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ANALYSES OF ENERGY, MOMENTUM, AND MASS TRANSFERS ABOVE VEGETATIVE SURFACES

Prepared by:

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FEBRUARY 1971

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ATMOSPHERIC SCIENCES LABORATORY

FORT HUACHUCA, ARIZONA

GRANT DA–AMC–28–043–68–G10

UNIVERSITY OF CALIFORNIA, DAVIS CALIFORNIA

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ECOM 68-G10-F
February 1971

ANALYSES OF ENERGY, MOMENTUM, AND MASS TRANSFERS ABOVE VEGETATIVE SURFACES

FINAL REPORT

Under Grant Number DA-AMC-28-043-68-G10
DA Task No. 1T061102B53A-17

Prepared by:
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For

United States Army Electronics Command
Atmospheric Sciences Laboratory
Fort Huachuca, Arizona

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ESCUELA DE INGENIERIA CIVIL
DEPARTAMENTO DE METEOROLOGIA E HIDROLOGIA

SUMMARY

Results of a two-year grant to analyze energy, momentum, and mass transfers, based on micrometeorological data gathered at Davis, California, in 1966 and 1967, are presented in four chapters containing discussions of the von Karman constant, the eddy-transfer coefficients and the Monin-Obukhov universal ϕ_M, ϕ_W, and ϕ_H functions, the dimensionless fluxes, and evaporation under advection conditions, respectively. Appendices reference other reports published under the grant, present basic smoothed data for the major field runs, and give a detailed presentation of the formulation and criteria used in processing the basic data.

Extensive surface shear-stress and wind-profile measurements during six separate field studies at Davis, California, indicate a value for the von Karman constant, k, of 0.42. The value of k for the six studies varied from a low of 0.40 to a high of 0.44. Expressions relating k_m^* to the Richardson number for both stable and unstable conditions, based on the Davis data, are presented and, for the most part, compare favorably with the findings of Webb (1965), Rossby and Montgomery (1935), and Holzman (1943).

Expressions relating ϕ functions to both the Richardson number and the Monin-Obukhov z/L are developed and compared with results of other researchers. For $\phi_M(Ri)$ an expression having the form of $\phi_M = (1+b|Ri|)^{|n|}$ gives a good fit to UCD data, with a b of 16 and an $|n|$ of 1/3 (- for unstable and + for stable conditions). This value for $|n|$ is 33% higher than the 1/4 power suggested by Ellison (1957) and as used in the KEYPS profile, and 33% lower than the exponent of 1/2 suggested by the expressions of Rossby and Montgomery (1935) and Holzman (1943). In relation to z/L, expressions giving good fit to UCD data were $(1-12z/L)^{-.46}$ and $(1+16z/L)^{.25}$ for unstable and stable cases, respectively.

The simplified Monin-Obukhov expression with an α of 0.6 appears to offer too small a correction even quite close to neutral. With an α of 4.5 for unstable or 2.0 for stable conditions, prediction of ϕ_M is adequate out to z/L values of -.06 and +.3, respectively.

Expressions for ϕ_W giving good fit to experimental data were $\phi_W = .885(1-22Ri)^{-.40}$ or $.885(1-14z/L)^{-.57}$ for unstable cases and $\phi_W = .885(1+34Ri)^{.40}$ or $.885(1+27z/L)^{.38}$ for stable cases. The expression for $\phi_W(z/L)$ for unstable conditions compares closely with Dyer's (1967) expression of $(1-15z/L)^{-.55}$ except for the significant difference for near-neutral conditions.

The ratio of K_W/K_M varied from a low of 0.7 at Ri = .3 up to 1.6 at Ri = -2. At neutral, K_W/K_M was 1.13 rather than 1.0.

The newly-derived dimensionless flux parameter for momentum, τ^*, was shown to respond to changing stability conditions in a fashion similar to H* and E*. The E* values for the Davis data are in excellent agreement with those reported by Crawford. While τ^* remained relatively constant beyond Ri = -.15, E* gradually increased reflecting increasing K_W/K_M under free convection.

For the advection of dry air over an irrigated grass turf, the earlier-reported UCD work was generally substantiated by additional analyses reported herein.

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PREFACE

Tribute should be given to the late Dr. Frederick A. Brooks, whose ideas for many of the experiments and some of the special instrumentation, in particular the drag-plate lysimeter, make possible the findings presented here. The unique data and exciting results reflect the vision of his searching mind. It is with deep appreciation and respect that we dedicate this final report, culminating many years of preparatory work and over ten years of intensive effort, to this stimulating scholar.

ACKNOWLEDGEMENTS

Additional support for instrumentation and personnel on this project has come from the Water Resources Center of the University of California and from the California State Department of Water Resources.

The authors gratefully acknowledge the faithful efforts of Mr. A. M. Brown, Mr. M. A. Johnson, Mrs. H. H. Laidlaw, Mr. W. S. Newhall, Mr. S. von Oettingen, and Mr. A. Servis in assisting with the painstaking analyses of the data. Deep appreciation is also extended to the many who assisted with the collection and processing of the basic data, in particular,Mr. W. B. Goddard, who was responsible for the development and calibrations of the drag-plate lysimeter, and Mr. F. V. Jones, Jr., who developed in large the computer program for processing the data collected.

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CHAPTER I

FINAL REPORT GRANT G-10 - INTRODUCTION

D. L. Morgan, W. O. Pruitt, and F. J. Lourence

This report represents the completion of a two-year grant to analyze energy, momentum, and mass transfers above vegetative surfaces. During the past year, several reports have been published on analyses of the micrometeorological data gathered during 1966 and 1967 at the Hydrometeorological Field Site at the University of California at Davis. These reports are referenced, along with abstracts of their content, in Appendix A.

In Chapter II of this report a detailed evaluation of the von Karman constant is presented. After a brief but rather complete exposition of the known studies of atmospheric drag, the determination of the von Karman constant from wind-profile and surface-drag measurements is discussed, and the generalized form of the von Karman constant is defined. The remainder of this chapter presents and discusses the values of the generalized von Karman constant for the Davis field runs and compares them with the findings of other researchers.

Chapter III presents the evaluation of the eddy-transfer coefficients and diabatic-profile functions based on the data from the Davis field runs. This chapter, we believe, is the first place in the micrometeorological literature where all three diabatic-profile functions, ϕ_M, ϕ_W, and ϕ_H, based on measured surface drag, are presented simultaneously. A discussion of the log-law and transfer-coefficient relationships opens this chapter. This is followed by the results of analyzing the Davis data in terms of both Richardson number and the Monin-Obukhov heat length and comparing the findings with those of many other researchers.

The dimensionless forms of heat, moisture, and momentum fluxes are presented in Chapter IV, after a brief introduction describing the designation of H* by Priestley and E* by Crawford and the ideas for an analogous expression for momentum, τ^*, also by Crawford. The results and a discussion of comparing the values of these dimensionless fluxes based on the Davis data with the work of others in this field make up the remainder of this chapter.

The material constituting Chapter V completes the information presented in the earlier report of Morgan, Lourence and Pruitt (1970), giving a more comprehensive picture of the effects of advection. This is done in the following manner. First, the results of analyzing the 1966 data applying the same method as used by Decker for 1967 data are presented. This is followed by a presentation of the 1967 wind, temperature, and energy-balance data, including a discussion of changes in the temperature profiles during mild advective conditions. To complete this analysis of advection, two of the methods used by Goltz and Pruitt in analyzing 1966 data are applied to the case of mild advection in 1967. The results are discussed, and a general critique is made of the effectiveness of various methods tested for estimating evapotranspiration under advective conditions.

Appendix A gives the references and abstracts of the research results accomplished under Grant G-10 which have been published previous to this final report.

Appendix B presents the smoothed temperature, humidity, and wind-speed profile data as well as the average wind directions, displacement height and surface roughness for six of the nine 1966-67 Davis field runs. Included with these profile data are corresponding values of the Richardson number, energy-balance components, and shear stress.

Instrumentation with the data collecting and processing procedures are also discussed in this appendix. A table, which identifies the dates, times, and duration of the nine field runs along with a very brief description of the general weather conditions accompanying each field run is also included in this appendix.

Appendix C includes a detailed presentation of the formulation used in calculating the multitude of micrometeorological variables discussed in the chapters of this report. These formulas are in a modified-computer form and include the units of the parameters and variables involved for internal checking. A step by step outline of the data analysis procedure used in processing the Davis field runs through this Eddy Diffusivity Program is also presented. This appendix concludes with a presentation of the criteria for rejection of undesirable data for processing through the program.

REFERENCE

Morgan, D. L., W. O. Pruitt, and F. J. Lourence. 1970. Evaporation from an irrigated turf under advection of dry air at Davis, California. Research and Development Technical Report ECOM 68-G10-1, University of California, Davis. 118 pages (AD 705 386)

CHAPTER II

EVALUATION OF THE VON KARMAN CONSTANT UNDER TURBULENT FLOW IN THE LOWER ATMOSPHERE

by

W. O. Pruitt, D. L. Morgan, and F. J. Lourence

1. INTRODUCTION

With measured values of surface drag made available at Davis from the very sensitive 6.1-meter-diameter, 50-ton floating lysimeter (Brooks et al, 1962, 1963, 1966, and Goddard, 1970), an excellent opportunity was afforded for evaluation of the von Karman constant, k. In an early analysis of k using data from this lysimeter, Brooks et al (1966) reported values for k of around 0.50. However, this value and similar high values reported by Dr. Brooks at the 1966 Pacific Science Congress in Tokyo, resulted from errors in data reduction. Brooks et al (1968), in a reanalysis of 1965 data, reported values of k ranging somewhat above 0.43. Goddard (1970) indicated that analysis of later data from the 1967 Cooperative Field Experiment at Davis shows a value for k of 0.41.

In this chapter data are analyzed from six of the eight studies conducted in 1966 and 1967 at Davis, including the Cooperative Field Experiment. Rather than considering only those periods of the study with neutral stability conditions, use was made of an expression for a generalized form of the von Karman constant, k_m^*. The value of k for each run was selected from the point at which a smoothed curve of k_m^* versus Richardson number passed through an Ri of zero.

2. ATMOSPHERIC DRAG STUDIES

Measurements of surface drag of the atmosphere originated with an instrument by Sheppard (1947). This consisted of a 22.5-cm-diameter aluminum drag plate floating on oil. Pasquill (1950) increased the size to 45.7 cm and used the first natural crop surface on a drag plate in open air by installing a pan for holding a grass turf. Rider (1954) arranged an array of six Pasquill drag plates to obtain measurements under varying wind directions. Poppendiek and Vehrencamp (1950) studied surface drag under desert conditions with a 91.5-cm-diameter drag plate. Vehrencamp (1952) provided the first unit where servo-mechanisms essentially eliminated drag-plate movement. Vector-component measurements were also incorporated allowing operation independent of wind direction. This greatly improved unit was used by University of California researchers in the 1953 O'Neill (Nebraska) studies, and results were compared with those from a Sheppard meter in a report by Lettau and Davidson (1957). Halstead and Ono (1954) reported results of surface drag measurements at Shirley, New Jersey, in 1952, using a Sheppard drag plate with a simulated soil surface. The same article also reported comparisons of their unit with the advanced Vehrencamp model, both at the 1953 O'Neill study and in a 1954 study over the extremely smooth El Mirage Dry Lake. In the latter study rather severe disagreement was noted between the two units in at least six of eleven runs, although the overall means were in good agreement. In the O'Neill study, Halstead et al (1954) used natural vegetation on the Sheppard drag plate but found that addition or removal of only a few spears of grass produced large changes in surface drag.

Consequently, Halstead used data from the Vehrencamp meter in a comparison of measured and computed shear stress. Even with this instrument, the variation was quite large, in part doubtless because of the quite small sample size in relation to the rather large scale of roughness of the bunch grass of the O'Neill study.

Gurvich (1961) measured surface drag from a piece of grass sod placed on a mobile platform suspended on threads. Monin and Yaglom (1965), reviewing the Gurvich system and others, concluded that "accuracy of the best of them does not reach the accuracy of the best of existing pulsating instruments (eddy correlation devices) designed for this purpose." Munn (1966) also exhibited considerable skepticism with regard to drag-plate lysimeters in use, suggesting that their accuracy was not likely to be much better than $\pm$30%. The consistency of recent results of Bradley (1968) suggests a better degree of accuracy was attained in studies with small drag plates described in a companion article (Bradley, 1968a). Surfaces tested, however, were artificial where standardization of roughness for all units is more easily achieved than for natural surfaces.

Perhaps relatively small sample size and/or nonrepresentative positioning of drag plates in some of the above-mentioned studies produced the high degree of uncertainty. That the level of accuracy is much greater for the large floating drag-plate lysimeter at Davis than for the earlier drag plates, can hardly be questioned in view of a recent report by Thurtell et al (1970). Data from the UCD unit were compared with pressure sphere measurements of shear at 1- and 4-meter heights collected during the 1967 Cooperative Field Experiment. Agreement was very good over a wide range of wind speed and stability conditions during a 4-day study.

The rather good accuracy of the UCD drag-plate lysimeter is also evident from the data presented in this and subsequent chapters, e.g., the range of the von Karman constant for the six separate studies conducted in 1966 and 1967 at Davis was only 0.04, a $\pm$5% variation about a mean of 0.42. The uniqueness and greater accuracy of the UCD unit in comparison to earlier drag plates is believed to be due to the combination of a reliable force measurement system (which some of the systems have had) with a vastly better field-representative sample than any of the prior units. The UCD lysimeter, with a surface area of 29.2 square meters, contained literally tens of thousands of grass plants. Because of the thin-walled construction of the plastic containing and retaining walls (6 mm) and the narrow gap between (25 mm), there is less than a 3% uncertainty in terms of effective area of the lysimeter, at least with short crops. With elaborate systems for providing proper soil-moisture suction and temperature at the bottom of the 90-cm-deep lysimeter, the chances of obtaining a representative energy balance are also excellent, which admittedly becomes increasingly important with increased sizes of drag plates.

3. WIND PROFILE AND SURFACE-DRAG MEASUREMENTS TO OBTAIN k

A major objective of Sheppard's drag-plate study was determination of the von Karman constant under natural atmospheric conditions near the ground surface. He obtained values for k ranging from 0.44 to 0.49 (average 0.46). This was for moderately unstable conditions, however, and hence Sheppard's values should be considered actually as relating to Priestley's (1959) later-defined parameter, K_M^*, which he called a generalized form of the von Karman

constant, or to Webb's (1965) equivalent parameter,

$$K_M^* = k_m^* = \frac{K_M}{zu_*} \tag{1}$$

where K_M is the eddy transfer coefficient for momentum, z is height above ground, and u_* is the friction velocity.

For adiabatic conditions and if the log-law holds, k_m^* becomes the von Karman constant, or

$$k_m^* = k = \frac{K_M}{zu_*} \tag{2}$$

Vehrencamp's (1954) determinations of k from drag-plate and wind-profile measurements ranged from 0.18 to 0.5 and must be considered actually as measurements of k_m^*, rather than k.

In the present work, the authors used Equation (1), solving for k_m^* from calculations of K_M and u_* as determined from the measured surface shear-stress and wind-profile data. The k_m^* data were then plotted on a linear scale as a function of the Richardson number, with Ri computed from

$$Ri = \frac{g\left(T_{v_2} - T_{v_1}\right)}{\bar{T}_v (u_2 - u_1)^2} (z_2 - z_1) \tag{3}$$

where g is the acceleration of gravity, T_{v_2} and T_{v_1} are the virtual temperatures, and u_2 and u_1 are the wind speeds at heights z_2 and z_1, respectively. $\bar{T}_v$ is the average virtual temperature.

From the linear plots of k_m^* versus Ri for each run, k was determined at the point where the curve passed through an Ri of zero. A 6-run average k_m^* curve was determined by summing up data obtained from each curve at various values of Ri and dividing by the number of runs where data were available at each selected Ri value. This composite curve was then compared with a curve based on a summary of all data obtained in the six 1966-67 field runs (equal weight thus given to each one-half-hour period).

The summary data were also plotted on log-log paper to help determine appropriate mathematical relationships for k_m^* as a function of Ri.

4. DISCUSSION OF RESULTS

A smooth-curve plot of k_m^* as calculated from (1) versus the Richardson number is shown in Fig. II-1 for Run 267, the May 2-5 portion of the 1967 Cooperative Field Experiment. A narrow range of Ri from -.10 to +.10 was selected in order to spread out the data points near Ri = 0 as much as possible. The intervals of Ri used in the condensed eddy diffusivity program (CEDP) had been selected on the basis of a logarithmic scale and hence the tendency for the data to be bunched up on a linear plot. Standard deviations are indicated except for data quite close to zero Ri. The number of data points from which the mean was obtained is also indicated.

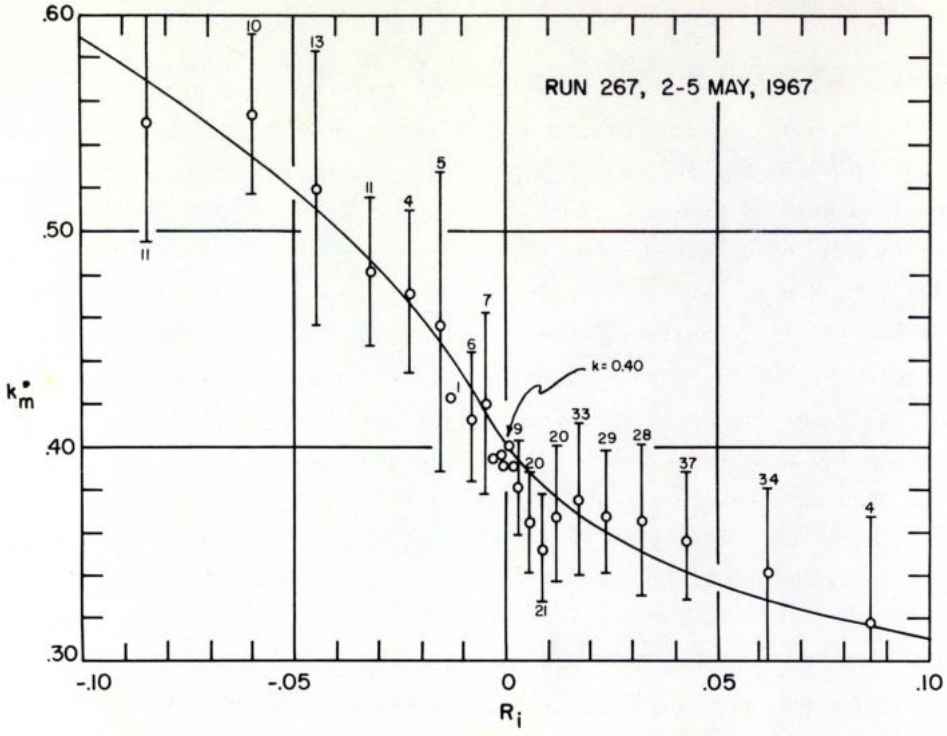


Figure II-1. Mean values of the parameter k_m^* for various narrow ranges of Ri for Run 267, the 1967 Cooperative Field Experiment. Geometric means for both k_m^* and Ri were used. Standard deviations are indicated as well as the value of n.

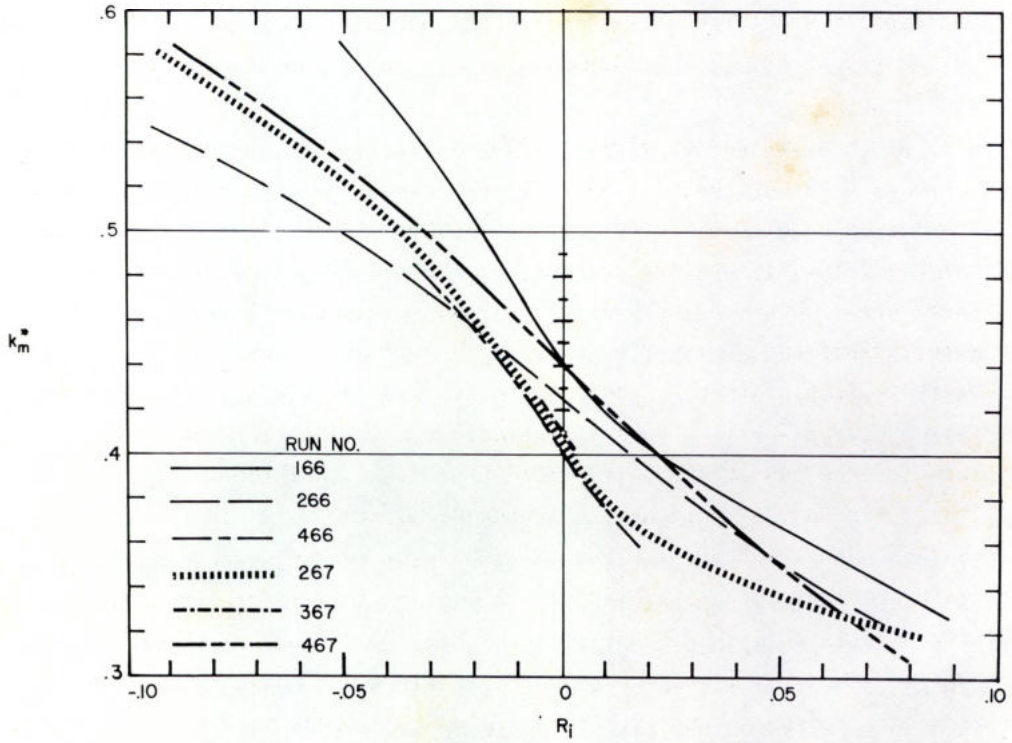


Figure II-2. Eye-smoothed curves of k_m^* versus Ri for each of the six runs of 1966 and 1967.

For Run 267 the eye-smoothed curve drawn through the data indicates a value for the von Karman constant of 0.40. This compares with a value of 0.41 reported by Goddard (1970) for the same study in which the analysis was based on a more theoretical consideration of wind-profile shape as well as measured flux. It should also be mentioned that in plotting individual data for Run 267 a tendency was noted for the value of k to gradually decrease from around 0.415 on 2 May to a value of around 0.39 by 5 May, especially for data at the lower height intervals. It is believed that had we allowed the value of the zero-plane displacement, d, to vary with time instead of using a constant of 10.6 cm for the entire run, the above variation in calculated k would not have occurred. Fescue grass grows quite rapidly during late spring months, our notes indicating the tips of the major share of grass blades increasing from an average height of 10 cm on 2 May to 14 cm on 5 May.

The variation of k_m^* with stability is quite dramatic, with, for example, a 20% increase in going from Ri = 0 to Ri of -.04. The rate of change in the stable case is less pronounced.

In Fig. II-2, similar analysis provided smooth curves of k_m^* for each of the six studies. Results for Run 466 and Run 367 show very similar values of k as for Run 267 (actually 0.40 and 0.41, respectively). The shape and location of the k_m^* curve for Run 466 is almost identical with that for Run 267, although the range of stability encountered in the former run was much smaller. It is interesting to recall here that the data for Run 466 in the stable cases come from a very strong advection situation with data collected at a site with an upwind fetch of grass of only 100 meters. Apparently wind data, at least up to a 70-cm height, were not affected significantly by advection. (Data above the 70-cm height were not included in the analyses). The curve of k_m^* in the unstable portion for Run 466 came from the data collected the second day of the advection study, when winds had dropped considerably but were still from the north.

The curve of k_m^* for Run 166 has a fairly similar shape to that for 466 and 267 but is displaced upward, giving a value of k of 0.44. For Runs 266 and 467 the shapes of the curves, especially near neutral, are quite different from the others. The value of k for 166 is identical to that for 467 (0.44), while k for Run 266 falls between the others, at 0.425.

Much of the variability between runs may be related to accuracy limitations of the shear meter, although some variation in k might be expected due to differences in the spectrum of turbulence encountered. Both of these aspects are discussed in a recent report by Lettau and Stearns (1970). A comparison by Stearns of aerodynamic computations of surface stress with measured stress for the 1967 Cooperative Field Experiment indicates a possible zero error in the lysimeter for Run 267 somewhat less than 0.1 dynes cm^{-2}. In the same report, Stearns also shows that when the surface stress is time variable and wind speed is averaged linearly, an erroneous estimate of profile structure parameters will result. This problem, of course, points to a basic weakness in use of aerodynamic equations which use time-averaged profile data and is, no doubt, a reason for some of the variation noted in Fig. II-2. Regardless, the variability noted presents a strong argument for the inclusion of several separate efforts at data gathering within any major micrometeorological study, preferably with each effort involving separate instrumentation set-up and calibration.

Fig. II-3 presents means and standard deviations of k_m^* for various intervals of Ri based

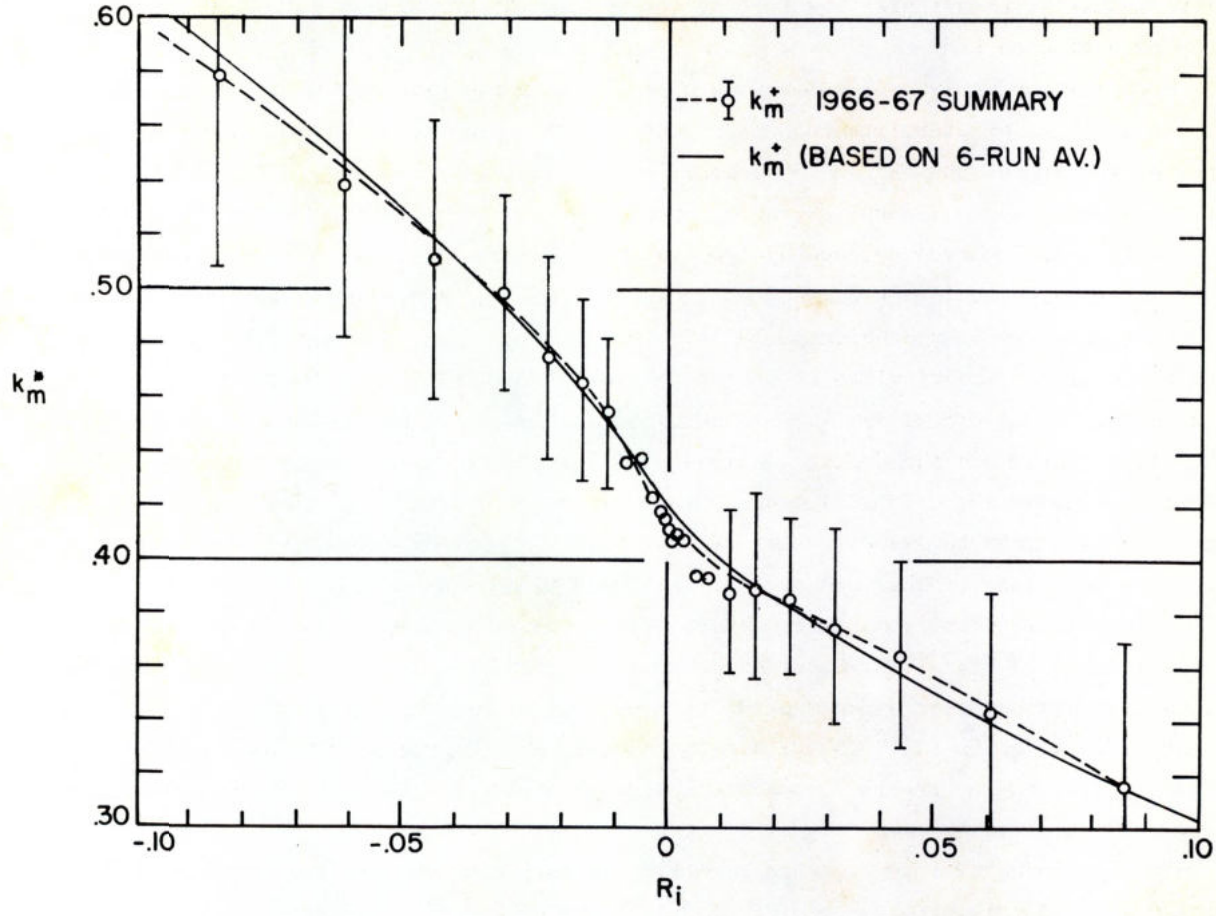


Figure II-3. Mean k_m^* versus Ri obtained from a summary of data coming from all six runs of 1966-67. Mean curve based on equal weighting of each run is also shown (solid line).

on data from all six runs (1966-67 summary). The light dashed line is an eye-fitted curve through these data. The solid curve is based on giving equal weight to the mean k_m^* of each run rather than to each half-hour period of all runs. With this procedure a mean k of 0.42 is indicated, whereas the dashed line suggests a k of 0.415. The value of 0.42 was selected for a reanalysis of all six runs to provide 1966-67 summary data for other parameters which are dependent upon k.

Fig. II-4 shows 1966-67 summary data for k_m^* as a function of Ri on log-log paper for the entire range of stability conditions encountered. The relationships are quite well defined by the expressions $k_m^* = .42\ (1\text{-}16Ri)^{+1/3}$ for the unstable case, and $k_m^* = .42\ (1+16Ri)^{-1/3}$ for the stable case. The only serious departure is in the stable case, for Ri > 0.4.

In Fig. II-5 curves defined by these expressions are reproduced on a graph having an expanded ordinate scale. Also shown are curves based on expressions suggested by Rossby and Montgomery (1935) and Holzman (1943). In the range of Ri from -.2 to +.2 the UCD derived curves are almost identical to those for the Holzman and the Rossby-Montgomery expressions using a σ of 9.0. Priestley (1959) showed fair agreement of experimental k_m^* data from several authors, with the Holzman expression using a σ of 8.2 for the range $-0.3 < Ri > 0.1$. Oke (1970), using a σ of 10.0 in the Rossby-Montgomery equation, showed rather good agreement with data from the same sources used by Priestley as well as with the more extensive data of Field (1963). This was true within the range $0 < Ri < +0.2$.

The Davis results indicate one could use a σ significantly smaller than 9.0, e.g., 6.0 as illustrated in Fig. II-5, to extend the usefullness of the Rossby-Montgomery and the Holzman expressions over a range of Ri from -1.0 to +1.0. However, this is at the expense of errors in k_m^* of up to 10-15% within zones of Ri around -0.1 and +0.1.

As indicated in Fig. II-5, a smooth curve drawn through the data of Gurvich for the range $-4 < Ri < -.05$ showed quite good agreement with the UCD expression for k_m^*. The expression $k_m^* = 0.97\left|Ri\right|^{1/4}$ suggested by Monin and Yaglom (1965, pg. 386), based on the Gurvich data as well as data from Deacon (1955), was less satisfactory.

In Fig. II-6, k_m^* data from Fig. II-4 are replotted on a linear scale for comparison with a relationship suggested by Webb (1965). Webb's curve is based on profile forms outlined on page 36-37 of his 1965 article. Although hypothetical, the curve does fall at about the middle of a spread of experimentally determined values given earlier by Priestley (1959, Fig. 8) and by Deacon and Webb (1962, Fig. 2). The scatter of points in both references is quite wide, and, without doubt, the UCD data in Fig. II-6, obtained with the large, drag-plate lysimeter, offer a very significant contribution in helping to extend and refine the relationship given by Webb.

In the unstable case there is close agreement between the Davis results and Webb's curve, with the minor differences largely produced by Webb's assumption of k = 0.4, as compared with our slightly higher measured value of k. There is serious departure in the stable case, with Webb's curve showing a much steeper dropping-off of k_m^* with increasing stability.

Webb (1965) also infers the same or similar curves for k_H^* and k_W^* which would require equality of K_M, K_H, and K_W at all stabilities. He indicated that the main uncertainty at

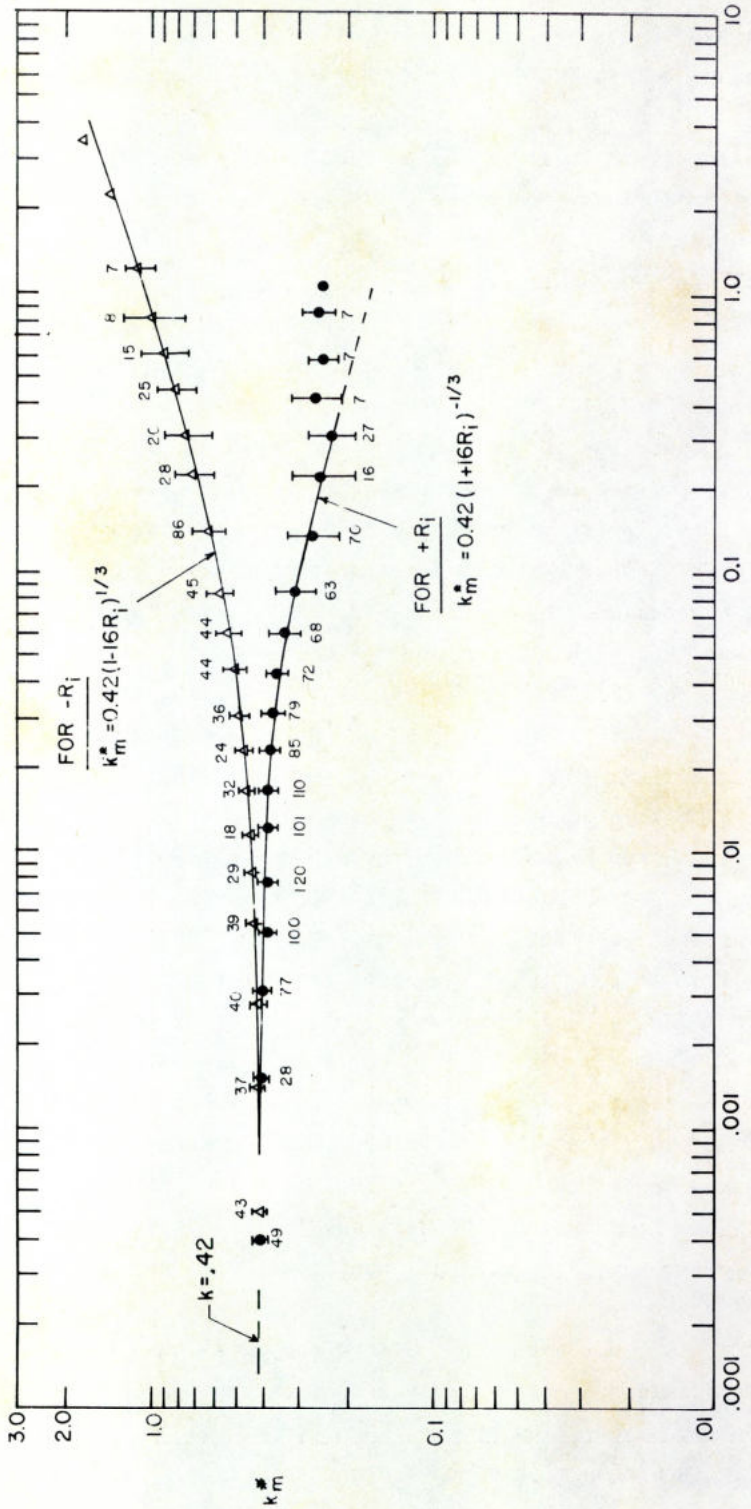


Figure II-4. A log-log plot of k_m^* versus Ri along with mathematical expressions and associated curves giving a good fit to data.

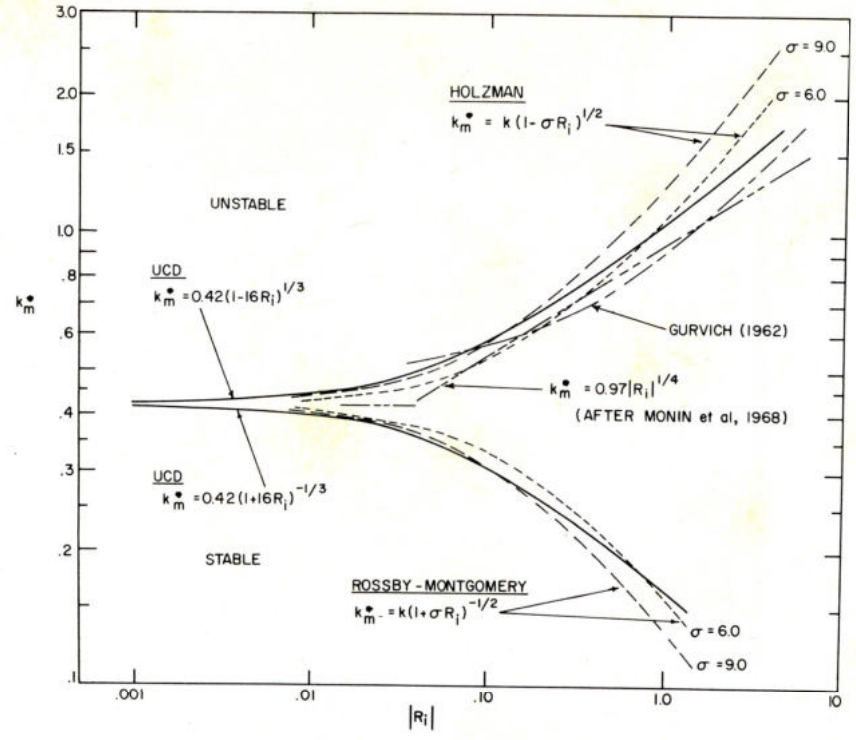


Figure II-5. A comparison of best-fit UCD $k_m^*(Ri)$ with results of previous research and various proposed relationships.

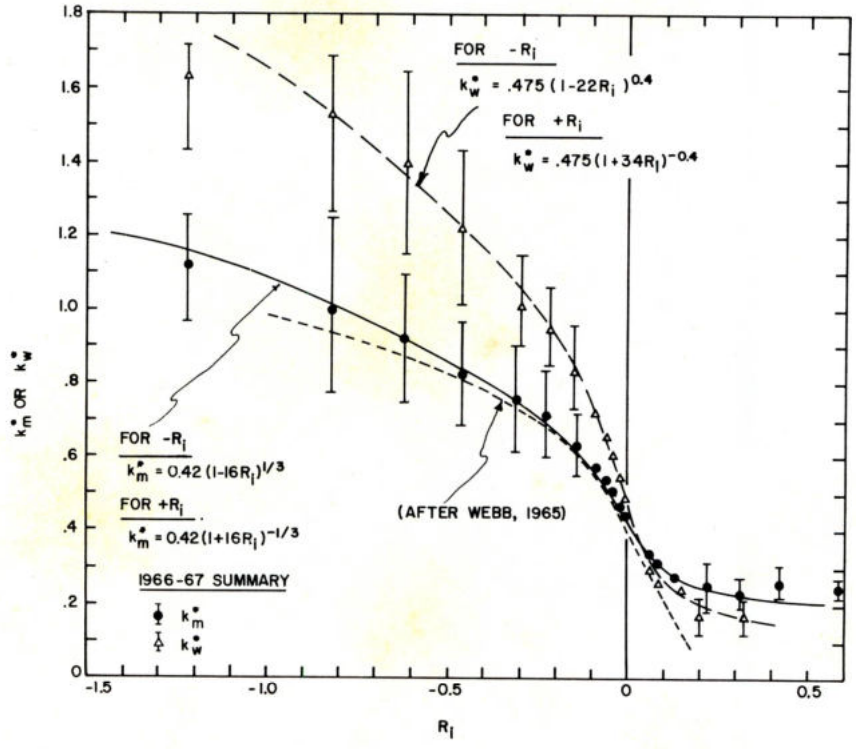


Figure II-6. A plot of 1966-67 summary $k_m^*(Ri)$ compared with suggested curve for k_m^* and k_W^* from Webb(1965). UCD k_W^* data are shown for comparison.

the time was whether the k_m^* curve should slope less steeply than the k_H^* curve with k_m^* smaller than k_H^* over a wide range of negative Ri. The UCD results for k_H^* in the unstable case are not considered reliable enough to answer the above. However, it is clear in Fig. II-6 that k_W^* certainly must exceed k_m^* throughout the entire range of unstable conditions encountered in the 1966-67 studies. Even at a neutral condition the results indicate that k_W^* exceeds k_m^* by 13%, indicating that $K_W/K_M = 1.13$ for neutral conditions. For k_W^*, expressions giving good fit with experimental data were $k_W^* = .475\ (1\text{-}22Ri)^{0.4}$ for unstable conditions, and $k_W^* = .475\ (1+34Ri)^{-0.4}$ for stable conditions.

At an Ri of +.03, k_m^* and k_W^* are about equal with k_W^* decreasing faster than k_m^* thereafter. At Ri > 0.15, however, only a limited number of k_W^* data were available and accuracy would be rather poor, since flux rates of water vapor were very low and gradients small.

5. CONCLUSIONS

Extensive surface shear-stress and wind-profile measurements during six separate studies conducted in 1966 and 1967 at Davis, California, indicate a value for the von Karman constant of 0.42, if equal weight is given to the results from each study. The value of k for the six studies varied from a low of 0.40 to a high of 0.44. If equal weight is given to each of the half-hour periods for the entire study, k averaged 0.415.

An expression giving excellent fit to experimentally determined values of k_m^* under unstable conditions out to an Ri of -3 was $k_m^* = 0.42\ (1\text{-}16Ri)^{+1/3}$. An expression with the same constants but with reversal of both signs gave an excellent fit under stable conditions out to an Ri of +0.3. These expressions were compared graphically with several relationships from past studies. From neutral stability out to an $|Ri|$ of 0.2, agreement was excellent with the Holzman equation (for negative Ri cases) and with the Rossby-Montgomery expression (for positive cases) using a σ of 9.0. The relationship for k_m^* shown by Webb (1965) was very close to the UCD data for unstable cases but not for the stable case.

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CHAPTER III

EVALUATION OF EDDY-TRANSFER COEFFICIENTS AND DIABATIC-PROFILE FUNCTIONS UNDER TURBULENT FLOW IN THE LOWER ATMOSPHERE

by

W. O. Pruitt, D. L. Morgan, and F. J. Lourence

1. INTRODUCTION

The prediction of heat and water-vapor transfers in the atmosphere just above the surface depends on knowledge of the relationship between momentum transfer and the horizontal wind-speed gradient. Under adiabatic conditions, log-law considerations have been shown to provide good accuracy in predicting momentum transfer. When eddy-transfer coefficients for heat and water vapor are assumed to be equal to that for momentum, these transfers also can be predicted. Under natural conditions, however, adiabatic or near-neutral stability conditions are seldom realized except with strong breezes, and prediction of all three fluxes then becomes complex. The log-law no longer holds, and variations in relationships between transfer coefficients also become a possibility that must be considered.

This chapter gives consideration first to diabatic correction of the log-law, and then gives attention to the transfer-coefficient relationships.

2. THE LOG-LAW AND TRANSFER COEFFICIENT RELATIONSHIPS

The log-law wind profile can be described by

$$\partial u/\partial z = \frac{u_*}{kz} \tag{1}$$

where u is the horizontal wind speed at height z, u_* is the friction velocity, and k is the von Karman constant.

Equation (1) was generalized by Monin and Obukhov (1954) to apply under all conditions, giving

$$\partial u/\partial z = \frac{u_*}{kz}\,\phi_M \tag{2}$$

where ϕ_M is an unknown stability-related function to be determined by experiment. Under neutral stability, $\phi_M = 1.0$. Monin and Obukhov (1954) proposed use of their dimensionless height ratio z/L in a Taylor series to describe this function, giving

$$\phi_M = 1 + \alpha_1 \left(\frac{z}{L}\right) + \alpha_2 \left(\frac{z}{L}\right)^2 + \ldots \tag{3}$$

where the scale length, L, was defined by Obukhov (1946) as

$$L = \frac{u_*^3\, c_p\, \rho\, \theta}{k\, g\, H} \tag{4}$$

where g is the acceleration of gravity, H is the sensible heat flux (positive if to the

surface), θ is the potential temperature, and ρ and c_p are the air density and specific heat at constant pressure.

Functions analogous to ϕ_M may also be used to describe generalized forms for temperature and humidity profiles, giving

$$\partial\theta/\partial z = \frac{H}{\rho\, c_p\, k\, u_* z}\, \phi_H \tag{5}$$

and

$$\partial q/\partial z = \frac{E}{\rho\, k\, u_*\, z}\, \phi_W \tag{6}$$

where previously undefined terms are q, the specific humidity, and E, the water vapor flux in gm cm^{-2} sec^{-1}, considered positive if to the surface.

This paper, we believe, is the first to present simultaneously determined values of all three functions, ϕ_M, ϕ_W, ϕ_H. It is therefore appropriate to point out the following. Although previous papers, for example Dyer (1965, 1967), show diagrams of ϕ_H and ϕ_W that approach a value of 1.0 as neutral conditions are approached, (5) and (6) imply such a condition only if the eddy-transfer coefficients for water vapor and heat (K_W and K_H) are equal to that for momentum, K_M, under neutral conditions. Although ϕ_M, by definition, does approach 1.0 under adiabatic conditions, it should be realized that

$$\phi_H = \phi_M\, K_M/K_H \tag{7}$$

and

$$\phi_W = \phi_M\, K_M/K_W \tag{8}$$

Hence, if K_W/K_M or K_H/K_M varied from unity, plots of ϕ_W and ϕ_H as a function of z/L or of the Richardson number would diverge from that for ϕ_M.

Dyer's (1967) paper showed very similar curves of ϕ_W and ϕ_H extending over the entire range of unstable conditions encountered (z/L from -.01 to -3.0) in CSIRO studies at Kerang and at Hay, in Australia. Those results, perhaps more clearly than any prior studies, pointed to the near equality of K_H and K_W throughout a wide range of unstable conditions.

Analyses by Swinbank and Dyer (1967) of humidity, temperature, and wind-profile shape factors provided additional proof of this, independent of measured fluxes. The results did suggest significant divergence of K_W/K_M and K_H/K_M.

3. DISCUSSION OF RESULTS

Fig. III-1 shows experimentally determined ϕ functions for Run 267 as calculated from (2), (5), and (6) and using measured fluxes [1/] and average gradients at the geometric mean height for five different intervals from the lowest height of 35 cm to 200 cm. The value used for k, the von Karman constant, was 0.42 on the basis of a mean k determined for the six runs of 1966-67 at Davis (see Chapter II).

These scatter diagrams of the ϕ functions clearly reveal the considerably better degree of accuracy for the field measurements involved in calculation of ϕ_M and ϕ_W as compared with ϕ_H, at least for unstable conditions. Under stable conditions, however, ϕ_W shows the greatest

[1/] Note: Actually, only the momentum flux (surface shear) and water vapor flux were measured. The heat flux, H, was calculated from $H = -(R_n + G + LE)$.

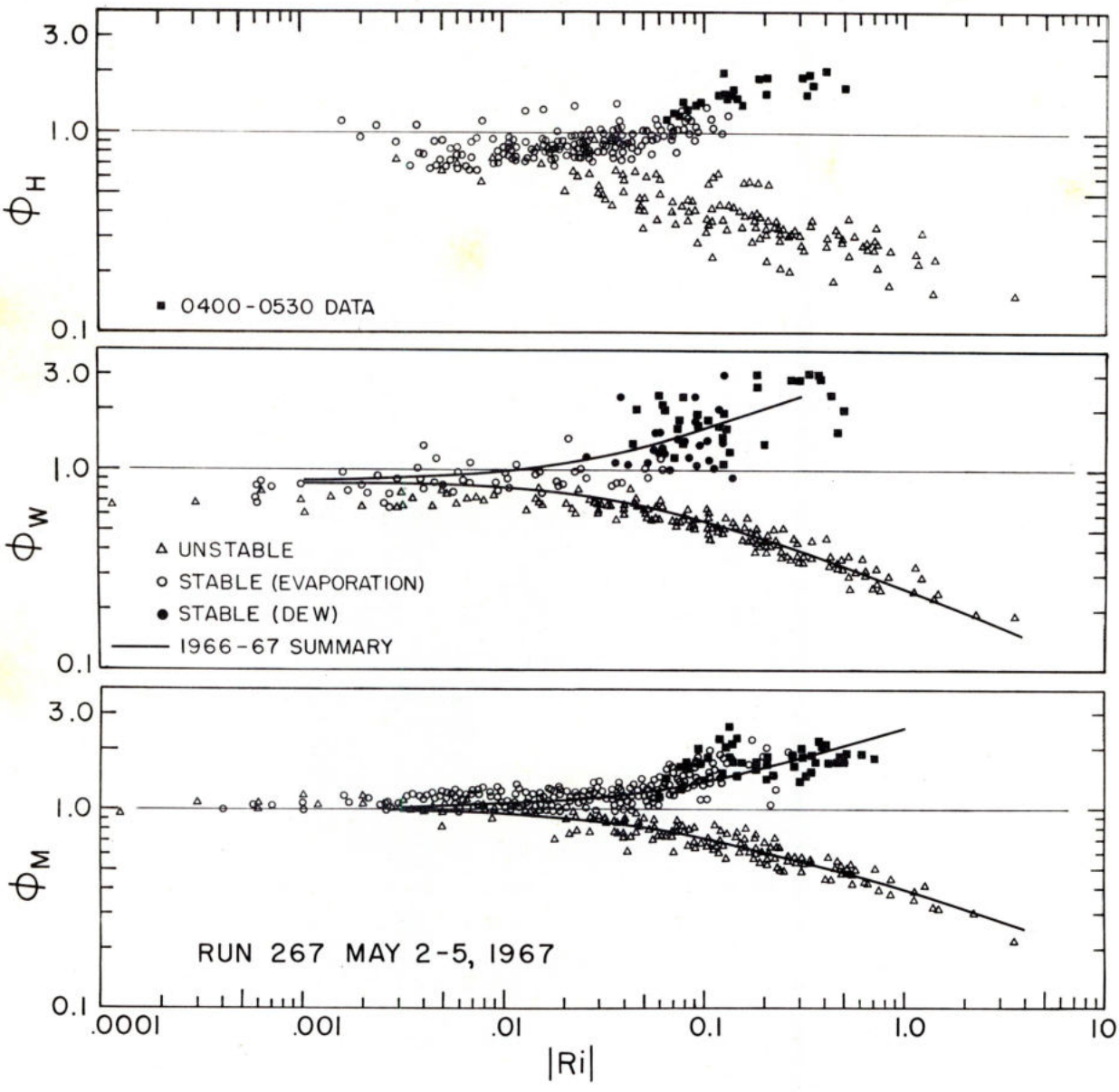


Figure III-1. Experimentally determined ϕ_M, ϕ_W, and ϕ_H data from Run 267, the Cooperative Field Experiment. Data from 0400 through 0930 were omitted in the original analyses to avoid periods of rapid change in gradients and fluxes. With sunrise at 0511 during Run 267, data from 0400-0530 should be adequate and are indicated by solid squares in this figure. All such data are for periods of dew fall.

scatter, no doubt due to the very low flux rates and generally small gradients involved in the dewfall cases. The curves shown were obtained from analysis of 1966-67 summary data (Fig. III-2). Good fit is noted except near neutral, where Run 267 ϕ_W data average some 10% low. The scatter for both ϕ_W and ϕ_M is significantly less than that shown by the ϕ_H data of Dyer (1967) and very much less than for his ϕ_W data. Dyer's Evapotron obviously provided more accurate measurement of H than of E, while at Davis the evaporation data from the 6.1-meter-diameter lysimeter (Pruitt and Angus, 1960) are far superior to the energy-balance determinations of H for unstable and near-neutral cases.

Fig. III-2 shows 1966-67 summary data for the ϕ_M and ϕ_W functions along with smooth curves and their associated mathematical expressions. The ϕ_H data are for Run 267 only. This is because revised values of H for 1966 runs were unavailable at the time the 1966-67 summary data were obtained from CEDP. Original values of H for 1966 had been based upon an energy balance with net radiation from a single radiometer. Final energy-balance data reported in Appendix B are based on data from three net radiometers.

The mean ϕ_M and ϕ_W data show little scatter away from the smooth curves indicated. The scatter is somewhat greater for ϕ_H, although this would be partially due to a paucity of data.

The best-fit smooth-curve relationship for ϕ_M takes on a form very similar to the KEYPS diabatic correction for the wind profile, except for the value of n. Indicated instead of the -1/4 power, originally suggested from dimensional analysis by Ellison (1957) for the free convection case, is a value for n of -1/3 in the unstable case. If anything, the slope of the relationship on the log-log plot around an Ri of -1.0 could be interpreted as slightly more negative than -1/3. Fig. III-3 (note the expanded ordinate scale) indicates slopes at an Ri around -1.5 that range from -.25 for Run 266 to -.44 for Run 166, with a slope of -.33 for Run 267, the 1967 Cooperative Field Study.

In the stable case, Fig. III-2 shows a curve expressed by $(1 + 16Ri)^{1/3}$ giving a good fit out to an Ri = 0.3 with the points falling away thereafter. The last four points which fall below the curve came from Run 166 only and unexplainably fall well below any reasonable extension of the smooth curve for that run shown in Fig. III-3.

In considering Figs. III-3 and 4, the variation between runs for both ϕ_M and ϕ_W is quite significant, as was the case for k_m^* noted in Chapter II. Near neutral, the variation is small for ϕ_M but quite large for ϕ_W. Under high instability, as pointed out earlier in considering slopes near an Ri of -1.5, the divergence of ϕ_M is quite great. By comparison ϕ_W shows little difference between runs under the highly unstable conditions. This smaller variation of ϕ_W might be expected since both the gradients and flux of water vapor are normally strong under such conditions, while low wind, and hence low momentum flux,is needed to produce these conditions. The chance for good accuracy is thus much better for ϕ_W than for ϕ_M as free convection is approached. Why ϕ_W for Run 267 falls well below data for other runs under near-neutral conditions, is not known. The wide variation between runs of ϕ_W under highly stable conditions could be expected since the vapor flux and the humidity gradient would then be very small.

