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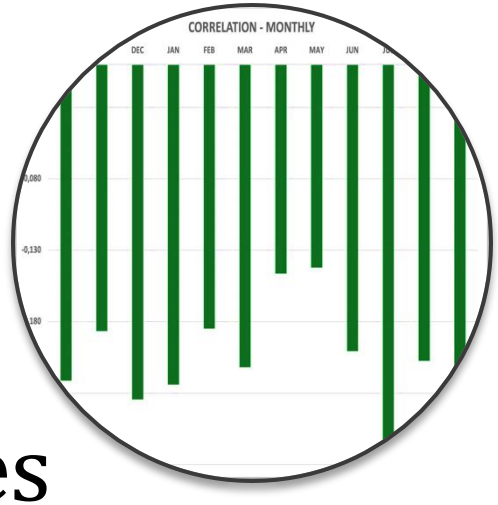

Stochastic Simulation of wind and solar processes for reliable renewable energy decision-making

European Geosciences Union (EGU) General Assembly 2025

Vienna, Austria

Despoina Balachtari, Theano Iliopoulou, Panayiotis Dimitriadis,
Nikos Mamassis, Demetris Koutsogiannis

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Problem – Uncertainty of natural processes affects reliability of renewable energy decision-making

Idea – Investigating and simulating historical data, by applying stochastic models reproducing the process' marginal distribution and dependence structure (Hurst-Kolmogorov dynamics) using the Symmetric Moving Average scheme

Contribution – Synthetic time series are generated, emulating realistic patterns & critical process' characteristics

Outcome – Enhancing reliability of renewable energy resource assessments, planning and designing

BASIC ANALYSIS & SIMULATION STEPS

I. Standardising – Normalising empirical data

II. Estimating Hurst parameter through "Climacogram" method (logarithmic plot of the variance vs scale)

III. Fitting theoretical distribution to the empirical ones, by optimising three classic error estimations. Maximum Likelihood Method is also tested.

IV. Implementation of Symmetrical Moving Average model, preserving the process' first three moments and the Hurst parameter.

V. Generating new time series and validating with respect to the target series.

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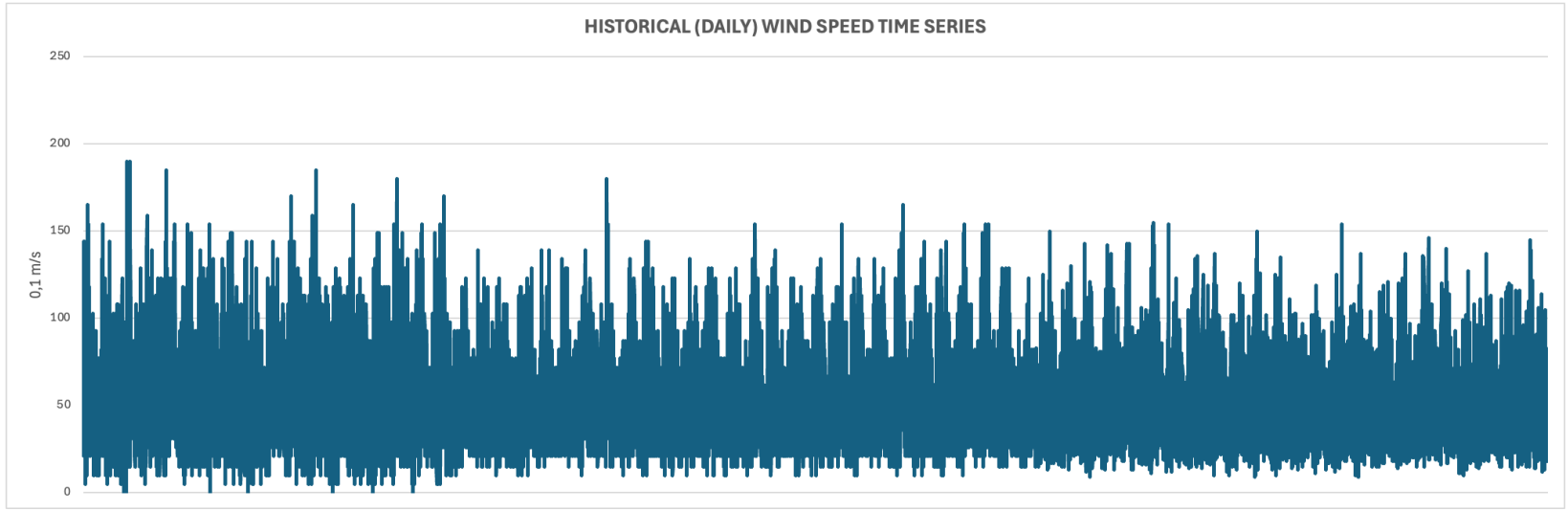
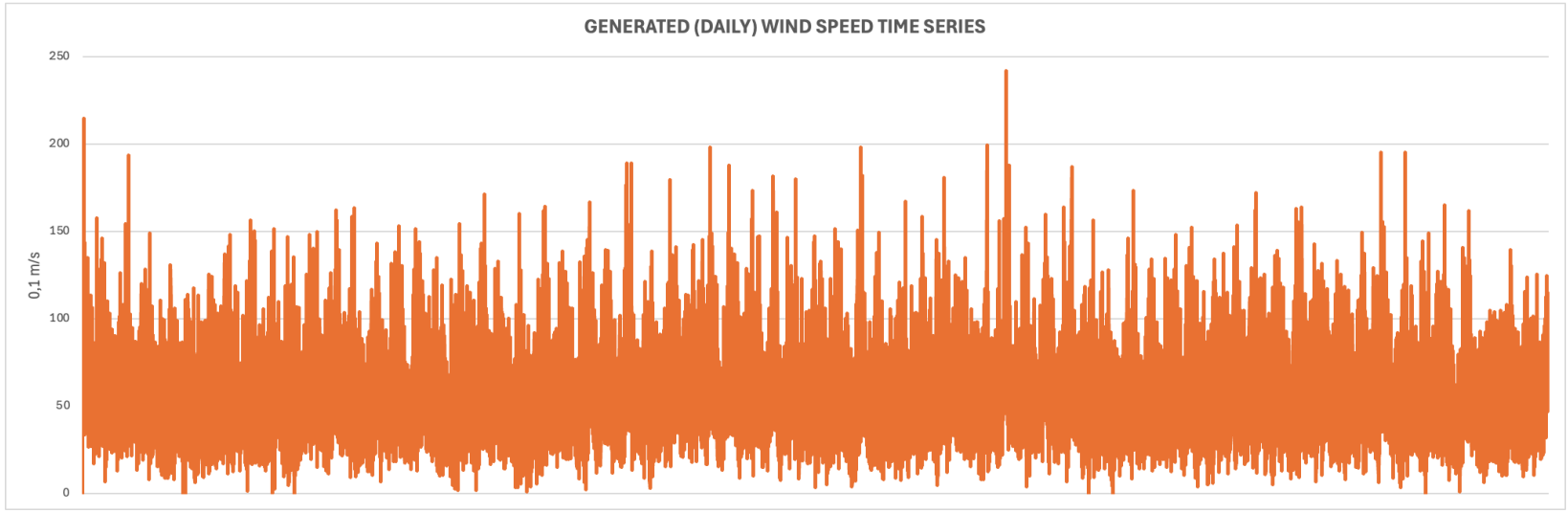
HISTORICAL VS SYNTHETIC TIME SERIES





