PRELIMINARY RESULTS OF THE SOLAR RADIATION OBSERVATION AT MID-LATITUDE STATION IN CHINA

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Summary. The article is devoted to the solar radiation observation at mid-latitude station in China. Observations of the solar and terrestrial radiation budget at the Earth's surface are very important for climate change studies and climate modelling.

Keywords: solar radiation, China, the solar radiation observation

The radiative forcing concept allows the quantitative evaluation of changes in Earth's climate system energy balance caused by each atmosphere constituent [1]. Current assessments of radiative forcing of aerosol, ozone and water vapor obtained by different techniques can be found in [1], while global radiative forcing of long-lived greenhouse gases is also annually published by NOAA (http://www.esrl.noaa.gov/gmd/aggi/).

Observations of the solar and terrestrial radiation budget at the Earth's surface are very important for climate change studies and climate modelling. These observations yield a perspective on the influence of various species on the transfer of radiation in the atmosphere. Also, these observations provide basic data for monitoring the Earth's global energy budget and radiation balance [1]. Accurate measurement of radiation balance is fundamental in quantifying the radiative forcing of the Earth's climate system as well as diagnosing the radiative properties of the
atmosphere and surface, which are crucial for understanding radiative feedback processes. At the top of the atmosphere (TOA), satellites provide excellent spatial coverage but poorer temporal sampling, the reverse is true at the surface (at the bottom of the atmosphere – BOA) with only a limited number of high-quality point measurements but with excellent temporal coverage [2, 3]. Ground-based measurements are particularly important for verifications of Global Circulation Models (GCM) results and satellite retrieved data.

Satellite and ground-based observations provide data for analysis of both temporal and spatial variability of atmosphere radiation fluxes at the TOA and at the BOA [4]. The most harmonized ground-based networks for solar radiation measurements are the Solar Radiation Network (SolRad-Net, http://solrad-net.gsfc.nasa.gov/) and the Baseline Surface Radiation Network (BSRN, http://www.bsrn.awi.de/). The BSRN provides near-continuous long-term ground-based broadband irradiances (solar and thermal infrared) and certain related parameters from a network of more than 50 globally distributed sites [5].

The set of instruments for solar radiation measurements has been recently installed (in June, 2023) at the Nanling station (43.85°N, 125.33°E) of Jilin University, Changchun, China, where the microwave radiometer for study ozone and CO profiles are operated since 2020 (Figure 1). One of the instruments for solar radiation measurements is usually a pyranometer that collects a light from the whole hemisphere and accept radiation from both sun and sky obtaining the global solar radiation. To measure the direct radiation the sun we use a pyrheliometer with about 5° view angle that provide accepting the direct sun energy but does not cover the rest of the sky [6]. To make measurements it must point precisely at the sun and this is achieved using an automatic two-axis sun tracker. A shading assembly blocks the direct solar radiation from reaching a pyranometer mounted on the SOLYS2 tracker so that the ‘diffuse’ solar radiation from the sky can be measured [7]. That sun tracking system is installed in Nanling station (Figure 1).

Solar, atmospheric and terrestrial radiation drive almost every dynamic process on the Earth’s surface and above, from ocean current circulation to weather, climate and life itself [2]. Small changes can have large and long-lasting effects that are difficult to predict. Accurate data regarding the radiation at the Earth’s surface is
fundamental to understanding its climate system, global warming and global dimming.

The sun transmits energy outward in the form of optical quantum electromagnetic waves, called solar radiation (irradiance), and the energy transmitted in this process is called solar radiation energy. Several major solar radiation components directly related to solar energy use are global horizontal irradiance (GHI), direct normal irradiance (DNI), diffuse horizontal irradiance (DHI). By definition, irradiance is the power of electromagnetic radiation per unit area (radiative flux) incident on a surface [5]. Radiant emittance or radiant exitance is the power per unit area radiated by a surface in Wm$^{-2}$. Irradiance characterizes the total amount of radiation present, at all waveband of light. Global horizontal irradiance is defined as the total solar radiation received at ground level, including direct radiation and scattered radiation DHI. The factors that affect the total radiation are solar angle, atmospheric transparency, latitude, cloud cover, altitude. The proportion of direct radiation and scattered radiation in the total radiation of different regions is different. In the area with more clouds and rain, the scattered radiation has a greater effect than the direct radiation, and in the dry region the direct radiation prevails.

The amount of solar radiation received per unit area along the normal direction of the sun correspond to the direct normal irradiance DNI. The strength of DNI depends mainly on the solar zenith angle and atmospheric turbidity.

When sunlight passes through the atmosphere and reach the ground, it passes through clouds, gas molecules of the atmosphere, dust, other aerosols, which diffusively scatters the energy that reaches the earth's surface. Its strength also depends mainly on the solar altitude angle and atmospheric extinction. A strong influence on scattered radiation also has clouds and altitude above m.s.l.

The relationship between three radiation parameters is:

$$GHI = DHI + (\cos \theta \times DNI),$$

where $\theta$ – solar zenith angle.

Using the data collected from the Sun tracker at the Nanling station, and analyzing its changing image, we can figure out on clear days, the diurnal variation of total radiation is roughly the same as that of direct solar radiation. During the day, the total solar radiation is of 0 at night, gradually increases after sunrise, reaches the maximum at noon, and decreases in the afternoon. It is worth noting that due to the frequent convective clouds in the afternoon of summer, the maximum occurs before or after noon. Due to the variation of the sun's altitude angle, the direct radiation has a remarkable variation law. In cloudless conditions, the maximum value of direct radiation during the day occurs at noon and decreases as the sun's altitude angle decreases, reaching "0" at sunrise and sunset. Figure 2 shows the preliminary observation results solar irradiance.

It should be noted that sometimes the development of afternoon convection makes the influencing factors change, and then the direct radiation is affected. The variation of scattered radiation mainly depends on the variation of the sun's altitude angle, but also on the variation of cloud cover. The maximum amount of scattered radiation during the day occurs around noon. The maximum value occurs in the summer months and the minimum value occurs in the winter months.
The scattered radiation on both sunny and cloudy days increases with the increase of the sun’s altitude, but the maximum value at noon on cloudy days is more than double that at noon on sunny days. The changes of the cloud cover causes the scattered radiation to exhibit extremely irregular variations.

One of the main tasks of the establishing the set of instruments for solar radiation measurements at Nanling station in Jilin University (JLU) is founding and providing the operation of the research station for the continuous measurements with high accuracy of direct, diffuse and global irradiance in the wide range of spectrum. The station must meet the high standards to execute measurements in accordance with the World Climate Research Program (WCRP) and in the future to be included in the BSRN. That will enable to solve the number of research and applied tasks (such as solar energy stations development in the north China region). The project will assist in development of the Atmospheric Laboratory for research in the field of atmosphere physics and climatology in Jilin University (Changchun, China), equipped with modern equipment at the level of world standards, such as AERONET sites, Dobson or Brewer MK-III spectrophotometer, BTS-Solar spectroradiometer, meteorological station, GPS site, and in future – the BSRN station. The Atmospheric Laboratory in JLU will serve both for scientific researchers and for the training of the specialists in the relevant field of science, as well as for students and post-graduate students practical work. These developments, in particular, will give an opportunity to estimate uncertainty of solar direct, total and diffuse radiation measurements made in this region during last decades and compare the results of observations with those performed by international networks and include our data in the world data archives. Fulfillment of the project will promote researchers of Jilin University for integration to the international scientific community of atmospheric research, ecology, environment and air pollution, climate change studies.

References:


