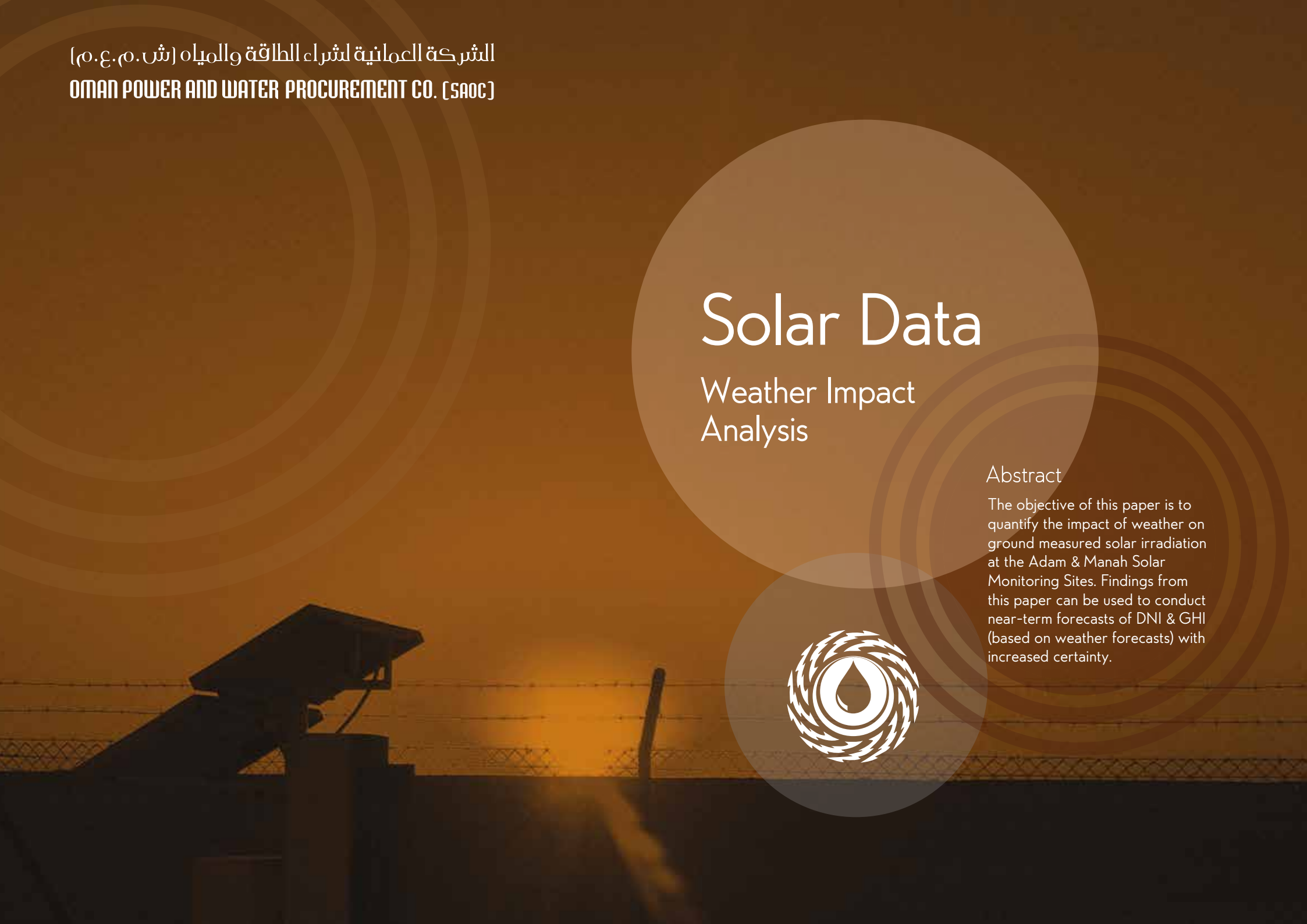
الشركة العمانية لشراء الطاقة والمياه (ش.م.ع.م)
OMAN POWER AND WATER PROCUREMENT CO. (SAOC)

Solar Data

Weather Impact Analysis

Abstract

The objective of this paper is to quantify the impact of weather on ground measured solar irradiation at the Adam & Manah Solar Monitoring Sites. Findings from this paper can be used to conduct near-term forecasts of DNI & GHI (based on weather forecasts) with increased certainty.



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Introduction

This paper is provided as supported material to the previous Solar Reports available on the Oman Power & Water Procurement ("OPWP") website and aims to publicize a closer look that was taken into the measured Solar Data for 2013[1] by reviewing the measured monthly trend, and correlate any discrepancies in the data with cloud cover as was captured by satellite infrared imagery [2].

Analysis of the data in this paper begins on the month upon re-introducing the equipment back onto site post conducting the required re-calibration and repair works.

The purpose behind this paper is to establish a link between the measureable, ground-available Direct Normal Irradiance ("DNI") & Global Horizontal Irradiance ("GHI") data from the Adam & Manah weather stations, with the amount of cloud cover in the area during the period of interest. Amongst the benefits of establishing this link would be the ability to predict the availability of DNI & GHI based on forecasted weather conditions. The methodology to determine this is by establishing numeric estimate of what the GHI & DNI should have been had there not been any variations detected, and this estimate is calculated by following the increase & decrease in measured solar radiation data and also to take into account the maximum measured solar radiation for the closest day that is not affected by clouds and overcast.

Alongside the above mentioned, and as part of the report to summarize the Solar Data, the following parameters will be included in the month-by-month analysis:

1. Max measured DNI & GHI in W/m^2.
2. GHI & DNI measured in $kWh/m^2/day$.

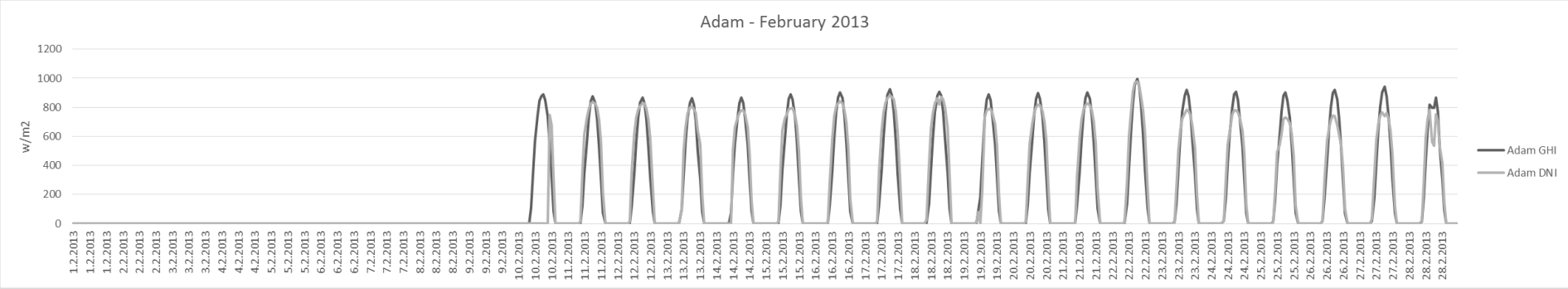
For further information on the status of the Solar Project and/or the steps taken since the commencement of the feasibility study that was initiated by the Public Authority for Electricity and Water, please refer back to the previous Solar Reports that are available on the OPWP website.

All the raw Solar Data from the beginning of 2011 as measured by the Adam & Manah weather monitoring stations can also be found on the OPWP website.

[1] Solar Data is available from January 2011 and will be routinely updated on the company's' website (www.omanpwp.com) as they become available to OPWP.
[2] All satellite imagery were captured from Weather Underground archives and is publically available.

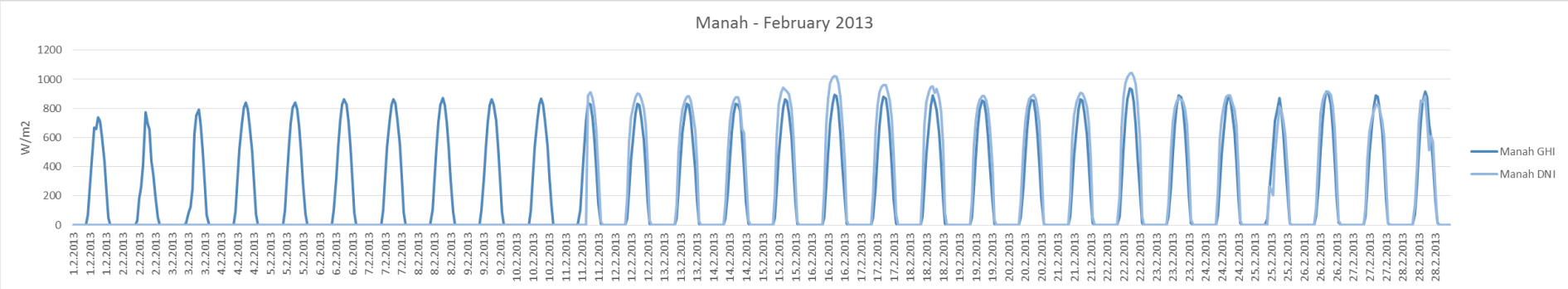
February

The following graphs show the measured solar data for the month of February for both Adam & Manah:



Max measured DNI (W/m²)	975.71
Max measured GHI (W/m²)	993.79

Monthly average DNI in (kWh/m2/day)	6.82
Monthly average GHI in (kWh/m2/day)	6.17



Max measured DNI (W/m²)	1044.73
Max measured GHI (W/m²)	936.38

Monthly average DNI in (kWh/m2/day)	7.51
Monthly average GHI in (kWh/m2/day)	5.74

Weather Impact

DNI & GHI data for both Adam & Manah station shows a consistent trend throughout the month, which implies that for most of the month, no adverse weather conditions impacted the site.

The only day that showed a slight variation was on the 28th of February. The image below is the satellite infrared imagery for that day and shows mild overcast and cloud cover. This can be attributed to the cause of the variation in the data – more noticeable in Adam's DNI measurements.

Date	Station	Expected DNI (kWh/m2/day)	Actual DNI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)	Expected GHI (kWh/m2/day)	Actual GHI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) - %
28.2.2013	Adam	6.57	6.05	0.43 (7.9%)	6.51	6.23	0.28 (4.3%)
28.2.2013	Manah	6.89	6.45	0.44 (6.4%)	6.12	6.08	0.04 (0.7%)

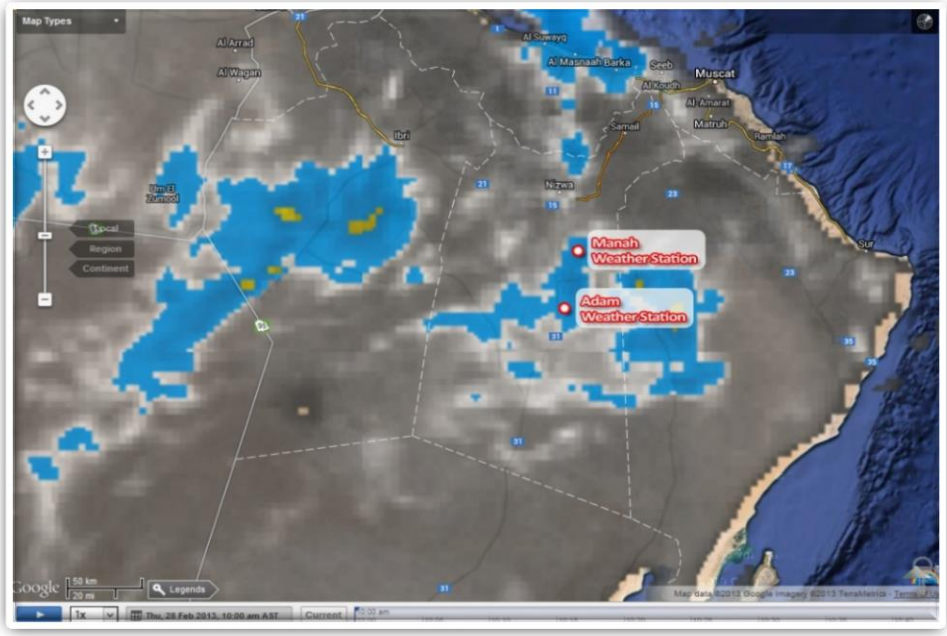
Measured Precipitation in February

Total Measured Precipitation in February (mm)	0

Comments

It's worth to note that the DNI measurement devices were re-installed back on-sites on the 10th & 11th of February and that OPWP didn't have direct access to the data logging system prior to that day. Due to this, the following can be observed:

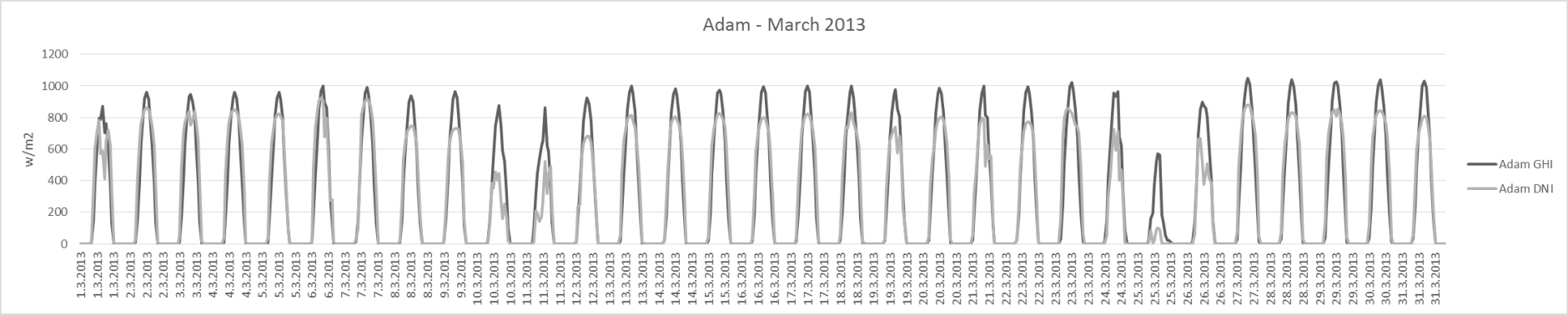
1. DNI & GHI data (except for Manah GHI) prior to 10th & 11th of February is unavailable (due to factors out of OPWP's control).



