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NOAA Eastern Region Computer Programs
and Problems NWS ERCP - No. 44

TURB: Turbulence Forecasting for Small/Medium and Large Aircraft

Steven J. Naglic
National Weather Service Forecast Office
Cleveland, Ohio

Scientific Services Division
Eastern Region Headquarters
July 1988

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NOAA TECHNICAL MEMORANDUM
National Weather Service, Eastern Region Computer Programs and Problems

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1 An AFOS version of the Flash Flood Checklist. Cynthia M. Scott, March 1981. (PB81 211252).

2 An AFOS Applications Program to Compute Three-Hourly Stream Stages. Alan P. Blackburn, September 1981. (PB82 156886).

3 PUPPY (AFOS Hydrologic Data Reporting Program). Daniel P. Provost, December 1981. (PB82 199720).

4 Special Search Computer Program. Alan P. Blackburn, April 1982. (PB83 175455).

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15 MDR--Processing Manually Digitized Radar Observations. Matthew R. Peroutka, November 1983. (PB84 161462) (Revised June 1985, PB85-220580/AS)

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21 WARN - A Warning Formatter. Gerald G. Rigdon, June 1984. (PB84 204551)

22 Plotting TDL Coastal Wind Forecasts. Paula Severe, June 1984 (Revised) (PB84 220789)

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24 WXR. Harold Opitz, August 1984. (PB84 23722) (Revised August 1985, PB84 100815/AS)

25 FTASUM: Aviation Forecast Summaries. Matthew Peroutka, August 1984. (PB85 112977)

26 SAOSUM: A Short Summary of Observations. Matthew Peroutka, October 1984. (PB85 120384)

27 TRAJ - Single Station Trajectory Plot. Tom Niziol, December 1984. (PB85 135002)

28 VIDTEX. Gerald G. Rigdon, February 1985. (PB85 175669/AS)

29 Isentropic Plotter. Charles D. Little, February 1985. (PB85 175651/AS)

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32 Scatter Diagram and Histogram Program - SCATR. Hugh M. Stone, May 1985. (PB85 213346/AS)

33 TIMCHEK. Gerald G. Rigdon, June 1985. (PB85-221257/AS)

34 A MOS Temperature - PoP Forecast Plot. William C. Randel, October 1985. (PB86 120029/AS)

35 ROTODRAW. Thomas Niziol, November 1985 (PB86 131828/AS)

36 LAWEB: Data Processing for the Great Lakes. William C. Randel and Matthew R. Peroutka, March 1986. (PB86 176658/AS)

37 Convective Parameters & Hodograph Program - Convect. Hugh M. Stone, April 1986.(PB86-197225/AS)

38 DWXR - SHEF Product Compression Program. Harold H. Opitz, September 1986.

39 CRASHQ: Listing Products Being Transmitted At the Time of a Crash William C. Randel, January 1987 (PB87-151890/AS)

40 AVGPLOT and AVGCLIM. Alan Blackburn, March 1987 (PB87-180626/AS)

41 Severe Weather Potential (SPOT) Plotfile Generator. Ken LaPenta, July 1987. (PB87 217717/AS)

42 COARS Family of Programs. Lawrence Cedrone, November 1987 (PB88-131602)

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NOAA Eastern Region Computer Programs and Problems
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TURB: Turbulence Forecasting for Small/Medium and Large Aircraft

Steven J. Naglic
National Weather Service Forecast Office
Cleveland, Ohio

Scientific Services Division
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July 1988

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

ACKNOWLEDGEMENTS

To Matthew R. Peroutka (WSFO Cleveland) for use of his subroutines and his greatly appreciated programming and coding assistance.

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To the ZOB CWSU staff: Ernie Marion, Gerry Andress and Dennis Nelson whose data collection helped make this study, its testing, verification, and the resulting program possible.

TURB: Turbulence Forecasting for Small/Medium and Large Aircraft

Steven J. Naglic
WSFO Cleveland, OH

I. Introduction

This program was developed to provide Center Weather Service Unit (CWSU) meteorologists and FAA flight service station personnel with a local product they can use to describe areas of significant turbulence.

The program takes upper air data from any raob site (Figure 1), processes it, and generates a turbulence forecast for the area within a 100nm radius of the raob site. This information is quite valuable to the CWSU meteorologists as their forecasts, meteorological impact statements, and center weather advisories are used by the FAA for planning purposes and for the routing or rerouting of air traffic. The forecast product (Figure 2) gives the layers analyzed in thousands of feet, the wind shear per thousand feet, and the turbulence forecast for small/medium aircraft and large aircraft. (Small/medium size aircraft are those such as Cessnas, Pipers, Citations, Lear jets, etc., while large aircraft are those such as the Boeing 700 series, McDonnel Douglas DC8/9's, and Air Force KC135's, C5's, B52's, etc.) A testing period of nine months yielded a mean verification of nearly 75%.

II. Methodology and Software Structure

The program TURB is initiated by entering the command

```
RUN:TURB XXX XXX YYY/A
```

at an ADM. XXX is the three letter station identifier for any raob site (Figure 1), and YYY is the AFOS addressee (such as SDC for state distribution circuit; defaults to 000). An example might be

```
RUN:TURB FNT DAY PIT BUF TOL/A
```

These four raob sites cover Cleveland Center's airspace (Figure 3), and are used in conjunction with other data in making its turbulence forecast. Up to six raob sites may be entered on the command line.

When the command line is entered the main program TURB.FR calls the subroutine TURBARG which checks the command line arguments for switches. The subroutine NDASIN then checks the station arguments XXX given on the command line with their corresponding nodes CCC and WMO block numbers NNN to make sure each station is a raob site. If any are not, an error message will be returned to the ADM. (Any station may be used for the addressee.)

Next, the subroutine SGLDEC is called to decode the TTBB and PPBB transmissions into two RDOS files: one for temperatures and dew points (SOUNDING.T), and one for winds (SOUNDING.W). If the formats of these products are not correct SGLDEC will type out a flag message to that effect at the Dasher and exit that portion of the program. (It should be noted that the reason why the program is set up to decode the significant level reports and create its own file is so that any WSO can request raob reports along an intended flight path to get an entire turbulence profile and forecast. The TTBBD program used at most WSFO's often may not contain the raob sites along an intended flight path, especially if it is cross-country.)

After the raob data is decoded, the subroutine TURBULENCE is called. TURBULENCE utilizes the sounding data and other subroutines within itself to determine the turbulence forecast for each layer of the significant levels. First the RDOS files SOUNDING.T and SOUNDING.W are opened to access the decoded raob data. Then the header and the output file TURB are created by the subroutine HEADER.

A loop is then initiated to calculate the turbulence parameters. The subroutine PRSINT is called to interpolate a given height in hundreds of feet to a pressure level in the U.S. Standard Atmosphere. INTRPOLATE is then called to interpolate between the pressure levels of the file SOUNDING.T to give the temperature and dew point at any given pressure level (PRSLVL). A temperature or dew point of -99 means that no interpolation was possible or that the dew point was not measured at one of the levels necessary for the interpolation. In synoptic situations where the interpolated station elevation is greater than the first reported wind level, the subroutine COMPACT is called to eliminate the lowest pressure level. (This often happens when there is a deep surface low in the area.) The vector wind shear for each layer is then computed by the subroutine COMSHR and rounded to an integer by the subroutine MKRND. The variables for the Richardson number are computed and then the Richardson number itself. After this, the nondimensional variable CALPI2 is calculated. This variable and the Richardson number are used to determine the turbulent intensity of each layer by use of a series of conditional statements. (A more detailed discussion of the research and methods used to develop this program, including the derviation of CALPI2, may be found in the Appendix.) The program also checks to see if the raob data for Great Falls, MT, Lander, WY, or Denver, CO is being analyzed. If so, then a series of conditional statements for mountain waves are run through at the end of the loop.

After the program has looped through all the layers, the turbulence labels are assigned and the output is stored in the output product cccTURB. If more than one station was run, the whole process begins again with the output stored in a separate version of cccTURB for each station. If for some reason the program aborts within the subroutine TURBULENCE, an error message will be loaded into the output product.

Figure 4 shows the relationship among the disk files, program files and input/output data. Figure 5 gives an abbreviated form of the software structure and shows the flow of logic from the main program to the subroutines. Many subroutines have been used in this program, some of which were adapted from John Jannuzzi (1980).

The equations and algorithms used in developing this program may be found in Part A of the Appendix and in the program listings section.

III. Cautions and Restrictions

Turbulence associated with convection (i.e., thunderstorms) is not handled by this program.

The "PSBL MOUNTAIN WAVE" indication can occur <u>only</u> for Great Falls MT, Lander, WY and Denver, CO.

This program uses only the data from the second transmission of a raob sounding (TTBB and PPBB) and not the mandatory levels. Generally, the interpolated temperatures at the mandatory levels are quite close to the observed values.

Based upon the assumptions described in the Appendix, the forecasts are generally good for six hours and are valid for a 100nm radius of the raob site. (Rapidly changing conditions may invalidate the forecasts more quickly.) So the 00Z forecast is good until 06Z and the 12Z forecast until 18Z. As one can readily see, there are two periods when no forecast is available: 06Z-12Z and 18Z-00Z. The program output should only be used as a guide during these periods.

If the program fails for some reason, an error message will be either returned to the ADM, Dasher, or loaded into the product output. Be sure all stations entered on the command line without a local switch are upper air stations. Check the significant level reports. Two spaces are required after the TTBB and PPBB, and each part should end with an equal (=) sign. Or, perhaps only a partial or incomplete report was sent by the raob site.

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V. Program Information and Procedures for Installation and Execution

ERCP #44
July 1988

TURB: Generation of Turbulence Forecasts

PART A: INFORMATION AND INSTALLATION

PROGRAM NAME: TURB

AAL ID:
REVISION NO.: 1.00

PURPOSE: TURB takes upper air data from the significant level TTBB and PPBB groups, processes it, and develops a turbulence profile of the atmosphere surrounding an upper air station.

PROGRAM INFORMATION:

Development Programmer:
Steven J. Naglic
Location: WSFO CLE
Phone: (FTS) 942-4949
Language: DG FORTRAN IV/5.57

Maintenance Programmer:
Steven J. Naglic
Location: WSFO CLE
Phone: (FTS) 942-4949
Type: Standard

Save File Creation Dates:
Original Release/Version 1.00 07/05/88

Running Time: 1-2 minutes for six stations

Disk Space:

Program	64 RDOS blocks
Data	7 RDOS blocks

PROGRAM REQUIREMENTS

Program Files:

Name	Disk Location	Comments
TURB.SV	APPL1	

Data Files:

Name	Disk Location	R/W	Comments
SOUNDING.T	SYSZ	W/R	decoded temps/dewpts
SOUNDING.W	SYSZ	W/R	decoded winds
TURB	SYSZ	W	temporary output

AFOS Products:

ID	Action	Comments
cccSGLxxx	Input	up to six per run
cccTURB	Output	at least six versions should be in the database (one per raob site used)

LOAD LINE

```
RLDR/P TURB TURBULENCE COMSHR PRSINT INTRPOLATE MKRND COMPACT MPNDASIN
MPSGLDEC TURBARG HEADER TURBREV <TOP BG UTIL FORT>.LB TURB.LM/L
```

PROGRAM INSTALLATION

1. Install TURB.SV in APPL1 with a link from SYSZ.

2. Add sufficient copies of cccTURB to the database to accomodate all stations TURB will be run for.

TURB: Generation of Turbulence Forecasts

PART B: EXECUTION AND ERROR CONDITIONS

PROGRAM NAME: TURB

AAL ID:
REVISION NO.: 1.00

PROGRAM EXECUTION:

The program is executed by typing

```
RUN:TURB xxx [xxx xxx xxx xxx xxx] [yyy/A]
```

at an ADM (optional terms in brackets). The xxx's are the raob sites whose reports are to be analyzed (up to six per run) and yyy is the optional addressee for the output (defaults to 000, local storage only). Each forecast is stored in a separate version of cccTURB. For example,

```
RUN:TURB FNT DAY PIT BUF SDC/A
```

will generate turbulence forecasts for Flint, Dayton, Pittsburgh and Buffalo and transmit them on the SDC.

Successful completion is signaled by the alert light at the ADM.

ERROR CONDITIONS

Messages from ADM	Meaning
STN XXX UNKN	A non-upper-air site was used for xxx in the command line

Dasher Messages	Meaning
CAN'T OPEN COM.CM	Incorrect command line format

In addition, the following message is stored in cccTURB if a station's data is garbled or incomplete:

```
DATA NOT LOADED BY SGLDECODER, CHECK THE
SIGLEVEL REPORT FOR FORMAT, SPACING ERRORS,
ETC.. TWO SPACES ARE REQUIRED AFTER THE TTBB
```

AND PPBB...AND AN = SIGN IS NEEDED AFTER THE LAST DATA GROUP IN BOTH THE TTBB AND PPBB SECTIONS.

