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Use of the ND Tool: An Open Tool for the Synthetic Generation of 1-min Solar Data from Hourly Means with Geographic Flexibility

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Abstract. In this paper, we present a description of how to use a web based tool employing the ND model by Larrañeta et al. [1]. The tool is suited for downscaling DNI, GHI or coupled DNI and GHI from 1-h to 1-min. It requires only an annual solar radiation dataset in the hourly resolution as input and provides 1-min data in any location without local adaptation. We have applied the tool in three locations with different climates. The similitude between measured and generated DNI distributions has been evaluated through the Kolmogorov-Smirnov test Integral (KSI) for annual synthetic 1-min datasets. Obtained KSI values range from 6.2 W/m^2 to 11.5 W/m^2.

INTRODUCTION

Solar data with high resolution is required for the detailed performance simulations of solar systems. However, most of the extended databases are generally available at hourly scale. There have been many attempts to generate high-resolution solar irradiance data in the recent years based in stochastic procedures. Polo et al. [2] developed a model to generate synthetic 10-min uncoupled DNI and GHI data by combining a deterministic and a stochastic component. . Larrañeta et al. [3] and Grantham et al. [4] based on this model for generating 10-min DNI series and matched pairs of 5-min GHI and DNI values, respectively. In a different approach, Bright et al. [5] used Markov Transition Matrix to stochastically simulate cloud cover for generating 1-min DNI, GHI and diffuse irradiance. This model was improved including the spatial dimension variation in the synthetic generation [6]. A different approach based on the generation of a dimensionless high frequency database of daily solar radiation profiles obtained promising results [7-10]. The implemented method in the open tool presented in this paper is based on the dimensionless concept but with several improvements proposed by Larrañeta et al [1].

In this paper, we perform a walkthrough the open tool synthetic generation process in order to facilitate a user guide for any potential users.

THE IMPLEMENTED ALGORITHM

The ND model consists in the dimensionalization of the daily solar GHI and DNI profiles by the extraterrestrial irradiation and the clear sky envelope respectively for several locations with different climates creating daily dimensionless profiles from observed solar radiation data. The time scale and the solar irradiation scale from 0 to 1. In Figure 1, we present a daily solar profile and the dimensionless shape.

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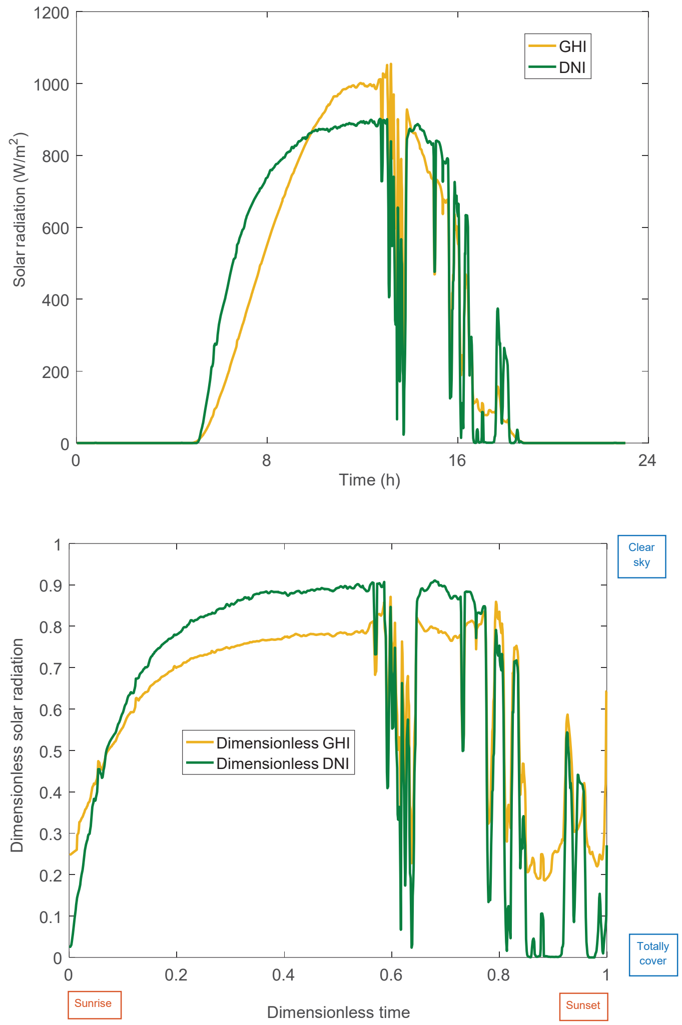


