Intra-hour classification of direct normal irradiance for two sites in Spain and India

Bijan Nouri[1], Stefan Wilbert[2], Natalie Hanrieder[2], Pascal Kuhn[2], Marion Schroedter-Homscheidt[3], Robert Pitz-Paal[2], Luis F. Zarzalejo[4], Sharad Kumar[5], Neeraj Goswami[5], Ravi Shankar[5], Roman Affolter[6]

[1]M.Eng., Researcher, German Aerospace Center (DLR), Institute of Solar Research, bijan.nouri@dlr.de
[2]DLR, Institute of Solar Research
[3]DLR, Deutsches Fernerkundungsdatenzentrum (DFD
[4]CIEMAT Energy Department – Renewable Energy Division
[5]NETRA, NTPC Ltd.
[6]CSP Services

Temporal DNI variability class

Temporal and spatial DNI variability has a considerable impact on the dispatched electricity of a CSP power plant [1]. Sites with less variable conditions are preferable. Therefore, the DNI variability should always be considered during site assessments.
The most relevant source of intra-hour DNI variability are clouds. A classification method with eight distinct variability classes for 1 minute resolved DNI (Table 1) on an hourly basis is introduced by [2].

Table 1: Overview variability classes (clear sky index defined by quotient of measured DNI to clear sky DNI)

Class	Variability	Clear sky index
Class 1	Low	Very high
Class 2	Low	High
Class 3	Intermediate	High
Class 4	High	Intermediate
Class 5	Intermediate	Intermediate
Class 6	High	Low/Intermediate
Class 7	Intermediate	Low
Class 8	Low	Very low

This classification is adapted for an intra-hour application of 15 minutes and applied for two sites in Spain and India. Figure 1 shows the DNI and assigned variability class of a day with highly variable and stable time windows. The time windows marked in Fig. 1 in orange show that the 60 min approach is often too inert for an inter-hour consideration. Clear conditions are completely missed, whereas the 15 min approach reacts within 2 minutes.

Influence of spatial aggregation effects on classification

For CSP plants, the field average of the DNI is more relevant than the DNI at a singular point within the solar field. Therefore, we investigated if the DNI variability class of point like measurement is well-correlated to the class of the field average. We used a quadratic area of 2 km² and a data set of 30 days. DNI maps with spatial information (see Fig. 2) are provided by a camera based nowcasting system [3].

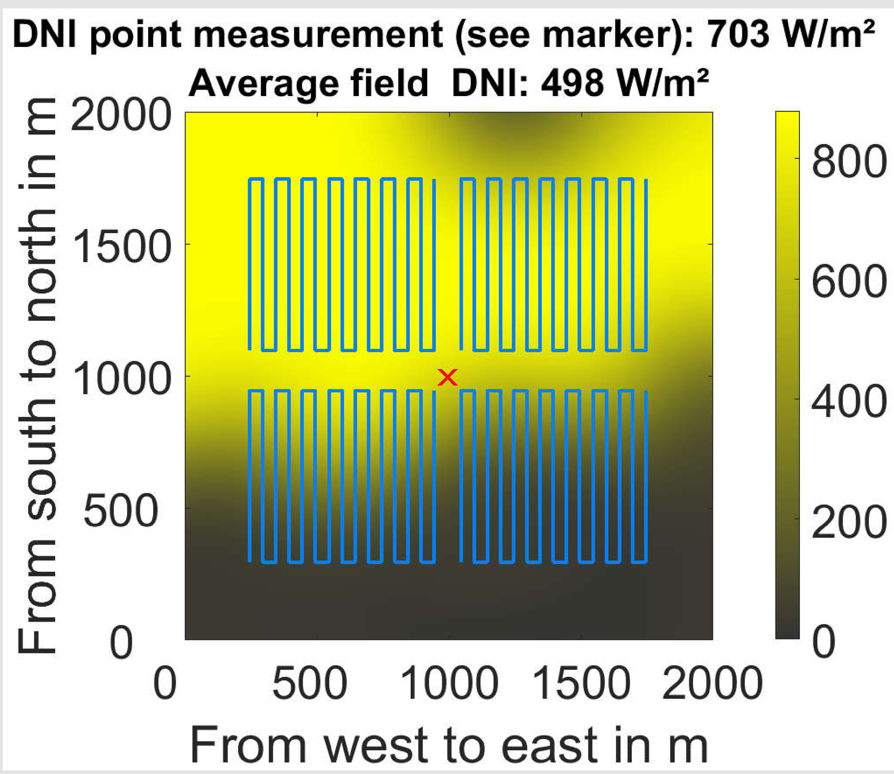

Figure 2: Example DNI map with marked solar field (2 km²).

Fig. 3 shows good agreement between the point like measurement based classification and the classification based on spatial solar field average DNI.

Comparison of variability for two sites Netra facility near New Delhi and PSA, Spain

The DNI variability probability for both sites is illustrated in Fig. 4.

