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# A STUDY OF WIND VELOCITY PROFILE AT SANTA CRUZ EXPERIMENT STATION, VENEZUELA

by

Omar Gutierrez

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Irrigation Engineering

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1970

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Omar Gutierrez

Omar Gutierrez

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## LIST OF SYMBOLS

The following symbols are used in the present work:

| | |
|---|---|
| $U_z$ | wind velocity in kilometers per hour (KPH) at the height z in meters (m), (z1, z2, z3 . . .) |
| Z | height of wind measurement in meters, (Z1, Z2, Z3 . . .) |
| d | zero plane displacement in meters |
| k | von Karman constant = .42, dimensionless |
| $U_*$ | shear velocity ($LT^{-1}$) in this work KPH |
| Zo | roughness factor (L) in this work m |
| U06, U2 U10 | mean wind velocity at .6, 2, and 10 meters above ground level |
| U2C6 | U2 calculated from U06 KPH |
| U10C6 | U10 calculated from U06 KPH |
| U10C2 | U10 calculated from U2 KPH |
| E062 | absolute error of computation of U2 calculated from U06 percent |
| E0610 | absolute error of computation of U10 calculated from U06 percent |
| E210 | absolute error of computation of U10 calculated from U2 percent |
| p12 | coefficient for U10 computed from U2 |
| p16 | coefficient for U10 computed from U06 |
| p26 | coefficient for U2 computed from U06 |

ABSTRACT

A Study of Wind Velocity Profile

at Santa Cruz Experiment Station, Venezuela

by

Omar Gutierrez, Master of Science

Utah State University, 1970

Major Professor: Jerald E. Christiansen
Department: Agricultural and Irrigation Engineering

Data from five years of daily records of wind velocity at heights .6, 2, and 10 meters above the ground taken at Santa Cruz Experiment Station, Venezuelan Ministry of Public Works, were used to study the characteristics of wind profile with respect to height above the ground level in the lower 10 meters of the atmosphere.

The information was used to compare formulas for wind velocity profile found in the literature, and formulas developed at Utah State University with actual data. The formulas that best fit the Santa Cruz Experiment Station data are Christiansen-Hargreaves', Power-law and Stutler-Hardee's. All of these formulas were either developed at, or modified at, Utah State University.

The other formulas ranked in the following order: Geigher's as modified by Gutierrez, Logarithmic, and Sutton's.

A simple and practical relation was proposed to correct Geigher's formula. Computer programs were developed to process the information.

(53 pages)

# INTRODUCTION

The velocity of the wind near the ground is of great importance in the plant water needs as well as in the environment surrounding the plant habitat. Increased wind movement is usually attended by atmospheric turbulence which increases the evaporation from water and soil surface and from vegetation. In the study of water demands by crops the influence of wind cannot be overlooked since the evaporation process is part of an energy balance in which the atmospheric factors interact as sources of energy which create the water demand of the crops. The advection process, which is an important factor in the evaporation phenomenon, is also a direct consequence of the wind movement.

In Venezuela the measurement of wind velocities has been made at different (not standardized) heights. There is a need for a relationship correlating the velocity of the wind at different heights of measurement, especially because most of the formulas used to compute evapotranspiration include values of wind velocity at specified heights.

Five years of records of mean daily wind velocities, measured by cup-type anemometers at .6, 2 and 10 meters above the ground obtained at Santa Cruz Experiment Station (Venezuelan Ministry of Public Works) have been used to study the characteristics of the wind profile with respect to the height above the ground level in the lower 10 meters of the atmosphere. These data have been used to

evaluate different formulas found in the literature and formulas developed at Utah State University.

The Santa Cruz Experiment Station is located in the state of Aragua, Venezuela. The coordinates are $10^{\circ}$ 11' N latitude and $67^{\circ}$ 30' W longitude. The altitude is 438 meters above the sea level. The Station was established in 1964 for the purpose of studying water- soil-plant relationships in the area.

## Objectives

The objectives of this study are:

1. To compare formulas for wind velocity found in the literature with actual data.

2. To compare formulas developed by researchers at the Agricultural and Irrigation Engineering Department at USU with actual data.

3. To determine the best formula for use in Venezuela.

## REVIEW OF LITERATURE

The problem of converting the wind velocity measured at one height above the ground surface to another height has not been adequately solved for all conditions.

Taylor (1918) presented a graph with a series of curves showing the wind velocity at any height for a given velocity gradient and for a given value of K, K being the transport constant for momentum frequently known as the coefficient of eddy diffusivity. He developed the graph from experiments conducted at the Eiffel Tower in Paris. Since the relationships shown on the graph were not given in the form of equations, they could not be used for comparison in this study.

### Geigher's Formula

Geigher (1965) refers to the increase of wind velocity with height as expressed by him in 1927 by the use of the simplified power law:

$$U_z = U_1 Z^p \qquad \ldots 1$$

The disadvantages of this equation are: a) the wind velocity at a height of one meter must be known, and b) the exponent p has daily and seasonal variations (Sutton, 1932; Bakart, 1932).

Sutton (1932), using data obtained by Heywood (1931), subdivided this exponent for summer and winter; from April to September, he found that p varied between 0.07 at noon and 0.17 at night, and from

October to March, between 0.08 and 0.13. Henning, 1957 (see Geigher, 1965) found seasonal averages deduced from measurements made in Lindenberg to be 0.32, 0.39, 0.53 and 0.28 during the day in spring, summer, autumn and winter; while by night the values were 0.38, 0.49, 0.59 and 0.28. Except for the autumn values, which were for the first five meters, the values of p were determined for the lowest ten meters of the atmosphere.

The wind velocity gradient has also been related to the temperature gradient (Heywood, 1931; Sutton, 1936; Frost, 1948; Deacon, 1949). Heywood (1931) stated that for "a given temperature gradient the wind gradient increases approximately linearly with the wind velocity." (Heywood, 1931, page 447)

Sutton's Formula

Sutton (1936) proposed the equation:

$$U_{z1} = U_{z2} \log \left( \frac{a\, Z1}{Z2} + 1 \right) / \log (a + 1) \qquad \ldots 2$$

where

$U_{z1}$ is unknown wind velocity at height Z1,

$U_{z2}$ is known wind velocity at height Z2, and

a is a dimensionless number.

He regarded a as an indicator of turbulence and presented a tabulation relating a with the difference in temperature and the velocity ratio $U_{150}/U_{50}$. His tabulation is presented on the following page.

Values of a as presented by Sutton, p. 126.

| Temperature Difference °F | -5 | -4 | -3 | -2 | -1 | 0 |
|---|---|---|---|---|---|---|
| $U_{150}/U_{50}$ | 1.01 | 1.035 | 1.11 | 1.11 | 1.128 | 1.17 |
| a | $5 \times 10^{47}$ | $4 \times 10^{13}$ | $2.2 \times 10^{4}$ | $2.2 \times 10^{4}$ | 5260 | 620 |

| Temperature Difference °F | +1 | +2 | +3 | +4 | +5 | +6 | +7 |
|---|---|---|---|---|---|---|---|
| $U_{150}/U_{50}$ | 1.21 | 1.27 | 1.45 | 1.55 | 1.66 | 1.85 | 1.98 |
| a | 174 | 51 | 8.1 | 4.8 | 3.3 | 1.7 | 1.1 |

$U_{150}$ and $U_{50}$ are wind velocities at 150 and 50 feet above the ground level. This extreme range in the value of a is difficult to understand. Since a is a function of the temperature difference at two specified heights, 50 and 150 feet, which is not known, the formula as stated is impractical.

Power-law Formula

A more generalized power law has been considered by many investigators including Scrase 1930 (see Sutton, 1953), and Frost (1948). Frost measured wind velocities at heights from 1.5 to 122 meters and from 1.2 to 305 meters and stated that the wind profile can be represented by the relation:

$$U_{z1} = U_{z2} \left(\frac{Z1}{Z2}\right)^{p} \qquad \ldots 3$$

He considered the exponent p to be a linear function of the difference in temperatures measured between 1.5 and 122 meters above the ground level. Scrase found p = .13 to be appropriate in the layer from 3 to 13 meters. Equation 3 is basically the same equation as proposed by Geigher but in a more general form. Many researchers working

with evaporation and evapotranspiration have considered the relationship between the velocities at two heights to have a constant ratio as indicated by a constant value for p (Penman, 1948; Harbeck, 1962).

The Shear Velocity and the Roughness Factor

More complex expressions are given in the literature where new elements are introduced. Of these new elements the shear velocity, $U_*$ defined as $U_* = (\frac{\tau}{\rho})^{1/2}$, and the roughness factor, Zo, are the most important, where $\tau$ = shear stress ($FL^{-2}$) and $\rho$ = density of air ($FT^2 L^{-4}$) (Calder, 1939; Sheppard, 1947; Deacon, 1949; BJorgum, 1952; Sutton, 1953; Lettau, 1959; Hagan et. al., 1967; Chang, 1968). The introduction of these elements began perhaps with Prandtl's logarithmic law in 1932 (see Geigher, 1965; Lake, 1952). Prandtl proposed the following relationship for neutral or adiabatic conditions:

$$U_z = \frac{U_*}{k} \ln (Z/Zo) \qquad \ldots 4$$

where the wind profile depends upon $U_*$ and Zo, and k is the von Karman constant, a dimensionless number with a value of 0.42.

Deacon's Formula

Deacon (1949) presented results of an extensive investigation of vertical profiles of mean wind velocity in the lowest 10 meters of the atmosphere (mainly carried out at the Chemical Defense Experimental Station, Porton, Salisbury Plain, England). He showed that the ratio of the wind velocity at height Z, to that at 1 meter plotted against log Z

fitted close to straight lines, and concluded that a logarithmic velocity profile gave a very good representation in the lowest 10 meters or so of the atmosphere when the stability was neutral. From an examination of carefully measured profiles between heights of .5 to 4 meters Deacon proposed the general law:

$$\frac{du}{dz} = a\, Z^{-B} \qquad \ldots 5$$

in which a is independent of Z, with B = 1 for neutral stability, $B > 1$ for unstable conditions, and $B < 1$ for stable conditions. He presented the following expression for a:

$$a = U_*/(k\, Zo^{1-B}) \qquad \ldots 5a$$

By integrating equation 5, Deacon proposed the following formula:

$$U_z = \frac{U_*}{k\,(1 - B)}\,[\,(Z/Zo)^{1 - B} - 1] \qquad \ldots 5b$$

He suggested that B could be evaluated by solving equation 5b by trial and error when the velocities at two heights and Zo are known. In this same reference, Deacon gave values of the roughness factor (Zo) for various surfaces. Several writers have commented on ways of determining this value of B (Lake, 1952; Davison and Barad, 1956; Martin, 1960). Later Deacon (1953) related the wind speed gradient, du/dz, with the thermal stability. The writer was not successful in evaluating B for the Santa Cruz data.

The Logarithmic Formula

Many researchers have mentioned the so-called logarithmic profile law (Pasquill, 1950; Inohue et. al., 1953; Sutton, 1953; Hay, 1955; Lettau, 1959; Lemon, 1963; Hagan et. al., 1967; Chang, 1968). Although there are slight differences in its presentation the most generalized expression is:

$$U_z = \frac{U*}{k} \ln \left(\frac{Z - d}{Zo}\right) \qquad \ldots 6$$

Although the constancy of $\tau$ with height (consider that $U_* = (\tau/\rho)^{1/2}$) has been mentioned by Calder (1939) and Ertel in 1933 (see Chang (1968), recent works show disagreement with this criteria (Pasquill, 1950; Inohue, 1952; Allen, 1968).

The same comment can be made for the roughness factor Zo, which is not constant but varies with the roughness of the ground surface and with the wind velocity (Lemon, 1963; Allen, 1968; Chang, 1968). With respect to k, or the von Karman constant, Sheppard (1947) found the value of 0.42, as developed from laboratory investigations, also applied to field conditions.

## FORMULAS DEVELOPED AT UTAH STATE UNIVERSITY

Stutler and Hardee, and Hargreaves and Christiansen (personal communication at USU, 1970) working with Venezuelan wind data as related to evapotranspiration have developed two wind profile formulas that can be stated as follows:

### Stutler-Hardee's Formula

Stutler and Hardee (personal communication 1970) developed a formula for converting wind velocities at any height, Z1, to the velocity at 10 meters from a study of wind velocity data from the Santa Cruz Experiment Station and other Venezuelan stations. The general formula can be written:

$$U_z = U_{z1} \; C_z \; C_v \qquad \ldots 7$$

where

$U_z$ = unknown wind velocity at height Z,

$U_{z1}$ = known wind velocity at height Z1,

$C_z$ = coefficient for height,

$C_v$ = coefficient for velocity.

The equation for $C_z$ to convert velocities to $U_{10}$ is

$$C_z = 1.9725 + 0.0436\,(10/Z_1) - 2.0631\,(Z_1/10) + 1.047\,(Z_1/10)^2 \qquad \ldots 7a$$

The values of $C_z$ for $Z_1$ = 0.6 and 2 meters are 2.591 and 1.8198. They found that to convert U06 to U2, the value of $C_z$ is given by

the ratio, 2.591/1.8198 = 1.4172. The values of $C_v$ are given by the following equations:

$$C_{v12} = 1.58 - .734\ (U2/4) + .174\ (U2/4)^2 \qquad \ldots\ 7b$$

$$C_{v16} = 1.83 - 1.39\ (U06/4) + .46\ (U06/4)^2 \qquad \ldots\ 7c$$

$$C_{v26} = 1.28 - .37\ (U06/4) + .10\ (U06/4)^2 \qquad \ldots\ 7d$$

The units of wind velocity in equations 7b, 7c, and 7d are given in kilometers per hour.

