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ARTICLE

Variability of Albedo and Utility of the MODIS Albedo Product in Forested Wetlands

David M. Sumner · Qinglong Wu · Chandra S. Pathak

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Abstract Albedo was monitored over a two-year period (beginning April 2008) at three forested wetland sites in Florida, USA using up- and down-ward facing pyranometers. Water level, above and below land surface, is the primary control on the temporal variability of daily albedo. Relatively low reflectivity of water accounts for the observed reductions in albedo with increased inundation of the forest floor. Enhanced canopy shading of the forest floor was responsible for lower sensitivity of albedo to water level at the most dense forest site. At one site, the most dramatic reduction in daily albedo was observed during the inundation of a highly-reflective, calcareous periphyton-covered land surface. Satellite-based Moderate-Resolution Imaging Spectroradiometer (MODIS) estimates of albedo compare favorably with measured albedo. Use of MODIS albedo values in net radiation computations introduced a root mean squared error of less than 4.7 W/m^2 and a mean, annual bias of less than 2.3 W/m^2 (1.7%). These results suggest that MODIS-estimated albedo values can reliably be used to capture areal and temporal variations in albedo that are important to the surface energy balance.

Keywords Net radiation · Remote sensing · Big Cypress National Preserve

D. M. Sumner (✉)
US Geological Survey,
Orlando, FL, USA
e-mail: dmsumner@usgs.gov

Q. Wu · C. S. Pathak
South Florida Water Management District,
West Palm Beach, FL, USA

Introduction

The albedo of a surface quantifies the fraction of incoming solar radiation that is reflected back to the atmosphere. Albedo is a critical parameter in defining the energy budget of a given landscape and of the Earth as a whole. Variability in albedo can create variability in the non-radiant energy budget fluxes of latent and sensible heat, in the temperature of terrestrial systems, and in the gross primary production of an ecosystem (Coakley 2002; Chen et al. 2004). The mass equivalent of latent heat flux—evapotranspiration—is likewise affected by changes in albedo, which necessarily implies albedo-sensitivity of the other water budget components, including streamflow and infiltration. Uncertainty in quantifying albedo is a challenge to climate and hydrologic models (Henderson-Sellers and Wilson 1983; Pielke et al. 1993; Sellers 1995; Liang et al. 1999; Myhre and Myhre. 2003; Twine et al. 2004).

Wetlands are critical components of many hydrologic and biologic systems. Lafleur (2008) observed the energy budget of wetlands can be important, not only to the local environment, but to regional and global climates, despite the relatively small fraction of Earth that is covered by wetlands. The albedo of wetlands can be particularly difficult to quantify because of temporal and spatial variations in inundation. The (mean daily) albedo of water is lower than that of most other common natural land covers (Brutsaert 1982) and, therefore, the contrast between the reflective qualities of a dry and wet wetland should be substantial. Kim and Verma (1996) noted that the albedo of a fen-type wetland in Minnesota increased as the water table fell below land surface. A further complication to

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albedo estimation of forested wetlands is the degree to which canopy shading dampens the impact of variations in forest floor inundation. Betts and Ball (1997) noted that the impact of a change in the forest floor cover on forest albedo was muted by denser canopy shading.

Satellite-Based Measurement of Albedo

Satellite measurements offer the only practical means to estimate spatial-temporal variations in albedo over large areas. Moderate-Resolution Imaging Spectroradiometer (MODIS) instruments have been borne by the Terra and Aqua satellites since December 1999 and May 2002, respectively (Justice et al. 2002; Salomonson et al. 2006). These NASA satellites are sun-synchronous, nearly-polar orbiting and allow MODIS coverage of the entire Earth over 36 spectral bands (0.4 to 14.4 μm) every one to two days. The Terra satellite crosses the equator at about 10:30 AM (accurate timezone) in a descending orbit, whereas Aqua crosses at about 1:30 PM in an ascending orbit. MODIS shortwave spectral data are processed, archived and distributed by the Earth Resources Observation and Service (EROS) Center of the US Geological Survey (USGS 2010a). MODIS albedo products (Strahler et al. 1999) are developed for full shortwave, visible, and near infrared spectral bands for each of white-sky (diffuse), black-sky (direct beam), and blue-sky (actual) radiation conditions. A composite albedo product (MCD43A3) utilizes cloud-free data from both the Terra and Aqua sensors, providing superior coverage (Salomon et al. 2006). This 500-m resolution global albedo product is based on 16-day composites and is available at 8-day intervals. Satellite sensor measurements made when cloud cover obscures a given location for a given day are excluded and the 16-day albedo is computed using the remaining clear-sky data.

