

Solar Resource Mapping in Vietnam

SITE SELECTION REPORT

MAY 2017



This report was prepared by [Suntrace](#), under contract to [The World Bank](#).

It is one of several outputs from the solar resource mapping component of the activity “Renewable Energy Resource Mapping and Geospatial Planning – Vietnam” [Project ID: P145513]. This activity is funded and supported by the Energy Sector Management Assistance Program (ESMAP), a multi-donor trust fund administered by The World Bank, under a global initiative on Renewable Energy Resource Mapping. Further details on the initiative can be obtained from the [ESMAP website](#).

This report is an interim output from the above-mentioned project. Users are strongly advised to exercise caution when utilizing the information and data contained, as this has not been subject to validation using ground measurement data or peer review. The final output from this project will be a validated Vietnam Solar Atlas, which will be published once the project is completed.

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SOLAR MEASUREMENT CAMPAIGN IN VIETNAM

SELECTION #: 1231900

Site Selection Report

23 May 2017

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EXECUTIVE SUMMARY

Vietnam is a highly promising country for installation of photovoltaic (PV) systems. The highest solar resource is found in the Southern part of the country, but also the Northern regions provide quite promising solar conditions. For validation of a countrywide satellite-based solar mapping measurement stations should be spread across the whole country.

- Visits to 6 site areas took place from 22.02.2017 to 02.03.2017
- Various possible locations were visited and evaluated during the Inception Mission.
- As potential vandalism seems to be a serious issue solar measurement stations should be situated at rooftops where no direct 24/7 surveillance of the station by guards can be assured.
- At those sites where longterm operation of the station has good chances the high quality Tier 1 stations with pyrheliometers should be realized, which require daily cleaning. In Vietnam best chances for such Tier 1 stations seem to be given at locations under permanent operation by EVN.

The following locations are identified as most suitable locations for equipment (listed from north to south):

Site name and description	Type	Site code	Elevation	Latitude	Longitude
Hanoi region: Bac Ninh on rooftop of new EVN bldg.	Tier1	VNHAN	40 m	21.2015°N	106.0630°E
Quang Tri (potential 6 th site) on top of local EVN headquarter near Quang Tri	Tier2	VNQUT	11 m	16.7711 °N	107.1677°E
Da Nang region on rooftop of private house near village Dien Than Bac	Tier2	VNDA N	9 m	16.01257°N	108.18649°E
Central Highlands region on ground before EVN bldg. near hydro spillway	Tier1	VNCEH	275 m	12.7534°N	107.8763°E
Song Binh station location on private house rooftop	Tier2	VNSOB	59 m	11.2640°N	108.3452°E
Tri An region near HCMC on top of EVN bldg. near water spillway	Tier1	VNTRA	57 m	11.1024°N	107.0378°E

Table 1: Proposed locations for installation of solar measurement stations in ESMAP Vietnam.

It is not clear yet whether there is sufficient budget for a 6th station. At least the 3 Tier 1 stations should be installed at the EVN sites and 2 Tier 2 stations at private rooftops. Placing a third Tier 2 station at the EVN-CPC rooftop at Quang Tri, is our strongest recommendation for selection of options. Providing another good point for validation of satellite-derived solar radiation in an area, which shows quite independent climate from the region South of Cloud Pass is seen as great advantage. Of the technical options we give the strongest recommendation for upgrading the pyranometers to ventilated pyranometers to fulfill Class A of the new IEC 61724-1:2017 standard. Measuring soiling and corrosion at all sites for us has almost equally high importance to better characterize the site for large-scale solar plants. The addition of rain gauges would be nice to have to better understand these observations. As it is expected that aerosol contents is high at those 3 stations equipped with pyrheliometers, we recommend to opt for the aerosol post-processing service.

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1. INTRODUCTION

Background

This report is prepared within the World Bank ESMAP project Selection #1231900 on solar measurements in Vietnam. Under this project at least five solar measurement stations funded from a World Bank executed trust fund will be commissioned. These are to be installed at different sites distributed throughout the whole country from North to South. These sites should well represent the local climatic conditions and be situated at sites favorable for solar energy projects. The intention is to begin measurements at these sites as soon as possible, to provide validation data. The Government of Vietnam has a target to add solar energy generation capacity of 12 GW by 2030.

However, Vietnam currently has limited data on renewable energy resource potential. The World Bank team supporting the Government of Vietnam is therefore launching a parallel activity to support country level renewable energy resource assessment and mapping, focusing on solar, with technical and financial support from World Bank-executed trust funds.

Objectives and approach

This assignment of Suntrace GmbH with its local partner Vatec Inc. includes the planning, commissioning and implementation of a high quality solar measurement campaign at least at 5 sites in Vietnam, including regular delivery of bankable solar data over a two-year period. The solar measurement equipment shall conform to ESMAP Tier 1 and Tier 2 station standards.

The measurements shall primarily provide validation data for the satellite-derived solar maps of the World Bank ESMAP Global Solar Atlas. Where the stations are located near promising solar power projects they also should be the key for delivering bankable data. Central in this effort is a focus on reducing uncertainty of the available model estimations on solar resources and thus reducing financial and technical risk during implementation of photovoltaic solar power plants at the selected sites.

The criteria for selection of sites for solar measurements are the following:

1. Well distributed across the country for good validation of satellite maps
 - cover various climate zones
2. Promising solar power sites
 - preferably at EVN sites
3. Secure locations, where equipment will likely not be stolen or damaged
 - avoid vandalism
4. Safe locations
 - low risk of natural hazards

Geographic and climate conditions in Vietnam

Vietnam is a country in the Eastern part of South Asia covering an area of 332 698 km². It is relatively narrow East to West – at parts just 50 km wide, but has a long North-South axis of more than 1 600 km. Many parts are low lands along the coast and the dominant rivers of the Mekong in the South near Ho Chi Minh City (HCMC) and the Red River Delta near Hanoi in the North. Considerable areas are covered by highlands in the South East, the Central Highlands and the Northern. In the South and Central part the highlands have a typical elevation of around 500 m while the Northern Highlands are partly above 1 000 m with few peaks above 3 000 m (see Figure 1).

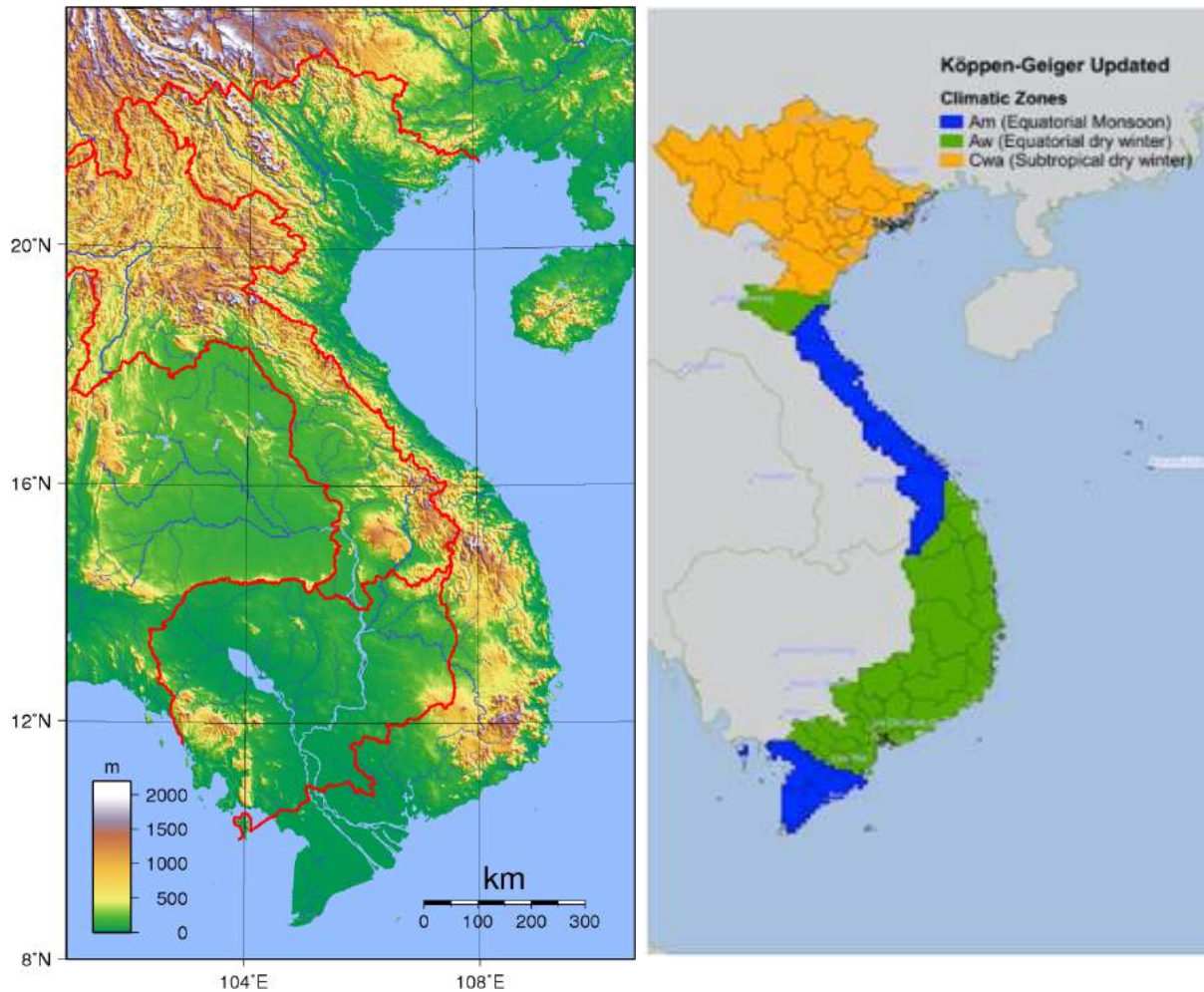


Figure 1: Topographic map of Vietnam (left) and Köppen-Geiger climate classification (right) (Sources: Topographic map of Vietnam created by Sadalmelik with GMT from publicly released GLOBE digital elevation model data and Köppen –Geiger map from AEAID & MOIT Report on Solar Maps, 2015).

Ranging from about 23°N down to 8°N latitude Vietnam covers several climatic zones, which all are influenced by monsoon rainfall at various times of the year (see Figure 1 right). Vietnam can be divided into 3 main climatic zones, which are characterized by equatorial monsoon, equatorial dry winter and subtropical dry winter climate.

Selection of locations for solar measurement stations

Based on the site selection criteria above the following sites (list from North to South) have been pre-selected:

- Hanoi region in the North
- Quang Tri region about 150 km NW of Da Nang North of Cloud Pass
- Dan Nang region South of Cloud Pass
- Central Highlands inlands of Nah Trang near EVN hydro power plants
- Song Binh EVN PV site in the South East
- Tri An EVN hydro power plant about 40 km NE of HCMC

For each site several potential locations are checked, where the stations actually could be installed. A suitable location for proper and secure station operation should fulfill the following criteria:

- The micro-climate should well represent the climate of the region
- Low obstructions by nearby terrain, preferably situated in flat terrain
- Homogeneous landscape and land use well representing the satellite pixel to validate
- Sufficient distance from coastlines (preferably > 10 km), large water bodies, mountains, frequently used dirt roads, industrial pollution and open pit mining operations
- Site should be accessible for installation and regular maintenance via roads
- Availability and quality of GSM/GPRS connections
- Local assistance should be available

- Station should be placed where provision of secure operation is possible
- Danger of flooding should be low.

The locations to be inspected were chosen and visited during Inception Mission for this project, which was conducted from Monday, February 20 until Thursday, March 2 2017. Suntrace GmbH together with its Local Partner Vatec Inc. and stakeholders involved in this project visited each site and searched for favorable locations to place the measurement stations.

