7th International Congress
Energy and Environment Engineering and Management

An empirical assessment of several machine learning approaches to estimate long-term wind speed conditions

Topic – 2.3 Renewable energies: Potential of wind energy

Authors:
Santiago Díaz Ruano; Fernando Castellano Hernández; José Antonio Carta González

UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA
itc INSTITUTO TECNOLÓGICO DE CANARIAS
Gobierno de Canarias

ENERMAC
Energías Renovables y Eficiencia Energética
Desarrollo Sostenible de África Occidental e Islas de la Macaronesia
MAC 2014-2020
Cooperación Territorial
Interreg

Introduction

Measure-Correlate-Predict (MCP) Methodology:

Description:

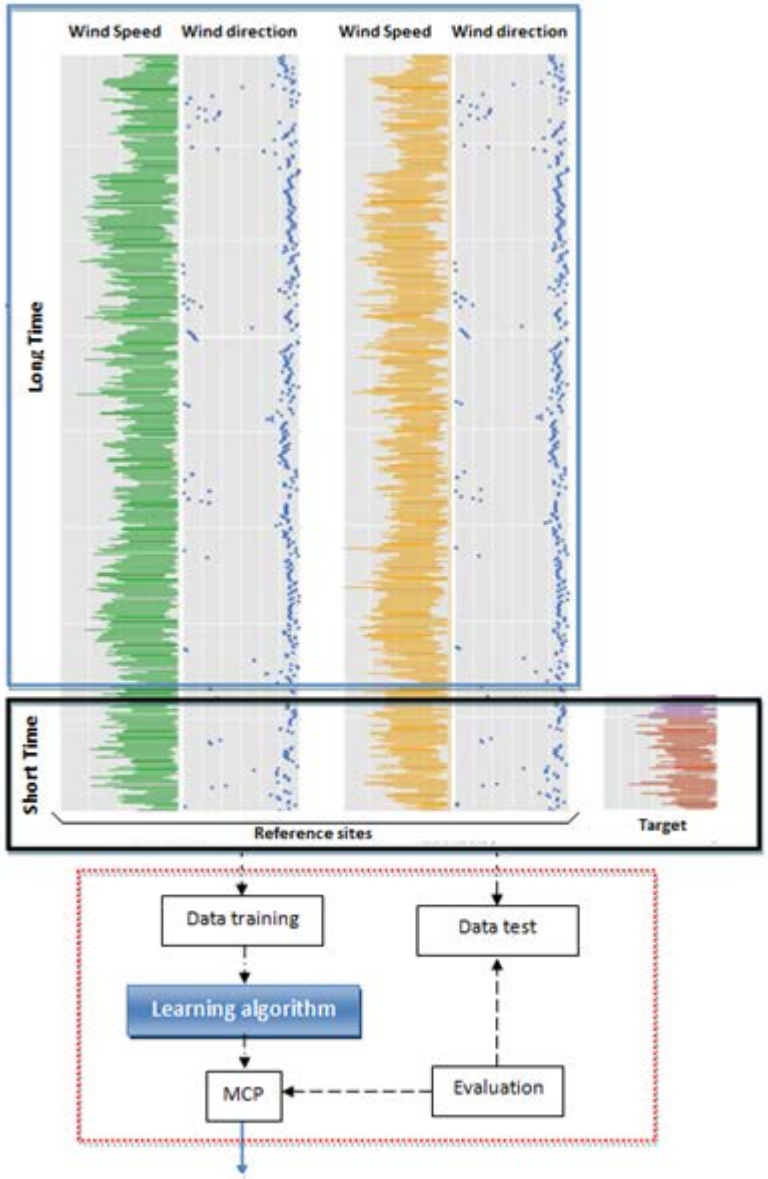
Method to recognize long-term wind characteristics at target sites for which only measurements recorded over short-term are available.

Machine learning techniques:

- These methods are able to determine non-linear relationships between features.
- Allows the use of multiple reference stations.
- The **most commonly** used data mining technique have been **Artificial Neural Networks (ANNs)**.

Main goal of the research work:

Demonstrate the validity of **Support Vector Regression (SVR)** and **Random Forest (RF)** methods to estimate long-term wind speed conditions considering multiple reference station.