Christiansen-Hargreaves' Formula

Christiansen, 1969 (personal communication) used a linear equation of the form $U_{z1} = A + B\ U_{z2}$. Although this seems to hold true, it does not generalize the profile and can only be used for specific values of Z1 and Z2, since the values of A and B are functions of these heights. Hargreaves and Christiansen (personal communication 1970), developed the following formula:

$$U_{z1} = U_{z2} + DU \qquad \ldots\ 8$$

where

$U_{z1}$ unknown wind velocity at height Z1,

$U_{z2}$ known wind velocity at height Z2,

DU difference in velocity between $U_{z1}$ and $U_{z2}$ in kilometers per hour.

The value of DU is computed from:

$$DU = C_E\ [.30 + SL\ (2/(ZH + ZL))\ ] \qquad \ldots\ 8a$$

where

ZH height of higher anemometer in meters,

ZL height of lower anemometer in meters,

$C_E$ = ZH - ZL

SL $= A + B\,U_{z2}$ . . . 8b

A is a coefficient determined from the expression

A = .23 - .053 Z2

B is an empirical coefficient.

They found the following values for B to give the best fit for the Santa Cruz data:

B12 = .130

B16 = .288

B26 = .230

# PROCEDURE

For the Santa Cruz Experiment Station in Venezuela, 1025 values of wind velocities, at the heights .6, 2, and 10 meters above the ground level, were selected from a five-year period of daily observations. The actual data were used to study formulas 3, 6, 2, 7, 8 and 1; and they are presented with the following names:

| | |
|---|---|
| 1. Logarithmic formula | Equation 6 |
| 2. Sutton's formula | Equation 2 |
| 3. Power-law formula | Equation 3 |
| 4. Stutler-Hardee's formula | Equation 7 |
| 5. Christiansen-Hargreaves formula | Equation 8 |
| 6. Geigher's formula modified by Gutierrez | Equation 1 |

The above formulas were compared with actual data, and when there was not agreement, correction factors were developed to improve agreement between the formula and the data. The results are presented on comparative tables to illustrate their particular variations.

Computer programs shown in Appendix B developed by Professor J. E. Christiansen and other graduate students at USU have been used to process the information. The programs were run at the Remote Computer Terminal Center, Engineering Building, Utah State University, using the Univac computer at the University of Utah, Salt Lake City.

Adjustments Made On Existing Formulas Are:

Geigher's Formula has been adjusted by the use of the following expressions:

$$U16 = .2702 + 1.081\ U06 \qquad \ldots 9$$

$$U12 = .895\ U2 - .41 \qquad \ldots 10$$

where

U16 = U at height 1 meter computed from U06

U12 = U at height 1 meter computed from U2

The exponent p is proposed to be computed by the use of the expression

$$p = \ln (U_z/U_1)/ \ln Z \qquad \ldots 11$$

where $U_z$ is known wind velocity at height Z in meters. All the above units of velocity are expressed in kilometers per hour.

Sutton's Formula has been used with value of a = 9, which has been determined by trial and error.

The Power-law Formula has been used with the following values for the exponent p:

$$p12 = .740 - .48\ (U2/4) + .12\ (U2/4)^2 \qquad \ldots 12$$

$$p16 = .58 - .40\ (U06/4) + .12\ (U06/4)^2 \qquad \ldots 12a$$

$$p26 = .51 - .30\ (U06/4) + .08\ (U06/4)^2 \qquad \ldots 12b$$

where p26, p16 and p12 are used to compute U2C6, U10C6, and U10C2 respectively, U06, U2, given in kilometers per hour. Equations 12, 12a, 12b were developed by Professor J. E. Christiansen (personal communication, 1970).

The Logarithmic Formula has been used with the following modifications:

a) The shear velocity $U_*$ was computed by

$$U_* = 1.30 - .1\,U + .015\,U^2 \qquad \ldots 13$$

where

$U_*$ is shear velocity in kilometers per hour

$U$ known velocity in kilometers per hour

b) The zero plane displacement d was substituted by:

$$d = -D$$

D was computed by trial and error, by plotting Z versus U on semi-log paper and adjusting the values of Z + D to fit a straight line as shown in figure 1.

c) The roughness factor Zo was then determined from the expression:

$$Zo = (Z + D)/\,e^{(k\,U_z)/U_*} \qquad \ldots 14$$

where

$k$ is von Karman's constant

$U_z$ = known wind velocity at height Z

$e$ base of natural logarithms

This formula, although it has a strong theoretical base, is rather complex, and at least three wind velocities at three different heights are needed in order to find by trial and error a dependable value for the parameter D.

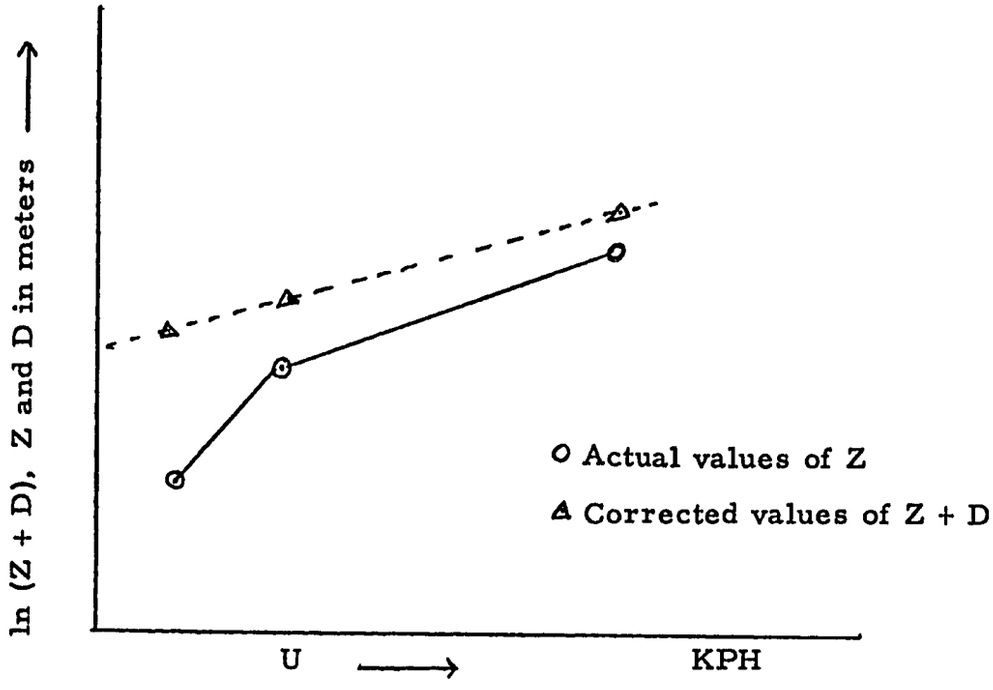


Fig. 1 Determination of parameter D
to be used in Logarithmic formula

# RESULTS

Comparative values of actual wind velocities and computed wind velocities for the different formulas studied are presented in Tables 1, 2 and 3, which also give the mean absolute error for the 1025 daily values studied.

In the Appendix A, for each of the formulas studied the following information is given:

a) Actual values of wind velocities at a given height.

b) Values of the wind velocities as computed from each formula.

c) Ratios of the actual velocity to that of the computed velocity for each height.

d) The mean absolute error for the computed values.

e) Average values of all the above computations are also given.

The values on each line represent the mean of 41 daily values of wind velocity sorted in increasing order. There are, therefore, 25 groups of 41 values each, in each table. The Appendix tables referred to above are:

Table 4, which compares the actual and the computed values for the Logarithmic formula.

Table 5, which compares the actual and the computed values for the Sutton formula.

Table 6, which compares the actual and the computed values for the Power-law formula.

Table 7, which compares the actual and the computed values for Stutler-Hardee's formula.

Table 8, which compares the actual and the computed values for Christiansen-Hargreaves' formula.

Table 9, which compares the actual and the computed values for the modified Geigher formula.

In Appendix B, the computer program used for each of the formulas is given so that the procedures can be duplicated; these programs are presented as follows:

| Program No. | Formula |
|---|---|
| 1 | Logarithmic |
| 2 | Sutton's |
| 3 | Power-law |
| 4 | Stutler-Hardee's |
| 5 | Christiansen-Hargreaves' |
| 6 | Geigher's modified |

Table 1. U2 Computed from U06 for different formulas - KPH

| Group No. | U2 | Logarithmic | Sutton | Power-law | Stutler-Hardee | Christiansen-Hargreaves | Geigher modified by Gutierrez |
|---|---|---|---|---|---|---|---|
| 1 | 1.894 | 2.079 | 1.693 | 1.904 | 1.900 | 2.050 | 2.064 |
| 2 | 2.334 | 2.358 | 2.092 | 2.307 | 2.308 | 2.383 | 2.472 |
| 3 | 2.605 | 2.546 | 2.404 | 2.613 | 2.618 | 2.644 | 2.722 |
| 4 | 2.892 | 2.852 | 2.669 | 2.866 | 2.875 | 2.866 | 2.928 |
| 5 | 3.133 | 3.203 | 2.946 | 3.123 | 3.137 | 3.098 | 3.145 |
| 6 | 3.441 | 3.535 | 3.233 | 3.383 | 3.402 | 3.338 | 3.370 |
| 7 | 3.783 | 3.866 | 3.687 | 3.787 | 3.813 | 3.718 | 3.729 |
| 8 | 4.060 | 4.079 | 4.015 | 4.071 | 4.102 | 3.992 | 3.989 |
| 9 | 4.423 | 4.323 | 4.383 | 4.381 | 4.417 | 4.300 | 4.282 |
| 10 | 4.650 | 4.469 | 4.604 | 4.567 | 4.606 | 4.486 | 4.458 |
| 11 | 5.081 | 4.872 | 5.205 | 5.058 | 5.104 | 4.988 | 4.937 |
| 12 | 5.332 | 5.107 | 5.553 | 5.341 | 5.391 | 5.279 | 5.216 |
| 13 | 5.800 | 5.499 | 6.125 | 5.794 | 5.849 | 5.757 | 5.673 |
| 14 | 5.952 | 5.680 | 6.384 | 5.999 | 6.055 | 5.974 | 5.881 |
| 15 | 6.302 | 5.977 | 6.813 | 6.335 | 6.394 | 6.333 | 6.224 |
| 16 | 6.770 | 6.426 | 7.448 | 6.832 | 6.894 | 6.864 | 6.734 |
| 17 | 7.048 | 6.684 | 7.810 | 7.115 | 7.178 | 7.167 | 7.024 |
| 18 | 7.294 | 6.785 | 7.949 | 7.225 | 7.289 | 7.284 | 7.136 |
| 19 | 7.413 | 7.036 | 8.293 | 7.498 | 7.559 | 7.572 | 7.413 |
| 20 | 7.940 | 7.447 | 8.859 | 7.946 | 8.014 | 8.045 | 7.867 |
| 21 | 8.174 | 7.644 | 9.125 | 8.162 | 8.213 | 8.268 | 8.081 |
| 22 | 8.298 | 7.667 | 9.159 | 8.184 | 8.254 | 8.296 | 8.108 |
| 23 | 8.698 | 8.075 | 9.706 | 8.633 | 8.674 | 8.754 | 8.548 |
| 24 | 9.547 | 8.762 | 10.614 | 9.401 | 9.379 | 9.513 | 9.278 |
| 25 | 10.290 | 9.722 | 11.845 | 10.480 | 10.385 | 10.543 | 10.268 |
| Mean 1025 | 5.726 | 5.468 | 6.105 | 5.720 | 5.752 | 5.741 | 5.662 |
| Mean Error % | | 6.228 | 9.325 | 4.708 | 4.725 | 4.931 | 5.019 |

