International Disaster Reduction Alliance Forum, Room Kairaku, Kobe Portopia Hotel
January 28, 2025

Climate Change Adaptation for Natural Disasters

Eiichi NAKAKITA

Deputy Executive Director, Kyoto University

Director, Center for Climate Change Adaptation Strategy, Disaster Prevention Research Institute, Kyoto University

Professor, Hydrometeorology, Kyoto University

Technical Advisor to Ministry of Education, Culture, Sports, Science and Technology

Senior researcher, Disaster Reduction and Human Renovation Institution

Member of the Council for Infrastructure for the Ministry of Land, Infrastructure, Transport and Tourism

Member of the Advisory Board on Climate Change for the Ministry of Education, Culture, Sports, Science and Technology, and Japan Meteorological Agency

nakakita@hmd.dpri.kyoto-u.ac.jp

DPRI-KU

Lecture Contents

1. Climate change is starting to have impacts
2. What are scientific climate change predictions?
3. Torrential rains and impacts of climate change
4. Hazards and climate change
5. What is no-regret climate change adaptation?
6. Conclusion

Flood and landslide disasters in recent years

[2011.7 Torrential rains in Niigata/Fukushima]

○Flood damage, Tadami River
(Onuma District, Fukushima)

[2012.7 Torrential rains in northern Kyushu]

①Flood damage, Shira River
(Kumamoto City, Kumamoto)

[2013.9 Typhoon Man-yi (No. 18)]

②Flooding, Yura River
(Fukuchiyama City, Kyoto)

[2014 Heavy rains from 8.19]

③Landslide
(Hiroshima City, Hiroshima)

[2015.9.10 Torrential rains in Kanto and Tohoku]

④Flood due to bank breach, Kinu River
(Joso City, Ibaraki)

[2016.8 Typhoon Lionrock (No. 10)]

⑤Flood damage due to overflow,
Omoto River (Iwaizumi Town, Iwate)

[2017.7 Torrential rains in northern Kyushu]

⑥Flood damage, Katsura River
(Asakura City, Fukuoka)

[2018.7 Torrential rains]

⑦ Flood damage, Oda River
(Kurashiki City, Okayama)

[2018 Typhoon Jebi (No. 21)]

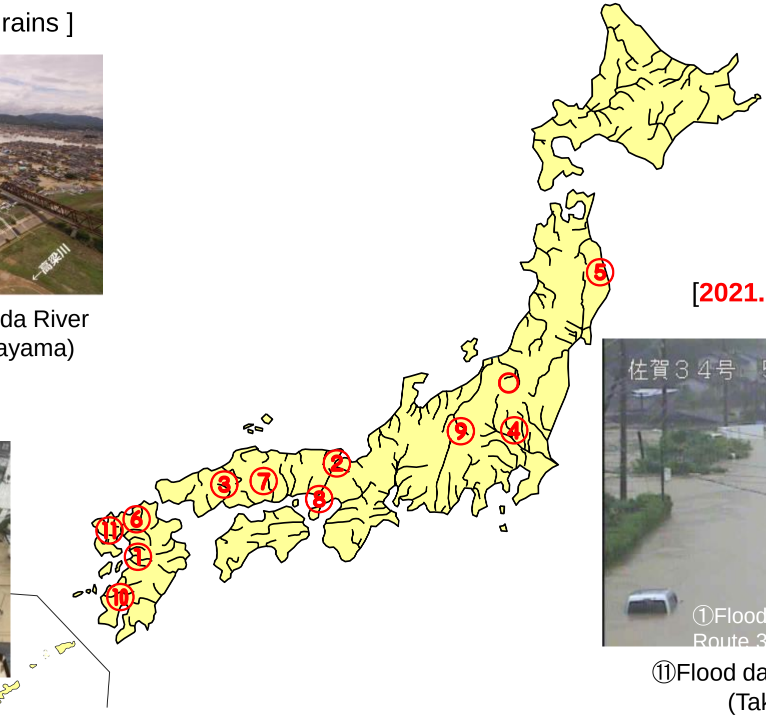
⑧Flood damage at Kobe Port,
Rokko Island (Kobe City, Hyogo)

[2019 Typhoon Hagibis (No.19)]

⑨Hokuriku Shinkansen rail yard
(Nagano City, Nagano)

[2020.7 Torrential rains]

⑩Flood damage, Kuma River
(Hitoyoshi City, Kumamoto)



[2021.8 Torrential rains]

⑪Flood damage, Rokkaku River
(Takeo City, Saga)

MLIT (2019) and Nakakita

More severe and frequent water disasters caused by climate change

国土交通省

○ Due to an increase in short-term heavy rainfall and larger typhoons, flood damage has become more frequent in recent years, and it appears that the impacts of global warming are already becoming apparent. Furthermore, it is predicted that water disasters will become more severe and frequent in the future due to climate change.

■ **Major disasters that occurred between 2013 and 2023**

①2013 Typhoon Man-yi (No. 18)

Flood damage due to overflow, Yura River (Fukuchiyama City, Kyoto)

② 2015.9 Torrential rains in Kanto and Tohoku

Flood damage due to bank breach, Kinu River (Joso City, Ibaraki)

③2016.8 Typhoon Lionrock (No. 10)

Flood damage due to overflow, Omoto River (Iwaizumi Town, Iwate)

Flood damage due to bank breach, Sorachi River (Minamifurano Town, Hokkaido)

④2017.7 Torrential rains in northern Kyushu

Flood damage, Akaya River (Asakura City, Fukuoka)

⑤2018.7 Torrential rains

Flood damage, Oda River (Kurashiki City, Okayama)

Flood damage, Hiji River (Ozu City, Ehime)

⑥2019 Typhoon in Eastern Japan

Flood damage, Chikuma River (Nagano City, Nagano)

⑦2020.7 Torrential rains

Flood damage, Kuma River (Hitoyoshi City, Kumamoto)

⑧2021.8 Heavy rains

Flood damage, Ikemachi River (Kurume City, Fukuoka)

⑨2022.8 Heavy rains

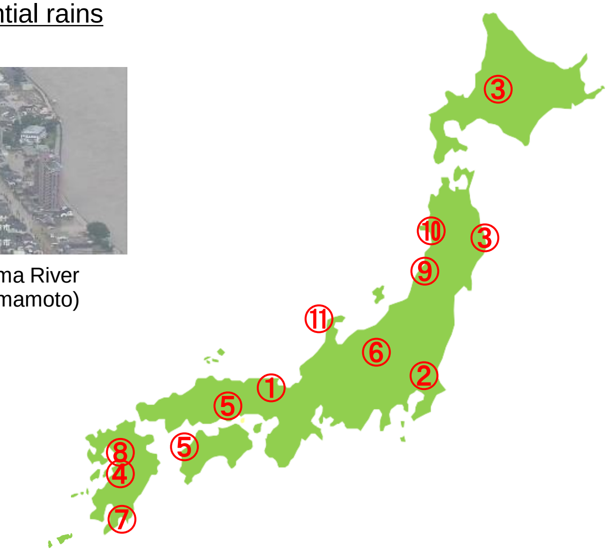
Flood damage, Mogami River (Oe Town, Yamagata)

⑩2023.7 Heavy rains

Flood damage, Taihei River (Akita City, Akita)

⑩2024.9 Heavy rains

Flood damage, Kawarada River (Wajima City, Ishikawa)



* In addition to those shown above, earthquakes, heavy rains, etc. have caused damage all over the country.

MLIT (2024)

Impact of global warming on major disasters (event attribution)

国土交通省

- ○ A quantitative assessment of the impact of global warming on precipitation is being carried out by the Meteorological Research Institute of the Japan Meteorological Agency and the Ministry of the Environment.
- ○ At present, it is estimated that total precipitation has already increased by approx. 6.5% to 16% due to the impacts of global warming.
- ○ In the future, total precipitation is likely to increase by an additional 4.4% to 19.8% compared to the present.

Global warming happening at present

Global warming that will happen in the future

Water disasters (Torrential rain events)	**Present** Impacts of rising air temperatures and sea surface temperatures due to global warming since 1980	**Future** Future climate situation compared to present situation (2-degree Celsius increase scenario to 4-degree Celsius increase scenario)
Torrential rains, July 2018	Total precipitation increased by **about 6.5%**. (1)	—
Typhoon in Eastern Japan, 2019	Total precipitation increased by **about 11%**. (1)	In the future, total precipitation will further increase by **4.4% to 19.8%**. (2)
Torrential rains, July 2020	Total precipitation increased by **about 15%**. (1)	—
Heavy rains, June to early July 2023	Total precipitation increased by **about 16%**. The total number of linear precipitation bands formed increased by **about 1.5 times**. (1)	—

