Climate Change and Extreme Events

Tosiyuki NAKAEGAWA
Meteorological Research Institute,
Japan Meteorological Agency
and
many collaborative researchers

TOUGOU | Integrated Research Program for Advancing Climate Models

Self-introduction

- Member, Iinternational Commission on Climate, IAMAS, IUGG
- Board member, Meteorological Society of Japan
- Vice Editor-in-Chief, SOLA
- Co-leader, Expert team on Sector-specific Indices, WMO
- Member, Expert team for Impact of Climate Change on Tropical Cyclone, ESCAP/WMO

World Meteorological Organisation

ESCAP/WMO Typhoon Committee

Why am I here?

Hydrological Research Letters **7**(2), 23–29 (2013)
Published online in J-STAGE (www.jstage.jst.go.jp/browse/HRL). doi: 10.3178/HRL.7.23

Hydroclimate projections for Panama in the late 21st Century

José Fábrega[1], Tosiyuki Nakaegawa[2], Reinhardt Pinzón[1], Keisuke Nakayama[3], Osamu Arakawa[2] and SOUSEI Theme-C Modeling Group[2]
[1]*Centro de Investigaciones Hidráulicas e Hidrotécnicas, Universidad Tecnológica de Panamá, Republic of Panamá*
[2]*Climate Research Department, Meteorological Research Institute, Japan*
[3]*Dept. of Civil and Environmental Engineering, Kitami Institute of Technology, Japan*

Abstract: 1764 mm (133.2 km³), translating to a runoff coefficient of 60.3% (Programa Hidrológico Internacional, 2008). Panama

Hydrological Research Letters **11**(2), 106–113 (2017)
Published online in J-STAGE (www.jstage.jst.go.jp/browse/hrl). DOI: 10.3178/hrl.11.106

Virtually experiencing future climate changes in Central America with MRI-AGCM: climate analogues study

Reinhardt E. Pinzón[1]*, Kenshi Hibino[2], Izuru Takayabu[3] and Tosiyuki Nakaegawa[3,2]*
[1]*Centro de Investigaciones Hidráulicas e Hidrotécnicas, Universidad Tecnológica de Panamá, Panamá*
[2]*Institute of Industrial Science, The University of Tokyo, Japan*
[3]*Meteorological Research Institute, Japan Meteorological Agency, Japan*

Abstract: this region, the thermal differences between the continents

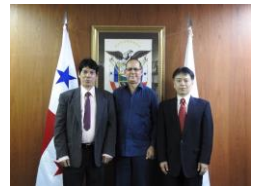
Climate Dynamics
https://doi.org/10.1007/s00382-019-04842-w

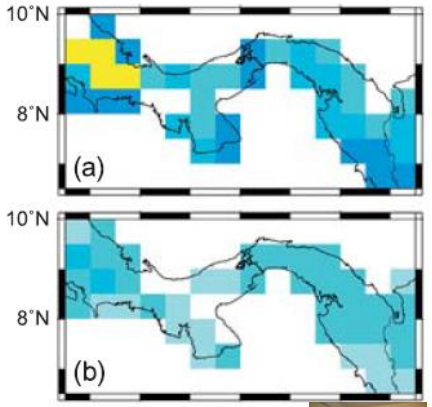
Future precipitation changes over Panama projected with the atmospheric global model MRI-AGCM3.2

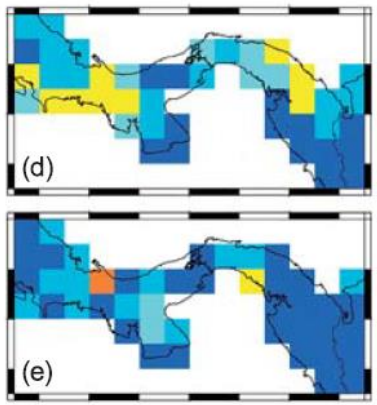
Shoji Kusunoki[1,2] · Tosiyuki Nakaegawa[1] · Reinhardt Pinzón[3] · Javier E. Sanchez-Galan[4,5] · José R. Fábrega[3]

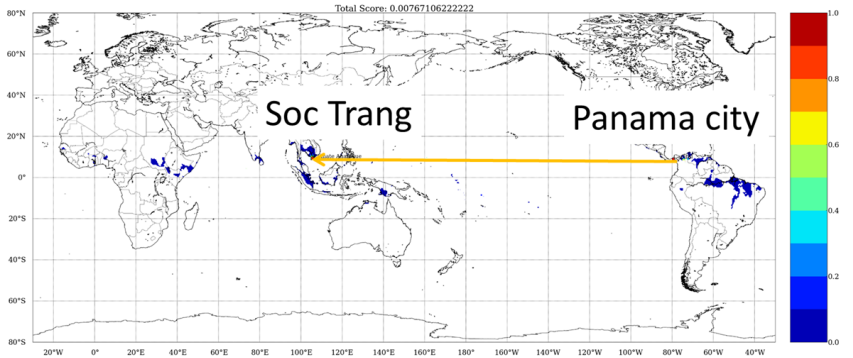
Received: 13 November 2018 / Accepted: 3 June 2019

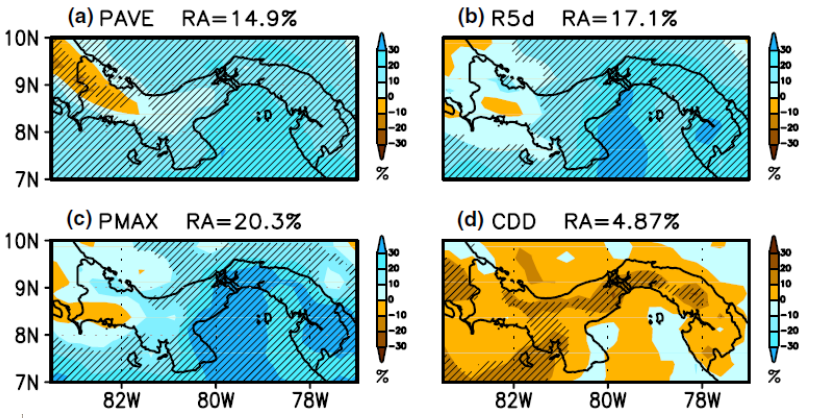
Abstract











My faint relationship to IAHR

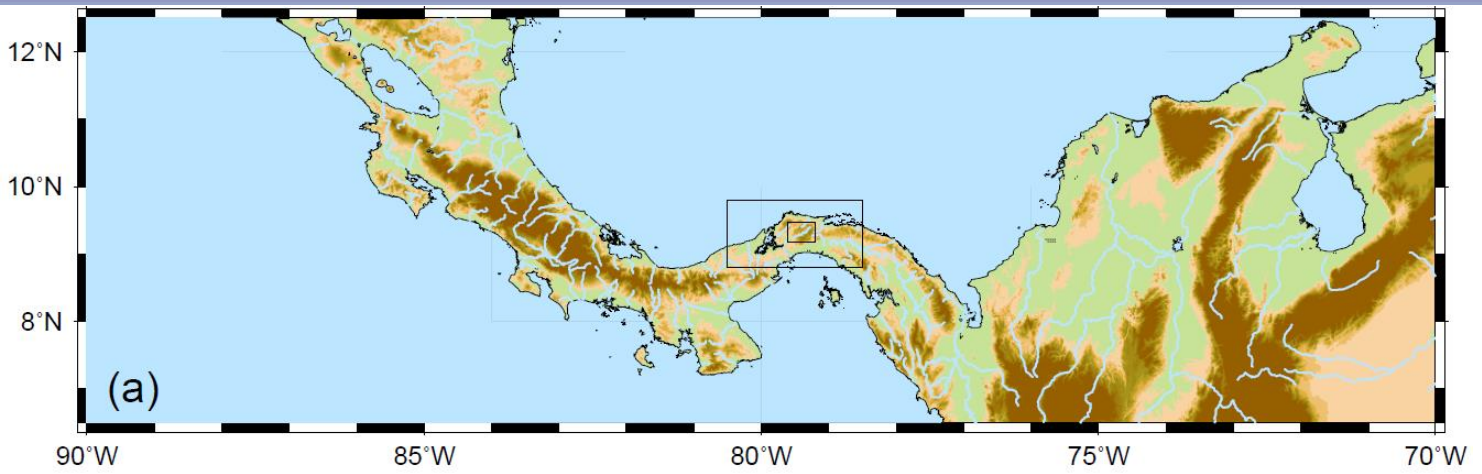
2007 - 2011

(https://iahr.org/Portal/About_US/IAHR_World_Congresses/35

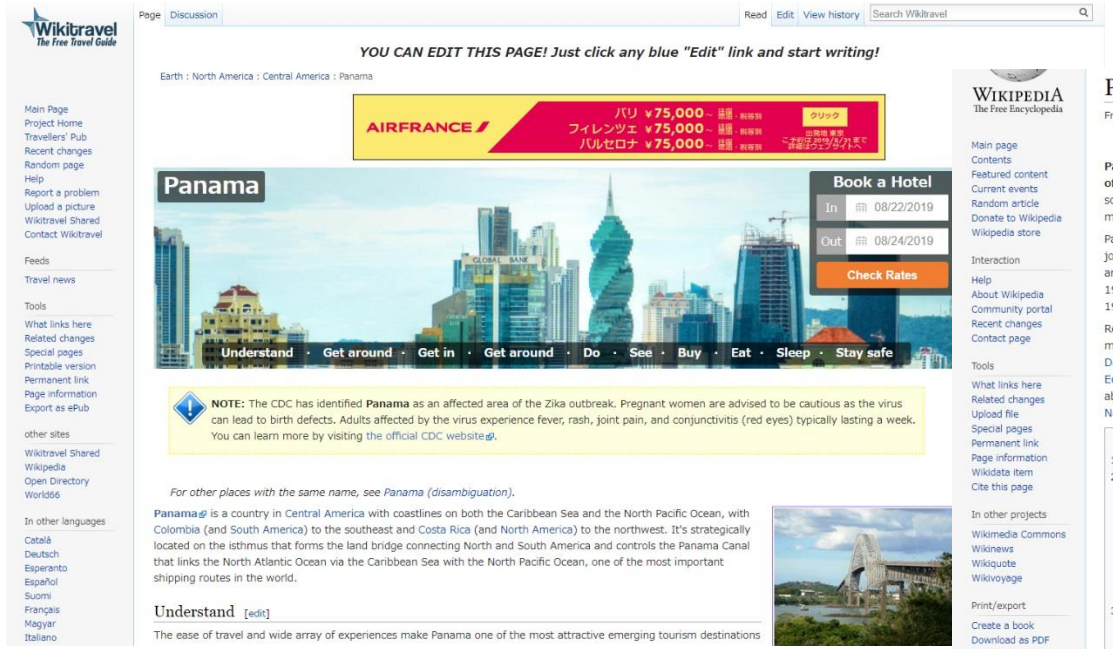
Density flow

Hydraulics

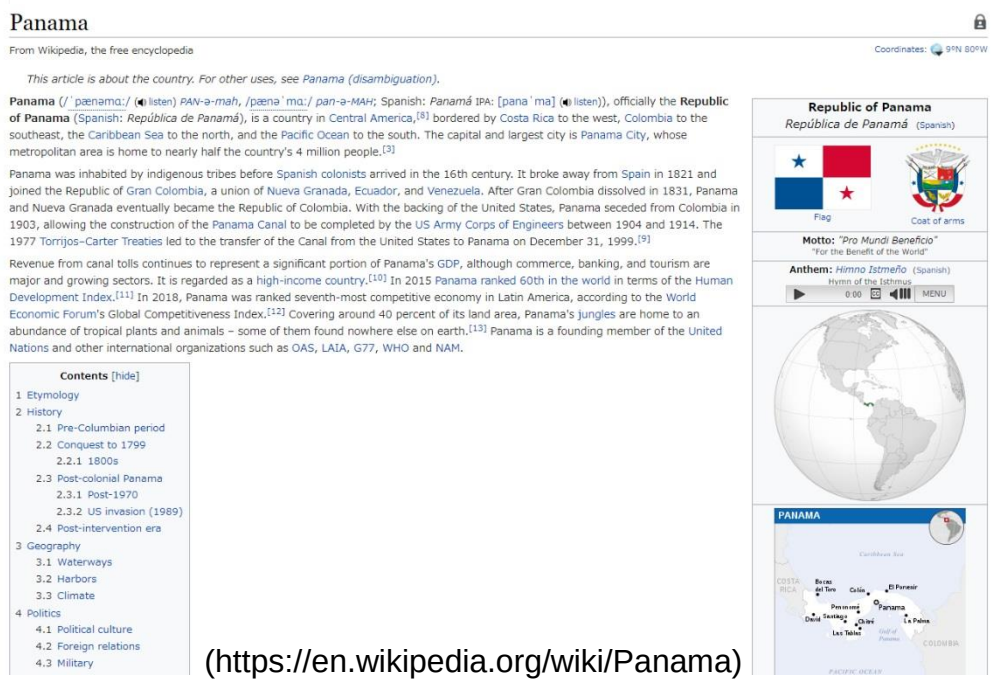
Welcome to Panama



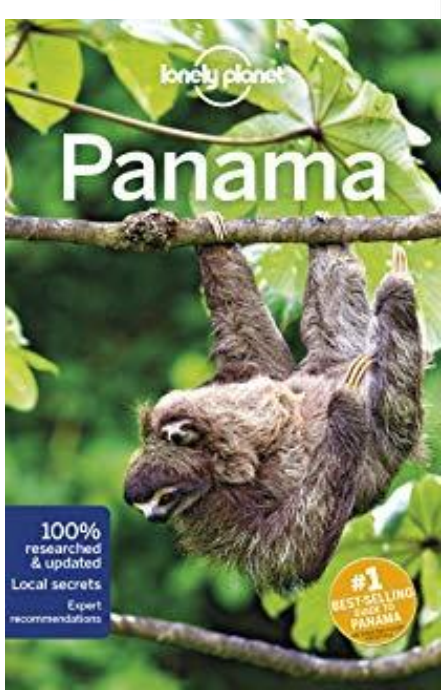
(https://www.lonelyplanet.com/panama)



(https://en.wikitravel.org/en/wiki/Panama)

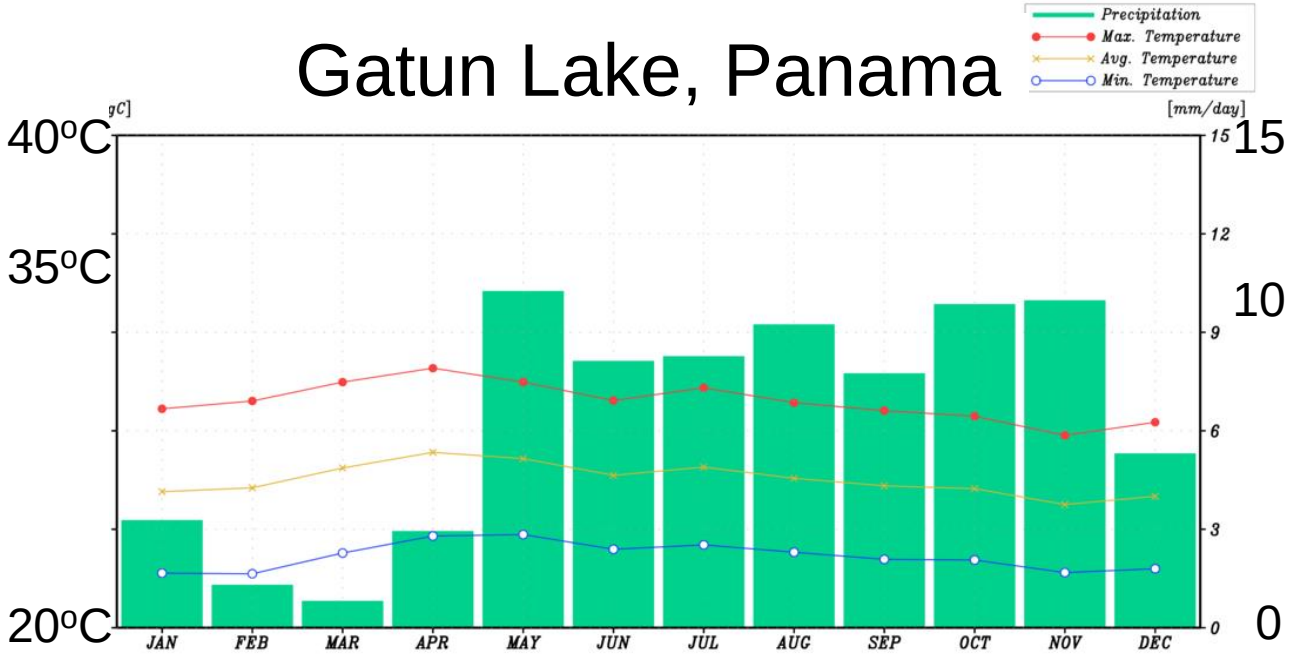


(https://en.wikipedia.org/wiki/Panama)

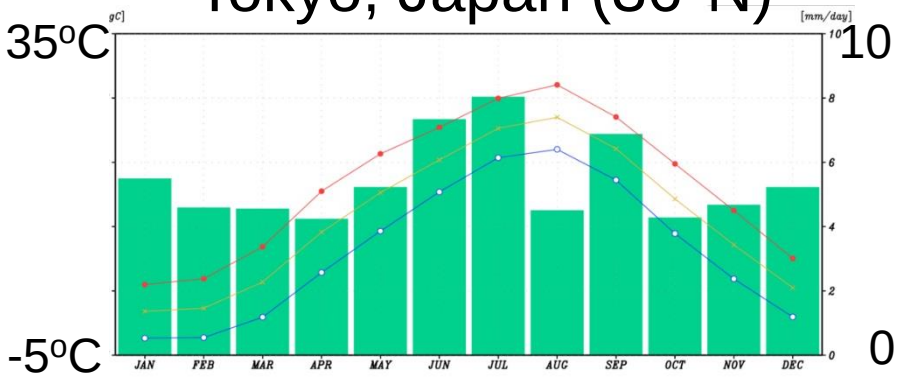


Climates of Panama

Gatun Lake, Panama



Tokyo, Japan (36ºN)

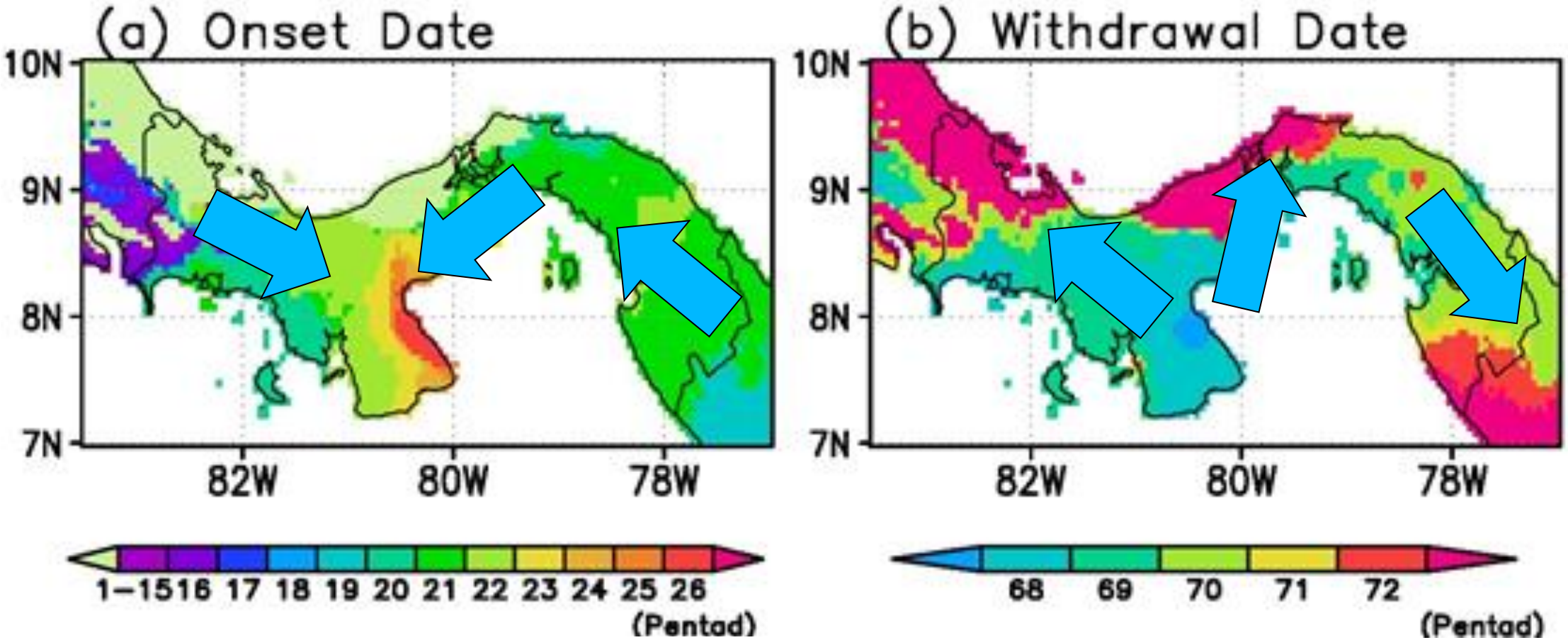


(Nakaegawa et al., 2015, HRL)

Rainy season

May to June

October to December

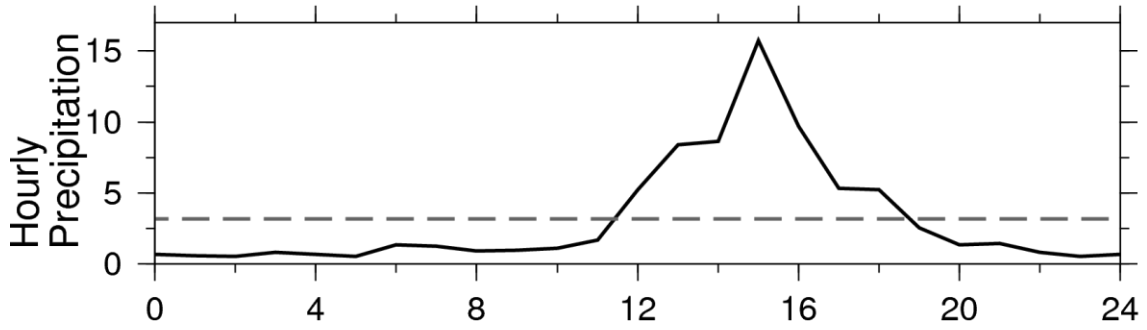


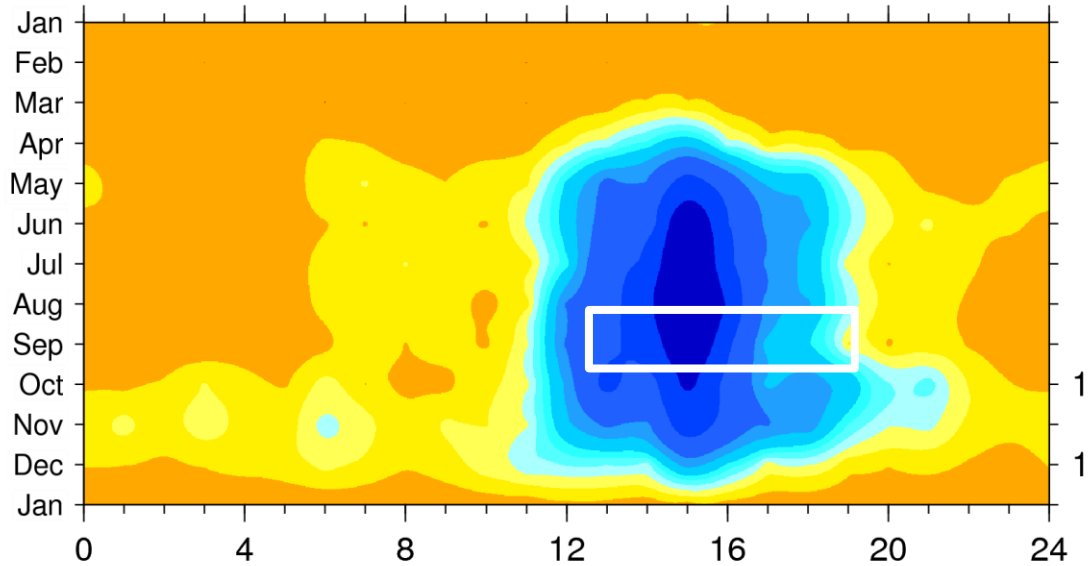
Geographical distributions of the (a) onset and (b) withdrawal dates of the rainy season in Panama. The onset and withdrawal dates have been defined with the uniform threshold value method and a threshold value of 3 mm day^{-1}.