Introduction

Measure-Correlate-Predict (MCP) Methodology:

Description:

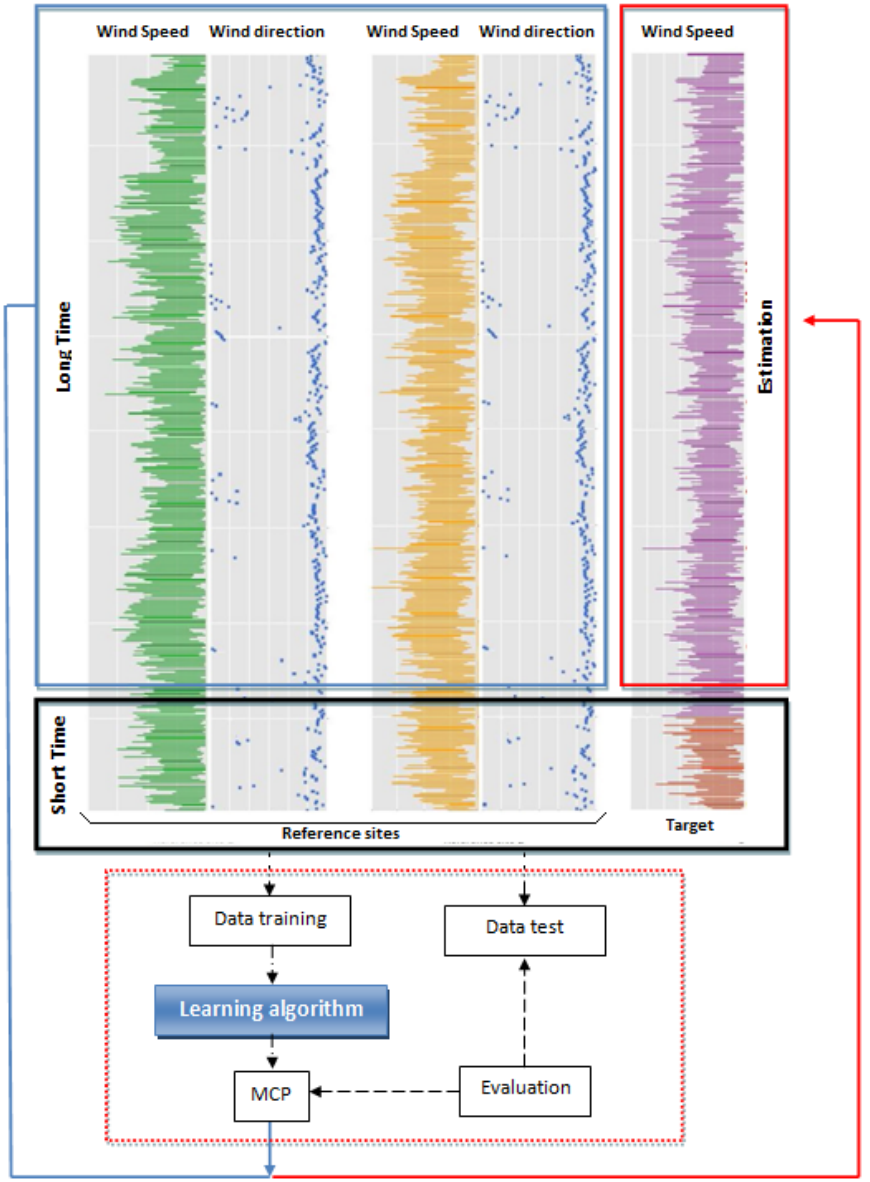
Method to recognize long-term wind characteristics at target sites for which only measurements recorded over short-term are available.

Machine learning techniques:

- These methods are able to determine non-linear relationships between features.
- Allows the use of multiple reference stations.
- The **most commonly** used data mining technique have been **Artificial Neural Networks (ANNs)**.

Main goal of the research work:

Demonstrate the validity of **Support Vector Regression (SVR)** and **Random Forest (RF)** methods to estimate long-term wind speed conditions considering multiple reference station.



Materials

Data:

• **Wind speed and direction** recorded over the course of 2014 at **10 weather stations.**

• All data series were captured at **10 meters** above ground level**.**

• The length of these data series allowed determination of **the seasonal variation patterns** as MCP methodology recommends.

