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Assessment of clear and cloudy sky parameterizations for daily downwelling longwave radiation over different land surfaces in Florida, USA

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Assessment of clear and cloudy sky parameterizations for daily downwelling longwave radiation over different land surfaces in Florida, USA

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[1] Clear sky downwelling longwave radiation (R_{ldc}) and cloudy sky downwelling longwave radiation (R_{ld}) formulas were tested across eleven sites in Florida. The Brunt equation, using air vapor pressure and temperature measurements, provides the best R_{ldc} estimates with a root mean square error of less than around 12 Wm^{-2} across all sites. The Crawford and Duchon's cloudiness factor with Brunt equation is recommended for R_{ld} calculations. This combined approach requires no local calibration and estimates R_{ld} with a root mean square error of less than around 13 Wm^{-2} and squared correlation coefficients that typically exceed 0.9. **Citation:** Choi, M., J. M. Jacobs, and W. P. Kustas (2008), Assessment of clear and cloudy sky parameterizations for daily downwelling longwave radiation over different land surfaces in Florida, USA, *Geophys. Res. Lett.*, *35*, L20402, doi:10.1029/2008GL035731.

1. Introduction

[2] Net radiation is a critical component of the surface energy budget [*Brutsaert*, 1975; *Sugita and Brutsaert*, 1993; *Crawford and Duchon*, 1999]. Enhanced estimation of net radiation using reliable downward longwave radiation (R_{ld}) values will contribute to a better understanding of the surface energy budget and result in improved characterization of evapotranspiration for many applications in hydrology, climatology, biology, and ecology. While R_{ld} can be directly measured by a pyrgeometer, the instrument is rarely part of weather stations. Additionally, pyrgeometers are expensive as compared to shortwave radiation instruments and their measurements often have significant errors [*Sridhar and Elliott*, 2002; *Duarte et al.*, 2006].

[3] Lacking the required data and measurements noted above, R_{ld} can be calculated using screen height measurements of air vapor pressure and temperature from weather stations via simple physical or empirical models [*Sellers*, 1965; *Idso and Jackson*, 1969; *Brutsaert*, 1975; *Satterlund*, 1979; *Sugita and Brutsaert*, 1993; *Prata*, 1996; *Crawford and Duchon*, 1999; *Rizou and Nnadi*, 2007]. More reliable R_{ld} estimation can be obtained by radiative transfer models such as MODTRAN [*Snell et al.*, 1995]. However, required input data such as vertical profiles of temperature and air vapor are not typically available [*Niemela et al.*, 2001; *Duarte et al.*, 2006].

[4] Most models make empirical estimates of atmospheric emissivity (ε_a) from measured air temperature and relative humidity. In contrast, the *Brutsaert* [1975] model and the *Prata* [1996] model which basically follows *Brutsaert* [1975] derivation using adjusted slab emissivity are based on analytical equations using radiative transfer theory [*Kjaersgaard et al.*, 2007]. Both physical and empirical model parameters and performance are significantly affected by geographical location and local atmospheric conditions including cloud characteristics [*Rizou and Nnadi*, 2007] and require site specific validation and parameterization.

[5] The main objective of this study is to identify the best models with original parameters available to estimate R_{ld} from meteorological data, resulting in reliable quantification of net radiation and evapotranspiration in Florida, United States. This study is unique compared to previous studies because: 1) it uses simultaneous measurements collected over a 2 year period at eleven experimental sites over an extensive geographical area and 2) includes both clear and cloudy sky conditions in Florida that are characteristic of humid, convective climate conditions, in the southeastern United States and other subtropical locations.

2. Study Region and Ground Based Data

[6] The central Florida study region has a humid, subtropical climate, with an average annual rainfall of 1500 mm [*Black*, 2003]. Almost 70% of the annual rainfall occurs from May to November. Average annual temperature is 32.2°C and average annual relative humidity is higher than 50% [*Black*, 2003]. Average annual wind speed from Florida Automated Weather Network (FAWN, http://fawn.ifas.ufl.edu/, 2002) is about 2.2 m/s [*Black*, 2003]. Thunderstorms usually occur in the afternoon during summer due to strong convective activity. During the study period, 2004 to 2005, the average daytime cloud cover was 32% from May to October.

