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AFGWC'S UPPER AIR VALIDATOR SYSTEM

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13. Abstract: This technical note describes the Upper Air Validator system at AFGWC. Detailed descriptions of internal error checking and data quality assurance functions are the major part of this tech note. Problems with the previous Validator and improvements within this Validator are also addressed. Reject and suspect limits for temperature, height, wind speed, and density used by the Validator are included.

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PREFACE

This Technical Note (TN) describes the Upper Air Validator (UAV) system currently used at the Air Force Global Weather Central (AFGWC) at Offutt AFB, NE. The emphasis of this technical note is on the internal functions and operations of the main modules of the Upper Air Validator (UAV). This TN also discusses problems with the previous validator, improvements in this validator, operation of the UAV, its internal diagnostic printout function, and the databases that it produces. Planned improvements to UAV are also addressed.

I would like to thank the people at OL-A, USAFETAC, Database branch, for their assistance in helping me prepare this document while I was stationed there.

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INTRODUCTION

1.1 BACKGROUND

The old Upper Air Validator (oUAV) at AFGWC began operation in the early 1970's, concurrent with implementation of the Data Save (DATSAV) system. DATSAV is an automated system to decode and validate worldwide surface and upper air observations for use in AFGWC automated analysis and forecast models. Listed below are the types of upper air observations that are processed by the validator:

a. Part A RAOB. Contains height, temperature, dewpoint depression, and usually wind data for mandatory pressure levels from the earth's surface through 100 millibars. This report may also include tropopause and maximum wind information.

b. Part B RAOB. Contains temperature and dewpoint depression data for significant pressure levels from the earth's surface through 100 millibars. This report may also include significant level wind data.

c. Part C RAOB. Contains height, temperature, dewpoint depression and usually wind data for mandatory pressure levels above 100 millibars. This report may also contain tropopause and maximum wind information.

d. Part D RAOB. Contains temperature and dewpoint depression data for all significant levels above 100 millibars. This report may also include significant level wind data.

e. SLAM. This report contains selected level (850, 700 and 500 millibars) height, temperature, dewpoint depression and wind data.

f. Part A Dropsonde. This report is the same as a Part A RAOB, but without winds. It is reported by weather reconnaisance aircraft.

g. Part B Dropsonde. This report is the same as a Part B RAOB. It is reported by weather reconnaisance aircraft.

h. Part A PIBAL. Contains wind data for mandatory pressure levels from the earth's surface through 100 millibars.

i. Part B PIBAL. Contains wind data for fixed regional levels and significant levels according to World Meteorological Organization (WMO) specifications, from the earth's surface through 100 millibars.

j. Part C PIBAL. Contains wind data for mandatory pressure levels above 100 millibars.

k. Part D PIBAL. Contains wind data for fixed regional levels and significant levels per WMO specifications, above 100 millibars.

l. ROCOB. Contains high altitude (from 20 up to 95 kilometers) density, winds, and derived temperature data.

m. GOES. Satellite-derived wind data for one mandatory level. The mandatory level selected is a function of the height of the observed cloud tops.

1.2 PROBLEMS WITH THE OLD UPPER AIR VALIDATOR.

Over the years, changes were made to the code within the oUAV. Unfortunately, all changes were not documented and some changes affected more data than was planned. In 1979, a joint effort by AFGWC, the US Air Force Environmental Technical Applications Center (USAFETAC) at Scott AFB, IL, and Operating Location A (OL-A), USAFETAC in Asheville, NC identified major problems with the oUAV. The major deficiencies were:

a. Variations in the sequence of processing and merging new mandatory or significant levels with previously stored data permitted erroneous and inconsistent computations of data. As a result, correct data were sometimes replaced by erroneous data.

b. Mandatory and significant level reports were each validated as separate observations. As a result, inordinate weight was given to computed mandatory level heights during the processing of significant level reports. These computed heights replaced reported mandatory level heights if differences exceeded established tolerances. This occasionally resulted in a recomputing of all height values in a RAOB based solely on the single erroneous value of station pressure or station elevation.

c. Data thrown out or changed were not saved for future consideration when more data were received in a later report.

d. Checks concerning temperature lapse rates (superadiabatic and inversion) were not sufficient to correctly identify significant level temperature errors under certain conditions.

e. Two meteorological checks detected temperature errors and height code errors, but thickness computational errors at the station were misinterpreted and miscorrected.

f. A constant mean temperature error tolerance was used in thickness check calculations which created a variable thickness tolerance for the different mandatory levels. These variable thickness tolerances were applied when checking for height code and station thickness errors which caused corrections to be applied to the wrong level.

g. Moisture was not considered in thickness calculations.

h. No provision was made for merging duplicate reports.

i. Corrected reports were not used.

j. Gross error check limits were too broad.

k. Database flags were not sufficient to fully describe the origin of the values contained in the database, i.e., reported, computed, recomputed, extrapolated, etc.

l. The old upper air validator database separated temperature/dew point data (RAOB) and wind data (RAOB and PIBAL) into separate sections. Each of these sections contained a pressure and a height. The heights for each section were often derived by different methods and at times were not compared with each other. As a result, the same pressure level for a report might have had two different heights in the two sections.

m. The old validator (OUAV) was developed without the use of structured design and programming concepts. It was not well documented, was modified by many programmers over a period of years, and the code was extremely interconnected. This created a software package that was difficult to maintain.

