Update to CATRADER and Touchstone Re Loss Estimates

Version 21.0/Version 7.0 Technical Update

Publication Date: June 2019

Copyright

Trademarks

Confidentiality

Contact Information

AIR is headquartered in Boston with additional offices in North America, Europe, and Asia. For information on our office locations, visit www.air-worldwide.com/About-AIR/Offices/.

AIR Worldwide Corporation
131 Dartmouth Street
Boston, MA 02116-5134
USA

Tel: (617) 267-6645
Fax: (617) 267-8284

AIR welcomes feedback on its documentation. To contact us regarding this document please email us at: ModelDocumentationFeedback@air-worldwide.com.

Revision History

Date	Description
June 2019	Original release

Table of Contents

REVISION HISTORY iii

1 EXECUTIVE SUMMARY 1

2 THE AIR EARTHQUAKE MODEL FOR NEW ZEALAND 2

2.1 Overview of Model Updates and Changes 2

2.2 Catalogs and Event Sets 3

2.3 Event Generation 4

2.4 Local Intensity Calculation 7

2.5 Damage Estimation 11

2.6 Treatment of Uncertainty in the Model 19

2.7 Sub-Peril Updates and Additions 19

2.8 Industry Exposure Database 30

2.9 General Impact of Model Updates on Loss Estimates 31

2.10 Analysis Settings 40

3 THE AIR INLAND FLOOD MODEL FOR CENTRAL EUROPE 41

3.1 Overview of Model Updates and Changes 41

3.2 Model Domain 41

3.3 Catalogs and Event Sets 42

3.4 Hazard 43

3.5 Vulnerability 45

3.6 Industry Exposure Database 56

3.7 Component-level Impact of Model Updates 56

3.8 General Impact of Model Updates on Loss Estimates 69

3.9 Analysis Settings 73

4 THE AIR EXTRATROPICAL CYCLONE MODEL FOR EUROPE 74

4.1 Overview of Model Updates and Changes 74

4.2 Catalogs and Event Sets 76

4.3 Event Generation 76

4.4 Local Intensity Calculation 77

4.5 Damage Estimation 78

4.6 Industry Exposure Database Updates 85

4.7 General Impact of Model Updates on Loss Estimates 85

4.8 Impact of Model Updates on Storm Surge Loss Estimates........ 90
4.9 Analysis Settings........ 94

5 THE AIR HURRICANE MODEL FOR THE UNITED STATES........ 95
5.1 Overview of Model Updates and Changes........ 95
5.2 Catalogs and Event Sets........ 95
5.3 Wind Vulnerability and Damage Estimation........ 96
5.4 Industry Exposure Database........ 98
5.5 General Impact of Model Updates on Loss Estimates........ 99
5.6 Analysis Settings........ 112

6 THE AIR U.S. HURRICANE MODEL FOR OFFSHORE ASSETS........ 113
6.1 Overview of Model Updates and Changes........ 113
6.2 Catalogs and Event Sets........ 113
6.3 Update to the Industry Exposure Database........ 113
6.4 General Impact of Model Updates on Loss Estimates........ 114
6.5 Analysis Settings........ 117

7 EVENT ID UPDATES........ 118

8 INDUSTRY EXPOSURE DATABASE UPDATES........ 119

List of Figures

Figure 1. Domain of the AIR Earthquake Model for New Zealand.......... 5

Figure 2. Weighted average GMPEs for the 2019 model (solid lines) and the 2007 model (dashed lines) for a single measure of ground motion from Mw 6.5 and Mw 7.5 earthquakes..........8

Figure 3. The amplification factors in the existing 2007 model (dots) and the 2019 update (solid lines). The factors are shown by site conditions A (very hard rocks) through E (very soft soil) and ground motion measures PGA and Sa(1s)..........10

Figure 4. Vulnerability (Code Level) assignments based on two vintages of design maps (1965 – top and 2004 – bottom) on spatial and temporal variation of vulnerability for engineered buildings.......... 12

Figure 5. Spatial and temporal variation of vulnerability for timber-framed buildings..........13

Figure 6. Contents damage relationships for wood frame construction in the existing model (green points) and the updated model (blue line) and historical observations (orange and purple points) used for model calibration.......... 17

Figure 7. Contribution of building and contents damage to the time element calculation.......... 18

Figure 8. Contribution of sub-perils to average annual loss for New Zealand..........20

Figure 9. Liquefaction modeling coverage for New Zealand..........21

Figure 10. Gross insurable occurrence impact to loss – countrywide and selected zones – due to the introduction of liquefaction..........22

Figure 11. Gross insurable aggregate impact to loss – countrywide and selected zones – due to the introduction of liquefaction..........23

Figure 12. Landslide susceptibility map of New Zealand..........24

Figure 13. Gross insurable occurrence impact to loss – countrywide and selected zones – due to the introduction of landslide..........25

Figure 14. Gross insurable aggregate impact to loss – countrywide and selected zones – due to the introduction of landslide..........26

Figure 15. Gross insurable occurrence impact to loss – countrywide and selected zones – due to the introduction of tsunami.......... 28

Figure 16. Gross insurable aggregate impact to loss – countrywide and selected zones – due to the introduction of tsunami.......... 28

Figure 17. High-density commercial (left) and low-density residential (right) characteristic blocks..........29

Figure 18. Gross insurable occurrence impact to loss – countrywide and selected zones – due to the introduction of fire following..........30

Figure 19. Gross insurable aggregate impact – countrywide and selected zones – due to the introduction of fire following..........30

Figure 20. Countries included in the model domain and hydrological model river network...................... 42

Figure 21. Changes to the standards of protection for Austria, Czech Republic, Germany, and Switzerland...44

Figure 22. CORINE land cover data used to determine drainage capacity for Germany......................... 45

Figure 23. Overall building and component-level damage functions for a 1-story, single family home..... 48

Figure 24. Change in vulnerability of wood frame and general masonry 2-story single-family homes...... 49

Figure 25. Change in vulnerability of mid-rise condominium buildings of common construction types..... 49

Figure 26. Single-family home on-floodplain damage function validation with German claims data......... 50

Figure 27. Change in on-floodplain vulnerability of 2-story general commercial buildings built using common construction types...51

Figure 28. Change in on-floodplain vulnerability of 2-story general industrial buildings built using common construction types...51

Figure 29. Commercial on-floodplain damage function validation with German claims data.................... 52

Figure 30. Comparison of off-floodplain mean damage ratios as a function of relative elevation, for a surface with relative runoff = 1.1...52

Figure 31. Change in content vulnerability of wood frame and general masonry 2-story single-family homes with the model update...54

Figure 32. Change in contents vulnerability of mid-rise, masonry apartments and commercial buildings with the model update... 54

Figure 33. Relativity of residential and commercial flood claims data... 55

Figure 34. On-floodplain damage function relativity for buildings (1-story masonry)................................ 55

Figure 35. On-floodplain damage function relativity for contents...56

Figure 36. Storm surge coverage..75

Figure 37. Representation of secondary uncertainty distributions around a given mean damage ratio, defined by claims data (data points)..81

Figure 38. Smoothly transitioning shapes of the Residential Coverage A distributions............................ 82

Figure 39. Comparison of updated and previous Residential Coverage A distributions........................... 83

Figure 40. Smoothed parametric fit of residential coverage A distributions to claims data.......................84

List of Tables

Table 1. Historical Events available in CATRADER....3

Table 2. Tsunamigenic events in the AIR stochastic catalogs by source zone....26

Table 3. Gross insurable overall loss changes – time-dependent catalog (shake only) – countrywide....31

Table 4. Gross insurable overall loss changes – time-dependent catalog (shake only) – Wellington....32

Table 5. Gross insurable overall loss changes – time-dependent catalog (shake only) – Canterbury....32

Table 6. Gross insurable overall loss changes – time-dependent catalog (shake only) – Auckland....32

Table 7. Gross insurable overall loss changes – time-dependent catalog (shake only) – Hawke's Bay....33

Table 8. Gross insurable loss changes with constant exposure – time-dependent catalog (shake only) – countrywide....33

Table 9. Gross insurable loss changes with constant exposure – time-dependent catalog (shake only) – Wellington....34

Table 10. Gross insurable loss changes with constant exposure – time-dependent catalog (shake only) – Canterbury....34

Table 11. Gross insurable loss changes with constant exposure – time-dependent catalog (shake only) – Auckland....34

Table 12. Gross insurable loss changes with constant exposure – time-dependent catalog (shake only) – Hawke's Bay....35

Table 13. Gross insurable overall loss changes – time-independent catalog (shake only) – countrywide....36

Table 14. Gross insurable overall loss changes – time-independent catalog (shake only) – Wellington....36

Table 15. Gross insurable overall loss changes – time-independent catalog (shake only) – Canterbury....36

Table 16. Gross insurable overall loss changes – time-independent catalog (shake only) – Auckland....37

Table 17. Gross insurable overall loss changes – time-independent catalog (shake only) – Hawke's Bay....37

Table 18. Gross insurable loss changes with constant exposure – time-independent catalog (shake only) – countrywide....38

Table 19. Gross insurable loss changes with constant exposure – time-independent catalog (shake only) – Wellington....38

Table 20. Gross insurable loss changes with constant exposure – time-independent catalog (shake only) – Canterbury....39

Table 21. Gross insurable loss changes with constant exposure – time-independent catalog (shake only) – Auckland....39

Table 22. Gross insurable loss changes with constant exposure – time-independent catalog (shake only) – Hawke's Bay....39

Table 23. CATRADER/Touchstone Re analysis settings for AIR Earthquake Model for New Zealand runs to determine occurrence and aggregate loss changes....40

Table 24. Historical events available in the AIR Inland Flood Model for Central Europe.... 43

Table 25. Height bands....46

Table 26. Auto damage functions, relative vulnerability change with the model update, by country.... 53

Table 27. Model versions used for incremental loss change runs.... 57

Table 28. Parameters and outputs common to all component-level change model runs....57

Table 29. Austria, component level loss changes, ground-up, all LOBs....58

Table 30. Austria, component level loss changes, ground-up, residential.... 59

Table 31. Austria, component level loss changes, ground-up, commercial.... 59

Table 32. Austria, component level loss changes, ground-up, industrial.... 59

Table 33. Austria, component level loss changes, ground-up, agriculture....60

Table 34. Austria, component level loss changes, ground-up, auto....60

Table 35. Czech Republic, component level loss changes, ground-up, all LOBs.... 61

Table 36. Czech Republic, component level loss changes, ground-up, residential.... 61

Table 37. Czech Republic, component level loss changes, ground-up, commercial....62

Table 38. Czech Republic, component level loss changes, ground-up, industrial.... 62

Table 39. Czech Republic, component level loss changes, ground-up, agriculture.... 63

Table 40. Czech Republic, component level loss changes, ground-up, auto....63

Table 41. Germany, component level loss changes, ground-up, all LOBs....64

Table 42. Germany, component level loss changes, ground-up, residential....64

Table 43. Germany, component level loss changes, ground-up, commercial.... 65

Table 44. Germany, component level loss changes, ground-up, industrial....65

Table 45. Germany, component level loss changes, ground-up, agriculture....66

Table 46. Germany, component level loss changes, ground-up, auto.... 66

Table 47. Switzerland, component level loss changes, ground-up, all LOBs.. 67

Table 48. Switzerland, component level loss changes, ground-up, residential.. 67

Table 49. Switzerland, component level loss changes, ground-up, commercial....................................... 68

Table 50. Switzerland, component level loss changes, ground-up, industrial... 68

Table 51. Switzerland, component level loss changes, ground-up, agriculture....................................... 68

Table 52. Switzerland, component level loss changes, ground-up, auto.. 69

Table 53. Percentage change in GROSS INSURABLE OCCURRENCE losses, by LOB – 10,000 yr catalog.. 70

Table 54. Percentage change in GROSS INSURABLE AGGREGATE losses, by LOB – 10,000 yr catalog.. 71

Table 55. CATRADER/Touchstone Re analysis settings for central Europe inland flood model runs........ 73

Table 56. Support for primary characteristics in the previous and updated model versions..................... 80

Table 57. Percentage change in gross-to-ground up loss ratio from previous to updated Residential Coverage A distributions.. 84

Table 58. Percentage change in gross-to-ground up loss ratio from previous to updated Commercial Coverage A distributions.. 85

Table 59. Percentage change in GROSS INSURABLE losses, wind only 20.0 vs wind + surge 21.0 – 10K catalog.. 86

Table 60. Percentage change in GROSS INSURABLE losses, surge only 20.0 vs surge only 21.0 – 10K catalog.. 91

Table 61. CATRADER/Touchstone Re analysis settings for model runs to determine OCCURRENCE and AGGREGATE loss changes - surge only 20.0 vs surge only 21.0... 94

Table 62. CATRADER/Touchstone Re analysis settings for model runs to determine OCCURRENCE and AGGREGATE loss changes - wind only 20.0 vs wind + surge 21.0.. 94

Table 63. Percentage change in insurable occurrence loss estimates using the 10K Standard catalog.. 100

Table 64. Percentage change in insurable occurrence loss estimates using the 10K WSST catalog..... 103

Table 65. Percentage change in insurable aggregate loss estimates using the 10K Standard catalog... 106

Table 66. Percentage change in insurable aggregate loss estimates using the 10K WSST catalog....... 109

Table 67. CATRADER/Touchstone Re analysis settings for model runs to determine the loss changes.. 112

Table 68. Summary of exposure changes to active platforms and rigs, CATRADER 21.0 and CATRADER 20.0.. 114

Table 69. Percentage change in insurable aggregate losses by LOB— 10K Standard Catalog............. 115

Table 70. Percentage change in insurable aggregate losses by LOB— 10K WSST Catalog................ 115

Table 71. Percentage change in insurable occurrence losses by LOB— 10K Standard Catalog............116

Table 72. Percentage change in insurable occurrence losses by LOB— 10K WSST Catalog................116

Table 73. CATRADER/Touchstone Re analysis settings for model runs to determine the loss changes..117

Table 74. Event ID Updates... 118

1 Executive Summary

AIR Worldwide is proud to announce that the summer 2019 releases of Touchstone, Touchstone Re, and CATRADER include updates to existing model offerings in New Zealand, the United States, and Europe.

The AIR Earthquake Model for New Zealand sees a significant update to all model features, including overhauls to the hazard and vulnerability modules, the addition of several subperils, and a full update to the AIR Industry Exposure Database. Hazard updates include a completely revamped view of seismicity, new local and global ground motion prediction equations (GMPEs) for the estimation of shaking intensity, the effects of recent large earthquakes, and more. Vulnerability updates include the application of AIR's vulnerability classification framework, the addition of several age and height bands, and the explicit consideration of building ductility, among others. The liquefaction, landslide, tsunami, and fire following subperils are newly added in the 2019 update.

Updates to the AIR Inland Flood Model for Central Europe and the AIR Extratropical Cyclone Model for Europe underscore the AIR focus on Europe. The model domain of the AIR Inland Flood Model for Central Europe is expanded to include Poland. A recalibrated hydrological model and significant vulnerability updates round out this model's renewal. The AIR Extratropical Cyclone Model for Europe is now integrated with the AIR Coastal Flood Model for Great Britain to incorporate a new peril, storm surge, and a new domain for that peril that comprises all coastal areas of England and Wales. The storm surge addition is supported by a new, high-resolution view of detailed coastal sea defenses.

For the United States, AIR has updated its hurricane models, the AIR Hurricane Model for the United States and the AIR U.S. Hurricane Model for Offshore Assets. The AIR Hurricane Model for the United States includes updates to all the stochastic catalogs based on the addition of significant 2015-2016 hurricanes to the historical catalog, updated unknown year-built vulnerability factors, and now supports the marine cargo line of business. AIR U.S. Hurricane Model for Offshore Assets includes the same catalog updates, as well as updates to market prices of oil and gas.

2 The AIR Earthquake Model for New Zealand

2.1 Overview of Model Updates and Changes

Updates to the AIR Earthquake Model for New Zealand are the result of several years of research and development by many professionals at AIR and represent major advancements in the scientific understanding of earthquakes and how buildings respond to them. The AIR Earthquake Model for New Zealand captures the effects of ground shaking, liquefaction, landslide, tsunami, and fire following earthquakes on properties in New Zealand. This is a stochastic, event-based model.

Updates to the hazard component of the AIR model were motivated by recent scientific studies and revelations regarding how seismic strain is built up, released and transferred through the earth as ground shaking during an earthquake. The studies incorporated into the AIR seismicity model are primarily work published by GNS Science (GNS) including the 2010 National Seismic Hazard Model (NSHM), the United States Geological Survey (USGS) including the NGA Ground Motion Prediction Equations (GMPEs) and framework behind the third version of the Uniform California Earthquake Rupture Forecast (UCERF3) model, the Global Earthquake Model (GEM) Foundation, as well as by numerous other researchers. New understandings leading to an updated seismic source characterization for New Zealand, along with the latest publications on site amplification and ground motion prediction equations for a variety of crustal settings have been incorporated into this model update. The new earthquake model also introduces explicit modeling of liquefaction, earthquake-induced landslides, fire following, land damage throughout the entire model domain, and explicitly models the risk of earthquake-triggered tsunamis along the coast of New Zealand.

The damage estimation component of the AIR Earthquake Model for New Zealand has been extensively validated against published research and observed damage data from historical earthquakes. The vulnerability module has also undergone external peer review. Overall model performance has been validated against historical loss data from various events as well as location-specific claims when available. The model domain includes 16 regions on the North and South Islands, the Stewart, Auckland, and Campbell Islands, as well as distant tsunamigenic earthquake sources in the Pacific Basin. Shake, liquefaction, landslide, tsunami, and fire-following losses are separable in Touchstone 7.0 for the AIR Earthquake Model for New Zealand. The updated model features a Historical Event Set consisting of 29 (as compared to one in the previous model version) historical events for analysis, along with 16 Extreme Disaster Scenarios.

The following sections provide descriptions of the updated model components and how the updates affect losses.

2.2 Catalogs and Event Sets

Stochastic Catalog

The offering of catalogs in the 2019 model release is expanded to support the time-dependent (TD) in addition to the time-independent (TID) views of seismicity. Furthermore, the updated model includes a portion of the TD event set representing Transient Elevated Localized Seismicity (TELS) events. The TELS events represent the temporary increase in seismicity for areas impacted by recent events, including the 2010–2011 Canterbury Earthquake Swarm (CES) and the 2016 Kaikoura Earthquake. The model provides each of these views of seismicity in catalogs of both 10,000 and 100,000 simulated years of events.

Historical Event Set

The AIR Earthquake Model for New Zealand features a new Historical Event Set that includes scenarios representing the recurrence of 29 historical events. More recent events, for which ground motions have been extensively recorded and studied, are provided as calibrated stochastic ground motion footprints and aim to represent the ground shaking that actually occurred during these events to the truest extent possible.

Table 1 lists 29 historical seismic events available in the model.

Table 1. Historical Events available in CATRADER

Earthquake	Magnitude (M_w)	Year	Earthquake	Magnitude (M_w)	Year
Marlborough	7.4	1848	Arthurs Pass	6.7	1994
Wairarapa	8.2	1855	Fiordland	7.2	2003
North Canterbury	7.1	1888	Gisborne	6.7	2007
Arthurs Pass	7	1929	Dusky Sound	7.8	2009
Murchison	7.3	1929	Maule (Chile)	8.8	2010
Hawkes Bay	7.4	1931	Darfield	7	2010
Wairarapa I	7.2	1942	Darfield Boxing Day Aftershock	4.7	2010
Wairarapa II	6.8	1942	Christchurch I	6.2	2011
Gisborne	7.1	1947	Christchurch II	6	2011
Valdivia (Chile)	9.5	1960	New Brighton	5.8	2011
Inangahua	7.1	1968	Seddon	6.493	2013
Edgecumbe	6.5	1987	Lake Grassmere	6.469	2013
Te Anau	6.7	1988	Eketahuna	6.23	2014
Weber II	6.4	1990	Kaikoura	7.82	2016
Gisborne	6.2	1993			

World Scenarios Event Set

AIR is including Extreme Disaster Scenarios for New Zealand in AIR's World Scenarios Event Set. The events represent various extreme scenarios that have been studied and discussed within the scientific community, such as low-probability, high-impact events for the cities of Auckland and Wellington, as described in the 2014 Geological and Nuclear Sciences (GNS) reports for the Auckland and Wellington regions. AIR Extreme Disaster Scenarios also include the occurrence of a large earthquake on the Alpine Fault and a megathrust earthquake along the Hikurangi subduction zone.

2.3 Event Generation

The updated AIR Earthquake Model for New Zealand offers both time-dependent and time-independent versions of 10,000- and 100,000-year stochastic catalogs. These four catalogs contain events whose frequency, epicenter, moment magnitude, rupture length, azimuth, depth, and rupture mechanism are simulated for individual source zones.

In the following sections, changes in hazard due to the update of the time-dependent 10,000-year stochastic catalog are discussed. The change in losses reflects only the update to the stochastic catalog, with ground motion, vulnerability, and the AIR view of industry exposure held constant.

Model Domain

The size and shape of the stochastic catalog domain for the AIR Earthquake Model for New Zealand (shown in Figure 1) have changed, relative to the previous version of the model. Stochastic events in the New Zealand earthquake catalog are generated both on land and off the shores of New Zealand, as indicated by the red boundary in Figure 1. The stochastic event set also includes distant tsunamigenic earthquakes from the following modelled regions: the Kermadec-Tonga subduction zone, New Hebrides trench, and South American subduction zone.

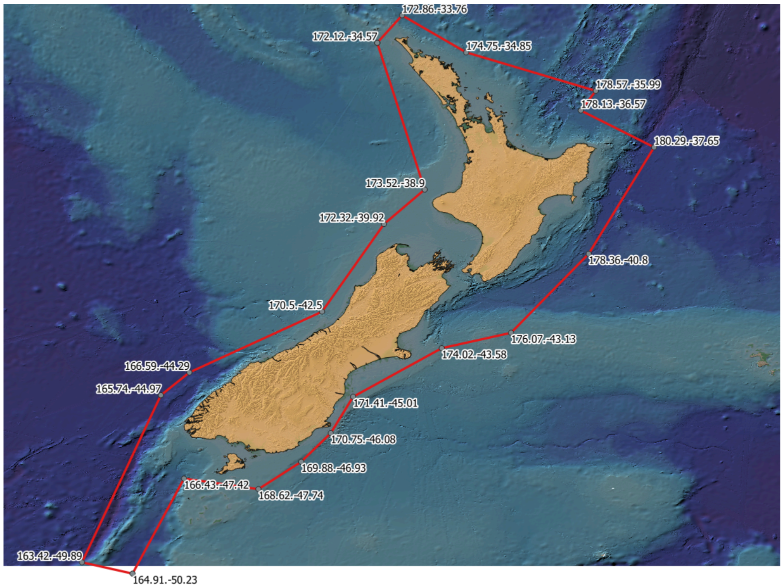


Figure 1. Domain of the AIR Earthquake Model for New Zealand

Generating the Stochastic Catalog

The AIR Earthquake Model for New Zealand captures the complex seismicity of New Zealand by generating events along known active crustal faults, within special seismic zones, and along subduction zones in the Hikurangi and Puysegur trenches. Through the use of smoothed background seismicity, the model also captures the potential for earthquakes to occur where there has been little or no recorded historical seismic activity. The stochastic event generation process includes determination of the magnitude, location, rupture length and the width, depth, and fault orientation and mechanism. AIR provides a time-dependent view of seismicity in New Zealand, along with a time-independent view.

In 2010, GNS Science (GNS) released the National Seismic Hazard Model[1] (2010 NSHM, also referred to as 2012 NSHM due to several component updates in 2012). The 2010 NSHM's output is a set of seismic hazard maps that display earthquake ground motions for various probability levels across New Zealand. These maps are important because they are adopted into the seismic provisions of building codes, used for structuring insurance rates, performing deterministic risk assessments, and developing public policy; in addition to being important inputs for catastrophe models. AIR researchers have used the updated NSHM for New Zealand to generate stochastic earthquakes in the AIR New Zealand earthquake model. The methodology used represents a complex integration of many different types of empirical earthquake data and results from physical models. Another significant change from the previous version of the New Zealand earthquake model is that AIR has used a methodology similar to the Uniform California Rupture Earthquake Forecast (UCERF3) to generate multi-

[1] https://www.gns.cri.nz/Home/Our-Science/Natural-Hazards/Earthquakes/Earthquake-hazard-modelling/2010-National-Seismic-Hazard-Model

fault rupture scenarios with complex geometry as part of the stochastic event set. This is the first time the UCERF3 framework has been applied to model these types of earthquakes in and around New Zealand.

Impact of the Event Generation Update

The previous version of the AIR Earthquake Model for New Zealand generally assumes that earthquakes are either confined to individual fault segments or that long faults, similar to the Alpine Fault or Hikurangi subduction zone, can be divided into different distinct segments that can rupture individually. However, recent observations have demonstrated that earthquakes are not confined to rupture based on isolated fault segmentation. Most notably, the November 2016 M_w 7.8 Kaikoura earthquake ruptured in a cascading fashion that involved many segments across numerous faults, resulting in what is called a multi-fault rupture (MFR). Since the amount of energy released by an earthquake (as measured by its moment magnitude, M_w) is proportional to the amount of area that slips during a rupture, an earthquake that ruptures many faults inherently releases more energy and results in a larger magnitude.

Given these observations, the updated model follows the methodology of UCERF3[2] in considering the possibility of multi-fault ruptures on the vast interconnected fault systems that run through New Zealand. As a consequence, based on a total of 540 active faults in the GNS 2010 NSHM model, AIR considers a branch of the fault model with about 1200 multi-fault rupture scenarios that can affect numerous locations simultaneously. The number of possible scenarios with complex rupture geometries and potentially larger magnitudes in the updated model doubles the number of such scenario in the GNS model, including the number of ruptures that can impact both the North and South islands.

For a given seismic source zone, there is an amount of seismic energy that has accumulated over time based on slip rates and the recurrence of earthquake activity in a given area. The recurrence (or probability) of earthquakes of a certain magnitude occurring within a given source zone is dictated by the magnitude and recurrence rate curves that are derived from historical earthquake activity. The physical modeling of earthquake scenarios within the stochastic event set requires the identification of which faults are capable of generating earthquakes of a given magnitude in order to utilize the built-up seismic energy and produce a modeled magnitude-rate curve that is consistent with historical observations. The inclusion of these multi-fault cascading ruptures—similar to those observed in past earthquakes in New Zealand and around the world—results in a larger portion of the built-up seismic energy being released by large-magnitude events. The inclusion of these multi-fault ruptures allows for a higher probability of large-magnitude events and a lower probability of low-magnitude events, providing better agreement with historical observations. The impact of including the MFR events is generally a reduction in losses at lower return periods (less than 100 years), and an increase in losses at longer return periods. This impact is most notably seen in the areas of Canterbury and Hawkes Bay.

[2] https://pubs.usgs.gov/fs/2015/3009/pdf/fs2015-3009.pdf

The previous version of the AIR Earthquake Model for New Zealand includes a time-independent (TID) view of the seismicity. This means that the recurrence rate of certain events is assumed to be constant over time and does not consider the occurrence of recent seismic events. The updated model includes a time-dependent (TD) view of seismicity as the default and preferred view of the hazard. The time-dependent view considers the impact that recent events, such as the 2016 Kaikoura earthquake, have on the view of seismicity. It also permits the more accurate modeling of earthquakes on faults where there has not been recent seismicity that the historical recurrence rate would suggest. For example, the time since the last rupture on the Alpine fault is longer than historical observations would suggest is the average recurrence interval for that fault. Consequently, a TD view would result in an elevated probability of an earthquake occurring on the Alpine fault in the near future, relative to the probability that would be modeled by a TID view. This new TD view takes into account more information and results in a more realistic view of near-term seismicity.

The impact of time dependency on the country-wide EP is relatively minor, with single digit increases in losses at shorter return periods (less than 100 years); with double digit decreases in the moderate return periods (100–1000 years); and no impact to very large events that impact the tail of the EP curve (greater than 1000 years). The impact of time dependency can be quite regional, as modeling either the increase or decrease of event probability is generally tied to specific faults. For example, the impact of time dependency for Hawkes Bay and Canterbury results in an increase in the seismicity, whereas the impact for Wellington follows the country-wide trend of increased losses at shorter return periods and decreased losses at longer return periods. The impact of time dependency for Auckland is relatively negligible due to the low rate of seismicity and the lack of data regarding recent events to suggest a radically different view of expected earthquakes.

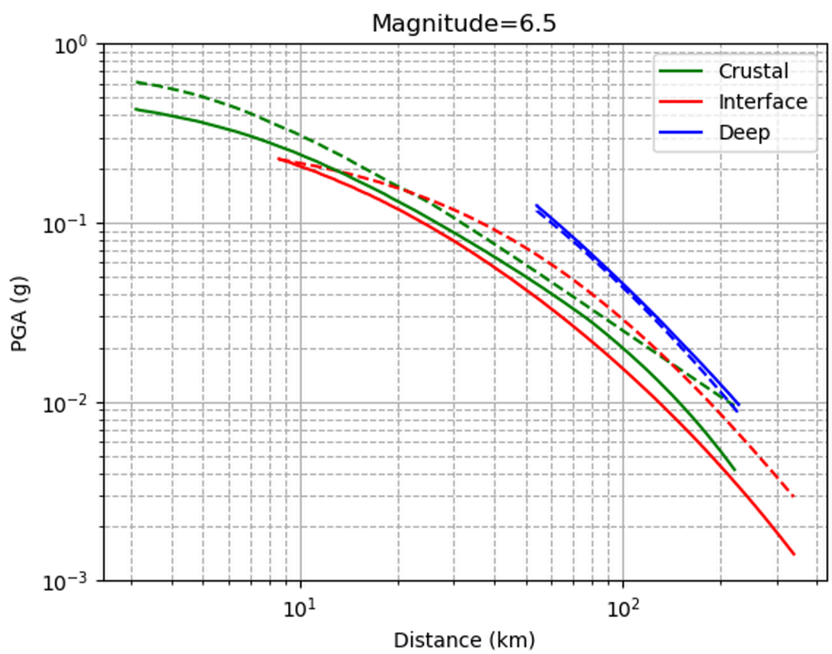
A feature of the time-dependent view of seismicity is the ability to model Transient Elevated Localized Seismicity (TELS) events. This portion of the stochastic event set can be turned on or off to either include or exclude localized pockets of relatively small-magnitude events that have been occurring as a result of the recent 2010–2011 Christchurch and 2016 Kaikoura earthquakes. These small events have a very localized impact of increasing the seismicity and subsequent losses in some very localized areas at shorter return periods (less than 100 years). The main affected areas include Canterbury, Marlborough, and Wellington.

2.4 Local Intensity Calculation

The calculation of local shake intensity requires the following distinct components: soil maps, ground motion prediction equations (GMPEs), site amplification equations, and localized basin effect models. The 2019 version of the earthquake model for New Zealand includes vastly more refined soil maps, which use 26 different site soil classifications, as opposed to nine in the 2007 version of the model. This permits more realistic amplification and de-amplification of ground shaking intensity at a higher geospatial resolution than the 2007 version of the model.

For the active crustal tectonic region of New Zealand, the model employs the latest Next Generation Attenuation West-2 (NGA-W2) GMPEs, as well as four subduction zone interface/ deep (intraslab) equations, including work from the BC Hydro project[3]. Updated GMPEs for the active crustal suite of GMPEs generally reduces modelled ground motion due to faster decay away from the source. The subduction zone interface/deep (intraslab) equations predict higher ground motion near sources, but decay faster than previous models. In the 2019 update, AIR also defines a ground motion transition zone—blending crustal and deep GMPEs between 30–50 km depth.

Figure 2 compares the weighted average GMPEs from the 2019 version of the model (solid lines) and GMPEs from the 2007 version of the model (dashed lines) for a single measure of ground motion.



3 https://www.bchydro.com/energy-in-bc/projects.html

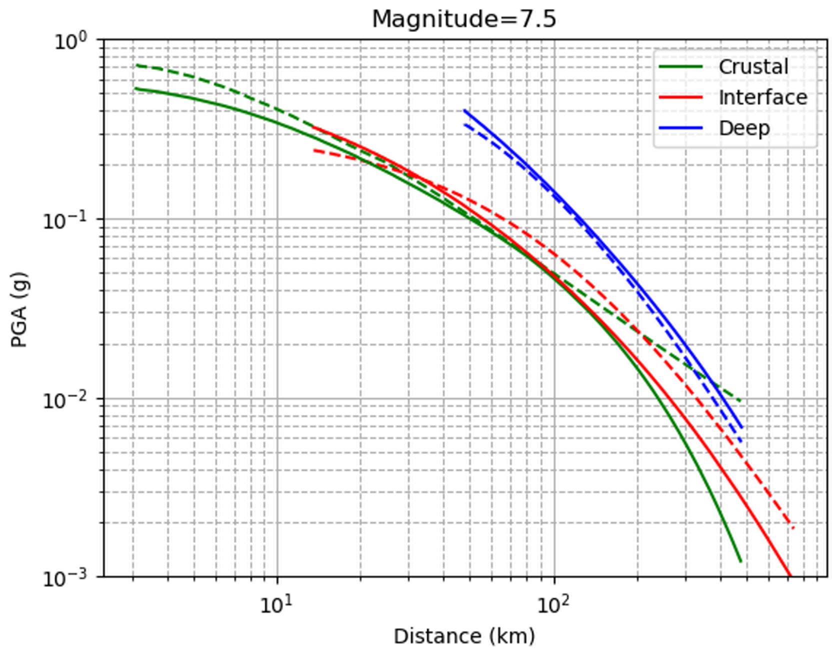


Figure 2. Weighted average GMPEs for the 2019 model (solid lines) and the 2007 model (dashed lines) for a single measure of ground motion from M_w 6.5 and M_w 7.5 earthquakes
The vertical axis indicates the peak ground acceleration (PGA) and the horizontal axis indicates distance from the rupture plane. Most updated GMPEs show faster decay with distance compared to older GMPEs. Deep earthquakes create large ground motions near to the source then decay faster with distance.

