Changes in Climate and Estimated Evaporation Across a Large Irrigated Area in Idaho

R. D. Burman, J. L. Wright, M. E. Jensen
MEMBER ASAE FELLOW ASAE

Ground level climatic measurements were taken along a 50 km transect going from dry sagebrush land into the center of a large irrigated area in southern Idaho. Measurements in May, when the desert area was dry, indicated that climatic changes across the transect were minimal. In August, when the desert was obviously very dry, air temperatures decreased, vapor pressure increased, and windspeed was reduced about 40 percent within the irrigated area. The results demonstrate that any weather service agency or group must consider the distance from dry surroundings when selecting sites that are to be representative of climatic conditions over irrigated fields.

INTRODUCTION

Climatic changes caused by large irrigated areas may influence the potential for the evaporation of water from irrigated crops and soils. Improved management of irrigated farmland requires knowledge of environmental conditions and the relationship to water requirements of crops. Additional knowledge of the variations in meteorological conditions across an irrigated area surrounded by desert lands is needed to improve the accuracy of estimates of daily evapotranspiration (ET) which are used to schedule irrigations. For this study, climatic observations were obtained to evaluate the magnitude of spatial and daily summer variations in temerature, vapor pressure, and windspeed in the irrigated areas of arid southern Idaho.

REVIEW OF LITERATURE

The theoretical aspects of the horizontal transport of sensible heat and moisture from one area to another have been discussed by several researchers. Philip (1959) analyzed advection for about the first kilometer into an irrigated area, and Estoque (1963) developed a system of equations derived from fluid mechanics and an equation of state which were solved by numerical procedures.

Field studies on the effect of irrigation on climate have shown variations in the extent of climatic modification. Studies in Africa (Davenport and Hudson 1967) and in Australia (de Vries and Birch 1961) indicated that air temperature decreased and vapor pressure increased within an irrigated area. Both studies reported decreased windspeed within the irrigated area as compared with the dry surrounding area. Davenport and Hudson (1967) postulated that the lower windspeeds resulted from the increased drag of cultivated crops. The African study involved intermittent 300-m wide fields of cotton and fallow. Transect measurements were not used in the Australian study. Korven and Pelton (1967) reported that air temperatures were 5 C cooler over a 1.5-ha alfalfa field than over surrounding dryland. Fritschen and Nixon (1967) measured temperature and vapor pressure on a 56-km traverse of the lower San Joaquin Valley through intermixed dry and irrigated lands during midday in the summer with sensors mounted on a small truck traveling at a velocity of about 17 km/hr. They found that air temperatures decreased less than 2 C, while vapor pressure increased about 7 mb. Aircraft measurements by Holmes (1970) indicated that the temperature and moisture content of air flowing over alternate dry and moist areas were modified to heights of over 60 m.

Some attempts have been made to characterize the effect of distance on advection and ET. Decker (1970) evaluated Philip's (1959) advection model at Davis, California and found that the predicted values of ET agreed with those measured with a weighing lysimeter. A study on the influence of local advection on evapotranspiration from irrigated rice in a semiarid region of Australia (Lang et al. 1974) showed that for many purposes the evapotranspiration measured at the center of a uniform field does not need to be corrected for local advection. Their results, however, did show that ET rates were much larger than would be due to radiant energy capture alone, indicating a considerable contribution from large-scale advection. Hanks et al. (1971) discussed three kinds of advection encountered in eastern Colorado: within-canopy advection from dry soil between the rows, border advection for air passing from dry plots to moist irrigated plots, and large-scale advection at night along with temperature inversions.

However, a climatological study of the Columbia Basin by Fowler and Helvey (1974) showed that the large irrigation development in the area caused only a minimal change in air temperature. Pan evaporation was more indicative of changes in air moisture from irrigation.