[7] Data collected at eleven net radiation experiment sites (two open water, two wetland, two urban, two rangeland, one forest, and two agriculture sites) in central Florida are used in this study (Figure 1). Field locations and attributes are given in Table 1. Two years of data, January 1, 2004 to December 31, 2005, were available for this analysis. The 15 minute data were averaged to provide daily average values.

[8] Each site was instrumented with a new Kipp & Zonen CNR1 four-channel radiometer composed of a pyranometer and pyrgeometer pair installed approximately 2 m above the canopy surfaces. The net radiometer measured incoming and outgoing shortwave and longwave radiation every 15 minutes. The radiometer calibration was provided by

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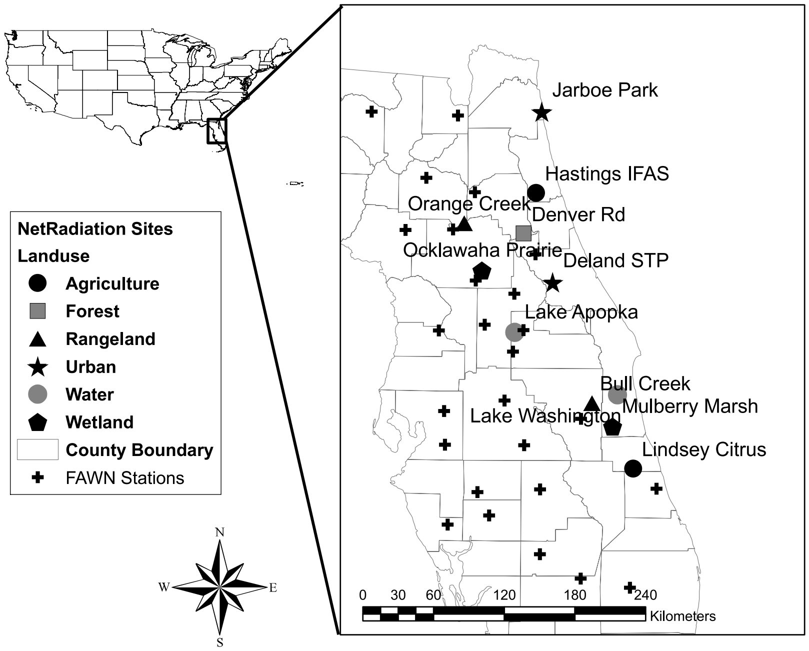

Figure 1. The eleven experimental sites in Florida at which incoming longwave radiation was measured from 2004 to 2005 and the nearby FAWN stations at which temperature and relative humidity were measured.

manufacturer. The sensitivity of the radiometer ranges from 10 to 35 Wm^{-2} and maximum error due to heating is 10 Wm^{-2} [*Tien et al.*, 2008]. Systematic error of incoming longwave radiation as measured by pyrgeometer may be up to ±5 Wm^{-2} due to solar radiation and wind speed [*Perez and Alados-Arboledas*, 1999]. The radiometer data were quality checked weekly by comparing measurements within the same region. Radiometers were visually inspected and side-by-side comparisons were made with a dedicated reference radiometer bi-monthly. Radiometers were sent to Kipp & Zonen for recalibration bi-annually (personal communication G. Robinson, St. Johns River Water Management District, 2008). Daily downward shortwave radiation data were plotted against theoretical clear sky downward solar radiation [*Allen et al.*, 1998; *Kjaersgaard et al.*, 2007] and with few exceptions were enveloped below the theoretical clear sky downward solar radiation.

[9] Daily temperature and relative humidity data were obtained from the nearby FAWN meteorological stations located within 10 km. Each FAWN tower measures temperature and relative humidity every 15 minutes using a Campbell Scientific CS215 probe mounted at 2 m (FAWN, 2002). In this study, the FAO quality assurance procedures for temperature and relative humidity were applied to the FAWN data [*Allen et al.*, 1998].