The model includes site amplification factors to explicitly account for the effects of local site amplification from alluvial deposits—loose gravel, sand, silt, or clay — that are known to amplify earthquake shaking. In calculating the local ground shaking intensity, the ground motion intensity module also takes into account the travel path of seismic waves, adjusting the intensity of ground motion as waves travel between different crustal types.

In the 2019 version of the model, the site amplification factors have been updated to the NGA-West2 relationships, where AIR's scientists have adjusted site amplifications to more accurately reflect the conditions in New Zealand. Figure 3 compares the 2007 and 2019 amplification curves by site condition and ground motion measurement. As can be seen from Figure 3, the relationships between site conditions, ground motion measurements, and amplification factors are complex. Generally, the new amplification equations result in higher amplification for site classes C, D, and E with more de-amplification for site classes A and B.

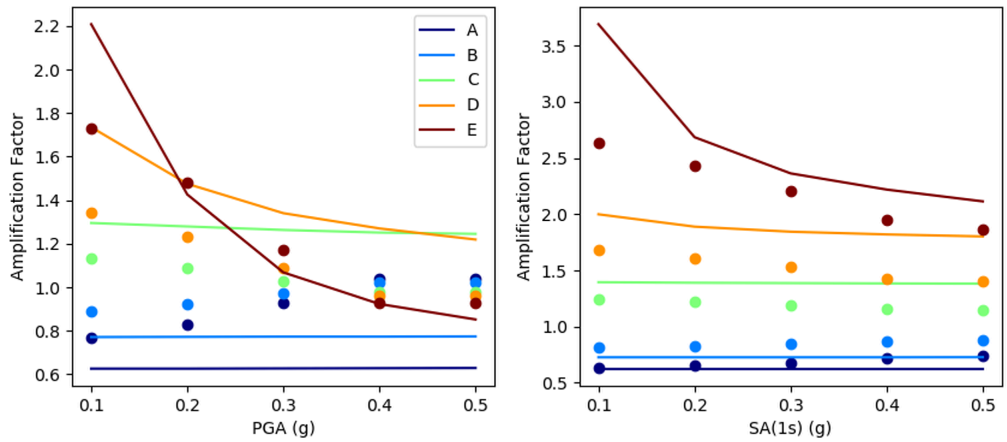


Figure 3. The amplification factors in the existing 2007 model (dots) and the 2019 update (solid lines). The factors are shown by site conditions A (very hard rocks) through E (very soft soil) and ground motion measures PGA and Sa(1s).

A new feature of the 2019 model update is the inclusion of a 3D basin model for the area around Christchurch. The use of a 3D basin model in conjunction with the NGA-West2 GMPEs allows the local intensity calculation model to explicitly account for the impact that deep sedimentary basins have on amplifying the intensity of long-period ground motion waves. This was explicitly observed during the 2010 and 2011 Canterbury Earthquake Sequence (CES) events, where ground shaking with a period of 3 seconds was significantly higher than what would be predicted from an unmodified GMPE. However, using a 3D basin model and the updated suite of GMPEs permits more realistic simulation of ground shaking for longer-period waves in the Christchurch area.

Impact of the Local Intensity Calculation Update

All four components of the updated local intensity calculation model (GMPEs, soil, site amplification, and basin effects) have been updated and developed to work with a more refined site soil classification scheme and are, therefore, not interchangeable with the GMPEs, soil maps, and site amplification equations implemented in the previous model. As a result, the total impact of the four updated components have been considered in aggregate rather than individually.

For the country-wide view of the shaking hazard, the impact of the updated local shaking intensity calculation is generally a large increase in losses at shorter return periods (less than 1000 years) and a decrease in losses at longer return periods (greater than 1000 years). This impact is generally seen throughout most regions of the country as a result of higher near-source intensity and more rapid attenuation (decay with distance) that are modeled by the GMPEs for an event with a given magnitude. The impact of the update to the local intensity calculation can be significant, resulting in more than a 100% increase in relatively small losses at the shorter return periods (less than 1000 years). Additionally, the increase in losses due to the local shake intensity calculation is more pronounced in areas of softer soil conditions that are exposed to smaller magnitude events, such as Hawkes Bay and Canterbury. For these areas, there is a combined effect of the increase in the near-field intensity from the GMPEs as a well as an increase in the shaking intensity at the ground surface that results from higher site amplification. The impact to the Wellington area is more muted and follows the similar trends as the country-wide loss impact: higher losses at shorter return periods and a slight decrease in losses at longer return periods.

2.5 Damage Estimation

The improvements to the AIR Earthquake Model for New Zealand include a substantial overhaul of the model's vulnerability component.

At its core, the vulnerability framework has been updated from a Capacity Spectrum Method-based approach to an Intensity-Based Damage Function (IBDF) approach. While the Capacity Spectrum Method (CSM) is a suitable framework for assessing the performance of a specific building at a single location, the performance of the CSM and IBDF approaches has been observed to be similar for the purposes of catastrophe risk modeling. This is due to the fact that the accuracy of the CSM approach applied to a known building can be overshadowed by the variability and uncertainty associated with a portfolio of spatially distributed buildings.

In addition to the shift in methodology, a significant improvement is the application of AIR's uniform vulnerability assessment framework for deriving vulnerability classes from the chronology of historical building codes. This facilitates the derivation of age bands and seismic zones that define the spatial and temporal changes in vulnerability. An illustration of this approach can be seen in Figure 4, where the seismic hazard maps from two different vintages of the earthquake loading standard for New Zealand have been digitized, and the lateral seismic demand has been quantified for a grid of locations throughout the country. In these maps, the cooler green colors denote areas of higher hazard and, therefore, more stringent design standards, resulting in buildings with lower vulnerability. Conversely, the locations in yellow and orange represent areas of moderate to low hazard, where the design requirements are less strict, resulting in buildings with higher vulnerability.

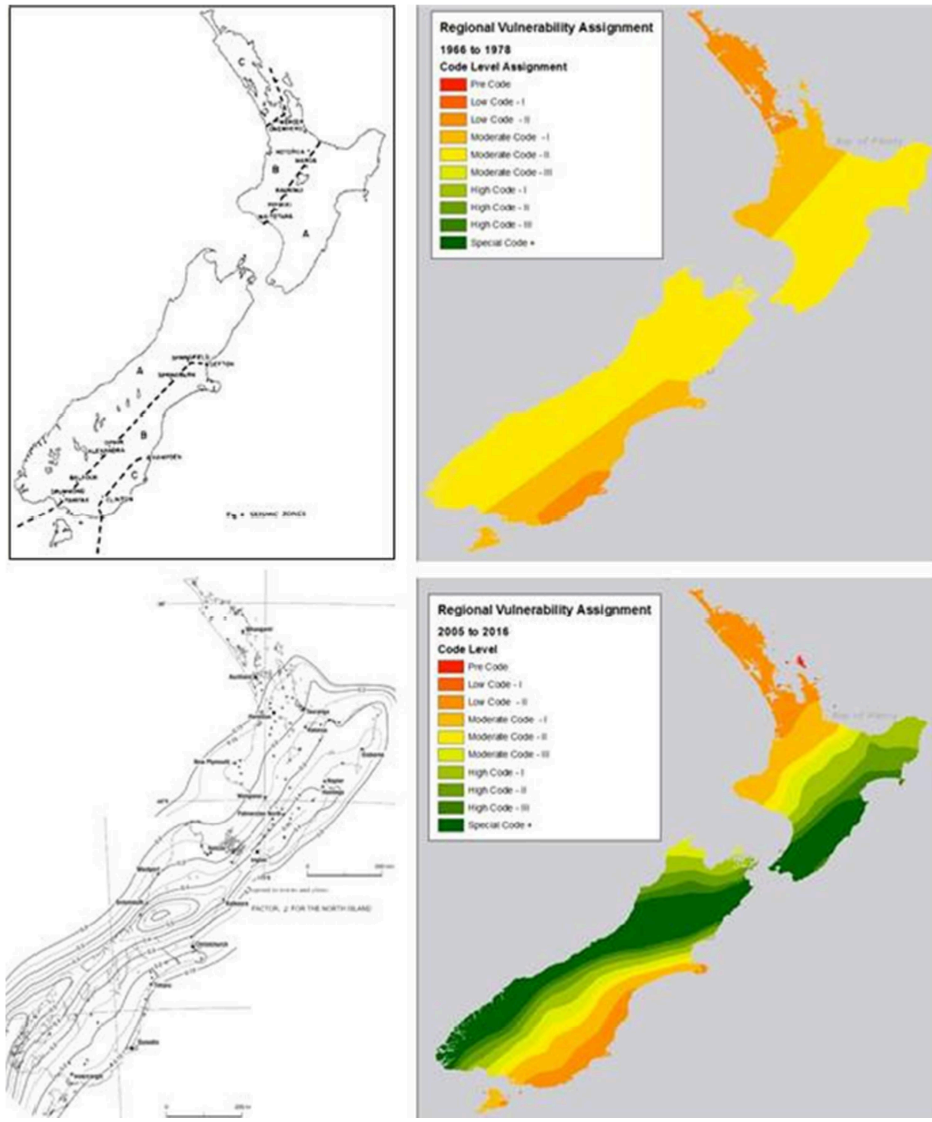


Figure 4. Vulnerability (Code Level) assignments based on two vintages of design maps (1965 – top and 2004 – bottom) on spatial and temporal variation of vulnerability for engineered buildings

Through the application of AIR's externally reviewed vulnerability classification framework, the updated model provides significantly improved resolution for determining the evolving vulnerability, both geospatially and throughout many different years of construction. The temporal and spatial variations of building vulnerability are critical factors in determining the shake vulnerability of a specific risk. In the previous version of the model, there are four age bands to define the temporal changes in engineered building vulnerability. The updated model explicitly includes eight distinct time periods of unique design requirements for engineered buildings with each age band exhibiting its own unique seismic zones.

A similar approach was adopted for the determination of age bands and vulnerability zones for non-engineered timber-framed buildings. In the updated version of the AIR Earthquake Model for New Zealand, rather than utilizing quantifiable seismic base shear design loads as the basis for determining the spatial and temporal differences in timber frame vulnerability, a more qualitative approach is adopted. This approach leverages past studies regarding the changes in building practices and observations of building performance from past events. Figure 5 depicts both the regional and time-varying changes in vulnerability with the cooler green colors denoting lower vulnerability and the warmer red colors denoting higher vulnerability.

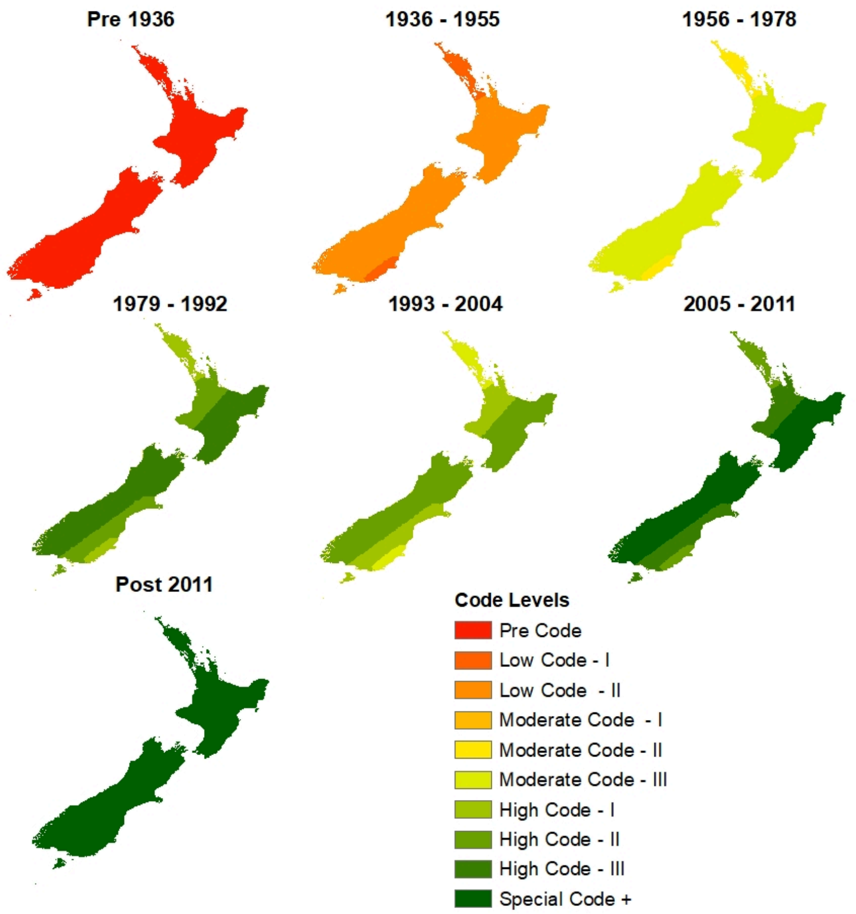


Figure 5. Spatial and temporal variation of vulnerability for timber-framed buildings

The historical performance of timber buildings and timber damage data from previous earthquakes were widely used in updating the damage functions for timber frame construction in the 2019 version of the AIR Earthquake Model for New Zealand. In the previous version of the model, the vulnerability of non-engineered timber-framed buildings varied based on three age bands. However, based on an analysis of claims and the reported changes in timber design and construction practices in New Zealand, the updated model defines seven periods of time during which the performance of timber-framed buildings is expected to be distinct.

The vulnerability class assignments for both engineered and non-engineered buildings have been extensively evaluated through a peer review process by which AIR engineers have learned about the prevalence of code adoption and enforcement to ensure that the theoretically derived vulnerability classes are in alignment with historical building performance. For details on the evolution of building codes and classification of building vulnerability, refer to the Damage Estimation section of the AIR Earthquake Model for New Zealand description on the www.air-worldwide.com website.

In addition to increasing the number of age bands and vastly improving the spatial resolution of vulnerability classes for conventional buildings, the model also adds a new “tall” height class for the modeling of super tall structures. While the current building stock of New Zealand does not include many super tall structures, there can be a significant amount of value concentrated in these buildings, which means their unique behavior and performance must be accurately modeled.

Furthermore, the updated model explicitly includes the impact of ductility detailing for engineered reinforced concrete and steel construction classes. The new feature of the 2019 update to the AIR Earthquake Model for New Zealand allows for the more accurate consideration for the impact of structural ductility on the expected damage. Ductility is a characteristic of a building that allows it to deform and dissipate earthquake energy without experiencing total failure in the form of a collapse. This is obviously an advantageous and desirable quality from a life-safety perspective; however, it can result in ductile buildings that are less stiff and strong than their non-ductile counterparts. As a result, more ductile buildings have the tendency to experience larger deformations under weak shaking which can cause an earlier onset of damage. However, a significant benefit is achieved for stronger shaking, where the mitigation of collapse can result in significantly reduced vulnerability. The updated AIR's earthquake model explicitly accounts for these nuanced differences in the performance of more ductile buildings.

When primary features, such as construction, occupancy, height, and age are unknown, the AIR earthquake model provides the vulnerability as a weighted average of known construction types. This weighted average for unknown vulnerability is calculated based on the distribution of building characteristics within a given geographical area. Furthermore, as more information is provided about a specific risk, the unknown vulnerability becomes more refined and conditioned on whatever known information is provided. The support of damage functions with unknown primary characteristics has been substantially improved for this model update and now is modeled uniquely for all 16 distinct regions of New Zealand.

Newly Supported Risk Types

A significant improvement of the updated vulnerability module is the greatly expanded support for a variety of new risk types, including damageable land, large industrial facilities, infrastructure, marine cargo, and construction risks.

Large Industrial Facilities

The vulnerability module of the AIR Earthquake Model for New Zealand has been substantially expanded to include support for large industrial facilities.

AIR classifies large industrial facilities (IMFs) as high-value industrial sites. Unlike the vulnerability of conventional buildings that are built to withstand site-specific seismic demands, the vulnerability of industrial facilities does not vary significantly from region to region. Additionally, due to high operating loads imposed by their daily functions, IFMs are often built to withstand forces that are larger than what would be imposed by most earthquakes, they also undergo more frequent inspection and regular maintenance. Therefore, their vulnerability is not expected to vary much over time. The damage estimation module for large industrial facilities employs a component-based approach, which accounts for vulnerability of individual facility components and types. In addition, the model can estimate content damage for an industrial facility. AIR engineers gathered, analyzed, and employed damage functions that had been developed and published by other researchers.

Infrastructure

The AIR Earthquake Model for New Zealand can estimate earthquake damage to various infrastructure and lifeline.

The design and construction practices for each sub-class of infrastructure vary considerably in addition to variability in applicable regulations and standards. For example, major highways, highway bridges, and tunnels are regulated by the New Zealand Transport Agency (NZTA) standards, while the design and construction of local roads fall under the jurisdiction of regions or local governments. The design and retrofitting of railroads and railroad bridges are governed by the New Zealand Railways Department (NZR), but stations and maintenance facilities are usually regulated by building codes. Moreover, the design of many types of infrastructure is determined by operational loads, wind loads, or hydrodynamic loads. For example, the design requirements of towers (e.g., broadcast towers or electrical transmission lines) are usually governed by high wind loads.

Each of these infrastructure types has a different response to earthquake ground shaking. For example, bridges are susceptible to damage and failure due to the bridge deck sliding from abutments or piers, whereas the large amount of mass within storage tanks filled with solids or liquid substances (e.g., grains, cement, water or fuel) can lead to the development of significant inertial forces during ground shaking.

Specialized Risks

The AIR Earthquake Model for New Zealand also supports a variety of specialized risks: builder's risk (buildings under construction), marine hull, and marine cargo.

The AIR Earthquake Model for New Zealand supports buildings under construction (builder's risk). Builder's risk is calculated by varying replacement value and vulnerability of the building under construction over the lifespan of the construction project. Most construction projects can be divided into four phases. The builder's risk ("construction all risks/erection all risks"; CAR/EAR) line of business determines potential losses resulting from earthquake damage to buildings while they are still under construction. Builder's risk can be applied to all supported 100-series construction classes, for all height bands. It supports all conventional residential, commercial, and industrial occupancy classes but does not apply to large complex industrial facilities (400-series occupancy classes) or to infrastructure. Note that contractor equipment is not modeled under builder's risk; it is modeled using existing construction and occupancy classes.

In the AIR model, the marine hull risk type includes the hull and machinery of a vessel. This risk can be modeled at a specific port location and for a particular status of port risk, builder's risk, or repair risk. The status that is used depends on whether the vessel is at port (loading, unloading cargo, or undergoing regular maintenance) or if it is under construction. In the AIR model, damage to marine hulls can be caused by ground shaking, liquefaction, and tsunami. In estimating earthquake-related damage, three different conditions are considered for marine hulls; namely, "at port", "at repair", and "under construction" (i.e., builder's risk). These three conditions for marine hull are represented by occupancy types 354, 314 and 381, respectively. Marine hull damage functions are developed using worldwide resources (mainly from Japan), but are applicable to other regions, including New Zealand.

Marine cargo covered in the AIR model includes general containers, heavy cargo, refrigerated containers, dry bulk cargo, liquid bulk cargo, and carpool. In the AIR model, damage to these risks is estimated for the ground shaking, landslide, liquefaction, and tsunami perils. Note that marine cargo is modeled as an independent risk type, and the total value should be entered under Coverage A. It is assumed that the collapse of container cranes is the primary cause of shake damage to a ship's hull when it is located at a port, as the cranes are located next to the ship for loading and unloading. Records of crane damage and the corresponding PGA values at which this damage occurred were collected from field surveys and experimental studies.

Automobiles, Trucks, Trains and Airplanes

In addition to continuing to support automobiles and pleasure boats, the AIR Earthquake Model for New Zealand now provides damage estimates for trucks, trains, and airplanes. The automobile line is intended to include passenger cars, pickup trucks, vans, three-wheelers, and other types of personal and commercial uses. Since most of the automobiles in New Zealand are general passenger cars, the damage function for automobiles is weighted particularly towards passenger cars. In addition to shake damage, damage due to liquefaction, landslide, tsunami, and fire following is also supported. Trucks, trains and airplanes are recommended to be coded as (246, 351), (246, 352) and (246,353) respectively. Since their exact location in the event of an earthquake is not known, the regional loss estimation should be regarded statistically.

Contents Damage

In the previous version of the AIR Earthquake Model for New Zealand, the relationship that defined the vulnerability of contents was developed with respect to ground shaking intensity. However, based on observations from past earthquakes and an analysis of available claims data, it has been shown that contents damage (Coverage C) is more correlated to the damage of the building (Coverage A) in which the contents reside. Therefore, in the 2019 version of the AIR earthquake model, the vulnerability of contents is developed and implemented with respect to the modeled building damage. Figure 6 displays the contents damage relationship from the previous model (the green points) and the updated model (the blue line) for timber frame construction. The orange and purple circles show data from claims following the 2010 Darfield and 2011 Christchurch earthquakes, respectively. It can be seen that the contents vulnerability of the updated model is more closely aligned with the observed vulnerability obtained from claims analysis. Furthermore, from comparing the relationships from both versions of the model, it is clear that the modeled contents vulnerability for the updated model is significantly lower than the previous model, which results in a significant reduction in contents losses.

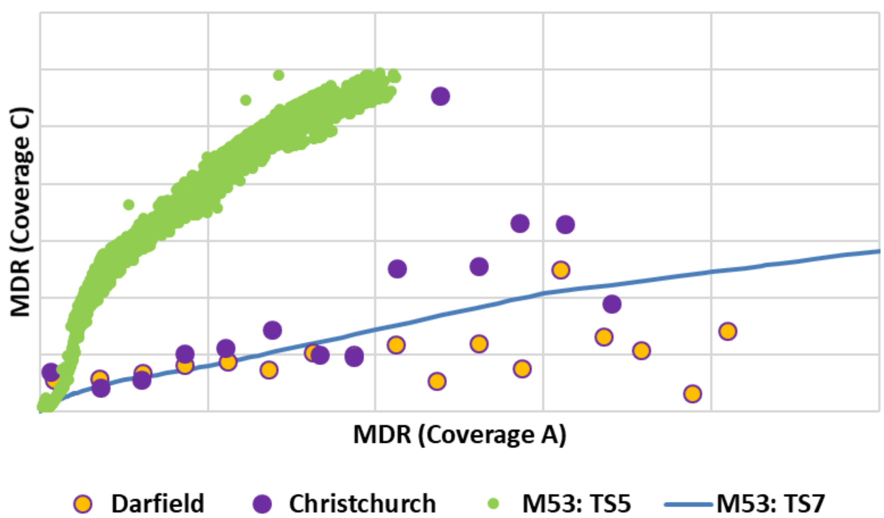


Figure 6. Contents damage relationships for wood frame construction in the existing model (green points) and the updated model (blue line) and historical observations (orange and purple points) used for model calibration

Loss of Use (Business Interruption and Additional Living Expenses)

In addition to direct losses incurred from physical damage to buildings and contents, losing functionality of buildings as a result of damage, lack of access, or safety concerns can lead to further monetary losses. In the 2019 version of the AIR Earthquake Model for New Zealand, loss of use or "Time Element" for residential properties that may result in a relocation or temporary lodging is considered "Additional Living Expenses" or ALE. For other properties (commercial, industrial, and other occupancies), loss of use or "Time Element" is referred to as "Business Interruption" or BI.

The time element loss is calculated as a function of the building and contents damage, which are used to estimate the number of days required to replace, repair, or rebuild the structure or contents. The number of days that are required to bring a property back to the condition it had been in prior to the earthquake and fully operational (in the case of a business) is a function of both the extent of building and contents damage. However, the degree to which both of these types of damage contribute to the overall downtime can vary depending on the severity of each damage type. For example, when damage to the building is relatively minor, the majority of downtime is related to re-supplying the contents so that the building can be brought back to use. However, when building damage becomes more extensive, the time required for extensive repair or reconstruction outweighs the time required to replace the damaged contents.

The damage functions for Time Element (ALE or BI) have been significantly improved in the 2019 version of the model, especially for large industrial facilities. The functions take into consideration such factors as the facility's size, occupancy class, architectural complexity, and product chain, among other factors. As can be seen in Figure 7, the module has been validated and analyzed against the latest research and claims data that has been made available from the 2010 and 2011 Canterbury Earthquake Sequence events.

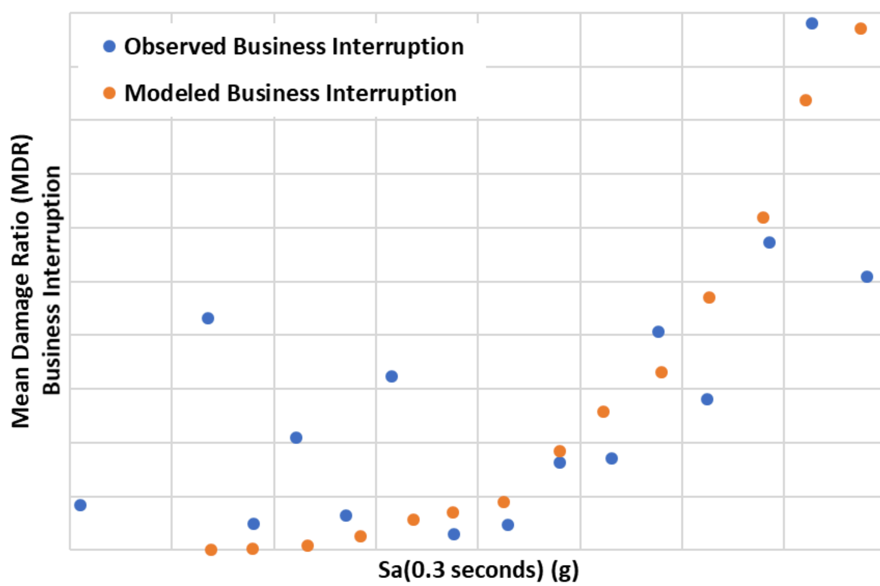


Figure 7. Contribution of building and contents damage to the time element calculation

Impact of the Damage Estimation Update

The vulnerability updates for the New Zealand Earthquake Model generally result in a moderate reduction of building losses at shorter (less than 100 year) return periods with an increase in losses at longer return periods. The reductions and increases to building loss are typically within +/- 50% with very minimal impact around the 100 to 250-year return periods country-wide. Similar trends are exhibited at different locations throughout New Zealand with minimal difference in the regional changes in losses due to the impact of the vulnerability update on the modeled loss results.

The impact of the updates to content vulnerability is more significant than the impact on building losses. The loss impact for contents is a consistent reduction across all return periods and all regions. This loss reduction ranges between -40% to -100% depending on the exact return period and region. Furthermore, in the updated model, contents vulnerability is modeled as a function of building damage. Therefore, the reduction in building damage for shorter return periods exacerbates the reduction in contents damage for return periods shorter than 100 years, where the reduction in contents losses can be as high as 100%. However, the increase in building damage at longer return periods mitigates the reduction in contents losses due to updated vulnerability with the combined impact on the contents losses being around -40%.

The methodology for estimating downtime and business interruption has also been updated in the AIR Earthquake Model for New Zealand. Similar to the approach for modeling contents vulnerability, downtime is calculated as a function of both building damage and contents damage. The impact on the downtime calculation is a reduction in the number of estimated downtime days for a building that has experienced little building and contents damage. The impact of the downtime estimate on Business Interruption (BI) losses becomes smaller for locations that have experienced more extensive modeled building and contents damage.

2.6 Treatment of Uncertainty in the Model

Accounting for uncertainties in earthquake loss analysis plays a critical role in catastrophe risk modeling in general and in AIR models in particular. Large parametric and model uncertainties exist in earthquake ground motions and the response of buildings to ground motions. Two sources of ground motion uncertainty, including inter-event (i.e., earthquake–to–earthquake) and intra-event (i.e., site-to-site), are specifically revised to improve damage and loss estimates within the context of stochastic modeling and provide a more accurate view of risk. Uncertainty in building damage, which considers variations in the response of buildings of similar characteristics, is also updated for shake, tsunami, and fire following, respectively.

For more information, refer to the Accounting for Uncertainty section in the New Zealand earthquake model description, available on the AIR Client Portal.

2.7 Sub-Peril Updates and Additions

The comprehensive updates to the AIR Earthquake Model for New Zealand include the newly modeled subperils of liquefaction, landslide, tsunami, and fire following modules. Figure 8 shows the contribution of sub-perils to the average annual loss for New Zealand.

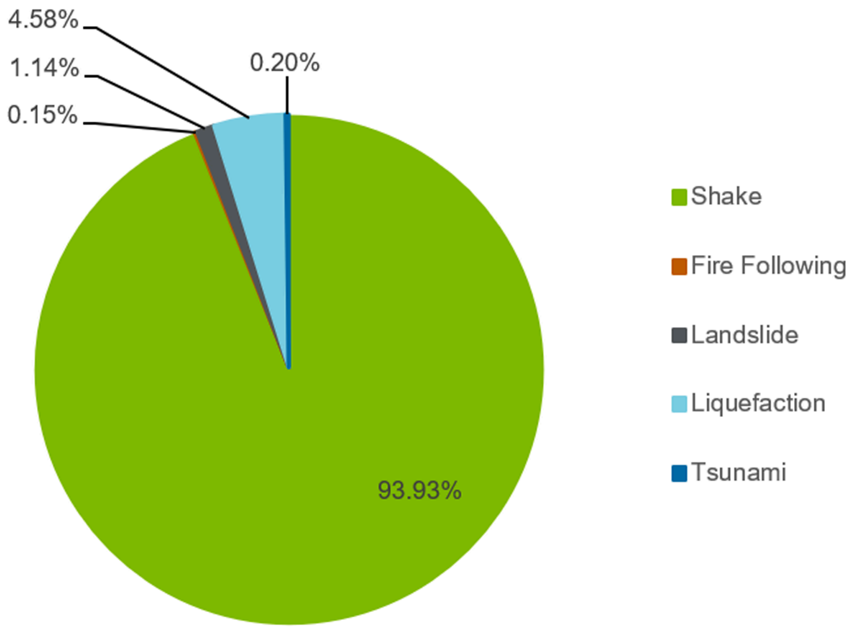


Figure 8. Contribution of sub-perils to average annual loss for New Zealand

Liquefaction

A significant enhancement of the 2019 version of the AIR Earthquake Model for New Zealand is the explicit inclusion of the liquefaction subperil. The liquefaction component incorporates many local liquefaction studies conducted throughout New Zealand between 1997 and 2017.

Liquefaction occurs when loose, saturated soils lose strength and act as a fluid due to intense shaking during an earthquake. Liquefaction can cause ground and foundation settlement that can damage buildings, port facilities, bridges, roads, automobiles and pipelines. Liquefaction hazard now can be modeled explicitly at a high resolution of 30 m in major urban areas, namely Auckland, Wellington, Christchurch, and Napier-Hastings, and throughout the entire country at a lower resolution of 250 m. This coverage is achieved by leveraging a large number of published and unpublished maps and geotechnical data from researchers, state, and local agencies. Liquefaction coverage is shown in terms of modeled liquefaction susceptibility classes in Figure 9.

