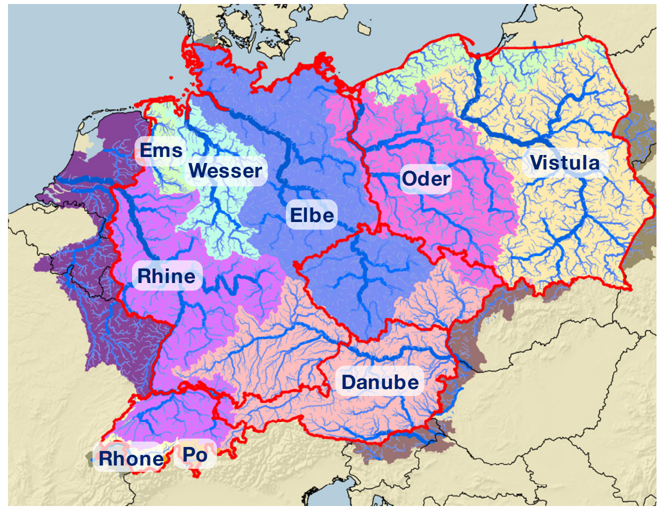
AIR Inland Flood Model for Central Europe

Between May 30 and June 2, 2013, heavy rainfall over Central Europe caused floodwaters to rise to their highest levels, surpassing those observed during the Elbe flood in 2002 in some areas. The costliest natural catastrophe of 2013, this flood incurred insured losses of EUR 1.8 billion in Germany alone, with further losses in Austria, Czech Republic, and Poland. With the AIR Inland Flood Model for Europe, companies can make more informed underwriting and pricing decisions and develop more effective portfolio management and risk financing strategies.

AIR

Flooding is a regular occurrence in Central Europe in both low-lying river valleys and off the floodplains. Record-breaking flood events such as the Central European floods of 2013 are a stark reminder of the loss potential they hold. Despite the ubiquity and frequency of this hazard, historical data alone are insufficient to estimate losses from future catastrophic events. Exposure growth, the uneven take-up of flood insurance, and development of flood protection measures further complicate loss estimation.

AIR's inland flood model sets the standard for managing flood risk in Central Europe, providing a probabilistic approach for determining the extent and likelihood of losses from inland floods, including the most extreme events that far exceed historical experience.



AIR's model captures the risk of flood across nine major river basins, comprising a river network extending ~252,000 km and more than 45,000 distinct river catchments.

A Comprehensive View of Flood Risk in Austria, Czech Republic, Germany, Poland, and Switzerland—Both On and Off the Floodplains

The AIR Inland Flood Model for Central Europe captures the flood risk across nine major river basins, comprising a river network extending approximately 252,000 km and more than 45,000 distinct river catchments that stretches beyond the borders of the modeled countries to include all streams contributing to floods within those countries.

A hydraulic model is used to explicitly model every stream with a drainage area of more than 10 km^2. Off-floodplain (pluvial) flooding—which can account for a significant share of claims—is modeled using precipitation, local topography, and drainage conditions.

Precipitation in Europe is typically associated with large-scale frontal systems of storms that develop over the Atlantic and generally track in easterly directions. Depending on the state of the atmosphere, however, the location of storm system formation and track direction can alter significantly.

Based on the particular atmospheric conditions at the time, a variety of precipitation patterns can develop. The storm systems migrate across the region and can span several hundred kilometers, potentially causing flooding that affects several river basins. Simulating the full spectrum of storms requires a model capable of reproducing the atmospheric conditions at a sufficiently high resolution over large areas. More localized floods are frequently caused by small-scale torrential downpours from convective summer storms.

Advanced Modeling Captures Precipitation at High Resolution

To meet the challenge of capturing both large-scale and small-scale precipitation patterns, AIR has developed a technique that couples a Global Circulation Model (GCM) with a high-resolution Numerical Weather Prediction (NWP) model and an advanced statistical downscaling algorithm. This innovative approach simulates realistic and statistically robust precipitation patterns over space and time.

