WESAT - Development of a Payload for the Comparison of Solar Radiation and UV Index Measurements

Technical Report

Dr. Lizy Abraham
Principal Investigator
LBSITW, Trivandrum, Kerala
Email: lizyabraham@lbsitw.ac.in
Contact: +91-9495123331

LBS Institute of Technology for Women (LBSITW)
Poojappura, Thiruvananthapuram – 695 012

WESAT - Women Engineered Satellite Payload Technical Report

1. INTRODUCTION

WESAT (Women Engineered SATellite) payload was launched on January 1, 2024, at 9:10 AM IST, UTC +5:30, with India's 60th PSLV mission PSLV-C58 from Satish Dhawan Space Centre (SDSC), Sriharikota. WESAT has successfully completed 500 orbits. WESAT payload is crafted to measure the intensity of Ultraviolet Radiations and Solar Irradiance in Space, tracing the PSLV Orbital Experiment Module (POEM) trajectory 350 Kilometres above sea level. UV Index (UVI) can be derived from this, which can be compared with the corresponding UV Index at earth's surface which will provide important clues for the climate changes and global warming phenomena. Normally, UV radiation intensity data are obtained from the multispectral satellite metadata (spectroradiometers) which are used in meteorological satellites such as MODIS, TEMIS, and NOAA; but with the launch of WESAT, exclusive point source data is received for UV Radiation intensity.

1.1. WHY UV-A ?

UV radiation covers a range of wavelengths from 200nm to 400nm and can be divided into UVA (320~400nm), UVB (280~320nm), and UVC (200~280nm). All of the UVC radiation and 90% of UVB radiation is absorbed, while UVA radiation is scarcely attenuated as the absorption is strongest in the shortest wavelength and absorption decreases sharply with increasing wavelength. Therefore, About 95% of radiation that reaches the earth's surface is UVA.

2. PECULIARITY OF DATA OBTAINED FROM WESAT

The space data that we are providing is the actual point data from the measuring instruments of the WESAT payload, not the data derived from the multispectral satellite metadata which is only available now. In Satellite-derived data, power is derived after filtering the corresponding UV bands from the spectral telemetry data which is the conventional procedure for measuring UVI in space. Whereas, WESAT provides direct measurement of power from the telemetry data. The measuring instruments used in WESAT measures the intensity of UV radiations and Solar Irradiance that provide output in millivolts, which is then converted into corresponding power in Watt/m2. Thus, rather than obtaining UVI indirectly from the satellite-derived data, WESAT helps in providing direct UVI data which is not available at present.

From the power measurements, UV index can be calculated using the following equation:

$$UVI = 0.002 \times UV^2 + 0.02 \times UV \quad \text{----------(1)}$$

where UV is the intensity of UV radiations in W/m^2

Studies related to UVI and correlating it with the Solar Radiation Intensity above and below the earth's atmosphere are important as climate changes and global warming are becoming significant. Particularly, considering the climate changes in Kerala given the recent floods and heat waves. Hence the results from this payload can be considered as a pilot study leading to further research which will support the research community and help them to identify the trends that will lead to important inferences.

3. SELF POWERED WESAT PAYLOAD

WESAT is a first kind of payload which doesn't require any power for its operation. Generally, once the payload will be lift off, to power on the payload requires time as it has to reach the exact orbital path and only after that the telemetry data will be received by the earth station. But in the case of WESAT, the measuring instruments use a novel technology that doesn't require a power source for its working. The solar irradiance measuring instruments used in WESAT payload will directly transform incident sunlight into corresponding power using inner photovoltaic effect. For UV measuring instruments used in the payload, an additional filter will be present in it which will allow the passage of only the required UV bands which will also be converted into the corresponding power. When the sunlight is not present, it is not required to measure either the solar irradiance or UV radiation and hence it does not require a battery too. Hence, power on is not required for the working of WESAT payload; it also doesn't require a battery as there is no need for the payload to work at night time. This suggests the device or technology eliminating the need for power storage for night time operation.