Table 2. U10 Computed from U06 for different formulas - KPH

| Group No. | U10 | Logarithmic | Sutton | Power-law | Stutler-Hardee | Christiansen-Hargreaves | Geigher modified by Gutierrez |
|---|---|---|---|---|---|---|---|
| 1 | 4.382 | 4.823 | 2.473 | 4.309 | 4.288 | 4.887 | 4.351 |
| 2 | 5.072 | 5.096 | 3.056 | 5.020 | 5.043 | 5.290 | 5.266 |
| 3 | 5.575 | 5.242 | 3.512 | 5.517 | 5.573 | 5.607 | 5.492 |
| 4 | 5.954 | 5.702 | 3.900 | 5.904 | 5.986 | 5.875 | 5.660 |
| 5 | 6.230 | 6.255 | 4.305 | 6.275 | 6.377 | 6.156 | 5.861 |
| 6 | 6.563 | 6.758 | 4.723 | 6.628 | 6.747 | 6.446 | 6.088 |
| 7 | 7.024 | 7.110 | 5.388 | 7.157 | 7.288 | 6.907 | 6.464 |
| 8 | 7.395 | 7.310 | 5.866 | 7.506 | 7.636 | 7.239 | 6.751 |
| 9 | 7.701 | 7.545 | 6.404 | 7.868 | 7.982 | 7.612 | 7.087 |
| 10 | 8.044 | 7.687 | 6.727 | 8.083 | 8.187 | 7.836 | 7.289 |
| 11 | 8.439 | 8.090 | 7.604 | 8.631 | 8.687 | 8.444 | 7.854 |
| 12 | 8.809 | 8.328 | 8.114 | 8.944 | 8.970 | 8.797 | 8.185 |
| 13 | 9.177 | 8.742 | 8.948 | 9.441 | 9.408 | 9.376 | 8.740 |
| 14 | 9.562 | 8.938 | 9.327 | 9.674 | 9.623 | 9.638 | 8.994 |
| 15 | 9.941 | 9.258 | 9.954 | 10.044 | 9.946 | 10.073 | 9.414 |
| 16 | 10.370 | 9.760 | 10.882 | 10.624 | 10.495 | 10.716 | 10.042 |
| 17 | 10.760 | 10.053 | 11.411 | 10.962 | 10.826 | 11.083 | 10.403 |
| 18 | 11.078 | 10.174 | 11.615 | 11.109 | 10.987 | 11.224 | 10.542 |
| 19 | 11.385 | 10.470 | 12.117 | 11.478 | 11.377 | 11.573 | 10.887 |
| 20 | 11.747 | 10.958 | 12.943 | 12.079 | 12.072 | 12.146 | 11.454 |
| 21 | 12.115 | 11.195 | 13.333 | 12.394 | 12.340 | 12.416 | 11.722 |
| 22 | 12.582 | 11.219 | 13.382 | 12.404 | 12.441 | 12.450 | 11.755 |
| 23 | 13.157 | 11.723 | 14.181 | 13.102 | 13.129 | 13.004 | 12.307 |
| 24 | 13.901 | 12.594 | 15.507 | 14.326 | 14.215 | 13.924 | 13.225 |
| 25 | 15.411 | 13.867 | 17.306 | 16.033 | 15.655 | 15.170 | 14.475 |
| Mean 1025 | 9.295 | 8.756 | 8.919 | 9.420 | 9.411 | 9.356 | 8.812 |
| Mean Error % | | 7.357 | 17.202 | 5.339 | 5.435 | 5.140 | 7.090 |

Table 3. U10 Computed from U2 for different formulas - KPH

| Group No. | U10 | Logarithmic | Sutton | Power-law | Stutler-Hardee | Christiansen-Hargreaves | Geigher modified by Gutierrez |
|---|---|---|---|---|---|---|---|
| 1 | 4.382 | 4.545 | 3.150 | 4.505 | 4.374 | 4.788 | 3.767 |
| 2 | 5.072 | 4.980 | 3.881 | 5.211 | 5.128 | 5.304 | 4.961 |
| 3 | 5.575 | 5.218 | 4.331 | 5.616 | 5.564 | 5.621 | 5.288 |
| 4 | 5.954 | 5.665 | 4.809 | 6.012 | 5.989 | 5.959 | 5.591 |
| 5 | 6.230 | 6.117 | 5.210 | 6.326 | 6.325 | 6.242 | 5.858 |
| 6 | 6.563 | 6.610 | 5.722 | 6.709 | 6.732 | 6.603 | 6.210 |
| 7 | 7.024 | 7.006 | 6.289 | 7.117 | 7.157 | 7.003 | 6.608 |
| 8 | 7.395 | 7.298 | 6.751 | 7.436 | 7.483 | 7.329 | 6.939 |
| 9 | 7.701 | 7.695 | 7.354 | 7.837 | 7.879 | 7.755 | 7.381 |
| 10 | 8.044 | 7.940 | 7.732 | 8.090 | 8.133 | 8.022 | 7.657 |
| 11 | 8.439 | 8.432 | 8.449 | 8.562 | 8.579 | 8.527 | 8.190 |
| 12 | 8.809 | 8.716 | 8.866 | 8.831 | 8.835 | 8.822 | 8.500 |
| 13 | 9.177 | 9.279 | 9.644 | 9.355 | 9.309 | 9.370 | 9.085 |
| 14 | 9.562 | 9.462 | 9.897 | 9.526 | 9.463 | 9.549 | 9.276 |
| 15 | 9.941 | 9.893 | 10.478 | 9.925 | 9.817 | 9.959 | 9.716 |
| 16 | 10.370 | 10.492 | 11.257 | 10.500 | 10.325 | 10.509 | 10.308 |
| 17 | 10.760 | 10.849 | 11.719 | 10.840 | 10.616 | 10.835 | 10.659 |
| 18 | 11.078 | 11.182 | 12.128 | 11.179 | 10.923 | 11.123 | 10.971 |
| 19 | 11.385 | 11.341 | 12.325 | 11.339 | 11.063 | 11.263 | 11.122 |
| 20 | 11.747 | 12.067 | 13.202 | 12.091 | 11.751 | 11.882 | 11.794 |
| 21 | 12.115 | 12.398 | 13.501 | 12.431 | 12.079 | 12.156 | 12.092 |
| 22 | 12.582 | 12.562 | 13.797 | 12.612 | 12.221 | 12.301 | 12.249 |
| 23 | 13.157 | 13.141 | 14.463 | 13.218 | 12.864 | 12.771 | 12.760 |
| 24 | 13.901 | 14.418 | 15.874 | 14.508 | 14.155 | 13.767 | 13.846 |
| 25 | 15.411 | 15.592 | 17.109 | 15.636 | 15.258 | 14.639 | 14.799 |
| Mean 1025 | 9.295 | 9.316 | 9.521 | 9.416 | 9.281 | 9.284 | 9.025 |
| Mean Error % | | 4.985 | 12.005 | 4.655 | 4.774 | 4.501 | 5.952 |

## DISCUSSION OF RESULTS

Based on the mean absolute error the formulas studied fit the actual data in the following rank:

| | Mean absolute error, percent |
|---|---|
| 1. Christiansen-Hargreaves' | 4.857 |
| 2. Power-law, as modified by Christiansen | 4.901 |
| 3. Stutler-Hardee's | 4.978 |
| 4. Geigher's modified by Gutierrez | 6.020 |
| 5. Logarithmic, as modified | 6.190 |
| 6. Sutton's, constant a as determined | 12.844 |

In general, with the exception of Sutton's formula, the rest of the formulas studied gave results that were well within the range of accuracy expected as can be observed in Tables 1, 2 and 3. It should be remembered that the Christiansen-Hargreaves' and Stutler-Hardee's formulas were developed using wind data from the Santa Cruz Experiment Station, whereas Geigher's, Power-law, Logarithmic and Sutton's were developed from other data, although they were modified to some extent to produce better agreement with the Santa Cruz Experiment Station data.

The Christiansen-Hargreaves' formula gave values slightly high for low velocities, as shown in the Appendix Table 8 with an absolute error up to 11.829 percent for U10C6 for the first 41 lowest values of wind velocity, but for the remainder of the data the agreement was very

good. This formula presents the problem that the factor DU is computed by the use of two empirical coefficients A and B, which may not apply for other data.

The Power-law formula gave higher values for U10C6 and U10C2 as can be observed in Table 6, Appendix A, under columns U10/U10C6 and U10/U10C2, with values for this ratio as low as .958 but with an absolute error never greater than 8.657 percent. The proposed formulas to compute the exponent p may not apply for other data. Previous investigators have considered the exponent p to have seasonal variations but evidence developed here shows that p is a function of the wind velocity.

Stutler-Hardee's formula gave very good results all the way through with an absolute error never greater than 8.348 percent as shown in Table 7, Appendix A. The empirical coefficients $C_z$ and $C_v$ for height and velocity may not apply for other data.

Geigher's formula as modified by Gutierrez did not give good results for low wind velocities. This can be observed in Table 9, Appendix A, where the mean error for the first 41 values of U10C2 is of the order of 17.5 percent. The proposed formulas to convert U2 and U06 to U1 may not apply to another data. This formula as proposed here is a simple one that can be applied to most wind velocity data.

The Logarithmic formula, for which the results are tabulated in Table 4, Appendix A, gave values slightly higher for low velocities

with an absolute mean error up to 10.935 percent for U2C6 for the first 41 computed lowest values of wind velocity. The shear velocity, $U_*$, appears to be a function of wind velocity and not a constant as suggested by Calder (1939). The writer agrees with Pasquil's (1950), Inohue (1952), Allen (1968) and Lemon (1963) with respect to the non-constancy of the shear velocity. The shear velocity, $U_*$, is given in Table 4, Appendix A, under the columns of $U_*06$ and $U_*2$ and variation of this parameter with wind velocity is shown.

Sutton's formula as given in Appendix A, Table 5, gave too low values for low velocities and too high values for high velocities. It agreed fairly well for U2C6 but not for U10C6 or U10C2. In the first case the highest value of mean absolute error was 16.3 percent and in the second case the highest value was 43.7 percent for low velocities.

In general, all the formulas present problems for low velocities. This can be explained by the fact that at low velocities the wind profile is strongly influenced by the boundary layer of a fluid over a rough surface where friction and vegetation are determinant forces capable of creating distortion over the general pattern that should exist if a smooth surface was considered.

## SUMMARY AND CONCLUSIONS

1. The objectives of this study were:

a) To compare formulas for wind velocity found in the literature with actual data.

b) To compare formulas developed by researchers at the Agricultural and Irrigation Engineering Department at USU with actual data.

c) To determine the best formula for use in Venezuela.

2. Five years of daily records of wind velocity at .6, 2, and 10 meters above the ground obtained at Santa Cruz Experiment Station (Venezuelan Ministry of Public Works) have been used to study the characteristics of the wind profile with respect to the height above the ground level in the lower 10 meters of the atmosphere.

3. Six existing formulas of wind velocity profile were studied. Four of them found in the literature and two of them developed at USU. Based on the absolute mean errors, the studied formulas ranked in the following order:

a) Christiansen-Hargreaves' formula

b) Power-law formula

c) Stutler-Hardee's formula

d) Geigher's formula as modified by Gutierrez

e) Logarithmic formula

f) Sutton's formula

4. This study indicates that Christiansen-Hargreaves', Power-law, and Stutler-Hardee's formulas best fit the Santa Cruz Experiment Station wind data. It must be remembered that Christiansen-Hargreaves' and Stutler-Hardee's formulas were developed using wind velocity data from that station.

5. A simple and practical correction to Geigher's formula is presented to compute the exponent p by the use of:

$$p = \ln (U_z/U_1)/ \ln Z$$

when wind velocity at 1 meter above the ground ($U_1$) is known or determined from a dependable relationship.

6. The exponent p of the Power-law formula was shown to be not a constant value but a function of wind velocity.

7. The Logarithmic formula gave satisfactory results when the following considerations were taken into account:

a) Shear velocity $U_*$ is not constant but varies with wind velocity.

b) Zero plane displacement d needs at least three actual wind measurements at three different heights to be determined by trial and error by plotting on semi-log paper.

8. Sutton's formula, when constant value of a = 9, was used, did not give good results.

9. More detailed studies should be made including:

a) More heights of measurement within the range 1 to 10 meters above the ground level.

b) Study of the same heights of measurement at two or more different meteorological stations to relate the universality of the proposed formulas.

