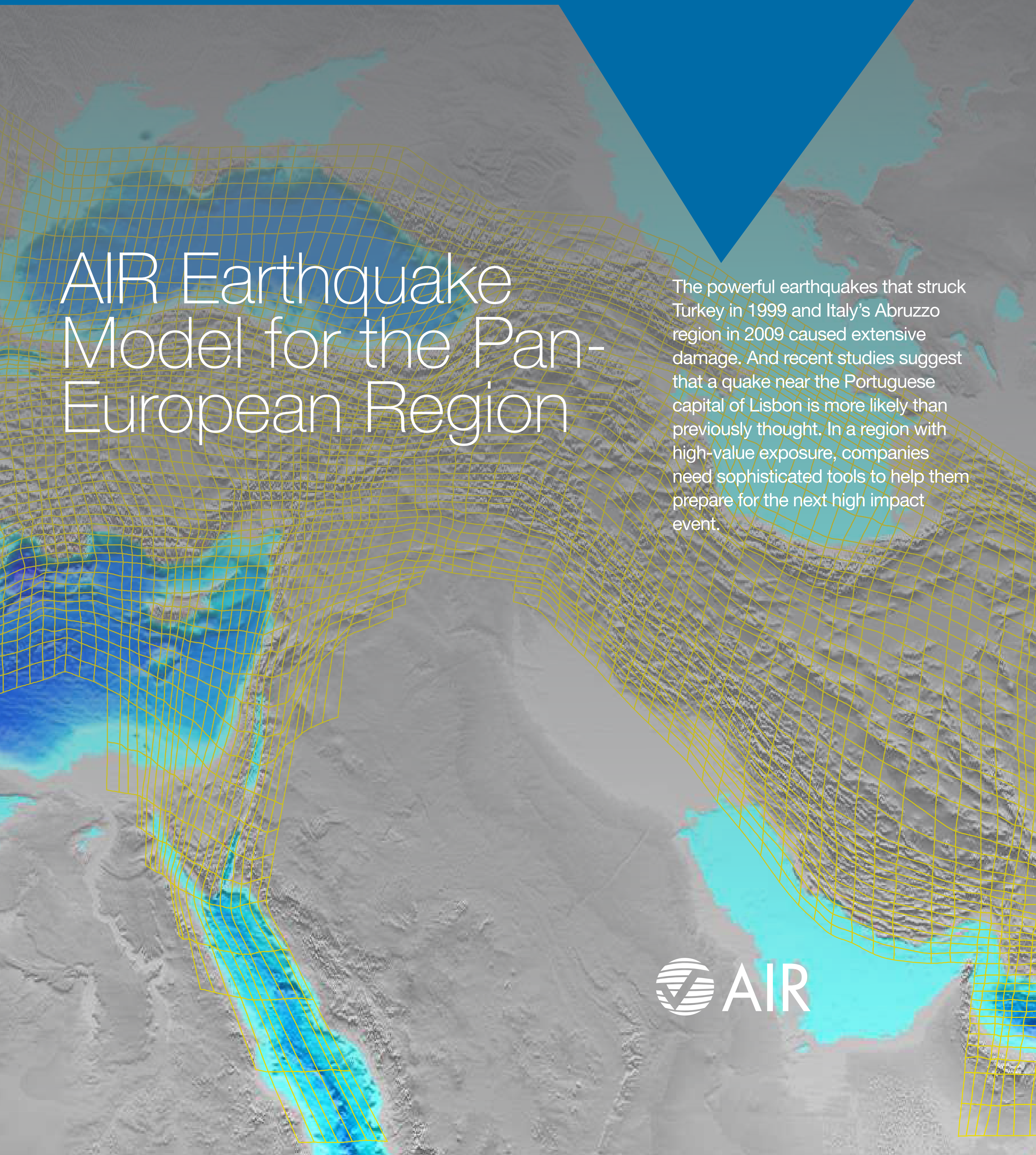
AIR Earthquake Model for the Pan-European Region

The powerful earthquakes that struck Turkey in 1999 and Italy's Abruzzo region in 2009 caused extensive damage. And recent studies suggest that a quake near the Portuguese capital of Lisbon is more likely than previously thought. In a region with high-value exposure, companies need sophisticated tools to help them prepare for the next high impact event.