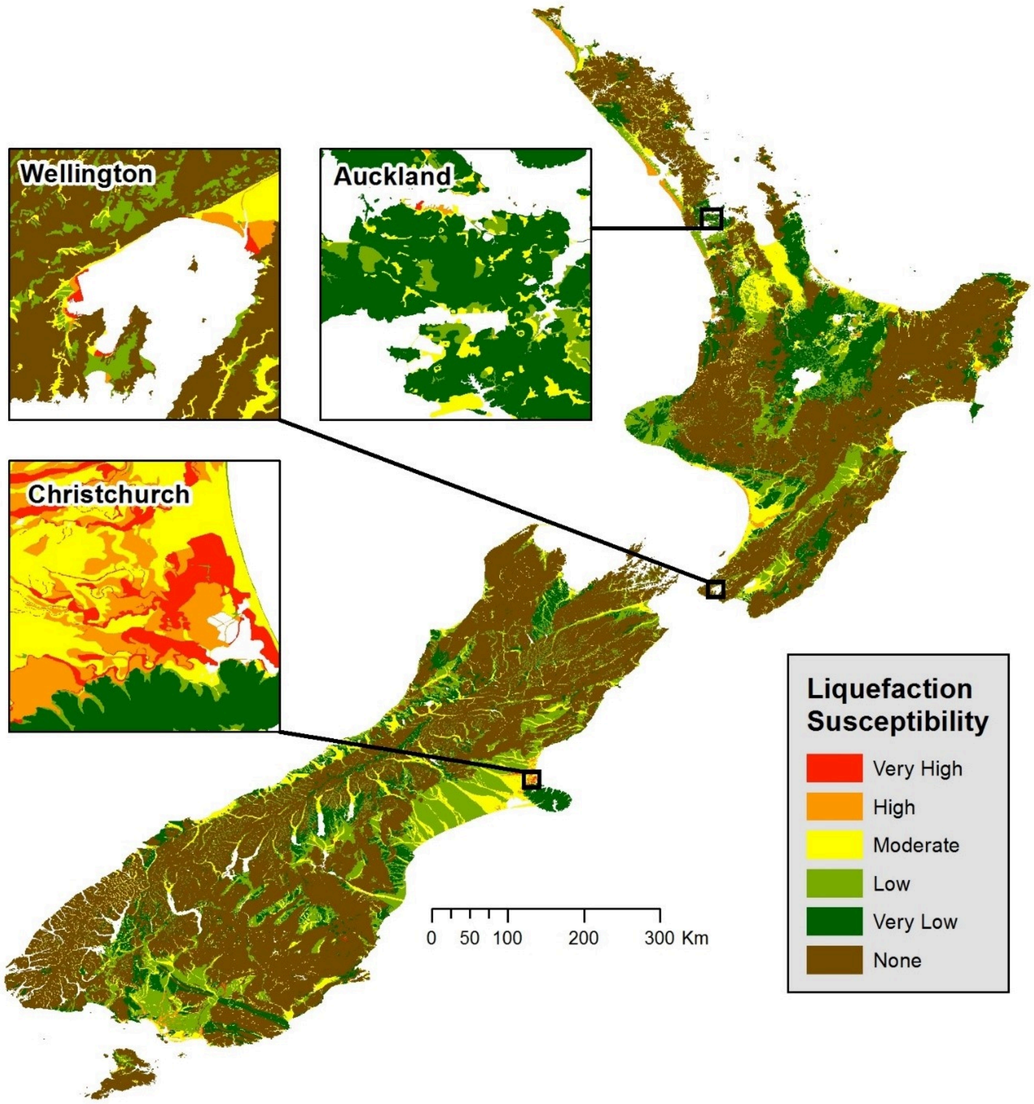


Figure 9. Liquefaction modeling coverage for New Zealand

Hundreds of soil profiles across New Zealand were collected and used by AIR researchers to determine representative soil profiles for various susceptibility classes in different regions. For groundwater depth, the liquefaction model relies on a new set of groundwater maps—explicitly developed to capture shallow groundwater depth—based on observations and filled in data gaps using a groundwater model forced by climate, terrain, and water bodies.

A critical feature in the 2019 update is the introduction of liquefaction likelihood functions, which enable modeling of widespread liquefaction similar to that observed during the 2011 Christchurch earthquake. These functions are based on the correlation of Liquefaction Potential Index (LPI) with the severity and extent of liquefaction manifestation in each susceptibility class.

The model's liquefaction component has been thoroughly validated against several historical events across New Zealand. Observational and claims data from major liquefaction events, including the 1987 Edgecumbe Earthquake, the 2010-2011 Canterbury Earthquake Sequence, and the 2016 Kaikoura Earthquake are used to validate the modeled liquefaction hazard and develop the liquefaction vulnerability functions when sufficient damaging liquefaction has occurred.

Figure 10 and Figure 11 present **occurrence** and **aggregate** impact to loss, for selected annual exceedance probabilities using the 10,000-year time-dependent catalog, due to the introduction of liquefaction modeling methodology in the updated AIR Earthquake Model for New Zealand.

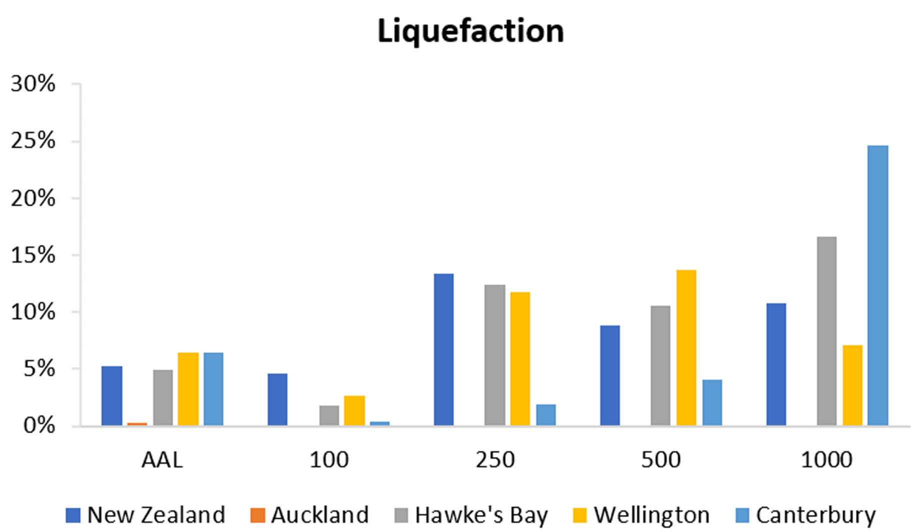


Figure 10. Gross insurable occurrence impact to loss – countrywide and selected zones – due to the introduction of liquefaction

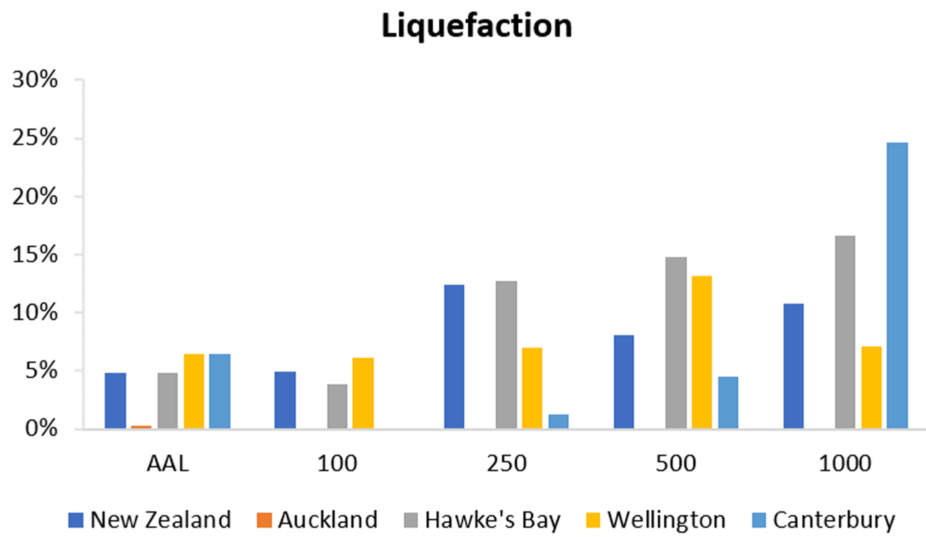


Figure 11. Gross insurable aggregate impact to loss – countrywide and selected zones – due to the introduction of liquefaction

Landslide

Earthquake-triggered landslides can cause the destruction of buildings, roads, power lines, pipelines and other exposures. In some locations, the damage caused by earthquake-triggered landslides can exceed those directly inflicted by strong ground shaking and fault rupture. Historical data shows that many historical events have caused numerous landslides, the most notable events being the 1855 Wairarapa, 1904 Cape Turnagain, 1934 Pahiatua, 1942 Wairarapa, 2011 Christchurch, and 2016 Kaikoura earthquakes.

Newly supported in the 2019 version of AIR Earthquake Model for New Zealand, is a module that assesses the damaging effects of earthquake-triggered landslides. The module covers the entire country. Input data for the landslide module includes Digital Elevation Model (DEM) data, surficial and bedrock geological maps, and seasonal precipitation data from the National Institute of Water and Atmospheric Research (NIWA). AIR scientists used DEM information to derive slope maps, and surficial and bedrock geological maps—to classify geological units based on their material strength. Precipitation data from NIWA is used to estimate seasonal fluctuations in water saturation of soils, which affects the stability of slopes.

AIR uses a physics-based earthquake-triggered landslide module that relies upon the mechanics of slope failure and employs models of seismic slope stability to assess the deformation of the slope following an earthquake. The soil susceptibility is determined based on the steepness of the slope, the strength of the geological materials, and soil wetness conditions which vary depending on the month of the year. Landslide probability (see Figure 12) is then calculated based on level of ground shaking, and damage to exposure is estimated as a function of expected ground displacement resulting from the landslide.

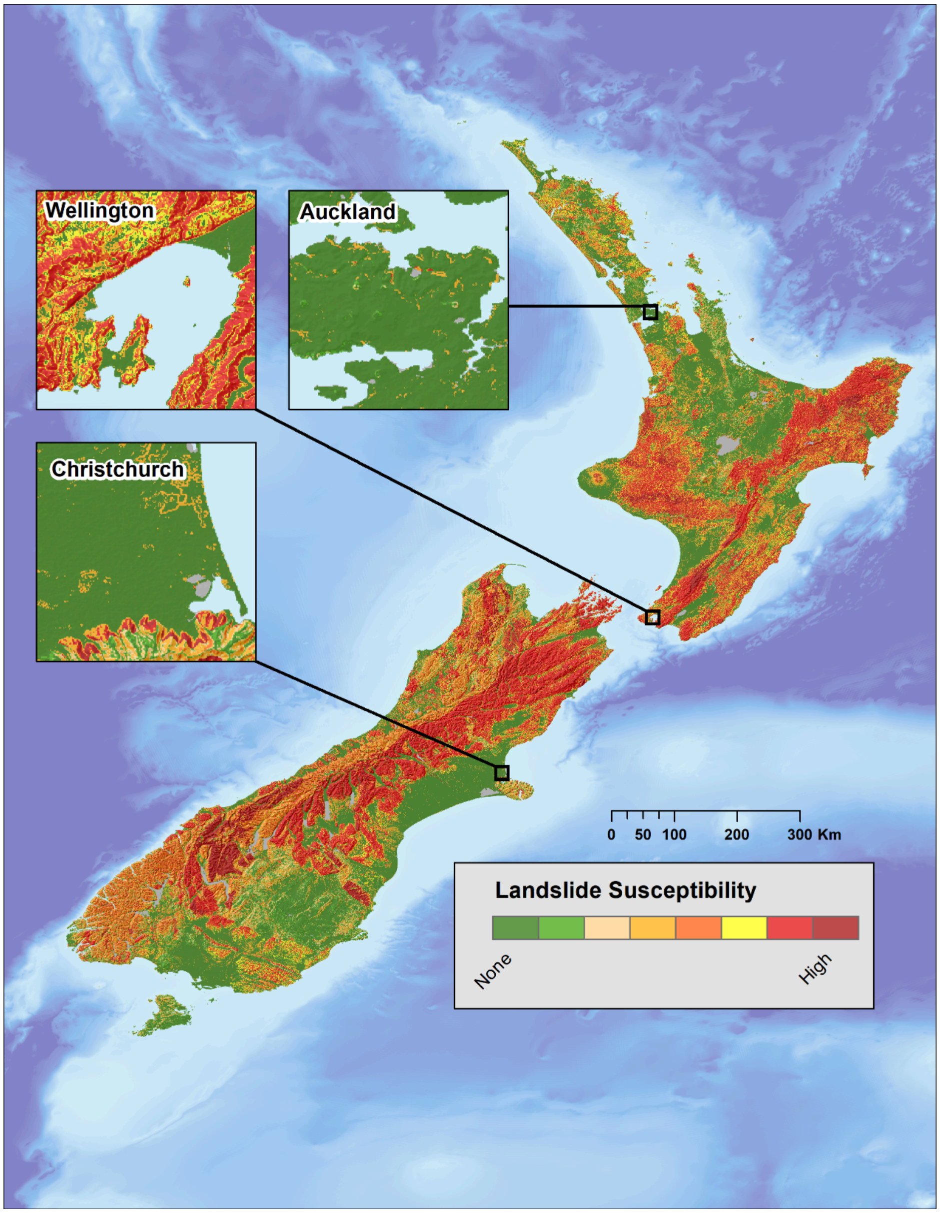


Figure 12. Landslide susceptibility map of New Zealand

As seen in Figure 12, numerous regions of New Zealand can be identified as particularly susceptible to landslides. Specifically, the Southern Alps mountain range on the South Island (which extends the length of the island from southwest to northeast) and the rugged Rimutaka, Tararua, Ruahine, Kaweka, Huiarau, and Raukumara ranges on the North Island are areas prone to earthquake-induced landslides. Other areas susceptible to earthquake-induced landslides on the North Island include Wellington City and its suburbs. On the South Island, many smaller cities in the mountainous areas along the Southern Alps are prone to landslide; in particular, the area around Nelson.

The landslide module was thoroughly validated using data from three major earthquake-triggered landslide events: 1987 Edgecumbe, 2011 Christchurch, and 2016 Kaikoura; other less known historical earthquake-triggered landslides and local studies were also examined and used for validation.

Figure 13 and Figure 14 present **occurrence** and **aggregate** impacts to loss, for selected annual exceedance probabilities using the 10,000-year time-dependent catalog, due to the introduction of landslide modeling methodology in the AIR Earthquake Model for New Zealand.

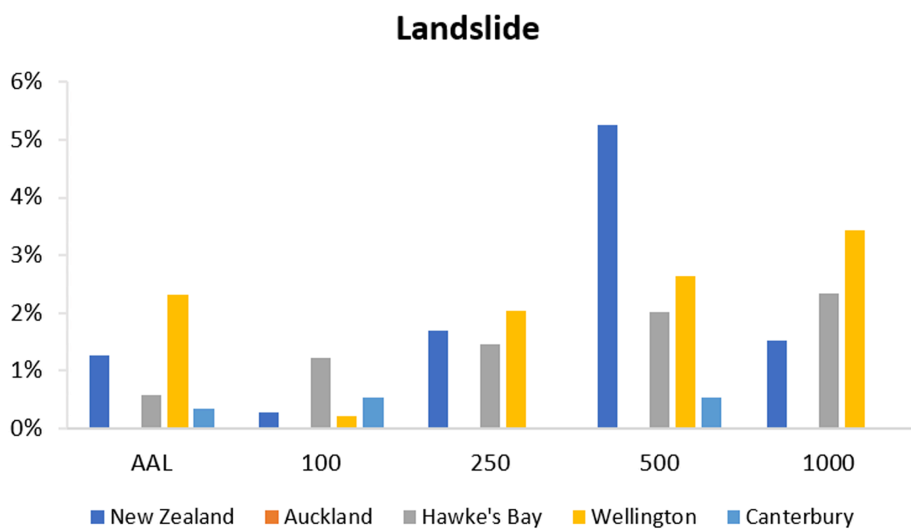


Figure 13. Gross insurable occurrence impact to loss – countrywide and selected zones – due to the introduction of landslide

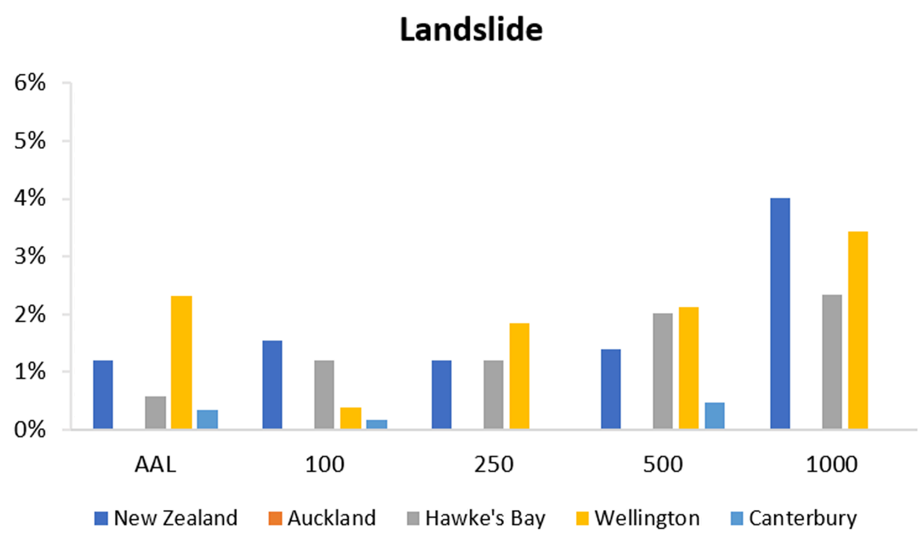


Figure 14. Gross insurable aggregate impact to loss – countrywide and selected zones – due to the introduction of landslide

Tsunami

The updated AIR Earthquake Model for New Zealand includes a new, probabilistic tsunami module. This is the first AIR earthquake model that will support the modeling of trans-ocean basin tsunami sources; that is, large earthquakes occurring off the coast of South America that result in inundation along the coast of New Zealand. Tsunami inundation is modeled along the south, east, north and northwest coasts of New Zealand, which are exposed to various tsunamigenic sources: the Hikurangi subduction zone, the New Hebrides subduction zone, the Kermadec-Tonga trench, selected faults off South America, as well as local offshore faults, multi-segment ruptures, and background seismicity. Table 2 shows a breakdown of tsunamigenic events in the AIR 10,000-year time-dependent and 10,000-year time-independent catalogs by source zone.

Table 2. Tsunamigenic events in the AIR stochastic catalogs by source zone

AIR Catalog	Source Region							
	Hikurangi	New Hebrides	Kermadec-Tonga	South America	Local Faults	Multi-Segment Rupture	Background Seismicity	Total
10K-year Time-Dependent	57	10	20	54	200	3	63	407
10K-year Time-Independent	40	10	20	54	201	3	63	391

To identify tsunamigenic events in the catalog, AIR researchers first determine which stochastic earthquake events are capable of producing a tsunami. In the catalogs, all offshore events of M_w >7 that are predominantly thrust or normal faulting, with a dip angle of less than 75 degrees are flagged as tsunamigenic. For the Kermadec-Tonga and New Hebrides subduction zones, AIR uses a minimum magnitude threshold of M_w 8; smaller events are not modeled. For distant events, such as those associated with a subduction zone at the Peru-Chile trench, a minimum magnitude threshold of M_w 8.8 is used. Earthquakes below this magnitude are unlikely to cause significant tsunami-induced flooding or inundation in New Zealand.

For events that are determined to be potentially tsunamigenic, AIR scientists estimate the slip distribution of the rupture plane. The amount of vertical displacement an earthquake can cause at the ocean floor depends not only on the fault parameters used in the ground motion intensity calculation (e.g., dip, fault length, fault width, depth, etc.), but also on the amount of fault slip, the slip direction or rake angle (which are not required to calculate ground motion intensity). Earthquakes, in general, rupture with a heterogeneous slip distribution on their rupture planes. This is especially the case for large magnitude subduction interface earthquakes. Therefore, AIR uses a model with non-uniform slip distribution, where peak slip occurs in certain areas. The mean fault slip on the entire rupture plane is estimated using the relationship between the seismic moment of the event, the rupture area, and the shear modulus of the fault plane.

After generating the slip model, AIR scientists calculate the vertical deformation of the ocean floor which then generates the tsunami. Tsunami propagation is simulated numerically by solving the non-linear shallow water equation(s) using high-resolution bathymetry/elevation data, variable Manning's coefficient friction/roughness maps, while accounting contribution from astronomical tides to calculate coastal inundation and run-up.

The AIR Earthquake Model for New Zealand uses the tsunami damage functions derived from empirical relationships between observed tsunami damage and inundation depth, wave velocity, debris effects, and data from significant tsunamis throughout the world, including the 2004 Indian Ocean, 2010 Gaulle, Chile, and 2011 Tohoku, Japan events.

Figure 15 and Figure 16 present **occurrence** and **aggregate** impact to losses, for selected annual exceedance probabilities using the 10,000-year time-dependent catalog, due to the introduction of tsunami modeling methodology in the AIR Earthquake Model for New Zealand.

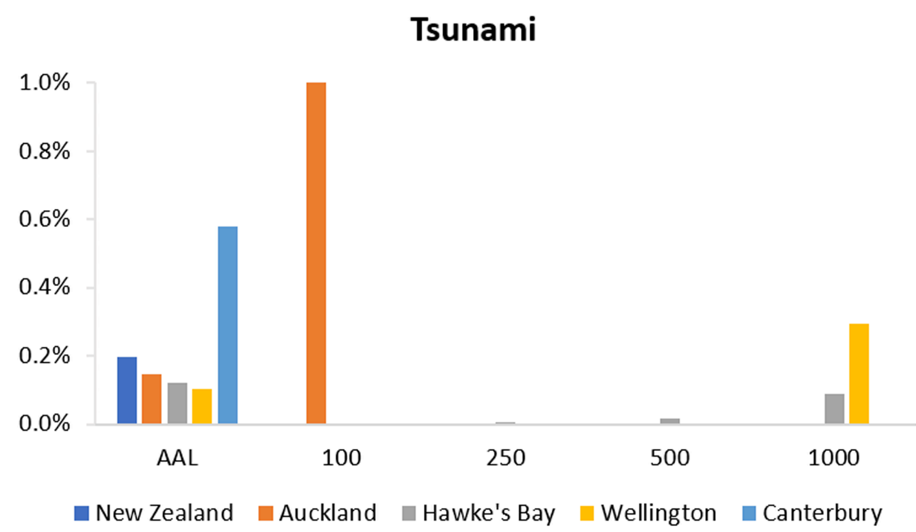


Figure 15. Gross insurable occurrence impact to loss – countrywide and selected zones – due to the introduction of tsunami

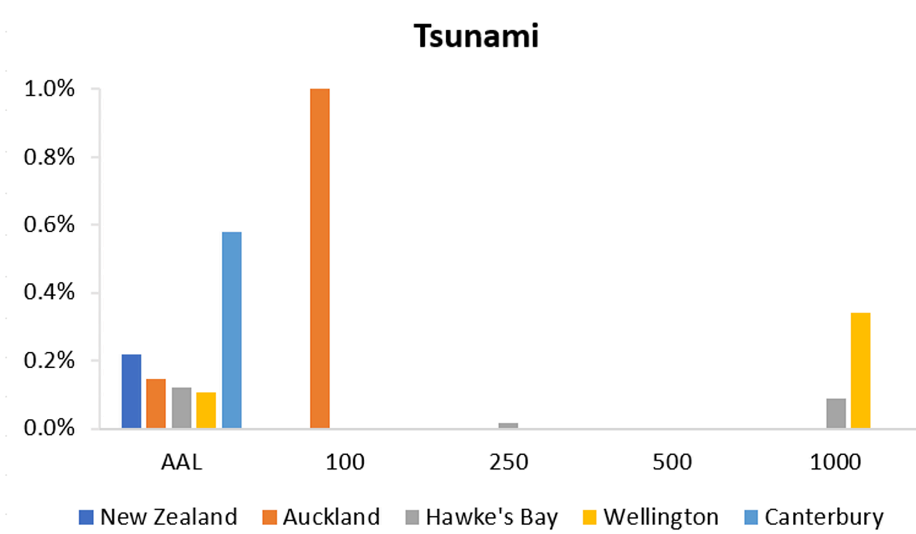


Figure 16. Gross insurable aggregate impact to loss – countrywide and selected zones – due to the introduction of tsunami

Fire Following

The AIR Earthquake Model for New Zealand includes a new fire-following earthquake module. The new fire-following module implements a cellular automata approach to model fire spread from building to building within a city block. AIR models regional fire-following damage at 1-km resolution and offers a reliable method for estimating ignition rates. The updated model also supports fire following for the automobile line of business and calculates fire-following damage to large industrial facilities.

Fire spread between buildings on a city block is modeled using a cellular automata approach, which works on a 3-m resolution grid and takes into account building type and layout. Individual buildings are represented by 3-m x 3-m grid cells with uniform fire properties. AIR models fire spread based on fire physics and historical fire spread experience, and accounts for the impact of building shapes and the spacing between buildings. The cellular automata model is used to obtain the burning area as a function of time on a city block after an ignition occurs. This is done for a set of 40 characteristic city blocks of varied density and occupancy. Figure 17 shows examples of characteristic blocks.

Figure 17. High-density commercial (left) and low-density residential (right) characteristic blocks

Regional fire spread over a wider area is modeled at 1-km resolution, with each 1-km x 1-km grid cell approximated as a 3 x 7 array of 21 city blocks, consisting of some combination of the 20 characteristic city blocks, based on the amount of building floor area of different occupancies and combustibilities and the amount of open area, within the grid cell. The combination of characteristic city blocks that represents a particular grid cell is determined by the probabilities assigned by an optimization algorithm. Uncertainty is accounted for by stochastically varying the exact choice of characteristic blocks for each of the multiple fire simulations that are run for an event.

In the fire-following module, fire ignition rates are modeled using a negative binomial distribution that specifies the probabilities of one or more ignitions occurring in each 1-km grid cell as a function of the ground shaking intensity, total building floor area, and ratio of commercial to total floor area in the grid cell.

Figure 18 and Figure 19 present **occurrence** and **aggregate** impact to loss, for selected annual exceedance probabilities using the 10,000-year time-dependent catalog, due to the introduction of fire following modeling methodology in the AIR Earthquake Model for New Zealand.

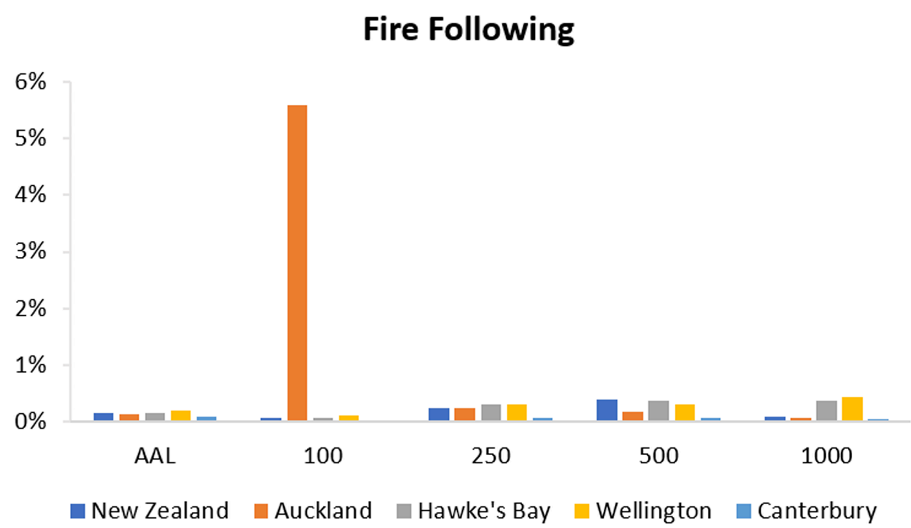


Figure 18. Gross insurable occurrence impact to loss – countrywide and selected zones – due to the introduction of fire following

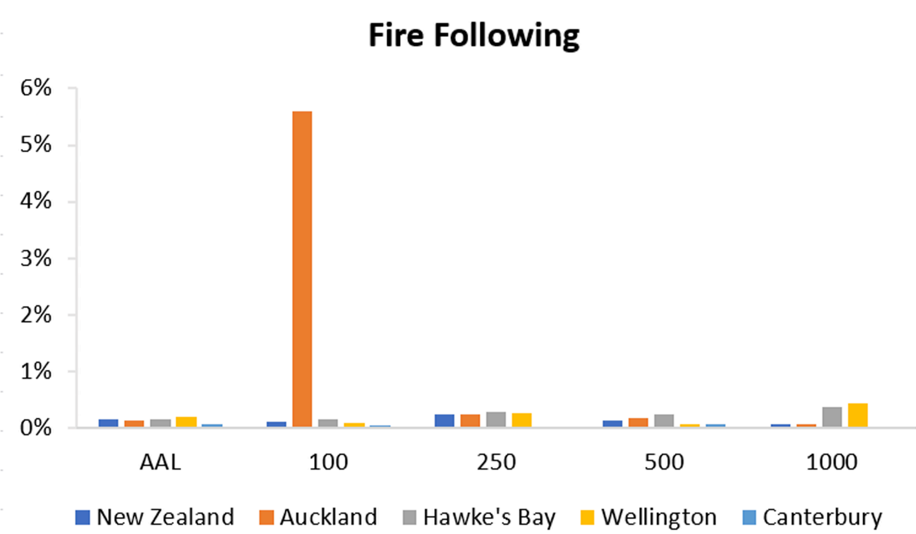


Figure 19. Gross insurable aggregate impact – countrywide and selected zones – due to the introduction of fire following

2.8 Industry Exposure Database

The New Zealand Industry Exposure Database is updated to the year 2018. The database is constructed at a high-resolution (1-km by 1-km) and contains risk counts and their respective replacement values, along with information about the occupancy and physical characteristics of structures, such as construction type and height classification. Large industrial facilities are identified and valued separately from the rest of the industrial line.

For more information, see the AIR Industry Exposure Database for New Zealand, available on the AIR Client Portal at www.air-worldwide.com following the summer 2019 software release.

2.9 General Impact of Model Updates on Loss Estimates

The following tables illustrate the overall impact of model updates on loss estimates from the previous versions of Touchstone Re and CATRADER (20.0) to the 2019 versions of Touchstone Re and CATRADER (21.0).

Table 3 through Table 12 present the percentage change in insurable aggregate and occurrence losses, respectively, for New Zealand and four selected modeled zone, using the **time-dependent** 10,000-year catalog. CATRADER and Touchstone Re settings used in the associated model runs are provided in the next section. Time-dependent catalog losses include short-term increased seismicity (TELS) events. The losses do not reflect the impacts of demand surge.

The **Overall Change** columns provide the change in industry occurrence losses that will be experienced if one simply reruns company exposures already entered in the previous version of the software. **Overall Change** represents the combined effects of all changes (e.g. updates to the catalog, damage estimation module, policy conditions, etc.), including updated property values. **Overall Change** is calculated by comparing the total industry insurable losses in the prior industry loss file to the total industry insurable losses in the new industry loss file. In CATRADER, 100% user-specified market shares are analyzed against each loss file, and the percentage differences calculated in the resulting loss distributions.

The **Change with Constant Exposure** columns represent the combined effects of all changes (e.g. updates to the catalog, damage estimation module, policy conditions, etc.), excluding updated property values.

