30 November 2018

Bermuda Monetary Authority

# Catastrophe Risk in Bermuda

*BSCR Stress Testing and Modelling Practice Analysis*

*2017 Report*

# Foreword

Bermuda is predominantly an insurance-based International Financial Centre specialising in the niche of catastrophe reinsurance.

With such a relatively high concentration of catastrophe risk in Bermuda's market, a broad understanding of the potential adverse impacts, including identification of any concentration risks and catastrophe modelling practices in Bermuda is central to the Bermuda Monetary Authority's (Authority or BMA) supervisory framework. This information is also important to Bermuda insurers and other stakeholders and markets around the globe.

Realising the significant role that Bermuda plays as a leader in the regulation of the catastrophe market, and in an effort to continue to reemphasize our commitment to high standards of transparency, the Authority produces this report, on an annual basis, to give a high-level overview of the catastrophe risk stress testing and modelling practices in Bermuda.

Overall, this year's results (2017) again highlighted the industry's resilience to major, but improbable, catastrophe events and the sophistication and advancement of the modelling practices in Bermuda. This underscored the reputation of Bermuda insurers as being generally well capitalised and technically proficient.

Compared to 2016, this year's net catastrophe exposure slightly decreased by about 2.0%, while the insurers have increased their statutory capital & surplus by 12.0%. Consequently, the overall industry's resilience to potential catastrophe events has further strengthened compared to last year. In addition, the global share of gross estimated potential loss assumed by Bermuda insurers on major catastrophe perils (combined) increased by about 2.0%. The increase in the statutory capital & surplus and global share are largely attributed to the inclusion of more insurance entities in the survey. The report also reviewed cyber risk stress testing and the analysis shows that the insurers' own defined worst impacts from cyber risk would have a minimal effect on their statutory capital.

Craig Swan
Managing Director, Supervision (Insurance)

## Catastrophe Risk Report

This is the third annual Catastrophe Risk Report published by the BMA. The content of this report is the result of analysis carried out by BMA staff. Should you have any questions, comments or suggestions to improve this report, please contact enquiries@bma.bm.

## About the BMA

The Authority was established by statute in 1969. Its role has evolved over the years to meet the changing needs in the financial services sector. Today it supervises, regulates and inspects financial institutions operating in the jurisdiction. It also issues Bermuda's national currency, manages exchange control transactions, assists other authorities with the detection and prevention of financial crime, and advises Government on banking and other financial and monetary matters.

The Authority develops risk-based financial regulations that it applies to the supervision of Bermuda's banks, trust companies, investment businesses, investment funds, fund administrators, money service businesses, corporate service providers, digital asset businesses and insurance companies. It also regulates the Bermuda Stock Exchange.

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This publication is available on the BMA website www.bma.bm

# Acronyms

| | |
|---|---|
| AAL | Average Annual Loss |
| AIR | AIR Worldwide |
| AMO | Atlantic Multi-decadal Oscillation |
| BMA | Bermuda Monetary Authority |
| BSCR | Bermuda Solvency Capital Requirement |
| BU | Business Unit |
| Cat | Catastrophe |
| Cat Return | Catastrophe Risk Return and Schedule of Risk Management |
| CSR | Capital and Solvency Return |
| EQECAT | Catastrophe Risk Management (CoreLogic) |
| EP | Exceedance Probability |
| IAIS | International Association of Insurance Supervisors |
| IFC | International Financial Centre |
| ILS | Insurance Linked Securities |
| ISD | Insurance Supervision Team |
| Mph | Miles per hour |
| PML | Probable Maximum Loss |
| RMS | Risk Management Solutions |
| RDS | Realistic Disaster Scenarios |
| The Authority | Bermuda Monetary Authority |
| SAC | Segregated Account Companies |
| SPI | Special Purpose Insurer |
| SST | Sea Surface Temperatures |
| TVaR | Tail Value at Risk |

# Contents

# 1. Executive Summary

This report has four main objectives. First, it gives a high-level overview of the capacity of the sector to absorb shocks from various Cat risk events underwritten by Bermuda insurers[1]. Second, the report reviews various stress tests to assess if Bermuda insurers are adequately capitalised to withstand severe, but remote, underwriting losses from various possible Cat events that might adversely impact their balance sheets. Third, the report analyses the exceedance probability curve trends, including the level of reliance and sufficiency of the reinsurance, and pricing dynamics. Finally, the report analyses the Cat modelling practices in Bermuda.

Overall, the 2017 Cat underwriting stress test results demonstrated that the Bermuda insurance market is resilient to potential adverse impacts from various global Cat underwriting loss scenarios, and that there is a variation in reliance on reinsurance by insurers. The results also establish Bermuda insurers' ability to absorb these unlikely potential large losses and still have capital remaining to settle policyholder obligations.

Same as last year, insurers will retain, on average, 76.0% on a gross basis (before reinsurance) of their statutory capital & surplus after the largest single Cat underwriting loss event. On a net basis (after reinsurance), insurers will retain approximately 92.0% of their statutory capital & surplus, an increase of 3 points from last year, after the largest single Cat underwriting loss event. These results highlight the industry's overall resilience. The results also show that there was no significant impact from the standardised terrorism stress scenario and cyber risk worst-case annual aggregate loss scenario carried out by insurers. Overall, the global share of gross estimated potential loss assumed by Bermuda insurers on the major catastrophe perils (combined) has increased by about 2.0%, largely attributed to the inclusion of more insurance entities in the survey.

An analysis of the exceedance probability curves demonstrates that Bermuda insurers are more exposed to Atlantic Hurricane than any other peril, with gross average modelled losses over all companies stretching from US$773.5 million for the "1-in-50" year events up to US$1.5 billion for the "1-in-1,000" year events. Other perils show lower modelled losses for the "1-in-50" and the "1-in-1,000" year events, however, with significant variation between firms. The use of reinsurance[2] is widespread with the Atlantic Hurricane net average

[1] For the purpose of this report, insurers also include reinsurers.
[2] Net results are also net of reinstatement premiums so not all of the differentials may arise from reinsurance.

modelled losses ranging from US $295.2 million for the “1-in-50” year events up to US $770.4 million for the “1-in-1,000” year events. The use of reinsurance is generally more pronounced for lower frequency return periods for Atlantic Hurricane and North American Earthquake, while other named perils exhibit the opposite pattern such as Japanese Earthquake and Japanese Typhoon.

Average loading factors in the accumulation process have been declining steadily since 2012, reaching 6.7% in 2017 versus 9.2% in 2012 for Bermuda legal entities. For groups in 2017 the average loading factor was 8.3% compared to 8.9% in 2012. This could reflect (but not be limited to) improved modelling approaches, more robust model exposure coverage and/or greater modelling precision by insurers. For 2017, both more insurers and groups have taken a long-term view of Atlantic multi-decadal oscillation than a medium-term view when compared to 2016.

AIR and RMS are the most frequently used modelling software and are occasionally used in tandem with EQECAT. In-house modelling[3] has reached a level of 33.3% of legal entities and 44.4% of groups in 2017. And 40.5% of legal entities and 50.0% of groups reported that they use more than one model in their accumulation process. Legal entities use their models on a quarterly basis with 54.8% of insurers doing so, while 55.6% of groups accumulate as frequently.

[3] In-house model is a proprietary model built by an insurer.

# 2. Introduction

Bermuda's insurance sector is regulated and supervised by the Authority. As part of the regulatory and supervisory measures, the Authority requires all Class 3B and Class 4 insurers to submit a capital and solvency return, which includes a Catastrophe Risk Return and Schedule of Risk Management (Cat Return), as part of their annual statutory filing, detailing the insurers' catastrophe risk management practices.

Within the Cat Return, insurers report their catastrophe exposures, their Exceedance Probability (EP) curves for various return periods, their Average Annual Loss (AALs) and Probable Maximum Loss (PMLs) as well as stress test results that the Authority designates for their own solvency assessment. The Cat Return serves as a point of reference in the prudential filings for quantification of catastrophe risk assumed in Bermuda.

The Cat Return also determines the extent of reliance on vendor models to assess catastrophe exposures and highlights the actions insurers take to mitigate model risk, including a description of procedures and analytics in place to monitor and quantify exposure to vendor models. It also serves as a tool to assist the Authority in assessing the reasonableness of inputs into the catastrophe risk component of the regulatory capital requirement, and whether standards are being applied evenly.

The global insurance market and the Bermuda market, in particular, significantly rely upon vendor models to assess catastrophe exposures. If the vendor models underestimate potential losses arising from events, the industry as a whole may have capital levels impacted to a greater extent than expected. Not only is this a strategic and risk management issue for an insurer, it also impacts its regulatory capital requirement since the Catastrophe Risk Charge is generally a significant contributor to this requirement. Therefore, a comprehensive understanding of the modelling practices in Bermuda is a central aspect of the Authority's supervisory framework.

Drawing from the information in the Cat Returns, this report gives a high level overview of the capacity of the Bermuda insurance sector to absorb shocks from various Cat risk events underwritten by Bermuda insurers, including identification of any concentration of risks and an analysis of the catastrophe modelling practices.

The report contributes to improved understanding of Bermuda as an insurance-based International Financial Centre (IFC) and a leader in the regulation of the catastrophe market.

This ultimately demonstrates the contribution of Bermuda and emphasises the commitment of the Authority to a high standard of transparency.

# 3. Methodology

The report was produced using aggregated and non-aggregated data from the Bermuda Capital and Solvency Return (CSR) filings of Class 3B, Class 4 legal entities and insurance groups for the period ended 31st December 2017[4]. Specifically, the following schedules from the CSR were used as data sources:

- Schedule V(e) – Schedule of Risk Management: Stress/Scenario Test;
- Schedule X(a) - Catastrophe Risk Return: EP Curve Total;
- Schedule X(c) - Catastrophe Risk Return: EP Curve for Regions-Perils;
- Schedule X(e) – Catastrophe Risk Return: Accumulations Overview;
- Schedule X(f) - Catastrophe Risk Return: Data Analysis; and
- Schedule X(g) - Catastrophe Risk Return: Reinsurance Disclosures

Data was aggregated only when it could be. For example the BMA did not use aggregated EP curve data, while aggregated AAL data were used. EP curves were not aggregated since they represent upper quantiles of distributions and quantiles are not additive functions. AALs on the other hand, since they represent averages over distributions, can be aggregated without logical inconsistencies.

When data could not be aggregated, an augmented box plot, presenting percentiles and averages, was used in order to describe the distribution of the variable within the industry. Care has been taken not to identify individual insurers to preserve the confidentiality of the CSR filings. In total, the report was able to capture a high level overview of the Cat risk exposure in Bermuda.

The exclusion of all other classes, such as Special Purpose Insurers (SPIs)[5], limits the conclusions that can be gleaned from the results of this survey. Therefore, one should view the results as being reflective of a segment of the industry and not the entire exposure of the Bermuda insurance market[6] which is expected to be larger than what is presented in this report. It should also be noted that, having excluded the long-term (life) insurers, the report does not consider mortality catastrophic risk.

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[4] Not all insurers have 31st December year end, therefore, the data used in the report may not fully reconcile with the BMA annual report which will include fall end underwriting data.
[5] The BMA publishes a quarterly report on Bermuda's Insurance-Linked Securities market.
[6] Bermuda insurance market includes the Bermuda reinsurance market.

The analysis of the accumulation process is based on responses from insurers in the 2017 and previous years' CSR filings. The accumulation process provides insights into the relationship between the modelling process of insurers and the actual management of those risks from an operational point of view.

The analysis in this report was based purely from original CSR data input. No reference was made to other supporting documents separately required as part of the CSR filing. These additional documents are also reviewed by the Authority's supervisory team at the micro level in the context of individual insurers. As such, subtle nuances provided from an insurer's full return that might otherwise impact these results are not reflected in this report.

**Information Box**

Class 3B and Class 4 insurers are larger property and casualty commercial insurers required to maintain statutory capital and surplus of at least 99% TVaR over a one year time horizon.

**Aggregate Statistics for Classes 3B and 4, 2017. (In US$ billions)**

| | |
|---|---|
| **Net Written Premiums** | **49.4** |
| **Net Earned Premiums** | 49.9 |
| **Net Income** | 1.5 |
| **Total Claims** | 38.7 |
| **Total Assets** | 212.9 |

*Source:* BMA

**Aggregate Statistics for Insurance Groups, 2017. (In US$ billions)**

| | |
|---|---|
| **Net Written Premiums** | **33.4** |
| **Net Earned Premiums** | 32.6 |
| **Net Income** | -0.6 |
| **Total Claims** | 25.7 |
| **Total Assets** | 197.4 |

*Source:* BMA

# 4. Catastrophe Risk Stress Test

As part of the annual statutory CSR filing, insurers are required to carry out rigorous and comprehensive forward-looking stress tests to measure the sensitivity of their statutory capital & surplus to various significant Cat risk underwriting loss scenarios[7].

