ICT
Instituto de Ciências da Terra
Institute of Earth Sciences

UNIVERSIDADE DE ÉVORA

Workshop: Numerical Weather Prediction in Portugal 2021

IMPROVEMENT OF MESO-NH SOLAR RADIATION SIMULATIONS WITH ARTIFICIAL NEURAL NETWORKS

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INTRODUCTION

- Renewable energy has been and is still growing, including photovoltaic (PV) energy.
- Being able to do an accurate assessment of solar radiation allows for better planning and design of PV systems.
- Since generation of energy maps using observations require various instruments dispersed throughout the desired domain, numeric weather prediction (NWP) models can be used.
- NWP models have some difficulties in correctly simulating solar radiation, mainly direct normal irradiation (DNI).

SIMULATION DATA

- Generation of Typical Meteorological Year (TMY) based on 16-year observation data at Évora;

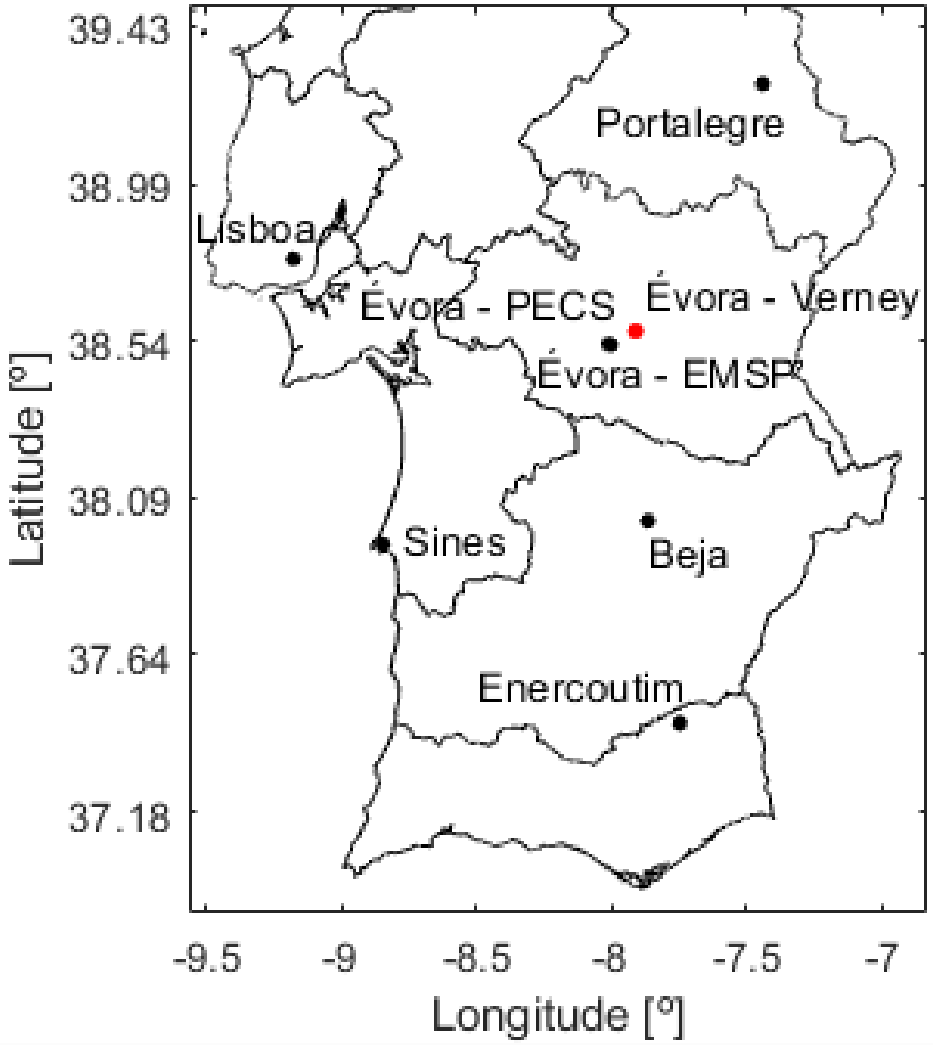
Selected years/months											
Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2018	2006	2017	2008	2005	2010	2014	2007	2011	2008	2004	2018

- Simulation of TMY for the South of Portugal using Meso-NH model. Some important details:
  - 72h simulations initiated and forced with analysis data from ECMWF model.
  - 1.25 km of horizontal resolution.
  - Radiation scheme - ecRad (v 1.0.1).
  - Spartacus solver.
  - Aerosol climatology: MACC (12 aerosols species).

- Obtained 1-minute data converted to 10-minute values of the variables:
  - Global Horizontal Irradiance (GHI).
  - Direct Normal Irradiance (DNI).
  - Diffuse Horizontal irradiance (DHI).
  - Air Temperature (T).
  - Wind Speed (WS).
  - Wind Direction (WD).
  - Average Cloud Fraction (avgCF).
  - Maximum Cloud Fraction (maxCF).