Fig. III-5 makes a direct comparison of ϕ_M and ϕ_W. The most significant observation here in relation to the literature is the fact that ϕ_W does not approach 1.0 as Ri $\rightarrow$ 0, but,

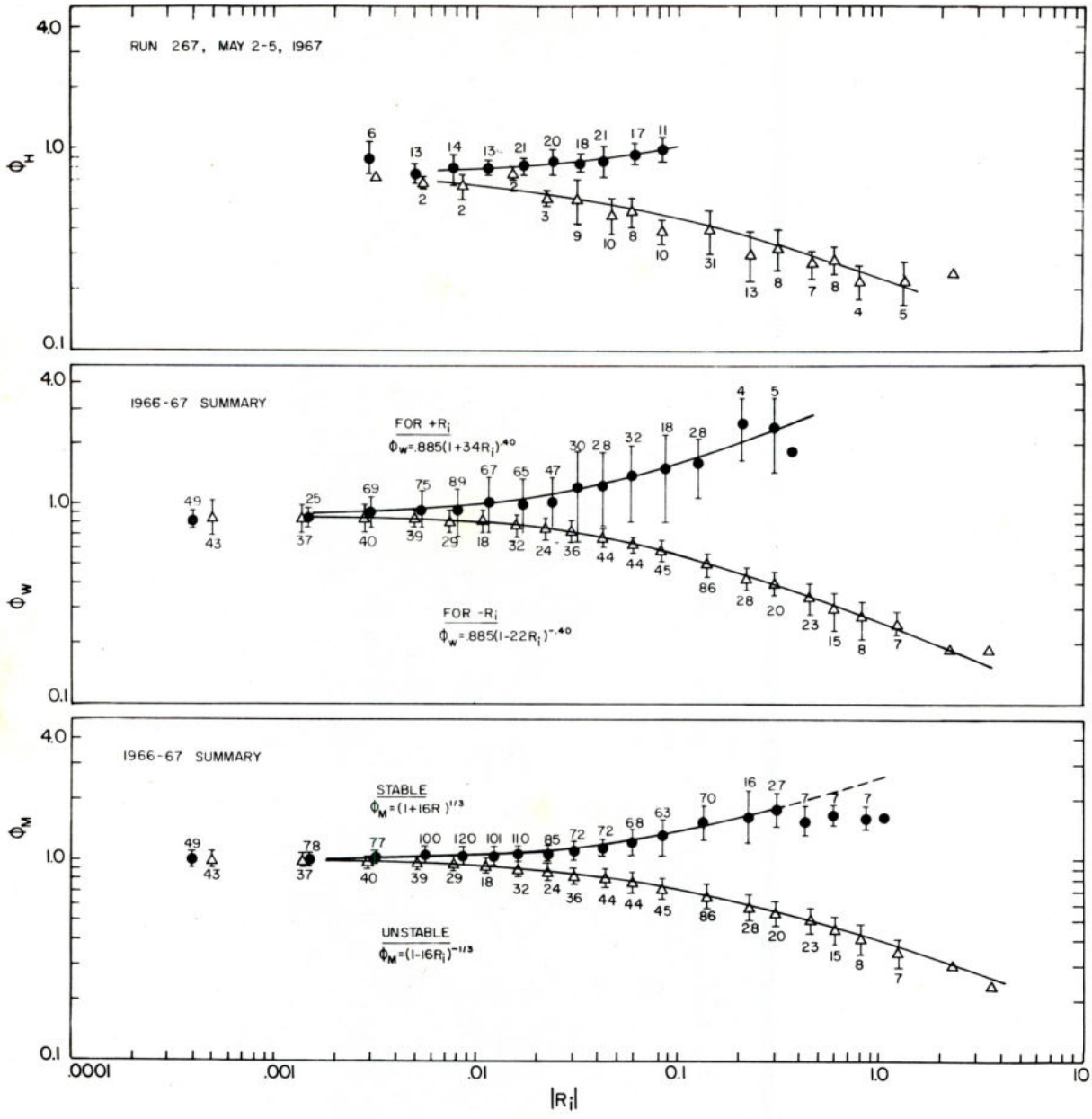


Figure III-2. Mean values of ϕ functions for momentum, water vapor, and heat for narrow intervals of Ri along with mathematical expressions and associated curves giving reasonable fit to data. The ϕ_H data are for Run 267 only, the 1967 Cooperative Field Experiment.

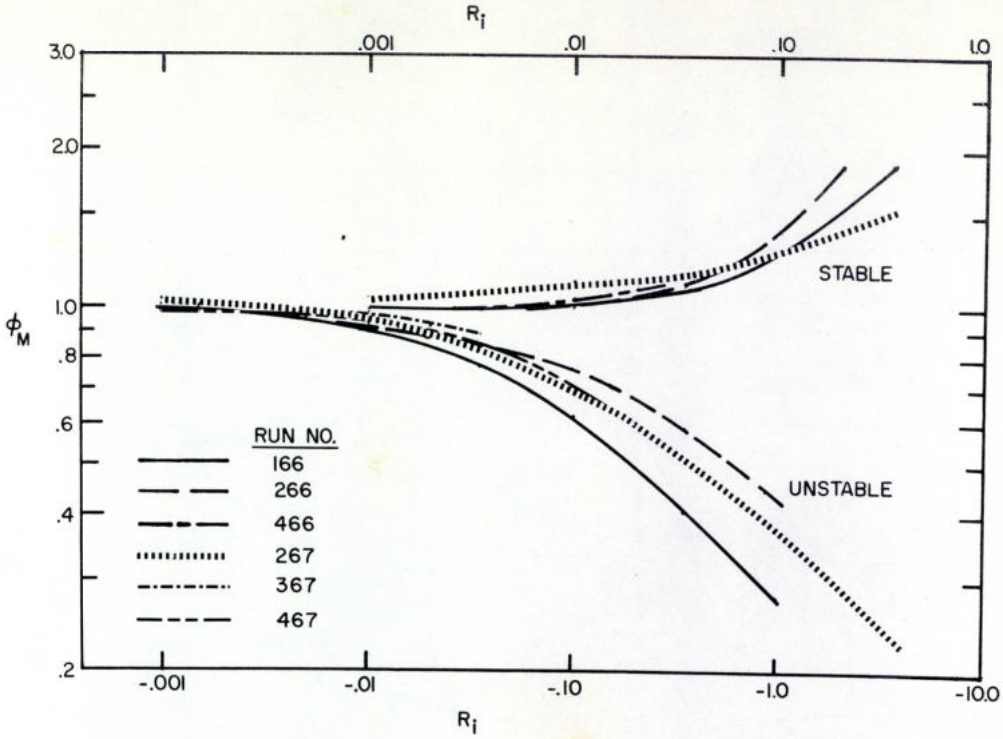


Figure III-3. Curves obtained by eye-smoothing of mean $\phi_M(Ri)$ data from each of the six runs of 1966-67.

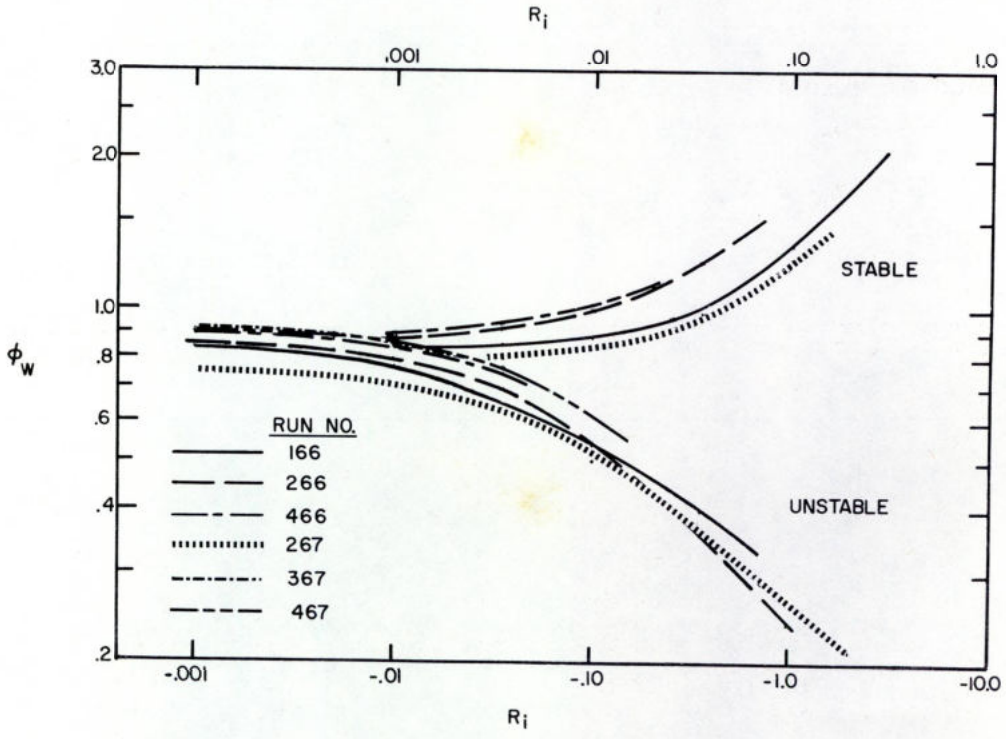


Figure III-4. Curves obtained by eye-smoothing of $\phi_W(Ri)$ data from each of the six runs of 1966-67.

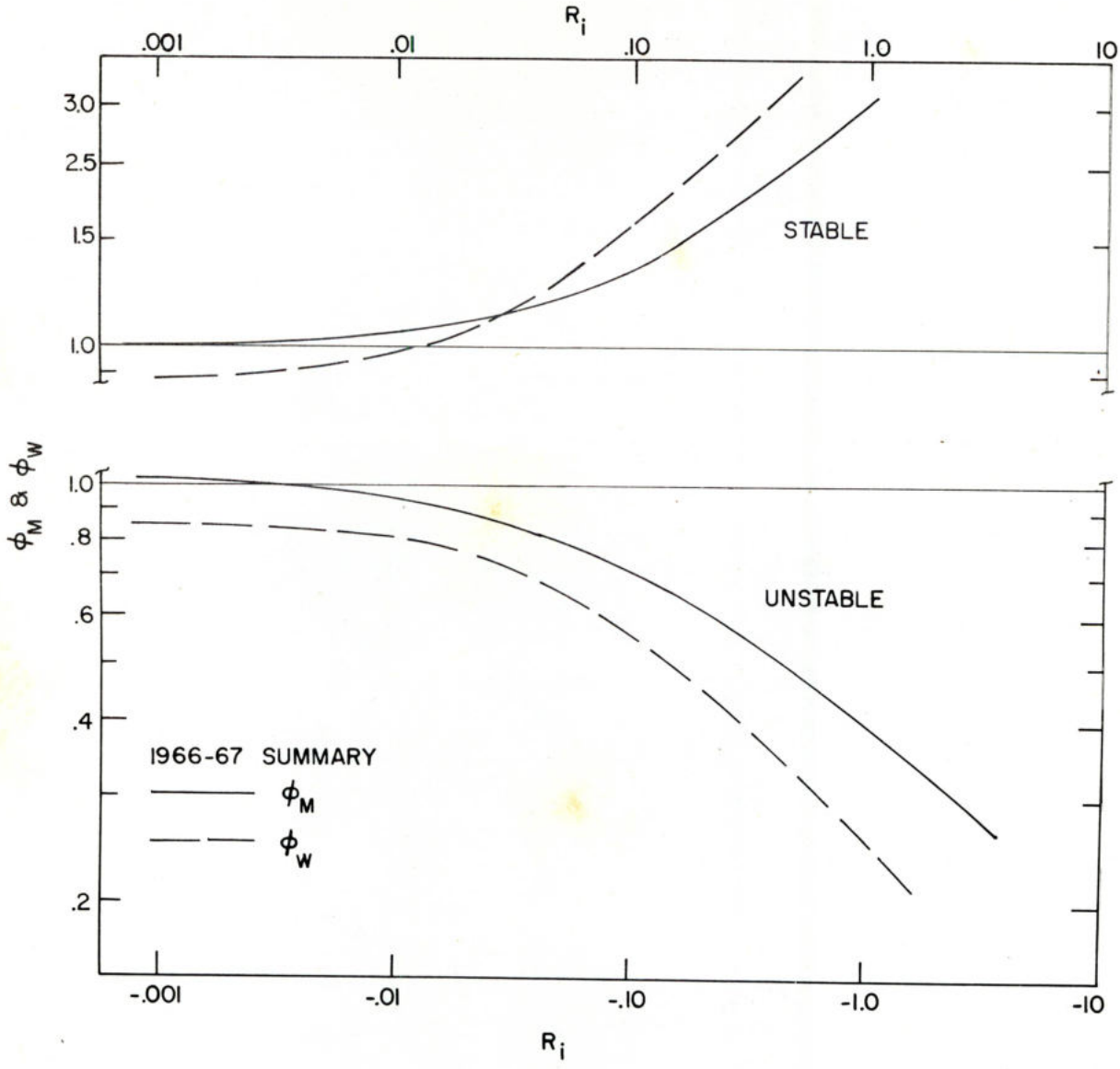


Figure III-5. Comparison of smooth curves of $\phi_M(Ri)$ and $\phi_W(Ri)$ obtained from the mathematical expressions given in Figure III-2.

rather, approaches a value of 0.885 (as determined by plots on a linear scale). As pointed out earlier, ϕ_M must, by definition, $\rightarrow$ 1.0 as Ri $\rightarrow$ 0, but this could not be expected for ϕ_W unless $K_W = K_M$. These results, then, suggest a K_W/K_M of around 1.13 for neutral conditions. Additionally, as might be expected from the literature, the divergence of ϕ_W from ϕ_M with increasing instability becomes greater, indicating an increase in the ratio of K_W/K_M. The intersection of ϕ_W and ϕ_M curves indicates $K_W = K_M$ at an Ri of +0.027. Thereafter, with increasing stability, ϕ_W exceeds ϕ_M indicating a $K_W/K_M < 1.0$.

Concentrating on ϕ_M at this point, Fig. III-6 compares the UCD ϕ_M versus Ri relationship with several suggested in earlier studies. In the unstable case the curve for the KEYPS expression, with a b of 18 gives an excellent fit to an Ri = -.01, but fails to drop fast enough thereafter. With an Ri = -1.0 ϕ_M is 23% higher than the UCD curve , but the difference reaches 40% by the time Ri = -3.5. Opposite trends are noted in the stable case, although the divergence is less with the KEYPS value only 12% low at an Ri = .35. Sellers (1965) indicates that most of the experimental values of b determined by other researchers fall within the range from 14 to 24. Panofsky et al (1960), in a study comparing several sources of data, suggested a b of 18, the value checked in Fig. III-6. To predict the value of ϕ_M at Ri values around -1.0, would require a b of 38 in the KEYPS expression. The fit of this curve with UCD data at smaller values of Ri is still fair, for example, giving ϕ_M predictions only 6% too low at an Ri of -.1 and only 4% low at an Ri of -.03.

Assuming the correctness of UCD data, it is easy to understand the large range of values for b which appear in the literature. With either too low or too high a value of n in the KEYPS expression, experimentally determined values of b become very much a function of the range of stability encountered.

The expression suggested by Oke (1970) for stable conditions of $(1 + 10Ri)^{1/2}$ gives quite a good fit to the UCD data, but the curve appears to rise too steeply at larger Ri values. This expression is, of course, equivalent to the expression $(1 + \sigma Ri)^{-1/2}$ suggested by Rossby and Montgomery (1935) as a diabatic correction term for prediction of a dimensionless K_M under stable conditions. In Chapter II, the Rossby-Montgomery expression was compared with the UCD k_m^* data with values for σ of both 6.0 and 9.0 being tried.

The equivalent form of the expression proposed by Holzman (1943) for unstable cases is also shown in Fig. III-6. Using a σ of 9.0 in the expression $\phi_M = (1 - \sigma Ri)^{-1/2}$ provides excellent agreement with UCD data in the range -.2 < Ri < 0. At greater instabilities, lower values of σ would be needed to give a good estimate of ϕ_M, e.g. 5-6 at an Ri of around -1.0. These results are in good agreement then with the review of Priestley (1959), where within the range -.3 < Ri < + .1 a value for σ of around 7.5 to 8.5 was indicated.

As in the case of the KEYPS expression, the power to which $(1 \pm \sigma Ri)$ is raised presents a problem when trying to select a value for σ which is widely applicable to the UCD results.

A number of other expressions for ϕ_M as well as ϕ_W and ϕ_H have been related to the stability parameter, z/L, proposed by Monin and Obukhov (1954). Regrettably, z/L is directly proportional to the sensible heat flux, H, and hence the UCD computations of z/L are subject to the same degree of error as that experienced for H. Also, as of the writing of this report, correct values of R_n and hence of H (as reported in Appendix B) for all three 1966 runs had not been used in the co-eddy diffusivity program. Hence 1966-67 summary z/L data

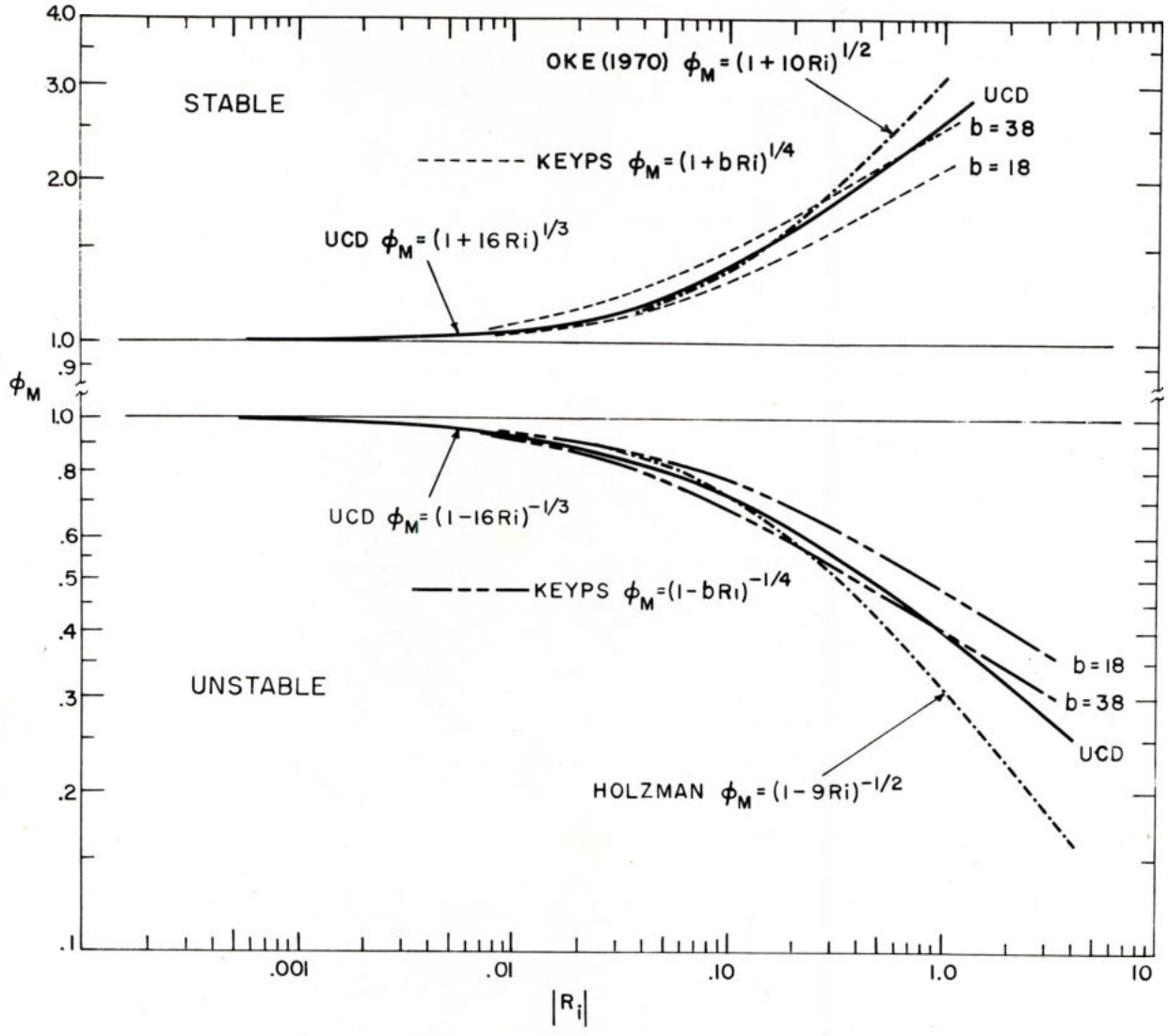


Figure III-6. Comparison of suggested UCD $\phi_M(Ri)$ relationships with earlier ones suggested in the literature.

are as yet unavailable. Consequently, z/L values for Run 267 only are compared with Ri data in Fig. III-7 in order to establish a relationship between the two.

The data for z/L as a function of Ri for Run 267 show a rather small scatter about the eye-smoothed curve indicated, at least for unstable conditions. The corrected values and associated curve represent corrected z/L data to allow for likely errors in H. Wesely et al (1970) indicate that, in relation to data for H obtained during Run 267 with their pressure sphere and fast-thermometer system (P.S.A.T.), the UCD values appear high during the day. This, along with the seemingly 15-30% high H* data for unstable conditions of Run 267 (See Chapter IV), led to the conclusion that some adjustment of our H values and hence our z/L data was appropriate, at least in the unstable case. The P.S.A.T. measurements at night as well as the H* data suggest the UCD measurements at night might also overestimate the flux of heat to the surface. Hence, correction of z/L data under highly stable conditions was deemed necessary as well.

The corrected data in Fig. III-7 were obtained by multiplying the derived z/L value for each Ri interval of Run 267 by the corresponding factor E*/H*. This presumes the dimensionless flux parameter E* to be data of good quality and that H* and E* should be equal ($K_H = K_W$).

The smooth curve drawn through the corrected z/L data compares fairly closely with a relationship suggested by Webb (1965) for the unstable case. A relationship suggested by Panofsky (1963) for unstable conditions comes even closer to the corrected UCD curve than does the Webb curve. Swinbank's (1968) curve fits original UCD data well for Ri > -.10.

In the stable case out to an Ri approaching .06, both the original and corrected z/L data are in close agreement with the relationship suggested by Webb of $z/L = Ri(1 - 5.2Ri)^{-1}$. At greater stabilities both Webb's curve and the curve for the original UCD data curve upward more steeply while the corrected curve continues on at about the same slope. An expression giving adequate fit to the corrected data is $z/L = 1.84(Ri)^{1.09}$.

The corrected curves in Fig. III-7 were then used with the Ri data from the 1966-67 summary to establish estimated z/L values for comparison with the ϕ_M and ϕ_W summary data. The results for ϕ_M are plotted in Fig. III-8 along with curves based on formulations for ϕ_M suggested by earlier studies.

The ϕ_M data are fitted best by expressions having the form of $(1 - bz/L)^{-n}$ for unstable conditions and by $(1 + bz/L)^{+n}$ for stable conditions. Since under highly unstable conditions $|z/L| < Ri$, the value of n for the UCD ϕ_M expression is more negative (-.46) than for the earlier expression involving Ri (-.33). The opposite is true where z/L exceeds Ri under highly stable conditions.

A review of the curves representing the simplified Monin-Obukhov expression of $1 + \alpha z/L$ reveals that with an α of 0.6 it is entirely inadequate beyond a z/L of -.01. Bernstein's presentation (1966, Fig. 1) of Swinbank's Kerang data and of the O'Neill data also suggested this, although Bernstein did not feel the data were sufficient to verify or refute any of the three expressions tested.

The UCD data show that an α of 4.5 as suggested recently by Webb (1970) provides a very adequate prediction of ϕ_M in the range $-0.06 < z/L < 0$. For the stable case, however, the curve with an α of 5.2, also suggested by Webb's work, departs seriously from the UCD

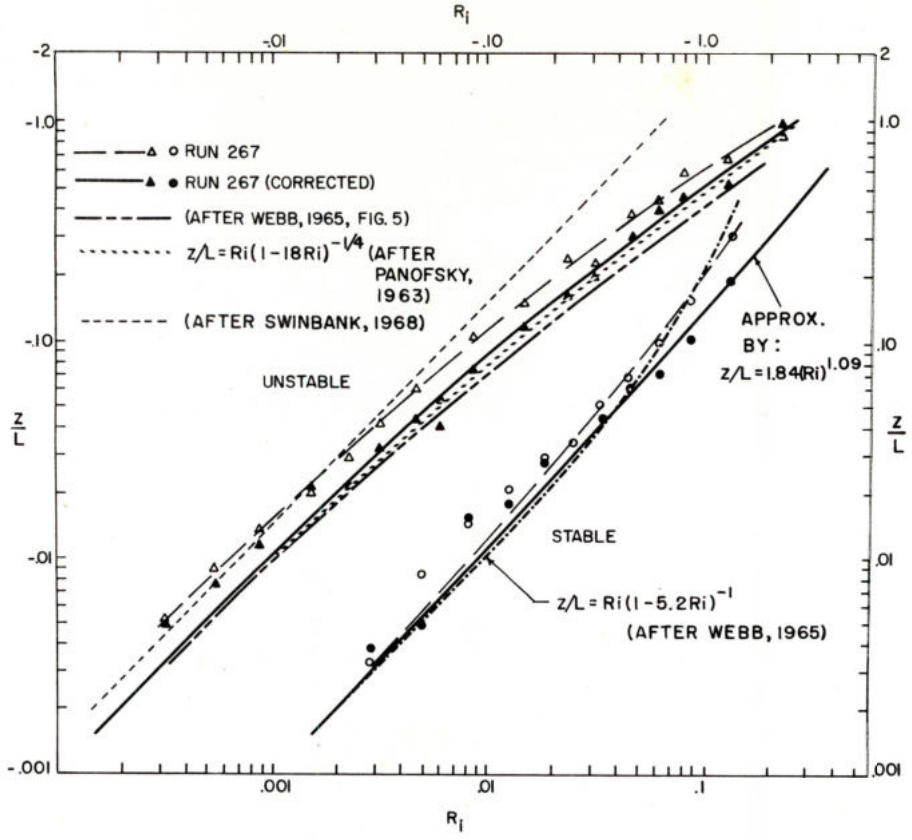


Figure III-7. Experimental values of z/L as a function of Ri for Run 267 compared with results of other researchers.

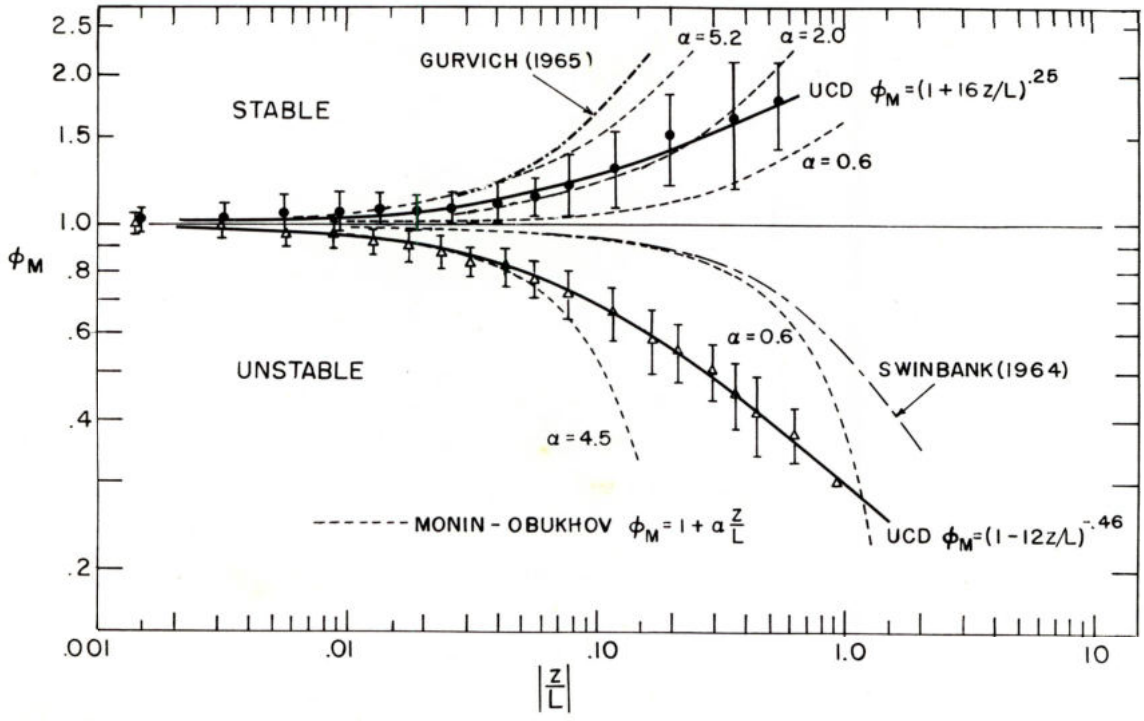


Figure III-8. Comparison of UCD $\phi_M(z/L)$ relationships with Monin-Obukhov expression, Swinbank's exponential profile, and data of Gurvich (1965).

curve at a z/L of only .03 to .04. By contrast, Webb's analysis of Australian and O'Neill data showed adequate representation out to z/L values approaching 1.0. His analysis was based strictly upon wind profile shape rather than the flux-gradient analysis used herein. It is interesting that the curve of Gurvich (1965) based on studies in Russia does correspond fairly well with the Monin-Obukhov curve with an α of 5.2.

Use of the expression (1 + 2z/L) does give a good fit to the UCD ϕ_M data for stable conditions out to a z/L of 0.3. The large standard deviations of the UCD data beyond z/L = .1, however, precludes any clear-cut conclusions.

Swinbank's (1964) exponential profile form is expressed as

$$\frac{kz}{u_*}\frac{\partial u}{\partial z} = \frac{z}{L}\left\{1 - \exp\left(-\frac{z}{L}\right)\right\}^{-1} \qquad (9)$$

Like the Monin-Obukhov equation with an α of 0.6, the Swinbank curve fits the UCD data only at very close to neutral conditions. Bernstein's (1966) presentation likewise shows poor agreement of the Swinbank expression with Australian and O'Neill data.

The UCD ϕ_W expression for unstable conditions in Fig. III-9 is quite similar to the relationship reported by Dyer (1967) of $\phi_W = (1 - 15z/L)^{-.55}$ except that the near-neutral ϕ_W at Davis approaches 0.885 instead of 1.0. The actual ϕ_W (and ϕ_H) data of Dyer's tend to exceed 1.0 slightly, even at a z/L of -.01. By comparison, the UCD data indicate a ϕ_W of only 0.82 at a z/L = -.01. Had Dyer calculated his ϕ functions using a k of .42 instead of .40, his values would run even 5% higher. Hence, there appears to be a serious discrepancy (around 20%) between ϕ_W data for the two studies, at least for near-neutral conditions. If equal accuracy in determination of $\partial q/\partial z$ and u_* is presumed for the two studies, agreement of ϕ_W for near-neutral could be obtained by an adjustment upward of Dyer's measurements of E by about 10% with an equal percentage reduction of the UCD evaporation data. Such a reduction would force a revision of our values of H upward, and yet they are, if anything, already too high, as indicated earlier. With the high degree of accuracy obtainable both for E and $\partial q/\partial z$ at Davis, and recognizing from experience the fair amount of uncertainty involved in Evapotron determinations of E, the authors tend to accept the UCD results as the more reliable of the two studies.

Well away from neutral, the differences between Dyer's curve and the UCD ϕ_W curve may not be significant. The reader is reminded of the fact that our ϕ_W data were plotted against a derived z/L rather than from a z/L based on measured data. Near neutral, of course, there is no reason to suspect a significant difference in z/L and Ri, and, hence, we can be confident that the differences between the two curves are indeed real.

Elliott (1966) derived a theoretical expression for ϕ_H assuming a lapse rate varying as $z^{-3/2}$ in very light winds. In Fig. III-9 a curve for ϕ_H based on his derivation is seen to be in generally good agreement with both the UCD ϕ_W curve and Dyer's curve. Elliott's curve coincides almost exactly with the UCD curve in the range $-.2 < z/L < -.01$. Beyond a z/L of -.4 it is more closely related to the Dyer curve. This is also true near neutral. This would be expected since Elliott's derivation tacitly assumed that $K_H = K_M$ under neutral conditions. Curves for ϕ_M are reproduced here for comparison on the same graph.

For the stable case, no expressions relating ϕ_W and z/L were found in the literature.

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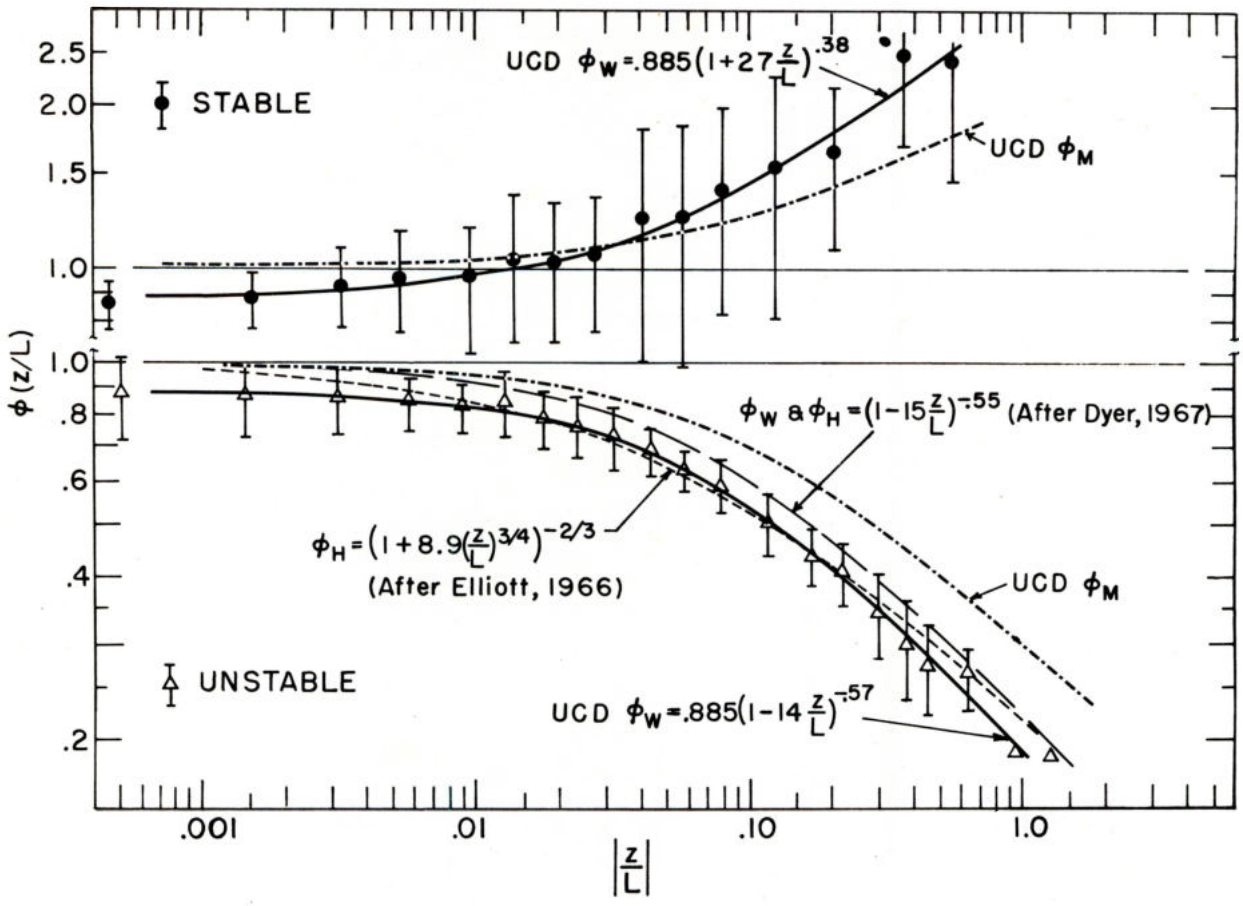


Figure III-9. Comparison of UCD $\phi_W(z/L)$ relationships with ϕ_W (and ϕ_H) expression by Dyer (1967) and with Elliott's (1966) ϕ_H relationship. The UCD $\phi_M(z/L)$ curves are reproduced again for comparison.

The UCD data in Fig. III-9 show considerable scatter except fairly close to neutral. As explained earlier, this might be expected since both E and $\partial q/\partial z$ are very small under highly stable conditions.

Turning now to transfer-coefficient relationships, Fig. III-10 shows 1966-67 summary data for K_W/K_M plotted as a function of $|Ri|$. The great sensitivity of ratios to variation of either or both entities making up the ratio, is obvious from the very large standard deviations indicated. For clarity, the upper or lower half of some of the vertical lines is left off.

In spite of the high standard deviations indicated for individual means, taken as a whole, the results indicate a systematic and significant change in K_W/K_M with changing stability. To a very significant extent the large standard deviations, especially near neutral, were produced by one run (267), which had unusually high values in relation to those of the other five runs. It is obvious from Figs. III-3 and 4 that this is the case, since, for Run 267, ϕ_W near neutral is the lowest for any run, whereas ϕ_M is the highest. This produced a K_W/K_M for Run 267 at neutral of around 1.38, while the values for other runs ranged from a low of 1.04 for Run 467 to a high of 1.20 for Run 466.

Perhaps a more logical way of arriving at a more definitive relationship for K_W/K_M lies in making use of the mathematical expressions obtained from the ϕ_M and the ϕ_W relationships as shown in Fig. III-2. By dividing the ϕ_M expression by that for ϕ_W at various Ri levels, values of K_W/K_M were obtained. From these data mathematical expressions were determined which provide estimates of K_W/K_M as determined above within $\pm$4% at all stability levels. The smooth curves of Fig. III-10 represent these formulations.

The results in Fig. III-10 suggest that K_W/K_M ranged from a low of around 0.75 at Ri = +.4 to a high of 1.6 at Ri = -2. Since aerodynamic predictions of latent heat flux are directly proportional to the ratio of K_W/K_M, it is obvious that serious errors can be expected if the assumption is made that $K_W = K_M$. The UCD data indicate this is a problem even under neutral conditions, suggesting that $K_W/K_M = 1.13$. The problem becomes most serious under highly unstable conditions where K_W/K_M approaches 1.7. This combined with the need for ϕ_M corrections, which enter as a squared term in the flux equations, presents possibilities of errors approaching an order of magnitude. The total diabatic correction needed in the flux equations is actually expressed by $K_W/K_M \times 1/\phi_M^2$, giving, for example, at Ri = 1 a correction of 1.53 x 1/0.16 = 9.57. In earlier work, Pruitt and Lourence (1966) derived a total diabatic correction expression of $(1 - 50Ri)^{1/2}$ for unstable conditions by merely dividing lysimeter measurements of evapotranspiration by Thornthwaite-Holzman (1939) estimates. This earlier work, using 1962-63 measurements at Davis, suggested an order of magnitude error at an Ri of about -2.

The literature on the subject of transfer coefficient relationships offers many diverse opinions. That K_W/K_M and K_H/K_M both range around unity for neutral conditions seems to be a common conclusion, although examples discussed below offer evidence to the contrary. Priestley's (1959) presentation of Swinbank's (1955) results suggests a K_H/K_M of around 0.77 for neutral conditions. However, Dyer (1965) indicates that Swinbank's measurements of H were known to be too low by one third. Assuming, then, that Priestley's curve (Fig. 1) needs a general 50% revision upward, means a revised K_H/K_M of 1.15 at neutral stability. The work

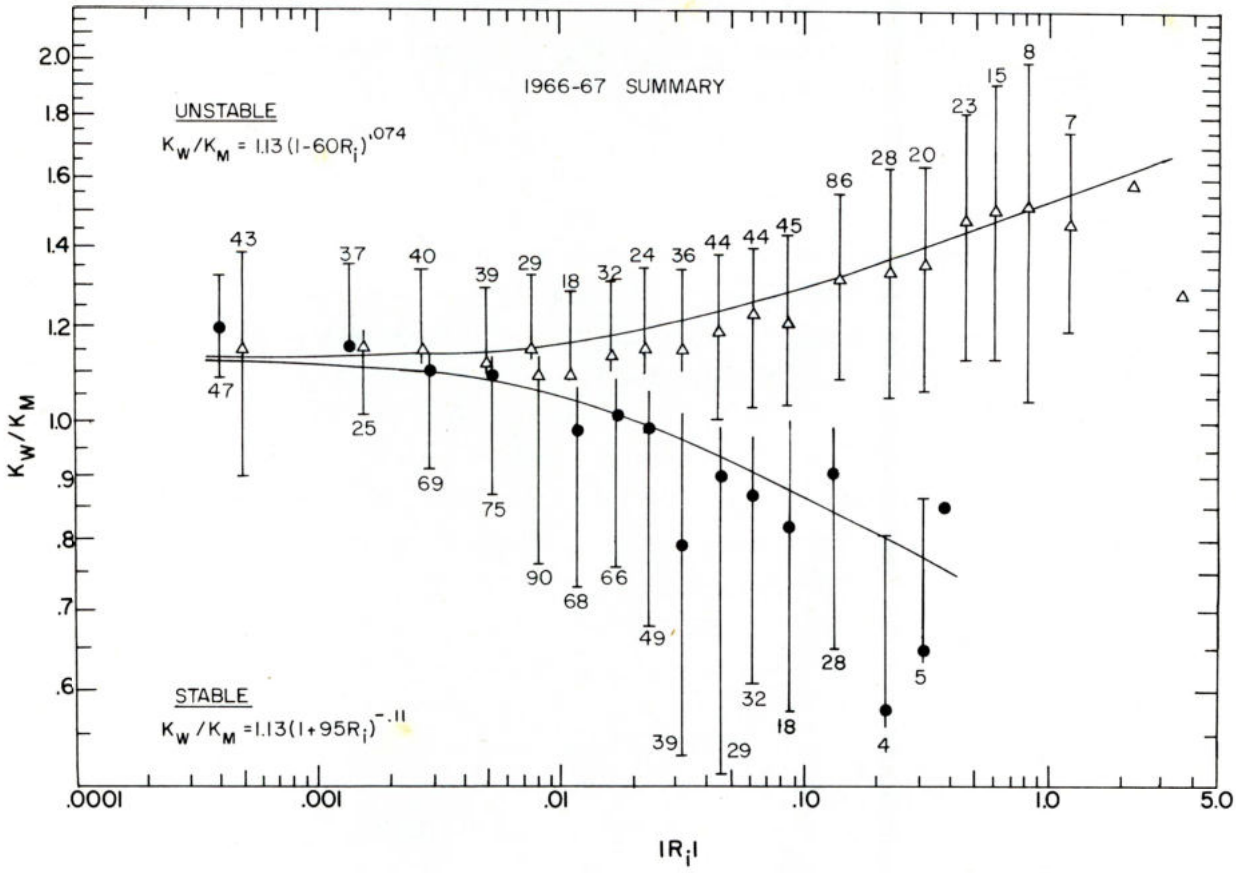


Figure III-10. Experimentally determined data for K_W/K_M plotted as a function of Ri. Smooth curves represent expressions shown and are based on use of ϕ_M vs. ϕ_W relationships of Figure III-2 rather than on the experimental K_W/K_M data.

of Rider (1954) suggested a value of 1.3 for K_H/K_M near neutral, and Cramer and Record (1953) often found values of $K_H > K_M$ under neutral conditions. Ellison (1957) developed a hypothetical expression for K_H/K_M which suggested a ratio of 1.2 for neutral conditions.

From the above it is seen that the UCD results in Fig. III-10 showing a K_W/K_M greater than unity for neutral conditions has considerable support from earlier studies.

As indicated earlier, analyses by Swinbank and Dyer (1967) of humidity, temperature, and wind profile shape factors, although showing K_W and K_H to be equal throughout a wide range of stability, did suggest significant divergence of both K_W and K_H from K_M. On the other hand, Webb (1970) using a different method of profile analysis on data from the same Australian study as well as the O'Neill study, claimed to show that the ratios of K_H/K_M and K_W/K_M remain constant and equal to unity over a wide range of stable conditions (z/L from 0 to 1.0) as well as out to a z/L of -.03 in the unstable case. Swinbank and Dyer's profile shape analysis did imply, however, quite a significant departure of K_M from both K_H and K_W by the time Ri reached -.03. They did not investigate the stable case.

Results of Oke (1970), in Ontario, Canada, are more in agreement with Webb's conclusion regarding stable cases, with near equality for K_M, K_H, and K_W indicated under stable cases even at large Ri values. Harbeck (1967), using an intriguing analysis of Lake Hefner data, found K_H to almost exactly equal K_M under near-neutral stability conditions. Lumley and Panofsky (1964) concluded that under unstable conditions K_H/K_M usually exceeds unity reaching an order of 1.2 to 1.3. They suggest this ratio may become smaller than unity in very stable air.

In Fig. III-10 K_W/K_M was presented in relation to Ri. Most of the comparisons in the literature relate to z/L. Hence, in Fig. III-11, the UCD data for K_W/K_M have been replotted as a function of z/L.

To be consistent, the ratios of K_W/K_M were obtained by dividing the expression for $\phi_M(z/L)$ by the one for $\phi_W(z/L)$ as shown in Fig. III-8 and 9. There are, therefore, some slight discrepancies if one uses the corrected z/L(Ri) relationship directly to replot Fig. III-10 values of K_W/K_M as a function of z/L. The only significant departure, however, is beyond z/L = .2, with a 7% difference developing by the time $z/1 \rightarrow .5$.

For the UCD data, a smooth transition is indicated in Fig. III-11 with K_W/K_M increasing from a low of 0.7 at z/L = .5, to 1.13 at z/L = 0, to 1.63 at z/L = -1.0. The results are not in good agreement with published results in the literature especially for $z/L < -.15$. Although the relationships suggested by Swinbank (1968), Laykhtman et al (1969), and Pandolfo (1966) are all three in relatively good agreement for $z/L < -.10$, their predicted K_H/K_M values exceed the UCD data very significantly. (In light of widespread acceptance of the near equality of K_H and K_W, the authors presume agreement between K_H/K_M and K_W/K_M should be close).

There is considerably closer agreement with the UCD curve in Fig. III-11, if the KEYPS expression for $\phi_M(z/L)$ with a b of 18 is used in the Pandolfo expression of $K_H/K_M = 1/\phi_M(z/L)$. At z/L = -1.0, the lower Pandolfo curve, using the KEYPS expression for ϕ_M, is only 27% above the UCD curve. Although not shown, Ellison's (1957) theoretical treatment suggested a K_H/K_M of 1.6 under free convection. As indicated earlier, his derivation led to a ratio of 1.2 for neutral conditions. Both are in good agreement with UCD results.

The results of Laykhtman et al (1969) are in serious disagreement with UCD data near

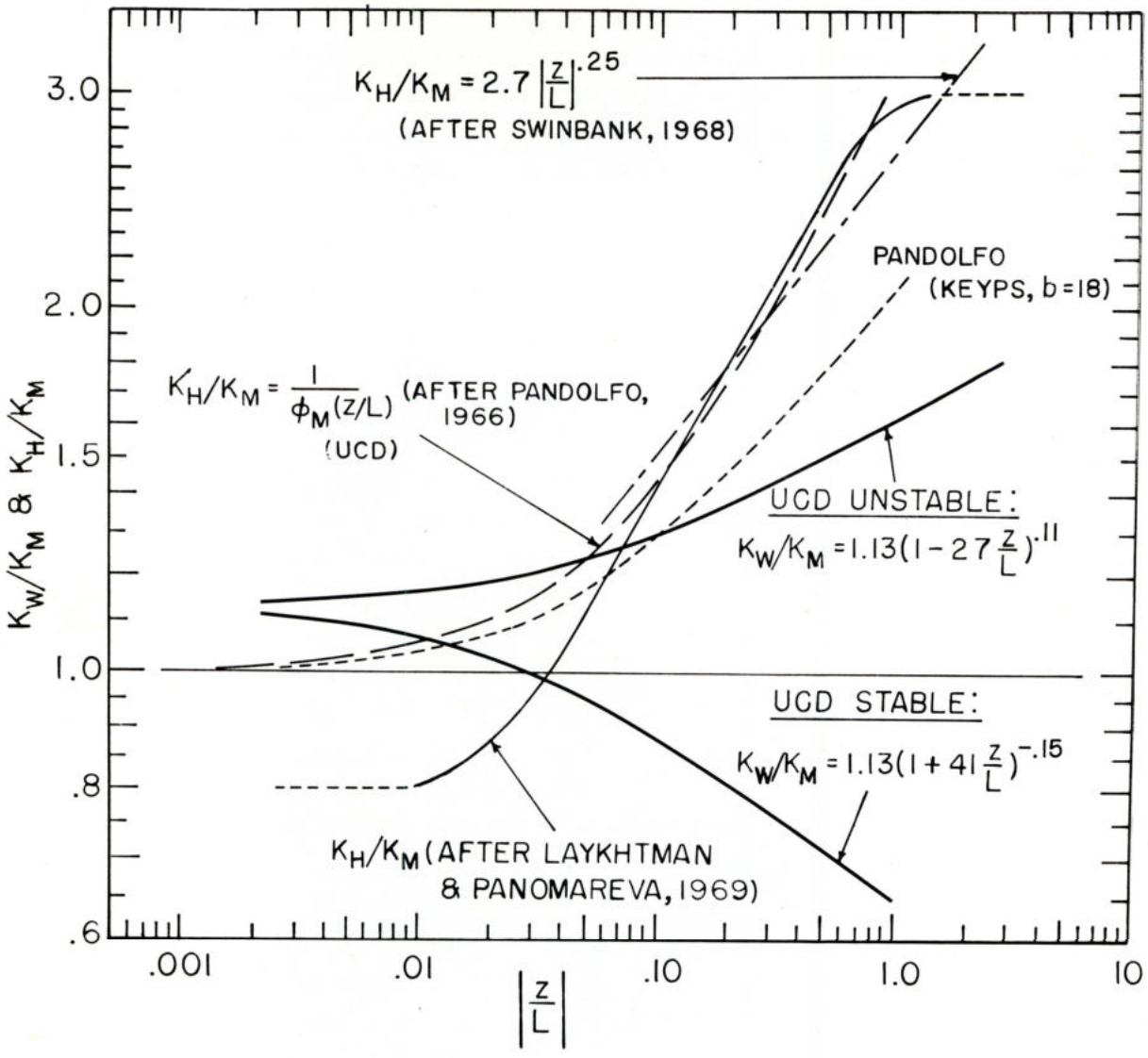


Figure III-11. Comparison of UCD K_W/K_M vs. z/L relationships with K_H/K_M vs. z/L relationships suggested by other researchers. The upper curve after Pandolfo (1966) results from use of UCD ϕ_M data in his expression of $K_H/K_M = 1/\phi_M(z/L)$. For the lower Pandolfo curve, the KEYPS expression for ϕ_M was used with a b of 18.

neutral as well as under highly unstable conditions. Although not shown on the graph, their studies indicated an approximately constant K_H/K_M of around 0.8 for the stable case. Monin and Yaglom (1965, Fig. 69) show a family of curves for K_H/K_M in the stable case based on one of Ellison's derivations. Their plot is in relation to Ri rather than to z/L, however, and thus related to Fig. III-10. The only curve in agreement with the UCD data near neutral, drops off much more quickly, suggesting a K_H/K_M of approximately 0.4 at an Ri of 0.1. This is less than half the UCD value of 0.86. At Ri = 1.0 the same Ellison curve indicates a low of less than 0.1 for K_H/K_M. The highest curve in the family of four gives a K_H/K_M of 0.4 at Ri = 1.0. It may very well be that K_W/K_M drops off much more quickly with increasing stability than a projected UCD curve beyond Ri = .3 would predict. Monin et al (1965, p.404), for example, indicate that values of .02 to .05 for K_H/K_M were found in at least two studies by other researchers for extremely stable conditions ($4 < Ri < 10$).

4. CONCLUSIONS

A number of conclusions can be drawn from this study which included, probably for the first time, very extensive and simultaneous determination of both evaporation and surface drag using absolute measurement systems (6.1-meter-diameter weighing lysimeter and floating drag-plate lysimeter). Excellent wind-profile data, along with surface drag measurements on a sample size consisting of thousands of plants, provided data for calculation of the Monin-Obukhov universal ϕ_M function, which the authors believe are unmatched in accuracy by any previous study.

Expressions for ϕ_M having the form of $(1-16Ri)^{-1/3}$ or $(1-12z/L)^{-.46}$ fit the unstable data very well, while the stable cases are represented well by $(1+16Ri)^{1/3}$ and $(1+16z/L)^{1/4}$. It is evident that, for a wide range of stability conditions, the general form of $(1+b|Ri|)^{\mp n}$ offers by far the best mathematical representation of the $\phi_M(Ri)$ relationship. However, the exponent apparently needs to be 33% higher than the (1/4) power proposed by Ellison (1957) and used in the KEYPS profile. On the other hand, the exponent of 1/2 suggested in the diabatic influence functions equivalent to those proposed by Rossby and Montgomery (1935) and by Holzman (1943), is 50% too high.

Although giving an excellent fit to UCD ϕ_M data, out to an $|Ri|$ of .01, the KEYPS prediction in the form of $\phi_M = (1+18|Ri|)^{\mp 1/4}$ fails to change quickly enough with increasing $|Ri|$ beyond that point. Because of this, the value of the coefficient in the KEYPS expression needs to be considerably higher than the 14-20 normally accepted in order to predict ϕ_M under highly stable or unstable conditions. For example, with stabilities represented by an $|Ri|$ around -.5 to -2.0, a value of 38 for the coefficient in the KEYPS expression gives very adequate prediction of ϕ_M without producing unacceptable large errors at lesser instabilities. For the Rossby-Montgomery and Holzman equations, a coefficient of around 5 to 6 is needed to give good prediction under these conditions.