4. UNIQUE FEATURE OF WESAT

Since the WESAT payload doesn't require power, it did not need to wait till the POEM to arrive in its orbital path at 350Km and was powered up to get the telemetry data as compared to other satellite payloads. As soon as the heat shield of PSLV C-58 separated at 113.68 Km after approximately 3 minutes from the launch, the WESAT payload was exposed to the external environment, it automatically started providing telemetry data. That is, the payload started to provide us with the telemetry data, the moment the heat shield was separated from 113.68Km onwards just after 3 minutes after the launch.

Due to this unique feature, the variation of UV radiation intensity from heat shield separation of 113.68Km up until the XPoSat orbital path of 650Km and then moving downwards towards POEM orbital path of 350Km - i.e, from 113.68 Km to 650 Km and then to 350Km has been continuously obtained as telemetry data from the WESAT. This moving data with respect to the altitude from outer atmosphere towards space is considered to be one-of-a-kind data, which cannot be obtained from any of the satellite payloads, as the power on will not be done before arriving its exact orbital path and therefore until that no telemetry data will be obtained. Hence

this unique data from WESAT will provide the variation of UV intensity, from the outer atmosphere towards the upper space i.e., from 113.68 Km to 650 Km and towards 350Km.

5. DYNAMIC RANGE OF WESAT PAYLOAD

Based on the specifications of the WESAT measuring instruments, the maximum output voltage that can be measured from the pyranometer is 400 mV and from the UVA sensor is 12 mV. That means, The maximum power that can be measured using the WESAT measuring instruments are 2000 Watt/m^2 and 120 Watt/m^2 respectively for solar irradiance and UV radiation. This gives a UVI of 31, which is the maximum dynamic range of the WESAT payload. The maximum average UVI reported on the earth's surface is 11 -12.

6. GROUND MONITORING STATION AT COLLEGE CAMPUS

To understand the variation of UV intensity in space with respect to earth's surface, an intact ground monitoring station is set up at our campus, which has been continuously recording UV radiations, solar irradiance, temperature and humidity in real-time for the past 4 months. A dedicated website https://wesat.in/ has been developed and interfaced with the ground monitoring station to display the parameters in real-time on a daily basis. Since the geographical location of Kerala lies in the tropical zone, it always experiences high UVI during the summertime. The maximum instantaneous UVI reported at the Ground Monitoring Station at LBS Institute of Technology for Women (LBSITW), Trivandrum, Kerala, India is 11 which extreme according to the exposure category. This high value of the index was obtained due to the sudden high solar radiation just after the rain. UV radiation before reaching the earth's surface can be scattered by many factors such as pollution particles, aerosol etc. and therefore intensity will be decreased once it arrives on earth's surface.

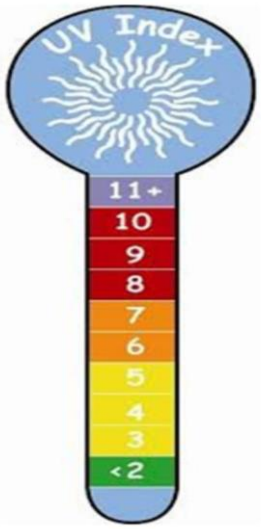


Fig 6.1 UV Exposure Level

But just after the rain, the pollution particles and other atmospheric components are washed away, resulting in a clear sky. Therefore, UV radiations directly hit the earth surface without any interference. To summarise, the percentage of interference due to pollution particles at that instance was very low and the intensity of solar radiation was very high. Hence providing an output of 11 as the instantaneous UVI.

7. PRELIMINARY DATA ANALYSIS OF WESAT PAYLOAD

Our project aims to comprehend UV radiation intensity and solar irradiance in space both above and below the Earth's atmosphere and subsequently compare the obtained values to determine the filtering rate of the Earth's atmosphere. Currently, based on our research findings, it appears that WESAT stands as the sole source providing point source of data for both UV

and Sun intensity. The deciphering of the raw data acquired by the WESAT payload during its mission, and an initial comparison of the obtained telemetry data with the Ground Monitoring Station data is done.