Validation of MODIS Albedo Products

Validation of MODIS albedo products is best achieved with near-surface measurements of incoming and reflected solar radiation. However, spatial hetereogeneity can complicate the comparison between small-scale, near-surface measurements and the coarser MODIS resolution (Liu et al. 2009). Disney et al. (2004) compared the MODIS broadband albedo over an agricultural site with albedo measurements made at a variety of spatial scales ranging from near point measurements (field-based pyranometers and spectroradiometers) to several meters (airborne measurements of spectral reflectance) to 30 m (satellite-borne Landsat sensor) to 1 km (satellite-borne SPOT-VGT sensor) and found general agreement. Jin et al. (2003) performed a comparison of field and MODIS albedo over a period of several months at six stations representing diverse regions of the United States and found agreement that generally met an accuracy of 0.02. Wang et al. (2004) compared field and MODIS albedo measurements over three years in a generally homogeneous semi-arid landscape in the Tibetan Plateau and also found that the MODIS albedo product met an accuracy of 0.02, with no distinctive bias.

Role of Albedo in the Landscape Energy Budget

The impact of uncertainty or a change in albedo on evapotranspiration and sensible heat from a landscape can be examined with the energy budget equation:

$$\underbrace{\mathrm{SW}\downarrow - \alpha\mathrm{SW}\downarrow + \mathrm{LW}\downarrow - \mathrm{LW}\uparrow}_{\text{Net radiation}} = \lambda\mathrm{ET} + \mathrm{H} + \mathrm{G} \tag{1}$$

where SW↓ is incoming shortwave radiation; α is albedo; αSW↓ is reflected shortwave radiation; LW↓ is downwelling longwave radiation emitted from the atmosphere; LW↑ is upwelling longwave radiation emitted from the surface; λET is the latent heat flux—the product of the latent heat of vaporization (λ) and evapotranspiration (ET); H is sensible heat flux from the surface to the atmosphere; and G is the heat flux into the soil/canopy.

Net radiation, defined as the left hand side of (1), accounts for the net radiative balance of a surface, including incoming and outgoing shortwave (0.2–5 μm wavelengths) and longwave (5–30 μm wavelengths) radiative fluxes. Shortwave radiation is of solar origin, whereas longwave radiation is of terrestrial origin. Net radiation is important because it quantifies the energy available for the processes of evapotranspiration, sensible heat flux, and soil/canopy heating. Increasing albedo increases reflected shortwave radiation and, therefore, decreases the net radiation.

Reflected solar radiation generally is the smallest of the four radiative components of net radiation. However, net radiation can be viewed as a difference of incoming and outgoing terms and any mathematical difference can be subject to amplification of uncertainty in any term. Also, although the two longwave radiation terms generally are the largest in magnitude of the four radiative components of net radiation at day or longer scale, the net shortwave radiation (SW↓–αSW↓) is larger and more temporally variable than the net longwave radiation (LW↓–LW↑). So, the magnitude and temporal variability of net radiation is largely determined by the net shortwave radiation, a quantity that is directly related to albedo.

The objectives of this investigation were to (1) describe the variability of albedo of selected forested wetlands in Big Cypress National Preserve, Florida, USA, (2) examine the utility of the MODIS albedo product for application to

forested wetlands, and (3) evaluate the impact of uncertainty in albedo estimation on computed net radiation.

Methods

Measurement Sites

Three sites (Table 1; Fig. 1) within Big Cypress National Preserve (BCNP) in the State of Florida were selected for field monitoring of solar and terrestrial radiation during a two-year period (April 11, 2008–April 10, 2010). Land covers at the three sites are representative of forested settings within BCNP—two bald cypress (*Taxodium distichum)* sites and a site consisting of slash pine (*Pinus elliottii)* forest with interspersed bald cypress domes. The deeper limestone bedrock and thicker soil at the "tall" bald cypress site allows for greater density and tree stature (about 20 m) compared to the shorter (less than 8 m height), sparser trees at the "dwarf" bald cypress site in an area of shallow bedrock and thin soil. The tall and dwarf cypress exist as laterally extensive land covers. In contrast, the cypress occurring within the pine matrix are discrete "domes," often circular features, averaging 100 m in diameter, with deeper soils and taller trees near the center of the dome. The radiometer at the pine/cypress site was placed in an area of locally extensive pine coverage (approximate 150 m radius), although the surrounding area is about 30% cypress. The pine forests are in slightly elevated areas and have a shorter period of inundation than do the wetter cypress forests. Forest canopy shading of the understory is lowest at the dwarf cypress site and greatest at the tall cypress site, with the pine site showing intermediate shading.