After potentially flood-causing storms are identified from the NWP output, the unique characteristics of each precipitation field—which can determine the likelihood of localized flash floods—are captured in detail. This requires a finer resolution than that used to identify the storms themselves. AIR has developed a sophisticated downscaling technique in which the statistical properties of the precipitation field at a coarser resolution (i.e., the 90-km resolution of the NWP model) are "downscaled" based on turbulence theory, which characterizes precipitation intensity with changing scales. The result is realistic patterns of precipitation at higher resolution of 8 km x 8 km.

A Comprehensive Approach to Estimating Soil Moisture Conditions and Their Impact on Runoff

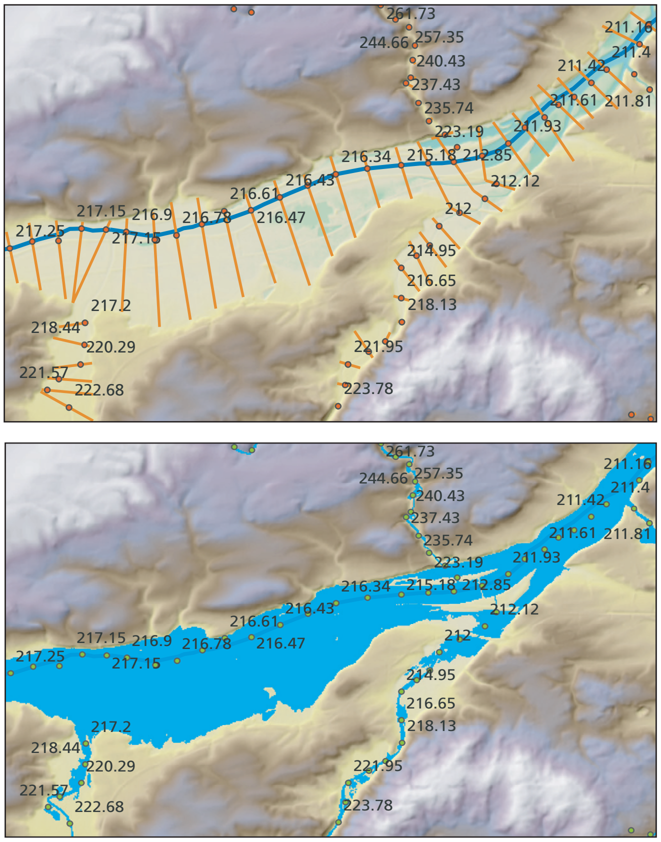
If the soil is dry, even extreme rainfall may not cause flooding. By contrast, when soils are already saturated from previous storms or snowmelt, the chances of flooding increase. Thus the amount of soil moisture prior to flooding—referred to as antecedent conditions—is critical to modeling flood risk. To account for the antecedent conditions at the onset of each storm, the AIR model leverages high-resolution precipitation data and considers snow buildup and snowmelt to compute a continuous local soil-water balance.

Surface runoff—that is, the water that is not absorbed by the soil and ends up in the river network on short time scales—is routed downstream along a river network using the widely accepted Muskingum-Cunge flood routing scheme. This physically based flood routing module accounts for the river cross-sectional shape and captures the mitigating effects on peak flow of more than 400 dams and the influence of lakes or larger bodies of water on about 9,000 river segments.

A Sophisticated Hydraulic Model to Determine Flood Depth

A physically based hydraulic model transforms river flow to water level, or elevation. This step is critical for calculating inundation depth at each location of interest for each flood event and, ultimately, for determining resulting damage and loss.

