AIR Extratropical Cyclone Model for Europe

In 2007, Kyrill roared across Europe, causing widespread damage and resulting in insured losses of more than EUR 4.5 billion. Sometimes several storms can strike in rapid succession, as Christian, Xaver, Dirk, and Anne did in the winter of 2013-2014, for example.

The AIR model helps you assess the risk from wind for single storms as well as storms clustered in space and time, including the most extreme events.

AIR

With European windstorm losses, on average, surpassing those of any other peril in the region, companies need a realistic, detailed model to manage the risk.

The AIR Extratropical Cyclone Model for Europe captures the meteorological complexities that define the hazard, including storm frequency and storm clustering; provides seamless spatial coverage across 22 countries; and explicitly accounts for differences in regional and temporal vulnerability for traditional and specialty risks. To ensure the most robust and scientifically rigorous model possible, each component is independently validated against multiple sources.

The model's damage functions leverage findings from comprehensive engineering studies, the analyses of billions of euros of the latest claims data from various market segments, and AIR's detailed post-disaster surveys. A wide array of policy conditions is supported—including coverage limits, deductibles, loss triggers, and reinsurance conditions.

A Comprehensive View of Extratropical Cyclone Risk Across Europe

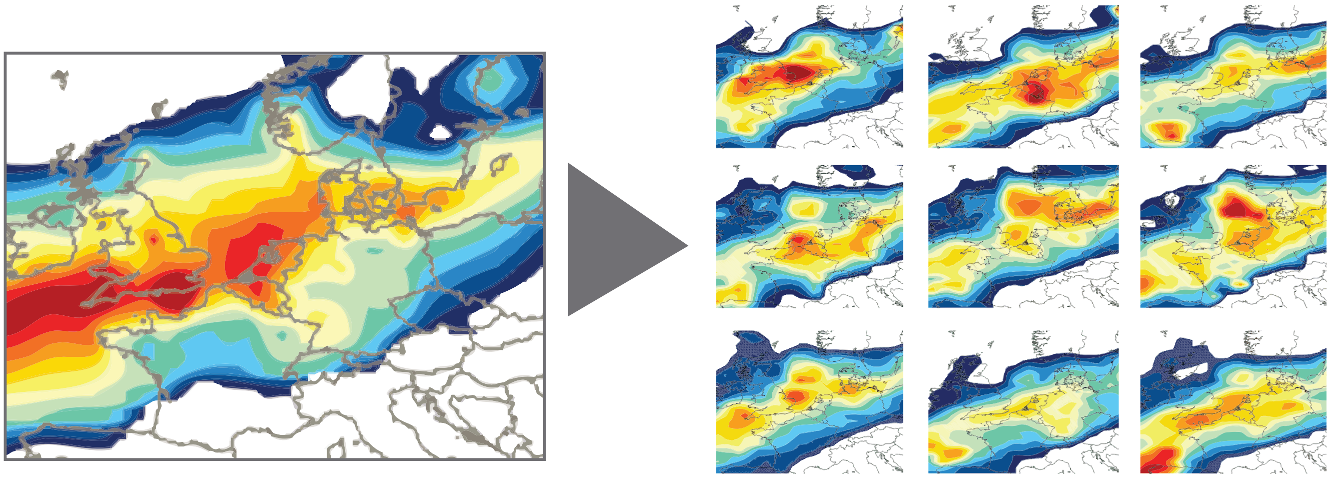
While tropical cyclones exhibit relatively symmetrical structures, extratropical cyclone (ETC) systems are markedly more complex. The AIR Extratropical Cyclone Model for Europe captures this complexity, from the unstable atmospheric environments in which the storms form, to the sophisticated processes needed to translate winds aloft to high resolution surface-level winds, to the observed clustering of storms in time and space

Robust Catalog Captures Even the Most Extreme Events

Because of the complex structure and the dynamic conditions that favor ETC development, conventional statistical techniques for producing a catalog of potential ETCs are not sufficient for capturing the unique wind fields associated with these storms. The processes AIR used to generate the model's stochastic event catalog are significantly enhanced. The AIR model employs a hybrid approach that leverages both Numerical Weather Prediction (NWP), a physical model that can effectively capture the complex three-dimensional structure of ETCs in time and space, and advanced statistical methods to create simulated storms that are grounded in reality.

