Sharing is encouraged

“Investigation of stochastic similarities between wind and waves and their impact on offshore structures”

Sofia Efraimia Vrettou, Alexandra Trompouki, Theano Iliopoulou, G.-Fivos Sargentis, Panayiotis Dimitriadis, Demetris Koutsoyiannis

Department of water and environmental resources engineering

School of civil engineering

National Technical University of Athens

European Geosciences Union

source:fkg.org

Introduction

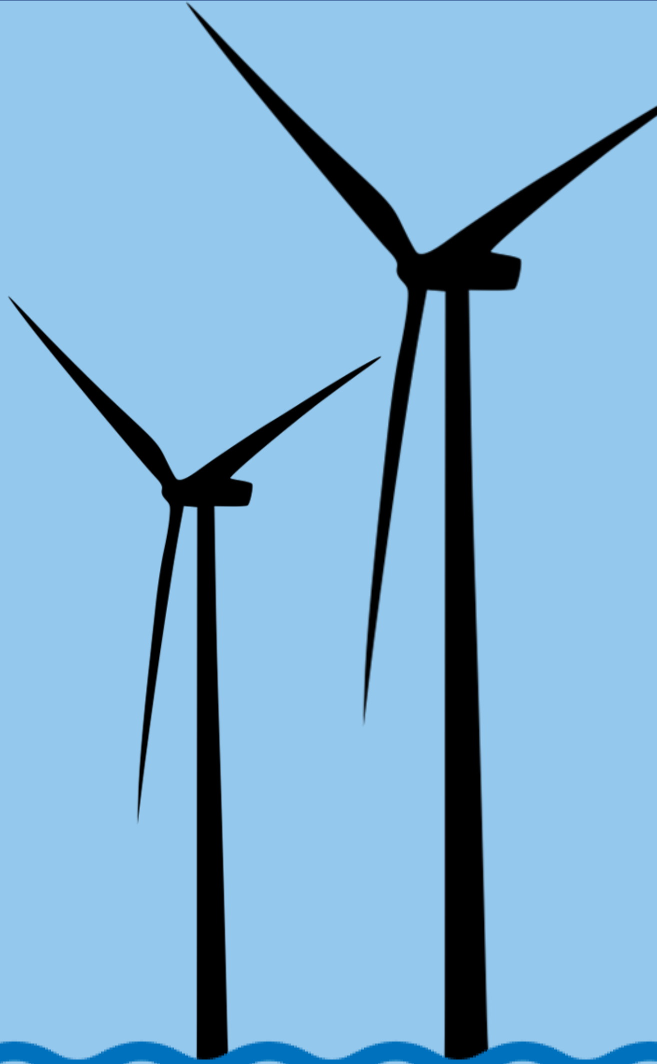
- Fatigue decreases energy production or in some cases causes failure.

- Fatigue originates from the wind and waves.

In this work we examine the similarities among the :

- marginal moments
- correlation function
- seasonality

of the wind velocity and the wave height and period.



Data source

Data source: Poseidon system [1]