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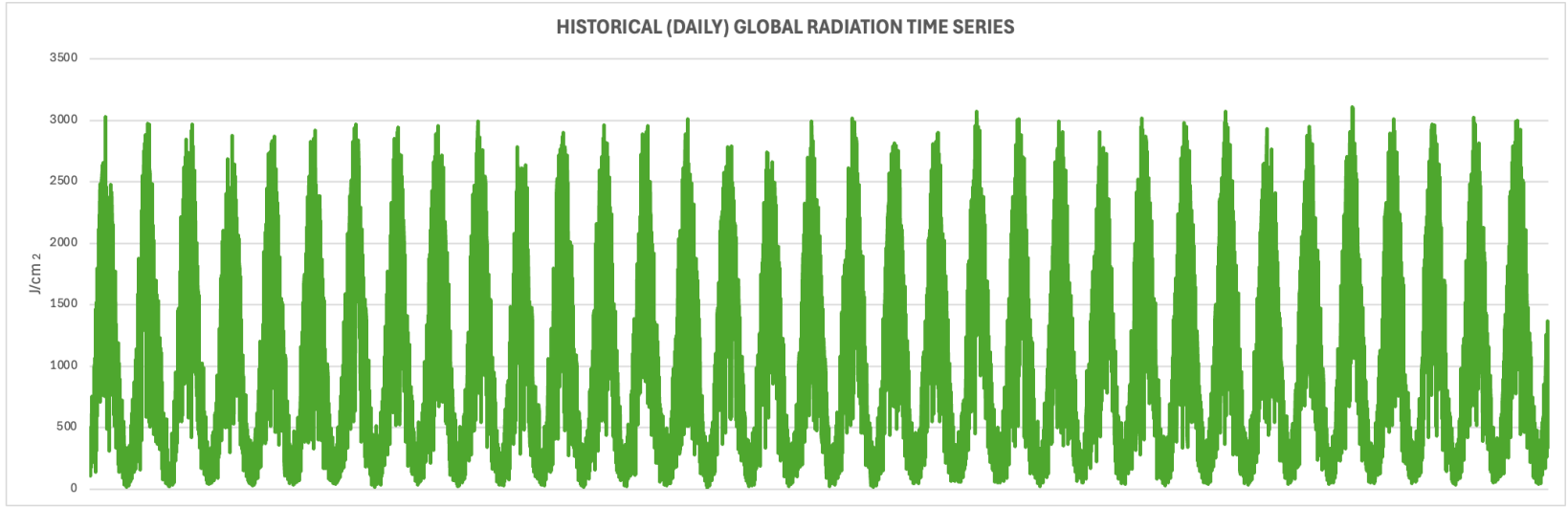
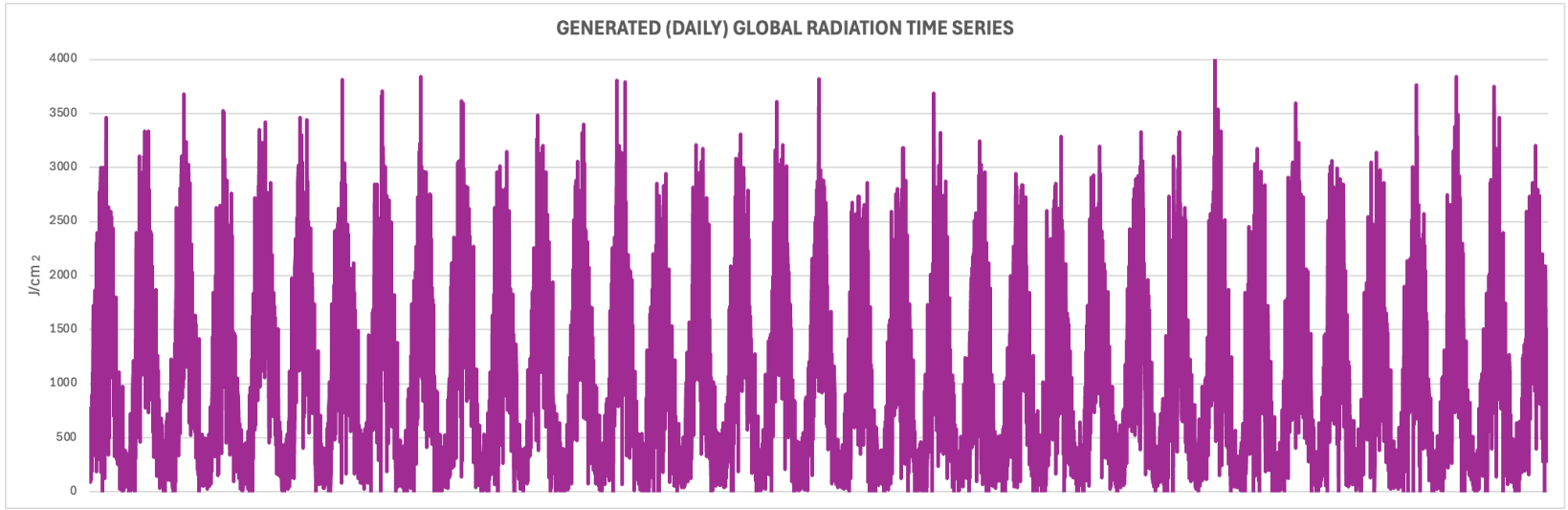
HISTORICAL VS SYNTHETIC TIME SERIES





