Government of India
MINISTRY OF NEW AND RENEWABLE ENERGY

NATIONAL INSTITUTE OF WIND ENERGY

Karthik Ramanathan

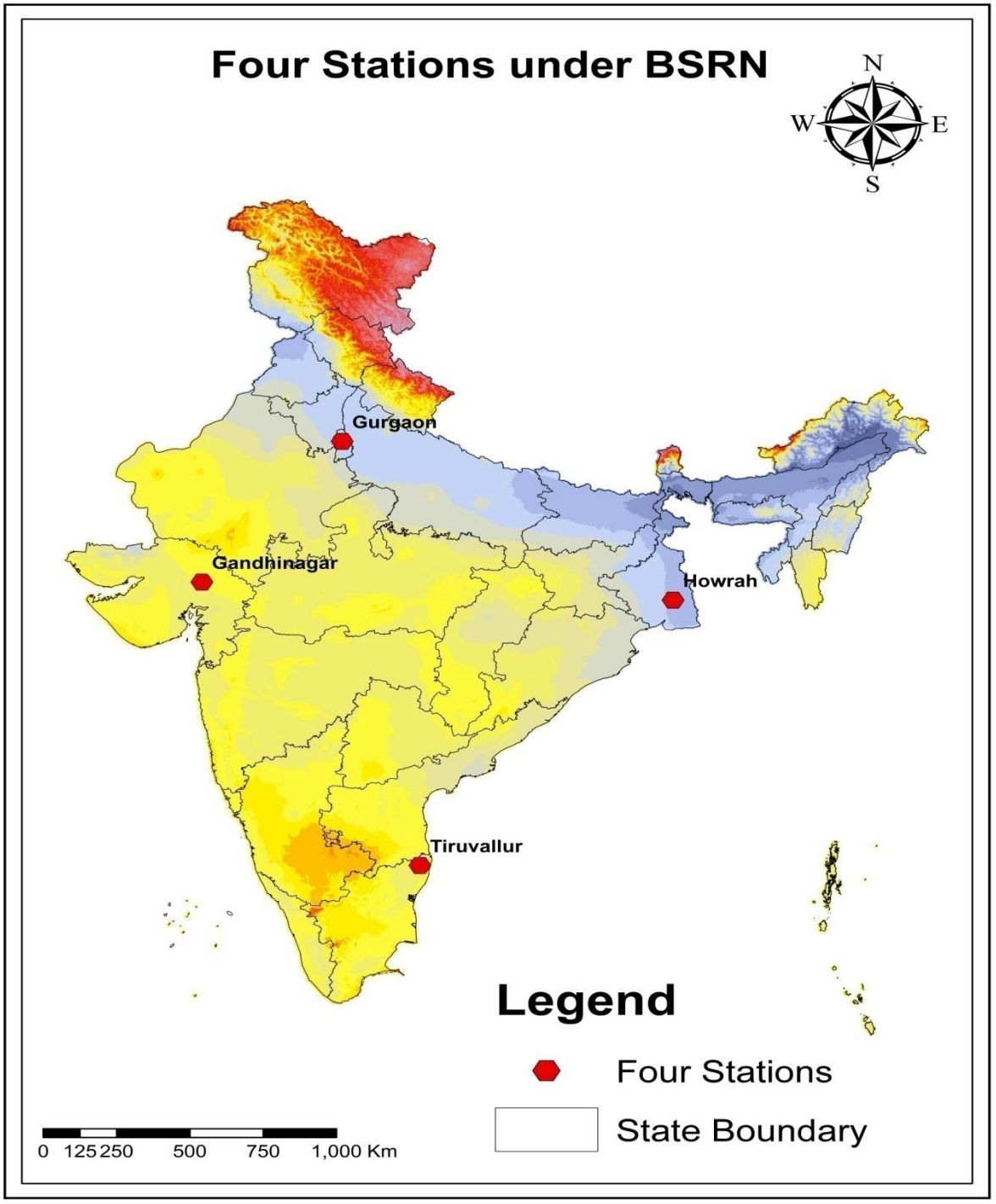
Bringing SRRA India under BSRN Net Work National Institute of Wind Energy Chennai, India

14th BSRN Science & Review Workshop

Bureau of Meteorology
Canberra, Australia
26-04-2016

Introduction

- Set up 4 SRRA Stations, out of 121,with additional sensors.
- Cost of setting up of each station is around $17590 AUD(Rs.90.00 Lakhs) including civil works and installation.
- All the sensors are traceable to the World Meteorological Organization (WMO) and World Radiometric Reference (WRR) with high accuracy to ensure the good quality of recorded data.
- Solar sensors are calibrated every 2 years in our calibration laboratory



Sl. No.	State	Stations
1	Gujarat	1
2	Haryana	1
3	Tamil Nadu	1
4	West Bengal	1
	Total	4

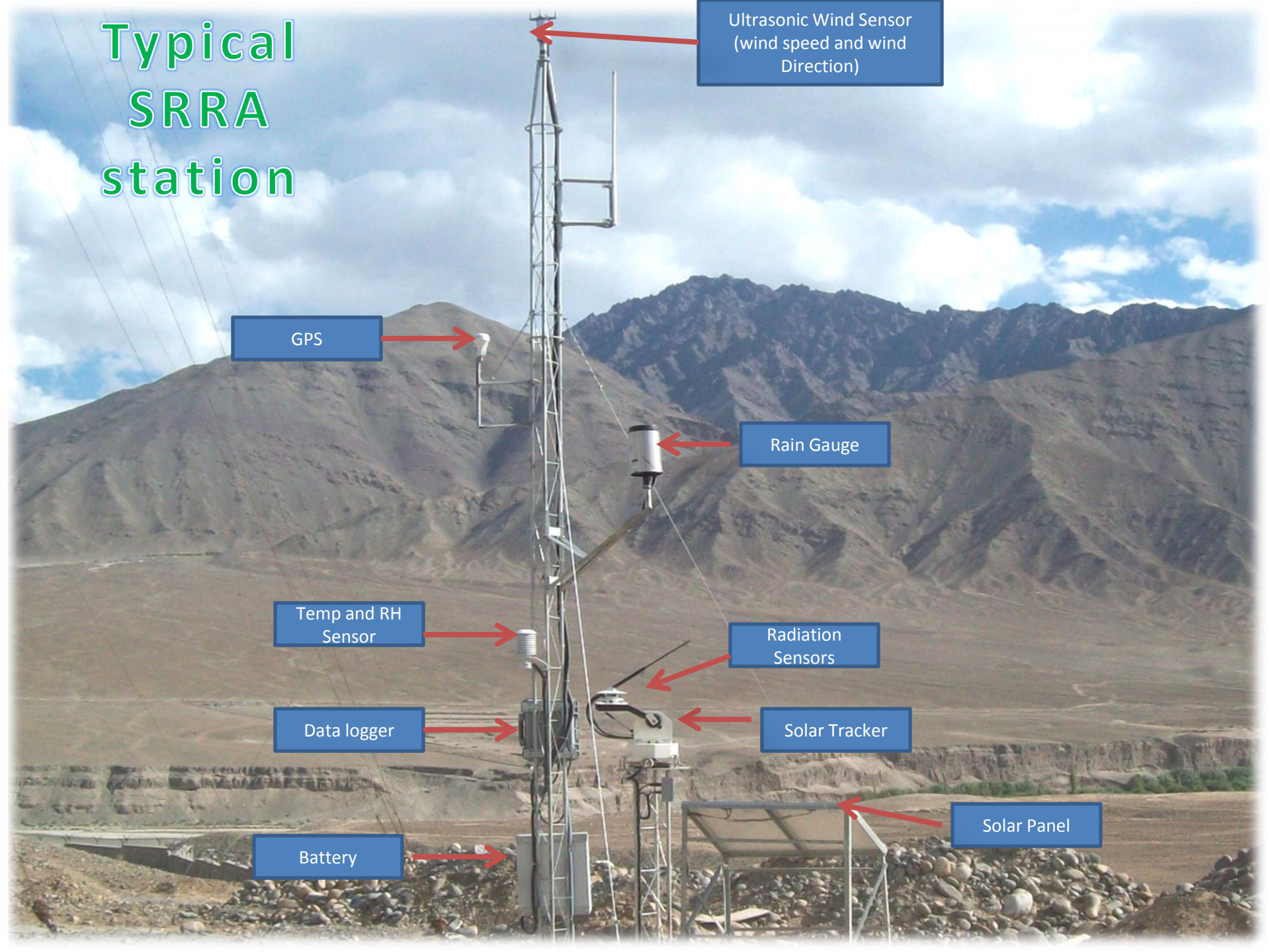
Details of Four Stations

- 4 Stations:
  - 4 regions (North, East, South and West) of the country.
  - 1-National Institute of Solar Energy, Gurgaon; Haryana
  - 2-Bengal Engineering & Science University, Kolkata;
  - 3-Prathyusha Institute of Technology & Management, Thiruvallur Chennai;
  - 4- Gujarat Energy Research & Management Institute, Gandhi Nagar
- Objectives:
  - Measure the solar radiation(GHI,DNI&DHI) and metrological parameters and Study effect of suspended particulate matter (aerosol), water vapor, gases in the atmosphere on scattering or absorption of solar radiation
  - Provide continuous information on radiation, metrological parameters, aerosol column, atmospheric turbidity, ozone column, water vapor in the atmosphere.

