Climate Change and Extreme Events

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Meteorological Research Institute,

Japan Meteorological Agency

and

many collaborative researchers

World Water Day 2020, March 22: Water and climate change

Photo by Nguyễn Thanh Quang)

(https://www.worldwaterday.org/)

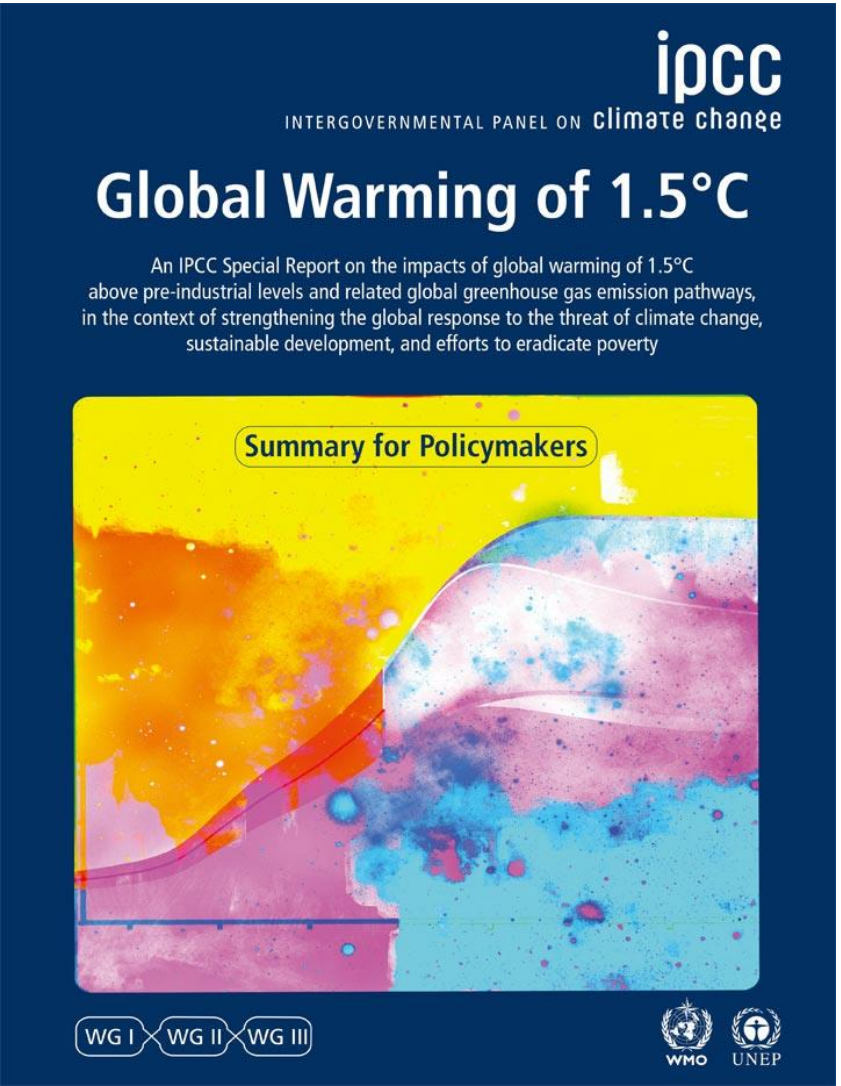
(Photo byUSAID)

Scientific contents of my today's talk

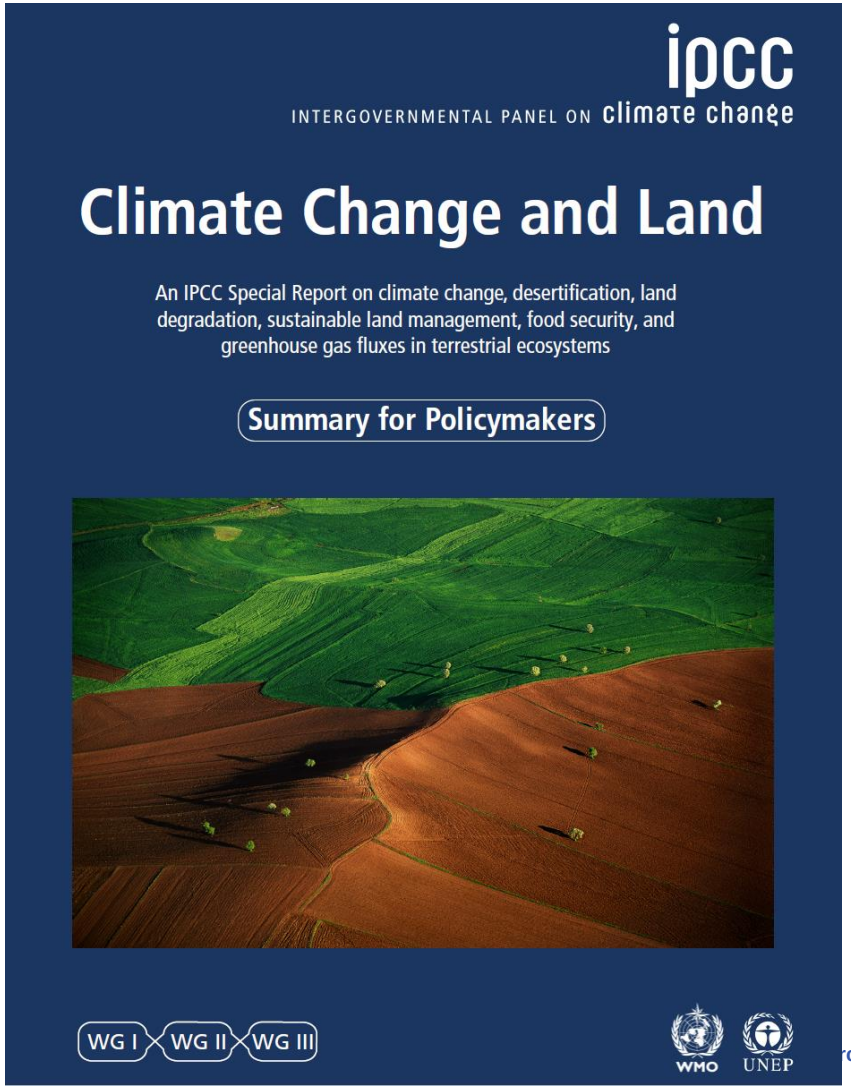
1. Future climates and extremes:
   - Recent assessments on climate changes and impacts
2. Emerging climate extremes:
   - Attribution of extremes recently occurred
     - Event-based approach
     - Probabilistic approach
3. Latest information in CMIP6 climate model community
   - Uncertainty in future climate projections

IPCC Special Reports between AR5 and AR6

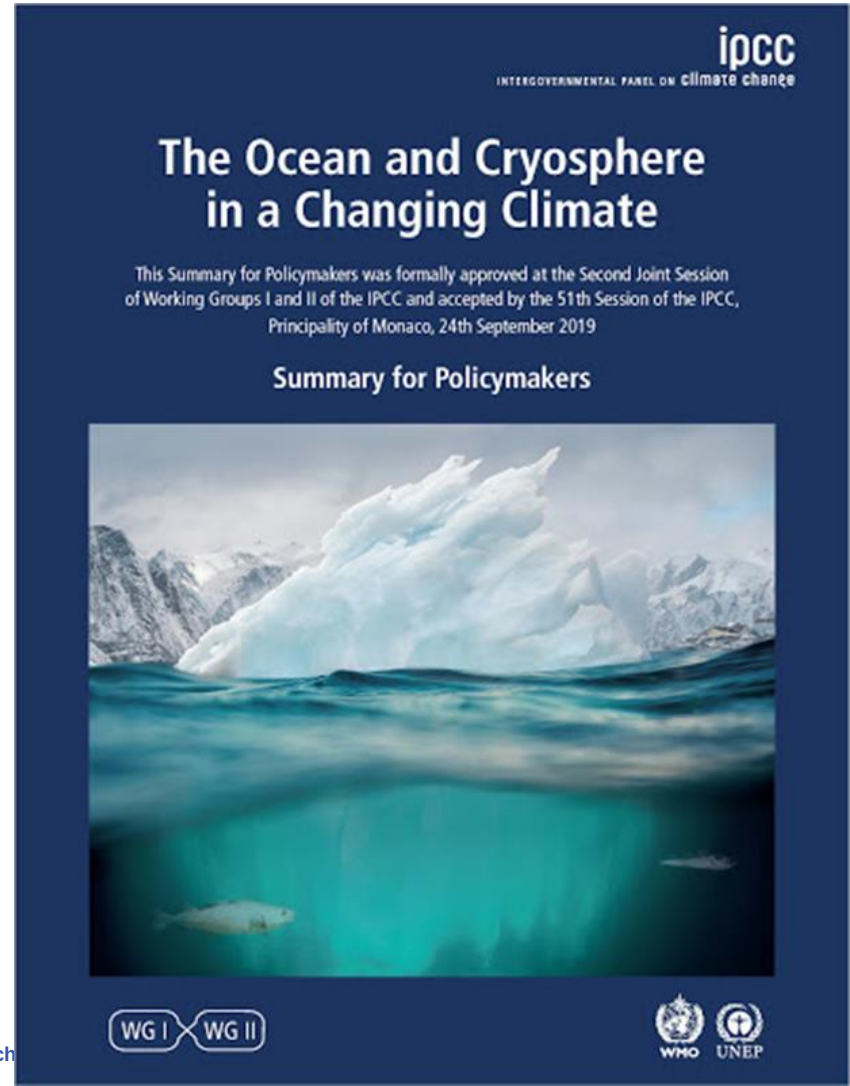
October 6, 2018



August 7, 2019



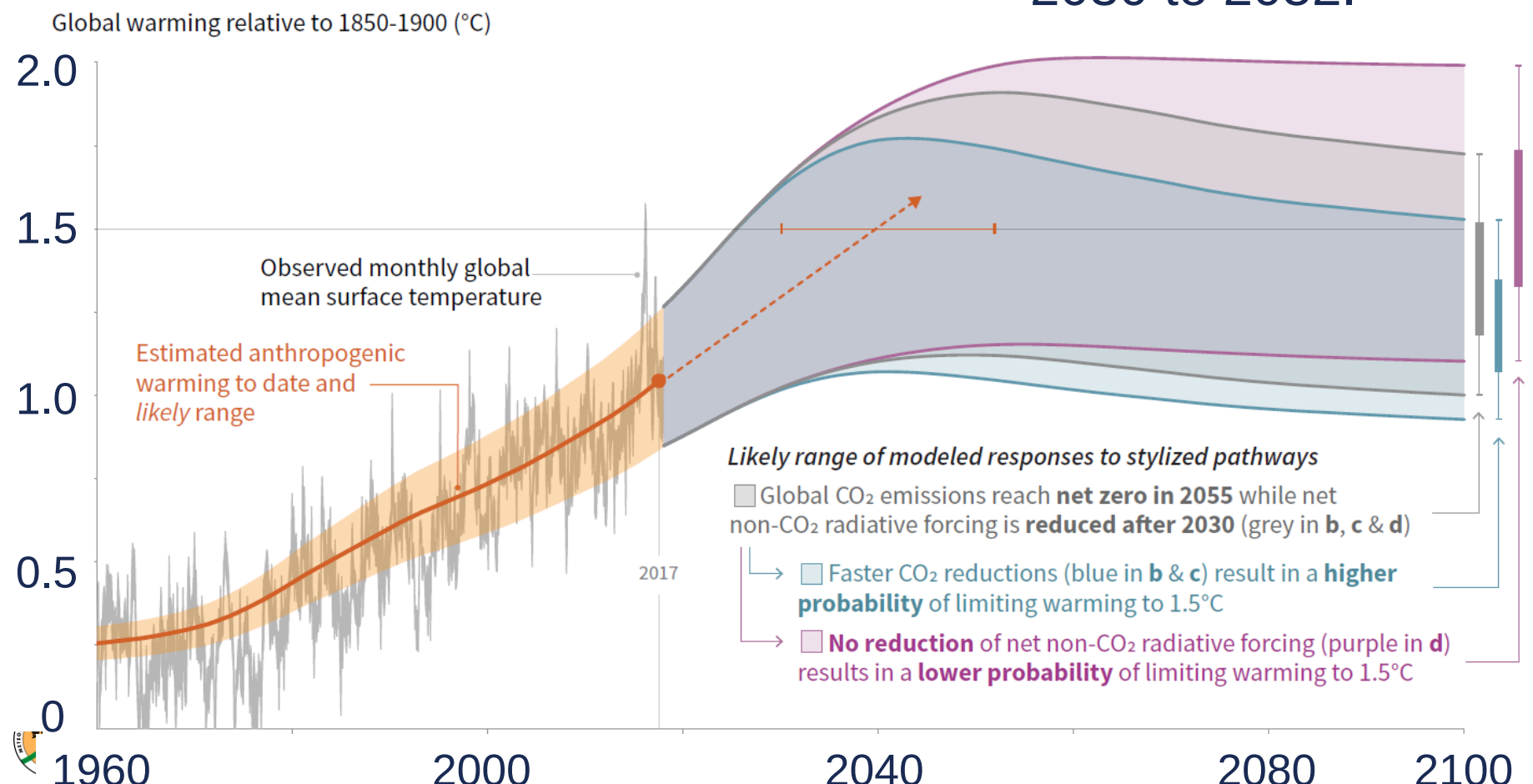
September 25, 2019



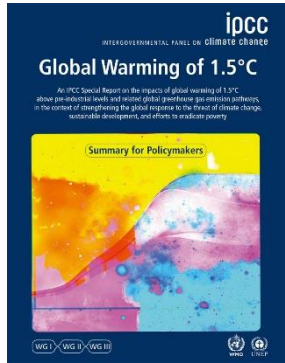
IPCC Special Report on Global Warming of 1.5℃

Cumulative emissions of CO_2 and future non-CO_2 radiative forcing determine the probability of limiting warming to 1.5°C

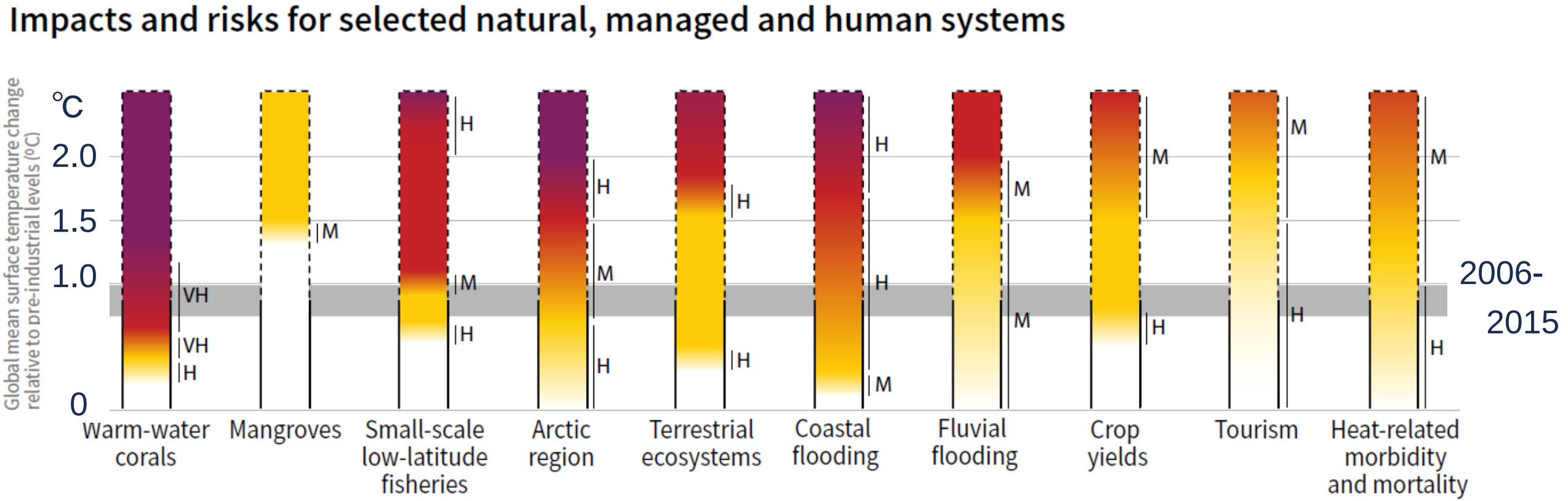
a) Observed global temperature change and modeled responses to stylized anthropogenic emission and forcing pathways



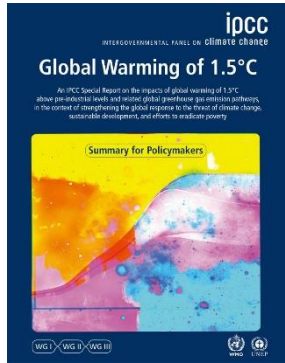
- The current global warming is about 1.0℃
- Global warming will likely reach 1.5℃ around 2030 to 2052.
- 1.5℃ target will be possible if we success the net zero emission in 2055.