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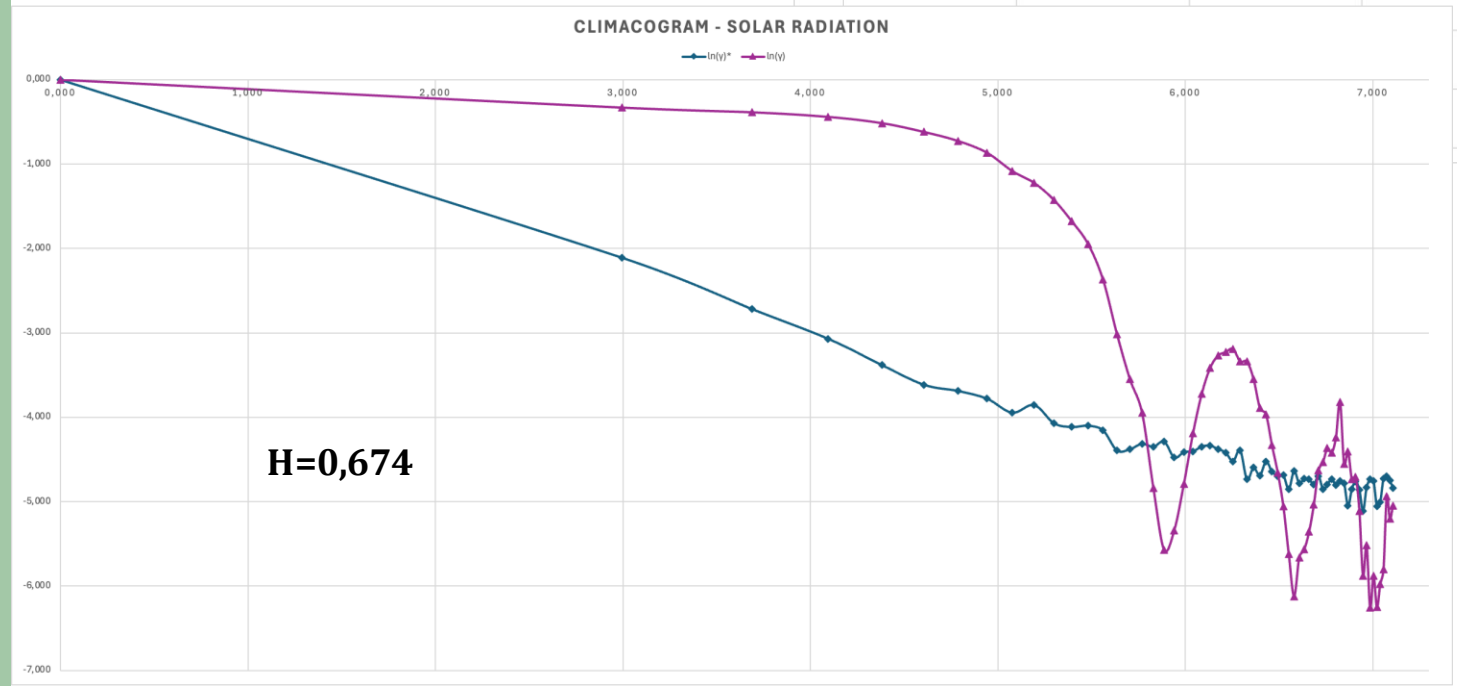
CLIMACOGRAM AND HURST – KOLMOGOROV DYNAMICS