1.3 NEW UPPER AIR VALIDATOR (NUAV) DEVELOPMENT.

A Data Project Plan (DPP) was issued by AFGWC in 1982 to begin work on the New Upper Air Validator (NUAV). The objective of this project was to improve the quality of the real-time, operational upper air database and the Air Weather Service (AWS) climatological upper air database by replacing the old Upper Air Validator at AFGWC with a New Validator which would meet AFGWC and USAFETAC requirements. The validation is done in a purely objective (automated) way. The pass/no pass validation criteria were derived in part from subjective principles. There is no way to ensure a 100 percent error-free database. The only quantifiable objective is that no identifiable class problems appear in the upper air database resulting from under-application or over-application of validation techniques. A class problem is a systematic error that occurs under a given set of conditions.

The NUAV was designed and programmed at AFGWC. OL-A, USAFETAC assisted AFGWC in the development of the NUAV in several ways. OL-A reviewed validation techniques used by the old validator at AFGWC, the National Meteorological Center (NMC), the European Centre for Medium-Range Weather Forecasting (ECMWF), the United Kingdom Meteorological Office (UKMO), the German Military Geophysical Office (GMGO), Sweden, Japan (JMS), New Zealand and the USSR. OL-A provided recommendations to AFGWC on their findings.

OL-A also developed algorithms for checking superadiabatic lapse rates at the surface and aloft, allowable vertical wind shear limits based on layer thickness, and suspect/reject limits for temperature, height, wind speed and density at all mandatory levels.

As a final step in the initial development and testing process, OL-A developed a test data set to specifically check certain elements and functions of the Validator. The test set contains several hundred actual upper air observations, with approximately 50 of these observations modified by OL-A. The observations were modified to test specific functions of the new Validator. Functions OL-A was able to test were: gross and suspect limits for RAOBs, PIBALs, and ROCOBs; wind shear and temperature lapse rates; and miscoding of temperature, height, and pressure values. These test data, along with other actual data added by OL-A and AFGWC, will be used to verify new operational changes to the Validator.

On 22 December 1986, at 1113Z, the New Upper Air Validator was implemented operationally at AFGWC. This culminated over 5 years of work, involving over 20,550 programming hours. The NUAV source code contains approximately 98,000 lines; 70 percent of which is documentation for the executable code. This documentation was extremely useful in preparing this Tech Note. The NUAV consists of 177 subroutines, with almost all subroutines containing a diagnostic print feature to assist in identifying any problems that develop.

1.4 SPECIFIC IMPROVEMENTS WITHIN NUAV.

Improvements within NUAV, as compared to the oUAV, are as follows:

a. The NUAV identifies each data element as to whether or not the data element was meteorologically sound. In the case of suspect/reject data elements, the test that the element failed is also identified.

b. When an observation is retrieved from the sorted file, it is merged with any previously validated data for the same station and the same time, prior to revalidation.

c. The decoded data are retained and stored in the database for those data elements which the NUAV changed/rejected.

d. The NUAV recognizes that superadiabatic lapse rates can exist in the atmosphere, and performs detailed checks on these layers before deciding to accept or reject the data.

e. Instead of checking the thicknesses between mandatory levels, NUAV computes the heights of mandatory levels, and compares the computed height to the reported height. This eliminates the problem of assigning a corrected height to the wrong level.

f. Virtual temperature is used in all height computations. Virtual temperature includes the density effects of atmospheric moisture.

g. Duplicate reports are validated.

h. Corrected reports are validated.

i. Gross error checks are more realistic. The gross limits used are a result of the OL A, USAFETAC research of validators used by other countries and the examination of climatic upper air data.

j. Selected mandatory level data elements are checked against the most current forecast fields.

k. Observations taken at different times from a site are stored as separate observations and are not merged into a composite report as long as the observations are at least one hour apart.

l. RAOBs and PIBALs are merged. RAOB data are considered in computing PIBAL heights to prevent the possibility of decreasing height with decreasing pressure.

m. NUAV produces a print of suspicious and rejected data. These data are saved in a statistics file that is summarized as required.

