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Photovoltaic solar cells white Spot Phenomenon in high humidity Coastal: Environmental Factors and Performance Implications

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Abstract-

This paper presets a "cell spotting" phenomenon that was noticed on the rooftop PV systems along the coast in Tartous, Syria, during the summer, mainly in the early morning and late evening hours under specific environmental conditions. This phenomenon appeared as white spots on the photovoltaic cells. Repeated periodic measurements were taken over four months during the summer, revealing a strong correlation between the appearance of these spots and high humidity levels (above 50%), high temperatures, low direct solar radiation, and dust accumulation. Infrared images were taken of the studied panels during the study period in order to show the temperature deference between the cells with white spots and the other cells in the same panel, and the deference was about 2°C. After cleaning the cleaning the panels, the phenomenon was disappeared. Also, when the sunlight is not direct on the PV panel surface, the phenomenon does not appear. Practical measurements of temperature, humidity, and solar radiation monitoring revealed a strong correlation between the presence of this phenomenon and high humidity, temperature, dust accumulation, and indirect solar radiation on the surface of the panels. It was concluded that this phenomenon is a transient effect caused by a dust and moisture interaction, a condensation related process and appears as a white layer on the outer surface of the panel above the effected cells.

Keywords: PV Cell spots, dust effects, potential degradation, humidity effects, shading effects, hot spots, mismatch cells.

1 - Introduction

Solar Photovoltaic (PV) panels have become an unavoidable advanced technology in modern electrical grids due to economic viability for consumers and environmental aspects. However, the interaction of PV panels with natural surrounding factors like humidity, temperature, dust, and pollution leads to significant impact on their efficiency and radiation that reaches the panels. Regular or scheduled inspection of PV panels may not be carried out due to accessibility challenges, limited maintenance resources, and budget limits. However, some visual observations in walk-through energy audits would have initial concerns about performance degradation. In order to deduce such preliminary visual indicators, a visual observation should be conducted with concurrent electricity and meteorological data in order to deduce a reliable correlation. Rooftop PV systems along the coastal strip of Tartus, Syria, on the eastern Mediterranean coast, were monitored. A spotting phenomenon was observed on the cells, appearing during the morning and before sunset, when solar radiation is indirect on the panel surface and humidity levels are generally high. This phenomenon appears as white spots covering the entire cell surface and may appear on multiple cells within the same panel. These spots create shading effects on the affected cells and may extend to several adjacent or isolated cells within the same panel, as well as across different panels within the same photovoltaic solar energy system, and cause the temperature to be increased. This temperature increase persists as long as the environmental conditions favorable to this phenomenon remain. Conversely, the spots disappear, and the cells return to their normal temperature once these conditions or environmental factors change.

While existing research primarily addresses phenomena like hotspots, the specific white spot phenomenon observed here exhibits distinct characteristics. Hot spots are localized regions of elevated temperature resulting from shading, cell defects, or connection failures, which accelerate material degradation [1] [2]. These hot spots often occur when

partially shaded cells operate in reverse bias, producing excessive heat that can reach temperatures above 130°C, leading to irreversible damage.[3]

Measurements have shown that this phenomenon is closely linked to high temperature and humidity, dust accumulation, and indirect solar radiation. Therefore, it differs from shading caused by other factors such as internal defects. Numerous studies have indicated that environmental factors, such as high humidity, high temperature, and low solar radiation, affect the physical and chemical properties of photovoltaic cell surfaces, promoting phenomena such as discoloration, dirt accumulation, and thermal anomalies [4][5]. For example, condensation under high humidity conditions can lead to crystallization or surface changes that appear visually as white spots, sometimes accompanied by localized temperature increases [6] [7].

Multiple studies have demonstrated that cleaning reduces temperature differentials and diminishes the extent of discoloration, underscoring the importance of maintenance in mitigating environmental effects [8].

Furthermore, the interaction between moisture, dust, and solar radiation can induce complex phenomena, including changes in optical properties and surface charge distributions, which can explain the irregular shapes and spreading of white patches, often extending beyond cell boundaries under high humidity levels (>50–75%). The greatest impact occurs in warm coastal areas where salt and dust deposits may accumulate on the panel surfaces, leading to faster panel deterioration, especially at high humidity levels [9] [10], this necessitates regular monitoring and specialized management to maintain a longer service life [10] [11].

Hot spots in PV modules are common phenomena that significantly affect their performance and durability. These localized high-temperature areas result from temporary shading, permanent defects, cell failures, or damage to interconnection lines [1] [2]. In cases of temporary shading, such as bird droppings, the affected area may revert to normal once the shading is removed; however, if the incident lasts for a long period or

in prolonged shading, the hot spot may become permanent, and can lead to permanent hot spots, causing irreversible damage to the cells or the entire module .[3]

In the case of shaded cells hotspots, the hotspots occur when shaded cells produce less power compared with other series-connected PV cells and operate in reverse mode, causing current to flow through the shaded cells from unshaded cells. Hot spot cells consume power instead of producing it, leading to temperature increases —temperatures can reach 130°C or higher—exceeding the operational limits of the cells and potentially causing material degradation, mechanical stress, and fire hazards, and can cause up to 6% power reduction .[4]

The severity of the temperature increase is approximately linearly related to the length of the series-connected string of cells, with longer strings tending to produce higher temperatures [5]. The IEC 61215-2:2021 standard includes a hot-spot endurance test to evaluate the ability of modules to withstand partial shading conditions, with temperature adjustments based on actual operating conditions, especially for residential systems exposed to frequent shading from structures or trees [6]. Studies have shown that hotspots can form at lower temperatures depending on cell quality and string configuration, and accelerated aging tests or modified testing protocols can predict the durability of modules under real shading scenarios, optimize test conditions, and reduce testing time while maintaining reliability .[2]

When dust and dirt accumulate on the surface of photovoltaic cells, less solar radiation reaches them, and the trapped heat causes a rise in temperature, leading to the cells turning white or lighter shades [12]. High levels of humidity that form during the early morning and sunset periods lead to water condensation on the surface of cells, and in the presence of dust and salts, white spots may form.