VI. Figures

Figure 1. NWS RAOB Sites

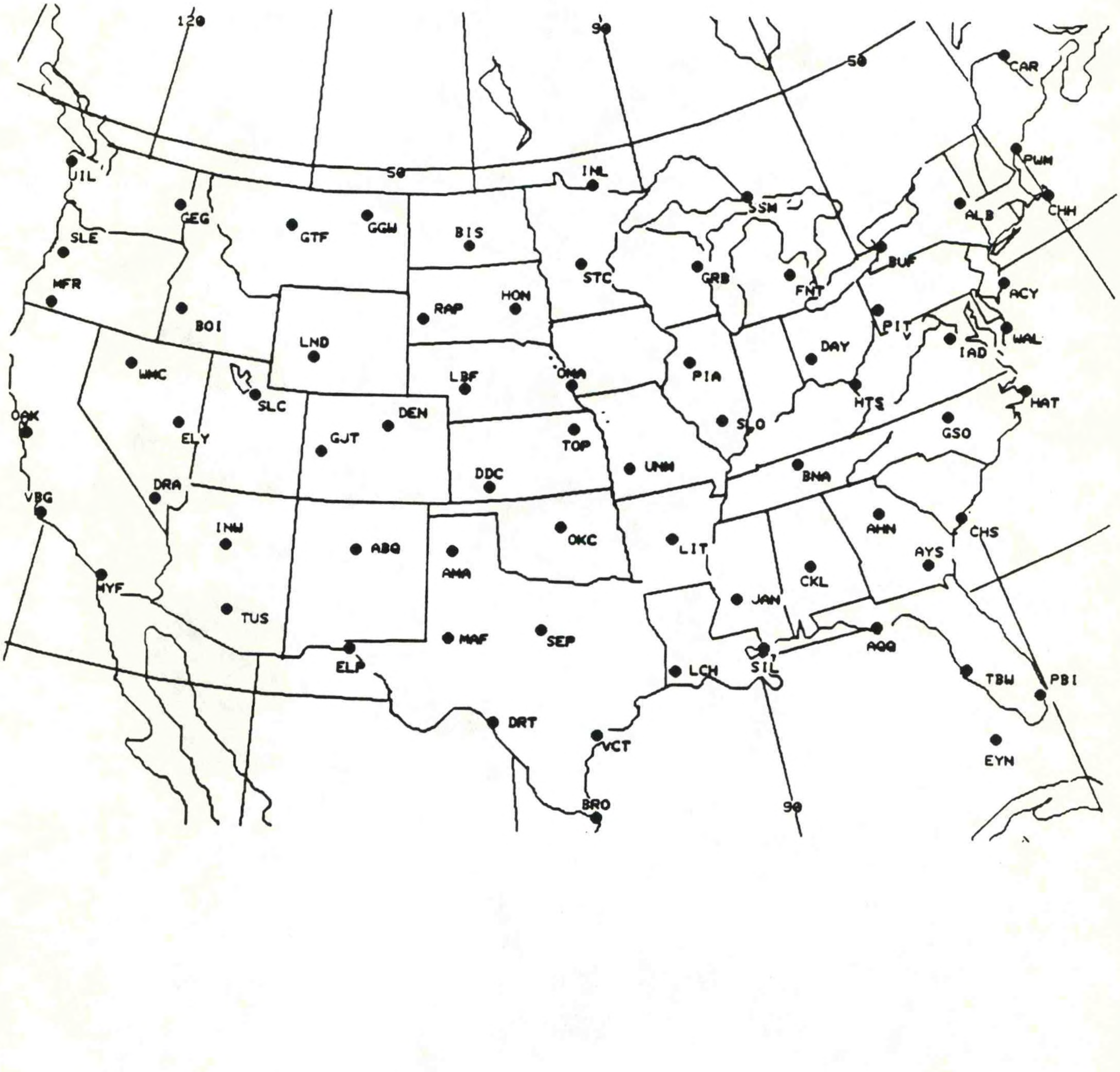


Figure 2. Sample Turbulence Forecast Product

```
CLETURB
ETTAA00 KCLE


                                 DEN

                   TURBULENCE DATA VALID   9/25  0Z

                                SML/MED ACFT                     LRG ACFT
     LAYER          SHEAR        TURBULENCE        LAYER        TURBULENCE
  (1000'S FT)    (KT/1000FT)      FORECAST      (1000'S FT)      FORECAST
   SFC -  6           1           SM - MD        SFC -  6         SM - MD
     6 -  7           6           LT - MD          6 -  7         LT - MD
     7 -  8           2           SM - LT          7 -  8         SM - LT
     8 -  9           4           MD - SV          8 -  9         LT - MD
     9 - 12           5           MD - SV          9 - 12         MD - SV
    12 - 13           4           MD - SV         12 - 13         LT - MD
    13 - 14           4       PSBL MTN WAVE       13 - 14     PSBL MTN WAVE
    14 - 16           2       PSBL MTN WAVE       14 - 16     PSBL MTN WAVE
    16 - 19           1           SM - LT         16 - 19         SM - LT
    19 - 20          10           LT - MD         19 - 20         LT - MD
    20 - 22           9           LT - MD         20 - 22         LT - MD
    22 - 25          15           LT - MD         22 - 25         LT - MD
    25 - 26          13           LT - MD         25 - 26         LT - MD
    26 - 29           7           LT - MD         26 - 29         LT - MD
    29 - 30           7           LT - MD         29 - 30         LT - MD
    30 - 35           7           LT - MD         30 - 35         LT - MD
    35 - 36           5           LT - MD         35 - 36         LT - MD
    36 - 40           8           MD - SV         36 - 40         LT - MD
    40 - 44          17           LT - MD         40 - 44         LT - MD
    44 - 48           6           SM - LT         44 - 48         SM - LT
    48 - 50           9           LT - MD         48 - 50         LT - MD
    50 - 53          10           LT - MD         50 - 53         LT - MD
```

Figure 3. Cleveland Center Airspace

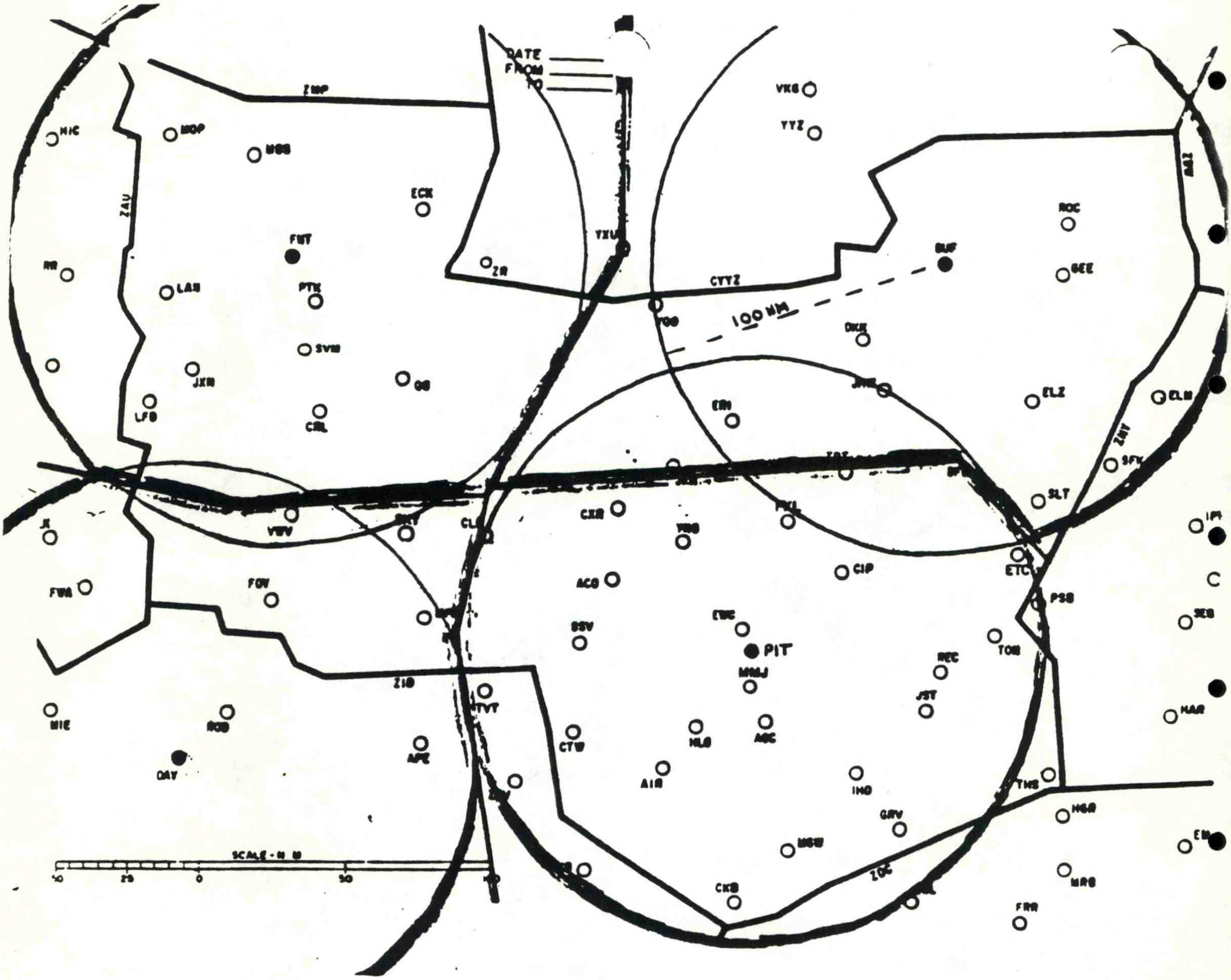


Figure 4. Program and Data Flow

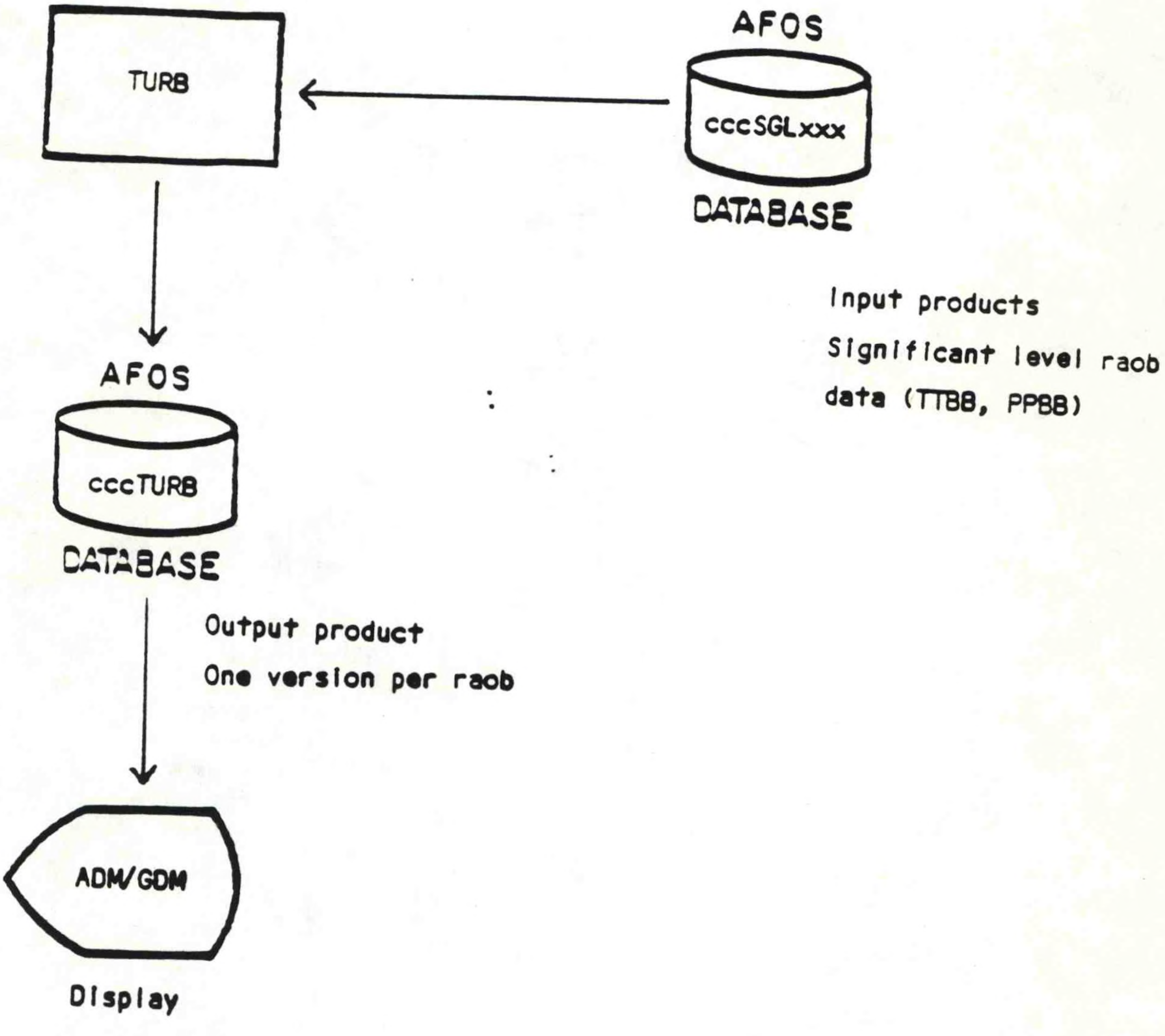


Figure 5: Software Structure and Load Line

```
Main Program
TURB


     Subroutines
     TURBARG - - ->| FCOM
                   | COMCM

     NDASIN  - - ->| FORKE

     KSRCF

     SGLDEC  - - ->| NXBKF
                   | UNPACK
                   | DFILW
                   | CFILW
                   | GCHN
                   | OPENN
                   | WRS
                   | RESET

     TURBULENCE  ->| OPEN
                   | READR
                   | CLOSE
                   | HEADER - - - - - - ->| GCHN
                   |                      | OPEN
                   |                      | RDS
                   |                      | CLOSE
                   |                      | DATE
                   |                      | KFILL
                   |                      | UBNDEC
                   |                      | PACK
                   |                      | PRSINT
                   |                      | INTRPOLATE
                   |                      | COMPACT
                   |                      | COMSHR
                   |                      | MKRND
                   |                      | FSTORE
CLOSE

FORKE
```