Table 3. Gross insurable overall loss changes – time-dependent catalog (shake only) – countrywide

New Zealand: All Modeled Zones								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Overall Change							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	136%	-15%	19%	60%	122%	-18%	14%	51%
2% (50)	137%	-17%	34%	59%	126%	-23%	29%	56%
1% (100)	140%	-27%	45%	71%	119%	-30%	34%	61%
0.4% (250)	60%	-44%	-2%	18%	61%	-43%	1%	14%
0.2% (500)	51%	-40%	6%	17%	56%	-37%	7%	17%
0.1% (1000)	73%	-24%	22%	37%	74%	-25%	25%	39%
Est. AAL	**91%**	**-29%**	**13%**	**37%**	**82%**	**-32%**	**9%**	**31%**

Table 4. Gross insurable overall loss changes – time-dependent catalog (shake only) – Wellington

New Zealand: Wellington								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Overall Change							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	-49%	-64%	-82%	-66%	-49%	-63%	-82%	-66%
2% (50)	25%	-49%	-42%	-17%	23%	-53%	-44%	-20%
1% (100)	48%	-57%	-6%	2%	43%	-57%	-10%	-1%
0.4% (250)	13%	-57%	-21%	-9%	13%	-58%	-20%	-9%
0.2% (500)	22%	-52%	-5%	-1%	23%	-53%	-5%	-1%
0.1% (1000)	41%	-44%	26%	26%	41%	-44%	26%	26%
Est. AAL	**20%**	**-56%**	**-19%**	**-9%**	**17%**	**-57%**	**-20%**	**-11%**

Table 5. Gross insurable overall loss changes – time-dependent catalog (shake only) – Canterbury

New Zealand: Canterbury-Christchurch								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Overall Change							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	214%	112%	82%	149%	210%	105%	78%	146%
2% (50)	169%	193%	18%	120%	166%	186%	17%	116%
1% (100)	261%	152%	43%	160%	260%	152%	42%	157%
0.4% (250)	>500%	157%	202%	340%	>500%	160%	194%	331%
0.2% (500)	>500%	103%	297%	408%	>500%	103%	297%	412%
0.1% (1000)	>500%	88%	346%	448%	>500%	88%	346%	448%
Est. AAL	**339%**	**120%**	**135%**	**228%**	**332%**	**117%**	**132%**	**223%**

Table 6. Gross insurable overall loss changes – time-dependent catalog (shake only) – Auckland

New Zealand: Auckland								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Overall Change							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2% (50)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1% (100)	-87%	-79%	-66%	-80%	-87%	-79%	-66%	-80%
0.4% (250)	-81%	-67%	-67%	-72%	-81%	-67%	-67%	-72%

New Zealand: Auckland								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Overall Change							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
0.2% (500)	-65%	-53%	-39%	-59%	-66%	-53%	-39%	-59%
0.1% (1000)	22%	-39%	-9%	-7%	22%	-39%	-9%	-7%
Est. AAL	**147%**	**-22%**	**144%**	**106%**	**146%**	**-22%**	**144%**	**105%**

Table 7. Gross insurable overall loss changes – time-dependent catalog (shake only) – Hawke's Bay

New Zealand: Hawke's Bay-Napier								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Overall Change							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	46%	-27%	16%	15%	44%	-26%	15%	14%
2% (50)	81%	-41%	34%	33%	80%	-40%	32%	36%
1% (100)	139%	-41%	84%	85%	146%	-40%	90%	86%
0.4% (250)	205%	-34%	131%	137%	205%	-33%	130%	135%
0.2% (500)	208%	-27%	143%	144%	203%	-26%	140%	140%
0.1% (1000)	210%	-21%	134%	146%	210%	-26%	135%	139%
Est. AAL	**118%**	**-35%**	**79%**	**72%**	**117%**	**-34%**	**79%**	**72%**

Table 8. Gross insurable loss changes with constant exposure – time-dependent catalog (shake only) – countrywide

New Zealand: All Modeled Zones								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Change with Constant Exposure							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	5%	-59%	-35%	-22%	-2%	-60%	-37%	-28%
2% (50)	17%	-60%	-21%	-17%	10%	-62%	-27%	-21%
1% (100)	24%	-62%	-16%	-6%	14%	-62%	-23%	-10%
0.4% (250)	-11%	-67%	-38%	-31%	-11%	-67%	-40%	-33%
0.2% (500)	-13%	-64%	-34%	-27%	-12%	-63%	-34%	-27%
0.1% (1000)	-6%	-58%	-26%	-23%	-4%	-58%	-23%	-21%
Est. AAL	**-7%**	**-65%**	**-35%**	**-29%**	**-12%**	**-67%**	**-37%**	**-33%**

Table 9. Gross insurable loss changes with constant exposure – time-dependent catalog (shake only) – Wellington

New Zealand: Wellington								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Change with Constant Exposure							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	-65%	-74%	-88%	-76%	-65%	-74%	-88%	-77%
2% (50)	-13%	-64%	-61%	-43%	-15%	-67%	-63%	-45%
1% (100)	3%	-70%	-38%	-30%	-1%	-70%	-40%	-33%
0.4% (250)	-22%	-70%	-47%	-39%	-22%	-70%	-47%	-38%
0.2% (500)	-15%	-66%	-37%	-33%	-15%	-67%	-37%	-33%
0.1% (1000)	-2%	-61%	-17%	-17%	-2%	-61%	-17%	-17%
Est. AAL	**-17%**	**-69%**	**-46%**	**-39%**	**-19%**	**-70%**	**-47%**	**-40%**

Table 10. Gross insurable loss changes with constant exposure – time-dependent catalog (shake only) – Canterbury

New Zealand: Canterbury-Christchurch								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Change with Constant Exposure							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	23%	-14%	3%	7%	22%	-17%	1%	5%
2% (50)	6%	18%	-33%	-8%	5%	15%	-34%	-10%
1% (100)	42%	2%	-19%	10%	41%	2%	-20%	9%
0.4% (250)	136%	4%	71%	93%	136%	5%	66%	92%
0.2% (500)	189%	-18%	125%	129%	189%	-18%	125%	130%
0.1% (1000)	214%	-24%	153%	143%	214%	-24%	153%	143%
Est. AAL	**72%**	**-11%**	**33%**	**43%**	**70%**	**-12%**	**32%**	**41%**

Table 11. Gross insurable loss changes with constant exposure – time-dependent catalog (shake only) – Auckland

New Zealand: Auckland								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Change with Constant Exposure							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2% (50)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

New Zealand: Auckland								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Change with Constant Exposure							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
1% (100)	-92%	-87%	-75%	-87%	-92%	-87%	-75%	-87%
0.4% (250)	-88%	-79%	-75%	-81%	-88%	-79%	-75%	-81%
0.2% (500)	-79%	-71%	-55%	-72%	-79%	-71%	-55%	-72%
0.1% (1000)	-25%	-62%	-33%	-38%	-25%	-62%	-33%	-38%
Est. AAL	**51%**	**-51%**	**81%**	**38%**	**51%**	**-51%**	**81%**	**38%**

Table 12. Gross insurable loss changes with constant exposure – time-dependent catalog (shake only) – Hawke's Bay

New Zealand: Hawke's Bay-Napier								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Change with Constant Exposure							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	-22%	-60%	-37%	-38%	-23%	-59%	-37%	-38%
2% (50)	-3%	-67%	-27%	-28%	-3%	-67%	-28%	-27%
1% (100)	28%	-68%	0%	0%	32%	-67%	3%	0%
0.4% (250)	63%	-64%	25%	27%	63%	-63%	24%	27%
0.2% (500)	65%	-59%	32%	31%	62%	-59%	30%	29%
0.1% (1000)	66%	-56%	27%	31%	66%	-59%	27%	28%
Est. AAL	**17%**	**-64%**	**-3%**	**-7%**	**16%**	**-64%**	**-3%**	**-8%**

Table 13 through Table 22 present the percentage change in **insurable** aggregate and occurrence losses, respectively, for New Zealand and four selected modeled zone, using the **time-independent** 10,000-year catalog. CATRADER and Touchstone Re settings used in the associated model runs are provided in the next section. The losses do not reflect the impacts of demand surge.

The **Overall Change** columns provide the change in industry occurrence losses that will be experienced if one simply reruns company exposures already entered in the previous version of the software. **Overall Change** represents the combined effects of all changes (e.g. updates to the catalog, damage estimation module, policy conditions, etc.), including updated property values. **Overall Change** is calculated by comparing the total industry insurable losses in the prior industry loss file to the total industry insurable losses in the new industry loss file. In CATRADER, 100% user-specified market shares are analyzed against each loss file, and the percentage differences calculated in the resulting loss distributions.

The **Change with Constant Exposure** columns represent the combined effects of all changes (e.g. updates to the catalog, damage estimation module, policy conditions, etc.), excluding updated property values.

Table 13. Gross insurable overall loss changes – time-independent catalog (shake only) – countrywide

New Zealand: All Modeled Zones								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Overall Change							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	108%	-22%	7%	45%	100%	-27%	3%	34%
2% (50)	119%	-23%	18%	41%	109%	-29%	12%	37%
1% (100)	123%	-30%	34%	60%	106%	-35%	21%	47%
0.4% (250)	65%	-42%	4%	23%	64%	-41%	3%	20%
0.2% (500)	60%	-38%	17%	26%	64%	-37%	16%	29%
0.1% (1000)	87%	-23%	49%	59%	86%	-23%	49%	58%
Est. AAL	**77%**	**-35%**	**7%**	**28%**	**69%**	**-37%**	**3%**	**22%**

Table 14. Gross insurable overall loss changes – time-independent catalog (shake only) – Wellington

New Zealand: Wellington								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Overall Change							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	-51%	-66%	-83%	-67%	-52%	-65%	-83%	-68%
2% (50)	5%	-54%	-47%	-27%	3%	-57%	-49%	-30%
1% (100)	25%	-61%	-25%	-8%	22%	-61%	-22%	-12%
0.4% (250)	13%	-57%	-20%	-9%	15%	-57%	-20%	-9%
0.2% (500)	34%	-46%	4%	10%	34%	-47%	4%	10%
0.1% (1000)	85%	-31%	62%	69%	85%	-31%	62%	69%
Est. AAL	**17%**	**-57%**	**-19%**	**-10%**	**15%**	**-58%**	**-20%**	**-12%**

Table 15. Gross insurable overall loss changes – time-independent catalog (shake only) – Canterbury

New Zealand: Canterbury-Christchurch								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Overall Change							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	54%	-3%	-10%	28%	58%	-6%	-10%	32%

New Zealand: Canterbury-Christchurch								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Overall Change							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
2% (50)	67%	86%	-23%	36%	65%	81%	-23%	34%
1% (100)	180%	117%	-1%	107%	180%	123%	-2%	105%
0.4% (250)	474%	152%	170%	306%	473%	150%	162%	297%
0.2% (500)	>500%	102%	264%	404%	>500%	101%	264%	404%
0.1% (1000)	>500%	86%	345%	399%	>500%	86%	345%	399%
Est. AAL	**265%**	**73%**	**101%**	**173%**	**258%**	**71%**	**99%**	**168%**

Table 16. Gross insurable overall loss changes – time-independent catalog (shake only) – Auckland

New Zealand: Auckland								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Overall Change							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2% (50)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1% (100)	-87%	-79%	-66%	-80%	-87%	-79%	-66%	-80%
0.4% (250)	-81%	-67%	-67%	-72%	-81%	-67%	-67%	-72%
0.2% (500)	-65%	-53%	-39%	-59%	-66%	-53%	-39%	-59%
0.1% (1000)	22%	-39%	-9%	-7%	22%	-39%	-9%	-7%
Est. AAL	**147%**	**-22%**	**144%**	**106%**	**146%**	**-22%**	**144%**	**105%**

Table 17. Gross insurable overall loss changes – time-independent catalog (shake only) – Hawke's Bay

New Zealand: Hawke's Bay-Napier								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Overall Change							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	29%	-33%	2%	3%	29%	-32%	3%	2%
2% (50)	68%	-45%	21%	24%	62%	-45%	20%	22%
1% (100)	119%	-45%	67%	65%	122%	-43%	67%	65%
0.4% (250)	191%	-36%	102%	109%	192%	-36%	103%	109%
0.2% (500)	196%	-29%	128%	132%	189%	-30%	127%	128%
0.1% (1000)	204%	-22%	133%	140%	204%	-26%	133%	133%

New Zealand: Hawke's Bay-Napier								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Overall Change							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
Est. AAL	**100%**	**-39%**	**63%**	**57%**	**98%**	**-39%**	**63%**	**57%**

Table 18. Gross insurable loss changes with constant exposure – time-independent catalog (shake only) – countrywide

New Zealand: All Modeled Zones								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Change with Constant Exposure							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	-6%	-64%	-41%	-31%	-12%	-65%	-44%	-36%
2% (50)	6%	-62%	-31%	-23%	2%	-65%	-34%	-27%
1% (100)	7%	-65%	-23%	-17%	1%	-66%	-31%	-25%
0.4% (250)	-6%	-65%	-35%	-27%	-7%	-65%	-36%	-28%
0.2% (500)	-6%	-61%	-23%	-22%	-3%	-61%	-23%	-21%
0.1% (1000)	22%	-53%	-2%	-2%	22%	-53%	-2%	-2%
Est. AAL	**-12%**	**-67%**	**-37%**	**-33%**	**-18%**	**-69%**	**-40%**	**-37%**

Table 19. Gross insurable loss changes with constant exposure – time-independent catalog (shake only) – Wellington

New Zealand: Wellington								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Change with Constant Exposure							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	-66%	-76%	-88%	-77%	-67%	-76%	-89%	-78%
2% (50)	-27%	-68%	-65%	-50%	-28%	-70%	-67%	-52%
1% (100)	-14%	-72%	-50%	-37%	-15%	-72%	-48%	-40%
0.4% (250)	-22%	-70%	-47%	-39%	-20%	-70%	-47%	-38%
0.2% (500)	-7%	-62%	-31%	-27%	-7%	-63%	-31%	-27%
0.1% (1000)	28%	-51%	7%	10%	28%	-51%	7%	10%
Est. AAL	**-19%**	**-70%**	**-46%**	**-40%**	**-20%**	**-71%**	**-47%**	**-41%**

Table 20. Gross insurable loss changes with constant exposure – time-independent catalog (shake only) – Canterbury

New Zealand: Canterbury-Christchurch								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Change with Constant Exposure							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	-40%	-61%	-49%	-43%	-38%	-62%	-49%	-43%
2% (50)	-34%	-25%	-56%	-41%	-35%	-27%	-56%	-43%
1% (100)	10%	-12%	-44%	-12%	10%	-10%	-44%	-14%
0.4% (250)	125%	2%	53%	76%	125%	1%	49%	72%
0.2% (500)	183%	-19%	106%	124%	183%	-19%	106%	124%
0.1% (1000)	181%	-25%	152%	123%	181%	-25%	152%	123%
Est. AAL	**43%**	**-30%**	**14%**	**19%**	**41%**	**-31%**	**13%**	**17%**

Table 21. Gross insurable loss changes with constant exposure – time-independent catalog (shake only) – Auckland

New Zealand: Auckland								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Change with Constant Exposure							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2% (50)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1% (100)	-92%	-87%	-75%	-87%	-92%	-87%	-75%	-87%
0.4% (250)	-88%	-79%	-75%	-81%	-88%	-79%	-75%	-81%
0.2% (500)	-79%	-71%	-55%	-72%	-79%	-71%	-55%	-72%
0.1% (1000)	-25%	-62%	-33%	-38%	-25%	-62%	-33%	-38%
Est. AAL	**51%**	**-51%**	**81%**	**38%**	**51%**	**-51%**	**81%**	**38%**

Table 22. Gross insurable loss changes with constant exposure – time-independent catalog (shake only) – Hawke's Bay

New Zealand: Hawke's Bay-Napier								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Change with Constant Exposure							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
5% (20)	-31%	-63%	-45%	-45%	-31%	-62%	-44%	-45%
2% (50)	-10%	-70%	-34%	-33%	-13%	-69%	-35%	-34%

New Zealand: Hawke's Bay-Napier								
EP (Return Period in years)	Insurable Occurrence				Insurable Aggregate			
	Change with Constant Exposure							
	RES BLD	RES CNT	COM	Total	RES BLD	RES CNT	COM	Total
1% (100)	17%	-69%	-9%	-11%	19%	-69%	-9%	-11%
0.4% (250)	56%	-65%	9%	12%	56%	-65%	10%	12%
0.2% (500)	59%	-61%	23%	25%	55%	-61%	23%	23%
0.1% (1000)	63%	-57%	26%	29%	63%	-59%	26%	25%
Est. AAL	**7%**	**-66%**	**-12%**	**-15%**	**6%**	**-66%**	**-12%**	**-16%**

See Also
Analysis Settings

2.10 Analysis Settings

Table 23. CATRADER/Touchstone Re analysis settings for AIR Earthquake Model for New Zealand runs to determine occurrence and aggregate loss changes

Setting	Selected Option(s)
Perils modeled	Ground shaking
Catalog	• 10,000-year Time-Dependent 100% Limits (default) • 10,000-year Time-Independent
Industry exposure vintage	New Zealand 2018
Demand surge**	Off

* For more information on take-up rate assumptions, see the document *AIR Industry Exposure Database for New Zealand*, available on the AIR Client Portal.

** Development of region-specific demand-surge functions is currently underway at AIR. While AIR recommends incorporating demand surge into modeled loss estimates where appropriate, AIR makes no recommendation as to the form of the demand-surge functions for shake in New Zealand. Clients may apply a user-defined demand-surge function if they choose.

See Also
General Impact of Model Updates on Loss Estimates

3 The AIR Inland Flood Model for Central Europe

3.1 Overview of Model Updates and Changes

Updates available in the AIR Inland Flood Model for Central Europe include an expanded model domain, recalibrated hydrological model, and significant updates to the vulnerability module. Details of these improvements are presented in the following sections and summarized below:

- Expanded model domain, now includes Poland
- 10,000 year catalog – includes new events
- Historical event set – expanded from 3 to 7 events
- Pluvial (off-floodplain) hazard module update
- Updated flood defense standards of protection
- Additional lines of business and construction/occupancy codes supported
- Updated on- and off-floodplain damage functions
- Expanded list of secondary risk characteristics
- Updated secondary damage distributions

3.2 Model Domain

By expanding the model domain to include Poland, the model now covers five central European countries (Figure 20):

- Austria
- Czech Republic
- Germany
- Poland
- Switzerland

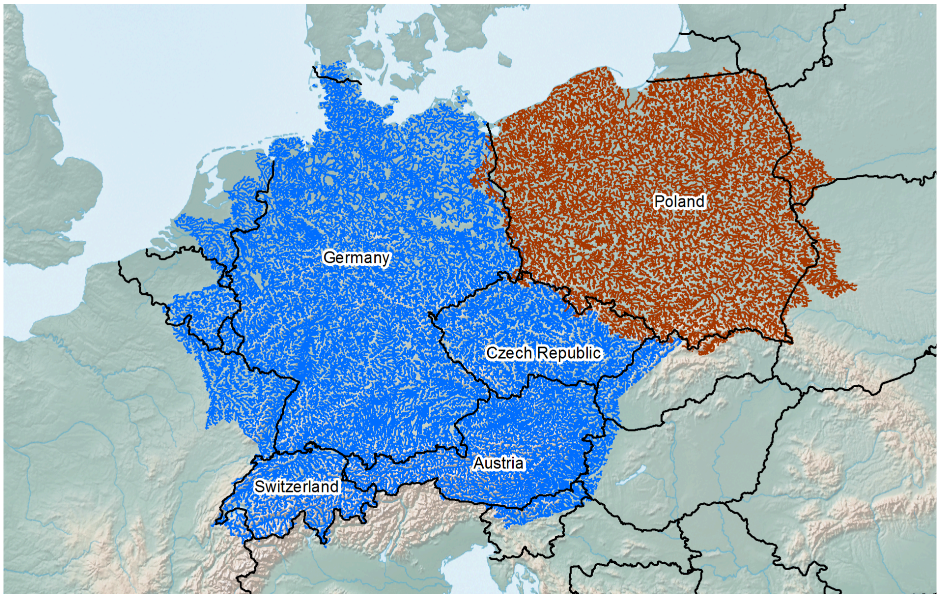


Figure 20. Countries included in the model domain and hydrological model river network

The addition of Poland brings a significant amount of additional data to the hazard module:

- 2 major river basins – Oder and Vistula
- About 14,000 catchments
- Over 85,000 km of river network
- Over 260,000 river cross-sections at intervals of roughly 500 m

3.3 Catalogs and Event Sets

Stochastic Catalog

AIR has updated the 10,000-year stochastic catalog, given the expanded model domain. The stochastic catalog now includes approximately 123,000 events, with about 90,000 events affecting Poland. Approximately 78,000 events have footprints that impact Poland and at least one other modeled country.

All event IDs are new.

Historical Event Set

The updated historical event set includes 7 flood events. Four events (1997, 2001, 2010, and 2013) are new.

Table 24. Historical events available in the AIR Inland Flood Model for Central Europe

Year	Event Name	Countries Impacted
1997	Central European Flood	Poland
2001	Poland Flood	Poland
2002	German-Austrian-Czech Republic Flood	Austria, Czech Republic, and Germany
2005	Swiss-Austrian Flood	Austria and Switzerland
2007	Swiss Flood	Switzerland
2010	Poland Flood	Poland
2013	European flood	Austria, Czech Republic, Germany, and Poland

3.4 Hazard

The hazard module includes multiple updates including changes related to the addition of Poland, the incorporation of new flood defenses data, and an enhanced off-floodplain local intensity calculation.

Event Generation

There are multiple updates to the event generation component of the model. These updates incorporate the model domain extension (Poland), new information for Austria, Czech Republic, Germany, and Switzerland, and improve consistency across country boundaries.

Given the large area covered by Poland, AIR redefined events for the updated model. For example, a single event that began in Germany and extended into the Czech Republic may now exist as two separate events – one in Germany, and one in the Czech Republic/Poland, as the addition of Poland created a better demarcation between events. The updated model includes a completely new event set.

Since AIR first released the Germany inland flood model[4], a significant amount of data has become available. Data from events such as the 2013 and 2016 floods have been used to re-evaluate the flood hazard in Germany.

The updated model includes revised precipitation downscaling for Austria, Czech Republic, and Switzerland. While the methodology remains unchanged, the parameters have been re-estimated.

Based on client feedback, the updated model includes revised relative runoff in border areas, which allows for realistic transitions across country boundaries.

[4] Germany was not updated when AIR introduced flood models for Austria, Czech Republic, and Switzerland.

Local Intensity Calculation

There are multiple updates to the local intensity module, as detailed below.

Flood Defenses

Updates to flood defense standards of protection have been made for Austria, Czech Republic, Germany, and Switzerland, based on newly available data. This data includes direct information on level of protection for specific river segments, the latest CORINE land cover data, and specific, country-wide guidance on level of protection based on land use data, among others. Figure 21 illustrates the number of river segments for each standard of protection (return period) included in the updated model and the previous version.

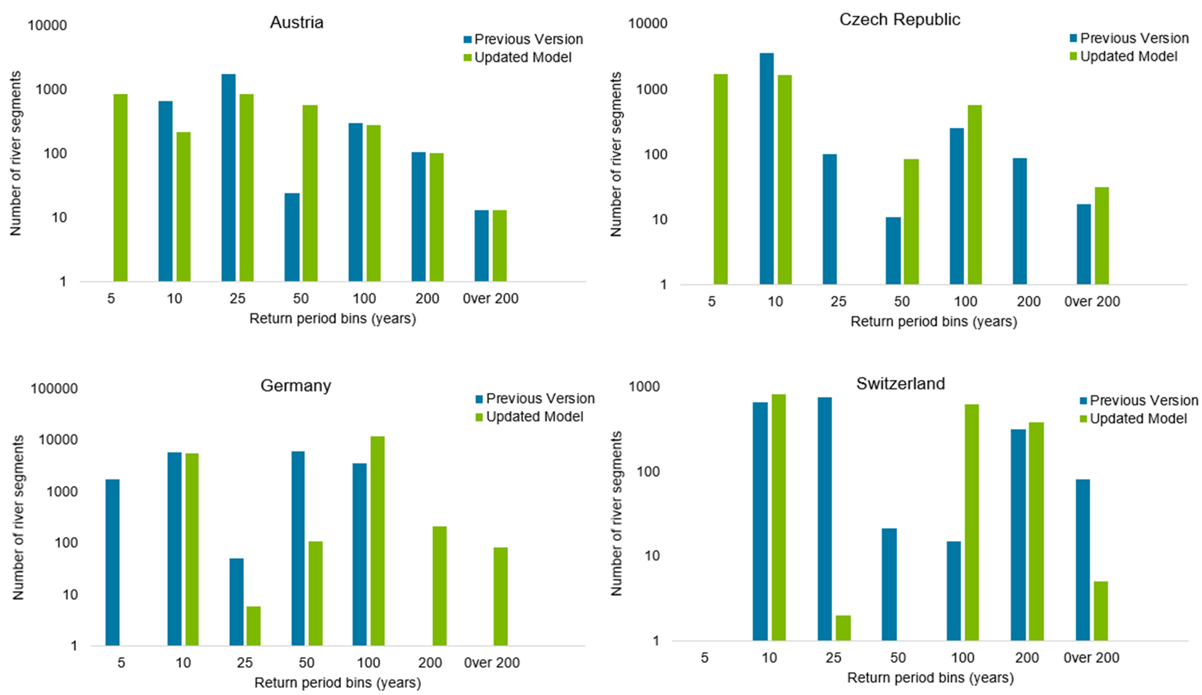


Figure 21. Changes to the standards of protection for Austria, Czech Republic, Germany, and Switzerland

Off-floodplain Enhancements

In keeping with the previous version of the model, the updated off-floodplain model uses a statistical model that relates the mean damage ratio to the variables relative elevation and relative peak runoff. In the updated model, the relative elevation layer, used to calculate losses, has been updated for all countries.

The new relative elevation, based on the land elevation relative to the river network, is used to determine the magnitude of the off-plain hazard at a location. To estimate the relative elevation, a surface with a 25 m x 25 m grid spacing is created using river network with a drainage area of 5 km^2, where the elevation of each river pixel is equal to zero along the surface. The surface is then subtracted from the DTM to produce the relative elevation above this surface. With this resolution, the model can include even small stream links in the loss estimation.

In addition, the updated model no longer uses population density to determine the threshold for off-plain losses caused by surface runoff. Instead, the model relies on CORINE land cover data. A drainage capacity grid was created to mitigate the most frequent runoff intensities for cities. To calculate drainage capacity of a grid cell in Europe, the model uses the relative runoff intensity corresponding to the design target. According to data gathered from Eurocodes, the design target capacity of most storm drainage networks ranges from 2 to 10 years. Since the available data is limited, AIR researchers assumed a target design capacity of a 5-year return period in the cities. To estimate the location of cities in a grid the model uses the urban classes derived from the CORINE land cover dataset. Figure 22 shows the drainage capacity relative runoff layer for Germany. Areas where the CORINE grids indicate land cover classes 1-7 (urban or artificial surfaces) have been assigned the 5-year relative runoff protection layer.

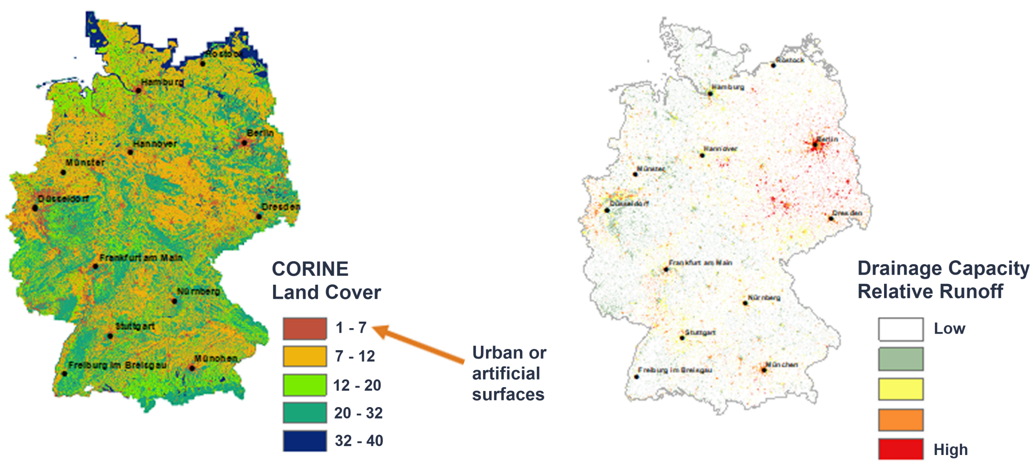


Figure 22. CORINE land cover data used to determine drainage capacity for Germany

Finally, the model also designates thresholds for the extent of off-floodplain losses within a catchment. A relationship between relative runoff and maximum relative elevation is used as a threshold to calculate losses. As a result, many locations with high relative elevation will result in low or zero loss.

3.5 Vulnerability

Improvements to the AIR Inland Flood Model for Central Europe include a substantial overhaul of the model's vulnerability component. These enhancements include the application of a component-based approach to building damage functions, which account for both primary and secondary features, significantly improved resolution for determining unknown damage functions, and support for large industrial facilities and special lines of business.

Supported Risk Types

The updated model supports additional risks, in addition to residential, commercial, agriculture, and auto:

- Builder's Risk
- Large industrial facilities
- Marine cargo and inland transit
- Marine hull
- Wind turbines

Construction and Occupancy Codes

The updated model supports several new construction and occupancy codes.

Construction

- Confined masonry (120) – confined masonry
- Steel frame with concrete shear wall / steel reinforced concrete (158/159)
- Marine cargo (270-276)
- Marine inland transit warehouse (259)
- Marine hull (260)
- Wind turbines, onshore (239)

Occupancy

- Builder's Risk (381-384)
- Large industrial facilities (400 series)

Height Bands

The updated model includes two additional height bands. The low rise category has been broken up into three distinct bands: 1-story, 2-story, and 3-story. The previous version includes a single low-rise height band that covered 1-3 stories.

Table 25. Height bands

Height Category	Height Bands	
	Previous Version	Updated Model
Low-rise	1-3 stories	1-story
		2-story
		3-story
Mid-rise	4-7 stories	4-7 stories
High-rise	8+ stories	8-20 stories

Secondary Risk Characteristics

The updated model supports five secondary risk characteristics (SRC). In addition to **foundation type** and **floor of interest**, there are three new SRC:

Custom elevation	The elevation of the local ground surface can be entered for this feature, which will override the underlying modeled digital terrain elevation.
Custom flood standard of protection	For buildings safeguarded by a custom flood protection system (e.g., levee or flood wall), the user may enter the flood protection system's height above the ground surface, or the return period for which the system was designed
First floor height	The height of the first floor, above the ground surface, can be entered for all residential, commercial, and small industrial buildings.

Vulnerability Enhancements to Buildings in Traditional Lines of Business

The updated model provides a unified approach, across countries, for on- and off-floodplain damage. Through these vulnerability enhancements, combined with extensive model validation, AIR has updated vulnerability of buildings across the traditional lines of business.

Component-based Approach for Residential Buildings

The new on-floodplain vulnerability model assesses damage at the component level for residential, commercial, and small industrial buildings. In the previous version, component-level damage assessment was only applied to commercial and small industrial structures. Based on extensive claims data, damage to residential buildings is now considered in terms of 3 components:

Building structure	All load-carrying structural parts of the building including the foundation, roof frame, structural envelope, and exterior walls
Interior and fixtures	Interior walls (e.g., partition walls and drywall), flooring and floor coverings, and other interior finishes
Services	Heating, ventilation, and air conditioning (HVAC), electrical, and plumbing systems

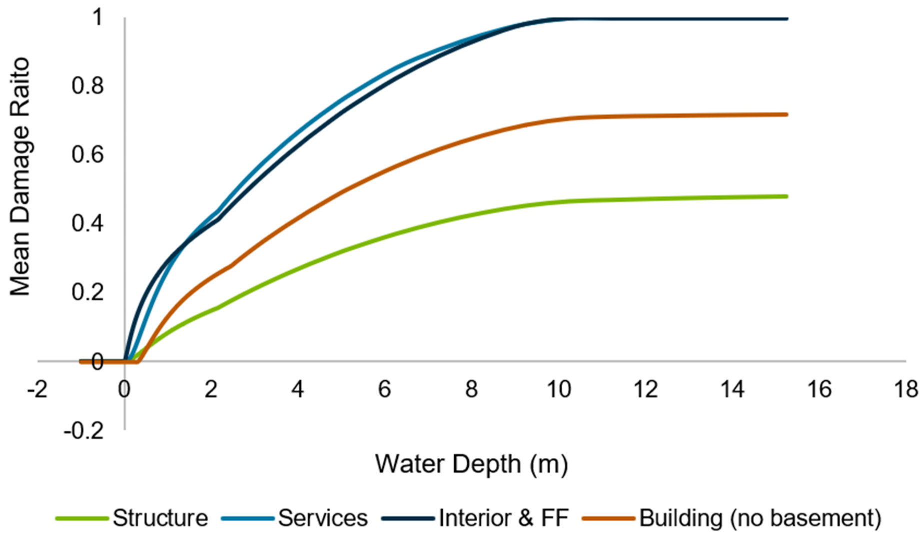


Figure 23. Overall building and component-level damage functions for a 1-story, single family home

Off-floodplain damage functions have been updated to include the latest findings from the component-based approach. In addition, AIR has re-evaluated the 2002 flood event in Germany, based on the new relative elevation physical property.

See Also

Event Generation
Off-floodplain Enhancements

On-floodplain Building Damage Functions

The following sections provide details of damage function updates, by line of business, as well as associated validation.

Residential Buildings

In Europe, the family of residential buildings encompasses single family homes (AIR occupancy 302), multi-family homes (303), temporary lodging (304), group institutional housing (305), condominium buildings (306) and general residential buildings (301). Figure 24 and Figure 25 show the change in vulnerability of selected residential buildings with different construction types and height categories across various countries. The changes shown represent the percentage change in the average mean damage ratios, which characterize the respective damage functions, for a flood depth of 0 to 2 meters.

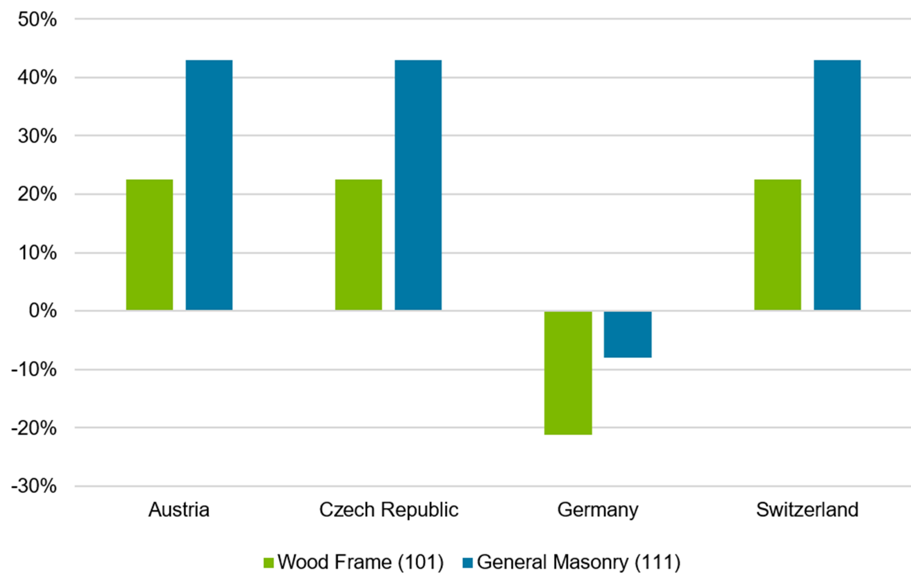


Figure 24. Change in vulnerability of wood frame and general masonry 2-story single-family homes

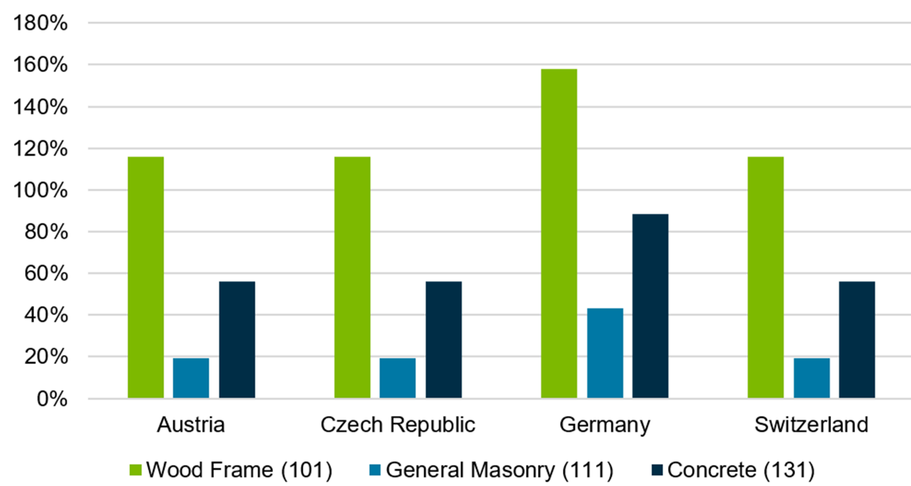


Figure 25. Change in vulnerability of mid-rise condominium buildings of common construction types

Changes to the residential damage functions were driven by the updated hazard, re-evaluation of detailed claims data for Germany, and new loss data from the 2013 event in Germany and research publications. Figure 26 shows validation of the AIR single-family home damage function against Germany claims data.