The UCD $\phi_M(z/L)$ data indicate that the simplified Monin-Obukhov expression of $\phi_M = 1 + \alpha\,(z/L)$ with their originally proposed value for α of 0.6, offers too small a correction even very close to neutral, (e.g. for $|\frac{z}{L}| \simeq .01$). Swinbank's exponential profile expression is also inadequate, giving results similar to the above.

With larger values of α e.g. 2 to 4, the Monin-Obukhov expression appears quite adequate in the stable case, and with an α of 4.5 as suggested by Webb, excellent ϕ_M prediction

results out to $\frac{z}{L} \simeq -.06$. It becomes highly inadequate at greater instability. It is interesting to note that the first two terms of the Monin-Obukhov universal function have the same form as those discussed earlier, but with an exponent, n, of 1.0. As indicated earlier, an exponent of |0.46| gives an excellent fit for a wide range of unstable conditions. In the stable case, an even lower exponent (.25) is needed to provide good prediction of ϕ_M.

With the good quality ϕ_W data as well as ϕ_M, the UCD results are of particular value in relationship to the excellent report of Dyer (1967) presenting $\phi_H(z/L)$ and $\phi_W(z/L)$ relationships determined in the extensive C.S.I.R.O. studies under unstable conditions. Agreement, in general, is excellent between the two studies except for near-neutral stability where ϕ_W for the UCD studies approaches 0.885 rather than 1.0. For $\phi_W(z/L)$ good fit to UCD data is obtained by $\phi_W = .885(1-14z/L)^{-.57}$ for unstable conditions. This compares with Dyer's ϕ_W and ϕ_H expression of $(1-15z/L)^{-.55}$. In the stable case, the expression giving good fit to UCD data is $\phi_W = .885(1+27z/L)^{.38}$. With respect to Ri, the respective expressions are $.885(1-22Ri)^{-.40}$ and $.885(1+34Ri)^{.40}$.

Considering the relationship between the two stability parameters, Ri and z/L, the UCD data from Run 267 (with corrected values of H) indicate adequate prediction of the relationship by Panofsky's suggested $z/L = Ri(1-18Ri)^{-1/4}$ in the unstable case. In the stable case, the relationship appears to be almost straightline on a log-log plot with $z/L = 1.84(Ri)^{1.09}$ giving a good fit to experimental data corrected for H.

In considering transfer coefficient relationships, K_W/K_M changed smoothly from a low of 0.75 at Ri = +.4 to a high of 1.6 at Ri = -2. Very significant is the fact that at neutral $K_W/K_M \neq 1.0$ but $\simeq 1.13$. The relationship was quite adequately represented by $K_W/K_M = 1.13\ (1-60Ri)^{.074}$ in the unstable case and by $1.13\ (1+95Ri)^{-.11}$ in the stable case. Considering $K_W/K_M(z/L)$, the UCD results showed a close relationship to Ellison's (1957) hypothetical derivations for K_H/K_M but showed poor agreement with K_H/K_M relationships suggested by Swinbank (1968), Laykhtman et al (1969), and Pandolfo (1966).

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CHAPTER IV

DIMENSIONLESS FORMS OF MOMENTUM, HEAT, AND MOISTURE FLUXES, τ^*, H*, AND E*

by

W. O. Pruitt, D. L. Morgan, and F. J. Lourence

1. INTRODUCTION

Prediction of heat and moisture transfers from dimensionless formulations involving only gradients of temperature in the former and both temperature and specific humidity in the latter, have been respectively proposed by Priestley (1959) and Crawford (1965). These have been designated H* and E*. Dr. T. V. Crawford, before leaving the Davis Campus of the University of California, also derived an analogous expression for momentum transfer, τ^*, involving gradients of both temperature and wind. If variation with stability of these dimensionless flux forms were known, the prediction of all three would be obtainable from gradients of temperature, humidity, and wind. One strong advantage of such an approach is that in the near-free convection regime the magnitudes of H*, E*, and τ^* seemingly remain fairly constant throughout a wide range of stability. It is in this stability regime that the more traditional aerodynamic expressions (e.g. the Thornthwaite-Holzman) require diabatic correction factors approaching 10 (Pruitt, 1963 and Pruitt and Lourence, 1966).

2. FORMULATIONS

Priestley (1959) presented theoretical relationships involving sensible heat flux, H, in both the forced- and free-convection regimes. Assuming equality of transfer coefficients for heat and momentum, K_H and K_M, an expression for forced convection of

$$H = \rho\, c_p\, k^2 z^2 \left(\frac{\partial u}{\partial z}\right)\left(\frac{\partial \theta}{\partial z}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

was suggested, where H is the sensible heat flux, considered positive with downward flow to the surface, ρ is the air density, c_p is the specific heat of the air at constant pressure, k is the von Karman constant, z is the height above the zero plane, u is the mean horizontal wind speed, and θ is the potential temperature.

For free convection with thermally generated mixing, Priestley (1954) and, independently, Monin and Obukhov (1954) derived from dimensional analyses the relation

$$H = h\, \rho\, c_p \left(\frac{g}{\theta}\right)^{1/2} z^2 \left|\frac{\partial \theta}{\partial z}\right|^{3/2} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

where h was considered to be a constant and g is the acceleration of gravity.

From (1) and (2) the following was suggested

$$H^* = \frac{H}{\rho\, c_p\, (g/\theta)^{1/2} \left|\partial\theta/\partial z\right|^{3/2} z^2} \quad \ldots\ldots\ldots\ldots (3)$$

where H* is the dimensionless form for sensible heat flux such that for forced convection under near-neutral conditions, and assuming $K_H = K_M$,

$$H^* = k^2 \left| Ri \right|^{-1/2} \quad \ldots \quad (4)$$

where Ri is the Richardson number having the form

$$Ri = \frac{g}{\theta} \frac{\partial\theta/\partial z}{(\partial u/\partial z)^2} \quad \ldots \quad (5)$$

For free convection

$$H^* = h \quad \ldots \quad (6)$$

Crawford's (1963, 1965) derivation of the dimensionless evaporative heat flux, E*, gave

$$E^* = \frac{E}{\rho\ (g/\theta)^{1/2} \left| \partial\theta/\partial z \right|^{1/2} z^2\ \partial q/\partial z} \quad \ldots \quad (7)$$

where E is the water vapor flux, considered positive with downward flow to the surface, and q is the specific humidity.

For forced convection under near-neutral conditions, and if the transfer coefficient for water vapor, K_W, is equal to K_M,

$$E^* = k^2 \left| Ri \right|^{-1/2} \quad \ldots \quad (8)$$

For free convection, Crawford with the assumption of $K_W = K_H$ suggested

$$E^* = h \quad \ldots \quad (9)$$

In light of the later development by Crawford of a nondimensional form of momentum flux, τ^*, the authors at this point suggest a revision of (9) giving for free convection,

$$E^* = h_e \quad \ldots \quad (10)$$

where h_e can be considered a constant analogous to h, though not necessarily equal to h unless $K_W = K_H$ under free convection.

Crawford's derivation of the dimensionless expression for momentum flux, τ^*, resulted in

$$\tau^* = \frac{\tau}{\rho\ (g/\theta)^{1/2} \left| \partial\theta/\partial z \right|^{1/2} z^2\ \partial u/\partial z} \quad \ldots \quad (11)$$

where τ is the actual momentum flux and u is the wind speed in cm sec^{-1}.

Under strictly forced-convection, it can be stated that

$$\tau^* = k^2 \left| Ri \right|^{-1/2} \quad \ldots \quad (12)$$

without having to make any assumptions about transfer-coefficient relationships, although the log-law wind profile must still hold.

Under free convection, we now propose

$$\tau^* = h_\tau \quad \ldots \quad (13)$$

where h_τ can be considered a constant analogous to h in (6) and h_e in (10).

It should be worth noting that

$$E^* = \tau^*\ K_W/K_M \quad \ldots \quad (14)$$

and

$$H^* = \tau^* \, K_H/K_M \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

and hence

$$h_e = h_\tau \, K_W/K_M \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

and

$$h = h_\tau \, K_H/K_M \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

In the above formulations, potential temperature is used rather than actual dry-bulb temperature to account for the adiabatic lapse rate. As Crawford (1965) points out, although the adiabatic lapse rate can be neglected where small height intervals are used, the effect of rather strong specific-humidity gradients on buoyancy should not be overlooked. This is especially true during near-neutral conditions in midafternoon. At least at Davis over grass, this is frequently a time of day when the humidity gradient is greatest. If not taken to account, and dry-bulb temperatures are used in computing the Richardson number, the switch from - to + Ri can come as much as 1 to 1 1/2 hours earlier than the actual time of passing through neutral conditions.

Crawford (1965) pointed out that in the definition of E* (and this would hold for τ^* as well) the temperature gradient is really a buoyancy term and hence for calculation of E* and τ^* virtual temperature, T_v, was used. The zero-plane displacement, d, which varied with the different tests, was also taken into account, giving replacement equations for E* in (7) and τ^* in (11) of

$$E^* = \frac{E}{\rho \, (g/\theta)^{1/2} \left|\partial T_v/\partial z\right|^{1/2} \, (z-d)^2 \, \partial q/\partial z} \quad \ldots\ldots\ldots \quad (18)$$

and

$$\tau^* = \frac{\tau}{\rho \, (g/\theta)^{1/2} \left|\partial T_v/\partial z\right|^{1/2} \, (z-d)^2 \, \partial u/\partial z} \quad \ldots\ldots\ldots \quad (19)$$

where θ is the potential temperature and T_v is the virtual temperature in °K and d is the zero-plane displacement in cm.

In the formulation for H* in (3), the potential temperature gradient to the 3/2 power appears. To separate out the portion of the equation related to buoyancy and to relate to the form of (18) and (19), we obtain

$$H^* = \frac{H}{\rho \, c_p \, (g/\theta)^{1/2} \left|\partial T_v/\partial z\right|^{1/2} \, (z-d)^2 \, \partial\theta/\partial z} \quad \ldots\ldots\ldots \quad (20)$$

The similarity of formulations for all three is now easily noted in (18), (19), and (20), where in each case the dimensionless flux is inversely proportional to the gradient of the entity being considered, and the term, $\left|\partial T_v/\partial z\right|^{1/2}$ relates only to the buoyancy effects.

One other comment on procedure is called for. Actual profiles of wind, temperature, and humidity are not linear, and yet, as explained in the Appendixes, the average gradient between various height intervals was used. The height above the zero-plane displacement at which this average gradient occurs is not halfway between the two height intervals but somewhat lower. As an estimate, the geometric mean heights were used, such that the (z-d) term

in (18), (19), and (20) was obtained from

$$z-d = e^{\left[\frac{\ln(z_2-d) + \ln(z_1-d)}{2}\right]} \quad \ldots\ldots\ldots\ldots\ldots\ldots (21)$$

3. DISCUSSION

Figs. IV-1 and 2 summarize τ^* and E^* values obtained in the six micrometeorological studies conducted at Davis in 1966 and 1967. Fig. IV-3 gives H^* data for Run 267 only, since correct H^* data were not yet available for the 1966 studies. For ease of comparison, Fig. IV-4 presents only eye-smoothed curves for each of the parameters. To avoid confusion, data for stable conditions are displaced one cycle to the left of the unstable cases. All three cases are considered together because of the expected interrelationships as shown by Equations 14-17.

Although in Figs. IV-1, 2, 3 the data have been segmented into regions where straight-line relationships give a reasonable fit, it is obvious that the data really indicate a smoothly changing relationship in the unstable case. For positive Ri, however, there does appear to be a rather definitive change in slope for τ^* and E^* at an Ri between 0.02 to 0.03. The H^* data for Run 267 indicate a slight change only. Crawford (1965), in discussing 1962-63 Davis data, suggested the beginning of a decay in turbulence between Ri = 0.05 to 0.1. The complete decay of turbulent mixing or marked change in character of flow at Ri values of around 0.2 to 0.35 suggested from independent studies by Businger (1959), Townsend (1957), Portman et al (1962), and Oke (1970) does not appear to be borne out by the limited amount of τ^* data obtained within and beyond that region in the present study. Crawford's original E^* data were far too scattered beyond Ri = .05 to reach a definite conclusion. In the present study also, a wide scatter of E^* data beyond Ri = .05 is indicated by the large standard deviations. Data for E^* in this range come mostly from periods of condensation or dew fall, when the flux rate is very small and moisture gradients may be small as well. The H^* data, however, in this range appear to be as good in quality as the τ^* data. Data were not available for E^* or H^* beyond Ri = 0.35 due to limitations set on minimum acceptable heat and moisture fluxes or on gradients of temperature and humidity.

From (12), the slope of the relationship of τ^* to Ri near neutral stability conditions should be -0.5 if the log-law wind-profile theory holds. This would also be the case for E^* and H^* if the ratios of K_W/K_M and K_H/K_M were holding steady as neutral conditions were approached. The results for τ^* are in excellent agreement with log-law theory showing a slope of -0.50 at Ri around -.0005 and -0.52 at an Ri of around +.0005. Corresponding slopes for the E^* relationship were -0.49 and -0.51. H^* data are too limited in the unstable case, but at an Ri of +.003 the slope for H^* is very similar to that for τ^*.

As mentioned earlier, in the unstable case all three parameters show a smoothly changing relationship with increasing instability. Monin and Yaglom (1965) indicate that a similar smooth transition between limiting conditions for H^* was evident from data of Perepelkina and of Panofsky et al (1960). Although two distinct regimes for unstable conditions were suggested for H^* by examples of Priestley (1955 and 1959), he shows a hypothetical relationship in a later article, with a smooth transition from forced to free convection (Priestley, 1960).

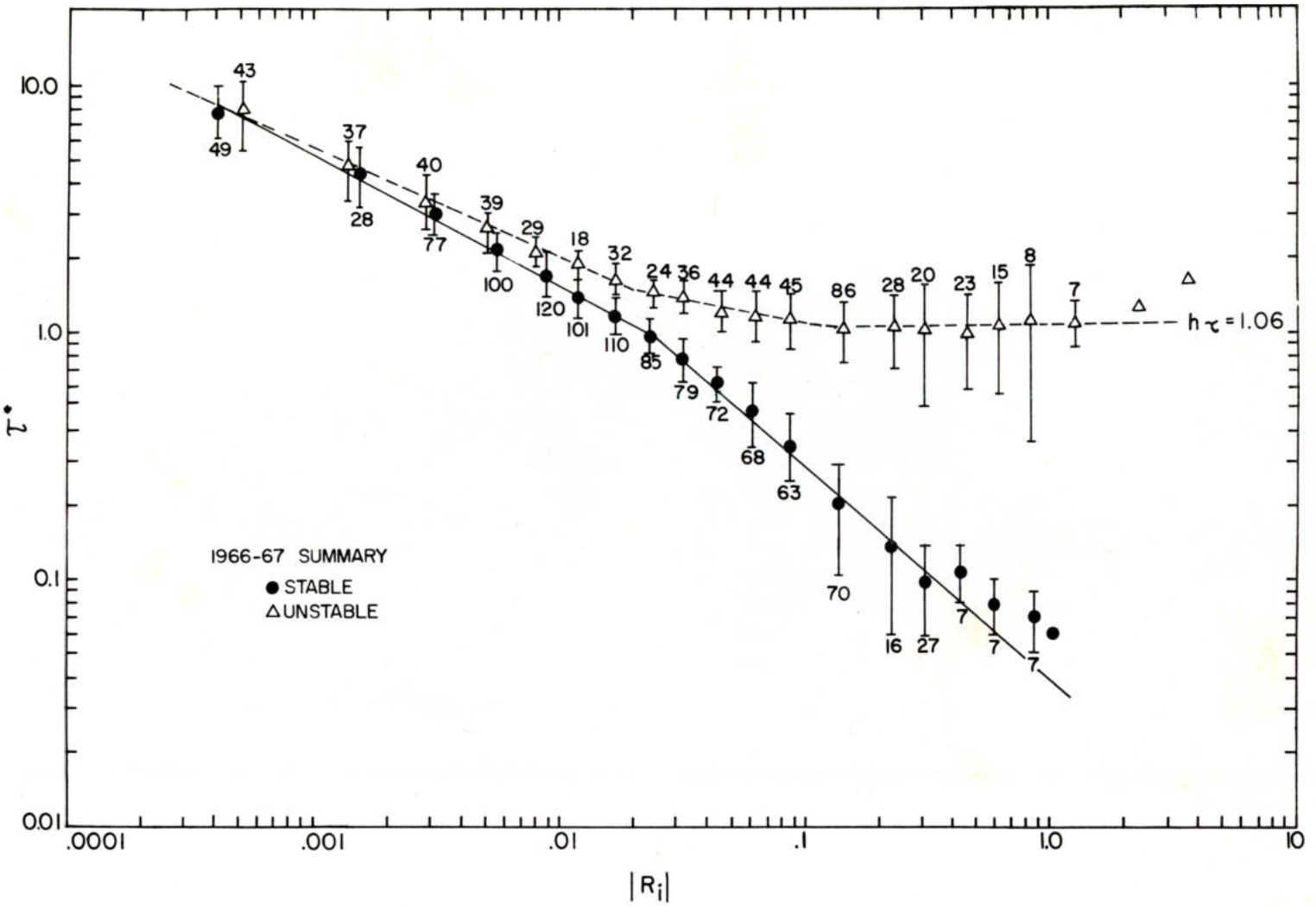


Figure IV-1. The newly-formulated dimensionless momentum flux, τ*, plotted as a function of $|Ri|$. Mathematical expressions for straight-line segments are given in Table IV-2.

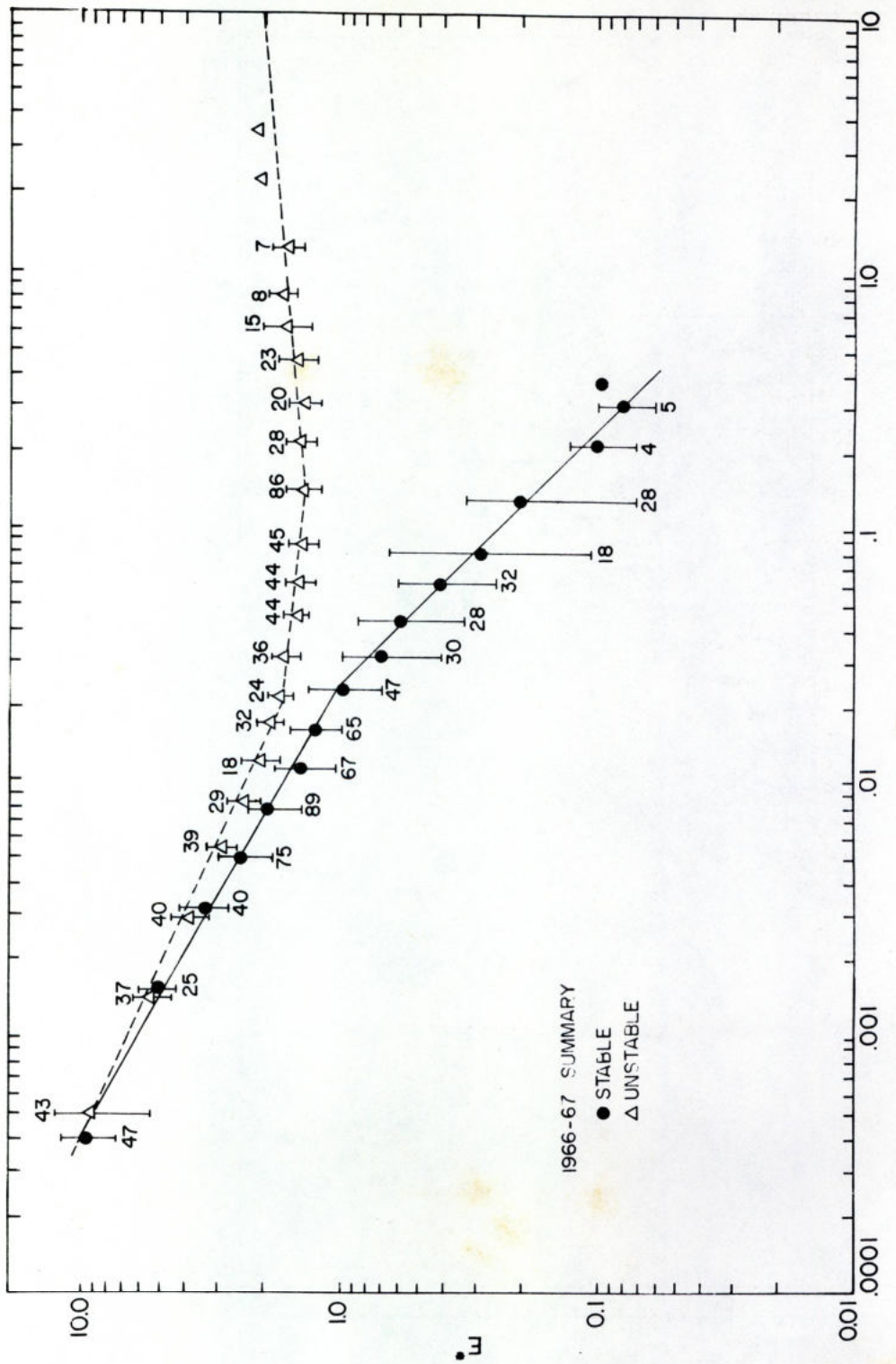


Figure IV-2. Crawford's (1965) dimensionless evaporation flux, E*, plotted as a function of $|Ri|$.

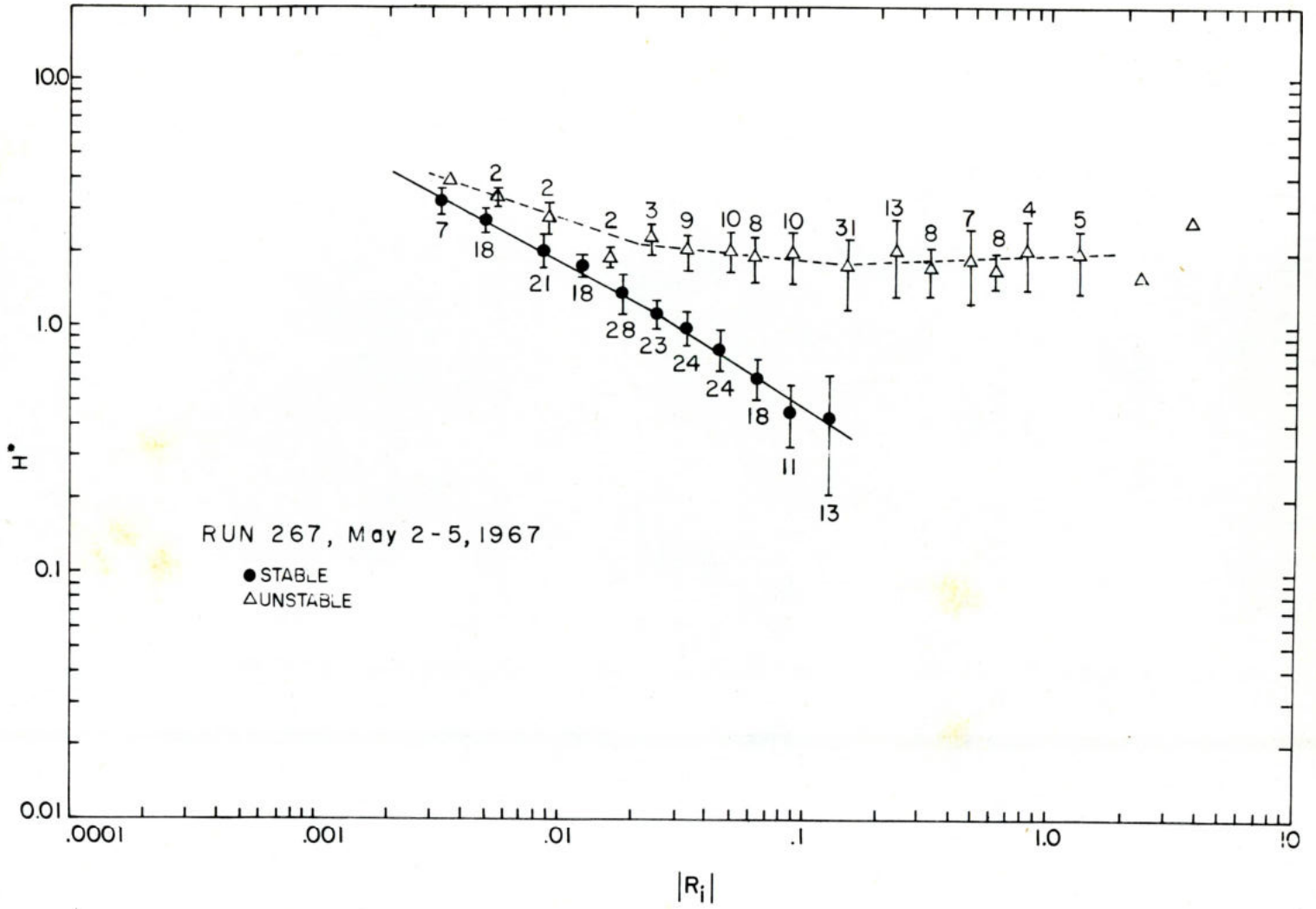


Figure IV-3. Priestley's (1959) dimensionless heat flux, H*, plotted as a function of $|Ri|$ for Run 267 data only.

The smooth transitions in unstable conditions back up Crawford's (1965) suggestions that "there are not two distinct regimes of forced and free convection but instead, a rather broad regime of mixed convection where both thermally and mechanically generated turbulence are significant." The agreement of the 1966-67 E* data and Crawford's E* data from earlier Davis studies is striking as indicated in Fig. IV-4. At least out to an Ri of -0.4 the two curves are never more than 12% apart. The degree of change suggested for E* is rather small in the predominantly forced-convection regime. Considering the availability of 188 values for E* in the range $-.0005 < Ri < -.02$ for the present paper, as compared with only 40 values in Crawford's study, the authors believe these results to be a significant refinement of the earlier work. This is especially true in the zone approaching neutral where Crawford had very few data points. For the range $-0.02 < Ri < -0.2$ there is near perfect agreement between the study of Crawford and the present data.

The only seemingly significant divergence of the two E* curves is produced by an upward trend in the 1966-67 curve following the reaching of a low of about 1.40 at an Ri of around -.15. There is a wide range ($-0.05 < Ri < -0.5$) where the value of E* would be within $\pm$5% of 1.45. Considering this rather flat zone to provide the equivalent of h_e of Equation (10), its magnitude is seen to be 10% higher than the value of h suggested by Dyer (1965) and of h_e (our designation) suggested by Crawford (1965).

In a re-analysis of the CSIRO data, Dyer (1967) suggested even lower values for h and h_e. Within a range of z/L from -0.02 to -0.6, Dyer found a mean value of H* of 1.27 and of E* of 1.21. His analysis came from measurements of $\Delta\theta$, Δq, and Δu between 1-meter and 4-meter levels, and he suggested a needed correction within the stability range above of 6.8%. This would reduce his h and h_e to 1.15 and 1.10, respectively. The analogous correction of the Davis data, to make up for the use of finite-difference data rather than actual gradients, would be insignificant since the height intervals used were so small (35-50 cm, 50-70 cm, etc.). The Davis results for h, obviously, cannot be used to dispute Dyer's results for h. The CSIRO measurements of H with the eddy-correlation technique must be considered superior to our energy-balance determination of H, which involved cumulative errors in measurements of three other components and the neglect of several others, e.g. heat storage. On the other hand, the Davis measurements of E with the very sensitive 6.1-meter-diameter weighing lysimeter (Pruitt and Angus, 1960) are, no doubt, superior to the Australian measurements of E. As described by Swinbank and Dyer (1967), their evaporation data were obtained from very small lysimeters (45 cm^2 and 40 cm deep) as well as from eddy-correlation measurements by the 'Evapotron'. The profiles of absolute humidity obtained at Davis with an infrared hygrometer and a time-averaging sampling system described by Lourence (1967) are likely more reliable than the Australian data obtained with a crystal hygrometer. Evidence of the superiority of the Davis evaporation and humidity data can be found by comparing the ϕ_W data of Dyer's (in Fig. 2 of his 1967 paper) with the Davis ϕ_W data in Fig. III-2 of this report, where the scatter of the Davis data is quite insignificant by comparison.

The data in Figs. IV-1 and 4 would indicate a value for h_τ in the stability range beyond an Ri of -.13, of 1.06, a value only slightly lower than the h and h_e suggested in Dyer's 1967 paper. However, in light of this value and of the preponderance of data in the literature suggesting values of K_W/K_M and K_H/K_M well above 1.0 as free convection becomes

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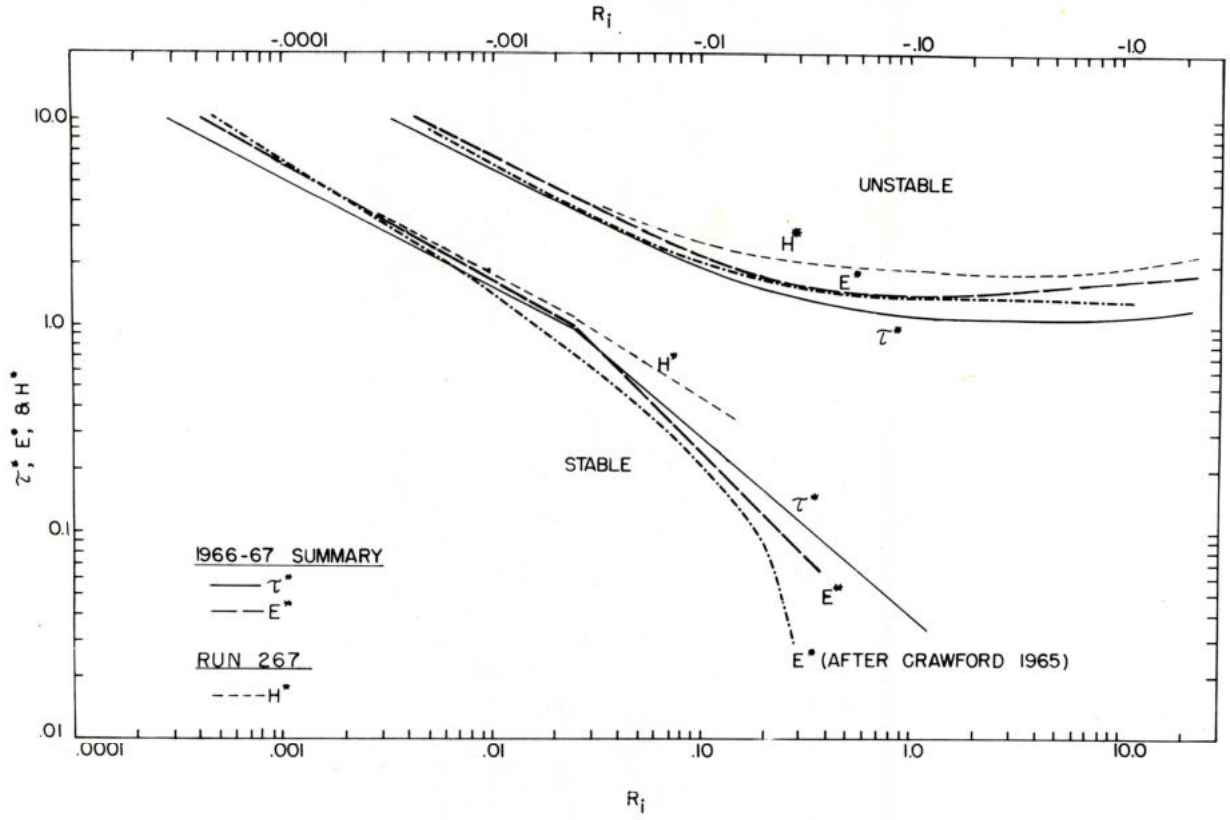


Figure IV-4. A comparison of τ^*, E*, and H* smoothed curves. Curve for H* is for Run 267 only. The E* relationship found by Crawford (1965) in earlier work at Davis is shown for comparison.

predominant, the authors suggest that a value of h_e at least as high as 1.30 to 1.40 appears to be reasonable.

A look at the variation of h_τ, h_e, and h for the six studies conducted at Davis should be helpful at this point. Since there was some variation in the range of stability over which τ^*, E*, and H* are relatively constant, the writers have chosen to present in Table IV-1 the minimum value of τ^*, E*, and H* reached under unstable conditions and indicate the Richardson number at which this occurred.

TABLE IV-1. MINIMUM VALUES OF τ^*, E*, AND H* UNDER UNSTABLE CONDITIONS AS OBTAINED FROM SMOOTHED CURVES FOR 1966 AND 1967 STUDIES

Study	Ri	τ^*	Ri	E*	Ri	H*
1-3 June 1966	-.12	1.48	-.11	1.60	----	----
12-14 July 1966	-.30	0.83	-.17	1.30	----	----
13-14 Oct. 1966	----	1.00[a]	----	1.20[a]	----	----
2-5 May 1967	-.25	1.03	-.20	1.47	-.30	1.80
5&9 May 1967	----	1.05[a]	----	1.25[a]	----	----
28-29 Sept 1967	-.25	1.03	-.15	1.19	----	----
AVERAGE	-.23	1.07	-.16	1.34	----	----
SUMMARY '66-'67	-.25	1.06	-.15	1.40	----	----

[a] Data based on an extrapolation to a minimum value in relation to relative position of curves at lowest Ri value where data were available.

The data for τ^* indicate almost identical minimum values for the last four studies averaging about 1.03. For the first and second studies, the minimum τ^* was respectively 53% greater and 19% less. Weighting all half-hour periods equally, the summary data indicate a minimum τ^* of 1.06.

The variability between runs of the minimum E* reached under unstable conditions was somewhat greater than for τ^*, but the overall range of values was much narrower. The average value for the six runs was 1.34, while equal weighting of all one-half hour periods gave a value for E* of 1.40. The range and variability of the minimum E* and τ^* are quite similar to those shown by Dyer (1967) for H* and E* in the CSIRO studies.

The 1.80 minimum value for H* for unstable conditions in Run 267 is well above values for h reported in the literature. Assuming a value for h of 1.35 - 1.40 would be more nearly correct, the H values reported for Run 267, at least under highly unstable conditions, may be as much as 30% too high. Wesely et al (1970) indicate that, in relation to data for H obtained during Run 267 with their pressure sphere and fast thermometer system, the UCD values appear high during the day.

The variation between runs of τ^* and E* at all observed stabilities is shown in Figs.

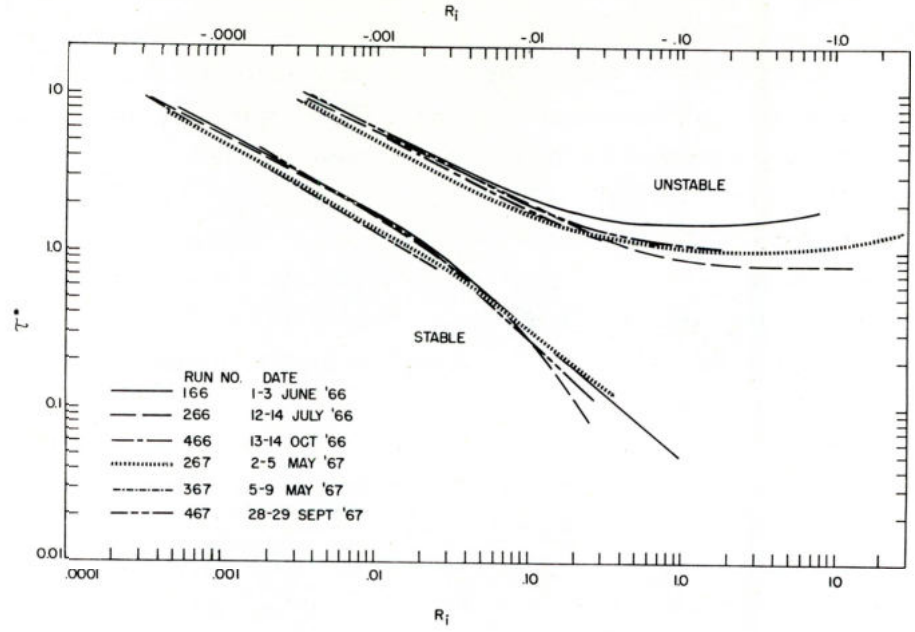


Figure IV-5. Smooth curves of τ^* for each of the runs conducted during 1966-67.

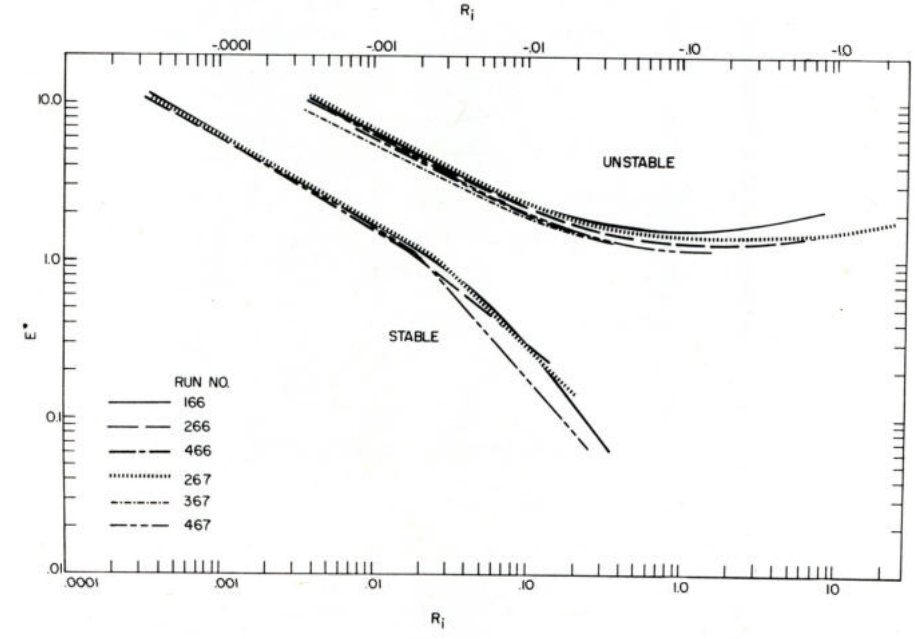


Figure IV-6. Smooth curves of E* for each of the runs conducted during 1966-67.

IV-5 and 6. Except for the fairly wide range separating the τ^* curves for Runs 166 and 266 under highly unstable conditions, the variation between the various studies is seen to be rather small. In these figures the curves for Run 267 are emphasized since the data for this run relate to analyses by other research groups; for example, the Davis shear-stress and heat-flux data for this run have already been compared with independent measurements by Thurtle et al (1970) and Wesely et al (1970).

One further item for discussion concerns the shape of the dimensionless flux curves as the influence of free convection becomes more and more predominant. Referring back to Figs. IV-1 and 2, the E* data show a significant increase following the reaching of a minimum value of 1.40 at an Ri of around -.15. On the other hand, τ^* tends to remain constant beyond an Ri of -.15.

Although dealing with H* rather than E*, Elliott (1966), using a $\phi_M(z/L)$ relationship found by Dyer (1967) and a value for h of 1.3, derived the smooth curve for H* reproduced in Fig. IV-7. For comparison, E* data are shown for Run 266 (12-14 July 1966) with E* plotted as a function of z/L. For Run 266, where the minimum E* was very close to the h used by Elliott, the agreement between the Davis data and Elliott's curve is almost perfect. Both show an increase in value with increasing instability beyond Ri = -.2. The smooth curve of E* for Run 267 is also shown. It has similar form, but shows a somewhat sharper rise with increasing instability beyond z/L = -.15. No attempt was made to correct z/L data for either run, since only the general shape of these curves is of importance here.

Swinbank (1968), although failing to identify the parameter plotted on the ordinate of his Fig. 6 as such, shows a plot of H* versus Ri using Kerang and Hay observations in Australia. Swinbank's H* data are replotted as a function of z/L in Fig. IV-8 making use of the z/L(Ri) relationship suggested from Swinbank's (1968) report as reproduced in Fig. III-7. In spite of Crawford's 1965 E* presentation and Priestley's 1959 presentation, it is believed that evidence obtained in the comprehensive studies at Davis and in Australia proves the absence of any extensive range of stability where H* and E* can be expected to remain constant. If τ^* really does tend to remain constant beyond an Ri of around -.15 as the UCD results indicate, the shape of E* and H* curves should be expected to slope upward if, as the literature (and the present study) seem to indicate, the ratios of K_W/K_M and K_H/K_M are increasing as free convection is approached.

Crawford (1965) suggested use of the relationship he found between E* and Ri to estimate evaporation under a wide range of stability conditions. The closeness of his results to the 1966-67 studies add further to the reasonableness of his suggestion. The newly established relationship of τ^* versus Ri, indicated in the present study, could be used in a similar way to predict momentum flux. For this reason the following table provides the mathematical expression describing the various straight-line relationships shown in Figs. IV-1 and 2. Similar expressions for H* are not given since data for one run were available. With all of the indication from recent studies of the near equality of K_H and K_W (e.g. Dyer, 1967 and Swinbank and Dyer, 1967), the authors suggest direct substitution of our E* relationships in estimating sensible heat flux H.

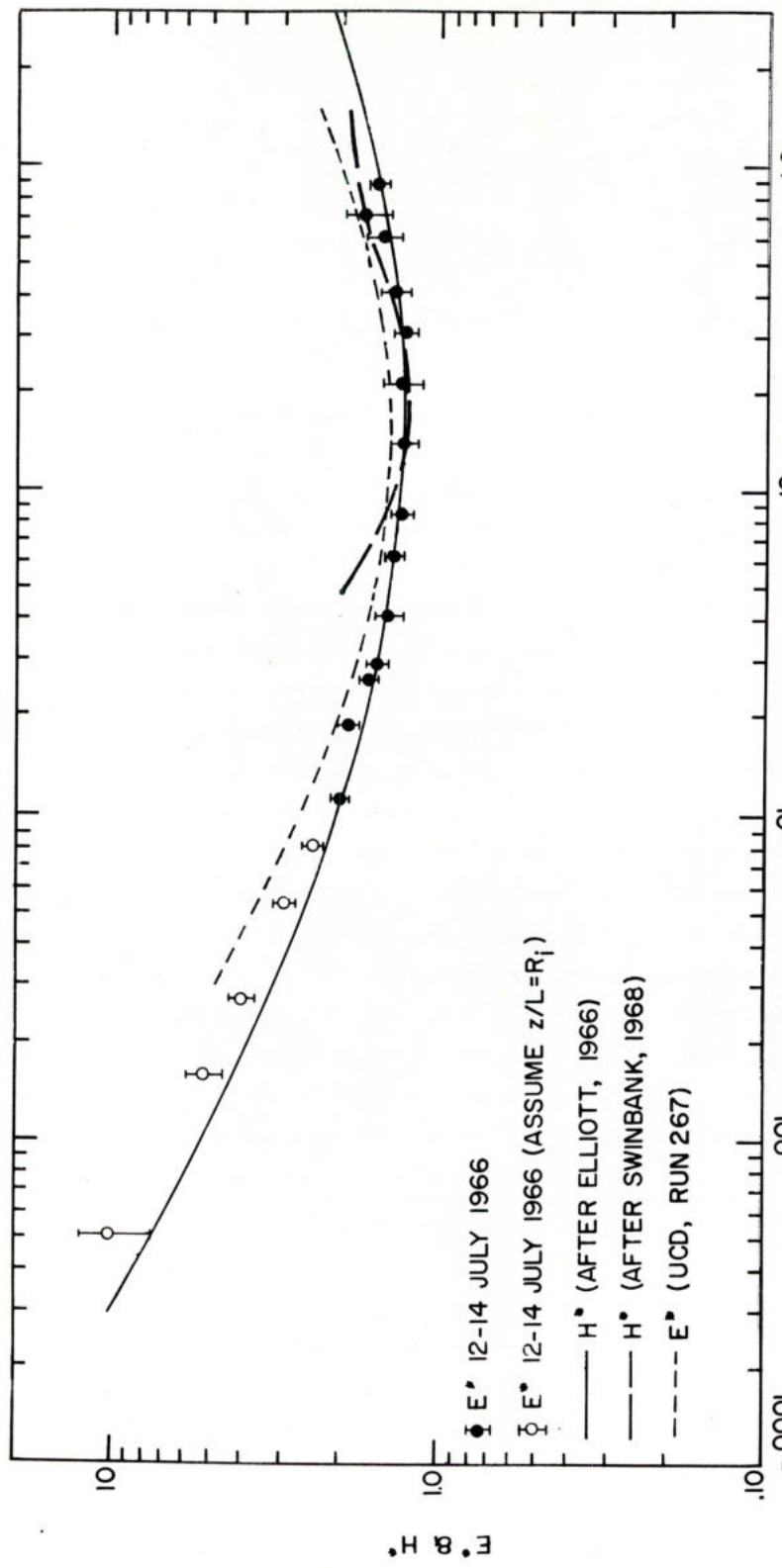


Figure IV-7. Comparison of UCD E* data plotted as a function of z/L (uncorrected) with H* data of Swinbank (1968) and with a hypothetical relationship for H* after Elliott (1966).

TABLE IV-2. RELATIONSHIPS OF THE DIMENSIONLESS FLUXES OF MOMENTUM AND MOISTURE TO THE RICHARDSON NUMBER FOR VARIOUS STABILITY RANGES

Range of Ri	$\tau^* = a\|Ri\|^n$		$E^* = a_1\|Ri\|^{n_1}$	
	a	n	a_1	n_1
Ri < -0.13	1.06	0.0	1.66	+0.095
-0.13 to -0.02	0.667	-0.212	1.14	-0.103
-0.02 to 0	0.265	-0.440	0.292	-0.450
0 to 0.025	0.137	-0.525	0.130	-0.552
Ri > 0.025	0.040	-0.863	0.024	-1.01

4. CONCLUSIONS

The newly derived dimensionless flux parameter for momentum, τ^*, was shown to respond to changing stability conditions in a fashion similar to that shown for the previously derived analogous parameters H* and E*. The most significant difference occurred under highly unstable conditions where, beyond an $|Ri|$ of .15, τ^* remained essentially constant at 1.06. This is some 24% below the minimum E* reached under unstable conditions and from 10 to 20% below values of 'h' reported most recently in the literature.

The E* data of the present study were in excellent agreement with those reported in an earlier UCD study by Crawford (1965) except for the significant increase in E* following the reaching of a minimum value of 1.40 at an Ri of $\simeq -.15$. If τ^* does indeed remain constant beyond an Ri of -.15, the magnitude of both E* and H* should be expected to increase with increasing instability, since K_W/K_M and K_H/K_M, according to the literature, increase significantly as free convection conditions are approached.

Although the dimensionless flux parameters show a smoothly changing relationship when plotted against Ri, five simple mathematical expressions are given for both τ^* and E* which provide a close fit to the data throughout the entire range of stabilities encountered. Especially under highly unstable conditions, these expressions are believed to offer a more reliable approach to estimation of either momentum or moisture flux than do the classic aerodynamic equations.

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CHAPTER V

EVAPORATION FROM AN IRRIGATED GRASS TURF UNDER ADVECTION OF DRY AIR AT DAVIS, CALIFORNIA ---- A COMPLETED REPORT

By D. L. Morgan, W. O. Pruitt, and F. J. Lourence

1. INTRODUCTION

A recent report by Morgan, Pruitt, and Lourence (1970a) presents data from a field run made under conditions of relatively strong advection on the 13th and 14th of October 1966. This report includes corresponding calculated values of evapotranspiration for an irrigated pasture grass as a function of distance downwind from the trailing edge of a dry, fallow area. Three methods of evapotranspiration (latent heat flux) calculation were employed. The sensible heat flux was determined first, with latent heat flux then being computed from the energy balance relation, assuming net radiation minus soil heat flux to be equal everywhere in the irrigated pasture. In the calculation of sensible heat flux, the first method made use of a stability-corrected aerodynamic prediction equation. The second method involved calculation of the sensible heat extracted from the air, based on the horizontal change in temperature profiles at these locations below an average inversion height. The third method used the approach of Philip (1959) to calculate the pattern of sensible heat flux downwind from the trailing edge of the fallow area.

W. L. Decker, using a modified Philip approach, which provides a direct calculation of evapotranspiration from humidity and wind-speed data, analyzed the data gathered at Davis under conditions of mild advection on the 7th and 9th of October 1967. The details of Decker's analysis, excluding the basic data, are given by Morgan, Pruitt, and Lourence (1970a).

The material constituting this chapter completes the information presented in the above-referenced report, giving a more comprehensive picture of the effects of advection. This is done in the following manner. First are presented the results of analyzing the 1966 data applying the same method as used by Decker for 1967 data. This is followed by a presentation of the 1967 wind, temperature, and energy-balance data, including a discussion of changes in the temperature profiles during mild advective conditions. To complete this analysis of advection, two of the methods used by Goltz and Pruitt in analyzing 1966 data are applied to the case of mild advection in 1967. The results are discussed, and a general critique is made of the effectiveness of various methods tested for estimating evapotranspiration under advective conditions.

2. ANALYSIS OF THE 13 AND 14 OCTOBER 1966 DATA USING A MODIFIED PHILIP APPROACH

The model for advection developed by Philip, and its application to micrometeorological data, are discussed in detail by W. L. Decker in the report by Morgan, Pruitt, and Lourence (1970a). The field layout and basic data for the strong advection case of 13-14 October 1966 are presented in the Goltz and Pruitt portion of this report.

Table V-1 in this chapter presents the parameters used in calculating the advective component of the evapotranspiration model for the 1966 data. It can be seen that for the 1966 data a definite surface inversion existed for all of the times data were taken. The

moisture conditions over the fallow, dry field upwind from the irrigated turf were about three times as dry for this strong advection case as for the case of mild advection in 1967. This is probably due to two features. First, the strong winds in the 1966 case were very effective in "sweeping" away what little moisture existed in this dry surface. Second, the conditions of the fallow area for the 1966 case were those of a dried, disked field, while those for the 1967 case were those of a chemically sprayed turf largely killed but with some green weeds present.

The relatively large differences in values for the humidity of the surface air over the grass (Site A) as reported by Decker for the 1967 data* and as those surface humidity values presented for the 1966 data, come from the method of estimation. Decker used the saturated absolute humidity corresponding to the surface temperature derived by extrapolating the air-temperature profile at Mast A to the height z - d equals four centimeters. This assumes that the grass is acting as a saturated water surface although that is unlikely, especially under the severe advection conditions of the 1966 study. By contrast, the present analysis involved the use of 30-minute average values of absolute humidity as measured at 9 centimeters (z_o + d = 9 cm) above the lysimeter by an infrared hygrometer system (Lourence, 1967). More will be said later about the problems of obtaining representative measurements of moisture content of the air in contact with fallow and transpiring surfaces.

Table V-2 shows the 30-minute average values of estimated evapotranspiration as a function of distance downwind from the trailing edge of the dry, fallow field. Figure V-1 plots these values along with results of Goltz and Pruitt for several 30-minute mean periods, completing the analysis of the strong advection case of 1966. It will be noted that, in general, there is an exponential decrease in evapotranspiration from the trailing edge of the dry field into the freely transpiring turf in accordance with the governing equation of Philip. When compared with results of Goltz and Pruitt and evapotranspiration measured with the lysimeter as shown in Fig. V-1, it is readily seen that the Philip method, when used for calculating evapotranspiration directly, gives results which are low by about 33 percent. This could be the result of not having good measures of the water-vapor content over the fallow and turf surfaces. However, the absolute humidity was measured directly in the grass canopy and should be quite representative of this transpiring surface. The humidity over the fallow area was obtained by extrapolating the wet- and dry-bulb temperature profiles to the surface and calculating the absolute humidity therefrom. These upwind measures of humidity agree closely with the general air-mass humidity as measured by the infrared hygrometer at a height of 3 meters above the grass field. It is concluded, therefore, the method itself may be causing the underprediction. In general the daytime values of evapotranspiration are slightly larger for the 1966 case than those values presented by Decker for the 1967 data. This is a reflection of the stronger advection conditions on 13 October 1966.

Table V-3 compares estimated evapotranspiration by the advection model with that measured by the lysimeter during the strong advection case when the wind direction and speeds

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*NOTE: There is an error in the column heading under "Downwind (Site A)" in Table 1, p. 81 of Morgan, Pruitt, and Lourence (1970a). It should read 10^{-6} gm/cm^3.