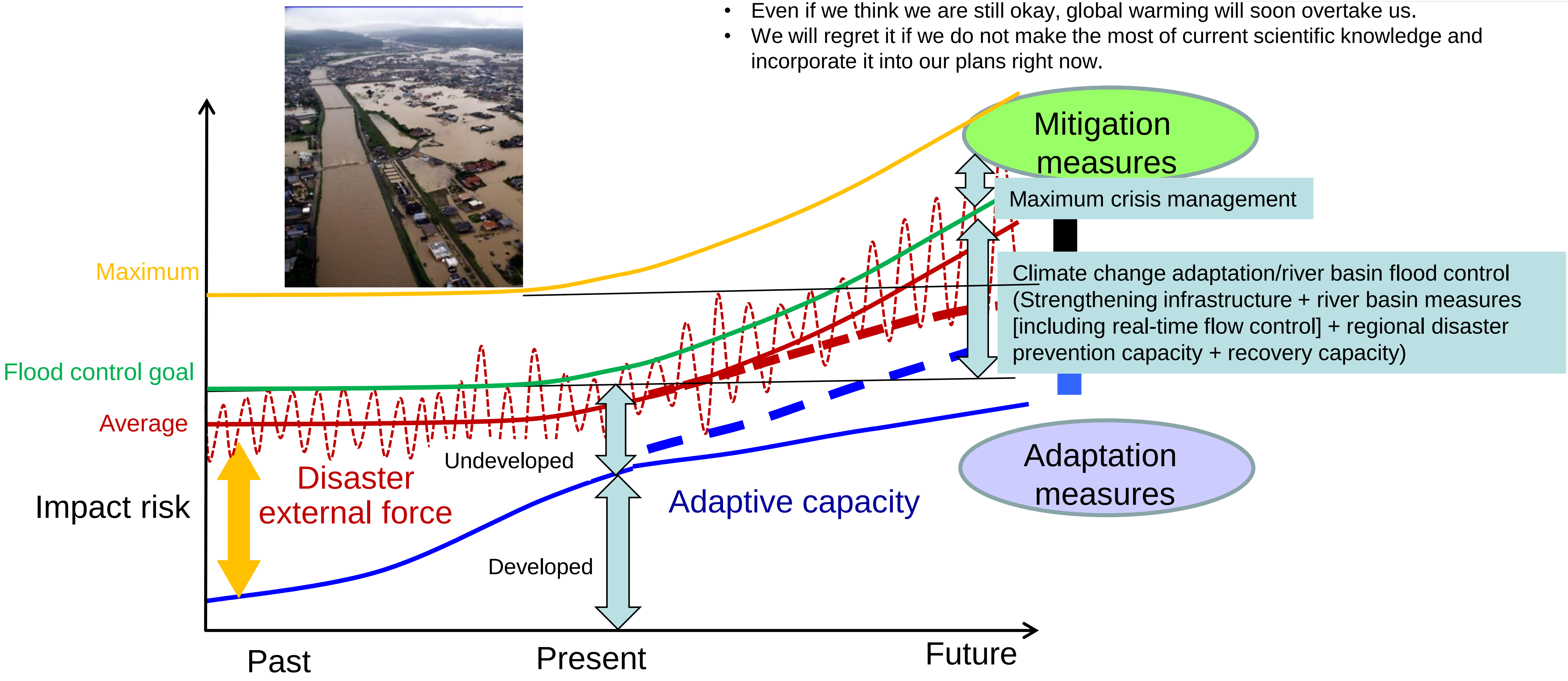
<Notes>

* Prepared by the Water and Disaster Management Bureau of the Ministry of Land, Infrastructure, Transport and Tourism based on each source. [(1): Published by the Meteorological Research Institute of the Japan Meteorological Agency, (2): Published by the Ministry of the Environment]
* A quantitative assessment of the impact of global warming is carried out by faithfully reproducing actual torrential rain phenomena using numerical simulations of the atmosphere, and then by removing the temperature rise caused by global warming, or by further raising the temperature based on a global warming scenario and performing a numerical simulation of the atmosphere again.
* The rate of increase in total precipitation due to the torrential rains in July 2020 was achieved by evaluating only the linear precipitation bands that occurred near the Kuma River basin.
* The rate of increase in total precipitation due to heavy rains from June to early July 2023 was achieved by evaluating the heavy rains that occurred in northern Kyushu from July 9 to 10, 2023.
  The rate of increase in the total number of linear precipitation bands was achieved by evaluating those that occurred during the period of heavy rains from June to early July 2023.

Summary by MLIT (2024)

Role of adaptation measures

- Global warming is starting to occur.
- Even if we think we are still okay, global warming will soon overtake us.
- We will regret it if we do not make the most of current scientific knowledge and incorporate it into our plans right now.



Komatsu (Kyushu University, 2012), Mimura (Ibaraki University, 2014) and Nakakita (2019)

Lecture Contents

1. Climate change is starting to have impacts
2. **What are scientific climate change predictions?**
3. Torrential rains and impacts of climate change
4. Hazards and climate change
5. What is no-regret climate change adaptation?
6. Conclusion

01 Sep 208X 00 UTC

What changes will global warming bring to the Earth?

Science-based future projections using climate models

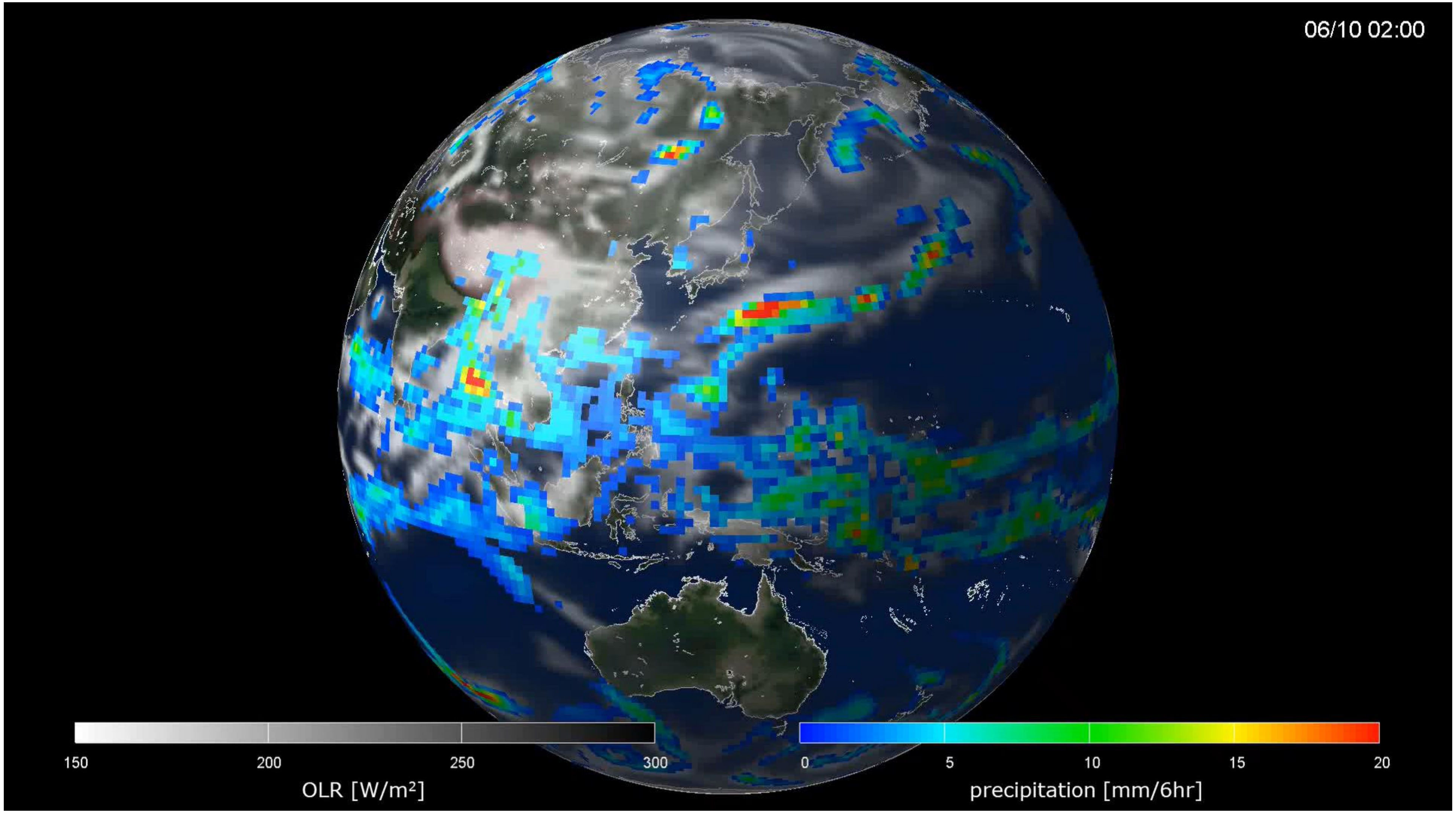
Global warming heats up the atmosphere.
Heat is absorbed by the ocean.
The sea surface temperature rises and sea water evaporates more easily.
More water vapor is produced, creating more clouds and more rain.

TOUGOU
SOUSEI
KAKUSHIN

Integration of climatology, computer science, and geoengineering

Integrated Research Program for Advancing Climate Models by MEXT: Integrated Climate Change Projection

Large ensembles d4PDF d2PDF (20 km) and downscaling model (5 km)



DPRI-KU

気候変動予測先端研究プログラム
Advanced Study of Climate Change Projection (SENTAN)

Lecture Contents

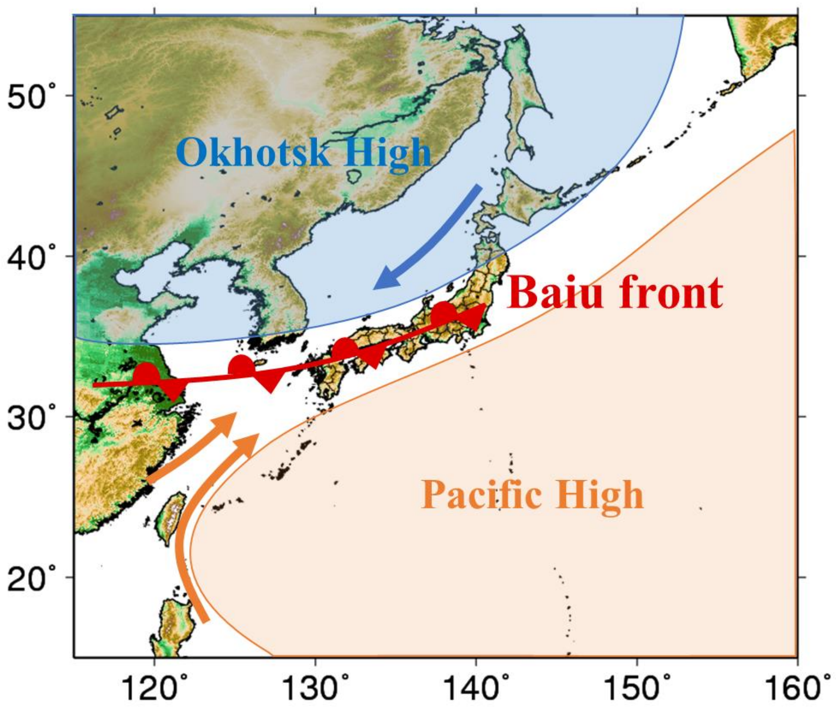
1. Climate change is starting to have impacts
2. What are scientific climate change predictions?
3. Torrential rains and impacts of climate change
4. Hazards and climate change
5. What is no-regret climate change adaptation?
6. Conclusion

Estimated impacts of global warming on Japan

TOUGOU
SOUSEI
KAKUSHIN

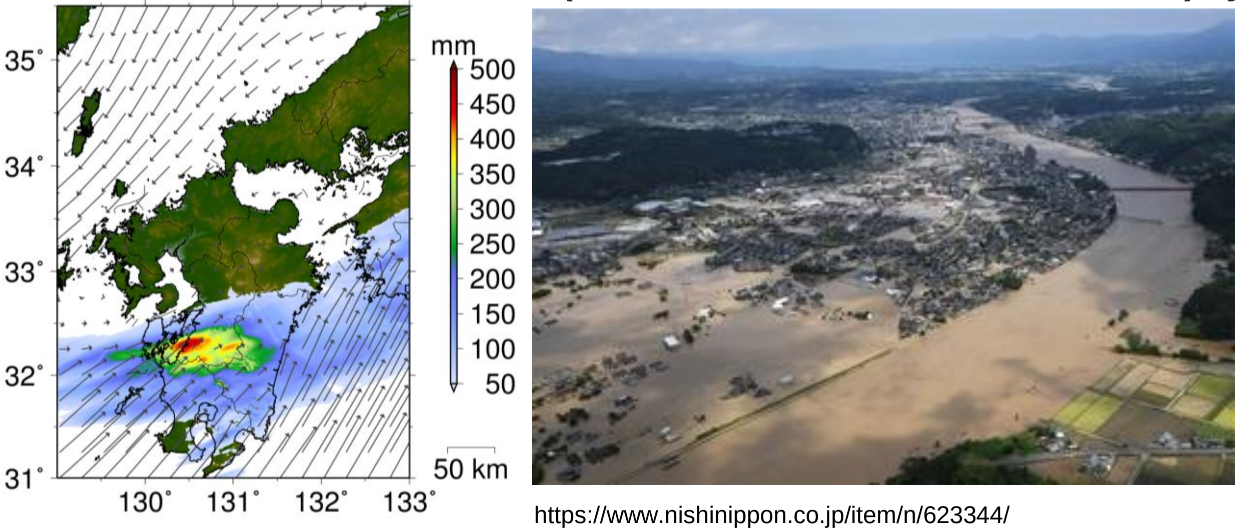
- **Typhoon:**
  - As the atmosphere becomes more stable, the number of typhoons occurring and arriving in Japan will decrease.
  - However, rising sea temperatures will increase the risk of super typhoons.
  - Typhoon tracks around Japan will shift eastward.
- **Rainy season:**
  - Rising sea surface temperatures will increase the inflow of low-level water vapor, increasing the proportion of days with rainfall of 100 mm or more in early July and the frequency of localized torrential rains.
  - Areas susceptible to torrential rains will expand eastward and northward.
  - Torrential rains will also increase in the areas along the Sea of Japan.
- **Guerrilla rainstorm:**
  - Rising sea surface temperatures will increase the inflow of low-level water vapor, leading to increased intensity and frequency of rainstorms.

