NASA-CR-193357

# Preliminary Analysis of University of North Dakota Aircraft Data from the FIRE Cirrus IFO-II

Semi-annual Status Report

for the period

October 15, 1992 to April 14, 1993

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## 1.0 Introduction

This report describes the progress and performance by the University of North Dakota under NASA Research Award NAG-1-1351 - "Preliminary Analysis of University of North Dakota Aircraft Data from the FIRE Cirrus IFO-II," for the period October 15, 1992 to April 14, 1993. Included is a summary of the data archival status and preliminary analysis efforts.

## 2.0 Data Archival

During this reporting period, data archival efforts were directed toward providing reduced data for the FIRE data archive and fulfilling special requests for reduced and value-added data.

### 2.1 FIRE Data Archive

Three sets of data collected by the UND Citation II research aircraft during the second cirrus IFO have been submitted for inclusion in the FIRE Data Archive. One consists of all meteorological and flight data **excluding** the data generated by the Particle Measuring Systems (PMS) probes and the Desert Research Institute (DRI) particle replicator. The PMS data files are described below; the DRI replicator films are archived at DRI. The flight data have been submitted in ASCII format. A description of the file layout, a list of parameters, and some brief comments on data quality are attached to this report ("ASCII Flight Data Files").

The other two data sets include the PMS 1D-P, 1D-C, 2D-C, and FSSP probe data. These are the raw data (channel counts, image slices, probe activity, etc.) generated by these probes; these are not particle concentrations, size distributions and the like. The 1D-P, 1D-C, and FSSP data are combined into one file. These probes were sampled at a rate of 4 Hz. The 2D-C probe image slice data are contained in a separate file. These images were generated only when the probe detected the presence of particles and were recorded at a rate of up to 4 Hz. A description of the layout of these two file types and notes regarding their use are attached to this report as "PMS One-D" and "PMS Two-D" record descriptions.

### 2.2 Special Data Requests

A number of requests for UND Citation data were received from FIRE investigators and were filled. A few of these requests were for reduced data before it had been formally archived. Most were for value-added products, especially cloud microphysical parameters derived from PMS data, for specific missions or flight

times. A total of seven individual requests were satisfied during this reporting period.

## 3.0 Analysis

Analysis efforts focused on three separate studies. Work continued on a collaborative investigation of the possible effects of volcanic aerosols on cirrus morphology. This is a case study of remote and in situ measurements made during the nighttime hours of 5 December 1991; the analysis is being led by Dr. Kenneth Sassen of the University of Utah. The Citation microphysical and aerosol data show a high likelihood that this cirrus system existed within an airmass recently affected by a stratospheric intrusion. Volcanic aerosols from the eruption of Mt. Pinatubo appear to have been brought down into the upper troposphere; coincidentally, the cirrus cloud particles were sampled in the highest concentrations of the project. The results of this study have been submitted for publication.

A second on-going study was a comparison of cloud microphysical characteristics as sampled by PMS probes and the DRI particle replicator. Preliminary findings confirm that there are significant numbers of ice particles in cirrus which are too small to be detected by the PMS optical array probes. The measurements show good overlap for concentrations and sizes of particles with diameters of 100-200 um, and some oversizing by the replicator of the larger particles. These findings have implications for the modeling of the radiative effects of cirrus clouds and other uses of these microphysical data.

The third area of analysis is in support of the development by NASA investigators of a scheme for the retrieval of multiple cloud-top heights from satellite data. The Citation data are being used to determine actual cloud-top heights in a case where there were multiple cloud layers. These data are being compared with the output of the retrieval and with ground-based measurements made simultaneously in the same area.

## 4.0 Meetings Attended

The Principal Investigator traveled to Fairfax, VA, to attend the FIRE Science Team Meeting - Cirrus Working Group, November 11-15, 1993. Discussions were held regarding preliminary analysis findings and the status and organization of case study groups. A status report of the data processing and archival of the UND Citation data was presented.