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# APPENDIXES

## Appendix A

## Tables 4 to 9

TABLE 4 CHECK ON THE LOGARITHMIC FORMULA FOR WIND ADJUSTMENT. SANTA CRUZ STATION. VENEZUELA

| | U2 | U2C6 | U2/U2C6 | E062 | U06 | U10C6 | U10/U10C6 | E0610 | U10 | U10C2 | U10/U10C2 | E210 | U*06 | U*2 | ZR6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEAN 41 | 1.894 | 2.079 | .911 | 10.935 | 1.135 | 4.823 | .909 | 10.500 | 4.382 | 4.545 | .964 | 5.327 | 1.206 | 1.165 | 2.429 |
| MEAN 41 | 2.334 | 2.358 | .990 | 5.240 | 1.402 | 5.096 | .995 | 3.161 | 5.072 | 4.980 | 1.018 | 4.801 | 1.190 | 1.150 | 2.159 |
| MEAN 41 | 2.605 | 2.546 | 1.023 | 6.278 | 1.612 | 5.242 | 1.064 | 6.898 | 5.575 | 5.218 | 1.068 | 7.109 | 1.178 | 1.142 | 2.012 |
| MEAN 41 | 2.892 | 2.852 | 1.014 | 5.492 | 1.790 | 5.702 | 1.044 | 10.640 | 5.954 | 5.665 | 1.051 | 8.929 | 1.170 | 1.137 | 1.682 |
| MEAN 41 | 3.133 | 3.203 | .978 | 5.909 | 1.976 | 6.255 | .996 | 10.625 | 6.230 | 6.117 | 1.018 | 8.230 | 1.162 | 1.135 | 1.317 |
| MEAN 41 | 3.441 | 3.535 | .973 | 5.338 | 2.168 | 6.758 | .971 | 5.620 | 6.563 | 6.610 | .993 | 4.540 | 1.155 | 1.135 | 1.017 |
| MEAN 41 | 3.783 | 3.866 | .978 | 4.741 | 2.473 | 7.110 | .988 | 2.442 | 7.024 | 7.006 | 1.003 | 3.400 | 1.145 | 1.138 | .852 |
| MEAN 41 | 4.060 | 4.079 | .995 | 3.751 | 2.692 | 7.310 | 1.012 | 2.778 | 7.395 | 7.298 | 1.013 | 3.905 | 1.141 | 1.143 | .783 |
| MEAN 41 | 4.473 | 4.323 | 1.023 | 5.550 | 2.939 | 7.545 | 1.021 | 3.866 | 7.701 | 7.695 | 1.001 | 5.112 | 1.138 | 1.155 | .716 |
| MEAN 41 | 4.650 | 4.469 | 1.041 | 5.160 | 3.087 | 7.687 | 1.046 | 5.229 | 8.044 | 7.940 | 1.013 | 3.939 | 1.136 | 1.161 | .676 |
| MEAN 41 | 5.041 | 4.872 | 1.043 | 5.002 | 3.490 | 8.090 | 1.043 | 4.908 | 8.439 | 8.432 | 1.001 | 4.713 | 1.136 | 1.183 | .584 |
| MEAN 41 | 5.332 | 5.107 | 1.044 | 5.670 | 3.724 | 8.328 | 1.058 | 5.842 | 8.809 | 8.716 | 1.011 | 3.315 | 1.137 | 1.195 | .535 |
| MEAN 41 | 5.800 | 5.499 | 1.055 | 6.241 | 4.107 | 8.742 | 1.050 | 6.003 | 9.177 | 9.279 | .989 | 4.467 | 1.145 | 1.228 | .470 |
| MEAN 41 | 5.952 | 5.680 | 1.048 | 5.213 | 4.280 | 8.938 | 1.070 | 8.227 | 9.562 | 9.462 | 1.011 | 4.257 | 1.150 | 1.239 | .446 |
| MEAN 41 | 6.302 | 5.977 | 1.054 | 5.861 | 4.568 | 9.258 | 1.074 | 7.510 | 9.941 | 9.893 | 1.005 | 3.816 | 1.158 | 1.268 | .404 |
| MEAN 41 | 6.770 | 6.426 | 1.054 | 6.259 | 4.994 | 9.760 | 1.062 | 6.832 | 10.370 | 10.492 | .988 | 3.992 | 1.177 | 1.314 | .356 |
| MEAN 41 | 7.048 | 6.684 | 1.054 | 5.648 | 5.237 | 10.053 | 1.070 | 7.337 | 10.760 | 10.849 | .992 | 3.444 | 1.190 | 1.342 | .333 |
| MEAN 41 | 7.294 | 6.785 | 1.075 | 6.913 | 5.330 | 10.174 | 1.089 | 8.814 | 11.078 | 11.182 | .991 | 4.412 | 1.196 | 1.373 | .326 |
| MEAN 41 | 7.413 | 7.036 | 1.054 | 5.483 | 5.661 | 10.470 | 1.087 | 9.102 | 11.385 | 11.341 | 1.004 | 4.488 | 1.212 | 1.387 | .310 |
| MEAN 41 | 7.940 | 7.447 | 1.066 | 6.342 | 5.940 | 10.958 | 1.072 | 7.470 | 11.747 | 12.067 | .973 | 5.543 | 1.239 | 1.457 | .283 |
| MEAN 41 | 8.174 | 7.644 | 1.069 | 6.396 | 6.119 | 11.195 | 1.082 | 8.613 | 12.115 | 12.398 | .977 | 5.618 | 1.254 | 1.491 | .273 |
| MEAN 41 | 8.298 | 7.667 | 1.082 | 7.959 | 6.141 | 11.219 | 1.121 | 10.836 | 12.582 | 12.562 | 1.002 | 3.389 | 1.254 | 1.506 | .270 |
| MEAN 41 | 8.698 | 8.075 | 1.077 | 8.004 | 6.508 | 11.723 | 1.122 | 10.989 | 13.157 | 13.141 | 1.001 | 3.795 | 1.288 | 1.568 | .253 |
| MEAN 41 | 9.547 | 8.762 | 1.090 | 8.043 | 7.117 | 12.594 | 1.104 | 9.631 | 13.901 | 14.418 | .964 | 6.157 | 1.353 | 1.720 | .232 |
| MEAN 41 | 10.290 | 9.722 | 1.058 | 8.266 | 7.942 | 13.867 | 1.111 | 10.061 | 15.411 | 15.592 | .988 | 7.915 | 1.464 | 1.872 | .217 |
| ALL MEAN | 5.726 | 5.468 | 1.047 | 6.228 | 4.093 | 8.756 | 1.062 | 7.357 | 9.295 | 9.316 | .998 | 4.985 | 1.199 | 1.304 | .757 |

TABLE 5 CHECK ON SUTTON FORMULA FOR WIND ADJUSTMENT. SANTA CRUZ STATION. VENEZUELA

| | U2 | U2C6 | U2/U2C6 | E062 | U06 | U10C6 | U10/U10C6 | E0610 | U10 | U10C2 | U10/U10C2 | E210 | A | C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEAN 41 | 1.894 | 1.693 | 1.119 | 12.433 | 1.135 | 2.473 | 1.772 | 43.711 | 4.382 | 3.150 | 1.391 | 28.133 | 9.000 | 1.000 |
| MEAN 41 | 2.334 | 2.092 | 1.116 | 10.380 | 1.402 | 3.056 | 1.660 | 39.844 | 5.072 | 3.881 | 1.307 | 23.563 | 9.000 | 1.000 |
| MEAN 41 | 2.605 | 2.404 | 1.084 | 9.604 | 1.612 | 3.512 | 1.587 | 36.973 | 5.575 | 4.331 | 1.287 | 22.316 | 9.000 | 1.000 |
| MEAN 41 | 2.892 | 2.669 | 1.084 | 7.834 | 1.790 | 3.900 | 1.527 | 34.554 | 5.954 | 4.809 | 1.238 | 19.335 | 9.000 | 1.000 |
| MEAN 41 | 3.133 | 2.946 | 1.063 | 7.525 | 1.976 | 4.305 | 1.447 | 30.900 | 6.230 | 5.210 | 1.196 | 16.473 | 9.000 | 1.000 |
| MEAN 41 | 3.441 | 3.233 | 1.064 | 8.287 | 2.168 | 4.723 | 1.389 | 28.019 | 6.563 | 5.722 | 1.147 | 13.037 | 9.000 | 1.000 |
| MEAN 41 | 3.783 | 3.687 | 1.026 | 5.526 | 2.473 | 5.388 | 1.304 | 23.359 | 7.024 | 6.289 | 1.117 | 11.103 | 9.000 | 1.000 |
| MEAN 41 | 4.060 | 4.015 | 1.011 | 4.629 | 2.692 | 5.866 | 1.261 | 20.807 | 7.395 | 6.751 | 1.095 | 9.999 | 9.000 | 1.000 |
| MEAN 41 | 4.423 | 4.383 | 1.009 | 6.179 | 2.939 | 6.404 | 1.203 | 17.871 | 7.701 | 7.354 | 1.047 | 9.355 | 9.000 | 1.000 |
| MEAN 41 | 4.650 | 4.604 | 1.010 | 4.912 | 3.087 | 6.727 | 1.196 | 16.889 | 8.044 | 7.732 | 1.040 | 6.729 | 9.000 | 1.000 |
| MEAN 41 | 5.081 | 5.205 | .976 | 6.312 | 3.490 | 7.604 | 1.110 | 11.040 | 8.439 | 8.449 | .999 | 6.810 | 9.000 | 1.000 |
| MEAN 41 | 5.332 | 5.553 | .960 | 7.209 | 3.724 | 8.114 | 1.086 | 9.580 | 8.809 | 8.866 | .994 | 4.561 | 9.000 | 1.000 |
| MEAN 41 | 5.800 | 6.125 | .947 | 6.948 | 4.107 | 8.948 | 1.026 | 7.782 | 9.177 | 9.644 | .952 | 7.227 | 9.000 | 1.000 |
| MEAN 41 | 5.952 | 6.384 | .932 | 7.950 | 4.280 | 9.327 | 1.025 | 9.149 | 9.562 | 9.897 | .966 | 5.891 | 9.000 | 1.000 |
| MEAN 41 | 6.302 | 6.813 | .925 | 8.857 | 4.568 | 9.954 | .999 | 6.419 | 9.941 | 10.478 | .949 | 6.734 | 9.000 | 1.000 |
| MEAN 41 | 6.770 | 7.448 | .909 | 10.318 | 4.994 | 10.882 | .953 | 6.963 | 10.370 | 11.257 | .921 | 8.797 | 9.000 | 1.000 |
| MEAN 41 | 7.048 | 7.810 | .902 | 10.996 | 5.237 | 11.411 | .943 | 6.763 | 10.760 | 11.719 | .918 | 8.993 | 9.000 | 1.000 |
| MEAN 41 | 7.294 | 7.949 | .918 | 9.265 | 5.630 | 11.615 | .954 | 7.323 | 11.078 | 12.128 | .913 | 9.963 | 9.000 | 1.000 |
| MEAN 41 | 7.413 | 8.293 | .894 | 11.748 | 5.561 | 12.117 | .940 | 8.804 | 11.385 | 12.325 | .924 | 9.061 | 9.000 | 1.000 |
| MEAN 41 | 7.940 | 8.859 | .896 | 12.725 | 5.840 | 12.943 | .908 | 10.908 | 11.747 | 13.202 | .890 | 12.768 | 9.000 | 1.000 |
| MEAN 41 | 8.174 | 9.125 | .896 | 11.670 | 6.119 | 13.333 | .909 | 10.550 | 12.115 | 13.591 | .891 | 12.260 | 9.000 | 1.000 |
| MEAN 41 | 8.298 | 9.159 | .906 | 13.414 | 6.141 | 13.382 | .940 | 7.574 | 12.582 | 13.797 | .912 | 9.702 | 9.000 | 1.000 |
| MEAN 41 | 8.698 | 9.706 | .896 | 12.530 | 6.508 | 14.181 | .928 | 8.831 | 13.157 | 14.463 | .910 | 10.224 | 9.000 | 1.000 |
| MEAN 41 | 9.547 | 10.614 | .899 | 12.522 | 7.117 | 15.507 | .896 | 12.024 | 13.901 | 15.874 | .876 | 14.706 | 9.000 | 1.000 |
| MEAN 41 | 10.290 | 11.845 | .869 | 16.340 | 7.942 | 17.306 | .890 | 13.411 | 15.411 | 17.109 | .901 | 12.389 | 9.000 | 1.000 |
| ALL MEAN | 5.726 | 6.105 | .938 | 9.325 | 4.093 | 8.919 | 1.042 | 17.202 | 9.295 | 9.521 | .976 | 12.005 | 9.000 | 1.000 |