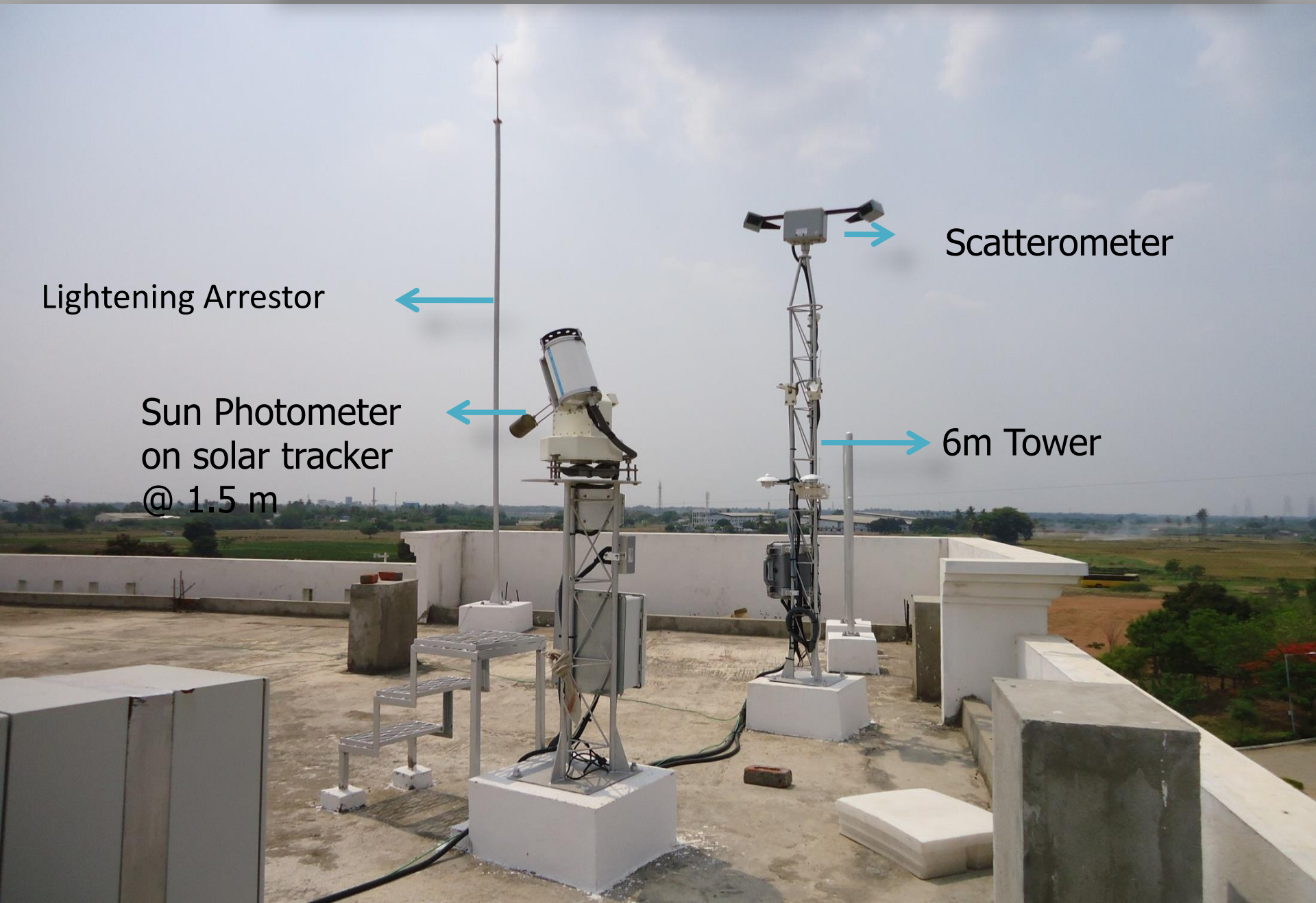
Guidelines for Site Selection

Location	Organization	Avoid
• Well exposure locations • Free Horizon • Strong network signal	• Academic institutions , R&D institutions etc for mutual beneficial • Safe and Secured Places	• Close proximity of industrial heat source • High tension power lines nearby

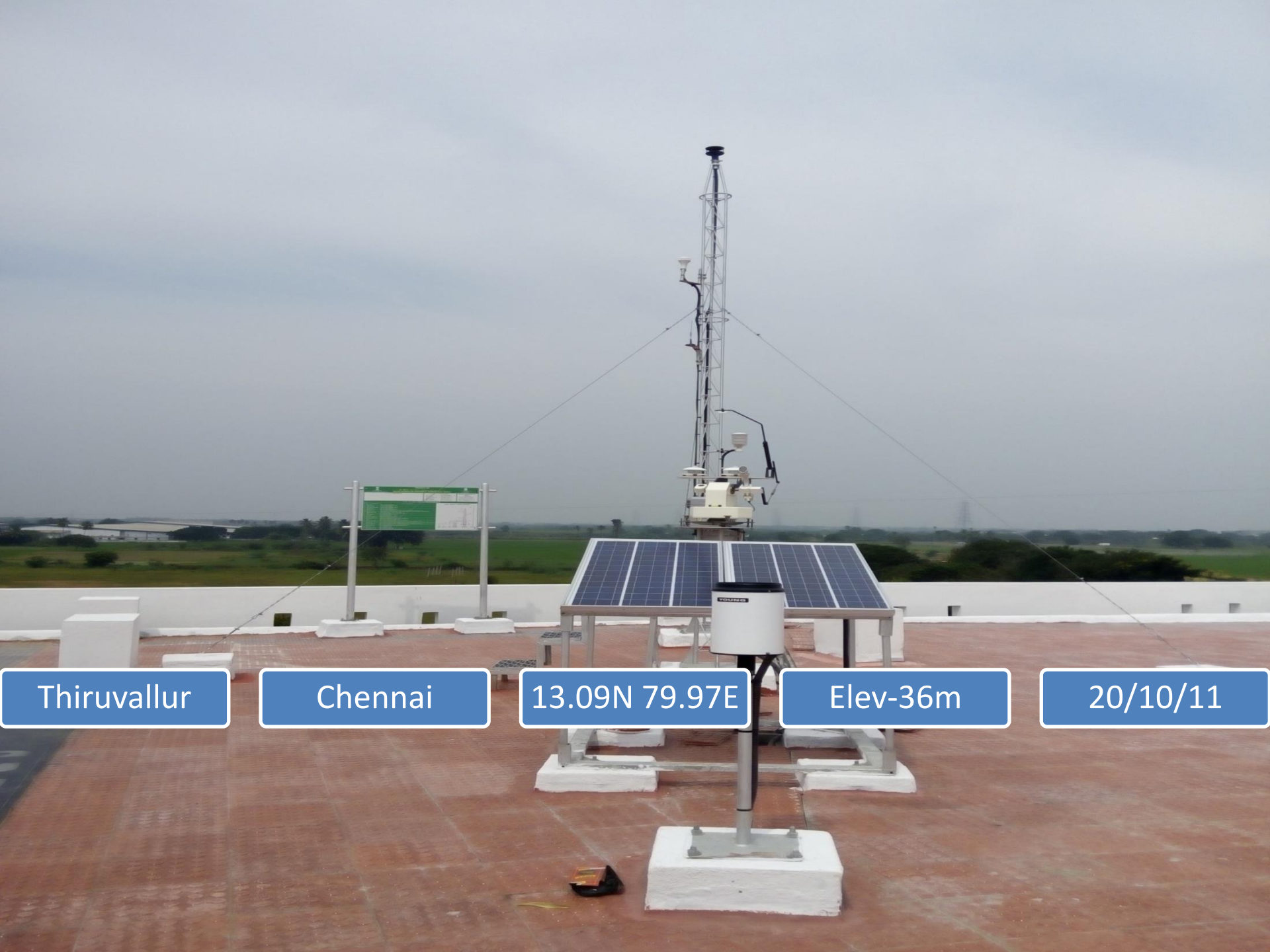
MEASUREMENT STATIONS


Typical SRRA station
Ultrasonic Wind Sensor (wind speed and wind Direction)
GPS
Rain Gauge
Temp and RH Sensor
Radiation Sensors
Data logger
Solar Tracker
Solar Panel
Battery

Advanced Measurement Station(AMS)