To create the model's catalog of simulated events, AIR scientists use historical data from meteorological agencies across Europe and around the world. This includes complex atmospheric reanalysis data of global environmental conditions (e.g., sea surface temperatures, air temperature, wind speed, water content, and pressure) from the European Centre for Medium-Range Weather Forecasts.

AIR EXTRATROPICAL CYCLONE MODEL FOR EUROPE



Using state-of-the-art NWP technology, a historical seed storm is perturbed to create a set of realistic simulated storms.

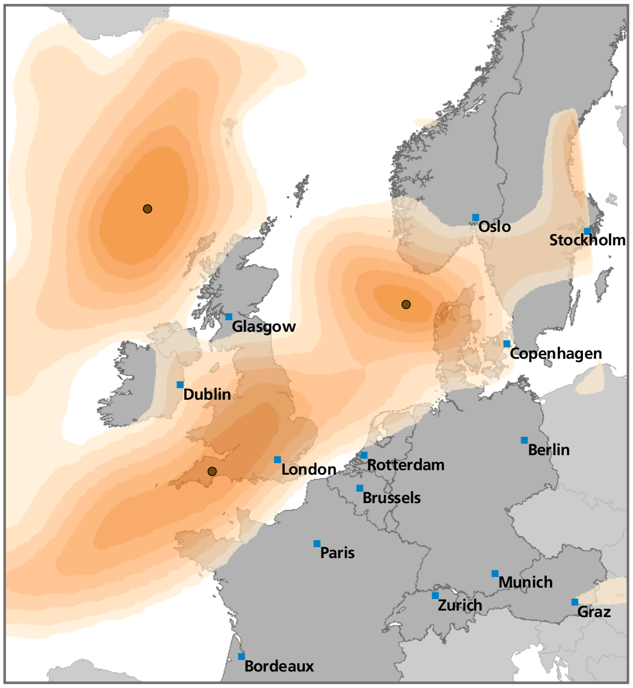
Based on NWP analysis, the physical characteristics of approximately 1,500 historical seed storms are perturbed to produce a 69,212 events, including 42,707 wind-only events, 15,390 surge-only events, and 11,115 combined wind and surge events, whose wind field, track parameters, and flood depth footprints reflect the complete range of potential windstorm experience across Europe and storm surge experience in England and Wales. AIR's perturbation methods ensure that extreme wind events that have limited past historical precedence are realistically represented. More explicit modeling of the effects of the North Atlantic Oscillation better represents the tracks and intensities of the storms. The temporal range of the catalog is year-round because, while most storms occur during the winter season, they can also occur at other times.

The stochastic catalog is supplemented by 38 historical ETCs occurring between 1976 and 2015, six Extreme Disaster Scenarios, and the Lloyd's Realistic Disaster Scenario (RDS).

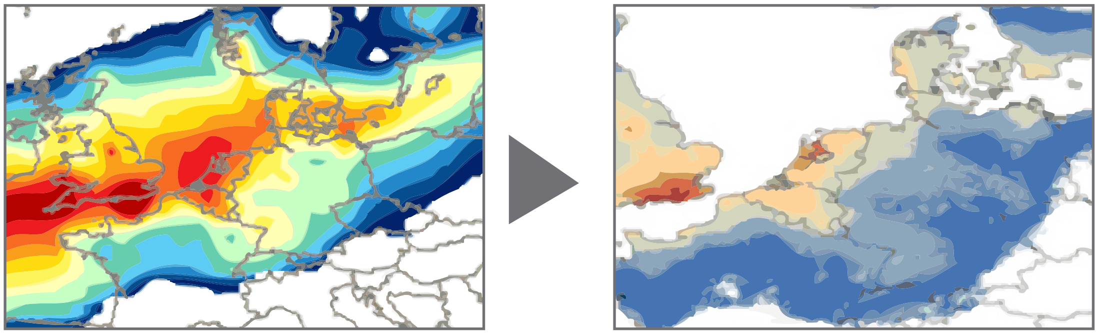
Explicit Modeling of Storm Clustering

Windstorms over Europe display a pattern of temporal and spatial clustering. Europe can be struck by several storms in rapid succession, and individual locations can experience relentless gale-force winds for several days. Yet an examination of wind speed observations alone might suggest that only a single, large storm swept through.

