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User's Guide for Monthly Vector Wind Profile Model

S. I. Adelfang
Computer Sciences Corporation, Huntsville, Alabama

Prepared for Marshall Space Flight Center
under Contract NAS8–60000

May 1999

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FOREWORD

This document presents work performed under Contract NAS8–60000, Program Information Systems Mission Services (PrISMS), Computer Sciences Corporation. This work was sponsored by the Electromagnetics and Aerospace Environments Branch, Systems Engineering Division, Systems Analysis and Integration Laboratory of the NASA Marshall Space Flight Center.

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LIST OF ACRONYMS

CA	clocking angle
CSC	Computer Sciences Corporation
FPR	flight performance review
KSC	Kennedy Space Center
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
P	probability
PE	probability ellipse
PrISMS	Program Information Systems Mission Services
U	zonal wind component
V	meridional wind component
VWP	vector wind profile

A MONTHLY VECTOR WIND PROFILE MODEL

1. INTRODUCTION

The purpose of this user's guide is to provide an understanding of the background, theoretical concepts and methodology for construction of vector wind profiles based on a statistical model. With this understanding the user can embark on the intended application, to provide the launch vehicle engineering design community a product that has wide application in establishing realistic estimates of the dispersions of critical vehicle design parameters related to wind profile dispersions. This user's guide includes a description of the computational process for the model including specification of input data, parameter settings, and output data formats. Sample output data listings are provided to aid the user in the verification of test output generated by the user.

2. BACKGROUND

The most useful engineering design application of a wind profile model is the establishment of preliminary design ranges for angle of attack, α, angle of sideslip, β, aerodynamic pressure, q, and the two aerodynamic load indicators, products, $q\alpha$, and $q\beta$. These and other flight variables are derived from ascent flight 6-degree of freedom trajectory simulations using wind model profiles. The trajectory variables are used in the evaluation of load indicators at locations of expected vehicle wind sensitivity. A load indicator is an algorithm that relates an external loads such as q to stress at a specific point on the vehicle structure; for the Space Shuttle, the algorithms are for rigid body loads.[1] Elastic body loads are determined from flutter and vibration analyses using model wind profiles augmented to include small scale wind perturbations. Another useful application is the estimation of flight performance reserve (FPR) for propellant to ensure orbital insertion by protecting for flight dispersions attributable in part to wind profile dispersions.[2,3] Following the preliminary vehicle design using a wind profile model, trade studies are made to establish a requirement to bias steering to reduce wind loads. The usual procedure is to establish first-stage steering based on the profile of monthly mean winds in the pitch and yaw planes. Wind profile models were developed for alternatives other than the monthly means.[3] When sufficient engineering data are established, structural loads and performance assessments are made using samples of high resolution wind profile measurements. Currently, for Kennedy Space Center (KSC) this data sample is 150 Jimsphere profiles per month.

3. APPLICATION

The monthly vector wind profile (VWP) model is suitable for applications in preliminary launch vehicle design studies that require assessments of vehicle trajectory and aerodynamic loads dispersions attributable to monthly wind profile dispersions. Launch vehicle ascent guidance and control system (auto-pilot) steering commands are programmed for flight through the profile of monthly mean wind. Various vehicle programs have used different terms for the programmed steering commands. The early Saturn program called the commands the chi-tilt program, later the wind-biased trajectory, and the Space Shuttle program calls the steering commands the I-Load.

During initial studies a number of months are used to establish the model profiles that produce the largest monthly dispersions of ascent vehicle aerodynamic load indicators, $Q\alpha$ and $Q\beta$. Because the largest monthly dispersions for wind occur during the winter high-wind months, it is appropriate to use the worst month from the winter season for establishment of the design reference, $Q\alpha$ and $Q\beta$, dispersions.

4. THEORETICAL CONCEPTS

The theoretical basis for the vector wind model is the wind components at any two altitudes within the altitude range of the model are quadravariate normal.

A quadravariate normal distribution for wind vectors, $\{U_1, V_1\}$, at an altitude, Z_1, and wind vectors, $\{U_2, V_2\}$, at an altitude, Z_2, has the property that the conditional wind vectors at an altitude, Z_2 , are bivariate normally distributed given specific values for the wind vector, $\{U_1^*, V_1^*\}$, at altitude, Z_1.

Symbolically, this is

$$f\left(U_2, V_2 \middle| U_1^*, V_1^*\right) = \frac{f\left(U_1, V_1, U_2, V_2\right)}{f\left(U_1^*, V_1^*\right)} \qquad (1)$$

The 14 statistical parameters for the quadravariate normal distribution for the zonal, U, and meridional, V, wind components are the four mean values, $\overline{U}_1$, $\overline{V}_1$, $\overline{U}_2$, and $\overline{V}_2$; the four standard deviations, SDU_1, SDV_1, SDU_2, and SDV_2; and the six correlation coefficients for like and unlike variables between altitudes Z_1 and Z_2: $R(U_1,U_2)$, $R(V_1,V_2)$ and $R(U_1,V_2)$ and $R(V_1,U_2)$, respectively, and unlike variables at the same altitude Z_1 or Z_2 : $R(U_1,V_1)$ and $R(U_2,V_2)$.

5. WIND PROFILE CONSTRUCTION

The procedure is (1) define 12 specific wind vectors to the 99 percent probability ellipse at a fixed reference altitude, (2) compute the five parameters for the conditional bivariate normal probability distributions for all altitude levels above and below the reference altitude, and (3) find the intercept to the conditional probability ellipse toward the mean values at the reference altitude. This conditional wind vector closely approximates the largest vector wind shear between the reference altitude and each of the other altitudes.

For engineering applications, the conditional wind vectors are expressed in polar coordinates as wind speed and wind direction in the standard meteorological coordinate system. Thus, the vector wind profile model is defined by the 12 equally spaced (30-degree) increments from the centroid of the 99 percent probability ellipses at each reference altitude, which are the given values for the 99 percent conditional wind vectors that yield the largest shear at all other altitudes above and below the reference altitude.

For the N altitudes for the available data base there are 12 by N vector wind profiles from the surface (station elevation) to the maximum altitude. These vector wind profiles as a function of altitude above mean sea level are expressed as wind speed and wind direction in the standard meteorological coordinate system. The vector wind profiles are derived from the vector wind profile model for a selected month, called the design reference month, representative of the high wind months.