3. Methods

3.1. Clear Sky Downwelling Longwave Radiation

[10] R_{ld} is typically estimated by first determining the clear sky radiation (R_{ldc}), which is then corrected for cloud cover. The general form of the R_{ldc} equation is

$$R_{ldc} = \varepsilon_a \sigma T_a^4 \tag{1}$$

where ε_a is the atmospheric emissivity, σ is the Stefan-Boltzman constant [Wm^{-2} K^{-4}], and T_a is the air temperature [K]. The surface emissivity is typically estimated as a function of the air temperature and actual vapor pressure (e_a). Nornally, e_a and T_a are measured at screen level height around 2 m. Table 2 lists the five R_{ldc} models with original parameters that were compared.

Table 1. Florida Study Sites, Locations, Land Use, and Number of Clear and Cloudy Sky Observations From 01/01/2004 to 12/31/2005

Site	Land Use	Latitude	Longitude	Count of Clear Sky Days	Count of Cloudy Sky Days
Lake Washington	Water	28.1	−80.7	59	630
Lake Apopka	Water	28.6	−81.6	85	689
Mulberry Marsh	Wetland	27.9	−80.8	57	725
Ocklawaha Prairie	Wetland	29.1	−81.9	114	731
Jarboe Park	Urban	30.3	−81.4	107	731
Deland STP	Urban	29.0	−81.3	103	724
Bull Creek	Rangeland	28.1	−81.0	68	731
Orange Creek	Rangeland	29.5	−82.1	96	731
Denver Rd	Forest	29.4	−81.6	102	712
Hastings IFAS[a]	Agriculture	29.7	−81.4	41	225
Lindsey Citrus	Agriculture	27.6	−80.6	68	731

[a] Partial years.

Table 2. R_{ldc} Models Compared for Clear Sky Conditions[a]

Clear Sky Longwave Radiation	Variables	Source
$R_{ldc} = (a_1 + b_1 e_a{}^{1/2})\ \sigma T_a{}^4$	$a_1 = 0.605\ b_1 = 0.048$	*Brunt* [1932][b]
$R_{ldc} = (1 - a_2 \exp(-b_2(273 - T_a)^2))\ \sigma T_a{}^4$	$a_2 = 0.261\ b_2 = 7.77 \times 10^{-4}$	*Idso and Jackson* [1969]
$R_{ldc} = a_3\ (e_a/T_a)_3{}^b \sigma T_a{}^4$	$a_3 = 1.24\ b_3 = 0.14$	*Brutsaert* [1975]
$R_{ldc} = \{a_4(1 - \exp(-e_a{}^{(Ta/b_4)}))\}\ \sigma T_a{}^4$	$a_4 = 1.08\ b_4 = 2016$	*Satterlund* [1979]
$R_{ldc} = \{1 - (1 + a_5(e_a/T_a))\exp(-(b_5 + a_5 c_5(e_a/T_a))^{1/2})\}\ \sigma T_a{}^4$	$a_5 = 46.5\ b_5 = 1.20\ c_5 = 3.0$	*Prata* [1996]

[a] Note: e_a [10^{-3} bar], T_a [K].

[b] The variables were obtained by *Sellers* [1965].

3.2. Cloudy Sky Downwelling Longwave Radiation

[11] Under cloudy conditions, fractional cloud cover required to estimate R_{ld} may be determined from visual observations. However, when fractional cloud cover measurements are not available, they can be estimated by *Crawford and Duchon* [1999] equation

$$c = 1 - R_s/R_{so} \tag{2}$$

where R_s is the downward solar radiation at the surface and R_{so} is the theoretical clear sky downward solar radiation [*Allen et al.*, 1998]. However, this equation can be used for only daylight hours [*Duarte et al.*, 2006]. We identified clear sky days at the 11 sites as those days having average c values less than 0.05 [*Duarte et al.*, 2006]. The clear sky calculations were conducted for only these days, while cloudy sky calculations were conducted using all days (Table 1).

[12] Cloudy sky downwelling longwave radiation formulations generally have one of two basic structures [*Duarte et al.*, 2006].

$$R_{ld} = R_{ldc}\left(1 + \alpha c^{\beta}\right) \tag{3}$$

$$R_{ld} = R_{ldc}(1 - c^{\gamma}) + \delta c^{\zeta} \sigma T_a^4 \tag{4}$$

where α, β, γ, δ, and ζ are the locally calibrated constants determined from cloud types. Seven cloudy sky correction models with original parameters were evaluated in this study (Table 3).