Stress testing is a fundamental element of an insurer's overall risk management framework and capital adequacy determination[8]. The main objective of underwriting stress testing is to assess the capacity of individual insurers, and the entire sector, to absorb shocks from adverse events and to identify any concentration of risk that may emerge. Stress testing can also be used to assess the effect of tail events beyond the measured level of confidence.

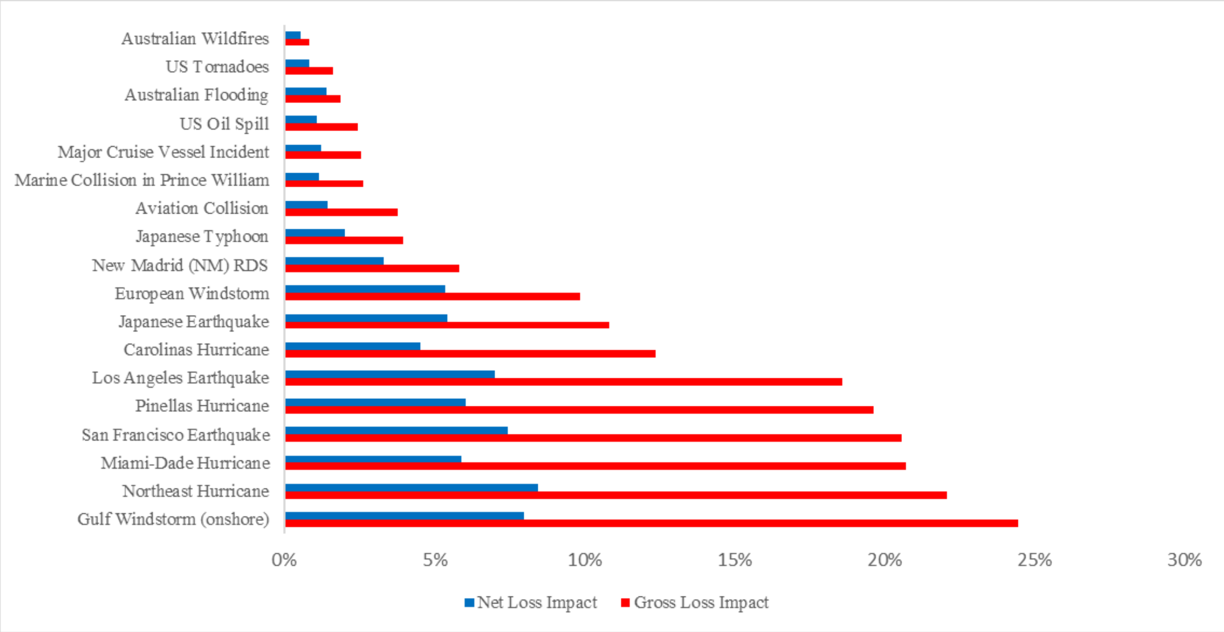
The Authority assesses Cat risk stress tests at three different levels: First, using both the Lloyd's developed Realistic Disaster Scenarios (RDS) and other scenarios designed internally by the Authority, each insurer is required to estimate its loss impact for 18 standardised Cat underwriting loss scenarios (see Appendix 1 for details on each underwriting loss scenario's key assumptions that insurers use as a guide to estimate their market share). Second, the insurer is required to submit to the Authority three of its own highest underwriting loss scenarios if the 18 standardised RDS underwriting loss scenarios provided by the Authority do not fully apply to the insurer's underwriting exposure. Third, the insurer is required to consider and provide estimates for its worst-case underwriting loss scenario based on its own independent underlying assumptions.

In general, the 2017 Cat underwriting loss scenario results showed that not only is the Bermuda insurance market resilient to potential Cat underwriting loss impacts arising from all major perils underwritten[9], but will still hold satisfactory capital to settle policyholders' obligations. Out of the 18 standardised underwriting loss scenarios, Gulf Windstorm (onshore) had the largest potential adverse effect with an estimated gross loss impact[10] to statutory capital & surplus of 24.0% (and 8.0% net loss impact), followed by Northeast Hurricane which had the potential to deplete 22.0% (and 8.0% net loss impact) of the total

[7] Insurers are also required to conduct stress scenarios to assess their capital adequacy under an adverse financial market and a combination of an adverse financial market scenario with an adverse underwriting scenario. However, this report only discusses the underwriting loss scenarios from Cat events.
[8] IAIS
[9] The underwriting loss impact and associated assumptions reported by insurers are probabilistic outcomes and represent calculated estimates. Actual results may significantly differ from these estimates.
[10] Gross loss impact is before any reinsurance and/or other loss mitigation instruments.

statutory capital & surplus[11]. Australian Wildfires had the least impact with only 1.0% gross and net impact on the statutory capital & surplus. The gross impact of each of all the other perils ranges from 2.0% to 21.0% with the majority of the perils (9) having a gross loss impact of less than 10.0% (see Appendix II).

**Figure 1. Stress Testing - Cat Loss Scenarios**
**(As percent of Total Capital & Surplus)**

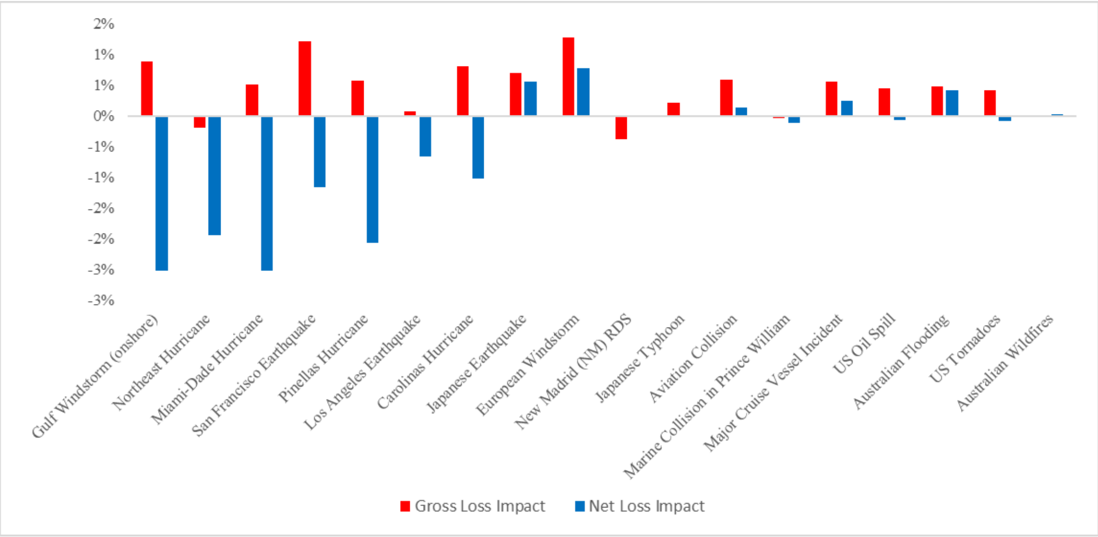



*Source:* BMA staff calculations.

The 17.0% increase (compared to 2016) in the gross modelled losses and 12.0% increase in statutory capital & surplus are largely attributed to the inclusion of more insurance entities in the survey. Overall, the insurers have ceded more exposure resulting in a decrease in the net loss impact by 2.0% compared to 2016 (see Appendix II). The decrease in net total exposure is primarily driven by the decrease on the net loss impact of Gulf Windstorm (3.0%), Miami-Dade Hurricane (3.0%) and Northeast Hurricane (2.0%) compared to 2016. The majority of the perils have either seen a minor decrease of their net loss impact or their impact has stayed relatively the same (see Figure 2 below).

[11]Total Capital & Surplus includes only Capital & Surplus for insurers that underwrite Cat risk i.e. Capital & Surplus for insurers that do not underwrite Cat risk is not included.

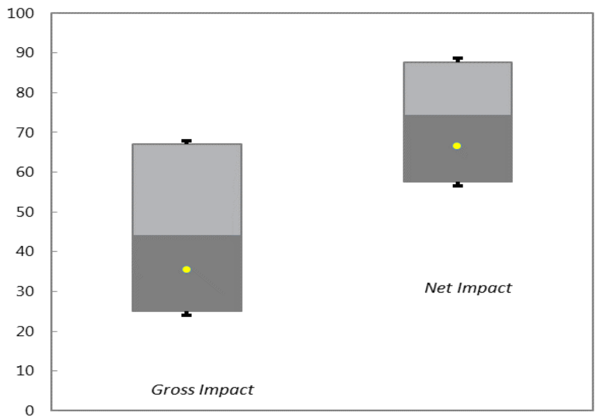
**Figure 2 - Year on Year (2016 and 2017) Gross and Net Loss Impact Change**




*Source:* BMA

At the individual entity level, the results showed that Bermuda's insurance entities are resilient to the worst-case annual aggregate underwriting loss scenario (Figure 3 below). For the worst-case annual aggregate loss scenario, the insurers are required to run: either a series of loss simulations or other analysis performed related to extreme tail events that include all policies at the beginning of the year; or its own worst-case annual aggregate loss scenario at a level considered extreme but plausible, substantiated with the relevant underlying assumptions.

**Figure 3 – Statutory Capital after Gross and Net Worst-Case Aggregate Underwriting Loss Scenario. (In percent)**




*Source:* BMA staff calculations. *Note:* Boxplots include the mean (yellow dot), the 25th and 75th percentiles (grey box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers).

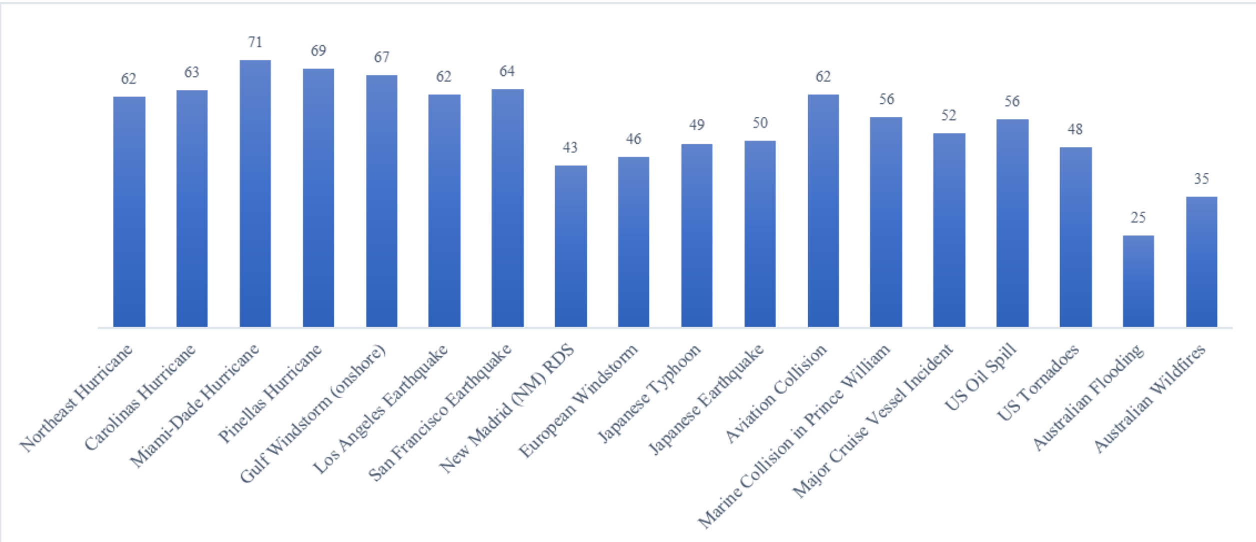
Insurers are also required to carry out a separate stress test for terrorism coverage by estimating the potential loss impact using a standardised scenario of an explosion of a two-tonne bomb. The results from the test showed that all entities would comfortably withstand their worst impact from this standardised scenario, retaining on average 89.0% of the statutory capital & surplus on a gross basis and 92.0% on a net basis.

Finally, insurers are required to provide cyber risk data, including their estimated aggregate exposure and their own cyber risk worst-case annual aggregate loss scenarios, and the underlying assumptions. The data showed that the insurers' own worst impacts from cyber risk would have a minor effect on their statutory capital and surplus, i.e. average of 5.0% gross impact and 4.0% net impact[12].