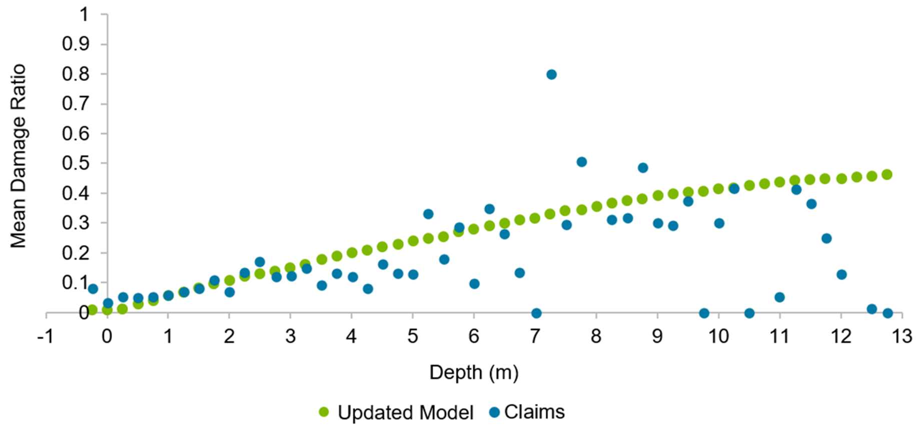


Figure 26. Single-family home on-floodplain damage function validation with German claims data

Other noteworthy differences between the previous and updated versions of the model are described below:

- Damage functions for all masonry construction classes in the new model are the same. This differs from the previous version, where the damage functions for 111 and 114 were identical in shape and distinguished by a construction modifier.
- The damage functions for mid-rise and high-rise wood and light steel structures are the same as their respective 3-story damage functions. The previous model included height variation for these construction types.

Commercial and Industrial Buildings

In the previous model version, AIR engineers considered the relative vulnerability between residential, commercial, and industrial buildings, or other lines of business, in areas where more detailed data is available (e.g., the United States and the United Kingdom) to inform similar relativities for Europe, where such data was not available. However, given the updated component-based approach for commercial and industrial lines, and the availability of published research, AIR was able to evaluate damage function performance. This evaluation led to a reduction of the base vulnerability functions for commercial and industrial buildings by approximately 20% and 60%, respectively, across the model domain. In Germany, however, the industrial lines exhibit different patterns, due to changes in the distribution of structures with basements.

Figure 27 and Figure 28 show the change in vulnerability of select commercial and industrial buildings with different construction types and height categories across various countries. This change represents the percentage change in the average mean damage ratios that characterize their respective damage functions in both versions of the model within the depth range of 0-2 meters, which is common in inland flood events.

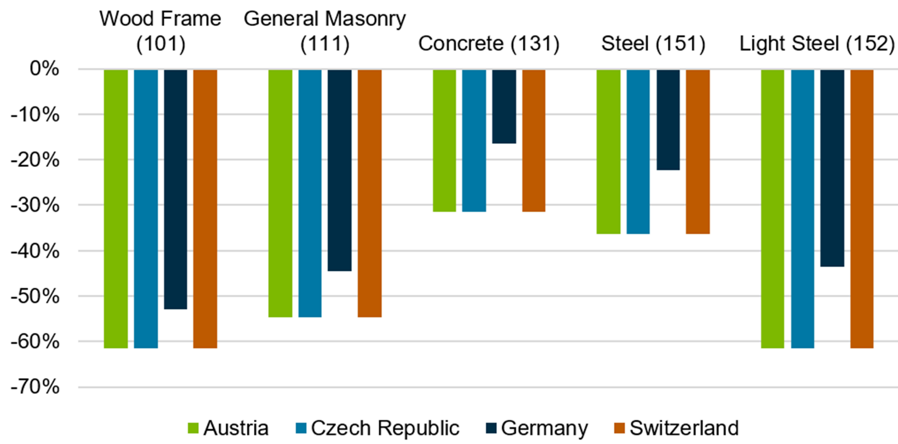


Figure 27. Change in on-floodplain vulnerability of 2-story general commercial buildings built using common construction types

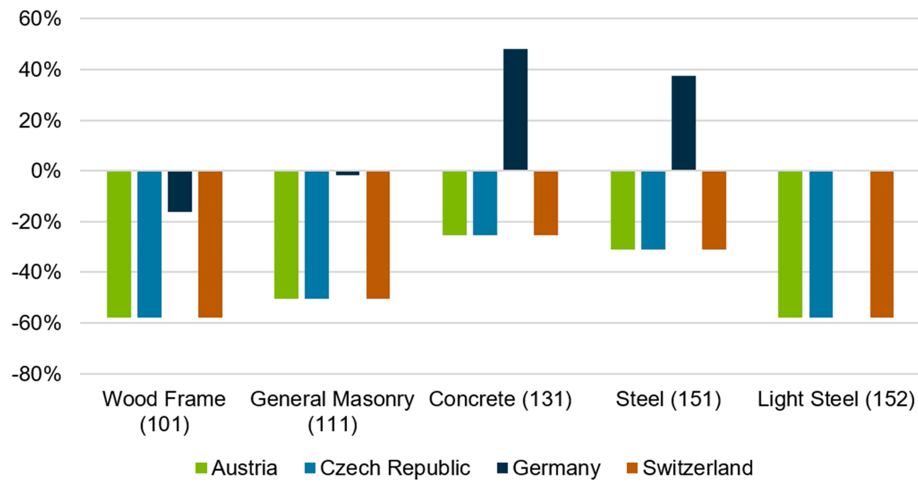


Figure 28. Change in on-floodplain vulnerability of 2-story general industrial buildings built using common construction types

AIR validated the commercial on-floodplain damage function against claims data for Germany (Figure 29).

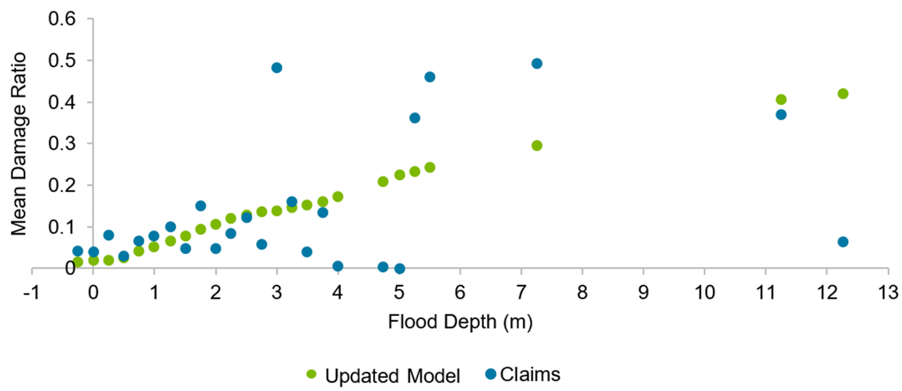


Figure 29. Commercial on-floodplain damage function validation with German claims data

Off-floodplain Building Damage Functions

AIR engineers updated the damage surface for off-floodplain properties to account for changes in the off-floodplain intensity calculation. AIR used residential claims data from the Germany 2002 flood event to estimate the surface mean damage ratios for the off-floodplain footprint. The model uses approximately 5,000 claims outside the on-floodplain event footprint to create a surface mean damage ratio for the residential building class. Figure 30 compares the mean damage ratio as a function of relative elevation, where the relative runoff is 1.1, for the updated model, previous version, and claims data.

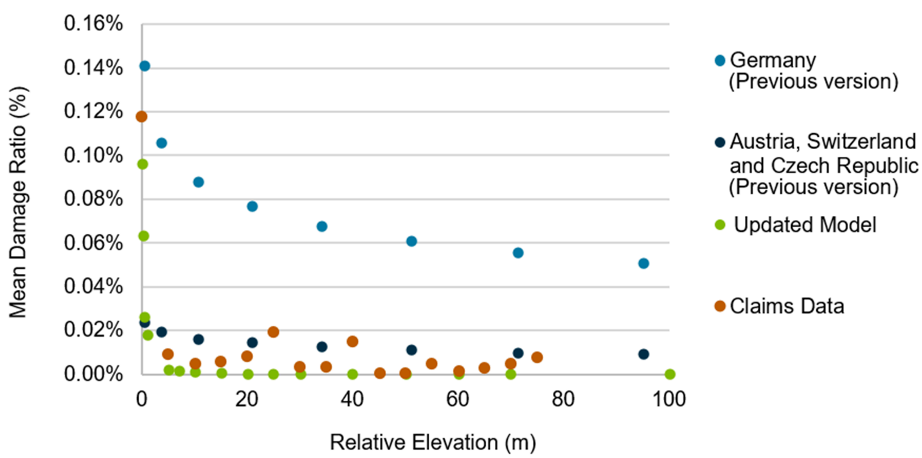


Figure 30. Comparison of off-floodplain mean damage ratios as a function of relative elevation, for a surface with relative runoff = 1.1
Single-family home, masonry construction

To obtain the mean damage ratio for other occupancy, construction and height combinations, the surface is further modified to account for relative vulnerability changes from the new on-floodplain component-based approach.

See Also

Off-floodplain Enhancements

Large Industrial Facilities

The addition of the large industrial facilities line of business allows separate and specialized loss modeling for large industrial facilities. In most cases, losses modeled with these damage functions (for 400 series) are lower than losses for the same exposures modeled with the traditional small industrial damage functions (for 300 series).

Agriculture

Limited data exist to validate flood losses for the agriculture line of business. The updated damage functions follow the same component-based approach as commercial. AIR engineers then updated the relative vulnerability between commercial and agriculture, based on data from the United States.

Auto

The enhancements to automobile damage functions stem primarily from the availability of event-level actual loss data and updated damage functions taken from the Inland Flood Model for Japan, which was validated with claims data.

Damage functions in the previous version of the model were based on a comparison of the performance of automobiles to the performance of residential single-family homes. However, many other factors that affect automobile vulnerability can impact actual losses (e.g., location during an event and evacuation considerations). The new AIR damage function decreases the automobile vulnerability at low depths. At this level of intensity automobiles do not experience material damage. However, the new damage function increases vulnerability at high depths, compared to the previous version. This increased vulnerability captures the damage to electrical systems as water levels rise.

Table 26 explains the relative vulnerability changes to the auto damage functions for various intensity ranges.

Table 26. Auto damage functions, relative vulnerability change with the model update, by country

	Water Depth (m)				
Country	**<=0.25**	**0.30-0.60**	**0.65-1.00**	**1.05-1.55**	**1.55+**
Austria	-100%	>500%	>500%	>500%	>500%
Czech Republic	-100%	>500%	>500%	>500%	>500%
Germany	-100%	-79%	-30%	52%	82%
Switzerland	-100%	>500%	>500%	>500%	>500%

Vulnerability Enhancements to Contents in Traditional Lines of Business

In the updated model, contents damage functions are also enhanced with the component-based approach. The new functions explicitly capture the location of vulnerable contents such as equipment, furniture, and inventory for the residential and commercial/industrial lines of business. Furthermore, new contents damage function for multi-story buildings evenly distribute the contents replacement value over the number of stories in the building. Figure 31 and Figure 32 show the change in vulnerability of selected residential and commercial contents with different construction types and height categories across various countries. The changes shown represent the percentage change in the average mean damage ratios characterizing their respective damage functions at a flood depth of 0 to 2 meters.

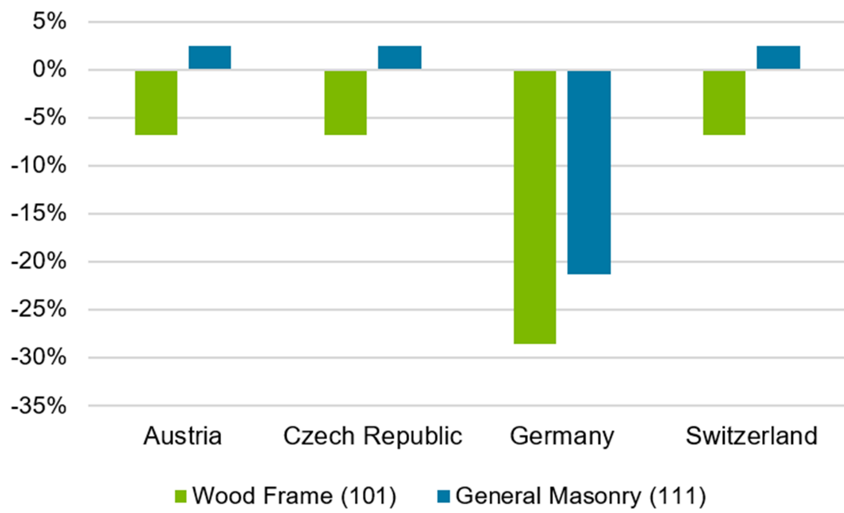


Figure 31. Change in content vulnerability of wood frame and general masonry 2-story single-family homes with the model update

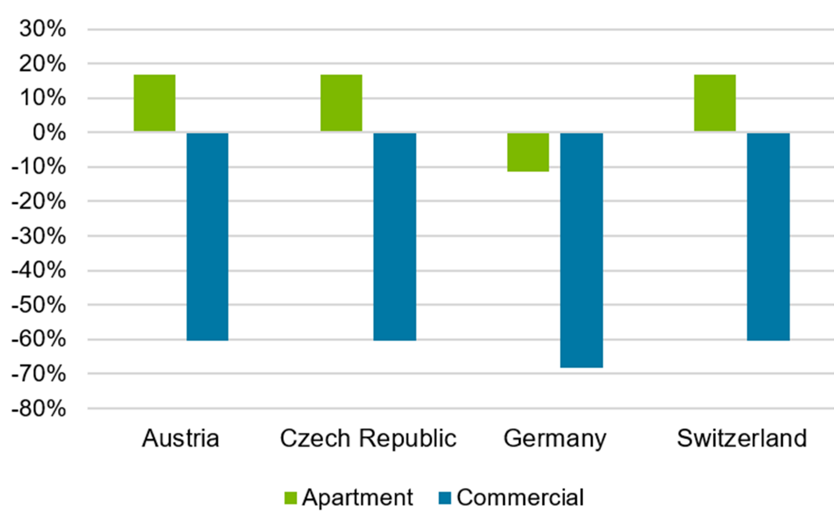


Figure 32. Change in contents vulnerability of mid-rise, masonry apartments and commercial buildings with the model update

Relative Vulnerability Changes in Residential, Commercial, and Industrial Lines of Business

The updated model includes improved relative vulnerability between residential and commercial lines of business, based on claims analysis (Figure 33).

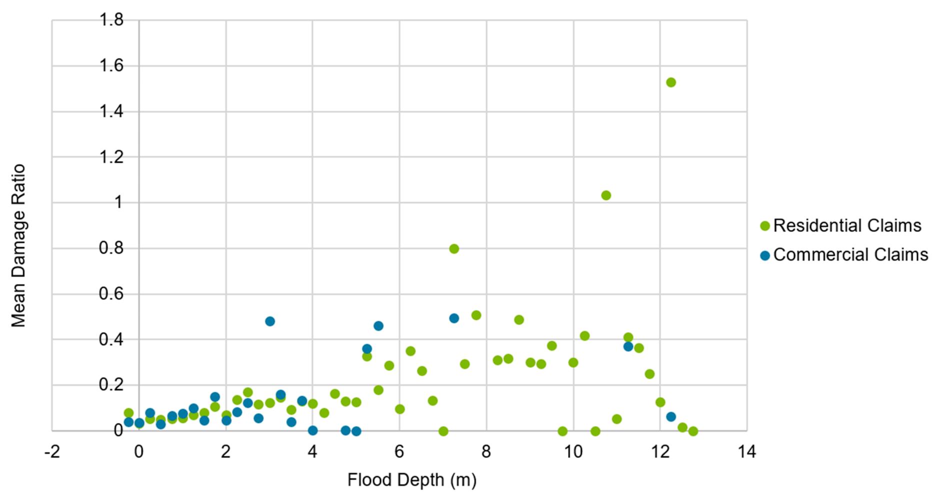


Figure 33. Relativity of residential and commercial flood claims data

As illustrated in Figure 34 and Figure 35, the model update more closely aligns residential and commercial vulnerability for 1-story masonry damage functions. Industrial buildings remain less vulnerable than commercial buildings, since they are better protected against flooding.

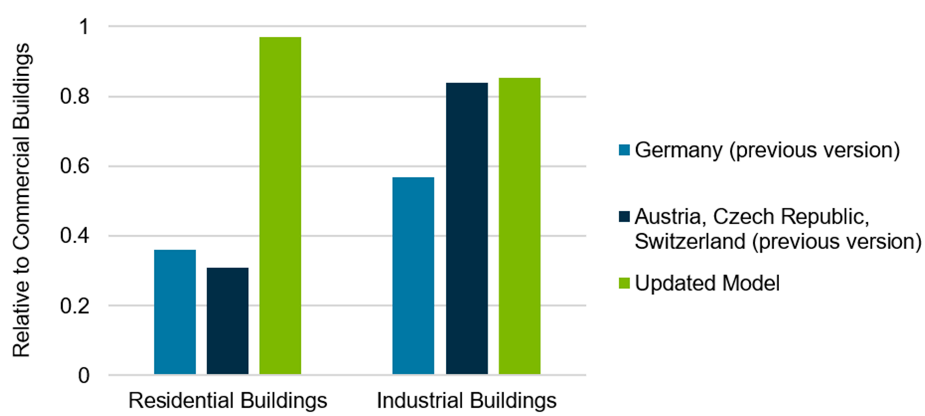


Figure 34. On-floodplain damage function relativity for buildings (1-story masonry)

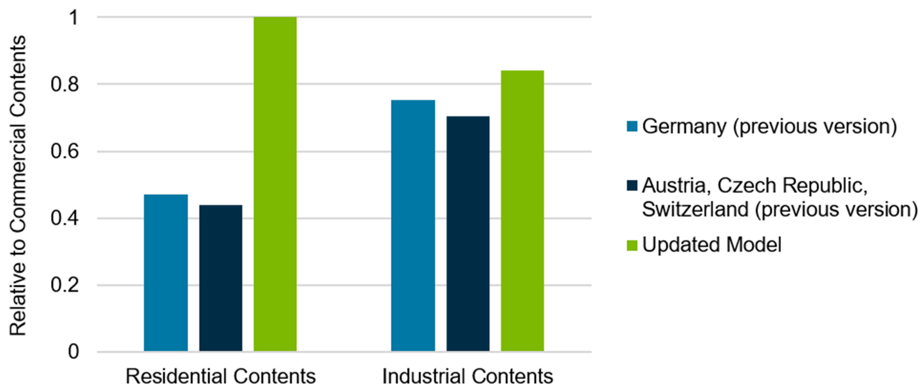


Figure 35. On-floodplain damage function relativity for contents

Figure 34 and Figure 35 also demonstrate that the updated model provides a unified approach, across countries, for on-floodplain damage functions. The updated model uses the same damage functions across the model domain. Unknown damage functions are country-specific and addressed separately.

Loss Calculation

Damage Distribution

The updated inland flood model uses an inflated transformed beta distribution, combined with empirically derived probabilities of 0% and 100% damage levels, to model the uncertainty around the mean damage. This technique, which relies on claims data, allows the correct representation of the shape of the loss distributions throughout the financial loss estimation process. Preserving the correct shape is particularly important when insurance terms apply to the "tails" of the distributions.

The previous version of the model employed an “inflated” beta distribution (a combination of beta and Bernoulli distributions).

3.6 Industry Exposure Database

The updated model uses the AIR Industry Exposure Databases for the Pan-European Region, available on the AIR Client Portal. Exposures in the databases are current as of the end of 2017.

3.7 Component-level Impact of Model Updates

AIR has evaluated component-level changes to modeled losses, based on hazard and vulnerability updates. Details and loss changes are provided in the following sections.

Setup of Loss Comparison Analyses

To produce component level loss changes, AIR researchers established baseline values with three runs:

Run 0 used all previous components and the latest industry exposure database.

Run 1 maintained constant exposure with the latest industry exposure database, used the previous model's damage functions, and used the new hazard component to show loss changes from the hazard side.

Run 2 maintained constant exposure with the latest industry exposure database and used both the new hazard and new vulnerability components to show incremental loss changes from the new and updated damage functions.

Table 27 summarizes these steps.

Table 27. Model versions used for incremental loss change runs

Components Used	Run 0	Run 1	Run 2
Hazard	PREVIOUS	UPDATED	UPDATED
Vulnerability	PREVIOUS	PREVIOUS	UPDATED
Exposure	AIR industry Exposure Database for the Pan-European Region (Exposure vintage 2017)		

Note:

- **Only ground-up loss perspectives are shown return periods and the average annual loss (AAL).**
- **These runs were completed in the AIR Research model.**

To obtain the most accurate comparisons possible, each run was conducted with the same parameters and outputs, as listed in Table 28.

Table 28. Parameters and outputs common to all component-level change model runs

Setting	Selections
Perils modeled	Inland Flood
Lines of Business modeled	• Residential (includes contents) • Commercial • Industrial • Agriculture • Automobile
Catalog	10,000-year
Take-up Rates	100% for all LOBs

Loss Change Drivers

Hazard changes in Austria, Czech Republic and Switzerland decrease the losses because of smaller events, on average, in the new catalog. For Germany, the new stochastic catalog includes new and larger events, increasing both occurrence and aggregate losses.

From a vulnerability perspective, loss changes are driven by multiple enhancements, described previously, across specific lines of business and coverages. For all modeled countries, there is a general increase in the country-wide residential lines of business and a decrease to the commercial lines of business. However, this is not the same for all the cases, particularly for events dominated by off-floodplain losses, where the pattern can be reversed.

Caution should be exercised before relating the component level changes shown here to a portfolio. The changes to individual books may deviate from the losses represented here to the extent that their spatial distribution and construction/ occupancy mix deviate from industry averages.

See Also
Hazard
Vulnerability Enhancements to Buildings in Traditional Lines of Business
Vulnerability Enhancements to Contents in Traditional Lines of Business

Component-level Loss Changes, by Country

Austria

Table 29. Austria, component level loss changes, ground-up, all LOBs

Austria, Ground-up, All Lines of Business Combined					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
AAL	-16%	-18%	**AAL**	-23%	-18%
2	-38%	-30%	**2**	-49%	-28%
5	-13%	-18%	**5**	-23%	-21%
10	-5%	-17%	**10**	-17%	-18%
20	-7%	-15%	**20**	-12%	-16%
50	-18%	-17%	**50**	-22%	-15%
100	-29%	-15%	**100**	-30%	-17%
250	-16%	-20%	**250**	-22%	-20%
500	-17%	-11%	**500**	-13%	-14%

Table 30. Austria, component level loss changes, ground-up, residential

Austria, Ground-up, Residential					
Occurrence			Aggregate		
Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)	Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)
AAL	-14%	37%	**AAL**	-21%	34%
2	-36%	13%	**2**	-48%	17%
5	-12%	31%	**5**	-23%	28%
10	-8%	37%	**10**	-16%	32%
20	-7%	38%	**20**	-11%	36%
50	-17%	41%	**50**	-18%	38%
100	-25%	40%	**100**	-30%	42%
250	-14%	42%	**250**	-21%	41%
500	-16%	59%	**500**	-7%	42%

Table 31. Austria, component level loss changes, ground-up, commercial

Austria, Ground-up, Commercial					
Occurrence			Aggregate		
Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)	Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)
AAL	-20%	-58%	**AAL**	-29%	-59%
2	-51%	-67%	**2**	-61%	-66%
5	-20%	-60%	**5**	-35%	-62%
10	-9%	-58%	**10**	-23%	-60%
20	-9%	-56%	**20**	-16%	-57%
50	-21%	-55%	**50**	-25%	-56%
100	-31%	-56%	**100**	-32%	-57%
250	-19%	-58%	**250**	-24%	-59%
500	-18%	-56%	**500**	-20%	-55%

Table 32. Austria, component level loss changes, ground-up, industrial

Austria, Ground-up, Industrial					
Occurrence			Aggregate		
Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)	Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)
AAL	-15%	-42%	**AAL**	-21%	-42%

Austria, Ground-up, Industrial					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
2	-33%	-49%	**2**	-46%	-48%
5	-13%	-42%	**5**	-21%	-43%
10	-6%	-42%	**10**	-18%	-42%
20	-8%	-40%	**20**	-11%	-41%
50	-16%	-41%	**50**	-21%	-42%
100	-33%	-42%	**100**	-33%	-43%
250	-19%	-42%	**250**	-22%	-43%
500	-15%	-39%	**500**	-16%	-42%

Table 33. Austria, component level loss changes, ground-up, agriculture

Austria, Ground-up, Agriculture					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
AAL	-1%	-18%	AAL	1%	-19%
2	33%	-25%	2	27%	-26%
5	6%	-18%	5	8%	-20%
10	-3%	-18%	10	1%	-20%
20	-10%	-17%	20	-5%	-18%
50	-16%	-15%	50	-9%	-19%
100	-13%	-16%	100	-14%	-16%
250	-7%	-19%	250	-10%	-19%
500	-11%	-13%	500	-11%	-19%

Table 34. Austria, component level loss changes, ground-up, auto

Austria, Ground-up, Auto					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
AAL	-27%	>500%	**AAL**	-42%	>500%
2	-57%	>500%	**2**	-64%	>500%
5	-26%	>500%	**5**	-44%	>500%

Austria, Ground-up, Auto					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
10	-12%	>500%	**10**	-33%	>500%
20	-8%	>500%	**20**	-28%	>500%
50	-6%	>500%	**50**	-23%	>500%
100	-6%	>500%	**100**	-21%	>500%
250	-6%	>500%	**250**	-20%	>500%
500	4%	>500%	**500**	-14%	>500%

Czech Republic

Table 35. Czech Republic, component level loss changes, ground-up, all LOBs

Czech Republic, Ground-up, All Lines of Business Combined					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
AAL	-21%	-11%	**AAL**	-26%	-11%
2	-41%	-27%	**2**	-51%	-29%
5	-13%	-13%	**5**	-22%	-14%
10	-19%	4%	**10**	-21%	-2%
20	-24%	-4%	**20**	-24%	-3%
50	-15%	-13%	**50**	-19%	-7%
100	-24%	-13%	**100**	-26%	-12%
250	-29%	-14%	**250**	-31%	-10%
500	-36%	-16%	**500**	-37%	-15%

Table 36. Czech Republic, component level loss changes, ground-up, residential

Czech Republic, Ground-up, Residential					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
AAL	-21%	34%	**AAL**	-27%	32%
2	-38%	21%	**2**	-49%	16%
5	-19%	38%	**5**	-26%	36%

Czech Republic, Ground-up, Residential					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
10	-21%	38%	**10**	-24%	35%
20	-20%	38%	**20**	-23%	37%
50	-15%	38%	**50**	-24%	41%
100	-20%	36%	**100**	-24%	40%
250	-28%	40%	**250**	-32%	38%
500	-35%	38%	**500**	-37%	39%

Table 37. Czech Republic, component level loss changes, ground-up, commercial

Czech Republic, Ground-up, Commercial					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
AAL	-29%	-57%	**AAL**	-35%	-58%
2	-51%	-65%	**2**	-60%	-66%
5	-30%	-59%	**5**	-38%	-59%
10	-29%	-56%	**10**	-34%	-58%
20	-19%	-56%	**20**	-30%	-57%
50	-11%	-56%	**50**	-23%	-56%
100	-27%	-55%	**100**	-31%	-56%
250	-38%	-55%	**250**	-39%	-55%
500	-40%	-48%	**500**	-47%	-50%

Table 38. Czech Republic, component level loss changes, ground-up, industrial

Czech Republic, Ground-up, Industrial					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
AAL	-16%	-13%	**AAL**	-19%	-14%
2	-39%	-57%	**2**	-49%	-58%
5	-21%	-45%	**5**	-27%	-47%
10	-18%	24%	**10**	-20%	22%
20	-21%	-1%	**20**	-21%	-5%

Czech Republic, Ground-up, Industrial					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
50	-17%	-12%	**50**	-17%	-2%
100	-19%	-18%	**100**	-19%	-12%
250	-16%	-28%	**250**	-27%	-15%
500	-31%	-28%	**500**	-32%	-13%

Table 39. Czech Republic, component level loss changes, ground-up, agriculture

Czech Republic, Ground-up, Agriculture					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
AAL	1%	-25%	**AAL**	6%	-25%
2	77%	-27%	**2**	52%	-27%
5	23%	-24%	**5**	26%	-24%
10	-3%	-24%	**10**	5%	-24%
20	-14%	-24%	**20**	-9%	-23%
50	-20%	-24%	**50**	-13%	-24%
100	-21%	-22%	**100**	-19%	-22%
250	-23%	-23%	**250**	-16%	-24%
500	-25%	-25%	**500**	-25%	-21%

Table 40. Czech Republic, component level loss changes, ground-up, auto

Czech Republic, Ground-up, Auto					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
AAL	-46%	>500%	**AAL**	-56%	>500%
2	-66%	>500%	**2**	-71%	>500%
5	-49%	>500%	**5**	-57%	>500%
10	-39%	>500%	**10**	-51%	>500%
20	-31%	>500%	**20**	-47%	>500%
50	-22%	>500%	**50**	-44%	>500%
100	-23%	>500%	**100**	-40%	>500%

Czech Republic, Ground-up, Auto					
Occurrence			Aggregate		
Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)	Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)
250	-23%	>500%	**250**	-37%	>500%
500	-25%	>500%	**500**	-40%	>500%

Germany

Table 41. Germany, component level loss changes, ground-up, all LOBs

Germany, Ground-up, All Lines of Business Combined					
Occurrence			Aggregate		
Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)	Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)
AAL	376%	-74%	**AAL**	>500%	-79%
2	>500%	-88%	**2**	>500%	-89%
5	>500%	-82%	**5**	>500%	-85%
10	385%	-76%	**10**	>500%	-80%
20	307%	-69%	**20**	405%	-74%
50	248%	-65%	**50**	320%	-70%
100	200%	-58%	**100**	257%	-64%
250	149%	-53%	**250**	218%	-60%
500	141%	-55%	**500**	177%	-61%

Table 42. Germany, component level loss changes, ground-up, residential

Germany, Ground-up, Residential					
Occurrence			Aggregate		
Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)	Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)
AAL	367%	-66%	**AAL**	>500%	-72%
2	>500%	-84%	**2**	>500%	-84%
5	>500%	-76%	**5**	>500%	-79%
10	360%	-69%	**10**	499%	-74%
20	285%	-58%	**20**	394%	-66%
50	233%	-51%	**50**	295%	-60%
100	198%	-46%	**100**	246%	-50%

Germany, Ground-up, Residential					
Occurrence			Aggregate		
Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)	Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)
250	163%	-38%	**250**	197%	-43%
500	147%	-34%	**500**	179%	-49%

Table 43. Germany, component level loss changes, ground-up, commercial

Germany, Ground-up, Commercial					
Occurrence			Aggregate		
Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)	Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)
AAL	356%	-85%	**AAL**	>500%	-88%
2	>500%	-93%	**2**	>500%	-93%
5	>500%	-90%	**5**	>500%	-91%
10	374%	-86%	**10**	>500%	-89%
20	292%	-82%	**20**	392%	-85%
50	230%	-79%	**50**	301%	-82%
100	184%	-75%	**100**	230%	-77%
250	145%	-72%	**250**	199%	-75%
500	111%	-72%	**500**	167%	-76%

Table 44. Germany, component level loss changes, ground-up, industrial

Germany, Ground-up, Industrial					
Occurrence			Aggregate		
Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)	Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)
AAL	488%	-73%	**AAL**	>500%	-78%
2	>500%	-90%	**2**	>500%	-90%
5	>500%	-84%	**5**	>500%	-86%
10	>500%	-77%	**10**	>500%	-81%
20	433%	-69%	**20**	>500%	-74%
50	372%	-63%	**50**	414%	-66%
100	283%	-57%	**100**	329%	-62%
250	208%	-52%	**250**	268%	-59%
500	184%	-57%	**500**	213%	-60%

Table 45. Germany, component level loss changes, ground-up, agriculture

Germany, Ground-up, Agriculture					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
AAL	282%	-20%	**AAL**	382%	-35%
2	>500%	-64%	**2**	>500%	-68%
5	381%	-40%	**5**	491%	-49%
10	282%	-19%	**10**	378%	-33%
20	238%	0%	**20**	310%	-16%
50	180%	13%	**50**	232%	-2%
100	158%	16%	**100**	201%	4%
250	149%	26%	**250**	152%	7%
500	109%	29%	**500**	134%	15%

Table 46. Germany, component level loss changes, ground-up, auto

Germany, Ground-up, Auto					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
AAL	382%	-43%	**AAL**	>500%	-54%
2	>500%	-76%	**2**	>500%	-77%
5	>500%	-64%	**5**	>500%	-68%
10	371%	-50%	**10**	>500%	-58%
20	291%	-30%	**20**	399%	-44%
50	236%	-14%	**50**	302%	-28%
100	213%	-3%	**100**	266%	-14%
250	158%	12%	**250**	206%	4%
500	174%	14%	**500**	159%	-5%

Switzerland

Table 47. Switzerland, component level loss changes, ground-up, all LOBs

Switzerland, Ground-up, All Lines of Business Combined					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
AAL	-10%	-25%	**AAL**	-21%	-26%
2	-60%	-30%	**2**	-64%	-31%
5	-27%	-32%	**5**	-40%	-30%
10	-3%	-24%	**10**	-18%	-25%
20	23%	-22%	**20**	4%	-24%
50	16%	-24%	**50**	0%	-24%
100	-14%	-25%	**100**	-14%	-25%
250	-17%	-25%	**250**	-20%	-22%
500	-24%	-13%	**500**	-31%	-19%

Table 48. Switzerland, component level loss changes, ground-up, residential

Switzerland, Ground-up, Residential					
Occurrence			**Aggregate**		
Return Period (yrs)	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**	**Return Period (yrs)**	**Hazard Change Impact (%)**	**Vulnerability Change Impact (%)**
AAL	-14%	32%	**AAL**	-24%	29%
2	-56%	13%	**2**	-61%	12%
5	-29%	17%	**5**	-39%	17%
10	-11%	32%	**10**	-22%	29%
20	10%	37%	**20**	-6%	32%
50	5%	40%	**50**	-7%	38%
100	-16%	38%	**100**	-21%	39%
250	-20%	40%	**250**	-23%	43%
500	-20%	50%	**500**	-27%	44%

Table 49. Switzerland, component level loss changes, ground-up, commercial

Switzerland, Ground-up, Commercial					
Occurrence			Aggregate		
Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)	Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)
AAL	-11%	-53%	**AAL**	-23%	-54%
2	-68%	-58%	**2**	-70%	-59%
5	-33%	-60%	**5**	-46%	-59%
10	-5%	-55%	**10**	-22%	-55%
20	31%	-51%	**20**	6%	-52%
50	18%	-52%	**50**	4%	-52%
100	-13%	-52%	**100**	-13%	-51%
250	-15%	-48%	**250**	-19%	-49%
500	-20%	-46%	**500**	-33%	-47%

Table 50. Switzerland, component level loss changes, ground-up, industrial

Switzerland, Ground-up, Industrial					
Occurrence			Aggregate		
Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)	Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)
AAL	-3%	-40%	**AAL**	-12%	-40%
2	-54%	-40%	**2**	-58%	-41%
5	-23%	-44%	**5**	-34%	-42%
10	0%	-38%	**10**	-10%	-38%
20	38%	-39%	**20**	20%	-40%
50	23%	-35%	**50**	11%	-37%
100	-1%	-39%	**100**	-6%	-39%
250	-15%	-40%	**250**	-19%	-38%
500	-21%	-36%	**500**	-32%	-32%

Table 51. Switzerland, component level loss changes, ground-up, agriculture

Switzerland, Ground-up, Agriculture					
Occurrence			Aggregate		
Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)	Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)
AAL	-3%	-43%	**AAL**	-5%	-44%

Switzerland, Ground-up, Agriculture					
Occurrence			Aggregate		
Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)	Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)
2	117%	-54%	2	105%	-56%
5	18%	-45%	5	24%	-46%
10	-4%	-43%	10	3%	-43%
20	-4%	-41%	20	-3%	-42%
50	-16%	-38%	50	-22%	-39%
100	-19%	-39%	100	-25%	-39%
250	-27%	-36%	250	-28%	-39%
500	-27%	-36%	500	-33%	-39%

Table 52. Switzerland, component level loss changes, ground-up, auto

Switzerland, Ground-up, Auto					
Occurrence			Aggregate		
Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)	Return Period (yrs)	Hazard Change Impact (%)	Vulnerability Change Impact (%)
AAL	-32%	>500%	AAL	-43%	>500%
2	-67%	247%	2	-70%	232%
5	-34%	287%	5	-47%	297%
10	-22%	>500%	10	-37%	>500%
20	-12%	>500%	20	-30%	>500%
50	-8%	>500%	50	-28%	>500%
100	-12%	>500%	100	-32%	>500%
250	-16%	>500%	250	-31%	>500%
500	-17%	>500%	500	-33%	>500%

3.8 General Impact of Model Updates on Loss Estimates

The following tables illustrate the overall impact of model updates on loss estimates from the previous version of CATRADER and Touchstone Re to CATRADER 21.0 / Touchstone Re 7.0. Table 53 and Table 54 present the percentage change in insurable occurrence and aggregate losses, respectively, for each country (Austria, Czech Republic, Germany, and Switzerland). There are no loss changes for Poland, as this country is a new addition. Settings used in the associated model runs are provided in the next section.

