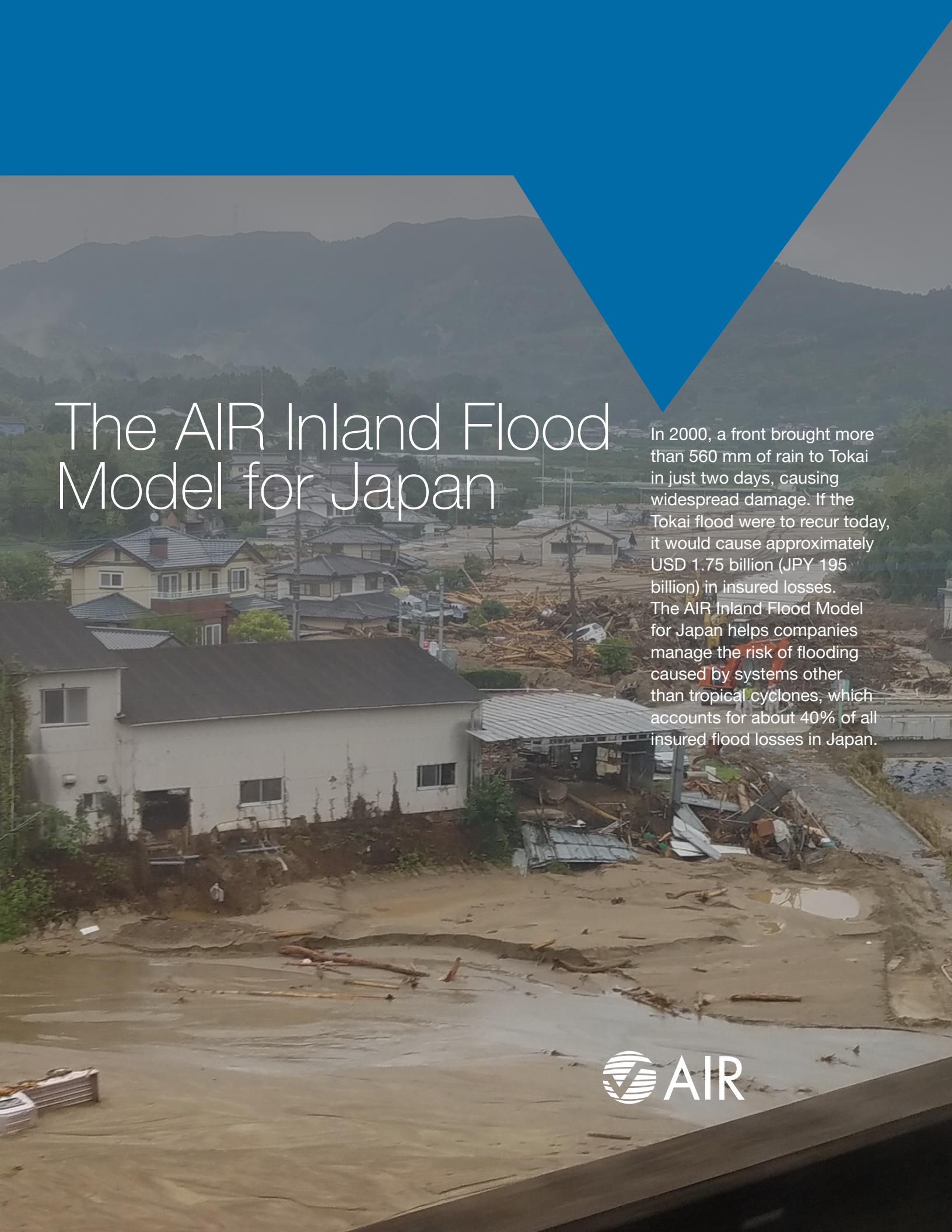


# The AIR Inland Flood Model for Japan

Aerial view of a flooded residential area in Japan, showing damaged houses and debris.

In 2000, a front brought more than 560 mm of rain to Tokai in just two days, causing widespread damage. If the Tokai flood were to recur today, it would cause approximately USD 1.75 billion (JPY 195 billion) in insured losses.

The AIR Inland Flood Model for Japan helps companies manage the risk of flooding caused by systems other than tropical cyclones, which accounts for about 40% of all insured flood losses in Japan.



Approximately 75% of total insurable property is located on Japan's floodplains. The existing concentration of exposure in areas of high hazard and continued urbanization exacerbate both riverine (on-floodplain or fluvial) and non-riverine (off-floodplain or pluvial) risk in an already flood-prone region. Until now, (re)insurers could appropriately assess only about 60% of their precipitation-induced flood risk in Japan with typhoon models.

