Using Remote Sensing to Develop ET Fluxes for the Mesilla Valley Aquifer

By

Zohrab A. Samani, Professor

A. Salim Bawazir, Associate Professor

Ian Hewitt, Research Assistant, WRRI

Juan Solis, Graduate Student

Kevin Bokyo, Graduate Student

Civil Engineering Department and New Mexico Water Resources Research Institute

New Mexico State University

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Civil Engineering Department

New Mexico State University

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ABSTRACT

Remote sensing ET models are used for calculating large scale ET. For this study two models, Simplified Surface Energy Balance for operational application (SSEBop) and Regional ET Estimation Model (REEM), are being evaluated for use in New Mexico statewide water budget assessment. The work is in progress. Preliminary ET calculations by the models are presented. Measured ET values from alfalfa field and climate data from Leyendecker III climate station, and ET referenced to grass are also presented. The model algorithms are still being tested, pending ground ET measurements and climate data for the rest of the year 2017 and 2018.

Keywords: Evapotranspiration, remote sensing, satellite, energy balance, eddy covariance, New Mexico, water management

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INTRODUCTION

Quantification of the water budget in the State of New Mexico is needed to properly plan and manage the State's water resources. The evapotranspiration (ET) is a major component of water budget. This proposed work is to develop a usable remote sensing model to estimate consumptive use (i.e. ET) of the Mesilla Basin. In order to validate the proposed remote sensing model, a flux tower is installed in the Valley to collect ET data for 2017 and 2018. Data collection is in progress and the modeling process is in progress in tandem with ground measurements. The ultimate goal of this work is to use field measured data of ET and climate to modify remote sensing models (SSEBop and REEM) and to validate their results.

OBJECTIVE

The specific objectives of this project are:

1. Install and operate evapotranspiration (ET) flux instrumentation in the Mesilla Valley.
2. Collect ET time series data (30 minute and 24-hr) for alfalfa during 2017-2018
3. Conduct quality analysis of the measured data
4. Compare and analyze measured ET values with remotely sensed values from Simplified Surface Energy Balance for operational application or SSEBop (collaboration with Dr. Gabriel Senay of USGS) and Regional ET Estimation Model (REEM)
5. Develop calibration parameters to improve models' predictions from the analysis in step 4.

METHODOLOGY

Ground Measurement of ET

Evapotranspiration (ET) of alfalfa was measured using energy budget method. In the energy budget method, net radiation, soil heat, sensible, and latent heat fluxes into and out of a hypothetical plane surface at the earth-air interface are measured. The eddy covariance technique is utilized in the measurement of sensible and latent heat fluxes. Sensible and latent heat fluxes in this project was measured using 3D-sonic anemometer (or CSAT3) by Campbell Scientific

Inc., Logan, Utah and Li-COR 7500A open path CO_2/H_2O analyzer by LI_COR Inc., Lincoln, Nebraska. Net radiation was measured using a net radiometer. Soil heat flux was measured using heat flux plates in combination with soil moisture and averaging soil temperature thermocouples. A data logger of model CR5000 by Campbell Scientific Inc. was used to collect and store the data for later downloading by a laptop computer. The system was equipped with solar panel and battery. The data were collected at frequency of 10 Hz and averaged every 30-minutes. The eddy covariance data are corrected for humidity effects, frequency response, oxygen, and sensor separation according to published literature. Corrected data are totaled to daily (24-hr) values.

Grass referenced ET was calculated using ASCE standardized ET equation (or ETsz) following Allen et al. (2005). Data for calculating ETsz was obtained from a climate station installed in the vicinity of the alfalfa field at Leyendecker Plant Science Research Center, New Mexico State University.

Remote Sensing ET Models

Two models, Regional ET Estimation Model (REEM) by Samani et al. (2009) and Simplified Surface Energy Balance for operational application (SSEBop) by Senay et al. 2007, are being used to estimate regional ET. Landsat8 spectral images (hhtp://gloves.usgs.gov/) combined with ground level climate and ET flux measurements are used in REEM to calculate daily ET and crop coefficient using surface energy balance method. Similarly, the SSEBop model is used to calculate ET.

