degC | CO2 mg/m$^3$ | H2O gm/m$^3$ | WT W/m$^2$ | WC kg/hh | WQ W/m$^2$ | UW N/m$^2$ | Z/L |
| L-PATTERN , EAST/WEST RUNS, FW5-FE5 | | | | | | | | | | | | | | | | | | | | | | | | |
| 300' BELOW PBL TOP | | | | | | | | | | | | | | | | | | | | | | | | |
| 152827. | 316. | 15.71 | 624. | 204. | 19.53 | 13.50 | 25.7 | 2.27 | 632. | 602.7 | 086 | 054 | 5.1 | 0.57 | 0.64 | 0.74 | 0.10 | 2.9 | 0.24 | 24. | 19.6 | 216. | -0.11 | -3.1 |
| 155758. | 338. | 16.74 | 653. | 244. | 19.75 | 13.10 | 26.9 | 2.25 | 699. | 590.0 | 085 | 047 | 5.5 | 0.81 | 0.77 | 0.91 | 0.11 | 2.3 | 0.24 | 43. | 7.7 | 307. | -0.27 | -1.6 |
| 1626 4. | 220. | 10.91 | 660. | 275. | 20.14 | 12.93 | 29.2 | 1.89 | 757. | 590.5 | 081 | 047 | 5.9 | 0.73 | 0.51 | 0.94 | 0.07 | 1.1 | 0.09 | 16. | -10.2 | 70. | -0.47 | -0.2 |
| 163449. | 287. | 16.66 | 993. | 587. | 18.10 | 10.53 | 27.9 | 2.17 | 783. | 558.9 | 275 | 037 | 6.1 | 0.77 | 0.68 | 0.46 | 0.63 | 3.8 | 0.88 | -32. | -1.1 | 21. | 0.00 | ****** |
| 17 326. | 288. | 16.32 | 957. | 552. | 17.83 | 12.21 | 29.2 | 2.13 | 825. | 562.7 | 274 | 035 | 5.2 | 0.65 | 0.79 | 0.62 | 0.26 | 1.5 | 0.47 | -29. | 3.9 | 132. | -0.09 | 5.5 |
| 175544. | 305. | 16.12 | 1084. | 681. | 17.49 | 11.44 | 31.8 | 2.04 | 879. | 548.4 | 082 | 002 | 5.2 | 0.74 | 0.76 | 0.76 | 0.20 | 0.9 | 0.43 | 1. | -2.6 | 69. | 0.00 | 1518.2 |
| 1600'MSL | | | | | | | | | | | | | | | | | | | | | | | | |
| 153624. | 290. | 16.42 | 501. | 83. | 20.85 | 13.75 | 25.5 | 2.48 | 645. | 610.2 | 273 | 054 | 5.7 | 0.77 | 0.73 | 0.68 | 0.12 | 1.6 | 0.18 | 48. | -6.1 | 143. | -0.17 | -1.0 |
| 16 520. | 283. | 16.41 | 506. | 92. | 21.42 | 13.37 | 27.4 | 2.43 | 709. | 597.0 | 272 | 049 | 5.5 | 0.69 | 0.78 | 0.74 | 0.16 | 1.9 | 0.22 | 86. | -15.7 | 233. | -0.19 | -1.6 |
| 165537. | 327. | 16.33 | 510. | 98. | 22.08 | 13.46 | 30.6 | 2.30 | 805. | 595.3 | 086 | 046 | 4.1 | 0.75 | 0.91 | 0.84 | 0.20 | 2.2 | 0.23 | 129. | -27.5 | 308. | -0.11 | -5.9 |
| 172513. | 316. | 16.23 | 508. | 93. | 22.60 | 13.47 | 31.9 | 2.28 | 838. | 588.2 | 085 | 031 | 4.3 | 0.89 | 0.94 | 0.85 | 0.17 | 2.0 | 0.23 | 102. | -21.3 | 254. | -0.18 | -2.1 |
| 173236. | 299. | 16.41 | 501. | 87. | 22.83 | 13.29 | 31.7 | 2.35 | 840. | 587.6 | 274 | 028 | 5.1 | 0.81 | 0.86 | 0.88 | 0.17 | 1.8 | 0.22 | 108. | -25.8 | 278. | -0.18 | -2.1 |
| L-PATTERN , NORTH/SOUTH RUNS, FS3-FN3 | | | | | | | | | | | | | | | | | | | | | | | | |
| 300' BELOW PBL TOP | | | | | | | | | | | | | | | | | | | | | | | | |
| 1551 7. | 231. | 13.24 | 652. | 266. | 19.63 | 13.19 | 28.0 | 1.81 | 687. | 601.8 | 174 | 043 | 5.8 | 0.79 | 0.89 | 0.92 | 0.10 | 2.9 | 0.26 | 23. | 34.7 | 304. | -0.26 | -1.3 |
| 161921. | 238. | 13.60 | 659. | 276. | 20.10 | 12.86 | 29.9 | 1.76 | 744. | 589.3 | 173 | 044 | 5.6 | 0.74 | 0.77 | 0.97 | 0.11 | 1.2 | 0.20 | 67. | -4.2 | 195. | -0.17 | -4.5 |
| 164232. | 267. | 13.45 | 956. | 574. | 18.06 | 11.39 | 31.0 | 1.71 | 798. | 563.7 | 002 | 043 | 5.1 | 0.81 | 0.71 | 0.68 | 0.46 | 2.9 | 0.75 | -26. | 2.5 | 90. | -0.08 | 6.6 |
| 171110. | 282. | 13.82 | 952. | 572. | 18.17 | 12.17 | 32.5 | 1.69 | 834. | 562.2 | 000 | 032 | 4.5 | 0.75 | 0.79 | 0.93 | 0.15 | 1.0 | 0.32 | -14. | 1.2 | 191. | 0.06 | -0.2 |
| 174916. | 208. | 12.49 | 1077. | 703. | 17.83 | 11.08 | 34.1 | 1.60 | 870. | 550.6 | 178 | 011 | 6.0 | 0.90 | 0.65 | 0.75 | 0.17 | 0.6 | 0.34 | -26. | -1.6 | 230. | 0.04 | -12.6 |
| 1600' MSL | | | | | | | | | | | | | | | | | | | | | | | | |
| 1545 4. | 260. | 13.02 | 505. | 114. | 20.97 | 13.51 | 27.6 | 1.91 | 669. | 614.8 | 004 | 054 | 5.7 | 0.80 | 0.83 | 0.88 | 0.14 | 2.2 | 0.18 | 77. | -4.5 | 171. | -0.15 | -2.5 |
| 1613 8. | 260. | 12.97 | 502. | 114. | 21.61 | 13.16 | 29.8 | 1.87 | 726. | 602.6 | 004 | 052 | 5.6 | 0.93 | 0.81 | 0.82 | 0.17 | 1.9 | 0.21 | 101. | -10.0 | 191. | -0.14 | -3.5 |
| 164853. | 240. | 13.60 | 514. | 128. | 22.02 | 13.23 | 32.6 | 1.81 | 797. | 594.9 | 175 | 044 | 4.7 | 0.94 | 0.78 | 0.89 | 0.14 | 1.2 | 0.15 | 85. | -14.8 | 166. | -0.12 | -3.9 |
| 1718 7. | 252. | 14.16 | 512. | 125. | 22.63 | 13.15 | 34.3 | 1.79 | 832. | 591.0 | 176 | 032 | 4.8 | 1.00 | 0.87 | 0.93 | 0.19 | 1.1 | 0.20 | 140. | -14.5 | 182. | -0.21 | -2.8 |
| 174119. | 292. | 13.58 | 499. | 112. | 23.27 | 12.75 | 35.1 | 1.82 | 842. | 589.3 | 000 | 021 | 4.9 | 0.96 | 0.88 | 1.00 | 0.19 | 1.0 | 0.18 | 124. | -12.3 | 234. | -0.26 | -1.7 |
| **INTERCOMPS WITH KINGAIR | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 854. | 235. | 16.64 | 592. | 182. | 22.39 | 12.45 | 32.9 | 2.21 | 870. | 579.4 | 274 | 014 | 5.4 | 0.76 | 0.97 | 1.00 | 0.13 | 1.6 | 0.20 | 84. | -25.4 | 295. | -0.25 | -2.2 |
| 181620. | 240. | 16.52 | 507. | 95. | 23.48 | 12.66 | 33.8 | 2.27 | 865. | 584.1 | 086 | 013 | 4.2 | 1.02 | 1.09 | 0.87 | 0.16 | 1.9 | 0.24 | 93. | -28.3 | 330. | -0.15 | -2.7 |

TABLE 9(h): TWIN OTTER DATA - FIFE89 FLIGHT 08 - 06 AUGUST, 1989

**NAE C-FPOK , FILE 1ARCFIFE89 (05 AUG 89), FLIGHT DAT 06-AUG-89 PRINT DATE 06-AUG-89 FIFE 09, GRID ,REG C**

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200

| RUN AVERAGES | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP $W/m^2$ | LICOR $mg/m^3$ | HDGL T | T | WINDLD $ms^{-1}$ | UGEL | VGEL $ms^{-1}$ | WEP | TS degC | CO2 $mg/m^3$ | H2O $gm/m^3$ | WT $W/m^2$ | WC kg/hh | WQ $W/m^2$ | UW $N/m^2$ | Z/L |
| RUN NEAR TOP OF PBL, 4800', FEO-FWO | | | | | | | | | | | | | | | | | | | | | | | | |
| 193820. | 323. | 17.17 | 1484. | * | 14.39 | 10.59 | 31.0 | 1.70 | 826. | 525.9 | 281 | 358 | 9.1 | 0.81 | 1.02 | 1.19 | 0.13 | 1.0 | 0.50 | -10. | -5.7 | 165. | 0.00 | 96.1 |
| 8-LINE GRID, 1600' MSL, WORKING NORTH TO SOUTH | | | | | | | | | | | | | | | | | | | | | | | | |
| 1947 3. | 310. | 16.51 | 503. | 135. | 24.30 | 12.69 | 34.6 | 1.86 | 785. | 588.8 | 079 | 354 | 9.4 | 1.15 | 1.38 | 1.14 | 0.24 | 1.2 | 0.12 | 184. | -14.9 | 226. | -0.65 | -0.7 |
| 195332. | 288. | 15.28 | 507. | 106. | 24.40 | 12.72 | 31.5 | 2.13 | 767. | 587.7 | 280 | 347 | 9.8 | 1.21 | 1.82 | 1.12 | 0.23 | 1.4 | 0.18 | 165. | -18.6 | 299. | -0.48 | -0.8 |
| 195938. | 296. | 15.56 | 505. | 98. | 24.39 | 12.66 | 32.2 | 2.19 | 795. | 587.7 | 080 | 358 | 8.6 | 1.20 | 1.34 | 0.98 | 0.19 | 1.3 | 0.19 | 120. | -15.8 | 273. | -0.53 | -0.5 |
| 20 557. | 309. | 16.22 | 503. | 88. | 24.43 | 12.72 | 33.0 | 2.02 | 794. | 586.7 | 278 | 359 | 8.7 | 1.10 | 1.19 | 0.88 | 0.19 | 1.3 | 0.19 | 111. | -15.9 | 245. | -0.27 | -1.1 |
| 2013 4. | 317. | 16.73 | 504. | 95. | 24.32 | 12.61 | 31.7 | 2.36 | 778. | 586.1 | 079 | 000 | 8.8 | 0.98 | 1.04 | 0.82 | 0.15 | 1.3 | 0.19 | 67. | -10.8 | 181. | -0.36 | -0.5 |
| 2020 2. | 309. | 16.42 | 508. | 92. | 24.40 | 12.78 | 30.9 | 2.42 | 756. | 584.1 | 279 | 000 | 9.7 | 0.99 | 1.07 | 0.89 | 0.16 | 1.6 | 0.21 | 90. | -19.7 | 265. | -0.36 | -0.7 |
| 202636. | 311. | 16.20 | 507. | 87. | 24.44 | 12.84 | 31.8 | 2.32 | 730. | 583.3 | 079 | 359 | 9.1 | 1.08 | 1.41 | 0.80 | 0.19 | 1.9 | 0.22 | 96. | -20.5 | 257. | -0.41 | -0.5 |
| 2033 3. | 284. | 15.07 | 506. | 78. | 24.59 | 13.05 | 31.5 | 2.16 | 691. | 582.3 | 278 | 004 | 9.2 | 1.47 | 1.27 | 0.94 | 0.20 | 2.0 | 0.24 | 107. | -24.7 | 288. | -0.48 | -0.4 |
| RUN 300' BELOW TOP OF PBL, FE6-FW6 | | | | | | | | | | | | | | | | | | | | | | | | |
| 204717. | 298. | 15.64 | 1760. | * | 12.74 | 7.85 | 28.9 | 1.82 | 757. | 508.7 | 283 | 355 | 10.6 | 0.65 | 0.71 | 0.43 | 0.23 | 0.9 | 0.39 | -16. | 1.7 | -3. | -0.09 | 6.4 |
| 8-LINE GRID, 1600', WORKING SOUTH TO NORTH | | | | | | | | | | | | | | | | | | | | | | | | |
| 205712. | 296. | 15.75 | 509. | 83. | 24.39 | 12.06 | 31.3 | 2.32 | 703. | 582.8 | 079 | 004 | 9.4 | 1.38 | 1.18 | 0.95 | 0.19 | 1.8 | 0.22 | 103. | -20.1 | 257. | -0.34 | -0.7 |
| 21 422. | 305. | 16.35 | 506. | 85. | 24.21 | 11.77 | 30.1 | 2.24 | 686. | 583.3 | 280 | 003 | 9.8 | 1.22 | 1.33 | 0.86 | 0.16 | 1.8 | 0.22 | 77. | -18.4 | 225. | -0.50 | -0.3 |
| 211124. | 334. | 17.05 | 505. | 91. | 24.12 | 11.25 | 29.4 | 2.57 | 663. | 584.4 | 078 | 001 | 9.8 | 1.13 | 1.19 | 0.87 | 0.14 | 1.5 | 0.20 | 74. | -16.6 | 227. | -0.30 | -0.7 |
| 211838. | 468. | 24.67 | 506. | 79. | 24.02 | 11.34 | 28.7 | 2.36 | 657. | 583.5 | 280 | 007 | 10.2 | 1.13 | 1.20 | 0.85 | 0.13 | 1.6 | 0.21 | 61. | -17.8 | 236. | -0.37 | -0.4 |
| 212819. | 337. | 16.66 | 508. | 90. | 23.94 | 11.39 | 30.8 | 2.15 | 621. | 582.4 | 081 | 018 | 7.8 | 1.17 | 1.23 | 0.88 | 0.16 | 1.2 | 0.16 | 92. | -11.7 | 194. | -0.47 | -0.4 |
| 213557. | 295. | 16.19 | 505. | 92. | 23.90 | 11.43 | 29.3 | 2.17 | 606. | 581.9 | 278 | 014 | 8.3 | 1.01 | 1.11 | 0.87 | 0.13 | 1.0 | 0.12 | 67. | -9.9 | 141. | -0.36 | -0.5 |
| 214227. | 317. | 15.55 | 503. | 99. | 23.93 | 11.51 | 29.4 | 2.23 | 588. | 581.5 | 081 | 020 | 7.3 | 1.04 | 1.32 | 0.91 | 0.17 | 1.2 | 0.14 | 108. | -13.4 | 191. | -0.46 | -0.5 |
| 214911. | 295. | 16.18 | 502. | 124. | 23.93 | 11.30 | 29.7 | 1.95 | 570. | 582.2 | 277 | 024 | 7.6 | 1.00 | 1.05 | 1.03 | 0.16 | 1.0 | 0.11 | 100. | -12.5 | 180. | -0.40 | -0.8 |
| RUN 200' BELOW TOP OF PBL, 4800'MSL | | | | | | | | | | | | | | | | | | | | | | | | |
| 215925. | 301. | 16.05 | 1488. | * | 14.61 | 8.60 | 28.8 | 1.71 | 567. | 523.0 | 079 | 000 | 8.2 | 1.21 | 0.99 | 0.70 | 0.38 | 1.4 | 0.38 | 56. | 2.6 | -73. | 0.06 | 35.0 |
| REGIONAL C, 500' AGL | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 714. | 556. | 37.92 | 570. | 150. | 23.48 | 11.42 | 28.6 | 2.10 | 519. | 577.8 | 244 | 025 | 7.8 | 1.00 | 1.05 | 0.88 | 0.11 | 1.0 | 0.13 | 53. | -10.9 | 143. | -0.34 | -0.7 |
| 221636. | 594. | 40.38 | 555. | 151. | 24.31 | 11.40 | 32.5 | 1.51 | 479. | 580.0 | 242 | 034 | 7.6 | 1.04 | 0.99 | 0.92 | 0.13 | 0.9 | 0.11 | 71. | -8.2 | 123. | -0.29 | -1.1 |