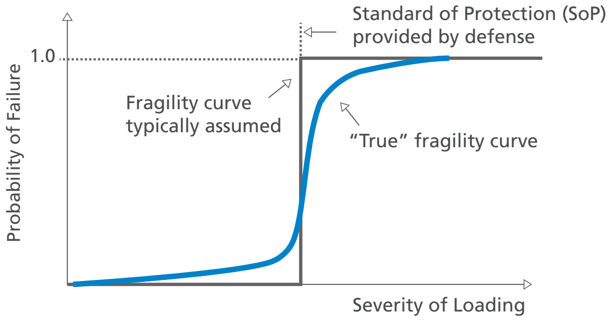
The hydraulic model used in AIR's Central European inland flood model uses the same computational algorithm as employed in the Hydrologic Engineering Center's River Analysis System (HEC-RAS), a widely used hydraulic engineering software. Inundation depths are derived using a digital terrain model at 25-meter resolution.



To calculate damage and loss, both flood extent and depth must be determined. AIR's hydraulic model realistically simulates flood extent using flood elevation levels at cross sections along rivers. The numbers along the indicated cross section in the top panel show the computed water elevation along the river network, while the bottom panel shows the corresponding flood extent, a continuous water surface. Flood depth is derived by subtracting terrain elevation from water elevation.

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

Flood defenses play a critical role in protecting properties within the floodplains of Austria, Czech Republic, Germany, Poland, and Switzerland. The AIR Inland Flood Model for Central Europe accounts for levees, dikes, flood walls, and mobile flood defenses using a probabilistic approach that incorporates the latest information and standards of protection used within each country. The model also accounts for differences in the levels of flood defense among the five countries. The model addresses the possibility that defenses will fail in a probabilistic framework, using fragility curves that indicate the probability of failure given a level of loading. Within each area protected by a flood defense, the fragility curves are used to determine if and under what conditions a defense fails. Without proper treatment of flood defense failure, modeled losses can be off by an order of magnitude.



Fragility curves provide the probability of flood defense failure.

Separate Assessment of Off-Floodplain Risk—A Significant Driver of Loss

Significant losses in Central Europe occur off the floodplain. To address the risk, AIR has developed a statistical module for off-floodplain loss estimation. Off-floodplain flooding occurs when intense precipitation falls on saturated soil or paved urban areas, and/or on areas with poor drainage that causes local pooling or sewer backups. As the excess runoff flows downhill, it can form dangerous temporary brooks and rills that can damage buildings as water flows past or through.

Record-breaking flooding across Central Europe in 2013 caused significant insured losses. Flood defenses like this dike on the River Vltava (Moldau) in Prague—constructed during the 2013 flood event—are built in advance of flooding to protect against rising water. AIR's Inland Flood Model for Central Europe accounts for the impacts of levees, dikes, and flood walls, as well as mobile and temporary defense barriers.

An In-Depth Approach to Assessing Vulnerability

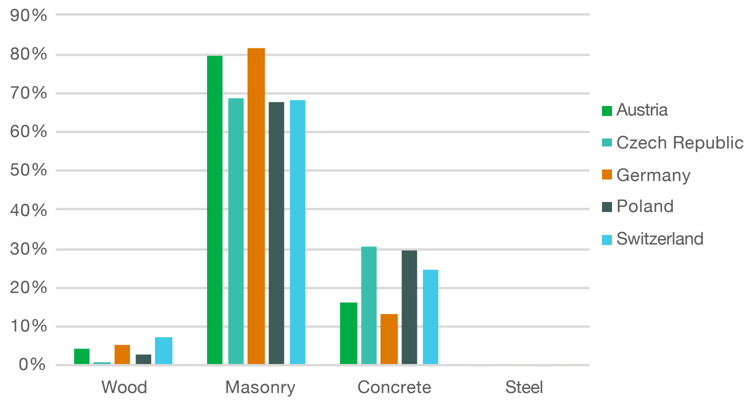
Building characteristics such as construction and occupancy type, often relate to a building's level of protection against flood or to the likelihood that a basement is present. Height is another variable that can affect a building's response to flood; typically, greater engineering attention and more stringent construction practices are applied to high-rise buildings (such as waterproofing) that often results in better flood resilience. AIR engineers have developed damage functions for 47 different construction classes and 117 occupancy classes across all five modeled countries. These damage functions are based on engineering analyses, findings from published research, damage surveys conducted by AIR, and flood insurance loss data.