TABLE 6 CHECK ON THE POWER-LAW FORMULA FOR WIND ADJUSTMENT. SANTA CRUZ STATION. VENEZUELA

| | U2 | U2C6 | U2/U2C6 | E062 | U06 | U10C6 | U10/U10C6 | E0610 | U10 | U10C2 | U10/U10C2 | E210 | P12 | P16 | P26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEAN 41 | 1.894 | 1.904 | .995 | 8.243 | 1.135 | 4.309 | 1.017 | 7.548 | 4.382 | 4.505 | .973 | 5.073 | .540 | .476 | .431 |
| MEAN 41 | 2.334 | 2.307 | 1.012 | 5.428 | 1.402 | 5.020 | 1.010 | 5.707 | 5.072 | 5.211 | .973 | 5.711 | .501 | .455 | .415 |
| MEAN 41 | 2.605 | 2.613 | .997 | 6.839 | 1.612 | 5.517 | 1.011 | 6.277 | 5.575 | 5.616 | .993 | 5.059 | .479 | .439 | .402 |
| MEAN 41 | 2.892 | 2.866 | 1.009 | 4.448 | 1.790 | 5.904 | 1.008 | 4.495 | 5.954 | 6.012 | .990 | 4.306 | .456 | .425 | .392 |
| MEAN 41 | 3.133 | 3.123 | 1.003 | 5.294 | 1.976 | 6.275 | .993 | 5.511 | 6.230 | 6.326 | .985 | 5.620 | .438 | .412 | .382 |
| MEAN 41 | 3.441 | 3.383 | 1.017 | 6.161 | 2.168 | 6.628 | .990 | 5.597 | 6.563 | 6.709 | .978 | 4.938 | .417 | .399 | .371 |
| MEAN 41 | 3.783 | 3.787 | .999 | 4.478 | 2.473 | 7.157 | .982 | 4.647 | 7.024 | 7.117 | .987 | 3.936 | .394 | .379 | .355 |
| MEAN 41 | 4.060 | 4.071 | .997 | 4.149 | 2.692 | 7.506 | .985 | 4.534 | 7.395 | 7.436 | .995 | 3.948 | .377 | .366 | .345 |
| MEAN 41 | 4.423 | 4.381 | 1.010 | 5.611 | 2.939 | 7.868 | .979 | 5.147 | 7.701 | 7.837 | .983 | 5.071 | .358 | .352 | .333 |
| MEAN 41 | 4.650 | 4.667 | 1.018 | 4.444 | 3.087 | 8.083 | .995 | 4.830 | 8.044 | 8.090 | .994 | 3.762 | .345 | .344 | .327 |
| MEAN 41 | 5.081 | 5.059 | 1.005 | 4.448 | 3.490 | 8.631 | .978 | 5.700 | 8.439 | 8.562 | .986 | 4.572 | .326 | .324 | .310 |
| MEAN 41 | 5.332 | 5.341 | .998 | 4.871 | 3.724 | 8.944 | .985 | 3.945 | 8.809 | 8.831 | .997 | 3.102 | .314 | .312 | .301 |
| MEAN 41 | 5.800 | 5.794 | 1.001 | 4.650 | 4.107 | 9.441 | .972 | 4.828 | 9.177 | 9.355 | .981 | 4.229 | .298 | .297 | .287 |
| MEAN 41 | 5.959 | 5.999 | .992 | 4.222 | 4.280 | 9.674 | .988 | 4.877 | 9.562 | 9.526 | 1.004 | 3.779 | .293 | .291 | .282 |
| MEAN 41 | 6.302 | 6.335 | .995 | 4.531 | 4.568 | 10.044 | .990 | 3.873 | 9.941 | 9.925 | 1.002 | 3.571 | .283 | .281 | .272 |
| MEAN 41 | 6.770 | 6.832 | .991 | 4.053 | 4.994 | 10.629 | .976 | 4.241 | 10.370 | 10.500 | .988 | 3.900 | .273 | .269 | .261 |
| MEAN 41 | 7.048 | 7.115 | .991 | 3.182 | 5.237 | 10.962 | .982 | 3.597 | 10.760 | 10.840 | .993 | 3.390 | .268 | .263 | .255 |
| MEAN 41 | 7.294 | 7.225 | 1.010 | 2.947 | 5.330 | 11.109 | .997 | 4.035 | 11.078 | 11.179 | .991 | 4.510 | .266 | .262 | .253 |
| MEAN 41 | 7.413 | 7.498 | .989 | 3.482 | 5.561 | 11.478 | .992 | 5.932 | 11.385 | 11.339 | 1.004 | 4.621 | .264 | .258 | .249 |
| MEAN 41 | 7.940 | 7.946 | .999 | 4.039 | 5.940 | 12.079 | .973 | 6.142 | 11.747 | 12.091 | .972 | 5.813 | .261 | .253 | .242 |
| MEAN 41 | 8.174 | 8.162 | 1.002 | 2.685 | 6.119 | 12.394 | .977 | 5.739 | 12.115 | 12.431 | .975 | 5.921 | .261 | .251 | .240 |
| MEAN 41 | 8.298 | 8.184 | 1.014 | 3.644 | 6.141 | 12.404 | 1.014 | 4.896 | 12.582 | 12.612 | .998 | 3.476 | .260 | .250 | .239 |
| MEAN 41 | 8.698 | 8.633 | 1.008 | 4.757 | 6.508 | 13.102 | 1.004 | 5.682 | 13.157 | 13.218 | .995 | 3.915 | .260 | .249 | .235 |
| MEAN 41 | 9.547 | 9.401 | 1.015 | 3.963 | 7.117 | 14.326 | .970 | 7.001 | 13.901 | 14.508 | .958 | 6.385 | .260 | .249 | .231 |
| MEAN 41 | 10.290 | 10.480 | .982 | 6.733 | 7.942 | 16.033 | .961 | 8.657 | 15.411 | 15.636 | .986 | 7.764 | .260 | .250 | .230 |
| ALL MEAN | 5.726 | 5.720 | 1.001 | 4.708 | 4.093 | 9.420 | .987 | 5.339 | 9.295 | 9.416 | .987 | 4.655 | .338 | .324 | .306 |

TABLE 7 CHECK ON THE STUTLER-HARDEE FORMULA FOR WIND ADJUSTMENT. SANTA CRUZ STATION. VENEZUELA

| | U2 | U2C6 | U2/U2C6 | E062 | U06 | U10C6 | U10/U10C6 | E0610 | U10 | U10C2 | U10/U10C2 | E210 | CV12 | CV16 | CV26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEAN 41 | 1.894 | 1.900 | .997 | 8.348 | 1.135 | 4.288 | 1.022 | 8.127 | 4.382 | 4.374 | 1.002 | 4.962 | 1.272 | 1.474 | 1.183 |
| MEAN 41 | 2.334 | 2.308 | 1.012 | 5.470 | 1.402 | 5.043 | 1.006 | 6.058 | 5.072 | 5.128 | .989 | 6.011 | 1.212 | 1.400 | 1.163 |
| MEAN 41 | 2.605 | 2.618 | .995 | 6.904 | 1.612 | 5.573 | 1.000 | 6.560 | 5.575 | 5.564 | 1.002 | 5.271 | 1.176 | 1.345 | 1.147 |
| MEAN 41 | 2.892 | 2.875 | 1.006 | 4.487 | 1.790 | 5.986 | .995 | 4.781 | 5.954 | 5.985 | .994 | 4.681 | 1.141 | 1.301 | 1.135 |
| MEAN 41 | 3.133 | 3.137 | .999 | 5.361 | 1.976 | 6.377 | .977 | 5.700 | 6.230 | 6.325 | .985 | 5.950 | 1.113 | 1.257 | 1.122 |
| MEAN 41 | 3.441 | 3.402 | 1.012 | 6.146 | 2.168 | 6.747 | .973 | 6.170 | 6.563 | 6.732 | .975 | 5.308 | 1.079 | 1.214 | 1.109 |
| MEAN 41 | 3.783 | 3.813 | .992 | 4.638 | 2.473 | 7.288 | .964 | 5.254 | 7.024 | 7.157 | .981 | 4.196 | 1.043 | 1.148 | 1.090 |
| MEAN 41 | 4.060 | 4.102 | .990 | 4.264 | 2.692 | 7.636 | .968 | 5.077 | 7.395 | 7.483 | .988 | 4.015 | 1.016 | 1.105 | 1.077 |
| MEAN 41 | 4.423 | 4.417 | 1.001 | 5.767 | 2.939 | 7.982 | .965 | 5.438 | 7.701 | 7.879 | .977 | 5.148 | .984 | 1.061 | 1.063 |
| MEAN 41 | 4.650 | 4.606 | 1.010 | 4.265 | 3.087 | 8.187 | .982 | 4.897 | 8.044 | 8.133 | .989 | 3.755 | .963 | 1.035 | 1.055 |
| MEAN 41 | 5.081 | 5.104 | .995 | 4.958 | 3.490 | 8.687 | .971 | 5.525 | 8.439 | 8.579 | .984 | 4.416 | .931 | .972 | 1.034 |
| MEAN 41 | 5.332 | 5.391 | .989 | 5.117 | 3.724 | 8.970 | .982 | 3.603 | 8.809 | 8.835 | .997 | 2.899 | .912 | .938 | 1.023 |
| MEAN 41 | 5.800 | 5.849 | .992 | 4.530 | 4.107 | 9.408 | .975 | 4.233 | 9.177 | 9.309 | .986 | 3.748 | .884 | .893 | 1.007 |
| MEAN 41 | 5.952 | 6.055 | .983 | 4.561 | 4.280 | 9.623 | .994 | 4.548 | 9.562 | 9.463 | 1.010 | 3.557 | .875 | .876 | 1.000 |
| MEAN 41 | 6.302 | 6.394 | .986 | 4.621 | 4.568 | 9.946 | .999 | 3.586 | 9.941 | 9.817 | 1.013 | 3.282 | .857 | .847 | .989 |
| MEAN 41 | 6.770 | 6.894 | .982 | 4.146 | 4.994 | 10.495 | .988 | 4.090 | 10.370 | 10.325 | 1.004 | 3.973 | .839 | .817 | .975 |
| MEAN 41 | 7.048 | 7.178 | .982 | 3.399 | 5.237 | 10.826 | .994 | 3.891 | 10.760 | 10.616 | 1.014 | 3.406 | .828 | .802 | .968 |
| MEAN 41 | 7.294 | 7.289 | 1.001 | 2.823 | 5.330 | 10.987 | 1.008 | 4.615 | 11.078 | 10.923 | 1.014 | 4.872 | .824 | .801 | .966 |
| MEAN 41 | 7.413 | 7.559 | .981 | 3.500 | 5.561 | 11.377 | 1.001 | 6.635 | 11.385 | 11.063 | 1.029 | 5.353 | .821 | .794 | .960 |
| MEAN 41 | 7.940 | 8.014 | .991 | 4.347 | 5.940 | 12.072 | .973 | 7.192 | 11.747 | 11.751 | 1.000 | 5.323 | .814 | .788 | .953 |
| MEAN 41 | 8.174 | 8.213 | .995 | 2.708 | 6.119 | 12.340 | .982 | 6.190 | 12.115 | 12.079 | 1.003 | 6.563 | .812 | .782 | .948 |
| MEAN 41 | 8.298 | 8.254 | 1.005 | 3.499 | 6.141 | 12.441 | 1.011 | 5.892 | 12.582 | 12.221 | 1.030 | 4.957 | .809 | .785 | .949 |
| MEAN 41 | 8.698 | 8.674 | 1.003 | 4.439 | 6.508 | 13.129 | 1.002 | 5.713 | 13.157 | 12.864 | 1.023 | 4.749 | .813 | .782 | .941 |
| MEAN 41 | 9.547 | 9.379 | 1.018 | 3.650 | 7.1[illegible] | 14.215 | .978 | 5.319 | 13.901 | 14.155 | .982 | 5.656 | .815 | .775 | .931 |
| MEAN 41 | 10.290 | 10.385 | .991 | 6.176 | 7.942 | 15.655 | .984 | 6.783 | 15.411 | 15.258 | 1.010 | 7.297 | .815 | .765 | .923 |
| ALL MEAN | 5.726 | 5.752 | .995 | 4.725 | 4.093 | 9.411 | .988 | 5.435 | 9.295 | 9.281 | 1.002 | 4.774 | .946 | .990 | 1.028 |

TABLE 8 CHECK ON CHRISTIANSEN-HARGREAVES FORMULA FOR WIND ADJUSTMENT, SANTA CRUZ STATION, VENEZUELA

| | U2 | U2C6 | U2/U2C6 | E062 | U06 | U10C6 | U10/U10C6 | E06I0 | U10 | U10C2 | U10/U10C2 | E210 | SL12 | SL16 | SL26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEAN 41 | 1.894 | 2.050 | .924 | 9.934 | 1.135 | 4.887 | .897 | 11.829 | 4.382 | 4.788 | .915 | 9.573 | .370 | .525 | .459 |
| MEAN 41 | 2.334 | 2.383 | .979 | 5.881 | 1.402 | 5.290 | .959 | 4.764 | 5.072 | 5.304 | .956 | 5.425 | .427 | .602 | .581 |
| MEAN 41 | 2.605 | 2.644 | .985 | 6.945 | 1.612 | 5.607 | .994 | 4.348 | 5.575 | 5.621 | .992 | 4.211 | .463 | .662 | .569 |
| MEAN 41 | 2.892 | 2.866 | 1.009 | 4.400 | 1.790 | 5.875 | 1.013 | 3.302 | 5.954 | 5.959 | .999 | 3.777 | .500 | .714 | .810 |
| MEAN 41 | 3.133 | 3.098 | 1.011 | 5.115 | 1.976 | 6.156 | 1.012 | 4.789 | 6.230 | 6.242 | .998 | 4.979 | .531 | .767 | .653 |
| MEAN 41 | 3.441 | 3.338 | 1.031 | 6.246 | 2.168 | 6.446 | 1.018 | 5.060 | 6.563 | 6.603 | .994 | 4.305 | .571 | .822 | .697 |
| MEAN 41 | 3.783 | 3.718 | 1.017 | 4.449 | 2.473 | 6.907 | 1.017 | 4.406 | 7.024 | 7.003 | 1.003 | 3.910 | .616 | .910 | .767 |
| MEAN 41 | 4.060 | 3.992 | 1.017 | 4.225 | 2.692 | 7.239 | 1.022 | 4.610 | 7.395 | 7.329 | 1.005 | 4.162 | .652 | .974 | .817 |
| MEAN 41 | 4.423 | 4.300 | 1.028 | 5.644 | 2.939 | 7.612 | 1.012 | 5.451 | 7.701 | 7.755 | .993 | 5.314 | .699 | 1.045 | .874 |
| MEAN 41 | 4.650 | 4.486 | 1.037 | 5.288 | 3.087 | 7.836 | 1.027 | 5.444 | 8.044 | 8.022 | 1.003 | 3.981 | .729 | 1.087 | .908 |
| MEAN 41 | 5.081 | 4.988 | 1.019 | 5.179 | 3.490 | 8.444 | .999 | 6.001 | 8.439 | 8.527 | .990 | 4.797 | .785 | 1.203 | 1.001 |
| MEAN 41 | 5.332 | 5.279 | 1.010 | 5.018 | 3.724 | 8.797 | 1.001 | 4.581 | 8.809 | 8.822 | .999 | 3.307 | .817 | 1.271 | 1.055 |
| MEAN 41 | 5.800 | 5.757 | 1.007 | 4.921 | 4.107 | 9.376 | .979 | 5.253 | 9.177 | 9.370 | .979 | 4.435 | .878 | 1.381 | 1.143 |
| MEAN 41 | 5.952 | 5.974 | .996 | 4.361 | 4.280 | 9.638 | .992 | 5.616 | 9.562 | 9.549 | 1.001 | 3.795 | .898 | 1.431 | 1.183 |
| MEAN 41 | 6.302 | 6.333 | .995 | 4.676 | 4.568 | 10.073 | .987 | 4.412 | 9.941 | 9.959 | .998 | 3.606 | .943 | 1.514 | 1.249 |
| MEAN 41 | 6.770 | 6.864 | .986 | 4.339 | 4.994 | 10.716 | .968 | 4.809 | 10.370 | 10.509 | .987 | 3.544 | 1.004 | 1.636 | 1.347 |
| MEAN 41 | 7.048 | 7.167 | .983 | 3.433 | 5.237 | 11.083 | .971 | 4.080 | 10.760 | 10.835 | .993 | 3.094 | 1.040 | 1.706 | 1.403 |
| MEAN 41 | 7.294 | 7.284 | 1.001 | 2.969 | 5.330 | 11.224 | .987 | 4.296 | 11.078 | 11.123 | .996 | 3.926 | 1.072 | 1.733 | 1.424 |
| MEAN 41 | 7.413 | 7.572 | .979 | 3.709 | 5.661 | 11.573 | .984 | 5.650 | 11.385 | 11.263 | 1.011 | 4.111 | 1.088 | 1.800 | 1.477 |
| MEAN 41 | 7.940 | 8.045 | .987 | 4.592 | 5.940 | 12.146 | .967 | 5.767 | 11.747 | 11.882 | .989 | 4.460 | 1.156 | 1.909 | 1.564 |
| MEAN 41 | 8.174 | 8.268 | .989 | 2.892 | 6.119 | 12.416 | .976 | 4.938 | 12.115 | 12.156 | .997 | 4.912 | 1.187 | 1.960 | 1.606 |
| MEAN 41 | 8.298 | 8.296 | 1.000 | 3.630 | 6.141 | 12.450 | 1.011 | 4.117 | 12.582 | 12.301 | 1.023 | 3.714 | 1.203 | 1.967 | 1.611 |
| MEAN 41 | 8.698 | 8.754 | .994 | 4.808 | 6.508 | 13.004 | 1.012 | 4.433 | 13.157 | 12.771 | 1.030 | 4.374 | 1.255 | 2.073 | 1.695 |
| MEAN 41 | 9.547 | 9.513 | 1.004 | 3.865 | 7.117 | 13.924 | .998 | 4.788 | 13.901 | 13.767 | 1.010 | 4.337 | 1.365 | 2.248 | 1.835 |
| MEAN 41 | 10.290 | 10.543 | .976 | 6.752 | 7.942 | 15.170 | 1.016 | 5.747 | 15.411 | 14.639 | 1.053 | 6.477 | 1.462 | 2.486 | 2.025 |
| ALL MEAN | 5.726 | 5.741 | .997 | 4.931 | 4.093 | 9.356 | .994 | 5.140 | 9.295 | 9.284 | 1.001 | 4.501 | .868 | 1.377 | 1.140 |