The gross insurable loss changes presented below may differ from the loss changes presented in the component-level change section of this document and loss changes produced in Touchstone. In addition to reflecting updates to the model and catalog, these loss changes reflect an updated industry exposure distribution[5] and updated policy assumptions.

Caution should be exercised before relating the industry changes shown here to a particular portfolio. The changes to individual books of business may deviate from the losses represented here to the extent that their spatial distribution and construction/ occupancy mix deviate from industry averages.

Table 53. Percentage change in GROSS INSURABLE OCCURRENCE losses, by LOB – 10,000 yr catalog

Austria						
Insurable (Occurrence) Losses						
EP (Return Period)	**Overall Change**					
	RES	**COM**	**IND**	**AG**	**AUTO**	**TOTAL**
10% (10yr)	23%	-14%	-3%	64%	>500%	33%
5% (20yr)	11%	-11%	1%	53%	>500%	26%
2% (50yr)	-18%	-36%	-12%	43%	>500%	2%
1% (100yr)	-45%	-41%	-27%	51%	>500%	-21%
0.5% (200yr)	-40%	-34%	-18%	38%	>500%	-14%
0.2% (500yr)	-33%	-36%	-8%	41%	>500%	-3%
0.1% (1000yr)	-22%	-27%	13%	57%	>500%	15%
Est. AAL	-17%	-36%	-16%	57%	>500%	-1%

Czech Republic						
Insurable (Occurrence) Losses						
EP (Return Period)	**Overall Change**					
	RES	**COM**	**IND**	**AG**	**AUTO**	**TOTAL**
10% (10yr)	-14%	-63%	274%	-47%	>500%	12%
5% (20yr)	-12%	-58%	142%	-53%	>500%	-3%
2% (50yr)	-13%	-55%	43%	-57%	>500%	-13%
1% (100yr)	-23%	-64%	2%	-58%	>500%	-31%
0.5% (200yr)	-28%	-71%	-18%	-58%	>500%	-38%
0.2% (500yr)	-40%	-68%	-40%	-61%	>500%	-50%
0.1% (1000yr)	-39%	-65%	-41%	-60%	>500%	-51%
Est. AAL	-18%	-64%	36%	-45%	>500%	-19%

5 The construction /occupancy distribution of exposures, on which the industry loss file (ILF) is based, differs from CATRADER 20.0 to CATRADER 21.0.

Germany						
Insurable (Occurrence) Losses						
EP (Return Period)	Overall Change					
	RES	COM	IND	AG	AUTO	TOTAL
10% (10yr)	21%	6%	-22%	-37%	128%	10%
5% (20yr)	33%	24%	-24%	-32%	154%	21%
2% (50yr)	32%	18%	-21%	-27%	162%	19%
1% (100yr)	31%	27%	-23%	-32%	168%	22%
0.5% (200yr)	31%	21%	-20%	-29%	171%	22%
0.2% (500yr)	8%	4%	-35%	-37%	133%	7%
0.1% (1000yr)	-4%	2%	-31%	-49%	80%	-11%
Est. AAL	29%	18%	-22%	-40%	152%	17%

Switzerland						
Insurable (Occurrence) Losses						
EP (Return Period)	Overall Change					
	RES	COM	IND	AG	AUTO	TOTAL
10% (10yr)	28%	-12%	-24%	-48%	>500%	5%
5% (20yr)	67%	35%	7%	-47%	>500%	38%
2% (50yr)	67%	12%	4%	-49%	>500%	30%
1% (100yr)	41%	-19%	-21%	-52%	>500%	-4%
0.5% (200yr)	41%	-19%	-35%	-55%	>500%	-1%
0.2% (500yr)	47%	-28%	-36%	-50%	>500%	-5%
0.1% (1000yr)	33%	-38%	-40%	-50%	>500%	-15%
Est. AAL	31%	-21%	-27%	-46%	>500%	-3%

Table 54. Percentage change in GROSS INSURABLE AGGREGATE losses, by LOB – 10,000 yr catalog

Austria						
Insurable (Aggregate) Losses						
EP (Return Period)	Overall Change					
	RES	COM	IND	AG	AUTO	TOTAL
10% (10yr)	2%	-36%	-20%	58%	>500%	7%
5% (20yr)	5%	-26%	-7%	53%	>500%	15%
2% (50yr)	-13%	-31%	-17%	46%	>500%	1%
1% (100yr)	-44%	-42%	-30%	43%	>500%	-19%
0.5% (200yr)	-34%	-39%	-21%	41%	>500%	-12%

Austria						
Insurable (Aggregate) Losses						
EP (Return Period)	**Overall Change**					
	RES	**COM**	**IND**	**AG**	**AUTO**	**TOTAL**
0.2% (500yr)	-29%	-31%	-11%	42%	>500%	0%
0.1% (1000yr)	-32%	-37%	-7%	47%	>500%	2%
Est. AAL	-22%	-46%	-27%	55%	>500%	-11%

Czech Republic						
Insurable (Aggregate) Losses						
EP (Return Period)	**Overall Change**					
	RES	**COM**	**IND**	**AG**	**AUTO**	**TOTAL**
10% (10yr)	-15%	-65%	164%	-40%	>500%	-5%
5% (20yr)	-16%	-63%	88%	-50%	>500%	-10%
2% (50yr)	-18%	-60%	69%	-53%	>500%	-14%
1% (100yr)	-23%	-66%	21%	-55%	>500%	-28%
0.5% (200yr)	-26%	-69%	-6%	-55%	>500%	-34%
0.2% (500yr)	-38%	-72%	-25%	-58%	>500%	-47%
0.1% (1000yr)	-39%	-66%	-25%	-60%	>500%	-47%
Est. AAL	-22%	-67%	20%	-41%	478%	-25%

Germany						
Insurable (Aggregate) Losses						
EP (Return Period)	**Overall Change**					
	RES	**COM**	**IND**	**AG**	**AUTO**	**TOTAL**
10% (10yr)	33%	17%	-16%	-42%	149%	19%
5% (20yr)	37%	25%	-18%	-33%	161%	25%
2% (50yr)	28%	19%	-18%	-31%	165%	19%
1% (100yr)	40%	30%	-24%	-31%	179%	26%
0.5% (200yr)	34%	28%	-18%	-32%	172%	28%
0.2% (500yr)	13%	12%	-27%	-35%	123%	2%
0.1% (1000yr)	11%	22%	-18%	-34%	118%	15%
Est. AAL	43%	30%	-14%	-42%	171%	27%

Switzerland						
Insurable (Aggregate) Losses						
EP (Return Period)	**Overall Change**					
	RES	**COM**	**IND**	**AG**	**AUTO**	**TOTAL**
10% (10yr)	13%	-32%	-33%	-45%	365%	-12%
5% (20yr)	40%	5%	-9%	-47%	>500%	13%
2% (50yr)	45%	0%	-8%	-54%	>500%	12%
1% (100yr)	27%	-20%	-26%	-56%	>500%	-5%
0.5% (200yr)	24%	-26%	-34%	-55%	>500%	-17%
0.2% (500yr)	24%	-36%	-40%	-59%	>500%	-18%
0.1% (1000yr)	27%	-42%	-46%	-57%	>500%	-28%
Est. AAL	14%	-33%	-35%	-48%	>500%	-15%

See Also

Analysis Settings
Industry Exposure Database Updates

3.9 Analysis Settings

Table 55. CATRADER/Touchstone Re analysis settings for central Europe inland flood model runs

Setting	Selected Option(s)
Perils modeled	Inland flood
Catalogs	10,000-year
Industry exposure vintage	2017 Flood Insurable
Take-up rates	N/A
Demand surge	Off

4 The AIR Extratropical Cyclone Model for Europe

4.1 Overview of Model Updates and Changes

In this release, the AIR Extratropical Cyclone Model for Europe is updated to incorporate the AIR Coastal Flood Model for Great Britain for greater convenience and better consistency with other AIR wind models that incorporate the storm surge peril, such as the AIR Hurricane Model for the United States. This is accomplished by including storm surge in the United Kingdom as a new peril in the AIR Extratropical Cyclone Model for Europe. The integrated model includes a major update to the storm surge component, including new storm surge events for the stochastic catalog and an expanded model domain that includes all coastal areas of England and Wales. Note that the addition of the storm surge peril affects only the regions of the United Kingdom shown in Figure 36 (all of England and Wales), where the previously modeled coastal area is shown in blue, and the newly added modeled coastal area is shown in fuchsia.

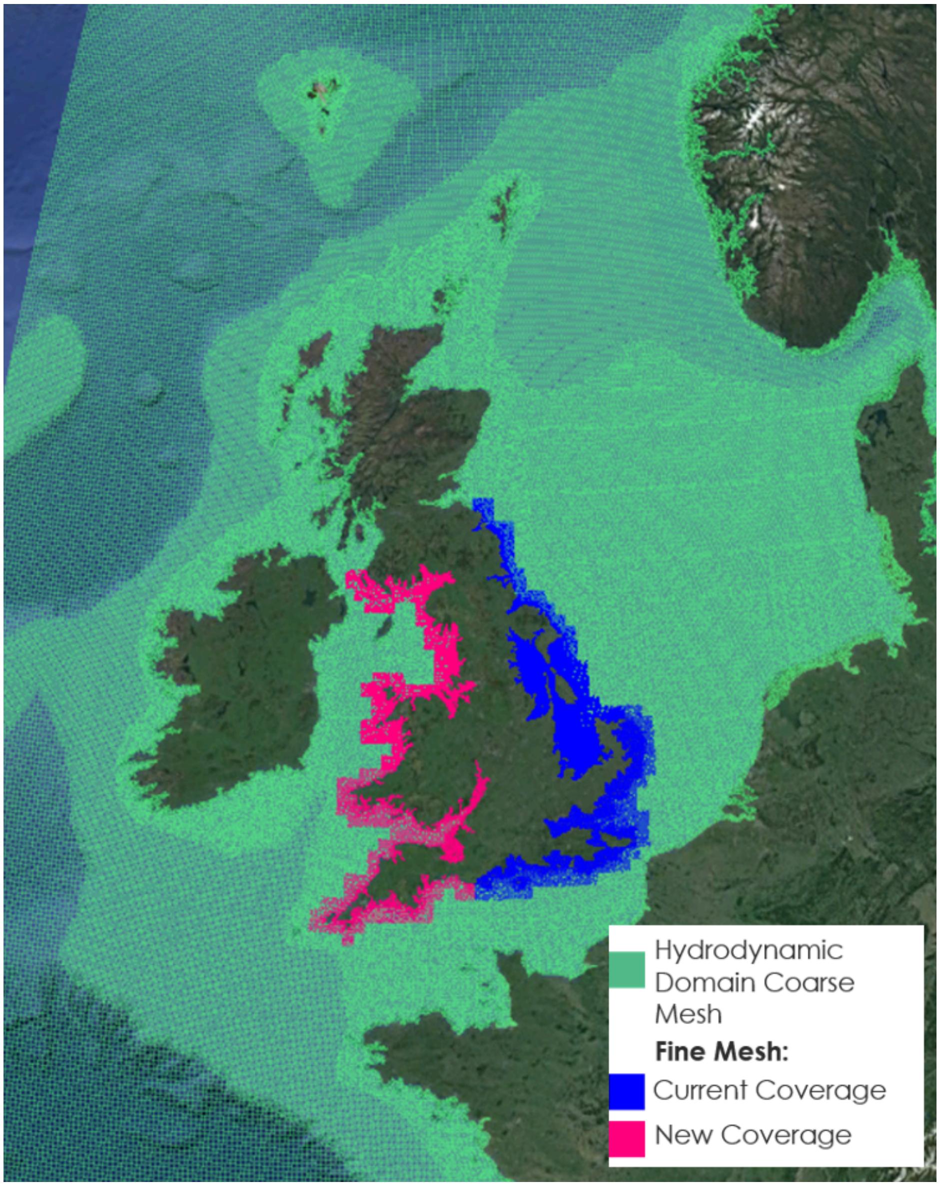


Figure 36. Storm surge coverage

Catalog development, event generation, and local intensity calculation for storm surge events are greatly modified and enhanced relative to the previous AIR Coastal Flood Model for Great Britain. Surge events are directly based on the wind and pressure characteristics from existing events in the AIR Extratropical Cyclone Model for Europe stochastic catalog. Several extratropical cyclone events are also updated.

The storm surge peril update incorporates detailed coastal sea defenses such as levees and sea walls and their probability of failure based on modeled fragility curves. Damage functions for the storm surge peril are newly developed or updated based on the damage functions in the original AIR Coastal Flood Model for Great Britain.

4.2 Catalogs and Event Sets

Stochastic Catalog

The 10,000-year stochastic catalog for the integrated model includes both extratropical cyclone wind events throughout Europe and storm surge events in Great Britain, including 26,505 loss-causing storm-surge events. Because coastal surge flooding in Great Britain is nearly always caused by strong wind forcing on the ocean surface by an extratropical cyclone, the storm surge events are derived from the same internal historical catalog of 1,750 extratropical cyclone seed storms as is used for the wind peril, using a statistical regression model to select the storms that might cause significant surge.

Historical Event Set

The historical event set now includes six storm surge events in Great Britain, for a total of 39 events. The historical Xaver extratropical cyclone event now has two versions to accommodate the storm surge peril, one with vintage levees and one with modern levees, using the same wind and pressure fields. Historical event IDs are renumbered to include the new storm surge events. Further, the historical events Lothar, Martin, Jeanett, and Kyrill have been enriched with additional hazard information to represent the storms more accurately.

World Scenarios Event Set

The AIR Extratropical Cyclone Model for Europe includes one new extreme disaster scenario (a 1953 North Sea Flood storm surge event replicated without coastal defenses in place, event ID 7). The Lloyd's Realistic Disaster Scenario (RDS, event ID 6) simulating a European windstorm with a central track has been modified to more closely replicate the RDS event included in the Touchstone 5.0 model version.

4.3 Event Generation

The stochastic catalog for the AIR Extratropical Cyclone Model for Europe was updated in the 2018 release of Touchstone, Touchstone Re, and CATRADER. Stochastic events in the extratropical cyclone model were generated using 1,750 historical storms as seed events for stochastic perturbation, yielding a master catalog of nearly 500,000 events. Wind events were selected from this master catalog in a process described in the detailed model documentation for the AIR Extratropical Cyclone Model for Europe, available on the AIR Client Portal.

Storm surge events were selected from the master AIR Extratropical Cyclone Model for Europe stochastic catalog using a statistical regression model. Using local wind speed and pressure fields, the regression model recreates the surge and total water levels, which are then used to identify potentially flood-causing stochastic events. The model was first trained using atmospheric and storm surge parameters from the Dutch Continental Shelf Model (DCSM), a numerical model that was run on every storm in the historical catalog.

After training the regression model and validating the results for historical storms against observations, the regression model used the DCSM parameters to reconstruct storm surge and total water levels for every event in the master stochastic catalog. This process yielded a set of 104,910 events that could cause storm surge damage. Using the DCSM, these events were then re-modeled, and the resulting water levels were used to select the 26,505 potentially loss-causing surge events that comprise the model's surge event catalog.

The stochastic catalog of the previously supported AIR Coastal Flood Model for Great Britain contained approximately 1,000 loss-causing storm surge events, and the updated storm surge catalog in the AIR Extratropical Cyclone Model for Europe contains 26,505 loss-causing events. This increase in total loss-causing events in the stochastic catalog results in an increase in surge losses at low return periods when comparing the previous AIR Coastal Flood Model for Great Britain to surge losses from the expanded AIR Extratropical Cyclone Model for Europe.

4.4 Local Intensity Calculation

To add surge characteristics to the stochastic, historical, and EDS events, they are run with both a coarse mesh model (Dutch Continental Shelf Model) and fine mesh models to define tidal and wind forcing for each event, including surface roughness and possible breach or overtopping of flood defenses. If the fine mesh has an embedded superfine mesh, the superfine mesh is run with no wind forcing, using the fine mesh for boundary conditions, as the small size of the superfine meshes make the boundary conditions more important than wind forcing. Flood defenses and surface roughness are also accounted for in the superfine mesh.

Hydrodynamic Model Domains

The measure of storm surge intensity used in the AIR Extratropical Cyclone Model for Europe is the effective inundation depth, in meters, from the ground floor of the affected building. To obtain this measure, the effective inundation elevation for each storm was numerically simulated by a series of three increasingly fine resolution hydrodynamic models, all built on the Deltares D-Flow-FM platform. The 10-m resolution digital terrain model (DTM) was then subtracted from the location-level effective inundation elevation to obtain effective inundation depth. In order of resolution, the three hydrodynamic models are the Dutch Continental Shelf Model (DCSM), fine-mesh model, and super-fine-mesh model.

For a given extratropical storm, the coarse-mesh-model (DCSM) identifies water levels at specified tide gauges within each of the five fine-mesh model domains and determines which fine mesh models to run. The event's atmospheric parameters (i.e. wind and pressure) are applied to the model mesh to simulate the wind setup across the entire domain. The fine-mesh models vary in resolution from approximately 2 km off shore to approximately 200 m on the coast. The CORINE Land Use/Land Cover (LULC) database is used to determine physical properties of the land surface, such as Manning's roughness coefficients, to calculate the impact of friction on storm surge propagation and model the appropriate surge extent over land.

Six super-fine mesh models are embedded within a parent fine mesh model and simulate water levels in areas of high exposure in England and Wales. These models range in resolution from 80 m to 21 m and run whenever the fine mesh in which they are embedded are run for a given event. This higher resolution is necessary to model certain high-exposure areas located up narrow tidal river channels that cannot be simulated properly at the resolution of the parent fine mesh model. The resolution offered by the super-fine mesh models in the AIR Extratropical Cyclone Model for Europe, coupled with the 10-m resolution DTM is an improvement over surge modeling in the AIR Coastal Flood Model for Great Britain, which modeled surge at a maximum resolution of 100 m and coastal terrain at a resolution of 50 m.

Coastal Flood Defenses

The previous version of the AIR Coastal Flood Model for Great Britain included information on flood defenses in southeastern England from the National Rivers Authority, supplemented with data for the Thames Barrier and other defenses along the Thames River from the United Kingdom Environment Agency. In the updated version of the AIR Extratropical Cyclone Model for Europe, a vintage 2016 database containing information on coastal defenses is incorporated. This database covers the entirety of the expanded model domain and includes information on the location, physical characteristics, and structural condition of public and private sea defenses.

These coastal defenses are incorporated into both the fine and super-fine mesh models, and a two-phase defense failure simulation is used to stochastically simulate the failure of flood defenses. This simulation accounts for both overtopping and structural failure and is used to calculate the final water elevation for a given domain. Fragility curves derived from the U.K. Environment Agency database are assigned to each coastal defense based on its design and indicate the probability of failure, based on the severity of the load. The improved resolution and coverage of coastal defenses in the updated model generally drive decreases in modeled losses at higher return periods, when compared to losses in the previous version of the AIR Coastal Flood Model for Great Britain.

4.5 Damage Estimation

New storm surge damage functions for the AIR Extratropical Cyclone Model for Europe were developed from United Kingdom-specific depth-damage data. These damage functions are based on a component-level framework for building and content-coverage type that explicitly integrates primary and secondary building features. In addition, updated time element functions are implemented. Buildings are divided into key components: structure, foundation, interior, and service equipment, including electrical, mechanical and plumbing equipment.

Views of risk can be further refined for foundation types, presence of basement, first floor height and floor of interest, as well as surrounding mitigation details such as custom flood standard of protection and custom elevation.

The new storm-surge damage functions support all existing lines of business in the AIR Extratropical Cyclone Model for Europe except forestry and include functions for unknown primary and secondary characteristics at the CRESTA level. This enables the storm surge component of the model to account for regional differences in the building stock as represented in the Industry Exposure Database, making the damage estimates with unknown characteristics more accurate.

To evaluate the model, AIR researchers used the most current damage and loss information available from published literature.

Component-Level Damage Functions

Newly introduced in the 2019 release of Touchstone, Touchstone Re, and CATRADER are component-level functions for the assessment of damage due to storm surge in Great Britain. The previous version of Great Britain storm surge modeling in the AIR Coastal Flood Model for Great Britain executed component-level damage estimation for commercial occupancies only. In the updated version of the AIR Extratropical Cyclone Model for Europe, a building is divided into three key components (foundation and structure, service equipment, and interior and fixtures), which are further broken out by sub-group and collectively add up to the building's total replacement cost.

The component-level damage functions in the AIR model are based primarily on the Flood and Coastal Erosion Risk Management manual (also known as the Multi-Coloured Manual, or MCM) and database, published by Middlesex University. The MCM database contains a wealth of depth-damage data for buildings and contents at the component level, based on data from damage surveys in Great Britain. The database was peer reviewed and is widely used by research communities in Great Britain. The data in the MCM database was supplemented by RIDERS Digest and the AIR Industry Exposure Database. The damage functions for storm surge in the AIR Extratropical Cyclone Model for Europe were calibrated with recent historical surge event loss footprints and validated with component-level damage relationships from the MCM database.

Updates to Primary Characteristics

With respect to surge modeling in the AIR Coastal Flood Model for Great Britain, the updated AIR Extratropical Cyclone Model for Europe supports additional occupancy, construction, and height classes, as shown in Table 56.

Table 56. Support for primary characteristics in the previous and updated model versions

Primary Characteristic	AIR Coastal Flood Model for Great Britain	Storm Surge Modeling in the AIR Extratropical Cyclone Model for Europe
Construction Classes	33	47
Occupancy Classes	50	115
Height Bands	4	6

Included in the expanded support for new construction and occupancy classes is newly added modeling of specialized risks, including large industrial facilities, infrastructure (marine hull, wind turbines), and builder's risk.

Addition of Secondary Risk Characteristics

The updated model supports five secondary risk characteristics (SRC):

Custom elevation

The elevation of the local ground surface can be entered for this feature, which will override the underlying modeled digital terrain elevation.

Custom flood standard of Protection

For buildings safeguarded by a custom flood protection system (e.g., levee or flood wall), the user may enter the flood protection system's height above the ground surface, or the return period for which the system was designed.

First floor height

The height of the first floor, above the ground surface, can be entered for all residential, commercial, and small industrial buildings.

Floor of Interest:

in cases in which the entire building is not covered, the user may enter the floor number to obtain losses the damage of each floor.

Foundation type:

The model considers the presence of a basement, or cellar, through the foundation type SRC.

Estimating Damage to Buildings of Unknown Characteristics

The updated version of the AIR Extratropical Cyclone Model for Europe expands on storm surge damage assessment for risks of unknown characteristics from the AIR Coastal Flood Model for Great Britain. The model in the 2019 release now supports higher resolution damage estimation at the CRESTA level. Each combination of unknown characteristics is calculated as a weighted average of the damage functions of the different classes that are in the AIR Industry Exposure Database, with weights determined by the relative share of total insurable value of each class.

Specialty Lines of Business

The updates to storm surge modeling in Great Britain include the addition of support for several specialty lines of business not previously included in the AIR Coastal Flood Model for Great Britain. These include risk modeling for large industrial facilities (400-series occupancies), builder's risk, infrastructure, marine hull, and wind turbines. The agriculture line of business is also added.

Updates to Secondary Uncertainty Distributions

The model updates included in the 2019 update to CATRADER and Touchstone Re include updates to secondary distributions for storm surge. These relationships represent a distribution around a mean damage ratio (MDR) of a location that is due to randomness, uncertainty, and other unknown factors. Secondary uncertainty distributions typically have two discrete spikes at 0% and 100% damage ratio, representing the probability of no damage or full damage, respectively. The main part of the distribution corresponds to the range of damage ratios between those two extremes.

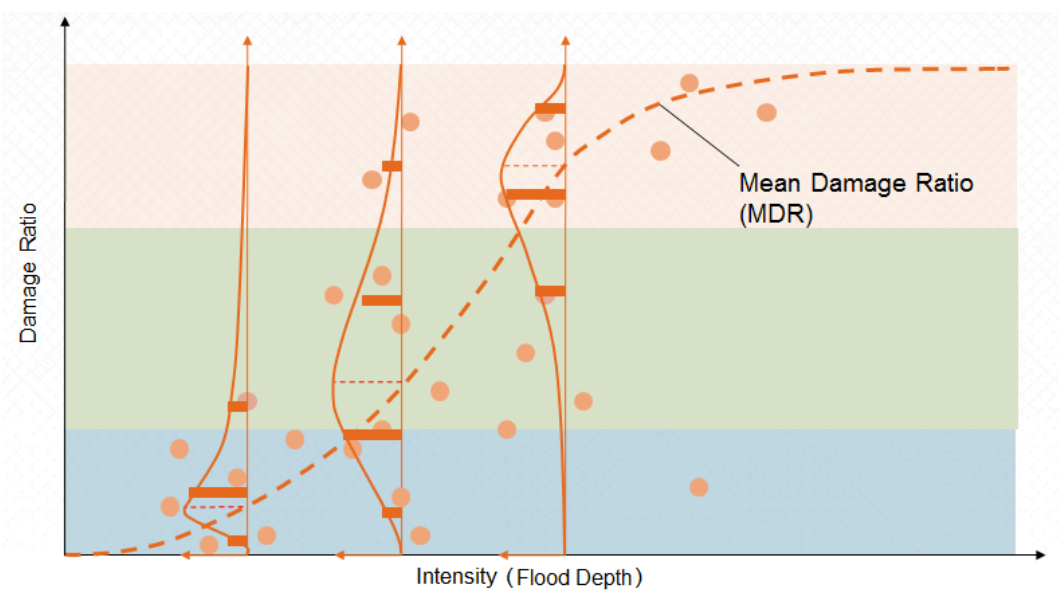


Figure 37. Representation of secondary uncertainty distributions around a given mean damage ratio, defined by claims data (data points)

The updated secondary distributions for storm surge are based on available claims from four historical flood events between 2002 and 2007 from two insurance companies. The approximately 67,000 claims cover the residential line of business. In addition to being informed by claims data, the updated distributions were constructed using the inflated transformed beta family of distributions. Distributions based on these claims were created for the Residential and Commercial lines of business for Coverages A through D. Figure 38 shows the updated distributions transitioning smoothly from low to high damage ratios.

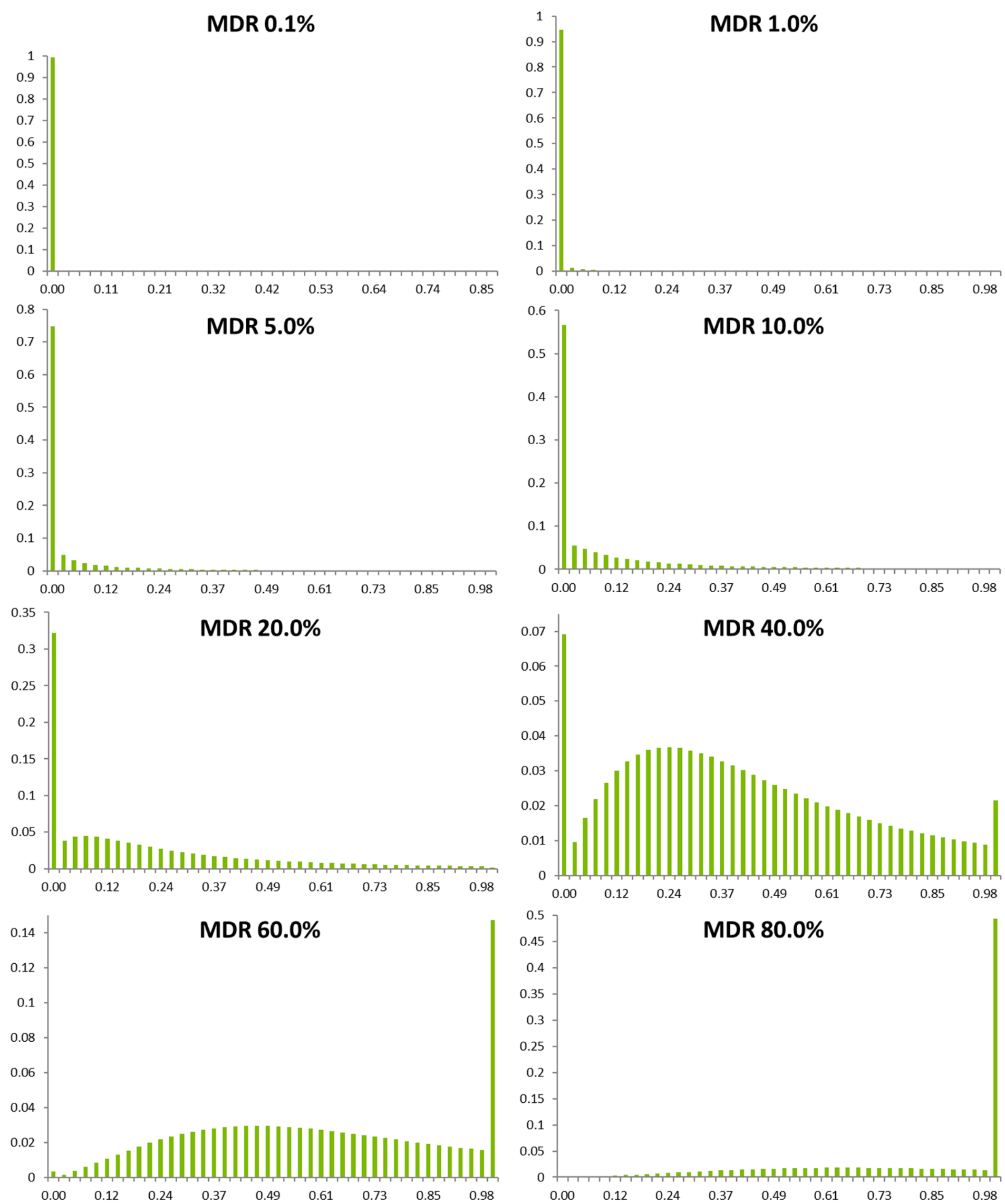


Figure 38. Smoothly transitioning shapes of the Residential Coverage A distributions

Figure 39 compares the updated residential distributions to the previously implemented secondary distributions, which shows that the previous distributions were mostly spikes at no damage or total damage.