**TABLE 9(i): TWIN OTTER DATA - FIFE89 FLIGHT 09 - 06 AUGUST, 1989**

NAE C-FPOK , FILE 2ARCFIFE89 (05 AUG 89), FLIGHT DAT 07-AUG-89 PRINT DATE 07-AUG-89 FIFE 10, T-PATTERN

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200

| RUN AVERAGES | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP $W/m^2$ | LICOR $mg/m^3$ | HDGL T | WINDLD T | $ms^{-1}$ | UGEL $ms^{-1}$ | VGEL $ms^{-1}$ | WEP | TS degC | CO2 $mg/m^3$ | H2O $gm/m^3$ | WT $W/m^2$ | WC kg/hh | WQ $W/m^2$ | UW $N/m^2$ | Z/L |
| T-PATTERN FLIGHT | | | | | | | | | | | | | | | | | | | | | | | | |
| EAST/WEST FW5-FE5 | | | | | | | | | | | | | | | | | | | | | | | | |
| 155136. | 291. | 16.19 | 501. | 77. | 16.42 | 4.42 | 24.2 | 2.56 | 729. | 590.3 | 275 | 026 | 6.7 | 1.09 | 1.28 | 0.93 | 0.19 | 1.6 | 0.16 | 136. | -24.1 | 198. | -0.47 | -0.5 |
| 155824. | 335. | 16.32 | 596. | 174. | 15.45 | 4.30 | 25.3 | 2.43 | 752. | 583.8 | 083 | 026 | 6.4 | 1.04 | 1.12 | 0.93 | 0.14 | 1.3 | 0.12 | 88. | -15.2 | 144. | -0.07 | -14.8 |
| 16 616. | 304. | 16.29 | 891. | 467. | 12.52 | 3.58 | 24.6 | 2.41 | 769. | 564.3 | 276 | 023 | 7.2 | 0.98 | 0.87 | 1.03 | 0.11 | 1.2 | 0.10 | 47. | -11.7 | 136. | 0.01 | 344.8 |
| 161549. | 341. | 17.33 | 1756. | 1332. | 4.44 | 1.77 | 24.5 | 2.13 | 833. | 511.2 | 080 | 013 | 7.0 | 1.01 | 1.02 | 0.71 | 0.17 | 0.8 | 0.19 | -20. | -1.0 | 56. | -0.19 | 2.2 |
| 173532. | 308. | 16.89 | 1762. | 1334. | 5.21 | 2.31 | 28.8 | 2.07 | 962. | 510.0 | 277 | * | * | 0.82 | 0.88 | 0.97 | 0.14 | 0.9 | 0.13 | -4. | -7.5 | 106. | -0.02 | -8.9 |
| 174424. | 334. | 17.36 | 906. | 479. | 13.74 | 4.01 | 31.0 | 2.21 | 931. | 562.4 | 082 | 017 | 6.2 | 1.34 | 1.01 | 1.26 | 0.11 | 1.0 | 0.09 | 73. | -10.3 | 136. | -0.13 | -11.6 |
| 175252. | 303. | 16.52 | 600. | 173. | 16.96 | 4.53 | 31.1 | 2.31 | 1022. | 582.3 | 275 | 020 | 6.3 | 1.05 | 1.05 | 1.24 | 0.15 | 1.3 | 0.13 | 137. | -21.1 | 221. | -0.11 | -10.4 |
| 18 0 9. | 333. | 16.42 | 513. | 84. | 18.05 | 4.73 | 31.4 | 2.37 | 936. | 587.0 | 084 | 022 | 5.1 | 1.07 | 1.39 | 1.00 | 0.24 | 1.8 | 0.20 | 188. | -28.0 | 299. | -0.32 | -1.4 |
| NORTH/SOUTH FS2-FN2 | | | | | | | | | | | | | | | | | | | | | | | | |
| 163025. | 371. | 17.74 | 1762. | 1341. | 4.36 | 2.42 | 25.5 | 2.05 | 838. | 512.2 | 003 | 017 | 6.2 | 1.07 | 0.86 | 0.89 | 0.11 | 0.9 | 0.13 | -6. | -5.9 | 86. | -0.05 | -0.1 |
| 163929. | 288. | 16.60 | 900. | 479. | 12.96 | 3.65 | 26.5 | 2.19 | 822. | 568.6 | 179 | 017 | 6.9 | 0.94 | 0.91 | 1.16 | 0.10 | 1.4 | 0.06 | 65. | -11.7 | 100. | -0.01 | ****** |
| 164656. | 366. | 16.46 | 595. | 174. | 16.09 | 4.16 | 27.6 | 2.31 | 861. | 588.4 | 004 | 025 | 6.4 | 1.01 | 1.09 | 1.00 | 0.13 | 1.2 | 0.11 | 88. | -15.6 | 147. | 0.08 | 10.0 |
| 165444. | 280. | 16.29 | 522. | 102. | 16.95 | 4.32 | 28.1 | 2.29 | 876. | 591.9 | 179 | 018 | 6.0 | 1.23 | 0.96 | 0.96 | 0.21 | 1.4 | 0.16 | 147. | -20.6 | 214. | 0.01 | 493.9 |
| 17 124. | 347. | 16.33 | 522. | 101. | 17.07 | 4.35 | 28.2 | 2.35 | 874. | 590.5 | 003 | 003 | 5.3 | 1.17 | 1.08 | 1.00 | 0.19 | 1.6 | 0.15 | 145. | -20.8 | 218. | -0.07 | -12.7 |
| 17 850. | 281. | 15.97 | 603. | 183. | 16.34 | 4.17 | 28.5 | 2.26 | 895. | 583.7 | 179 | 018 | 6.1 | 1.11 | 1.21 | 1.01 | 0.15 | 1.2 | 0.10 | 102. | -14.7 | 145. | -0.37 | -1.3 |
| 171547. | 353. | 16.46 | 903. | 479. | 13.36 | 3.78 | 28.8 | 2.20 | 897. | 562.7 | 004 | 023 | 6.2 | 0.98 | 1.10 | 1.32 | 0.10 | 1.0 | 0.08 | 65. | -8.0 | 106. | -0.09 | -20.0 |
| 172540. | 271. | 16.38 | 1763. | 1341. | 5.14 | 2.24 | 27.8 | 2.00 | 926. | 508.5 | 179 | 006 | 6.6 | 1.09 | 0.93 | 0.85 | 0.12 | 1.0 | 0.16 | -2. | -1.6 | 35. | -0.11 | -0.2 |
| REGIONAL RUN C, 500 AGL **PASS KINGAIR IN SEGMENT 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 181649. | 582. | 38.71 | 581. | 156. | 17.56 | 4.54 | 32.4 | 2.07 | 943. | 582.7 | 244 | 015 | 5.7 | 1.18 | 1.22 | 1.21 | 0.21 | 1.3 | 0.13 | 201. | -21.6 | 266. | -0.37 | -2.2 |
| 182638. | 606. | 39.79 | 556. | 151. | 18.19 | 4.28 | 37.9 | 1.57 | 941. | 583.6 | 244 | 013 | 5.4 | 1.24 | 1.34 | 1.31 | 0.19 | 1.1 | 0.11 | 199. | -11.8 | 157. | -0.03 | -101.7 |

TABLE 9(j): TWIN OTTER DATA - FIFE89 FLIGHT 10 - 07 AUGUST, 1989

NAE C-FPOK , FILE 1ARCFIFE89 (05 AUG 89), FLIGHT DAT 08-AUG-89 PRINT DATE 08-AUG-89 FIFE 89-11, GRIDS

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200

| RUN AVERAGES | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP $W/m^2$ | LICOR $mg/m^3$ | HDGL T | WINDLD T | $ms^{-1}$ | UGEL $ms^{-1}$ | VGEL $ms^{-1}$ | WEP | TS degC | CO2 $mg/m^3$ | H2O $gm/m^3$ | WT $W/m^2$ | WC kg/hh | WQ $W/m^2$ | UW $N/m^2$ | Z/L |
| REGIONAL RUN C, 500' | | | | | | | | | | | | | | | | | | | | | | | | |
| 152428. | 660. | 39.89 | 548. | 160. | 19.01 | 7.35 | 30.0 | 1.62 | 650. | 580.9 | 058 | 349 | 2.1 | 0.68 | 0.65 | 0.88 | 0.12 | 2.0 | 0.17 | 71. | 10.2 | 190. | -0.17 | -2.6 |
| 153534. | 643. | 38.98 | 563. | 159. | 19.33 | 7.24 | 27.0 | 2.19 | 683. | 575.0 | 057 | 343 | 3.0 | 0.71 | 0.79 | 0.94 | 0.13 | 2.0 | 0.23 | 85. | -10.3 | 210. | -0.11 | -6.2 |
| UPPER RUNS NEAR PBL TOP | | | | | | | | | | | | | | | | | | | | | | | | |
| NORTH EDGE | | | | | | | | | | | | | | | | | | | | | | | | |
| 155351. | 339. | 17.38 | 894. | 533. | 16.30 | 6.81 | 28.0 | 1.98 | 723. | 552.3 | 272 | 328 | 3.2 | 0.75 | 0.88 | 0.90 | 0.07 | 3.0 | 0.27 | 6. | 21.9 | 220. | -0.24 | -1.4 |
| 181756. | 258. | 15.47 | 2167. | * | 5.69 | 2.99 | 31.8 | 1.63 | 853. | 470.7 | 088 | 314 | 1.9 | 0.96 | 0.82 | 1.11 | 0.11 | 1.1 | 0.23 | -14. | -10.1 | 240. | -0.02 | -11.9 |
| SOUTH EDGE | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 8 6. | 342. | 19.47 | 2006. | * | 6.33 | 3.45 | 30.8 | 1.98 | 809. | 482.0 | 272 | 358 | 2.2 | 0.80 | 0.91 | 0.80 | 0.11 | 1.4 | 0.26 | 1. | -11.7 | 199. | 0.04 | 17.8 |
| GRID, 1600' MSL WORKING NORTH TO SOUTH | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 143. | 295. | 16.38 | 501. | 135. | 20.36 | 7.98 | 31.1 | 1.89 | 731. | 581.2 | 087 | 319 | 2.6 | 0.92 | 0.92 | 0.95 | 0.18 | 2.5 | 0.16 | 128. | -13.5 | 151. | -0.15 | -4.8 |
| 16 8 3. | 300. | 15.52 | 505. | 106. | 20.50 | 7.77 | 29.3 | 2.26 | 742. | 579.1 | 272 | 326 | 3.3 | 0.85 | 0.95 | 0.92 | 0.16 | 1.7 | 0.16 | 110. | -18.0 | 193. | 0.02 | 94.2 |
| 161448. | 292. | 16.06 | 502. | 103. | 20.60 | 7.88 | 29.6 | 2.24 | 757. | 579.1 | 087 | 312 | 2.9 | 0.87 | 0.98 | 0.96 | 0.16 | 1.5 | 0.17 | 119. | -10.5 | 221. | -0.05 | -19.7 |
| 162122. | 305. | 15.63 | 502. | 94. | 20.73 | 7.51 | 30.9 | 2.24 | 767. | 576.9 | 271 | 325 | 3.3 | 0.91 | 0.94 | 0.89 | 0.16 | 1.6 | 0.21 | 119. | -14.0 | 277. | -0.16 | -2.9 |
| 162810. | 298. | 16.13 | 506. | 102. | 20.86 | 7.43 | 30.4 | 2.32 | 786. | 575.9 | 087 | 316 | 2.8 | 0.98 | 0.91 | 0.97 | 0.17 | 1.8 | 0.23 | 137. | -23.9 | 318. | -0.14 | -4.3 |
| 163454. | 331. | 16.50 | 501. | 91. | 21.00 | 7.23 | 29.4 | 2.60 | 767. | 573.0 | 271 | 317 | 2.5 | 0.86 | 1.01 | 0.83 | 0.15 | 1.6 | 0.20 | 76. | -16.3 | 180. | 0.02 | 34.1 |
| 1642 9. | 293. | 15.94 | 502. | 87. | 21.08 | 7.15 | 31.3 | 2.37 | 786. | 573.1 | 088 | 305 | 2.5 | 0.84 | 1.00 | 0.88 | 0.17 | 1.7 | 0.20 | 118. | -25.1 | 231. | -0.12 | -3.7 |
| 164841. | 311. | 15.85 | 501. | 80. | 21.18 | 6.71 | 31.9 | 2.30 | 815. | 572.7 | 270 | 313 | 2.4 | 0.88 | 1.06 | 0.90 | 0.19 | 1.6 | 0.20 | 130. | -21.2 | 245. | -0.06 | -10.3 |
| GRID, 1600' MSL WORKING SOUTH TO NORTH | | | | | | | | | | | | | | | | | | | | | | | | |
| 171916. | 288. | 15.78 | 511. | 88. | 21.44 | 6.25 | 32.4 | 2.29 | 792. | 575.6 | 089 | 296 | 1.7 | 1.08 | 0.97 | 0.91 | 0.16 | 1.5 | 0.19 | 87. | -16.9 | 163. | -0.08 | -5.1 |
| 172537. | 311. | 16.32 | 507. | 88. | 21.55 | 6.41 | 32.7 | 2.33 | 845. | 576.3 | 270 | 318 | 1.4 | 1.12 | 1.07 | 0.94 | 0.15 | 1.4 | 0.17 | 83. | -16.6 | 187. | -0.06 | -8.5 |
| 173244. | 305. | 16.48 | 509. | 97. | 21.57 | 6.51 | 31.7 | 2.51 | 797. | 575.2 | 087 | 315 | 1.8 | 0.97 | 1.07 | 0.80 | 0.15 | 1.6 | 0.19 | 89. | -18.5 | 170. | -0.05 | -12.6 |
| 173932. | 312. | 16.17 | 510. | 98. | 21.69 | 6.45 | 32.7 | 2.33 | 841. | 574.1 | 269 | 301 | 1.2 | 0.98 | 1.06 | 0.99 | 0.16 | 1.4 | 0.17 | 110. | -23.0 | 250. | -0.05 | -16.9 |
| 174635. | 296. | 16.34 | 512. | 100. | 21.78 | 6.59 | 33.7 | 2.01 | 730. | 572.0 | 087 | 307 | 2.6 | 0.90 | 1.03 | 0.85 | 0.15 | 1.4 | 0.14 | 84. | -14.9 | 168. | 0.06 | 10.1 |
| 175319. | 311. | 16.32 | 510. | 103. | 21.93 | 6.61 | 33.5 | 2.19 | 841. | 570.9 | 270 | 310 | 1.9 | 1.13 | 0.97 | 1.08 | 0.20 | 1.4 | 0.15 | 150. | -18.4 | 212. | -0.08 | -10.6 |
| 18 011. | 285. | 15.63 | 513. | 115. | 21.95 | 6.26 | 33.0 | 2.18 | 808. | 569.6 | 088 | 285 | 1.9 | 0.87 | 1.03 | 1.05 | 0.18 | 1.1 | 0.13 | 122. | -13.6 | 166. | 0.03 | 50.6 |
| 18 633. | 316. | 16.17 | 508. | 137. | 22.12 | 6.34 | 34.5 | 1.91 | 758. | 570.3 | 269 | 293 | 2.3 | 1.06 | 1.09 | 1.23 | 0.18 | 1.0 | 0.11 | 166. | -9.5 | 131. | -0.06 | -24.1 |

TABLE 9(k): TWIN OTTER DATA - FIFE89 FLIGHT 11 - 08 AUGUST, 1989

NAE C-FPOK , FILE 1ARCFIFE89 (08 AUG 89), FLIGHT DAT 08-AUG-89 PRINT DATE 09-AUG-89 FIFE 89-12, MINIGRIDS

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200
MEAN WIND DIRECTION AND SPEED FROM LITTON

| RUN AVERAGES | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP $W/m^2$ | LICOR $mg/m^3$ | HDGL T | T | WIND $ms^{-1}$ | UGEL $ms^{-1}$ | VGEL | WEP | TS degC | CO2 $mg/m^3$ | H2O $gm/m^3$ | WT $W/m^2$ | WC kg/hh | WQ $W/m^2$ | UW $N/m^2$ | Z/L |
| UPPER LEVEL RUNS | | | | | | | | | | | | | | | | | | | | | | | | |
| NORTH EDGE | | | | | | | | | | | | | | | | | | | | | | | | |
| 195114. | 376. | 20.04 | 2303. | * | 5.24 | 2.29 | 32.4 | 1.75 | 871. | 467.2 | 273 | 342 | 3.5 | 1.00 | 0.85 | 0.76 | 0.11 | 0.7 | 0.22 | -11. | 0.9 | 10. | -0.09 | 4.2 |
| 212814. | 250. | 14.58 | 2322. | * | 5.89 | 1.66 | 30.2 | 1.86 | 684. | 465.1 | 087 | 003 | 3.2 | 0.89 | 1.01 | 1.10 | 0.14 | 1.0 | 0.26 | 2. | -1.6 | 51. | -0.09 | -2.2 |
| SOUTH EDGE | | | | | | | | | | | | | | | | | | | | | | | | |
| 204019. | 416. | 22.03 | 2304. | * | 5.73 | 0.71 | 31.4 | 1.92 | 817. | 467.8 | 271 | 303 | 4.6 | 0.87 | 0.67 | 0.67 | 0.11 | 1.1 | 0.36 | 1. | 1.5 | -26. | 0.00 | -36.2 |
| MINI GRID, TRACKS 2,4,6,8 -- 1600' MSL | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 129. | 286. | 15.54 | 501. | 101. | 23.41 | 5.76 | 37.8 | 2.19 | 873. | 576.1 | 089 | 303 | 1.1 | 0.92 | 1.13 | 1.08 | 0.20 | 1.4 | 0.15 | 175. | -20.7 | 212. | -0.06 | -17.9 |
| 20 815. | 314. | 16.17 | 500. | 87. | 23.39 | 5.53 | 35.5 | 2.07 | 789. | 576.9 | 270 | 329 | 2.1 | 0.85 | 1.24 | 0.86 | 0.15 | 1.3 | 0.17 | 86. | -11.0 | 150. | -0.04 | -14.0 |
| 201560. | 308. | 16.42 | 503. | 90. | 23.51 | 4.58 | 33.8 | 2.62 | 815. | 578.0 | 088 | 354 | 2.1 | 1.00 | 1.21 | 0.96 | 0.14 | 1.7 | 0.31 | 81. | -16.7 | 181. | -0.02 | -35.9 |
| 2024 0. | 304. | 15.93 | 504. | 78. | 23.54 | 5.31 | 33.9 | 2.29 | 809. | 575.9 | 269 | 325 | 1.9 | 0.93 | 1.12 | 0.90 | 0.17 | 1.6 | 0.23 | 111. | -18.7 | 232. | -0.09 | -5.0 |
| MINI GRID, TRACKS 8,6,4, AND 2, - 1600' MSL | | | | | | | | | | | | | | | | | | | | | | | | |
| 2054 6. | 290. | 15.66 | 502. | 74. | 23.89 | 4.62 | 34.2 | 2.41 | 747. | 578.1 | 087 | 341 | 1.7 | 1.05 | 1.05 | 0.86 | 0.15 | 1.8 | 0.32 | 93. | -16.0 | 209. | -0.11 | -3.1 |
| 21 1 0. | 301. | 15.94 | 503. | 87. | 23.89 | 5.05 | 32.2 | 2.48 | 701. | 576.9 | 271 | 337 | 1.9 | 0.96 | 1.07 | 0.90 | 0.25 | 1.4 | 0.22 | 98. | -16.8 | 204. | -0.12 | -3.2 |
| 21 835. | 308. | 16.65 | 504. | 95. | 23.99 | 5.24 | 34.8 | 2.23 | 697. | 575.8 | 086 | 000 | 2.3 | 0.90 | 1.02 | 1.09 | 0.15 | 1.3 | 0.19 | 106. | -17.0 | 226. | -0.15 | -2.8 |
| 2116 9. | 302. | 15.57 | 503. | 96. | 24.01 | 5.08 | 31.7 | 2.28 | 665. | 575.7 | 269 | 292 | 0.4 | 0.95 | 1.10 | 0.90 | 0.12 | 1.1 | 0.16 | 76. | -12.7 | 167. | 0.01 | 87.4 |
| REGIONAL RUN C, 500' AGL | | | | | | | | | | | | | | | | | | | | | | | | |
| 213629. | 626. | 38.98 | 574. | 156. | 23.43 | 5.10 | 31.9 | 2.16 | 594. | 572.9 | 240 | 003 | 1.5 | 0.96 | 1.05 | 1.10 | 0.12 | 1.0 | 0.15 | 68. | -12.4 | 186. | 0.07 | 10.4 |
| 2147 2. | 617. | 39.84 | 560. | 159. | 24.29 | 4.05 | 37.5 | 1.58 | 593. | 577.1 | 240 | 349 | 1.1 | 1.03 | 1.26 | 1.11 | 0.15 | 0.9 | 0.09 | 114. | -7.6 | 100. | 0.02 | 81.9 |

