

Improved Lumping method for fatigue damage estimation of offshore wind Turbines



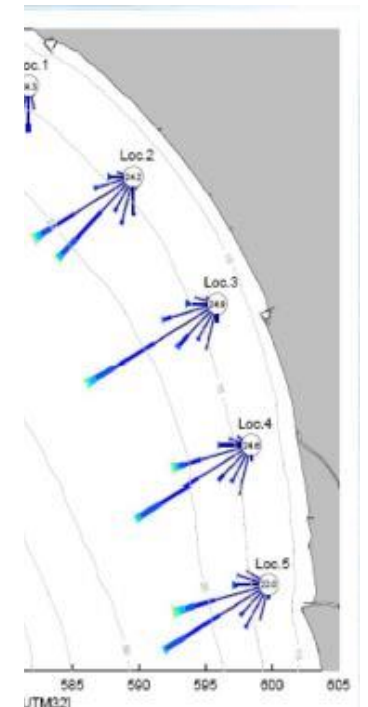
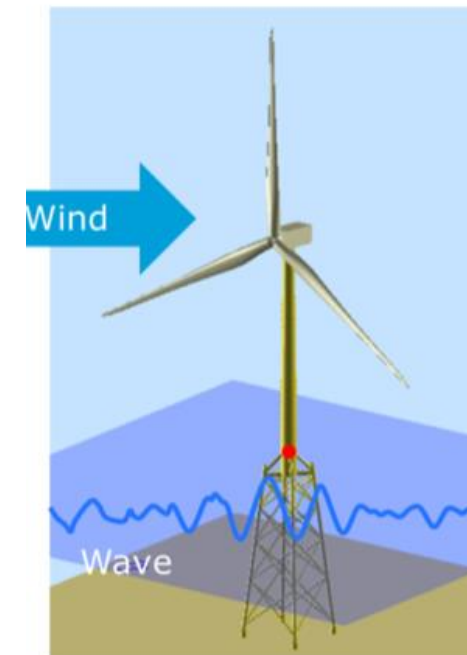
Alahyar Koochekali

Professor Michael Muskulus



What is Lumping of Sea states?

- Marine Structures - Coastal perturbation
- Random Wave - Wind in various directions
- Long term response of coast
- Fatigue damage of Wind turbine
- Dynamically sensitive structure
- Full sea state



What is Lumping of Sea states

Definition

Topic

Procedure

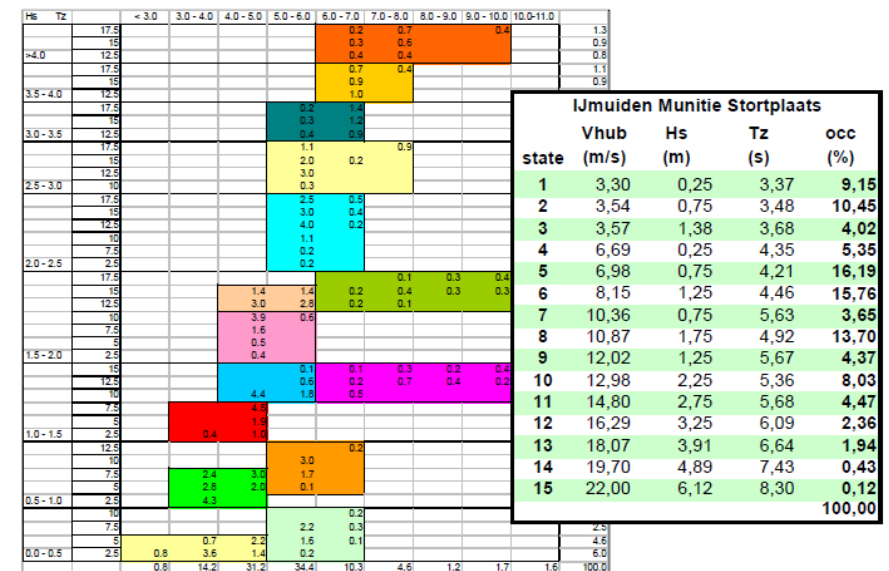
Input data

Calculations

Results

- Grouping of Random wave and wind (H_s, T_p, W_s)
- Average sea state
- Several Scatter Diagrams, Joint distribution
- Define Design Scenarios
- Correct Response?
- Sensitive structures accuracy

Copula



What is Copula?

- Joint dependence of X & Y fully and uniquely characterized

$$F_{X,Y}(x,y) = C(F_X(x), F_Y(y))$$

- Probability distribution of joints on $[0,1]^2$ Domain
- Application
 - Known Copula and the marginal, no need for joint data
 - Missing data
 - How good is it in determining the response for dynamic sensi

What is under investigation

- Find a Copula for North Sea
 - Lump Wind and wave based on Copula to:
 - Reduce number of simulations
 - correct fatigue damage estimation
 - Example:
 - wind speed range = 37
 - * wind & wave direction = 144
-
- scatter diagram = 5328

How to do that?

