Toward the Development of Multi-Year Total and Special Solar Radiation Budgets at the Three ARM Locales

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Introduction

Over the past decade, an unprecedented amount of high-quality observational data pertaining to atmospheric and surface parameters has been collected at Atmospheric Radiation Measurement (ARM) locales around the globe. These data have been critical in the development and validation of models used to study the complex interaction of cloud, aerosols, and the surface on the solar radiative budget (SRB), the primary force driving atmospheric circulation. As the next step forward, the challenge of generating total and spectral SRBs of varying spatial and temporal resolutions has arisen with the goal of advancing the parameterization of radiative processes for use in general circulation models. Toward this purpose, we present some examples of multi-year SRBs at the North Slope of Alaska (NSA), Southern Great Plains (SGP), and Tropical Western Pacific (TWP) sites, derived from satellite platforms and instruments (primarily, geostationary operational environmental satellite (GOES) and advanced very high resolution radiometer (AVHRR)) and ancillary data gathered at the ARM sites.

Methodology

The surface total solar radiation budgets at the ARM locales are generated using the algorithm of Li et al. (1993). The correction scheme of Masuda et al. (1995) is also used here to account for the presence of aerosols, ozone column amount, and cloud-top height. Generation of the surface spectral (visible) solar radiation budget (photosynthetically available radiation [PAR]) follows the model of Li and Moreau (1996). Surface albedo over land is estimated from satellite retrievals of top of the atmosphere (TOA) albedo using the model of Li and Garand (1994); over the oceans, the surface albedo parameterization of Briegleb et al. (1986) is utilized.

Inputs to the various models include broadband and narrowband visible TOA albedos retrieved by GOES (resolution of $0.5^o \times 0.5^o$) and cover different periods depending on the ARM site. For the SGP, the period covered ranges from 1997-2002 and for the TWP, the period covered ranges from June-November 1999, the year 2000, and January-May 2001. For the NSA, AVHRR-derived broadband TOA solar fluxes for May-July 1998 are used (resolution of $0.5^o \times 1.5^o$). The National Aeronautics and Space Administration (NASA) Langley ARM team led by Dr. Minnis provides these datasets. Aerosol measurements, when available, are obtained from the Aerosol Robotic Network (AERONET); measurements are taken at the Central Facility (CF) in the SGP, at Nauru in the TWP, and at Barrow in the NSA. Precipitable water amounts are interpolated from National Centers for Environmental Prediction Reanalysis and ozone column amounts are obtained from the total ozone mapping experiment spectrometer (TOMS) (excluding the TWP region).

Surface radiation measurements are used to validate the satellite retrievals and include Solar and Infrared Radiation Station (SIRS) measurements at the CF of the SGP (which include the corrected diffuse component) and upward-pointing radiometer measurements at Manus and Nauru in the TWP and at Barrow in the NSA.

Results

Examples of the spatial distribution of surface insolation are given in Figures 1 (for the SGP domain) and 2 (for the NSA domain) and illustrate the seasonal changes in insolation over these regions. The low resolution of the input TOA parameters over both regions is reflected in the coarseness of the spatial distributions; TOA data of higher resolution from other space-borne sensors would serve to improve details of the distributions and this will be explored. Figure 3 shows the broadband and PAR downwelling surface fluxes over the TWP region and illustrates that there is some correspondence between the spatial distribution of broadband and PAR downwelling surface fluxes. Figures 4 and 5 illustrate the mean daily surface insolation over the NSA domain and the mean monthly net surface radiation over the TWP domain and Manus/Nauru sites, respectively. Over the NSA and as the seasons progress from spring into summer, mean daily surface insolation increases from 65.2 Wm^{-2} to 179.4 Wm^{-2}. Over the time period covered for the TWP domain, mean monthly net surface radiation ranges from about 270 Wm^{-2} to 340 Wm^{-2}. Comparisons of all-sky daily means of downwelling surface fluxes with surface measurements taken at Manus and Nauru are shown in Figure 6. At the Manus site, the mean difference between modelled (using the model of Li et al, 1993) and observed fluxes is -19.2 Wm^{-2}; at Nauru, the mean difference is –29.2 Wm^{-2}. If correction factors for aerosol and cloud-top height are included in the calculations, the mean differences at Manus and Nauru become -27.6 Wm^{-2} and –32.5 Wm^{-2}, respectively. Inclusion of correction factors does not appear to improve the agreement between modelled and observed downwelling surface fluxes at these sites, warranting further study.