$$\gamma(k) = \lambda^2 \left(\frac{a}{k}\right)^{(2-2H)}$$

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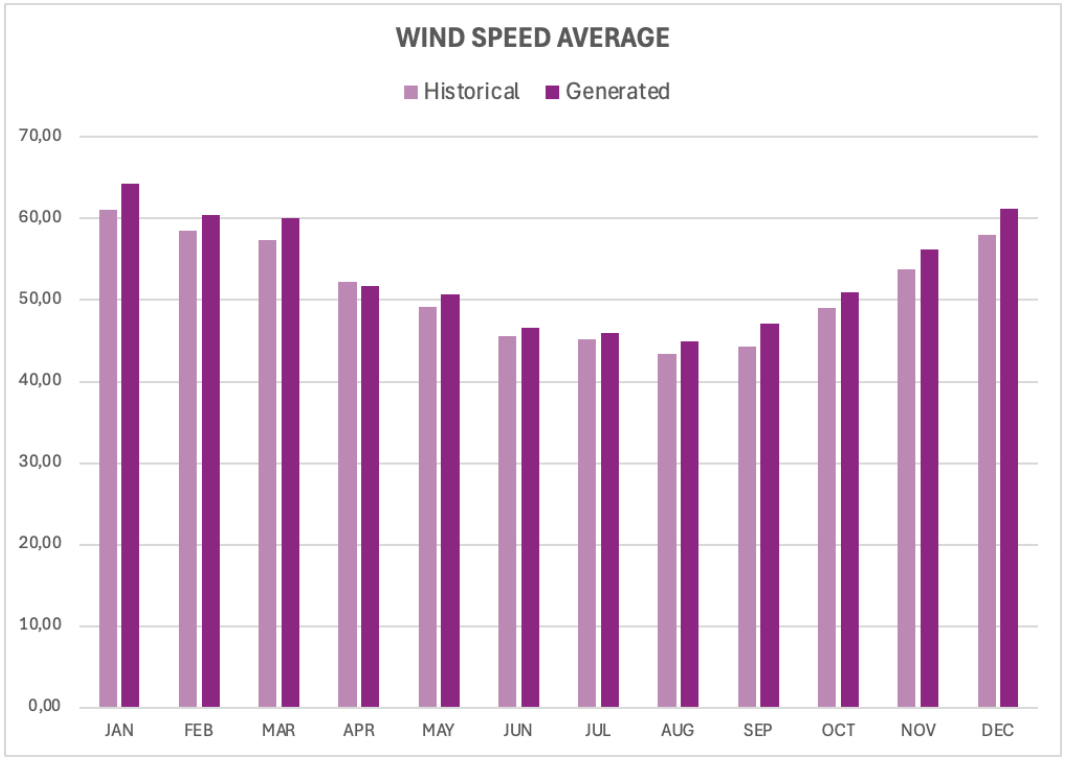
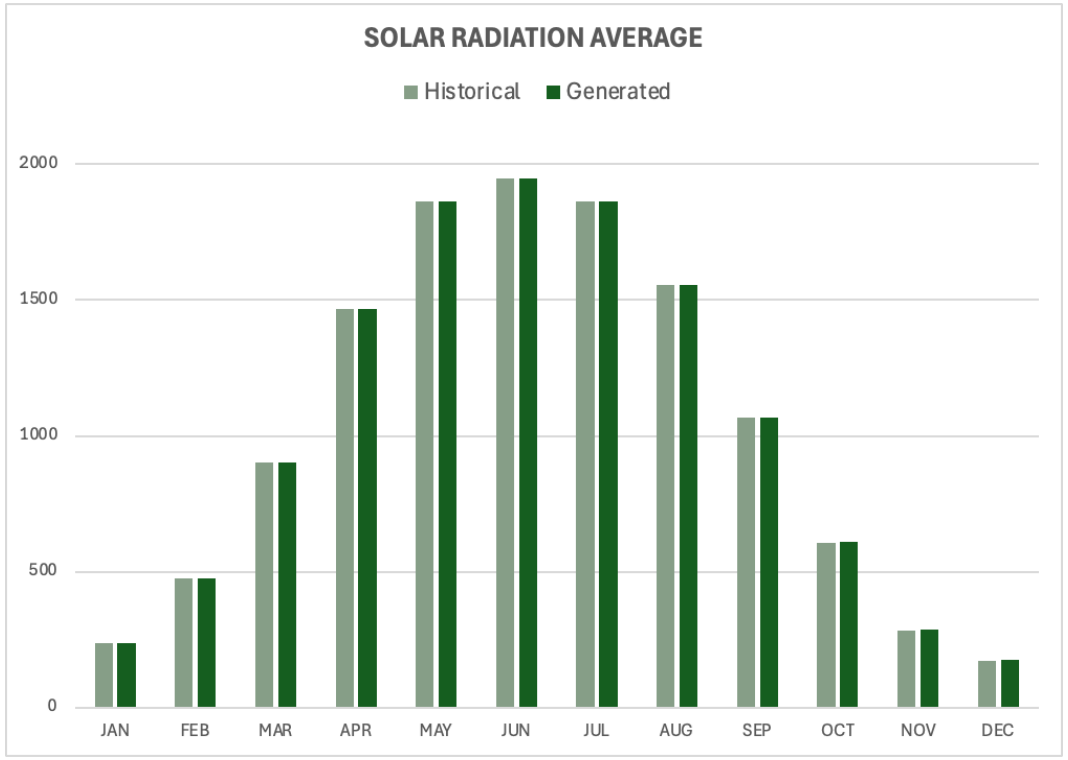
AVERAGE BY MONTH

