Technical Report No. 180

METEOROLOGICAL INSTRUMENTION, DATA, AND DATA ANALYSIS, 1971

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GRASSLAND BIOME

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ABSTRACT

At the Pawnee Site 1-min integrated samples of wind velocity and direction, soil temperature and air temperature gradients, and incoming solar, net, and reflected radiation were continued with the simultaneous and continuous meteorological recording equipment (Nunn, 1971*a*). An informatic data sheet was prepared to depict data availability for other IBP scientists. Hourly averages of each parameter were compiled for distribution to interested investigators. Major modifications to the data acquisition system were initiated in order to realize more fully the potential use of data from the lysimeter and to meet intra-biome needs. Construction of the Grassland Biome's Intensive Site lysimeter was completed. A summarization of equipment and construction technique as well as an evaluation of the lysimeter was prepared.

Data analysis programs resulted in compact 800 BPI (bits per inch) data tapes for the Natural Resource Ecology Laboratory and keyed LABEL tapes for augmenting University of Wyoming modeling. Progress has been made toward the development of a model to predict net radiation from solar radiation. Work on prediction of evapotranspiration was introduced.

DATA

The information gathered in connection with this project consisted of 1-min integrated values of meteorological parameters measured near the lysimeter exclosure area of the Pawnee Site. In addition to the parameters listed in Nunn (1971*a*), information on evapotranspiration as measured by the lysimeter beginning September 1, 1971, was secured. The data system was run in a continuous fashion except during periods of power failures, calibration, or when the system was moved from one place to another.

Data Processing

A computer program was developed to transfer field data secured on tape at a density of 200 BPI (bits per inch) to another tape with a density of 800 BPI. Introductory comments including type of data, intervals of sampling, and conversion constants were included on the compacted tape. This 800 BPI tape was made in a format compatible with NREL's data analysis routines.

A program entitled "Compact 556" was designed to screen and transfer all data from 200 BPI field tapes to keyed LABEL tapes with a density of 556 BPI. This LABEL tape was necessary to augment modeling efforts where data for specific intervals and averaged over various periods were required. From this program a list "KEYS" program was developed which indicates each hour when at least one minutes worth of data was recorded. This keyed list is then the basis from which all averaging, plotting, and modeling programs function.

"Average 556" computes averages from a LABEL tape by utilizing the starting and ending times (KEYS) and the interval over which the averages are to be computed. The output from this program displays the starting and ending times, the interval which was averaged, and the corresponding averages of data from all 36 channels.

Program "D-Plot" was designed to plot averages over any time period where the number of data points is less than or equal to 100. Each graph may contain 100 data points per plotted channel with a limit of two channels. The control cards must specify the starting and ending times (KEYS) of each plot and which channels are to be plotted (any combination of 2 from the 36 measured as well as a single channel). All observations that are plotted are printed cut previous to each graph to help in its interpretation.

Processing the LABEL tapes has yielded a set of hourly and daily averages (Appendix I). Verification of all information has been attempted and an informatic data summary sheet was prepared (Nunn, 1971*b*). Due to the quantity of information, some of the errors may not have been identified, but the number is assumed to be small.

Data Availability

The Pawnee Site meteorological data acquisition system was operated in a continuous fashion during the calendar year 1971. Some 51,840 samples were taken per 24 hr of operation. All samples taken are in the process of being or have been compacted at 800 BPI on .5-inch magnetic tape. These tapes are available at the Central Data Processing Center at the Natural Resource Ecology Laboratory in Fort Collins, Colorado. The 200 BPI data field tapes from which the compacted 800 BPI tapes were made are located at the University of Wyoming, Agricultural Engineering Division. The equipment used for collection of all data is described by Nunn (1971*a*).

An informatic format (Nunn, 1971*b*) was developed to depict data availability. The availability for the summer months of June, July, and August is shown in Fig. 1.

Hourly and daily averages for the above period were also compiled (Appendix I). Table 1 lists the parameters measured, conversion constants, and units of the data.

Data System Modifications

To more fully develop the potential use of data secured from the Pawnee Site lysimeter and satisfy other demands on the Grassland Biome Intensive Site, a major instrumentation change was initiated. The noted instrumentation changes in Table 2 will meet the accuracy demands of modeling efforts and yield the additional necessary information.

This modification necessitated the redesign of fourteen amplifier cards within the data system. Mr. Richard Weeks of the Electrical Engineering Department of the University of Wyoming was contracted to design, construct, and debug the amplifier cards. A new interphase wiring system will be made within the Agricultural Engineering Division to accommodate the changes. Field testing and verification of an operational status will be completed within 3 months following receipt of all transducers.

