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Paper

A New Simple Model of Direct Spectral Irradiance with Easily Observable Atmospheric Parameters

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Direct irradiance and direct spectral irradiance were measured for 16 months along with other basic atmospheric parameters. The direct irradiance changed smoothly on a clear day and fluctuated on a fair day. Then, we considered the possibility of a new, simple model of direct spectral irradiance expressed with fewer atmospheric parameters and applicable for even fair days. This new model, called DISPEC, can calculate the direct spectral irradiance from basic atmospheric parameters for wavelengths >400 nm. In DISPEC, the ozone absorption was ignored and the thin cloud effect was taken into account as a new parameter, which was considered to be proportional to the direct irradiance, instead of aerosol parameters. The performance of DISPEC was then compared with that of a well-known model of SPCTRAL2. Although the calculation results by SPCTRAL2 exhibited considerable error, especially in visible wavelength range on a fair day, those calculated using DISPEC showed good agreement with observed data on both clear and fair days.

Keywords: direct irradiance, spectral irradiance, model DISPEC, atmospheric parameters

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1. Introduction

A model of spectral irradiance is especially required in a variety of fields such as atmospheric science, architecture, biology, and energy technology (photovoltaic systems, high-performance glazing, solar heating, etc.). Especially, a direct spectral irradiance model is required for calculating the electricity generation of a concentrator photovoltaic (PV) system. Two types of spectral irradiance models may be used to estimate solar radiation at the earth's surface: sophisticated rigorous codes (or radiative transfer codes) and simple transmittance parameterizations [1]. An example of the former kind is the MODerate resolution atmospheric TRANsmission (MODTRAN) [2,3]. This type of model depends on the fact that the atmosphere is composed of different layers, and so observed vertical profiles of gaseous and aerosol constituents are used [4]. Examples of the latter kind are simple models based on Leckner's formulation such as SPCTRAL2 [5] and SMARTS2 [1,6]. Especially, SPCTRAL2, which has been evaluated and applied in many papers [4,7–10] is one of the well-known simple models. However, SPCTRAL2 is available only for a stable, clear atmosphere and still requires many atmospheric parameters to calculate the spectral irradiance as well as other models. Every atmospheric parameter cannot be readily observed. For example, a sun photometer is necessary to observe parameters of aerosol (the Ångstrom turbidity coefficient β and the exponent related to the size distribution of aerosol particles α), and a Dobson spectrometer is necessary to observe the ozone amount. However, many meteorological observation sites do not have such facilities since they are very expensive devices.

In this study, we propose a simple model, called 'DISPEC', of direct spectral irradiance using fewer parameters. DISPEC is able to provide estimated direct spectral irradiance in more sites than conventional models. First, we observed direct spectral irradiance and other weather data such as direct and global irradiance, air temperature, humidity, wind speed, and wind direction in the long term, and analyzed the changes in direct spectral irradiance by time and weather. Next, important atmospheric parameters to calculate the direct spectral irradiance were determined. Finally, direct spectral irradiance calculated by DISPEC was compared with that by SPCTRAL2. In this study, direct irradiance means direct normal irradiance.

2. Observation of Direct Spectral Irradiance Introduction

2.1. Measurement system Direct spectral irradiance was observed at Toyohashi University of Technology (TUT) in Toyohashi City in eastern Aichi Prefecture in central Japan near the Pacific Ocean (34°42′04.33″N, 137°24′41.06″E, 45 m above mean sea level).

Direct spectral irradiance was measured with a spectroradiometer (NIRSystems Co., Ltd., OL-6500) mounted on a sun tracker (EKO Instruments Co., Ltd., STR-02A) every 1 min. The STR-02 had a tracking error of <0.02°. The OL-6500 can observe the wavelength range 0.4–2.5 μm with a resolution of 2 nm in an exposure time of 0.56 s. A photometric standard lamp (tungsten-halogen lamp with a quartz bulb) used for calibration of the OL-6500 was traceable to a standard of the National Metrology Institute of Japan, Advanced Industrial Science and Technology. Its uncertainty was 2.8–6.0%. The optical system of OL-6500 was

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