NWP allows such storms to be properly separated and identified by their vortex centers—a critical capability for estimating occurrence losses and reflecting observed correlations of risk between countries. Representing these clusters appropriately in the stochastic catalog is also important for reinsurance contracts that cover annual aggregate losses, as well as contracts that limit losses to damage occurring within a specified period.

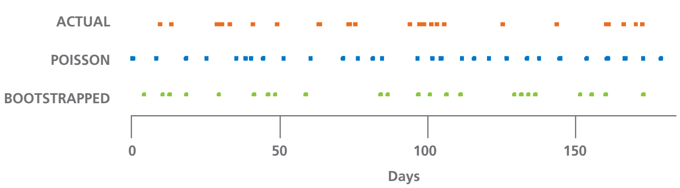


The AIR model accurately identifies individual storms within spatial and temporal clusters. In 2000, three low pressure systems (from left to right: Nicole, Oratia, and an unnamed storm) swept over Europe in quick succession.



Using advanced downscaling procedures, NWP output (left) is enhanced to 3-second gust wind speeds at approximately 1 km × 1 km resolution (right).

The AIR Extratropical Cyclone Model for Europe preserves the observed propensity for storms to occur in clusters through an advanced "block bootstrapping" method. This approach is more accurate than drawing storm occurrences from a Poisson or other parametric distribution fitted to the historical data and results in more realistic temporal occurrence patterns.



A block bootstrapping approach produces a more realistic temporal occurrence pattern than a Poisson distribution, capturing the tendency of storms to cluster temporally.

Advanced Downscaling of Winds Aloft to High-Resolution Surface Winds

To translate the output of AIR's NWP model to high-resolution wind speeds at the surface—where exposure is at risk—AIR meteorologists use a state-of-the-art downscaling technique. Local effects are incorporated, including those from land use/land cover, surface terrain and roughness, and gustiness. The AIR model also accounts for the wind direction at property locations.

Although lower-resolution models may perform adequately for assessing losses at the industry level, downscaled wind fields are far more accurate for analyzing company portfolios. Statistics from hundreds of local wind stations are used to dramatically improve the resolution and realism of modeled winds at the surface.

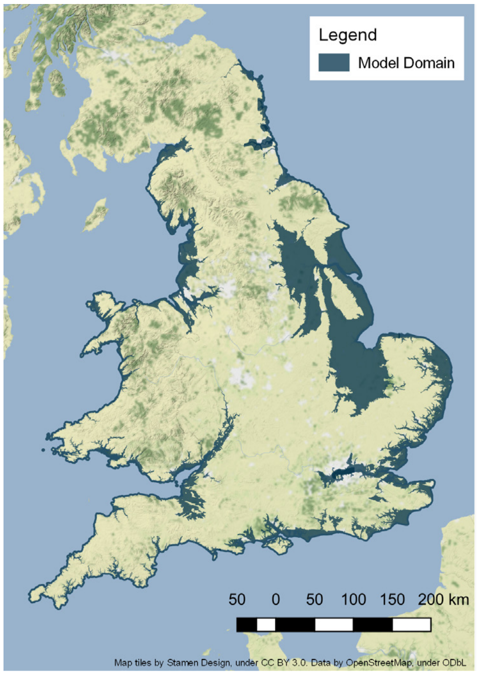
These advanced downscaling techniques result in a model with a much higher degree of fidelity, particularly in coastal and mountainous regions.