This coordinate system is chosen because a vehicle could have a flight azimuth different from either axis associated with the wind components. Furthermore, for operations the wind data is provided in the meteorological coordinate system.

The wind coordinate system used in the Space Shuttle program as a function of flight azimuth, FA, is

$$W_x(FA) = W \cos(\theta - FA) \text{ [in-plane wind component]} \tag{2}$$

where, a headwind is a positive in plane wind component and a tailwind is negative.

$$W_y(FA) = W \sin(\theta - FA) \text{ [out-of-plane wind component]} \tag{3}$$

where, a right-to-left out-of-plane wind component is a positive crosswind and left-to-right is negative crosswind. The wind direction, θ, measured in degrees clockwise from true north, is the direction from which the wind is blowing. W is wind speed and FA is flight azimuth measured in degrees clockwise from true north.

6. EQUATIONS

This section presents the specific equations to compute (1) the given wind vectors at the reference altitude, Z_1, and (2) the five conditional bivariate normal parameters at Z_2, i.e., the conditional component means, the conditional component standard deviations, and the conditional correlation coefficients.[1] The five conditional statistical parameters are used to compute the conditional bivariate normal 99 percent probability ellipse from which the conditional wind vector that approximates the largest shear between the reference altitude, Z_1, and all other altitudes Z_2 above and below the reference altitude. Notation used for the statistical parameters is the following:

Means	Variances	Standard Deviations	Correlation Coefficients	Covariances
(m/s)	(m^2/s^2)	(m/s)	(unitless)	(m^2/s^2)
MU_1	SU_1	SDU_1	RU_1V_1	SU_1V_1
MV_1	SV_1	SDV_1	RU_1V_2	SU_1V_2
MU_2	SU_2	SDU_2	RV_1U_2	SV_1U_2
MV_2	SV_2	SDV_2	RU_2V_2	SU_2V_2
			RU_1U_2	SU_1U_2
			RV_1V_2	SV_1V_2

The general expression for the covariance is $SU_iV_j = RU_iV_j(SDU_i)(SDV_j)$.

The first step is to define the 12 given wind vectors to the 99 percent probability ellipse at the reference altitude. These given wind vectors from the centroid of the probability ellipse are defined at 30-degree increments of clocking angle, CA, measured in the standard mathematical convention (counterclockwise).

$$U_1^* = MU_1 + RS\cos(CA) \tag{4}$$

$$V_1^* = MV_1 + RS\sin(CA) \tag{5}$$

where,

$$RS = \frac{1}{A\sqrt{-2\ln(1-P)}}$$

where P is probability = 0.99 , and

$$A^2 = \frac{1}{1-(RU_1V_1)^2}\left[\left(\frac{\cos(CA)}{SDU_1}\right)^2 - \frac{2RU_1V_1\cos(CA)\sin(CA)}{SDU_1\,SDV_1} + \left(\frac{\sin(CA)}{SDV_1}\right)^2\right]. \tag{6}$$

The conditional mean vectors, $\{CMU_2, CMV_2\}$, at altitude, Z_2, given specific wind vectors, $\{U_1^*, V_1^*\}$, at the reference altitude are

$$CMU_2 = MU_2 + (T_1 + T_2) / [1 - RU_1V_1 * RU_1V_1)] \tag{7}$$

where

$$T_1 = [RU_1U_2 - RU_1V_2 * RU_1V_1] * (U_1^* - MU_1)(SDU_2 / SDU_1)$$

and

$$T_2 = [RU_1V_2 - RU_1U_2 * RU_1V_1] * (V_1^* - MV_1)(SDU_2 / SDV_1)$$

$$CMV_2 = MV_2 + (T_3 + T_4) / [1 - RU_1V_1 * RU_1V_1] \tag{8}$$

where,

$$T_3 = [RV_1U_2 - RV_1V_2 * RU_1V_1] * (U_1^* - MU_1) * (SDV_2 / SDU_1)$$

and

$$T_4 = [RV_1V_2 - RV_1U_2 * RU_1V_1] * (V_1^* - MV_1) * (SDV_2 / SDV_1)$$

The conditional standard deviations are

$$CSDU_2 = [\text{sigma}\ (1,1)]^{1/2} \tag{9}$$

and

$$CSDV_2 = [\text{sigma}\ (2,2)]^{1/2} \tag{10}$$

The conditional correlation coefficient is

$$CRU_2V_2 = \text{sigma}\ (1,2) / (CSDU_2)(CSDV_2) \tag{11}$$

where

$$\text{sigma}\ (1,1) = SU_2 - SU_1U_2\,[SU_1U_2 * SV_1 - SU_2V_1 * SU_1V_1] / D$$
$$- SV_1U_2\,[- SU_1U_2 * SU_1V_1 + SU_2V_1 * SU_1] / D$$

$$\text{sigma}\ (2,2) = SV_2 - SU_1V_2\,[SU_1V_2 * SV_1 - SV_1V_2 * SU_1V_1] / D$$
$$- SV_1V_2\,[- SU_1V_2 * SV_1U_2 + SV_1V_2 * SU_1] / D$$

$$\text{sigma}\ (1,2) = SU_2V_2 - SU_1V_2\,[SU_1U_2 * SV_1 - SU_2V_1 * SU_1V_1] / D$$
$$- SV_1V_2\,[SU_1U_2 * SU_1V_1 + SU_2V_1 * SU_1](1/D)$$

and, $D = (SU_1)(SV_1) - (SU_1V_1)(SU_1V_1)$.

Note that the given wind values U_1^* and V_2^* are required for the conditional mean component and not for the conditional standard deviations.

A vector wind model profile consists of the given wind vector at Z_1 and wind vectors UC_1 and UC_2 calculated from each conditional 99 percent probability ellipse (PE) at all other altitudes Z_2 above and below Z1. Selection of UC1 and UC_2 on the conditional PE at a clocking angle 180 degrees from the clocking angle of the given wind vector produces the desired near maximum vector shear between Z_1 and Z_2.

$$UC_2 = CMU_2 + RSC\cos(CC) \tag{12}$$

and

$$VC_2 = CMV_2 + RSC\sin(CC) \tag{13}$$

where

CC = CA + 180, i.e., the clocking angle to the given vector plus 180 degrees

$$RSC = \frac{1}{A_c\sqrt{-2\ln(1-P)}}$$

where

P is probability = 0.99, and,

$$A_c^2 = \frac{1}{1-(CRU_2V_2)^2}\left[\left(\frac{\cos(CC)}{CSDU_2}\right)^2 - \frac{2CRU_2V_2\cos(CC)\sin(CC)}{CSDU_2 * CSDV_2} + \left(\frac{\sin(CC)}{CSDV_2}\right)^2\right] \tag{14}$$

The schematic in figure1 illustrates the construction of a given wind vector at 12-km altitude for a clocking angle of 30 degrees and the conditional wind vector at 10-km, which is at a clocking angle of 210 degrees, (30 + 180), on the 99 percent conditional probability ellipses.

