7th International Congress

Energy and Environment Engineering and Management

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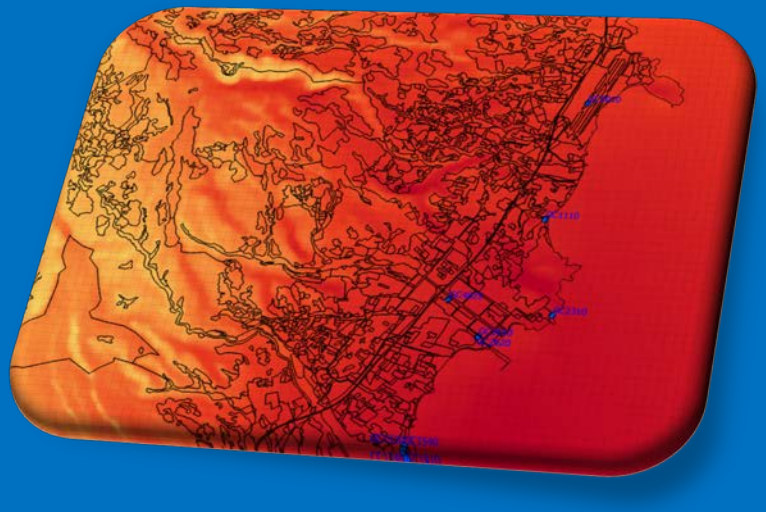

Adjustment of wind maps through data recovered in weather stations Case study: Canary Islands

Topic – 2.3 Renewable energies: Potential of wind energy

Authors:

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Gobierno de Canarias

UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA

This research work has been co-funded by FEDER funds INTERREG MAC 2014 – 2020 programme within The ENERMAC project and the Canary Island Government.

Introduction

OBJECTIVES:

- Improvement of the wind resource estimations and mathematical models included in the Wind Atlas of the Canary Islands.
- Test Mesoscale Atmospheric Simulation System (MASS) models and Numerical Weather Prediction system (NWP) to create high resolution maps for the Canary Islands.
- Check original and adjusted maps accuracy by calculating wind farms production.

This work has been developed in the Renewable Energy Department of the Canary Islands Institute of Technology in the framework of the project *"**Revisión de la cartografía eólica de Canarias, 2016**"*; project financed and supervised by the Canary Islands Energy Directorate.

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This research line has now been included within the **ENERMAC** project, co-funded by FEDER funds INTERREG MAC 2014 – 2020 program.

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

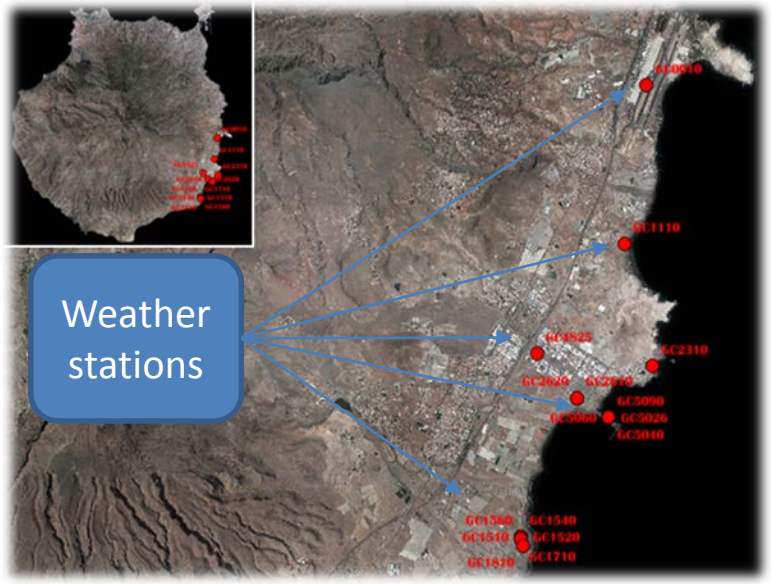
MAC 2014-2020 Cooperación Territorial

Interreg
Fondo Europeo de Desarrollo Regional
EUROPEAN UNION

Methodology

Canary Islands

Total weather stations evaluated: 157
Time series: 1999/2015
Met mast height: 10 - 90 m.