Heermann, et al. (1974) found it necessary to adjust windspeed and vapor pressure when the data taken at a dryland weather station near

---

Article was submitted for publication in May 1975; reviewed and approved for publication by the Soil and Water Division of ASAE in October 1975. Presented as ASAE Paper No. 74-4007.

Contribution from the Western Region, Agricultural Research Service, USDA, in cooperation with the University of Wyoming, Laramie.

Authorized for publication as Journal Article No. 702 of the Wyoming Agricultural Experiment Station.

The authors are: R. D. BURMAN, Professor, Agricultural Engineering Dept., University of Wyoming, Laramie; J. L. WRIGHT, Soil Scientist, and M. E. JENSEN, Agricultural Engineer, Snake River Conservation Research Center, Kimberly, ID.

Acknowledgment: The writers are grateful for the efforts of James E. Chapman and John L. Stevens, who helped develop and install much of the instrumentation and who faithfully helped collect data, often at irregular times.

This article is reprinted from the TRANSACTIONS of the ASAE (Vol. 18, No. 6, pp. 1089, 1090, 1091, 1092, 1093, 1975)
Published by the American Society of Agricultural Engineers, St. Joseph, Michigan

TABLE 1. AVERAGE TEMPERATURE AND PRECIPITATION FOR A 30-YEAR PERIOD (1940-1969) AT TWIN FALLS, IDAHO

	Long term monthly mean			
	Temperature, C			Precipitation,
Month	Max.	Min.	Mean	mm
April	17.0	1.3	9.2	22
May	22.3	5.6	13.9	26
June	26.6	9.0	16.7	25
July	32.8	12.5	22.7	5
August	31.3	10.9	23.8	7
September	25.9	6.4	16.2	15

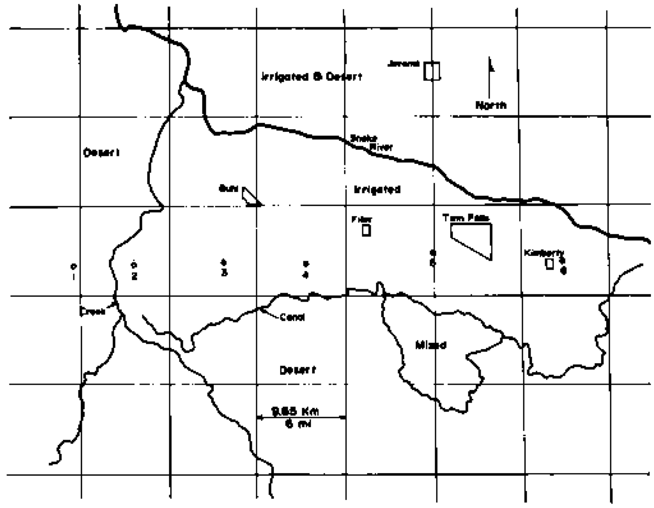

FIG. 1 General map of the area.

Akron, Colorado were used to schedule irrigations for an area within three center-pivot sprinkler systems. Beebe (1974) found tornadoes were more frequent in irrigated areas as compared with dryland. Increased convection was attributed to irrigation which added moisture to the lower atmosphere thereby increasing the possibility of severe storms.

Previous results have generally shown that the air layer over irrigated lands was cooler, moved slower, and contained more water than air over nearby dry areas. While some field studies indicated little modification of the lower atmosphere over irrigation projects, others indicated major changes in moisture, temperature, and wind velocity. Because site conditions varied among the referenced studies, it is difficult to determine from previous results the magnitude of the effect of climatic modification on estimates of ET. We conducted this study during 1972 and 1973, therefore, to determine the effects of summer climatic variation across an irrigated project surrounded by desert rangeland on ET estimates used for irrigation scheduling.