IPCC Special Report on Global Warming of 1.5℃



- Each sector has different level of impacts
- Robust difference in impacts between 1.5℃ and 2.0℃



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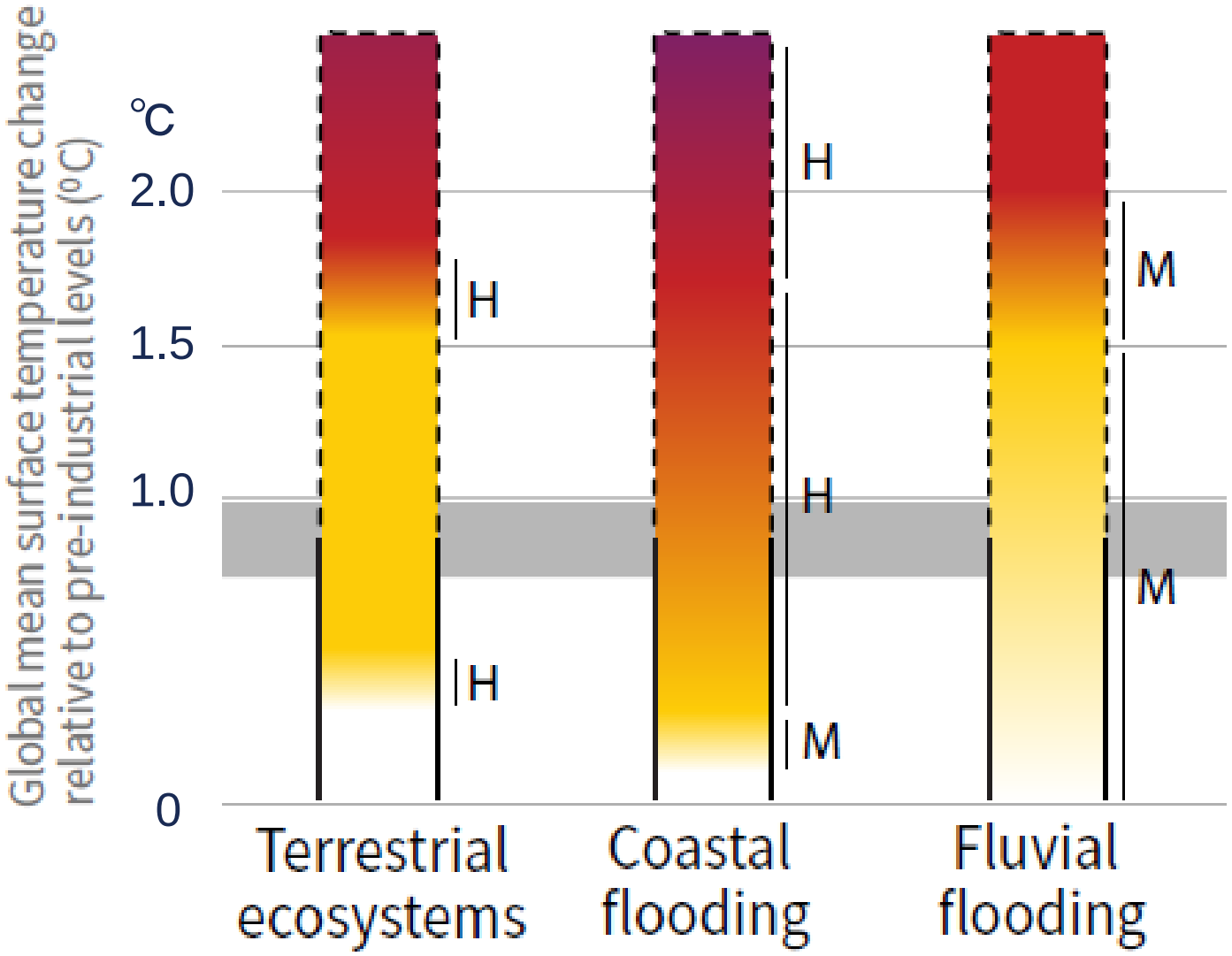

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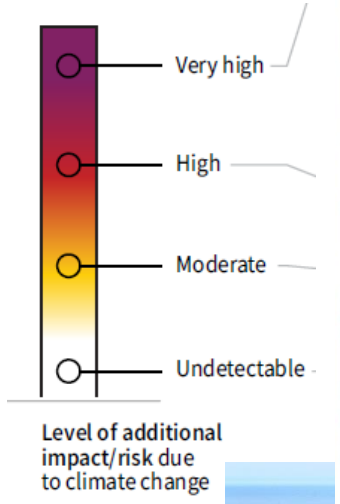
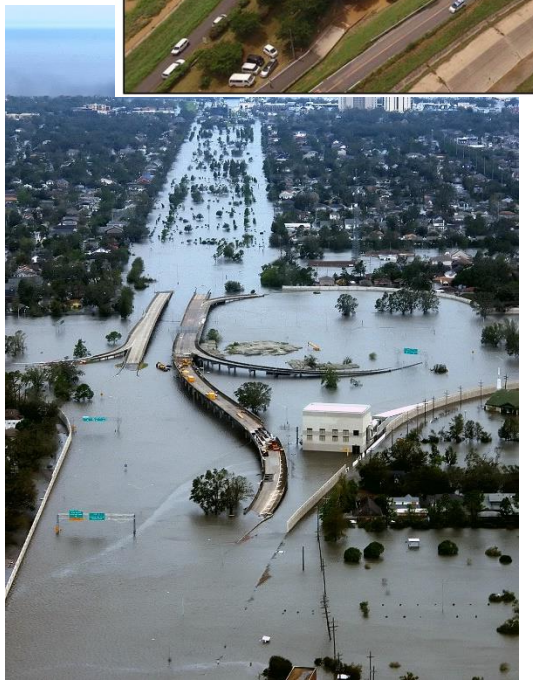
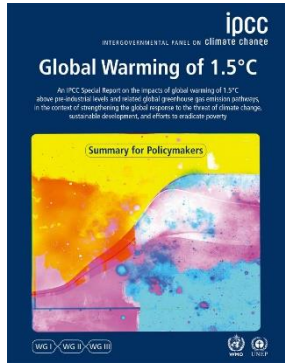


2006-2015

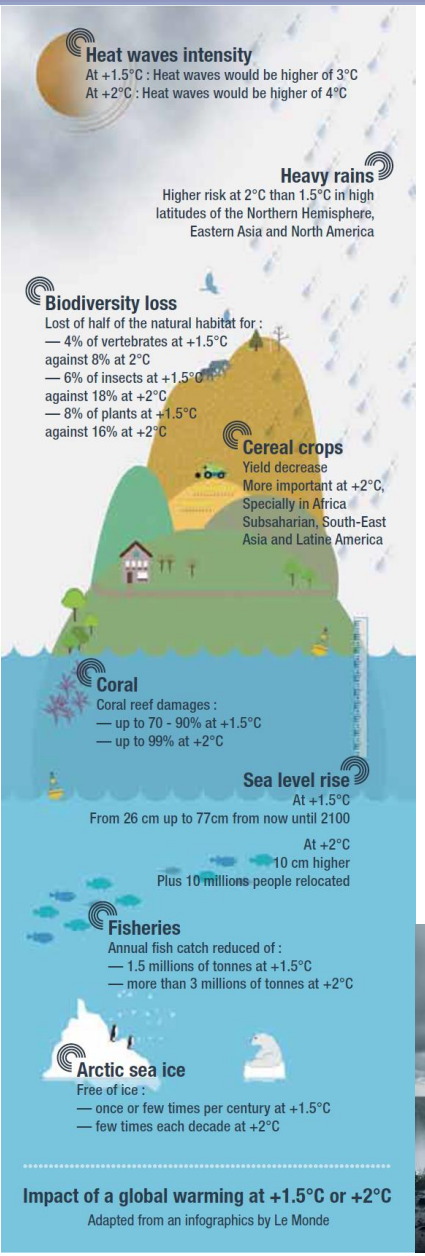
(Ministry of Land, Infrastructure, Transport and Tourism, Japan)



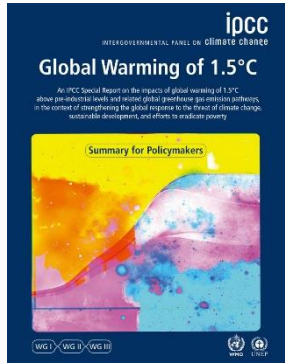
(USGS/Wikipedia, 2005, Katrinam)



IPCC Special Report on Global Warming of 1.5℃

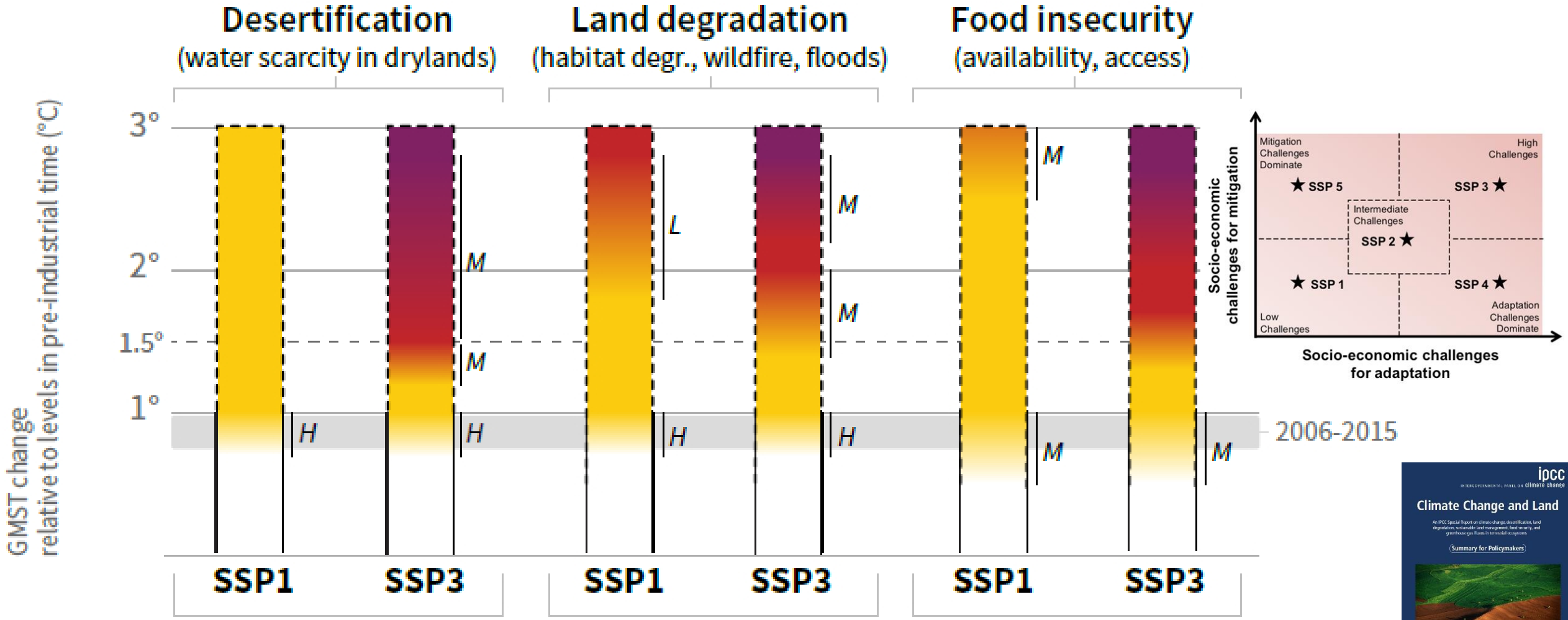


- Heavy rainfalls:
  - –Higher risk at 2℃ than 1.5℃ in high latitudes of the Northern Hemisphere, Eastern Asia, and North America
- Heat waves intensity:
  - –At +1.5℃: Heat waves would be higher of 3℃
  - –At +2℃: Heat waves would be higher of 4℃
- Sea level rise:
  - –At +1.5℃: 26 cm to 77 cm from now until 2100
  - –At +2℃: 10 cm higher that that of +1.5 ℃ plus 10 millions people relocated



IPCC Special Report on Climate Change and Land

B. Different socioeconomic pathways affect levels of climate related risks



Sustainable vs business as usual

Scientific contents of my today's talk

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2. **Emerging climate extremes:**
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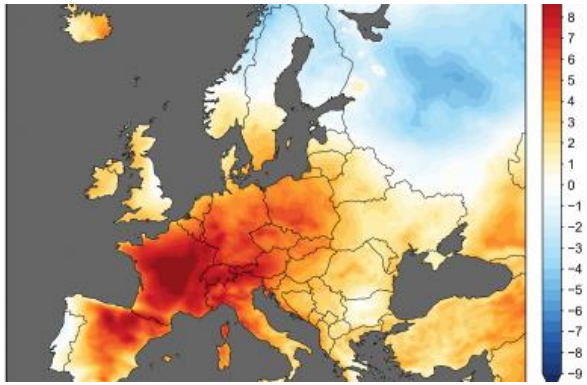
2019 July



(WMO webpages)

Attribution of climate extremes

A climate extreme is due to an attribution or just crazy weather by chance?

El Nino/La Nina causes such an extreme event!

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Attribution of climate extremes

A climate extreme is due to an attribution or just crazy weather by chance?

Global warming causes such an extreme event!

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Attribution of climate extremes

A climate extreme is due to an attribution or just crazy weather by chance?

From a scientific view point, we cannot exactly say…

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Approach to attributing global warming influences

- **Event-based Quantitative Approach**

  Analysis of differences in specific event simulations under between global warming and non-global warming conditions

  e.g. storyline approach **[e.g., Kawase et al., 2012; Takayabu et al. 2015]**

  Contribution of global warming can be quantified for a specific event but change in frequency cannot be discussed as climatology.

- **Probabilistic Qualiative Approach**

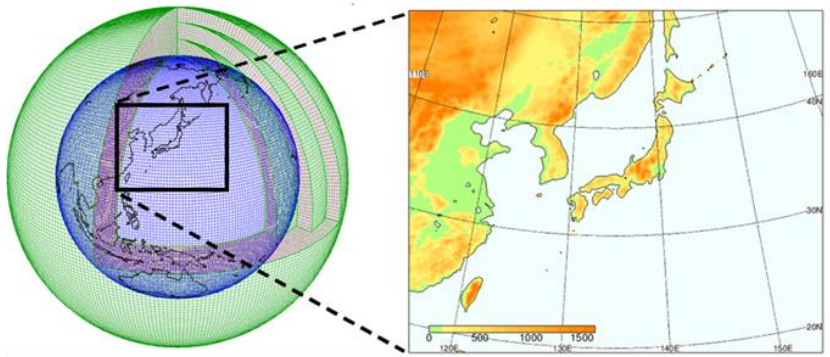
  Analysis of changes in frequency of extremes due to global warming in a huge ensemble simulations with climate models.

  e.g. event attribution **[e.g., Pall et al., 2011; Imada et al., 2014, 2019; Kawase et al. 2019, JGR]**

  Changes in frequency can be discussed as climatology but attribution of global warming cannot be discussed for an actual extreme event

Approach to attributing global warming influences

Probabilistic approach: Large ensemble



60-km AGCM　　20-km NHRCM

d4PDF

A set of experiments

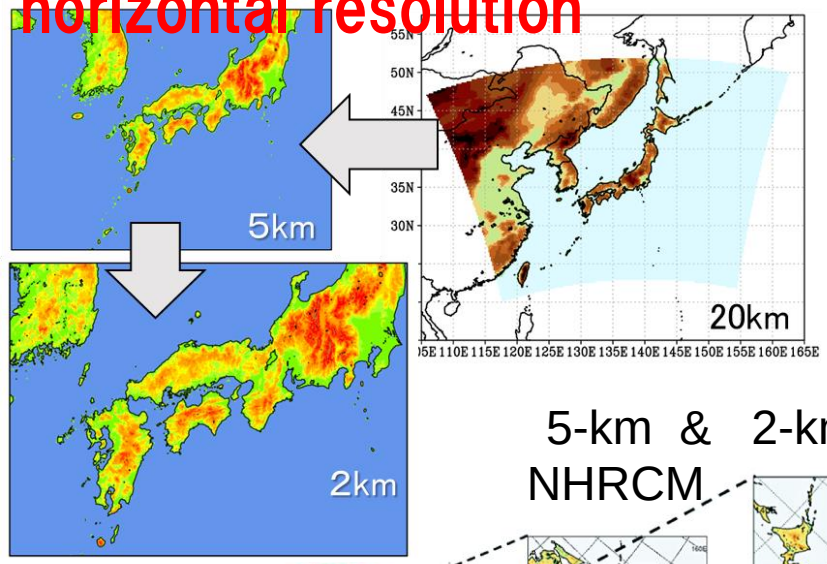
Non-Warming

Present-day

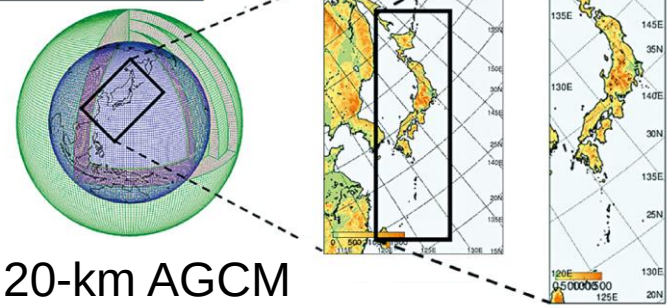
Warming

Complementary

Event-based approach: High horizontal resolution



5-km & 2-km NHRCM



20-km AGCM

- **huge sampling of heavy rainfall**
- **Autonomous simulation of atmospheric phenomena**

- **high performance of present-day climate simulations**
- **representation of dynamical structures of heavy rainfall**

