Mapping Solar-Wind complementarity in Madagascar : Insights from ERA5 and High-Resolution ALADIN Data for decentralised Hybrid Systems



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Policy Power People

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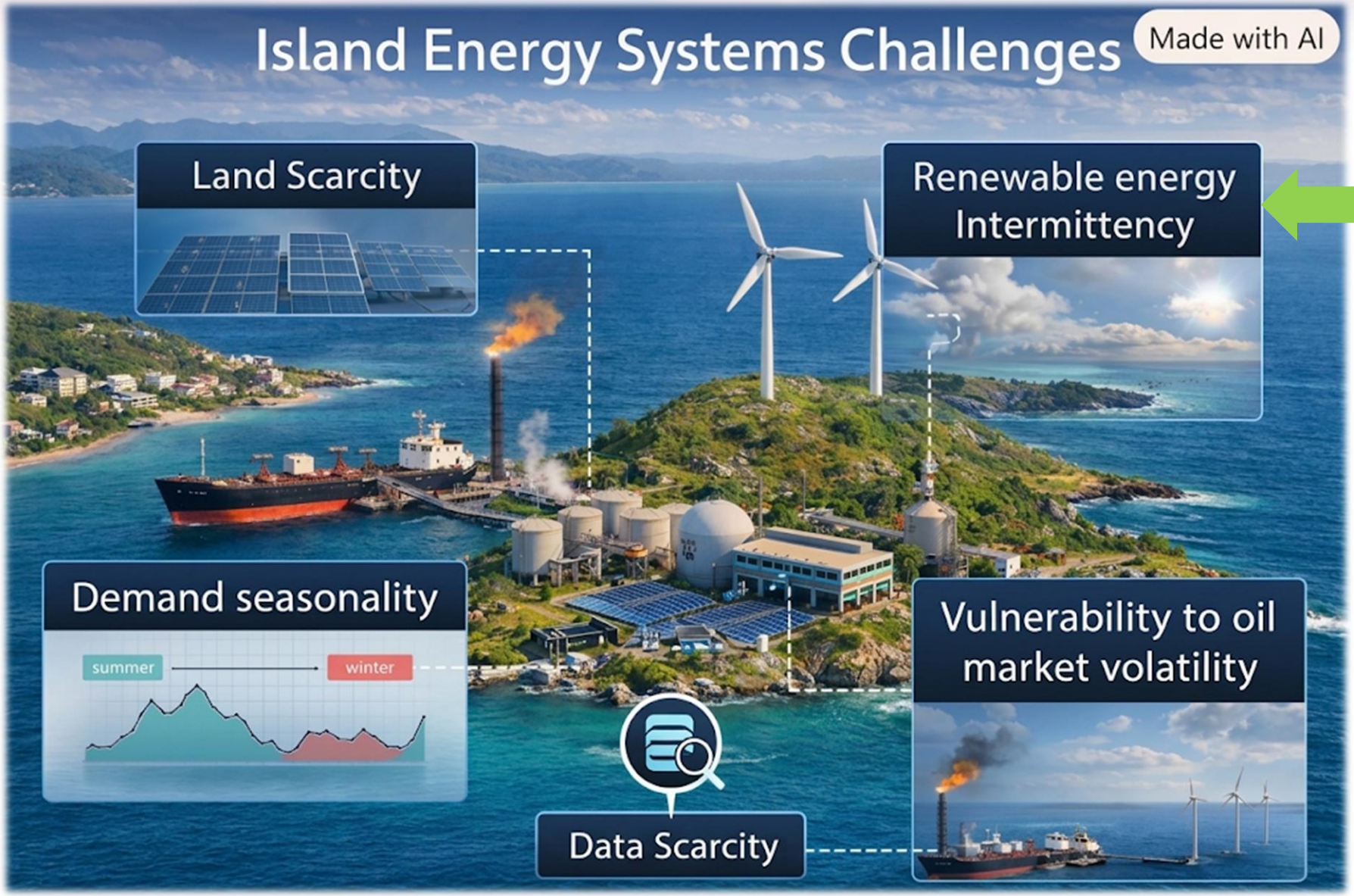
Made with AI



Island territories context :

- Non-interconnected
- High demand rate
- Imported resources (fuel or biomass)