Definition

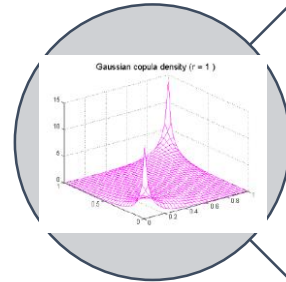
Topic

Procedure

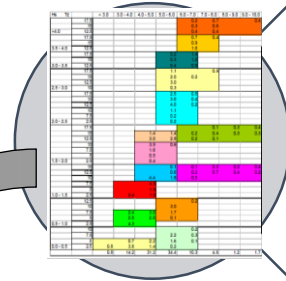
Input data

Calculations

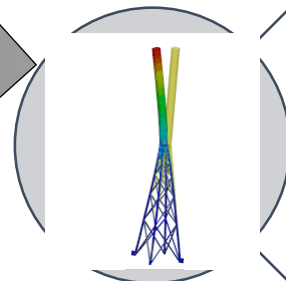
Results



Find Copula for North sea?
Joint distribution



Coming up with improved
lumping method



Simulation of dynamic
response and fatigue damage

Definition

Topic

Procedure

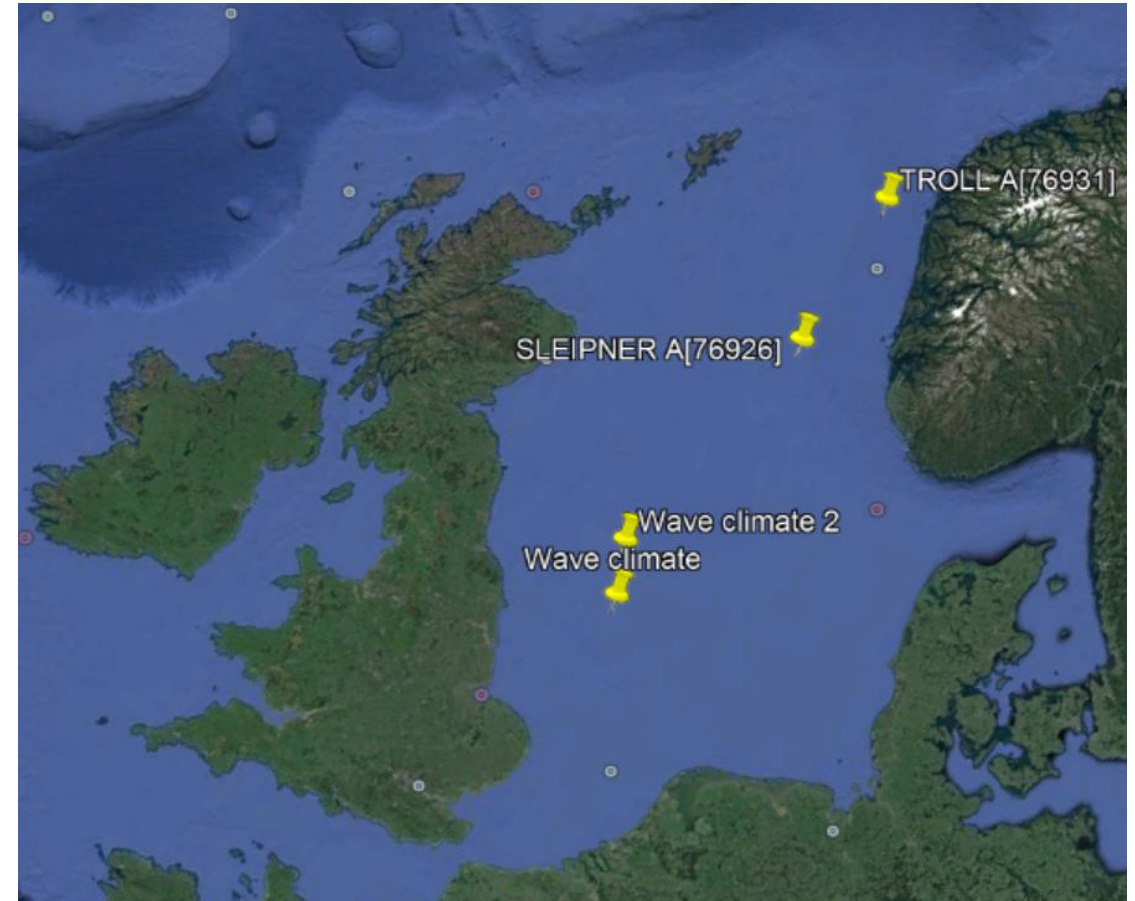
Input data

Calculations

Results

Input data

- 4 locations at North sea
 - Eklima.no
 - Wave climate
 - 15~25 Years



Long term measurements

Definition

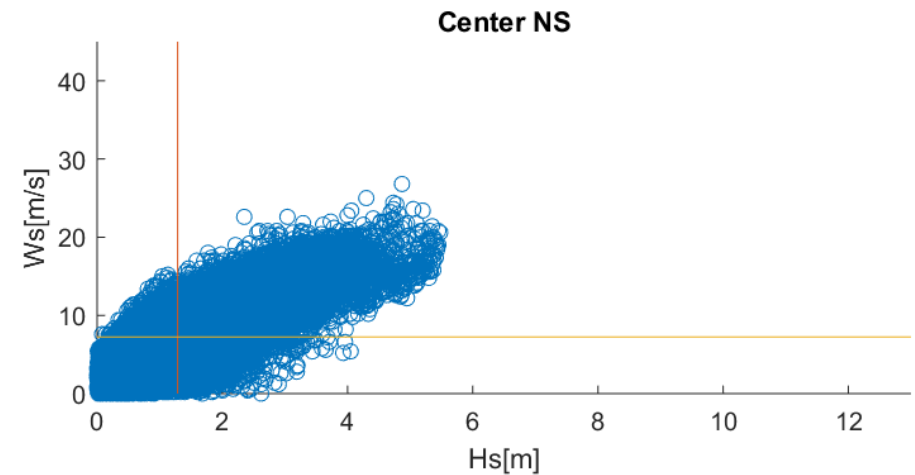
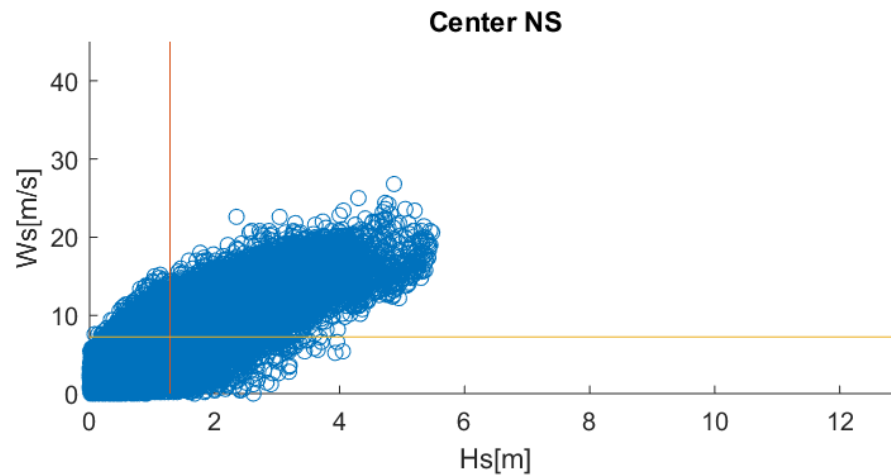
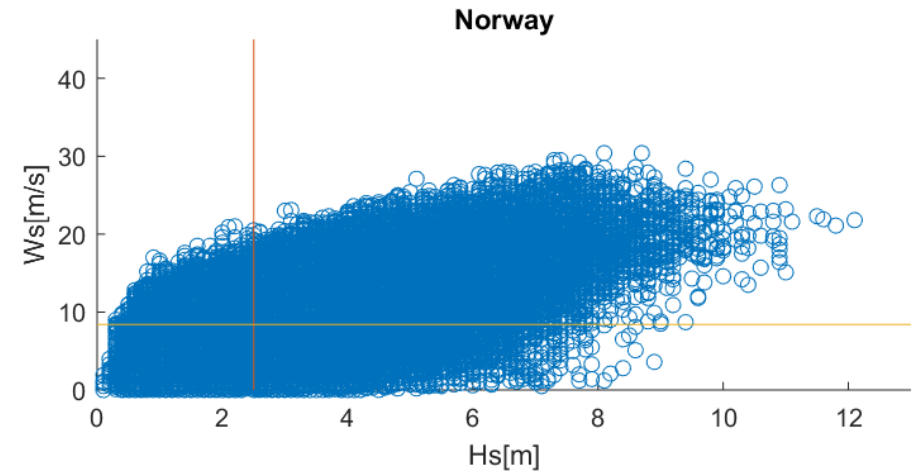
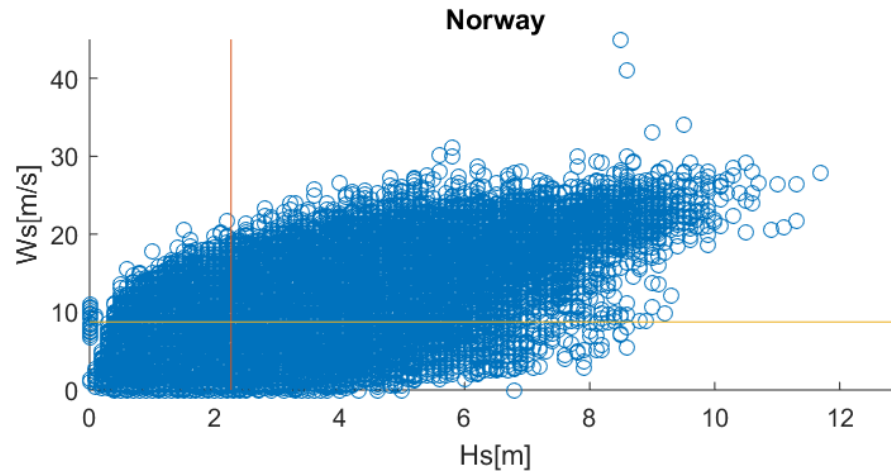
Topic