FIGURE 1. Example of observed solar radiation (top) and dimensionless profile (bottom)

We have generated a dimensionless database in 1-min resolution from several locations with different climates from observed time series. For the synthetic generation of 1-min data, we find the most similar day in the dimensionless database to the input hourly profile in terms of the energy, variability and distribution, to subsequently combine the dimensionless selected profile to the clear sky envelope. In Figure 2, we present the flow diagram of the algorithm.

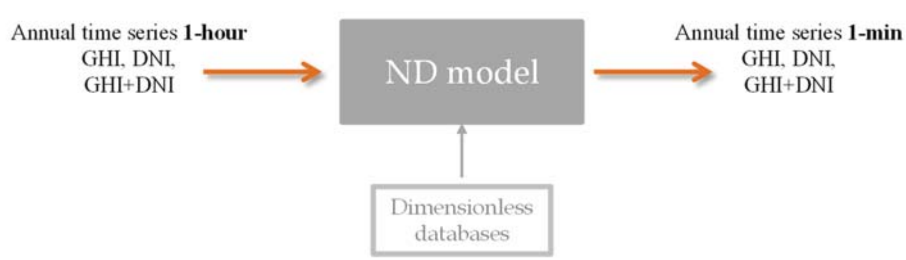


FIGURE 2. Flow diagram of the ND algorithm for the synthetic generation high temporal resolution solar data

WALKTRHOUGH THE TOOL

The tool is widely available at https://gter.es/2020/06/02/tools/ where the user should click on the "ND model" logo. It will them prompt a new window with the main page tool interface. In next image, we present the main page ND tool interface. On the left page side, we can see all the empty blanks to be fulfilled by the user. On the right side, the explanation of how to fill each of the empty spaces. In the next lines, we explain step by step, the information that the user is asked to introduce.

