| | |
|---|---|
| Document title | Article 003: Random Realizations |
| Project number | N.A. |
| Prepared by: | Leadline Maritime |
| Date | September 2025 |
| Classification | Public |

Abstract

The aim of this article is to describe the importance of including a variation of random seeds in time domain simulations. Each random seed initializes a distinctive environmental time series for which the responses of the model will be calculated. The environment is a random process, that behaves within known statistical distribution(s). By further analyzing the statistical responses due to a variation in seeds, more accurate results can be calculated.

In this article it is explained that running time domain simulations with at least 10 seeds is required for accurate results. It is shown that it greatly increases the trends compared to 1 seed as a starting point for further analysis.

This article considers the variation in wind conditions. The same concept is applies to other time series of forces generated from a spectrum (such as wind and/or swell generated waves).

Leadline Maritime's approach is to run by default 10 different realizations for each condition. If from further processing it is observed that more realizations are required, additional runs will be included. In case when mooring line failure may well lead to unacceptable consequences such as uncontrolled outflow of oil and gas or collision with an adjacent platform, more 20-30 are generally considered.

# 1. Mooring model

## 1.1. Setup

In this example, a tanker type vessel is moored next to a jetty by using 12 mooring lines on 6 bollards. The manifold eccentricity is 2.00m. Lines are pretension with 5% of the Minimum Breaking Load (MBL). The Working Load Limit (WLL) is 50% of the MBL. Wind is modelled in 22.5° sectors, incrementally increasing from 8 to 18m/s (API spectrum).

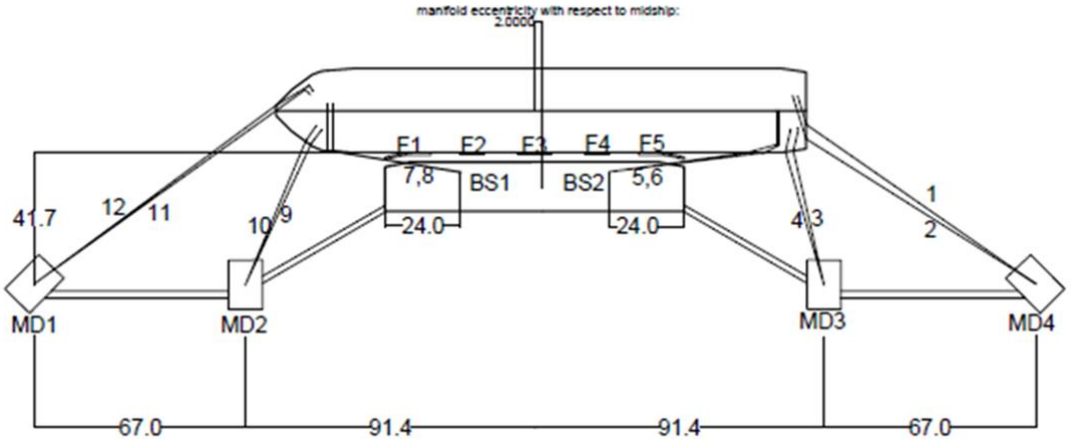



**Figure 1-1: moored vessel setup**

## 1.2. Simulation

The result of a single simulation are time-series of all relevant parameters such as:

- Six degrees of vessel motions and three degrees of manifold motions.
- Elongations and loads in all mooring lines.
- Loads in the shore based mooring connection points (e.g. jetty bollards).
- Deflections and loads in all fenders

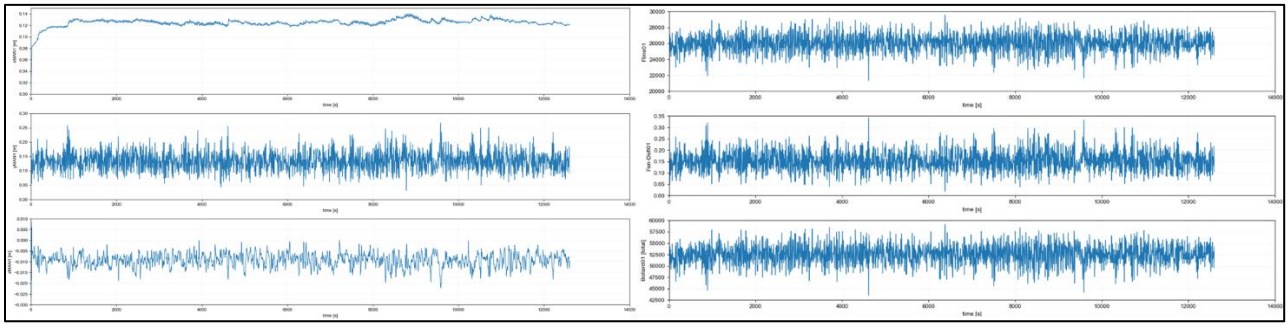


**Figure 1-2: example time series of responses obtained from a 3-hour simulation**

## 1.3. Processing

In this example, the occurrence of maximum values of line forces in mooring line #1 is shown for a certain wind speed and wind direction for 200 different realizations in Figure 1-3. It can be seen that line loads can be expected between approximately 8t and 13t (e.g. running just 1 simulation can give any value between this range and can therefore largely over-or underpredict the actual value).

