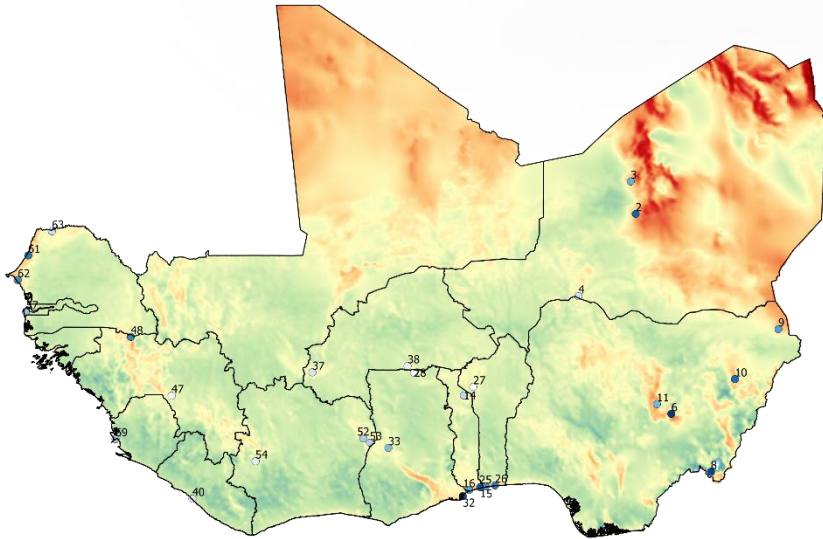


ECOWREX II



July 26, 2016 – Dakar, Senegal

Vincent Maupas - NOVELTIS



Space



Environment



Sustainable development



Technological innovation

- NOVELTIS and our contribution to ECOWREX II
- Methodology for data production
 - ▶ TMY
 - ▶ Meso-scale and micro-scale models
 - ▶ Main indicators (wind & solar)
- Results
 - ▶ Solar
 - ▶ Wind
- Conclusion

- An private company, created in **1998** based in **Toulouse, France**
- **50 employees, including 43 PdDs and engineers**
- Working in close relationship with academic research
- Business core:
 - Providing **high level Scientific and technical expertise** for space domain
 - Performing **innovative applications and services** for environmental and renewable energy domain
- Involved as a coordinator or partner in various large-scale **European and International projects**





NOVELTIS

NOVELTIS: Examples of RE projects

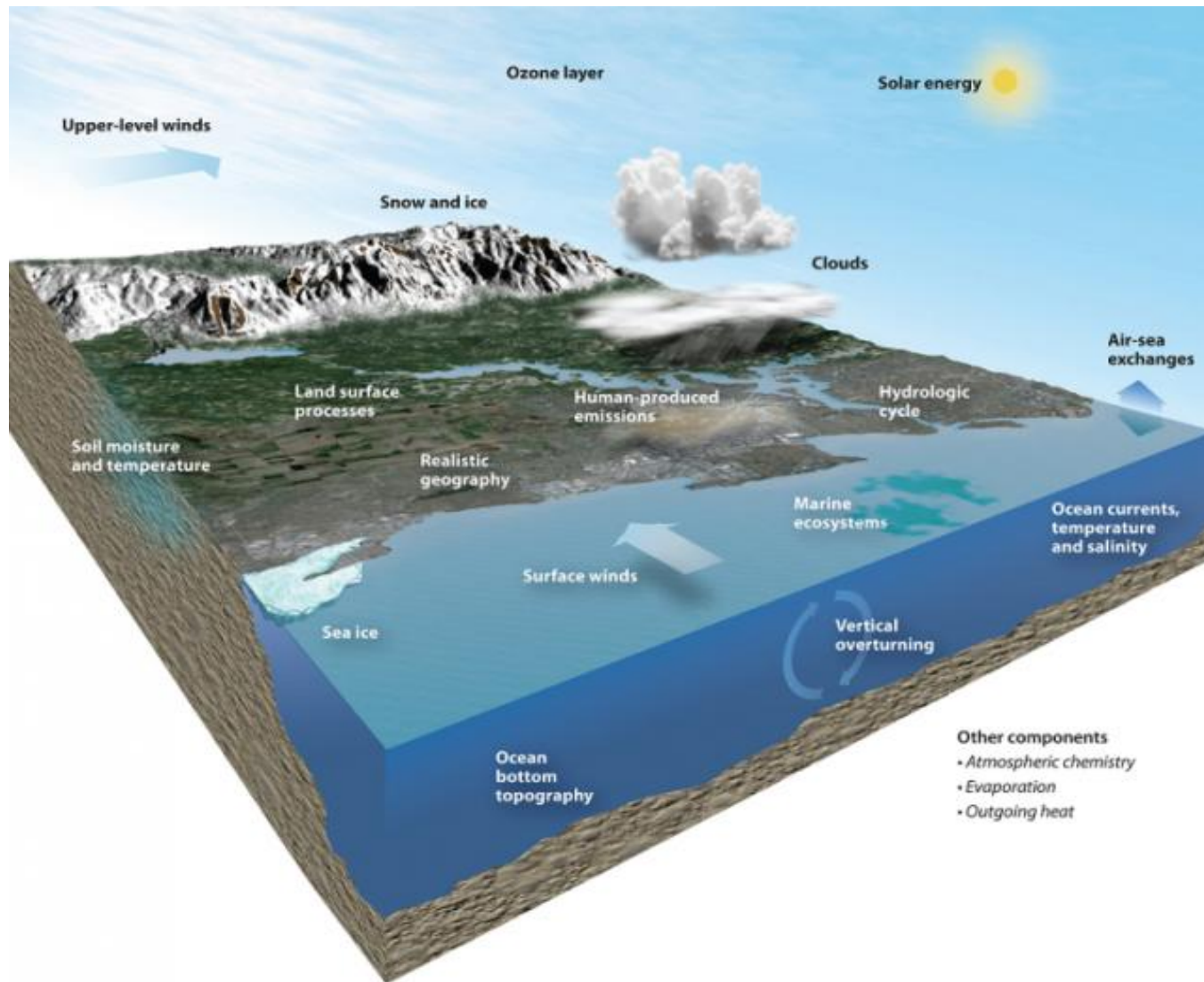
- Renewable Energy Atlas:
 - ▶ Morocco, Palestine, Tunisia, ECOWREX
- Energy potential & Yield estimation:
 - ▶ Resource Assessment
 - ▶ Spatial and temporal variations
 - ▶ Worldwide
- Services in operational mode:
 - ▶ Mid and short term forecasting
 - ▶ Solar and wind plants production forecast
 - ▶ Sea wave and current forecast



- WP 3.1 : Solar & wind Critical analysis
- WP 3.2: Solar & wind Comparative analysis
- WP 3.3/3.4:
 - ▶ Full year time series data
 - ▶ 3 Solar sites (Cape Verde, Sierra Leone)
 - ▶ 5 wind sites (Togo, Cape Verde, Gambia)
- Production of data:
 - ▶ Cape Verde, Sierra Leone, Togo, Senegal/Gambia
 - ▶ Wind maps: Wind speed, Wind power density
 - ▶ Solar maps: GHI, DNI
 - ▶ Temperature

- Two main approaches:
- **Statistical approach** is based on measurements.
 - ▶ Number of measuring stations
 - ▶ Quality of the dataset
 - ▶ Does not measure what's needed (height ...)
 - ▶ Extrapolate the data in the horizontal and vertical using either statistical or geo-statistical models.
- **Model approach** : NWP
 - ▶ Advocated by international stakeholders (ESMAP)
 - ▶ Data consistency
 - ▶ Evaluation of errors and bias

- Selection of TMY (typical meteorological year)
- Meso-scale modelisation :
 - ▶ Using WRF
 - ▶ Resolution 8x8 or 4x4 km
- Micro-scale modelisation
 - ▶ Using CALMET
 - ▶ Downscale to 200 x 200 m resolution
- Input:
 - ▶ Global weather data
 - ▶ SRTM topography data
 - ▶ USGS land cover data



- ▶ TMY is a dataset of a complete seasonal cycle (1 year) that best represents the climate for a given period.
- ▶ Climatology analysis:
 - ▶ precipitation, temperature, wind
 - ▶ 14 years: 2000 to 2013
 - ▶ 32 x 32km resolution



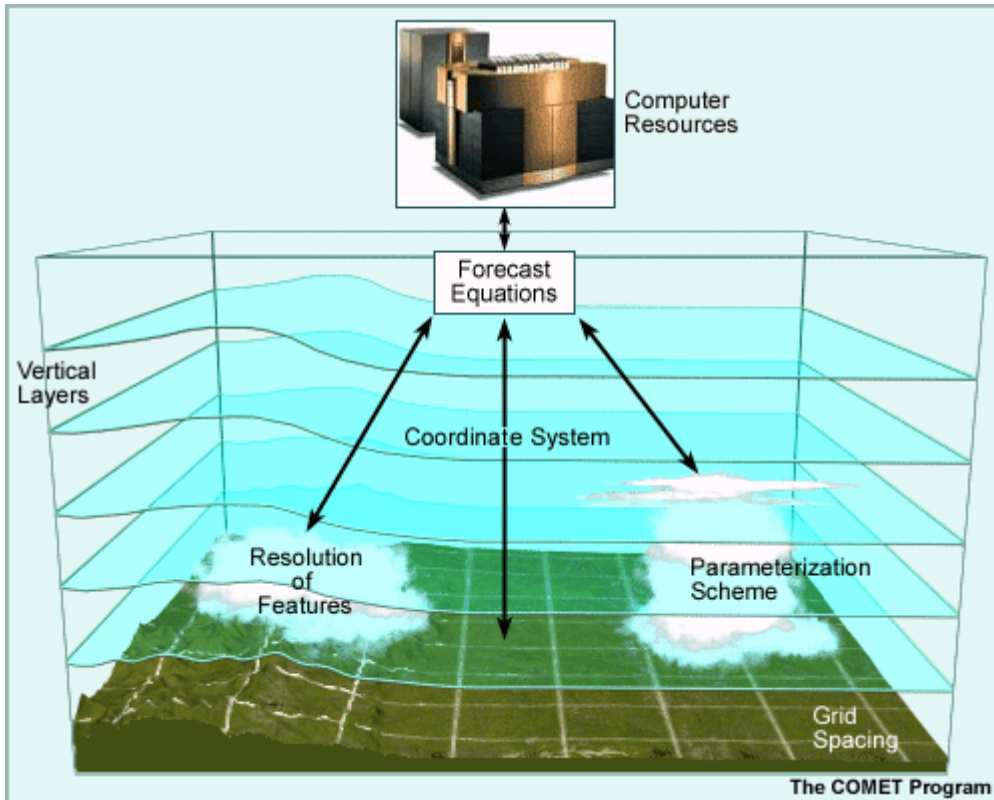
- Resolution of physic equations

- Downscaling

- ▶ 24 x 24 km
- ▶ 8 x 8 or 4 x 4 km

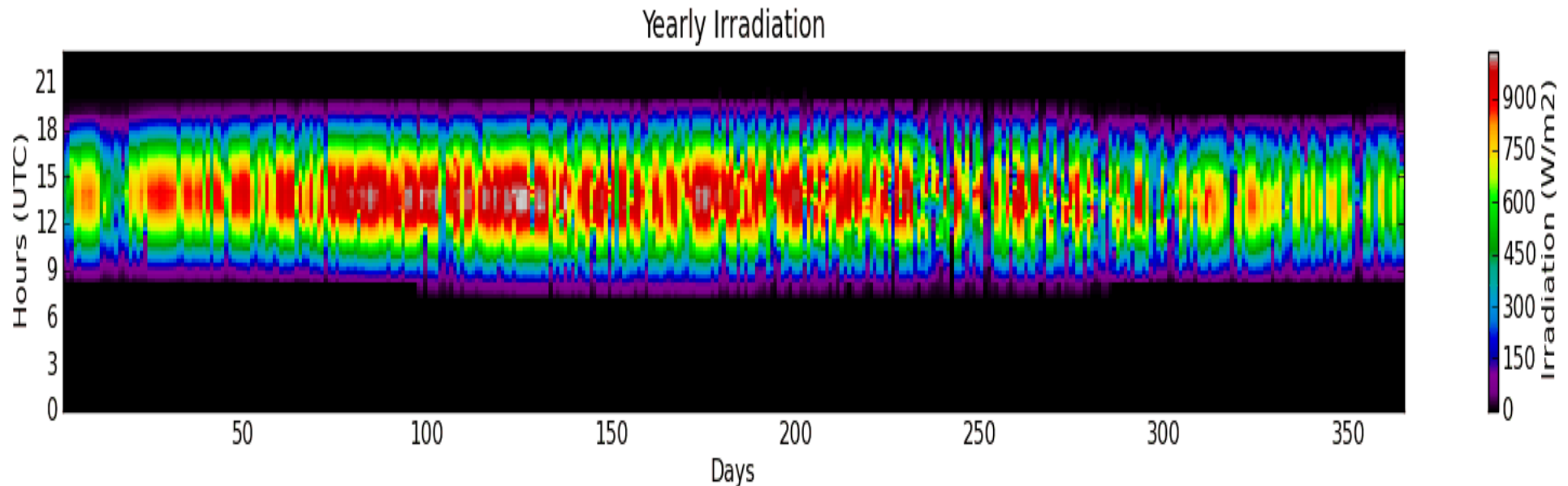
- Output:

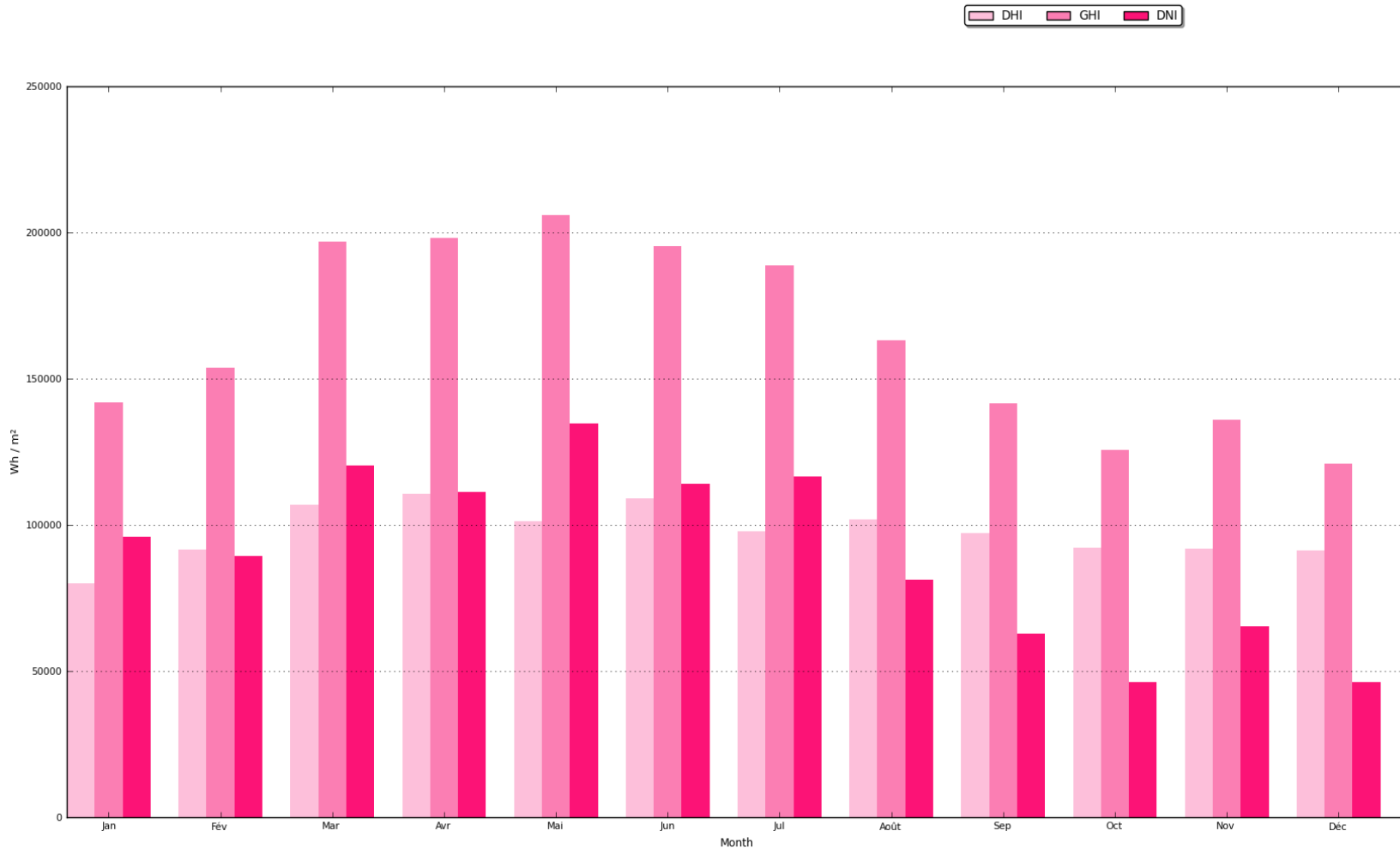
- ▶ Hourly time series (8760 steps)
- ▶ Solar irradiations
- ▶ Temperature
- ▶ Pressures
- ▶ Wind speed and direction
- ▶ Air density
- ▶ 23 vertical levels



- CALMET: Diagnostic wind model (DFW)
 - ▶ Statistical model based on 3 grid data provided by meso-scale model
- Steps:
 - ▶ Interpolation
 - ▶ Kinematic effects of terrain
 - ▶ Slope flows
 - ▶ Blocking effects
 - ▶ Smoothing
 - ▶ Divergence minimization
- Output:
 - ▶ Solar irradiations
 - ▶ Wind speed and direction
 - ▶ Air density
 - ▶ 16 vertical levels
 - ▶ Hourly time series (8760 steps)
 - ▶ Down to 200 x 200 m resolution

- Annual irradiation : GHI, DNI, DHI (kWh/m²)
- Annual AC Energy Production : AEP (MWh)
- Capacity factor (%)
- Hours of Full Capacity (hours per year)



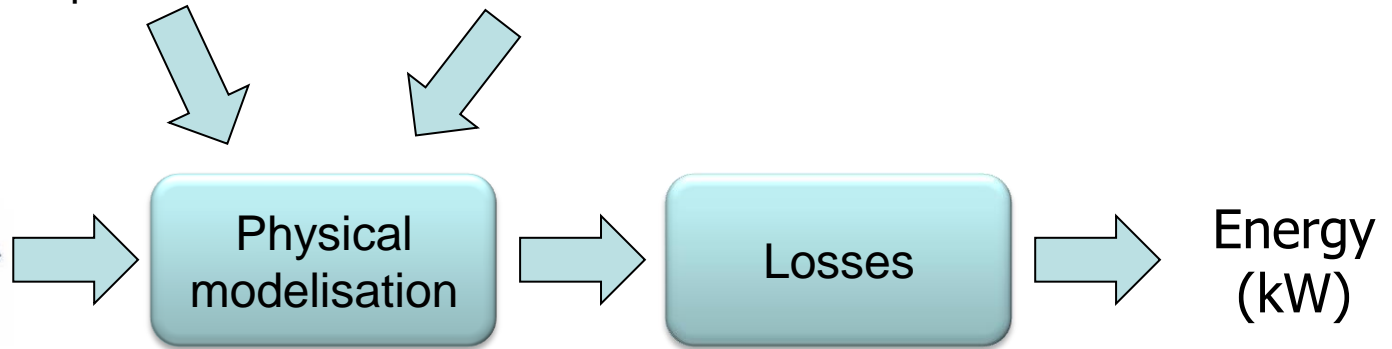
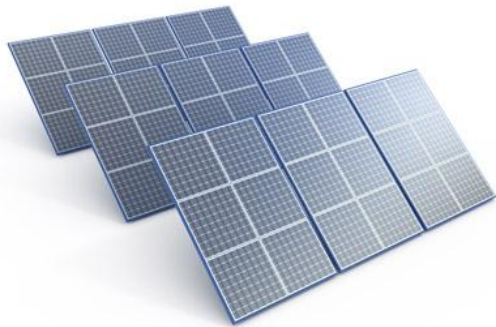


- ▶ GHI
- ▶ DNI
- ▶ DHI

- Data from model:
- ▶ GHI, DNI
 - ▶ T°
 - ▶ Wind speed



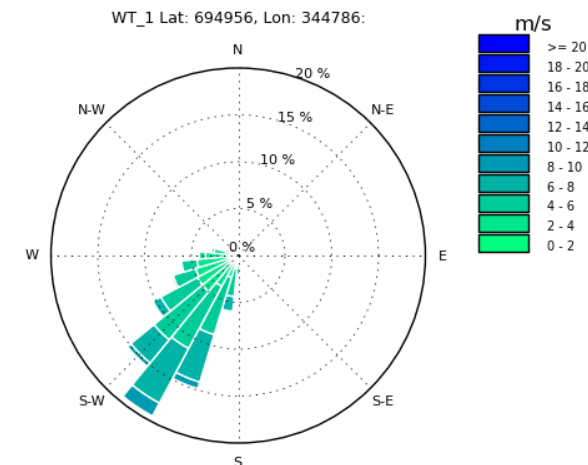
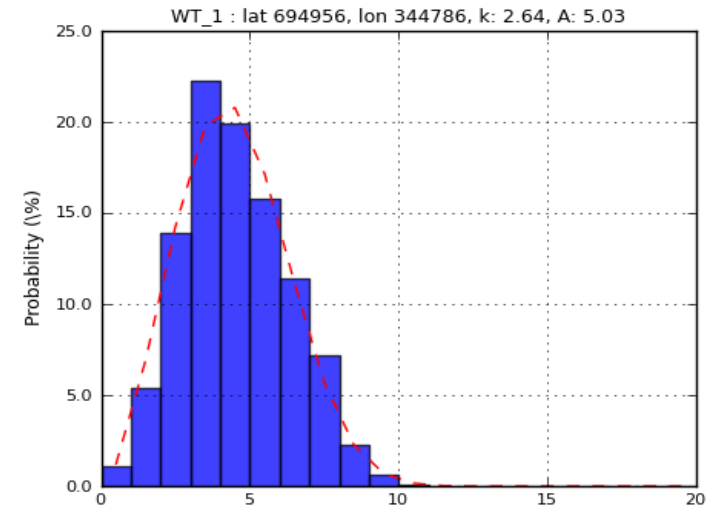
Sun path