AFGWC UPPER AIR VALIDATOR DATA FLOW

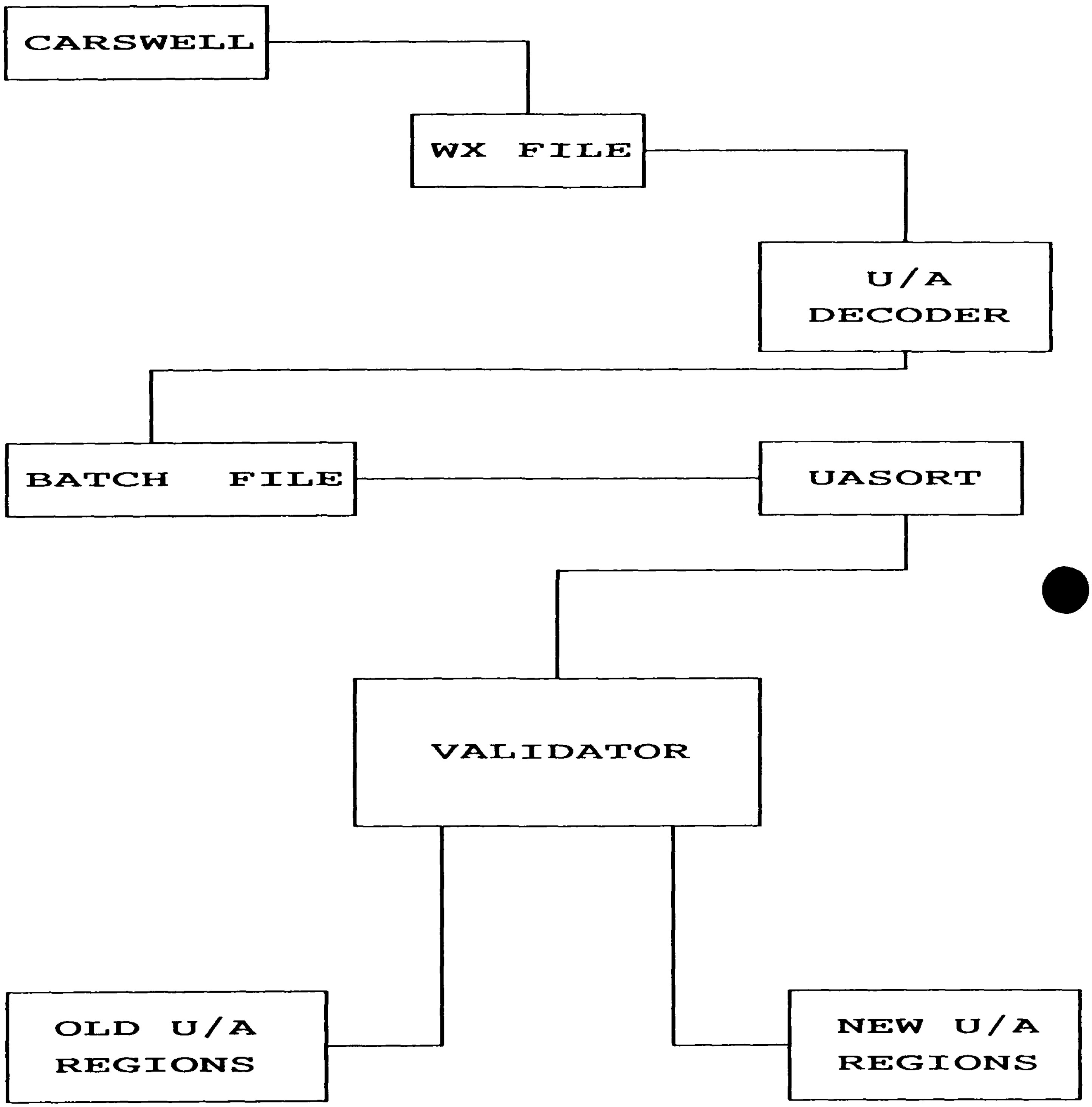

FIGURE 1

SECTION 2

OPERATION

2.1 DATA FLOW.

The Automated Weather Network (AWN) sites at Hickam AFB, Hawaii, and RAF Croughton, England, collect meteorological data disseminated by various countries over Radio Teletype Transmission (RATT) and Continuous Wave (CW) broadcasts. These observations are then transmitted to the Automatic Digital Weather Switch (ADWS) at Detachment 7, AFGWC, Carswell AFB, TX. The National Meteorological Center (NMC) collects data through the World Meteorological Organization's (WMO's) Global Telecommunications System (GTS) and sends it to Carswell. Other data collected directly by Carswell are added to the overseas and NMC collected data and transmitted by high-speed datalink to AFGWC.

Data received from Carswell (see Figure 1) are decoded as they are received ("real-time") and sorted at intervals by time and location prior to validation. Approximately 15,000 conventional upper air reports are received and decoded per day. Data are received continuously with peak receipt two to three hours after the primary observation hours of 00Z and 12Z. Observations are also taken at 06Z and 18Z as well as other times.

The data are validated on a station-by-station basis. New input data are merged with previously validated data, and then the entire composite sounding is revalidated. The updated validated report replaces the previously validated data in the NEW UPPER AIR REGIONS Database. Duplicate data are eliminated with previously validated data receiving priority over new data. Any data element replaced or changed from its received value is retained in the database.

2.2 NUAV MODULES.

The NUAV System is broken into 11 logically separate subsystems (modules) that are all tied together and controlled by the main driver (see Figure 2).

2.2.1 NUAVMN.

NUAV Main Driver program. The Main Driver provides the linkage between modules and controls access to the system. Data that must be passed back and forth between the main driver and the modules are passed through common blocks and/or arguments. After initialization of the common areas, NUAV starts reading the file "UPAIRSORT", which contains sorted observations received from Carswell. After reading in the observation, NUAV examines the NEW UPPER AIR REGIONS Database and looks for any other data for this station for the same time, and merges that data into a composite observation. Next, NUAV performs gross error checks and sets validation flags. Then the observation is compared to the first-guess analysis fields. The next step performs the detailed meteorological checks on the observation and

AFGWC UPPER AIR VALIDATOR

UAV

INIT - Initialize common blocks

UASRD - Read in new reports

FSTPRT - Selectable print feature

GECK - checks for gross errors of pressure, height, temperature, wind speed and direction

FGFCK - check for mislocated stations

METCK - Meteorological checks

INCNCK - Internal Consistency checks

FILLIN - Fill in the control words

LSTPRT - Selectable print feature

UAWRT - Write out complete report to NEW & OLD databases

Figure 2

sets any necessary validation flags. Next, NUAV does an internal consistency check. Finally, NUAV merges report description data (control words) to the report before writing the data to the NEW UPPER AIR REGIONS Database and the OLD UPPER AIR REGIONS Database.

At AFGWC, the database the validator writes to is divided into regions. These regions are numbered storage locations within the database which correspond to 76 geographically defined regions on the earth's surface. Upper air sounding information is stored in these 76 regions, and in four additional non-geographic regions: Region 77 contains late reports, Region 78 contains no identification (NOID) reports, Region 79 contains rejected reports, and Region 80 contains any extra reports that will not fit in Regions 1 through 79. The regions database concept is also used for surface and aircraft data storage at AFGWC.

NUAVMN also checks to see that each routine it calls completes successfully. If a routine errors, NUAV prints the diagnostics and determines whether to continue processing any further reports.