EVAPOTRANSPIRATION

Although no actual evapotranspiration data from the lysimeter has been published for the 1971 growing season, some data was used to experiment with

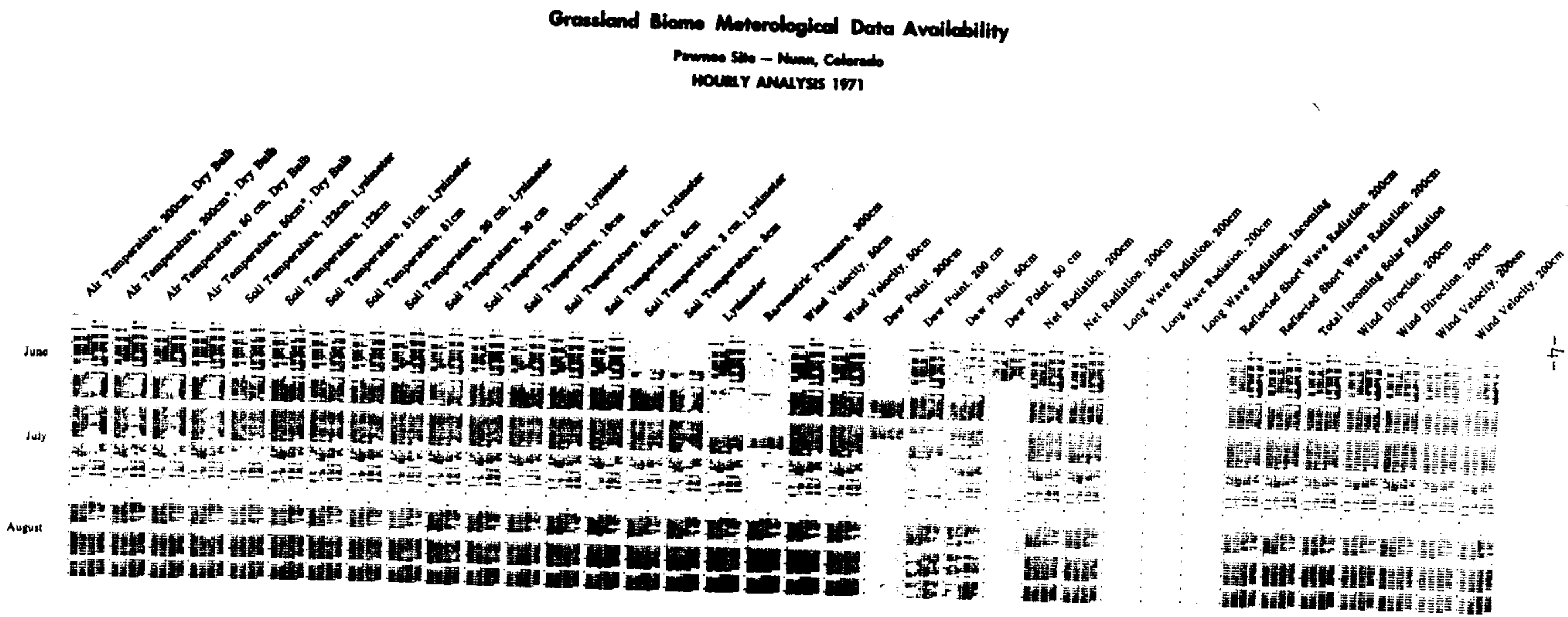

Fig. 1. Lysimeter schematic IBP Grassland Study.

LEGEND
*Wet Bulb 7-16-71—8-31-71

Table 1. Meteorological instrumentation description.

Parameter	Sensing Height (cm)	Constant	Units
1 Air temperature	200	(X-500)/10	°C
2 Air temperature (Wet)	200	(X-500)/10	°C
3 Air temperature	50	(X-500)/10	°C
4 Air temperature (Wet)	50	(X-500)/]0	°C
5 Soil temperature (LYS)	-122	(X-500)/10	°C
6 Soil temperature	-122	(X-500)/10	°C
7 Soil temperature (LYS)	- 51	(X-500)/10	°C
8 Soil temperature	- 51	(X-500)/10	°C
9 Soil temperature (LYS)	- 20	(X-500)/10	°C
10 Soil temperature	- 20	(X-500)/10	°C
11 Soil temperature (LYS)	- 10	(X-500)/10	°C
12 Soil temperature	- 10	(X-500)/10	°C
13 Soil temperature (LYS)	- 6	(X-500)/10	°C
14 Soil temperature	- 6	(X-500)/10	°C
15 Soil temperature (LYS)	- 3	(X-500)/10	°C
16 Soil temperature	- 3	(X-500)/10	°C
17 Lysimeter	00	X†.028665	†
18 Barometric pressure	300	.17X + 745.8	mbar
19 Wind velocity	50	(X/10)1.5116†44.72	cm/sec
20 Wind velocity	50	(X/10)1.5116†44.72	cm/sec
21 Dew point	200	(X-444.44)/11.11	°C
22 Dew point	200	(X-444.44)/11.11	°C
23 Dew point	50	(X-444.44)/11.11	°C
24 Dew point	50	(X-444.44)/11.11	°C
25 Net radiation	200	((X-333)/167)/1.6818	Langleys/min
26 Net radiation	200	((X-333)/167)/1.6818	Langleys/min
27 Longwave radiation	200	(X/333)/3.67	Langleys/min
28 Longwave radiation	200	(X/333)/3.05	Langleys/min
29 Longwave radiation	300		Langleys/min
30 Reflected shortwave radiation	200	(X/100)/7.9	Langleys/min
31 Reflected shortwave radiation	200	(X/100)/7.9	Langleys/min
32 Total incoming shortwave radiation	300	(X/66.67)/7.52	Langleys/min
33 Wind direction	200	(X/2.78)	°azimuth
34 Wind direction	200	(X/2.78)	°azimuth
35 Wind velocity	200	(X/10)1.5116+44.72	cm/sec
36 Wind velocity	200	(X/10)1.5116+44.72	cm/sec

