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Estimating Daily Advective Contributions to Potential Evapotranspiration

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ESTIMATING DAILY ADVECTIVE CONTRIBUTIONS TO POTENTIAL EVAPOTRANSPIRATION

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ABSTRACT

Wind speeds, local and up-wind temperatures, and dew-point temperatures extracted from 1200-GMT surface maps were found to explain 37 to 57 percent of the variance in the ratios of equivalent latent energy (LE) to net radiation (RN) for "crop stage" subgroups of soybeans at four site-year combinations in eastern and central Nebraska. The corresponding linear regression relationships were consistent between subgroups. Differences between subgroup ratios which were not explained by the data may have resulted from differences in crop maturity, methodology, or insufficient weather information. A similar analysis applied to alfalfa at the same sites was less conclusive. This possibly was due to underestimation of advective heat by the Bowen Ratio Energy Balance method used.

Key words: Advection effects, potential evapotranspiration, synoptic weather applications

This paper was prepared for limited distribution to the research community outside the Department of Agriculture. The views expressed herein are not necessarily those of SRS or USDA.

FOREWORD

Many of the physiologic crop yield models now being developed estimate moisture loss through evapotranspiration as a function of solar radiation and precipitation. While this may be suitable for humid areas, it is known that the lateral transfer of heat from other regions does have a material effect on the potential evapotranspiration in arid and sub-arid regions. Therefore this study was sponsored in the interest of determining to what degree the lateral transfer of heat could be approximated, even anticipated, from synoptic weather maps.

I do particularly want to express my gratitude to Dr. Blaine L. Blad, University of Nebraska, for providing the on-site data required by this study.

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TABLE OF CONTENTS

SUMMARY 1

INTRODUCTION 2

METHODS 3

RESULTS AND DISCUSSION 7

CONCLUSIONS 21

REFERENCES 22

APPENDIX 24

ESTIMATING DAILY ADVECTIVE CONTRIBUTION
TO POTENTIAL EVAPOTRANSPIRATION

SUMMARY

Estimates of daily contributions of advection to potential evapotranspiration were examined for possible relationships to variables derived from conventional surface weather maps. Contributions were expressed in terms of the ratio of equivalent latent energy (LE) to net radiation (RN). They were derived on a total of 105 days from lysimeter measurements for soybeans and from the Bowen Ratio Energy Balance measurements for alfalfa in four site-year combinations in eastern and central Nebraska. Wind speeds estimated from the surface pressure gradients, local and up-wind temperatures, and dew-point temperatures were extracted from 1200-GMT surface maps corresponding to the field observations. Other weather variables were derived from combinations of the original variables.

In "crop stage" subgroups of the soybean data, 1200-GMT temperatures, dew-point depressions, and wind direction were found to explain 37 to 57 percent of the variance in the LE/RN ratios. The corresponding linear regression relationships were consistent between subgroups. Mean differences between subgroup ratios which could not be explained by the data may have been due to crop maturity, methodologies, or insufficient weather information. The less conclusive results obtained from the sample of alfalfa data were possibly due to underestimation of advection by the Bowen Ratio Energy Balance method. The overall results would support further development of weather-map approaches to estimating advection effects.

INTRODUCTION

In many field situations more water will evapotranspire (ET) from a crop than would be indicated by the net radiation (RN) supply of energy at the site. Various micrometeorological studies have documented that the extra water consumed is attributable to horizontal transfer (advection) of heat and/or vapor pressure deficits. This advection results from the component of the wind which flows at right angles to a discontinuity or gradient in temperature or humidity. The effects of advection on ET are largest in small isolated wet fields in dry areas. It appears to contribute to ET in about 75 percent of the spring and summer days where dry conditions prevail and may account for 40 to 50 percent of the total evapotranspiration (ref. 1 and 2). In extreme cases advection may contribute more to evapotranspiration (LE) than net radiation ($LE/RN \geq 2$) as often as 1 day in 4. More commonly, advection may contribute for 70 to 90 percent as much energy as net radiation (1.7 - LE/RN -1.9, ref. 4 & 5).

The most common and extensively studied type of horizontal heterogeneity are boundaries created by different ground covers in adjacent fields. Part of any subsequent advection is due to direct transport through the edge of the canopy. This has been labeled the "clothesline" effect and considered local advection (ref. 6). Roughness effects, buoyancy differences, interactions between horizontal temperature and moisture gradients, etc. have prevented a useful analytical solution to the corresponding differential equations (ref. 7). Micrometeorological measurements and empirical relationships indicate that the edge effects extend 40 to 100 times the height of instruments depending on wind speed, roughness, etc.

A second type of advection results from airflow above canopies which transports properties from gradients along horizontal transverses extending up to synoptic scales. This is called regional advection for its origin or "oasis effect" for its mode of action. The resulting exchanges of heat and water vapor can extend tens of miles across a contrasting surface (ref. 8 and 9). Regional advection accounts for the major part of the total advective contributions to evapotranspiration in normal size agricultural fields. In a small field (2 hectares) of irrigated alfalfa in eastern Nebraska, regional advection averaged over 90 percent of the total observed advection (ref. 10).

If actual evapotranspiration is less than the potential rate due to limited soil moisture or plant resistances, an initial transport of sensible heat would not appear as advection measured by ET. It would manifest in terms of an increase in temperature of the canopy and adjacent air layers and increased fluxes of sensible heat to the soil and atmosphere. The resulting increase in both heat and moisture stress on the crop would be detrimental to yields. In an adjacent irrigated field the effect is manifest in the extra cost of water for the increased ET. In such events, it is typical that crop yield is also increased. The negative effects of advection are increased during occurrences of droughts (ref. 4).

In addition to causing increases in evapotranspiration rates in irrigated fields and immediately after rains, another reason that advection is a problem is due to the lack of applicable methods of including its effect in PET estimation models. Brakke et.al. (ref. 19) found that micrometeorological modifications to the Bowen ratio - energy balance method did not completely correct the advection related underestimates of LE. Similar deficiencies have been found for modifications of the Penman combination method (ref. 1). A procedure proposed by Jury and Tanner (ref. 11) for the Priestly-Taylor model was found to be unsatisfactory by Kanemasu (ref. 12). Alternative approaches investigated particularly in the USSR (ref. 13) are based on more synoptic meteorological-climatological indicators of advection and PET relationships. Independent assessments of these accuracy and applicability of these methods are limited.

Conceptually, advection can be well defined, but efforts to quantify it in terms of evapotranspiration have met with limited success. Its contribution to PET depends on wind speed, characteristics of the upwind gradients of temperatures and vapor deficits, and fetch and roughness features of the field. Part of the quantification problem is due to the lack of direct methods of measuring advection; it must be estimated from a combination of precision micrometeorological and lysimetric measurements and controls of which few are available (ref. 14).

The purpose of this study was to utilize a set of advection estimates available from Nebraska to determine the degree to which advection days can be identified from information provided through regular synoptic weather maps.

METHODS

Data consisting of LE and RN values were provided to the USDA by the University of Nebraska. It covered four crop-year combinations which are listed in table 1. Fetch data and references that give additional descriptions of the sites and measurement methods are also given in Table 1. The Mead and Schuyler sites are in east central Nebraska and the Cozad site is about 300 kilometers west of Mead in the central part of the state.

A major distinction exists between the methodology used for the soybean versus the alfalfa data. The latent energy for soybeans was derived by lysimeter measurements of ET while the LE for alfalfa was computed by the Bowen Ratio Energy Balance (BREB) method.