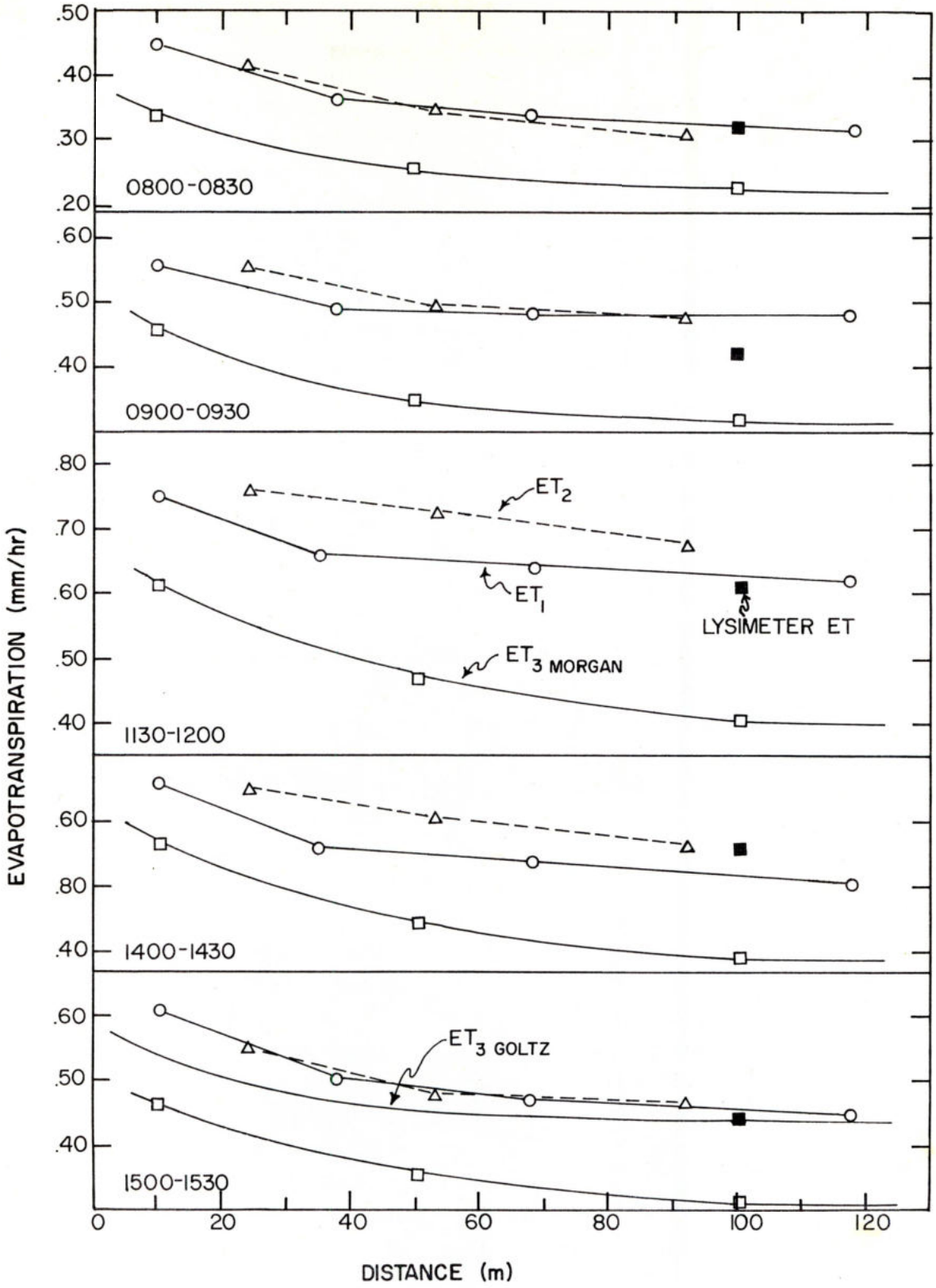


Figure V-1. Comparison of downwind changes in predicted values of evapotranspiration from the direct method of Philip used by Morgan (ET_3 Morgan) with the three indirect methods used by Goltz and Pruitt (ET_1, ET_2, and ET_3 Goltz). These comparisons are for five selected half-hour periods on 13 October 1966.

were quite steady during the majority of the data-gathering period in 1966. This is reflected in the closeness of the values for the calculated distance of the lysimeter downwind from the trailing edge of the dry field. An average value of 100.6 meters for the distance of the lysimeter downwind corresponds nicely with the point of 100 meters used as a basis for the model-calculated values of evapotranspiration. The differences between the lysimeter-measured values of evapotranspiration and the calculated values average almost twice those reported by Decker and show the tendency of the model to underpredict values of evapotranspiration for cases of strong advection. The ratios become large during the night hours because of the very small values of evapotranspiration during the dark period. The ratios remain large on the second morning, reflecting the waning of the strong advection conditions as the winds decreased in strength.

3. THE DATA FOR MILD ADVECTION OF 7 AND 9 OCTOBER 1967

Table V-4 shows average wind speeds at various heights and wind direction for half-hour periods during the days of 7 and 9 October 1967. Wind speeds were measured by Thornthwaite cup anemometers mounted at the heights indicated. The wind direction represents an average for the half-hour period and was measured by a wind vane mounted 4 meters above the surface.

Values of z_o, the surface roughness, and d, the displacement height, were obtained by plotting the wind speeds at the five lowest levels for neutral temperature-profile conditions on semi-log paper and fitting a straight line to the data. For the 7 October 1967 data, an average surface roughness of 0.74 cm with a displacement height of 5.0 cm was determined. The 9 October 1967 data yielded a surface roughness of 0.80 cm and a displacement height of 6.0 cm.

Temperature-profile data are tabulated in Tables V-5, 6, 7, 8, and 9, representing dry-bulb temperature data gathered by the psychrometer system described by Lourence and Pruitt (1969) and are respectively for masts D, G, C, B, and A. Figs. V-2 and 3 plot temperature vs. height minus displacement height for two special cases. Sequential sets of temperature profiles show the interesting effects of early-morning surface heating during mild advection conditions (Fig. V-2) and of a shift in wind direction and subsequent reversal of advection conditions (Fig. V-3). Mast-D profiles represent conditions over the fallow, dry field upwind from the irrigated grass turf, while masts G, C, B, and A represent temperature conditions 9, 36, 63, and 109 meters into the grass field south of the dry field.

In the case of early-morning heating while the winds remain rather steady in direction and speed (shown in Fig. V-2), the whole cluster of profiles shows general warming and steepening of lapse rate as the morning progresses. However, it is interesting to note the more rapid heating of the low-level air over the dry field as most of the energy from increasing positive net radiation goes into sensible heat. This additional heat causes a steeper lapse rate in temperature over the fallow area, with a more rapid penetration of heat into the layers of air immediately above the surface. As this warmed air moves over the grass turf, less heat is added in the form of sensible heat and more is utilized as latent heat of evaporation, resulting in a cooling of the air at all levels.

This form of horizontal advection, where the air temperature is dropping in spite of

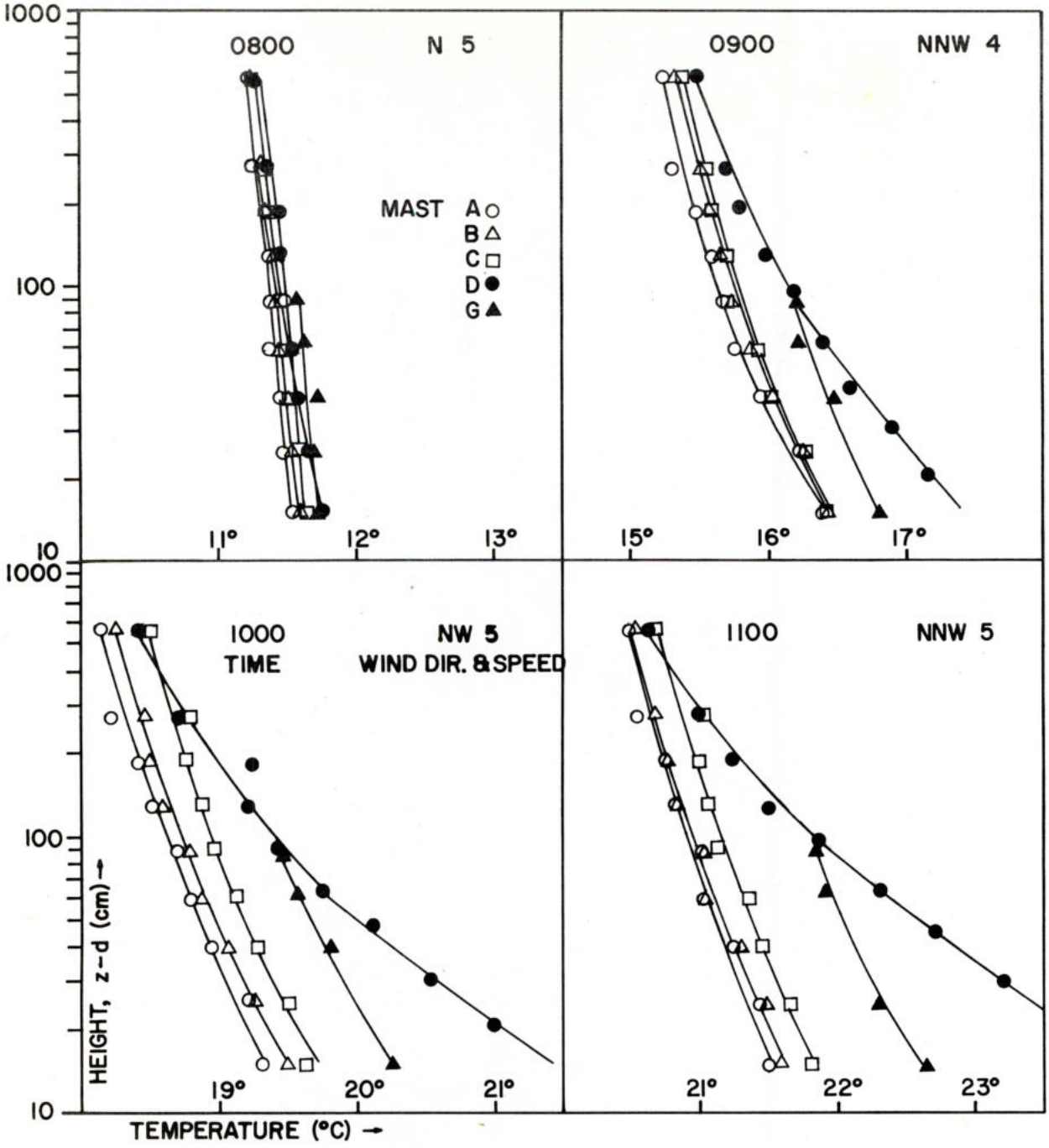


Figure V-2. Sequential half-hour average temperature profiles for the special case of early-morning solar heating on 7 October 1967. Mast D represents conditions over the fallow, dry field, while masts G, C, B, and A represent temperature conditions progressively downwind into the grass-covered field. Wind direction is in cardinal points, and wind speed is in meters per second.

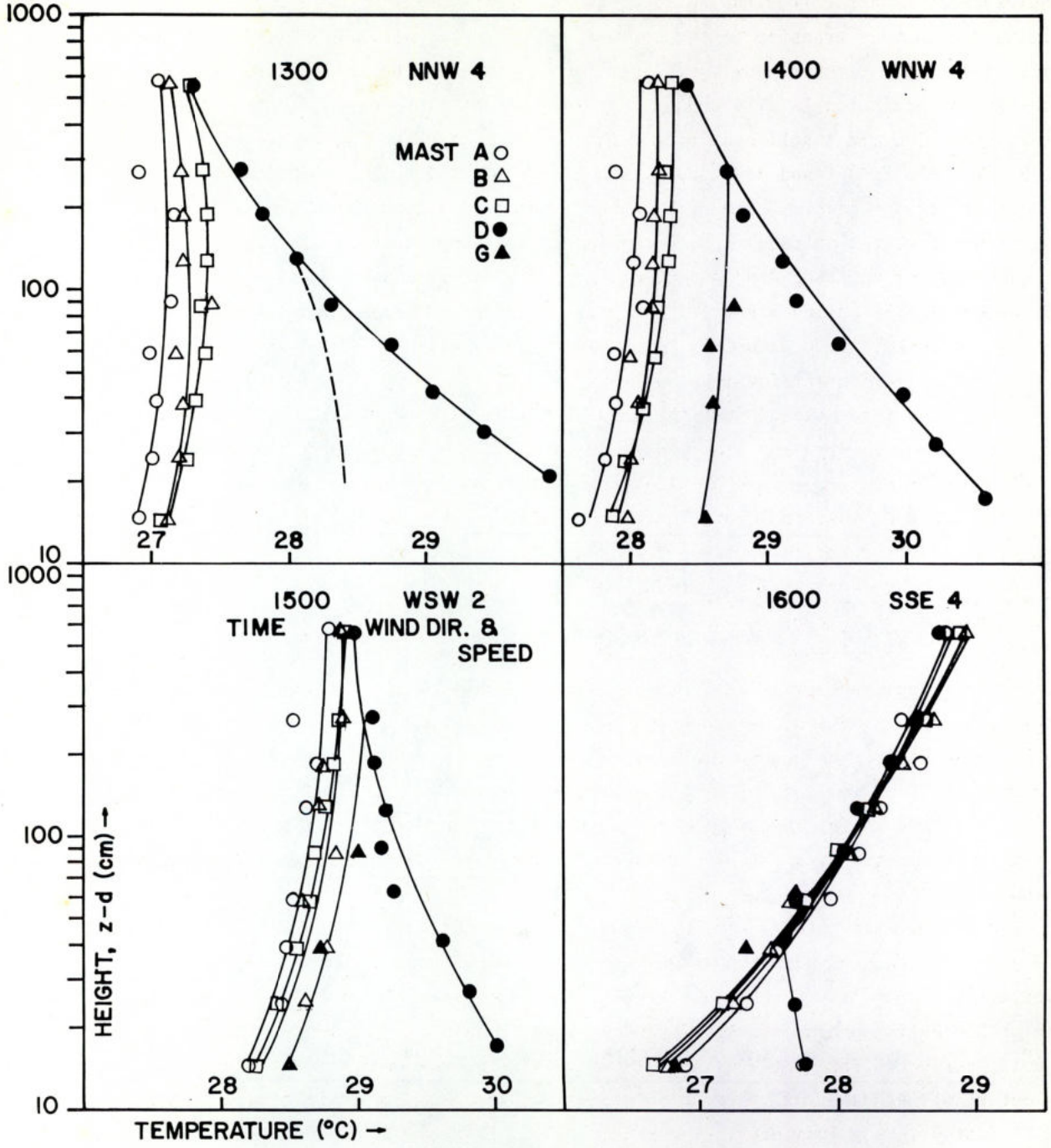


Figure V-3. Sequential half-hour average temperature profiles for the special case of winds shifting from a mild advection situation to a non-advection situation on 9 October 1967. Wind direction is in cardinal points, and wind speed is in meters per second.

sensible heat transfer from the surface, has not been so well recognized as that involving cooling due to heat transfer to the surface. Dyer and Crawford (1965), in earlier work at Davis, show similar cases, however. Such conditions could be expected in transition zones whenever the advection is mild enough that latent heat flux does not exceed the magnitude of net radiation minus soil heat flux. This might be the case only under mild wind speeds if the air mass is hot and dry; or, with cold, fairly moist air, such conditions could occur even under strong winds. The more familiar form of advection, with inversion profiles and heat transfer to the surface, is represented in the upper half of Fig. V-3.

The case of shifting wind direction (Fig. V-3) demonstrates how the temperature profiles over an originally upwind dry field and over an irrigated grass area downwind change with time as a mild advection situation gives way to a reversal of flow and a reversal of conditions. The profile set for 1300 is similar to those in Fig. V-2 except that a slight temperature inversion exists over the grass turf while strong lapse conditions exist over the strongly warmed dry area. As the winds shift to the west, the air represented by all of the profiles continues to warm slightly and then holds rather steady. The temperature profile at mast G, just inside the north edge of the grass field, begins to reflect the loss of warm air advection from the dry area to the north and reflects more the generally cooler air coming over the grass field. By the time the wind has shifted to the west-southwest, the temperature profile of mast G is entirely representative of the grass-covered field, as are the profiles at masts A, B, and C. Also, at this time the profile over the dry, fallow area (mast D) is beginning to show a decrease in lapse rate, in the upper levels looking like the profiles over the grass area. By the time the wind has shifted to the south-southeast, making a complete reversal of flow over the field site, all of the temperature profiles are similar, reflecting the nonadvective properties of flow over the grass field. The very lowest layers of air over the dry, fallow field still reflect some warming as a reverse advective situation has developed, that is, cool, moist air flowing over a dry, fallow field.

The energy-balance data at the lysimeter site are tabulated in Table V-10 and plotted in Fig. V-4. The net radiation values are the averaged values of net radiation measured by three net radiometers. See Morgan, Pruitt, and Lourence (1970b). The soil heat-flux-data were obtained from measurements of the half-hour changes in heat content of the upper 10 cm of soil, corrected for heat flux at the 10-cm level as measured with flux plates. The lysimeter latent heat-flux values were calculated from evapotranspiration data measured by the 20-foot weighing lysimeter. The sensible heat flux, H, was calculated as a remainder term from solving the energy-balance equation with the aforementioned data. A check on the values of latent and sensible heat fluxes is provided by Bowen Ratio values based on independent temperature and humidity profile measurements. On 9 October the complete temperature profiles over the grass area, of which the 25-cm and 100-cm levels are shown in Fig. V-4, indicated an inversion condition existing all day, while the heat flux determined by the energy-balance method shows a loss from the surface. This is not reasonable. On 7 October the temperature profiles indicate an inversion condition after 1400, while, again, the heat flux determined by the energy balance shows a continuing loss from the surface. For this reason the values of latent and sensible heat derived from the Bowen Ratio method

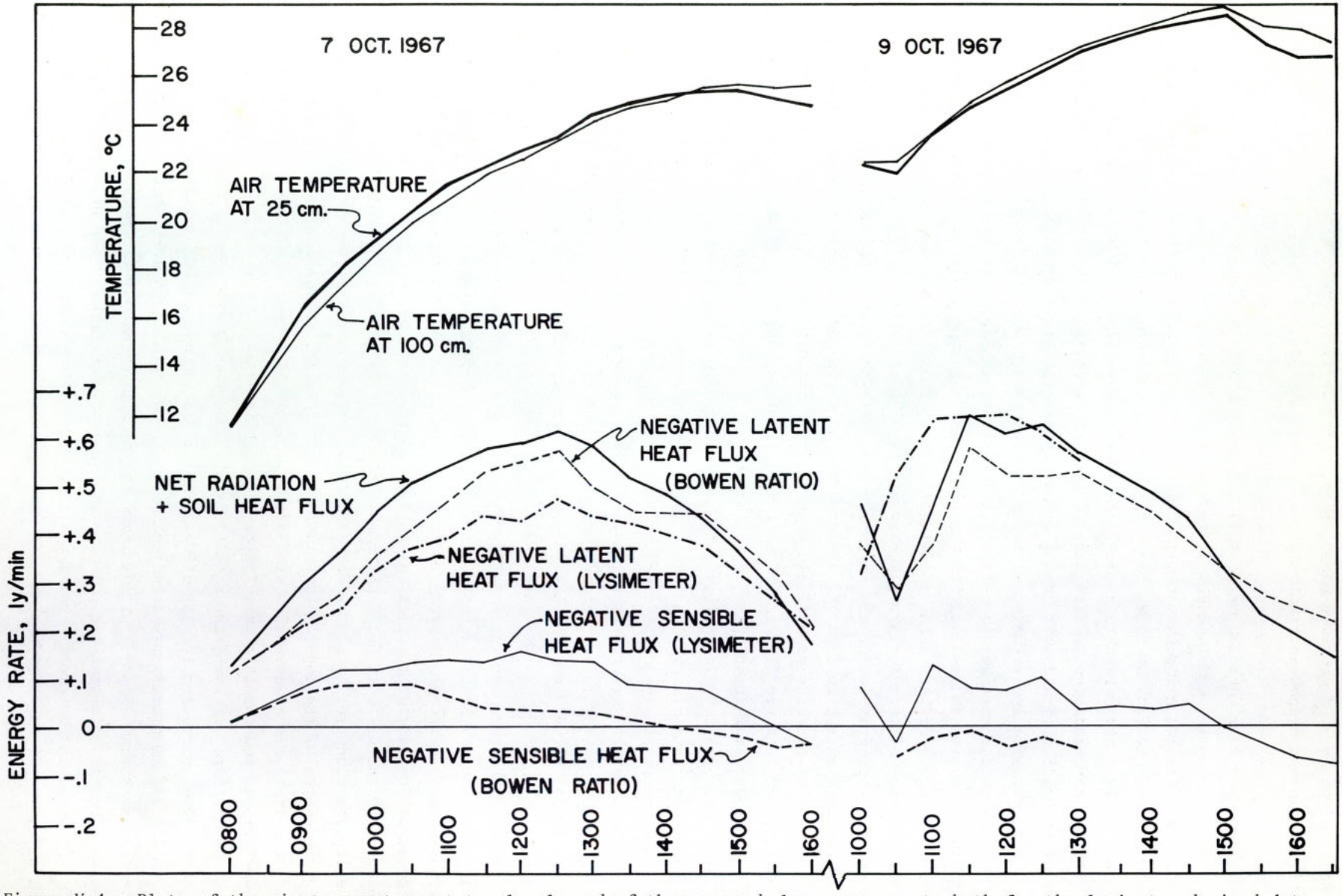


Figure V-4. Plots of the air temperature at two levels and of the energy-balance components both for the lysimeter-derived data and for the Bowen-Ratio-derived data.

were selected to be used wherever these fluxes were needed in the methods for calculating advective values of evapotranspiration.

4. RESULTS OF TESTING THE 1967 DATA WITH METHODS EMPLOYED BY GOLTZ AND PRUITT

Goltz and Pruitt, using the strong advection data of 1966, applied three methods to estimate sensible heat flux as a function of distance from the trailing edge of a dry, fallow field into an irrigated grass-covered field. The energy-balance equation was then used to solve for the corresponding values of latent heat flux (evapotranspiration), having measured values of net radiation and soil heat flux and assuming these were uniform over the turf area.

In attempting to apply the same procedures to the cases of mild advection in 1967, only two of the three methods could be applied. The first method, which is based on flux-gradient relationships, could not be used with the 1967 data because of the rather light winds. These light winds were reflected in the very minimal temperature differences between surface and air temperatures, making meaningful determination of these differences questionable. In contrast, the strong advection conditions of 1966 allowed for relatively large temperature differences between the surface and air, and therefore meaningful results are obtained by applying the flux-gradient method. In keeping with this situation, there are no values of sensible heat (H_1) or evapotranspiration (ET_1) calculated by this method reported herein for the 1967 advection cases.

The second method employed requires that an inversion in the temperature profile exist relatively near the surface. If such an inversion exists, then the differences between temperature profiles measured at two locations in the field are converted into an average value for temperature difference, ΔT, which is then divided by the distance between the profiles ΔX. Tables V-11, 12, and 13 give the values for the mean inversion height and values for $\Delta T/\Delta X$ between masts G-C, C-B, and B-A, respectively. It can be seen that, during almost half of the time while these cases of mild advection were in progress, no temperature inversions existed, and therefore no further calculations could be made. For those times when an inversion existed, the mean height in general became greater as the distance into the grass area from the trailing edge of the fallow field increased. The values of $\Delta T/\Delta X$ were greatest just inside the grass area near the trailing edge of the fallow field, as represented by the mast G-C data. Also presented in these tables are values for the slope of the log-law wind profile and values of the calculated sensible heat flux, H_2. In comparing the slopes of the log-law wind profiles for the 1967 data with those for the 1966 data, the differences in advection conditions between these periods are quite apparent. Goltz and Pruitt found much steeper slopes, reflecting the stronger winds of the 1966 period. Calculated values of the sensible heat flux are somewhat smaller for the 1967 data than were those calculated for the strong advection case by Goltz and Pruitt.

Table V-14 summarizes latent heat flux, LE_2, determined from the energy balance using the values of sensible heat (H_2) calculated by the method described above.

The third method used to calculate sensible heat flux (H_3), based on work of Philip (1959), produced the parameters and results shown in Table V-15. Here, the corresponding values of H_3 and LE_3 are for a point 100 meters downwind into the turf field from the trailing

edge of the dry area. The values of latent heat flux, LE_2 and LE_3, were then converted to evapotranspiration, ET_2 and ET_3, respectively.

Fig. V-5 compares downwind changes in predicted values of evapotranspiration, ET_2 and ET_3, for selected half-hour periods. Also included are values of evapotranspiration measured by the lysimeter and estimated from the Bowen Ratio. For four of the half-hour periods compared, there is generally good agreement between the results from the two methods for the predicted downwind changes in evapotranspiration. However, for the periods 1000-1030 and 1200-1230, the two methods give divergent results. The values of evapotranspiration measured by the lysimeter appear generally too low when compared with those estimated by the Bowen Ratio, especially on 9 October. By October 9th it had been 16 days since the turf field last received an irrigation. The lysimeter could have been beginning to show slightly reduced evapotranspiration due to developing moisture stress within it. It is felt that the Bowen Ratio values are the most representative of these two independent measures during the 7 and 9 October periods because of this possible situation. The values of calculated evapotranspiration at distances nearest to the lysimeter compare favorably with the Bowen Ratio estimation, thus giving some confidence in these two methods as predictive tools.

5. GENERAL CRITIQUE OF THE CALCULATION OF EVAPOTRANSPIRATION FOR ADVECTIVE CONDITIONS

Based on the results of Goltz and Pruitt, Decker, and our analysis described above, the following points can be made.

First, in the study made by Goltz and Pruitt, the displacement height, d, which was equal to 8.0 cm, was not included in some of the analyses. For example, equation 17, to be completely accurate, should read:

$$Ri = \frac{g(T_{25}-T_o)(25-(d+z_o))}{T_{25}(u_{25}-u_o)^2}$$

The failure to include the displacement height in the relevant calculations would affect some of the data display and analysis. However, the overall results should remain unaffected and valid even though this factor was not included. Note also the change in displacement height for the 1967 data between that used by Decker (d = 8.0 cm) and the corrected values used in our analysis.

Second, difficulties in applying the first method used by Goltz and Pruitt, based on flux-gradient relationships, have already been pointed out, in that one needs good contrasts in temperatures between the surface and air above in order for the approach to be valid.

Third, in using the second method applied by Goltz and Pruitt, based on diffusion theory applied to heat, one needs to have an upper boundary (temperature inversion) in studying horizontal transport (advection) of heat. For the case of strong advection, this condition was satisfield. For the mild advection cases, however, it was satisfield only part of the time, and then by rather weak inversion conditions.

Fourth, in applying Philip's method for calculation of sensible heat flux, as Goltz and Pruitt did, or for calculation of latent heat flux, as Decker did, the following

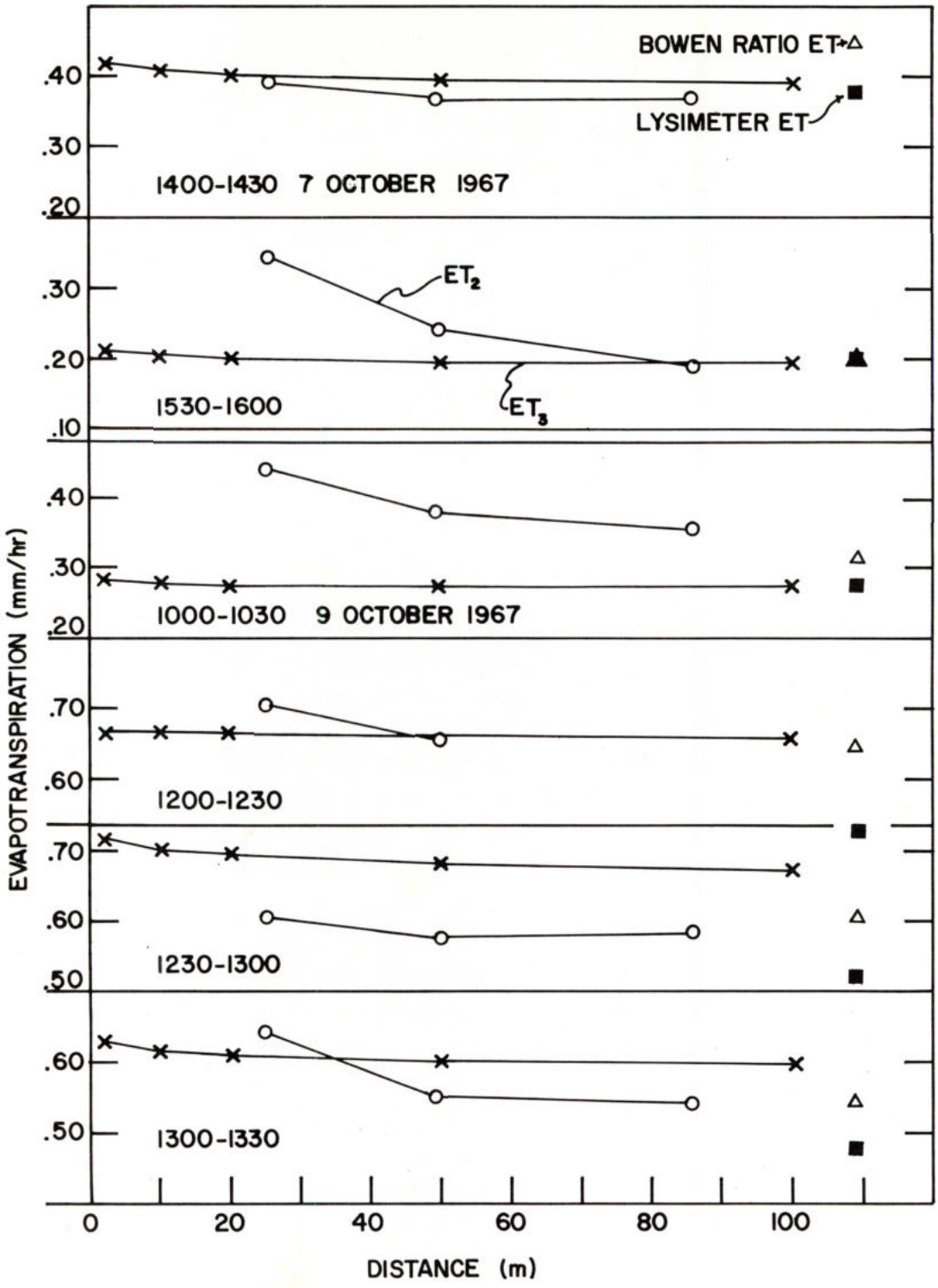


Figure V-5. Comparison of downwind changes in predicted values of evapotranspiration ET_2 and ET_3 for selected half-hour periods on 7 and 9 October 1967.

assumptions were made.

It was assumed that the transfer coefficients for momentum were the same over both the dry, fallow field and the irrigated grass field. This same assumption was also applied to the transfer coefficients for heat and for water vapor. This is probably a poor assumption, especially for the 1966 data, because of the differing aerodynamic characteristics of the adjoining surfaces as shown in Table V-16 below.

TABLE V-16. Displacement Height and Surface Roughness during the Advection Field Runs.

Date	Location	Condition	d (cm)	z_o (cm)
13 & 14 Oct. 1966	Fallow field	disked, dried clods	4.0 est.	1.0 est.
	Grass field	mowed fescue grass	8.0	1.0
7 Oct. 1967	Fallow field	spray-killed fesue grass	4.0 est.	0.5 est.
	Grass field	mowed fescue grass	5.0	0.74
9 Oct. 1967	Fallow field	spray-killed fescue grass	4.0 est.	0.5 est.
	Grass field	mowed fescue grass	6.0	0.86

The assumption of equality of transfer coefficients under all conditions is also not borne out by results presented in earlier chapters of this report.

Two other assumptions inherent in Philip's method are that the stability is the same over the dry and "wet" areas and that the profiles of temperature and moisture are equilibrium profiles. Now, these assumptions, coupled with the similarity of transfer coefficients over different surfaces assumption, amount to saying that the fields of turbulence over the dry, fallow area and over the irrigated grass area are identical and unchanging at any particular time. This most likely untrue, but one can only speculate as to how large an error is injected into the results.

It was assumed by Decker in calculating the evapotranspiration directly for the 1967 data that the grass surface was accurately represented by a saturated condition, allowing the use of the saturated vapor density corresponding to the surface temperature. Our calculations using the 1967 data make no such assumption but, rather, use measured values of the vapor density at the grass "surface," as discussed earlier. Hence, we face the twofold problem of what is the "surface" in mowed turf, and how wet is this surface. It does not seem realistic to treat the physical surface of the grass as if covered with free water, except perhaps near sunrise, when dew frequently has wet the grass blades. Therefore, measurement of the moisture content of the air immediately adjacent to and within the grass "surface" is preferable.

Aside from the difficulties of estimating the moisture content in the air near dry and transpiring surfaces, there exists the challenge of obtaining a truly representative surface temperature. Data were available during both the 1966 and 1967 advection runs in the form of Barnes infrared thermometer readings over the grass, leaf thermocouple data, and extrapolation of accurate temperature profiles to the "surface." Decker used extrapolation of temperature profiles over both the dry and the grass areas to determine surface

temperatures. Goltz and Pruitt used mean leaf temperatures in their calculations over grass, and extrapolation of the air temperature profile to the surface over the dry area. In our analysis we followed the method of estimation used by Decker. This remains a knotty problem and affects the results in subtle ways. Goltz and Pruitt point out some of the difficulties in the report of their analysis of the 1966 advection case.

Fifth, and last, is the assumption made by Goltz and Pruitt and by us in using the energy-balance equation to solve for the variation in evapotranspiration over the grass field having first calculated the variation in sensible heat flux. This assumption is that the net radiation and soil heat flux measured at one location in the grass field were representative of these parameters over the entire grass field. This is probably not a bad assumption, in that the grass condition was quite uniform throughout the field, as were the general soil type and moisture condition of the soil.

In summary, in spite of the various assumptions involved in the three methods as used by Goltz and Pruitt to predict the variation of evapotranspiration downwind from the leading edge of an irrigated turf field, and in spite of the problems in getting the real temperature and moisture conditions of the surfaces involved, the second and third methods do a relatively accurate and consistent job of matching measurements of evapotranspiration at a point 100 meters into the turf field. The results of using Philip's method in calculating the evapotranspiration directly show an underestimation of the measured evapotranspiration for both mild and strong advection conditions.

One must be careful to be selective in choosing the method to be used and to be certain to match properly the data available both in type and quality, since erroneous results could result from improper match of data with method. As for the flux-gradient type of method, Goltz and Pruitt have the results for only one half-hour period for comparison with the results from the other two methods, while we were unable to apply this method to the 1967 data. Thus, not much can be said concerning the relative accuracy of this method in estimating evapotranspiration under advective conditions.

The conclusions of Goltz and Pruitt and of Decker were generally substantiated by the additional work reported in this chapter of the Final Report.

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TABLE V-1

PARAMETERS USED IN CALCULATING THE ADVECTIVE COMPONENT

OF THE EVAPOTRANSPIRATION MODEL

Date	Period PST	m	u_1 cm/sec	k_2 cm^2/sec	Surface absolute humidity Upwind (Site D) $gr/cm^3 \times 10^{-6}$	Surface absolute humidity Downwind (Site A) $gr/cm^3 \times 10^{-6}$	Surface inversion
13 October 1966	0800	.276	200	51.55	4.03	5.45	yes
	0900	.261	243	59.58	4.13	6.02	yes
	1000	.262	245	48.37	3.66	6.38	yes
	1100	.286	225	-----	3.74	6.59	yes
	1200	.275	230	58.09	3.68	6.53	yes
	1300	.293	212	59.39	3.35	6.25	yes
	1400	.255	239	51.42	3.34	6.32	yes
	1500	.252	219	59.78	3.23	5.86	yes
	1600	.254	211	49.77	3.21	5.23	yes
	1700	.244	218	46.30	3.48	4.45	yes
	1800	.264	169	38.81	3.39	3.96	yes
	1900	.275	161	30.94	3.67	4.10	yes
	2000	.263	168	34.64	3.17	4.31	yes
	2100	.233	169	17.42	3.69	4.33	yes
	2200	.287	109	30.43	3.84	4.41	yes
	2300	.273	118	29.93	3.73	4.40	yes
	2400	.254	138	21.05	3.60	4.28	yes
14 October 1966	0100	.279	140	30.56	3.62	4.19	yes
	0200	.304	120	26.86	3.81	4.34	yes
	0300	.282	105	26.47	3.64	4.27	yes
	0400	.279	126	37.02	3.58	4.18	yes
	0500	.267	137	22.01	3.62	4.10	yes
	0600	.280	115	30.66	3.58	4.18	yes
	0700	.269	107	23.65	3.66	4.66	yes
	0800	.279	135	36.75	3.64	5.30	yes
	0900	.253	148	29.66	3.37	6.13	yes
	1000	.253	120	26.79	3.73	7.46	yes

TABLE V-2

EVAPOTRANSPIRATION (mm/30-min) ESTIMATED BY ADVECTION

AS A FUNCTION OF DISTANCE DOWNWIND

Date	30-minute period ending	Downwind distance (meters)					
		1	5	10	50	100	500
13 Oct. 1966	0800	.204	.153	.136	.102	.090	.067
	0900	.307	.233	.207	.157	.139	.106
	1000	.373	.283	.251	.191	.169	.128
	1100	----	----	----	----	----	----
	1200	.461	.347	.307	.231	.204	.154
	1300	.489	.363	.319	.237	.209	.154
	1400	.424	.324	.288	.220	.196	.149
	1500	.412	.315	.280	.214	.191	.146
	1600	.271	.207	.184	.141	.125	.096
	1700	.121	.093	.083	.064	.057	.044
	1800	.061	.047	.041	.031	.027	.021
	1900	.039	.029	.026	.020	.017	.013
	2000	.111	.084	.075	.057	.050	.038
	2100	.033	.025	.023	.018	.016	.012
	2200	.050	.038	.033	.025	.022	.016
	2300	.056	.042	.037	.028	.025	.019
	2400	.042	.032	.028	.022	.019	.015
14 Oct. 1966	0100	.050	.038	.033	.025	.022	.017
	0200	.043	.032	.028	.021	.018	.013
	0300	.047	.035	.031	.023	.021	.015
	0400	.061	.046	.040	.030	.027	.020
	0500	.031	.024	.021	.016	.014	.011
	0600	.052	.039	.035	.026	.023	.017
	0700	.067	.050	.045	.034	.030	.023
	0800	.169	.127	.112	.084	.074	.056
	0900	.219	.167	.149	.137	.101	.077
	1000	.272	.207	.185	.141	.125	.096

TABLE V-3

COMPARISON OF ESTIMATED EVAPOTRANSPIRATION BY

ADVECTION MODEL AND LYSIMETER

Date	Ending time	Lysimeter downwind distance m	Lysimeter ET mm/30 min	Advection ET 100m mm/30 min	Difference	Ratio of difference to lysimeter ET	Surface inversion
13 October 1966	0800	100.03	.131	.090	.041	.31	yes
	0900	98.84	.185	.139	.046	.25	yes
	1000	99.42	.247	.169	.078	.32	yes
	1100	-----	.285	----	----	----	yes
	1200	102.12	.308	.204	.104	.34	yes
	1300	100.03	.308	.209	.099	.32	yes
	1400	102.12	.293	.196	.097	.33	yes
	1500	101.38	.247	.191	.056	.23	yes
	1600	100.03	.193	.125	.068	.35	yes
	1700	101.38	.131	.057	.074	.56	yes
	1800	102.12	.154	.027	.127	.82	yes
	1900	102.12	.046	.017	.029	.62	yes
	2000	102.12	.046	.050	-.004	-.09	yes
	2100	102.90	.039	.016	.023	.60	yes
	2200	98.84	.031	.022	.009	.30	yes
	2300	98.30	.039	.025	.014	.37	yes
	2400	101.38	.039	.019	.020	.51	yes
14 October 1966	0100	100.03	.039	.022	.017	.43	yes
	0200	102.12	.031	.018	.013	.42	yes
	0300	101.38	.039	.021	.018	.47	yes
	0400	102.12	.031	.027	.004	.14	yes
	0500	101.38	.039	.014	.025	.64	yes
	0600	102.12	.039	.023	.016	.41	yes
	0700	102.12	.062	.030	.032	.52	yes
	0800	100.70	.123	.074	.049	.40	yes
	0900	95.45	.220	.101	.119	.54	yes
	1000	95.17	.216	.125	.091	.42	yes

TABLE V-4

MEAN WIND VELOCITIES FROM SMOOTHED WIND PROFILES

7 OCTOBER 1967
(cm/sec) and (degrees)

Half-hour ending	Elevation in cm.					Wind direction
	25	50	100	200	400	
0800	169	211	249	275	300	353
0830	141	174	200	218	229	4
0900	126	153	173	190	202	334
0930	119	141	160	174	185	338
1000	163	201	229	250	270	325
1030	168	208	233	255	272	343
1100	158	209	239	260	275	334
1130	147	179	201	220	233	332
1200	141	171	197	214	229	299
1230	110	133	150	162	172	336
1300	96	118	129	139	145	265
1330	90	108	120	129	136	291
1400	86	104	117	122	130	278
1430	117	141	165	180	195	0
1500	100	126	147	158	163	351
1530	115	143	171	190	203	31
1600	82	104	128	142	152	17

MEAN WIND VELOCITIES FROM SMOOTHED WIND PROFILES

9 OCTOBER 1967
(cm/sec) and (degrees)

Half-hour ending	Elevation in cm.					Wind direction
	25	50	100	200	400	
1000	190	241	289	329	360	321
1030	155	199	237	270	299	315
1100	165	215	257	290	319	329
1130	190	250	300	334	365	317
1200	201	268	315	355	389	316
1230	168	219	258	289	311	335
1300	130	169	198	220	236	338
1330	129	165	192	218	239	309
1400	110	140	169	189	206	273
1430	102	134	160	179	192	245
1500	72	91	109	120	129	219
1530	110	142	170	195	215	176
1600	115	152	181	210	232	156
1630	129	170	210	249	279	161
1700	110	150	190	230	262	160

TABLE V-5

MEAN AIR TEMPERATURES FROM SMOOTHED TEMPERATURE PROFILES AT MAST D

(4.3 meters downwind from trailing edge of dry fallow field)

(°C)

7 OCTOBER 1967

Half-hour ending	Elevation in cm.					
	25	50	100	200	280	600
0800	11.77	11.59	11.46	11.38	11.34	11.25
0830	14.54	14.04	13.70	13.46	13.37	13.26
0900	17.52	16.72	16.20	15.82	15.67	15.47
0930	19.30	18.34	17.72	17.27	17.11	16.90
1000	21.50	20.29	19.52	18.95	18.72	18.43
1030	22.98	21.66	20.75	20.12	19.90	19.62
1100	24.10	22.85	21.90	21.25	21.00	21.62
1130	25.03	23.75	22.85	22.22	22.01	21.63
1200	25.92	24.70	23.85	23.24	23.01	22.64
1230	26.04	25.02	24.31	23.80	23.62	23.34
1300	26.57	25.57	24.92	24.35	24.28	23.92
1330	26.95	26.03	25.40	24.95	24.77	24.47
1400	27.55	26.50	25.83	25.37	25.22	24.99
1430	27.95	27.09	26.49	26.05	26.38	25.59
1500	27.84	26.95	26.40	25.99	25.85	25.72
1530	27.37	26.78	26.36	26.07	25.95	25.83
1600	27.05	26.67	26.40	26.20	26.13	26.02

MEAN AIR TEMPERATURES FROM SMOOTHED TEMPERATURE PROFILES AT MAST D

(4.3 meters downwind from trailing edge of dry fallow field)

(°C)

9 OCTOBER 1967

Half-hour ending	Elevation in cm.					
	25	50	100	200	280	600
1000	25.16	24.02	23.23	22.68	22.47	22.15
1030	24.83	23.81	23.34	23.01	22.83	22.71
1100	26.83	25.59	24.75	24.18	23.97	23.64
1130	28.55	27.10	26.10	25.38	25.12	24.66
1200	29.36	28.03	27.06	26.38	26.12	25.70
1230	29.83	28.58	27.68	27.05	26.80	26.41
1300	27.25	29.16	28.37	27.77	27.58	27.23
1330	30.82	29.79	29.03	28.42	28.25	27.83
1400	30.77	29.90	29.28	28.80	28.65	28.33
1430	30.53	29.91	29.45	29.09	28.98	28.75
1500	30.10	29.67	29.35	29.11	29.04	29.89
1530	28.38	28.13	28.23	28.52	28.64	28.86
1600	27.73	27.61	28.00	28.39	28.54	28.73
1630	26.62	26.69	27.24	27.86	28.06	28.45
1700	24.61	25.01	25.83	26.95	27.25	27.74

TABLE V-6

MEAN AIR TEMPERATURE FROM SMOOTHED TEMPERATURE PROFILES AT MAST G

(9.11 meters downwind from trailing edge of dry fallow field)

(°C)

7 OCTOBER 1967

Half-hour ending	Elevation in cm.			
	25	50	75	100
0800	11.72	11.67	11.62	11.57
0830	14.42	14.05	13.91	13.82
0900	16.83	16.41	16.25	16.15
0930	18.35	17.89	17.70	17.60
1000	20.28	19.76	19.57	19.45
1030	21.48	21.02	21.88	21.67
1100	22.65	22.15	21.94	21.80
1130	23.42	22.98	22.84	22.68
1200	23.82	23.61	23.50	23.43
1230	24.42	24.23	24.12	24.03
1300	24.93	24.64	24.51	24.43
1330	25.30	25.11	25.01	24.95
1400	25.77	25.59	25.51	25.45
1430	26.31	26.37	26.33	26.28
1500	25.89	25.98	26.00	26.00
1530	25.82	26.08	26.17	26.21
1600	25.70	26.08	26.23	26.32

MEAN AIR TEMPERATURE FROM SMOOTHED TEMPERATURE PROFILES AT MAST G

(9.11 meters downwind from trailing edge of dry fallow field)

(°C)

9 OCTOBER 1967

Half-hour ending	Elevation in cm.			
	25	50	75	100
1000	-----	23.61	23.44	23.24
1030	-----	23.41	23.41	23.36
1100	24.92	25.00	24.91	24.75
1130	26.60	26.49	26.32	26.10
1200	27.39	27.35	27.22	27.05
1230	27.95	27.87	27.75	27.62
1300	28.40	28.37	28.30	28.22
1330	28.87	28.90	28.86	28.80
1400	28.57	28.60	28.61	28.61
1430	28.50	28.64	28.68	28.69
1500	28.45	28.65	28.71	28.77
1530	27.25	27.76	28.02	28.16
1600	26.78	27.58	27.87	28.08
1630	25.78	26.59	27.01	27.31
1700	24.09	24.86	25.51	26.00

TABLE V-7

MEAN AIR TEMPERATURES FROM SMOOTHED TEMPERATURE PROFILES AT MAST C

(38.6 meters downwind from trailing edge of dry fallow field)

(°C)

7 OCTOBER 1967

Half-hour ending	Elevation in cm.					
	25	50	100	200	280	600
0800	11.60	11.55	11.47	11.40	11.36	11.26
0830	14.20	13.88	13.63	13.45	13.38	13.26
0900	16.38	16.07	15.78	15.62	15.55	15.40
0930	18.03	17.80	17.31	17.16	17.03	16.89
1000	19.70	19.24	18.93	18.70	18.62	18.48
1030	21.04	20.62	20.28	20.01	19.91	19.62
1100	21.84	21.45	21.16	20.94	20.85	20.72
1130	22.55	22.24	22.02	21.84	21.78	21.70
1200	23.08	22.90	22.74	22.60	22.54	22.39
1230	23.78	23.62	23.48	23.70	23.29	23.17
1300	24.51	24.32	24.17	24.03	23.92	23.80
1330	24.90	24.74	24.62	24.51	24.45	24.34
1400	25.26	25.18	25.11	25.04	25.01	24.94
1430	25.56	25.59	25.60	25.59	25.57	25.00
1500	25.45	25.63	25.73	25.78	25.78	25.73
1530	25.09	25.48	25.72	25.82	25.90	25.82
1600	24.89	25.51	25.88	26.07	26.10	26.03

MEAN AIR TEMPERATURES FROM SMOOTHED TEMPERATURE PROFILES AT MAST C

(38.6 meters downwind from trailing edge of dry fallow field)

(°C)

9 OCTOBER 1967)

Half-hour ending	Elevation in cm.					
	25	50	100	200	280	600
1000	22.52	22.52	22.48	22.40	22.33	22.14
1030	21.96	22.39	22.66	22.80	22.82	22.71
1100	25.04	25.10	25.09	25.02	25.69	25.55
1130	25.04	25.10	25.09	25.02	24.95	24.66
1200	25.73	25.91	26.00	25.99	25.96	25.70
1230	26.40	26.63	26.72	26.72	26.68	26.46
1300	27.22	27.35	27.40	27.40	27.37	27.23
1330	27.61	27.82	27.92	27.97	27.97	27.83
1400	27.88	28.08	28.21	28.28	28.30	28.28
1430	28.17	28.43	28.58	28.69	28.72	28.73
1500	28.36	28.59	28.75	28.85	28.88	28.90
1530	27.19	27.72	28.13	28.45	28.56	28.78
1600	26.87	27.52	28.08	28.51	28.64	28.84
1630	25.82	26.62	27.36	28.06	28.26	28.60
1700	24.11	25.12	26.12	27.20	27.46	27.91

TABLE V-8

MEAN AIR TEMPERATURES FROM SMOOTHED TEMPERATURE PROFILES AT MAST B

(67.5 meters downwind from trailing edge of dry fallow field)

(°C)

7 OCTOBER 1967

Half-hour ending	Elevation in cm.					
	25	50	100	200	280	600
0800	11.57	11.49	11.42	11.33	11.29	11.19
0830	14.06	13.79	13.54	13.40	13.34	13.23
0900	16.38	16.04	15.82	15.56	15.50	15.33
0930	18.00	17.57	17.27	17.05	16.97	16.86
1000	19.47	19.03	18.70	18.47	18.38	18.23
1030	20.66	20.27	19.98	19.74	19.65	19.48
1100	21.60	21.24	20.92	20.75	20.68	20.53
1130	22.46	22.11	21.87	21.62	21.55	21.44
1200	23.01	22.83	22.67	22.52	22.43	22.23
1230	23.73	23.55	23.40	23.28	23.21	23.07
1300	24.55	24.36	24.12	23.94	23.86	23.68
1330	24.85	24.77	24.72	24.53	24.45	24.24
1400	25.18	25.12	25.07	25.00	24.95	24.81
1430	27.45	27.48	27.48	27.46	27.44	27.36
1500	25.40	25.62	25.71	25.75	25.75	25.68
1530	24.93	25.30	25.70	25.87	25.90	25.82
1600	24.83	25.38	25.72	25.95	26.01	26.02

MEAN AIR TEMPERATURES FROM SMOOTHED TEMPERATURE PROFILES AT MAST B

(67.5 meters downwind from trailing edge of dry fallow field)

(°C)

9 OCTOBER 1967

Half-hour ending	Elevation in cm.					
	25	50	100	200	280	600
1000	22.37	22.32	22.27	22.19	22.13	21.98
1030	21.87	22.25	22.48	22.63	22.67	22.60
1100	24.85	24.85	24.84	24.74	24.70	24.55
1130	24.85	24.84	24.81	24.74	24.70	24.66
1200	25.57	25.67	25.72	25.72	25.70	25.63
1230	26.36	26.63	26.72	26.73	26.68	26.46
1300	27.12	27.25	27.29	27.28	27.25	27.12
1330	27.48	27.64	27.72	27.75	27.75	27.68
1400	27.91	28.05	28.12	28.07	28.18	28.18
1430	28.31	28.49	28.60	28.67	28.68	28.64
1500	28.30	28.54	28.70	28.82	28.85	28.89
1530	27.22	27.75	28.15	28.48	28.57	28.80
1600	26.75	27.50	28.08	28.52	28.66	28.82
1630	25.87	25.67	27.36	28.08	28.28	28.62
1700	24.27	25.15	26.15	27.26	27.53	27.92

TABLE V-9

MEAN AIR TEMPERATURES FROM SMOOTHED TEMPERATURE PROFILES AT MAST A

(116.7 meters downwind from trailing edge of dry fallow field)

(°C)

7 OCTOBER 1967

Half-hour ending	Elevation in cm.					
	25	50	100	200	280	600
0800	11.53	11.47	11.40	11.33	11.30	11.19
0830	14.02	13.75	13.54	13.31	13.28	13.13
0900	16.38	15.98	15.69	15.47	15.37	15.20
0930	17.97	17.54	17.24	17.01	16.93	16.78
1000	19.34	18.92	18.62	18.38	18.29	18.13
1030	20.58	20.17	19.81	19.63	19.54	19.38
1100	21.49	21.17	20.93	20.74	20.65	20.50
1130	22.28	22.00	21.79	21.62	21.55	21.43
1200	22.94	22.78	22.65	22.50	22.42	22.22
1230	23.51	23.38	23.26	23.13	23.06	22.88
1300	24.34	24.24	24.12	24.00	23.92	23.72
1330	24.87	24.76	24.66	24.55	24.50	24.34
1400	25.05	25.04	25.01	24.96	24.92	24.82
1430	25.29	25.36	25.39	25.37	25.35	25.26
1500	25.43	25.57	25.63	25.65	25.65	25.60
1530	24.86	25.31	25.56	25.78	25.86	26.03
1600	24.80	25.30	25.57	25.85	25.96	26.02

MEAN AIR TEMPERATURES FROM SMOOTHED TEMPERATURE PROFILES AT MAST A

(116.7 meters downwind from trailing edge of dry fallow field)

(°C)

9 OCTOBER 1967

Half-hour ending	Elevation in cm.					
	25	50	100	200	280	600
1000	22.29	22.23	22.15	22.05	21.99	21.83
1030	21.62	22.03	22.26	22.38	22.43	22.47
1100	23.45	23.55	23.58	23.57	23.55	23.47
1130	24.62	24.62	24.58	24.52	24.49	24.38
1200	25.27	25.45	25.55	25.60	25.60	25.56
1230	26.02	26.14	26.20	26.25	26.25	26.23
1300	26.90	27.02	27.10	27.12	27.12	27.07
1330	27.28	27.45	27.56	27.62	27.62	27.59
1400	27.70	27.87	28.00	28.09	28.12	28.15
1430	28.23	28.43	28.53	28.37	28.57	28.57
1500	28.20	28.50	28.68	28.78	28.81	28.81
1530	27.28	27.75	28.10	28.38	28.50	28.73
1600	26.85	27.63	28.13	28.48	28.60	28.82
1630	25.95	26.90	27.55	28.01	28.19	28.50
1700	24.44	25.60	26.47	27.15	27.43	27.93

TABLE V-10

ENERGY BALANCE AT WEIGHING LYSIMETER SITE

7 OCTOBER 1967
(langleys/minute)

Half-hour ending	Net radiation (R_n)	Soil heat flux (G)	Lysimeter latent heat flux (LE)	Remainder sensible heat flux (H)	Bowen Ratio: Latent heat flux (LE_{BR})	Bowen Ratio: Sensible heat flux (H_{BR})
0800	.148	-.020	-.106	-.022	-.116	-.012
0830	.240	-.030	-.165	-.045	-.163	-.047
0900	.335	-.037	-.211	-.087	-.225	-.073
0930	.408	-.042	-.247	-.120	-.280	-.086
1000	.495	-.048	-.324	-.122	-.361	-.086
1030	.553	-.043	-.374	-.135	-.421	-.089
1100	.606	-.062	-.398	-.145	-.474	-.070
1130	.639	-.059	-.440	-.140	-.539	-.041
1200	.651	-.062	-.434	-.156	-.553	-.036
1230	.644	-.030	-.469	-.145	-.577	-.037
1300	.618	-.037	-.442	-.139	-.553	-.028
1330	.571	-.051	-.433	-.087	-.498	-.022
1400	.525	-.036	-.403	-.086	---	-.006
1430	.456	-.017	-.380	-.060	-.448	---
1500	.373	-.005	-.324	-.044	-.385	.017
1530	.275	.002	-.270	-.007	-.317	.040
1600	.166	.005	-.204	.032	-.203	.032

ENERGY BALANCE AT WEIGHING LYSIMETER SITE

9 OCTOBER 1967
(langleys/minute)

Half-hour ending	(R_n)	(G)	(LE)	(H)	(LE_{BR})	(H_{BR})
1000	.493	-.024	-.383	-.086	---	---
1030	.290	-.027	-.289	.026	-.320	.057
1100	.555	-.044	-.377	-.134	-.529	.018
1130	.691	-.041	-.580	-.070	-.644	-.006
1200	.645	-.032	-.526	-.087	-.647	.034
1230	.663	-.034	-.523	-.107	-.650	.021
1300	.605	-.038	-.528	-.039	-.610	.043
1330	.578	-.047	-.487	-.044	-.555	.024
1400	.533	-.045	-.448	-.040	---	---
1430	.469	-.033	-.388	-.048	---	---
1500	.359	-.030	-.329	.001	---	---
1530	.278	-.037	-.270	.028	---	---
1600	.218	-.027	-.249	.058	---	---
1630	.163	-.017	-.216	.070	---	---
1700	.034	---	-.136	---	---	---

TABLE V-11

DATA FOR COMPUTATION OF SURFACE SENSIBLE HEAT FLUX BETWEEN MASTS G-C

AS DETERMINED BY INTEGRATION FROM SURFACE TO INVERSION HEIGHT
(22.5 meters from the trailing edge of dry fallow field)

Date	Half-hour ending	Mean inversion height* (cm)	Mean value $\Delta T/\Delta X$ ($°C/cm \times 10^{-4}$)	Slope of log law wind profile (cm/sec)	Computed surface sensible heat flux H_2 (ly/min)
7 October 1967					
	0800	No inversion			
	1000	No inversion			
	1200	No inversion			
	1400	No inversion			
	1430	37	2.14	27.7	.082
	1500	105	1.07	31.4	.029
	1530	204	1.89	38.2	.105
	1600	325	2.60	28.8	.175
9 October 1967					
	1030	162	2.96	56.0	.182
	1100	77	2.44	57.6	.068
	1130	No inversion			
	1200	No inversion			
	1230	83	2.48	58.4	.074
	1300	90	1.74	42.8	.042
	1330	124	3.74	41.1	.117

* Height above zero-plane displacement d, where d = 5 cm for 7 October 1967.
d = 6 cm for 9 October 1967.

