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CONCEPTUAL PAPER

Utilization of GPS Satellites for Precise Irradiation Measurement and Monitoring

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Abstract. Precise measurement of irradiance over the earth under various circumstances like solar flares, coronal mass ejections, over an 11-year solar cycle, etc. leads to better understanding of Sun–earth relationship. To continuously monitor the irradiance over earth-space regions several satellites at several positions are required. For that continuous and multiple satellite monitoring we can use GPS (Global Positioning System) satellites (like GLONASS, GALILEO, future satellites) installed with irradiance measuring and monitoring instruments. GPS satellite system consists of 24 constellations of satellites. Therefore usage of all the satellites leads to 24 measurements of irradiance at the top of the atmosphere (or 12 measurements of those satellites which are pointing towards the Sun) at an instant. Therefore in one day, numerous irradiance observations can be obtained for the whole globe, which will be very helpful for several applications like Albedo calculation, Earth Radiation Budget calculation, monitoring of near earth-space atmosphere, etc. Moreover, measuring irradiance both in ground (using ground instruments) and in space at the same instant of time over a same place, leads to numerous advantages. That is, for a single position we obtain irradiance at the top of the atmosphere, irradiance at ground and the difference in irradiance from over top of the atmosphere to the ground. Measurement of irradiance over the atmosphere and in ground at a precise location gives more fine details about the solar irradiance influence over the earth, path loss and interaction of irradiance with the atmosphere.

Key words. Albedo—global positioning system—solar irradiation.

1. Introduction

Solar irradiance is the driving factor behind the earth's life cycle. Any small change in solar irradiance will have a straight forward effect on the earth. Measuring and monitoring the precise irradiation will lead to a better understanding of the Sun–earth relationship. The irradiation variation over earth surface and on top of the atmosphere is very small. But that very small change will play a crucial role in the earth's radiation budget and also affect the earth climate. The well-known reason for the irradiation variation is that the Sun is not a constant source of radiator. The Sun keeps on changing throughout its lifetime and these variations are due to solar flares, coronal mass ejections, solar cycle variations, etc. Until now the irradiance measurements are made at several places and these are inter or extrapolated to obtain the global irradiance over earth and on the surface. To obtain the precise irradiation value over the earth irradiation is to be monitored over the top of the atmosphere and at the earth's surface simultaneously. The reason to monitor the irradiation over top of atmosphere and on the surface of the earth at the same point is to enable monitoring the irradiation loss during the atmosphere transmission and also to understand small changes in the irradiation.

2. GPS

Global Positioning System is a constellation of 24 satellites which orbit at an altitude of 20,200 km above the earth's surface in an inclined elliptical orbit. GPS provides very precise latitude and longitude details which will be in centimetres. GPS covers the whole earth and any point on the earth surface can be pin-pointed. The reason for choosing GPS satellite is because of its continuous availability throughout the year. If the future GPS satellites like GLONASS, GALILEO, etc., are equipped with irradiation measuring instruments like Total Irradiance Monitor [SORCE], etc., and moreover, if the measurements are made continuously over the earth's atmosphere then the amount of irradiation data available are enormous which will lead to better results in irradiance monitoring. During any particular year at least a minimum of 12 satellites will be facing the Sun and monitoring the irradiance over that region and the orbital paths of the satellite will be well-known. One more added advantage of using the GPS satellite is the repetitive coverage over an area on a single day, so the variation in the same area over a short period of time can also be calculated.

3. Space- and ground-based measurement and monitoring

At any instant nearly 12 satellites will be facing the Sun and they will measure the irradiance. The orbital path of the satellites are predefined and well-known. To measure the irradiation precisely the measurement should be made at ground also at the same instant of time when the satellite is passing over a certain area. The ground measurements are performed to reveal the solar irradiation available on the ground after several atmospheric path losses. The reasons to measure the irradiation both on top of the atmosphere and on the ground are to understand the changes occurring in the irradiation during their travel to the surface, etc. Ground instruments are required at several clearly available places for measurement.

For example, if the satellite is at a specific location in space and their co-ordinates in terms of latitude and longitude are known by pre-calculations, e.g., 13°′00″ N 80°′00″ E, the satellite measures the irradiation at that particular position in space and if the measurements are made in the ground at the same place then we can compare the changes in the values. If more number of ground stations are established then for each ground station data we will obtain the top of the atmosphere data from the satellite. More stations will lead to better results, because we can compare more ground data with the satellite data.

For a particular instant of time and at a particular point we will get the irradiation at the top of the atmosphere, at the ground, the difference in irradiation, the amount of loss during that time and the variation in irradiation when compared to the corresponding previous readings at the same point of observation. Though the irradiation variation on the top of the atmosphere is very small, monitoring those small variations will also help us to understand the influence of solar radiation on earth. The ground monitoring is difficult also because of the multiple scattering of radiation from the ground which makes the reading difficult. Though there are some difficulties, the data obtained from these calculations will be better than the interpolated or extrapolated values which are widely used.

4. Possible outputs and advantages

- For a single day, numerous data would be obtained from single locations in space and on earth. Averaging these irradiances will lead to accurate irradiance values for a day which would be a better output than either by interpolation or extrapolation techniques or current estimation techniques.
- If the irradiations are monitored for an 11-year solar cycle, then the effects of the Sun on earth can be studied with the real data.
- For precise irradiance calculation and to monitor their changes, the ground and space data should be incorporated which will yield better output of irradiance values.
- Continuous measurement decreases uncertainties and removes random errors.

5. Conclusion

- GPS satellites can measure and monitor solar activities and measurements of one full solar cycle (11 years) will provide us enormous details about the Sun–earth relations.
- Combining ground and satellite data will provide us much more details like path loss, atmospheric variation over a period, irradiation variation, etc.
- To completely understand the Sun–earth relationship, monitoring the solar activity and their effects on earth with the use of GPS satellites and simultaneous monitoring at ground will improve our knowledge in their relationships.

References

Annette, Hammer *et al.* 2003, Solar energy assessment using remote sensing technologies, *Rem. Sens. Envi.*, **86**, 423.

Gunter, Seeber 2003, Satellite Geodesy, 2nd edn. Walter de gruyter.

Holmes, J. M., Thome, K. 2001, Comparison of modeled and measured downwelling, diffuse irradiance at a ground-reference calibration test site, *Ieee*, 0-7803-7031-7/01.

Kokhanovsky, A. 2004, The Depth of Sunlight Penetration in Cloud Fields for Remote Sensing, *Ieee Geoscience and Remote Sensing Lett.*, **1**, 4.

Puckrin, E., Evans, W. F. J., Li, J., Lavoie, H. 2004, Comparison of clear-sky surface radiative fluxes simulated with radiative transfer models, *Can. J. Remote Sensing*, **30(6)**, 903.

Russak, V. 1991, Changes in Solar radiation, cloudiness and atmospheric transparency during recent decades, *Ieee*, ch2971-0/091.

Tanahashi, S. *et al.* 2001, A system to distribute satellite incident solar radiation in real-time, *Rem. Sens. Envi.*, **75**, 412.