Surface synoptic weather maps prepared by the National Weather Service for 1200 GMT (6:00A.M.CST) were acquired for each day the field research data were collected. These maps were analyzed by NOAA to show the pressure centers and fronts as well as display the plotted data for each reporting station. A sample map is shown in Figure 1.

Table 1
Identification and characteristics of the Nebraska measurements data used in the study.

YEAR	CROP	SITE	NUMBER OF OBSERVATIONS	MIN.FETCH (METERS)	DOCUMENTATION
1969	Soybeans	Mead	37	40	ref. 2
1970	Soybeans	Mead	27		ref. 15
1973	Alfalfa	Schulyer	29		
1973	Alfalfa	Cozad	12	125	ref. 16

Further analyses were performed to obtain values for variables which conceivably could represent components or factors related to heat or moisture advection. Values were visually interpolated to the approximate locations of the field sites. They included:

wind speed - estimated using the geostrophic wind relationship based on isobaric spacing, knots/hour

prevailing wind direction- as above, to the nearest of 8 cardinal points

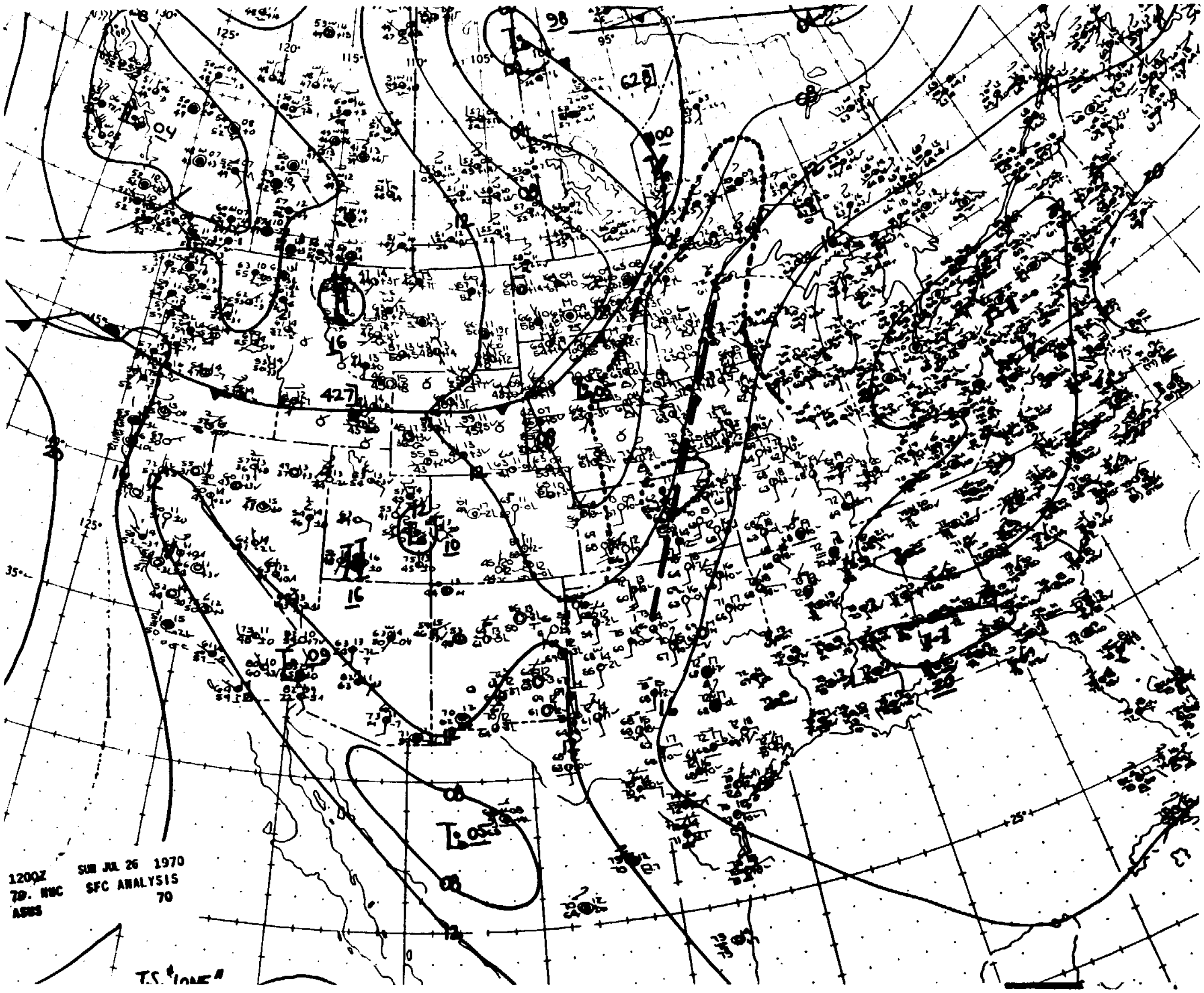
temperature gradient in the upwind direction, deg./mile

dew-point temperature gradient upwind direction, deg./mile

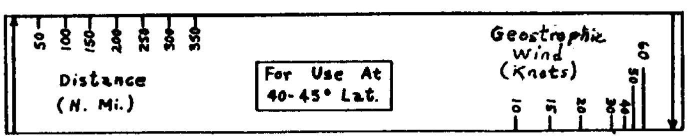
dew-point temperature at 1200Z, ^{o}F

dew-point depression at 1200Z, ^{o}F.

To estimate advection of sensible heat or vapor pressure deficits, it was assumed that the trajectory of the air reaching the target during the next 12-hour period was represented by the local tangent to the horizontal surface pressure field pattern. The temperature and dew-point temperatures were estimated along upwind trajectories for distances equal to 12 time the wind speed. The magnitude of the temperature or dew-point "advection" was computed as the product of the gradient and wind speed. Negative values would indicate that relatively lower temperatures would be advected. A moisture "advection" variable was computed as the 1200Z dew-point depression plus the temperature "advection" minus the dew-point temperature "advection". Negative values were set equal to zero.



SCALE FOR WIND SPEED ESTIMATION



KEY

—— ISOBAR

— — TANGENT TO PRESSURE PATTERN

.... ISOTHERM

Figure 1. Sample map and analysis of weather features for Mead, Nebraska, July 26, 1970 (south wind at 30 knots, synoptic type B)

Each day's synoptic weather pattern was placed into one of eight possible categories. The categories used were:

A. high pressure to the north with general N to E circulation
B. advancing low or front to the west with strong southerly circulation
C. low pressure or front traversing the area, variable winds
D. between pressure systems, little or no predominant winds
E. front to the east, general W or NW circulation
F. low pressure or trough to the south, E to SE circulation
G. high pressure dominating, little or nor predominant circulation
H. high pressure to the east, general SE to SW circulation.

The local temperature at 1200Z was derived as the sum of the dew-point temperature and dew-point depression. Days of the year where numbered from March 1 (climatological day). A listing of the abbreviations used for the variables is given in the appendix. All data were entered and filed on the USDA/Martin Marietta computer system. The Statistical Analysis System, SAS (ref. 17) was used for all the computations performed in the study.

The ratio of the latent energy equivalent of the evapotranspiration to the daytime total of net radiation (LE/RN) was used as a relative measure of the results of advection. The principal assumptions required for the ratios to be valid measures are:

- water for evapotranspiration is unrestricted in availability

- sensible heat transfer with the soil and other components of the energy balance are essentially constant over the period.

Cases where either LE or RN were missing were deleted from the analysis.