**Reliance on reinsurance**

The Authority also assesses the level of insurers' reliance on reinsurance and/or other loss mitigation instruments for each peril. Overall, looking at the aggregate loss impact, the results showed that the level of reliance on reinsurance has increased compared to last year and varies across each peril. Typically, perils that have potential for the largest losses, such as Gulf Windstorm, Miami-Dade Hurricane and San Francisco Earthquake are heavily reinsured.

**Figure 4. Gross Loss Impact Ceded (in percent)**

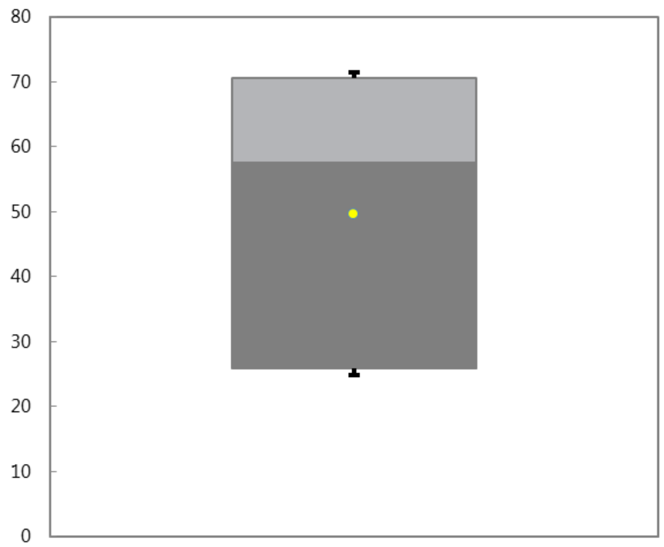



*Source:* BMA staff calculations.

On average, insurers ceded close to 50.0% of gross losses (Figure 4), which is an increase of about 5.0% compared to last year.

[12] Insurers provided cyber risk data on consolidated basis, i.e. Bermuda entities consolidating foreign subsidiaries.

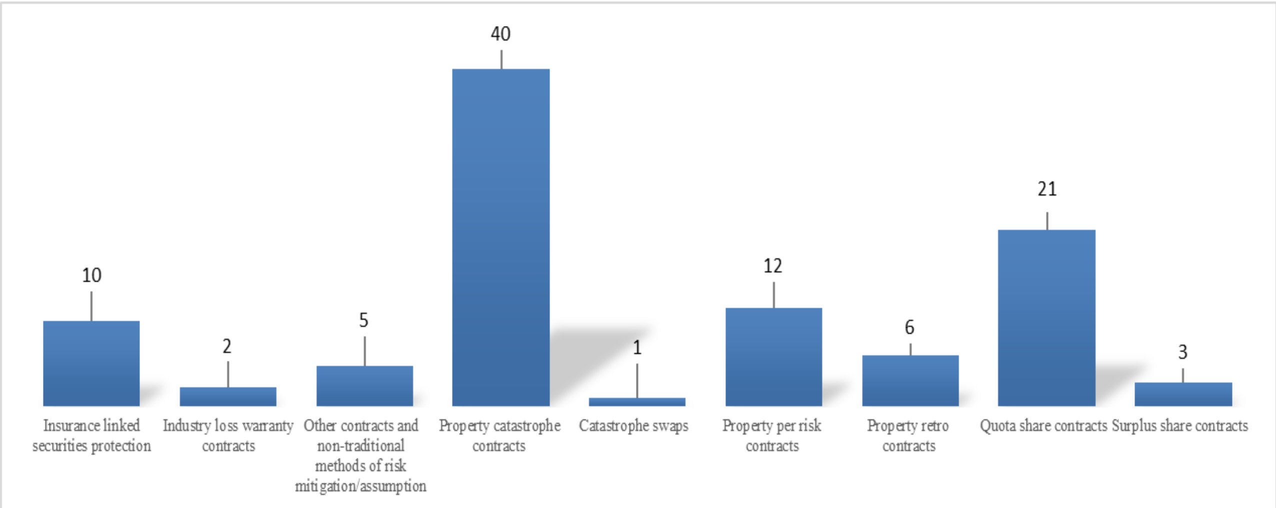
**Figure 5. Loss Impact Ceded (In percent)**




*Source:* BMA staff calculations. *Note:* Boxplots include the mean (yellow dot), the 25th and 75th percentiles (grey box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers).

The results also showed that Bermuda insurers use a variety of reinsurance methods to cede some of their Cat exposure, which include the traditional property catastrophe contracts, quota share contracts, Insurance Linked Securities (ILS) protection and industry loss warranty contracts among others.

**Figure 6. Reinsurance Strategy - Aggregate Occurrence Limit (in percent)**




*Source:* BMA staff calculations.

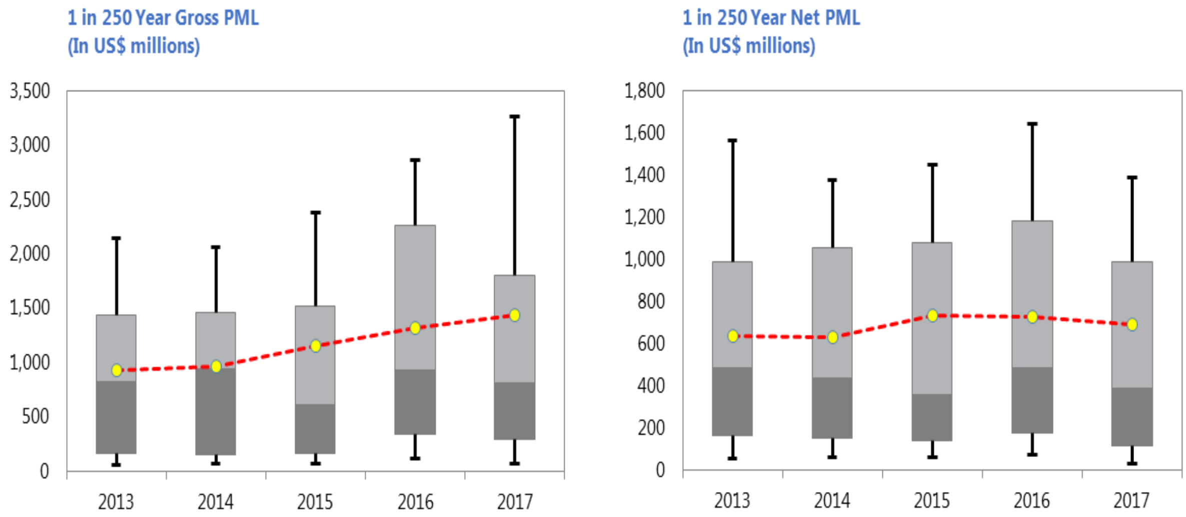
## 5. Exceedance Probability Curves

This section presents some outputs from the catastrophe models in Bermuda on an aggregated basis for Bermuda legal entities. Insurers are asked to produce EP curves for named perils. These perils are Atlantic Hurricane, North American Earthquake, European Windstorm, Japanese Earthquake and Japanese Typhoon.

The BMA compiles the data from the EP curves by drawing the distribution of EP curves in the cross section for firms for named perils across return periods. The BMA plots for each peril and for each return period a box plot which includes the mean, median, 10th, 25th, 75th and 90th percentiles of the EP curves[13].

Historical trends of the gross and net "1-in-250" year Probable Maximum Loss (PML) for aggregate exposures for the past five years were evaluated. The "1-in-250" year event is the most representative of the extreme risk that the insurer is exposed to. The following panel presents the distribution of the PML for the aforementioned return period.

**Panel 1. Gross and Net "1 in 250" PML**




*Source:* BMA staff calculations. *Note:* Boxplots include the mean (yellow dot), the 25th and 75th percentiles (grey box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers).

[13] EP curves cannot be aggregated by summing individual EP curves since an event for one firm can be completely unrelated with the event of another company even for the same peril and the same return period. For example, a 1-in-250 year event in North America Earthquake means something different for a company with exposures to San Francisco versus to a company with exposures to Northern California outside large urban centres. Moreover, the simple addition of EP curves does not recognise diversification benefits since it assumes that all events for all perils and for all return periods can occur at the same time even if some events may be mutually exclusive.

The insurers have increased their average gross exposure between 2016 and 2017 by 9.2%. The variation within the sample in 2017 increased significantly with few companies having large increases in their exposures and many smaller firms with smaller exposures. The 90th percentile exposure reached $3.3 billion, up by 14.0% since 2016.

Average net exposure dropped by 4.8% between 2016 and 2017, while the variation of exposures within samples increased as in the case of gross exposures. The 90th percentile net exposure dropped by 15.5% in 2017.

The largest exposure for Bermuda insurers is North Atlantic Hurricane with average gross exposure between US $773.5 million for "1-in-50" year events up to almost US $1.5 billion for "1-in-1,000" year event. This is an average figure with significant variation within firms. For example, at the 90th percentile of losses there are firms with "1-in-50" year exposures north of US $2.0 billion, while there are firms who exceed US $2.5 billion exposures for "1-in-1,000" year events for the same peril. The BMA calculates the net to gross exposure ratio and present some descriptive statistics in the next table.

**Table 1. Net to Gross Exposure for Atlantic Hurricane (In percent)**

| Return Period | 1 in 50 | 1 in 100 | 1 in 250 | 1 in 500 | 1 in 1000 |
|---|---|---|---|---|---|
| **Mean** | 49.2 | 50.9 | 53.1 | 55.2 | 57.3 |
| **Median** | 43.8 | 47.6 | 52.5 | 53.4 | 51.9 |

*Source*: BMA

The data show that the purchase of reinsurance becomes less pronounced at higher risk layers. The median insurer retains 49.2% of the gross exposure for "1-in-50" year events, while the median insurer retains 57.3% of the gross exposure for "1-in-1,000" year events. The BMA also shows average exposure per peril, per return period (both gross and net) in the next tables.

**Table 2. Average Gross Exposure (In US$ millions)**

| Return Period | 1 in 50 | 1 in 100 | 1 in 250 | 1 in 500 | 1 in 1000 |
|---|---|---|---|---|---|
| **Atlantic Hurricane** | 773.5 | 942.8 | 1,168.3 | 1,343.6 | 1,521.1 |
| **NA. Earthquake** | 522.9 | 691.7 | 901.4 | 1,046.4 | 1,195.7 |
| **European Windstorm** | 261.5 | 332.9 | 417.0 | 472.8 | 528.9 |
| **Japanese Earthquake** | 189.4 | 251.9 | 325.9 | 366.6 | 399.0 |
| **Japanese Typhoon** | 132.9 | 169.1 | 196.1 | 213.0 | 232.6 |

*Source*: BMA

**Table 3. Average Net Exposure (In US$ millions)**

| Return Period | 1 in 50 | 1 in 100 | 1 in 250 | 1 in 500 | 1 in 1000 |
|---|---|---|---|---|---|
| **Atlantic Hurricane** | 295.2 | 383.7 | 518.6 | 639.9 | 770.4 |
| **NA. Earthquake** | 201.2 | 270.9 | 380.1 | 473.6 | 578.2 |
| **European Windstorm** | 133.4 | 166.5 | 206.4 | 234.3 | 264.9 |
| **Japanese Earthquake** | 91.7 | 117.6 | 150.8 | 170.8 | 187.8 |
| **Japanese Typhoon** | 66.1 | 81.1 | 95.5 | 104.9 | 114.9 |

*Source:* BMA

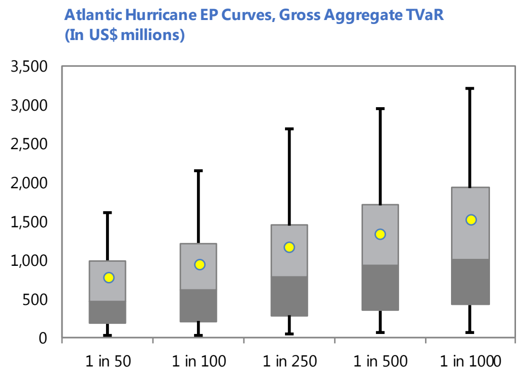
As mentioned previously, the largest exposure across all return periods is Atlantic Hurricane, followed by North American Earthquake. The BMA also plots the aggregate gross and net EP curves which include all the catastrophic risks in an insurer's portfolio.