The following Chapter gives an overview of all Sites and gives details of each Location, which was visited during the Inception Mission. For each site a preferred Location is selected. In the final Chapter we explain the choice of Sites and give a ranking. Therein we also recommend details for the equipment of each station so that the final choice for ordering can be made and the drafting of the Implementation Report for the Solar Measurement Campaign in Vietnam can begin.

2. SITE SELECTION FOR SOLAR MEASUREMENT STATIONS

Based on the list of sites already announced by World Bank in the ToR and on the criteria given in Chapter 1, a preliminary list of sites was created. This list of sites is shown in Table 2. The sites should be checked out in detail during the Inception Mission. At each of these sites, several potential locations should be identified and visited so that the most suitable for solar measurements can be selected.



Figure 2: Country map showing promising sites for solar measurement stations currently considered for the Vietnam ESMAP project.

Site name and description	Type	Site code	Elevation	Latitude	Longitude
Hanoi region: Bac Ninh on rooftop of new EVN building.	Tier1	VNHAN	40 m	21.2015°N	106.0630°E
Quang Tri (potential 6 th site) on top of local EVN headquarter near Quang Tri	Tier2	VNQUT	11 m	16.7711 °N	107.1677°E
Da Nang region on rooftop of private house near village Dien Than Bac	Tier2	VNDAN	9 m	16.01257°N	108.18649°E
Central Highlands region on ground before EVN bldg. near hydro spillway	Tier1	VNCEH	275 m	12.7534°N	107.8763°E
Song Binh station location on private house rooftop	Tier2	VNSOB	59 m	11.2640°N	108.3452°E
Tri An region near HCMC on top of EVN bldg. near water spillway	Tier1	VNTRA	57 m	11.1024°N	107.0378°E

Table 2: Overview of potential sites for installation of solar measurement stations in Vietnam from North to South.

In the following sub-chapters detailed descriptions of each site are given. The various visited Locations are described and for each site a preferred location is recommended.

The potential locations of the sites are colored-coded as the following on the figures:

Icon color coding:

green: suitable location, which has favorable horizon conditions (WMO DNI class 1), representative for the site, safe location and expected to be well to maintain.

brown: suitable location, which has good horizon conditions (WMO DNI class 2-4) or not fully representative, safe location and expected to be well to maintain.

yellow: location, which might be suitable, but may have some issues.

red: unsuitable either due to unfavorable horizon, unsafe location, poor maintenance, difficult to access etc.

Text color coding:

green: permission for erecting and operating a solar measurement station is very likely.

brown: permission for erecting and operating a solar measurement station is likely or can be costly.

yellow: permission for erecting and operating a solar measurement station is unclear.

red: permission for erecting and operating a solar measurement station can not be expected.

2.1 Bac Ninh near Hanoi - VNHAN

General description of the region

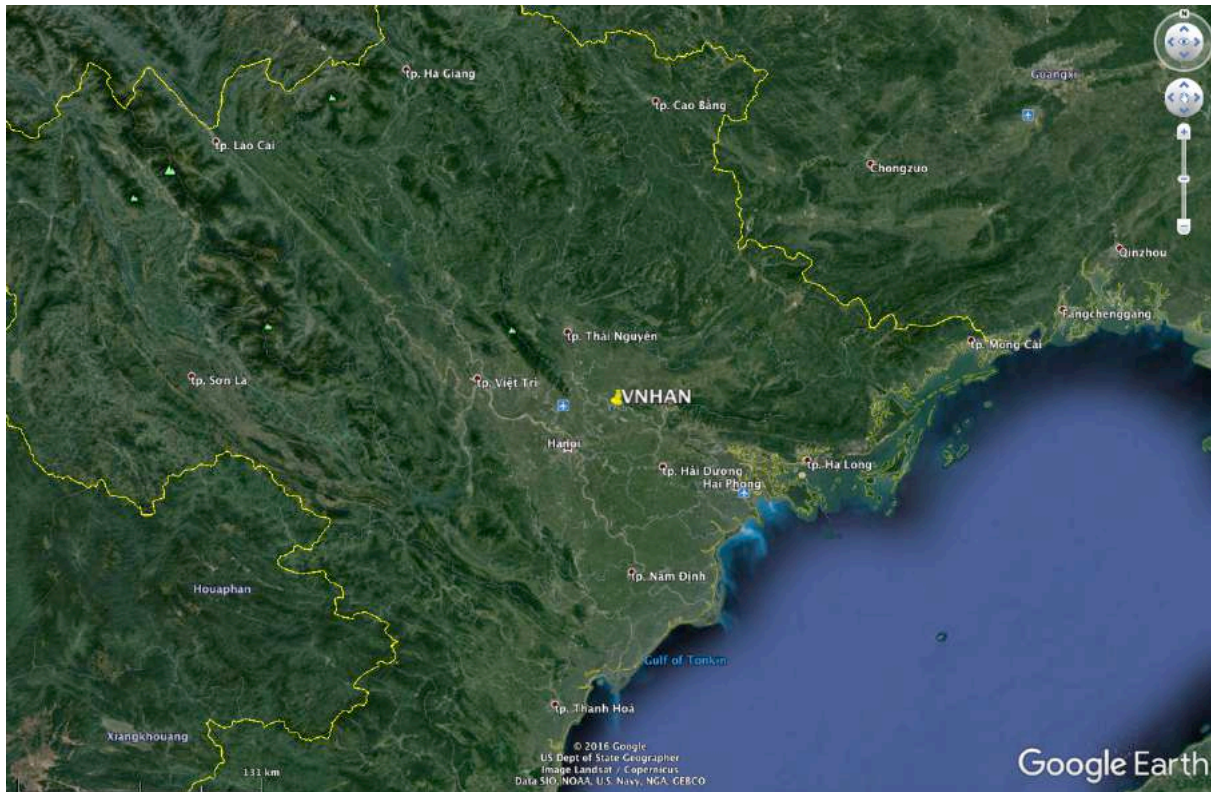


Figure 3: Country map showing Bac Ninh province.

With more than 6 million inhabitants Hanoi is the second biggest city of Vietnam. It is situated along the Red River, which is near sea level. Various smaller cities can be found in the surrounding, which also have industrial production sites. Due to the strong load of emissions coming from China in the predominately winds from the Northeast, aerosol load is relatively high in the Red River basin. This is significantly reducing visibility during many months each year. Consequently, it is not known how this might influence the quality of solar resources in the region. It is assumed that aerosol content might be highest near Hanoi where strong local emissions come on top of the already high background. As it is expected that large solar plants will rather be installed outside of Hanoi and the satellite validation should be done for a site, which is not severely influenced by local emissions, it is proposed to better select a site outside of Hanoi and preferably towards the main wind direction to avoid a downwind situation. To simplify logistics it was recommended to select a site, which is not too far from Hanoi international airport.

The small city of Bac Ninh, the capital of Bac Ninh Province with about 100 000 people was chosen. Located about 30 km Northeast of Hanoi with about 45 min car travel to the Hanoi international airport, Bac Ninh fulfills well the criteria described above. In the East of Bac Ninh a large industrial park is situated, where larger PV rooftop installations are expected to be built. Thus, measurements in this region are not only well representative, but can also have practical value to allow easier financing if this site will be measured well.

Potential locations in the region

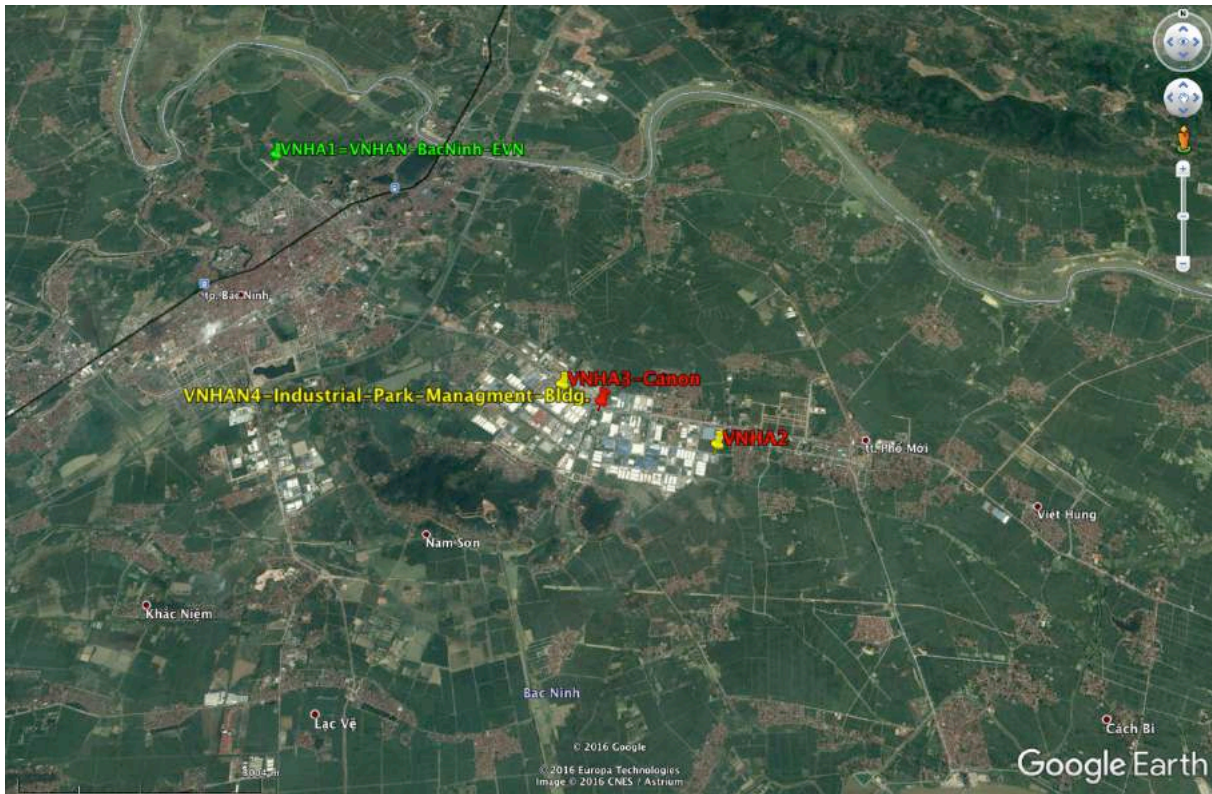


Figure 4: Various good rooftops have been pre-selected in Bac Ninh 30 km NE of Hanoi.



Figure 5: Map of industrial park of Bac Ninh 30 km NE of Hanoi

Description of inspected locations

Site description	Site code	Elevation	Latitude	Longitude
Bac Ninh – new EVN building	VNHA1	40 m	21.2015°N	106.0630°E
Industrial park Nobel Company	VNHA2	20 m	21.1520°N	106.1324°E
Industrial park Canon Company roof	VNHA3	20 m	21.1610°N	106.1107°E
Industrial park management company KINHBAC	VNHA4	35 m	21.1584°N	106.1163°E

Table 3: Overview of potential locations near Hanoi



Figure 6: New building of EVN with spacious rooftop and fully flat horizon (VNHA1)



Figure 7: Rooftop new building of EVN with fully flat horizon. (horizon picture overlaid with Sun path) (VNHA1)

Comparison of locations for site VNHAN

The access to the rooftops of companies as originally thought seems to be more difficult than expected. As the focus of the companies is not producing solar energy, it is also questionable whether they would provide sufficient support for operation of such stations. The rooftop provided by EVN is on a relatively high building at about 35 m. Advantages are that local staff is highly motivated to support the operations and the horizon there is perfectly flat. The constraints of the height was agreed by Solargis and we come to the conclusion that this location is positioned away from local emissions and the big city Hanoi as prevailing wind is NE. The main source of aerosol may therefore rather be coming from China and thus a thick layer of small sized particles, which do

not show a strong gradient with height. Missing the lowest 40 m of perhaps about 2000 m of low visibility air masses should not cause too much deviation from a 2 m high surface measurement. Thus, it is regarded to be quite representative for the region. As land use is so dense, rooftop installations on said nearby large industrial roofs have good potential for PV. Assuming humid adiabatic temperature as a rule of thumb $-0.5 \text{ K} / 100 \text{ m}$ applies. It is more important to place the T/RH sensor away from heat sources at the roof like AC outlets.