STUDY AREA

The study area is located in southcentral Idaho at about 1,180 m elevation and 42 deg north latitude. The major irrigation projects (Twin Falls, Northside, Burley, Minidoka A and B, and Big Wood) comprised about 263,000 ha and are located in the sagebrush-grass area classified by Koppens method as a Steppe climate with summer dryness (Petterssen 1958). Twin Falls, Idaho, is located near the center of this irrigated area. The 30-yr average maximum, minimum, and monthly mean temperatures and precipitation for Twin Falls are summarized in Table 1. The elevation changes only slightly (about 100 m) across the irrigated area. It is bordered on the south by a low mountain range and on the north (about 60 km away) by a higher range. The area to the west is primarily rangeland with sagebrush and grass intermixed.

METHODS

Six climatic stations were located within alfalfa fields along a 47-km transect running westward from the Snake River Conservation Research Center near Kimberly, Idaho (Station No. 6) to a sagebrush-grass site (Station No. 1) about 6 km west of the boundary between the desert and the major irrigated area (Fig. 1). This transect was chosen to permit monitoring changes in the predominantly westerly airflow, as it moved across the irrigated land from the desert. Each station was located within an alfalfa field to provide uniform surroundings.

Windspeed was measured in 1972 and 1973 at an elevation of 2 m with 3 cup anemometers. Standard Weather Service anemometers were used in 1972, and Casella anemometers were used in 1973. Hygrothermographs enclosed in small screened shelters were also located at this height. In 1973, additional concurrent temperature and humidity measurements were obtained with two or three sling psychrometers manually operated at certain sites. These data were used to adjust the hygrothermograph data from which 24-hr records were obtained. Photographs of typical installations in the alfalfa fields and at the desert site are shown in Fig. 2.

ET was estimated for the various sites with a modified Penman combination equation as used by Wright and Jensen (1972). Mean daily climatic measurements along the transect and solar radiation data for Kimberly were used in the calculations. The wind function developed by Wright and Jensen (W_f in their equation [1]), $W_f = (0.75 + 0.0185\ W)$, was used in the estimates where W is daily wind travel at 2 m elevation. Because of the limitations in recording the wind data at the climate stations, daily wind travel for a midnight-to-midnight period was not available, so the average daily wind travel for the period was used along with the daily averages for the other parameters to compute estimates of potential ET.

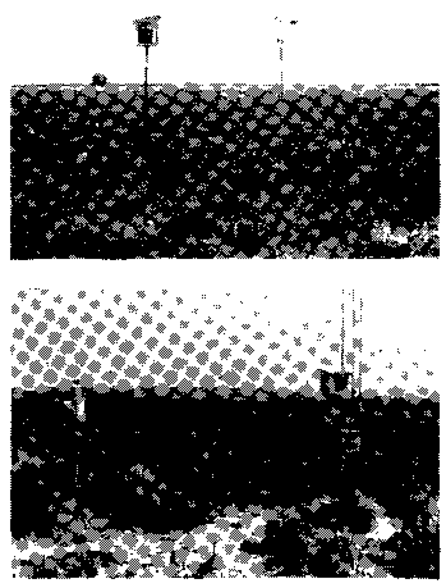

FIG. 2 Typical climatic stations.

TABLE 2. AVERAGE CLIMATIC CONDITIONS FOR PERIODS OF STUDY, MAY 16-19, AND AUGUST 1-10, 1972, ALONG EAST-WEST TRANSECT

Site no.	Distance from desert km	Traverse from desert to Kimberly, Idaho Temperature Max. deg C	Min. deg C	Avg. deg C	Dewpoint* deg C	Windspeed km/day	Etp mm/day
May 16-19							
1	-6	19.6	8.2	13.9	1.8	159	5.0
2	2	20.9	7.5	14.2	3.6	174	5.1
3	10	21.1	6.9	14.0	6.2	150	4.6
4	25	21.3	7.2	14.2	5.7	182	5.0
5	32	21.1	6.9	14.0	6.4	164	4.7
6	46	21.8	6.2	14.0	6.1	161	4.8†
Mean		20.9	7.1	14.0	—	165	4.9
Standard deviation		0.7	0.7	0.1	—	11	—
August 1-10							
1	-6	33.1	16.6	24.8	—	260	10.0
2	2	33.4	14.5	23.9	—	204	9.2
3	10	33.3	13.4	23.3	—	164	8.2
4	25	32.2	13.6	22.9	—	169	8.9
5	32	33.9	13.7	23.8	—	160	8.5
6	46	30.9	12.3	21.7	—	152	7.9‡
Mean		32.8	14.0	23.4	—	185	8.8
Standard deviation		1.1	1.4	1.1	—	40	0.8