RESULTS AND DISCUSSION

The LE/RN ratios were first plotted by dates to examine their magnitudes and seasonal distribution. The plot for soybeans is presented in Figure 2; it shows a distinct seasonal pattern which parallels normal seasonal trends of each component - LE and RN. Seasonal trends in LE are primarily determined by RN, crop development stages, and advection. Forming the dimensionless ratio, LE/RN, adequately removed the correlation (r=0.68) between the two in that the correlation between the ratios and RN was 0.09. Since there was no direct way for testing for crop maturation effects, the soybean ratios were split into parts to study their association with other variables. Ratios from July 1 to July 21 were considered group 1 and the others as group 2.

The soybean ratios from 1969 and 1970 were compared for between year differences with a paired-t test. A subset of 8 pairs of ratios which had matching dates of observations in the two years was selected. The mean difference between the two years was 0.08 and the paired-t statistic (0.58) did not reject the null hypothesis of equal means. With the added assumption that the field "surroundings" were the same in both years, the data were pooled then subdivided into groups 1 and 2 as described previously.

The ratios for alfalfa at Schuyler and Cozad were distinctly lower in July than corresponding values in soybeans with a trend upward to similar levels in August (Figure 2 - Triangles). This result be itself would indicate there was less advection at the Schuyler site in 1973 than observed at Mead in 1969 and 1970. In terms of crop effects, alfalfa normally has less resistance to transpiration fluxes than other crops. Another possible explanation would be bias in the BREB method used to derive LE values for the Schuyler alfalfa. Research at Nebraska has shown that underestimates of 20 to 40% by this method are proportional to amounts of advection (ref. 10 and 15). Other ratios for alfalfa which are based on lysimeter measurements (ref. 4) were plotted in Figure 3 for comparisons. The lysimeter based ratios also show higher levels of advection with a downward trend in late July and August.

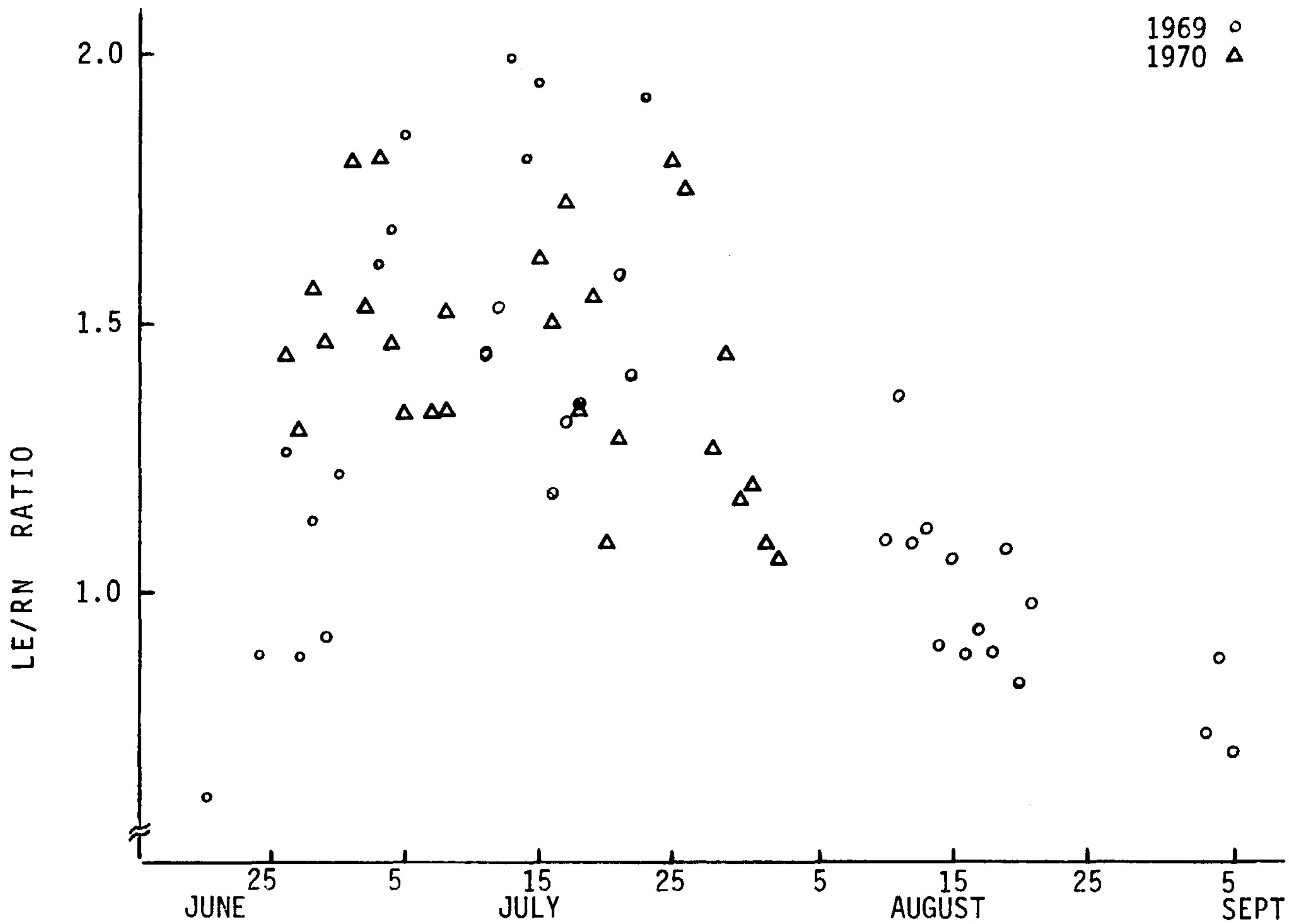


Figure 2. Seasonal distributions of advection as indicated by the ratio of LE to RN for soybeans at Mead, Nebraska.