Concerning the wind measurement, to be safer from lightning and make fixing easier, it is recommended to install just a 7 m wind mast under the consideration to measure at a height with not much disturbed free flow. To avoid shading of the solar measurements it is important to have a sufficient distance between solar and wind mast. As the highest rooftop is often above the relatively small staircase, the wind mast must be installed at the 4 m lower platforms. Thus, wind mast of around 7 m might be most suitable. Since the proposed wind mast is telescopic, it can be adjusted individually. It should be measured as well defined as possible. Thus, a transfer model to the standard height of 10 m should be used.

For the selected location on the EVN rooftop in the outskirts of Bac Nanh we propose code VNHAN, which should indicate Vietnam – close to Hanoi. This site code shall be used in all related communications, file-names etc.

2.2 Dong Ha, Quang Tri Province - VNQUT

General description of the region

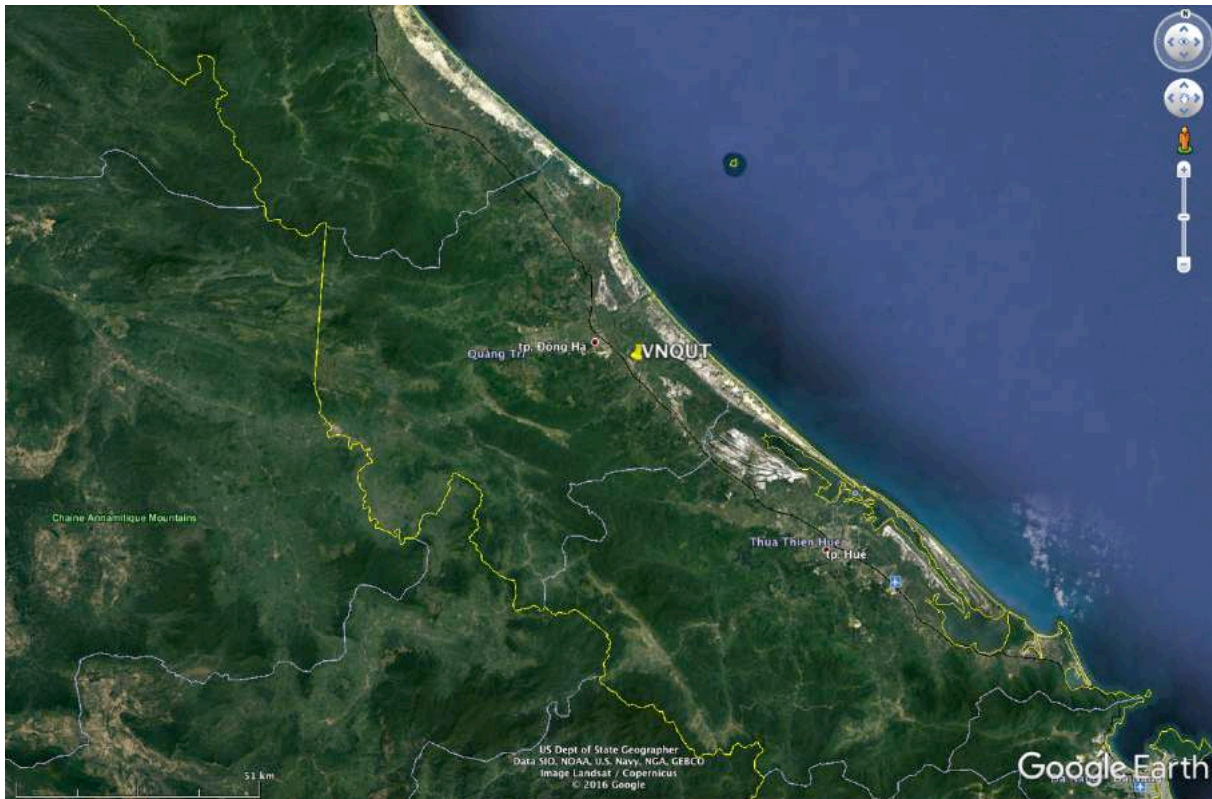


Figure 8: Country map showing Quang Tri province

Inhabited by 616 600 people, Quang Tri is located in the northern border of Vietnam with Laos and has 75 km of seaside on its eastern part. The provinces Quang Binh and Thua, Thien-Hue also surround it.

Highlands with steep slopes, sharp crests, narrow valleys and dense broadleaf evergreen forest are predominant. Its peaks reach above 2 400 m but are generally between 1 000 m and 2 100 m high. Additionally, narrow piedmont plains with rocky headlands, belts of sand dunes and rice fields, characterize the coastal portion of its territory.

The highlands' drainage flows eastward the sea or westward Laos and Cambodia. While the first follows through deep narrow valleys over rocky bottoms, the latter have longer traces, eventually passing by deep canyons exposed to seasonal flooding.

The temperature is highly volatile. Its annual average is 24°C but may fall to 7°C during the rain season (November to mid-March). During the rest of the year, the Southwest Monsoon with hot and dry southwest winds marks the weather.

Potential locations in the region

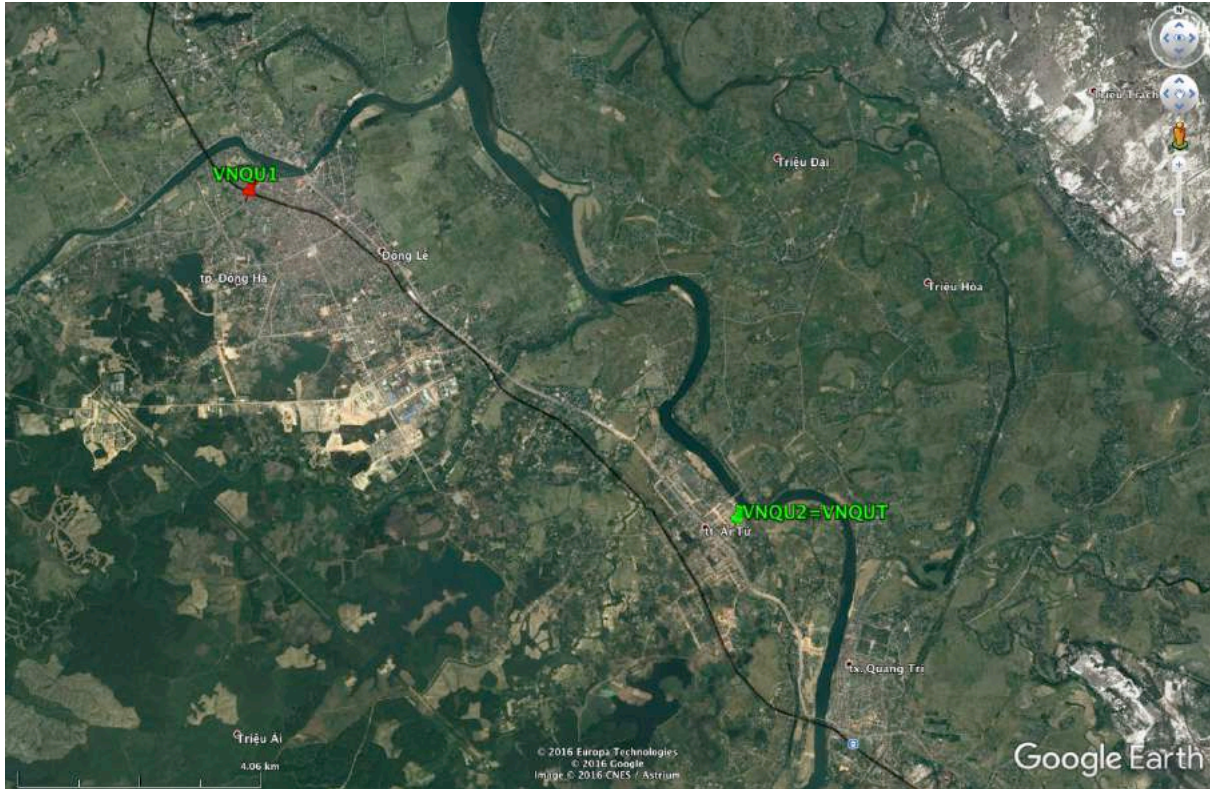


Figure 9: Options for measurement location in Dong Ha, Quang Tri Province

Site description	Site code	Elevation	Latitude	Longitude
Quang Tri PC	VNQU1	10 m	16.8210°N	107.0905°E
Location on top of local EVN headquarter near Quang Tri	VNQU2	10 m	16.7711°N	107.1677°E

Description of inspected locations



Figure 10: ESMAPVN potential station location on top of local EVN headquarter near Quang Tri (VNQU2)

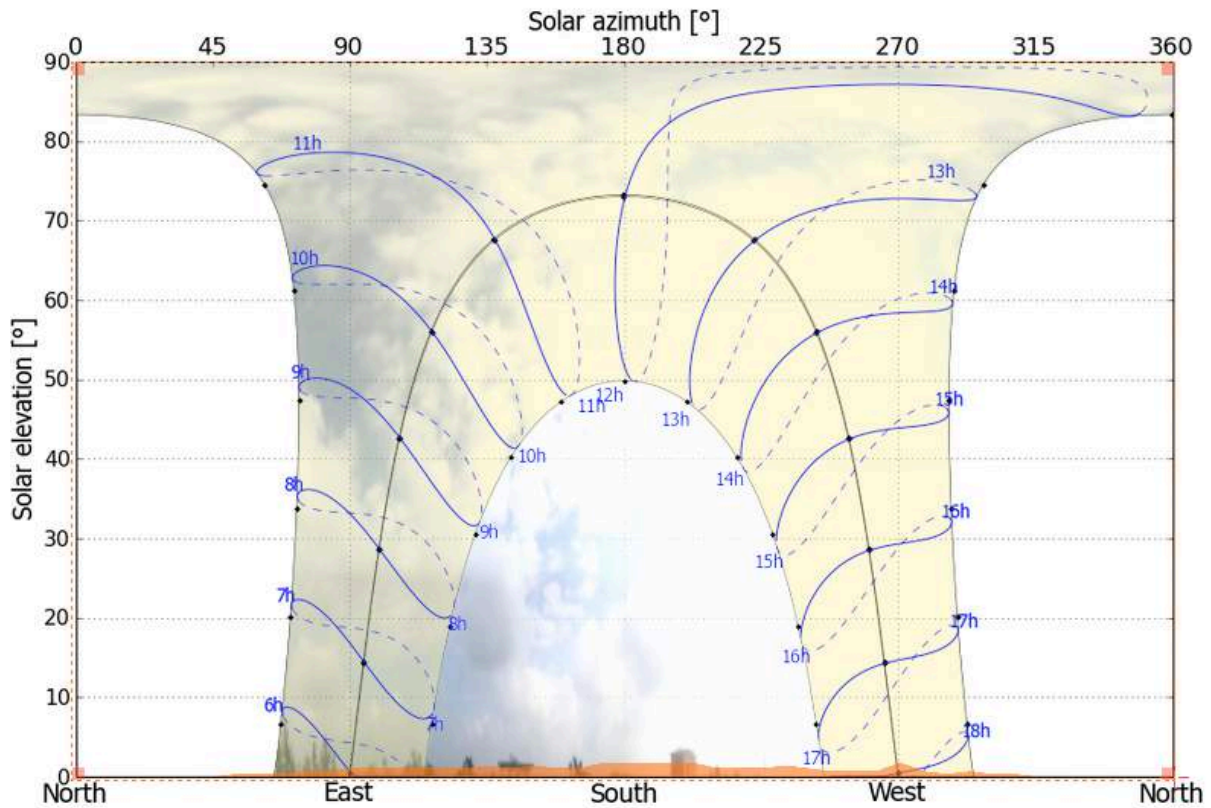


Figure 11: Sun path horizon of ESMAPVN potential station location on top of local EVN headquarter near Quang Tri (VNQU2)

Comparison of locations for site VNQUT

VNQU1 is not suitable because it does not have a feasible roof (gable).