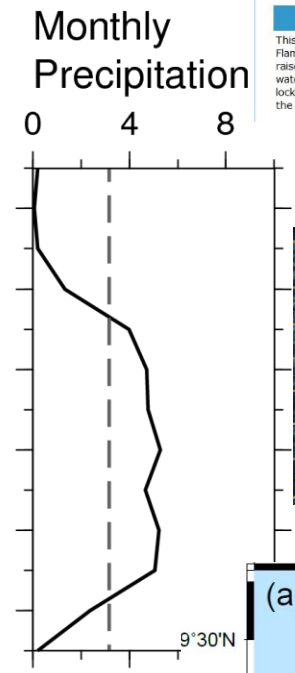
(Nakaegawa et al., 2015, J. Clim)

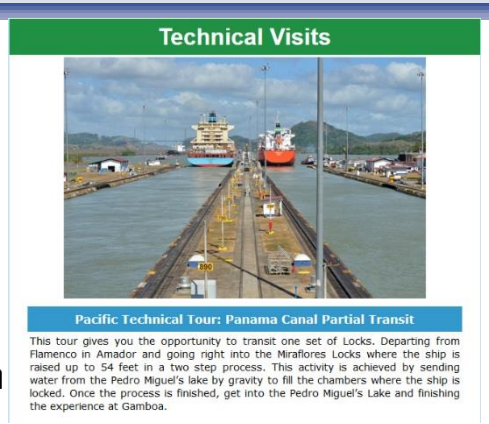
You had better bring an umbrella when …

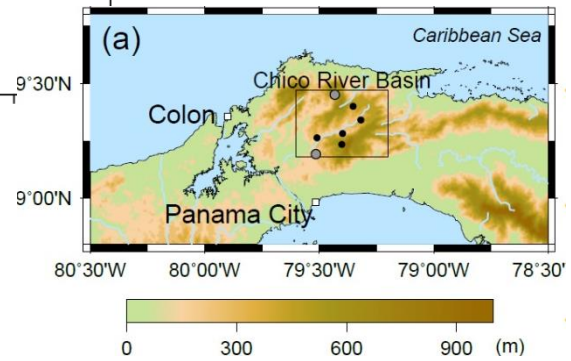
Diurnal cycle of rainfall

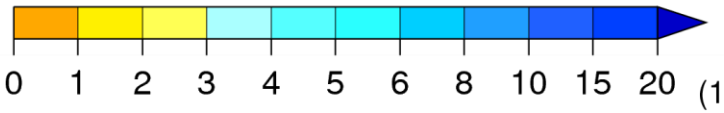












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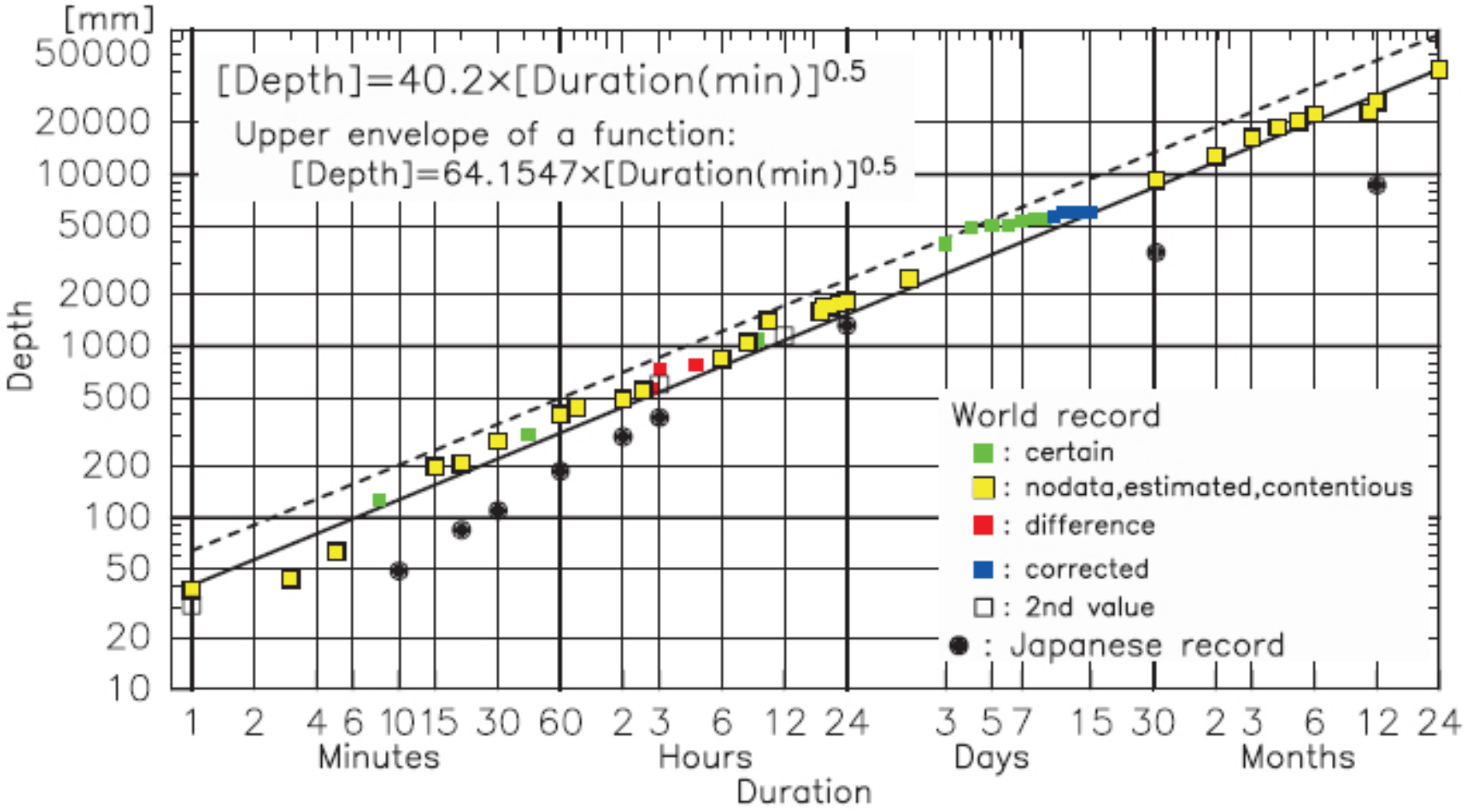
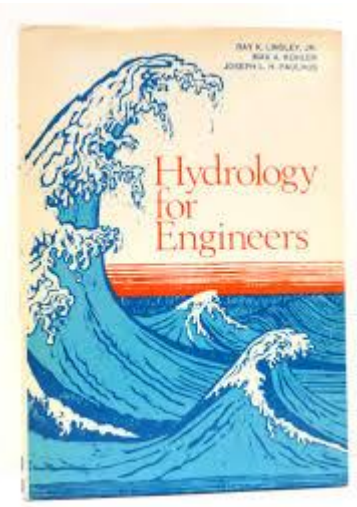
3, 2019

(Nakaegawa et al. 2019, in review, PLOS ONE)

Extreme rainfall events

Cross section of depth and duration of world-record rainfall extremes

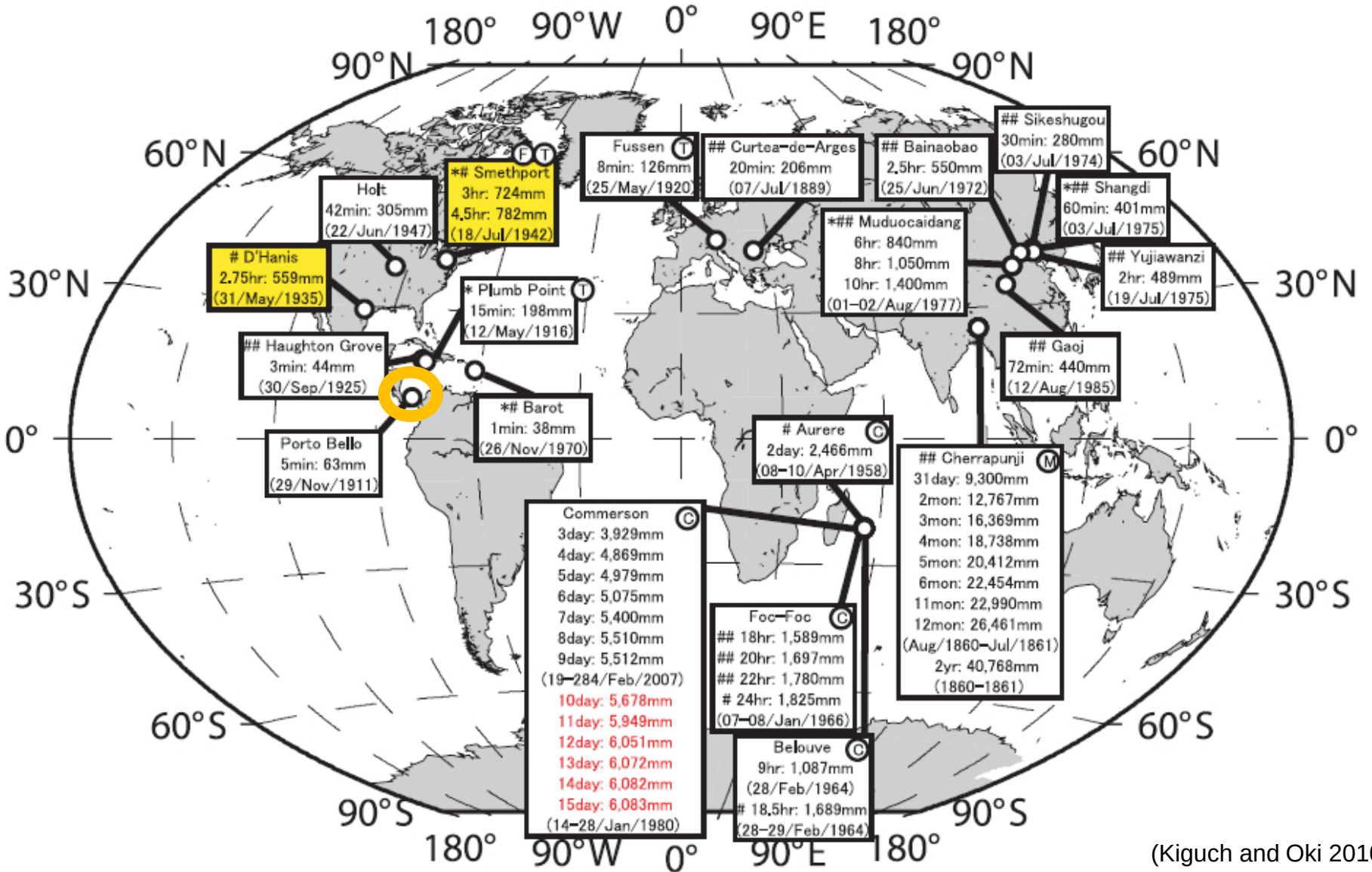




(Kiguch and Oki 2010, JSHWR)

Extreme rainfall events

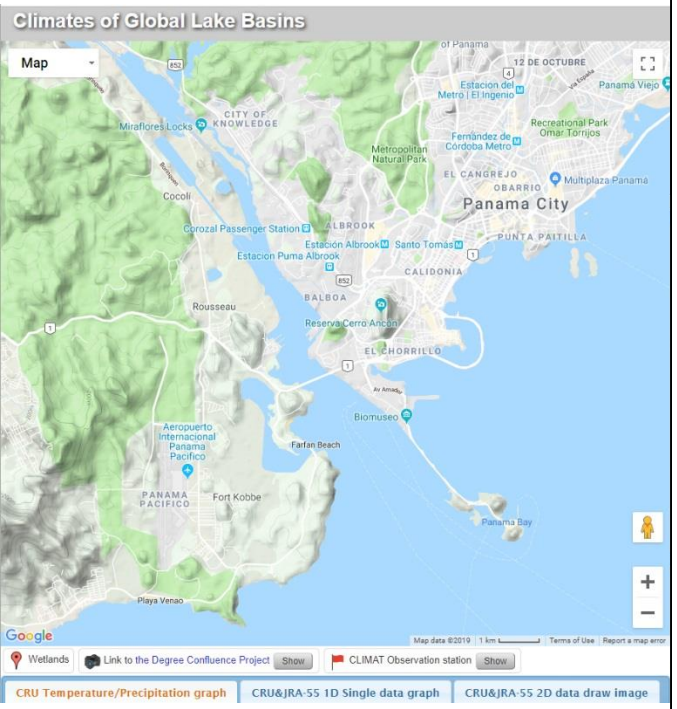
World record point of extreme rainfall



(Kiguch and Oki 2010)

World record point of extreme rainfall

Pacific Ocean



298 MONTHLY WEATHER REVIEW. MAY, 1919

PANAMA RAINFALL.

By H. G. CORNTHWAITE, Chief Hydrographer.

[Dated: Balboa Heights, C. Z., Jan. 31, 1919.]

SYNOPSIS.—The writer sketches the geographical distribution of the rainfall in Panama, and follows with an account, with tables and figures, of monthly and hourly precipitation, local showers, and excessive rainfall. Whatever rain occurs on the Isthmus must be attributed to local convection currents in conjunction with the deflective effects of hills and mountains on such winds as there are.

The rainfall on the north side exceeds that on the south side of the Isthmus, and is greatest on the north coast and locally on the higher portions of the Caribbean slope. The mean annual rainfall at Colon is 129.04 inches; at Porto Bello 169.15 inches, and at Balboa, 91.61 inches.

An excessive downpour in a brief period, probably 2.48 inches in 5 minutes at Porto Bello, May 1, 1910, seems to have been the most intense rainfall ever recorded.—H. L.

"(3) Cyclonic circulation."

Since the Isthmus of Panama is in that section of the globe where the influence of convection is very great and where cyclonic disturbances are almost unknown, it follows that the greater part of the Isthmian rainfall must be attributed to the first two processes mentioned above.

Panama is situated in the Torrid Zone, where tropical weather conditions prevail. The year is divided into two seasons, a dry season of approximately four months duration, January to April, inclusive, and a rainy

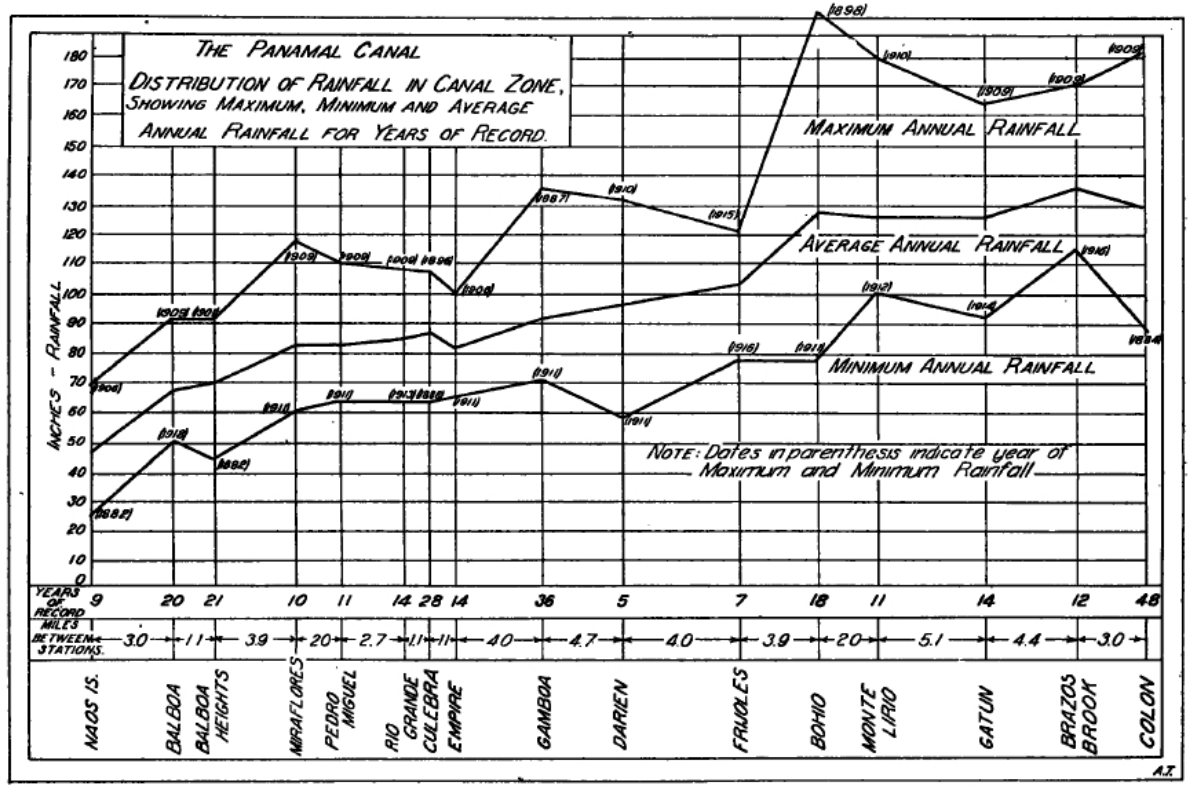
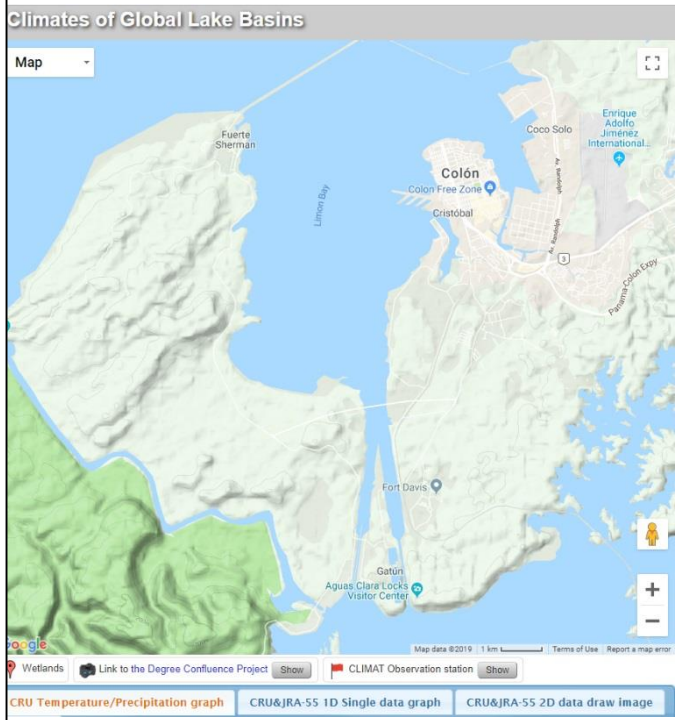


FIG. 1.

May,1919

Caribbean Sea



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5-min rainfall record at Porto Bello

TABLE 1.—*Maximum rainfall in Canal Zone October, 1905, to January, 1919.*

Stations.	Maximum rainfall.					
	5 minutes.		1 hour.		24 hours.[1]	
	Inch.	Date.	Inch.	Date.	Inch.	Date.
Balboa (June 10, 1906).	.90	May 12, 1912	5.86	June 2, 1906	7.57	Nov. 16–17, 1906.
Balboa Heights (Oct. 1, 1905).	.64	Aug. 7, 1908	3.98	Oct. 9, 1911	7.23	May 12–13, 1912.
Miraflores (June 19, 1914).	.50	Sept. 6, 1917	4.09	Sept. 6, 1917	4.75	Sept. 6, 1917.
Pedro Miguel (Jan. 1, 1908).	.60	Nov. 11, 1908	3.46	Sept. 6, 1917	5.45	Nov. 19–20, 1917.
Rio Grande (Dec. 29, 1905).	.75	July 24, 1908	4.14	Nov. 20, 1917	8.24	Nov. 19–20, 1917.
Empire (July 18, 1906).	.60	July 25, 1906	4.19	Oct. 21, 1908	6.15	Dec. 3, 1906.[2]
Gamboa (Nov. 18, 1905).	.59	July 27, 1908	3.32	May 11, 1911	6.56	Dec. 2–3, 1906.
Alhajuela (Mar. 31, 1907).	.60	July 20, 1909	4.19	July 8, 1915	8.19	Dec. 2–3, 1906.[2]
Gatun (Oct. 1, 1905)	.62	Aug. 3, 1912 Aug. 12, 1914	4.72	Aug. 12, 1914	10.48	Dec. 3, 1906.[2]
Bohio (Oct. 1, 1905)	.67	June 16, 1909	4.51	Aug. 7, 1908	8.85	Aug. 7–8, 1908.
Colon (Oct. 1, 1905).	.64	Aug. 25, 1909	4.90	Oct. 8, 1909	8.53	Dec. 2–3, 1906.
Porto Bello (May 1, 1908).[3]	[4] 2.48	Nov. 29, 1911	4.53	Nov. 29, 1911	10.86	Dec. 28–29, 1909.