TABLE 9 CHECK ON THE GEIGHER MOD. FORMULA FOR WIND ADJUSTMENT. SANTA CRUZ STATION. VENEZUELA

| | U2 | U2C6 | U2/U2C6 | E062 | U06 | U10C6 | U10/U10C6 | E0610 | U10 | U10C2 | U10/U10C2 | E210 | P12 | P16 | U16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEAN 41 | 1.894 | 2.063 | .918 | 10.308 | 1.135 | 4.350 | 1.007 | 10.514 | 4.382 | 3.767 | 1.163 | 17.501 | .464 | .462 | 1.887 |
| MEAN 41 | 2.334 | 2.472 | .945 | 8.039 | 1.402 | 5.263 | .964 | 5.899 | 5.072 | 4.961 | 1.022 | 5.099 | .473 | .471 | 1.786 |
| MEAN 41 | 2.605 | 2.721 | .957 | 7.687 | 1.612 | 5.489 | 1.016 | 3.540 | 5.575 | 5.288 | 1.054 | 5.640 | .442 | .437 | 2.013 |
| MEAN 41 | 2.892 | 2.927 | .988 | 4.521 | 1.790 | 5.657 | 1.053 | 5.009 | 5.954 | 5.591 | 1.065 | 6.691 | .411 | .411 | 2.205 |
| MEAN 41 | 3.133 | 3.144 | .997 | 5.222 | 1.976 | 5.858 | 1.064 | 6.274 | 6.230 | 5.858 | 1.063 | 7.148 | .391 | .388 | 2.406 |
| MEAN 41 | 3.441 | 3.369 | 1.021 | 5.957 | 2.168 | 6.085 | 1.079 | 7.544 | 6.563 | 6.210 | 1.057 | 6.351 | .369 | .369 | 2.613 |
| MEAN 41 | 3.783 | 3.728 | 1.015 | 4.229 | 2.473 | 6.461 | 1.087 | 8.037 | 7.024 | 6.608 | 1.063 | 6.643 | .348 | .343 | 2.943 |
| MEAN 41 | 4.060 | 3.988 | 1.018 | 4.155 | 2.692 | 6.748 | 1.096 | 9.048 | 7.395 | 6.939 | 1.066 | 7.109 | .334 | .328 | 3.180 |
| MEAN 41 | 4.423 | 4.281 | 1.033 | 5.705 | 2.939 | 7.083 | 1.087 | 9.123 | 7.701 | 7.381 | 1.043 | 7.344 | .320 | .314 | 3.447 |
| MEAN 41 | 4.650 | 4.457 | 1.043 | 5.538 | 3.087 | 7.286 | 1.104 | 9.952 | 8.044 | 7.657 | 1.051 | 6.225 | .311 | .307 | 3.608 |
| MEAN 41 | 5.081 | 4.936 | 1.029 | 5.274 | 3.490 | 7.851 | 1.075 | 7.532 | 8.439 | 8.190 | 1.030 | 6.038 | .298 | .290 | 4.043 |
| MEAN 41 | 5.332 | 5.214 | 1.023 | 5.107 | 3.724 | 8.182 | 1.077 | 7.698 | 8.809 | 8.500 | 1.036 | 4.534 | .290 | .281 | 4.295 |
| MEAN 41 | 5.800 | 5.672 | 1.023 | 5.208 | 4.107 | 8.736 | 1.051 | 6.886 | 9.177 | 9.085 | 1.010 | 4.997 | .280 | .269 | 4.710 |
| MEAN 41 | 5.952 | 5.879 | 1.012 | 4.142 | 4.280 | 8.989 | 1.064 | 8.723 | 9.562 | 9.276 | 1.031 | 5.217 | .276 | .265 | 4.897 |
| MEAN 41 | 6.302 | 6.223 | 1.013 | 4.574 | 4.568 | 9.409 | 1.057 | 6.802 | 9.941 | 9.716 | 1.023 | 4.233 | .269 | .257 | 5.208 |
| MEAN 41 | 6.770 | 6.732 | 1.006 | 4.355 | 4.994 | 10.038 | 1.033 | 5.848 | 10.370 | 10.308 | 1.006 | 4.407 | .262 | .249 | 5.659 |
| MEAN 41 | 7.048 | 7.023 | 1.004 | 3.205 | 5.237 | 10.398 | 1.035 | 5.536 | 10.760 | 10.659 | 1.010 | 3.558 | .257 | .244 | 5.931 |
| MEAN 41 | 7.294 | 7.135 | 1.022 | 3.365 | 5.330 | 10.538 | 1.051 | 6.653 | 11.078 | 10.971 | 1.010 | 4.700 | .254 | .243 | 6.032 |
| MEAN 41 | 7.413 | 7.411 | 1.000 | 3.594 | 5.561 | 10.882 | 1.046 | 7.529 | 11.385 | 11.122 | 1.024 | 5.015 | .253 | .239 | 6.282 |
| MEAN 41 | 7.940 | 7.865 | 1.010 | 4.006 | 5.940 | 11.448 | 1.026 | 5.810 | 11.747 | 11.794 | .996 | 4.850 | .246 | .234 | 6.691 |
| MEAN 41 | 8.174 | 8.080 | 1.012 | 2.848 | 6.119 | 11.716 | 1.034 | 6.452 | 12.115 | 12.092 | 1.002 | 5.513 | .244 | .231 | 6.885 |
| MEAN 41 | 8.298 | 8.106 | 1.024 | 3.984 | 6.141 | 11.749 | 1.071 | 7.062 | 12.582 | 12.249 | 1.027 | 4.140 | .242 | .231 | 6.989 |
| MEAN 41 | 8.698 | 8.546 | 1.018 | 4.809 | 6.508 | 12.301 | 1.070 | 7.221 | 13.157 | 12.760 | 1.031 | 4.640 | .238 | .227 | 7.305 |
| MEAN 41 | 9.547 | 9.276 | 1.029 | 3.998 | 7.117 | 13.219 | 1.052 | 6.317 | 13.901 | 13.846 | 1.004 | 4.712 | .231 | .220 | 7.964 |
| MEAN 41 | 10.240 | 10.266 | 1.002 | 5.690 | 7.942 | 14.468 | 1.065 | 6.884 | 15.411 | 14.799 | 1.041 | 6.490 | .226 | .214 | 8.856 |
| ALL MEAN | 5.726 | 5.661 | 1.012 | 5.021 | 4.093 | 8.808 | 1.055 | 7.116 | 9.295 | 9.025 | 1.030 | 5.952 | .309 | .301 | 4.695 |

# Appendix B

## Computer programs no. 1, 2, 3, 4, 5 and 6

```
00100     1•    C      PROGRAM NUMBER 1.
00100     2•    C      LOGARITHMIC FORMULA
00100     3•    C      THIS PROGRAM COMPUTES VALUES OF WIND VELOCITY AT A GIVEN ELEVATION
00100     4•    C      FROM THE VELOCITY AT OTHER GIVEN ELEVATION
00100     5•    C      U06 = WIND VELOCITY AT .6 METERS IN KM. PER HOUR.
00100     6•    C      U2 = WIND VELOCITY AT 2 METERS IN KM. PER HOUR.
00100     7•    C      U10=WIND VELOCITY AT 10 METERS IN KM. PER HOUR
00100     8•    C      Z06,Z2,Z10, MEAN HEIGHTS AT .6, 2, AND 10 METERS   RESPECTIVELY
00101     9•           DIMENSION X(22),SU(22),A(22),SUM(22),AV(22)
00103    10•       100 FORMAT(15,3I2,2F4.0,F12.0)
00104    11•       102 FORMAT(1H1'TABLE  1  CHECK ON THE LOGARITHMIC    FORMULA FOR WIND
00104    12•          2ADJUSTMENT, SANTA CRUZ STATION, VENEZUELA'/)
00105    13•       111 FORMAT(1H0'                U2    U2C6  U2/U2C6   E062    U06     U10C
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00105    14•          16  U10/U10C6 E0610    U10   U10C2  U10/U10C2 E210    U•06     U•2
00105    15•           3    2R6 '•/)
00106    16•       105 FORMAT(2I3)
00107    17•       124 FORMAT(1H0'ALL MEAN'•15F8.3)
00110    18•       123 FORMAT(1H0'MEAN 41 '•15F8.3)
00111    19•           XX=0.
00112    20•           DO 22  I=1,18
00115    21•        22 SUM(I)=0.
00117    22•           WRITE(6,102)
00121    23•           WRITE(6,111)
00123    24•           READ(5,105)M,N
00127    25•           DO 30  L=1,M
00132    26•           DO 23 I=1,23
00135    27•        23 SU(I)=0.
00137    28•           XN=N
00140    29•           DO 17 J=1,N
00143    30•           READ(5,100)NST,MYR,MO,NDA,W06,W2,W10
00154    31•           U10=W10/24.
00155    32•           U2=W2/24.
00156    33•           U06=W06/24.
00157    34•           XK=.42
00160    35•           Z06=.6
00161    36•           Z2=2.
00162    37•           Z10=10.
00163    38•           IF(U2.GT.3.)GO TO 44
00165    39•           D=3.
00166    40•           GO TO 51
00167    41•        44 D=1.5
00170    42•        51 CONTINUE
00171    43•           V06=1.30-.1•U06+.015•U06••2
00172    44•           V2=1.3   1•U2+ 11••2••2
00173    45•           ZR6=(Z06+D)/EXP((1/XK•U06)/V06)
00174    46•           '  '  '  '  '  '  '  '
00175    47•           U2C6=V06/XK•ALOG((Z2+D)/ZR6)
00176    48•           U10C6=V06/XK•ALOG((Z10+D)/ZR6)
00177    49•           U10C2=V2/XK•ALOG((Z10+D)/ZR2)
00200    50•           E210=100.•ABS((U10-U10C2)/U10)
00201    51•           E0610=100.•ABS((U10-U10C6)/U10)
00202    52•           E062=100.•ABS((U2-U2C6)/U2)
00203    53•           X(1)=U2
00204    54•           X(2)=U2C6
00205    55•           X(3)=U2/U2C6
00206    56•           X(4)=E062
00207    57•           X(5)=U06
00210    58•           X(6)=U10C6
00211    59•           X(7)=U10/U10C6
00212    60•           X(8)=E0610
00213    61•           X(9)=U10
00214    62•           X(10)=U10C2
00215    63•           X(11)=U10/U10C2
00216    64•           X(12)=E210
00217    65•           X(13)=V06
00220    66•           X(14)=V2
00221    67•           X(15)=ZR6
00222    68•           DO 40 I=1,15
00225    69•        40 SU(I)=SU(I)+X(I)
00227    70•        17 CONTINUE
00231    71•           DO 41 I=1,15
```