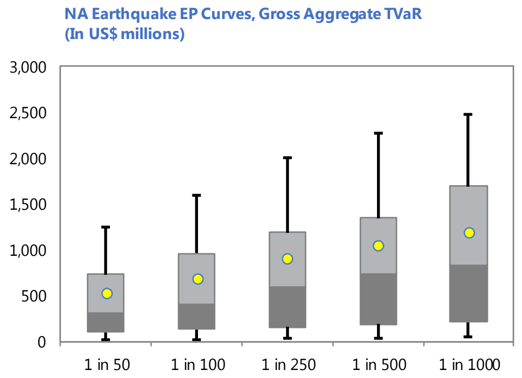
**Table 4. Average Exposure for all Perils (In US$ millions)**

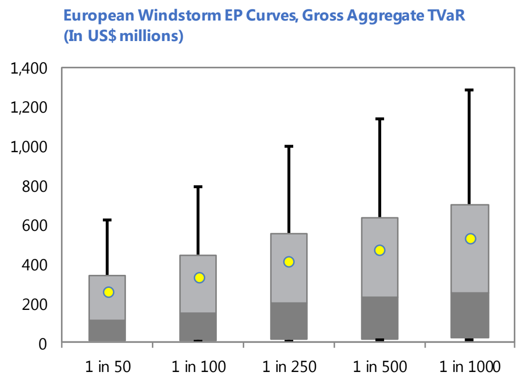
| Return Period | 1 in 50 | 1 in 100 | 1 in 250 | 1 in 500 | 1 in 1000 |
|---|---|---|---|---|---|
| **Gross** | 1,028.5 | 1,185.2 | 1,436.8 | 1,611.0 | 1,791.9 |
| **Net** | 437.9 | 526.5 | 688.4 | 818.4 | 960.1 |

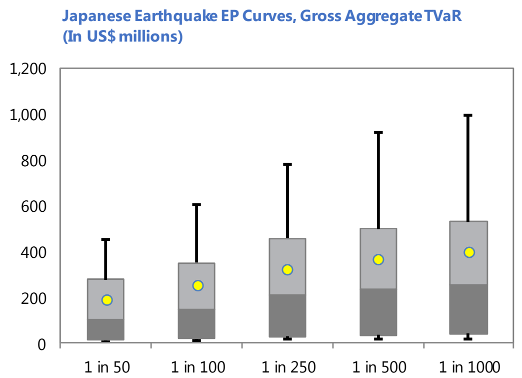
*Source:* BMA

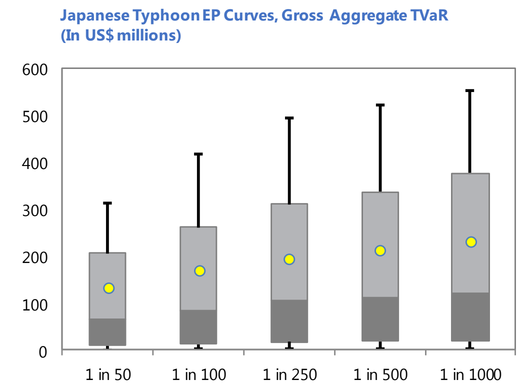
## Panel 2. Gross EP Curves for Named Perils



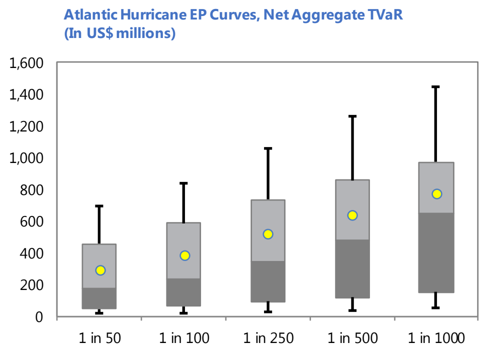



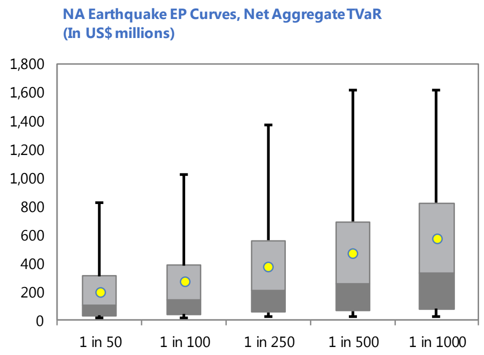



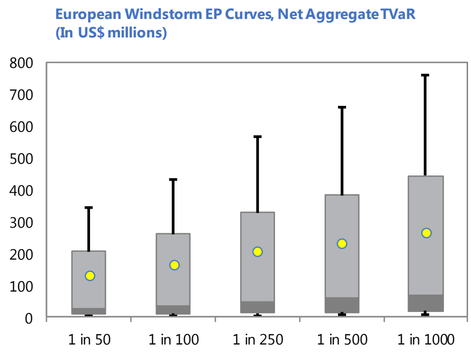



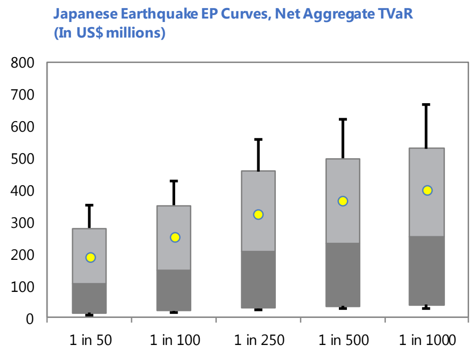

Source*:* BMA staff calculations. *Note:* Boxplots include the mean (yellow dot), the 25th and 75th percentiles (grey box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers).

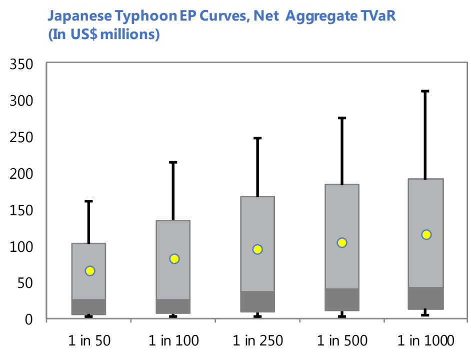
## Panel 3. Net EP Curves for Named Perils



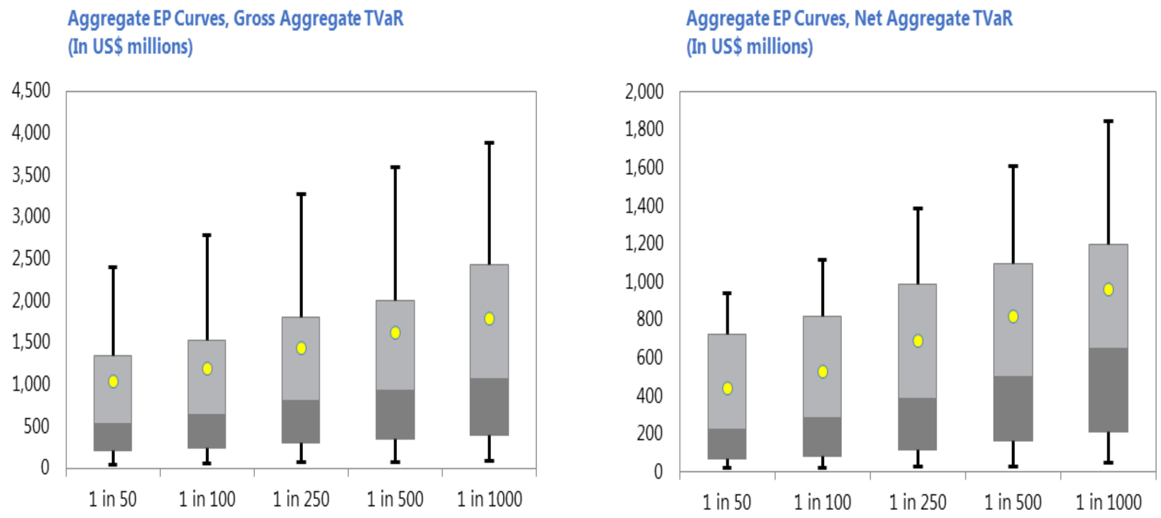




Source*:* BMA staff calculations. *Note:* Boxplots include the mean (yellow dot), the 25th and 75th percentiles (grey box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers).

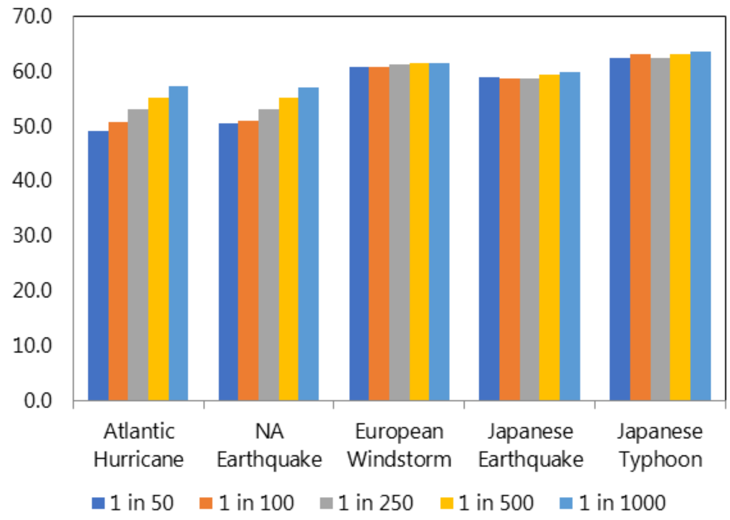
**Panel 4. Gross and Net Aggregate EP Curves for all Perils**




*Source:* BMA staff calculations. *Note:* Boxplots include the mean (yellow dot), the 25th and 75th percentiles (grey box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers).

**Figure 7. Average Net to Gross EP Exposure per Peril and Return Period**

**(Aggregate EP Curves, in percent)**




*Source:* BMA staff calculations.

For Atlantic Hurricane, the ratio of net to gross exposure increases as the return period increases. The rarer the event the more the insurer retains risk on average.

Observations indicate that less reinsurance is being purchased for rare events (“1-in-1,000”), compared to less rare events (“1-in-50”). This is true for all perils except Japanese Typhoon where there is no monotonic relationship between retention and return periods. Nevertheless for Japanese Typhoon the average retention ratios are close for all return periods. European

Windstorm exhibits a rather flat demand for reinsurance across return periods. But Atlantic Hurricane and North American Earthquake are the major perils where significant variation of the use of reinsurance per return period is evident.

## 6. Pricing Dynamics

The following panel shows the pricing dynamics, across time, of the catastrophe market based on aggregated data only for legal entities.

**Panel 5. Average Annual Loss, Risk & Pricing Ratios[14]**


*Source:* BMA staff calculations. Note: The ratios are calculated only for modelled exposures and modelled premium.

Gross Average Annual Loss (AAL) increased between 2016 and 2017 and reached US $8.1 billion, compared to US $6.3 billion in 2016. Similarly, net AAL reached US $4.3 billion in 2017 compared to US $3.6 billion in 2016.

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[14] The BMA uses only modelled exposures and premium.

Plots of the risk and the pricing dynamics were drawn to show the ratios of the Cat AAL to Cat premium for both gross and net exposures in panel 5. The AAL largely represents the modelled estimation of the expected Cat losses, and the gross premium includes provisions for profit and expenses. The relationship between the two ratios provides an indication of the amount of expenses; profit and other loadings charged to insured entities. We observe that on average this ratio had been steadily increasing since 2013 but started to drop in 2016 compared to 2015. This drop continued for this year with Cat premiums growing faster than AALs.

The ratio of AAL to Cat premium has dropped from 84.1% in 2015 to 81.5% of gross exposures in 2016 and has further dropped to 75.8% in 2017. For net exposures the ratio has dropped from 72.9% in 2015, to 66.3% in 2016 and in 2017 stood at 62.8%. There is evidence of some hardening in the Cat market, but it is yet to be seen whether this will be a continuing trend.