Type of data: wind and wave(height and period) time series

Gauging station: Athos,
Latitude**:** 39.975
Longitude**:** 24.7294

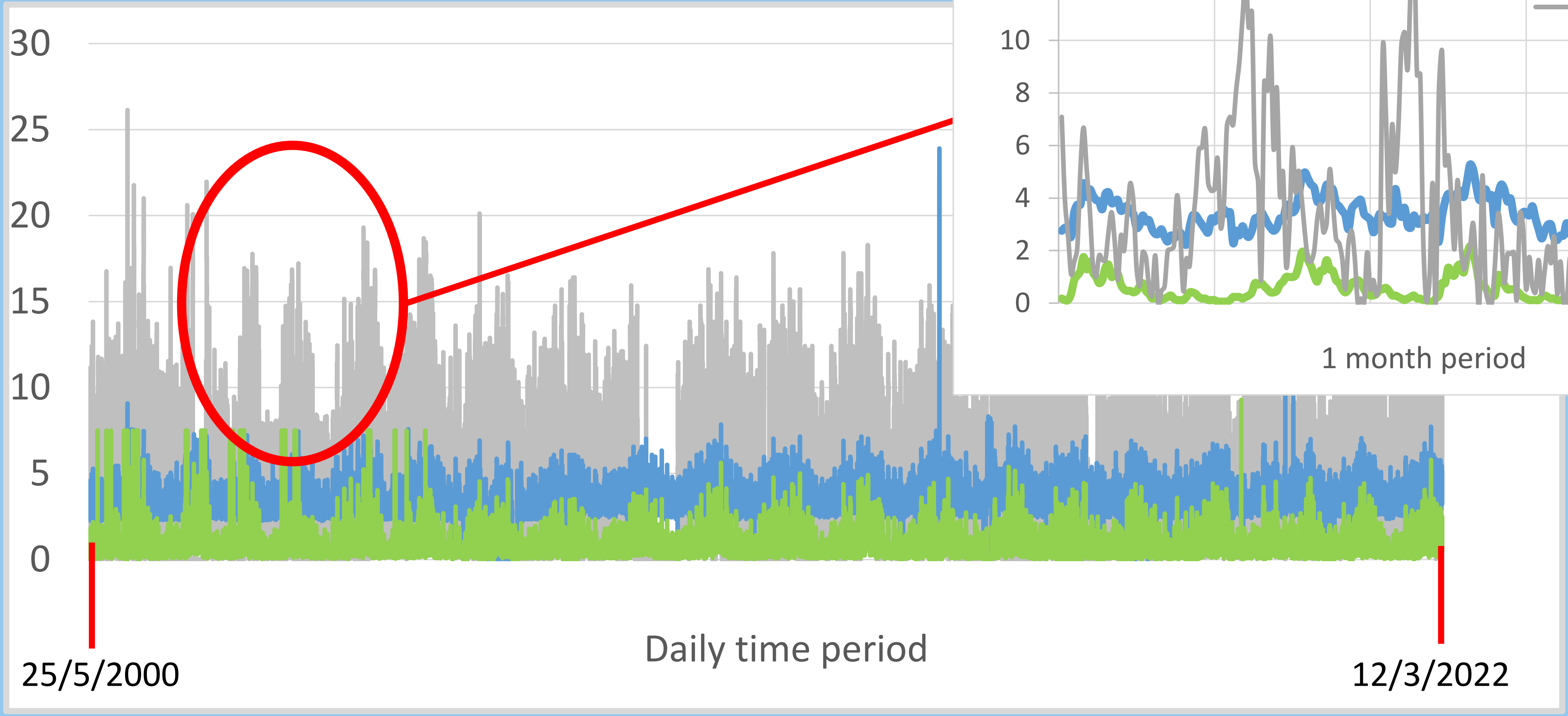
First date: 25/5/2000
Last date: 12/3/2022