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00234    72•           A(I)=SU(I)/XN
00235    73•        41 CONTINUE
00237    74•           A(3)=SU(1)/SU(2)
00240    75•           A(11)=SU(9)/SU(10)
00241    76•           A(11)=SU(9)/SU(10)
00242    77•           WRITE(6,12)(A(I), I=1,15)
00250    78•           XX=XX+XN
00251    79•           DO 42 I=1,15
00254    80•           SUM(I)=SUM(I)+SU(I)
00255    81•        42 CONTINUE
00257    82•        30 CONTINUE
00261    83•           DO 43 I=1,15
00264    84•        43 A=      =    ''
00266    85•           A=      ,  ' = ''
00267    86•           AV(I)=SUM(I)/SUM(6)
00270    87•           A=  ,    = =  ' = , '
00271    88•           '          =  =          ''
00277    89•           STOP
00300    90•           END
```

END OF UNIVAC 1108 FORTRAN V COMPILATION.  0 •DIAGNOSTIC• MESSAGE(S)

```
00100     1•   C      PROGRAM NUMBER 2.
00100     2•   C      SUTTON'S FORMULA
00100     3•   C      THIS PROGRAM COMPUTES VALUES OF WIND VELOCITY AT A GIVEN ELEVATION
00100     4•   C      FROM THE VELOCITY AT A LOWER ELEVATION.
00100     5•   C      U06 = WIND VELOCITY AT .6 METERS IN KM. PER HOUR.
00100     6•   C      U2 = WIND VELOCITY AT 2 METERS IN KM. PER HOUR.
00100     7•   C      U10 = WIND VELOCITY AT 10 METERS IN KM. PER HOUR.
00101     8•          DIMENSION X(22),SU(22),A(22),SUM(22),AV(22)
00103     9•      100 FORMAT(I5,3I2,2F4.0,F12.0)
00104    10•      102 FORMAT(1H1'TABLE  2  CHECK    ON     SUTTON      FORMULA FOR WIND
00104    11•         2ADJUSTMENT, SANTA CRUZ STATION, VENEZUELA'/)
00105    12•      111 FORMAT(1H0'                U2    U2C6  U2/U2C6   E062    U06     U10C
00105    13•         16  U10/U10C6 E061D    U10   U10C2  U10/U10C2 E210       A       C
00105    14•         3  DUMMY './)
00106    15•      105 FORMAT(2I3)
00107    16•      124 FORMAT(1H0'ALL MEAN'.15F8.3)
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```
00110    17•      123 FORMAT(1H0'MEAN 41 '.15F8.3)
00111    18•          XX=0.
00112    19•          DO 22  I=1.18
00115    20•       22 SUM(I)=0.
00117    21•          WRITE(6.102)
00121    22•          WRITE(6.111)
00123    23•          READ(5.105)M.N
00127    24•          DO 30  L=1.M
00132    25•          DO 23 I=1.23
00135    26•       23 SU(I)=0.
00137    27•          XN=N
00140    28•          DO 17 J=1.N
00143    29•          READ(5.100)NST.NYP.MO.NDA.W06.W2.W10
00154    30•          U10=W10/24.
00155    31•          U2=W2/24.
00156    32•          U06=W06/24.
00157    33•          Z06=.6
00160    34•          Z2=2.
00161    35•          Z10=10.
00162    36•          T=9.
00163    37•          C=1.
00164    38•          U2C6=U06*(ALOG10(T+Z2/Z06+C)/ALOG10(T+C))
00165    39•          U10C6=U06*(ALOG10(T+Z10/Z06+C)/ALOG10(T+C))
00166    40•          U10C2=U2*(ALOG10(T+Z10/Z2+C)/ALOG10(T+C))
00167    41•          EP10=100.*ABS((U10-U10C2)/U10)
00170    42•          E0610=100.*ABS((U10-U10C6)/U10)
00171    43•          E062=100.*ABS((U2-U2C6)/U2)
00172    44•          X(1)=U2
00173    45•          X(2)=U2C6
00174    46•          X(3)=U2/U2C6
00175    47•          X(4)=E062
00176    48•          X(5)=U06
00177    49•          X(6)=U10C6
00200    50•          X(7)=U10
00201    51•          X(8)=E0610
00202    52•          X(9)=U10
00203    53•          X(10)=U10C2
00204    54•          X(11)=U10/U10C2
00205    55•          X(12)=E210
00206    56•          X(13)=T
00207    57•          X(14)=C
00210    58•          X(15)=0.
00211    59•          DO 40 I=1.15
00214    60•       40 SU(I)=SU(I)+X(I)
00216    61•       17 CONTINUE
00220    62•          DO 41 I=1.15
00223    63•          A(I)=SU(I)/XN
00224    64•       41 CONTINUE
00226    65•          A(3)=SU(1)/SU(2)
00227    66•          A(7)=SU(9)/SU(6)
00230    67•          A(11)=SU(9)/SU(10)
00231    68•          WRITE(6.123)(A(I).I=1.15)
00237    69•          XX=XX+XN
00240    70•          DO 42 I=1.15
00243    71•          SUM(I)=SUM(I)+SU(I)
00244    72•       42 CONTINUE
00246    73•       30 CONTINUE
00250    74•          DO 43 I=1.15
```

```
00253    75•       43 AV(I)=SUM(I)/XX
00255    76•          AV(3)=SUM(1)/SUM(2)
00256    77•          AV(7)=SUM(9)/SUM(6)
00257    78•          AV(11)=SUM(9)/SUM(10)
00260    79•          WRITE(6.124)(AV(I).I=1.15)
00266    80•          STOP
00267    81•          END
```

END OF UNIVAC 1108 FORTRAN V COMPILATION.  0 •DIAGNOSTIC• MESSAGE(S)

```
00100      1*   C      PROGRAM NUMBER 5.
00100      2*   C      POWER-LAW FORMULA
00100      3*   C      THIS PROGRAM COMPUTES VALUES OF WIND VELOCITY AT A GIVEN ELEVATION
00100      4*   C    FROM THE VELOCITY AT OTHER GIVEN ELEVATION
00100      5*   C      U06 = WIND VELOCITY AT .6 METERS IN KM. PER HOUR.
00100      6*   C      U2 = WIND VELOCITY AT 2 METERS IN KM. PER HOUR.
00100      7*   C      U10 = WIND VELOCITY AT 10 METERS IN KM. PER HOUR.
00101      8*         DIMENSION U(22),SU(22),A(22),SUM(22),AV(22)
00103      9*     100 FORMAT(1H,,11X,F4.0,F12.0)
00104     10*     102 FORMAT(1H1*TABLE   * CHECK ON THE  POWER-LAW     FORMULA FOR WIND
00104     11*         *ADJUSTMENT, SANTA CRUZ STATION, VENEZUELA*/)
00105     12*     111 FORMAT(1H0*                U2    U2C6  U2/U2C6   E062    U06     U10C
00105     13*         1S U10/U10C6 E0610     U10   U10C2  U10/U10C2 E210     P12     P16
00105     14*         3    P26*/)
00106     15*     175 FORMAT(2I3)
00107     16*     176 FORMAT(1H0*ALL MEAN*,15X,8.3)
```

```
00110     17*     177 FORMAT(1H0*MEAN *1 *,15X,8.3)
00111     18*         SUM=0.
00112     19*         DO 22  I=1,18
00115     20*      22 SUM(I)=0.
00117     21*         WRITE(6,102)
00121     22*         WRITE(6,111)
00123     23*         READ(5,175)M,N
00127     24*         DO 30  L=1,M
00132     25*         DO 23 I=1,23
00135     26*      23 SU(I)=0.
00137     27*         K=N
00140     28*         DO 17 I=1,N
00143     29*         READ(5,176)NST,NYR,MO,NDA,U06,U2,U10
00150     30*         U10=U10/24.
00155     31*         U2=U2/24.
00156     32*         U06=U06/24.
00157     33*         P12=.78-.4*(U2/4.1**.12*(U2/4.1**2
00160     34*         P16=.53-.4*(U06/4.1**.12*(U06/4.1**2
00161     35*         P26=.51-.70*(U06/4.1**.08*(U06/4.1**2
00162     36*         IF(U06-7.15)50,50,51
00164     37*      51 P16=.25
00166     38*         P26=.33
00167     39*      50 IF(U2-4.16)60,60,61
00172     40*      61 P12=.26
00173     41*      60 CONTINUE
00174     42*         U10C2=U2*(10./2.)**P12
00175     43*         U10C6=U06*(10./.6)**P16
00176     44*         U2C6=U06*(2./.6)**P26
00177     45*         E210=100.*ABS(U10-U10C2)/U10)
00200     46*         E0610=100.*ABS(U10-U10C6)/U10)
00201     47*         E062=100.*ABS(U2-U2C6)/U2)
00202     48*         X(1)=U2
00203     49*         X(2)=U2C6
00204     50*         X(3)=U2/U2C6
00205     51*         X(4)=E062
00206     52*         X(5)=U06
00207     53*         X(6)=U06/U2C6
00210     54*         X(7)=U10/U10C2
00211     55*         X(8)=E210
00212     56*         X(9)=U10
00213     57*         X(10)=U10C2
00214     58*         X(11)=U10/U10C6
00215     59*         X(12)=E0610
00216     60*         X(13)=P12
00217     61*         X(14)=P16
00220     62*         X(15)=P26
00221     63*         DO 40 I=1,15
00224     64*      40 SU(I)=SU(I)+X(I)
00226     65*      17 CONTINUE
00230     66*         DO 41 I=1,15
00233     67*         A(I)=SU(I)/K
00234     68*      41 CONTINUE
00236     69*         A(3)=SU(3)/SU(2)
00237     70*         A(6)=SU(6)/SU(5)
00240     71*         A(11)=SU(11)/SU(10)
00241     72*         WRITE(6,173)(A(I),I=1,15)
00247     73*         K=K+N
00250     74*         DO 42 I=1,15
```

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00251     75*         SUM(I)=SUM(I)+SU(I)
00254     76*      42 CONTINUE
00256     77*      30 CONTINUE
00260     78*         DO 43 I=1,15
00263     79*      43 AV(I)=SUM(I)/N
00265     80*         AV(3)=SUM(3)/SUM(2)
00266     81*         AV(6)=SUM(6)/SUM(5)
00267     82*         AV(11)=SUM(11)/SUM(10)
00270     83*         WRITE(6,173)(AV(I),I=1,15)
00276     84*         STOP
00277     85*         END

      END OF UNIVAC 1108 FORTRAN V COMPILATION.     0 DIAGNOSTIC MESSAGE(S)
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```
00100     1•   C      PROGRAM NUMBER 4.
00100     2•   C      STUTLER-HARDEE'S FORMULA
00100     3•   C      THIS PROGRAM COMPUTES VALUES OF WIND VELOCITY AT A GIVEN ELEVATION
00100     4•   C    FROM THE VELOCITY AT OTHER GIVEN ELEVATION
00100     5•   C      U06 = WIND VELOCITY AT .6 METERS IN KM. PER HOUR.
00100     6•   C      U2 = WIND VELOCITY AT 2 METERS IN KM. PER HOUR.
00100     7•   C      U10 = WIND VELOCITY AT 10 METERS IN KM. PER HOUR.
00101     8•          DIMENSION X(22),SU(22),A(22),SUM(22),AV(22)
00103     9•      100 FORMAT(I5,3I2,2F4.0,F12.0)
00104    10•      102 FORMAT(1H1'TABLE  4  CHECK ON THE STUTLER-HARDEE FORMULA FOR WIND
00104    11•         2ADJUSTMENT, SANTA CRUZ STATION, VENEZUELA'/)
00105    12•      111 FORMAT(1H0'                U2    U2C6  U2/U2C6   E062    U06    U10C
00105    13•         1G U10/U10C6 E0610     U10   U10C2  U10/U10C2 E210    CV12    CV16
00105    14•         3   CV26'/)
00106    15•      105 FORMAT(2I3)
00107    16•      124 FORMAT(1H0'ALL MEAN'.15F8.3)
```

```
00110    17•      123 FORMAT(1H0'MEAN 41 '.15F8.3)
00111    18•          EE=0.
00112    19•          DO 22  I=1,18
00115    20•       22 SUM(I)=0.
00117    21•          WRITE(6,102)
00121    22•          WRITE(6,111)
00123    23•          READ(5,105)M,N
00127    24•          DO 30  L=1,M
00132    25•          DO 23 I=1,23
00135    26•       23 SU(I)=0.
00137    27•          EN=N
00140    28•          DO 17 J=1,N
00143    29•          READ(5,100)NST,NYP,MO,NDA,W06,W2,W10
00154    30•          U10=W10/24.
00155    31•          U2=W2/24.
00156    32•          U06=W06/24.
00157    33•          C22=1.8193
00160    34•          C206=2.5791
00161    35•          C23 C206/C22
00162    36•          CV12=1.58-.73*(U2/4.)+.174*(U2/4.)**2
00163    37•          CV16=1.83-1.39*(U06/4.)+.46*(U06/4.)**2
00164    38•          CV26=1.28-.37*(U06/4.)+.10*(U06/4.)**2
00165    39•          IF(U06-7.) 51,51,50
00170    40•       50 CONTINUE
00171    41•          CV16=.760
00172    42•          CV26=.920
00173    43•       51 CONTINUE
00174    44•          IF(U2-4.5) 61,61,60
00177    45•       60 CONTINUE
00200    46•          CV12=.815
00201    47•       61 CONTINUE
00202    48•          U10C2=U2*C22*CV12
00203    49•          U10C6=U06*C206*CV16
00204    50•          U2C6=U06*C23*CV26
00205    51•          E210=100.*ABS((U10-U10C2)/U10)
00206    52•          E0610=100.*ABS((U10-U10C6)/U10)
00207    53•          E062=100.*ABS((U2-U2C6)/U2)
00210    54•          X(1)=U2
00211    55•          X(2)=U2C6
00212    56•          X(3)=U2/U2C6
00213    57•          X(4)=E062
00214    58•          X(5)=U06
00215    59•          X(6)=U06
00216    60•          X(7)=U10/U10C6
00217    61•          X(8)=E0610
00220    62•          X(9)=U10
00221    63•          X(10)=U10C2
00222    64•          X(11)=U10/U10C2
00223    65•          X(12)=E210
00224    66•          X(13)=CV12
00225    67•          X(14)=CV16
00226    68•          X(15)=CV26
00227    69•          DO 40 I=1,15
00232    70•       40 SU(I)=SU(I)+X(I)
00234    71        17 CONTINUE
00236    72•          DO 41 I=1,15
00241    73•          A(I)=SU(I)/EN
00242    74•       41 CONTINUE
```