Summary

A multitude of surface radiation budget products that may be of use to the GCM modeling community are being generated. These include spatial distributions of total and spectral (visible) surface radiation budgets over the larger ARM domains and inter-annual and annual variations in mean monthly surface radiation.

The spatial distribution of surface insolation over the SGP region for the months of January, April, and September of the year 2002 is shown; use of higher resolution satellite data to generate more detailed surface radiation budgets is being explored. Validation results performed at the central and extended facilities located within the SGP domain show generally good agreement between model and observed downwelling surface fluxes, with mean differences on the order of less than 10%.

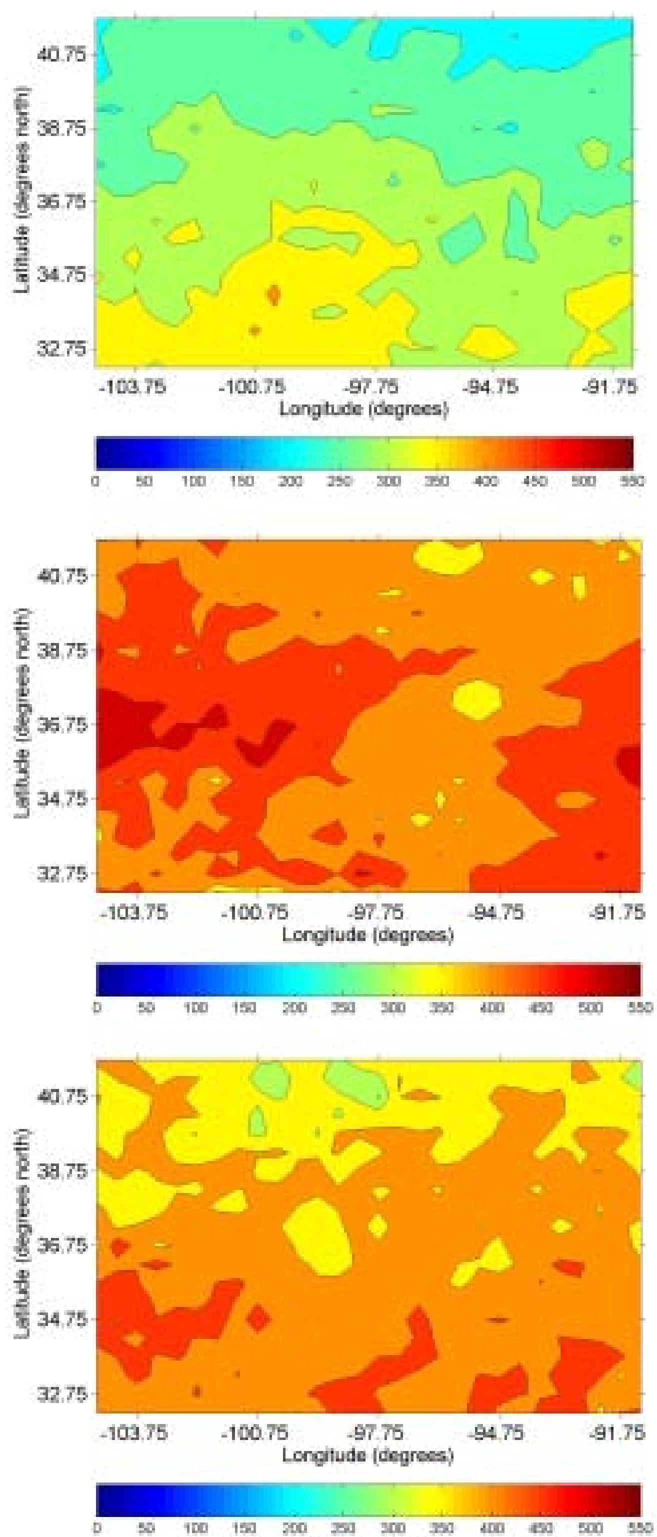

Figure 1. Spatial distribution of surface insolation over the SGP domain for January (top), April (middle), and September (bottom) of year 2002. Units are in Wm^{-2}.

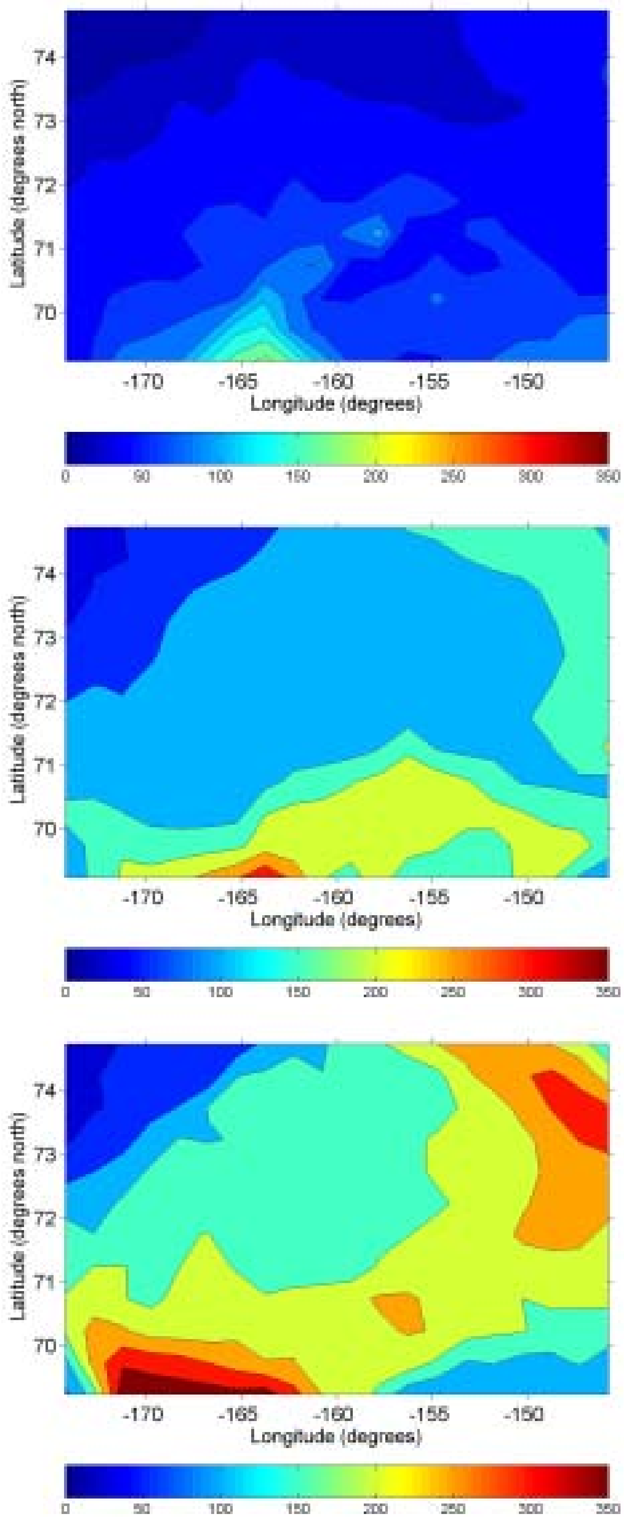

Figure 2. Spatial distribution of surface insolation over the NSA domain for May, June, and July (top to bottom) in year 1998. Units are in W m^{-2}.