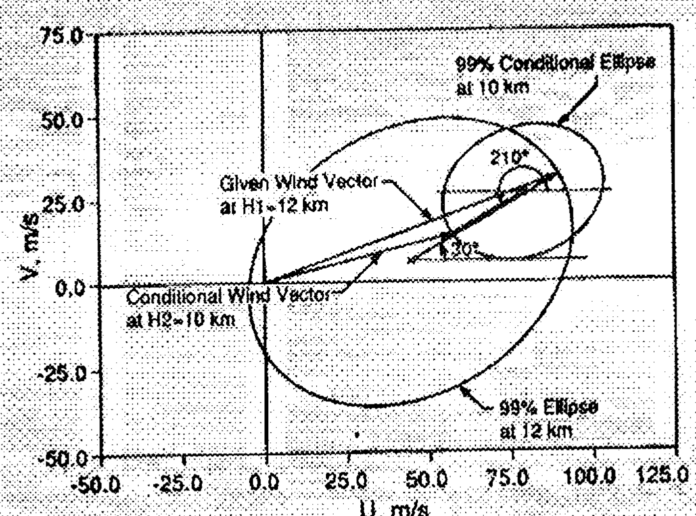

Figure 1. Schematic of Profile Construction Between a Reference Altitude of 12 km and an Altitude of 10 km, Clocking Angle 30°.

The monthly mean profile and the 12 wind profiles for KSC, February for a reference altitude of 12-km are illustrated in figure 2 for the zonal wind component (U) and figure 3 for the meridional wind component (V).

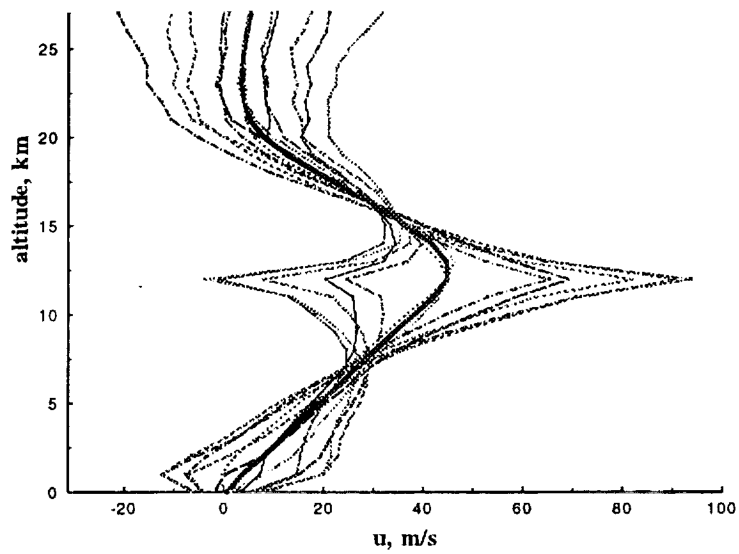

Figure 2. Mean Profile (thick solid) and Vector Wind Model Profiles for $Z_0 = 12$ km, U-Component KSC, February

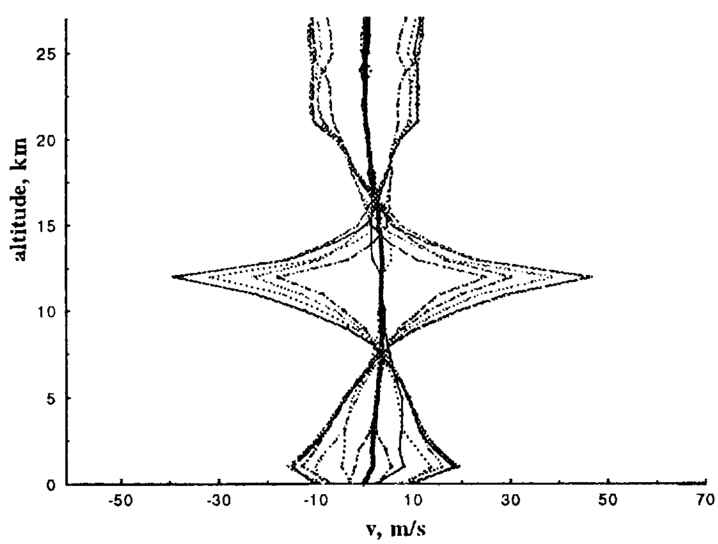

Figure 3. Mean Profile (thick solid) and Vector Wind Model Profiles for $Z_0 = 12$ km, V-Component KSC, February

7. COMPUTATIONAL PROCESS

Preferably, the input data consist of a statistically representative sample of twice daily wind profiles obtained during at least a ten-year period of record yielding approximately 600 profiles per month. The database used for KSC in the example presented in this guide is the 19-year (1956-74) serially complete Rawinsonde profile set established by NASA for the Space Shuttle Program.

The computer code for the Monthly Vector Wind Profile Model consists of three subroutines. The first subroutine, QUAD, uses the input data file for calculations of the monthly quadravariate normal statistics at any reference altitude, H0, and any other altitude, H, above or below H0, within the altitude range of the available data base. The quadravariate normal statistics are used in the second subroutine, CSTAT, for the calculations of the conditional bivariate normal statistics at H given a wind vector to the pth percentile ellipse at H0. The 12 given wind vectors at each H0 and the conditional bivariate normal statistics are used in the third subroutine, PRO, for the construction of 12 vector wind profiles for each H0.