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00244    75•          A(3)=SU(3)/SU(2)
00245    76•          A(7)=SU(9)/SU(6)
00246    77•          A(11)=SU(9)/SU(10)
00247    78•          WRITE(6,123)(A(I),I=1,15)
00255    79•          EE=EE+EN
00256    80•          DO 42 I=1,15
00261    81•          SUM(I)=SUM(I)+SU(I)
00262    82•       42 CONTINUE
00264    83•       30 CONTINUE
00266    84•          DO 43 I=1,15
00271    85•       43 AV(I)=SUM(I)/EE
00273    86•          AV(3)=SUM(3)/SUM(2)
00274    87•          AV(7)=SUM(9)/SUM(6)
00275    88•          AV(11)=SUM(9)/SUM(10)
00276    89•          WRITE(6,123)(AV(I),I=1,15)
00304    90•          STOP
00305    91•          END
```

END OF UNIVAC 1108 FORTRAN V COMPILATION.  0 *DIAGNOSTIC* MESSAGE(S)

```
00100     1•   C      PROGRAM NUMBER 5.
00100     2•   C      CHRISTIANSEN-HARGREAVES'  FORMULA
00100     3•   C      THIS PROGRAM COMPUTES VALUES OF WIND VELOCITY AT A GIVEN ELEVATION
00100     4•   C     FROM THE VELOCITY AT OTHER GIVEN ELEVATION
00100     5•   C      U06 = WIND VELOCITY AT .6 METERS IN KM. PER HOUR.
00100     6•   C      U2 = WIND VELOCITY AT 2 METERS IN KM. PER HOUR.
00100     7•   C      U10 = WIND VELOCITY AT 10 METERS IN KM. PER HOUR.
00101     8•          DIMENSION X(22),SU(22),A(22),SUM(22),AV(22)
00103     9•      100 FORMAT(I5,3I2,2F4  ,F12. )
00104    10•      102 FORMAT(1H1'TABLE  5  CHECK ON CHRISTIANSEN-HARGREAVES FORMULA FOR
                    2WIND ADJUSTMENT,SANTA CRUZ STATION, VENEZUELA'/)
00105    12•      111 FORMAT(1H0'                U2    U2C6  U2/U2C6    E062    U06    U10C
00105    13•         16  U10/U10C6 E0610    U10   U10C2  U10/U10C2 E210    SL12    SL16
00105    14•         3   SL26'/)
00106    15•      105 FORMAT(2I3)
00107    16•      124 FORMAT(1H0'ALL MEAN',15F8.3)
```

```
00110    17•      123 FORMAT(1H0'MEAN 41 ',15F8.3)
00111    18•          XX=0.
00112    19•          DO 22  I=1,18
00115    20•       22 SUM(I)=0.
00117    21•          WRITE(6,102)
00121    22•          WRITE(6,111)
00123    23•          READ(5,105)M,N
00127    24•          DO 30  L=1,M
00132    25•          DO 23 I=1,23
00135    26•       23 SU(I)=0.
00137    27•          XN=N
00140    28•          DO 17 J=1,N
00143    29•          READ(5,100)NST,NYR,MO,NDA,WD6,W2,W10
00154    30•          U10=W10/24.
00155    31•          U2=W2/24.
00156    32•          U06=WD6/24.
00157    33•          B12=.13
00160    34•          B16=.28
00161    35•          B26=.23
00162    36•          A2=.23-.053*2.
00163    37•          A3=.23-.053*.6
00164    38•          SL12=A2*B12*U2
00165    39•          SL16=A3*B16*U06
00166    40•          SL26=A3*B26*U06
00167    41•          DU12=A.*(.30+SL12*(2./12.))
00170    42•          DU16=9.4*(.30+SL16*(2./10.6))
00171    43•          DU26=1.4*(.30+SL26*(2./2.6))
00172    44•          U10C2=U2+DU12
00173    45•          U10C6=U06+DU16
00174    46•          U2C6=U06+DU26
00175    47•          E210=100.*ABS((U10-U10C2)/U10)
00176    48•          E0610=100.*ABS((U10-U10C6)/U10)
00177    49•          E062=100.*ABS((U2-U2C6)/U2)
00200    50•          X(1)=U2
00201    51•          X(2)=U2C6
00202    52•          X(3)=U2/U2C6
00203    53•          X(4)=E062
00204    54•          X(5)=U06
00205    55•          X(6)=U10C6
00206    56•          X(7)=U10/U10C6
00207    57•          X(8)=E0610
00210    58•          X(9)=U10
00211    59•          X(10)=U10C2
00212    60•          X(11)=U10/U10C2
00213    61•          X(12)=E210
00214    62•          X(13)=SL12
00215    63•          X(14)=SL16
00216    64•          X(15)=SL26
00217    65•          DO 40 I=1,15
00222    66•       40 SU(I)=SU(I)+X(I)
00224    67•       17 CONTINUE
00226    68•          DO 41 I=1,15
00231    69•          A(I)=SU(I)/XN
00232    70•       41 CONTINUE
00234    71•          A(3)=SU(1)/SU(2)
00235    72•          A(7)=SU(9)/SU(6)
00236    73•          A(11)=SU(9)/SU(10)
00237    74•          WRITE(6,123)(A(I),I=1,15)
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00245    75•          XX=XX+XN
00246    76•          DO 42 I=1,15
00251    77•          SUM(I)=SUM(I)+SU(I)
00252    78•       42 CONTINUE
00254    79•       30 CONTINUE
00256    80•          DO 43 I=1,15
00261    81•       43 AV(I)=SUM(I)/XX
00263    82•          AV(3)=SUM(1)/SUM(2)
00264    83•          AV(7)=SUM(9)/SUM(6)
00265    84•          AV(11)=SUM(9)/SUM(10)
00266    85•          WRITE(6,123)(AV(I),I=1,15)
00274    86•          STOP
00275    87•          END
```

END OF UNIVAC 1108 FORTRAN V COMPILATION.  0 •DIAGNOSTIC• MESSAGE(S)

```
00100     1•   C      PROGRAM NUMBER 6.
00100     2•   C      GEIGHER'S MODIFIED FORMULA
00100     3•   C      THIS PROGRAM COMPUTES VALUES OF WIND VELOCITY AT A GIVEN ELEVATION
00100     4•   C     FROM THE VELOCITY AT OTHER GIVEN ELEVATION
00100     5•   C      U06 = WIND VELOCITY AT .6 METERS IN KM. PER HOUR.
00100     6•   C      U2 = WIND VELOCITY AT 2 METERS IN KM. PER HOUR.
00100     7•   C      U10 = WIND VELOCITY AT 10 METERS IN KM. PER HOUR.
00101     8•          DIMENSION X(22),    7    8    ' ,SUM(22),AV(22)
00103     9•     100 FORMAT(15,3I2,2F4.0,F12.0)
00104    10•     102 FORMAT(1H1'TABLE   6  CHECK ON THE GEIGHER   MOD. FORMULA FOR WIND
00104    11•        2ADJUSTMENT. SANTA CRUZ STATION. VENEZUELA'/)
00105    12•     111 FORMAT(1H0'                U2    U2C6  U2/U2C6   E062    U06     U10C
00105    13•        16 U10/U10C6 E0610     U10   U10C2  U10/U10C2 E210     P12     P16
00105    14•        3    U16'./)
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00106    15•     105 FORMAT(2I3)
00107    16•     124 FORMAT(1H0'ALL MEAN'•15F8.3)
00110    17•     123 FORMAT(1H0'MEAN 41  '•15F8.3)
00111    18•         XX=0.
00112    19•         DO 22  I=1,18
00115    20•      22 SUM(I)=0.
00117    21•         WRITE(6,102)
00121    22•         WRITE(6,111)
00123    23•         READ(5,105)M,N
00127    24•         DO 30  L=1,M
00132    25•         DO 23 I=1,23
00135    26•      23 SU(I)=0.
00137    27•         XN=N
00140    28•         DO 17 J=1,N
00143    29•         READ(5,100)NST,NYR,MO,NDA,W06,W2,W10
00154    30•         U10=W10/24.
00155    31•         U2=W2/24.
00156    32•         U06=W06/24.
00157    33•         C2=ALOG(2.)
00160    34•         C6=ALOG(.6)
00161    35•         U16=1.081*U06+.2712
00162    36•         U12=.895*U2-.41
00163    37•         IF   2   1 2 , ( ) 9
00165    38•         P12=.45
00166    39•         P16=.45
00167    40•         GO TO 7
00170    41•       9 P12=ALOG(U2/U12)/C2
00171    42•         P16= ALOG(U06/U16)/C6
00172    43•       7 CONTINUE
00173    44•         U2C6=U16*2.**P16
00174    45•         U10C6=U16*10.**P16
00175    46•         U10C2=U12*10.**P12
00176    47•         E210=100.*ABS((U10-U10C2)/U10)
00177    48•         E0610=100.*ABS((U10-U10C6)/U10)
00200    49•         E062=100.*ABS((U2-U2C6)/U2)
00201    50•         X(1)=U2
00202    51•         X(2)=U2C6
00203    52•         X(3)=U2/U2C6
00204    53•         X(4)=E062
00205    54•         X(5)=U06
00206    55•         X(6)=U10C6
00207    56•         X(7)=U10/U10C6
00210    57•         X(8)=E0610
00211    58•         X(9)=U10
00212    59•         X(10)=U10C2
00213    60•         X(11)   ,    1 1 2
00214    61•         X(12)=E210
00215    62•         X(13)=P12
00216    63•         X(14)=P16
00217    64•         X(15)=U16
00220    65•         DO 40 I=1,15
00223    66•      40 SU(I)=SU(I)+X(I)
00225    67•      17 CONTINUE
00227    68•         DO 41 I=1,15
00232    69•         A(I)=SU(I)/XN
00233    70•      41 CONTINUE
00235    71•         A(3)=SU(1)/SU(2)
00236    72•         A(7)=SU(9)/SU(6)
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00237    73•         A(11)=SU(9)/SU(10)
00240    74•         WRITE(6,123)(A(I),I=1,15)
00246    75•         XX=XX+XN
00247    76•         DO 42 I=1,15
00252    77•         SUM(I)=SUM(I)+SU(I)
00253    78•      42 CONTINUE
00255    79•      30 CONTINUE
00257    80•         DO 43 I=1,15
00262    81•      43 AV(I)=SUM(I)/XX
00264    82•         AV(3)=SUM(1)/SUM(2)
00265    83•         AV(7)=SUM(9)/SUM(6)
00266    84•         AV(11)=SUM(9)/SUM(10)
00267    85•         WRITE(6,124)(AV(I),I=1,15)
00275    86•         STOP
00276    87•         END
```

END OF UNIVAC 1108 FORTRAN V COMPILATION.  0 •DIAGNOSTIC• MESSAGE(S)

# VITA

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Personal Data: Born at Siquisique, Lara, Venezuela, April 26, 1938, son of Benjamin Gutierrez and Rosa Melendez; married Nulbia Saturno July, 1968, one daughter--Marielena.

Education: Attended elementary school in Barquisimeto, Venezuela; attended secondary education at the Liceo "Lisandro Alvarado", Barquisimento, Venezuela; received the degree of Ingeniero Agronomo from Universidad del Zulia, Maracaibo, Venezuela in 1964, completed requirements for the Master of Science degree at Utah State University, June 1970.

Professional Experience: 1965, working with Venezuelan Ministry of Public Works, made the study of salinization of the waters of Limon River, Zulia State, Venezuela; 1966, made the study of physical properties of the soils of Camatagua basin (3000 Hectares); since

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