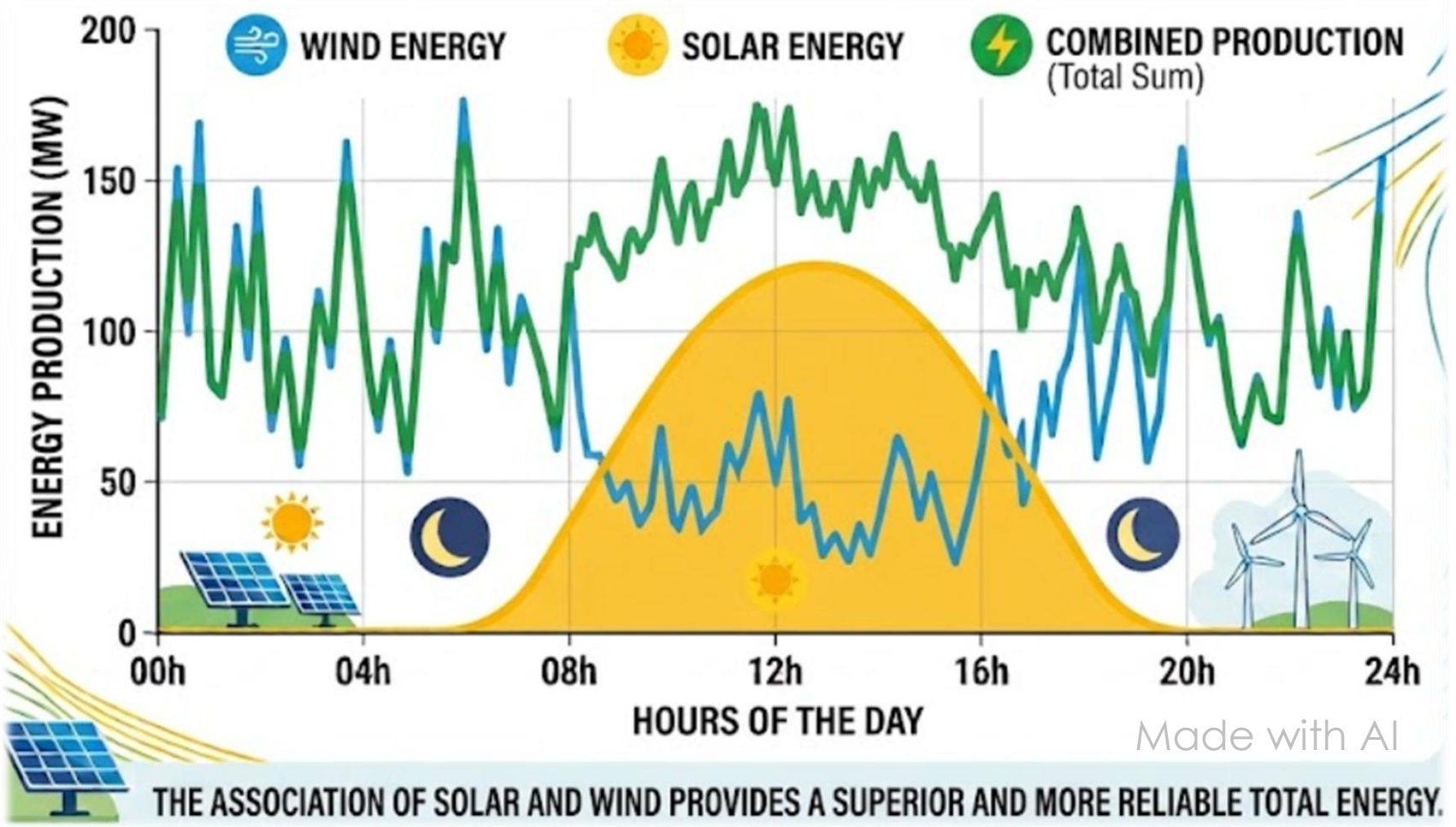
→ Explore all local renewable energy sources