Load Line

```
RLDR/P  TURB  TURBULENCE  COMSHR  PRSINT  INTRPOLATE MKRND COMPACT
MPNDASIN MPSGLDEC TURBARG HEADER TURBREV  <TOP BG  UTIL  FORT>.LB
TURB.LM/L
```

Figure 6. Turbulence Study Results

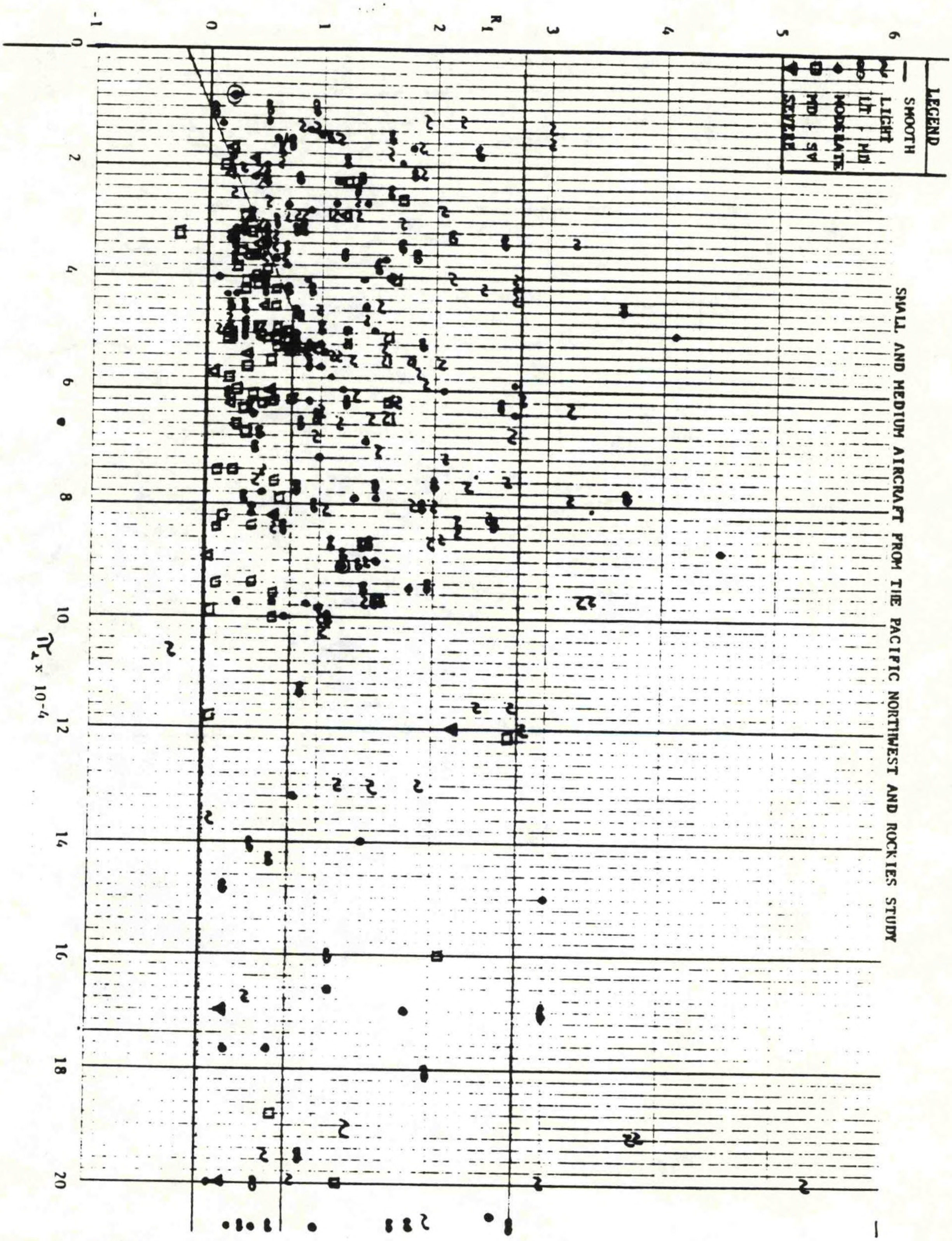
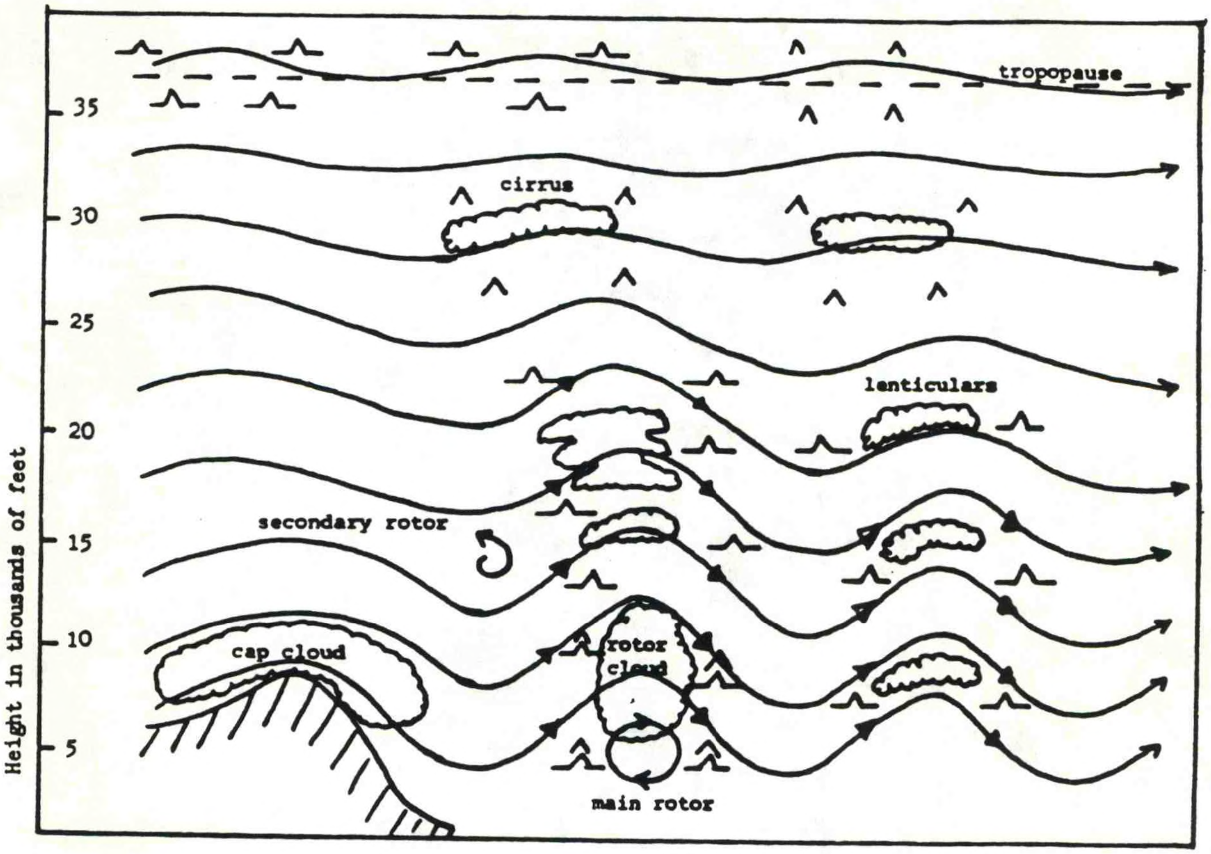


Figure 7. Mountain Wave Conditions



VII. Appendix

The research for this project was performed in three phases: theoretical development of equations; data collection and analysis; and program development, testing, and verification.

A. Theoretical Development of Equations: the Buckingham Pi Theory

During the course of my graduate work I was introduced to a theory that was based upon dimensional analysis and took an objective approach to any given hypothesis. It's known as the Buckingham Pi theory.

1. Theory

Buckingham introduced his pi theory in early part of this century (Buckingham, 1914). The essential context of the theory is as follows: "If an equation is dimensionally homogeneous, it can be reduced to a relationship among a complete set of dimensionless products...A set of dimensionless products of given variables is complete if each product in the set is independent of the others, and every other dimensionless product of variables is a product of powers..." (Perry et. al., 1963).

The dependence of n quantities or variables Q_n, may be expressed in the form of

(1) $$Q_1 \ Q_2 \ Q_3 \ldots Q_n = \pi_i$$

where π_i represents the dimensionless pi groups, and $i=1,2,3\ldots p$. In formulating a problem, this method requires the investigator to know beforehand how many dimensionless groups will constitute a complete set.

Langaar (1951) was the first to successfully perform a rigorous proof of the Buckingham Pi theory. He subsequently showed that the number of dimensionless groups p, constituting a complete set for n quantities Q_n, is given by the equation

(2) $$p = n - m$$

Langaar has also shown that m, the number of restrictions on (1), is equal to the number of primary (independent) dimensions.

In accordance with the theory, the p dimensionless groups $\pi_1, \pi_2, \pi_3, \ldots \pi_p$ can then be related by the general functional equation

(3) $$\phi\,(\pi_1, \pi_2, \pi_3, \ldots \pi_p) = 0$$

where the function ϕ is found empirically. Thus, any problem that can be described in terms of the n quantities involved in the problem can alternately be described by the p pi groups. Usually, p is much smaller than n, easing the number of independent quantities to be correlated from laboratory or field experiments.

2. Application

The intent here is to apply the Buckingham Pi theory to determine the complete set of dimensionless pi (π) groups related to atmospheric turbulence. Then, the functional relationships between these pi groups can be found empirically. These relationships, if properly formulated, can then be used to determine turbulent intensity.

It should be noted that dimensional analysis is simply a tool which helps the investigator plan and/or correlate results of an experiment. The analysis usually reduces the number of experimental variables to be correlated, and often shows the best approach to the problem. However, it does not result directly in giving quantitative information. The investigator must take the resulting pi groups and find correlations and functional relationships by researching along the lines of the theoretical aspects pertaining to the experiment at hand. If the results are at first poor, then the investigator must be critical of the variables initially used, hypothesize a new set of important variables, and work out the new pi groups and subsequent correlations again. This process can be quite painstaking, but it is an objective approach to the problem which has the properties (good or bad) of not forcing physical equations into the problem.

In using the Buckingham Pi theory one can follow an established set of procedures.

<u>STEP ONE</u>: hypothesize what variables are important to the problem. Initial consideration was given to dividing the atmosphere into two parts, the planetary boundary layer (PBL) and the free atmosphere. Significant variables considered for the PBL were the surface stress τ_0, the density ρ and the roughness length Z_0. Interpolated roughness values were taken from Lee, Stull and Irvine (1979, Figure 11). Problems arose, however, in programming interpolating schemes for τ_0 and Z_0 for areas around the raob stations, especially in the intermountain region. Even at the point sources of the raob stations themselves, the pi groups obtained gave poor results for the PBL. On the other hand, excellent results were obtained in the free atmosphere, and the resulting pi groups were adapted to the PBL where the results became quite good. By researching a complete set of variables considered to be important to the turbulent intensity of the atmosphere, a unique subset was resolved. In the final analysis, the group of variables that were found to be most successful in describing turbulent intensity are $g/\bar{\theta}$, $|\vec{V}|$, Z, $\partial\vec{V}/\partial Z$, and

$\partial\theta/\partial Z$, where $g/\bar{\theta}$ is a buoyancy term, $|\vec{V}|$ is the wind speed, Z is the height (msl), $\partial\vec{V}/\partial Z$ is the vector wind shear and $\partial\theta/\partial Z$ is the lapse rate. Hence we have

$$\phi\,(g/\bar{\theta},\ |\vec{V}|,\ Z,\ \partial\vec{V}/\partial Z,\ \partial\theta/\partial Z) = \tag{4}$$

where is yet the undetermined function.

STEP TWO: Find the dimensions of each of the variables in terms of the fundamental dimensions. The fundamental dimensions are length L, mass M, time T, temperature K, electric current A, and luminous intensity I; the latter two, A and I, are not relevant to this problem. So the variables expressed in their dimensional components are

(5a-e)

$$g/\bar{\theta} \sim (LT^{-2}\,K^{-1})$$

$$|\vec{V}| \sim (LT^{-1})$$

$$Z \sim (L)$$

$$\partial\vec{V}/\partial Z \sim (LT^{-1}L^{-1}) = (T^{-1})$$

$$\partial\theta/\partial Z \sim (KL^{-1})$$

STEP THREE: Count the number of fundamental dimensions that are involved in the problem. Here we have the dimensions of L, T, and K giving us three dimensions.

STEP FOUR: Pick certain primary variables from the original group of variables, subject to the following restrictions: (1) all fundamental dimensions must be represented, (2) no dimensionless group must be possible from any combination of the primary variables, and (3) the number of primary variables must equal the number of fundamental dimensions, ie., three in this case. Let's choose $g/\bar{\theta}$, Z, and $|\vec{V}|$ as the primary variables. It should be noted that any of the variables in the set can be primary variables so long as they meet the preceding restrictions.