Detailed Knowledge of the Building Stock

The model's damage functions incorporate findings from AIR's comprehensive study of building risk features, such as construction materials, height and foundation type, and mitigation features. Building stock in Austria, Czech Republic, Germany, Poland, and Switzerland is modeled at 90-meter resolution. The residential building stock is typically of non-engineered masonry construction. Flood damage to such structures is typically limited to basements, which are present in most single-family homes. For properties of unknown characteristics, such as construction or occupancy, unknown damage functions vary by CRESTA to account for the regional distribution of building stock.

Commercial buildings in all five countries display a wide variety of construction materials. The AIR model captures the differences in vulnerability among various construction types. Most commercial buildings have a basement, which has a significant effect on losses, particularly in cases where the basement is used for the storage of inventory or for business purposes. This important loss driver is accounted for in the AIR model.

The AIR model also estimates damage to industrial facilities, marine cargo, marine hull, wind turbines, builder's risk, automobiles, and agricultural buildings—which may include barns, silos, greenhouses, and any other buildings located on an agricultural property.

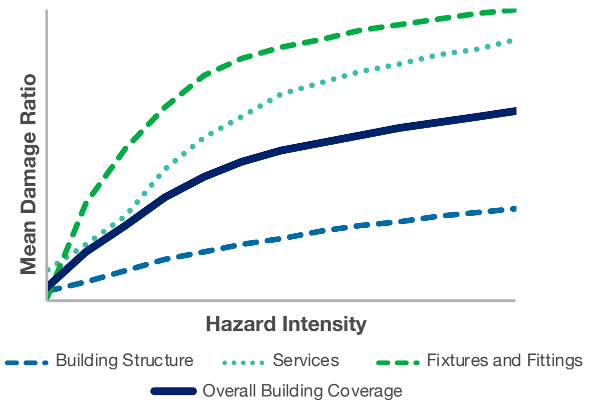


Most residential building stock in Central Europe is of masonry construction, as shown for apartments and single-family homes.

A Comprehensive Suite of Damage Functions That Considers Secondary Risk Characteristics and Off-Floodplain Losses

The AIR model incorporates damage functions that vary by occupancy, construction, and building height. A component-based approach that considers the building structure, fixtures and fittings, and services (i.e., mechanical, electrical, and plumbing) is used to estimate damage. The relative vulnerability of the individual components—which total 100% of the replacement value of the structure—is assessed and then combined to produce an overall loss estimate.

Damage increases quickly with the first few centimeters of inundation but slows as the floodwaters continue to rise; this reflects the fact that the most vulnerable building components (i.e., mechanical, electrical, and plumbing systems) are often situated at or below the ground floor level.



Damage functions for a retail shop in Central Europe show the differences in vulnerability of building components and the combined result for the building overall.

Location-specific flood protection and mitigation measures, as well as first floor height and structure elevation, can be incorporated, if known. In addition, companies can analyze the risk to a specific floor or floors of interest, including basements.

Time element damage functions account for alternative accommodation and related expenses, which are modeled in terms of the number of days before the building becomes inhabitable or usable. The model accounts for the time required for drying and cleaning the property.

The damage functions for business interruption vary by occupancy and account for building size and complexity, and business characteristics, such as resilience and the possibility to relocate.

Off-floodplain damage functions are statistically based, correlating property damage to relative runoff, the relative elevation from the nearest stream or river, and urbanicity. The model uses relative runoff and urbanicity to estimate off-floodplain drainage capacity in urban areas.