[1] Maximum rainfall in 24 consecutive hours.
[2] No automatic record on this date, total for 24 hours ending at noon.
[3] Station closed in August, 1914, and reopened in December, 1918.
[4] Approximate, automatic record indistinct due to unusually excessive rate of rainfall. [This rate exceeds that of 205 mm. (8.07 in.) in 20 minutes at Curtea-de-Arges, Roumania, July 7, 1889, heretofore considered the greatest on record.—ED.]
Dates in parenthesis refer to the installation of automatic raingages.

World Heritage Site


(Lombana, Wikipedia)


(Tedder, Wikipedia)

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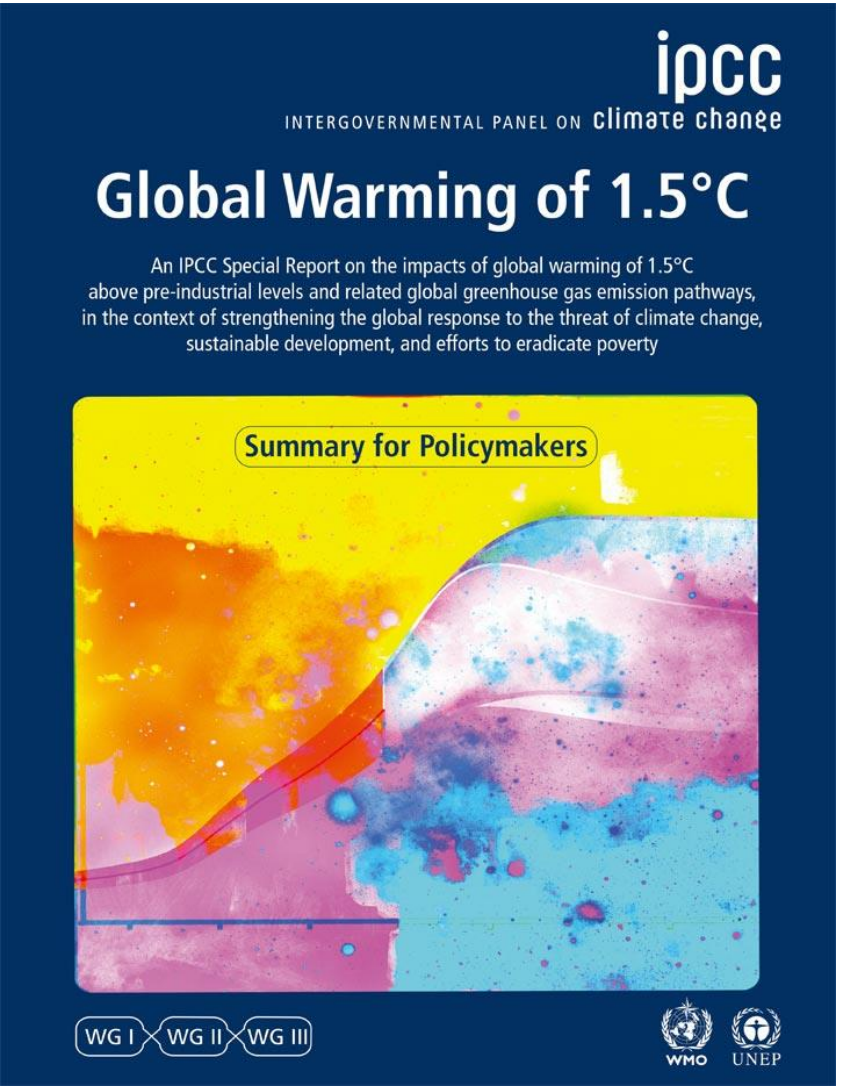
Scientific contents of my today's talk

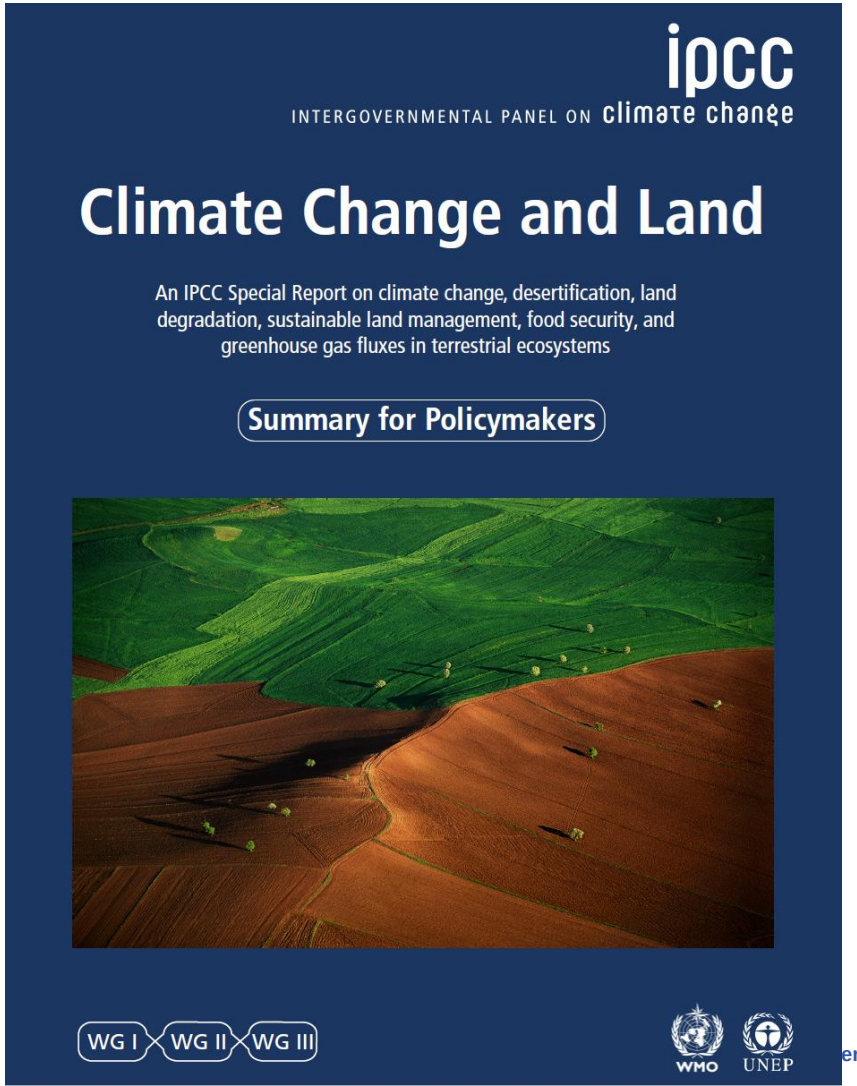
1. Future climates and extremes:
   - Recent assessments on climate changes and impacts
2. Emerging climate extremes:
   - Attribution of extremes recently occurred
     - Event-based approach
     - Probabilistic approach
3. Latest information in CMIP6 climate model community
   - Uncertainty in future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

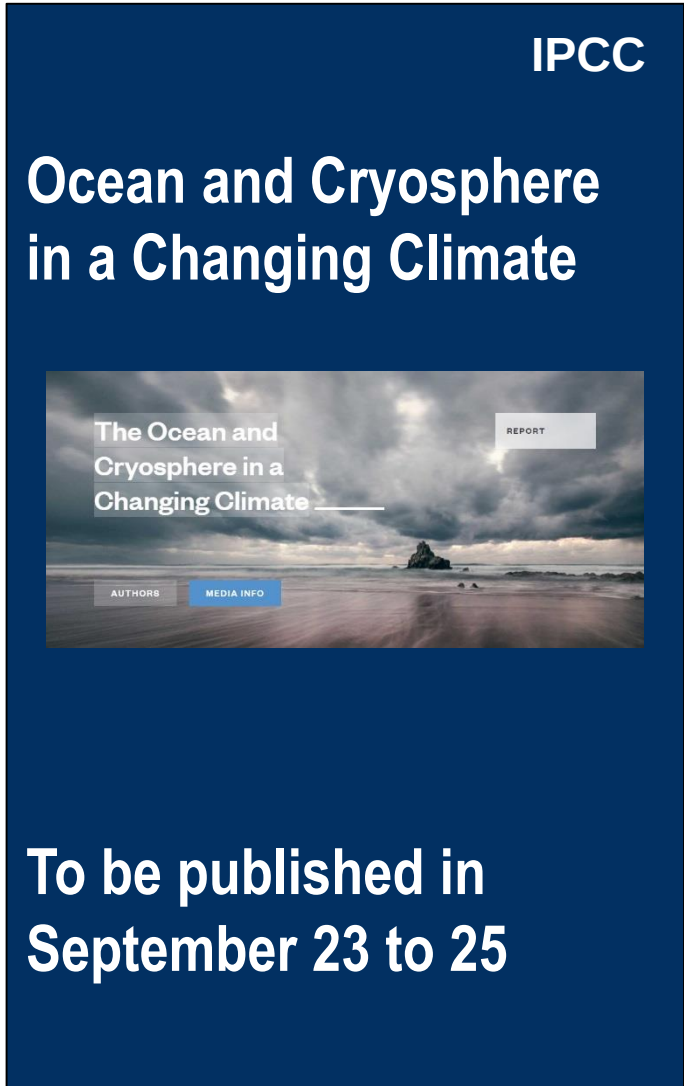
IPCC Special Reports between AR5 and AR6

October 6, 2018



August 7, 2019

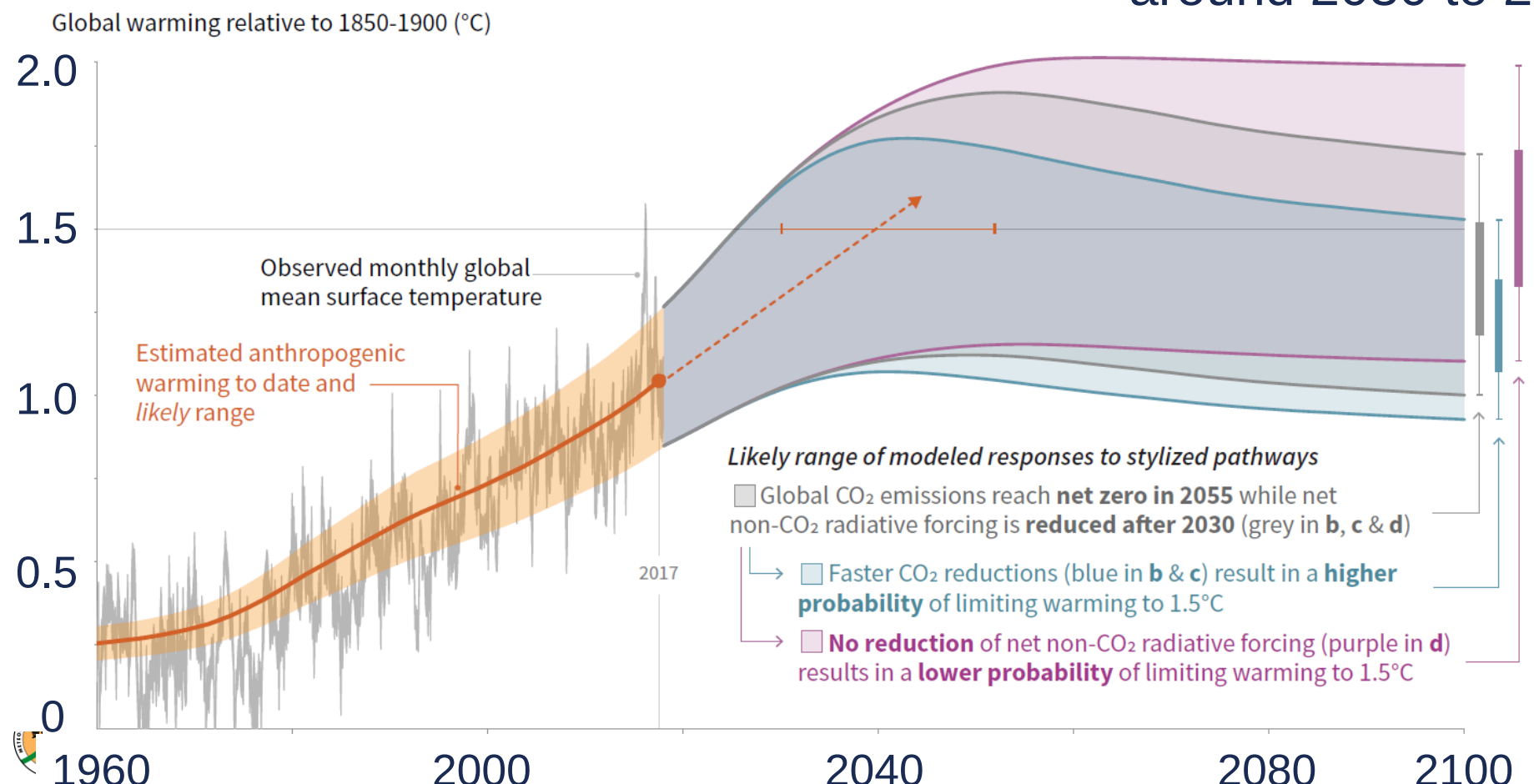




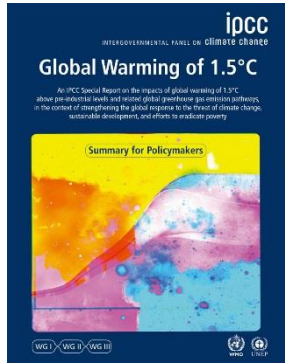
IPCC Special Report on Global Warming of 1.5℃

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

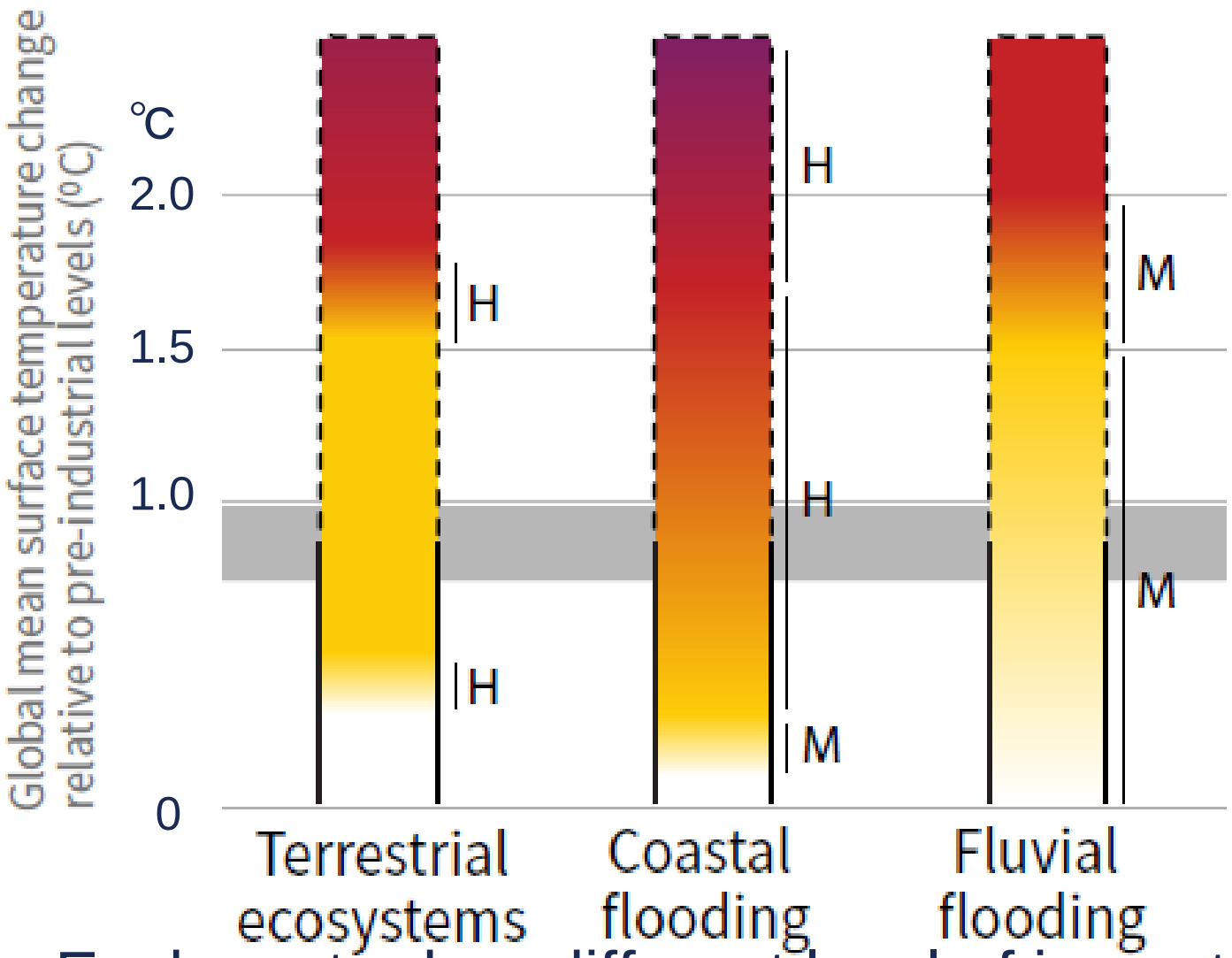
a) Observed global temperature change and modeled responses to stylized anthropogenic emission and forcing pathways

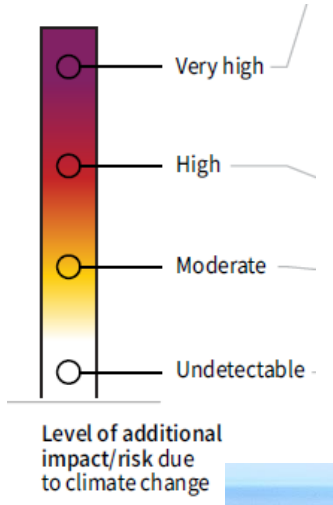


- The current global warming is about 1.0℃
- Global warming will likely reach 1.5℃ around 2030 to 2052.
- 1.5℃ target will be possible if we success the net zero emission in 2055.



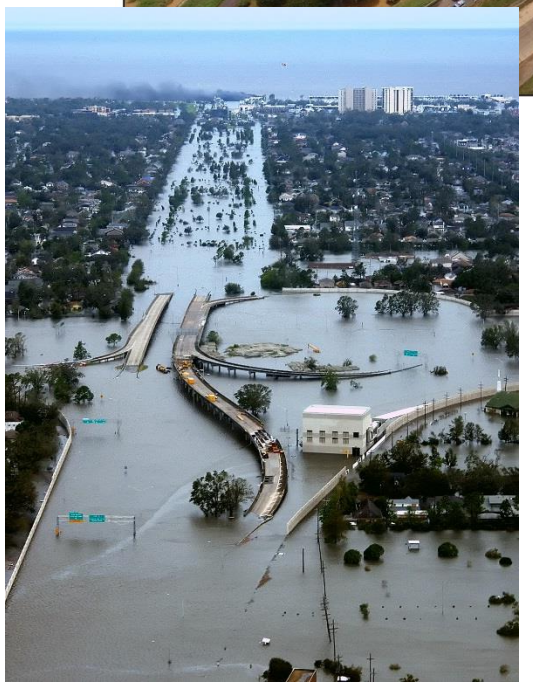
IPCC Special Report on Global Warming of 1.5℃



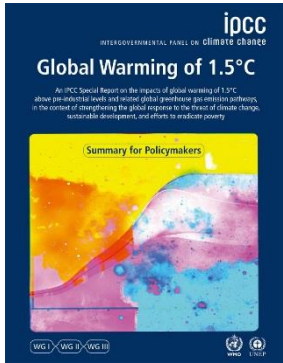


2006-2015

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



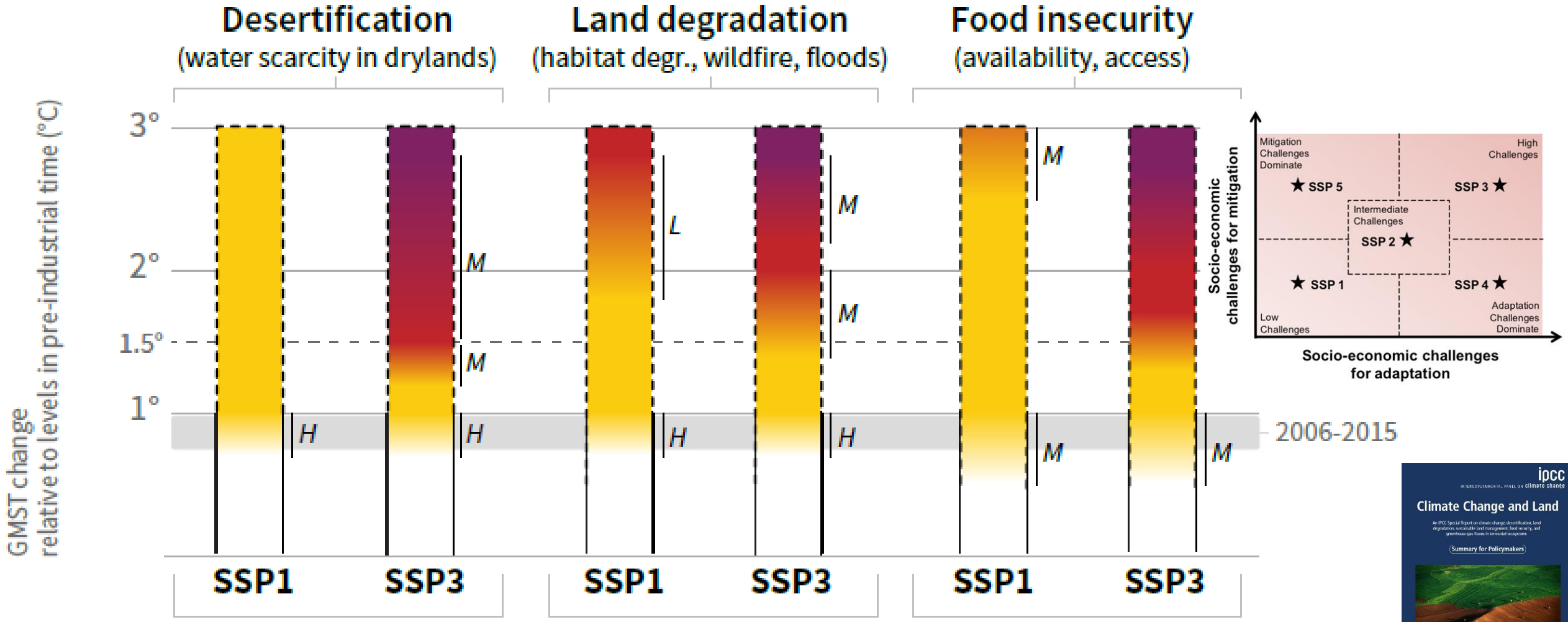
(USGS/Wikipedia, 2005, Katrinam)



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

IPCC Special Report on Climate Change and Land

B. Different socioeconomic pathways affect levels of climate related risks

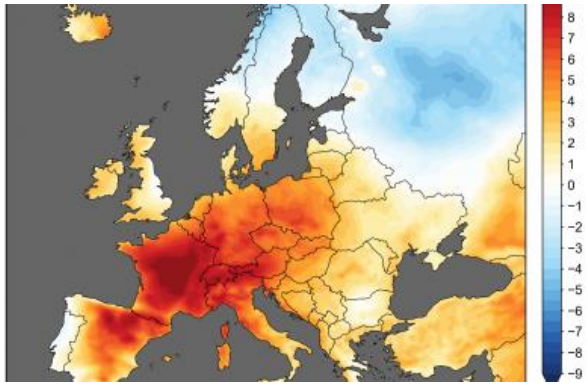


Sustainable vs business as usual

Scientific contents of my today's talk

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
4. Future climate in Panama

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!