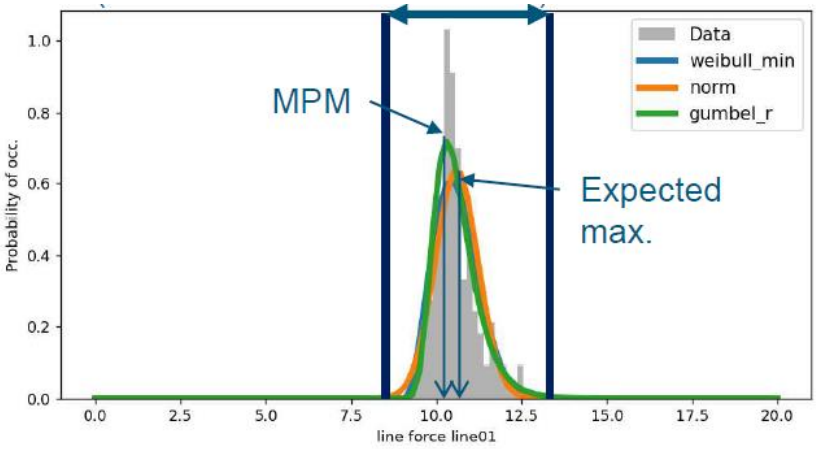



**Figure 1-3: Line force variations for different seeds**

In following comments are made with respect to the above figure:

- Three different distributions are fitted: Weibull, Normal (Gaussian) and Gumbel. Typically the maximum value of responses (e.g. line force) within a 3-hour simulation can be considered a Gumbel distribution. The derivation of this statement is not further regarded in this article.
- The most probable maximum (MPM) is a value that has the largest probability of occurrence, while the expected maximum has a value that is exceeded 50% of the instances (the mean value of the different samples). Due to the heavy tail of the distribution, the MPM is lower than the expected value (around 0.45 times the standard deviation of the samples is subtracted from the mean value). Both MPM and mean values can be processed by Leadline Maritime.
- The larger the sample size, the smaller the confidence interval and the more the extreme value (Gumbel) distribution will get closer to a normal distribution (according to the central limit theorem). However, increasing the sample size also increases the computational effort, therefore increasing numerical costs.

## 1.4. Test Case

In below plot the maximum force in Line-01 is shown as a function of wind direction and wind speed. It can be seen that running just 1 seed provides a poor starting point for trend analysis: the line forces is not monotonously increasing for wind speeds between 13m/s and 18 m/s. This is due the bandwidth of forces that can be expected as shown in Figure 1-3. Running 10 seeds and averaging results to get an expected maximum of values greatly increases the trends. However, still at 112.5°N for wind speeds 13-14m/s this can be improved by considering even more random seeds. Generally, 10 seeds are sufficient to increase the accuracy of the results, without being too computationally too expensive. DNV-OS-E301: Mooring Positioning recommends to run 10- 30 seeds for each unique environmental condition.