EXPERIMENTAL DATA

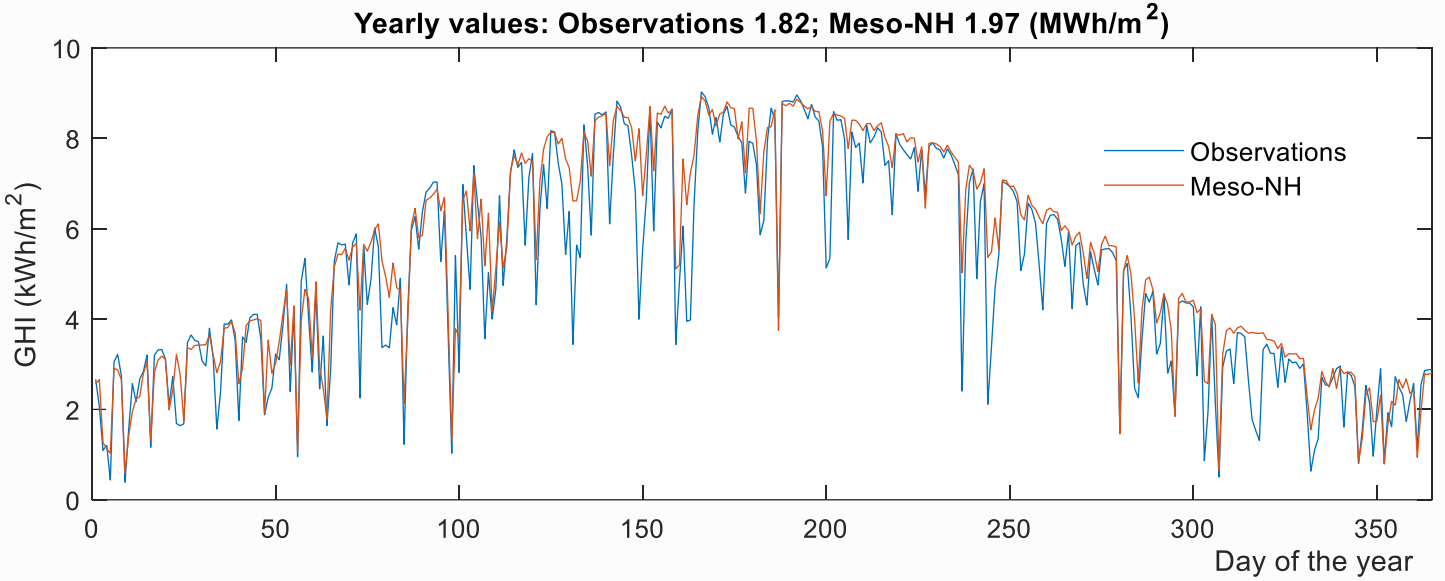
- At Évora - Verney:
  - Before 2017:
    - 10min time-step experimental data of GHI and DHI.
    - Computation of DNI from observations of GHI and DHI.
  - 2017 and 2018:
    - 1min time-step experimental data of GHI, DNI and DHI from the sunTracker.



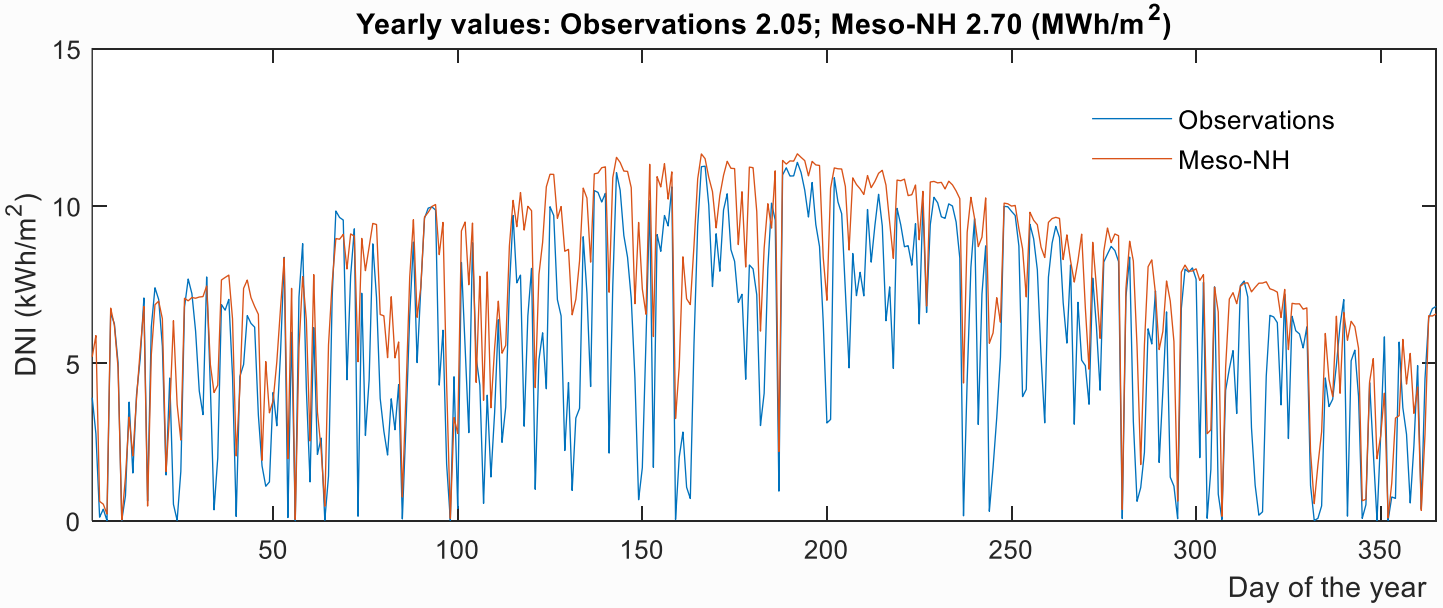
ANALYSIS OF MESO-NH OUTPUT (ÉVORA)