The REEM and SSEBop differ in their methodologies of ET calculation. The REEM is based on surface energy balance similar to that presented by Bastiaanssen et al. (1995) where the latent heat flux (LE) is determined as a residual of the surface energy equation. Landsat images coupled with ground level measurements of latent, sensible, net radiation, and soil heat fluxes and climate data are used in REEM model to calculate crop ET. The ground flux data are used to calibrate the REEM for the days when the satellite images are available. The calibrated model is then used to forecast ET and crop coefficient for intermediate days during the growing season. The SSEBop model uses a virtual theoretical hot and cold pixel for computing daily ET. The model ET is determined by multiplying the calculated ET fraction (ET_f) with standardized grass reference ET (or ET_{sz}) and adjusting it by using a scaling coefficient (k). The ET fraction, ET_f, is calculated from the temperature differential (dT) which the difference in temperature between the virtual hot and cold pixels.

Assessment of Models for NM State Water Budget ET Estimates

Both REEM and SSEBop estimates of ET will be compared to the ground level ET flux measurements from the growing season of 2017 and 2018. ET estimates using modified models which are independent of ground flux measurements will then be validated using the ground flux measurements of 2018.

RESULTS

Field Setup of Instrumentation

The following is a summary of work accomplished:

- Instrumentation for ET measurements were installed in an alfalfa field with an area of about 85 acres (Figure 1). The collage of instrumentation to measure ET is referred in this report as "ET Flux Tower" See Figure 2. The instrumentation included eddy covariance system, net radiometer, soil heat flux plates, soil temperature thermocouples, soil moisture sensor, and microclimate station (weather station)
- A 2-in diameter piezometer with pressure transducer was installed to measure depth to groundwater. The piezometer is 21.94 ft from the ground surface and 1.56 ft above ground. The piezometer is screened at the bottom 8 ft.
- Six moisture sensors (model SC650 by Campbell Scientific Inc.) were installed at 1-ft increments to measured soil moisture profile up to 6 ft below the ground. See Figure 3.
- Climate station was installed at NMSU Leyendecker Plant Science Research Center located near the alfalfa field where ET is measured. The purpose of this climate station is to collect data for many years and for use in management of irrigation for crops in the Mesilla Valley. This station was named Leyendecker III. See Figure4.
- Pluvio rain gage station with windshield was installed also near the Leyendecker III station. See Figure5.

