Quality assessment of global tilted irradiance by automatic and manual procedures

Source: https://midcdmz.nrel.gov/apps/sitehome.pl?site=BMS

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Why ground measurements

Ground measurements are essential asset for development and operation of PV plant

Usage of ground measurements

- Improvement of satellite-based model
- Improvement of forecast accuracy
- PV performance evaluation
- Identification of PV operation issues

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About ground measurements

Current status (our experience)

- Missing knowledge of proper operation
- Suboptimal practices
- Solar and meteo measurements are often degraded

Best practices

- More than one instrument on a site (if feasible)
- Choice of high quality instruments
- Fine temporal resolution of data (1min, 5 min)
- Regular cleaning, maintenance and calibration of instruments by trained personnel
- Data quality assessment by a knowledgeable expert

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Ground measured GTI

Every bigger power plant - typically several GTI instruments

Global tilted irradiance (GTI) data used for

- **PV performance evaluation**
- Validation and site-adaptation of solar models

Photo: GeoSUN Africa

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Ground measured GTI

High quality GTI ground measurements are needed for reliable PV performance evaluation (raw measured data → reference data)

From our research → there is not much knowledge, standards and procedures for GTI QC

- What we have
  - Existing public knowledge about GTI QC
  - Experience with GTI
  - Existing methods and procedures for global, direct normal and diffuse irradiation (GHI, DNI, DIF)

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Solargis quality assessment procedure (GHI, DNI, DIF)

- Step 1: Time reference control
- Step 2: Automated test of unphysical values
  - minima, maxima, static values, night values, 2-component tests, consistency tests
- Step 3: (Semi-)automated tests for systematic data errors
  - shading, degradation, dew/frost, pyrheliometer tracker malfunction, instrument misalignment
- Step 4: Visual quality assessment

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Solargis quality assessment procedure (GTI)

Methods and procedures can be largely reused but additional complexity

- Fixed vs tracker mounting
- Inherited PV features (e.g. parking/stowing position)
- Tracking configuration
- Partial sky-dome and reflected component (albedo)

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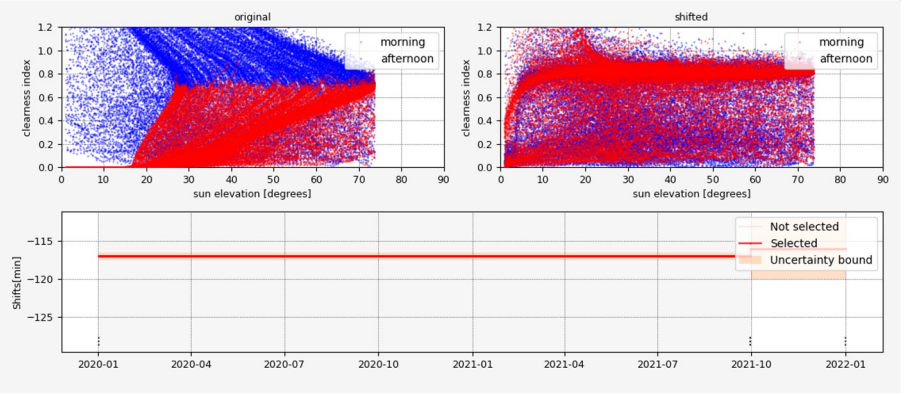
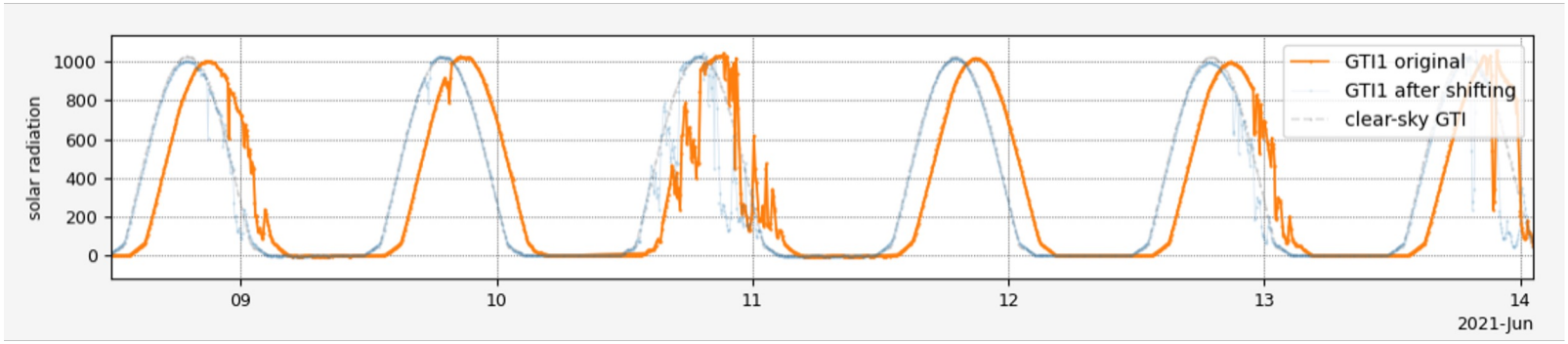
Time reference check

