TECHNIQUES FOR THE COMPUTATION OF WIND, CEILING, AND EXTINCTION—ETC(U)

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TECHNIQUES FOR THE COMPUTATION OF WIND, CEILING, AND EXTINCTION COEFFICIENT USING CURRENTLY ACQUIRED RPV DATA

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Proper deployment and accurate targeting of precision guided munitions depend partly on knowledge of wind velocity, ceiling, and electro-optical extinction in the target area; and knowledge of wind in the target area is crucial for the correct placement of smoke munitions. Wind velocity, ceiling, and volume extinction coefficient in the data silent region near the target may be computed by methods developed in this report using only data currently.
acquired by a remotely piloted vehicle of the type now being developed for use by the Army. No new instrumentation is required. The required input consists of flight data and data from an on-board imaging system.
CONTENTS

LIST OF FIGURES................................................................. 4
LIST OF TABLES......................................................................... 5
1. INTRODUCTION....................................................................... 7
2. ALGORITHMS......................................................................... 8
  2.1 Wind Velocity...................................................................... 8
    2.1.1 First Technique: Distance and Time Input...................... 8
    2.1.2 Second Technique: Drift or Correction Angle Input......... 12
    2.1.3 A Shorter Version....................................................... 12
  2.2 Volume Extinction Coefficient.......................................... 12
    2.2.1 Technique A: Overflight of Target................................. 16
    2.2.2 Technique B: Standoff from Target.............................. 19
    2.2.3 Computation of Radiance from Voltage......................... 20
    2.2.4 Computer Programs..................................................... 21
  2.3 Ceiling.............................................................................. 21
3. SAMPLE COMPUTER RUNS....................................................... 26
  3.1 Wind Velocity...................................................................... 26
  3.2 Extinction Coefficient and Ceiling..................................... 26
4. CONCLUSION........................................................................... 35
APPENDIX. COMPUTER CODES IN BASIC FOR THE RPV PROGRAMS.... 36
LIST OF FIGURES

Figure 1. Flowchart of the first technique for computation of wind velocity ........................................... 9

Figure 2. Illustration of the computation of wind velocity by the first algorithm where the orientation is "left," C > 0 and D < 0, and both Dr₁ and Dr₂ are known ........................................... 11

Figure 3. Flowchart of the second technique for the computation of wind velocity ............................................ 13

Figure 4. Illustration of the computation of wind velocity by the second algorithm where the orientation is "right," C > 0 and D < 0, and both Dr₁ and Dr₂ are known .................... 15

Figure 5a. The geometry for finding the volume extinction coefficient (k = k'm) by viewing the same target .......... 17

Figure 5b. Finding k by viewing two closely similar targets .............................................................. 17

Figure 5c. Finding k by viewing the same target along different slant paths (different angles, both > 0°) .......... 18

Figure 6. Flowchart of technique A for estimation of volume extinction coefficient ........................................ 22

Figure 7. Flowchart of technique A for estimation of volume extinction coefficient using voltage input .......... 23

Figure 8. Flowchart of technique B for estimation of volume extinction coefficient ........................................ 24

Figure 9. Change in the flowchart (figure 8) for estimation of extinction coefficient with two slant paths when voltage input replaces radiance input ........................................ 25

Figure 10. Geometry for estimation of ceiling (c = h + z) ................. 27

Figure 11. Flowchart for the estimation of ceiling .............................................................. 28

Figure 12. Use of method 1 to compute wind velocity .............................................................. 29

Figure 13. Use of method 1 to compute wind velocity when both Dr₁ and Dr₂ are known ........................................ 30

Figure 14. Use of method 2 to compute wind velocity when both Dr₁ and Dr₂ are known ........................................ 31

Figure 15. Use of method 2 to compute wind velocity .............................................................. 32
LIST OF TABLES

TABLE 1. COMPUTER OUTPUT FOR THE FOUR EXAMPLES OF FIGURES 12 THROUGH 15 .................................................... 33

TABLE 2. SAMPLE COMPUTATIONS OF VOLUME EXTINCTION COEFFICIENT USING TECHNIQUE A WITH RADIANCE INPUT .................. 33

TABLE 3. SAMPLE COMPUTATIONS OF VOLUME EXTINCTION COEFFICIENT USING TECHNIQUE B WITH RADIANCE INPUT .................. 34

TABLE 4. SAMPLE COMPUTATION OF CEILING ........................................ 34

TABLE 5. SAMPLES OF OUTPUT FROM THE COMPUTER PROGRAMS FOR CEILING AND VOLUME EXTINCTION COEFFICIENT .............. 35
1. INTRODUCTION

Proper deployment and accurate targeting of precision guided munitions depend partly on knowledge of wind velocity, ceiling, and electro-optical extinction in the target area. Knowledge of wind in the target area is crucial for the correct placement of smoke munitions, since wind velocity near the location where the artillery is deployed may differ considerably from that near the target. The ability to accurately estimate atmospheric characteristics in the target area also should permit the more efficient use of both guided and unguided munitions and thereby reduce the number of rounds needed to accomplish a specific task.

Wind velocity, ceiling, and volume extinction coefficient may be computed by methods (developed in this report) that use only data currently acquired by a remotely piloted vehicle (RPV). No new instrumentation is required; the input consists of flight data and data from an on-board imaging system. Since some of the principal uses of RPV now and in the near future\(^1\) are surveillance of enemy-held territory and target detection and designation, techniques developed herein may be used to describe the above atmospheric variables in the data silent region near the target while the aircraft performs other missions such as surveillance. (See Robinson\(^2\) for a general description of a number of RPV and their instrumentation and Elson\(^3\) for information on the RPV system being developed for the Army.)

The data for the first algorithm for wind velocity, which uses along-wind information, consists of heading, airspeed, and ground speed (or distance flown and time to fly that distance) for two perpendicular courses. The second wind velocity algorithm, which uses crosswind information, requires heading, airspeed, and drift or correction angle for two perpendicular courses. Input for the algorithm for computation of volume extinction coefficient consists of horizontal flight or ground distance, altitude, angles between the vertical and the line of sight (LOS) to the radiating surface, and radiances or equivalent voltages from the radiating surface to the RPV over two separate paths. The ceiling algorithm includes horizontal flight or ground distance, altitude, angle between the flight path and the LOS to the cloudbase, and the angle between the flight path and the LOS to a landmark vertically below the viewed cloudbase. These methods are embodied in computer programs that can be run on a desktop computer. An alternate shorter program is presented for calculation of wind velocity when both headings are known. The computer codes, in BASIC, are shown in the appendix.


\(^3\)B. M. Elson, 1980, "Mini-RPV Being Developed for Army," Aviation Week and Space Technology, 7 January 1980, pp 2-7
2. ALGORITHMS

The algorithms described in this report are mathematically simple and easy to understand. The manual versions of these procedures require only a simple calculator or trigonometric tables, graph paper, a fine-scaled ruler, and a pencil and paper. A desktop computer able to use BASIC is sufficient to perform the automated versions. The operator need only type in the requested quantities.

2.1 Wind Velocity

2.1.1 First Technique: Distance and Time Input

The input data are (1) airspeed in meters per second along the initial course and the second perpendicular path (X and Y), (2) distance in meters along each path and the associated time in seconds (D_{X}, T_{X} and D_{Y}, T_{Y}), and (3) heading (direction to) of each course (D_{R1} and D_{R2}). To obtain ground speed (X_{g} and Y_{g}), simply divide the distances by the appropriate times (X_{g} = D_{X}/T_{X}, Y_{g} = D_{Y}/T_{Y}). Subtracting X from X_{g} gives the difference C; similarly Y_{g} - Y = D. The windspeed (V) is computed from the formula for the hypotenuse of a right triangle. \( V = \sqrt{C^2 + D^2} \).