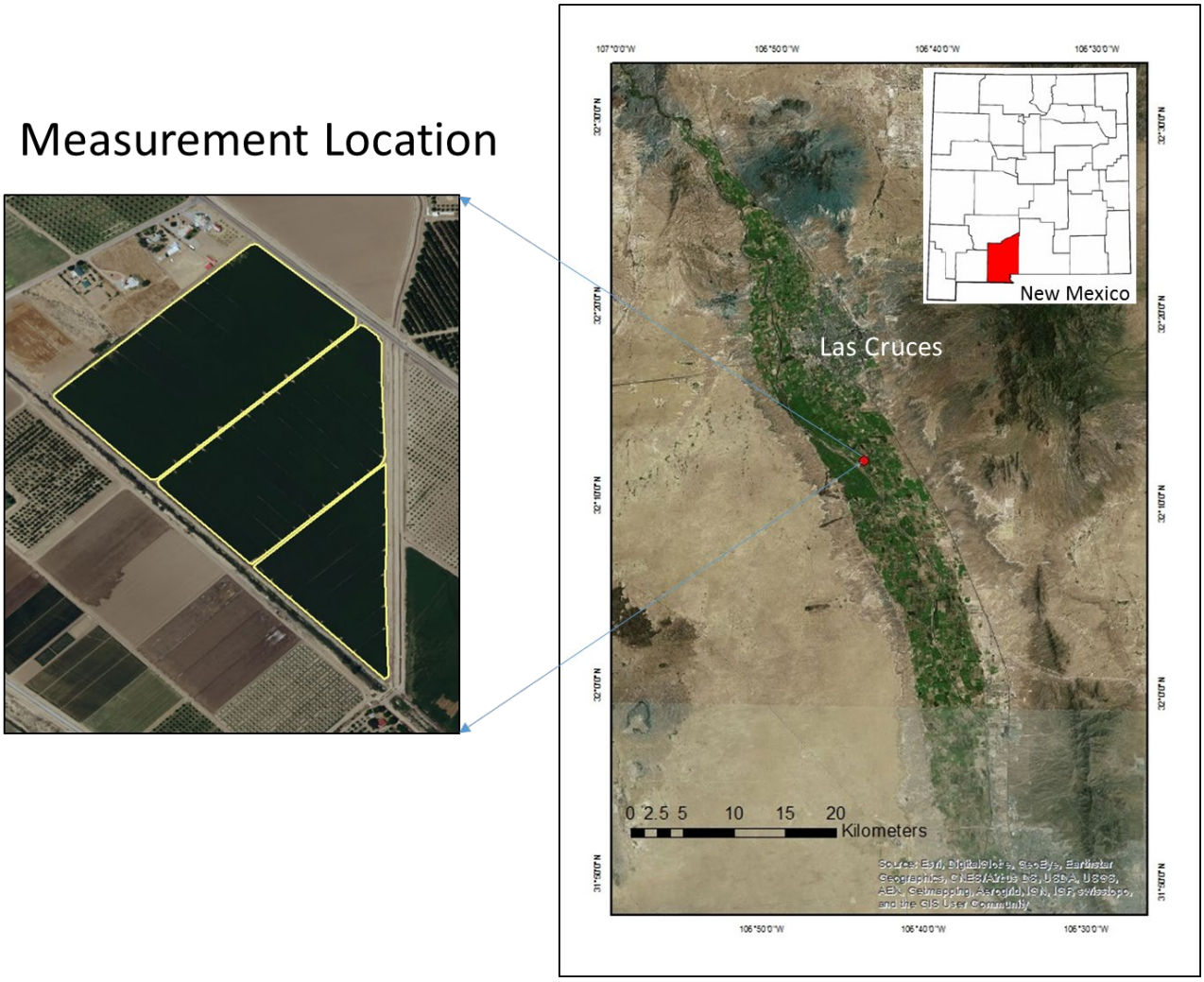

Figure 1. Location of alfalfa field in the Mesilla Valley, Dona Ana County, NM

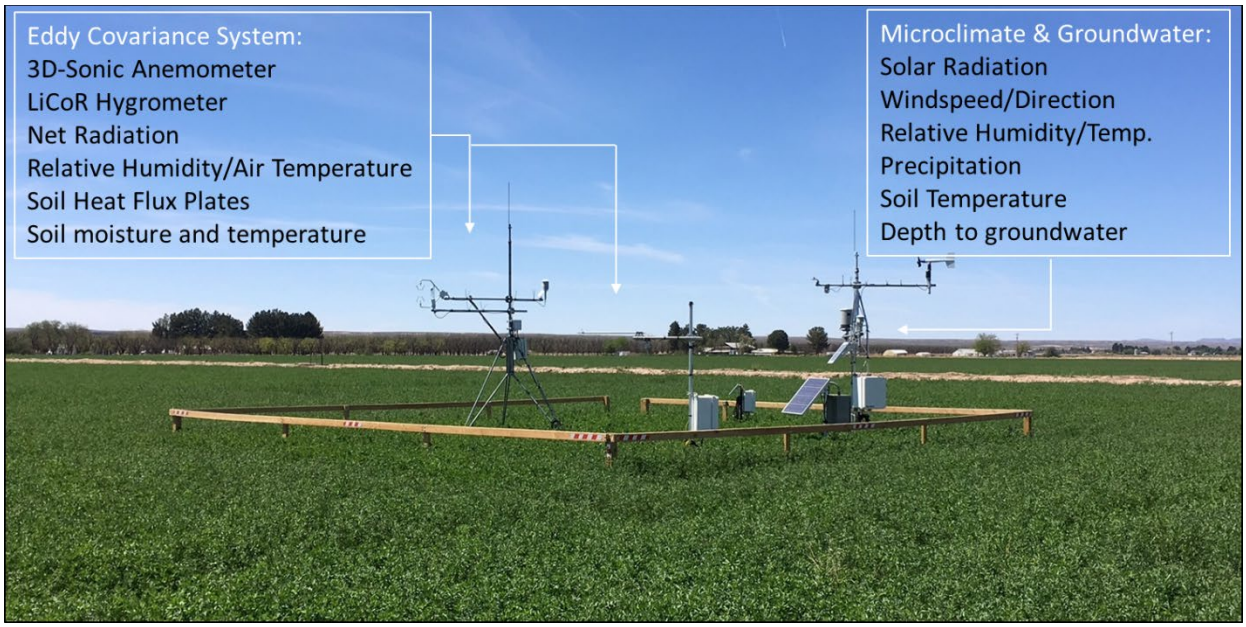

Figure 2. Evapotranspiration (ET) flux tower in 85 acres of alfalfa field


Figure 3. Soil moisture profile

Figure 4. Leyendecker III climate station

Figure 5. Pluvio rain gauge with wind shield

Evapotranspiration and Climate

The results presented in this report are preliminary as the rest of data for 2017 and 2018 have not been collected. Preliminary ET values measured for alfalfa are shown in Table 1. Measured ET increased as the growing season progressed. The depth to groundwater was about 19 ft. Precipitation measured at the site was very low with a maximum of 3.30 mm during the month of May. Daily values of climate data collected at Leyendecker III station since its operation are listed in the appendix.

