2nd Scenario Analysis on Climate-Related Risks [Insurance Sector]

(Non-life Insurance/Acute Physical Risks)

June 2025

Financial Services Agency

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I. Executive Summary

1. The Financial Services Agency (FSA), in cooperation with numerous non-life insurers and the General Insurance Rating Organization of Japan (GIROJ), conducted the 2nd scenario analysis, drawing on the 4th vintage of scenarios published by the Network for Greening the Financial System (NGFS).

2. The requirements of the 2nd scenario analysis are shown in the table below. The impact of climate-related risks is assessed as changes in claim payments by non-life insurers.

Risk model used	The GIROJ's risk models (typhoon and flood loss models)
Perils analyzed	Typhoons and floods
Lines of business	Change in fire insurance claim payments
Methodology	Hybrid (top-down and bottom-up)
Policies Portfolio	Policies in force at the end of September 2023
Insurers	Top-down: All insurers, bottom-up: 19 insurers
NGFS scenarios	Net Zero 2050 (Orderly), Current Policies (Hot House World)
Time horizon	2050, 2100

3. Results of the 2nd scenario analysis

(1) Things to be mindful of

Climate models are still being developed and upgraded, and there is a certain difference among the six climate models that the risk models developed and owned by the GIROJ (the GIROJ models) are based on. Therefore, the results should be treated with recognition that they have uncertainties.

(2) Top-down analysis

Analyzing the impact of global warming on typhoons and floods by dividing them into ① the annual number of events and ② claim payments per event, the following table shows the results.

	Typhoons	Floods
① Annual number of events	Decreasing with warming	Increasing with warming
② Claim payments per event	Increasing with warming	Slightly increasing with warming

Regarding typhoons, the effects of ① the annual number of events and ② claim payments per event move in opposite directions, meaning that the overall results depend on which effect is greater. However, the effect of ② is larger, and the average of annual claim payments increases.

In addition, analyzing by return periods[1], the longer the return period is, the higher the rate of increase for claim payments is.

As for floods, both ① the annual number of events and ② claim payments per event increase as temperature rises, and the average of annual claim payments increases.

Analyzing by return periods, the rate of increase for claim payments tends to decrease until 50 to 70 years and then increase again.

When comparing typhoons and floods, the amount of the average claim payments and claim payments by return periods are larger for typhoons, but the rate of increase for claim payments when temperatures rise is higher for floods than for typhoons in all cases.

(3) Bottom-up analysis

Comparing the rate of increase for claim payments against the average and by return periods by insurers, there are certain differences for both typhoons and floods. Due to the lack of detailed data, it is difficult to analyze further. However, the cause can be differences in the policies portfolio such as location, building material[2], construction age, and insured objective[3].

4. Lessons learned from the 2nd scenario analysis

(1) The results show the magnitude of acute physical risks that occur when climate change progresses. In addition, they show that it is important to transition to a decarbonized society while paying attention to transition risks so that physical risks do not increase.

(2) If the claim payments paid by non-life insurers increase, it is unavoidable that there will be consequences to policyholders through insurance premium increases.

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[1] The years until a Nat Cat of a certain size occurs again. For example, "a typhoon with a return period of 100 years" is a typhoon that occurs once every 100 years on the scale of claim payments.

[2] The difference between a wooden building and a non-wooden (or fireproof) building.

[3] The difference between a building or mobile property (or household goods).

The increasing rate of fire insurance premiums for properties whose location, building material, and construction age make them vulnerable to typhoons and floods may be higher than that of total claim payments. Therefore, considering the availability of insurance to each policyholder, non-life insurers need to encourage individuals and companies to utilize disaster prevention and mitigation services so that not only the total amount but also each amount of claim payments will not increase. In addition, even if insurers need to increase premiums, they should consider mitigations, including appropriate revision of policy conditions (deductible amounts, etc.), so as not to impair insurance availability.

(3) In the case of progressed climate change, non-life insurers need to utilize reinsurance (including ILS[4]) more. But if overseas reinsurers and investors do not underwrite Japanese Nat Cat risks, it is difficult for Japanese non-life insurers to continue to provide fire insurance. Accordingly, Japanese non-life insurers need to communicate more closely with reinsurers and engage in dialogue from a long-term perspective on how to share risks and returns as business partners amid increasing climate-related risks.

[4] ILS stands for Insurance-Linked Securities, which is a transaction to transfer insurance risk to the capital markets. A CAT bond is a typical example.

II. Background

Climate-related risks are likely to materialize over the medium to long-term, and how they materialize and the significance of their impacts when materialized are highly uncertain. Scenario analysis is considered to be an effective tool to quantitatively assess climate-related risks. It uses simulations to assess the timing and magnitude of impacts on financial institutions' earnings and financial soundness via plausible transmission mechanisms under certain scenarios about future rises in temperatures and policy responses by governments.

With the aim of improving the capacity of central banks and financial supervisory authorities in scenario analysis and enhancing the comparability of scenario analysis conducted by institutions, the NGFS published the guidance on scenario analysis for central banks and financial supervisory authorities and the 1st vintage of the Common Scenarios in June 2020. The scenarios were subsequently updated, and the 4th vintage was published in November 2023.

The FSA[5] conducted the pilot exercise of scenario analysis (the 1st scenario analysis) in FY2021 using the NGFS scenarios as common scenarios in collaboration with three major non-life insurance groups[6] and announced the results in August 2022[7]. The FSA considered the 1st scenario analysis as a means to continuously improve the scenario analysis and focused on understanding data constraints, assessing the validity of analytical assumptions and methods, and identifying issues for future improvement.

From these backgrounds, considering the issues identified in the 1st scenario analysis, the FSA conducted the 2nd scenario analysis in collaboration with many non-life insurers and the GIROJ, referring to the 4th vintage of the NGFS scenarios[8].

In addition, the IMF Financial Sector Assessment Program (FSAP), which was conducted from 2023 to May 2024, pointed out the need to enhance scenario

[5] For banks, the FSA conducted the pilot exercise jointly with the Bank of Japan in collaboration with the three major banks.

[6] MS & AD Insurance Group Holdings, Sompo Holdings and Tokio Marine Holdings.

[7] https://www.fsa.go.jp/en/news/2022/20220826/03.pdf

[8] The 1st scenario analysis used the 2nd vintage of the NGFS scenarios.

analysis concerning climate change risk regulation and supervision[9]. In addition, the 4th Report of the Expert Committee on Sustainable Finance (announced on July 9th, 2024) states the importance of conducting the 2nd scenario analysis to continuously improve the methodology and framework of scenario analysis.

[9] https://www.imf.org/en/Publications/CR/Issues/2024/05/10/Japan-Financial-Sector-Assessment-Program-Technical-Note-on-Financial-Supervision-and-548825

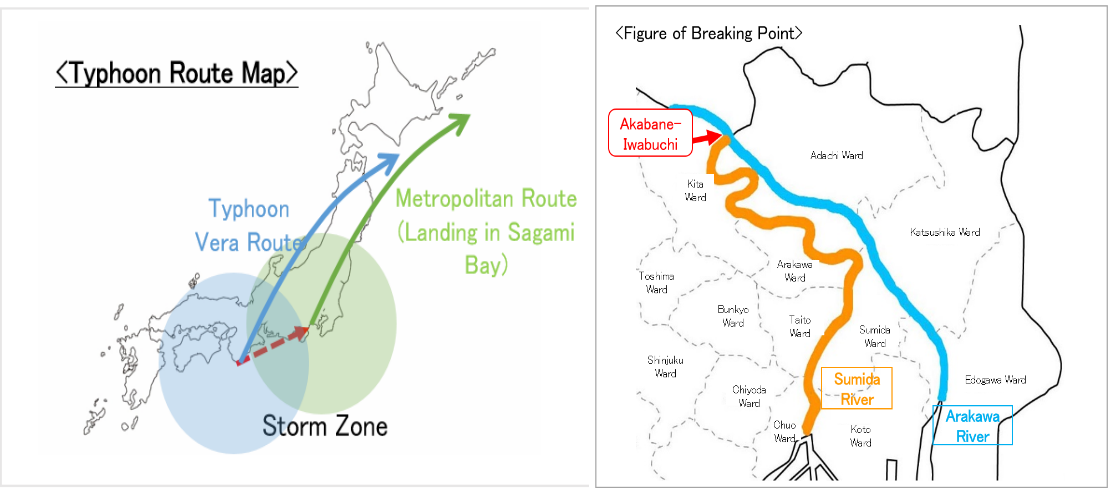
III. The 1st scenario analysis recap

In the 1st scenario analysis, given the importance (impact) of climate-related risks on non-life insurers, we analyzed changes in claim payments for physical risks (acute risks by typhoons and floods) related to their underwriting business, using the risk models that non-life insurers used and the method with intensified magnitude of specific scenarios in Figure 1.

Figure 1: Specific scenarios used in the 1st scenario analysis

Specific scenarios	Typhoons	➢ Sample: Typhoon Vera (intense typhoon with the intensity of one that hits once in 70 years that hit Ise-Bay in 1959) ➢ Central pressure: lowered in several patterns than the original ➢ Routes: Typhoon Vera's original route and the Metropolitan route
	Floods	➢ Sample: Flood, which would record a heavy loss equal to that of a flood that hits once in 200 years ➢ Breaking point: Akabane-Iwabuchi (See Figure 2) ➢ Rainfall and river flow: intensified in several patterns

Figure 2. Typhoon routes and breaking point used in the 1st scenario analysis



As a result of analysis, the amount of claim payments increased as central pressure of typhoon dropped due to temperature rise for typhoons, and as rainfall and river flow increased due to temperature rise for floods. However, in addition to the difference in risk models, there were some inconsistencies in assumptions among risk models, the amount of claim payments varied by groups. In addition, it had become clear that the analysis of some sampling scenarios couldn't capture the impact of other scenarios and overall pictures like changes in the probability of disaster occurrence.

