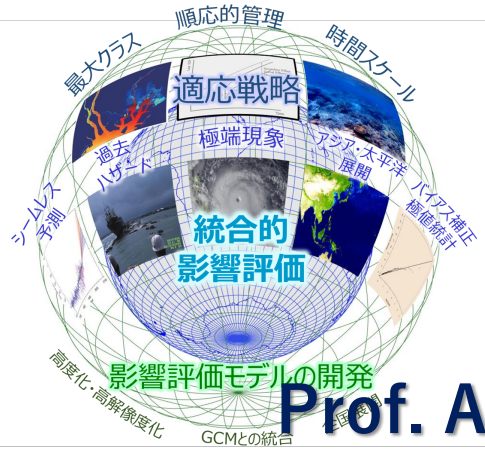
International Disaster Reduction Alliance Forum (DRA Forum 2022)
KOBE PORTOPIA HOTEL, Jan. 26th, 2022

Climate change impact on water-related disasters and adaptation



Eiichi NAKAKITA

Prof. Atmosphere-Hydrosphere Research Division,
Director, Disaster Prevention Research Institute,
Kyoto University

TOUGOU
Integrated Research Program for Advancing Climate Models

Lecture Contents

- Introduction: Increased impacts of climate change
- What is scientific climate change predictions?
- Torrential rains during the rainy season and impacts of climate change
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- Conclusion: Adaptation to climate change without regret

Serious water-related disasters in Japan occurring annually

[2012.7 Heavy Rain in Kyushu]

①Damage from flood
(Shira-river, Kumamoto City, Kumamoto)

[2013.9 Typhoon Man-yi]

②Inundation
(Yura-river, Fukuchiyama City, Kyoto)

[2014.8.19 Heavy Rain]

③Landslide
(Hiroshima City, Hiroshima)

[2015.9 Heavy rain in Kanto/Tohoku]

④Flood due to bank rip
(Kido-river, Joso City, Ibaraki)

[2016.8 Typhoon Lionrock]

⑤Overflow of the river
(Omoto-river, Iwaizumi Town, Iwate)

[2017.7 Heavy rain in Kyushu]

⑥Inundation damage
(Katsura-river, Asakura City, Fukuoka)

[2018.7 Heavy rain in western Japan]

⑦Inundation
(Kurashiki City, Okayama)

[2018 Typhoon Jebi]

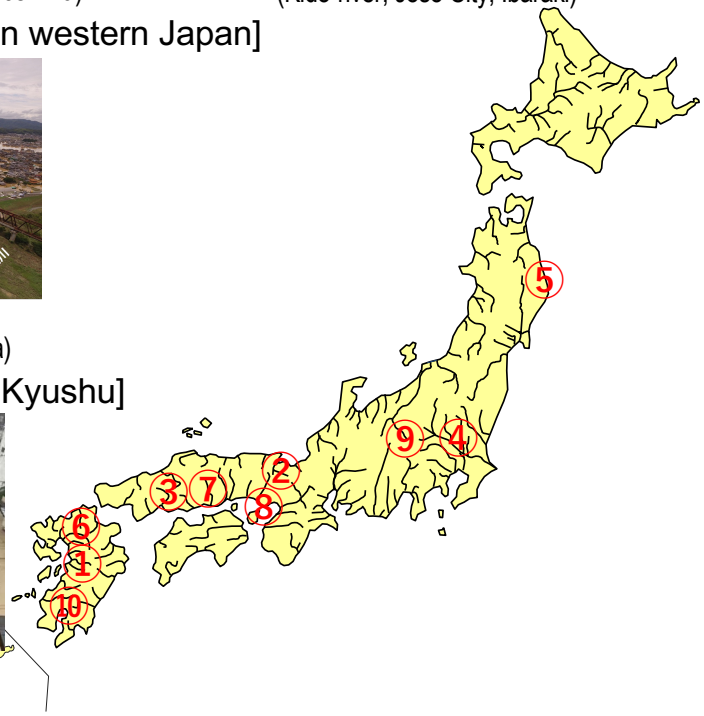
⑧Inundation damage
(Kobe port, Kobe City, Hyogo)

[2019 Typhoon Hagibis]

⑨Rolling stock yard of Hokuriku-Shinkansen
(Nagano City, Nagano)

[2020.7 Heavy rain in Kyushu]

⑩ Inundation damage
(Hitoyoshi City, Kumamoto)



MLIT (2019) and Nakakita (2020)

Serious water-related disasters occurred in recent years in Japan

- **People are concerned that this is due to global warming**
  - Antecedent frequency, intensity, total volume, and location of heavy rainfall
  - Hazards and disasters never experienced before
- **No-regret adaptation to global warming is required based on**
  - Enhancement of
    - Major infrastructures
    - Crisis management
    - Reduction in community's vulnerability
  - Such enhancements take time compared to the speed of global warming
    - We must start now without waiting
    - Based on a new master plan
- **Scientific-based future projections are indispensable**
- **Learn from the past (historical) wisdom**

Nakakita (2018, 2019)

Disaster due to long-lasting rainfall in July 2018

Disaster due to localized heavy rainfall in July 2017

AR6: *Climate changes is already affecting worldwide with human influence to observed changes in weather and climate extremes (heat wave, heavy precipitation, drought, tropical cyclones, etc.)*

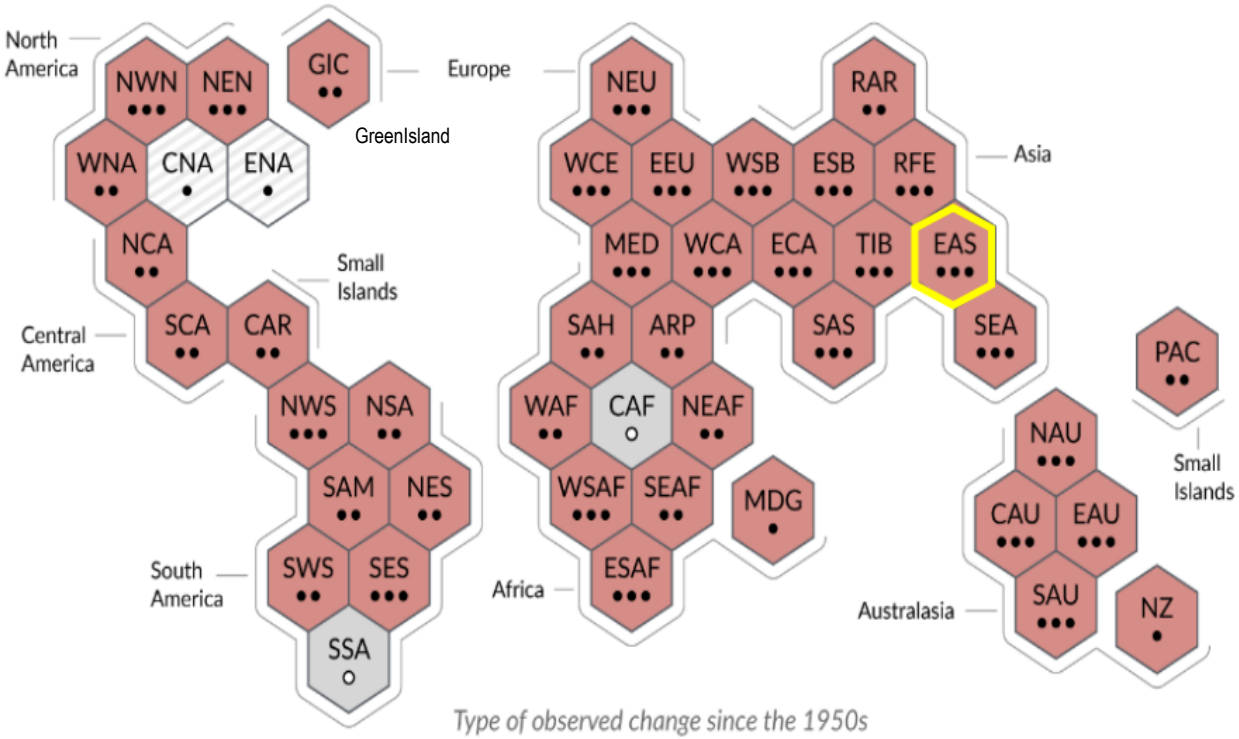
Observed change in hot extremes and confidence in human contribution to the changes worldwide

Type of observed change
in hot extremes

- Increase: 41
- Decrease: 0
- **Low agreement in the type of change:** 2
- **Limited data and/or literature**: 2

Confidence in human contribution
to the observed change

- ●●● High confidence
- ●● Medium confidence
- ● Low confidence due to limited agreement
- ○ Low confidence due to limited evidence



Type of observed change since the 1950s

IPCC AR6 GR1 (2021)

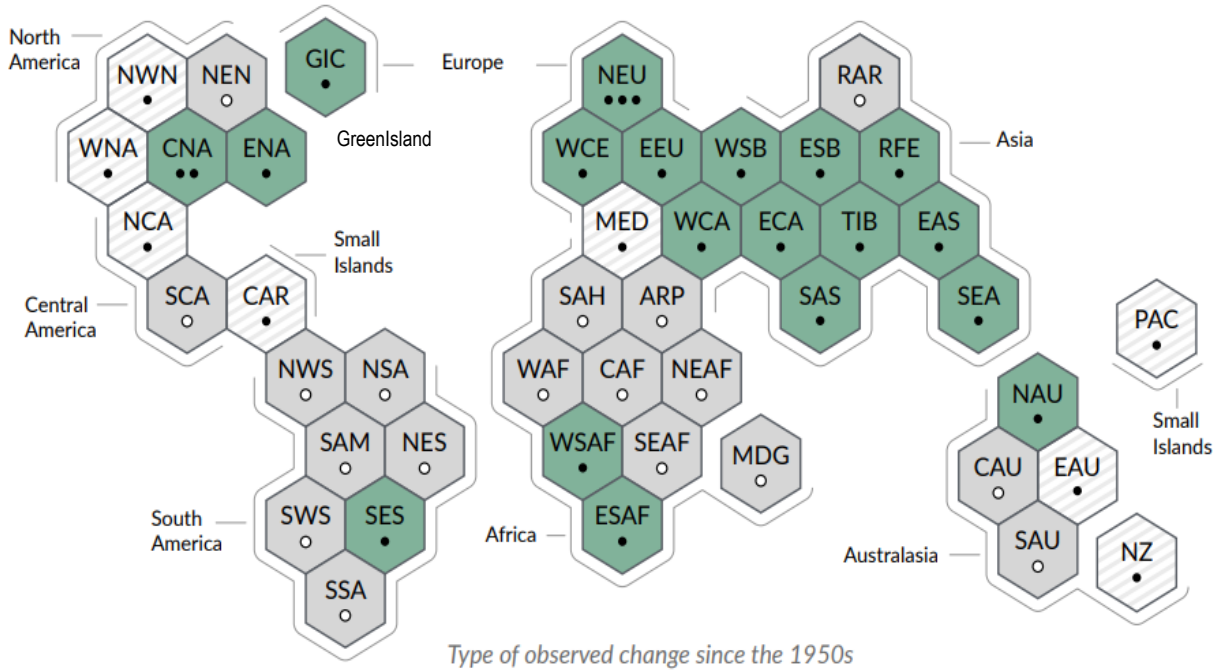
Observed change in heavy precipitation and confidence in human contribution to the changes worldwide

Type of observed change
in heavy precipitation

- Increase: 19
- Decrease: 0
- **Low agreement in the type of change:** 8
- **Limited data and/or literature**: 18

Confidence in human contribution
to the observed change

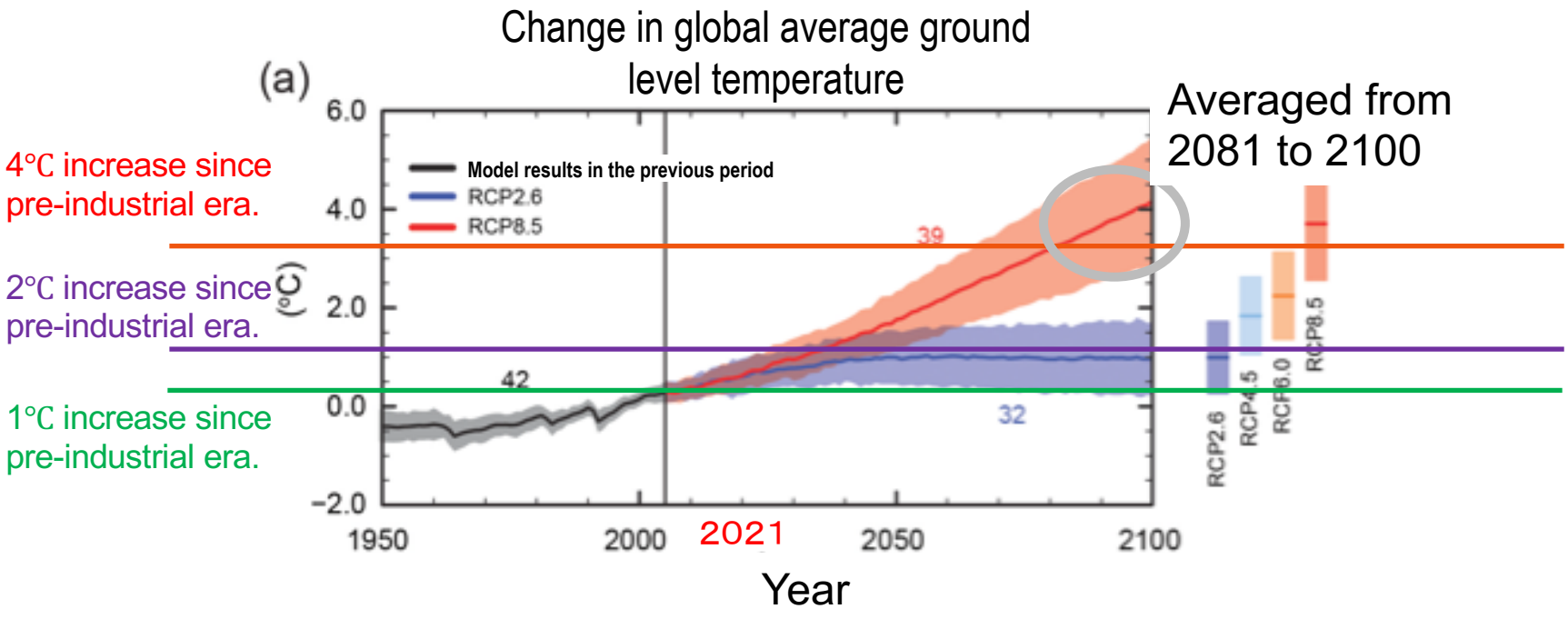
- ●●● High confidence
- ●● Medium confidence
- ● Low confidence due to limited agreement
- ○ Low confidence due to limited evidence