The computation of wind direction (Dir) in the desktop computer version requires values of C, D, D_{R1}, and D_{R2}. If either D_{R1} or D_{R2} is missing (input a 999 for the missing value) two values of Dir are computed, one of which is correct. The correct value may be determined with the aid of other information (for example, a synoptic chart can indicate which of the two values is most likely). When both D_{R1} and D_{R2} are not available, a message is printed saying that no directions were given or computed. A further condition for the computation of direction is whether the orientation of the flight paths is "right" or "left." In the context of this report, the orientation is determined by whether the Y vector is to the right or left of the X vector when facing the direction of flight along the X vector (that is, toward D_{R1}). Numerically, "right" occurs when D_{R2} > D_{R1} (360° added to D_{R2} if D_{R1} < 90° and 270° < D_{R1} < 360°) and "left" occurs when D_{R1} > D_{R2} (360° added to D_{R1} if D_{R1} < 90° and 270° < D_{R2} < 360°).

A "flowchart" (partly in plain English) can provide a better understanding of the intricacies of the first method than a written explanation which could be tedious and somewhat confusing for the reader. Such a chart is presented in figure 1. Figure 2 illustrates the computation of wind velocity for a left orientation when C > 0 and D < 0, in the case of both D_{R1} and D_{R2} known. These two figures should be used together to gain a basic understanding of the first technique.

The present form of this algorithm uses distance flown and time to fly that distance to compute ground speed. Simple modifications to the program will permit ground speed to be input directly. The input routine would need a slight modification, and the simple computation of ground speed would be eliminated.
Input for two perpendicular courses:
1. Airspeeds in meters/second (X, Y)
2. Distances in meters (DX, DY)
3. Times in seconds (TX, TY)
4. Headings (Dr1, Dr2)

Compute ground speed
\[ X_g = \frac{D_x}{T_x} \]
\[ Y_g = \frac{D_y}{T_y} \]

Compute parallel components
of the wind
\[ C = X_g - X \]
\[ D = Y_g - Y \]

Compute the wind speed
\[ V = (C^2 + D^2)^{1/2} \]

Compute angles (P, Q) relating
wind and flight directions
\[ P = \arctan \frac{C}{D} \]
\[ Q = \arctan \frac{D}{C} \]

Set flag for C and D with the
same sign (L = 1) or opposite
signs (L = 0)

Is Dr1, and/or Dr2 unknown?

Dr2 missing
Set Dr2 = Dr1 + 90°
Is this step in the
first or second pass?
No
Dr2 = Dr2 + 360°
Yes
Dr2 = Dr2 - 360°
Is Dr2 < 0?
No
Is Dr2 > 360°?
No
First
Dr1 missing
Set Dr1 = Dr2 + 90°
Is this step in the
first or second pass?
No
Dr1 = Dr1 - 90°
Yes
Dr1 = Dr1 + 360°
Is Dr1 < 0?
No
Is Dr1 > 360°?
No
Print "no direction given
or computed"
Print value for windspeed

Figure 1. Flowchart of the first technique for computation of wind velocity.
Figure 1 (cont.)
Figure 2. Illustration of the computation of wind velocity by the first algorithm where the orientation is "left," $C > 0$ and $D < 0$, and both $Dr_1$ and $Dr_2$ are known. $X$ and $Y$ are airspeeds and $X_g$ and $Y_g$ are ground speeds. $C = X_g - X$ and $D = Y_g - Y$. $V$ is the wind vector and $P$ and $Q$ are computed by the arctangents of the absolute values of $C/D$ and $D/C$, respectively. $Dr_1$ and $Dr_2$ are the directions toward which the RPV flies along the $X$ and $Y$ flight paths, respectively. In this example, the wind is blowing from a direction slightly less than 90°.
2.1.2 Second Technique: Drift or Correction Angle Input

The input data are (1) airspeed in meters per second along the two perpendicular courses (X and Y), (2) a flag to indicate whether drift (I = 1) or correction (I = -1) angles are utilized, (3) the drift or correction angles (A and B) in degrees, and (4) the heading of each course (Dr1 and Dr2). An angle is considered positive if it describes an arc running to the right of the flight path when facing in the direction of flight. The tangent of the angle times the relevant airspeed gives the crosswind component for each course. 

\[ C = X \tan A, \quad D = Y \tan B. \]

The windspeed \( V \) is computed from the same formula as in the first algorithm; that is \[ V = \left( C^2 + D^2 \right)^{1/2}. \]

The computation of wind direction (Dir) requires \( C, D, Dr1, \) and \( Dr2 \) as input. If either \( Dr1 \) or \( Dr2 \) is missing (input a 999 for the missing value) two values of Dir are computed, one of which is correct. When both \( Dr1 \) and \( Dr2 \) are missing, a message is printed saying that no directions were given or computed. The orientation, left or right, is determined as in the first method.

A "flowchart" similar to that of figure 1 is presented in figure 3, but for the second method. Figure 4 illustrates the computation of wind velocity for a right orientation where \( C > 0 \) and \( D < 0 \), when both \( Dr1 \) and \( Dr2 \) are known. These two figures should be used together to gain a basic understanding of the second technique.

2.1.3 A Shorter Version

A shorter version of the computer program was developed that has about two-thirds the number of statements and storage requirement as the program described in sections 2.1.1 and 2.1.2 of this report. To reduce the number of statements, it was assumed that \( Dr1 \) and \( Dr2 \) would always be known. If either direction is unknown, this program can be run twice with the unknown direction = the known direction +90°. (One of the two velocities will be correct.) Consequently, all statements associated with the extra computation required to handle the cases of either \( Dr1 \) or \( Dr2 \) unknown were removed, along with those activated when both directions were missing. A listing of the shorter version is in the appendix along with the listing of the complete version. Figures 2 and 4 illustrate the output from the shorter program.

2.2 Volume Extinction Coefficient

The computer programs for the calculation of volume extinction coefficient require the input of either (1) horizontal flight or ground distance, (2) altitude, (3) or both distance and altitude. If either distance or altitude is unknown, then (4) the angle between the vertical and the slant path (technique A) or (5) the angles between the vertical and the two slant paths (technique B) are input. Finally (6) radiances or (7) equivalent voltages are entered for the respective views of the radiating surface(s).

The equations are derived by first assuming that the vertical distribution and amount of scatterers and absorbers in any vertical column of the same height are constant over the area of interest. This assumption is reasonable to a fair accuracy over small areas of the order of a few tens of square kilometers or less, not in the immediate vicinity of atmospheric "discontinuities" such
Input for two perpendicular courses:
(1) Airspeed in m/s (X, Y)
(2) Whether using drift (I = 1) or correction (I = -1) angle
(3) Angles in degrees (A, B)
+ if to right of direction of flight
- if to left of direction of flight
(4) Headings (Dr₁, Dr₂)

A = I x A
B = I x B

* Compute perpendicular components of the wind
C = X tan A
D = Y tan B

Compute windspeed
V = (C² + D²)½

Compute angles relating wind and flight directions
P = arctan IC/DI
Q = arctan IO/CI

Set flag for C and D with the same sign (L = 1)
or opposite signs (L = 0)

Neither missing

Dr₂ missing
Set Dr₂ = Dr₁ + 90°

Is this step in the first or second pass?
First
Second
Dr₂ = Dr₁ - 90°

Is Dr₂ < 0
Yes
Dr₂ = Dr₂ + 360°

Is Dr₂ > 360°
Yes
Dr₂ = Dr₂ - 360°

Dr₁ missing
Set Dr₁ = Dr₂ + 90°

Is this step in the first or second pass?
First
Second
Dr₁ = Dr₁ - 90°

Is Dr₁ < 0
Yes
Dr₁ = Dr₁ + 360°

Is Dr₁ > 360°
Yes
Dr₁ = Dr₁ - 360°

Both missing

Print "No direction given or computed"
Print value for windspeed

Figure 3. Flowchart of the second technique for the computation of wind velocity.
Set Dir = Dr₁ - P

Determine whether headwind or tailwind

(1) If Dr₁ < 90° and 270° ≤ Dr₂ ≤ 360°
then Dr₁ = Dr₁ + 360°
If Dr₂ < 90° and 270° ≤ Dr₁ ≤ 360°
then Dr₁ = Dr₁ + 360°
(2) Tailwind if:
(a) D > 0 and Dr₁ > Dr₂
(b) D < 0 and Dr₁ < Dr₂

Determine orientation
"Right" if Dr₁ < Dr₂
"Left" if Dr₁ > Dr₂

Is orientation "right" and
L = 1 (C and D have same sign)?
or
Is orientation "left" and
L = 0 (C and D have opposite signs)?
Yes
Dir = Dr₁ + P

Set Dir = Dr₂ + Q

Determine whether headwind or tailwind

(1) Same as for (a)
(2) Tailwind if:
(a) C < 0 and Dr₁ > Dr₂
(b) C > 0 and Dr₁ < Dr₂

Determine orientation as for (a)

Is orientation "right" and
L = 1?
or
Is orientation "left" and
L = 0?
Yes
Dir = Dir₂ - Q

Is there a tailwind?