TABLE 9(I): TWIN OTTER DATA - FIFE89 FLIGHT 12 - 08 AUGUST, 1989

NAE C-FPOK , FILE 1ARCFIFE89 (10 AUG 89), FLIGHT DAT 10-AUG-89 PRINT DATE 10-AUG-89 FIFE- 89-13, GRIDS

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200
MEAN WIND DIRECTION AND SPEED FROM LITTON

| RUN AVERAGES | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP $W/m^2$ | LICOR $mg/m^3$ | HDGL T | WIND T | $ms^{-1}$ | UGEL $ms^{-1}$ | VGEL $ms^{-1}$ | WEP | TS degC | CO2 $mg/m^3$ | H2O $gm/m^3$ | WT $W/m^2$ | WC kg/hh | WQ $W/m^2$ | UW $N/m^2$ | Z/L |
| REGIONAL RUN C, 500' AGL | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 08 32 | 571 | 40.42 | 547. | 159. | 21.79 | 10.20 | 31.2 | 1.49 | 641. | 567.7 | 066 | 195 | 11.2 | 1.21 | 1.08 | 0.97 | 0.16 | 1.0 | 0.13 | 109. | -8.3 | 164. | -0.53 | -0.7 |
| 16 18 08 | 549 | 38.52 | 564. | 164. | 22.15 | 10.23 | 31.3 | 1.99 | 722. | 562.7 | 065 | 197 | 9.5 | 1.09 | 1.09 | 1.03 | 0.15 | 1.3 | 0.15 | 101. | -14.3 | 148. | -0.32 | -1.4 |
| PBL RUNS - NORTH EDGE THEN SOUTH EDGE | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 36 40 | 332 | 17.36 | 1755. | * | 10.69 | 7.56 | 30.8 | 1.58 | 811. | 489.4 | 261 | 194 | 8.6 | 0.73 | 0.81 | 0.89 | 0.16 | 0.7 | 0.24 | -15. | -3.2 | 217. | 0.03 | -0.5 |
| 17 47 17 | 316 | 16.86 | 1855. | * | 10.11 | 7.30 | 30.1 | 1.74 | 658. | 480.6 | 260 | 194 | 8.4 | 0.69 | 0.74 | 0.80 | 0.11 | 1.0 | 0.17 | -11. | -6.8 | 109. | 0.02 | -19.1 |
| GRID, 1600', WORKING NORTH TO SOUTH | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 46 01 | 296 | 16.05 | 496. | 132. | 23.37 | 10.65 | 34.6 | 1.83 | 832. | 568.3 | 097 | 187 | 8.4 | 1.09 | 1.15 | 1.19 | 0.23 | 1.3 | 0.15 | 204. | -18.7 | 173. | -0.34 | -2.0 |
| 16 52 47 | 312 | 15.49 | 499. | 106. | 23.39 | 10.66 | 32.3 | 2.14 | 764. | 567.2 | 259 | 189 | 9.1 | 1.21 | 1.11 | 1.04 | 0.19 | 1.3 | 0.13 | 131. | -15.8 | 157. | -0.52 | -0.6 |
| 16 59 52 | 285 | 15.37 | 504. | 107. | 23.47 | 10.63 | 34.0 | 2.09 | 808. | 565.2 | 098 | 185 | 8.1 | 1.09 | 1.22 | 1.07 | 0.21 | 1.3 | 0.13 | 146. | -15.0 | 167. | -0.45 | -0.8 |
| 17 06 30 | 324 | 16.14 | 507. | 101. | 23.42 | 10.49 | 32.0 | 2.02 | 666. | 564.0 | 258 | 191 | 9.2 | 1.09 | 1.22 | 0.93 | 0.19 | 1.6 | 0.16 | 125. | -22.2 | 205. | -0.48 | -0.6 |
| 17 13 16 | 297 | 16.04 | 508. | 105. | 23.52 | 10.52 | 33.0 | 2.20 | 805. | 562.9 | 098 | 192 | 8.6 | 1.12 | 1.47 | 0.98 | 0.22 | 1.8 | 0.17 | 161. | -27.7 | 263. | -0.44 | -0.9 |
| 17 20 14 | 326 | 16.25 | 506. | 98. | 23.44 | 10.42 | 31.8 | 2.35 | 714. | 562.6 | 259 | 194 | 9.1 | 1.05 | 1.30 | 0.93 | 0.19 | 1.5 | 0.14 | 119. | -17.0 | 174. | -0.39 | -0.7 |
| 17 27 21 | 301 | 16.40 | 507. | 96. | 23.50 | 10.39 | 32.7 | 2.22 | 742. | 562.5 | 098 | 196 | 8.6 | 1.12 | 1.38 | 0.92 | 0.19 | 1.7 | 0.16 | 113. | -22.3 | 211. | -0.38 | -0.7 |
| 17 34 12 | 318 | 16.01 | 509. | 91. | 23.52 | 10.45 | 31.5 | 2.15 | 680. | 561.2 | 259 | 195 | 9.4 | 1.19 | 1.16 | 1.14 | 0.19 | 1.5 | 0.13 | 142. | -23.2 | 199. | -0.31 | -1.1 |
| GRID, 1600', WORKING SOUTH TO NORTH | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 57 31 | 295 | 15.72 | 512. | 92. | 23.65 | 10.27 | 31.8 | 2.12 | 640. | 564.0 | 097 | 182 | 7.6 | 1.13 | 1.25 | 1.04 | 0.19 | 1.2 | 0.10 | 134. | -17.1 | 156. | -0.39 | -0.8 |
| 18 04 25 | 311 | 16.24 | 509. | 95. | 23.76 | 10.38 | 31.5 | 2.15 | 595. | 563.8 | 260 | 180 | 8.4 | 1.22 | 1.25 | 1.13 | 0.19 | 1.4 | 0.14 | 153. | -24.6 | 225. | -0.38 | -1.0 |
| 18 11 50 | 319 | 17.12 | 506. | 99. | 23.88 | 10.42 | 32.0 | 2.31 | 619. | 563.1 | 097 | 174 | 7.6 | 1.06 | 1.39 | 0.98 | 0.18 | 1.6 | 0.15 | 130. | -23.5 | 206. | -0.26 | -1.5 |
| 18 18 38 | 310 | 16.16 | 506. | 100. | 23.91 | 10.43 | 33.2 | 2.11 | 725. | 562.5 | 259 | 172 | 8.6 | 1.04 | 1.29 | 1.08 | 0.19 | 1.6 | 0.16 | 135. | -24.7 | 233. | -0.27 | -1.5 |
| 18 25 36 | 314 | 16.68 | 506. | 99. | 23.98 | 10.41 | 35.3 | 1.96 | 741. | 561.9 | 097 | 171 | 7.7 | 0.99 | 1.38 | 0.92 | 0.17 | 1.5 | 0.16 | 97. | -20.2 | 193. | -0.29 | -1.0 |

TABLE (m): TWIN OTTER DATA - FIFE89 FLIGHT 13 - 10 AUGUST, 1989

NAE C-FPOK , FILE 1ARCFIFE89 (10 AUG 89), FLIGHT DAT 10-AUG-89 PRINT DATE 10-AUG-89 FIFE 89-14, NIGHT FLIGHT

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200
MEAN WIND DIRECTION AND SPEED FROM LITTON

| RUN AVERAGES | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 GRN degC | RADUP $W/m^2$ | LICOR $mg/m^3$ | HDGL T | WIND T | $ms^{-1}$ | UGEL $ms^{-1}$ | VGEL | WEP | TS degC | CO2 $mg/m^3$ | H2O $gm/m^3$ | WT $W/m^2$ | WC kg/hh | WQ $W/m^2$ | UW $N/m^2$ | Z/L |
| NIGHT RUNS, VERMA LINE, FW2-FE2 | | | | | | | | | | | | | | | | | | | | | | | |
| 01 18 21 | 286 | 15.69 | 565. | 155. | 22.34 | 10.28 | 17.2-3.07 | 1. | 559.8 | 100 | 183 | 7.9 | 0.23 | 0.13 | 0.11 | 0.06 | 0.5 | 0.07 | -1. | -0.1 | 2. | -0.01 | 2.7 |
| 01 32 23 | 302 | 16.03 | 506. | 95. | 22.60 | 10.58 | 16.5-5.61 | -11. | 562.9 | 098 | 179 | 8.1 | 0.28 | 0.17 | 0.12 | 0.07 | 0.5 | 0.06 | -1. | 0.2 | 5. | -0.01 | 1.2 |
| 01 46 36 | 304 | 16.23 | 507. | 98. | 22.54 | 10.52 | 15.7-7.00 | -16. | 561.0 | 098 | 178 | 8.3 | 0.22 | 0.14 | 0.10 | 0.05 | 0.5 | 0.04 | -1. | 0.2 | 3. | -0.01 | 2.5 |
| 02 01 06 | 296 | 15.75 | 502. | 93. | 22.48 | 10.55 | 15.7-7.21 | -17. | 560.3 | 098 | 182 | 7.8 | 0.21 | 0.13 | 0.10 | 0.07 | 0.5 | 0.04 | 0. | 0.1 | 2. | 0.00 | 1.6 |
| 02 15 17 | 298 | 16.06 | 504. | 99. | 22.41 | 10.47 | 15.4-7.28 | -18. | 559.5 | 098 | 188 | 7.1 | 0.18 | 0.10 | 0.09 | 0.06 | 0.4 | 0.04 | -2. | 0.1 | 1. | 0.00 | 23.2 |
| 02 30 08 | 311 | 16.52 | 503. | 101. | 22.37 | 10.37 | 14.9-7.21 | -19. | 559.8 | 097 | 189 | 6.6 | 0.21 | 0.12 | 0.10 | 0.06 | 0.4 | 0.06 | -1. | 0.0 | 3. | 0.00 | 12.5 |
| LINE FNW-FNE | | | | | | | | | | | | | | | | | | | | | | | |
| 01 25 17 | 303 | 15.61 | 564. | 166. | 22.37 | 10.30 | 17.1-4.54 | -8. | 559.2 | 258 | 184 | 9.4 | 0.16 | 0.14 | 0.09 | 0.04 | 0.4 | 0.04 | 0. | 0.1 | 1. | 0.00 | 2.7 |
| 01 39 29 | 298 | 15.48 | 505. | 104. | 22.63 | 10.57 | 16.3-6.24 | -14. | 561.9 | 259 | 182 | 9.1 | 0.21 | 0.15 | 0.14 | 0.05 | 0.5 | 0.05 | 0. | -0.1 | 2. | 0.00 | 1.7 |
| 01 54 01 | 309 | 15.93 | 506. | 108. | 22.54 | 10.53 | 15.7-7.22 | -16. | 560.5 | 260 | 184 | 8.9 | 0.21 | 0.14 | 0.11 | 0.06 | 0.6 | 0.10 | -1. | 0.1 | 3. | -0.01 | 3.3 |
| 02 08 09 | 311 | 16.05 | 501. | 104. | 22.47 | 10.54 | 15.6-7.30 | -17. | 559.8 | 259 | 188 | 8.3 | 0.22 | 0.17 | 0.11 | 0.08 | 0.6 | 0.06 | -2. | 0.3 | 6. | -0.01 | 4.1 |
| 02 22 25 | 314 | 16.05 | 502. | 109. | 22.47 | 10.40 | 15.0-7.22 | -18. | 559.3 | 259 | 192 | 7.6 | 0.16 | 0.13 | 0.10 | 0.07 | 0.5 | 0.06 | 0. | 0.2 | 0. | 0.00 | 2.5 |
| 02 37 17 | 307 | 15.63 | 502. | 109. | 22.47 | 10.24 | 15.0-7.17 | -19. | 559.5 | 258 | 190 | 8.2 | 0.15 | 0.16 | 0.10 | 0.07 | 0.5 | 0.07 | 0. | 0.2 | 0. | 0.00 | -8.6 |

TABLE 9(n): TWIN OTTER DATA - FIFE89 FLIGHT 14 - 10 AUGUST, 1989

NAE C-FPOK , FILE 1ARCFIFE89 (10 AUG 89), FLIGHT DAT 11-AUG-89 PRINT DATE 11-AUG-89 FIFE 89-15, T-PATTERN

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200
MEAN WIND DIRECTION AND SPEED FROM LITTON

| RUN AVERAGES | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP $W/m^2$ | LICOR $mg/m^3$ | HDGL T | WIND T | WIND $ms^{-1}$ | UGEL $ms^{-1}$ | VGEL $ms^{-1}$ | WEP | TS degC | CO2 $mg/m^3$ | H2O $gm/m^3$ | WT $W/m^2$ | WC kg/hh | WQ $W/m^2$ | UW $N/m^2$ | Z/L |
| REGIONAL RUN C, 500 ' AGL (FORMATION WITH KINGAIR) | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 36 13 | 602 | 40.54 | 559. | 169. | 21.39 | 11.69 | 31.3 | 1.40 | 490. | 565.3 | 064 | 181 | 6.7 | 0.95 | 1.04 | 1.02 | 0.16 | 1.1 | 0.15 | 103. | -11.7 | 171. | -0.35 | -1.3 |
| 16 46 18 | 577 | 38.66 | 565. | 162. | 21.64 | 11.56 | 28.4 | 1.94 | 510. | 560.7 | 066 | 176 | 6.6 | 0.89 | 0.96 | 0.93 | 0.12 | 1.2 | 0.21 | 71. | -15.4 | 210. | -0.29 | -1.3 |
| T-PATTERN, EAST/WEST PROFILE STACK, FNW-FNE | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 09 57 | 297 | 15.50 | 506. | 111. | 22.51 | 10.82 | 31.7 | 2.04 | 685. | 563.0 | 261 | 173 | 8.0 | 0.95 | 1.01 | 0.97 | 0.22 | 1.2 | 0.13 | 150. | -13.8 | 139. | -0.42 | -0.9 |
| 17 16 54 | 298 | 15.28 | 592. | 201. | 21.65 | 10.60 | 32.9 | 1.91 | 728. | 557.1 | 098 | 170 | 7.6 | 0.96 | 0.90 | 1.16 | 0.18 | 1.2 | 0.17 | 159. | -13.3 | 266. | -0.32 | -2.8 |
| 17 24 30 | 298 | 15.69 | 839. | 449. | 19.20 | 10.07 | 32.3 | 1.83 | 733. | 540.5 | 261 | 176 | 8.0 | 0.92 | 0.83 | 1.30 | 0.13 | 1.2 | 0.20 | 114. | -5.7 | 362. | -0.42 | -3.2 |
| 17 33 26 | 318 | 17.28 | 1481. | 1089. | 13.08 | 8.15 | 32.5 | 1.56 | 847. | 501.8 | 098 | 178 | 7.4 | 0.63 | 0.74 | 0.76 | 0.17 | 1.0 | 0.46 | -24. | -5.6 | 311. | 0.01 | -27.2 |
| 18 52 29 | 310 | 17.58 | 1543. | 1145. | 13.20 | 7.93 | 33.0 | 1.59 | 708. | 498.3 | 262 | 170 | 6.6 | 0.90 | 0.81 | 1.10 | 0.14 | 2.0 | 0.44 | -11. | -16.3 | 264. | -0.09 | -3.3 |
| 19 01 17 | 318 | 15.88 | 865. | 474. | 20.03 | 9.52 | 34.9 | 1.77 | 717. | 539.1 | 097 | 170 | 6.3 | 0.92 | 0.89 | 1.25 | 0.14 | 1.5 | 0.16 | 115. | -18.1 | 89. | -0.13 | -16.7 |
| 19 08 47 | 294 | 15.58 | 597. | 196. | 22.88 | 9.82 | 34.3 | 1.93 | 738. | 554.5 | 261 | 173 | 7.1 | 0.86 | 1.02 | 1.14 | 0.19 | 1.2 | 0.18 | 147. | -19.0 | 172. | -0.28 | -2.9 |
| 19 15 29 | 295 | 15.42 | 509. | 108. | 23.84 | 10.27 | 35.6 | 1.96 | 721. | 558.8 | 095 | 168 | 5.2 | 0.91 | 1.26 | 0.95 | 0.20 | 1.2 | 0.18 | 135. | -14.4 | 134. | -0.19 | -2.7 |
| T-PATTERN, NORTH/SOUTH , FN2-FS2 | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 44 22 | 383 | 17.23 | 1536. | 1126. | 12.68 | 7.41 | 30.1 | 1.64 | 773. | 500.1 | 181 | 173 | 8.4 | 0.53 | 0.65 | 0.50 | 0.14 | 0.7 | 0.44 | -7. | -1.4 | -3. | -0.04 | 10.2 |
| 17 53 07 | 278 | 16.49 | 865. | 460. | 19.27 | 9.38 | 33.3 | 1.91 | 848. | 541.6 | 003 | 177 | 7.7 | 0.71 | 0.74 | 0.90 | 0.12 | 1.1 | 0.22 | 30. | -4.0 | 66. | -0.07 | -11.5 |
| 18 00 41 | 371 | 16.89 | 599. | 190. | 22.10 | 10.06 | 34.7 | 2.00 | 864. | 557.9 | 181 | 177 | 7.9 | 0.85 | 1.04 | 1.03 | 0.16 | 1.2 | 0.16 | 100. | -14.8 | 138. | -0.17 | -4.1 |
| 18 08 43 | 274 | 16.75 | 520. | 104. | 23.05 | 10.34 | 34.7 | 2.12 | 839. | 562.3 | 001 | 181 | 7.1 | 0.94 | 1.05 | 0.93 | 0.19 | 1.6 | 0.16 | 129. | -20.2 | 146. | -0.16 | -3.0 |
| 18 15 53 | 363 | 16.52 | 523. | 108. | 23.07 | 10.29 | 35.0 | 2.04 | 857. | 560.9 | 181 | 171 | 7.9 | 1.04 | 0.96 | 0.88 | 0.18 | 1.4 | 0.17 | 122. | -18.2 | 166. | -0.13 | -4.5 |
| 18 23 53 | 280 | 16.63 | 590. | 178. | 22.36 | 10.16 | 34.7 | 2.04 | 800. | 555.8 | 003 | 179 | 7.5 | 0.92 | 0.88 | 1.14 | 0.15 | 1.3 | 0.19 | 115. | -18.6 | 125. | -0.40 | -1.2 |
| 18 30 53 | 368 | 16.51 | 869. | 463. | 19.61 | 9.73 | 34.0 | 1.87 | 776. | 536.8 | 181 | 171 | 7.2 | 0.96 | 0.89 | 1.03 | 0.11 | 1.1 | 0.17 | 59. | -9.4 | 104. | -0.10 | -13.5 |
| 18 39 56 | 263 | 16.71 | 1549. | 1138. | 12.90 | 8.35 | 32.1 | 1.67 | 782. | 495.8 | 003 | 176 | 6.5 | 0.90 | 0.85 | 1.39 | 0.13 | 1.6 | 0.44 | 13. | -19.7 | 434. | -0.18 | -6.3 |
| REGIONAL RUN ON RETURN, FRE-FRW2 | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 35 39 | 618 | 38.18 | 574. | 159. | 23.33 | 10.09 | 35.6 | 1.89 | 725. | 553.4 | 235 | 174 | 6.2 | 1.05 | 1.16 | 0.99 | 0.14 | 1.4 | 0.22 | 90. | -15.4 | 159. | -0.20 | -2.5 |
| 19 46 03 | 653 | 40.76 | 554. | 154. | 23.96 | 9.66 | 39.9 | 1.43 | 762. | 558.0 | 234 | 177 | 7.3 | 1.10 | 1.35 | 1.35 | 0.23 | 1.2 | 0.11 | 213. | -14.5 | 125. | -0.12 | -11.6 |

