

Range Reference Atmosphere 2019

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1.0 INTRODUCTION

1.1 Definition of a Range Reference Atmosphere

A reference atmosphere is a statistical description of the Earth's atmosphere derived from upper-air measurements over some geographical area. Typically, reference atmospheres provide mean values and some measures of variability for a number of atmospheric state variables, such as pressure, density, temperature, wind speed, etc. The first reference atmosphere, developed in the 1920's [1], was referred to as a "standard atmosphere." Standard atmospheres are intended to be applicable over large spatial domains (mid-latitudes, for example). For higher-fidelity characterization of the atmosphere at a particular location, site-specific reference atmospheres were later developed. This type of reference atmosphere is referred to as a Range Reference Atmosphere (RRA). RRAs are, formally, a product of the Range Commander's Council (RCC) Meteorology Group (RCC-MG). The Marshall Space Flight Center (MSFC) Natural Environments (NE) Branch has developed a new series of RRAs on behalf of the RCC-MG. This document details the development methodology and the results obtained for the 2019 RRAs.

1.2 Purpose

A series of revised and expanded RRAs are to be published for locations of interest to the RCC. These datasets will serve as authoritative reference sources on certain upper air statistics and as atmospheric models for their respective range sites (locations). The technical usefulness of these documents for the ranges, range users, U.S. aerospace industries, and the scientific community is recognized because of the standardization of the development techniques and the presentation of the tabulations.

1.3 History

Many RRAs have been produced over the years. The Inter-Range Instrumentation Group Meteorology Working Group (IRIG-MWG), the organizational predecessor to the RCC-MG, published several RRAs from 1963 through 1974. Beginning in 1983, the RCC-MG published a new updated series of RRAs (RRA version 1983) to take advantage of improved measurement systems and data processing capabilities [2]. A standardized process was implemented to generate this series of RRAs, in contrast to previous versions, which were generated using non-standardized, site-specific methodologies. Beginning in 2002, a second series of RRA updates was generated by the Air Force Combat Climatology Center (now known as the 14th Weather Squadron) [3]. These datasets were published by the RCC-MG in 2006 (RRA version 2006). Beginning in 2013, MSFC NE produced a third series of RRA updates (RRA version 2013). The RCC-MG intends to produce new RRA versions quasi-periodically to maintain the best possible current representations of the upper atmospheres (surface to 30 km altitude) at selected ranges of interest. In 2018, MSFC-NE agreed to develop a fourth series of RRA updates, resulting in the current document and associated data tables. These new datasets will be referred to as RRA version 2019.

1.4 Scope, Contents, and Arrangement of Data Tables

The RRA contains tabulations for monthly and annual statistics. Means (μ), medians, standard deviations (σ), and skewness coefficients are given for wind speed (WS), atmospheric pressure (P), air temperature (T), density (D), water vapor pressure (VP), virtual temperature (Tv), and dewpoint temperature (Td). Means, medians, and standard deviations are given for the zonal (U) and meridional (V) wind components. The linear (product moment) correlation coefficient (R_{UV}) between the U and V wind components is also given. Counts of the number of observations used in the computations are given for each month and altitude level.

The statistical quantities are computed at the surface elevation (relative to Mean Sea level), and at 0.5 km intervals up to 30 km altitude. Table 1 summarizes the various statistical quantities computed for each meteorological parameter.

Table 1 Range Reference Atmosphere Physical Parameters and Statistical Quantities

Meteorological Parameter	Units	Statistical Quantities
Geometric altitude (Z)	km	Vertical coordinate (independent variable)
Zonal wind component (U)	m/s	Mean, median, standard deviation
Meridional wind component (V)	m/s	Mean, median, standard deviation
Wind component correlation (R_{UV})	dimensionless	Linear product-moment correlation coefficient
Wind speed (WS)	m/s	Mean, median, standard deviation, skewness
Number of wind observations	dimensionless	Arithmetic sum
Atmospheric pressure (P)	mb	Mean, median, standard deviation, skewness
Atmospheric temperature (T)	C	Mean, median, standard deviation, skewness
Atmospheric density (D)	g/m^3	Mean, median, standard deviation, skewness
Number of thermodynamic observations	dimensionless	Arithmetic sum
Water vapor pressure (VP)	mb	Mean, median, standard deviation, skewness
Virtual temperature (Tv)	C	Mean, median, standard deviation, skewness
Dewpoint temperature (Td)	C	Mean, median, standard deviation, skewness
Number of humidity observations	dimensionless	Arithmetic sum

In addition to the primary RRA spreadsheet files, auxiliary text files are produced containing the same data, but formatted for use in the Earth Global Reference Atmospheric Model (Earth-GRAM), which is an MSFC-NE analysis tool. A separate text document is produced that lists the inventory of individual profiles that were used in the final dataset production.