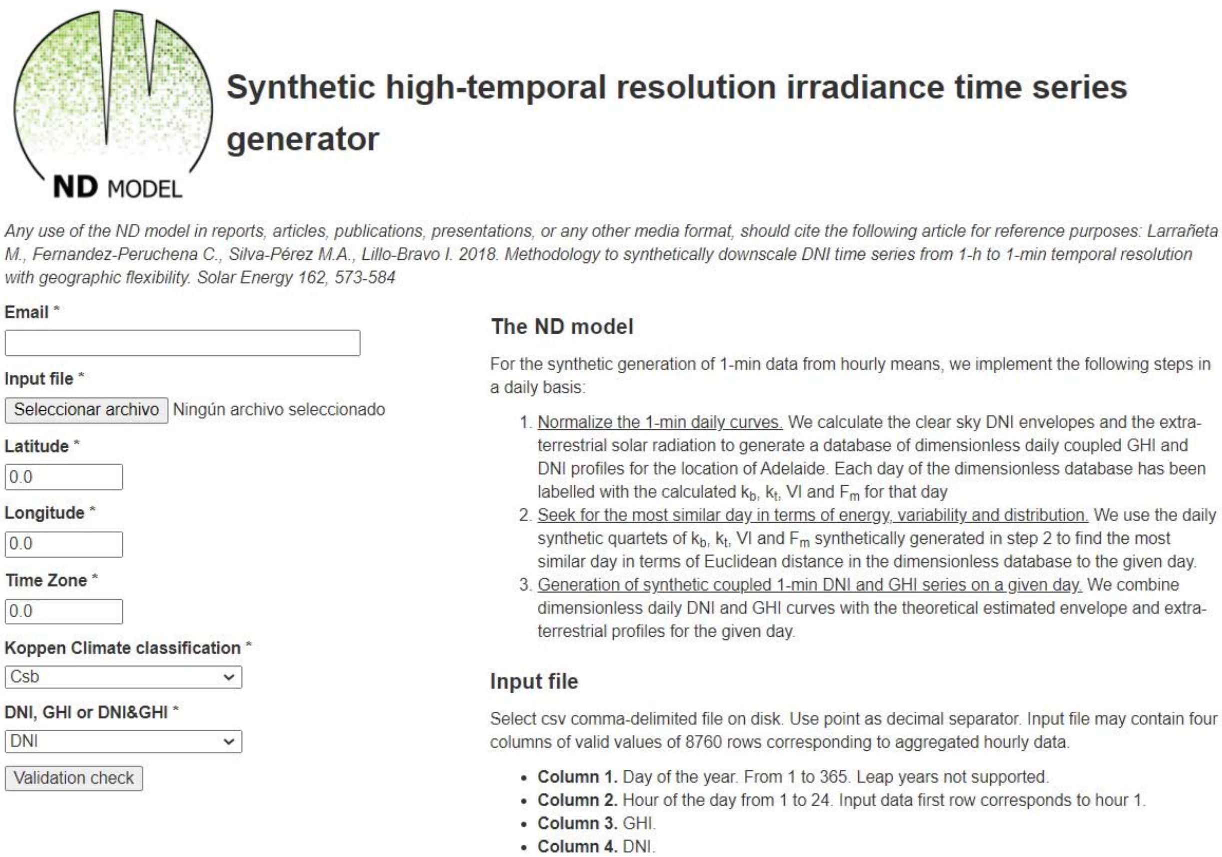


FIGURE 3. Main page ND tool interface

Email: First, the user has to introduce an e-mail address where the synthetic data will be sent at the end of the synthetic generation process.

Input file: Then, we shall select a csv comma-delimited file on disk. Use point as decimal separator. Input file may contain four columns of valid values of 8760 rows corresponding to aggregated hourly data from an entire annual set.

- Column 1. Day of the year. From 1 to 365. Leap years not supported.
- Column 2. Hour of the day from 1 to 24. Input data first row corresponds to hour 1.
- Column 3. GHI.
- Column 4. DNI.

In the case of generating only one variable (GHI or DNI) the algorithm will take the data from the corresponding column. For instance, if we intend to generate only DNI, user shall include the hourly DNI data input in the fourth column, leaving the third column empty.

We have included a sample file available to download with hourly-coupled DNI+GHI data from Seville, Spain (37.41ºN, 6.01ºW, UTC time reference).

GTER and / or any partner will not use input data for any industrial/academic purpose without the permission of the data owner.

Latitude: The user has to introduce the latitude of the site under study in degrees, north positive.

Longitude: The user has to introduce the longitude of the site under study in degrees, east positive.

Time Zone: The user shall introduce the time reference of the input file in terms of hours offset from GMT.

DNI, GHI or DNI&GHI: Select the variables to downscale in the drop-down menu.

Köppen climate classification: The user shall select the Köppen climate classification of the drop-down menu list referred to the input data. We include a link to the Köppen classification world map for the users to find the location under study climate classification. We use a different dimensionless database for the synthetic generation depending on the selected climate since we observed in Larrañeta et al., (2018) [1] that the intra-day variability of the solar radiation was not properly reproduced when using Seville dimensionless data (Csa) to reproduce Pretoria 1-min data (Cwa). Moreover, the Köppen Classification climate is necessary for the choice of the appropriate clear sky model parameters.

We have generated 7 dimensionless databases from locations with several Köppen climates. To that end, we have used GTER 1-min observations from Seville and the Australian Bureau of Meteorology 1-minute observations from several locations in Australia. In Figure 4, we present a map of the selected locations and their corresponding Köppen climate classification in Australia [11].