- Time reference needs to be in UTC
  - → determines the solar position calculation
- Prerequisite for data quality tests



Detection

- Look at when day begins and ends or profile symmetry
- Similar logic can be used for GTI measurements



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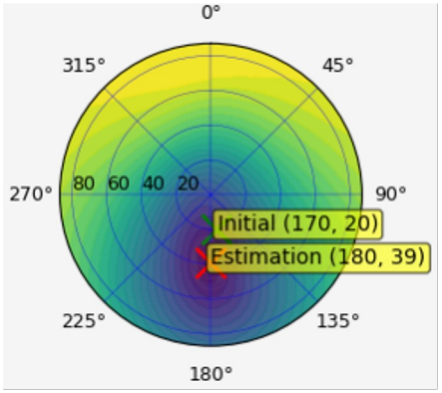
Instrument configuration check

GHI configuration is given but instrument can be misaligned

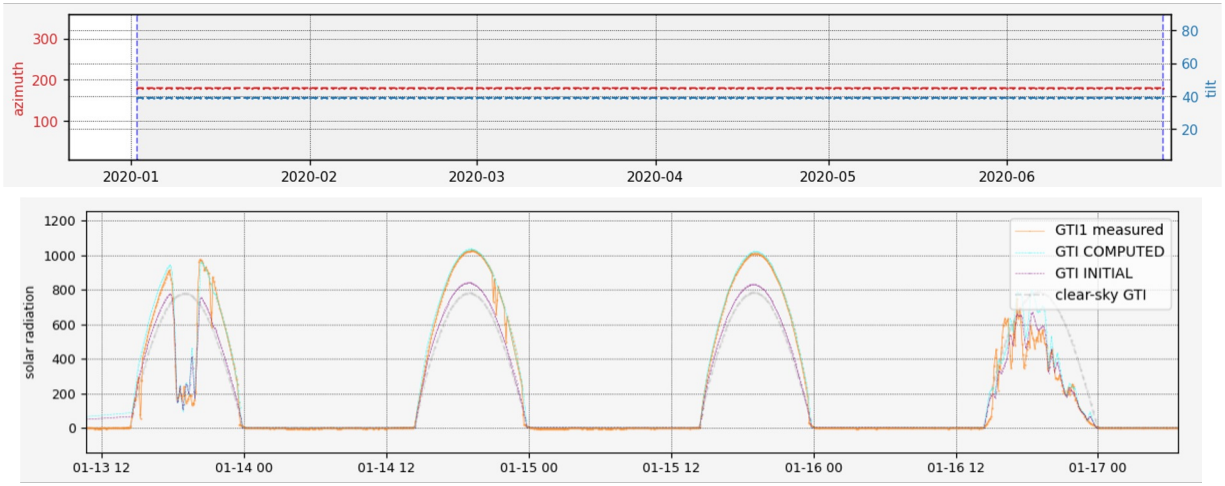


Additional complexity for GTI

- Fix vs tracker (1 or 2-axis)
- Fixed systems: Azimuth, tilt
- Tracker: Rotational limits, backtracking, (azimuth, tilt)