- 10-minute data analysis (Wh/m^2):

Metrics	GHI	DNI
MBE	5.41	24.24
RMSE	21.52	49.22



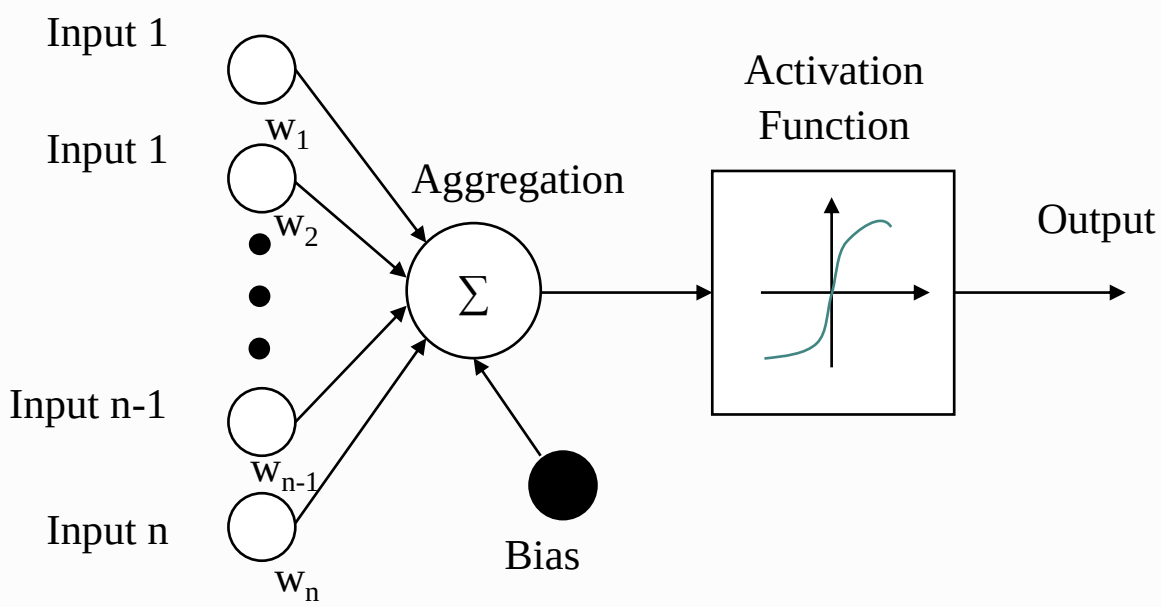
- Relative MBE for the TMY:
  - GHI: 8.24%.
  - DNI: 31.71%.