† Value for this channel is in millimeters. Actual water loss is computed by substracting this value from the previous value; result equals water loss in millimeters for that time period.

Table 2. Instrumentation changes for 1972 and subsequent years.

Parameter	Level (cm)	Transducer
Air temperature	200, 152, 50, 5	Thermistor
Wet bulb temperature	200, 152, 50, 5	Thermistor
Wind velocity	5	Hot wire anemometer
Wind velocity	50, 200	Rimco anemometer
CO_2 gradient	5, 50	Beckman
Rain gage	0	Bellford
Photosynthetic active radiation	300	Eppley
Soil water	-3, -6, -10, -20, -51, -122	Coleman resistance blocks

an evapotranspiration prediction. Following the rain storm of August 9, 1971, a test was conducted using Bowen's (1926) method in the form shown by Ferguson (1966), that is:

$$B = \frac{K_h}{K_v}\left\{\frac{1}{[(\alpha + \delta)/\alpha]\ [(\Delta T_w/\Delta T) - 1]}\right\} \qquad (1)$$

where

B = Bowen's ratio

K_h = Molecular diffusivity for air

K_v = Molecular diffusivity for water vapor

α = Psychrometric constant

δ = Slope of vapor pressure-temperature curve

ΔT_w = Differential wet bulb temperature between heights Z_1, Z_2

ΔT = Differential dry bulb temperature between heights Z_1, Z_2

Other measurements necessary to complete the calculation of evapotranspiration (ET) were net radiation (R_n) and soil heat flux (S). The ET prediction then takes the form:

$$ET = \frac{R_n - S}{1 + B} \qquad (2)$$

Results utilizing the above equation were compared against moisture changes as detected by the lysimeter. The comparison is depicted in Fig. 2. It is noted that the Bowen ratio method tends to over estimate the actual evapotranspiration. Part of this difference can be explained by recognizing the errors (±.2°C) associated with ΔT measurements from the data acquisition