Type of observed change since the 1950s

IPCC AR6 GR1 (2021)

Projected future change of global averaged surface temperature



Role of Adaptation Measures

Hazard

Max

Goal of Infrastructure

Average

Impact
Risk

Undeveloped

Developed

Adaptive
Capacity

Past

Present

Future

Mitigation

Maximum crisis management

Climate Adaptation
（Infrastructure＋Watershed management＋Crisis management）

Adaptation

Komatsu（2012），Mimura（2014）and Nakakita (2019)

Two Paradigm Shifts in Japan's Flood Control Administration

- Modern flood control in Japan after the Meiji Restoration in 1868 was designed to prevent overflow. Climate change was taken into account, and wisdom accumulated in premodern times was also used.
- **Renewal of** the flood control **goal** based on scientific climate change predictions: **First paradigm shift**
- Although the ability to prevent overflow (basic flood control) was further improved,
- Basinwide flood control, with the involvement of everyone in the entire basin (upper, middle and lower) including companies as well we administrative bodies to deal with target torrential rains even if a river overflows, has been incorporated into flood control plans. This is the second paradigm shift in which overflowing water is controlled in the entire basin even if a river overflows, allowing for **legislation and the improvement of financial systems**.
- **Going forward, we need to come up with ideas of adaptation measures and quantify the effect of the measures for basinwide flood control.**

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History of National Program by MEXT

- **Kyousei(共生)Program: 2002-2007**
  - **20kmRCM (daily rainfall)**
- **Kakushin(革新)Program: 2007-2012**
  - **20kmGCM, 5,2,1kmRCM (hourly rainfall)**
  - **Natural hazards (incl. water resources)**
- **Sousei(創生)Program: 2012-2017**
  - **Impact assessment and producing adaptation methodologies (first priority)**
  - **for Natural Disaster, Water resources, Ecosystem and Eco services**
- **Tougo(統合)Program: 2018-2022**
  - **Seamless projection until end of the century**
  - **No-regret adaptation**

TOUGOU
Integrated Research Program for Advancing Climate Models

SOUSEI

KAKUSHIN

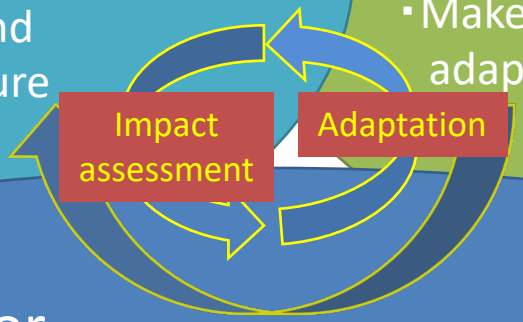
Importance of cooperation among Climatologists & Academia for climate change assessment and adaptation, and Implementing authorities

Climate meteorologist (Climate change projection)

・Provide scientific basis and projections of climatic future change

Implementation authorities (policy makers)

・Assessment of future impacts
・Review and re-build of planning policy
・Make, Evaluation, Implementation of adaptation policy



Accademia for climate change impact assessment and adaptation

・Provide Scientific basis and projection of future change and social impact of hazard
・Creation of basic idea of no-regret adaptation policy
・Development of evaluation method for no-regret adaptation policy

SOUSEI

TOUGOU

Integrated Research Program for Advancing Climate Models (Tougou) by MEXT

Construction of integrated research program in collaboration with 4 research themes

***Global* scale climate change forecast and fundamental model development**
(*Tokyo Univ. etc.*)

Develop a "**Global Climate Model**" to forecast climate change and use the results for other research and forecasting.

Elucidation of carbon cycle, climate sensitivity, tipping elements, etc.
(JAMSTC etc.)

Develop a "**Global system Model**" including carbon / nitrogen cycle; to elucidate **climate sensitivity** (*) **and tipping elements** (**).

Integrated Climate Change Forecast
(Meteorological Research Institute etc.)

Develop a "**Regional Climate Model**" around Japan for creating high-resolution forecasting to be used in adaptation measures.

Integrated Hazard Forecast
(Kyoto Univ. etc.)

Forecast of hazards such as high tide and floods which could intensify due to global warming

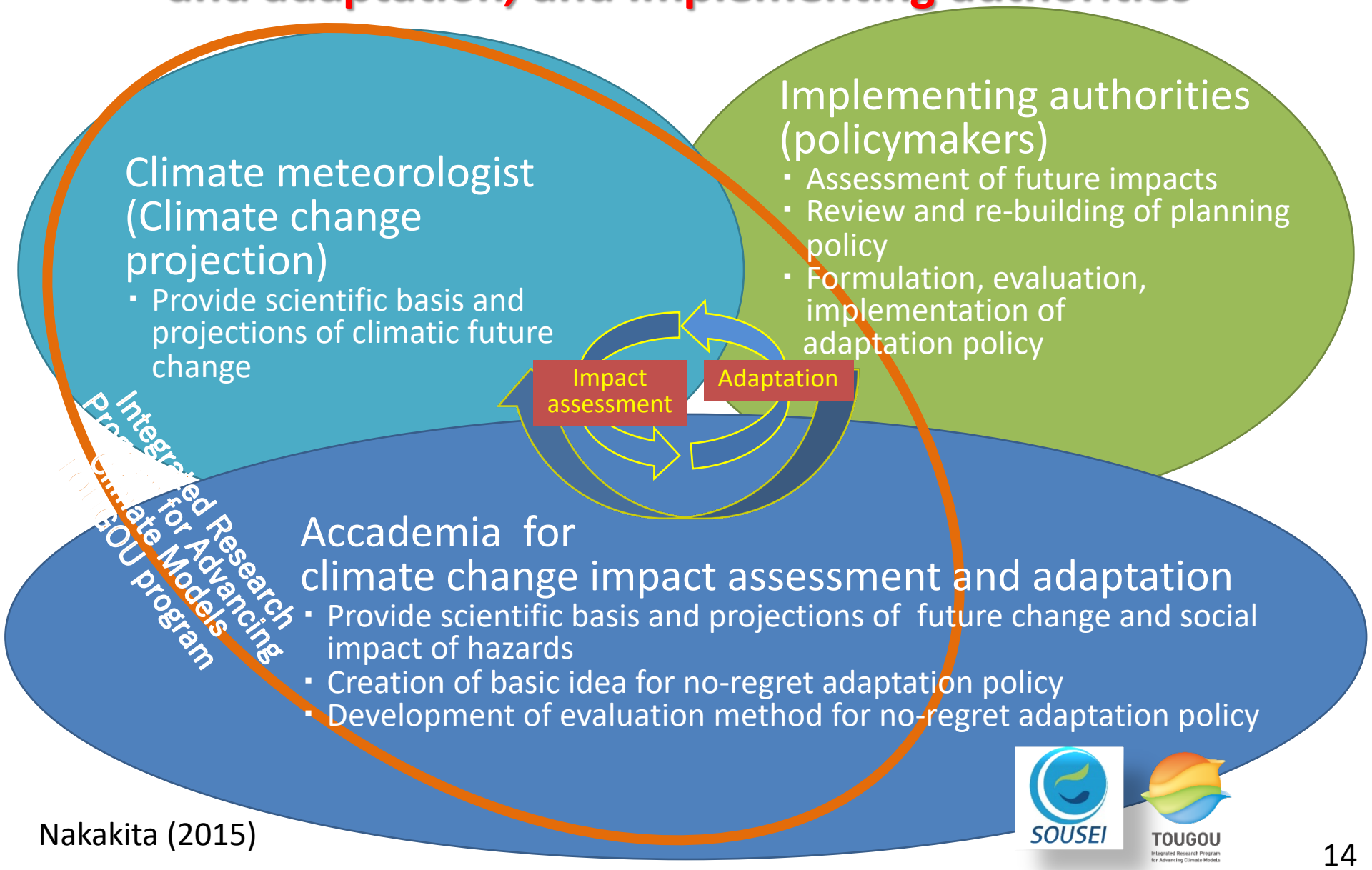
* Climate Sensitivity: the degree of temperature rise when CO2 concentration doubles in the atmosphere.
** Tipping Element: irreversible drastic change of the climate system occurring sometimes when climate change exceeds a certain level.

○Our climate model developed in Japan since the predecessor program acquired one of the highest number of users globally.

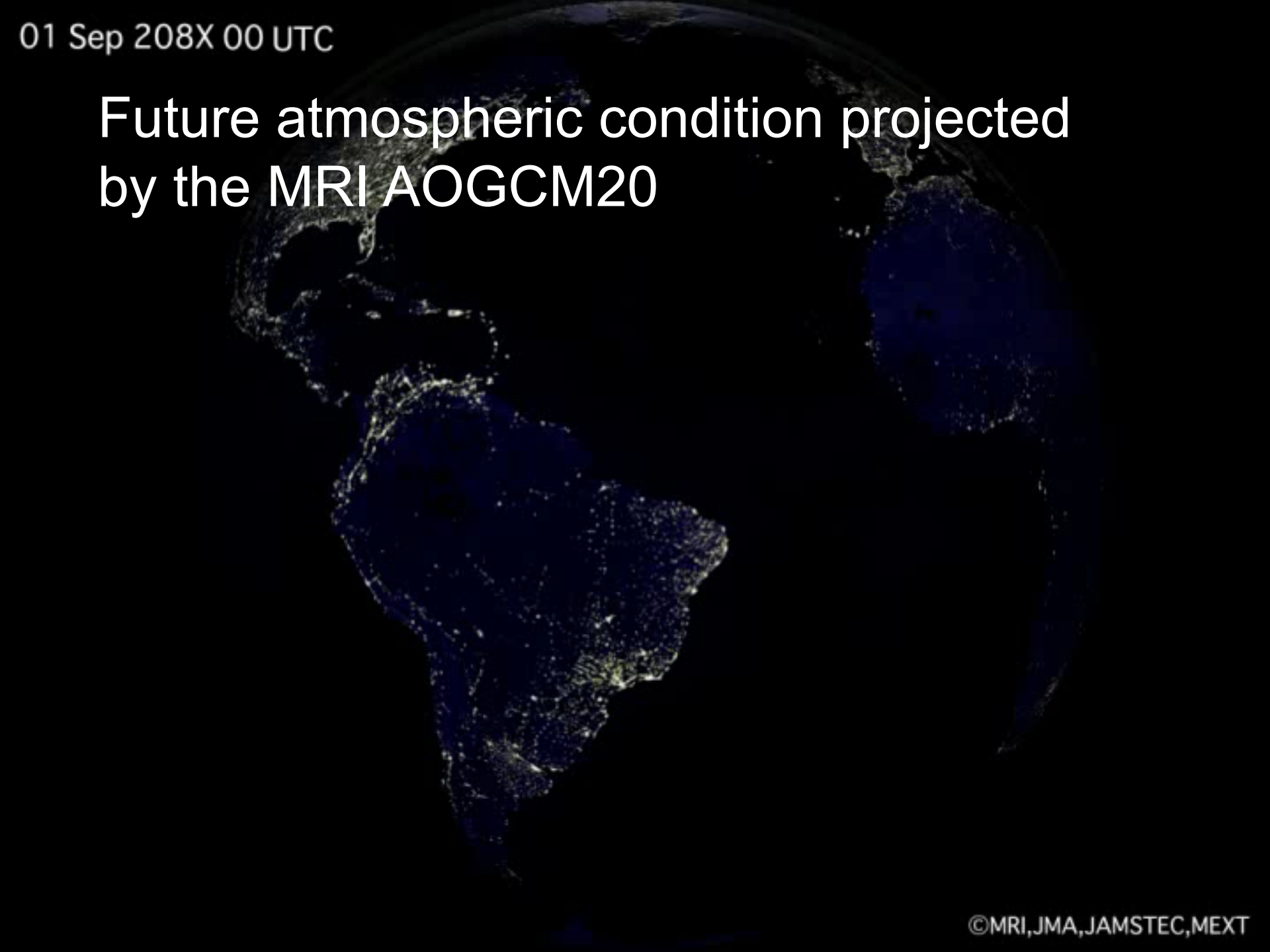
○Climate change forecast information is used as foundation for climate impact assessment.

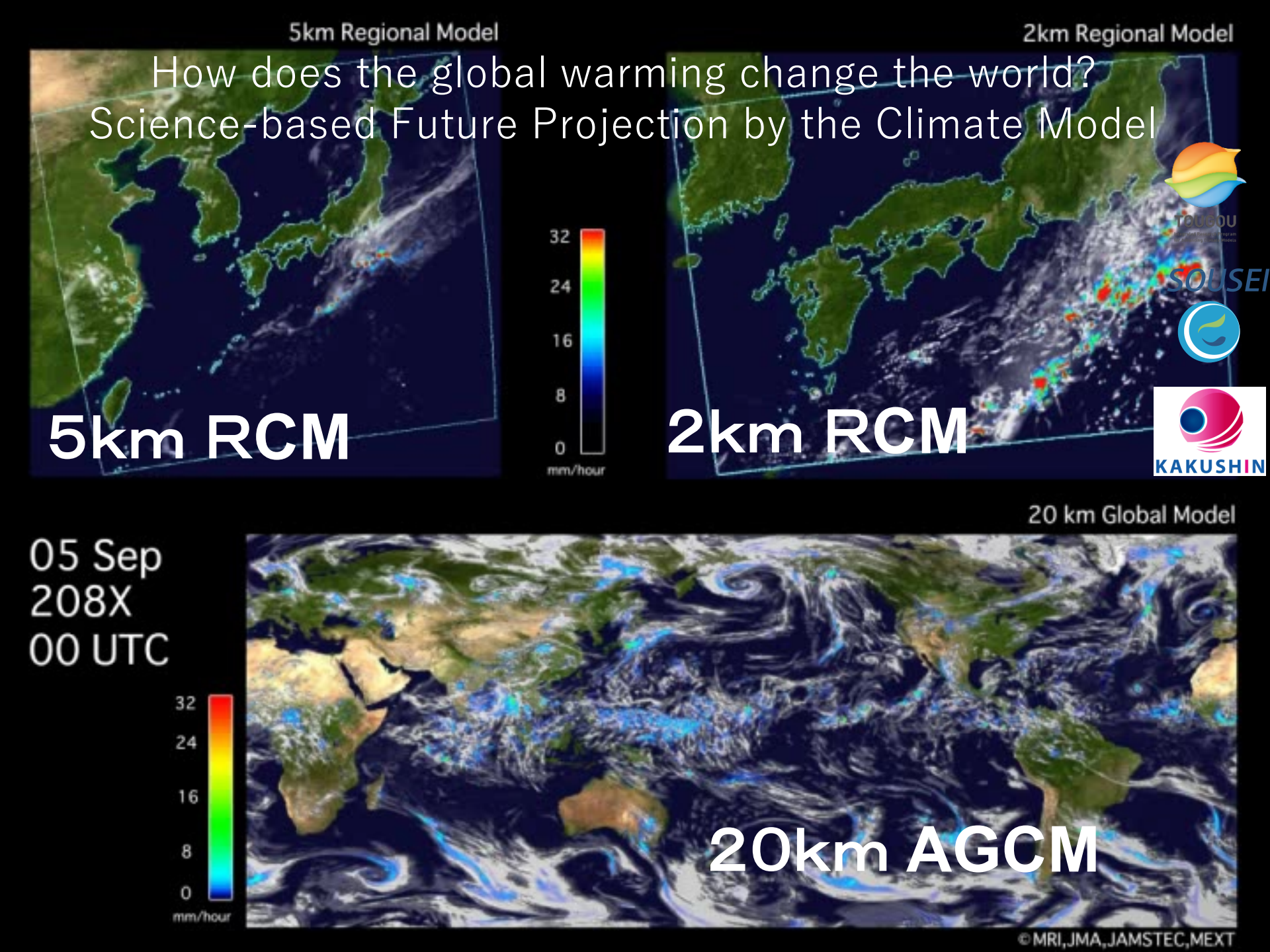
MEXT、2109

Importance of cooperation among Climatologists & Academia for climate change assessment and adaptation, and Implementing authorities