DEVELOPMENT OF ANN MODEL

ANN Default Parameters

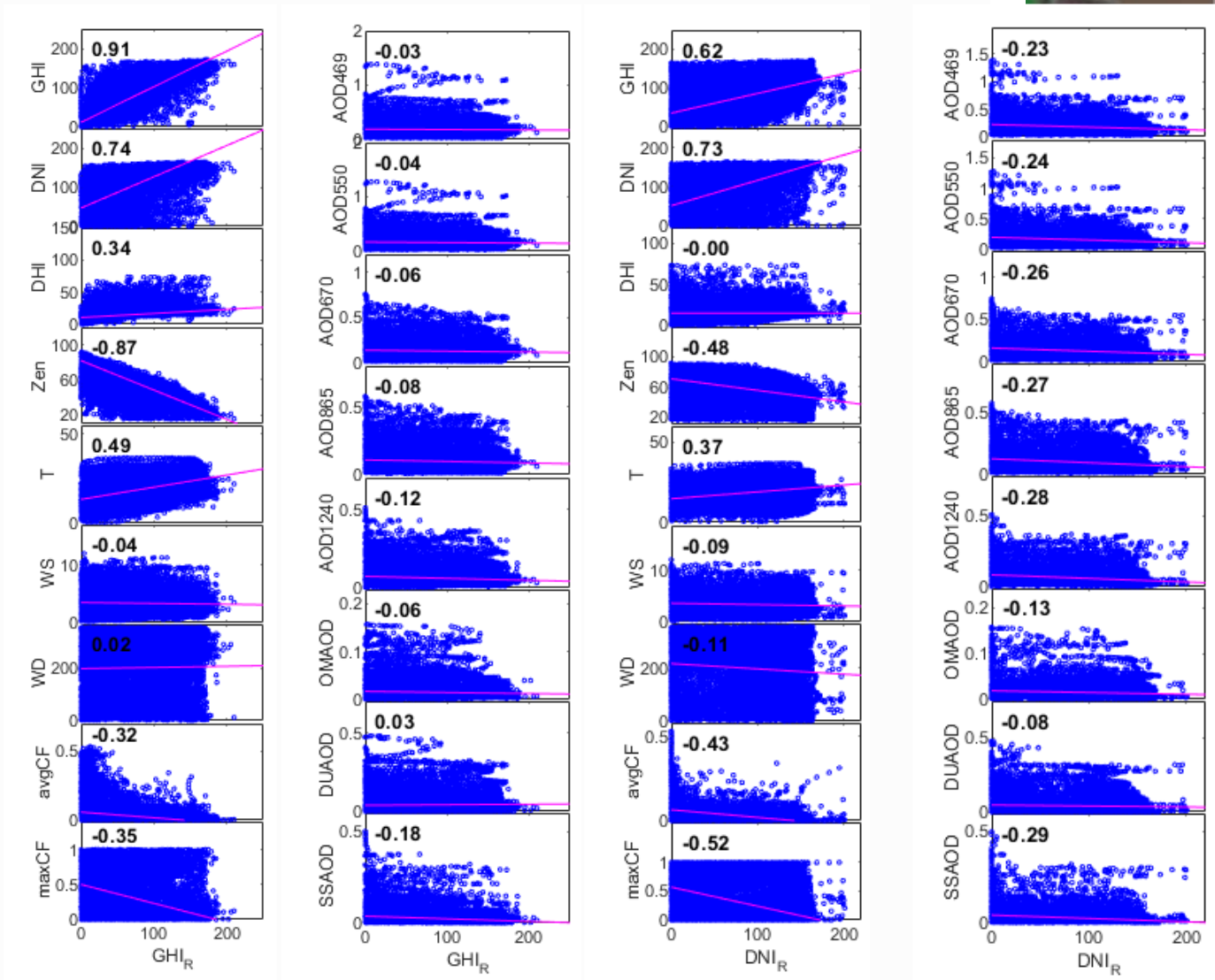
- Architecture: fitting network with 3 layers.
- Activation Function: hyperbolic tangent sigmoid.
- Performance Function: mean squared error.
- Data division: randomly into 70% for training and 30% for validation.



DEVELOPMENT OF ANN MODEL

Selection of Inputs

- Introducing the CAMS analysis data set:
  - Spatial resolution: 0.125º.
  - Temporal resolution: 3h.
  - Variables tested:
    - Aerosol optical depth at
      469 nm (AOD469),
      550 nm (AOD550),
      670 nm (AOD670),
      865 nm (AOD865) and
      1240 nm (AOD1240).
    - Sea salt aerosol optical depth at 550 nm (SSAOD).
    - Organic matter aerosol optical depth at 550 nm (OMAOD).
    - Dust aerosol optical depth at 550 nm (DUAOD).



DEVELOPMENT OF ANN MODEL

Testing ANN models

- Metric:

$$MSE_{rd} = \frac{MSE_{Meso-NH} - MSE_{ANN}}{MSE_{Meso-NH}} \times 100\%$$

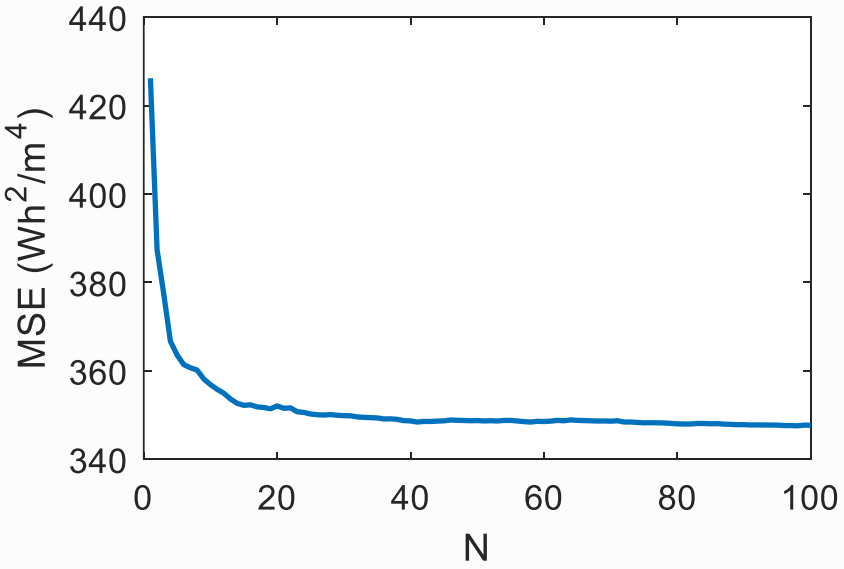
- Training Function:
  - Levenberg-Marquardt backpropagation.
  - Bayesian regularization backpropagation.
- Number of Neurons in the Hidden Layer: from 1 to 100.
- Addition of inputs in order of their Pearson's linear correlation coefficients.