7.1.INFERENCE

After the analysis of the telemetry data obtained from the WESAT payload until now, it was inferred that the highest UV readings were recorded in orbits 18, 51, and 76. The time and date in which the highest UV reading recorded was noted and the corresponding reading for the Solar Irradiance (SI) was found. The UVI was then calculated using equation (1). Table 7.1.1 shows the maximum value of telemetry data recorded by the WESAT payload and the Ground monitoring station data at the same time. From this, it can be inferred that the highest UVI recorded is 23 on 51st orbit on 04-01-2024 at 13:58:04 in space, 350Km away from earth's surface. On the same day the maximum reported UVI recorded in the Ground Monitoring Station is 5, which is on the earth's surface in Thiruvananthapuram city. The figures 7.1.1 - 7.1.4, show the plot of corresponding values from the primary and redundant measuring instrument for UV and SI on 04-01-2024 at the 51st orbit, where the highest UVI was recorded. Fig. 7.1.5 & 7.1.6 shows the corresponding plots for UV and SI respectively for Ground Monitoring Station.

Table 7.1.1: Maximum Telemetry readings recorded by WESAT

Sl. No.		Orbit	Date	Time (IST)	Maximum Obtained Reading		
					UV (W/m2)	SI (W/m2)	UVI
1	WESAT Payload	18	02-01-2024	11:37:07	97.67	1260.88	21.03 ≈ 21
		51	04-01-2024	13:58:04	100.24	1317.38	23.47 ≈ 23
		76	06-01-2024	03:21:14	95.07	1235.08	19.98 ≈ 20
2	Ground Monitoring Station		04-01-2024	12:22:59	46.2	808.80	5.2 ≈ 5

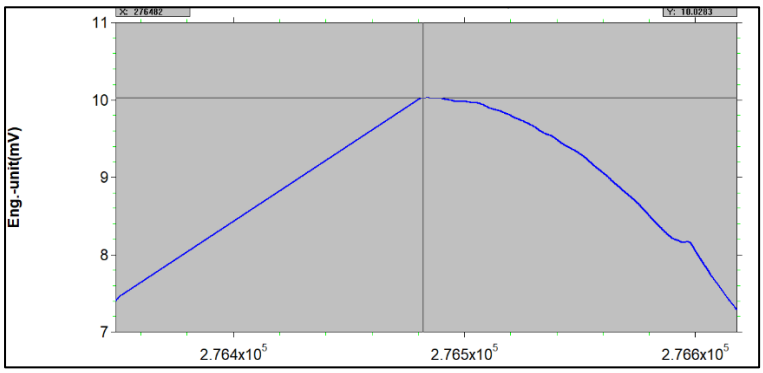
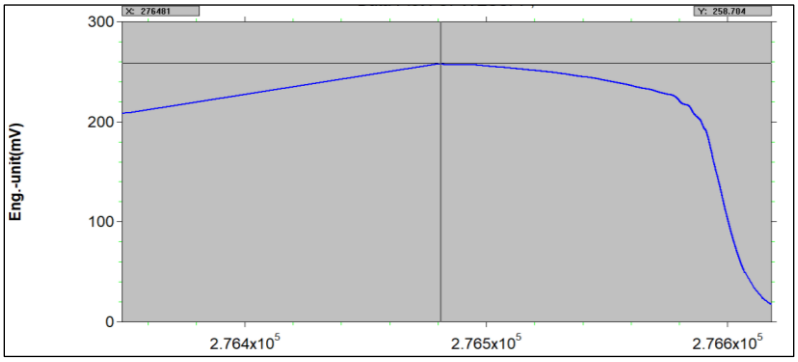
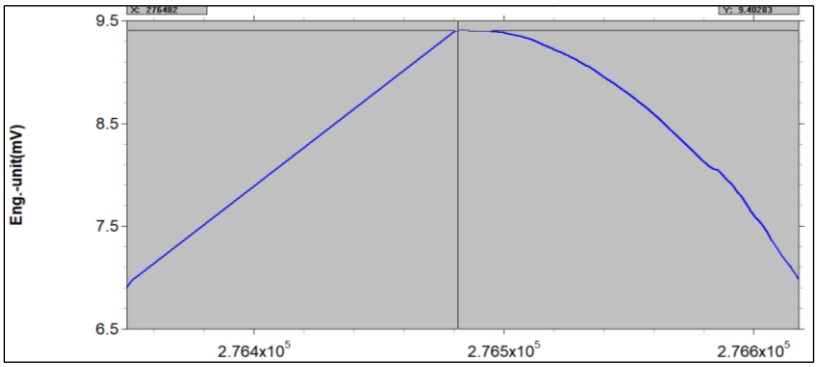