Nakakita (2015)


01 Sep 208X 00 UTC
Future atmospheric condition projected by the MRI AOGCM20
©MRI,JMA,JAMSTEC,MEXT


5km Regional Model
2km Regional Model
How does the global warming change the world?
Science-based Future Projection by the Climate Model
32
24
16
8
0
mm/hour
5km RCM
2km RCM
KAKUSHIN
20 km Global Model
05 Sep
208X
00 UTC
32
24
16
8
0
mm/hour
20km AGCM
©MRI,JMA,JAMSTEC,MEXT

Projected future change in extreme events

- **Typhoon：**
  - Number approaching Japan will decrease
  - Risk of super-typhoons will increase
- **Asia monsoon-related heavy rainfall：**
  - Frequency and total amount of rainfall will increase
  - This will occur over entire Japanese Archipelago over a wider area of water vapor invasion
- **Extremely localized rainfall (shower)：**
  - Number and intensity will increase

Projected future change in hazards

- Increase in once-in-100-years maximum river discharge all over Japan
- Increase in once-in-10-years river discharge in many watersheds except in northern part and central mountain areas of Japan. Decrease and acceleration of the peak of snow melting in the areas where snow-melting water is used.
- Change in validity of dam operations (both flood and drought)
- Increase in the risk of large-scale surface collapse and deep collapse around the Western Pacific coast of Japan
- Aggravation of once-in-100-years-scale damage from high tide and high surge in major bays
- Increase in water stress due to changes in snowfall and its accumulation

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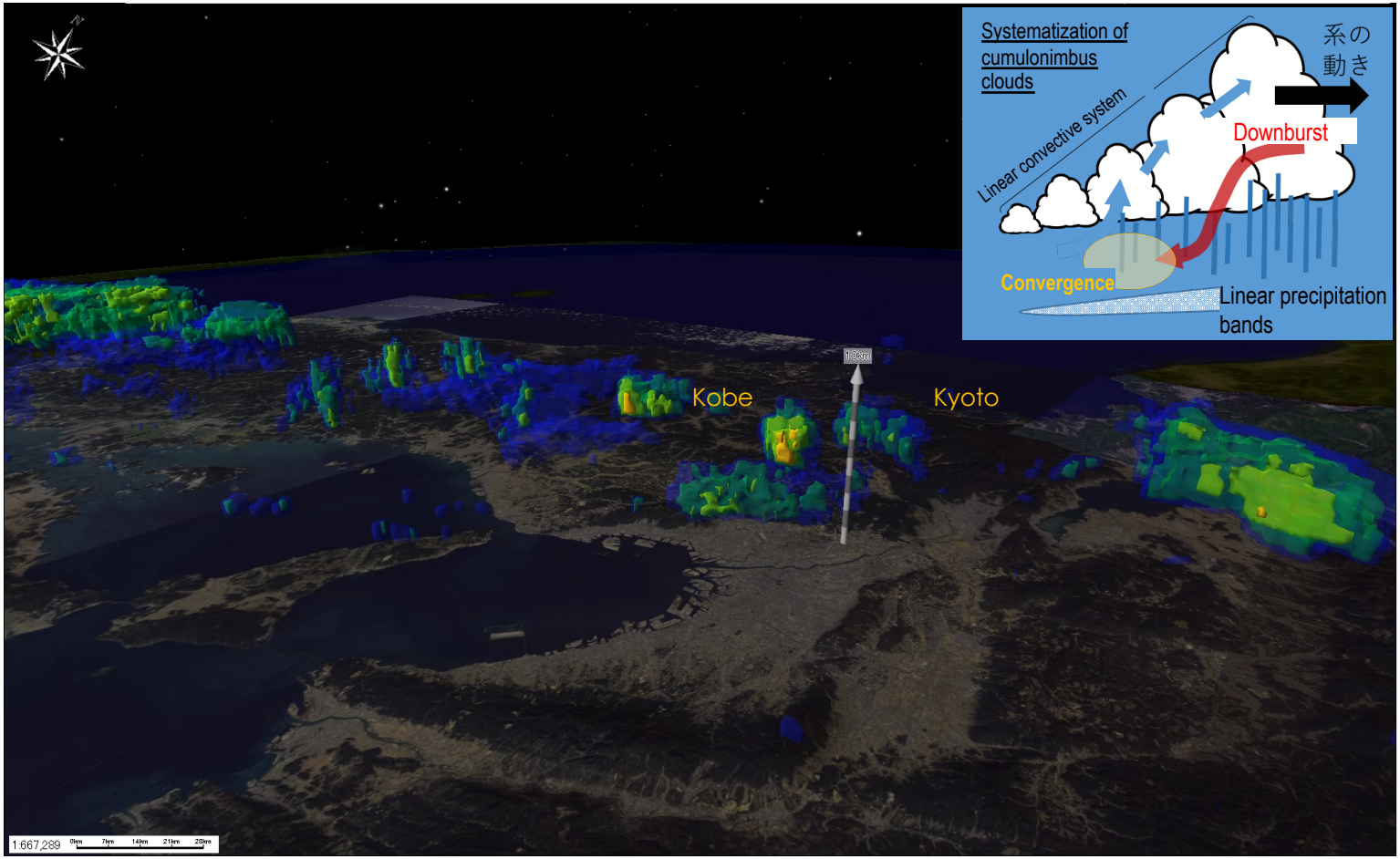
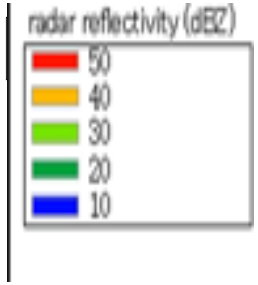
Torrential rain in Kyoto and Kameoka on July 15, 2021 captured by XRAIN

Torrential rain during the rainy season captured by the MLIT's X band polarimetric radar observation network (XRAIN)



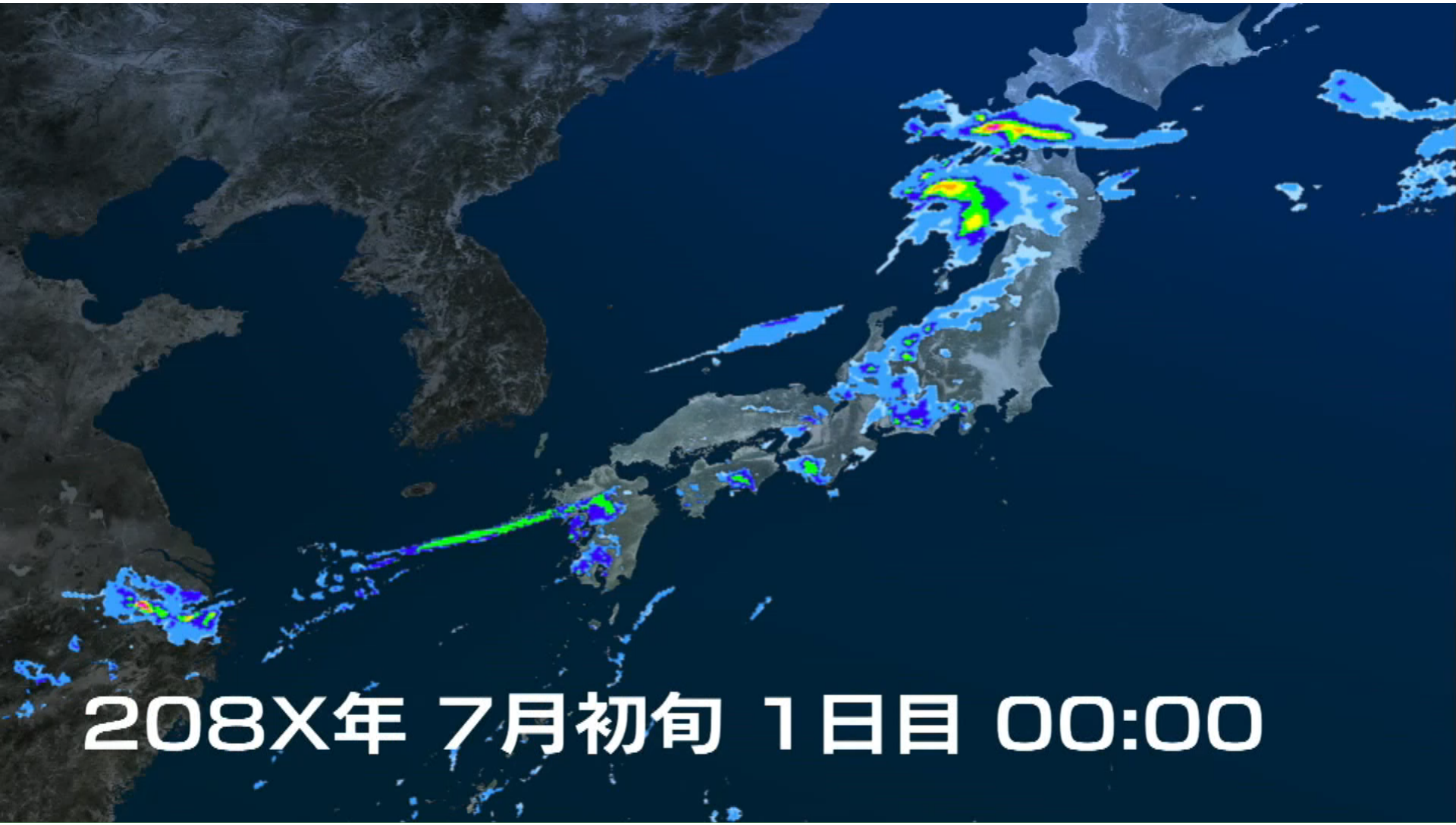


From lateral side

20:00
2012-07-14

Damage situation along the right bank of the Chikugo River basin in the torrential rains in northern Kyushu in 2017

Ministry of Land, Infrastructure, Transport and Tourism Kyushu Regional Development Bureau



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Monsoon related Baiu rainfall ：MRI of JMA
Animastion：NHK

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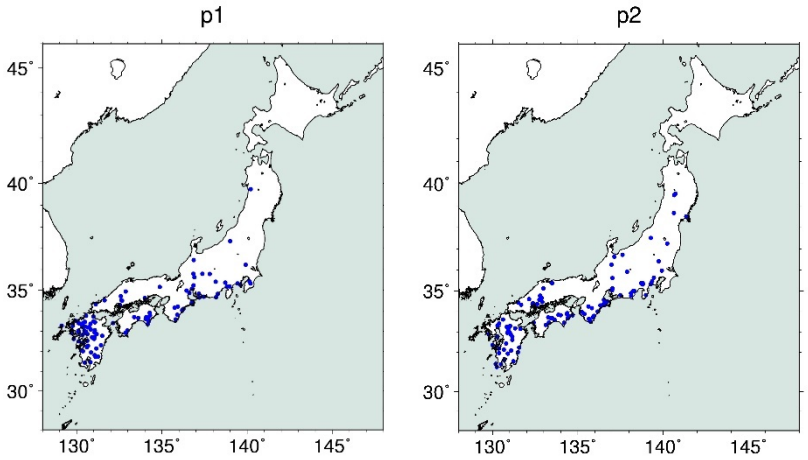
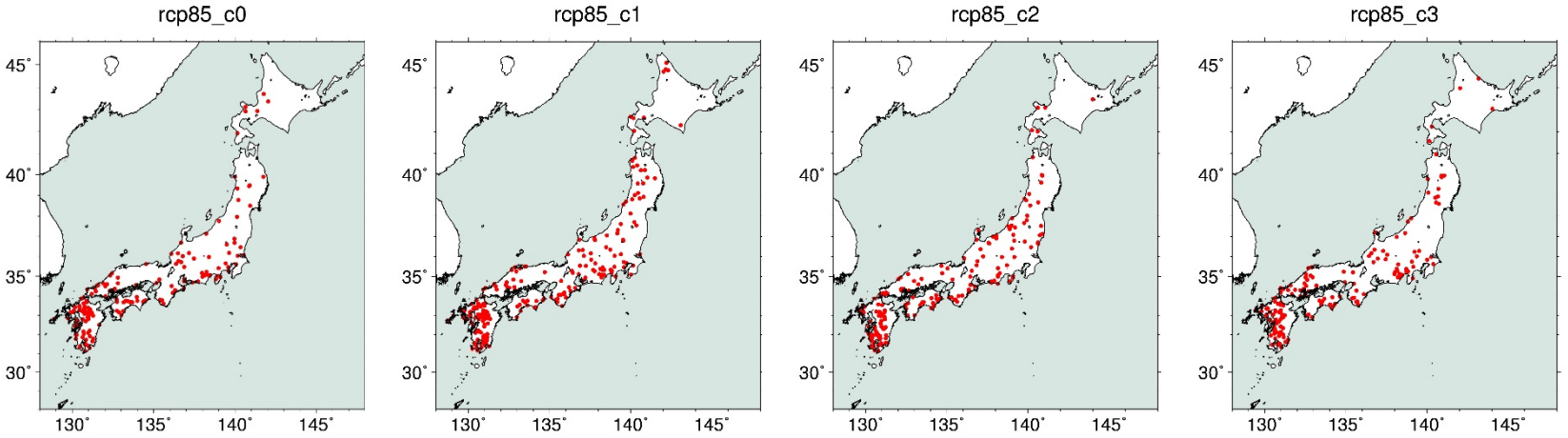
Analysis : Nakakita lab, Kyoto University
Animation : NHK

Nakakita and Osakada (2017), Osakada and Nakakita (2018)