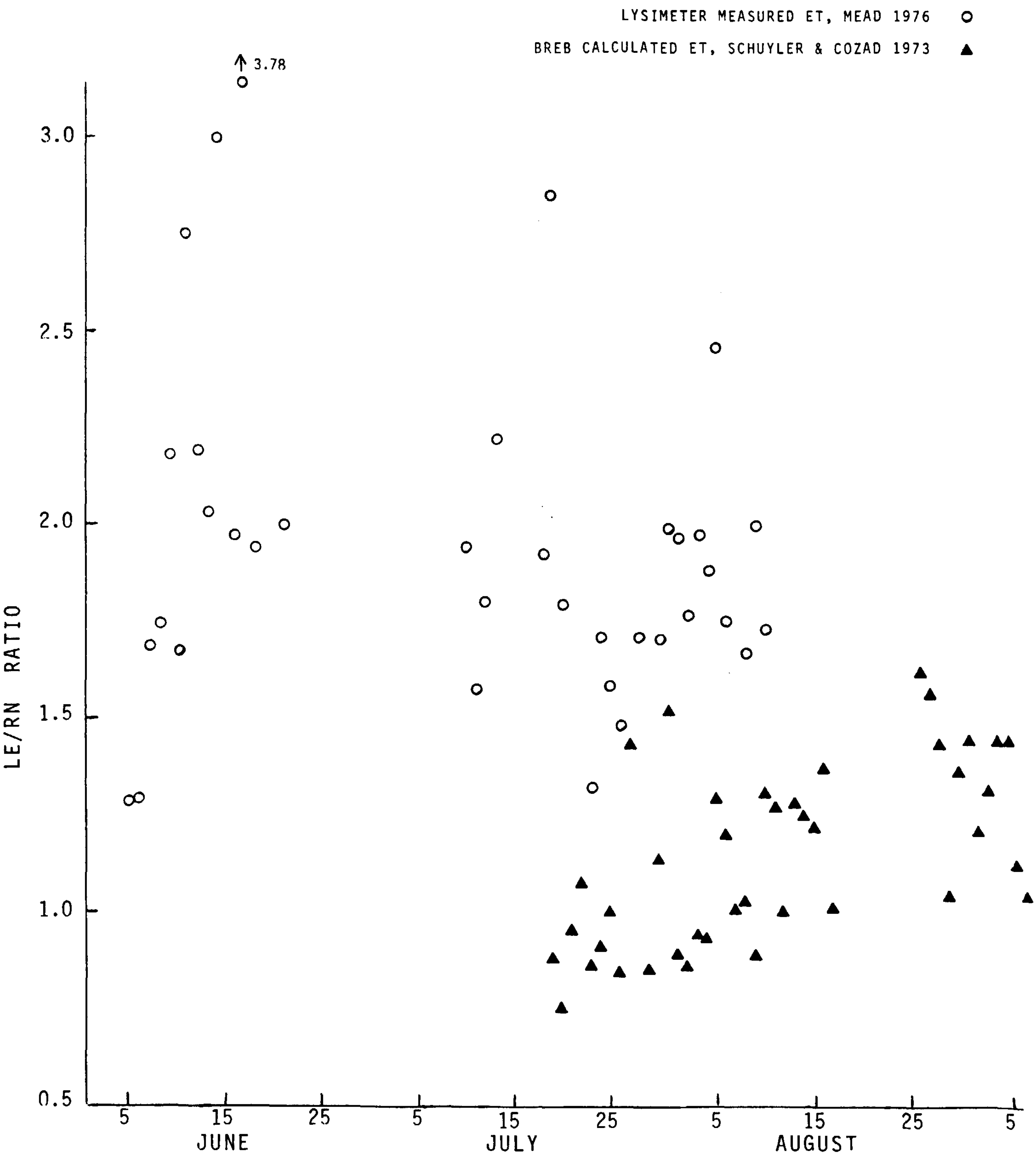


Figure 3. Seasonal distribution of advection as indicated by the ratio of LE to RN for alfalfa at the indicated locations in Nebraska.

If 1973 was not a unusual year, both the level and trends in the ratios could be due to bias in the BREB method. Therefore the alfalfa data were separated for individual analysis and tests.

The first factor examined in the soybean data was wind direction. The mean LE/RN ratios are plotted in Figure 4. Individual subgroups did not have enough data to derive reliable means (n-3) for each direction. The June-August (group 2) cases had predominately south and easterly winds, while the July (group 1) cases had more occurrences of not and northwest winds which had higher value of the ratio. Thus the seasonal distribution of wind directions help to explain the higher value of the ratios observed in July. When both groups were combined, it was found that the ratios increased almost symmetrically with rotation from a direction slightly south or east (Figure 4). Subsequently, directions were coded in terms of degree deflection from E - SE to form a single linear variable. The simple correlation with ratios were 0.37 and 0.26 for groups 1 and 2 respectively.

The matrix of Pearson product-movement correlation coefficients was computed for each group of soybean data - Table 2. Wind speed, dew-point depression, wind direction, initial temperature, and dew-point depression advection were the independent variables having the largest correlation with the ratios. Coefficients - 0.35 are significant at the 95% level of probability.

To statistically search for combinations of variables associated with the ratio, R-squared values for all possible regressions with 2 and 3 independent variables were computed. The results are given in Table 3. Initial temperature-dew-point depression and initial temperature-wind direction were the pairs of variables which gave the highest R-squares.

The association between the ratios, initial temperature and dew point depression, was examined by linear regression. It was found that initial temperature and dew point depression, individually or jointly, explained significant proportions of the variation in the ratios. The t-test for equality of slopes ($t = 1.185$ vs. $t_{(60,0.90)} = 1.296$) did not reject the null hypothesis ($H_o: b_1 = b_2$). The regression coefficients are given in Figures 5A and 5B. The results, particularly for subgroup 2, generally agree with results found by investigators in the USSR (ref.13). They frequently used different combinations of temperature and humidity as criteria for classifying sukhovei. Failure of minimum daily temperatures to reach the dew point has also been cited as a sukhovei criterion. The regression for subgroup 2 would indicate that advection contributions begin when the average 1200Z dew-point depression is greater that 2.5^{o}F.

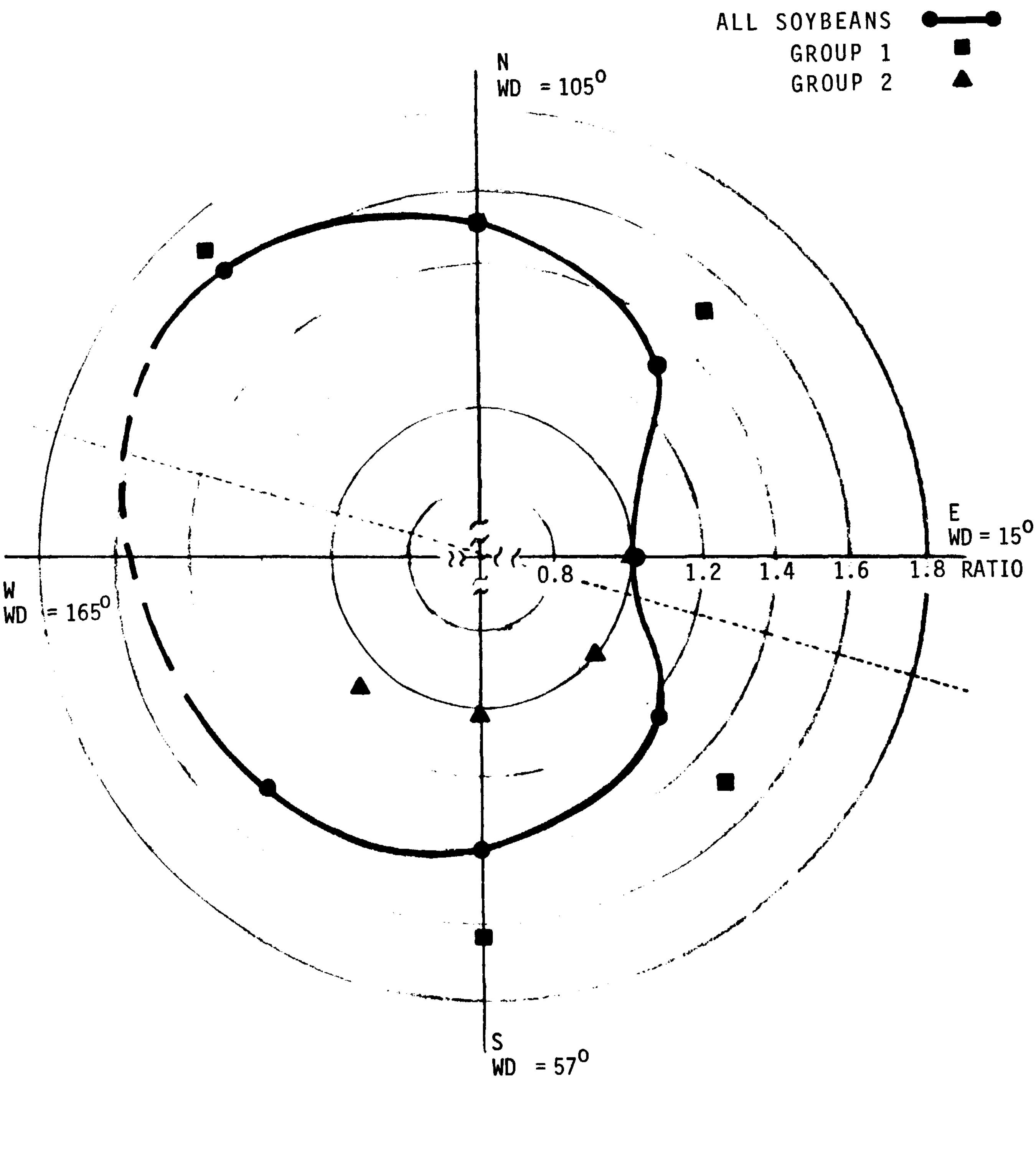


Figure 4. Distribution of average LE/RN ratios for Mead soybeans according to wind directions.

