J4.6 A NEW APPROACH TO MONITOR NET SURFACE SOLAR RADIATION FROM GEOSTATIONARY SATELLITES

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1. INTRODUCTION

The net surface radiation controls the energy and water exchanges between the biosphere and the atmosphere, and has major influences on the Earth's weather and climate. Therefore, the ability to better monitor each of the shortwave and long wave radiative components at the surface is essential to better understand existing feedbacks between the surface energy and hydrological cycles, and to better assess future effects of climate change. The Earth's surface net shortwave (SW) radiation, i.e. the difference between the incoming and outgoing SW radiation, represents the amount of solar radiation absorbed by the surface and can be obtained from satellite observations.
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During the last few decades, various statistical (Tarpley 1979) and physically-based methods (Diak and Gautier 1983; Pinker et al 1992; Otkin et al 2005 to name just a few) have been developed to estimate surface insolation from satellite data. Detailed reviews of various approaches have been given by (Schmetz 1989 and Pinker et al 1995). Li et al (1993) employed detailed radiative transfer calculations to derive a relationship between the top of atmosphere (TOA) SW radiation and the solar flux absorbed by the surface depending on solar zenith angle and the column water vapor amount. An extension of the Li et al (1993) scheme developed later (Masuda et al 1995) is an operational component of the NASA Clouds and Earth's Radiant Energy System (CERES) processing sub-system 4.6.

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The paper presents a methodology to derive the net surface radiation in the SW domain at high temporal and spatial resolution using visible imagery from Geostationary Operational Environmental Satellite (GOES). The retrieval algorithm represents an adaptation to GOES data of the standard algorithm initially developed for CERES data (Masuda et al 1995). First we have developed a scheme to relate the GOES narrowband measurements with the broadband radiative fluxes measured by CERES, followed by application of the standard CERES TOA-to-surface parameterization to obtain the net surface flux. The performance of the algorithm is evaluated using ground-based measurements from NOAA's Surface Radiation (SURFRAD) observation network. The relative performance of the CERES SW models with the present GOES-based results have been compared with ground measurements.

2. DATA DESCRIPTION

The methodology is based on multi-sensor measurements made by the visible imager onboard GOES-10 and by the CERES instrument onboard the Earth Observing System (EOS) Terra and Aqua satellites. The algorithm uses visible imagery in the 0.55-0.75 μm spectral domain measured by GOES-10 at hourly intervals and full native spatial resolution (1 km at nadir), and instantaneous measurements of TOA SW radiation available from the CERES Single Satellite Footprint (SSF) data (Edition 3A). The net surface radiation products from the CERES are used in the validation part.

The column water vapor and the aerosol optical depth at 550 nm represent the ancillary data required by the methodology. We have used water vapor and aerosol products derived from the Moderate Resolution Imaging Spectroradiometers (MODIS) on board EOS Terra and Aqua platforms. The standard MODIS column water vapor product (named MOD05_L2) has a spatial resolution of around 5 km. Water vapor products retrieved under clear-sky conditions have been interpolated to correspond to the GOES observation times. The aerosol optical depth level-3 product derived from MODIS have been retrieved from the Giovanni – Interactive Visualization and Analysis tool (http://disc.sci.gsfc.nasa.gov/giovanni), over a 1×1 degree domain surrounding each ground validation site. For three of the selected sites located near Bondville, IL, Boulder, CO, and Desert Rock, NV, we have used additionally, an aerosol optical depth product derived from ground-based measurements.

The field data used for validation consists of ground-based measurements from four different sites of the CERES Atmospheric Radiation Measurement (ARM) Validation Experiment (CAVE, http://www-cave.larc.nasa.gov/cave/) covering winter, spring and summer periods for the year 2003. In addition to radiation data, the CAVE dataset also provides the surface meteorology and aerosol optical depths when available. The selected sites are part of the Surface Radiation (SURFRAD) observation network (Augustine et al 2000; Augustine et al 2005), operated by NOAA. The sites are located near Lamont, OK in the Southern Great Plains (referred as SGP hereafter), Desert Rock, NV (DRA), Table Mountain near Boulder, CO (BOS) and Bondville, IL (BON). These sites represent a variety of surface types and climate conditions: grassland (SGP), agricultural landscape (BON), arid area (DRA) and high elevation grassland (BOS).

