NOTE 2

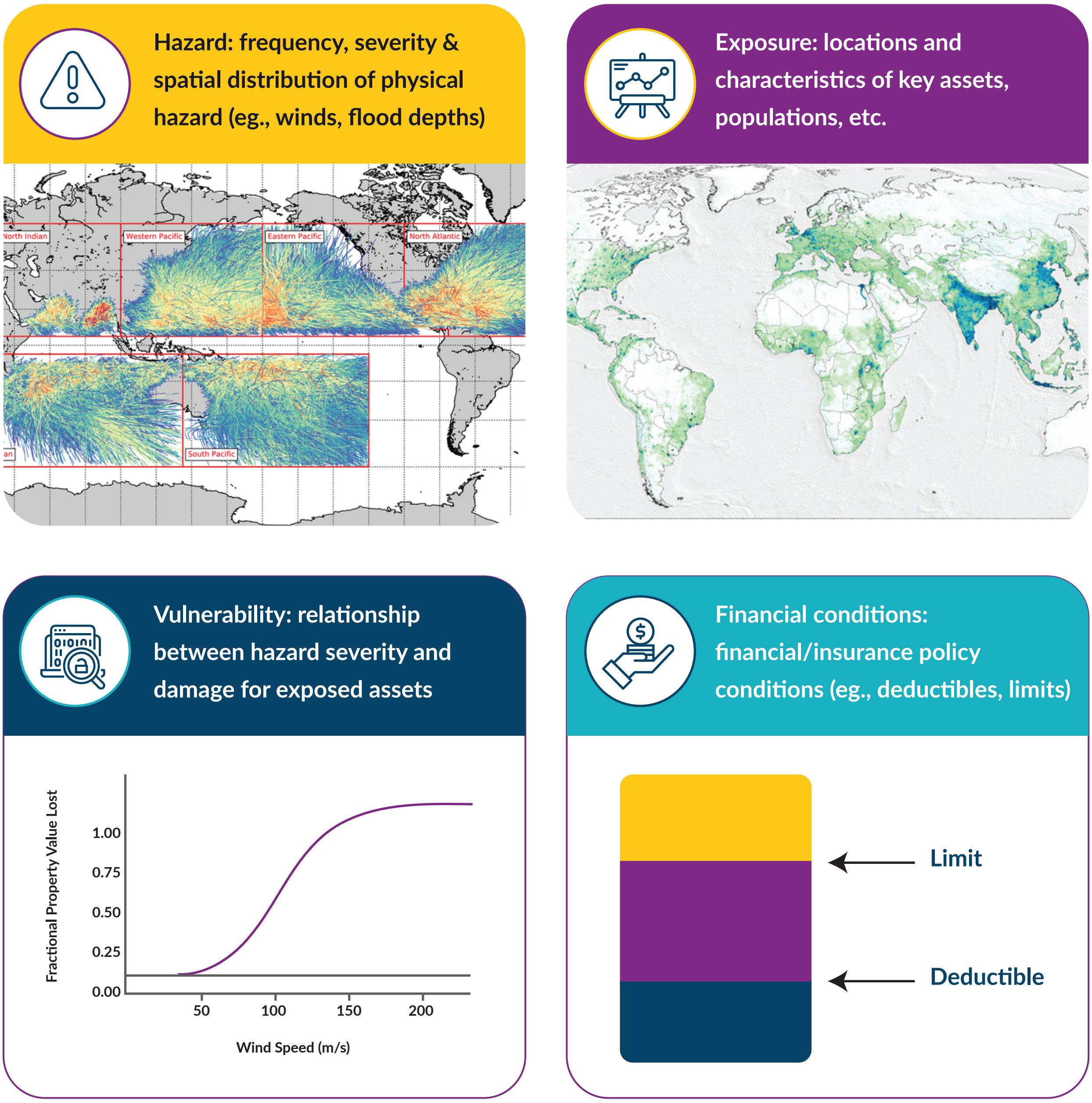
Catastrophe Risk Models: An Overview

Catastrophe risk models combine natural science, engineering, statistics, and data to quantify the risk affecting a particular region. Until the early 1990s much of the insurance industry still based many business decisions on historical data. The use of probabilistic catastrophe risk models in the insurance industry grew dramatically after Hurricane Andrew struck Florida in 1992, and insured losses turned out to be much greater than those expected based on historical experience. Catastrophe risk models are now commonplace in catastrophe insurance markets in developed countries, and they are typically a prerequisite for pricing and placing catastrophe insurance. Governments have also increasingly started to use risk modelling to assess their exposure to disaster events.

Catastrophe risk models quantify the potential impact of disasters such as floods, tropical cyclones, and earthquakes. These analytics can be used to inform investments that mitigate risk (disaster risk reduction) or inform the design of financial instruments to finance the cost of responding or recovering from these events (financial preparedness). They can provide an assessment of how likely an event is to occur and its potential impacts, which could be quantified in terms of people or assets (e.g. buildings) affected, or their financial implications.

To obtain a probabilistic quantification of the financial impacts of a disaster event in a specific geographic region, we would look at four modules—hazard, exposure, vulnerability, and financial conditions (illustrated in Figure 1 and briefly described below).