STEP FIVE: Form equations for each of the remaining variables, $\partial\theta/\partial Z$ and $\partial\vec{V}/\partial Z$, as functions of the primary variables, where the number of equations (and pi groups) are equal to the number of variables (five) minus the number of dimensions (three). In this case we can expect two pi groups, hence two equations. These equations are

$$\partial\theta/\partial Z = (g/\bar{\theta})^a\ (Z)^b\ (|\vec{V}|)^c \tag{6}$$

$$\partial\vec{V}/\partial Z = (g/\bar{\theta})^d\ (Z)^e\ (|\vec{V}|)^f \tag{7}$$

STEP SIX: Substitute the dimensions for the variables and solve for the exponents (powers) which yield a dimensionally consistent equation. Equation (6) will be used as an example.

$$\partial\theta/\partial Z = (g/\bar{\theta})^{a}\ (Z)^{b}\ (|\vec{V}|)^{c}$$

or $$(KL^{-1}) = (LT^{-2}K^{-1})^{a}\ (L)^{b}\ (LT^{-1})^{c}$$

(8) For K we have: $1 = -a$
(9) For L we have: $-1 = a + b + c$
(10) For T we have: $0 = -2a - c$

Solving (8) through (10), we find: $a = -1$, $b = -2$, $c = 2$, and (6) now becomes

(11) $$\partial\theta/\partial Z = (g/\bar{\theta})^{-1}\ (Z)^{-2}(|\vec{V}|)^{2}$$

This method is again used to find the exponents of (7), which then becomes

(12) $$\partial\vec{V}/\partial Z = (g/\bar{\theta})^{0}\ (Z)^{-1}\ (|\vec{V}|)^{1} = |\vec{V}|/Z$$

STEP SEVEN: The final step is to solve for the dimensionless pi groups. By dividing either side of (11) by the other side one obtains the resulting pi group

(13) $$\pi_1 = \left(\frac{g}{\bar{\theta}}\frac{\partial\theta}{\partial z}\right)\left(\frac{z}{|\vec{V}|}\right)^{2}$$.

similarly, (12) yields

(14) $$\pi_2 = \left(\frac{|\vec{V}|}{z}\right)\Big/\left(\frac{\partial\vec{V}}{\partial z}\right)$$

According to Buckingham, the problem can now be described in terms of the two pi groups. However, his theory also states that the initial pi groups can be linearly combined to form new pi groups. Keep in mind, though, that only two of the pi groups are independent, and can be used in making correlation studies. So, by squaring π_2 and multiplying it times π_1, we have

(15) $$\pi_3 = \left(\frac{g}{\bar{\theta}}\frac{\partial\theta}{\partial z}\right)\Big/\left(\frac{\partial\vec{V}}{\partial z}\right)^{2}$$

which is the Richardson number. Thus, the resulting pi groups used in this study to correlate atmospheric turbulence are

(16) $$\underset{\text{(CALPI2)}}{\pi_2 = \left(\frac{|\vec{V}|}{z}\right)\Big/\left(\frac{\partial\vec{V}}{\partial z}\right)} \qquad \underset{\text{(Ri)}}{\pi_3 = \left(\frac{g}{\bar{\theta}}\frac{\partial\theta}{\partial z}\right)\Big/\left(\frac{\partial\vec{V}}{\partial z}\right)^{2}}$$

B. Data Collection and Analysis

According to Buckingham one can now take the resulting pi groups and attempt to find a correlation with atmospheric turbulence. To accomplish this a short program was written to calculate the Richardson number and pi2 values for each significant level reported in the TTBB and PPBB raob transmissions. Pilot reports (PIREPs) of turbulence were collected from the Pacific Northwest and the Rocky Mountain region for a period of three months. The turbulence reports were color coded and plotted on a graph (Figure 6) with their corresponding Richardson numbers and pi2 values. Since multiple colored graphs can not be reproduced with this paper various symbols were substituted. Most of the pilots reported turbulence as being smooth, light, light to moderate, moderate, moderate to severe, severe, and extreme. Only two reports of extreme turbulence were received. It was assumed that atmospheric conditions were nearly homogeneous within a 100nm radius of a raob site six hours either side of the 00Z and 12Z runs. Thus, calculated pi values from 00Z were used for PIREPs received from 18Z to 06Z, and pi values from 12Z were used for PIREPs received from 06Z to 18Z.

Looking at Figure 6 one can see there is a distinct clustering of moderate to severe and severe PIREPs below the pi3, or Richardson number (Ri), value of .75. This is in good agreement with Kennedy and Shapiro (1980) who found that Ri values less than .7 in areas of strong vertical wind shear could be considered an empirical criterion for shear induced turbulence. Theoretically it has been determined that a Ri value of less than or equal to .25 will allow dynamic turbulence to exist. However, Reed and Hardy (1972) suggest that the balloon-based observing systems are unable to resolve the highest values of $|\partial\vec{V}/\partial Z|$, thereby increasing the critical Richardson number (Ri_c) to greater than .25 but less than 1.00. Keller (1981) also agrees with this. He states that the "ability of a rising balloon system to directly sense turbulent motions is dependent on the sensitivity of the balloon system to turbulent motions above the noise level of the system and the vertical resolution. Possible sources of system error include 1) errors in tracking, 2) self-induced balloon motions, and 3) imperfect balloon response."

Looking at Figure 6 again one can see that moderate through severe PIREPs are generally not observed left of the line

$$Ri = (\pi_2 \times .20833 \times 10^4) - .2 \tag{17}$$

This line, and the line

$$Ri = .75 \text{ for } \pi_2 > 4.6\text{X}10^{-4} \tag{18}$$

are the upper limits for moderate through severe turbulence. This entire line [(17) and (18)] will be designated Ri_c for this paper. Further analysis of the data found that light through moderate turbulence was most frequently observed when Ri is greater than Ri_c, and less than or equal to 2.75. Smooth through light conditions were most frequently observed when Ri is greater than 2.75.

Several other important features of turbulence were discovered when analyzing the data. These were 1) the variations of PIREPs from smooth through moderate turbulence in and near the boundary layer during the early morning and mid to late afternoon hours, and 2) relatively high values of Ri were observed between 8 and 20 thousand feet during periods of reported mountain wave activity.

The variations of turbulence conditions during the early morning hours can most likely be attributed to the development and dissipation of the nocturnal boundary layer jet and temperature inversion. Badner (1979) gives a good description of how this process works. The development of the nocturnal boundary layer jet and inversion most commonly occur under clear skies. Strong radiational cooling at the surface allows the inversion to set up and suppress mixing and momentum transfer from the large scale flow above the inversion to the surface where the winds become light. The inversion eliminates the effects of friction which allows a wind maximum to develop just above it. It is the strong vertical wind shear between the boundary layer jet and the surface, and the change in static stability which give rise to small (<.75) Richardson numbers in the boundary layer under these synoptic conditions. As a result, the turbulence program would be predicting moderate through severe turbulence. However, during these synoptic conditions an equal distribution of smooth, light to moderate, and moderate turbulence conditions were observed by pilots flying in or up/down through the boundary layer. A plausible explanation could be that pilots who encountered moderate turbulence may have penetrated the jet at or near its time of peak strength. The pilots who reported smooth or light to moderate turbulence may have been flying through the boundary layer just after or during the jet's dissipation which occurs shortly after sunrise. As a result, the program looks at the wind and temperature profile in the boundary layer and will forecast turbulent conditions as smooth through moderate (SM-MD) if the appropriate conditions exist.

Similar variations of turbulence were observed in the boundary layer during the mid to late afternoon hours on mostly sunny days. Shortly after sunrise turbulent mixing begins. This causes the breakdown of the nocturnal temperature inversion and hence, the rapid dissipation of the boundary layer jet. The mixing process begins at the surface and grows upward, destabilizing each successive layer. Eventually, the once statically stable boundary layer becomes statically unstable and turbulence convection begins. This turbulence within the boundary layer is usually felt as bumpy thermals of hot air known as convective plumes. As an aircraft flies through and between these convective plumes it will encounter variations of turbulence (SM-MD) due to the rising, sinking, and neutral vertical motions of the air. These conditions were usually observed on mostly sunny days when the winds within the boundary layer were less than 25kts and Ri was <.75. The turbulence program checks for these conditions and forecasts smooth through moderate turbulence within the boundary layer if they arise.

One of the most important aspects to come out of the analysis was the correlation of relatively high Richardson numbers with mountain wave induced turbulence. Special attention was given to pilot reports of mountain wave turbulence over and along the east slopes of the Rockies from northern Montana to southern Colorado. I found that moderate to strong mid level winds blowing perpendicular, or nearly so, to the mountains would generate mountain waves above and below the average tops (about 14,000ft). It was observed that if the Richardson number was greater than 3.00 and the wind direction was from 230 to 310 degrees blowing greater than 22kts, mountain waves were reported by aircraft in the vicinity of and downstream of the Great Falls, Lander and Denver raob sites. The direction (230-310 deg) and the speed (>22kts) are in good agreement with Harrison (1957), George (1960), Clodman et. al. (1961), Calabrese (1966) and Sorenson (1976). The large Richardson numbers are in good agreement with Wallington (1961) who found that the greatest vertical speeds in mountain waves are located at the inflection points between the troughs and crests. Thus, the least vertical shear occurs at or near the inflection points which would yield large Richardson numbers. Other authors such as Queney (1960), Lester and Fingerhut (1974), Klemp and Lilly (1975) and Hopkins (1977) have found that a stable layer (e. g., isothermal or subadiabatic) exists at or near the mountain top level when mountain waves are observed. This stable layer often extends from the mountain tops to many kilometers downstream and is most likely responsible for the large Richardson numbers being observed by the rawinsondes. Such thermal stratification in conjunction with observed vertical wind shear has been connected with the development of short gravity waves of the Helmholtz type. These waves are recognized as an intermediate stage between laminar flow and fully developed turbulence.

The amplitudes of the mountain waves are another factor to consider since the waves vary in height. Harrison (1957) found the largest amplitudes at plus or minus 4000ft centered at the height of the mountain tops (14,000ft), while Wallington (1961) found the largest amplitudes to be plus or minus 6,000ft. Lester and Fingerhut (1974) observed that the entire vertical dimensions of mountain wave induced turbulence ranged from a few meters above the surface to 3km. The Wallington values of +/- 6,000ft centered at 14,000ft were used in the turbulence program to define the mountain wave regime.

As a result of the above observations a series of conditional statements were incorporated into the turbulence program to detect mountain waves along the east slopes of the Rockies. If the above criteria are met, the program simply states "possible mountain wave" (PSBL MTN WAVE) in the turbulence forecast column. The reason it doesn't give a specific forecast magnitude of turbulence is because turbulent conditions can vary with respect to the locations of the aircraft to the mountain wave, i.e., is the aircraft in the crest or trough of the wave, or near the inflection points, or above the crest or trough? Generally, smooth to light conditions will prevail along a flight path through or near the inflection points and the pilot will remark about up or down drafts. Moderate to severe conditions will be near the troughs and crests. According to Lee, Stull and Irvine (1979), the wind shear at the troughs and crests can be enhanced to the point where dynamic instabilities and significant turbulence will occur. Scorer (1967) and Nicholls (1973) also concluded that the most favorable locations for a decrease in Richardson number are in the zones of uphill deceleration for forward shear (crests) and downhill deceleration for backward shear (troughs). Lester and Fingerhut (1974) have also found that pilots observed light, moderate, or severe turbulence over more than 90% of the total distance flown in the lower turbulence zone (LTZ). They define the LTZ as "a highly turbulent region of nearly neutral stability found immediately to the lee of mountains between the ground and a elevated stable layer in which the wave motion is occurring." The main areas of severe turbulence were just under the crests, while moderate turbulence was observed under the troughs. The only areas of extreme turbulence observed were in the upstream side of the rotor, just beneath the rotor clouds, where the largest horizontal and vertical wind and temperature gradients were. The rotor clouds are located under the first crest to the lee of the mountains (Figure 7). According to Queney et. al. (1960) horizontal wavelengths can range from 5 to 25km with the majority observed between 10 to 15km. Thus, as one can readily see the odds are small that a rawinsonde release from Great Falls, Lander or Denver will penetrate and observe a rotor. Even if one did, it might not survive the extreme turbulence, or because of the turbulence inaccurate data could be transmitted. Therefore, because of the various reasons previously mentioned, "PSBL MTN WAVE" is put into the turbulence forecast if the appropriate conditions are observed. It's simply meant to alert pilots that mountain wave activity may be occurring and to be cautious. The observance of either cap clouds, rotor clouds or lenticular clouds near the mountains can be a visual hint to pilots that mountain wave activity is occurring. These clouds may or may not be observed, depending on the vertical distribution of humidity and stability conditions at the time.

C. Program Development, Testing and Verfication

After the data collection and analysis were completed an initial turbulence program was written to test and verify its competency. The program was set up to decode the significant level raob transmissions and provide an output product. This product produced the altitudes, total vector wind shear, Richardson number, calculated values (CALPI2), and turbulence forecast for each layer. The original program was biased towards small and mediun size aircraft since they provided the vast majority of PIREPs. However, meteorologists at air route traffic control centers are primarily interested in turbulent conditions that will affect large, mostly commercial jet aircraft. So the program was tested for a six-month period. Pilot reports were collected from all types of aircraft and separated into categories of small/medium and large aircraft according to their weight class and size given in Chapter 6 of the U. S. Dept. of Transportation FAA Contractions Manual. This was done to see how well the program would verify for each class of aircraft. The verification was performed on each turbulence forecast category of smooth through light (SM-LT), light through moderate (LT-MD), and moderate through severe (MD-SV) with an overall product average determined for each class of aircraft. The verification was performed by comparing PIREPs from 18Z-06Z for the 00Z runs, and 06Z-18Z for the 12Z runs, with the forecasts. For example, a 0132Z pilot report of light to moderate turbulence at 9,000ft within a 100nm radius of Pittsburgh would be compared to the turbulence forecast given by the 00Z run for that altitude and recorded as either a hit or a miss. The word "through" should be noted in the forecast categories. That is, a forecast of moderate through severe (MD-SV) means that turbulence may be either moderate, moderate to severe, or severe. This definition also holds for the other two categories (SM-LT AND LT-MD). The turbulence forecasts for small and medium size aircraft verified at 76% and 77% respectively, while the large aircraft verified at 69%. The smooth through light category for the large aircraft had the poorest showing, verifying at only 63%. This figure may be biased as numerous PIREPs were received from large aircraft that gave winds and/or temperatures aloft without mentioning turbulence or lack of turbulence. That is, they didn't indicate a "smooth ride even though they were probably having one. This was especially true during fair weather periods. If one would have assumed smooth conditions existed because of the lack of turbulence being mentioned, the SM-LT category would more likely have verified near 80%. Because of the lower verification percentage of the large aircraft the data was reanalyzed with Ri_c being lowered to a value of .50. This improved the verification for the large aircraft from 69% to 74%. As a result, the current program uses an Ri_c value of .75 for the small/medium and .50 for large aircraft. This idea is consistent with Queney et. al. (1960) and Turner et. al. (1981), who show that the degree of bumpiness experienced in an aircraft in a given state of turbulence varies widely according to the size, speed and characteristics of the particular aircraft. That is, what may be moderate to severe turbulence to a Cessna may only be light to moderate to a Boeing class jet.