Designed for the Insurance Industry

After the Elbe floods of 2002, the 504 hours clause was introduced and is generally applied by the reinsurance market to flood events in Europe. Thus, flood losses incurred within a specified geographic area and within the time frame of 504 hours constitute a single event, whatever their cause—as was the case with the 2013 flood. The simulated events in the AIR stochastic catalog generally conform to the 504 hours event definition in most reinsurance contracts.

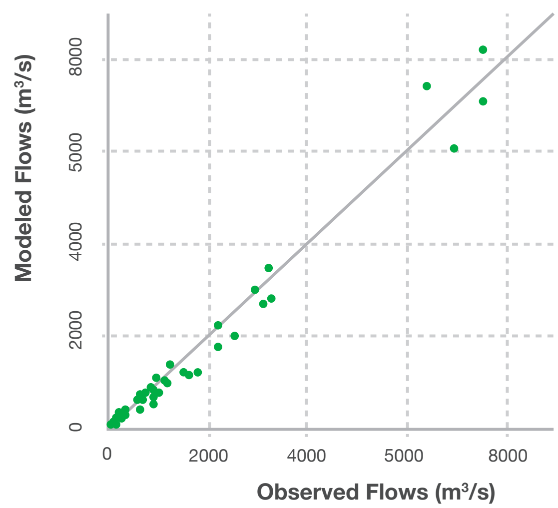
In Touchstone®, companies can apply standard policy conditions found in Austria, Czech Republic, Germany, Poland, and Switzerland and can use the software to capture a complete view of their catastrophe risk by analyzing inland flood risk in conjunction with windstorm and earthquake risk in all five countries.

A Comprehensive Approach to Model Validation

To ensure the reliability of modeled loss estimates, the AIR Inland Flood Model for Central Europe has been thoroughly validated against actual loss experience.

Insured losses for Austria, Czech Republic, Germany, Poland, and Switzerland caused by the 1997, 2001, 2002, 2005, 2007, 2010, and 2013 floods have been validated using aggregated data as reported by industry sources.

Validation, however, is not limited to final modeled loss estimates. Every component of the model has been carefully verified against multiple sources and data obtained on historical events. For example, 100-year river flow characteristics were validated using data from more than 2,780 gauging stations across the five modeled countries.



100-year river flows were validated using data from more than 2,780 gauging stations for the five modeled countries. Shown here is the validation for Poland.

Model at a Glance

Modeled Perils	Inland flooding, both on- and off-floodplain
Model Domain	Austria, Czech Republic, Germany, Poland, Switzerland
Stochastic Catalog	10,000 years
Supported Geographic Resolution	CRESTA, municipality, postal code, location level (latitude/longitude)
Supported Construction Classes and Occupancies	— 47 construction classes and 117 occupancy classes are supported in all five countries — Unknown Damage Functions by CRESTA for instances when exposure information (e.g., construction type, occupancy, or height) is unavailable
Supported Policy Conditions	AIR's detailed software system supports a wide variety of country-specific insurance and reinsurance terms.

Model Highlights

— The industry's first Central European inland flood model accounting for intra-country correlation of flooding using a joined physical modeling domain

— Couples a Global Circulation Model (GCM) and Numerical Weather Prediction (NWP) model to produce realistic and statistically robust rainfall patterns in space and time

— State-of-the-science statistical downscaling simulates precipitation fields at high resolution for improved risk modeling

— Accounts for all key components of the water cycle such as snowmelt in a hydrological module

— Uses urbanicity and runoff to account for drainage in urban areas

— Supports custom flood defenses, which is particularly useful for accurately assessing the risk to high-value properties

— Explicitly models off-floodplain losses to capture a significant source of insured losses

— Features a component-based approach to damage estimation for structures—one which comprises six components that equal 100% of the replacement value

— Supports the evaluation of reinsurance contracts incorporating a 504 hours clause

— Validated against both aggregate and detailed loss experience data, including those from the 1997, 2001, 2002, 2005, 2007, 2010, and 2013 floods

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 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.

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