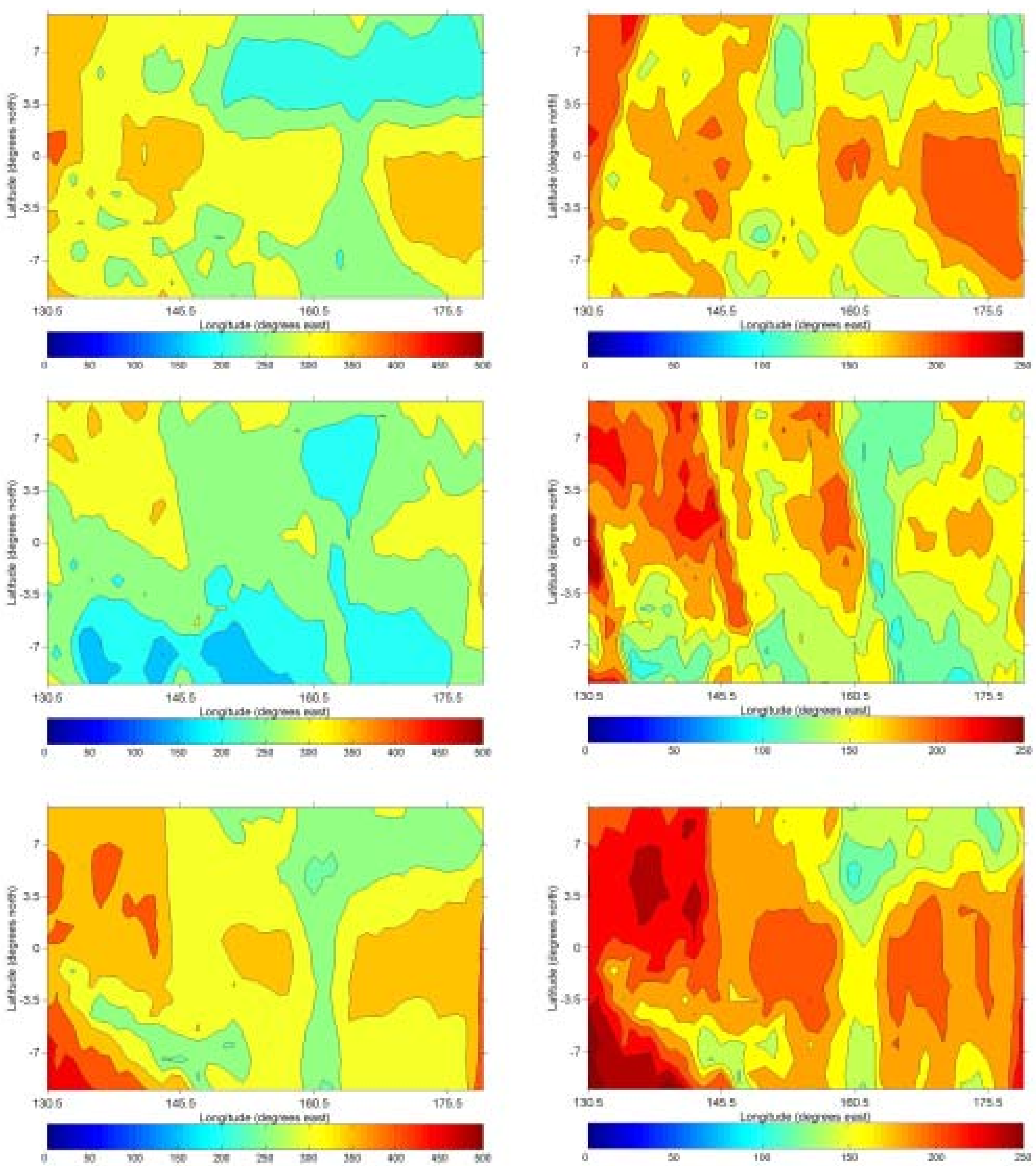

Figure 3. On the left: Spatial distribution of mean downwelling broadband surface solar fluxes over the TWP for the months of (top to bottom) January, June, and September. On the right: Spatial distribution of mean downwelling photosynthetically active radiation (PAR) (0.4 - 0.7 um) over the TWP for the months of (top to bottom) January, June, and September. Units are W m^{-2}.