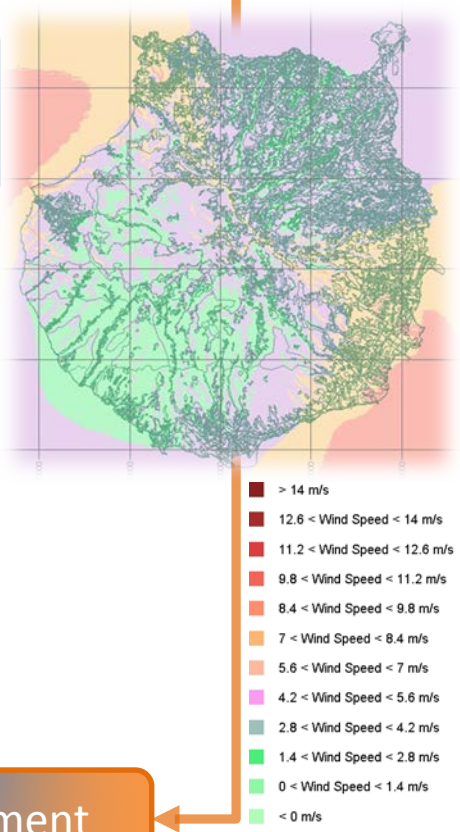
Weather stations

Quality Assessment
- Range test
- Test for trends
- Related parameter test
- Test of periods

Filling process
- Identification of data series affected
- Identification of reference stations

MCP process
- Correlation study
- ANN simulation
- Lon-term prediction

Original wind maps



Met. Mast Adjustment

Adjusted wind maps

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Data quality assessment & filtering

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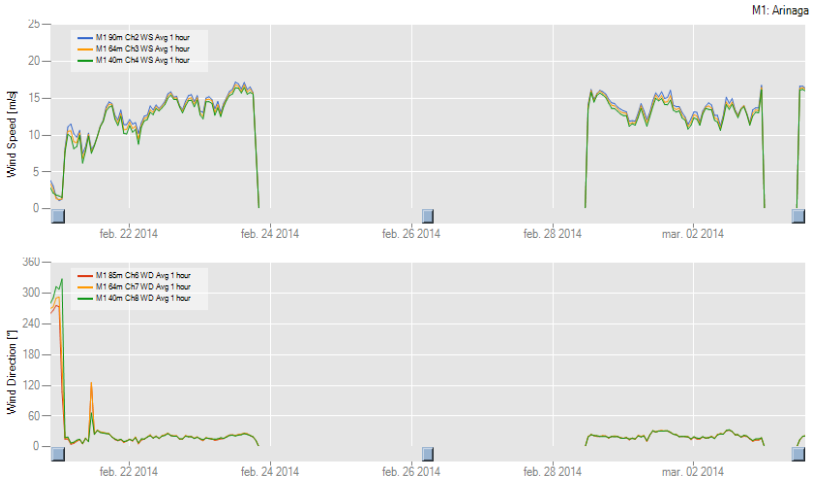
Visual and completeness checking:



Test for trends and inconsistencies:

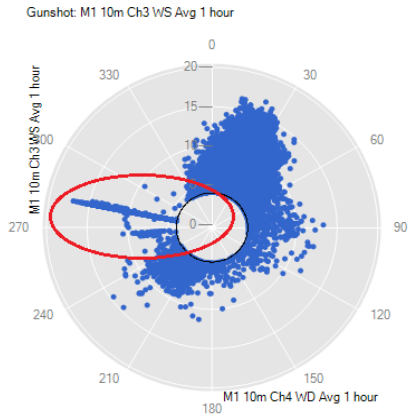
	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	Hora	Minuto	10m SE	10m NW	20m SE	20m NW	40m SE	40m NW	60m	Veleta		Test tendencias						
17831	14	0	12,1	12,1	14,1	13,6	16,1	15,8	15,8	23,7		No	No	No	No	No	No	No
17832	15	0	10,6	10,9	12,7	12,4	14,8	14,5	14,3	21,7		No	No	No	No	No	No	No
17833	16	0	11,5	11,7	13,4	13,1	14,5	14,4	14	31,7		No	No	No	No	No	No	No
17834	17	0	10	10,4	12	11,7	13,6	13,7	13,2	30,4		No	No	No	No	No	No	No
17835	18	0	9,7	10,3	11,8	11,4	15,2	16,7	13,5	17,9		No	No	No	No	No	Si	No
17836	19	0	10	10,6	12,1	11,7	17,1	22,1	14,1	11,8		No	No	No	No	Si	No	No
17837	20	0	9,6	10,2	11,6	11,3	10,1	21,2	13,5	191,6		No	No	No	No	No	No	No
17838	21	0	6,8	8,1	9	8,9	6,4	18,2	10,9	174,2		No	No	No	No	Si	Si	No
17839	22	0	9,4	10,1	11,9	11,4	15,9	23,2	14,4	66,1		No	No	No	No	No	No	No
17840	23	0	7,8	9	10,2	10,1	12,1	18,3	11,9	18,4		No	No	No	No	No	Si	No
17841	0	0	12,5	12,4	14,8	14,2	16,4	24	16,1	28		No	No	No	No	No	No	No
17842	1	0	8,8	9,7	11	10,8	13,5	20,4	12,8	22,8		No	No	No	No	No	No	No
17843	2	0	8,1	9,1	10,4	10,3	12,8	19,7	12,3	23,9		No	No	No	No	No	No	No
17844	3	0	10,1	10,6	12,1	11,8	16,4	24,1	14,4	19,2		No	No	No	No	No	No	No
17845	4	0	11,6	11,8	13,5	13,1	18,4	27,2	16,1	16,7		No	No	No	No	No	No	No
17846	5	0	13,2	12,8	15,1	14,5	20,8	31,1	17,9	11,7		No	No	No	No	No	No	No
17847	6	0	12	11,9	13,9	13,2	19	29,2	16,1	13,3		No	No	No	No	No	No	No
17848	7	0	11,5	11,8	13,5	13	17,9	27,1	15,6	21,4		No	No	No	No	No	No	No
17849	8	0	12,4	12,3	14,5	14,1	18,8	26,4	16,3	25,9		No	No	No	No	No	No	No
17850	9	0	11,4	11,4	13,3	12,9	17,7	24,7	14,9	26,5		No	No	No	No	No	No	No
17851	10	0	10,4	10,8	12,5	12,2	16,9	22,3	14,3	24,3		No	No	No	No	No	No	No
17852	11	0	12,4	12,4	14,4	13,9	19,4	25,3	16,5	21,9		No	No	No	No	No	No	No