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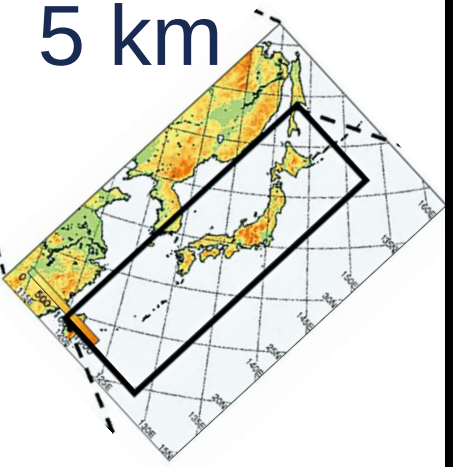
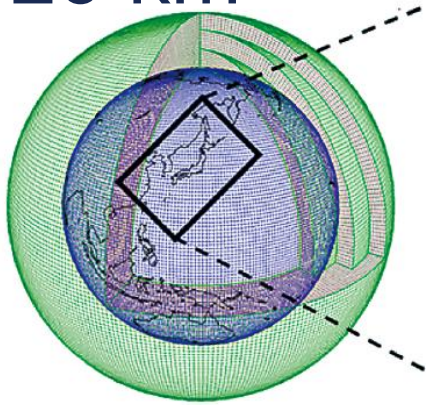
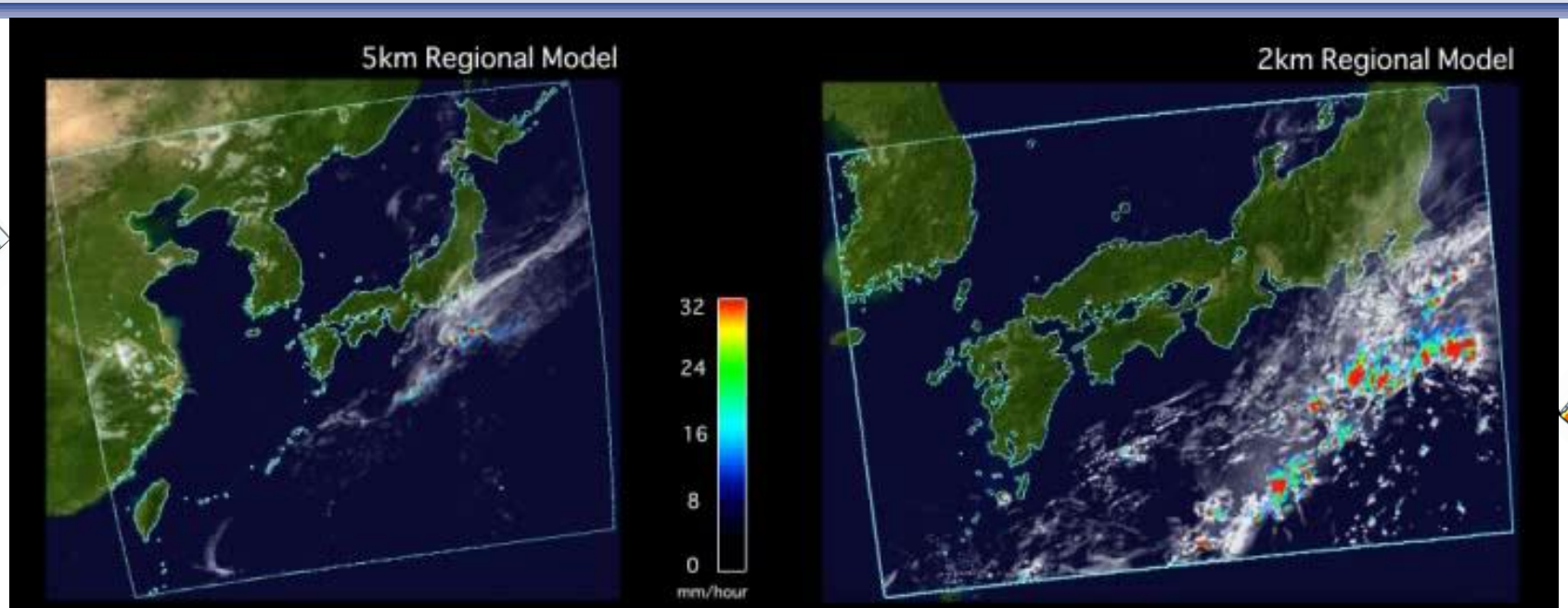
Dynamical downscaling with MRI-AGCM and NHRCM

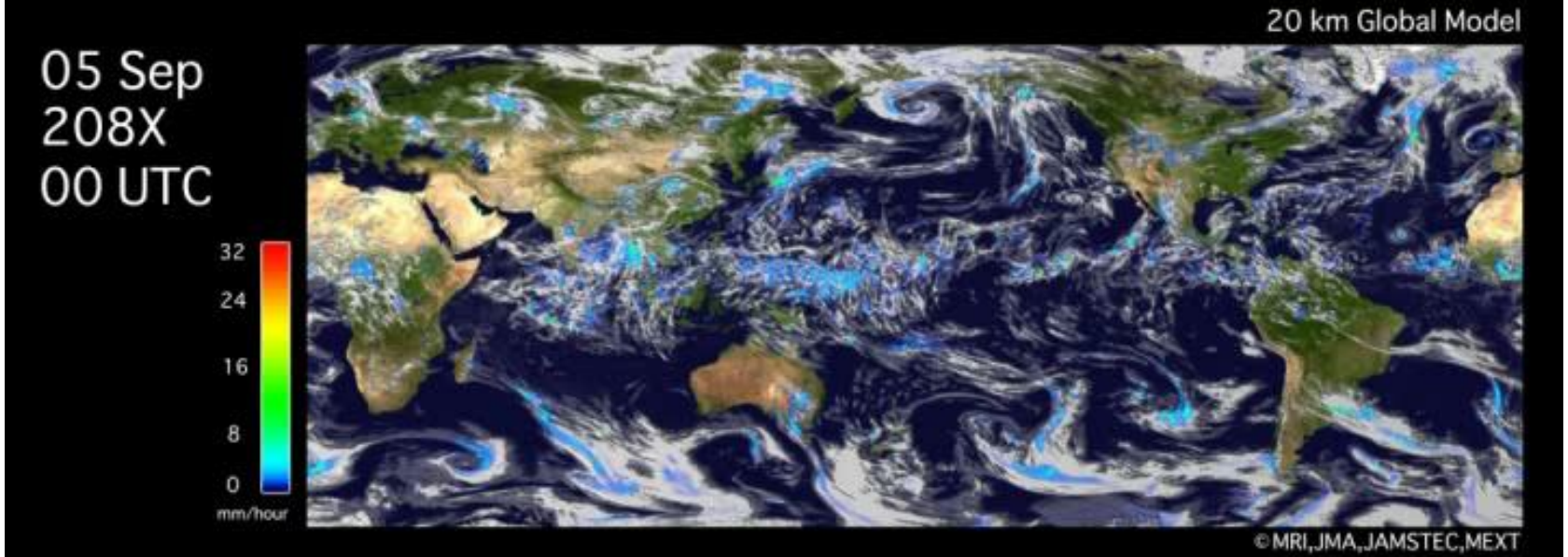
5 km



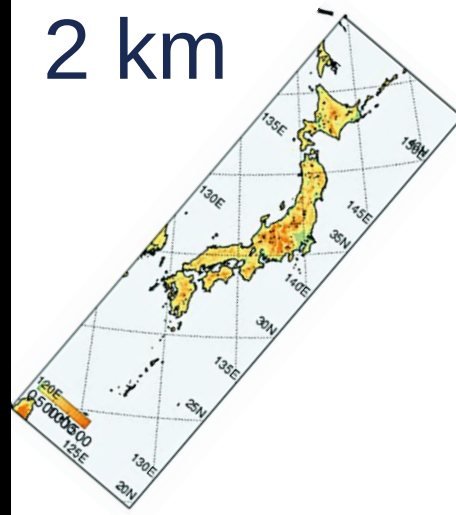
20 km







2 km



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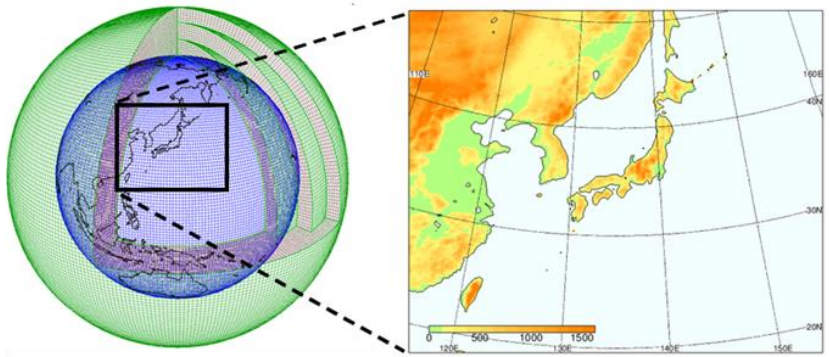
Approach to attributing global warming influences

Probabilistic approach: Large ensemble



60-km AGCM　　20-km NHRCM

d4PDF

A set of experiments

Non-Warming

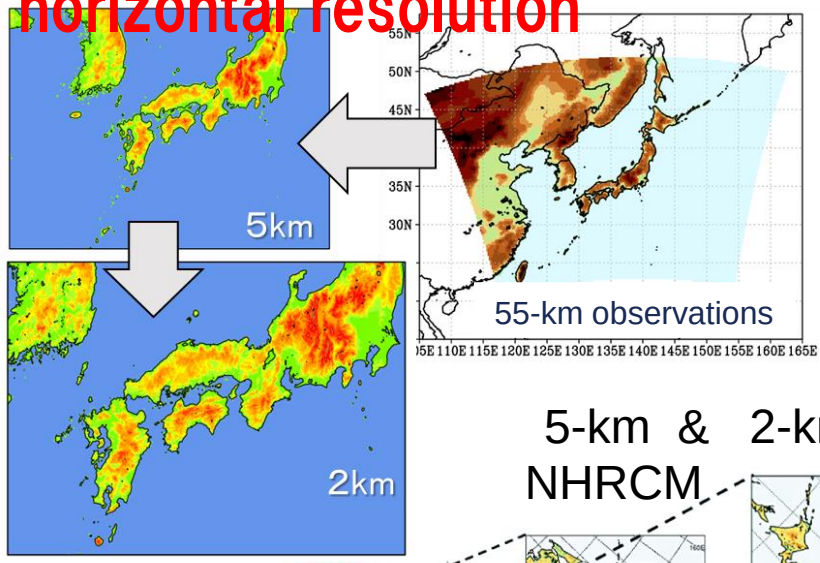
Present-day

Warming

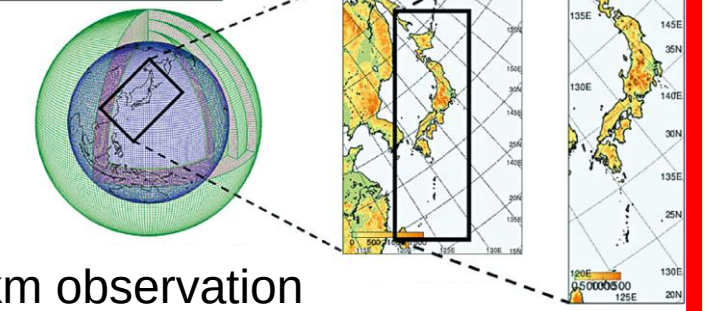
Complementary

- **huge sampling of heavy rainfall**
- **Autonomous simulation of atmospheric phenomena**

Event-based approach: High horizontal resolution



5-km & 2-km NHRCM



55-km observation

- **high performance of present-day climate simulations**
- **representation of dynamical structures of heavy rainfall**

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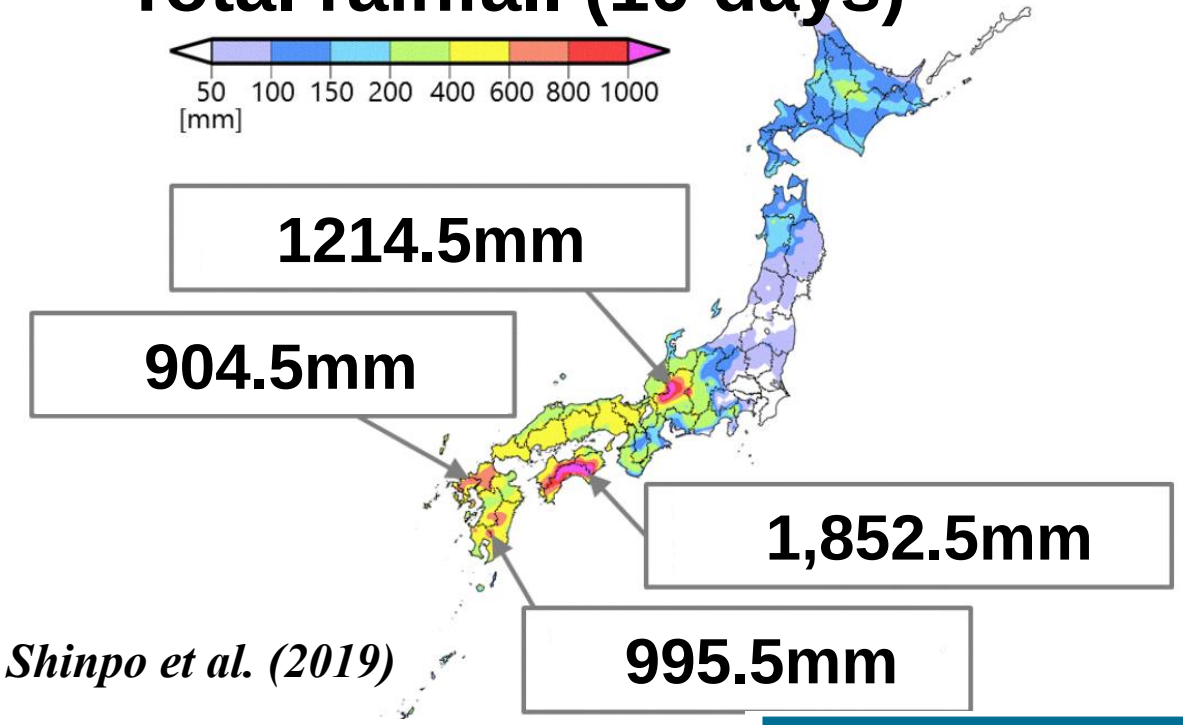
Heavy Rain Event of July 2018 in Japan

(Ministry of Land, Infrastructure, Transport and Tourism, Japan)

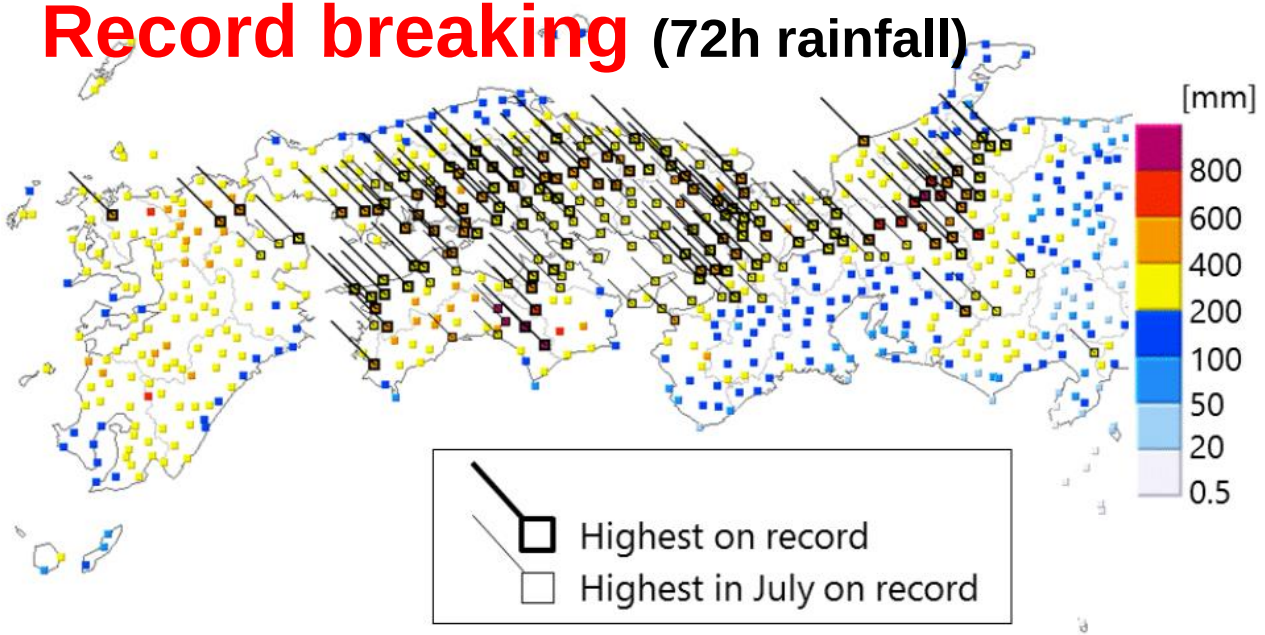
Heavy Rain Event of July 2018 in Japan

Total rainfall (10 days)



Shinpo et al. (2019)

Record breaking (72h rainfall)



	Location	Fatalities (persons)	Completely destroyed (buildings)	Inundations above floor level (houses)	References: Cabinet Office, Government of Japan	Meteorological systems
July 1982	Nagasaki city	299	584	17,909	(2005)	LS+SBF
August 2014	Hiroshima city	76	179	1086	(2015)	LS+SF
September 2015	Kanto and Tohoku	8	80	1925	(2016)	LS+RTC
July 2017	Northern Kyushu	42	325	222	(2018a)	LS+SBF
July 2018	Western Japan and Tokai region	221	6296	8929	(2018b)	LS+SBF