* At 0800 hr, calculated per hygrothermograph data
† Kimberly lysimeter measurement, 5.8 mm/day
‡ Kimberly lysimeter measurement, 8.0 mm/day

RESULTS AND DISCUSSION

1972 Study

For the first test series in 1972, the climatic stations were operated (May 15 to 23) when soil moisture conditions favored similar evaporation on the desert and irrigated areas. For the second series (August 1 to 10), the desert was very dry, and, although the alfalfa fields had 12 to 18 in. of growth, the irrigated area was not completely covered with well watered, actively growing crops because many fields of grain and peas had already been harvested. The average temperatures, windspeeds, and estimates of potential ET along the transect are summarized in Table 2. As expected, differences in temperature and windspeed between the desert and irrigated sites were less in May when surface conditions for evaporation were more similar across the entire area than in August when the desert was much drier than the irrigated area. Humidity data for August are not reported because of calibration difficulties with the hygrothermographs.

For the 10-day period in August, the average air temperature decreased about 3 C from the desert site (No. 1) to the Kimberly site (No. 6). The average windspeed in August was also about 42 percent lower at the Kimberly site. Although Davenport and Hudson (1967) postulated that reduction in windspeed was due to increased aerodynamic roughness within the irrigated area, the differences found in this study could be due to stability effects on momentum transfer since the sagebrush-grass desert site would probably be aerodynamically rougher than the cultivated area within the irrigated project. Exceptions would be trees located along canals, roadways, and buildings, but such locations were avoided in selecting the station sites. Possibly, also, mesoscale surface features could account for spatial windspeed differences. However, a more comprehensive study is needed to verify this theory.

Estimates of potential ET for August ranged from 10 mm per day for the desert site to 7.9 mm per day for the Kimberly site. The decreased windspeed and vapor pressure deficit along the transect operated in the same direction to decrease the estimated potential ET.

The Et_p values of Table 2 for Kimberly agreed reasonably well with the measured values. These values, calculated from daily averages as explained previously, did not compare as well with those measured in May as in August. However, errors introduced by the averaging procedure should have been similar for the various climate stations so the results for the transect should be comparable and the relative differences meaningful. Calculating potential ET for the Kimberly site where daily wind data were available, gave an average daily Et_p of 6.5 mm for the May period, as compared with the 4.8 mm shown in Table 2 calculated with average daily data, and the 5.8 mm measured with the lysimeter. For the August period, comparable values were 8.5 mm, 7.9 mm, and 8.0 mm, respectively. The difference in agreement for the two periods is no doubt due to the variations in daily climatic conditions with consecutive days being much more alike in August than in May.

1973 Study

Because of incomplete humidity data, the transect measurements were repeated in 1973 from August 14 through 23 at five climatic sites at similar locations along the same transect. Some had to be moved small distances because of changes in farm fields and the 1972 site No. 5 was eliminated in 1973. Sling psychrometer measurements were made periodically to obtain more definitive humidity measurements across the transect and to provide data for verifying or adjusting the hygrothermograph data. The diurnal variation in temperature, vapor pressure, and vapor pressure deficit for August 16 and 17 at the desert (No. 1), Gier (No. 4), and the Kimberly (No. 6) sites are shown in Figs. 3, 4, and 5, respectively. There were major differences in vapor pressure between the desert and irrigated sites during the daytime hours. Between 6:00 a.m. and 6:00 p.m., vapor pressure increased about 8 mb at the irrigated sites and only about 4 mb at the desert site. Most of the increase in vapor pressure with distance into the irrigated area occurred within the first 2 km. Air temperature was generally higher during day and night at the desert site than at the irrigated sites, especially at abut 4:00 p.m. Consequently, the mid-afternoon vapor pressure deficit was substantially greater at the desert site than at