AIR

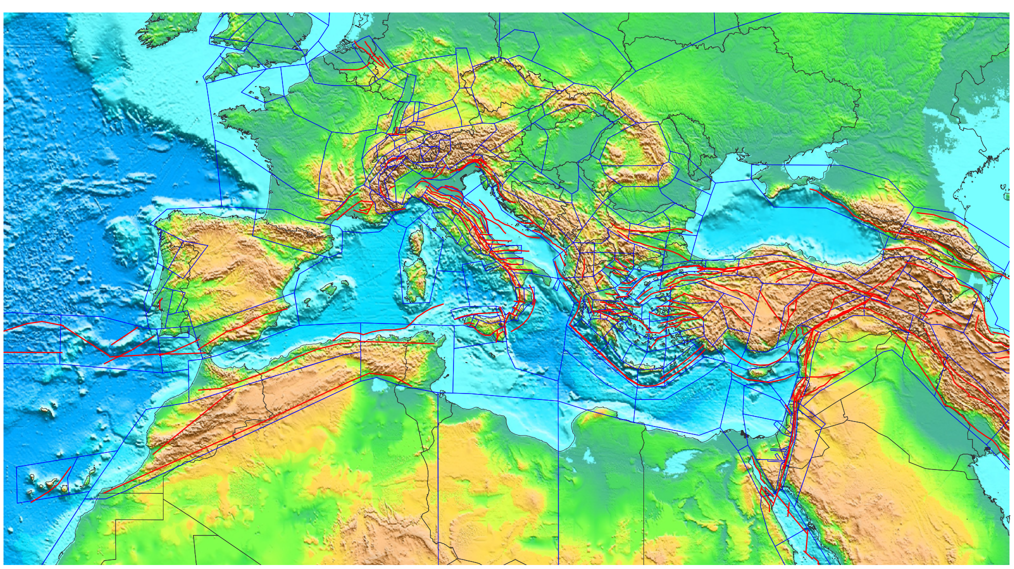
Underlying the Pan-European region is a vast and complex pattern of plate boundaries and crustal faults that have produced some of history's most devastating earthquakes. The collision between the Eurasian and African continental plates, coupled with the movement of a handful of smaller plates, account for most of the seismicity in this region. The AIR Earthquake Model for the Pan-European Region is a seamless regional model that ensures full spatial coverage.

While the hazard is highest at the plate boundaries impacting Turkey, Italy, Greece, and Portugal, the rest of Europe is also subject to varying levels of earthquake risk. In some cases, it is precisely the relative infrequency of seismic activity that makes the exposed population and properties especially vulnerable. For example, a magnitude 6.0 earthquake—the strongest in France's recorded history—struck the Provence region in 1909, destroying more than 2,000 buildings. Were this event to recur with present day building inventory, insured losses are estimated to exceed EUR 3.5 billion.

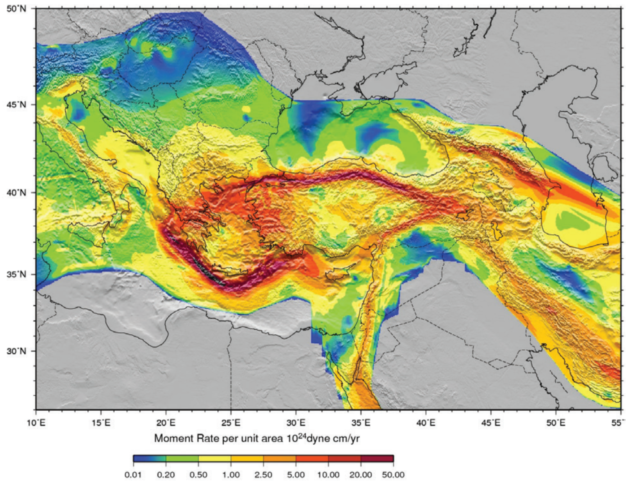
To develop a seamless model that encompasses the entire Pan-European region, AIR scientists defined more than 300 seismic source zones to create a catalog of more than 800,000 simulated events. For portfolios that span multiple countries, AIR's regional model provides companies with a consistent and comprehensive view of their earthquake risk.

Kinematic Model Supplements Knowledge of Past Ruptures, Providing Insight into the Unknown

To model the region's seismicity, AIR uses information from several data sources, including national seismic hazard maps from across Europe, historical catalogs, and AIR's own in-house research. AIR seismologists meticulously cleaned and compiled information from numerous national and regional historical catalogs, carefully standardizing magnitude estimates and removing duplicate events. Because the historical and instrumental record is less complete for relatively infrequent,



The model has defined more than 300 seismic source zones (indicated by the blue outlines, while known faults are indicated in red) to capture the effects of crustal earthquakes, large subduction interface earthquakes, shallow background seismicity, and deep seismic activity.



GPS data, plate motion velocities, and all other available sources of information are used to determine where seismic energy is accumulating at high rates.

large magnitude events, AIR supplements historical data with paleoseismic data (geological evidence of prehistoric earthquakes) and geodetic data (GPS measurements of the deformation rate of the earth's crust) to better estimate their recurrence intervals. This information is integrated into a continuous kinematic model—a physical approach to capturing plate movement—to determine where seismic energy is accumulating throughout the Pan-European region.

Time Dependence and Cascading Rupture Scenarios Reflect Realistic Earthquake Processes

For certain well-studied faults, earthquake occurrence is modeled as time-dependent, meaning that the probability of occurrence in any given time period is assumed to be dependent on the amount of time since the last event. In addition, because an earthquake can load stress onto neighboring faults, cascading scenarios in which two or more faults or fault segments are triggered simultaneously are considered.

Optimized Catalogs Improve Business Workflows

To represent the seismicity in regions away from plate boundaries that experience very infrequent but potentially catastrophic earthquakes, a catalog of 100,000 years or longer is better able to reflect the low probability of highly destructive events. However, larger catalogs require considerable computation resources and longer run times.

AIR has pioneered a sophisticated and innovative catalog optimization procedure that provides vastly improved computation speeds without compromising the statistical accuracy achieved when using larger catalogs. The result is shorter run times, which allow more frequent analyses and sensitivity testing.

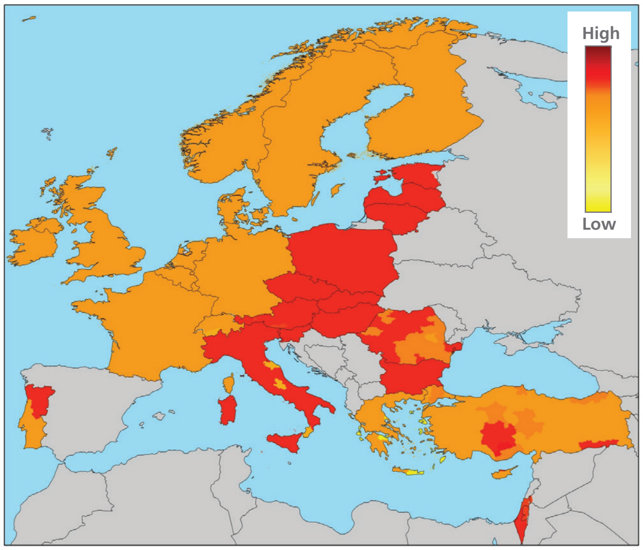
Cascading scenarios, in which multiple segments rupture in quick succession, are captured in the AIR model. Shown here are segments of the western North Anatolian Fault.

Understanding Regional Differences in Building Vulnerability

How well a building withstands shaking varies dramatically with age, design, construction type, and regional practices. Based on recent engineering research (including the well-known EMS98, RISK-UE and LessLoss projects), damage observation data from past earthquakes, and an extensive review of construction practices and building codes, AIR engineers have developed region-specific damage functions that capture temporal and spatial variations in vulnerability. These damage functions reflect differences between and within the 30 countries of the model domain.

CAPTURING THE UNIQUE SEISMICITY OF ROMANIA

AIR's model accounts for the unique seismic setting of Romania, which has a long history of subcrustal earthquakes. In 1977, an M7.4 event destroyed thousands of buildings in the Vrancea region, with damage highly concentrated in the capital of Bucharest. A total of 17 earthquakes of magnitude 7 or greater have occurred in Romania in the past 1,000 years.



The AIR model captures the significant variation in seismic vulnerability in the Pan-European region.