3. METHODOLOGY & RESULTS

Matching of CERES field of view with GOES pixels is accomplished according to the criteria: (1) the GOES pixels closest to the center of the CERES footprint are aggregated to a 0.1 degree bin; (2) the time difference between times of observation are within 15 minutes; (3) the difference in viewing zenith angles is less than 10^0; (4) the standard deviation of GOES pixels surrounding the CERES footprint is less than 10 %, and (5) the difference between the maximum and minimum count values in the GOES domain is less than 20 % of the domain mean value.

The regression relationship between the domain-averaged GOES raw counts and observed CERES TOA SW radiative flux is performed for 5 different intervals of the Normalized Difference Vegetation Index (NDVI) to differentiate between the different anisotropic scattering characteristics of the underlying surface. Fig. 1 shows an example for two different NDVI intervals for Feb-Mar 2003. The correlation is seen to be higher than 0.96 between the two products. The GOES-retrieved TOA SW flux can then be employed to estimate the net surface flux through using the parameterization (Masuda et al 1995) known as “Model A” in the CERES sub-system.

The uncertainties associated with net SW radiation budgets thus retrieved from GOES have been evaluated using ground-based measurements collected at four selected sites (shown in Fig. 2 for one site only) during the year 2003. Overall, comparisons between GOES-retrieved and ground-based net surface shortwave radiation yield very good agreement with average bias lower than 5 Wm^{-2} and root mean square difference around 80 W m^{-2} . Time series comparison at Lamont, OK (SGP site) (Fig. 2, top panel) shows very good agreement between ground-based and GOES-derived surface net SW radiation budget. All of the hourly GOES observations that fall within 15 minutes of the measurement have been paired up in the comparison. The bottom panel (Fig. 2) shows a scatter plot of these pairs of values with the error statistics. For GOES-derived products, we have found a negative overall bias of -2.5 W m^{-2}. We observed a larger bias of around +34 W m^{-2} when considering CERES-based products. The observed difference is partly due to two main sources of discrepancies: possible presence of clouds in a coarser CERES pixel, and the effect of the spatial variability of surface net SW radiation within a pixel at coarser resolution due to variations in term of surface types and biophysical parameters.

4. CONCLUSIONS

In this paper, we have presented and evaluated a methodology to derive surface net radiation in the SW domain at 1-hour temporal resolution and 1 km spatial resolution using visible imagery GOES. The retrieval algorithm represents an adaptation to GOES data of a standard algorithm initially developed for the CERES sub-system. The GOES visible imagery has been found to be very well correlated with CERES-retrieved SW TOA radiative flux and matching of the collocated imageries provides the calibration design of the narrow band to broadband relationship. The scheme does not require knowledge of cloud structure or cloud optical properties, but needs additional ancillary input parameters such as the column water vapor amount and the aerosol optical depth at 550 nm. Comparisons between ground-based measurements from NOAA's SURFRAD observation network and GOES-derived surface net SW radiation have shown good agreements. The performance of the algorithm is significantly better over homogeneous landscape in terms of surface albedo and vegetation density. One of the primary advantages of using surface net radiation products from geostationary satellites is the significantly extended spatial and temporal domain of coverage than is offered by the CERES instrument for instance.

