Improving the Risk Assessment of Offshore Structures

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1 Motivation

- Engineers **test offshore structure** designs using **complicated** computer models
- They use specially selected **design conditions** in their simulations

Figure: An oil rig in the North Sea

The Problem

How do we decide which **design conditions** (e.g., wave height) to use to test offshore structure designs?

2 Methodology

- **Old methods** make **assumptions** about the how the waves **affect** the structure
- They **do not** model the structure or the **individual** waves

Our Solution

We model **individual waves** and the **structure**, meaning our **design conditions** are found using **real physics**.

3 Storm Peak Data

- Our **data** comes from the worst part of the storm
- It tells us **averages** of properties like wave **height**

Storm Peaks

H_S Significant Wave Height

T_P Significant Wave Period

S_2 Significant Wave Steepness

We call these $\boldsymbol{X}$.

4 Modelling Storm Peak Data

- We use **Extreme Value Theory** to estimate the joint **probability density**
- **Darker** combinations of variables are **more likely** to occur

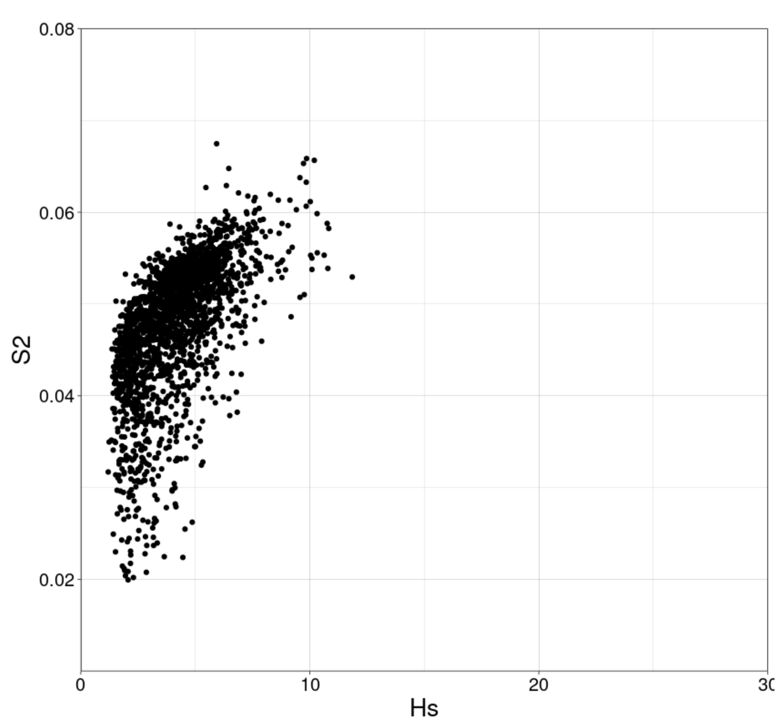

Figure: Storm Data from the North Sea

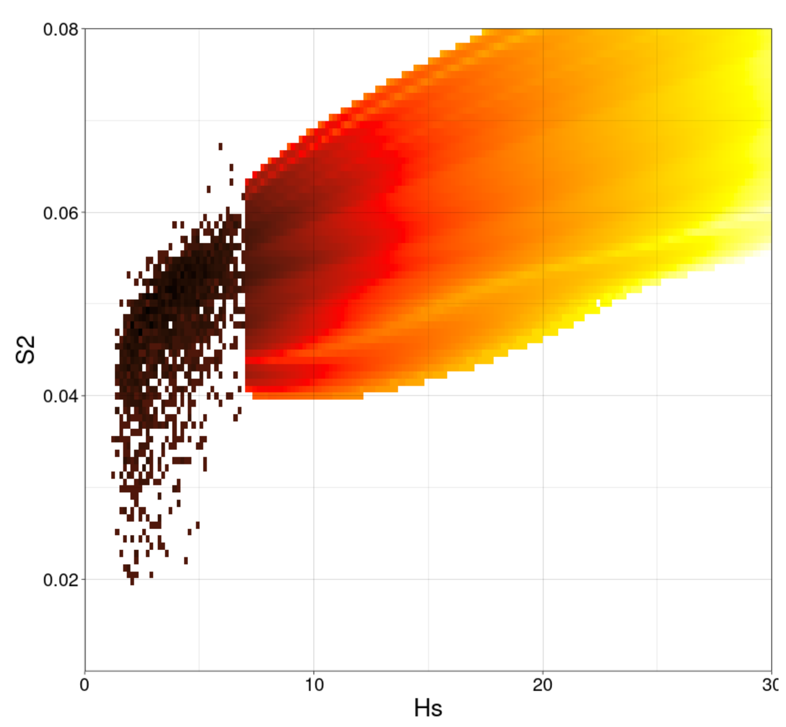

Figure: Probability density

Extreme Value Theory

Extreme Value Theory is an area of **statistics** that focuses on modelling **large** values of variables.