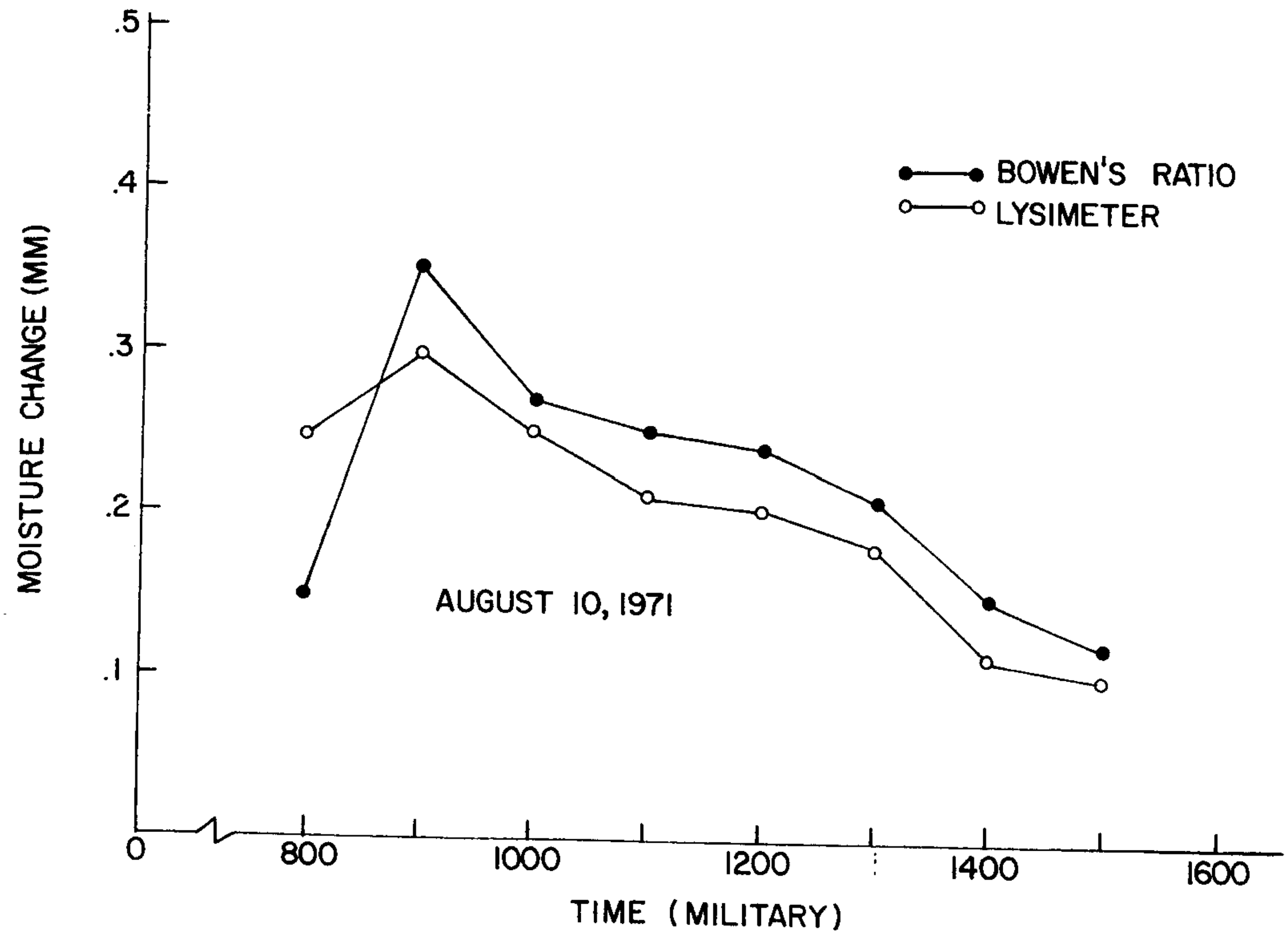

Fig. 2. Comparison between Bowen's ET prediction and ET as indicated by the lysimeter.

system. However, it appears that this method and others similiar should be applicable to the grassland area.

NET RADIATION

Introduction

Estimation and/or measurement of net all-wave radiation, hereinafter termed net radiation, is of great importance in the fields of forestry, hydrology, meteorology, and agriculture as indicated by Penman (1948); House, Rider, and Tugwell (1960); and others. Surface energy balance studies depend upon net radiation as an essential parameter, but long-term records for particular areas of interest are seldom available; however, total incoming solar radiation is more frequently available. Davies (1967), Linacre (1968), and others have indicated that net radiation depends largely on global solar radiation. This analysis deals with the above dependence for the purpose of estimating daytime net radiation intensities from global radiation measurements.

Data

Global solar radiation, net radiation, and reflected solar radiation measurements have been made on a continuous basis at the Pawnee Site, near Nunn, Colorado, during the growing season of 1971. These values are included in Appendix I. The data used for this analysis consisted of approximately 1000 daytime radiation observations (integrated hourly averages) from the months of June, July, and August of 1971. Method of data acquisition and transducers used to obtain the above data are described in Nunn (1971*a*).

Analysis

The total energy available at the ground surface is measured as the balance between incoming and outgoing solar and terrestrial radiation, normally net radiation. Given the conventional sign notation, i.e., radiation received at the surface is positive, net radiation (R_n) may be shown as:

$$R_n = (1 - \alpha) R_s + L_n \tag{3}$$

where R_s is the global solar radiation, L_n is the net longwave radiation, and α is the albedo of the ground surface. The daily reflection coefficient may be considered as nearly constant from June to September (Monteith, 1959) if one neglects the albedo changes due to changes in solar elevation with season. The net radiation on clear days with a given amount of incoming solar radiation depends mainly on net longwave radiation. The net longwave radiation is dependent upon the emissivity of the ground surface and its radiative temperature, amount of precipitable water, air temperature, and the carbon dioxide content of the atmosphere. Increases in radiative temperature of the ground surface are noted with decreasing soil water content or wind speed when all other factors remain constant.

It was assumed that net radiation depends on global solar radiation and that net longwave radiation is a linear function of R_s. Therefore:

$$L_n = a_1 R_s + b \tag{4}$$

By the combination of equations (3) and (4):

$$R_n + aR_s + b \tag{5}$$

where $a = (1-\alpha+a_1)$. Note that a_1 and b are regression constants. From the data points of incoming shortwave and net radiation, the regression coefficients and correlation index were computed and are given in Fig. 3. The estimated net radiation values were then compared with those measured (Fig. 4), and the results were summarized in Table 3 and Fig. 5, together with the line of unit slope.