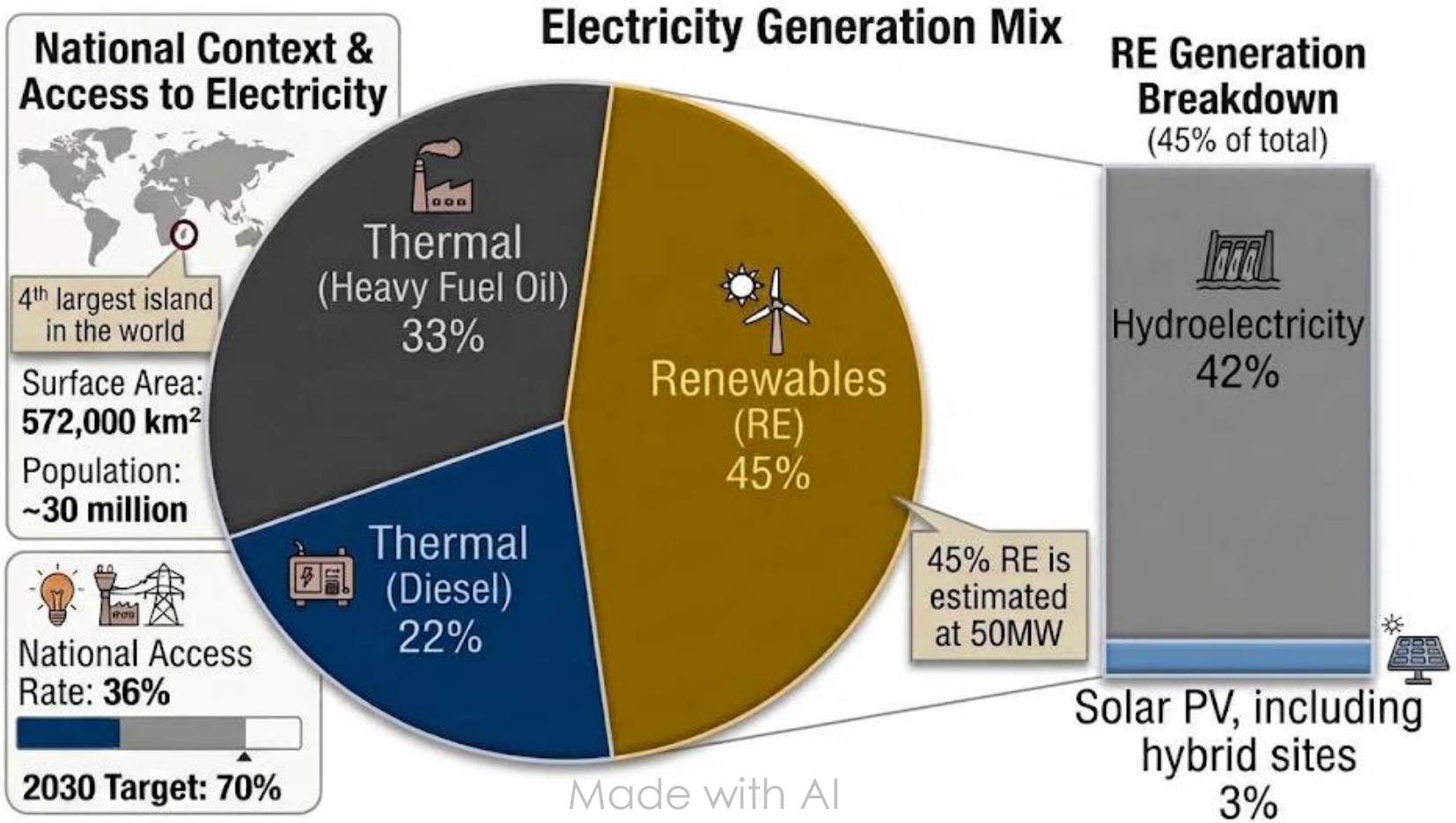
Resource Complementarity

Complementarity

Energy complementarity refers to combining different energy sources whose production patterns compensate for one another.



Madagascar:



Source : WorldBank. 2025. *PACTE ENERGETIQUE NATIONAL POUR MADAGASCAR*.

Objective:

To present an approach for assessing Madagascar's potential and temporal complementarity of local renewable energy resources using climate data and statistics.

Methodology:

1. **Mapping averages solar irradiance and wind speed for 2025 (ERA5 and ALADIN)**
2. **Mapping the IP-PB and finding the 10 highest over Madagascar**
3. **Mapping the correlation of solar irradiance and wind speed**
4. **Plotting the diurnal, daily, weekly and monthly curves of some sites with high IP-PB values.**

Data used:

Characteristic	ALADIN-Climat	ERA5
Source	CNRM-ESM	ECMWF
Type	Climate simulation	Historical reanalysis
Spatial resolution	12 km	~28 km
Temporal resolution	Daily	Hourly
Period available	2015 - 2100	1940 - present