Examples of numerical simulations on future changes in locations of heavy rainfall during the rainy season (20-year period)



Results of numerical simulations in current climate (2 candidates)

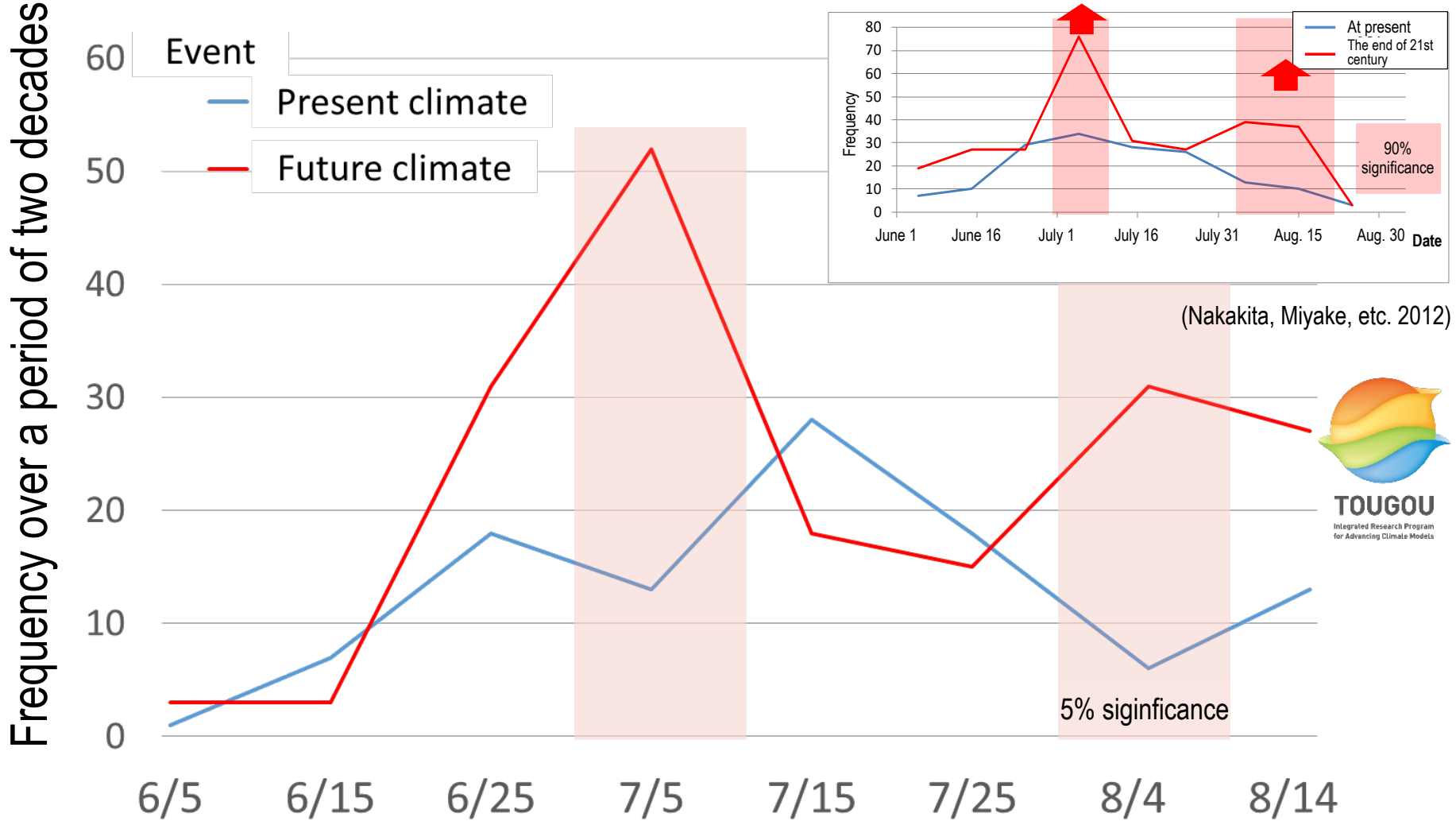


Results of numerical simulations in a future RCP8.5 world (4 candidates)

- Increase throughout Japan; occurring in Hokkaido, where there is no heavy rain during the rainy season.

Osakada and Nakakita (2018)

Increased torrential rains during the rainy season in early July



Nakakita and Osakada (2017)

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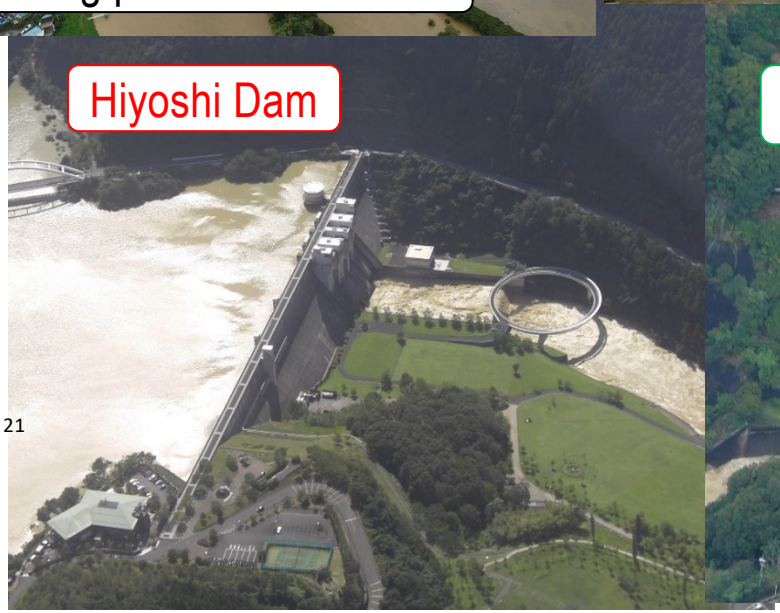
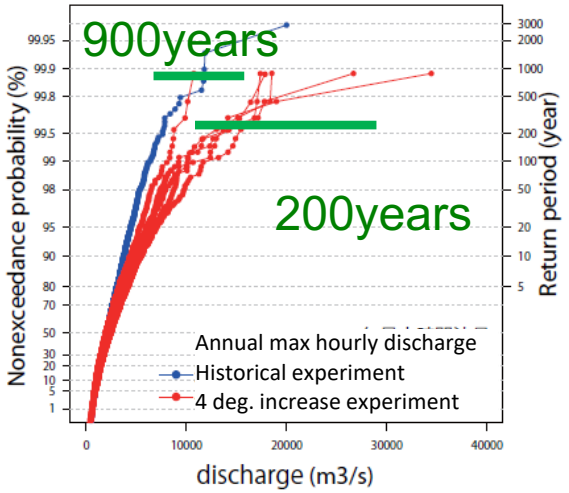
Disasters by Typhoons

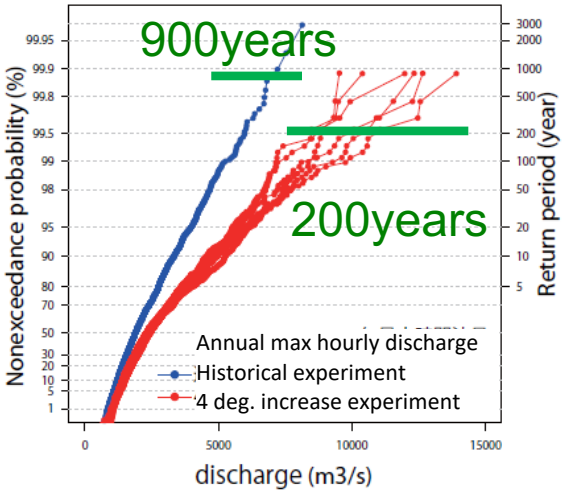


Ministry of Land, Infrastructure, Transport and Tourism Kinki Regional Development Bureau (MLIT) (2013)

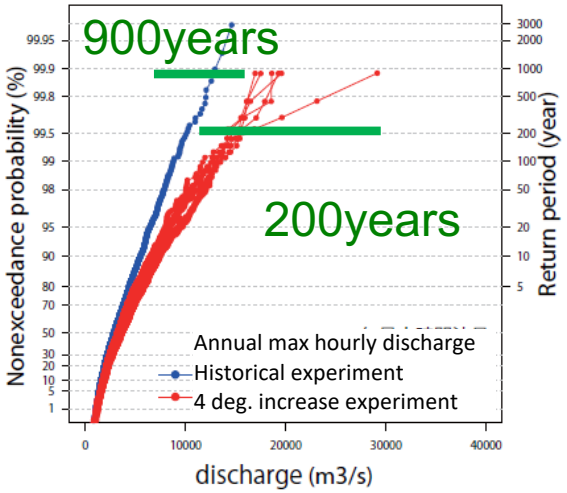
Change of Annual Maximum Hourly Discharge



Ara River basin



Shounai River basin



Yodo River basin

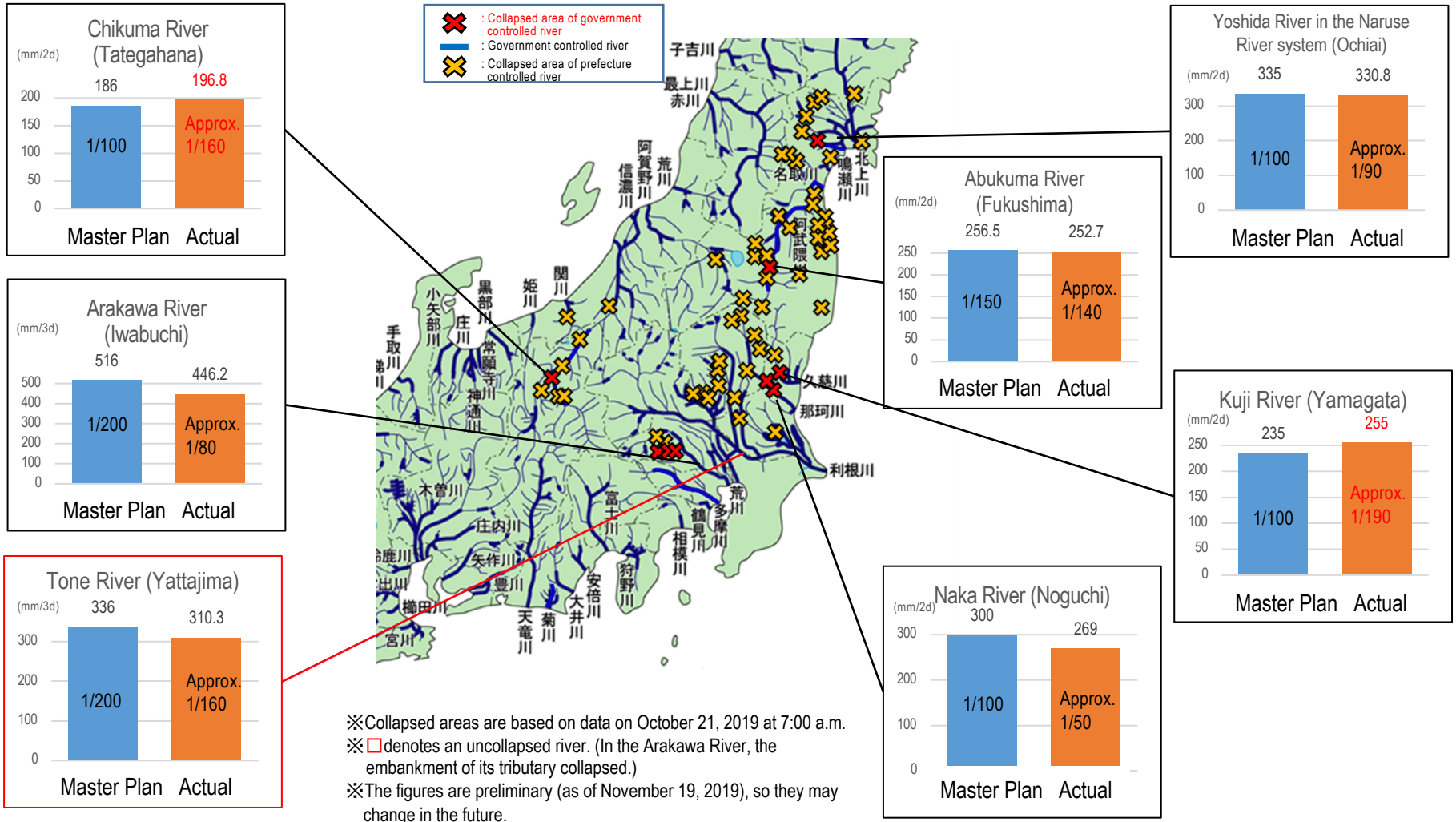
Catchment		Annual maximum hourly river discharge (m^3/sec)					
		Return period 200 years			Return period 900 years		
		Historical	4 deg. increase*1		Historical		4 deg. increase*2
Ara River (Iwabuchi)		7,611	12,801		11,780	1.09	20,934
Shounai River (Biwajima)		5,975	9,525		7,240	1.32	11,794
Yodo River	With dam	10,100	15,165		12,987	1.17	20,168
(Hirakata)	Without dam	12,307	18,328		15,723	1.17	23,191

1.1 – 1.3 times larger

Rainfall situation by Typhoon Hagibis (T1919)