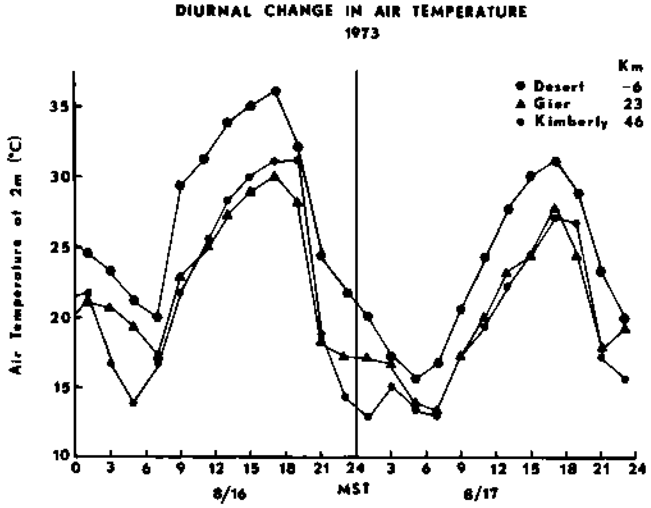

FIG. 3 Diurnal change in air temperature 1973.

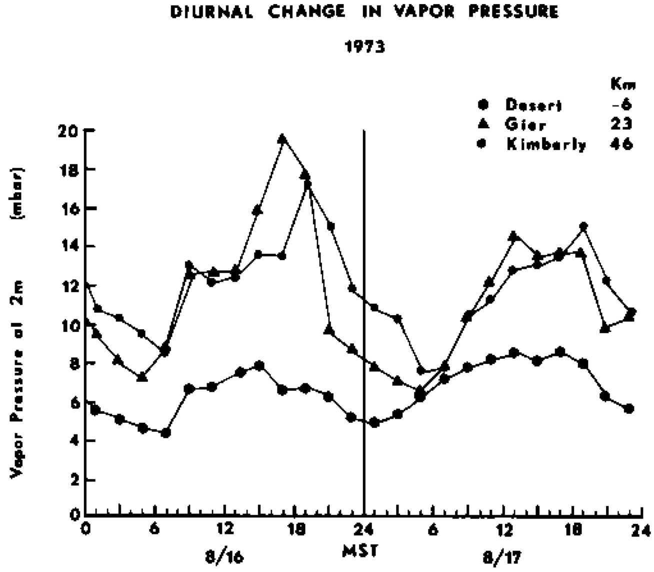

FIG. 4 Diurnal change in vapor pressure 1973.

the irrigated sites (Fig. 5). When the combination equation was used for estimating potential ET, lower vapor pressure deficit and windspeed conditions decreased the estimated potential ET. Transects of air temperature and vapor pressure deficits for several times during the day are shown in Figs. 6 and 7, respectively. While indicating real or significant differences between these curves is difficult, the consistency of the trends certainly indicates the nature of the changes along the transect.

In an intensive study using aircraft along the same transect in 1970, Holmes and Wright (1971) observed an inversion boundary layer during the daytime within the irrigated area created by the high evaporation rates from the well watered green fields. Possibly the increased stability associated with this inversion condition results in decreased momentum transfer causing the observed decrease in windspeed with distance into the irrigated area rather than differences in aerodynamic roughness as previously proposed (Davenport and Hudson 1967). The 1973 data showed that the surface windspeed on the desert was relatively high and consistently from the west, while several kilometers into the irrigated area it was reduced and the direction was often variable (Table 3). The mean flow aloft was westerly during the study period, according to routine Weather Service data obtained in Boise, Idaho.