The verification results may also be diminished (in a consistent manner) by the constraints of the rawinsonde system, including the data processing. Reed and Hardy (1972) suggest that the balloon-based observing systems are unable to resolve the highest values of $|\partial \overline{V}/\partial Z|$, thereby increasing the critical Richardson number. Keller (1981) agrees by saying that "the ability of a rising balloon system to directly sense turbulent motions is, of course, dependent on the sensitivity of the balloon system to turbulent motions above the noise level of the system and the vertical resolution. Possible sources of system error include 1) errors in tracking, 2) self-induced balloon motions and

3) imperfect balloon response." Keller also mentions that the nature of the processing of the rawinsonde data usually results in values representative of layers 2 to 3 thousand feet thick. This results in smoothing of the vertical wind structure and generally smaller shears.

The final and current turbulence program gives the layer in thousands of feet, the total vector wind shear in knots per thousand feet, and separate turbulence forecasts for both small/medium size aircraft and large aircraft. The program doesn't verify at 100%, but it can be used as a fairly reliable product and be quite useful to the aviation community.

VIII. PROGRAM LISTINGS

```
C
C     PROGRAM NAME: TURB.SV           1.00
C
C     NOVEMBER 1986     STEVEN J. NAGLIC     ZOB CWSU  FTS:292-8164
C
C     FORTRAN IV 5.57  DG ECLIPSE S230    RDOS 6.17
C
C     LOAD LINE:
C     RLDR TURB TURBULENCE CONSHR PRSINT INTRPOLATE MKRND COMPACT^
C      MPNDASIN MPSGLDEC TURBARG HEADER TOP.LB UTIL.LB FORT.LB
C
C     PURPOSE:
C     TURB.FR IS THE FUN FILE WHICH CALLS VARIOUS SUBROUTINES TO
C     OBTAIN THE TURBULENCE FORECAST.
C
C     EXTERNALS:
C     TURBARG    NDASIN    KSRCF    SGLDEC    TURBULENCE    FORK
C
C     CHANNELS: NONE
C
C     VARIABLES:
C     NSTA - NUMBER OF STATIONS READ
C     ID - CURRENT STATION ID
C     IDS - STATIONS ON COMMAND LINE
C     IFILE - PIL ID
C     INODE - STATION NODE
C     INUM - WMO STATION BLOCK NUMBER
C     KREC - KEY RECORD
C     IADR - PRODUCT ADDRESSEE
C
C
C
      DIMENSION ID(2),IFILE(5),INODE(2),INUM(2)
      DIMENSION KREC(20),IADR(2),IDS(6,2)
      IFILE(3) = 'GL'
C       TURBARG IS THE FILE CONTAINING THE COMMAND LINE
      CALL TURBARG(IDS,IADR,NSTA)
      DO 25 K = 1,NSTA
      ID(1) = IDS(K,1)
      ID(2) = IDS(K,2)
C       ASSIGN THE PROPER NODE NAME, CCC, TO THE STATION NAME, XXX.
      CALL NDASIN(ID,INODE,INUM)
      IF(INUM(1) .EQ. -1) GO TO 25
      IFILE(1) = INODE(1)
      IFILE(2) = IOR(INODE(2),123K)
      IFILE(4) = ID(1)
      IFILE(5) = IOR(ID(2),040K)
C       IFILE CONTAINS THE AFOS FILE NAME FOR THE RAOB TO BE ANALYZED
C       IE., CCCSGLXXX.
C       KSRCF IS A SUBROUTINE USED TO RETRIEVE AN AFOS PRODUCT FROM
C       THE DATA BASE AND IS FOUND IN THE BACKGROUND LIBRARY BG.LB
      CALL KSRCF(IFILE,KREC,IER)
C       SGLDEC IS A SUBROUTINE OF THE DECODING PROGRAM SGLDECODER; IT
C       IS CALLED AND THE DECODED INFO IS PUT INTO FILES SOUNDING.T
C       AND SOUNDING.W ON DPO.
      CALL SGLDEC(IFILE,KREC)
C       THE PROGRAM TO CALCULATE THE TURBULENCE PARAMETERS IS CALLED.
      CALL TURBULENCE(ID,IADR)
C       IF ADDITIONAL STATIONS ARE TO BE ANALYZED, THE PROGRAM LOOPS
C       BACK TO DO THEM; IF NOT THE PROGRAM ENDS.
   25 CONTINUE
C       THE ALERT IS TRIGGERED AT THE INITIATING CONSOLE TO SIGNIFY THAT
C       THE PROGRAM IS FINISHED.
      CALL FORK('TURB',IER)
      STOP
      END
```

```
      SUBROUTINE TURBULENCE(ID,IADR)
C
C     NOVEMBER 1986     STEVEN J. NAGLIC     ZOB CWSU  FTS:292-8164
C
C     FORTRAN IV 5.57  DG ECLIPSE S230    RDOS 6.17
C
C     PURPOSE:
C     THIS SUBROUTINE UTILIZES THE SOUNDING DATA AND SUBROUTINES PRSINT,
C     INTRPOLATE, COMSHR, COMPACT, AND MKRND TO CALCULATE THE RICHARDSON
C     NUMBER AND THE NONDIMENSIONAL VARIABLE CALPI2, WHICH DETERMINE THE
C     TURBULENCE FORECAST FOR EACH LAYER OF THE SIGNIFICANT LEVELS.
C
C     EXTERNALS:
C     OPEN    READR    CLOSE    HEADER    UBNDEC    PACK    PRSINT
C     INTRPOLATE    COMPACT    COMSHR    MKRND     CLOSE   FSTORE
C
C     CHANNELS:
C     SOUNDING.W IS OPENED ON FORTRAN CHANNEL 5
C     SOUNDING.T IS OPENED ON FORTRAN CHANNEL 7
C     TURB IS OPENED ON FORTRAN CHANNEL 6
C
C     VARIABLES:
C     LAREL - TURBULENT INTENSITY LABELS USED IN OUTPUT
C     LEVEL - A SPECIFIC LEVEL IN THE ATMOSHPERE
C     IDIRN - WIND DIRECTION FROM SOUNDING.W
C     ISPEED - WIND SPEED FROM SOUNDING.W
C     PRESS - PRESSURE LEVEL FROM SOUNDING.T
C     TEMP - TEMPERATURE AT THE PRESSURE LEVEL FROM SOUNDING.T
C     DEPR - DEW POINT DEPRESSION AT THE PRESSURE LEVEL FROM SOUNDING.T
C     ID - CURRENT STATION ID
C     IADR - PRODUCT ADDRESSEE
C     THETA1/2 - POTENTIAL TEMPERATURES FOR LEVELS(J,J+1)
C     DZ - THICKNESS BETWEEN TWO LEVELS
C     WNDSHR - WIND SHEAR BETWEEN THE LEVELS(J,J+1)
C     DVDZ2 - WIND SHEAR SQUARED
C     RNUM - RICHARDSON NUMBER
C     VBAR - MEAN WIND SPEED FOR A LAYER
C     ZBAR - HEIGHT DIFFERENCE BETWEEN LEVELS(J,J+1)
C     CALPI2 - NONDIMENSIONAL VARIABLE USED TO DETERMINE THE TURBULENT
C              INTENSITY
C     DEFPI2 - DEFINED PI VALUE COMPARED TO THE CALCULATED (CALPI2)
C              VALUE TO DETERMINE TURBULENT INTENSITY
C
C
C
C
C
      DIMENSION LEVEL(70),IDIRN(70),ISPEED(70),PRESS(70),TEMP(70),
      DIMENSION LABEL(12),IPRESS(70),DEPR(70),ID(2),IADR(2),IWORK(8)
      G=9.8
      CALL OPEN(5,'SOUNDING.W',2,IER,2)
      CALL OPEN(7,'SOUNDING.T',2,IER,2)
      I=1
C       READ DATA FROM FILE SOUNDING.T
      CALL READR(7,0,ISTATN,1,IER)
      CALL READR(7,1,IDATE,1,IER)
      CALL READR(7,2,ITIME,1,IER)
      J=3
    4 CALL READR(7,J,IPRESS(I),1,IER)
      IF(IER.EQ.9) GO TO 10
```

```
      PRESS(I)=FLOAT(IPRESS(I))
      J=J+1
      CALL READR(7,J,TEMP(I),2,IER)
      J=J+2
      CALL READR(7,J,DEPR(I),2,IER)
      J=J+2
      I=I+1
      GO TO 4
   10 CALL CLOSE(7,IER)
C       HEADER AND OUTPUT FILE 'TURB' ARE CREATED
      CALL HEADER(ID,IDATE,ITIME,IADR)
C       READ DATA FROM FILE SOUNDING.W
      I=1
      J=3
   19 CALL READR(5,J,LEVEL(I),1,IER)
      IF(IER.EQ.9) GO TO 50
      J=J+1
      CALL READR(5,J,IDIRN(I),1,IER)
      J=J+1
      CALL READR(5,J,ISPEED(I),1,IER)
      J=J+1
      IF(((IDIRN(I)/5)*5) .EQ. IDIRN(I)) GO TO 25
      ISPEED(I) = ISPEED(I) + 100
      IDIRN(I) = IDIRN(I) - 1
   25 I=I+1
      GO TO 19
   50 I=I-2
      IF(I .LT. 1) GO TO 210
C       LOOP TO CALCULATE TURBULENCE PARAMETERS
      DO 200 J=1,I
      IF(LEVEL(J+1) .EQ. -1) GO TO 250
      L = 1
C       URNDEC AND PACK ARE USED TO CONVERT DECIMAL INTEGERS TO ASCII
C       AND ARE FOUND IN THE UTILITY LIBRARY UTIL.LB
      CALL URNDEC(LEVEL(J),IWORK,L)
      CALL PACK(IWORK(4),3,IWORK)
      IF (J.EQ.1) IWORK(1) = 'SF'
      IF (J.EQ.1) IWORK(2) = 'C'
C       INTERPOLATE THE HEIGHTS OF THE SIGLVL WINDS TO PRESSURE HEIGHTS
      CALL PRSINT(LEVEL(J),PRSLVL,PRESS(1))
C       INTERPOLATE AN ENVIRONMENTAL TEMP FOR THE DESIRED PRESSURE LEVEL
      CALL INTRPOLATE(PRSLVL,PRESS,TEMP,DEPR,TMPLVL,DEWLVL,1)
      THETA1=(TMPLVL+273.16)*((1000./PRSLVL)**.286)
  101 CALL PRSINT(LEVEL(J+1),PRSLVL,PRESS(1))
      IF(PRSLVL.GE.PRESS(1)) CALL COMPACT(J+1,I,LEVEL,IDIRN,ISPEED,$101)
      CALL INTRPOLATE(PRSLVL,PRESS,TEMP,DEPR,TMPLVL,DEWLVL,1)
      IF(J.EQ.1)SFC=29.3*(TEMP(1)+273.2)*(ALOG(1013/PRESS(1)))*3.3/1000.
      SFCLVL = SFC * 1000
      IF(J.EQ.1) TYPE 'STN SURFACE ELEVATION (MSL) = ',SFCLVL
      IF(ISPEED(J) .EQ. ISPEED(J+1) .AND. IDIRN(J) .EQ. IDIRN(J+1))
     1 GO TO 147
C       COMPUTE WNDSHR PER 1000 FT FOR SIGLVLS
      CALL CONSHR(LEVEL,IDIRN,ISPEED,J,WNDSHR,AWNDSHR)
C       ROUND WNDSHR TO NEAREST INTERGER
      CALL MKRND(WNDSHR,IWNDSH)
C
C       COMPUTE VARIABLES FOR THE RICHARDSON NUMBER
      THETA2=(TMPLVL+273.16)*((1000./PRSLVL)**.286)
      THETAM=(THETA1+THETA2)/2.0
      DTHETA=THETA2-THETA1
```

```
      IF(J .EQ. 1) DZ=((LEVEL(J+1)-SFC)/3.28)*1000.
      IF(J .EQ. 1) GO TO 113
      DZ=((LEVEL(J+1)-LEVEL(J))/3.2808399)*1000.
 113  IF(J .EQ. 1) WNDSHR = AWNDSHR/(LEVEL(J+1) - SFC)
      DVDZ2=((WNDSHR*3.2808399)/1942.54)**2