■Damage due to flooding and its situation

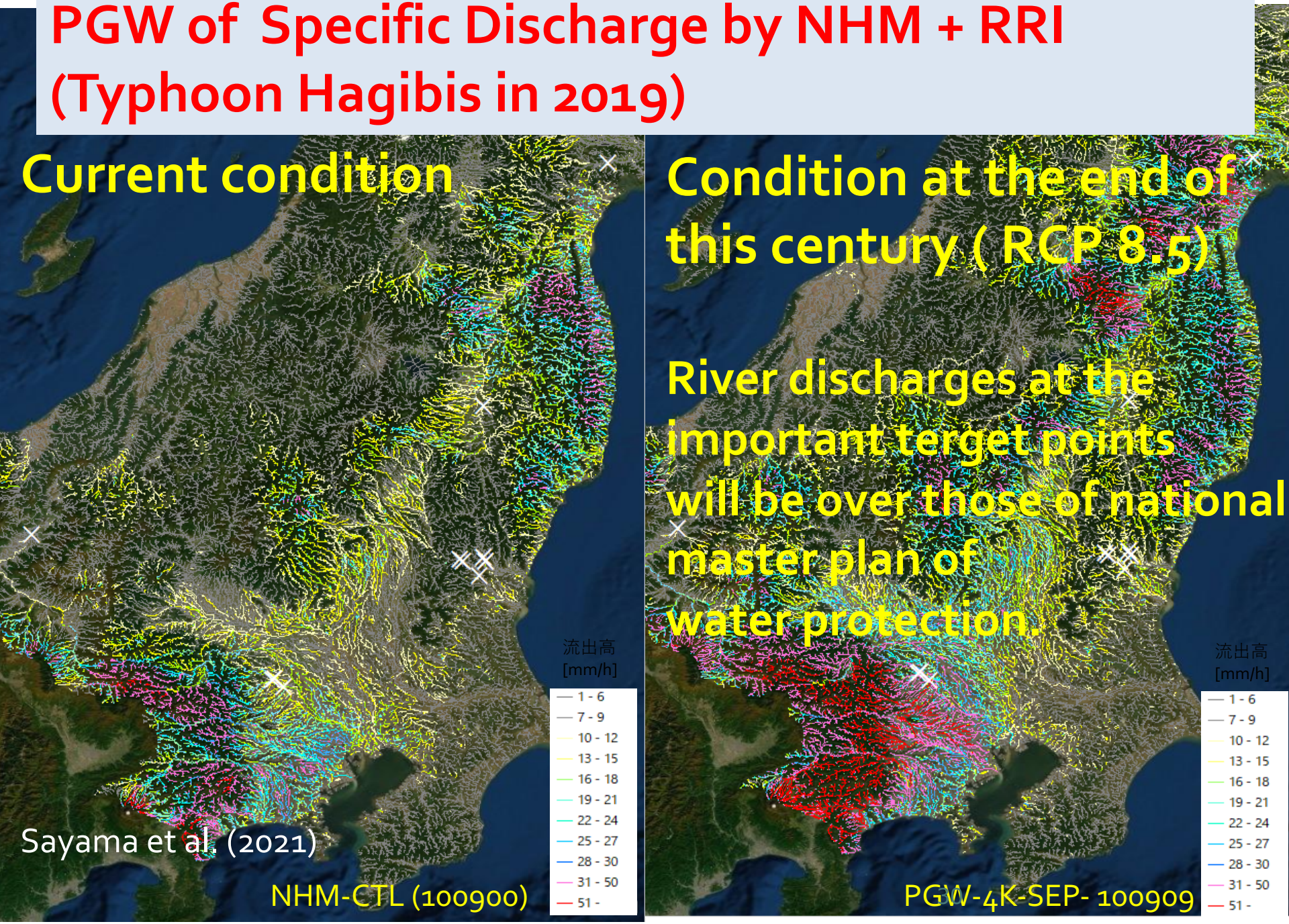
- In the government controlled Abukuma River in the Abukuma River system, Yoshida River in the Naruse River system, Chikuma River in the Shinano River system, Kuji River in the Kuji River system (three locations), Naka River in the Naka River system (three locations) and Oppe River (two locations) and Toki River in the Arakawa River system, their embankments collapsed.
- In these rivers, the amount of average rainfall on their upper reaches at observation points exceeded or nearly reached the target rainfall specified in the basic policy on the development of rivers.



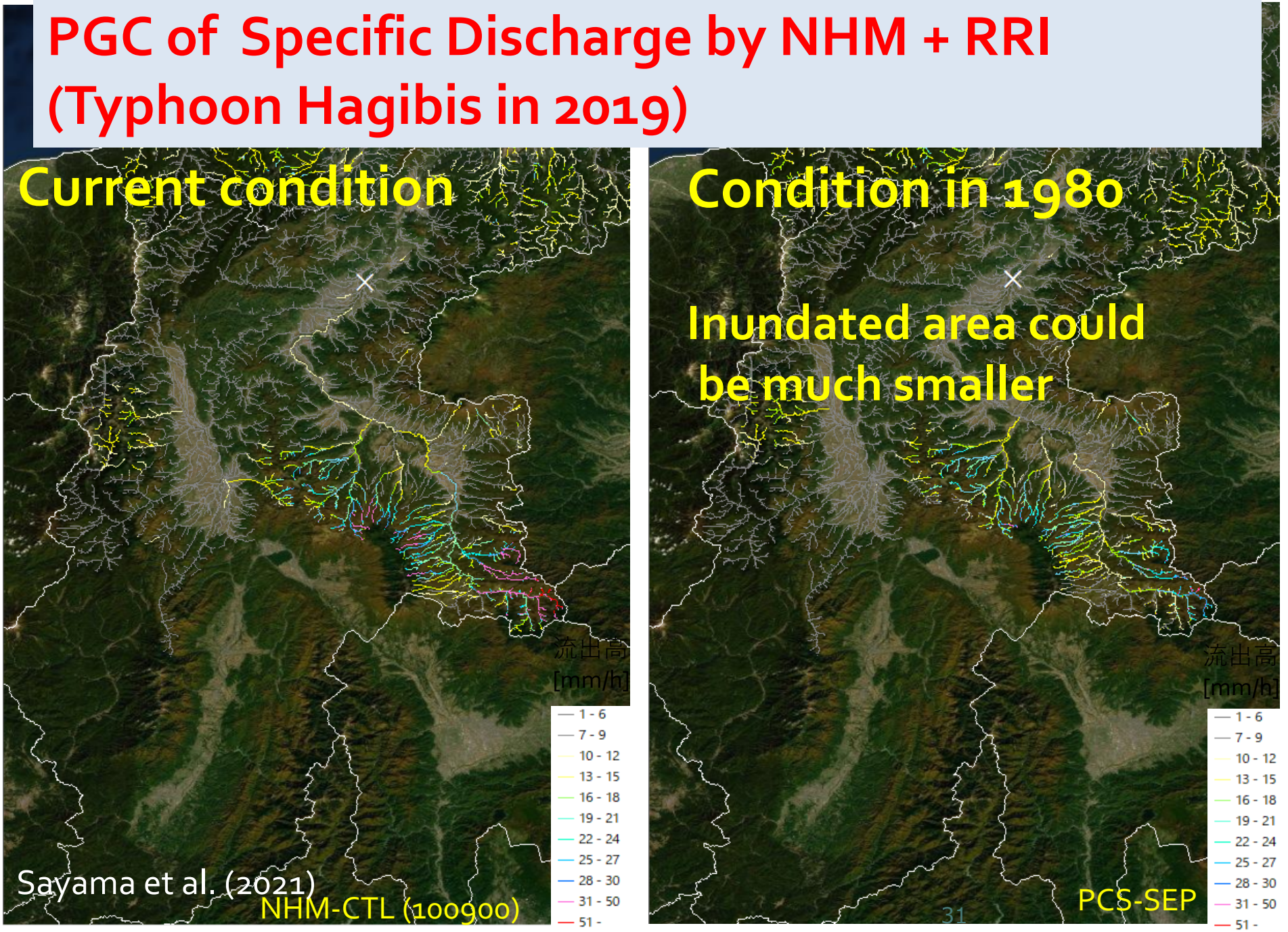
※Collapsed areas are based on data on October 21, 2019 at 7:00 a.m.
※□denotes an uncollapsed river. (In the Arakawa River, the embankment of its tributary collapsed.)
※The figures are preliminary (as of November 19, 2019), so they may change in the future.

MLIT, 2019

PGW of Specific Discharge by NHM + RRI (Typhoon Hagibis in 2019)



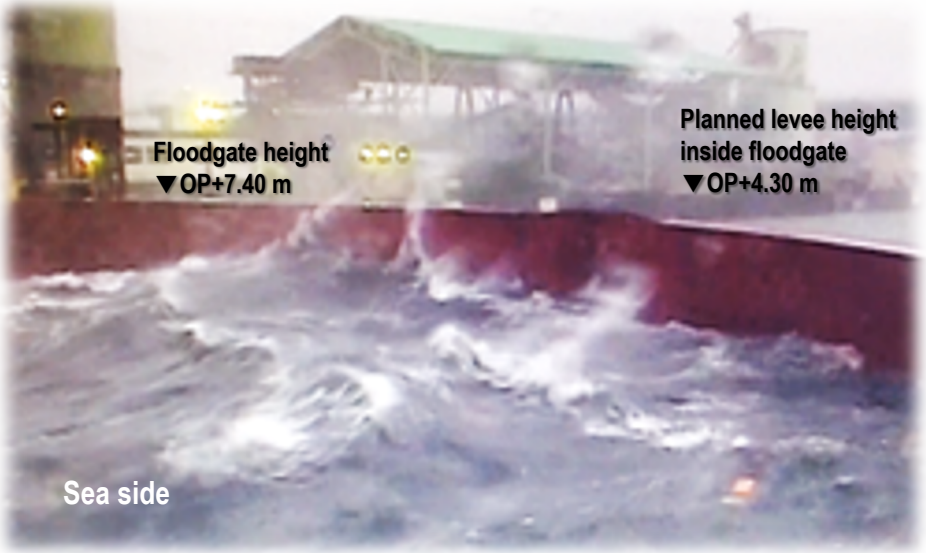
PGC of Specific Discharge by NHM + RRI (Typhoon Hagibis in 2019)



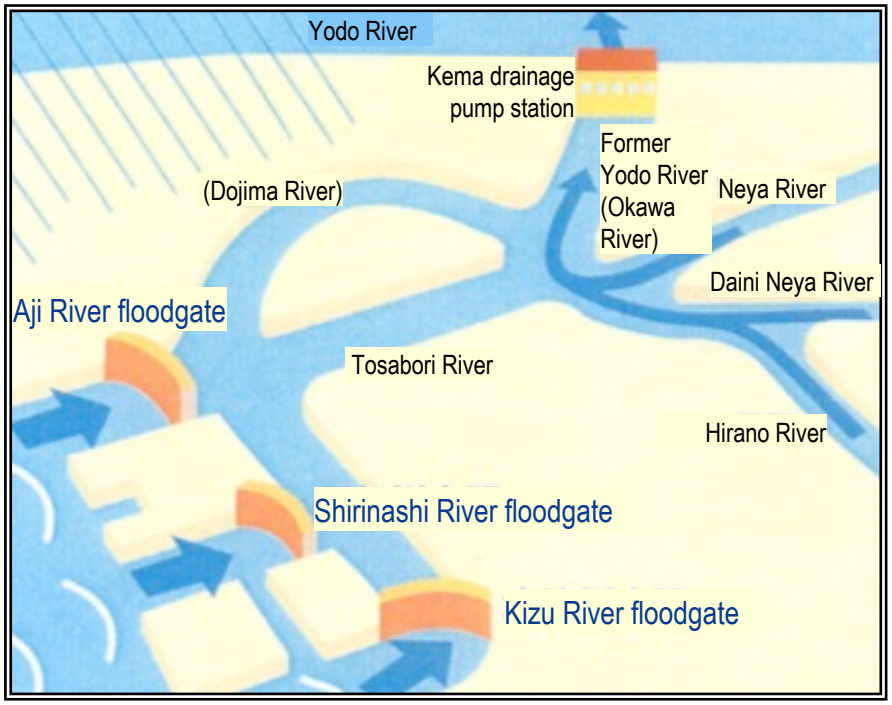
Utilization status of facilities against high tide

Materials provided by Osaka Prefecture

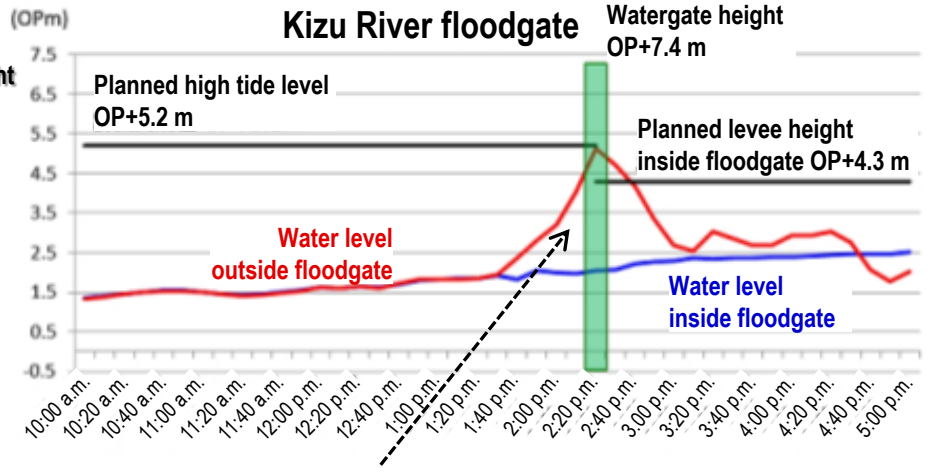
Floodgate system



Close status of Aji River floodgate



Close status of Kizu River floodgate



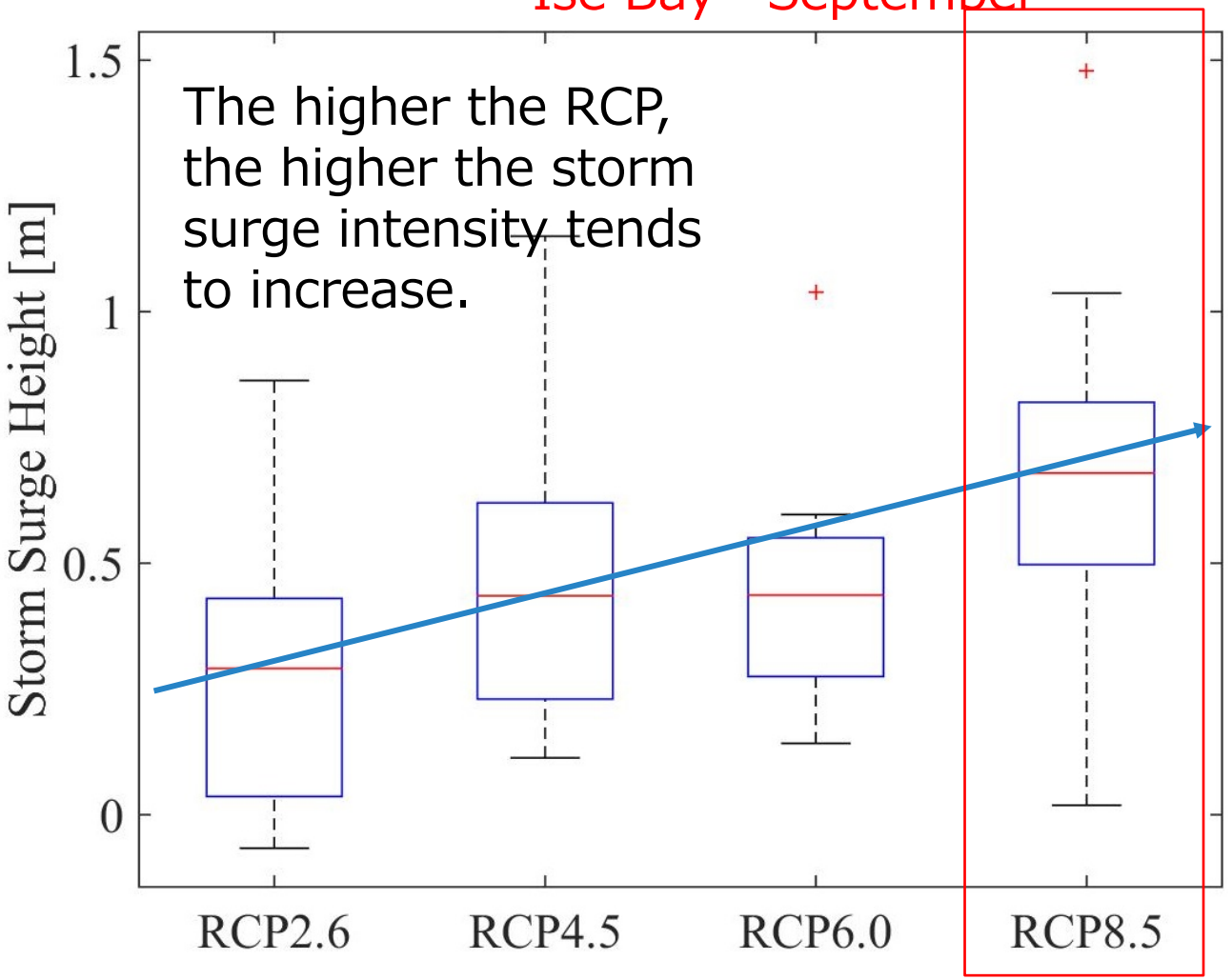
Up to about 3.0 m water level difference between inside and outside the floodgate