Thiruvallur
Chennai
13.09N 79.97E
Elev-36m
20/10/11


Thiruvallur
Chennai
13.09N 79.97E
Elev-36m
20/10/11


Thiruvallur
Chennai
13.09N 79.97E
Elev-36m
16/04/14


Gurgaon
Haryana
28.42N 77.15E
Elev-259m
20/10/11


Gurgaon
Haryana
28.42N 77.15E
Elev-259m
21/04/14

Gandhinagar	Gujarat	72.66E 23.15N	Elev-65m	07/08/11


Gandhinagar
Gujarat
72.66E 23.15N
Elev-65m
19/05/14

Howrah | West Bengal | 22.55N 88.30E | Elev-51m | 14/09/13

06/05/14

INSTRUMENTATION

Meteorological Sensors

Ultrasonic Anemometer

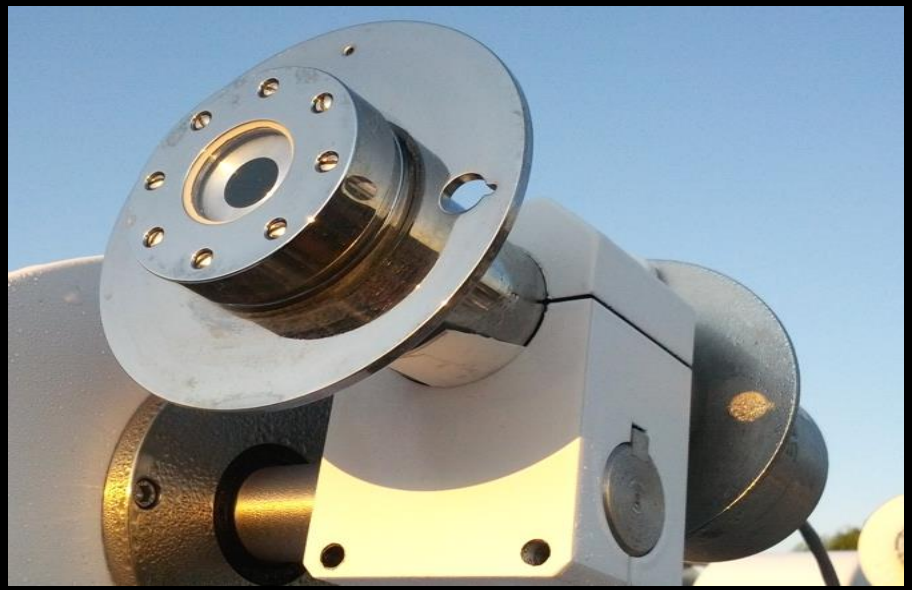
Rain Gauge

Barometer

Temperature & Humidity sensor

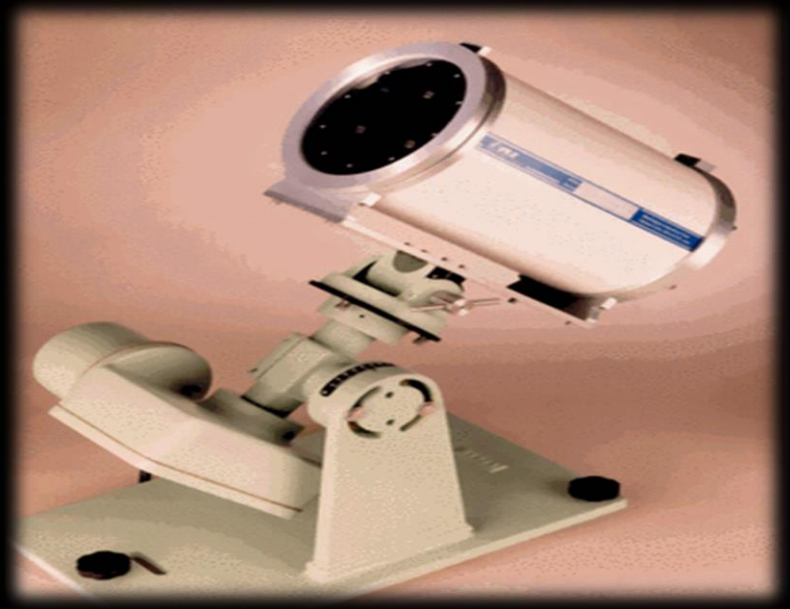
Solar Sensors

Pyranometer-PSP (Eppley)



Pyrheliometer-SNIP(Eppley)

Solar Tracker-Geonica



Direct Beam Filter Spectrometer-YES, USA

Scatterometer - Envirotech USA

Albedometer-Hukseflux-SRA20

Silicon Pyranometer

Pyrgeometer-Hukseflux-IR20

Sensors installed at field Station

Sl. No	Instrument	Model & Make
1	Pyranometer	PSP, Eppley/Hukseflux Make
2	Pyranometer with Shade	PSP, Eppley/Hukseflux Make
2	Pyrheliometer	PSP, Eppley/Hukseflux Make
3	Solar Tracker System	Sun Tracker, Geonica
4	Rain Gauge	52203, R.M. Young
5	Wind Speed and Direction Sensors	Ultrasonic 85000, R.M. Young
6	Temperature Sensor	Model 41382VC ,R.M. Young
7	Relative Humidity Sensor	
8	Pressure Sensor	61302 L , R.M. Young

Sensors installed at field Station

Sl. No	Instrument	Model & Make
9	Data logger	3000 SeriesGeonica
10	Solar Panels	80 Watts X 2, Moserbear
11	GPS External	Garmin, USA
12	GPRS Antenna	Geonica, High Gain
13	Battery Charge Controller	PWM 20 Watts
14	External Batteries	Exide 42 AH x 2 numbers
15	6m& 1.5m Mast	Galvanized Triangular Mast
16	GPRS Connectivity	Data/Voice Card
17	Direct Beam Filter Spectrometer	Yankee, USA
18	Albedo meter & Pyrgeometer	Hukseflux, Netherland
19	Scatterometer	Envirotech Sensors, USA
20	Silicon Pyranometer	Licor, USA

Parameters Measured

Sl. No	Instrument	Parameter
1	Pyranometer	Global Radiation
2	Pyranometer with Shade	Diffuse Radiation
2	Pyrheliometer	Direct Beam Radiation
3	Solar Tracker System	Tracking the Sun movement
4	Rain Gauge	Daily Accumulated Rainfall
5	Wind Speed and Direction Sensors	Wind speed & Direction
6	Temperature Sensor	Ambient Temperature
7	Relative Humidity Sensor	Ambient Humidity
8	Pressure Sensor	Atmospheric Pressure

Continued

	Instruments	Parameter
	Direct Beam Filter spectrometer (Sun Photometer)	Direct spectral irradiance at narrow wavelengths
	Albedo meter	Albedo (shortwave reflection) of the earth's surface (upwelling)
	Pyrgeometer	Incoming long wave radiation (downwelling)
	Scatterometer	Atmospheric visibility / extinction
	Silicon Pyranometer	Global radiation on horizontal & inclined plane with spectral response as crystalline Si PV

Spectrometer Details

Wavelength(nm)	Importance
300,325	Absorption by small size aerosol
368	Weak absorption by ozone
500	Aerosol, dust particle
615,675,778,870,940	Water vapour
1020	Weak absorption by ozone and water vapour

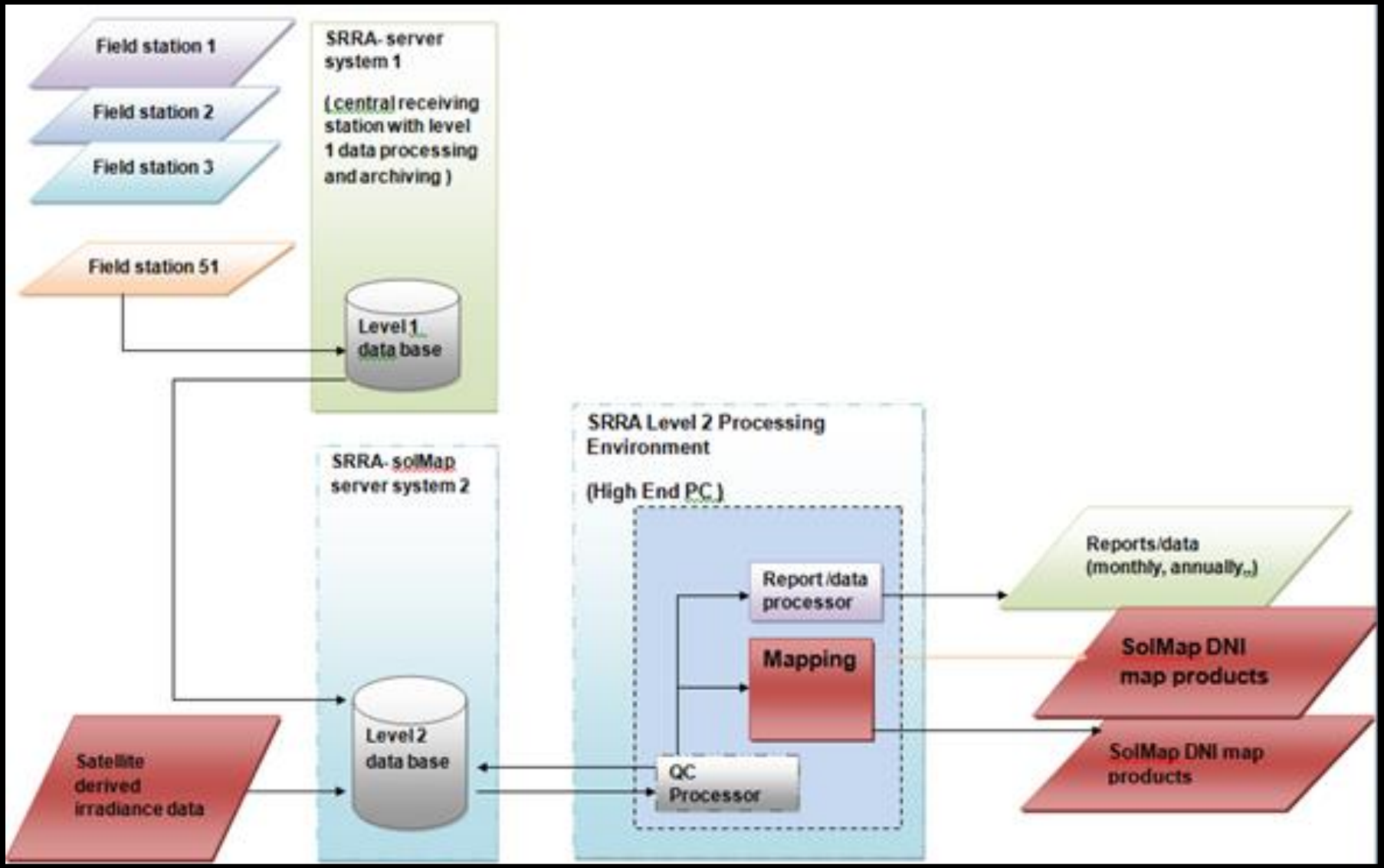
- Measurements of various parameters from AMS are useful in many ways. For example, UV radiation for solar system durability, Aerosol Optical Depth (AOD) for accurate DNI estimates and to find out the contribution of anthropogenic & natural aerosols,
- Reflectivity of the Earth surface for surface characterization,
- Infrared Sky Radiation for estimation of thermal losses,
- Atmospheric visibility for measuring the transparency of the atmosphere and for the estimation of the amount of light scattered by smoke, dust, haze, fog, rain etc