Related parameter test:

Test relacional

Velocidades máximas		26	40	60	90					
	GC50	22,362	23,076	23,352	23,493					
		10 SE	10 NW	20 SE	20 NW	40 SE	40 NW	60		
	GC15	18,723	18,412	21,910	20,875	26,683	32,387	24,642	Consigna	<30
Desviación de la direccion		26	40	60	90					
	GC50	82,592	78,377	73,232	71,483					
		10 SE	10 NW	20 SE	20 NW	40 SE	40 NW	60		
	GC15	72,9							Consigna	3 - 75º
Diferencias a la misma altura		10 SE	10 NW	20 SE	20 NW	40 SE	40 NW			
V medias	GC15	0,828		0,143		1,794			Consigna	<0.5
Diferencias a la misma altura		10 SE	10 NW	20 SE	20 NW	40 SE	40 NW			
V max	GC15	0,312		1,035		5,704			Consigna	<3
Diferencias entre alturas 60/40		Pozo 60	Pozo 40	Arin 60	Arin 40	Pozo 60	Ari 40	Ari 60	Pozo 40	
V medias	GC15	-0,072		0,277		0,705		-0,501	Consigna	<3

Constant value test:



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Data filling – MCP process

CONDITIONS:

- Gaps in data series between 1 and 3 months
- Possible when reference stations with data in the same period are available

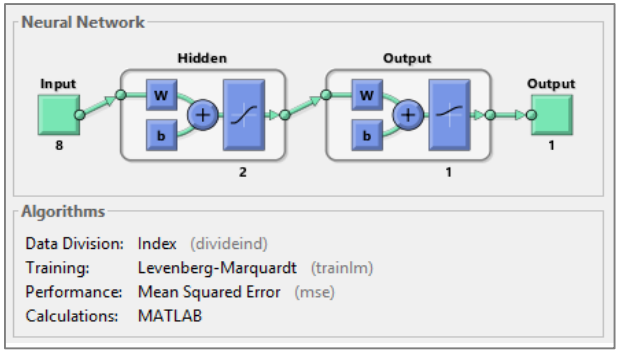
STEPS:

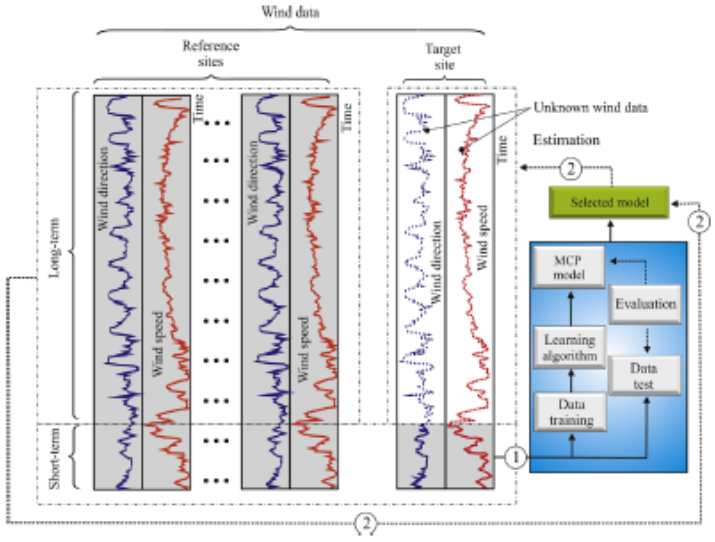
1. Selection of reference stations

2. Correlation test

ESTUDIO DE CORRELACIONES PARA PRUEBAS DE RELLENADO DE DATOS							
Estaciones	Pozo Izq. 3 10 m	Pozo Izq. 3 20 m	Muelle Viejo	Dep. Sureste 10	Dep. Sureste 20	AGA	Aeropuerto
Pozo Izq. 3 10 m	100.0%	99.7%	70.1%	90.5%	90.4%	89.8%	83.8%
Pozo Izq. 3 20 m	99.7%	100.0%	69.9%	90.5%	90.5%	90.4%	83.9%
Muelle Viejo	70.1%	69.9%	100.0%	69.4%	68.5%	66.5%	67.6%
Dep. Sureste 10	90.5%	90.5%	69.4%	100.0%	99.5%	96.3%	92.2%
Dep. Sureste 20	90.4%	90.5%	68.5%	99.5%	100.0%	96.4%	92.1%
AGA	89.8%	90.4%	66.5%	96.3%	96.4%	100.0%	90.9%
Aeropuerto	83.8%	83.9%	67.6%	92.2%	92.1%	90.9%	100.0%