Instrumentation

Field-scale albedo measurements were obtained with radiometers (Kipp and Zonen, Inc.—Model CNR1) deployed on telecommunications-type towers extending above the trees at each forested site (Table 1). The CNR1 radiometer consists of an upward-facing pyranometer/pyrgeometer pair of sensors to measure incoming shortwave and longwave radiation, respectively, and a downward-facing pair of similar sensors to measure reflected/emitted radiation. The pyranometers have a spectral range (0.3 to 3 μm) targeting the solar/shortwave radiation band; the pyrgeometers have a spectral range (5 to 50 μm) targeting the far infrared/longwave radiation band. The CNR1 heater was operated continuously to quickly remove water from the sensor surfaces. The sensors were continuously monitored with Campbell Scientific, Inc. CR10X dataloggers at 60-s intervals and the 30-min averages were recorded. Daily albedo was computed as mean daily reflected shortwave radiation divided by mean daily incoming shortwave radiation. Water levels at each site also were monitored at 30-minute intervals using pressure transducers placed in shallow wells. Missing water level data were estimated using regression relations between water levels at the site of interest and nearby water level measurements, or omitted, if suitable relations were not apparent. The shallow limestone at the three sites limited the depth of the wells below land surface to a few tens of centimeters or less; at "dry" times when the water table fell below the bottom of a well, the water level was known only to be deeper than the well depth.

Moderate-Resolution Imaging Spectroradiometer (MODIS) Data

Remotely-sensed estimates of albedo at field-measurement locations were based on the combined (Terra and Aqua) MCD43A MODIS product web-delivered by the Oak Ridge National Laboratory (ORNL DAAC 2010). The MODIS albedo data used in this study assumed a local solar noon zenith angle and an aerosol optical depth of 0.2. The former assumption is a convenient standard and diurnal variations in albedo generally are subdued near noon, allowing for a more stable estimate. The MODIS full shortwave (0.3 to 5.0 μm), blue-sky albedo was used as the standard for comparison with the field-measured estimates. However, MODIS albedo values also are available within the visible (0.3 to 0.7 μm) and near infrared (0.7 to 5.0 μm) components of shortwave radiation and the blue-sky varieties of these values were also retrieved to aid in a

Table 1 Characteristics of monitoring stations in Big Cypress National Preserve

Forest type	Understory	Latitude	Longitude	Canopy height (m)	Radiometer height (m)
Tall cypress	Mixed grasses, ferns, forbs and shrubs in long duration standing water	25° 49′ 20″	−81° 06′ 06″	18	29
Dwarf cypress	Sawgrass, mixed grasses and periphyton in long duration standing water	25° 45′ 45″	−80° 53′ 36″	6	18
Pine/cypress	Pine: palmetto, mixed grasses, sedges and forbs in short duration standing water Cypress: grasses, forbs and shrubs in long duration standing water	26° 00′ 01″	−80° 55′ 34″	18	26

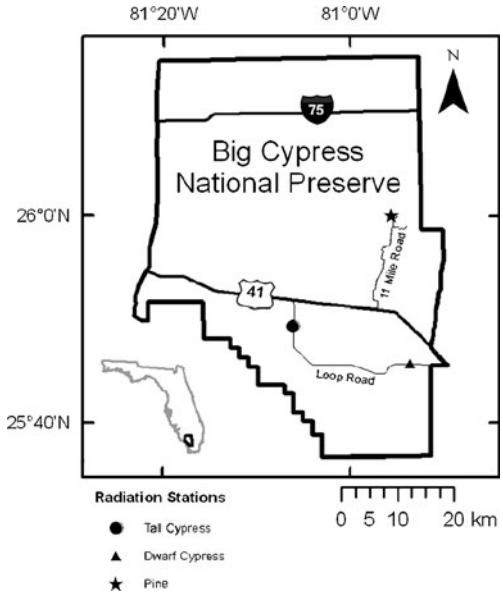

Fig. 1 Location of radiation stations in Big Cypress National Preserve

wavelength-specific understanding of albedo variability. The middle eight days of each 16-day MODIS composite were used for comparison with each of the associated eight days of field-measured albedo. The land covers within the 500-m MODIS pixels containing the location of the field-measured albedo values were evaluated to ascertain the consistency between the two scales and modes of albedo measurement. About 90% of the source area of a downward-facing radiometer is contained within a radius equal to three times the measurement height, indicating that the field-measured source area is less than 100 m in radius at all sites. Favorable consistency between the spatial scales of the MODIS (500 m) and field (less than 100 m) measurements was noted at the tall and dwarf cypress locations. However, at the pine/cypress location, the field-scale measurement of albedo is based on a source area that is largely pine, whereas the MODIS-scale pixel contains both pine forests (70%) and cypress domes (30%).