DATA COLLECTION

&

QUALITY ASSESSMENT

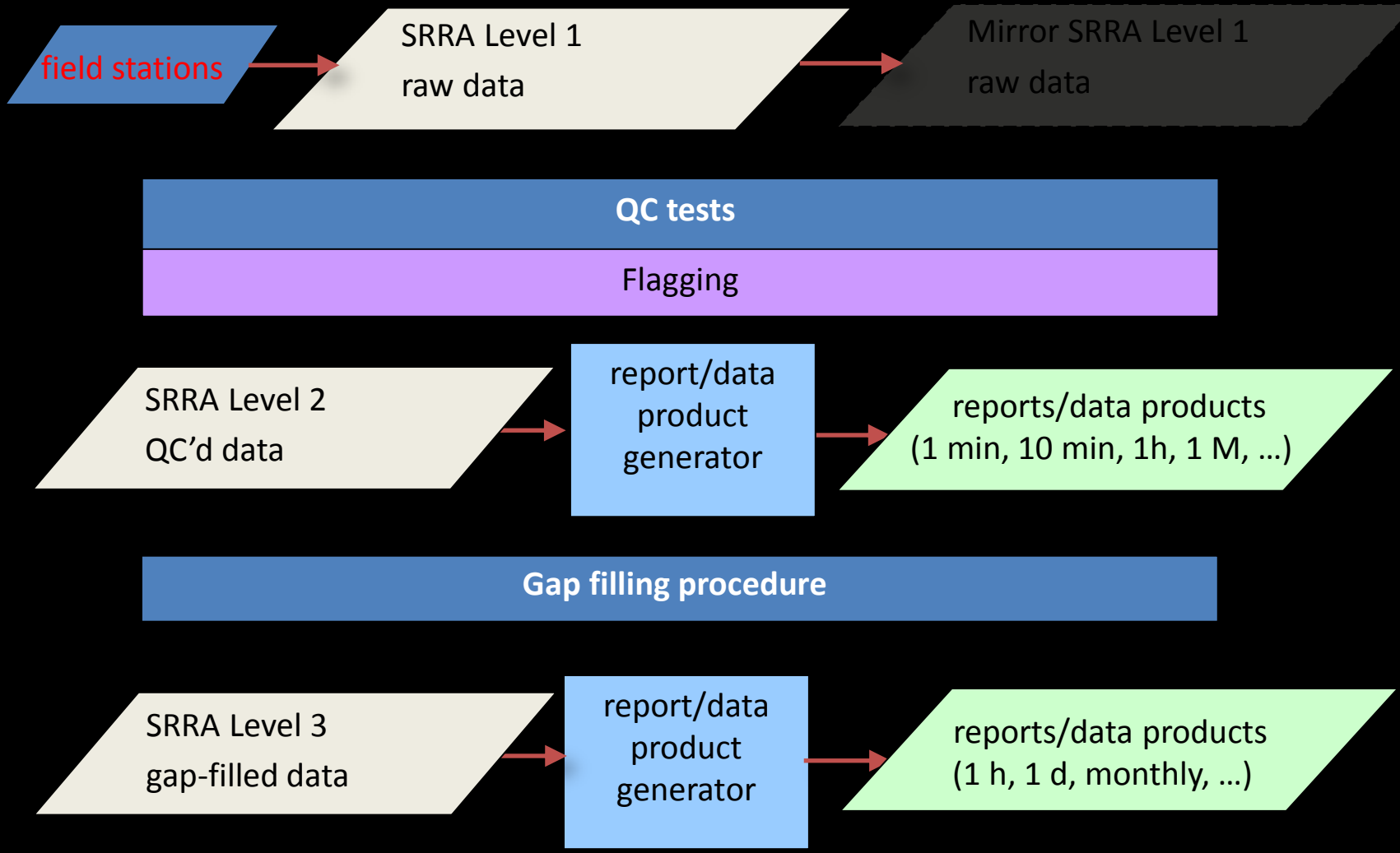
SRRA-SolMap data flow diagram



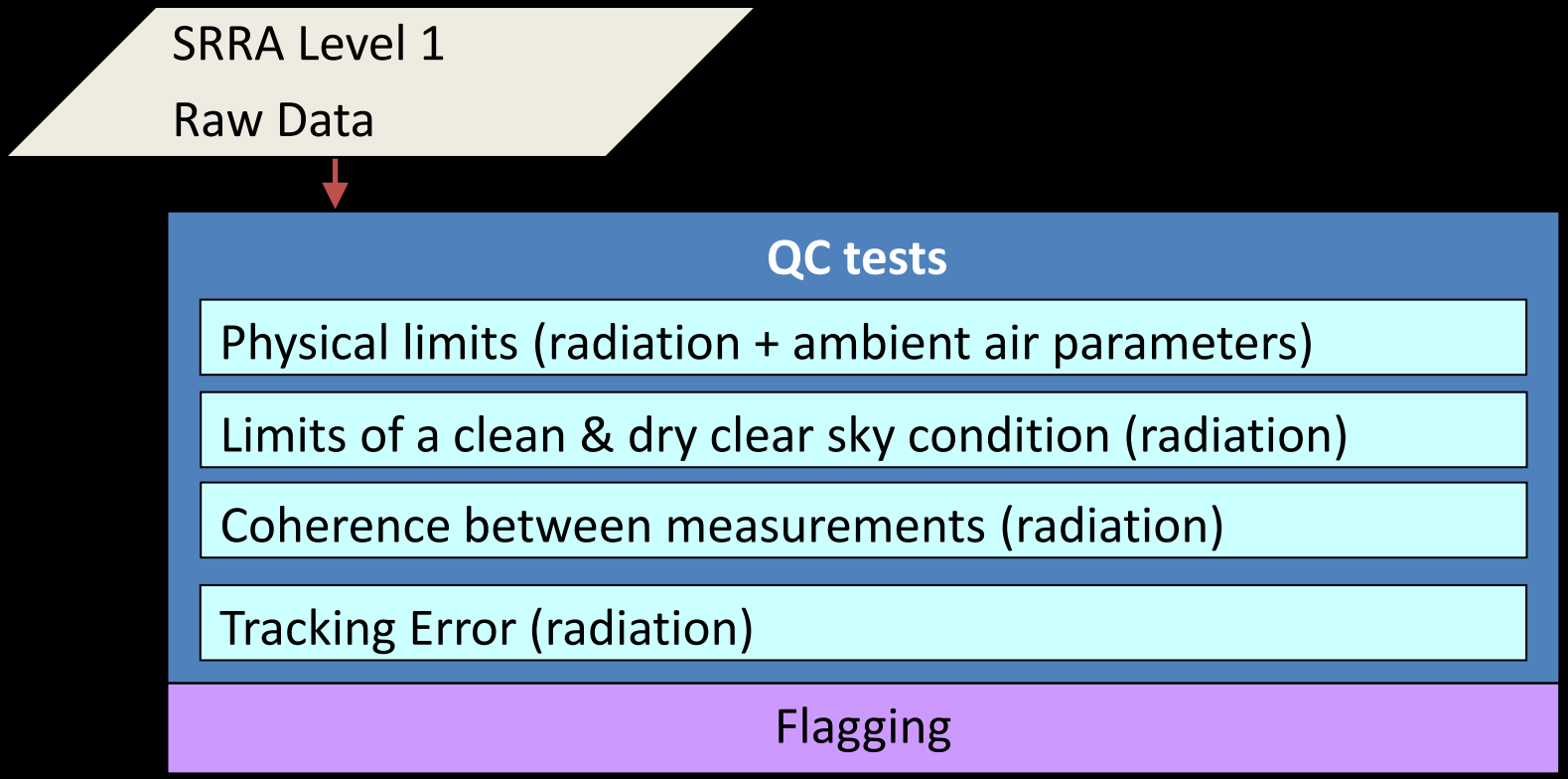
Quality Assessment

- The field solar & meteorological data collected is archived in Central Receiving Server.
- Fully automated quality control procedure is in force in the data processing & analysis.
- QC includes flagging and gap filling method using quality check algorithms directly applying on the raw data.
- For the values of Global Horizontal Irradiance (GHI), Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DHI), applied quality control is based on Baseline Surface Radiation Network (BSRN) rules by the World Meteorological Organization(WMO), elaborated by the Management and Exploitation of Solar Resource Knowledge(MESOR).
- QC controlled data is available in report format as well as time series data. Reports are generated on daily, monthly and yearly basis besides 1 minute, 10 minute and 1 hourly time series data.