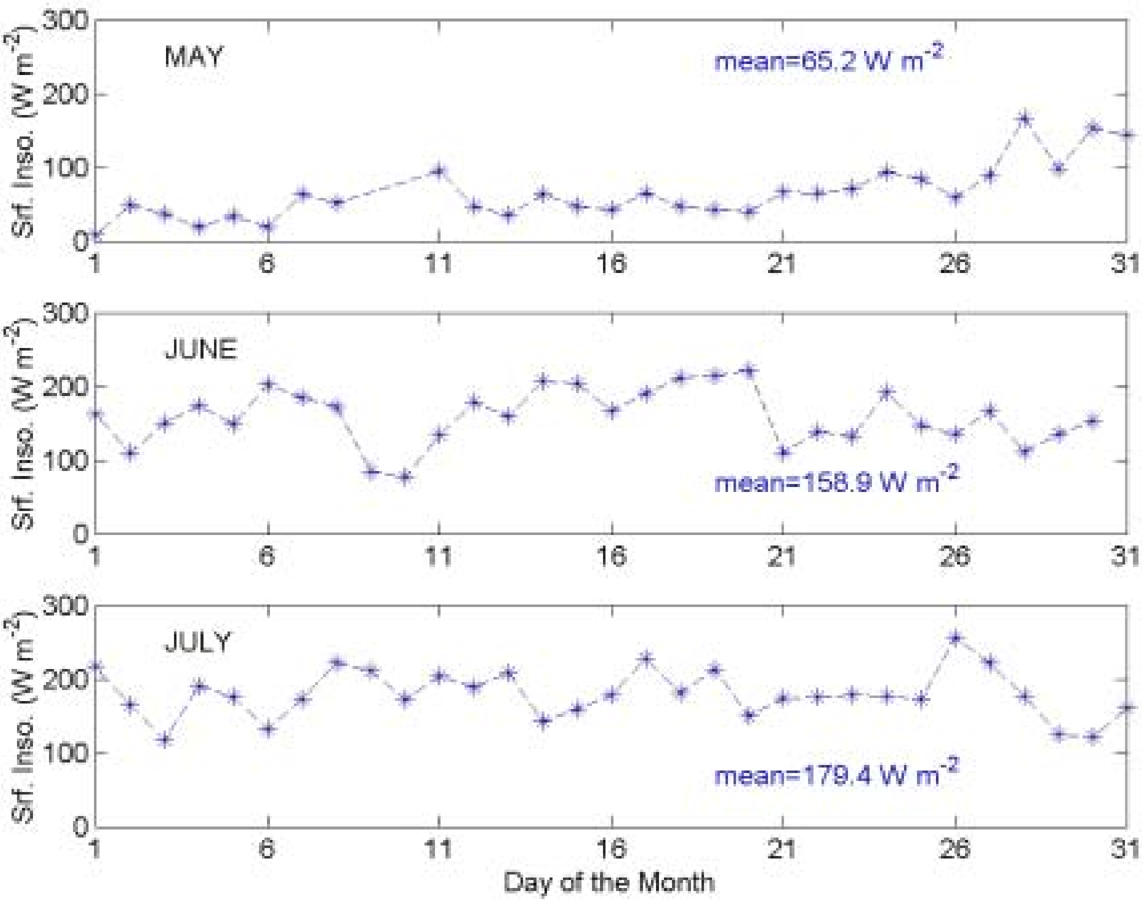

Figure 4. Mean daily surface insolation over the NSA domain for the months of May, June, and July 1998.

In the TWP, validation work at Manus and Nauru illustrate the need for future work to estimate the effectiveness of the correction schemes. The distribution of PAR and total downwelling surface fluxes show some general spatial correspondence, with the magnitude of PAR roughly half that of the total surface radiation budget.