Fig 7.1.1: UV readings from the primary measuring instrument of WESAT Payload on 04/01/2024



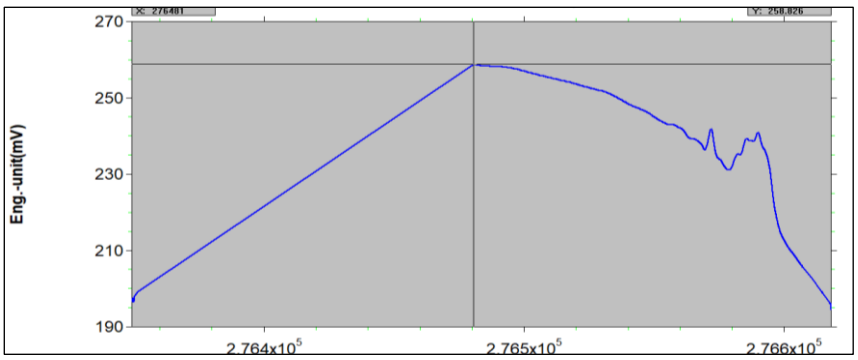
Flight Time (s)

Fig 7.1.2: SI readings from the primary measuring instrument of WESAT Payload on 04/01/2024



Flight Time (s)

Fig 7.1.3: UV readings from the redundant measuring instrument of WESAT Payload on 04/01/2024



Flight Time (s)

Fig 7.1.4: SI readings from the redundant measuring instrument of WESAT Payload on 04/01/2024