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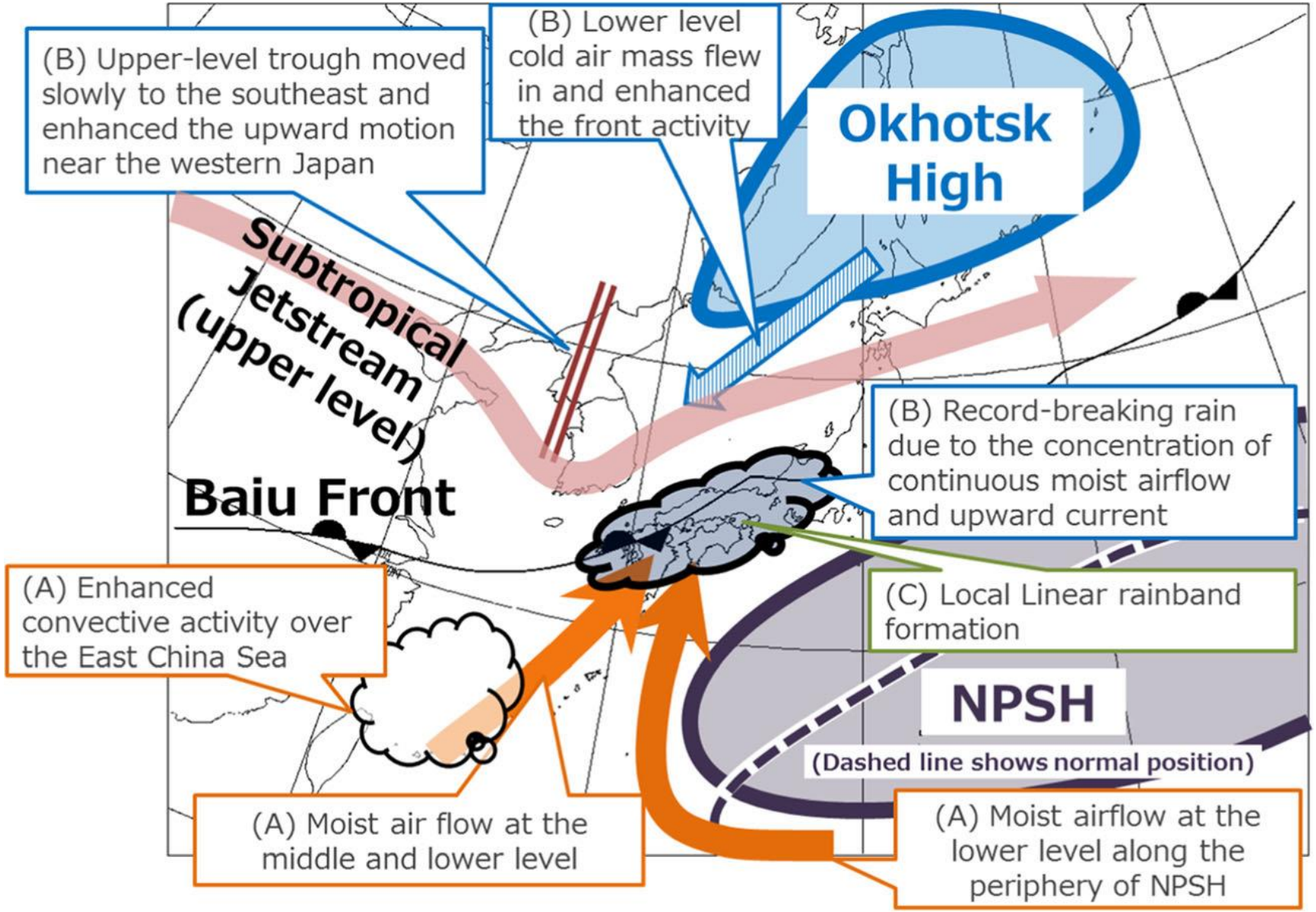
(TCC, JMA, 2018;
Tuguti et al, 2018; Land Slides)

Meteorological overview of heavy rain event of July 2018

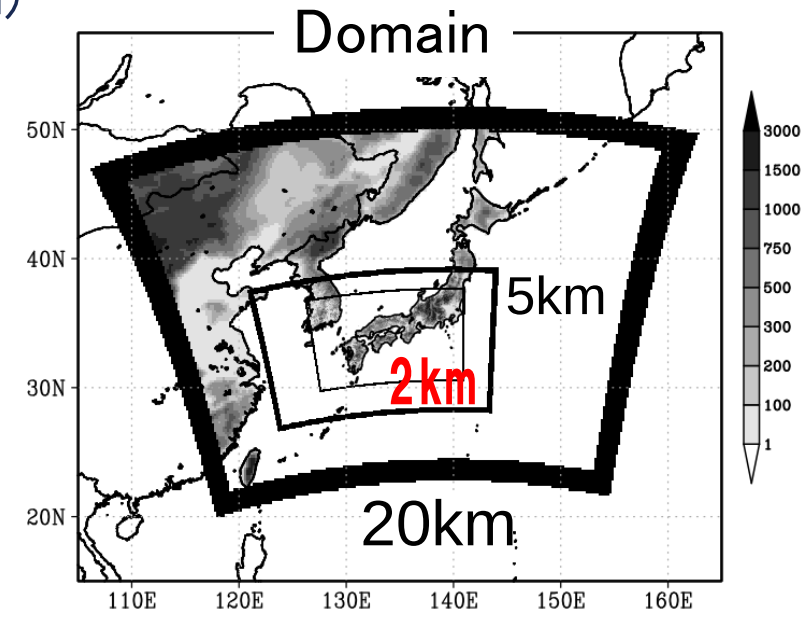


(TCC, JMA, 2018;
Tuguti et al, 2018; Land Slides)

Simulation of the heavy rain event (Current)

- Model : NHRCM: Non-Hydrostatic Regional Climate Model [Sasaki et al. 2008]
- Horizontal resolution : 20km, 5km, 2km (one-way nesting) with vertical 50 layers
- Initial and boundary conditions : Japan 55-year Reanalysis (JRA-55)
- Sea surface temperatures : COBE SST with 1° resolution
- Initial time : June 20 (20km), June 22 to 26 (5km), June 27 (2km)

※ 5 ensembles for 5km

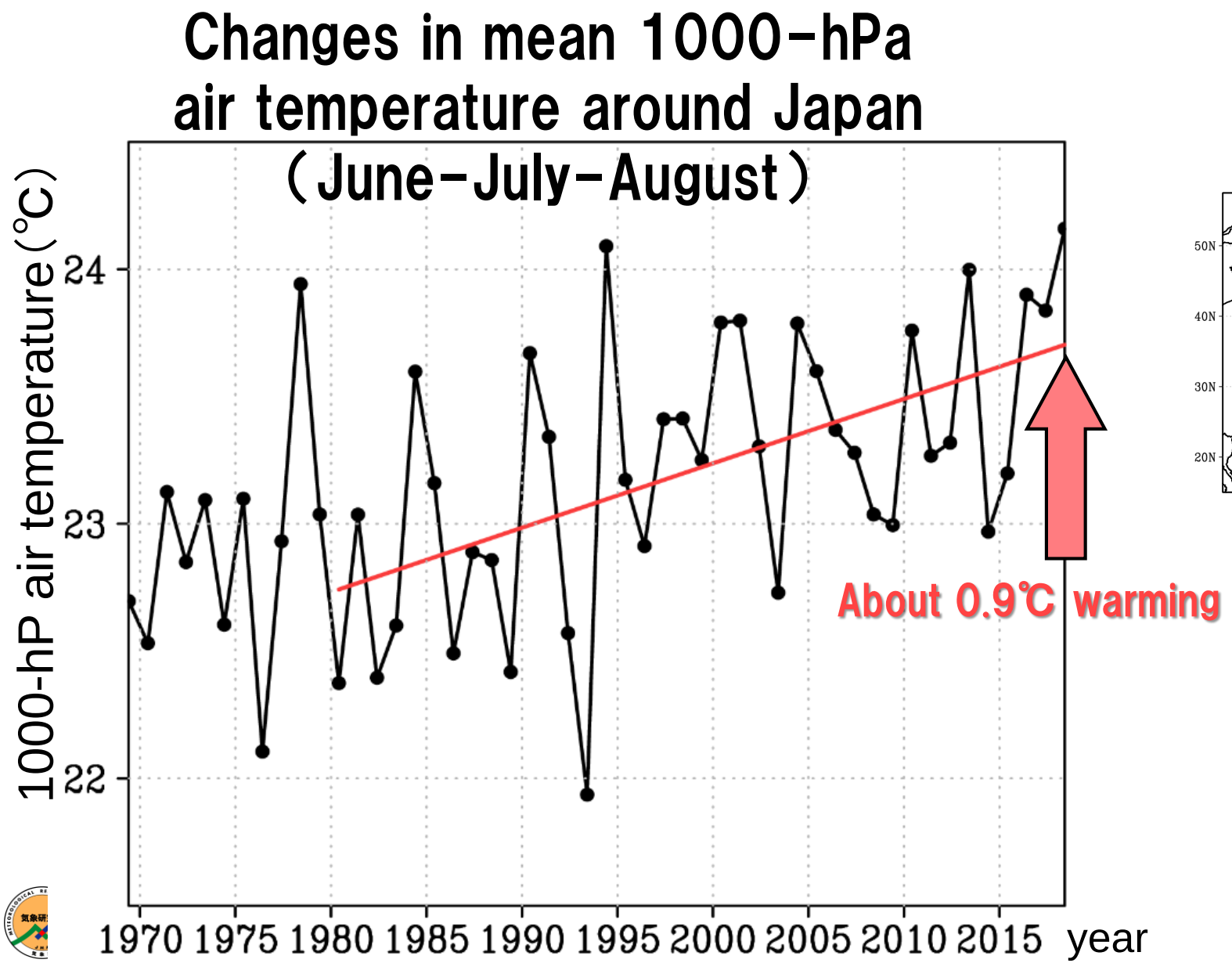


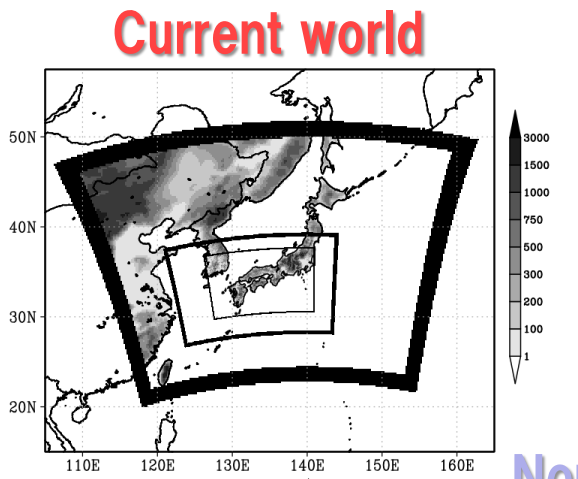
- Physical parameterization in

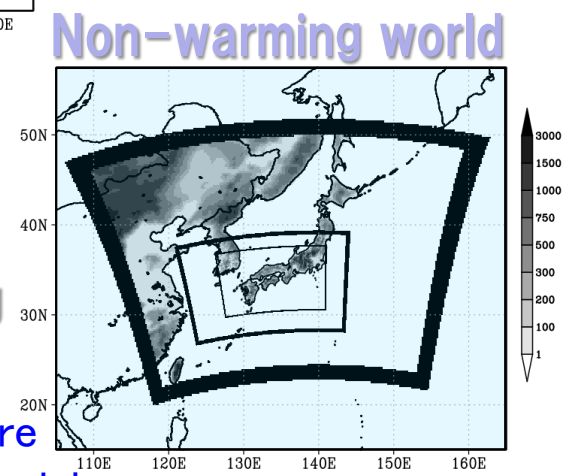
[Convection scheme] Kain and Fritsch (1993) for 20km/5km
[Cloud microphysics] Ikawa et al. (1991) for 20km/5km/2km
[Clear sky radiation] Yabu et al. (2005)
[Cloud radiation] Kitagawa (2000)
[Land surface] Improved MJ-SiB (iSiB) [Hirai and Oh'izumi, 2004]
[Boundary layer] MYNN scheme [Nakanishi and Niino, 2004]

(Kawase et al. 2019, in review, BAMS)

Non-warming experiment (Non-warming)







0.9℃ cooling

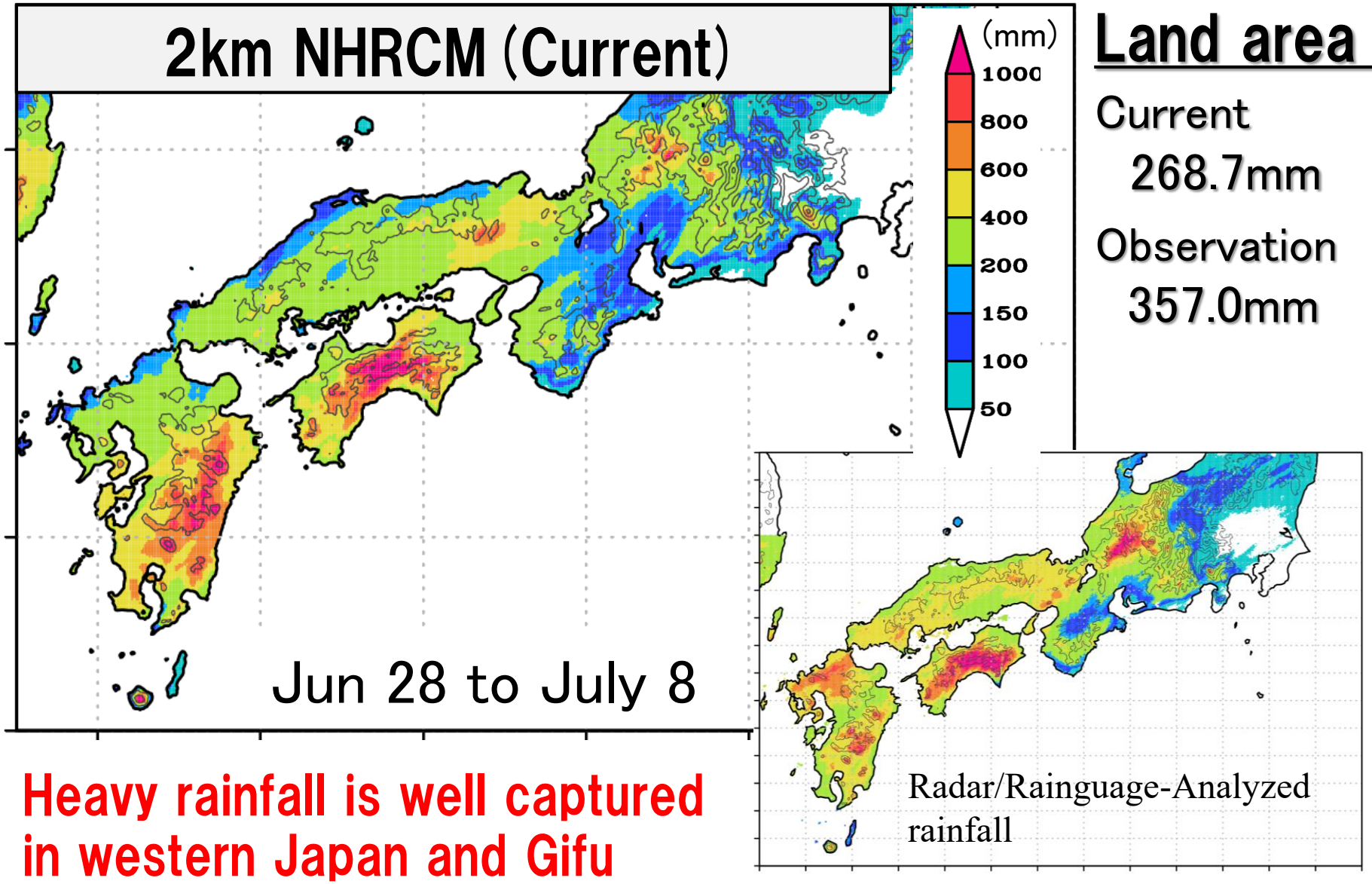
SST

Air temperature

Geopotential height

(Kawase et al. 2019, in review, BAMS)

Representation of heavy rainfall with 2km NHRCM (Current)



