MODELLING NON-STATIONARY LOADS INDUCED BY CHANGING CLIMATE

Nadia Kudryavtseva*

* Tallinn University of Technology, School of Science, Department of Cybernetics
Akadeemia tee 21, Tallinn, Estonia
e-mail: nadezhda.kudryavtseva@taltech.ee,
web page: https://www.researchgate.net/profile/Nadia-Kudryavtseva

ABSTRACT

Due to climate change, the properties of many environmental loads, such as, for example, snow cover, precipitation, sea levels and ocean wave heights, are expected to change and experience a significant positive or negative trend[1]. However, civil infrastructure reliability and performance are currently estimated using an assumption of stationarity of environmental loads. The strength and stiffness of the infrastructure will deteriorate by systemic changes in loads beyond the baseline conditions assumed during design. In this lecture, I will describe the method of estimating the changes in environmental extremes using the sea level extremes as an example. Understanding and predicting the characteristics of sea-level extreme events and their potential changes in frequency and magnitude is of fundamental importance in estimating the coastal flooding risks and managing the coastal areas. The method combines a 3D high-resolution ocean model, statistical analysis of extremes and simulation of the probability of construction failure.

Novel non-stationary modelling of parameters of a generalized extreme value (GEV) distribution is implemented based on the block maximum approach, testing for linear trends in the parameters of the GEV distribution[2]. The analysis is performed for simulated NEMO-Nordic water level data along the Baltic Sea coast for 1979–2012 with a spatial resolution of ~3.7 km (2 nm) and a time resolution of 1 hr together with in-situ sea level data.

In the Gulf of Riga, a strong regime shift appeared: a drastic abrupt drop of the shape parameter from $\xi \approx 0.03 \pm 0.02$ to $\xi \approx -0.36 \pm 0.04$ around 1986 followed by an increase of a similar magnitude around 1990[3]. This means a sudden switch from a Fréchet distribution to a three-parameter Weibull distribution and back. The extraordinary change in the shape of the distribution was linked to the significant weakening of the connection with the North Atlantic Oscillation (NAO) pattern. During the weak relationship with the NAO in the region, a strong correlation with the Scandinavian and Pacific/North American patterns appeared, changing the shape of the distribution of the sea level extremes.

The results show high spatial variations in linear trends in the location parameter of GEV, indicating that in the case of regional seas, the changes in the extreme value behaviour can have a characteristic spatial scale as small as ~100 km. The most notable linear trends are detected along the Pomeranian Bay, where it was found that the difference between non-stationary and stationary 30-yr return values reaches up to 20%. Therefore, it is critical to consider non-stationary effects in extreme value modelling for the coastal engineering constructions to prevent underestimating the risks from the water level extremes.

REFERENCES

[1] Kudryavtseva, N. & Soomere, T. 2017. ESD, 8, 697−706.10.5194/esd-2016-68.
[2] Kudryavtseva, N., Pindsoo, K., Soomere, T. 2018. JCR, SI 85, 586−590.
[3] Kudryavtseva, N., Soomere, T., Männikus, R. 2021. NHESS, 21, 4, 1279–1296.