2.2.2 INIT

Initialize Common Blocks. This module initializes the common blocks. It reads in the appropriate values from the permanent file NUAV*CONSTANTS. This file contains setup information for running the validator such as: the RCON data listed below, the size of the individual Regions within the database, any special interest stations or observation types that are selected, etc. Certain gross error checks are performed on the common blocks to verify that the file contains valid values for processing the upper air data. INIT also sets up several other common blocks prior to returning to NUAVMN. INIT is only called once each time NUAV is started. See Table 1 for the contents of the RCON common block.

TABLE 1

LAPSE RATE AND WIND SHEAR LIMITS

RCON	ELEMENT:	VALUE:
1	MIN Pos. Lapse Rate - SFC SUSPECT	.015 Km-1
2	MAX Pos. Lapse Rate - SFC SUSPECT	.025 Km-1
3	Pressure Interval - SFC SUSPECT	340 meters
4	MIN Pos. Lapse Rate - SFC REJECT	-.020 Km-1
5	MAX Pos. Lapse Rate - SFC REJECT	-.060 Km-1
6	Pressure Interval - SFC REJECT	340 meters
LIMITS for inversions:		
7	MIN Neg. Lapse Rate - SFC SUSPECT	-.060 Km-1
8	MAX Neg. Lapse Rate - SFC SUSPECT	-.100 Km-1
9	Pressure Interval - SFC SUSPECT	340 meters
10	MIN Neg. Lapse Rate - SFC REJECT	-.090 Km-1
11	MAX Neg. Lapse Rate - SFC REJECT	-.050 Km-1
12	Pressure Interval - SFC REJECT	340 meters
13	MIN Pos. Lapse Rate - ALOFT SUSPECT	.013 Km-1
14	MAX Pos. Lapse Rate - ALOFT SUSPECT	.015 Km-1
15	Pressure Interval - ALOFT SUSPECT	300 meters
16	MIN Pos. Lapse Rate - ALOFT REJECT	.015 Km-1
17	MAX Pos. Lapse Rate - ALOFT REJECT	.030 Km-1
18	Pressure Interval - ALOFT REJECT	300 meters
LIMITS for inversions:		
19	MIN Neg. Lapse Rate - ALOFT SUSPECT	-.020 Km-1
20	MAX Neg. Lapse Rate - ALOFT SUSPECT	-.040 Km-1
21	Pressure Interval - ALOFT SUSPECT	300 meters
22	MIN Neg. Lapse Rate - ALOFT REJECT	-.030 Km-1
23	MAX Neg. Lapse Rate - ALOFT REJECT	-.060 Km-1
24	Pressure Interval - ALOFT REJECT	300 meters
35	MAX Height for Wind Shear Checks	60000 meters
36	MIN Suspect Wind Shear Limit	20.0 ms-1

2.2.3 UASRD

Upper Air Sorted File Read. UASRD reads new observations from the sorted file UPAIRSORT. UASRD determines if the new observation is a SLAM, RAOB, PIBAL, DROP, GOES or ROCOB report and reads it in appropriately. All reports for the same station and time are read into the work arrays. As data are read into the work arrays, UASRD checks heights for validity (are heights less than -1100 meters?). UASRD also converts geometric heights to geopotential heights. Next, UASRD checks to see if there are any previously validated data for this station and time in the NEW UPPER AIR REGIONS Database. If there are, UASRD reads that data into the work arrays. UASRD will recompute any missing validated pressures based on known pressure - height relationships, or one of the two standard atmospheres is selected depending on the latitude of the reporting station. If the latitude is south of 50 degrees South, the Antarctic standard atmosphere is used. Otherwise, the US standard atmosphere is selected. The standard atmospheres are used by UASRD to make sure every level of the sounding has a pressure. UASRD will also check to assure the previously validated data are merged with the new data in the correct pressure sequence. Then UASRD checks all new levels for new or different meteorological information. If there are no new or different data, that level is eliminated. Priority is given to keeping previously validated information. UASRD calculates a virtual temperature for each level in the sounding. Errors detected during any of the above processing will cause the module diagnostics to print out.

2.2.4 FSTPRT

First Print Controller. This module determines whether or not to print diagnostics for the sounding being processed based on the value of print control words in the NUAV Constants file. The print control words are set by the programmer. FSTPRT can be set to print diagnostic information for a specific type of upper air report, special WMO numbers, or selected AFGWC region, etc. for quality control purposes.

2.2.5 GECK

Gross Error Checks. GECK checks for gross errors of validated heights, temperatures, wind speeds, wind direction, and densities for all pressure levels. Gross errors are defined as a value outside the high/low limits established by OL-A, USAFETAC. Any of these elements will be identified as suspect or reject. The actual reject/suspect limits used by the validator are listed in Table's 2 and 3. If an element is rejected, that element will be set to its missing value and its validation code will be set. The original value of the element will be retained for future use. To attempt to recover incorrectly coded temperatures (+/-sign errors), GECK reverses the sign of the temperature if the temperature is within +/-10 degrees of 0 degrees Celsius. This recovered temperature is checked against the temperature suspect/reject limits one more time. If the wind speed is identified as rejected, then the wind direction for that level will also be identified as rejected. This will only happen for an extremely high wind speed. Wind direction is checked to assure it is a valid value between 000 and 360. If not, both direction and speed are rejected. If direction is missing and speed is good, reject the speed. If speed is missing and direction is good, reject the direction. If speed is calm and direction is not 000, both are rejected. GECK will check for corrected reports. Corrected reports will take precedence over non-corrected reports. If a corrected report is found, and different data for a specified level are found which is not marked as coming from a corrected report, then the non-corrected data will be marked as failed.