TABLE 9(o): TWIN OTTER DATA - FIFE89 FLIGHT 15 - 11 AUGUST, 1989

NAE C-FPOK , FILE 1ARCFIFE89 (10 AUG 89), FLIGHT DAT 12-AUG-89 PRINT DATE 12-AUG-89 FIFE 16, REG, GRIDS, RESERVOIR, REG

FUSELAGE TEMPERATURE DATA USED; FILTERED AT 0.01200; MEAN WIND DIRECTION AND SPEED FROM LITTON

| RUN AVERAGES | | | | | | | | | | | | | | | RMS | | | | | | CORRECTED FLUXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST GMT | SEC | DIST km | PALT m | RALT m | TEMP degC | DEWPT degC | PRT5 degC | GRN | RADUP $W/m^2$ | LICOR $mg/m^3$ | HDGL T | T | WIND $ms^{-1}$ | UGEL $ms^{-1}$ | VGEL | WEP | TS degC | CO2 $mg/m^3$ | H2O $gm/m^3$ | WT $W/m^2$ | WC kg/hh | WQ $W/m^2$ | UW $N/m^2$ | Z/L |
| REGIONAL RUN, 500 ALG, ** INTERCOMP WITH KING AIR | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 10 09 | 606 | 40.59 | 548. | 161. | 22.74 | 11.14 | 33.7 | 1.45 | 626. | 561.1 | 064 | 178 | 5.7 | 0.92 | 1.03 | 1.07 | 0.18 | 1.1 | 0.12 | 150. | -14.3 | 148. | -0.29 | -2.3 |
| 16 20 19 | 583 | 38.49 | 540. | 139. | 22.81 | 10.82 | 32.5 | * | 684. | 561.1 | 064 | 178 | 5.2 | 0.82 | 1.14 | 0.95 | 0.17 | 1.4 | 0.14 | 101. | -17.4 | 170. | -0.23 | -2.0 |
| UPPER PBL RUNS, NORTH EDGE | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 43 02 | 299 | 16.42 | 1333. | * | 15.08 | 7.44 | 33.2 | 1.42 | 743. | 515.2 | 262 | 177 | 6.7 | 0.61 | 0.73 | 0.80 | 0.13 | 2.1 | 0.62 | -23. | -15.7 | 322. | -0.06 | 0.2 |
| 19 02 42 | 291 | 16.78 | 1948. | * | 10.85 | 5.26 | 36.5 | 1.36 | 871. | 478.3 | 096 | 202 | 4.8 | 0.68 | 0.74 | 0.60 | 0.18 | 2.1 | 0.57 | -12. | -2.8 | 83. | -0.07 | 3.8 |
| UPPER PBL RUNS, SOUTH EDGE | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 53 14 | 328 | 17.69 | 1846. | * | 11.09 | 5.71 | 33.8 | 1.60 | 873. | 486.1 | 264 | 187 | 5.5 | 0.95 | 0.85 | 0.86 | 0.27 | 2.4 | 0.97 | 3. | 6.2 | -150. | 0.02 | -23.0 |
| 8-LINE GRID, 1600 MSL, WORKING NORTH TO SOUTH | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 50 56 | 293 | 14.21 | 504. | 143. | 23.51 | 9.49 | 33.9 | 1.80 | 666. | 566.5 | 098 | 175 | 5.5 | 0.76 | 1.12 | 1.04 | 0.16 | 1.4 | 0.13 | 142. | -17.0 | 162. | -0.32 | -1.7 |
| 16 57 34 | 292 | 15.52 | 508. | 113. | 23.57 | 9.41 | 32.3 | 2.08 | 655. | 566.3 | 263 | 176 | 6.0 | 0.83 | 1.18 | 0.96 | 0.18 | 1.4 | 0.17 | 132. | -19.4 | 221. | -0.21 | -2.4 |
| 17 03 59 | 310 | 16.23 | 508. | 112. | 23.72 | 9.59 | 35.9 | 2.00 | 761. | 566.0 | 095 | 169 | 4.6 | 0.97 | 1.15 | 0.93 | 0.20 | 1.8 | 0.14 | 120. | -16.5 | 177. | -0.29 | -1.3 |
| 17 10 41 | 311 | 16.69 | 505. | 98. | 23.87 | 9.54 | 36.2 | 1.95 | 769. | 565.5 | 263 | 180 | 5.3 | 0.92 | 1.23 | 1.04 | 0.19 | 1.5 | 0.17 | 139. | -20.7 | 176. | -0.05 | -19.4 |
| 17 17 55 | 316 | 16.70 | 506. | 103. | 23.96 | 9.42 | 35.4 | 2.10 | 769. | 565.9 | 095 | 184 | 5.1 | 0.84 | 1.26 | 1.02 | 0.19 | 1.7 | 0.22 | 120. | -22.9 | 210. | -0.17 | -2.9 |
| 17 24 45 | 308 | 16.46 | 506. | 96. | 23.99 | 9.67 | 34.9 | 2.24 | 770. | 565.7 | 263 | 183 | 5.2 | 0.87 | 1.12 | 0.93 | 0.19 | 1.6 | 0.25 | 123. | -21.4 | 206. | -0.06 | -11.5 |
| 17 32 05 | 309 | 16.24 | 508. | 93. | 24.09 | 9.85 | 36.0 | 2.16 | 810. | 565.3 | 094 | 185 | 4.5 | 0.93 | 1.03 | 1.05 | 0.19 | 1.6 | 0.19 | 161. | -25.8 | 238. | -0.20 | -2.6 |
| 17 39 09 | 298 | 15.76 | 505. | 83. | 24.20 | 9.79 | 36.3 | 2.10 | 815. | 565.5 | 263 | 187 | 5.0 | 1.07 | 1.21 | 0.99 | 0.20 | 1.5 | 0.24 | 151. | -18.1 | 202. | -0.19 | -2.2 |
| 8-LINE GRID, 1600' MSL, WORKING SOUTH TO NORTH | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 04 08 | 297 | 15.56 | 509. | 84. | 24.54 | 9.73 | 37.5 | 2.07 | 816. | 565.1 | 095 | 166 | 5.2 | 1.07 | 1.34 | 0.97 | 0.24 | 1.6 | 0.22 | 165. | -23.0 | 227. | -0.24 | -1.8 |
| 18 10 46 | 300 | 16.10 | 508. | 89. | 24.57 | 9.72 | 35.9 | 2.11 | 685. | 565.2 | 264 | 167 | 5.2 | 0.96 | 1.29 | 0.89 | 0.18 | 1.4 | 0.17 | 117. | -19.0 | 207. | -0.20 | -1.8 |
| 18 17 38 | 304 | 15.90 | 510. | 95. | 24.65 | 9.53 | 34.1 | 2.29 | 698. | 564.9 | 095 | 158 | 4.7 | 1.06 | 1.30 | 0.82 | 0.16 | 1.5 | 0.24 | 90. | -16.5 | 191. | -0.21 | -1.4 |
| 18 24 33 | 296 | 16.12 | 509. | 97. | 24.72 | 9.66 | 34.7 | 2.08 | 659. | 563.9 | 264 | 158 | 4.9 | 0.93 | 1.22 | 0.94 | 0.19 | 1.6 | 0.19 | 130. | -21.5 | 226. | -0.11 | -5.0 |
| 18 31 32 | 314 | 16.27 | 510. | 98. | 24.88 | 9.72 | 38.5 | 1.95 | 798. | 562.9 | 093 | 158 | 4.6 | 0.88 | 1.10 | 0.84 | 0.19 | 1.6 | 0.17 | 112. | -18.3 | 181. | -0.16 | -2.8 |
| 18 38 29 | 298 | 16.05 | 506. | 100. | 24.98 | 9.65 | 38.6 | 2.00 | 859. | 563.3 | 264 | 164 | 4.6 | 0.94 | 1.22 | 1.04 | 0.22 | 1.2 | 0.15 | 170. | -18.1 | 248. | -0.26 | -1.9 |
| 18 45 03 | 303 | 15.61 | 505. | 101. | 25.06 | 9.63 | 40.2 | 1.94 | 871. | 563.0 | 095 | 163 | 4.4 | 1.07 | 1.35 | 1.05 | 0.25 | 1.2 | 0.13 | 206. | -15.5 | 174. | -0.34 | -1.6 |
| 18 51 55 | 294 | 16.14 | 508. | 135. | 25.06 | 9.47 | 37.7 | 1.82 | 752. | 562.2 | 264 | 171 | 4.5 | 1.00 | 1.21 | 1.21 | 0.18 | 1.0 | 0.13 | 156. | -11.1 | 172. | -0.13 | -7.1 |
| RUNS OVER RESERVOIR | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 13 33 | 43 | 2.79 | 423. | 83. | 26.16 | 9.46 | 23.6 | 0.59 | 827. | 570.7 | 272 | 176 | 6.0 | 1.08 | 1.05 | 0.87 | 0.09 | 0.6 | 0.15 | 5. | 1.9 | 144. | -0.22 | -0.2 |
| 19 15 32 | 49 | 2.88 | 431. | 92. | 26.17 | 9.46 | 23.5 | 0.55 | 828. | 570.5 | 101 | 161 | 4.7 | 0.91 | 0.88 | 0.88 | 0.14 | 0.6 | 0.16 | 91. | -4.6 | 142. | -0.06 | -7.8 |
| REGIONAL RUN 500' AGL | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 26 28 | 603 | 38.15 | 574. | 153. | 24.81 | 9.22 | 36.7 | 1.88 | 674. | 557.6 | 236 | 166 | 5.7 | 1.03 | 1.27 | 0.95 | 0.16 | 1.2 | 0.16 | 99. | -13.1 | 148. | -0.09 | -9.2 |
| 19 36 35 | 651 | 40.59 | 559. | 156. | 24.64 | 10.20 | 38.0 | 1.40 | 615. | 555.7 | 236 | 185 | 6.3 | 1.09 | 1.07 | 1.05 | 0.18 | 1.0 | 0.09 | 134. | -8.3 | 90. | -0.23 | -2.7 |

TABLE 9(p): TWIN OTTER DATA - FIFE89 FLIGHT 16 - 12 AUGUST, 1989

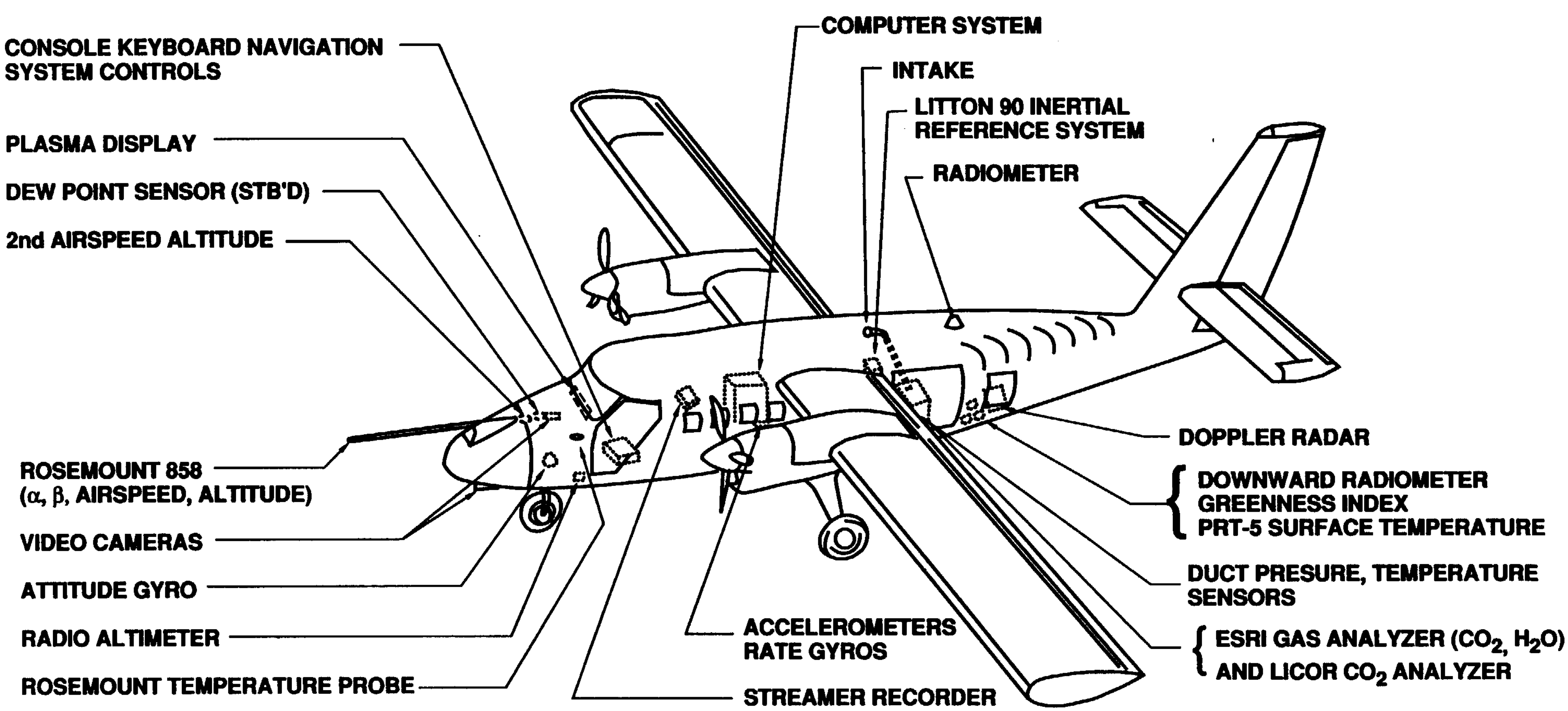



**FIG. 1: NAE TWIN OTTER ATMOSPHERIC RESEARCH AIRCRAFT AS INSTRUMENTED FOR GASEOUS EXCHANGE MEASUREMENT**

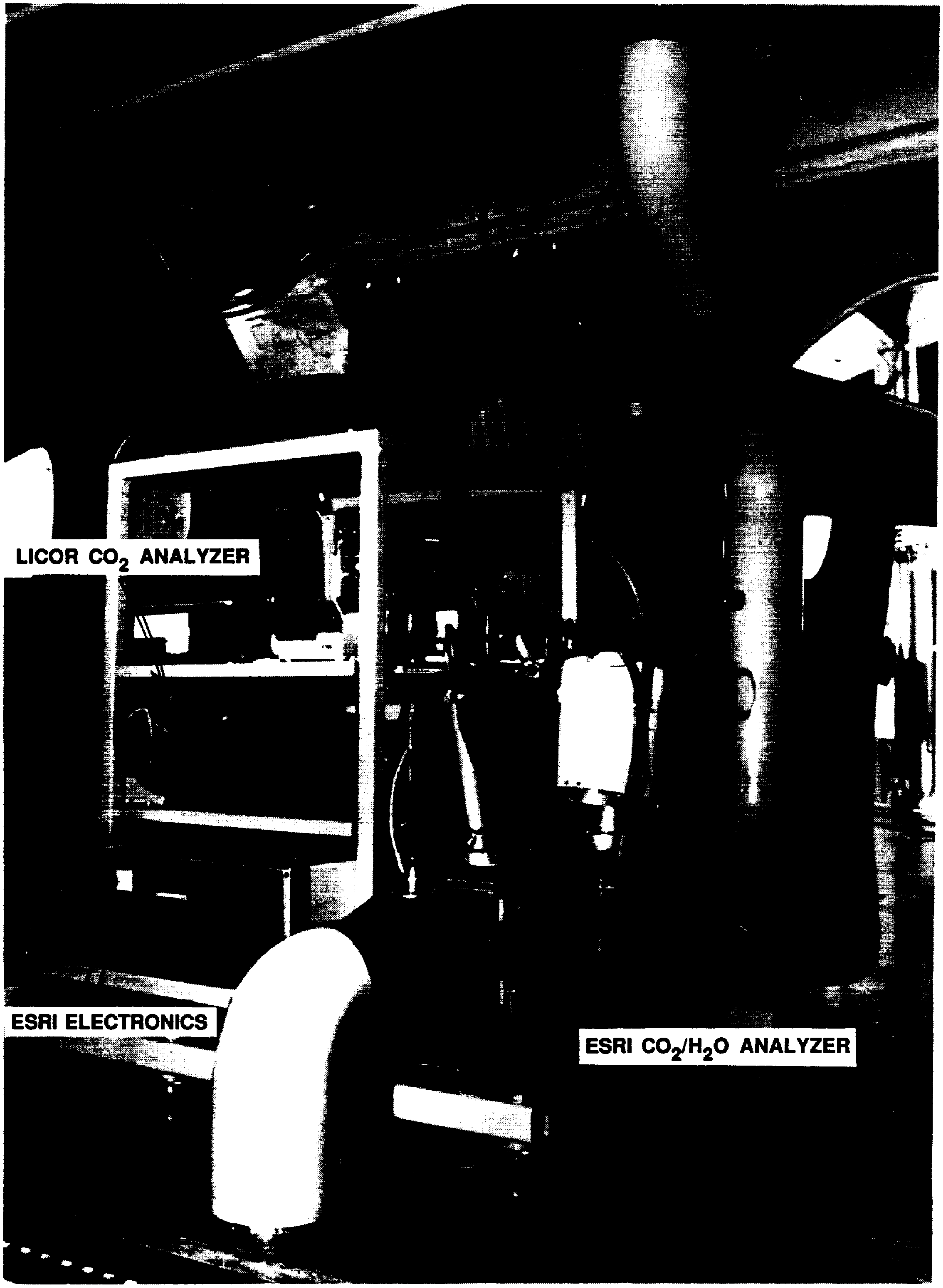
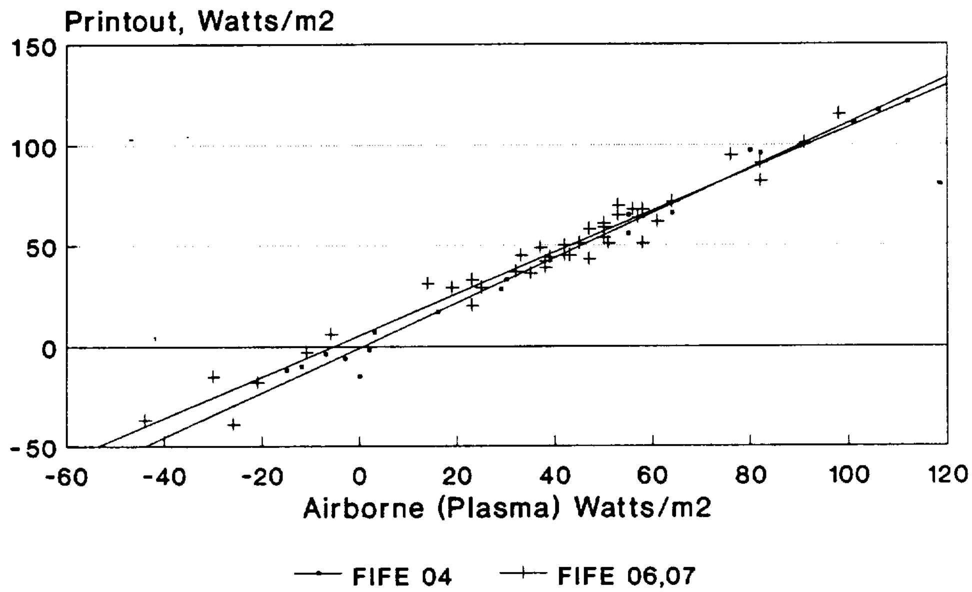