4. Results and Discussion

4.1. Estimation for Clear Sky Downwelling Longwave Radiation

[13] The R_{ldc} models were applied for those days having clear sky conditions as indicated by fractional cloud cover values less than 0.05. For this region, only 5 to 20% of all available days are clear sky days (Table 1). The majority of these days were during the winter and spring. Three statistics, the root mean square error ($RMSE = [(\sum_{i=1}^{n}(observed_i - calculated_i)^2/n)]^{1/2}$), the ratio of the calculated mean to the observed mean (RCO), and the squared correlation coefficient (R^2), were used to compare calculated R_{ldc} values to observed R_{ldc} values (Table 4).

[14] All the methods overestimated the measured R_{ldc}. The *Satterlund* [1979] equation had the largest systematic and random errors and the highest bias as compared to the other equations. The two methods, the *Brutsaert* [1975] model and the *Brunt* [1932] model using the coefficients obtained by *Sellers* [1965], performed the best. While the *Brutsaert* [1975] equation had the best agreement with observed data (average R^2 = 0.871), the *Brunt* [1932] equation had the lowest RMSE (average RMSE = 12.3 Wm^{-2}) and RCO values closest to one (average RCO = 1.014) values (Table 4). Of the 11 experiment sites, the Ocklawaha Prairie and Deland STP sites had more scatter as compared to the other sites. This may be due to multiple land covers surrounding the sites [*Rizou and Nnadi*, 2007].

[15] The average RMSE values predicted by the *Brunt* [1932] and the *Brutsaert* [1975] equations were low compared to all other selected clear sky equations regardless of land cover types. *Sridhar and Elliott* [2002], *Duarte et al.* [2006], *Kjaersgaard et al.* [2007], and *Rizou and Nnadi* [2007] agreed that the *Brutsaert* [1975] equation was the best method to predict R_{ldc}. *Sugita and Brutsaert* [1993] and *Kjaersgaard et al.* [2007] pointed out that the *Brunt* [1932] equation provided a similar results to the *Brutsaert* [1975] equation. For this region, both the *Brunt* [1932] and the *Brutsaert* [1975] equations with existing parameterizations are viable methods to estimate R_{ldc} with the *Brunt* [1932] equation performing slightly better.

[16] The value of regionally calibrated parameters was examined for a_1 and b_1 of the *Brunt* [1932] equation and a_3 and b_3 of the *Brutsaert* [1975] equation. Using the 11 sites, the regional calibration of *Brunt* [1932] equation parameters is a_1 = 0.575 and a_2 = 0.054 and for the *Brutsaert* [1975] equation, the values are a_3 = 1.14 and b_3 = 0.13. These values are quite similar to *Brunt's* [1932] original values obtained by *Sellers* [1965] (0.605 and 0.048) and *Brutsaert's* [1975] original values (1.24 and 0.14). Interestingly when the e_a units are converted from hPa to Pa, the *Brutsaert* [1975] a_3 value becomes $1.14 \times (1/100)^{0.13} = 0.626$; this pair of values, 0.626 and 0.13 is virtually identical to that obtained by *Duarte et al.* [2006] (whose e_a is in Pa) at their Ponta Grossa, Brazil site: a_3 = 0.625 and b_3 = 0.131.

Table 3. R_{ld} Models Compared for All Measurement Periods[a]

Cloudy Sky Longwave Radiation	Source
$R_{ld} = R_{ldc}(1 + 0.26c)$	*Jacobs* [1978]
$R_{ld} = R_{ldc}(1 + 0.22c^{2.75})$	*Maykut and Church* [1973]
$R_{ld} = R_{ldc}(1 + 0.0496c^{2.45})$	*Sugita and Brutsaert* [1993]
$R_{ld} = R_{ldc}(1 - c^4) + 0.952c^4 \sigma T_a{}^4$	*Konzelmann et al.* [1994]
$R_{ld} = R_{ldc}(1 - c) + c\sigma T_a{}^4$	*Crawford and Duchon* [1999]
$R_{ld} = R_{ldc}(1 + 0.242c^{0.583})$	*Duarte et al.* [2006, equation (21)]
$R_{ld} = R_{ldc}(1 - c^{0.671}) + 0.990c^{0.671} \sigma T_a{}^4$	*Duarte et al.* [2006, equation (22)]

[a] Here c is the fractional cloud cover, e_a is vapor pressure [10^{-3} bar], and T_a is air temperature [K].