1.5 Site locations selected for dataset development

The RCC-MG has selected 11 sites for development of the 2019 series of RRAs. These sites are listed in Table 2.

2.0 METHODOLOGY OVERVIEW

In order to facilitate diagnostic analysis and minimize duplicating run-time overhead, the RRA production follows a series of discrete computational steps. Each step performs a specific function

and the outputs from one step are used as inputs for the next subsequent step. Details for each step are given in the following sections.

Table 2 Sites Selected for RRA 2019 Production

Sites for RRA 2019	Abbreviation
Edwards Air Force Base, CA	EAFB
Vandenberg Air Force Base, CA	VAFB
Yuma Proving Grounds, AZ	YPG
Dugway Proving Grounds, UT	DPG
Naval Air Station Point Mugu, CA	MUGU
Naval Air Weapons Station China Lake, CA	CHLK
Pacific Missile Research Facility, HI	PMRF
Reagan Test Site, Kwajalein, Marshall Islands	KWAJ
Wallops Flight Facility, VA	WFF
White Sands Missile Range, NM	WSMR
Cape Canaveral Air Force Station, FL	CCAFS

3.0 STEP 1: DEFINE/OBTAIN/INITIALIZE INPUT DATA

Input data consist of upper-air profiles taken by weather office personnel at the various range sites. Data from weather balloon flights made from around 1990 to present are combined to generate individual input datasets for each range site. Table 3 gives the resulting periods of record (POR), the numbers of unprocessed (input) profiles obtained for each site, and the numbers of resulting, quality-controlled (output) profiles used for final RRA statistical computations. During step 1, the data received are reformatted to a standardized format to facilitate downstream computations. Each profile is saved as a separate text file. The first line of each contains meta data; the year, month, day, and time of the profile as well as the number of data lines in the profile, and a string noting the source (filename) of the given profile. Following the meta data line are sequential altitude/level data lines containing values for Z, WS, WD, T, Td, and P for each level in the profile. While initial quality control (QC) procedures are performed on the raw data during the standardization process (which are not described here), additional RRA-specific QC procedures are performed, as described in the following sections.

For the input data, the preferred period of record was from 1990 to current. However, due to low sample sizes, the Point Mugu period of record was extended to start in January 1971. It was preferred to use data provided by the site weather offices. All sites provided such data except for PMRF, which does not typically launch balloons. Thus, soundings from the Lihue airport were used for PMRF, as downloaded from the National Climatic Data Center (NCDC). Finally, due to formatting vagaries of the KWAJ data provided, NCDC data was used to supplement the data provided by the site weather office.

Table 3 Numbers of Input and Output Profiles Used for RRA Production

Site	Period of Record	# Input Profiles	# Output Profiles
EAFB	1/1/1990 to 10/30/2018	10354	10293
VAFB	12/2/1992 to 2/25/2019	12559	12464
YPG	5/13/1992 to 12/20/2018	26898	24485
DPG	1/1/1990 to 3/10/2019	13624	13513
MUGU	1/23/1971 to 2/20/2019	9227	9061
CHLK	2/1/1990 to 10/31/2018	8507	8317
PMRF	1/1/1990 to 6/30/2019	24400	20459
KWAJ	1/1/1990 to 8/18/2019	16782	16118
WFF	1/1/1990 to 12/31/2018	19527	18839
WSMR	1/2/1992 to 12/18/2018	11125	10990
CCAFS	11/26/1988 to 11/18/2018	22448	22263

4.0 STEP 2: PERFORM QUALITY CONTROL

A series of QC checks are performed to identify and remove bad data. Any profiles identified with bad data are removed before any further computations are performed. The individual QC procedures performed during step 2 are discussed in the following sections.

4.1 Out of Bounds Value Check

When the profiles are being read in, data values are checked against a set of realistic value constraints. Upper and lower constraint limits applied to each parameter are shown in Table 4.