Table 2. Matrix of correlation coefficients for variables in the two subgroups of soybean data.

G=1

CORRELATION COEFFICIENTS / N = 32

	WS	TG	TA	DG	DA	DW	DP	WD	RN	LE	R	TI	SA
WS	1.00000	-0.13365	0.17434	-0.24077	-0.32633	0.13802	0.19748	0.43102	0.15051	0.29191	0.32321	0.22488	0.65097
TG	-0.13365	1.00000	0.78721	0.72556	0.58462	0.04397	-0.18254	-0.53877	0.07138	-0.08323	-0.20284	-0.05219	0.05877
TA	0.17434	0.79721	1.00000	0.48281	0.53601	0.14893	-0.18087	-0.53627	0.19500	0.06270	-0.12598	0.04389	0.33120
DG	-0.24077	0.72556	0.48281	1.00000	0.94271	-0.20239	0.14269	-0.27755	-0.14589	-0.19814	-0.09516	-0.11166	-0.35007
DA	-0.32633	0.59462	0.53601	0.84271	1.00000	-0.22231	0.13331	-0.38516	-0.01032	-0.14108	-0.20736	-0.13448	-0.47393
DW	0.13802	0.04397	0.14893	-0.20239	-0.22231	1.00000	-0.08516	-0.21875	-0.12121	0.16008	0.36350	0.86446	0.34814
DP	0.19748	-0.18254	-0.18087	0.14269	0.13331	-0.08516	1.00000	0.15346	0.08815	0.27510	0.35389	0.42726	0.24271
WD	0.43102	-0.53877	-0.53627	-0.27755	-0.38516	-0.21875	0.15346	1.00000	-0.07899	0.08396	0.26823	-0.12107	-0.03770
RN	0.15051	0.07138	0.19500	-0.14589	-0.01032	-0.12121	0.08815	-0.07899	1.00000	0.82683	0.10167	-0.06552	0.26179
LE	0.29191	-0.08323	0.06270	-0.19914	-0.14108	0.16008	0.27510	0.08396	0.82683	1.00000	0.63025	0.28406	0.37747
R	0.32321	-0.20284	-0.12599	-0.09516	-0.20736	0.36350	0.35389	0.26823	0.10167	0.63025	1.00000	0.50840	0.30231
TI	0.22488	-0.05219	0.04389	-0.11166	-0.13448	0.86446	0.42726	-0.12107	-0.06552	0.28406	0.50840	1.00000	0.43836
SA	0.65097	0.05877	0.33120	-0.35007	-0.47393	0.34814	0.24271	-0.03770	0.26179	0.37747	0.30231	0.43836	1.00000

G=2

CORRELATION COEFFICIENTS / N = 32

	WS	TG	TA	DG	DA	DW	DP	WD	RN	LE	R	TI	SA
WS	1.00000	0.26056	0.47147	0.19663	0.19408	-0.00458	0.39077	0.46580	0.18447	0.34618	0.32111	0.24100	0.59638
TG	0.26056	1.00000	0.85742	0.82315	0.75255	0.22573	-0.05617	-0.11802	0.03455	-0.04958	-0.13098	0.19914	0.06066
TA	0.47147	0.85742	1.00000	0.70076	0.80913	0.23333	0.06989	-0.21106	0.06114	0.03611	-0.03724	0.28631	0.24847
DG	0.19663	0.82315	0.70076	1.00000	0.90009	-0.04964	0.09458	-0.02346	0.11599	0.00235	-0.09386	0.00793	-0.18403
DA	0.19408	0.75255	0.80913	0.90009	1.00000	-0.07671	0.08934	-0.21415	0.02796	-0.09145	-0.15406	-0.02349	-0.18129
DW	-0.00458	0.22573	0.23333	-0.04964	-0.07671	1.00000	-0.36309	-0.20298	-0.17454	0.09111	0.28890	0.81031	0.09587
DP	0.39077	-0.05617	0.06989	0.09458	0.08934	-0.36309	1.00000	0.39464	0.22622	0.45386	0.51499	0.25179	0.69565
WD	0.46580	-0.11802	-0.21106	-0.02346	-0.21415	-0.20298	0.39464	1.00000	0.19160	0.33495	0.35791	0.03736	0.29482
RN	0.18447	0.03455	0.06114	0.11599	0.02796	-0.17454	0.22622	0.19160	1.00000	0.77749	0.13865	-0.03901	0.20195
LE	0.34618	-0.04958	0.03611	0.00235	-0.09145	0.09111	0.45386	0.33495	0.77749	1.00000	0.72103	0.38007	0.47719
R	0.32111	-0.13098	-0.03724	-0.09386	-0.15406	0.28890	0.51499	0.35791	0.13865	0.72103	1.00000	0.52395	0.50971
TI	0.24100	0.19914	0.28631	0.00793	-0.02349	0.81031	0.25179	0.03736	-0.03901	0.39007	0.62395	1.00000	0.53708
SA	0.59638	0.06065	0.24847	-0.18403	-0.18129	0.09587	0.69565	0.29482	0.20195	0.47719	0.50971	0.53708	1.00000

NOTE: SAS INSTITUTE, SAS CIRCLE, BOX 8000, CARY NC 27511
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Table 3. Maximum R-square values from all possible regressions of ratios on combinations of 2 and 3 independent variables.

G-1

N- 32 REGRESSION MODELS FOR DEPENDENT VARIABLE R

NUMBER IN MODEL	R-SQUARE	VARIABLES IN MODEL
2	0.28050179	TA TI
2	0.29131929	DP TI
2	0.29963705	TG TI
2	0.30442451	WS TI
2	0.36884399	WD TI
3	0.37005900	TA WD TI
3	0.37270885	DG WD TI
3	0.37302922	WS WD TI
3	0.37481213	DP WD TI
3	0.37568069	WD TI SA

G=1

G-2

N= 32 REGRESSION MODELS FOR DEPENDENT VARIABLE R

NUMBER IN MODEL	R-SQUARE	VARIABLES IN MODEL
2	0.43215585	TI SA
2	0.44008305	TA TI
2	0.45714786	TG TI
2	0.50142464	WD TI
2	0.52606616	DP TI
3	0.54954390	TG WD TI
3	0.55729345	DA DP TI
3	0.56786426	DP WD TI
3	0.57163695	TG DP TI
3	0.57644081	TA DP TI

Since the contributions to the ratio from a degree increase in temperature or dew-point depression were nearly the same, these two variable were combined to simplify the examination of further multiple variable relationships. Coefficients for the linear regression of temperature and dew-point depression sums and other statistics for the subgroups are given in Table 4. The between group differences in any of the other variables except the temperature "advection" could potentially explain the mean difference in ratios between groups.

Table 4
Regression equation for the temperature-plus-dew-point depression variable and mean values of other variables for soybean subgroups.