Yes
Dir = Dir + 180°

Is Dir > 360°?

Yes
Dir = Dir - 360°

Is Dir < 0?

Yes
Dir = Dir + 360°

Is the input value of Dr₁ or Dr₂ unknown
and does this step end the first pass?

Yes
Return to (*) above

Print values of windspeed and direction
(2 values if each if Dr₁ or Dr₂ unknown)

---

Figure 3 (cont)
Figure 4. Illustration of the computation of wind velocity by the second algorithm where the orientation is "right," $C > 0$ and $D < 0$, and both $Dr_1$ and $Dr_2$ are known. The variables shown are the same as in figure 2 except that $A$ and $\beta$ are the drift angles (correction angles) for the X and Y flight paths, respectively. The crosswind components are $C = X \tan A$ and $B = Y \tan B$. In this example, the wind is from slightly less than $360^\circ$. 

\[ 0^\circ \text{ or } 360^\circ\] 

\[ 180^\circ \] 

\[ 270^\circ \] 

\[ 90^\circ \] 

\[ Dr_2 \quad D < 0 \quad \beta \] 

\[ \phi \] 

\[ Y \] 

\[ X \] 

\[ Dr_1 \] 

\[ C > 0 \]
as a sharp front. Therefore, between a given flight level and the ground, a change in total mass of absorber or scatterer roughly is dependent only on the difference in path length.

Taking the ratio of two radiances from the same source but over different path lengths and using Beer's law, we have:

\[
\frac{R_2}{R_1} = R_0 e^{-k'mZ_2} / R_0 e^{-k'mZ_1}
\]

where \(R = \text{radiance}, \ k' = \text{mass extinction coefficient, } m = \text{mass of absorber and scatterer per unit volume, } Z_1 \text{ and } Z_2 \text{ are path lengths, and the subscripts } 0, 1, 2 \text{ refer to values at the source and at the sensor for the two paths, respectively. If we let the volume extinction coefficient } (k) = k'm, \text{ and we factor out } R_0, \text{ we have}

\[
\frac{R_2}{R_1} = e^{-kZ_2} / e^{-kZ_1}
\]

\[
= e^{-kZ_2 + kZ_1}
\]

\[
= e^{k(Z_1 - Z_2)}
\]

Taking the lograithm, we have:

\[
\ln \left( \frac{R_2}{R_1} \right) = k (Z_1 - Z_2)
\]

and for \(k:\)

\[
k = \ln \left( \frac{R_2}{R_1} \right) / (Z_1 - Z_2)
\]

(1)

If the RPV can fly directly over the radiating surface, we can use technique A (see figures 5a and 5b). If overflight is not possible, then use technique B (figure 5c). These techniques are described below; the reader should refer to the appropriate figure (5a, b, or c) in the following descriptions.

2.2.1 Technique A: Overflight of Target

Here we assume overflight is possible. The RPV observes two surfaces of closely similar properties such as different regions of a lake with a very nearly uniform surface temperature, or it looks at the same surface, once vertically and again along a slant path.
Figure 5a. The geometry for finding the volume extinction coefficient \( k = k' m \) by viewing the same target. \( k' = \text{mass extinction coefficient}, m = \text{mass of absorber and scatter per unit distance.} \) \( x = \text{ground or horizontal distance}, \beta = \text{angle between vertical and line of sight to target, and } z_1 \text{ and } z_2 \text{ are the vertical and slant paths.} \)

Figure 5b. Finding \( k \) by viewing two closely similar targets. Variables are as in 5a.
Figure 5c. Finding k by viewing the same target along different slant paths (different angles, both > 0°). Here Z = altitude, Z₁ and Z₂ = slant paths, R₁ and R₂ = respective radiances, β₁ and β₂ = angles between the line of sight to the target and the vertical, and X₁ and X₂ are horizontal distances along the ground or flight path.
Referring to figures 5a and 5b, we see that $X = \text{distance along the ground}$, $Z = Z_1 = \text{altitude (vertical path)}$, $Z_2 = \text{slant path}$, and $\theta = \text{angle between the vertical and the slant path}$.

a. If $X$ and $Z$ are known but not $\theta$, then

$$\theta = \arctan \left( \frac{X}{Z} \right)$$

and $Z_2 = Z / \cos \theta$.

b. If $Z$ and $\theta$ are known but not $X$, then as in a

$$Z_1 = Z / \cos \theta.$$  

c. If $X$ and $\theta$ are known but not $Z$, then

$$Z_1 = \frac{X}{\sin \theta}$$

and $Z = \frac{X}{\tan \theta}$.

Using equation (1) and the above geometrical relationships, we have for the first two cases (a, b):

$$k = \ln \left( \frac{R_1}{R_2} \right) / Z (1 - 1 / \cos \theta) \quad (2)$$

and for the third case (c)

$$k = \ln \left( \frac{R_2}{R_1} \right) / X (1 / \tan \theta - 1 / \sin \theta) \quad (3)$$

2.2.2 Technique B: Standoff from Target

Here we assume overflight is not possible. The RPV views the same surface from two different angles (neither path vertical as in figure 5c) or views two closely similar surfaces (no figure shown).

Referring to figure 5c, we see that $X_1$ and $X_2 = \text{horizontal distances along the flight path or the ground}$, $Z = \text{altitude}$, $Z_1$ and $Z_2$ are slant paths, and $\theta_1$ and $\theta_2$ are the respective angles between $Z_1$ and $Z_2$ and the vertical. Therefore:

d. If $X_1$, $X_2$ and $Z$ are known but not $\theta_1$, $\theta_2$, then

$$\theta_1 = \arctan \left( \frac{X_1}{Z} \right)$$

and $Z_1 = Z / \cos \theta_1$, $Z_2 = Z / \cos \theta_2$.

e. If $Z$ and $\theta_1$, $\theta_2$ are known but not $X_1$, $X_2$, then as in d

$$Z_1 = Z / \cos \theta_1$$

and $Z = Z / \cos \theta_2$.
f. If \( X_1, X_2 \) and \( \theta_1, \theta_2 \) are known* but not \( Z \), then

\[
Z_1 = \frac{X_1}{\sin \theta_1}, \quad Z_2 = \frac{X_2}{\sin \theta_2}
\]

and

\[
Z = \frac{X_1}{\tan \theta_1} = \frac{X_2}{\tan \theta_2}
\]

Using equation (1) and the above geometrical relationships, we have for cases d and e:

\[
k = \ln \left( \frac{R_2}{R_1} / Z(1/\cos \theta_1 - 1/\cos \theta_2) \right)
\]  

(4)

and for case f:

\[
k = \ln \left( \frac{R_2}{R_1} / \left( \frac{X_1}{\sin \theta_1} - \frac{X_2}{\sin \theta_2} \right) \right)
\]  

(5)

However, for \( \theta_1 = 0 \) (see figure 5c) equation (5) fails. To avoid this problem, replace \( \frac{X_1}{\sin \theta_1} \) with \( Z = \frac{X_2}{\tan \theta_2} \) for small values of \( \theta_1 \) (several degrees or less). Therefore, in place of equation (5) use:

\[
k = \ln \left( \frac{R_2}{R_1} / \frac{X_2}{\tan \theta_2} - 1/\sin \theta_2 \right)
\]  

(6)

Note that equations (6) and (3) are the same, where \( X_2 = X \) and \( \theta_2 = \theta \) (compare figures 5a and 5c).

