Evaluation of Two New Net Radiometers and a Model to Predict Net Radiation

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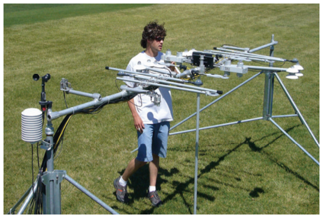
Introduction

Net radiation is a key component of the surface energy balance, but it is difficult to measure. Two new net radiometers have been released in the past year. We compared these models and two, less-expensive older model net radiometers over turfgrass. Additionally, we predicted net radiation from solar radiation, air temperature, and absolute humidity measurements with a commonly used model.



Materials and Methods

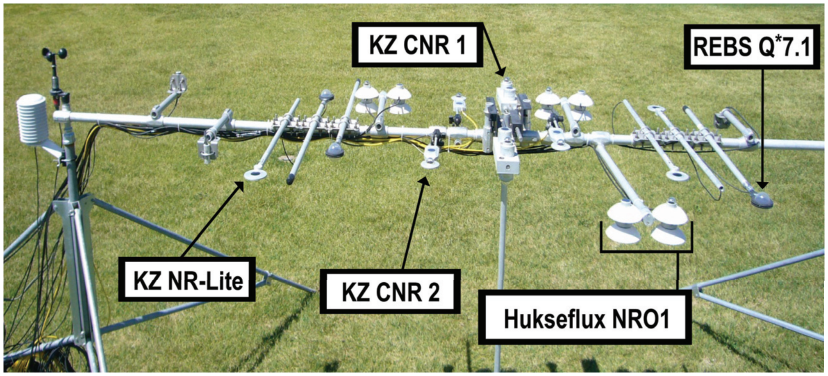
The net radiometers compared in the study are as listed:

Manufacturer	Model	Cost	Reps	Output
Kipp & Zonen	CNR 1	$6200	2	SW_i ,SW_o, LW_i, LW_o
Hukseflux	NR01	$4200	3	SW_i, SW_o, LW_i, LW_o
Kipp & Zonen	CNR 2	$2600	3	SW_n, LW_n
Kipp & Zonen	NR-Lite	$1600	3	R_n
REBS	Q*7.1	$1200	3	R_n

The output refers to the radiation balance components measured by the sensors, where SW_i is incomming shortwave, SW_o is outgoing shortwave, LW_i is incomming longwave, LW_o is outgoing longwave, SW_n is net shortwave (SW_i - SW_o), LW_n is net longwave (LW_i - LW_o), , and R_n is net radiation (SW_i - SW_o + LW_i - LW_o).

All radiometers were mounted over a uniform turfgrass plot at the Utah State University Greenville Farm in Logan, Utah. The radiometers were mounted at a 1.5 meter height on a cross bar between two tripods. A datalogger (Campbell Scientific model CR7) was used to make and record the net radiation measurements, which were taken every 10 seconds and averaged over 1 hour intervals. Wind speed (R.M. Young model 03101), air temperature (Campbell Scientific model 107-L), relative humidity (Vaisala model HMP50), and precipitation (Texas Electronics model TE525WS) were also measured. Irrigation on the turfgrass plot occurred approximately every 3 days. Following each irrigation event the radiometers were cleaned (using dilute vinegar and de-ionized water) and re-leveled. Data recorded during irrigation events and before cleaning and re-leveling following irrigation events was excluded. To determine the effects of precipitation, data were analyzed before and after precipitation events, but the data collected during precipitation events are not presented here. The NR-Lite and Q*7.1 radiometers were corrected for wind speed effects based on the equations published by the manufacturers.