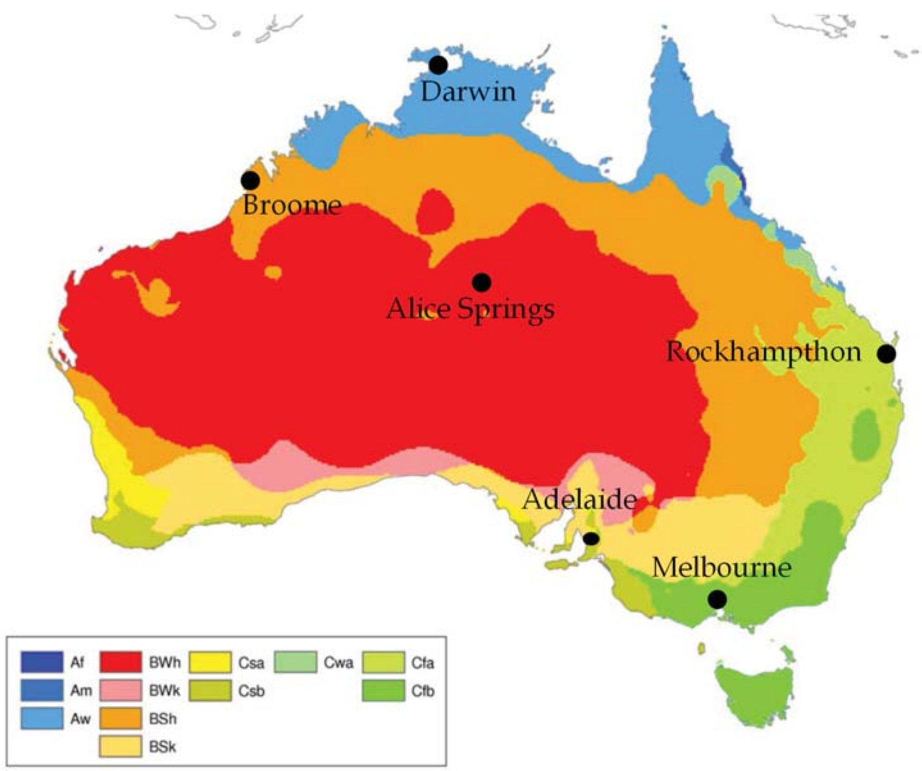


FIGURE 4. Köppen climate classification of Australia [11] and the selected sites for the dimensionless databases

Selected sites cover a wide range of climates but not all of them. Depending on the input climate selected by the user, the tool would select the most similar climate to downscale the solar radiation. This way, we intend to reproduce the intra-day variability of the input climate site. In Table 1, we present the location of the available dimensionless databases, their climates, and their correlated climate without available dimensionless database.

TABLE 1. Dimensionless databases available sites, their Köppen climate and their correlated Köppen climate

Location	Köppen Classification climate (observed)	Köppen Classification climate (correlated)
Seville (Spain)	Csa	*Csa*
Darwin (Australia)	Aw	*Aw*, Am, Af, As
Broome (Australia)	Bsh	*Bsh*, Bsk
Alice Springs (Australia)	Bwh	*Bwh*, Bwk
Rockhampton (Australia)	Cfa	*Cfa*, Cwa
Melbourne (Australia)	Cfb	*Cfb*, Cfc, Cwb, Cwc, ET, EF, Dfc, Dfd, Dwc, Dwd, Dsc, Dsd, Dsa, Dsb, Dwa, Dwb, Dfa, Dfb
Adelaide (Australia)	Csb	*Csb*

Once the empty blanks have been fulfilled, the user should click on the validation check button. The tool will check the input file format prompting a message if necessary and then it will run a time reference validation. Time reference is a common source of errors when dealing with hourly solar radiation values. We calculate the clear sky hourly profile and plot it together with the clearest daily profile of the observed input hourly file for each month. This way, the user can test if the time reference of the input file and the tool calculations are consistent or if a modification of the input data is required. In this case, the user can modify the input CSV file or the time zone blank and run again the validation check.

Our hourly solar calculations are referred to the midpoint of the last hour and the record correspond to the latest hour, e.g. data at 11:00 correspond to values from 10:00 to 10:59 and solar calculations are performed at 10:30.

After checking the time reference, the user can click on the synthetic generation button and the synthetic 1-min data will be sent via e-mail after a few minutes.

RESULTS EVALUATION

In this section, we evaluate the tool performance in three locations with different climates. We select the same locations as selected in Larrañeta et al., [1] and evaluate the DNI synthetic generation for three annual sets in order to quantify the improvement that carry the implementation of several dimensionless databases depending on the climate. In Table 2, we present the selected locations for the results evaluations.