Based on the above, to enhance the analysis, it is desirable that all companies use the same risk model and conduct stochastic analysis for all scenarios (e.g., tens of thousands of scenarios), including future climate change impacts, taking into account the probability of occurrence of the scenarios. Therefore, the utilization of the risk model owned by the GIROJ should be discussed.

IV. Requirements of the 2nd scenario analysis

1. Risk model used

The GIROJ model[10] is used in the 2nd scenario analysis.

In order to resolve the following two issues identified in the 1st scenario analysis, the FSA discussed with the GIROJ whether the GIROJ model could be utilized.

- Results tend to vary due to differences in risk models and limitations in the uniformity of assumptions.
- An analysis sampling a specific scenario (disaster) cannot capture changes in the probability of occurrence (frequency of disaster occurrence) in the future.

The GIROJ had studied how to incorporate climate-related risks into the typhoons and floods risk models. Aligned with discussions with the FSA, the GIROJ released the version of the GIROJ model to non-life insurers in August 2023, incorporating climate-related risks.

See VII. Appendix 1. for the GIROJ model, incorporating climate-related risks.

2. Perils analyzed

The 2nd scenario analysis, like the 1st, analyzes typhoons and floods. Floods include not only river floods but also inland (water) floods, storm surges and other floods caused by heavy rainfall.

The 4th vintage of the NGFS scenarios[11] provides stochastic estimates, categorized by country, of the impact on GDP of four typical perils of acute physical risks: droughts, typhoons (tropical cyclones), heatwaves and floods. It estimates that droughts and heatwaves globally have a large negative impact on GDP. It is also estimated that Japan takes a very large negative GDP impact from

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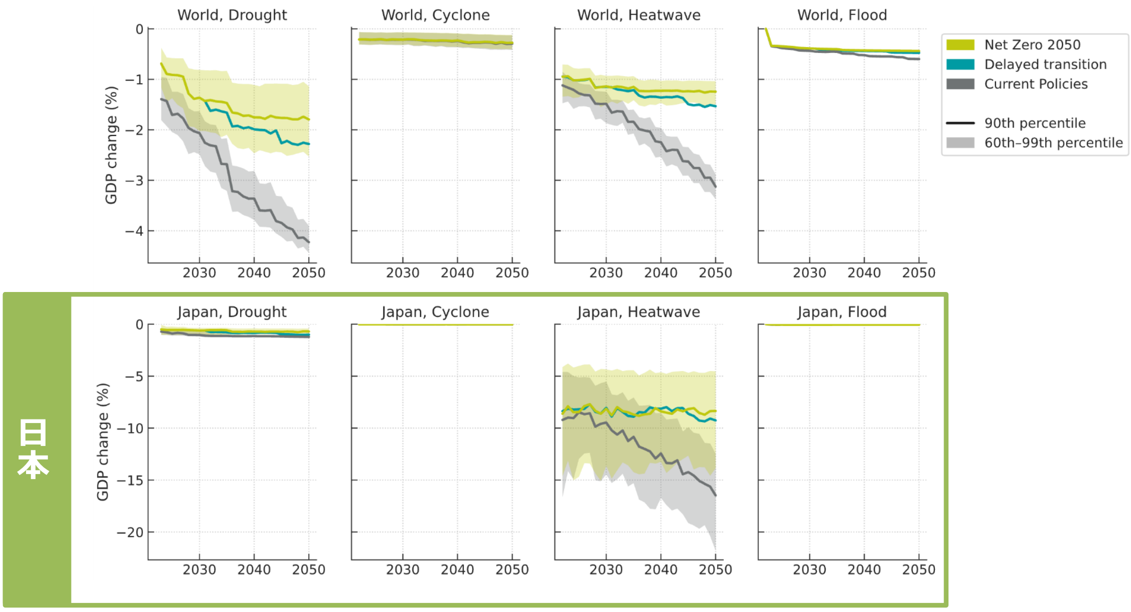
[10] The GIROJ has developed and maintains its own risk models for earthquakes, typhoons, and floods for operations such as the calculation and provision of Reference Loss Cost Rates for fire insurance. For more information, see "Natural hazard risk model" (https://www.giroj.or.jp/english/dandp_2.html).

[11] The 3rd vintage of the NGFS scenarios covered only typhoons (tropical cyclones) and floods, while the 4th vintage added droughts and heatwaves. Also, while the 3rd vintage only provided estimates at the global level, the 4th vintage was updated to provide estimates by countries.

heatwaves but a very small impact from typhoons (tropical cyclones) and floods.

Figure 3: Impact of acute physical risks on GDP (estimated by NGFS)



(Source) FSA 2023 Research Report: Survey on Use of NGFS Scenario Analysis[12]

The 2nd scenario analysis focuses on the impact of climate-related risks on claim payments for non-life insurers, not on GDP. In light of the results presented in Figure 3, we conducted a survey of participants of the 2nd scenario analysis regarding the impact of droughts and heatwaves on claims payments.

As a result of the survey, some insurers indicated droughts and heatwaves could cause fire accidents or wildfires to occur or spread, and hospital visits or deaths due to heatstroke could increase. However, many of them indicated that their impact on claim payments was less than that of typhoons and floods[13].

Based on the above, typhoons and floods are continuously analyzed in the 2nd scenario analysis[14].

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[12] The graph has the comments as follows:
Acute risks were assessed only by the three scenarios described.
Other than floods they were assessed on a stochastic basis. In the figure, 90th percentile values were shown as lines, indicating the upper and lower ranges (60–99%) for Net Zero 2050 and Current Policies.

[13] See V. 3.(6) for this survey.

[14] In addition, droughts and heatwaves cannot be analyzed by the GIROJ models because the GIROJ only has an earthquake model other than typhoons and floods.

3. Lines of business

The 2nd scenario analysis analyzes fire insurance claim payments in the same way as the 1st one.

In addition to fire insurance, claim payments for various lines of business, including auto insurance (vehicle insurance) and casualty insurance, increase when typhoons and floods occur. But fire insurance has the largest portion in terms of claim payments[15].

In addition, the GIROJ model only covers fire insurance[16], then fire insurance is selected and analyzed. Properties covered by fire insurance and analyzed in the 2nd scenario analysis are both residential and business properties in Japan.

4. Methodology

In the 2nd scenario analysis, a hybrid approach combined with top-down and bottom-up analysis is adopted.

The main operation[17] of the GIROJ is to calculate and provide Reference Loss Cost Rates. As part of this operation, the GIROJ is regularly reported insurance policies and claims data by non-life insurers, and the GIROJ has stored them.

The FSA obtained and analyzed claim payments data calculated through the GIROJ model using all insurers' policy data (top-down analysis). Top-down analysis provides an overview of macro trends based on all insurers' data and makes it possible to share a sense of the amount among the FSA and insurers.

In addition, each non-life insurer can use the GIROJ model and calculate its own

[15] For example, Typhoon Jebi (No.21 in 2018) caused claim payment JPY 969.8 bn in total and JPY 879 bn in fire insurance (as of March 11, 2022) based on the data of Largest Claim payments for typhoons and windstorms announced by the General Insurance Association of Japan as of the end of March 2024.

[16] The GIROJ model for floods under the current climate covers auto insurance (vehicle insurance), while the version that incorporates climate-related risks only covers fire insurance.

[17] The main operations of the GIROJ are (1) calculation and provision of Reference Loss Cost Rates and Standard Full Rates, (2) investigation of compulsory automobile liability insurance claims, and (3) data bank. (https://www.giroj.or.jp/english/main_1.html)

claim payments from its own policy data[18]. The FSA requested the insurers to provide the claim payments data calculated by the GIROJ model (quantitative responses) and to respond to a questionnaire on the results of their analysis (qualitative responses). The FSA conducted a comparative analysis of insurers based on quantitative responses and a qualitative analysis based on qualitative responses (bottom-up analysis). The FSA expects that the bottom-up analysis provides the participants opportunities to consider more seriously and discuss measures to climate-related risks as they review and analyze the results based on their policy portfolios through the bottom-up analysis. The FSA also expects that the bottom-up analysis offers insurers, who have already developed their own risk models and analyzed the impact of climate-related risks, an opportunity to refine their risk models by comparing them with the results from the GIROJ model.

5. Policies portfolio and participant insurers

The policies in force as of the end of September 2023 are used, which were the most recent data to which the GIROJ model could be applied at the time when the FSA asked the participants to conduct the 2nd scenario analysis (June 2024).

In the 2nd scenario analysis, the top-down analysis covers all domestic direct insurers[19], while the bottom-up analysis covers the 19 insurers in Figure 4.

Figure 4. Insurers covered in the 2nd scenario analysis

1	Sompo Japan Insurance Inc.
2	Tokio Marine & Nichido Fire Insurance Co., Ltd.
3	Mitsui Sumitomo Insurance Co., Ltd.
4	Aioi Nissay Dowa Insurance Co., Ltd.
5	AIG General Insurance Company, Ltd.
6	The Kyoei Fire & Marine Insurance Co., Ltd.
7	The Nisshin Fire & Marine Insurance Co., Ltd.
8	Chubb Insurance Japan
9	SECOM General Insurance Co., Ltd.

[18] More precisely, the GIROJ model under the current climate is available for all insurers selling fire insurance, while the GIROJ model incorporating climate-related risks is only available to insurers that have signed for the consulting services as described later.