In summary, while prior research provides insights into hotspots and environmental degradation, the specific white spot phenomenon linked to humidity, dust, and temperature observed in coastal environments such as Tartous warrants further

investigation. The findings suggest that high humidity and temperature, combined with dust accumulation, are key factors influencing the appearance and spread of these white discolorations, which are reversible with cleaning and direct sunlight.

This study analyzed the factors related to this phenomenon and identified the upper and lower values of the factors that must be present together for this phenomenon to occur, in addition to studying its effect on exposed solar panels in terms of temperature.

Based on measurements and observations, it was determined that this phenomenon is related to multiple factors that must coexist for it to manifest. The humidity level must exceed 50% where the phenomenon did not appear on dry days, when the humidity was lower than 50%. Additionally, there should be no direct solar irradiance incident on the panel surface. Dust accumulation also plays a role, along with more than 5 kWh of shortwave solar energy, particularly during the morning and evening periods before sunset. The appearance of this phenomenon is often accompanied by a solar azimuth angle (20°-35°), dew point (17°-21°), and temperature (25°-28°) during the morning hours, and solar azimuth (0°-10°), dew point (18°-21°), and temperature (24°-27°) during the evening hours. The results showed that the ultra-violet and atmospheric pressure had no role in the phenomenon. This phenomenon caused white spots on cells, causing temperature differences (above 2°C) between colored cells with white spots and other cells in the same panel. The rest of paper is organized as follows: section.2 presents the paper methodology, section.3 discusses the study results, section.4 reports the conclusion of the paper, section.5 states implications and recommendations.

2- Methodology and Materials

This section describes Study area: Syria, Tartous, Corniche

Cases studied: Off-grid rooftop photovoltaic solar systems of varying capacities using different panel types from different manufacturers, none of which are typically cleaned of dust.

Monitoring period: This phenomenon was tracked over four months during the summer season (June to September).

This phenomenon was monitored, and weather parameters were measured for four months during the summer, and temperature measurements of the cells within these panels were also recorded during the monitoring period.

Photographs and infrared thermography were taken of these systems. The temperatures within these panels for the colored and uncolored cells were compared. An IR thermometer/HYTIS TS550 and Fluke TiS Thermal Imaging Scanner/TIS-9HZ were used.

Weather data, including temperature, humidity, dew point, ultraviolet (UV) radiation, and shortwave solar energy, were also obtained from the weather Spark. Com (which records weather parameters at nearby locations such as Hmeimim Airport in Latakia) and weather.com.

Weather data were recorded, and photos and IR images were taken of the studied PV systems over several days for a period of four months, in both the morning and afternoon periods, to identify the conditions that cause this phenomenon. The results of the measurements for each case are displayed with the corresponding photos for each measurement day.

Table 1 shows the measurement sequences, sunrise and sunset timing, and temperature of each measuring day during the monitoring months.

Table 1: measurement days information

m-seq	Measurement date	Sunrise time (am)	Temperature at sunrise	Sunset time (pm)	Temperature at sunset C°
1 in june	9/6/2025	05:23	25	07:49	26
2 in june	13-15/6/2025	05:33	26	07:51	30
1 in August	9/8/2025	05:52	27	07:31	29
1 in September	4/9/2025	06:15	27	06:52	28
2 in September	13/9/2025	06:19	27	06:46	29
3 in September	20/9/2025	06:23	27	06:36	27
4 in September	26/9/2025	06:28	25	06:29	28

The Studied rooftop PV solar systems:

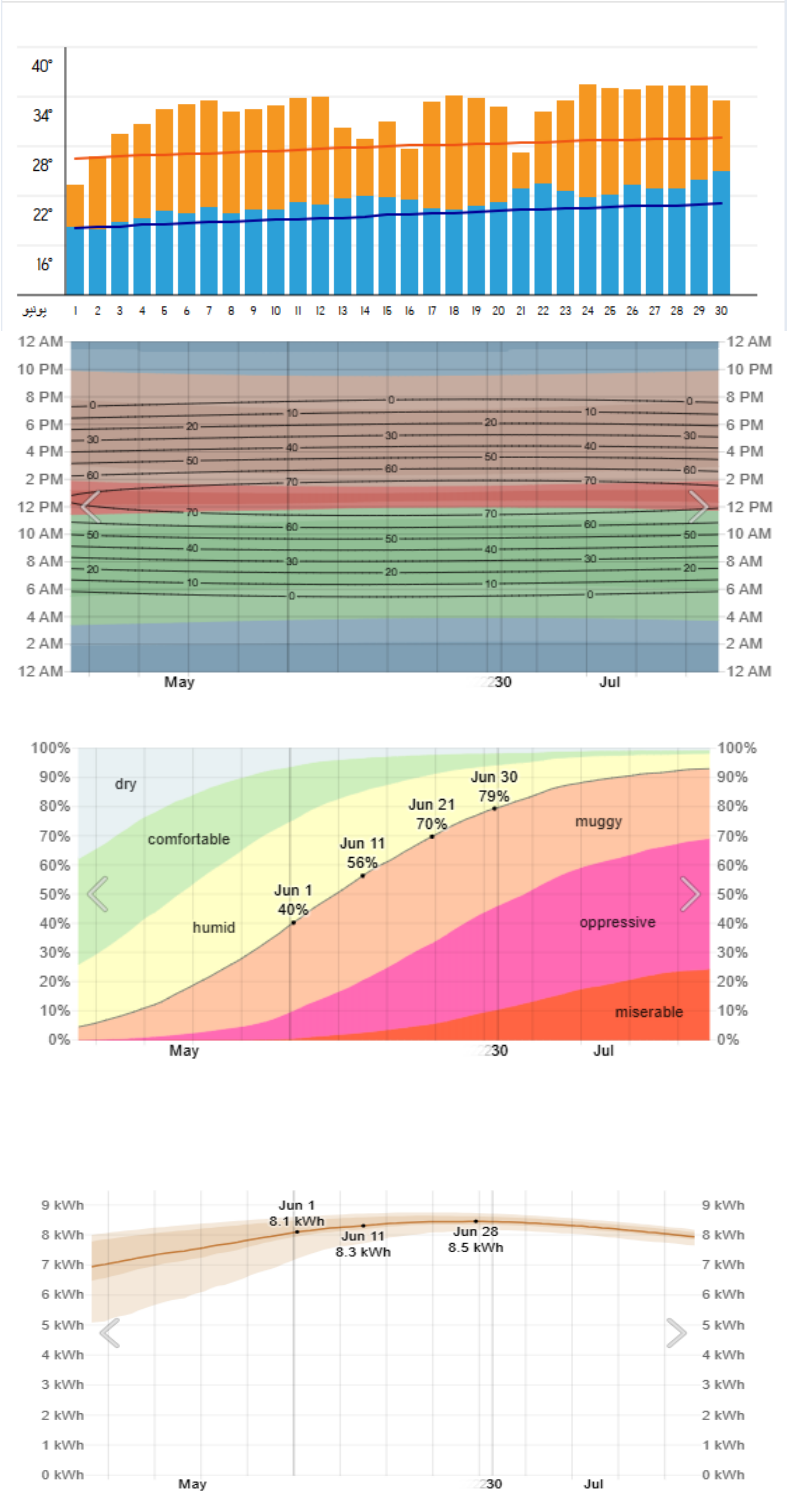
1-1.665 kW PV solar system: consists of three panels: panel orientation: south 170°, panel tilt 60°, module operating age: 2 year, LR5-72HPH-555M, 555 W, 6 × 24 half cells, V_{mp}=42.10 V, I_{mp}=13.19 A, V_{oc}=49.95 V, I_{sc}=14.04 A.