TABLE 2. Locations selected for the evaluation of the ND tool

	Latitude	Longitude	Altitude (m)	Climate	Period	Radiometric Network
Almería	37.1 °N	2.3 °E	500	Bsk	2013	CIEMAT-DLR
Pretoria	25.7 °S	28.2 °W	1410	Cwa	2016	SAURAN
Payerne	46.8 °N	6.9 °W	491	Cfb	2014	BSRN

We use the KSI to evaluate similitudes between the observed and synthetic sets. The unit of this index is the same for the corresponding magnitude (W/m^2). The higher the KSI values, the worse the model fit

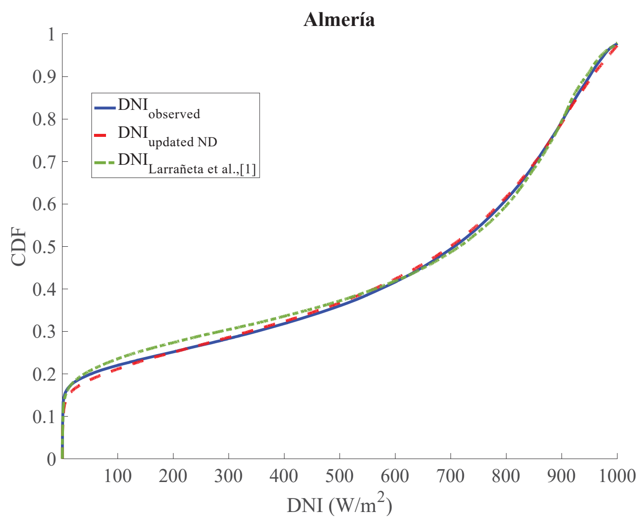
$$KSI = \int_{x_{min}}^{x_{max}} D_n dx,$$

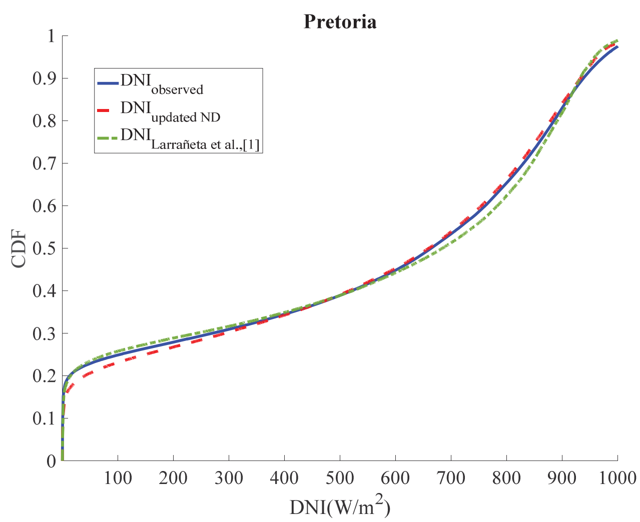
where, x_{max} and x_{min} are the extreme values of the observed 1-min data, and D_n are the differences between the CDFs of the observed and synthetic datasets. The KSI shows comparable results regardless of the time resolution of the synthetic data.

In Table 3, we present the KSI values obtained in the previous approach and the results of the updated model including the dimensionless databases for several climates. In Figure 5, we present the CDFs of the observed and synthetic sets obtained with the updated ND model and the previous approach.

TABLE 3. KSI of the updated ND model and the Larrañeta et al., [1] approach for the three selected locations

Parameter	Station	Updated ND model	Nd model (previous approach)
	Almería	6.2	12.3
KSI (W/m^2)	Pretoria	9.1	11.4
	Payerne	11.5	16.5





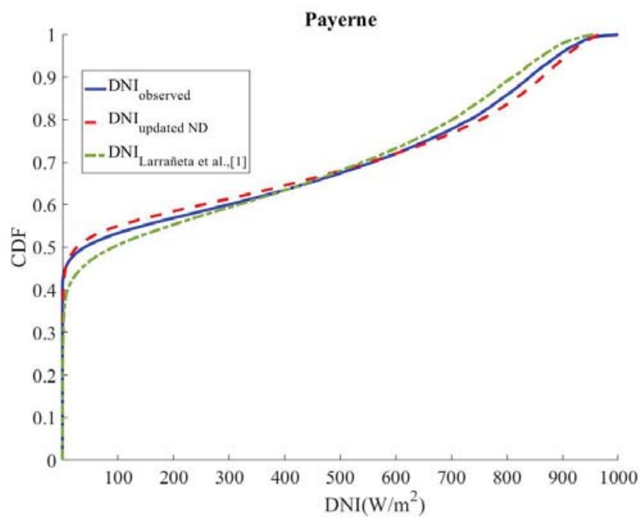


FIGURE 5. CDFs of the observed and synthetic 1-min DNI datasets obtained with the updated ND model and the previous approach for Almeria (top), Pretoria (middle) and Payerne (bottom)