2.2.3 Computation of Radiance from Voltage

Modifications of the two techniques were developed where radiance is not input directly, but is computed from voltages. Commonly, sensors use devices that transform received energy into voltages, which in turn are converted into radiances by the means of some algorithm. Although the form of the conversion algorithm may differ from one sensor to another (for example, linear or quadratic), a simple linear form was used here only to indicate how such equations would fit into the techniques described in this report. The equations have the form \( R = a + bV \) where \( R = \) radiance, \( V = \) voltage, and \( a \) and \( b \) are constants determined empirically during calibration. It is assumed that one voltage is produced for each of the two views of the radiating surface or target, yielding the two required radiances.

*These computations may be performed if either \( \theta_1 \) or \( \theta_2 \) is known. For example, if \( X_1 \) and \( \theta_1 \) are known, we can compute \( Z_1 \) and \( Z \). Having \( Z \) and \( X_2 \), we can then calculate \( \theta_2 \).
2.2.4 Computer Programs

Four "flowcharts" were constructed to enable the reader to understand the computer programs more easily and to avoid the possible confusion an entirely written explanation would cause. The reader should refer to figure 5 when viewing these flowcharts. Figure 6 shows the chart for technique A, where the RPV can overfly the target (= radiating surface) and radiances are input. Figure 7 presents the chart for technique A when voltages are input. Figure 7 differs from figure 6 in the substitution of the voltage input and conversion algorithm in place of the radiance input statement. Figure 8 has the flowchart for technique B, where the RPV cannot overfly the target and radiances are input. Figure 9 illustrates the difference in the flowchart for technique B when voltage input replaces radiance input; the entire flowchart is not shown. The programs for both techniques are presented in the appendix.

2.3 Ceiling

Ceiling (c) may be computed by using simple geometry and data from an RPV carrying a movable sensor active in any imaging wavelength region. The required input includes (1) upward elevation angle which is the angle between the flight path and the LOS to cloudbase, and either (2) horizontal flight or ground distance, (3) altitude, or (4) both altitude and distance. If only altitude or distance is known, then input (5) the depression angle which is the angle between the flight path and the LOS to a landmark vertically below the view of the cloudbase.

Referring to figure 10, we have for the ceiling

\[ c = h + Z \]

where \( Z \) = altitude and \( h \) = vertical distance from flight level to cloudbase. Furthermore, \( h = Xtan \beta \), where \( X \) = horizontal flight or ground distance and \( \beta \) = upward elevation angle. Substituting for \( h \), we have for the case of \( X \) and \( Z \) known:

\[ c = Z + Xtan \beta. \quad (7) \]

If \( X \) is known but not \( Z \), we have for \( Z \)

\[ Z = Xtan \alpha, \]

where \( \alpha \) = depression angle. Using equation (7) and substituting for \( Z \), we have for \( c \)

\[ c = Xtan \alpha + Xtan \beta \]
\[ = X(tan \alpha + tan \beta). \]

If \( Z \) is known but not \( X \), we have for \( X \)

\[ X = Z \, ctn \alpha \]
Set horizontal distance \((X)\) and altitude \((Z)\) = 0

Set flag: 
1 = 1, only distance known
1 = 2, only altitude known
1 = 3, both known

1 = 1

Input distance \((X)\) in meters

Input angle \((\beta)\) between vertical and slant path in degrees

Input vertical and slant path radiances \((R, R'')\)

Change units of \(X\) and \(Z\) to kilometers

Does \(I = 3\) ?

Yes: \(\beta = \arctan (X/Z)\)

No: \(\alpha = \log (R/R_1)\)

Does \(Z = 0\) ?

Yes: Compute value of extinction coefficient \((\alpha)\):
\[\alpha = \alpha_0 / (X^2 + (1/T\tan(\beta) - 1/\sin(\beta)))\]

No: Compute value of extinction coefficient \((\alpha)\):
\[\alpha = \alpha_0 / (Z^2 + (1/\cos(\beta)))\]

Output value of \(\alpha\)

Figure 6. Flowchart of technique A for estimation of volume extinction coefficient.
Figure 7. Flowchart of technique A for estimation of volume extinction coefficient using voltage input.
Figure 8. Flowchart of technique R for estimation of volume extinction coefficient.
In place of:

- **Input slant path radiances** \((R_1, R_2)\)

substitute:

- **Input voltage coefficients** \((A, B)\)
- **Input voltages for both slant paths** \((V_1, V_2)\)
- **Compute radiances** \((R_1, R_2)\):
  - \(R_1 = A + B \cdot V_1\)
  - \(R_2 = A + B \cdot V_2\)

Figure 9. Change in the flowchart (figure 8) for estimation of extinction coefficient with two slant paths when voltage input replaces radiance input.
Using equation (7) and substituting for $X$, we have for $c$

$$c = Z + Z \cot \alpha \tan \beta$$

$$= Z (1 + \tan \beta/\tan \alpha).$$

It has been assumed that the cloudbase can be observed directly above the landmark from the RPV (see figure 10). The computation of $c$ becomes less accurate as the cloudbase to landmark path departs from vertical, although a departure of only a few degrees is not significant. Furthermore, it is assumed that the distance $X$ is the same for both views, to the cloudbase and to the landmark. The value of $c$ will depart from the real value as the difference in $X$ for the two views. This problem could be solved if a side looking sensor was used or the RPV flew at a low speed and $X$ was large. For example, relatively little degradation will occur if the speed of the RPV $= 20 \text{ ms}^{-1}$, $X = 4000 \text{ m}$, and the sensor viewed both scenes within $2 \text{ s}$.

The program for calculation of ceiling is presented as a "flowchart" in figure 11. The reader also should refer to figure 10 as an aid to understanding the flowchart. The computer code for this program is presented in the appendix.

3. SAMPLE COMPUTER RUNS

3.1 Wind Velocity

Four examples, two for each algorithm, are presented in this section to better demonstrate the computation of wind velocity by the two methods. For each example, a table shows the calculations required and an accompanying graph shows the graphical solution. Each set of one table and one graph is presented in the form of one figure for ease of understanding (figures 12 through 15). Although more than four situations exist (for example, "right" orientation for both $C$ and $D > 0$ and both $D_1$ and $D_2$ known), to include them all for both methods would make this report unnecessarily large and tedious. Table 1 gives the computer output for these four examples.

Figures 12 and 13 present solutions for the first algorithm. In figure 12, $C > 0$ and $D < 0$, and the orientation is not known since only $D_1$ is given. Two solutions are computed, one of which is correct. Figure 13 has a "left" orientation where $C < 0$ and $D > 0$. Figure 2 and section 2.1.1 describe the relevant variables.

Figures 14 and 15 show solutions for the second algorithm. Figure 14 has an orientation that is "left" and $C$ and $D$ are negative. In figure 15, the orientation is unknown since only $D_1$ is known, and $C$ and $D$ are both positive. Figure 4 and section 2.1.2 describe the relevant variables.

3.2 Extinction Coefficient and Ceiling

A series of runs of the ceiling and the extinction coefficient (radiance input) programs were made to illustrate the algorithms. Sample output from the extinction programs that input voltage are not shown here because they essentially repeat the results of the radiance versions and a lengthy series of examples would be unnecessarily tedious. Tables 2 and 3 show computations for both techniques in which both manual and computer-generated values are
shown. Input values are listed with the appropriate equations. The radiance values have no specific units since they could have any standard (or nonstandard) units without affecting the results. In any case, the ratio of the radiances is dimensionless. Also, the values of $k$ in these tables were computed for comparison and technique demonstration purposes, assuming perfect input. In the real world, the last two or three digits to the right of the decimal point probably would be meaningless.

Ceiling computations are shown in table 4 in a format similar to that of tables 2 and 3. Input values are listed along with the appropriate equations and both manual and computer-generated values are shown. Finally, table 5 presents samples of output from the computer programs used to generate the values in tables 2 through 4, and output from the "voltage" versions of the extinction programs.