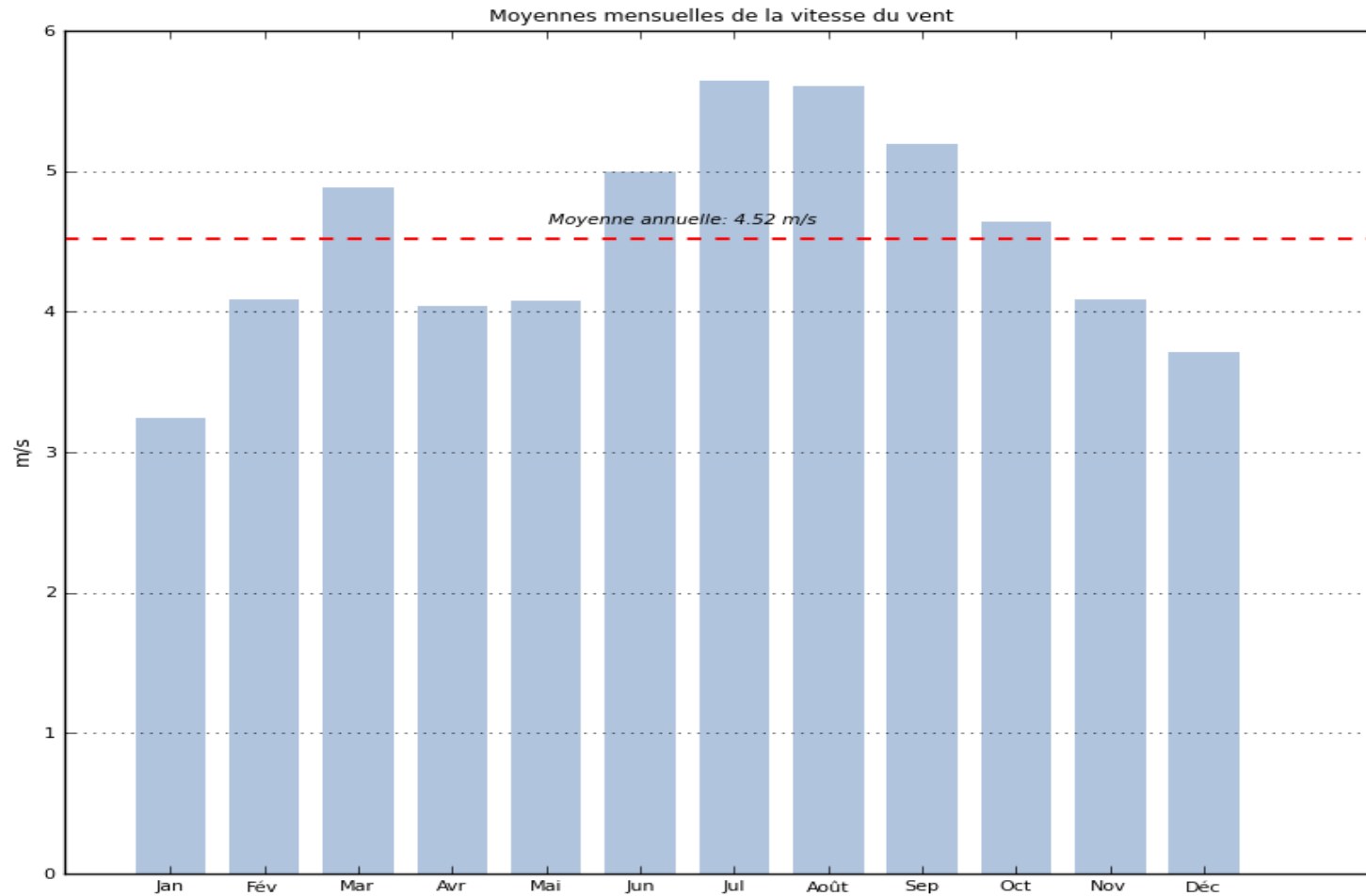


- ▶ Orientation, tilt
- ▶ Nbre, type of panels
- ▶ Layout
- ▶ Nbre, type of invertors

- ▶ Effective irradiation
- ▶ Cell response
- ▶ Temperature effect

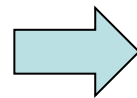
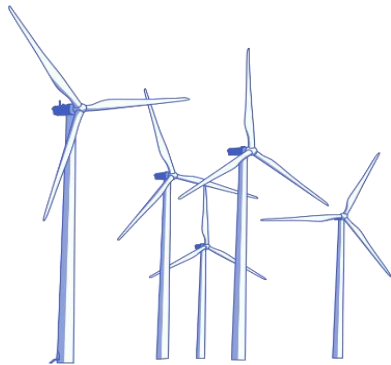
- Average wind speed (m/s)
- Average power density (W/m²)
- Prevailing wind direction
- Weibull parameters (A, k)
- Annual Energy Production (MWh)
- Capacity factor (%)



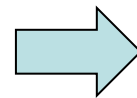


Data from model:

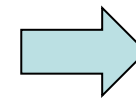
- ▶ Wind speed
- ▶ Wind direction
- ▶ Air density



Turbine modeling



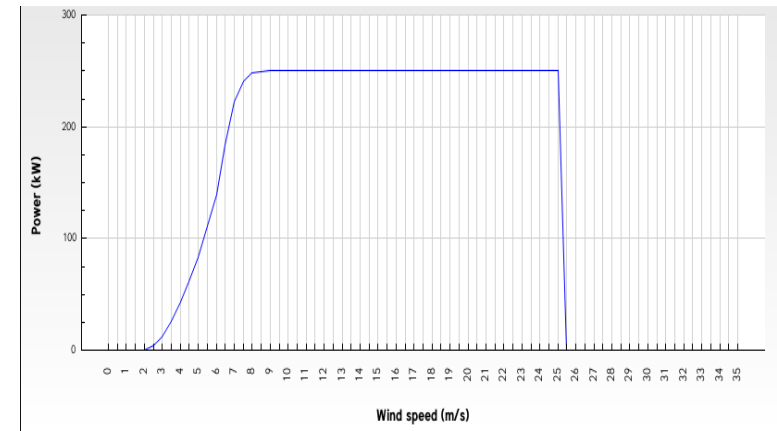
Losses



Energy (MW)

- ▶ Nbre, type of turbine
- ▶ Hub height
- ▶ Power curve

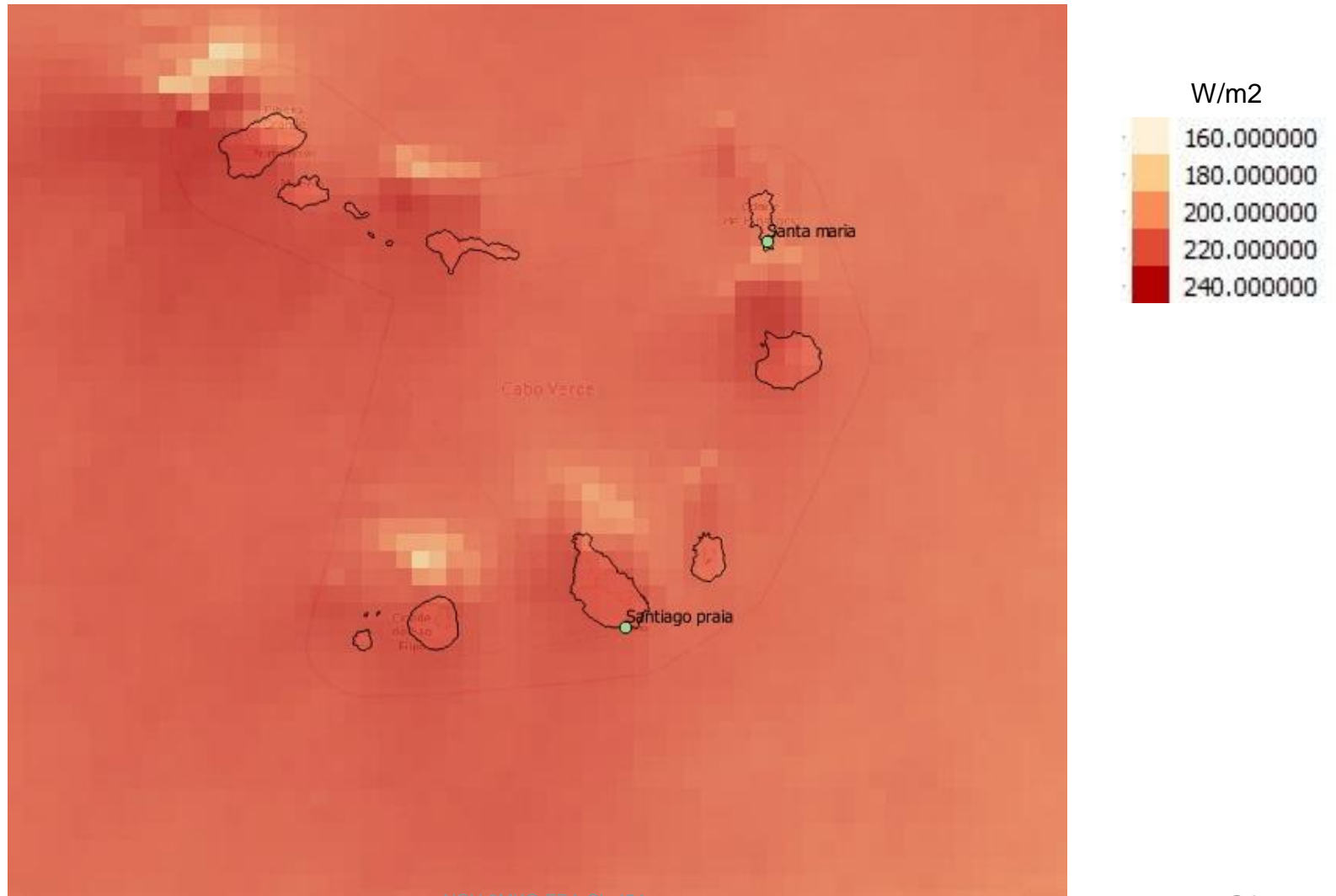
- ▶ Wind at hub height
- ▶ Apply manufacturer Power curve
- ▶ Air density correction