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TABLE V-12

DATA FOR COMPUTATION OF SURFACE SENSIBLE HEAT FLUX BETWEEN MASTS C-B

AS DETERMINED BY INTEGRATION FROM SURFACE TO INVERSION HEIGHT
(49.5 meters from the trailing edge of dry fallow field)

Date	Half-hour ending	Mean inversion height* (cm)	Mean value $\Delta T/\Delta X$ ($°C/cm \times 10^{-4}$)	Slope of log law wind profile (cm/sec)	Computed surface sensible heat flux H_2 (ly/min)
7 October 1967	0800	No inversion			
	1000	No inversion			
	1200	No inversion			
	1400	No inversion			
	1430	40	.30	27.7	.008
	1500	217	.00	31.4	.000
	1530	340	.07	38.2	.008
	1600	500	.60	28.8	.074
9 October 1967					
	1030	432	.57	56.0	.117
	1100	115	.59	57.6	.024
	1130	No inversion			
	1200	No inversion			
	1230	137	.57	58.4	.029
	1300	135	.22	42.8	.013
	1330	170	.49	41.1	.027

* Height above zero-plane displacement d, where d = 5 cm for 7 October 1967.
d = 6 cm for 9 October 1967.

TABLE V-13

DATA FOR COMPUTATION OF SURFACE SENSIBLE HEAT FLUX BETWEEN MASTS B-A

AS DETERMINED BY INTEGRATION FROM SURFACE TO INVERSION HEIGHT
(86.0 meters from the trailing edge of dry fallow field)

Date	Half-hour ending	Mean inversion height* (cm)	Mean value $\Delta T/\Delta X$ ($^{\circ}C/cm \times 10^{-4}$)	Slope of log law wind profile (cm/sec)	Computed surface sensible heat flux H_2 (ly/min)
7 October 1967					
	0800	No inversion			
	1000	No inversion			
	1200	No inversion			
	1400	No inversion			
	1430	43.5	.35	27.7	.011
	1500	142	.26	31.4	.007
	1530	355	.24	38.2	.027
	1600	550	.15	28.8	.021
9 October 1967					
	1030	500	.41	56.0	.100
	1100	105	.22	57.6	.008
	1130	No inversion			
	1200	No inversion			
	1230	No inversion		58.4	
	1300	155	.37	42.8	.016
	1330	140	.43	41.1	.016

* Height above zero-plane displacement d, where d = 5 cm for 7 October 1967.
d = 6 cm for 9 October 1967.

TABLE V-14

SUMMARY OF SURFACE LATENT HEAT FLUX DETERMINED FROM THE ENERGY BALANCE

USING SURFACE SENSIBLE HEAT FLUX DETERMINED BY INTEGRATION FROM SURFACE TO INVERSION HEIGHT

(ly/min)

Half-hour ending		Distance from trailing edge of dry fallow field					
		22.5 meters		49.5 meters		86.0 meters	
	$(R_n + G)$ [1/]	H_2 [2/]	LE_2 [3/]	H_2	LE_2	H_2	LE_2
7 October 1967							
0800	No inversion						
1000	No inversion						
1200	No inversion						
1400	No inversion						
1430	0.439	.082	-.524	.008	-.467	.011	-.498
1500	0.368	.029	-.397	.000	-.368	.007	-.375
1530	0.277	.105	-.382	.008	-.285	.027	-.304
1600	0.171	.175	-.346	.074	-.245	.021	-.192
9 October 1967							
1030	0.263	.182	-.445	.117	-.380	.100	-.363
1100	0.511	.068	-.579	.024	-.535	.008	-.519
1130	No inversion						
1200	No inversion						
1230	0.629	.074	-.703	.029	-.658	----	----
1300	0.567	.042	-.609	.013	-.580	.016	-.583
1330	0.531	.117	-.648	.027	-.554	.016	-.545

1/ Net radiation plus soil heat flux.

2/ Computed surface sensible heat flux.

3/ Surface latent heat flux computed from $LE_2 = -(R_n + G + H_2)$.

TABLE V-15

SUMMARY OF SURFACE LATENT HEAT FLUX DETERMINED FROM THE ENERGY BALANCE USING SURFACE SENSIBLE HEAT FLUX DETERMINED USING PHILIP'S METHOD

Half-hour ending	K_1 cm^2/sec	n 1	u_1 cm/sec	m 1	C_s $cal/cm^2 \times 10^{-3}$	H_3 ly/min	R_n+G ly/min	LE_3 ly/min
7 OCTOBER 1967								
0800	185	.536	175	.250	.260	.021	.128	.149
0900	160	.767	130	.200	.041	.002	.298	.300
1000	170	.686	170	.217	1.047	.070	.447	.517
1100	215	.750	175	.233	1.672	.123	.544	.667
1200	206	.690	148	.200	1.999	.149	.589	.738
1300	240	.617	102	.167	1.377	.110	.581	.691
1400	---	---	88	.200	1.726	----	.489	----
1500	89	.983	105	.250	1.717	.027	.368	.395
1600	51	.892	81	.333	2.412	.026	.171	.197
9 OCTOBER 1967								
1030	108	.950	157	.300	2.044	.024	.263	.287
1100	143	1.100	171	.300	2.321	-----	.511	----
1130	---	----	200	.300	2.378	-----	.650	----
1200	142	.967	211	.317	2.710	.025	.613	.638
1230	140	.950	174	.283	2.505	.037	.629	.666
1300	261	.900	136	.267	2.255	.109	.567	.676
1330	120	.867	136	.250	2.286	.067	.531	.598

Values of H_3 and corresponding values of LE_3 are for the point 100 cm downwind from the trailing edge of the fallow area.

APPENDIX A

RESEARCH RESULTS ACCOMPLISHED UNDER GRANT G-10 REPORTED PRIOR TO THIS FINAL REPORT

APPENDIX A

The following three reports present the results of analyses of the micrometeorological data collected partly under earlier Army sponsorship and published prior to this Final Report for Grant G-10.

1. Morgan, D. L., W. O. Pruitt, and F. J. Lourence, 1970: Evaporation from an irrigated grass turf under advection of dry air at Davis, California. Research and Development Technical Report ECOM 68-G10-1. University of California, Davis. 118 pages. (AD 705 386)

Abstract

Detailed micrometeorological data were collected during three periods in October 1966 and 1967 at Davis, California, when dry, northerly winds passed from an extensive dry area onto a moist irrigated grass field. The two studies comprising this report use these data to test several advection models.

Goltz and Pruitt, analyzing 13-14 October 1966 data, used three independent methods to study the horizontal extent of the transition zone of surface evaporative flux and the magnitude and variation of evapotranspiration within this zone. The results showed that the reduction of evapotranspiration 117 meters downwind from the leading edge of an irrigated grass field under conditions of strong advection of cool, dry air was, in general, 20 to 25 percent, with all three independent methods providing compatible results. Indications were that even at this distance into the grass field, evapotranspiration reductions had not completely stabilized.

Decker, using Philip's model for advection, tested the variation of evapotranspiration over the same irrigated grass field during conditions of mild advection of warm, dry air represented by the 7 and 9 October 1967 data. He found that predicted values of surface evapotranspiration during inversion periods compared quite closely with values of evapotranspiration measured by the 20-foot weighing lysimeter located 100 meters downwind in the grass field. During periods without surface temperature inversions, however, the lysimeter evapotranspiration was 20 to 60 percent higher than the evapotranspiration predicted by the advection model.

2. Morgan, D. L., W. O. Pruitt, and F. J. Lourence, 1970: Radiation data and analyses for the 1966 and 1967 micrometeorological field runs at Davis, California. Research and Development Technical Report ECOM 68-G10-2. University of California, Davis. 66 pages. (AD 702 236)

Abstract

This report presents basic radiation data gathered at the University of California at Davis during nine intensive micrometeorological data-gathering periods in 1966 and 1967.

A comparison is made between measurements of the total incoming solar radiation taken with an Eppley pyranometer and the combination of two components of incoming solar radiation measured by a tracking pyrheliometer and a shaded pyranometer, respectively. The results indicate relatively small differences between the sums of the components and the measured totals, giving a high degree of confidence in these data.

Two independent checks are made of the measured net radiation, a key in energy-balance considerations. A comparison of measured net radiation with the proper combination of other measured radiation components, the first independent check, shows very close agreement between the two for both clear- and cloudy-sky conditions. The second method of checking the measured net radiation, incorporating an estimate of the longwave atmospheric radiation, agrees closely for clear-sky periods but underestimates the

measured net radiation for cloudy conditions.

Various methods of estimating atmospheric radiation, including the use of radiation charts and six empirical formulae, are examined. The effectiveness of a method for adjusting the clear-sky estimates of atmospheric radiation from empirical formulae for cloudy conditions is studied using observed cloud conditions and measured atmospheric radiation. This method works well for overcast low-cloud conditions. For higher clouds with less than complete sky coverage, however, problems are encountered in representing the cloud conditions analytically.

3. Luther, F. M., 1970: A numerical model of the energy transfer processes in the lower atmosphere. Contributions in Atmospheric Science No. 2, Departments of Agricultural Engineering and Water Science & Engineering, University of California, Davis. 65 pages.

Preface

This report comprises a Ph.D. dissertation by Frederick M. Luther, in Engineering-Applied Science, University of California, Davis.

Dr. L. O. Myrup, of the University of California at Davis, was Luther's dissertation advisor. His interest in micro-mesoscale meteorological interactions and participation in Army Grant DA-AMC-028-043-68-G10 are reflected in the guidance of the work presented in this report.

The Davis micrometeorological data used in testing the numerical model were gathered during the Cooperative Field Experiment in May 1967 and processed under the direction of W. O. Pruitt, D. L. Morgan, and F. J. Lourence, of the Hydrometeorological Research Group of the Department of Water Science and Engineering at UC Davis, with the primary sponsorship coming from the United States Army Electronics Command, Atmospheric Sciences Laboratory at Fort Huachuca, Arizona, Contract DA-02-086-AMC-0447(E). The corresponding upper-air data used by Luther were gathered by members of the ESSA Weather Bureau Research Station, Fort Huachuca, Arizona, and the Atmospheric Sciences Office, ASL, USAECOM, White Sands Missile Range, New Mexico. Additional support for instrumentation and personnel was furnished by the Water Resources Center, University of California.

Abstract

A one-dimensional numerical model is used to compute temperature and moisture profiles and to analyze constituents of the energy budget in the lower atmosphere. The energy-transfer processes involved in the calculation include convection, advection, absorption of solar radiation, exchange of terrestrial radiation, evaporation, condensation, and conduction of heat into the soil. The wind field is specified for the duration of the calculation, and the mean vertical motion is assumed equal to zero.

The region of primary interest is the first two thousand meters of the atmosphere, which is the region where temperature and moisture content change most rapidly. The model covers a region extending to a height of eight thousand meters above the earth's surface in order to include the water vapor in this region in the terrestrial radiation calculation. The model also includes a layer of soil extending to a depth of one meter, which is needed for the energy-balance calculation at the earth's surface.

An expanding vertical grid is used in the atmospheric region in which each grid length is 1.25 times the size of the one below it, thus providing greater resolution in the lower layers. The minimum grid length is 2.0 meters.

Temperature and moisture fields are computed for two twenty-four hour periods, one beginning at 1230 LST on August 24, 1953, at O'Neill, Nebraska,

and the other beginning at 0100 LST on May 4, 1967, at Davis, California. In both cases the computed temperature and moisture fields agree well with the observed values.

The O'Neill calculation demonstrates the ability of the numerical model to predict temperature and moisture fields under conditions of strong winds.

The Davis calculation demonstrates the ability of the numerical model to predict temperature and moisture profiles under conditions of light winds. Results show that the calculation of accurate convective heat fluxes near the earth's surface is more difficult under conditions of strong thermal stability. Accurate wind data are particularly important under these conditions.

Comparison of calculated values of the constituents of the energy budget at the earth's surface with measured values for both the Davis and O'Neill calculations showed the terrestrial and solar radiation calculations to be very accurate. Satisfactory results were obtained for the water-vapor calculation by specifying either the latent heat flux or the specific humidity at the earth's surface as functions of time.

Advection is shown to be an important energy-transfer process and should not be neglected in atmospheric calculations. Advection has a significant effect upon convective heat transfer near the earth's surface even though the rate of change of temperature due to advection may be small in this region.

APPENDIX B

INSTRUMENTATION AND DATA COLLECTION, PROCESSING, AND PRESENTATION

APPENDIX B

1. INTRODUCTION

During 1966 and 1967 detailed micrometeorological data were gathered at the Davis Hydrometeorological Field Site on nine different occasions. These data-gathering field runs are summarized in Table B-1, which includes the dates, times, durations, and identification numbers of the runs. Also included are approximating rough averages for the general meteorological conditions during the period of each run. More complete weather summaries are found in Pruitt et al (1967) for the 1966 field runs, and in Pruitt et al (1968), for the 1967 field runs. Detailed weather-condition data, along with field site layout and other special information, are included in Stenmark and Drury (1970a, 1970b, 1970c).

2. INSTRUMENTATION

Instrumentation used in the gathering of these micrometeorological data can be classified in two major groups, i.e., the flux-measuring devices and the profile-measuring systems.

Of the flux-measuring devices there were an array of radiometers measuring the components of solar radiation, infrared radiation, total incoming radiation, and net radiation. Morgan et al (1970b) describe the instrumentation used in making these radiation-component measurements. The latent heat flux was measured by a 20-foot weighing lysimeter, which is described by Pruitt and Angus (1960), and by a 20-foot floating drag-plate lysimeter. This drag-plate lysimeter, described by Goddard (1970), also gave the basic data for momentum flux. Heat-flux measurements were made during the majority of the field runs by W. B. Goddard, using the Evapotron described by Goddard and Pruitt (1966). The soil heat flux was obtained by using heat flux measured at 10 cm below the soil surface and the time rate of temperature change averaged through the 10-cm-deep layer of soil as measured by buried thermistor and thermocouple elements.

The profile data for temperature and humidity were gathered by wet- and dry-bulb thermopile sensors described by Lourence and Pruitt (1969). A separate system which measured profiles of absolute humidity, using an infrared hygrometer as the sensor, is described by Lourence and Pruitt (1967) and in Chapter II Part III of Lourence (1967). Wind profile data were measured by Thornthwaite cup anemometers mounted at fixed geometric heights above the surface.

3. DATA

The raw data gathered during these field runs were processed by computer into 30-minute mean values, which were flagged by the ending time of the half hour to which they apply. The profile data for temperature, humidity, and wind speed were plotted on semi-log paper against height less the displacement height (z-d) for each individual run and smooth curves drawn through the data points. Values were then selected from these curves for heights of 25, 35, 50, 70, 100, 140, 200, 280, 400 (wind only), and 600 cm. These smoothed data are presented for the nonadvection runs (166, 266, 267, 367, and 467) and for one of the advection runs (466) in Tables B-2 through B-16. These tables list the temperature,

humidity* and wind data for the lowest seven heights, the Richardson number for the height intervals 35-50, 50-70, 70-100, 100-140, and 140-200 cm, the energy-balance data, and the flux data, including shear stress for all of the nonadvection runs (except run 167**) and for one advection run (466). Average wind direction for 30-minute periods at a 4-meter height is presented in Table B-17. General displacement height and surface roughness for each of the six runs are given in Table B-18. Plots of the energy-balance components for these runs, along with a discussion of the energy balance, are presented in Pruitt et al (1967) and Pruitt et al (1968) for the nonadvection runs. Comparable smoothed profile data and energy-balance data for the advection runs (466, 567, and 667) are found in Morgan et al (1970a) and in Chapter V of this report. Detailed radiation data, including the solar components, infrared components, and net radiation, are available for all nine field runs in Morgan et al (1970b). Thirty-minute means of the unsmoothed usable data for all nine of the field runs can be found in Stenmark and Drury (1970a, 1970b, 1970c).

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Morgan, D. L., W. O. Pruitt, and F. J. Lourence. 1970b. Radiation data and analyses for the 1966 and 1967 micrometeorological field runs at Davis, California. Research and Development Technical Report ECOM 68-G10-2, University of California. 66 pages. (AD 702 236)

Pruitt, W. O. and D. E. Angus. 1960. Large weighing lysimeter for measuring evapotranspiration. Transactions of the ASAE, Vol. 3, No. 2, 13-15 and 18. ASAE, St. Joseph, Mich.

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* For absolute humidity the 25-cm-height data were not used, because of concern over possible residual adsorbed water vapor in the system when switching from very moist canopy air to the dry air aloft. See Lourence and Pruitt (1967) for details of sampling procedure.

**Data for run 167 are not included in these tables because there were no measured values of shear stress. No detailed analyses of the micrometeorological variables could be made without this important parameter, so this run is not included in the analyses and findings presented in this report.

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Stenmark, E. B. and L. D. Drury. 1970a. Micrometeorological Field Data from Davis, California;1966-67 Runs Under Non-Advection Conditions. Tech Report ECOM-6051, August.

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Stenmark, E. B. and L. D. Drury. 1970c. Micrometeorological Field Data from Davis, California; 1967 Cooperative Field Experiment Runs. Tech Report ECOM-6053. August.

TABLE B-1 SUMMARY OF FIELD RUNS

Date	Time	Hours	Run No.	Wind	Average weather conditions			Remarks
					Sky conditions	Tmax	Tmin	
1966								
1-3 Jun.	1430-2330	57	166	Southerly 5- 7m/s	Mostly clear	21°C	5°C	Windy afternoons
12-14 Jul.	1000-2330	61 1/2	266	Southerly 5- 7m/s	Clear	24°C	10°C	Cool summer case
13-14 Oct.	0730-1000	26 1/2	466	Northerly 10-12m/s	Clear	18°C	10°C	Strong advection
1967								
27-28 Apr.*	0930-1630	31	167	Southwesterly 2- 7m/s	Mostly clear	14°C	1°C	Some cumulus clouds
2-5 May *	0900-1700	80	267	Southerly 5- 7m/s	Mostly clear	22°C	5°C	High, thin cloudiness second and third days. Low cloudiness last day.
9 May	0600-1800	12	367	Southerly 7-12m/s	Low cloudiness	15°C	11°C	Overcast most of period
28-29 Sep.	1000-1930	33 1/2	467	Southerly 5- 7m/s	Mostly clear	29°C	17°C	High,thin cloudiness
7 Oct.	0800-1600	8	567	Northerly 2- 5m/s	Clear	27°C	15°C	Mild advection
9 Oct.	1000-1700	7	667	Northerly 2- 5m/s	Mostly clear	29°C	22°C	Mild advection High, thin cloudiness

* Cooperative Field Experiment field runs.

TABLES B-2 THROUGH B-16. SMOOTHED DATA for:

Nonadvection runs:	166, 1-3 June 1966
	266, 12-14 July 1966
	267, 2-5 May 1967
	367, 9 May 1967
	467, 28-29 September 1967
Advection run	466, 13-14 October 1966

The tables include the time at end of half-hour period, date, temperature, absolute humidity, wind speed, Richardson Number, energy balance, and fluxes.

* Where times are marked with an asterisk these data were not processed through the Eddy Diffusivity Program (EDP) because of unfavorable wind direction. See Appendix C for more detail.

TIME	TEMPERATURE							ABSOLUTE HUMIDITY						WIND SPEED							RICHARDSONS NUMBER					ENERGY BALANCE				FLUXES		TIME
1 JUN 66	DEGREES C							GRAMS PER CUBIC CM X 10**6						CM PER SEC							FOR INTERVALS					LY PER MIN				MM PER HR	DNS PER CM2	
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
1430	21.45	21.30	21.18	21.08	20.99	20.91	20.87	8.22	7.78	7.40	7.05	6.76	6.48	260	310	355	392	427	459	489	-0.0046	-0.0076	-0.0116	-0.0161	-0.0181	0.781	-0.042	-0.672	-0.067	-.693	2.049	1430
1500	21.03	20.98	20.92	20.88	20.83	20.79	20.76	8.09	7.74	7.43	7.13	6.89	6.61	311	378	432	482	529	569	609	-0.0019	-0.0023	-0.0043	-0.0063	-0.0090	0.739	-0.030	-0.674	-0.035	-.693	3.022	1500
1530	21.06	21.05	21.04	21.03	21.02	21.01	21.00	7.71	7.40	7.13	6.88	6.64	6.39	355	414	470	519	568	612	660	-0.0009	-0.0014	-0.0020	-0.0031	-0.0041	0.654	-0.024	-0.599	-0.031	-.616	3.648	1530
1600	20.68	20.70	20.71	20.73	20.75	20.76	20.76	7.42	7.15	6.92	6.71	6.50	6.30	378	446	508	562	613	662	711	-0.0004	-0.0003	-0.0004	-0.0012	-0.0025	0.559	-0.015	-0.554	0.010	-.569	3.762	1600
1630	20.13	20.20	20.27	20.30	20.33	20.35	20.37	7.34	7.11	6.92	6.73	6.57	6.39	390	455	516	570	623	674	725	0.0005	0.0000	0.0001	-0.0002	-0.0005	0.456	-0.011	-0.481	0.036	-.493	3.606	1630
1700	19.26	19.33	19.40	19.48	19.51	19.53	19.58	7.51	7.38	7.22	7.08	6.92	6.75	372	435	494	545	596	643	693	0.0007	0.0015	0.0004	-0.0002	0.0020	0.329	-0.004	-0.390	0.065	-.400	3.810	1700
1730	18.73	18.88	18.98	19.06	19.13	19.20	19.26	7.51	7.39	7.27	7.12	7.00	6.84	360	420	477	527	576	622	670	0.0013	0.0017	0.0020	0.0033	0.0032	0.225	0.003	-0.316	0.088	-.323	3.358	1730
1800	18.17	18.32	18.48	18.60	18.70	18.79	18.88	7.30	7.21	7.12	7.01	6.90	6.78	311	367	417	460	505	548	589	0.0030	0.0039	0.0042	0.0054	0.0087	0.116	0.007	-0.241	0.118	-.246	2.635	1800
1830	16.96	17.19	17.39	17.56	17.72	17.85	17.99	7.09	7.02	6.98	6.90	6.81	6.71	282	330	377	417	456	493	532	0.0044	0.0069	0.0099	0.0116	0.0167	0.019	0.020	-0.166	0.127	-.169	2.169	1830
1900	15.87	16.18	16.43	16.68	16.89	17.07	17.22	6.83	6.77	6.70	6.63	6.59	6.51	229	272	312	350	386	420	454	0.0077	0.0113	0.0157	0.0204	0.0243	-0.049	0.014	-0.090	0.125	-.092	1.663	1900
1930	13.83	14.18	14.49	14.74	14.98	15.19	15.38	6.86	6.81	6.76	6.71	6.67	6.61	189	227	260	291	321	350	379	0.0143	0.0173	0.0265	0.0331	0.0441	-0.096	0.016	-0.061	0.141	-.062	1.213	1930
2000	12.31	12.58	12.81	13.06	13.29	13.50	13.75	6.81	6.79	6.76	6.71	6.69	6.65	165	194	223	249	276	302	329	0.0139	0.0250	0.0315	0.0421	0.0690	-0.107	0.020	-0.030	0.117	-.031	0.860	2000
2030	10.95	11.31	11.65	11.94	12.22	12.50	12.76	6.81	6.80	6.80	6.79	6.76	6.72	128	153	177	197	220	240	264	0.0305	0.0500	0.0545	0.0950	0.0912	-0.103	0.020	-0.031	0.114	-.031	0.481	2030
2100	10.07	10.35	10.61	10.86	11.09	11.31	11.55	6.73	6.72	6.71	6.70	6.68	6.65	128	153	177	197	220	241	266	0.0233	0.0431	0.0449	0.0681	0.0782	-0.102	0.022	-0.000	0.080	-.000	0.568	2100
2130	8.59	9.00	9.36	9.70	10.03	10.38	10.70	6.70	6.70	6.69	6.69	6.68	6.65	104	126	147	165	184	204	224	0.0426	0.0727	0.0953	0.1210	0.1642	-0.099	0.022	-0.015	0.092	-.015	0.305	2130
2200	8.20	8.52	8.83	9.10	9.39	9.63	9.90	6.79	6.78	6.77	6.76	6.75	6.73	122	142	162	182	203	224	248	0.0404	0.0468	0.0684	0.0753	0.0967	-0.101	0.023	-0.015	0.093	-.015	0.389	2200
2230*	6.70	7.18	7.63	8.05	8.50	8.91	9.33	6.50	6.51	6.53	6.57	6.59	6.60	82	97	114	131	149	168	189	0.0821	0.1023	0.1473	0.1595	0.1997	-0.095	0.025	0.000	0.070	0.000	0.193	2230
2300	6.50	6.90	7.30	7.68	8.05	8.43	8.88	6.40	6.42	6.45	6.47	6.49	6.49	80	95	112	129	147	167	189	0.0733	0.0931	0.1207	0.1337	0.1946	-0.094	0.028	0.000	0.066	0.000	0.151	2300
2330*	5.79	6.27	6.75	7.19	7.68	8.10	8.50	6.20	6.25	6.29	6.32	6.36	6.39	59	72	86	100	115	130	147	0.1309	0.1595	0.2308	0.2645	0.2930	-0.091	0.029	0.000	0.062	0.000	0.116	2330
2400	4.31	5.08	5.80	6.43	7.11	7.73	8.28	5.88	5.99	6.08	6.13	6.19	6.21	60	80	97	114	130	147	165	0.1345	0.1564	0.2825	0.3045	0.3578	-0.085	0.030	0.000	0.055	0.000	0.118	2400

TIME	TEMPERATURE							ABSOLUTE HUMIDITY						WIND SPEED							RICHARDSONS NUMBER					ENERGY BALANCE				FLUXES		TIME
2 JUN 66	DEGREES C							GRAMS PER CUBIC CM X 10**6						CM PER SEC							FOR INTERVALS					LY PER MIN				MM PER HR	DNS PER CM2	
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
30	5.52	5.92	6.30	6.66	7.01	7.40	7.82	6.10	6.14	6.18	6.20	6.21	6.22	83	104	124	142	162	184	207	0.0509	0.0793	0.0929	0.1134	0.1673	-0.098	0.029	0.000	0.069	0.000	0.236	30
100	5.23	5.59	5.95	6.30	6.70	7.11	7.57	6.12	6.16	6.20	6.21	6.22	6.23	75	91	107	123	139	157	177	0.0754	0.0977	0.1653	0.1782	0.2425	-0.097	0.028	0.015	0.054	0.015	0.223	100
130	3.40	4.58	5.46	6.07	6.51	6.87	7.19	5.72	5.86	5.97	6.04	6.11	6.17	39	47	53	59	65	70	75	1.3226	1.2227	1.3170	2.0757	2.7620	-0.078	0.031	0.015	0.032	0.015	0.077	130
200*	3.50	4.07	4.60	5.04	5.49	5.90	6.30	5.70	5.80	5.87	5.92	5.99	6.02	56	70	84	96	109	122	136	0.1472	0.2206	0.2861	0.3498	0.4353	-0.083	0.030	0.015	0.038	0.015	0.099	200
230*	2.76	3.55	4.25	4.80	5.31	5.80	6.10	5.57	5.68	5.77	5.84	5.90	5.95	57	72	85	96	107	115	122	0.2249	0.3287	0.4548	1.0974	1.3222	-0.080	0.032	0.015	0.033	0.015	0.071	230
300*	3.00	3.60	4.12	4.50	4.89	5.43	5.96	5.55	5.65	5.72	5.80	5.85	5.92	64	77	93	111	132	153	172	0.1108	0.0851	0.0964	0.1751	0.3159	-0.083	0.035	0.000	0.048	0.000	0.108	300
330*	4.42	4.60	4.82	5.04	5.30	5.65	5.90	5.85	5.89	5.91	5.93	5.95	5.97	107	128	150	169	187	208	228	0.0247	0.0436	0.0859	0.1128	0.1335	-0.093	0.031	0.000	0.062	0.000	0.393	330
400	3.60	3.88	4.19	4.50	4.82	5.13	5.46	5.70	5.75	5.78	5.80	5.85	5.89	97	117	137	156	175	195	217	0.0421	0.0616	0.0948	0.1119	0.1467	-0.091	0.032	0.015	0.044	0.015	0.321	400
430	4.68	4.91	5.14	5.35	5.58	5.79	6.00	5.84	5.84	5.84	5.84	5.84	5.85	103	121	138	155	171	190	211	0.0422	0.0513	0.0951	0.0820	0.1013	-0.096	0.030	0.015	0.051	0.015	0.319	430
500	2.60	3.48	4.15	4.69	5.12	5.47	5.78	5.48	5.51	5.56	5.57	5.60	5.59	55	62	71	80	91	102	115	0.4427	0.4777	0.3779	0.4129	0.3862	-0.074	0.027	0.000	0.047	0.000	0.122	500
530	3.28	3.79	4.23	4.60	4.95	5.30	5.64	5.68	5.70	5.72	5.73	5.75	5.78	42	49	57	66	75	86	97	0.3678	0.3257	0.4600	0.4117	0.6016	-0.051	0.025	0.015	0.011	0.015	0.118	530
600	6.59	6.74	6.89	7.01	7.13	7.23	7.32	6.30	6.26	6.20	6.17	6.11	6.06	59	70	81	91	102	113	125	0.0629	0.0786	0.1008	0.1065	0.1216	0.011	0.024	-0.015	-0.020	-.015	0.120	600
630	9.35	9.32	9.31	9.30	9.30	9.30	9.30	6.92	6.78	6.67	6.57	6.50	6.40	86	100	112	124	133	142	152	-0.0106	-0.0121	-0.0176	-0.0164	-0.0285	0.074	0.020	-0.030	-0.064	-.031	0.249	630
700	11.72	11.73	11.65	11.56	11.48	11.40	11.32	7.10	6.90	6.79	6.61	6.50	6.38	97	112	126	137	147	155	163	-0.0285	-0.0601	-0.1087	-0.2056	-0.3130	0.178	0.012	-0.091	-0.099	-.093	0.319	700
730	13.10	12.92	12.78	12.65	12.55	12.45	12.37	6.87	6.62	6.45	6.31	6.21	6.16	61	68	75	80	86	90	94	-0.1842	-0.4231	-0.3428	-0.9805	-1.1227	0.278	0.002	-0.166	-0.114	-.170	0.215	730
800	14.40	14.16	13.95	13.80	13.65	13.54	13.42	7.39	7.10	6.88	6.70	6.57	6.49	77	86	94	100	107	113	117	-0.2014	-0.3445	-0.3679	-0.4887	-1.6881	0.374	-0.006	-0.240	-0.128	-.246	0.254	800
830	15.90	15.59	15.31	15.08	14.88	14.74	14.58	7.65	7.32	7.08	6.87	6.72	6.62	80	89	97	104	110	115	119	-0.2612	-0.3677	-0.6536	-0.8811	-2.2312	0.480	-0.018	-0.286	-0.176	-.293	0.263	830
900	16.51	16.25	16.03	15.85	15.69	15.55	15.42	7.40	7.01	6.75	6.52	6.39	6.30	58	62	66	69	71	73	75	-0.8790	-1.6415	-4.9220	-5.3975	-7.2970	0.576	-0.024	-0.345	-0.207	-.354	0.228	900
930	17.85	17.56	17.33	17.15	16.98	16.82	16.70	7.37	6.92	6.60	6.32	6.12	5.99	90	98	106	112	117	121	126	-0.2340	-0.4254	-0.8551	-1.5996	-1.1287	0.676	-0.037	-0.404	-0.235	-.416	0.377	930
1000	18.80	18.52	18.30	18.10	17.94	17.79	17.65	7.60	7.15	6.80	6.54	6.31	6.20	72	80	87	93	98	103	108	-0.2947	-0.4703	-0.8012	-0.9909	-1.2647	0.748	-0.043	-0.478	-0.227	-.493	0.467	1000
1030	19.36	19.05	18.77	18.56	18.38	18.22	18.10	7.85	7.30	6.88	6.52	6.20	6.01	115	130	142	153	163	172	180	-0.1264	-0.1510	-0.2350	-0.3440	-0.4669	0.824	-0.047	-0.567	-0.210	-.585	0.493	1030
1100	20.15	19.87	19.63	19.43	19.25	19.11	18.98	7.80	7.20	6.72	6.33	5.99	5.80	117	135	150	162	173	182	190	-0.0734	-0.1261	-0.1976	-0.3151	-0.4975	0.877	-0.052	-0.612	-0.213	-.632	0.637	1100
1130	20.80	20.47	20.20	20.00	19.80	19.64	19.47	7.90	7.30	6.80	6.41	6.08	5.89	127	145	160	172	183	193	203	-0.0801	-0.1274	-0.2140	-0.2799	-0.3987	0.920	-0.056	-0.641	-0.223	-.662	0.576	1130
1200	20.85	20.56	20.33	20.12	19.95	19.80	19.68	7.54	6.90	6.41	6.00	5.65	5.45	102	118	132	142	152	160	167	-0.0831	-0.1891	-0.2317	-0.4223	-0.6137	0.936	-0.058	-0.686	-0.192	-.709	0.582	1200
1230	21.44	21.20	20.96	20.80	20.65	20.50	20.39	7.75	7.15	6.68	6.26	5.87	5.65	150	172	190	205	220	234	247	-0.0509	-0.0682	-0.0946	-0.1418	-0.1693	0.950	-0.060	-0.731	-0.159	-.755	0.868	1230
1300	21.63	21.38	21.16	21.00	20.83	20.70	20.55	8.08	7.47	7.00	6.56	6.15	5.90	170	200	227	250	272	290	307	-0.0213	-0.0290	-0.0487	-0.0787	-0.1299	0.947	-0.060	-0.731	-0.156	-.755	1.258	1300
1330	22.13	21.89	21.67	21.50	21.36	21.23	21.13	7.85	7.20	6.73	6.30	5.95	5.75	100	112	124	132	138	145	150	-0.1100	-0.2501	-0.5670	-0.4958	-1.0392	0.872	-0.057	-0.671	-0.144	-.693	0.530	1330
1400	22.61	22.36	22.16	21.99	21.84	21.71	21.60	8.00	7.38	6.87	6.46	6.10	5.91	110	127	142	155	169	180	190	-0.0649	-0.0970	-0.1077	-0.2023	-0.2766	0.837	-0.050	-0.612	-0.175	-.632	0.533	1400
1430	22.45	22.25	22.08	21.95	21.85	21.76	21.68	8.50	7.99	7.57	7.20	6.86	6.54	210	247	281	310	337	364	387	-0.0106	-0.0153	-0.0213	-0.0257	-0.0483	0.810	-0.046	-0.642	-0.122	-.662	1.379	1430
1500	21.67	21.55	21.43	21.33	21.25	21.19	21.13	8.48	8.08	7.75	7.43	7.14	6.82	285	338	385	426	468	502	540	-0.0041	-0.0059	-0.0072	-0.0119	-0.0149	0.755	-0.038	-0.629	-0.088	-.647	2.643	1500
1530	21.57	21.48	21.40	21.33	21.26	21.21	21.15	8.37	8.05	7.80	7.55	7.31	7.07	310	370	422	470	513	555	595	-0.0024	-0.0031	-0.0058	-0.0065	-0.0120	0.673	-0.031	-0.569	-0.073	-.585	3.018	1530
1600	21.20	21.15	21.12	21.10	21.06	21.04	21.01	8.56	8.30	8.07	7.85	7.64	7.44	300	355	405	450	490	530	570	-0.0014	-0.0018	-0.0045	-0.0043	-0.0075	0.533	-0.017	-0.494	-0.022	-.508	2.740	1600
1630	21.01	21.00	20.99	20.98	20.98	20.98	20.97	8.41	8.15	7.90	7.68	7.45	7.25	258	305	350	385	422	455	490	-0.0012	-0.0026	-0.0024	-0.0042	-0.0065	0.456	-0.014	-0.420	-0.022	-.431	1.967	1630
1700	20.49	20.50	20.52	20.55	20.56	20.60	20.62	8.20	7.95	7.75	7.55	7.38	7.20	242	290	335	370	408	440	475	-0.0004	0.0000	-0.0014	0.0020	-0.0011	0.333	-0.008	-0.360	0.035	-.369	1.639	1700
1730	19.83	19.92	20.00	20.06	20.12	20.18	20.22	8.08	7.85	7.68	7.50	7.35	7.19	240	285	328	360	400	430	465	0.0013	0.0023	0.0021	0.0057	0.0027	0.228	-0.006	-0.271	0.049	-.278	1.464	1730
1800	18.78	18.91	19.03	19.12	19.22	19.31	19.40	7.98	7.84	7.71	7.60	7.48	7.38	262	312	360	400	440	475	510	0.0022	0.0030	0.0053	0.0080	0.0124	0.124	-0.003	-0.195	0.074	-.200	1.984	1800
1830	17.45	17.65	17.85	18.00	18.14	18.25	18.36	7.88	7.80	7.73	7.63	7.54	7.41	268	319	365	405	442	477	511	0.0045	0.0059	0.0093	0.0107	0.0160	0.020	0.005	-0.166	0.141	-.170	2.033	1830
1900	16.44	16.68	16.89	17.06	17.25	17.42	17.58	7.70	7.65	7.61	7.55	7.46	7.40	240	285	325	360	399	430	465	0.0065	0.0091	0.0121	0.0221	0.0251	-0.055	0.007	-0.121	0.169	-.123	1.779	1900
1930	15.26	15.54	15.76	15.98	16.19	16.36	16.55	7.65	7.61	7.56	7.52	7.46	7.41	208	245	280	310	340	370	400	0.0089	0.0161	0.0232	0.0244	0.0414	-0.099	0.017	-0.061	0.143	-.062	1.258	1930
2000	14.15	14.44	14.71	14.95	15.16	15.37	15.57	7.56	7.52	7.50	7.47	7.42	7.39	175	205	235	263	290	318	347	0.0151	0.0207	0.0289	0.0353	0.0476	-0.107	0.017	-0.030	0.120	-.031	0.801	2000
2030	12.85	13.17	13.48	13.73	14.00	14.26	14.54	7.52	7.51	7.49	7.47	7.42	7.38	130	157	182	205	228	251	275	0.0254	0.0321	0.0519	0.0655	0.0977	-0.105	0.014	-0.015	0.106	-.015	0.487	2030
2100	10.04	10.67	11.25	11.80	12.42	13.04	13.63	7.18	7.19	7.19	7.18	7.17	7.14	68	85	104	123	144	165	183	0.0836	0.1053	0.1451	0.1930	0.3724	-0.089	0.019	-0.015	0.085	-.015	0.512	2100
2130	9.48	10.04	10.58	11.10	11.69	12.20	12.69	7.03	7.05	7.06	7.05	7.04	7.03	70	89	107	124	140	157	175	0.0872	0.1249	0.2384	0.2428	0.3115	-0.086	0.019	0.000	0.067	0.000	0.117	2130
2200	8.68	9.01	9.38	9.70	10.09	10.48	10.89	7.03	7.05	7.06	7.05	7.04	7.03	88	106	124	141	160	180	203	0.0601	0.0774	0.1122	0.1348	0.1606	-0.094	0.021	0.000	0.073	0.000	0.271	2200
2230*	8.62	8.86	9.10	9.35	9.62	9.92	10.28	6.95	6.96	6.96	6.95	6.92	6.90	103	120	137	153	172	191	214	0.0437	0.0680	0.0777	0.1139	0.1407	-0.099	0.023	0.000	0.076	0.000	0.343	2230
2300	8.37	8.58	8.80	9.01	9.29	9.57	9.84	6.86	6.88	6.89	6.89	6.88	6.86	110	127	145	162	180	200	224	0.0360	0.0510	0.0903	0.0970	0.0968	-0.098	0.027	0.000	0.071	0.000	0.409	2300
2330	7.39	7.61	7.89	8.13	8.45	8.79	9.17	6.78	6.81	6.84	6.87	6.88	6.87	87	104	120	135	153	172	193	0.0583	0.0759	0.1048	0.1320	0.1795	-0.095	0.029	0.000	0.066	0.000	0.277	2330
2400	5.05	5.75	6.68	7.42	8.19	8.69	9.08	6.51	6.70	6.81	6.88	6.91	6.92	45	56	66	76	86	95	105	0.5043	0.5297	0.8183	0.8692	0.8186	-0.075	0.030	0.000	0.045	0.000	0.067	2400

TIME	TEMPERATURE							ABSOLUTE HUMIDITY						WIND SPEED							RICHARDSONS NUMBER					ENERGY BALANCE			FLUXES		TIME
3 JUN 66	DEGREES C							GRAMS PER CUBIC CM X 10**6						CM PER SEC							FOR INTERVALS					LY PER MIN			MM PER HR	ONS PER CM2	
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
30	5.69	6.20	6.79	7.30	7.91	8.49	8.96	6.50	6.61	6.69	6.76	6.81	6.85	57	75	92	106	121	135	149	0.1103	0.1864	0.2892	0.4185	0.5076	-0.077	0.029	0.000	0.048	0.000	0.136	30
100	4.65	5.75	6.60	7.25	7.82	8.29	8.69	6.29	6.48	6.59	6.70	6.75	6.80	29	33	37	42	48	54	61	2.8879	1.8666	1.7069	1.8520	1.7388	-0.064	0.029	0.000	0.035	0.000	0.054	100
130	3.78	5.60	6.53	6.94	7.35	7.75	8.19	6.22	6.41	6.50	-0.00	-0.00	-0.00	28	34	41	47	55	64	74	1.0295	0.8235	-0.0000	-0.0000	-0.0000	-0.060	0.030	0.000	0.030	0.000	0.050	130
200	3.41	4.80	6.08	7.15	8.09	8.79	9.40	6.08	6.35	6.50	6.59	6.63	-0.00	35	46	56	66	76	85	95	0.6964	0.7660	1.0001	1.2162	-0.0000	-0.060	0.031	0.000	0.029	0.000	0.073	200
230	3.09	4.41	5.62	6.69	7.60	8.31	8.94	5.75	5.98	6.14	6.30	6.31	6.31	33	46	56	66	76	84	92	0.6573	0.7680	0.9799	1.5546	2.0603	-0.058	0.031	0.015	0.012	0.015	0.063	230
300	2.58	3.54	4.68	5.79	6.70	7.42	8.03	5.69	5.90	6.08	6.25	6.39	6.42	44	58	72	84	97	109	121	0.3167	0.5560	0.5824	0.7199	0.8954	-0.060	0.032	0.000	0.028	0.000	0.071	300
330	3.09	3.67	4.30	5.03	5.75	6.31	6.82	5.80	5.95	6.09	6.25	6.31	6.37	53	72	91	107	124	140	157	0.0957	0.2069	0.2715	0.3125	0.3779	-0.070	0.031	0.015	0.024	0.015	0.174	330
400	2.75	3.53	4.25	4.89	5.49	6.00	6.45	5.88	6.07	6.21	6.37	6.44	6.49	34	47	59	70	81	91	103	0.2753	0.3852	0.5439	0.7321	0.6695	-0.069	0.032	0.000	0.037	0.000	0.059	400
430	2.19	3.15	4.06	4.82	5.59	6.11	6.55	5.75	5.99	6.20	6.37	6.40	6.44	29	40	51	61	70	79	89	0.4144	0.5578	1.0365	0.9116	0.9398	-0.064	0.033	0.000	0.031	0.000	0.037	430
500	3.59	4.43	5.12	5.63	6.10	6.46	6.80	5.69	5.82	5.95	5.99	6.01	6.02	33	42	52	61	71	82	96	0.3751	0.4593	0.5023	0.4217	0.3670	-0.059	0.033	0.000	0.026	0.000	0.055	500
530	4.19	4.91	5.52	6.00	6.40	6.74	7.03	5.99	6.03	6.09	6.11	6.14	6.18	35	45	54	60	66	71	75	0.4023	0.9553	1.1806	1.9340	3.8876	-0.030	0.031	0.015	-0.016	0.015	0.077	530
600	7.81	7.99	8.17	8.31	8.48	8.61	8.77	6.76	6.68	6.60	6.52	6.47	6.40	49	61	72	82	93	102	113	0.0733	0.0903	0.1378	0.2123	0.2603	0.024	0.026	-0.031	-0.019	-.031	0.121	600
630	10.29	10.38	10.45	10.51	10.58	10.60	10.63	7.07	6.92	6.80	6.69	6.58	6.48	123	146	167	185	202	218	234	0.0058	0.0093	0.0197	0.0026	0.0132	0.099	0.020	-0.076	-0.043	-.077	0.471	630
700	12.51	12.51	12.50	12.49	12.48	12.44	12.40	7.29	7.14	7.01	6.89	6.77	6.66	151	180	205	226	247	265	283	-0.0026	-0.0044	-0.0063	-0.0241	-0.0353	0.193	0.007	-0.121	-0.079	-.123	0.652	700
730	14.32	14.20	14.09	13.99	13.91	13.84	13.79	7.30	7.10	6.93	6.79	6.65	6.50	205	245	280	308	337	360	385	-0.0058	-0.0108	-0.0122	-0.0232	-0.0234	0.302	0.000	-0.212	-0.090	-.216	1.061	730
800	15.62	15.53	15.45	15.36	15.26	15.16	15.04	7.31	7.10	6.91	6.75	6.59	6.46	227	277	322	357	393	422	451	-0.0028	-0.0065	-0.0097	-0.0199	-0.0337	0.416	-0.007	-0.301	-0.108	-.308	1.401	800
830	16.71	16.64	16.58	16.50	16.41	16.33	16.25	7.60	7.32	7.11	6.92	6.75	6.60	242	294	339	378	414	446	477	-0.0025	-0.0049	-0.0092	-0.0138	-0.0215	0.522	-0.010	-0.360	-0.152	-.369	1.717	830
900	17.22	17.13	17.04	16.98	16.88	16.78	16.68	7.60	7.30	7.06	6.85	6.66	6.49	244	303	355	397	439	475	508	-0.0025	-0.0036	-0.0075	-0.0133	-0.0233	0.628	-0.015	-0.420	-0.193	-.431	1.685	900
930	18.60	18.46	18.31	18.20	18.08	17.95	17.83	7.52	7.19	6.91	6.67	6.42	6.20	245	303	355	395	435	468	500	-0.0037	-0.0064	-0.0098	-0.0206	-0.0301	0.734	-0.018	-0.525	-0.191	-.539	1.796	930
1000	19.27	19.12	19.00	18.89	18.75	18.62	18.48	7.68	7.30	6.99	6.69	6.42	6.18	232	284	332	370	407	440	470	-0.0038	-0.0072	-0.0136	-0.0210	-0.0393	0.814	-0.025	-0.553	-0.236	-.569	1.688	1000
1030	20.26	20.08	19.90	19.75	19.60	19.45	19.30	8.12	7.63	7.25	6.87	6.56	6.26	204	246	282	312	341	365	389	-0.0098	-0.0154	-0.0246	-0.0456	-0.0679	0.870	-0.033	-0.613	-0.224	-.632	1.385	1030
1100	20.92	20.78	20.52	20.37	20.21	20.07	19.94	8.31	7.81	7.42	7.05	6.72	6.42	188	228	264	293	319	341	361	-0.0129	-0.0165	-0.0319	-0.0522	-0.0876	0.920	-0.038	-0.657	-0.225	-.677	1.352	1100
1130	21.46	21.23	21.04	20.89	20.73	20.60	20.49	8.72	8.11	7.65	7.20	6.82	6.48	164	196	223	246	267	285	302	-0.0193	-0.0276	-0.0516	-0.0769	-0.1113	0.948	-0.044	-0.686	-0.218	-.709	0.855	1130
1200	22.00	21.76	21.54	21.39	21.22	21.10	20.98	8.84	8.21	7.71	7.23	6.86	6.50	148	177	202	222	242	258	274	-0.0251	-0.0374	-0.0604	-0.0913	-0.1358	0.959	-0.048	-0.700	-0.211	-.724	0.817	1200
1230	22.31	22.06	21.86	21.69	21.51	21.40	21.29	8.69	7.98	7.42	6.97	6.61	6.29	130	157	180	199	215	228	240	-0.0289	-0.0468	-0.0965	-0.1291	-0.2191	0.926	-0.051	-0.701	-0.174	-.724	0.644	1230
1300	22.98	22.72	22.52	22.38	22.22	22.11	22.00	8.31	7.59	7.01	6.55	6.18	5.82	136	162	185	204	222	237	251	-0.0290	-0.0418	-0.0705	-0.0978	-0.1669	0.946	-0.053	-0.670	-0.223	-.693	0.766	1300
1330	23.16	22.92	22.73	22.59	22.47	22.35	22.24	7.79	7.01	6.44	5.97	5.59	5.24	128	152	174	192	208	222	235	-0.0316	-0.0462	-0.0742	-0.1200	-0.1917	0.913	-0.056	-0.731	-0.126	-.755	0.703	1330
1400	23.90	23.70	23.52	23.39	23.27	23.18	23.09	7.62	6.97	6.43	5.97	5.61	5.30	103	120	136	149	162	174	185	-0.0540	-0.0829	-0.1114	-0.1328	-0.2247	0.839	-0.053	-0.701	-0.085	-.724	0.567	1400
1430	24.02	23.91	23.81	23.72	23.63	23.58	23.49	7.52	6.82	6.28	5.80	5.45	5.13	117	140	159	175	190	203	216	-0.0283	-0.0444	-0.0717	-0.0806	-0.1626	0.807	-0.049	-0.641	-0.117	-.662	0.739	1430
1500	24.11	24.01	23.93	23.89	23.81	23.76	23.70	7.50	6.82	6.30	5.85	5.51	5.23	109	128	145	157	169	178	187	-0.0314	-0.0545	-0.1020	-0.1656	-0.2508	0.609	-0.046	-0.492	-0.071	-.508	0.530	1500
1530*	22.99	23.10	23.21	23.29	23.36	23.41	23.47	7.38	6.78	6.30	5.89	5.55	5.25	102	123	142	156	171	182	193	0.0027	0.0027	0.0037	-0.0013	0.0243	0.394	-0.038	-0.404	0.048	-.416	0.413	1530
1600*	22.93	23.09	23.21	23.31	23.40	23.49	23.56	7.86	7.29	6.80	6.37	5.98	5.60	87	104	119	132	144	155	166	0.0076	0.0104	0.0175	0.0343	0.0209	0.308	-0.032	-0.330	0.054	-.339	0.305	1600
1630*	22.69	22.88	23.02	23.17	23.29	23.39	23.48	7.70	7.22	6.82	6.41	6.03	5.64	93	115	135	151	166	180	192	0.0085	0.0233	0.0258	0.0290	0.0432	0.242	-0.025	-0.254	0.037	-.261	0.383	1630
1700*	21.56	21.82	22.09	22.32	22.58	22.75	22.91	8.18	7.78	7.44	7.10	6.80	6.48	73	88	103	116	128	140	151	0.0468	0.0707	0.1450	0.1155	0.1846	0.132	-0.017	-0.179	0.064	-.184	0.275	1700
1730*	20.50	20.79	21.03	21.26	21.56	21.82	22.08	8.30	8.00	7.76	7.50	7.28	7.04	116	141	164	184	203	222	240	0.0186	0.0325	0.0726	0.0840	0.1384	0.065	-0.009	-0.150	0.094	-.154	0.474	1730
1800	19.80	20.00	20.20	20.39	20.59	20.80	21.02	8.02	7.92	7.81	7.68	7.51	7.33	171	205	236	265	294	321	350	0.0097	0.0139	0.0216	0.0340	0.0461	0.014	0.003	-0.106	0.089	-.108	1.112	1800
1830	18.99	19.19	19.39	19.58	19.79	19.99	20.20	7.53	7.40	7.30	7.19	7.09	6.98	145	173	200	224	248	271	296	0.0125	0.0205	0.0339	0.0470	0.0624	-0.013	0.001	-0.106	0.118	-.108	0.877	1830
1900	18.08	18.30	18.53	18.76	19.02	19.28	19.50	7.60	7.48	7.34	7.20	7.09	6.93	94	115	135	153	172	190	211	0.0269	0.0436	0.0671	0.1013	0.0899	-0.016	0.010	-0.061	0.067	-.062	0.416	1900
1930	17.13	17.42	17.70	17.97	18.25	18.52	18.80	7.49	7.35	7.22	7.10	6.98	6.82	72	91	111	128	146	164	182	0.0330	0.0588	0.0821	0.1052	0.1602	-0.023	0.010	-0.045	0.058	-.046	0.220	1930
2000	16.30	16.60	16.89	17.18	17.48	17.75	18.09	7.39	7.29	7.19	7.07	6.94	6.80	72	91	110	127	144	162	180	0.0389	0.0646	0.0993	0.1049	0.2000	-0.040	0.009	-0.045	0.076	-.046	0.272	2000
2030	14.50	14.74	15.01	15.28	15.58	15.89	16.24	6.94	6.87	6.80	6.73	6.67	6.60	100	124	146	166	186	207	229	0.0275	0.0443	0.0741	0.0931	0.1433	-0.079	0.016	-0.015	0.078	-.015	0.429	2030
2100	12.02	12.58	13.10	13.57	14.06	14.53	15.05	6.90	6.82	6.76	6.70	6.63	6.54	55	75	94	111	129	146	165	0.0727	0.1096	0.1528	0.2178	0.2878	-0.071	0.016	-0.045	0.100	-.046	0.183	2100
2130	11.36	12.08	12.72	13.30	13.87	14.38	14.89	6.88	6.80	6.73	6.66	6.59	6.52	36	55	73	90	107	124	142	0.1002	0.1356	0.1994	0.2369	0.3164	-0.055	0.017	-0.015	0.053	-.015	0.130	2130
2200	10.11	10.95	11.82	12.72	13.50	14.10	14.62	7.11	7.13	7.10	7.02	6.92	6.80	33	51	69	84	99	114	131	0.1396	0.2743	0.3521	0.3569	0.3572	-0.053	0.020	-0.015	0.048	-.015	0.098	2200
2230	9.50	10.40	11.23	11.90	12.55	13.10	13.60	6.99	7.00	6.69	6.93	6.85	6.78	36	53	70	84	99	114	131	0.1494	0.2209	0.3140	0.3293	0.3492	-0.063	0.025	0.000	0.038	0.000	0.094	2230
2300	8.35	9.49	10.35	11.00	11.55	12.02	12.54	6.94	7.01	7.00	6.95	6.85	6.72	25	39	52	64	78	91	108	0.2681	0.3121	0.2874	0.3725	0.3589	-0.055	0.027	0.015	0.013	0.015	0.058	2300
2330	7.75	8.42	9.10	9.80	10.62	11.38	12.00	6.73	6.80	6.80	6.78	6.72	6.67	31	52	72	90	108	126	146	0.0902	0.1503	0.2626	0.3211	0.3174	-0.061	0.025	0.000	0.036	0.000	0.079	2330