3. Artificial Neural Net simulation (ANN)





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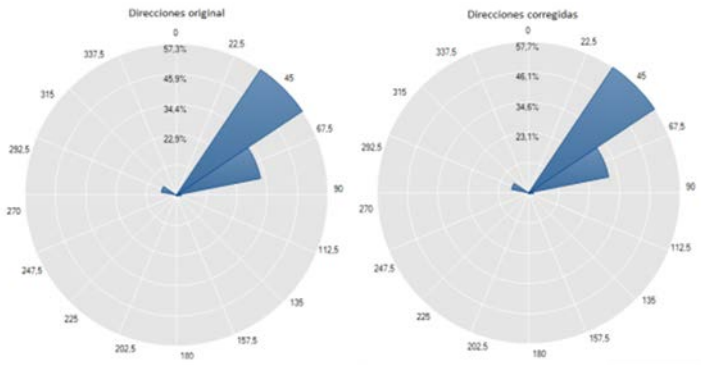
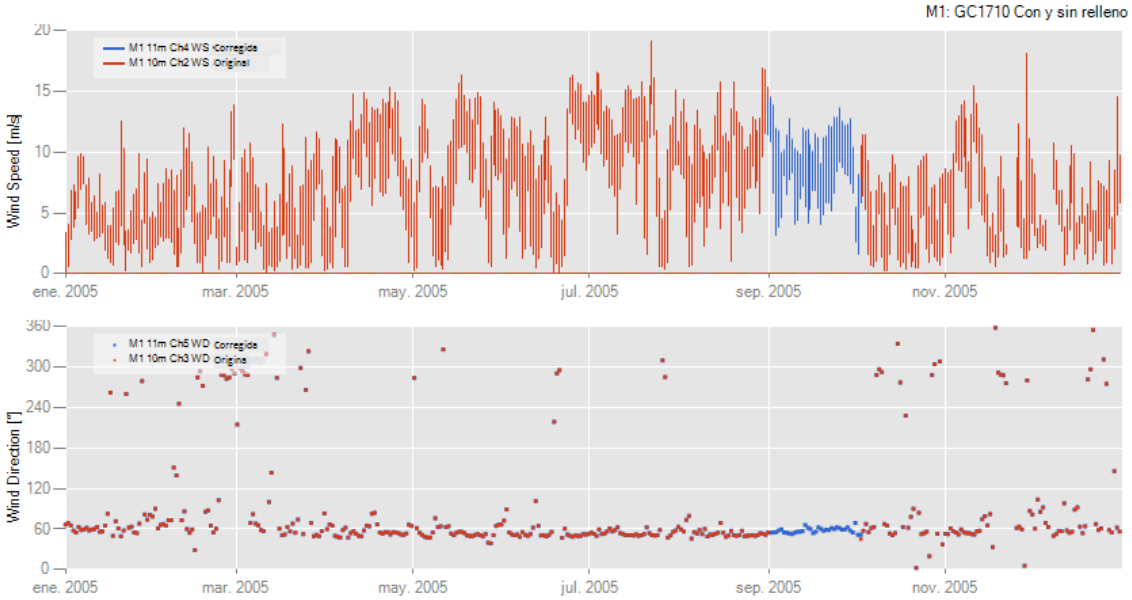
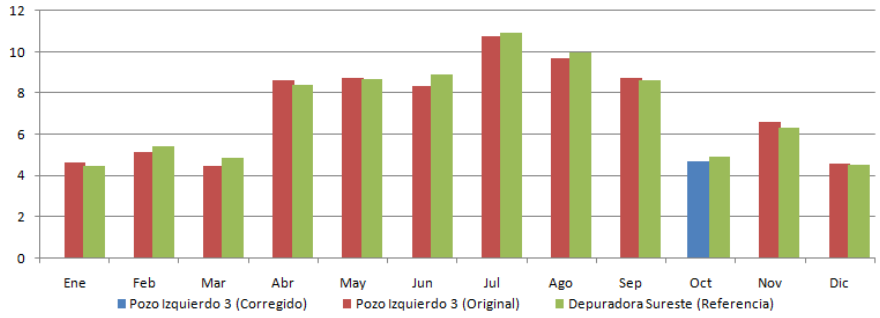
Data filling – MCP process