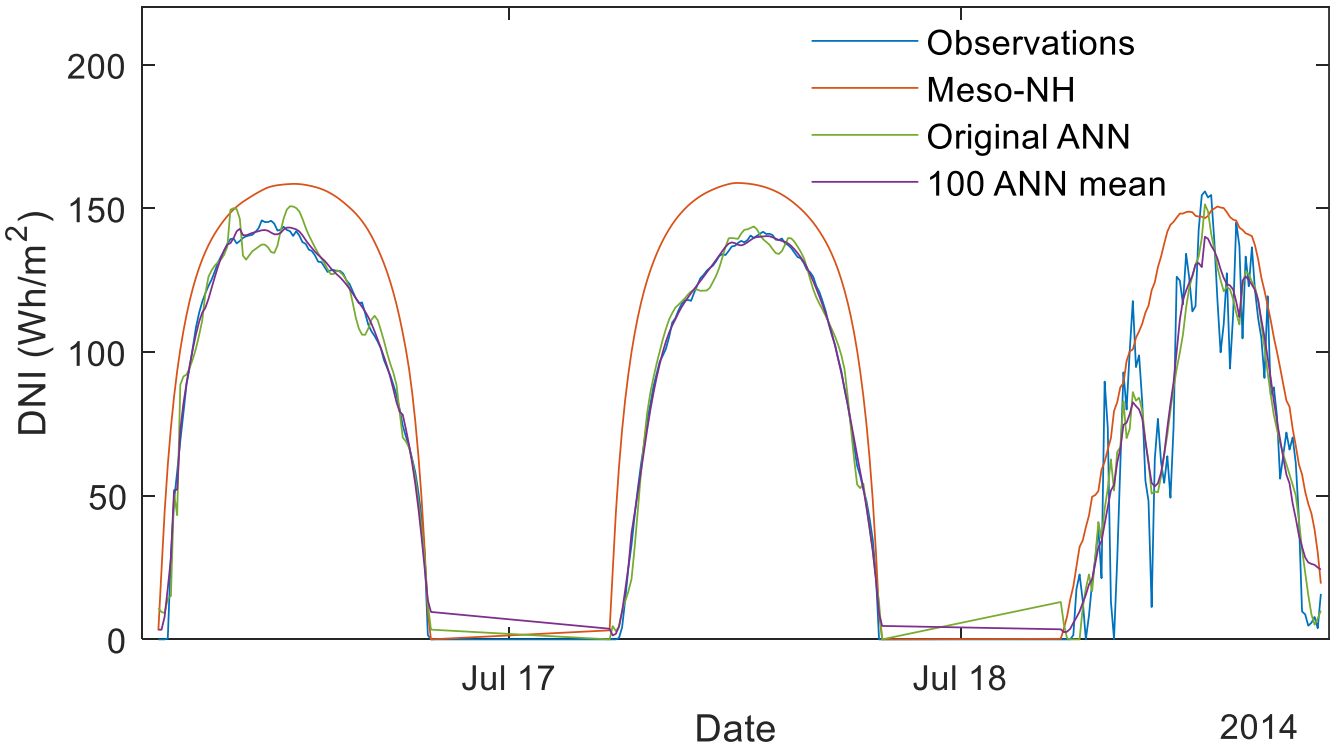
Variable of interest		GHI					DNI				
ANN model rank		**1**	2	3	4	5	**1**	2	3	4	5
MSE_{rd} (%)		**67.60**	67.07	66.95	66.92	66.83	**82.41**	82.34	82.28	82.24	81.89
Number of neurons		**100**	99	95	97	98	**97**	99	100	98	96
	GHI	×	×	×	×	×	×	×	×	×	×
	DNI	×	×	×	×	×	×	×	×	×	×
	DHI	×	×	×	×	×	×	×	×	×	×
	Zen	×	×	×	×	×	×	×	×	×	×
	T	×	×	×	×	×	×	×	×	×	×
	WS	×	×	×	×	×	×	×	×	×	×
	WD	×	×	×	×	×	×	×	×	×	×
	avgCF	×	×	×	×	×	×	×	×	×	×
Inputs	maxCF	×	×	×	×	×	×	×	×	×	×
	AOD469	×	×	×			×	×			×
	AOD550	×	×	×	×	×	×	×	×	×	×
	AOD670	×	×	×	×	×	×	×	×	×	×
	AOD865	×	×	×	×	×	×	×	×	×	×
	AOD1240	×	×	×	×	×	×	×	×	×	×
	OMAOD	×	×	×	×	×	×	×	×	×	×
	DUAOD	×	×	×	×	×	×	×	×	×	×
	SSAOD	×	×	×	×	×	×	×	×	×	×