Seasonal baiu rain front and torrential rains



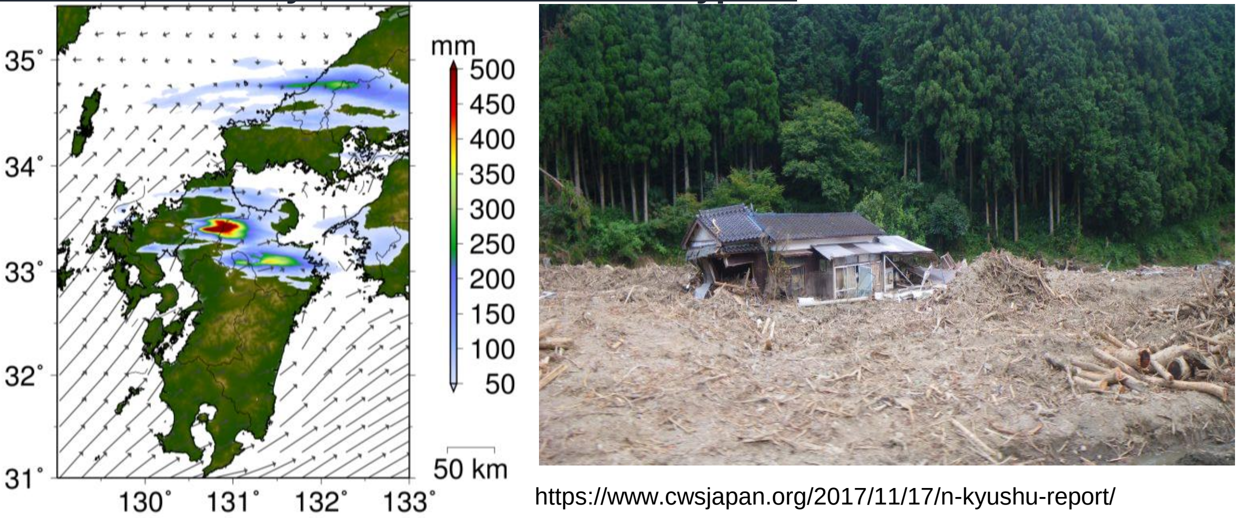
- Torrential rains due to the baiu rain front cause severe floods and landslides.

2020 Kumamoto torrential rains (Kuma River torrential rain disaster) Type A



https://www.nishinippon.co.jp/item/n/623344/

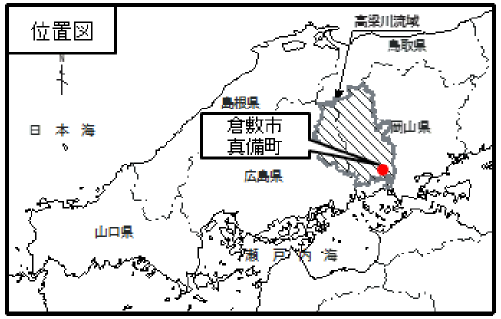
2017 Northern Kyushu torrential rains Type B



https://www.cwsjapan.org/2017/11/17/n-kyushu-report/

Torrential rain in July 2018, flood damage along Oda River, Takahashi River system, Kurashiki City

Mabicho, Kurashiki City, Okayama Prefecture

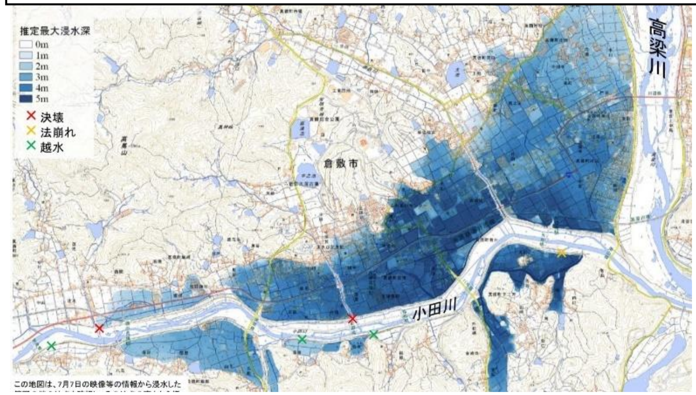


Deaths (Okayama Prefecture): 86

Source: Okayama Prefecture
"July 2018 Torrential Rain Disaster Record"

Kurashiki City Flood and Landslide Hazard Map (created in 2017)

July 2018 Torrential rain: Flood estimation colored map



Land disasters caused by torrential rains in July 2018

As of September 25

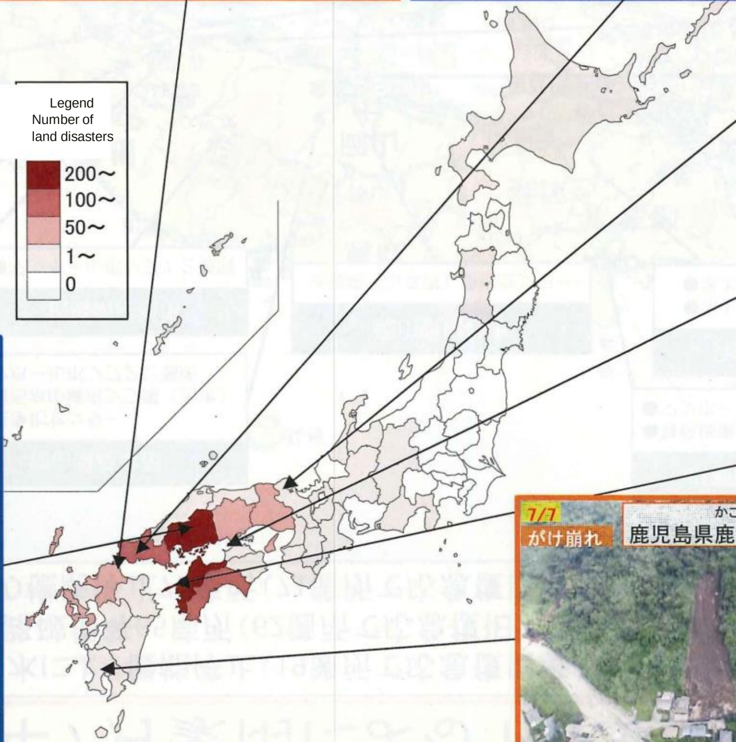
Number of landslides
(Counted from July 2 onwards)
(Prefectural reports)
31 prefectures
2,512*
Mudflows, etc.: 769
Landslides: 55
Rockfalls: 1,688

[Damage situation]

Human damage: Deaths:	119
Casualties:	29
House damage:	
Completely destroyed:	213
Partially destroyed:	340
Partially damaged:	290

* Damage details are under review.

*1 The average number of land disasters in the previous 10 years (2008-2017) was 1,106 per year.
*2 The largest number of land disasters recorded in the previous 10 years (2008-2017) was 1,514 (2017).



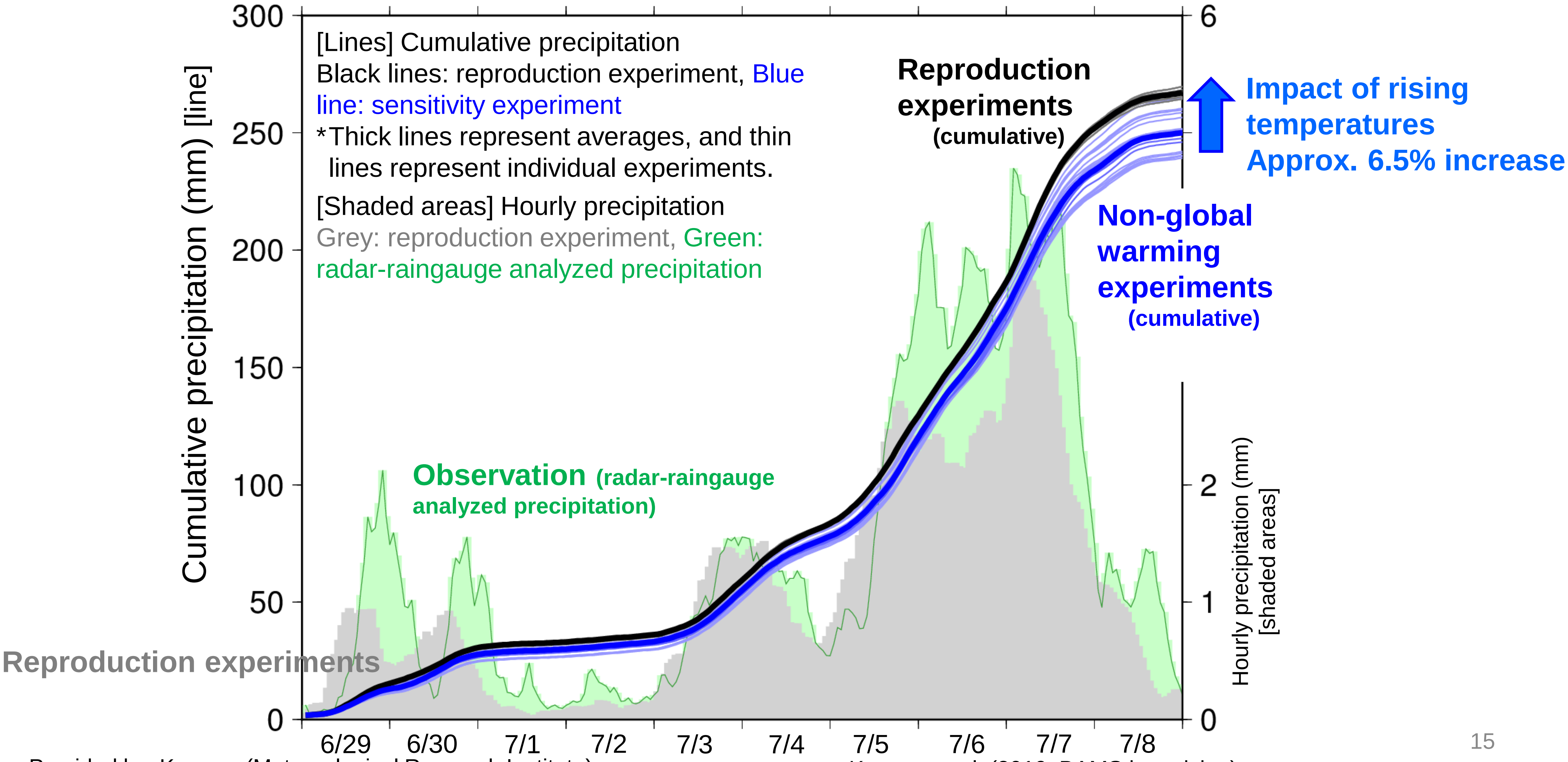
(Not necessary to translate)