Table 1. Monthly measured total evapotranspiration (ET) of alfalfa and precipitation

Month	N[a](ET)	ET	N[a](Rain)	Rain[b]
Year 2017	Days	mm	Days	mm
February	11	16.01	11	1.02
March	31	122.66	31	0.00
April	30	172.41	30	1.78

May	31	196.37	31	3.30
June	22	95.32	7	1.78

[a]N is the number of samples in days the data was collected; [b] rain data collected at Leyendecker III station

Satellite-Based Evapotranspiration

Four satellite images have been downloaded and the regional ET has been calculated by using satallite images and ground level climate data. Figure 6 shows an image of ET for April 30th, 2017. This work is in progress. More images will be downloaded and processed during the rest of 2017 and 2018 depending on the availability of funds. These remote sensing results will eventually be combined with flux and climate data to develop regional ET maps and develop the calibration of the SSEBop model. The models can then be used to calculate ET on regular basis for water assessment of the State.

CONCLUSION

This reports presents the work accomplished. Instrumentation to measure ET and climate data have been installed and are collecting data. Data collection and maintenance of the instrumentation are conducted regularly as required. Processing of all the data collected is in progress. Preliminary results were presented. Measured ET for about 6 months of data collection was presented. The results shows a trend of ET as the season progresses. Four images from satellite since the beginning of the year in conjunction with ground measurements have been downloaded and processed. Process of new images are pending upon their availability in the coming months and year.

****The remote sensing component of this project is terminated effective 6/30/17 due to lack of funding.**

REFERENCES

Allen RG, Walter IA, Elliot RL, Howell TA, Itenfisu D, Jensen ME, Snyder RL (Eds.). 2005. The ASCE Standardized Reference Evapotranspiration Equation. American Society of Civil Engineers: Reston: Virginia.