28th of February

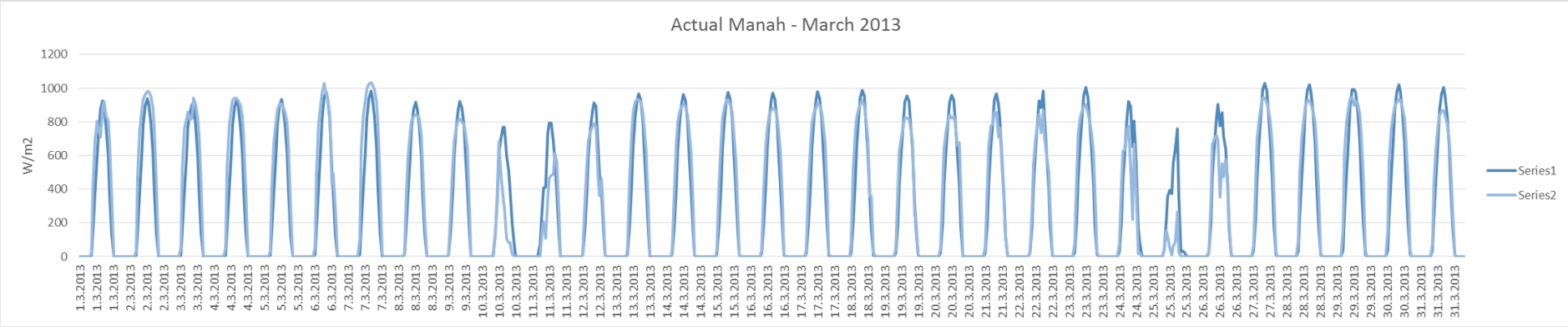
March

The following graphs show the measured solar data for the month of March for both Adam & Manah:



Max measured DNI (W/m²)	922.85
Max measured GHI (W/m²)	1048.93

Monthly average DNI in (kWh/m2/day)	6.56
Monthly average GHI in (kWh/m2/day)	6.78



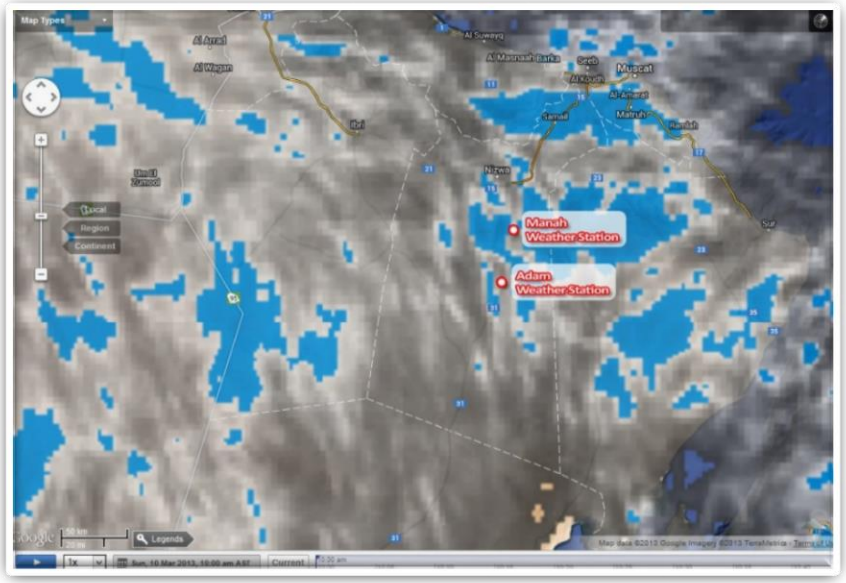
Max measured DNI (W/m²)	1035.08
Max measured GHI (W/m²)	1027.15

Monthly average DNI in (kWh/m2/day)	7.32
Monthly average GHI in (kWh/m2/day)	6.64

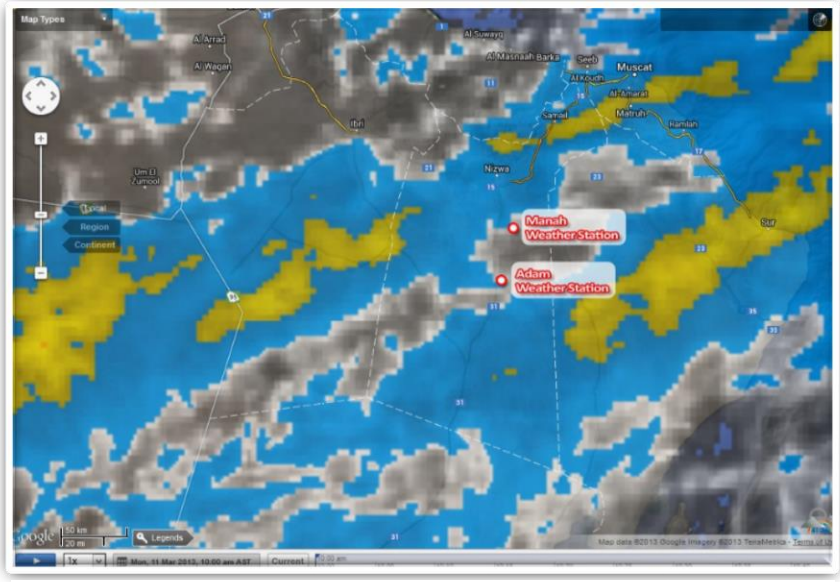
Weather Impact

While a majority of the month showed steady and consistent readings, a few days during the month of March was subject to fluctuations in the measured solar data. The fluctuations measured occurred during the 10th and 11th due to cloud cover and overcast. Fluctuations in the measured solar data were also observed during the 25th and the 26th, and this was due to rainfall that was measured in both the Adam & Manah areas. These statements are further supported by the following satellite infrared imagery:

Date	Station	Expected DNI (kWh/m2/day)	Actual DNI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)	Expected GHI (kWh/m2/day)	Actual GHI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)
1.3.2013	Adam	7.61	6.41	1.20 (15.8%)	6.74	6.19	0.55 (8.2%)
1.3.2013	Manah	8.43	7.87	0.56 (6.6%)	6.59	6.38	0.21 (3.2%)
10.3.2013	Adam	6.33	3.05	3.28 (51%)	6.77	5.82	0.95 (14%)
10.3.2013	Manah	7.16	2.65	4.51 (63%)	6.53	5.13	1.40 (21.4%)
11.3.2013	Adam	6.41	3.02	3.39 (52.6%)	6.78	5.28	1.50 (22.1%)
11.3.2013	Manah	7.17	3.70	3.47 (48.4%)	6.52	5.27	1.25 (19%)

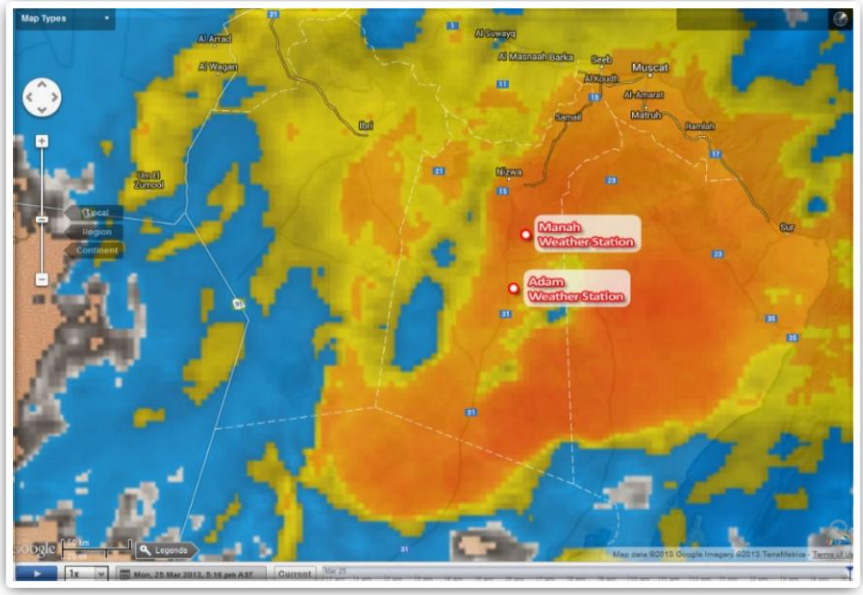


10th of March

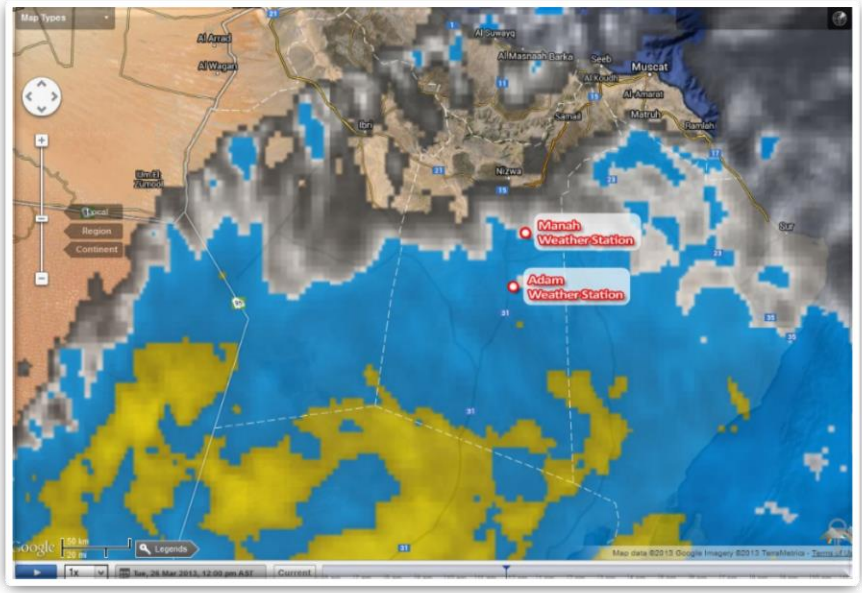


11th of March

Date	Station	Expected DNI (kWh/m2/day)	Actual DNI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)	Expected GHI (kWh/m2/day)	Actual GHI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) - %
25.3.2013	Adam	8.26	0.40	7.86 (95.2%)	7.68	2.82	4.86 (63.3%)
25.3.2013	Manah	8.48	0.81	7.67 (90.4%)	7.46	3.77	3.69 (49.5%)
26.3.2013	Adam	8.26	4.55	3.71 (44.9%)	7.68	6.68	1.0 (13.0%)
26.3.2013	Manah	8.48	5.76	2.72 (32.1%)	7.47	6.67	0.8 (10.7%)



25th of March



26th of March

Measured Precipitation in March

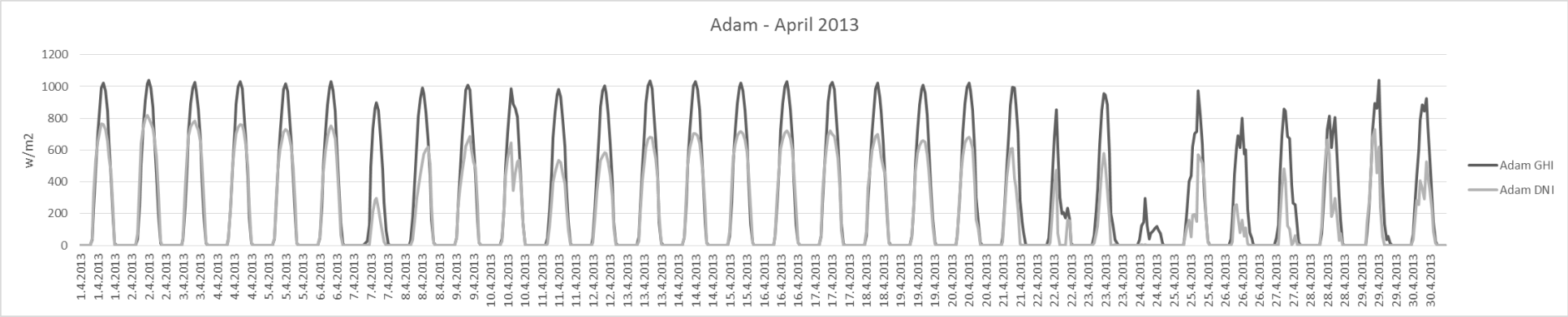
Adam		Manah	
Date	**Precipitation (mm)**	**Date**	**Precipitation (mm)**
25.3.2013	8.8	25.3.2013	5.8
26.3.2013	0.4	26.3.2013	0.2
Total	9.2	**Total**	6.0

Comments

The month of March signifies the first complete month in which all the equipment in both the Adam & Manah station were re-installed and were working as per initially intended.

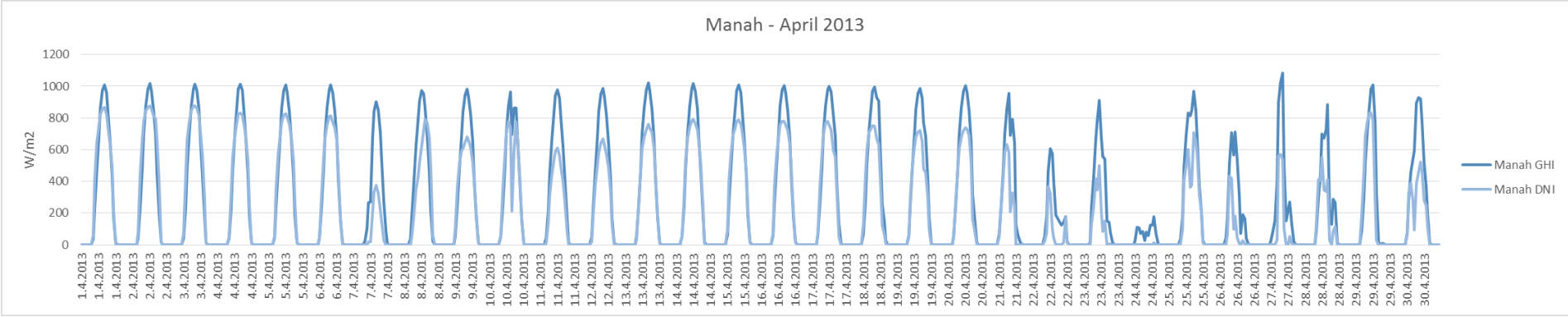
April

The following graphs show the measured solar data for the month of April for both Adam & Manah:



Max measured DNI (W/m²)	818.63
Max measured GHI (W/m²)	1041.97

Monthly average DNI in (kWh/m2/day)	4.51
Monthly average GHI in (kWh/m2/day)	6.61