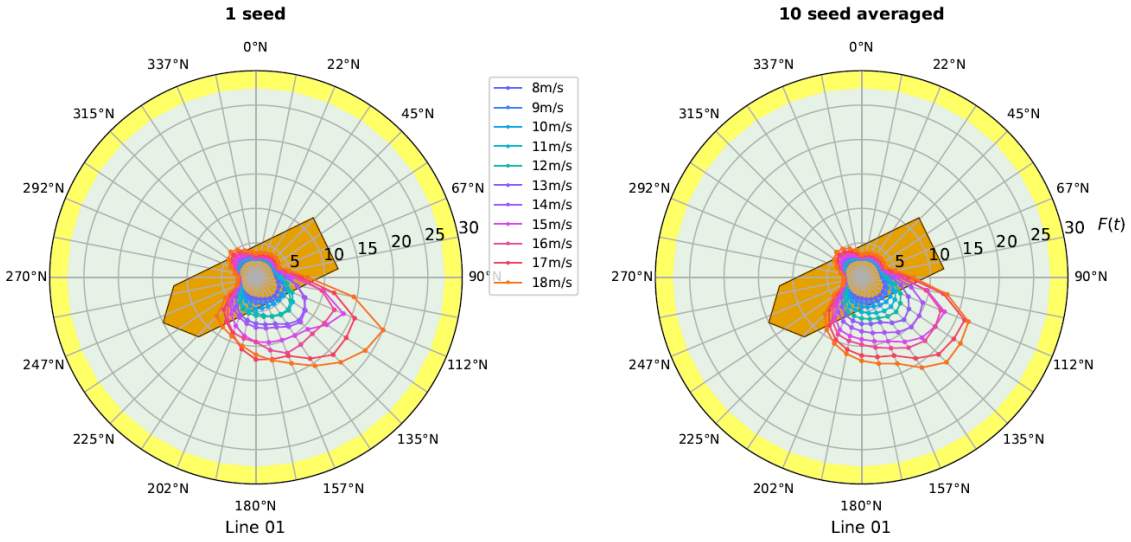


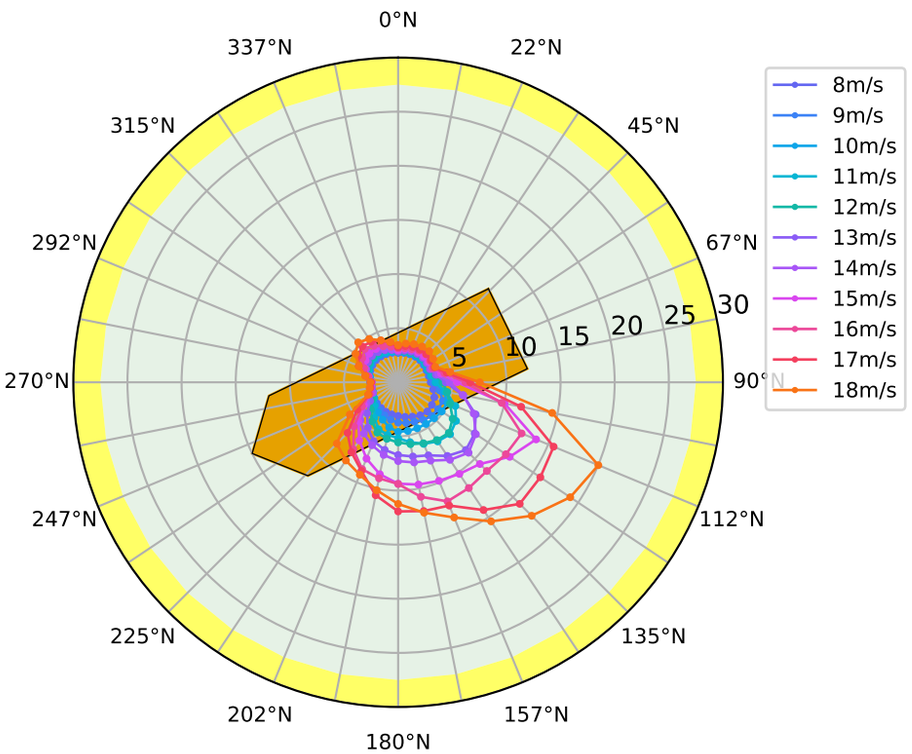

**Figure 1-4: Forces [t] in line 01 due to: 1 seed (left) and 10 seed averaged (right) results**

On the next pages, additional plots are created for the different line forces and bollard loads.

# Appendix A. Plots

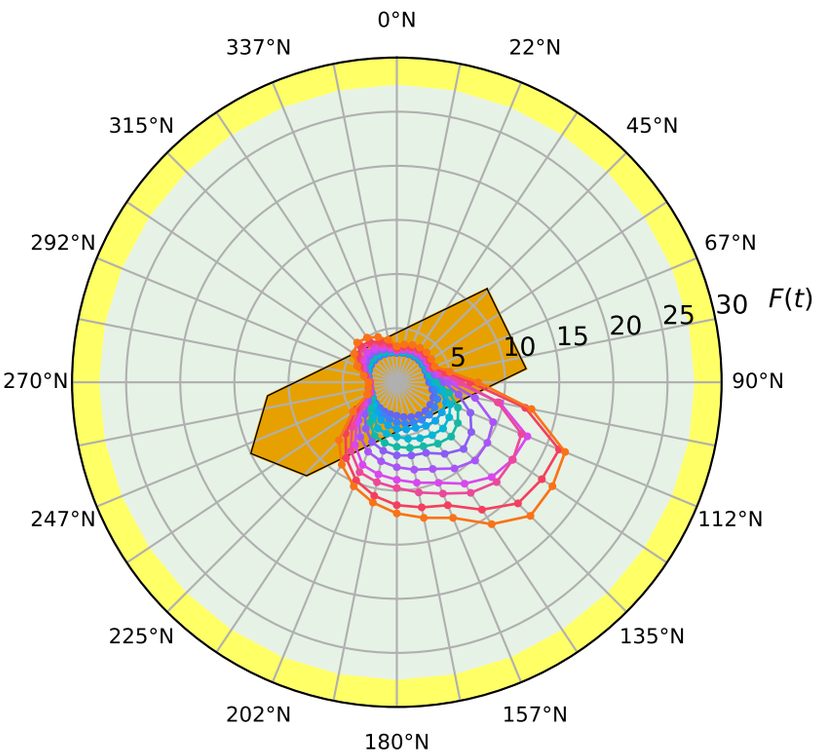
Maximum Line forces [t] for increasing wind speeds.
WLL = 27.5t (yellow)