Field and MODIS Comparisons

Field-measured (daily) and MODIS-derived albedo (central eight days of 16-day compositing intervals) values were compared directly. Additionally, indirect comparisons were made through an evaluation of the error introduced into net radiation computed using MODIS estimates of albedo. Field-measured net radiation was compared with net radiation computed using Eq. 1 and MODIS-estimated albedo (α). Likewise, the utility of a constant albedo assumption in reproducing measured net radiation was evaluated. The assumed constant albedo value (0.149) was that assumed for non-water areas in the Statewide Florida potential evapotranspiration product (Jacobs et al. 2008; USGS 2010b). In both field-measured, MODIS, and constant albedo-based estimates of net radiation, daily incoming solar radiation and longwave radiation were assumed equal to the field-measured values.

Results and Discussion

Field Measurements

The observed hydroperiod at the three sites was consistent with climate patterns for south Florida. The lowest water levels occurred during the dry season (March–May) (Fig. 2). Water levels rose rapidly at the beginning of the wet season (June–September), and declined during the dry season. The hydroperiod at the topographically-elevated pine site was shorter in duration than at the cypress sites (Table 2), which was expected based on the lower tolerance of pine for surface water inundation. The deciduous cypress trees exhibited a phenological pattern of initial leafout in March, full leafout in April, leaves starting to brown in August, leaves fully brown in October, and leaf drop in November.

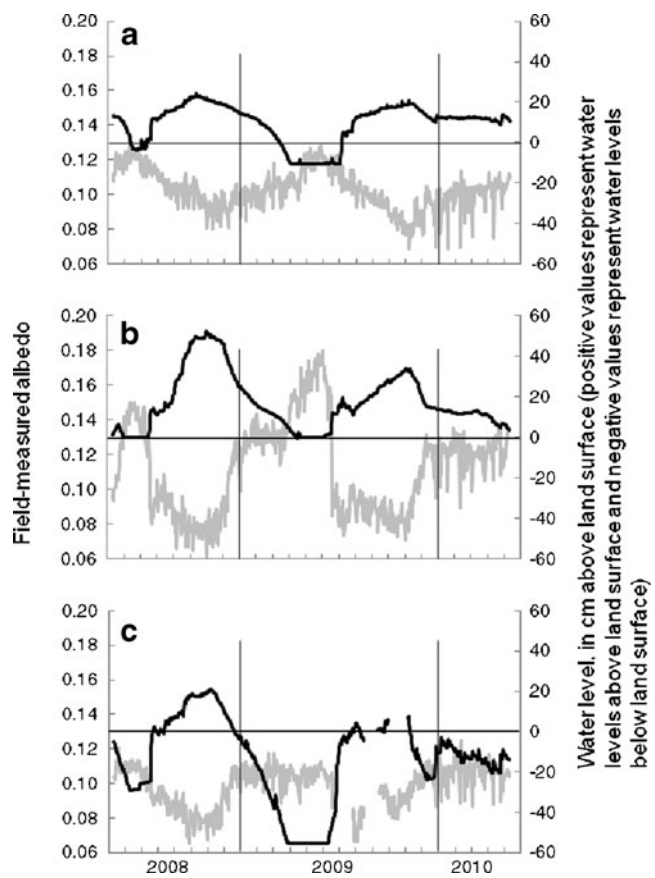

Fig. 2 Measured daily albedo (*grey line*) and water level (*black line*) at **a** tall cypress, **b** dwarf cypress, and **c** pine sites

Table 2 Summary of hydroperiod and maximum inundation for year 1 (April 11, 2008–April 10, 2009) and year 2 (April 11, 2009–April 10, 2010)

	Hydroperiod (days per year inundated)	Maximum inundation (cm) and date
Year 1		
Tall cypress	280	24 September 10
Dwarf cypress	297	52 October 1
Pine	143	21 October 5
Year 2		
Tall cypress	310	21 October 6
Dwarf cypress	341	34 October 3
Pine	98	>8 (missing data) August 30–October 7