TABLE 2

HEIGHT AND TEMPERATURE REJECT/SUSPECT LIMITS

Pressure	Height (meters)				Temperature (Kelvin)			
Level(Mb)	LR	LS	HS	HR	LR	LS	HS	HR
1000.000	-1100	-410	410	700	183.16	223.16	319.16	333.16
850.000	200	800	1700	2050	183.16	231.16	305.16	315.16
700.000	1900	2400	3350	3600	183.16	235.16	291.16	305.16
500.000	4300	4710	5890	6300	192.16	223.16	271.16	290.16
400.000	6100	6510	7690	8100	200.16	220.16	261.16	278.16
300.000	7500	8080	9720	10300	198.16	211.16	251.16	268.16
250.000	8500	9140	10960	11600	194.16	208.16	246.16	264.16
200.000	9800	10520	12580	13300	190.16	205.16	243.16	260.16
150.000	11400	12200	14500	15300	184.16	203.16	239.16	253.16
100.000	13500	14430	17070	18000	177.16	198.16	236.16	245.16
70.000	15400	16450	19450	20500	175.16	193.16	236.16	244.16
50.000	17300	18450	21750	22900	173.16	191.16	236.16	244.16
30.000	20500	21770	25430	26700	175.16	193.16	238.16	247.16
20.000	23000	24440	28560	30000	177.16	196.16	242.16	258.16
10.000	27200	28600	32600	34000	186.16	202.16	251.16	272.16
7.000	29800	31160	35040	36400	193.16	207.16	258.16	281.16
5.000	32200	33560	37440	38800	197.16	210.16	263.16	290.16
3.000	35300	36760	40940	42400	198.16	212.16	271.16	305.16
2.000	38400	40110	44990	46700	197.16	219.16	281.16	307.16
1.000	41700	43670	49330	51300	195.16	226.16	290.16	305.16
0.700	44900	47040	53160	55300	196.16	225.16	291.16	303.16
0.500	47700	49920	56280	58500	199.16	223.16	287.16	300.16
0.400	49700	51900	58200	60400	201.16	221.16	282.16	300.16
0.300	51200	53480	60020	62300	200.16	218.16	275.16	304.16
0.200	54100	56360	62840	65100	200.16	212.16	268.16	308.16
0.100	57600	60190	67610	70200	179.16	202.16	278.16	315.16
0.070	60400	62990	70410	73000	167.16	198.16	278.16	308.16
0.050	63300	65910	73390	76000	157.16	194.16	277.16	304.16
0.030	66500	69110	76590	79200	144.16	186.16	266.16	297.16
0.020	69000	71610	79090	81700	135.16	176.16	259.16	292.16
0.010	72900	75490	82910	85500	123.16	153.16	255.16	285.16
0.007	76000	78470	85530	88000	118.16	143.16	252.16	280.16

**NOTE: LR = Low Reject Limit   LS = Low Suspect Limit
HS = High Suspect Limit   HR = High Reject Limit

TABLE 3

WIND SPEED AND DENSITY REJECT/SUSPECT LIMITS

Pressure Level(Mb)	Wind Speed (m/s) Suspect	Reject	Density (grams/meter^3) LR	LS	HS	HR
1000.000	35.0	70.0	1045.56	1091.41	1560.84	1901.64
850.000	35.0	70.0	939.48	970.29	1280.81	1616.39
700.000	45.0	80.0	799.04	837.45	1036.85	1331.15
500.000	70.0	110.0	600.24	642.29	780.42	906.30
400.000	85.0	140.0	500.91	533.51	632.84	696.06
300.000	100.0	160.0	389.69	416.06	494.86	527.32
250.000	105.0	170.0	329.66	353.76	426.52	448.48
200.000	110.0	160.0	267.78	286.50	348.03	366.33
150.000	100.0	150.0	206.39	218.47	262.33	283.70
100.000	85.0	130.0	142.08	147.49	175.77	196.60
70.000	70.0	120.0	99.86	103.25	126.22	139.19
50.000	75.0	130.0	71.33	73.75	91.10	100.57
30.000	80.0	130.0	42.28	43.88	54.1	59.65
20.000	90.0	130.0	26.99	28.77	35.51	39.32
10.000	105.0	140.0	12.8	13.87	17.23	18.71
7.000	115.0	150.0	8.67	9.44	11.77	12.62
5.000	125.0	170.0	6.00	6.62	8.29	8.83
3.000	155.0	210.0	3.42	3.85	4.93	5.27
2.000	170.0	220.0	2.27	2.48	3.18	3.53
1.000	180.0	220.0	1.14	1.20	1.54	1.78
0.700	185.0	220.0	0.80	0.84	1.08	1.25
0.500	185.0	220.0	0.58	0.61	0.78	0.87
0.400	180.0	220.0	0.46	0.49	0.63	0.69
0.300	170.0	210.0	0.34	0.38	0.48	0.52
0.200	155.0	190.0	0.23	0.26	0.33	0.35
0.100	150.0	170.0	0.11	0.13	0.17	0.19
0.070	150.0	170.0	0.079	0.088	0.123	0.146
0.050	145.0	170.0	0.057	0.063	0.090	0.111
0.030	130.0	160.0	0.035	0.039	0.056	0.072
0.020	125.0	150.0	0.024	0.027	0.040	0.052
0.010	115.0	150.0	0.012	0.014	0.023	0.028
0.007	115.0	150.0	0.009	0.010	0.017	0.021

**NOTE:
LR = Low Reject Limit
LS = Low Suspect Limit
HS = High Suspect Limit
HR = High Reject Limit

Density values were computed using the following equation from the Smithsonian Meteorological Tables, Table 71:

$$D = (348.38 \times P)/T \qquad (1)$$

where P = Pressure, in millibars, and
T = Temperature (reject and suspect values for each level), in degrees Kelvin.