Figure 10. Geometry for estimation of ceiling ($c = h + z$) where $z =$ altitude, $h =$ height of cloudbase above flight level, $x =$ ground distance, and $\alpha$ and $\beta$ are angles relating $z$ and $h$ to $x$, respectively.
Set horizontal distance (X) and altitude (Z) = 0

Set flag: I = 1, only distance known
I = 2, only altitude known
I = 3, both known

Input upward elevation angle (Beta)

\[ \text{Input distance (X) in meters} \]
\[ \text{and depression angle (Alpha) in degrees} \]

Compute Ceiling (C):
\[ C = X \times (\tan(\text{Alpha}) + \tan(\text{Beta})) \]

Output value of C

Figure 11. Flowchart for the estimation of ceiling.
Figure 12. Use of method 1 to compute wind velocity. Variables are explained in figure 2 and first technique. Only $Dr_2$ is known, and $C > 0$ and $D < 0$. Two values of $Dr_2$, $X$, $X_g$, $V$, $P$, $Q$, $C$, and $D$ are shown because $Dr_1$ may be $15^\circ$ or $195^\circ$. Two wind velocities ($V$) are computed.
Figure 13. Use of method 1 to compute wind velocity when both Dr₁ and Dr₂ are known. Variables are explained in figure 2 and first technique. Here C < 0 and D > 0. The orientation of this figure is "left."
\[ V = \sqrt{C^2 + D^2} = 14.3 \text{ ms}^{-1} \]

\[ P = \arctan \left| \frac{C}{D} \right| = 14.6^\circ \]

\[ Q = \arctan \left| \frac{D}{C} \right| = 75.4^\circ \]

\[ \text{Dir} = \text{Dr}_1 + P = 104.6^\circ \]

**Figure 14.** Use of method 2 to compute wind velocity when both Dr\(_1\) and Dr\(_2\) are known. Variables are explained in Figure 4 and second technique. Both C and D are negative. The orientation of this figure is "left."
\[ A = 50 \text{ ms}^{-1} \quad A = -15^\circ \quad Dr_1 = 245^\circ \quad I = -1 \]
\[ Y = 50 \text{ ms}^{-1} \quad B = -25^\circ \quad Dr_2 = 999^\circ \text{ (unknown)} \]

\[ A = I \times A = 15^\circ \]
\[ B = I \times B = 25^\circ \]
\[ C = X \tan A = 13.4 \text{ ms}^{-1} \]
\[ D = Y \tan B = 23.3 \text{ ms}^{-1} \]

\[ V = (C^2 + D^2)^{1/2} = 26.9 \text{ ms}^{-1} \]

\[ P = \arctan \left| \frac{C}{D} \right| = 29.9^\circ \]
\[ Q = \arctan \left| \frac{D}{C} \right| = 60.1^\circ \]

\[ Dr_2 = Dr_1 \pm 90^\circ = 335^\circ \text{ or } 155^\circ \]

(1) \[ \text{Dir} = Dr_1 - P = 215.1^\circ \]
(2) \[ \text{Dir} = Dr_1 + P + 180 = 454.9 - 360 = 94.9^\circ \]

*Figure 15. Use of method 2 to compute wind velocity. Variables are explained in Figure 4 and second technique. Only Dr_1 is known, and C and D are both positive. More than one value of some variables is shown because Dr_2 may be 155° or 335°. Two wind velocities (V) are computed.*
TABLE 1. COMPUTER OUTPUT FOR THE FOUR EXAMPLES OF FIGURES 12 THROUGH 15. AS NOTED IN THOSE FIGURES, TWO ANSWERS ARE GIVEN WHEN ONE HEARING IS UNKNOWN. THE MOST PROBABLE OF THE TWO WIND DIRECTIONS IS DETERMINED WITH THE AID OF OTHER DATA (FOR EXAMPLE, A SYNOPTIC CHART).

<table>
<thead>
<tr>
<th>Windspeed</th>
<th>Wind direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>39.1 ms⁻¹</td>
<td>245.2°</td>
</tr>
<tr>
<td>39.1 ms⁻¹</td>
<td>324.8°</td>
</tr>
</tbody>
</table>

ONE ANSWER IS CORRECT

<table>
<thead>
<tr>
<th>Windspeed</th>
<th>Wind direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.7 ms⁻¹</td>
<td>1.6°</td>
</tr>
</tbody>
</table>

6 WIND VELOCITY

<table>
<thead>
<tr>
<th>Windspeed</th>
<th>Wind direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.2 ms⁻¹</td>
<td>104.7°</td>
</tr>
</tbody>
</table>

7 WIND VELOCITY

<table>
<thead>
<tr>
<th>Windspeed</th>
<th>Wind direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.9 ms⁻¹</td>
<td>215.1°</td>
</tr>
<tr>
<td>26.9 ms⁻¹</td>
<td>94.9°</td>
</tr>
</tbody>
</table>

ONE ANSWER IS CORRECT

TABLE 2. SAMPLE COMPUTATIONS OF VOLUME EXTINCTION COEFFICIENT USING TECHNIQUE A WITH RADIANCE INPUT. \( k \) = VOLUME EXTINCTION COEFFICIENT, \( x \) = HORIZONTAL DISTANCE, \( z \) = ALTITUDE, \( \theta \) = ANGLE BETWEEN VERTICAL AND LOS TO TARGET, AND \( R \) AND \( R_1 \) = RADIANCES FROM THE TARGET WITH VERTICAL AND SLANT VIEWING, RESPECTIVELY. FOR THESE EXAMPLES \( R = 100 \) AND \( R_1 = 25 \) UNITS; THEREFORE, \( \frac{R_1}{R} = 0.25 \) AND \( \ln \left(\frac{R_1}{R}\right) = -1.3863 \). NOTE THAT HERE AND IN THE COMPUTER PROGRAMS \( R_1 = R_2 \) OF EQUATION (3) AND \( R = R_1 \) OF EQUATION (3).

<table>
<thead>
<tr>
<th>Known Variables</th>
<th>Equations and &quot;Manual&quot; Values</th>
<th>Computer Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) ( X = 1000 ) m = 1.0 km ( Z = 200 ) m = 0.2 km ( \theta = \arctan \left(\frac{X}{Z}\right) )</td>
<td>( k = \ln \frac{R_1}{R}/(1 - \cos \theta) )</td>
<td>( -1.3863/0.2(1 - 0.0990) )</td>
</tr>
<tr>
<td>b) ( Z = 300 ) m = 0.3 km ( \theta = 55^\circ )</td>
<td>( k = -1.3863/(1 - \cos \theta) )</td>
<td>( -1.3863/0.3(1 - 2.3662) )</td>
</tr>
<tr>
<td>c) ( X = 600 ) m = 0.6 km ( \theta = 50^\circ )</td>
<td>( k = -1.3863/(1 - \tan \theta - 1/\sin \theta) )</td>
<td>( -1.3863/0.6(0.8391 - 1.3054) )</td>
</tr>
</tbody>
</table>
TABLE 3. SAMPLE COMPUTATIONS OF VOLUME EXTINCTION COEFFICIENT USING TECHNIQUE \( P \)
WITH RADIANCE INPUT. \( k = \) VOLUME EXTINCTION COEFFICIENT, \( X_1 \) AND \( X_2 \) = HORIZONTAL DISTANCE, \( z = \) ALTITUDE, \( \alpha_1 \) AND \( \alpha_2 \) = ANGLES BETWEEN VERTICAL AND LOS TO TARGET, AND \( R_1 \) AND \( R_2 \) = RADIANCE FROM THE TARGET ALONG THE TWO SLANT PATHS. FOR THESE EXAMPLES, \( R_1 = 100 \) AND \( R_2 = 30 \) UNITS; THEREFORE, \( R_2/R_1 = 0.33 \) AND \( \ln (R_2/R_1) = -1.2040 \).