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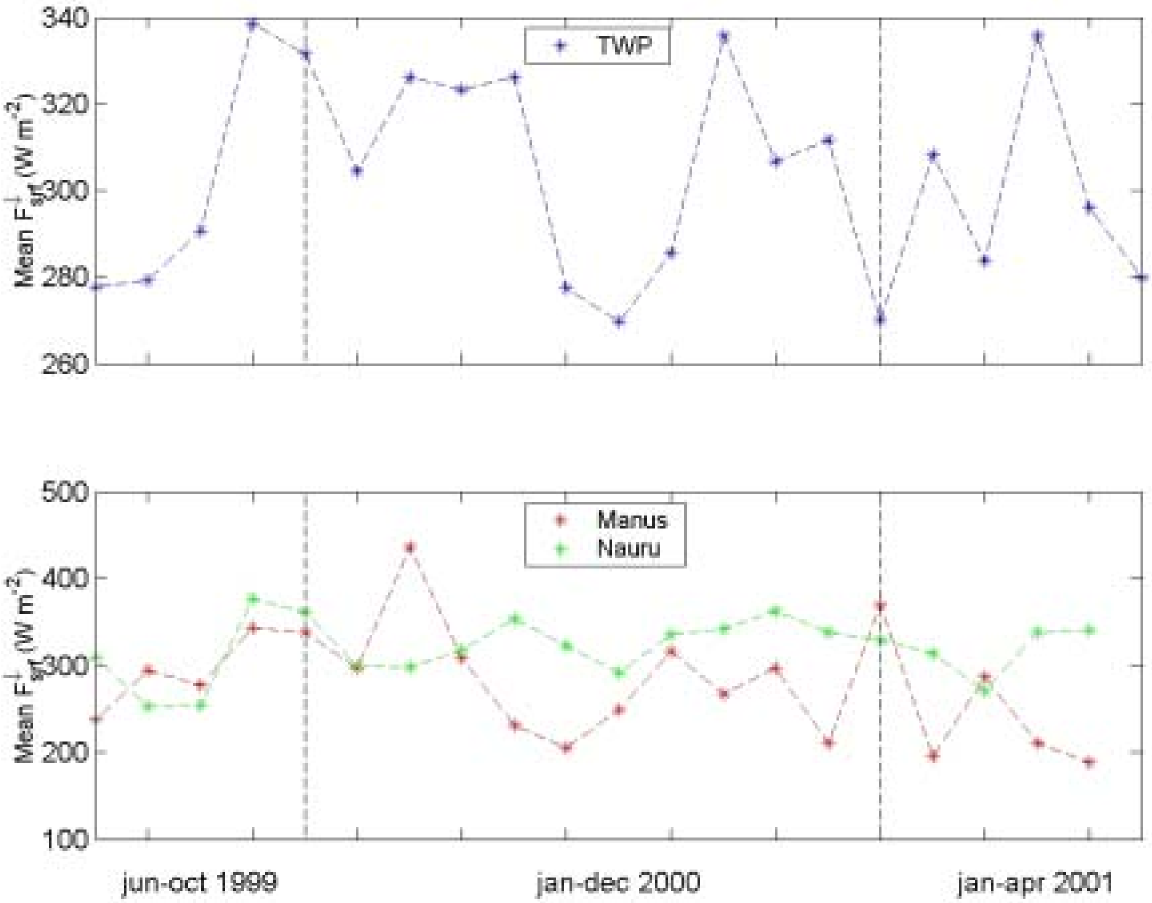

Figure 5. Mean monthly net surface radiation over the TWP domain (top panel) and at the Manus and Nauru sites (bottom panel).