DEVELOPMENT OF ANN MODEL

Testing ANN models

- Increase in performance (MSE_{rd}) when using the mean of 100 trained ANNs:
  - GHI: 4.76%
  - DNI: 3.24%

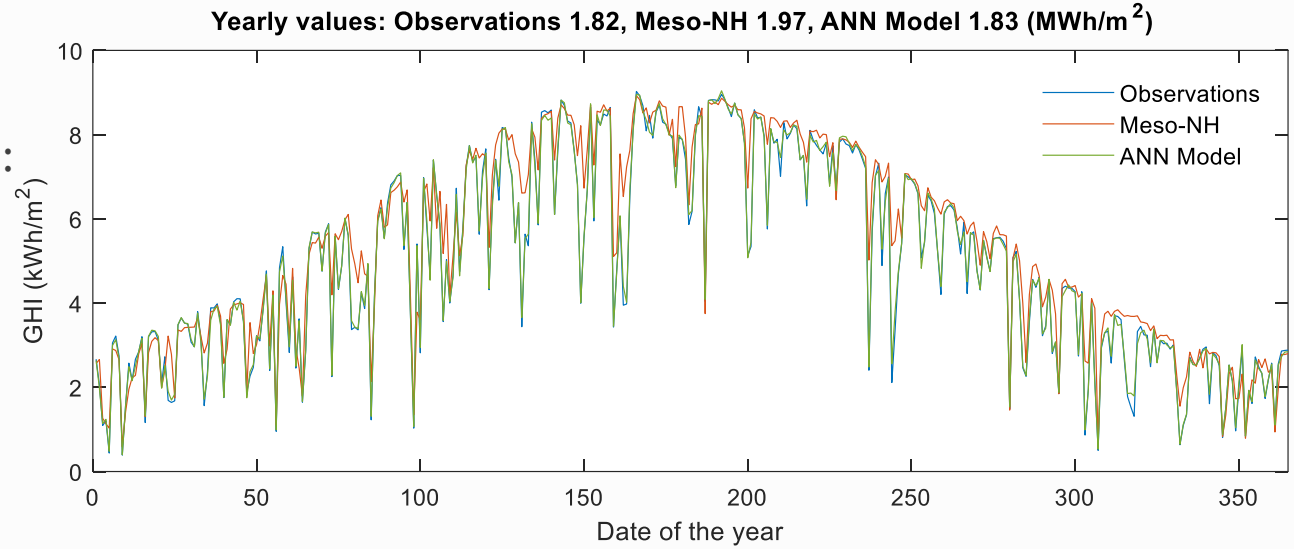




RESULTS

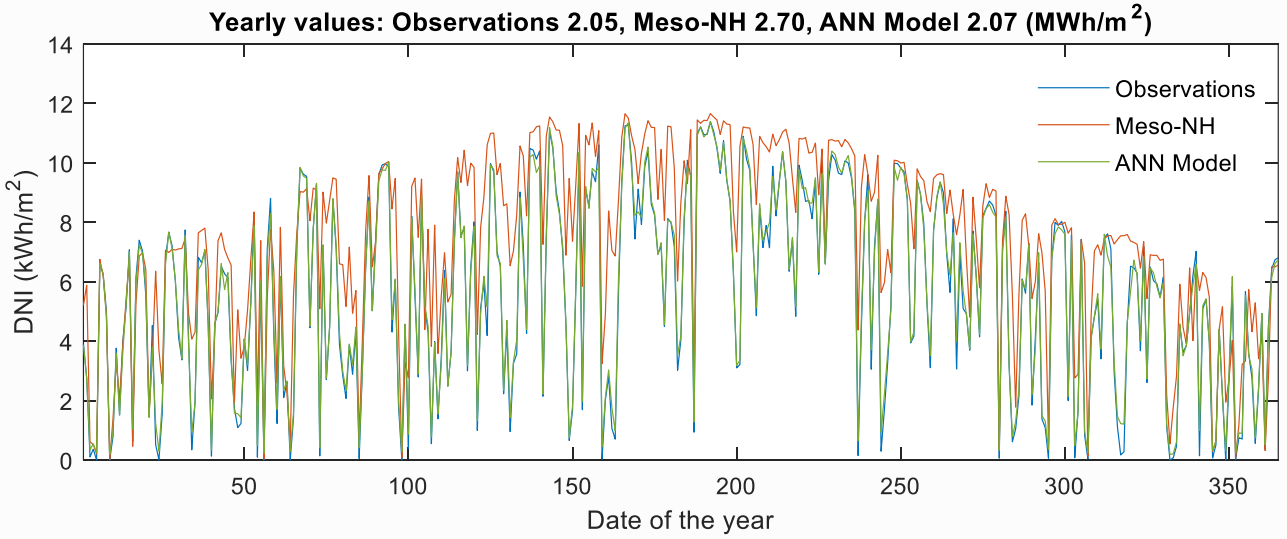
- 10-minute data analysis (Wh/m^2):