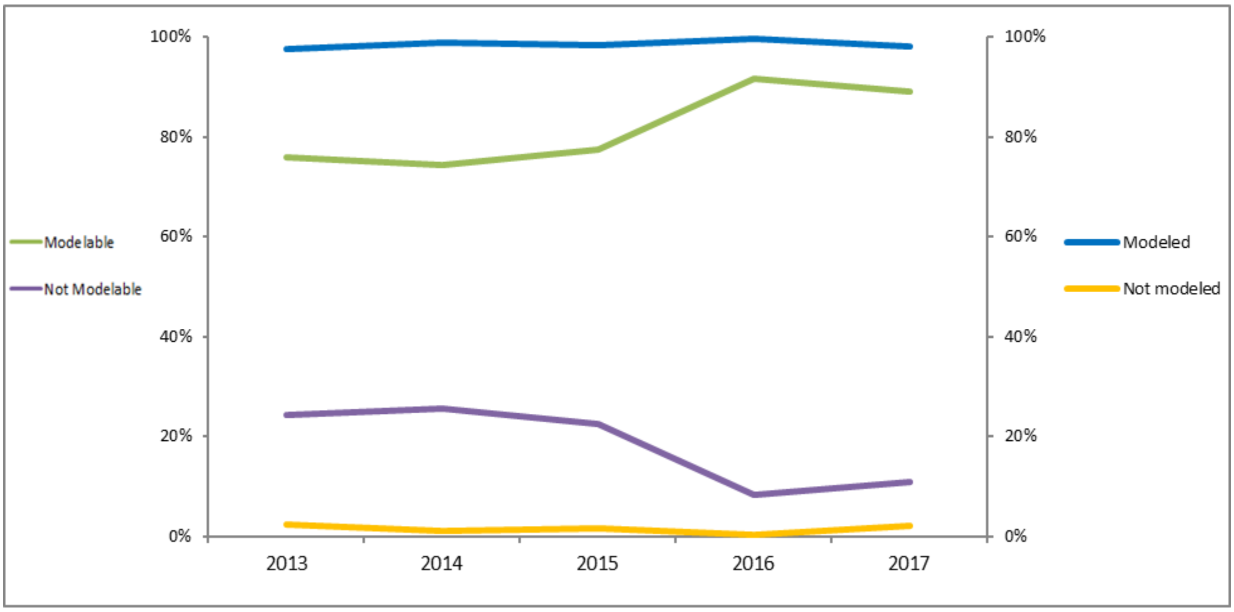
We also plot the ratio of Cat premium to Cat exposures which can be seen in the second row of panel 5. This ratio dropped significantly between 2015 and 2016 but it seems to have increased in 2017 with 2015 being a rather outstanding year. Removing 2015 as an exceptional year we see that compared to a ratio of 4.4% in 2013, the ratio in 2017 was 2.3%, slightly higher than 2.2% in 2016.

# 7. PMLs and Accumulation Process

The accumulation process is an important component of the modelling process and it is an integral part of risk management. The Authority collects on an annual basis, as part of the CSR filing, information about the accumulation process from the prudential filings of companies.

The 2017 CSR filing showed that 89% of the Cat risk exposure underwritten in Bermuda is modelable and that 98% of the modelable risk was modelled. The percentage of modelable exposure decreased from 92% in 2016 to 89% in 2017; the modelled exposure (as a percentage of modelable) also decreased by 2%[15] [16].

**Figure 8. Modelable and Modelled Exposure**




*Source:* BMA staff calculations.

In the following section, we will present results regarding catastrophe-modelling practices that we collect from class 3B and class 4 legal entities as well Bermuda groups which are domiciled in Bermuda and have the BMA as group-wide supervisor. In the next section, wherever we use the term legal entities we imply class 3B and 4 Bermuda insurers.

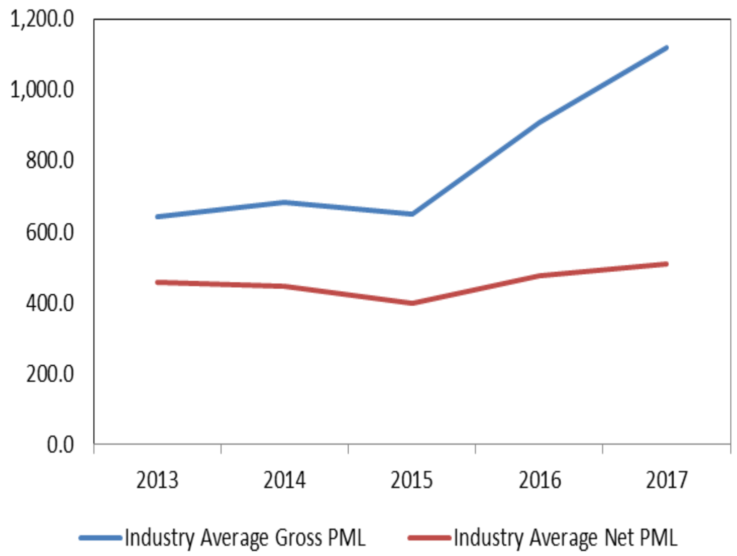
[15]**Modelable exposure** refers to the exposure that can be simulated through a vendor catastrophe model; **Non-Modelable exposure** refers to exposure that cannot be simulated through a vendor catastrophe model or where there are no catastrophe models that assess the risk of the region-peril under consideration; **Modelled exposure** refers to risks that the insurer was able to model.

[16]Reasons for non-modeled risk may include; data limitations that prevent the exposure from being run through a vendor catastrophe model. This may be due to the resolution (or frequency) of the data or the completeness of the data, which for other reasons is not sufficient to produce credible modelling results; Model deficiency, where there may be some modelable exposures but the vast majority of exposures are not modelable; and or there are no catastrophe models that assess the peril under consideration.

## 7.1 PMLs and Accumulation Process - Legal Entities

In this section we will present aggregated results from the statutory filings of insurers for the year 2017. As it was mentioned, Bermuda class 3B and 4 insurers are required to file the catastrophe risk schedule which is a questionnaire about modelling practices. It also includes quantitative information about catastrophe exposures. The catastrophe modelling process in referred to as "accumulation" in Bermuda and stands for accumulation of risks. Considering quantitative factors, Bermuda insurers report metrics on AAL, PML and factor loadings. The latest data are provided in the below figures and tables. PML is defined as 99.0% TVaR on an aggregate basis.

**Figure 9. Gross and Net Average Industry PML (In US$ millions)**



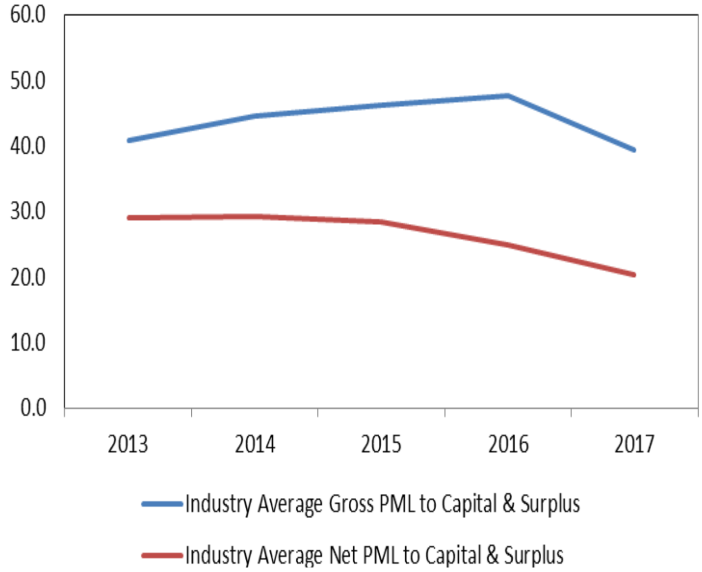

*Source:* BMA staff calculations.

**Table 5. PML (In US$ millions)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Industry Average Gross PML** | 1,118.0 | 910.0 | 648.9 | 682.0 | 642.4 |
| **Industry Average Net PML** | 509.8 | 476.2 | 398.1 | 445.2 | 456.0 |

*Source*: BMA

**Figure 10. Capital and Surplus to Gross and Net Industry PML (In percent)**




*Source:* BMA staff calculations.

**Table 6. PML Ratios (In percent)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Industry Average Gross PML to Capital & Surplus** | 39.3 | 47.7 | 46.1 | 44.6 | 40.8 |
| **Industry Average Net PML to Capital & Surplus** | 20.3 | 24.9 | 28.3 | 29.1 | 29.0 |

*Source:* BMA

Table 5 above represents the average PML for legal entities in dollar amounts. The PML for 2017 has had a significant increase on a gross basis while on a net basis the figure is lower due to extensive use of reinsurance.

Table 6 above presents ratios of the gross and net PML to capital and surplus. This ratio expresses whether the available capital and surplus can withstand a loss equal to 99.0% TVaR. On a gross basis, a 99.0% TVaR aggregate loss is expected to consume 39.3% of available capital and surplus. This ratio dropped in 2017 despite steadily increasing over the past four years. However, on a net basis after reinsurance the ratio drops to 20.3% in 2017, down from 24.9% in 2016, indicating a more pronounced use of reinsurance.

Table 7 below presents the loading factors that are used as add-ons to the outputs of catastrophe modelling. These factors compensate for model error as well increased conservatism in the modelling process and they are applied on the PML. For example, if the catastrophe model yields a PML of US $100.0, a 5.0% factor would raise the PML to U$105.0.

**Table 7. Loading Factors (In percent)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Average Loading Factor** | 6.7 | 5.4 | 5.9 | 8.3 | 8.4 |

*Source:* BMA

In 2017 the average loading factor reached 6.7%, which has increased since 2016 despite having steadily declined since 2013. One should be cautious in the interpretation of the factor since models themselves may become more accurate and conservative, thus reducing the need for higher safety buffers.

Insurers responded to how they estimate the factor; either the factor is determined analytically (meaning that insurers will analyse the total output of the model and back-test the results according to experience of the total loss), or insurers will take a per-risk view and blend the experience of single lines of business into the total portfolio PML. The responses can be found in table 8.

**Table 8. Loading Factor Estimation Methods (In percent of respondents)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Determined Analytically** | 36.4 | 29.6 | 20.4 | 38.7 | 40.0 |
| **Estimated** | 63.6 | 70.4 | 80.0 | 61.3 | 60.0 |

*Source:* BMA.

In 2017, 63.6% of insurers estimated the loading factor while 36.4% determined it analytically through modelling.

Another interesting modelling practice is the usage of the Atlantic Multi-decadal Oscillation (AMO). AMO refers to the alteration of Sea Surface Temperatures (SST) in the Northern Atlantic from cool to warm phases. These phases last for several years. Since the mid-1990s, a warm phase has existed. A correlation has been observed between warm SSTs and more frequent severe hurricanes and other destructive weather phenomena. Bermuda insurers responded as to whether they consider loadings for this risk factor on near-term or long-term views.

**Table 9. AMO Factor Consideration (In percent of respondents)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Near-Term Frequency** | 61.5 | 74.3 | 89.5 | 89.2 | 89.2 |
| **Long-Term Frequency** | 38.5 | 25.7 | 10.5 | 10.8 | 10.8 |

*Source:* BMA.

The BMA observes that in 2017, 61.5% of insurers consider the AMO for their near term modelling of Atlantic hurricane exposures. While 38.5% are also considering this factor for long-term modelling. The AMO factor has to do with trends that should be taken into account in modelling Atlantic hurricane exposures and the financial losses that stem from hurricane activity. Near-term frequency and long-term frequency estimations have been converging and this explains the fact that more insurers are using the long term view.

Part of the questionnaire asks about the vendors that insurers use. This gives an indication about whether insurers are forming their modelling opinions on one or multiple models, while the BMA can see which vendors are more prevalent in the market. Moreover, the BMA asks how frequently insurers perform modelling (or accumulations) and whether insurers develop their own models apart from those supplied by vendors. The next table summarises the responses.

**Table 10. Vendor Model Usage and Licensing (In percent of respondents)**

| **Model Usage** | **2017** | **2016** | **2015** | **2014** | **2013** |
|---|---|---|---|---|---|
| **AIR only** | 18.9 | 12.5 | 9.1 | 16.7 | 11.4 |
| **EQECAT only** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **RMS only** | 40.5 | 40.6 | 39.4 | 30.6 | 28.6 |
| **AIR and RMS** | 40.5 | 43.8 | 45.5 | 38.9 | 45.7 |
| **AIR and EQECAT** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **EQECAT and RMS** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **AIR, EQECAT and RMS** | 0.0 | 3.1 | 6.1 | 13.9 | 14.3 |
| **Model Licensing** | **2017** | **2016** | **2015** | **2014** | **2013** |
| **AIR only** | 17.5 | 13.9 | 7.7 | 15.0 | 10.3 |
| **EQECAT only** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **RMS only** | 27.5 | 25.0 | 17.9 | 10.0 | 15.4 |
| **AIR and RMS** | 55.0 | 58.3 | 66.7 | 60.0 | 46.2 |
| **AIR and EQECAT** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **EQECAT and RMS** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **AIR, EQECAT and RMS** | 0.0 | 2.8 | 7.7 | 15.0 | 28.2 |

*Source:* BMA

RMS seems to be the most commonly used standalone model. However, the use of three models in tandem seems to be the exception with a declining share of EQECAT use. It appears that no insurer used three models together in 2017 to perform their accumulations.