[19] More precisely, all domestic direct non-life insurers that had in-force fire insurance policies as of the end of September 2023.

10	Swiss Re International S.E.
11	Zurich Insurance Company Ltd
12	Sony Assurance Inc.
13	Rakuten General Insurance Co., Ltd.
14	The Daido Fire & Marine Insurance Co., Ltd.
15	The New India Assurance Company Limited
16	JI Accident & Fire Insurance Co., Ltd.
17	Meiji Yasuda General Insurance Co., Ltd.
18	SOMPO Direct Insurance Inc.
19	SBI Insurance Co., Ltd.

The bottom-up analysis involves 19 insurers[20] that can use the GIROJ model incorporating climate-related risks. The GIROJ provides services using this GIROJ model as part of the paid consulting services, and the insurers that have already signed for this consulting service are selected. These 19 companies accounted for 99.1% in terms of direct premiums written for fire insurance in FY 2023, which could be evaluated as sufficient.

6. NGFS scenarios used and time horizon

Two NGFS scenarios, the 2050 net zero (orderly) and the current policies (Hot house world), are used in the 2nd scenario analysis, as in the 1st one.

The 4th vintage of the NGFS scenarios[21] provides seven scenarios in four categories. Physical risks are essential in the scenario analysis of non-life insurers; then the "current policies (Hot house world)" with the largest physical risks and the "2050 net zero" with the most ideal decarbonization scenario are selected.

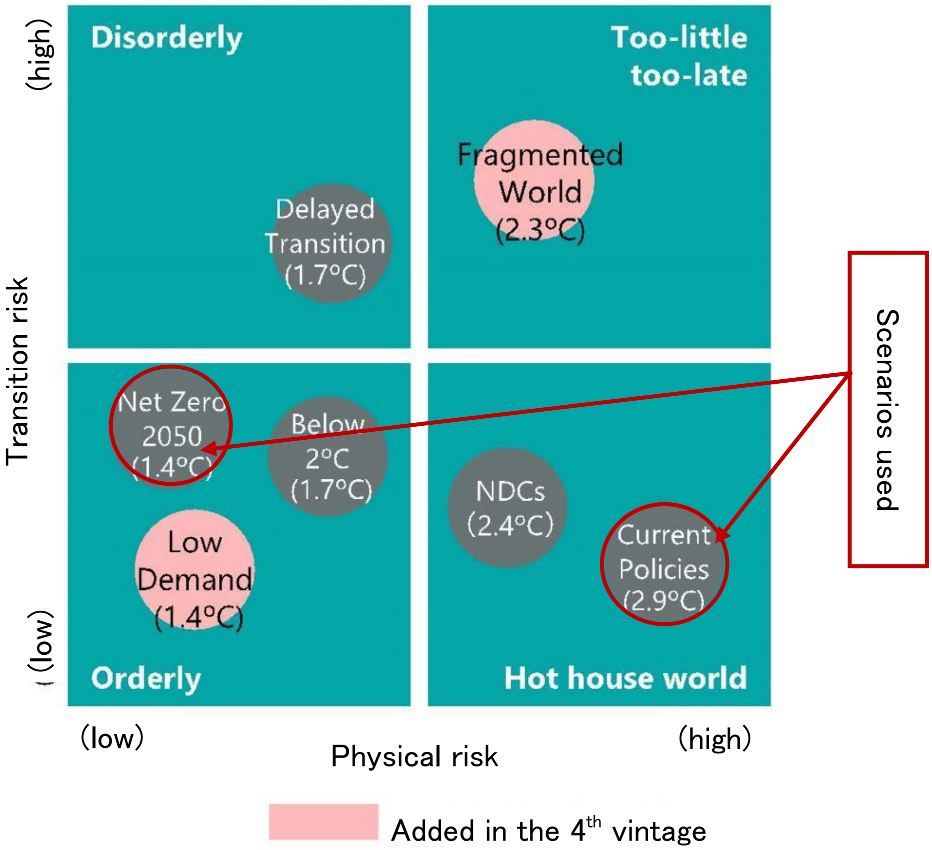
[20] More precisely, insurers, which could use the GIROJ model, incorporated climate-related risks at the time of the request for conducting the 2nd scenario analysis (June 2024).

[21] Though the 5th vintage of NGFS scenarios was published in November 2024, the 4th vintage was used in the 2nd scenario analysis as the latest version at the time of the request (June 2024).

Figure 5. NGFS scenarios (4th vintage)

Category	Scenarios and Narrative
Orderly	Low Demand assumes that significant behavioral changes – reducing energy demand – in addition to (shadow) carbon price and technology induced efforts, would mitigate pressure on the economic system to reach global net zero CO2 emissions around 2050.
	Net Zero 2050 limits global warming to 1.5°C through stringent climate policies and innovation, reaching global net zero CO2 emissions around 2050.
	Below 2°C gradually increases the stringency of climate policies, giving a 67% chance of limiting global warming to below 2°C.
Dis-orderly	Delayed Transition assumes annual emissions do not decrease until 2030. Strong policies are needed to limit warming to below 2°C. Negative emissions are limited.
Hot house world	NDCs[22] includes all pledged targets even if not yet backed up by implemented effective policies.
	Current Policies assumes that only currently implemented policies are preserved, leading to high physical risks.
Too-little too-late	Fragmented World assumes a delayed and divergent climate policy response among countries globally, leading to high physical and transition risks. Countries with net zero targets achieve them only partially (80% of the target), while the other countries follow current policies.

[22] NDC stands for "**N**ationally **D**etermined **C**ontribution" stated in the Paris Agreement.



(Source) FSA 2023 Research Report: Survey on Use of NGFS Scenario Analysis

While the NGFS 4th Scenario database provided a wide range of data[23], only global average temperature rises[24] are used in the 2nd scenario analysis due to the limitation of the GIROJ model. Figure 6[25] shows the global average temperature rises under the 4th vintage of the NGFS scenarios.

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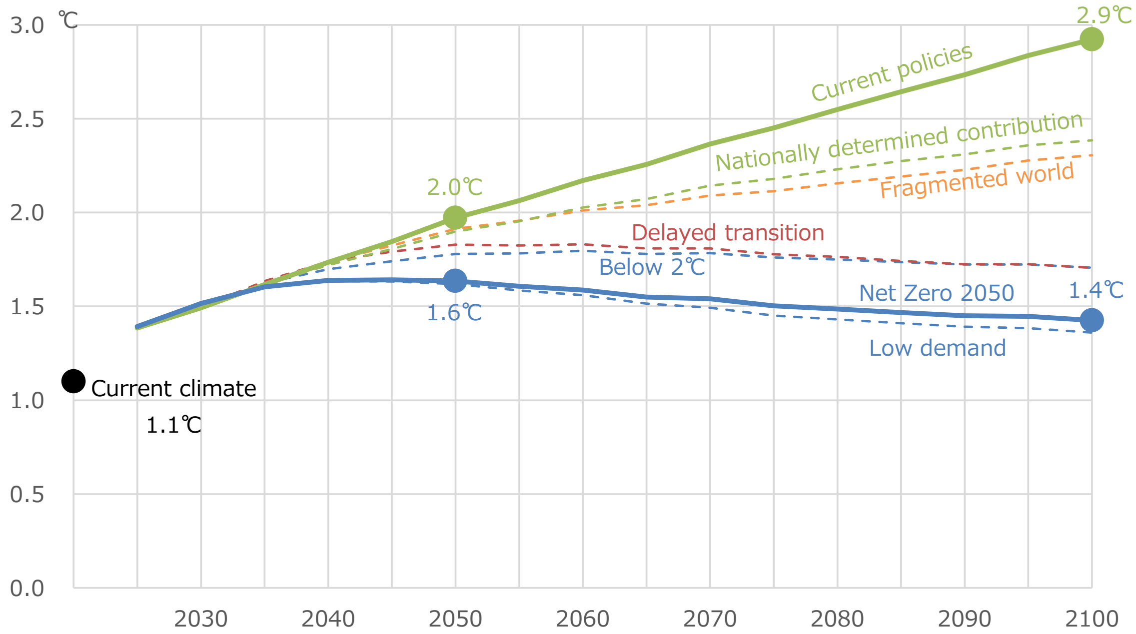
[23] FSA 2023 Research Report: "Survey on Use of NGFS Scenario Analysis." (Only Japanese version)

[24] Rise in global average temperature since pre-industrial times (1850 to 1900 average).

[25] The NGFS IIASA Scenario Explorer is used. There is also the NGFS CA Climate Impact Explorer for physical risks in the NGFS scenario database, but there is no significant difference between them. The former is adopted because there are many studies using the former. The NGFS IIASA Scenario Explorer has three models, GCAM, MESSAGE, and REMIND, to estimate global average temperature rises. The average of the three models is used, although there is no significant difference among them. (See VII. Appendix 3.)

Figure 6：Global average temperature rises under NGFS scenarios



The changes from the current climate are analyzed at the time horizons of 2050 and 2100 in the 2nd scenario analysis, as in the 1st one.

This is because physical risks are likely to materialize over the long term.

The global average temperature rise at the current climate is not provided in the 4th vintage of the NGFS scenarios but is used as 1.1℃ instead, which the IPCC[26] 6th Assessment Report (2022) announced as one from 2011 to 2020.

In summary, the global average temperature rises used in the 2nd scenario analysis are shown in Figure 7.