• The positions that are used as **target sites** are the **weather stations that have at least one reference station** with a correlation coefficient greater than 80%

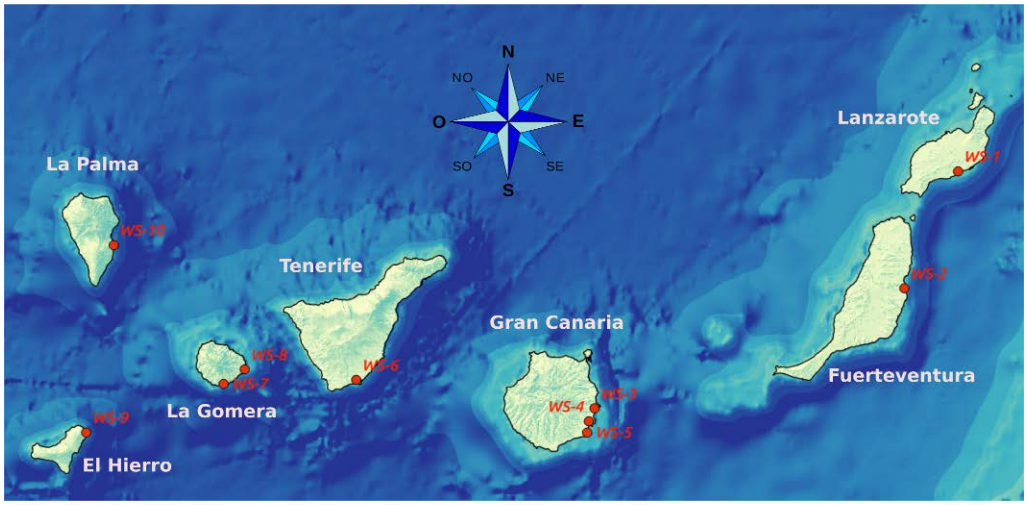
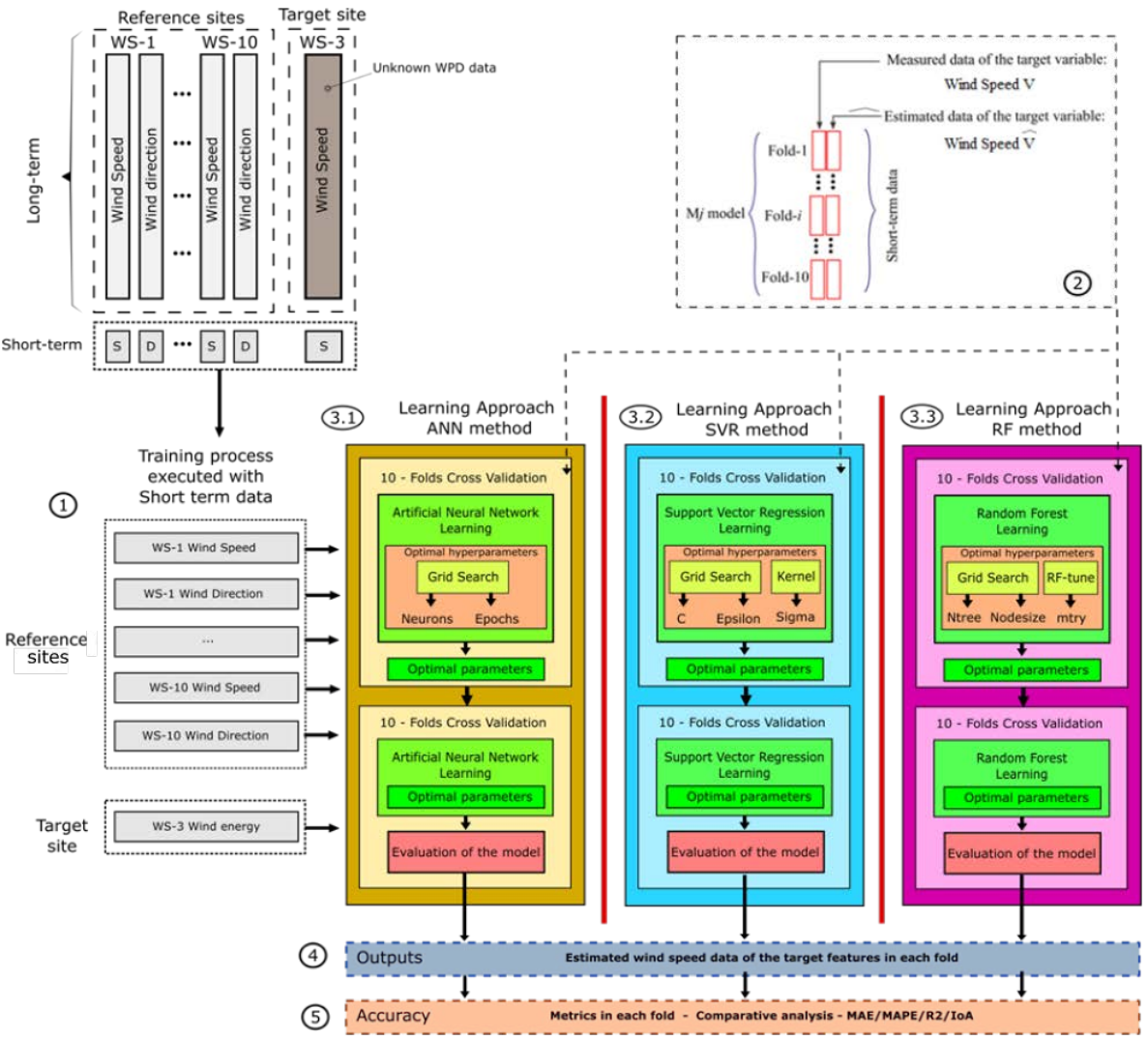