Conclusion

Considering the above scatter, Tanner and Pelton (1960) and Robinson (1962) show errors in measured net radiation may typically be 10%. Therefore, random errors in measuring net radiation intensity may be about the same as those from a local empirical formula. It is reasonable to assume, at a time of net radiation instrument failure, a local empirical formula may be used to estimate net radiation from measured incoming shortwave radiation. This approach has application to the Grassland Biome sites where little measured radiation data is available as well as where difficulties arise when trying to obtain continuous net radiation data. Estimation of missing records of net radiation with an empirical approach is practicable; however, possible errors associated with this type of estimation must be recognized (Gay, 1969).

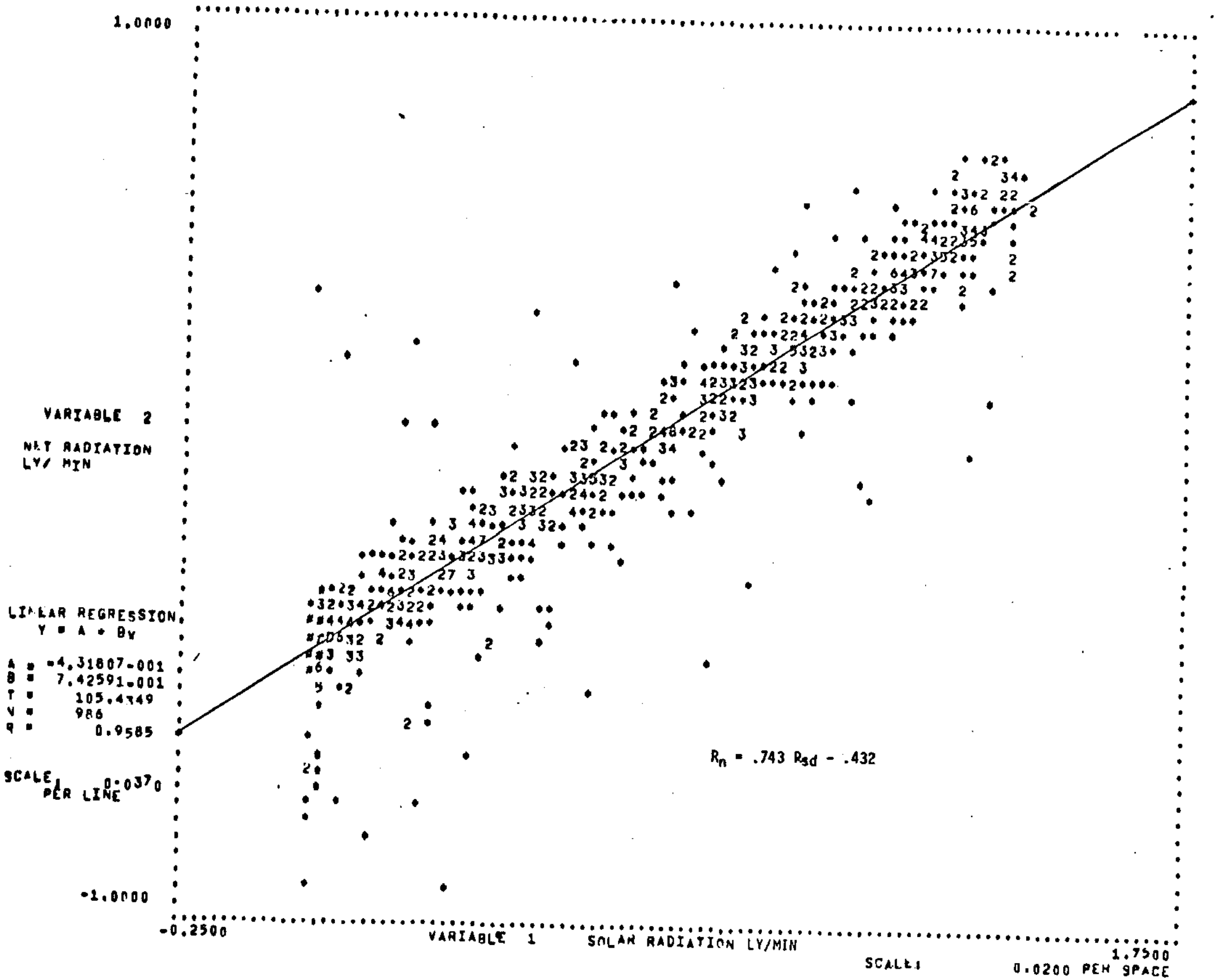

Fig. 3. Regression of net radiation on total incoming solar radiation.