Figure 7: Global average temperature rises used in the 2nd scenario analysis

	Current climate	2050	2100
Net Zero 2050 (Orderly)	1.1℃	1.6℃	1.4℃
Current Policies (Hot house world)	1.1℃	2.0℃	2.9℃

7. Other

The GIROJ models that incorporate climate-related risks are models that

[26] The Intergovernmental Panel on Climate Change is an intergovernmental organization established by the World Meteorological Organization and the United Nations Environment Programme in 1988.

calculate claims payments by typhoons and floods at 2℃ or 4℃ above pre-industrial levels. Thus, to calculate claim payments for, say, 1.6℃ above pre-industrial levels, one would estimate from claim payments for the current climate (1.1℃ above) and for the case of 2℃ above. Linear interpolation, which is the simplest method, is used because there is no standard method for this kind of estimation.

V. Results of the 2nd scenario analysis

1. Things to be mindful of

The GIROJ Model is one of the risk assessment models developed by the GIROJ with reference to the studies and research on climate-related risks and in consultation with the external experts at the Typhoons and Floods Subgroup of the Study Group on Disaster Science in the GIROJ, but it is just one of the risk assessment models developed from the estimated data calculated by climate models based on the current knowledge.

In addition, the GIROJ model incorporated climate change impacts by obtaining the change (rate) of parameters under climate change using the d4PDF[27] outputs, which are climate change projection data, and applying them to the GIROJ model. The d4PDF uses six different sea surface temperatures[28] (SSTs) to estimate future climate, and the GIROJ also developed six sub-models that incorporate climate change impacts for six SSTs, respectively. The 2nd scenario analysis uses the average of the six sub-models, but there are certain differences among the results of the six sub-models, which also means that there are uncertainties in the results of the scenario analysis.

In addition to the uncertainties due to the risk models, it is necessary to keep in mind the following limitations and uncertainties.

Figure 8. Limitations and uncertainties in the GIROJ model

Only fire insurance is analyzed and other lines of business, such as auto, casualty, and marine, are not analyzed for their impact.
It is assumed that the strength of buildings and embankments, and the capability of sewerage systems remain unchanged at present, and future disaster prevention and mitigation measures have not been incorporated.
The policies portfolio as of the end of September 2023 is assumed but not future demographic and construction dynamics by region.

[27] d4PDF stands for "Database for (4) Policy Decision making for Future climate change", supported by the Program for Risk Information on Climate Change sponsored by the Ministry of Education, Culture, Sports, Science and Technology. (https://climate.mri-jma.go.jp/d4PDF/index_en.html)

[28] See Ⅶ. Appendix 2 for six SSTs.

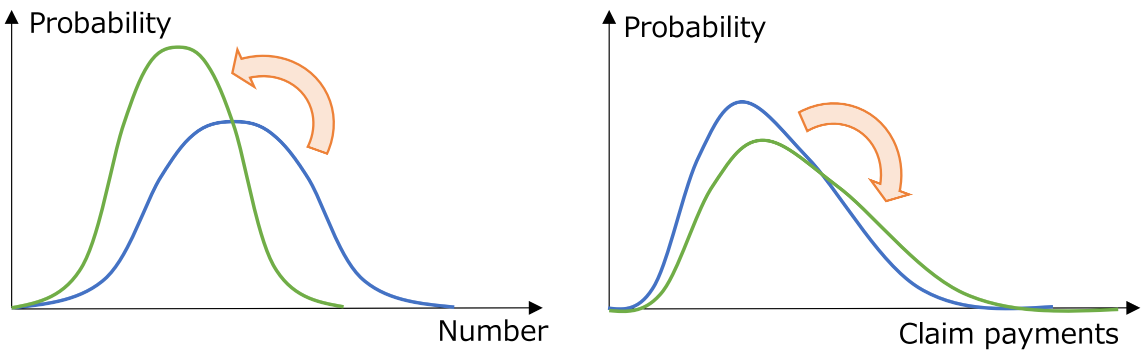
2. Results of the top-down analysis

(1) **Typhoon**[29]

a. Overview

The annual claim payments by typhoons can be described as (annual number of typhoons[30]) x (claim payments per typhoon). Each of them is expressed by a probability distribution, and it is analyzed as shown in Figure 9, to see how each probability distribution changes due to global warming. Global warming decreases the annual number of typhoons (shifting left)[31] and increases claim payments per typhoon (shifting right).

Figure 9: Distributions of the annual number of typhoons (left) and claim payments per typhoon (right)



These two factors move in opposite directions under the effects of global warming. Therefore, the results of multiplying them depend on which one has the largest impact. In the results of this study, the effect of claim payments per typhoon is larger, and the distribution of annual claim payments shifts right (the average increases) as well as the variance increases (flattens). In other words, the longer the return period is and the larger the claim payment is

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[29] Flood risks caused by typhoons are assessed using flood model.

[30] More precisely, it is the number of typhoons that cause claim payments in Japan.

[31] IPCC AR6 WG1 Technical Summary says, "The proportion of tropical cyclones that are intense is expected to increase (high confidence), but the total global number of tropical cyclones is expected to decrease or remain unchanged (medium confidence)." On the other hand, Climate Change in Japan 2025, announced by the Ministry of Education, Culture, Sports, Science and Technology and the Japan Meteorological Agency in March 2025, says, "No significant long-term trend is observed in the number of typhoons formed and the number approaching in Japan." Therefore, the scientific findings do not reach a consensus.
(https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_TS.pdf)
(https://www.data.jma.go.jp/cpdinfo/ccj/2025/pdf/cc2025_gaiyo_en.pdf)

(further to the right on the graph is), the higher the rate of increase for claim payments is.

Figure 10. Distribution of annual claim payments (Typhoons)

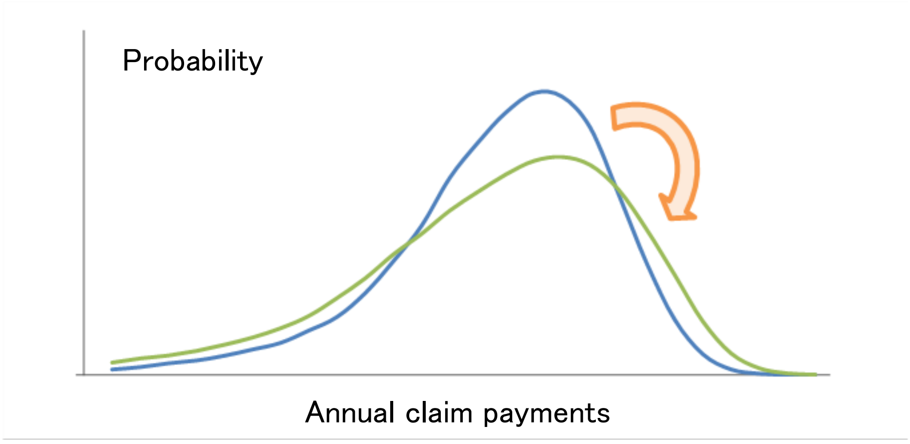


Figure 11 shows the rate of increase due to global warming by sorting the 100,000 cases in order of annual claim payments. It shows small annual claim payments tend to be smaller (the rate of increase is negative) while large ones tend to be larger (the rate of increase is positive). This shows that the variance increases (flattens) in Figure 10.

Figure 11 : The rate of increase for annual claim payments (Typhoons)

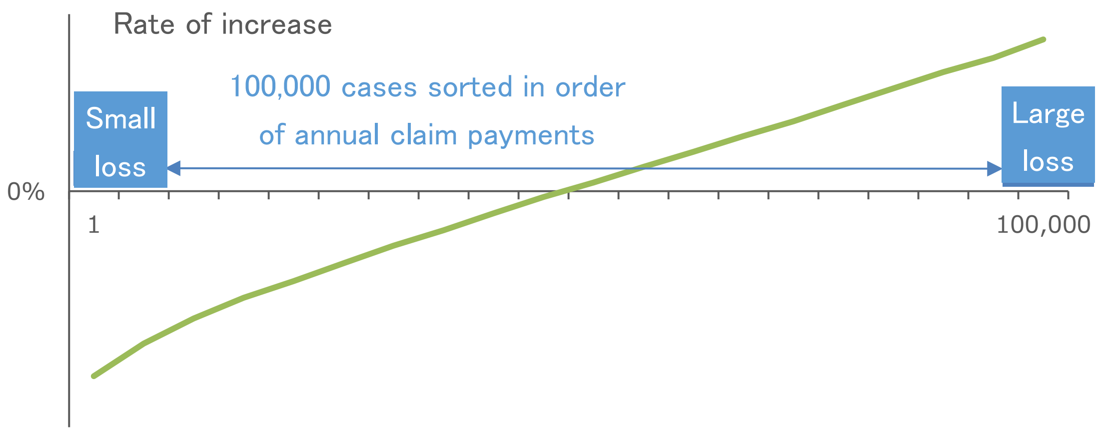
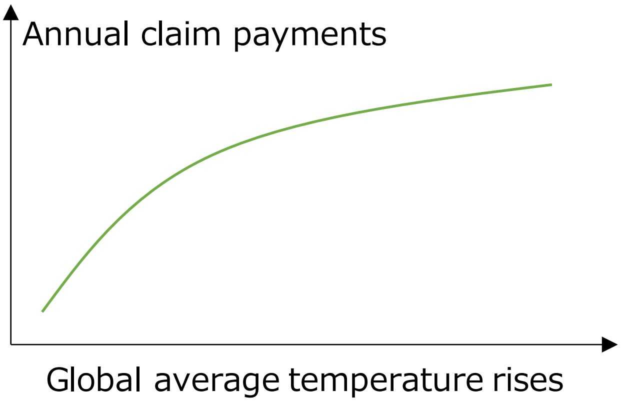


Figure 12 shows how the annual claim payments for tail events with a return period of 10 years or more shift with the change in temperature. When the temperature rises from the current climate (1.1℃), the rate of increase for claim payments tends to be high at first (steep slope) and then gradually becomes low (gradual slope).

