The importance of combined extreme events for nuclear regulation

TakeAIM 2021 – 3rd Place

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The Smith Institute, enabled by the generous sponsorship of our leading corporate partners, ran the TakeAIM competition in 2021 to make visible the crucial role that mathematics will increasingly play in all aspects of our lives. The competition, also celebrating its 11th anniversary this year, was open to undergraduate and postgraduate students working in the mathematical sciences. The first-place prize was £1000, the two second-place prizes were £500, and the two third-place prizes were £250.

On the 11th of March 2011 a 9.0 magnitude earthquake occurred off the coast of Japan, subsequently generating a 40m-high tsunami. The combination of these extreme events led to wide-scale destruction, including the meltdown at the Fukushima Daiichi nuclear power plant. This disaster resulted in the evacuation of a 20km radius area around the site and damages estimated at more than £138 billion.

A report released by the International Atomic Energy Agency concluded that the incident exposed critical weaknesses in the Japanese regulatory framework. In particular, little consideration was given to the probability of both extreme events occurring simultaneously. Consequently, good nuclear regulatory practice now considers combinations of hazards occurring simultaneously, allowing joint impact to be evaluated. This impact can be analysed via the so-called return curve, a risk measure which quantifies joint extremal behaviour.

Working with the Office for Nuclear Regulation, the UK's independent nuclear regulator for safety, security and safeguards, our research is focused on developing novel estimation techniques for return curves. Very limited literature is available for this topic, and our proposed methods have been shown to outperform existing techniques. We have also developed a framework for capturing trends related to climate change in curve estimates, something which had not been previously considered.

Return curve estimates obtained through this research may one day inform the design basis for nuclear facilities and help safeguard against extreme events. Furthermore, this research could help provide a good practice for nuclear regulation that may be applicable internationally.