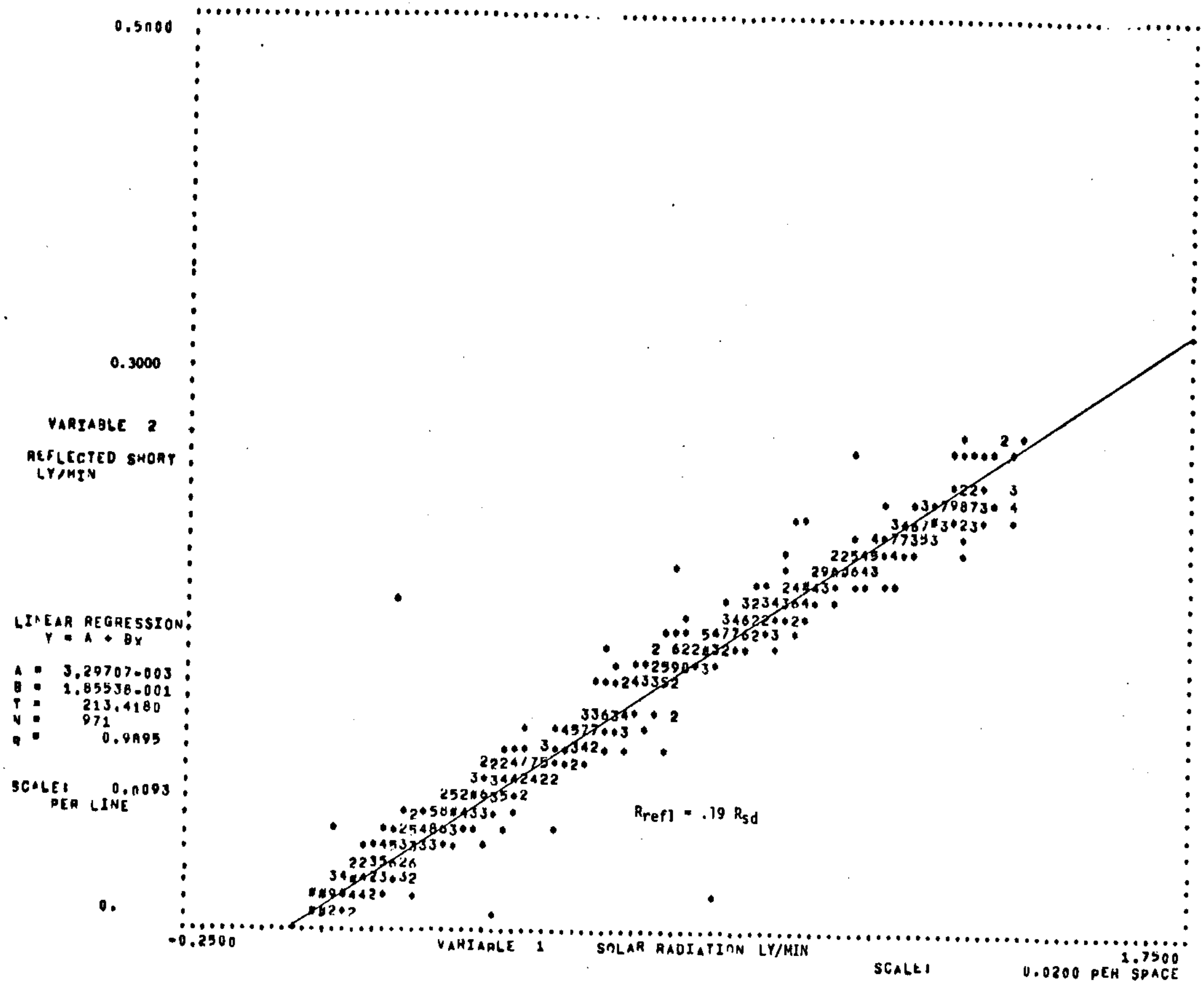

Fig. 4. Regression of reflected shortwave radiation (R_{refl}) on total incoming solar radiation.

Table 3. Comparison of net radiation estimate.

Radiation Values	Mean Albedo	Mean Net Infrared Flux
Regression	26	-.43
Measured	19	-.47