Figure 12: Annual claim payments by temperature change (Typhoons)



b. Net Zero 2050 (Orderly)

Average claim payments increase until 2050 and then decreases as temperatures go down. As for the rate of increase for claim payments by return periods, the longer the return period is, the higher the rate of increase for claim payments tends to be.

c. Current Policy (Hot house world)

Average claim payments increase as temperatures rise in 2050 and 2100. However, the rate increases particularly high until 2050 and remains relatively low from 2050 to 2100.

As for the rate of increase for claim payments by return periods, as same to the 2050 net zero, the longer the return period is and the larger the typhoon is, the higher the rate of increase for claim payments tends to be.

d. Comparison by property type

So far, we have looked at property totals including residential and business. Regardless of scenarios, the increased rate of residential properties is higher than that of business properties. Due to the lack of detailed data, it is difficult to comprehensively analyzed this. But residential properties, many of which are with wooden or tiled roofs, may be more vulnerable to typhoons than business ones.

(2) Floods

a. Overview

The annual claim payments by floods can be described as (annual number of floods) x (claim payments per flood). Each of them is expressed by a probability distribution, and it is analyzed as shown in Figure 13, to see how each probability distribution changes due to global warming. Global warming leads to an increase in the annual number of floods (shifting right). For lower annual numbers of floods (on the left side), the rate of increase is more significant, while for higher annual numbers (on the right side), the rate of increase is less pronounced. A rise in temperature increases claim payments per flood slightly (shifting right slightly).

Figure 13. Distributions of the annual number of floods (left) and claim payments per flood (right)

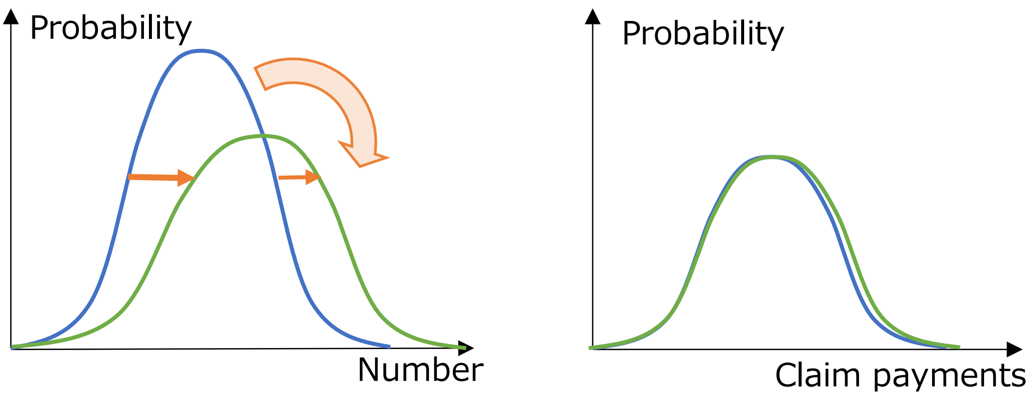
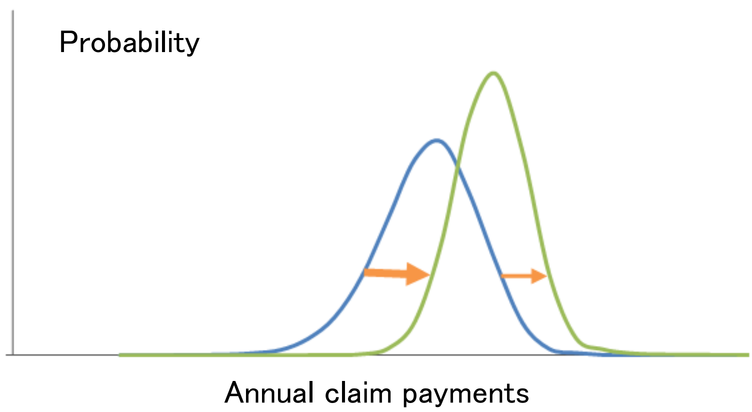


Figure 14. Distribution of annual claim payments (Floods)



As a result of multiplying these two factors, the distribution of annual claim payments shifts right (the average increases). For smaller annual claim payments (on the left side), the rate of increase is more significant, while for larger annual claim payments (on the right side), the rate of increase is less pronounced.

Figure 15 shows the rate of increase due to global warming by sorting the 100,000 cases in order of annual claim payments. As seen above, the rate of increase for smaller annual claim payments tends to be higher and generally decreases gradually. However, it tends to increase again in the case of large floods whose return period exceeds 70 years.

Figure 15: The rate of increase for annual claim payments (Floods)

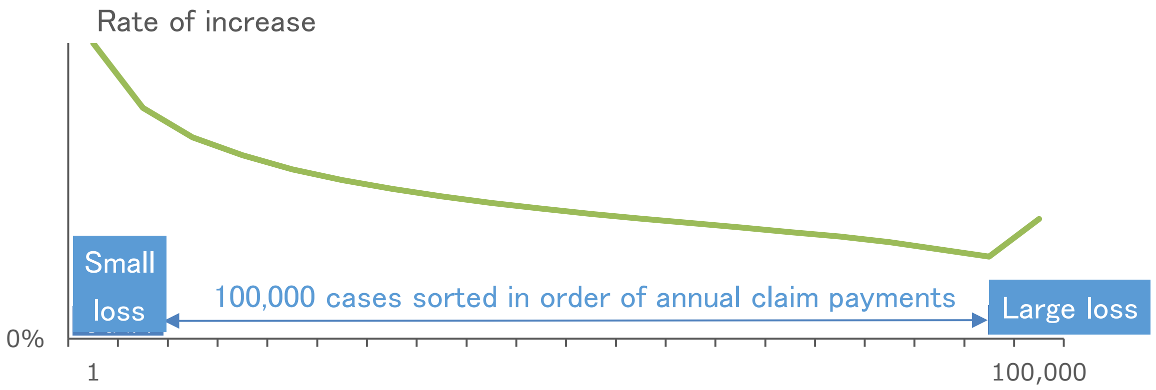
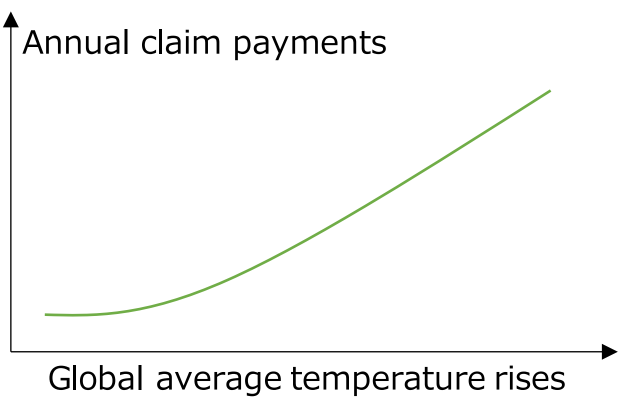


Figure 16 shows how the annual claim payments for tail events with a return period of 10 years or more shift with the change in temperature.

Figure 16: Annual claim payments by temperature change (Floods)



Unlike the typhoons in Figure 12, when the temperature rises from the current climate (1.1℃), the rate of increase for claim payments tends to be low at first (gradual slope) and then gradually becomes high (steep slope).

b. Net Zero 2050 (Orderly)

As with typhoons, average claim payments increase until 2050 and then decrease as temperatures go down.

The rate of increase for claim payments by return periods decreases until it reaches 50 to 70 years, after which it increases again, although it remains lower than the average.

When comparing typhoons and floods, the amount of the average claim payments and claim payments by return periods are larger for typhoons, but the rate of increase for claim payments when temperatures rise is higher for floods than for typhoons in all cases.

c. Current Policies (Hot house world)

Average claim payments increase as temperatures rise in 2050 and 2100. As for the rate of increase for claim payments by return periods, that initially decreases as the return period is longer and then increases again. At some return periods, that is higher than the average, but lower in many cases.

When comparing typhoons and floods, the trend is the same as Net Zero 2050.

d. Comparison by property type

So far, we have looked at property totals including residential and business. Regardless of scenarios, the increased rate of business properties is higher than that of residential properties, rather than typhoons. Due to the lack of detailed data, it is difficult to comprehensively analyze this. However, business properties, many of which are near rivers or the sea, may be more vulnerable to floods than residential ones.