Comparing historical and simulation moments





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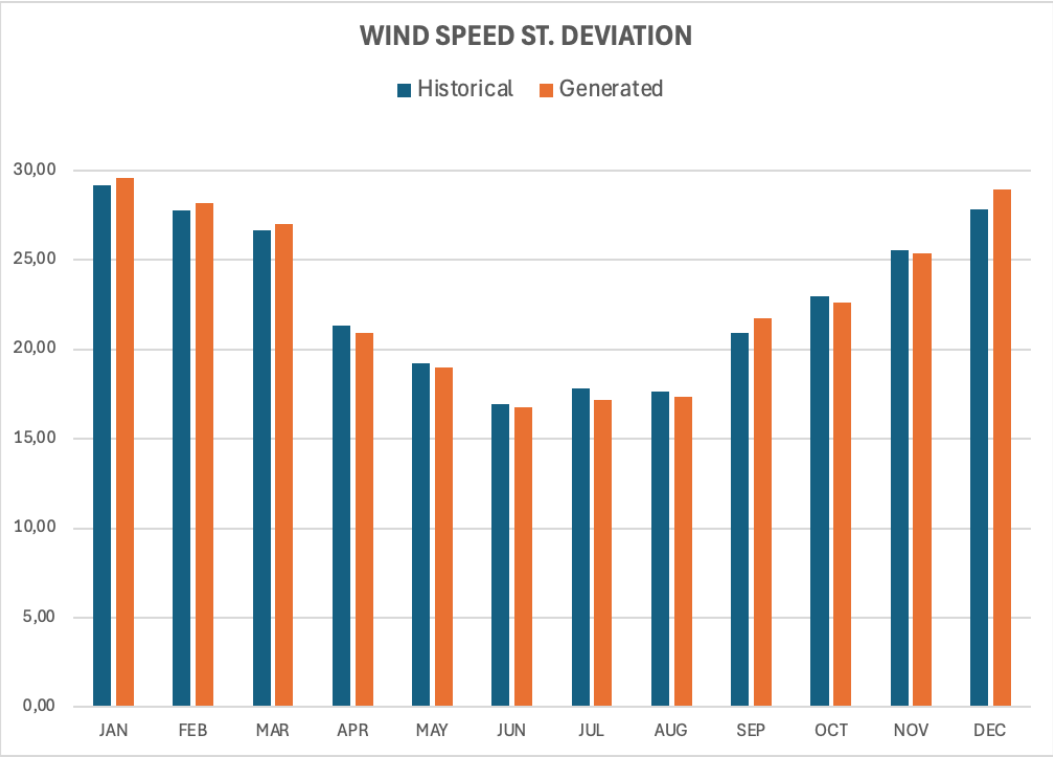
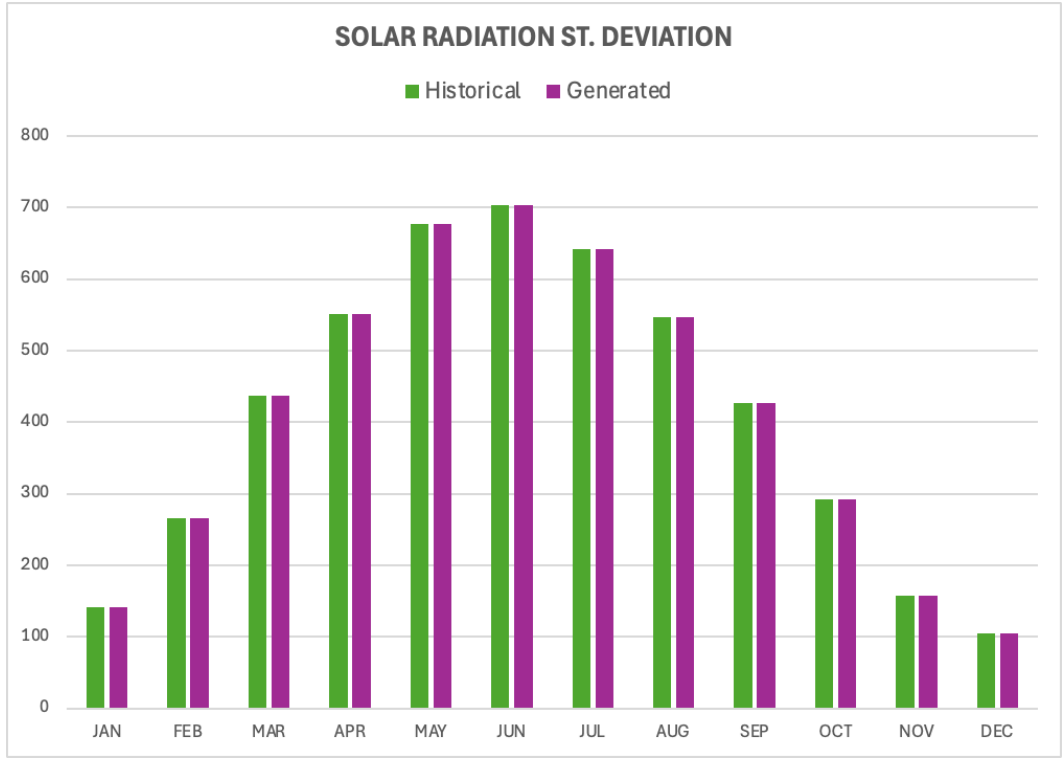
STANDARD DEVIATION BY MONTH

