Land surface shortwave radiation budget estimation from AVIRIS data

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ABSTRACT

Hyperspectral remote sensing data offer unique advantages in characterization of land surface and atmosphere in the spectral domain. Unlike existing multi-spectral sensors, hyperspectral sensor provides information with much finer spectral resolution, giving us a chance to improve the quantification of surface shortwave radiation budget, which may otherwise suffered from reduced accuracy of atmospheric and surface component retrievals. In this study, we proposed a method to estimate surface shortwave radiation budget from the Airborne Visible Infrared Imaging Spectrometer (AVIRIS) data. Surface albedo and downward radiation were estimated separately and then converted to net shortwave radiation. Preliminary evaluation on the proposed method that was made using AmeriFlux ground measurements showed that our albedo estimates have a bias of -0.003 with a root mean square error (RMSE) of 0.027 and the net radiation estimates have a bias of 5.559 Wm^{-2} with an RMSE of 32.461 Wm^{-2}. Further improvements will focus on cloud/shadow detection. More validations will be made using other remote sensing data sets.

INTRODUCTION

The energy exchange between the land surface and the atmosphere is a vital component of the climate system. The energy budget components at the land surface (Fig. 1) play significant roles in driving various kinds of land processes, e.g., snow melting, photosynthesis, respiration, ET, and so on. On the other hand, the land system also responds to the climate variability (i.e. drought and extreme heat) through the exchange of energy, matter and momentum.

In the past decade, only a few researchers have used hyperspectral remote sensing data to estimate surface broadband albedo (e.g., Painter et al. 2003; Roberts et al. 2004), let alone the net shortwave radiation. However, in these approaches, the atmospheric components must be pre-measured to obtain the surface reflectance.

In this study, we developed some algorithms to estimate the surface shortwave albedo and net radiation from AVIRIS data to help improve our understanding of radiation budget under changing climate.