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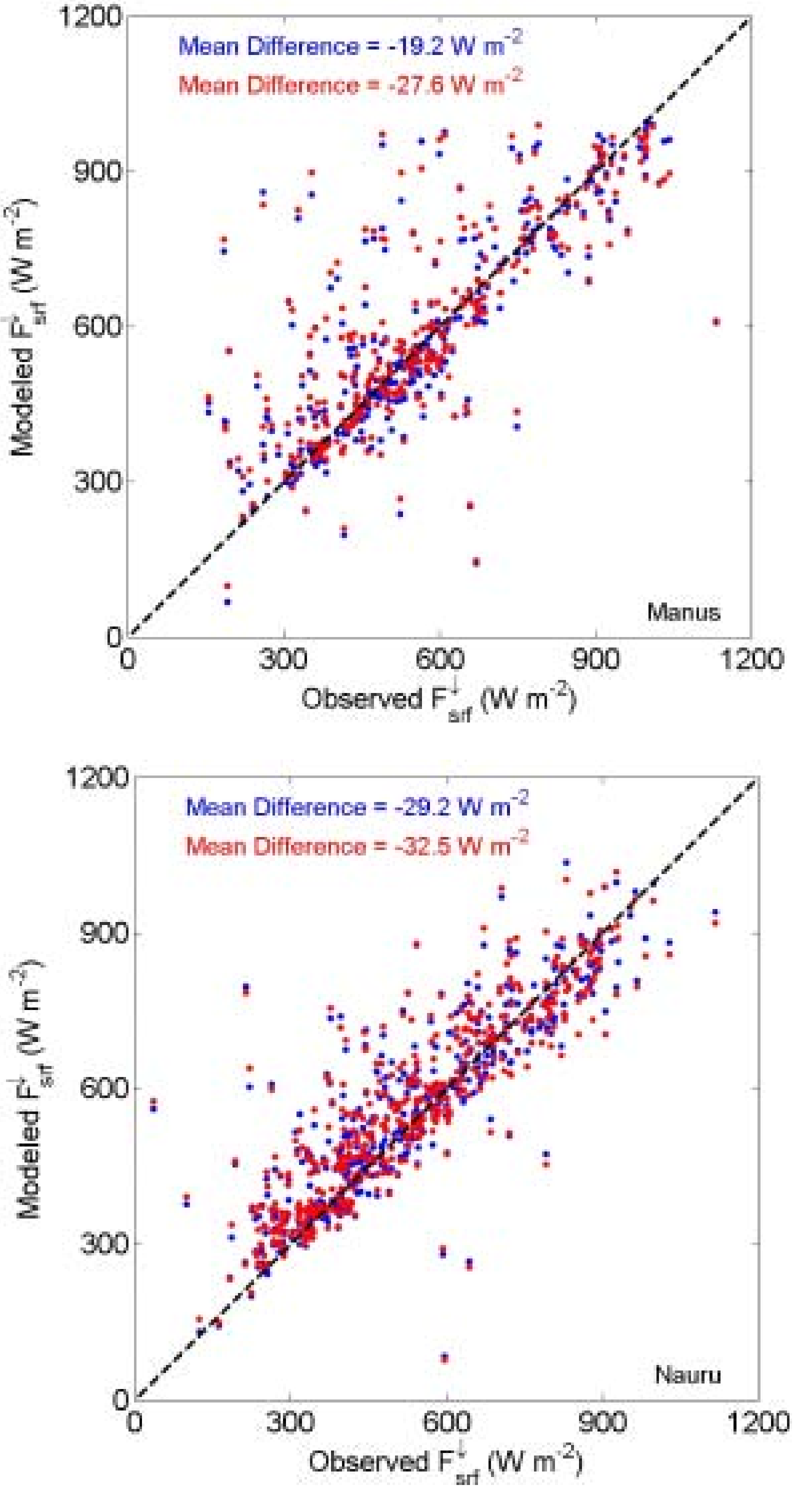

Figure 6. Comparisons of all-sky (cloud top heights <5 km) downwelling surface fluxes (daily means) estimated with the Li et al. (1993) algorithm using GOES data against surface measurements recorded at the Manus and Nauru sites. In blue: basic model - in red: with corrections for aerosol and cloud-top height.