Comparing historical and simulation moments





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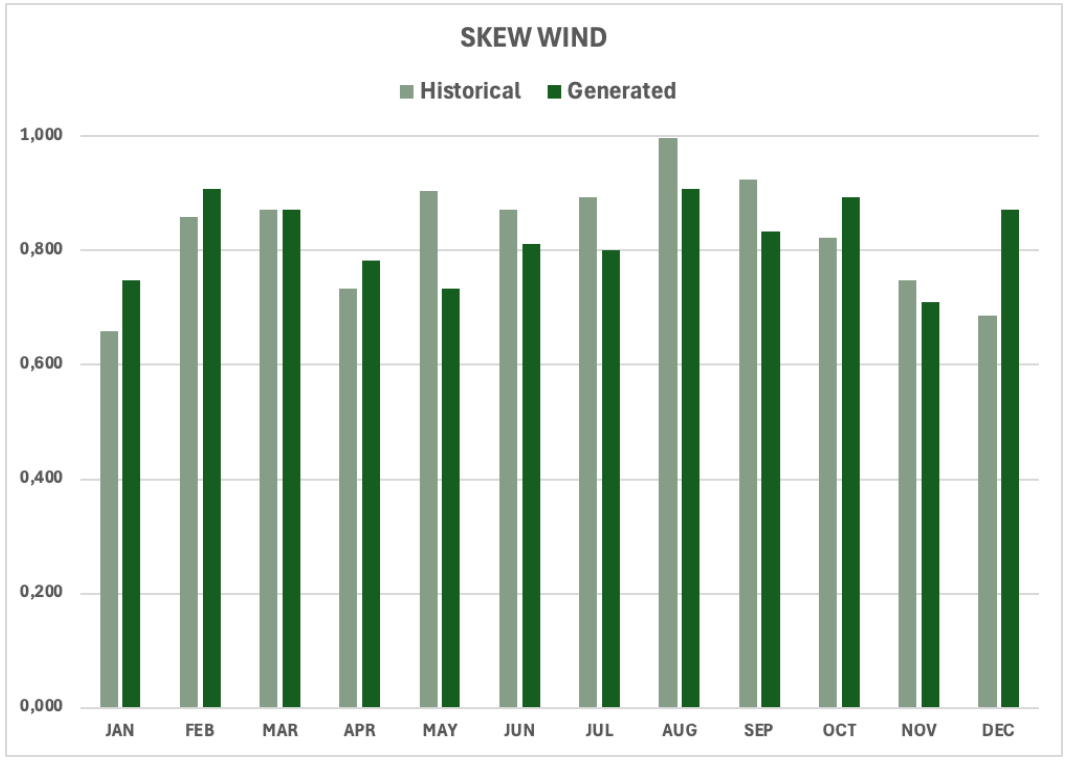
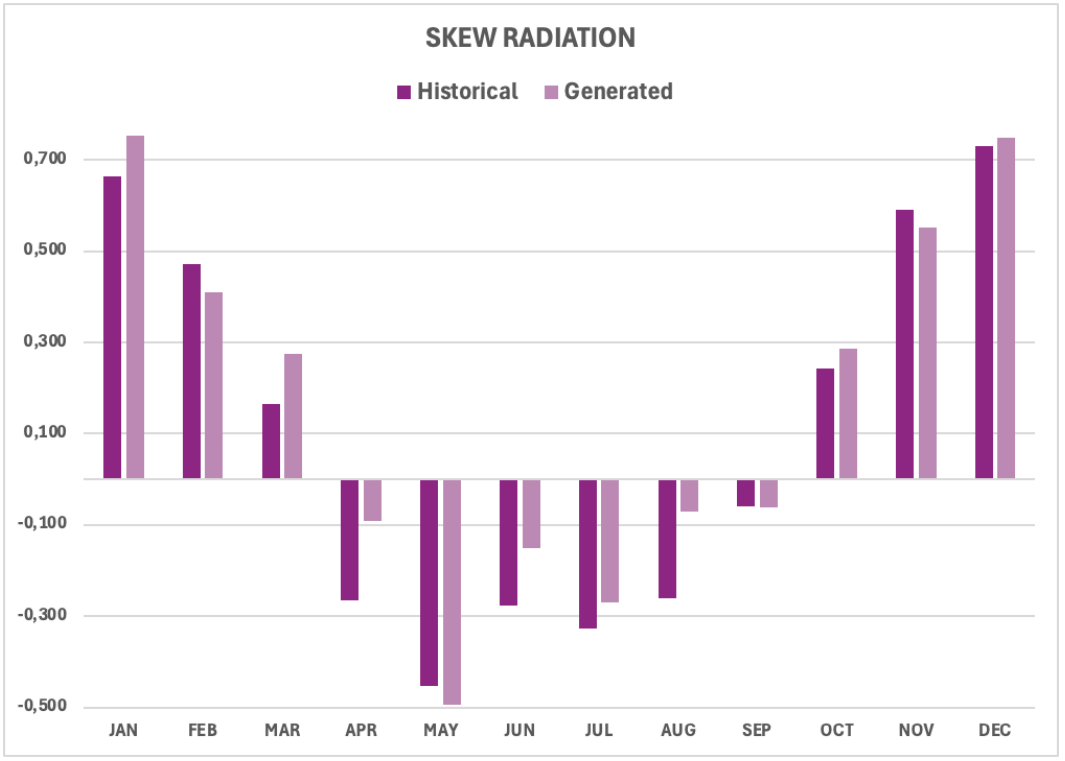
SKEWNESS BY MONTH