The mean values of the measured radiative terms were generally comparable from year-to-year and from site-to-site (Table 3). The tall cypress site received the highest mean net radiation for both years, largely related to a slightly higher flux of downwelling longwave radiation at this site. Net shortwave radiation (averaging 182 to 186 W/m^2) was more than three times net longwave radiation (−47 to−58 W/m^2) and was, therefore, the primary component of net radiation. Net shortwave radiation also explained most of the daily variations in net radiation (r^2>0.87), whereas net longwave radiation had little explanatory value for daily net radiation (r^2<0.04). These results emphasize that an accurate estimate of net radiation depends primarily on quantification of net shortwave radiation and, therefore, of albedo.

Daily albedo showed seasonal variability that was strongly related to water level at all the sites (Fig. 2). Inflection points in albedo trends generally coincided with inflection points in water level trends. Albedo was generally high during low water levels and was low during high water levels. This observation is consistent with Brutsaert (1982, p. 136), who indicated that the albedo of water (0.04–0.08) is lower than most vegetated surfaces (>0.10) and, therefore, that greater surface exposure of water will reduce albedo. Surface exposure of water increases as the land surface is inundated, and will continue to increase with rising water levels in wetlands as vegetation and microtopographic ridges are submerged. Albedo exhibited an approximately piece-wise linear relation with water level that is shown by the measured values and regression-derived relations of Fig. 3. Albedo was relatively constant for water levels below land surface and declined somewhat linearly when water levels were above land surface at mean rates of −0.0011, −0.0014, and −0.0015 cm^{-1} for the tall cypress, dwarf cypress, and pine sites, respectively. The lower sensitivity of albedo at the tall cypress site to water level fluctuations may be related to the higher canopy shading of the forest floor at this densely-forested site; these results are analogous to those of Betts and Ball (1997), who noted greater albedo sensitivity to the presence of forest floor snow cover at more open forests than at less open forests.

The dwarf cypress site showed the largest variation in albedo (from 0.06 to 0.18) because of relatively large albedo values during lower water levels (Figs. 2 and 4). Measured albedo at the other two sites never exceeded 0.13 (Figs. 2 and 4). Albedo differences between the sites were relatively small during inundated periods. The relatively high albedo values noted at the dwarf cypress site during low water conditions are probably related to the presence of high reflectivity calcareous periphyton, an algal complex. As the water level fell below land surface at the dwarf cypress site, the reflective soils and periphyton were exposed, resulting in high albedo. Upon inundation, the

Table 3 Summary of mean values of radiation for year 1 (April 11, 2008–April 10, 2009) and year 2 (April 11, 2009–April 10, 2010); all radiation values given in units of Watts per square meter. Missing 56 days of measurements in year 2 at the pine site were gap-filled with year 1 values

	Incoming solar radiation	Reflected solar radiation	Incoming longwave radiation	Upwelling longwave radiation	Net radiation
Year 1					
Tall cypress	208	22	393	443	136
Dwarf cypress	206	24	382	440	124
Pine/cypress	206	20	389	445	130
Year 2					
Tall cypress	203	21	397	444	135
Dwarf cypress	209	23	386	441	131
Pine/cypress	203	20	393	445	131

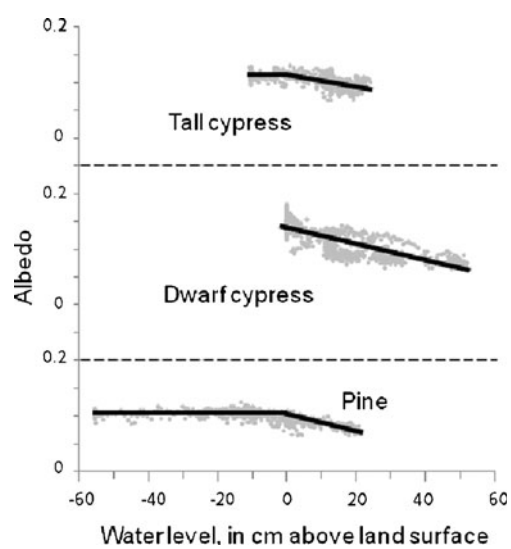

Fig. 3 Measured daily albedo (*grey points*) and regression-derived albedo (*black line*) versus water level