2-2.220 kW PV solar system: Consists of four panels: panel orientation: south 170°, panel tilt 60°, module operating age: 1 year, LR5-72HPH-555M, 555 W, 6 × 24 half cells, V_{mp}=42.10 V, I_{mp}=13.19 A, V_{oc}=49.95 V, I_{sc}=14.04 A.

3. Results and discussion:

3.1. June measurements:

Weather data were first obtained in June, as shown in Figure (1-a), Figure (1-b), Figure (1-c), (1-d), showing the minimum and maximum temperatures, azimuth and angle of the sun, humidity, and average shortwave temperatures during June, respectively.



(a)

(b)

(c)

(d)

Figure 1: a-Temperature, b-solar elevation & azimuth, c-humidity, d-Average daily incident shortwave solar energy in June, Tartus, Syria

As shown in Table 1, the measurement days were the 9th, 13th, and 15th of August, and returning to Figure (1), we conclude that the values of temperature, azimuth, humidity, and quantity of shear waves corresponding to the measurement days were as shown in Table 2.

Table 2: Temperature, solar elevation & azimuth, humidity and Average daily incident shortwave solar energy for measurement dates in June

date	Temperature C°	Solar elevation & azimuth (sunrise duration)	Solar elevation & azimuth (sunset duration)	Humitidy %	Average daily incident shortwave solar energy
6/6/2025	32◦	20◦-30◦	0◦-10◦	≈50◦	8kWh
13-15/6/2025	31◦	20◦-30◦	0◦-10◦	≈60◦	5.5kWh

3.1.1. Measurement number 1:

Day 9/6/2025: A sunny, high-humidity day, the1.665 kW PV solar system:

Images of the studied PV systems showed the spread of this phenomenon during the morning and evening periods. Figure (2-a) shows an image of the panels during the afternoon period before sunset, and the phenomenon of some half-cells turning white is clearly visible.

Temperature measurements were performed on the half-cells during this period. Figure (2-b) shows the same panels after two days, and an increase in the number of white cells can be noted. Figure (2-c) shows the measured temperatures of the colored cells in panel 3, where an equivalent matrix for the cell positions was formed, and the measured temperatures of the equivalent cells were determined on this matrix.

The temperatures in the colored cells were approximately two degrees higher than those in the surrounding uncolored cells.



a





b

6	5	4	3	2	1	[3]
						1
						2
						3
26.8	26.7					4
28	25.7	25.7	25.7	26		5
28	26.3	25.4	26	27.5	26	6
26.8		25.2	25.2	27.5	26	7
				27.7	26	8
				25.4		9
						10
						11
						12
24.7						1
24.7	24.7	25.4	24.9	26.3	24.5	2
24.7						3
						4
						5
						6
						7
						8
						9
						10
						11
						12

6	5	4	3	2	1	[3]
						1
						2
27						3
27						4
29	27					5
29	27	29				6
						7
						8
						9
						10
27						11
27	27	27	27	27	27	12
29	28	27	26	26		1
28	28	28	29	26		2
28	28	27	27			3
26	26	29	27			4
		28	27			5
						6
						7
						8
						9
						10
						11
						12

c

Figure 2: a-The phenomenon of coloring on the studyed PV solar panels, b-panel number 3, c- temperature matrix of panel 3.

Figure (3) shows the phenomenon on other nearby rooftop PV systems under the same weather conditions, and this phenomenon was observed to be widespread on them, whether they were half-cell or full-cell panels.



Figure 3: The phenomenon on other nearby rooftop PV systems

3.1.2. Measurement number 2:

Day 13/6/2025: A sunny, high-humidity day, the1.665 kW PV solar system:

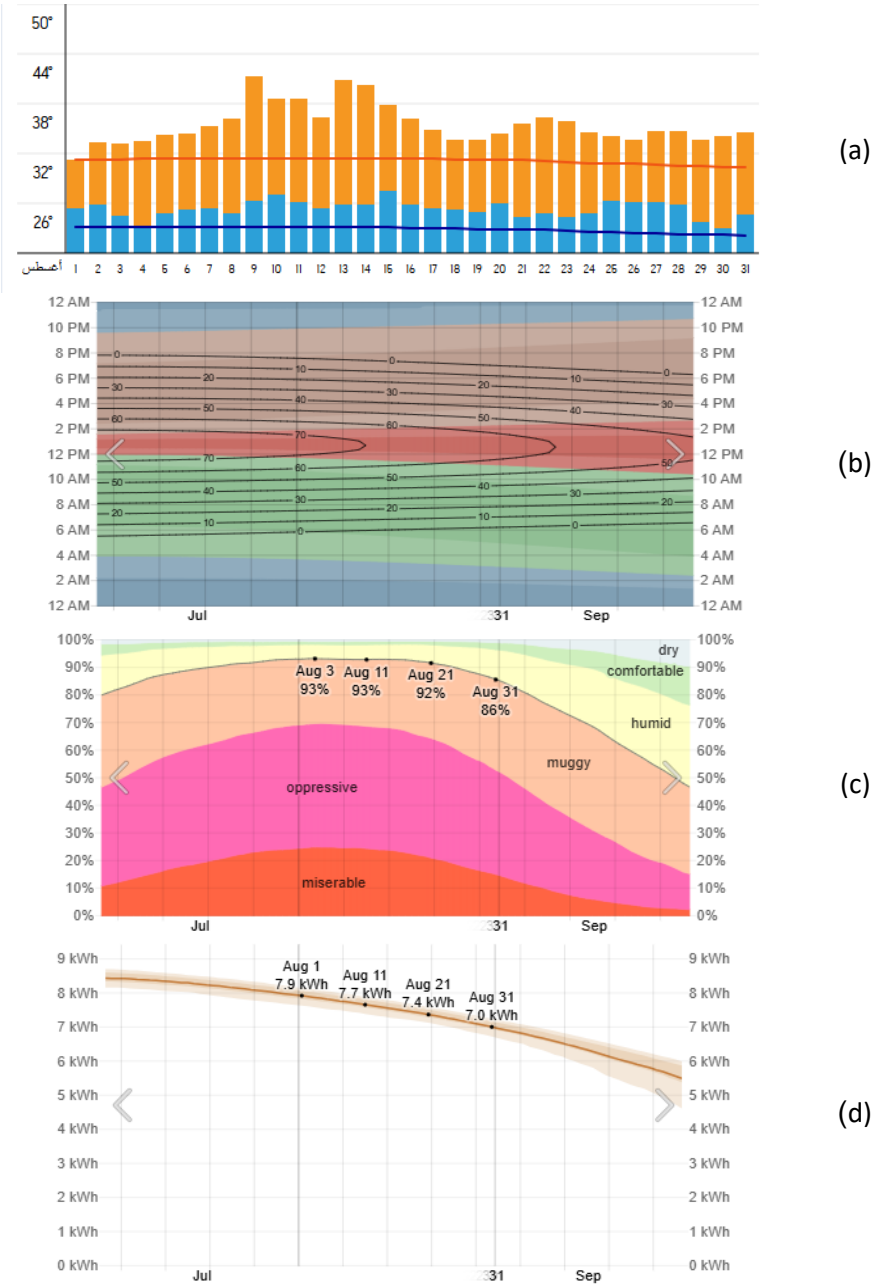
The images taken of the studied PV solar system on this day showed that this phenomenon was more widespread and present in a greater number of half-cells during the morning and evening periods. Figure (4,a) shows an image of the panels in the afternoon, just before sunset, clearly demonstrating the increased prevalence of the discoloration phenomenon across a larger number of half-cells. Returning to the temperature readings of the half-cells in Figure (2, c) which had been stained, an increase in temperature was observed since the previous measurement. Temperature measurements were taken on the cells during this period, and the results showed a temperature difference of approximately two degrees Celsius between the colored and uncolored cells.



Figure 4: The studied PV solar system at the second measurement number2

3.2. August measurement:

Figure (5) shows the temperature, solar elevation and azimuth, humidity, and average daily incident shortwave solar energy data in August.



(a)

(b)

(c)

(d)

Figure 5: a-Temperature, b-solar elevation & azimuth, c- humidity, d- Average daily incident shortwave solar energy dates in August, Tartus, Syria

3.2.1. Measurement number 1:

Day 9/8/2025: A sunny day with very high humidity

From Table 1, the measurement day was the 9th of August, and returning to Figure (5), we conclude that the values of temperature, azimuth, humidity, and quantity of shear waves corresponding to the measurement day are as shown in Table 3.

Table 3: Temperature, solar elevation & azimuth, humidity and Average daily incident shortwave solar energy for measurement date in August

date	Temperature C°	Solar elevation & azimuth (sunrise duration)	Solar elevation & azimuth (sunrise duration)	Humidity %	Average daily incident shortwave solar energy
9/8/2025	45◦	25◦-35◦	0◦-10◦	≈50◦	8kWh

The average humidity was very high on 9/8/2025, and the temperature was over 45 °C. As shown in Figure (6), the phenomenon of white discoloration of the cells has spread and exceeded the geometric boundaries of the cell shape as a result of the significant increase in temperatures coinciding with the increase in humidity. Therefore, the cells have indistinct edges close to a curved shape instead of the rectangular shape that perfectly matches the cell shape.