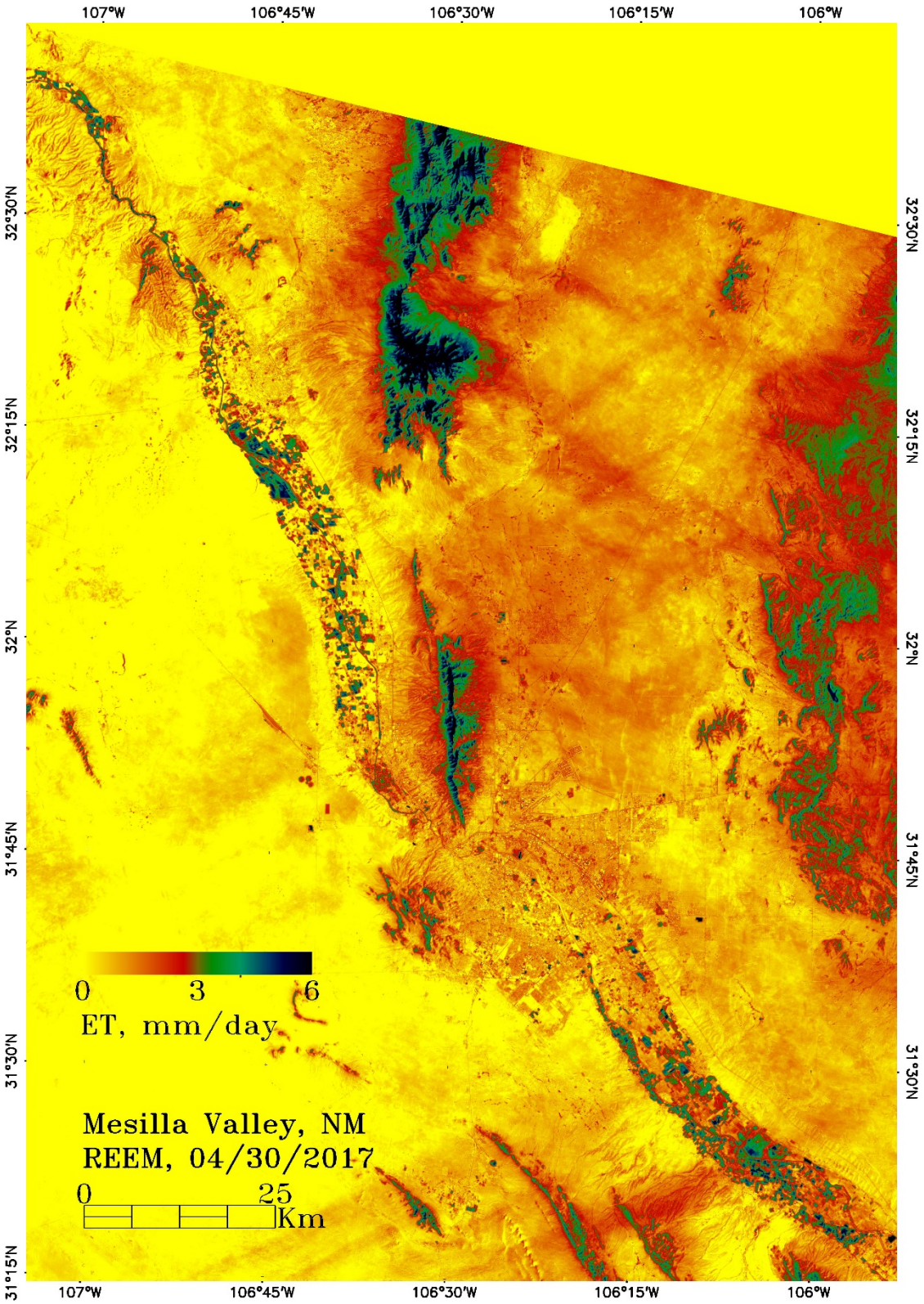

Figure 6. Evapotranspiration map of the Mesilla Valley for April 30, 2017

APPENDIX

Weather Station Name: Leyendecker III
Location: NMSU Leyendecker Plant Science Research Center
County: Dona Ana
Lat/Long: 32°12'3.29"N and 106°44'34.01"W
Elevation: 1176 m

Daily Climate Data from Leyendecker III Climate Station (Tmx and Tmn are max. and min. Temp.; RHmx and RHmn are max. and min. relative humidity; Rs is global shortwave radiation, Prec. is rain; U is average daily wind speed measured at 2.94 m; ETsz is ASCE grass-reference evaportranspiration)

Date	Tmx Deg.	Tmn Deg. C	RHmx %	RHmn %	Rs MJ/m²	Prec _mm	U m/s	ETsz mm
1/1/2017	14.53	2.39	98.30	56.38	6.70	7.11	0.99	1.09
1/2/2017	12.65	0.39	93.70	37.01	13.05	0.00	1.56	1.54
1/3/2017	15.67	0.28	97.60	23.07	12.43	0.00	1.14	1.60
1/4/2017	18.59	4.85	91.10	23.87	13.47	0.00	1.56	2.06
1/5/2017	17.56	0.55	91.60	33.45	11.41	0.00	1.69	1.92
1/6/2017	14.05	0.41	95.60	32.21	12.53	0.00	2.70	2.09
1/7/2017	9.43	-3.53	78.03	28.28	13.94	0.00	2.35	1.82
1/8/2017	15.28	-3.92	92.40	24.07	13.85	0.00	0.91	1.50
1/9/2017	20.64	-0.93	90.30	24.91	11.80	0.00	1.07	1.85
1/10/2017	20.78	4.48	75.71	12.84	13.71	0.00	2.28	2.99
1/11/2017	22.38	-1.40	85.30	17.66	14.53	0.00	1.28	2.29
1/12/2017	18.92	-1.14	78.88	17.14	11.81	0.00	1.08	1.87
1/13/2017	16.67	3.31	79.48	26.27	5.31	0.00	1.18	1.63
1/14/2017	19.51	9.65	94.00	45.50	12.52	3.05	4.23	2.76
1/15/2017	11.21	4.92	92.60	69.02	4.34	23.37	2.73	1.13
1/16/2017	14.11	1.76	97.00	42.54	12.62	0.00	1.03	1.45
1/17/2017	10.33	1.02	98.60	59.25	5.76	0.76	1.06	0.97
1/18/2017	14.15	0.14	100.00	42.31	10.72	0.25	1.20	1.45
1/19/2017	12.69	2.40	91.60	32.30	10.50	0.00	2.40	1.95
1/20/2017	14.06	-1.58	97.20	36.28	11.41	0.00	1.96	1.83
1/21/2017	10.63	4.25	91.20	37.37	12.02	4.57	5.27	2.35
1/22/2017	12.59	0.79	86.50	27.02	15.56	0.00	1.81	1.98
1/23/2017	19.80	-1.94	97.50	19.05	15.71	0.00	1.62	2.48
1/24/2017	13.62	5.19	69.47	27.10	15.65	0.00	3.53	2.88
1/25/2017	9.74	-3.02	77.41	17.45	16.43	0.00	2.48	2.23
1/26/2017	10.79	-6.48	89.10	16.90	16.49	0.00	0.91	1.56
1/27/2017	9.39	-4.33	81.80	21.93	13.06	0.00	1.50	1.68
1/28/2017	12.73	-7.46	82.80	14.46	16.77	0.00	1.13	1.85