Figure 1: Modules of a catastrophe risk model



Source: World Bank, drawing on N. Bloemendaal et al., "Generation of a Global Synthetic Tropical Cyclone Hazard Dataset Using STORM," Scientific Data 7, no. 40 (2020), https://doi.org/10.1038/s41597-020-0381-2; V. Silva et al., "Development of a Global Seismic Risk Model," Earthquake Spectra 2020, doi.org/10.1177/8755293019899953; Jane W. Baldwin et al., "Vulnerability in a Tropical Cyclone Risk Model: Philippines Case Study," American Meteorological Society 2022, https://escholarship.org/uc/item/13637399, citing Kerry Emanuel, "Global Warming Effects on U.S. Hurricane Damage," Weather, Climate, and Society 3, no. 4 (2011), http://dx.doi.org/10.1175/wcas-d-11-00007.1.

Hazard:

This module includes the size, strength, location, and frequency of the hazard experienced at each location in the region (e.g., flood depth or earthquake shaking) for each event. It outputs tens to hundreds of thousands of possible events in the form of a stochastic event set—a catalog of simulated plausible events based on scientific modeling and historical experience. This catalog provides a more complete view of possible events, including extremes, than the historical record alone.

Exposure:

This module includes critical information on the type of exposure being modeled, including the specific assets exposed (e.g., buildings, crops, people, etc.) and as much additional information as possible about the assets' characteristics (e.g., information for buildings would include occupancy, construction type, number of stories, flood area, etc.). When granular data are not available, techniques can be used to disaggregate coarse data into individual points based on predefined algorithms and assumptions.

Vulnerability:

This module looks at the relationship between the damage a particular asset is likely to suffer and the intensity of hazard (e.g., how much damage is a certain asset likely to experience when exposed to a hazard event of a certain intensity). The level of damage is very sensitive to risk information contained in the exposure data, and the levels of damage for the same level of hazard can vary considerably (e.g., buildings of different construction types can be differently impacted by the same intensity of ground shaking; households of different socioeconomic levels can prepare differently and therefore experience different impacts from the same event). The vulnerability module comprises a set of vulnerability functions or curves, which describe the level of damage for increasing hazard intensity (e.g., 50 percent damage associated with sustained winds of 150 kph). These functions/curves are determined in one of two ways: empirically (i.e., based on claims data from historical events) or analytically (i.e., using engineering models and testing). Due to the relatively small number of events and the myriad factors that can impact an asset's vulnerability, the level of uncertainty in this module is high.

Financial Conditions:

The financial module provides information on financial contracts (e.g., insurance contracts) that determine the financial liability to different parties (e.g., insured, insurer, or reinsurer). This includes information on (for example) deductibles and limits.

A critical part of the model-building process is to validate the model against other data. All models have specific strengths and weaknesses, which model users must recognize to ensure that decision-making based on modeled results is robust. Any model should be validated against appropriate measures of historical experience both at the component level and at the level of the model as a whole. At a minimum, this validation should include a comparison against the historical record to ensure consistency with actual observations, including historical losses.

FAQs

Do catastrophe risk models predict what is going to happen in the future?

No. These models are not tools to forecast the future; they instead model tens or hundreds of thousands of plausible events to provide a more complete view of possible outcomes than the historical record alone (which often doesn't capture sufficient extreme events). They do not provide an exhaustive list of all future possible events, but rather generate a range of events that can shed light on the range of potential future losses. Catastrophe models account for the uncertainty in each step of the process for calculating these events.

What can the outputs of a catastrophe risk model be used for?

Catastrophe models produce a number of different metrics, including the average annual loss (AAL) and return period (RP) losses. These outputs can be used for several purposes— for example: to understand the potential impacts from disasters; to quantify the extent to which physical adaptation measures can reduce risk (e.g., the impact of building a new flood defense system); to support government risk layering decisions (see Note 1); and to inform development and pricing of risk transfer products.

Which catastrophe risk model should I use for CDRF?

Risk models are developed by a range of actors (e.g., specialized risk modeling firms, academia, the insurance industry, public institutions) for a range of purposes, from increasing the understanding of risk to placement of financial instruments. Not all catastrophe risk models are appropriate for every purpose: they don't all include the four modules described above (for example, risk models focused on understanding or managing disaster risk do not necessarily require insurance data and a financial module) and they are calibrated and tested to suit their specific focus.

Some models are more readily accepted by financial markets (e.g., insurance and insurance-linked securities markets) than others; this is due to differences in familiarity, robustness of scientific basis, transparency, and the extent of model validation (particularly for the geography where the model is being applied). Before engaging with a particular model or modeler, always seek the advice of a risk modeling specialist for guidance on the approach to take.

In the past, risk models tended to be seen as black boxes that provided limited transparency on the calculation being done internally; but this has been changing in recent years as models have become more open through use of open platforms and open data.

Why are catastrophe risk models not available for many emerging market and developing economies (EMDEs)?

Catastrophe risk models have traditionally been developed by the insurance industry and are therefore concentrated where such markets are well developed. Through global open models, as well as country-level investment by governments and development partners, risk modeling and risk understanding in EMDEs is growing.

Reading List

Foote, Matthew, John Hillier, Kirsten Mitchell-Wallace, and Matthew Jones. 2017. *Natural Catastrophe Risk Management and Modelling: A Practitioner's Guide. Wiley.*

GFDRR. Understanding Risk in an Evolving World: *Emerging Best Practices in Natural Disaster Risk Assessment. 2014*
https://openknowledge.worldbank.org/entities/publication/d8e4a704-378d-5fed-9ba1-89c01f18adcc