Procedure

Input data

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Results



One site example; raw data

Definition

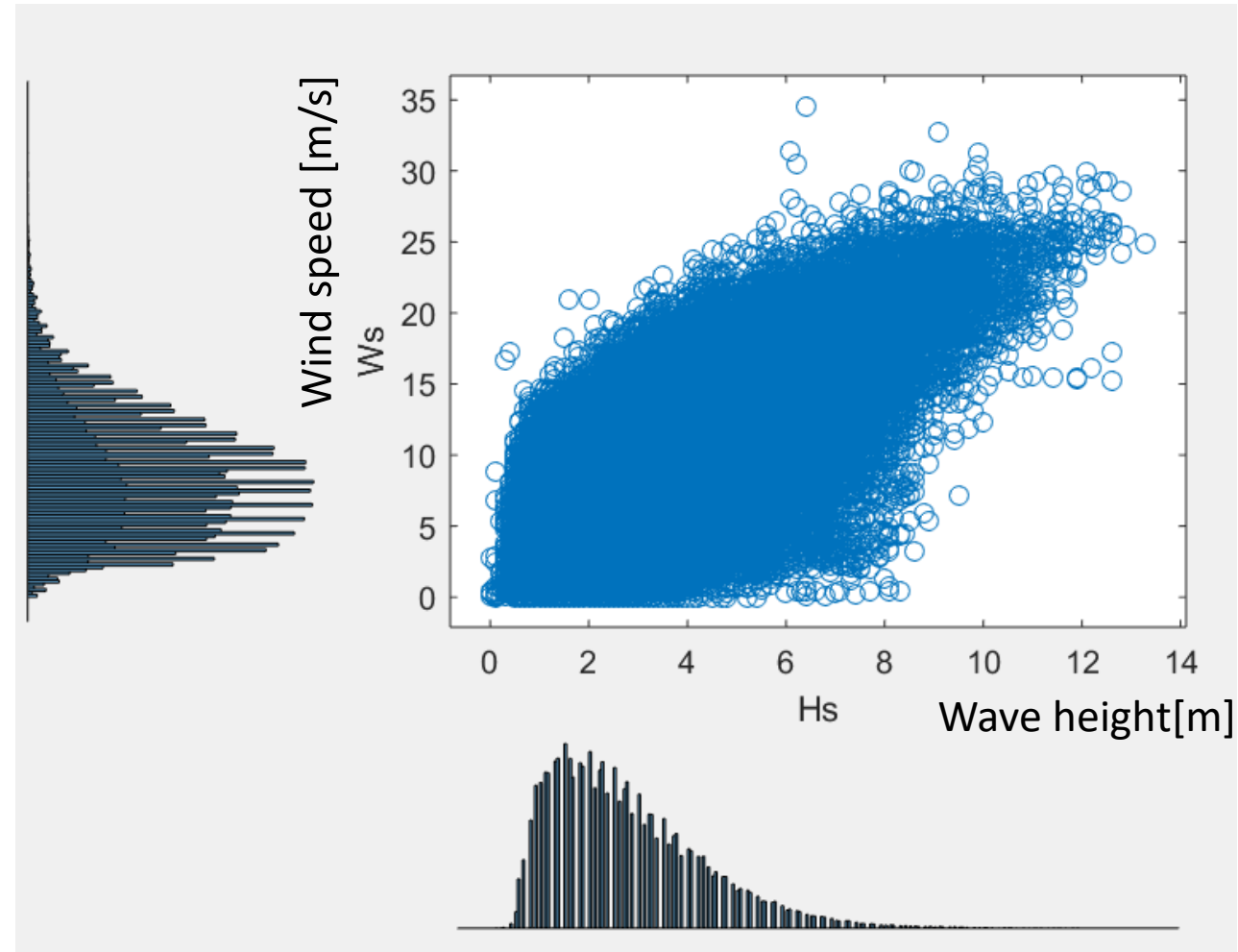
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Definition

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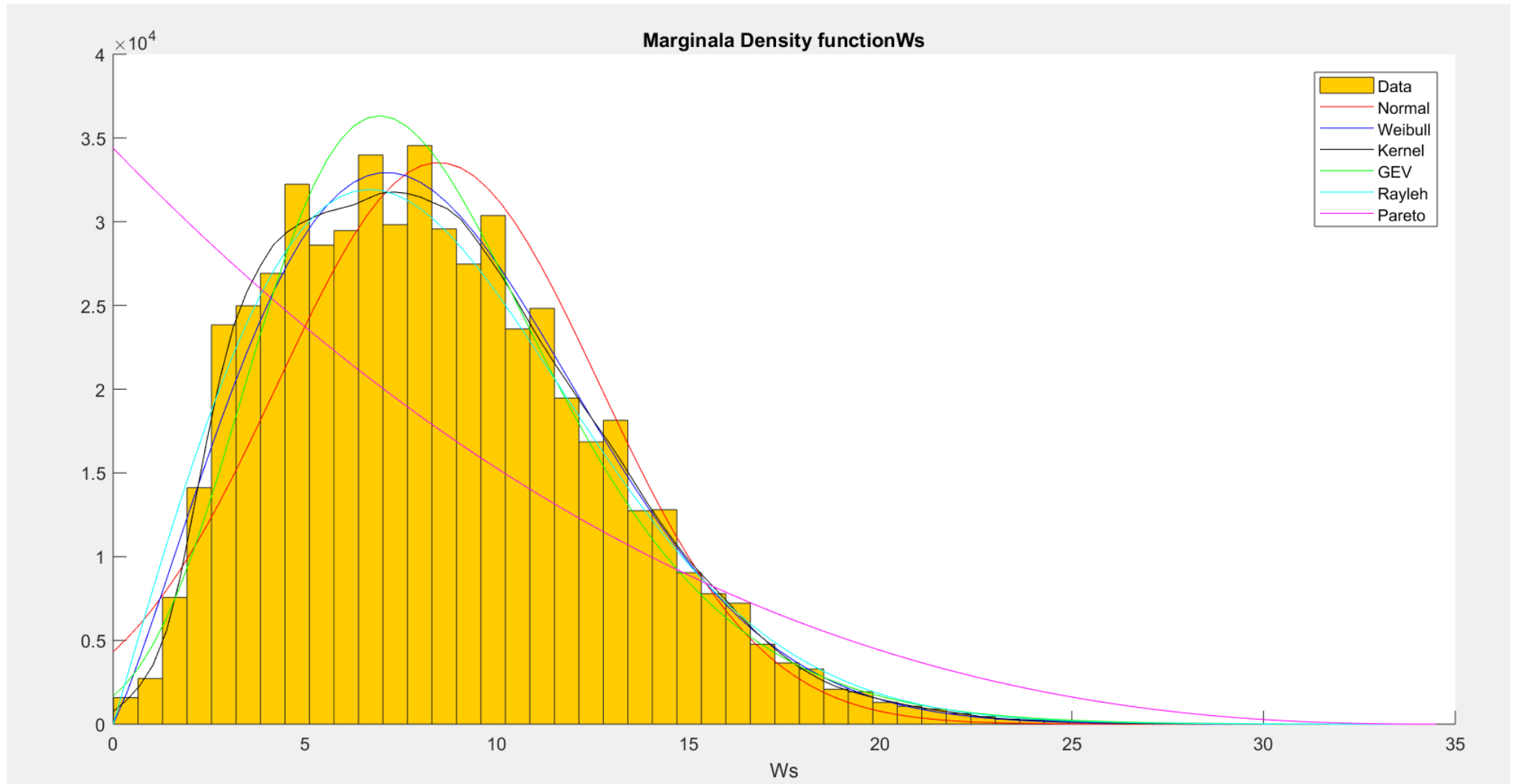
Procedure