Detection

- Multidimensional fit



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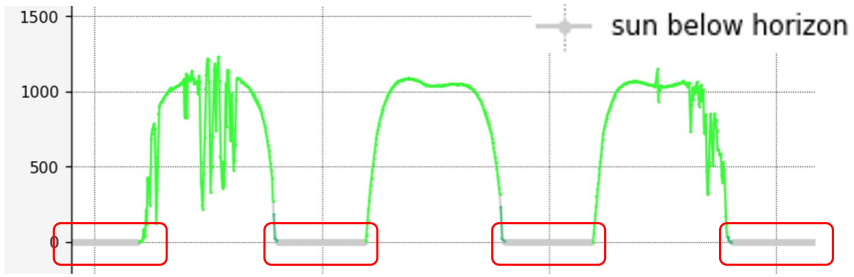
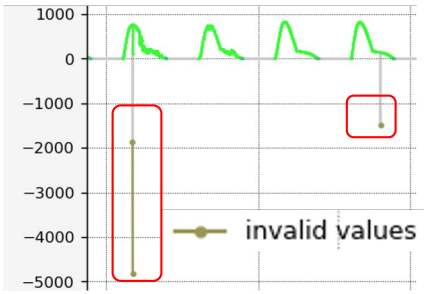
Basic automated test of unphysical values

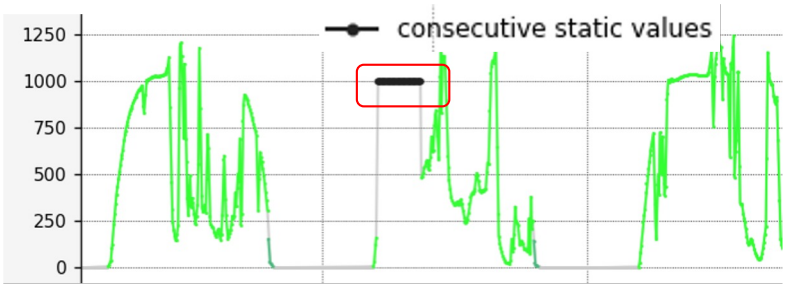
- Invalid values
- Sun below horizon
- Consecutive static values



Detection

- No difference between GHI and GTI tests





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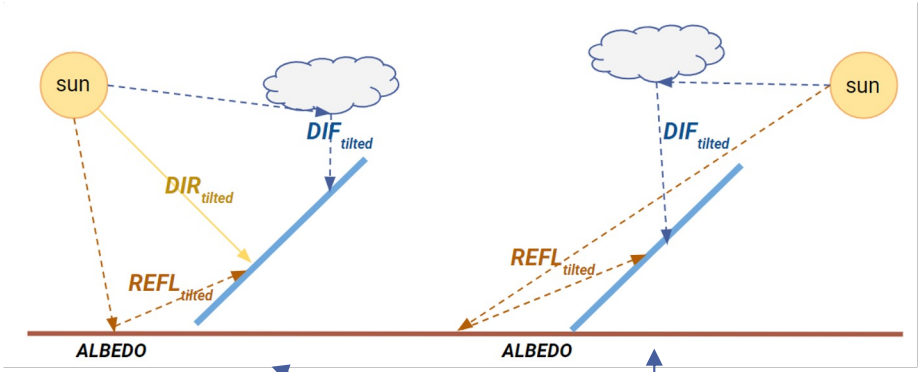
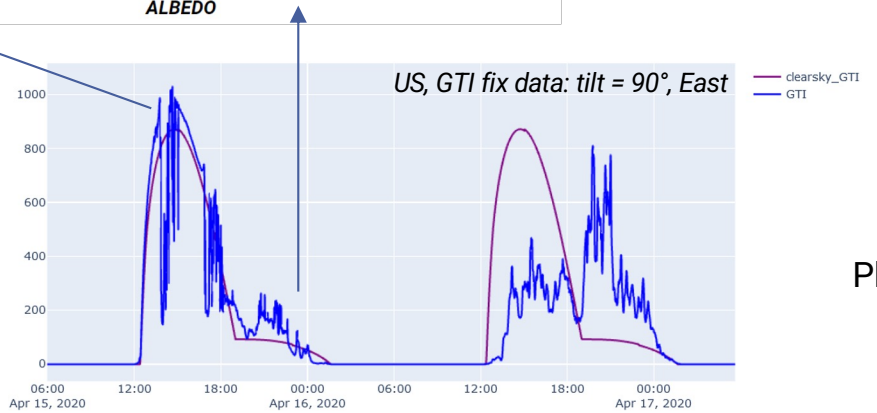
Physical maxima and minima



$$GTI = DIR_{tilted} + REFL_{tilted} + DIF_{tilted}$$



Physical minimum GTI = 0

Direct tilted irradiation $DIR_{tilted} = DNI * cos(incidence\_angle)$

Reflected tilted irradiation $REFL_{tilted} = ALB * GHI * refl\_transposition\_factor$