3. Results of the bottom-up analysis

(1) Average claim payments

Figures 17 and 18 show a comparison of the increase rates of the average claim payments among insurers as temperatures rise from the current climate using the GIROJ model. There are some differences in the rate of increase for average claim payments for both typhoons and floods.[32]

Figure 17. Rate of increase for average claim payments (Typhoons)

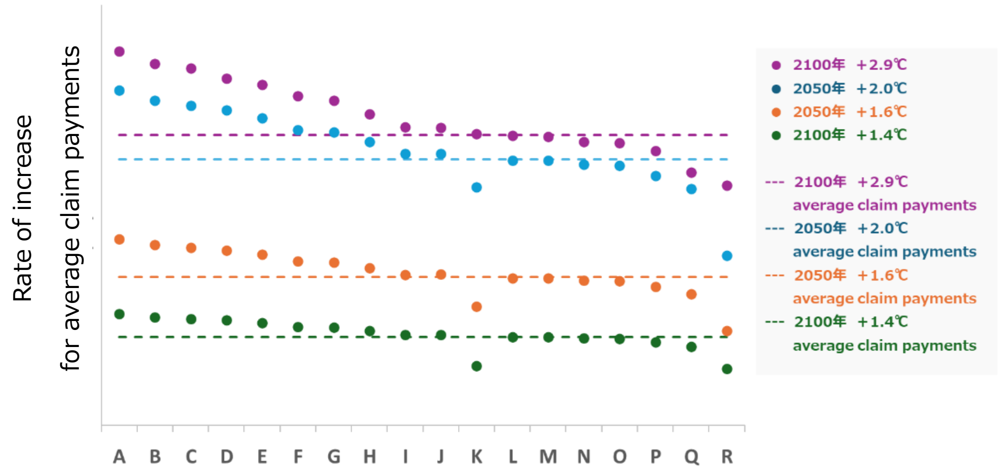
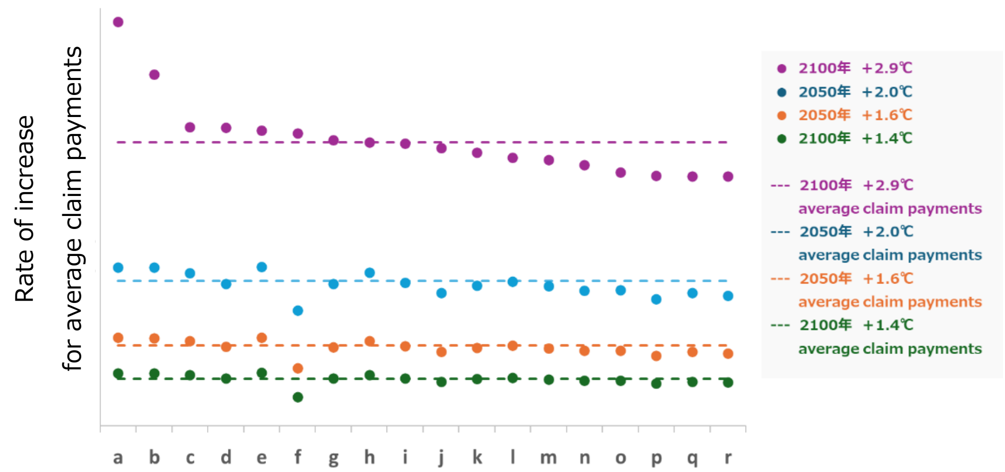


Figure 18. Rate of increase for average claim payments (Floods)



[32] For peer comparison, 18 of the 19 insurers in the bottom-up analysis that sell fire insurance nationwide are plotted. Insurers are sorted in order of the rates of increase for claim payments at 2.9℃ above for typhoons and floods, respectively.

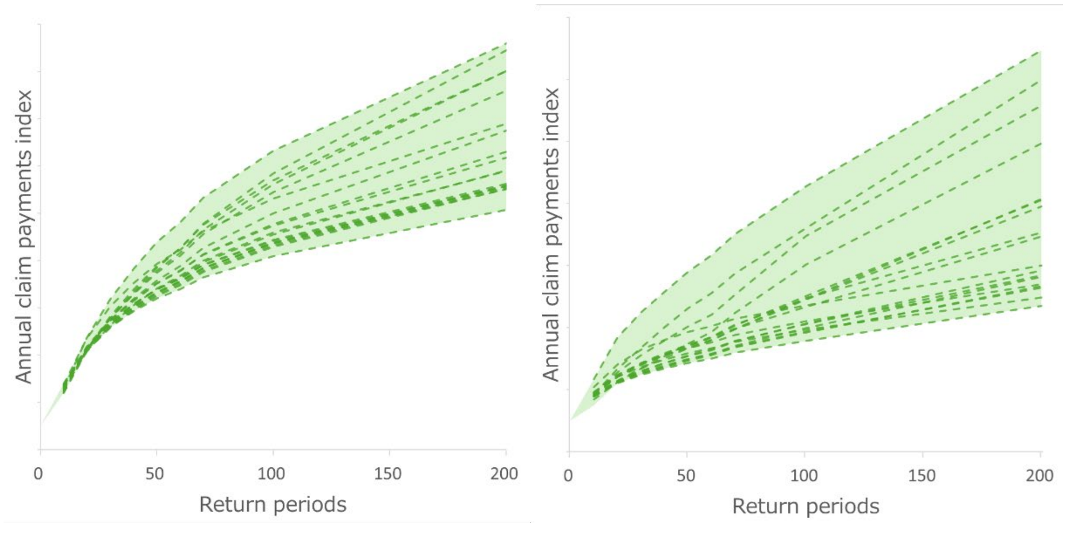
Comparing the rates of increase by typhoons, those tend to be higher for insurers with high ratios of residential properties to the total policies in force (insurers with low ratios of commercial properties).

In the case of floods (as opposed to typhoons), the rates of increase tend to be higher for insurers with high ratios of commercial properties to the total policies in force (insurers with low ratios of residential properties).[33]

(2) Distribution of claim payments (rate of increase for claim payments by return period)

Figure 19 shows a comparison of changes[34] in claim payments by insurers[35] for each return period at 2.9°C above for typhoons and floods (as of 2100 under the current policy). The longer the return period is, the larger the dispersion among insurers is. The dispersion is larger for floods than for typhoons[36].

Figure 19. Change in claim payments by return period and insurer
(Typhoons [left], Floods [right])



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[33] The vertical axis of the graph has a different scale for typhoons and floods.
[34] The index is calculated by dividing the claim payment amount for each return period by the average claim payment amount.
[35] The dotted line in the graph plots 18 of the 19 insurers included in the bottom-up analysis that sell fire insurance nationwide.
[36] The vertical axis of the graph has a different scale for typhoons and floods.

(3) Opinions and requests on scenario analysis and the GIROJ models

Figure 20 shows the opinions and requests by insurers on the next steps and issues to be improved in scenario analysis and the GIROJ model.

Figure 20. Opinions and requests on scenario analysis and the GIROJ models

Opinions and requests by insurers	
GIROJ (Model)	✓ Implement the function for breaking down by regions into the GIROJ models. ✓ Add the function for the analysis by steps to address issues related to large data volumes and high computational costs. ✓ Proactively provide information on the revision of the GIROJ models and scenarios.
FSA	✓ Announce in advance the next steps of scenario analysis and the direction of supervisory policies for insurers.
Other	✓ Study alternative methods for interpolation between the current climate and a temperature increase of 2°C, as well as between a temperature increase of 2°C and 4°C.

It is technically possible to implement the function of breaking down by regions into the GIROJ models, but the high computational cost of simulation seems an issue.

In addition, the GIROJ has provided information on the revision of the GIROJ models to non-life insurers as much as possible, but this may not have been fully utilized in the past.

Many insurers are interested in the GIROJ model incorporating climate-related risks through this scenario analysis and request more easy-to-understand information. The FSA expects that communication between the GIROJ and insurers will deepen through this scenario analysis

(4) Initiatives for sustainable business models

Against the uncertainty of the business environment in the long term, like 2050 and 2100, it is difficult to expect non-life insurers to take management actions at present. Therefore, we surveyed to find out what actions they should take by 2100 if climate change progresses in line with the current policy scenario. We received opinions from insurers as shown in Figure 21.

In particular, there were many opinions on the need to ① raise premiums, ② revise policy conditions (such as the lifting of deductibles[37]), and ③ review underwriting policies and standards in response to the increasing severity of natural disasters due to climate change[38]. On the other hand, there were issues, such as ① a premium revision might make premiums surge and insurance unaffordable; ② product revision, such as the lifting of deductibles, might make the retention risk of policyholders (the possibility of self-payment) go up; and ③ a review of underwriting policies and standards might make insurance unavailable. Therefore, many opinions were expressed that it is necessary to accelerate disaster prevention and mitigation measures while paying attention to availability and affordability to minimize the impact of these issues.

In addition, the maximum insurance period for fire insurance has been gradually reduced from 35 years to 10 years and then to 5 years[39] due to the difficulty of long-term risk assessment amid increasing claim payments by natural disasters. However, many opinions were expressed that it is necessary to reduce the maximum insurance period again if climate change progresses further.

Figure 21. Actions to be considered in the case of climate change progress

	Opinions by insurers
Insurance products	✓ Reduction of the maximum insurance period (currently 5 years) ✓ Introduction of high deductibles and limits for claim payments against typhoons and floods coverage (in order to mitigate premium increase rates) ✓ Study and introduction of the index insurance[40] (which claim operations are simple even under natural catastrophes) ✓ Study and introduction of public-private partnerships to ensure the stable underwriting of high risks, such as reinsurance of

[37] In general, if the deductibles are raised, insurance premiums are reduced, but claim payments are reduced by the deductibles in the event of a disaster, so the policyholders have to pay as much as the deductibles by themselves.
[38] Only a few insurers touched withdrawal from covering typhoons and floods or from fire insurance.
[39] The maximum insurance period of Reference Loss Cost Rates was reduced to 10 years in June 2014 and to 5 years in June 2021.
[40] Insurance that pays a specific amount of claim payments when the indicators relating to the cause and effect of damage meet predetermined criteria. Also known as parametric insurance.

	earthquake insurance undertaken by government[41] and nuclear insurance pools[42].
Insurance premium	✓ Appropriate raise of insurance premiums in line with the increase in claim payments. ✓ Incorporation of future climate-related trends or uncertainties into premiums. ✓ Further fragmentation of premiums that appropriately reflects the level of risk for each policyholder (such as fragmentation by locations and of premiums for flood cover (currently 5 segments), etc.) ✓ Development of insurance products that provide incentives to enhance disaster resilience (e.g., discounts when disaster prevention and mitigation measures are implemented)
Underwriting policy	✓ Establishment of business processes and frameworks that enable flexible revisions of underwriting policies in order to cope with rapid changes in the business environment and profits ✓ Examination of underwriting policy in consideration of risk conditions like locations ✓ Promotion of disaster prevention and mitigation services and encouragement to policyholders.
Claims payment operation	✓ Improvement of the efficiency of claims service operations by using digital technology, AI, etc.. and increasing and appropriate recruitment and allocation of human resources for claims service. ✓ Establishment of business processes that enable remote claim settlement and multi-site operations to natural catastrophes.
Risk management	✓ Revision of products and underwriting policies for direct business. ✓ Further risk hedging through reinsurance, etc. ✓ Refinement of future risk assessments through enhanced scenario analysis of climate-related risks and enhancement of

[41] The Earthquake Insurance is established with the government reinsuring massive earthquake damage that exceeds certain amounts of liability that private insurers underwrite.