<table>
<thead>
<tr>
<th>Known Variables</th>
<th>Equations and &quot;Manual&quot; Values</th>
<th>Computer Values</th>
</tr>
</thead>
</table>
| a) \( X_1 = 330 \) m = 0.3 km \( X_2 = 1500 \) m = 0.5 km \( z = 500 \) m = 0.5 km | \( \alpha_1 = \arctangent \left( X_1/z \right) = 30.96^\circ \) \( \alpha_2 = \arctangent \left( X_2/z \right) = 71.57^\circ \) \( k = \ln \left( R_2/R_1 \right) / \left( 1/\cos \alpha_1 - 1/\cos \alpha_2 \right) \) \( = -1.2040/0.5(1.661 - 3.1631) \) \( = 1.2058 \text{ km}^{-1} \) \( = 1.2063 \text{ km}^{-1} \) | \( = 1.2054 \text{ km}^{-1} \) |}
| b) \( z = 500 \) m = 0.5 km \( X_1 = 30^\circ \) \( X_2 = 70^\circ \) | \( k = \ln \left( R_2/R_1 \right) / \left( 1/\cos \alpha_1 - 1/\cos \alpha_2 \right) \) \( = -1.2040/0.5(1.0642 - 2.9239) \) \( = 1.2949 \text{ km}^{-1} \) \( = 1.2949 \text{ km}^{-1} \) | \( = 1.2949 \text{ km}^{-1} \) |}
| c) \( X_2 = 300 \) m = 0.3 km \( X_1 = 1500 \) m = 2.0 km \( z = 150 \) m \( \alpha_1 = 15^\circ \) \( \alpha_2 = 69.53^\circ \) | \( k = \ln \left( R_2/R_1 \right) / \left( 1/\cos \alpha_1 - 1/\cos \alpha_2 \right) \) \( = -1.2040\left(1/cos 15^\circ - 1/cos 69.53^\circ \right) \) \( = 0.8943 \text{ km}^{-1} \) \( = 0.8839 \text{ km}^{-1} \) | \( = 0.8943 \text{ km}^{-1} \) |}
| d) \( X_1 = 40 \) m = 0.04 km \( X_2 = 1500 \) m = 1.5 km \( z = 30^\circ \) \( \alpha_1 = 3^\circ \) \( \alpha_2 = 63.03^\circ \) | \( k = \ln \left( R_2/R_1 \right) / \left( 1/\cos \alpha_1 - 1/\cos \alpha_2 \right) \) \( = -1.2040\left(1/cos 3^\circ - 1/cos 63.03^\circ \right) \) \( = 1.3009 \text{ km}^{-1} \) \( = 1.3009 \text{ km}^{-1} \) | \( = 1.3009 \text{ km}^{-1} \) |}

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TABLE 4. SAMPLE COMPUTATION OF CEILING. \( C = \) CEILING (HEIGHT OF CLOUDBASE), \( z = \) ALTITUDE, \( h = \) HEIGHT OF CLOUDBASE ABOVE FLIGHT PATH, \( X = \) HORIZONTAL DISTANCE, \( \alpha = \) UPWARD ELEVATION ANGLE BETWEEN FLIGHT PATH AND LOS TO CLOUDBASE, AND \( \delta = \) DEPRESSION ANGLE BETWEEN FLIGHT PATH AND LOS TO LANDMARK (VERTICALLY BELOW VIEW OF CLOUDBASE). COMPUTER VALUES OF \( C \) ARE TO THE NEAREST METER.

<table>
<thead>
<tr>
<th>Known Variables</th>
<th>Equations and &quot;Manual&quot; Values</th>
<th>Computer Values</th>
</tr>
</thead>
</table>
| a) \( X = 700 \) m \( z = 150 \) m \( \alpha = 22^\circ \) | \( C = Z + \tan \alpha \) \( = 150 + 293 \) \( = 433 \text{ m} \) | \( = 433 \text{ m} \) |}
| b) \( z = 300 \) m \( \alpha = 14^\circ \) \( \delta = 10^\circ \) | \( C = Z \left( 1 + \tan \alpha / \tan \delta \right) \) \( = 303(1 + 0.24933/0.1533) \) \( = 724 \text{ m} \) | \( = 724 \text{ m} \) |}
| c) \( X = 1000 \) m \( \alpha = 20^\circ \) \( \delta = 30^\circ \) | \( C = X(\tan \alpha + \tan \delta) \) \( = 1000(0.5735 + 0.34397) \) \( = 941 \text{ m} \) | \( = 941 \text{ m} \) |
TABLE 5. SAMPLES OF OUTPUT FROM THE COMPUTER PROGRAMS FOR CEILING AND VOLUME EXTINCTION COEFFICIENT. ONLY THE ANSWER (FOR EXAMPLE, Ceiling = 100 m) IS PRINTED BY THE COMPUTER. SINCE THE DESKTOP COMPUTER CANNOT PRINT SUPERSSCRIPTS, km⁻¹ IS PRINTED AS 1/km.

1. Ceiling given altitude (Z) = 150 m, horizontal distance (X) = 700 m, and elevation angle (θ) = 22°.
   Ceiling = 433 m

2. Volume extinction coefficient using one slant path given Z = 200 m, X = 450 m, and radiances (R and R₁) = 110 and 25 units.
   Volume extinction coefficient = 5.0663 I/km

3. Volume extinction coefficient using two slant paths given horizontal distances (X₁ and X₂) = 200 and 1800 m, one of the two angles between the LOS to the target and the vertical (θ₁) = 18°, and radiances (R₁ and R₂) = 100 and 20 units.
   Volume extinction coefficient = 1.2823 I/km

4. Volume extinction coefficient using one slant path, and using voltages as input given Z = 200 m, X = 450 m, voltage coefficients (A and B) = 2.2 and 11.0, and voltages (V₁ and V₂) = 8.0 and 2.0 v.
   Volume extinction coefficient = 4.4989 I/km

5. Volume extinction coefficient using two slant paths, and using voltages as input given Z = 200 m, X₁ and X₂ = 200 and 450 m, θ₁ = 45°, A and B = 2.2 and 11.0, and V₁ and V₂ = 8.0 and 2.0 v.
   Volume extinction coefficient = 6.2771 I/km

4. CONCLUSION

Useful tools for silent area analysis have been developed in the form of simple methods for the computation of wind velocity, ceiling, and volume extinction coefficient. These algorithms use information already gathered by an RPV of the type being developed for the Army; no new instrumentation is required. Windspeed should be accurate to several tenths of a meter per second and wind direction to less than a degree, assuming that the input is "perfectly" accurate. Similarly, ceiling should be correct to about 1 or 2 percent and extinction coefficient to about 10 percent. However, under operational conditions, the accuracy of the input data probably would determine the accuracy of the output.

Computations may be performed via a desktop computer able to use the BASIC computer language, or by the use of a hand-held calculator, a fine-scaled ruler, and graph paper. The former technique only requires the operator to input numbers that are specifically requested; the latter manual technique requires some knowledge of the situation.
APPENDIX

COMPUTER CODES IN BASIC FOR THE RPV PROGRAMS

(A) is the full version and (B) is the shortened version of the wind velocity program; (C) is the ceiling program; (D) and (E) are the extinction coefficient programs with one and two slant paths, respectively; (F) and (G) are the extinction coefficient programs using voltage inputs, with one and two slant paths, respectively.

10 | COMPUTE WIND VELOCITY USING RPV PROGRAM
30 | A$="Wind Speed = "
50 | B$="Wind Direction = "
70 | D$=" m/s"
90 | E$=" Degrees"
110 | F$="WIND VELOCITY"

10 | H=0
120 | M=0
140 | INPUT "Input L-1 to compute V using Method 1 or L-2 for Method 2",L
160 | IF L=2 THEN GOTO Math
180 | INPUT "Input airspeeds in m/s (X and Y)",X,Y
200 | INPUT "Input distances (m) and times (s) (Dx,Tx,Dy,Ty)",Dx,Tx,Dy,Ty
220 | INPUT "Input headings in degrees (Dri and Dr2)",Dr1,Dr2
240 | PRINT USING Heading;F$
260 | GOTO Anda

300 | Print USING Heading;F$
320 | PRINT USING Out
340 | PRINT USING Title;A$,V,D$,B$,Dir,E$