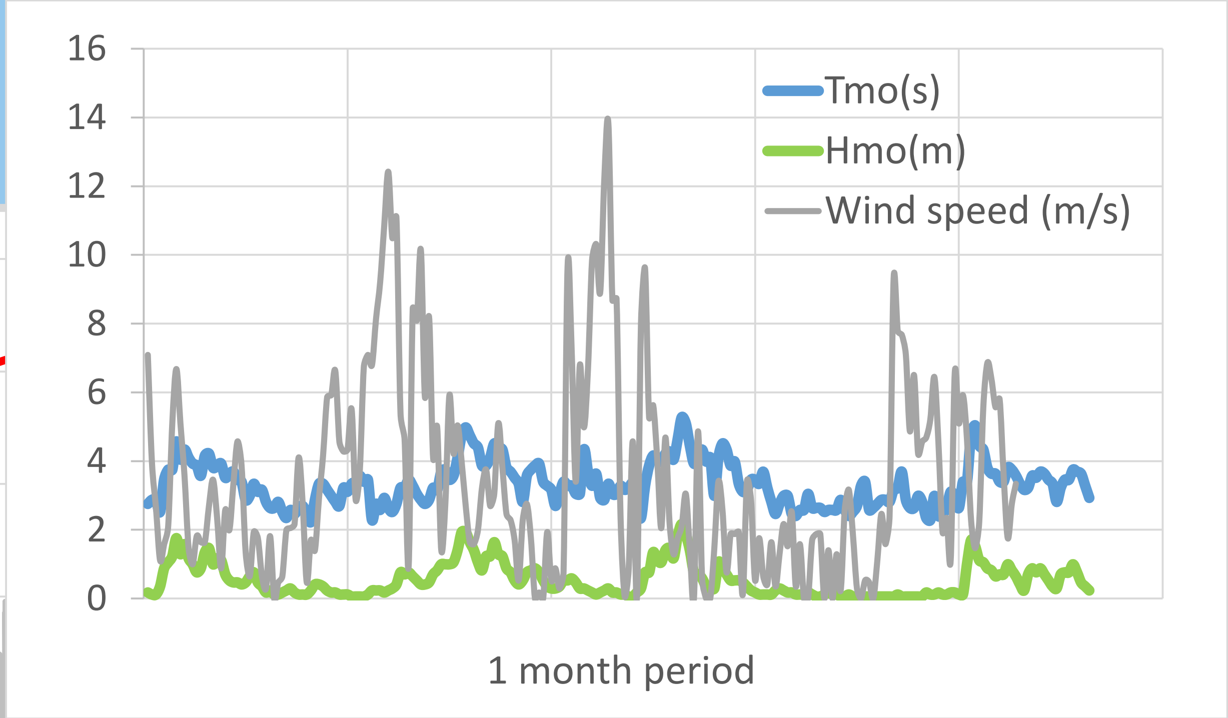
Amount of data: 53533 values

source:worldometers

Timeseries

Station of Athos, 22-year time series:





Marginal moments

Calculation of the marginal moments [2]:

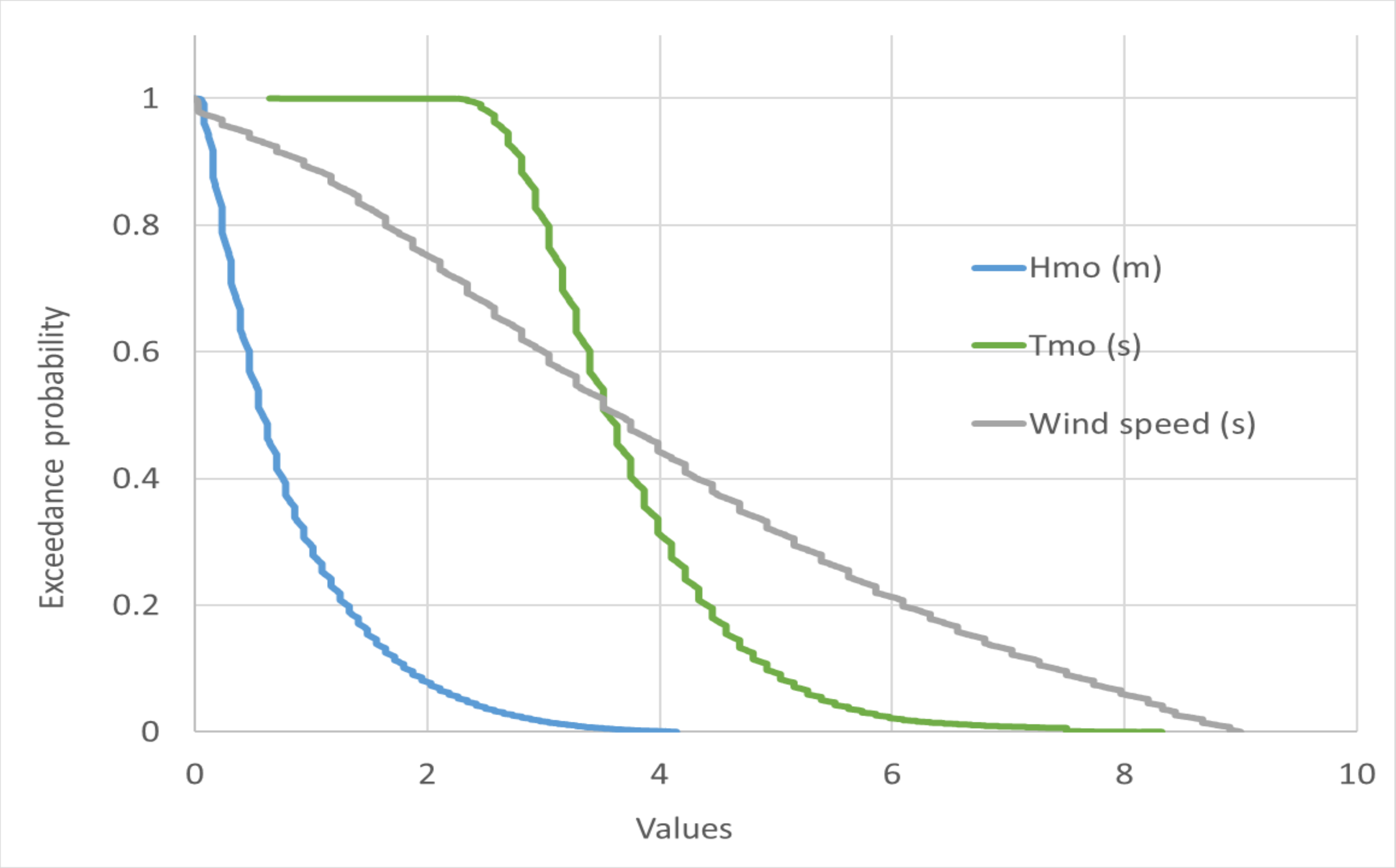
Tmo (s)	
mean	3.75
st.dev.	0.90
skewness	1.68
kurtosis	12.93