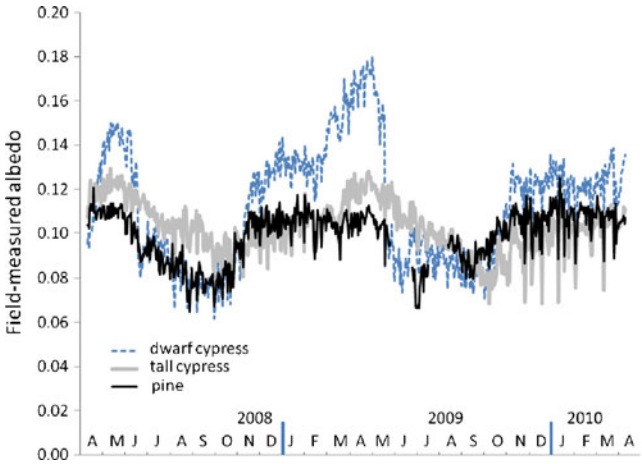

Fig. 4 Measured daily albedo at three radiation monitoring sites

albedo of the dwarf cypress site fell dramatically within a single day (e.g., from 0.15 to 0.09 in May 2009) as the periphyton was covered by water. The pine and tall cypress sites have little periphyton present, perhaps because of the relative dryness of the pine site and the greater canopy shading of the tall cypress site. Single-day reductions in albedo (up to a 0.03 decrease) from the longer-term trend were frequent at all sites; these events appear to be related to rainfall that wets the canopy before evaporating or dripping off.

Albedo did not show a primary relation to the seasonal greening and browning cycles of the understory and cypress trees, to the leaf drop of the cypress trees or to seasonal changes in solar zenith angle. However, albedo at the deciduous tall cypress site was higher than at the evergreen pine site following March/April leafout and until August–November leaf browning/fall (Fig. 4). An apparent hysteresis in the relation between albedo and water level at the dwarf cypress site (Fig. 3) was observed—albedo was higher during water level recession than during water level rise—which may be explained by secondary phenological or solar angle factors. Other secondary factors for albedo may have been present that were masked by the more prominent water level relation. An example of the role of undetermined, secondary factors in controlling albedo