Land area mean

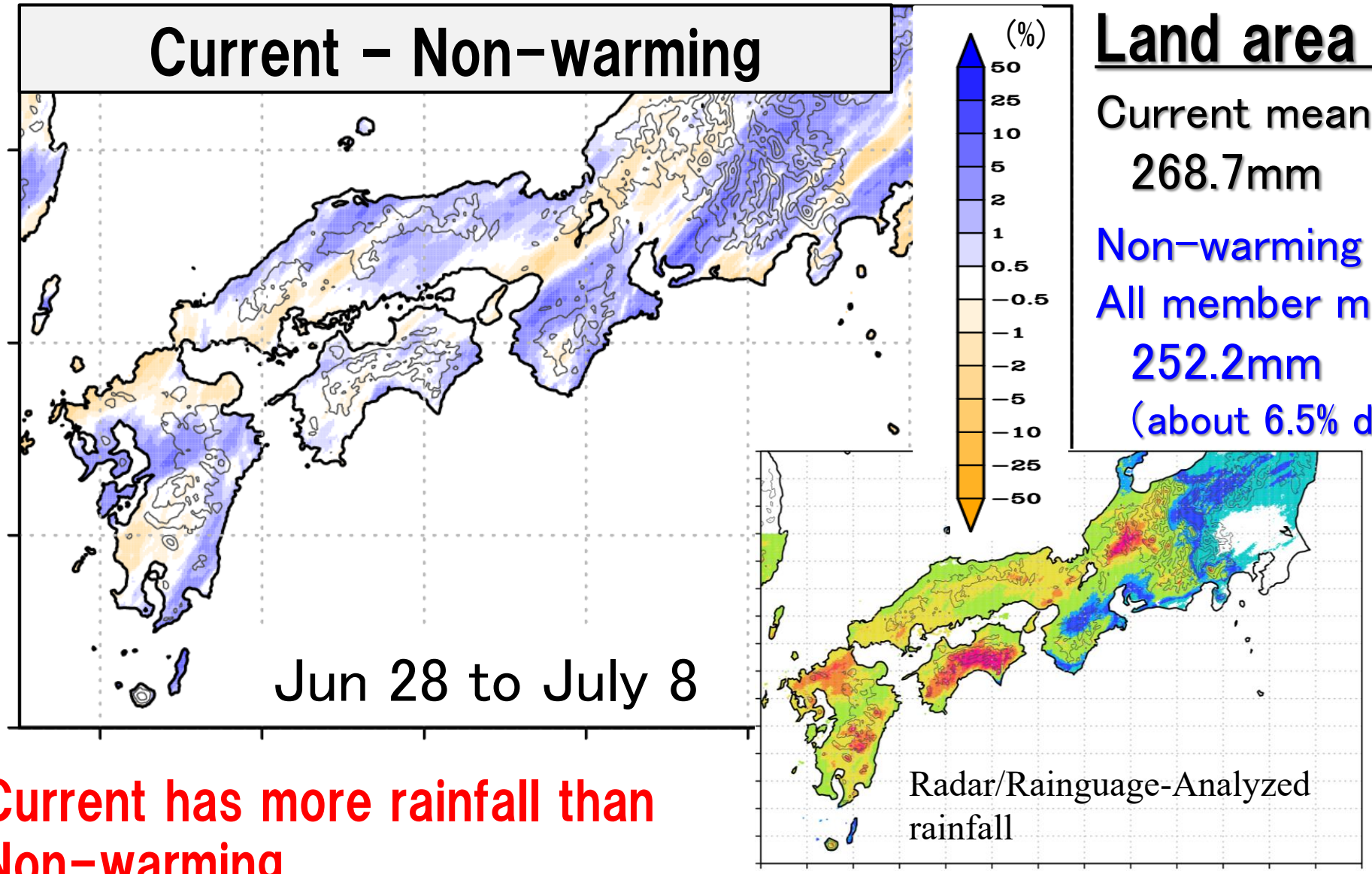
Current
268.7mm

Observation
357.0mm

Heavy rainfall is well captured in western Japan and Gifu

(Kawase et al. 2019, in review, BAMS)

Differences between current and non-warming



Land area mean

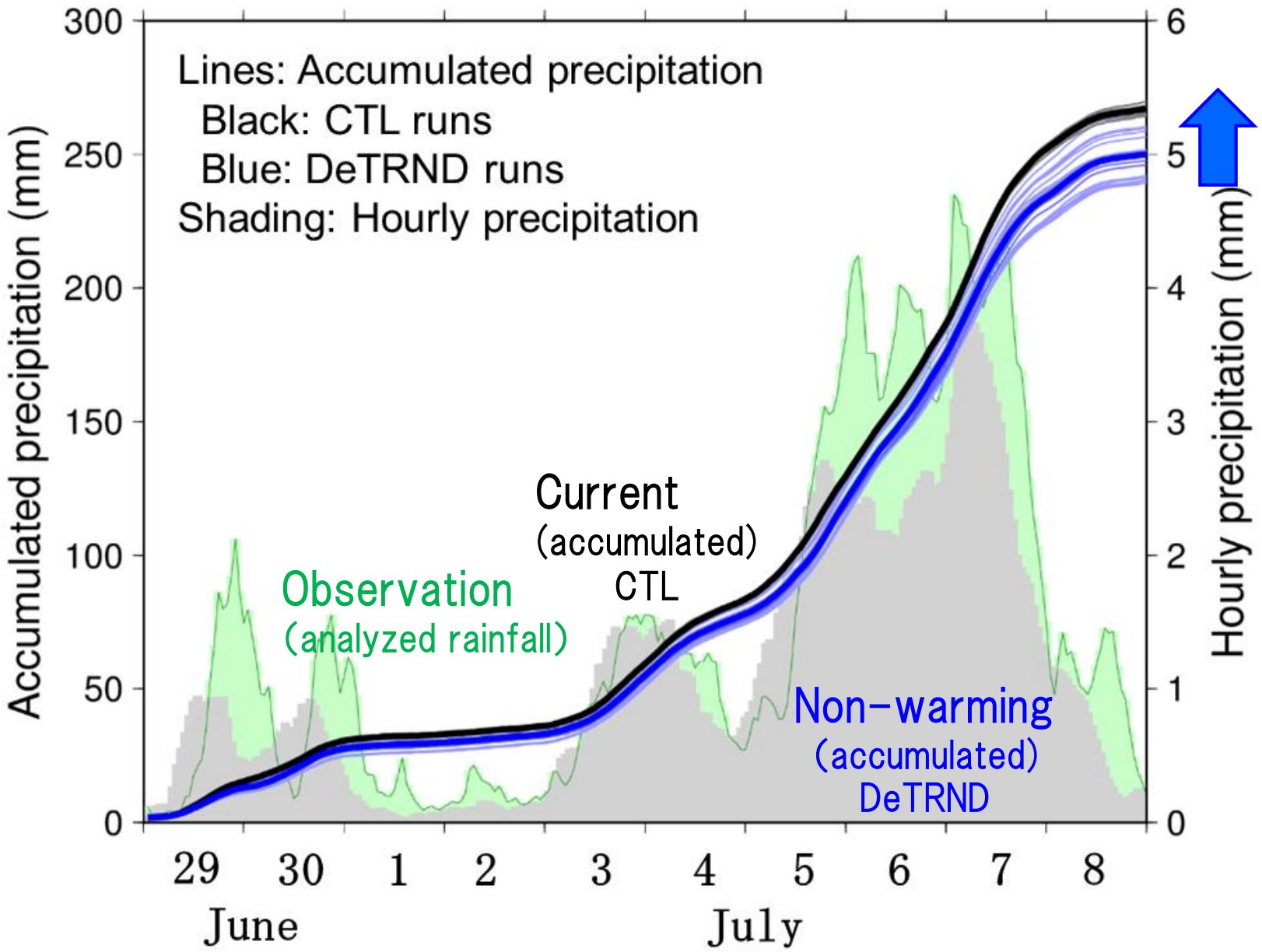
Current mean
268.7mm

Non-warming
All member mean
252.2mm
(about 6.5% difference)

Current has more rainfall than Non-warming

(Kawase et al. 2019, in review, BAMS)

Time series of regional-mean hourly and accumulated rainfall



Influence of recent warming

About 6.5% increase

(+2.7 to +10.7 %)

Thermodynamical effect explains this increase.

(Kawase et al. 2019, in review, BAMS)

Attribution of climate extremes

A climate extreme is due to an attribution or just crazy weather by chance?

From a scientific view point, we can say

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Emerging climate extremes: Heavy rains in Kyusyu

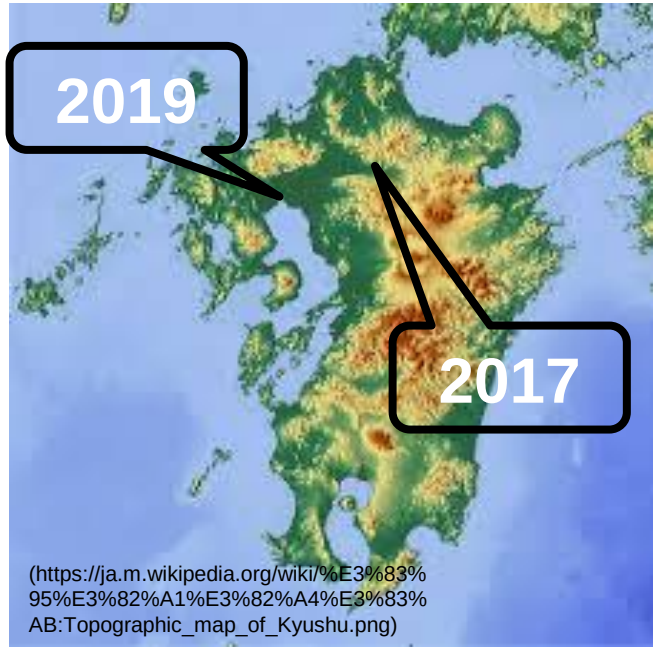
5-Level Warning System

Warning Level	Action to take	Information provided by local government	Wearther alerts issued by JMA
5	People must take measures to protect lives	Disaster information	Early warning infromation
4	...ts must	Evacuation order / instruction	Landslide alert information etc.
3			...rge
2	You should check evacuation behaviors	Advisories	Rain / flood / storm surge advisories etc.
1	You should stay on alert for disasters	Early warning infromation	-

Level of 50-yr return period

(NHK; https://www3.nhk.or.jp/nhkworld/en/news/ataglance/481/)

(Geospatial Information Authority of Japan)

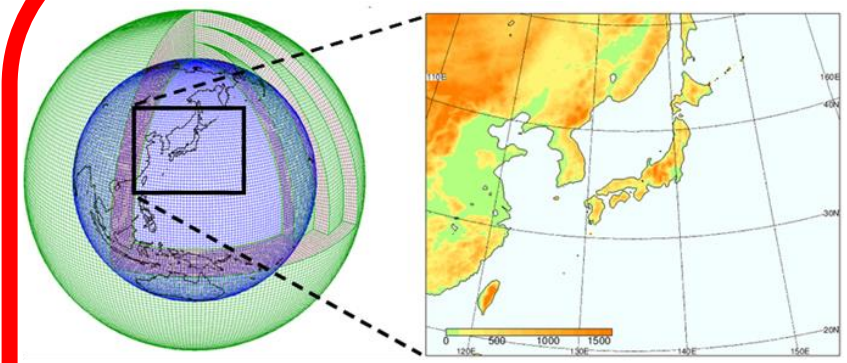


(https://ja.m.wikipedia.org/wiki/%E3%83%95%E3%82%A1%E3%82%A4%E3%83%AB:Topographic_map_of_Kyushu.png)

(NHK; https://www3.nhk.or.jp/nhkworld/en/news/ataglance/483/)

Approach to attributing global warming influences

Probabilistic approach: Large ensemble



60-km AGCM　　20-km NHRCM

d4PDF

A set of experiments

Non-Warming

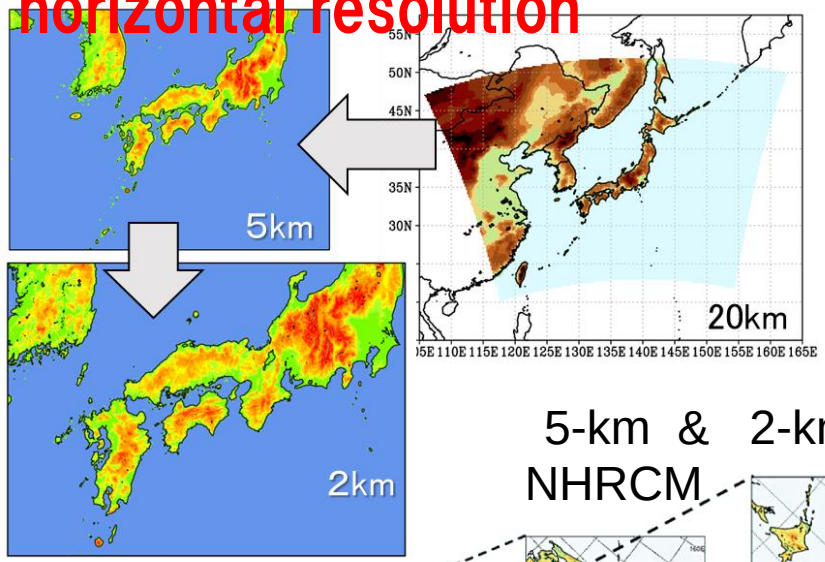
Present-day

Warming

Complementary

- huge sampling of heavy rainfall
- Autonomous simulation of atmospheric phenomena

Event-based approach: High horizontal resolution



5-km & 2-km NHRCM

20-km AGCM

- high performance of present-day climate simulations
- representation of dynamical structures of heavy rainfall

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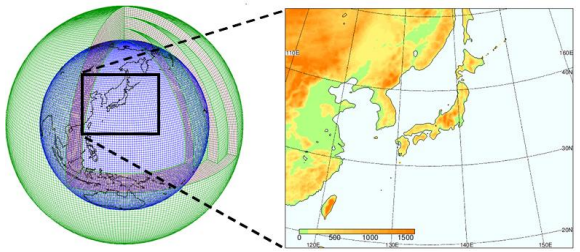
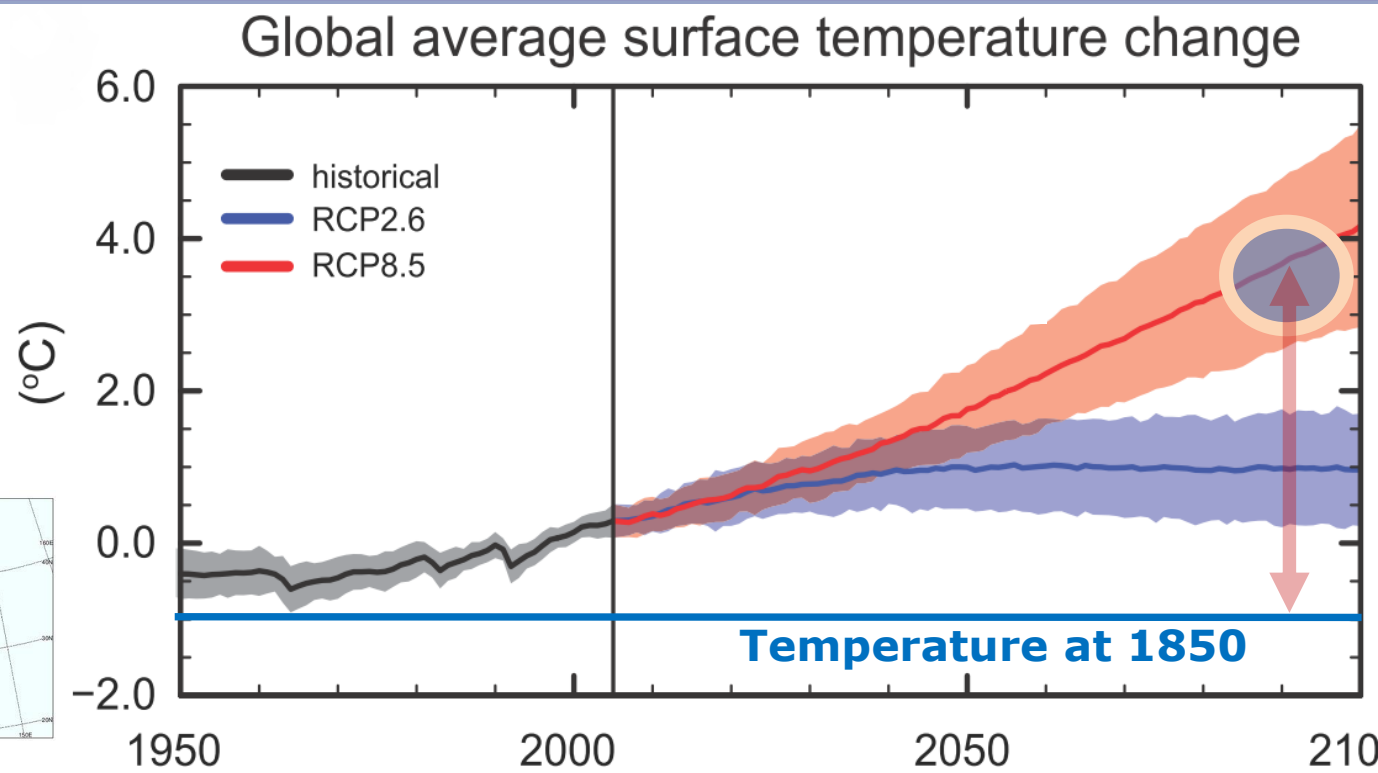
database for Policy Decision making for Future climate change

TOUGOU

Themes A-C collaboration





+4℃

d4PDF

(Mizuta et al. 2016, BAMS)

60km AGCM

100members

90members
(6ΔT×15δT)

20km NHRCM for Japan

50 members

90members

60years

historical 1951 ⟷ 2010

60years

4℃ Global Warming

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database for Policy Decision making for Future climate change