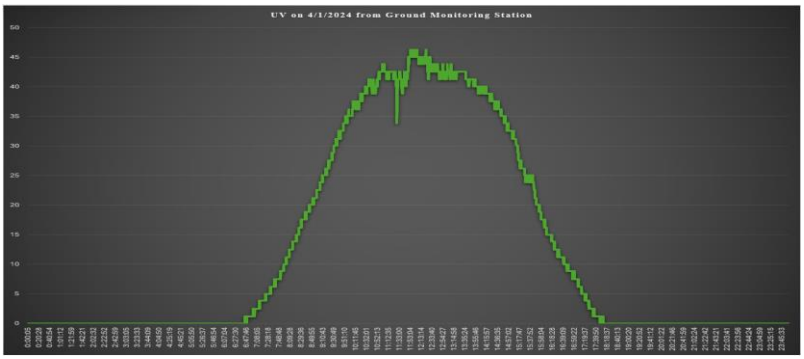


Fig 7.1.5: Plot of UV data on 04/01/2024 from the Ground Monitoring Station

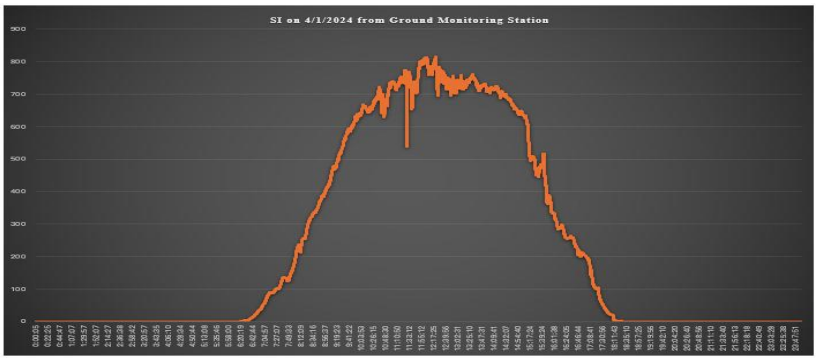


Fig 7.1.6: Plot of SI data on 04/01/2024 from the Ground Monitoring Station

After launch, the highest UVI recorded at the Ground Monitoring Station is on 11-01-2024 which is 8.7. On the same day the maximum UVI recorded in Space is 14. The corresponding readings recorded by both the ground monitoring station and payload, is given in Table 7.1.2. The plots for UV and SI are shown in figures 7.1.7 – 7.1.12.

Table 7.1.2: Maximum value of UVI readings recorded from the Ground Monitoring Station after launch

Sl. No.		Date	Time	Maximum Obtained Reading		
				UV (W/m2)	SI (W/m2)	UVI
1	Ground Monitoring Station	11-01-2024	12:23:13	61.20	1095.00	8.7
2	WESAT Payload	11-01-2024	11:23:41	78.06	1049.76	14