**Table 11. Model Frequency Usage (In percent of respondents)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Ad-hoc** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Annual** | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Semi-annual** | 2.4 | 0.0 | 0.0 | 3.0 | 3.0 |
| **Quarterly** | 54.8 | 52.6 | 43.9 | 35.0 | 38.5 |
| **Monthly** | 19.0 | 26.3 | 24.4 | 25.0 | 20.5 |
| **Weekly** | 2.4 | 2.6 | 2.4 | 5.0 | 5.1 |
| **Daily** | 14.3 | 13.2 | 22.0 | 20.0 | 20.5 |
| **Real time** | 4.8 | 5.3 | 7.3 | 12.5 | 12.8 |

*Source:* BMA

Insurers use and update catastrophe modelling in fixed periods, usually quarterly and monthly. For each quarter, either 'renewals' or 'supervisory reporting' are the most common reasons to run the catastrophe models, with 54.8% of insurers reporting quarterly use in 2017 (up from 52.6% in 2016). Real time use has declined to 4.8% of insurers in 2017 (compared to 12.8% in 2013). Only 2.4% of respondents use and update their model annually.

**Table 12. Model Frequency and Business Units Differences (In percent of respondents)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Yes** | 30.0 | 39.5 | 36.6 | 32.5 | 35.1 |
| **No** | 70.0 | 60.5 | 63.4 | 67.5 | 64.9 |

*Source:* BMA

Insurers were asked whether different business units use catastrophe models at different frequencies. In 2016, 60.5% of respondents said that they do not perform accumulations at different frequencies while this percentage jumped to 70.0% in 2017.

**Table 13. Internal Model Usage (In percent of respondents)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Yes** | 33.3 | 34.2 | 39.0 | 42.5 | 43.6 |
| **No** | 66.7 | 65.8 | 61.0 | 57.5 | 56.4 |

*Source:* BMA

Insurers develop internal catastrophe models with a rather stable percentage of them doing so between 2013 and 2017. In 2017, 33.3% of insurers developed their own stochastic model. Insurers with very specialised lines of business (outside the cover of traditional vendors) are more likely to develop such in-house models to capture their unique risks.

The BMA also asked insurers about how catastrophe risk modelling accounts for reinsurance and retrocessions. The responses are shown in table 14.

**Table 14. External Reinsurance Model Usage (In percent of respondents)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **The company has minimal catastrophe exposure protection and as such gross is effectively net.** | 20.0 | 10.5 | 12.2 | 15.0 | 12.8 |
| **The accumulations are calculated on a gross basis with reinsurance protections calculated approximately outside the system.** | 0.0 | 2.6 | 0.0 | 0.0 | 0.0 |
| **The accumulations are calculated on a gross basis with reinsurance protections calculated explicitly outside the system.** | 5.0 | 5.3 | 7.3 | 7.5 | 7.7 |
| **The accumulations are calculated on a gross basis with the effect of reinsurance protections calculated explicitly for some types of protection within the system.** | 30.0 | 31.6 | 26.8 | 25.0 | 20.5 |
| **The accumulations are calculated on a gross basis with the effect of reinsurance protections calculated explicitly for each type of protection within the system.** | 45.0 | 50.0 | 53.7 | 52.5 | 59.0 |

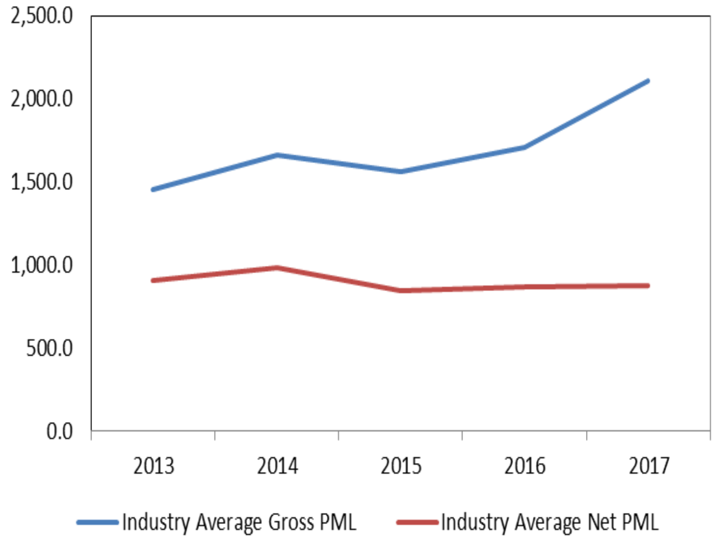
*Source:* BMA

The BMA observes that the number of insurers that purchase little or no external catastrophe reinsurance, jumped from 10.5% of respondents in 2016, to 20.0% of respondents in 2017. The vast majority of insurers model catastrophic risk by taking into account explicitly external reinsurance either for some types or for each treaty separately. In 2017, 75.0% of respondents consider explicitly either some external reinsurance or all reinsurance treaties in their catastrophe modelling. In 2017, only 5.0% of respondents do not consider directly external reinsurance in their modelling practices, compared to 5.3% in 2016.

## 7.2 PMLs and Accumulation Process - Insurance Groups

The same data for legal entities is also recorded for insurance groups.

**Figure 11. Gross and Net Average Industry PML (In US$ millions)**




*Source:* BMA staff calculations.

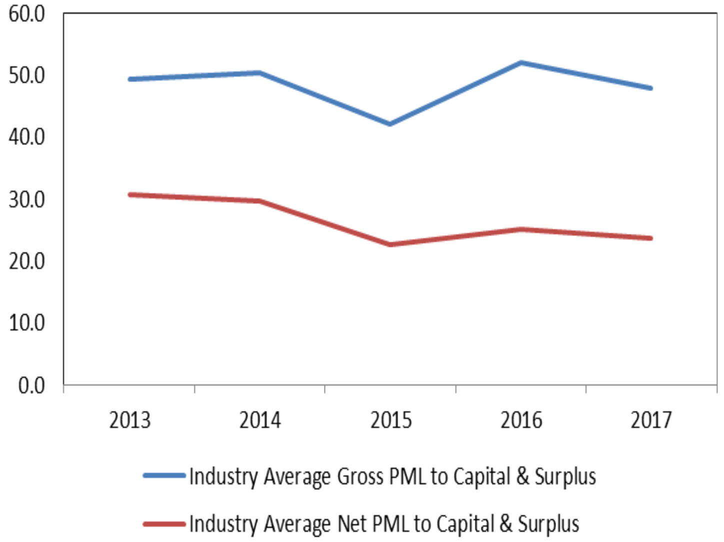
**Table 15. PML (In US$ millions)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Industry Average Gross PML** | 2,105.5 | 1,705.7 | 1,563.0 | 1,659.0 | 1,451.7 |
| **Industry Average Net PML** | 873.9 | 870.2 | 842.9 | 979.7 | 905.4 |

*Source:* BMA

The BMA again observes the increase in gross exposures which is attenuated by extensive reliance on reinsurance, thus decreasing the net PML.

**Figure 12. Capital and Surplus to Gross and Net Industry PML (In percent)**




*Source:* BMA staff calculations.

**Table 16. PML Ratios (In percent)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Industry Average Gross PML to Capital & Surplus** | 47.8 | 52.0 | 42.0 | 50.4 | 49.3 |
| **Industry Average Net PML to Capital & Surplus** | 23.6 | 25.0 | 22.6 | 29.7 | 30.7 |

*Source:* BMA

As in the case of legal entities the BMA reports average loading factors for groups in table 17.

**Table 17. Loading Factors (In percent)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Average Loading Factor** | 8.3 | 6.8 | 7.6 | 5.9 | 7.2 |

*Source:* BMA

As in the case of legal entities, the loading factor for groups has varied for the period 2013 to 2016, increasing in 2017. Again, a declining loading factor does not necessarily imply less conservatism but the fact that models are incorporating additional assumptions themselves, making the need for externally imposed assumptions less important. It remains to be seen how the active 2017 hurricane season will impact the loading factors in 2018.

Table 18 shows how groups estimate loading factors.

**Table 18. Loading Factor Estimation Methods (In percent of respondents)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Determined Analytically** | 33.3 | 35.7 | 40.0 | 50.0 | 61.1 |
| **Estimated** | 66.7 | 64.3 | 60.0 | 50.0 | 38.9 |

*Source:* BMA

Groups and legal entities seem to be converging into how loading factors are determined. In 2017, 66.7% of groups estimate their factors non-analytically by relying on expert judgements.

**Table 19. AMO Factor Consideration (In percent of respondents)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Near-Term Frequency** | 52.9 | 58.8 | 64.7 | 66.7 | 76.2 |
| **Long-Term Frequency** | 47.1 | 41.2 | 35.3 | 33.3 | 23.8 |

*Source:* BMA

Similar to legal entities (but to a lesser extent in 2017) 52.9% of groups use the near-term frequency of the AMO compared to 58.8% in 2016. Model results are converging based on either near-term or long-term frequency of the AMO. Therefore, the BMA sees that insurers use both the near-term and the long-term view equally.

The Authority also has statistics about model vendor licensing and model usage for Bermuda groups.

**Table 20. Vendor Model Usage (In percent of respondents)**

| **Model Usage** | **2017** | **2016** | **2015** | **2014** | **2013** |
|---|---|---|---|---|---|
| **AIR only** | 12.5 | 18.8 | 6.3 | 11.8 | 20.0 |
| **EQECAT only** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **RMS only** | 37.5 | 31.3 | 37.5 | 41.2 | 45.0 |
| **AIR and RMS** | 50.0 | 43.8 | 56.3 | 29.4 | 25.0 |
| **AIR and EQECAT** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **EQECAT and RMS** | 0.0 | 0.0 | 0.0 | 5.9 | 0.0 |
| **AIR, EQECAT and RMS** | 0.0 | 6.3 | 0.0 | 11.8 | 10.0 |
| **Model Licensing** | **2017** | **2016** | **2015** | **2014** | **2013** |
| **AIR only** | 11.1 | 16.7 | 5.9 | 11.1 | 9.5 |
| **EQECAT only** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **RMS only** | 22.2 | 16.7 | 17.6 | 11.1 | 19.0 |
| **AIR and RMS** | 66.7 | 61.1 | 70.6 | 55.6 | 47.6 |

| | | | | | |
|---|---|---|---|---|---|
| **AIR and EQECAT** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **EQECAT and RMS** | 0.0 | 0.0 | 0.0 | 5.6 | 4.8 |
| **AIR, EQECAT and RMS** | 0.0 | 5.6 | 5.9 | 16.7 | 19.0 |

*Source:* BMA

For groups, RMS takes the largest share, either as standalone or in combination with other models, such as AIR. This is similar to legal entities which tend to inherit the vendor models from their parent groups. Again, we notice the concentration of the market into two vendors.

**Table 21. Model Frequency Usage (In percent of respondents)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Ad-hoc** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Annual** | 5.6 | 5.6 | 5.9 | 11.1 | 9.5 |
| **Semi-annual** | 5.6 | 5.6 | 5.9 | 5.6 | 4.8 |
| **Quarterly** | 55.6 | 44.4 | 35.3 | 27.8 | 33.3 |
| **Monthly** | 16.7 | 27.8 | 35.3 | 33.3 | 23.8 |
| **Weekly** | 0.0 | 0.0 | 0.0 | 0.0 | 9.5 |
| **Daily** | 11.0 | 11.1 | 11.8 | 11.1 | 9.5 |
| **Real time** | 5.6 | 5.6 | 5.9 | 11.1 | 9.5 |

*Source:* BMA

Accumulation frequency follows similar patterns for groups and legal entities as well. Most groups perform accumulations quarterly (55.6% of respondents in 2017 compared to 44.4% in 2016.) Like legal entities, in 2017, some groups also perform annual accumulations at 5.6% of respondents in 2017.

**Table 22. Model Frequency and Business Units Differences (In percent of respondents)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Yes** | 64.7 | 64.7 | 52.9 | 56.3 | 57.9 |
| **No** | 35.3 | 35.3 | 47.1 | 43.8 | 42.1 |

*Source:* BMA

When it comes to whether different business units employ different frequencies of accumulations, the picture is reversed for groups compared to legal entities. And 64.7% of groups had frequency differences whereas, only 30.0% of legal entities did so. The diversity of the groups is more pronounced than legal entities and is expected that groups will employ different modelling practices across their entities. The BMA also surveyed groups about the use of internal models.