**1 seed**



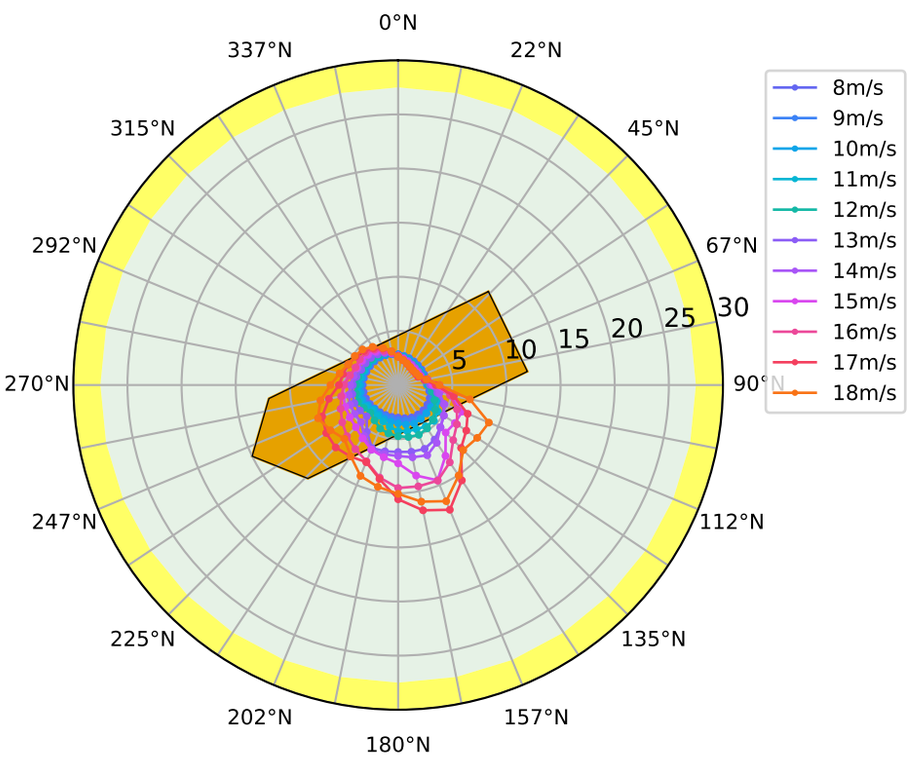

Line 01

**10 seed averaged**



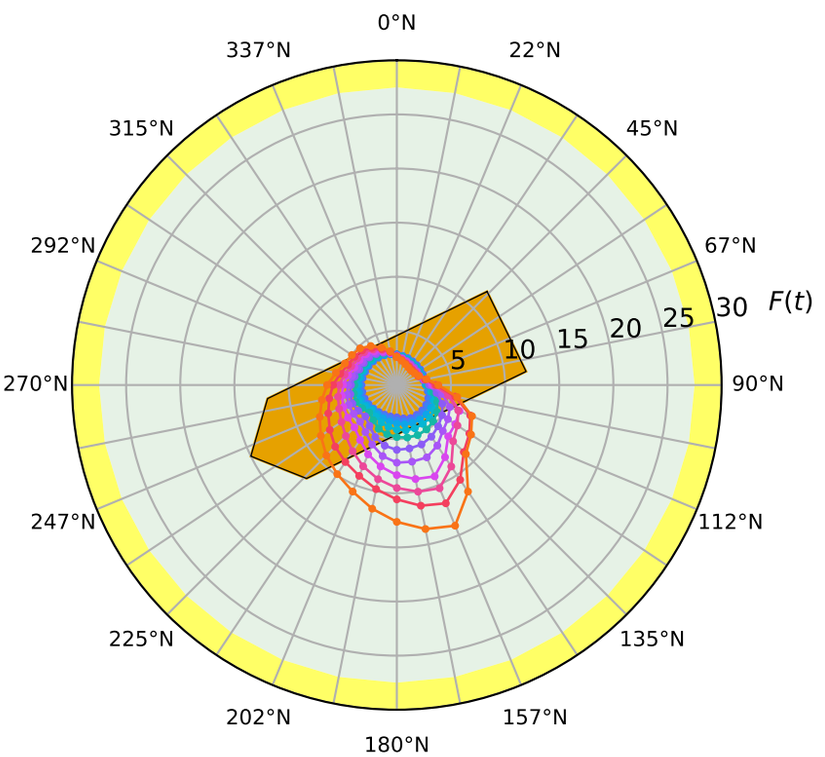

Line 01

**1 seed**




Line 05