- Cape Verde:
 - ▶ Praia, Santiago
 - ▶ Santa Maria, Sal

- Sierra Leone:
 - ▶ Katu Town

GHI in Cape Verde

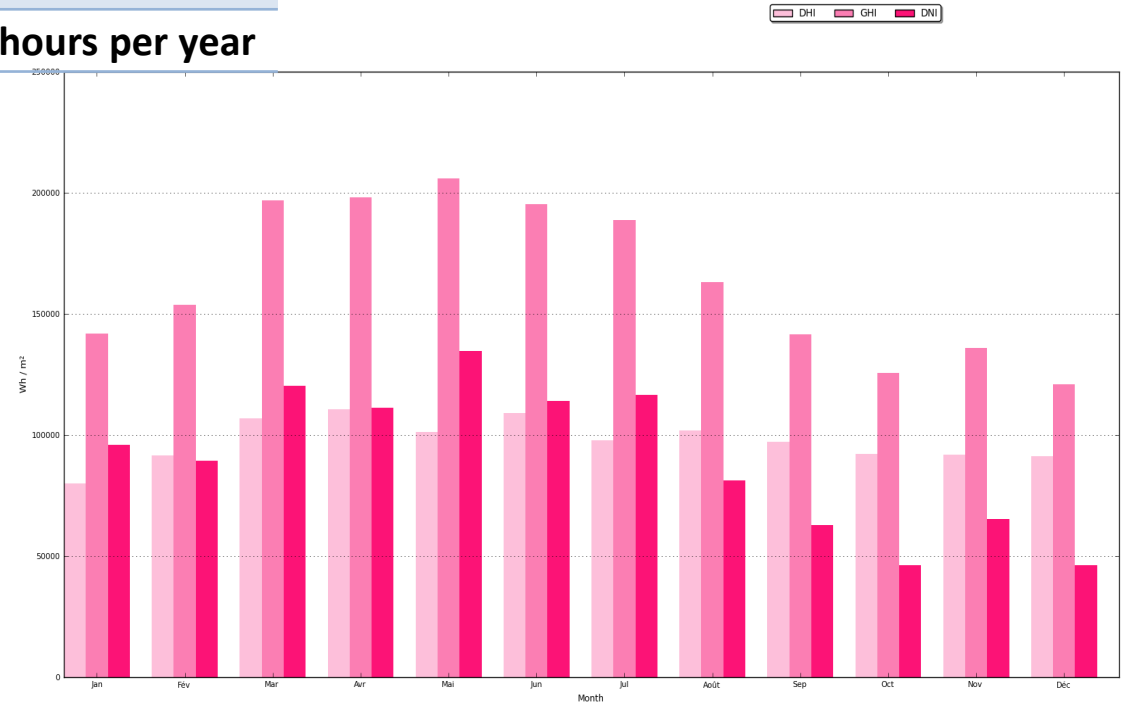






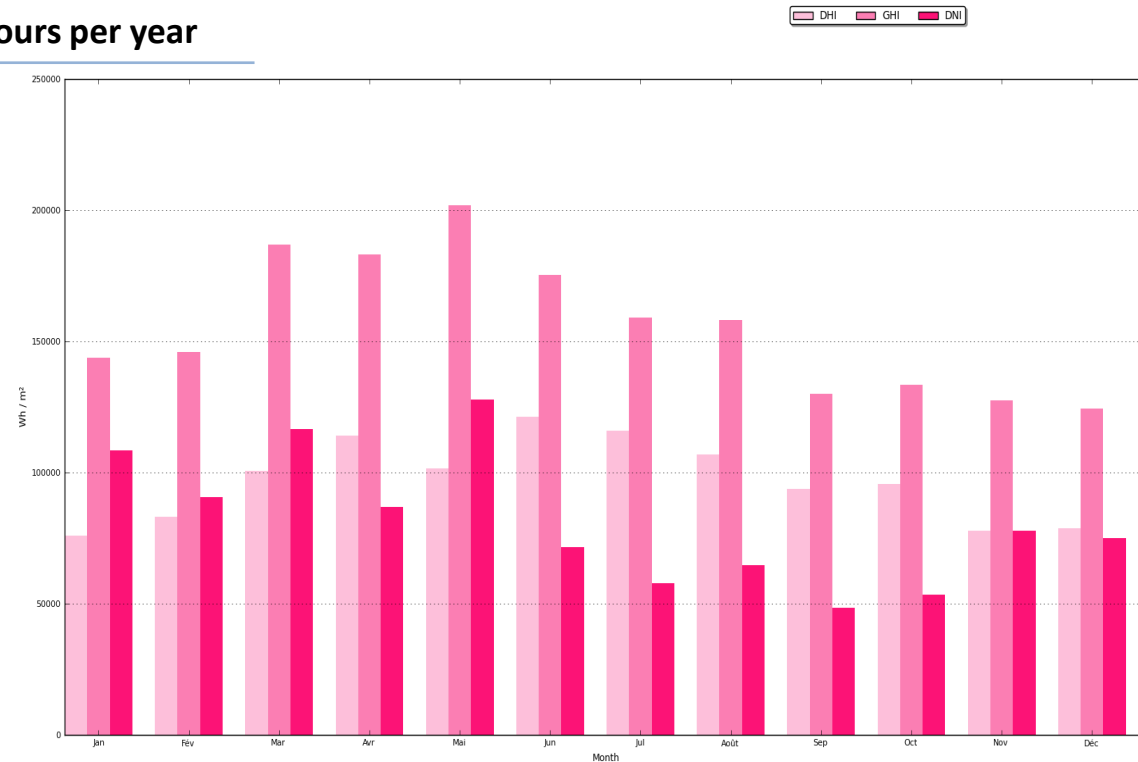
Citadela, Praia in Santiago

Annual irradiation	1968 kWh/m ²
Estimated Annual AC Energy Production	6908.89 MWh
Capacity factor	18.4 %
Hours of Full Capacity	1615 hours per year

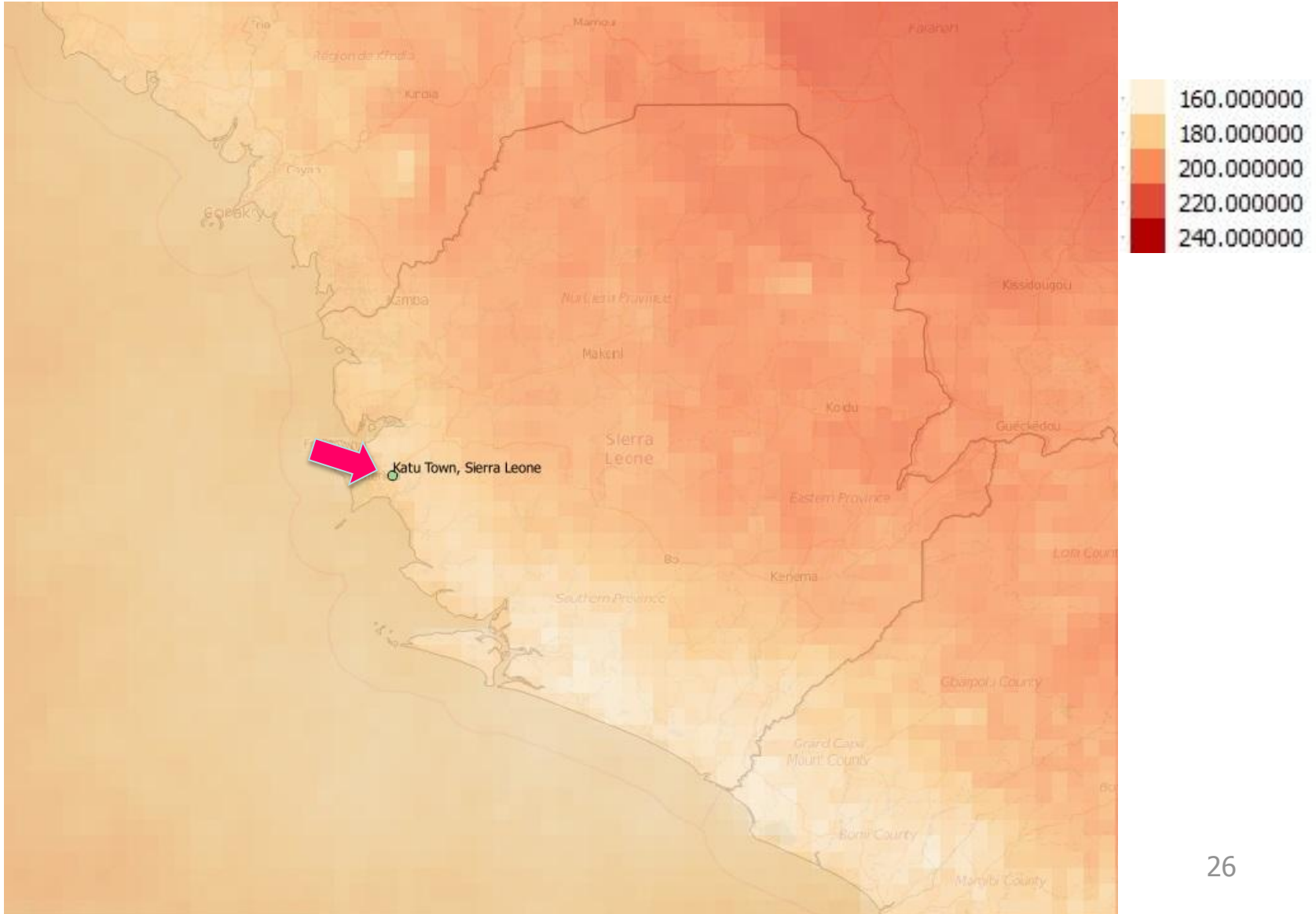


Santa Maria in Sal

Annual irradiation	1869 kWh/m ²
Estimated Annual AC Energy Production	3256.22 MWh
Capacity factor	16.8 %
Hours of Full Capacity	1474 hours per year

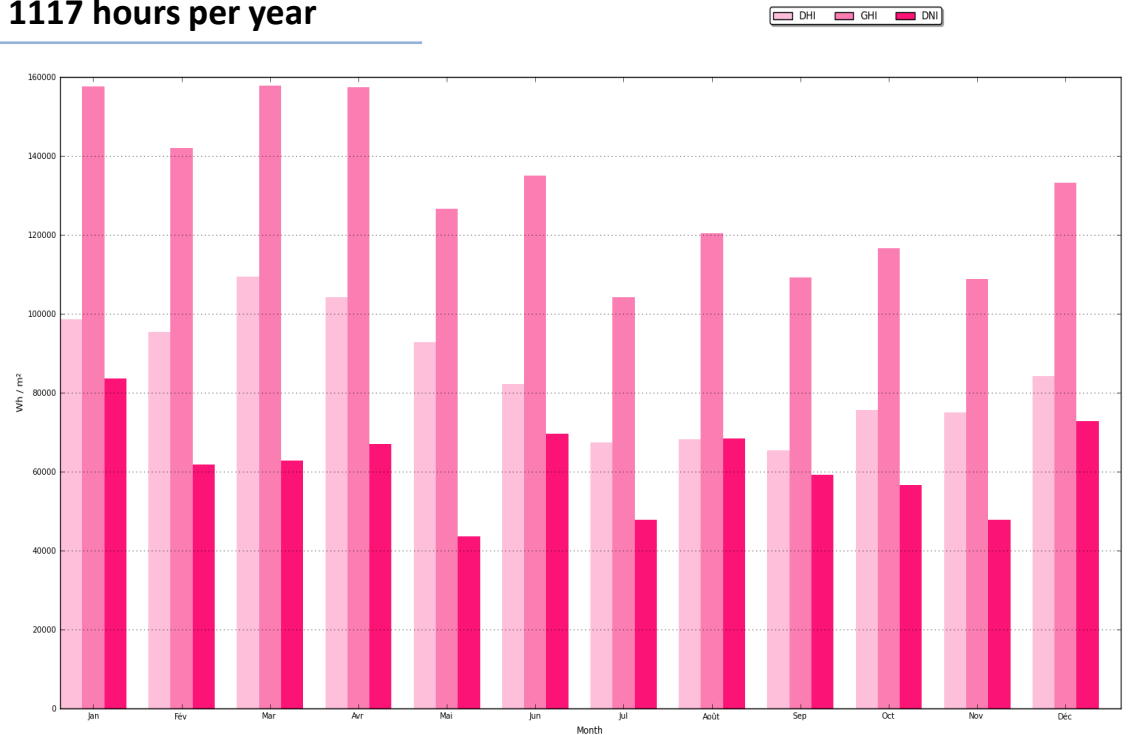


Katu Town, Sierra Leone



Katu Town in Sierra Leone

Annual irradiation	1568 kWh/m ²
Estimated Annual AC Energy Production	6686.31 MWh
Capacity factor	12.7 %
Hours of Full Capacity	1117 hours per year

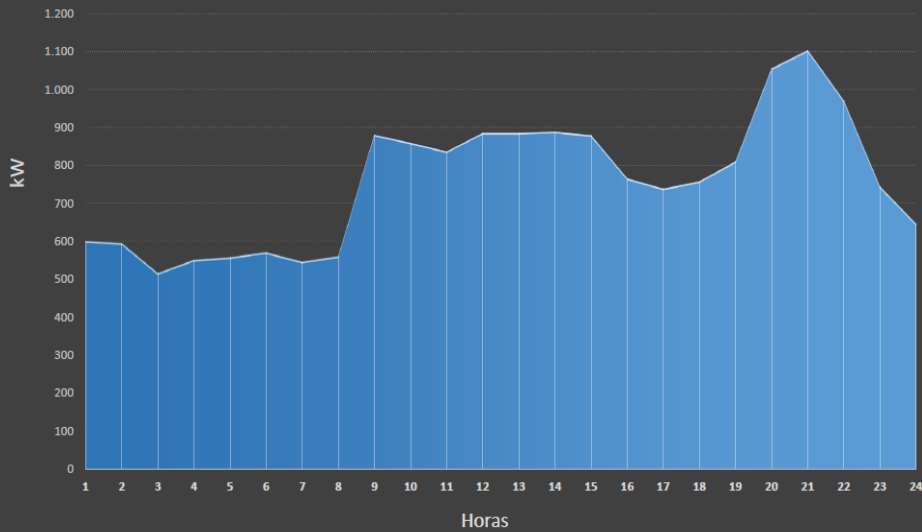


- Togo:
 - ▶ Aneho
 - ▶ Togoville
- Cape Verde:
 - ▶ Sao Nicolao
 - ▶ Maio
- The Gambia:
 - ▶ Cape point