Meteorological Research Institute

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!

Meteorological Research Institute

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…

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]**

  % change due to global warming can be quantified for a specific event but change in frequency cannot be discussed as climatology.

- **Probabilistic Qualiative Approach**

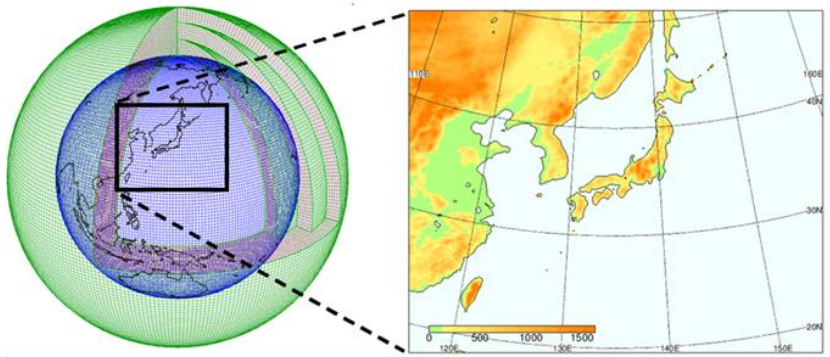
  Analysis of changes in frequency of extremes due to global warming in a huge ensemble simulations with climate models.

  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 identified as climatology but % change due to 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

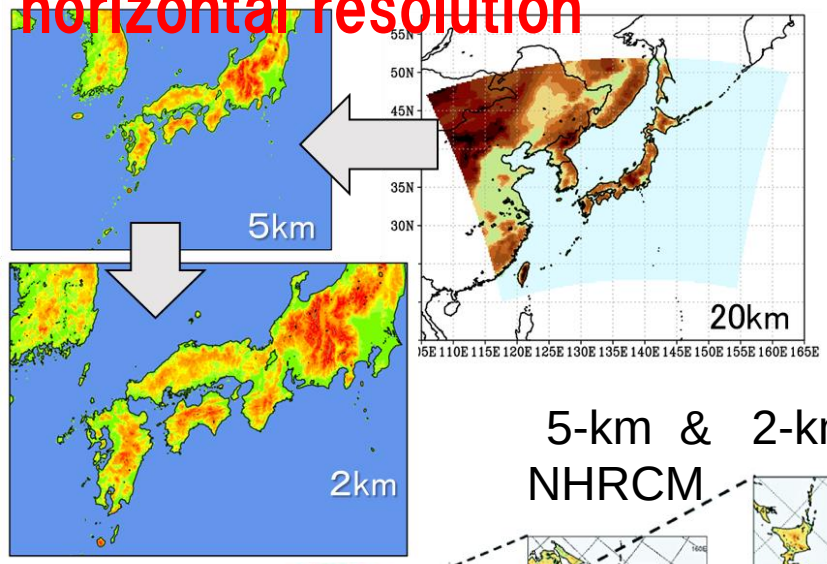
Non-Warming

Present-day

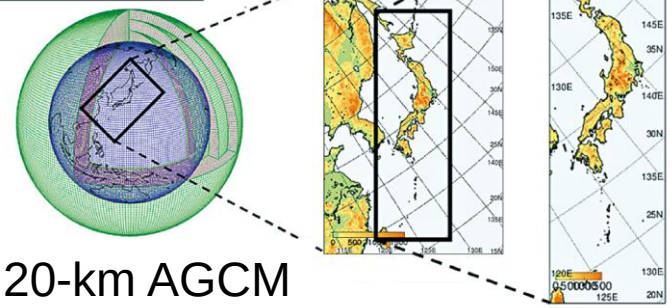
Warming

Complementary

Event-based approach: High horizontal resolution



5-km & 2-km NHRCM



20-km AGCM

- **huge sampling of heavy rainfall ~ 6000-yr equivalent**
- **Autonomous simulation of atmospheric phenomena**

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

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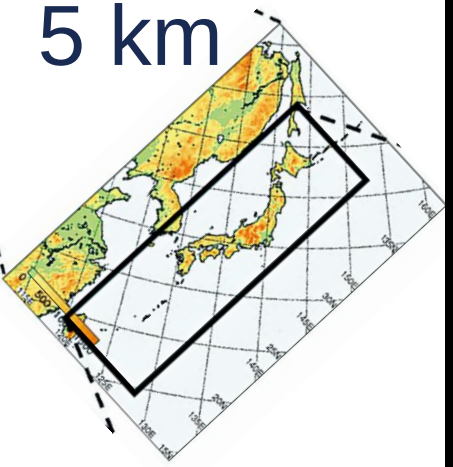
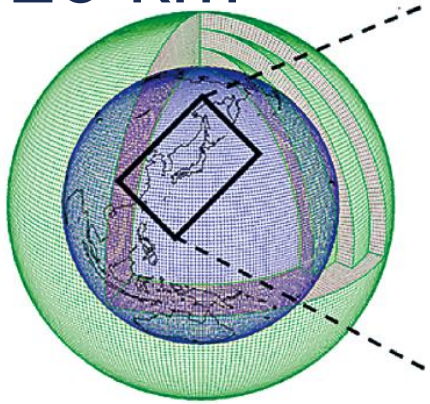
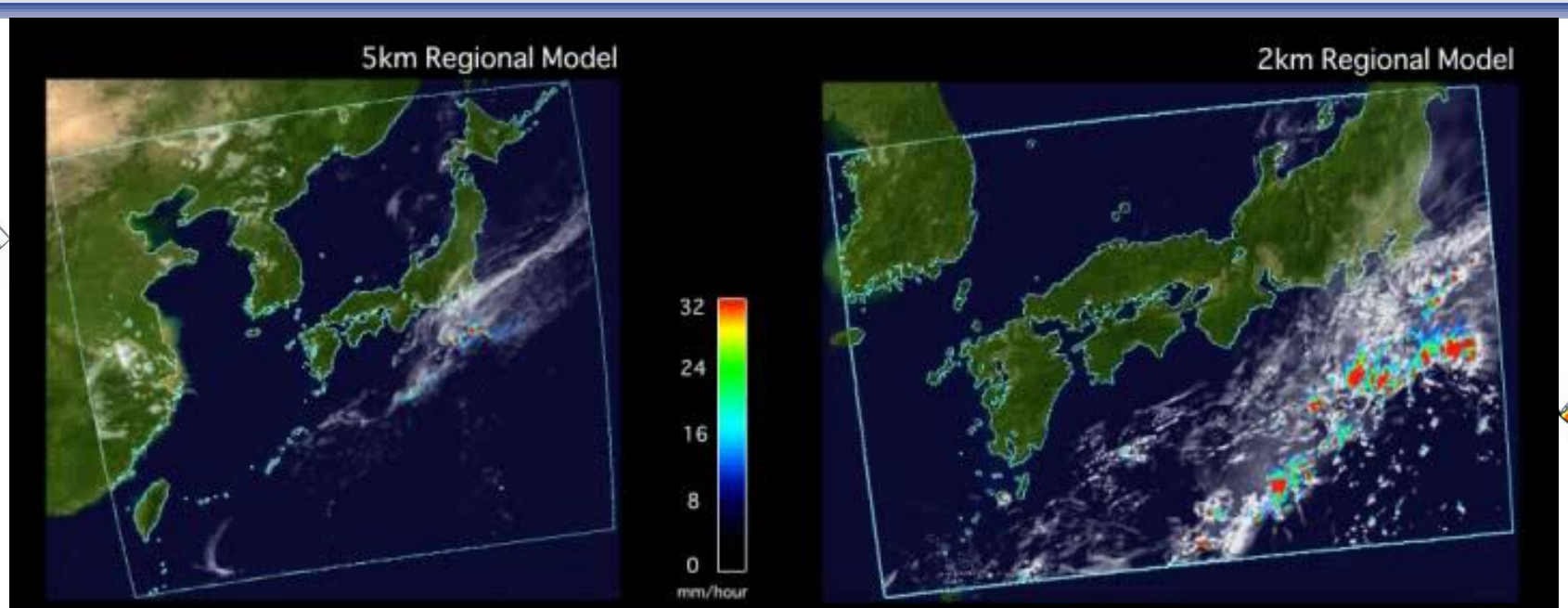
Dynamical downscaling with MRI-AGCM and NHRCM

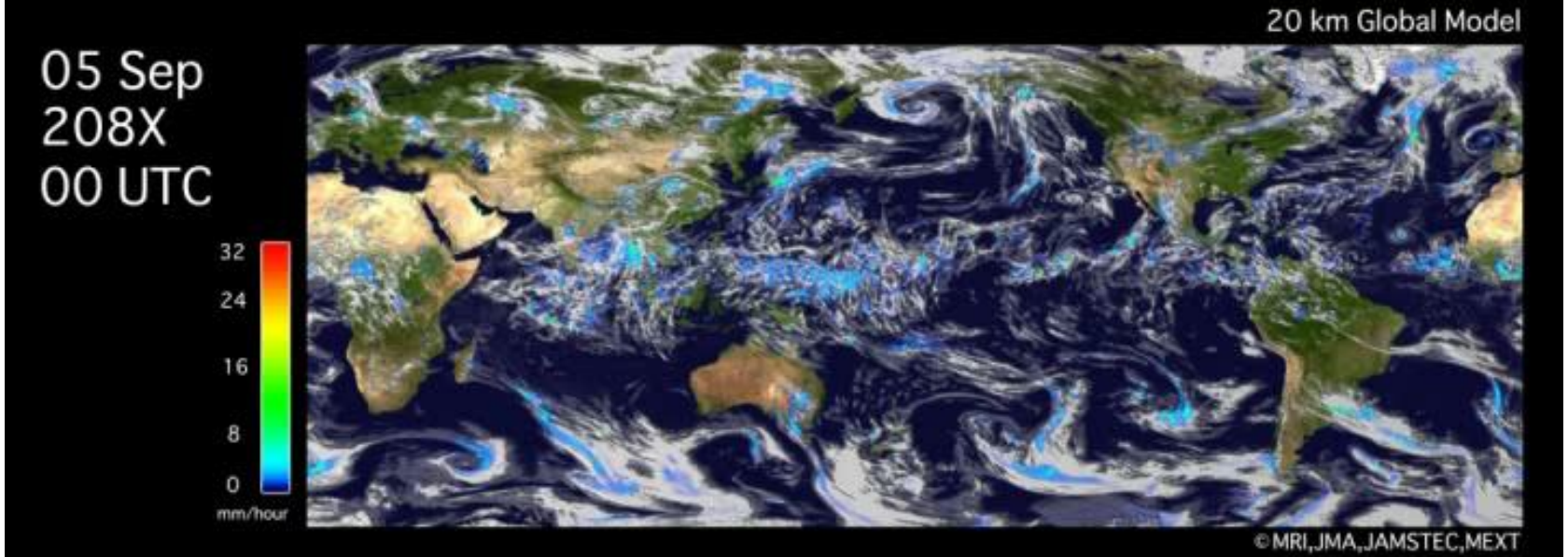
5 km



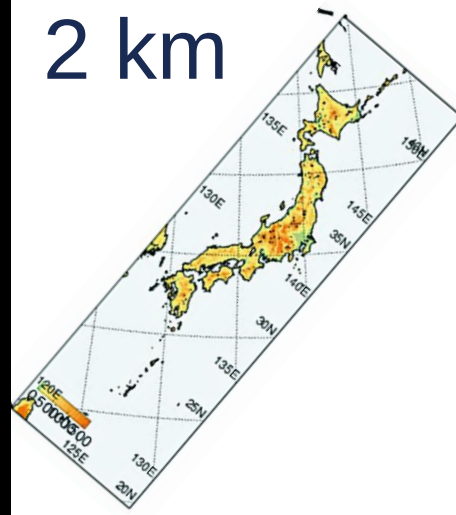
20 km







2 km



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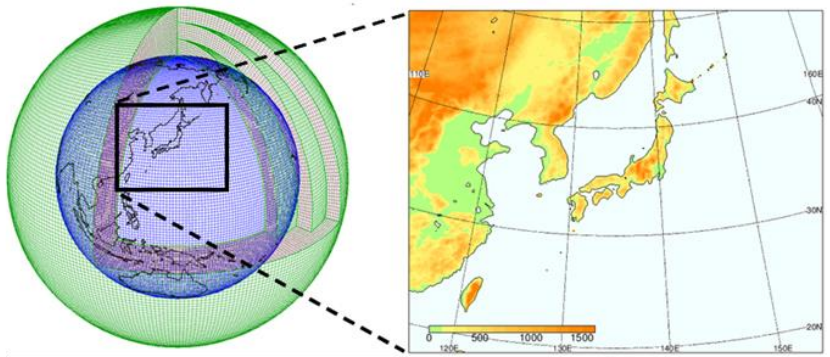
Scientific contents of my today's talk

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

Approach to attributing global warming influences

Probabilistic approach: Large ensemble



60-km AGCM　　20-km NHRCM

d4PDF

A set of experiments

Non-Warming

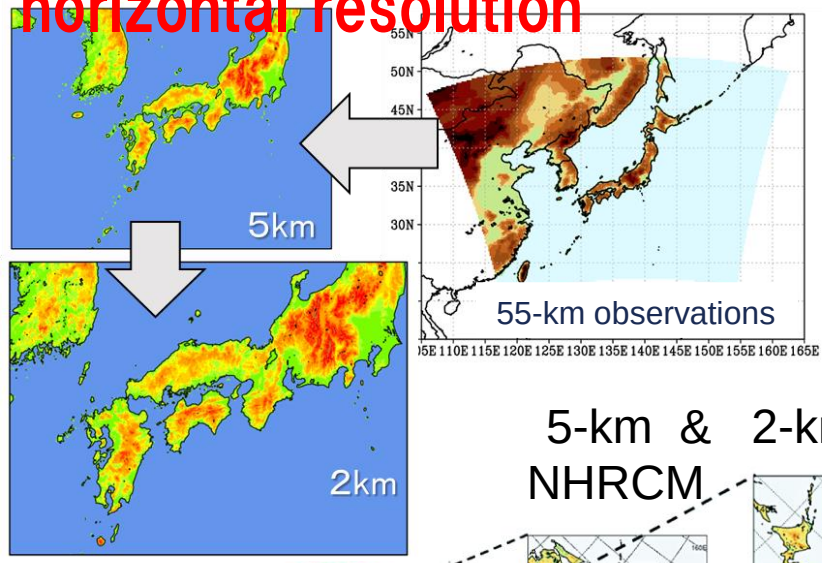
Present-day

Warming

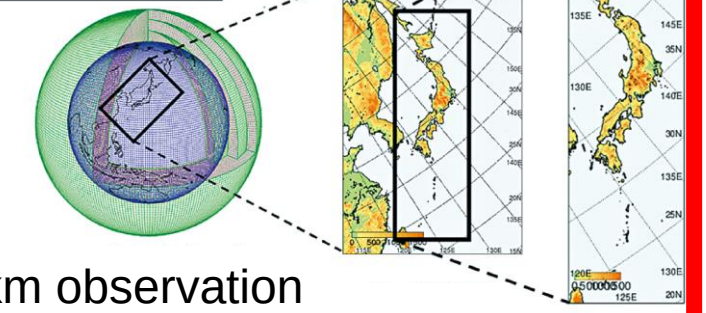
Complementary

- **huge sampling of heavy rainfall ~ 6000-yr equivalent**
- **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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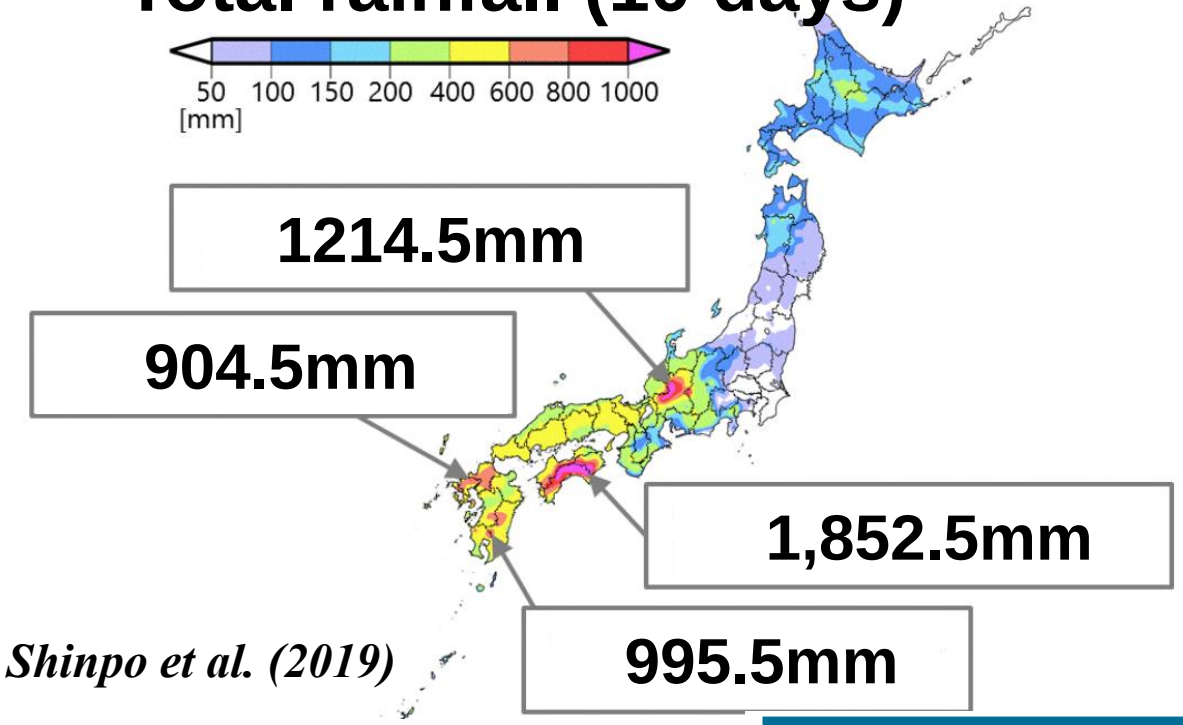
Heavy Rain Event of July 2018 in Japan