VNQU2 shows a perfect flat horizon without obstructions. This is a safe rooftop of permanently manned EVN/CPC office building.

For the selected location on top of the local EVN headquarter near Quang Tri (VNQU2), we propose code VNQUT, which should indicate Vietnam – close to Quang Tri. This site code shall be used in all related communications, file-names etc.

2.3 Da Nang - VNDAN

General description of the region

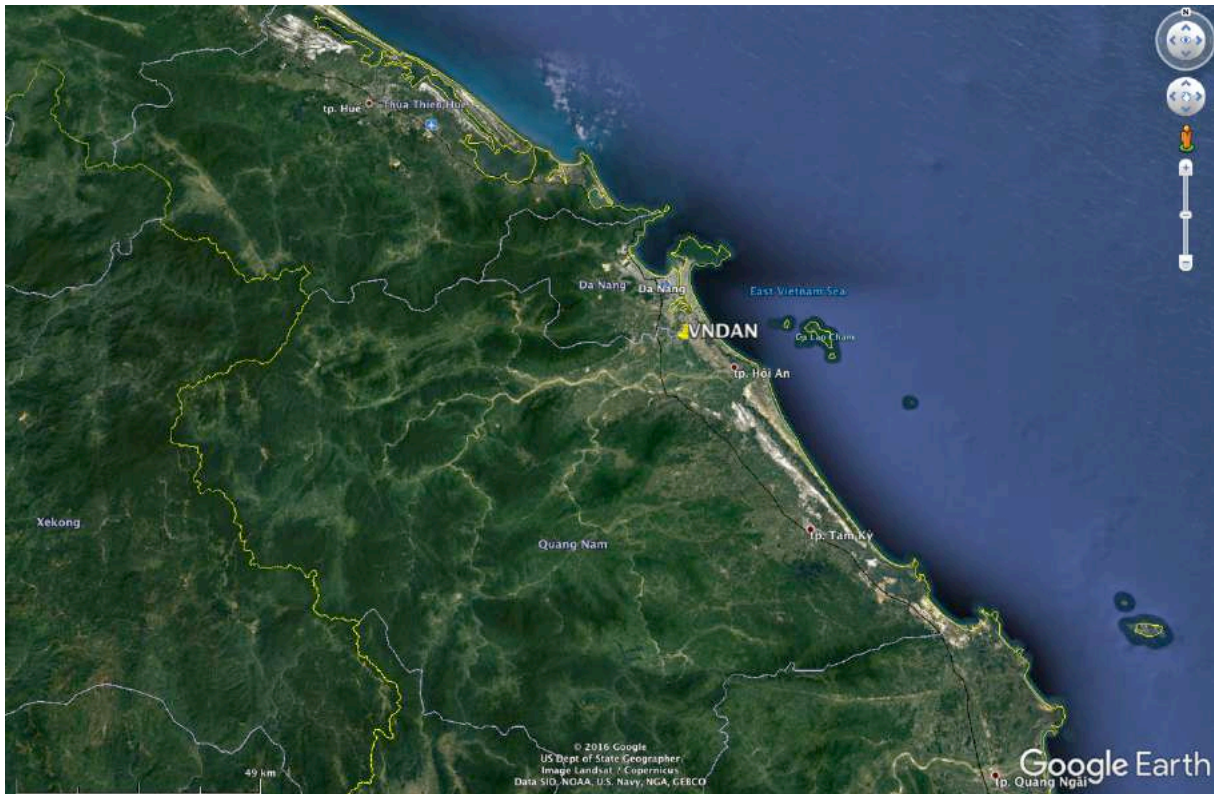


Figure 12: Country map showing Da Nang province

Over one million people inhabit Da Nang, the third largest city and a major port city in Vietnam. It has access to the China South Sea and the Han River while also bordering the provinces Thua Thien-Hue and Hui Van Pass, which is also known as Cloud Pass.

Located over the Paleozoic fold belt Truong Son Orogenic Zone, the city is divided between the steep Annamite Mountain, with peaks between 700 and 1 500 m, and the coastal plains, with sandy beaches.

Da Nang's tropical climate has a rain and typhoon season (September-March) and a dry season (April-August). The annual average temperature is 25.9°C, but the record extremes vary from 41.1°C (April) to 7.2°C (November). The city has, on average, 144 precipitation days a year and 6.1 sunshine hours a day.

Potential locations in the region



Figure 13: Options for measurement location in Da Nang region

Description of inspected locations

Site description	Site code	Elevation	Latitude	Longitude
Da Nang City, EVN/CPC rooftop	VNDA1	24 m	16.0125°N	108.1865°E
Da Nang region, CPC-110kV Thang Binh Substation	VNDA2	18 m	15.7231°N	108.3513°E
Da Nang region, Foster Company rooftop about 10 km inlands near airport at highway 14B	VNDA3	34 m	16.0096°N	108.1798°E
Da Nang region, Hotel Rooftop	VNDA4	7 m	15.9082°N	108.2401°E
Potential Station Location near Da Nang checked as suitable roof on private house	VNDA5	8 m	15.9299°N	108.2298°E

Table 4: Overview of potential locations at Da Nang



Figure 14: Location at Da Nang region, roof on EVN/CPC rooftop (VNDA1).



Figure 15: Location at Da Nang region, CPC-110kV Thang Binh (VNDA2).



Figure 16: Location at rooftop about 10 km inlands near airport at highway 14B on Foster Company (VNDA3).



Figure 17: Hotel rooftop in Da Nang region (VNDA4)

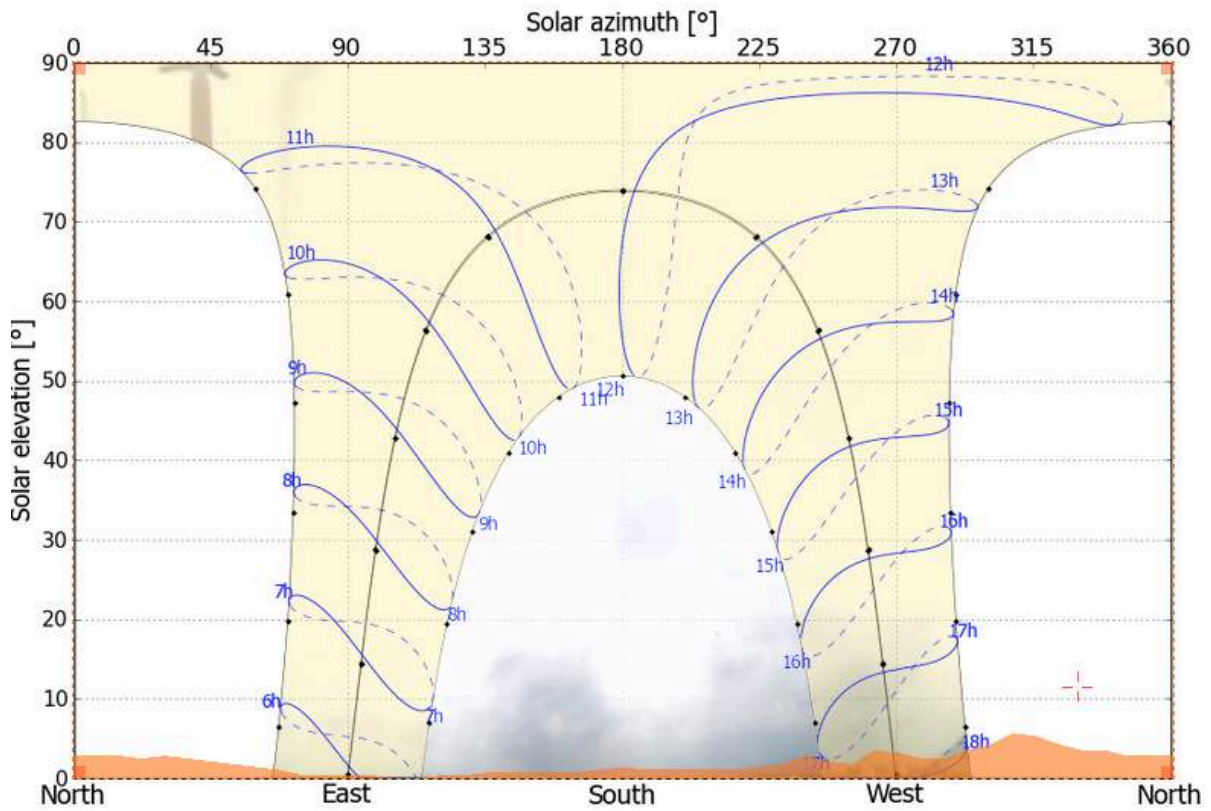


Figure 18: Sun path horizon of hotel rooftop in Da Nang region (VNDA4)



Figure 19: Horizon of hotel rooftop in Da Nang region (VNDA4)

Comparison of locations for site VNDAN

VNDA1: The CPC roof is suitable with free horizon. Shortcoming is that this location is close to the sea and Da Nang is expected to show micro-climatic effects. The minimum distance to the coast is 6 km towards the North and 7 km towards the Eastern beaches of Da Nang.

VNDA2: The substation is generally not suitable as erecting any additional installations on a sub-station requires a lengthy permission process in Vietnam and this substation has no free area unobstructed by electricity wires / poles.

VNDA3: The Foster Company was not accessible and it shows no interest to cooperate. This location is therefore not suitable.

VNDA4: The Hotel roof was accessible and has a good horizon, but does not have enough space. This location is therefore not suitable.

VNDA5: The private house could not be climbed, as there is no ladder installed yet. The house owner is highly motivated and would be ready to host and maintain the solar measurement station. The minimum distance to the coastline in the East is 8 km. Thus, compared to the other suitable location VNDA1 this location would have a slight advantage concerning representatives for the area in the satellite pixels.

Given the disadvantage of VNDA1 being situated closer to the coast-line and having micro-climatic effects expected in the city also due to nearby mountains, VNDA5 would be even better for the installation of a solar measurement station than VNDA1. However, both locations are suitable. We know that the World Bank Group has strong interest in Da Nang city being a part of the PV-GIS rooftop-mapping project. In the wrap-up meeting, Suntrace rather recommended the private roof of VNDA5. Yet, after analyzing the sites in detail within the framework of this report, we recognize VNDA1 as suitable location as well. Furthermore, choosing another location on an EVN subsidiary rooftop might also be the better solution for sustained measurements.

We propose the site code VNQUT either for the location VNDA1 or VNDA5, as both sites are suitable. This will be determined depending on which location will be selected by the World Bank Group.