We observe strong similitudes between the CDFs of the observed and synthetic sets- We find an improvement in the KSI in average from 13.4W/m^2 in the previous approach to 8.9W/m^2 in the updated ND model, a 34% of improvement. The best results are found for Almería reaching a KSI of 6.2W/m^2.

SUMMARY AND CONCLUSIONS

In this paper, we present the use of the ND tool: an open tool suitable for the synthetic generation of high-resolution solar radiation. The tool requires only an annual set of hourly solar radiation data as input, and provides 1-min solar data at any location without any local adaptation as output. The implemented model is an updated version of the ND model Larrañeta et al., [1]. We have evaluated the tool for the calculation of DNI data in three locations with different climates finding an improvement in the KSI (W/m^2) of 34%.

In this paper, we have documented a walkthrough the tool that can be used as user manual in the next years. The tool just requires solar data and geographical and climatological information about the site under study and runs a validation procedure in order to avoid errors in the time reference between the user and the calculation. It has been developed with a user-friendly interface that makes it accessible to the scientific community.

REFERENCES

1. Larrañeta M., Fernandez-Peruchena C., Silva-Pérez M.A., Lillo-Bravo I. 2018. "Methodology to synthetically downscale DNI time series from 1-h to 1-min temporal resolution with geographic flexibility." *Solar Energy* 162, 573-584.
2. Polo, J., Zarzalejo, L.F., Marchante, R., Navarro, A.A., 2011. "A simple approach to the synthetic generation of solar irradadiance time series with high temporal resolution." *Solar Energy* 85, 1164-1170.
3. Larrañeta, M., Moreno-Tejera, Silva-Pérez, M.A., Lillo-Bravo, I. 2015. "An improved model for the synthetic generation of high temporal resolution direct normal irradiation time series." *Solar Energy* 122. 517–528.
4. Grantham, A.P., Pudney, P.J., Ward, L.A., Belusko, M., Boland, J.W., 2017. Generating synthetic five-minute solar irradiance values from hourly observations. *Solar Energy* 147, 209-221.
5. Bright, J.M., Babacan, O., Kleissl, J Taylor, P.G., Crook, R., 2017. "A synthetic, spatially decorrelating solar irradiance generator and application to a LV grid model with high PV penetration." *Solar Energy* 115 229–242.
6. Bright, J.M., Smith, C.J., Taylor, P.G., Crook, R., 2015. Stochastic generation of synthetic minutely irradiance time series derived from mean hourly weather observation data." *Solar Energy* 115 229–242.
7. Peruchena C.F., Larrañeta M., Blanco M., Bernardos A. 2018. "High frequency generation of coupled GHI and DNI based on clustered Dynamic Paths." *Solar Energy* 159, 453-457.

8. Fernández-Peruchena, C. M. F., Gastón, M., Schroedter-Homscheidt, M., Kosmale, M., Marco, I. M., García-Moya, J. A., & Casado-Rubio, J. L. (2017). "Dynamic Paths: Towards high frequency direct normal irradiance forecasts." *Energy* 132, 315-323.
9. Fernández-Peruchena, C.M., Gastón, M., 2016. "A simple and efficient procedure for increasing the temporal resolution of global horizontal solar irradiance series n. Renew." *Energy* 86, 375–383.
10. Fernández-Peruchena, C.M., Blanco, M., Gastón, M., Bernardos, A., 2015." Increasing the temporal resolution of direct normal solar irradiance series in different climatic zones." *Solar Energy* 115, 255-263.
11. Peel, M. C., Finlayson, B. L., and McMahon, T. A.: Updated world map of the Köppen-Geiger climate classification Hydrol. Earth Syst. Sci., 11, 1633–1644, https://doi.org/10.5194/hess-11-1633-2007, 2007.