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

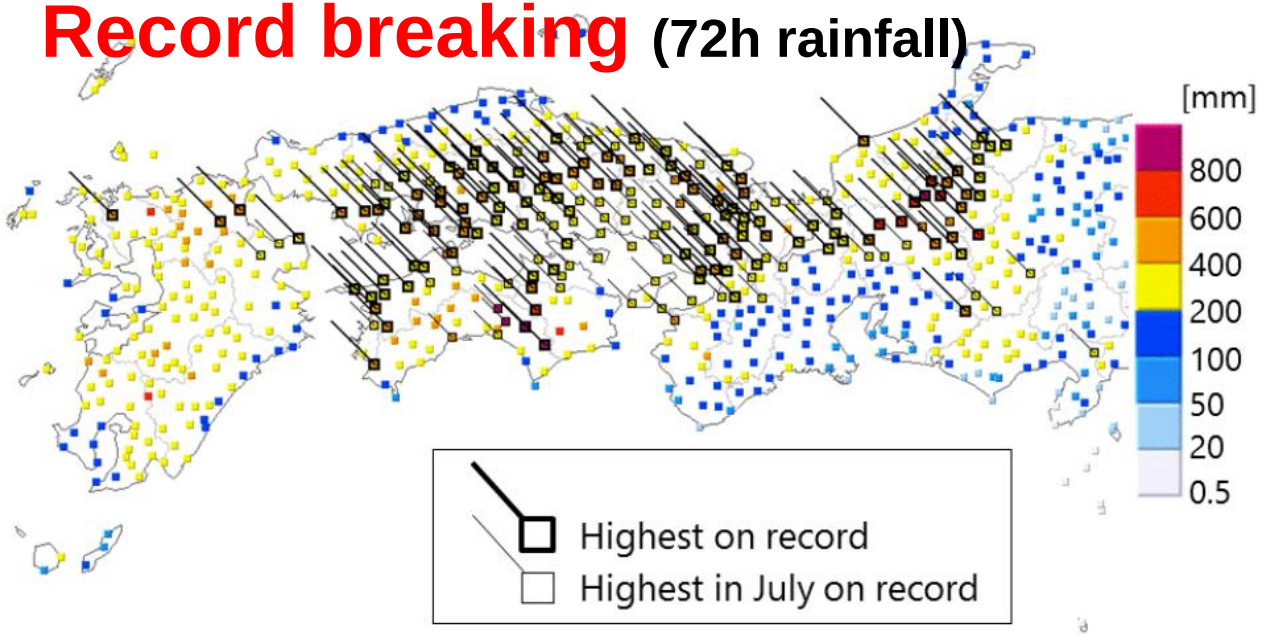
Heavy Rain Event of July 2018 in Japan

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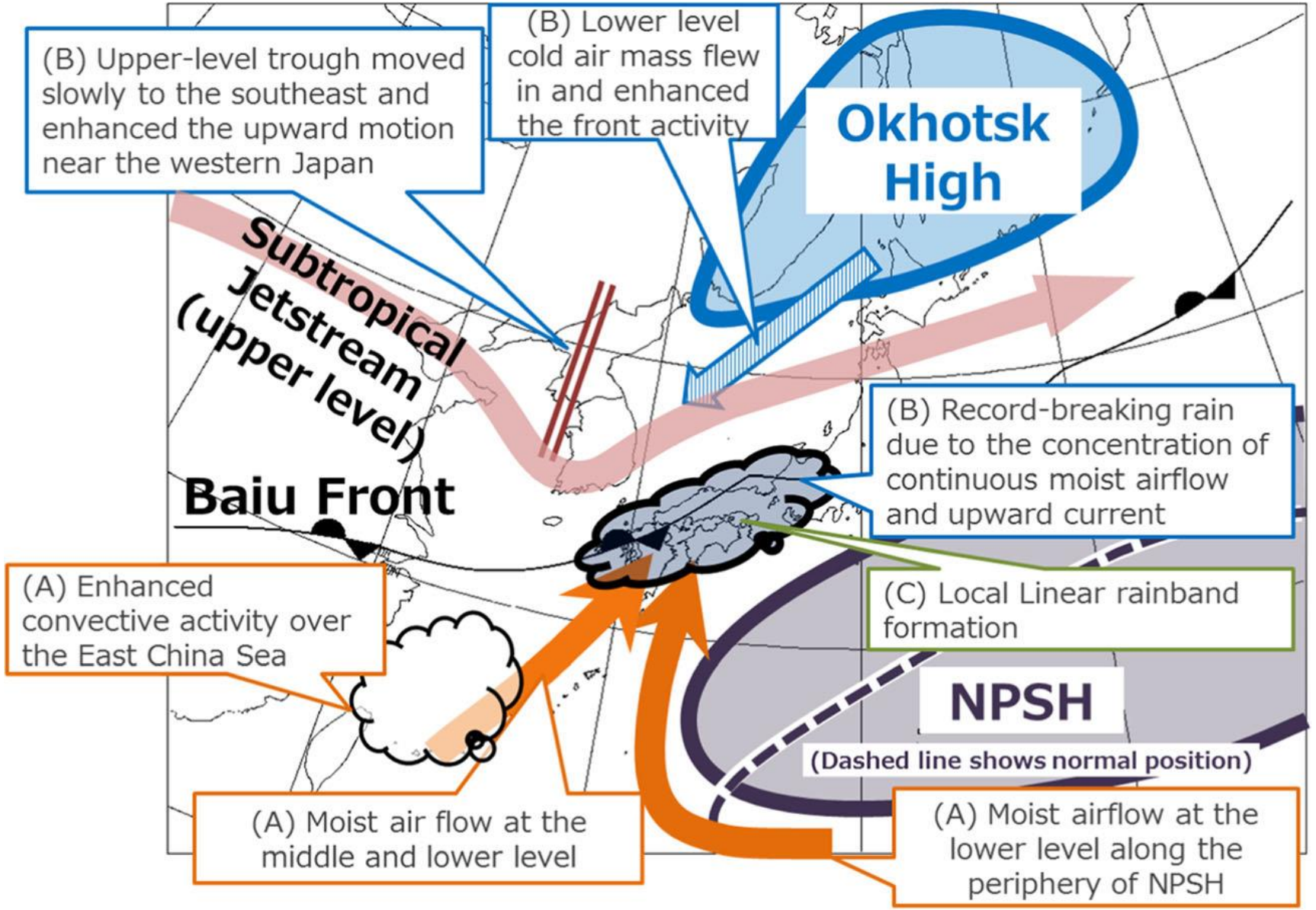
(TCC, JMA, 2018;
Tuguti et al, 2018; Land Slides)

Meteorological overview of heavy rain event of July 2018



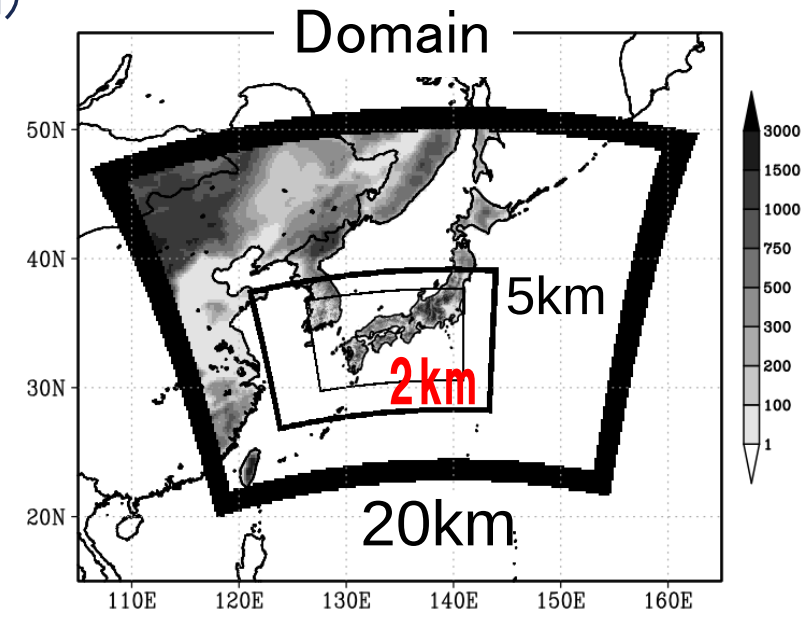
(TCC, JMA, 2018;
Tuguti et al, 2018; Land Slides)

Simulation of the heavy rain event (Current)

Dr. Kawase

- 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

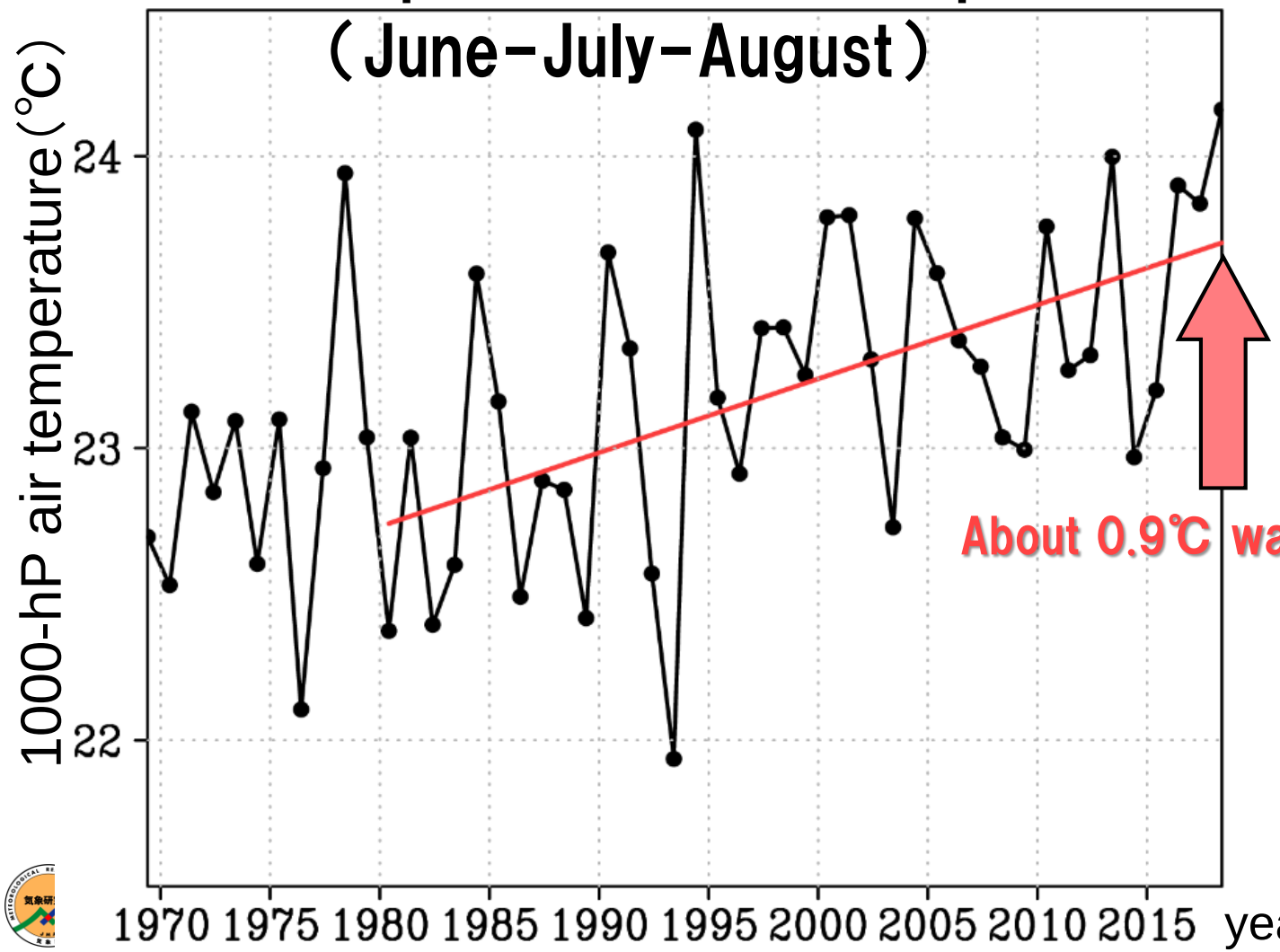
[Convection scheme] Kain and Fritsch (1993) for 20km/5km
[Cloud microphysics] Ikawa et al. (1991) for 20km/5km/2km
[Clear sky radiation] Yabu et al. (2005)
[Cloud radiation] Kitagawa (2000)
[Land surface] Improved MJ-SiB (iSiB) [Hirai and Oh'izumi, 2004]
[Boundary layer] MYNN scheme [Nakanishi and Niino,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

(Kawase et al. 2019, accepted, BAMS)

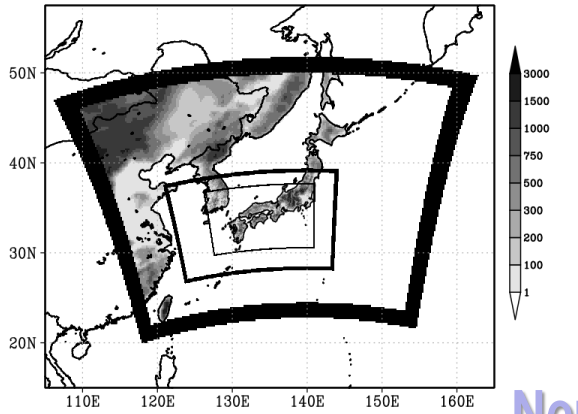
Non-warming experiment (Non-warming)

Dr. Kawase

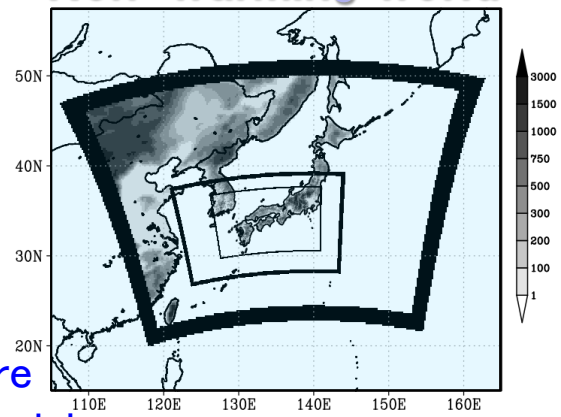
Changes in mean 1000-hPa air temperature around Japan (June-July-August)



Current world



Non-warming world



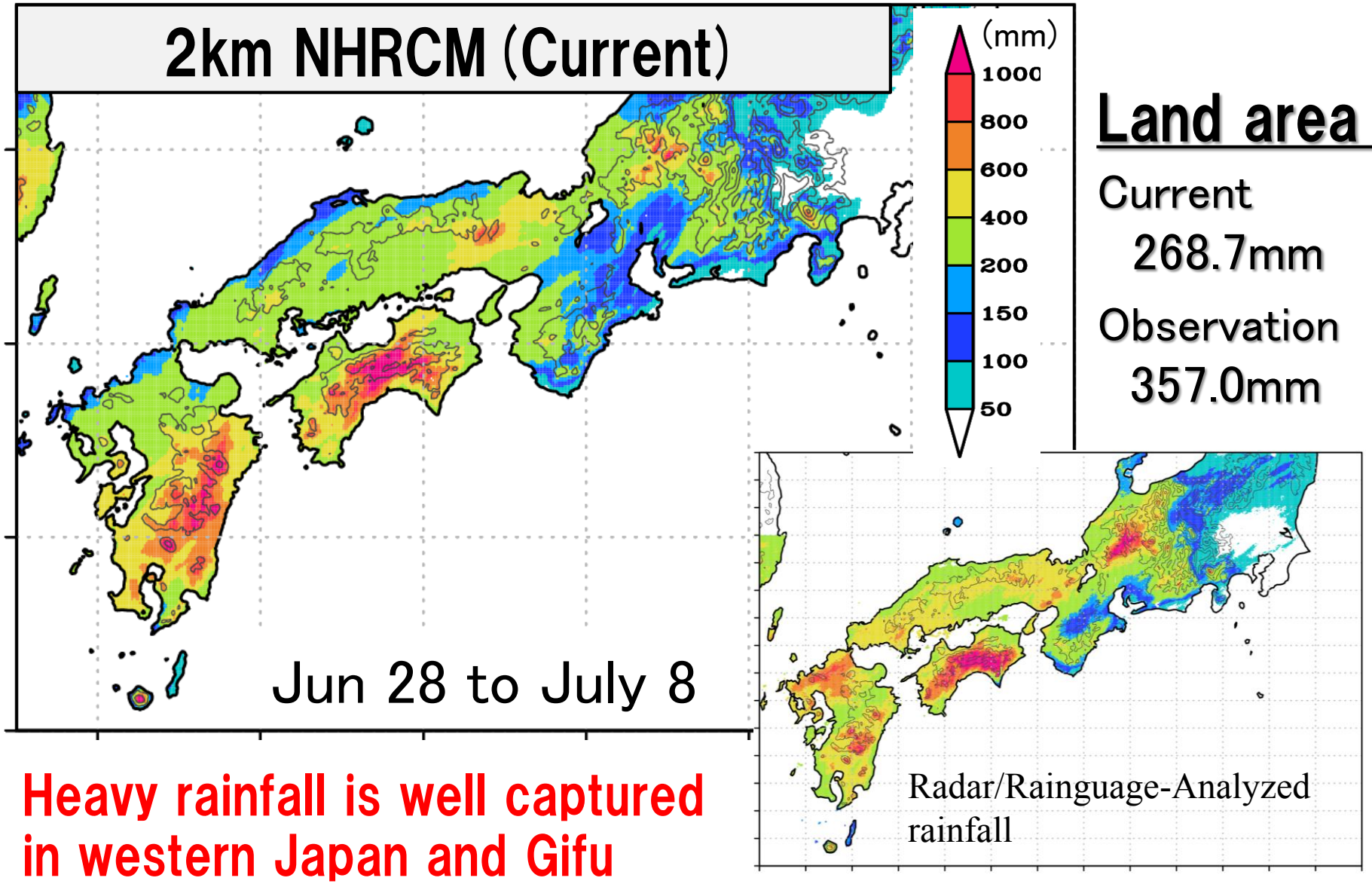
0.9℃ cooling

SST
Air temperature
Geopotential height

(Kawase et al. 2019, accepted, BAMS)

Representation of heavy rainfall with 2km NHRCM (Current)

Dr. Kawase



Land area mean

Current
268.7mm

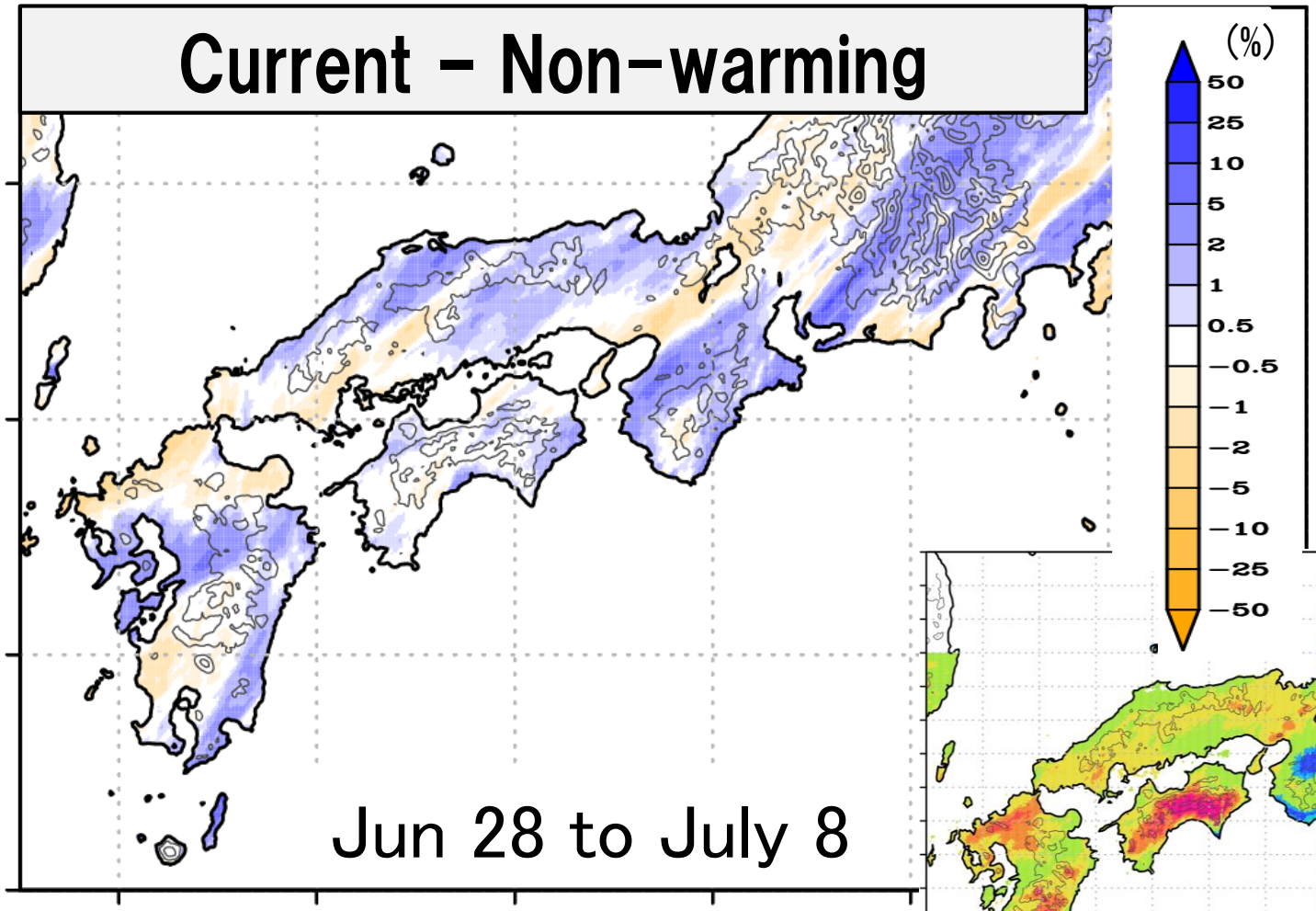
Observation
357.0mm

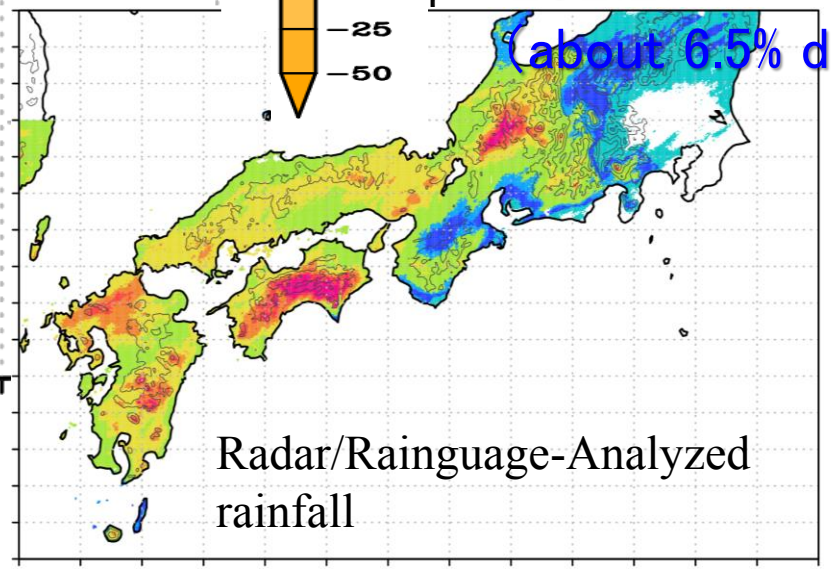
Heavy rainfall is well captured in western Japan and Gifu

(Kawase et al. 2019, accepted, BAMS)

Differences between current and non-warming

Dr. Kawase





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

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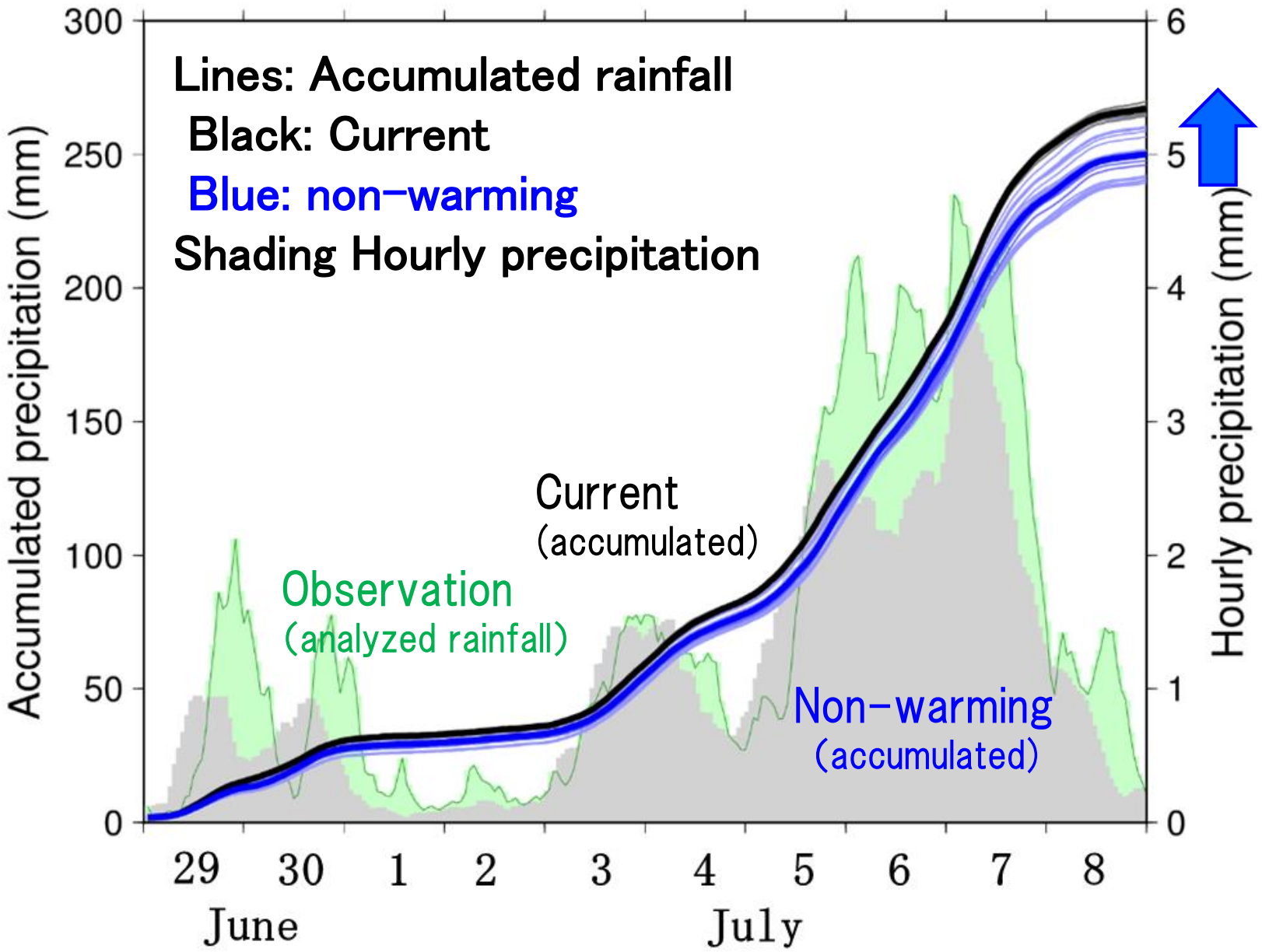
(Kawase et al. 2019, accepted, BAMS)

Time series of regional-mean hourly and accumulated rainfall



Dr. Kawase

Influence of recent warming

About 6.5% increase

(+2.7 to +10.7 %)

Thermodynamical effect explains this increase.