2.4 Central Highlands - VNCEH

General description of the region

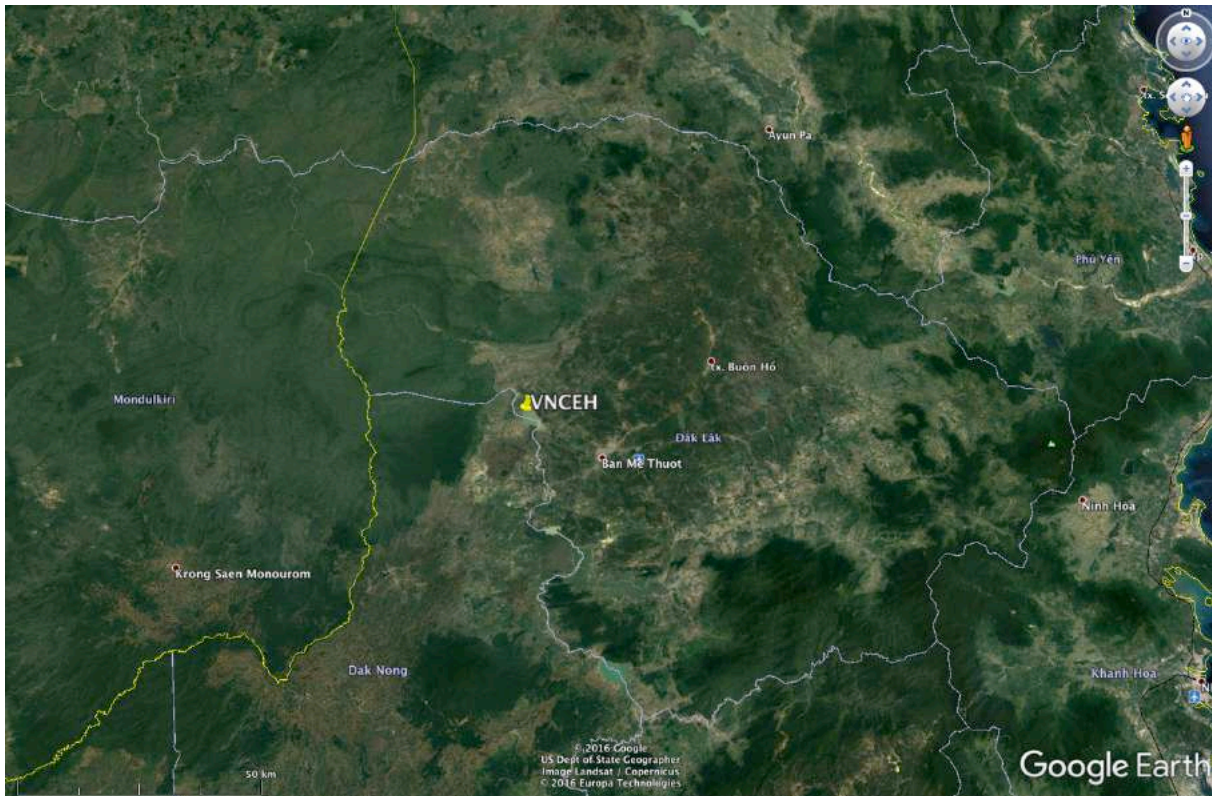


Figure 20: Country map showing Central Highlands

Located in the Vietnamese border with Laos and Cambodia, Dak Lak, Dak Nong, Gia Lai, Kon Tum and Lam Dong are part of the Central Highlands, locally known as Tay Nguyen. Its total population surpasses 4.8 million people.

The region is surrounded by mountains and mounds in the South Annamite Range and lies over several plateaus, ranging from 500 m (Kon Tum Plateau) to 1 500 m (Lam Vien Plateau) high.

One of its major cities, Da Lat has a daily mean temperature of 17.9°C with steady averages throughout the year. Still, in the past decades its extrema ranged from -0.6°C to 31°C, both in February. The city has ca. 161 rainy days and 2 036 sunshine hours a year.

Potential locations in the region

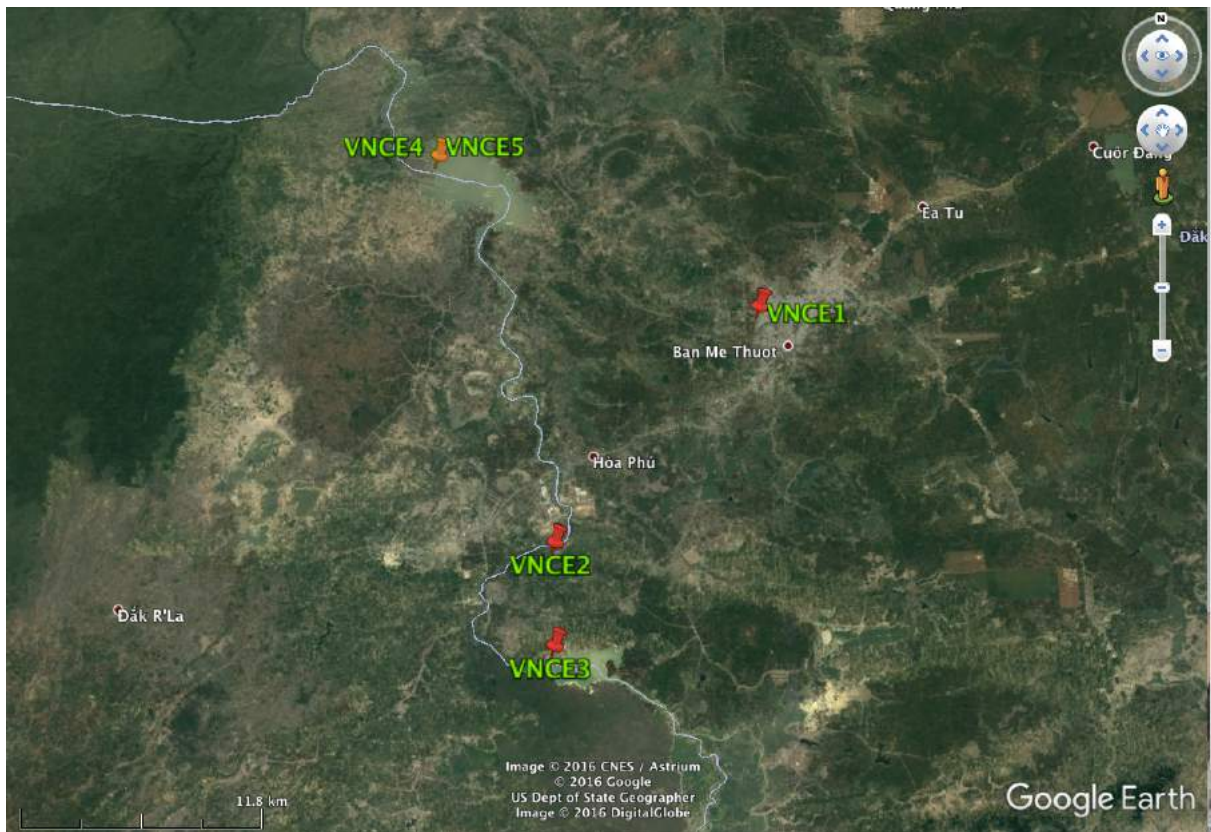


Figure 21: Options for measurement location in Central Highlands



Figure 22: Options VNCE4 and VNCE5 for measurement location in Central Highlands

Description of inspected locations

Site description	Site code	Elevation	Latitude	Longitude
Location at EVN-CPC on rooftop of worker's home building	VNCE1	440 m	12.6791°N	108.0237°E
Location on roof of turbine house at river	VNCE2	335 m	12.5758°N	107.9258°E
Location on rooftop of hydro dam's spillway gate house	VNCE3	409 m	12.5303°N	107.9243°E
Location on rooftop of guard house at water spillway at Tan Hoa dam	VNCE4	274 m	12.7531°N	107.8766°E
Location on ground apart from guard house at water spillway Tan Hoa dam	VNCE5	274 m	12.7534°N	107.8763°E

Table 5: Overview of potential locations in the Central Highlands



Figure 23: Location at EVN-CPC on rooftop of worker's home building (VNCE1).

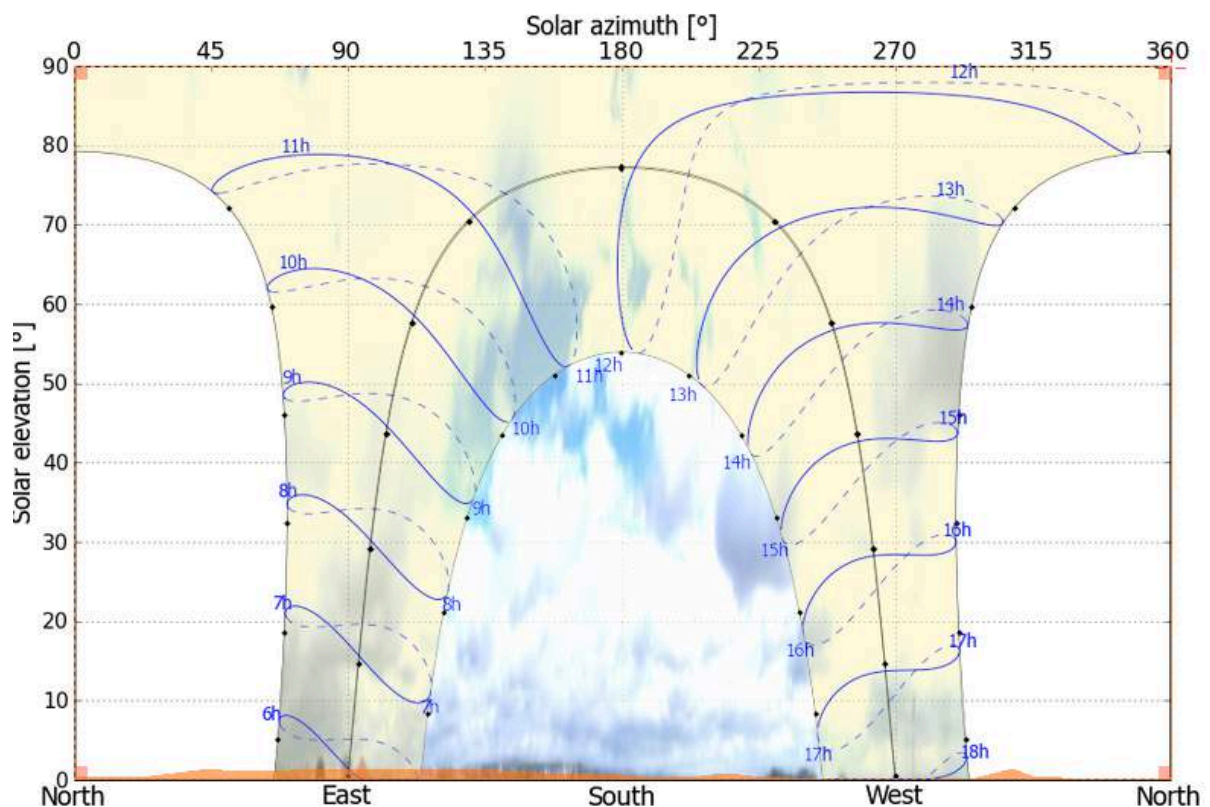


Figure 24: Sun path horizon of the location at EVN-CPC on rooftop of worker's home building (VNCE1).



Figure 25: Location on roof of turbine house at river (VNCE2).



Figure 26: Location on rooftop of hydro dam's spillway gate house (VNCE3).



Figure 27: Location on rooftop of guardhouse at water spillway (VNCE4).