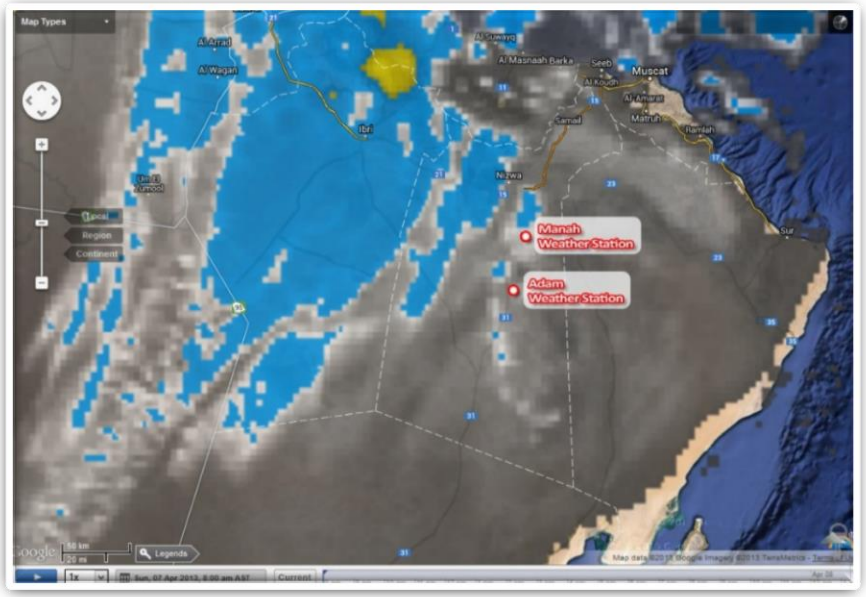
Max measured DNI (W/m²)	878
Max measured GHI (W/m²)	1084

Monthly average DNI in (kWh/m2/day)	4.98
Monthly average GHI in (kWh/m2/day)	6.43

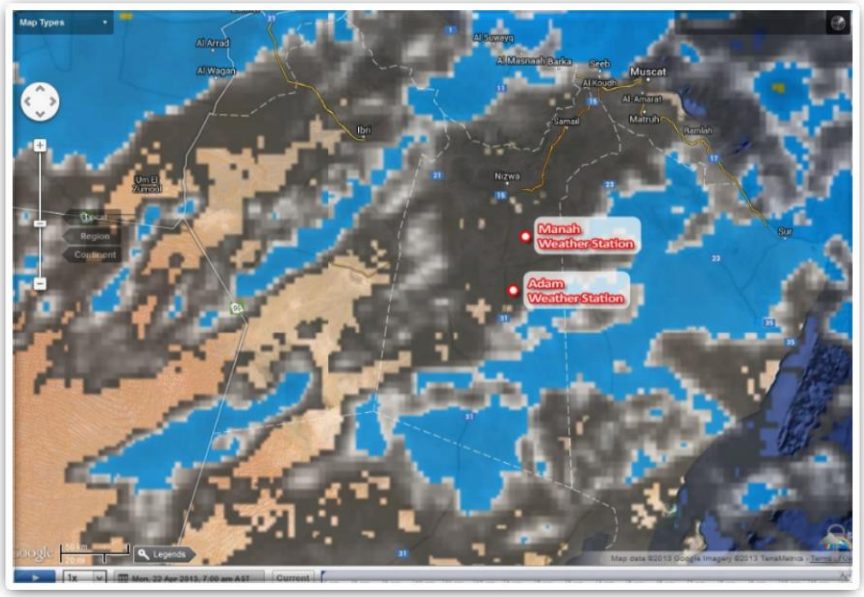
Weather Impact

During the month of April, notable adverse weather conditions played a part in affecting the ground-measured data – especially during the final week of April. The storm that covered the area for almost a week was large enough and stable enough to affect both Adam & Manah station with equal consistency. GHI measurements dropped by an average of 35%, and while DNI was also affected by the storm formations, it was affected on a greater scale with measurements dropping as low as 99.7%, with an average of 64% loss in measured solar energy during the period of the storm. However, this was not the only instance of weather impact on the stations during the month of April as fluctuations on the data were also observed during the 7th of April.

Date	Station	Expected DNI (kWh/m2/day)	Actual DNI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)	Expected GHI (kWh/m2/day)	Actual GHI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) - %
07.4.2013	Adam	6.25	1.36	4.89 (78.2%)	7.37	5.53	1.84 (25.0%)
07.4.2013	Manah	6.75	1.67	5.08 (75.3%)	7.33	5.54	1.79 (24.4%)
22.4.2013	Adam	6.28	1.46	4.82 (76.8%)	7.55	4.06	3.49 (46.2%)
22.4.2013	Manah	6.87	1.14	5.73 (83.4%)	7.47	3.24	4.23 (56.6%)

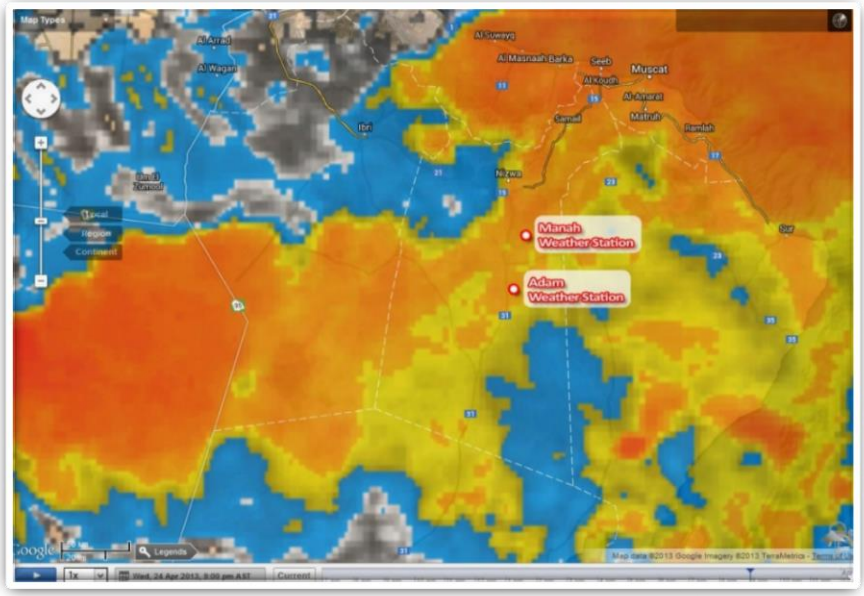


7th of April

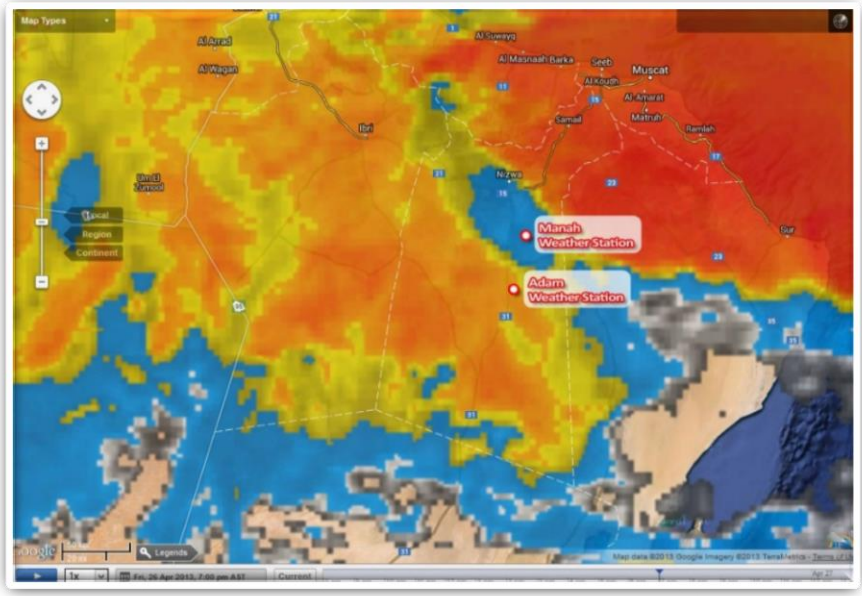


22nd of April

Date	Station	Expected DNI (kWh/m2/day)	Actual DNI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)	Expected GHI (kWh/m2/day)	Actual GHI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) - %
23.4.2013	Adam	5.95	2.61	3.34 (56.1%)	7.53	5.86	1.67 (22.2%)
23.4.2013	Manah	6.81	2.08	4.73 (69.5%)	7.51	5.19	2.32 (30.9%)
24.4.2013	Adam	6.45	0.02	0.02 (99.7%)	7.53	1.34	6.19 (82.2%)
24.4.2013	Manah	6.76	0.02	0.02 (99.7%)	7.53	1.06	6.47 (85.9%)
25.4.2013	Adam	6.28	3.15	3.13 (49.8%)	7.59	6.13	1.46 (19.2%)
25.4.2013	Manah	6.87	4.78	2.09 (30.4%)	7.49	6.94	0.55 (7.3%)
26.4.2013	Adam	5.95	1.13	4.82 (81.0%)	7.52	4.90	2.62 (34.8%)
26.4.2013	Manah	6.81	1.27	5.54 (81.4%)	7.53	4.04	3.49 (46.3%)



24th of April



26th of April

Date	Station	Expected DNI (kWh/m2/day)	Actual DNI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)	Expected GHI (kWh/m2/day)	Actual GHI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) - %
27.4.2013	Adam	6.45	1.72	4.73 (73.3%)	7.53	5.38	2.15 (28.6%)
27.4.2013	Manah	6.76	1.87	4.89 (72.3%)	7.65	4.95	2.70 (35.5%)
28.4.2013	Adam	6.59	3.33	3.26 (49.5%)	7.60	5.60	2.00 (26.3%)
28.4.2013	Manah	6.90	2.82	4.08 (59.1%)	7.51	4.70	2.81 (37.4%)
29.4.2013	Adam	6.14	3.73	2.41 (39.3%)	7.55	5.75	1.80 (23.8%)
29.4.2013	Manah	7.39	4.89	2.50 (33.8%)	7.63	5.64	1.99 (26.1%)
30.4.2013	Adam	6.45	3.38	3.07 (47.6%)	7.59	6.53	1.06 (14.0%)
30.4.2013	Manah	6.80	3.62	3.18 (46.8%)	7.56	6.57	0.99 (13.1%)

28th of April

30th of April

Measured Precipitation in April

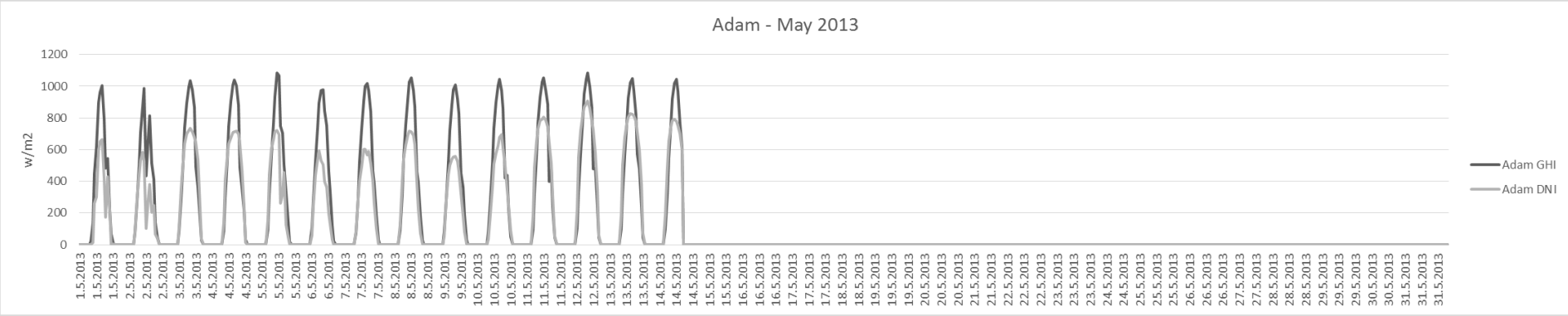
Adam		Manah	
Date	**Precipitation (mm)**	**Date**	**Precipitation (mm)**
07.4.2013	0.2	07.4.2013	0.0
22.4.2013	0.4	22.4.2013	0.0
23.4.2013	3.0	23.4.2013	3.6
24.4.2013	2.0	24.4.2013	3.0
26.4.2013	0.0	26.4.2013	0.2
28.4.2013	2.6	28.4.2013	33.8
29.4.2013	1.0	29.4.2013	17
Total	9.2	**Total**	57.6

Comments

No further comments given with regards to the month of April.

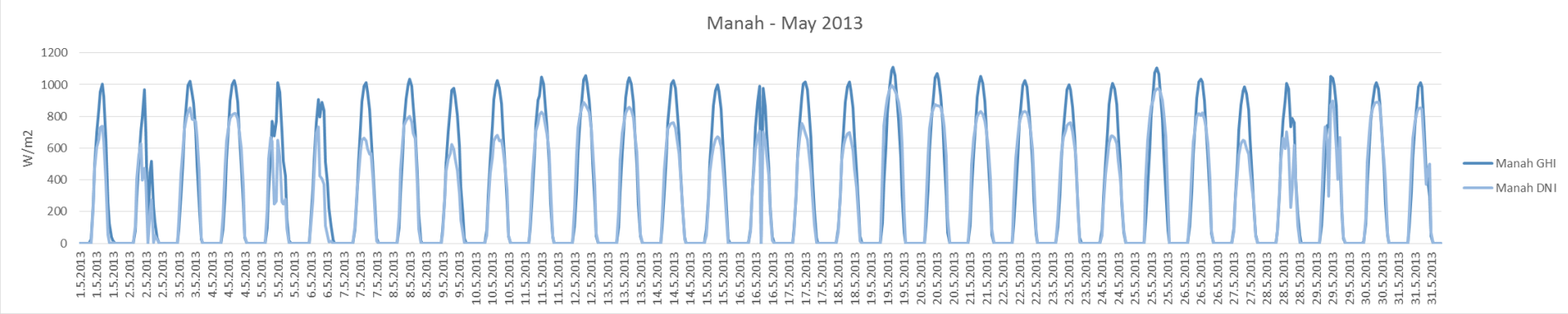
May

The following graphs show the measured solar data for the month of May for both Adam & Manah:



Max measured DNI (W/m²)	906
Max measured GHI (W/m²)	1084

Monthly average DNI in (kWh/m2/day)	5.79
Monthly average GHI in (kWh/m2/day)	7.33



Max measured DNI (W/m²)	995.47
Max measured GHI (W/m²)	1111.13

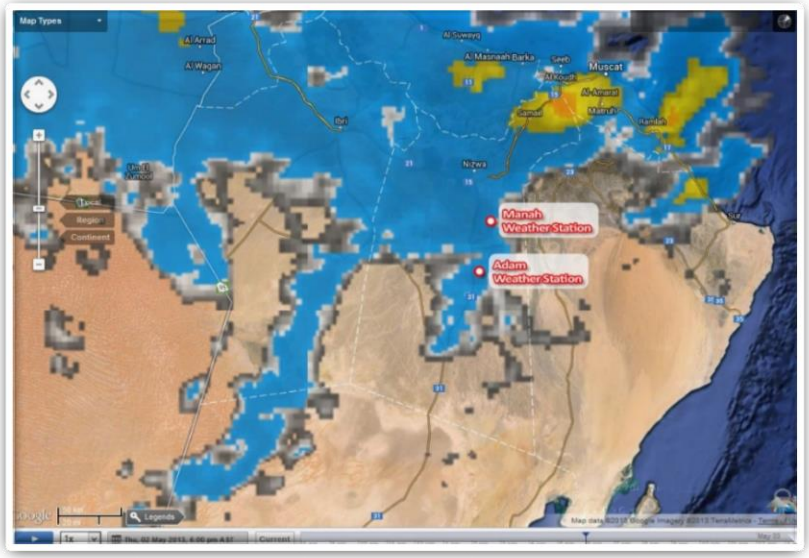
Monthly average DNI in (kWh/m2/day)	6.72
Monthly average GHI in (kWh/m2/day)	7.71

Weather Impact

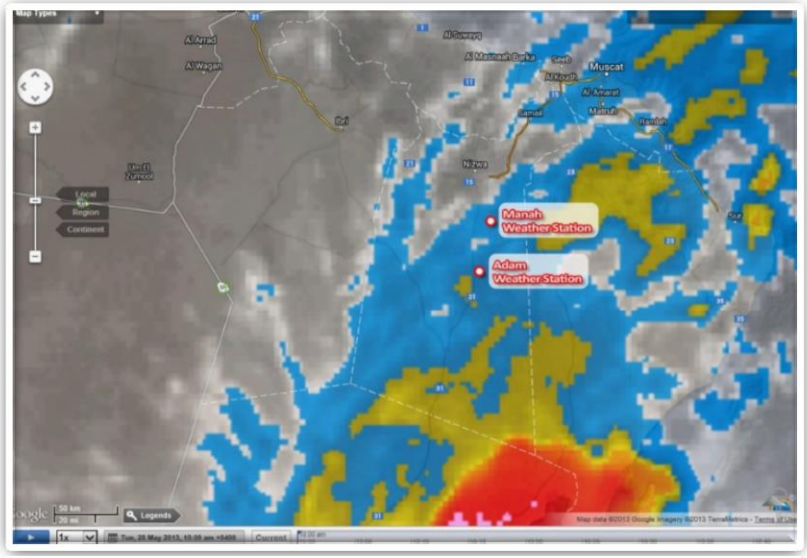
The beginning of May showed signs of cloud cover with slight rain on the 5th, which were most likely the remnants of the storm that hit the area towards the end of April.