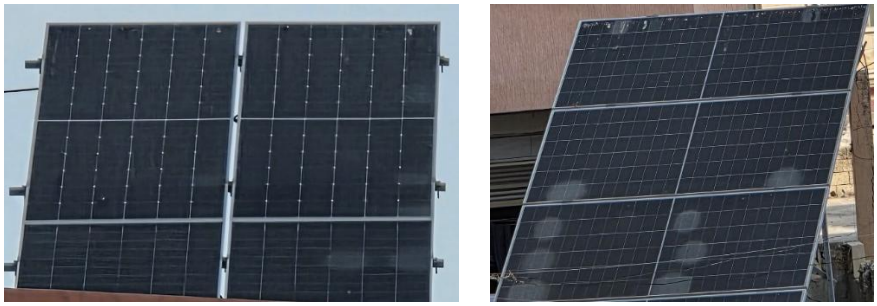
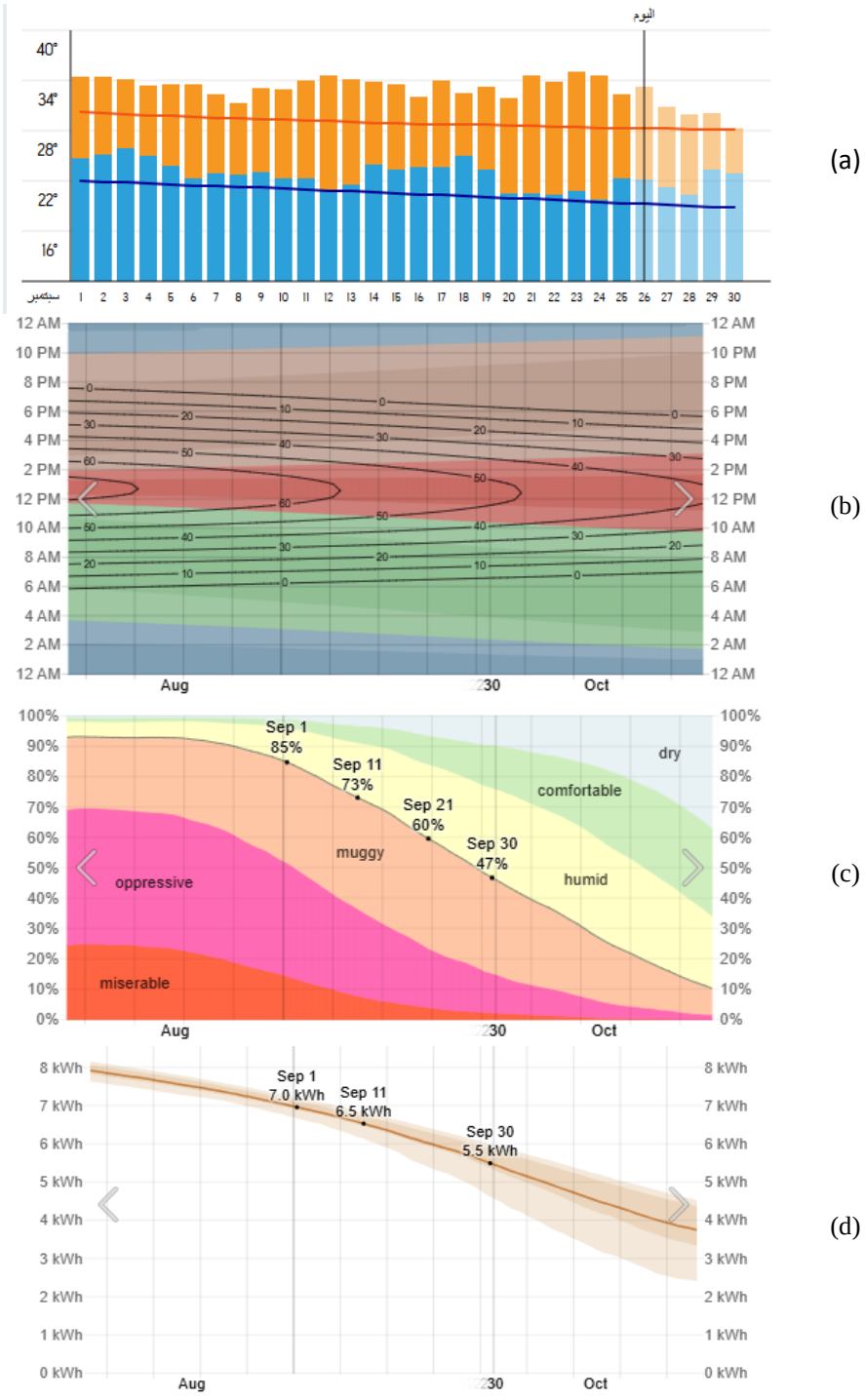


Figure 6: a nearby PV solar systems at 9/8/2025

3.3. September measurements:

Figure (7), shows the temperature, solar elevation & azimuth, humidity and average daily incident shortwave solar energy dates in September.



(a)

(b)

(c)

(d)

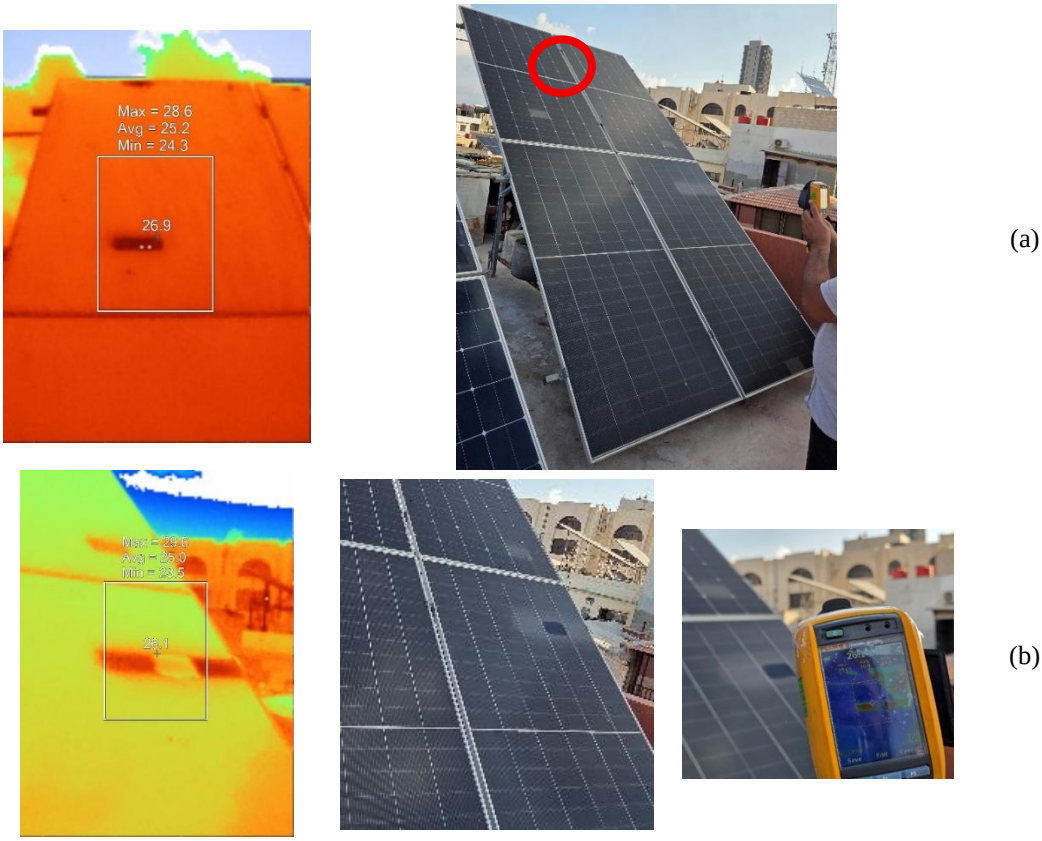
Figure 7: a-Temperature, b-solar elevation & azimuth, c- humidity, d- Average daily incident shortwave solar energy dates in September, Tartus, Syria