Group	Regression Equation	R^2	Means			
			WS	WD	TA	SA
1	R = 0.61 + 0.013(TI+DP)	0.28	17.7	63	-.13	8.5
2	R = -0.48 + 0.022(TI+DP)	.52	15.7	40	1.56	6.7

The negative relationship between temperature "advection" values and ratios were found both between and within subgroups. To examine this unexpected result, the values were examined by wind direction groups. Scatter diagrams containing all the soybean data in any given wind direction are plotted in Figure 6. The negative relationship is indicated most strongly in the north and northwest groups. Multiple linear regressions were run with the N and NW data points removed, but the slopes and partial correlations for the temperature "advection" variable remained negative in all cases where any other statistically significant variable was in the equation.

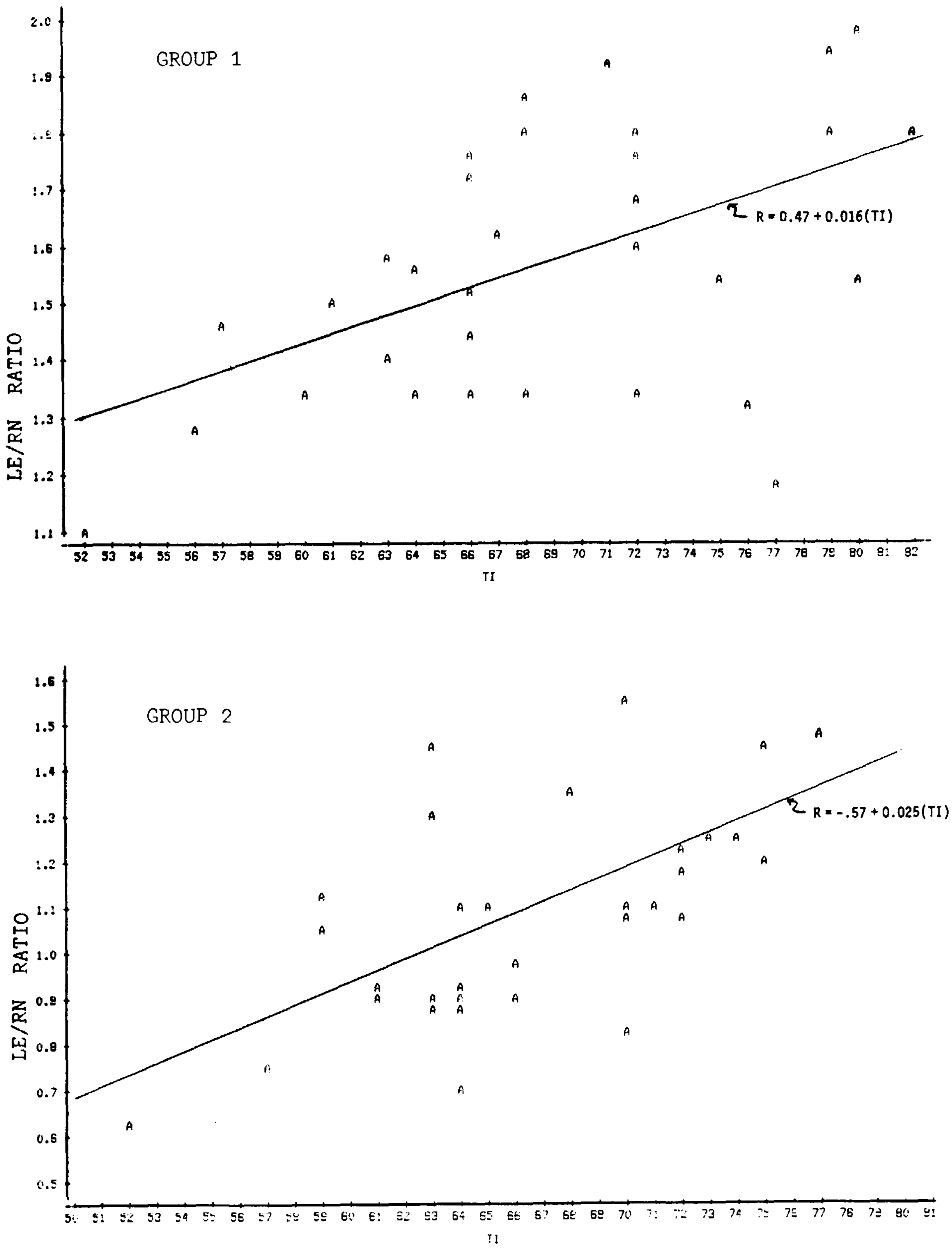

Figure 5A. Plots and simple linear regression relationships between LE/RN ratios and initial temperatures (TI in ^{o}F) for soybean subgroups.

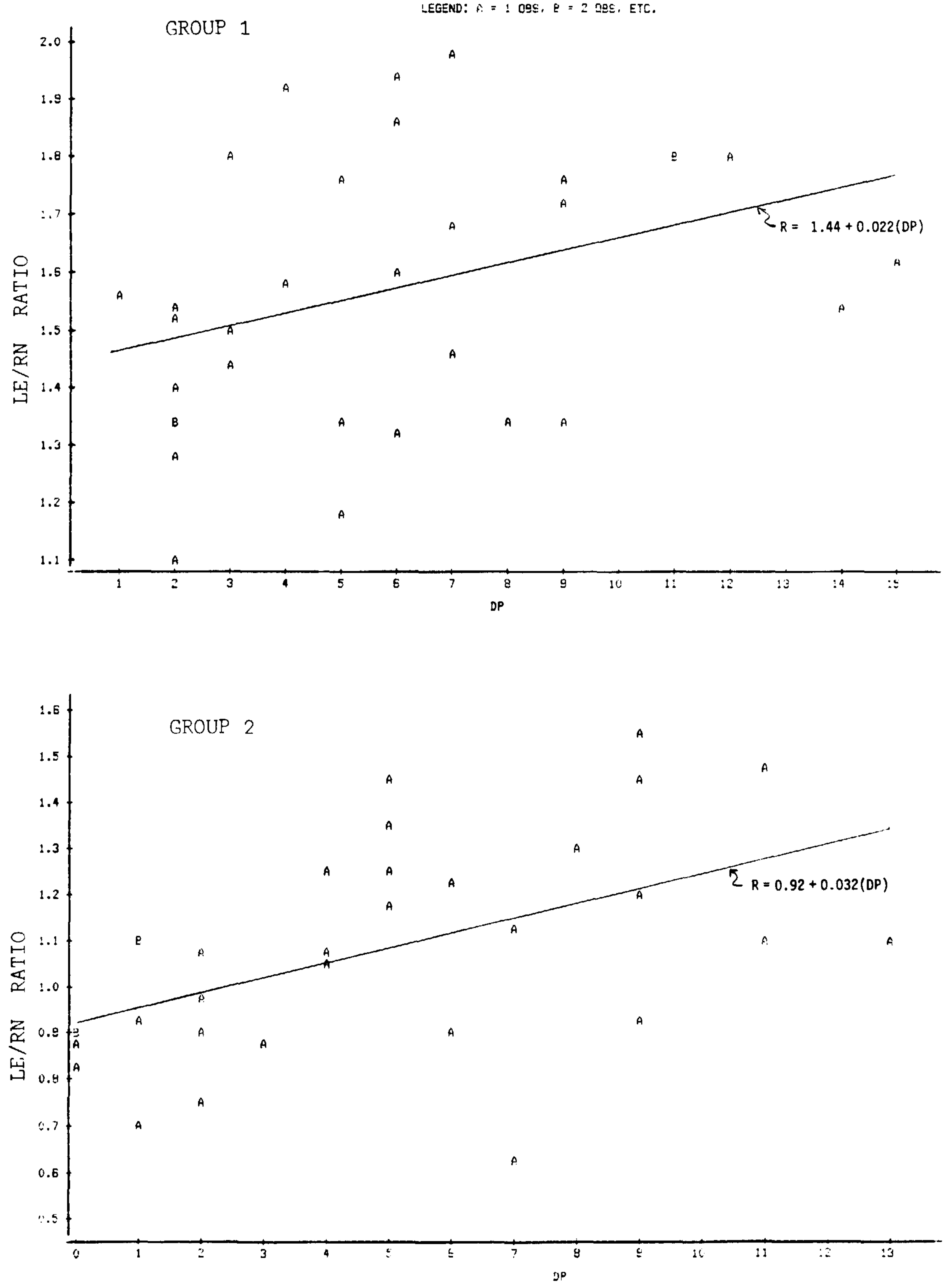

Figure 5B. Plots and simple linear regression relationships between ratios and dew-point depressions (DP in °F) for soybean subgroups.