(Kawase et al. 2019, accepted, 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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     - Probabilistic approach by Drs. Kawase and Imada
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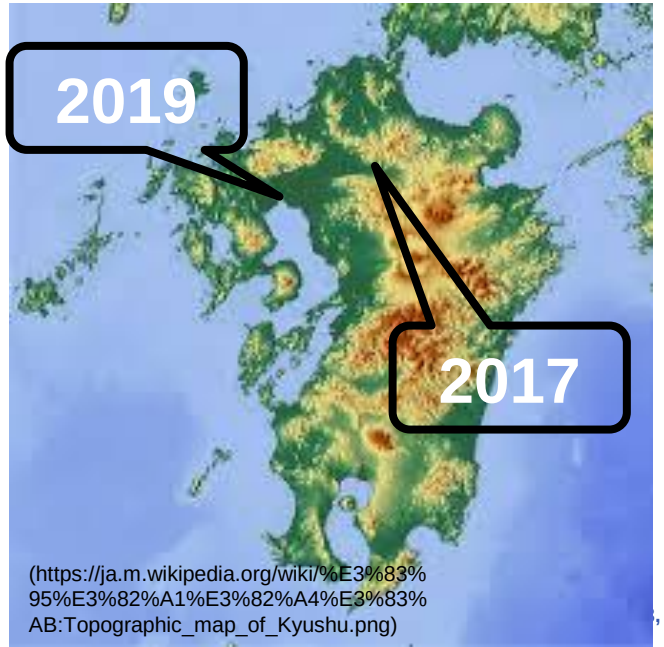
   - Uncertainty in future climate projections
4. Future climate in Panama

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

(Geospatial Information Authority of Japan)

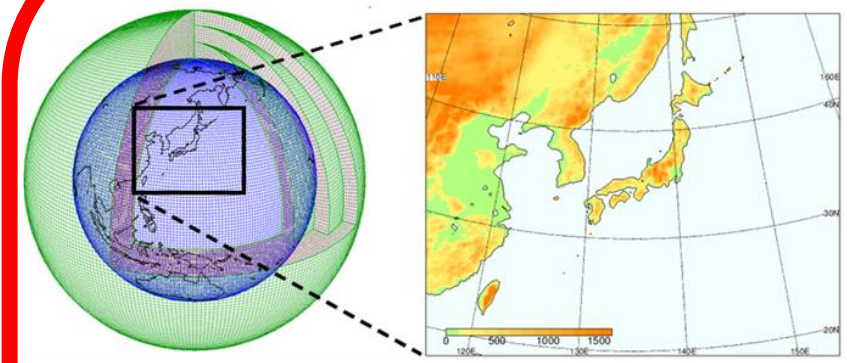


(https://ja.m.wikipedia.org/wiki/%E3%83%95%E3%82%A1%E3%82%A4%E3%83%AB:Topographic_map_of_Kyushu.png)

(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

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

A set of experiments

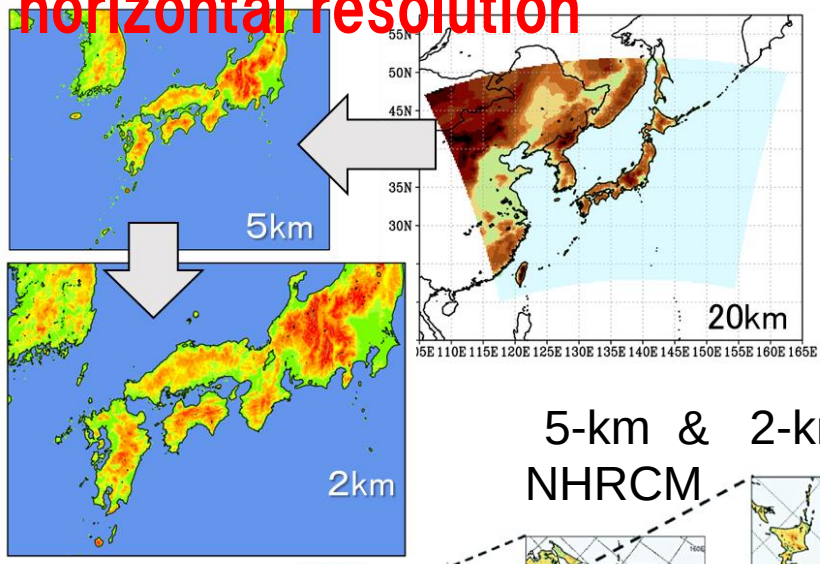
Non-Warming

Present-day

Warming

Complementary

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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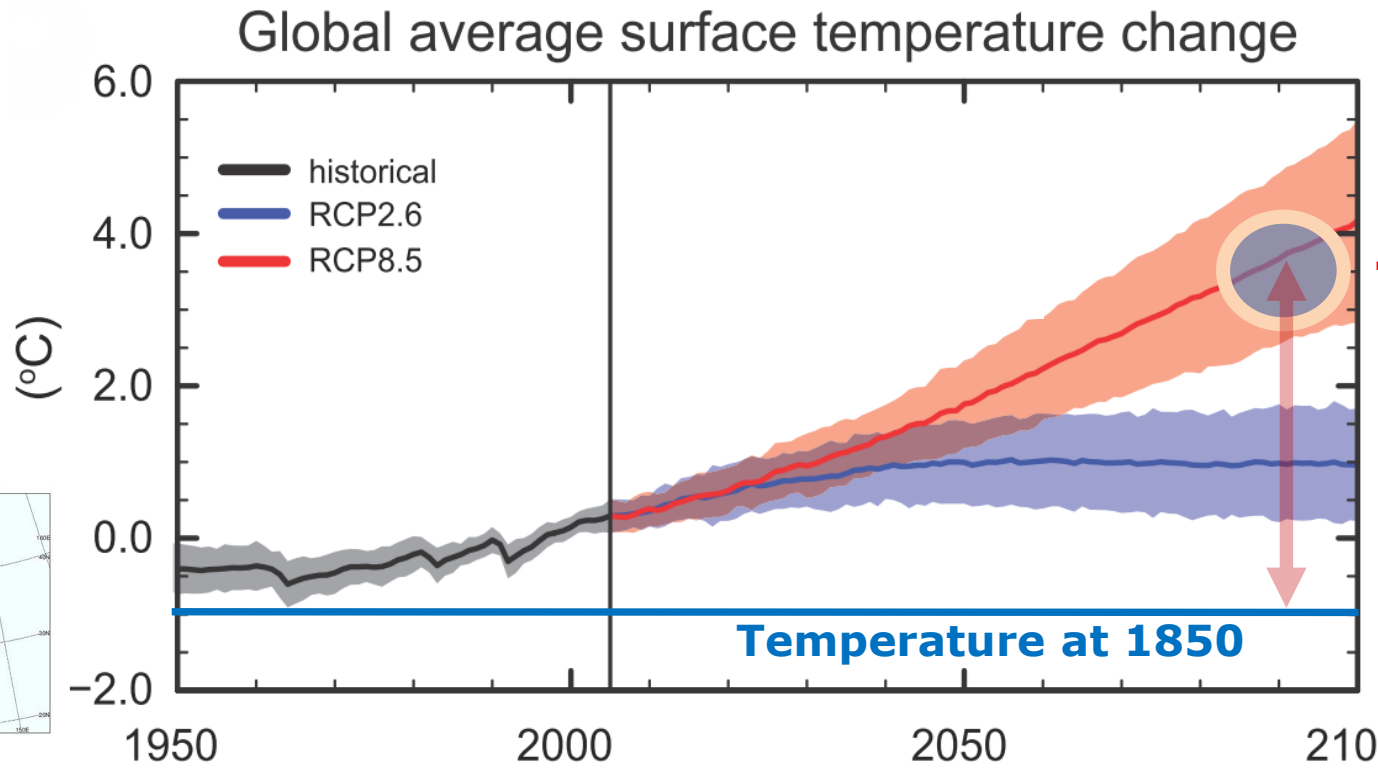
database for Policy Decision making for Future climate change

TOUGOU

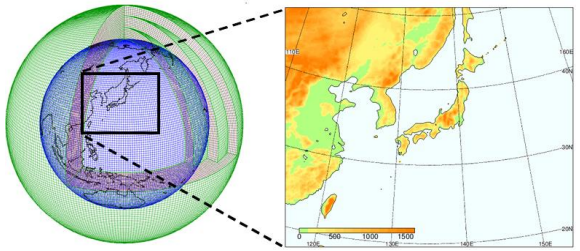
Themes A-C collaboration

Dr. Kawase



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

Meteorological Research Institute

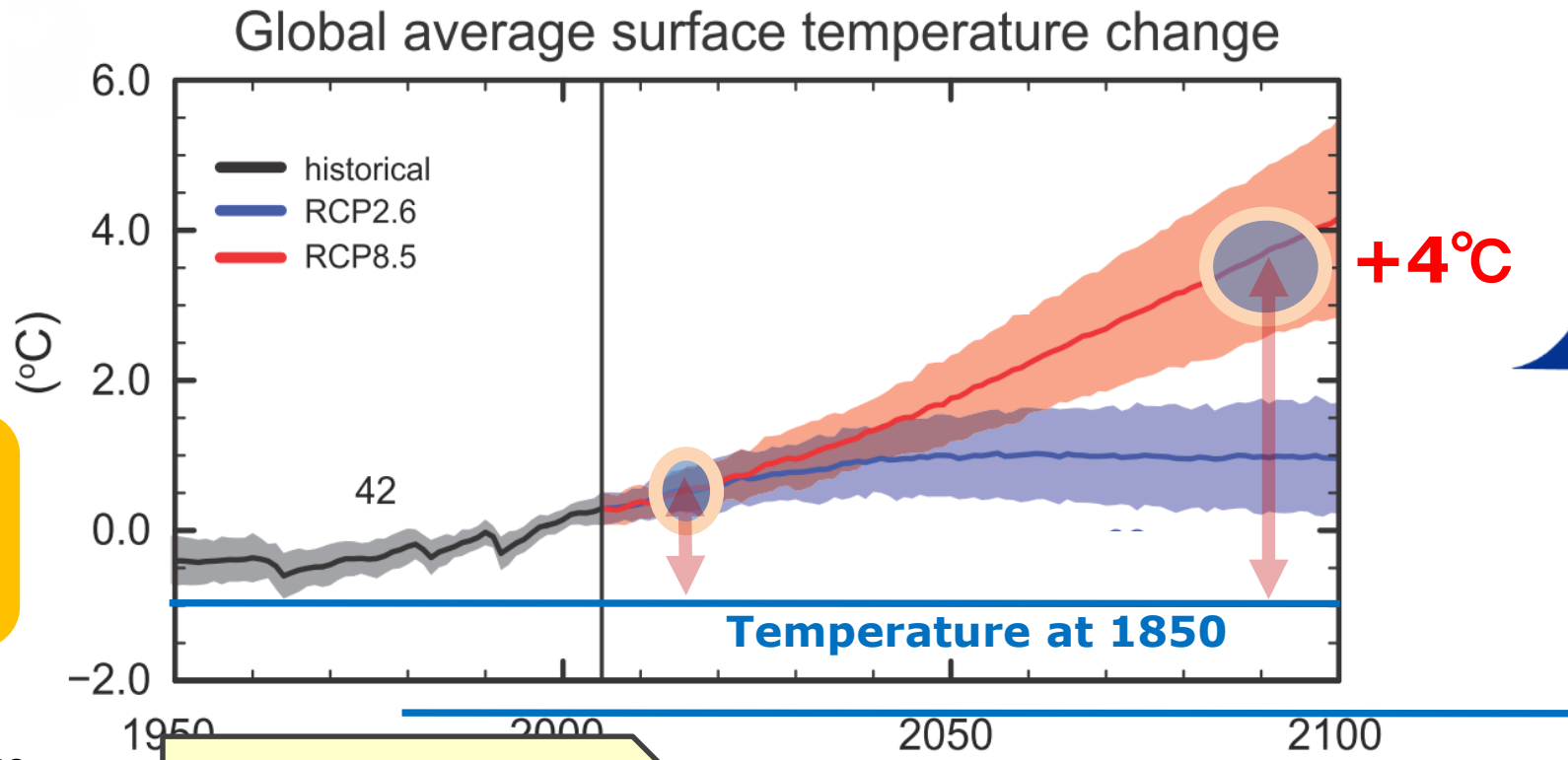
database for Policy Decision making for Future climate change

TOUGOU
Themes A-C collaboration

Dr. Kawase

Expansion of d4PDF

- 100 members
- non-warming
- to ~ 2018



d4PDF
(Mizuta et al. 2016, BAMS)

60km AGCM

100members
Non-warming 100

20km NHRCM for Japan

100members
Non-warming 100

90members
(6ΔT×15δT)

90members

60years

historical
68years

1951 ⟷ 2018

4℃ Global Warming

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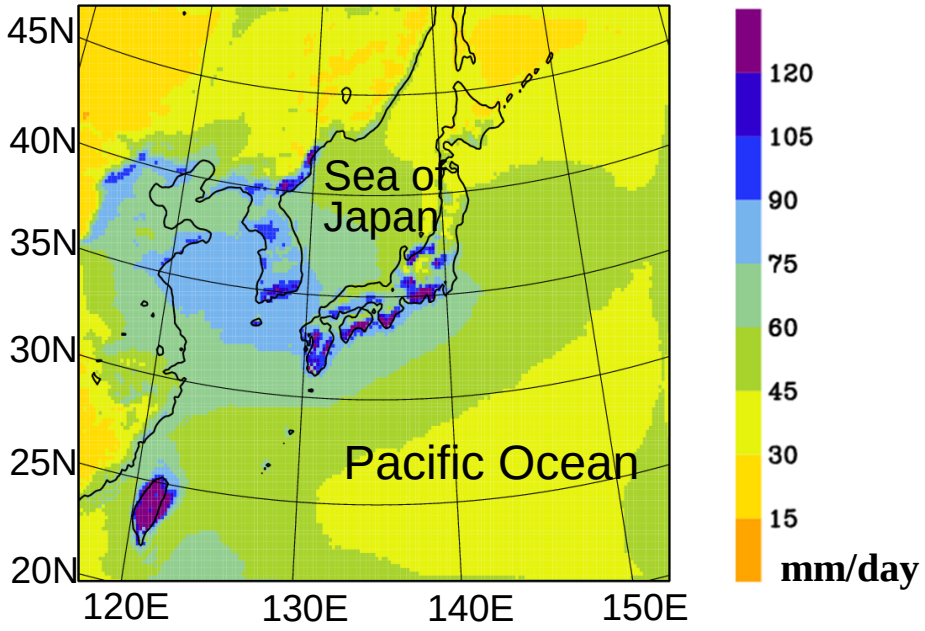
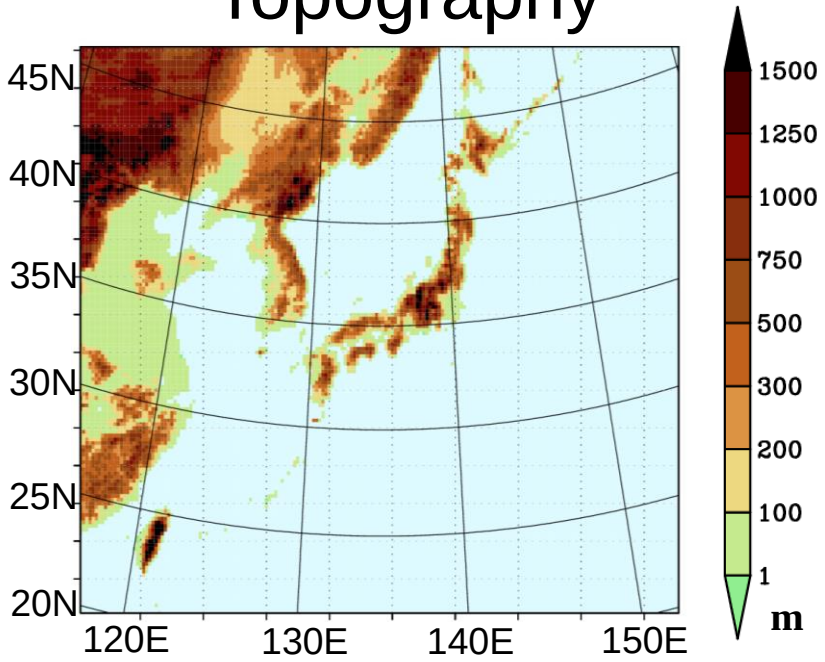
Extreme daily rainfall in July (all members in NHRCM)

Dr. Kawase

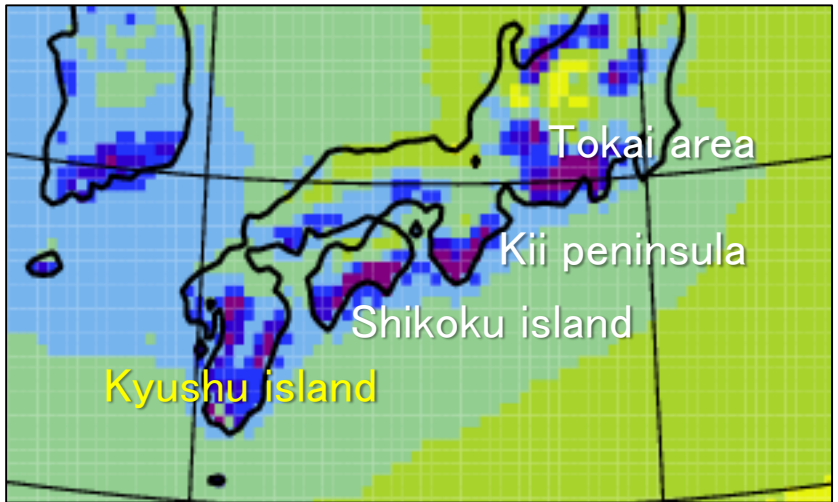
95%ile daily rainfall (Current)

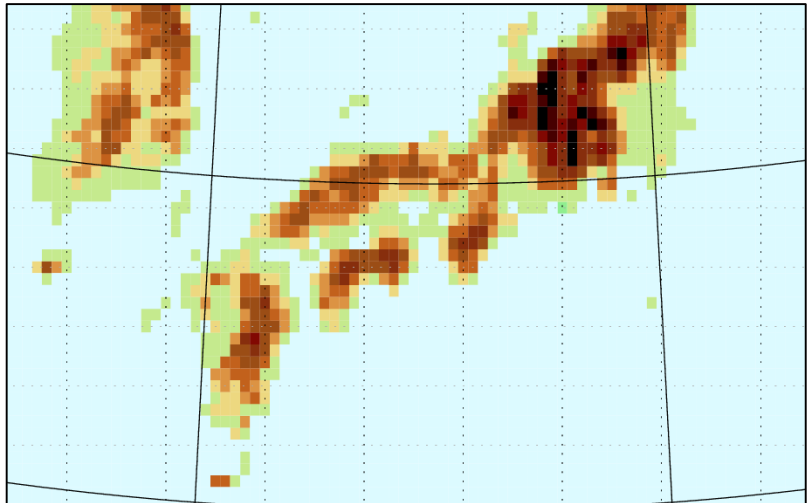


Topography



Current: current simulation,
NonW: non-warming simulation





(Kawase et al, 2019; JGR)