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Fit Marginals_Weibull



Fit Marginals_Weibull

Definition

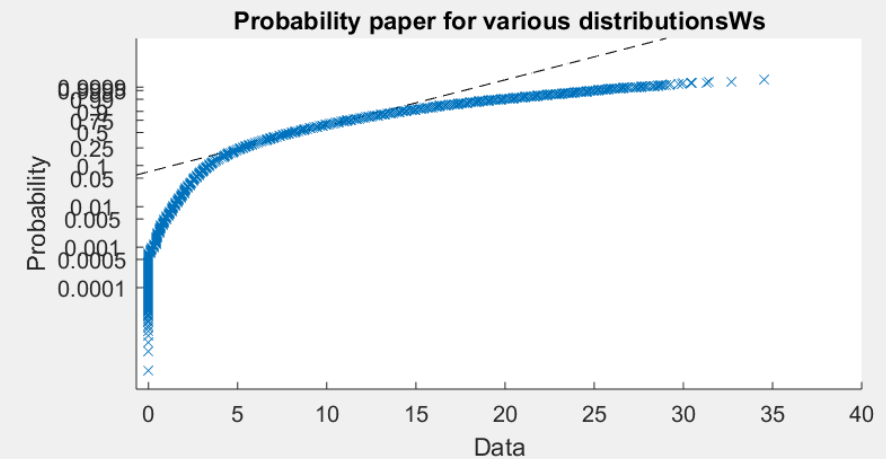
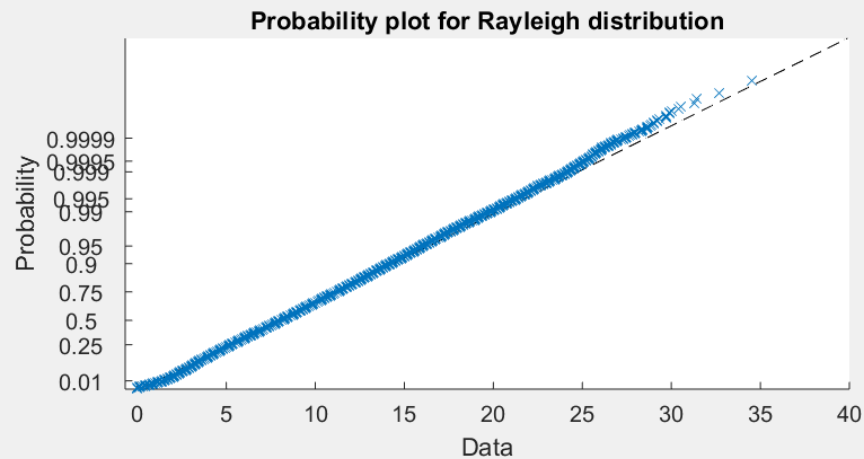
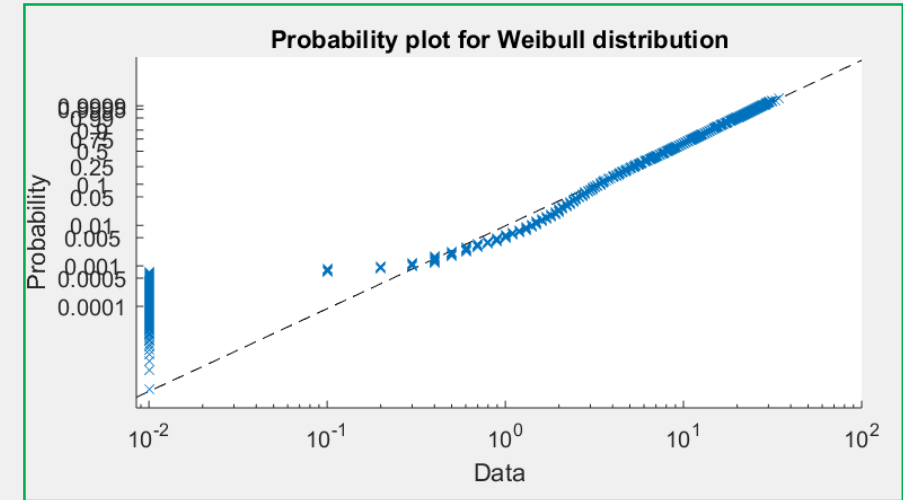
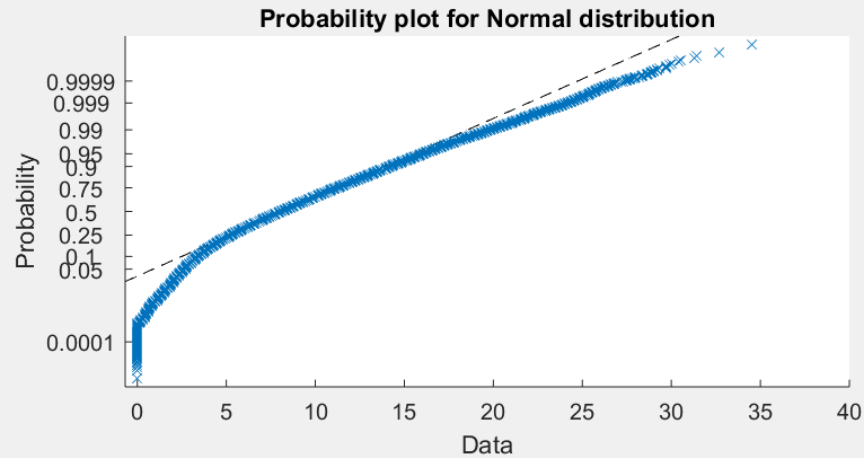
Topic