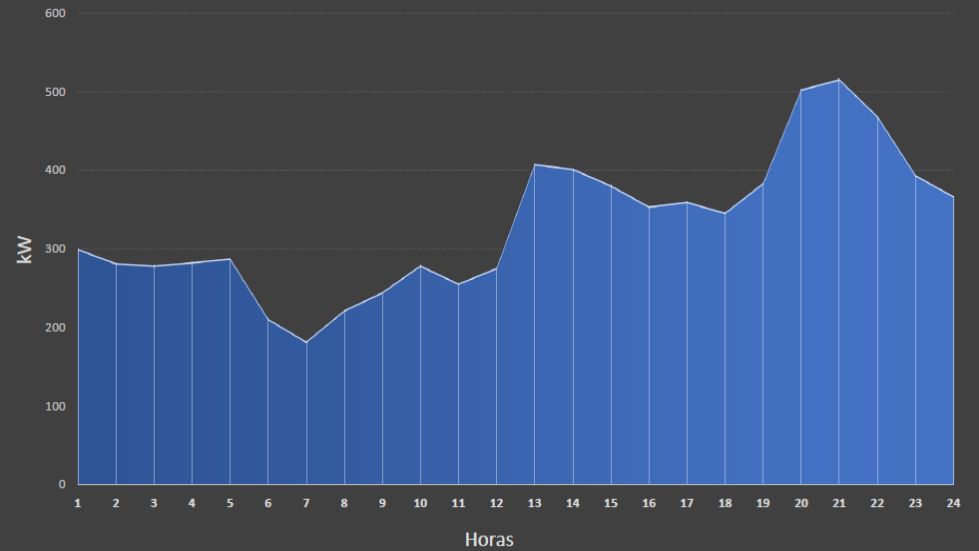
Choosing the wind turbine

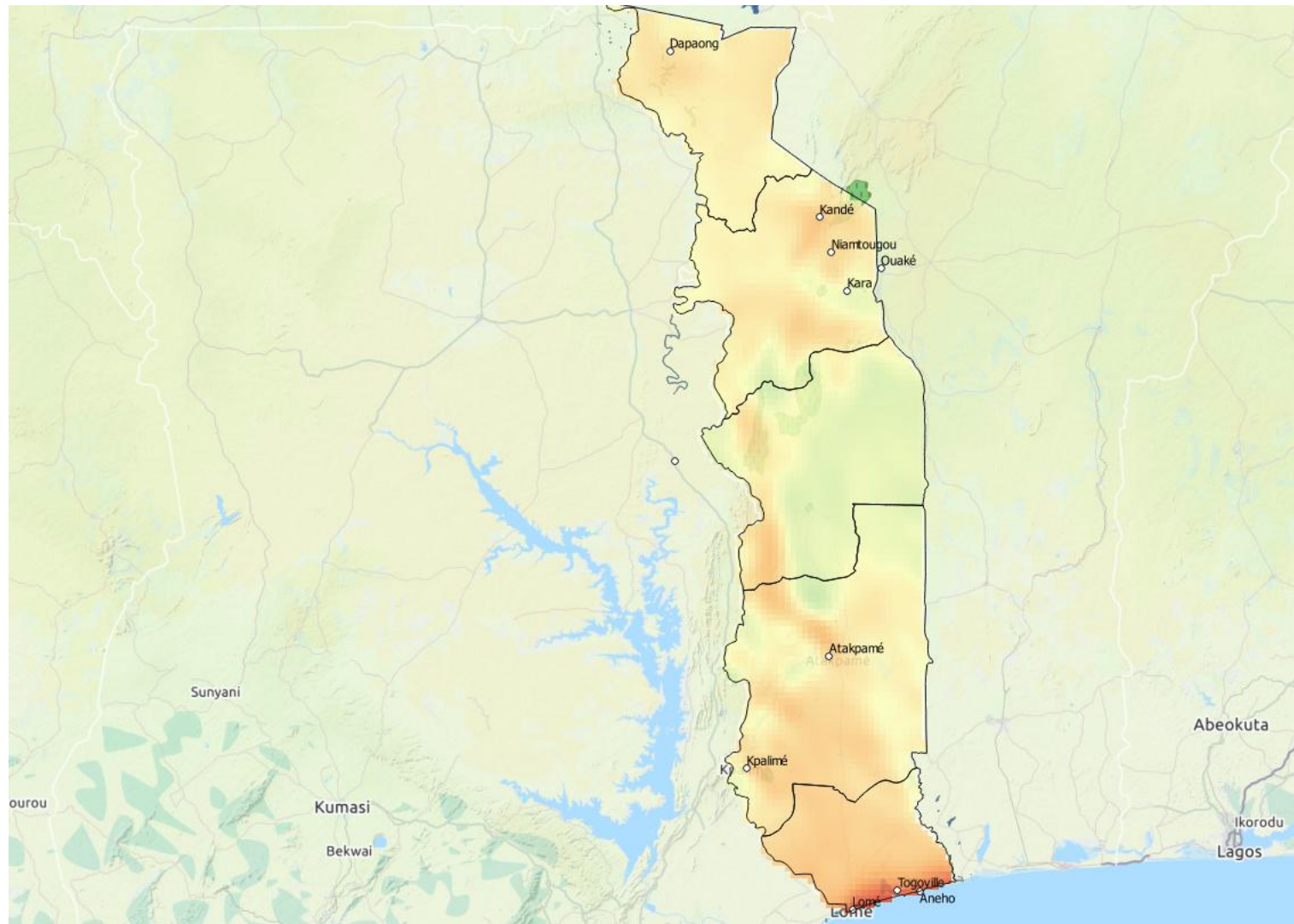
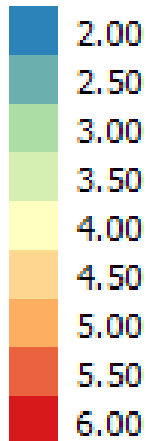
Turbine	Rated Power	IEC class	Hub height	Blade length	AEP	Capacity factor
NPS 100-24	100 kW	Ila	37 m	21 m	0.14 GWh	17 %
EWT 250 - 54	250 kW	IIla	50 m	26 m	0.49 GWh	22 %
GE 1.7-100	1.7 MW	IIIs	80 m	48 m	2.6 GWh	17 %
Siemens SWT 93	2.3 MW	Ila	80 m	45 m	3 GWh	15 %
Enercon E82	2.3 MW	Ila	108 m	40 m	3.1 GWh	16 %

Load Diagram_São Nicolau



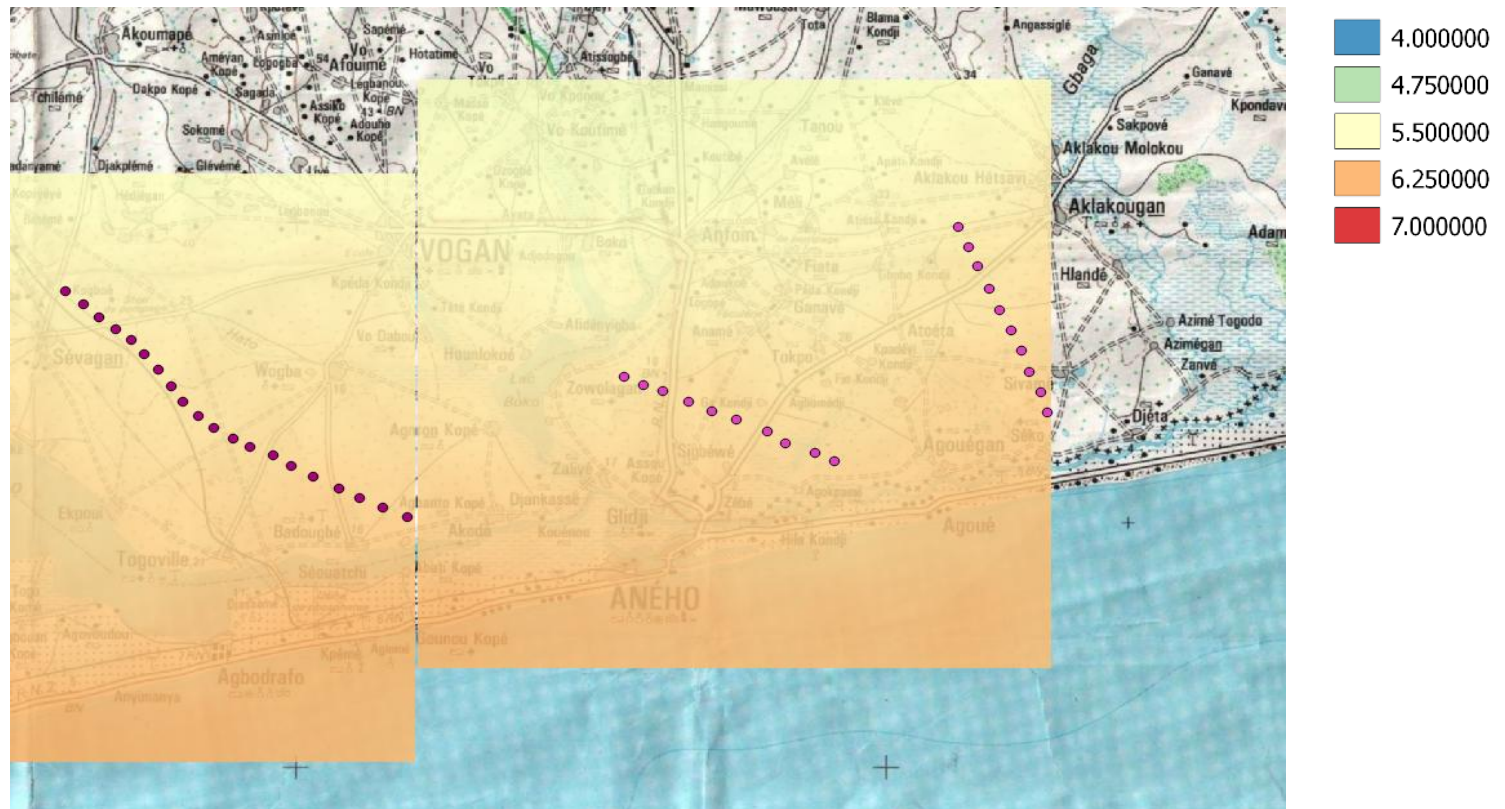
Load Diagram_Maio



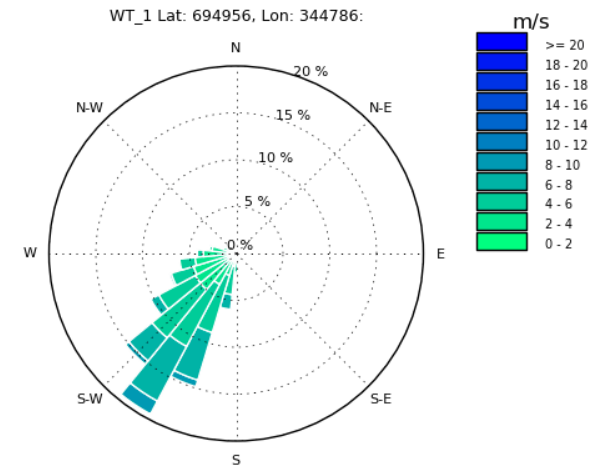
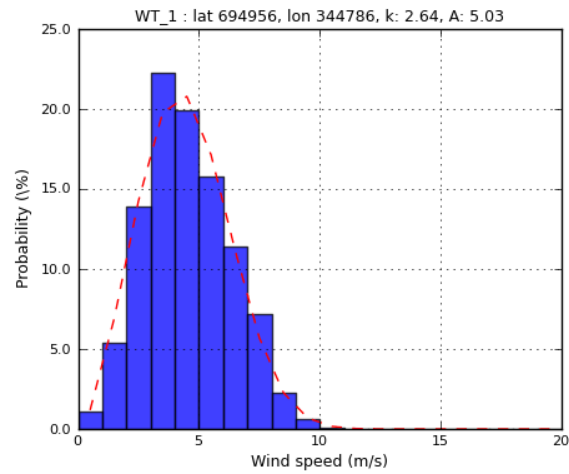
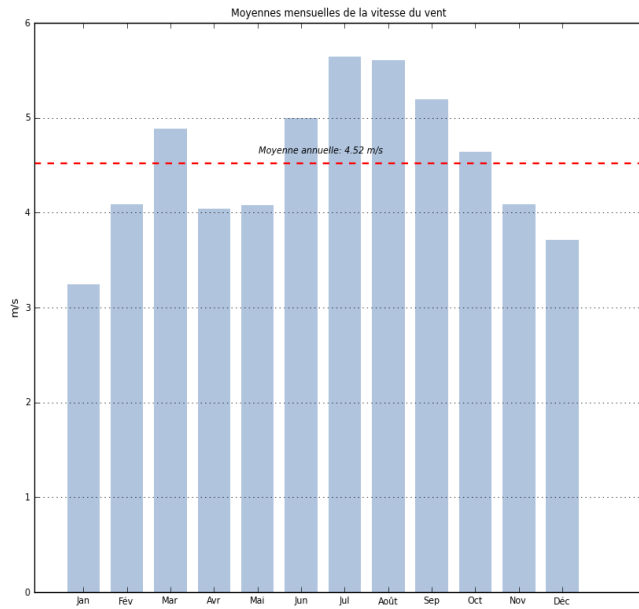