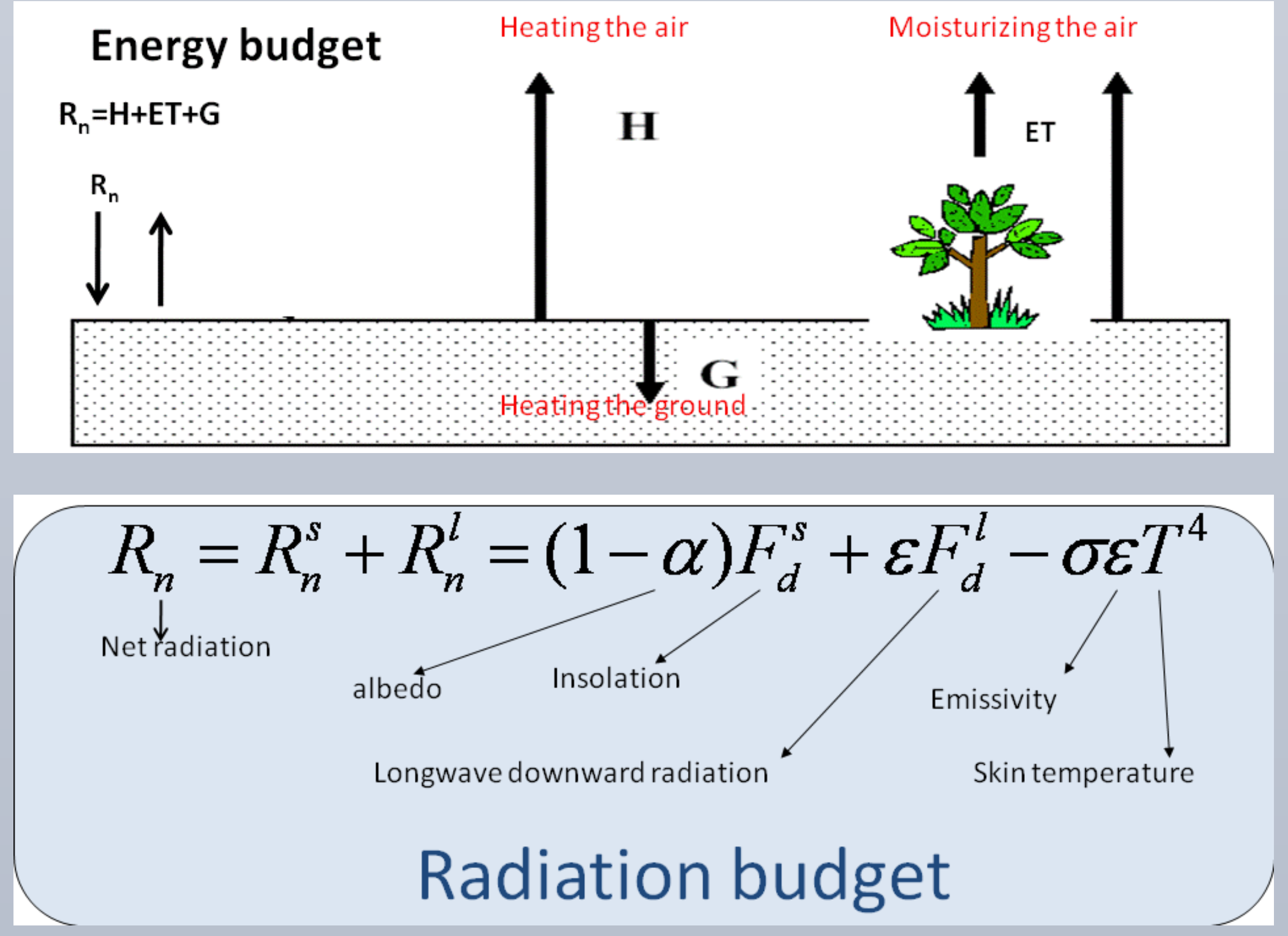


Fig 1. Surface energy budget components.

DATA AND METHODOLOGY

In this study we used a refined direct estimation method (He et al. 2013a) that links AVIRIS top-of-atmosphere (TOA) narrowband reflectance with land surface broadband albedo directly based on a database created from extensive radiative transfer simulations. The direct estimation method doesn't require surface reflectance that is resulted from atmospheric correction (Liang et al. 1999). The direct estimation algorithm has been improved later and applied on different satellite sensors (Liang 2003; Liang et al. 2005; Qu et al. 2013; Wang et al. 2013a).

Although the direct estimation algorithm has been widely used, it has not been used for hyperspectral data. The nature of the direct albedo estimation algorithm is such that it relies on the data from extensive radiative transfer simulations under different geometries and atmospheric conditions, to overcome the lack of pre-measured atmospheric components needed for atmospheric correction. As the direct estimation algorithm is based heavily on spectral signatures, hyperspectral data would be better than multispectral data to examine its performance in albedo estimation, without using angular signatures.

We applied two methods to estimate surface net shortwave radiation. The first one is based on the similar procedure to the albedo direct estimation except linking the TOA narrowband radiance to surface net radiation (Wang et al. 2013b). The second method is to estimate surface downward radiation (Zhang et al. 2013) and then calculate net radiation using our surface albedo estimates (He et al. 2013a).