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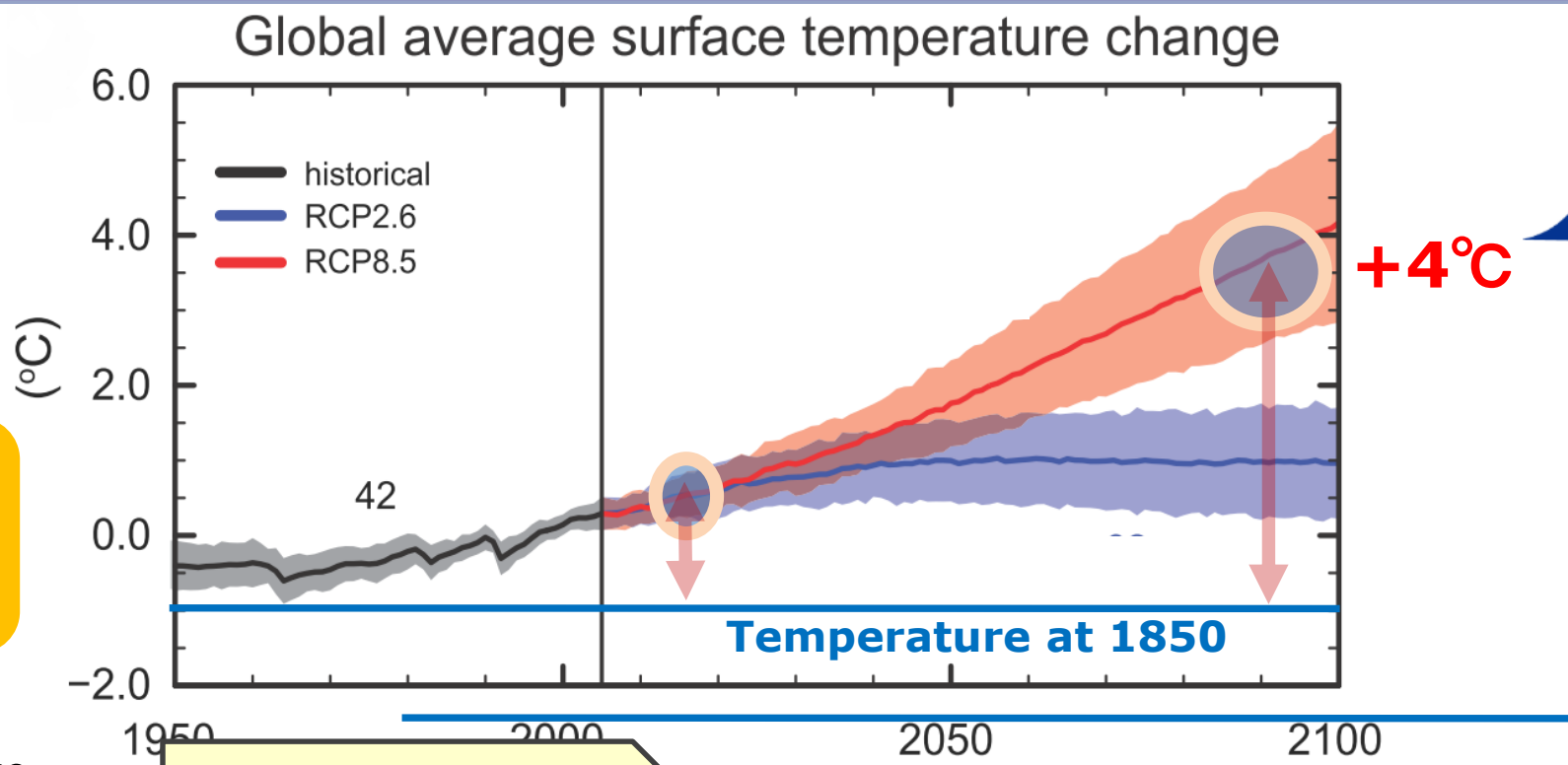
Themes A-C collaboration

Expansion of d4PDF

- 100 members
- non-warming
- to ~ 2018



+4℃

d4PDF

(Mizuta et al. 2016, BAMS; Kawase et al, 2019; JGR)

60km AGCM

100members

Non-warming 100

20km NHRCM for Japan

100members

Non-warming 100

historical
68years

1951 ⟷ 2018

90members
(6ΔT×15δT)

90members

⟷
60years

4℃ Global Warming

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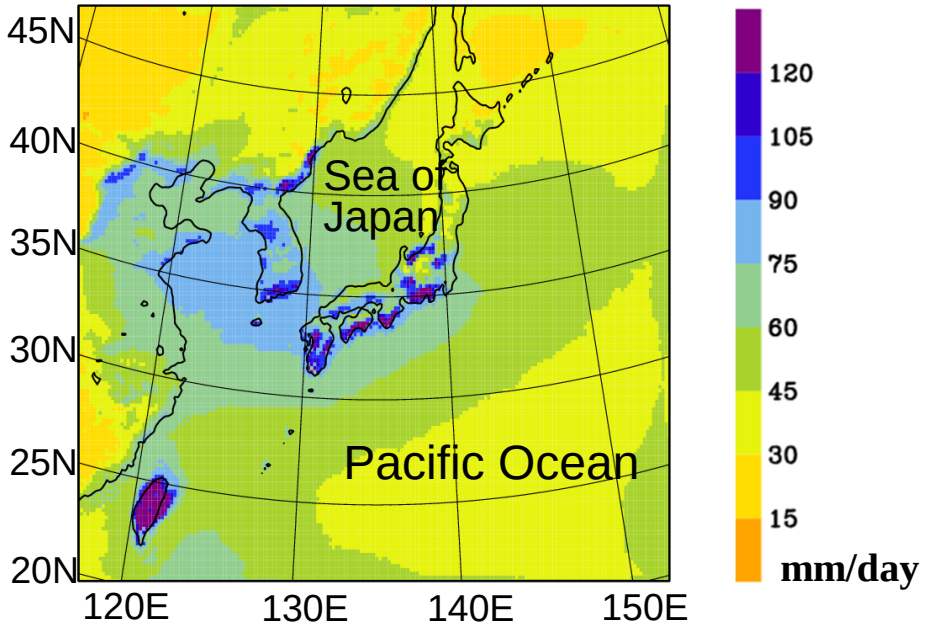
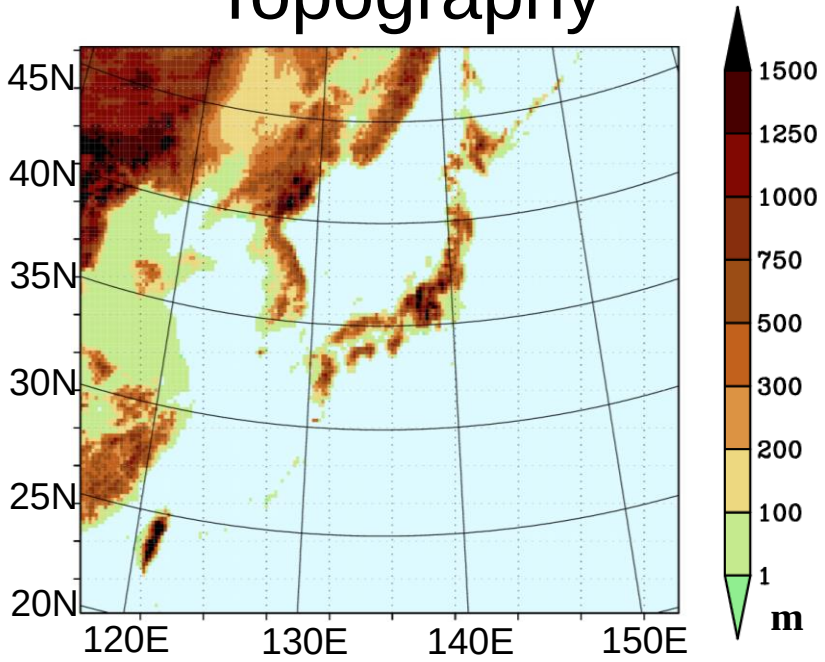
Extreme daily rainfall in July (all members in NHRCM)

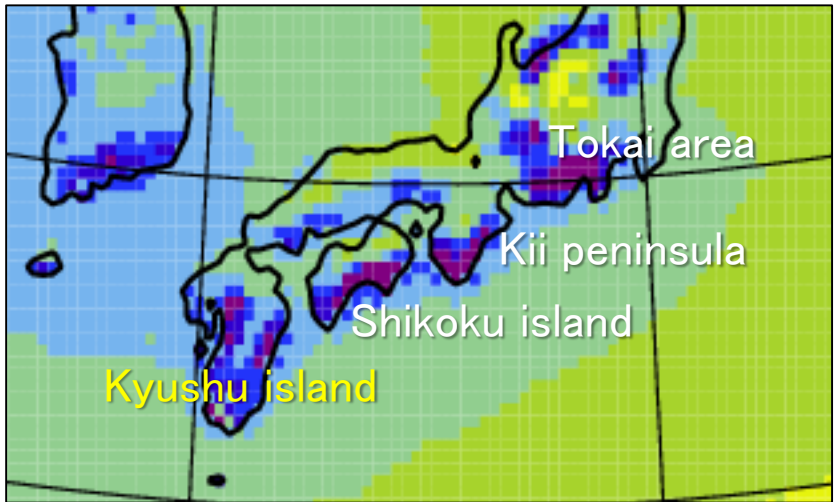
95%ile daily rainfall (Current)

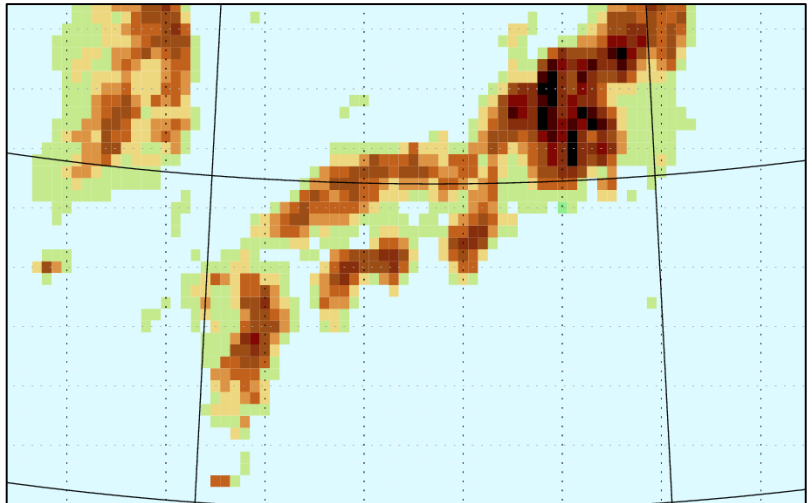


Topography



Current: current simulation,
NonW: non-warming simulation





(Kawase et al, 2019; JGR)

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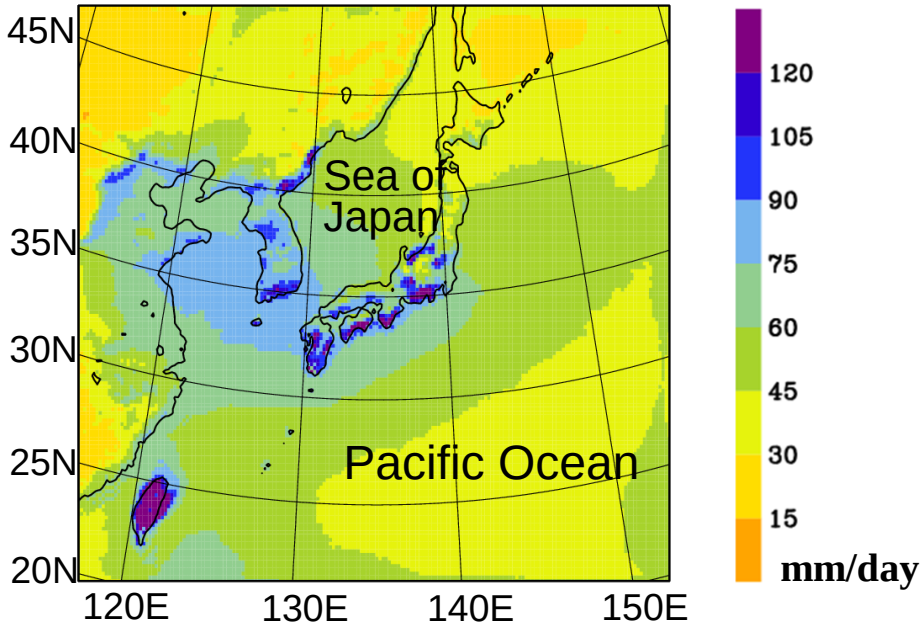
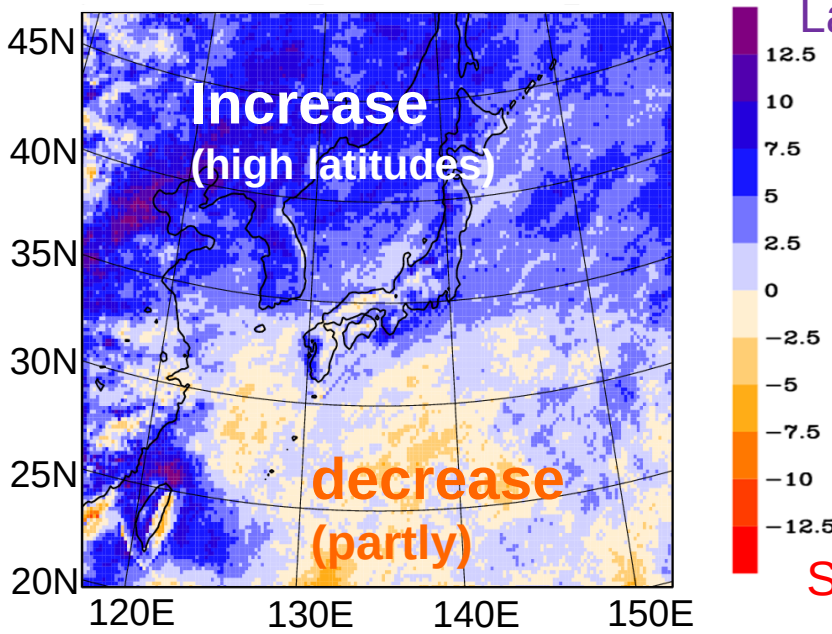
Extreme daily rainfall in July (all members in NHRCM)

95%ile daily rainfall (Current)



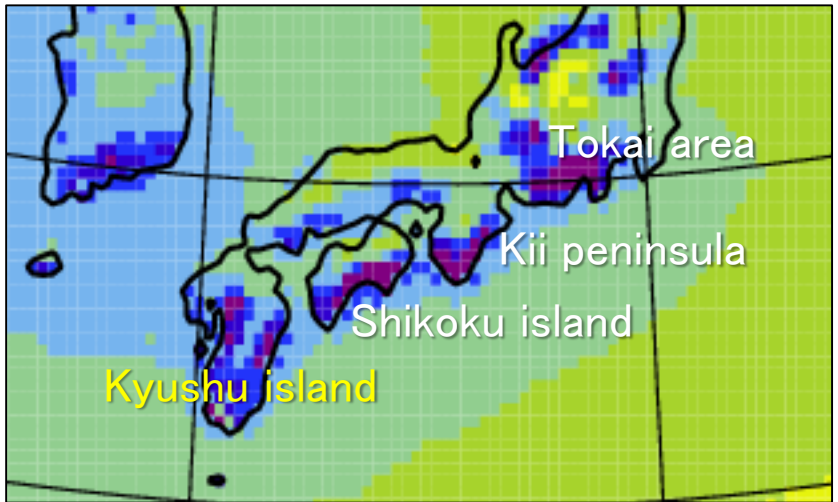
(Current-NonW)/Current

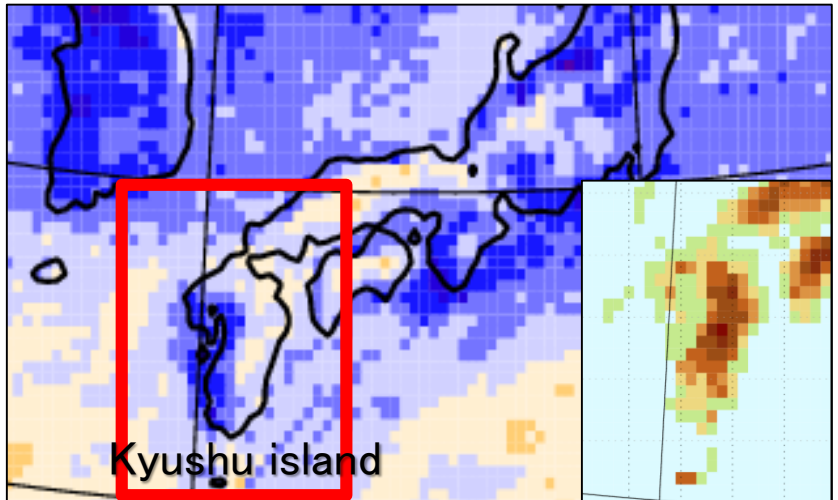


Larger in Current

Current: current simulation, NonW: non-warming simulation

Smaller in Current





(Kawase et al, 2019; JGR)

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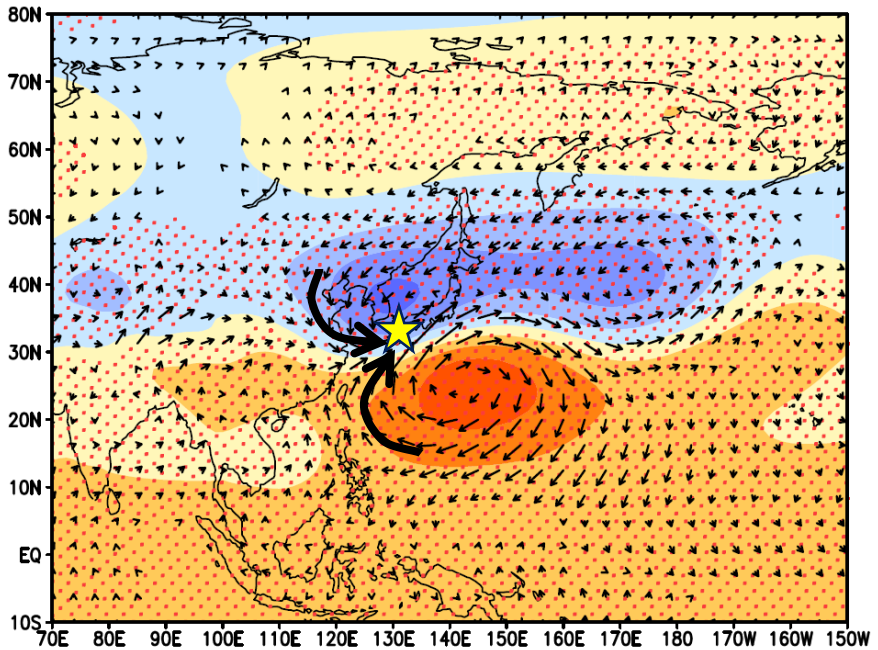
Correlation between heavy rainfall days in RCM atmospheric circulation (qV, Z) at 850hPa in GCM