**University of North Dakota Citation II**
**FIRE Cirrus IFO - II**
**ASCII Flight Data Files**
(all data excluding microphysics)

Flight data collected by the University of North Dakota Citation II research aircraft during the FIRE Cirrus IFO-II are available in ASCII format at a 1 Hz rate. Cloud microphysics data from the PMS probes or the DRI replicator are not included in these files. The following is a description of the file layout and equipment concerns.

The ASCII file record length is 512-bytes. The first six records of each file contain file description and calibration information. Data records are written as 51F10.3 format and contain the time (UTC) followed by 50 parameters expressed in meteorological/engineering units, as follows:

| Parameter | Units |
|---|---|
| Time | seconds after midnight |
| Pressure altitude | m |
| Static pressure | mb |
| Indicated airspeed | $m\ s^{-1}$ |
| True airspeed | $m\ s^{-1}$ |
| Ground speed | m s-1 |
| Pitotstatic pressure, nose | mb |
| Pitotstatic pressure, wing | mb |
| Temperature, Rosemount | deg-C |
| Temperature, reverse flow | deg-C |
| Dew point temperature | deg-C |
| Ice detector | V |
| Ice detector liquid water | $g\ m^{-3}$ |
| JW liquid water | $g\ m^{-3}$ |
| VOR radial | deg |
| DME | km |
| Vertical acceleration | $m\ s^{-2}$ |
| Attack delta pressure | mb |
| Sideslip delta pressure | mb |
| Attack angle | deg |
| Sideslip angle | deg |
| Ozone concentration | ppb |
| $NO_2$ concentration | $ppb_3$ |
| Condensation nuclei | $cm^{-3}$ |
| DRI film speed | 1-8 (5-40 frames $s^{-1}$) |
| DRI frame count | frames |
| DRI event mark | V |
| Potential temperature | deg-K |
| Ice detector heater flag | V |
| Track angle | deg |

| | |
|---|---|
| Drift angle | deg |
| True heading | deg |
| Magnetic heading | deg |
| Pitch angle | deg |
| Roll angle | deg |
| INS wind direction | deg |
| INS wind speed | $m\ s^{-1}$ |
| Aircraft vertical velocity | $m\ s^{-1}$ |
| Vertical wind | $m\ s^{-1}$ |
| Calculated wind speed | $m\ s^{-1}$ |
| Calculated wind direction | deg |
| INS latitude | deg |
| INS longitude | deg |
| INS latitude, VOR/DME corrected | deg |
| INS longitude, VOR/DME corrected | deg |
| GPS time | hr |
| GPS latitude | deg |
| GPS longitude | deg |
| GPS altitude | m |
| GPS velocity north | $m\ s^{-1}$ |
| GPS velocity east | $m\ s^{-1}$ |

GPS Data Quality

Due to DOD system test, GPS signal was not valid all flights

| Flight | Position | Altitude |
|---|---|---|
| 11/14 | Good | Good |
| 11/22 A | Last 40% | No |
| 11/22 B | No | No |
| 11/25 | Good | Good |
| 11/26 | Good | Good |
| 11/28 | Good | Good |
| 11/30 | No | No |
| 12/5 A | Last 40 min | No |
| 12/5 B | Good | Good |
| 12/7 | Good | Good |

Other equipment concerns:

CN - valid only from 11/26 to end of program
$O_3$ - not calibrated
- inoperative 11/28, 11/30
$NO_2$ - inoperative 11/14, 11/28
2D-C - inoperative last 35% of 11/26, all of 11/28

The **PMS One-D record** has 8 logical records per physical record. The physical record is 2048 bytes total. Hwrd is a 16 bit integer. Here is the format for each logical record of PMS data.