Procedure

Input data

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Sort data _ Rank vs Rank

Definition

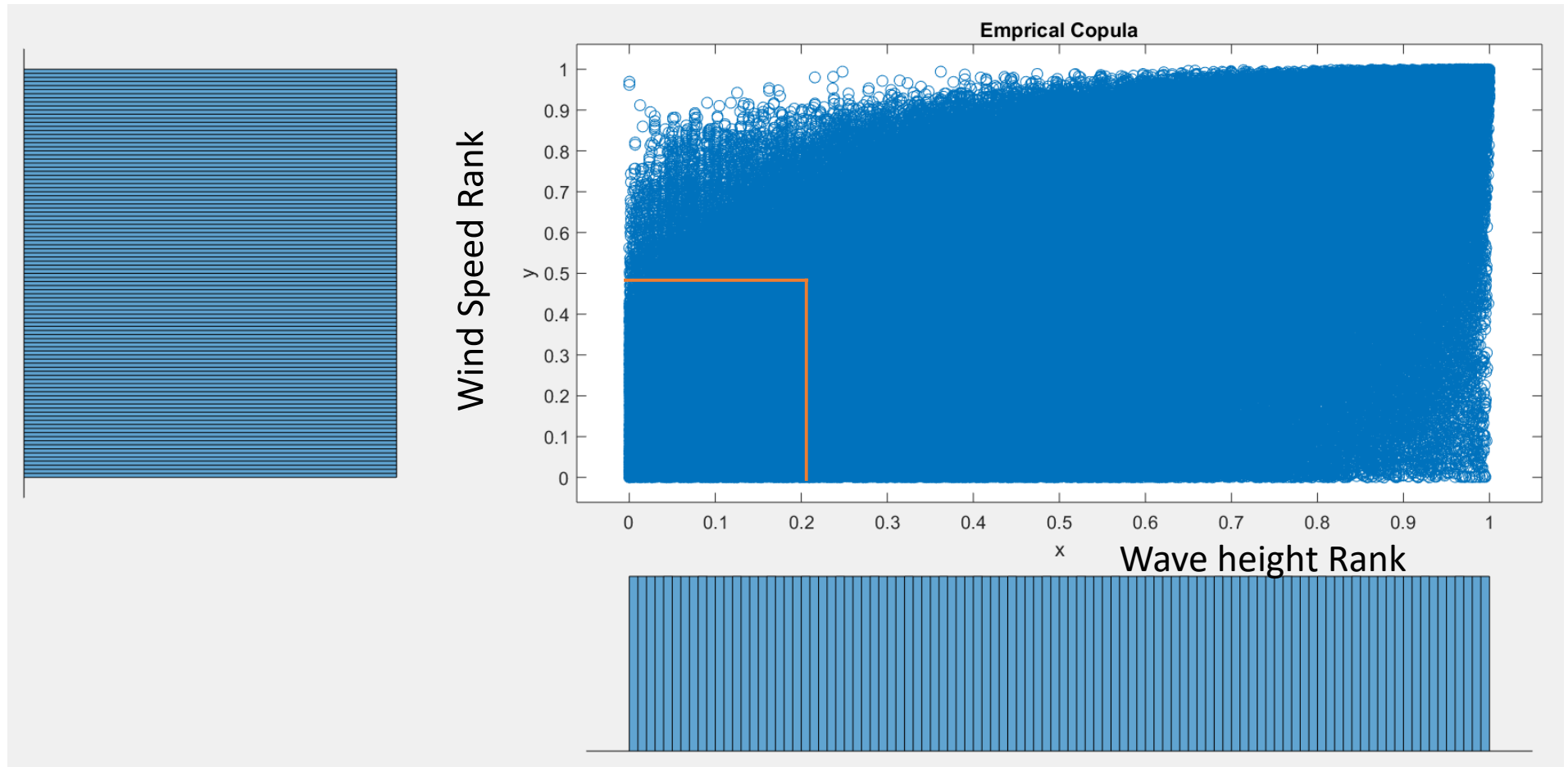
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Normalized Rank (Copula)

Definition

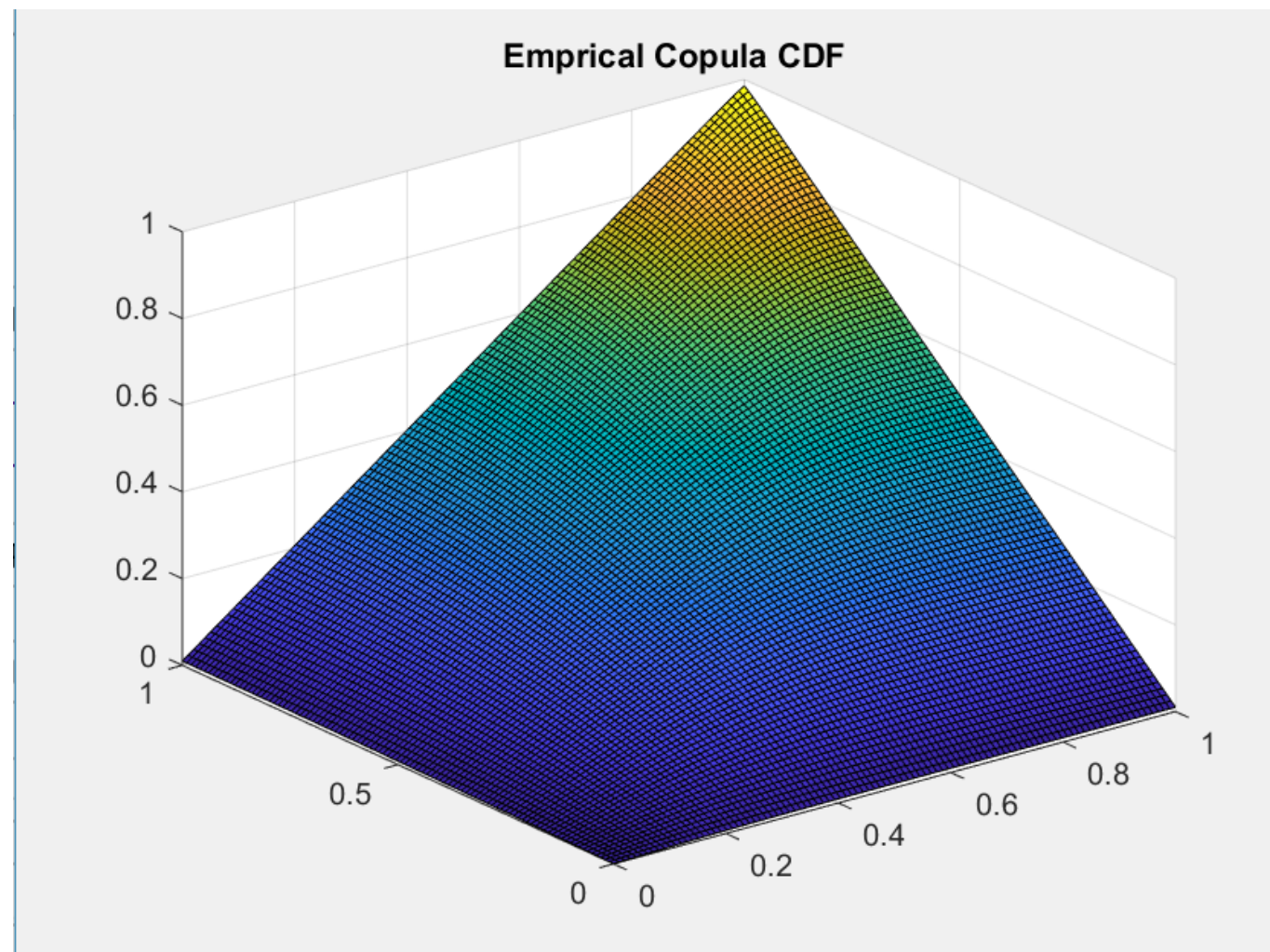
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Application: Copula based on Marginal