Table 4 Out of Bounds Value Quality Control Check Constraint Limits

Parameter	Units	Out-of-Bounds Value Limits	
		Lower Limit	Upper Limit
WD	Degrees, clockwise from North	WD < 0	WD > 360
WS	m/s	WS < 0.0	WS > 200.0
T	C	T < -100	T > 70.0
Td	C	Td < -100	Td > 70.0
P	mb	P < 0.0	P > 1200.0

Some of these limits correspond to physically unrealistic values. These include the lower WS range, both upper and lower WD ranges, and the lower P range. Other limits correspond to values that were deemed by subject matter experts (SMEs) to be outside the range of expected observable values. These include the upper WS range, both upper and lower T ranges, both upper and lower Td ranges, and the upper P range. Any values outside these limiting bounds are replaced with a value representing the Institute of Electrical and Electronics Engineers floating point standard for Not-a-Number (NaN) [4]. One additional check is performed on dewpoint based on the observed temperature. If the temperature at a given level is below -60°C , then the Td for that level is treated as missing data. The rationale for implementing this check is that dewpoint instrument sensitivity

decreases rapidly for temperatures below -60°C . At these temperatures, it is reasonable to assume that the moisture content in the air is negligible.

4.2 Surface level Check

Profiles are required to start with valid data values within 0.1 km of the nominal surface elevation for each site. Any profile with a lowest reporting altitude above this limit is removed.

4.3 Duplicate Profile Check

Occasionally, data from the same balloon flight are represented in the archive at multiple vertical resolutions. For example, a given profile may be present in both 100 ft and 1000 ft resolutions. When data from a given balloon flight exist in multiple resolutions, only the data with the lowest resolution are retained.

4.4 Missing Data Check

Various “missing data” flags (for example, -999.99) are occasionally present in the data archive in place of valid data entries. Any missing data flags are replaced with NaN.

4.5 Minimum Number of Valid Data Levels Check

A test is performed to ensure that each input profile contains at least five levels with valid data values. This test is performed independently for the parameters WS, T, Td, and P. Any profile containing less than five levels with valid observations of WS, T, Td, or P are removed. Note that this QC check does not require a profile to have at least five levels containing valid observations of all test parameters simultaneously at that same level.

4.6 Maximum Data Gap Interval Check

A test is performed to ensure that no data gaps larger than 5 km were present. Any profiles with data gaps (altitude differences between adjacent levels with valid data values) larger than 5 km are removed. This test is performed sequentially for WS, T, Td, and P.

4.7 Wind Speed Shear Check

A maximum wind shear limit is established with a value of 0.3 s^{-1} . Any profile containing wind speed shears between adjacent data reporting levels that exceeded the established limit is removed.

4.8 Negative Altitude Change Between Adjacent Levels Check

Occasionally a profile is noted to be corrupt as though portions of two separate profiles are written on a single line. Typically, this is manifested as a profile that appears valid up to some given level, after which the profile data is over-written by a second full profile. In these instances, the given, N^{th} data level corresponds to a given altitude, say Z_N , while the next subsequent, $(N+1)^{\text{th}}$ data level

corresponds to a second altitude, Z_{N+1} , where $Z_{N+1} < Z_N$. Any profiles where $Z_{N+1} < Z_N$, for any adjacent levels N and N+1, are removed.

4.9 Visual Inspection Check Based on Subject Matter Expertise

At various points in the data processing, certain profiles are noted as suspect based on assorted computational anomalies. For example, on occasion, an alphabetic text string will exist in one of a given profile's data fields, causing the processing program to terminate due to an inability to interpret the text string as a numerical value. In these instances, the profile is inspected manually to determine the source of the anomaly. Those profiles that were deemed to be corrupted or otherwise unacceptable are removed. This QC check is an event-driven process that is active both prior to and subsequent to statistical computations.

5.0 STEP 3: INTERPOLATE PROFILE DATA

The desired vertical resolution for the RRA tables is established as 0.5 km. Thus, individual profiles must be interpolated to this grid resolution. Once all values have been interpolated onto the output grid, the profiles are written to a separate text file. The individual tasks in the interpolation process are detailed in the following sections.

5.1 Establish Output Altitude Grid

An output grid of altitude values, Z_{out} , is established covering the vertical domain from surface to 30 km with a 0.5 km vertical resolution. The lowest grid value is set at the nominal surface for each site.

5.2 Compute Geopotential Heights for Output Grid Altitudes

To facilitate interpolations, an array of geopotential heights, H_{out} , is computed, with elements corresponding to each element of Z_{out} . The process of computing geopotential heights, adapted from [2] and [5], is detailed in the following sections.