Revised:

| Ver. | Date | Programmer |
|---|---|---|
| 7.0 | 16 November 1989 | Martin Brown |

PMS calculations have been added to the record for inclusion in the Amiga data. The data are in Concurrent Computer floating point format. Bytes 208 through 239.

| Byte | Hwrd | Value |
|---|---|---|
| 00-03 | 1-2 | Recorded Time (10000*SecondsFromMidnight) |
| 04-05 | 3 | TAS (100*TAS) in meters per second |
| 06-07 | 4 | Spare |
| 08-11 | 5-6 | Date (mmddyy) |
| 12-13 | 7 | 2-DA Shadow Or Count |
| 14-15 | 8 | 2-DA Housekeeping Channel |
| 16-17 | 9 | 2-DA TAS Count |
| 18-19 | 10 | 2-DA Housekeeping Channel Number |
| 20-21 | 11 | FSSP Size Range (See notes) |
| 22-23 | 12 | FSSP Channel One Count |
| : | : | : : : |
| : | : | : : : |
| 50-51 | 26 | FSSP Channel Fifteen Count |
| 52-53 | 27 | Spare FSSP counter |
| 54-55 | 28 | FSSP total (Ch 1-15) |
| 56-57 | 29 | FSSP total strobes |
| 58-59 | 30 | FSSP activity |
| 60-63 | 31-32 | Spare |
| 64-65 | 33 | Particle Spacing Monitor (PSM) Range/Control |
| 66-67 | 34 | PSM Channel One |
| : | : | : : : |
| : | : | : : : |
| 94-95 | 48 | PSM Channel Fifteen |
| 96-97 | 49 | 1D-C Range/Control |
| 98-99 | 50 | 1D-C Channel One Count |
| : | | : : : |
| : | | : : : |
| 158-159 | 80 | 1D-C Channel Thirty-one Count |
| 160-161 | 81 | 1D-C Total (Ch 1-31) |
| 162-163 | 82 | 1D-C Spare Counter #1 |
| 164-165 | 83 | 1D-C Spare Counter #2 |
| 166-167 | 84 | 1D-C Spare Counter #3 |
| 168-175 | 85-88 | Spare |
| 176-177 | 89 | 1D-P Range/Control |
| 178-179 | 90 | 1D-P Channel One Count |
| : | | : : : |
| : | | : : : |
| 206-207 | 104 | 1D-P Channel Fifteen Count |

The remaining values were generated for real-time display.

| | | |
|---|---|---|
| 208-211 | 105-106 | FSSP concentration, no./cc. |
| 212-215 | 107-108 | FSSP mean volume diameter, microns. |
| 216-219 | 109-110 | FSSP liquid water, gm/cu.meter. |
| 220-223 | 111-112 | 1DC concentration, no./liter. |
| 224-227 | 113-114 | 1DC mean volume diameter, microns. |
| 228-231 | 115-116 | 1DP concentration, no./cu.meter. |
| 232-235 | 117-118 | 1DP mean volume diameter, microns. |
| 236-239 | 119-120 | 2DC concentration, no./liter. (shadow/or) |

Notes:

For the FSSP, PSM, 1-DC and 1-DP size ranges, each is stored in a halfword with other information on a bit function. With bit 0 being the high order bit, the information is --

| | |
|---|---|
| bits 0-3 | always 0 |
| bit 4 | transit delay - should be 0 |
| bit 5 | velocity averaging - should be 0 |
| bits 6-7 | size range |

Transit delay and velocity averaging are no longer available. These lines are being used for FSSP total strobes and FSSP activity.

The 1-DC probe and the 1-DP probe are not adjustable and have no size range. The size range values reflect the setting of the switches on the front pannel of the SEA Model 100. The 1-DP size range halfword and the PSM size range halfword is being used by the display and may have any value.

The FSSP probe has four size ranges (0-3):

***(for FIRE, only range 0 was used)***

| | | |
|---|---|---|
| 0 | - | 3.0 to 47.5 microns |
| 1 | - | 2.0 to 32.0 microns |
| 2 | - | 1.0 to 16.0 microns |
| 3 | - | 0.5 to 8.0 microns |

The FSSP size range is set using the switches on the front panel of the SEA Model 100.