SRRA/SolMap data Processing



Quality Assessment



Physical plausibility tests for solar radiation values

Parameter	Min	Max
GHI (Global Horizontal Irradiance)	$0\ \frac{\mathrm{W}}{\mathrm{m}^2}, -4\ \frac{\mathrm{W}}{\mathrm{m}^2}$	$DNI_0 \times 1.5(\cos\theta_z)^{1.2} + 100\ \frac{\mathrm{W}}{\mathrm{m}^2}$
DNI (Direct Normal Irradiance)	$0\ \frac{\mathrm{W}}{\mathrm{m}^2}, -4\ \frac{\mathrm{W}}{\mathrm{m}^2}$	DNI_0
DHI (Diffuse Horizontal Irradiance)	$0\ \frac{\mathrm{W}}{\mathrm{m}^2}, -4\ \frac{\mathrm{W}}{\mathrm{m}^2}$	$DNI_0 \times 0.95(\cos\theta_z)^{1.2} + 50\ \frac{\mathrm{W}}{\mathrm{m}^2}$

Tests based on physical limits by Long & Dutton (2002),
with $DNI_0 = I_0 \cdot \varepsilon$ (I_0: Solar 'Constant' (1367 W/m²), ε: eccentricity)

Test of coherence between measurements for solar radiation values

Parameter	Conditions	Limits
$\frac{GHI}{DHI + DNI\cos\theta_z}$	$\theta_z < 75°, GHI > 50\frac{\mathrm{W}}{\mathrm{m}^2}$	> 0.92 < 1.08
$\frac{GHI}{DHI + DNI\cos\theta_z}$	$93° > \theta_z > 75°, GHI > 50\frac{\mathrm{W}}{\mathrm{m}^2}$	> 0.85 < 1.15
$\frac{DHI}{GHI}$	$\theta_z < 75°, GHI > 50\frac{\mathrm{W}}{\mathrm{m}^2}$	< 1.05
$\frac{DHI}{GHI}$	$93° > \theta_z > 75°, GHI > 50\frac{\mathrm{W}}{\mathrm{m}^2}$	< 1.10

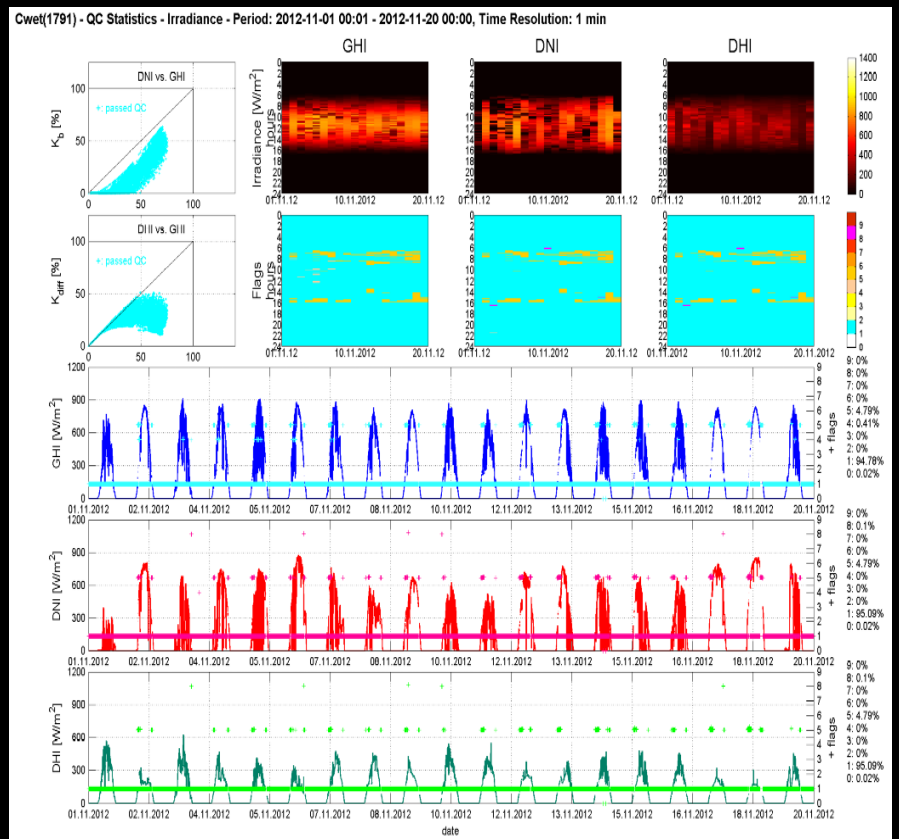
Test against limits of a clean and dry clear sky condition for solar radiation values

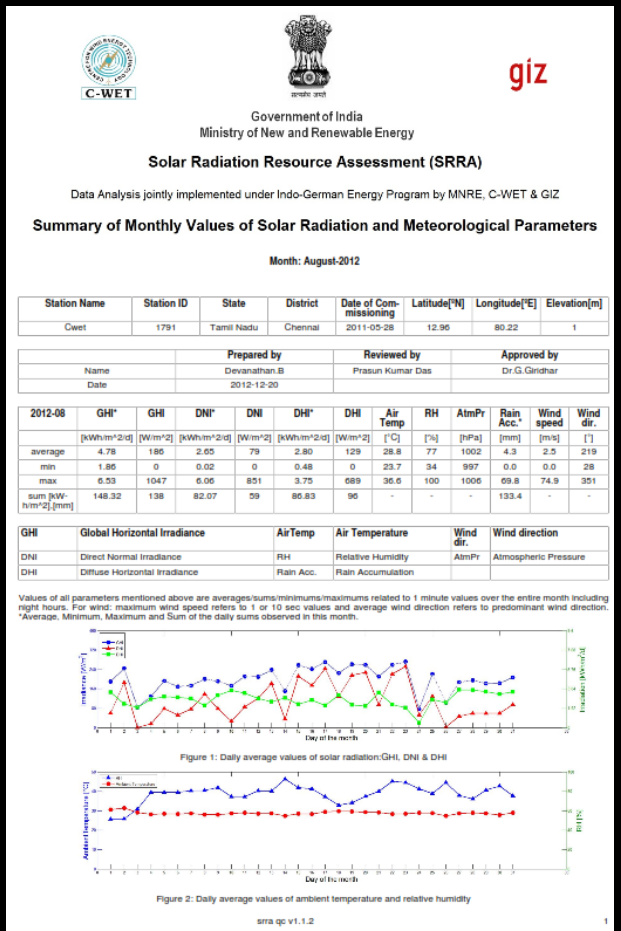
Parameter	Limit
GHI	$< GHI_{Clear}$, $GHI_{Clear}(\theta_z > 85^o) = GHI_{Clear}(\theta_z = 85^o)$, $GHI > 5\frac{W}{m^2}$
DNI	$< DNI_{Clear}$, $DNI_{Clear}(\theta_z > 85^o) = DNI_{Clear}(\theta_z = 85^o)$, $DNI > 5\frac{W}{m^2}$
DHI	$< GHI_{Clear}$, $GHI_{Clear}(\theta_z > 85^o) = GHI_{Clear}(\theta_z = 85^o)$, $DHI > 5\frac{W}{m^2}$ $> (R_L - 1.0)$, $DHI / GHI < 0.8$, $DHI > 5\frac{W}{m^2}$

Quality Check Procedure

Usually daily QC processing of the newest data from L1 to L2

- → **flagged L2 data**
- → **quality assessment summary sheets**
- → **automatic error alert emails to operators**





C-WET

giz

Government of India
Ministry of New and Renewable Energy

Solar Radiation Resource Assessment (SRRA)

Data Analysis jointly implemented under Indo-German Energy Program by MNRE, C-WET & GIZ

Summary of Monthly Values of Solar Radiation and Meteorological Parameters

Month: August-2012

Station Name	Station ID	State	District	Date of Commissioning	Latitude[°N]	Longitude[°E]	Elevation[m]
Cwet	1791	Tamil Nadu	Chennai	2011-05-28	12.96	80.22	1

	Prepared by	Reviewed by	Approved by
Name	Devanathan.B	Prasun Kumar Das	Dr.G.Giridhar
Date	2012-12-20		

2012-08	GHI*	GHI	DNI*	DNI	DHI*	DHI	Air Temp	RH	AtmPr	Rain Acc.*	Wind speed	Wind dir.
	[kWh/m^2/d]	[W/m^2]	[kWh/m^2/d]	[W/m^2]	[kWh/m^2/d]	[W/m^2]	[°C]	[%]	[hPa]	[mm]	[m/s]	[°]
average	4.78	186	2.65	79	2.80	129	28.8	77	1002	4.3	2.5	219
min	1.86	0	0.02	0	0.48	0	23.7	34	997	0.0	0.0	28
max	6.53	1047	6.06	851	3.75	689	36.6	100	1006	69.8	74.9	351
sum [kWh/m^2],[mm]	148.32	138	82.07	59	86.83	96	-	-	-	133.4	-	-

GHI	Global Horizontal Irradiance	AirTemp	Air Temperature	Wind dir.	Wind direction
DNI	Direct Normal Irradiance	RH	Relative Humidity	AtmPr	Atmospheric Pressure
DHI	Diffuse Horizontal Irradiance	Rain Acc.	Rain Accumulation		

Values of all parameters mentioned above are averages/sums/minimums/maximums related to 1 minute values over the entire month including night hours. For wind: maximum wind speed refers to 1 or 10 sec values and average wind direction refers to predominant wind direction. *Average, Minimum, Maximum and Sum of the daily sums observed in this month.