4. Checking of results:

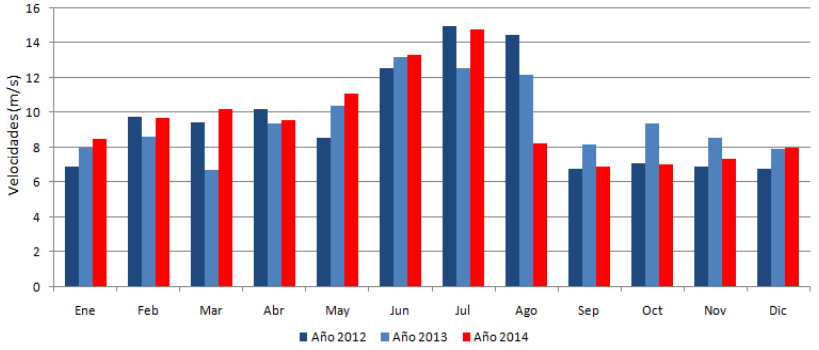




Annual analysis: compare results between reference and objective station



Long-term analysis: capture variations not registered in short term analysis



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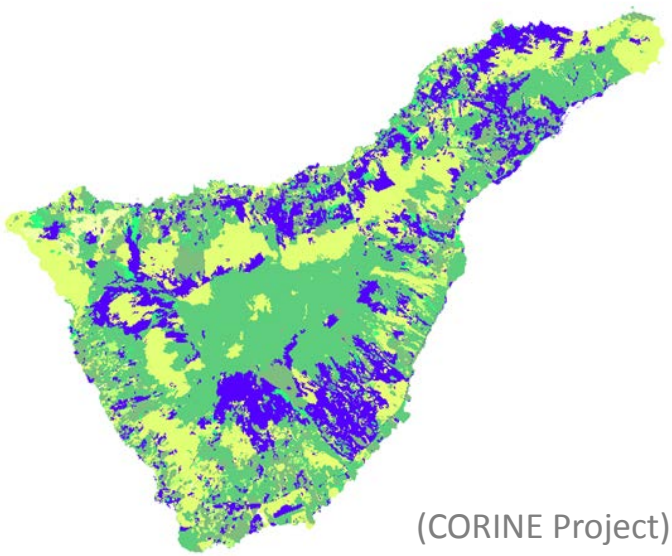
Maps adjustment requirements

- Filtered weather stations, with long-term adjustment, and extrapolated to the heights of 40, 60, 80 and 100 meters.
- Other important aspects must be defined for the modeling: including the exact coordinates where the station is located, aspects related to average temperature and air density, number of sectors of the wind rose and obstacles in the vicinity.
- Different maps are also used in the process:

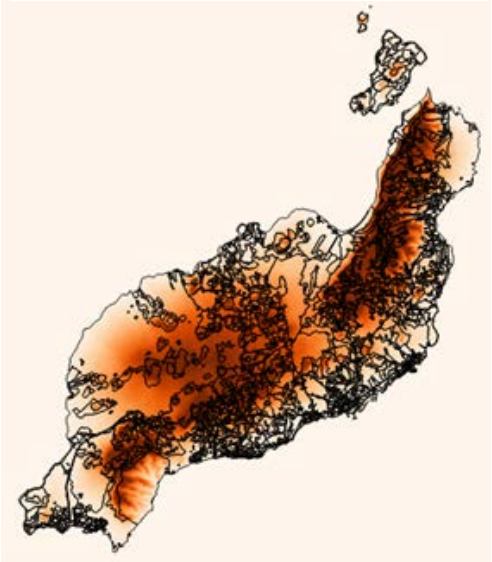
Roughness



(CORINE Project)

Roughness length data coming from "SIOSE" database of uses of the terrain

Elevation



Wind speed

Heights:
40, 60, 80 & 100 m.