Extreme

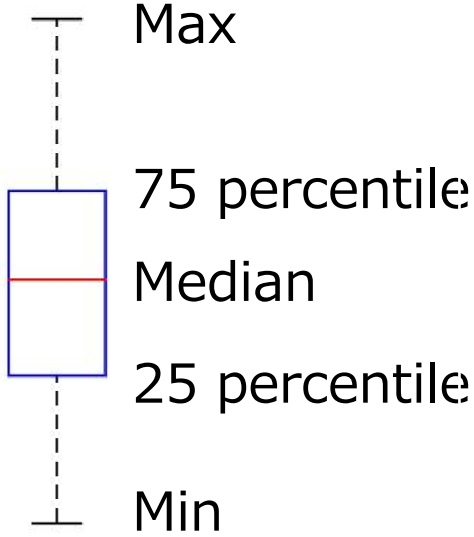
Theme D
Coast WG

MPSSH (Maximum possible storm sugehight)
CMIP5:(2075-2099)-(1979-2003)

Ise Bay・September



Outliner
(Maximum whisker length is 1.5 times of interquartile range.)



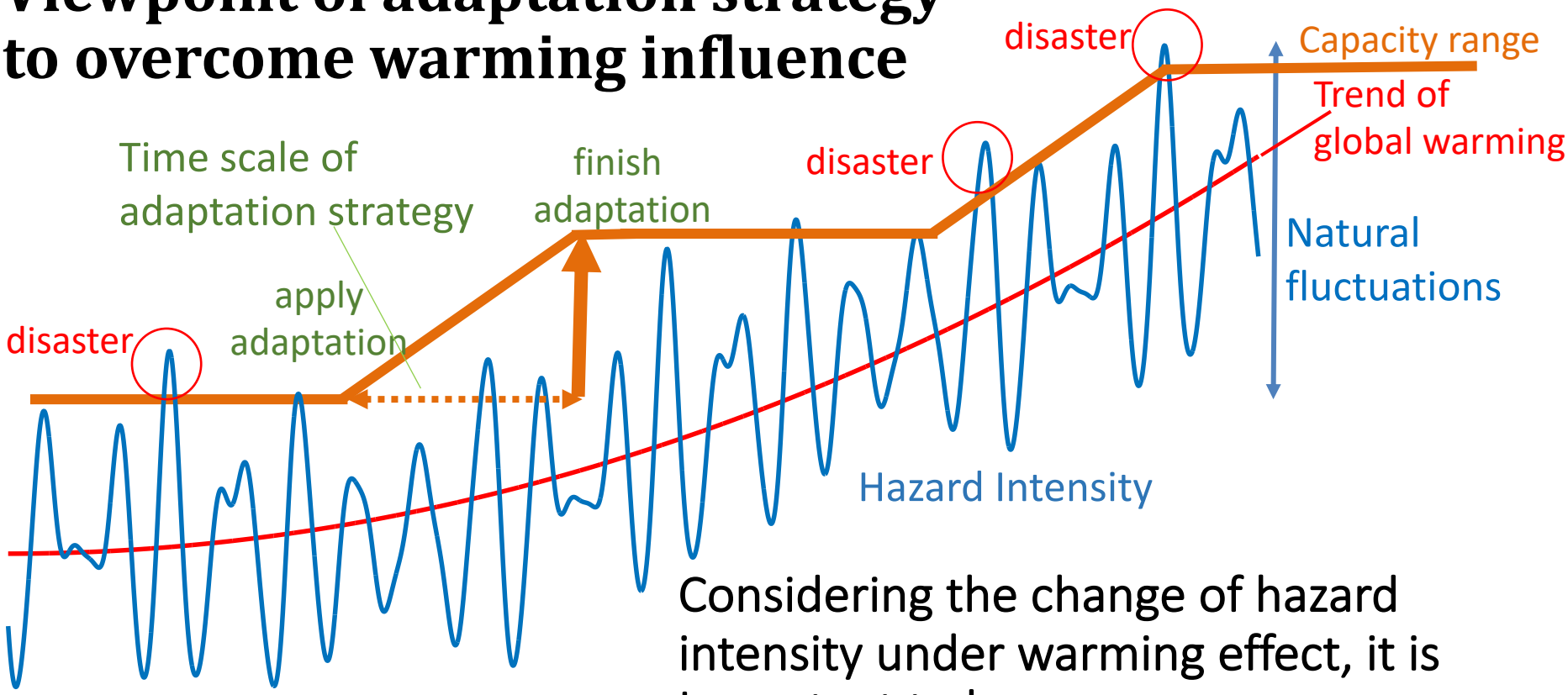
Sensitivity MPSSH to SST
Is 0.12m/℃ in average

Mori and Shimura 2018

Average: About 0.7 m

Importance of Non-regret adaptation strategies with consideration for various changes

Viewpoint of adaptation strategy to overcome warming influence



Considering the change of hazard intensity under warming effect, it is Important to know:

- Time scale of global warming effect;
- Width of natural fluctuations;
- Time scale of adaptation strategy;
- Cost effectiveness.

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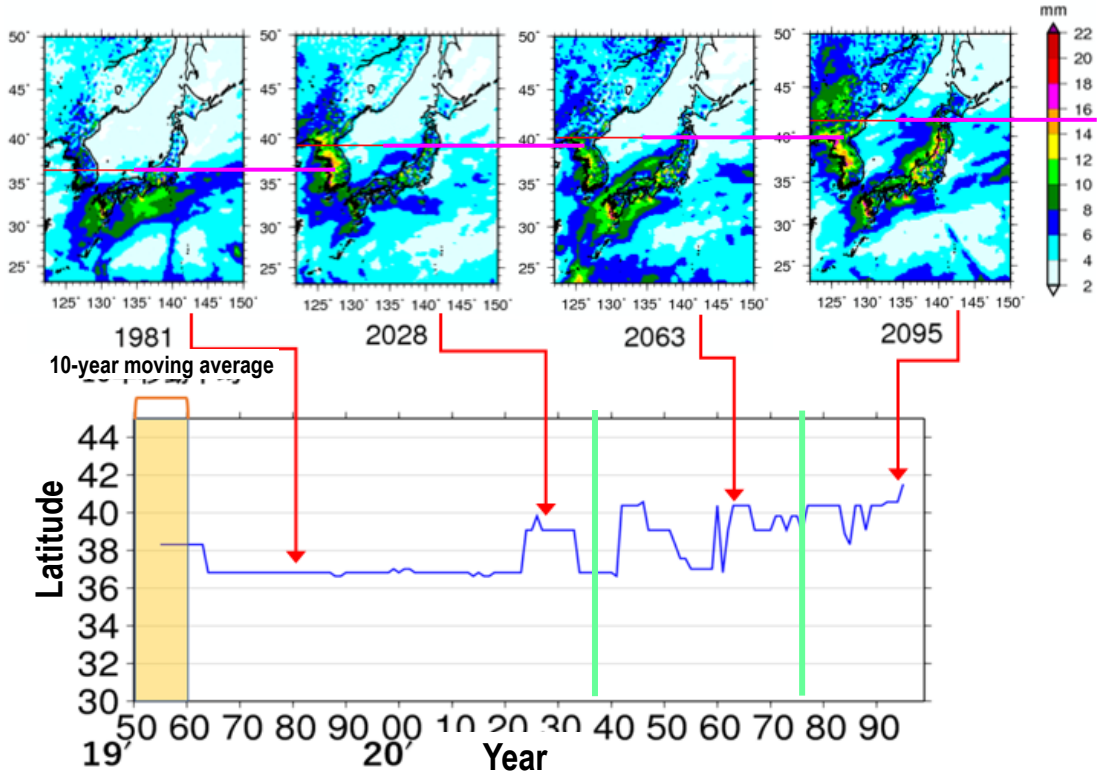
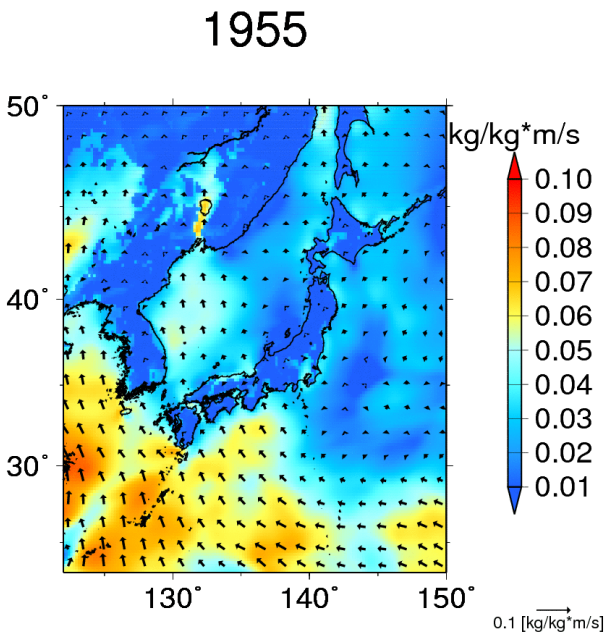
Future changes of position of Baiu rain belt and spatial distribution of surface water vapor flux



position of Baiu rain belt



surface water vapor flux

Nakakita, Harada and Osakada (2021)

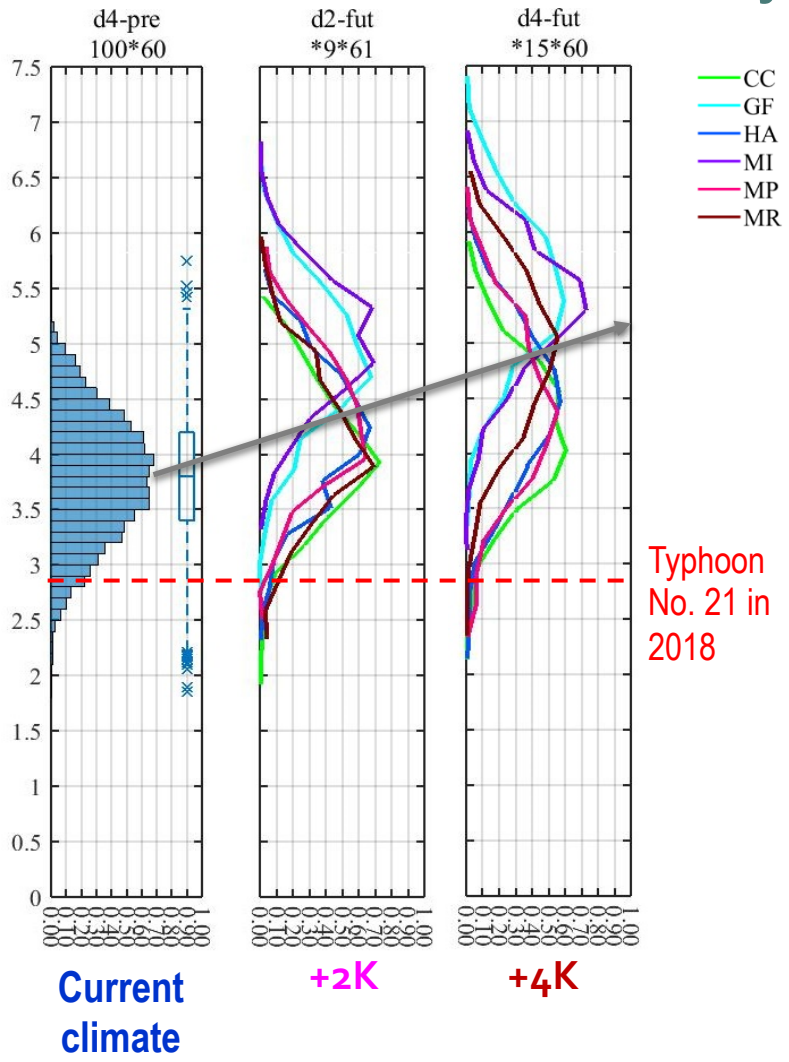
Mori and Mori (Disaster Prevention Research Institute, Kyoto University)

Theme D
i. Extreme

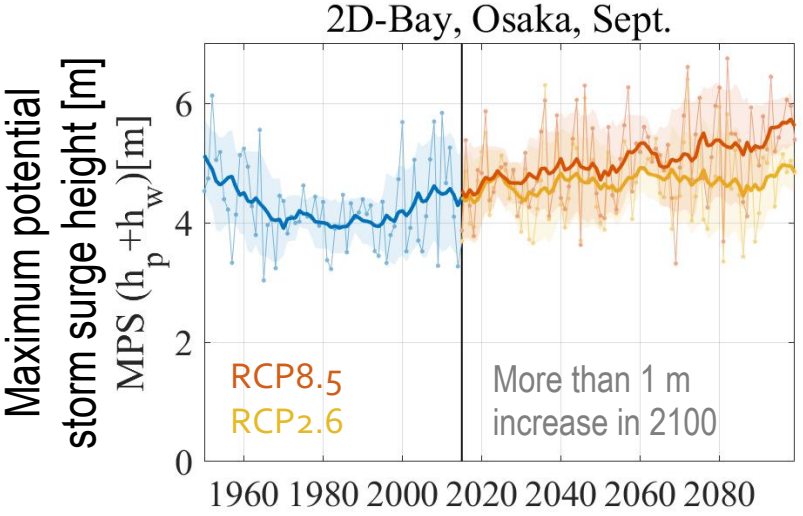
150-year Run and d4PDF [Coast Disasters]