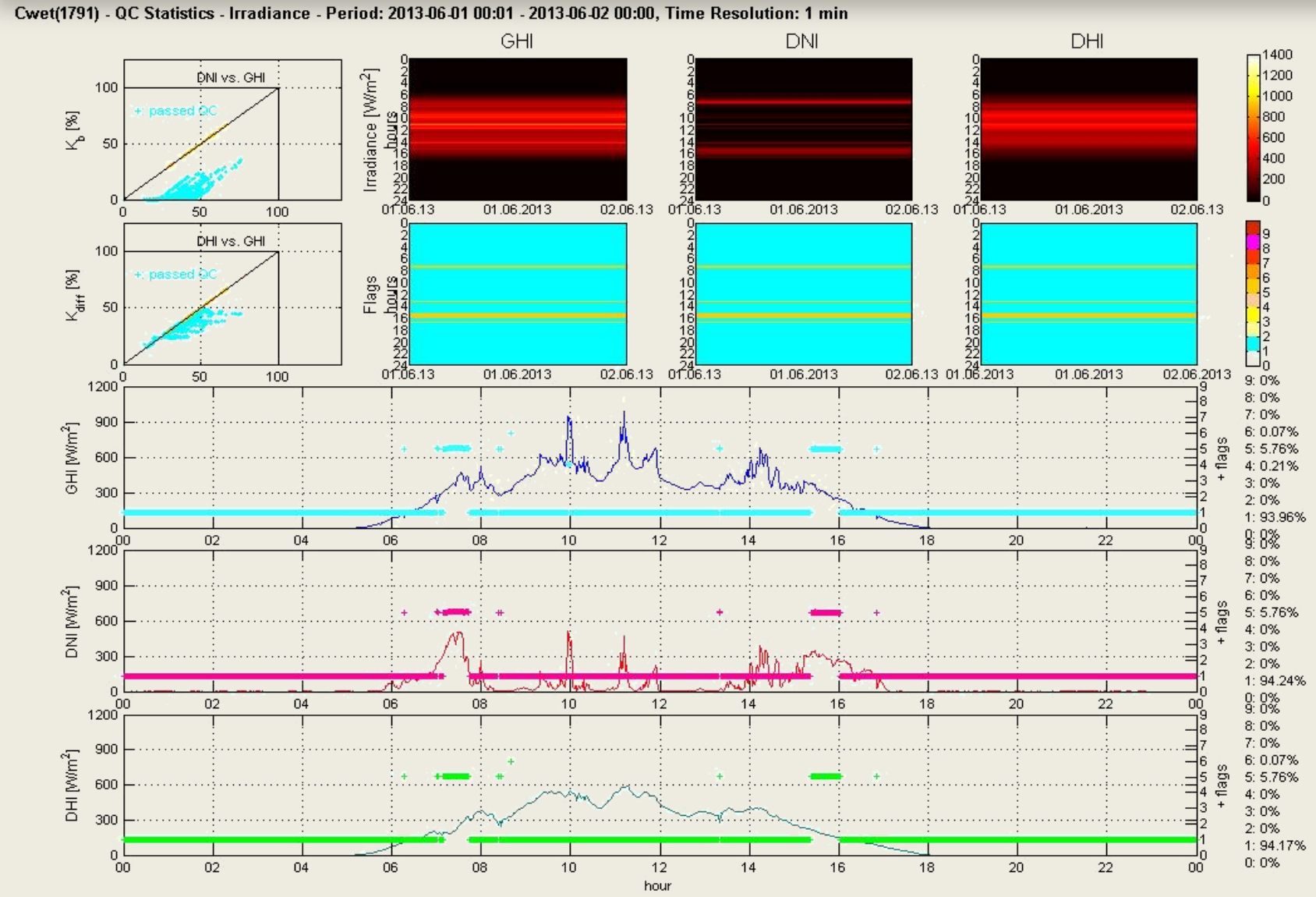
Figure 1: Daily average values of solar radiation:GHI, DNI & DHI

Figure 2: Daily average values of ambient temperature and relative humidity

srra qc v1.1.2

1

QC summary sheet: Solar parameters

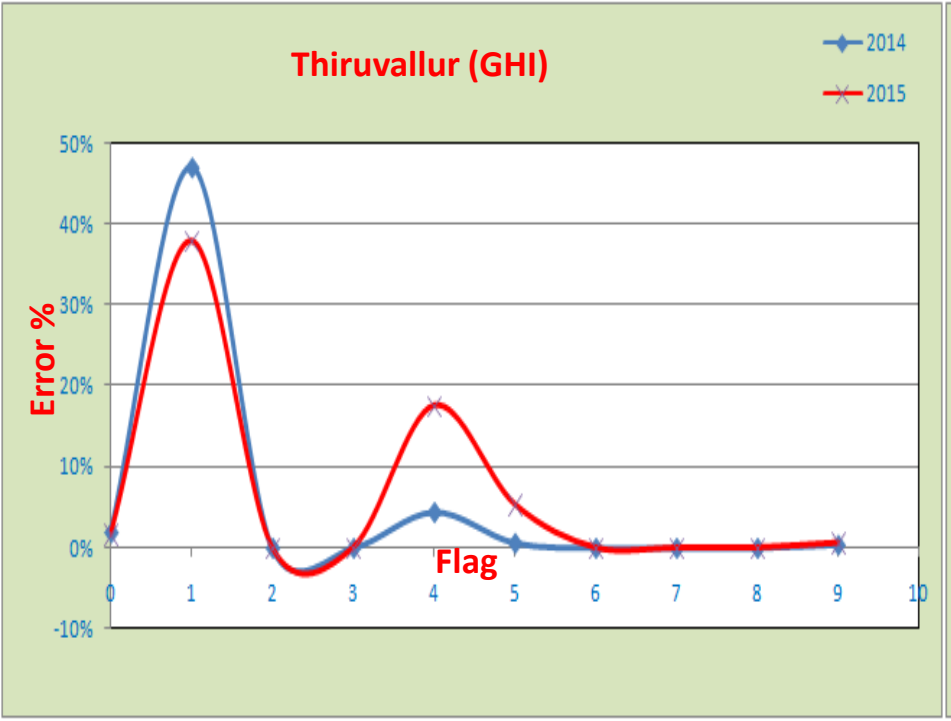


SRRA flagging convention

0____ : Missing value
1____ : Value seems to be correct.
2____ : Value is smaller than the minimum physical limit.
3____ : Value is greater than the maximum physical limit.
4____ : Value is higher than the value for a clear sky condition, inside max physical limit
5____ : GHI measured and GHI calculated by sum of diffuse and direct do not match, inside the clear sky and physical limits
6____ : DHI is greater than GHI beyond the acceptable tolerance.
7____ : Value is below the min limit derived from a model.
8____ : Tracking error, DHI-Pyranometer-Shading error, all other test approved
9____ : Shading by obstructions

_000_ : The value doesn't exceed the limits (also for missing values).
xxx : The value exceeds the limit by xxx=$|x_{meas}-x_{lim}|$

____0: not replaced
____1: replaced by linear interpolation
____2: replaced by satellite data
____3: replaced manually by other values from a different source
____4: replaced by data from a model / night hours set to 0