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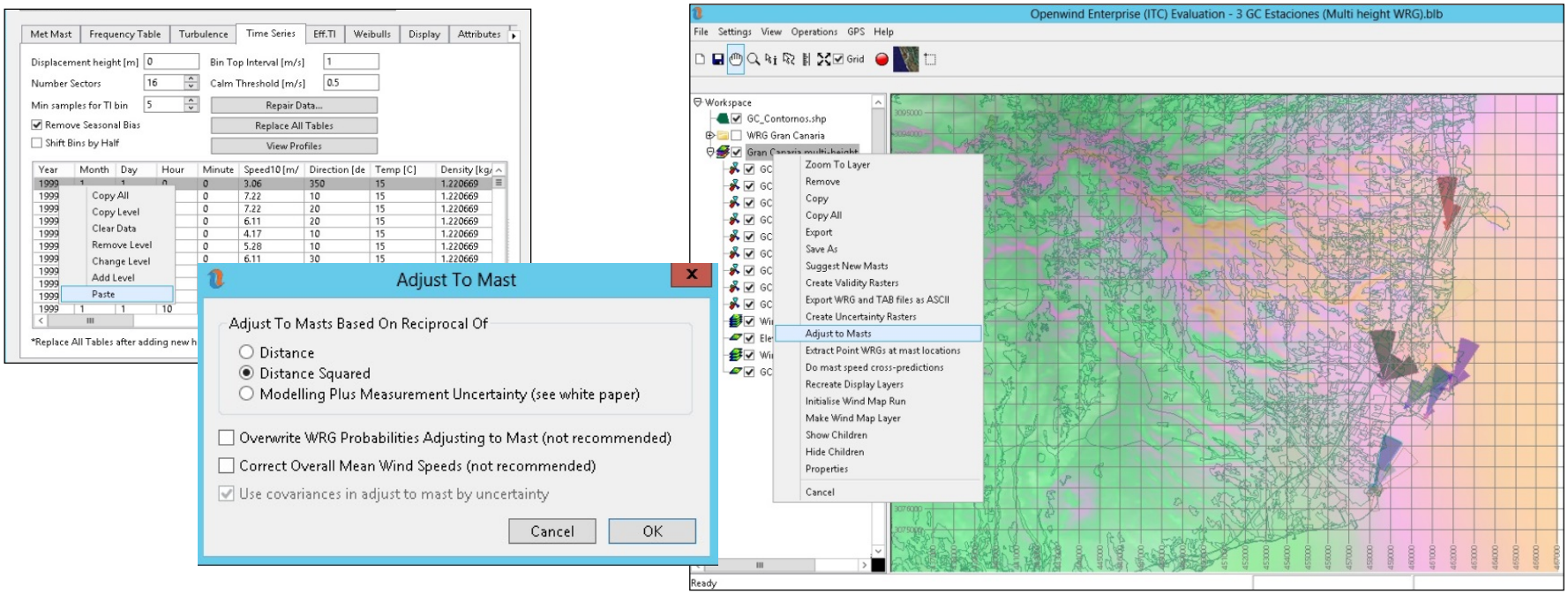
Maps adjustment

- MCP process is done with selected weather stations (2 heights required)
- Long-term data from the weather stations are introduced in OpenWind[1] software to execute the process of “Adjunts To Mast”, obtaining new maps:



Adjustment method:

Distance Squared: as the coordinate increase the distance to the met mast, the wind speed value is more approximated to the original wind map value.

[1] Openwind® Enterprise: wind project design and optimization software application, using geographical information systems (GIS) interface

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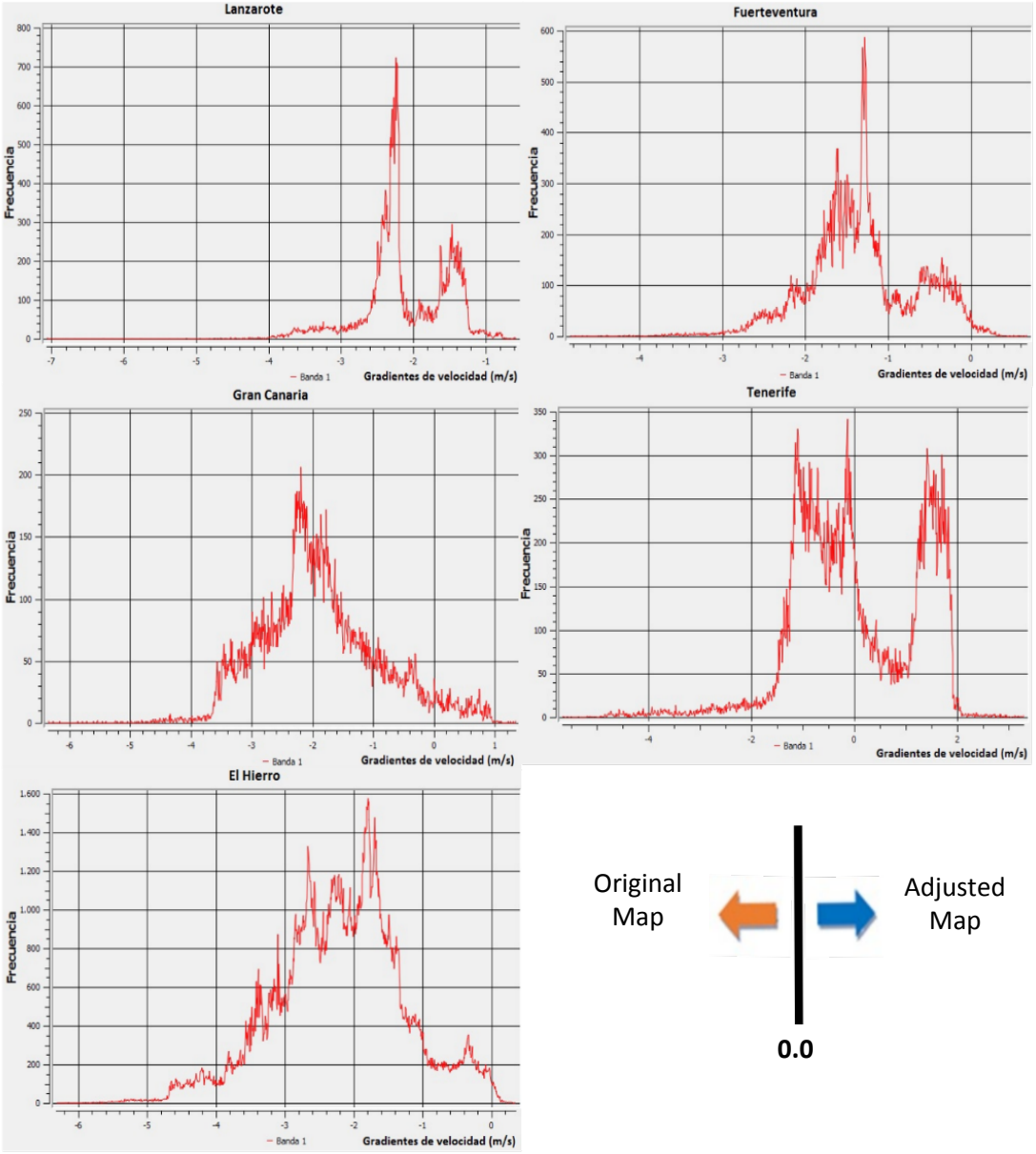
Comparison of wind maps. Results & conclusions