5 Simulating Forces on Structures

- We **efficiently** simulate **forces** on structures
- We use models for wave **kinematics** and structural **forces**

5.1 Wave Simulation

- We **simulate wave** elevation, speed and acceleration
- This is for a **known** storm peak $\boldsymbol{X}$

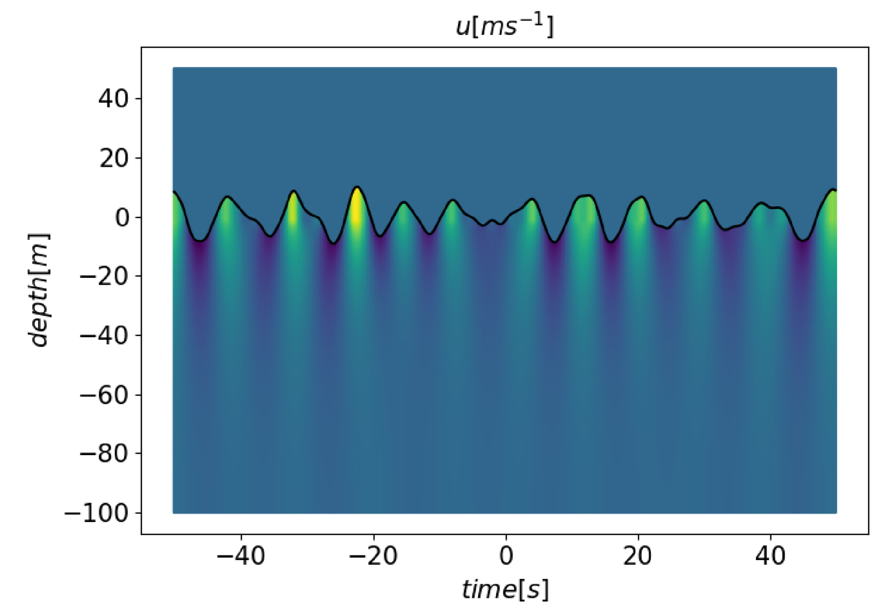

Figure: A simulated wave profile

5.2 Force Modelling

- We generate the **total force** on the **structure** at each **time**
- Then we find the **density** $f_{R|X}$ of the maximum response on the structure **per storm** R for storm peak $\boldsymbol{X}$.

Probability Density

A **probability density** can tell us the **chance** of a variable being **larger than** a given value.

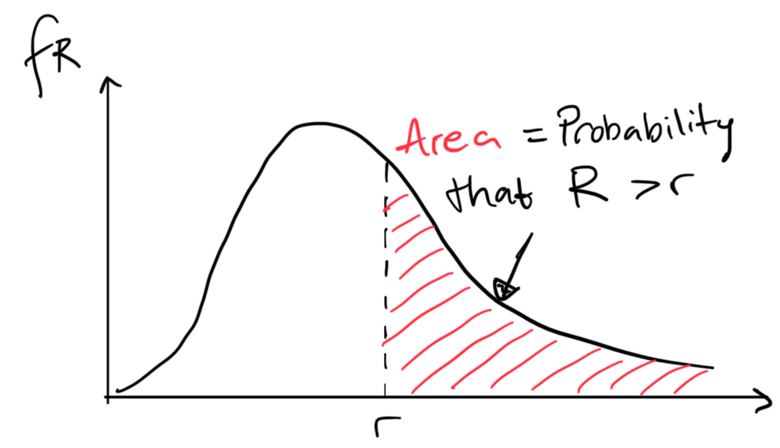

Figure: Example Probability Density

6 Conditional Density of the Environment

- We find a **new density** to get our **design conditions**

$$f_{\boldsymbol{X}|R}(\boldsymbol{x}|r) = \frac{f_{\boldsymbol{X}}(\boldsymbol{x}) \times f_{R|\boldsymbol{X}}(r|\boldsymbol{x})}{f_R(r)}$$

The CDE

The CDE tells us which **storm peaks** relate to a **given force**.

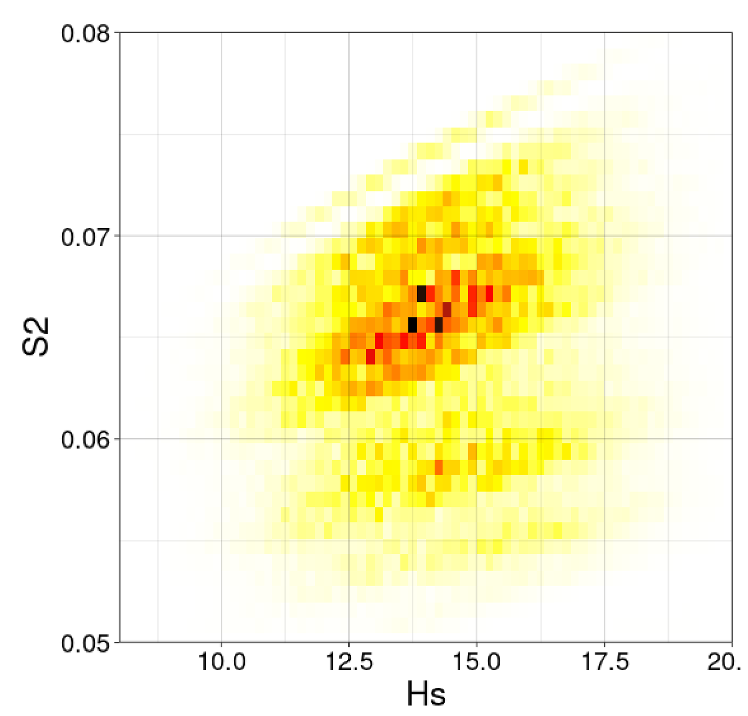

Figure: Example CDE

7 Impact

We have made a **Python package** for use by **data scientists** at Shell, for **risk assessment** of existing and future designs.

Notation

$\boldsymbol{X}$ Storm peak variables

R Maximum force per storm

$R|\boldsymbol{X}$ Max force for known storm peak

f_Y Probability density of Y

GitHub

See below for the Python code used to generate these results!

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