For example, in Italy, a country with a long and notable history of powerful earthquakes, unreinforced masonry residential structures can be centuries old. The poor seismic performance of these structures was all too evident in the 2009 L'Aquila earthquake, which severely damaged thousands of buildings in L'Aquila and surrounding villages. The performance of reinforced concrete buildings was highly variable; older structures experienced significant damage, while those built after 2003 (when the building code was last updated) fared quite well.

Masonry construction is dominant throughout Switzerland, Germany, and France, although wood and reinforced concrete are used as well. Unreinforced stone masonry, which exhibits poor seismic performance, was commonly used in residential housing from the mid-19th century through the beginning of the 20th century.

In Portugal, the majority of the insurable building stock consists of engineered structures that are expected to perform reasonably well in future earthquakes. However, a large number of older buildings that predate modern building codes are located in city centers, and these remain highly susceptible to earthquake ground motion. In Romania, and especially in the earthquake-prone capital of Bucharest, reinforced concrete apartment buildings are susceptible to partial collapse due to poor design, inadequate detailing, and subpar construction materials. During the Vrancea earthquake in 1977, more than 30 buildings collapsed in Bucharest, killing more than 1,400 residents.

In much of Greece and Turkey, the ground floors of residential buildings feature large open areas used as commercial space or for parking. Often lacking adequate lateral support, these "soft stories" were responsible for numerous building collapses during the Izmit earthquake.

High Resolution Industry Exposure Database for the Pan-European Region Is Built from the Ground Up

AIR has developed a robust and detailed industry exposure database (IED) based on the latest available information on risk counts and building characteristics from various government offices and statistics bureaus. Because this data can vary considerably in resolution, AIR uses a sophisticated disaggregation algorithm that takes into account topography, satellite-derived land use/land cover information, and NOAA's "Night Lights" data to improve the accuracy of the spatial distribution of risks. Spatial cost indices, which reflect regional differences in the cost of construction labor and materials, are used to estimate replacement values.

This modern building experienced cracking to brick infill walls but sustained no permanent damage to its reinforced concrete frame during the 2009 L'Aquila earthquake. (Source: AIR)

HELPING CLIENTS MEET SOLVENCY II REQUIREMENTS

AIR is actively helping companies prepare to meet the requirements of the new Europe-wide risk management regulation, Solvency II. Output from the AIR Earthquake Model for the Pan-European Region can readily be used to evaluate capital adequacy for Solvency II purposes.

The IED serves as the basis for AIR's reliable industry loss estimates for historical and real-time events, and provides the foundation for market share analysis in CATRADER®. Using Touchstone®, companies with access only to coarse resolution exposure data can leverage the IED to disaggregate the data in their own portfolios to a highly detailed level in line with the spatial distribution of AIR's industry data to obtain better loss estimates.

Robust Financial Module Accurately Applies Policy Conditions, Reinsurance Terms, and Earthquake Pools

The AIR Earthquake Model for the Pan-European Region supports a wide variety of location, policy, and reinsurance conditions, including limits and deductibles by site or by coverage. Supported policy terms include blanket and excess layers, minimum and maximum deductibles, and sublimits. Reinsurance terms include facultative certificates and various types of risk-specific and aggregate treaties with occurrence and aggregate limits. The model also reflects the latest policy conditions of the Turkish Catastrophe Insurance Pool (TCIP) and the Romanian Pool-ul de Asigurare Împotriva Dezastrelor Naturale (PAID).

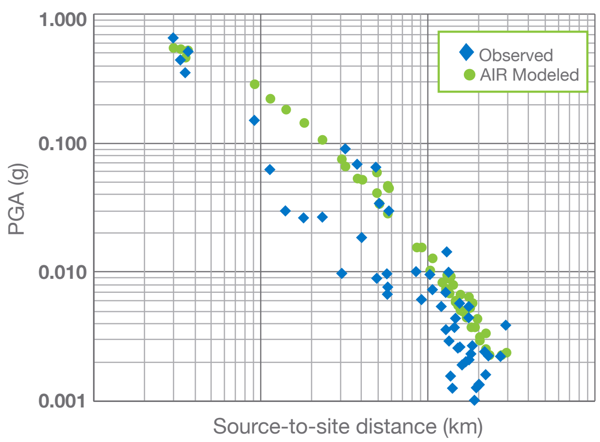
A Comprehensive Approach to Model Validation

AIR carefully validates each model component against actual data. The frequency and intensity distributions of events in the stochastic catalog, for example, are validated against historical seismicity data, and local shaking intensity calculations are validated against recorded observations from ground motion stations. These stations were especially numerous in the region affected by the 2009 L'Aquila earthquake in Italy, and a comparison between observed and AIR modeled ground motion is shown below.