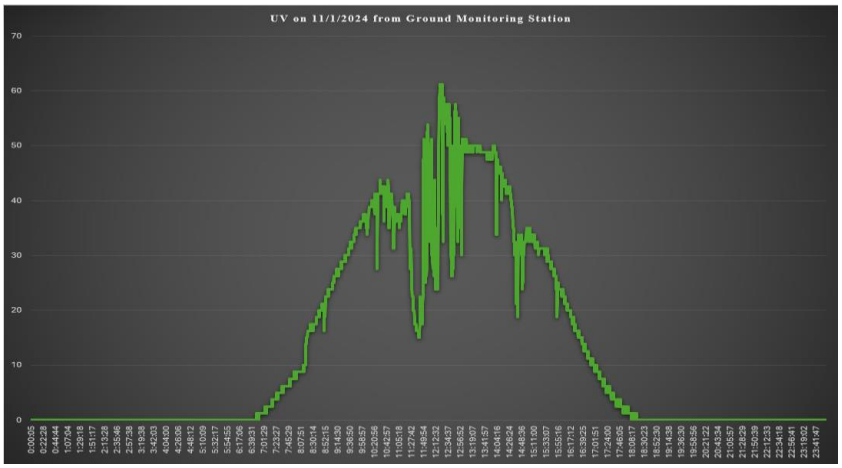


Fig 7.1.7: Plot of UV data on 11/01/2024 from the Ground Monitoring Station

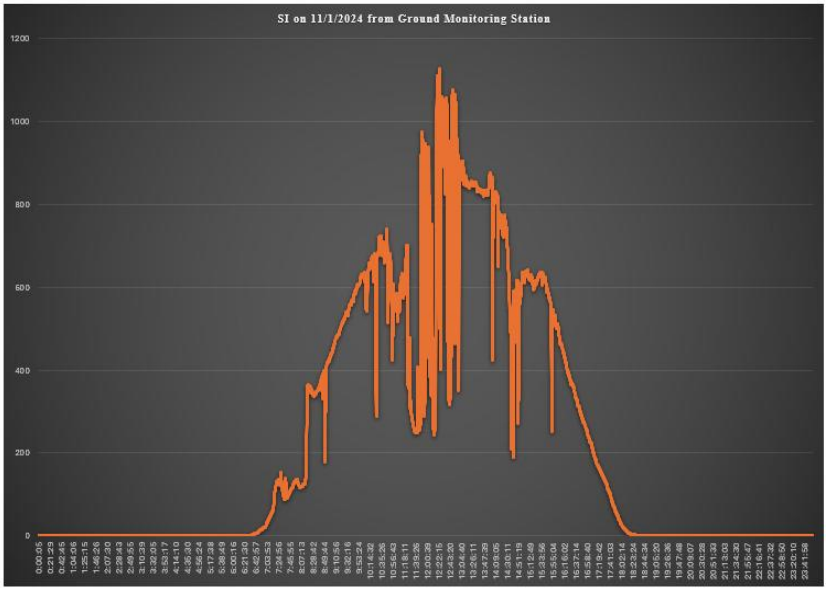


Fig 7.1.8: Plot of SI data on 11/01/2024 from the Ground Monitoring Station

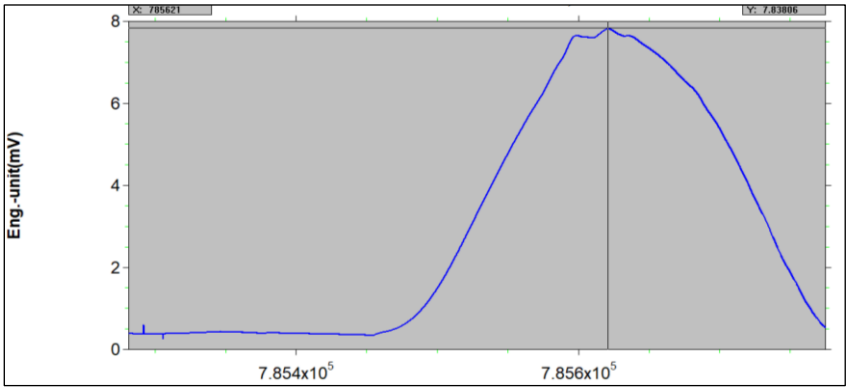


Fig 7.1.9: UV readings from the primary measuring instrument of WESAT Payload on 11/01/2024

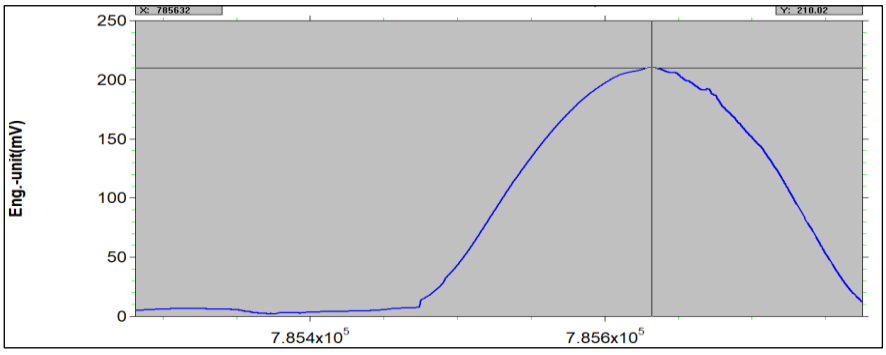


Fig 7.1.10: SI readings from the primary measuring instrument of WESAT Payload on 11/01/2024

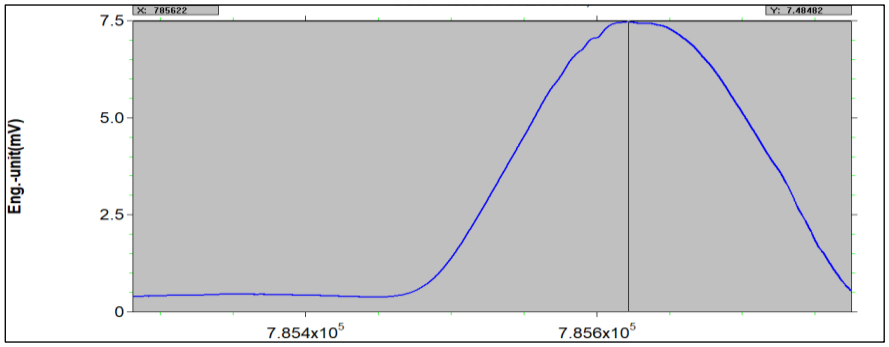


Fig 7.1.11: UV readings from the redundant measuring instrument of WESAT Payload on 11/01/2024