2.2.6 FGFCK

First Guess Field Check. FGFCK's main purpose is to check for mislocated stations and attempt to find where they belong. FGFCK will also count the number of superadiabatic layers, number of tropopause reports, number of maximum wind reports, and number of surface reports. FGFCK attempts to recover any surface pressure that may have been mistyped by first switching the hundreds and tens digit, and then trying a switch of the tens and units digits to obtain a "better" pressure. FGFCK will also attempt to obtain a "better" pressure by adding or subtracting 100 millibars. This "better" pressure is an estimated pressure - the recovery attempt with the smallest difference between the estimated pressure and the recovered pressure is selected as the "best". This routine also checks for offset of coded digits (i.e. 1002.2 mb entered as 1022.) and, lastly, checks for encoding errors (i.e. 1020.2 mb coded as 202).

FGFCK compares multiple reports at the mandatory levels against the appropriate field in either the High Resolution Analysis System (HIRAS) or Global Spectral Model (GSM) databases. FGFCK must convert station latitude and longitude to the I-J coordinates of the HIRAS/GSM Database. Then FGFCK will execute a 4-point interpolation for the I-J coordinates using meridional interpolation. FGFCK next gets the U/V wind components from the HIRAS/GSM database and calculates total wind speed using the Pythagorean theorem. FGFCK computes wind direction by taking the arcsine of the U-wind component divided by total wind speed, then multiplying that value by 180 divided by pi to convert to degrees.

2.2.7 METCK

Meteorological Checks. METCK contains the lapse rate checks, thickness checks and wind shear checks. Also, METCK generates mandatory level data from significant level data when the mandatory level information is not reported.

First, a check is made to assure the data passed to METCK are valid. If the data are valid, then a virtual temperature is computed for each level with non-missing data for pressure and temperature. Virtual temperature is computed as follows:

$$TVIRT = TK * (1 + (0.61 * MIXRAT)) \text{ (virtual temperature)} \qquad (2)$$

$$\text{and } MIXRAT = ((0.622 * EVAPOR)/(P - EVAPOR)) \text{ (mixing ratio)} \qquad (3)$$

and EVAPOR = 6.11 * 10**((A*TD)/(TD+B)) (vapor pressure, over water) (4)

where TK = Temperature in degrees Kelvin,
P = Pressure in millibars,
TD = Dew point Temperature in degrees Celsius,
for TC = Temperature, in degrees Celsius, use
A = 7.5 and B = 237.3 if TC > 0 or
A = 9.5 and B = 265.5 if TC < 0.

Note: the function EVAPOR is only meant to apply to meteorologically significant temperatures (i.e. temperatures between -50 and +50 degrees Celsius).

If dewpoint depression is missing for a level, then temperature is used in its place to calculate virtual temperature. If the data are invalid, then a diagnostic message is printed and METCK goes to the next sounding.

Next, METCK will check for a RAOB/ROCOB overlap. If there is an overlap, the ROCOB data within the overlap region will be tested against the RAOB data within that region. RAOB data have priority in the overlap region. ROCOB data may remain as they are, or they may receive an interpolated value, or they may be set to missing and their validation codes set to failed. ROCOB data will be tested against the RAOB data as follows:

	A	B	C
a. NO RAOB LVLs ABV or BLO ROCOB	X		
b. RAOB LVL ABV & NONE BLO ROCOB			X
c. RAOB LVL BLO & NONE ABV ROCOB	X		X
d. RAOB LVL ABV & BLO ROCOB	X	X	X

A = Leave ROCOB data alone.
B = Interpolate new values.
C = Set ROCOB values to missing.

If the validation codes are set to failed because of this check, they will be reset prior to the ROCOB being written to the database.

The lapse rate is computed by taking the difference between the temperatures at two pressure levels (P1 and P2). That difference is computed using equation 5. The constant was derived from the definition of lapse rate and from the hydrostatic equation. The output lapse rate is in degrees Kelvin per meter.

Computed Lapse Rate = (T1-T2)/((T1+T2) * 14.64285 * ALOG(P1/P2)) (5)

The Gamma limit, or threshold lapse rate limit for a layer is based on several assumptions. This method assumes stronger lapse rates can exist at the surface than aloft. Also, stronger lapse rates may be sustained through shallower layers than through deep layers. The Gamma limit for reject and suspect threshold limits is computed based upon the thickness of the layer. There are four Gamma limits; reject and suspect for surface-based layers, and reject and suspect for layers aloft. See Table 1, RCON values 1 - 12 for surface-based layer limits, and RCON values 13 - 24 for layers aloft limits.

Temperatures are validated next using lapse rates. If the lapse rate calculated for a layer is greater than the maximum suspect threshold value or less than the minimum suspect threshold value, the base or top of the layer will be marked as suspect as appropriate. If the calculated lapse rate is greater than the maximum fail threshold value, an attempt is made to recover the temperature for the top of the layer. Temperatures are recovered by changing to Celsius and comparing this value to the temperature recovery limit. If the value is within 10 degrees of the zero degree isotherm, the sign of the Celsius temperature is reversed, the temperature is changed back to Kelvin and the lapse rate checks are run again. If the temperature cannot be recovered, it is set to missing. Otherwise, the routine attempts to recover the temperature for the base of the layer. The recovery process is the same as described above. If it cannot be recovered, the temperature is set to missing. If the calculated lapse rate is greater than the maximum suspect threshold value, the top level is marked as suspect. If the calculated lapse rate is less than the minimum suspect threshold value, the top level is marked as suspect.