Micro-scaling:

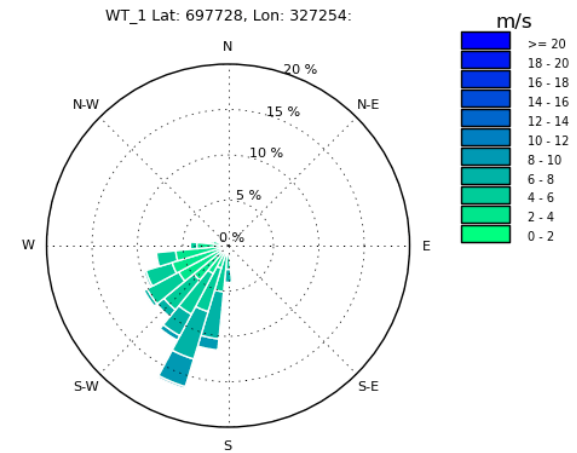
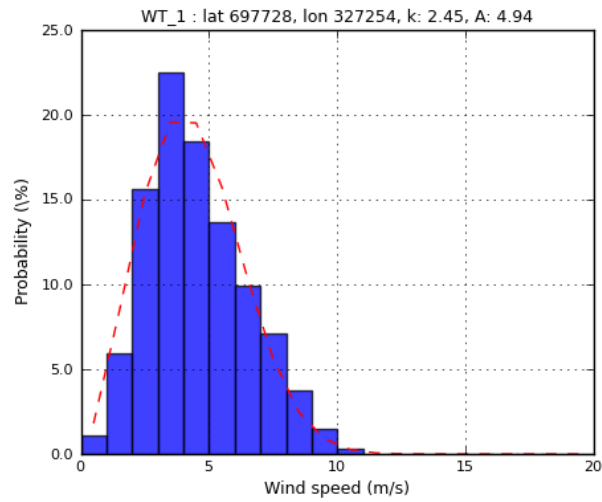
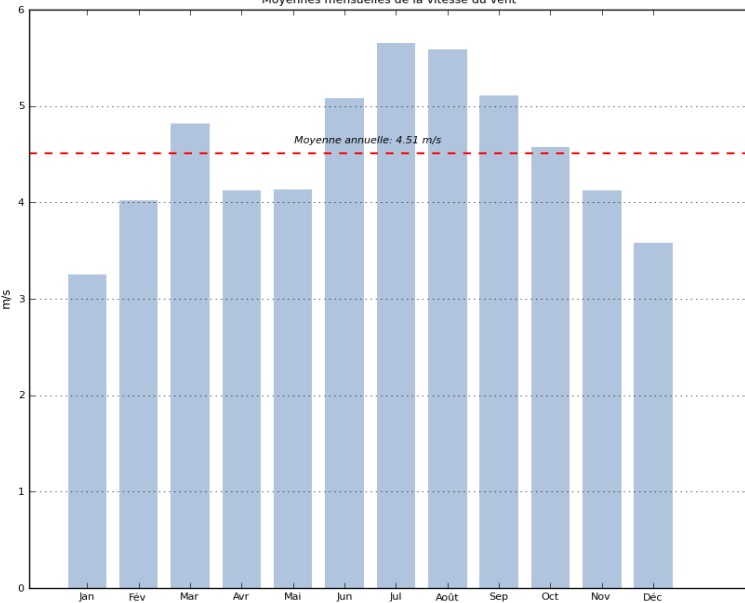
- 200 x 200 m resolution
- Levels : 60, 80, 100, 150 m

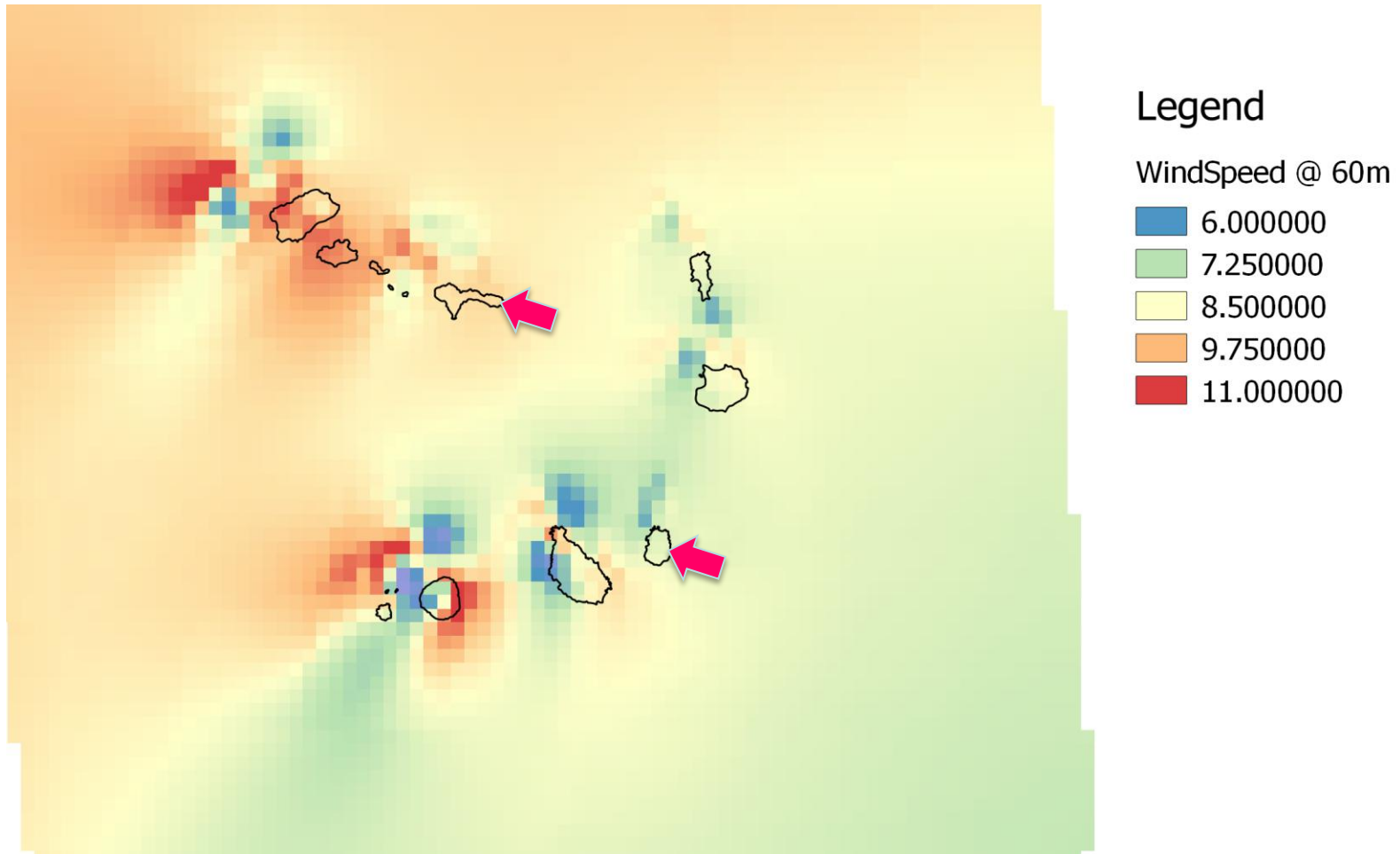


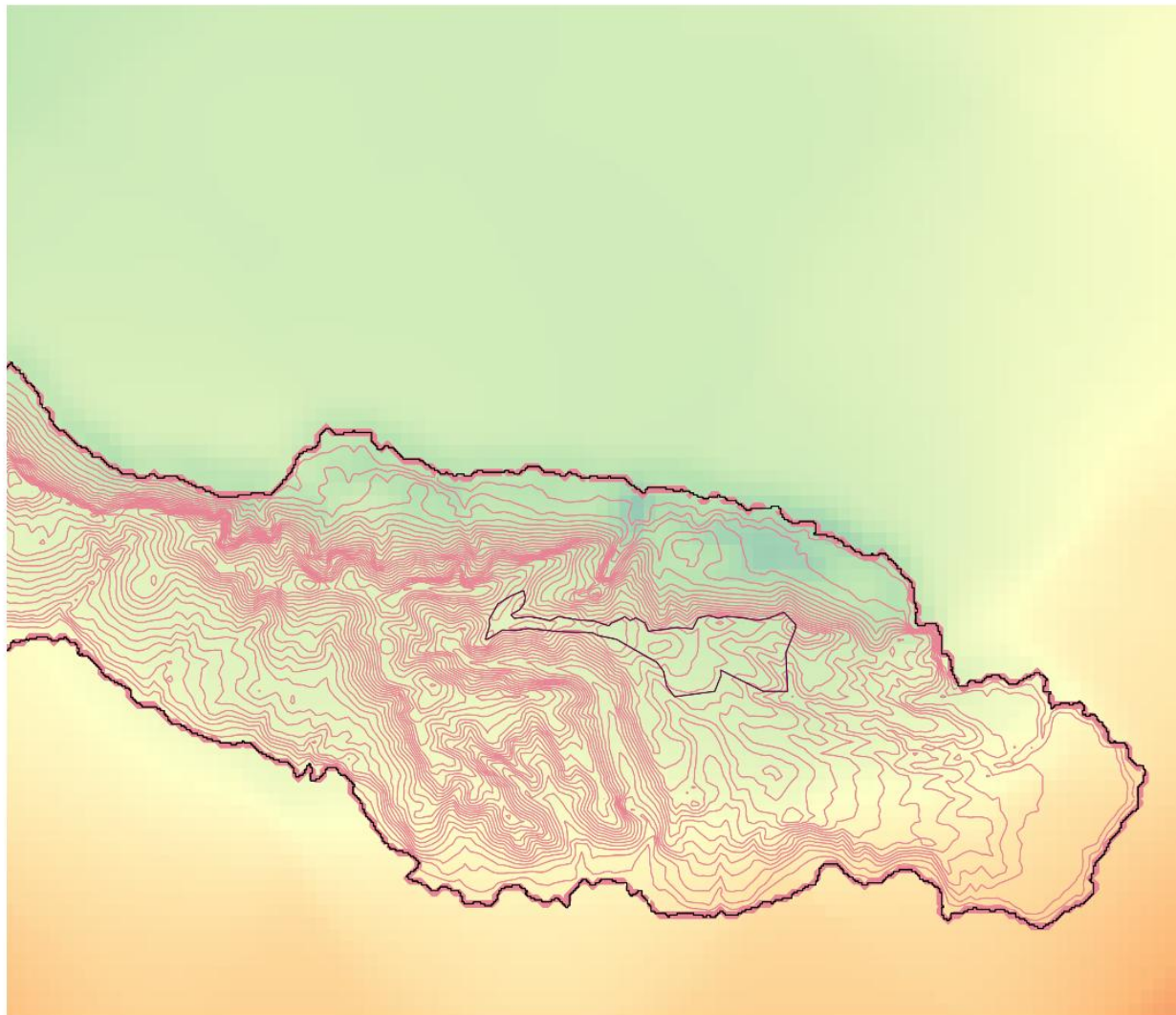
Indicator	Aneho	Togoville
Wind turbine	EWT 250-54	
Annual average wind speed	4.52 m/s	4.51 m/s
Prevailing wind direction	SW	SSW
Maximum wind speed	17.1 m/s	17.2 m/s
Weibull A (scale)	5.03 m/s	4.94 m/s
Weibull k (shape)	2.64	2.45
Annual average wind power density	63 W/m ²	66 W/m ²
Estimated Annual AC Energy Production	9.8 GWh	10.3 GWh
Capacity factor	22 %	23 %