Western Kyushu

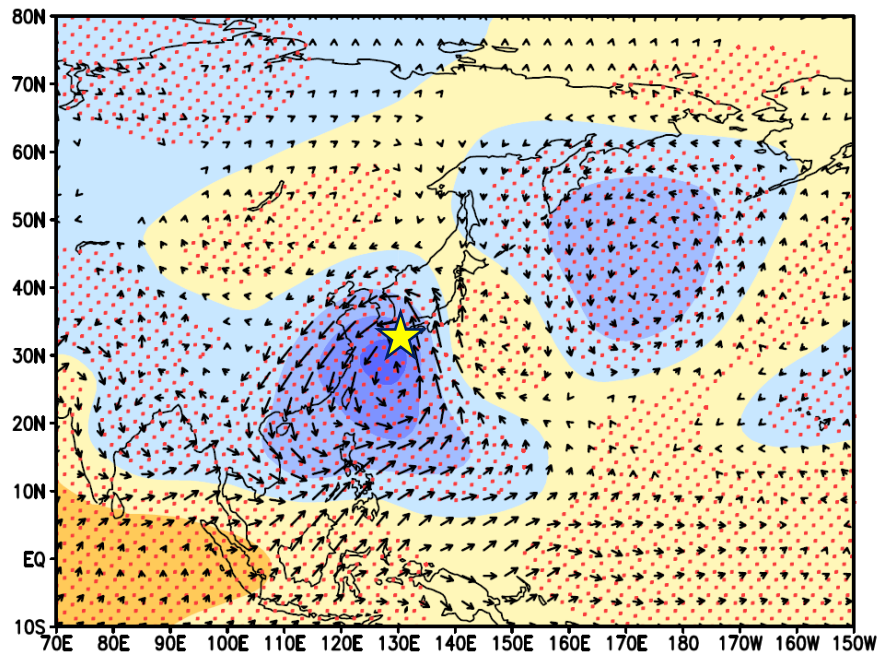


Shading: Z850, vector: qV850 → 1 [1981-2010]

Positive correlation over northwestern Pacific Ocean, Negative correlation over Sea of Japan

➔ Heavy rainfall occurs due to enhanced Pacific High, troughs, and southwesterly moisture advection

Eastern Kyushu



Shading: Z850, vector: qV850 → 1 [1981-2010]

Negative correlation over Northwestern Pacific to East China Sea

➔ Heavy rainfall relates to cyclonic circulation (typhoon??)

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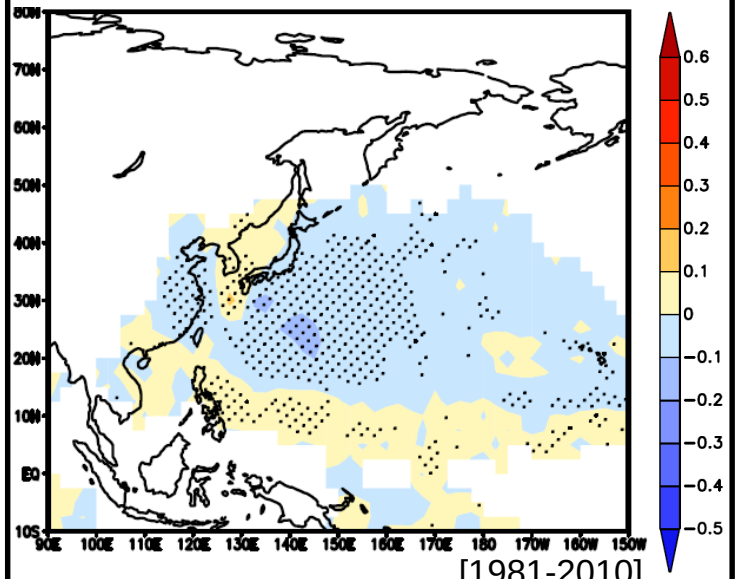
(Kawase et al, 2019; JGR)

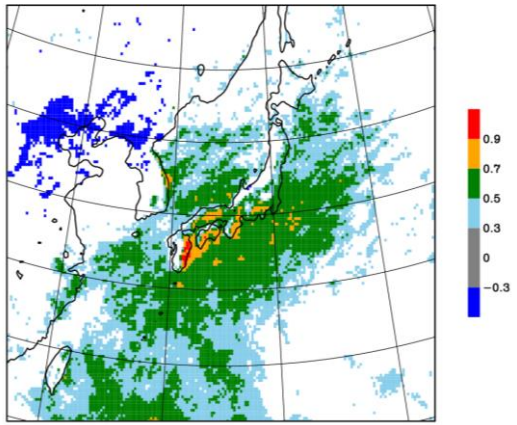
Correlation between heavy rainfall days and typhoon density

Western Kyushu



[1981-2010]

No or small negative correlation with typhoon density



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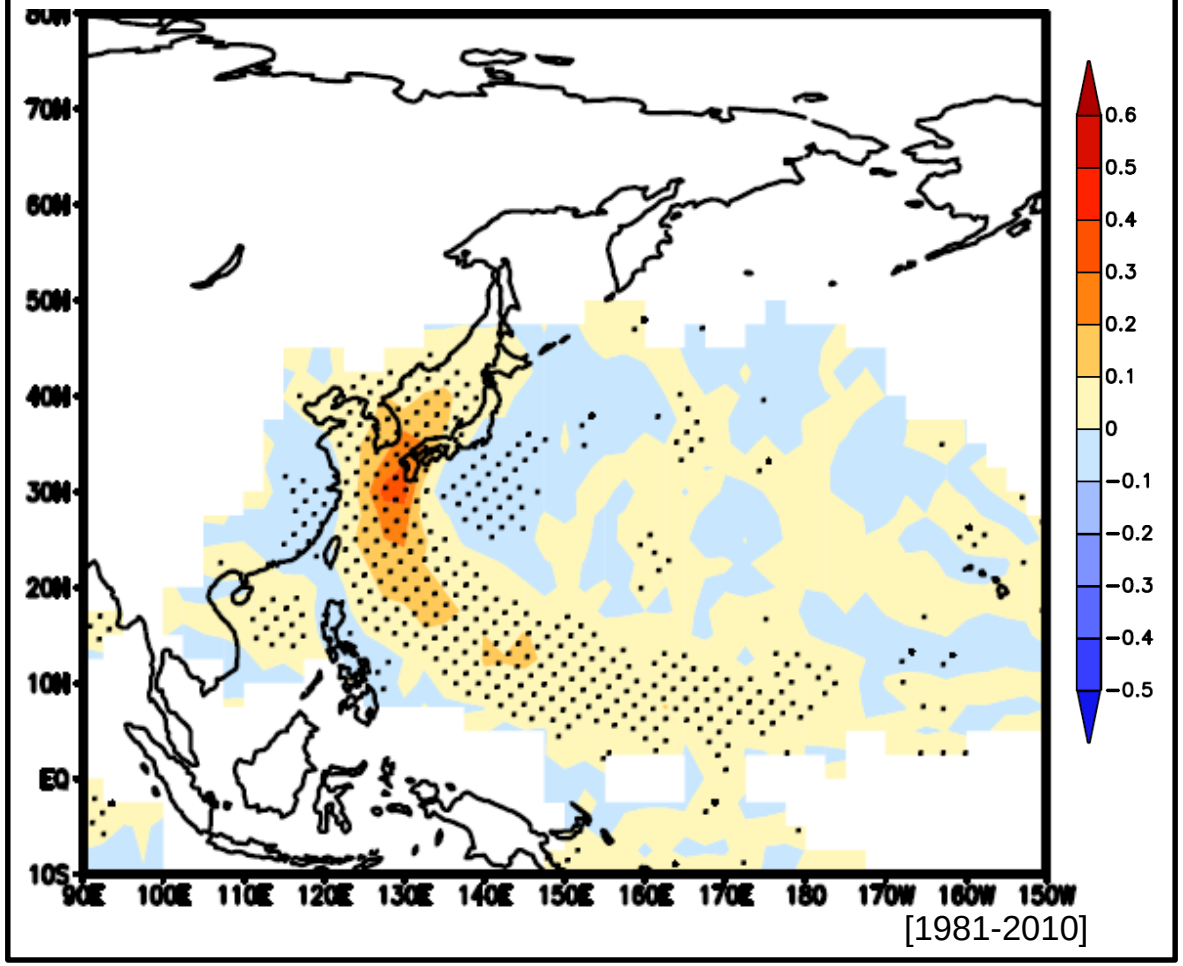
Eastern Kyushu



[1981-2010]

TC track data was obtained from K. Yoshida (MRI).

Clear positive correlation with Typhoon density and heavy rainfall in Eastern Kyushu

(Kawase et al, 2019; JGR)

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Breakthrough in the attribution of an extreme event

Expansion of d4PDF

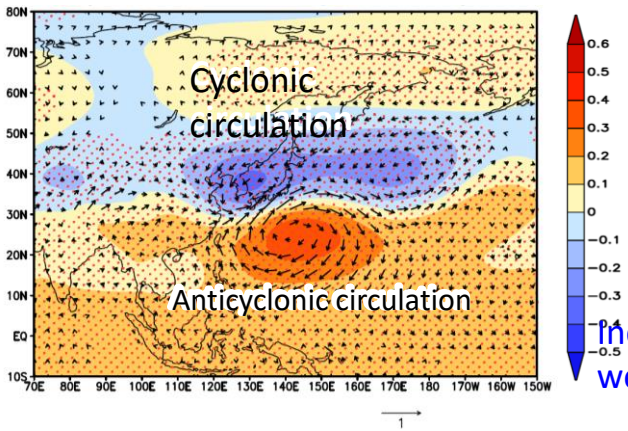
Good reproductivity of rainfall with dynamical Downscaling with 20-km NHRCM is bringing breakthrough in regional EA and flood design

Explicit analysis of rainfall

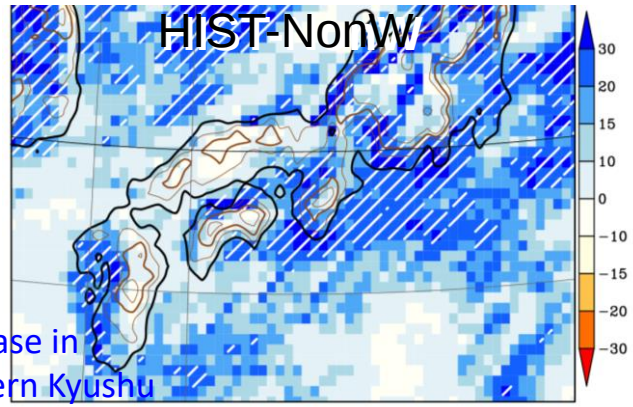
Societal implementation

Previous studies → Current Study → Flood design

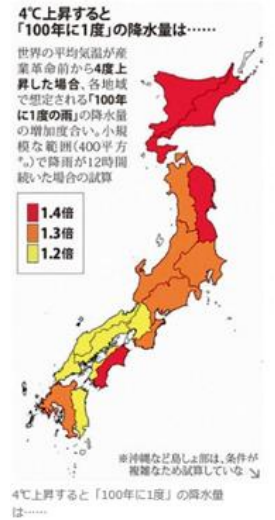
Correlation between heavy rainfall proxy and large scale circulations



Number of days with heavy rainfall of 95%tile

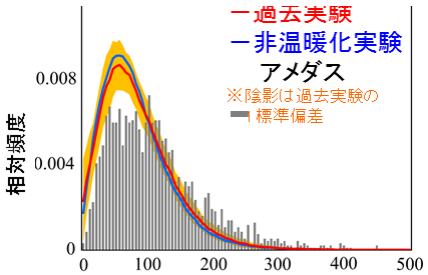


Kawase et al. (2019, JGR)



(Mainichi Newspaper May 31, 2019)

Frequency of heavy rainfall in the western Kyushu



Increase trend in heavy rainfall in western Kyusyu

- Water vapor convergence induces heavy rainfall
- Increase in precipitable water increases the frequency of heavy rainfall
- Global warming enhances water vapor fluxes

Attribution of climate extremes

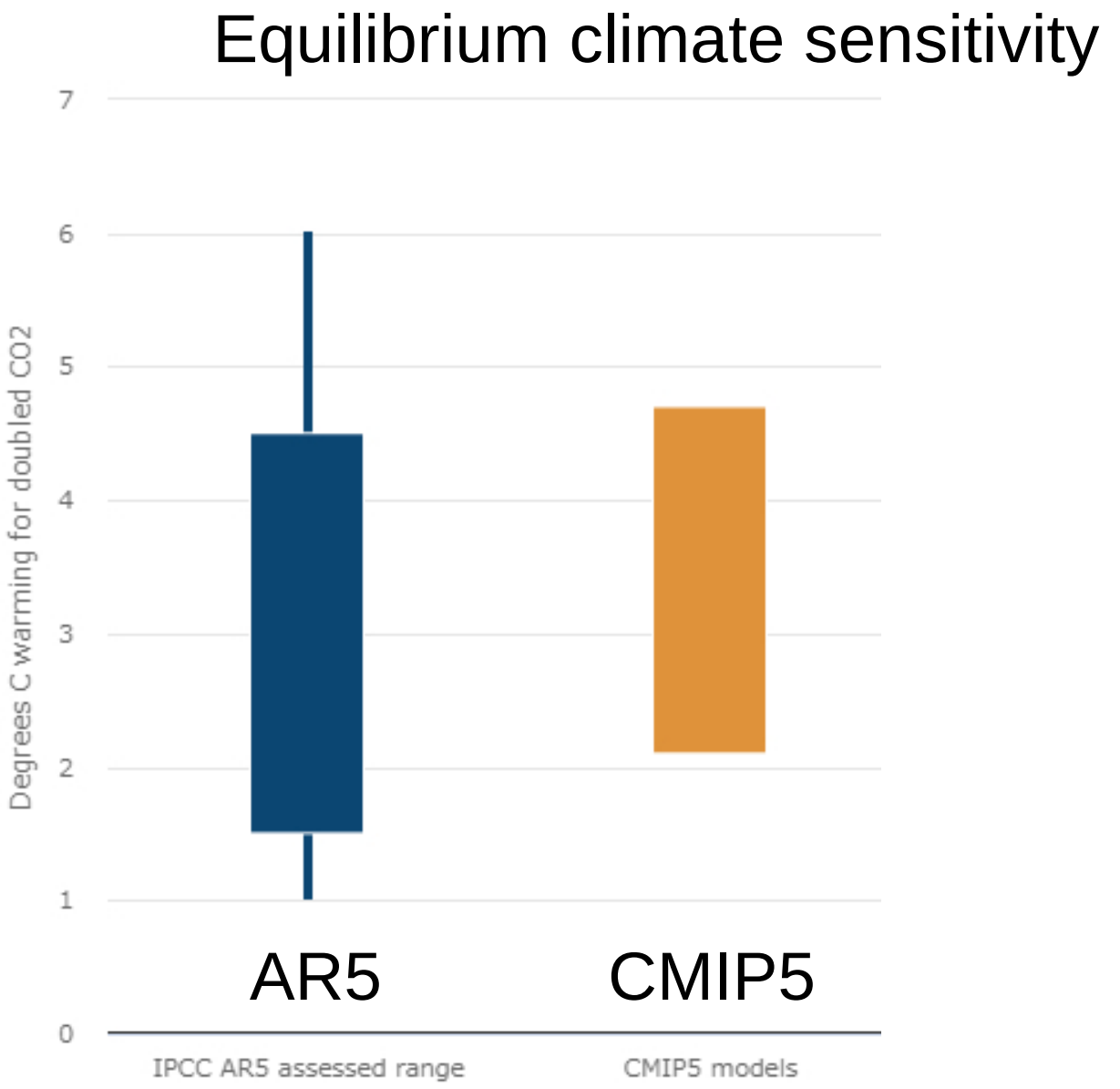
A climate extreme is due to an attribution or just crazy weather by chance?