For example, given a layer aloft with a thickness of 200 meters, METCK selects a reference layer thickness of 300 meters, a maximum positive suspect lapse rate (MAXS) of 0.015 degrees K/meter, a minimum positive suspect lapse rate (MINS) of 0.013, a maximum positive fail lapse rate (MAXF) of 0.030 degrees K/meter, and a minimum positive fail lapse rate (MINF) of 0.015. METCK computes the values C1 and C2 prior to computing the maximum suspect (GMAXS) and maximum fail (GMAXF) lapse rates for this 200 meter thick layer as follows:

$$C1 = (MAXS - MINS)/300 = (0.015 - 0.013)/300 = 0.002/300$$

$$C2 = (MAXF - MINF)/300 = (0.030 - 0.015)/300 = 0.015/300$$

$$GMAXS = MAXS - (C1 * 200) = 0.01367 = 13.67 \text{ degrees/kilometer}$$

$$GMAXF = MAXF - (C2 * 200) = 0.029 = 29 \text{ degrees/kilometer}$$

GMAXF and GMAXS are compared to the actual lapse rate (ALR) from equation 5. If ALR is greater than GMAXF, then temperature at the bottom of the layer fails the lapse rate check. If ALR is greater than GMAXS, then the temperature at the bottom of the layer is suspect.

With multiple reports of temperature at a pressure level, METCK will eliminate all temperatures but the "best" one for a pressure level. Step 1 examines the validation codes of the temperatures. Temperatures with the most bits set in the validation code are failed. If there are still multiple reports, step 2 uses lapse rate checks above and below this level to eliminate the worst temperatures. A quality factor is assigned to the lapse rates computed above and below this level. The quality factor ranges from 0 to 4 (0 is best, and 4 is worst) and is based on comparing the computed lapse rate to the suspect and reject lapse rate limits. Values with the worst quality are rejected. If there are still multiple reports, all are rejected except the first one received.

The reported layer thickness values are validated next. This is done by finding the surface pressure level of the sounding. METCHK finds the "best" height value for that surface pressure. This "best" height is called the base level height. A height error value is calculated by subtracting the station elevation from the validated surface height value. Next, calculate the absolute error value for all other validated heights at this pressure level. Whichever error value is lowest is declared the "best" value for this level. If there is only one height value for the surface level, this value is the "best" height value. Now NUAV counts the number of levels in the sounding. The number of levels minus 1 gives the number of layers within the sounding. METCK calculates the absolute thickness error value by subtracting the validated height value for the top of the layer from the validated height value for the bottom of the layer, and then subtracting that number from the calculated thickness value for the layer. The thickness of the layer is calculated from the hypsometric equation:

THICKNESS = ABS(29.2857 * TVBAR * ALOG(PRESS1/PRESS2)) (6)

where ABS = the absolute value
TVBAR = mean virtual temperature of level PRESS1,
ALOG = the natural logarithm,
PRESS1 = Pressure in millibars at level 1,
PRESS2 = Pressure in millibars at level 2.

The difference between the calculated thickness and computed thickness is called the absolute thickness error value. The heights that give the lowest absolute thickness error value are selected as the "best" he[illegible] these pressure levels.

A height is calculated for each pressure level with a missing height using either reported data or standard atmospheric values. Heights are interpolated using the subroutine ESTP2V, which performs a logarithmic interpolation between the reported levels. If the pressures are too far apart to perform a meaningful interpolation, then the heights are calculated from standard atmosphere values and are reset to missing after the wind shear checks are performed. A height is needed for each level to perform the wind shear checks that follow. All the heights calculated in this section from standard atmosphere values are reset to missing after the wind shear checks are performed.

A vertical consistency check for winds is performed, including vector wind shear and wind shear rate. First, the wind shear checking subroutine looks through the work arrays identifying levels with non-missing winds. The subroutine tries to eliminate all but one wind at each pressure level by checking validation codes. The level with the lowest validation code is kept. If there is still more than one wind at a pressure level, check the shear above and shear below. The wind with the lowest wind shear rate is kept. The wind shear rate is computed from the thickness and the vector wind shear as follows:

Thickness(THK) = ABS(Height,level 1 - Height,level 2), (7)

where ABS = absolute value, and height is in meters, and

vector wind shear (VWS) = SQRT(Speed1*Speed1 + Speed2*Speed2
-2*Speed1*Speed2*cosine(Theta)), (8)

where SQRT = square root, and

Theta = ABS(DIR2-DIR1) * ArcCosine(-1)/180 (9)

where DIR = wind direction in degrees, then

windshear rate(WSR) = (VWS * 1000)/THK (10)

See Table 4 for the wind shear rate limits used. If the layers are less than 250 meters apart, or greater than 4000 meters apart, shear above and below is not checked. If all pressures are missing, no checking is done. If a wind fails the wind shear rate test, the wind direction validation code is set to rejected. If a wind fails the max wind shear test, the wind speed validation code is set. In either case, the validated wind speed and direction are set to missing.

TABLE 4

WIND SHEAR RATE CHECK LIMITS

HEIGHT (Geopotential meters)	SUSPECT LIMIT	REJECT LIMIT
2000	200	450
4000	210	480
6000	240	520
8000	260	570
10000	240	630
12000	270	670
14000	300	660
16000	300	660
18000	270	710
20000	240	690
22000	220	590
24000	210	510
26000	250	480
28000	250	450
30000	250	450
>30000-40000	200	550
40000	200	550
>40000-50000	210	530
50000	210	530
>50000-60000	240	490
60000	240	490
>60000	850	1250

NOTE: 1. SUSPECT and REJECT limits are in tenths of meters per second (i.e. 24 meters/second is listed in the table as 240).