22

MLIT

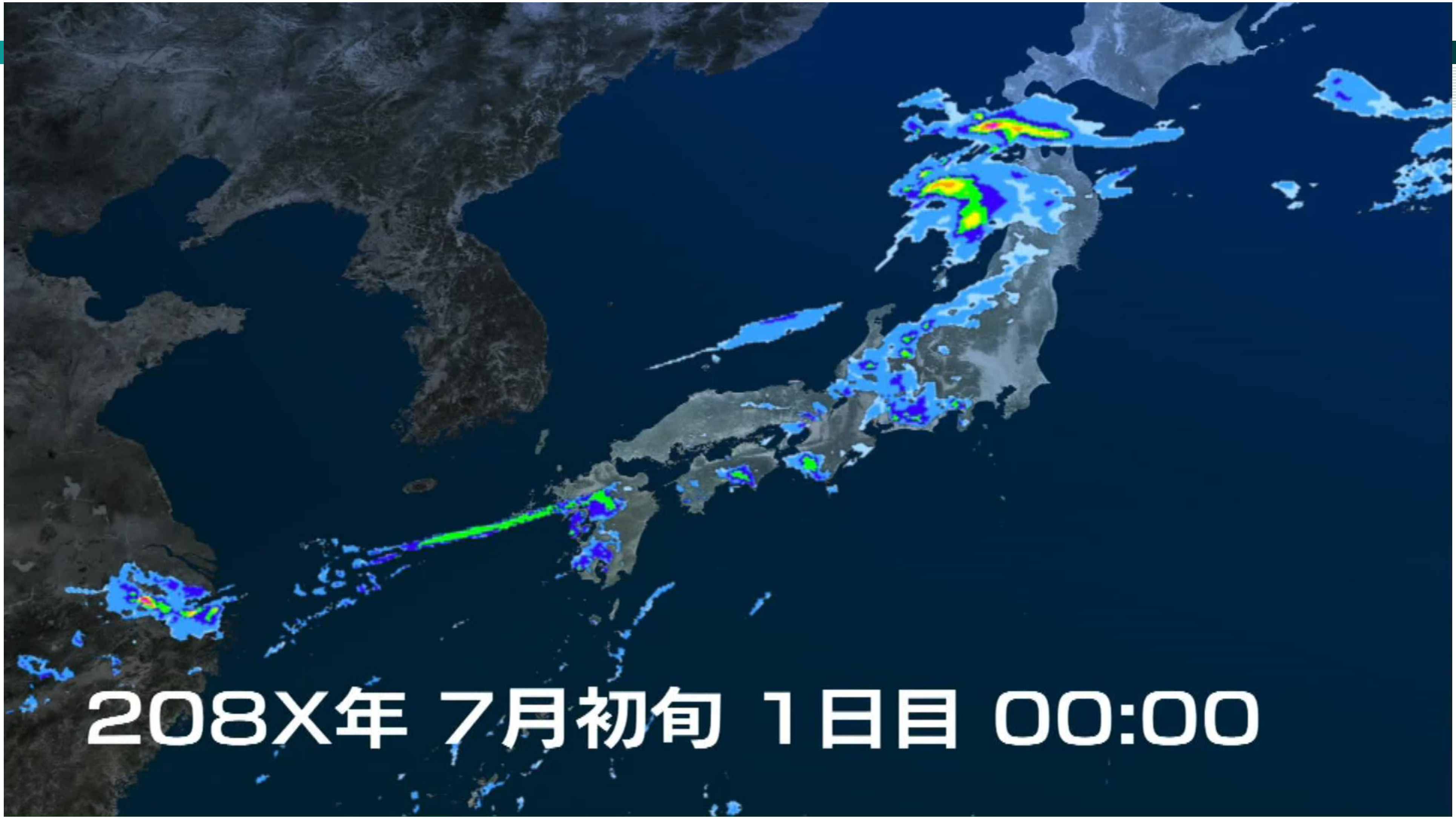
—Quantitative approach based on actual cases—
To what extent did global warming "quantitatively" contribute to the torrential rains of July 2018?

Average precipitation over land from eastern to western Japan



Provided by: Kawase (Meteorological Research Institute)

Kawase et al. (2019, BAMS in revision)



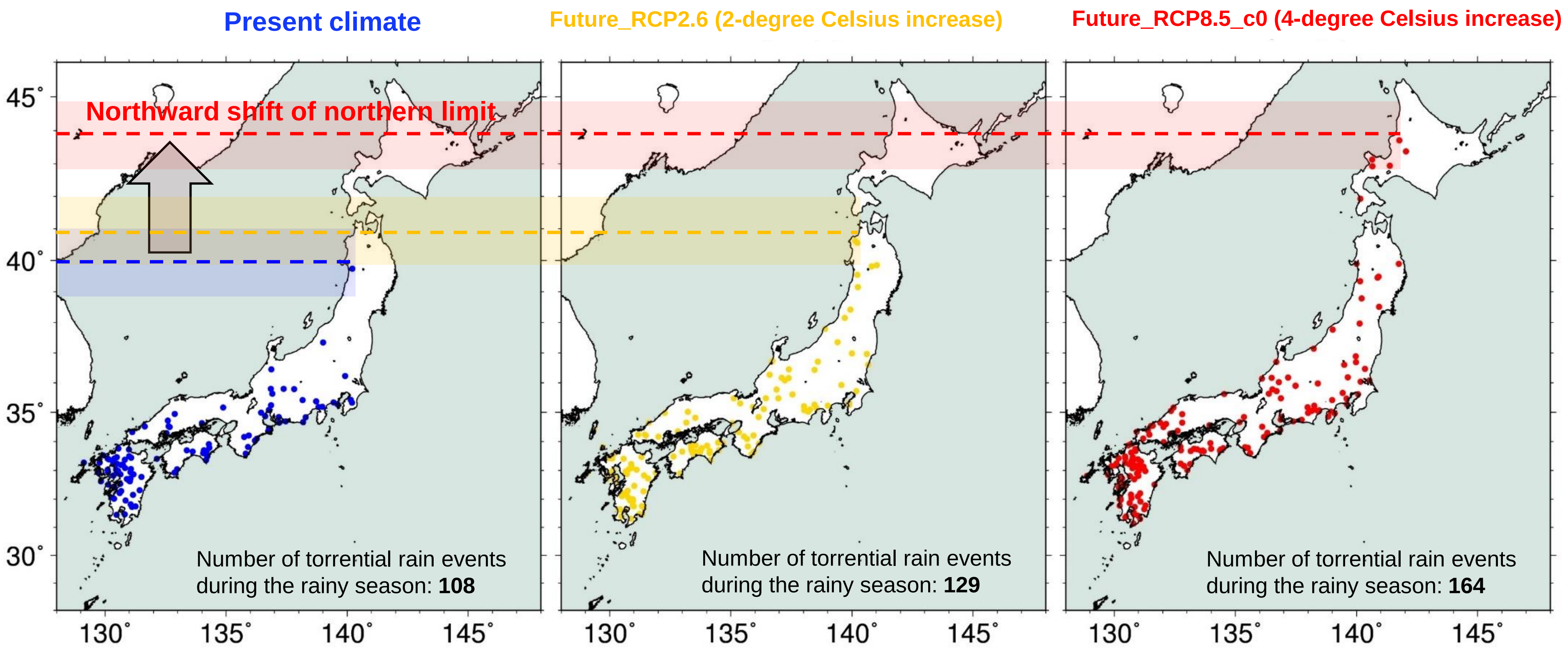
Simulation: Meteorological Research Institute, Japan Meteorological Agency
Image creation: NHK

TOUGOU
Integrated Research Program for Advancing Climate Models

Future changes in frequency of torrential rains during the rainy season

Locations of torrential rains during the rainy season in the present and future climates (RCP8.5 and RCP2.6) based on RCM05

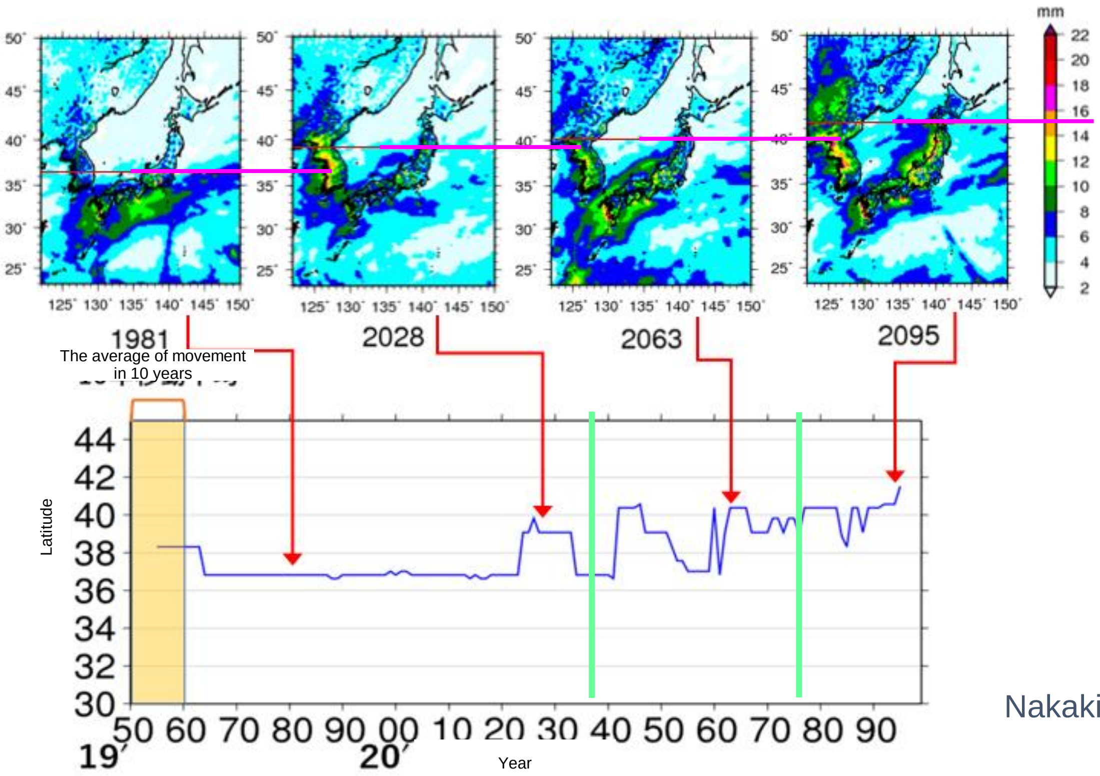
- Present climate: 20 years (1981–2000)
- Future climate: 20 years

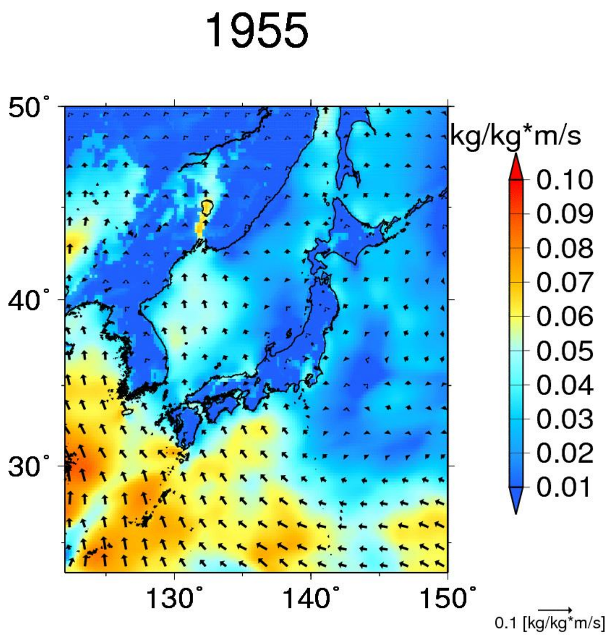


- The number of torrential rain events during the rainy season **will increase** in the future climate.
- The **northern limit** of the area where heavy rain occurs will also move **further north**.
- A **new risk** will emerge in areas, such as Hokkaido, that have never experienced torrential rains in the rainy season before.