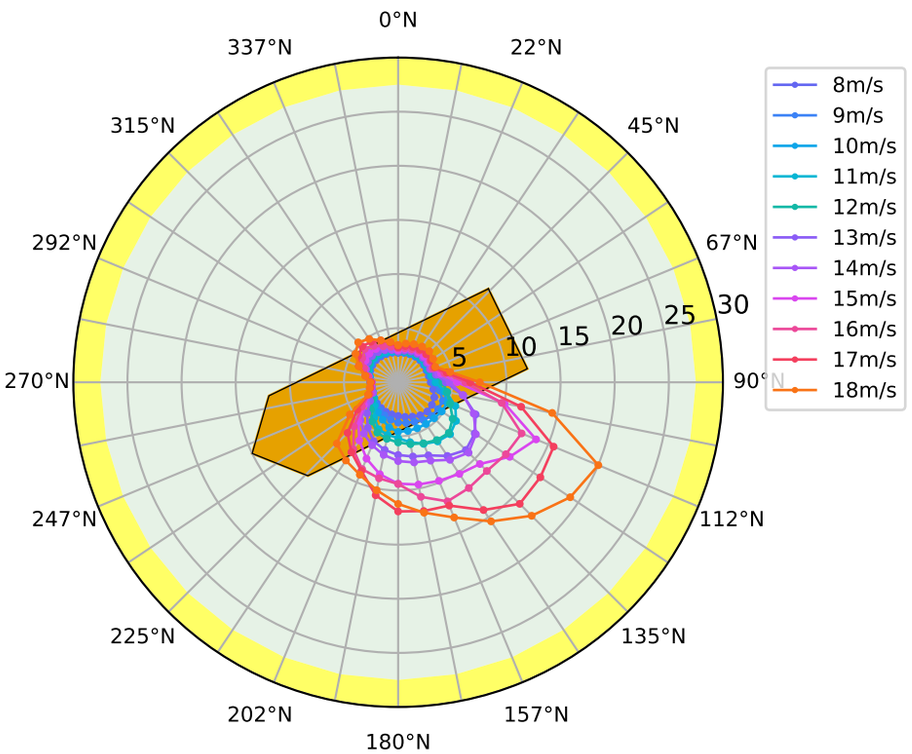
**10 seed averaged**




Line 05

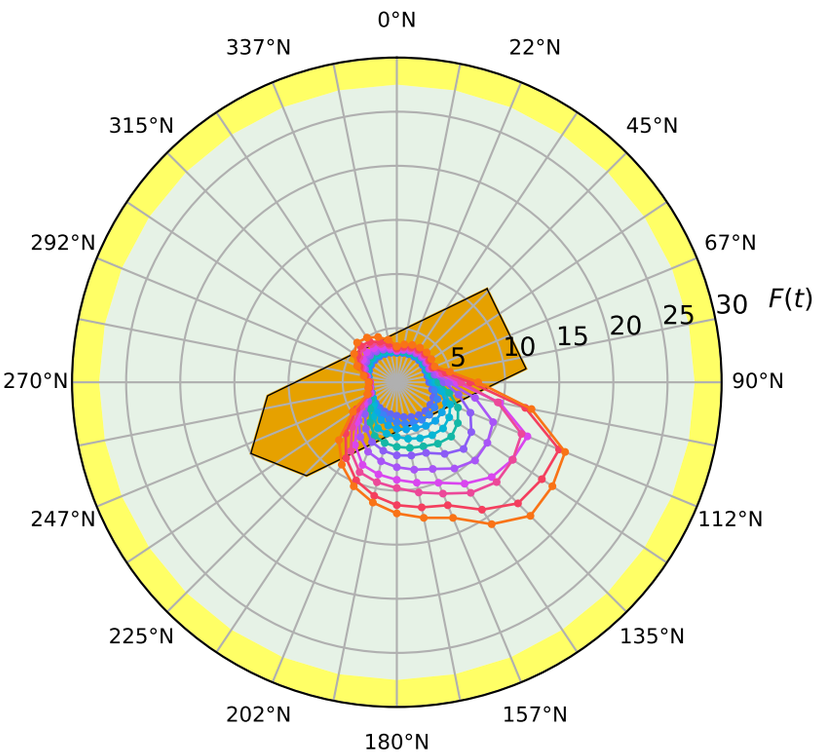
Maximum Line forces [t] for increasing wind speeds.
WLL = 27.5t (yellow)