Hmo (m)	
mean	0.86
st.dev.	0.88
skewness	3.07
kurtosis	16.04

Wind speed (m/s)	
mean	4.79
st.dev.	3.35
skewness	0.93
kurtosis	0.67

Probability distribution function

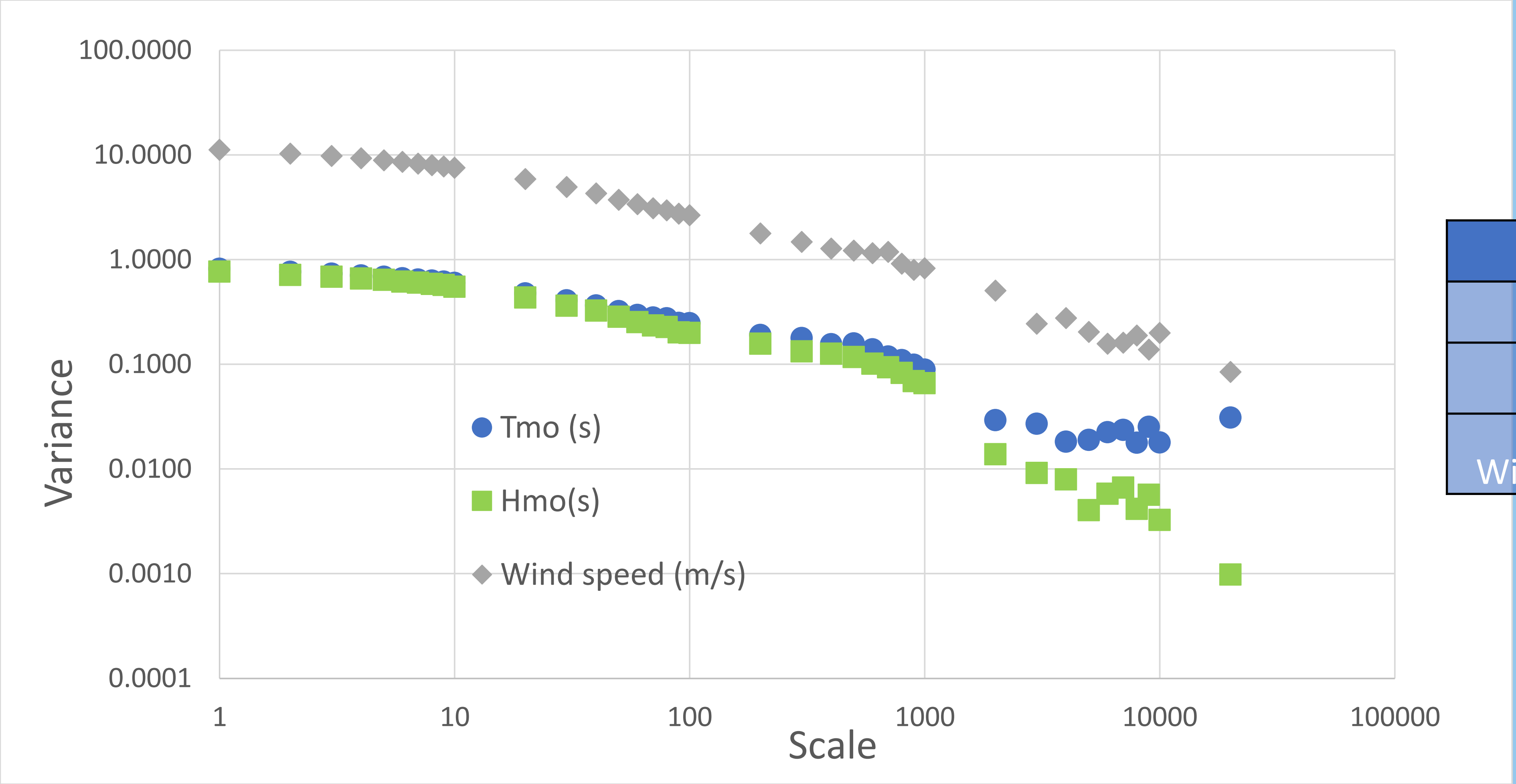
Survival function [3]:



$\bar{F}(x) := P\{\underline{x} > x\} = 1 - F(x)$, [3]

Cross correlation

Climacogram [4]:



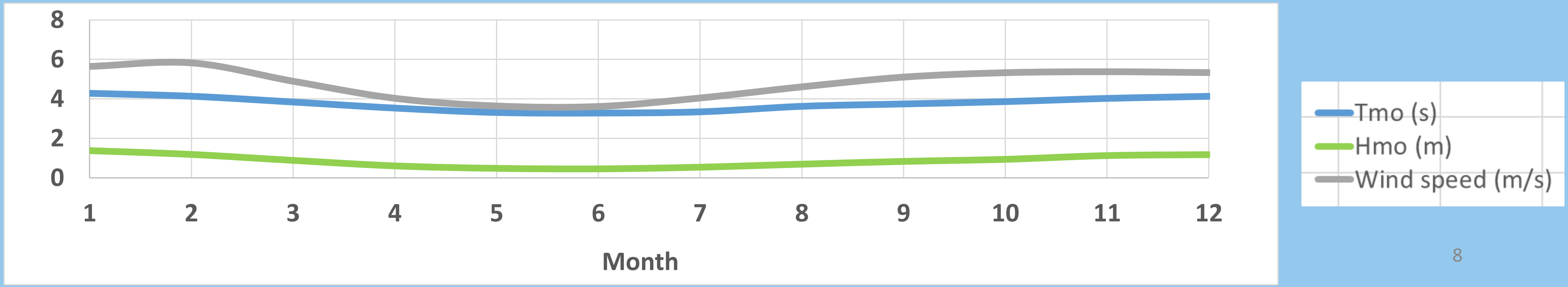
Parameter	Hurst
To(s)	0.79
Hmo(m)	0.77
Wind speed(m/s)	0.76