Comparing historical and simulation moments





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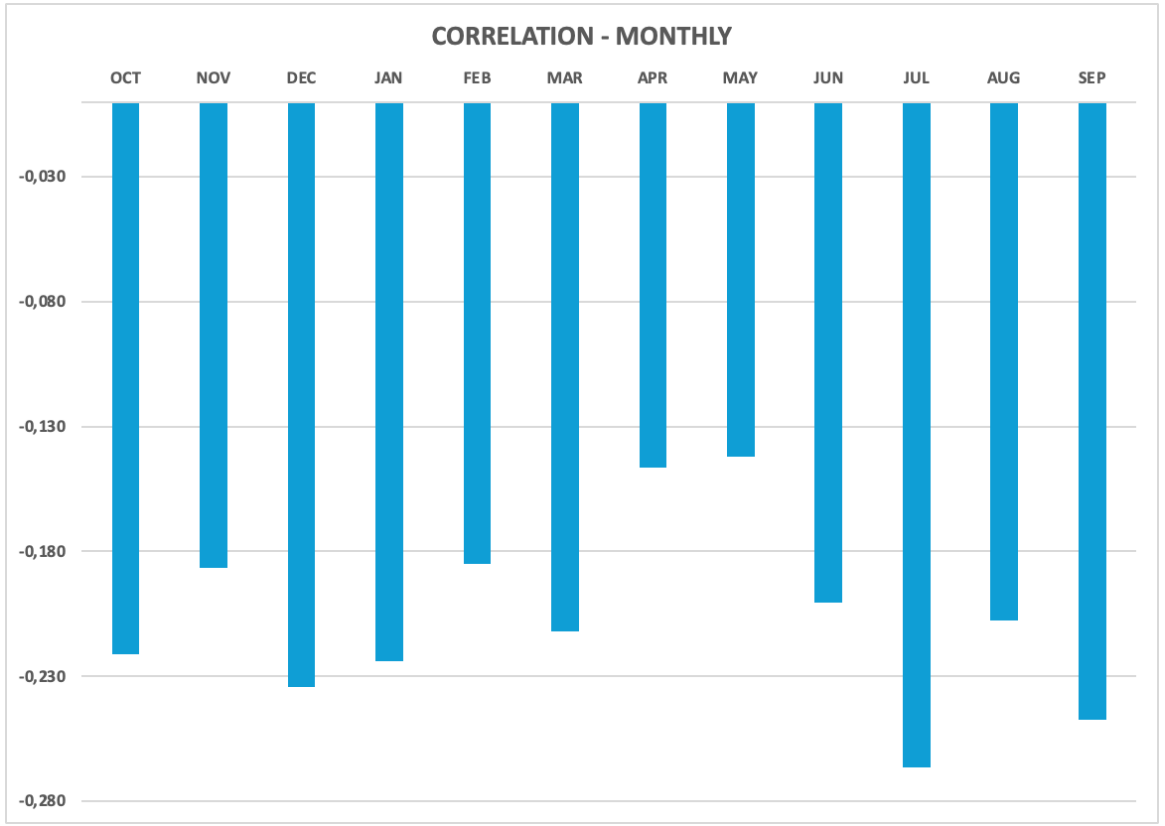
CORRELATION BETWEEN NATURAL PROCESSES



	Correlation
OCT	-0,221
NOV	-0,187
DEC	-0,234
JAN	-0,224
FEB	-0,185
MAR	-0,212
APR	-0,146
MAY	-0,142
JUN	-0,201
JUL	-0,267
AUG	-0,207
SEP	-0,247

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SYMMETRIC MOVING AVERAGE SCHEME