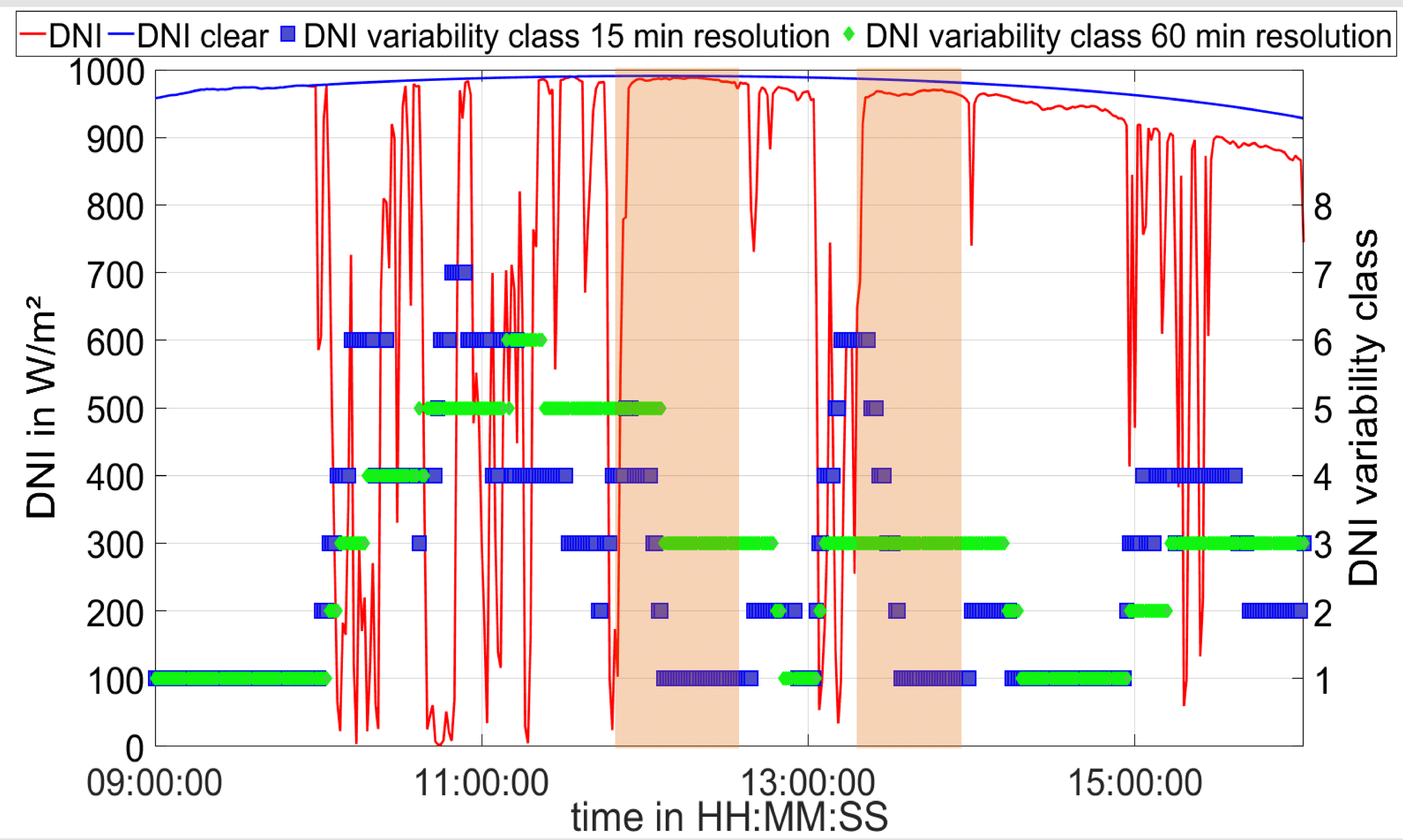

Figure 1: DNI and variability classification with 60 min and 15 min resolution.