In these graphs the mean wind speed difference between the two maps is represented on the *X axis*:

- **Negative** values represent higher mean wind speed in the adjusted maps with respect to the original
- **Positive** values represent lower mean wind speed in the adjusted maps with respect to the original

On the *Y axis* the frequency with which a given difference has occurred is represented

CONCLUSION:

Adjusted wind maps produces a general increase in mean wind speed with reference to the original maps

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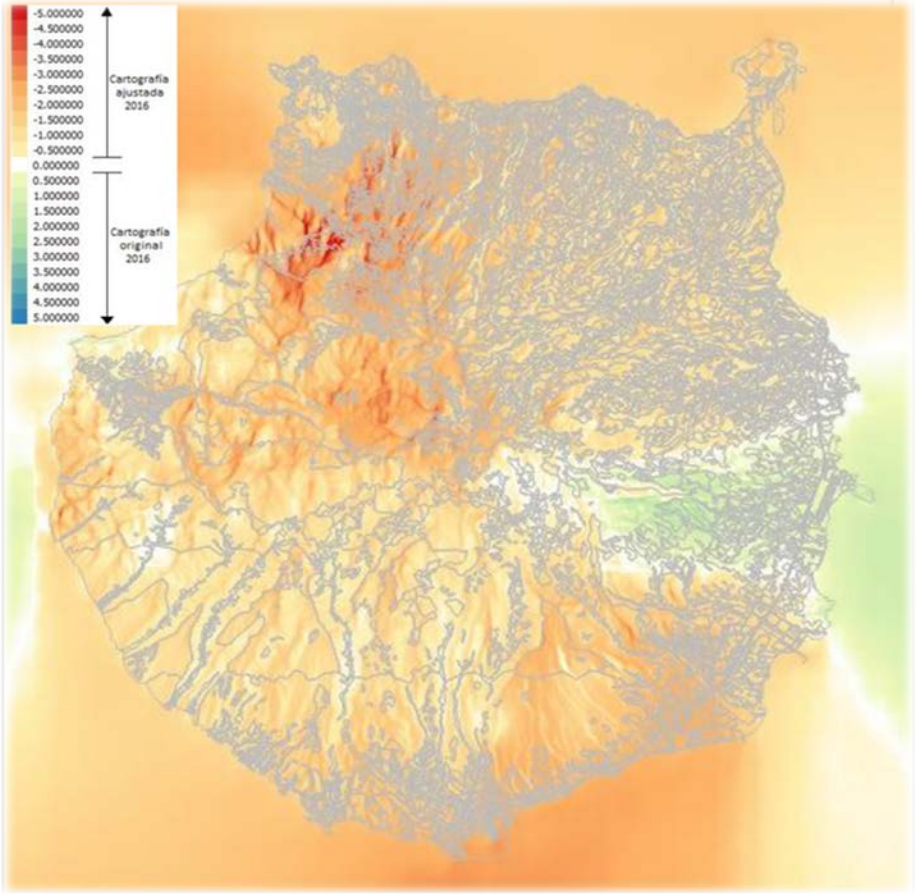
Comparison of wind maps. Results & conclusions

- Warm tones (**yellow - red**): regions where the mean wind speed is higher in adjusted maps than in original maps.
- Cold tones (**green - blue**): regions where the mean wind speed is smaller in adjusted maps than in original maps.
- **White** tone: regions where both wind maps have the same mean wind speed value.