Great Britain Storm Surge Module Captures Complexity of This Costly Sub-Peril

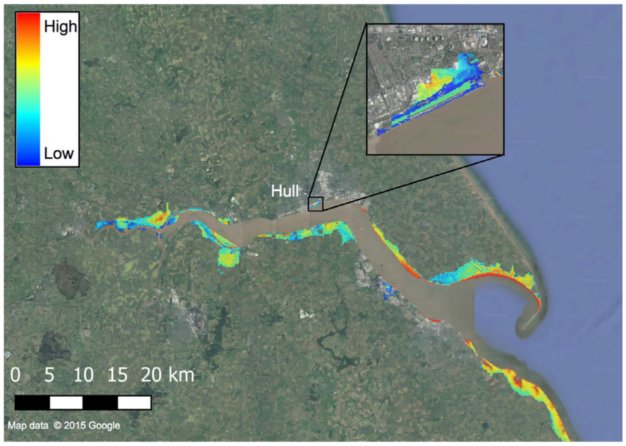
The destructive impact of storm surge driven by European extratropical cyclones can affect residential and commercial exposures in Great Britain from the immediate coast to miles inland. Losses from wind and surge are typically covered under the same policy in the UK. The AIR Extratropical Cyclone Model for Europe captures both wind and the complexity of Great Britain storm surge, a costly sub-peril.

Although a small fraction of storm surge stems from air pressure differences, most is caused by a storm's winds pushing water toward land. The modeling of Great Britain (GB) storm surge is driven by the wind and pressure fields from the AIR Extratropical Cyclone Model for Europe.

The domain of the GB storm surge model includes the entire coast of England and Wales. Major coastal flooding events, such as Storm Xaver in 2013 and the devastating North Sea Flood of 1953, have impacted the UK's east coast. They are caused by low pressure systems moving out of the northwest and pushing water down the North Sea as it narrows and gets shallower toward the English Channel. The west coast, however, can also be impacted by storms such as Undine (1991) and Anne (2014) that follow a more southern track, creating a southwesterly flow into the Irish Sea.



The model domain includes all of England and Wales.



The 0-4 m flood depth footprint for storm Xaver along the Humber Estuary around the city of Hull. (Source: AIR)

Hydrodynamically Simulates Tides and Surge for a More Accurate View of Risk

While storm surge is strongly correlated with wind speed and duration, other factors also influence it, including bathymetry and tide. The GB storm surge module employs a hydrodynamic coastal flood model that accounts for spatial and temporal tidal variability, complex coastal geometry, and localized changes in elevation.

The module uses the Delft3D Flexible Mesh modeling suite, which focuses on coastal, estuarine, riverine, rural, and urban environments. It provides high resolution where it is most needed at the coast and along tidal rivers and uses a lower resolution offshore to maximize computational efficiency without sacrificing the quality of results.

The tidal cycle is important because storm surge is water raised above the background astronomical tide level. The state of the tide can have a huge impact upon whether surge penetrates inland and the extent of any flooding, especially in parts of GB where the tidal range is large.

Accounts for Flood Defenses and Their Failure

Coastal defenses and levees exist to mitigate the effects of storm surge. The UK's extensive network includes major infrastructure such as the Thames Barrier and its up- and downstream defenses. The GB storm surge module incorporates the 2016 vintage UK Environment Agency's Spatial Flood Defences Dataset, which includes location information for the entire UK, as well as defined crest heights, material, quality condition, and design type. Where levee heights were undefined, this information was extracted from high resolution (2- to 10-meter) DTM sources.

Levees may fail below the specific standard of protection they are designed for or withstand floods above it. Using fragility curves obtained from recent UK Environment Agency reports, the model addresses the possibility that defenses will fail, given a level of loading, in a probabilistic framework. 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.

Using 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.

Accounts for Secondary Risk Characteristics and Time Element Damage

The amount of surge damage that a building will suffer depends principally on the depth and duration of inundation and on the building construction and occupancy type. Secondary risk characteristics, such as floor of interest and basements, are explicitly modeled.

To estimate damage to buildings and contents caused by storm surge, the AIR model incorporates damage functions that vary by occupancy, construction, and height. For commercial properties, the model's damage functions use a component-based approach to capture the relative vulnerability of different building components, including building, fixtures and fittings, and services, as well as their contribution to total replacement value.