Table I. Linear correlation coefficients between the wind speeds of the Weather Stations

WS	WS-1	WS-2	WS-3	WS-4	WS-5	WS-6	WS-7	WS-8	WS-9	WS-10
WS-1	**1.00**	0.73	0.74	0.67	0.69	0.54	0.26	0.56	0.52	0.56
WS-2	0.73	**1.00**	0.68	0.58	0.63	0.55	0.30	0.54	0.58	0.57
WS-3	0.74	0.68	**1.00**	**0.82**	**0.83**	0.53	0.23	0.60	0.51	0.58
WS-4	0.67	0.58	**0.82**	**1.00**	**0.83**	0.51	0.18	0.55	0.45	0.50
WS-5	0.69	0.63	**0.83**	**0.83**	**1.00**	0.63	0.21	0.55	0.42	0.50
WS-6	0.54	0.55	0.53	0.51	0.63	**1.00**	0.39	0.36	0.31	0.40
WS-7	0.26	0.30	0.23	0.18	0.21	0.39	**1.00**	0.23	0.24	0.34
WS-8	0.56	0.54	0.60	0.55	0.55	0.36	0.23	**1.00**	0.56	0.55
WS-9	0.52	0.58	0.51	0.45	0.42	0.31	0.24	0.56	**1.00**	0.56
WS-10	0.56	0.57	0.58	0.50	0.50	0.40	0.34	0.55	0.56	**1.00**

Methodology



Main characteristics:

- **Targets**: WS3, WS4, WS5.
- **References**: the remaining nine.

- **Techniques**: ANN, SVR and RF.
- **Hyper-parameters**: Grid Search.
- **Validation**: 10-Folds Cross Validation.
- **Metrics**: MAE, MAPE, R2 and IoA.

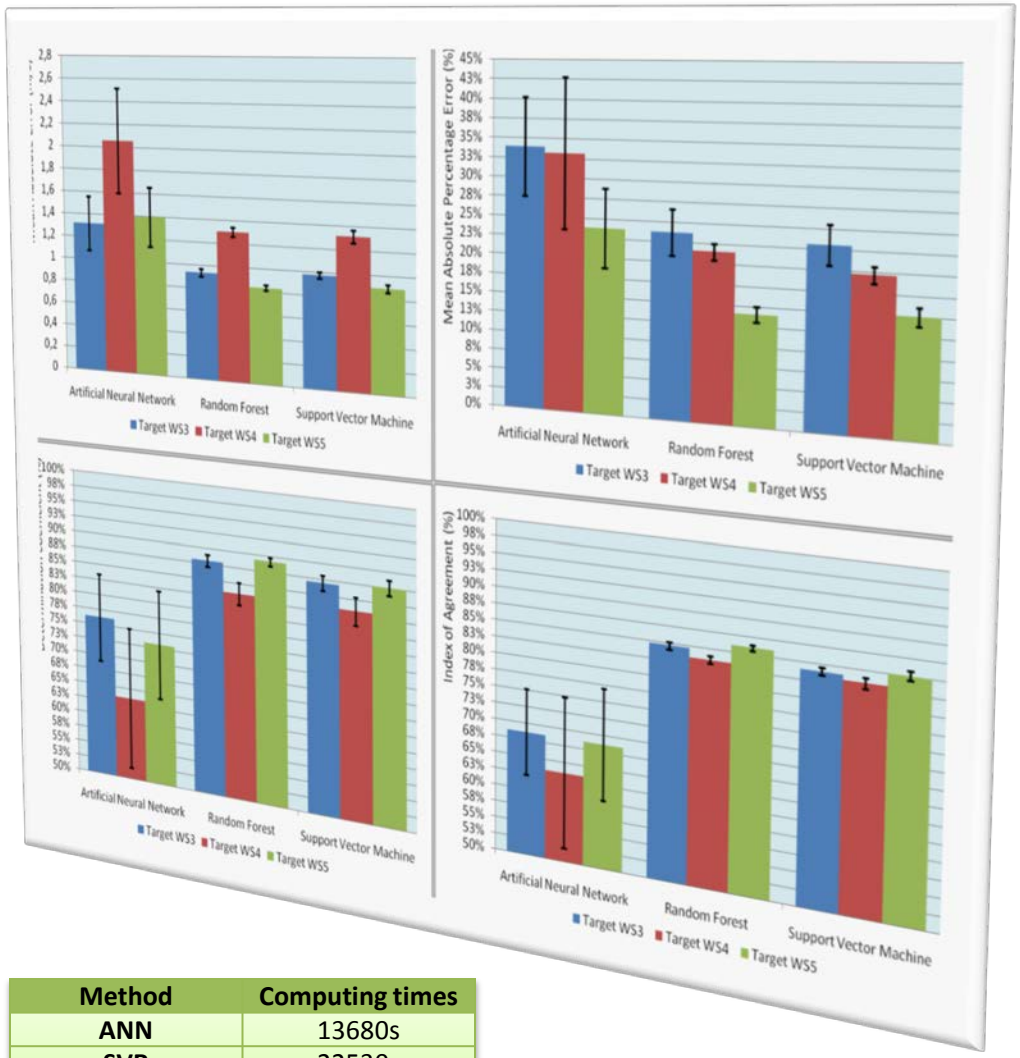
- **Technologies**: R Statistics.
- **Packages**:
  - **ANN**: nnet R package.
  - **SVR**: Kernlab R package.
  - **RF**: randomForest R package.