**Table 23. Internal Model Usage (In percent of respondents)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **Yes** | 44.4 | 44.4 | 47.1 | 38.9 | 42.9 |
| **No** | 55.6 | 55.6 | 52.9 | 61.1 | 57.1 |

*Source:* BMA

In 2017, 55.6% of groups did not use internally developed models, while 44.4% did so. A similar picture is evident for legal entities.

**Table 24. External Reinsurance Model Usage (In percent of respondents)**

| | 2017 | 2016 | 2015 | 2014 | 2013 |
|---|---|---|---|---|---|
| **The company has minimal catastrophe exposure protection and as such gross is effectively net.** | 6.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| **The accumulations are calculated on a gross basis with reinsurance protections calculated approximately outside the system.** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **The accumulations are calculated on a gross basis with reinsurance protections calculated explicitly outside the system.** | 0.0 | 5.6 | 5.9 | 5.6 | 4.8 |
| **The accumulations are calculated on a gross basis with the effect of reinsurance protections calculated explicitly for some types of protection within the system.** | 31.3 | 22.2 | 29.4 | 33.3 | 23.8 |
| **The accumulations are calculated on a gross basis with the effect of reinsurance protections calculated explicitly for each type of protection within the system.** | 62.5 | 72.2 | 64.7 | 61.1 | 71.4 |

*Source:* BMA

On the group level, groups use models for their reinsurance treaties when they are cedents. In 2017, 6.3% of groups do not have external reinsurance treaties due to minimal catastrophe exposure. And 62.5% of groups compared to 45.0% of legal entities model explicitly for all treaties within the Cat model, while 31.3% of groups consider some treaties as cedents in their accumulation process.

## Appendix I – Underwriting Loss Scenarios Guideline

### 1. Northeast Hurricane

The insurer/group should assume a US $78.0 billion industry property loss, including consideration of demand surge and storm surge from a northeast hurricane making landfall in New York State. The hurricane also generates significant loss in the States of New Jersey, Connecticut, Massachusetts, Rhode Island and Pennsylvania.

In assessing its potential exposures, the insurer/group should consider exposures in:

a. Both main and small ports that fall within the footprint of the event
b. Both main international and small airports that fall within the footprint of the event

The insurer/group should assume the following components of the loss:

a. Residential property US $47.50 billion
b. Commercial property US $30.50 billion
c. Auto US $1.75 billion
d. Marine US $0.75 billion

The insurer/group should consider all other lines of business that would be affected by the event.

Exclusion: The insurer/group should exclude contingent business interruption losses from this event.

### 2. Carolinas Hurricane

The insurer/group should assume a US $36.0 billion industry property loss, including consideration of demand surge and storm surge from a hurricane making landfall in South Carolina.

In assessing its potential exposures, the insurer/group should consider exposures in:

a. Main and small ports that fall within the footprint of the event
b. Main international and small airports that fall within the footprint of the event

The insurer/group should assume the following components of the loss:

a. Residential property US $24.0 billion

b. Commercial property US $12.0 billion

c. Auto US $0.53 billion

d. Marine US $0.27 billion

The insurer/group should consider all other lines of business that would be affected by the event.

Exclusion: The insurer/group should exclude contingent business interruption losses from this event.

**3. Miami-Dade Hurricane**

The insurer/group should assume a US $125.0 billion industry property loss, including consideration of demand surge and storm surge from a Florida hurricane making landfall in Miami-Dade County.

The insurer/group should assume the following components of the loss:

a. Residential property US $63.0 billion

b. Commercial property US $62.0 billion

c. Auto US $2.25 billion

d. Marine US $1.0 billion

The insurer/group should consider all other lines of business that would be affected by the event.

Exclusion: The insurer/group should exclude contingent business interruption losses from this event.

**4. Pinellas Hurricane**

The insurer/group should assume a US $125.0 billion industry property loss, including consideration of demand surge and storm surge from a Florida hurricane making landfall in Pinellas County.

The insurer/group should assume the following components of the loss:

a. Residential property US $88.0 billion

b. Commercial property US $37.0 billion

c. Auto US $2.0 billion

d. Marine US $1.0 billion

The insurer/group should consider all other lines of business that would be affected by the event.

Exclusion: The insurer/group should exclude contingent business interruption losses from this event.

**5. Gulf Windstorm (onshore)**

The insurer/group should assume a US $107.0 billion industry property loss, including consideration of demand surge and storm surge from a Gulf of Mexico hurricane making landfall.

In assessing its potential exposures, the insurer/group should consider exposures in:

a. Main and small ports that fall within the footprint of the event
b. Main international and small airports that fall within the footprint of the event

The insurer/group should assume the following components of the loss:

a. Residential property US $65.0 billion
b. Commercial property US $42.0 billion
c. Auto US $1.0 billion
d. Marine US $1.0 billion

The insurer/group should consider all other lines of business that would be affected by the event.

Exclusion: The insurer/group should exclude contingent business interruption losses from this event.

**6. Los Angeles Earthquake**

The insurer/group should assume a US $78.0 billion industry property (shake and fire following) loss, including consideration of demand surge.

The insurer/group should assume the following components of the loss:

a. Residential property US $36.0 billion
b. Commercial property US $42.0 billion
c. Workers Compensation US $5.5 billion
d. Marine US $2.25 billion

e. Personal Accident US $1.0 billion

f. Auto US $1.0 billion

The insurer/group should consider all other lines of business that would be affected by the event. For Personal Accident and Workers Compensation losses, the insurer/group should assume that there will be 2,000 deaths and 20,000 injuries as a result of the earthquake and that 50% of those injured will have Personal Accident cover.

Exclusion: The insurer/group should exclude contingent business interruption losses from this event.

**7. San Francisco Earthquake**

The insurer/group should assume a US $78.0 billion industry property (shake and fire following) loss, including consideration of demand surge.

The insurer/group should assume the following components of the loss:

a. Residential property US $39.0 billion

b. Commercial property US $39.0 billion

c. Workers Compensation US $5.5 billion

d. Marine US $2.25 billion

e. Personal Accident US $1.0 billion

f. Auto US $1.0 billion

The insurer/group should consider all other lines of business that would be affected by the event. For Personal Accident and Workers Compensation losses, the insurer/group should assume that there will be 2,000 deaths and 20,000 injuries as a result of the earthquake and that 50% of those injured will have Personal Accident cover.

Exclusion: The insurer/group should exclude contingent business interruption losses from this event.

**8. New Madrid Earthquake**

The insurer/group should assume a US $47.0 billion industry property (shake and fire following) loss, including consideration of demand surge.

The insurer/group should assume the following components of the loss:

a. Residential property US $32.5 billion
b. Commercial property US $14.5 billion
c. Workers Compensation US $2.5 billion
d. Marine US $1.5 billion
e. Personal Accident US $0.5 billion
f. Auto US $0.5 billion

The insurer/group should consider all other lines of business that would be affected by the event. For Personal Accident and Workers Compensation losses, the insurer/group should assume that there will be 1,000 deaths and 10,000 injuries as a result of the earthquake and that 50% of those injured will have Personal Accident cover.

For business interruption, the insurer/group should assume that the overland transport systems are severely damaged and business impacted, leading to significant business interruption exposure for a period of 30 days. This is restricted to the inner zone of maximum earthquake intensities.

**9. European Windstorm**

This event is based upon a low pressure track originating in the North Atlantic basin resulting in an intense windstorm with maximum/peak gust wind speeds in excess of 20 metres per second (45 mph or 39 knots). The strongest winds occur to the south of the storm track, resulting in a broad swath of damage across southern England, northern France, Belgium, Netherlands, Germany and Denmark. The insurer/group should assume a €23.0 billion industry property loss.

The insurer/group should assume the following components of the loss:

a. Residential property €15.5 billion
b. Commercial property €6.00 billion
c. Agricultural €1.50 billion
d. Auto €0.75 billion
e. Marine €0.40 billion

The insurer/group should consider all other lines of business that would be affected by the event. The loss amount should be reported in Bermuda equivalent as noted under the general instructions above.

**10. Japanese Typhoon**

This event is based on the Isewan ('Vera') typhoon event of 1959. The insurer/group should assume a ¥1.5 trillion industry property loss.

In assessing its potential exposures, the insurer/group should consider exposures in:

a. Main and small ports that fall within the footprint of the event
b. Main international and domestic airports as well as small airports that fall within the footprint of the event
The insurer/group should assume the following components of the loss:

- a. Residential property ¥650.0 billion
- b. Commercial property ¥850.0 billion
- c. Marine ¥50.0 billion

The insurer/group should consider all other lines of business that would be affected by the event. The loss amount should be reported in Bermuda equivalents as noted under the general instructions above.

**11. Japanese Earthquake**

This event is based on the Great Kanto earthquake of 1923. The insurer/group should assume a ¥5 trillion insured industry property loss from this event.

In assessing its potential exposures, the insurer/group should consider exposures in:

- a. Main ports as well as smaller ports that fall within the footprint of the event
- b. Main international and domestic airports as well as smaller airports that fall within the footprint of the event

The insurer/group should assume the following components of the loss:

- a. Residential property ¥1.5 trillion
- b. Commercial property ¥3.5 trillion
- c. Marine ¥150.0 billion
- d. Personal Accident ¥50.0 billion

The insurer/group should consider all other lines of business that would be affected by the event. The loss amount should be reported in Bermuda equivalent as noted under the general instructions above.

For Personal Accident losses, the insurer/group should assume that there will be 2,000 deaths and 20,000 injuries as a result of the earthquake and that 50% of those injured will have Personal Accident cover. Liability exposures should also be considered.

For business interruption, the insurer/group should assume that the overland transport systems are severely damaged and business impacted, leading to significant business interruption exposure for a period of 60 days. This is restricted to the inner zone of maximum earthquake intensities.

**12. Aviation Collision**

The insurer/group should assume a collision between two aircrafts over a major city, anywhere in the world, using the insurer's or groups two largest airline exposures.

The insurer / group should assume a total industry loss of up to US $4.0 billion, comprising up to US $2 billion per airline and any balance up to US $1.0 billion from a major product manufacturer's product liability policy(ies) and/or traffic control liability policy(ies), where applicable.

Consideration should be given to other exposures on the ground and all key assumptions should be stated clearly.

The information should include:

a. The city over which the collision occurs;
b. The airlines involved in the collision;
c. Each airline's policy limits and attachment points for each impacted insurance contract (policy);
d. The maximum hull value per aircraft involved;
e. The maximum liability value per aircraft involved;
f. The name of each applicable product manufacturer and the applicable contract
g. (Policy) limits and attachment points (deductibles); and
h. The name of each applicable traffic control authority and the applicable contract (policy) limits and attachment points (deductibles).
f) Marine Event

The insurer/group is to select one scenario from below which would represent its largest expected loss.

**13. Marine Collision in Prince William Sound**

A fully-laden tanker calling at Prince William Sound is involved in a collision with a cruise vessel carrying 500 passengers and 200 staff and crew. The incident involves the tanker spilling its cargo and loss of lives aboard both vessels.

Assume 70% tanker owner and 30% cruise vessel apportionment of negligence and that the collision occurs in US waters.

Assume that the cost to the tanker and cruise vessel owners of the oil pollution is US $2 billion. This would lead to oil pollution recoveries on the International Group of P&I Associates' General Excess of Loss Reinsurance Programme of US $1 billion from the tanker owner and US $0.55 billion from the cruise owner.

Assume: 1) 125 fatalities with an average compensation of US $1.5 million for each fatality, 2) 125 persons with serious injuries with an average compensation of US $2.5 million for each person, and 3) 250 persons with minor injuries with an average compensation of US $0.5 million for each person.

**14. Major Cruise Vessel Incident**

A US-owned cruise vessel is sunk or severely damaged with attendant loss of life, bodily injury, trauma and loss of possessions. The claims were to be heard in a Florida court.

Assume: 1) 500 passenger fatalities with an average compensation of US $2.0 million, 2) 1,500 injured persons with an average compensation of US $1.0 million, and 3) assume an additional Protection and Indemnity loss of US $500.0 million to cover costs such as removal of the wreck and loss of life and injury to crew.