Diffuse tilted irradiation $DIF_{tilted} = DIF * diffuse\_transposition\_factor$

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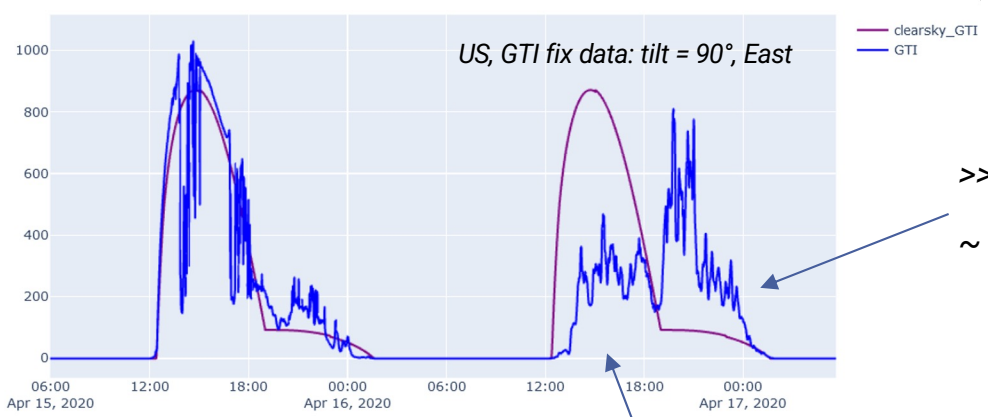
Physical maxima



>> clearsky_DIF$_{tilted}$ + clearsky_REFL$_{tilted}$

*~ (Const * clearsky_REFL$_{tilted}$ + max_DIF$_{tilted}$) + q*

*~ Const * clearsky_GTI + q*

GTI specifics to take into account

- Albedo variability - snow, grass, sand, … → need to take maximalist value
- Configuration mistake → we vary incidence angle
- High diffuse radiation part