Naka and Nakakita, 2023.

The importance of predicting the gradual northward movement of the area susceptible to torrential rains due to the baiu rain front



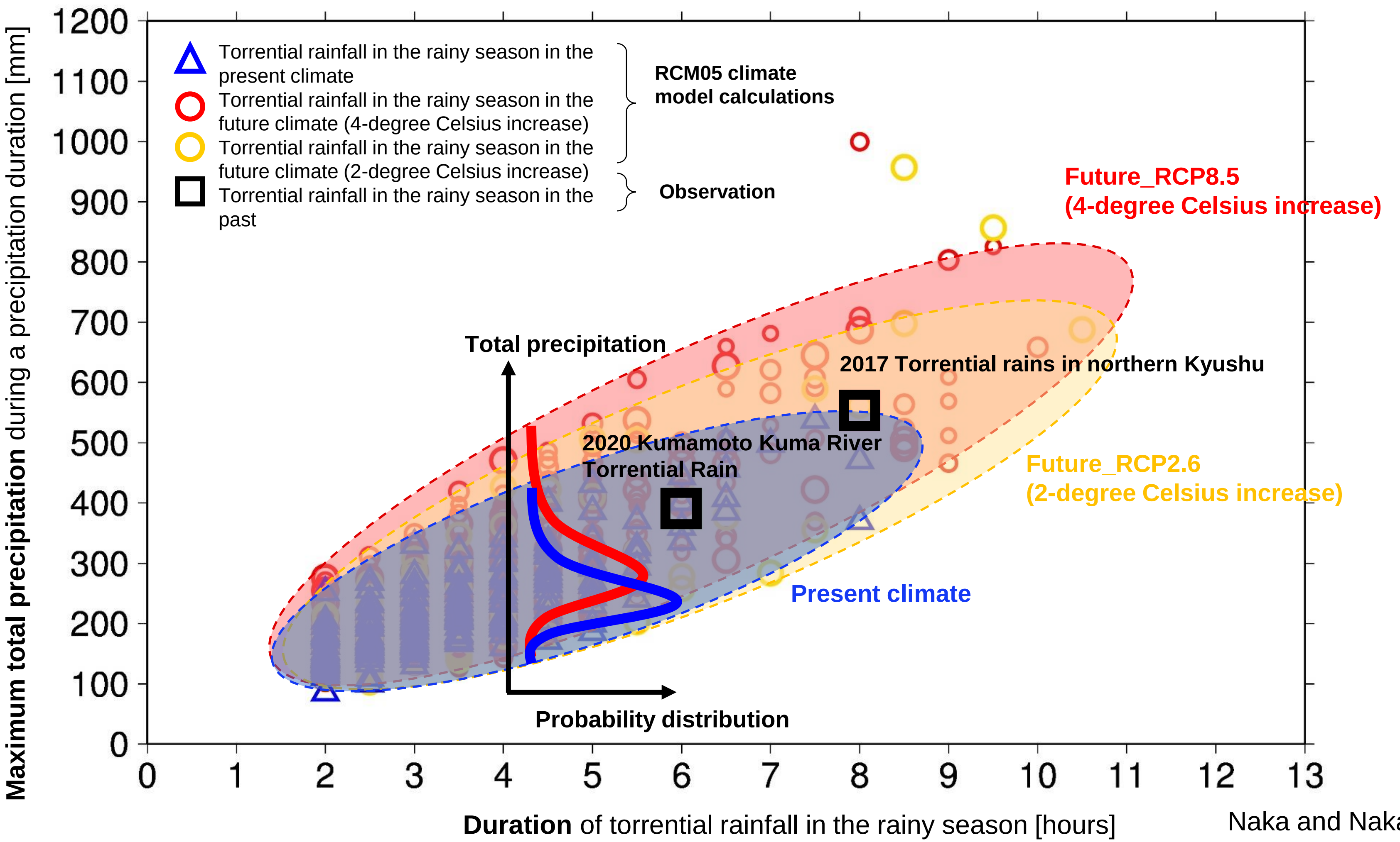


Nakakita, Harada, and Osakada (2021)

- Although this is only a result of analyzing one ensemble, the position of the seasonal baiu rain front remained almost unchanged until the 2010s. Due to the increasing influx of water vapor from the south, however, the rain front is expected to gradually move northward with some fluctuation from the 2020s to the 2050s.
- Meanwhile, torrential rain disasters during the rainy season have become more frequent since the 2010s.
- To formulate a climate change adaptation plan “now” (adaptation without regrets), it is extremely important to predict changes in the next 10 years in the characteristics of torrential rain events during the rainy season, including the frequency, the total amount of precipitation, and the eastward and northward expansion of the susceptible areas.

Future changes in duration of and total precipitation from torrential rains

*The duration and total precipitation are very important **engineering indicators** in considering flood control plans, etc.



Naka and Nakakita, 2023.

- In the future climate, **both the duration and total precipitation** of torrential rainfall in the rainy season **will increase** (Regarding the total precipitation, the result is considered to be statistically significant).
- Recent examples such as the torrential rains in northern Kyushu in 2017 are considered as extreme cases in the present climate, but are more similar to future examples.

Lecture Contents

1. Climate change is starting to have impacts
2. What are scientific climate change predictions?
3. Torrential rains and impacts of climate change
4. Hazards and climate change
5. What is no-regret climate change adaptation?
6. Conclusion

Projected future change in water disasters and water resources in Japan

- Increase in once-in-100-year-level maximum annual river discharge across the country
- Aggravation of once-in-10-year-level drought water-discharge in many watersheds
- Decrease in snowmelt peak discharge and earlier snowmelt peak in areas where snowmelt water is used
- Changes in the effectiveness of dam operation (both during floods and droughts)
- Increased risk of surface landslides, and deep-seated landslides that are tens of meters deep and have large horizontal areas
- Intensification of once-in-100-year-scale storm surges and waves in major bays
- Increase in water stress due to reduced snowfall and accumulation along the Japan Sea coast south of southern Tohoku
- However, Fukui, Ishikawa, and Toyama will see the intensification of extreme snowfall events.