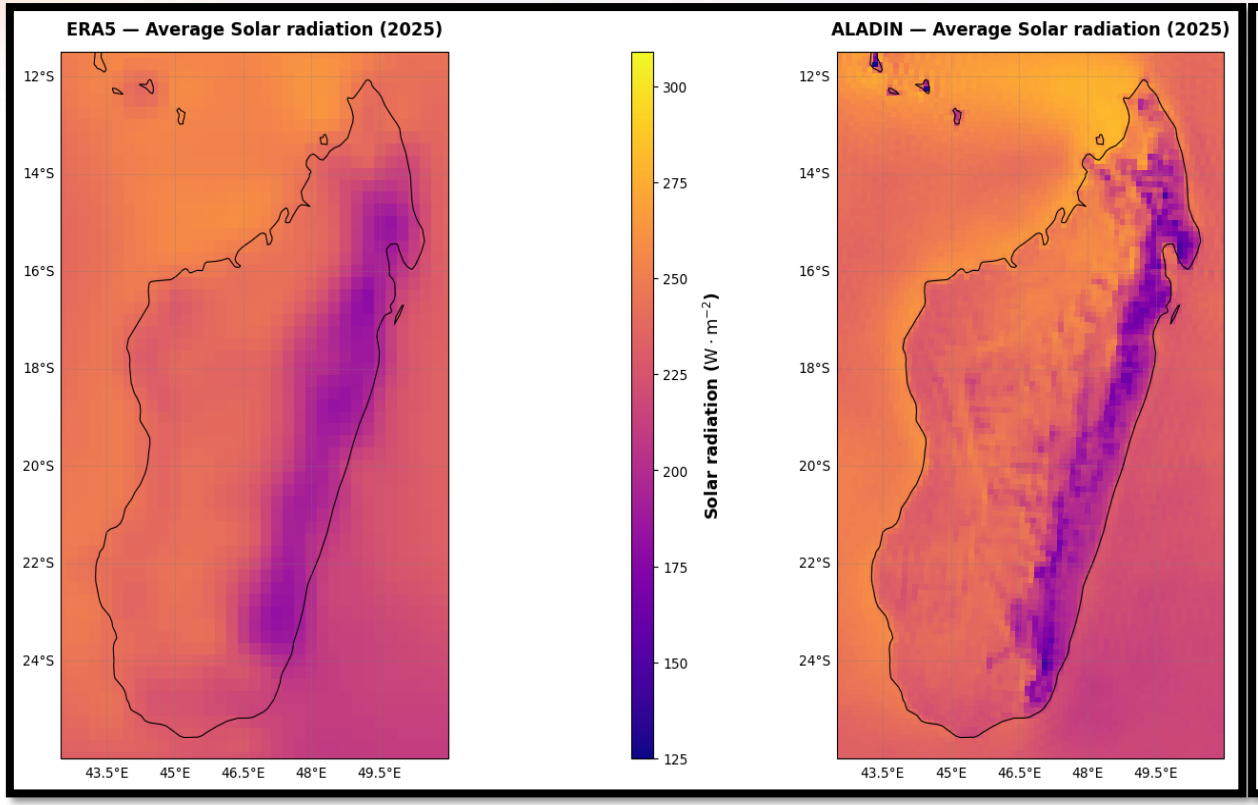
Considered period : harmonised year 2025 (daily average)

Metrics:

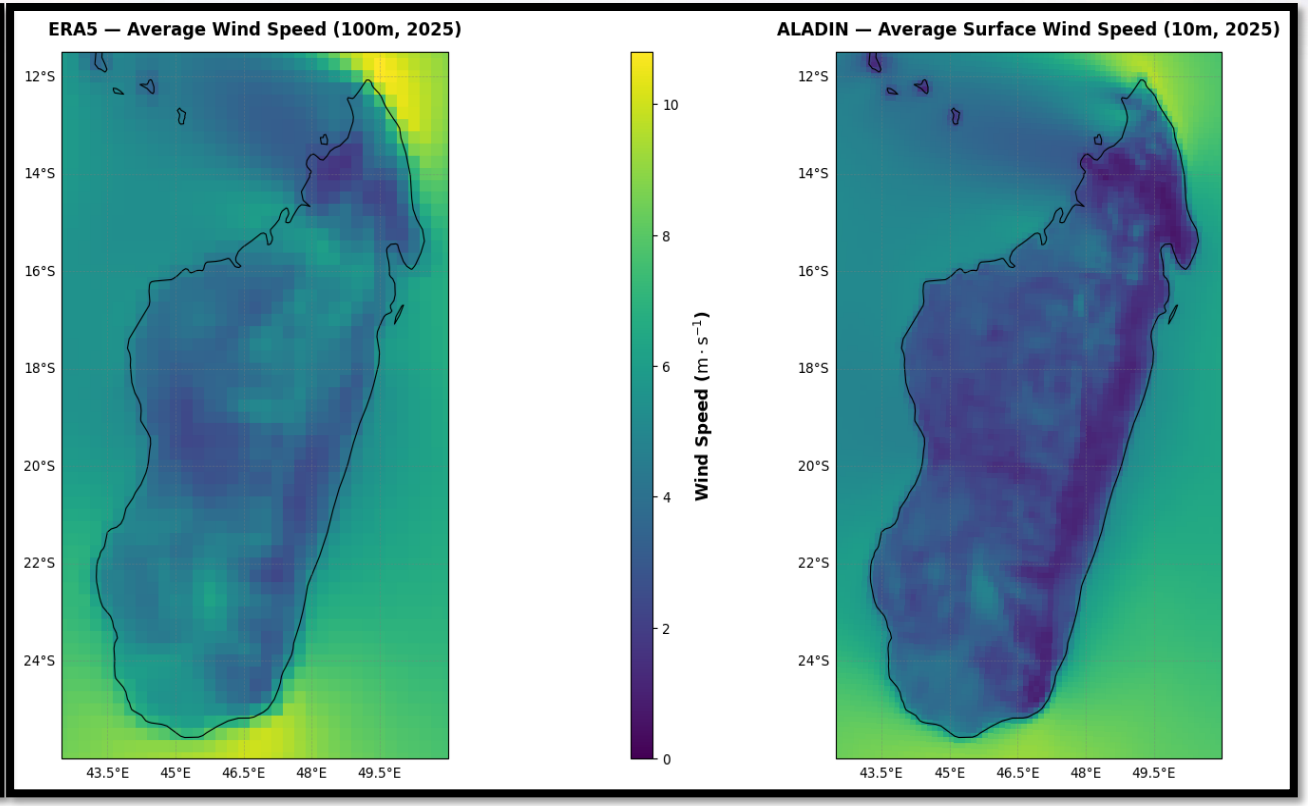
Pearson Coefficient	Kendall Tau Coefficient	Paraìba's Hybrid generation potential index
$r_p = \frac{S_{XY}}{S_X S_Y} \in [-1, +1]$ • S_{XY}: covariance of X and Y • S_X: standard deviation of X • S_Y: standard deviation of Y	$r_p = \frac{C - D}{n(n-1)/2} \in [-1, +1]$ • C: concordant rate • D: discordant rate • N: number of observations	$IP - PB = IsN + WsN \in [0, 2]$ • IsN : normalized solar irradiance • WsN: normalized wind speed • Normalization: $N_i = \frac{V_i - V_{min}}{V_{max} - V_{min}} \in [0, 1]$