CONCLUSIONS

Temperature and windspeed changed only slightly from a surrounding arid area to within a large irrigated area in May when soil moisture conditions for evaporation were similar in both areas. During a 10-day period in August, relatively large decreases in windspeed were measured at sites within the irrigated area as compared with a site on the desert rangeland. Average air temperature at the desert site was about 3 C warmer than at the central irrigated site in August, and vapor pressure increased with distance into the irrigated area, but changed most within the first 2 km. The estimated potential ET computed from these data showed a 20 percent decline along the transect. The vapor pressure deficit at the desert site increased greatly during the day because of the large increase in air temperature and small changes in humidity.

In general, evaporation from the irrigated fields did change the clima-

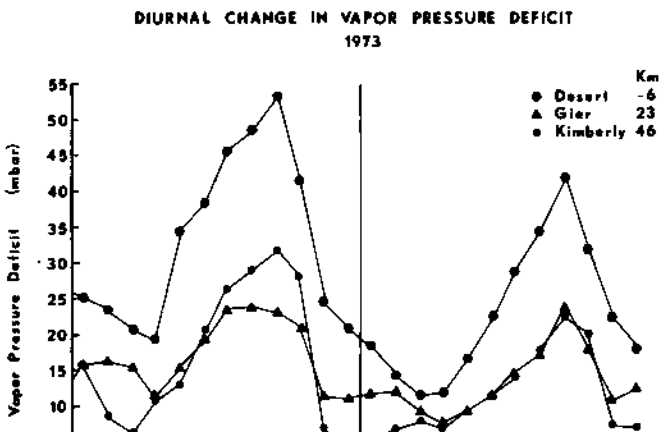

FIG. 5 Diurnal change in vapor pressure deficit 1973.

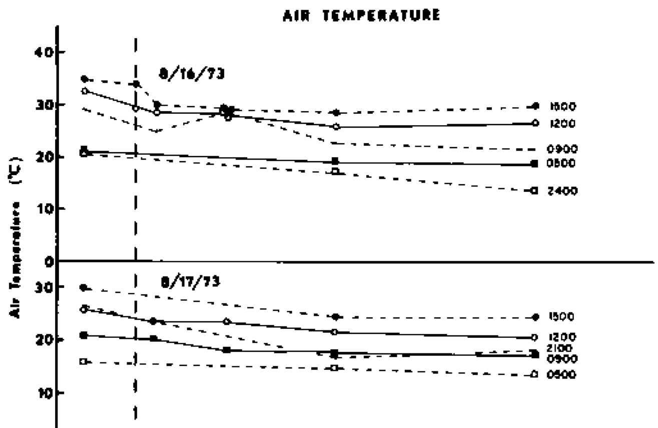

FIG. 6 Transects of air temperature at several times during the day 1973.

TABLE 3. TRANSECT WIND CONDITIONS, AUGUST 16, 1973 P.M.

Site no.	Distance from boundary km	Wind Direction	Wind Speed m/sec	Vapor pressure mb	Vapor pressure deficit mb	Time p.m.
1 desert	-6	W	4-6	7.1	44.1	1:25
Border	0	SSW	2-4	13.1	29.3	1:40
2	2	E	<2	9.8	30.0	2:15
3	10	E	—	10.9	28.3	2:08
4	25	NE	—	13.5	21.4	1:27

tology of the irrigated area, resulting in lower temperatures, higher humidity, lower windspeed, and decreased ET. Accordingly, careful site selection is important for measuring meteorological parameters to be used for irrigation scheduling. Also, adjustments should be made for distance to represent the climatic modification.

References

1 Beebe, R. C. 1974. Large scale irrigation and severe storm enhancement. Mimeo paper, Symp. Diffusion and Air Pollution, Am. Meteorol. Soc., Santa Barbara, CA, Sept. 9-13.