The AIR Inland Flood Model for Japan provides risk management tools for the 40% of Japan's insured flood losses attributed to atmospheric systems other than tropical cyclones. It simulates both the weather systems and the flooding they cause, while accounting for a broad range of climatic conditions, local soil conditions, land use, and topography. The river network extends 103,000 km, comprising more than 20,200 catchments and 17,400 river segments to capture flood risk over an area of 338,000 km<sup>2</sup>.

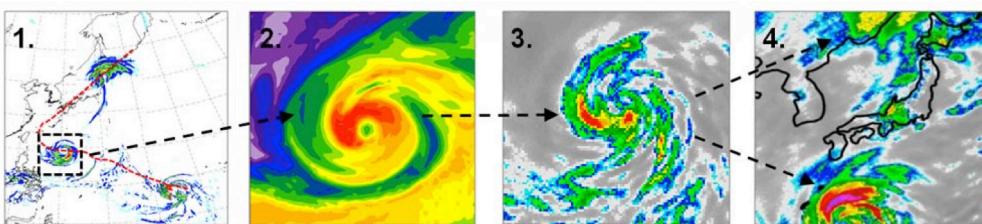


The river network in Japan extends 103,000 km and comprises more than 20,200 catchments and 17,400 river segments over an area of 338,000 km<sup>2</sup>.

### An Innovative Approach to Modeling Precipitation for a Robust View of Flood Risk

AIR employed a four-step framework to develop a unified hazard catalog, one that captures precipitation from all sources.

First, global climate data was dynamically downscaled via a Numerical Weather Prediction (NWP) model to realistically simulate rainfall patterns of historical events at a finer resolution (Box 1). Because precipitation is not continuous in space and time, a continuous field better suited for statistical modeling was created (Box 2). Although this so-called “pseudo-precipitation” field—which represents a spectrum of atmospheric moisture (i.e., humidity)—is continuous, it lacks the small-scale fluctuations present in actual precipitation patterns; these were reintroduced through statistical perturbation (Box 3). Finally, precipitation from all sources—both tropical and non-tropical—was combined to create a unified view of the hazard that realistically captures rainfall patterns and intensities over space and time (Box 4).

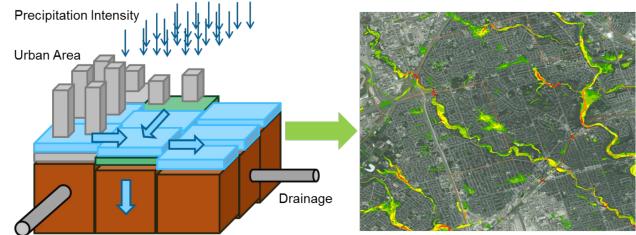


An illustration of the four-step precipitation framework developed by AIR to create a unified view of the hazard for the Japan inland flood model.

The hazard catalog was then partitioned such that stochastic tropical storm tracks and associated precipitation were extracted for use in the AIR Typhoon Model for Japan and the remaining weather systems and precipitation were retained for the AIR Inland Flood Model for Japan.

## MODELING ALL WATER-BASED PERILS IN JAPAN

Because policies in Japan are often written to cover all water-based perils, users of Touchstone® who license both the AIR Inland Flood Model for Japan and the AIR Typhoon Model for Japan can assess the risk of losses from precipitation from all sources and storm surge.



A schematic of the two-dimensional pluvial component of the hydraulics module based on shallow water equations (left) and its application to modeling in the AIR Inland Flood Model for Japan (right).

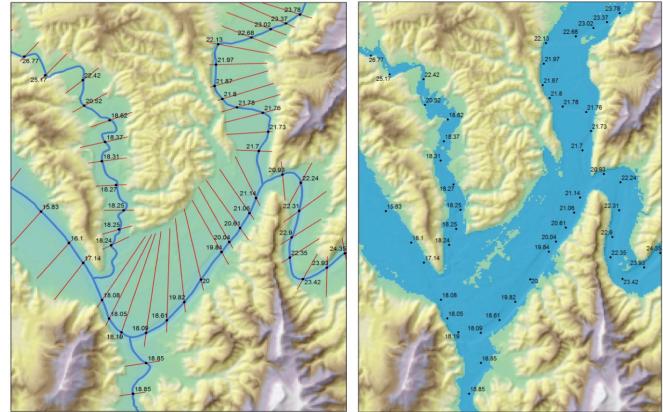
Two-dimensional modeling has also been applied across the floodplain in the new on-floodplain (fluvial) component for selected regions on Japan's major rivers to provide a more robust view of the risk under more complex conditions. The model uses a physically based hydraulics module that calculates the extent and depth of flooding at each location of interest on the floodplain.