From a scientific view point, we can say

Scientific contents of my today's talk

1. Future climates and extremes:
   - Recent assessments on climate changes and impacts
2. Emerging climate extremes:
   - Attribution of extremes recently occurred
     - Event-based approach
     - Probabilistic approach
3. Latest information in CMIP6 climate model community
   - Uncertainty in future climate projections

High climate sensitivity in CMIP6 models



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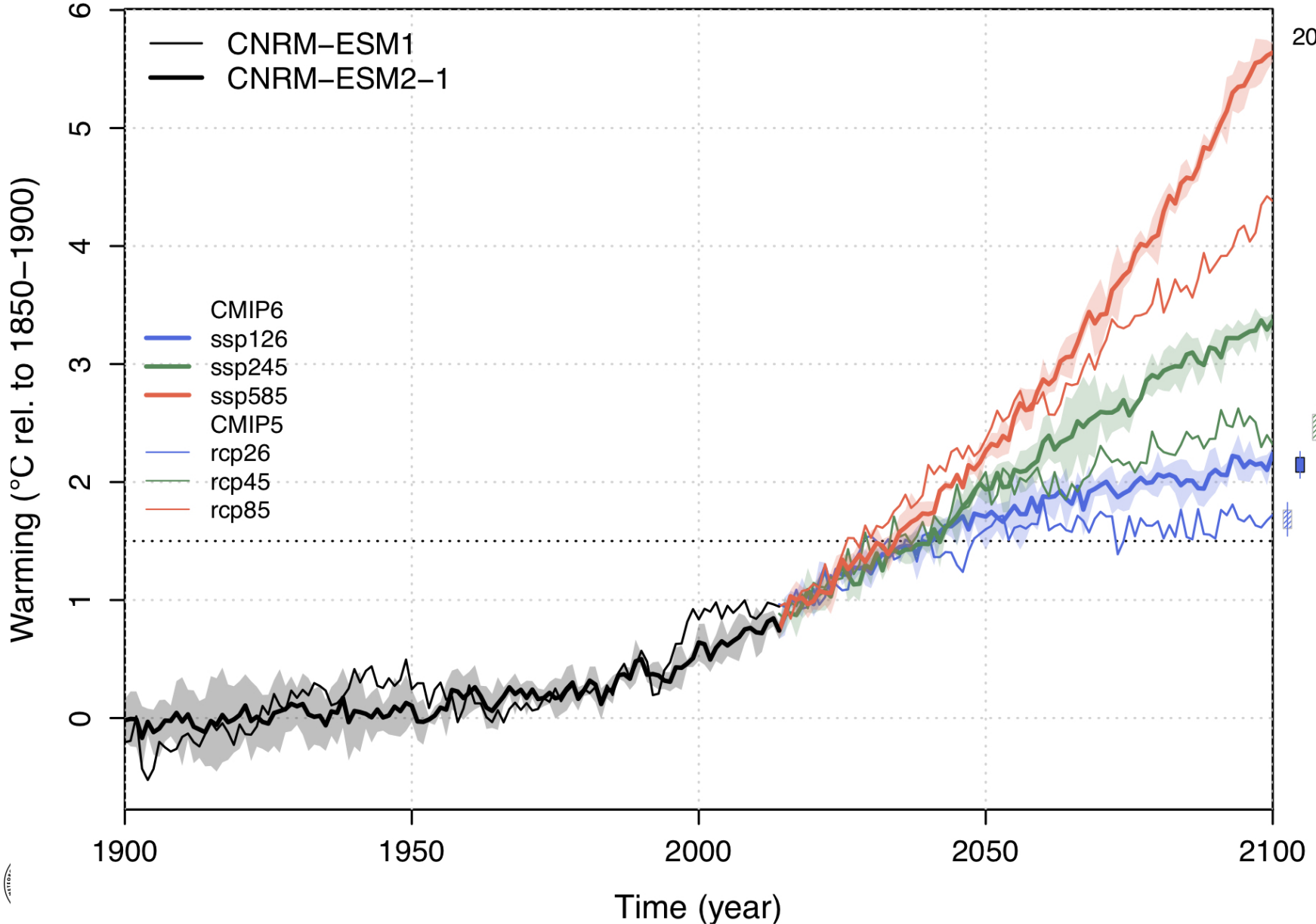
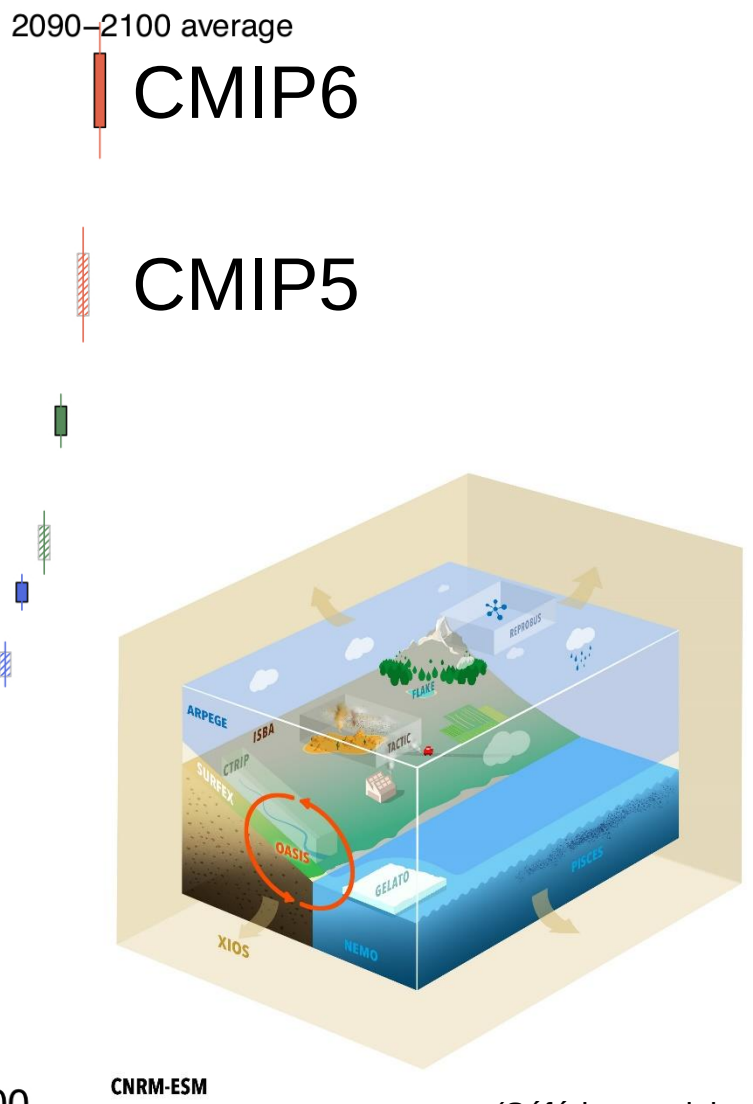
High climate sensitivity in CMIP6 models



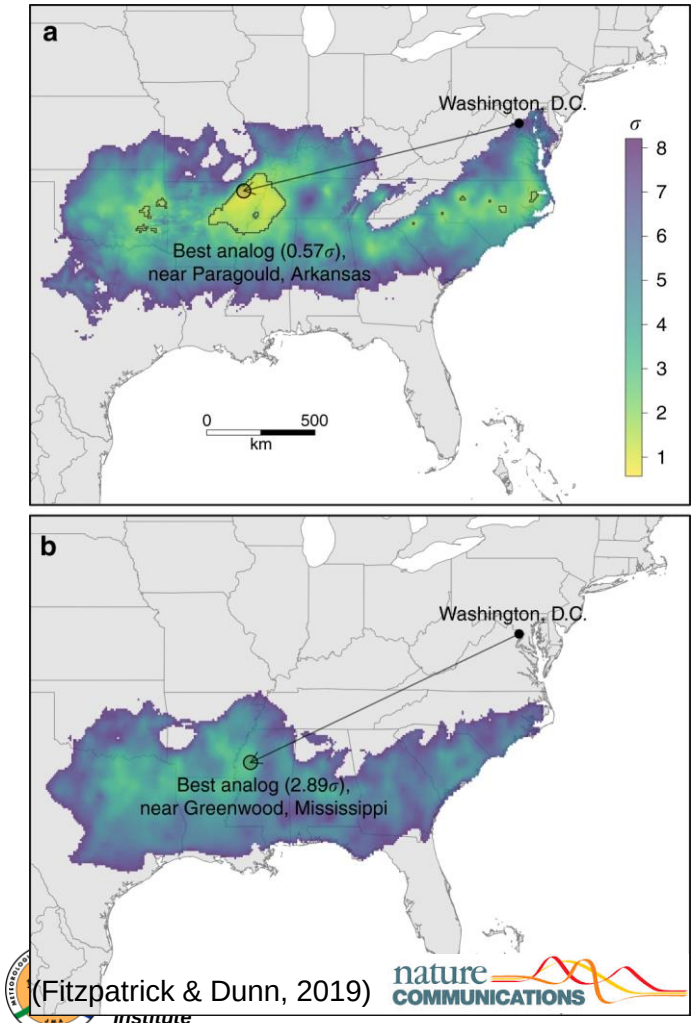


(Séférian et al. in prep.)

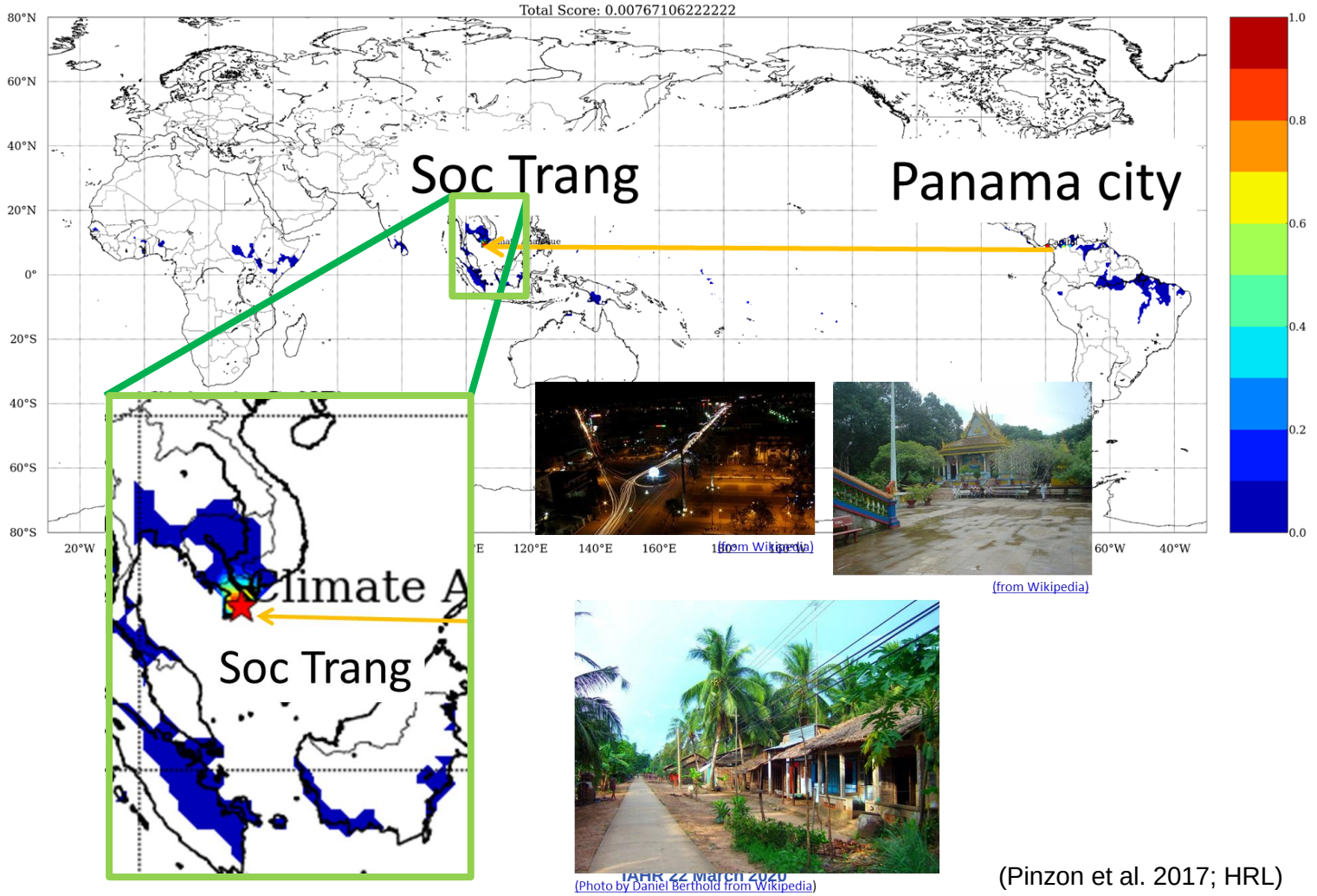
(http://www.umr-cnrm.fr/cmip6/spip.php?article10)

How can you tell a future climate to public?

Climate analogue: matching the expected future climate at a target city with current climate of another

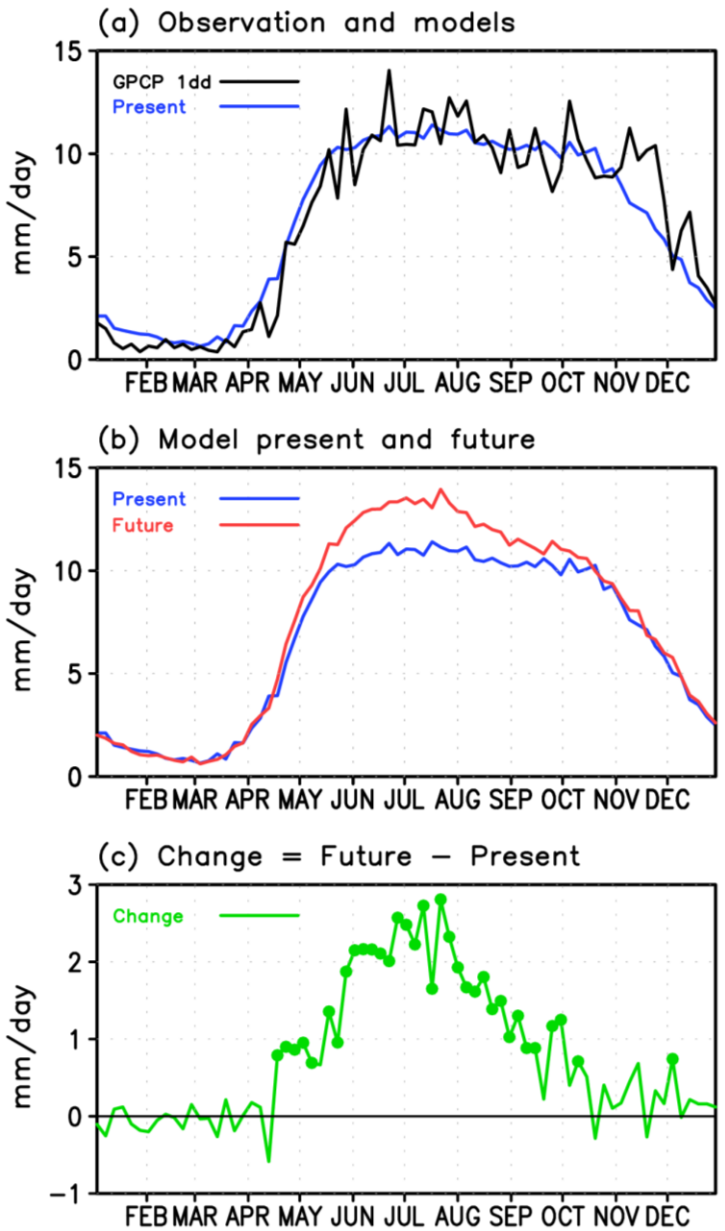


(Fitzpatrick & Dunn, 2019)

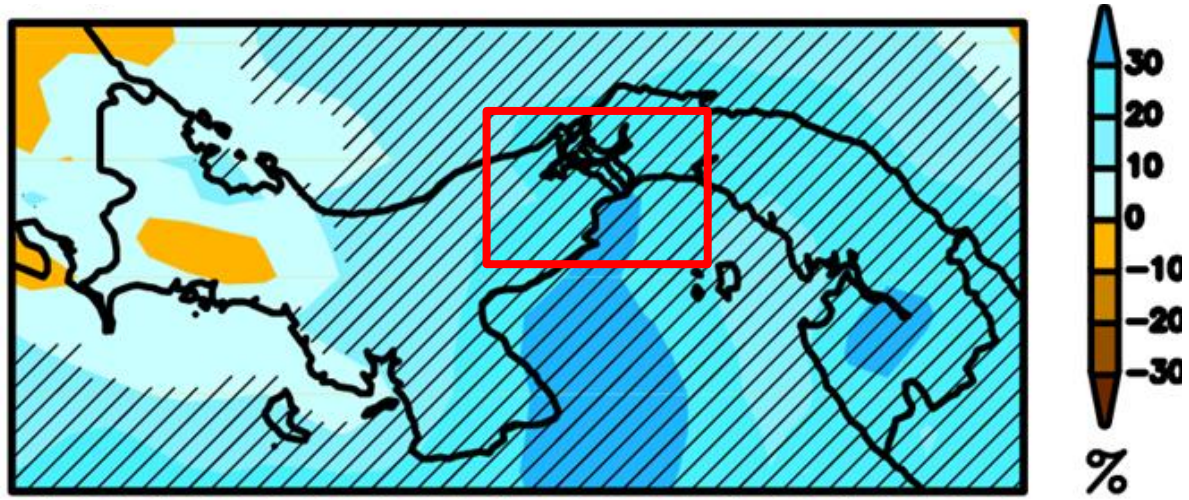


(Pinzon et al. 2017; HRL)

Future rainfall in Panama canal region



Annual maximum 5-day rainfall total: 17.1%



December 9, 2010

(Kusunoki et al, 2019; JGR)

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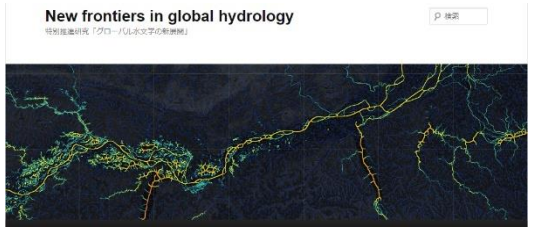
Scientific contents of my today's talk

1. Future climates and extremes:
   - IPCC Special Reports provides the latest assessments
   - 1.5℃ target will be possible if we success the net zero emission in 2055.
   - Global warming impacts is emerging in a current world.
2. Emerging climate extremes:
   - Attribution of extremes recently occurred to global warming in scientific approaches
3. Latest information in CMIP6 community
   - Global warming is projected to more rapid in CMIP6 than in CMIP5

Thank you for your attention!



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