      IF(DVDZ2 .EQ. 0.) GO TO 114
      LABEL(1)='SM'
C     LABEL(2)='TH'
      LABEL(3)='LT'
      LABEL(4)='MD'
      LABEL(5)='SV'
      LABEL(6)='- '
C       COMPUTE THE RICHARDSON NUMBER
      RNUM=((G/THETAM)*(DTHETA/DZ))/DVDZ2
C       COMPUTE THE VARIABLES FOR THE NONDIMENSONAL GROUP CALPI2
      IF(J .EQ. 1) LEVEL(J) = SFC
      VBAR=(ISPEED(J) + ISPEED(J+1))/2.
      ZBAR=((LEVEL(J) + LEVEL(J+1))/2.)*1000.
C       COMPUTE CALPI2
      CALPI2=(VBAR/ZBAR)/WNDSHR
      PI2=CALPI2/(1.0E-04)
C     TYPE 'RNUM = ',RNUM,'    PI2 = ',PI2,'    J = ',J
 114  LEVEL2=LEVEL(J+1)
C       CHECK GREAT FALLS, MT...LANDER, WY...AND DENVER, CO FOR POSSIBLE
C       MOUNTAIN WAVE ACTIVITY.
       IF((ISTATN.EQ.775.OR.ISTATN.EQ.576.OR.ISTATN.EQ.469).AND.(LEVEL(J)
     1  .GE.8.AND.LEVEL2.LE.20).AND.(RNUM.GT.3.).AND.(ISPEED(J).GE.22
     2  .AND.ISPEED(J+1).GE.22).AND.((IDIRN(J).LE.310.AND.IDIRN(J+1).LE.
     3  310).AND.(IDIRN(J).GE.230.AND.IDIRN(J+1).GE.230))) GO TO 144
       IF(RNUM.GT.2.75.OR.IWNDSH.EQ.0) WRITE(6,117) IWORK(1),IWORK(2),
     1  LEVEL2,IWNDSH,IWORK(1),IWORK(2),LEVEL2
       IF(RNUM.GT.2.75.OR.IWNDSH.EQ.0) GO TO 200
       IF(IWNDSH .NE. 0) WRITE(6,116) IWORK(1),IWORK(2),LEVEL2,
     1 IWNDSH
       IF(RNUM.LE.-.20) GO TO 150
C       CHECK FOR BOUNDARY LAYER PLUME ACTIVITY.
      IF(J.LE.4.AND.RNUM.LE..75.AND.ISPEED(J).LT.25.AND.ISPEED(J+1)
     1  .LT.25) GO TO 146
 116  FORMAT(/1X,'(12)',5X,A2,A1,' - ',I2,8X,I2,Z)
 117  FORMAT(/1X,'(12)',5X,A2,A1,' - ',I2,8X,I2,8X,'SM - LT',5X,A2,A1,
     1' - ',I2,6X,'SM - LT')
C       LOOP TO DETERMINE TURBULENCE FORCAST FOR SMALL (K=0) AND
C       LARGE (K=1) AIRCRAFT.
      DO 140 K=0,1
      IF(K.EQ.0.AND.RNUM.GT..75.AND.RNUM.LE.2.75) WRITE(6,130)LABEL(3),
     1   LABEL(6),LABEL(4)
      IF(K.EQ.1.AND.RNUM.GT..50.AND.RNUM.LE.2.75) WRITE(6,132)IWORK(1),
     1   IWORK(2),LEVEL2,LABEL(3),LABEL(6),LABEL(4)
      IF(K.EQ.0.AND.RNUM.LE..75.AND.RNUM.GT.-.20.AND.CALPI2.GE.4.6E-04)
     1   WRITE(6,130) LABEL(4),LABEL(6),LABEL(5)
      IF(K.EQ.1.AND.RNUM.LE..50.AND.RNUM.GT.-.20.AND.CALPI2.GE.3.4E-04)
     1 WRITE(6,132) IWORK(1),IWORK(2),LEVEL2,LABEL(4),LABEL(6),LABEL(5)
      IF(K.EQ.0.AND.RNUM.LE..75.AND.RNUM.GT.-.20.AND.CALPI2.LT.4.6E-04)
     1   GO TO 122
      IF(K.EQ.1.AND.RNUM.LE..50.AND.RNUM.GT.-.20.AND.CALPI2.LT.3.4E-04)
     1   GO TO 122
      GO TO 140
 122  DEFPI2=(RNUM + .20)/2.0833E03
      IF(K.EQ.0.AND.CALPI2.GE.DEFPI2) WRITE(6,130) LABEL(4),LABEL(6),
     1 LABEL(5)
```

```
       IF(K.EQ.1.AND.CALP12.GE.DEFP12) WRITE(6,132) IWORK(1),IWORK(2),
      1 LEVEL2,LABEL(4),LABEL(6),LABEL(5)
       IF(K.EQ.0.AND.CALP12.LT.DEFP12) WRITE(6,130) LABEL(3),LABEL(6),
      1 LABEL(4)
       IF(K.EQ.1.AND.CALP12.LT.DEFP12) WRITE(6,132) IWORK(1),IWORK(2),
      1 LEVEL2,LABEL(3),LABEL(6),LABEL(4)
  130  FORMAT(9X,A2,1X,A2,A2,Z)
  132  FORMAT(6X,A2,A1,' - ',I2,6X,A2,1X,A2,A2)
  140  CONTINUE
  142  FORMAT(9X,A2,1X,A2,A2,5X,A2,A1,' - ',I2,6X,A2,1X,A2,A2)
       GO TO 200
  144  WRITE(6,145) IWORK(1),IWORK(2),LEVEL2,IWNDSH,IWORK(1),IWORK(2),
      1  LEVEL2
  145  FORMAT(/1X,'(12)',5X,A2,A1,' - ',I2,8X,I2,5X,'PSBL MTN WAVE',
      1  2X,A2,A1,' - ',I2,3X,'PSBL MTN WAVE')
       GO TO 200
  146  WRITE(6,142)LABEL(1),LABEL(6),LABEL(4),IWORK(1),IWORK(2),LEVEL2,
      1  LABEL(1),LABEL(6),LABEL(4)
       GO TO 200
  147  LEVEL2 = LEVEL(J+1)
       WRITE(6,149) IWORK(1),IWORK(2),LEVEL2,IWORK(1),IWORK(2),LEVEL2
  149  FORMAT(/1X,'(12)',5X,A2,A1,' - ',I2,9X,'0',8X,'SM - LT',5X,A2,A1,
      1' - ',I2,6X,'SM - LT')
       GO TO 200
  150  WRITE(6,142) LABEL(4),LABEL(6),LABEL(5),IWORK(1),IWORK(2),LEVEL2,
      1  LABEL(4),LABEL(6),LABEL(5)
  200  CONTINUE
       GO TO 250
  210  WRITE(6,215)
C        ERROR MESSAGE LOADED INTO OUTPUT FILE TURB
  215  FORMAT(/1X,'(12)',/1X,'(12)',20X,'DATA NOT LOADED BY SGLDECODER',
      1  /1X,'(12)',20X,'CHECK THE SIGLEVEL REPORT FOR',/1X,'(12)',20X,
      2  'FORMAT, SPACING ERRORS, ETC..',/1X,'(12)',20X,'TWO SPACES ARE R
      3EQUIRED AFTER',/1X,'(12)',20X,'THE TTBB AND PPBB....AND AN = ',/1X
      4,'(12)',20X,'SIGN IS NEEDED AFTER THE LAST',/1X,'(12)',20X,'DATA G
      5ROUP IN BOTH THE TTBB',/1X,'(12)',20X,'AND PPBB SECTIONS.')
  250  WRITE(6,333)
  333  FORMAT(/1X,'(12)','(203)')
       CALL CLOSE(5,IER)
       CALL CLOSE(6,IER)
       CALL FSTOR('TURB',0,IER)
       RETURN
       END
```

```
      SUBROUTINE CONSHR(LEVEL,IDIRN,ISPEED,J,WNDSHR,AWNDSHR)
C
C     JANUARY 1980     JOHN JANNUZZI     POX WSFO  FTS:423-3611
C
C     FORTRAN IV 5.57  DG ECLIPSE S230    RDOS 6.17
C
C     PURPOSE:
C     CONSHR IS A SUBROUTINE WHICH, GIVEN A LEVEL J, COMPUTES THE
C     VECTOR WIND SHEAR BETWEEN LEVEL(J) AND LEVEL(J+1).
C
C     EXTERNALS: NONE
C
C     CHANNELS: NONE
C
C     VARIABLES:
C     LEVEL - A SPECIFIC LEVEL IN THE ATMOSPHERE
C     IDIRN - WIND DIRECTION FROM SOUNDIG.W
C     ISPEED - WIND SPEED FROM SOUNDING.W
C     WNDSHR - CALCULATED VECTOR WIND SHEAR
C
C
C
C
      DIMENSION LEVEL(70),IDIRN(70),ISPEED(70)
      ADIR=IDIRN(J)*.01745329
      BDIR=IDIRN(J+1)*.01745329
      COSJ=(SIN(ADIR))*FLOAT(ISPEED(J))
      COSK=(SIN(BDIR))*FLOAT(ISPEED(J+1))
      IF(COSJ .LT. 0.0 .AND. COSK .GT. 0.0) GO TO 130
      IF(COSK .LT. 0.0 .AND. COSJ .GT. 0.0) GO TO 130
      DSPD1=ABS(COSJ-COSK)
      GO TO 140
 130  DSPD1=ABS(COSJ)+ABS(COSK)
 140  SHR1=DSPD1
      SINJ=(COS(ADIR))*FLOAT(ISPEED(J))
      SINK=(COS(BDIR))*FLOAT(ISPEED(J+1))
      IF(SINJ .LT. 0.0 .AND. SINK .GT. 0.0) GO TO 150
      IF(SINK .LT. 0.0 .AND. SINJ .GT. 0.0) GO TO 150
      DSPD2=ABS(SINJ-SINK)
      GO TO 160
 150  DSPD2=ABS(SINJ)+ABS(SINK)
 160  SHR2=DSPD2
      AWNDSHR=SQRT((SHR1**2)+(SHR2**2))
      IDIRN2=IDIRN(J+1)
      ISPEED2=ISPEED(J+1)
C     IF(J.LE.6) TYPE 'IDIRN(J)',IDIRN(J),'ISPEED(J)',ISPEED(J),
C    1  'IDIRN(J+1)',IDIRN2,'ISPEED(J+1)',ISPEED2
C     REDUCES THE WINDSHEAR TO A VALUE PER 1000 FT
      WNDSHR=AWNDSHR/(FLOAT(LEVEL(J+1)-LEVEL(J)))
C     IF(J.LE.6) TYPE 'AWNDSHR',AWNDSHR,'WNDSHR',WNDSHR
      RETURN
      END
```

```
      SUBROUTINE PRSINT(IHT,PRSLVL,SFCPRS)
C
C     JANUARY 1980     JOHN JANNUZZI    PDX WSFO  FTS:423-3611
C
C     FORTRAN IV 5.37  DG ECLIPSE S230    RDOS 6.17
C
C     PURPOSE:
C     THIS SUBROUTINE INTERPOLATES A GIVEN HEIGHT IN HUNDREDS OF FEET
C     TO A PRESSURE LEVEL IN THE U.S. STANDARD ATMOSPHERE.
C
C     EXTERNALS: NONE
C
C     CHANNELS: NONE
C
C     VARIABLES:
C     IHT - HEIGHT FROM SOUNDING.W
C     PRSLVL - INTERPOLATED PRESSURE LEVEL
C     SFCPRS - SURFACE PRESSURE
C
C
C
C
      DIMENSION IINT(10)
C     TYPE 'IHT',IHT
      IINT(1)=04
      IINT(2)=32
      IINT(3)=64
      IINT(4)=99
      IINT(5)=138
      IINT(6)=184
      IINT(7)=236
      IINT(8)=300
      IINT(9)=386
      IINT(10)=532
      ILVL=IHT*10
C     TYPE 'ILVL',ILVL
      IF(ILVL .LT. IINT(1)) PRSLVL = SFCPRS
      IF(ILVL .LT. IINT(1)) GO TO 450
      DO 425 IJ=2,10
      IJM1=IJ-1
      IF(ILVL .GE. IINT(IJ)) GO TO 425
      A=FLOAT(ILVL)-FLOAT(IINT(IJM1))
      B=FLOAT(IINT(IJ))-FLOAT(IINT(IJM1))
      A=(A/B)*100.0
      B=1100.-((FLOAT(IJM1))*100.0)
      PRSLVL=B-A
C     TYPE 'PRSINT PRSLVL',PRSLVL
      GO TO 450
 425  CONTINUE
 450  RETURN
      END
```

```
      SUBROUTINE INTRPOLATE(PRSLVL,PRESS,TEMP,DEPR,TMPLVL,DEWLVL,IPART)
C
C     JANUARY 1980     JOHN JANNUZZI    PDX WSFO  FTS:423-3611
C
C     FORTRAN IV 5.57  DG ECLIPSE S230    RDOS 6.17
C
C     PURPOSE:
C     THIS SUBROUTINE INTERPOLATES BETWEEN PRESSURE LEVELS OF THE FILE
C     SOUNDING.T TO GIVE THE TEMPERATURE AND DEWPOINT AT ANY GIVEN
C     PRESSURE LEVEL (PRSLVL). A TEMPERATURE OR DEW POINT OF -99 MEANS
C     THAT NO INTERPOLATION WAS POSSIBLE OR THAT THE DEWPOINT WAS NOT
C     MEASURED AT ONE OF THE LEVELS NECESSARY FOR THE INTERPOLATION.
C     IF IPART IS 1, ONLY THE TEMPERATURE INTERPOLATION IS PERFORMED.
C
C     EXTERNALS: NONE
C
C     CHANNELS: NONE
C
C     VARIABLES:
C     PRSLVL - INTERPOLATED PRESSURE LEVEL
C     PRESS - PRESSURE LEVELS FROM SOUNDING.T
C     TEMP - TEMPERATURE FROM SOUNDING.T
C     DEPR - DEW POINT DEPRESSION FROM SOUNDING.T
C     TMPLVL - INTERPOLATED TEMPERATURE FROM SOUNDING.W
C     DEWLVL - INTERPOLATED DEW POINT FROM SOUNDING.W
C
C
C
C
      DIMENSION PRESS(70),TEMP(70),DEPR(70),Y(3),X(3)