2. The HEIGHT value to use is the highest level of the layer being checked. For example, if the layer being checked is from 9,000 to 13,000 meters in altitude, then use the SUSPECT and REJECT limits for 12,000 meters.

2.2.8 INCNCK

Internal Consistency Checks. INCNCK manages the internal consistency of the sounding within the work arrays. The internal consistency checks are the last checks made on the data prior to storing the sounding in the database. If this sounding is a ship report, the reported Marsden square is checked against the reported latitude and longitude values. If they do not match, the sounding is set to "No ID", since it cannot be determined geographically where this sounding belongs. Next, INCNCK checks "101" groups for suspect layers. "101" groups are used to indicate that there may have been a problem with this sounding at the time it was taken. INCNCK is looking for the "101" codes that indicate the data are doubtful between two levels. INCNCK will set the validation codes to mark the heights and/or temperatures as suspect between the levels indicated by the "101" codes. Next, the sequence number of each level is checked. Since the sounding is already sorted according to pressure, a pressure that was either moved to a new level, or had levels moved past it will have the sequence number incremented for every level moved. A level having a high sequence number is considered suspect. All meteorological data for that level are marked as suspect. INCNCK next checks that pressures decrease with height, and heights increase as pressures decrease. If INCNCK finds two or more heights for the same pressure, INCNCK attempts to determine which height is correct. The more correct height is the one with the least number of validation flags set. If no distinction could be made after that check then the height with the smallest absolute D-value is the correct height. If INCNCK cannot determine which is correct, then both heights are rejected. This module generates data for missing mandatory levels in the sounding. Mandatory levels are generated in the sounding if: a. the last data level in the sounding is below 100 millibars; or b. one mandatory level has not been generated above the last data level; or c. the last mandatory level is less than 25 millibars above the last data level. After the mandatory pressure level is generated, INCNCK will estimate height and temperature values for this level. Mandatory levels are only generated for RAOB Part A, B, C, or D, DROP Part A and B, and ROCOB reports.

2.2.9 FILLIN

FILLIN fills in the 91 control words of a report in the appropriate arrays prior to writing the sounding to the database. The contents of the control words depend on whether this is a RAOB, PIBAL, ROCOB, SLAM, DROP or GOES report. GOES reports are not filled. The other types of reports will require the calculation of some of the following data: freezing level(s); Showalter and "SWEAT" stability indices; precipitable water and saturation moisture ratio; mean wind direction and speeds (surface to 5000 feet, and 5000 to 10,000 feet); wind equipment type; thermal wind direction and speed; RAOB instrument type; temperature/wind units indicator; cloud code indicators; thermodynamic sensing equipment; thermodynamic correction/reduction techniques; rocket motor type. The last element FILLIN computes is the overall sounding quality. Quality is determined by counting the number of suspect and fail flags set for the sounding, plus assigning suspect and fail "weights" to each flag. The quality value range is between 0 and 100. The final quality value is tested by AFGWC to see whether or not the AFGWC models will use this sounding. If the quality is less than "40", this sounding will not be used in any of the models at AFGWC. If the quality is less than "80", this sounding is considered suspect by AFGWC, but will be used by any model at AFGWC requiring upper air data.

2.2.10 LSTPRT

Last Print Controller. LSTPRT determines if special conditions exist where a dump of the work arrays is necessary. Activation is selected by the programmer. LSTPRT can be set to print diagnostic information for: recovered level reports, specific validation codes, soundings that contain any kind of processing errors, etc. See FSTPRT for further details.

2.2.11 UAWRT

Upper Air Write. UAWRT packs the soundings in the work arrays to eliminate excess levels. Excess levels are generally duplicate levels that contain data that have been marked as failed by the validation process. This also eliminates duplicate information by combining level information to make the first occurrence of a pressure level the most complete. Then UAWRT searches through the work arrays for a surface level indicator (only one allowed), any tropopause level indicators (up to four allowed), or any maximum wind indicators (up to four allowed). Next, UAWRT collects all the GCES reports, sorts them, and stores them in the NEW UPPER AIR REGIONS Database.

For all other types of reports, UAWRT will first collect all the data that make up that kind of report (i.e. the 91 control words, the validated data, additional data, non-decoded data, and reject data) and build a complete report. Next UAWRT will check the NEW UPPER AIR REGIONS Database to see if there is room to store this report in the correct region within the database. If there is room, UAWRT writes the sounding information to the NEW UPPER AIR REGIONS Database. If there isn't room in the correct region, the report can be written to region 80, the overflow region. Writing to region 80 will cause diagnostic information to be printed.

Another routine within UAWRT will write the observations from the work arrays to the OLD UPPER AIR REGIONS Database. Again, GCES reports are collected, sorted, and written first. Then RAOB, PIBAL, and ROCOB reports are written out

2.2.12 PRINT

Print Support Routine. PRINT will print diagnostic information from the work arrays and the common areas for the programmer/analyst to use to detect problem areas in processing or in the resulting data files. This routine activates automatically if any processing error occurs within one of the above modules. FSTPRT and LSTPRT must be selected before they will print.

2.3 OPERATIONAL CHANGES.

Changes to the UAV code will be run against the AFGWC Test Data Set prior to operational implementation. Comparison against previous runs of the Test Data Set will help assure only the planned changes have been implemented. The comparison should help determine if any unplanned changes (i.e. typographical errors, compiling problems, etc.) occurred. After the modified version is implemented, a copy of the new source code will be sent to OL-A, USAFETAC for use on their computer system.

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