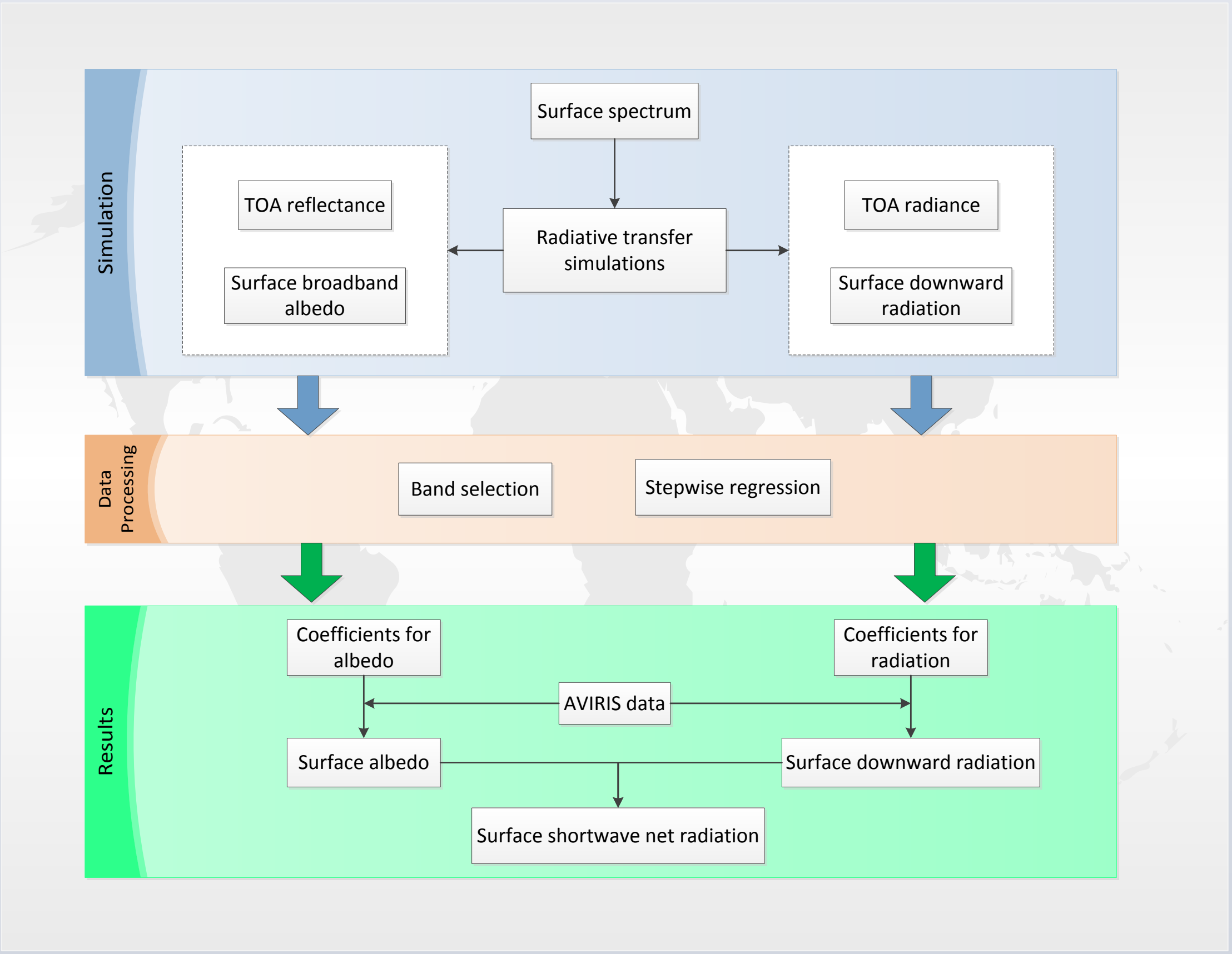


Fig 2. Direct estimation of surface albedo and net shortwave radiation.

Table 1. AVIRIS flights over AmeriFlux sites during 2007–2011 with valid ground shortwave albedo measurements

Site	Lat/Lon	IGBP	Flight No.	Year	DOY	UTC	Pixel size
US-Var	38.407, -120.951	GRA	f070805t01p00r05	2007	217	18:59	3.2
			f070805t01p00r07	2007	217	19:25	3.2
US-NR1	40.033, -105.546	ENF	f100825t01p00r07	2010	237	18:11	13.9
			f110807t01p00r06	2011	219	16:42	8.9
			f110807t01p00r10	2011	219	17:30	9.3
			f110807t01p00r18	2011	219	18:53	9
US-Skr	25.365, -81.078	EBF	f100523t01p00r12	2010	143	15:30	17
US-UMB	45.560, -84.714	DBF	f090704t01p00r10	2009	185	17:28	16.9
			f110814t01p00r12	2011	226	18:17	16.8
			f110816t01p00r13	2011	228	17:05	16.7
US-Ne1	41.165, -96.477	CRO	f080713t01p00r09	2008	195	17:16	16.9
			f080713t01p00r10	2008	195	17:27	16.9
US-Ne3	41.180, -96.440	CRO	f080713t01p00r09	2008	195	17:16	16.9
			f080713t01p00r10	2008	195	17:27	16.9
US-ChR	35.931, -84.332	DBF	f090724t01p00r06	2009	205	15:19	4.6
US-Los	46.083, -89.979	CSH	f080709t01p00r10	2008	191	17:09	16.8
			f080714t01p00r06	2008	196	17:03	16.8
US-CaV	39.063, -79.421	GRA	f090706t01p00r12	2009	187	16:06	15.9
US-UMd	45.563, -84.698	DBF	f090704t01p00r10	2009	185	17:28	16.9
			f110814t01p00r12	2011	226	18:17	16.8
			f110816t01p00r13	2011	228	17:05	16.7