**1 seed**



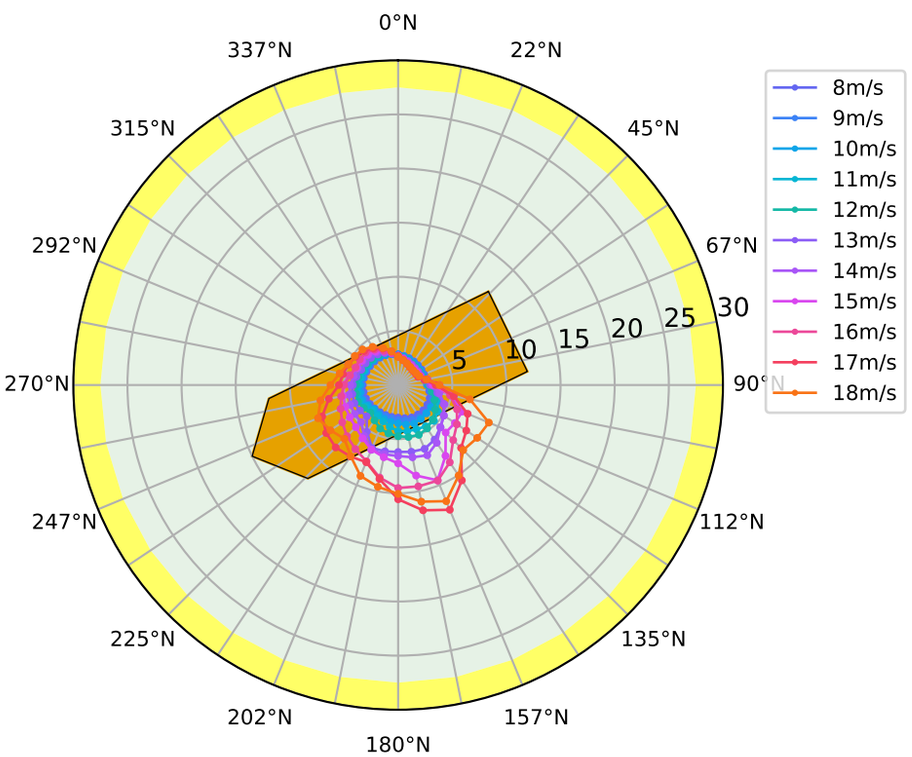

Line 01

**10 seed averaged**



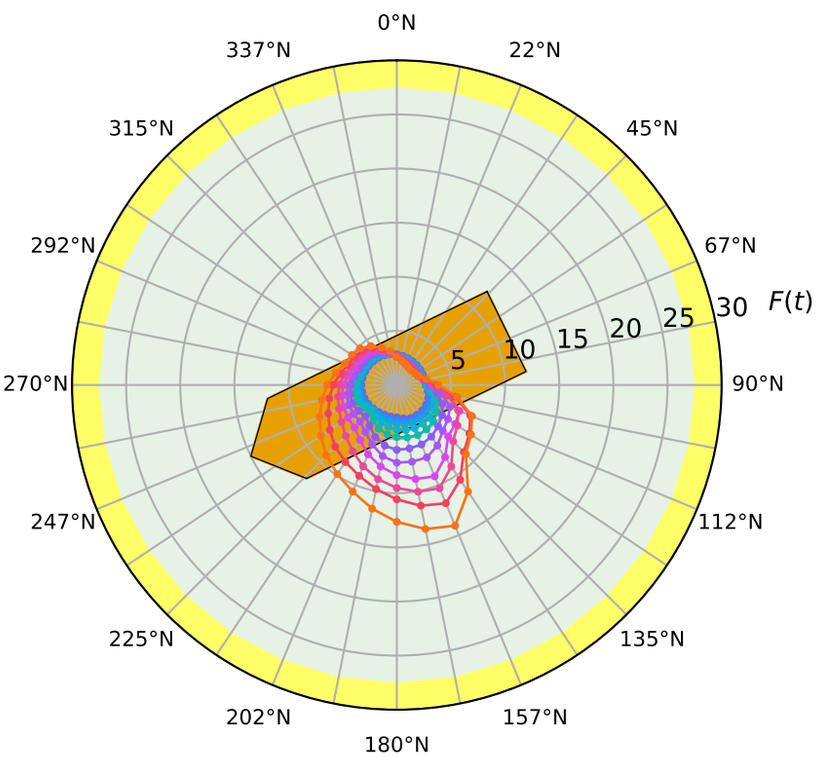

Line 01

**1 seed**



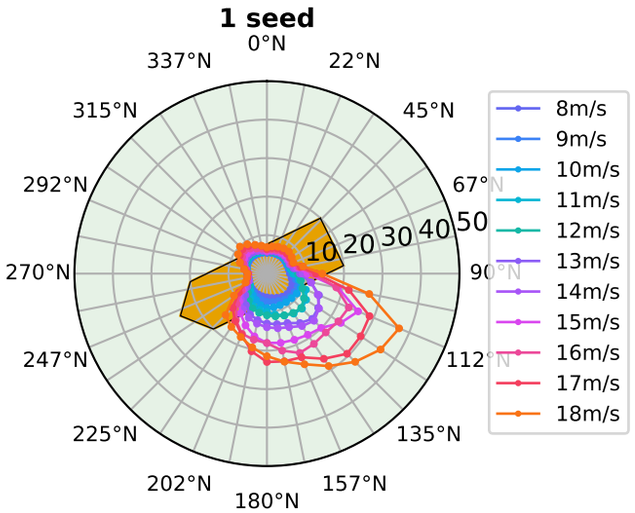

Line 05

**10 seed averaged**

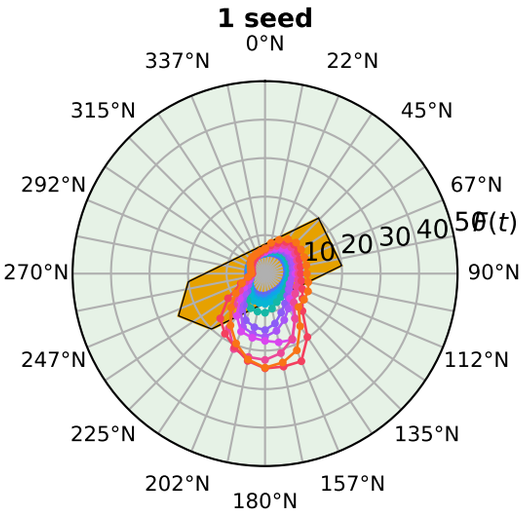



Line 05

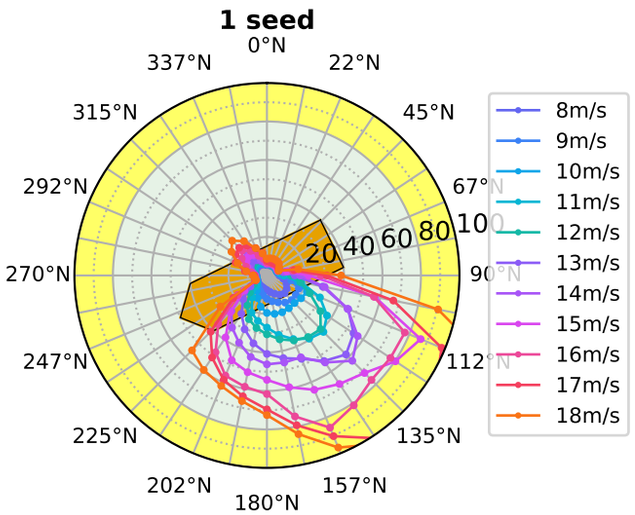
Maximum Bollard forces [t] for increasing wind speeds for 1 seed.
SWL = 80.0t (yellow)