The **Symmetric Moving Average (SMA)** scheme was introduced by **Koutsoyiannis (2000)** and transforms a white noise sequence v_ι into a sequence x_i with autocorrelation according to the equation:

$$x_\tau = \sum_{j=-J}^{J} a_{|j|} \nu_{\tau+j} = a_J \nu_{\tau-J} + \ldots + a_1 \nu_{\tau-1} + a_0 \nu_\tau + a_1 \nu_{\tau+1} + \ldots + a_J \nu_{\tau+J}$$

where the $\boldsymbol{a_j}$ are weighting coefficients and the number $\boldsymbol{J}$ is theoretically infinite but in practice it is taken as a finite value. The method is suitable for random autocorrelation functions. In the case of simple scaling models, it is shown that the weighting coefficients are:

$$a_\eta \approx \frac{\sqrt{(2-2H)\gamma_1}}{3-2H} \left((|\eta+1|^{H+0.5} + |\eta-1|^{H+0.5} - 2|\eta|^{H+0.5}) \right)$$

The method can also preserve the asymmetry coefficient $C_s^{(x)}$ of x_i if the white noise v_i has asymmetry coefficient, $C_v^{(x)}$ given by:

$$\left(a_0^3 + 2 \sum_{j=1}^{q} a_j^3 \right) C_S^{(v)} = C_S^{(x)} \gamma(1)^{3/2}$$

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FITTING EFFECT

WIND

- Weibull Distribution
- Gamma Distribution
- Pareto Distribution

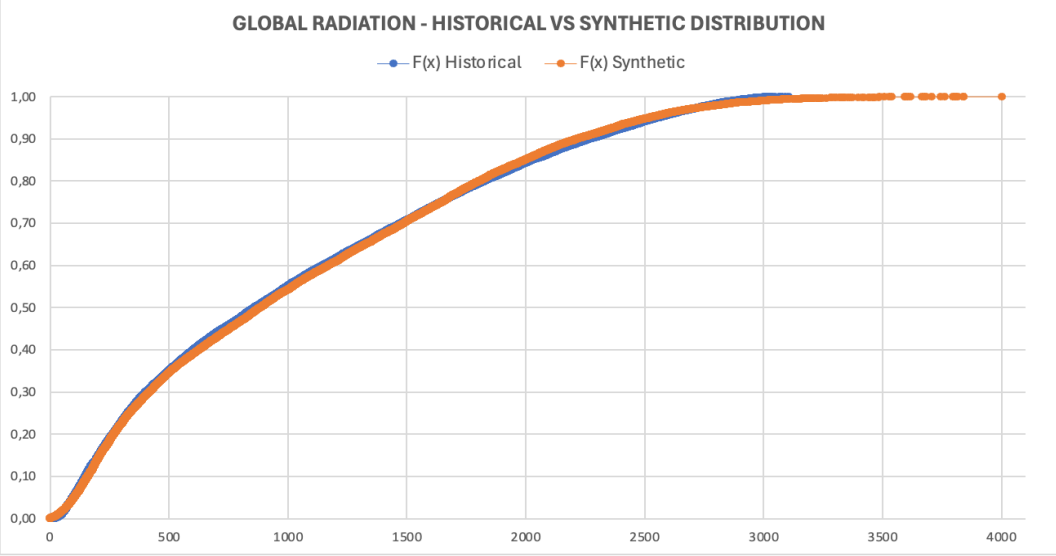
SOLAR RADIATION

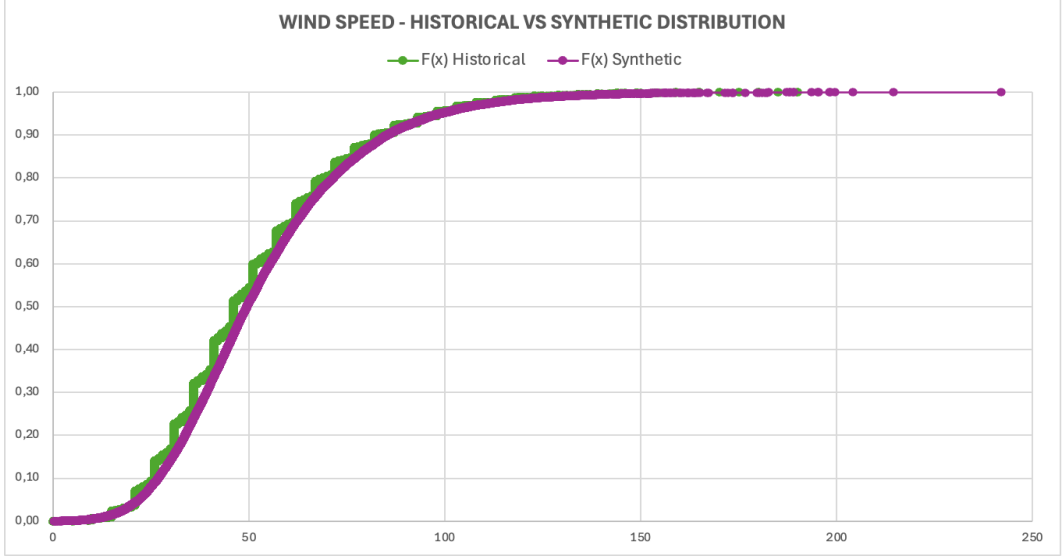
- Kumaraswamy Distribution
- Beta Distribution

CRITERIA

- Mean Average Error
- Mean Logarithmic Square Error
- Root Mean Square Error
- Maximum Likelihood Method

SYMMETRIC MOVING AVERAGE SCHEME





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