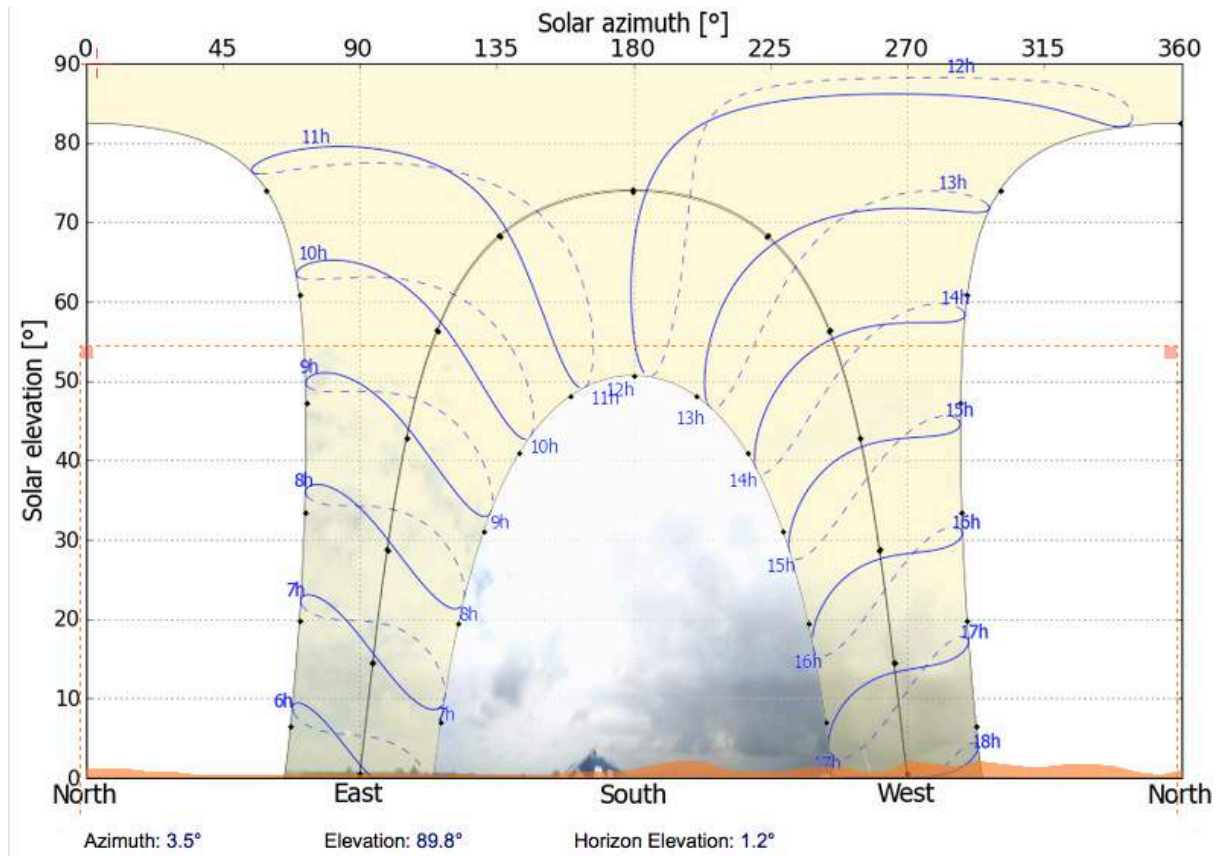


Figure 28: Sun path of location on rooftop of guard house at water spillway (VNCE4)

Comparison of locations for site VNCEH

The selection of the location for a station in the Central Highlands turns out to be easy. As all locations VNCE1-VNCE3 had inaccessible horizon issue, the clear choice is to place the station near the spillway of the Tan Hoa dam (VNCE4 & VNCE5). VNCE4 is another location for a rooftop installation. VNCE5 is in front of the guardhouse on the ground. As locations on ground deliver more realistic wind measurements, VNCE5 would be the preferred location.

For the selected location on ground apart from the guardhouse at water spillway near the Central Highlands (VNCE5), we propose code VNCEH, which should indicate Vietnam – close to the Central Highlands. This site code shall be used in all related communications, file-names etc.

2.5 EVN Song Binh - VNSOB

General description of the region

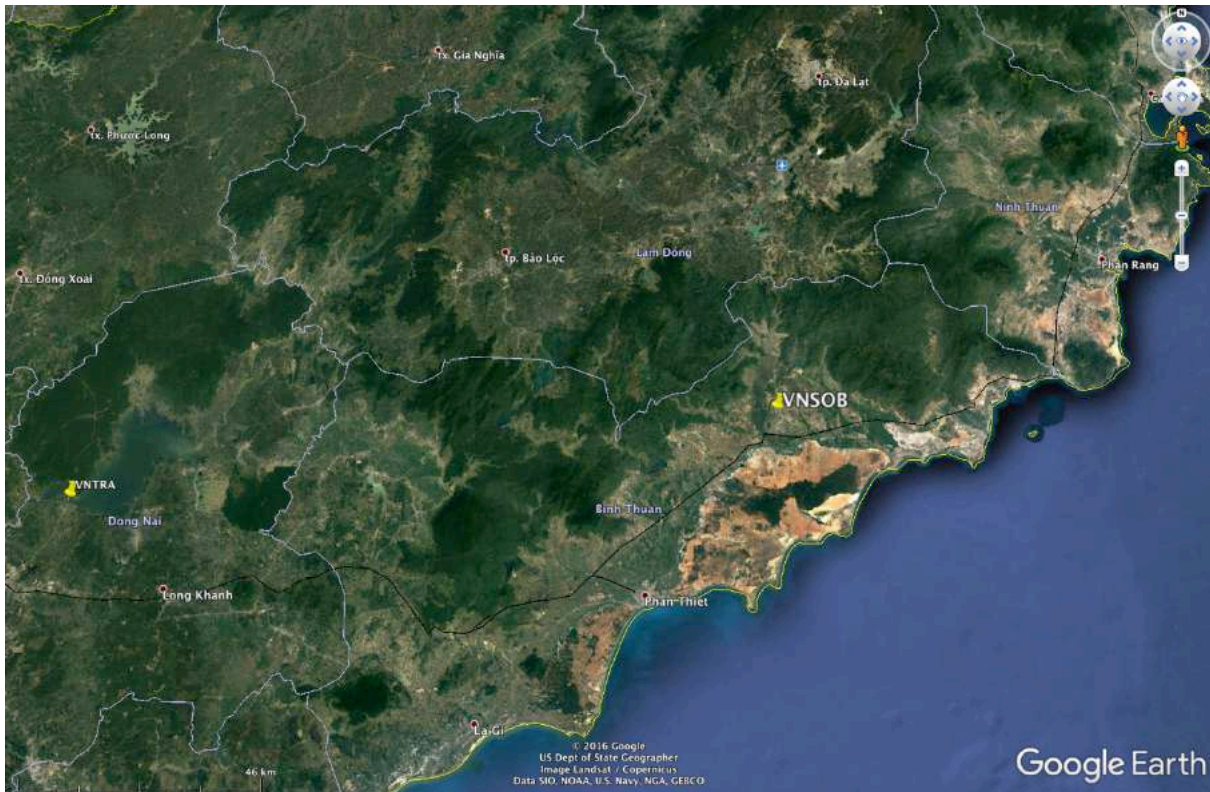


Figure 29: Country map showing Binh Thuan province

Song Binh is located within the province of Binh Thuan, in Vietnam's South Central Coast. The province borders Lam Dong, Ninh Thuan, Dong Nai and Ba Ria-Vung Tau.

Whereas it is majorly flat, the province contains hills above 200 m along its coast and a peak of 1 548 m at its Tanh Linh district. Whereas Binh Thuan is covered by forests (50%), it is also possible to find 284 000 ha of agricultural lands at its territory. The latter is the largest figure among the Vietnamese provinces.

The region has a steady annual average temperature of 26°C with heavy rains from May to October and a dry season in the rest of the year. It has a steady amount of sunshine hours throughout the year, ranging from 11.9 hours a day in December to 13.1 in June-July.

Potential locations in the region

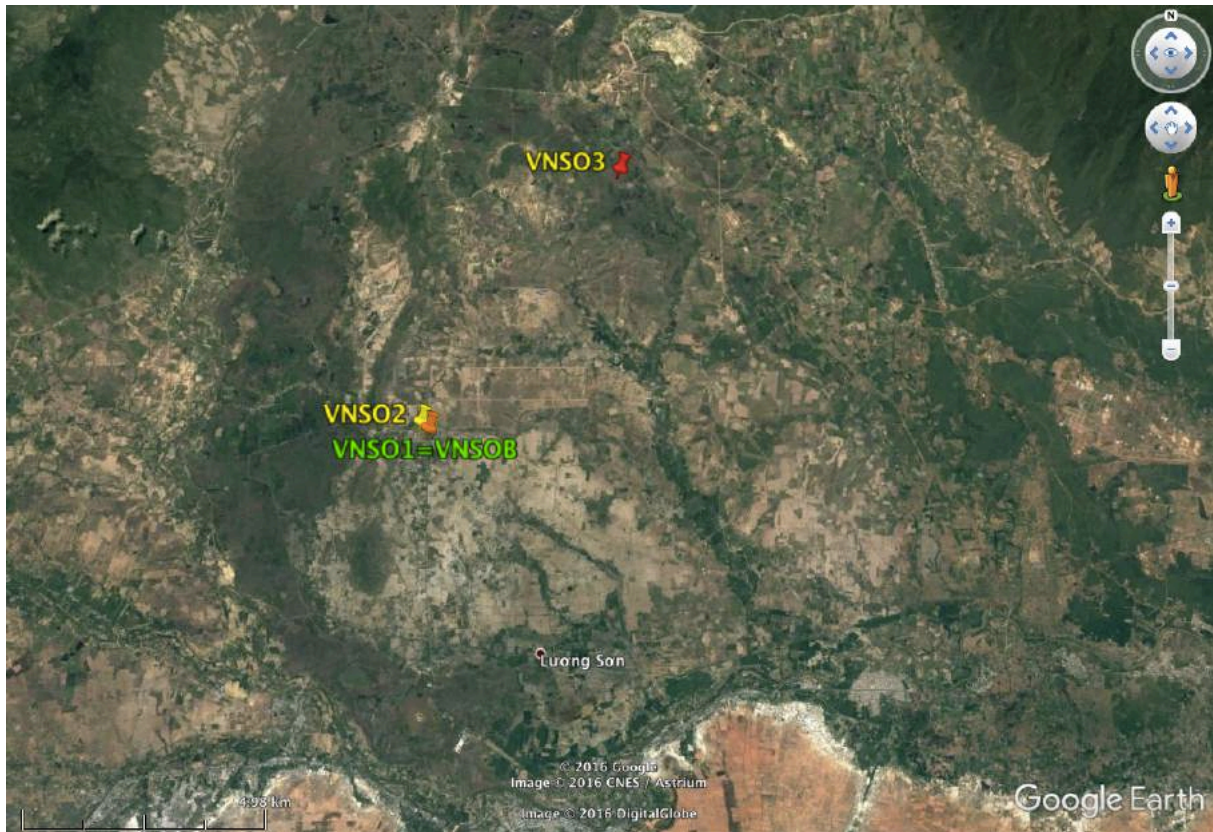


Figure 30: Options for measurement location in Song Binh

Description of inspected locations

Site description	Site code	Elevation	Latitude	Longitude
Song Binh, roof on private house	VNSO1	58 m	11.2640°N	108.3452°E
Song Binh, water treatment facility	VNSO2	57 m	11.265°N	108.344°E
Song Binh site acc. to TOR from WB	VNSO3	57 m	11.316°N	108.383°E

Table 6: Overview of potential locations at EVN Song Binh



Figure 31: Location at Song Binh, roof on private house (VNSO1)