3.3.1 Measurement number 1:

Day 9/9/2025: A sunny, high humidity day, the 2.220kW PV solar system:

Figure (8) shows the 2.22kW PV solar system at the morning duration in 9/9/2025. It could be noted in Figure (8, a) the high temperature of the colored cell in the Infra-Red photo. It is about two degrees higher than the uncolored cells.

To ensure the strong connection between the coloring phenomenon and the dust that cover the panel, we have cleaned on cell as showing in Figure (8, b). It is very clear that the cleaned cell has a lower temperature than the uncleaned nearby cells.



(a)

(b)

Figure 8 (a,b): The 2.220kW PV solar system in 9/9/2025

Figure (9), shows other nearby rooftop PV solar systems at the same high temperature and humidity measuring day, in morning duration. We could note from Figure (9, a) the temperature differences between the colored and uncolored cells, while figure (9, b)

shows another rooftop PV soar system with the large scale of the phenomenon on the panels. In Figure (9, c), IR photos of several rooftop PV system were displayed.

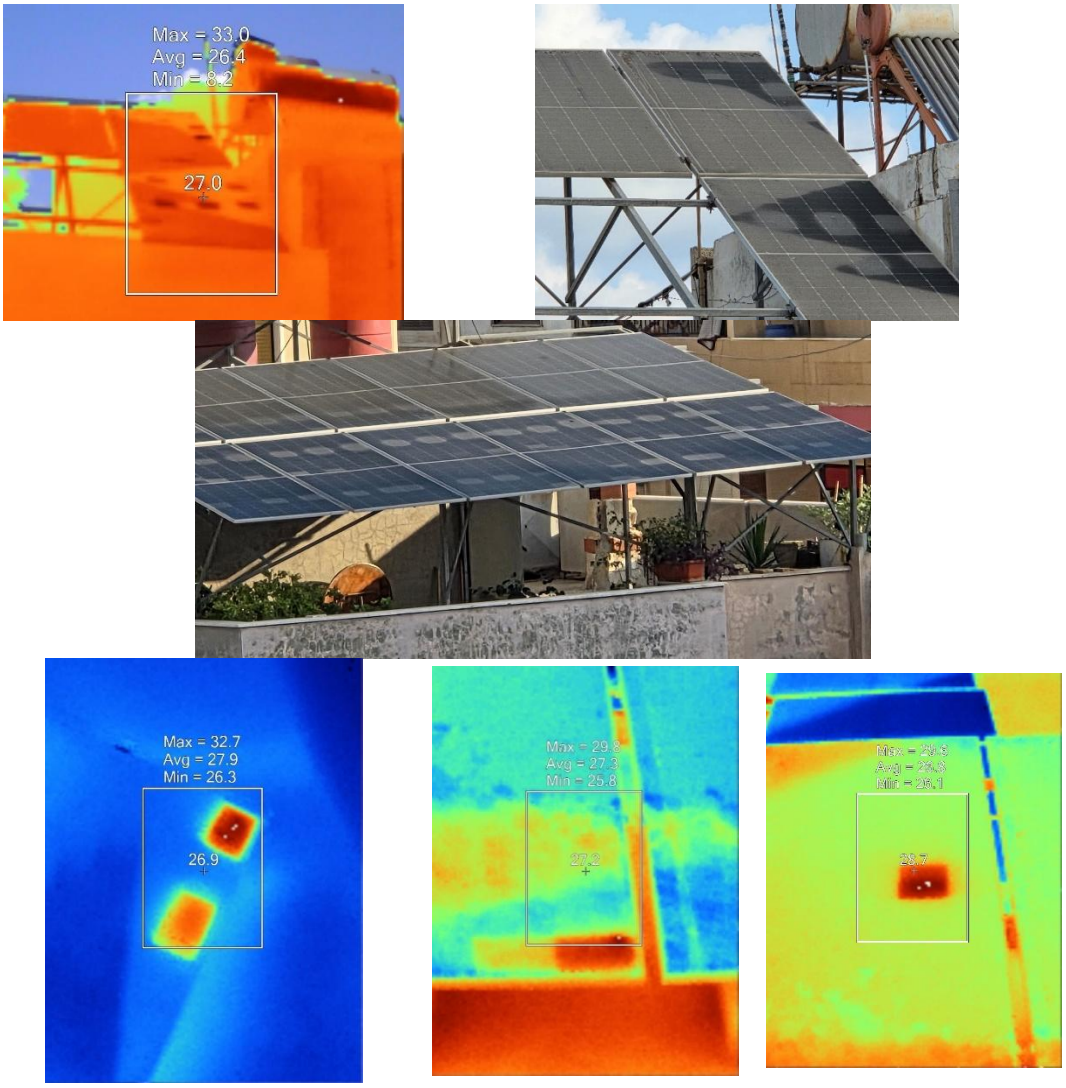


Figure 9 (a,b,c): Different nearby rooftop PV solar systems in 9/9/2025

3.3.1. Measurement number 2:

Day 13/9/2025: A sunny, high humidity day, the 1.665 kW PV solar system:

Back to 1.665 kW PV system in 13/9/2025, we noted the increasing in the number of colored cells, as showed in Figure (10, a). We have cleaned the panel number 3, in order

to clear the effect of dust in this phenomenon. Figure (10, b) shows the temperature matrix of panels number 1 and 2.



