Flood risk assessment

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Flood events

1.1 Flood risk methodology

Physical climate risk models typically consist of three main components: a hazard module, an exposure module, and a vulnerability module. This model structure is widely accepted in the literature on this topic.

The hazard module includes information about the specific hazards that we want to consider in our model, along with their fundamental characteristics. Let us stress that in the hazard module we do not refer to any group of assets yet instead focusing on the hazard events themselves. The exposure component includes information about the assets, including their descriptions and specific locations. Finally, the vulnerability component serves as a connection between hazard, exposure, and loss, allowing for the estimation of the relative damage to an asset based on a specific hazard level. In many cases, vulnerability models are structured as a set of damage functions, which facilitate the mapping of hazard intensity to estimated damage as a ratio of the total value.

1.2 Hazard module

The hazard component captures the scope and intensity of a peril based on a specific hazard metric. This typically represents the variation in hazard intensity across a predefined geospatial framework, either in the form of a regular raster (grid cell-based) or an irregular vector structure (such as postcode zones or points). In either case, each event footprint represents the relative intensity of the hazard during the defined time period of the event.

The selection of a hazard metric is a crucial aspect of the hazard model, and it typically follows a widely accepted approach. However, it is important to note that the chosen metric may not fully capture all the factors contributing to damage. For instance, in the context of flood damage, the primary metric is typically the flood depth, however, factors such as the duration of inundation, flow velocity, and water pollution may also have a significant impact.

A convenient way to represent flood hazard datasets is through the use of return period maps. These maps provide information about the probability of a flood of a specific intensity occurring within a given time period. An example of such a map is shown in Figure 1.1.

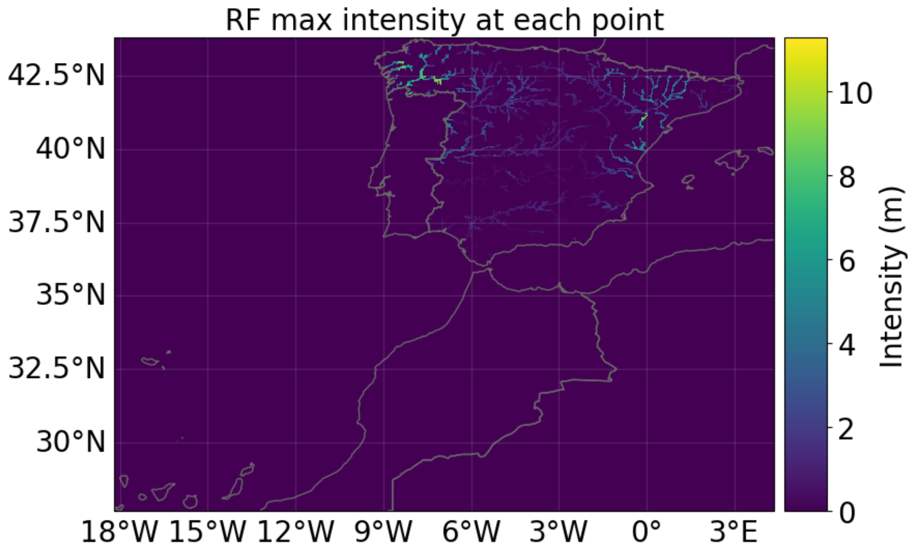

Figure 1.1: Maximum intensity of river floods in various locations in Spain, measured in terms of flood depth.

1.3 Exposure module

Exposure refers to the collection of assets that are susceptible to potential hazards. The exposure model encompasses data regarding the assets, properties, and infrastructure, along with their vulnerability to potential risks. This information serves as a vital input for the catastrophe model. However, the creation of a comprehensive exposure model or database is also an integral part of the overall development of the catastrophe model.

In practical applications, an exposure database typically includes the following information:

- Type of assets (e.g., buildings, infrastructure, machines, etc.)
- Location of assets (specified in terms of latitude and longitude)
- Value of the assets

These details are crucial for precisely evaluating and measuring the potential risk and impact of flood events on the exposed assets.

1.4 Vulnerability module

While in the hazard module we are interested in hazard events themselves, the aim of the vulnerability module is to translate the intensity of a hazard to the damage incurred by the assets exposed to it. This damage is usually measured by various metrics, such as the damage ratio. Since this damage will strongly depend on the hazard and exposure characteristics, this module is naturally built on the foundation of the hazard and exposure modules. More precisely, the output of the hazard and exposure modules is usually used as the input for the vulnerability module.

It turns out that the main concept in the vulnerability module is the so-called damage functions that quantify the impact of a hazard intensity on a given asset. The damage function of an asset, also called the vulnerability curve, is a function that relates the intensity of a hazard to the loss incurred on that asset. Let us consider an example of a damage function. Let $A = (a_1, a_2, ..., a_n)$ be a set of assets and $H = (h_1, ..., h_k)$ a set of hazard events of given intensity. We define $C(a_i, h_j)$ as the cost of repairing asset a_i after being damaged by event h_j, and $V(a_i)$ as the value of replacing asset a_i with a new one. The function

$$D(a_i, h_j) = \frac{C(a_i, h_j)}{V(a_i)}$$

is an example of a damage function. If a hazard event affects a portfolio consisting of n assets, then the damage function of the entire portfolio can be defined as

$$M(a_i, h_j) = \frac{\sum_i^n C(a_i, h_j)}{\sum_i^n V(a_i)}$$

The above examples are just some of the many choices for constructing a damage function. In practice, damage functions can take many different forms that consider specific features of the assets.