Results: resources map

Average downward solar radiation



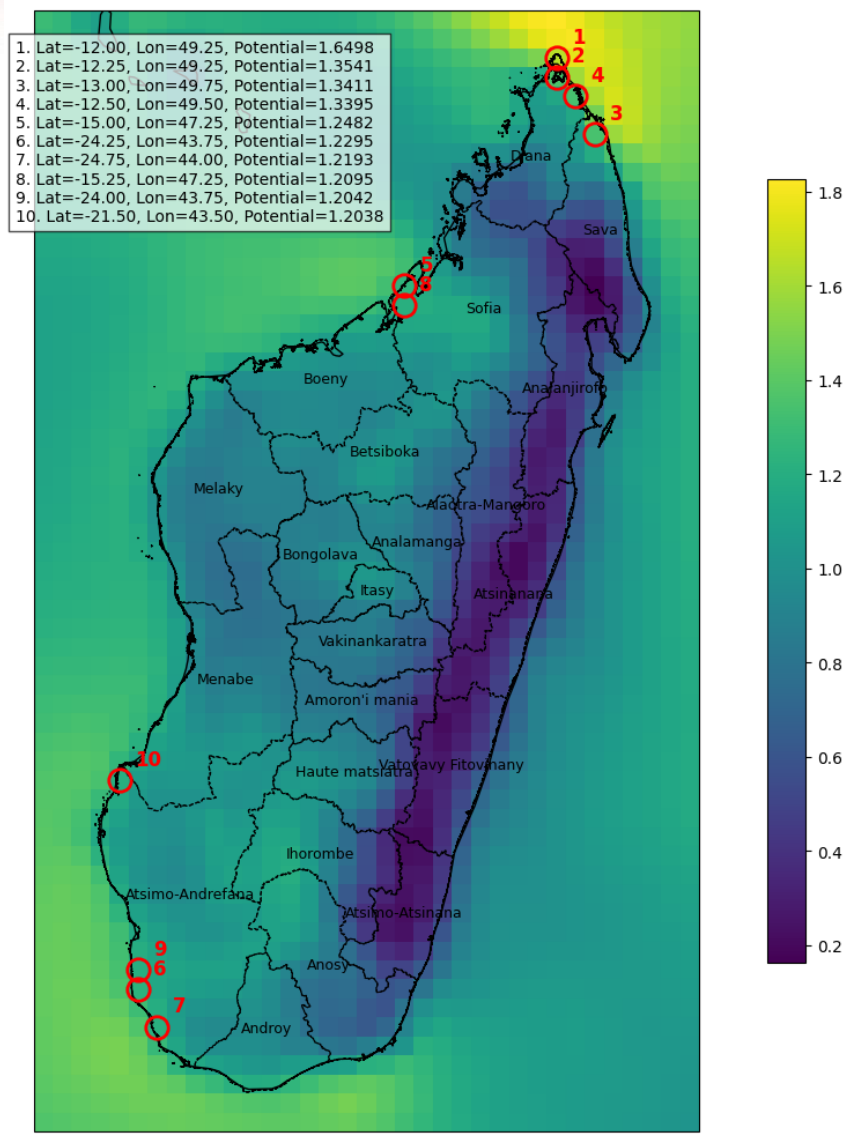
Average wind speed



- ALADIN reveals more coastal shear effects (high resolution)
- Solar : both datasets show high potential along the northern and western coasts.
- Wind : maximum speed at the extreme north and south.