5.2.1 Compute Latitude-Dependent Surface Gravity

Considering the Earth as a reference ellipsoid, the acceleration of gravity, g , at the surface, and at latitude, ϕ , is approximated by the following equation:

$$g_{\phi} = 9.780356 \times (1 + 5.2885E^{-3} \times \sin^2\phi - 5.9E^{-6} \times \sin^2 2\phi) \quad \text{Eq. 1}$$

5.2.2 Compute Vertical Derivative of Gravity

Gravitational acceleration is known to decrease with altitude. An expression for the rate of change of g with altitude, evaluated at the surface is obtained from the following equation:

$$\left(\frac{\partial g}{\partial z}\right)_{z=0} = -3.085462E^{-6} + 2.27E^{-9} \times \cos 2\phi - 2E^{-12} \times \cos 4\phi \quad \text{Eq. 2}$$

Although this derivative is explicitly only valid at the surface, it has been shown to be valid for the current application up to 600 km altitude [5].

5.2.3 Compute Effective Earth Radius

An effective radius, R_{EFF} , can be defined that takes into account the non-spherical shape of the Earth and centrifugal forces caused by the Earth's rotation. This radius does not necessarily correspond to the actual Earth radius at a given point on the surface. The effective radius is computed using the following equation:

$$R_{EFF} = \frac{-2g\phi}{\left(\frac{\partial g}{\partial Z}\right)_{Z=0}} \quad \text{Eq. 3}$$

5.2.4 Compute Geopotential Heights

The geopotential height, H , as a function of altitude is then computed using the following:

$$H_Z = \frac{g\phi}{g_0} \times R_{EFF} \times \frac{Z}{R_{EFF}+Z} \quad \text{Eq. 4}$$

In this expression, g_0 is the reference gravitational acceleration with a value of 9.80665 m/s².

5.3 Compute Wind Components

Zonal and meridional wind components are computed from WS and WD at each input grid altitude using the following equations:

$$U = -WS \times \sin(WD) \quad \text{Eq. 5}$$

$$V = -WS \times \cos(WD) \quad \text{Eq. 6}$$

5.4 Interpolate Wind Speed and Wind Components to Output Grid

Wind parameters (WS, U, and V) are interpolated linearly with respect to geopotential height. First, an array of geopotential heights, H_{in} , is computed (as in Section 5.2) with elements corresponding to each altitude in the input grid. Next, for each Nth level in the output grid, the output grid geopotential height for that level, computed in section 5.2, is noted as $H_{out,N}$. Then, the closest bounding geopotentials (above, H_A , and below, H_B) from the input grid are selected as follows:

$$H_A = \text{minimum of } H_{in} \text{ values where } H_{in} > H_{out,N}$$

$$H_B = \text{maximum of } H_{in} \text{ values where } H_{in} \leq H_{out,N}$$

Further, the input grid altitude array indices for H_A and H_B are defined as I_A and I_B such that

$$H_{in}(I_A) = H_A, \text{ and } H_{in}(I_B) = H_B$$

Then, upper and lower input grid values for WS, U, and V are determined as the array elements defined by the indices I_A and I_B :

$$\begin{aligned} WS_A &= WS(I_A) \\ WS_B &= WS(I_B) \\ U_A &= U(I_A) \\ U_B &= U(I_B) \\ V_A &= V(I_A) \\ V_B &= V(I_B) \end{aligned}$$

Now, a term, C_1 , can be defined where $C_1 = (H_{out,N} - H_B)/(H_A - H_B)$. Then, the N^{th} interpolated values for WS, U, and V are computed:

$$WS_N = WS_B + (WS_A - WS_B) * C_1 \quad \text{Eq. 7}$$

$$U_N = U_B + (U_A - U_B) * C_1 \quad \text{Eq. 8}$$

$$V_N = V_B + (V_A - V_B) * C_1 \quad \text{Eq. 9}$$

5.5 Interpolate Pressure to Output Grid

Pressures are interpolated from each level of the input grid onto the output grid by applying a form of the hypsometric equation shown in [2]. First, H_A , H_B , I_A , and I_B are determined as in Section 5.4. Then, P_B is computed as $P_B = P(I_B)$. Next, virtual temperatures need to be computed for the two input grid levels corresponding to I_A and I_B . The process of computing virtual temperature is detailed in Section 6.2 below. It is convenient to define the upper and lower bounding values for virtual temperature as $T_{vA} = T_v(I_A)$ and $T_{vB} = T_v(I_B)$. Then, the layer-averaged virtual temperature is given by $T_{vAVE} = (T_{vA} + T_{vB}) / 2$. Finally, the interpolated pressure, P_{OUT} , is computed using the following equation:

$$P_{OUT} = P_B \times EXP\left(\frac{H_B - H_A}{29.2712617 \times T_{vAVE}}\right) \quad \text{Eq. 10}$$