Seasonality

Month	Tmo(s)
January	4.28
February	4.13
March	3.84
April	3.53
May	3.31
June	3.28
July	3.34
August	3.62
September	3.74
October	3.86
November	4.02
December	4.13

Month	Hmo(m)
January	1.38
February	1.19
March	0.89
April	0.61
May	0.48
June	0.46
July	0.54
August	0.69
September	0.83
October	0.94
November	1.13
December	1.18

Month	Wind speed(m/s)
January	5.64
February	5.82
March	4.89
April	4.03
May	3.64
June	3.61
July	4.04
August	4.61
September	5.10
October	5.33
November	5.37
December	5.33



Wind loads equation

Aerodynamic forces [5]:

$$Xw = \frac{1}{2}\rho_{air} V^2{}_{rw} \cdot C_{Xw}(a_{rw}) A_T$$

$$Yw = \frac{1}{2}\rho_{air} V^2{}_{rw} \cdot C_{Yw}(a_{rw}) A_L$$

$$Nw = \frac{1}{2}\rho_{air} V^2{}_{rw} \cdot C_{Xw}(a_{rw}) A_L \cdot L$$

- Xw : wind force at x axis
- Yw: wind force at y axis
- Nw: wind moment at x axis
- ρ_{air}= ρ_{water}/800 : density of air
- V_{rw}: relative wind speed
- a_{rw}: relative wind acceleration
- A_T: transverse projected wind area
- A_L: lateral projected wind area
- L: length off offshore construction
- C_{*w}(αrw): wind acceleration constant

Wave loads equation

Hydrodynamic forces [6]:

$F(t) = F_I(t) + F_D(t)$

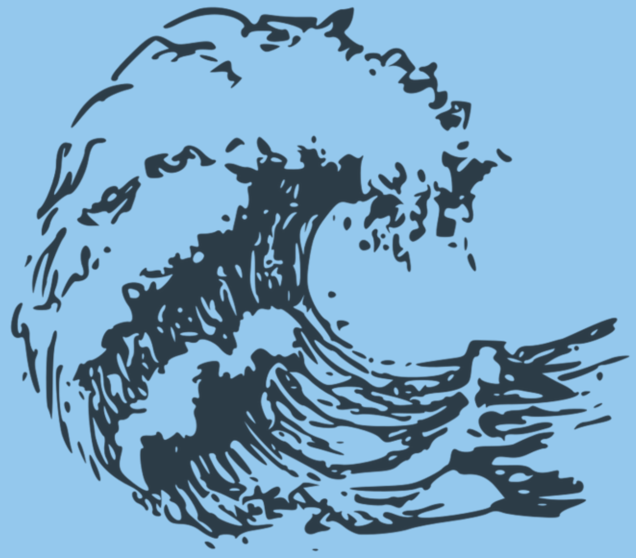
- $F(t)$: net force
- $F_I(t)$: inertial force
- $F_D(t)$: drag force

- $F_I = \frac{1}{2} M u^2$

F_I: inertial force
M: mass that was moved away due to the cylinder
u: system's velocity

- $F_D = \frac{1}{2} \rho U^2 C_D D$

F_D: drag force
ρ: mass density of the fluid
C_D: dimensionless coefficient
D: cylinder diameter
U: undistributed flow velocity