Requirements and specifications for input parameters and input and output data files are included in the process description below. **The computer codes for the various subroutines are not included in this report.**

The driver for the computations contains dimension statements for the derived statistical arrays of the form illustrated below for 28 altitude levels.

```
  DIMENSION XB(28),YB(28),SDX(28),SDY(28),RXY(28),DET1(28,28),DET2(28,28)
C
C SET MONTH AND NUMBER OF LEVELS
C IMM=MONTH,
C NLV=NUMBER OF ALTITUDE LEVELS FROM SURFACE TO MAXIMUM ALTITUDE USUALLY BUT NOT RESTRICTED
C     TO 1KM INTERVALS
C
      DATA IMM/2/
      DATA NLV/28/
C
C CALCULATE QUADRAVARIATE NORMAL STATISTICS
      CALL QUAD(XB,SDX,YB,SDY,RXY,DET1,DET2,NLV,IMM)
C
C CALCULATE CONDITIONAL STATISTICS
      CALL CSTAT(XB,SDX,YB,SDY,RXY,DET1,DET2,NLV,IMM)
C
C CONSTRUCT PROFILES
      CALL PRO(NLV,IMM)
      STOP
      END
C
      SUBROUTINE QUAD(XB,SDX,YB,SDY,RXY,DET1,DET2,NLV,IMM)
C THIS PROGRAM GENERATES THE QUADRAVARIATE NORMAL STATISTICS REQUIRED
C FOR COMPLETE VECTOR WIND PROFILE MODEL FOR A SELECTED MONTH
C
C NOTE:DIMENSION STATEMENTS BELOW ARE FOR A MAXIMUM OF 28 LEVELS,WHICH IS THE
C      PRACTICAL LIMIT FOR RAWINSONDE PROFILES.
C
      DIMENSION SX(28),SY(28),SSX(28),SSY(28),SSXY(28),XB(28),YB(28),
     $SDX(28),SDY(28),RXY(28),SXXP(28,28),SYYP(28,28),SXYP(28,28),
     $SYXP(28,28),RXXP(28,28),RYYP(28,28),RXYP(28,28),RYXP(28,28),
     $IDD(5),IWD(28),IWS(28),X(28),Y(28),KK(28),DET1(28,28),DET2(28,28)
      CHARACTER*10 MON,MONTH(12)
```

```
      DATA MONTH/ 'JANUARY  ','FEBRUARY ','MARCH    ','APRIL    ',
     $'MAY      ','JUNE     ','JULY     ','AUGUST   ','SEPTEMBER',
     $'OCTOBER  ','NOVEMBER ','DECEMBER '/
C
C  PARAMETERS TO BE SPECIFIED IN DATA STATEMENTS BELOW
C  SFC=ELEVATION IN KM TO 3 DECIMAL PLACES (IE. TO NEAREST METER)
C  IOUT1=1 FOR BIVARIATE NORMAL STATISTICS OUTPUT TO UNIT 97
C  IOUT2=1 FOR INTERLEVEL CORRELATION COEFFICIENTS BETWEEN LIKE COMPONENTS
C          OUTPUT TO UNIT 98
C  IOUT3=1 FOR INTERLEVEL CORRELATION COEFFICIENTS BETWEEN UNLIKE COMPONENT
C          OUTPUT TO UNIT 99
C
      DATA SFC/0.003/
      DATA IOUT1/1/
      DATA IOUT2/1/
      DATA IOUT3/1/
C
C INPUT DATA FROM UNIT 2 IS SERIALLY COMPLETE RAWINSONDE DATA BASE
C FORMAT OF INPUT DATA IS GIVEN IN STATEMENT 450 BELOW
C INPUT FILE
      OPEN(UNIT=2,FILE='SERCOMKSC.TXT')
C OUTPUT FILES (IF NEEDED)
C NOTE "2" IN OUTPUT FILE NAME SPECIFIES THE APPLICABLE MONTH,FEBRUARY FOR THIS EXAMPLE
      OPEN(UNIT=97,FILE='BNSKSC2.TXT')
      OPEN(UNIT=98,FILE='CORAKSC2.TXT')
      OPEN(UNIT=99,FILE='CORBKSC2.TXT')
C
      SUBROUTINE CSTAT(XB,SDX,YB,SDY,RXY,DET1,DET2,NLV,IMM)
C
C CALCULATES CONDITIONAL BIVARIATE NORMAL STATISTICS FOR PTH PERCENTILE
C CONDITIONAL ELLIPSES AT ALL ALTITUDES H, FOR EACH OF 12 GIVEN VECTORS
C TO THE PTH PERCENTILE ELLIPSE AT REFERENCE ALTITUDE H0 (ALL ALTITUDES
C SURFACE TO MAXIMUM ALTITUDE). NOTE THAT P IS SET BELOW.
C
      DIMENSION XB(28),SDX(28),RXY(28),YB(28),SDY(28),DET1(28,28),
     *DET2(28,28),RYYPUP(28),RXXPDN(28),RXXPUP(28),RYYPDN(28),RYXPUP(28)
     *,RXYPDN(28),RXYPUP(28),RYXPDN(28),XGG(28),YGG(28),YYCLK(28,28),
     *CBNUP(28,28,5),CBNDN(28,28,5),XCLK(28),YCLK(28),XXCLK(28,28),
     *RCC(12)
      CHARACTER IMO*10,ID1*7,ID6*15
      CHARACTER*10 IMONN(12)
      DATA IMONN/'JANUARY  ','FEBRUARY  ','MARCH    ','APRIL    ',
     *'MAY      ','JUNE      ','JULY      ','AUGUST    ','SEPTEMBER ',
     *'OCTOBER   ','NOVEMBER  ','DECEMBER  '/
      DATA ID1/'     KSC'/
      DATA ID6/' GENERAL CASE '/
C SET PROBABILITY LEVEL FOR DERIVATION OF GIVEN WIND VECTOR TO PTH PERCENTILE
C ELLIPSE AT H0
      DATA P/.99/
      DATA IOUT4/1/
C OUTPUT FILE IF NEEDED SET IOUT4=1
C NOTE "2" IN OUTPUT FILE NAME SPECIFIES THE APPLICABLE MONTH
      OPEN(UNIT=27,FILE='CSTATKSC2.TXT')

      SUBROUTINE CONDELL(XB0,YB0,SDX0,SDY0,RXY0,XB2,YB2,SDX2,SDY2,RXY2,
     *RXXP,RYYP,RXYP,RYXP,XG,YG,CMX,CMY,CSDX,CSDY,CRXY)
      DIMENSION SIGMA(2,2),XU(2),VX(2),US(2),COR(2,2),V1(2,2),
     *V2(2,2),V3(2,2),V4(2,2),U1(2),U2(2),X(2),VV24(2,2),VVV(2,2),SD(4),
     *RHO(4,4),U(4),S(4,4)
************************************************************************
C DEFINITION OF INPUT VARIABLES
C U(1)=MEAN OF X COMPONENT AT ALT H0
      U(1)=XB0
C U(2)=MEAN OF Y COMPONENT AT ALT H0
      U(2)=YB0
C U(3)=MEAN OF X COMPONENT AT ALT H2
      U(3)=XB2
C U(4)=MEAN OF Y COMPONENT AT ALT H2
      U(4)=YB2
C SD(1)=STD.DEV.OF X AT ALT H0