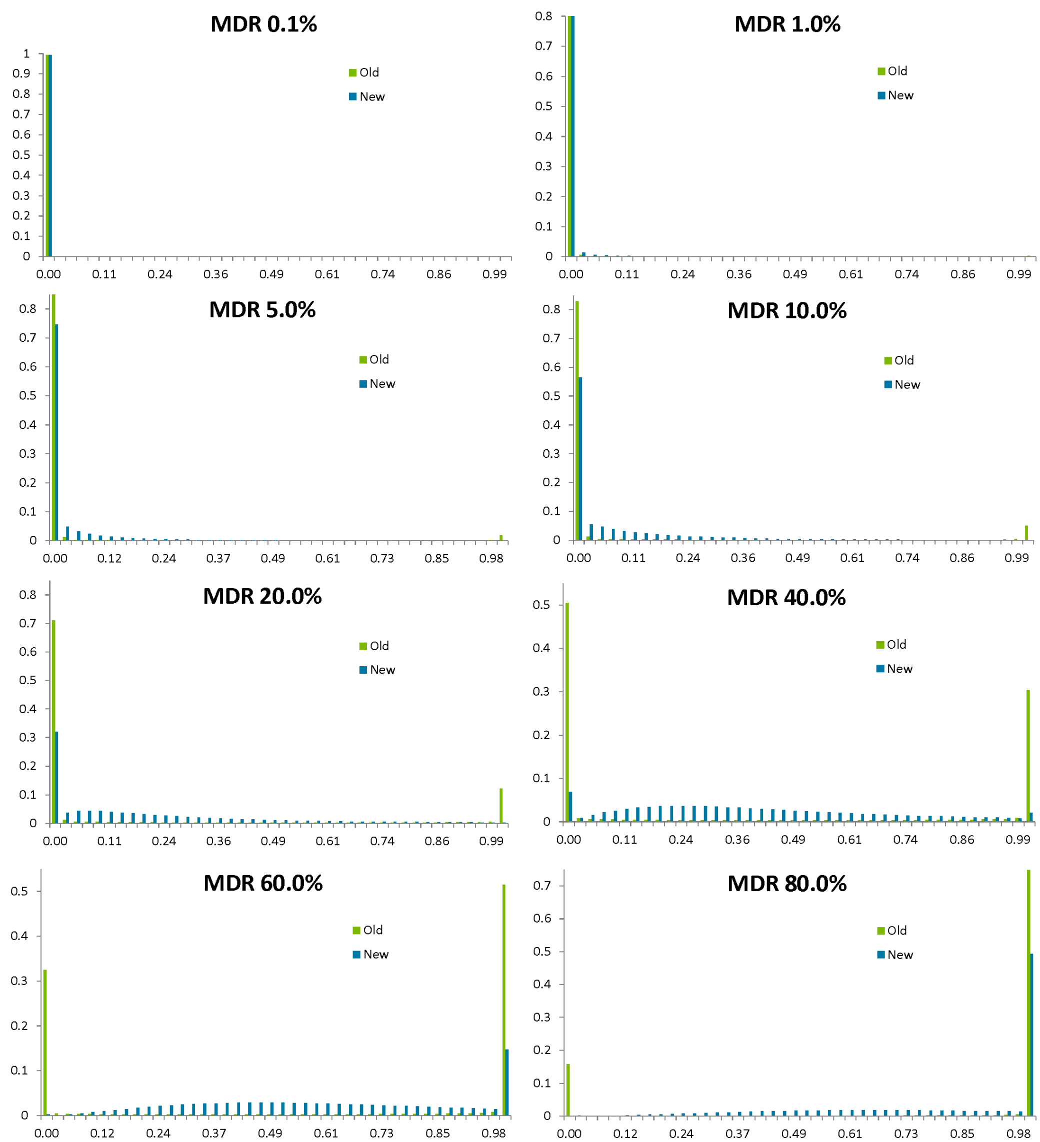


Figure 39. Comparison of updated and previous Residential Coverage A distributions

Figure 40 demonstrates that the updated distributions better capture the behavior of the available claims data.

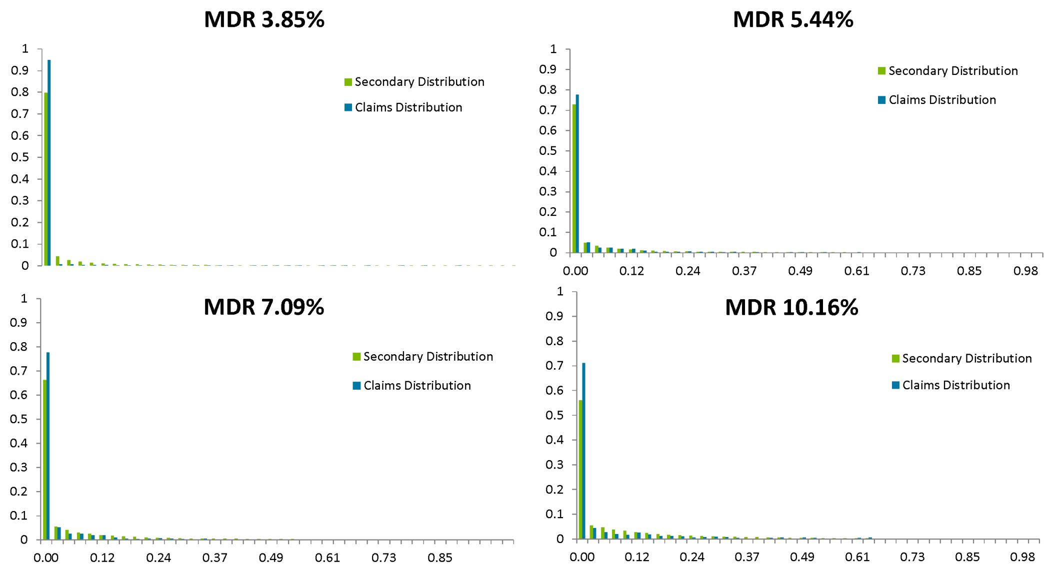


Figure 40. Smoothed parametric fit of residential coverage A distributions to claims data

When updating the old distributions to the new distributions, the ratio between gross and ground up losses will change. This change has a complex dependence on MDR and deductible ratio and is shown in Table 57 and Table 58 for some of the most common deductible proportions.

The most immediate observation is that the ratio decreases for most MDR and deductible values because the new distributions have higher probabilities for intermediary losses, as supported by claims data. Other key observations to note are that the most significant change occurs at low MDRs and high deductible proportions, but it becomes less significant at high MDRs. The reason the residential and commercial loss ratios are similar stems from the fact that the two have the same probabilities of zero loss. Note that this change analysis presented here is restricted to a single location, and the impact on losses for an entire portfolio is even more complex and dependent on the portfolio locations in their entirety.

Table 57. Percentage change in gross-to-ground up loss ratio from previous to updated Residential Coverage A distributions

MDR	Deductible = 0.5%	Deductible = 1%	Deductible = 2%	Deductible = 5%
0.001	-0.61%	-1.24%	-4.51%	-11.97%
0.005	-1.01%	-2.05%	-5.13%	-12.36%
0.010	-1.25%	-2.53%	-5.81%	-13.39%
0.050	-1.55%	-3.12%	-6.57%	-15.13%
0.100	-1.33%	-2.69%	-5.57%	-13.37%
0.200	-0.98%	-1.97%	-4.05%	-10.18%
0.500	-0.40%	-0.80%	-1.62%	-4.23%

MDR	Deductible = 0.5%	Deductible = 1%	Deductible = 2%	Deductible = 5%
0.800	-0.10%	-0.20%	-0.41%	-1.05%

Table 58. Percentage change in gross-to-ground up loss ratio from previous to updated Commercial Coverage A distributions

MDR	Deductible = 0.5%	Deductible = 1%	Deductible = 2%	Deductible = 5%
0.001	-0.61%	-1.24%	-4.51%	-11.57%
0.005	-1.01%	-2.05%	-5.13%	-12.03%
0.010	-1.25%	-2.53%	-5.81%	-13.05%
0.050	-1.55%	-3.12%	-6.57%	-14.70%
0.100	-1.33%	-2.69%	-5.57%	-13.08%
0.200	-0.98%	-1.97%	-4.05%	-10.08%
0.500	-0.40%	-0.80%	-1.62%	-4.22%
0.800	-0.10%	-0.20%	-0.41%	-1.05%

4.6 Industry Exposure Database Updates

The AIR Extratropical Cyclone Model for Europe uses the AIR Industry Exposure Database for the pan-European region, current as of the end of 2017, as released with Touchstone, Touchstone Re, and CATRADER in 2018. Please note that the Industry Exposure Databases are constructed at a resolution of 1 km grid for extratropical cyclone wind, and a higher resolution of 90 m grid for surge.

4.7 General Impact of Model Updates on Loss Estimates

The following tables illustrate the overall impact of model updates on loss estimates from the previous version of CATRADER to version 2019. Table 59 presents the percentage change in insurable occurrence and aggregate losses, for Great Britain, between the previous version of the AIR Extratropical Cyclone Model for Europe (wind only) and the updated model version (wind and storm surge in Great Britain). CATRADER settings used in the associated model runs are provided in a later section.

Each table provides an "Overall Change," or the change in industry occurrence losses that will be experienced if one simply reruns company exposures already entered in the previous version of the software. "Overall Change" represents the combined effects of all changes (e.g. updates to the catalog, damage estimation module, policy conditions, etc.). "Overall Change" is calculated by comparing the total industry insurable losses in the prior industry loss file to the total industry insurable losses in the new industry loss file. In CATRADER, 100% user-specified market shares are analyzed against each loss file and the percentage differences calculated in the resulting loss distributions.

Note that caution should be exercised before relating the industry changes shown here to a particular portfolio. The changes to individual books of business may deviate from the losses represented here to the extent that their spatial distribution and construction/occupancy mix deviate from industry averages.

Table 59. Percentage change in GROSS INSURABLE losses, wind only 20.0 vs wind + surge 21.0 – 10K catalog

United Kingdom										
EP (Return Period)	**Overall Change**									
	Insurable Aggregate					**Insurable Occurrence**				
	RES	**COM/ IND**	**AG**	**AUTO**	**TOTAL**	**RES**	**COM/ IND**	**AG**	**AUTO**	**TOTAL**
10% (10 yr)	4%	13%	11%	3%	7%	3%	13%	4%	2%	3%
4% (25 yr)	3%	10%	5%	3%	4%	3%	10%	4%	3%	5%
2% (50 yr)	5%	10%	4%	4%	6%	5%	6%	1%	4%	5%
1% (100 yr)	3%	8%	4%	3%	5%	7%	8%	0%	5%	8%
0.5% (200 yr)	4%	14%	4%	6%	6%	3%	11%	0%	4%	5%
0.2% (500 yr)	7%	19%	2%	3%	12%	2%	14%	2%	1%	2%
0.1% (1,000 yr)	1%	37%	0%	3%	7%	2%	45%	1%	1%	12%
Est. AAL	6%	18%	12%	4%	9%	4%	14%	6%	3%	7%

UK - CATRADER 20.0 Domain										
EP (Return Period)	**Overall Change**									
	Insurable Aggregate					**Insurable Occurrence**				
	RES	**COM/ IND**	**AG**	**AUTO**	**TOTAL**	**RES**	**COM/ IND**	**AG**	**AUTO**	**TOTAL**
10% (10 yr)	8%	24%	71%	5%	11%	6%	21%	60%	4%	9%
4% (25 yr)	7%	22%	29%	5%	11%	3%	20%	18%	4%	5%
2% (50 yr)	5%	16%	21%	5%	8%	4%	13%	9%	6%	5%
1% (100 yr)	8%	14%	12%	8%	11%	9%	13%	10%	7%	11%
0.5% (200 yr)	8%	34%	4%	13%	13%	9%	19%	6%	13%	15%
0.2% (500 yr)	15%	34%	15%	11%	19%	19%	29%	6%	14%	21%
0.1% (1,000 yr)	7%	37%	13%	9%	19%	9%	32%	11%	15%	18%
Est. AAL	12%	29%	53%	8%	17%	10%	27%	39%	7%	14%

East Midlands										
EP (Return Period)	**Overall Change**									
	Insurable Aggregate					**Insurable Occurrence**				
	RES	**COM/ IND**	**AG**	**AUTO**	**TOTAL**	**RES**	**COM/ IND**	**AG**	**AUTO**	**TOTAL**
10% (10 yr)	4%	4%	170%	2%	6%	3%	4%	134%	1%	4%
4% (25 yr)	4%	6%	92%	3%	6%	5%	7%	54%	3%	5%
2% (50 yr)	4%	9%	48%	5%	10%	8%	6%	16%	7%	9%
1% (100 yr)	22%	23%	14%	23%	21%	24%	23%	9%	25%	25%
0.5% (200 yr)	43%	40%	19%	37%	43%	25%	28%	13%	28%	23%
0.2% (500 yr)	9%	26%	10%	9%	8%	7%	23%	9%	10%	7%
0.1% (1,000 yr)	16%	17%	5%	6%	19%	22%	26%	2%	10%	27%
Est. AAL	11%	17%	86%	7%	16%	12%	18%	64%	8%	15%

East of England										
EP (Return Period)	**Overall Change**									
	Insurable Aggregate					**Insurable Occurrence**				
	RES	**COM/ IND**	**AG**	**AUTO**	**TOTAL**	**RES**	**COM/ IND**	**AG**	**AUTO**	**TOTAL**
10% (10 yr)	37%	67%	412%	15%	50%	37%	62%	392%	17%	47%
4% (25 yr)	28%	43%	192%	15%	36%	15%	29%	160%	10%	23%
2% (50 yr)	17%	35%	94%	14%	23%	13%	26%	68%	8%	17%
1% (100 yr)	9%	19%	60%	4%	13%	4%	19%	33%	1%	9%
0.5% (200 yr)	8%	32%	23%	7%	13%	3%	30%	16%	5%	7%
0.2% (500 yr)	7%	63%	29%	9%	44%	9%	53%	21%	13%	46%
0.1% (1,000 yr)	3%	39%	5%	2%	4%	7%	44%	5%	5%	11%
Est. AAL	26%	62%	183%	16%	41%	22%	56%	148%	13%	34%

London										
EP (Return Period)	**Overall Change**									
	Insurable Aggregate					**Insurable Occurrence**				
	RES	**COM/ IND**	**AG**	**AUTO**	**TOTAL**	**RES**	**COM/ IND**	**AG**	**AUTO**	**TOTAL**
10% (10 yr)	20%	32%	10%	10%	22%	16%	30%	14%	9%	19%
4% (25 yr)	21%	28%	17%	15%	23%	23%	29%	17%	16%	25%
2% (50 yr)	18%	29%	5%	11%	21%	18%	31%	6%	15%	24%
1% (100 yr)	4%	14%	1%	5%	3%	3%	12%	0%	4%	5%
0.5% (200 yr)	5%	5%	0%	6%	5%	2%	7%	0%	4%	5%

London										
EP (Return Period)	Overall Change									
	Insurable Aggregate					Insurable Occurrence				
	RES	COM/ IND	AG	AUTO	TOTAL	RES	COM/ IND	AG	AUTO	TOTAL
0.2% (500 yr)	1%	11%	0%	12%	4%	2%	6%	0%	6%	4%
0.1% (1,000 yr)	0%	11%	0%	9%	12%	0%	5%	0%	1%	6%
Est. AAL	14%	22%	5%	9%	16%	13%	21%	5%	9%	15%

North East										
EP (Return Period)	Overall Change									
	Insurable Aggregate					Insurable Occurrence				
	RES	COM/ IND	AG	AUTO	TOTAL	RES	COM/ IND	AG	AUTO	TOTAL
10% (10 yr)	0%	21%	2%	2%	4%	0%	19%	0%	1%	2%
4% (25 yr)	1%	12%	1%	1%	2%	0%	4%	0%	0%	0%
2% (50 yr)	1%	5%	0%	0%	1%	0%	4%	1%	0%	0%
1% (100 yr)	0%	1%	0%	0%	0%	0%	2%	0%	0%	0%
0.5% (200 yr)	0%	3%	0%	0%	1%	0%	9%	0%	0%	4%
0.2% (500 yr)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
0.1% (1,000 yr)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Est. AAL	1%	13%	3%	2%	4%	0%	9%	1%	1%	2%

North West										
EP (Return Period)	Overall Change									
	Insurable Aggregate					Insurable Occurrence				
	RES	COM/ IND	AG	AUTO	TOTAL	RES	COM/ IND	AG	AUTO	TOTAL
10% (10 yr)	4%	10%	4%	2%	5%	3%	4%	3%	2%	3%
4% (25 yr)	2%	6%	2%	2%	4%	2%	4%	2%	1%	3%
2% (50 yr)	3%	5%	2%	3%	3%	2%	4%	3%	1%	4%
1% (100 yr)	4%	5%	0%	2%	3%	1%	2%	0%	2%	2%
0.5% (200 yr)	1%	2%	0%	2%	2%	3%	2%	0%	2%	2%
0.2% (500 yr)	0%	1%	3%	4%	2%	0%	1%	0%	0%	0%
0.1% (1,000 yr)	0%	1%	0%	3%	3%	0%	0%	0%	3%	5%
Est. AAL	3%	14%	3%	3%	6%	3%	7%	3%	2%	4%

South East										
EP (Return Period)	**Overall Change**									
	Insurable Aggregate					**Insurable Occurrence**				
	RES	**COM/ IND**	**AG**	**AUTO**	**TOTAL**	**RES**	**COM/ IND**	**AG**	**AUTO**	**TOTAL**
10% (10 yr)	9%	21%	30%	7%	16%	7%	21%	23%	4%	14%
4% (25 yr)	5%	32%	20%	5%	16%	4%	34%	12%	4%	18%
2% (50 yr)	5%	44%	11%	8%	14%	4%	49%	8%	6%	13%
1% (100 yr)	4%	56%	11%	6%	5%	4%	53%	5%	3%	5%
0.5% (200 yr)	5%	54%	3%	7%	15%	5%	58%	6%	5%	11%
0.2% (500 yr)	4%	38%	5%	4%	5%	1%	33%	1%	3%	3%
0.1% (1,000 yr)	10%	35%	1%	7%	18%	3%	43%	4%	1%	12%
Est. AAL	10%	35%	30%	7%	17%	8%	35%	23%	6%	15%

South West										
EP (Return Period)	**Overall Change**									
	Insurable Aggregate					**Insurable Occurrence**				
	RES	**COM/ IND**	**AG**	**AUTO**	**TOTAL**	**RES**	**COM/ IND**	**AG**	**AUTO**	**TOTAL**
10% (10 yr)	3%	17%	14%	3%	7%	3%	7%	7%	2%	4%
4% (25 yr)	5%	9%	9%	3%	6%	2%	4%	2%	2%	3%
2% (50 yr)	3%	7%	5%	3%	4%	5%	3%	3%	2%	4%
1% (100 yr)	3%	10%	2%	1%	6%	2%	7%	0%	3%	5%
0.5% (200 yr)	2%	8%	1%	1%	4%	4%	3%	0%	2%	3%
0.2% (500 yr)	8%	12%	7%	0%	4%	0%	7%	0%	2%	3%
0.1% (1,000 yr)	0%	3%	1%	0%	1%	4%	6%	0%	0%	2%
Est. AAL	4%	26%	15%	4%	10%	3%	14%	8%	2%	5%

Wales										
EP (Return Period)	**Overall Change**									
	Insurable Aggregate					**Insurable Occurrence**				
	RES	**COM/ IND**	**AG**	**AUTO**	**TOTAL**	**RES**	**COM/ IND**	**AG**	**AUTO**	**TOTAL**
10% (10 yr)	5%	16%	9%	3%	8%	4%	14%	8%	3%	9%
4% (25 yr)	4%	22%	8%	4%	8%	4%	18%	6%	4%	10%
2% (50 yr)	5%	25%	5%	5%	10%	6%	33%	3%	3%	12%
1% (100 yr)	5%	36%	3%	2%	12%	4%	43%	1%	5%	9%
0.5% (200 yr)	3%	50%	3%	3%	11%	4%	63%	0%	4%	13%

Wales										
EP (Return Period)	Overall Change									
	Insurable Aggregate					Insurable Occurrence				
	RES	COM/ IND	AG	AUTO	TOTAL	RES	COM/ IND	AG	AUTO	TOTAL
0.2% (500 yr)	1%	101%	4%	1%	10%	6%	138%	2%	7%	23%
0.1% (1,000 yr)	15%	84%	3%	10%	26%	4%	101%	0%	5%	24%
Est. AAL	5%	28%	9%	4%	10%	5%	26%	7%	4%	9%

Yorkshire										
EP (Return Period)	Overall Change									
	Insurable Aggregate					Insurable Occurrence				
	RES	COM/ IND	AG	AUTO	TOTAL	RES	COM/ IND	AG	AUTO	TOTAL
10% (10 yr)	3%	11%	1%	4%	6%	2%	10%	1%	3%	5%
4% (25 yr)	5%	13%	1%	3%	6%	5%	14%	1%	4%	8%
2% (50 yr)	7%	22%	2%	6%	13%	6%	23%	0%	7%	11%
1% (100 yr)	14%	38%	2%	9%	21%	18%	47%	1%	16%	28%
0.5% (200 yr)	30%	44%	2%	18%	33%	27%	42%	3%	20%	27%
0.2% (500 yr)	25%	69%	0%	18%	29%	25%	67%	0%	20%	28%
0.1% (1,000 yr)	17%	31%	0%	13%	9%	18%	32%	0%	14%	11%
Est. AAL	9%	26%	1%	6%	13%	9%	24%	1%	6%	12%

4.8 Impact of Model Updates on Storm Surge Loss Estimates

The following tables illustrate the overall impact of model updates on loss estimates from the previous version of CATRADER to version 2019. Table 60 presents the percentage change in insurable occurrence and aggregate losses for storm surge between the previously supported AIR Coastal Flood Model for Great Britain and the updated AIR Extratropical Cyclone Model for Europe, updated in 2019 to include storm surge for Great Britain. CATRADER settings used in the associated model runs are provided in the next section.

Each table provides an "Overall Change," or the change in industry occurrence losses that will be experienced if one simply reruns company exposures already entered in the previous version of the software. "Overall Change" represents the combined effects of all changes (e.g. updates to the catalog, damage estimation module, policy conditions, etc.). "Overall Change" is calculated by comparing the total industry insurable losses in the prior industry loss file to the total industry insurable losses in the new industry loss file. In CATRADER, 100% user-specified market shares are analyzed against each loss file and the percentage differences calculated in the resulting loss distributions.

Note that caution should be exercised before relating the industry changes shown here to a particular portfolio. The changes to individual books of business may deviate from the losses represented here to the extent that their spatial distribution and construction/occupancy mix deviate from industry averages.

Table 60. Percentage change in GROSS INSURABLE losses, surge only 20.0 vs surge only 21.0 – 10K catalog

United Kingdom						
EP (Return Period)	Overall Change					
	Insurable Aggregate			Insurable Occurrence		
	RES	COM/IND	TOTAL	RES	COM/IND	TOTAL
10% (10 yr)	N/A	N/A	N/A	N/A	N/A	N/A
4% (25 yr)	309%	85%	171%	273%	53%	136%
2% (50 yr)	15%	-13%	-5%	0%	-21%	-18%
1% (100 yr)	-53%	-65%	-65%	-58%	-67%	-68%
0.5% (200 yr)	-78%	-83%	-83%	-80%	-85%	-84%
0.2% (500 yr)	-82%	-88%	-86%	-82%	-88%	-86%
0.1% (1,000 yr)	-62%	-81%	-74%	-67%	-83%	-76%
Est. AAL	-37%	-56%	-49%	-43%	-63%	-56%

UK - CATRADER 20.0 Domain						
EP (Return Period)	Overall Change					
	Insurable Aggregate			Insurable Occurrence		
	RES	COM/IND	TOTAL	RES	COM/IND	TOTAL
10% (10 yr)	N/A	N/A	N/A	N/A	N/A	N/A
4% (25 yr)	257%	35%	122%	230%	19%	102%
2% (50 yr)	2%	-28%	-14%	-8%	-35%	-26%
1% (100 yr)	-58%	-68%	-69%	-63%	-69%	-71%
0.5% (200 yr)	-80%	-85%	-85%	-82%	-86%	-86%
0.2% (500 yr)	-82%	-88%	-87%	-82%	-88%	-87%
0.1% (1,000 yr)	-62%	-81%	-74%	-67%	-83%	-76%
Est. AAL	-46%	-67%	-60%	-50%	-70%	-63%

East Midlands						
EP (Return Period)	Overall Change					
	Insurable Aggregate			Insurable Occurrence		
	RES	COM/IND	TOTAL	RES	COM/IND	TOTAL
10% (10 yr)	N/A	N/A	N/A	N/A	N/A	N/A
4% (25 yr)	-88%	-48%	-75%	-88%	-57%	-77%
2% (50 yr)	-97%	-95%	-96%	-98%	-96%	-97%
1% (100 yr)	-95%	-96%	-95%	-95%	-96%	-95%
0.5% (200 yr)	-94%	-98%	-96%	-94%	-98%	-96%
0.2% (500 yr)	-94%	-98%	-96%	-94%	-98%	-97%
0.1% (1,000 yr)	-68%	-90%	-81%	-70%	-91%	-82%
Est. AAL	-80%	-90%	-86%	-80%	-90%	-86%

East of England						
EP (Return Period)	Overall Change					
	Insurable Aggregate			Insurable Occurrence		
	RES	COM/IND	TOTAL	RES	COM/IND	TOTAL
10% (10 yr)	N/A	N/A	N/A	N/A	N/A	N/A
4% (25 yr)	>500%	481%	>500%	>500%	420%	>500%
2% (50 yr)	126%	-46%	4%	106%	-53%	-7%
1% (100 yr)	-41%	-75%	-61%	-46%	-79%	-65%
0.5% (200 yr)	-64%	-86%	-76%	-69%	-87%	-78%
0.2% (500 yr)	-72%	-84%	-82%	-73%	-84%	-82%
0.1% (1,000 yr)	-77%	-79%	-82%	-80%	-79%	-83%
Est. AAL	-15%	-49%	-36%	-21%	-54%	-41%

London						
EP (Return Period)	Overall Change					
	Insurable Aggregate			Insurable Occurrence		
	RES	COM/IND	TOTAL	RES	COM/IND	TOTAL
10% (10 yr)	N/A	N/A	N/A	N/A	N/A	N/A
4% (25 yr)	N/A	N/A	N/A	N/A	N/A	N/A
2% (50 yr)	N/A	N/A	N/A	N/A	N/A	N/A
1% (100 yr)	283%	71%	142%	280%	68%	134%
0.5% (200 yr)	-14%	-40%	-33%	-14%	-42%	-34%
0.2% (500 yr)	-44%	-78%	-68%	-45%	-78%	-68%
0.1% (1,000 yr)	-81%	-92%	-89%	-81%	-92%	-89%

London						
EP (Return Period)	Overall Change					
	Insurable Aggregate			Insurable Occurrence		
	RES	COM/IND	TOTAL	RES	COM/IND	TOTAL
Est. AAL	-57%	-84%	-77%	-57%	-85%	-77%

North East						
EP (Return Period)	Overall Change					
	Insurable Aggregate			Insurable Occurrence		
	RES	COM/IND	TOTAL	RES	COM/IND	TOTAL
10% (10 yr)	N/A	N/A	N/A	N/A	N/A	N/A
4% (25 yr)	>500%	27%	51%	>500%	17%	32%
2% (50 yr)	-28%	-27%	-26%	-39%	-42%	-34%
1% (100 yr)	-83%	-49%	-68%	-84%	-57%	-72%
0.5% (200 yr)	-89%	-76%	-84%	-90%	-78%	-86%
0.2% (500 yr)	-90%	-76%	-81%	-90%	-78%	-82%
0.1% (1,000 yr)	-91%	-73%	-80%	-92%	-74%	-81%
Est. AAL	-78%	-29%	-45%	-80%	-38%	-53%

South East						
EP (Return Period)	Overall Change					
	Insurable Aggregate			Insurable Occurrence		
	RES	COM/IND	TOTAL	RES	COM/IND	TOTAL
10% (10 yr)	N/A	N/A	N/A	N/A	N/A	N/A
4% (25 yr)	420%	31%	145%	394%	23%	133%
2% (50 yr)	112%	42%	61%	103%	40%	59%
1% (100 yr)	41%	56%	53%	29%	56%	52%
0.5% (200 yr)	17%	43%	29%	6%	36%	23%
0.2% (500 yr)	-55%	-68%	-68%	-59%	-68%	-70%
0.1% (1,000 yr)	-65%	-80%	-75%	-66%	-80%	-75%
Est. AAL	39%	-26%	-9%	31%	-29%	-14%

Yorkshire						
EP (Return Period)	Overall Change					
	Insurable Aggregate			Insurable Occurrence		
	RES	COM/IND	TOTAL	RES	COM/IND	TOTAL
10% (10 yr)	N/A	N/A	N/A	N/A	N/A	N/A

Yorkshire						
EP (Return Period)	Overall Change					
	Insurable Aggregate			Insurable Occurrence		
	RES	COM/IND	TOTAL	RES	COM/IND	TOTAL
4% (25 yr)	120%	-75%	-50%	65%	-86%	-66%
2% (50 yr)	126%	-85%	-69%	103%	-90%	-75%
1% (100 yr)	-61%	-88%	-85%	-66%	-88%	-86%
0.5% (200 yr)	-91%	-86%	-87%	-92%	-86%	-87%
0.2% (500 yr)	-83%	-79%	-81%	-84%	-79%	-81%
0.1% (1,000 yr)	-42%	-63%	-58%	-47%	-63%	-58%
Est. AAL	-53%	-69%	-64%	-55%	-72%	-66%

4.9 Analysis Settings

Table 61. CATRADER/Touchstone Re analysis settings for model runs to determine OCCURRENCE and AGGREGATE loss changes - surge only 20.0 vs surge only 21.0

Setting	Selected Option(s)
Perils modeled	• Flood/Coastal Flood
Catalog	10,000 year
Industry exposure vintage	2017
Take-up rates	None
Demand surge*	Off

Table 62. CATRADER/Touchstone Re analysis settings for model runs to determine OCCURRENCE and AGGREGATE loss changes - wind only 20.0 vs wind + surge 21.0

Setting	Selected Option(s)
Perils modeled	• Wind/Winterstorm (CATRADER) • Wind/Tropical Cyclone (Touchstone Re)
Catalog	10,000 year
Industry exposure vintage	2017
Take-up rates	None
Demand surge*	Off

* Development of region-specific demand-surge functions is currently underway at AIR. While AIR recommends incorporating demand surge into modeled loss estimates where appropriate, AIR makes no recommendation as to the form of the demand-surge function for wind nor storm surge in Europe. Clients may apply a user-defined demand-surge function if they choose.

5 The AIR Hurricane Model for the United States

5.1 Overview of Model Updates and Changes

The AIR Hurricane Model for the United States is updated in the 2019 release to include:

- Historical catalog updates based on the most recent release of the North Atlantic Hurricane Database (HURDAT2)
- Stochastic catalog updates to the 10K and 50K Standard and WSST stochastic catalogs
- Building and component age updates.
- Event-level demand surge factor updates
- Unknown year-built vulnerability factor updates to reflect the age of the building stock in 2018

Other software enhancements include:

- ZIP code database updates to December 2018
- Support for the marine cargo line of business, including inland transit, ocean-going cargo, and marine hull

5.2 Catalogs and Event Sets

Updates to the Historical Catalog

The historical catalog incorporates the most recent release of the North Atlantic Hurricane Database, HURricane DATa 2nd generation (HURDAT2) from the National Oceanic and Atmospheric Administration (NOAA). This is NOAA's official record of all known tropical cyclones and subtropical cyclones since 1851. Of particular significance, HURDAT2 provides the “best track” analysis of storm tracks and intensity, as well as explicit estimates of landfall time and location and radius of maximum winds.

Based on HURDAT2 data as of September 2016, the historical catalog is updated to contain:

- Two additional hurricanes
- Three re-analyzed storms

Data from the three re-analyzed hurricanes is included in the model's historical catalog.

The additional hurricanes are:

- Hermine (2016)

- Matthew (2016)

The re-analyzed hurricanes are:

- Flossy (1956)
- Donna (1960)
- Ethel (1960)

As a result of the re-analysis, the tracks of these three storms did not significantly change. For Hurricane Donna, the intensity increased a bit over the Florida Keys and decreased at the other three landfall locations.