For flood events, one can obtain data on damage functions from publicly available sources. One such source is the Joint Research Centre, operating under the European Commission[2]. An example of a damage function for residential assets is shown in Figure 1.2.

1.5 Impact assessment

Once we have collected the necessary data on hazard, exposure, and vulnerability, we can proceed with assessing the impact in the following manner. First, using the return period map, we determine the flood intensity or inundation depth associated with the location of each asset. This step allows us to identify the specific flood hazard level that each asset is exposed to.

Next, we estimate the potential damage to each asset by applying the appropriate dam-

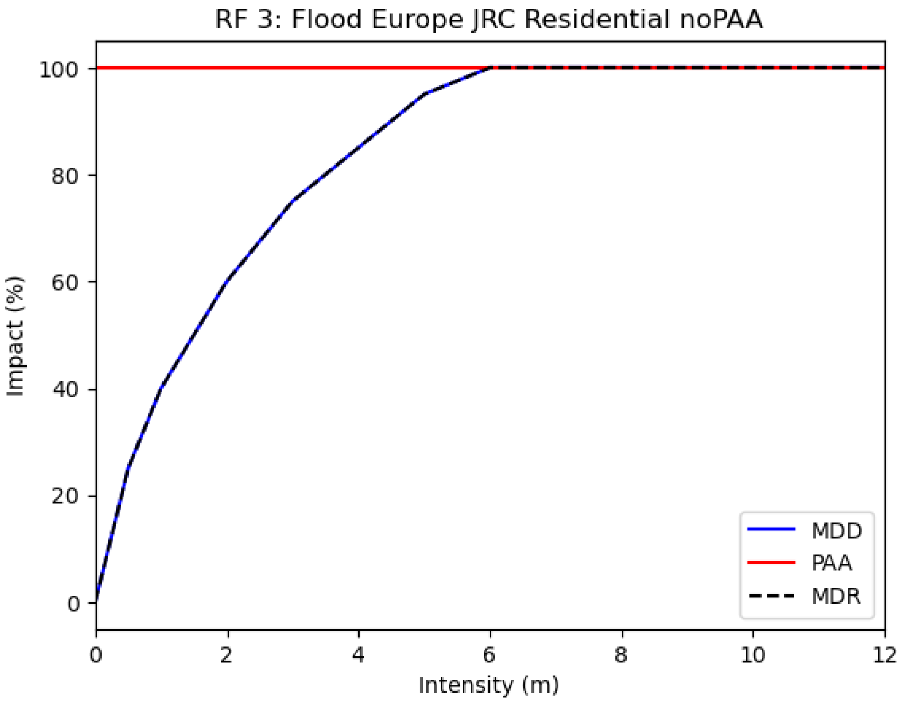

Figure 1.2: The plots demonstrate the conversion of flood depth into a damage factor ranging from 0% to 100%. This damage factor is subsequently applied to the exposed assets in each grid cell to determine the corresponding local damage. Here, MDD represents the mean damage (impact) degree, PAA denotes the percentage of affected assets, and MDR is the mean damage ratio calculated as MDR = MDD·PAA.

age functions, which quantify the relationship between flood intensity and asset vulnerability. By utilizing these functions, we can calculate the expected level of damage or loss for each asset based on the corresponding flood intensity.

Once the asset damage estimates are obtained, we aggregate and analyze the results to gain an overall assessment of the risk. This involves summarizing the estimated damages for all exposed assets, calculating the total expected losses, and identifying areas or assets that are at higher risk. Additionally, by considering factors such as asset valuation, replacement costs, business interruption losses, and indirect expenses, an estimation of the financial impact can be made. An example of such an estimation is shown in Figure 1.3.

By following these steps and considering the interplay between hazard, exposure, and vulnerability, we can assess the impact of flood events on exposed assets and gain valuable insights for risk management and mitigation strategies.

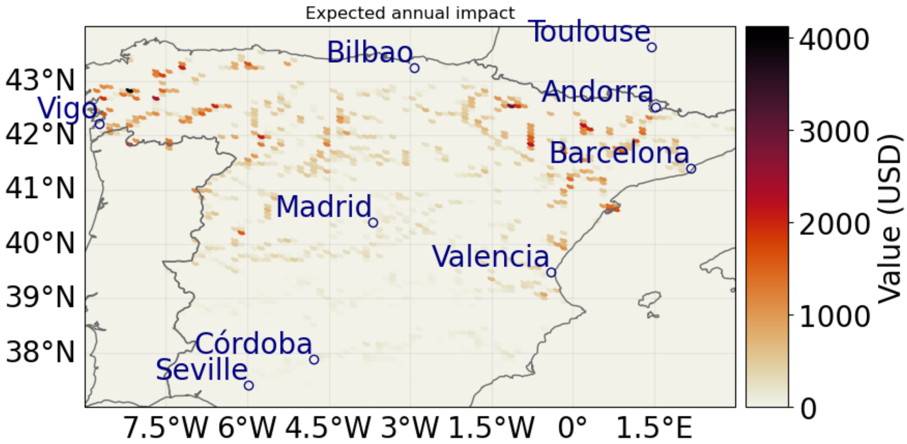

Figure 1.3: Map illustrating the annual expected impact on assets in different locations.

Bibliography

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[2] Huizinga, J., De Moel, H. and Szewczyk, W., Global flood depth-damage functions: Methodology and the database with guidelines, EUR 28552 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-67781-6, doi:10.2760/16510, JRC105688.

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