The housekeeping channel number for the 2-D probes identifies a particular housekeeping channel. Only one of the eight housekeeping channels is recorded with each logical record for each probe (the same channel for both probes, however.)

| | | |
|---|---|---|
| 0 | - | +15 V power supply |
| 1 | - | mirror temperature |
| 2 | - | spare |
| 3 | - | spare |
| 4 | - | end element #1 |
| 5 | - | end element #32 |
| 6 | - | -15 V power supply |
| 7 | - | +5 V power supply |

The -15 volt power supply value is recorded as positive. Each of the values has been changed from a voltage to a frequency. One volt is changed to one kilohertz. The -15 volt and +15 volt power supplies are scaled with a gain of .1 requiring those values to be multiplied by 10 to get the correct frequency. To get the frequency, it is necessary to divide the value by the time interval since the last logical record. The mirror temperature is fitted to a double exponential curve, and the inverse formula is:

$$Temp = -124.2 * \ln(\ln(freq)) - 1.765)$$

This value is in degrees Centigrade.

Sample area for the FSSP in square centimeters is 0.00362.

FSSP channel boundaries in microns:

Channel-0 and channel-1 numbers are from Darrel Baumgardner's calibration software (FSPCL.FTN). Numbers for channel-2 and 3 are from the FSSP manual.

```
Channel 0   2.80,  5.51,  8.57, 11.43, 13.79,
           16.12, 19.58, 23.21, 27.70, 31.83,
           36.36, 40.25, 43.71, 47.14, 50.63, 54.19

Channel 1   2.7,  3.1,  5.0,  8.3, 11.3,
           13.3, 13.6, 15.4, 17.5, 20.7,
           23.6, 25.8, 27.7, 30.1, 34.2, 36.8

Channel 2   1.0,  2.0,  3.0,  4.0,  5.0,
            6.0,  7.0,  8.0,  9.0, 10.0,
           11.0, 13.0, 13.0, 14.0, 15.0, 16.0

Channel 3   0.5,  1.0,  1.5,  2.0,  2.5,
            3.0,  3.5,  4.0,  4.5,  5.0,
            5.5,  6.0,  6.5,  7.0,  7.5,  8.0
```

PMS One-DC Channel sample areas in square centimeters.

```
         0.00227, 0.01733, 0.05056, 0.09413, 0.13872,
         0.18911, 0.24402, 0.28060, 0.26840, 0.25620,
         0.24400, 0.23180, 0.21960, 0.20740, 0.19520,
         0.18300, 0.17080, 0.15860, 0.14640, 0.13420,
         0.12200, 0.10980, 0.09760, 0.08540, 0.07320,
         0.06100, 0.04880, 0.03660, 0.02440, 0.01220
```

PMS One-DC Channel boundaries in microns.

```
          14.2,  34.0,  53.8,  73.6,  93.4,
         113.2, 132.8, 152.4, 172.2, 193.6,
         211.8, 231.2, 251.0, 270.6, 290.4,
         310.0, 330.0, 350.0, 370.0, 390.0,
         410.0, 430.0, 450.0, 470.0, 490.0,
         510.0, 530.0, 550.0, 570.0, 590.0, 610.0
```

PMS One-DC Channel mid-points in microns.

```
          24.1,  43.9,  63.7,  83.5, 103.3,
        123.0, 142.6, 162.3, 182.9, 202.7,
        221.5, 241.1, 260.8, 280.5, 300.2,
        320.0, 340.0, 360.0, 380.0, 400.0,
        420.0, 440.0, 460.0, 480.0, 500.0,
        520.0, 540.0, 560.0, 580.0, 600.0/
```

PMS One-DP Channel sample areas in square centimeters.

```
         14.85, 16.57, 15.78, 14.99, 14.20,
         13.41, 12.62, 11.83, 11.05, 10.26,
          9.47,  8.68,  7.89,  7.10,  6.31
```