TOUGOU
Integrated Research Program for Advancing Climate Models

SOUSEI

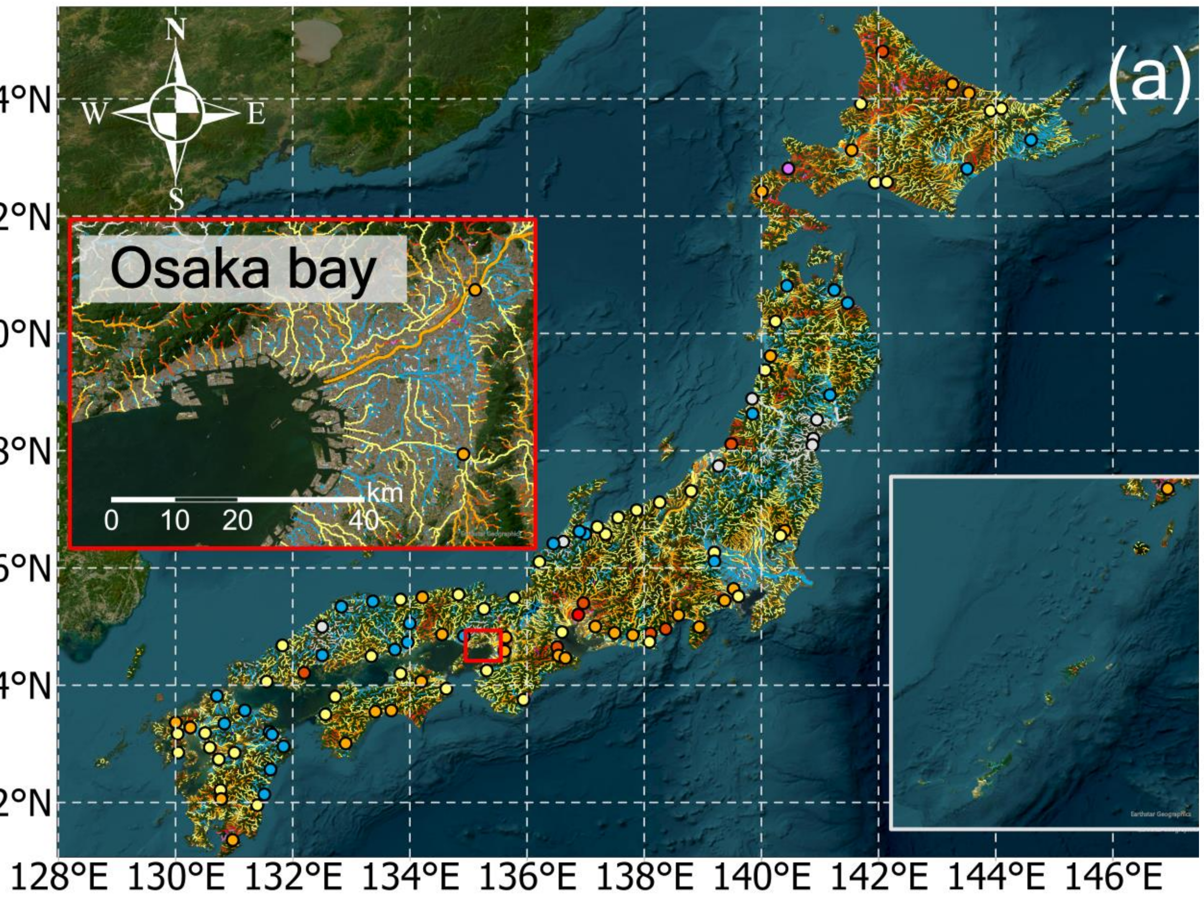
KAKUSHIN

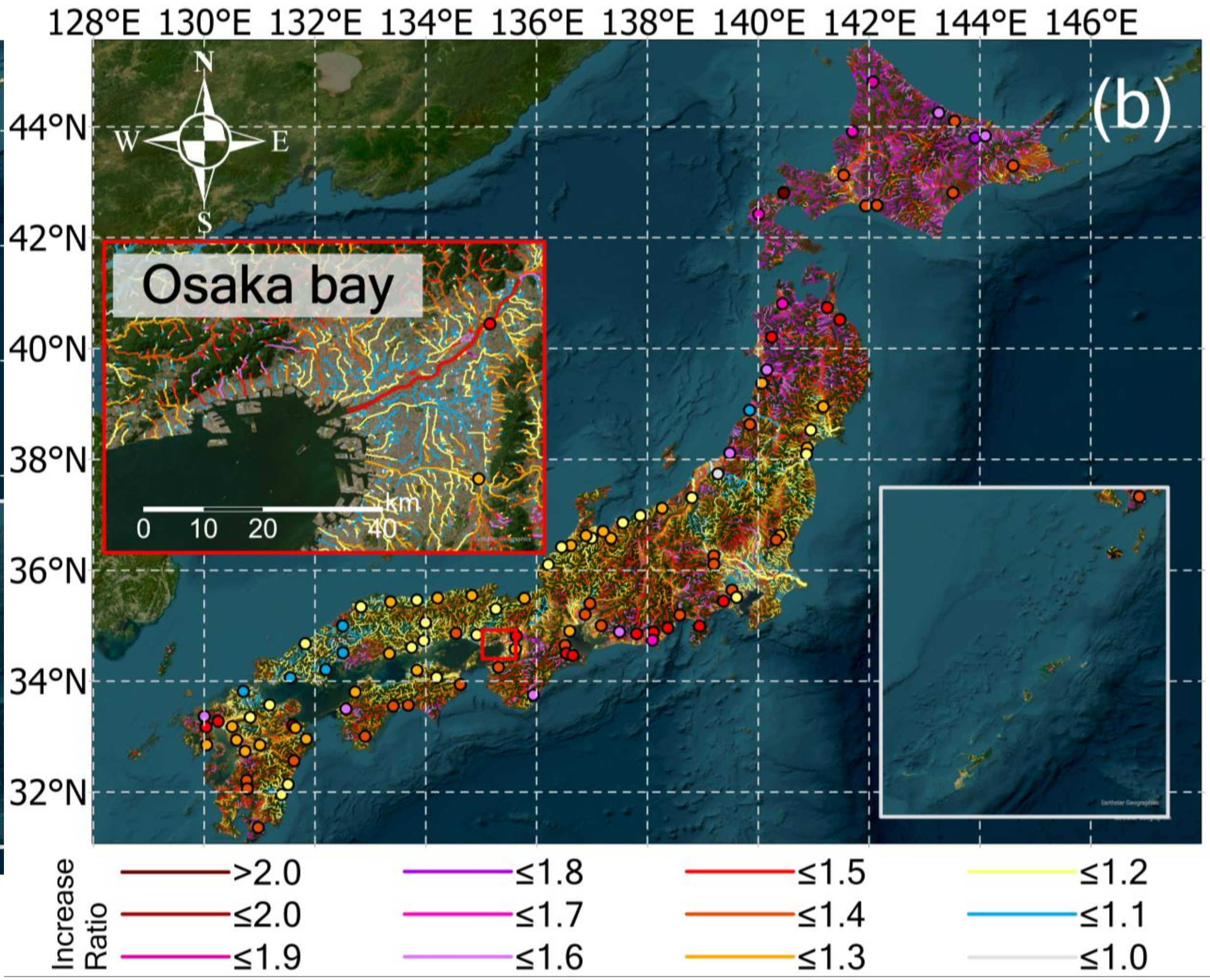
Change rate of 100-year stochastic inflow for rivers nationwide

Chen, Sayama, Yamamoto, Sugawara, and Tanaka
(Kyoto University) (2024, unpublished).

(a) Under a 2-degree Celsius increase

(b) Under 4-degree Celsius increase





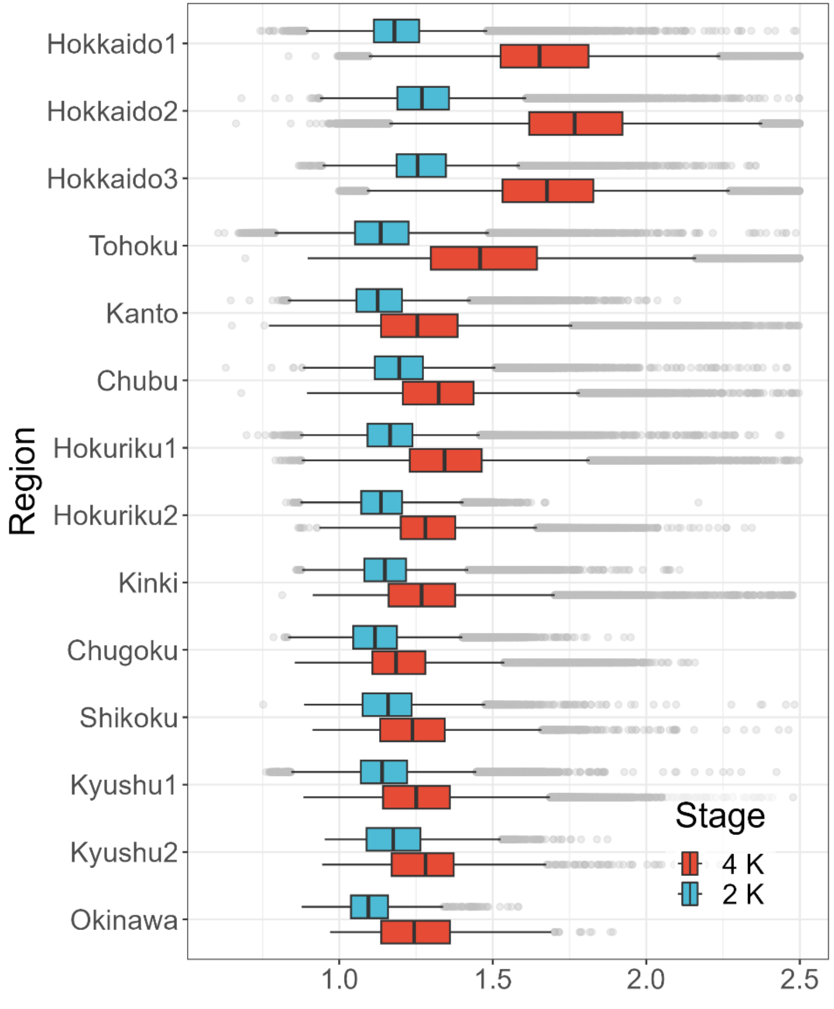
KYOTO UNIVERSITY

京都大学

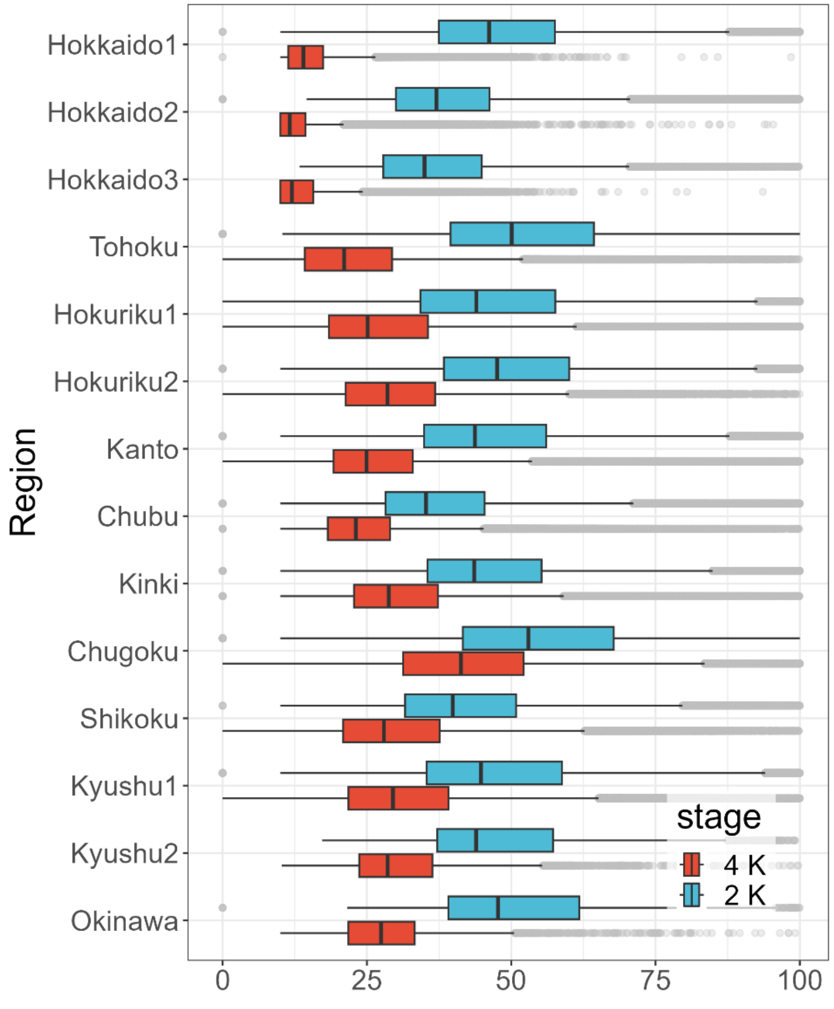
At the reference points marked with "○," flood discharge is about 1.1 to 1.3 times higher under a 2-degree Celsius increase, which roughly corresponds to previous research using d4PDF 20 km and the results of calculations by the Ministry of Land, Infrastructure, Transport and Tourism.

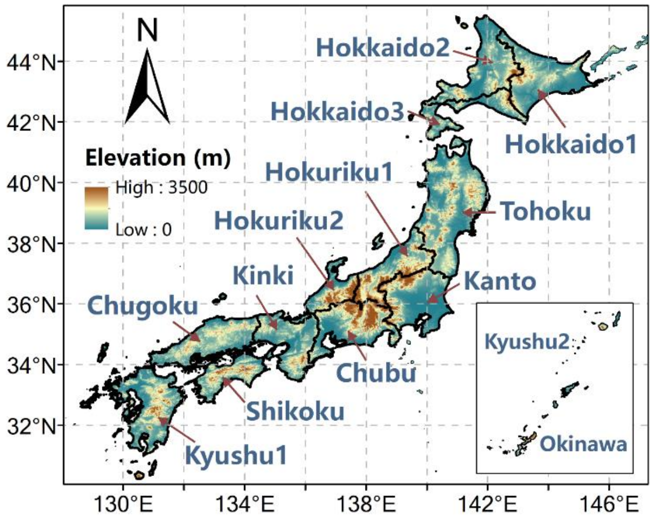
Data collection covering all river course areas, including small and medium-sized rivers