400 | H=0
420 | M=0
440 | INPUT "Input L-1 to compute V using Method 1 or L-2 for Method 2",L
460 | IF L=2 THEN GOTO Math
480 | INPUT "Input airspeeds in m/s (X and Y)",X,Y
500 | INPUT "Input whether drift (I=1) or correction (I=-1) angle",I
520 | INPUT "Input angles in degrees (A and B)",A,B
540 | INPUT "Input headings in degrees (Dri and Dr2)",Dr1,Dr2
560 | A=I*A
580 | B=I*B
600 | PRINT USING Heading;F$
620 | GOTO Anda
640 | CALL Comp1(X,Y,Ox,Tx,Dy,Ty,Orf,Or2,V,ir,N)
660 | GOTO Printer
680 | CALL Comp2(X,Y,A,B,Drl,Dr2,U,V,Dir,IM)
700 | PRINT USING Title;A$,V,D$,B$,Dir,E$
720 | IF N=1 THEN GOTO Anda
740 | IF M=1 THEN GOTO Anda
760 | IF (N=2) OR (M=2) THEN PRINT "ONE ANSWER IS CORRECT"
780 | PRINT USING Out
800 | PRINT USING Title;A$,V,D$,B$,Dir,E$

840 | IF/DD/ END
860 | SUBPROGRAMS
880 | Xg=Dx/Tx
900 | Yg=Dy/Ty
920 | C=Xg*X
940 | D=Yg*Y
960 | V=V*(2*D*2.5)
980 | IF C=0 THEN C=.001
1000 | IF D=0 THEN D=.001

1020 | Computation of Direction
1040 | P=ATN(ABS(C/D))
1060 | Q=ATN(ABS(D/C))
1080 | IF (C>0) AND (D>0) OR (C<0) AND (D>0) THEN L=1
1100 | Drto=Dr1
1120 | Drto=Dr2
1140 | IF Dr1=999 THEN GOTO Second
1160 | IF Dr2=999 THEN Drto=Dr1+90
1180 | IF (Dr2=999) AND (N=1) THEN Drto=Dr1-90
640 IF Dir1<>0 THEN Dir1=Dir1+360
670 IF Dir1=360 THEN Dir1=Dir1-360
690 IF (Dr1<90) AND (Dr2<>270) AND (Dr1<>360) THEN Dir1=Dr1+360
850 IF (Dr1=90) AND (Dr2=270) AND (Dr1<>360) THEN Dir1=Dr1+360
710 Dir1=Dir1-90
710 IF (Dr1=Dr2) AND (L=0) THEN Dir1=Dir1+90
730 IF C>0 THEN Dir1=Dir1+180
740 GOTO Direct
750 Second: IF Dr2=999 THEN GOTO Alt
760 Dir2=Dr2+90
770 IF N=1 THEN Dir2=Dir2-90
780 IF Dr2<>0 THEN Dr2=Dr2+360
890 IF Dr2=360 THEN Dir2=Dr2-360
900 IF (Dr1<90) AND (Dr2<>270) AND (Dr1<>360) THEN Dr1=Dr1+360
910 IF (Dr1=90) AND (Dr2<>270) AND (Dr1<>360) THEN Dr2=Dr2+360
920 Dir2=Dir2+P
930 IF (Dr1=Dr2) AND (L<>0) THEN Dir2=Dir2-P
940 IF (Dr1=Dr2) AND (L=1) THEN Dir2=Dir2+P
950 IF Dr2<>0 THEN Dir2=Dir2+180
960 GOTO Direct
870 Alt: IF (N=1) THEN "NO DIRECTION GIVEN OR COMPUTED"
880 Direct: IF Dir1=360 THEN Dir1=Dir1-360
890 IF Dir1<>0 THEN Dir1=Dir1+360
900 IF (Dr1=999) OR (Dr2=999) THEN N=N+1
910 SUBEND
920 IF C<>0#0.0 THEN C=0.001
930 IF D<>0#0.0 THEN D=0.001
950 Comp2(X,Y,A,B,Dr1,Dr2,U,V,Dir1,LM)
960 Dir=0
970 K=0
980 U=0
990 DEG
1000 C=X*TAN(A)
1010 D=Y*TAN(B)
1020 W=C^2+D^2)^.5
1030 IF C<>0 THEN C=0.001
1040 IF D<>0 THEN D=0.001
1050 IF C<>0) AND (D<>0) THEN K=0
1060 IF C<0 AND D>0 THEN K=1
1100 Dir=Dir1
1120 Dir2=Dr2
1130 IF Dr1<>999 THEN GOTO Second
1140 IF Dr2<>999 THEN Dir1=Dir1+360
1150 IF (Dr1=999) AND (L<>1) THEN Dir1=Dir1-360
1160 IF Dr1<>0 THEN Dir1=Dr1+360
1170 IF Dr2=360 THEN Dir2=Dir2+360
1180 IF (Dr1<90) AND (Dr2<>270) AND (Dr1<>360) THEN Dir1=Dr1+360
1190 IF (Dr1=90) AND (Dr2<>270) AND (Dr1<>360) THEN Dr2=Dr2+360
1200 IF (D<>0) AND (Dr2<>0) THEN U=1
1210 IF (D<>0) AND (D<>0) THEN U=1
1220 Dir1=Dr1-P
1230 IF (Dr1<>0) AND (K<>1) THEN Dir1=Dr1+P
1240 IF (Dr1<>0) AND (K<>1) THEN Dir1=Dr1+P
1250 IF U=1 THEN Dir1=Dir1+180
1260 GOTO Direct
1270 Second: IF Dr2<>999 THEN GOTO Alt
1280 Dir1=Dir2+90
1290 IF M<>1 THEN Dir1=Dir1+90
1300 IF Dr1<>0 THEN Dir1=Dir1+360
1710 IF Dr1=360 THEN Dir1=Dir1-360
130 IF (Drnt<450) AND (Drtn<270) AND (Ortn>360) THEN (Drnt=0)
135 IF (Ornt>0) AND (Drnt<Drto) THEN (Drnt=0)
140 IF (Drnt>0) AND (Drnt<Drto) THEN (Drnt=Drto)
145 Dir=Dr2+0
150 IF (Drnt<Drto) AND (Drnt<Drto) THEN (Drnt=Dr2+0)
155 IF (Drnt<Drto) AND (Drnt<Drto) THEN (Drnt=Dr2+0)
160 IF (Ornt<0) THEN (Dir=Dir+180)
165 GOTo Direct
170 Alt: PRINT "NO DIRECTION GIVEN OR COMPUTER"
180 Direct: IF Dir<360 THEN Dir=Dir-360
185 IF Dir<0 THEN Dir=Dir+360
190 IF (Ornt=999) OR (Ornt=999) THEN Alt=1
195 GoTo SHEENG
COMPUTE WIND VELOCITY USING RPV PROGRAM - MINI VERSION

A$="Wind Speed = "
B$="Wind Direction = "
D$="m/s"
E$="Degrees"
F$="WIND VELOCITY"

INPUT "Input L=1 to compute V using Method 1 or L=2 for Method 2";L
100 IF L=2 THEN GOTO Meth
110 INPUT "Input airspeeds in m/s (X and Y)";X,Y
120 INPUT "Input distances (m) and times (s) (Dx,Tx,Dy,Ty)";Dx,Tx,Dy,Ty
130 INPUT "Input headings in degrees (Dr1 and Dr2)";Dr1,Dr2
140 PRINT USING Heading;F$
150 GOTO Anda
170 Meth: INPUT "Input airspeeds in m/s (X and Y)";X,Y
180 INPUT "Input whether drift (I=1) or correction (I=-1) angle";I
190 INPUT "Input angles in degrees (A and B)";A,B
200 INPUT "Input headings in degrees (Dr1 and Dr2)";Dr1,Dr2
210 A=I*A
220 B=I*B
230 PRINT USING Heading;F$
240 GOTO Anda
260 Anda: CALL Comp(X,Y,Dx,Tx,Dy,Ty,Dr1,Dr2,V,Dir)
260 GOTO Printer
270 Anda: CALL Comp2(X,Y,A,B,Dr1,Dr2,U,V,Dir,1)
280 Printer: PRINT USING Title:A$,V,D$,B$,Dir,E$
290 Title: IMAGE 5X,13A,DDD.D,5X.17A,DDD.D,DA,/
300 PRINT USING Out
310 Out: IMAGE 5X,6/
320 END