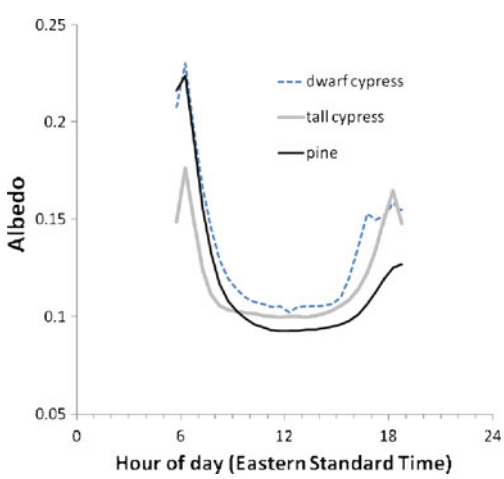

Fig. 5 Mean diurnal pattern of albedo

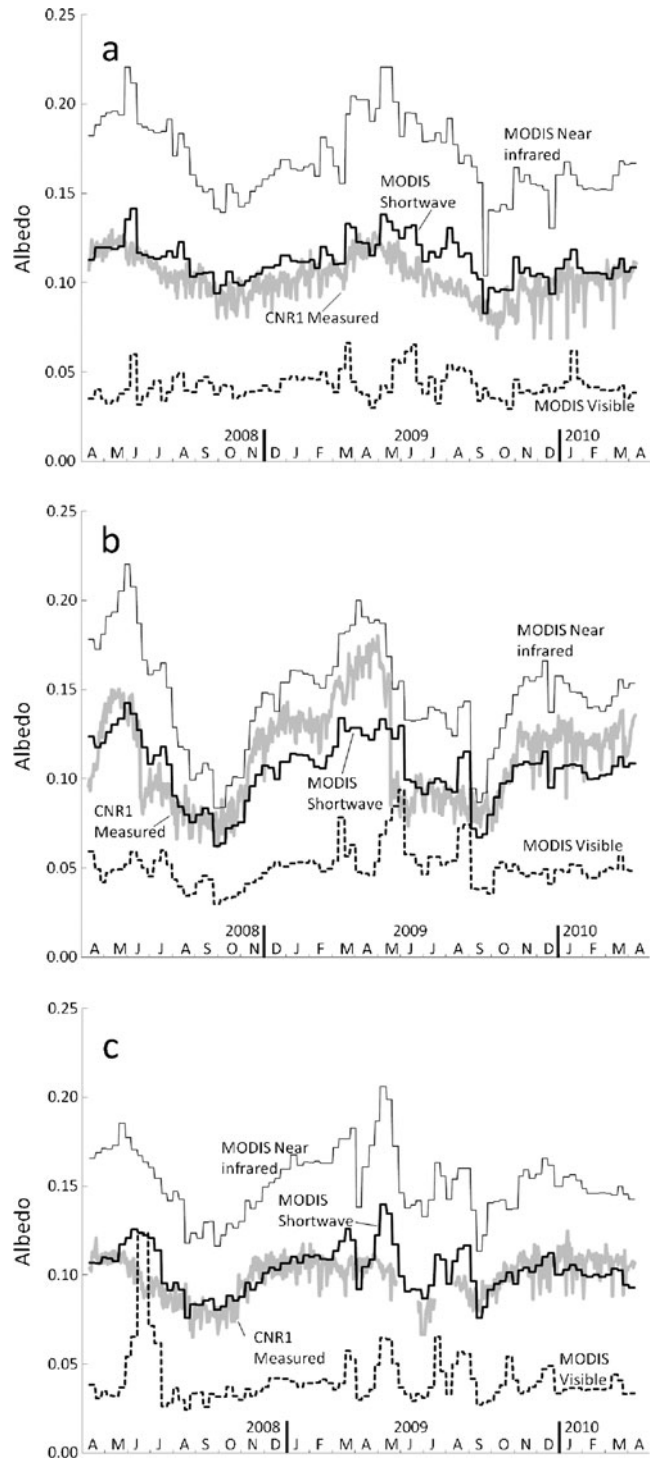

Fig. 6 Field-measured full shortwave albedo and MODIS-estimated full shortwave, near infrared, and visible albedos at **a** tall cypress, **b** dwarf cypress, and **c** pine sites

variations can be seen at the tall cypress site (Fig. 2) in the nearly one-month lag between maximum water level in early-September 2008 and the minimum albedo in early-October 2008. However, water level is the clearly dominant control on albedo at this site during the same period of the following year, when albedo and water inflect on the same day.

The half-hour measurements of incoming and reflected solar radiation allowed examination of the sub-day variability in albedo. The "U-shaped" patterns of mean diurnal albedo were similar at the three sites (Fig. 5). During mid-day hours, when solar zenith angle was relatively low (sun was high), albedo values were low and showed little hour-to-hour variability. Minimum albedo values generally occurred around solar noon; solar noon varies seasonally between about 1205 and 1240 Eastern Standard Time at the sites. During morning and late-afternoon hours, albedo values generally increased sharply with increasing solar zenith angle (lower sun). The resulting U-shaped pattern of diurnal albedo is a commonly-observed effect that is the result of greater photon penetration of the plant canopy at lower solar zenith angle and, therefore, a greater likelihood of absorption of direct beam solar radiation, resulting in a lower albedo (Kimes et al. 1987). Absorption of diffuse (omni-directional) radiation is unaffected by solar zenith angle, generally resulting in a less pronounced U-shaped diurnal albedo pattern during periods when the proportion of diffuse radiation in total solar radiation is relatively high (i.e., during cloudy periods). Asymmetry was apparent in the diurnal albedo pattern with forenoon albedo often higher than afternoon albedo. This commonly-observed asymmetry has been explained at other sites as the result of reflective morning dew, more diffuse solar radiation during often cloudy afternoons, and/by the effect of prevailing wind direction on the canopy structure (Minnis et al. 1997; Song 1998; Liu et al. 2009). The daily albedo (mean reflected solar radiation divided by mean incoming solar radiation) was only slightly greater than solar noon albedo, despite the large variations in diurnal albedo, because of the greater weight associated with high solar intensity, mid-day albedo values. Mean, effective daily albedo was 9.5%, 4.5%, and 6.8% greater than mean solar noon albedo for the dwarf cypress, tall cypress, and pine sites, respectively.

