The AIR Typhoon Model for Japan

In 2018 and 2019, four powerful typhoons struck Japan, incurring total insured losses of more than USD 30 billion from wind, precipitation-induced flooding, and storm surge damage. As the number and value of properties in Japan's risk-prone areas continues to grow, it is essential for companies operating in this market to have the tools that will help effectively manage and mitigate the financial risks from future devastating typhoons.

AIR

While in the context of Japan's recent typhoon history, the losses for the back-to-back seasons of 2018 and 2019 seem high, we know that if Typhoon Ida (1958) and Typhoon Vera (1959) were to recur today, the losses would be even higher. In the stochastic catalog of the AIR Typhoon Model for Japan, there are 698 instances of aggregated insured losses from two consecutive years of storm activity totaling more than USD 30 billion, 251 of which total more than USD 50 billion. All four significant 2018/2019 typhoons—Jebi, Trami, Faxai, and Hagibis—are included as historical events in the AIR model, while extensive loss data from these and other recent storms affecting the Japanese insurance market have been used to validate model results.

The AIR Typhoon Model for Japan—part of AIR's Northwest Pacific Basinwide Typhoon Model—provides a realistic view of potential losses from tropical cyclones with a catalog incorporating cutting-edge science that best reflects the current understanding of the spatial-temporal characteristics of tropical cyclones in this basin. To facilitate risk assessment and risk differentiation at a highly granular level, the model incorporates the latest engineering research in the resilience of local construction to the perils of typhoon winds, precipitation-induced flooding, and storm surge.

Robust Catalog Leverages Data from Leading Regional Organizations

The model features a large catalog of simulated events that appropriately characterizes the frequency, track, and other meteorological aspects of potential future storms. To create this catalog, AIR scientists utilized historical data provided by leading regional organizations, including the Japan Meteorological Agency (JMA) and the Shanghai Typhoon Institute (STI). Based on these comprehensive data sets, the AIR model features a 10,000-year catalog containing 193,000 simulated loss-causing events ranging from tropical storm to super typhoon.

Wind Hazard Modeling Reflects Latest Research on Regional Typhoon Behavior

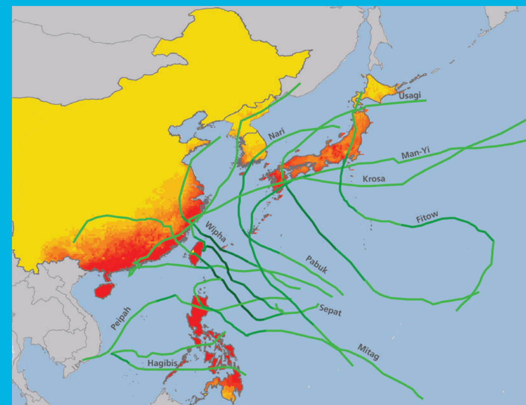
Observation data indicate that the central pressure–wind speed relationship is different in different ocean basins. For example, for the same central pressure, typhoons in the Northwest Pacific tend to have lower wind speeds than hurricanes in the North Atlantic. In the AIR model, the generation of a typhoon's local wind field involves computing winds aloft at each point in the model domain using a central pressure–wind speed relationship that incorporates region-specific data to best reflect the current understanding of winds generated by Northwest Pacific typhoons.

The model's wind field formulation is further supported by the latest available data and scientific literature on the rate of decrease in wind speeds after landfall. Overestimating this rate can significantly underestimate inland losses.

A Comprehensive Approach to Assessing Regional Risk

Today, insurers and reinsurers operating globally need the ability to quantify the risk to policies and portfolios that span multiple countries—particularly in the Northwest Pacific Basin, where, given the configuration of landmasses, more than half of all landfalling typhoons affect more than one country.

To provide a consistent and comprehensive view of risk to companies with regional portfolios, AIR has developed a unified basinwide catalog shared by all modeled countries in the Northwest Pacific basin. The catalog enables seamless risk assessment for multi-country policies and portfolios, an approach of critical importance to global companies.



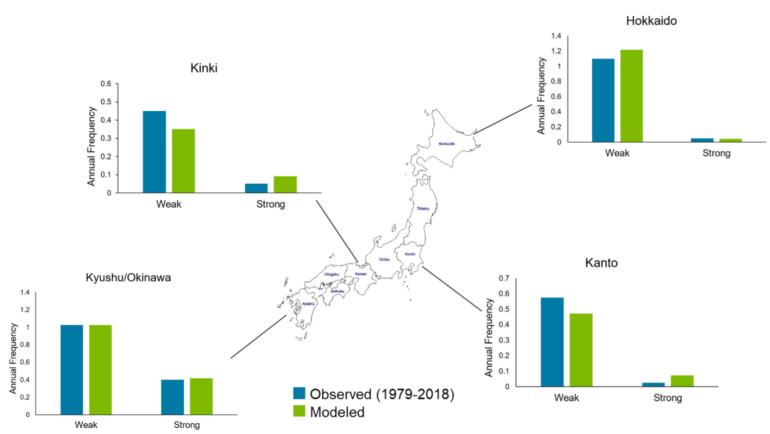
The majority of storms during the 2007 Northwest Pacific typhoon season impacted more than one country.