Similar logic for fix and tracker systems

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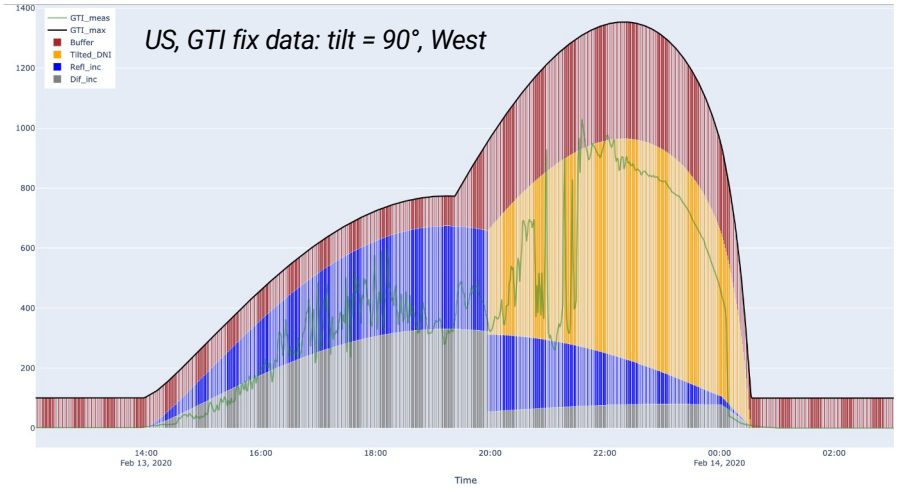
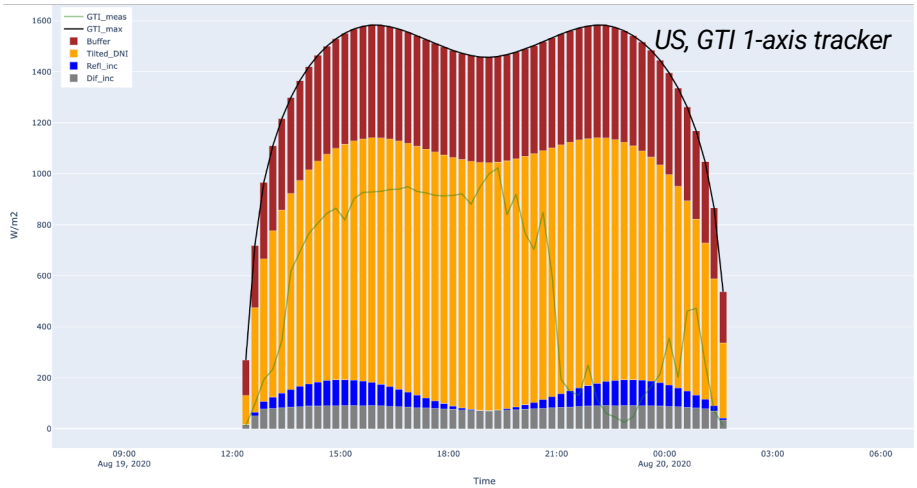
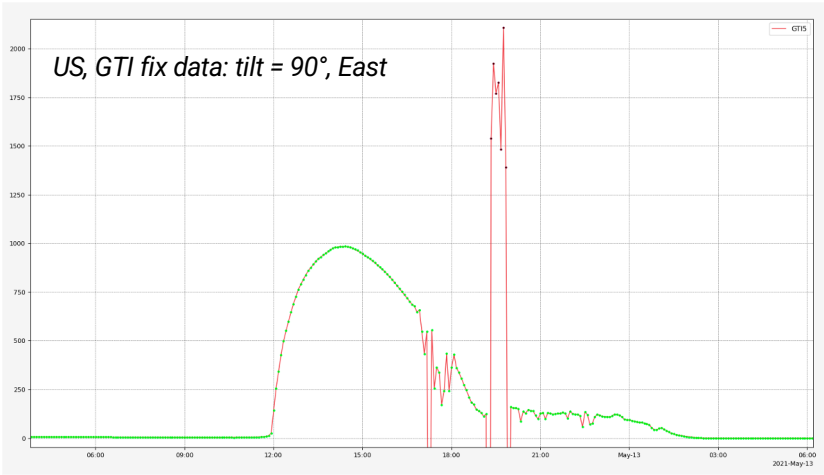
Physical maxima



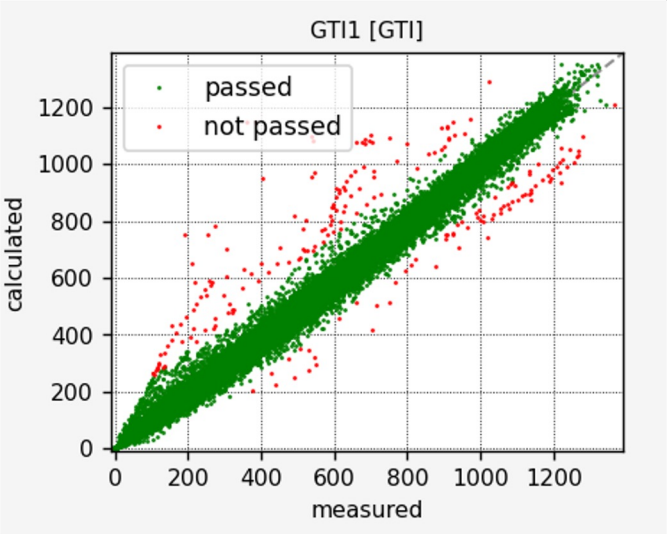




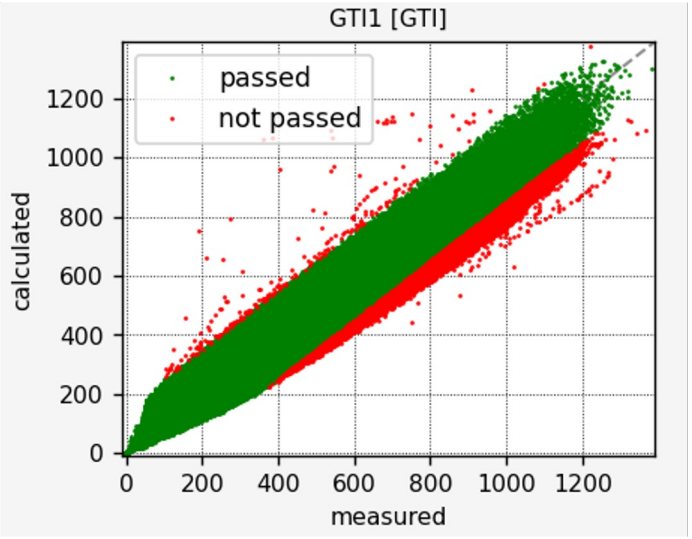
2-component tests and consistency

- No “classical” consistency tests as for DNI, GHI and DIF (*GHI = DIF + DNI * cos(z)*)
- But GTI can be calculated from other solar radiation parameters (e.g. GHI)