C     SEARCHES FOR THE PRES LVLS ON BOTH SIDES OF THE DESIRED LVL
      J=1
C     TYPE 'PRESS(1)',PRESS(1)
      IF(PRSLVL .GT. PRESS(1)) GO TO 70
      IF(PRSLVL .EQ. PRESS(1)) GO TO 50
      PRESS1=PRESS(1)
      DO 20 I=2,30
      J=I
C     TYPE 'PRESS(J)',PRESS(J)
      IF(PRSLVL .EQ. PRESS(I)) GO TO 50
      IF(PRSLVL .GT. PRESS(I) .AND. PRSLVL .LT. PRESS1) GO TO 60
      PRESS1=PRESS(I)
      IF(I .EQ. 30) GO TO 70
   20 CONTINUE
C     INTERPOLATES FOR THE TEMP
   60 Y(1)=((7.196-(PRESS1**.2857))*720.71)
      Y(2)=((7.196-(PRESS(J)**.2857))*720.71)
      X(1)=(((TEMP(J-1)+70.0)*25.0)+500.0)
      X(2)=(((TEMP(J)+70.0)*25.0)+500.0)
      IF((X(2)-X(1)) .EQ. 0.0) X(2)=X(2)+.1
      SLOPE=(Y(2)-Y(1))/(X(2)-X(1))
      Y(3)=((7.196-(PRSLVL**.2857))*720.71)
      X(3)=((Y(3)-Y(2))/SLOPE)+X(2)
      TMPLVL=((X(3)-500.0)/25.0)-70.0
      IF(IPART .EQ. 1) GO TO 55
      IF(DEPR(J-1) .EQ. -1 .OR. DEPR(J) .EQ. -1) DEWLVL=-99
      IF(DEWLVL .EQ. -99) GO TO 100
C     INTERPOLATES FOR THE DEWPOINT
      X(1)=(((TEMP(J-1)-DEPR(J-1)+70.0)*25.0)+500.0)
      X(2)=(((TEMP(J)-DEPR(J)+70.0)*25.0)+500.0)
```

```
      IF((X(2)-X(1)) .EQ. 0.0) X(2)=X(2)+.1
      SLOPE=(Y(2)-Y(1))/(X(2)-X(1))
      X(3)=((Y(3)-Y(2))/SLOPE)+X(2)
      DEWLVL=((X(3)-500.0)/25.0)-70.0
      GO TO 100
  50  TMPLVL=TEMP(J)
  55  IF(IPART .EQ. 1) DEWLVL=-99
      IF(IPART .EQ. 1) GO TO 100
      DEWLVL=TEMP(J)-DEPR(J)
      GO TO 100
  70  TMPLVL=TEMP(1)
      DEWLVL=TEMP(1)-DEPR(1)
 100  RETURN
      END
```

```
      SUBROUTINE MKRND(BINT,IBINT)
C
C     JANUARY 1980     JOHN JANNUZZI    PDX WSFO  FTS:423-3611
C
C     FORTRAN IV 5.57  DG ECLIPSE S230    RDOS 6.17
C
C     PURPOSE:
C     THIS SUBROUTINE ROUNDS OFF A POSITIVE OR NEGATIVE REAL NUMBER
C     TO AN INTERGER VALUE BETWEEN LEVEL(J) AND LEVEL(J+1).
C
C     EXTERNALS: NONE
C
C     CHANNELS: NONE
C
C     VARIABLES:
C     BINT - A REAL VARIABLE TO BE ROUNDED
C     IBINT - THE INTERGER VERSION OF BINT
C
C
C
C
      IBINT=IFIX(BINT)
      DEC=ABS(IBINT-BINT)
      IF(BINT .LT. 0.0) GO TO 30
      IF(DEC .GE. 0.5) IBINT=IBINT+1
      GO TO 50
  30  IF(DEC .GE. 0.5) IBINT=IBINT-1
  50  RETURN
      END
```

```
      SUBROUTINE COMPACT(J.I,LEVEL,IDIRN,ISPEED,IRTN)
C
C     JANUARY 1980     JOHN JANNUZZI    PDX WSFO  FTS:423-3611
C
C     FORTRAN IV 5.57  DG ECLIPSE S230    RDOS 6.17
C
C     PURPOSE:
C     THIS SUBROUTINE ELIMINATES THE LOWEST PRSLVL IN SITUATIONS WHERE
C     THE INTERPOLATED STATION ELEVATION IS GREATER THAN THE FIRST
C     REPORTED WIND LEVEL.
C
C     EXTERNALS: NONE
C
C     CHANNELS: NONE
C
C     VARIABLES:
C     LEVEL - A SPECIFIC LEVEL IN THE ATMOSPHERE
C     IDIRN - WIND DIRECTION FROM SOUNDIG.W
C     ISPEED - WIND SPEED FROM SOUNDING.W
C
C
C
C
      DIMENSION LEVEL(70),IDIRN(70),ISPEED(70)
C     TYPE 'J = ',J,'I = ',I,'LEVEL = ',LEVEL
      DO 100 K = J,I
      L = K+1
      LEVEL(K) = LEVEL(L)
      IDIRN(K) = IDIRN(L)
      ISPEED(K) = ISPEED(L)
 100  CONTINUE
      LEVEL(I+1) = -1
C     TYPE 'J = ',J,'I = ',I,'LEVEL = ',LEVEL
      RETURN IRTN
      END
```

```
      SUBROUTINE NOASIN(ID,INODE,INUM)
C
C     JANUARY 1980     JOHN JANNUZZI     PDX WSFO  FTS:423-3611
C     NOTE: ORGINAL PROGRAM WRITTEN BY JOHN JANNUZZI THEN MODIFIED BY
C     MATTHEW R. PEROUTKA AND STEVEN J. NAGLIC
C
C     FORTRAN IV 5.57  DG ECLIPSE S230    RDOS 6.17
C
C     PURPOSE:
C     THIS SUBROUTINE CHECKS THE STATION ARGUMENTS GIVEN ON THE COMMAND
C     LINE WITH ITS NODE CCC, STATION XXX, AND WMO BLOCK NUMBER NNN, TO
C     MAKE SURE IT'S A RAOB SITE. IF A NONUPPER AIR STATION IS ENTERED
C     WITHOUT A SWITCH, THEN AN ERROR MESSAGE IS RETURNED TO THE AOM.
C
C     EXTERNALS:
C     FORKE
C
C     CHANNELS: NONE
C
C     VARIABLES:
C     ID - CURRENT STATION ID
C     INODE - STATION NODE
C     INUM - STATION WMO BLOCK NUMBER
C
C
      COMMON/JB1/ISTATN(200),ND(200),NN(200),IMSG(6)
      DIMENSION ID(2),INODE(2),INUM(2)
      DATA ISTATN/"ABQ BOI BIS LND GJT DEN GGW GTF SAN SLE MFR INW
     1 TUS WMC ELY DRA UIL GEG OAK VBG SLC RAP HON LBF OMA DDC TOP
     2 OKC AMA ELP MAF SEP GGG DRT VCT BRO INL STC GRB PIA SLO UMN
     3 LIT JAN LCH BVE SSM FNT BUF ALB PWM DAY PIT ACY CHH HTS IAD
     4 WAL BNA GSO HAT CKL AHN AYS CHS AQQ TBW PBI EYW CAR "/
C
         DATA ND/"ABQ BOI BIS CYS DEN DEN GTF GTF LAX PDX PDX PHX
     1 PHX RNO RNO RNO SEA SEA SFO SFO SLC FSD FSD OMA OMA TOP TOP
     2 OKC LBB LBB LBB FTW FTW SAT SAT SAT MSP MSP MKE CHI CHI STL
     3 LIT JAN NEW NEW ARB ARB BUF ALB PWM CLE PIT PHL BOS CRW WBC
     4 WBC MEM RDU RDU BHM ATL ATL CAE BHM MIA MIA MIA PWM "/
C
         DATA NN/"365 681 764 576 476 469 768 775 290 694 597 374
     1 274 583 486 387 797 785 493 393 572 662 654 562 553 451 456
     2 353 363 270 264 260 247 261 255 250 747 658 635 532 433 349
     3 340 235 240 232 734 637 528 518 606 429 520 407 494 425 403
     4 402 327 317 304 279 311 213 208 220 210 203 201 712 "/
C
C
C     ERROR MESSAGE RETURNED TO AOM
      DATA IMSG/"STN XXX UNKN"/
      ID(2)=IAND(ID(2),177400K)
      ID(2)=IOR(ID(2),040K)
      N=0
      DO 50 J=1,141,2
      JP1=J+1
      IF(ID(1) .EQ. ISTATN(J) .AND. ID(2) .EQ. ISTATN(JP1)) N=J
      IF(N .EQ. J) GO TO 55
 50   CONTINUE
      IMSG(3) = ID(1)
      IMSG(4) = ID(2)
      ID(2) = ID(2) - 40K
      INUM(1) = -1
      CALL FORKE(ID,IMSG,IER)
      RETURN
 55   NP1=N+1
      INODE(1)=ND(N)
      INODE(2)=ND(NP1)
      INODE(2)=IAND(INODE(2),177400K)
      INUM(1) = NN(N)
      INUM(2) = NN(NP1)
      INUM(2) = IAND(INUM(2),177400K)
      ID(2)=ID(2)-040K
      RETURN
      END
```

```
      SUBROUTINE SGLDEC(IFILE,KREC)
C
C     JANUARY 1980      JOHN JANNUZZI      PDX WSFO  FTS:423-3611
C     NOTE: THIS PROGRAM WAS MODIFIED BY MATTHEW R. PEROUTKA
C
C     FORTRAN IV 5.57  DG ECLIPSE S230    RDOS 6.17
C
C     PURPOSE:
C     THIS SUBROUTINE DECODES THE TTBB AND PPBB RAOB TRANSMISSIONS INTO
C     TWO RDOS FILES; ONE FOR TEMPERATURES AND DEWPOINTS, AND ONE FOR
C     WINDS. IF THE FORMAT IN THE FILE IS NOT CORRECT, IT WILL TYPE OUT
C     A FLAG MESSAGE TO THAT EFFECT AT THE DASHER AND EXIT THAT PORTION
C     OF THE PROGRAM.
C     SPLITS THE 'WORDS' OF THE AFOS FILE NOW STORED IN 'RAOB.BB' INTO
C     THE TWO BYTE COMPONENTS AND PUTS EACH BYTE ASCII CHARACTER INTO
C     SEPARATE WORDS OF A NEW ARRAY NAMED 'IARRAY'.
C
C     EXTERNALS:
C     RDBKF     NXBKF     UNPACK    DFILW    CFILW
C     OPENW     GCHN      WRS       RESET
C
C     CHANNELS: NONE
C
C     VARIABLES:
C     IFILE - PIL ID
C     KREC - KEY RECORD
C     ITEMP - TEMPERATURE AT LEVEL N
C     IDEPR - DEW POINT DEPRESSION AT LEVEL N
C     IDIR - WIND DIRECTION AT LEVEL N
C     ISPEED - WIND SPEED AT LEVEL N
C
C
C
C
      DIMENSION IARRAY(512),IDATA(1024),IPRESS(70),TEMP(70),DEPR(70)
      DIMENSION ILVL(70),IDIR(70),ISPEED(70),IFILE(5),KREC(20)
      CALL RDBKF(0,IDATA,IER)
      DO 2 I=1,128
    2 IARRAY(I)=IDATA(I)
      N=1
    3 CALL NXBKF(IDATA,IER)
      IF(IER .NE. 1 .OR. N .EQ. 4) GO TO 6
      DO 4 I=1,126
      K=(N*128)+I-((N-1)*2)
    4 IARRAY(K)=IDATA(I+2)
      N=N+1
      GO TO 3
    6 CALL UNPACK(IARRAY,1024,IDATA)
      N=1
C     N IS A CHARACTER POINTER USED TO GUIDE US THRU THE ARRAY 'IDATA'
      N=1
C     STRING SEARCH FOR 'B''B''SPACE'
      DO 50 I=1,500
      IF (IDATA(I).NE.102K.OR.IDATA(I+1).NE.102K.OR.IDATA(I+2).NE.40K)
     1GOTO 50
      N = I + 3
      GOTO 49
   50 CONTINUE
      GO TO 215
   49 IF (IDATA(N).EQ.40K) N = N + 1
```

```
C     ASSIGNS THE DATE, TIME, AND STATION NUMBER.
      NP1=N+1
      NP2=N+2
      NP3=N+3
      IDATE=(10*(IDATA(N)-48))+(IDATA(NP1)-48)-50
      ITIME=(10*(IDATA(NP2)-48))+(IDATA(NP3)-48)
      N=N+8
      NP1=N+1
      NP2=N+2
      ISTATN=(100*(IDATA(N)-48))+(10*(IDATA(NP1)-48))+(IDATA(NP2)-48)
      N=N+4
      M=1
      IPOINT=0
      NP20=N+20
C     STRING SEARCH FOR '00' GROUP.
      DO 70 I=N,NP20
      IP1=I+1
      IF((IDATA(I)-48) .EQ. IPOINT .AND. (IDATA(IP1)-48) .EQ. IPOINT)
     1GO TO 80
      N=N+1
   70 CONTINUE
      GO TO 215
C     ASSIGNS THE PRESSURE AT THIS LEVEL.
   80 N=N+2
      NP1=N+1
      NP2=N+2
      IF(IDATA(N) .EQ. 057K) N=N-1
      IF(IDATA(N) .EQ. 057K) GO TO 73