CONCLUSIONS:

- The mean wind speed in areas near the weather stations is lower in the adjusted maps compared to the original maps.
- The analysis shows that the adjusted version of the wind maps tends to reduce the wind potential estimation in the east zones (where wind potential is higher) with reference to the original version of the maps.
- Higher wind potential in the West slope of all the adjusted islands may be due to the lack of reference stations for adjustment in the western slopes, which, together with the more complex terrain, make it impossible to make acceptable adjustments in these areas.

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Results. Wind farm production

Original and adjusted maps accuracy has been checked by calculating wind farm production where data of farms are available.

The table shows a sample of the results obtained in the comparison between the wind farm production results calculated with the adjusted maps and the original versions:

WIND FARM ENERGY PRODUCTION (REAL) vs ESTIMATIONS WITH WIND MAPS

WIND FARM	Energy Production (kWh)			Absolute Errors (kWh)		Relative Errors (%)	
	Real	Original Map	Adjusted Map	Original Map	Adjusted Map	Original Map	Adjusted Map
Los Valles II	23.000.000	23.572.550	23.647.565	572.550	647.565	2%	3%
Bahía de Formas II	6.478.214	7.145.654	7.381.656	667.440	903.442	10%	14%
Bahía de Formas III	20.078.615	17.657.510	19.653.008	2.421.105	425.607	12%	2%
Bahía de Formas IV	19.850.345	17.529.844	19.722.937	2.320.501	127.408	12%	1%
ITC Enercon	1.897.859	1.813.094	1.885.955	84.765	11.904	4%	1%
Lomo cabezo	8.127.786	6.816.035	7.674.576	1.311.751	453.210	16%	6%
La Punta	22.619.913	22.319.726	23.949.911	300.187	1.329.998	1%	6%
La Gaviota	21.253.388	22.508.354	25.908.361	1.254.966	4.654.973	6%	22%
Montaña Pelada	12.024.388	12.513.589	9.891.162	489.201	2.133.226	4%	18%
La Florida	13.960.305	9.333.058	10.823.384	4.627.247	3.136.921	33%	22%
Pesban	2.992.572	2.541.604	3.130.233	450.968	137.661	15%	5%
ITER Enercon 33	940.640	1.132.308	900.662	191.668	39.978	20%	4%
Granadilla	10.126.346	12.864.963	9.986.973	2.738.617	139.373	27%	1%
ITER Enercon E40-1	1.563.553	1.569.028	1.246.223	5.475	317.330	0%	20%
ITER Enercon E40-2	1.599.458	1.586.061	1.448.996	13.397	150.462	1%	9%
Granadilla II	15.569.875	15.643.766	12.999.776	73.891	2.570.099	0%	17%
Llanos de la Esquina	14.689.700	19.333.442	12.969.743	4.634.742	1.728.957	32%	12%

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Wind farm production. Results & conclusions

CONCLUSION:

The average bias in the energy estimation obtained with the adjusted maps are lower to those obtained with the original version

STADISTICAL ANALYSIS OF THE ENERGY SIMULATIONS			
Metrics		Original Map	Adjusted Map
MAPE	Mean absolute perceptual Error	11,6%	9,5%
MAE	Mean absolute Error	1.303.439	1.112.242
RSquared	Coefficient of determination	93,8%	96,0%
IoA	Index of Agreement	88,6%	90,5%

- The studies of the wind farm production show that, although the average errors obtained with the adjusted models are lower, it cannot be concluded that these estimations represent a significant improvement with respect to their original version.
- In addition, there are doubts regarding the wind farms sample used for the evaluation, since it may not be statistically representative as all wind farms are located in regions with high wind potential.
- Another significant finding in relation to the suitability of the statistical sample used is the fact that it was only possible to assess the reliability of the estimation for three of the five islands where adjustment procedures could be applied.

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General conclusions

- The Canary Islands Wind Resource Map is a tool that allows initial assessment for wind projects. With this tool, promoters can make prospection of sites for the installation of wind farms, but it is outside the scope of the application the micrositing study of a specific project.
- With the objective of maximizing the reliability of the estimations in the actual Wind Map, a validation procedure to adjust the wind maps with weather stations, widely applied in the wind industry, was carried out. However, the study confirmed the lack of certified weather stations to ensure the reduction of uncertainty at levels lower than those obtained with the original wind maps.
- Although a reduction of relative and absolute errors is achieved with the tests performed, the differences are not considered sufficiently significant.

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Future works

- The study reveals a significant shortage of certified data from weather stations at different heights in the archipelago that complicate the use of information to make conclusions with valid scientific support.
- The adjustment of the wind maps with weather stations would only be possible if a mesh of stations with measurement at several heights and with a control of the data collection that guarantees the uncertainty of the measurement is available. In the short term, ITC intends to increase the network of measurement stations through several projects, including the ENERMAC project. Another possible source of information are the met mast associated with wind farms, but this option requires coordination and collaboration, that is not viable at this moment.
- As part of the previous work for the Canary Island Energy Directorate it was concluded that regional studies in each island should be done in order to have more accurate results.

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Thank you !

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