The end of the month also showed signs of slight fluctuations, and this was due to a storming passing just south of the stations on around the 2of May.

Date	Station	Expected DNI (kWh/m2/day)	Actual DNI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)	Expected GHI (kWh/m2/day)	Actual GHI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) - %
2.5.2013	Adam	6.48	3.78	2.70 (41.7%)	7.33	6.45	0.88 (12.0%)
2.5.2013	Manah	7.31	3.52	3.79 (51.8%)	7.95	5.52	2.43 (30.6%)
5.5.2013	Adam	6.8	5.21	1.59 (23.4%)	8.16	7.25	0.91 (11.2%)
5.5.2013	Manah	7.9	4.65	3.25 (41.1%)	8.04	6.99	1.05 (13.1%)
28.5.2013	Adam	N/A	N/A	N/A	N/A	N/A	N/A
28.5.2013	Manah	8.2	5.19	3.01 (36.7%)	8.18	7.54	0.64 (7.8%)
29.5.2013	Adam	N/A	N/A	N/A	N/A	N/A	N/A
29.5.2013	Manah	8.68	7.05	1.63 (18.8%)	8.27	7.79	0.48 (5.8%)



2nd of Mav



28th of May

Measured Precipitation in May

Adam		Manah	
Date	**Precipitation (mm)**	**Date**	**Precipitation (mm)**
10.5.2013	0.2	10.5.2013	0.2
Total	0.2	**Total**	0.2

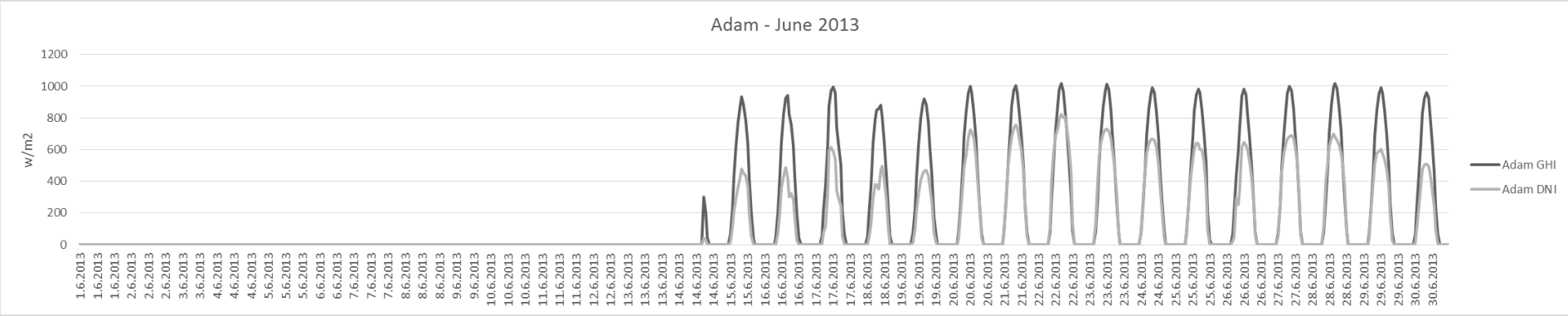
Comments

Due to events beyond OPWP's control, a portion of the data that was being collected during the month of May for the Adam station was lost. This was due to two main reasons: 1. Loss of remote connectivity to the sites for a period of time, 2. Malfunction in the back-up disk space with the unit on-site.

The sources of these issues were investigated and promptly resolved when discovered in the following month.

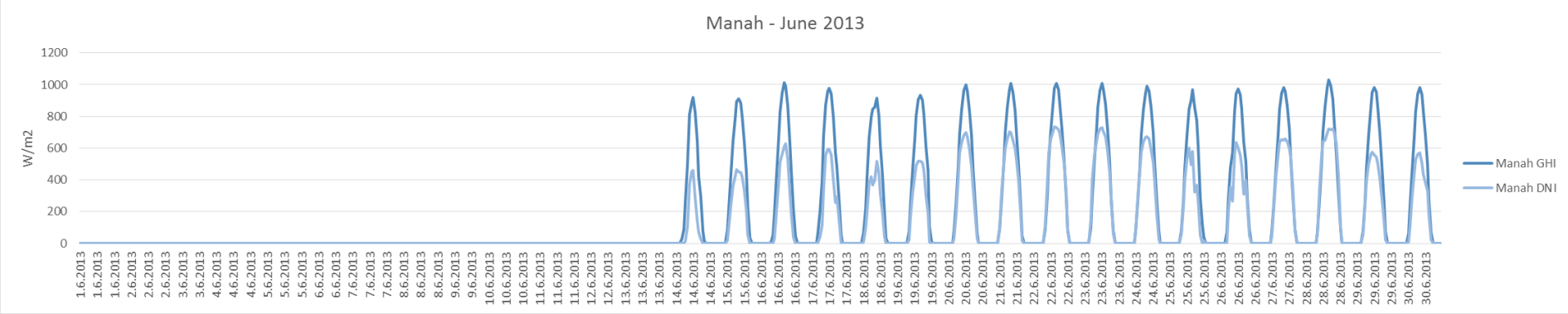
June

The following graphs show the measured solar data for the month of June for both Adam & Manah:



Max measured DNI (W/m²)	824
Max measured GHI (W/m²)	1020

Monthly average DNI in (kWh/m2/day)	5.09
Monthly average GHI in (kWh/m2/day)	7.43



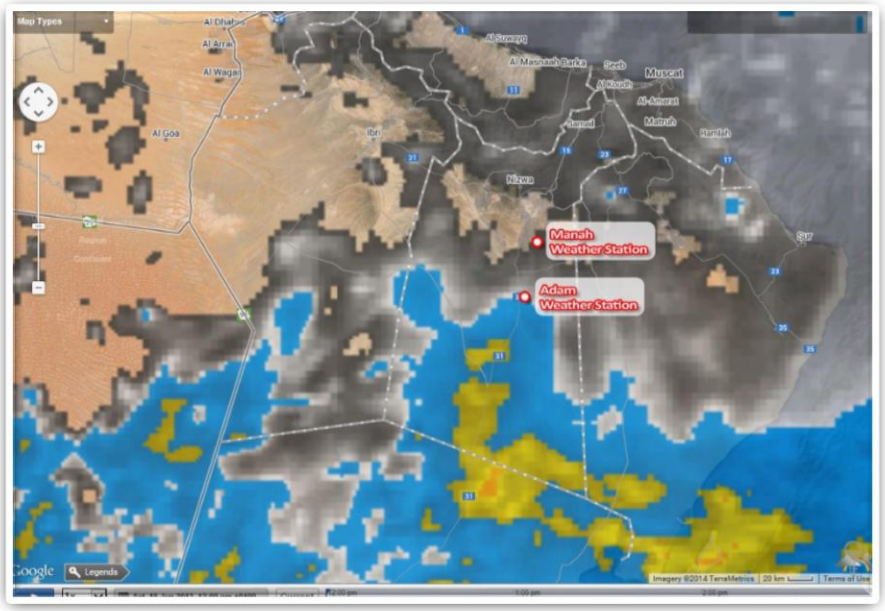
Max measured DNI (W/m²)	735
Max measured GHI (W/m²)	1030

Monthly average DNI in (kWh/m2/day)	4.83
Monthly average GHI in (kWh/m2/day)	7.37

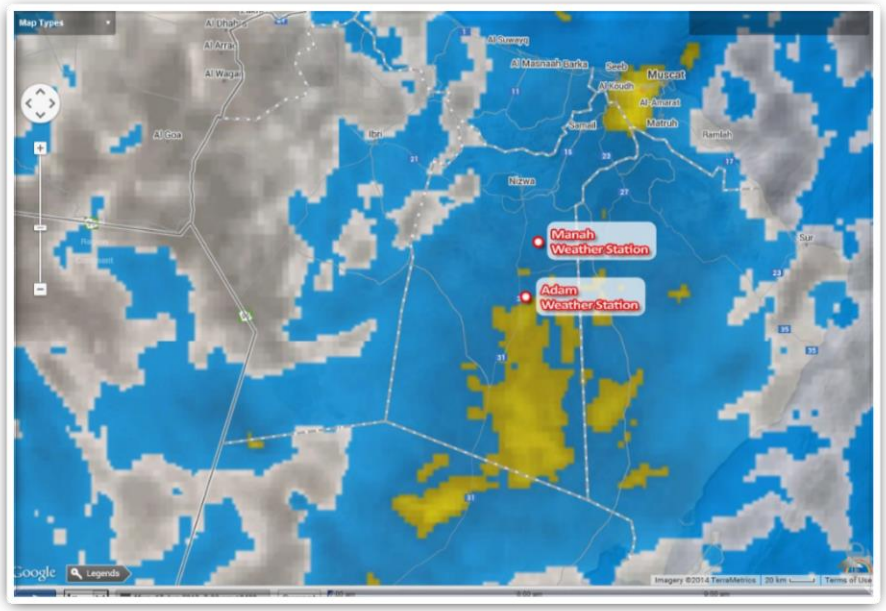
Weather Impact

The available solar data for the month of June shows no extreme decline in measured DNI or GHI. Rather, there is a consistent fluctuation in measured data during the period of the 15th to the 19th of June, this can be attributed to consistent overcast that was documented in the area during this period, along with slight rainfall on the 19th.

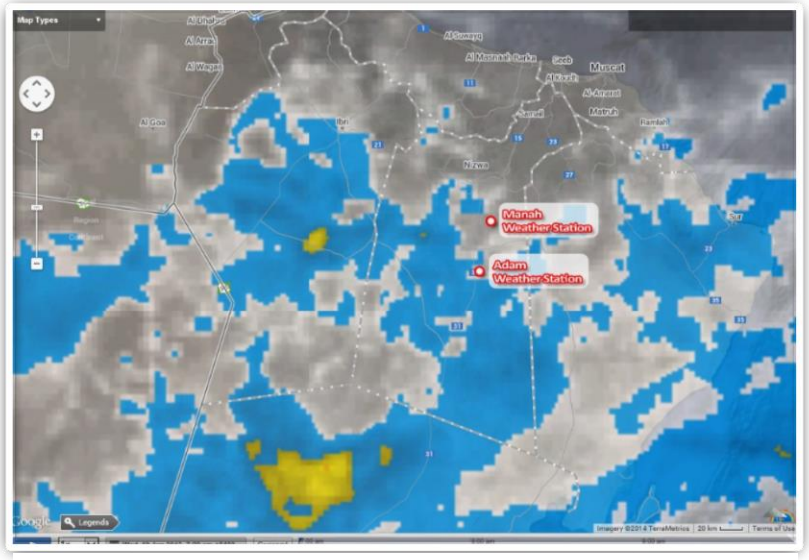
Date	Station	Expected DNI (kWh/m2/day)	Actual DNI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)	Expected GHI (kWh/m2/day)	Actual GHI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) - %
18.6.2013	Adam	4.13	3.30	0.83 (20.1%)	7.32	6.78	0.54 (7.4%)
18.6.2013	Manah	4.17	3.36	0.81 (19.4%)	7.37	6.85	0.52 (7.1%)



15th of June



17th of June



19th of June

Measured Precipitation in June

Adam		Manah	
Date	**Precipitation (mm)**	**Date**	**Precipitation (mm)**
19.6.2013	0.0	19.6.2013	0.2
Total	0.0	**Total**	0.2

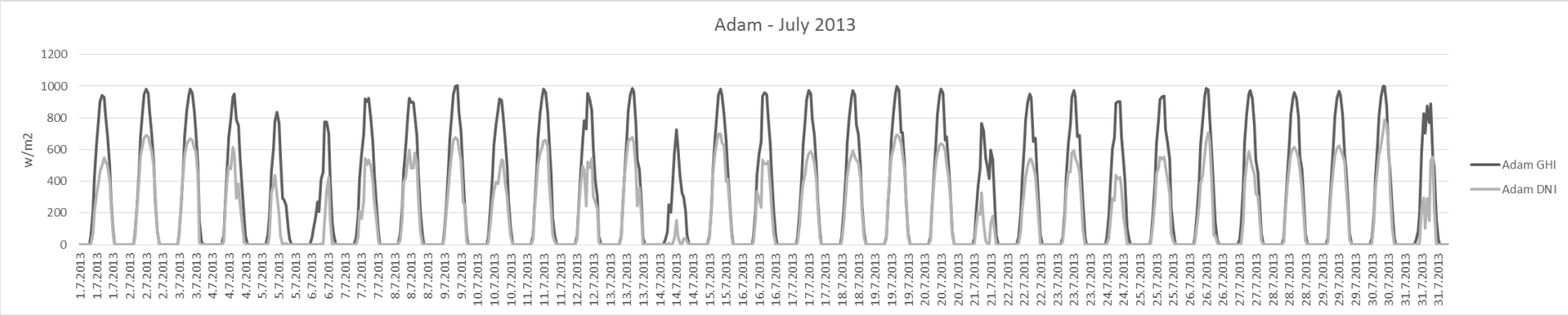
Comments

Halfway during the month of June, cause of the loss of remote-connectivity with the sites and the back-up disk space issue were identified and promptly resolved.