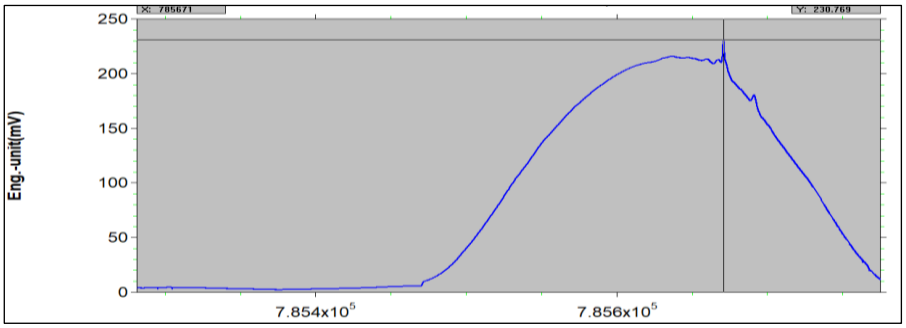


Fig.7.1.12: SI readings from the redundant measuring instrument of WESAT Payload on 11/01/2024

7.2. INITIAL FINDINGS ON FILTERING RATE

The filtering rate of the measured parameters can be defined as the percentage of UV and Solar radiation intensities from space where the WESAT payload is orbiting at a distance of 350Km penetrating the earth's atmosphere and reaching the earth's surface after the attenuation through factors such as the ozone layer, atmospheric conditions, cloud cover, air quality, dust particles, etc. Table 7.2.1 provides a sample calculation of the filtering rate when the UVI has reported maximum in space. The values of the parameters are taken from Table 7.1.1.

(Telemetry data from WESAT payload) – (Measurement from Ground Monitoring Station) x 100 ----------(2)

Telemetry data from WESAT payload

Table 7.2.1:Rate of filtering

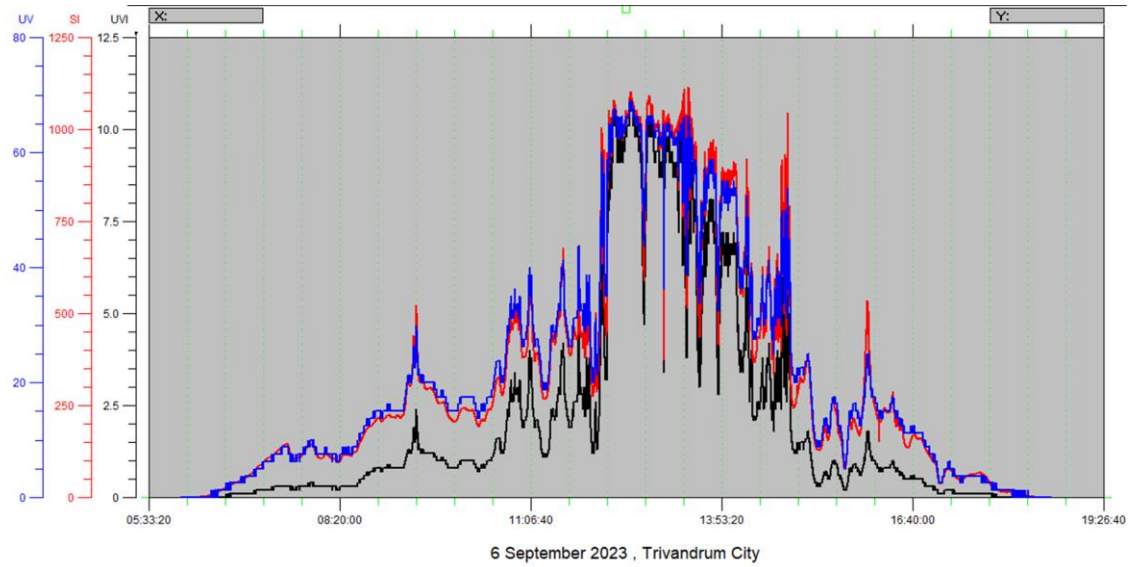
Parameters	Telemetry data from WESAT payload	Measurement from Ground Monitoring Station	Rate of filtering (%)
SI	1317.38	808.80	37.36
UV	100.24	46.20	53.90
UVI	22	5	77.27