Moyennes mensuelles de la vitesse du vent










Legend


 ZDER_san_nicolao


 topographie


Wind Speed @ 100m

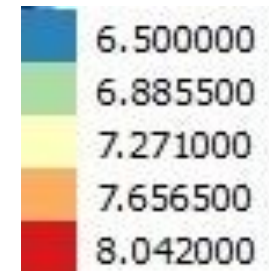
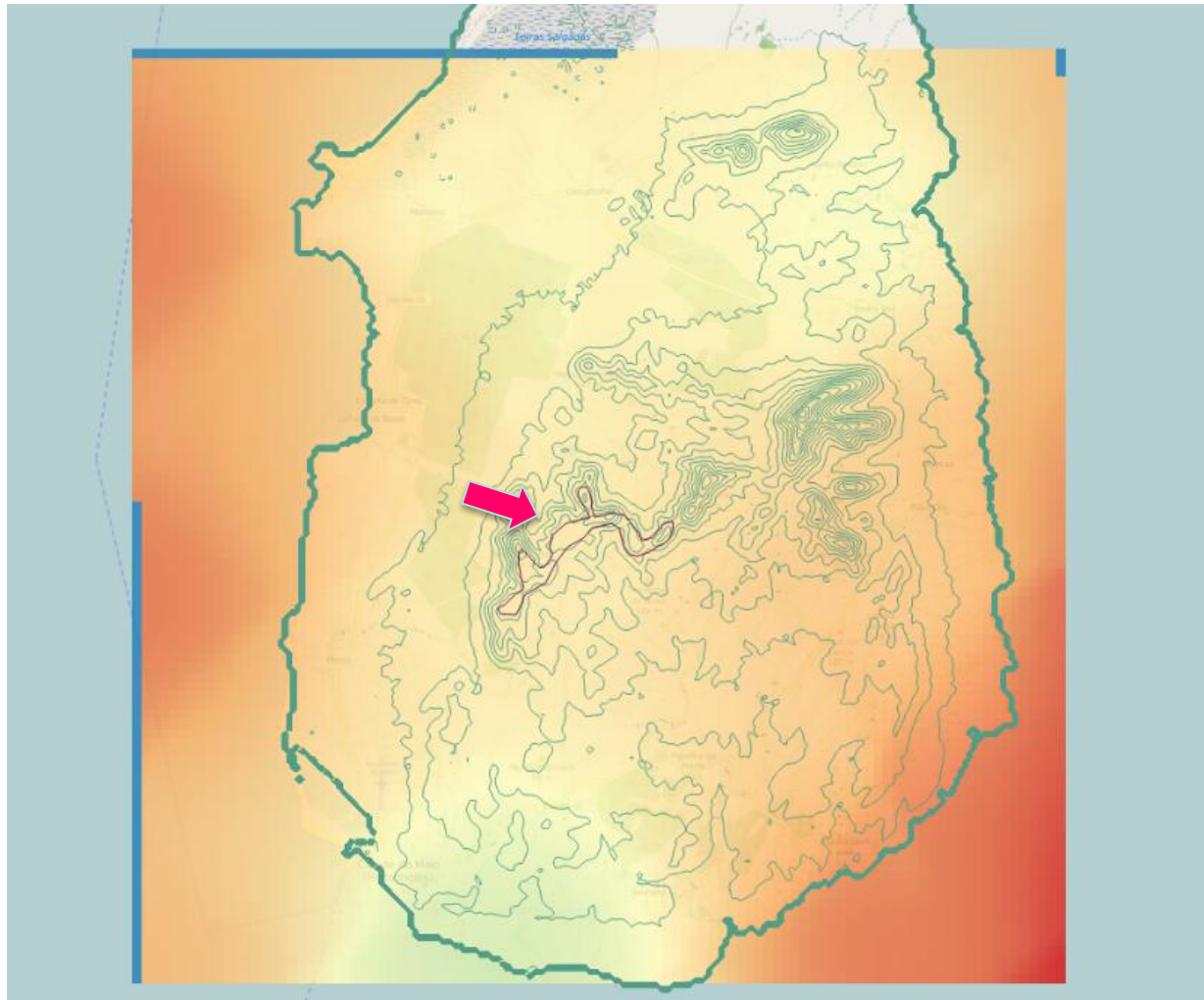
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 8.37500

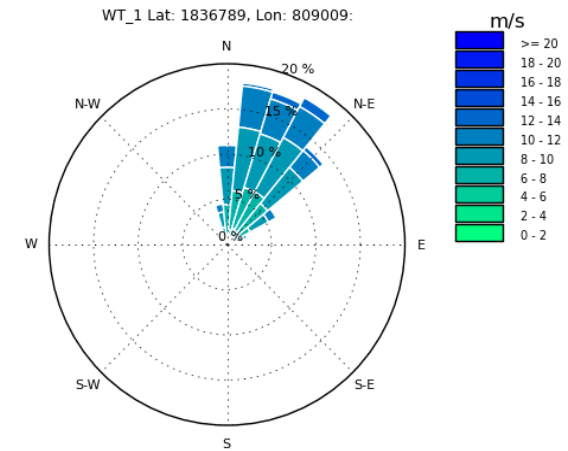
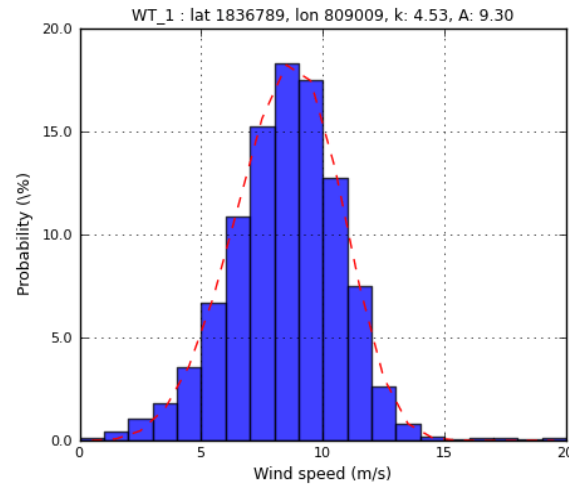
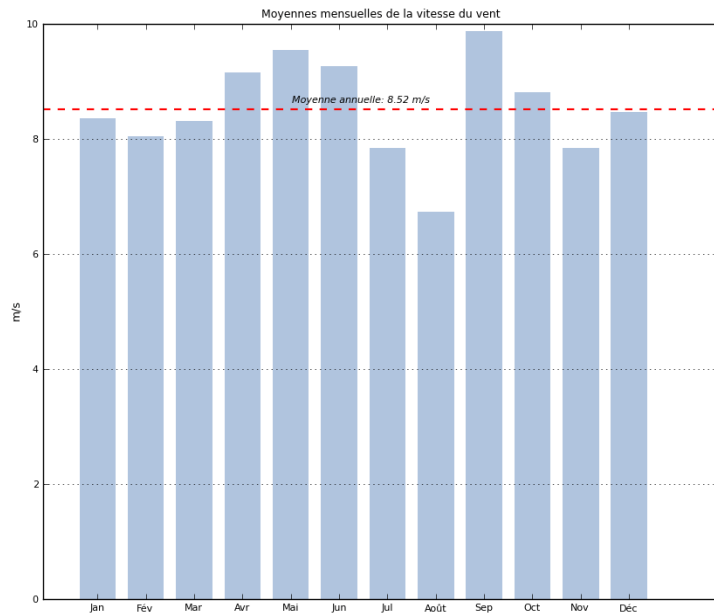
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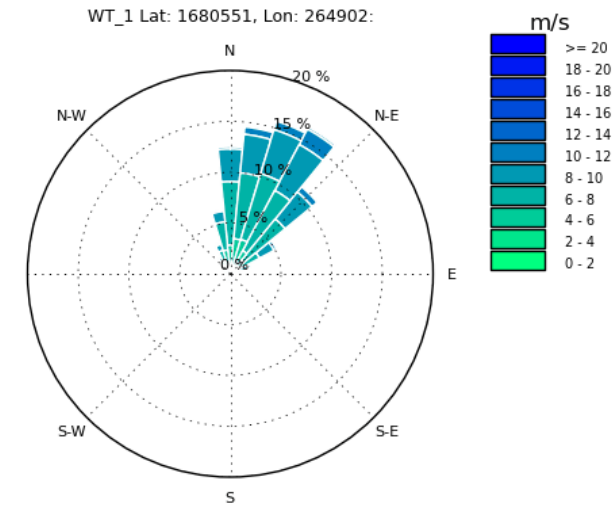
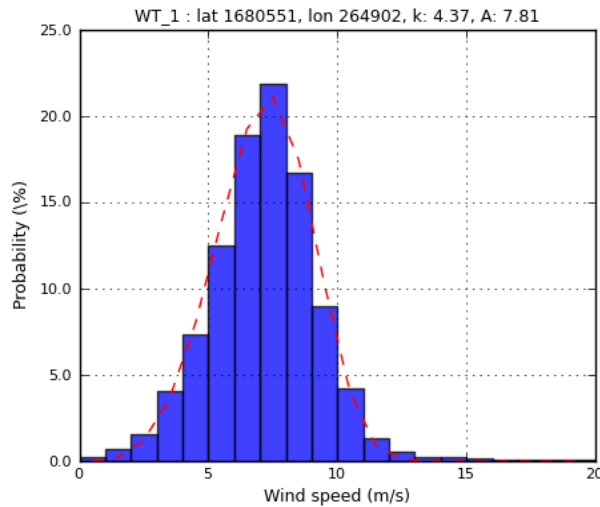
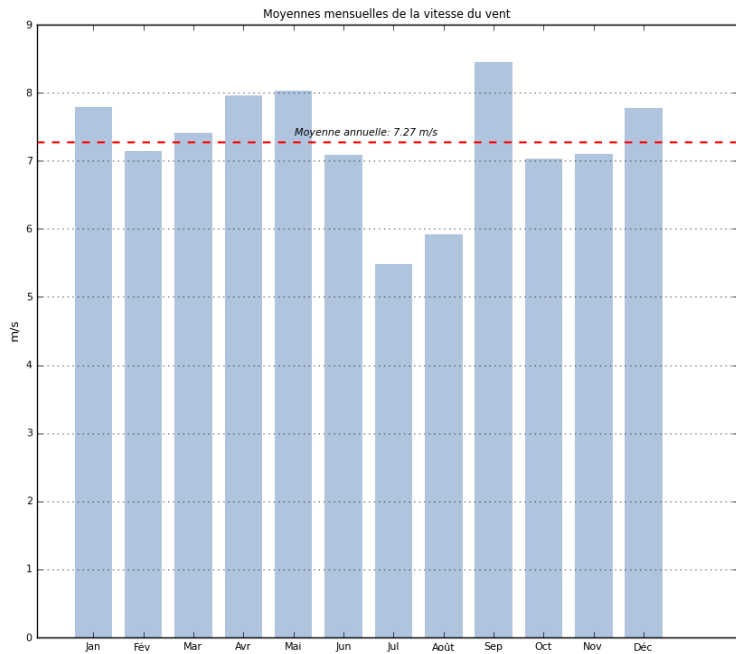
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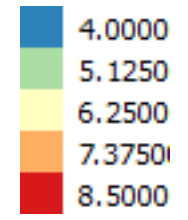
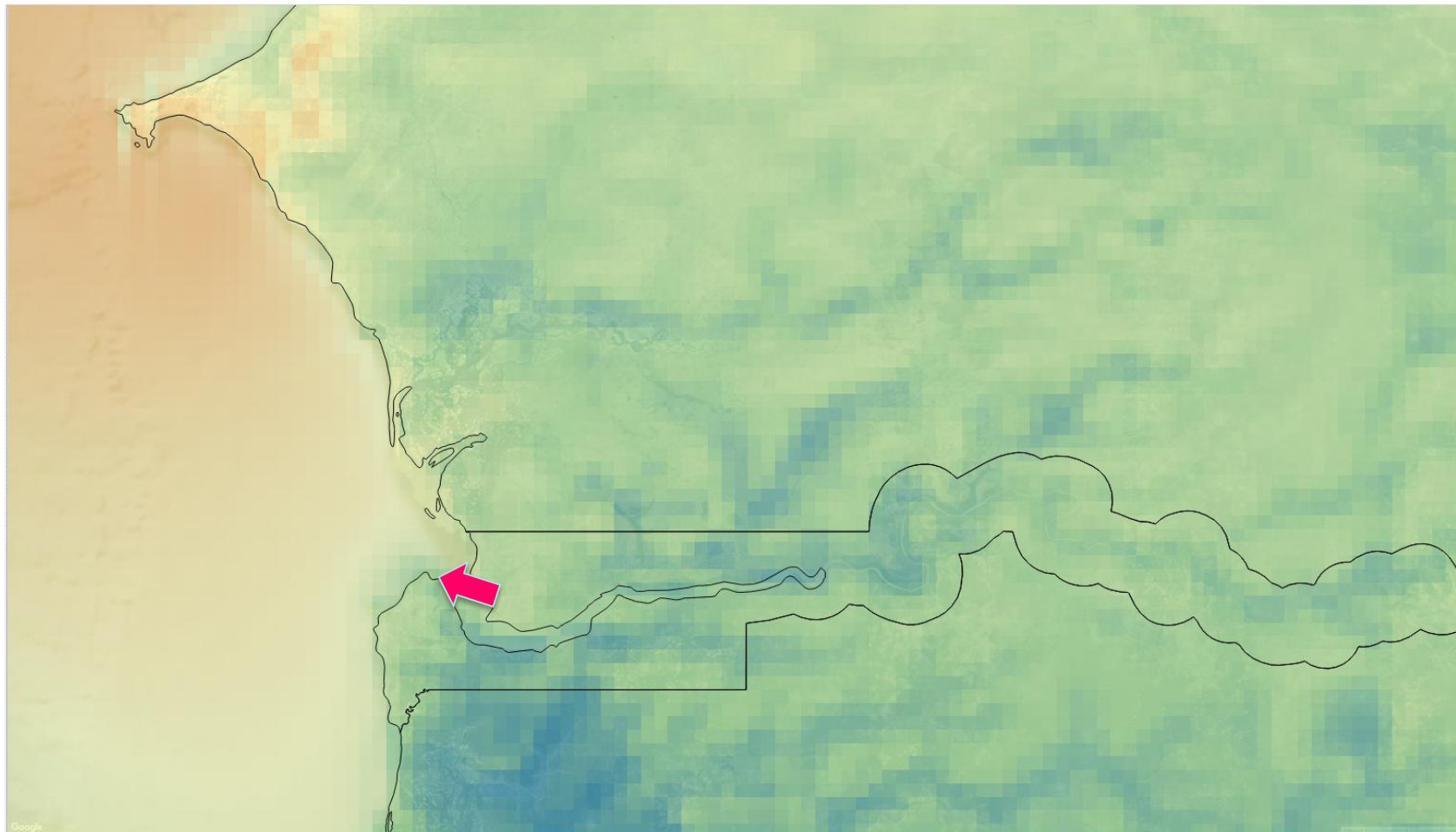
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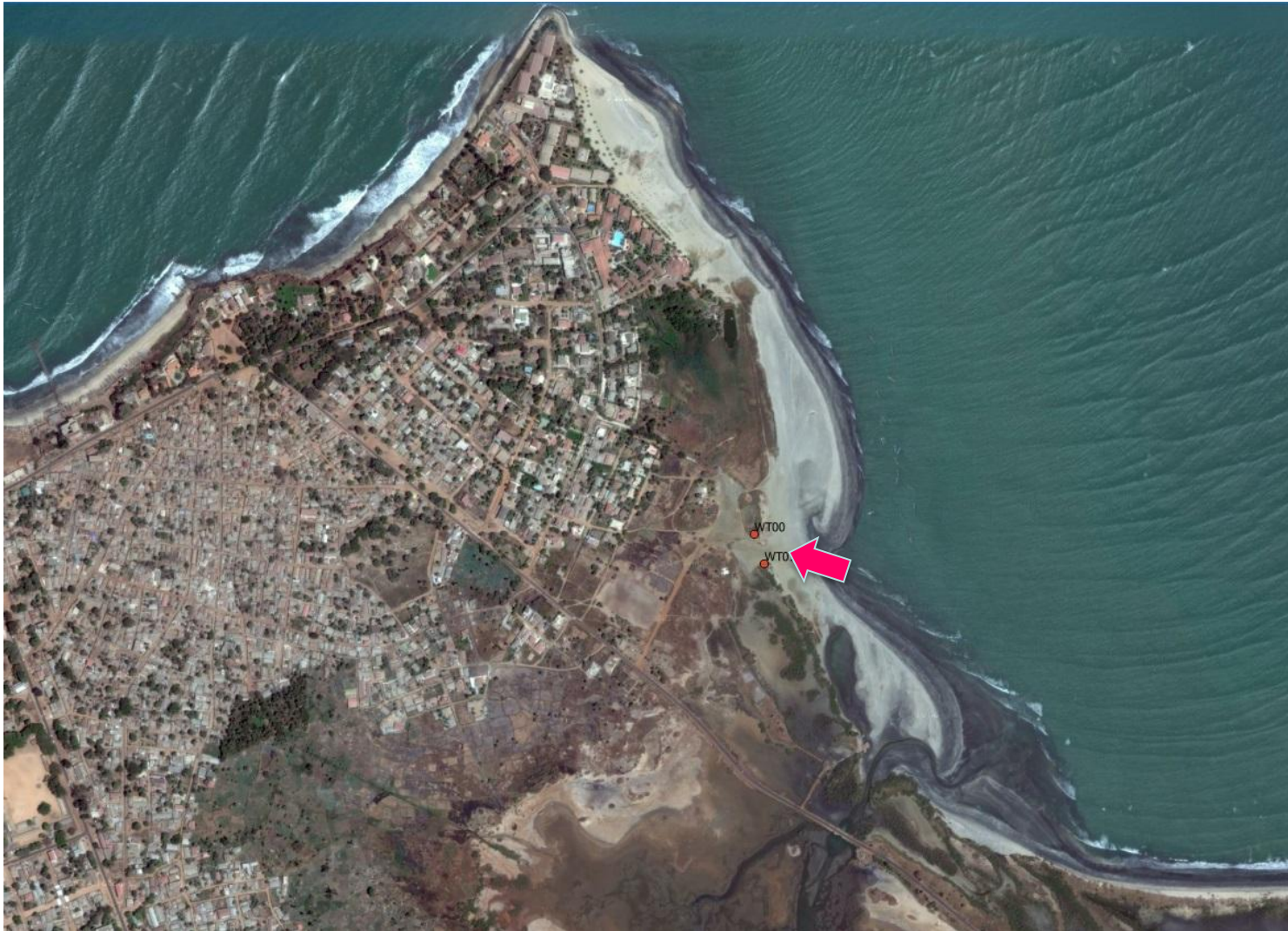