5.6 Interpolate Temperature and Dewpoint to Output Grid

Temperatures and dewpoints are interpolated logarithmically with respect to pressure. First, H_A , H_B , I_A , and I_B are determined for each output grid level, as in Section 5.4. Then, the upper and lower bounding values for temperature and dewpoint are determined as follows:

$$\begin{aligned} T_A &= T(I_A) \\ T_B &= T(I_B) \\ TD_A &= TD(I_A) \\ TD_B &= TD(I_B) \end{aligned}$$

Next, it is convenient to define a term, C_2 , where $C_2 = [\ln(P_{OUT}) - \ln(P_B)] / [\ln(P_A) - \ln(P_B)]$. Then, the interpolated values of T and TD are computed as follows:

$$T_{OUT} = T_B + (T_A - T_B) * C_2 \quad \text{Eq. 11}$$

$$Td_{OUT} = Td_B + (Td_A - Td_B) * C_2 \quad \text{Eq. 12}$$

6.0 STEP 4: COMPUTE DERIVED QUANTITIES

Once all profiles of WS, U, V, T, Td, and P have been interpolated to the output grid resolution, values for the additional derived quantities of VP, Tv, and D are computed as shown in the following sections. These equations and methods are adapted from [2].

6.1 Compute Vapor Pressure

Vapor pressure is computed from dewpoint using the following equation:

$$VP_{OUT} = 6.112 \times 10^{\left[\frac{17.67 \times TdC}{TdC + 243.5}\right]} \quad \text{Eq. 13}$$

In this equation, TdC is the dewpoint expressed in units of degrees C. For upper levels where Td is undefined (NaN), VP is set identically equal to zero.

6.2 Compute Virtual Temperature

To compute virtual temperature, first, the water vapor mixing ratio, w , is computed using the following equation:

$$w = \epsilon \times \frac{VP}{P - VP} \quad \text{Eq. 14}$$

where ϵ is the dimensionless ratio of the molecular weight of water vapor to the molecular weight of dry air, with a constant value of 0.622. Then, virtual temperature (in Kelvins) is computed using the following equation:

$$TV_{OUT} = T \times \frac{1 + \frac{w}{\epsilon}}{1 + w} \quad \text{Eq. 15}$$

6.3 Compute Density

Density is computed from output pressure and virtual temperature values using the following equation:

$$D_{OUT} = 348.36787 \times \frac{P_{OUT}}{TV_{OUT}} \quad \text{Eq. 16}$$

7.0 STEP 5: COMPUTE STATISTICS

Computation of the RRA statistics is straight forward. The collected data from all profiles are segregated by month and altitude level. Then, for each month and altitude combination, mean values, median values, and standard deviations are computed for WS, U, V, P, T, D, VP, Tv, and Td. Skewness values are computed for WS, P, T, D, VP, Tv, and Td. Numbers of observations are counted for WS, P, T, and Td. Lastly, the correlation between the U and V wind components

is calculated. Data values of NaN are not used in these computations. All computed values are tabulated in an intermediate output file.

8.0 STEP 6: PERFORM DIAGNOSTIC TESTING

Diagnostic testing is performed individually for the variables WS, U, V, T, P, and Td. After computing monthly mean values and standard deviations at each RRA altitude, all profiles of a given variable for a given month are plotted together along with the $\mu \pm 6\sigma$ envelopes. All profiles with values that exceeded the envelope limits at any level are flagged for removal.

After removing these flagged profiles, step 5 is repeated to give a new set of RRA statistics. Then, step 6 is repeated with new envelopes derived from the new means and standard deviations. Steps 5 and 6 are iterated until no profiles exceed any of the $\mu \pm 6\sigma$ envelopes.