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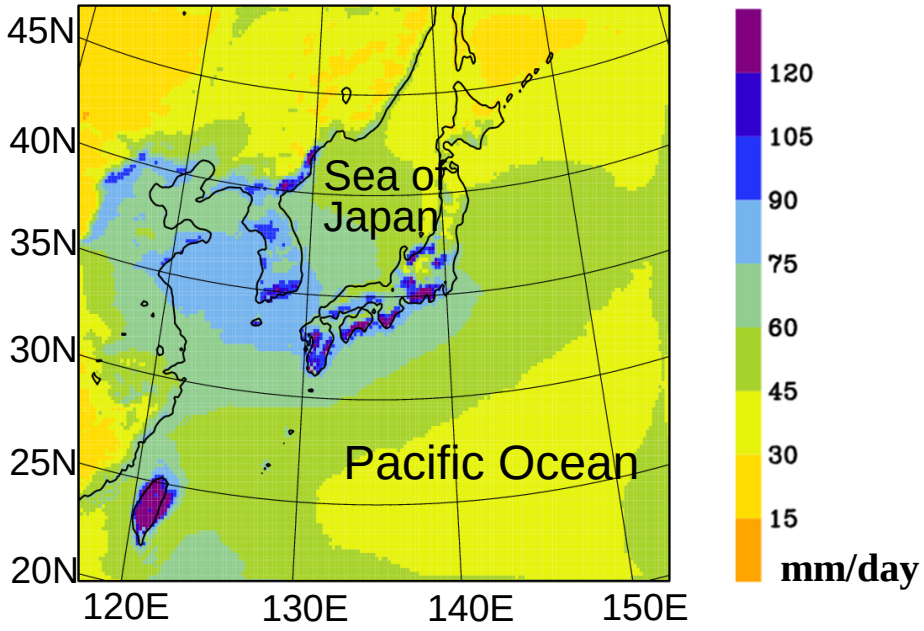
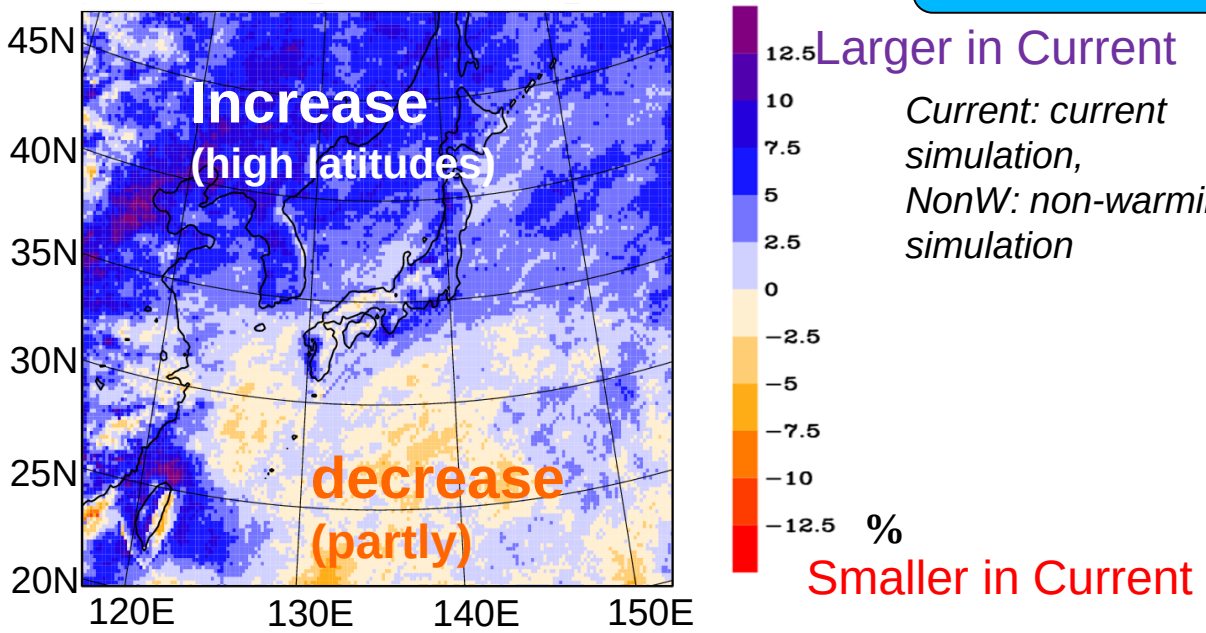
Extreme daily rainfall in July (all members in NHRCM)

Dr. Kawase

95%ile daily rainfall (Current)



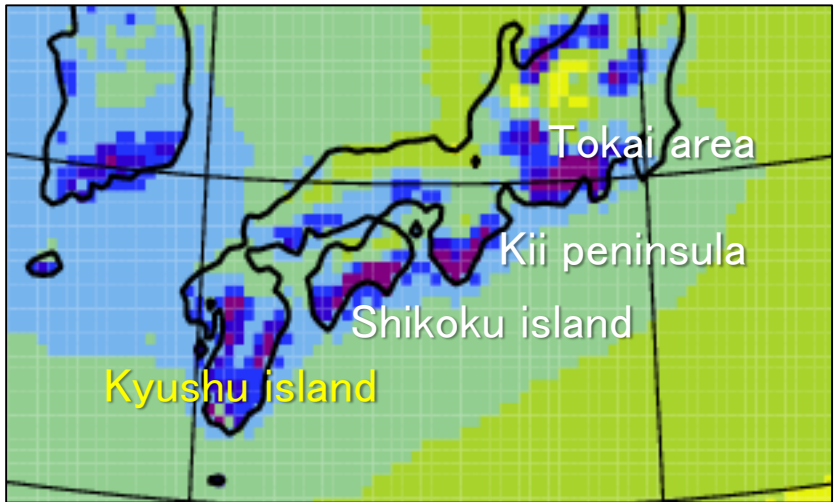
(Current-NonW)/Current

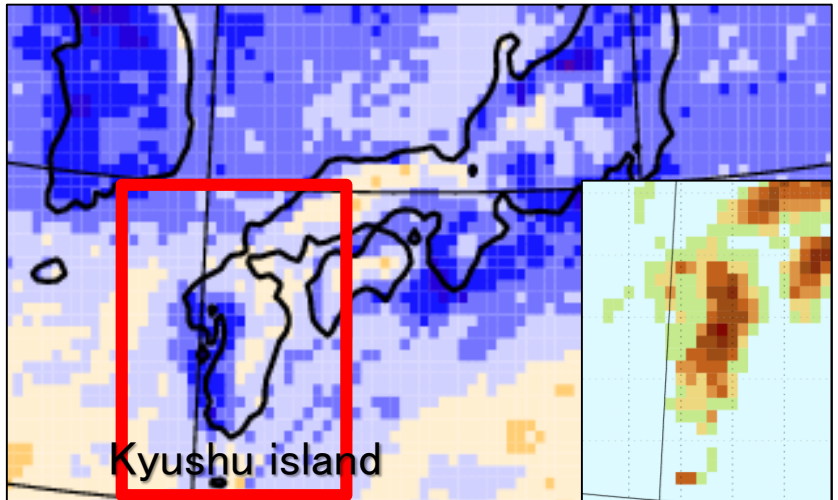


Larger in Current

Current: current simulation, NonW: non-warming simulation

Smaller in Current





(Kawase et al, 2019; JGR)

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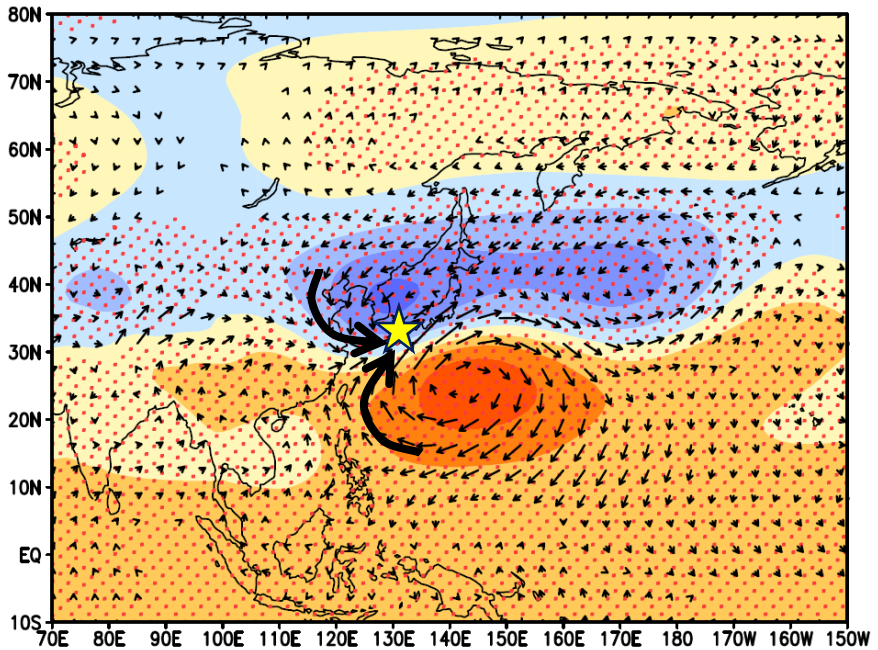
Correlation between heavy rainfall days in RCM atmospheric circulation (qV, Z) at 850hPa in GCM

Dr. Kawase

Western Kyushu

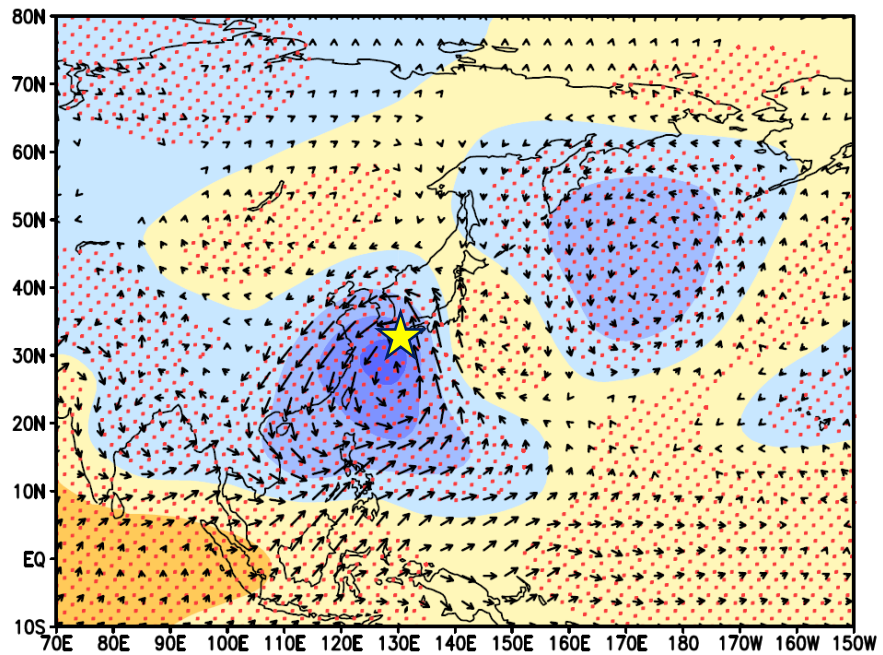


Shading: Z850, vector: qV850 → 1 [1981-2010]

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??)

(Kawase et al, 2019; JGR)

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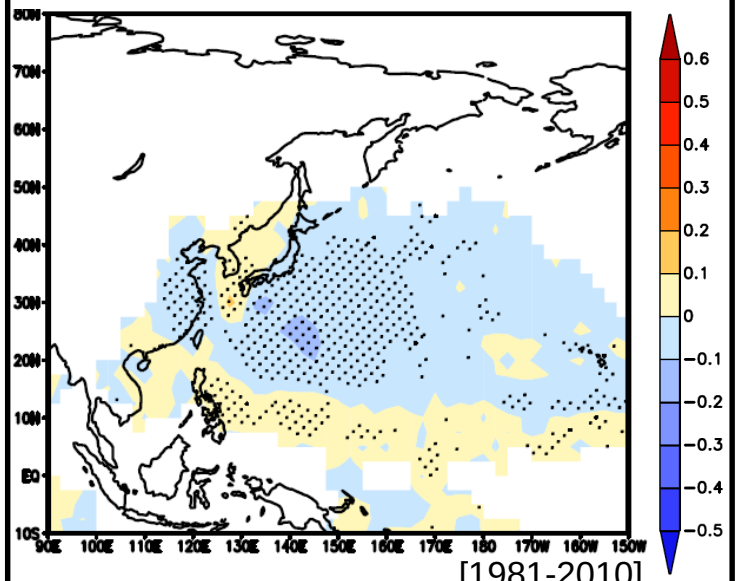
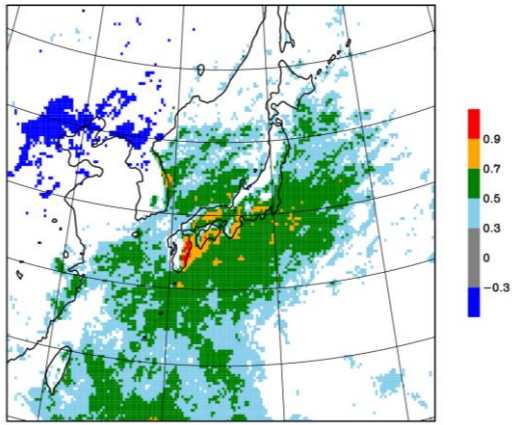
Correlation between heavy rainfall days and typhoon density

Western Kyushu



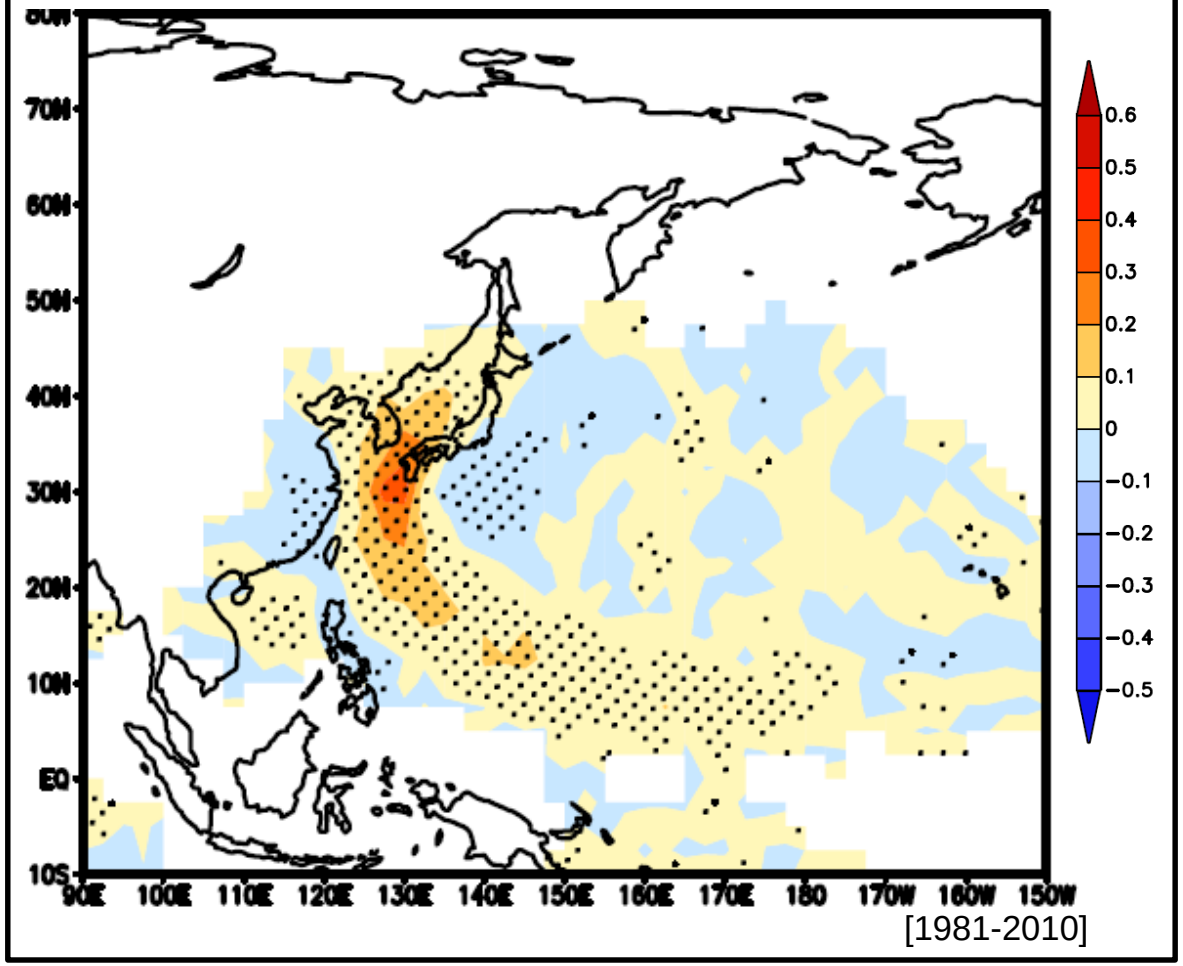
[1981-2010]

No or small negative correlation with typhoon density



=

Eastern Kyushu



[1981-2010]

Dr. Kawase

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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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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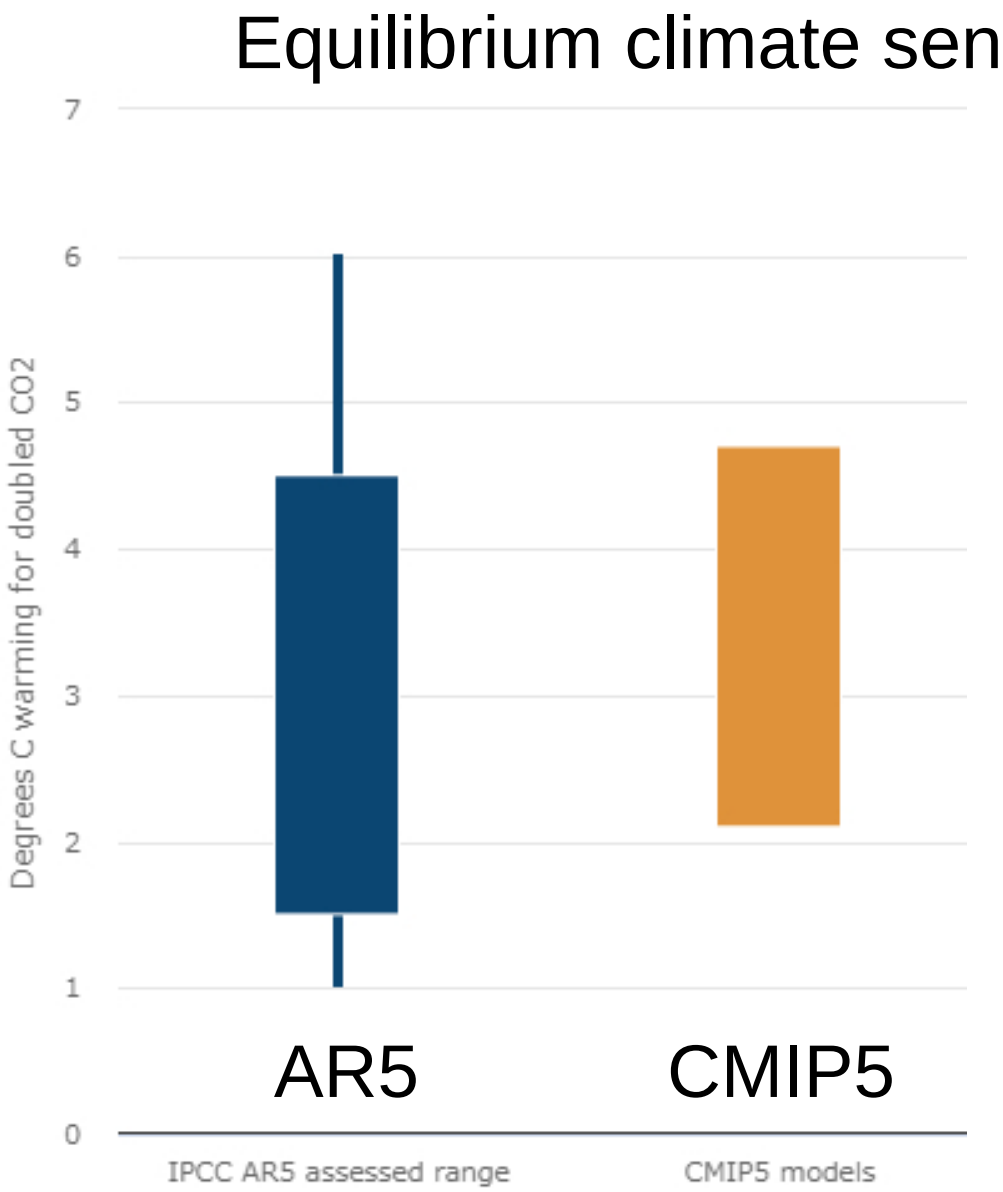
High climate sensitivity in CMIP6 models