## Calibration of the Hydrology Module

Nestled within the Japan inland flood model is the hydrology module, which captures antecedent soil moisture, rainfall runoff over land, and flows in the region's rivers, as well as the topological, land use, and soil characteristics of the region. To ensure good agreement between measured historical and modeled river flows for about 17,500 catchments across Japan, AIR collaborated with the University of California, Irvine, to calibrate the hydrology model. Using a model evaluation and uncertainty assessment tool called DREAM, machine learning was employed to calibrate model outputs against observed data.

## A Two-Dimensional Hydraulics Module for More Realistic Flood Extent Simulations

Off-floodplain (pluvial) flooding occurs when heavy precipitation falls on saturated soil or paved urban surfaces, and/or on areas with poor drainage conditions. The hydraulics module features a new pluvial component that realistically models off-floodplain risk over the course of an event. Because storm drainage capacity in urban areas is highly variable and can greatly impact flood extent and depth, AIR researchers combined data on drainage systems in urban/populated regions, their design capacity, and their upkeep to assess off-floodplain risk.



## Modeling Flood Defenses and Their Failure—a Critical Part of Managing Flood Risk

Recognizing that flood defenses can fail is critical to understanding and managing flood risk comprehensively, the AIR model accounts for the current state of the country's flood defenses by using data on design return periods from the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT). The model also accounts for the failure of flood defenses—such as levees—on one or both sides of a river, depending on the river flow rate as compared to the design capacity of the flood defense. The flood protection provided by the recently constructed largest underground floodwater drainage system in the Tokyo and Saitama prefectures has also been accounted for by the model.



An aerial view of the area flooded by a levee breach (circled in orange) on one side of the Kinugawa in Joso, Ibaraki Prefecture, Japan, in 2015. (Source: Geospatial Information Authority of Japan)

## An In-Depth Approach to Assessing Vulnerability

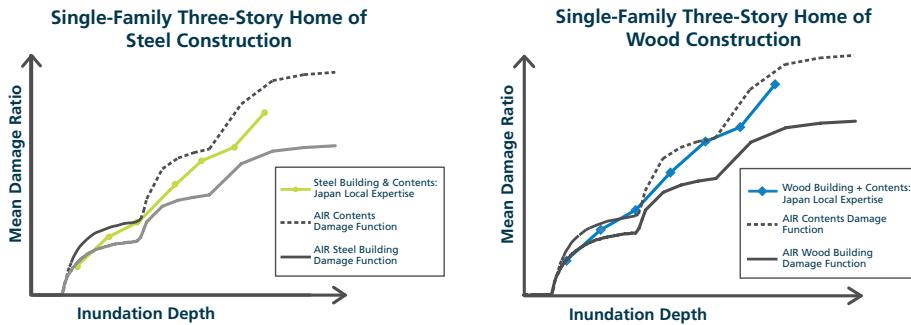
Based on published engineering studies, post-disaster surveys, and local data about property risk features, AIR engineers have developed damage functions for 62 different construction classes and 116 occupancy classes in Japan.

Among the drivers of flood losses are building characteristics, such as the presence of basements, structure height, construction type, and occupancy class. In addition to these primary risk characteristics, highlights of the AIR model's vulnerability module include:

- Support for secondary characteristics, such as foundation type, first floor height, custom elevation, and custom flood protection—including super levees along the six major rivers in the Tokyo and Kinki metropolitan areas
- Method for estimating business interruption that varies by occupancy and accounts for business characteristics (i.e., resiliency, the ability to relocate) and building size and complexity
- Specialized risks, including large industrial facilities, additional composite construction classes (to enhance support of Japan's old and new fire codes), marine cargo, marine hull, railways, inland transit, and buildings under construction
- Flood damage estimation that accounts for the existing flood defenses
- When detailed exposure data (e.g., construction type or height) is unavailable, the model applies an “unknown” damage function that takes into account the building inventory in Japan that varies by prefecture

## Building Damage Is Determined at the Component Level

The majority of the damage caused by most floods is to nonstructural components, especially the mechanical, electrical, and plumbing (MEP) systems. To capture the difference in the relative vulnerability of MEP systems and a building's interior, foundation, and structural components, the model uses a component-based approach to develop building damage functions.