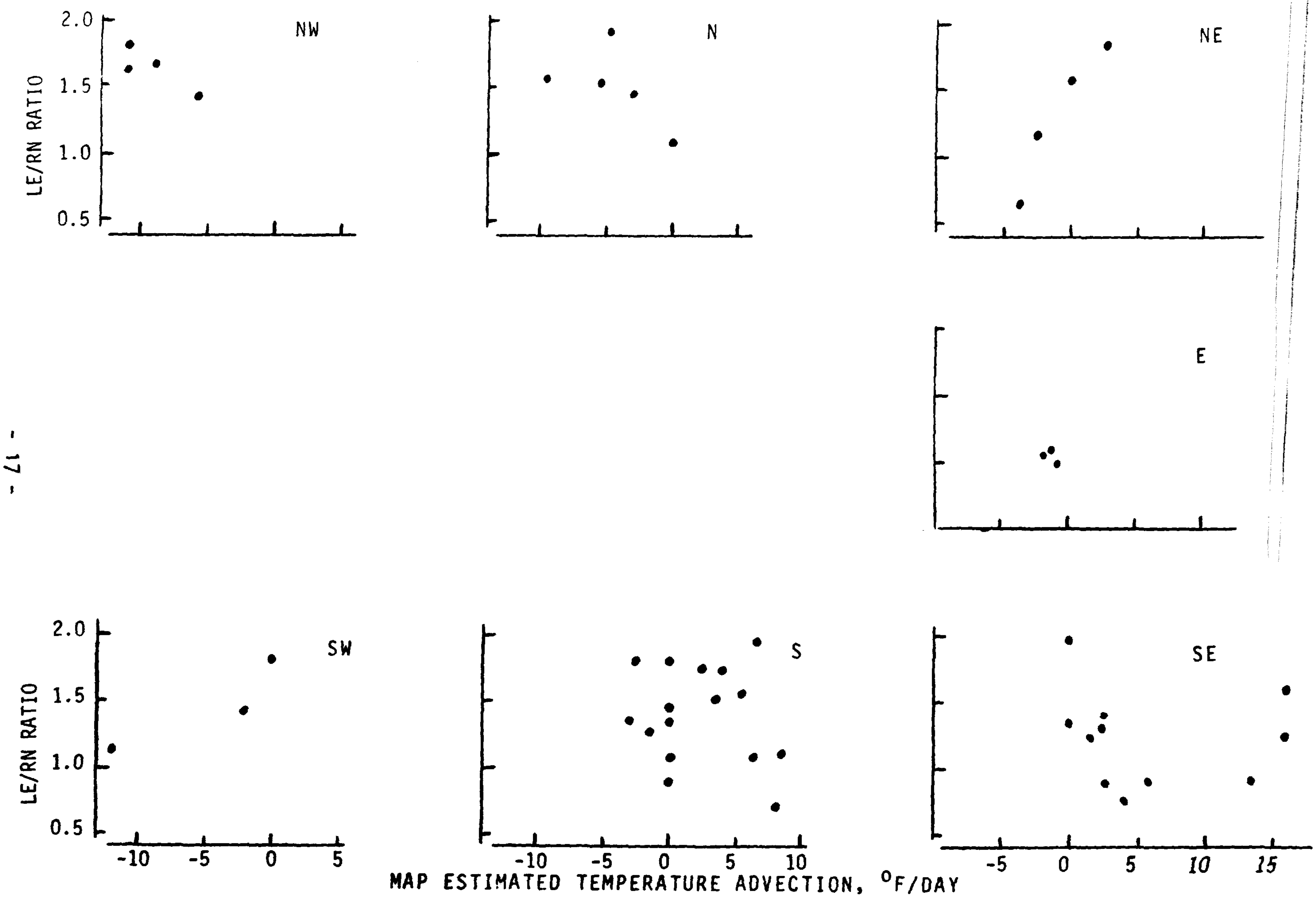

Figure 6. Scatter diagrams of weather map derived temperature "advection" and ratios of LE to RN.

The negative relationship between R and TA was probably a "time of day" phenomena corresponding to the 1200Z maps. Source region conditions associated with larger advective effects or daytime ET are usually associated with lower minimum temperatures in the early morning. Thus, cool air advection (negative TA) in the morning would probably switch to warm air advection later in the day. Since the LE/RN ratios are an integrated result of advection over a day, map estimates of heat and moisture advection based on more than one observation time should give more useful variables.

Except for wind direction, none of the other variables were found to give a significant additional reduction in R-squares after the temperature-dew point depression variable entered a regression in stepwise procedures. The resulting equations with wind direction included were:

Group 1, $\text{Ratio} = 0.51 + 0.013(TI + DP) + 0.0014(WD)$ with $R^2 = 0.37$

Group 2, $\text{Ratio} = -0.43 + 0.021(TI + DP) + 0.0012(WD)$ with $R^2 = 0.57$

Wind direction in this case may be a substitute for heat and moisture advection variables by appearing more significant statistically due to weaknesses in the latter as described above. If it were possible to replace wind direction with advection variables, a more universal relationship should be obtained.

After accounting for regression the ratios were still 0.3 to 0.5 units higher in group 1 than in group 2 over the range of temperatures and wind directions encountered. Thus it is possible that the lower ratios early and late in the season are due in part to soybean development or maturity effects. Ratios of irrigated soybean ET to pan evaporation display similar seasonal distributions (ref. 19).

The only synoptic weather pattern associated with a distinct LE/RN ratio for soybeans was the "E" category; it was always larger than one with a relative small standard deviation. Large variances in ratios within the other seven categories suggested that the classification by itself was of little value in estimating advection.

The alfalfa data were separated by sites since the ratios for Cozad (all dates after August 20, see Figure 2) had a higher mean level than Schuyler -- 1.34 vs 1.07. THe higher ratios at Cozad could be due to physical differences between sites and time periods or a bias in the BREB method as discussed previously.

In attempts to fit the variables found to be statistically significant in the soybean data in all possible regressions, none were found to be significant (F $\leq$ 0.1) with the Schuyler alfalfa. However, with the small sample (12 observations) of Cozad alfalfa, relationships similar to those in soybeans were found. The multiple regression result was:

$\text{Ratio} = 0.37 + 0.011(TI + DP) \quad 0.0020(WD)$ with $R^2 = 0.70$

The coefficients for the Pearson product-moment correlations are given in Table 5.

An additional test on the Schuyler data was performed by comparing the observed ratios with those predicted by the three regression equations containing TI + DP and WD derived from the other data subgroups. There were no correlations between the observed and ratios predicted by any of the equations (maximum r= -0.04). Also the time trend which was significant in the BREB derived ratio did not occur in the predictions. However, both the observed and predicted values in the Schuyler data subset has smaller variances than other subsets and this reduces the strength of the test results.