Metrics	GHI		DNI	
	Meso-NH	ANN	Meso-NH	ANN
MBE	5.41	**0.13**	24.24	**0.88**
RMSE	21.52	**11.32**	49.22	**18.65**



- Relative MBE for the TMY:

GHI		DNI	
Meso-NH	ANN	Meso-NH	ANN
8.24%	**0.55%**	31.71%	**0.98%**



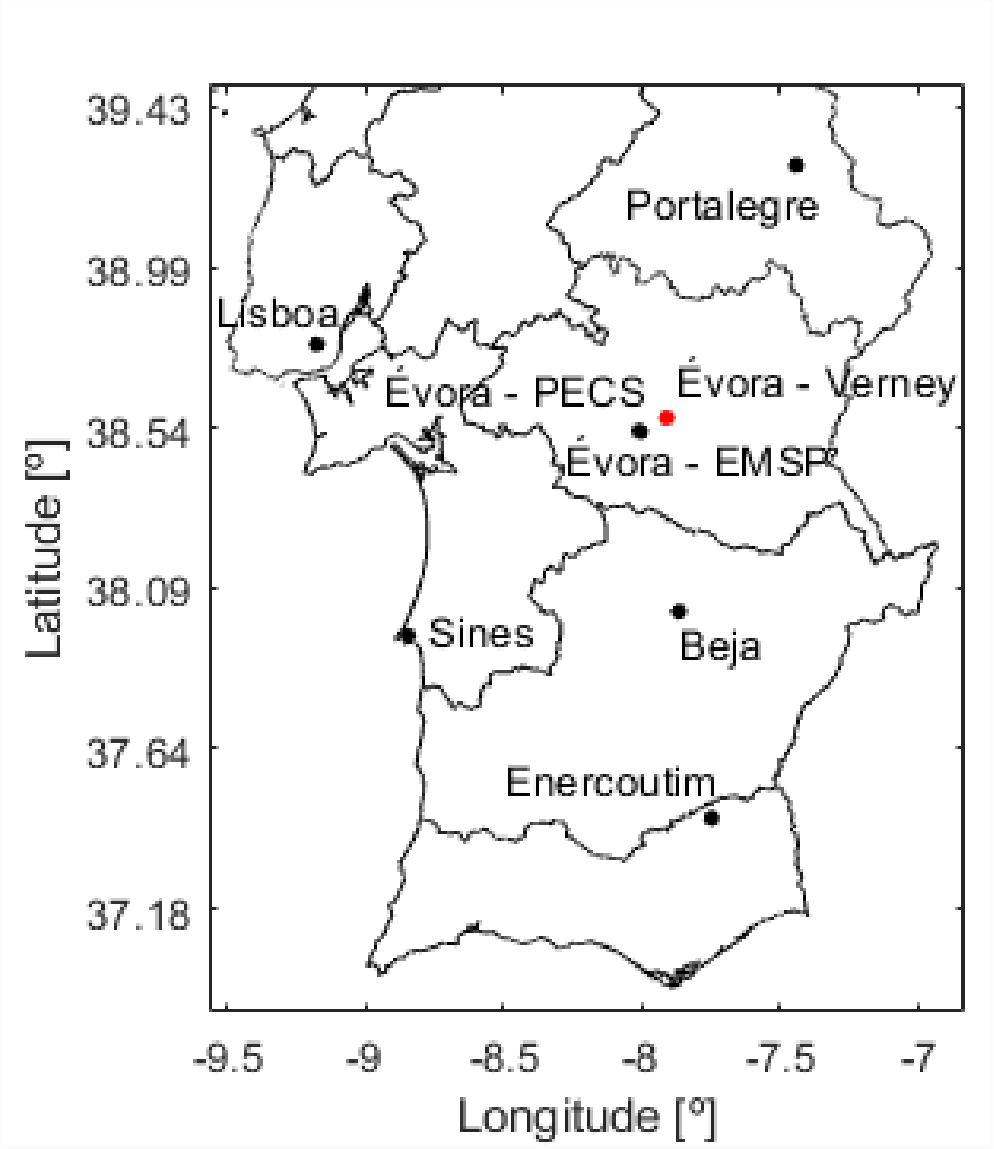
RESULTS

- GHI and DNI data from stations of the DNI-A network.
- Monthly data analysis (kWh/m^2):