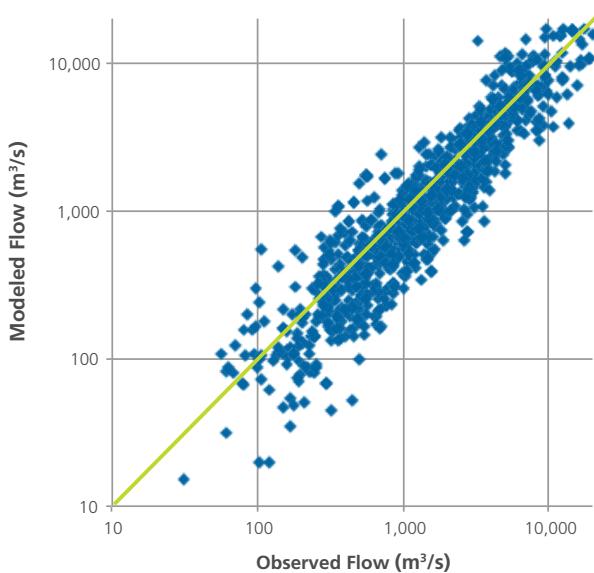


Component-level damage functions for steel buildings and contents (left) and wood buildings and contents (right) show good agreement with local expertise

## Comprehensive Model Validation

Validation is not limited to final model results. All components of the inland flood model were rigorously validated, from the spatial distribution of precipitation and its accumulation to modeled precipitation amounts for different return periods, and from modeled historical events to river flow characteristics using data from more than approximately 1,000 streamflow gauge stations across Japan.

To ensure the reliability of modeled loss estimates, the AIR Inland Flood Model for Japan has been thoroughly validated against loss data from industry reports, research publications, claims, and the Japan Ministry of Land, Infrastructure, Transport and Tourism (MLIT) National Flood Database.



River flow was validated using data from more than 1,000 gauging stations across Japan.

## Model at a Glance

<b>Modeled Peril</b>	Precipitation-induced inland flood from non-tropical atmospheric systems
<b>Model Domain</b>	Northwest Pacific Ocean and the Japanese archipelago
<b>Stochastic Catalog</b>	10,000-year stochastic catalog, two historical events from non-tropical storms
<b>Supported Geographic Resolution</b>	Latitude/Longitude, JIS/Ku/Sonpo/Yubin, and Prefecture
<b>Supported Construction and Occupancy Classes</b>	<ul style="list-style-type: none"> <li>– 62 construction classes and 116 occupancies</li> <li>– Unknown damage functions vary by prefecture</li> </ul>
<b>Industry Exposure Database</b>	<ul style="list-style-type: none"> <li>– 125-meter grid resolution</li> <li>– Detailed representation of residential, commercial, industrial, and agricultural building stock</li> </ul>

## Model Highlights

- Captures the inland flood risk posed by non-tropical weather systems, which account for 40% of flood losses in Japan
- State-of-the-art approach to downscaling simulates precipitation fields at high resolution for improved risk selection and accurate assessments of portfolio risk
- Applies two-dimensional hydraulics modeling to explicitly and physically model off-floodplain risk—a major source of insured flood losses
- Accounts for the existing flood defenses in flood damage estimation
- Features a component-based approach—one that divides a building's mechanical, electrical, and plumbing (MEP) aspects of design, as well as its interior, foundation, and structural elements—to estimate the vulnerability of buildings and their contents for all lines of business
- Enables users of Touchstone who license both the AIR Inland Flood Model for Japan and the AIR Typhoon Model for Japan to model all water-based perils for the country
- Specialized risks, including large industrial facilities, additional composite construction classes (to enhance support of Japan's old and new fire codes), marine cargo, marine hull, railways, inland transit, and buildings under construction
- Low-rise building height can be specified as one-, two-, or three-story to account for regional building practices

## ABOUT AIR WORLDWIDE

AIR Worldwide (AIR) provides risk modeling solutions that make individuals, businesses, and society more resilient to extreme events. In 1987, AIR Worldwide founded the catastrophe modeling industry and today models the risk from natural catastrophes, terrorism, pandemics, casualty catastrophes, and cyber attacks, globally. Insurance, reinsurance, financial, corporate, and government clients rely on AIR's advanced science, software, and consulting services for catastrophe risk management, insurance-linked securities, site-specific engineering analyses, and agricultural risk management. AIR Worldwide, a Verisk ([Nasdaq:VRSK](#)) business, is headquartered in Boston with additional offices in North America, Europe, and Asia. For more information, please visit [www.air-worldwide.com](#).