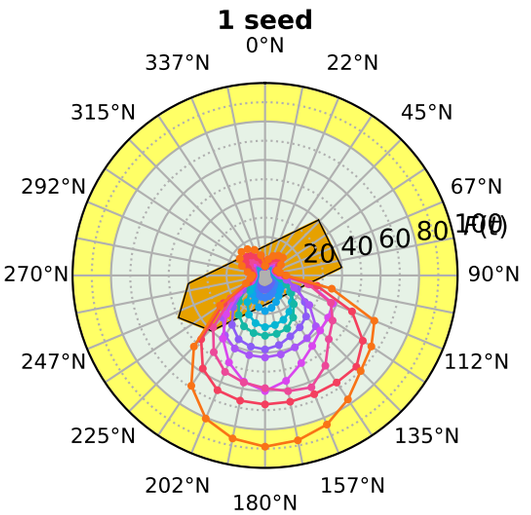
Bollard 01



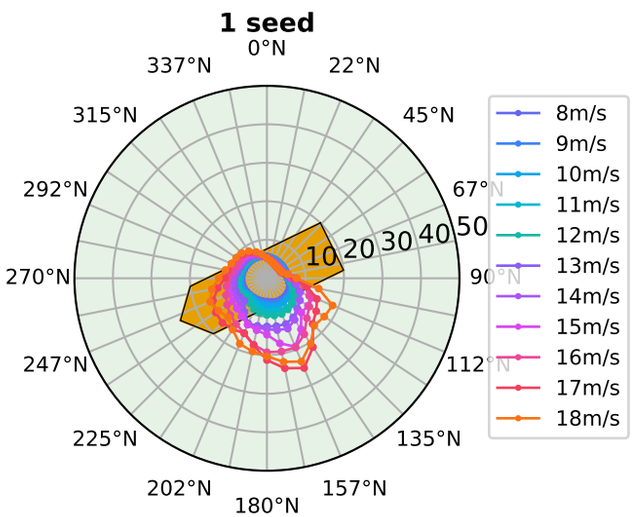
Bollard 04



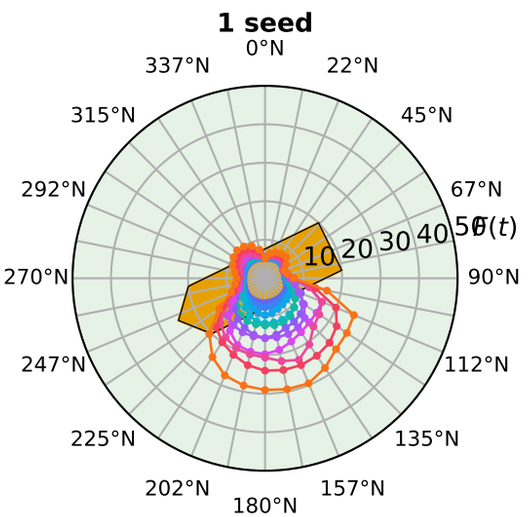
Bollard 02



Bollard 05

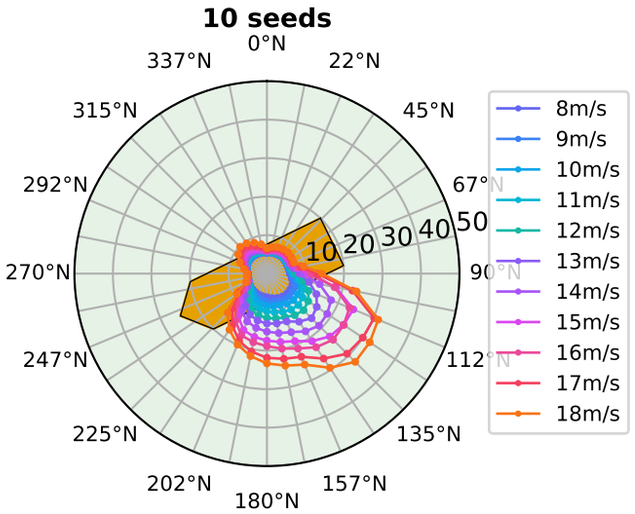


Bollard 03

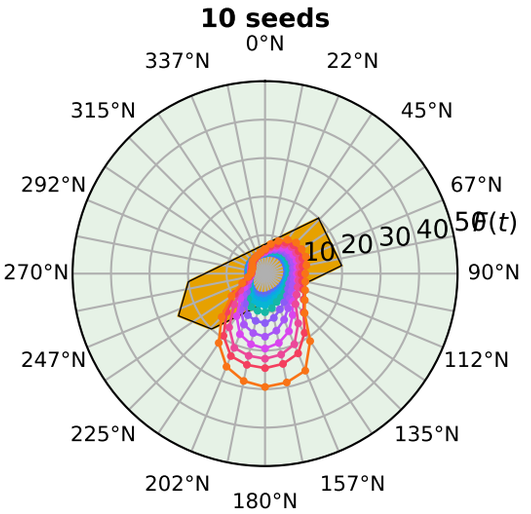


Bollard 06

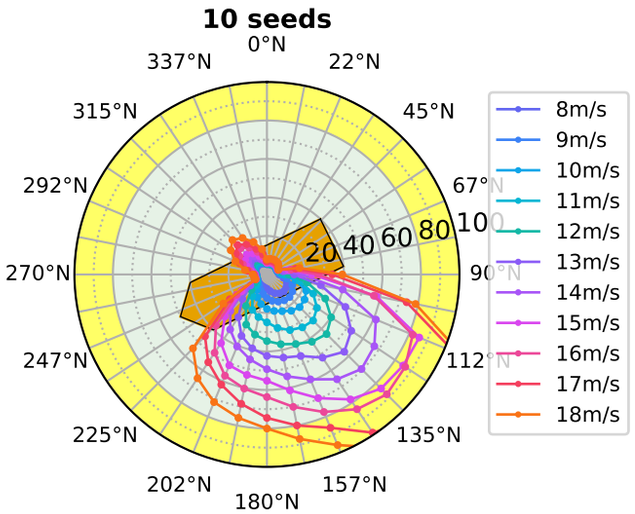