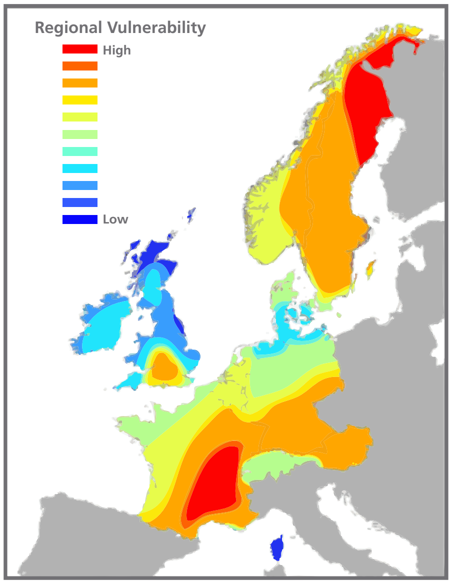
Time element damage functions account for alternative accommodation and related expenses and business interruption losses. The model accounts for the time required for drying and cleaning the property, which can account for a significant share of the time to re-occupy a building.

Accounts for Differences in Regional Vulnerability

Europe displays considerable diversity in climate and seasonal storm intensity, with certain regions subject to higher levels of wind speeds more frequently than others. Over decades, this has resulted in variations in building vulnerability across regions, as each country has adopted construction practices that reflect its historical storm experience. The AIR model takes into consideration the effect that regional wind hazard characteristics can have on local design levels, building code enforcement, and construction practices.

Roof tile damage is commonly observed in residential and small commercial structures (left) while severe roof damage (right) occurs less frequently (Source: AIR)

Roof tile damage is commonly observed in residential and small commercial structures while severe roof damage occurs less frequently. Due to the big footprint of ETCs the overall loss from large numbers of claims is often significant.



Buildings in regions that frequently experience higher wind speeds tend to be less vulnerable because they are subject to more stringent building codes and local construction practices. AIR damage functions take into account variations in regional vulnerability.

The model's damage functions leverage meticulous literature reviews, engineering studies, post-disaster surveys, and analyses of large sets of the latest claims data. The AIR Extratropical Cyclone Model for Europe estimates losses at location, postal code, and CRESTA level to traditional lines, including residential, commercial, large industrial facilities, and agricultural exposures (including greenhouses). Specialty lines, including forestry, inland and oceangoing marine cargo, marine hull, builder's risk, and wind turbines can also be modeled. Losses can vary greatly depending on location, which is significant when modeling buildings with a combination of unknown primary characteristics. The AIR model significantly enhances modeling of these unknown combinations by considering local building attributes at the CRESTA level.

Damage to the building envelope can cause damage to contents in addition to time element losses due to business interruption or additional living expenses. The AIR model supports separate contents and time element damage across all market segments.

A Wide Range of Policy Terms Modeled Across 22 Countries

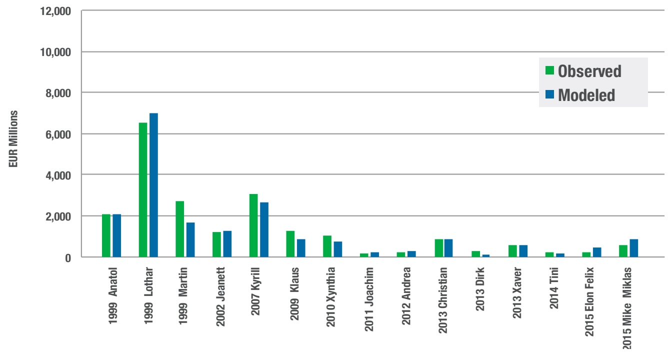
Virtually all types of primary insurance and reinsurance terms for traditional and specialty lines can be modeled in AIR's Touchstone® and Touchstone Re™ products, including layers with deductibles, attachment points and limits, sublimits, location deductibles and limits, and treaty and facultative reinsurance.

The AIR Industry Exposure Database for Europe: An Unparalleled Resource

For all modeled countries, AIR has developed a high- resolution 1-km^2 (wind)/90-meter^2 (surge) industry exposure database (IED) that is based on the latest available information on risk counts, building characteristics, and construction costs from a wide variety of local sources. The benefits and uses of AIR's IED are numerous. It provides a foundation for all modeled industry loss estimates as well as being a critical part of model validation. Risk transfer solutions, such as industry loss warranties that pay out based on industry losses, rely on the IED. Using AIR's detailed modeling application, companies can also leverage the IED for Europe to disaggregate the exposure data in their own portfolios to a highly detailed level, for improved loss estimates.