Thiruvallur (GHI)
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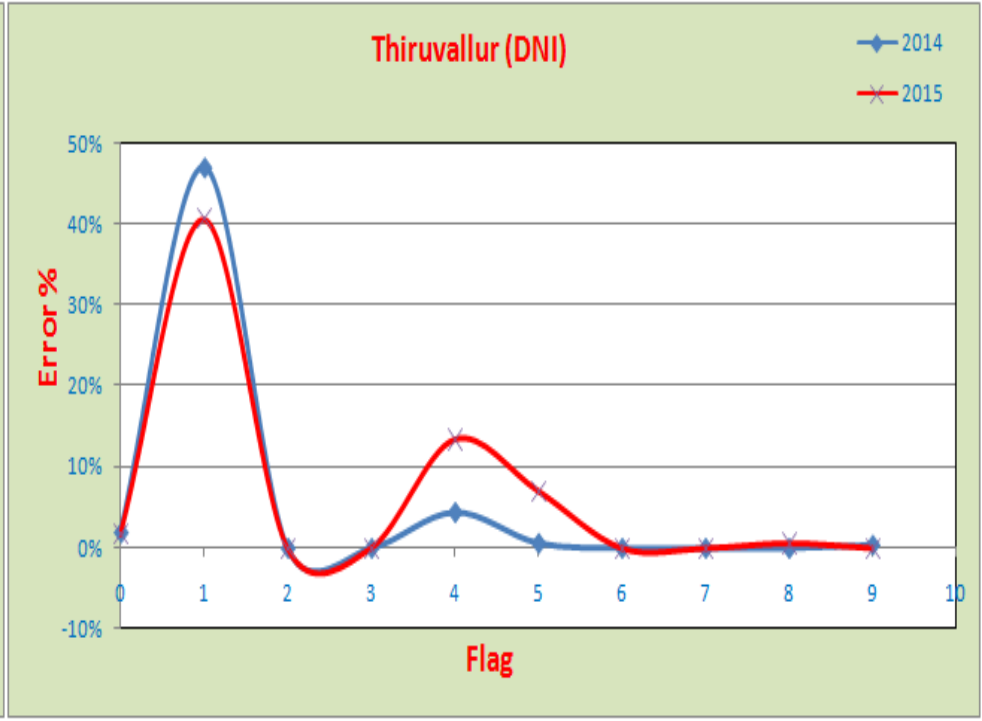
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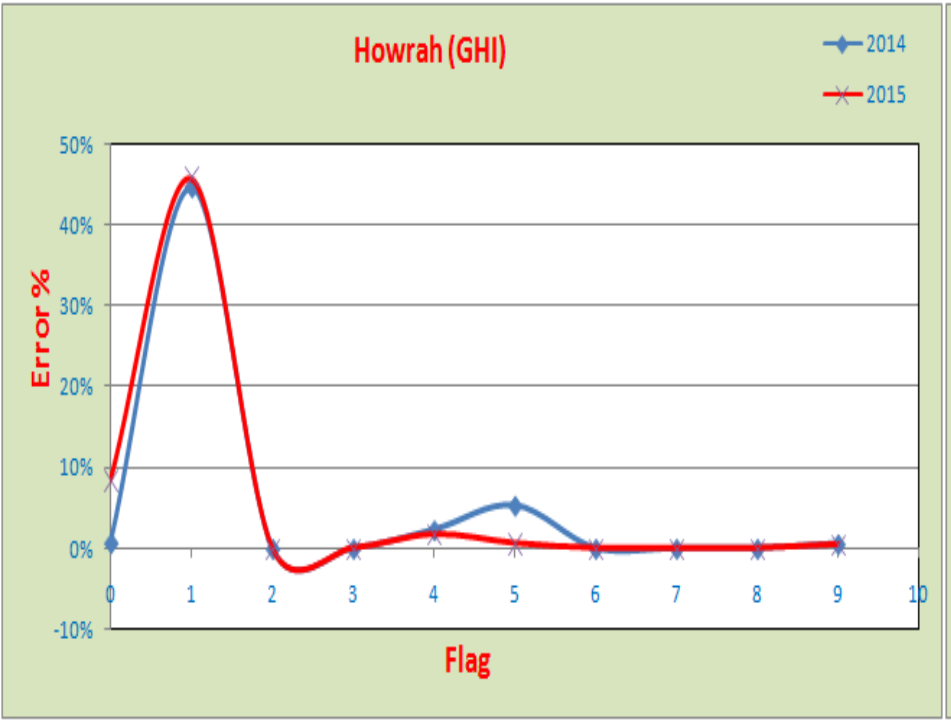
Howrah (GHI)
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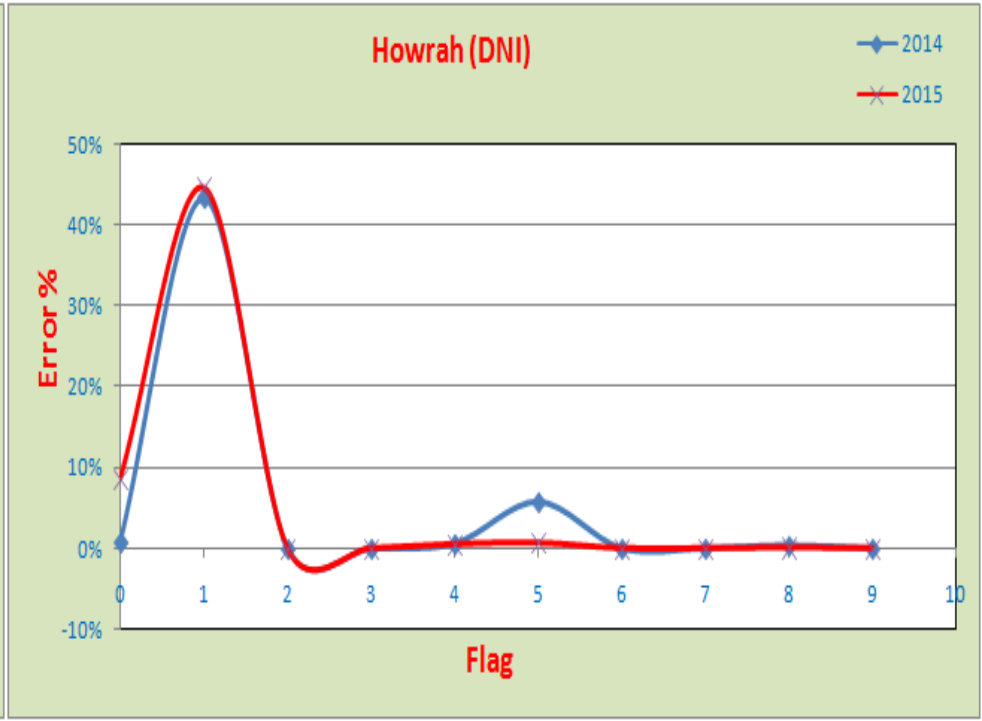
Howrah (DNI)
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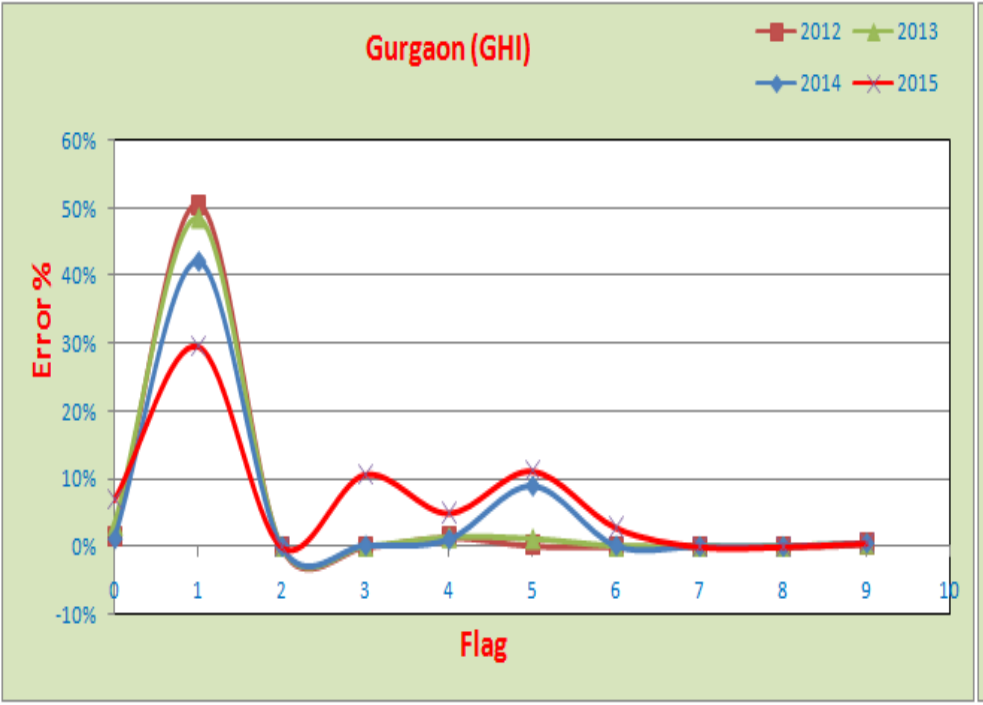
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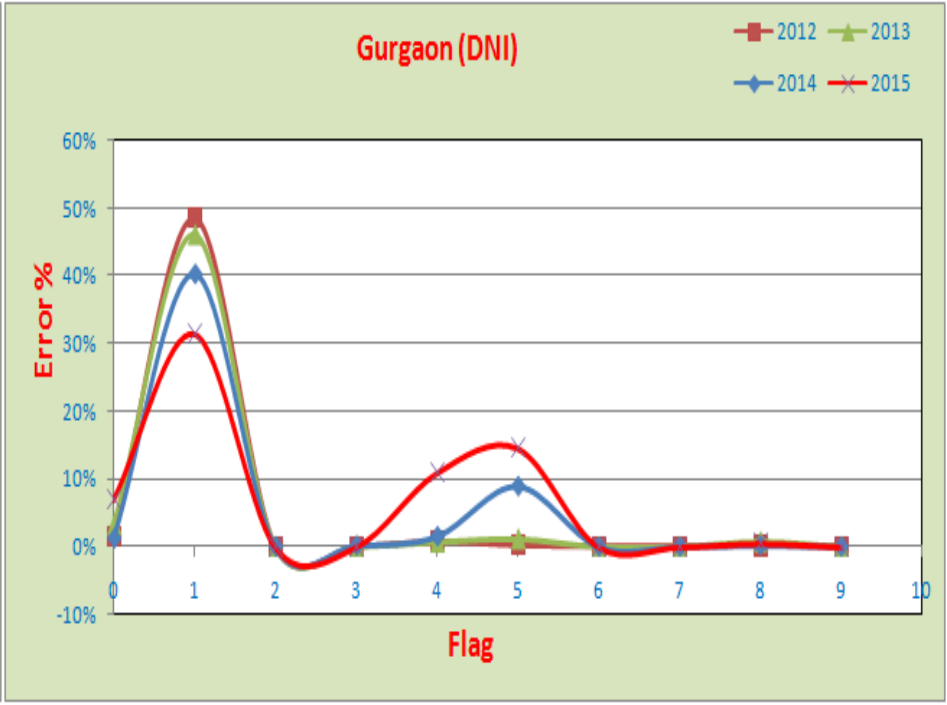
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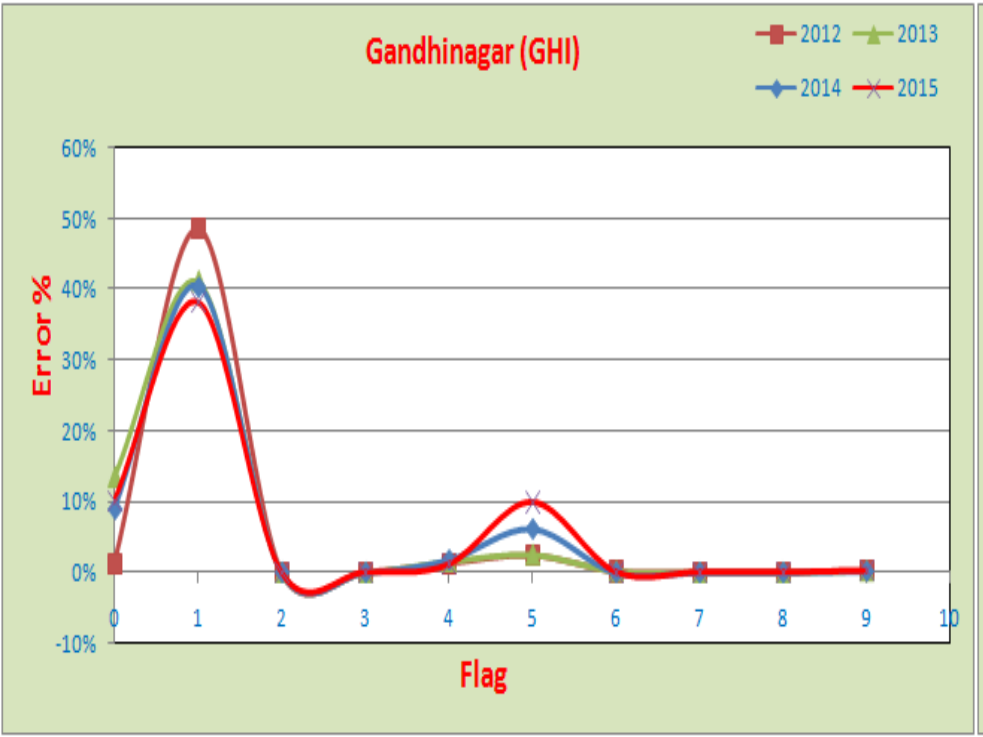
Gandhinagar (GHI)
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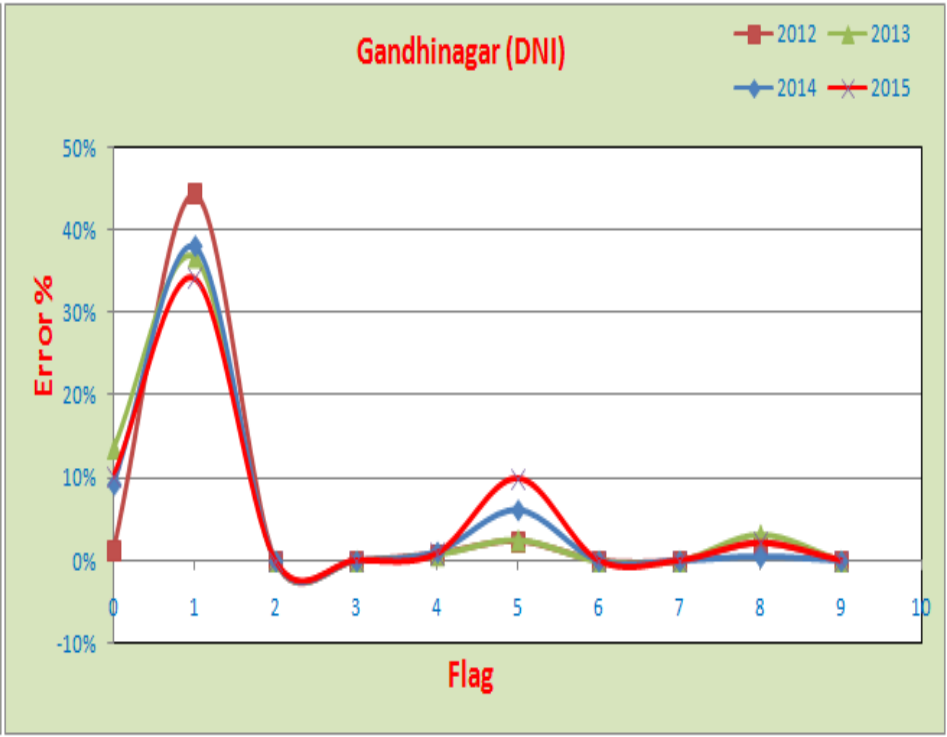
Gandhinagar (DNI)
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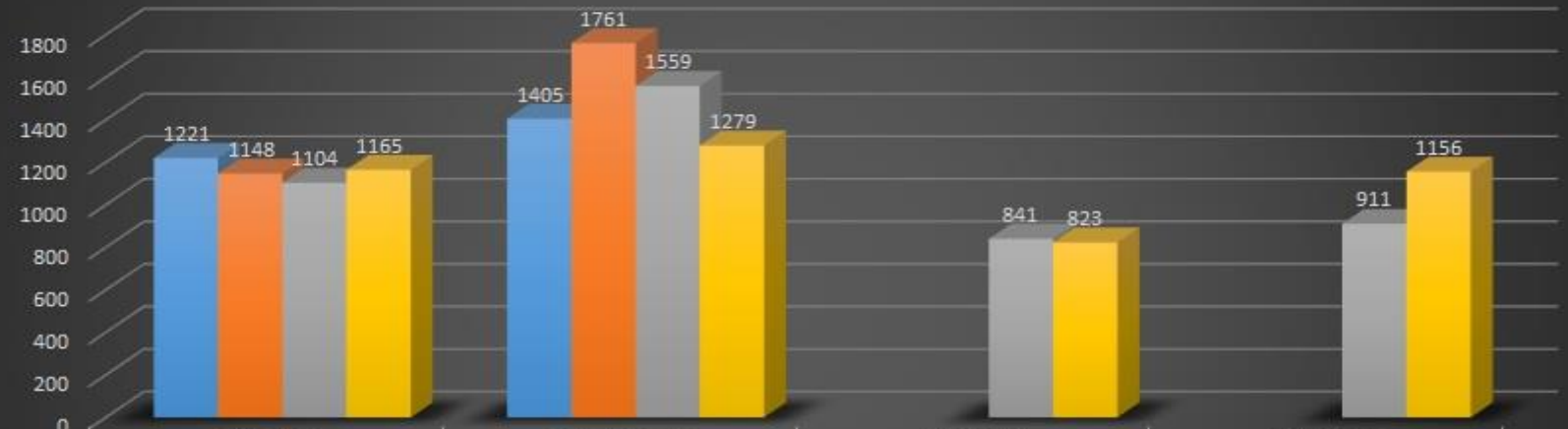
GHI(kWh/m^2)