2017 events supported in the historical event set are:

- Harvey (2017)
- Irma (2017)

Updates to the Stochastic Catalog

HURDAT2 is the foundation of AIR's stochastic catalog; therefore, changes to storm parameters and landfall distributions in the historical catalog drive similar changes in the Standard and in the Warm Sea Surface Temperature (WSST) 10K and 50K stochastic catalogs. AIR researchers have re-calibrated landfall frequency distribution for Florida and adjacent states. This was accomplished, as in the prior update, by adding, removing, and moving a small fraction of the storms.

5.3 Wind Vulnerability and Damage Estimation

Vulnerability and damage estimation updates include:

- Updates to building and component age (updated to 2018)
- Updates to unknown year-built factors to be relevant through 2018, using the latest census and tax assessor data for building stock age
- Updates to roof age bands to be current as of 2018
- Enhancements to the support for the marine lines of business to explicitly model the vulnerability of:
    - Inland transit/transit warehouse cargo
    - Marine hull
    - Ocean-going cargo

Updates to Building and Component Age

Vulnerability adjustments were made to account for the additional aging and deterioration of buildings and components, and of roofs in particular, since the previous model release. Building technology changes through 2018 were also incorporated into the model.

The Roof Year-Built secondary risk characteristic was enhanced to default to a new roof Year-Built for structures built within the last ten years.

Updates to Unknown Year-Built Factors

When the user does not provide year-built information, the model uses pre-computed factors that adjust the base wind structural vulnerability. The underlying year-built weighting assumptions were updated to reflect the latest census and tax assessor data, through 2018, to determine building stock age.

Support for the Marine Lines of Business

The Hurricane Model for the United States now explicitly models damage estimation due to wind and storm surge for the marine lines of business, including:

- Inland transit/transit warehouse cargo (construction code 259)
- Marine hull (construction code 260)
- Ocean-going cargo (construction codes 270-276)

Inland Transit / Transit Warehouse Cargo Risks

The updated model contains damage functions that model cargo located in warehouses as well as the warehouses themselves. The following occupancy codes are supported for inland transit/transit warehouse cargo risks:

- 300: Unknown
- 313: Wholesale
- 322: Heavy fabrication
- 323: Light fabrication
- 324: Food and drug
- 325: Chemical processing
- 327: High technology

The cargo risks are considered to be coverage C. The replacement value of the warehouse itself is considered to be coverage A.

Marine Hull Risks

The updated model contains damage functions that model physical damage to a vessel or to its machinery and equipment. Examples of marine hull risks are the vessel's engine, lighting, and HVAC systems. The cargo inside the vessel is not included in marine hull risks. The following occupancy codes are supported for marine hull risks:

- 300: Unknown
- 314: Marine hull receiving repair services
- 354: Marine hull at port
- 381: Marine hull under construction

The replacement value of the vessel and its machinery is classified as coverage A. Enter the exposure value at the time of the event into the software in terms of the average daily exposure. For occupancy code 381, use the total replacement value.

Ocean-going Cargo Risks

The updated model contains damage functions that model physical damage to cargo and related liabilities when the cargo is in transit by sea and when the cargo is in storage for less than 60 days. Enter the risk location as the location of the residence or the business location of the insured property.

Ocean-going cargo is classified using the following construction codes:

- 270: Carpool--cars parked in open areas near harbors before shipment on car containers
- 271: General and containerized cargo--transport freight on ships. They are approximately 20-40 ft long by 8 ft wide by 8 ft high.
- 272: Heavy cargo--oversized items that are too large to fit into general cargo containers
- 273: Refrigerated cargo--contain additional electrical cooling equipment to maintain temperatures in the containers
- 274: Dry bulk cargo--grains and solid materials such as coal, metal, and lumber that are stored on the ground in an open yard
- 275: Liquid bulk cargo--onshore tanks that store oil, liquid natural gas, and liquid chemicals
- 276: General/unknown

The Sea and Inland Waterways occupancy code 354 is supported for ocean-going cargo risks.

The replacement value of the ocean-going cargo is classified as coverage A. Enter the exposure value into the software as the daily exposure.

5.4 Industry Exposure Database

The United States Industry Exposure Database December 2017 version is used in the updated model.

The updates to the United States Industry Exposure Database include updates to the event-level demand surge factors for exposures in the United States.

5.5 General Impact of Model Updates on Loss Estimates

The following tables show the overall impact of the updates to the AIR Hurricane Model for the United States on gross insurable occurrence and aggregate losses. Loss changes represent the percentage change in loss estimates calculated by CATRADER 21.0 as compared with those calculated by version 20.0 and from the previous version of Touchstone Re to version 7.0 for all modeled states combined, as well as by region. The regions are defined as follows:

Florida	
Texas	
Gulf States	Alabama, Louisiana, Mississippi
Southeast	Georgia, North Carolina, South Carolina
Mid-Atlantic	Delaware, Maryland, Pennsylvania, Virginia, Washington D.C.
Northeast	Connecticut, Massachusetts, Maine, New Hampshire, New Jersey, New York, Rhode Island, Vermont
Interior	Arkansas, Illinois, Indiana, Kentucky, Missouri, Ohio, Oklahoma, Tennessee, West Virginia

CATRADER and Touchstone Re settings used in the associated model runs are provided in the next section.

Note that caution should be exercised before relating the industry changes shown here to a particular portfolio. The changes to individual books of business may deviate from the losses represented here to the extent that their spatial distribution and construction/occupancy mix deviate from industry averages.

The following table shows the percentage change in gross insurable occurrence loss estimates using the 10,000-year Standard catalog. The losses due to wind and storm surge are combined. Demand surge is included.

Table 63. Percentage change in insurable occurrence loss estimates using the 10K Standard catalog

All Modeled States					
10K Standard Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	0%	0%	-1%	0%
2% (50 yr)	1%	0%	0%	0%	1%
1% (100 yr)	0%	0%	2%	0%	0%
0.4% (250 yr)	0%	0%	1%	0%	0%
0.2% (500 yr)	1%	0%	0%	0%	0%
0.1% (1000 yr)	1%	0%	-1%	0%	0%
Est. AAL	**0%**	**0%**	**0%**	**0%**	**0%**

Gulf States					
10K Standard Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	-1%	0%	-2%	0%	-1%
2% (50 yr)	0%	0%	-3%	-1%	-1%
1% (100 yr)	0%	0%	-3%	0%	0%
0.4% (250 yr)	0%	0%	-2%	0%	-2%
0.2% (500 yr)	0%	0%	-1%	0%	-1%
0.1% (1000 yr)	0%	0%	-2%	0%	0%
Est. AAL	**0%**	**0%**	**-2%**	**-1%**	**-1%**

Interior					
10K Standard Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	0%	-2%	-1%	-1%
2% (50 yr)	0%	0%	-1%	0%	0%
1% (100 yr)	0%	-1%	-3%	-1%	-1%
0.4% (250 yr)	0%	0%	-1%	0%	0%
0.2% (500 yr)	1%	0%	-1%	0%	0%
0.1% (1000 yr)	0%	0%	-1%	0%	0%

Interior					
10K Standard Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
Est. AAL	**0%**	**0%**	**-1%**	**0%**	**0%**

Mid Atlantic					
10K Standard Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	0%	-2%	0%	0%
2% (50 yr)	1%	0%	-1%	0%	0%
1% (100 yr)	1%	0%	-2%	0%	0%
0.4% (250 yr)	1%	0%	-3%	0%	0%
0.2% (500 yr)	1%	0%	0%	0%	0%
0.1% (1000 yr)	1%	0%	-1%	0%	0%
Est. AAL	**1%**	**0%**	**-2%**	**0%**	**0%**

Northeast					
10K Standard Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	0%	-2%	0%	1%
2% (50 yr)	1%	-1%	1%	0%	0%
1% (100 yr)	1%	1%	0%	0%	1%
0.4% (250 yr)	1%	0%	3%	0%	1%
0.2% (500 yr)	1%	0%	2%	0%	1%
0.1% (1000 yr)	2%	0%	1%	0%	1%
Est. AAL	**1%**	**0%**	**1%**	**0%**	**1%**

Southeast					
10K Standard Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	0%	-1%	0%	0%

Southeast					
10K Standard Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
2% (50 yr)	1%	0%	-1%	0%	0%
1% (100 yr)	0%	0%	-2%	0%	0%
0.4% (250 yr)	-1%	0%	-2%	0%	-1%
0.2% (500 yr)	-1%	0%	-1%	0%	0%
0.1% (1000 yr)	0%	0%	-1%	0%	0%
Est. AAL	**1%**	**0%**	**-1%**	**0%**	**0%**

US - Florida					
10K Standard Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	0%	0%	-1%	1%
2% (50 yr)	0%	-1%	0%	0%	0%
1% (100 yr)	1%	0%	1%	0%	1%
0.4% (250 yr)	1%	0%	0%	0%	1%
0.2% (500 yr)	0%	0%	1%	0%	0%
0.1% (1000 yr)	0%	0%	0%	0%	0%
Est. AAL	**0%**	**0%**	**0%**	**-1%**	**0%**

US - Texas					
10K Standard Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	0%	1%	0%	1%
2% (50 yr)	1%	0%	2%	-1%	0%
1% (100 yr)	0%	0%	2%	0%	1%
0.4% (250 yr)	0%	0%	3%	0%	2%
0.2% (500 yr)	0%	0%	1%	0%	1%
0.1% (1000 yr)	1%	0%	2%	0%	1%
Est. AAL	**1%**	**0%**	**2%**	**0%**	**1%**

The following table shows the percentage change in gross insurable occurrence loss estimates using the 10,000-year Warm Sea Surface Temperature (WSST) catalog. The losses are due to the combination of wind and storm surge. Demand surge is included.

Table 64. Percentage change in insurable occurrence loss estimates using the 10K WSST catalog

All Modeled States					
10K WSST Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	0%	0%	0%	0%
2% (50 yr)	1%	0%	0%	0%	0%
1% (100 yr)	0%	0%	0%	0%	0%
0.4% (250 yr)	1%	0%	0%	0%	0%
0.2% (500 yr)	1%	0%	0%	0%	0%
0.1% (1000 yr)	0%	0%	0%	0%	1%
Est. AAL	**0%**	**0%**	**0%**	**0%**	**0%**

Gulf States					
10K WSST Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	0%	-2%	0%	-1%
2% (50 yr)	0%	0%	-3%	-1%	-2%
1% (100 yr)	0%	0%	-4%	-1%	0%
0.4% (250 yr)	0%	0%	-2%	0%	-1%
0.2% (500 yr)	0%	0%	-3%	0%	0%
0.1% (1000 yr)	0%	0%	-1%	0%	0%
Est. AAL	**0%**	**0%**	**-2%**	**-1%**	**-1%**

Interior					
10K WSST Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	0%	-1%	0%	-1%
2% (50 yr)	0%	-1%	-1%	0%	0%
1% (100 yr)	0%	0%	-2%	0%	0%

Interior					
10K WSST Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
0.4% (250 yr)	1%	0%	0%	0%	0%
0.2% (500 yr)	0%	0%	-1%	0%	0%
0.1% (1000 yr)	1%	0%	1%	0%	0%
Est. AAL	**0%**	**0%**	**-1%**	**0%**	**0%**

Mid Atlantic					
10K WSST Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	1%	-2%	0%	0%
2% (50 yr)	0%	0%	-1%	0%	0%
1% (100 yr)	1%	1%	-1%	0%	0%
0.4% (250 yr)	1%	0%	0%	0%	0%
0.2% (500 yr)	1%	0%	-2%	0%	0%
0.1% (1000 yr)	1%	0%	-1%	0%	0%
Est. AAL	**1%**	**0%**	**-1%**	**0%**	**0%**

Northeast					
10K WSST Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	-1%	-2%	0%	1%
2% (50 yr)	0%	1%	2%	1%	1%
1% (100 yr)	1%	-1%	2%	0%	1%
0.4% (250 yr)	1%	0%	2%	0%	1%
0.2% (500 yr)	1%	0%	2%	0%	1%
0.1% (1000 yr)	2%	0%	1%	0%	1%
Est. AAL	**1%**	**0%**	**1%**	**0%**	**1%**

Southeast					
10K WSST Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	0%	-2%	0%	0%
2% (50 yr)	1%	0%	-2%	0%	0%
1% (100 yr)	1%	0%	-1%	0%	0%
0.4% (250 yr)	0%	-1%	-1%	0%	0%
0.2% (500 yr)	0%	0%	-1%	1%	0%
0.1% (1000 yr)	1%	0%	-1%	0%	0%
Est. AAL	**0%**	**0%**	**-1%**	**0%**	**0%**

US - Florida					
10K WSST Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	0%	0%	-1%	0%
2% (50 yr)	1%	-1%	0%	0%	0%
1% (100 yr)	0%	0%	0%	-3%	0%
0.4% (250 yr)	0%	0%	1%	0%	0%
0.2% (500 yr)	0%	0%	0%	0%	0%
0.1% (1000 yr)	1%	0%	0%	0%	0%
Est. AAL	**0%**	**0%**	**0%**	**-1%**	**0%**

US - Texas					
10K WSST Catalog - Insurable Occurrence					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	0%	0%	-1%	0%
2% (50 yr)	1%	1%	2%	0%	0%
1% (100 yr)	1%	0%	2%	-1%	1%
0.4% (250 yr)	1%	0%	2%	0%	1%
0.2% (500 yr)	-1%	0%	2%	0%	1%
0.1% (1000 yr)	1%	0%	3%	0%	1%
Est. AAL	**1%**	**0%**	**2%**	**0%**	**1%**

The following table shows the percentage change in gross insurable aggregate loss estimates using the 10,000-year Standard catalog. The losses are due to the combination of wind and storm surge. Demand surge is included.

Table 65. Percentage change in insurable aggregate loss estimates using the 10K Standard catalog

All Modeled States					
10K Standard Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	0%	-1%	0%	0%
2% (50 yr)	1%	0%	0%	0%	0%
1% (100 yr)	0%	0%	0%	0%	1%
0.4% (250 yr)	1%	0%	1%	0%	1%
0.2% (500 yr)	0%	0%	1%	0%	0%
0.1% (1000 yr)	1%	-1%	0%	0%	0%
Est. AAL	**0%**	**0%**	**0%**	**-1%**	**0%**

Gulf States					
10K Standard Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	0%	-2%	-1%	-2%
2% (50 yr)	0%	0%	-2%	-1%	-1%
1% (100 yr)	0%	0%	-2%	-4%	-1%
0.4% (250 yr)	0%	0%	-1%	0%	-1%
0.2% (500 yr)	0%	0%	-2%	0%	-1%
0.1% (1000 yr)	0%	0%	-1%	0%	0%
Est. AAL	**0%**	**0%**	**-2%**	**-1%**	**-1%**

Interior					
10K Standard Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	-1%	-2%	-1%	0%
2% (50 yr)	0%	0%	-1%	-2%	-2%
1% (100 yr)	-1%	0%	-1%	0%	0%

Interior					
10K Standard Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
0.4% (250 yr)	0%	0%	-1%	0%	0%
0.2% (500 yr)	1%	0%	-1%	0%	0%
0.1% (1000 yr)	0%	0%	0%	0%	0%
Est. AAL	**0%**	**0%**	**-1%**	**0%**	**0%**

Mid Atlantic					
10K Standard Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	0%	-2%	0%	1%
2% (50 yr)	1%	1%	-1%	0%	0%
1% (100 yr)	1%	1%	-2%	-1%	0%
0.4% (250 yr)	1%	0%	-2%	0%	0%
0.2% (500 yr)	1%	0%	0%	0%	0%
0.1% (1000 yr)	1%	0%	-1%	0%	0%
Est. AAL	**1%**	**0%**	**-2%**	**0%**	**0%**

Northeast					
10K Standard Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	-1%	-4%	0%	2%
2% (50 yr)	0%	0%	0%	0%	1%
1% (100 yr)	1%	0%	1%	0%	2%
0.4% (250 yr)	1%	1%	3%	0%	1%
0.2% (500 yr)	2%	0%	2%	0%	1%
0.1% (1000 yr)	1%	0%	1%	0%	1%
Est. AAL	**1%**	**0%**	**1%**	**0%**	**1%**

Southeast					
10K Standard Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	0%	-1%	0%	0%
2% (50 yr)	1%	0%	-1%	0%	0%
1% (100 yr)	0%	-1%	-2%	0%	0%
0.4% (250 yr)	0%	-1%	-1%	0%	0%
0.2% (500 yr)	0%	-1%	-2%	0%	-1%
0.1% (1000 yr)	0%	0%	-1%	0%	0%
Est. AAL	**1%**	**0%**	**-1%**	**0%**	**0%**

US - Florida					
10K Standard Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	-1%	0%	0%	0%	0%
2% (50 yr)	0%	0%	-1%	0%	0%
1% (100 yr)	1%	0%	0%	0%	0%
0.4% (250 yr)	0%	0%	0%	0%	0%
0.2% (500 yr)	0%	0%	1%	0%	1%
0.1% (1000 yr)	1%	0%	0%	0%	0%
Est. AAL	**0%**	**0%**	**0%**	**-1%**	**0%**

US - Texas					
10K Standard Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	0%	1%	-1%	1%
2% (50 yr)	1%	0%	2%	-1%	0%
1% (100 yr)	1%	0%	2%	-1%	1%
0.4% (250 yr)	-1%	0%	3%	0%	2%
0.2% (500 yr)	0%	0%	2%	0%	1%
0.1% (1000 yr)	1%	0%	2%	-1%	1%
Est. AAL	**1%**	**0%**	**2%**	**0%**	**1%**

The following table shows the percentage change in gross insurable aggregate loss estimates using the 10,000-year Warm Sea Surface Temperature (WSST) catalog. The losses are due to the combination of wind and storm surge. Demand surge is included.

Table 66. Percentage change in insurable aggregate loss estimates using the 10K WSST catalog

All Modeled States					
10K WSST Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	0%	0%	0%	0%
2% (50 yr)	1%	0%	0%	0%	0%
1% (100 yr)	0%	-1%	0%	0%	0%
0.4% (250 yr)	0%	0%	-1%	0%	0%
0.2% (500 yr)	1%	0%	0%	0%	0%
0.1% (1000 yr)	1%	0%	0%	0%	0%
Est. AAL	**0%**	**0%**	**0%**	**-1%**	**0%**

Gulf States					
10K WSST Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	0%	-3%	0%	-1%
2% (50 yr)	0%	-1%	-3%	-1%	-1%
1% (100 yr)	0%	-1%	-6%	0%	-2%
0.4% (250 yr)	0%	0%	-2%	0%	-1%
0.2% (500 yr)	0%	0%	-2%	0%	-1%
0.1% (1000 yr)	0%	0%	-1%	0%	-2%
Est. AAL	**0%**	**0%**	**-2%**	**-1%**	**-1%**

Interior					
10K WSST Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	-1%	-1%	0%	0%
2% (50 yr)	0%	0%	-1%	0%	0%
1% (100 yr)	0%	-1%	0%	0%	0%

Interior					
10K WSST Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
0.4% (250 yr)	0%	0%	0%	0%	0%
0.2% (500 yr)	0%	0%	-1%	0%	0%
0.1% (1000 yr)	0%	0%	-1%	0%	0%
Est. AAL	**0%**	**0%**	**-1%**	**0%**	**0%**

Mid Atlantic					
10K WSST Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	0%	-2%	0%	0%
2% (50 yr)	1%	0%	-1%	0%	0%
1% (100 yr)	1%	1%	0%	0%	0%
0.4% (250 yr)	1%	0%	-3%	0%	0%
0.2% (500 yr)	1%	0%	-2%	0%	0%
0.1% (1000 yr)	1%	0%	-2%	0%	0%
Est. AAL	**1%**	**0%**	**-1%**	**0%**	**0%**

Northeast					
10K WSST Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	0%	-3%	0%	1%
2% (50 yr)	1%	0%	2%	0%	1%
1% (100 yr)	1%	0%	2%	0%	1%
0.4% (250 yr)	1%	1%	3%	0%	1%
0.2% (500 yr)	2%	0%	2%	0%	1%
0.1% (1000 yr)	1%	0%	1%	0%	1%
Est. AAL	**1%**	**0%**	**1%**	**0%**	**1%**

Southeast					
10K WSST Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	0%	-1%	0%	0%
2% (50 yr)	1%	-1%	-2%	0%	0%
1% (100 yr)	0%	-1%	-1%	-1%	0%
0.4% (250 yr)	0%	0%	-1%	0%	0%
0.2% (500 yr)	0%	0%	-2%	0%	0%
0.1% (1000 yr)	0%	0%	0%	0%	0%
Est. AAL	**1%**	**0%**	**-1%**	**0%**	**0%**

US - Florida					
10K WSST Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	0%	0%	0%	-1%	0%
2% (50 yr)	0%	-1%	0%	-1%	0%
1% (100 yr)	0%	0%	0%	0%	0%
0.4% (250 yr)	0%	0%	0%	0%	1%
0.2% (500 yr)	0%	0%	0%	0%	0%
0.1% (1000 yr)	1%	0%	0%	0%	0%
Est. AAL	**0%**	**0%**	**0%**	**-1%**	**0%**

US - Texas					
10K WSST Catalog - Insurable Aggregate					
Exceedance Probability (Return Period)	Overall Change				
	Residential	Manufactured Home	Commercial	Auto	Total
5% (20yr)	1%	0%	1%	-1%	1%
2% (50 yr)	0%	0%	1%	0%	2%
1% (100 yr)	2%	1%	3%	-1%	1%
0.4% (250 yr)	1%	0%	4%	0%	1%
0.2% (500 yr)	1%	0%	1%	0%	1%
0.1% (1000 yr)	1%	0%	2%	-1%	1%
Est. AAL	**1%**	**0%**	**2%**	**0%**	**1%**

5.6 Analysis Settings

Table 67. CATRADER/Touchstone Re analysis settings for model runs to determine the loss changes.

Setting	Selected Option(s)
Perils modeled	Wind and storm surge combined
Catalog	10,000-year Standard 10,000-year Warm Sea Surface Temperature (WSST)
Industry exposure vintage	October 2017
Take-up rates	N/A Analyses were done for insurable loss estimates only. Take-up rates do not apply.
Demand surge*	On

* Development of region-specific demand-surge functions is currently underway at AIR. While AIR recommends incorporating demand surge into modeled loss estimates where appropriate, AIR makes no recommendation as to the form of the demand-surge function for hurricanes in the United States. Clients may apply a user-defined demand-surge function if they choose.

6 The AIR U.S. Hurricane Model for Offshore Assets

6.1 Overview of Model Updates and Changes

The AIR U.S. Hurricane Model for Offshore Assets is updated in the 2019 release to include:

- Historical catalog updates based on the most recent release of the North Atlantic Hurricane Database (HURDAT2)
- Stochastic catalog updates to the Standard and WSST 10K and 50K stochastic catalogs
- Industry Exposure Database updates that account for changes in the counts, locations, and production rates of platforms and rigs in the Gulf of Mexico (GOM).
- Replacement cost updates to current values
- Oil and gas market prices updates to current values

6.2 Catalogs and Event Sets

Updates to the Stochastic Catalog

HURDAT is the foundation of AIR's stochastic catalog. Therefore, changes to storm parameters and landfall distributions in HURDAT2 as of September 2016 drive similar changes in the Standard and in the Warm Sea Surface Temperature (WSST) 10K and 50K stochastic catalogs. This was accomplished, as in prior updates, by adding, removing, and moving a small fraction of the storms. The stochastic catalog for the AIR U.S. Hurricane Model for Offshore Assets is consistent with the stochastic catalog for the AIR Hurricane Model for the United States.

6.3 Update to the Industry Exposure Database

The Industry Exposure Database is updated to reflect changes in the counts, locations, and production rates of platforms and rigs in the Gulf of Mexico. Replacement values were updated to current values, and the market prices of oil and gas were updated to current prices.

Data regarding moveable exposures (mobile rigs and floating platforms) is obtained from RigLogix, a product of RigZone. Data regarding platforms in federal waters is obtained from the Bureau of Ocean Energy Management (BOEM). Both databases are current to the end of 2018. The market prices of oil and gas were updated using data from BOEM and the U.S. Energy Information Administration (EIA).

Compared to the previous release of the model in CATRADER 20.0), the total number of platforms has decreased by about 5%. The total replacement value of the AIR industry exposure in CATRADER 21.0 has decreased by about 5% as compared to CATRADER 19.0.

In CATRADER 21.0, the production rate of gas has decreased by about 15% and the production rate of oil has decreased by 2% in comparison to CATRADER 19.0. The production rates for assets in federal waters were revised based on 2018 production reports from BOEMRE.

The following table summarizes the changes in exposure between CATRADER 21.0 and CATRADER 20.0. Note that the numbers in the table represent active platforms capable of producing losses today.

Table 68. Summary of exposure changes to active platforms and rigs, CATRADER 21.0 and CATRADER 20.0

Parameter	CATRADER 20.0	CATRADER 21.0	Percent Change
Number of Platforms and Rigs	3,935	3,749	-5%
Replacement Value (USD billions)	128.1	121.9	-5%
Oil Production (BLLS/day)	1,769,700	1,732,357	-2%
Gas Production (MCF/day)	3,167,908	2,680,253	-15%
Oil Unit Price (USD/BLLS)	51.86	68.64	32%
Gas Unit Price (USD/MCF)	2.69	2.40	-11%

6.4 General Impact of Model Updates on Loss Estimates

The following tables illustrate the overall impact of the updates to the AIR U.S. Hurricane Model for Offshore Assets on loss estimates. Loss changes represent the percentage change in loss estimates calculated by CATRADER as compared with those calculated in the previous version of CATRADER and from the previous version of Touchstone Re to version 2019. The tables present the percentage change in insurable **ground-up** occurrence and aggregate losses, respectively, for offshore assets in the Gulf of Mexico. CATRADER and Touchstone Re settings used in the associated model runs are provided in the next section.

Note that to prepare the comparisons below, the price of oil ($68.64/bbl) used with the current model is also used in the comparison runs in order to avoid unrealistically large changes in business interruption losses.

Note that caution should be exercised before relating the industry changes shown here to a particular portfolio. The changes to individual books of business may deviate

from the losses represented here to the extent that their spatial distribution and construction/occupancy mix deviate from industry averages.

The following table shows the percentage change in insurable ground-up aggregate loss estimates, by line of business, using the 10,000-year Standard catalog. The analysis assumes a constant oil price of $68.64/BBL.

Table 69. Percentage change in insurable aggregate losses by LOB— 10K Standard Catalog

Gulf of Mexico						
Insurable Aggregate Losses						
Overall Change						
Exceedance Probability (Return Period)	**Physical Damage**	**Removal of Debris**	**Operator's Extra Expense**	**Total Excluding Business Interruption**	**Business Interruption**	**TOTAL**
5% (20 yr)	3%	33%	117%	35%	-2%	9%
2% (50 yr)	3%	12%	26%	15%	-2%	6%
1% (100 yr)	0%	7%	22%	10%	-4%	1%
0.4% (250 yr)	5%	3%	13%	6%	-5%	2%
0.2% (500 yr)	1%	3%	8%	10%	-5%	0%
0.1% (1000 yr)	4%	2%	7%	6%	-6%	0%
Est. AAL	**0%**	**25%**	**71%**	**28%**	**-4%**	**4%**

The following table shows the percentage change in insurable ground-up aggregate loss estimates, by line of business, using the 10,000-year Warm Sea Surface Temperature (WSST) catalog. The analysis assumes a constant oil price of $68.64/BBL.

Table 70. Percentage change in insurable aggregate losses by LOB— 10K WSST Catalog

Gulf of Mexico						
Insurable Aggregate Losses						
Overall Change						
Exceedance Probability (Return Period)	**Physical Damage**	**Removal of Debris**	**Operator's Extra Expense**	**Total Excluding Business Interruption**	**Business Interruption**	**TOTAL**
5% (20 yr)	2%	30%	106%	32%	-3%	9%
2% (50 yr)	1%	13%	27%	15%	-3%	6%
1% (100 yr)	1%	8%	20%	11%	-2%	3%
0.4% (250 yr)	4%	3%	13%	6%	-5%	3%
0.2% (500 yr)	1%	6%	8%	8%	-5%	-1%
0.1% (1000 yr)	4%	1%	11%	5%	-6%	0%

Gulf of Mexico						
Insurable Aggregate Losses						
Overall Change						
Exceedance Probability (Return Period)	Physical Damage	Removal of Debris	Operator's Extra Expense	Total Excluding Business Interruption	Business Interruption	TOTAL
Est. AAL	**0%**	**25%**	**70%**	**28%**	**-4%**	**3%**

The following table shows the percentage change in insurable ground-up occurrence loss estimates, by line of business, using the 10,000-year Standard catalog. The analysis assumes a constant oil price of $68.64/BBL.

Table 71. Percentage change in insurable occurrence losses by LOB— 10K Standard Catalog

Gulf of Mexico						
Insurable Occurrence Losses						
Overall Change						
Exceedance Probability (Return Period)	Physical Damage	Removal of Debris	Operator's Extra Expense	Total Excluding Business Interruption	Business Interruption	TOTAL
5% (20 yr)	3%	29%	92%	34%	-2%	12%
2% (50 yr)	4%	12%	24%	13%	-1%	7%
1% (100 yr)	3%	6%	16%	9%	-4%	3%
0.4% (250 yr)	-1%	3%	8%	5%	-6%	-2%
0.2% (500 yr)	3%	1%	7%	5%	-7%	3%
0.1% (1000 yr)	-5%	11%	6%	1%	-8%	-2%
Est. AAL	**0%**	**23%**	**66%**	**28%**	**-3%**	**7%**

The following table shows the percentage change in insurable ground-up occurrence loss estimates, by line of business, calculated using the 10,000-year WSST catalog. The analysis assumes a constant oil price of $68.64/BBL.

Table 72. Percentage change in insurable occurrence losses by LOB— 10K WSST Catalog

Gulf of Mexico						
Insurable Occurrence Losses						
Overall Change						
Exceedance Probability (Return Period)	Physical Damage	Removal of Debris	Operator's Extra Expense	Total Excluding Business Interruption	Business Interruption	TOTAL
5% (20 yr)	4%	25%	83%	30%	-2%	12%

Gulf of Mexico						
Insurable Occurrence Losses						
Overall Change						
Exceedance Probability (Return Period)	**Physical Damage**	**Removal of Debris**	**Operator's Extra Expense**	**Total Excluding Business Interruption**	**Business Interruption**	**TOTAL**
2% (50 yr)	4%	12%	23%	14%	0%	6%
1% (100 yr)	3%	6%	16%	10%	-2%	3%
0.4% (250 yr)	-2%	3%	7%	4%	-5%	-1%
0.2% (500 yr)	1%	2%	6%	7%	-7%	2%
0.1% (1000 yr)	-5%	0%	9%	4%	-8%	-2%
Est. AAL	**0%**	**23%**	**65%**	**28%**	**-3%**	**7%**

6.5 Analysis Settings

Table 73. CATRADER/Touchstone Re analysis settings for model runs to determine the loss changes.

Setting	Selected Option(s)
Perils modeled	Wind and waves combined
Catalog	10,000-year Standard 10,000-year Warm Sea Surface Temperature (WSST)
Industry exposure vintage	October 2018
Take-up rates	N/A Analyses were done for insurable loss estimates only. In both the CATRADER 20.0 and CATRADER 21.0 runs, 100% market share was assumed. Therefore, take-up rates do not apply.
Demand surge	Off
Price of Oil	$68.64/BBL
Price of Gas	$2.40/MCF

7 Event ID Updates

The following table indicates changed event IDs in the updated models for CATRADER and Touchstone Re in 2019.

Table 74. Event ID Updates

AIR Model	Changed Event IDs
AIR Earthquake Model for New Zealand	Stochastic
AIR Inland Flood Model for Central Europe	Stochastic
AIR Extratropical Cyclone Model for Europe	Historical[6]
AIR Hurricane Model for the United States	Stochastic[7]
AIR U.S. Hurricane Model for Offshore Assets	Stochastic[7]

[6] Historical Event IDs have been renumbered in the AIR Extratropical Cyclone Model for Europe to accommodate storm surge events added with the inclusion of the storm surge peril for Great Britain.

[7] Stochastic event IDs will not change from the standpoint that an event with the same ID will be the same event in terms of wind speed parameters. However, some events are added, moved (in terms of longitude and latitude), or dropped to achieve consistency in the frequency and severity of stochastic events with the latest historical HURDAT database.

8 Industry Exposure Database Updates

With the release of updated versions of CATRADER and Touchstone Re, AIR is providing a full exposure update of the high-resolution AIR Industry Exposure Database for New Zealand, which is current as of the end of 2018. The Industry Exposure Database is constructed at a high resolution 1-km grid. Large industrial facilities are identified and valued individually and are separated from the rest of the industrial line. Additionally, residential land is included as its own line of business to support modeling of this risk type in the updated AIR Earthquake Model for New Zealand.

The Industry Exposure Database for Offshore Assets in the Gulf of Mexico is updated for the 2019 release of CATRADER and Touchstone Re to account for updates to the replacement values, counts, locations, and production of platforms and rigs in the Gulf of Mexico. The data in the Industry Exposure Database for Offshore Assets in the Gulf of Mexico is current as of October 2018.

For the United States, AIR is releasing county-level industry exposure change factors by line of business. Country-level industry exposure change factors by line of business are provided for Australia, Canada, Central America, China, India, and Southeast Asia. These factors will not be reflected in the industry exposure or loss files packaged in CATRADER; however, they can be used in CATRADER as the basis for scaling industry loss estimates to reflect the change in total property values.

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.

AIR®
A Verisk Business