      SD(1)=SDX0
C SD(2)=STD.DEV.OF Y AT ALT H0
      SD(2)=SDY0
C SD(3)=STD.DEV.OF X AT ALT H2
```

```
      SD(3)=SDX2
C SD(4)=STD.DEV.OF Y AT ALT H2
      SD(4)=SDY2
C RHO(1,2)=CORRELATION OF X AT H0 WITH Y AT H0
      RHO(1,2)=RXY0
C RHO(1,3)=CORRELATION OF X AT H0 WITH X AT H2
      RHO(1,3)=RXXP
C RHO(1,4)=CORRELATION OF X AT H0 WITH Y AT H2
      RHO(1,4)=RXYP
C RHO(2,3)=CORRELATION OF Y AT H0 WITH X AT H2
      RHO(2,3)=RYXP
C RHO(2,4)=CORRELATION OF Y AT H0 WITH Y AT H2
      RHO(2,4)=RYYP
C RHO(3,4)=CORRELATION OF X AT H2 WITH WITH Y AT H2
      RHO(3,4)=RXY2
C X(1)=X COMPONENT OF THE GIVEN VECTOR
      X(1)=XG
C X(2)=Y COMPONENT OF THE GIVEN VECTOR
      X(2)=YG
C     DEFINITION OF OUTPUT VARIABLES
C US(1)=CONDITIONAL MEAN OF X COMPONENT
C US(2)=CONDITIONAL MEAN OF Y COMPONENT
C COR(1,1)=CONDITIONAL STANDARD DEVIATION OF X COMPONENT
C COR(2,2)=CONDITIONAL STANDARD DEVIATION OF Y COMPONENT
C COR(1,2)=CONDITIONAL CORRELATION OF X AND Y COMPONENT
C***********************************************************
      SUBROUTINE PRO(NLV,IMM)
C MONTHLY WIND PROFILE MODEL
C CLOCKING ANGLE OF CONDITIONAL WIND VECTOR IS 180 DEG FROM CLOCKING
C ANGLE OF GIVEN WIND VECTOR
      DIMENSION XC(28),YC(28),VWS(28),XB(28),YB(28),SDX(28),
     *SDY(28),RXY(28),SPWS(28),SPWD(28),ICLA(28),
     *SPWSTE(336,28),SPWDTE(336,28),
     *RPYD(115000),RPYU(115000),
     *RPXD(115000),RPXU(115000),DATWD(28),DATWS(28),
     *DATWDD(336,28),DATWSS(336,28),UU(336,28),VV(336,28)
C SET PROBABILITY LEVEL FOR CONDITIONAL ELLIPSE
      DATA P/.99/
      CHARACTER IMO*10
      CHARACTER*10 IMONN(12),IMON
      DATA IMONN/'JANUARY   ','FEBRUARY  ','MARCH     ','APRIL     ',
     *'MAY       ','JUNE      ','JULY      ','AUGUST    ','SEPTEMBER ',
     *'OCTOBER   ','NOVEMBER  ','DECEMBER  '/
      CHARACTER ID1*7,ID5*15
      CHARACTER IDFI*3,IH0I*3
      DATA ID1/'KSC    '/
      DATA ID5/'               '/
C INPUT GIVEN WIND VECTORS AND CONDITIONAL BIVARIATE NORMAL STATISTICS
      OPEN(UNIT=27,FILE='CSTATKSC2.TXT')
C OUTPUT FILE: UNIT 86 LISTS WIND PROFILES AND SHEARS FOR EACH REFERENCE ALTITUDE H0
C (0 TO (NLV-1)KM) WITH RESPECT TO 12 CLOCKING ANGLES (0 TO 330 DEG AT 30 DEG INCREMENTS)
C       OPEN(UNIT=86,FILE='PROKSC2.TXT')
C OUTPUT FILE UNIT 72 LISTS WIND PROFILES IN SPREAD SHEET 673 COLUMN FORMAT
C COLUMN              CONTENTS
C      1              ALTITUDE IN KM
C      2              U PROFILE(M/S) FOR   0 DEG CLOCKING ANGLE FOR H0 = SFC
C      3              V PROFILE(M/S) FOR   0 DEG CLOCKING ANGLE FOR H0 = SFC
C      4              U PROFILE      FOR  30 DEG CLOCKING ANGLE FOR H0 = SFC
C      5              V PROFILE      FOR  30 DEG CLOCKING ANGLE FOR H0 = SFC
C      6              U PROFILE      FOR  60 DEG CLOCKING ANGLE FOR H0 = SFC
C      7              V PROFILE      FOR  60 DEG CLOCKING ANGLE FOR H0 = SFC
C      8              U PROFILE      FOR  90 DEG CLOCKING ANGLE FOR H0 = SFC
C      9              V PROFILE      FOR  90 DEG CLOCKING ANGLE FOR H0 = SFC
C     10              U PROFILE      FOR 120 DEG CLOCKING ANGLE FOR H0 = SFC
C     11              V PROFILE      FOR 120 DEG CLOCKING ANGLE FOR H0 = SFC
C     12              U PROFILE      FOR 150 DEG CLOCKING ANGLE FOR H0 = SFC
C     13              V PROFILE      FOR 150 DEG CLOCKING ANGLE FOR H0 = SFC
C     14              U PROFILE      FOR 180 DEG CLOCKING ANGLE FOR H0 = SFC
C     15              V PROFILE      FOR 180 DEG CLOCKING ANGLE FOR H0 = SFC
C     16              U PROFILE      FOR 210 DEG CLOCKING ANGLE FOR H0 = SFC
C     17              V PROFILE      FOR 210 DEG CLOCKING ANGLE FOR H0 = SFC
C     18              U PROFILE      FOR 240 DEG CLOCKING ANGLE FOR H0 = SFC
C     19              V PROFILE      FOR 240 DEG CLOCKING ANGLE FOR H0 = SFC
C     20              U PROFILE      FOR 270 DEG CLOCKING ANGLE FOR H0 = SFC
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C     21              V PROFILE      FOR 270 DEG CLOCKING ANGLE FOR H0 = SFC
C     22              U PROFILE      FOR 300 DEG CLOCKING ANGLE FOR H0 = SFC
C     23              V PROFILE      FOR 300 DEG CLOCKING ANGLE FOR H0 = SFC
C     24              U PROFILE      FOR 330 DEG CLOCKING ANGLE FOR H0 = SFC
C     25              V PROFILE      FOR 330 DEG CLOCKING ANGLE FOR H0 = SFC
C  26-49 SAME AS 2-25 EXCEPT H0 = 1KM
C  50-73 SAME AS 2-25 EXCEPT H0 = 2KM
C  ETC.
C  (H0+1)*24-22 TO (H0+1)*24+1 SAME AS 2-25 EXCEPT H0=H0
C  650-673 SAME AS 2-25 EXCEPT H0 =27KM
```