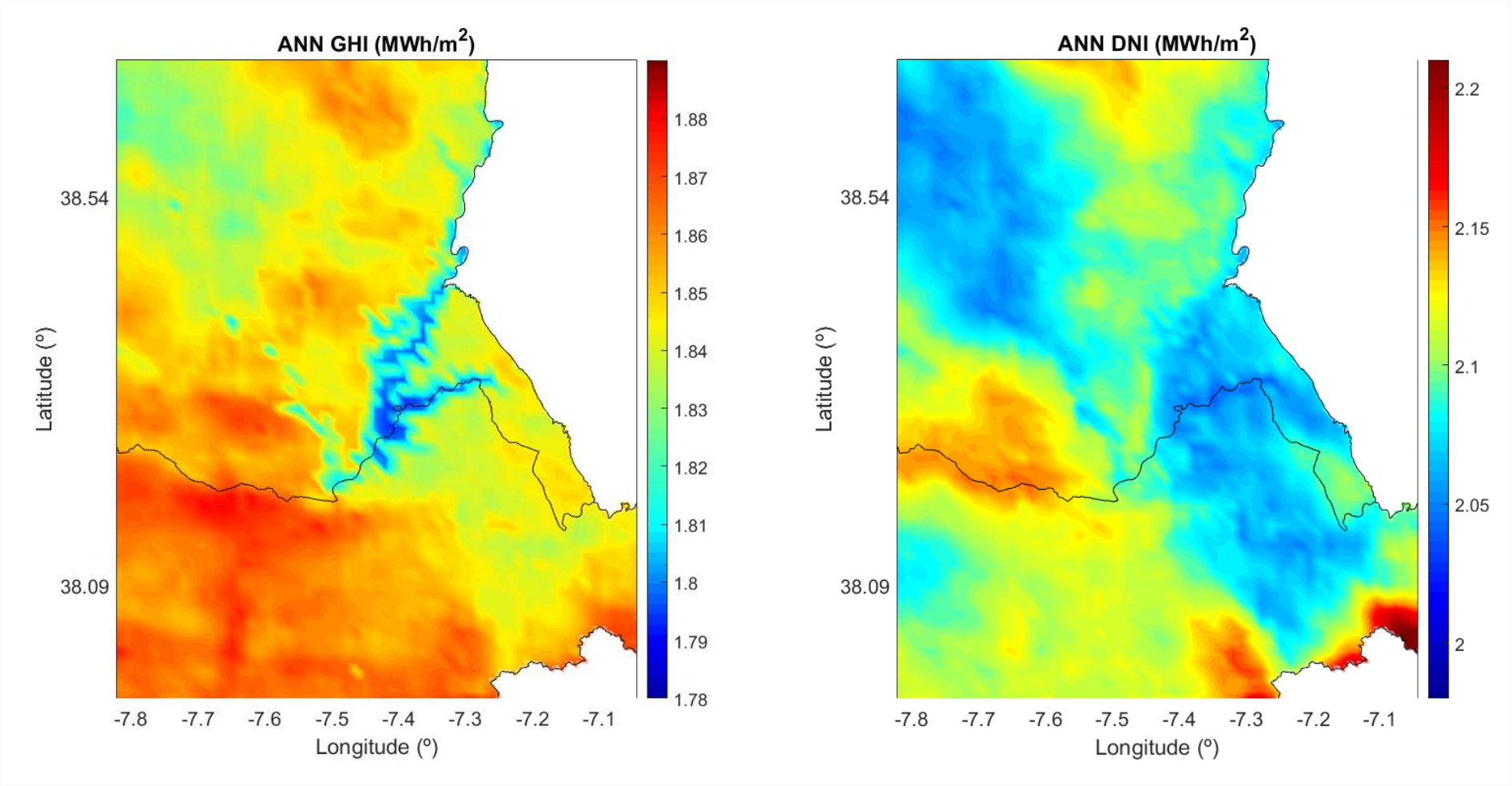
Metrics	GHI		DNI	
	Meso-NH	ANN	Meso-NH	ANN
MBE	9.63	2.63	43.67	5.97
RMSE	11.49	4.26	48.00	11.57

- Relative MBE for the available data:

GHI		DNI	
Meso-NH	ANN	Meso-NH	ANN
8.50%	2.34%	29.54%	3.41%



RESULTS


ANN GHI (MWh/m2)
38.54
38.09
Latitude (°)
-7.8 -7.7 -7.6 -7.5 -7.4 -7.3 -7.2 -7.1
Longitude (°)
1.88 1.87 1.86 1.85 1.84 1.83 1.82 1.81 1.8 1.79 1.78
ANN DNI (MWh/m2)
38.54
38.09
Latitude (°)
-7.8 -7.7 -7.6 -7.5 -7.4 -7.3 -7.2 -7.1
Longitude (°)
2.2 2.15 2.1 2.05 2

CONCLUSIONS

- The Meso-NH model shows overestimation of solar radiation probably due to poor cloud simulation and use of monthly-mean aerosol climatologies.
- GHI is better simulated by the Meso-NH model than DNI.
- The corrective algorithm dramatically improves not only the simulations of solar radiation for the station of Évora-Verney but also for the surrounding region.
- An accurate solar resource assessment is essential for applications related to the solar resource and, ultimately, for planning and design of photovoltaic energy systems.

THANK YOU!