[42] Since nuclear energy insurance cannot be underwritten by a single private insurer or by a single national insurance industry, national insurers organize a nuclear energy insurance pool and underwrite jointly. In addition, the national nuclear insurance pools enter into reinsurance agreements with each other to diversify the risk globally.

(5) Comparison with non-life insurers' model results

We surveyed insurers who had already developed their risk models incorporating climate-related risks to compare the results of the GIROJ model with those of their own models. Three major non-life insurance groups responded to this survey[43], and two of them commented that "the trends are almost the same" or "there are no major differences."

As for typhoons, another group commented that claim payments increase as temperatures rise according to the GIROJ model, but decrease according to its model.

As described in 2. (1) Typhoon, annual claim payments can be broken down into "annual number of typhoons" and "claim payments per typhoon." Depending on which factor has a greater impact, claim payments may move either upward or downward. This group's internal model is supposed to be more affected by the annual number of typhoons.

Additionally, regarding floods, this group noted that the fluctuation in the rate of increase for claim payments using the GIROJ model was moderate regardless of the return period, while its model showed a sharp increase in a short return period, which differed from the GIROJ model's results.

At present, it is difficult to evaluate which is more appropriate for the estimation by their models and the GIROJ model. The FSA expects that the 2nd scenario analysis gives an opportunity to brush up on their models and the GIROJ model.

(6) Acute physical risks with high impact on non-life insurers

Against the results in the 4th vintage of the NGFS scenarios that droughts and heatwaves have a large negative impact on GDP, we surveyed the impact

[43] One of the three major non-life insurance groups conducts scenario analysis using its own model only for typhoons.

of droughts and heatwaves on claim payments.

As a result, some insurers indicated that claim payments may increase for insurance business lines shown in Figure 22, but most insurers commented that the impact on claim payments was limited compared to typhoons and floods.

Figure 22. Insurance business lines affected by droughts and heatwaves

Opinions by insurers	
Fire insurance	Heatwaves and drought conditions increase the risk of fires, making it possible for fire incidents and wildfires to occur or spread easily.
Personal accident or Medical insurance	The claim payments could increase for personal accident or medical insurance that covers the risk of heatstroke, as heatwaves lead to more hospital visits or deaths by heatstroke.
Workers' compensation insurance	Employers may be held responsible if the risk of heatstroke increases for employees working in hazardous heatwave conditions.
Directors and Officers liability insurance	Companies and managers who do not take action to mitigate climate change, including but not limited to issues like heatwaves and droughts, may be held accountable.

VI. Lessons learned from the 2nd scenario analysis

(1) Importance of transitioning to a decarbonized society

While the quantitative results are not shown in this report, the results of the 2nd scenario analysis show the magnitude of acute physical risks that occur when climate change progresses. It is obviously important to consider and implement adaptation measures to prepare for the materialization of acute physical risks. At the same time, they show that it is important to transition to a decarbonized society while paying attention to transition risks so that physical risks do not increase.

(2) Impact on premiums

The 2nd scenario analysis shows how claims payments paid by non-life insurers would increase. However, if claims payments increase, non-life insurers will have to raise insurance premiums to cover the costs, which will inevitably have consequences for individuals and companies who are policyholders[44].

So far, we have looked at the total amount and the rate of increase for claim payments. However, if we shift the focus to each insurance premium paid by a policyholder, we need to look at insurance premiums by rate category, such as location, building materials, and construction age. From such a viewpoint, the increasing rate of fire insurance premiums for properties whose location, building materials, and construction age make them vulnerable to typhoons and floods may be higher than that of total claim payments.

Therefore, considering the availability of insurance to each policyholder, non-life insurers need to encourage individuals and companies to utilize disaster prevention and mitigation services so that not only the total amount but also each amount of claim payments will not increase. In addition, even if insurers need to increase premiums, they should consider mitigations, including appropriate revision of policy conditions (deductible amounts, etc.), so as not to impair insurance availability.

[44] Not the whole of fire insurance premium is affected by climate-related risks, as fire insurance covers accidents caused by fire, explosion, lightning, snow, water damage, theft and so on, other than typhoons (windstorms) and floods.

(3) Impact on reinsurance

Non-life insurers usually utilize reinsurance (including ILS) to hedge natural catastrophe risks. However, when climate change progresses, non-life insurers need to utilize reinsurance more. Natural catastrophe risks in Japan are primarily underwritten by overseas reinsurers and investors. Even if the premiums for fire insurance could be raised, it is difficult for Japanese non-life insurers to continue to provide fire insurance unless overseas reinsurers and investors underwrite the reinsurance.

Accordingly, Japanese non-life insurers need to communicate more closely with reinsurers and engage in dialogue from a long-term perspective on how to share risks and returns as business partners amid increasing climate-related risks. And they need to build their own sustainable business models, including the sustainability of reinsurance, to provide fire insurance continuously.

(4) Comprehensive analysis by non-life insurers

The 2^{nd} scenario analysis is significant because it includes participation from many non-life insurers, not just the major insurers. Each insurer can analyze its own policy portfolio by the same method as the top-down analysis. Additionally, the results of the top-down analysis, as well as the peer comparison from the bottom-up analysis, help understand its policy portfolio and climate-related risks. The FSA anticipates that insurers will carry out a comprehensive analysis and expand their deliberations on strategies to reduce climate-related risks.

(5) Future improvement

The 2^{nd} scenario analysis employs the GIROJ model. But there are many other risk models, and all of them are in the process of development. So, even though the results have some uncertainties, the FSA hopes that these results serve as a starting point for sharing a sense of amount for climate-related risks among the FSA and insurers, and as an opportunity to stimulate constructive discussions toward improving various risk models and scenario analyses.

VII. Appendix

1. The GIROJ models incorporating climate-related risks

Below is an overview of how the GIROJ incorporates climate-related risks into their typhoon and flood models. To include climate-related risks in typhoon and flood models, the GIROJ created the models in consultation with the external experts in the Typhoons and Floods Subgroup of the Study Group on Disaster Science in the GIROJ.

(1) Typhoon Model[45]

The GIROJ extracted data on typhoons from the current climate and future climate data sets of d4PDF, and based on the data, it assessed the impacts (changes) of climate change on major parameters of the typhoon model.

Figure 23: Key parameters of the typhoon model

1	Annual number of typhoons
2	Location of occurrence
3	Central pressure drops
4	Radius of maximum cyclostrophic wind
5	Wind direction in the sky
6	Wind speed in the sky

As a result, only the annual number of typhoons, the central pressure drops, and the wind speed in the sky were estimated to be affected (changed) by climate change. For these three parameters, the changes (rates) at 2℃/4℃ above were analyzed for the six climate models[46] in d4PDF, respectively.

By incorporating the changes (rates) of the three parameters obtained above into the GIROJ typhoon model, virtual typhoons at temperature of 2℃ /4℃ above were generated. For other parameters, those of the current climate were applied.

45 https://www.giroj.or.jp/english/pdf/summary/model_etyphoon.pdf

46 d4PDF data sets are based on six climate models, representative of the many models in the 5th Coupled Model Intercomparison Project (CMIP5) that were used in the IPCC 5th Assessment Report. See 2. for details.

(2) Flood model

The GIROJ flood model was comprised of four sub-models: ① River Flood Engineering Model, ② Inland Water Flood Engineering Model, ③ Storm Surge Flood Engineering Model, and ④ Statistical Flood Model. The sub-models had key parameters as shown in Figure 24.

Figure 24. Key parameters of the flood model

	Key parameters	Sub-model
1	Rainfall data	① River Flood, ② Inland Water Flood
2	River channel data	① River Flood,
3	Embankment data	① River Flood, ③Storm Surge Flood
4	Altitude data	① River Flood, ② Inland Water Flood, ③ Storm Surge Flood
5	Astronomical tide level data	③ Storm Surge Flood
6	Sewer system data	② Inland Water Flood

Among these parameters, river channel data, embankment data, altitude data and sewer system data were assumed to have no (direct) impact from climate change due to their nature. The two parameters affected (changed) by climate-related risks were rainfall data used in the River Flood Engineering Model and the Inland Water Flood Engineering Model, and astronomical tide level data used in the Storm Surge Flood Engineering Model[47].

Rainfall data were taken from the current climate and future climate data of d4PDF, and the changes (rates) at temperature of 2℃/4℃ above were analyzed for the six climate models in d4PDF, respectively[48].

Astronomical tide level data were taken from the dataset of the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, using a 20-year average around the reference year (2040 in RCP8.5 for 2℃ above, 2090 in RCP8.5 for 4℃ above) based on the estimated RCP scenarios.

The River Flood and the Inland Water Flood Engineering Models applied the

[47] From the results of previous climate-related risk studies, the GIROJ assumed that rainfall data and astronomical tide level data had an impact on climate-related risks.