SUBPROGRAMS

I

SUB Comp1(X,Y,Dx,Tx,Dy,Ty,Dr1,Dr2,V,Dir)
390 !
400 Dir=0
410 DEG
420 L=0
430 Xg=Dx/Tx
440 Yg=Dy/Ty
450 C=Xg-X
460 D=Yg-Y
470 V=(C^2+D^2)^.5
480 IF C=0 THEN C=.001
490 IF D=0 THEN D=.001
500 !
510 !
520 !
530 !
540 !
550 !
560 !
570 !
580 !
590 !
600 !
610 !
620 !
630 !
640 !
650 !
SUB Comp2(X,Y,H,B,Dr1,Dr2,U,V,Dir,I)

Dir=0
K=0
U=0
DEG
C=X*TAN(A)
D=Y*TAN(B)
V=(C^2+D^2)^.5
IF C=0 THEN C=.001
IF D=0 THEN D=.001

Computation of Direction

P=ATN(ABS(C/D))
IF C>0 AND (D>0) OR (C<0) AND (D<0) THEN K=1

Drn=Dr1
Drto=Dr2

IF (Drn<=90) AND (Drto>270) AND (Drto<360) THEN Drn=Drn+360
IF (Drn>90) AND (Drto>=270) AND (Drto<360) THEN Drn=Drn+360
IF (D>0) AND (Drn<Drto) THEN U=1
IF (D<0) AND (Drn>Drto) THEN U=1

Dir=Dr1-P

IF (Drn<Drto) AND (K=1) THEN Dir=Dr1+P
IF (Drn>Drto) AND (K=0) THEN Dir=Dr1+P

IF U=1 THEN Dir=Dr+r+180
IF Dir>360 THEN Dir=Dir-360
IF Dir<0 THEN Dir=Dir+360
SUBEND
ESTIMATION OF CEILING (STORED AS "PF-CEL")

10 INPUT
20 DEF
30 DIM V,0
40 READ X,Z
50 L#="Ceiling = ", B$="meters"
60 INPUT "Set I=1 if distance known. I=2 if altitude known. I=3 if both known"
70 I=2
80 IN1: INPUT "Input upward elevation angle (Beta) in degrees" , Beta
90 ON I GOTO In1,In2,In3
100 In2: INPUT "Input distance (X) in meters & depression angle (Alpha) in degrees", X,Alpha
110 GOTO Comp1
120 In3: INPUT "Input altitude (Z) in meters & depression angle (Alpha) in degrees", Z,Alpha
130 GOTO Comp2
140 In3: INPUT "Input distance (X) & altitude (Z) in meters", X,Z
150 GOTO Comp3
160 Comp1: C=X*(TAN(Alpha)+TAN(Beta))
170 GOTO Out
180 Comp2: C=Z+(1+TAN(Beta)*TAN(Alpha))
190 GOTO Out
200 Comp3: C=Z+X*TAN(Beta)
210 Out: PRINT USING Title
220 Title: "HEIGHT: .
230 END
ESTIMATION OF EXTINCTION COEFFICIENT - STORED WS "PPIRHE".

INPUT

DATA 0.0
PEND X:Z
INPUT "Set I=1 if distance known, I=2 if altitude known, I=3 if both known" 1
ON I GOTO In1, In2, In3
100 In1: INPUT "Input value of distance (X) in meters" X
110 GOTO Angle
120 In2: INPUT "Input value of altitude (Z) in meters" Z
130 GOTO Angle
140 In3: INPUT "Input distance (X) and altitude (Z) in meters" X2
150 GOTO In

Angle: INPUT "Input angle (Beta) between vertical and slant paths in degrees" Beta
170 In: INPUT "Input vertical and slant path radii, R1, R2". R1, R2
180

COMPUTATION

DEG

200 DIM H$(32)
210 X=1000
220 Z=1000
230 H$="Volume extinction coefficient = "
240 BS=" 1/Vm"
250 IF I=3 THEN Beta=ATN (X:Z)
260 Alpha=LOG (R1:R2)
270 IF Z=0 THEN GOTO Dist
280 Alpha=Alpha*2+1/COS Beta
290 GOTO Out
300 Dist: H1=Alpha (2+1.732)/(Beta-1.732)
300 GOTO Output
310 Out: PRINT USING Title; H1; BS
320 Title: IMAGE 0.5K:32M:00:0000:00:00:00
330 END
ESTIMATION OF EXTINCTION COEFFICIENT STORED AS "RHOPHY"

USING TWO SLANT PATHS

INPUT

DIM M#(32)

10 ON I GOTO In1,In2,In3

10 In1: INPUT "Set I=1 if distances known, I=2 if altitude known, I=3 if both known"

20 INPUT "Set I=1 if distances known, I=2 if altitude known, I=3 if both known"

30 GOTO Angle

40 In2: INPUT "Input values of distances (X1,X2 where X1,X2) in meters",X1,X2

50 GOTO Angle

60 In3: INPUT "Input values of altitude (Z) in meters",Z

70 GOTO Angle

80 Angle: INPUT "Input angles B1,B2 where B1,B2 between vertical and slant paths in degrees",B1,B2

90 INPUT "Input slant path radii (R1,R2) where R1>R2) in any standard units",R1,R2

100 COMPUTATION

110 IN: DEG

120 DIM M#(32)

130 X1=X1/1000

140 X2=X2/1000

150 Z=Z/1000

160 M$="Volume extinction coefficient = "

170 B$="1/km"

180 IF I<3 THEN GOTO H1f

190 IF I<3 THEN GOTO H1f

200 B1=ATN(X1/Z)

210 B2=ATN(X2/Z)

220 H1f: Alpha=LOG(R2/R1)

230 IF Z=0 THEN GOTO Dist

240 IF Z=0 THEN GOTO Dist

250 GOTO Out

260 Dist: IF B1<0 THEN GOTO Bet

270 Z=X2/TAN(B2)

280 B1=ATN(X1/Z)

290 Bet: IF B2>0 THEN GOTO Go

300 Z=X1/TAN(B1)

310 B2=ATN(X2/Z)

320 Go: IF B1<5 THEN GOTO Small

330 Alpha=Alpha/(X1*SIN(B1)+X2*SIN(B2))

340 GOTO Out

350 Small: Alpha=Alpha/(X2*(1/TAN(B2)-1/SIN(B2))

360 1

370 OUTPUT

380 1

390 Out: PRINT USING Title:Alpha,*B$

400 Title: IMAGE 0.5X 32u,00,0000,0n,/

410 END
ESTIMATION OF EXTINCTION COEFFICIENT STORED AS "PPVOLT":
USING VOLTAGES AS INPUT

INPUT
DATA 0,0
READ X,Z
INPUT "Set I=1 if distance known, I=2 if altitude known, I=3 if both known"
I
ON I GOTO In1,In2,In3
In1:
INPUT "Input value of distance (X) in meters".X
GOTO Angle
In2:
INPUT "Input value of altitude (Z) in meters".Z
GOTO Angle
In3:
INPUT "Input distance (X) and altitude (Z) in meters".X,Z
GOTO In
Angle:  INPUT "Input angle (Beta) between vertical and slant paths in degrees".Beta
In:
CALL Volt(R1,R2,VI,V2,A,B)

COMPUTATION

DEG
DIM A$(32)
X=X/1000
Z=Z/1000
W$="Volume extinction coefficient ="
B$=" 1/km"
IF I=3 THEN Beta=ATN(X/Z)
Alpha=LOG(R2/R1)
IF Z=0 THEN GOTO Dist
Alpha=Alpha/(2*(1-COS(Beta)))
GOTO Out
Dist:  Alpha=Alpha/(X*(1/TAN(Beta))-1/SIN(Beta))
OUTPUT
Out:  PRINT USING Title;W$.Alpha,B$
Title:  IMAGE 0.5%.32A.0D.000D.6A.7.
END
SUBPROGRAM TO CONVERT VOLTAGE TO RADIANCE
SUB Volt(R1,R2,VI,V2,A,B)
INPUT "Input voltage coefficients (A,B)".A,B
INPUT "Input voltages for vertical and slant paths: VI V2 where VI(V2)".VI,
V2
R1=A+B*VI
R2=A+B*V2
SUBEND
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