Results: Potential

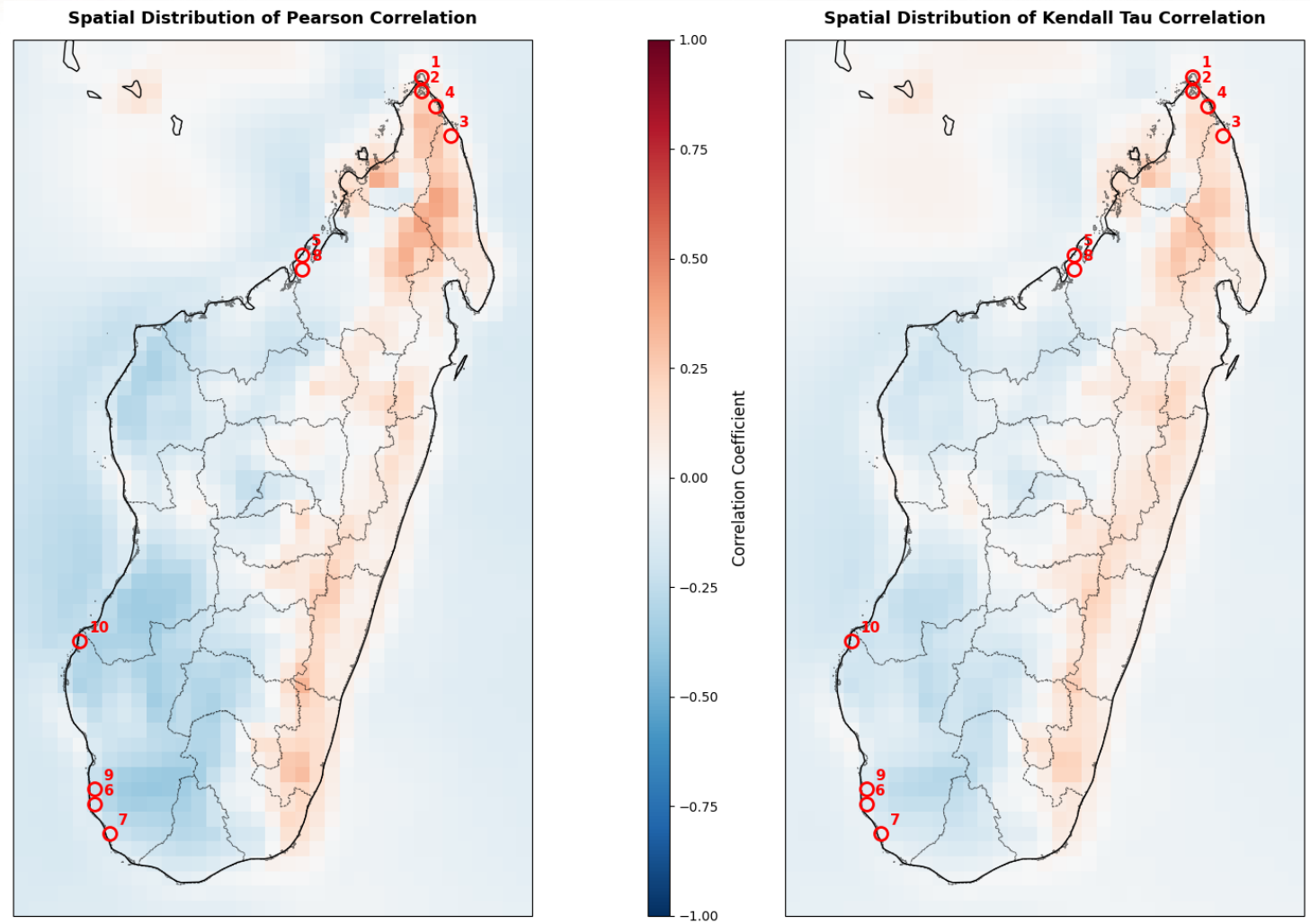
Combined potential (IP-PB) and 10 highest zones



Finding : North, North-West, South and South-West with IP-PB>1.20

- *Zone 1 (Lat : -12.00 ; Lon : 49.25) : IP-PB = 1.65*
- *Zone 2 (Lat : -12.25 ; Lon : 49.25) : IP-PB = 1.35*