      IPRESS(M)=(100*(IDATA(N)-48))+(10*(IDATA(NP1)-48))+(IDATA(NP2)-48)
C     STRING SEARCH FOR THE FIRST INTEGER; 0 THRU 9.
   73 N=N+3
      NP10=N+10
      DO 75 I=N,NP10
      DO 76 IJ=0,9
      IF(IDATA(I) .EQ. 057K) N=N+3
      IF(IDATA(I) .EQ. 057K) GO TO 91
      IF((IDATA(I)-48) .EQ. IJ) GO TO 85
   76 CONTINUE
      N=N+1
   75 CONTINUE
      GO TO 215
C     ASSIGNS THE TEMPERATURE AND DEW POINT DEPRESSION AT THIS LEVEL.
   85 NP1=N+1
      NP2=N+2
      ITEMP=((IDATA(N)-48)*100)+((IDATA(NP1)-48)*10)+(IDATA(NP2)-48)
      IISIGN=(ITEMP/2)*2
      IF(ITEMP .NE. IISIGN) ITEMP=-ITEMP
      TEMP(M)=(FLOAT(ITEMP)/10.0)
      N=N+3
      NP1=N+1
      IF(IDATA(N) .EQ. 057K) DEPR(M)=-1.0
      IF(IDATA(N) .EQ. 057K) GO TO 91
      IDEPR=(10*(IDATA(N)-48))+(IDATA(NP1)-48)
      DEPR(M)=FLOAT(IDEPR)
      IF(DEPR(M) .LE. 50) DEPR(M)=(DEPR(M)/10.0)
      IF(DEPR(M) .GE. 55.0) DEPR(M)=DEPR(M)-50.0
C     CHECK FOR AN '=' SIGN DENOTING THE END OF THE RAOB.
   91 N=N+2
      IF(IDATA(N) .EQ. 075K) GO TO 215
C     STRING SEARCH FOR THE FIRST INTEGER; 0 THRU 9.
```

```
      NP10=N+10
      DO 93 I=N,NP10
      DO 94 IJ=0,9
      IF((IDATA(I)-48) .EQ. IJ) GO TO 95
   94 CONTINUE
      N=N+1
   93 CONTINUE
      GO TO 215
C     CHECK TO SEE IF THIS IS THE NEXT LEVEL GROUP OR IF IT IS
C     THE END OF THE 'TTBB' SECTION OF THE RAOB; THE 51515 GROUP.
   95 IPOINT=IPOINT+1
      IF(IPOINT .EQ. 10) IPOINT=1
      NP1=N+1
      NP2=N+2
      NP3=N+3
      NP4=N+4
      IF(IDATA(N) .EQ. 065K .AND. IDATA(NP1) .EQ. 061K .AND.
     1IDATA(NP2) .EQ. 065K .AND. IDATA(NP3) .EQ. 061K .AND. IDATA(NP4)
     1.EQ. 065K) GO TO 215
      IF((IDATA(N)-48) .NE. IPOINT .AND. (IDATA(NP1)-48) .NE. IPOINT)
     1GO TO 215
      N=N+1
C     RECYCLES THRU THE LOOP TO ASSIGN VALUES AT THE NEW PRESSURE LEVEL.
      GO TO 80
C     STRING SEARCH FOR THE WIND SECTION OF THE RAOB; '8''8'
C     'SPACE''SPACE'.
  215 ISAVE=N
      N = 1
      NP30=N+30
      DO 200 I=N,NP30
      IF(IDATA(I) .NE. 102K) GO TO 206
      IP1=I+1
      IF(IDATA(IP1) .NE. 102K) GO TO 206
      IP2=I+2
      IF(IDATA(IP2) .NE. 040K) GO TO 206
      IP3=I+3
      IF(IDATA(IP3) .NE. 040K) GO TO 206
      N=I+4
      GO TO 201
  206 N=N+1
  200 CONTINUE
      GO TO 300
C     STRING SEARCH FOR THE BEGINNING OF THE FIRST GROUP SPECIFYING
C     THE WIND LEVELS; A 'SPACE''9'.
  201 NP10=N+50
      DO 205 I=N,NP10
      IP1=I+1
      IF(IDATA(I) .NE. 040K) GO TO 208
      IF((IDATA(IP1)-48) .NE. 9) GO TO 208
      GO TO 207
  208 N=N+1
  205 CONTINUE
      GO TO 300
C     ASSIGNS THE NEXT LEVEL OF WINDS GIVEN (IT CHECKS FOR '/'
C     FOR MISSING LEVELS).
  207 N=N+2
      NP1=N+1
      NP3=N+3
      NN=N
      DO 210 I=NP1,NP3
```

```
      IF(IDATA(I) .NE. 057K) ILVL(M)=(10*(IDATA(N)-48))+(IDATA(I)-48)
      IF(IDATA(I) .NE. 057K) M=M+1
  210 CONTINUE
C     ASSIGNS THE WINDS AT THE ABOVE DETERMINED LEVELS.
      N=N+4
      M=M-1
      DO 220 II=MM,M
      NP10=N+10
      DO 211 I=N,NP10
      DO 212 IJ=0,9
      IF((IDATA(I)-48) .EQ. IJ) GO TO 216
  212 CONTINUE
      N=N+1
  211 CONTINUE
      GO TO 300
  216 NP1=N+1
      NP2=N+2
      NP3=N+3
      NP4=N+4
      IDIR(II)=((IDATA(N)-48)*100)+((IDATA(NP1)-48)*10)+(IDATA(NP2)-48)
      ISPEED(II)=((IDATA(NP3)-48)*10)+(IDATA(NP4)-48)
      N=N+5
  220 CONTINUE
C     CHECKS FOR END OF FILE; '='.
      IF(IDATA(N) .EQ. 075K) GO TO 300
C     CHECK FOR NEXT '9' GROUP AND MAKES SURE THAT ALL THE
C     CHARACTERS IN THE GROUP ARE INTEGERS OR A '/'.
      NP10=N+10
      DO 230 I=N,NP10
      IF((IDATA(I)-48) .NE. 9) GO TO 229
      DO 232 IIJ=1,4
      DO 231 IJ=0,10
      JI=IIJ+I
      IF((IDATA(JI)-48) .EQ. IJ .OR. IDATA(JI) .EQ. 057K)
     1GO TO 232
      IF(IJ .EQ. 10) GO TO 300
  231 CONTINUE
  232 CONTINUE
      GO TO 235
  229 N=N+1
  230 CONTINUE
C     RECYCLES THRU THE LOOP TO ASSIGN THE WINDS AT THE NEXT LEVELS.
  235 M=M+1
      N=N-1
      GO TO 207
C     WRITES THE DECODED TEMPERATURE INFORMATION INTO AN RDOS FILE
C     NAMED 'SOUNDING.T' AND THE DECODED WIND INFORMATION INTO AN RDOS
C     FILE NAMED 'SOUNDING.W'.
  300 CALL DFILW('SOUNDING.T',IER)
      CALL CFILW('SOUNDING.T',2,IER)
      CALL DFILW('SOUNDING.W',IER)
      CALL CFILW('SOUNDING.W',2,IER)
      CALL GCHN(LCHN,IER)
      CALL OPENW(LCHN,'SOUNDING.T',0,IER)
      CALL WRS(LCHN,ISTATN,2,IER)
      CALL WRS(LCHN,IDATE,2,IER)
      CALL WRS(LCHN,ITIME,2,IER)
      DO 310 I=1,ISAVE
      IF(IPRESS(I) .LT. 100) IPRESS(I)=IPRESS(I) + 1000
      CALL WRS(LCHN,IPRESS(I),2,IER)
```

```
      CALL WRS(LCHN,TEMP(I),4,IER)
      CALL WRS(LCHN,DEPR(I),4,IER)
  310 CONTINUE
      CALL GCHN(KCHN,IER)
      CALL OPENN(KCHN,'SOUNDING.W',0,IER)
      CALL WRS(KCHN,ISTATN,2,IER)
      CALL WRS(KCHN,IDATE,2,IER)
      CALL WRS(KCHN,ITIME,2,IER)
      IF (N.EQ.1) GOTO 320
      DO 320 I=1,N
      CALL WRS(KCHN,ILVL(I),2,IER)
      CALL WRS(KCHN,IDIR(I),2,IER)
      CALL WRS(KCHN,ISPEED(I),2,IER)
  320 CONTINUE
      CALL RESET
      RETURN
      END
```

```
      SUBROUTINE TURBARG(IDS,IADR,NSTA)
C
C     NOVEMBER 1986     MATTHEW R. PEROUTKA     CLE WSFO  FTS:942-4949
C
C     FORTRAN IV 5.57  DG ECLIPSE S230    RDOS 6.17
C
C     PURPOSE:
C     THIS SUBROUTINE CHECKS THE COMMAND LINE FOR ARGUMENTS AND
C     SWITCHES. THE ADDRESSEE IS SET AT '000' SO THE PRODUCT WILL
C     REMAIN INHOUSE UNLESS A SPECIFIC ADDRESSEE IS GIVEN IE.,
C     SDC/A FOR STATE DISTRIBUTION CIRCUIT OR XXX/A FOR STATION XXX.
C
C     EXTERNALS:
C     FCOM COMCM
C
C     CHANNELS:
C     COMCM IS OPENED ON RDOS CHANNEL CHAN
C
C     VARIABLES:
C     IDS - STATIONS ON COMMAND LINE
C     IADR - PRODUCT ADDRESSEE
C     NSTA - NUMBER OF STATIONS READ
C
C
C
C
      INTEGER DAT(10),SW(2),CHAN,IADR(2),IDS(6,2)
C       FCOM OPENS THE FILE COM.CM
      CALL FCOM(CHAN,IER)
      IF(IER.EQ.1) GO TO 100
      TYPE 'CAN'T OPEN COM.CM'
      STOP
 100  NSTA = 0
      IADR(1) = '00'
      IADR(2) = '0'
      DO 500 I=1,8
C       COM.CM IS THE FILE GENERATED BY THE COMMAND LINE WHICH HOLDS
C       THE COMMAND LINE INFORMATION.
      CALL COMCM(CHAN,DAT,N,SW,IER)
      IF(IER.NE.1) GO TO 600
      IF(I.EQ.1) GO TO 500
      IF(.NOT.ISWSET(SW,'A')) GO TO 200
      IADR(1) = DAT(1)
      IADR(2) = IAND(DAT(2),177400K)
      GO TO 500
 200  NSTA = NSTA + 1
      IDS(NSTA,1) = DAT(1)
      IDS(NSTA,2) = IAND(DAT(2),177400K)
 500  CONTINUE
 600  RETURN
      END
```

```
      SUBROUTINE HEADER(ID,IDATE,ITIME,IADR)
C
C     NOVEMBER 1986      STEVEN J. NAGLIC        ZOB CWSU  FTS:292-8164
C                        MATTHEW R. PEROUTKA     CLE WSFO  FTS:942-4949
C
C     FORTRAN IV 5.57  DG ECLIPSE S230    RDOS 6.17
C
C     PURPOSE:
C     THIS SUBROUTINE BUILDS THE HEADER FOR THE OUTPUT FILE TURB.
C
C     EXTERNALS:
C     GCHN    OPEN    RDS    CLOSE    DATE    KFILL
C
C     CHANNELS:
C     SKEL IS OPENED ON RDOS CHANNEL IC TO RETRIEVE NODE ID
C     TURB IS OPENED ON FORTRAN CHANNEL 6 FOR OUTPUT
C
C     VARIABLES:
C     ID - CURRENT STATION ID
C     IADR - PRODUCT ADDRESSEE
C
C
C
      DIMENSION KSTA(2),MO(3),IPIL(5),IADR(2),ID(2)
      KSTA(2) = 0
      CALL GCHN(IC,IER)
      CALL OPEN(IC,'SKEL',0,IER)
      I = 3
      CALL RDS(IC,KSTA,I,IER)
      CALL CLOSE(IC,IER)
      CALL DATE(MO,IER)
      IPIL(1) = 'TU'
      IPIL(2) = 'RB'
      CALL OPEN(6,'TURB',2,IER,80)
      CALL KFILL(IPIL,IER)
      WRITE(6,10)(IPIL(I),I=1,5),(IADR(I),I=1,2)
   10 FORMAT(1X,4A2,A1,A2,A1,4('(377)'),'(5)',Z)
      WRITE(6,11) KSTA
   11 FORMAT(1X,'(305)(200)',/1X,'TTAA00 K',A2,A1)
      WRITE(6,30) ID
   30 FORMAT(/1X,'(12)',/1X,'(12)',33X,A2,A1)
      WRITE(6,50) MO(1),IDATE,ITIME
   50 FORMAT(/1X,'(12)',/1X,'(12)',19X,'TURBULENCE DATA VALID',2X,
     1I2,'/',I2,' ',I2,'Z')
      WRITE(6,57)
   57 FORMAT(/1X,'(12)',/1X,'(12)',29X,'SML/MED ACFT',15X,'LRG ACFT')
      WRITE(6,60)
   60 FORMAT(/1X,'(12)',7X,'LAYER',8X,'SHEAR',5X,'TURBULENCE',5X,
     1'LAYER',5X,'TURBULENCE')
      WRITE(6,70)
   70 FORMAT(/1X,'(12)',4X,'(1000'S FT)',2X,'(KT/1000FT)',3X,
     1'FORECAST',3X,'(1000'S FT)',3X,'FORECAST')
      RETURN
      END
```

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43 AEX - Automatic Program Execution. Harold H. Opitz, June 1988.

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