Maximum Bollard forces [t] for increasing wind speeds. Results are averaged over 10 seeds.
SWL = 80.0t (yellow)



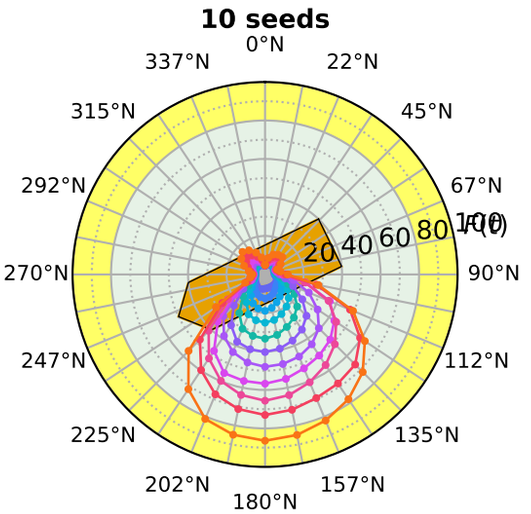
Bollard 01



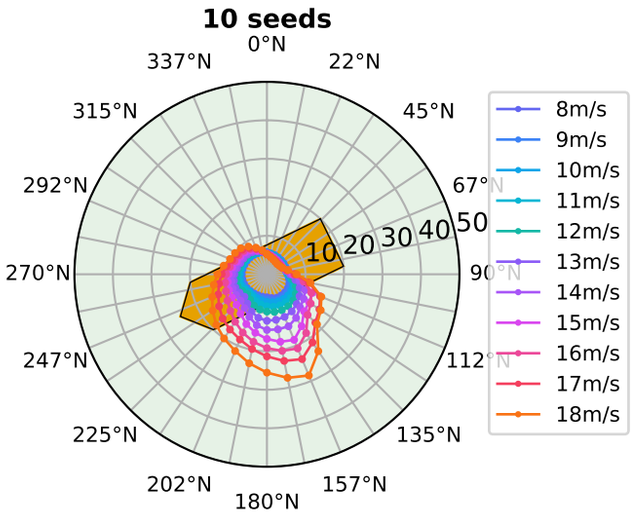
Bollard 04



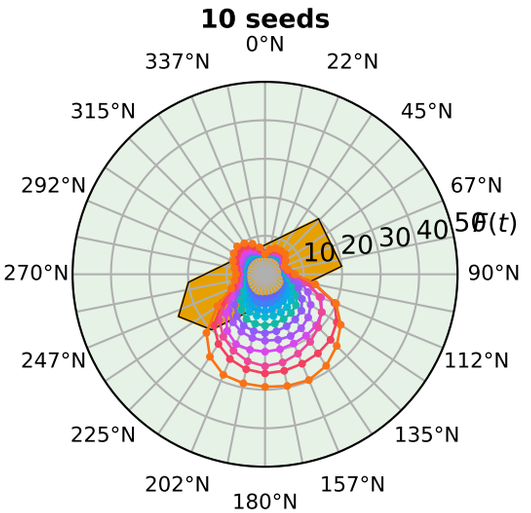
Bollard 02



Bollard 05



Bollard 03



Bollard 06