ALERT - AIR LOSS ESTIMATES IN REAL TIME

AIR's ALERT™ (AIR Loss Estimates in Real Time™) has provided estimates of insured losses from Japan typhoons in real time since 2000. AIR uses the storm parameters reported by the Japan Meteorological Agency, including forecast track, landfall location, wind speeds, and precipitation, to produce a realistic distribution of potential industry losses, as well as tools for insurers to assess the impact of each storm on their own portfolios. ALERT keeps companies well-informed at critical times, allowing them to communicate effectively within their organizations and set expectations for the insured and other stakeholders. AIR's real-time loss estimates can help insurers manage reserves and determine if reinsurance is adequate; ALERT can also help insurers decide how and where to effectively deploy claims resources, and even to understand where to suspend or continue writing business. Timely information is also extremely valuable in light of increasingly common financial instruments for hedging against catastrophe losses.

Climate Change And Japan Typhoon Risk

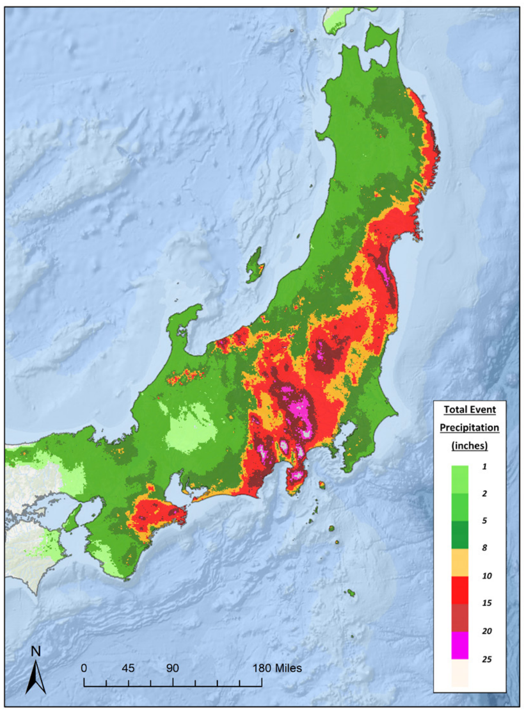
AIR incorporates the current and near-current climate in our catastrophe models to account for climate change impacts. For the AIR Typhoon Model for Japan, AIR extensively researched the latest scientific literature on how tropical cyclone wind, storm surge, and precipitation-induced flood events have changed and will change to ensure these trends are appropriately captured.



Comparison of observed (1979-2018) and AIR-modeled (1951-2006) annual landfall frequency distributions by relative storm intensity for selected regions (a weak-landfalling storm is defined as a storm with a central pressure no less than 965 mb when making landfall, while strong storms are those having landfall central pressure less than 965 mb).

Precipitation-Induced Flood Module Incorporates Detailed Information on Soil Characteristics, Land Use/Land Cover, and Topography

Precipitation-induced flooding can be a major driver of insured loss from typhoons impacting Japan. Unlike typhoon winds, which generally decrease as storms move inland, the intensity of tropical storm–induced precipitation can actually increase in inland regions. Furthermore, the precipitation footprints of typhoons typically extend for hundreds of kilometers (as opposed to tens of kilometers for the wind footprint); thus, even storms hundreds of kilometers offshore can cause significant flood damage on land.



Total event precipitation (inches) of Typhoon Hagibis (2018), the wettest tropical cyclone in Japan's recorded history.

The AIR model employs a separate module that is used to determine the spatial and temporal distribution of accumulated runoff in rivers and over land. High-resolution data on soil, land use/land cover, and slope are all used to simulate the hydrological response to precipitation over the model domain. Risk from both types of flooding—riverine floods and flash floods—is explicitly quantified for a comprehensive flood risk assessment in the country. To ensure the most accurate view of flood risk, AIR's model also accounts for extratropical transitioning, which can lead to an increase in the size of a storm's precipitation field.

COMPREHENSIVE VIEW OF WATER-RELATED PERILS RISK

Users of the AIR Typhoon Model for Japan and the AIR Inland Flood Model for Japan can easily assess the risk of tropical cyclone precipitation-induced flood, non-tropical cyclone precipitation-induced flood, and storm surge for a comprehensive view of water-related perils risk across Japan.