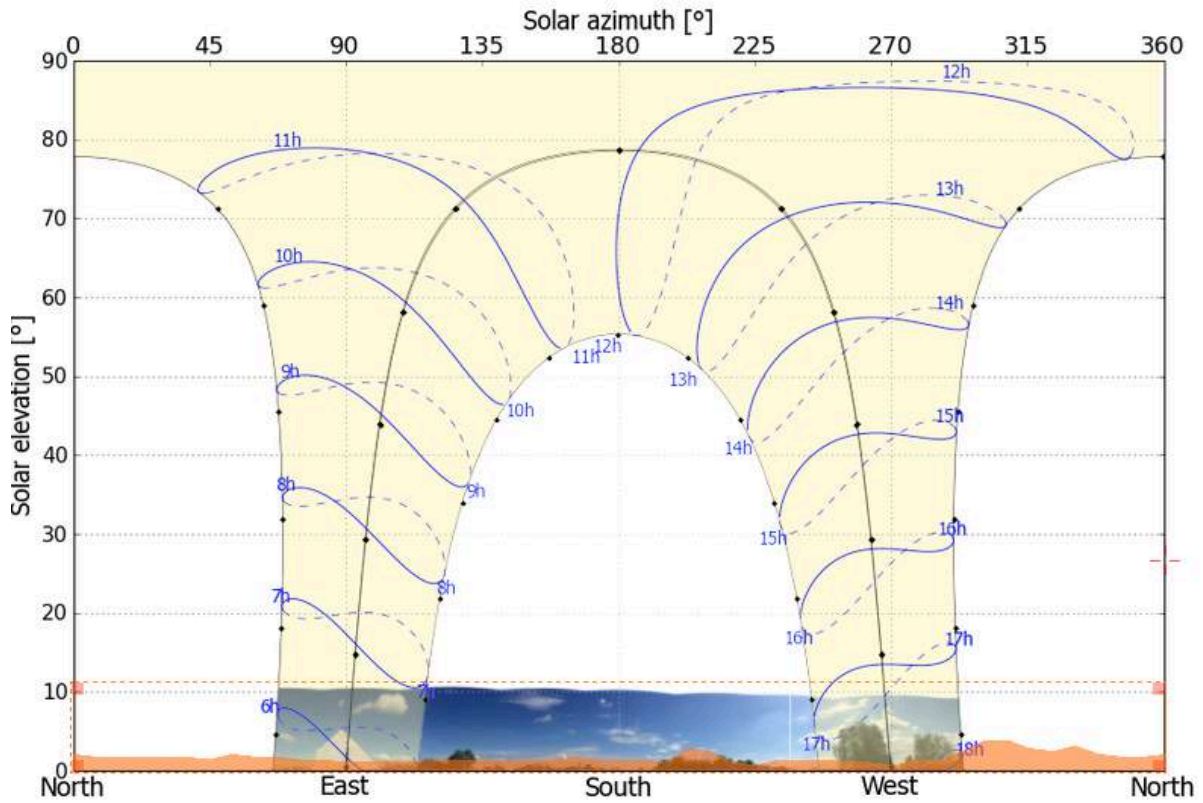


Figure 32: Sun path horizon of location at Song Binh, roof on private house (VNSO1)



Figure 33: Song Binh, water treatment facility

Comparison of locations for site VNSOB

VNSO1 is located on a private rooftop and shows the only suitable safe site. It is one of the few houses in the region, which has a concrete roof. This one is relatively free (only one water tank). Trees are so distant that they hardly influence solar radiation measurements. One obstacle to install a station there is the gable wall towards the East. This issue should be overcome, by installing the radiometers at a 3.5 m high pole and prepare a step for daily cleaning.

The alternative locations near Song Binh are not suitable. VNSO2 is not permanently staffed. Positioning the station directly at the site VNSO3 is not suitable as there is no house guard yet and many trees would obstruct viewing conditions.

For the selected location on the private rooftop near the Song Binh (VNSO1), we propose code VNSOB, which should indicate Vietnam – close to the Song Binh. This site code shall be used in all related communications, file-names etc.

2.6 EVN Tri An dam – VNTRA

General description of the region

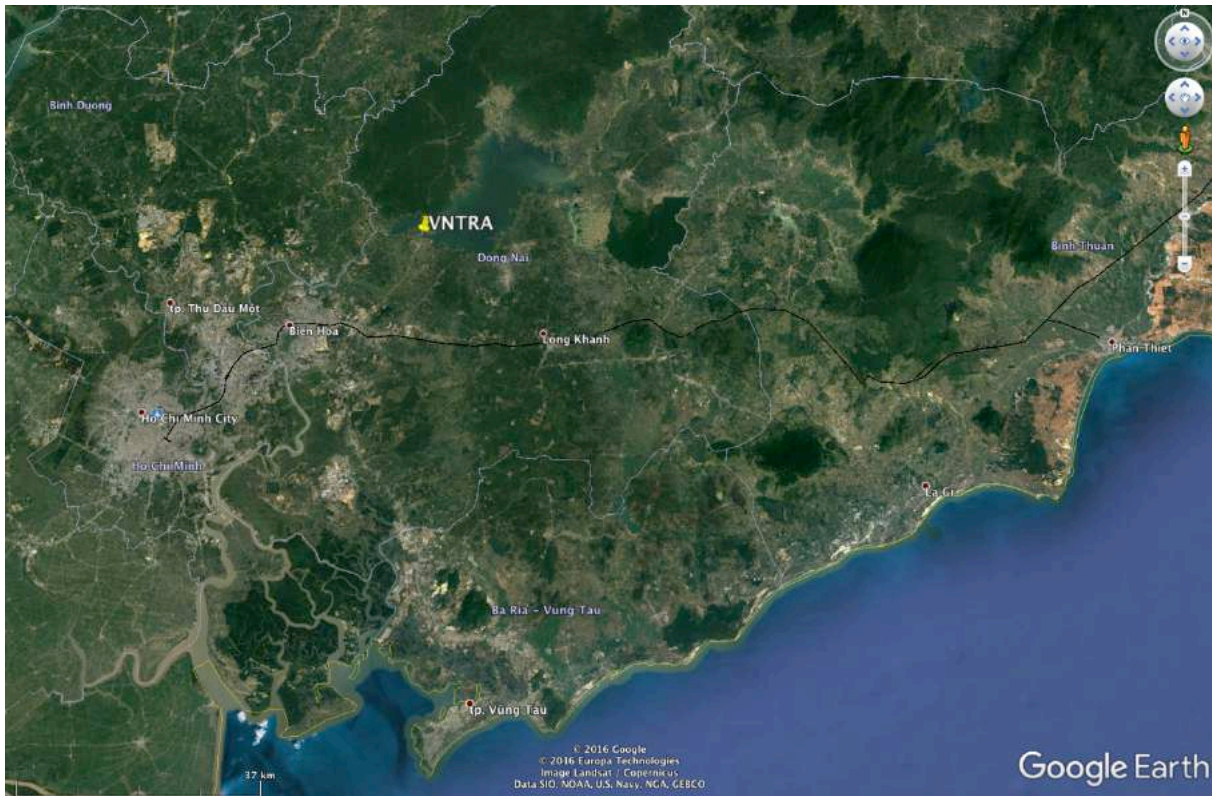


Figure 34: Country map showing Dong Nai province

Tri An is a hydroelectric dam on the Dong Nai River, which has approximately 586 km in length and is located in the rural district Vinh Cuu, part of the Dong Nai province. Inhabited by 106,067 people, Vinh Cuu is located in the southeast part of Vietnam and linked to the Cat Tien National Park.

Binh Thuan, Lam Dong, Binh Duong, Binh Puoc, Ba Ria-Vung Tau and Ho Chi Minh, Vietnam's largest city, surround Dong Nai. The province has over 60 rivers and lakes as large as the Tri An, with 323 km², where the dam is located. Its capital is Bien Hoa, located about 30 km from Tri An.

Affected by the northeast and southeast monsoon, and the Pacific Ocean tropic atmosphere, the province's climate is divided into the rain season (March-November) and the dry season (December to March). Its temperature range from 23.9°C to 29°C with annual rainfalls from 1 500 to 2 700 mm. Whereas on the sunniest days it might have 11.5 hours of sunlight, it is generally sunny from 4 to 9.5 hours a day.

Potential locations in the region



Figure 35: Options for measurement location at Tri An dam

Description of inspected locations

Site description	Site code	Elevation	Latitude	Longitude
Tri An Power Station	VNTR1	27 m	11.1056°N	106.9838°E
Tri An reservoir, inside dam at shore, which is thread by flooding	VNTR2	53 m	11.1092°N	107.0056°E
Tri An dam near water spillway on top of EVN Bldg., where geotechnical bore cores are stored	VNTR3	58 m	11.1024°N	107.0378°E

Table 7: Overview of potential locations at Tri An dam.



Figure 36: Location at EVN Tri An dam building near water spillway on top of EVN building (VNTR3)

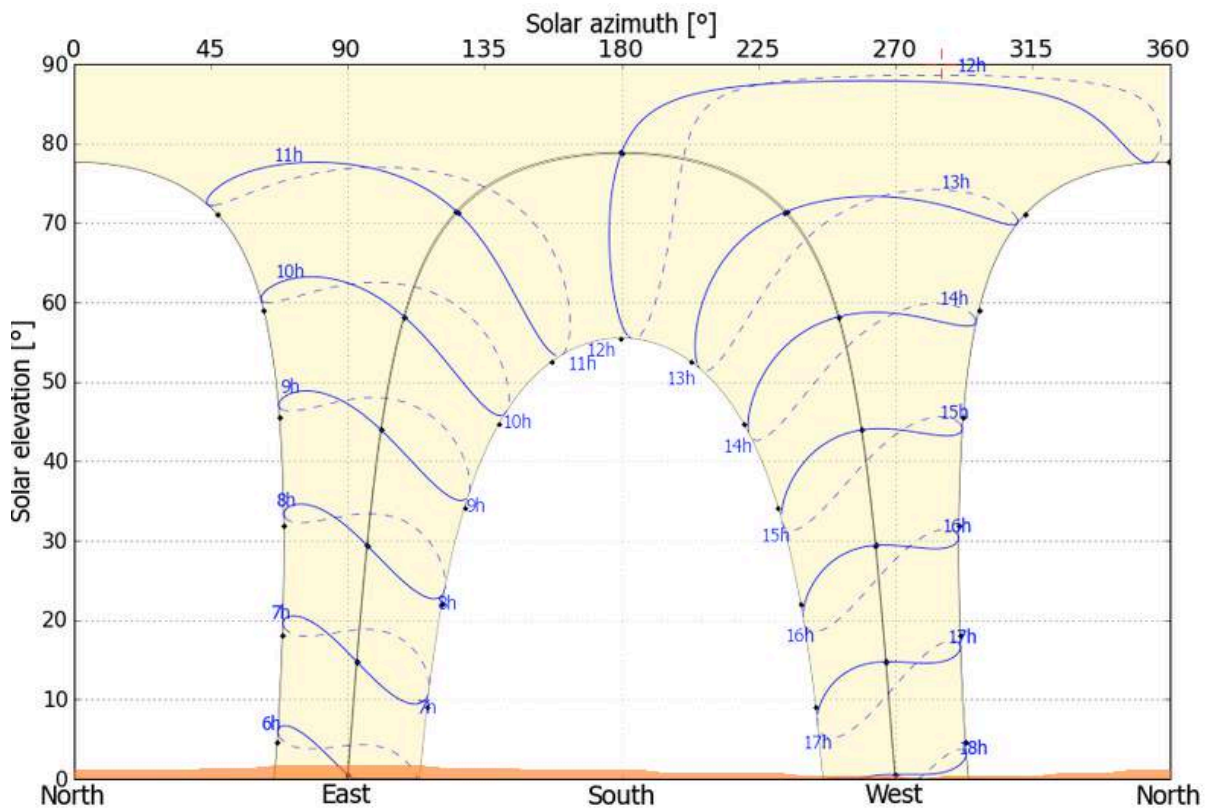


Figure 37: Sun path of location at EVN Tri An dam building near water spillway on top of EVN building (VNTR3)

Comparison of locations for site VNTRA

VNTR3 is the clear choice for this site. This location is close to the Tri An dam near water spillway on top of EVN building, where geotechnical bore cores are stored. Location VNTR1 is not suitable due to a strong horizon obstruction by dam and power line as well as an unsuitable rooftop. The location VNTR2 is unsafe due to flooding risk and unsecured because of missing guards. Tri An dam.

For the selected location on top of the EVN building at Tri An dam near water spillway (VNTR3), we propose code VNTRA, which should indicate Vietnam – close to the Tri An. This site code shall be used in all related communications, file-names etc.

3. RECOMMENDATION FOR SITES AND STATION TYPES

3.1 Recommendations for sites

After discussions with World Bank, EVN, screening the country using satellite data, and inspecting 6 regions for the potential installation of the ESMAP solar measurement stations in Vietnam we conclude the following:

- Solar measurement stations should be spread across the whole country as solar resource is abundant even in the Northern parts.
- As security issues due to vandalism or theft seem to be likely installation on rooftops is preferred.
- The following ranking of sites was derived:
 1. Tri An (VNTRA)
 2. Central Highlands (VNCEH)
 3. Hanoi region (VNHAN)
 4. Song Binh (VNSOB)
 5. Da Nang region (VNDAN)
 6. Quang Tri (VNOAT)

Our recommendation is to install Tier 1 stations at the highest ranking sites. The first three sites listed above are situated at well-protected locations, where security allows permanent supervision of the expensive Tier 1 stations. The recommended sites where these Tier 1 stations are to be installed are all at grounds of EVN and situated at locations where it is expected that the station may sustain for many years. As Tier 1 stations should be used for long-term supervision of solar resources this is important.