**FIG. 2: DUCT AND GAS ANALYZERS**

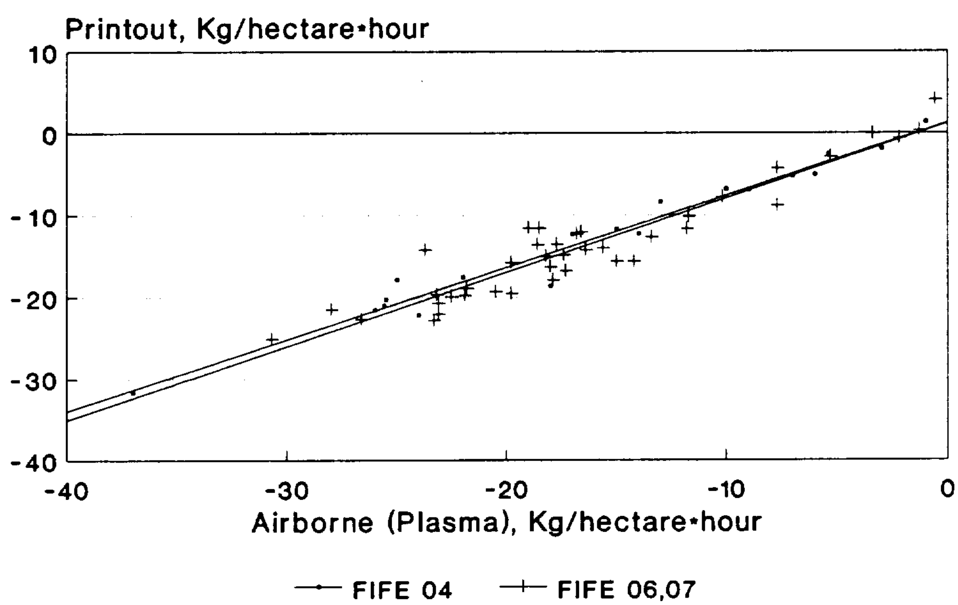
# FIGURE 3: PLAYBACK VS AIRBORNE FLUX

## Sensible Heat Flux

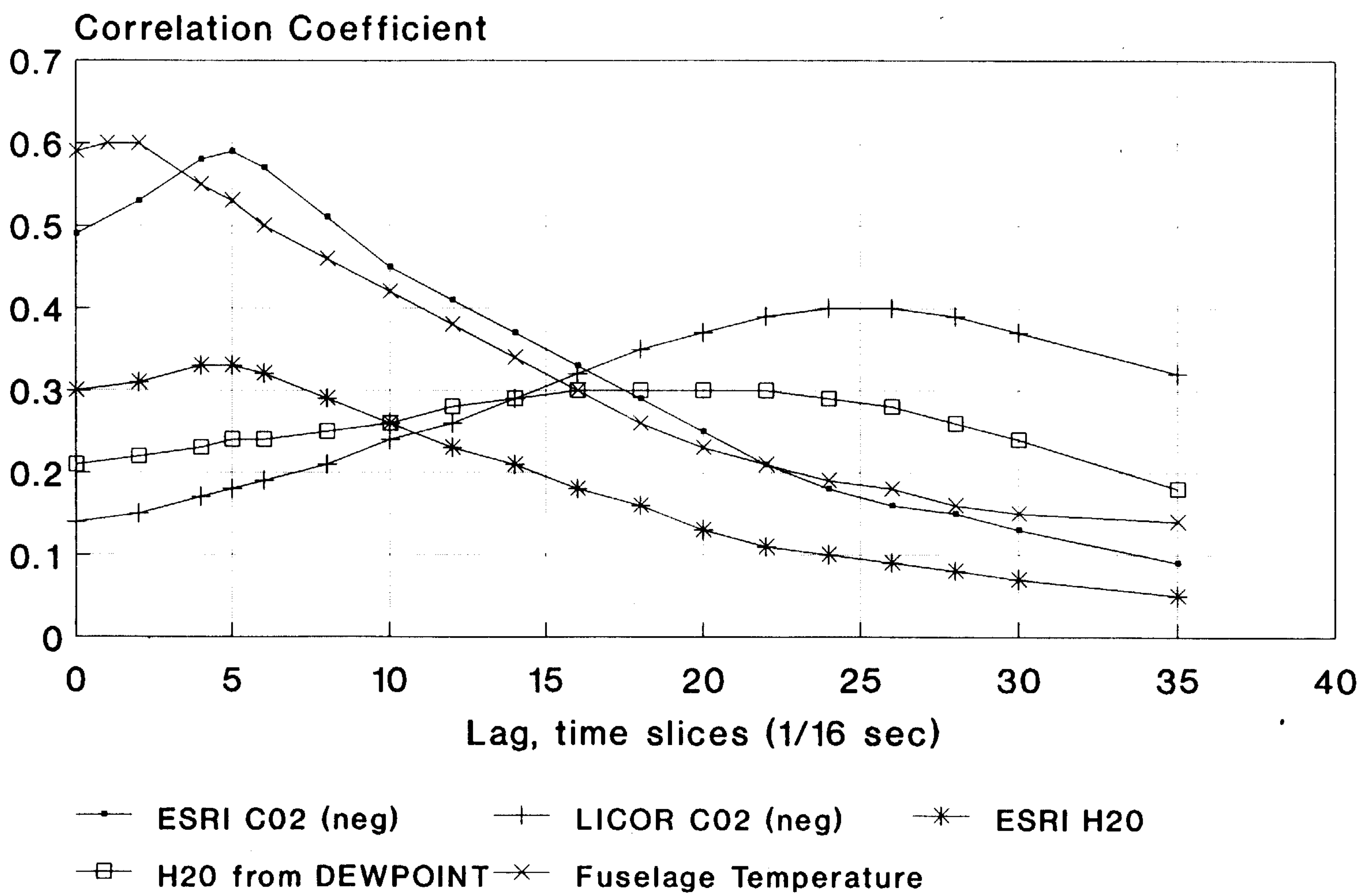


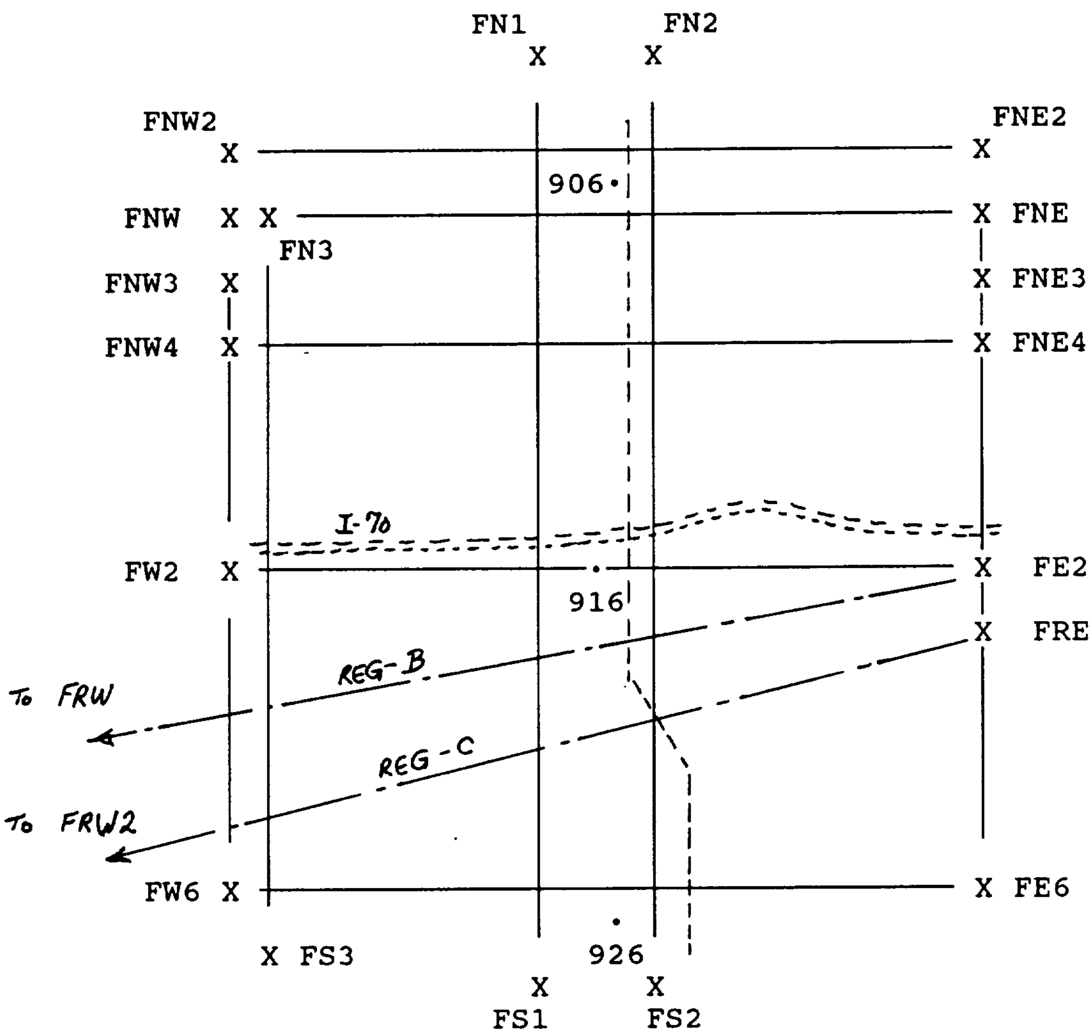

Module POK9CI; HP-filtered data

## C02 Fluxes



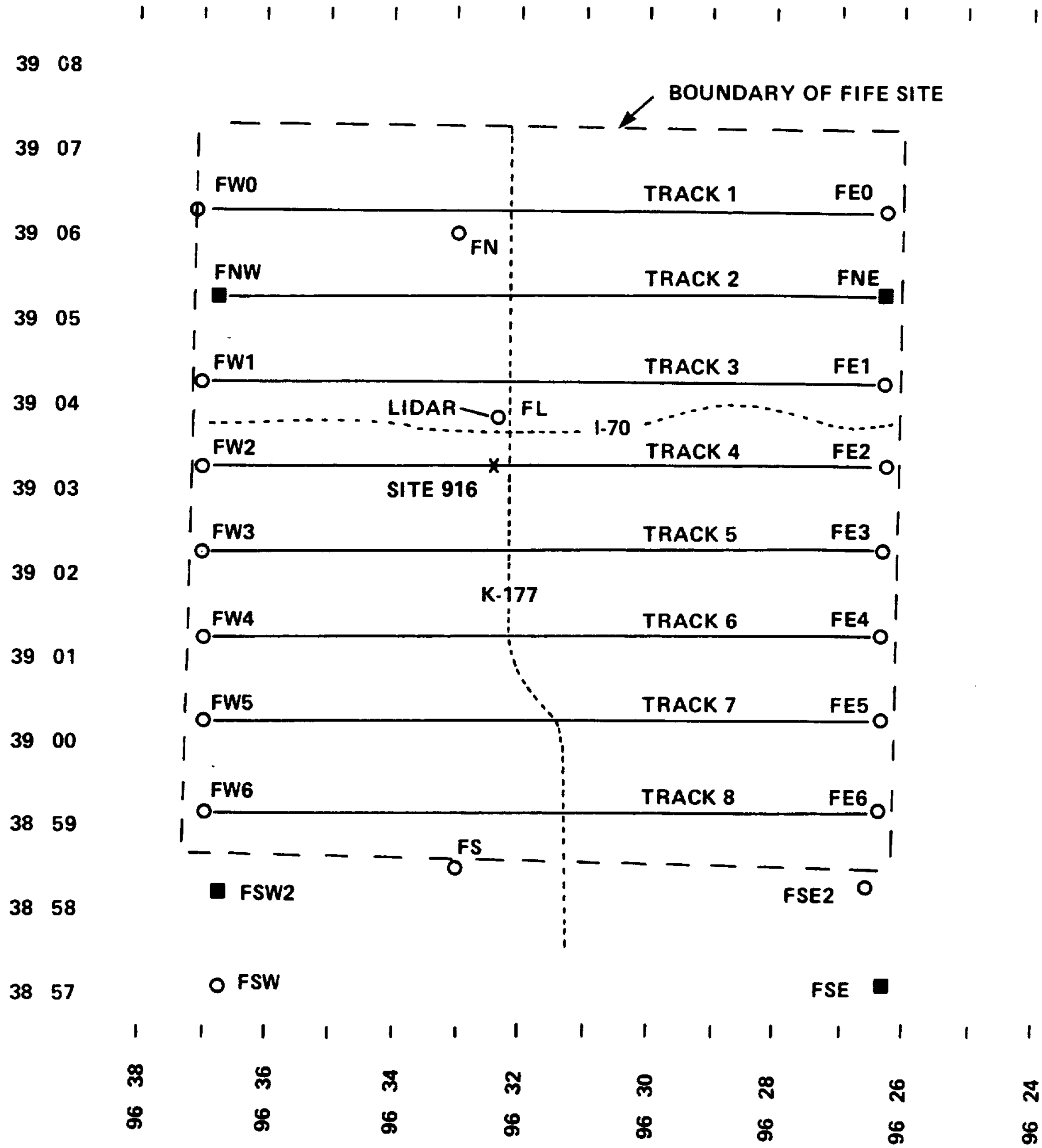
# Figure 4: Time Lag Study






| Label | Latitude | Longitude | Label | Latitude | Longitude |
|---|---|---|---|---|---|
| FN1 | 39 07.0 | 96 33.0 | FN2 | 39 07.0 | 96 31.0 |
| FNW2 | 39 05.8 | 96 37.0 | FNE2 | 39 05.8 | 96 26.3 |
| FNW | 39 05.3 | 96 37.0 | FNE | 39 05.3 | 96 26.3 |
| FN3 | 39 05.3 | 96 26.0 | | | |
| FNW3 | 39 05.3 | 96 37.0 | FNE3 | 39 05.3 | 96 26.3 |
| FNW4 | 39 04.8 | 96 37.0 | FNE4 | 39 04.8 | 96 26.3 |
| FW2 | 39 03.3 | 96 37.0 | FRE (FE2) | 39 02.8 | 96 26.3 |
| FW6 | 38 59.2 | 96 37.0 | FE6 | 38 59.2 | 96 26.3 |
| FS1 | 38 58.0 | 96 33.0 | FS2 | 38 58.4 | 96 31.5 |
| FS3 | 38 58.4 | 96 36.0 | | | |
| FRW | 38 49.0 | 97 16.0 | West point of Regional Run B | | |
| FRW2 | 38 42.0 | 97 13.4 | West Point of regional Run C | | |

**FIGURE 5: NAVIGATION WAYPOINTS - FIFE 89**




| | | LATITUDE | LONGITUDE | | | LATITUDE | LONGITUDE |
|---|---|---|---|---|---|---|---|
| ○ | FW0 | 39 06.3 | 96 37.0 | ○ | FE0 | 39 06.3 | 96 26.3 |
| ■ | FNW | 39 05.3 | 96 36.7 | ■ | FNE | 39 05.3 | 96 26.3 |
| ○ | FW1 | 39 04.3 | 96 37.0 | ○ | FE1 | 39 04.3 | 96 26.3 |
| ○ | FW2 | 39 03.3 | 96 37.0 | ○ | FE2 | 39 03.3 | 96 26.3 |
| ○ | FW3 | 39 02.3 | 96 37.0 | ○ | FE3 | 39 02.3 | 96 26.3 |
| ○ | FW4 | 39 01.3 | 96 37.0 | ○ | FE4 | 39 01.3 | 96 26.3 |
| ○ | FW5 | 39 00.3 | 96 37.0 | ○ | FE5 | 39 00.3 | 96 26.3 |
| ○ | FW6 | 38 59.2 | 96 37.0 | ○ | FE6 | 38 59.2 | 96 26.3 |
| ■ | FSW2 | 38 58.4 | 96 36.7 | ○ | FSE2 | 38 58.4 | 96 26.5 |
| ○ | FSW | 38 57.1 | 96 36.7 | ■ | FSE | 38 57.1 | 96 26.3 |
| ○ | FN | 39 06.0 | 96 33.0 | ○ | FS | 38 58.5 | 96 33.0 |
| ○ | FL | 39 03.8 | 96 32.3 | ■ | WAYPOINTS WITH RED MARKERS | | |

**FIG. 6: WAYPOINTS AND TRACKS FOR GRID FLIGHT PATTERN**

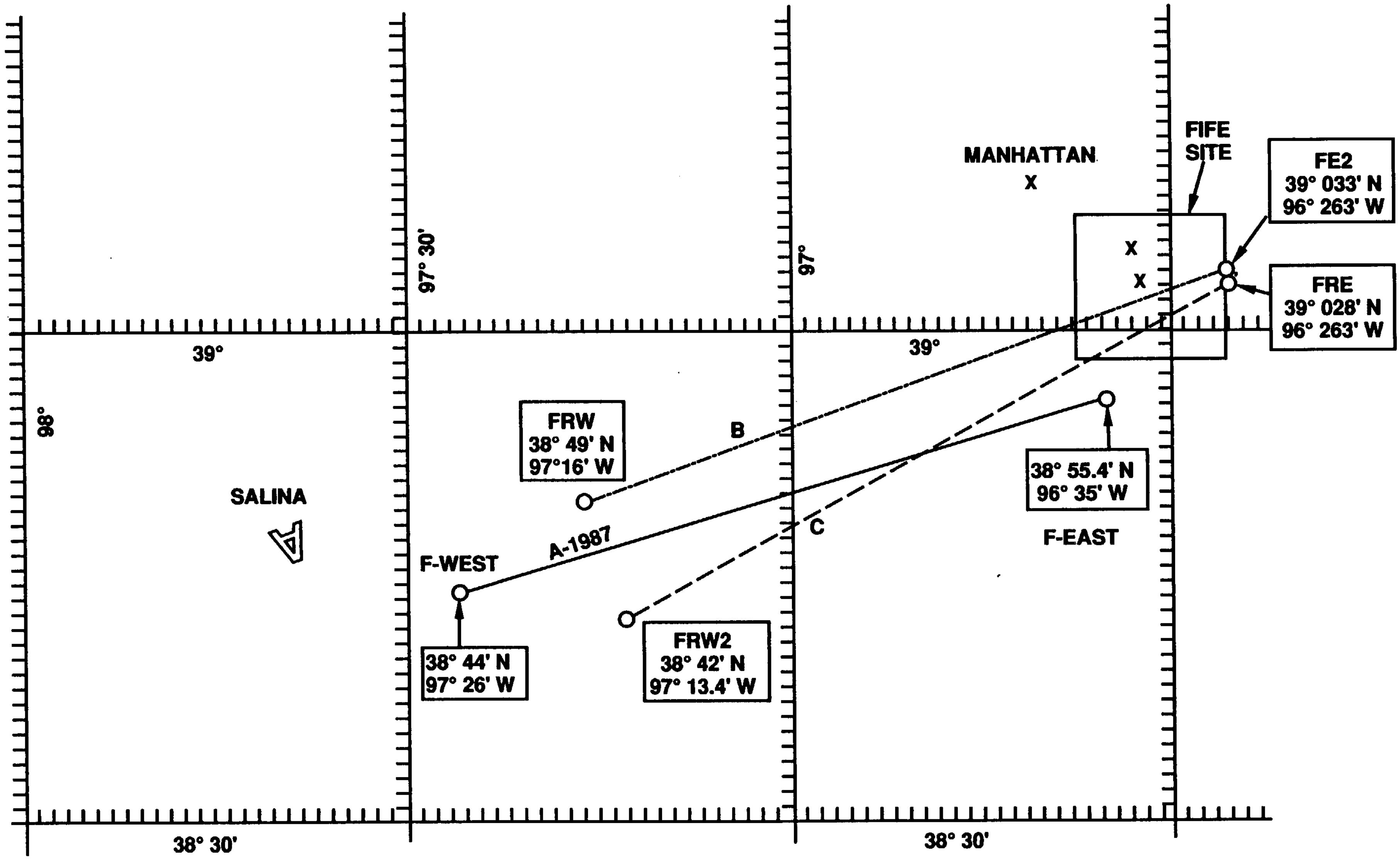
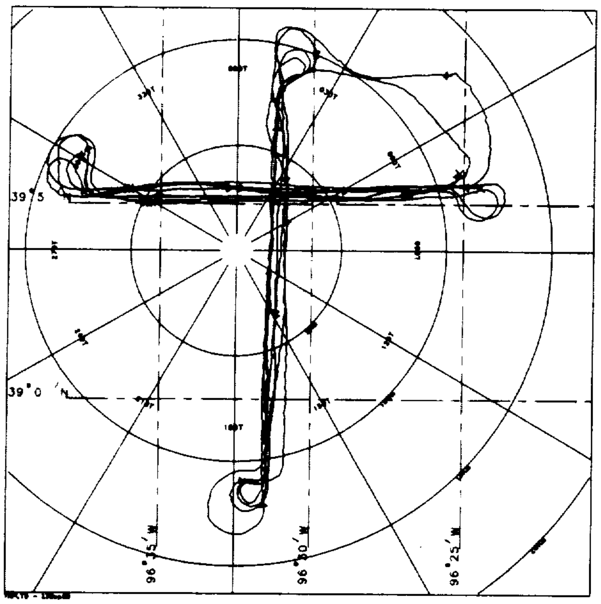