The "Monthly average DNI & GHI" were calculated based on the available data, and not based on the whole month. The justification for this is that there is currently no basis to model/estimate both GHI & DNI data for a single period, as such, the final two weeks average (in kWh/m^2/day) is taken to represent the entire month.

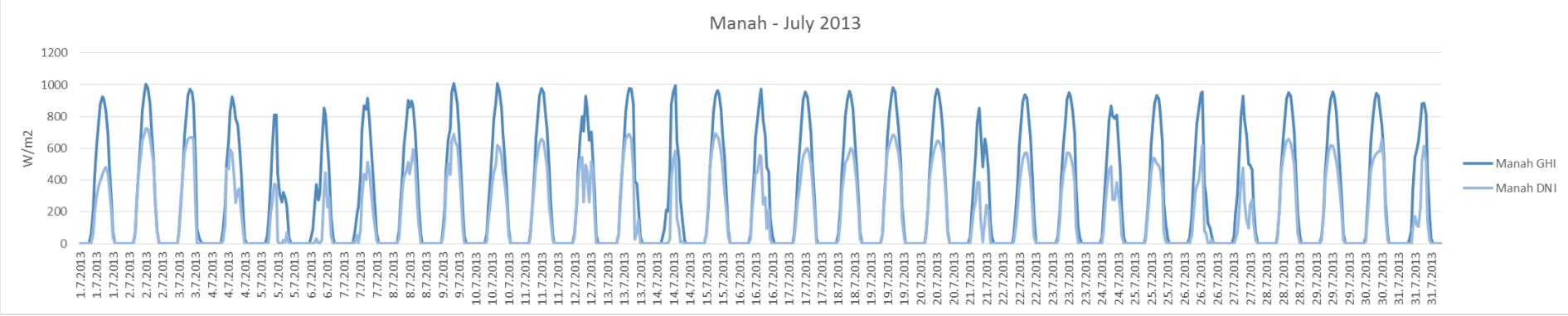
July

The following graphs show the measured solar data for the month of July for both Adam & Manah:



Max measured DNI (W/m²)	575.63
Max measured GHI (W/m²)	938.4

Monthly average DNI in (kWh/m2/day)	4.15
Monthly average GHI in (kWh/m2/day)	6.82



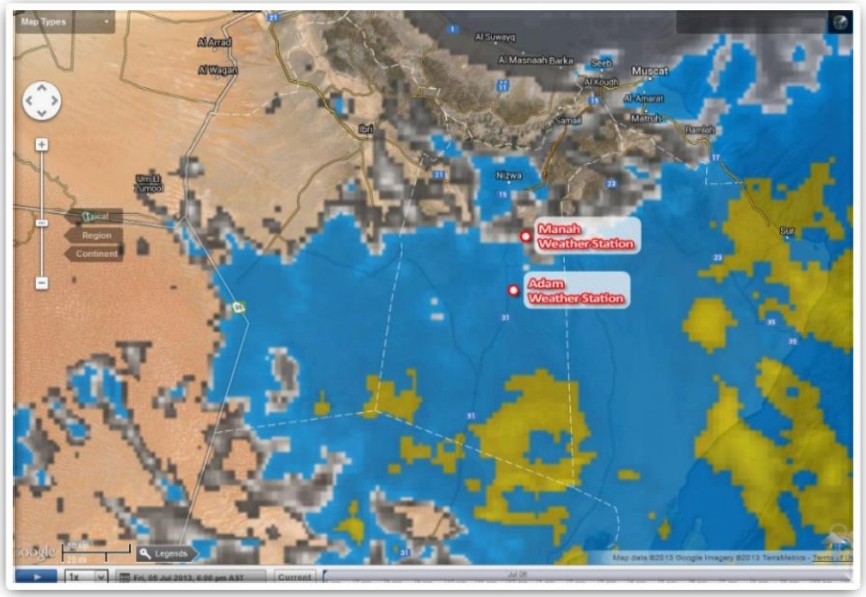
Max measured DNI (W/m²)	726.92
Max measured GHI (W/m²)	1008.6

Monthly average DNI in (kWh/m2/day)	4.03
Monthly average GHI in (kWh/m2/day)	6.77

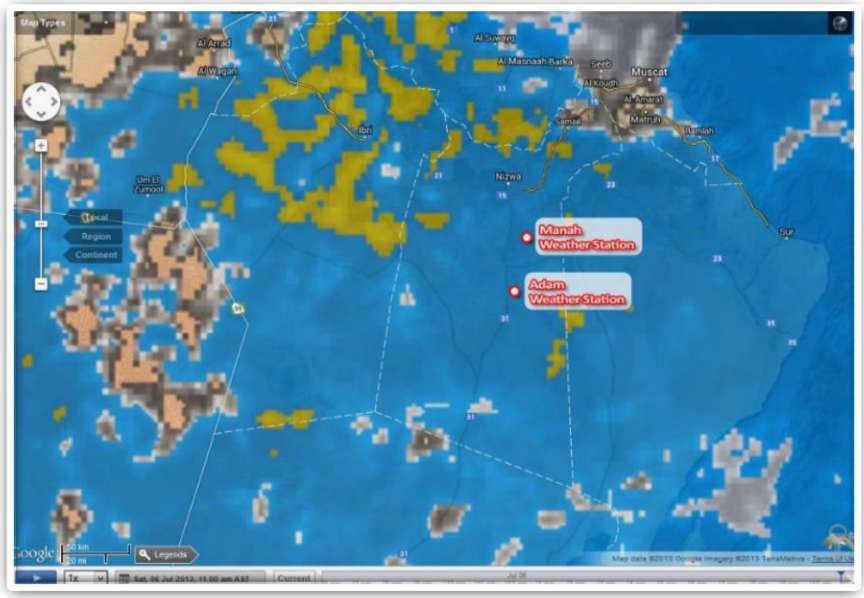
Weather Impact

It's observable from the measured DNI & GHI data that the month of July faced a greater-than-usual persistence of overcast & cloud-cover when compared to the previous months. During this month, the 5th, 6th, 14th, & the 31st proved to be the most affected.

Date	Station	Expected DNI (kWh/m2/day)	Actual DNI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)	Expected GHI (kWh/m2/day)	Actual GHI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) - %
5.7.2013	Adam	5.60	1.76	3.84 (68.6%)	7.44	5.20	2.24 (30.1%)
5.7.2013	Manah	6.30	1.32	4.98 (79.0%)	7.79	4.67	3.12 (40.1%)
6.7.2013	Adam	5.60	1.10	4.50 (80.4%)	7.47	4.53	2.94 (39.4%)
6.7.2013	Manah	6.30	1.41	4.89 (77.6%)	7.79	4.90	2.89 (37.1%)
14.7.2013	Adam	5.87	0.37	5.5 (93.7%)	7.43	4.18	3.25 (43.7%)
14.7.2013	Manah	5.69	1.84	3.85 (67.7%)	7.58	5.44	2.14 (28.2%)

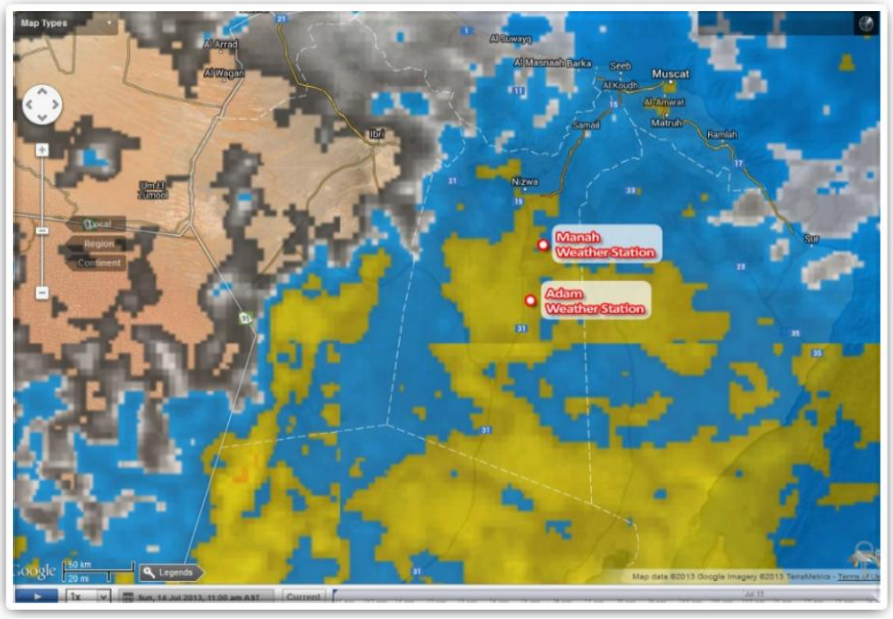


5th of July

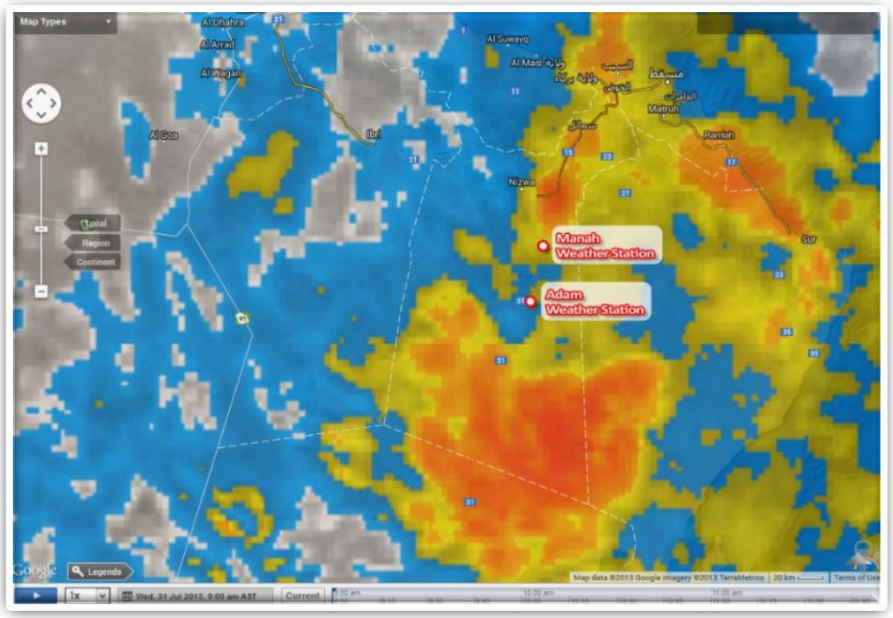


6th of July

Date	Station	Expected DNI (kWh/m2/day)	Actual DNI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)	Expected GHI (kWh/m2/day)	Actual GHI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) - %
21.7.2013	Adam	5.47	1.39	4.08 (74.6%)	7.47	5.46	2.01 (26.9%)
21.7.2013	Manah	5.61	2.10	3.51 (62.6%)	7.12	5.88	1.24 (17.4%)
31.7.2013	Adam	5.08	2.41	2.67 (52.6%)	7.34	6.20	1.14 (15.5%)
31.7.2013	Manah	5.30	2.55	2.75 (51.9%)	7.38	6.21	1.17 (15.9%)



14th of July



31st of July

Measured Precipitation in July

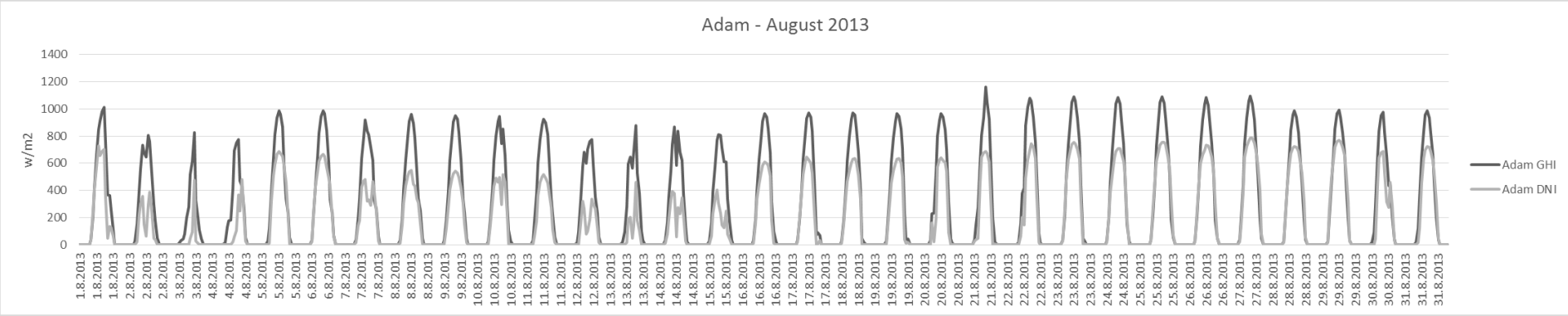
Adam		Manah	
Date	**Precipitation (mm)**	**Date**	**Precipitation (mm)**
04.7.2013	0.0	04.7.2013	0.2
23.7.2013	0.0	23.7.2013	5.2
31.7.2013	0.2	31.7.2013	0.0
Total	0.2	**Total**	5.4

Comments

No further comments given with regards to the month of July.