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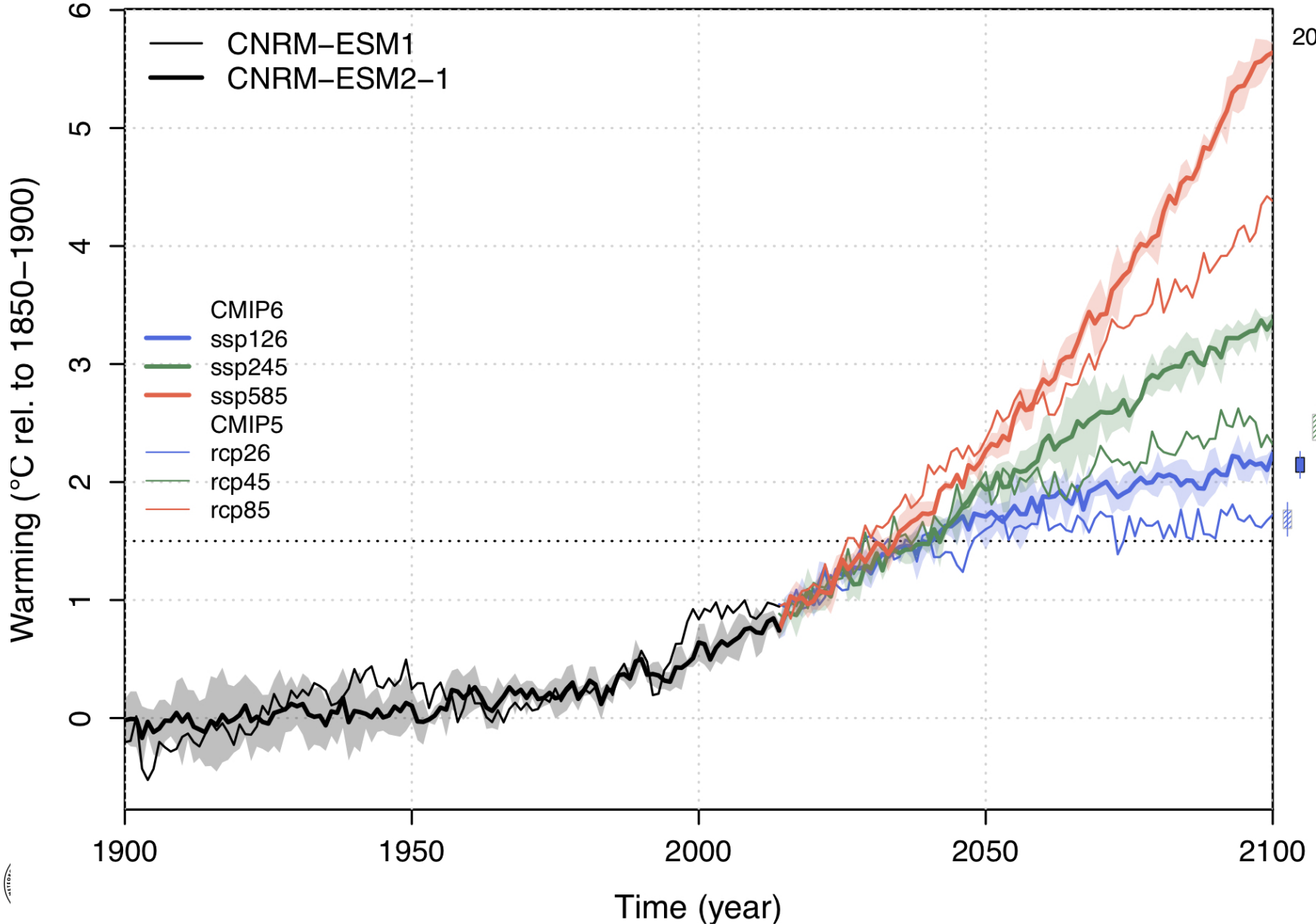
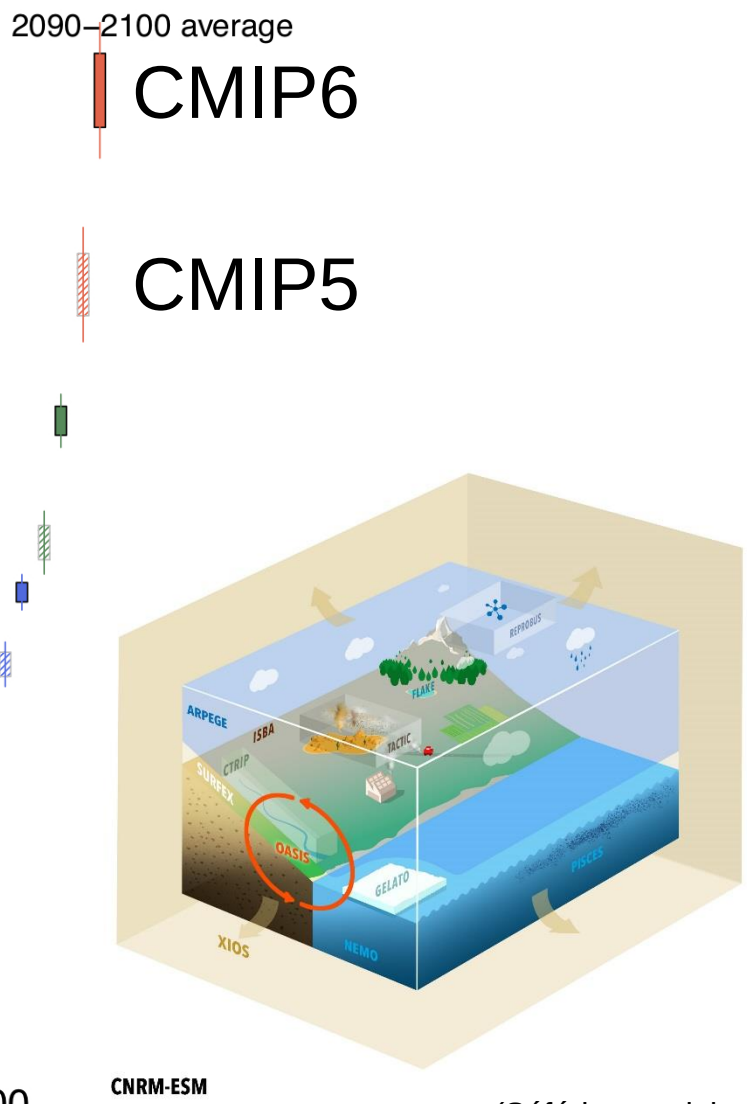
High climate sensitivity in CMIP6 models





(Séférian et al. in prep.)

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

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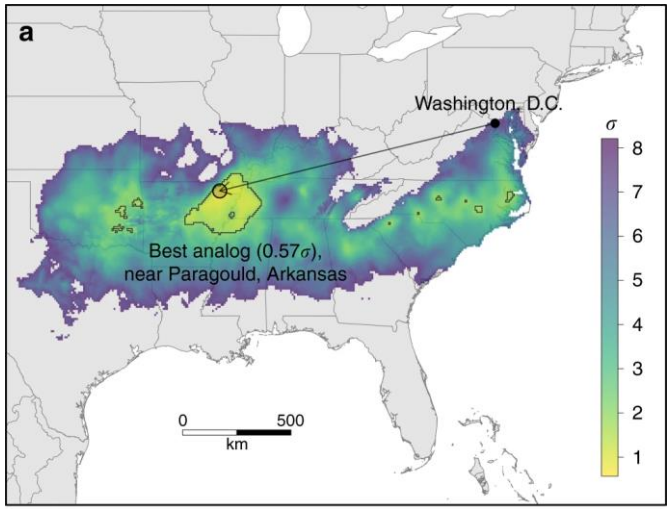
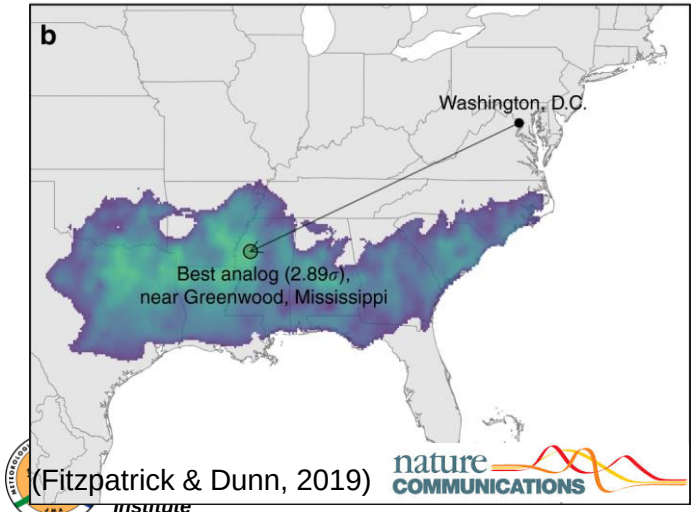
How can you tell a future climate to public?

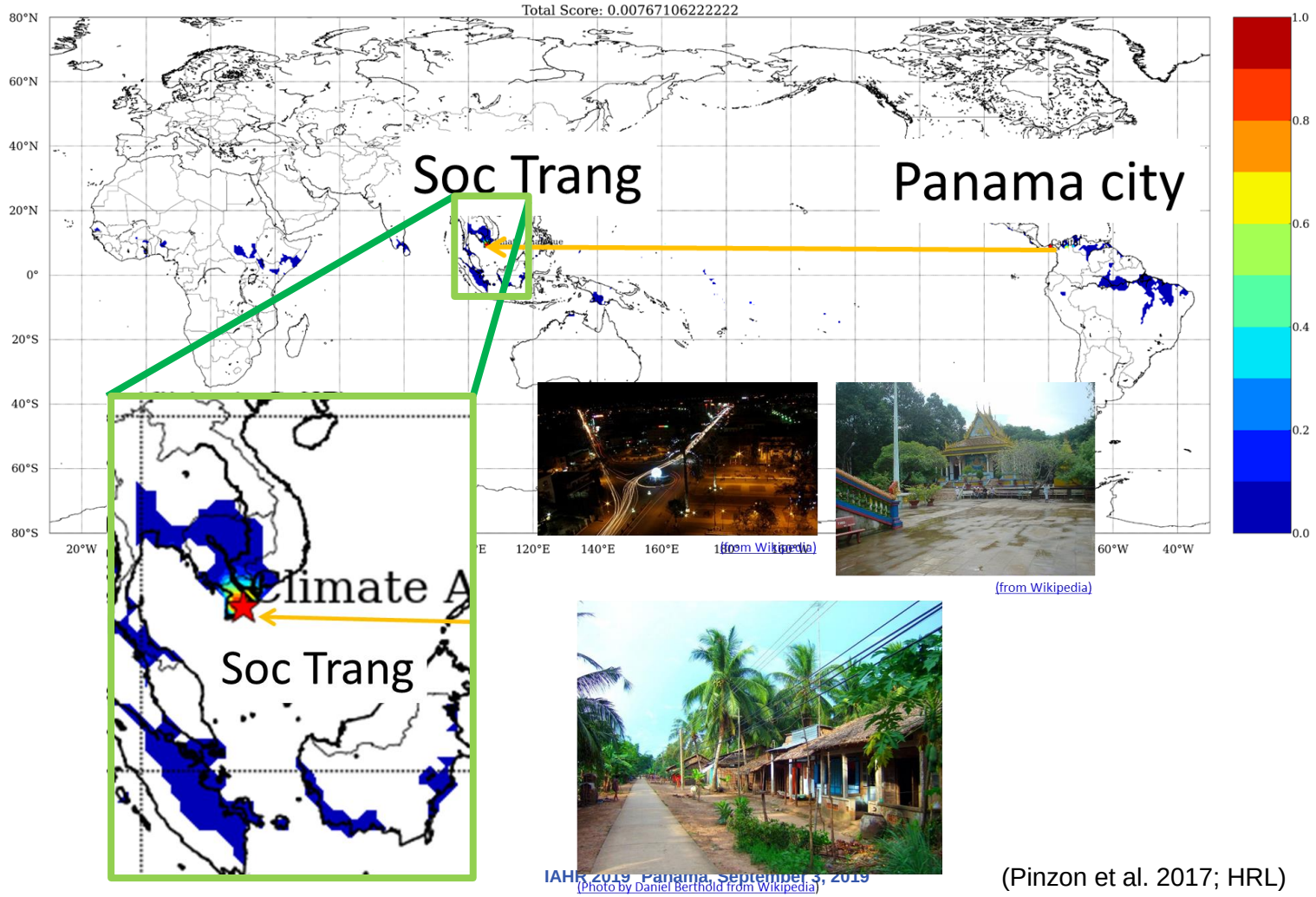
Dr. Pinzon

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





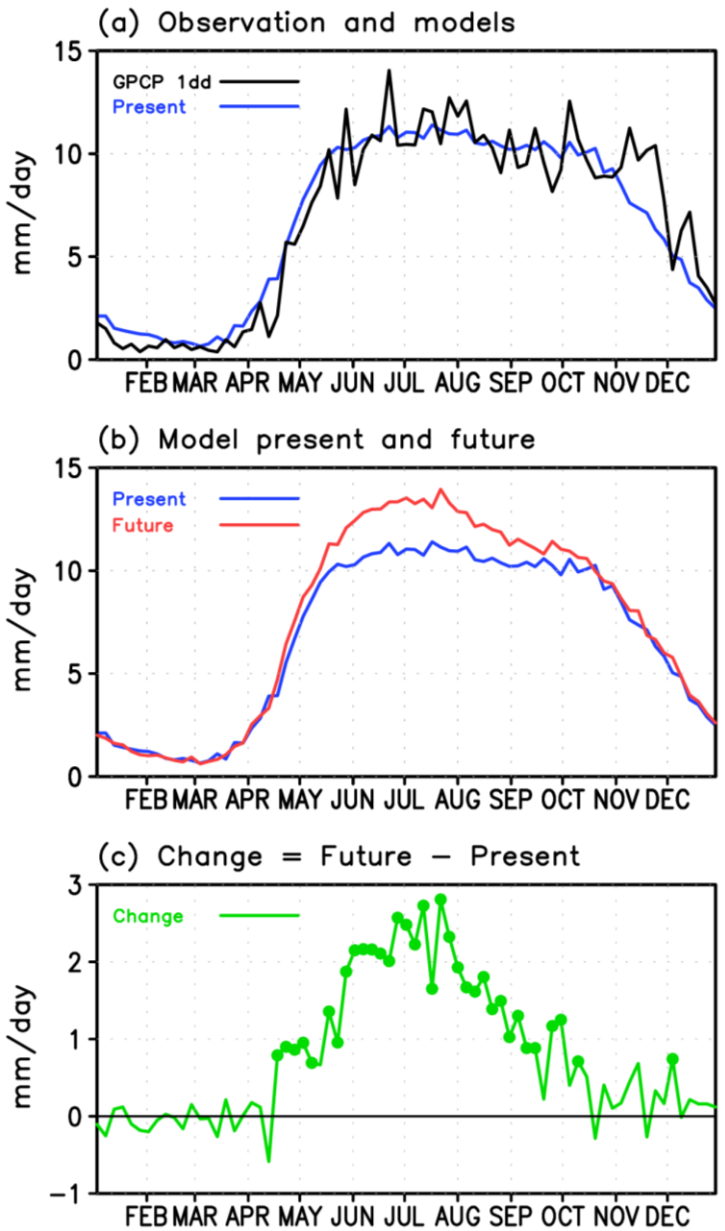
(Fitzpatrick & Dunn, 2019)



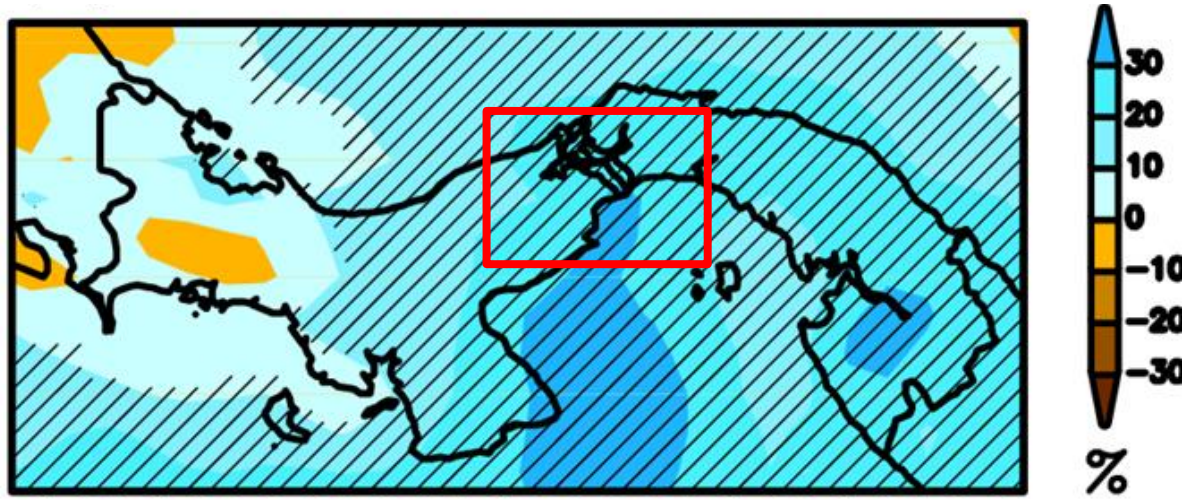
(Pinzon et al. 2017; HRL)

Future rainfall in Panama canal region

Dr. Kusunoki



Annual maximum 5-day rainfall total: 17.1%



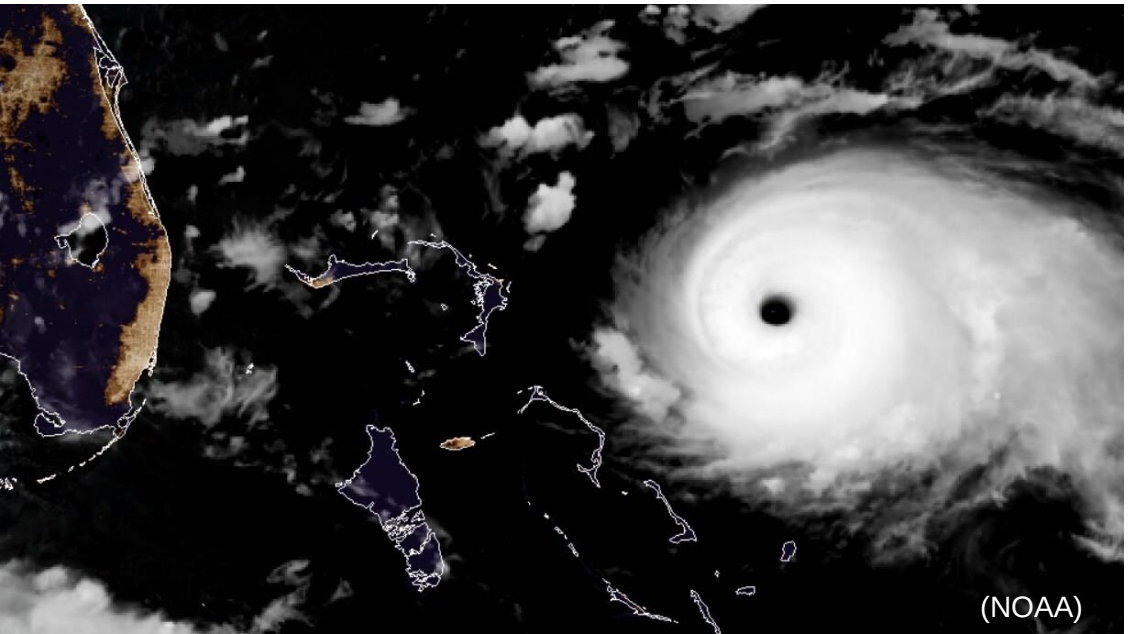
December 9, 2010

(Kusunoki et al, 2019; CD)

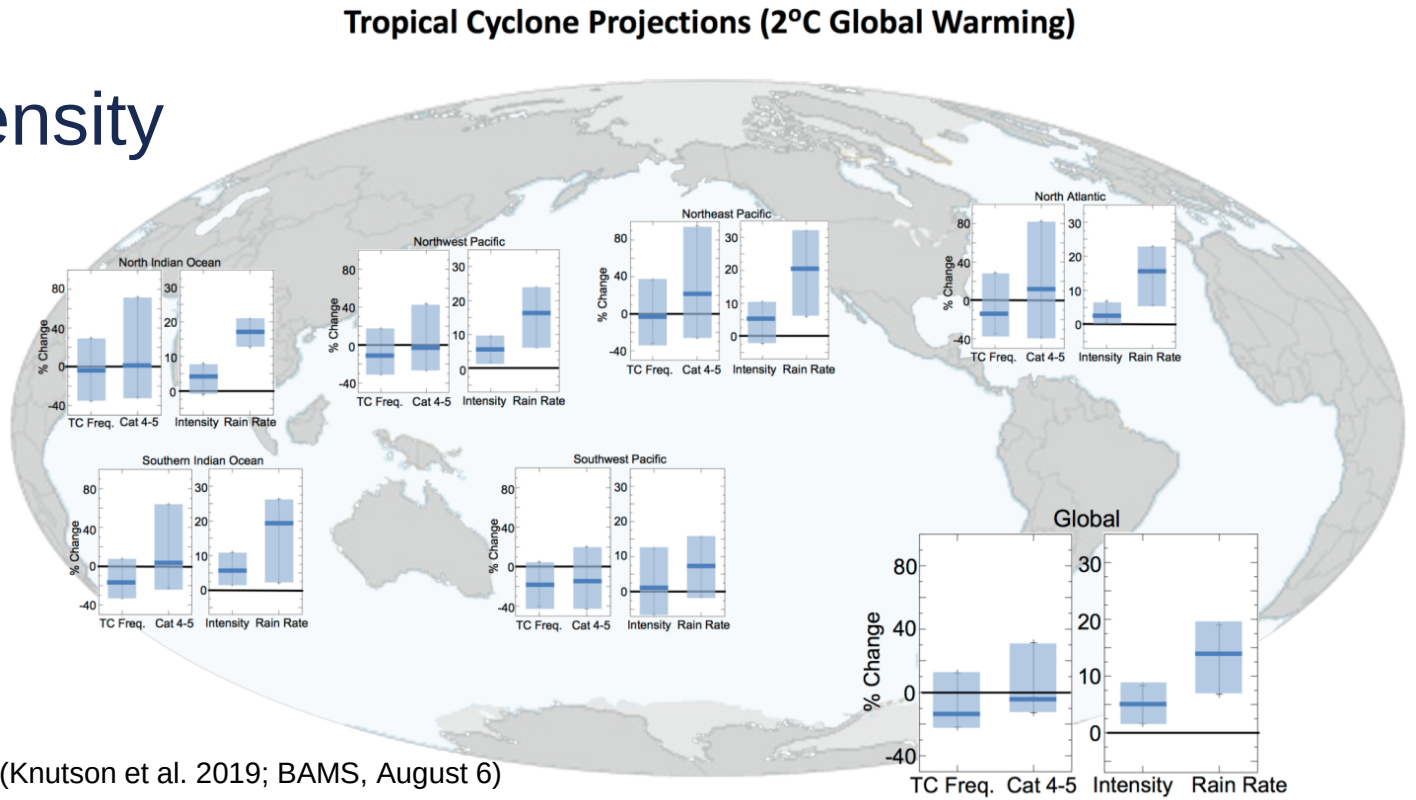
Future TCs in a warming climate

- Changes in tropical cyclone activity are assessed for a 2ºC anthropogenic warming with medium-to-high confidence projections
  - –increased tropical cyclone rainfall rates, intensity, and proportion of storms that reach Category 4-5 intensity

Hurricane Doryan, Category 5 intensity



(NOAA)



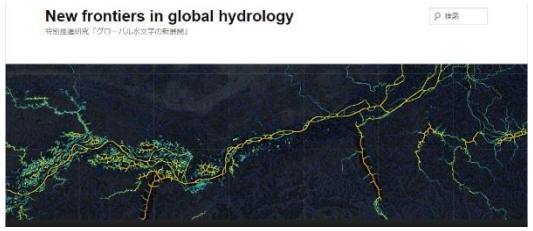
(Knutson et al. 2019; BAMS, August 6)

Scientific contents of my today's talk

1. Future climates and extremes:
   - 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:
   - Extremes recently occurred are attributed 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!

The main parts of this keynote speech were conducted under the TOUGOU Program of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan and in part JSPS KAKENHI Grant 16H06291.



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