Table 4. Comparison of Daily Clear Sky Downwelling Longwave Radiation Results for Each R_{ldc} Model by Site and Averaged Across Sites for Days When Fractional Cloud Cover is Less Than 5%[a]

			Calculated R_{ldc} (Wm^{-2})					Ratio of the Calculated Mean to Observed Mean (RCO) (−)				
Site	Land Use	Measured (Wm^{-2})	*Brunt* [1932]	*Brutsaert* [1975]	*Idso and Jackson* [1969]	*Satterlund* [1979]	*Prata* [1996]	*Brunt* [1932]	*Brutsaert* [1975]	*Idso and Jackson* [1969]	*Satterlund* [1979]	*Prata* [1996]
Lake Washington	Water	307	306	311	312	325	314	0.996	1.013	1.017	1.058	1.022
Lake Apopka	Water	301	299	303	306	318	306	0.993	1.008	1.018	1.059	1.019
Mulberry Marsh	Wetland	289	298	302	305	318	306	1.031	1.046	1.057	1.099	1.058
Ocklawaha Prairie	Wetland	296	301	305	308	320	308	1.016	1.032	1.042	1.082	1.043
Jarboe Park	Urban	292	295	300	300	314	303	1.012	1.028	1.028	1.077	1.039
Deland STP	Urban	297	291	295	298	311	299	0.981	0.994	1.004	1.047	1.006
Bull Creek	Rangeland	282	291	295	299	312	299	1.034	1.047	1.061	1.106	1.061
OrangeCreek	Rangeland	277	288	291	296	308	295	1.037	1.047	1.067	1.110	1.064
Denver Rd	Forest	296	296	300	303	315	304	0.999	1.013	1.022	1.065	1.025
Hastings IFAS1	Agriculture	303	311	317	315	329	319	1.025	1.047	1.040	1.086	1.052
Lindsey Citrus	Agriculture	291	300	305	307	320	308	1.032	1.049	1.055	1.100	1.059
Average		294	298	302	304	317	305	**1.014**	1.029	1.037	1.081	1.041

			RMSE (Wm^{-2})					R^2 (−)				
Site	Land Use	Measured (Wm^{-2})	*Brunt* [1932]	*Brutsaert* [1975]	*Idso and Jackson* [1969]	*Satterlund* [1979]	*Prata* [1996]	*Brunt* [1932]	*Brutsaert* [1975]	*Idso and Jackson* [1969]	*Satterlund* [1979]	*Prata* [1996]
Lake Washington	Water	307	8.9	9.8	11.5	20.4	11.1	0.926	0.928	0.905	0.919	0.926
Lake Apopka	Water	301	10.8	11.9	12.7	20.7	12.1	0.875	0.875	0.850	0.865	0.876
Mulberry Marsh	Wetland	289	12.7	16.2	19.4	30.3	19.0	0.910	0.911	0.894	0.904	0.911
Ocklawaha Prairie	Wetland	296	16.1	18.3	20.5	28.9	19.9	0.801	0.806	0.776	0.795	0.802
Jarboe Park	Urban	292	10.7	13.0	13.9	24.8	15.1	0.900	0.904	0.880	0.898	0.900
Deland STP	Urban	297	12.5	11.7	12.1	18.0	11.2	0.854	0.857	0.825	0.847	0.855
Bull Creek	Rangeland	282	13.5	16.7	20.1	31.4	19.7	0.793	0.800	0.758	0.788	0.794
OrangeCreek	Rangeland	277	14.5	16.5	22.0	32.4	20.5	0.867	0.877	0.820	0.857	0.868
Denver Rd	Forest	296	9.1	9.7	12.6	21.5	11.6	0.927	0.932	0.898	0.920	0.929
Hastings IFAS1	Agriculture	303	14.0	18.2	16.9	28.7	19.6	0.810	0.811	0.831	0.834	0.813
Lindsey Citrus	Agriculture	291	12.5	16.5	18.5	30.3	19.0	0.878	0.880	0.845	0.869	0.879
Average		294	**12.3**	14.4	16.4	26.1	16.3	0.867	**0.871**	0.844	0.863	0.868

[a] Bold indicates key point numbers discussed in the text.