consistency correct config:
azimuth: 180, tilt: 40



consistency wrong config:
azimuth: 170, tilt: 20

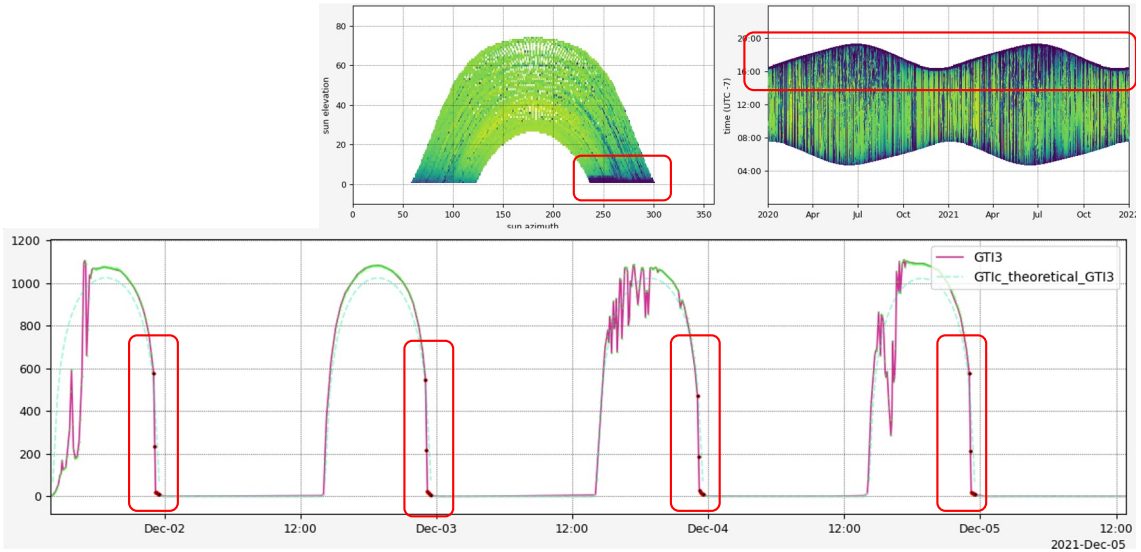


z = solar zenith angle

Semi-automated and visual assessment

- Shading
  - semi-automated
  - GHI approach can be reused (data separation in azimuth/elevation plane)
- Dew/frost
  - semi-automated
  - GHI approach can be reused in limited way (detection of characteristic S-shape)
- Degradation (insufficient cleaning, calibration issue)
  - Visual assessment
- Other issues - logger issues, bird droppings, issues which cannot be categorized
  - Visual assessment