TIME	TEMPERATURE							ABSOLUTE HUMIDITY						WIND SPEED							RICHARDSONS NUMBER FOR INTERVALS					ENERGY BALANCE				FLUXES		TIME
12 JUL 66	DEGREES C							GRAMS PER CUBIC CM X 10**6						CM PER SEC												LY PER MIN				MM PER HR	DNS PER CM2	
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
1000	19.74	19.38	19.08	18.86	18.66	18.50	18.36	10.82	10.43	10.15	9.92	9.74	9.60	84	95	105	114	121	127	133	-0.1805	-0.2172	-0.4825	-0.6986	-0.9028	0.588	-0.030	-0.404	-0.154	-.416	0.263	1000
1030	20.15	19.84	19.55	19.33	19.15	18.98	18.84	11.10	10.70	10.37	10.10	9.89	9.71	108	123	135	145	153	160	168	-0.1222	-0.1807	-0.3467	-0.5523	-0.5257	0.588	-0.039	-0.388	-0.161	-.400	0.305	1030
1100	21.28	20.88	20.55	20.28	20.05	19.87	19.69	11.76	11.29	10.91	10.60	10.35	10.15	103	117	129	138	147	155	162	-0.1396	-0.2702	-0.3430	-0.4554	-0.8622	0.733	-0.045	-0.507	-0.181	-.524	0.300	1100
1130	21.62	21.23	20.89	20.60	20.35	20.14	19.94	12.19	11.67	11.27	10.92	10.63	10.40	165	192	215	233	252	268	283	-0.0396	-0.0723	-0.0841	-0.1326	-0.2095	0.821	-0.050	-0.566	-0.205	-.585	0.697	1130
1200	21.87	21.55	21.14	20.81	20.51	20.27	20.05	12.35	11.80	11.37	10.97	10.65	10.36	181	215	244	268	290	309	327	-0.0294	-0.0458	-0.0747	-0.1068	-0.1634	0.886	-0.055	-0.656	-0.175	-.678	0.777	1200
1230	22.10	21.75	21.43	21.16	20.91	20.70	20.51	12.45	11.88	11.43	11.05	10.73	10.46	179	213	243	267	289	308	326	-0.0226	-0.0391	-0.0636	-0.0956	-0.1428	0.897	-0.059	-0.656	-0.182	-.678	0.893	1230
1300	22.11	21.79	21.50	21.25	21.03	20.83	20.63	12.38	11.81	11.39	11.00	10.70	10.41	178	210	238	261	282	300	318	-0.0240	-0.0395	-0.0633	-0.1011	-0.1508	0.887	-0.061	-0.656	-0.170	-.678	0.779	1300
1330	22.63	22.30	22.00	21.74	21.50	21.29	21.06	12.55	11.98	11.50	11.10	10.75	10.41	171	199	224	244	263	280	296	-0.0309	-0.0554	-0.0832	-0.1213	-0.2200	0.855	-0.061	-0.670	-0.124	-.693	0.765	1330
1400	22.82	22.59	22.29	22.02	21.77	21.58	21.40	12.25	11.73	11.31	10.93	10.61	10.33	179	212	240	264	286	304	321	-0.0241	-0.0386	-0.0635	-0.0980	-0.1538	0.818	-0.058	-0.610	-0.150	-.631	0.997	1400
1430	22.95	22.76	22.49	22.25	22.02	21.84	21.67	12.38	11.81	11.38	11.00	10.68	10.41	158	184	207	226	244	260	275	-0.0336	-0.0562	-0.0886	-0.1188	-0.1873	0.759	-0.050	-0.596	-0.113	-.616	0.717	1430
1500	23.19	23.07	22.87	22.69	22.51	22.37	22.25	12.38	11.84	11.42	11.06	10.77	10.51	171	203	221	253	274	293	309	-0.0433	-0.0158	-0.0530	-0.0677	-0.1242	0.693	-0.043	-0.552	-0.098	-.570	0.893	1500
1530	23.65	23.57	23.41	23.25	23.10	22.98	22.89	12.31	11.85	11.45	11.10	10.80	10.50	171	203	221	253	274	293	310	-0.0353	-0.0143	-0.0458	-0.0608	-0.0933	0.615	-0.036	-0.508	-0.071	-.524	0.831	1530
1600	23.99	24.00	23.93	23.81	23.71	23.63	23.56	12.25	11.78	11.35	10.97	10.65	10.38	170	202	231	255	278	298	316	-0.0083	-0.0213	-0.0296	-0.0426	-0.0681	0.529	-0.030	-0.448	-0.051	-.462	0.967	1600
1630	23.85	23.92	23.88	23.80	23.73	23.66	23.61	12.26	11.82	11.47	11.15	10.86	10.60	159	189	215	237	259	278	296	-0.0078	-0.0182	-0.0243	-0.0418	-0.0548	0.431	-0.024	-0.388	-0.019	-.400	0.559	1630
1700	23.42	23.54	23.55	23.56	23.57	23.58	23.59	12.10	11.76	11.47	11.18	10.92	10.65	181	213	243	269	293	315	338	-0.0023	-0.0033	-0.0058	-0.0080	-0.0116	0.331	-0.018	-0.330	0.017	-.339	0.939	1700
1730	22.86	22.97	23.07	23.14	23.20	23.26	23.31	11.78	11.49	11.25	11.02	10.82	10.61	178	211	243	270	295	319	342	0.0028	0.0031	0.0041	0.0069	0.0069	0.228	-0.012	-0.285	0.069	-.293	1.001	1730
1800	21.93	22.08	22.20	22.32	22.41	22.50	22.58	11.41	11.20	11.04	10.86	10.70	10.55	206	244	278	307	338	365	395	0.0038	0.0076	0.0066	0.0121	0.0128	0.138	-0.007	-0.195	0.064	-.200	1.171	1800
1830	20.80	21.00	21.17	21.33	21.46	21.58	21.70	11.18	11.06	10.93	10.80	10.69	10.56	203	238	272	302	330	357	385	0.0066	0.0105	0.0142	0.0190	0.0257	0.049	-0.002	-0.136	0.089	-.139	1.182	1830
1900	19.20	19.54	19.84	20.06	20.27	20.44	20.60	10.80	10.70	10.61	10.53	10.45	10.35	177	211	242	268	296	320	346	0.0150	0.0206	0.0255	0.0369	0.0432	-0.031	0.003	-0.090	0.118	-.092	0.913	1900
1930	17.60	17.88	18.14	18.35	18.56	18.75	18.94	10.45	10.40	10.30	10.23	10.17	10.13	187	220	252	278	306	331	357	0.0125	0.0195	0.0258	0.0392	0.0551	-0.076	0.008	-0.054	0.122	-.055	0.925	1930
2000	16.33	16.61	16.83	17.02	17.20	17.37	17.50	10.09	10.05	10.01	9.96	9.92	9.89	194	230	263	293	322	349	377	0.0100	0.0139	0.0209	0.0306	0.0326	-0.085	0.012	-0.036	0.109	-.037	0.955	2000
2030	15.16	15.42	15.68	15.89	16.08	16.21	16.39	9.80	9.78	9.76	9.74	9.70	9.67	161	193	222	247	273	297	321	0.0156	0.0226	0.0283	0.0294	0.0623	-0.083	0.016	-0.015	0.082	-.015	0.664	2030
2100	14.47	14.71	14.93	15.11	15.29	15.43	15.59	9.71	9.70	9.69	9.67	9.63	9.60	167	198	227	253	278	302	327	0.0133	0.0181	0.0290	0.0318	0.0510	-0.086	0.019	-0.009	0.076	-.009	0.642	2100
2130	14.01	14.29	14.50	14.67	14.85	15.06	15.20	9.58	9.58	9.55	9.53	9.50	9.46	148	177	204	227	251	273	295	0.0148	0.0214	0.0316	0.0581	0.0569	-0.085	0.021	-0.022	0.086	-.022	0.521	2130
2200	13.61	13.89	14.11	14.30	14.50	14.66	14.80	9.43	9.40	9.39	9.38	9.37	9.38	146	174	200	223	246	268	291	0.0164	0.0244	0.0386	0.0448	0.0549	-0.085	0.023	-0.007	0.069	-.007	0.486	2200
2230	13.25	13.49	13.69	13.88	14.02	14.18	14.31	9.39	9.40	9.40	9.40	9.37	9.34	142	168	191	212	233	253	275	0.0196	0.0296	0.0327	0.0534	0.0534	-0.084	0.024	-0.018	0.078	-.018	0.523	2230
2300	13.02	13.23	13.42	13.59	13.71	13.82	13.95	9.38	9.37	9.37	9.35	9.34	9.32	159	187	214	238	261	284	307	0.0133	0.0203	0.0228	0.0282	0.0495	-0.084	0.025	-0.007	0.066	-.007	0.647	2300
2330	12.50	12.71	12.91	13.08	13.21	13.35	13.48	9.27	9.27	9.28	9.28	9.27	9.27	130	154	177	197	217	235	254	0.0195	0.0295	0.0335	0.0588	0.0742	-0.080	0.025	-0.000	0.055	-.000	0.415	2330
2400	12.50	12.70	12.88	13.01	13.14	13.25	13.36	9.26	9.27	9.28	9.26	9.26	9.25	133	157	180	200	220	238	258	0.0177	0.0226	0.0328	0.0467	0.0560	-0.080	0.026	-0.000	0.054	-.000	0.590	2400

TIME	TEMPERATURE DEGREES C							ABSOLUTE HUMIDITY GRAMS PER CUBIC CM X 10**6						WIND SPEED CM PER SEC							RICHARDSONS NUMBER FOR INTERVALS					ENERGY BALANCE LY PER MIN				FLUXES MM PER HR	FLUXES DNS PER CM2	TIME
13 JUL 66																														
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
30	11.82	12.11	12.37	12.55	12.71	12.84	12.95	9.11	9.14	9.15	9.17	9.20	9.20	83	99	115	128	142	155	168	0.0534	0.0740	0.0858	0.1094	0.1344	-0.077	0.026	0.026	0.025	0.026	0.251	30
100*	11.80	12.09	12.30	12.47	12.60	12.69	12.78	9.21	9.23	9.25	9.27	9.27	9.29	91	109	126	141	156	169	184	0.0381	0.0530	0.0610	0.0734	0.0852	-0.077	0.026	0.006	0.045	0.006	0.236	100
130*	11.72	12.00	12.22	12.40	12.53	12.62	12.70	9.18	9.20	9.21	9.22	9.23	9.25	88	105	122	137	152	166	181	0.0399	0.0556	0.0604	0.0643	0.0761	-0.076	0.026	0.015	0.035	0.015	0.178	130
200*	11.55	11.81	11.92	12.05	12.20	12.33	12.48	9.22	9.25	9.27	9.29	9.30	9.30	96	114	132	147	162	177	191	0.0183	0.0408	0.0703	0.0806	0.1583	-0.076	0.026	0.015	0.035	0.015	0.221	200
230*	11.43	11.66	11.84	12.00	12.13	12.27	12.39	9.17	9.20	9.22	9.24	9.26	9.28	88	106	124	139	155	169	184	0.0295	0.0500	0.0537	0.1005	0.1129	-0.072	0.026	0.030	0.016	0.031	0.193	230
300	11.39	11.61	11.81	11.97	12.10	12.19	12.27	9.23	9.25	9.28	9.29	9.30	9.30	97	116	134	149	165	180	195	0.0324	0.0504	0.0532	0.0561	0.0736	-0.071	0.026	0.030	0.015	0.031	0.249	300
330	10.71	11.03	11.31	11.52	11.71	11.86	11.99	9.00	9.08	9.12	9.16	9.19	9.20	56	69	82	93	104	114	124	0.0894	0.1232	0.1676	0.2131	0.2722	-0.062	0.025	0.009	0.028	0.009	0.097	330
400	9.92	10.56	11.04	11.37	11.63	11.80	11.92	8.93	9.04	9.12	9.18	9.20	9.21	28	33	38	42	46	50	55	1.0299	1.4759	1.7399	1.4927	1.0062	-0.050	0.024	0.006	0.020	0.006	0.046	400
430	8.17	9.49	10.38	10.94	11.36	11.65	11.85	8.59	8.86	9.02	9.12	9.16	9.20	21	23	25	27	28	30	31	12.0865	10.0936	45.0638	10.2206	42.6160	-0.040	0.024	0.012	0.004	0.012	0.052	430
500*	8.34	9.16	9.84	10.34	10.74	11.04	11.30	8.39	8.59	8.73	8.85	8.97	9.06	25	31	37	42	47	52	57	1.0262	1.4433	1.7342	1.7553	2.2639	-0.035	0.023	0.003	0.009	0.003	0.059	500
530*	8.60	9.21	9.76	10.20	10.61	10.95	11.26	8.41	8.64	8.78	8.90	9.00	9.06	19	23	28	33	38	44	51	1.2148	1.2771	1.7766	1.3628	1.3497	-0.018	0.022	0.000	-0.004	0.000	0.050	530
600	10.97	11.10	11.22	11.30	11.39	11.46	11.52	9.11	9.12	9.12	9.11	9.10	9.08	51	61	71	79	87	94	102	0.0630	0.0865	0.1437	0.1937	0.1855	0.019	0.018	0.000	-0.037	0.000	0.138	600
630	12.78	12.80	12.80	12.78	12.76	12.74	12.70	9.70	9.63	9.58	9.52	9.47	9.42	91	107	122	134	146	156	165	-0.0023	-0.0129	-0.0204	-0.0372	-0.1199	0.083	0.013	-0.030	-0.066	-.031	0.209	630
700	14.23	14.18	14.13	14.08	14.03	13.97	13.90	10.31	10.17	10.05	9.92	9.82	9.74	108	128	146	160	175	187	199	-0.0111	-0.0234	-0.0313	-0.0706	-0.1162	0.166	0.005	-0.120	-0.051	-.123	0.150	700
730	15.60	15.47	15.35	15.25	15.15	15.05	14.95	10.62	10.41	10.25	10.09	9.95	9.83	107	126	143	157	170	182	193	-0.0266	-0.0428	-0.0745	-0.1138	-0.1984	0.259	-0.002	-0.150	-0.107	-.154	0.260	730
800	17.05	16.84	16.64	16.47	16.32	16.18	16.05	11.07	10.81	10.60	10.42	10.28	10.15	98	114	129	142	154	164	174	-0.0538	-0.0806	-0.1246	-0.2179	-0.3037	0.354	-0.009	-0.211	-0.134	-.216	0.188	800
830	18.40	18.08	17.80	17.59	17.41	17.25	17.12	11.65	11.34	11.10	10.89	10.72	10.57	103	121	138	151	164	174	184	-0.0571	-0.0981	-0.1266	-0.2504	-0.3088	0.445	-0.017	-0.270	-0.158	-.277	0.345	830
900	19.60	19.28	18.99	18.75	18.52	18.34	18.16	12.17	11.80	11.51	11.27	11.07	10.90	119	140	157	171	185	196	208	-0.0602	-0.0972	-0.1370	-0.2336	-0.2884	0.533	-0.024	-0.329	-0.180	-.339	0.426	900
930	20.50	20.17	19.87	19.63	19.39	19.20	19.02	12.33	11.89	11.58	11.31	11.10	10.94	97	112	125	136	147	155	163	-0.1088	-0.1588	-0.2334	-0.4649	-0.6429	0.621	-0.031	-0.403	-0.187	-.416	0.364	930
1000	21.20	20.81	20.47	20.19	19.94	19.71	19.52	12.93	12.41	12.05	11.75	11.50	11.32	121	142	160	175	189	200	210	-0.0648	-0.0994	-0.1514	-0.2966	-0.4371	0.695	-0.040	-0.447	-0.208	-.462	0.531	1000
1030	22.27	21.87	21.56	21.22	20.95	20.72	20.52	13.22	12.66	12.25	11.92	11.66	11.45	113	132	148	161	174	184	194	-0.0771	-0.1588	-0.1897	-0.3600	-0.4650	0.763	-0.048	-0.521	-0.194	-.539	0.409	1030
1100	23.15	22.76	22.42	22.15	21.90	21.70	21.53	13.40	12.76	12.30	11.93	11.64	11.43	106	119	131	141	151	159	167	-0.1514	-0.2261	-0.3058	-0.5079	-0.6308	0.793	-0.055	-0.550	-0.188	-.570	0.284	1100
1130	24.05	23.65	23.30	23.05	22.81	22.63	22.46	13.62	12.97	12.49	12.09	11.78	11.50	90	102	112	120	128	135	142	-0.2233	-0.3349	-0.4683	-0.6159	-0.8649	0.843	-0.058	-0.594	-0.191	-.616	0.278	1130
1200	24.94	24.56	24.23	23.96	23.71	23.51	23.33	14.01	13.31	12.79	12.35	12.00	11.72	119	141	159	174	188	199	209	-0.0669	-0.1028	-0.1608	-0.2776	-0.4430	0.873	-0.059	-0.624	-0.190	-.647	0.422	1200
1230	24.88	24.64	24.40	24.22	24.05	23.91	23.78	13.62	12.98	12.45	12.01	11.64	11.32	156	183	208	228	248	266	282	-0.0268	-0.0431	-0.0588	-0.0802	-0.1387	0.793	-0.060	-0.639	-0.094	-.662	0.722	1230
1300	25.50	25.25	25.02	24.84	24.66	24.50	24.35	13.90	13.18	12.55	12.04	11.61	11.25	154	183	208	228	248	266	283	-0.0269	-0.0456	-0.0639	-0.0921	-0.1407	0.884	-0.060	-0.713	-0.111	-.739	0.674	1300
1330	25.96	25.74	25.54	25.37	25.22	25.10	24.98	13.53	12.85	12.30	11.82	11.41	11.04	172	205	235	259	282	303	323	-0.0167	-0.0291	-0.0418	-0.0547	-0.0874	0.869	-0.058	-0.713	-0.098	-.739	0.891	1330
1400	26.18	26.11	26.00	25.89	25.79	25.70	25.62	13.02	12.42	11.90	11.43	11.01	10.61	210	250	287	319	350	377	404	-0.0073	-0.0122	-0.0177	-0.0279	-0.0383	0.829	-0.051	-0.714	-0.064	-.739	1.428	1400
1430	25.79	25.76	25.71	25.66	25.63	25.59	25.56	12.27	11.78	11.34	10.92	10.55	10.18	257	310	357	397	436	470	503	-0.0028	-0.0048	-0.0061	-0.0110	-0.0157	0.786	-0.042	-0.730	-0.014	-.755	2.342	1430
1500	25.62	25.65	25.67	25.69	25.70	25.70	25.70	11.76	11.36	11.00	10.64	10.30	9.95	295	355	407	454	498	539	580	-0.0008	-0.0010	-0.0023	-0.0041	-0.0063	0.719	-0.028	-0.731	0.040	-.755	2.750	1500
1530	25.46	25.51	25.55	25.59	25.61	25.63	25.65	11.71	11.34	11.01	10.69	10.39	10.08	292	355	410	457	506	549	593	-0.0003	-0.0003	-0.0012	-0.0018	-0.0028	0.634	-0.018	-0.672	0.056	-.693	2.352	1530
1600	25.07	25.17	25.26	25.34	25.40	25.46	25.52	11.45	11.07	10.74	10.40	10.10	9.78	295	355	409	457	504	546	589	0.0005	0.0009	0.0004	0.0011	0.0012	0.544	-0.010	-0.628	0.094	-.647	2.464	1600
1630	24.42	24.54	24.65	24.74	24.82	24.89	24.96	11.30	10.96	10.69	10.38	10.11	9.85	286	345	398	444	489	528	569	0.0010	0.0015	0.0016	0.0025	0.0036	0.453	-0.004	-0.538	0.089	-.554	2.299	1630
1700	23.42	23.60	23.75	23.87	23.98	24.06	24.14	11.16	10.90	10.66	10.42	10.19	9.96	285	345	397	441	485	525	567	0.0020	0.0029	0.0038	0.0037	0.0051	0.343	0.002	-0.433	0.088	-.445	2.115	1700
1730	22.40	22.61	22.80	22.95	23.08	23.18	23.28	10.74	10.53	10.33	10.12	9.92	9.71	274	330	379	421	464	502	540	0.0033	0.0045	0.0053	0.0064	0.0094	0.236	0.006	-0.345	0.103	-.354	2.171	1730
1800	21.67	21.90	22.12	22.29	22.44	22.56	22.68	10.59	10.40	10.23	10.05	9.88	9.69	249	300	347	387	425	460	497	0.0043	0.0060	0.0085	0.0103	0.0134	0.132	0.010	-0.255	0.113	-.262	1.870	1800
1830	20.59	20.83	21.04	21.21	21.38	21.52	21.68	10.15	10.03	9.90	9.75	9.62	9.50	256	310	356	400	440	477	515	0.0046	0.0052	0.0093	0.0118	0.0197	0.051	0.012	-0.181	0.118	-.185	1.876	1830
1900	18.84	19.12	19.37	19.57	19.79	19.97	20.15	9.86	9.75	9.64	9.54	9.45	9.37	224	268	310	346	383	416	450	0.0067	0.0095	0.0151	0.0206	0.0293	-0.038	0.014	-0.136	0.160	-.139	1.408	1900
1930	17.38	17.67	17.94	18.16	18.39	18.59	18.77	9.52	9.46	9.40	9.32	9.25	9.19	217	260	299	335	370	402	435	0.0087	0.0110	0.0181	0.0250	0.0318	-0.093	0.016	-0.090	0.167	-.092	1.277	1930
2000	16.10	16.39	16.62	16.82	17.01	17.19	17.39	9.20	9.15	9.10	9.02	8.97	8.91	232	279	322	360	398	433	468	0.0061	0.0091	0.0126	0.0191	0.0318	-0.109	0.018	-0.031	0.122	-.032	1.552	2000
2030	15.22	15.42	15.62	15.82	16.02	16.22	16.41	9.00	8.96	8.90	8.85	8.81	8.80	224	269	311	348	385	420	455	0.0056	0.0095	0.0144	0.0216	0.0314	-0.111	0.020	-0.030	0.121	-.031	1.308	2030
2100	14.24	14.45	14.66	14.86	15.08	15.28	15.48	9.03	9.00	8.96	8.90	8.86	8.83	182	219	254	285	316	345	375	0.0086	0.0138	0.0226	0.0315	0.0445	-0.108	0.021	-0.030	0.117	-.031	0.964	2100
2130	13.13	13.33	13.53	13.72	13.92	14.12	14.34	9.07	9.06	9.05	9.02	9.00	8.98	155	187	218	245	272	297	322	0.0106	0.0178	0.0276	0.0433	0.0714	-0.106	0.022	-0.015	0.099	-.015	0.644	2130
2200	12.81	13.04	13.21	13.38	13.54	13.72	13.92	9.13	9.12	9.10	9.09	9.07	9.05	168	204	236	264	292	318	345	0.0085	0.0147	0.0208	0.0360	0.0557	-0.105	0.023	-0.030	0.112	-.031	0.759	2200
2230	12.09	12.30	12.51	12.71	12.91	13.11	13.38	9.04	9.04	9.03	9.01	9.00	8.98	132	158	184	206	229	250	274	0.0161	0.0283	0.0385	0.0620	0.0957	-0.102	0.025	-0.003	0.080	-.003	0.414	2230
2300	12.32	12.51	12.70	12.88	13.06	13.22	13.43	9.01	9.00	8.98	8.96	8.93	8.90	177	210	240	269	296	322	349	0.0108	0.0145	0.0251	0.0317	0.0582	-0.105	0.026	-0.012	0.091	-.012	0.828	2300
2330	12.06	12.22	12.39	12.52	12.69	12.83	13.00	9.00	9.00	9.00	8.98	8.96	8.93	184	217	249	277	305	333	362	0.0086	0.0114	0.0220	0.0241	0.0407	-0.104	0.026	-0.015	0.093	-.015	0.846	2330
2400	12.06	12.20	12.33	12.49	12.63	12.76	12.93	9.07	9.06	9.05	9.03	9.02	9.00	214	252	287	318	351	382	415	0.0054	0.0114	0.0130	0.0184	0.0317	-0.104	0.026	0.000	0.078	0.000	1.141	2400

TIME	TEMPERATURE							ABSOLUTE HUMIDITY						WIND SPEED							RICHARDSONS NUMBER				ENERGY BALANCE				FLUXES		TIME
14 JUL 66	DEGREES C							GRAMS PER CUBIC CM X 10**6						CM PER SEC							FOR INTERVALS				LY PER MIN				MM PER HR	DNS PER CM2	
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
30	11.80	11.92	12.06	12.19	12.33	12.48	12.64	9.10	9.10	9.10	9.08	9.06	9.05	206	241	275	305	335	365	390	0.0063	0.0100	0.0158	0.0226	0.0525	-0.102	0.027	-0.006	0.081	-.006	1.086	30
100	11.76	11.92	12.07	12.18	12.31	12.42	12.53	9.22	9.22	9.22	9.21	9.20	9.16	210	247	280	311	342	371	403	0.0071	0.0079	0.0138	0.0178	0.0211	-0.103	0.027	-0.015	0.091	-.015	1.233	100
130	11.60	11.76	11.90	12.01	12.13	12.23	12.34	9.17	9.19	9.20	9.19	9.18	9.16	198	236	272	303	335	365	390	0.0057	0.0080	0.0120	0.0151	0.0355	-0.101	0.027	-0.006	0.080	-.006	1.218	130
200	11.14	11.28	11.40	11.51	11.63	11.77	11.90	9.14	9.14	9.15	9.15	9.13	9.13	170	205	237	265	294	320	347	0.0061	0.0098	0.0148	0.0281	0.0370	-0.098	0.027	0.012	0.059	0.012	0.937	200
230	11.07	11.20	11.32	11.43	11.57	11.70	11.83	9.13	9.13	9.13	9.12	9.12	9.10	182	218	252	282	312	338	367	0.0054	0.0085	0.0160	0.0266	0.0314	-0.097	0.027	0.015	0.055	0.015	1.016	230
300	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	9.14	9.15	9.14	9.13	9.12	9.10	197	235	270	302	337	362	391	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.097	0.027	0.000	0.070	0.000	1.303	300
330	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	9.01	9.03	9.03	9.02	9.01	9.00	172	205	237	264	291	316	343	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.096	0.027	0.015	0.054	0.015	0.981	330
400	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	9.00	9.00	9.00	9.00	9.00	9.00	202	242	279	311	344	374	404	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.099	0.027	0.015	0.057	0.015	1.278	400
430	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	8.98	8.99	8.99	8.97	8.96	8.94	197	236	272	304	335	365	395	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.099	0.026	0.000	0.073	0.000	1.204	430
500	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	8.81	8.83	8.84	8.85	8.84	8.84	152	182	210	234	258	281	304	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.094	0.025	0.006	0.063	0.006	0.722	500
530	10.39	10.53	10.65	10.76	10.89	11.02	11.14	8.83	8.84	8.85	8.84	8.84	8.82	144	174	201	224	249	270	294	0.0087	0.0146	0.0214	0.0408	0.0423	-0.075	0.024	0.015	0.036	0.015	0.669	530
600	11.30	11.38	11.46	11.54	11.61	11.67	11.73	9.14	9.11	9.10	9.09	9.06	9.02	86	104	122	136	151	164	179	0.0121	0.0277	0.0316	0.0457	0.0502	-0.017	0.021	-0.022	0.018	-.022	0.217	600
630	12.61	12.61	12.60	12.59	12.58	12.57	12.55	9.45	9.40	9.35	9.30	9.20	9.15	97	118	136	152	165	177	190	-0.0027	-0.0046	-0.0104	-0.0230	-0.0330	0.066	0.016	-0.030	-0.052	-.031	0.326	630
700	13.94	13.84	13.74	13.66	13.58	13.51	13.44	9.90	9.77	9.66	9.55	9.46	9.40	97	117	135	150	164	177	189	-0.0188	-0.0291	-0.0502	-0.0672	-0.1123	0.142	0.012	-0.090	-0.064	-.092	0.334	700
730	15.25	15.06	14.90	14.75	14.62	14.51	14.40	10.10	9.92	9.76	9.64	9.54	9.44	88	103	116	127	138	146	154	-0.0563	-0.0976	-0.1247	-0.2656	-0.3985	0.249	0.006	-0.150	-0.105	-.154	0.277	730
800	16.29	16.04	15.83	15.65	15.47	15.34	15.22	10.12	9.89	9.73	9.61	9.51	9.44	60	68	75	81	86	91	95	-0.2534	-0.3842	-0.8069	-0.7877	-1.6639	0.341	-0.001	-0.210	-0.130	-.216	0.237	800
830	17.51	17.20	16.93	16.72	16.54	16.38	16.25	10.33	10.05	9.85	9.69	9.55	9.44	62	70	76	81	85	88	91	-0.4389	-0.6489	-1.2936	-2.7220	-3.3061	0.450	-0.008	-0.269	-0.173	-.277	0.169	830
900	18.70	18.35	18.06	17.82	17.61	17.45	17.30	10.94	10.59	10.30	10.06	9.89	9.75	65	74	81	87	91	95	99	-0.3529	-0.5303	-1.5542	-1.5637	-2.1641	0.537	-0.015	-0.329	-0.193	-.339	0.157	900
930	19.90	19.47	19.11	18.85	18.61	18.42	18.25	11.61	11.20	10.86	10.56	10.34	10.15	90	102	112	121	129	136	143	-0.2123	-0.2579	-0.4490	-0.6122	-0.8179	0.624	-0.023	-0.373	-0.228	-.385	0.278	930
1000	20.86	20.45	20.10	19.84	19.60	19.40	19.24	12.00	11.50	11.15	10.82	10.55	10.34	92	106	118	128	136	144	150	-0.1482	-0.2094	-0.4549	-0.5041	-1.0709	0.705	-0.032	-0.462	-0.211	-.477	0.266	1000
1030	21.77	21.37	21.04	20.77	20.54	20.36	20.18	12.10	11.53	11.08	10.70	10.40	10.20	89	104	116	125	133	140	146	-0.1446	-0.2785	-0.4498	-0.6144	-1.1722	0.773	-0.040	-0.521	-0.212	-.539	0.265	1030
1100	22.70	22.38	22.05	21.74	21.42	21.23	21.04	12.58	11.90	11.39	10.94	10.58	10.32	110	132	150	164	177	187	195	-0.0667	-0.1316	-0.2296	-0.3258	-0.7173	0.826	-0.048	-0.581	-0.197	-.601	0.317	1100
1130	23.45	23.03	22.69	22.43	22.20	22.02	21.85	12.60	11.92	11.34	10.82	10.44	10.17	105	125	142	155	168	177	186	-0.0764	-0.1368	-0.1822	-0.3901	-0.5200	0.860	-0.055	-0.639	-0.166	-.662	0.391	1130
1200	24.11	23.70	23.35	23.09	22.86	22.67	22.50	12.67	11.92	11.37	10.90	10.50	10.18	126	153	175	193	210	223	236	-0.0477	-0.0703	-0.1038	-0.1970	-0.2577	0.890	-0.059	-0.683	-0.148	-.708	0.589	1200
1230	24.79	24.42	24.10	23.86	23.65	23.49	23.34	12.81	12.11	11.52	10.95	10.47	10.11	141	168	192	211	230	246	260	-0.0368	-0.0605	-0.0816	-0.1206	-0.2077	0.896	-0.062	-0.698	-0.136	-.724	0.673	1230
1300	25.00	24.84	24.65	24.45	24.25	24.09	23.94	12.96	12.25	11.59	11.01	10.55	10.18	155	188	218	241	263	281	300	-0.0164	-0.0376	-0.0591	-0.0939	-0.1135	0.880	-0.063	-0.713	-0.104	-.739	0.763	1300
1330	25.31	25.16	25.01	24.86	24.65	24.49	24.35	12.38	11.66	11.10	10.60	10.16	9.75	158	189	217	240	260	278	296	-0.0164	-0.0294	-0.0709	-0.0926	-0.1239	0.858	-0.062	-0.713	-0.083	-.739	0.790	1330
1400	25.61	25.51	25.39	25.27	25.13	24.99	24.88	12.35	11.66	11.10	10.59	10.13	9.70	155	187	215	239	260	278	296	-0.0142	-0.0235	-0.0489	-0.0857	-0.1074	0.817	-0.055	-0.684	-0.078	-.708	0.890	1400
1430	26.02	25.98	25.93	25.86	25.76	25.68	25.61	11.52	10.80	10.23	9.74	9.31	8.93	155	188	219	243	267	287	306	-0.0082	-0.0180	-0.0300	-0.0481	-0.0702	0.773	-0.046	-0.684	-0.043	-.708	0.833	1430
1500*	26.01	26.06	26.10	26.13	26.15	26.16	26.16	10.90	10.29	9.79	9.34	8.93	8.53	174	212	246	276	305	330	357	-0.0023	-0.0034	-0.0058	-0.0112	-0.0166	0.702	-0.038	-0.656	-0.008	-.678	0.901	1500
1530	25.99	26.03	26.06	26.08	26.10	26.11	26.12	11.12	10.50	10.01	9.55	9.16	8.79	170	203	234	259	285	308	331	-0.0033	-0.0058	-0.0074	-0.0124	-0.0175	0.617	-0.031	-0.596	0.010	-.616	0.993	1530
1600	25.66	25.74	25.77	25.81	25.87	25.95	26.04	11.45	10.96	10.54	10.12	9.73	9.35	191	230	267	298	330	359	390	-0.0016	-0.0017	-0.0004	0.0032	0.0065	0.529	-0.024	-0.544	0.039	-.561	1.225	1600
1630	25.53	25.63	25.71	25.78	25.84	25.90	25.95	11.60	11.10	10.65	10.18	9.77	9.41	151	183	211	235	260	282	307	0.0002	0.0001	-0.0019	-0.0008	-0.0016	0.429	-0.018	-0.442	0.031	-.456	0.712	1630
1700	25.00	25.15	25.25	25.35	25.48	25.59	25.70	11.29	10.87	10.51	10.16	9.84	9.50	165	200	233	261	287	314	339	0.0016	0.0038	0.0112	0.0111	0.0183	0.341	-0.012	-0.374	0.045	-.385	0.910	1700
1730	24.40	24.65	24.86	25.04	25.21	25.36	25.51	10.95	10.61	10.31	10.02	9.74	9.45	175	212	245	274	301	327	353	0.0072	0.0106	0.0171	0.0209	0.0309	0.231	-0.006	-0.314	0.089	-.323	1.029	1730
1800	23.19	23.46	23.70	23.90	24.10	24.26	24.42	10.89	10.65	10.43	10.21	10.01	9.80	195	235	272	305	337	367	398	0.0074	0.0102	0.0162	0.0191	0.0265	0.130	0.000	-0.240	0.110	-.246	1.276	1800
1830	21.60	21.88	22.13	22.34	22.55	22.75	22.94	10.01	9.84	9.69	9.53	9.37	9.22	205	248	282	322	355	387	420	0.0097	0.0078	0.0171	0.0229	0.0307	0.038	0.006	-0.204	0.160	-.209	1.334	1830
1900	19.95	20.28	20.59	20.85	21.10	21.35	21.56	9.41	9.29	9.17	9.05	8.94	8.82	185	223	257	289	320	349	380	0.0127	0.0159	0.0243	0.0372	0.0401	-0.039	0.010	-0.150	0.179	-.154	0.907	1900
1930	18.04	18.45	18.84	19.16	19.49	19.76	20.05	9.11	9.04	8.96	8.87	8.78	8.69	125	155	183	207	232	255	278	0.0245	0.0361	0.0512	0.0653	0.1054	-0.086	0.014	-0.042	0.114	-.043	0.567	1930
2000	15.68	16.06	16.42	16.78	17.15	17.51	17.95	9.10	9.04	8.99	8.92	8.86	8.78	94	115	137	157	177	198	220	0.0370	0.0599	0.0916	0.1080	0.1797	-0.089	0.017	-0.025	0.097	-.025	0.322	2000
2030	14.73	15.12	15.50	15.86	16.21	16.59	17.02	9.13	9.09	9.05	9.00	8.95	8.90	100	122	144	164	185	206	229	0.0396	0.0604	0.0794	0.1150	0.1628	-0.090	0.020	-0.022	0.092	-.022	0.427	2030
2100	14.66	15.03	15.41	15.76	16.10	16.42	16.80	9.03	8.99	8.95	8.90	8.84	8.78	91	114	137	157	178	200	224	0.0362	0.0587	0.0771	0.0875	0.1314	-0.089	0.022	-0.006	0.073	-.006	0.173	2100
2130	12.92	13.52	14.10	14.62	15.19	15.70	16.25	8.90	8.98	8.96	8.82	8.77	8.71	60	77	95	111	129	147	168	0.0939	0.1383	0.1740	0.2117	0.2507	-0.076	0.024	-0.003	0.055	-.003	0.085	2130
2200	12.59	13.09	13.56	14.00	14.48	14.95	15.27	8.82	8.81	8.79	8.76	8.74	8.71	65	83	102	118	136	151	171	0.0669	0.1172	0.1509	0.2839	0.1617	-0.076	0.025	-0.000	0.051	-.000	0.093	2200
2230	12.38	12.81	13.25	13.62	14.02	14.42	14.82	8.78	8.77	8.75	8.72	8.70	8.67	63	82	100	117	135	151	171	0.0698	0.0873	0.1257	0.2125	0.2030	-0.077	0.026	-0.000	0.051	-.000	0.124	2230

TIME	TEMPERATURE							ABSOLUTE HUMIDITY						WIND SPEED							RICHARDSONS NUMBER					ENERGY BALANCE			FLUXES		TIME
2 MAY 67	DEGREES C							GRAMS PER CUBIC CM X 10**6						CM PER SEC							FOR INTERVALS					LY PER MIN			MM PER HR	DNS PER CM2	
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
900	16.27	15.98	15.73	15.52	15.31	15.14	14.96	9.05	8.76	8.51	8.31	8.16	8.04	140	162	180	194	206	217	227	-0.0459	-0.0854	-0.1694	-0.2158	-0.4036	0.528	-0.052	-0.298	-0.178	-.305	0.460	900
930	17.47	17.21	16.97	16.76	16.53	16.35	16.15	8.93	8.58	8.30	8.05	7.85	7.68	165	193	216	234	249	263	275	-0.0279	-0.0524	-0.1204	-0.1447	-0.3177	0.628	-0.058	-0.358	-0.212	-.367	0.572	930
1000	18.37	18.06	17.80	17.57	17.35	17.16	16.96	9.10	8.71	8.41	8.15	7.95	7.77	141	163	181	197	210	222	232	-0.0495	-0.0723	-0.1548	-0.2059	-0.4595	0.708	-0.072	-0.405	-0.231	-.416	0.484	1000
1030	19.04	18.72	18.44	18.19	17.96	17.76	17.56	9.22	8.79	8.45	8.18	7.96	7.77	120	136	149	159	169	177	185	-0.1026	-0.2022	-0.2728	-0.4899	-0.7214	0.785	-0.089	-0.466	-0.229	-.480	0.363	1030
1100	19.60	19.32	19.08	18.87	18.66	18.50	18.32	9.14	8.66	8.30	8.00	7.79	7.60	120	137	150	160	169	176	183	-0.0927	-0.1768	-0.3167	-0.5246	-0.8577	0.839	-0.114	-0.499	-0.226	-.514	0.362	1100
1130	19.91	19.64	19.40	19.21	19.04	18.88	18.71	8.99	8.46	8.05	7.74	7.49	7.29	107	123	135	144	153	159	165	-0.1112	-0.2076	-0.2684	-0.7351	-1.1182	0.884	-0.091	-0.537	-0.256	-.554	0.363	1130
1200	20.48	20.15	19.86	19.64	19.44	19.25	19.08	8.72	8.15	7.69	7.31	7.04	6.79	113	130	142	151	159	166	172	-0.1307	-0.2384	-0.4028	-0.6299	-1.1581	0.908	-0.116	-0.547	-0.245	-.564	0.417	1200
1230	20.65	20.40	20.17	20.00	19.84	19.71	19.58	8.14	7.60	7.17	6.83	6.59	6.39	84	96	104	110	115	119	122	-0.2432	-0.4346	-0.8455	-1.3866	-3.5671	0.904	-0.109	-0.567	-0.228	-.585	0.229	1230
1300	21.41	21.11	20.86	20.66	20.47	20.30	20.14	8.80	8.19	7.71	7.31	7.01	6.75	121	143	160	173	183	193	202	-0.0591	-0.1073	-0.2502	-0.2871	-0.4923	0.890	-0.106	-0.576	-0.209	-.594	0.523	1300
1330	21.60	21.31	21.08	20.91	20.73	20.59	20.44	8.00	7.45	7.05	6.70	6.45	6.25	85	97	106	113	119	123	127	-0.1928	-0.3128	-0.6460	-1.4803	-2.2537	0.858	-0.103	-0.588	-0.167	-.607	0.255	1330
1400	21.84	21.54	21.28	21.08	20.89	20.73	20.55	8.29	7.70	7.21	6.85	6.56	6.30	113	132	145	154	164	172	178	-0.1030	-0.2249	-0.2440	-0.4241	-1.2181	0.807	-0.097	-0.543	-0.167	-.561	0.303	1400
1430	21.25	21.04	20.86	20.73	20.59	20.49	20.38	8.05	7.60	7.25	6.95	6.71	6.55	112	129	144	156	167	177	184	-0.0550	-0.0845	-0.1530	-0.1814	-0.5479	0.632	-0.078	-0.445	-0.109	-.459	0.413	1430
1500	20.39	20.34	20.28	20.24	20.18	20.12	20.06	9.09	8.68	8.31	8.02	7.77	7.55	164	190	213	232	249	264	280	-0.0114	-0.0175	-0.0357	-0.0577	-0.0726	0.501	-0.046	-0.402	-0.054	-.413	0.620	1500
1530	21.05	20.91	20.79	20.68	20.56	20.46	20.36	9.80	9.37	9.00	8.68	8.40	8.13	193	226	256	281	303	322	341	-0.0102	-0.0176	-0.0347	-0.0524	-0.0779	0.578	-0.050	-0.431	-0.097	-.444	0.929	1530
1600	20.60	20.51	20.44	20.36	20.29	20.23	20.15	9.35	8.99	8.65	8.38	8.13	7.90	193	225	254	278	300	320	340	-0.0074	-0.0151	-0.0228	-0.0325	-0.0573	0.462	-0.039	-0.371	-0.052	-.382	0.730	1600
1630	20.10	20.08	20.06	20.05	20.03	20.01	19.98	9.50	9.21	8.95	8.70	8.48	8.26	200	232	262	287	313	335	356	-0.0035	-0.0052	-0.0084	-0.0145	-0.0285	0.354	-0.026	-0.321	-0.007	-.330	0.825	1630
1700	19.35	19.41	19.46	19.50	19.53	19.54	19.55	9.82	9.60	9.40	9.24	9.07	8.91	255	296	335	369	403	435	466	0.0006	0.0006	0.0006	-0.0020	-0.0028	0.247	-0.014	-0.276	0.043	-.283	1.359	1700
1730	18.38	18.51	18.63	18.72	18.81	18.89	18.97	9.40	9.23	9.09	8.95	8.83	8.75	287	335	380	419	457	492	528	0.0024	0.0031	0.0049	0.0069	0.0107	0.141	0.002	-0.208	0.065	-.213	1.693	1730
1800	17.32	17.51	17.69	17.86	18.03	18.19	18.36	8.39	8.23	8.18	7.96	7.85	7.75	212	247	281	310	339	368	397	0.0069	0.0131	0.0167	0.0231	0.0374	0.047	0.011	-0.120	0.063	-.123	0.888	1800
1830	15.79	16.00	16.25	16.47	16.70	16.93	17.17	8.88	8.78	8.68	8.60	8.51	8.42	160	185	211	235	260	284	310	0.0178	0.0243	0.0356	0.0512	0.0683	-0.032	0.018	-0.075	0.089	-.077	0.561	1830
1900	13.37	13.65	13.94	14.23	14.53	14.80	15.10	8.85	8.80	8.76	8.74	8.70	8.66	126	147	167	188	209	229	251	0.0364	0.0442	0.0692	0.0904	0.1246	-0.088	0.025	-0.042	0.105	-.043	0.398	1900
1930	10.93	11.22	11.53	11.83	12.15	12.47	12.81	8.31	8.30	8.29	8.28	8.27	8.26	113	130	150	167	188	208	231	0.0400	0.0714	0.0748	0.1098	0.1322	-0.098	0.029	-0.012	0.081	-.012	0.271	1930
2000	9.78	10.02	10.27	10.51	10.75	11.00	11.25	8.12	8.11	8.11	8.12	8.14	8.15	122	140	159	177	197	215	237	0.0359	0.0514	0.0628	0.1081	0.1079	-0.097	0.032	-0.000	0.065	-.000	0.313	2000
2030	9.34	9.55	9.76	9.96	10.16	10.36	10.57	8.10	8.10	8.10	8.12	8.13	8.15	132	149	168	187	206	225	246	0.0304	0.0385	0.0585	0.0775	0.1004	-0.097	0.032	0.012	0.053	0.012	0.362	2030
2100	8.90	9.11	9.31	9.50	9.69	9.88	10.08	7.96	7.98	8.00	8.00	8.01	8.02	124	141	159	178	196	214	236	0.0327	0.0372	0.0612	0.0821	0.0867	-0.098	0.033	0.012	0.054	0.012	0.323	2100
2130	8.13	8.40	8.66	8.92	9.18	9.44	9.72	7.76	7.80	7.84	7.88	7.91	7.95	100	117	135	153	174	194	216	0.0429	0.0572	0.0629	0.0920	0.1231	-0.096	0.032	0.015	0.050	0.015	0.213	2130
2200	7.38	7.64	7.91	8.19	8.51	8.83	9.19	7.54	7.60	7.65	7.70	7.75	7.80	75	86	99	111	124	138	154	0.0864	0.1393	0.2027	0.2328	0.2997	-0.094	0.037	0.009	0.048	0.009	0.205	2200
2230	7.71	7.91	8.11	8.29	8.50	8.69	8.92	7.60	7.62	7.65	7.70	7.74	7.80	111	130	150	167	187	205	225	0.0266	0.0445	0.0568	0.0842	0.1246	-0.098	0.033	0.018	0.047	0.018	0.297	2230
2300	7.24	7.43	7.65	7.85	8.08	8.31	8.54	7.50	7.51	7.55	7.58	7.62	7.68	100	115	132	149	166	185	206	0.0403	0.0498	0.0850	0.0912	0.1132	-0.097	0.033	0.006	0.058	0.006	0.228	2300
2330	6.71	6.98	7.25	7.51	7.78	8.05	8.34	7.23	7.30	7.38	7.44	7.50	7.55	75	88	103	117	133	152	173	0.0654	0.0969	0.1141	0.1078	0.1411	-0.089	0.034	0.024	0.032	0.024	0.150	2330
2400	6.49	6.70	6.93	7.15	7.39	7.62	7.88	7.33	7.40	7.44	7.50	7.54	7.59	107	123	141	157	174	193	214	0.0389	0.0618	0.0903	0.0914	0.1271	-0.094	0.034	0.012	0.048	0.012	0.208	2400