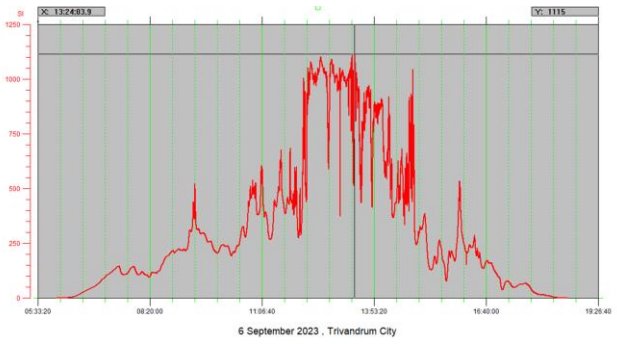
8. MAXIMUM UVI FROM GROUND MONITORING STATION

Since May 6, 2023, our Ground Monitoring Station has been operational, continuously providing earth surface data. As of now, it has been 8 months, and we are still receiving

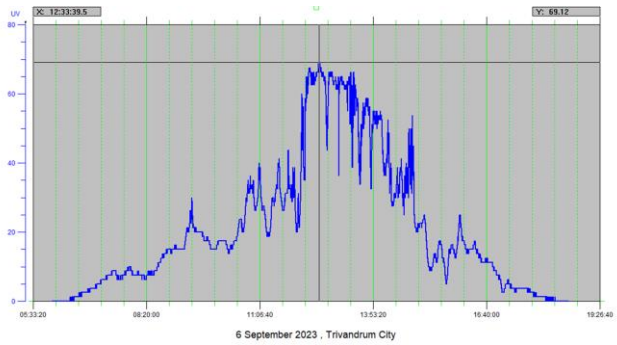
valuable data. Over the past 8 months, on September 8, 2023, the highest UVI has been reported which is 11 which corresponds to the exposure category of 'Extreme' (refer Fig. 6.1). By continuously collecting data over the past 8 months, it has been noted that Thiruvananthapuram city receives a high UVI with an average maximum index of 11. This depicts the need of further study of the effect of ultraviolet radiations.

8.1 ANALYSIS OF 06th SEPTEMBER 2023 DATA

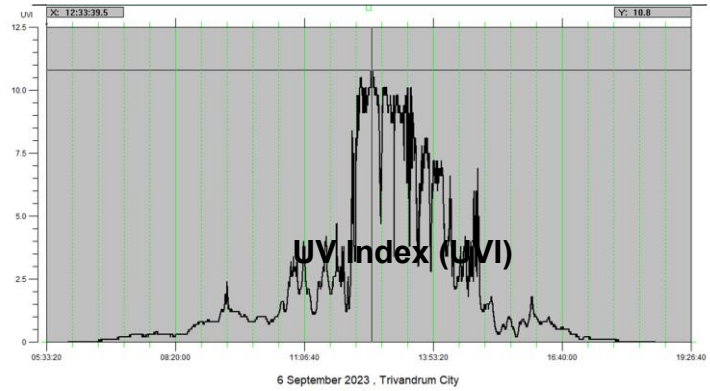




Solar Radiation W/m^2



UV-A W/m^2



UV Index (UVI)

9. CONCLUSION

The findings are crucial for the continued study in this area. We are now developing an automation tool for data analysis and a prediction model for UV index calculations. This would help researchers to study about further impact of UV at various levels. This is the first kind of study with this stipulated parameters. Further study will help Government agencies to invoke quick actions and formulating policies to reduce hazardous impacts on environment.