Change rate of 1/100 discharge



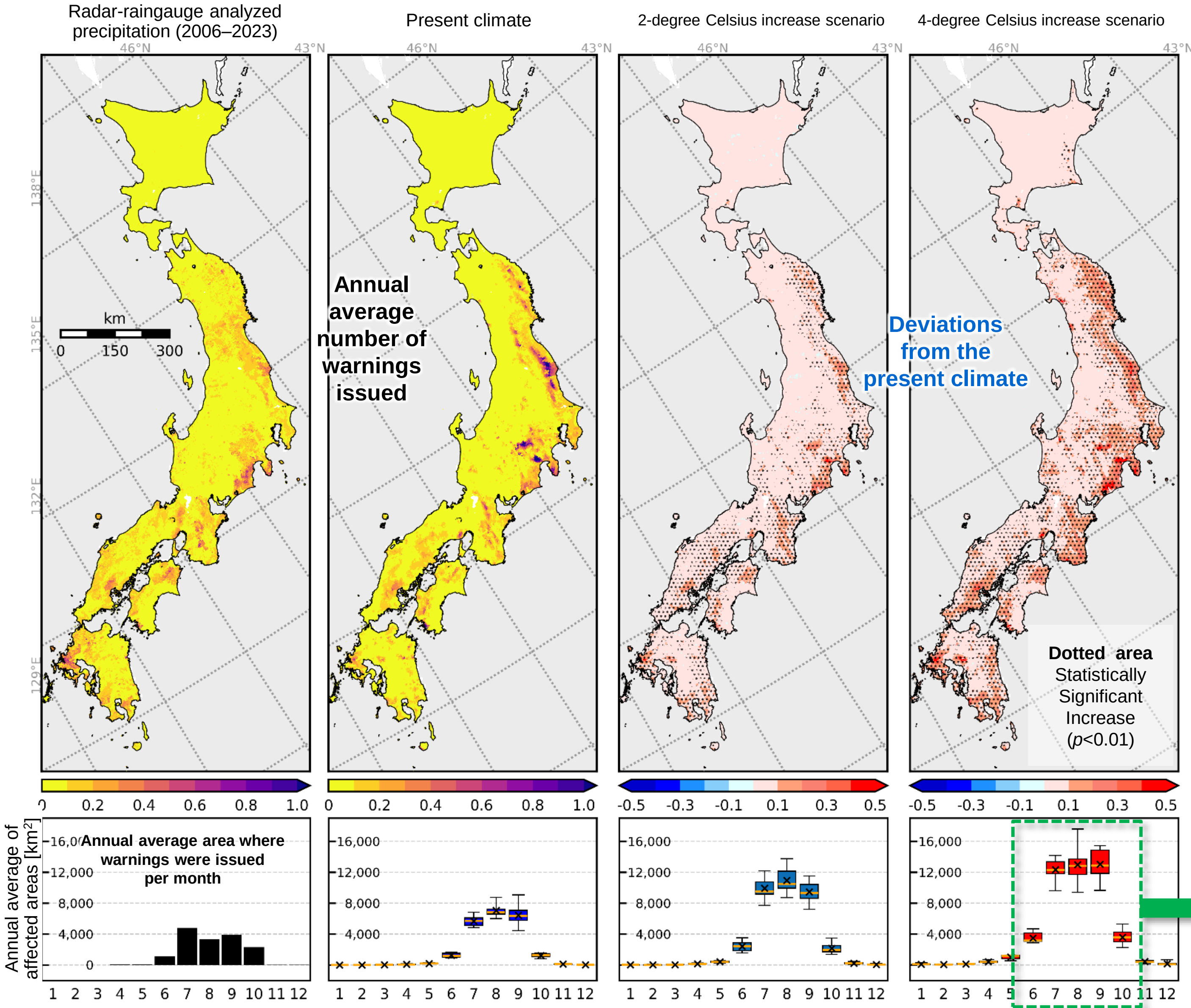
Return period of 1/100 discharge of the present climate

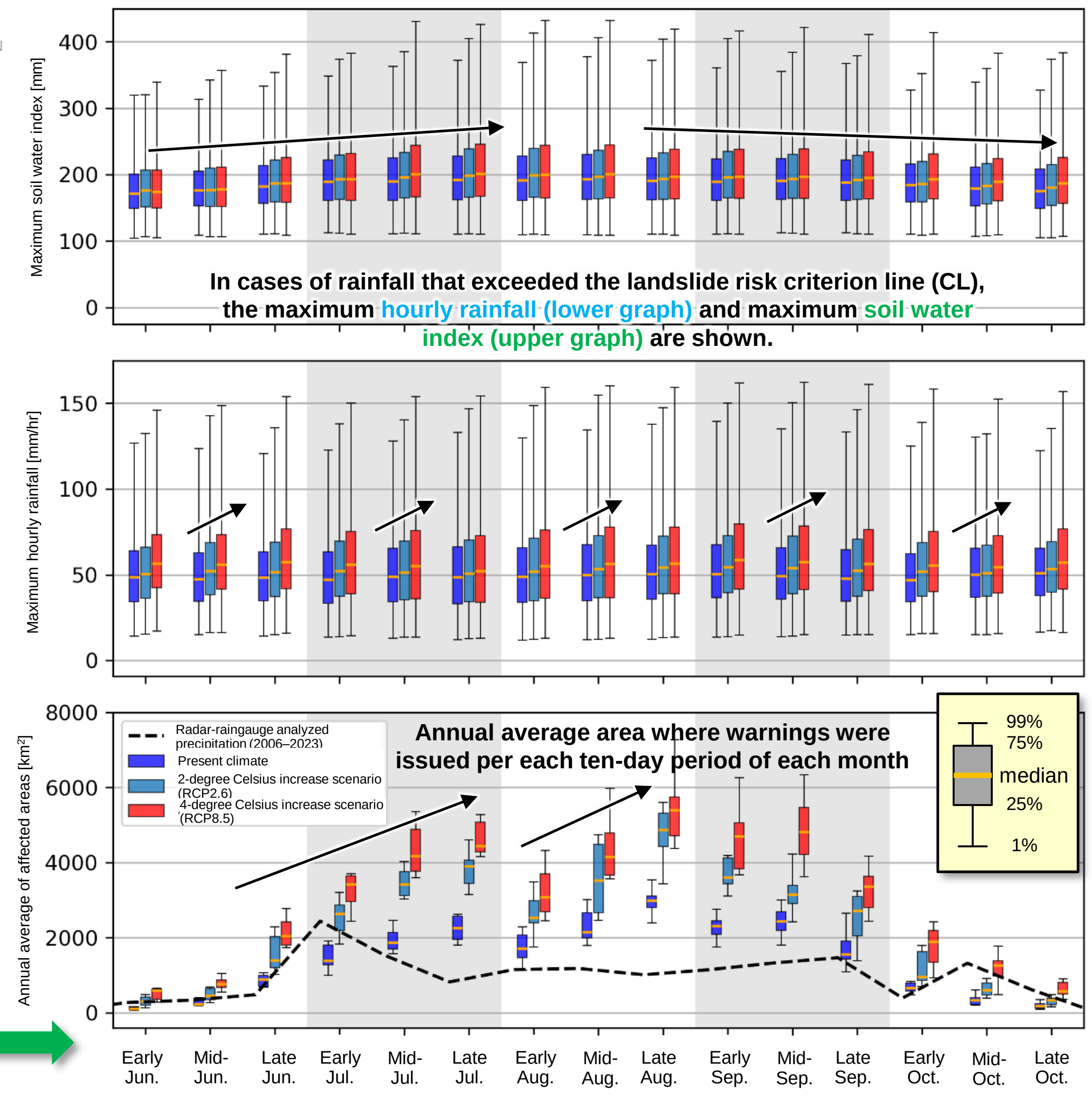




Chen, Sayama, Yamamoto, Sugawara, and Tanaka (Kyoto University) (2024, unpublished).

Future change analysis in frequency of landslide warning issuance using d4PDF (5 km)



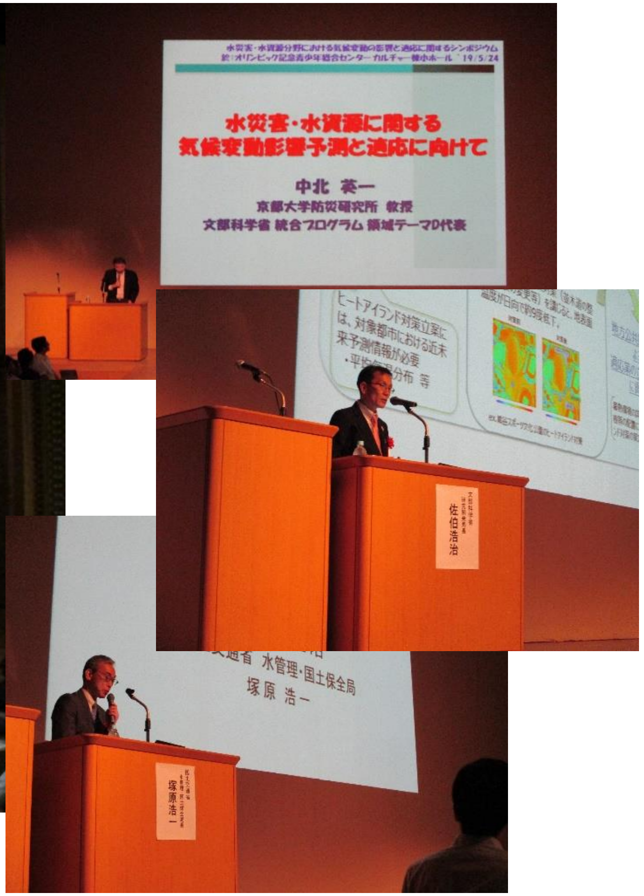


Statistical test: Student T-test

Lecture Contents

1. Climate change is starting to have impacts
2. What are scientific climate change predictions?
3. Torrential rains and impacts of climate change
4. Hazards and climate change
5. **What is no-regret climate change adaptation?**
6. Conclusion

Collaborative symposium between relevant ministries and TOUGOU program for water disaster and resource adaptation



May 24, 2019 National Olympics Memorial Youth Center

Organizers: MEXT Integrated Research Program for Advancing Climate Models (TOUGOU)/MEXT Research and Development Bureau /MLIT Water and Disaster Management Bureau

Sponsors : MAFF Rural Development Bureau, MOE Global Environment Bureau, Kyoto University IPCC Weeks, Japan Society of Civil Engineers Committee on Hydroscience and Hydraulic Engineering, Committee on Global Environment, Coastal Engineering Committee, Committee on Geotechnical Engineering, Committee of Infrastructure Planning and Management, Japan Society of Hydrology and Water Resources, Japanese Geotechnical Society, and Japan Society for Natural Disaster Science

Nakakita (2019)

○ Flood control plans will be revised from plans based on past rainfall records to plans that take into account increased rainfall due to climate change.

Until now

Plans to protect against floods, inland flooding, landslides, storm surges, and waves have been created **based on past rainfall, tide levels, etc.**

However, there is a risk that an effective level of safety will not be ensured at the time the current plan is implemented if taking into account the effects of climate change, such as increased rainfall and rising sea levels.

The plan will be revised to **take into account increased rainfall* and higher tides caused by climate change**

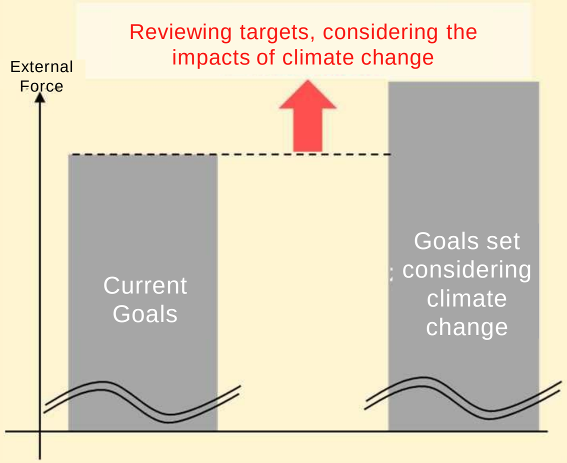
* A scenario in which the increase in global average temperature is limited to 2 degrees Celsius (the goal of the Paris Agreement)

Climate change scenario	Rainfall (Flood scale used as basis for river improvement (1/100, etc.)
Equivalent to a 2-degree Celsius increase	About 1.1 times

If the amount of rainfall increases by about 1.1 times

Nationwide average trends [Estimated results]	Discharge	Flood frequency
	About 1.2 times	About 2 times

* The change rates of discharge and flood frequency represent the national averages of the present and future change rates calculated with and without multiplying the rainfall of flood scale (1/100 to 1/200) used as the basis for river improvement of Class 1 river systems by the rainfall change rate.