[17] While these locally calibrated equations provide marginally better results as compared to original equations, the original parameterizations are recommended because they provide a consistent approach across a broader region and range of field conditions [*Sugita and Brutsaert*, 1993].

4.2. Estimation for Cloudy Sky Downwelling Longwave Radiation

[18] The seven methods that account for cloud cover (Table 3) were compared for all sites and days from 01/01/2004 to 12/31/2005 (Table 1). The *Brunt* [1932] clear sky radiation equations using the original parameters was used to estimate R_{ldc} for all seven methods. The results are summarized in Table 5. The *Jacobs* [1978] equation, the *Crawford and Duchon* [1999] equation, and the *Duarte et al.* [2006, equation (22)] provide excellent results with average RMSE values within 5% of the average measured values and very strong correlations with modest positive biases (Table 5). With respect to bias, our results are similar to *Duarte et al.*'s [2006] finding that the *Maykut and Church* [1973], the *Sugita and Brutsaert* [1993], and the *Konzelmann et al.* [1994] equations all underestimated the cloudy sky radiation. This is likely caused by differences between the ratio of the daytime cloud cover and nocturnal cloud cover between sites as well as the relative simple method used to estimate cloud cover.

[19] Overall, the *Crawford and Duchon* [1999] equation with the lowest RMSE values (average RMSE = 13.4 Wm^{-2}) is recommended for R_{ld} calculation in Florida. Even the worst performing method, the *Sugita and Brutsaert* [1993] method developed for the relatively dry mid-western region of the United States, gave reasonable results for this region.

[20] The results were fairly consistent across land uses. The open water sites had modestly higher downwelling longwave radiation as compared to the other land uses. All of the radiation models were able to capture these observed increases.

5. Conclusion

[21] In this study, daily R_{ld} estimation methods were compared under clear and cloudy sky at eleven sites in Florida. The *Brunt* [1932] and the *Brutsaert* [1975] equations are both viable methods to estimate clear sky radiation with the *Brunt* [1932] equation performing slightly better across all sites. Regionalized parameters were quite similar to the original parameters and did not appreciably improve estimates. The recommended approach to estimate downwelling longwave radiation in Florida is to use the *Brunt* [1932] equation for R_{ldc} and the *Crawford and Duchon* [1999] equation for R_{ld}. While more specific parameterization may be employed using cloud properties and profile temperature and humidity data, these recommended R_{ldc} and R_{ld} methods will provide reasonable estimates with relatively high accuracy and low errors under typical convective cloud conditions in Florida.

Table 5. Comparison of Daily Cloudy Sky Downwelling Longwave Radiation Results for Each R_{ld} Model by Site and Averaged Across Sites[a]