8. SAMPLE OUTPUT DATA

Samples of output data from the three subroutines are presented in tables 1 through 5.

Table 1 Bivariate Normal Statistics
Source: Subroutine QUAD
Input File: SERCOMKSC.TXT (KSC serially complete Rawinsonde, 1956-74)
Output File: BNSKSC2.TXT

```
BIVARIATE NORMAL STATISTICS FEBRUARY
KSC SC RAWINSONDE,1956-74
NUMBER OF PROFILES:  1074
```

Z KM	MEAN U M/S	S.D. U M/S	R(U,V)	MEAN V M/S	S.D. V M/S
0.003	0.653	3.274	-0.261	-0.213	3.676
1	3.699	7.167	-0.028	1.620	6.793
2	7.880	7.741	0.008	1.484	6.821
3	11.704	8.195	0.044	1.684	7.400
4	15.212	9.109	0.034	2.105	8.095
5	18.972	10.157	0.050	2.487	8.979
6	22.948	11.130	0.112	2.979	9.612
7	26.584	12.427	0.165	3.307	10.478
8	30.235	13.789	0.199	3.398	11.539
9	34.256	15.369	0.215	3.500	12.630
10	38.184	16.446	0.216	3.387	13.883
11	42.127	17.071	0.228	3.324	14.900
12	44.840	16.526	0.227	3.486	14.555
13	44.763	15.053	0.286	3.525	12.840
14	41.654	13.073	0.276	3.330	11.048
15	36.734	11.440	0.206	2.902	9.279
16	31.588	10.264	0.149	2.600	8.243
17	25.364	9.197	0.143	1.939	7.038
18	18.777	8.485	0.238	1.407	5.667
19	12.767	7.840	0.228	0.989	4.522
20	7.849	7.395	0.254	0.629	3.887
21	5.211	7.254	0.232	0.179	4.230
22	4.039	7.653	0.234	-0.140	4.103
23	3.465	7.862	0.274	-0.023	4.098
24	3.646	8.261	0.280	0.091	3.891
25	3.881	9.142	0.347	-0.020	3.846
26	4.478	9.819	0.307	0.111	4.091
27	5.140	10.570	0.230	0.352	4.132

Table 2 Correlation Coefficients Between Like Wind Components (Page 1 of 2)
Source: Subroutine QUAD
Input File: SERCOMKSC.TXT (KSC serially complete Rawinsonde, 1956-74)
Output File: CORAKSC2.TXT

```
INTERLEVEL CORRELATION COEFFICIENTS BETWEEN LIKE WIND COMPONENTS
ZONAL BELOW DIAGONAL MERIDIONAL ABOVE DIAGONAL
DATA: KSC SC RAWINSONDE FEBRUARY
NUMBER OF PROFILES: 1074
```

	0.003	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.003	1.000	0.723	0.552	0.455	0.405	0.311	0.246	0.188	0.144	0.083	0.032	0.009	-0.002	-0.030	-0.004
1	0.643	1.000	0.834	0.680	0.587	0.483	0.387	0.296	0.229	0.167	0.115	0.079	0.071	0.033	0.052
2	0.580	0.864	1.000	0.873	0.764	0.672	0.587	0.498	0.442	0.374	0.315	0.267	0.253	0.214	0.232
3	0.564	0.749	0.895	1.000	0.912	0.815	0.733	0.652	0.598	0.533	0.466	0.412	0.396	0.354	0.377
4	0.555	0.668	0.804	0.927	1.000	0.923	0.837	0.755	0.692	0.625	0.551	0.497	0.482	0.432	0.457
5	0.524	0.599	0.736	0.849	0.939	1.000	0.932	0.849	0.781	0.711	0.633	0.575	0.553	0.499	0.511
6	0.496	0.536	0.673	0.790	0.883	0.954	1.000	0.933	0.862	0.792	0.707	0.648	0.617	0.572	0.580
7	0.460	0.486	0.624	0.746	0.841	0.905	0.954	1.000	0.936	0.861	0.774	0.717	0.683	0.643	0.643
8	0.432	0.448	0.582	0.706	0.795	0.858	0.904	0.957	1.000	0.940	0.848	0.779	0.726	0.693	0.683
9	0.399	0.397	0.527	0.655	0.742	0.800	0.849	0.895	0.950	1.000	0.937	0.864	0.799	0.752	0.731
10	0.350	0.337	0.462	0.593	0.673	0.730	0.782	0.818	0.874	0.942	1.000	0.946	0.872	0.801	0.764
11	0.321	0.283	0.400	0.533	0.610	0.657	0.710	0.749	0.805	0.876	0.945	1.000	0.938	0.855	0.801
12	0.295	0.256	0.377	0.505	0.577	0.624	0.675	0.709	0.761	0.820	0.880	0.935	1.000	0.917	0.846
13	0.252	0.216	0.342	0.468	0.535	0.580	0.636	0.668	0.714	0.757	0.800	0.840	0.897	1.000	0.912
14	0.211	0.161	0.273	0.400	0.464	0.516	0.573	0.608	0.647	0.683	0.717	0.750	0.796	0.877	1.000
15	0.194	0.169	0.278	0.387	0.447	0.493	0.550	0.574	0.600	0.629	0.663	0.680	0.734	0.813	0.881
16	0.179	0.155	0.268	0.369	0.421	0.454	0.511	0.533	0.557	0.582	0.607	0.624	0.679	0.736	0.782
17	0.131	0.120	0.217	0.316	0.373	0.403	0.451	0.478	0.507	0.523	0.535	0.551	0.602	0.657	0.706
18	0.126	0.100	0.191	0.282	0.343	0.363	0.394	0.422	0.441	0.439	0.447	0.467	0.509	0.558	0.595
19	0.135	0.090	0.175	0.258	0.316	0.337	0.369	0.388	0.397	0.398	0.401	0.418	0.446	0.492	0.520
20	0.078	0.036	0.115	0.160	0.223	0.256	0.282	0.294	0.303	0.305	0.316	0.328	0.352	0.401	0.453
21	-0.007	-0.039	0.031	0.078	0.127	0.126	0.150	0.159	0.165	0.177	0.192	0.217	0.239	0.288	0.371
22	-0.021	-0.044	0.004	0.055	0.109	0.103	0.131	0.126	0.127	0.145	0.177	0.202	0.236	0.275	0.325
23	-0.064	-0.064	-0.021	0.013	0.063	0.060	0.086	0.085	0.087	0.091	0.126	0.159	0.166	0.213	0.268
24	-0.069	-0.043	0.000	0.037	0.094	0.103	0.126	0.120	0.132	0.145	0.173	0.190	0.193	0.223	0.275
25	-0.033	-0.021	0.016	0.050	0.101	0.113	0.135	0.131	0.120	0.127	0.150	0.164	0.160	0.181	0.230
26	-0.012	-0.002	0.036	0.071	0.116	0.117	0.130	0.118	0.116	0.120	0.138	0.139	0.136	0.159	0.202
27	-0.022	-0.010	0.037	0.070	0.113	0.119	0.126	0.109	0.110	0.113	0.139	0.139	0.137	0.146	0.187