a

6	5	4	3	2	1	[2]
						1
						2
						3
28.2	27.9	27.9	27.9		27.9	4
28.8	27.9	27.9	27.9	28.5	27.9	5
28.1	27.9	27.9	27.9	27.9	28.4	6
						7
						8
						9
						10
						11
						12
						1
						2
						3
						4
						5
						6
						7
						8
						9
						10
27.8	28.8	27.8	27.8	27.8	28.5	11
27.8	28.9	28.9	28.9	28.8	29.3	12

6	5	4	3	2	1	[1]
						1
	28.5	29				2
	28.1	28.1	28	29.1	27.9	3
28.7	28	27.9	28	28.2	27.9	4
28.5						5
						6
						7
						8
						9
						10
						11
						12
						1
						2
						3
						4
						5
						6
						7
						8
						9
28.5	28.7	28.1	28	28	28	10
30.3	29.5	29.7	29.3	29.2	29.2	11
30.4	29.8	30.4	29.3	30.4	29.9	12

b

Figure 10 (a,b) The 1.665 kW PV solar system in 13/9/2025

The weather parameters (temperature, humidity, Dew point, Atmospheric pressure, Ultra-Violet (UV)) were recorded in 13/9/2025 measuring day at the morning and afternoon durations. The recording was taken while the phenomenon was appearing on

the panels. It was noticed that the phenomenon was disappeared when the sunlight was directly fallen on the panel's surfaces.

Table 4, shows the weather records in 13/9/2025 during morning, while the phenomenon appeared. The coloring phenomenon was standing till 09:14 am, when the sunlight has become directly with the panel's surfaces.

Table 4: Weather records in 13/9/2025 during morning

Time (am)	UV	Atmospheric pressure (m bar)	Dew point ◦	Humidity %	Temperature C°	Notes
07:15	0	1011.8	18	73	24	Phenomenon started to appear
07:54	0	1011.8	19	69	25	phenomenon spread
08:04	1	1011.8	19	68	26	Phenomenon stared to disappear on the panels with direct sunlight on surfaces
08:14	1	1011.8	19	68	26	//
08:24	1	1011.8	19	67	26	//
08:34	1	1011.8	19	66	26	//
08:44	2	1011.8	19	65	27	//
08:54	2	1012.2	19	64	27	//
09:04	3	1012.2	19	63	27	//
09:14	3	1012.2	20	62	28	Sunlight was direct on all the PV panels, so the phenomenon was dis appeared

Table 5, shows the weather records in 13/9/2025 during afternoon, while the phenomenon was appearing.

Table 5: Weather records in 13/9/2025 during afternoon

Time (pm)	UV	Atmospheric pressure (m bar)	Dew point ◦	Humidity %	Temperature C°	Notes
06:15	0	1011.8	18	73	24	phenomenon started to appear
06:30	0	1011.8	19	69	25	phenomenon spread
06:35	1	1011.8	19	68	26	phenomenon stared to disappear in some PV systems
06:40	1	1011.8	19	68	26	It is sunset, no longer sunlight, so the phenomenon was disappeared

The sunset duration is shorter than the sunrise duration, so the phenomenon last for a longer time in the morning.

3.3.3. Measurement number 3:

Day 20/9/2025: A sunny, low humidity (dry) day:

It was a sunny dry day in 20/9/2025, where the humidity was lower than 35%. It has been noted that the phenomenon did not appear.

Table 5, shows the weather parameters in 20/9/2025 in the morning duration.

3.3.4. Measurement number 4:

Day 23/9/2025: A sunny, low humidity (dry) day:

For the next few dry days, the phenomenon did not appear.

Table 6: shows the weather parameter in 23/9/2025, in the morning, where the phenomenon did not appear.

Table 6: Weather records in 20/9/2025 during the morning

Time (am)	UV	Atmospheric pressure (m bar)	Dew point ◦	Humidity %	Temperature C°	Notes
07:15	0	1012.2	8	35	25	Phenomenon did not appear
07:30	0	1012.2	8	35	25	//
07:45	0	1012.2	9	35	25	//
08:00	1	1012.2	9	35	26	//
08:15	1	1012.2	9	35	26	//
08:30	2	1012.5	9	34	26	//
08:45	2	1012.5	9	34	26	//
09:00	2	1012.5	9	33	27	//
09:15	3	1012.5	9	32	27	//

3.3.5. Measurement number 5:

Day 24/9/2025: A sunny, high humidity day:

The phenomenon reappeared.

Table 7: shows the weather parameter in 24/9/2025, in the morning and the afternoon, where the phenomenon started to appear.

Table 7: Weather records in 23/9/2025 during the morning

Time (am)	UV	Atmospheric pressure (m bar)	Dew point ◦	Humidity %	Temperature C◦	Notes
08:30	2	1011.2	17	40	28	Phenomenon did not appear

When the humidity was 50% and above, the phenomenon was appeared.

3.3.6. Measurement number 6:

Day 25/9/2025: A sunny, high humidity day:

Table 8: shows the weather parameter in 24/9/2025, in the morning, where the phenomenon started to appear.

Table 8: Weather records in 24/9/2025 during the morning and the afternoon

Time	UV	Atmospheric pressure (m bar)	Dew point ◦	Humidity %	Temperature C◦	Notes
07:30 am	0	1011.8	16	56	25	Phenomenon appeared
07:45 am	0	1012.2	17	58	26	//
08:00 am	1	1012.2	17	59	27	//
06:15 pm	0	1009.8	21	68	27	//
06:30 pm	0	1009.8	21	69	27	//

From Table 7, we could console that the humidity is not the only condition for this phenomenon appearing, the fallen sunlight on the panel surfaces is another condition.

In 26/9/2025, it was a very high humidity day (more than 77%), so the phenomenon spread and exceeded the geometric boundaries of the cells. The temperature was 26◦, the dew point was 22 ◦.

When the humidity is more than 75%, the phenomenon spread and exceeded the geometric boundaries of the cells.

4 .Conclusions

This study addresses the phenomenon of white spots that appear on the surfaces of PV cells in rooftop solar systems in the coastal strip of Tartous city under specific environmental conditions. This phenomenon was studied over a period of four months during the summer season with practical measurements. Based on measurements and observations, it has been determined that this phenomenon is related to multiple factors that must coexist for it to manifest.