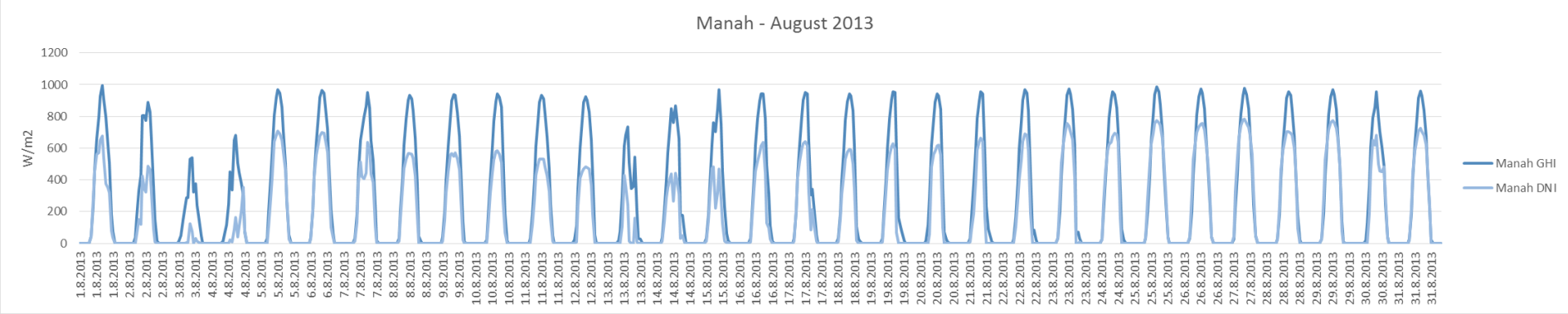
August

The following graphs show the measured solar data for the month of August for both Adam & Manah:



Max measured DNI (W/m²)	783
Max measured GHI (W/m²)	1159

Monthly average DNI in (kWh/m2/day)	4.32
Monthly average GHI in (kWh/m2/day)	6.62



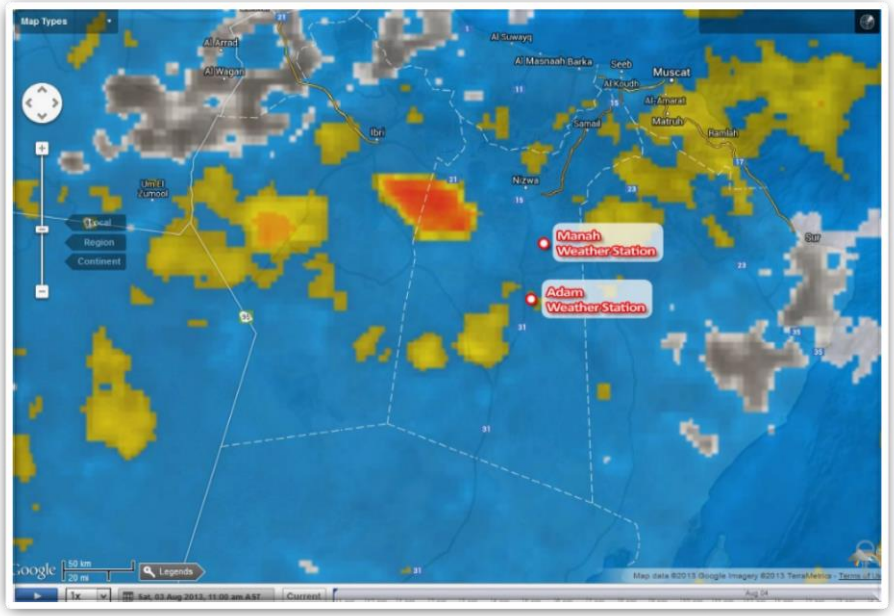
Max measured DNI (W/m²)	783.47
Max measured GHI (W/m²)	995.42

Monthly average DNI in (kWh/m2/day)	4.33
Monthly average GHI in (kWh/m2/day)	6.41

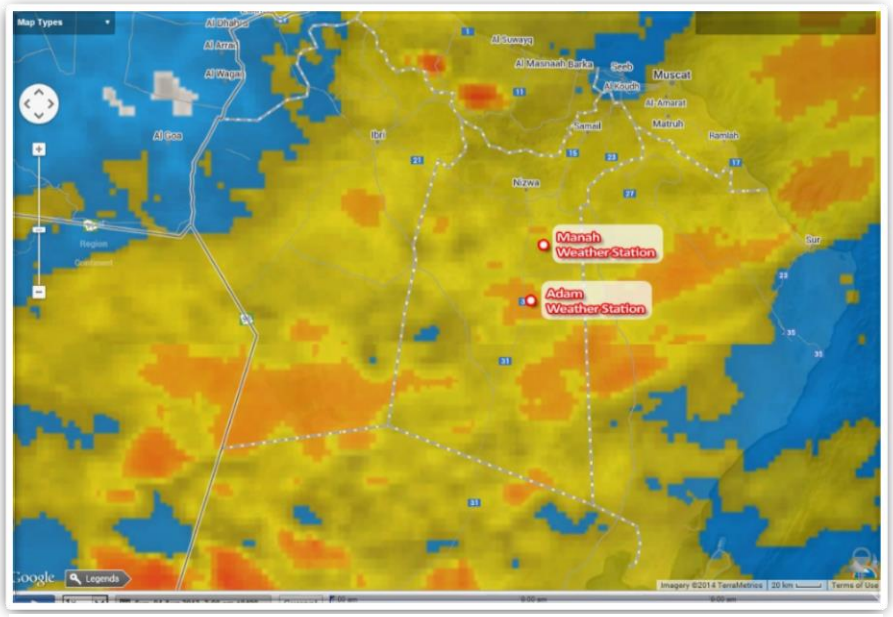
Weather Impact

The month of August experienced heavy rains at both of the Adam & Manah sites. Overhead clouds that covered the areas during the first two weeks of the month caused drops in expected measured DNI as high as 95%, and drops in DHI at around 56% (both on the 3rd of August, at the Manah station). While the rainfall that was measured on-site during the last two weeks of the month was high, it had happened only during the evening to late evening period, as such, the impact on ground measured solar radiation data was extremely low.

Date	Station	Expected DNI (kWh/m2/day)	Actual DNI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)	Expected GHI (kWh/m2/day)	Actual GHI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) - %
03.08.2013	Adam	5.36	0.66	4.70 (87.7%)	6.95	3.27	3.68 (52.9%)
03.08.2013	Manah	5.50	0.26	5.24 (95.3%)	7.23	3.18	4.05 (56.0%)
04.08.2013	Adam	5.40	1.51	3.89 (72.0%)	7.07	4.35	2.72 (38.5%)
04.08.2013	Manah	5.63	1.06	4.57 (81.2%)	7.29	4.27	3.02 (41.4%)

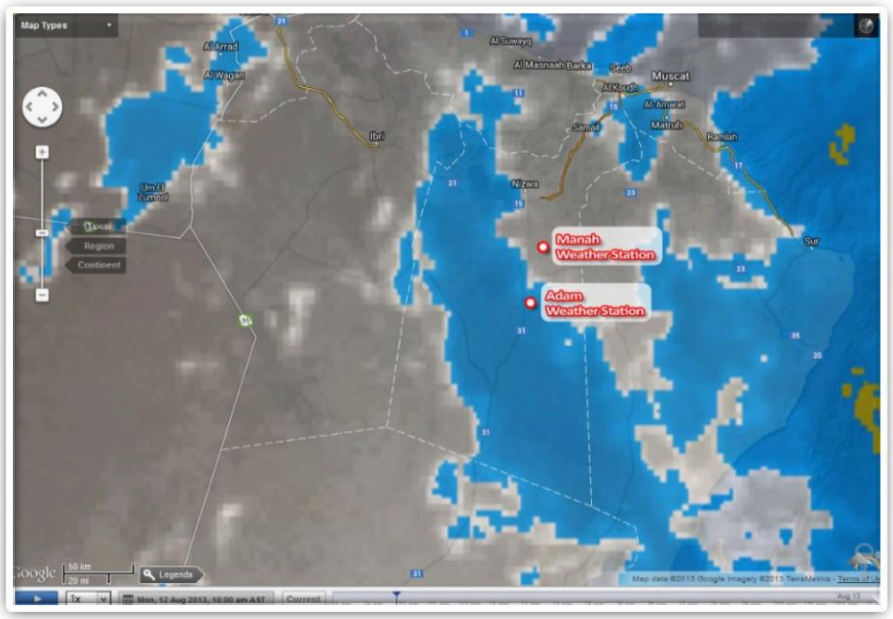


3rd of August

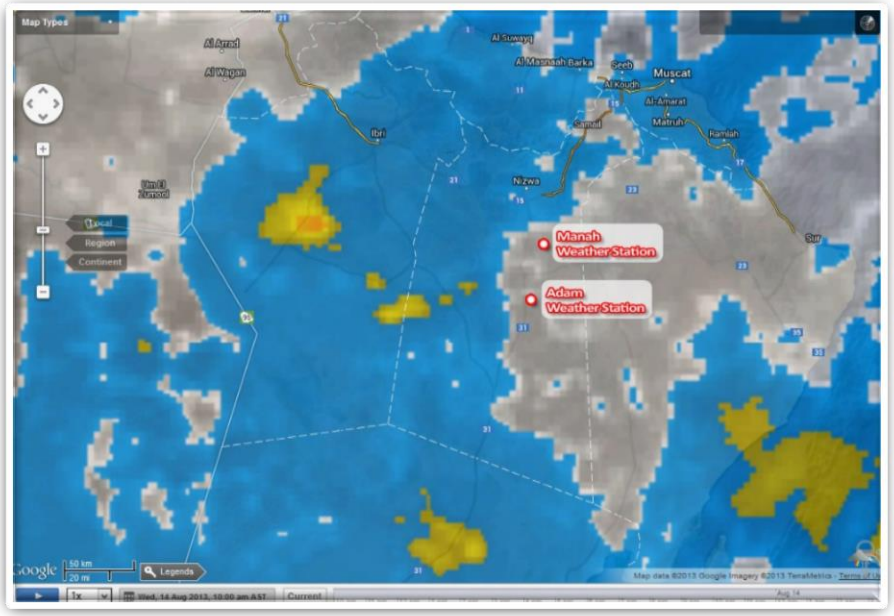


4th of August

Date	Station	Expected DNI (kWh/m2/day)	Actual DNI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)	Expected GHI (kWh/m2/day)	Actual GHI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) - %
12.8.2013	Adam	3.82	2.13	1.69 (44.3%)	6.73	5.75	0.97 (14.5%)
12.8.2013	Manah	4.31	3.56	0.76 (17.5%)	7.00	6.54	0.46 (6.5%)
13.8.2013	Adam	3.81	1.36	2.46 (64.4%)	6.81	4.81	2.00 (29.3%)
13.8.2013	Manah	4.31	1.34	2.98 (69.1%)	6.99	4.45	2.54 (36.3%)
14.8.2013	Adam	4.65	2.52	2.13 (45.9%)	6.93	5.96	0.97 (14.0%)
14.8.2013	Manah	4.21	3.14	1.07 (25.3%)	6.83	6.29	0.55 (8.0%)
15.8.2013	Adam	4.59	2.20	2.39 (52.1%)	6.92	6.00	0.92 (13.3%)
15.8.2013	Manah	4.13	2.84	1.30 (31.4%)	6.57	6.00	0.57 (8.7%)

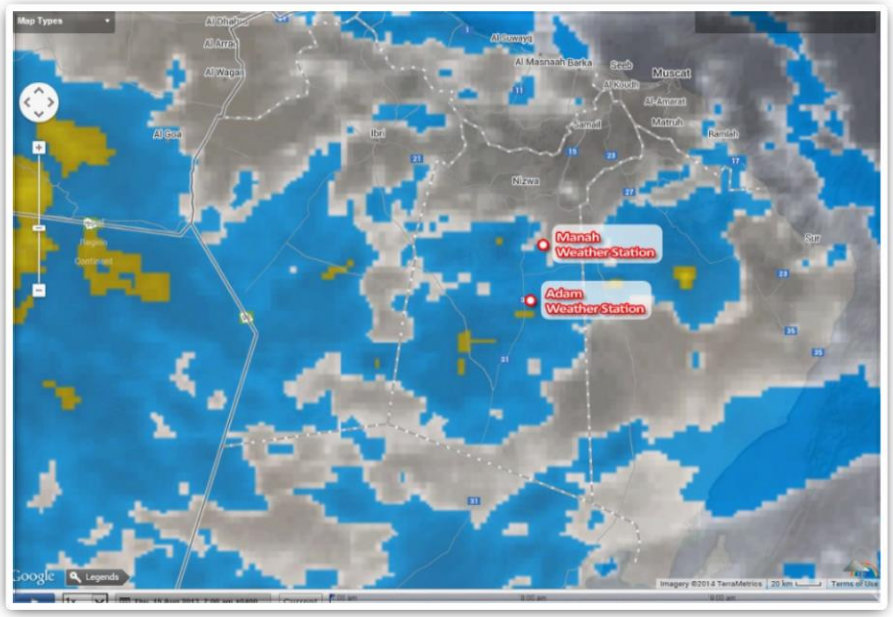


12th of August



13th of August

14th of August



15th of August

Measured Precipitation in August

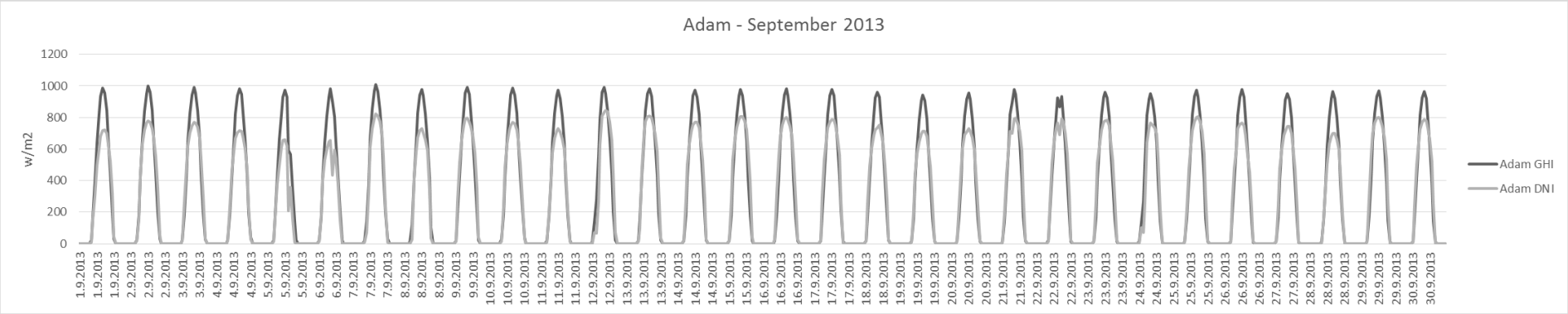
Adam		Manah	
Date	**Precipitation (mm)**	**Date**	**Precipitation (mm)**
02.8.2013	0.0	02.8.2013	0.2
04.8.2013	8.8	04.8.2013	4.4
09.8.2013	0.0	09.8.2013	0.4
10.8.2013	6.6	10.8.2013	18.8
12.8.2013	0.6	12.8.2013	2.4
16.8.2013	1.8	16.8.2013	0.0
17.8.2013	1.0	17.8.2013	4.2
18.8.2013	5.2	18.8.2013	3.0
19.8.2013	0.4	19.8.2013	0.0
20.8.2013	0.0	20.8.2013	1.0
21.8.2013	1.0	21.8.2013	0.0
22.8.2013	0.0	22.8.2013	9.0
23.8.2013	9.4	23.8.2013	0.0
Total	34.8	**Total**	43.4

Comments

No further comments given with regards to the month of August.