Storm Surge Module Incorporates High-Resolution Bathymetry and Terrain and Storm Surge Elevation Data

Although little correlation exists between typhoon wind speed and precipitation intensity, storm surge is strongly correlated with wind speed. Other factors influencing the storm surge threat include bathymetry and tide. A given typhoon will typically produce a larger storm surge along a coastline with shallow bathymetry than one with steep bathymetry. Background astronomical tide level—that is, the water height that would have been observed in the absence of a storm—influences the total water level seen during a tropical cyclone event. In addition, coastal defenses and levees have an impact on water levels, mitigating the effects of storm surge. Through the use of high-resolution bathymetry and terrain elevation data and by accounting for detailed coastal defense and levee information, the storm surge module simulates a storm surge event from its inception to its farthest extent inland.

ACCOUNTING FOR JAPAN'S ENGINEERED FLOOD DEFENSES

Japan continues to invest heavily in flood risk reduction measures by increasing the level of flood defenses, including levees, dams, cisterns, and storm drains. To provide the most accurate view of flood risk possible, the AIR model accounts for the designed capacity of flood defenses, as well as their current state of repair, which can differ notably from design conditions. The details of coastal defenses and levees are critical for accurately simulating the storm surge, especially in areas such as Hiroshima and Saga prefectures.

An underground cistern north of Tokyo (Source: Yomiuri Shimbun).

Damage Functions Provide Robust View of Wind, Precipitation-Induced Flood, and Storm Surge Risk

Based on engineering studies, post-disaster surveys following recent storms, and analyses of a large set of claims data, AIR engineers have developed peril-specific, intensity-based damage functions for 62 different construction classes and 116 occupancy classes in Japan. Further highlights of the AIR model's vulnerability module include:

- Separate damage functions for the wind, precipitation-induced flood, and storm surge perils
- Peril-specific damage functions that vary by building height, construction, and occupancy
- Damage functions that account for the duration of high winds at a building's location
- Method for estimating business interruption that varies by occupancy and accounts for business characteristics (i.e., resilience, the ability to relocate) and building size and complexity
- Detailed age bands for wood frame buildings
- Unknown damage functions for wind, precipitation-induced flood, and storm surge that vary by prefecture
- Flood damage estimations that account for existing flood defenses
- Five secondary risk characteristics for both the precipitation-induced flood and storm surge modules support: foundation type, custom protection, custom elevation, floor of interest, and first floor height
- Damage functions that support specialized risks, which include large industrial facilities, composite construction classes (to support Japan's old and new fire codes), marine hull, railways, and buildings under construction
- Employs a detailed, component-based approach for industrial facilities
- Support for marine, fine art, and specie lines of business, with 20 construction codes for asset types and 12 occupancy codes for storage conditions, enabling 107 distinct asset/storage risk combinations

Variability in Regional Building Practices Captured with Regional Vulnerabilities

The AIR Typhoon Model for Japan employs a detailed view of the temporal and spatial variation of vulnerability—incorporating findings from a comprehensive study of local construction practices and building codes—that supports peril-specific damage functions for wind, precipitation-induced flood, and storm surge, allowing the model to appropriately estimate losses even when not all the building characteristics are known. For engineered buildings, regional vulnerabilities were developed using design specifications from the Architectural Institute of Japan. For non-engineered structures—those not constructed to meet national codes—these vulnerabilities are based on the composite hazard: wind, seismic activity, and snow load.

AIR's Industry Exposure Database for Japan

AIR's industry exposure database for Japan is a detailed collection of information on exposures—including the occupancy and physical characteristics of structures, such as construction types and height classifications. AIR's industry exposure database is the foundation for all modeled industry loss estimates. It provides risk counts with replacement value breakdowns by line of business (LOB) and coverage, with take-up rates for wind and flood risk that reflect market conditions.

Companies can use our industry exposures to benchmark their own exposures, better estimate the vulnerability of unknown exposures, disaggregate exposures down to a detailed level (1 km^2), and assess real-time losses.