Definition

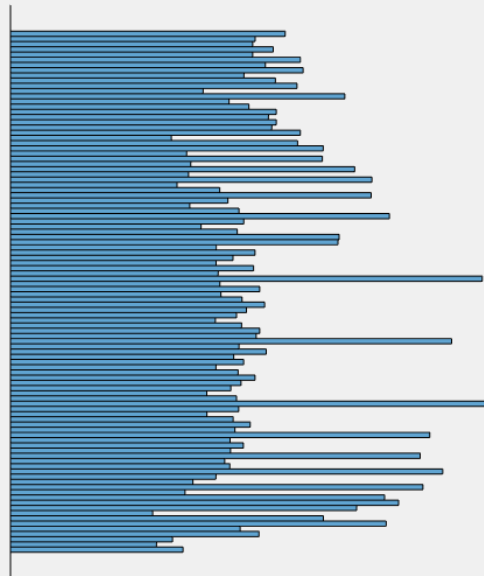
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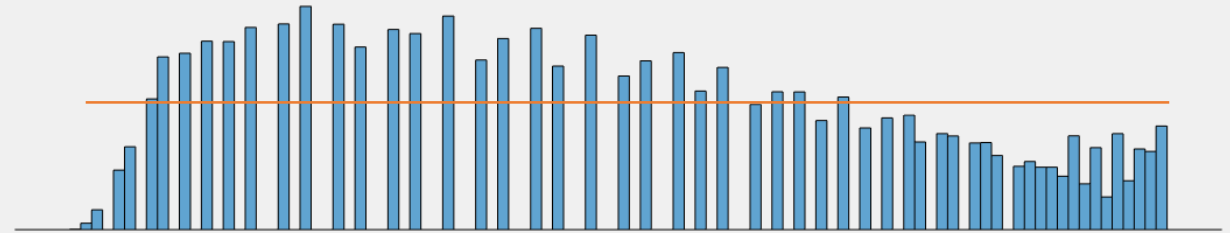
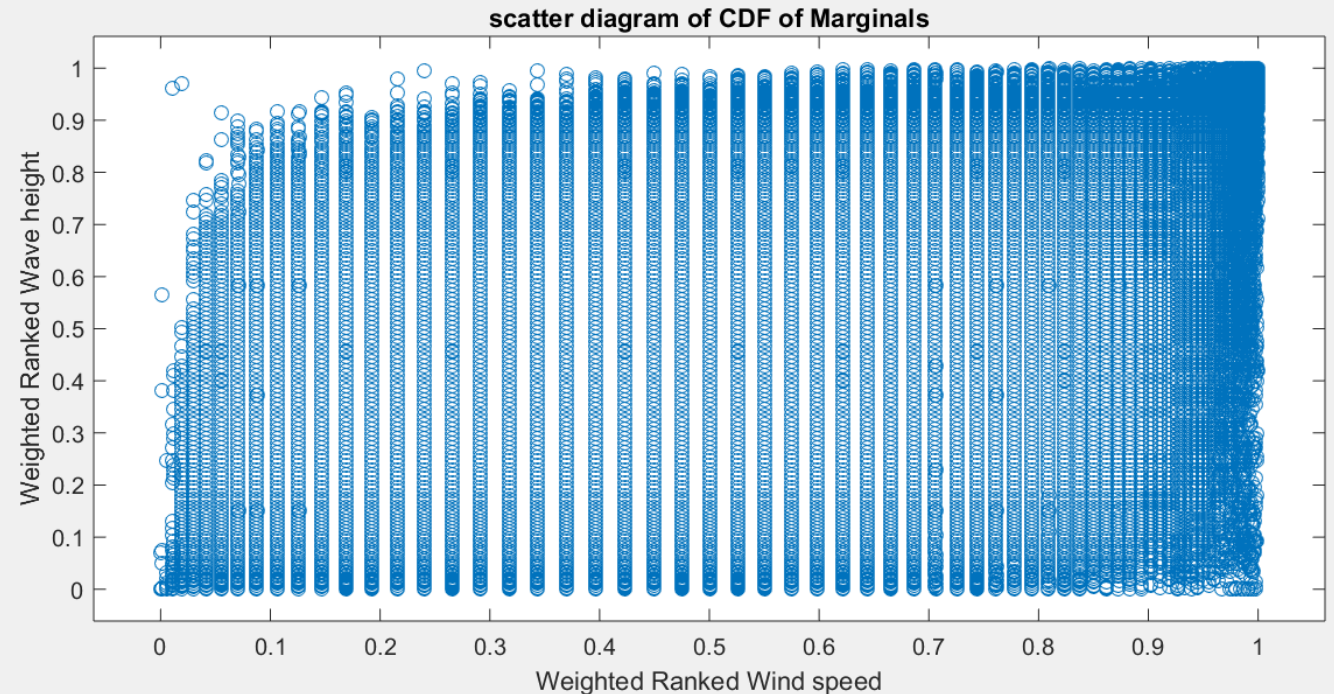
Results



- Known Copula
- Known Marginal



- Joint Parameters



Dynamic response simulation

Definition

Topic

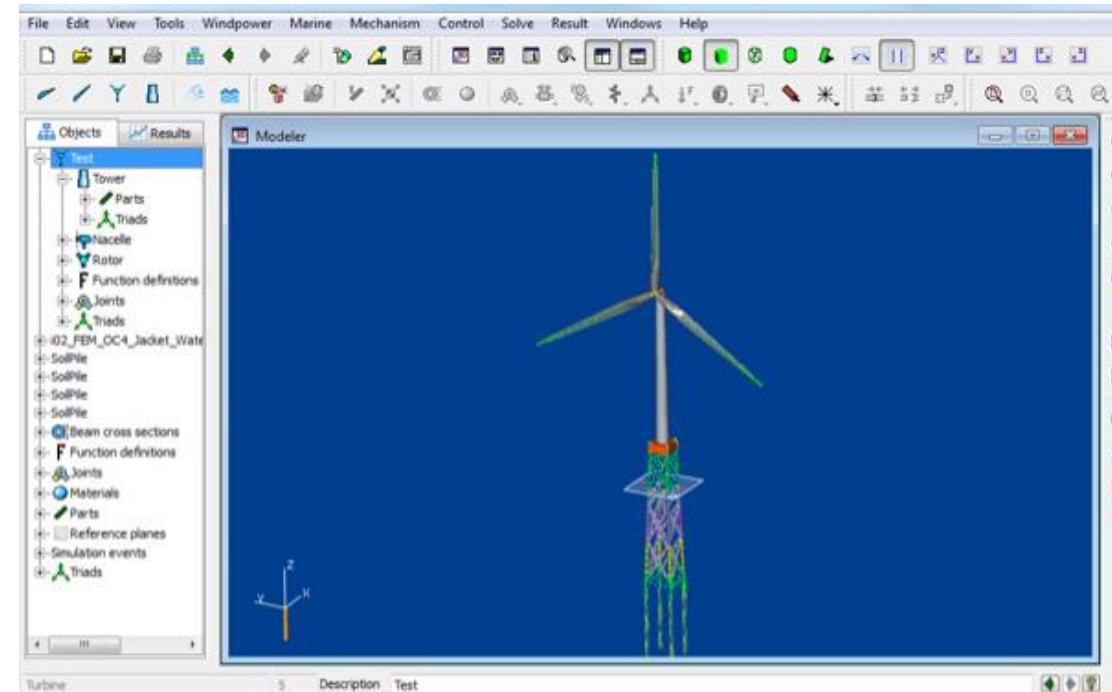
Procedure

Input data

Calculations

Results

- Time history response
- Integrated Time domain analysis using FEDEM or Frequency domain
 - Phase of Study, Preliminary
 - Type of structure
- Consider aerodynamic damping
- Generate wind field and sea state



Questions?