[48] More precisely, the River Flood Engineering Model and the Storm Surge Engineering Model used the results of analysis for each of the six climate models, and the Inland Water Flood Engineering Model and the Statistical Flood Model used those common to all six climate models.

change (rate) in rainfall data at 2℃/4℃ above, thereby generating river flood and inland water flood at 2℃/4℃ above[49].

As for storm surge flood, claim payments for 2℃/4℃ above were estimated by applying all virtual typhoons at 2℃/4℃ above generated at "(1) Typhoon Model," as well as astronomical tide level data, to the Storm Surge Flood Engineering Model.

The Statistical Flood Model is a risk model for floods that occur normally. It estimates the probability distribution of the annual frequency of events and the numbers of damaged properties for each of the seven causes of floods: typhoon, rainy season, heavy rainfall, wind waves, snow melting, landslide, and other floods. Since most of the number of damaged properties was caused by three causes of floods, i.e., typhoon, rainy season, and heavy rainfall, the impact of climate-related risks was assessed for these three causes of floods.

For the annual frequency of events, the GIROJ extracted rainfall events from the rainfall data in NHRCM05[50] developed by the Meteorological Research Institute of the Meteorological Agency, and these events were classified into three causes (heavy rainfalls by typhoons, rainy season, and others). The GIROJ estimated the annual frequency of these three causes, respectively, and the change between the annual frequency under the present climate and future climate was incorporated into the probability distribution of heavy rainfall in the Statistical Flood Model.

For the loss probability of properties, the GIROJ derived the relation formula between rainfall and loss probability (common to all heavy rainfalls) based on the flood statistics[51] and rainfall data from AMeDAS[52]. By incorporating rainfall in NHRCM05 into this formula, the GIROJ estimated the change between loss probability per event under the current climate and future climate, and incorporated the change above into the probability distribution of the Statistical Flood Model.

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[49] More precisely, the method of applying change (rate) differs between the five major rivers (Tone River, Arakawa River, Tsurumi River, Shonai River, and Yodo River) and others.

[50] NHRCM05 stands for "5 km grid **N**on-**H**ydrostatic **R**egional **C**limate **M**odel," which is the data set to forecast climate change around Japan.

[51] One of the statistics announced by the Ministry of Land, Infrastructure, Transport and Tourism.

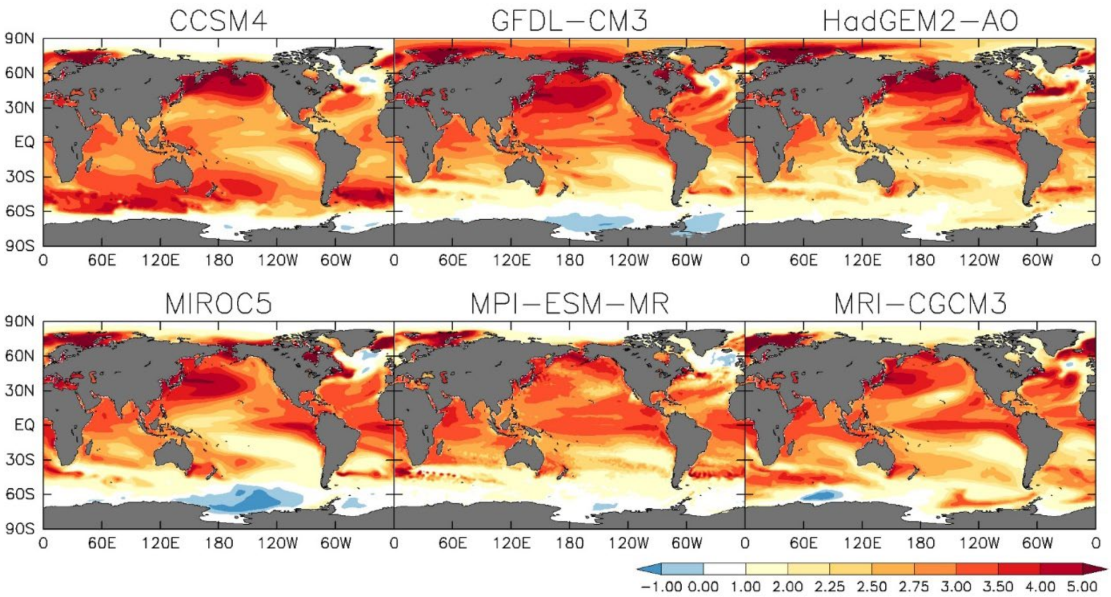
[52] AMeDAS stands for "**A**utomated **Me**teorological **D**ata **A**cquisition **S**ystem" and is one of the statistics announced by the Meteorological Agency.

2. Six climate models used in d4PDF

d4PDF is a number of ensemble experiments using six spatial distributions of future SST changes, each with 54 or 90 distributions with 9 or 15 perturbations of SST, based on the results of the global atmosphere-ocean coupled model that contributed to phase 5 of the Coupled Model Intercomparison Project (CMIP5) used in the IPCC 5th Assessment Report.

These spatial distributions of future SST change were defined as the average temperature change from 2070 to 2099 for the six climate models in Figure 26, as shown in Figure 25. These six climate models were selected based on a cluster analysis of geographical patterns of SST changes so that the six patterns cover most of the uncertainty of the patterns in all the CMIP5 models[53].

Figure 25: Distributions of SST change by six climate models[54]



(Source) d4PDF User's Guide Chapter 2

53 https://climate.mri-jma.go.jp/d4PDF/design_en.html

54 Annual-mean horizontal distributions of SST changes (K) for the six climate models.

Figure 26: Six Climate models used in d4PDF

Models		Institutions
CC	CCSM4	National Center for Atmospheric Research (US)
GF	GFDL-CM3	NOAA Geophysical Fluid Dynamics Laboratory (US)
HA	HadGEM2-AO	Met Office Hadley Centre (UK)
MI	MIROC5	Atmosphere and Ocean Research Institute (AORI), National Institute for Environmental Studies (NIES), and Japan Agency for Marine-Earth Science and Technology (JAMSTEC) (Japan)
MP	MPI-ESM-MR	Max Planck Institute for Meteorology (Germany)
MR	MRI-CGCM3	Meteorological Research Institute (Japan)

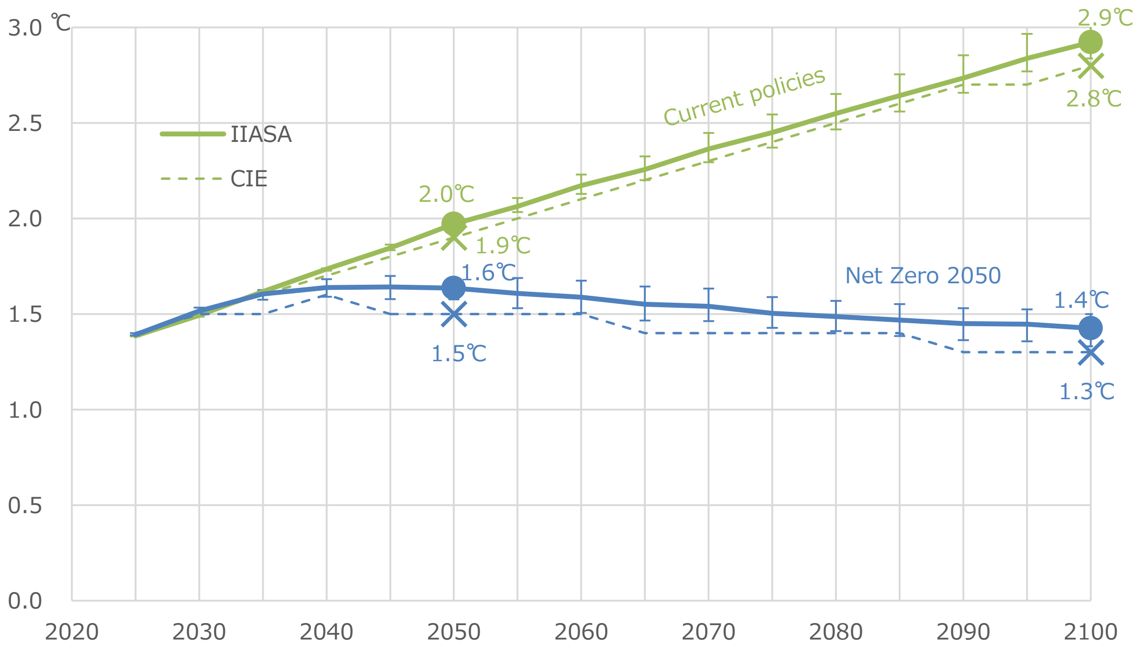
3. Global average temperature rises of the 4th NGFS Scenario Databases

There are two databases for the 4th vintage of NGFS scenarios: the NGFS IIASA Scenario Explorer, which deals mainly with transition risks and the macro economy, and the NGFS CA Climate Impact Explorer, which deals mainly with physical risks.

In addition, the NGFS IIASA Scenario Explorer uses three models – GCAM, MESSAGE, and REMIND – to provide data on global average temperature rises calculated by each model.

There are some differences in global average temperature rises among these databases and models; therefore, it should be decided which ones to use. Since many of the studies using NGFS scenarios used IIASA, we decided to use IIASA for the 2nd scenario analysis. In addition, we used the average of three IIASA models (GCAM, MESSAGE, and REMIND).

Figure 27: Difference in global average temperature rises between IIASA[55] and CIE[56]



55 Averages for the three IIASA models (GCAM, MESSAGE, and REMIND) are shown as solid lines, and differences between the three models are displayed as error ranges.

56 CIE stands for Climate Impact Explorer.