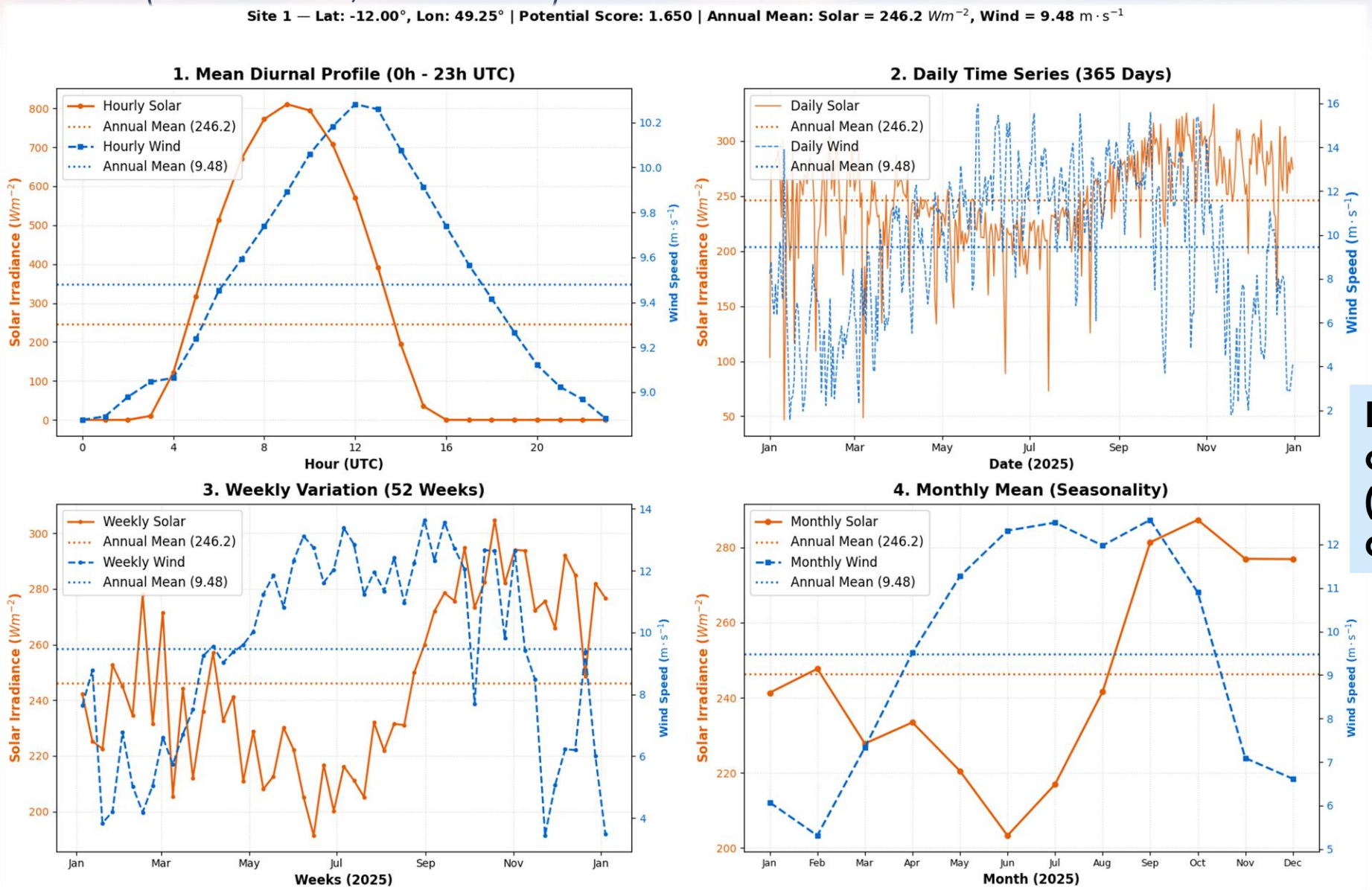
Results: Correlation Analysis



- Opposite relationship between wind and sun in central and western zones
- Pearson shows higher contrast, then higher correlation value