Definition

Topic

Procedure

Input data

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Results



Fit Marginal_Weibull

Definition

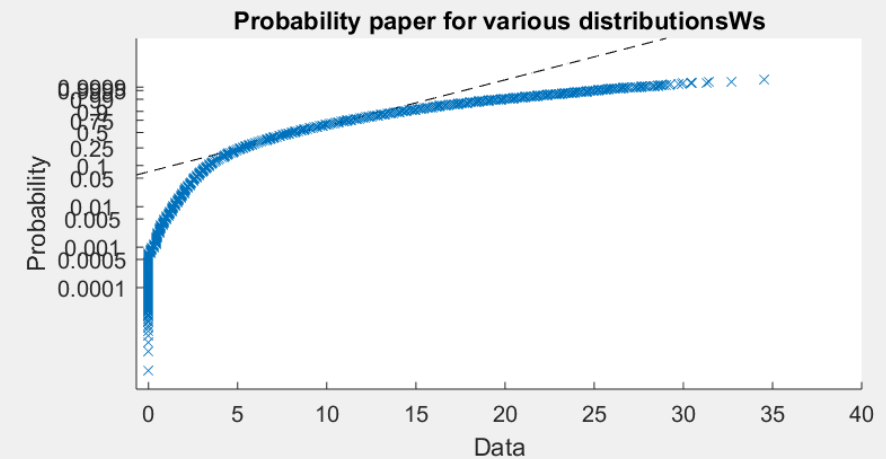
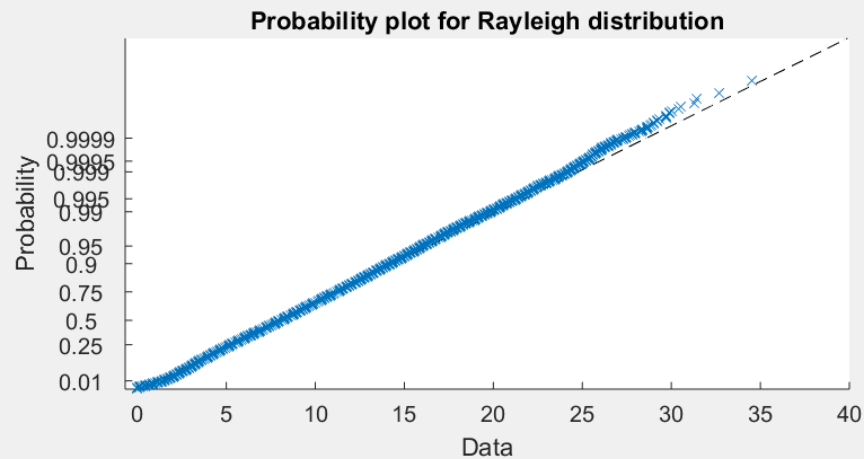
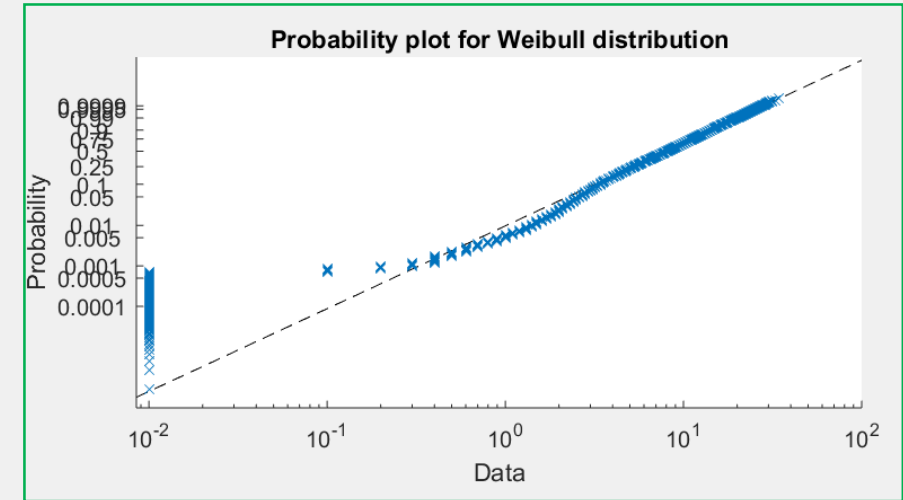
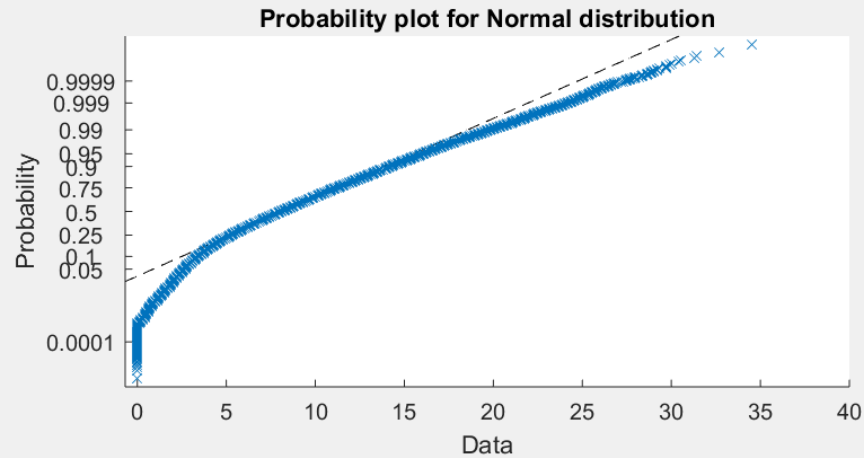
Topic

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Definition

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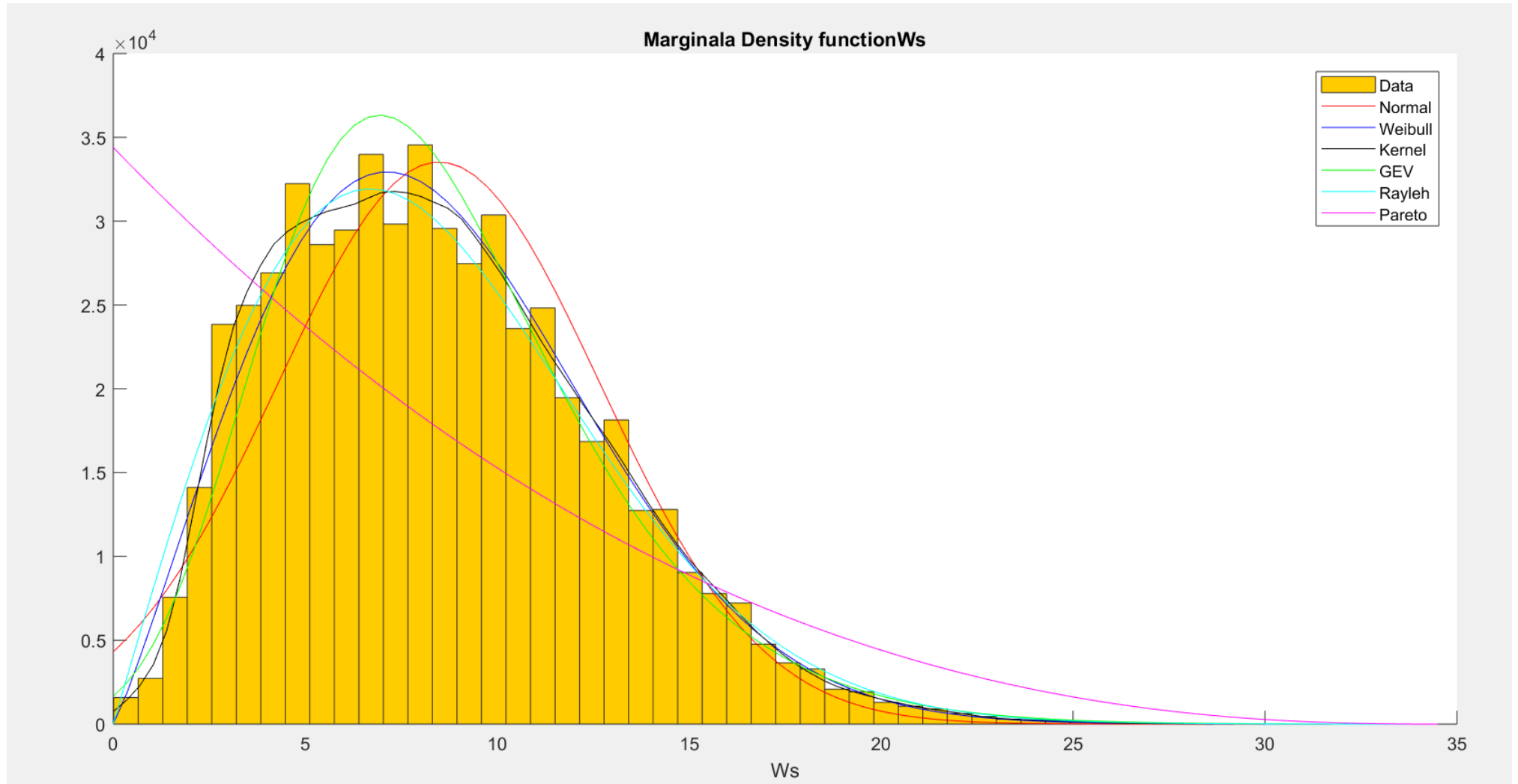
Procedure