PMS One-DP Channel boundaries in microns.

```
          213.0,  510.0,  813.0, 1104.0, 1404.0,
         1698.0, 1992.0, 2289.0, 2586.0, 2877.0,
         3180.0, 3465.0, 3750.0, 4050.0, 4350.0, 4650.0
```

PMS One-DP Channel mid-points in microns.

```
          361.5,  661.5,  958.5, 1254.0, 1551.0,
        1845.0, 2140.5, 2437.5, 2731.5, 3028.5,
        3322.5, 3607.5, 3900.0, 4200.0, 4500.0
```

The PMS 2D record is 4128 bytes long. Its format is as follows:

PMS 2-D RECORD

4128 BYTES, ARRAY(1032) is a 32 bit integer array.

| NAME(SIZE) | TYPE | DESCRIPTION | LOC IN ARRAY |
|---|---|---|---|
| FRONT(1) | INT | CONSTANT Y'55000000' | 0001 |
| IMAGE(1024) | INT | 2-D IMAGE SLICES | 0002-1025 |
| STTIME(1) | INT | SECONDS FROM MIDNIGHT * 10000 AT START OF 2-D IMAGE | 1026 |
| NDTIME(1) | INT | SECONDS FROM MIDNIGHT * 10000 AT END OF 2-D IMAGE | 1027 |
| STTAS(1) | INT2 | TAS * 100 AT START OF 2-D IMAGE. | 1028 |
| NDTAS(1) | INT2 | TAS * 100 AT END OF 2-D IMAGE. | 1028 |
| SPARE(1) | INT | SPARE LOCATION | 1029 |
| DATE(1) | INT | DATE (MMDDYY). | 1030 |
| SPRPMS(2) | INT | SPARE LOCATIONS FOR EXPANSION | 1031-1032 |

NOTES :

EACH ELEMENT OF IMAGE REPRESENTS ONE 2-D IMAGE SLICE. EACH BIT OF EACH SLICE INDICATES WHETHER THE CORRESPONDING 2-D PHOTO SENSOR WAS LIT OR UNLIT. A LIT SENSOR INDICATES NO IMAGE AND SETS THE BIT. AN UNLIT SENSOR INDICATES AN IMAGE IS PRESENT AND RESETS THE BIT.

AS WITH THE PMS SLOW RECORD, THE TIME IS ACCURATE TO ONLY THREE PLACES (AFTER DIVIDING BY 10000).

STTIME IS THE TIME WHEN THE 2-D PROBE WAS SIGNALED TO BEGIN COLLECTING 2-D IMAGES. NDTIME IS THE TIME WHEN THE 2-D PROBE'S BUFFER WAS FULL AND IT SIGNALED THAT CONDITION.

The diode spacing for this probe is 33 microns.

If you have any questions concerning the format, please contact Martin Brown at:

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P.O. Box 8064, University Station
Grand Forks, ND 58202-8064
vox: 701-777-2954
fax: 701-777-2940

**University of North Dakota Citation**
**FIRE Cirrus 2**
**PMS Probe Data Files**

1D Probe - 2048 byte records

| Flight # | No. of Records |
|---|---|
| 111491A | 5895 |
| 112291A | 6606 |
| 112291B | 6614 |
| 112591A | 8438 |
| 112691A | 6356 |
| 112891A | 8710 |
| 113091A | 4061 |
| 120591A | 4745 |
| 120591B | 4423 |
| 120791A | 5677 |

2D Probe - 4128 byte records (0 padded to 4608)

| Flight # | No. of Records |
|---|---|
| 111491A | 1616 |
| 112291A | 1388 |
| 112291B | 7433 |
| 112591A | 2358 |
| 112691A | 5459 |
| 113091A | 2485 |
| 120591A | 5177 |
| 120591B | 1794 |
| 120791A | 671 |

(no file for 11/28 - probe inop)