Table 2 Correlation Coefficients Between Like Wind Components (Page 2 of 2)

INTERLEVEL CORRELATION COEFFICIENTS BETWEEN LIKE WIND COMPONENTS
ZONAL BELOW DIAGONAL MERIDIONAL ABOVE DIAGONAL
DATA: KSC SC RAWINSONDE FEBRUARY
NUMBER OF PROFILES: 1074

	15	16	17	18	19	20	21	22	23	24	25	26	27
0.003	0.006	-0.019	0.007	0.008	0.004	-0.039	-0.032	-0.072	-0.092	-0.080	-0.056	-0.019	0.021
1	0.062	0.043	0.062	0.064	0.057	-0.021	-0.020	-0.091	-0.090	-0.102	-0.042	-0.007	0.017
2	0.240	0.220	0.244	0.227	0.190	0.097	0.034	-0.044	-0.061	-0.094	-0.027	-0.004	0.010
3	0.379	0.370	0.385	0.343	0.290	0.195	0.092	-0.005	-0.033	-0.058	-0.001	0.023	0.029
4	0.455	0.440	0.453	0.403	0.348	0.249	0.118	0.011	-0.016	-0.033	0.004	0.040	0.048
5	0.514	0.495	0.507	0.449	0.373	0.269	0.135	0.019	-0.014	-0.029	0.002	0.038	0.044
6	0.587	0.557	0.550	0.498	0.418	0.299	0.139	0.036	0.005	-0.016	-0.010	0.022	0.030
7	0.635	0.604	0.585	0.531	0.435	0.317	0.151	0.038	0.022	0.003	-0.007	0.022	0.027
8	0.648	0.620	0.595	0.538	0.438	0.319	0.142	0.049	0.034	0.019	0.008	0.024	0.029
9	0.681	0.644	0.615	0.552	0.466	0.338	0.147	0.066	0.063	0.031	0.019	0.024	0.023
10	0.705	0.663	0.635	0.569	0.491	0.333	0.154	0.083	0.095	0.070	0.051	0.044	0.053
11	0.734	0.689	0.650	0.583	0.506	0.343	0.158	0.096	0.103	0.059	0.049	0.053	0.062
12	0.765	0.731	0.682	0.615	0.530	0.357	0.147	0.098	0.106	0.059	0.046	0.068	0.081
13	0.811	0.769	0.720	0.651	0.548	0.371	0.138	0.090	0.109	0.085	0.036	0.052	0.052
14	0.893	0.822	0.771	0.706	0.596	0.400	0.169	0.094	0.101	0.082	0.057	0.060	0.055
15	1.000	0.894	0.807	0.746	0.640	0.424	0.230	0.113	0.110	0.106	0.053	0.066	0.053
16	0.870	1.000	0.875	0.776	0.662	0.451	0.249	0.140	0.125	0.103	0.061	0.071	0.044
17	0.747	0.851	1.000	0.842	0.694	0.481	0.289	0.193	0.167	0.131	0.102	0.081	0.049
18	0.605	0.663	0.801	1.000	0.780	0.516	0.360	0.241	0.183	0.146	0.103	0.108	0.089
19	0.543	0.603	0.658	0.755	1.000	0.657	0.407	0.322	0.236	0.180	0.158	0.138	0.093
20	0.475	0.530	0.551	0.545	0.681	1.000	0.561	0.376	0.314	0.233	0.201	0.179	0.108
21	0.359	0.399	0.419	0.461	0.495	0.660	1.000	0.645	0.462	0.359	0.305	0.234	0.136
22	0.341	0.375	0.393	0.428	0.483	0.548	0.729	1.000	0.674	0.465	0.421	0.309	0.178
23	0.292	0.303	0.320	0.368	0.416	0.527	0.614	0.774	1.000	0.655	0.477	0.339	0.233
24	0.290	0.281	0.309	0.350	0.387	0.443	0.611	0.690	0.771	1.000	0.613	0.390	0.302
25	0.258	0.263	0.270	0.311	0.354	0.411	0.503	0.624	0.685	0.812	1.000	0.715	0.472
26	0.221	0.235	0.248	0.288	0.334	0.391	0.492	0.552	0.640	0.764	0.857	1.000	0.717
27	0.208	0.219	0.226	0.264	0.299	0.343	0.459	0.535	0.581	0.736	0.801	0.902	1.000