	GURGAON	GANDHINAGAR	HOWRAH	TIRUVALLUR
2012	1669	1778		
2013	1603	1761		
2014	1551	1805	1551	1752
2015	1586	1726	1489	1918

2012 2013 2014 2015

DNI(kWh/m^2)



	GURGAON	GANDHINAGAR	HOWRAH	TIRUVALLUR
2012	1221	1405		
2013	1148	1761		
2014	1104	1559	841	911
2015	1165	1279	823	1156

2012 2013 2014 2015

Cleaning Trigger Switch

Show station graphs - CW | (no subject) - prasuntezu

www.cwetsolar.com/index.php?option=datos&estacion=254&fl=0

Centre for Wind Energy Technology

C-WET

UBIQUITAS

Start Stations

Hello,CWET End Session

Tamilnadu_C-WET

General Purpose
Town: Tamilnadu_C-WET Chennai
Longitude: 80°12' 59.75" E
Latitude: 12°57' 21.79" N
Altitude: 1

Last data

Jul 03 2014

00:12 LT

Last data

Wind Spd. (Avg.): 4.1 m/s

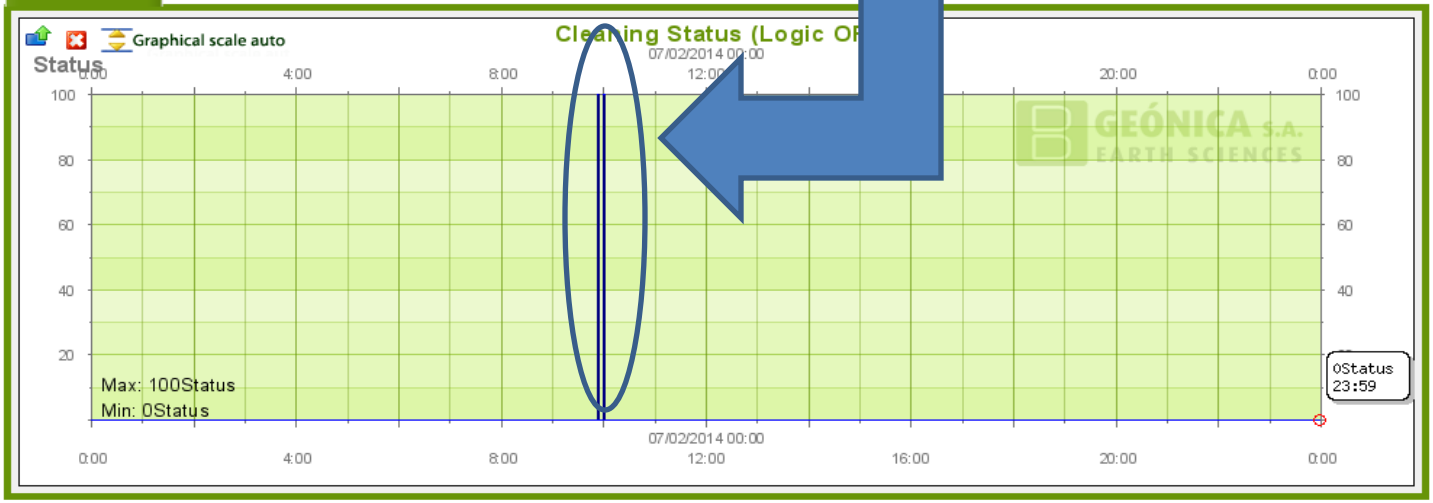
Wind Dir. (Avg.): 218 °

<< Previous Day | Next Day >> | Download in PDF format | Channels | Display gra | p of each other

Wind Spd.(Avg.) | Wind Dir.(Avg.) | Air.Temp.(Avg.) | Rel. Hum.(Avg.) | Dew Point(Avg.) | Atm.P | Atm.Pr.QNH(Avg.) | Globl Rad1(Avg.) | DiffuseRad(Avg.)

DirectRad1(Avg.) | Globlal.E1(Avg.) | Diffuse.E1(Avg.) | Direct.E1(Avg.) | Pyrhe.Err1(Avg.) | Ra | Solar Elev(Ins.) | Solar Az.(Ins.) | Battery(Avg.)

CleaningST(Logic OR)



www.cwetsolar.com/index.php?option=datos&estacion=254&fl=0#

12:39 AM
7/3/2014

References

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Thank you