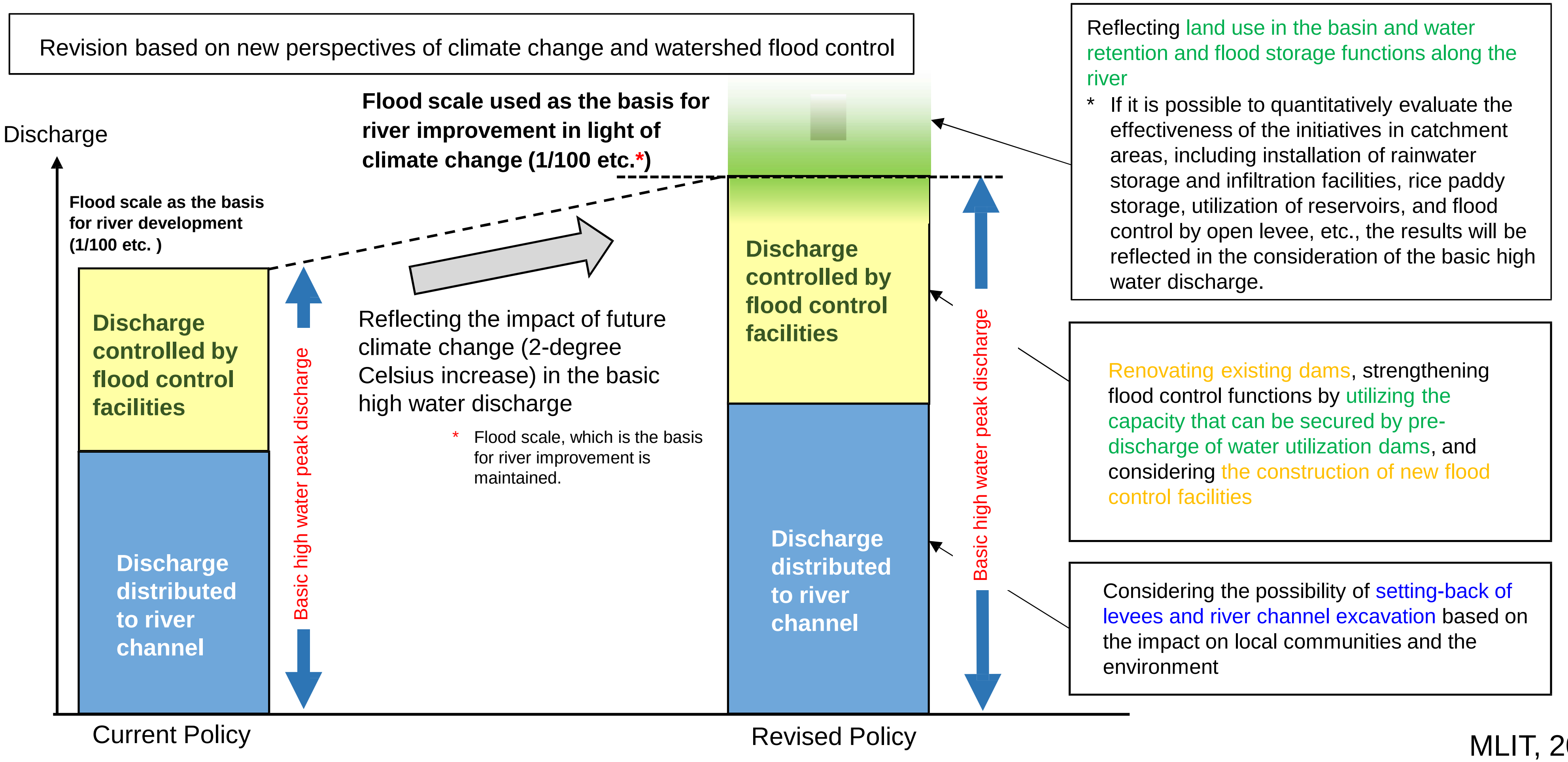


MLIT, 2020

Material for the 121st Subcommittee for River Improvement Basic Policy (2022)

Reflection of climate change impacts and river basin initiatives in basic high water discharge and flow distribution

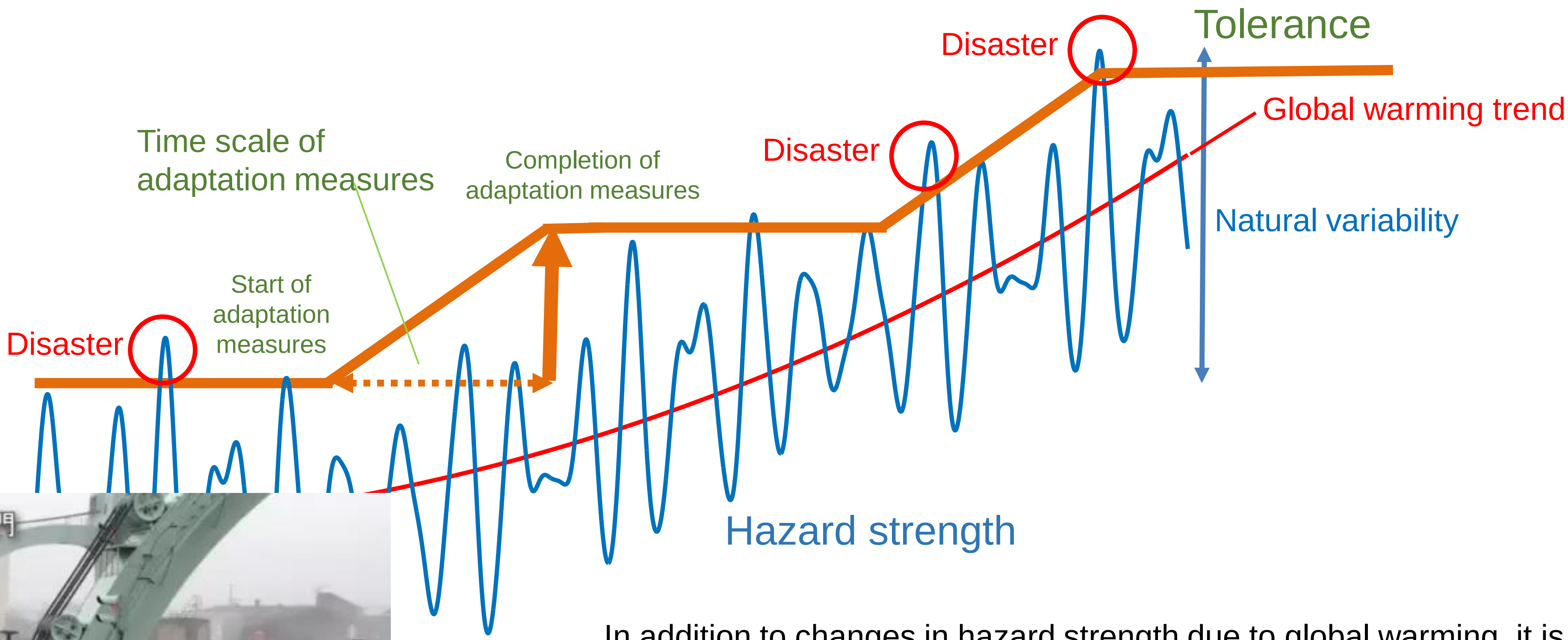
- ○ Based on the progress of science and technology and the current accumulation of data, the basic high water peak discharge is set considering the impacts of climate change, by using the future rainfall change rate and the predicted rainfall waveforms obtained by ensemble experiments.
- ○ In setting the basic high water discharge, the current and future trends of land use in the basin and the water retention and flood storage functions along the river are evaluated, and the results are reflected as the basin's rainfall-runoff characteristics and flood flow characteristics. (As for measures in catchment areas (rice paddy storage, use of reservoirs, etc.), once progress is made and quantitative evaluation of the effects becomes possible, they will be reflected in the consideration of the basic high water discharge.)
- ○ Regarding allocation to river channels and flood control facilities, etc., a decision will be made after considering the possibility of setting-back of levees and river channel excavation based on the impact on local communities and the environment, as well as the reinforcement of the existing dams' flood control functions.



MLIT, 2023

Concept of adaptive measures against global warming

What is no-regret adaptation without the need for reworking?



In addition to changes in hazard strength due to global warming, it is important to know:

- Natural range of variability
- Time scale of global warming effects
- Time scale of adaptation measures
- Cost-effectiveness

Lecture Contents

1. Climate change is starting to have impacts
2. What are scientific climate change predictions?
3. Torrential rains and impacts of climate change
4. Hazards and climate change
5. What is no-regret climate change adaptation?
6. Conclusion

Global warming impact prediction and adaptation

KAKUSHIN

- The hourly output from the climate model has made it possible to predict the impact of climate change on hazards and water resources in Japan.
- It is predicted that extreme events will become more serious towards the end of the century.
- If we delay adaptation because of uncertainty, future adaptation could become difficult or even impossible.
  - Start now! => No-regret adaptation
- Promote adaptation to climate change step by step through bottom-up practices.
  - It is important to recognize this as the first thing.
  - Ongoing measures are also important adaptation measures to global warming.
  - We need to discover vulnerabilities that have not been noticed even in the current climate (importance of disaster investigation, etc.).
- Proceed based on scientific future projections (main infrastructure planning).
  - Plan a step-by-step adaptation. Adaptation without reworking.
- Consider adaptation (crisis management) by anticipating the worst-case scenario.
  - It is also important to consider how to incorporate the worst-case scenarios of climate change into adaptation.
- Adaptation through regional, urban, town, and community development.

(Nakakita, 2010, 2019)

Conclusions

- **In recent years, climate related disasters have become more severe. Immediate implementation of adaptation measures is required.**
- **While scientific research is underway for the better assessment of climate change and its impact, which are used for formulation of adaptation measures, we must pay attention to the change in climate risk and its speed.**
- **There are uncertainties in predictions of climate change and its impacts. However, for "no-regret adaptation," we should apply the precautionary principle, and the lack of scientific evidence or information should not be reasons for inaction.**
- Action without delay is imperative. While bottom-up approaches based on local realities are essential, it is also necessary at national level to enhance cooperation among relevant government agencies and promote collaboration with both academic and DRR communities.
- **The Japanese government has decided on raising the standard of its flood control plan and transition to the policy of "river basin disaster resilience and sustainability by all."**
- **Sediment and flood (complex disaster)**
- **Sediment and flood caused by earthquakes and torrential rains (complex disasters)**

Thank you for your attention

My colleagues working on the impact assessment and the creation of adaptation measures

Photo: Tonoshima Island, Uji River