			Calculated R_{ld} (Wm^{-2})							Ratio of the Calculated mean to Observed mean (RCO) (−)						
Site	Land Use	Measured	*Jacobs* [1978]	*Maykut and Church* [1973]	*Sugita and Brutsaert* [1993]	*Konzelmann et al.* [1994]	*Crawford and Duchon* [1999]	*Duarte et al.* [2006] Eqn (21)	*Duarte et al.* [2006] Eqn (22)	*Jacobs* [1978]	*Maykut and Church* [1973]	*Sugita and Brutsaert* [1993]	*Konzelmann et al.* [1994]	*Crawford and Duchon* [1999]	*Duarte et al.* [2006] Eqn (21)	*Duarte et al.* [2006] Eqn (22)
Lake Washington	Water	380	391	370	358	366	386	401	392	1.027	0.973	0.941	0.962	1.015	1.053	1.030
Lake Apopka	Water	372	384	364	359	360	379	396	386	1.032	0.977	0.964	0.967	1.017	1.065	1.036
Mulberry Marsh	Wetland	369	380	360	355	356	375	392	382	1.030	0.974	0.960	0.963	1.015	1.063	1.035
Ocklawaha Prairie	Wetland	364	381	360	355	356	376	393	383	1.049	0.990	0.976	0.979	1.034	1.081	1.054
Jarboe Park	Urban	363	376	356	351	352	371	388	378	1.035	0.981	0.965	0.970	1.021	1.067	1.040
Deland STP	Urban	370	379	358	351	353	374	391	381	1.026	0.968	0.950	0.954	1.011	1.057	1.030
Bull Creek	Rangeland	368	383	361	356	356	377	395	384	1.041	0.981	0.968	0.970	1.025	1.075	1.046
OrangeCreek	Rangeland	359	378	357	351	353	372	389	380	1.051	0.992	0.977	0.981	1.036	1.083	1.056
Denver Rd	Forest	368	381	359	353	354	375	392	382	1.036	0.976	0.960	0.964	1.020	1.067	1.039
Hastings IFAS1	Agriculture	363	381	361	356	357	375	393	382	1.048	0.993	0.979	0.981	1.032	1.081	1.051
Lindsey Citrus	Agriculture	371	389	367	362	362	382	402	390	1.048	0.988	0.975	0.976	1.030	1.083	1.050
Average		368	382	361	355	357	377	394	384	1.038	0.981	0.965	0.970	1.023	1.070	1.042

			RMSE (Wm^{-2})							R^2 (−)						
Site	Land Use	Measured	*Jacobs* [1978]	*Maykut and Church* [1973]	*Sugita and Brutsaert* [1993]	*Konzelmann et al.* [1994]	*Crawford and Duchon* [1999]	*Duarte et al.* [2006] Eqn (21)	*Duarte et al.* [2006] Eqn (22)	*Jacobs* [1978]	*Maykut and Church* [1973]	*Sugita and Brutsaert* [1993]	*Konzelmann et al.* [1994]	*Crawford and Duchon* [1999]	*Duarte et al.* [2006] Eqn (21)	*Duarte et al.* [2006] Eqn (22)
Lake Washington	Water	380	18.8	20.4	25.7	23.9	13.2	25.8	14.7	0.879	0.863	0.835	0.849	0.890	0.899	0.901
Lake Apopka	Water	372	22.8	22.5	26.5	24.7	17.6	29.4	19.4	0.800	0.796	0.765	0.792	0.825	0.815	0.831
Mulberry Marsh	Wetland	369	16.9	18.1	23.1	21.6	11.5	25.6	15.4	0.902	0.883	0.841	0.865	0.919	0.911	0.922
Ocklawaha Prairie	Wetland	364	19.7	18.4	24.4	21.8	14.0	28.8	18.4	0.900	0.869	0.801	0.844	0.912	0.898	0.908
Jarboe Park	Urban	363	14.5	18.3	25.0	22.3	9.6	22.3	12.1	0.944	0.930	0.877	0.912	0.955	0.949	0.956
Deland STP	Urban	370	23.5	28.3	32.9	31.1	19.3	28.1	19.7	0.800	0.766	0.740	0.766	0.821	0.809	0.823
Bull Creek	Rangeland	368	18.1	16.0	21.7	20.2	12.0	28.4	17.5	0.941	0.911	0.860	0.887	0.950	0.943	0.949
OrangeCreek	Rangeland	359	19.8	15.7	22.3	19.4	13.5	30.0	19.2	0.942	0.911	0.845	0.887	0.955	0.940	0.953
Denver Rd	Forest	368	18.3	21.7	27.4	25.3	13.4	25.1	15.2	0.748	0.723	0.728	0.728	0.760	0.768	0.771
Hastings IFAS1	Agriculture	363	17.9	15.6	20.9	19.4	11.4	27.2	16.0	0.915	0.867	0.806	0.838	0.929	0.922	0.932
Lindsey Citrus	Agriculture	371	19.0	13.8	18.9	17.7	11.6	29.5	17.1	0.935	0.922	0.882	0.903	0.948	0.945	0.949
Average		368	19.0	19.0	24.5	22.5	**13.4**	27.3	16.8	0.882	0.858	0.816	0.843	0.897	0.891	0.900

[a] For all models, R_{ldc} was computed using the *Brunt* [1932] equation. Bold indicates key point numbers discussed in the text.

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