FIG. 7: THE REGIONAL RUNS

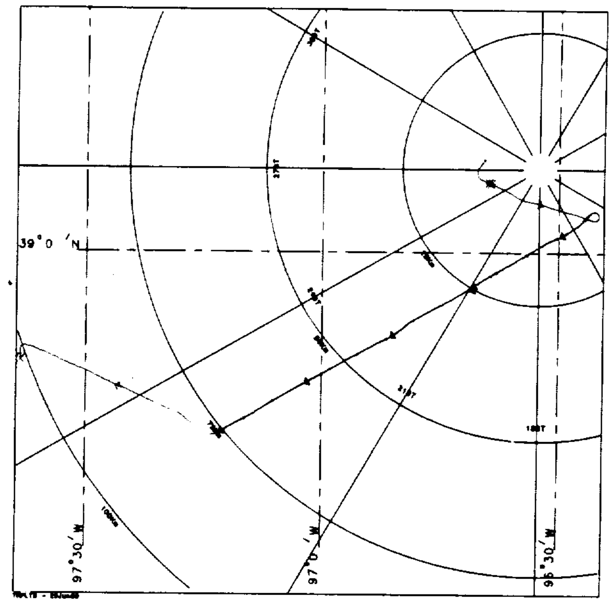
Twin Otter Track Plot
FIFE 89-01
Reference Point FIFE LIDAR
39 3 8 96 32 5
Flight Date 27-JUL-89
Segments (Files)
Start 16 450 End 18 505
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 6 3963

x = Start/end of file
Gaps = Loran out
+ = 5 min GMT
* = Photo event



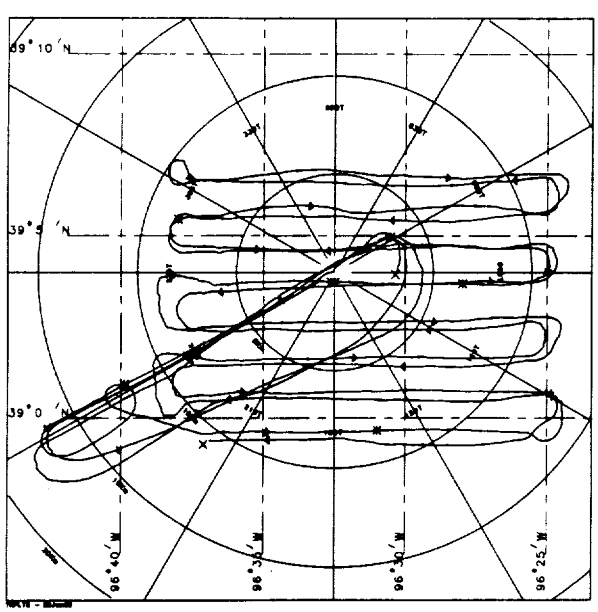

Twin Otter Track Plot
FIFE -02, REGION C
Reference Point FIFE LIDAR
39 8.3 96 32 5
Flight Date 27-JUL-89
Segments (Files):
Start 19 1028 End 19 5023
Grid Oriented True N
Range rings at 25.0 km
Scale (mm/km) = 1.6542

x = Start/end of file
Gaps = Loran out
+ = 5 min GMT
* = Photo event




Twin Otter Track Plot
FIFE FLT 89-03
Reference Point FIFE LIDAR
39 4.0 96 32.5
Flight Date 28-JUL-89
Segments (Files)
Start 15 1101 End 17 2604
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 6.0000

x = Start/end of file
Gaps = Loran out
+ = 5 min GMT
* = Photo event




Twin Otter Track Plot
FIFE FLIGHT 04
Reference Point FIFE LIDAR
39 4.0 96 32.5
Flight Date 02-AUG-89
Segments (Files):
Start 15 2601 End 17 4404
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 6.3963

x = Start/end of file
Gaps = Loran out
+ = 5 min GMT
* = Photo event

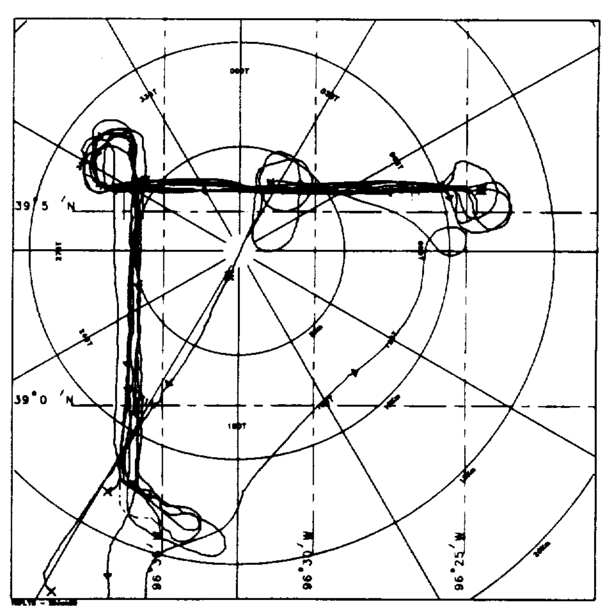
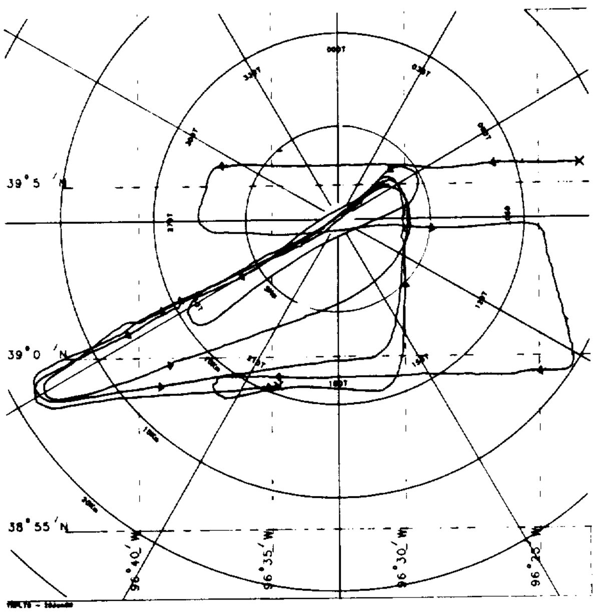



**FIG. 8(a): FLIGHT TRACK PLOTS - FLIGHTS 01 TO 04**

Twin Otter Track Plot
FIFE 89-05
Reference Point FIFE LIDAR
39 4.0 96 32.5

Flight Date 03-AUG-89
Segments (Files):
Start 17 4829 End 19 504
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 5.6438

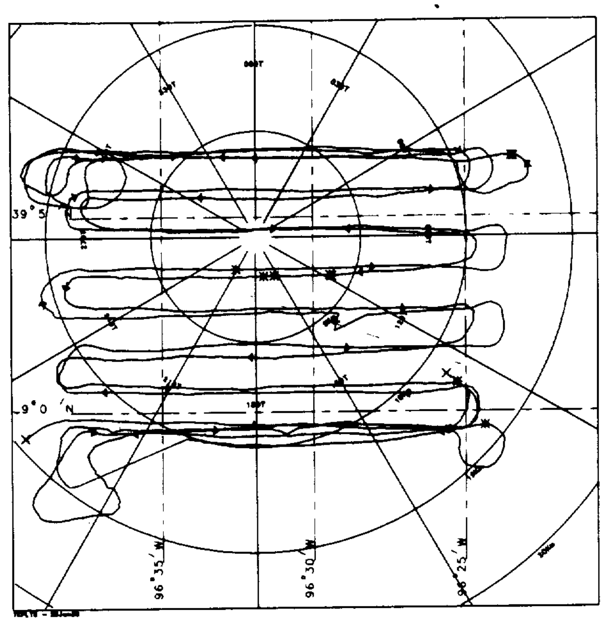
x = Start/end of file
Gaps = Loran out
+ = 5 min GMT
* = Photo event




Twin Otter Track Plot
FIFE 8906
Reference Point FIFE LIDAR
39 4.5 96 31.9

Flight Date 04-AUG-89
Segments (Files):
Start 14 4200 End 17 1605
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 6.3963

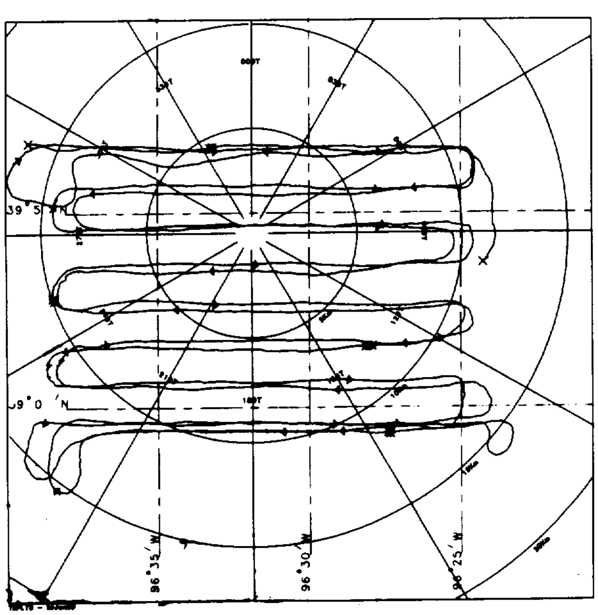
x = Start/end of file
Gaps = Loran out
+ = 5 min GMT
* = Photo event




Twin Otter Track Plot
FIFE 89-07
Reference Point FIFE LIDAR
39 4.5 96 31.9

Flight Date 04-AUG-89
Segments (Files):
Start 18 3703 End 20 4806
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 6.3963

x = Start/end of file
Gaps = Loran out
+ = 5 min GMT
* = Photo event




Twin Otter Track Plot
FIFE 89-08
Reference Point FIFE LIDAR
39 4.5 96 31.9

Flight Date 06-AUG-89
Segments (Files):
Start 15 2802 End 18 3028
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 6.3963

x = Start/end of file
Gaps = Loran out
+ = 5 min GMT
* = Photo event

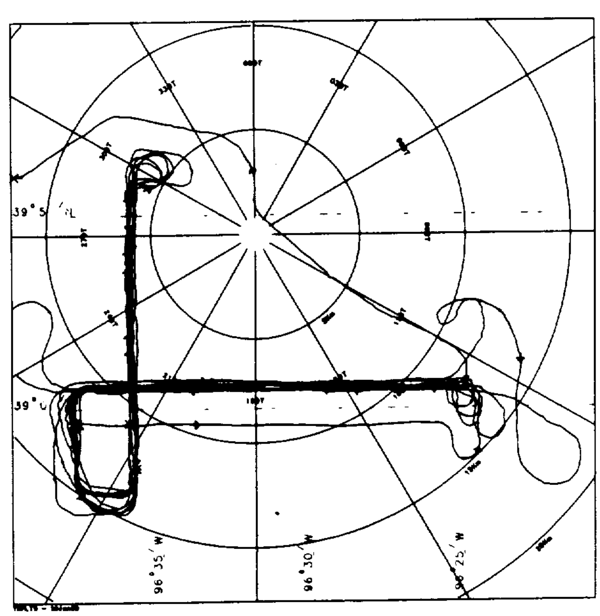
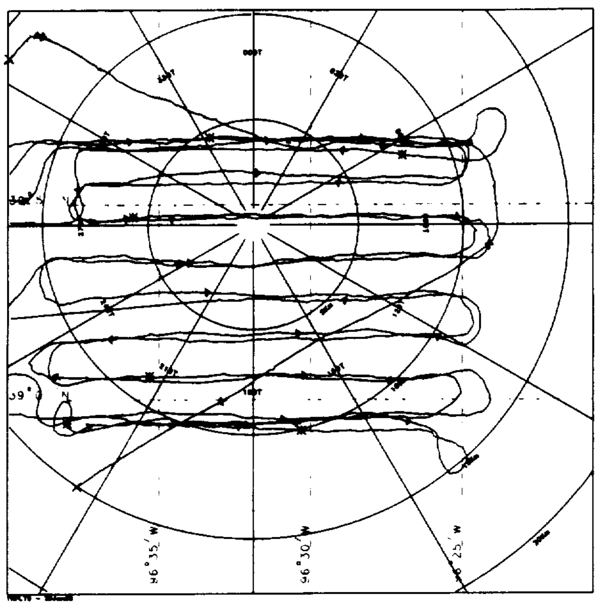



**FIG. 8(b): FLIGHT TRACK PLOTS - FLIGHTS 05 TO 08**

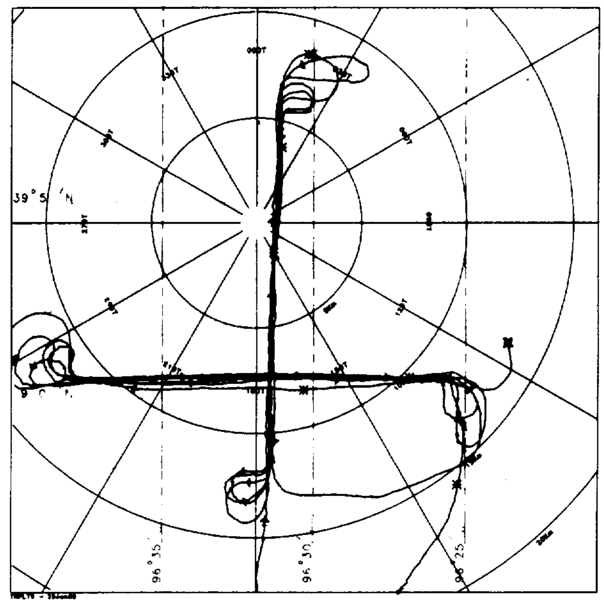
Twin Otter Track Plot
FIFE 89-09
Reference Point FIFE LIDAR
39 4.5 96 31.9
Flight Date 06-AUG-89
Segments (Files):
Start 19.2901 End 22.1203
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 6.3963

x = Start/end of file
Gaps = Loran out
+ = 5 min GMT
* = Photo event



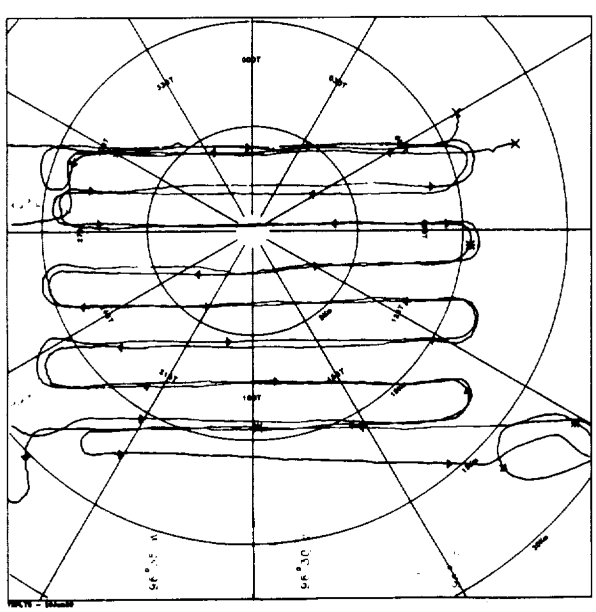
Twin Otter Track Plot
FIFE 89-10
Reference Point FIFE LIDAT
39 4.5 96 31.9
Flight Date 07-AUG-89
Segments (Files):
Start 15.5000 End 18.605
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 6.3963

x = Start/end of file
Gaps = Loran out
+ = 5 min GMT
* = Photo event



Twin Otter Track Plot
FIFE 89-11
Reference Point FIFE LIDAR
39 4.5 96 31.9
Flight Date 08-AUG-89
Segments (Files):
Start 15.5300 End 18.2306
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 6.3963

x = Start/end of file
Gaps = Loran out
+ = 5 min GMT
* = Photo event



Twin Otter Track Plot
FIFE 89-12
Reference Point FIFE LIDAR
39 4.5 96 31.9
Flight Date 08-AUG-89
Segments (Files):
Start 19.5000 End 21.4206
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 6.3963

x = Start/end of file
Gaps = Loran out
+ = 5 min GMT
* = Photo event

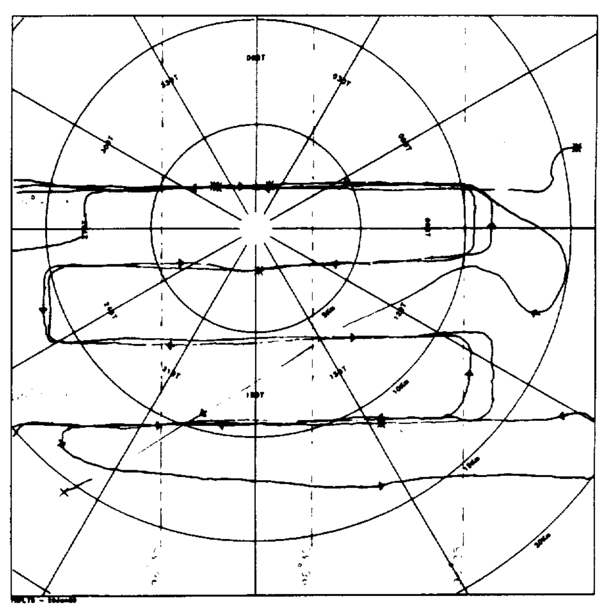
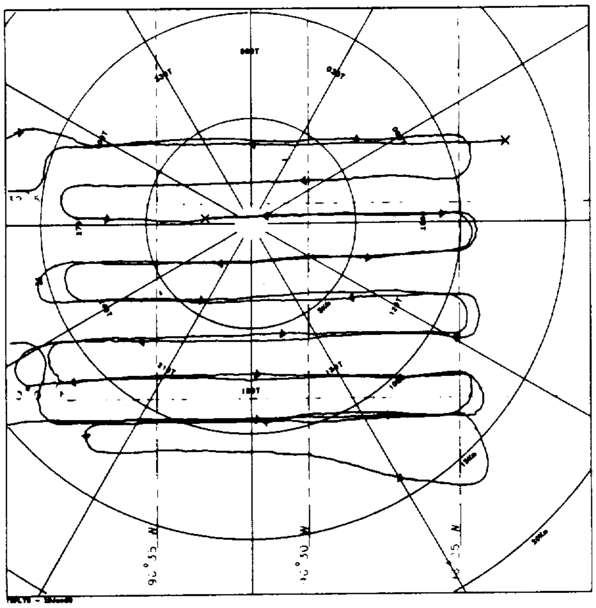