Comparison of Field-Measured and MODIS-Estimated Albedo

Field-measured and MODIS-estimated albedo at the three sites are displayed in Fig. 6 over the two-year period of record. More than 95% of the MODIS data were considered of "Acceptable Quality" as defined by Oak Ridge National Laboratory (ORNL DAAC 2010); the remaining data were gap-filled with linear interpolation of adjacent data. The full shortwave MODIS product showed utility in reproducing the general seasonal trends in field-measured albedo at the three sites. Additionally, the mean bias of the full shortwave MODIS albedo product relative to field-measured values was relatively low, varying from −.008 (−7%) at the dwarf cypress site in year 1 to +0.011 (+11%) at the tall cypress site in year 2 (Table 4). The modest negative bias in MODIS-estimated albedo that was expected by using the MODIS solar noon albedo, rather than daily mean albedo, was not apparent as two of the sites showed a mean positive bias (Table 4). Apparently, the bias introduced with the use of solar noon albedo as an estimate of daily mean albedo is small relative to other underlying biases and discrepancies between MODIS-derived and field-measured albedo. Some of the discrepancies between field-measured and MODIS-estimated albedo are undoubtedly related to the contrast between the smaller, radially-weighted source area of the radiometers and the larger, evenly-weighted source area of the satellite sensor. Examination of the two MODIS-derived

Table 4 Summary of mean values of albedo and net radiation estimation error for year 1 (April 11, 2008–April 10, 2009) and year 2 (April 11, 2009–April 10, 2010); mean albedo values are computed as quotient of mean reflected and incoming radiation values; all net radiation errors are in units of Watts per square meter; missing 56 days of measurements in year 2 at the pine site were gap-filled with year 1 values; Root mean square abbreviated as RMS

	Mean measured albedo	Mean MODIS albedo	Mean net radiation error—MODIS albedo	Mean net radiation error—constant albedo	Daily net radiation RMS error—MODIS albedo	Daily net radiation RMS error—constant albedo
Year 1						
Tall cypress	0.107	0.114	−1.51	−8.73	2.32	9.07
Dwarf cypress	0.115	0.107	1.59	−7.05	4.11	9.49
Pine/cypress	0.098	0.104	−1.17	−10.53	2.57	11.19
Year 2						
Tall cypress	0.102	0.113	−2.28	−9.55	3.27	10.1
Dwarf cypress	0.111	0.104	1.46	−7.85	4.69	10.36
Pine/cypress	0.100	0.104	−0.97	−10.03	3.25	10.80

components of the full shortwave spectrum in Fig. 6 indicates that most of the variability in albedo is related to variability in the near infrared part of the shortwave spectrum, with variations in the visible part of the shortwave spectrum playing a secondary role, a result that is consistent with previous studies (Lafleur 2008).

Impact of Uncertainty in Albedo Estimates on Net Radiation

Net radiation, and not albedo in isolation, ultimately defines the surface energy budget and, therefore, it is useful to examine the sensitivity of computed net radiation to uncertainty in albedo estimates. Use of MODIS-estimated albedo produced relatively little error in computed net radiation (Table 4). The mean error in computed net radiation varied from −2.28 W/m^2 at the tall cypress site in year 2 (1.7% of mean net radiation) to +1.59 W/m^2 at the dwarf cypress site in year 1 (1.3% of mean net radiation) indicating relatively unbiased estimates of net radiation are obtained with MODIS estimates of albedo. Also, daily values of net radiation were estimated with relatively low root mean square (RMS) error; the maximum RMS error (4.69 W/m^2 or 3.6% of mean net radiation) was obtained at the dwarf cypress site in year 2. The coefficient of determination (r^2) between measured and MODIS albedo-estimated values of daily net radiation was greater than 0.99 at all sites.

The application of a very simple albedo estimate (i.e., the constant albedo of 0.149 currently used in the Statewide Florida potential evapotranspiration product) produced relatively large errors in computed net radiation compared to the measured data at the three sites (Table 4). The mean error in computed net radiation varied from −7.05 W/m^2 at the dwarf cypress site in year 1 (5.6% of mean net radiation) to −10.03 W/m^2 at the pine site in year 2 (7.7% of mean net radiation) indicating relatively large, negatively biased estimates of net radiation were computed with the constant albedo assumption. Also, the constant albedo assumption produced RMS errors of daily net radiation that were more than twice those computed using MODIS estimates of albedo.

Conclusions

Water level is a primary control on daily albedo in forested wetlands of south Florida, USA. This result suggests an additional coupling of hydrologic and energy budgets as rising water levels can lead to greater net solar energy input to these forested wetlands. The utility of the MODIS albedo product to replicate measured albedo values and, perhaps more importantly, to produce unbiased estimates of computed net radiation with low error could prove extremely valuable to improved estimates of energy fluxes and potential evapotranspiration.

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