Table 3 Correlation Coefficients Between Unlike Wind Components (Page 1 of 2)

Source: Subroutine QUAD

Input File: SERCOMKSC.TXT (KSC serially complete Rawinsonde, 1956-74)

Output File: CORBKSC2.TXT

INTERLEVEL CORRELATION COEFFICIENTS BETWEEN UNLIKE WIND COMPONENTS
ZONAL WITH MERIDIONAL BELOW DIAGONAL, MERIDIONAL WITH ZONAL ABOVE DIAGONAL
INTRALEVEL CORRELATION COEFFICIENTS BETWEEN UNLIKE WIND COMPONENTS ARE ON THE DIAGONAL
DATA: KSC SC RAWINSONDE FEBRUARY
NUMBER OF PROFILES: 1074

	0.003	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.003	-0.261	0.142	0.032	-0.094	-0.175	-0.217	-0.249	-0.265	-0.280	-0.280	-0.275	-0.260	-0.220	-0.199	-0.205
1	-0.389	-0.028	-0.070	-0.167	-0.254	-0.288	-0.319	-0.331	-0.348	-0.336	-0.328	-0.320	-0.286	-0.230	-0.218
2	-0.294	0.020	0.008	-0.074	-0.156	-0.191	-0.222	-0.243	-0.254	-0.249	-0.238	-0.237	-0.209	-0.162	-0.146
3	-0.204	0.105	0.116	0.044	-0.042	-0.087	-0.118	-0.138	-0.156	-0.164	-0.170	-0.183	-0.164	-0.127	-0.108
4	-0.129	0.160	0.173	0.113	0.034	-0.020	-0.050	-0.066	-0.080	-0.094	-0.106	-0.126	-0.110	-0.079	-0.058
5	-0.064	0.193	0.219	0.174	0.111	0.050	0.013	0.002	-0.015	-0.031	-0.037	-0.059	-0.058	-0.036	-0.023
6	0.017	0.247	0.292	0.257	0.205	0.151	0.112	0.091	0.082	0.063	0.051	0.026	0.021	0.038	0.037
7	0.087	0.293	0.345	0.323	0.268	0.217	0.186	0.165	0.158	0.134	0.120	0.101	0.088	0.105	0.101
8	0.121	0.315	0.367	0.356	0.306	0.257	0.223	0.206	0.199	0.174	0.161	0.144	0.126	0.135	0.130
9	0.143	0.313	0.360	0.367	0.323	0.281	0.245	0.228	0.228	0.215	0.203	0.185	0.167	0.167	0.164
10	0.129	0.271	0.331	0.339	0.298	0.263	0.234	0.211	0.216	0.218	0.216	0.199	0.182	0.179	0.180
11	0.139	0.265	0.332	0.332	0.294	0.265	0.246	0.217	0.221	0.228	0.235	0.228	0.214	0.214	0.211
12	0.132	0.252	0.326	0.324	0.288	0.262	0.245	0.216	0.216	0.221	0.232	0.233	0.227	0.234	0.228
13	0.149	0.261	0.334	0.348	0.324	0.306	0.294	0.270	0.272	0.266	0.265	0.257	0.255	0.286	0.280
14	0.154	0.278	0.339	0.344	0.327	0.308	0.303	0.282	0.283	0.275	0.268	0.252	0.253	0.264	0.276
15	0.156	0.288	0.336	0.335	0.328	0.308	0.303	0.286	0.288	0.276	0.259	0.232	0.231	0.238	0.212
16	0.148	0.261	0.319	0.324	0.306	0.287	0.277	0.263	0.268	0.255	0.229	0.215	0.211	0.225	0.204
17	0.132	0.235	0.299	0.298	0.279	0.249	0.241	0.230	0.231	0.210	0.189	0.169	0.173	0.190	0.193
18	0.156	0.241	0.293	0.301	0.286	0.250	0.243	0.229	0.232	0.211	0.186	0.172	0.181	0.206	0.196
19	0.150	0.218	0.253	0.247	0.238	0.198	0.197	0.178	0.176	0.152	0.121	0.109	0.116	0.141	0.122
20	0.184	0.209	0.265	0.240	0.238	0.208	0.206	0.198	0.180	0.158	0.131	0.111	0.111	0.129	0.095
21	0.090	0.120	0.135	0.118	0.110	0.067	0.061	0.054	0.046	0.035	0.033	0.031	0.021	0.041	0.021
22	0.061	0.078	0.067	0.057	0.060	0.046	0.026	0.010	0.013	-0.005	0.007	-0.003	-0.004	0.011	-0.001
23	0.044	0.057	0.064	0.058	0.054	0.053	0.036	0.015	0.020	0.009	0.020	0.018	0.022	0.037	0.033
24	0.048	0.079	0.079	0.078	0.098	0.088	0.086	0.068	0.074	0.071	0.065	0.070	0.101	0.083	0.080
25	-0.048	-0.023	0.005	0.001	0.010	-0.006	-0.021	-0.042	-0.052	-0.070	-0.065	-0.049	-0.046	-0.050	-0.014
26	-0.092	-0.027	-0.016	-0.024	-0.008	-0.021	-0.033	-0.055	-0.060	-0.078	-0.079	-0.057	-0.051	-0.040	-0.011
27	-0.068	-0.014	-0.018	-0.024	-0.014	-0.028	-0.037	-0.061	-0.062	-0.063	-0.049	-0.033	-0.026	-0.043	-0.024

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13. ABSTRACT *(Maximum 200 words)*

The background, theoretical concepts, and methodology for construction of vector wind profiles based on a statistical model are presented. The derived monthly vector wind profiles are to be applied by the launch vehicle design community for establishing realistic estimates of critical vehicle design parameter dispersions related to wind profile dispersions. During initial studies a number of months are used to establish the model profiles that produce the largest monthly dispersions of ascent vehicle aerodynamic load indicators. The largest monthly dispersions for wind, which occur during the winter high-wind months, are used for establishing the design reference dispersions for the aerodynamic load indicators. This document includes a description of the computational process for the vector wind model including specification of input data, parameter settings, and output data formats. Sample output data listings are provided to aid the user in the verification of test output.

14. SUBJECT TERMS
vector wind profiles, vector wind model, wind profile dispersions, design reference dispersions, aerodynamic load indicators

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