Indicator	San Nicolao	Maio
Wind turbine	Gamesa G58 (850 kW)	
Annual average wind speed	8.5 m/s	7.3 m/s
Prevailing wind direction	NNE	NNE
Maximum wind speed	45 m/s	33 m/s
Weibull A (scale)	8.52 m/s	6.85 m/s
Weibull k (shape)	4.4	3.90
Number of turbines	4	2
Wind power density at hub height	381 W/m ²	204 W/m ²
Estimated Annual AC Energy Production	14 GWh	4.6 GWh
Capacity factor	50 %	32 %

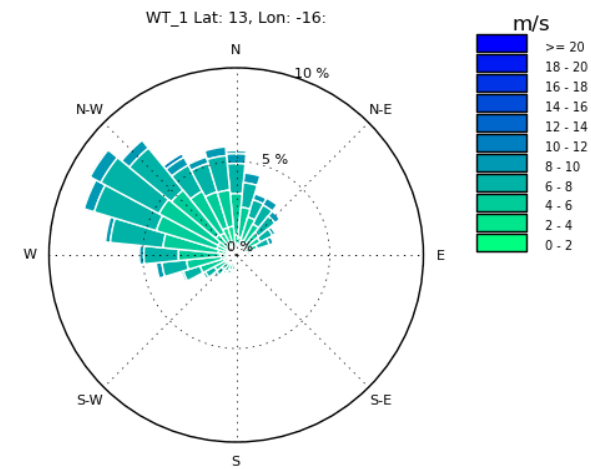
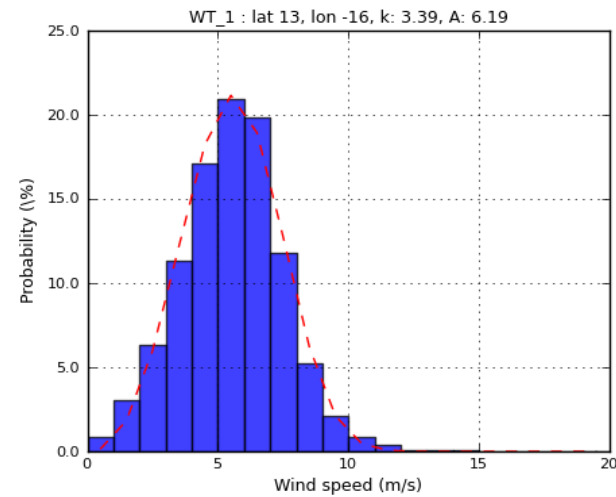
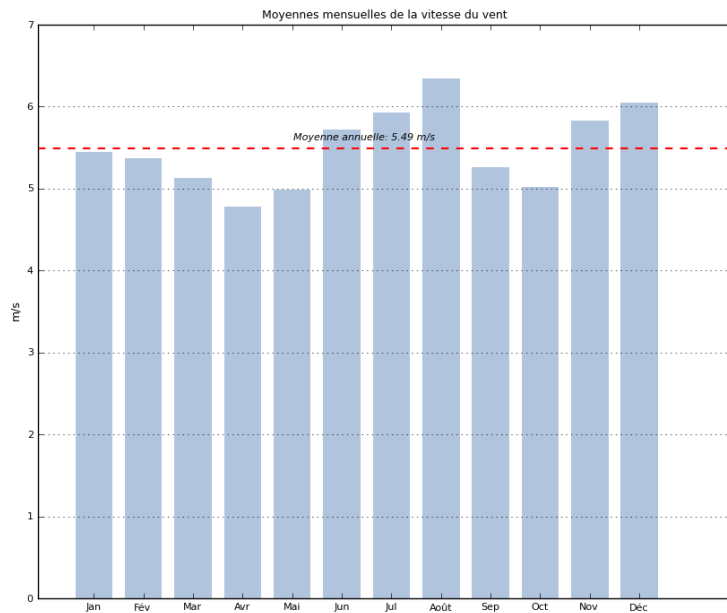








Indicator	Cape point
Wind turbine	EWT 250 – 54 (250 kW)
Annual average wind speed	5.51 m/s
Prevailing wind direction	NW
Maximum wind speed	23 m/s
Weibull A (scale)	6.19 m/s
Weibull k (shape)	3.39
Annual average wind power density	130 W/m ²
Estimated Annual AC Energy Production	1.2 GWh
Capacity factor	29 %



- Full annual times series for each site:
 - ▶ Wind speed or irradiation
 - ▶ Energy production
- Coordinates of the wind turbines
- Turbine datasheet (if exists)
- Maps: annual average in 4 areas
 - ▶ Cape Verde, Senegal/Gambia, Sierra Leone, Togo
 - ▶ Wind speed & Power density (60, 80, 100m)
 - ▶ GHI, DNI, Temperature

- Production of data
 - ▶ Pre-assessment of RE projects
 - ▶ 3 solar sites
 - ▶ 5 wind sites
- Production of maps + metadata
 - ▶ For ECOWREX GIS integration
- Not business case studies: requires more info
 - ▶ Local costs
 - ▶ Local regulations
 - ▶ Environmental & technical studies

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