The sites ranked 4 to 6 are recommended to be equipped with Tier 2 stations, which are less expensive, need less installed PV power, which might attract thieves, if placed remotely. Stations of Tier 2 can be easier moved to other locations compared to the heavier Tier 1 installations. For example the Tier 2 station recommended to be installed at the rooftop of a private house at Song Binh could be moved to the PV park under development nearby as soon as this park is guarded.

The basic request of World Bank for Vietnam was to install only 5 stations across the whole country. As this country is quite elongated and is covering 3 main climate zones having only 5 points for validation of the satellite-derived maps for this highly promising solar energy market seems to be sparse. With an area of 332 698 km² erecting only 5 stations, this would mean an average of 1 station for more than 66 540 km². Compared to uprising solar energy nations like India with an average solar station density of better than 27 000 km² or the Maldives with 1 station per 74 km² station density is low. Adding a 6th station would improve to 1 per 55 450 km². The proposed 6th location at Quang Tri would be strategically situated very well: It would be located in the North Central Coast region, which is characterized by a substantially different climate from that South of Cloud Pass, which will be measured by stations in Da Nang and in the Central Highlands. Further, we are convinced that also the northern part of Vietnam offers many reasonable sites for developing large solar energy parks. Installing lots of distributed PV capacity across the country would help to better balance the generation capacity and lower the impact of fluctuation due to correlated weather patterns.

3.2 Recommendations for selection of optional items

During contract negotiations it was agreed between World Bank and Suntrace that selection of optional items for the Vietnam World Bank ESMAP solar measurement campaign needs to be done after the inspection of the sites. Now as all potential sites in this country are visited and described in this report, we can give sound recommendations, which consider the general needs for solar projects in this region and more specific the local conditions at the locations selected at each site.

In Table 8 the list of optional items as given in Section 2 of the final Financial Proposal submitted at February 3rd 2017 is given. Our strongest recommendation is to add a 6th station for the reasons explained above. To provide this 6th station at reasonable price, which allows adding many of the items recommended below, we think a Tier 2 station would be sufficient.

The currently closed contract between World Bank and Suntrace only covers the basic measurement equipment following ESMAP requirements, including power supply and fixings. In the following we describe the basic selec-

tion of sensors for the solar measurement campaign for Vietnam and explain the various optional items. We describe each option, motivate its application in this case and conclude with a ranking of the options. Finally, the ranking of all optional items for this solar measurement campaign according to our expert advice is given in Table 9.

No.	Optional Item
1	Rain gauge (w/o heating) incl. cabling and mounts, per station
2	Corrosion test stand, 1 year of exposure, and scientific analysis
3	Soiling measurement assembly (with 3 PV Reference Cells) incl. IEC 17025 calibration cabling, data logger upgrade
4	AOD retrieval algorithm from pyrhemometers and application for 3 sites over 24 months
5	Ventilation of both pyranometers (including power supply upgrade)
6	Upgrade of Tier-2 station to 10m wind speed and direction measurement
7	Surveillance Camera per site
8	Satellite modem option (BGAN), including industrial switch and BGAN modem
9	Public workshop (per site) on solar measurement campaigns
10	Additional Tier-1 station, including additional shipping, site preparation, installation, maintenance, field re-calibration, regular quality checks, documentation, security, final recalibration
11	Additional Tier-2 station, including all efforts for: additional shipping, site preparation, installation, maintenance, field re-calibration, regular quality checks, documentation, security, final recalibration

Table 8: Optional items as offered in the final financial proposal submitted on February 3rd 2017.

For all sort of stations the basic HelioScale stations include these auxiliary measurement sensors:

- Air temperature and humidity sensor installed at approximately 1.5 m height
- Barometric pressure sensor installed at approximately 1.5 m height
- Wind speed sensor (cup anemometer)

At the selected basic Tier 2 stations the anemometer would be installed at 3 m height. At Tier 1 stations a wind direction sensor completes the anemometer and both are installed at 10 m height, which is the WMO standard for near-surface wind measurements. Measurements at only 3 m height in most locations are quite disturbed by vortexes induced by surface roughness due to nearby buildings or other objects, trees, bushes, ditches etc. Thus, 10 m wind measurements are generally much more representative for near surface wind. As 10 m wind levels are also the standard output of meteorological models, most solar yield simulation software such as PVSYST, SAM or greenius, this height is also recommended for this applications. Additional wind direction measurements as supplied with the 10 m wind mast option further support the design of solar plants. For fixed mounted solar panels wind direction can have implications on the design of foundations and mounts, if strong winds mainly are to be expected from specific directions. For floating PV wind direction can be of interest as wind-induced waves usually have preferred propagation depending on wind direction. In the case of the 3 locations, where we recommend Tier 2 stations all will be installed on rooftops. For such cases the wind measurement experts from Windtest Grevenbroich GmbH had recommended to adjust the height of the wind measurements above the ground to a total of 10 m. The HelioScale 10 m wind mast is delivered with a telescopic mast, which can be freely adjusted at any height from 3 m to 10 m. Thus, we recommend upgrading all Tier 2 stations from the 3 m wind speed to the full 10 m wind mast with the wind vane supplement.

The new IEC 61724-1:2017 standard for monitoring of PV plants has introduced an additional requirement for thermal pyranometers: Only instruments, which are ventilated and heated, in wet regions comply with the high-

est Class A level. All sites in Vietnam are in relatively humid tropical climates. Thus, we strongly recommend applying ventilated pyranometers at least for the high level Tier 1 stations. For Tier 1 stations with the shaded and unshaded pyranometers both thermopile instruments must be equipped with ventilation to balance the temperature of the glass dome, so that errors due to the dome temperature are minimized. We suggest to provide the Hukseflux SR30 pyranometers, which is the first pyranometer including ventilation in one housing. The advantages are relatively low additional power consumption and high durability, as it is known that the moving parts of open ventilation systems frequently get damaged due to dirt in the intake. The SR30 with built-in heating and ventilation is requiring relatively low power consumption. As this generally leads to a drier glass dome, which is lowering soiling of the dome, we also suggest applying these ventilated pyranometers to Tier 2 stations. As this option was not given in the Financial Proposal as an option, we offer this upgrade of only 1 instead of 2 pyranometers simply for half of the costs. The additional advantage of offering the same high grade SR30 pyranometer for all station types is that the 1 pyranometer supplied in the spare part kit would fit to all station types. If also the Tier 2 stations are selected with ventilated IEC 61724-1:2017 Class A pyranometers Suntrace offers to upgrade the spare part kit by supplying 1 ventilated SR30 instead of 1 unventilated SR20 pyranometer free of cost.

Soiling measurements for solar energy shall provide additional information to better qualify sites for large-scale solar plants. Operational Expenditures (OPEX) at sites with a substantial amount of dust can be largely increased. Based on our experience supporting utility scale solar energy projects in more than 20 countries and a joint research project with Fraunhofer ISE we strongly recommend adding a soiling measurement assembly to each of the sites. The HelioScale soiling measurement assembly consists of 3 PV reference cells, which are mounted at standard tilt. The first cell is cleaned regularly at least weekly to represent the best achievable level of cleanliness. The second cell is cleaned at the cleaning interval, which is to be expected in the region, e.g. monthly or quarterly, while the third cell shall never be cleaned. This should quantify the effect of PV plants in the region, which would never be cleaned at all. In extreme environments yield losses due to soiling can be higher than 20%. In non-monsoon months, which usually provide the highest solar yields, the natural cleaning due to rain is missing. Soiling in some regions of Vietnam, either due to emissions from the cities and industry, but also from biomass burning or pollen, can be severe. In addition, the PV reference cells are equipped with reference cell temperature readings. Therefore, it is strongly recommended to equip all stations with the soiling measurement assembly. We regard need for such measurements almost equal also for Tier 2 stations as level of knowledge on soiling in this region generally is quite low and it is expected that anthropogenic and natural sources of dust can be substantial.

Corrosion is regarded as a severe risk for sustainability of solar installations. Especially in tropical climates it is known that even stainless steel can get rusty and loading capacity of metal structures can diminish substantially within few years of outdoor exposure. Also the lifetime of floating devices, which may be applied for swimming solar plants, can be severely reduced in aggressive corrosion environments. Countermeasures to prevent rapid aging of metal and plastic structures can drastically increase capital expenditures (CAPEX) of solar parks. Thus, it is strongly advised to opt for the corrosion test stand. The test will be installed together with the station and after the first year of outdoor exposure during station maintenance the test material will be collected and sent to Fraunhofer ISE for evaluation.

For the better understanding of the corrosion process as well as for the soiling it is of good help, if rain events are also recorded. In the tropical and sub-tropical climate of Vietnam rain rates especially during monsoon can be intense. Then also severe flooding could harm non-floating PV parks. Thus, installation of rain gauges is recommended at each of the sites.

As it is expected that aerosol content is high at those 3 stations equipped with pyrhemometers, we recommend to opt for the aerosol post-processing service. The aerosol optical depth (AOD) is expected to be highest in the Northeast, where it is known that emissions from coal-fired plants in China are transported towards the Red River basin around Hanoi. High AOD is known to have strong impact especially on the direct beam radiation, but such high levels also may affect GHI significantly and AOD is known to be a big source of uncertainty of satellite-derived solar radiation levels. As it is also of interest how much e.g. biomass burning etc. may affect AOD levels in the South and the Central Highlands we also recommend to apply this service for the other 2 pyrhemometer stations.

During the Implementation Visit it was found that unobserved valuables are endangered. The value of the solar measurement stations supplied here is quite high and we made the experience that especially the power supply components like the PV panels might attract thieves. Therefore we also recommend installation of a surveillance camera system at each of the sites. This also would give us the additional advantage to remotely check e.g.

maintenance, and assist remotely in case of the need for repairs. Further a surveillance camera, which also observes parts of the sky, allows checking present weather to better understand readings, when doing interactive quality checks.

Rank	Item	Quantity
1	Additional Tier 2 station, including all efforts for: additional shipping, site preparation, installation, maintenance, field re-calibration, regular quality checks, documentation, security, final recalibration	1
2	Tier 1 stations upgrade with 2 ventilated pyranometers (SR30 instead of SR20, including power supply upgrade)	3
3	Tier 1 stations extension with Soiling measurement assembly (with 3 PV Reference Cells) incl. IEC 17025 calibration cabling, data logger upgrade	3
4	Tier 2 stations extension with Soiling measurement assembly (with 3 PV Reference Cells) incl. IEC 17025 calibration cabling, data logger upgrade	3
5	Tier 1 stations extension with Corrosion test stand, 1 year of exposure, and scientific analysis	3
6	Tier 2 stations extension with Corrosion test stand, 1 year of exposure, and scientific analysis	3
7	Tier 1 Stations extension with Rain gauge (w/o heating) incl. cabling and mounts, per station	3
8	Tier 2 Stations extension with Rain gauge (w/o heating) incl. cabling and mounts, per station	3
9	Tier 1 stations service upgrade with AOD retrieval from pyrhemometers and application to all 3 Tier 1 sites over 24 months	1
10	Tier 2 stations upgrade from 3 m wind mast to 10 m and addition of wind direction measurement sensor (incl. guy wire sets, add. foundations, cabling and data logger integration)	3
11	Tier 2 stations upgrade with 1 ventilated pyranometer (SR30 instead of SR20, including power supply upgrade)	3
12	Surveillance Camera (incl. power supply, cabling, data connection, per site)	6

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