TIME	TEMPERATURE							ABSOLUTE HUMIDITY						WIND SPEED							RICHARDSONS NUMBER					ENERGY BALANCE				FLUXES		TIME
3 MAY 67	DEGREES C							GRAMS PER CUBIC CM X 10**6						CM PER SEC							FOR INTERVALS					LY PER MIN				MM PER HR	DNS PER CM2	
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
30	6.71	6.86	7.03	7.19	7.35	7.51	7.68	7.41	7.46	7.50	7.54	7.58	7.60	123	143	162	180	198	217	240	0.0258	0.0358	0.0537	0.0642	0.0686	-0.102	0.029	0.022	0.052	0.022	0.337	30
100	6.52	6.75	6.99	7.22	7.44	7.65	7.88	7.30	7.36	7.40	7.45	7.48	7.50	81	96	110	124	139	152	168	0.0667	0.0843	0.1060	0.1775	0.1909	-0.096	0.034	0.015	0.047	0.015	0.171	100
130	6.37	6.55	6.74	6.92	7.09	7.27	7.45	7.28	7.33	7.38	7.41	7.44	7.48	95	112	127	140	153	165	179	0.0461	0.0776	0.1084	0.1793	0.1990	-0.099	0.026	0.022	0.052	0.022	0.186	130
200	6.11	6.30	6.47	6.62	6.77	6.90	7.04	7.30	7.36	7.40	7.45	7.47	7.50	93	110	124	138	149	160	174	0.0479	0.0557	0.1365	0.1541	0.1548	-0.100	0.034	0.028	0.039	0.028	0.184	200
230	5.75	6.02	6.26	6.49	6.70	6.88	7.06	7.09	7.18	7.25	7.31	7.36	7.40	76	90	103	115	127	138	152	0.0788	0.1169	0.1597	0.2168	0.1992	-0.092	0.028	0.028	0.037	0.028	0.130	230
300	5.50	5.73	5.95	6.15	6.35	6.54	6.74	7.00	7.06	7.13	7.20	7.23	7.26	80	95	110	121	132	143	155	0.0536	0.1219	0.1827	0.2256	0.2988	-0.092	0.032	0.022	0.038	0.022	0.133	300
330	5.69	5.90	6.10	6.27	6.45	6.61	6.77	7.02	7.09	7.13	7.17	7.20	7.22	96	112	128	143	157	173	189	0.0432	0.0549	0.0998	0.0901	0.1340	-0.097	0.035	0.022	0.041	0.022	0.195	330
400	4.77	5.01	5.26	5.50	5.76	6.00	6.24	6.64	6.74	6.84	6.92	7.00	7.06	75	88	102	117	132	148	164	0.0712	0.0795	0.1273	0.1380	0.2046	-0.090	0.030	0.028	0.032	0.028	0.135	400
430	4.60	4.92	5.25	5.54	5.81	6.06	6.29	6.67	6.81	6.91	7.00	7.06	7.10	57	68	82	95	107	118	130	0.0943	0.1267	0.2071	0.3005	0.3452	-0.084	0.040	0.022	0.023	0.022	0.097	430
500	3.54	4.11	4.66	5.16	5.67	5.97	6.19	6.39	6.60	6.79	6.91	7.02	7.09	53	69	83	99	112	123	135	0.1566	0.1451	0.3295	0.3666	0.3365	-0.079	0.032	0.003	0.044	0.003	0.064	500
530	2.68	3.32	3.93	4.47	5.03	5.45	5.77	6.24	6.48	6.69	6.84	6.96	7.05	35	47	60	71	82	92	102	0.2022	0.3326	0.5086	0.6158	0.7025	-0.056	0.043	-0.000	0.013	-.000	0.046	530
1230	20.67	20.27	19.93	19.66	19.41	19.21	19.02	10.32	9.82	9.42	9.10	8.85	8.63	115	132	146	157	167	174	182	-0.1062	-0.1826	-0.2995	-0.6498	-0.7012	0.604	-0.102	-0.563	0.060	-.582	0.357	1230
1300	20.53	20.25	20.00	19.80	19.60	19.43	19.26	10.28	9.81	9.40	9.05	8.74	8.47	150	176	197	215	230	243	257	-0.0364	-0.0539	-0.1126	-0.1714	-0.2157	0.811	-0.091	-0.582	-0.138	-.601	0.664	1300
1330	20.77	20.49	20.25	20.04	19.84	19.66	19.49	9.90	9.38	8.93	8.56	8.26	8.00	174	201	225	245	266	282	297	-0.0276	-0.0463	-0.0581	-0.1176	-0.1865	0.839	-0.089	-0.596	-0.154	-.616	0.869	1330
1400	20.95	20.65	20.37	20.15	19.94	19.75	19.55	10.10	9.58	9.11	8.72	8.41	8.13	154	183	206	224	240	254	267	-0.0339	-0.0599	-0.1051	-0.1614	-0.2876	0.844	-0.085	-0.582	-0.178	-.601	0.736	1400
1430	19.73	19.66	19.60	19.53	19.47	19.41	19.34	8.96	8.55	8.20	7.92	7.68	7.47	124	144	161	175	187	199	210	-0.0209	-0.0416	-0.0707	-0.0888	-0.1680	0.417	-0.051	-0.360	-0.006	-.370	0.473	1430
1500*	20.93	20.71	20.52	20.35	20.20	20.07	19.95	9.02	8.50	8.08	7.73	7.45	7.20	135	160	179	194	207	219	229	-0.0371	-0.0691	-0.1199	-0.1595	-0.3155	0.741	-0.056	-0.495	-0.190	-.511	0.443	1500
1530*	21.14	20.95	20.79	20.65	20.53	20.42	20.32	7.75	7.25	6.85	6.54	6.28	6.06	88	101	111	119	127	133	140	-0.1174	-0.2082	-0.2601	-0.5520	-0.5431	0.614	-0.064	-0.505	-0.045	-.521	0.251	1530
1600*	20.80	20.74	20.68	20.63	20.58	20.53	20.47	7.48	7.02	6.64	6.32	6.08	5.85	103	121	134	145	155	163	171	-0.0380	-0.0587	-0.0977	-0.1787	-0.2949	0.430	-0.037	-0.449	0.056	-.462	0.286	1600
1630*	19.83	19.89	19.93	19.96	19.99	20.00	20.02	7.38	6.96	6.58	6.23	5.93	5.68	106	123	138	152	163	174	183	-0.0049	-0.0089	-0.0179	-0.0378	-0.0417	0.291	-0.018	-0.285	0.012	-.293	0.310	1630
1700	19.33	19.39	19.45	19.49	19.52	19.55	19.57	9.06	8.78	8.53	8.32	8.13	7.92	178	208	237	262	286	309	332	0.0011	0.0004	-0.0001	0.0006	-0.0041	0.265	-0.013	-0.289	0.036	-.296	0.802	1700
1730	18.25	18.41	18.55	18.65	18.75	18.84	18.92	8.56	8.37	8.19	8.02	7.86	7.69	191	224	254	283	310	335	362	0.0063	0.0059	0.0104	0.0144	0.0153	0.143	0.001	-0.180	0.036	-.185	0.900	1730
1800	17.07	17.27	17.46	17.64	17.81	17.98	18.14	8.28	8.12	7.98	7.83	7.70	7.56	169	199	227	251	275	298	321	0.0108	0.0188	0.0261	0.0386	0.0535	0.057	0.011	-0.144	0.076	-.148	0.720	1800
1830	15.19	15.41	15.64	15.85	16.07	16.28	16.50	9.00	8.92	8.86	8.78	8.70	8.62	144	167	192	214	236	258	282	0.0179	0.0284	0.0440	0.0558	0.0738	-0.040	0.019	-0.100	0.121	-.102	0.632	1830
1900	13.36	13.63	13.88	14.11	14.35	14.60	14.87	8.82	8.78	8.73	8.70	8.67	8.63	143	166	189	210	234	257	281	0.0238	0.0347	0.0421	0.0636	0.0941	-0.087	0.025	-0.039	0.101	-.040	0.483	1900
1930	11.70	11.93	12.15	12.36	12.57	12.78	13.00	8.40	8.36	8.33	8.31	8.29	8.27	145	170	194	217	241	263	286	0.0193	0.0268	0.0372	0.0590	0.0847	-0.094	0.031	-0.009	0.072	-.009	0.468	1930
2000	10.83	11.02	11.20	11.37	11.54	11.70	11.87	8.20	8.17	8.15	8.13	8.12	8.11	153	177	201	224	246	268	292	0.0159	0.0219	0.0358	0.0453	0.0606	-0.088	0.032	-0.012	0.068	-.012	0.553	2000
2030	10.22	10.38	10.54	10.68	10.83	10.97	11.13	8.11	8.09	8.07	8.05	8.04	8.03	155	184	211	234	259	282	307	0.0112	0.0180	0.0245	0.0363	0.0527	-0.080	0.030	-0.018	0.068	-.018	0.623	2030
2100	9.93	10.08	10.23	10.36	10.48	10.60	10.71	7.92	7.90	7.88	7.87	7.85	7.85	188	222	254	281	307	332	356	0.0075	0.0121	0.0183	0.0260	0.0397	-0.084	0.033	-0.015	0.066	-.015	0.880	2100
2130	9.33	9.51	9.68	9.82	9.96	10.10	10.23	7.85	7.85	7.84	7.83	7.83	7.82	150	174	199	223	246	267	291	0.0142	0.0167	0.0273	0.0441	0.0465	-0.084	0.031	-0.018	0.071	-.018	0.613	2130
2200	9.05	9.18	9.33	9.45	9.60	9.72	9.86	7.82	7.80	7.80	7.80	7.80	7.80	157	185	211	233	257	280	302	0.0114	0.0173	0.0272	0.0316	0.0603	-0.087	0.030	-0.006	0.063	-.006	0.637	2200
2230	8.97	9.09	9.21	9.32	9.44	9.55	9.66	7.73	7.72	7.72	7.72	7.71	7.70	194	227	260	289	317	345	373	0.0057	0.0091	0.0160	0.0193	0.0289	-0.085	0.032	-0.000	0.053	-.000	0.816	2230
2300	8.68	8.82	8.95	9.07	9.20	9.31	9.43	7.74	7.74	7.73	7.73	7.72	7.71	151	174	199	222	246	267	291	0.0109	0.0156	0.0236	0.0343	0.0430	-0.079	0.034	-0.000	0.045	-.000	0.530	2300
2330	8.38	8.51	8.65	8.79	8.94	9.08	9.24	7.66	7.66	7.65	7.66	7.66	7.66	114	134	153	172	192	211	232	0.0203	0.0268	0.0396	0.0541	0.0758	-0.068	0.030	-0.000	0.038	-.000	0.333	2330
2400	8.27	8.40	8.55	8.68	8.83	8.99	9.14	7.68	7.67	7.67	7.67	7.67	7.68	109	124	142	159	178	197	217	0.0240	0.0314	0.0435	0.0618	0.0791	-0.063	0.037	-0.000	0.026	-.000	0.273	2400

TIME	TEMPERATURE							ABSOLUTE HUMIDITY						WIND SPEED							RICHARDSONS NUMBER				ENERGY BALANCE				FLUXES		TIME
4 MAY 67	DEGREES C							GRAMS PER CUBIC CM X 10**6						CM PER SEC							FOR INTERVALS				LY PER MIN				MM PER HR	DNS PER CM2	
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
30	8.22	8.35	8.49	8.61	8.74	8.86	9.00	7.64	7.64	7.63	7.63	7.62	7.62	105	120	138	155	174	192	213	0.0226	0.0287	0.0377	0.0511	0.0664	-0.063	0.030	0.000	0.033	0.000	0.257	30
100	8.18	8.32	8.44	8.54	8.65	8.74	8.84	7.66	7.66	7.66	7.66	7.65	7.65	115	134	152	170	187	203	221	0.0194	0.0216	0.0399	0.0483	0.0646	-0.065	0.025	0.003	0.037	0.003	0.313	100
130*	7.98	8.08	8.19	8.29	8.40	8.51	8.60	7.60	7.60	7.60	7.61	7.62	7.62	109	127	144	160	173	188	202	0.0200	0.0273	0.0691	0.0691	0.0962	-0.077	0.026	0.006	0.045	0.006	0.266	130
200*	7.74	7.91	8.07	8.20	8.35	8.46	8.56	7.50	7.53	7.55	7.58	7.60	7.60	86	101	116	130	144	158	173	0.0383	0.0473	0.0824	0.0804	0.0931	-0.083	0.029	0.009	0.045	0.009	0.167	200
230*	6.54	6.79	7.04	7.25	7.48	7.68	7.86	7.17	7.24	7.32	7.38	7.43	7.49	61	75	89	102	114	126	141	0.0697	0.0917	0.1739	0.2012	0.1756	-0.077	0.029	0.012	0.036	0.012	0.068	230
300*	6.80	7.01	7.19	7.35	7.49	7.61	7.72	7.30	7.36	7.41	7.46	7.50	7.54	87	100	114	127	139	152	167	0.0505	0.0692	0.1071	0.1040	0.1078	-0.087	0.032	0.003	0.052	0.003	0.154	300
330*	5.82	6.15	6.50	6.82	7.10	7.34	7.55	7.10	7.21	7.31	7.39	7.46	7.53	63	77	90	103	115	128	141	0.1139	0.1387	0.2126	0.2071	0.2731	-0.083	0.033	0.009	0.041	0.009	0.068	330
400	5.15	5.55	5.95	6.32	6.70	6.98	7.20	6.77	6.98	7.15	7.28	7.38	7.46	40	52	63	72	82	91	101	0.1870	0.3414	0.4192	0.5089	0.4859	-0.072	0.040	0.012	0.020	0.012	0.044	400
430	3.20	3.78	4.40	5.00	5.62	6.15	6.51	6.25	6.54	6.78	6.94	7.09	7.18	92	117	143	167	193	218	245	0.0518	0.0776	0.1005	0.1240	0.1077	-0.065	0.037	0.009	0.019	0.009	0.043	430
500	3.26	3.73	4.30	4.85	5.31	5.69	5.97	6.20	6.44	6.66	6.88	7.08	7.30	47	60	73	85	98	110	123	0.1893	0.2847	0.3068	0.3985	0.3870	-0.067	0.042	0.018	0.008	0.018	0.052	500
530	3.21	3.85	4.47	5.02	5.50	5.81	6.04	6.24	6.51	6.71	6.86	6.98	7.05	38	50	60	67	73	77	82	0.3485	0.8323	1.4711	2.8737	2.0237	-0.054	0.039	0.012	0.003	0.012	-.000	530
600	2.85	3.29	3.83	4.35	4.79	5.15	5.42	6.12	6.27	6.46	6.68	6.79	6.85	31	37	43	49	53	57	63	0.8283	1.0735	3.1130	3.3100	1.6358	-0.018	0.036	0.009	-0.027	0.009	-.000	600
630	6.65	6.61	6.62	6.64	6.68	6.75	6.79	7.27	7.17	7.12	7.12	7.14	7.19	57	69	80	88	96	103	110	-0.0015	0.0146	0.0659	0.2085	0.2009	0.053	0.025	0.018	-0.096	0.018	-.000	630
700	8.65	8.54	8.43	8.34	8.25	8.18	8.10	8.00	7.79	7.64	7.56	7.50	7.48	84	99	113	124	133	140	146	-0.0370	-0.0637	-0.1305	-0.2229	-0.4819	0.120	0.005	-0.028	-0.097	-.028	0.201	700
730	10.88	10.68	10.49	10.34	10.20	10.07	9.94	8.80	8.58	8.42	8.31	8.25	8.21	106	127	145	158	172	183	194	-0.0354	-0.0706	-0.0824	-0.1587	-0.2334	0.223	-0.004	-0.090	-0.129	-.092	0.356	730
800	12.14	11.85	11.60	11.40	11.22	11.08	10.94	9.02	8.86	8.70	8.60	8.50	8.43	83	98	111	120	128	135	142	-0.0835	-0.1896	-0.3143	-0.4346	-0.6346	0.329	-0.016	-0.165	-0.147	-.169	0.254	800
830	13.13	12.85	12.60	12.40	12.20	12.03	11.86	9.45	9.22	9.05	8.91	8.82	8.74	66	77	84	90	94	97	100	-0.2974	-0.4282	-1.4190	-2.7986	-4.1678	0.436	-0.045	-0.201	-0.190	-.206	0.182	830
900	14.47	14.11	13.80	13.56	13.34	13.17	13.01	9.40	9.14	8.97	8.81	8.72	8.65	70	78	85	90	93	97	100	-0.3638	-0.7245	-2.7753	-1.5687	-3.8919	0.531	-0.047	-0.261	-0.223	-.268	0.193	900
930	16.16	15.75	15.40	15.10	14.83	14.60	14.39	10.05	9.71	9.45	9.23	9.07	8.94	117	139	157	170	182	192	200	-0.0629	-0.1361	-0.2144	-0.3456	-0.7326	0.630	-0.065	-0.324	-0.241	-.333	0.521	930
1000	17.42	17.05	16.70	16.43	16.16	15.94	15.73	10.45	10.05	9.72	9.48	9.28	9.12	129	153	174	190	203	215	225	-0.0471	-0.0842	-0.1838	-0.2350	-0.4758	0.717	-0.063	-0.383	-0.271	-.394	0.534	1000
1030	18.07	17.72	17.40	17.13	16.87	16.65	16.42	10.62	10.22	9.87	9.56	9.31	9.10	127	151	171	187	200	210	220	-0.0480	-0.0849	-0.1835	-0.3476	-0.5303	0.792	-0.080	-0.463	-0.250	-.477	0.552	1030
1100	18.90	18.53	18.20	17.94	17.68	17.46	17.26	10.64	10.18	9.82	9.53	9.30	9.10	116	136	153	166	178	188	197	-0.0696	-0.1249	-0.2128	-0.3430	-0.5744	0.840	-0.093	-0.498	-0.249	-.514	0.486	1100
1130	19.35	18.98	18.65	18.38	18.11	17.87	17.65	11.01	10.55	10.15	9.80	9.50	9.24	163	192	216	237	256	272	287	-0.0349	-0.0502	-0.0901	-0.1498	-0.2324	0.888	-0.101	-0.516	-0.271	-.533	0.675	1130
1200	19.63	19.26	18.93	18.65	18.39	18.16	17.94	11.15	10.65	10.22	9.85	9.55	9.27	172	200	225	247	267	283	300	-0.0326	-0.0478	-0.0794	-0.1444	-0.1829	0.908	-0.093	-0.552	-0.264	-.570	0.743	1200
1230	20.00	19.63	19.30	19.03	18.77	18.55	18.35	11.10	10.62	10.22	9.87	9.58	9.32	163	191	217	238	257	274	290	-0.0299	-0.0502	-0.0871	-0.1224	-0.1881	0.913	-0.102	-0.566	-0.245	-.585	0.726	1230
1300	20.48	20.14	19.84	19.59	19.34	19.13	18.91	11.03	10.54	10.12	9.78	9.48	9.20	177	208	236	258	280	298	316	-0.0239	-0.0433	-0.0625	-0.1055	-0.1627	0.905	-0.105	-0.569	-0.231	-.588	1.151	1300
1330	20.57	20.18	19.85	19.58	19.34	19.14	18.95	10.88	10.38	9.94	9.56	9.24	8.94	169	198	224	246	266	283	300	-0.0301	-0.0465	-0.0746	-0.1150	-0.1635	0.867	-0.085	-0.566	-0.216	-.585	0.644	1330
1400*	20.59	20.30	20.05	19.84	19.63	19.45	19.28	10.76	10.29	9.90	9.55	9.26	8.99	179	210	238	262	283	302	320	-0.0205	-0.0312	-0.0597	-0.0829	-0.1305	0.818	-0.075	-0.543	-0.200	-.561	0.857	1400
1430*	20.22	20.02	19.85	19.70	19.57	19.46	19.35	10.40	10.01	9.68	9.38	9.13	8.89	183	216	247	272	295	315	335	-0.0119	-0.0213	-0.0332	-0.0493	-0.0732	0.637	-0.055	-0.454	-0.128	-.468	0.709	1430
1500	20.28	20.10	19.93	19.80	19.66	19.54	19.42	10.50	10.11	9.80	9.50	9.27	9.02	200	238	273	302	328	352	375	-0.0093	-0.0140	-0.0274	-0.0359	-0.0597	0.647	-0.047	-0.478	-0.122	-.493	1.096	1500
1530	20.01	19.90	19.77	19.68	19.57	19.48	19.39	10.17	9.85	9.57	9.30	9.08	8.85	212	256	295	328	359	386	411	-0.0059	-0.0081	-0.0157	-0.0225	-0.0399	0.572	-0.036	-0.449	-0.088	-.462	1.190	1530
1600	19.57	19.50	19.42	19.36	19.29	19.22	19.14	10.18	9.90	9.65	9.42	9.22	9.02	221	270	314	350	384	414	442	-0.0032	-0.0050	-0.0090	-0.0148	-0.0281	0.467	-0.027	-0.383	-0.056	-.394	1.407	1600
1630	18.77	18.75	18.73	18.70	18.65	18.61	18.56	10.30	10.10	9.94	9.76	9.60	9.46	250	305	355	397	436	472	505	-0.0010	-0.0020	-0.0051	-0.0066	-0.0131	0.364	-0.007	-0.322	-0.035	-.330	1.604	1630
1700	18.02	18.03	18.04	18.05	18.05	18.04	18.03	10.32	10.16	10.00	9.88	9.76	9.64	256	306	353	392	430	464	499	-0.0003	-0.0006	-0.0012	-0.0032	-0.0045	0.257	-0.002	-0.267	0.012	-.274	1.670	1700
1730	16.85	16.91	16.96	17.00	17.05	17.08	17.11	10.00	9.87	9.76	9.68	9.59	9.51	261	312	359	400	438	475	513	0.0007	0.0010	0.0027	0.0017	0.0026	0.138	0.003	-0.175	0.033	-.179	1.826	1730
1800	15.70	15.80	15.90	15.97	16.05	16.11	16.16	9.63	9.54	9.48	9.40	9.34	9.28	280	338	391	436	479	518	559	0.0016	0.0021	0.0038	0.0046	0.0050	0.042	0.017	-0.112	0.052	-.114	1.902	1800
1830	14.17	14.30	14.45	14.56	14.70	14.81	14.94	9.29	9.26	9.20	9.15	9.10	9.03	252	300	344	383	420	455	489	0.0039	0.0046	0.0100	0.0115	0.0213	-0.063	0.027	-0.064	0.100	-.065	1.448	1830
1900	12.76	12.94	13.10	13.25	13.40	13.54	13.69	8.99	8.94	8.90	8.88	8.85	8.83	204	245	282	315	346	374	405	0.0058	0.0091	0.0158	0.0238	0.0315	-0.093	0.028	-0.015	0.080	-.015	0.919	1900
1930	11.50	11.68	11.87	12.04	12.21	12.37	12.55	8.69	8.67	8.66	8.64	8.62	8.61	161	194	224	250	276	300	326	0.0108	0.0172	0.0256	0.0376	0.0546	-0.103	0.028	-0.015	0.090	-.015	0.706	1930
2000	10.90	11.08	11.26	11.43	11.60	11.76	11.93	8.55	8.54	8.52	8.51	8.50	8.50	164	194	224	249	275	300	325	0.0103	0.0185	0.0259	0.0351	0.0563	-0.102	0.031	-0.015	0.086	-.015	0.721	2000
2030	10.65	10.82	11.00	11.15	11.32	11.48	11.62	8.34	8.33	8.31	8.30	8.30	8.29	176	208	239	267	294	320	347	0.0097	0.0130	0.0240	0.0327	0.0394	-0.106	0.029	-0.015	0.092	-.015	0.746	2030
2100	10.20	10.35	10.50	10.64	10.79	10.92	11.07	8.06	8.04	8.02	8.00	8.00	7.98	198	236	271	301	332	360	388	0.0063	0.0106	0.0159	0.0230	0.0390	-0.105	0.032	-0.009	0.082	-.009	0.921	2100
2130	9.97	10.13	10.29	10.43	10.57	10.70	10.84	7.94	7.90	7.90	7.89	7.87	7.86	206	248	286	318	350	379	410	0.0056	0.0095	0.0141	0.0210	0.0300	-0.106	0.034	-0.018	0.090	-.018	0.850	2130
2200	9.54	9.70	9.85	9.99	10.13	10.26	10.40	7.89	7.86	7.84	7.81	7.81	7.82	184	218	252	281	309	336	365	0.0066	0.0113	0.0181	0.0248	0.0350	-0.102	0.032	-0.015	0.085	-.015	0.757	2200
2230	9.48	9.62	9.76	9.88	10.02	10.11	10.24	7.97	7.95	7.94	7.93	7.92	7.91	230	271	313	351	390	426	463	0.0041	0.0057	0.0095	0.0095	0.0196	-0.104	0.032	-0.015	0.087	-.015	1.228	2230
2300	9.18	9.31	9.45	9.56	9.69	9.80	9.91	8.00	8.00	7.99	7.99	8.00	8.01	203	243	279	312	344	373	403	0.0056	0.0069	0.0132	0.0184	0.0258	-0.100	0.033	-0.003	0.070	-.003	0.887	2300
2330	9.01	9.14	9.26	9.37	9.49	9.60	9.70	7.96	7.96	7.97	7.97	7.98	7.99	209	250	288	320	353	382	414	0.0043	0.0076	0.0115	0.0184	0.0207	-0.099	0.030	-0.000	0.069	-.000	0.985	2330
2400	8.93	9.05	9.16	9.27	9.38	9.50	9.61	8.06	8.05	8.04	8.01	8.00	7.98	230	276	318	355	390	423	457	0.0032	0.0055	0.0090	0.0152	0.0194	-0.098	0.029	-0.000	0.069	-.000	1.234	2400

TIME	TEMPERATURE							ABSOLUTE HUMIDITY						WIND SPEED							RICHARDSONS NUMBER					ENERGY BALANCE				FLUXES		TIME
5 MAY 67	DEGREES C							GRAMS PER CUBIC CM X 10**6						CM PER SEC							FOR INTERVALS					LY PER MIN				MM PER HR	DNS PER CM2	
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
30	8.85	8.97	9.09	9.19	9.30	9.41	9.52	7.90	7.88	7.87	7.87	7.87	7.88	225	269	311	345	380	413	445	0.0035	0.0059	0.0094	0.0141	0.0227	-0.100	0.030	-0.012	0.082	-.012	1.109	30
100	8.61	8.74	8.87	8.98	9.10	9.21	9.32	7.80	7.81	7.81	7.81	7.81	7.81	199	239	276	308	340	369	398	0.0050	0.0075	0.0123	0.0182	0.0273	-0.099	0.029	-0.009	0.079	-.009	0.846	100
130	8.51	8.63	8.75	8.85	8.98	9.10	9.21	7.78	7.78	7.78	7.78	7.77	7.76	205	245	283	315	347	377	408	0.0044	0.0068	0.0133	0.0184	0.0236	-0.097	0.027	-0.006	0.076	-.006	0.905	130
200	8.43	8.55	8.66	8.78	8.90	9.01	9.13	7.77	7.77	7.77	7.77	7.77	7.78	188	226	260	291	321	350	379	0.0050	0.0087	0.0140	0.0182	0.0302	-0.098	0.028	-0.000	0.070	-.000	0.814	200
230	8.26	8.40	8.53	8.65	8.76	8.88	9.00	7.72	7.72	7.72	7.72	7.72	7.72	180	218	252	283	312	339	367	0.0059	0.0087	0.0137	0.0230	0.0320	-0.095	0.026	-0.000	0.069	-.000	0.731	230
300	7.92	8.06	8.20	8.32	8.46	8.58	8.72	7.76	7.77	7.77	7.77	7.77	7.76	160	192	221	247	273	297	322	0.0088	0.0124	0.0217	0.0291	0.0465	-0.096	0.029	-0.000	0.067	-.000	0.545	300
330	7.85	7.99	8.13	8.25	8.37	8.50	8.63	7.81	7.83	7.84	7.85	7.85	7.85	159	193	224	251	277	302	326	0.0078	0.0116	0.0188	0.0291	0.0473	-0.096	0.027	-0.000	0.069	-.000	0.508	330
400	7.67	7.80	7.94	8.07	8.21	8.35	8.49	7.70	7.70	7.70	7.69	7.68	7.66	145	172	198	222	246	272	296	0.0109	0.0158	0.0252	0.0287	0.0500	-0.095	0.026	-0.000	0.069	-.000	0.439	400
430	5.98	6.17	6.39	6.60	6.83	7.07	7.33	7.08	7.16	7.24	7.30	7.35	7.41	78	95	111	127	145	164	185	0.0476	0.0606	0.0774	0.0960	0.1279	-0.084	0.027	0.015	0.042	0.015	0.188	430
500	5.24	5.49	5.75	6.00	6.28	6.55	6.85	6.87	6.98	7.09	7.18	7.25	7.32	64	78	93	108	126	144	166	0.0646	0.0829	0.0952	0.1213	0.1348	-0.079	0.033	0.015	0.031	0.015	0.097	500
530	5.72	5.92	6.15	6.37	6.60	6.84	7.10	7.05	7.11	7.19	7.25	7.31	7.38	74	88	105	121	139	157	178	0.0435	0.0634	0.0775	0.1076	0.1287	-0.071	0.029	0.015	0.027	0.015	0.153	530
600	6.96	7.19	7.40	7.61	7.82	8.02	8.22	7.54	7.51	7.53	7.57	7.60	7.65	49	60	72	82	92	102	113	0.0752	0.1491	0.2263	0.2856	0.3585	-0.030	0.022	0.015	-0.006	0.015	0.058	600
630	8.87	8.92	8.95	8.99	9.02	9.04	9.06	8.25	8.17	8.10	8.05	8.00	7.96	67	82	93	104	113	122	129	0.0083	0.0176	0.0300	0.0227	0.0621	0.033	0.015	-0.003	-0.046	-.003	0.122	630
700	10.62	10.50	10.40	10.32	10.24	10.17	10.11	8.62	8.51	8.42	8.35	8.30	8.25	86	101	116	128	139	146	155	-0.0266	-0.0445	-0.0771	-0.2179	-0.1720	0.125	0.001	-0.058	-0.068	-.059	0.218	700
730	12.05	11.88	11.72	11.60	11.47	11.35	11.25	8.74	8.58	8.47	8.37	8.30	8.24	127	151	172	190	207	222	235	-0.0214	-0.0288	-0.0516	-0.0797	-0.1330	0.233	-0.005	-0.121	-0.107	-.123	0.359	730
800	13.28	13.01	12.78	12.60	12.40	12.25	12.10	9.10	8.87	8.71	8.58	8.48	8.40	136	167	193	212	229	245	258	-0.0200	-0.0386	-0.0780	-0.0883	-0.1973	0.337	-0.013	-0.181	-0.144	-.185	0.513	800
830	14.00	13.67	13.41	13.22	13.05	12.91	12.78	9.34	9.13	8.96	8.81	8.71	8.62	122	150	171	188	203	215	228	-0.0338	-0.0508	-0.0875	-0.1471	-0.1742	0.329	-0.025	-0.156	-0.147	-.160	0.369	830
900	13.21	13.13	13.04	12.97	12.90	12.83	12.76	9.22	9.08	8.97	8.88	8.79	8.72	156	188	216	240	264	285	307	-0.0072	-0.0102	-0.0148	-0.0258	-0.0340	0.192	-0.013	-0.126	-0.053	-.129	0.628	900
930	13.48	13.40	13.32	13.24	13.17	13.10	13.02	9.34	9.23	9.11	9.02	8.93	8.84	213	255	293	326	357	385	413	-0.0034	-0.0061	-0.0089	-0.0145	-0.0244	0.249	-0.011	-0.139	-0.099	-.142	1.004	930
1000	13.60	13.52	13.44	13.37	13.30	13.23	13.15	9.31	9.19	9.08	8.98	8.89	8.80	227	272	313	348	382	413	443	-0.0030	-0.0048	-0.0075	-0.0118	-0.0212	0.271	-0.011	-0.181	-0.079	-.185	1.203	1000
1030	14.27	14.12	13.98	13.85	13.73	13.61	13.49	9.38	9.22	9.10	8.97	8.86	8.75	233	281	324	362	395	428	461	-0.0045	-0.0070	-0.0131	-0.0171	-0.0256	0.407	-0.019	-0.217	-0.171	-.222	1.541	1030
1100	15.20	14.96	14.74	14.55	14.35	14.17	13.99	9.68	9.45	9.24	9.04	8.85	8.65	252	301	346	384	421	454	486	-0.0064	-0.0104	-0.0171	-0.0260	-0.0418	0.575	-0.035	-0.354	-0.186	-.363	1.649	1100
1130	14.73	14.58	14.43	14.30	14.16	14.04	13.90	9.28	9.15	9.00	8.86	8.74	8.60	225	272	315	350	385	416	447	-0.0047	-0.0084	-0.0134	-0.0195	-0.0342	0.407	-0.029	-0.256	-0.122	-.262	1.572	1130
1200	14.90	14.75	14.61	14.50	14.37	14.25	14.12	9.35	9.16	8.99	8.82	8.70	8.58	213	256	294	326	357	385	412	-0.0059	-0.0090	-0.0165	-0.0239	-0.0414	0.415	-0.023	-0.231	-0.161	-.237	1.156	1200
1230	15.70	15.46	15.24	15.05	14.86	14.70	14.53	9.69	9.47	9.28	9.11	8.96	8.84	246	293	337	375	412	445	480	-0.0066	-0.0103	-0.0160	-0.0228	-0.0313	0.553	-0.037	-0.348	-0.168	-.357	1.510	1230
1300	15.75	15.58	15.42	15.29	15.15	15.01	14.87	9.60	9.38	9.20	9.04	8.91	8.81	226	270	311	346	379	408	438	-0.0058	-0.0087	-0.0153	-0.0257	-0.0351	0.459	-0.031	-0.295	-0.133	-.302	1.322	1300
1330	15.84	15.72	15.60	15.50	15.40	15.30	15.19	9.52	9.32	9.14	8.98	8.87	8.78	218	260	298	331	363	392	422	-0.0053	-0.0079	-0.0123	-0.0188	-0.0279	0.403	-0.026	-0.234	-0.143	-.240	1.204	1330
1400	16.04	15.94	15.84	15.75	15.66	15.57	15.47	9.57	9.36	9.17	9.01	8.88	8.75	244	289	334	375	414	449	483	-0.0033	-0.0047	-0.0076	-0.0121	-0.0210	0.410	-0.022	-0.283	-0.105	-.290	1.499	1400
1430	16.39	16.27	16.16	16.06	15.96	15.87	15.77	9.54	9.34	9.14	8.96	8.80	8.64	220	264	306	341	374	404	434	-0.0040	-0.0071	-0.0118	-0.0171	-0.0279	0.428	-0.027	-0.303	-0.098	-.311	1.265	1430
1500	16.47	16.37	16.28	16.19	16.11	16.03	15.94	9.50	9.26	9.06	8.90	8.74	8.60	195	235	271	301	330	355	382	-0.0049	-0.0090	-0.0125	-0.0224	-0.0308	0.363	-0.025	-0.264	-0.073	-.271	1.177	1500
1530	16.66	16.55	16.44	16.35	16.25	16.16	16.06	9.52	9.30	9.10	8.90	8.75	8.61	185	221	255	283	309	333	355	-0.0062	-0.0103	-0.0194	-0.0263	-0.0506	0.386	-0.027	-0.334	-0.026	-.342	0.765	1530
1600	16.36	16.29	16.22	16.16	16.10	16.04	15.97	9.46	9.24	9.04	8.88	8.71	8.58	169	207	242	270	296	318	340	-0.0042	-0.0077	-0.0125	-0.0237	-0.0374	0.300	-0.020	-0.217	-0.063	-.222	0.750	1600
1630	17.15	16.96	16.82	16.68	16.55	16.44	16.32	9.55	9.29	9.07	8.88	8.72	8.60	142	170	194	214	233	250	265	-0.0157	-0.0291	-0.0444	-0.0625	-0.1243	0.401	-0.026	-0.264	-0.111	-.271	0.484	1630
1700	17.10	16.91	16.76	16.65	16.55	16.47	16.38	9.40	9.14	8.91	8.71	8.56	8.42	107	127	145	160	175	188	201	-0.0294	-0.0432	-0.0583	-0.0816	-0.1328	0.289	-0.024	-0.186	-0.079	-.191	0.315	1700

TIME	TEMPERATURE							ABSOLUTE HUMIDITY ·						WIND SPEED							RICHARDSONS NUMBER					ENERGY BALANCE				FLUXES		TIME
9 MAY 67	DEGREES C							GRAMS PER CUBIC CM X 10**6						CM PER SEC							FOR INTERVALS					LY PER MIN				MM PER HR	DNS PER CM2	
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
600	11.31	11.41	11.52	11.61	11.70	11.78	11.85	8.52	8.48	8.43	8.39	8.34	8.30	109	133	157	175	195	212	230	0.0094	0.0177	0.0219	0.0349	0.0412	-0.003	0.005	-0.006	0.004	-.006	0.503	600
630	12.10	12.15	12.19	12.23	12.27	12.30	12.34	8.75	8.69	8.64	8.60	8.55	8.50	132	159	185	210	235	258	279	0.0024	0.0036	0.0057	0.0060	0.0155	0.042	0.002	-0.022	-0.023	-.022	0.706	630
700	12.74	12.76	12.79	12.80	12.82	12.84	12.85	8.88	8.80	8.73	8.68	8.60	8.54	139	175	205	232	259	281	305	0.0011	0.0000	0.0018	0.0025	0.0006	0.089	-0.005	-0.060	-0.024	-.061	0.872	700
730	13.24	13.25	13.26	13.27	13.28	13.29	13.29	9.09	9.00	8.89	8.80	8.72	8.64	138	172	205	230	258	280	302	-0.0001	-0.0006	-0.0003	-0.0004	-0.0048	0.107	-0.026	-0.077	-0.004	-.079	0.887	730
800	13.60	13.55	13.50	13.46	13.41	13.36	13.30	9.53	9.43	9.35	9.28	9.20	9.12	235	280	329	372	416	454	490	-0.0014	-0.0019	-0.0032	-0.0058	-0.0113	0.224	-0.019	-0.143	-0.062	-.146	2.362	800
830	14.26	14.20	14.14	14.07	14.00	13.94	13.86	9.88	9.78	9.68	9.60	9.50	9.40	245	301	353	398	440	479	518	-0.0014	-0.0028	-0.0047	-0.0067	-0.0127	0.299	-0.022	-0.199	-0.079	-.203	2.088	830
900	15.58	15.45	15.33	15.21	15.10	14.99	14.86	10.12	9.93	9.73	9.53	9.38	9.24	252	310	365	412	455	495	531	-0.0025	-0.0046	-0.0077	-0.0112	-0.0237	0.483	-0.027	-0.292	-0.164	-.299	2.089	900
930	14.95	14.90	14.83	14.77	14.71	14.65	14.57	9.82	9.69	9.52	9.37	9.23	9.10	239	298	350	395	435	475	512	-0.0017	-0.0028	-0.0052	-0.0068	-0.0148	0.328	-0.015	-0.266	-0.047	-.272	2.211	930
1000	15.25	15.16	15.08	15.00	14.92	14.84	14.74	10.06	9.90	9.73	9.58	9.45	9.32	269	330	385	432	479	521	567	-0.0017	-0.0032	-0.0047	-0.0076	-0.0115	0.411	-0.010	-0.228	-0.174	-.233	2.851	1000
1030	15.74	15.64	15.53	15.44	15.33	15.23	15.11	10.23	10.04	9.86	9.67	9.49	9.33	249	308	360	408	450	490	528	-0.0026	-0.0034	-0.0080	-0.0107	-0.0203	0.444	-0.020	-0.308	-0.116	-.315	2.398	1030
1100	15.35	15.31	15.27	15.23	15.18	15.12	15.05	9.91	9.75	9.60	9.47	9.33	9.21	290	351	410	460	508	550	596	-0.0009	-0.0017	-0.0030	-0.0062	-0.0084	0.360	-0.014	-0.285	-0.061	-.291	2.954	1100
1130	14.89	14.89	14.88	14.86	14.85	14.82	14.78	9.82	9.68	9.56	9.44	9.33	9.22	268	329	383	432	480	521	565	-0.0005	-0.0011	-0.0012	-0.0037	-0.0059	0.292	-0.007	-0.234	-0.052	-.239	2.606	1130
1200	14.75	14.76	14.77	14.77	14.76	14.74	14.71	9.77	9.65	9.55	9.46	9.37	9.28	292	359	420	475	525	571	618	-0.0001	-0.0003	-0.0009	-0.0021	-0.0040	0.249	-0.004	-0.143	-0.102	-.146	3.220	1200
1230	15.01	15.00	15.00	14.99	14.96	14.94	14.90	9.80	9.67	9.54	9.43	9.33	9.23	291	358	416	468	517	560	605	-0.0003	-0.0007	-0.0019	-0.0025	-0.0055	0.282	-0.004	-0.219	-0.058	-.224	3.162	1230
1300	14.48	14.52	14.57	14.60	14.63	14.65	14.66	9.66	9.58	9.49	9.39	9.30	9.21	290	355	416	468	520	565	615	0.0005	0.0004	0.0006	0.0005	-0.0002	0.178	0.006	-0.169	-0.015	-.173	3.059	1300
1330	14.64	14.65	14.66	14.66	14.65	14.64	14.61	9.92	9.82	9.72	9.63	9.54	9.46	302	376	442	500	554	601	651	-0.0000	-0.0003	-0.0008	-0.0014	-0.0034	0.224	0.000	-0.134	-0.090	-.137	3.455	1330
1400	15.49	15.44	15.38	15.34	15.27	15.21	15.15	10.11	9.98	9.83	9.71	9.58	9.46	319	391	459	514	570	618	668	-0.0009	-0.0014	-0.0028	-0.0047	-0.0063	0.421	-0.010	-0.254	-0.157	-.260	3.380	1400
1430	14.93	14.96	14.98	14.99	15.00	15.01	14.97	9.86	9.72	9.62	9.52	9.42	9.32	275	344	405	457	505	551	598	0.0000	-0.0001	-0.0002	-0.0003	-0.0050	0.220	-0.005	-0.205	-0.011	-.209	2.942	1430
1500	15.35	15.34	15.30	15.27	15.24	15.20	15.15	10.08	9.93	9.82	9.70	9.59	9.48	265	328	382	430	478	520	562	-0.0011	-0.0014	-0.0021	-0.0043	-0.0076	0.339	-0.006	-0.222	-0.111	-.227	2.813	1500
1530	17.19	17.02	16.87	16.74	16.60	16.46	16.34	10.58	10.35	10.18	9.98	9.78	9.60	282	353	418	470	521	570	615	-0.0022	-0.0039	-0.0066	-0.0096	-0.0147	0.577	-0.023	-0.402	-0.153	-.412	3.140	1530
1600	16.00	15.99	15.97	15.96	15.95	15.91	15.88	9.92	9.78	9.64	9.52	9.40	9.29	295	361	421	474	525	570	618	-0.0006	-0.0007	-0.0011	-0.0038	-0.0041	0.336	-0.007	-0.225	-0.104	-.230	3.151	1600
1630	16.07	16.05	16.01	15.97	15.94	15.89	15.83	9.98	9.82	9.69	9.59	9.48	9.38	320	395	464	521	580	630	680	-0.0007	-0.0012	-0.0013	-0.0036	-0.0061	0.352	-0.005	-0.299	-0.048	-.306	3.809	1630
1700	14.91	14.96	15.00	15.01	15.03	15.04	15.04	9.59	9.50	9.42	9.33	9.23	9.18	335	415	485	541	600	650	703	0.0003	-0.0000	0.0002	-0.0002	-0.0005	0.185	0.000	-0.210	0.025	-.215	3.692	1700
1730	14.25	14.34	14.39	14.43	14.48	14.50	14.53	9.40	9.32	9.27	9.20	9.12	9.08	350	430	506	568	629	685	741	0.0003	0.0006	0.0011	0.0004	0.0016	0.099	0.012	-0.116	0.004	-.118	3.989	1730
1800	13.84	13.91	13.98	14.03	14.08	14.11	14.14	9.42	9.88	9.32	9.28	9.21	9.16	280	341	400	450	500	548	592	0.0020	-0.0008	0.0018	0.0012	0.0024	0.058	0.016	-0.116	0.042	-.118	2.842	1800

TIME	TEMPERATURE							ABSOLUTE HUMIDITY						WIND SPEED							RICHARDSONS NUMBER					ENERGY BALANCE				FLUXES		TIME
28 SEP 67	DEGREES C							GRAMS PER CUBIC CM X 10**6						CM PER SEC							FOR INTERVALS					LY PER MIN				MM PER HR	DNS PER CM2	
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
1000	23.57	23.48	23.41	23.34	23.29	23.24	23.20	15.68	15.07	14.62	14.23	13.94	13.69	158	207	246	276	304	326	348	-0.0053	-0.0102	-0.0138	-0.0257	-0.0320	0.516	-0.026	-0.374	-0.116	-.385	0.957	1000
1030	24.75	24.58	24.44	24.33	24.23	24.14	24.07	16.46	15.78	15.18	14.71	14.31	13.99	108	134	155	171	185	197	209	-0.0274	-0.0520	-0.0868	-0.1386	-0.1636	0.577	-0.029	-0.439	-0.110	-.453	0.471	1030
1100	26.12	26.02	25.94	25.87	25.82	25.76	25.71	17.00	16.20	15.54	14.98	14.55	14.15	124	155	180	199	219	233	250	-0.0160	-0.0312	-0.0335	-0.0846	-0.0761	0.627	-0.045	-0.471	-0.111	-.487	0.641	1100
1130	27.09	27.00	26.93	26.88	26.83	26.79	26.75	16.60	15.60	14.89	14.30	13.88	13.50	104	130	150	165	181	194	205	-0.0276	-0.0465	-0.0542	-0.0814	-0.1604	0.659	-0.039	-0.521	-0.099	-.539	0.417	1130
1200	27.62	27.53	27.46	27.40	27.34	27.29	27.24	17.35	16.49	15.82	15.25	14.78	14.36	114	140	163	180	195	211	225	-0.0189	-0.0371	-0.0647	-0.0628	-0.1153	0.679	-0.050	-0.542	-0.087	-.561	0.406	1200
1230	27.60	27.57	27.54	27.52	27.49	27.47	27.45	17.20	16.11	15.31	14.70	14.20	13.71	114	146	171	191	209	224	237	-0.0156	-0.0235	-0.0377	-0.0567	-0.1114	0.679	-0.047	-0.568	-0.065	-.588	0.438	1230
1300	28.13	28.17	28.20	28.22	28.24	28.26	28.27	17.14	16.21	15.47	14.83	14.32	13.81	118	148	172	190	209	224	239	-0.0097	-0.0191	-0.0215	-0.0344	-0.0603	0.655	-0.044	-0.571	-0.040	-.591	0.494	1300
1330	28.31	28.43	28.52	28.61	28.68	28.74	28.79	16.97	16.02	15.22	14.55	13.98	13.40	140	178	209	235	259	281	303	-0.0029	-0.0033	-0.0058	-0.0077	-0.0163	0.622	-0.045	-0.595	0.018	-.616	0.646	1330
1400	28.23	28.43	28.60	28.75	28.89	29.02	29.13	16.15	15.40	14.75	14.16	13.64	13.10	184	232	271	305	336	366	397	0.0017	0.0028	0.0049	0.0071	0.0053	0.565	-0.031	-0.617	0.083	-.638	1.191	1400
1430	27.56	27.85	28.08	28.25	28.42	28.55	28.68	14.78	14.28	13.84	13.43	13.04	12.66	266	339	400	450	499	543	586	0.0020	0.0027	0.0044	0.0047	0.0075	0.512	-0.034	-0.624	0.146	-.644	2.681	1430
1500	26.54	26.82	27.08	27.30	27.50	27.70	27.88	12.21	11.80	11.40	11.05	10.70	10.35	316	402	473	532	587	637	688	0.0019	0.0030	0.0047	0.0076	0.0095	0.440	-0.000	-0.637	0.197	-.656	3.486	1500
1530	26.12	26.45	26.73	26.98	27.21	27.42	27.62	11.50	11.10	10.70	10.35	10.01	9.70	254	319	375	421	466	506	550	0.0034	0.0058	0.0086	0.0129	0.0154	0.316	-0.011	-0.541	0.236	-.557	2.177	1530
1600	24.60	24.93	25.22	25.46	25.70	25.90	26.11	11.32	11.00	10.70	10.40	10.16	9.91	247	317	375	419	464	502	542	0.0036	0.0066	0.0095	0.0149	0.0212	0.218	0.011	-0.389	0.161	-.400	2.289	1600
1630	24.08	24.45	24.76	25.00	25.23	25.44	25.62	11.40	11.11	10.85	10.60	10.40	10.18	234	300	355	401	445	484	525	0.0044	0.0063	0.0098	0.0156	0.0172	0.139	-0.001	-0.369	0.231	-.379	1.996	1630
1700	23.85	24.24	24.58	24.86	25.13	25.36	25.57	10.93	10.69	10.47	10.27	10.10	9.90	239	313	374	422	467	505	544	0.0041	0.0071	0.0117	0.0187	0.0234	0.060	0.012	-0.270	0.198	-.277	2.139	1700
1730	22.58	22.89	23.17	23.40	23.62	23.82	24.00	11.17	11.05	10.91	10.79	10.67	10.56	244	312	373	418	465	506	549	0.0035	0.0069	0.0091	0.0144	0.0176	-0.032	0.012	-0.172	0.192	-.176	2.298	1730
1800	21.55	21.84	22.08	22.30	22.50	22.68	22.88	11.37	11.27	11.18	11.09	11.00	10.95	246	313	368	415	462	503	545	0.0037	0.0062	0.0084	0.0132	0.0218	-0.076	0.019	-0.105	0.162	-.108	2.122	1800
1830	20.51	20.77	21.00	21.18	21.36	21.52	21.67	11.65	11.60	11.53	11.48	11.43	11.36	223	283	334	376	417	454	491	0.0043	0.0064	0.0103	0.0149	0.0205	-0.088	0.014	-0.045	0.119	-.046	1.772	1830
1900	19.45	19.65	19.82	19.97	20.11	20.24	20.37	11.89	11.83	11.80	11.73	11.70	11.66	242	305	359	405	446	486	525	0.0028	0.0046	0.0078	0.0106	0.0164	-0.080	0.021	-0.042	0.102	-.043	2.104	1900
1930	18.92	19.09	19.25	19.38	19.50	19.61	19.72	11.80	11.75	11.70	11.66	11.61	11.60	253	309	359	403	445	483	526	0.0031	0.0043	0.0065	0.0096	0.0119	-0.067	0.022	-0.036	0.081	-.037	2.206	1930
2000	18.72	18.90	19.06	19.19	19.32	19.44	19.55	11.85	11.81	11.80	11.75	11.71	11.70	247	312	367	411	454	493	533	0.0026	0.0045	0.0067	0.0101	0.0137	-0.064	0.018	-0.033	0.079	-.034	2.212	2000
2030	18.56	18.75	18.92	19.07	19.20	19.32	19.43	11.80	11.75	11.71	11.69	11.60	11.55	197	251	294	329	366	396	428	0.0045	0.0079	0.0094	0.0160	0.0203	-0.069	0.017	-0.054	0.106	-.055	1.323	2030
2100	19.16	19.38	19.58	19.76	19.94	20.07	20.22	11.38	11.30	11.25	11.20	11.15	11.11	202	259	306	347	382	415	449	0.0043	0.0069	0.0142	0.0151	0.0251	-0.069	0.018	-0.061	0.111	-.062	1.326	2100
2130	18.72	18.97	19.19	19.38	19.55	19.70	19.85	10.84	10.78	10.70	10.65	10.60	10.58	164	208	244	274	304	332	361	0.0082	0.0133	0.0183	0.0245	0.0353	-0.071	0.017	-0.061	0.114	-.062	1.036	2130
2200	18.15	18.34	18.52	18.67	18.80	18.92	19.02	10.80	10.75	10.70	10.65	10.60	10.55	172	218	258	290	322	350	379	0.0055	0.0094	0.0121	0.0194	0.0223	-0.049	0.017	-0.061	0.093	-.062	1.086	2200
2230	18.47	18.64	18.79	18.93	19.06	19.17	19.28	10.70	10.61	10.55	10.50	10.45	10.40	198	252	299	336	373	405	438	0.0031	0.0065	0.0091	0.0135	0.0191	-0.041	0.017	-0.045	0.069	-.046	1.315	2230
2300	18.68	18.83	18.99	19.12	19.26	19.39	19.52	10.60	10.53	10.48	10.42	10.37	10.32	258	325	381	428	473	513	554	0.0024	0.0037	0.0066	0.0103	0.0147	-0.052	0.014	-0.069	0.108	-.071	2.301	2300
2330	19.31	19.52	19.71	19.87	20.03	20.17	20.31	10.44	10.38	10.31	10.26	10.20	10.18	272	333	389	432	479	522	563	0.0029	0.0054	0.0070	0.0095	0.0164	-0.068	0.021	-0.075	0.122	-.077	2.504	2330
2400	19.68	19.88	20.06	20.22	20.37	20.50	20.63	10.20	10.12	10.06	10.00	9.95	9.90	243	303	355	396	438	474	514	0.0031	0.0060	0.0081	0.0127	0.0154	-0.054	0.019	-0.078	0.113	-.080	2.084	2400