Date	Tmx Deg.	Tmn Deg. C	RHmx %	RHmn %	Rs MJ/m²	Prec mm	U m/s	ETsz mm
1/29/2017	15.13	-5.07	79.61	14.80	16.86	0.00	1.12	2.00
1/30/2017	17.87	-4.02	76.73	12.78	16.99	0.00	0.78	1.91
1/31/2017	20.68	-4.87	87.00	11.66	17.19	0.00	1.40	2.68
2/1/2017	22.08	-2.88	78.09	11.18	17.38	0.00	0.94	2.36
2/2/2017	21.06	-4.36	82.60	12.16	16.76	0.00	0.70	2.01
2/3/2017	21.40	-2.44	80.20	14.49	14.94	0.00	0.98	2.27
2/4/2017	22.97	0.45	80.80	10.11	16.03	0.00	0.79	2.23
2/5/2017	23.38	-1.10	74.01	11.55	17.53	0.00	0.96	2.51
2/6/2017	20.45	3.17	68.02	14.57	11.56	0.00	1.79	2.87
2/7/2017	19.94	5.22	58.77	28.59	16.63	0.00	3.40	3.77
2/8/2017	23.38	4.08	84.20	22.00	17.35	0.00	1.28	2.80
2/9/2017	24.41	1.90	88.20	18.22	16.20	0.00	1.00	2.60
2/10/2017	28.33	2.16	83.00	10.00	18.14	0.00	1.16	3.21
2/11/2017	28.31	3.08	73.87	11.96	17.82	0.00	1.63	3.77
2/12/2017	18.53	5.97	82.60	28.36	13.10	2.79	4.85	3.80
2/13/2017	9.06	5.15	93.80	45.85	5.27	5.33	2.01	1.38
2/14/2017	10.39	3.98	92.90	56.23	9.09	0.25	1.53	1.43
2/15/2017	13.90	-0.29	98.20	27.31	18.68	0.00	0.97	2.10
2/16/2017	17.61	-1.94	98.10	18.24	19.12	0.00	0.87	2.30
2/17/2017	18.19	0.83	86.00	20.14	13.91	0.00	2.09	2.89
2/18/2017	18.70	3.07	91.80	29.70	11.25	0.00	1.47	2.30
2/19/2017	14.55	4.41	89.10	31.30	15.45	1.02	2.11	2.52
2/20/2017	19.03	2.66	91.80	19.48	19.62	0.00	2.15	3.30
2/21/2017	23.74	0.79	94.60	20.28	19.77	0.00	1.10	3.02
2/22/2017	26.52	1.86	89.90	12.93	20.01	0.00	1.14	3.35
2/23/2017	21.32	3.48	81.20	8.67	20.22	0.00	3.64	4.78
2/24/2017	15.39	1.39	49.81	10.15	20.91	0.00	2.81	3.79
2/25/2017	18.39	-3.89	85.00	8.43	21.04	0.00	1.54	3.18
2/26/2017	19.38	-1.03	66.20	12.41	16.07	0.00	1.80	3.24
2/27/2017	21.42	-1.20	72.63	12.37	19.56	0.00	1.73	3.54
2/28/2017	21.63	6.87	57.85	9.30	18.11	0.00	3.61	5.00
3/1/2017	18.53	1.43	65.88	13.82	21.53	0.00	1.31	3.14
3/2/2017	20.67	1.83	57.96	12.03	21.55	0.00	1.55	3.55
3/3/2017	17.37	3.94	47.96	18.65	10.57	0.00	2.20	3.15
3/4/2017	23.65	4.31	66.50	14.59	20.74	0.00	1.24	3.50
3/5/2017	24.52	3.58	73.38	22.04	18.49	0.00	2.05	4.00
3/6/2017	22.53	8.72	61.92	13.59	21.95	0.00	2.85	4.81
3/7/2017	22.42	0.68	77.67	9.57	22.63	0.00	1.05	3.40
3/8/2017	26.42	1.77	59.16	9.73	22.22	0.00	1.15	3.80
3/9/2017	28.20	4.62	62.83	8.39	21.74	0.00	1.11	3.90
3/10/2017	29.29	5.09	56.03	7.91	22.71	0.00	1.05	3.99