Comprehensive Approach to Validation

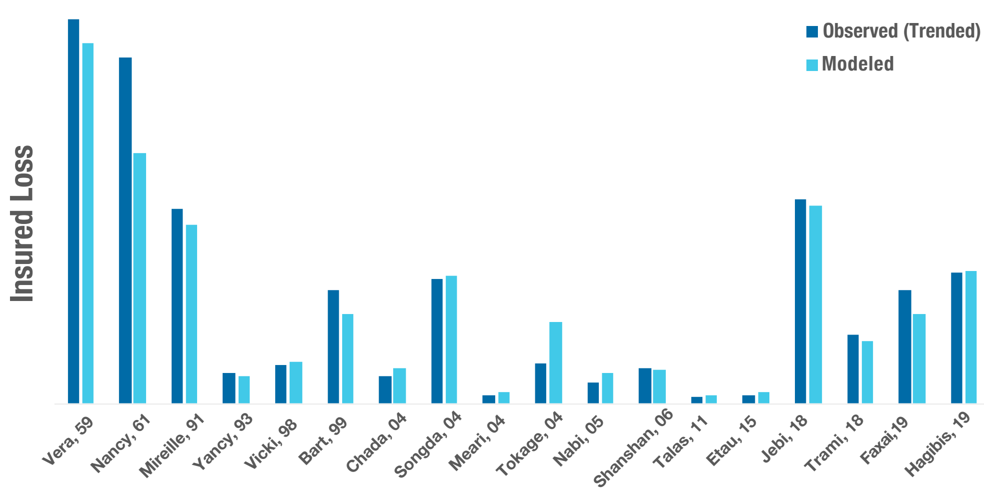
To produce realistic and robust model results, AIR builds its models from the ground up, validating each component independently against multiple sources. AIR modeled wind speeds, precipitation totals, and storm surge inundation depth are validated using Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) data and AMeDAS and buoy data from the Japan Meteorological Agency.

AIR also validates top down, comparing modeled losses to industry loss estimates and company data. Modeled losses for the AIR Typhoon Model for Japan have been validated against actual loss and claims data from major typhoons since 1991, from representative companies. AIR's comprehensive approach to validation confirms that overall losses are reasonable and that the final model output is consistent with both basic physical expectations of the underlying hazard and unbiased when tested against historical and real-time information.

Separating Wind, Precipitation-Induced Flood, and Storm Surge Losses for More Accurate Model Results

Insurance coverage for wind damage is automatically included in standard fire insurance policies. Flood and surge coverage are treated as "water" coverage and must be purchased separately from wind. Policy conditions in Japan differ significantly for water-related perils—including precipitation-induced flood and storm surge perils—as compared to the wind peril. Touchstone® allows users to input separate policy conditions for wind and water-related perils, and obtain separate loss estimates for the three sub-perils, leading to more accurate loss estimates.

Results can be made more accurate if disaggregation is applied to exposure data submitted at the aggregate level. Innovative disaggregation techniques available in Touchstone distribute prefecture-level, ku-level, or yubin-level exposure data down to a high-resolution grid based on distributions in AIR's detailed industry exposure database for Japan.



Modeled losses for select events compare well to observed losses based on individual company data. Note that for early events, such as Vera and Nancy, where observed losses are not available, industry loss estimates are used for comparison.

Model at a Glance

Modeled Perils	Tropical cyclone wind, precipitation-induced flood, and storm surge
Model Domain	Northwest Pacific Ocean and the Japanese archipelago
Supported Geographic Resolution	Latitude/longitude, JIS/ku/sonpo/yubin, and prefecture
Catalogs	10,000-year catalog includes more than 83,000 loss-causing events; historical catalog comprises 21 events, including Jebi (2018), Trami (2018), Faxai (2019), and Hagibis (2019); and one Lloyd's realistic disaster scenario (RDS) and four extreme disaster scenarios (EDS) are provided
Supported Construction Classes and Occupancies	— 62 construction classes and 116 occupancy classes — 107 modeled asset/storage code combinations support diverse marine, fine art, and specie lines, including marine cargo, inland transit, and builder's risk — Supports aviation, marine hull, railways, automobiles, infrastructure, and large industrial facilities — Supports five secondary risk characteristics for precipitation-induced flooding and storm surge to accurately differentiate vulnerability — 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, which varies by prefecture
Supported Policy Conditions	Supports a wide variety of location, policy, and reinsurance conditions, as well as Extra Expenses and Debris Removal; and complex policies that are commonly used in Japan, such as endowment or step policy functions

Model Highlights

- Basinwide modeling in the Northwest Pacific enables companies to estimate losses seamlessly for policies and portfolios that span multiple countries and territories
- Incorporates central pressure–wind speed relationship specific to the Northwest Pacific basin
- Explicit modeling of wind, precipitation-induced flooding, and storm surge
- Peril-specific vulnerability framework accounts for damage to buildings, contents, and business interruption from wind, precipitation-induced flooding, and storm surge
- Accounts for regional variations in building vulnerability due to multi-hazard environment
- Accounts for the impact of flood defense systems in mitigating flood risk
- AIR's industry exposure database for Japan reflects replacement values and policy conditions
- Touchstone enables users to run wind/flood/surge scenarios and can distribute aggregated exposure data down to a 1-km resolution grid based on distributions in AIR's detailed industry exposure database

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, supply chain disruptions, terrorism, pandemics, casualty catastrophes, and cyber incidents. Insurance, reinsurance, financial, corporate, and government clients rely on AIR's advanced science, software, and consulting services for catastrophe risk management, insurance-linked securities, longevity modeling, 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. For more information about Verisk, a leading data analytics provider serving customers in insurance, energy and specialized markets, and financial services, please visit www.verisk.com.

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