This consistency and level of statistical significance obtained for relationships between map derived weather variables and relative advection provide positive support for the approach of using synoptic map information [illegible] estimate advection. The use of additional site and crop information with [illegible] weather maps should allow development of empirical models that are phys[illegible]y sound and universal. Surface maps 1 or more other times during the da[illegible]uld allow integration of the diurnal temperatures before projection [illegible] the transport. Additional dependent data as well as the crop and weat[illegible]r data described above is available for Nebraska and other locations.

Table 5. Matrix of correlation coefficients for variables in the two subgroups of alfalfa data (1= Schuyler, 2=Cozad).

G=1

CORRELATION COEFFICIENTS / N = 29

	WS	TG	TA	DG	DA	DW	DP	WD	RN	LE	R	TI	SA
WS	1.00000	0.09626	0.21655	0.03947	0.15831	0.04029	0.07600	0.43797	0.07125	-0.09058	-0.18950	0.09289	0.15592
TG	0.09626	1.00000	0.82803	0.88885	0.76323	0.12320	-0.12230	-0.57961	-0.09306	-0.04228	0.10381	0.01578	-0.00467
TA	0.21655	0.82803	1.00000	0.78106	0.93542	0.06768	0.00290	-0.45310	-0.07040	-0.10100	-0.04303	0.06168	0.11671
DG	0.03947	0.88885	0.78106	1.00000	0.87596	-0.05863	-0.02131	-0.48848	0.04108	0.08082	0.12818	-0.06765	-0.12828
DA	0.15831	0.76323	0.93542	0.87596	1.00000	-0.06161	0.04985	-0.38480	0.02504	0.00983	0.01220	-0.01645	-0.01646
DW	0.04029	0.12320	0.06768	-0.05863	-0.06161	1.00000	-0.25912	-0.09296	0.36288	0.31786	-0.21040	0.68293	-0.06512
DP	0.07600	-0.12230	0.00290	-0.02131	0.04985	-0.25912	1.00000	0.29178	-0.01221	0.01754	0.08229	0.52858	0.87209
WD	0.43797	-0.57961	-0.45310	-0.48848	-0.38480	-0.09296	0.29178	1.00000	0.06065	0.01130	-0.01817	0.13897	0.16837
RN	0.07125	-0.09306	-0.07040	0.04108	0.02504	0.36288	-0.01221	0.06065	1.00000	0.87690	-0.30721	0.30970	-0.14289
LE	-0.09058	-0.04228	-0.10100	0.08082	0.00983	0.31786	0.01754	0.01130	0.87690	1.00000	0.14256	0.29263	-0.13675
R	-0.18950	0.10381	-0.04303	0.12818	0.01220	-0.21040	0.08229	-0.01817	-0.30721	0.14256	1.00000	-0.12268	0.00088
TI	0.09289	0.01578	0.06168	-0.06765	-0.01645	0.68293	0.52858	0.13897	0.30970	0.29263	-0.12268	1.00000	0.60235
SA	0.15592	-0.00467	0.11671	-0.12828	-0.01646	-0.06512	0.87209	0.16837	-0.14289	-0.13675	0.00088	0.60235	1.00000

G=2

CORRELATION COEFFICIENTS / N = 12

	WS	TG	TA	DG	DA	DW	DP	WD	RN	LE	R	TI	SA
WS	1.00000	-0.01263	0.00315	-0.25725	-0.26142	0.45167	0.16286	0.38055	-0.23286	0.37911	0.64982	0.47600	0.26308
TG	-0.01263	1.00000	0.96337	0.45616	0.43034	0.53373	-0.03625	-0.65114	0.05748	-0.13512	-0.21851	0.39555	0.29518
TA	0.00315	0.96337	1.00000	0.43519	0.44738	0.37273	-0.01433	-0.56832	0.05999	-0.15854	-0.24721	0.28425	0.31911
DG	-0.25725	0.45616	0.43519	1.00000	0.96379	0.40227	-0.43078	-0.59738	-0.53396	-0.85811	-0.67585	0.00362	-0.59066
DA	-0.26142	0.43034	0.44738	0.96379	1.00000	0.31123	-0.35977	-0.49494	-0.60983	-0.85620	-0.61399	-0.01653	-0.56586
DW	0.45167	0.53373	0.37273	0.40227	0.31123	1.00000	-0.13686	-0.37047	-0.38321	-0.09055	0.16808	0.69077	-0.04563
DP	0.16286	-0.03625	-0.01433	-0.43078	-0.35977	-0.13686	1.00000	0.25224	0.09211	0.54341	0.60539	0.62172	0.78606
WD	0.38055	-0.65114	-0.56832	-0.59738	-0.49494	-0.37047	0.25224	1.00000	0.09248	0.49662	0.55841	-0.10880	0.10997
RN	-0.23286	0.05748	0.05999	-0.53396	-0.60983	-0.38321	0.09211	0.09248	1.00000	0.60581	0.00630	-0.23575	0.47391
LE	0.37911	-0.13512	-0.15854	-0.85811	-0.85620	-0.09055	0.54341	0.49662	0.60581	1.00000	0.79887	0.32506	0.75450
R	0.64982	-0.21851	-0.24721	-0.67585	-0.61399	0.16808	0.60539	0.55841	0.00630	0.79887	1.00000	0.57480	0.58312
TI	0.47600	0.39555	0.28425	0.00362	-0.01653	0.69077	0.62172	-0.10880	-0.23575	0.32506	0.57480	1.00000	0.53770
SA	0.26308	0.29518	0.31911	-0.59066	-0.56586	-0.04563	0.78606	0.10997	0.47391	0.75450	0.58312	0.53770	1.00000

NOTE: SAS INSTITUTE, SAS CIRCLE, BOX 8000, CARY NC 27511

CONCLUSIONS

This study is considered a preliminary survey of agroclimatic relationships between advection and potential evapotranspiration; it involved small samples of two methods of measuring PET for two crops and only one weather map per day. Specific findings which were important relative to the more general conclusion are:

- variables which are "statistically" related to relative advection can be obtained from standard weather maps. Variables from the 1200Z map which contain information on advection in eastern Nebraska are temperature, dew point depression, wind direction, wind speed, and an estimate of moisture "advection".

- Linear combinations of morning temperature, dew-point depression, and wind direction explained from 37 to 57 percent of the variance of relative advection in cases where PET was measured by lysimeter. Information available for alfalfa where PET was estimated by the Bowen Ratio Energy Balance method was insufficient to explain the mixed results.

Some general observations which were indicated through the study are:

1. There are no practical micrometeorological models available to directly or indirectly provide estimates of advection fro crop moisture assessments; model estimates of PET are of limited value as components in variables representing advection.

2. Weaknesses in assumptions regarding crop effects, boundary, roughness effects, and other energy balance components restrict the availability and usefulness of field measurements for quantifying advection effects on PET.

3. Standard weather data and analysis contain useful information for estimating the contribution of advections; the weather information combined with area moisture indices and agricultural data provide feasible bases for developing statistical models of advection if the dependent data are available.

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APPENDIX

Abbreviations used for variables.

TI - 1200Z temperature

TG - temperature gradient in the "upwind" direction

TA - Estimated temperature "advection" based on the 1200Z temp. gradient

DW - 1200Z dew-point temperature

DP - dew-point temperature depression

DG - dew-point temperature gradient in the "upwind" direction

DA - estimated dew-point "advection"

SA - estimated dew-point depression, "moisture advection"

WS - wind speed

WD - coded wind direction

LE - latent energy equivalent of evapotranspiration

RN - net radiation

R - Ratio of LE to RN, dependent measure of advection

CD - climatological day of the year

TIDP - sum of the values of TI and DP.

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