Date	Tmx Deg.	Tmn Deg. C	RHmx %	RHmn %	Rs MJ/m²	Prec mm	U m/s	ETsz mm
3/11/2017	27.58	4.45	60.34	10.98	17.66	0.00	1.63	4.23
3/12/2017	26.00	6.50	69.21	14.48	21.97	0.00	2.47	5.01
3/13/2017	24.00	7.51	57.98	13.07	23.12	0.00	2.43	4.91
3/14/2017	29.42	4.01	70.22	8.38	23.55	0.00	1.24	4.39
3/15/2017	29.65	5.33	55.02	7.68	22.88	0.00	1.17	4.30
3/16/2017	28.79	4.76	60.07	7.54	21.82	0.00	1.83	4.97
3/17/2017	29.99	5.06	58.37	8.65	23.84	0.00	0.99	4.19
3/18/2017	31.37	4.99	59.08	8.85	23.88	0.00	1.13	4.51
3/19/2017	31.98	8.85	47.97	9.19	23.31	0.00	1.31	4.81
3/20/2017	31.10	8.28	59.20	9.80	20.46	0.00	1.09	4.23
3/21/2017	31.50	7.52	62.29	7.44	23.44	0.00	1.14	4.58
3/22/2017	32.04	5.16	70.72	5.46	24.92	0.00	1.57	5.37
3/23/2017	25.07	7.02	50.01	10.82	22.91	0.00	3.95	6.40
3/24/2017	23.42	6.71	51.31	13.85	25.02	0.00	3.58	5.91
3/25/2017	26.85	1.79	76.25	7.51	24.38	0.00	1.99	5.16
3/26/2017	23.43	8.24	45.77	11.29	25.29	0.00	3.03	5.74
3/27/2017	26.36	3.52	53.86	10.21	25.12	0.00	1.68	4.91
3/28/2017	17.92	9.96	70.32	22.81	16.06	0.00	2.97	3.95
3/29/2017	20.89	8.76	63.40	25.11	21.54	0.00	2.67	4.55
3/30/2017	26.77	2.60	88.50	8.73	26.07	0.00	1.93	5.24
3/31/2017	24.60	6.58	52.98	8.56	23.11	0.00	3.26	5.99
4/1/2017	18.95	4.28	66.16	18.33	15.71	0.00	1.63	3.36
4/2/2017	21.17	5.06	73.79	15.03	26.25	0.00	2.62	4.99
4/3/2017	24.89	10.23	43.95	11.93	26.17	0.00	2.56	5.81
4/4/2017	22.66	8.71	36.88	7.96	25.91	0.00	3.55	6.30
4/5/2017	22.10	2.74	70.14	9.16	26.95	0.00	1.19	4.27
4/6/2017	25.77	2.88	74.64	11.28	22.67	0.00	1.10	4.15
4/7/2017	30.09	4.69	77.20	7.44	26.80	0.00	1.45	5.36
4/8/2017	30.31	6.07	64.72	8.12	27.64	0.00	2.00	6.16
4/9/2017	25.41	7.28	53.83	9.23	25.02	0.00	2.44	5.70
4/10/2017	27.09	3.28	69.61	5.62	26.43	0.00	1.05	4.60
4/11/2017	28.89	6.47	64.55	11.49	24.87	0.00	2.34	6.01
4/12/2017	30.71	16.95	70.63	6.03	24.85	0.00	3.63	7.55
4/13/2017	29.81	12.95	81.40	10.71	25.48	0.00	1.77	5.65
4/14/2017	30.90	8.96	90.20	5.46	26.04	0.00	1.41	5.45
4/15/2017	29.80	8.35	73.46	7.58	28.32	0.00	1.27	5.42
4/16/2017	30.39	4.59	89.30	7.58	28.21	0.00	1.30	5.44
4/17/2017	31.17	4.55	81.10	5.96	28.48	0.00	1.24	5.50
4/18/2017	31.35	4.49	77.55	7.47	28.49	0.00	1.49	5.84
4/19/2017	31.08	7.18	67.52	8.82	28.72	0.00	1.69	6.10
4/20/2017	32.04	6.17	82.60	7.44	28.67	0.00	1.40	5.85