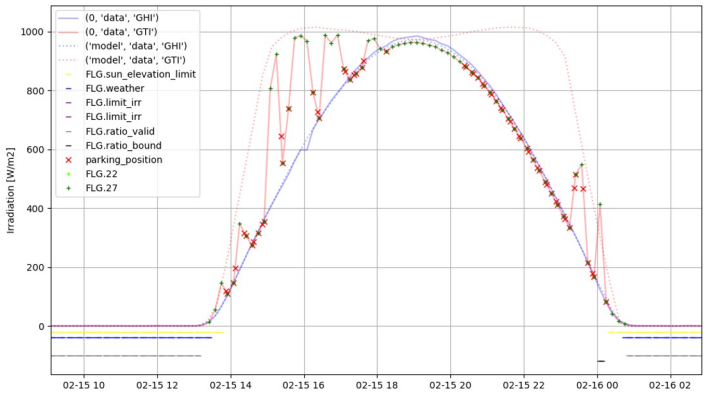
shading on GTI tracker data

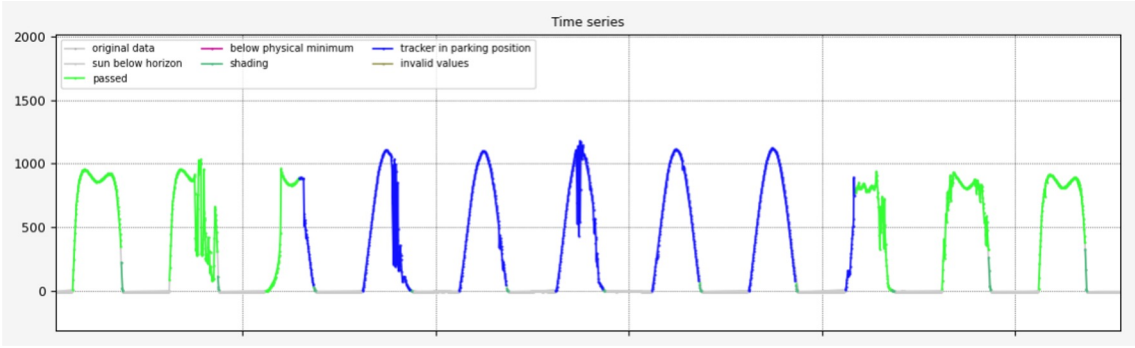


Semi-automated and visual assessment

There are issues which are specific only for GTI → typically they arise from the instrument installation

- Parking position and tracker malfunction
  - Detection is based on deviation from satellite-based data
- Row spacing, rotational limits, …
  - Detection via configuration check fit





tracker in parking position

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Supporting methods for quality assessment

- Parameter type detection
- Swapped columns detection
- Units detection
- Multi-instrument analysis

- Coordinates detection

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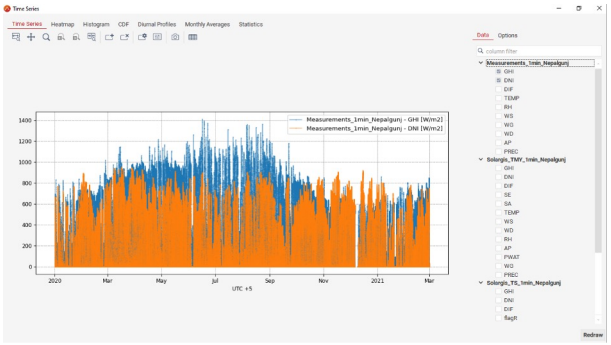
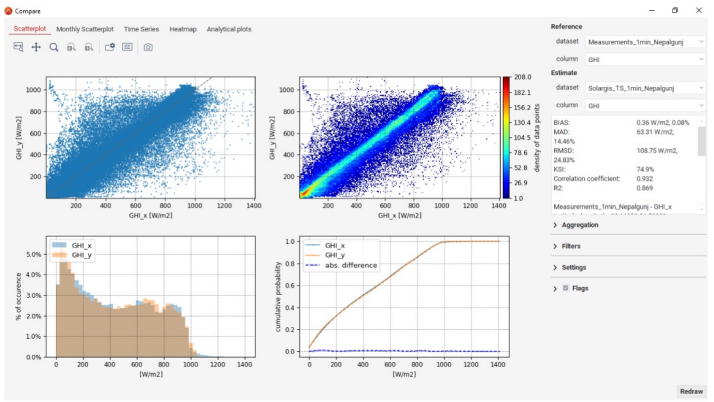
Solargis Analyst

Desktop software specifically designed for solar data assessment needs in the PV community

- Quality assessment of data
- Data management
- Visualisation
- Analysis of measured and model data





Introduced tools for quality assessment of solar data are being gradually integrated into Solargis Analyst

Conclusion

- Global tilted irradiance ground measurements are widely used for PV performance evaluation
- But these measurements suffer from many issues and poor maintenance
- The GTI measurements need to undergo strict quality assessment → accurate PV performance
- There is a lack of tools, standards and procedures for GTI QC but they can be developed

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Thank you

Backup

Data source: https://midcdmz.nrel.gov/apps/sitehome.pl?site=BMS

NREL Solar Radiation Research Laboratory

Baseline Measurement System

Latitude: 39.742° North

Longitude: 105.18° West

Elevation: 1828.8 meters AMSL

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