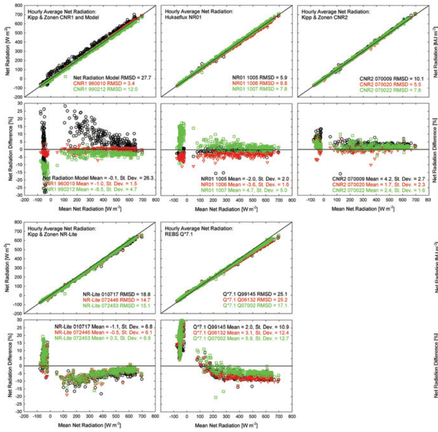
Net radiation was also predicted from solar radiation, air temperature, and air vapor pressure measurements using a model. In the model, net longwave radiation is calculated with a Brunt (1932; 1952) approach for predicting net emissivity. The ratio of measured solar radiation to predicted clear-sky solar radiation is used as a surrogate variable for cloud cover. Net shortwave radiation is determined by direct measurement of solar radiation and the albedo of the surface, which was assumed to be 0.23 for turfgrass.

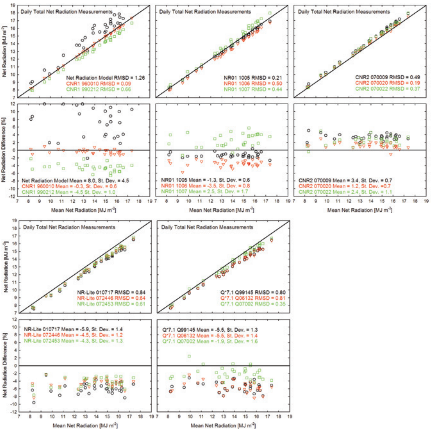


Model	Day (Hourly)		Night (Hourly)		All Hourly Data		Daily Total	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
CNR 1	-1.5		-7.0		-3.8		-2.4	
NR01	-0.7	2.3	0.3	7.7	-0.3	4.4	-0.8	3.0
CNR 2	1.7	1.0	4.4	1.9	2.8	1.3	2.4	1.1
NR-Lite	-5.2	0.8	5.9	0.9	-0.5	0.7	-4.9	0.9
Q*7.1	-5.3	1.7	15.4	2.8	3.7	2.0	-4.3	2.1
R_n Model	8.2		-15.3		-0.1		8.0	

Results

Comparisons of hourly average [W m^{-2}] and daily total [MJ m^{-2} d^{-1}] measurements (shown below) for the entire experiment show the correlation to the R_n reference and the difference [%] from the reference. Because there is not a reference standard for R_n measurements, the average of the two CNR 1, three NR01, and three CNR 2 radiometers was used as the R_n reference. The average percent difference and the standard deviation of the percent difference for each model is listed (table on previous page) to summarize the data from the figures.





Conclusions

1 – Accuracy compared to the reference (average of two CNR 1, three NR01, three CNR 2) generally increased with cost.
2 – For the **NR01**, the average % difference was < 1.0 % (percentages are group averages) for all hourly measurements and daily total, but there was high variability among replicate sensors, especially at night (St. Dev. = 7.7 %). The high variability is largely caused by the LW_i measurement on sensor S/N 1007. The discrepancy was reported to the manufacturer and they reported an error in the LW calibration procedure, which has been corrected.
3 – Under all conditions the **CNR 2** measured high relative to the reference, but was within 3.0 % for all hourly averages and daily total measurements, with low variability among replicate sensors (the maximum St. Dev. occurred at night and was 1.9 %).
4 – The **NR-Lite** had offsetting errors for day (5.2 % low) and night (5.9 % high), and had the lowest variability among replicate sensors (all St. Devs. were < 1.0 %). The NR-Lite agrees reasonably well with the more expensive models under most field conditions, but is not accurate following precipitation events when the thermopile surface is wet (data not shown). This was also seen by Cobos and Baker (2003) and Brotzge and Duchon (2000).
5 – The **Q*7.1** was only 3.7 % low for all measurements and 4.3 % low for daily total, but had large offsetting errors for day (5.3 % low) and night (15.4 % high), similar to the NR-Lite.
6 – The advantage of the NR-Lite and Q*7.1 is low cost. The advantage of the CNR 1, NR01, and CNR 2 is accuracy under all conditions. The advantage of the CNR 1 and NR01 over the CNR 2 is the ability to measure all four R_n components rather than SW_n and LW_n only.
7 – The commonly used **R_n model** was high (8.2 %) during the day and low (15.3 %) at night, yielding offsetting errors. The daily totals were always high with an average of 8.0 %. Even the least expensive radiometer was more accurate than the model.

References

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