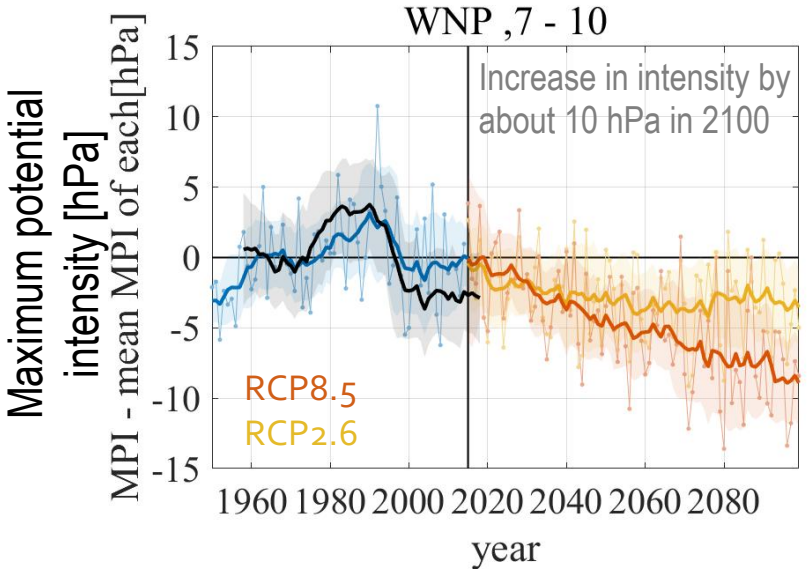
Projection of Maximum Potential Storm Surge Height

d4PDF: Example of Osaka Bay



150-year run: Osaka Bay





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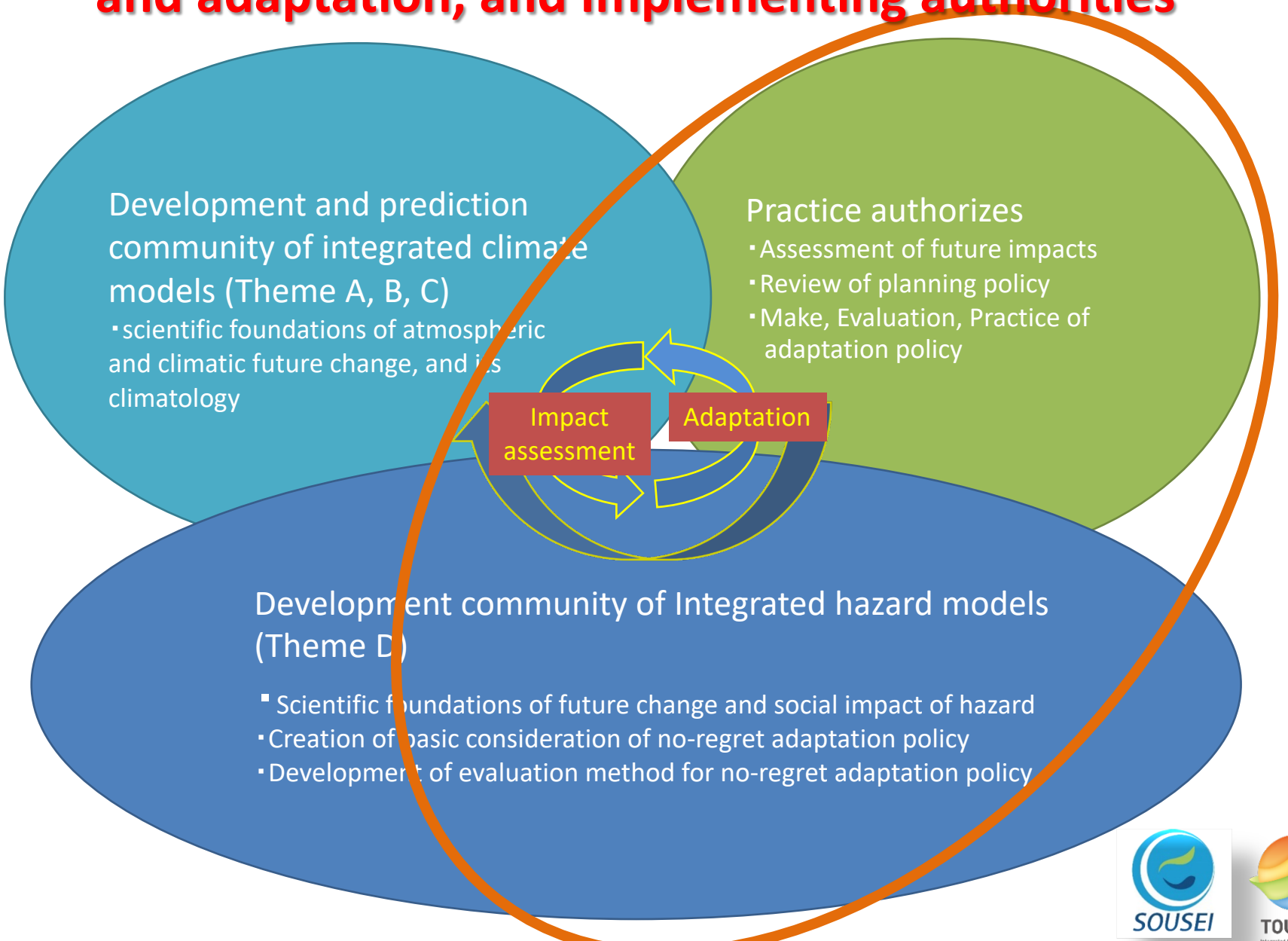
Importance of cooperation among Climatologists & Academia for climate change assessment and adaptation, and Implementing authorities



SOUSEI

TOUGOU

Collaborative symposium between Tougou Program and relevant Ministries

2019. 5.24 at National Olympics Memorial Youth Center

Organizers: MEXT Integrated Research Program for Advancing Climate Morels(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 Water Engineering Committee, Global Environment Committee, Coast Engineering Committee, Geotechnical Engineering Committee, Planning Science Committee, Hydrology and Water Resources Society, Geotechnical Society, Japan Natural Disaster Society

Nakakita (2019)

System for considering countermeasures based on recent disasters and climate change

(For the area of land security and water management

Integrative consideration by Panel on Infrastructure Development

- Panel on Infrastructure Development
  - Breakout Group on Rivers
    - Subcommittee on water disaster countermeasures considering climate change
    - Subcommittee on landslide disaster protection

Professional Meetings by Experts

- Technical study group on flood control plan considering climate change
- Exploration committee for coastal protection considering climate change
- Study group on urban inundation measures considering climate change
- Technical study group on erosion control (sabo) considering climate change
- Study on strengthening levees
- Study group on dam flood control
- Technical study group on flood risk assessment of small and medium rivers
- Study meeting for cooperation between water disaster countermeasures and city development

・・・Consideration by the Panel on Infrastructure Development

・・・Meeting by Experts

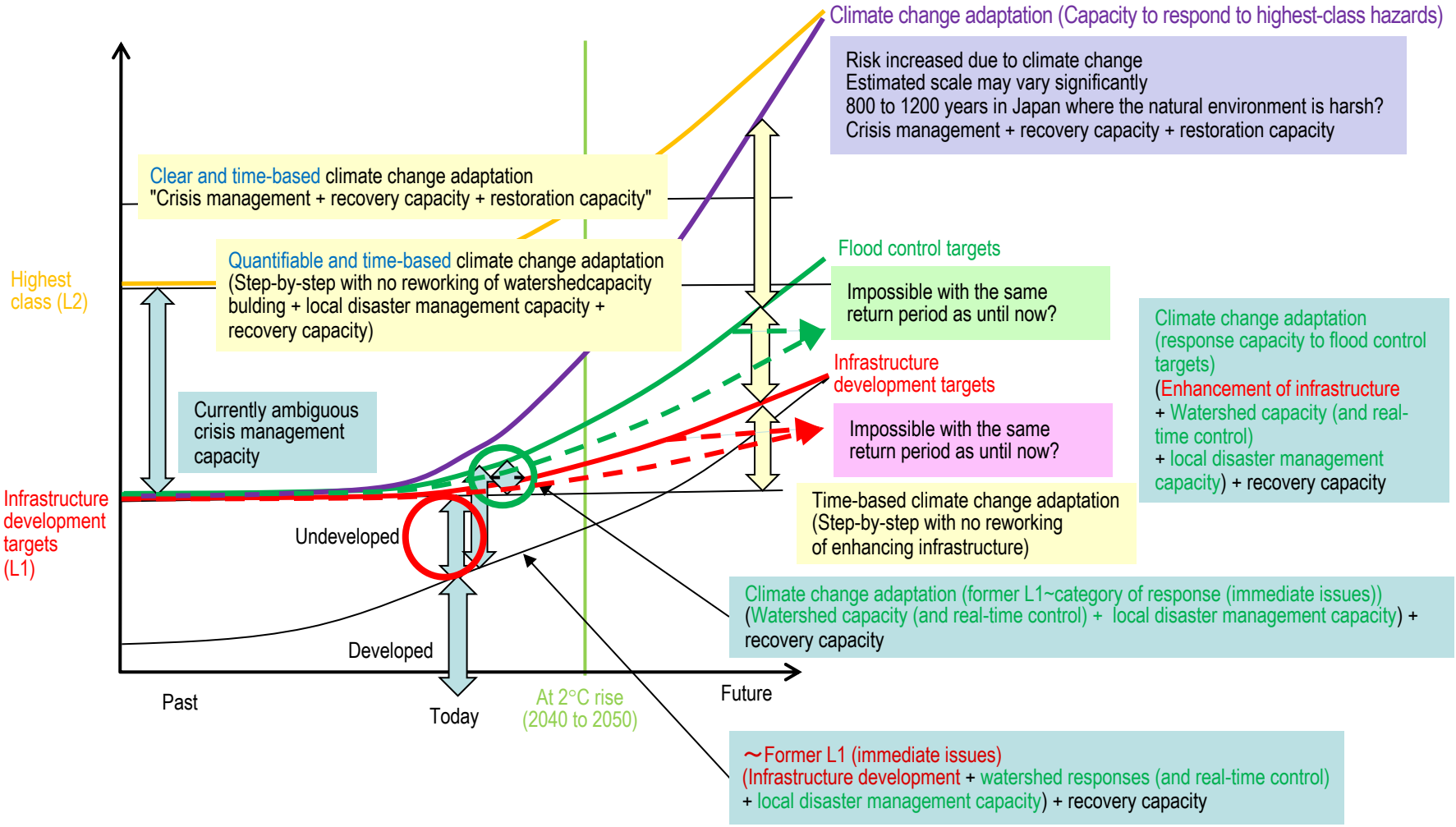
・・・Coordinaion meeting by relevant Ministries.

Coordination by the relevant Ministries

- Study Group to strengthen flood control function of existing dam
  (Cabinet Secretariat・MHLW・MAFF・METI・MLIT(including JMA))
- Verification team for improving river/weather information (MLIT Water Bureau/ JMA))

MLIT (2019)

Climate change adaptation in response to natural and societal changes



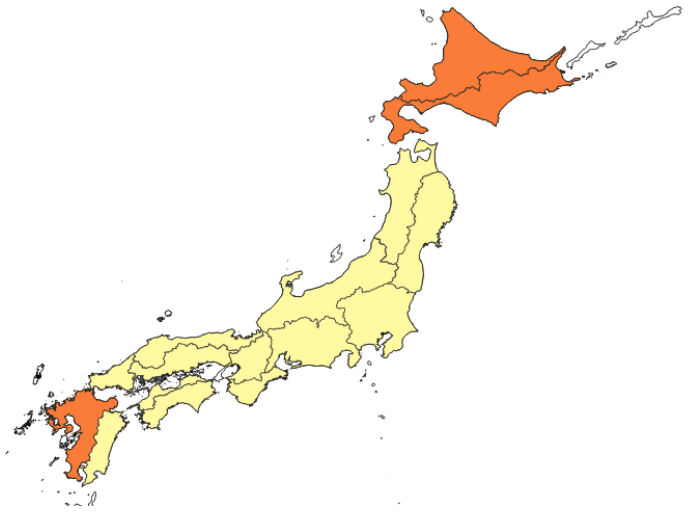
Nakakita (2020)

[Evaluation of future rainfall prediction data]

Climate change adaptation

＜Change rate of future rainfall＞

Area	RCP2.6 (2℃ Rise)	RCP8.5 (4℃ Rise)
Hokkaido, Northwest Kyusyu	1.15	1.4
The others	1.1	1.2
Average	1.1	1.3



- The future rainfall change rate, based on assumption of RCP2.6 (equivalent to a rise of about 2°C), is predicted to be about 1.1 times more than it is today on the national average.

* It is necessary to revise the values as required since prediction data are regularly revised by IPCC or other organizations.

* Islands, including Okinawa and Amami, are excluded from this review because there are some problems in terms of reproducibility of the island model.

MLIT (2019)

River Basin Disaster Resilience and Sustainability by All

- In light of the effects of climate change and changes in social conditions, all parties involved in the river basin will work together to switch to "basin control," a water control measure implemented throughout the basin
- Change the flood protection plan to ″considering the increase in rainfall due to climate change″ and consider it as one basin including not only the river channel but also the catchment area and the inundation area. (1) Measures to prevent and reduce innodation, (2) measures to reduce the target of damage, (3) measures to reduce damage, and measures for early recovery and reconstruction will be promoted in multiple layers with hardware and software.

①Measures to prevent or reduce flooding as much as possible

Expansion of rainwater storage function
[Prefectures/cities, companies, and residents]

Watershed

Development of rainwater storage and infiltration facilities, and utilization of reservoirs, etc. for flood control

Storage of wate
[The government/prefectures/cities/water consumers]

River channel

Construction and renewal of flood control dams, and utilization of water supply dams for flood adjustment by discharging storage water in advance

[The government/prefectures/cities]
Improvement of rainwater storage function together with land use

Sustainable river channel flow capacity Maintenance /improvement
[The government/prefectures/cities]
Excavation of riverbeds, backward displacement of levees, erosion control work, and development of rainwater drainage facilities, etc.