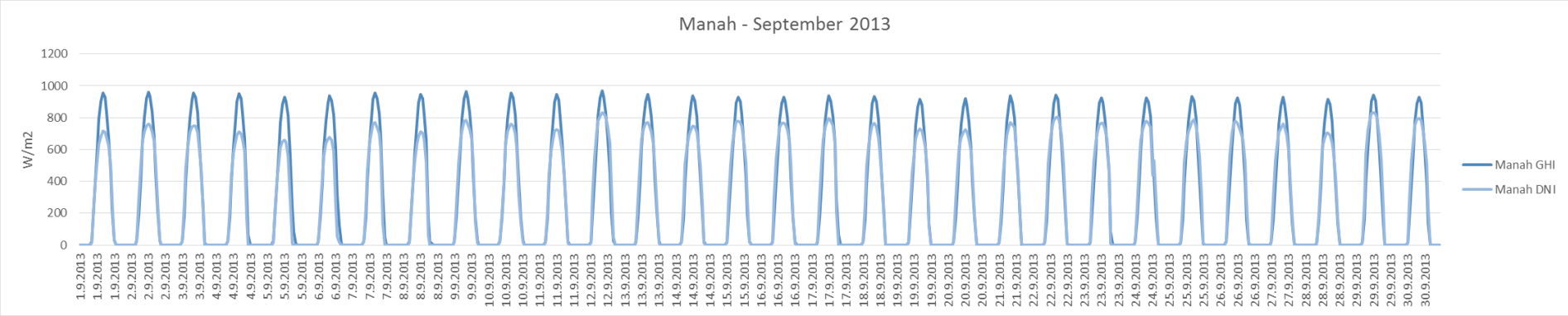
September

The following graphs show the measured solar data for the month of September for both Adam & Manah:



Max measured DNI (W/m²)	845.5
Max measured GHI (W/m²)	1009.20

Monthly average DNI in (kWh/m2/day)	6.49
Monthly average GHI in (kWh/m2/day)	6.84



Max measured DNI (W/m²)	832.67
Max measured GHI (W/m²)	968.27

Monthly average DNI in (kWh/m2/day)	6.45
Monthly average GHI in (kWh/m2/day)	6.60

Weather Impact

The impact of weather on the ground measured solar radiation data was minimal during the month of September. Scattered showers were measured at the Manah sites on various different days during the month, but this mostly happened during the evening to late-evening. As such, the impact on measured DNI & GHI was extremely low.

Measured Precipitation in September

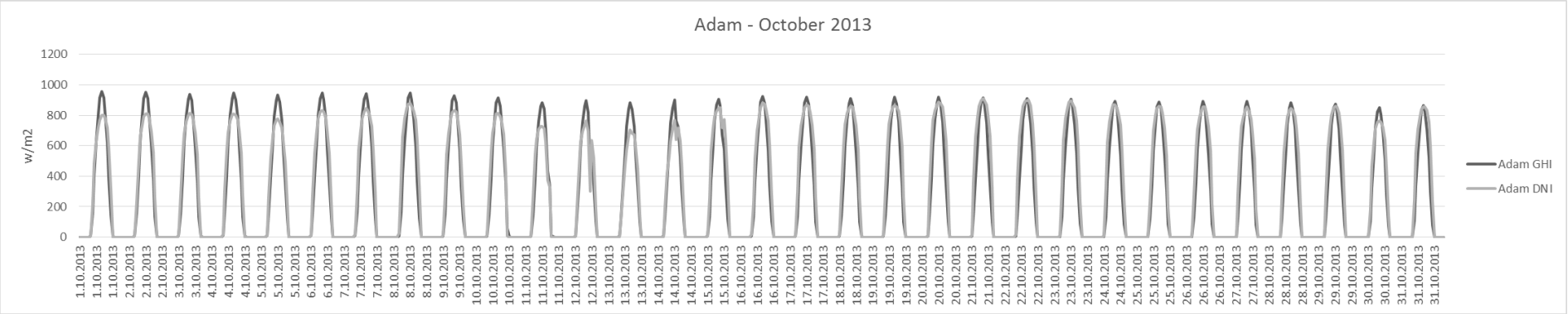
Adam		Manah	
Date	**Precipitation (mm)**	**Date**	**Precipitation (mm)**
08.9.2013	0.0	08.9.2013	1.4
14.9.2013	0.0	14.9.2013	0.2
18.9.2013	0.0	18.9.2013	0.8
19.9.2013	0.8	19.9.2013	0.2
20.9.2013	0.0	20.9.2013	0.6
Total	0.8	**Total**	3.4

Comments:

No further comments given with regards to the month of August.

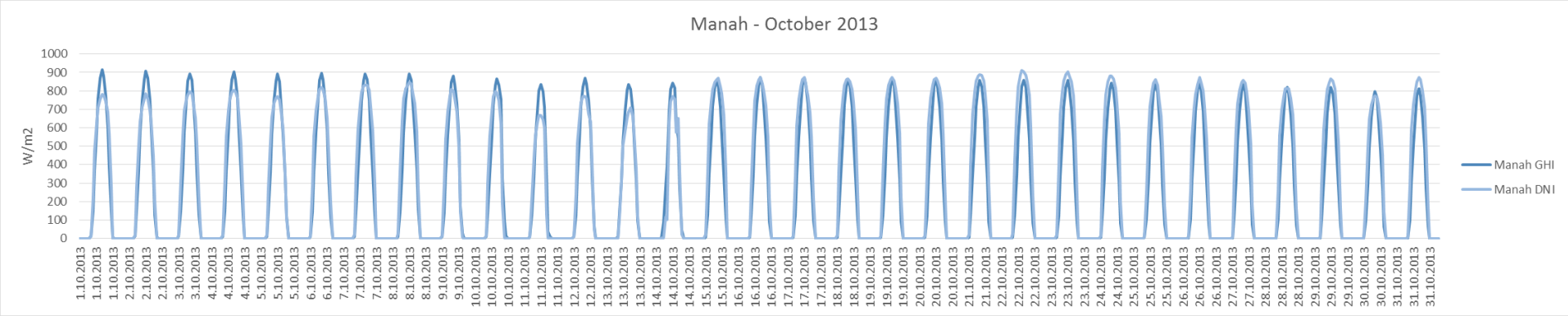
October

The following graphs show the measured solar data for the month of October for both Adam & Manah:



Max measured DNI (W/m²)	908.55
Max measured GHI (W/m²)	954.45

Monthly average DNI in (kWh/m2/day)	7.03
Monthly average GHI in (kWh/m2/day)	6.26



Max measured DNI (W/m²)	909.78
Max measured GHI (W/m²)	914.33

Monthly average DNI in (kWh/m2/day)	6.84
Monthly average GHI in (kWh/m2/day)	5.86

Weather Impact

Adam site experienced scattered showers on the 11th of October, while the Manah site experienced scattered showers on the 11th and 14th of October. These both occurred, however, at around 5 & 6 in the evening. Therefore, the impact on ground measured DNI & GHI was minial.

Measured Precipitation in October

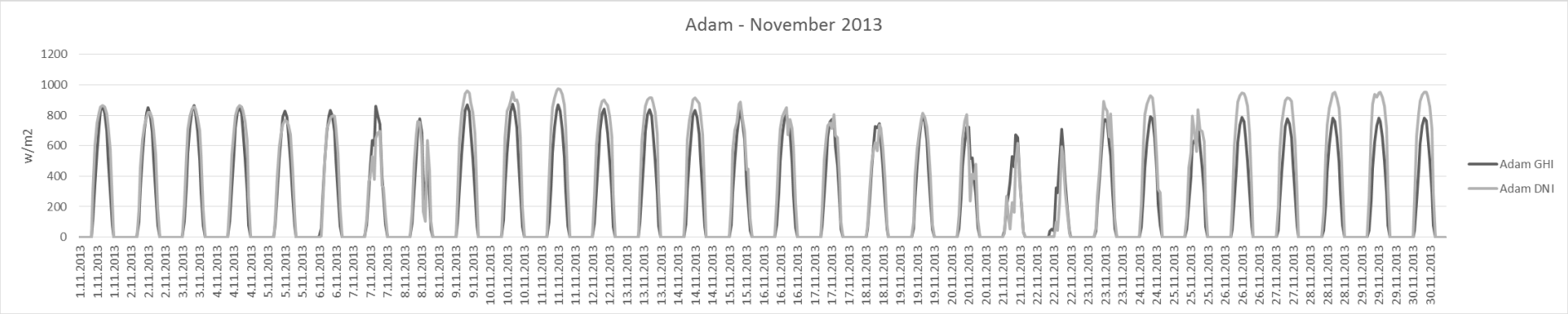
Adam		Manah	
Date	**Precipitation (mm)**	**Date**	**Precipitation (mm)**
11.10.2013	4.4	11.10.2013	0.2
14.10.2013	0.0	14.10.2013	0.4
Total	4.4	**Total**	0.6

Comments:

No further comments given with regards to the month of October.

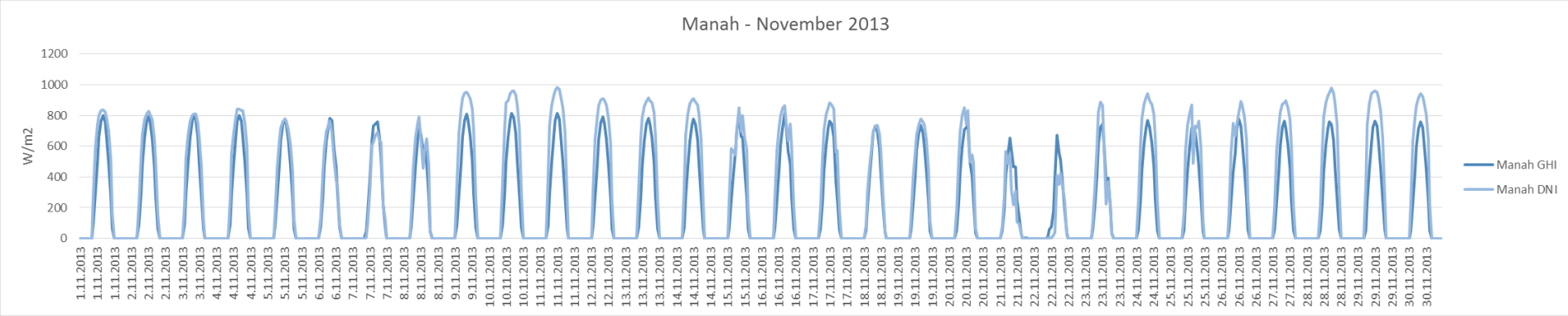
November

The following graphs show the measured solar data for the month of November for both Adam & Manah:



Max measured DNI (W/m²)	973.57
Max measured GHI (W/m²)	874.58

Monthly average DNI in (kWh/m2/day)	6.25
Monthly average GHI in (kWh/m2/day)	4.85



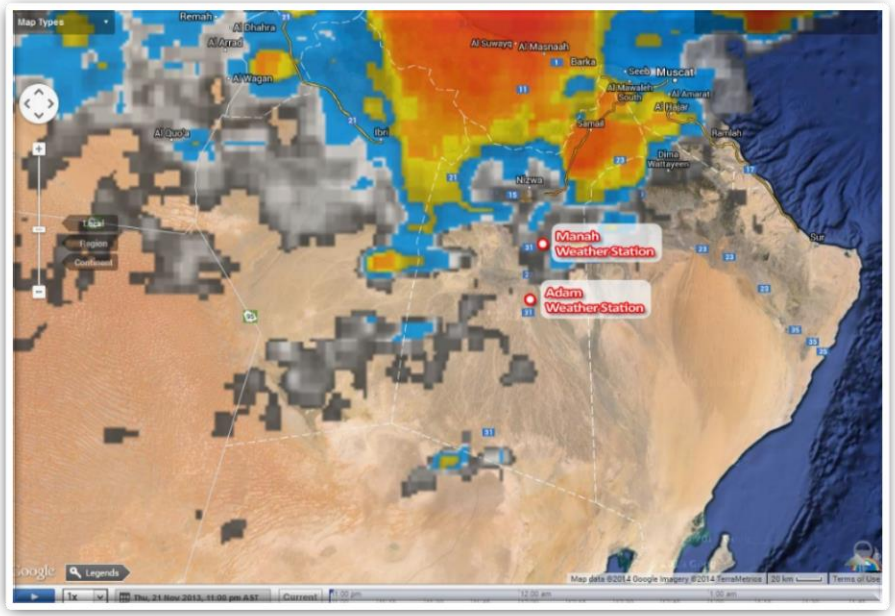
Max measured DNI (W/m²)	981.93
Max measured GHI (W/m²)	838.35

Monthly average DNI in (kWh/m2/day)	6.46
Monthly average GHI in (kWh/m2/day)	6.33

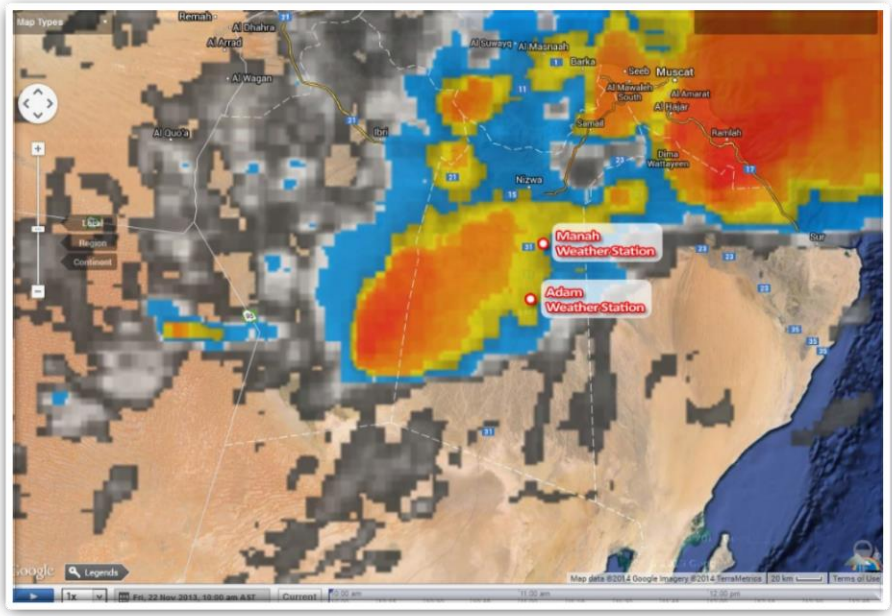
Weather Impact

November was a fairly stable month in terms of weather and its impact on ground measured data. Notably, the 7th and 8th of November experienced some days of cloud cover and overcast, which had more of an effect on the Adam station (drop in ground measured DNI & GHI estimated at 35.6% & 10.4%, respectively) than it did on Manah station (drop in ground measured DNI & GHI estimated at 21.4% & 3.2%, respectively). The period between the 20th and the 22nd of November experienced cloud cover with evidence of rainfall on the sites. Estimated drop in DNI and GHI during that period is within the range of 7.5% - 68.9%, and 3.4% - 35.7%, respectively.