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4/21/2017	30.78	6.21	56.38	5.39	29.59	0.00	2.23	6.89
4/22/2017	25.20	11.07	54.06	13.70	28.41	0.00	4.15	7.18
4/23/2017	27.08	11.85	63.58	15.63	28.41	0.00	2.99	6.65
4/24/2017	31.30	7.04	91.10	6.43	28.61	0.00	2.34	6.82
4/25/2017	27.09	15.29	41.76	12.13	26.87	0.00	4.25	7.85
4/26/2017	25.49	6.81	78.13	8.96	28.39	0.00	2.21	5.84
4/27/2017	30.06	8.18	62.17	11.79	26.95	0.00	2.85	7.00
4/28/2017	27.88	9.44	86.20	18.33	22.34	0.00	3.09	6.00
4/29/2017	16.22	3.44	91.40	17.78	19.31	1.78	2.67	3.84
4/30/2017	24.49	0.25	96.10	9.47	29.20	0.00	1.83	5.36
5/1/2017	29.19	2.77	84.90	7.37	29.23	0.00	0.95	5.13
5/2/2017	30.39	4.69	87.60	6.20	29.58	0.00	1.72	6.21
5/3/2017	31.20	7.37	73.09	9.12	28.75	0.00	1.43	5.94
5/4/2017	27.66	14.15	70.51	14.58	28.95	0.00	3.35	7.11
5/5/2017	31.87	12.18	83.40	10.27	29.03	0.00	1.71	6.40
5/6/2017	33.69	8.89	92.60	10.17	24.93	0.00	2.14	6.62
5/7/2017	31.41	9.87	85.20	7.41	29.32	0.00	1.78	6.45
5/8/2017	29.88	9.69	78.74	8.87	26.25	0.00	2.31	6.46
5/9/2017	25.34	12.02	58.40	16.71	28.68	0.00	2.95	6.53
5/10/2017	21.72	6.34	80.40	17.90	28.59	0.00	2.36	5.35
5/11/2017	27.70	5.36	77.54	15.77	30.37	0.00	1.61	5.82
5/12/2017	29.62	14.76	70.21	12.96	30.35	0.00	1.89	6.56
5/13/2017	33.39	14.15	61.68	8.89	30.22	0.00	1.88	7.05
5/14/2017	31.77	9.50	78.38	8.62	27.72	0.00	1.35	5.90
5/15/2017	30.97	9.43	68.72	10.51	30.47	0.00	1.64	6.43
5/16/2017	25.45	9.47	69.72	13.55	25.13	0.00	3.17	6.30
5/17/2017	28.34	4.08	75.18	9.77	30.97	0.00	2.05	6.45
5/18/2017	27.07	12.04	54.89	13.85	30.49	0.00	2.21	6.55
5/19/2017	26.63	8.52	63.58	7.65	31.18	0.00	2.02	6.36
5/20/2017	27.74	6.93	72.31	9.93	31.40	0.00	1.37	5.87
5/21/2017	31.12	13.61	61.64	12.30	28.58	0.00	2.06	6.77
5/22/2017	33.89	12.35	87.60	6.43	31.09	0.00	1.60	6.87
5/23/2017	32.01	12.63	62.89	9.76	31.13	0.00	3.00	8.08
5/24/2017	34.37	11.80	69.57	6.63	31.26	0.00	2.27	7.77
5/25/2017	33.77	15.06	47.33	7.34	27.94	0.00	2.49	7.71
5/26/2017	33.50	11.17	62.59	7.64	31.11	0.00	2.06	7.40
5/27/2017	33.40	10.14	71.87	6.97	31.78	0.00	1.79	7.15
5/28/2017	30.71	9.30	71.24	10.71	31.17	0.00	2.54	7.36
5/29/2017	32.15	19.79	54.08	11.95	29.32	0.00	3.42	8.47
5/30/2017	30.74	15.12	76.57	18.69	27.77	3.30	2.60	6.92
5/31/2017	28.82	14.96	93.50	25.02	24.87	0.00	2.01	5.67

Date	Tmx Deg.	Tmn Deg. C	RHmx %	RHmn %	Rs MJ/m²	Prec mm	U m/s	ETsz mm
6/1/2017	31.17	13.59	86.60	24.37	24.41	0.00	2.25	6.11
6/2/2017	30.76	13.49	93.00	18.65	25.97	0.00	1.49	5.73
6/3/2017	31.97	15.40	80.80	20.13	27.55	0.00	1.09	5.78
6/4/2017	34.33	15.10	81.60	17.20	28.61	0.00	1.08	6.11
6/5/2017	37.98	14.79	86.00	10.03	29.93	0.00	1.32	6.92
6/6/2017	35.48	23.78	41.89	13.55	25.38	1.78	3.19	8.56
6/7/2017	34.24	19.63	73.34	19.15	27.46	0.00	2.00	6.97