TIME	TEMPERATURE							ABSOLUTE HUMIDITY						WIND SPEED							RICHARDSONS NUMBER					ENERGY BALANCE				FLUXES		TIME
29 SEP 67	DEGREES C							GRAMS PER CUBIC CM X 10**6						CM PER SEC							FOR INTERVALS					LY PER MIN				MM PER HR	DNS PER CM2	
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
30	19.06	19.30	19.52	19.70	19.89	20.06	20.22	9.88	9.80	9.73	9.65	9.60	9.51	177	222	260	292	325	353	385	0.0073	0.0112	0.0165	0.0279	0.0289	-0.068	0.016	-0.067	0.119	-.068	1.061	30
100	15.76	16.38	16.96	17.45	17.94	18.39	18.83	10.10	10.00	9.90	9.80	9.70	9.61	66	87	107	125	144	161	182	0.0721	0.0996	0.1338	0.2037	0.1960	-0.048	0.016	-0.015	0.047	-.015	0.179	100
130	16.22	16.53	16.82	17.07	17.32	17.52	17.74	10.42	10.35	10.29	10.21	10.15	10.09	89	115	136	154	174	193	214	0.0324	0.0506	0.0607	0.0719	0.0974	-0.041	0.015	-0.015	0.041	-.015	0.283	130
200	16.57	16.80	17.00	17.18	17.36	17.52	17.68	10.82	10.75	10.66	10.58	10.50	10.40	80	101	119	135	152	166	185	0.0299	0.0443	0.0593	0.1027	0.0819	-0.013	0.014	-0.030	0.030	-.031	0.201	200
230	16.99	17.18	17.35	17.50	17.65	17.78	17.91	11.18	11.10	11.00	10.92	10.83	10.73	81	101	118	134	151	168	187	0.0279	0.0359	0.0487	0.0548	0.0650	-0.009	0.012	-0.015	0.012	-.015	0.172	230
300	17.53	17.74	17.94	18.10	18.27	18.43	18.60	11.99	11.80	11.67	11.55	11.44	11.32	52	66	79	93	105	120	137	0.0519	0.0488	0.1075	0.0866	0.1070	-0.012	0.013	-0.018	0.017	-.018	0.129	300
330	16.90	17.22	17.52	17.77	18.03	18.26	18.48	-0.00	-0.00	12.49	12.23	12.00	11.71	35	49	60	70	81	90	101	-0.0000	-0.0000	0.1868	0.3286	0.2982	-0.010	0.011	-0.027	0.027	-.028	0.053	330
400	16.58	16.85	17.11	17.32	17.53	17.72	17.92	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	34	48	62	75	89	101	116	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.012	0.010	-0.015	0.017	-.015	0.059	400
430	16.75	17.10	17.40	17.62	17.80	17.95	18.07	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	24	31	37	41	44	49	51	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.015	0.010	0.000	0.005	0.000	0.055	430
500*	15.90	16.37	16.76	17.09	17.40	17.66	17.90	12.25	12.02	11.80	11.58	11.35	11.14	22	31	40	46	54	58	64	0.2250	0.5633	0.4427	1.9220	1.1832	-0.016	0.006	-0.009	0.019	-.009	0.060	500
530*	15.72	16.11	16.48	16.77	17.05	17.34	17.52	11.86	11.70	11.55	11.40	11.28	11.15	44	65	83	98	112	125	138	0.0547	0.0812	0.1344	0.2191	0.1941	-0.038	0.016	-0.012	0.034	-.012	0.112	530
600*	15.19	15.59	15.94	16.22	16.50	16.73	16.95	11.10	11.00	10.93	10.90	10.82	10.80	46	62	76	88	100	110	120	0.0876	0.1277	0.1955	0.2972	0.4426	-0.046	0.013	-0.022	0.054	-.022	0.067	600
630*	14.55	14.88	15.19	15.46	15.72	15.95	16.18	11.20	11.13	11.08	11.00	10.95	10.90	60	77	92	104	115	127	141	0.0684	0.1247	0.2103	0.2111	0.2324	-0.024	0.015	-0.030	0.039	-.031	0.089	630
700	16.66	16.77	16.87	16.93	17.00	17.05	17.10	11.93	11.80	11.70	11.60	11.55	11.49	71	90	106	119	131	142	152	0.0162	0.0183	0.0394	0.0481	0.0843	0.040	0.011	-0.039	-0.012	-.040	0.203	700
730	17.82	17.82	17.82	17.82	17.82	17.82	17.81	12.49	12.35	12.21	12.10	12.00	11.90	112	144	172	194	216	234	255	-0.0013	-0.0028	-0.0033	-0.0061	-0.0113	0.110	0.009	-0.084	-0.035	-.086	0.474	730
800	19.21	19.17	19.14	19.11	19.08	19.05	19.03	13.35	13.15	12.95	12.75	12.60	12.42	107	136	160	179	195	211	226	-0.0052	-0.0111	-0.0234	-0.0274	-0.0416	0.183	0.001	-0.156	-0.028	-.160	0.411	800
830	21.02	20.92	20.82	20.74	20.66	20.60	20.53	13.95	13.60	13.28	13.00	12.75	12.55	132	167	194	216	236	253	269	-0.0105	-0.0176	-0.0305	-0.0450	-0.0783	0.381	-0.001	-0.267	-0.113	-.274	0.572	830
900	22.60	22.52	22.46	22.40	22.35	22.30	22.25	14.28	13.84	13.45	13.10	12.80	12.51	172	216	254	284	313	337	362	-0.0044	-0.0088	-0.0122	-0.0220	-0.0299	0.479	-0.020	-0.371	-0.088	-.382	1.001	900
930	22.16	22.25	22.32	22.38	22.45	22.50	22.55	13.85	13.48	13.13	12.80	12.54	12.25	153	194	226	255	282	306	332	0.0007	0.0006	0.0029	0.0026	0.0020	0.308	-0.018	-0.261	-0.029	-.268	0.776	930
1000	22.63	22.67	22.71	22.74	22.76	22.78	22.79	14.30	13.84	13.40	13.03	12.71	12.43	124	156	183	204	225	244	262	-0.0020	-0.0054	-0.0080	-0.0103	-0.0197	0.356	-0.014	-0.359	0.018	-.370	0.543	1000
1030	23.98	23.85	23.73	23.63	23.54	23.46	23.38	14.83	14.25	13.71	13.28	12.94	12.60	148	189	222	248	274	294	315	-0.0095	-0.0178	-0.0228	-0.0436	-0.0593	0.637	-0.030	-0.472	-0.135	-.487	0.854	1030
1100	24.54	24.38	24.23	24.11	23.99	23.88	23.79	15.65	14.92	14.29	13.79	13.38	13.01	152	193	226	252	276	296	315	-0.0119	-0.0211	-0.0338	-0.0571	-0.0805	0.719	-0.034	-0.522	-0.163	-.539	0.836	1100
1130	24.80	24.69	24.59	24.51	24.43	24.36	24.30	15.85	15.25	14.70	14.22	13.83	13.45	158	198	233	260	285	309	332	-0.0077	-0.0148	-0.0243	-0.0297	-0.0442	0.672	-0.038	-0.566	-0.068	-.585	0.968	1130
1200	25.35	25.26	25.18	25.11	25.05	24.98	24.91	16.00	15.29	14.68	14.15	13.72	13.34	164	210	247	277	305	329	352	-0.0068	-0.0120	-0.0178	-0.0311	-0.0479	0.700	-0.039	-0.587	-0.074	-.607	1.055	1200
1230	25.01	25.07	25.13	25.18	25.23	25.28	25.33	14.78	14.25	13.78	13.35	12.99	12.61	202	252	295	330	364	394	426	-0.0005	-0.0012	-0.0013	-0.0007	-0.0015	0.515	-0.036	-0.517	0.038	-.533	1.354	1230
1300	23.70	23.94	24.15	24.33	24.50	24.65	24.80	14.01	13.67	13.34	13.05	12.80	12.56	216	275	324	364	404	439	477	0.0033	0.0054	0.0078	0.0121	0.0156	0.318	-0.008	-0.330	0.020	-.339	1.570	1300
1330	24.91	24.93	24.94	24.95	24.96	24.97	24.98	14.65	14.19	13.76	13.35	13.00	12.62	256	324	380	425	469	508	549	-0.0009	-0.0018	-0.0027	-0.0038	-0.0056	0.698	-0.015	-0.672	-0.011	-.693	2.227	1330
1400	24.45	24.50	24.55	24.59	24.63	24.67	24.71	13.70	13.24	12.82	12.45	12.10	11.76	256	326	382	429	474	514	556	-0.0003	-0.0007	-0.0008	-0.0011	-0.0013	0.611	-0.017	-0.603	0.009	-.622	2.374	1400
1430	25.26	25.42	25.57	25.69	25.82	25.92	26.03	12.83	12.38	11.98	11.59	11.25	10.90	256	324	381	427	472	512	553	0.0012	0.0018	0.0034	0.0040	0.0066	0.530	-0.017	-0.576	0.063	-.594	2.279	1430
1500	26.12	26.34	26.54	26.71	26.87	27.03	27.18	12.02	11.57	11.15	10.76	10.40	10.05	252	322	377	424	469	511	553	0.0021	0.0031	0.0049	0.0078	0.0107	0.508	-0.007	-0.583	0.082	-.601	2.325	1500
1530	25.75	26.01	26.26	26.46	26.66	26.85	27.03	12.61	12.16	11.77	11.43	11.15	10.88	217	277	326	370	411	446	484	0.0037	0.0048	0.0087	0.0158	0.0189	0.352	-0.013	-0.509	0.170	-.524	1.692	1530
1600	24.30	24.51	24.69	24.85	25.01	25.15	25.31	13.62	13.32	13.04	12.78	12.54	12.31	247	312	365	412	456	496	534	0.0024	0.0035	0.0062	0.0086	0.0172	0.278	-0.002	-0.374	0.098	-.385	2.163	1600
1630	23.13	23.30	23.48	23.68	23.90	24.08	24.26	13.87	13.62	13.39	13.18	12.98	12.78	186	229	267	300	333	362	395	0.0049	0.0101	0.0172	0.0237	0.0274	0.129	-0.002	-0.246	0.119	-.253	1.102	1630
1700	23.00	23.20	23.38	23.55	23.72	23.88	24.02	13.92	13.70	13.48	13.25	13.07	12.86	180	230	271	304	340	369	402	0.0044	0.0084	0.0104	0.0210	0.0198	0.118	-0.001	-0.174	0.057	-.179	1.225	1700
1730	21.42	21.67	21.91	22.13	22.35	22.55	22.75	13.19	13.05	12.92	12.81	12.69	12.58	187	236	279	314	348	379	412	0.0059	0.0109	0.0176	0.0253	0.0337	-0.020	0.005	-0.129	0.144	-.132	1.257	1730
1800	19.87	20.08	20.29	20.48	20.68	20.87	21.07	12.55	12.48	12.40	12.34	12.28	12.22	175	223	262	296	330	361	393	0.0066	0.0104	0.0167	0.0253	0.0375	-0.077	0.012	-0.066	0.132	-.068	0.961	1800
1830	18.16	18.41	18.67	18.89	19.14	19.36	19.59	11.86	11.78	11.71	11.65	11.61	11.57	131	166	196	222	249	272	298	0.0140	0.0210	0.0335	0.0546	0.0670	-0.089	0.015	-0.033	0.107	-.034	0.544	1830
1900	17.13	17.35	17.56	17.74	17.93	18.10	18.29	11.76	11.72	11.68	11.63	11.59	11.54	147	191	228	259	289	314	343	0.0076	0.0123	0.0206	0.0356	0.0441	-0.096	0.016	-0.024	0.104	-.025	0.692	1900
1930	16.48	16.70	16.90	17.08	17.27	17.44	17.61	11.72	11.68	11.65	11.62	11.61	11.58	134	170	200	224	251	274	299	0.0110	0.0207	0.0259	0.0432	0.0539	-0.088	-0.000	-0.015	0.103	-.015	0.649	1930

TIME	TEMPERATURE							ABSOLUTE HUMIDITY						WIND SPEED							RICHARDSONS NUMBER					ENERGY BALANCE			FLUXES		TIME
13 OCT 66	DEGREES C							GRAMS PER CUBIC CM X 10**6						CM PER SEC							FOR INTERVALS					LY PER MIN			MM PER HR	DNS PER CM2	
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
1030	15.53	15.60	15.66	15.71	15.75	15.77	15.78	4.80	4.63	4.46	4.30	4.16	4.01	540	628	710	782	860	925	1000	0.0003	0.0003	0.0003	0.0000	-0.0004	0.479	0.009	-0.528	0.040	-.539	7.105	1030
1100	16.05	16.12	16.18	16.24	16.28	16.32	16.33	4.90	4.71	4.54	4.37	4.21	4.07	530	618	699	770	844	910	980	0.0003	0.0005	0.0003	0.0005	-0.0004	0.531	0.008	-0.558	0.019	-.570	6.762	1100
1130	16.81	16.88	16.95	17.00	17.04	17.05	17.04	4.90	4.69	4.50	4.32	4.14	3.96	510	602	688	761	838	910	982	0.0003	0.0003	0.0002	-0.0004	-0.0014	0.579	0.003	-0.572	-0.010	-.585	6.471	1130
1200	17.27	17.37	17.44	17.50	17.54	17.56	17.55	4.89	4.68	4.52	4.33	4.16	3.99	542	628	707	779	850	913	981	0.0003	0.0005	0.0003	-0.0002	-0.0015	0.593	0.002	-0.602	0.007	-.616	6.648	1200
1230	17.69	17.79	17.86	17.93	17.97	18.00	18.00	4.76	4.55	4.36	4.17	4.02	3.85	540	629	710	785	859	927	997	0.0003	0.0005	0.0002	0.0002	-0.0010	0.591	-0.001	-0.602	0.012	-.616	6.980	1230
1300	18.26	18.35	18.43	18.49	18.54	18.58	18.57	4.68	4.46	4.29	4.09	3.92	3.74	538	621	700	770	840	920	972	0.0004	0.0005	0.0004	0.0003	-0.0027	0.571	-0.001	-0.602	0.032	-.616	6.614	1300
1330	18.62	18.73	18.82	18.88	18.95	18.99	19.03	4.77	4.56	4.37	4.18	3.98	3.81	500	580	654	715	784	848	912	0.0005	0.0006	0.0009	0.0004	0.0008	0.533	-0.001	-0.587	0.055	-.601	6.001	1330
1400	18.80	18.95	19.06	19.14	19.22	19.27	19.31	4.76	4.54	4.34	4.14	3.96	3.78	512	590	662	730	795	852	916	0.0008	0.0007	0.0012	0.0010	0.0007	0.478	0.001	-0.572	0.093	-.585	5.944	1400
1430	18.80	18.99	19.15	19.26	19.38	19.45	19.51	4.55	4.34	4.16	3.97	3.79	3.61	472	549	620	685	750	808	869	0.0013	0.0013	0.0022	0.0017	0.0018	0.406	-0.001	-0.557	0.152	-.570	5.339	1430
1500	18.80	19.00	19.18	19.32	19.46	19.56	19.66	4.44	4.24	4.06	3.89	3.72	3.56	482	555	625	685	749	802	862	0.0016	0.0021	0.0028	0.0036	0.0043	0.308	0.001	-0.482	0.173	-.493	5.105	1500
1530	18.57	18.82	19.03	19.20	19.34	19.47	19.58	4.34	4.19	4.02	3.86	3.71	3.56	489	565	640	704	772	830	892	0.0017	0.0024	0.0025	0.0043	0.0046	0.211	0.003	-0.438	0.224	-.447	5.366	1530
1600	18.20	18.47	18.71	18.90	19.08	19.20	19.35	4.25	4.11	3.96	3.82	3.68	3.55	442	520	595	659	723	780	835	0.0020	0.0028	0.0039	0.0041	0.0087	0.116	0.006	-0.377	0.255	-.385	4.898	1600
1630	17.56	17.88	18.17	18.40	18.60	18.80	18.95	4.07	3.93	3.79	3.67	3.55	3.42	452	530	604	675	726	782	839	0.0025	0.0028	0.0071	0.0078	0.0081	0.021	0.008	-0.302	0.273	-.308	4.882	1630
1700	17.12	17.41	17.69	17.94	18.18	18.38	18.56	3.78	3.67	3.58	3.48	3.38	3.28	430	510	580	642	703	757	816	0.0027	0.0042	0.0061	0.0086	0.0096	-0.059	0.011	-0.257	0.305	-.262	4.732	1700
1730	16.43	16.75	17.08	17.33	17.56	17.77	17.98	3.59	3.52	3.43	3.36	3.28	3.21	370	434	495	546	601	650	700	0.0044	0.0062	0.0074	0.0112	0.0162	-0.116	0.012	-0.196	0.300	-.200	3.433	1730
1800	15.96	16.27	16.56	16.80	17.03	17.23	17.44	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	375	438	500	552	605	654	705	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.135	0.014	-0.151	0.272	-.154	3.061	1800
1830	15.53	15.83	16.13	16.36	16.63	16.85	17.05	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0	-0	-0	-0	-0	-0	-0	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.133	0.015	-0.137	0.255	-.139	2.586	1830
1900	15.13	15.43	15.72	15.95	16.17	16.37	16.58	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0	-0	-0	-0	-0	-0	-0	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.133	0.019	-0.090	0.204	-.092	2.831	1900
1930	14.95	15.25	15.53	15.75	15.98	16.18	16.39	3.86	3.80	3.75	3.70	3.65	3.60	370	440	499	559	614	666	722	0.0040	0.0040	0.0075	0.0097	0.0132	-0.135	0.016	-0.121	0.240	-.123	3.323	1930
2000	14.40	14.67	14.93	15.14	15.36	15.56	15.75	3.91	3.84	3.78	3.73	3.67	3.62	359	423	485	544	598	648	700	0.0033	0.0039	0.0075	0.0104	0.0138	-0.136	0.014	-0.090	0.212	-.092	3.430	2000
2030	13.72	14.00	14.27	14.50	14.73	14.92	15.09	3.89	3.84	3.79	3.74	3.69	3.64	345	408	468	523	574	621	675	0.0037	0.0050	0.0088	0.0113	0.0114	-0.135	0.014	-0.106	0.227	-.108	3.254	2030
2100	13.23	13.52	13.78	14.00	14.23	14.43	14.64	3.93	3.88	3.83	3.78	3.73	3.68	320	379	434	487	533	580	628	0.0043	0.0052	0.0108	0.0119	0.0180	-0.134	0.017	-0.076	0.193	-.077	2.436	2100
2130	12.58	12.86	13.13	13.35	13.56	13.75	15.95	3.93	3.87	3.82	3.78	3.73	3.68	303	360	411	459	505	548	592	0.0052	0.0063	0.0099	0.0136	0.2317	-0.132	0.016	-0.091	0.207	-.092	2.365	2130
2200	11.70	11.99	12.25	12.48	12.72	12.92	13.14	4.04	3.98	3.94	3.89	3.85	3.81	279	324	369	406	445	480	521	0.0064	0.0113	0.0158	0.0218	0.0263	-0.126	0.018	-0.061	0.169	-.062	1.735	2200
2230	11.36	11.63	11.87	12.09	12.30	12.48	12.67	4.07	4.03	3.99	3.94	3.90	3.86	319	375	423	470	514	556	600	0.0053	0.0067	0.0108	0.0136	0.0196	-0.126	0.018	-0.076	0.184	-.077	2.353	2230
2300	10.68	10.96	11.23	11.45	11.68	11.86	12.06	4.07	4.02	3.98	3.94	3.89	3.85	260	307	352	392	431	468	505	0.0067	0.0093	0.0153	0.0174	0.0293	-0.122	0.020	-0.076	0.178	-.077	1.549	2300
2330	10.40	10.68	10.94	11.16	11.37	11.57	11.80	4.12	4.07	4.02	3.97	3.92	3.88	238	282	324	361	400	432	470	0.0074	0.0108	0.0138	0.0260	0.0321	-0.119	0.018	-0.076	0.177	-.077	1.374	2330
2400	10.80	11.04	11.27	11.48	11.70	11.88	12.09	3.97	3.91	3.86	3.81	3.76	3.72	284	329	389	431	476	516	560	0.0032	0.0079	0.0109	0.0149	0.0218	-0.123	0.020	-0.076	0.179	-.077	2.116	2400

TIME	TEMPERATURE							ABSOLUTE HUMIDITY						WIND SPEED							RICHARDSONS NUMBER					ENERGY BALANCE				FLUXES		TIME
14 OCT 66	DEGREES C							GRAMS PER CUBIC CM X 10**6						CM PER SEC							FOR INTERVALS					LY PER MIN				MM PER HR	DNS PER CM2	
	25	35	50	70	100	140	200	35	50	70	100	140	200	25	35	50	70	100	140	200	35-50	50-70	70-100	100-140	140-200	RN	G	LE	H	E	TAU	
30	10.85	11.09	11.34	11.55	11.76	11.95	12.15	3.92	3.86	3.82	3.77	3.73	3.67	305	359	410	455	500	541	583	0.0048	0.0070	0.0104	0.0151	0.0224	-0.125	0.018	-0.076	0.183	-.077	2.178	30
100	10.85	11.12	11.36	11.57	11.78	11.96	12.15	3.85	3.79	3.75	3.70	3.65	3.60	310	368	415	465	512	556	602	0.0054	0.0056	0.0095	0.0123	0.0179	-0.125	0.019	-0.076	0.182	-.077	2.346	100
130	10.78	11.04	11.28	11.50	11.70	11.87	12.05	3.99	3.94	3.89	3.85	3.81	3.76	295	351	405	453	501	544	590	0.0041	0.0064	0.0087	0.0123	0.0169	-0.126	0.017	-0.061	0.170	-.062	2.257	130
200	10.80	11.05	11.28	11.47	11.68	11.85	12.02	4.00	3.95	3.90	3.85	3.81	3.76	313	364	414	458	502	544	590	0.0046	0.0065	0.0109	0.0129	0.0159	-0.127	0.019	-0.061	0.169	-.062	2.331	200
230	10.27	10.52	10.76	10.97	11.17	11.36	11.57	3.98	3.93	3.87	3.83	3.78	3.73	274	320	365	403	444	483	523	0.0060	0.0097	0.0120	0.0166	0.0263	-0.125	0.020	-0.076	0.181	-.077	1.787	230
300	9.78	10.05	10.30	10.50	10.73	10.94	11.16	3.93	3.87	3.82	3.77	3.73	3.68	253	293	334	372	410	445	488	0.0075	0.0093	0.0160	0.0231	0.0239	-0.123	0.021	-0.076	0.178	-.077	1.491	300
330	9.93	10.18	10.43	10.65	10.87	11.06	11.27	3.89	3.84	3.79	3.74	3.70	3.66	254	299	343	381	420	458	499	0.0065	0.0102	0.0145	0.0177	0.0252	-0.124	0.017	-0.076	0.183	-.077	1.499	330
400	10.19	10.44	10.67	10.86	11.09	11.27	11.47	3.85	3.80	3.75	3.70	3.66	3.62	308	359	410	452	500	542	588	0.0045	0.0072	0.0100	0.0137	0.0190	-0.126	0.017	-0.061	0.170	-.062	2.111	400
430	10.55	10.80	11.00	11.21	11.40	11.58	11.77	3.89	3.84	3.79	3.75	3.71	3.66	320	377	431	480	530	572	618	0.0034	0.0058	0.0076	0.0136	0.0179	-0.128	0.016	-0.061	0.173	-.062	2.480	430
500	10.53	10.78	11.02	11.22	11.42	11.61	11.80	3.87	3.81	3.76	3.72	3.66	3.62	303	352	402	448	493	534	581	0.0048	0.0063	0.0099	0.0149	0.0173	-0.127	0.019	-0.076	0.184	-.077	2.100	500
530	10.53	10.77	11.01	11.22	11.43	11.61	11.81	3.84	3.78	3.74	3.69	3.64	3.60	290	336	387	430	476	520	565	0.0046	0.0076	0.0099	0.0123	0.0199	-0.128	0.022	-0.061	0.167	-.062	2.027	530
600	10.38	10.64	10.89	11.10	11.31	11.51	11.74	3.82	3.76	3.71	3.66	3.61	3.57	270	315	360	400	441	480	522	0.0062	0.0088	0.0125	0.0175	0.0263	-0.126	0.022	-0.076	0.180	-.077	1.790	600
630	9.90	10.17	10.43	10.65	10.88	11.10	11.33	3.94	3.87	3.81	3.76	3.70	3.64	242	284	325	362	396	435	474	0.0077	0.0107	0.0200	0.0192	0.0302	-0.116	0.016	-0.106	0.206	-.108	1.364	630
700	10.00	10.27	10.54	10.77	11.00	11.23	11.45	4.12	4.02	3.94	3.85	3.76	3.68	243	284	328	364	403	439	476	0.0069	0.0117	0.0148	0.0232	0.0316	-0.072	0.012	-0.121	0.181	-.123	1.329	700
730	11.20	11.44	11.65	11.85	12.03	12.19	12.35	4.25	4.14	4.04	3.94	3.85	3.76	268	318	367	409	450	488	530	0.0042	0.0073	0.0102	0.0141	0.0173	0.013	0.015	-0.152	0.124	-.154	1.735	730
800	12.63	12.83	13.00	13.16	13.30	13.42	13.52	4.39	4.25	4.12	3.99	3.87	3.75	317	371	425	470	516	560	602	0.0027	0.0048	0.0059	0.0073	0.0097	0.101	0.016	-0.242	0.125	-.246	2.380	800
830	13.90	14.08	14.23	14.35	14.45	14.53	14.61	4.48	4.33	4.18	4.04	3.90	3.76	318	370	421	470	516	558	601	0.0025	0.0028	0.0039	0.0047	0.0067	0.201	0.013	-0.272	0.058	-.277	2.608	830
900	14.91	15.03	15.13	15.22	15.28	15.33	15.38	4.74	4.54	4.36	4.19	4.03	3.85	320	375	427	473	519	559	604	0.0014	0.0021	0.0017	0.0023	0.0025	0.295	0.006	-0.333	0.032	-.339	2.687	900
930	15.68	15.76	15.83	15.88	15.86	15.93	15.94	5.07	4.85	4.65	4.47	4.30	4.11	304	352	400	441	482	520	558	0.0009	0.0009	-0.0028	0.0043	-0.0024	0.378	0.001	-0.377	-0.002	-.385	2.540	930
1000	16.53	16.56	16.58	16.59	16.58	16.56	16.53	5.42	5.13	4.86	4.63	4.42	4.23	269	311	352	389	425	458	493	-0.0006	-0.0014	-0.0034	-0.0062	-0.0095	0.455	0.000	-0.422	-0.033	-.431	2.041	1000
1030	17.39	17.43	17.45	17.45	17.43	17.41	17.37	5.54	5.20	4.91	4.60	4.33	4.06	236	278	317	350	382	410	440	-0.0010	-0.0026	-0.0064	-0.0101	-0.0178	0.508	-0.005	-0.451	-0.052	-.462	1.645	1030
1100	18.28	18.30	18.28	18.24	18.18	18.13	18.07	5.74	5.32	4.92	4.55	4.22	3.89	191	223	253	280	304	326	349	-0.0045	-0.0090	-0.0199	-0.0272	-0.0412	0.543	-0.013	-0.451	-0.079	-.462	1.093	1100
1130	19.03	18.96	18.92	18.86	18.82	18.77	18.72	6.04	5.52	5.09	4.61	4.29	3.99	152	180	204	225	243	260	277	-0.0101	-0.0187	-0.0342	-0.0449	-0.0653	0.570	-0.017	-0.450	-0.103	-.462	0.580	1130
1200	19.65	19.62	19.55	19.50	19.48	19.39	19.33	6.44	5.84	5.32	4.86	4.52	4.22	111	129	145	160	172	182	194	-0.0310	-0.0375	-0.0609	-0.1874	-0.1451	0.578	-0.022	-0.449	-0.107	-.462	0.391	1200

TABLE B-17. MEAN WIND DIRECTION FOR PERIODS ENDING AT TIME DESIGNATED.

	June 1966			July 1966			Oct. 1966		May 1967					Sept. 1967	
Time	1	2	3	12	13	14	13	14	2	3	4	5	9	28	29
0030		196	184		169	206		339		189	184	210			201
0100		199	193		154	204		340		182	182	211			190
0130		170	188		134	201		338		122	123	205			182
0200		148	279		146	198		337		130	133	207			205
0230		149	235		142	200		338		130	154	209			220
0300		154	187		167	200		338		122	130	209			245
0330		157	180		169	192		337		145	145	201			198
0400		195	211		167	192		337		172	169	209			226
0430		165	223		166	199		338		175	220	222			267
0500		179	280		145	194		337		174	233	214			56
0530		176	190		148	194		337		215	210	211			75
0600		180	265		299	240		337			344	191	181		
0630		202	305		307	255		337			304	144	200		63
0700		203	316		327	246		337			283	178	208		217
0730		211	322		346	300		338			290	230	201		176
0800		186	320		336	317		338			305	239	198		215
0830		166	320		272	260		345			271	239	213		196
0900		174	321		276	228		349	341		228	222	217		204
0930		243	321		292	222		349	344		253	191	209		207
1000		318	328	227	194	209		7	334		243	191	205	176	192
1030		208	337	141	192	210	338	4	332		218	185	202	191	186
1100		331	343	250	210	227	337	12	3		253	186	210	194	191
1130		174	321	219	209	194	338	5	324		204	193	208	184	192
1200		201	322	217	218	187	337	357	262		183	191	208	208	197
1230		203	352	213	198	192	336		317	221	184	189	211	219	198
1300		178	328	220	208	220	339		286	188	180	199	210	209	192
1330		306	344	212	194	192	339		299	173	168	194	205	219	197
1400		287	286	193	192	188	337		241	178	154	205	211	200	191
1430	170	214	279	210	194	179	339		173	179	154	203	217	192	196
1500	182	192	185	209	206	154	338		172	157	166	196	201	197	185
1530	197	195	154	204	216	176	339		225	147	165	193	205	190	176
1600	207	196	156	177	218	182	339		210	142	174	203	214	188	195
1630	210	209	161	217	210	205	338		195	158	192	190	214	181	208
1700	206	214	158	204	210	180	337		199	167	186	240	221	181	191
1730	205	217	162	201	203	173	336		210	174	194		221	183	192
1800	210	203	188	204	204	181	337		217	180	196		211	189	204
1830	201	199	179	201	204	195	337		209	181	197			185	198
1900	195	200	187	201	206	205	336		186	176	197			192	186
1930	186	207	183	209	208	180	337		184	184	188			193	197
2000	190	211	175	215	210	179	337		187	181	188			191	
2030	185	213	175	212	215	195	337		187	186	192			194	
2100	180	203	179	212	208	208	337		190	193	196			196	
2130	171	150	186	218	202	184	339		211	194	205			173	
2200	174	166	181	216	204	168	342		207	194	201			175	
2230	165	165	183	207	203	179	343		203	201	200			190	
2300	168	170	189	211	205		342		203	204	198			194	
2330	163	172	196	209	208		336		201	213	200			202	
2400	175	218		192	210		338		190	198	205			198	

Direction in degrees in conventional meteorological notation.

TABLE B-18

DISPLACEMENT HEIGHT AND SURFACE ROUGHNESS FOR THE DAVIS FIELD RUNS IN 1966 AND 1967

Run	Date	Displacement Height* d(cm)	Surface Roughness z_o(cm)
166	1 June 1966	9.5	0.94
	2 June 1966	10.5	0.94
	3 June 1966	11.5	0.94
266	12-14 July 1966	10.6	1.0
466	13-14 Oct. 1966	8.0	1.0
267	2-5 May 1967	10.6	0.80
367	9 May 1967	11.2	1.27
467	28-29 Sept.1967	15.0	0.88

*These values were used in the Combined Eddy Diffusivity Program (CEDP).

APPENDIX C

MICROMETEOROLOGICAL VARIABLES - CALCULATION AND EDITING

APPENDIX C

1. CALCULATION

A computer program for calculating eddy diffusivities and other variables related to the turbulent transfers of heat, moisture, and momentum was developed by T. V. Crawford while he was at the University of California at Davis. Several years later, A. M. Brown, under the guidance of D. L. Morgan, expanded this computer program in preparation for analysis of the micrometeorological data then being gathered at the Davis Hydrometeorological Field Site. This program, which calculates some 32 variables, is referred to as the EDP (Eddy Diffusivity Program) in the discussion below. A later version of this EDP program, called the condensed eddy diffusivity program, CEDP, was developed to treat the data with respect to narrow intervals of Richardson number.

To aid our discussion of the EDP, Fig. C-1 presents a single computer-tabulated sheet containing a listing of the input data and output variables for a single half-hour period. The period ending 1300 on 4 May 1970 was selected because of the steady-state conditions prevailing at that time. Shown in the heading are the ending time of the half hour over which the data were averaged (1300 hours), and the run date (4 May 1967.) The input data appear in two locations on the tabulated page: along the top and near the bottom. The input parameters, with their definition and data sources, are as follows:

Top of page

D Displacement height (cm) - determined using both hand-plotted wind-profile data and a modified version of a computer program for calculating displacement height and roughness from the measured wind data (Stearns 1969).

K Von Karman's constant (1)- initially selected as 0.40 but later changed as discussed in the section on editing in this appendix.

WIND DIRECTION (degrees) - as measured with the Lourence wind vane at 4 meters above the surface. This parameter is just for information, and is not used in the program calculations.

P Atmospheric pressure(mb) - as measured at the nearby University of California climatological station and checked against the pressure as measured at the ESSA Weather Bureau Office in Sacramento.

G Gravity (cm/sec^2) - as measured by the California Division of Mines and corrected for the anomaly appropriate at Davis, Calif.

Bottom of page

DBT temperature profile (°C) - values averaged for corresponding levels at three masts (A, B, and C) within the turf field for the nonadvection runs and from mast A alone for the advection cases. In all cases these are smoothed temperature data for surface (measured with a Barnes infrared thermometer) and for the 25, 35, 50, 70, 100, 140, 200, 280, and 600 centimeter heights measured with 5-junction thermopiles in a psychrometer system. See Appendix B for details on the temperature measuring system.

TABLE OF EDDY DIFFUSIVITIES AND NON-DIMENSIONAL FLUXES
(VALUES ARE FOR THE CHANGES IN HEIGHTS WHERE HEIGHTS ARE IN CM.)

PROCESS DATE26 AUG 69
RUN DATE 4 MAY 67

TIME 1300 D= 10.60-CM. K=.400 WIND DIRECTION= 180.10 P= 1014.9 G= 979.977

	UNITS	25-35	35-50	50-70	70-100	100-140	140-200	200-280	280-400	400-600
CD	NON-DIMEN.	0.0307	0.0222	0.0172	0.0144	0.0122	0.0108	0.0096	0.0084	0.0078
RI	NON-DIMEN.	-0.0154	-0.0239	-0.0433	-0.0625	-0.1055	-0.1627	-0.2594	-0.0000	-0.0000
RHO	GMS./CM**3	0.00120	0.00120	0.00120	0.00120	0.00120	0.00120	0.00121	-0.00000	-0.00000
KHB	CM**2/SEC.	388.778	660.001	1054.765	1580.489	2506.332	3585.435	5838.137	-0.000	-0.000
KHE	CM**2/SEC.	354.823	602.359	962.646	1442.455	2287.438	3272.297	5328.256	-0.000	-0.000
KW	CM**2/SEC.	236.717	500.004	777.784	1441.188	2177.796	3500.028	5226.708	-0.000	-0.000
KM	CM**2/SEC.	309.904	513.945	871.127	1305.320	2125.167	3184.933	5091.712	-0.000	-0.000
KHB/KM	NON-DIMEN.	1.255	1.284	1.211	1.211	1.179	1.126	1.147	-0.000	-0.000
KHE/KM	NON-DIMEN.	1.145	1.172	1.105	1.105	1.076	1.027	1.046	-0.000	-0.000
KW/KM	NON-DIMEN.	0.764	0.973	0.893	1.104	1.025	1.099	1.027	-0.000	-0.000
HBSTAR	NON-DIMEN.	2.874	2.379	1.969	1.623	1.482	1.209	1.198	-0.000	-0.000
HESTAR	NON-DIMEN.	2.623	2.171	1.797	1.481	1.353	1.103	1.094	-0.000	-0.000
ESTAR	NON-DIMEN.	1.750	1.802	1.452	1.480	1.288	1.180	1.073	-0.000	-0.000
TAUSTR	NON-DIMEN.	2.291	1.852	1.626	1.341	1.257	1.074	1.045	-0.000	-0.000
PHIHB	NON-DIMEN.	0.598	0.582	0.568	0.571	0.531	0.540	0.478	-0.000	-0.000
PHIHE	NON-DIMEN.	0.655	0.638	0.622	0.625	0.582	0.592	0.524	-0.000	-0.000
PHIW	NON-DIMEN.	0.982	0.768	0.770	0.626	0.611	0.553	0.534	-0.000	-0.000
PHITAU	NON-DIMEN.	0.750	0.747	0.688	0.691	0.626	0.608	0.548	-0.000	-0.000
USTAR	CM./SEC.	30.995	30.974	30.955	30.939	30.925	30.911	30.898	-0.000	-0.000
STARKM	NON-DIMEN.	0.533	0.535	0.582	0.579	0.639	0.658	0.730	-0.000	-0.000
STARKW	NON-DIMEN.	0.407	0.521	0.519	0.639	0.655	0.723	0.749	-0.000	-0.000
STARHB	NON-DIMEN.	0.669	0.687	0.704	0.701	0.754	0.741	0.836	-0.000	-0.000
STARHE	NON-DIMEN.	0.611	0.627	0.643	0.640	0.688	0.676	0.763	-0.000	-0.000
Z/LHB	NON-DIMEN.	-0.0112	-0.0185	-0.0288	-0.0434	-0.0641	-0.0934	-0.1348	-0.0000	-0.0000
Z/LHE	NON-DIMEN.	-0.0102	-0.0168	-0.0263	-0.0396	-0.0585	-0.0852	-0.1230	-0.0000	-0.0000
ZP/LHB	NON-DIMEN.	-0.0132	-0.0218	-0.0340	-0.0513	-0.0758	-0.1103	-0.1593	-0.0000	-0.0000
ZP/LHE	NON-DIMEN.	-0.0122	-0.0202	-0.0315	-0.0475	-0.0702	-0.1022	-0.1475	-0.0000	-0.0000

DBT	24.95	20.4800	20.1400	19.8400	19.5900	19.3400	19.1300	18.9100	18.7300	-0.0000	18.3400
Q	11.7200	11.0300	10.5400	10.1200	9.7800	9.4800	9.2000	8.9500	-0.0000	-0.0000	
V	177.0	208.0	236.0	258.0	280.0	298.0	316.0	331.0	344.0	356.0	

E= -0.5880 HB= -0.2290 HE= -0.2090 TAU= 1.1510

VT	295.3810	294.9347	294.5589	294.2442	293.9415	293.6853	293.4221	293.2037	273.1600	291.5000

LHB= -1680.940 LHE= -1841.796 PLHB= -1422.882 PLHE= -1536.471

FIGURE C - 1. Computer listing of the input data and results of the calculation of many micrometeorological variables.

Q Absolute-humidity profile (gm/m^3) - as measured by an infrared hygrometer system (see Appendix B for details), which drew air samples from a mast located by the 20-foot weighing lysimeter central to the temperature masts.

V Wind-speed profile (cm/sec) - as measured by Thornthwaite anemometers mounted at heights of 25, 35, 50, 70, 100, 140, 200, 280, 400, and 600 centimeters on a mast central to the temperature masts.

E Evapotranspiration (mm/hr) - as measured by the 6.1-meter-diameter weighing lysimeter. Comparison was made with evapotranspiration from the floating drag-plate lysimeter, and agreement within 2% was usual.

HB Sensible heat flux (ly/min) - calculated as the remainder term from the energy balance.

HE Sensible heat flux (ly/min) - as measured with the Evapotron in the heat mode of operation. See Appendix B for details.

TAU Shear stress ($dynes/cm^2$) - as measured with the 6.1-meter-diameter floating drag-plate lysimeter. Goddard (1970) presents details on the performance of this instrument and states that it has a sensitivity of 20 grams (0.067 $dynes/cm^2$). Variability during light wind conditions will be noted in these data, reflecting the relative effects of sensitivity and of zero drift.

The remaining information shown on the computer listing (Fig. C-1) is the result of manipulation of the input data according to a variety of formulae in the EDP. The bulk of the micrometeorological variables calculated are listed by height intervals 25-35, 35-50, 50-70, 70-100, 100-140, 140-200, 200-280, 280-400, and 400-600 cm. Height intervals chosen for the finite differencing were narrow so as to maximize the representativeness of this method of calculation with respect to the real gradients existing in the profiles so treated.

A listing of the micrometeorological variable, its name, and formulation used in its calculation will follow the order in which these variables appear in the EDP. A few intermediate operations are also included in this list. For the most part these variables will be in the same order as in the listed output.

VT- Virtual temperature - listed in profile form in the next-to-last line of output.

$$VT[^\circ K] = T[^\circ K] + .61\left(\frac{622.}{.217}\right)\left[\frac{cm^3 mb}{gm\,^\circ K}\right] x\left(\frac{Q[gm/m^3]\,x\,(T[^\circ K])^2}{P[mb]}\right)x10^{-6}\left[\frac{m^3}{cm^3}\right]$$

where: 622. = constant based on mass of water vapor to mass of dry air.

.217 = constant from dividing the mass of water vapor by the universal gas constant.

.61 = constant from basic formulation $VT = T(1 + .61q)$

RI- Richardson number

$$RI[1] = \left(\frac{G[cm/sec^2] \times (VT_2[°K] - VT_1[°K])}{\overline{VT}[°K] \times (V_2[cm/sec] - V_1[cm/sec])^2} \right) \times (Z_2[cm] - Z_1[cm])$$

where: subscripts refer to values of the input data at selected respective heights Z_1 and Z_2, where Z_1 is the lower height.
$\overline{VT}$ = average virtual temperature.

RHO- Air density

$$RHO[gm/cm^3] = \frac{P[mb]}{2870. \left(\frac{cm^2}{sec^2 °K} \right) \times \overline{VT}[°K]} \quad , \quad [mb] = 1000[gm/cm\ sec^2]$$

where: 2870. = gas constant for dry air.

KHB- Transfer coefficient (eddy diffusivity) for heat using HB

$$KHB[cm^2/sec] = \frac{HB[cal/cm^2 min] \times (Z_2[cm] - Z_1[cm]) \times 1/60[min/sec]}{.241[cal/gm°C] \times RHO[gm/cm^3] \times (T_2[°C] - T_1[°C])}$$

where: .241 = Cp, specific heat of air at constant pressure.

KHE- Transfer coefficient for heat using HE

KW- Transfer coefficient for water vapor

$$KW[cm^2/sec] = \frac{E[mm/hr] \times 1.0[gm/cm^3] \times (Z_2[cm] - Z_1[cm]) \times 1/3600[hr/sec] \times 1/10[cm/mm]}{(Q_2[gm/m^3] - Q_1[gm/m^3]) \times 10^{-6}[m^3/cm^3]}$$

where: 1.0 = density of water

KM- Transfer coefficient for momentum

$$KM[cm^2/sec] = \frac{TAU[dynes/cm^2]\ or\ [gm/cm\ sec^2] \times (Z_2[cm] - Z_1[cm])}{RHO[gm/cm^3] \times (V_2[cm/sec] - V_1[cm/sec])}$$

KHB/KM, KHE/KM, KW/KM - all nondimensional ratios of the transfer coefficients (eddy diffusivities) represented by the example below.

$$KHB/KM[1] = \frac{KHB[cm^2/sec]}{KM[cm^2/sec]}$$

Geometric mean height - intermediate variable

$$Z[cm] = e^{\left[\frac{\ln(Z_2[cm] - D[cm]) + \ln(Z_1[cm] - D[cm])}{2} \right]}$$

HBSTAR- Nondimensional heat flux using HB data.

$$HBSTAR[1] = \frac{HB[cal/cm^2 min] \times 1/60[min/sec]}{RHO[gm/cm^3] \times .241[cal/gm°C] \times \left(\frac{G[cm/sec^2]}{\overline{VT}[°K]}\right)^{1/2} \times \left(\frac{VT_2[°K]-VT_1[°K]}{Z_2[cm]-Z_1[cm]}\right)^{1/2}} \times \frac{1}{(Z[cm])^2 \times \left(\frac{T_2[°C]-T_1[°C]}{Z_2[cm]-Z_1[cm]}\right)}$$

where: .241 = Cp, specific heat of air at constant pressure.

HESTAR - Nondimensional heat flux using HE data.

ESTAR - Nondimensional moisture flux.

$$ESTAR[1] = \frac{E[mm/hr] \times 1.0[gm/cm^3] \times 1/3600[hr/sec] \times 1/10[cm/mm]}{\left(\frac{G[cm/sec^2]}{\overline{VT}[°K]}\right)^{1/2} \times \left(\frac{VT_2[°K]-VT_1[°K]}{Z_2[cm]-Z_1[cm]}\right)^{1/2} \times (Z[cm])^2} \times \frac{1}{\left(\frac{Q_2[gm/m^3]-Q_1[gm/m^3]}{Z_2[cm]-Z_1[cm]}\right) \times \frac{1}{10^6}\ [m^3/cm^3]}$$

TAUSTR - Nondimensional momentum flux.

$$TAUSTR[1] = \frac{TAU[dynes/cm^2] \text{ or } [gm/cm\ sec^2]}{RHO[gm/cm^3] \times \left(\frac{G[cm/sec^2]}{\overline{VT}[°K]}\right)^{1/2} \times \left(\frac{VT_2[°K]-VT_1[°K]}{Z_2[cm]-Z_1[cm]}\right)^{1/2} \times (Z[cm])^2} \times \frac{1}{\left(\frac{V_2[cm/sec]-V_1[cm/sec]}{Z_2[cm]-Z_1[cm]}\right)}$$

USTAR - Friction velocity

$$USTAR[cm/sec] = \left(\frac{TAU[dynes/cm^2] \text{ or } [gm/cm\ sec^2]}{RHO[gm/cm^3]}\right)^{1/2}$$

CD - Drag coefficient - listed as the first item under the interval calculations.

$$CD[1] = \frac{TAU[dynes/cm^2] \text{ or } [gm/cm\ sec^2]}{RHO[gm/cm^3]} \times \frac{1}{(V[cm/sec])^2}$$

PHIHB - Phi function for heat flux using HB

$$PHIHB[1] = \frac{RHO[gm/cm^3]x.241[cal/gm°C]xK[1]xUSTAR[cm/sec]xZ[cm]x60[sec/min]}{HB[cal/cm^2min]} x$$

$$\frac{T_2[°C]-T_1[°C]}{Z_2[cm]-Z_1[cm]}$$

PHIHE - Phi function for heat flux using HE

PHIW - Phi function for water-vapor flux

$$PHIW[1] = \frac{K[1]xUSTAR[cm/sec]xZ[cm]}{1.0[gm/cm^3]xE[mm/hr]x1/3600[hr/sec]x1.0[cm/mm]} x$$

$$\frac{(Q_2[gm/m^3]-Q_1[gm/m^3])x1/10^6[m^3/cm^3]}{Z_2[cm]-Z_1[cm]}$$

PHITAU - Phi function for momentum flux

$$PHITAU[1] = \frac{K[1]xZ[cm]}{USTAR[cm/sec]} x \frac{V_2[cm/sec]-V_1[cm/sec]}{Z_2[cm]-Z_1[cm]}$$

$$STARKM[1] = \frac{KM[cm^2/sec]}{Z[cm]xUSTAR[cm/sec]} \text{ or } \frac{USTAR[cm/sec]}{Z[cm]} x \frac{Z_2[cm]-Z_1[cm]}{V_2[cm/sec]-V_1[cm/sec]}$$

STARKW - Generalized von Karman's constant for water vapor.

$$STARKW[1] = \frac{KW[cm^2/sec]}{Z[cm]xUSTAR[cm/sec]}$$

STARHB - Generalized von Karman's constant for heat using KHB.

$$STARHB[1] = \frac{KHB[cm^2/sec]}{Z[cm] \text{ x } USTAR[cm/sec]}$$

STARHE - Generalized von Karman's constant for heat using KHE instead of KHB.

LHB - Monin-Obukhov scale length using HB.

$$LHB[cm] = \frac{(USTAR[cm/sec])^3x.241[cal/gm°K]xRHO[gm/cm^3]xT_{100}[°K]}{K[1]xG[cm/sec^2]xHB[cal/cm^2min]x1/60[min/sec]}$$

where: T_{100} = dry-bulb temperature 100 cm above the surface.

LHE - Monin-Obukhov scale length based on HE instead of HB.

Z/LHB, Z/LHE - Normalized scale lengths.

PLHB, PLHE - Monin-Obukhov scale lengths based on HB and HE, respectively, which were calculated taking into account the presence of water vapor by correcting the heat flux as follows:

$$H[cal/cm^2min]+0.07(588.[cal/gm] \text{ x } E[mm/hr] \text{ x } 1/10[cm/mm] \text{ x } 1/60[hr/min] \text{ x } 1.0[gm/cm^3])$$

where: 588. = latent heat for vaporization of water.

ZP/LHB, ZP/LHE - Normalized moisture-corrected scale lengths.

The variety of variables just described were calculated by the following procedure from micrometeorological data gathered at Davis.

Step 1. Input data for each of the six field runs (see Appendix B for dates) consisting of smoothed profiles of temperature, moisture, and wind speed plus the measured fluxes were processed through the EDP using a von Karman's constant of 0.40. This enabled a first-estimate look at the values of the variables, in particular those of the Richardson number.

Step 2. For each separate field run these same input data were processed through the CEDP, which grouped the data within narrow intervals of Richardson number. (A von Karman's constant of 0.40 was used.) The program produced geometric-mean values of k_m^*, the generalized von Karman's constant, for the various intervals of Richardson number (Ri) as well as calculating the values of many other variables.

Step 3. The geometric mean values of k_m^* were plotted as a function of the geometrically averaged Richardson number for each run. The best-fit value for k was then determined for each run where the line passed through Ri equal to zero (neutral conditions). A detailed discussion of von Karman's constant is found in Chapter II of this report.

Step 4. For each run, Step 1 was repeated using the appropriate values of von Karman's constant as determined in Step 3. These values for the "constant" ranged from 0.40 to 0.44 for the field runs. A mean value of 0.42 was found when equal weighting was given to each run.

Step 5. For each run where k, as determined in Step 3, was not equal to 0.42, the field data were re-processed through the EDP using a k of 0.42. The resulting computed values of the variables were written on magnetic tape as well as being listed for future study. Detailed analysis of the phi functions, which depend on the values of the von Karman's constant, is found in Chapter III.

Step 6. The values of the micrometeorological variables for each run were recalculated according to Richardson number interval by processing the data stored on the magnetic tape produced in Step 5 through the CEDP.

At this point, certain criteria for rejection of undesirable input data were applied. These criteria are described in detail after a discussion of the final step, Step 7.

Step 7. Data from all of the field runs except Run 167, where no values of shear stress were measured, and Runs 567 and 667, which were mild advection cases, were lumped and processed through the CEDP to produce summary values of the micrometeorological variables. Values of the phi functions and dimensionless fluxes along with values of other micrometeorological variables from Step 6 were analyzed and the results are given in Chapter IV.

II. EDITING

General criteria for rejection of undesirable data for processing through the CEDP were as follows:

1. -Data between one hour before sunrise until 0930 hours were not used, to avoid times of drastic changes in the energy balance components and in the profiles of temperature, humidity, and wind, which can occur during this period of intense

solar heating. The late-afternoon data were left in for processing since changes are more gradual during this period than in the early-morning hours.

2. -Periods when the wind was coming from between 15 and 165 degrees were eliminated. Fetches to the east of the irrigated turf field site were poor for obtaining the desired nonadvective conditions in the lower levels of air moving over the area where the sensors were located.
3. -Periods when the evaporation was less than or equal to 0.01 mm/hr or when the condensation of dew was less than or equal to 0.01 mm/hr were eliminated because of the uncertainties inherent in such very small magnitudes.
4. -Periods when the values of sensible heat flux were very small lying between -0.05 and 0.05 ly/min were eliminated, for the same reasons as for small values of evaporation and condensation.
5. -Levels below 35 cm and above 200 cm were eliminated because of the possible nonrepresentativeness of the infrared humidity data. This is explained in more detail in Appendix B. For Run 466, a day of strong dry winds and a second morning with more moderate winds, height intervals above 100 cm were omitted during daylight hours to avoid the possibility of significant downwind changes in temperature and humidity. During night hours and on the second day of milder advection, only the height intervals of 25-35 and 140-200 cm were eliminated.

Specific data were eliminated:

1. If a value for STARKM was missing, all parameters at the corresponding height for that half-hour period were omitted.
2. If a value for STARKW was missing, the following parameters for the affected height were omitted: KW/KM, ESTAR, PHIW, ZP/LHB.
3. If a value for STARHB was missing, the following parameters for the corresponding height were omitted: KHB/KM, HBSTAR, PHIHB, Z/LHB, and ZP/LHB.
4. Entire half-hour periods were eliminated in cases where drastic changes in solar radiation (and hence in the energy balance and heat storage in the canopy) could have affected the results, e.g., for Run 267, 1430-1530, 2 May; 1400-1500, 3 May; and 1400-1500, 4 May.
5. Although 5 May was part of Run 267, since it was a predominantly cloudy day, as was 9 May (Run 367), a period from 0930 to the end of the day was omitted from the CEDP of Run 267 but was added to that for Run 367.

Additionally, some obviously wild data were omitted. In most cases of wild data elimination reasons were found such as:

1. An occasional case where an incorrect value of temperature, humidity, or wind speed had been picked off the smoothed curves and recorded. (Many of these were caught and corrected in early processing.)
2. An occasional profile of temperature, humidity, or wind speed which showed unusual changes in slope or indicated a possible discontinuity. Such changes or discontinuities in profiles could have been due to drastic increases or decreases in wind speed during a half-hour averaging period (conditions which are far from steady-state), or due to drastic changes in wind direction during the averaging

period.

Where no particular reason was obvious, any value of a parameter which seemed unreasonably out of agreement was omitted.

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Extensive surface shear-stress and wind-profile measurements during six separate field studies at Davis, California, indicate a value for the von Karman constant, k, of 0.42. Expressions relating k_m^* to the Richardson number for both stable and unstable conditions, based on the Davis data, are presented and compare favorably with the findings of several others.

Expressions relating the diabatic wind profile functions to both the Richardson number and z/L are developed and compared with the results of many other researchers. For $\phi_M(Ri)$ the data are fit best by expressions having the form of $\phi_M=(1+b\,|Ri|)^{|n|}$ indicating the Rossby-Montgomery, Holzman, and KEYPS expressions are sound in form. UCD data infer, however, that the exponent n should be 1/3 rather than 1/4 or 1/2 used in the above. K_W/K_M varied from a low of 0.7 at Ri=.3 up to 1.6 at Ri=-2. At neutral, K_W/K_M was 1.13 rather than 1.0. In a comparison of UCD ϕ_W data with that of Dyer, generally good agreement was noted except near neutral.

The newly derived dimensionless flux parameter for momentum, τ^*, was shown to respond to changing stability conditions in a fashion similar to H* and E*. The E* values for the Davis data are in excellent agreement with those reported by Crawford. While τ^* remained relatively constant beyond Ri=-.15, E* gradually increased reflecting increasing K_W/K_M under free convection.

For the advection of dry air over an irrigated grass turf, the earlier-reported UCD work was generally substantiated by additional analyses reported herein.

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