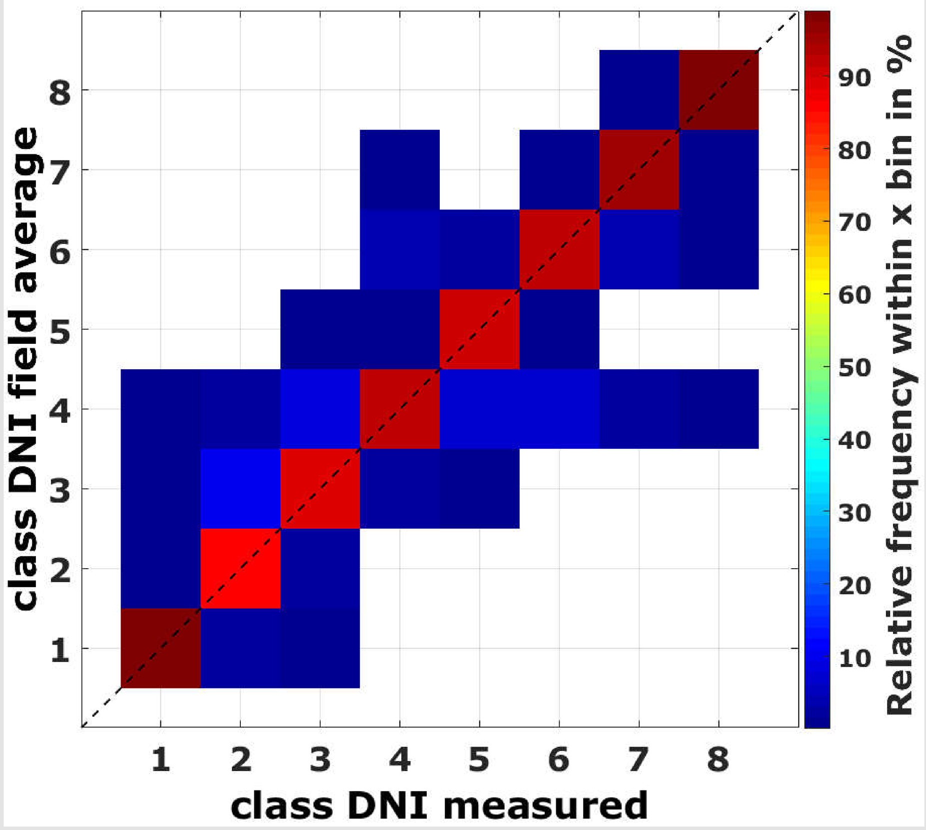

Figure 3: Scatter density plot comparison of DNI variability classifications point measurements to spatial field averages. All bins in one column add up to 100%.

The PSA shows in more than 60% of the cases clear sky conditions (class 1 & class 2), favorable for CSP plant operation.
Due to the hazy conditions at the NETRA site are class 1 conditions rare. Instead the more variable class 5 shows the highest occurrence.

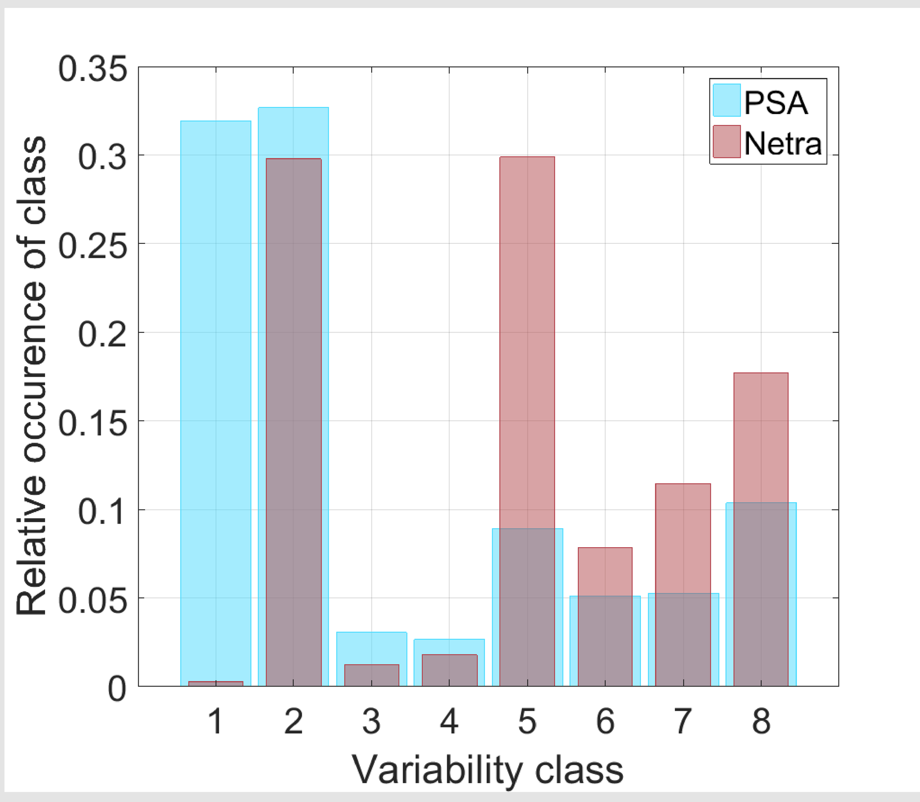

Figure 4: PSA and NETRA facility DNI variability class probability for the entire year 2017

Conclusion

- Highly variable DNI conditions pose a challenge for the control of CSP power plants.
- Site assessment for CSP plants should consider the DNI variability.
- A DNI classification method suitable for intra hour applications is presented.
- Classifications from point like measurements a well correlated to classifications from spatial DNI averages.
- A study on the DNI variability for a Netra site near New Delhi and the PSA was conducted.

Outlook

- CSP control optimization with irradiance maps and spatial/temporal DNI variability classifications

[1] Hirsch, T. et al., Direct Normal Irradiance Nowcasting methods for optimized operation of concentrating solar technologies, DNICast project, DNIcast Deliverable 2.1 (2014).
[2] Schroedter-Homscheidt M. et al., Classifying ground-measured 1 minute temporal variability within hourly intervals for direct normal irradiances, Meteorologische Zeitschrift, (2018).
[3] Nouri B. et al., Nowcasting of DNI maps for the solar field based on voxel carving and individual 3D cloud objects from all sky images, 23rd SolarPACES Conference, (2017).

DLR Deutsches Zentrum für Luft- und Raumfahrt