**FIG. 8(c): FLIGHT TRACK PLOTS - FLIGHTS 09 TO 12**

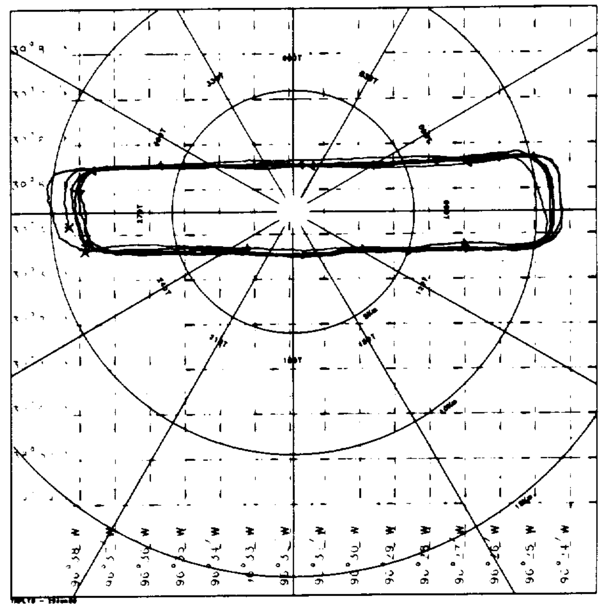
Twin Otter Track Plot
FIFE 89-13
Reference Point FIFE LIDAR
39 4.5 96 31.9
Flight Date 10-AUG-89
Segments (Files):
Start 16 3601 End 18 3603
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 6.3963

x = Start/end of file
Gaps = Loran out
↑ = 5 min GMT
* = Photo event



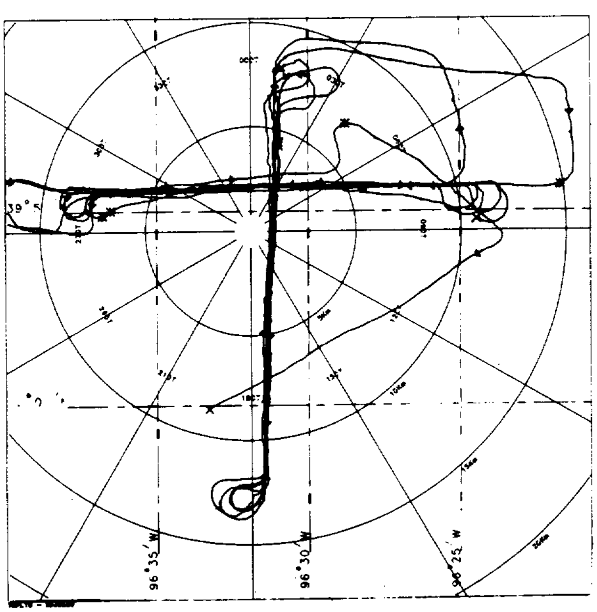
Twin Otter Track Plot
FIFE 89-14, NIGHT
Reference Point FIFE LIDAR
39 4.5 96 31.9
Flight Date 10-AUG-89
Segments (Files):
Start 1 1803 End 2 4406
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 7.3803

x = Start/end of file
Gaps = Loran out
↑ = 5 min GMT
* = Photo event



Twin Otter Track Plot
FIFE 89-15
Reference Point FIFE LIDAR
39 4.5 96 31.9
Flight Date 11-AUG-89
Segments (Files):
Start 17 803 End 19 3905
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 6.3963

x = Start/end of file
Gaps = Loran out
↑ = 5 min GMT
* = Photo event




Twin Otter Track Plot
FIFE 89-16
Reference Point FIFE 89-16
39 4.5 96 31.9
Flight Date 12-AUG-89
Segments (Files):
Start 16 4101 End 19 5816
Grid Oriented True N
Range rings at 5.0 km
Scale (mm/km) = 4.5688

x = Start/end of file
Gaps = Loran out
↑ = 5 min GMT
* = Photo event

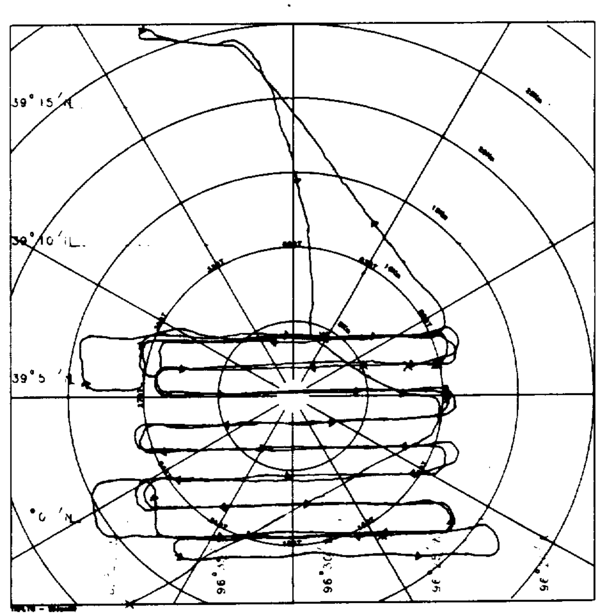


**FIG. 8(d): FLIGHT TRACK PLOTS - FLIGHTS 13 TO 16**

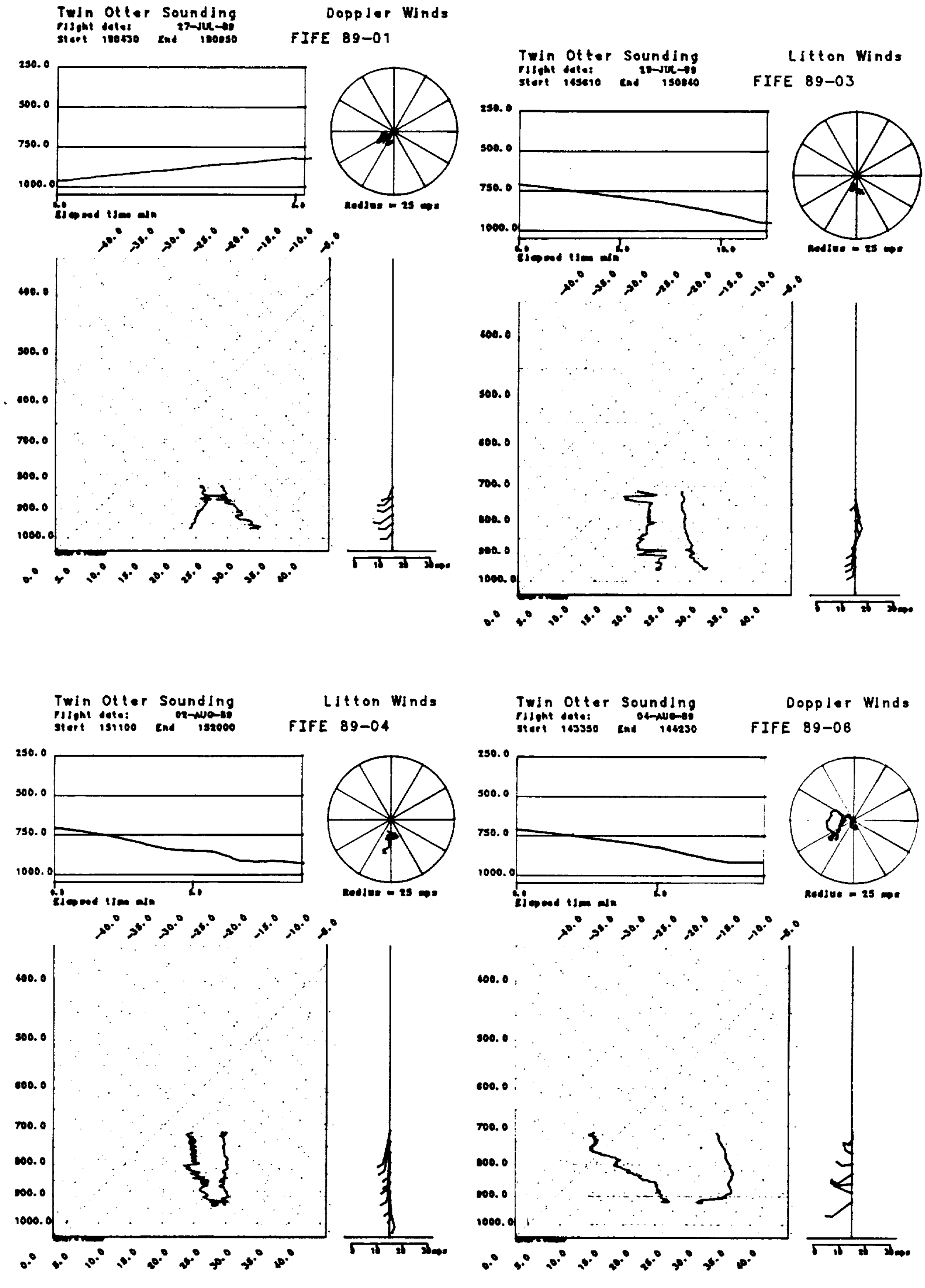



FIG. 9(a): TWIN OTTER SOUNDINGS - FLIGHTS 01, 03, 04 AND 06

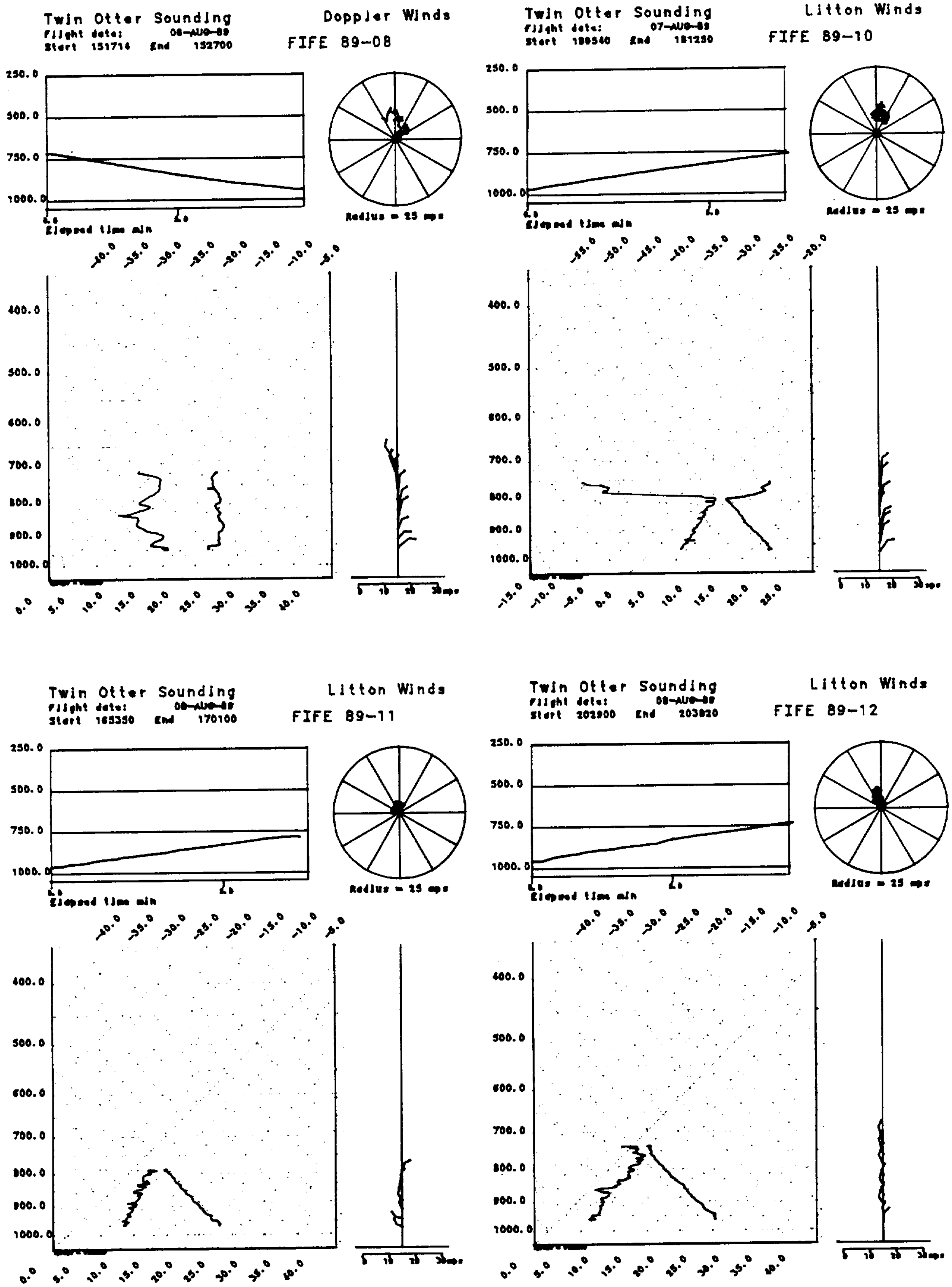



**FIG. 9(b): TWIN OTTER SOUNDINGS - FLIGHTS 08, 10, 11 AND 12**

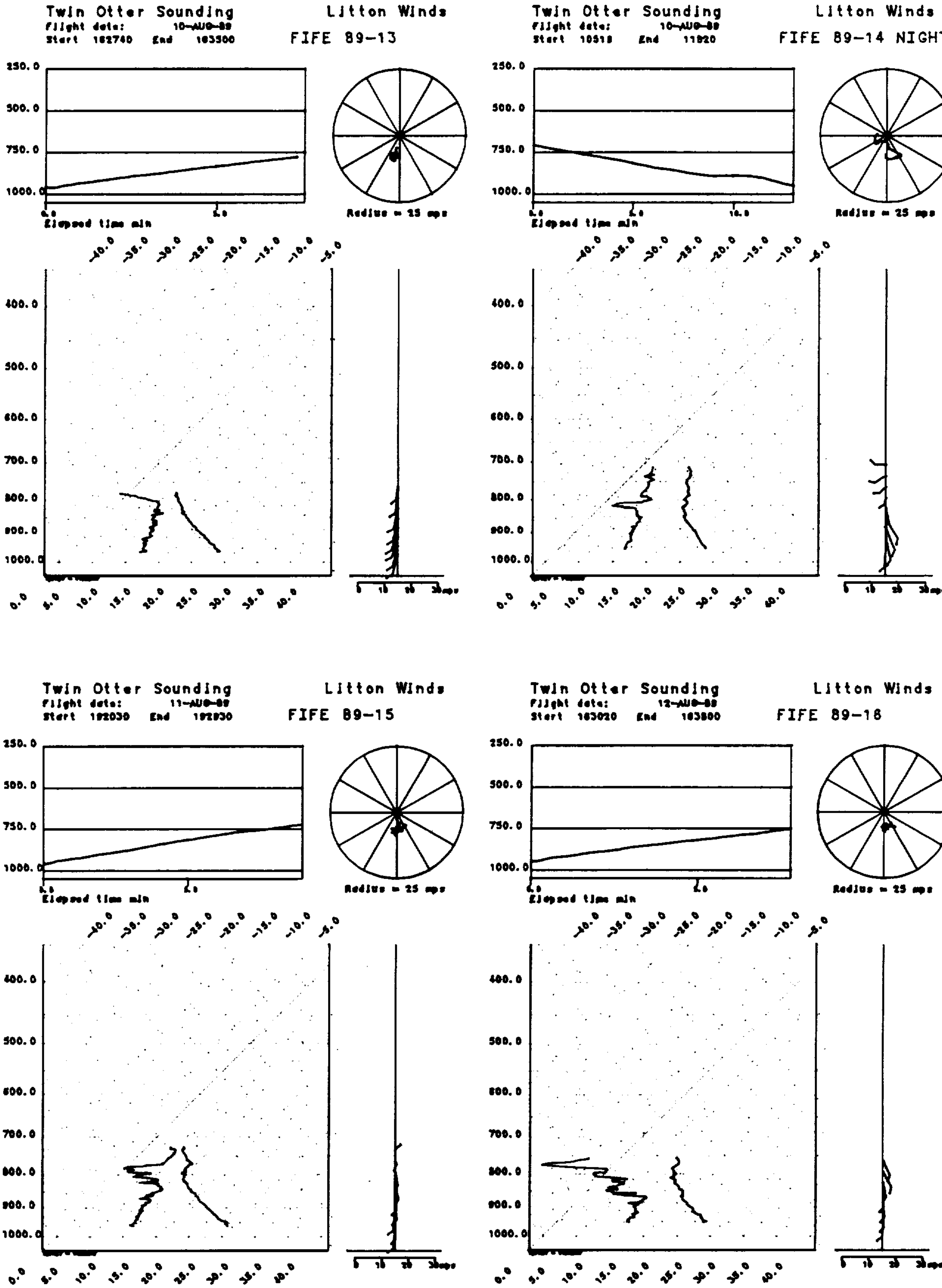
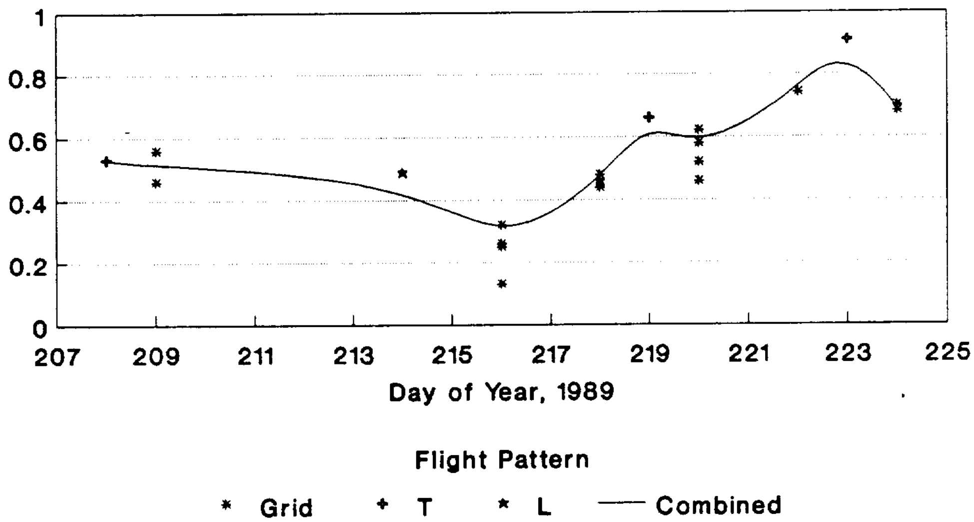