RESULTS

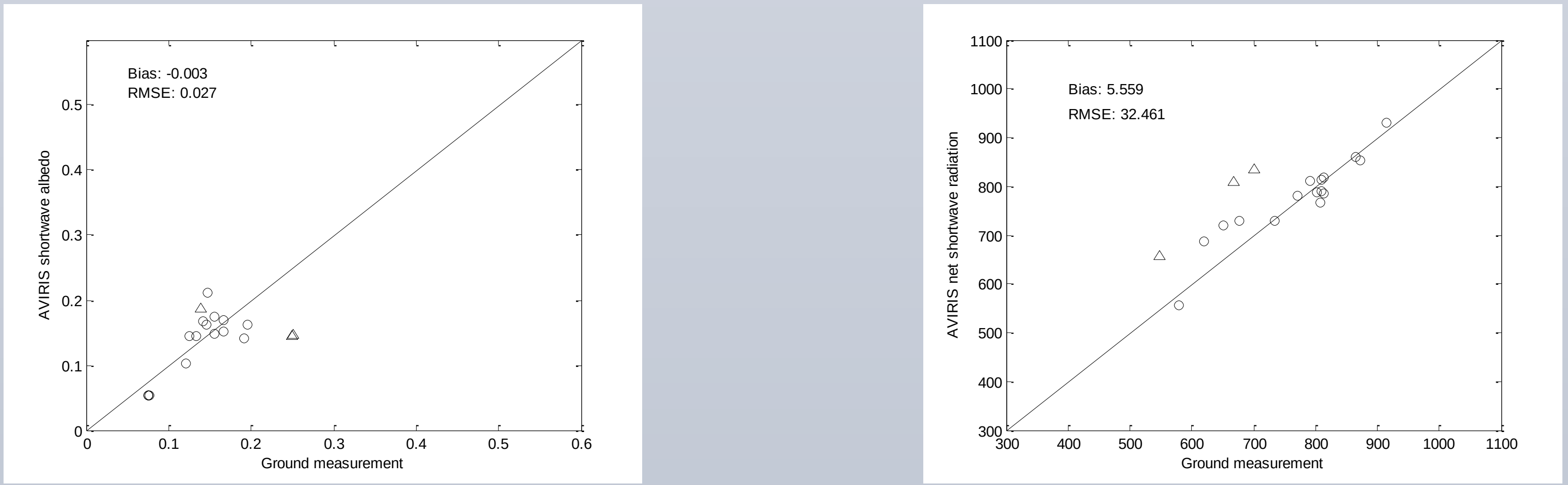
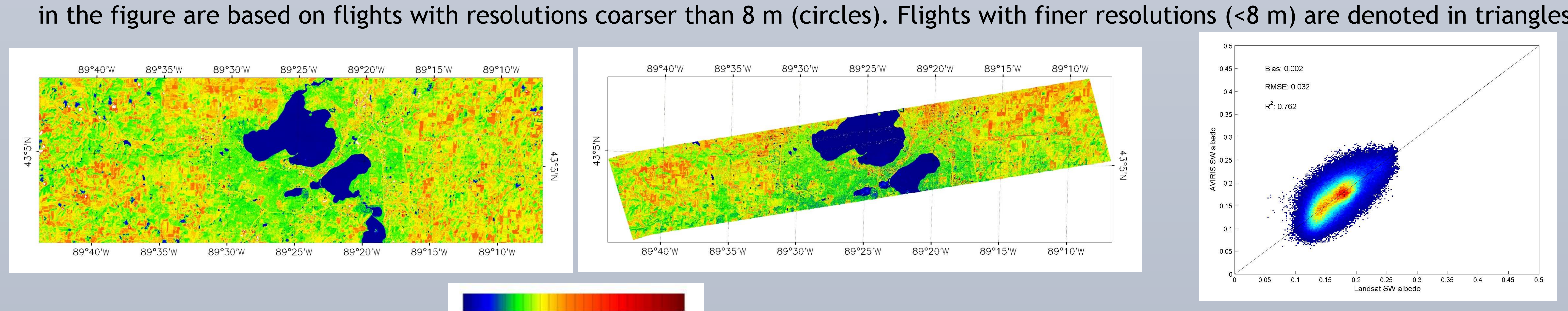


Fig 3. Comparison of ground measurements AVIRIS shortwave albedo and net radiation estimates at AmeriFlux sites (Table 1). Statistics shown in the figure are based on flights with resolutions coarser than 8 m (circles). Flights with finer resolutions (<8 m) are denoted in triangles.



(a) (b) (c)

Fig 4. Shortwave albedo estimations from: (a) Landsat TM (He et al. 2013b) on Aug 18th, 2010; (b) AVIRIS on Aug 26th; and (c) scatter plots of albedo estimations . Image is centered at 43.08°N, 89.41°W in Madison, WI, USA.

CONCLUSIONS

Estimation of surface shortwave radiation budget has seldom been attempted in previous research using data of either high spatial resolution or high spectral resolution. In this study, we proposed a refined direct estimation approach to estimate shortwave albedo and net radiation from AVIRIS data. Preliminary validation results based on ground measurements and Landsat data have shown that our algorithms were robust over various atmospheric and geometric conditions.

Direct comparison with ground measurements has been widely used to assess the medium/coarse resolution satellite albedo products; however, significant differences in scale were found. High spatial resolution albedo estimates can help bridge this gap. In addition, the AVIRIS-based albedo and net radiation estimates in this study can be very useful in urban environmental, ecological, and agricultural applications, which usually require surface energy balance components with a high spatial resolution.

The principle outcome of this study is that our algorithm can be refined and applied on future HyspIRI missions, thereby providing accurate surface radiation budget estimations on a global basis. Further study is needed, including the implementation of our algorithm on satellite hyperspectral data, and algorithm validation and refinement over bright surfaces, including snow and desert.

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