The results demonstrate a clear correlation between the appearance of the white spotting phenomenon and environmental parameters, notably high humidity levels and elevated temperatures (>45°C). The absence of direct solar radiation during the morning and pre-sunset periods, when the solar radiation strikes the panels at a lower angle, is a primary factor in the occurrence of this phenomenon. Direct solar radiation on the panel surface prevents its appearance. Furthermore, it was found that this phenomenon must be accompanied by high humidity levels, exceeding 50%, as the humidity was below 50% despite the presence of solar radiation.

When the humidity is more than 75%, the phenomenon spread and exceeded the geometric boundaries of the cells. In dry days with low humidity (less th50%), the phenomenon does not appear.

This phenomenon exhibits a dynamic time pattern, as it has been observed that the duration of this phenomenon during the morning period is longer as long as there is a decrease in the intensity of solar radiation, and it disappears as the intensity of radiation increases with the progress of the day and the angle of its fall on the surface of the panels changes, in addition to the evaporation of the condensed moisture on the surface of the panels It was also observed that this phenomenon is reversible, fading with direct exposure to sunlight and cleaning of the panel surfaces.

When high humidity and high temperature conditions combine, white spots may spread beyond the geometric boundaries of individual cells, taking on irregular and curved shapes instead of a precise rectangular form. This suggests that condensation of moisture and accumulation of heat contribute to the spread of this phenomenon.

The emergence of the phenomenon is related to with more than 5kWh of the shortwave solar energy, particularly during the morning and evening periods before sunset, and also related to the solar azimuth (20°-35°), the dew point (17°-21°) and the temperature (25°-28°) during the morning hours and solar azimuth (0°-10°), dew point (18°-21°) and temperature (24°-27°) during the evening hours.

Elevated temperatures in cells affected by spotting indicate the presence of greenhouse heat, possibly due to dust accumulation, which acts as an insulating layer preventing heat exchange and causing localized heating. This aligns with prior studies emphasizing dust as a critical factor in thermal degradation and performance loss in PV cells.

Infrared thermography revealed that affected within white spots cells tend to have temperatures approximately 2°C higher than the surrounding uncolored cells

The results showed that the Ultraviolet and the atmospheric pressure have no role in the phenomenon .

There can be an interaction. Dust particles, humidity, and solar radiation can influence surface charge distributions on solar panels. For instance, dust particles can become electrostatically charged, and humidity can facilitate charge accumulation or redistribution on the surface. These electrostatic effects might influence phenomena like dirt adhesion or localized electric fields, which can, in turn, affect the cell's performance or surface appearance. However, the primary visual changes (such as whitening) are more directly linked to physical and chemical alterations rather than charge accumulation alone, unless there's a specific electrostatic discharge or corrosion process involved.

5 .Implications and Recommendations

The study results indicate that the white spot phenomenon is caused by complex interactions between high humidity levels, temperature, dust accumulation, and solar radiation conditions. Its reversibility means that regular cleaning and maintenance can mitigate its negative effects, such as the increased temperature of affected cells.

However, it is necessary to conduct a study of the electrical parameters of the exposed panels, and a potential induced degradation in PV modules due to this phenomenon when lasting for a long time.

References

[1] A. Jain, S. Kumar, and R. Singh, "Partial shading detection and hotspot prediction in photovoltaic systems based on numerical differentiation and integration of the P–V curves," Renewable Energy, vol. 132, pp. 603–612, 2019.

[2] Y. Li, H. Zhang, and J. Wang, "The effect of partial shading on the reliability of photovoltaic modules in the built-environment," Solar Energy Materials & Solar Cells, vol. 212, p. 110533, 2020.

[3] R. Mishra, D. Patel, and S. Sinha, "Temperature and reverse voltage across a partially shaded Si PV cell under hot spot test condition," IEEE Journal of Photovoltaics, vol. 10, no. 4, pp. 1124–1132, 2020.

[4] P. Kumar, R. Singh, and S. Sinha, "Review of mismatch mitigation techniques for PV modules," IEEE Journal of Photovoltaics, vol. 12, no. 1, pp. 123–135, 2022.

[5] Zhang, Y. Wang, and Z. Chen, "Study of manufacturing and hotspot formation in cut cell and full cell PV modules," Applied Energy, vol. 283, p. 116287, 2021.

[6] Q. Liu, Y. Wang, and Z. Chen, "Comparative Analysis of Hotspot Stress Endurance in Pristine and Thermal Cycled Prestressed Glass–Glass Photovoltaic Modules," Renewable Energy, vol. 200, pp. 1235–1244, 2023.

[7] Badran, Ghadeer, and Mahmoud Dhimish. 2023. "Potential Induced Degradation in Photovoltaic Modules: A Review of the Latest Research and Developments" Solar 3, no. 2:322-346. https://doi.org/10.3390/solar3020019.

[8] Yadav A, Kumar A, K. M. "Performance impact of environmental and operational factors on solar photovoltaic panels". Environ Prog Sustainable Energy. 2025; 44(6):e70062. doi:10.1002/ep.70062.

[9] M. Waqar Akram, et.al, "Study of manufacturing and hotspot formation in cut cell and full cell PV modules", Solar Energy, Volume 203,2020,Pages 247-259,https://doi.org/10.1016/j.solener.2020.04.052.

[10] Olusola Bamisile, et. al, "The environmental factors affecting solar photovoltaic output", Renewable and Sustainable Energy Reviews, Volume 208,2025, 115073,https://doi.org/10.1016/j.rser.2024.115073.

[11]A. Elbaz and A. K. Elfaqih, "Impact of Dust Accumulation on Photovoltaic System Performance in a Coast Environment-Case Study in Libya," 2023 IEEE 11th International

Conference on Systems and Control (ICSC), Sousse, Tunisia, 2023, pp. 959-963, doi: 10.1109/ICSC58660.2023.10449762.

[12] Almukhtar, H.; Lie, T.T.; Al-Shohani, et.al. "Comprehensive Review of Dust Properties and Their Influence on Photovoltaic Systems: Electrical, Optical, Thermal Models and Experimentation Techniques", Energies, 2023, 16, 3401. https://doi.org/10.3390/en16083401.

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