Quick look at the equations

$E[Xw] = [\frac{1}{2}\rho_{air}{V^2}_{rw} \cdot C_{Xw}(a_{rw})A_T] = \frac{1}{2}E[\rho_{air}]E[{V^2}_{rw}] \cdot E[C_{Xw}(a_{rw})]E[A_T]$

$Var[\underline{V}]=E[\underline{V}^2]$

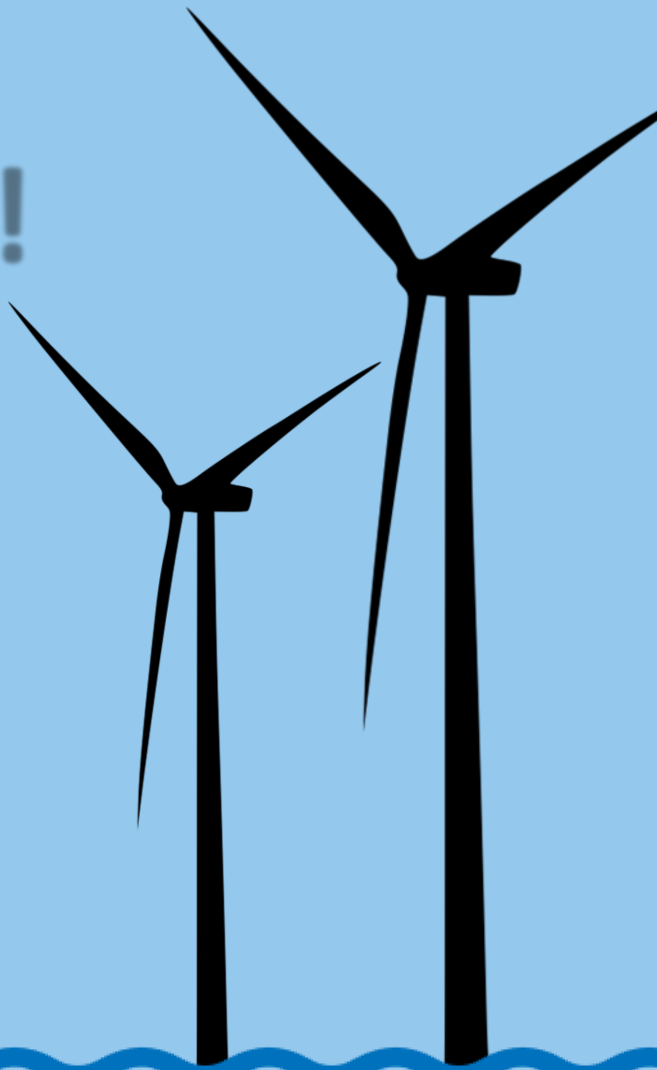
$Var[X]=\sigma^2 \geq 0$

$Var[\underline{V}]=E[(\underline{V}-m)^2]=E[\underline{V}^2]-2E[\underline{V}]E[m]+E[m]^2= E[\underline{V}^2]- E[m]^2 \geq 0, \quad E[\underline{V}^2] \geq E[m]^2$

Conclusions

- There are similarities among the marginal moments of the three parameters.
- Relevant Hurst ≈ 0.8 at the cross correlation process that indicates long term dependence.
- Similar seasonal behaviour.
- Results are in line with literature.
- Fatigue is related to the variability.
- For heavy tailed distributions it is suggested to take into account the variability i.e. the Climacogram.

Thanks for your attention!



[1]: https://poseidon.hcmr.gr/

[2]: D. Koutsoyiannis, *Statistical Hydrology*

[3]: D. Koutsoyiannis, *Stochastics of Hydroclimatic Extremes - A Cool Look at Risk*

[4]: D. Koutsoyiannis, Hurst-Kolmogorov dynamics and uncertainty

[5]: Massie& Journee: Offshore Hydromechanics, DELFT

[6]: [16]Κ.Μακρή: Υπολογισμός των Φορτίων με τύπο Morison, ΕΜΠ