- All simulations done with the same computer to evaluate the time requirements.

Results and discussion

7th International Congress
Energy and Environment Engineering and Management

TARGET SITE WS-3					
Method	**Variable**	**MAE**	**MAPE**	**R2**	**IoA**
ANN	**Mean**	1.31	33.87%	76.22%	68.68%
	Standard Desv.	0.24	6.32%	7.20%	6.48%
RF	**Mean**	**0.93**	23.70%	**88.03%**	**84.66%**
	Standard Desv.	0.03	2.94%	0.97%	0.55%
SVR	**Mean**	0.97	**23.06%**	87.00%	84.04%
	Standard Desv.	0.03	2.51%	1.16%	0.50%
TARGET SITE WS-4					
Method	**Variable**	**MAE**	**MAPE**	**R2**	**IoA**
ANN	**Mean**	2.05	33.12%	64.75%	63.43%
	Standard Desv.	0.46	9.62%	11.63%	11.39%
RF	**Mean**	**1.30**	21.51%	**79.53%**	**83.41%**
	Standard Desv.	0.04	0.98%	1.77%	0.54%
SVR	**Mean**	1.31	**19.71%**	77.41%	83.24%
	Standard Desv.	0.05	1.04%	2.24%	0.74%
TARGET SITE WS-5					
Method	**Variable**	**MAE**	**MAPE**	**R2**	**IoA**
ANN	**Mean**	1.39	23.80%	73.11%	68.61%
	Standard Desv.	0.26	5.08%	8.88%	8.33%
RF	**Mean**	**0.84**	**14.05%**	**89.20%**	**86.02%**
	Standard Desv.	0.02	0.94%	0.68%	0.42%
SVR	**Mean**	0.89	14.98%	87.57%	85.09%
	Standard Desv.	0.03	1.15%	1.19%	0.66%



Method	Computing times
ANN	13680s
SVR	22530s
RF	**15120s**

ENERMAC
Energías Renovables y Eficiencia Energética
Desarrollo Sostenible de África Occidental e Islas de la Macaronesia

Conclusions

Although the trend nowadays is towards using ANNs in implementation of MCP methodology, **there are some alternatives that display greater precision and efficiency**.

Random Forest gave the best results for all target sites when measuring the performance with the MAE, R^2 and IoA metrics. With MAPE metric it is unclear which is the best alternative (SVR or RF techniques).

SVR and RF techniques allow direct resolution of high dimensionality problems in a more efficient way than the ANN technique, but require a greater effort to optimize its hyper-parameters

The computing times required for the RF method were around 35% lower than those required by its main competitor, the SVR technique.

7th International Congress

Energy and Environment Engineering and Management

Thank you

For your Attention!

Santiago Díaz Ruano
santiago.diaz103@alu.ulpgc.es
sdruano@itccanarias.org

UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA

itc INSTITUTO TECNOLÓGICO DE CANARIAS

Gobierno de Canarias

ENERMAC
Energías Renovables y Eficiencia Energética
Desarrollo Sostenible de África Occidental e Islas de la Macaronesia

MAC 2014-2020
Cooperación Territorial

Interreg