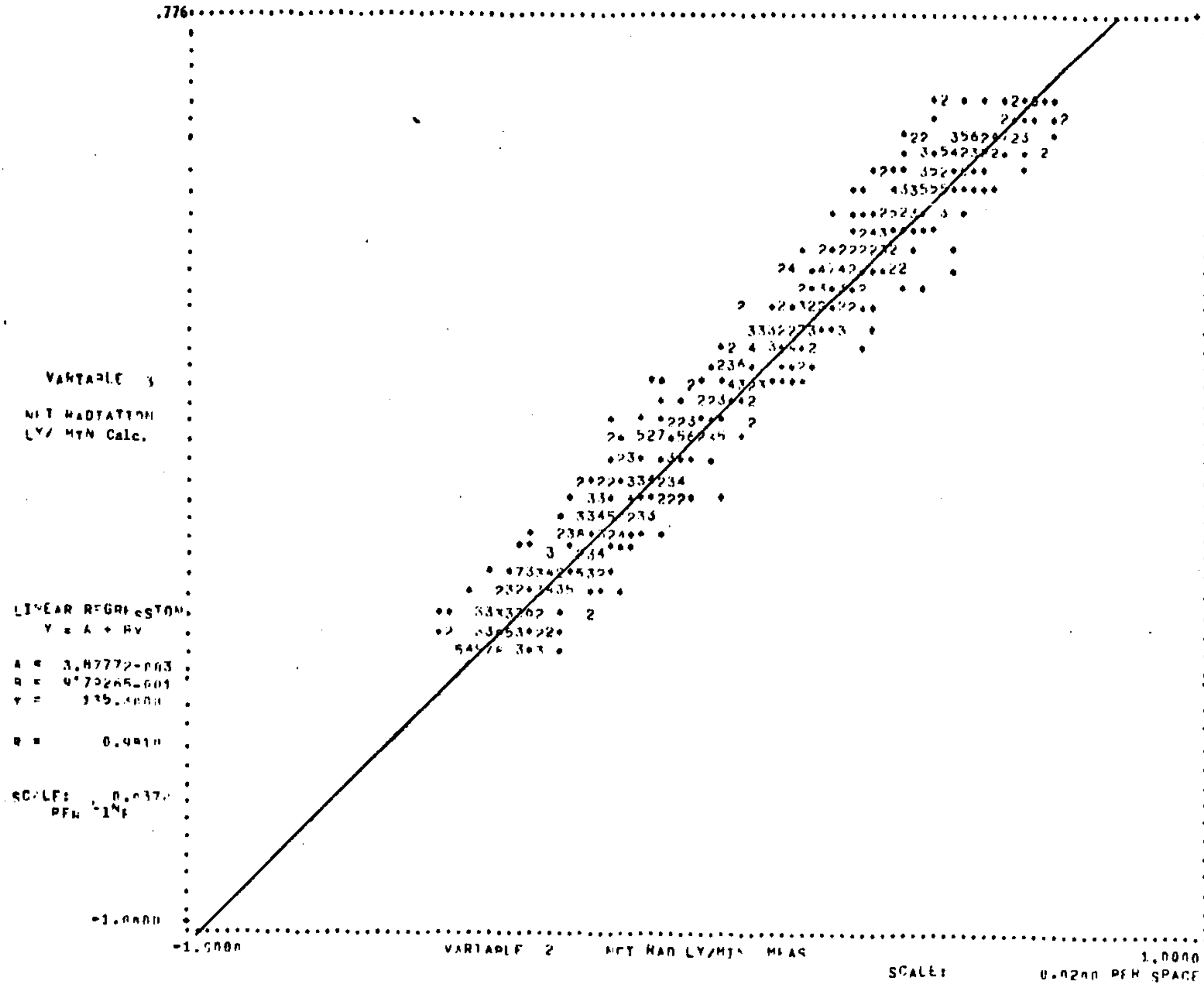

Fig. 5. Comparison of calculated net radiation with measured net radiation by regression.

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APPENDIX I

DATA

The meteorological parameter description data collected in 1971 is Grassland Biome data set number A2U705B. The data is available on tape at the Natural Resource Ecology Laboratory.

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19	149.51	60	274.56	60	403.68	60	417.08	60	408.18	60	352.53	60	566.48	60	215.87	60
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25	.67	60	.69	60	.74	60	.74	60	.81	60	.80	60	.84	60	.71	60
26	1.00	60	1.19	60	1.40	60	1.47	60	1.30	60	.65	60	.51	60	.40	60
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34	132.37	60	116.82	60	121.74	60	123.73	60	114.08	60	139.92	60	228.27	60	130.37	60
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2	15.96	60	14.32	60	12.35	60	10.95	60	9.77	60	8.39	60	7.82	57	6.56	59
3	16.18	60	14.67	60	12.73	60	11.16	60	9.67	60	8.21	60	7.63	57	6.33	58
4	15.36	60	13.93	60	12.06	60	10.45	60	9.06	60	7.69	60	7.07	57	5.81	58
5	16.74	60	15.29	60	13.53	60	10.85	60	8.71	60	7.01	60	6.28	57	5.12	58
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27	.01	60	.01	60	.01	60	.01	60	.01	60	.01	60	.01	58	.01	59
28	.01	60	.01	60	.01	60	.01	60	.01	60	.01	60	.01	58	.01	59
29	11.32	60	11.35	60	11.40	60	11.38	60	11.40	60	11.40	60	11.43	58	11.37	59
30	.20	60	.20	60	.20	60	.00	0	.00	0	.00	0	.00	0	.00	0
31	.19	60	.19	60	.19	60	.00	0	.00	0	.00	0	.00	0	.00	0
32	.01	60	.04	60	.02	60	.00	60	.00	60	.00	60	.00	58	.00	59
33	117.66	60	140.84	60	136.78	60	106.73	60	124.30	60	106.71	60	92.49	58	280.57	59
34	94.27	60	117.00	60	112.49	60	83.23	60	117.74	60	78.83	60	69.41	58	247.15	59
35	910.10	60	1082.48	60	740.21	60	420.80	60	293.38	60	291.46	60	305.59	58	250.46	59
36	879.23	60	1040.12	60	696.04	60	384.86	60	283.24	60	273.10	60	261.89	58	198.90	59