**FIG. 9(c): TWIN OTTER SOUNDINGS - FLIGHTS 13 TO 16**

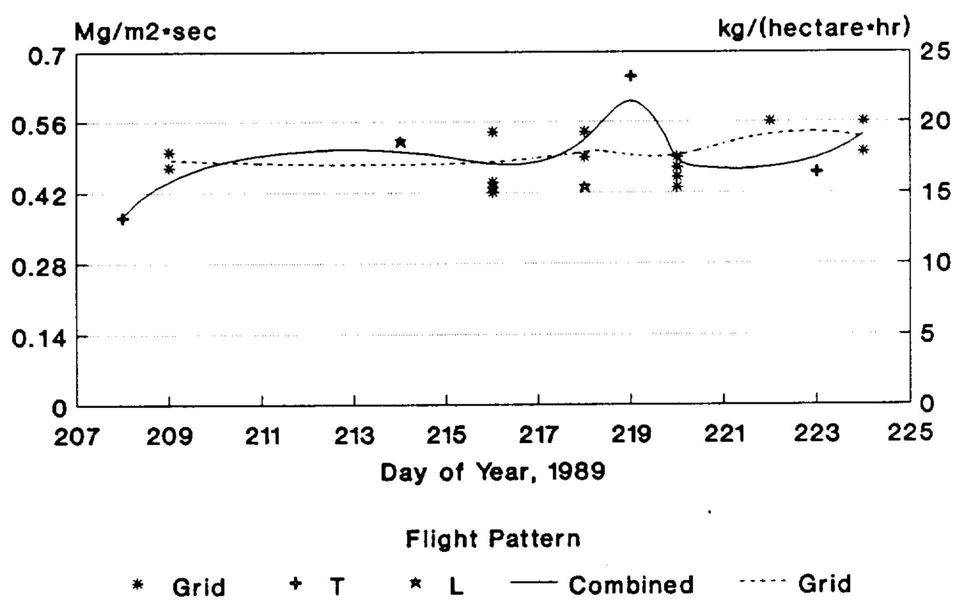
# Fig. 10: Twin Otter Flux Data

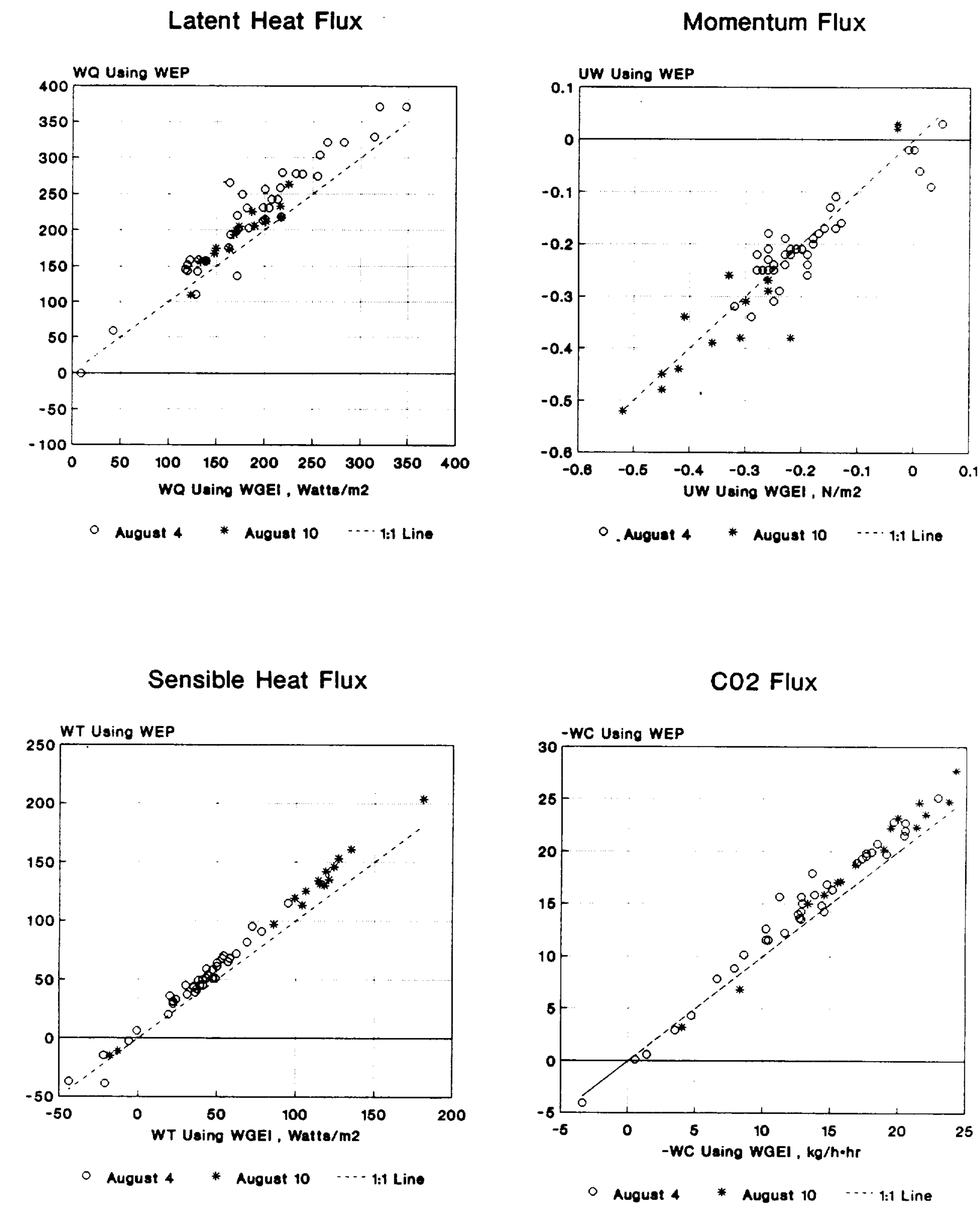
## Bowen Ratio H/LE




Each symbol is average of 4 to 10 runs
From data HP filtered at 5-km
All runs at 1600 ft msl (about 100m agl)

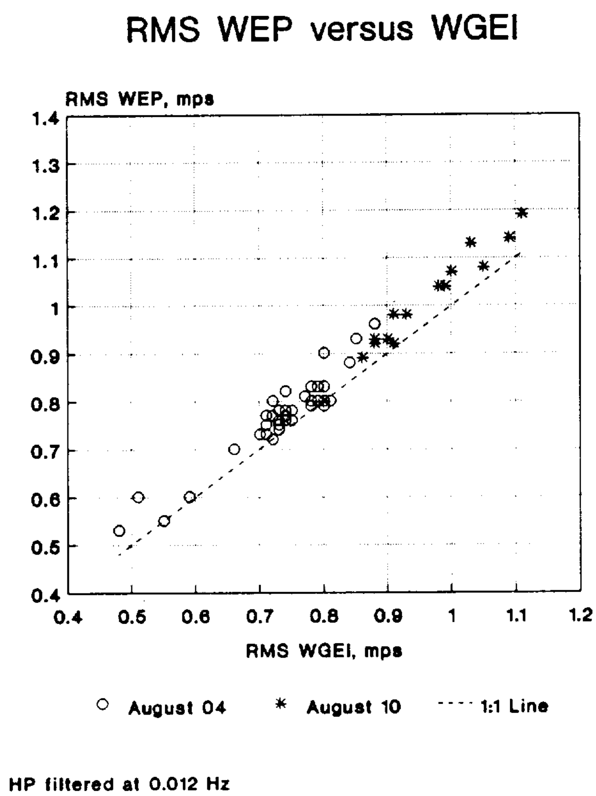
## C02 Flux - 100 m Altitude






All fluxes from data that was high-pass filtered at 0.012 Hz

Fig 11: Fluxes Using WEP vs WGEI



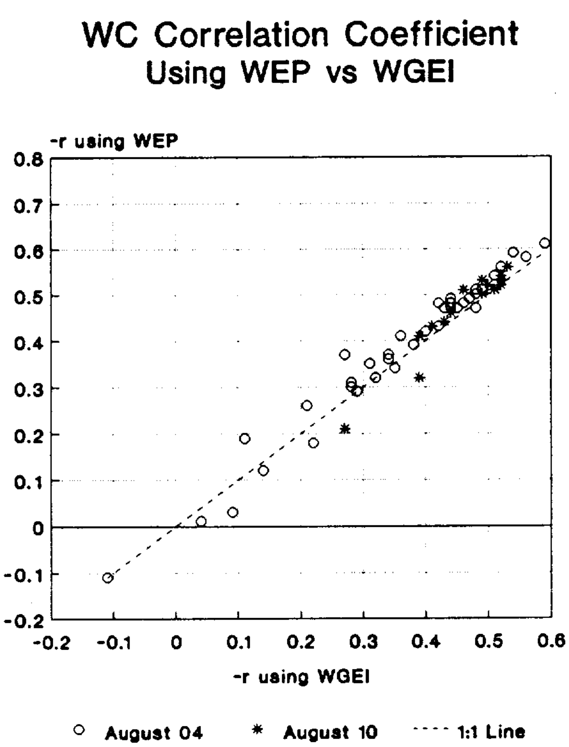




Fig 12: RMS and Correlation Coefficient

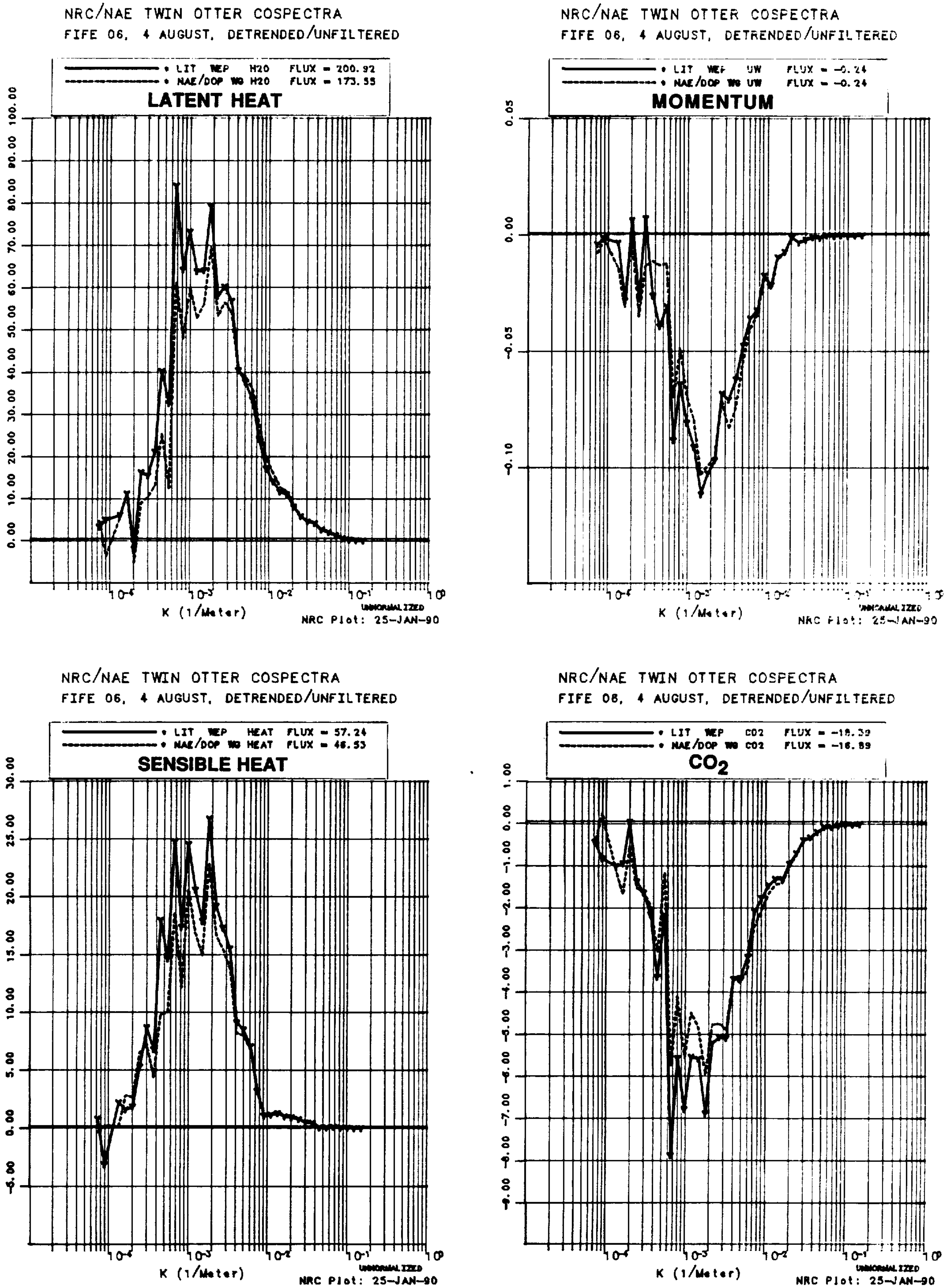



**FIG. 13: COSPECTRA USING WEP AND WGEI**

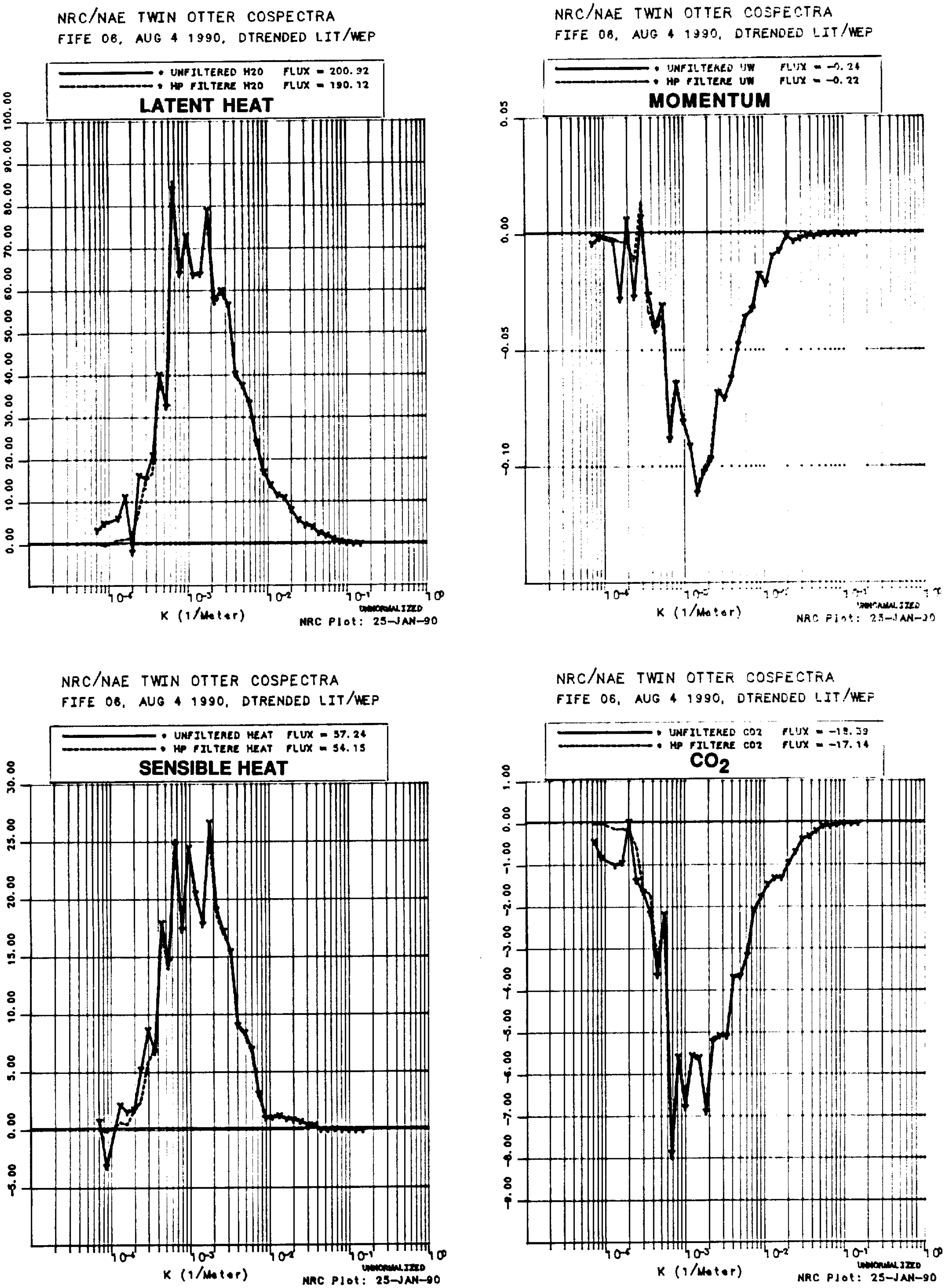
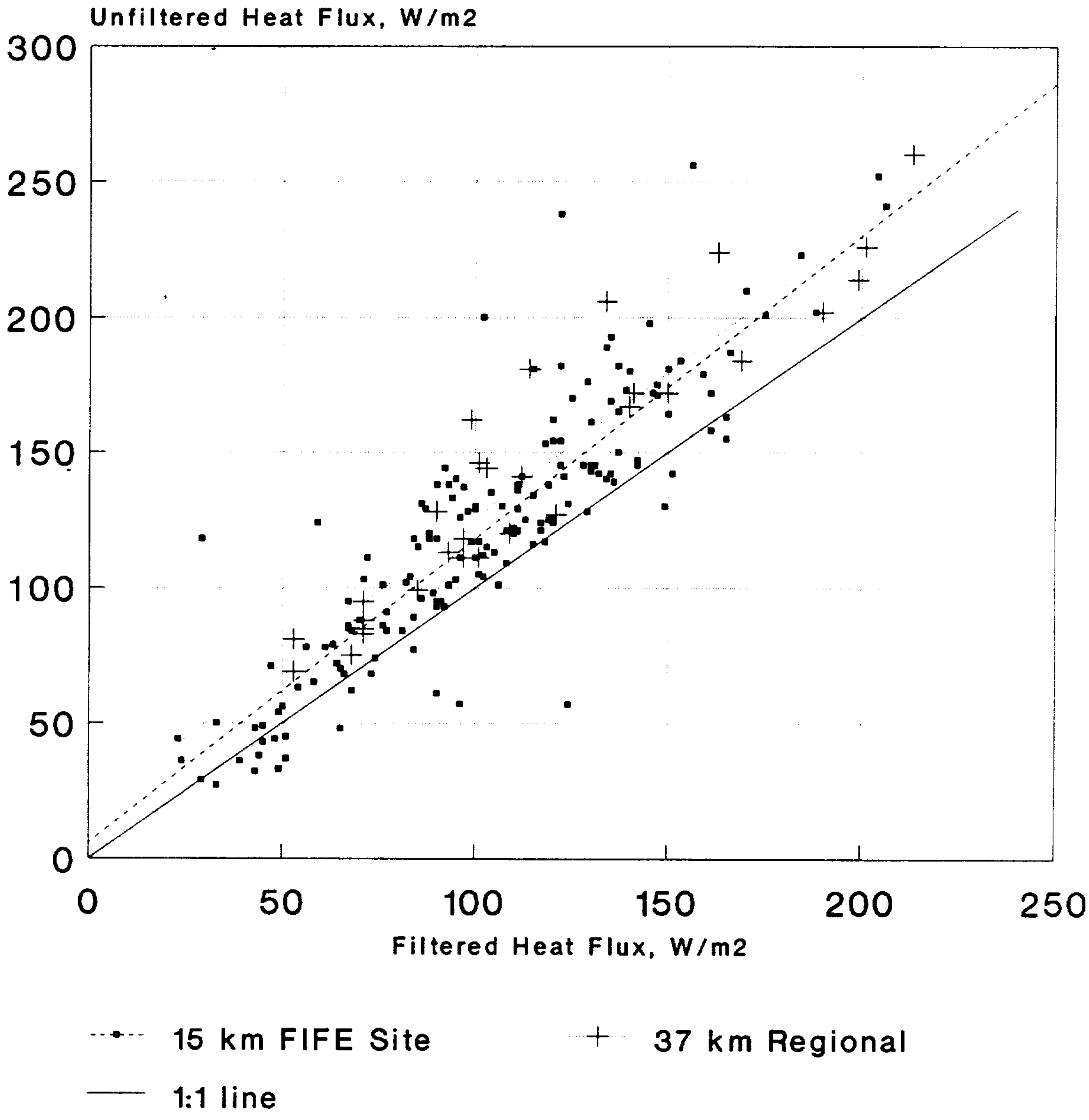



**FIG. 14: EFFECT OF HIGH-PASS FILTERING**

# Fig. 15: Unfiltered vs Filtered Sensible Heat Fluxes - 1989




All FIFE-89 Runs below 300 m
with no large trends in temperature

AS-00219