Input data

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Results

Marginal; Fit Distribution



Fit Marginal Distribution

Definition

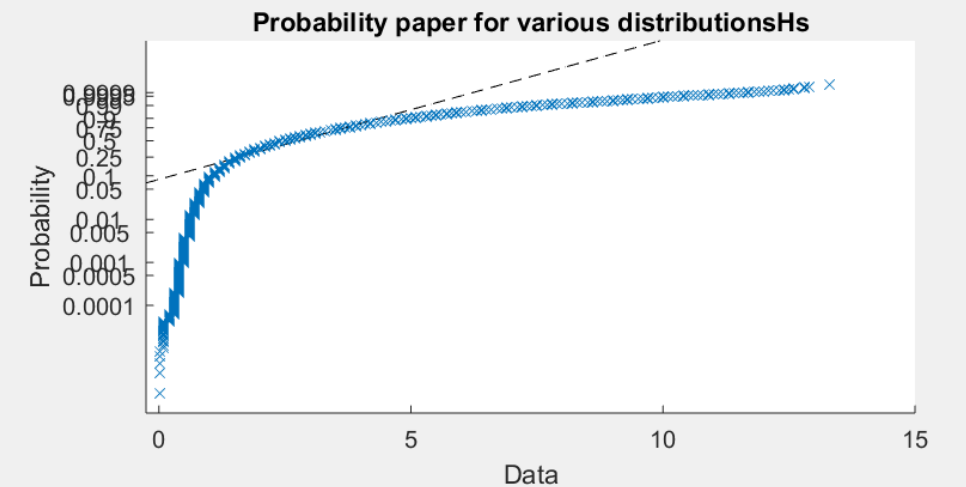
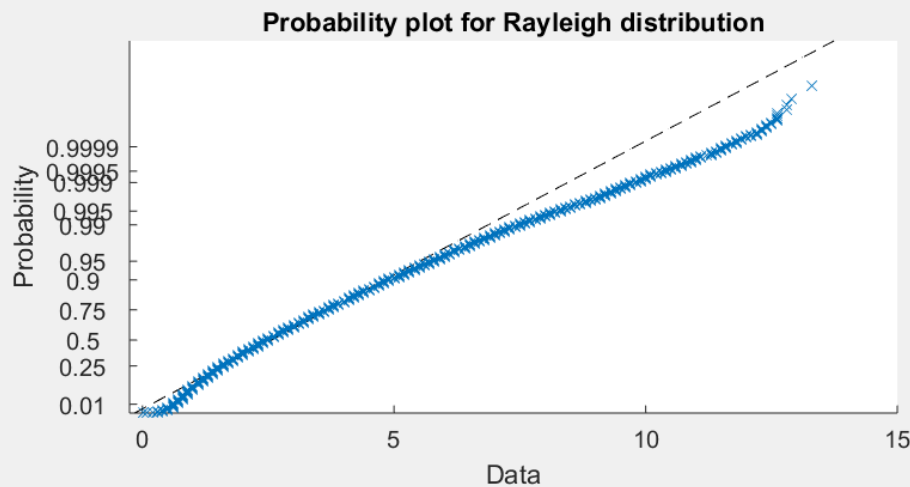
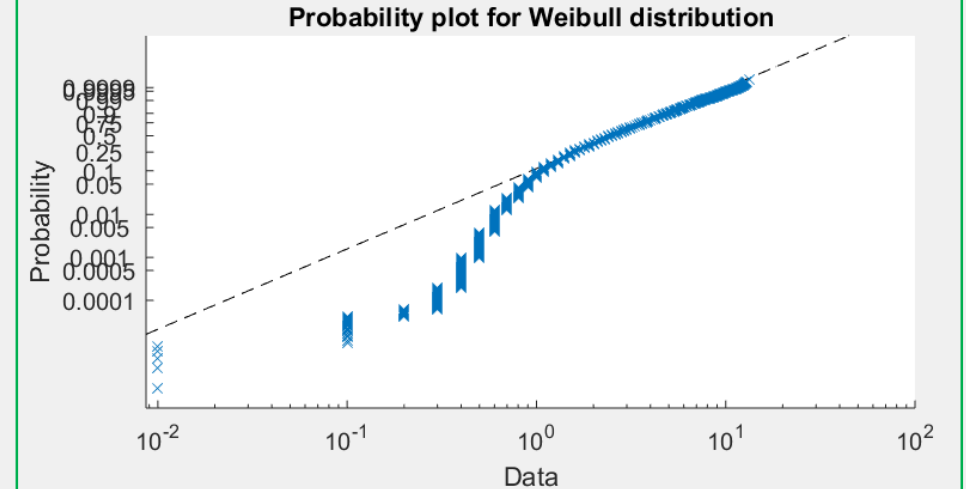
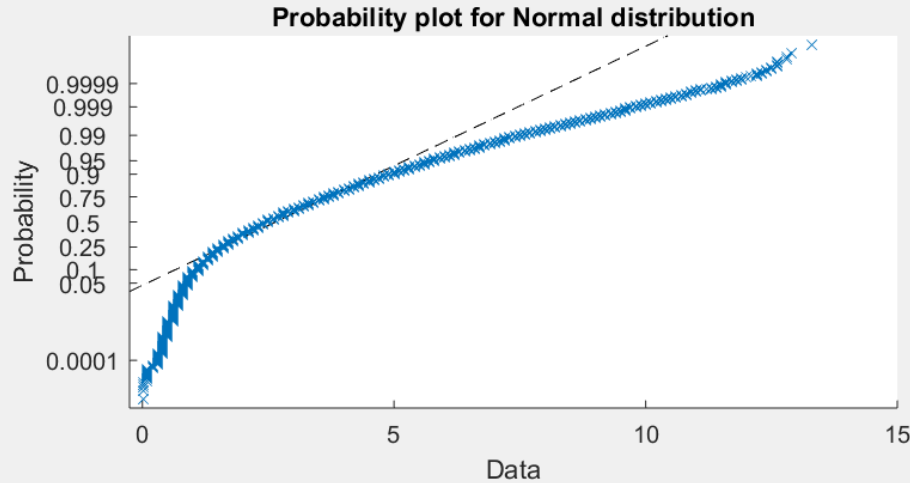
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Marginal; Fit Distribution

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