9.0 STEP 7: PERFORM VALIDATION TESTING

Once a set of RRA statistics successfully passes the diagnostic testing process, an additional series of tests are performed to establish the validity of the statistical values. The individual tests are described in detail in the following sections. Some of these tests have quantified success criteria while others require SME judgment to determine pass/fail conditions. It should be noted that a failure of one of these validation tests does not suggest a clear remediation process. For example, no individual profiles are indicated as the cause of the failure condition. Rather, these tests were used to indicate the presence of some problem. Once detected, the problem is addressed through in-depth manual inspection of the input data and various idiomatic analyses of the constituent data values. Any erroneous profiles discovered to be supporting the failure condition are removed from the input database and the development process is repeated beginning with step 5. This process is iterated until no validation test failures are noted.

9.1 Skewness Limit Tests

Bounds are placed on the acceptable skewness coefficients for WS, T, P, Td, and D. The threshold values applied to these tests are shown in Table 5. The success criterion for these tests is the condition that no skewness coefficient exceeded the limits defined in the table, for any month or altitude.

Table 5 **Thresholds for Skewness Limit Tests**

Parameter	Valid Skewness Conditions
WS	SKEW \leq 4.0 if mean WS < 15 m/s SKEW \leq 2.5 if mean WS \geq 15 m/s
P	SKEW \leq 2.5
T	SKEW \leq 2.5
D	SKEW \leq 3.5
Td	SKEW \leq 2.5

9.2 Buell Relationship Tests

Buell [6] derived a set of relationships based on the statistics of P, T, and D. These relationships define equalities between various terms involving the mean values (μ_P , μ_T , μ_D), the standard deviations (σ_P , σ_T , σ_D), and correlations between the variables for pressure and temperature (R_{PT}), pressure and density (R_{PD}), and temperature and density (R_{TD}). The three Buell relationships shown below are applied for these tests.

$$\text{(Buell relationship \#1)} \quad \frac{\sigma_p}{\mu_P} \cdot r_{PD} = \frac{\sigma_D}{\mu_D} + \frac{\sigma_T}{\mu_T} \cdot r_{TD} \quad \text{Eq. 17}$$

$$\text{(Buell relationship \#2)} \quad \frac{\sigma_p}{\mu_P} \cdot r_{PT} = \frac{\sigma_T}{\mu_T} + \frac{\sigma_D}{\mu_D} \cdot r_{TD} \quad \text{Eq. 18}$$

$$\text{(Buell relationship \#3)} \quad \frac{\sigma_p}{\mu_P} = \frac{\sigma_D}{\mu_D} \cdot r_{PD} + \frac{\sigma_T}{\mu_T} \cdot r_{PT} \quad \text{Eq. 19}$$

These tests are implemented individually for each relationship by computing each side of the equations using monthly RRA values (at each altitude), and subtracting the right hand side from the left hand side. These difference values are then plotted as a function of altitude and any significant deviations are noted. The success criterion for these tests is the condition that no deviations are present of sufficient magnitude to be judged by the SME to be problematic.

9.3 Gas Law Reconstruction Test

An expression for the gas constant, R_g , can be derived from the ideal gas law:

$$R_g = \frac{P}{D \cdot T} \quad \text{Eq. 20}$$

For this test, RRA monthly mean values are used to compute R_g at each altitude, and the computed values are compared to the accepted value of $287 \frac{J}{kg \cdot K}$, and any significant deviations are noted. The success criteria for this test is the condition that no deviations are present of sufficient magnitude to be judged by the SME to be problematic.

9.4 Wind Speed Reconstruction Test

An expression relating wind speed statistics and wind component statistics can be derived:

$$WS' = \sqrt{U^2 + V^2 + \sigma_U^2 + \sigma_V^2 - \sigma_S^2} \quad \text{Eq. 21}$$

For this test, RRA monthly mean values of U and V are used along with standard deviations for U, V, and WS, to compute a new wind speed estimate, WS'. WS' is then compared to the RRA monthly mean WS value for each month and altitude, and any significant deviations are noted. The success criteria for this tests is the condition that no deviations are present of sufficient magnitude to be judged by the SME to be problematic.

10.0 STEP 8: CREATE FINAL DATA PRODUCTS

Once all issues identified in validation testing are successfully addressed and a set of RRA statistics are generated that pass all validation tests, the following final data products are created: (1) a Comma Separated Variable Excel spreadsheet file containing computed RRA values for all statistical parameters for all months and altitudes, (2) an Earth-GRAM formatted text file containing wind statistics, (3) an Earth-GRAM formatted text file containing thermodynamic statistics, (4) an Earth-GRAM formatted text file containing moisture statistics, and (5) a listing, by timestamp, of the constituent profiles used to produce the final RRA product.

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