Date	Station	Expected DNI (kWh/m2/day)	Actual DNI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)	Expected GHI (kWh/m2/day)	Actual GHI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) - %
07.10.2013	Adam	7.19	4.63	2.56 (35.6%)	5.81	5.21	0.60 (10.4%)
07.10.2013	Manah	5.86	4.61	1.25 (21.4%)	5.11	4.94	0.16 (3.2%)
08.10.2013	Adam	7.16	4.88	2.28 (31.8%)	5.75	4.49	1.27 (22.0%)
08.10.2013	Manah	6.38	5.67	0.72 (11.2%)	5.35	4.81	0.54 (10.2%)
20.10.2013	Adam	6.38	5.03	1.35 (21.1%)	5.15	4.58	0.57 (11.1%)
20.10.2013	Manah	6.73	6.22	0.51 (7.5%)	4.83	4.67	0.17 (3.4%)
21.10.2013	Adam	5.64	2.52	3.12 (55.3%)	4.95	3.78	1.17 (23.7%)
21.10.2013	Manah	5.81	3.04	2.77 (47.7%)	4.66	3.77	0.88 (19.0%)
22.10.2013	Adam	5.98	1.97	4.00 (67.0%)	4.91	3.15	1.75 (35.7%)
22.10.2013	Manah	5.97	1.86	4.11 (68.9%)	4.45	3.03	1.42 (31.9%)



21st of November



22nd of November

Measured Precipitation in November

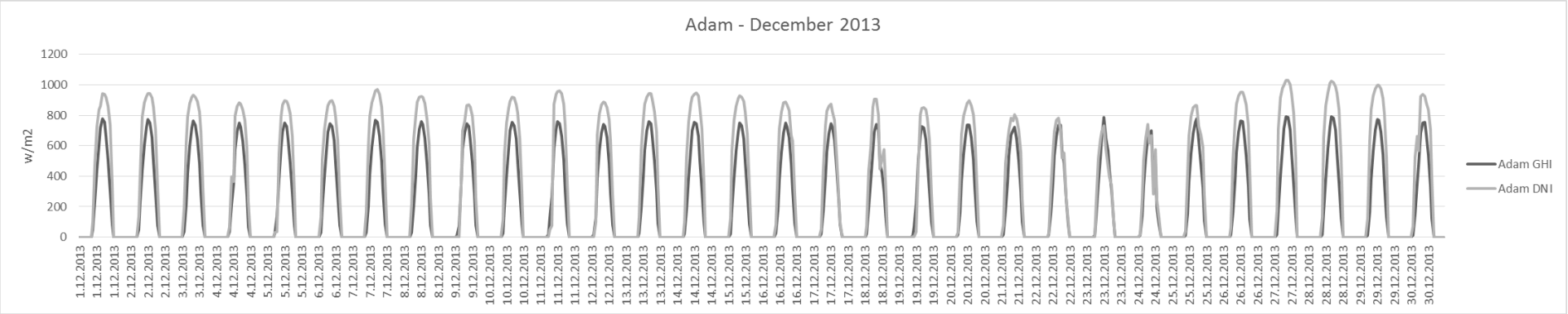
Adam		Manah	
Date	**Precipitation (mm)**	**Date**	**Precipitation (mm)**
21.11.2013	1.0	21.11.2013	12.8
22.11.2013	10.8	22.11.2013	9.2
Total	11.8	**Total**	22.0

Comments:

No further comments given with regards to the month of November.

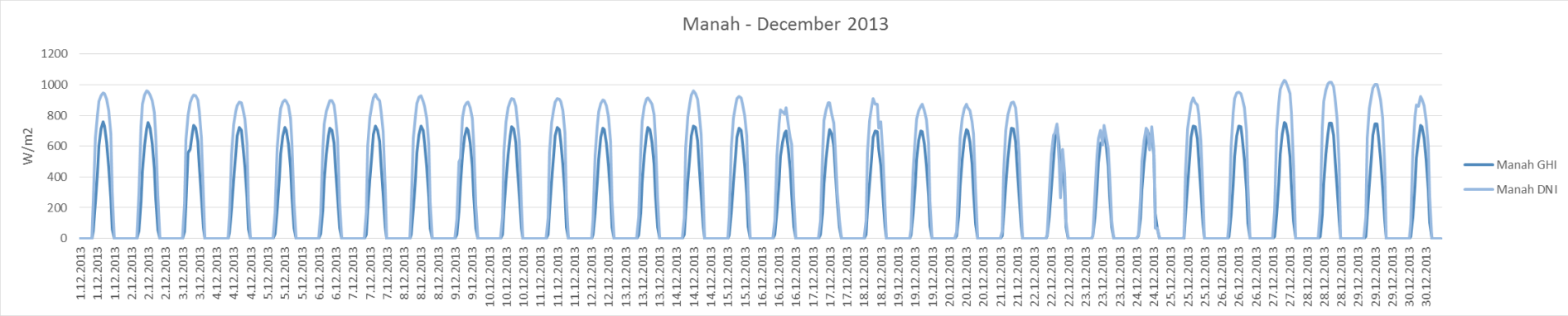
December

The following graphs show the measured solar data for the month of December for both Adam & Manah:



Max measured DNI (W/m²)	1029.02
Max measured GHI (W/m²)	791.00

Monthly average DNI in (kWh/m2/day)	7.12
Monthly average GHI in (kWh/m2/day)	4.83



Max measured DNI (W/m²)	1029.27
Max measured GHI (W/m²)	757.95

Monthly average DNI in (kWh/m2/day)	7.37
Monthly average GHI in (kWh/m2/day)	4.66

Weather Impact

The month of December also represented a month of fairly stable weather conditions. Ground measured DNI & GHI data show steady daily trends for most of the month, except for a few days in the period between the 22nd of December and the 24th of December. Measured DNI was 27% to 41% lower than expected, and measured GHI was 5% to 16% lower than expected during this period. Overcast and passing clouds are expected to be the cause of these drops in ground measured solar radiation.

Date	Station	Expected DNI (kWh/m2/day)	Actual DNI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) (%)	Expected GHI (kWh/m2/day)	Actual GHI (kWh/m2/day)	Loss in solar energy (kWh/m2/day) - %
22.12.2013	Adam	7.26	5.27	1.99 (27.4%)	4.84	4.57	0.26 (5.5%)
22.12.2013	Manah	7.06	4.86	2.20 (31.2%)	4.63	4.26	0.37 (8.1%)
23.12.2013	Adam	8.00	5.27	2.73 (34.1%)	5.01	4.52	0.49 (9.8%)
23.12.2013	Manah	8.07	4.86	3.21 (39.8%)	4.74	4.33	0.42 (8.8%)
24.12.2013	Adam	8.00	4.69	3.30 (41.3%)	4.99	4.16	0.83 (16.6%)
24.12.2013	Manah	8.07	5.32	2.75 (34.1%)	4.81	4.39	0.42 (8.8%)

Measured Precipitation in December

Total Measured Precipitation in December (mm)	0

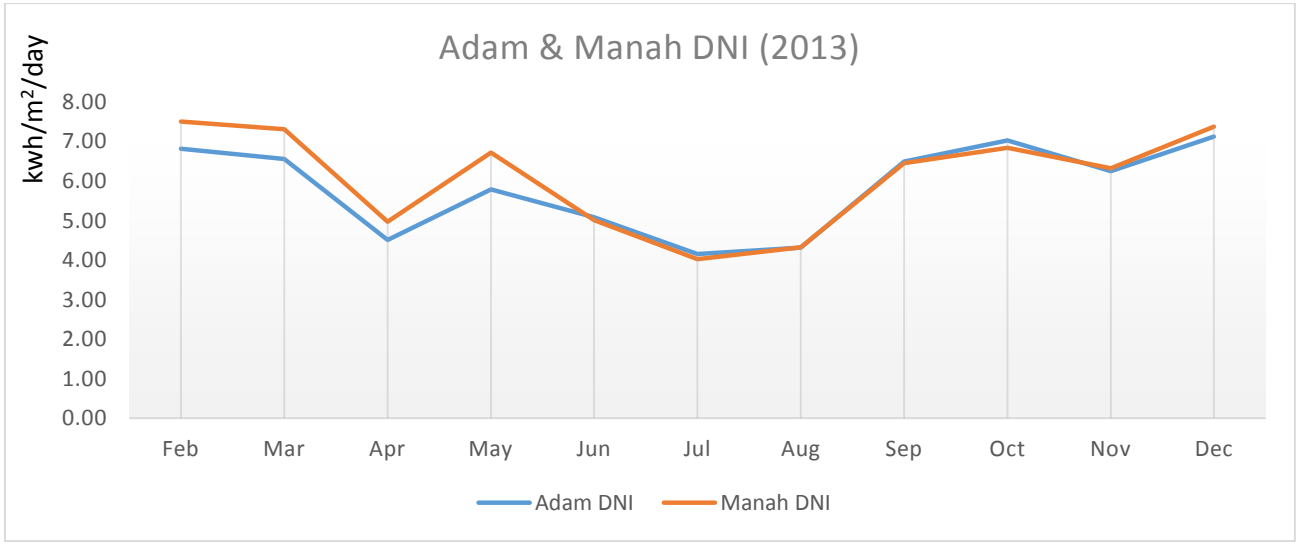
Comments:

Unfortunately, the weather maps from the same source showed some uncertainty for the period of unstable DNI & GHI readings stated above, as such, none were included for this month.

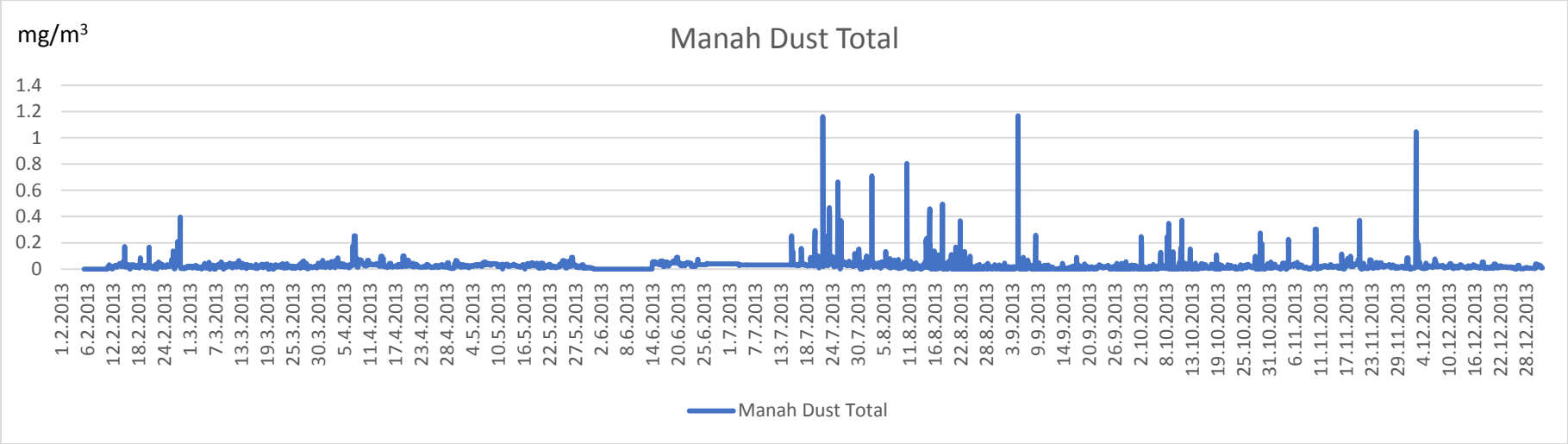
Conclusion

Upon conducting a review of 2013's Solar Data, the following are the conclusions and findings obtained throughout the duration of the study:

1. It was found that the annual average DNI measured at Adam was 5.35 kwh/m^2/day, whereas Manah measured slightly more at 5.75 kwh/m^2/day.

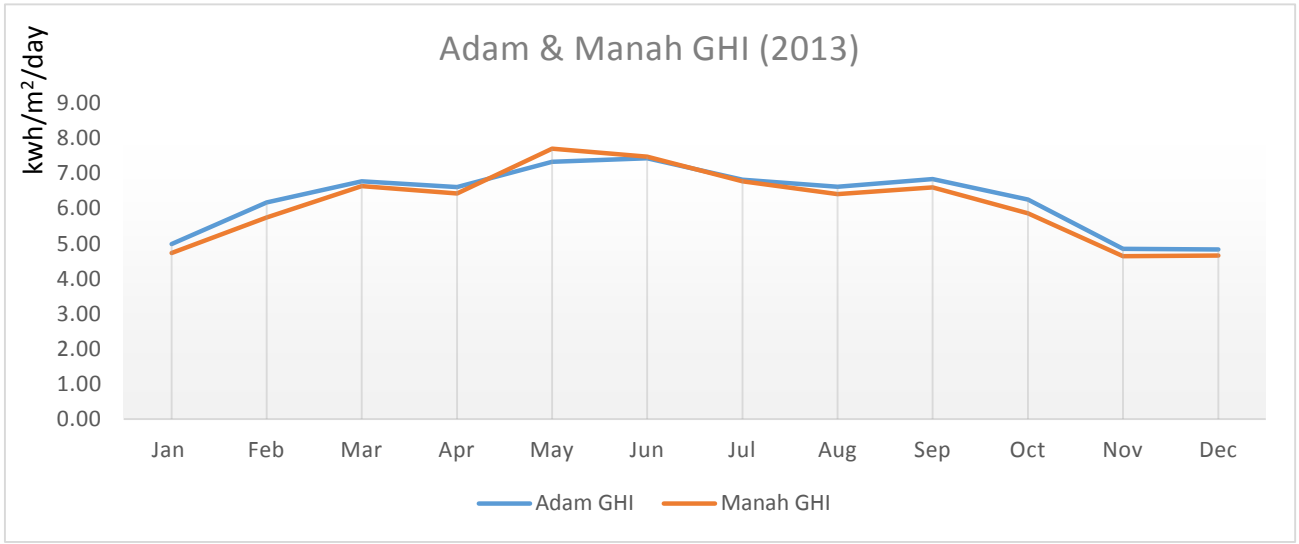


2. Contrary to initial assumptions, DNI measurements are found to decrease during the summer period (June-July-August). The cause for this is believed to be that because DNI readings relies on radiation absorbed directly from the sun, then there must be a higher degree of particles in the surrounding atmosphere to diffuse and disperse the incoming radiation. Dust measurements from the sites confirmed this rationale where we can see in the follow graph that the sites experienced higher levels of dust during the summer periods, than it did during the winter:



The continuation of this study for the coming years will result in additional data in order to gain further clarity with regards to this finding.

3. It was found that the annual average GHI measured at Adam was 6.29 kwh/m^2/day, whereas Manah measured slightly less at 6.14 kwh/m^2/day.



4. DNI measurements tend to fluctuate with a lot more intensity than GHI measurements during days of cloud cover and/or overcast. Therefore, GHI represents a source of energy that is be a lot more stable and consistent throughout the year when compared to DNI.
5. It's also noticed that GHI measurements drop during the winter are slightly lower on average than during the summer (this has been consistent throughout the past few years, see below graph).