**15. US Oil Spill**

The insurer/group is to assume an oil spill releasing at least five million barrels of crude oil into the sea. In addition to property, the insurer/group is also to consider in its assumptions the following coverage: business interruption, workers compensation, directors and officers, comprehensive general liability, environmental / pollution liability and other relevant exposures. Assume: 1) 15 fatalities, 2) 20 persons with serious injuries, and 3) an estimated insured industry loss of US $2.1 billion.

**16. US Tornadoes**

The insurer/group is to assume an EF5 multiple-vortex tornado touching down in several heavily populated cities and towns in the South and Mid-West regions of the US. Assume: 1) 125 fatalities, 2) 600 persons with mild-to-serious injuries, 3) 20,000 people are displaced and left homeless, 4) 50% to 75% of the 10,000 buildings (commercial, residential and other outbuildings included) have been damaged by the tornado's wind field, and 5) an estimated insured industry loss of US $5.0 billion. Consideration should be given to the cumulative effect of such a large number of total losses.

**17. Australian Flooding**

The insurer/group is to assume heavy rainfalls across major cities in Australia causing severe flooding and/or repeated flash flooding. Assume: 1) 40 fatalities, 2) 200,000 people are affected and displaced, 3) 190 persons with mild-to-serious injuries, 3) 70% of the 8,500 homes and businesses that are flooded could not be recovered, 4) suspension of all agricultural and mining operations, and 5) an estimated insured industry loss of US $2.2 billion. The insurer/group is to include landslides following then flood.

**18. Australian Wildfires**

The insurer/group is to assume a series of bushfires during extreme bushfire-weather conditions across Australian states affecting populated areas. Assume: 1) 180 fatalities, 2) 500 people with mild-to-serious injuries, 3) displacement of 7,600 people, and 4) destruction of over 5,000 buildings (commercial, residential and other outbuildings included). Assume an estimated insured industry loss of US $1.3 billion.

# Appendix II - Underwriting Loss Impact Analysis

**Table 25. Impact of Names Perils (In US$)**

| Standardised Cat Peril | Gross Loss Impact | Ceded Loss Impact | Net Loss Impact | Gross Loss Impact Ceded (in Percent) |
|---|---|---|---|---|
| Northeast Hurricane | 21,296,265,808 | 13,143,646,747 | 8,152,619,062 | 62 |
| Carolinas Hurricane | 11,940,672,580 | 7,575,170,085 | 4,365,502,496 | 63 |
| Miami-Dade Hurricane | 19,963,476,434 | 14,260,599,986 | 5,702,876,448 | 71 |
| Pinellas Hurricane | 18,917,172,431 | 13,078,336,378 | 5,838,836,053 | 69 |
| Gulf Windstorm (onshore) | 23,553,377,686 | 15,844,755,748 | 7,708,621,938 | 67 |
| Los Angeles Earthquake | 17,916,345,666 | 11,157,072,565 | 6,759,273,101 | 62 |
| San Francisco Earthquake | 19,816,604,227 | 12,622,188,111 | 7,194,416,116 | 64 |
| New Madrid (NM) RDS | 5,625,478,413 | 2,429,017,589 | 3,196,460,824 | 43 |
| European Windstorm | 9,482,861,028 | 4,327,337,256 | 5,155,523,771 | 46 |
| Japanese Typhoon | 3,803,143,829 | 1,869,560,448 | 1,933,583,381 | 49 |
| Japanese Earthquake | 10,439,486,535 | 5,214,678,153 | 5,224,808,382 | 50 |
| Aviation Collision | 3,659,899,083 | 2,278,372,176 | 1,381,526,907 | 62 |
| Marine Collision in Prince William | 2,537,825,555 | 1,426,970,600 | 1,110,854,955 | 56 |
| Major Cruise Vessel Incident | 2,478,115,422 | 1,287,399,123 | 1,190,716,298 | 52 |
| US Oil Spill | 2,378,436,268 | 1,322,790,377 | 1,055,645,890 | 56 |
| US Tornadoes | 1,551,927,207 | 747,875,093 | 804,052,115 | 48 |
| Australian Flooding | 1,820,339,342 | 450,218,248 | 1,370,121,094 | 25 |
| Australian Wildfires | 795,222,786 | 277,575,143 | 517,647,643 | 35 |
| **Total** | **177,976,650,299** | **109,313,563,826** | **68,663,086,473** | 61% |

**Table 26. Bermuda's Estimated Loss Impact Share Using Lloyd's Developed Realistic Disaster Scenarios (In US$)**

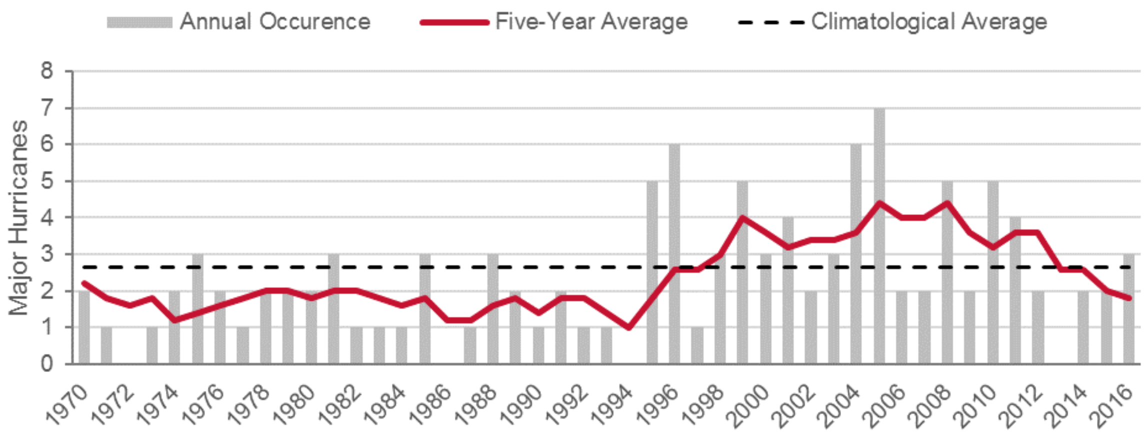
| Standardised Cat Peril | Estimated Total Industry Loss | Estimated Bermuda Share (Gross) | Bermuda Share (in percent) |
|---|---|---|---|
| Gulf Windstorm (onshore) | 107,000,000,000 | 23,553,377,686 | 22% |
| Northeast Hurricane | 78,000,000,000 | 21,296,265,808 | 27% |
| San Francisco Earthquake | 78,000,000,000 | 19,816,604,227 | 25% |
| Pinellas Hurricane | 125,000,000,000 | 18,917,172,431 | 15% |
| Los Angeles Earthquake | 78,000,000,000 | 17,916,345,666 | 23% |
| Miami-Dade Hurricane | 125,000,000,000 | 19,963,476,434 | 16% |
| Carolinas Hurricane | 36,000,000,000 | 11,940,672,580 | 33% |
| Japanese Earthquake | 45,758,000,000 | 10,439,486,535 | 23% |
| European Windstorm | 24,604,000,000 | 9,482,861,028 | 39% |
| New Madrid (NM) RDS | 47,000,000,000 | 5,625,478,413 | 12% |
| Japanese Typhoon | 13,727,000,000 | 3,803,143,829 | 28% |
| Total | 758,089,000,000 | 162,754,884,637 | 21% |

*Notes:* The data provided in these tables 25 and 26 above is for class 3B and 4 insurers only and was extracted from the CSR annual filings. The CSR filings for a handful of insurers that fall within these classes were still under review when this report was put together and that data were not included in this report. Therefore, one should view the results as being reflective of a segment of the industry and not the total potential total impact. Total Estimated Industry Loss numbers were taken from Lloyd's Realistic Disaster Scenarios report - January 2016 and exchange rates are as at 31st December 2016.

# Appendix III - Atlantic Multi-Decadal Oscillation (AMO)

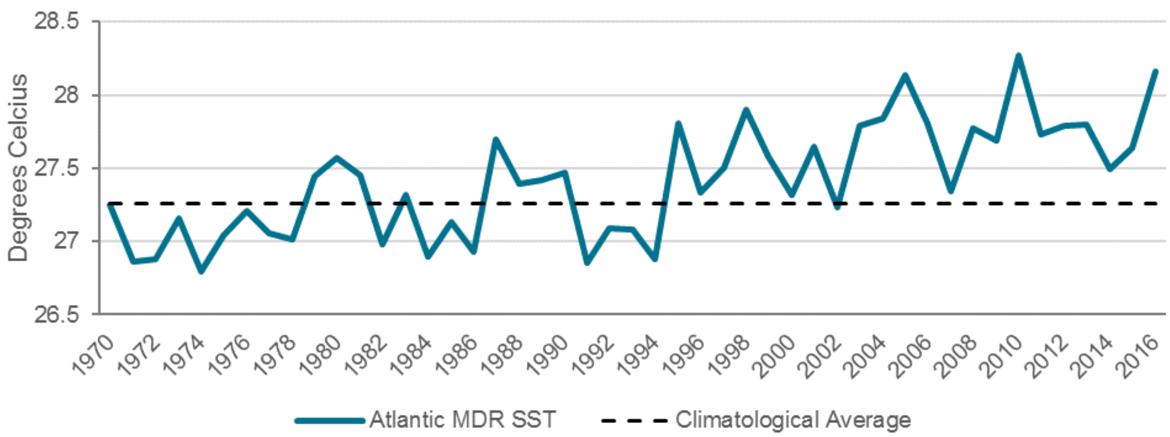
The AMO is a switch in many catastrophe risk models and is used as a predictor of future hurricane activity. As a predictor it uses sea surface temperatures (SST) in order to estimate hurricane activities since warm water is one of the fuels of a hurricane. In the past years SSTs have been rising but the last four year trend shows that hurricanes in numbers are declining. This is shown in figures 13 and 14.

**Figure 13. Number of Hurricanes**




*Source:* RMS

**Figure 14. Sea Surface Temperature**




*Source:* RMS

Assuming a four to five year near-term trend, catastrophe models would show that the number of hurricanes is expected to decline, while a longer term view over the past 20 years could indicate that this is a temporary phenomenon. According to RMS, for the first time since its introduction, the RMS medium-term rate forecast (MTRof) has dipped slightly below the long-term rate. For the US as a whole, the new 2017-2021 medium-term rate forecast MTRof hurricane landfall frequency is now 1% below the long-term rate for Category 1–5 storms, and six percent for major hurricanes (Category 3–5 storms). Therefore, in order to be more conservative, more companies are switching to the long-term view.

# Appendix IV - The Bermuda Framework for Catastrophe Risk Supervision

Bermuda has a comprehensive framework of catastrophe risk supervision since it is one of the largest property catastrophe reinsurance centres in the world. The supervisory framework rests on three pillars.

1) Catastrophe capital charge in prudential filings.
2) Supervisory assessment of prudential filings.
3) Public dissemination of catastrophe risk data on an aggregated basis.

The first pillar includes the capital charge for catastrophe risk that the insurer has to hold as part of its solvency capital requirements. The capital charge is a combination of a BMA in-house factor plus an insurer-specific factor which is supplied from the insurer. Once the capital charge for catastrophe risk has been calculated, it is further blended in the overall capital charge allowing for diversification.

Within the prudential filings, there are schedules which comprise the catastrophe risk return. The catastrophe risk return contains a questionnaire of "soft" qualitative information on the process of catastrophe risk modelling such as the type of models, the frequency of the modelling process, etc. In addition to the qualitative information, the insurer provides quantitative information such as AALs, PMLs and EP curves for major perils. In the second pillar the supervisory process validates the prudential filings. Since part of the calibration of the catastrophe risk capital charge hinges on the assumptions of the insurer, the BMA validates the results with a set of tools.

The catastrophe risk return is one source of cross validation. Another source of validation is the stochastic scenario generator that has been developed in-house by the BMA. This model runs on a spreadsheet and performs Monte Carlo simulations on the balance sheets of individual insurers by shocking assets and liabilities and producing income statements which are used to estimate probabilities of insolvency as well as financial results based on different return periods.

Finally, the BMA prescribes a set of stress tests based on the Lloyd's Realistic Disaster Scenarios (RDS) and they are reported on the prudential filings. The insurer has to show the capital position before and after the relevant RDSs while the insurer should provide its own scenarios should the RDSs be insufficient for the type of exposures of its portfolio. The insurer is also obligated to provide a reverse stress test that will render its business non-viable.

Regarding the third pillar, the BMA publicly publishes aggregated data of the catastrophe risk returns for information purposes of the market as well as for its macroprudential surveillance framework for the insurance sector.