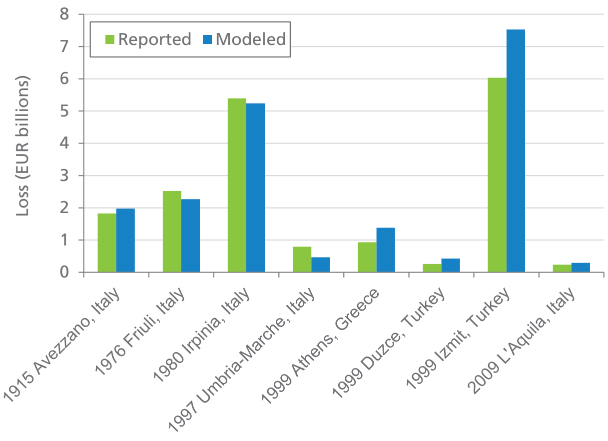
The damage functions in the AIR Earthquake Model for the Pan-European Region have been validated using the relative vulnerability of various construction classes specified by the European Macroseismic Scale (EMS '98) and using numerous vulnerability studies conducted by local researchers.

AIR has also compared modeled losses to reported losses for more than 60 historical events. To do this, reported estimates obtained from various sources are trended to reflect growth in the number of properties and their replacement cost. Insured loss estimates are adjusted to account for changes over time in the percentage of properties covered against the earthquake peril.

OBSERVED VS. SIMULATED GROUND MOTION FOR THE 2009 L'AQUILA EARTHQUAKE



MODELED VS. REPORTED INSURED LOSS FOR SIGNIFICANT HISTORICAL EVENTS



Model at a Glance

Model Domain	Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France (including Monaco), Germany, Greece, Hungary, Ireland, Israel, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Sweden, Switzerland, Turkey, and the United Kingdom.
Stochastic Catalogs	Optimized 100,000-year catalog of more than 800,000 simulated earthquakes
Supported Construction Classes and Occupancies	The model supports 34 construction classes and 51 occupancy classes. When detailed exposure data (for example, construction type or height) is unavailable, the model applies an "unknown" damage function that takes into account country-specific construction characteristics.
Supported Lines of Business	For all countries, supported lines of business include residential and commercial/industrial building and contents. In addition, for all countries except Portugal, Italy, Israel, Greece, and Turkey, the model supports the automobile and agriculture lines of business (including greenhouses in Denmark and Netherlands).
Policy Conditions	Touchstone supports a wide variety of location, policy, and reinsurance conditions, including limits and deductibles by site or by coverage. CATRADER features four different event sets reflecting earthquake pools in Turkey and Romania: — 100% Limits (included with all World All Perils event sets): Contains total insurable losses for all countries and all lines of business. TCIP and PAID limits for Turkey and Romania residential buildings are not applied. — Net of TCIP/PAID: Same as 100% limits perspective except Turkey residential building losses are in excess of TRY 150,000 TCIP policy limit. Romania residential building losses are in excess of EUR 20,000 policy limit for "Type A" homes and EUR 10,000 policy limit for "Type B" Homes. — TCIP: Contains only Turkey residential building losses subject to TCIP policy conditions. All other industry loss estimates are excluded. — PAID: Contains only Romania residential building losses subject to PAID policy conditions. All other industry loss estimates are excluded

Model Highlights

- Full spatial coverage ensures seamless risk assessment for portfolios that span multiple countries
- Seismic zones are defined based on extensive historical seismicity data, published research and original research undertaken by AIR seismologists
- Weighted combinations of attenuation functions properly reflect different focal depths, distances, and rupture mechanisms unique to each area
- Detailed damage functions for over 50 occupancy classes and nearly three dozen construction types reflect differences in age and regional variations in design codes
- Damage functions have been validated using recent research and damage reconnaissance data and are consistent with relative guidelines established by the European Macroseismic Scale (EMS '98)
- Includes latest policy conditions for the Turkish Catastrophe Insurance Pool (TCIP) and the Romanian Pool-ul de Asigurare Împotriva Dezastrelor Naturale (PAID)

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.

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