Results: Trend observations

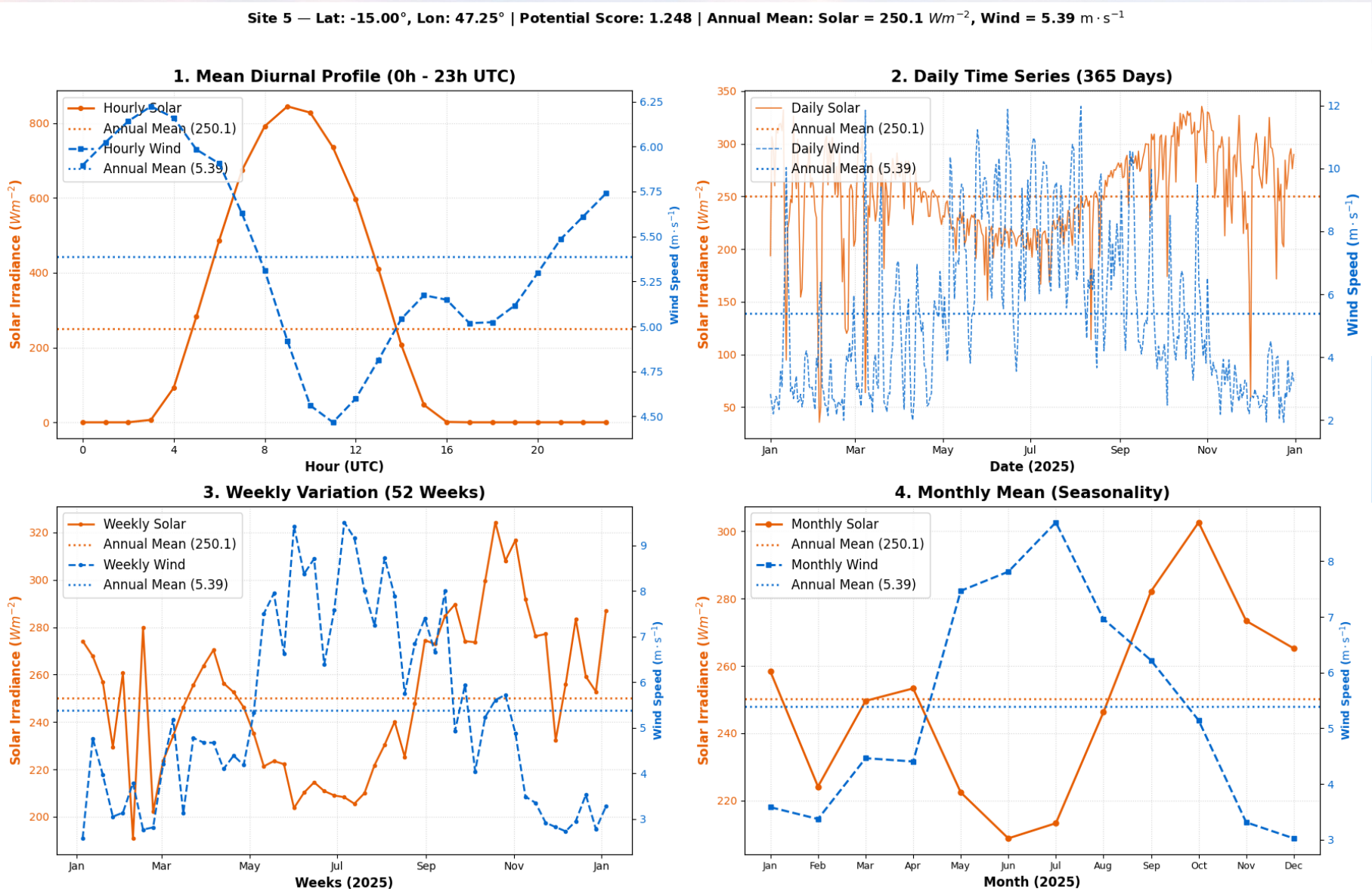
Zone 1 (Lat : -12.00 ; Lon : 49.25) : IP-PB = 1.65



Long-term complementarity (Daily,weekly and monthly)

Results: Trend observations

Zone 5 (Lat : -15.00 ; Lon : 47.25) : IP-PB = 1.25



Short-term and Long-term complementarity

Contributions:

- Introducing a methodology to assess renewable energy potential and analyse the complementarity
- Mapping high-resolution of resources
- Identifying 10 high hybrid renewable energy zones by sub-dataset
- Representing complementarity meaning from resource data

Limitations :

- Considered period too short
- No data validation
- Some pre-processing treatments are missing or incomplete

Conclusion:

- Climate data mapping and potential indices allow the identification of renewable energy resource potential.
- ALADIN reveals stronger coastal shear effects.
- Correlation mapping can be used as a complementarity metric, and Pearson's correlation provides higher contrast values than Kendall's.
- Some zones may exhibit short-term complementarity but not long-term complementarity, and vice versa.
- Thus, complementarity analysis can reduce short-term or long-term resource variability.

Future works :

- Analyze the type of compelementarity assessed by the correlation
- Apply the methodology for real assessement
- Analyze the energy potential from the identified resources

THANK YOU

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Cofinancé par l'Union européenne