AVG. OF 60MINUTES
STARTING AT MO= 5,DAY= 8,HOUR= 0,MINUTE=1
ENDING AT MO= 5,DAY= 8,HOUR=23,MINUTE=60

	1		2		3		4		5		6		7		8	
1	7.78	60	6.13	60	6.85	60	5.76	60	5.33	60	8.24	59	11.76	60	13.07	60
2	6.71	60	5.04	60	5.74	60	4.75	60	4.35	60	6.95	58	10.70	60	11.96	60
3	5.81	60	4.46	60	5.75	60	4.66	60	3.83	60	7.65	58	11.41	60	12.84	60
4	5.46	60	3.86	60	5.26	60	4.23	60	3.46	60	7.08	58	10.95	60	12.29	60
5	5.15	60	3.84	60	4.65	60	3.69	60	2.84	60	7.21	58	15.23	60	19.79	56
6	6.66	60	5.44	60	6.66	60	5.69	60	4.56	60	7.75	58	14.56	60	18.94	60
7	5.01	60	3.96	60	5.34	60	4.03	60	3.00	60	9.34	58	17.43	60	20.92	47
8	3.86	60	3.11	60	4.91	60	3.61	60	2.20	60	8.11	58	16.62	60	19.70	55
9	7.55	60	6.44	60	6.95	60	6.14	60	5.29	60	9.00	58	16.04	60	21.50	58
10	3.88	60	3.55	60	5.26	60	3.77	60	2.33	60	7.86	58	15.56	60	21.36	58
11	3.17	60	2.06	60	2.45	60	1.71	60	.70	60	5.38	58	11.52	60	16.50	60
12	3.10	60	2.56	60	4.77	60	3.15	60	1.66	60	8.68	58	18.90	60	25.73	55
13	5.58	60	4.44	60	5.16	60	4.30	60	3.42	60	7.52	58	15.35	60	21.05	60
14	4.36	60	3.49	60	5.14	60	3.97	60	2.88	60	7.94	58	16.18	60	23.08	60
15	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0
16	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0	27.70	1	[redacted]	0	[redacted]	0
17	14.04	60	14.03	60	14.05	60	14.07	60	14.07	60	14.25	59	14.01	60	13.92	60
18	[redacted]	60	[redacted]	60	[redacted]	60	[redacted]	60	[redacted]	60	[redacted]	58	[redacted]	60	[redacted]	60
19	5.86	60	8.45	60	86.64	60	11.94	60	5.86	60	18.76	58	204.94	60	171.59	60
20	11.15	60	51.94	60	162.46	60	57.91	60	9.01	60	21.68	58	234.34	60	202.57	60
21	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0
22	[redacted]	60	[redacted]	60	[redacted]	60	[redacted]	60	8.78	60	[redacted]	54	[redacted]	7	[redacted]	60
23	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	0	[redacted]	9	[redacted]	0
24	2.71	60	3.87	60	2.33	60	-4.29	25	[redacted]	0	[redacted]	0	2.15	47	.49	60
25	.60	60	.62	60	.59	60	.58	60	.59	60	.58	59	.61	60	.64	60
26	.07	60	.09	60	.06	60	.07	60	.10	60	.20	59	.42	60	.62	60
27	.01	60	.01	60	.01	60	.01	60	.01	60	.01	59	.01	60	.01	60
28	.01	60	.01	60	.01	60	.01	60	.01	60	.01	59	.01	60	.01	60
29	11.37	60	11.35	60	11.37	60	11.37	60	11.35	60	11.36	59	11.33	60	11.32	60
30	.00	0	.00	0	.00	0	.00	0	.00	0	.20	59	.20	60	.20	60
31	.00	0	.00	0	.00	0	.00	0	.00	0	.19	59	.19	60	.19	60
32	.00	60	.00	60	.00	60	.00	60	.00	50	.16	59	.33	60	.47	60
33	225.19	60	37.27	60	54.30	60	118.28	60	24.56	60	127.61	59	127.87	60	153.40	60
34	336.08	60	72.96	60	25.25	60	266.42	60	343.00	60	206.06	59	104.15	60	130.43	60
35	104.33	60	122.58	60	283.01	60	181.73	60	70.87	60	84.10	59	346.89	60	308.81	60
36	79.20	60	115.14	60	262.85	60	147.82	60	52.84	60	34.03	59	319.97	60	268.25	60