2 Davenport, J. C. and J. P. Hudson. 1967. Meteorological observations and Penman estimates along a 17-km transect in the Sudan Gezira. Agric. Meteorol. 4:405-414.

3 Decker, W. L. 1970. An evaluation of an advection model for latent heat transfer. From Evaporation from an Irrigated Turf under Advection of Dry Air, Davis, CA, U.S. Army Electronics Command E Com 68-G10-1, Fort Huachuca, AZ.

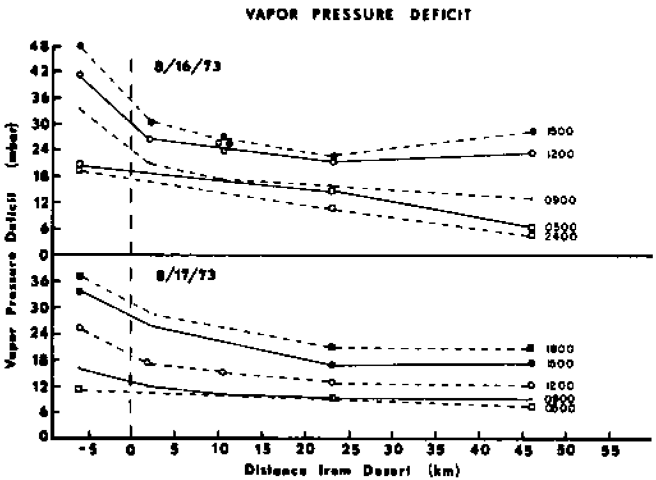

FIG. 7 Transects of vapor pressure at several times during the day 1973.

4 deVries, D. A. and J. W. Birch. 1961. The modification of climate near the ground by irrigation for pastures on the Rivertine Plain. Australian J. Agric. Res. 12(2):260-272.

5 Estoque, M. H. 1963. A numerical model of the atmospheric boundary layer. J. Geophys. Res. 68(4):1103-1113.

6 Fowler, W. B. and J. D. Helvey. 1974. Effect of large-scale irrigation on climate in the Columbia Basin. Science 184(4133): 121-127.

7 Fritschen, L. J. and P. R. Nixon. 1967. Microclimate before and after irrigation. Publ. No. 68, Am. Assn. Advance Sci., Washington, DC, p. 351-366.

8 Hanks, R. J., L. H. Allen and H. R. Gardner. 1971. Advection and evapotranspiration of wide-row sorghum in the central great plains. Agron. J. 62:520-527.

9 Heermann, D. F., H. H. Shull and R. H. Mickelson. 1974. Center pivot design capacities in eastern Colorado. Proc. Am. Soc. Civ. Eng., J. Irrig. and Drain Div. 100(IR2):127-141.

10 Holmes, R. M. 1970. Meso-scale effect of agriculture and a large prairie lake on the atmospheric boundary layer. Agron. J. 62:546-549.

11 Holmes, R. M., and J. L. Wright. 1971. The effect of mesoscale surface features on the atmospheric boundary layer. Tenth Conf. on Agricultural Meteorology, June 9-11, 1971 (Abstract in Bull. Am. Meteorol. Soc. 52:302.

12 Korven, H. C. and W. L. Pelton. 1967. Advection in Southwest Saskatchewan. Can. J. Agric. Engr. 9:88-90, 124.

13 Lang, A. R. G., G. N. Evans and P. Y. Ho. 1974. The influence of local advection on evapotranspiration from irrigated rice in a semiarid region. Agric. Meteorol. 13:5-13.

14 Petterssen, S. V. 1958. Introduction to meteorology, 2nd Ed., 327 p. McGraw-Hill, New York.

15 Philip, J. R. 1959. The theory of local advection. J. Meteorol. 16:535-547.

16 Wright, J. L., and M. E. Jensen. 1972. Peak water requirements of crops in southern Idaho. Proc. Am. Soc. Civ. Eng., Irrig. and Drain. Div., 98(IR2):193-201, June.