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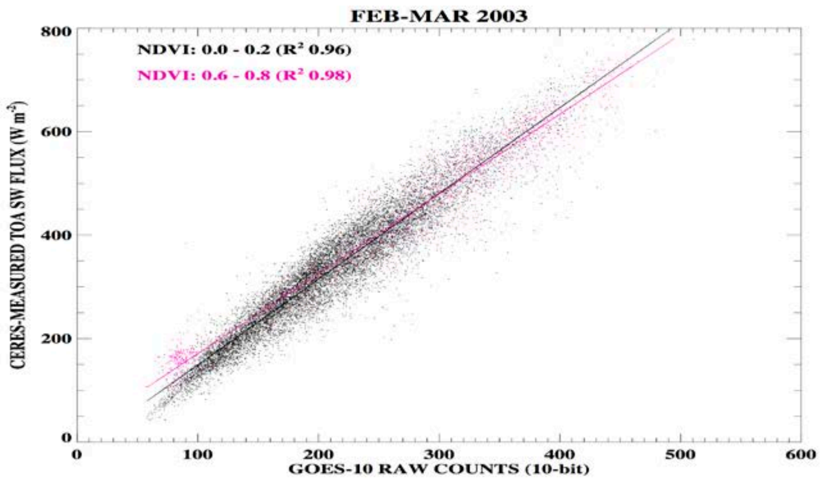

Fig. 1: Matched pairs of GOES-10 raw counts (abscissa) and CERES-measured TOA SW flux for Feb-Mar 2003 for two different NDVI intervals. Correlation coefficient (R^2) obtained between satellite data are represented

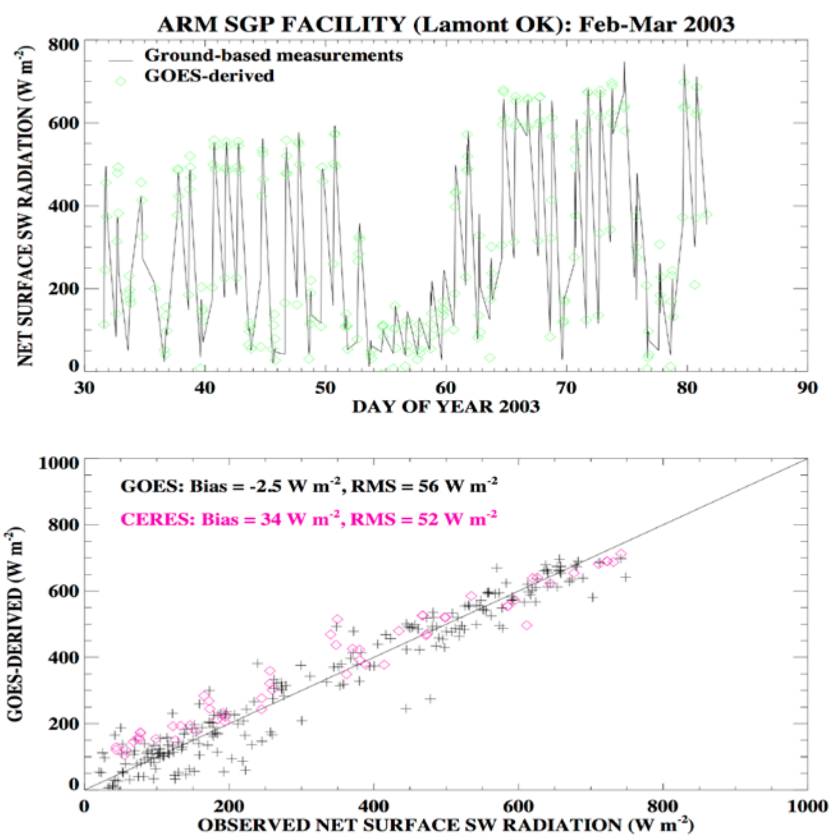

Fig. 2: Top: Time series of net surface SW flux measured at ground (continuous solid line) and those retrieved from GOES-10 (green symbols). Bottom: Scatter plot of matched pairs of observed and modeled values from top panel. Magenta diamond symbols show the comparison with CERES products (Model B in the CERES sub-system).