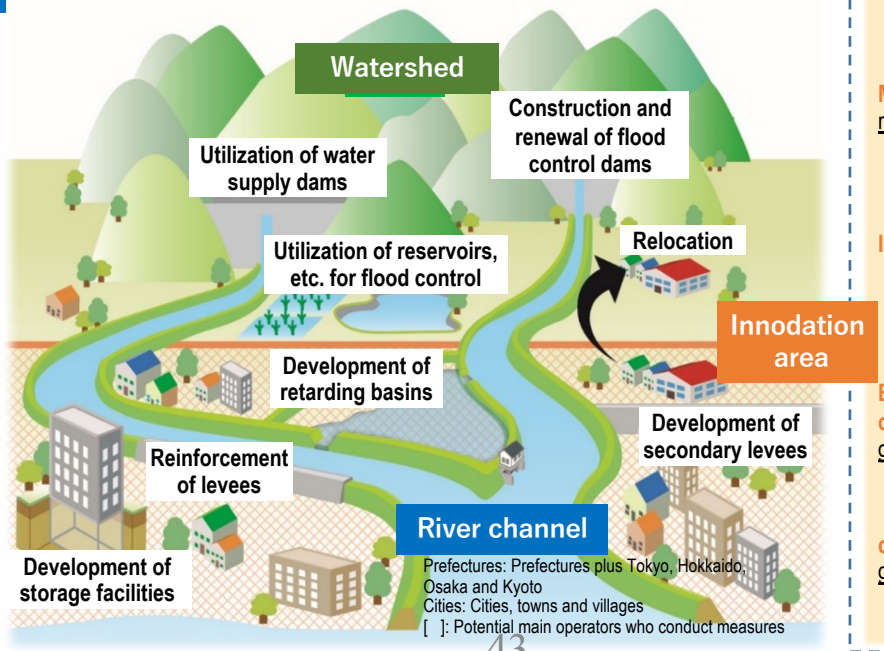
Reduce flood water
[The government/prefectures]
Reinforcement of embankments with the aim of gaining toughness and other initiatives

② Measures to reduce the damage target

Guide to low-risk areas / Ingenuity of living
[Prefectures/cities, companies, and residents]
Usage regulation, guidance and relocation promotion of land, provision of information on flooding risks at the time when buyers and renters sign their contracts, and consideration of guidance through financing

Innodation area

Reduce flood range [The government/prefectures/cities]
Development of secondary levees and maintenance of natural embankments



③ Measures for damage reduction, early recovery and reconstruction

Enrichment of land risk information [The government/prefectures]
Elimination of areas where there was no information on flooding risks and release of multistage information on flooding risks

Strengthen the evacuation system
[The government/prefectures/cities]
Development of technologies for long-term predictions and keeping track of flooding and collapse in real time

Minimize economic damage [Companies and residents]
Action against the inundation of factories and buildings and formulation of a business continuity plan

Ingenuity of living [Companies and residents]
Provision of information on flooding risks at the time when buyers and renters sign their contracts, and promotion of measure against inundation through financial products

Enhancement of support system for disaster-affected local governments [The government/companies]
Strengthening the TEC-FORCE system through public-private cooperation

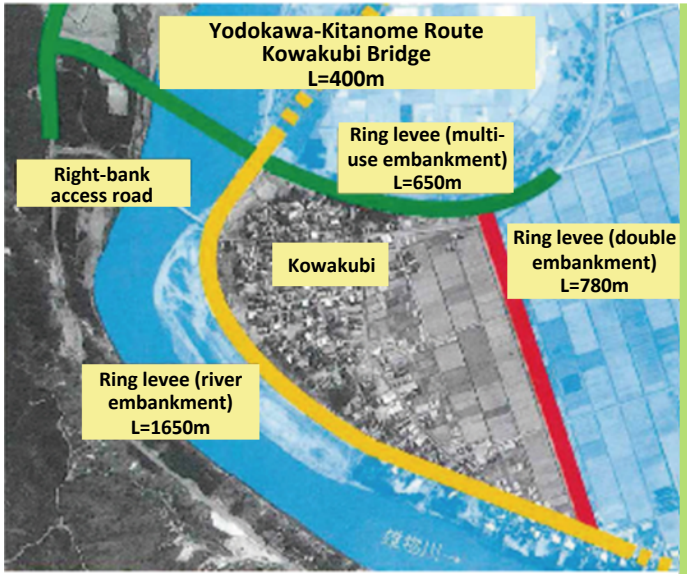
drainage of flood water quickly [The government/prefectures/cities, etc.]
Development of drainage gates, etc. and reinforcement of drainage

Use of Traditional Knowledge：Flood Control with Land Use Management (*Wajuu-tei*、*Kasumi-tei*)

Kasumi-tei：to guide water from the embankment to non-hazardous areas like rice fields when the level of water becomes extremely high.

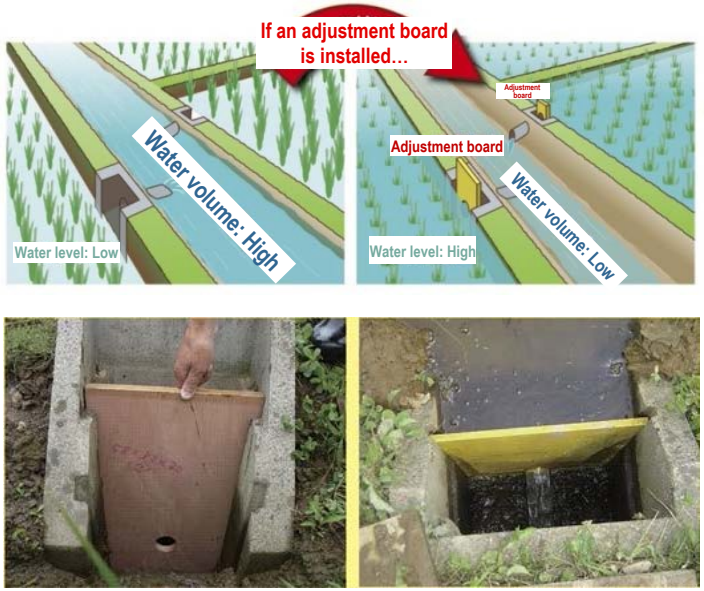
Wajuu-tei：to prevent the city and village from inundation by enclosing them with an embankment

(MLIT, 2019)




Flooding in June 2011

Integration of agriculture and flood control: Use of paddy fields as a dam (paddy field dam)



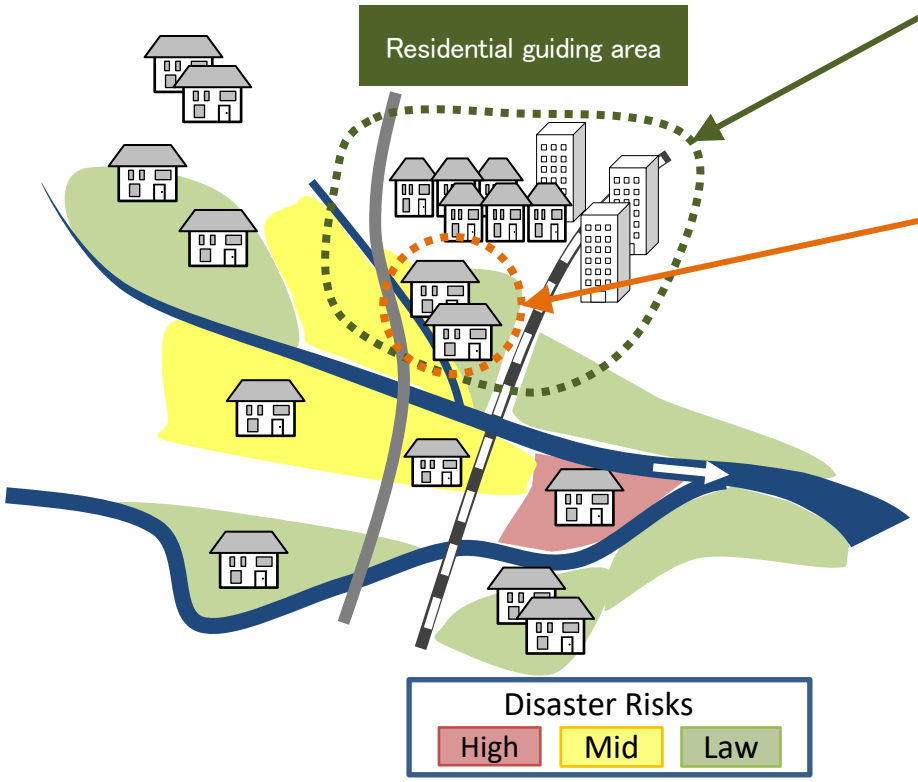
Paddy field dam: Insert a board to block a drainageway as a weir and temporarily store water in a paddy field. (Materials by Niigata Prefecture)

Smart paddy field dam: Remote controllable electric weir (The Kuma River basin photographed by Nakakita)

City Planning considering disaster risks

○Facilitate emigrating to low-risk residential areas and improving city functions by presenting the risks in a proper way, especially for areas with high frequency of inundation above floor level

○Enhancing improvements to building structures etc. by showing their disaster risks, especially for areas with severe threat to human life due to deep inundation.



○Setting of residential guiding area

・Guiding the residential area and city function to the lower risk area（collaboration with relevant departments）

○ Preparation of facilities（Acceleration of preliminary disaster prevention ）

・In areas where residence should be induced, etc., we will focus on the development of rivers and sewers, construction of levees, development of rainwater storage and infiltration facilities, etc.

○ Improvements to houses

・In areas where disaster risk is high, the structure of buildings is devised (in cooperation with related departments), and designated as disaster danger zones, etc. as necessary

・ Development of hills, emergency transport routes, etc. using levees etc. to support residents' evacuation and emergency restoration

○ Presentation of disaster risks etc.

・Presention of regional disaster risks in consideration of various types of disasters, occurrence probabilities, etc.

・Provision of detailed disaster prevention information

（MLIT、2109）

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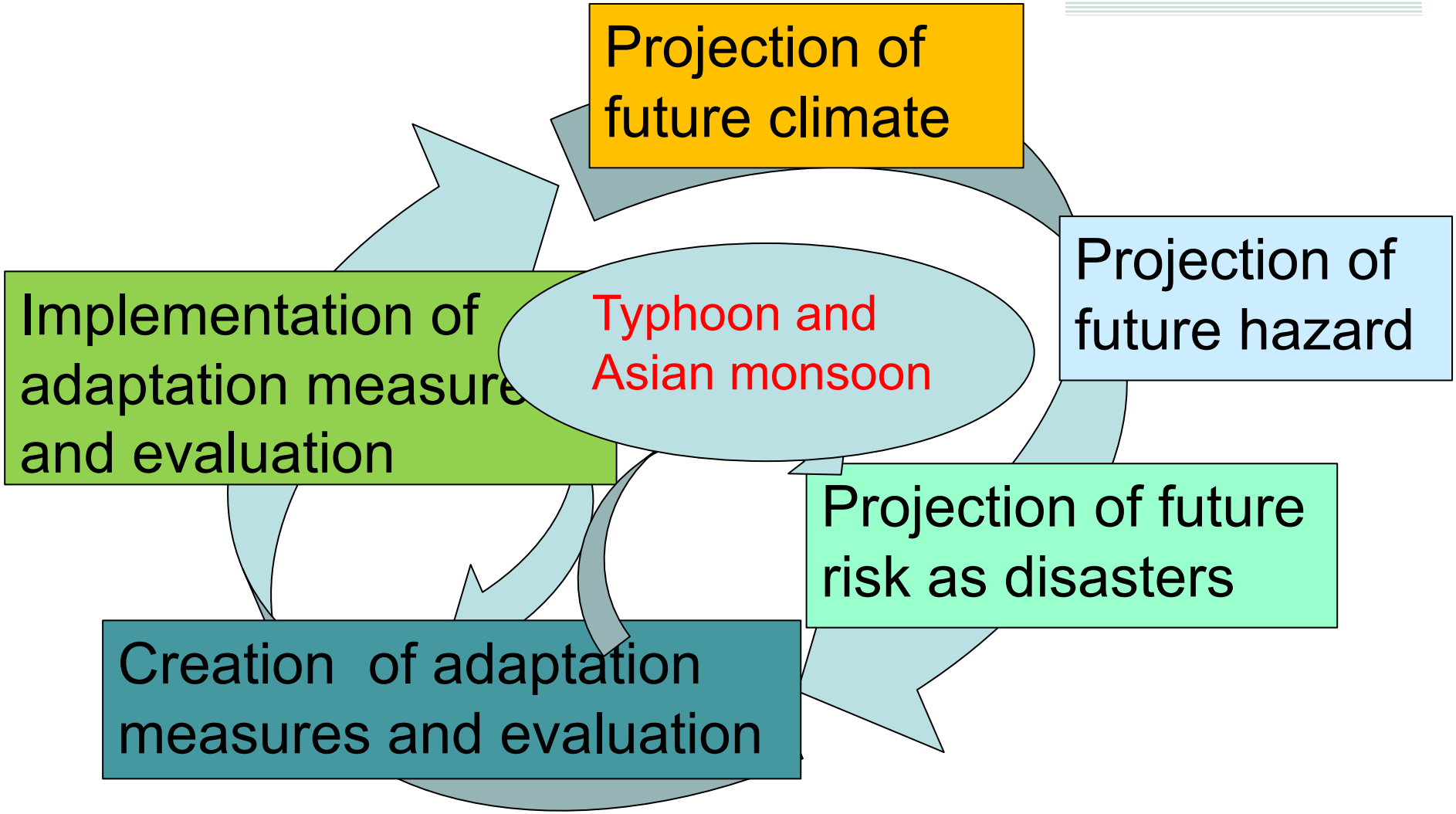
Future Projection and adaptation reseraches



Global Warming Impact Prediction and Adaptatio

KAKUSHIN

- Extreme events concerning hazards and water resources in Japan are predicted to be more severe according to the hourly output from climate models
- If we delay adaptation because of uncertainty, future adaptation could become difficult or even impossible.
  - Start now! => No-regret adaptation
- Promote climate adaptation step-by-step through bottom-up practices
  - It is important to recognize this as the first thing
  - Undergoing actions are also important adaptation measures
  - We should excavate vulnerability nobody has noticed yet (importance of disaster investigation)
- Proceed based on scientific future forecast (planning of main infrastructure)
  - Planning step-by-step adaptation. Adaptation without reworking.
- Adaptation considering the worst-case scenario such as crisis management
  - Important to consider how to incorporate worst-case scenario under climate change.
- Adaptation utilizing historical flood control measures
- Adaptation through regional/city/town planning

(Nakakita、2010, 2019)

Conclusions

- In recent years, climate related disasters have become more severe. Immediate implementation of adaptation measures is warranted.
- While scientific research is underway for the better assessment of climate change and its impact, which could be used for formulation of adaptation measures, we must pay attention to the change in and speed of climate risk.
- 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, at national level, it is also necessary to enhance cooperation among relevant government agencies and promote collaboration with both academic and DRR communities.
- Japanese government have decided razing water-protection standard and the transition to "River Basin Disaster Resilience and Sustainability by All"

Thanks for your attention

All members in SOUSEI C & D for impact assessment and adaptation strategy

Photo: Tower island, Uji River, Kyoto