A Comprehensive Approach to Model Validation

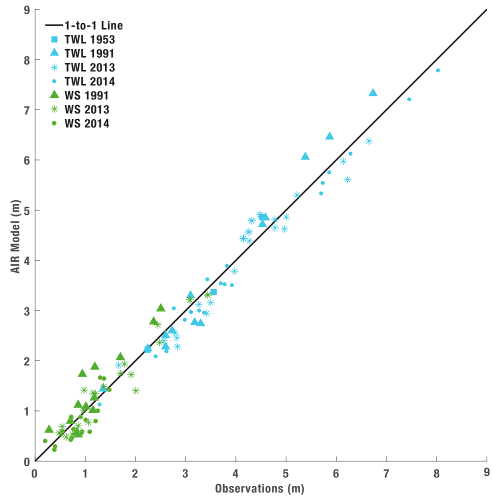
To ensure the most robust and scientifically rigorous model possible, the AIR model is carefully validated against actual experience. However, validation is not merely limited to final model results. Each component is independently validated against multiple sources; for example, the distribution of each storm characteristic in the stochastic catalog is carefully compared against historical storm data, and modeled wind fields are validated against wind speed observations from actual storms. Wind storm data is incorporated to calibrate the model.



Modeled wind losses are compared against reported losses for historical storms at an industry level (shown), as well as by company, by line of business, and by coverage.

To validate modeled storm surge footprints, AIR researchers compared the model with data from the UK's extensive network of tide gauges that give the height of surge at the coast before the model propagates flooding overland. Data from the CORINE Land Use/Land Cover Database is mapped to a Manning friction coefficient to help ensure reasonable flood propagation overland. Overland model storm surge footprints are then validated with footprints provided by the UK Environment Agency.

Modeled losses have been validated against industry insured loss estimates for all major historical events dating back to Capella (1976) in addition to nearly EUR 7 billion in claims data spanning 19 companies, 14 countries, and 16 historical events dating back to Daria (1990). Large claims data sets and data from newer events, which contain more detailed information—key for vulnerability assessment—are used as well.



Modeled total water level (TWL) and wind setup (WS).

Model at a Glance

Modeled Peril	Extratropical cyclone winds, Great Britain storm surge
Modeled Domain	Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France (including Monaco), Germany, Hungary, Ireland, Latvia, Liechtenstein, Lithuania, Luxembourg, Netherlands, Norway, Poland, Slovakia, Slovenia, Sweden, Switzerland, and the UK
Geographic Resolution	Country, CRESTA zone, postal code for the entire model domain. Risks can be modeled at individual latitude/longitude points. If only CRESTA or postal code information is available the model also supports the disaggregation of risks. Wind hazard resolution of the model is 1x1km, storm surge hazard resolution 10x10m
Supported Construction Classes, Occupancy Classes, and Specialty Lines	— 47 construction classes and 117 occupancy classes are supported — Large industrial facilities — Agricultural (including greenhouse), forestry, inland and oceangoing marine cargo, marine hull, builder's risk, wind turbines, and automobiles

Model Highlights

- Seamless spatial coverage across 22 countries
- Includes storm surge as a sub-peril for both east and west coasts of Great Britain
- Explicitly accounts for differences in regional and temporal wind vulnerability
- Captures the meteorological complexities that define the extratropical cyclone hazard
- High-resolution industry exposure database (IED) based on the latest available information on risk counts, building characteristics, and construction costs
- Damage functions based on rigorous engineering studies, AIR post-disaster surveys, and extensive claims data
- Unknown damage functions vary by CRESTA to account for regional distribution of building stock
- Supports a wide array of policy conditions—including coverage limits, deductibles, loss triggers, and reinsurance conditions
- Modeled losses extensively validated against more than EUR 7 billion of detailed client claims data spanning 19 companies, 14 countries, and 16 historical events