Future change analysis of extreme floods using large ensemble climate simulation data

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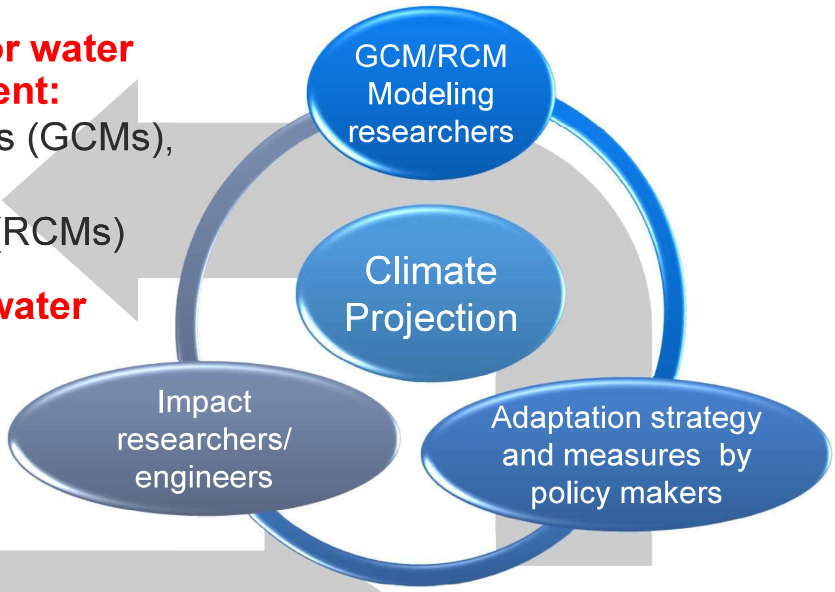
Impact assessment of climate change on water-related disasters and water resources

Future climate projection for water resources impact assessment:

- ●General Circulation Models (GCMs), and
- ●Regional Climate Models (RCMs)

Future change analysis of water resources:

- ●Hydrologic models,
- ●Hydraulic models,
- ●**Storm surge models,**
- ●Risk assessment models



Assessment of hazard and risk change:

- ●Probabilistic hazard analysis,
- ●Largest-class hazard analysis, and
- ●Risk analysis.

Adaptation strategy:

- ●Structural measures,
- ●Non-structural measures

Probable largest-class floods

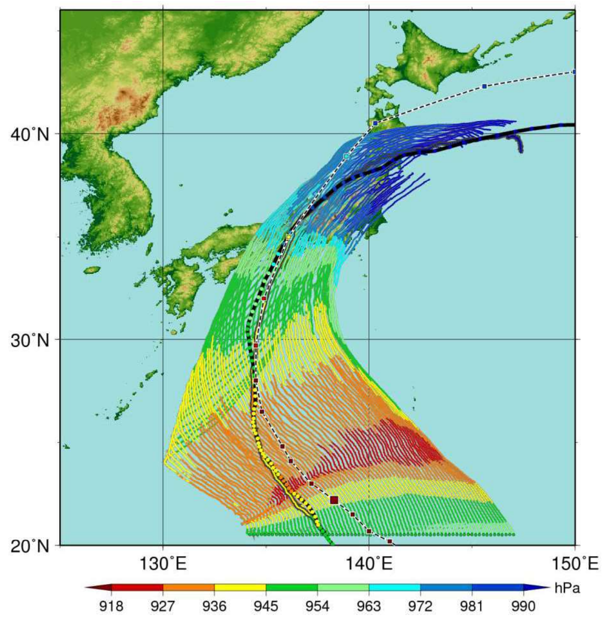
1) Estimate magnitude of probable largest-class floods caused by a historical typhoon using typhoon track ensemble simulation data.

2) Estimate magnitude of probable largest-class floods using the large ensemble climate simulation data.

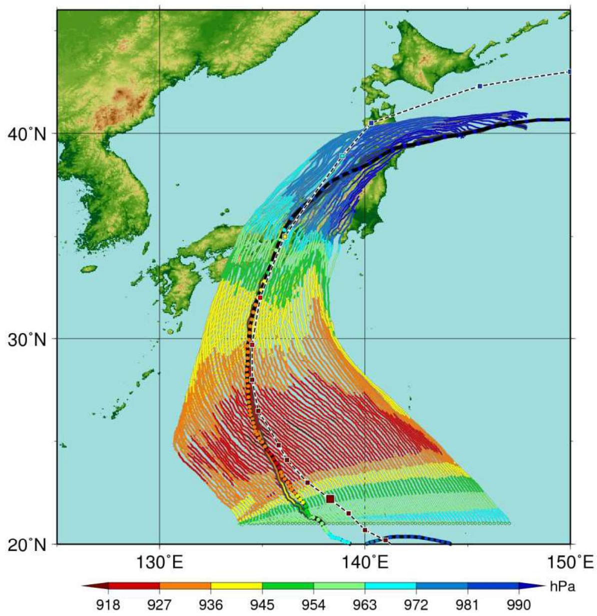
Estimation of probable largest-class floods by typhoons using typhoon track ensemble simulation

Kohei MIYAWAKI, Yasuto TACHIKAWA, Tomohiro TANAKA, Daiki ISHII, Yutaka ICHIKAWA, Kazuaki YOROZU, and Tetsuya TAKEMI, JSCE, 72(4), 2016

Virtual shifting of typhoon's initial position for the historical typhoon (Isewan Typhoon, 1959)



Control run



pseudo-global warming experiment

Takemi, Ishikawa et al:., DPRI, Kyoto Univ.

Flood and inundation simulations to estimate largest-class typhoons

Various typhoon courses of the largest-class typhoons under a climate change scenario

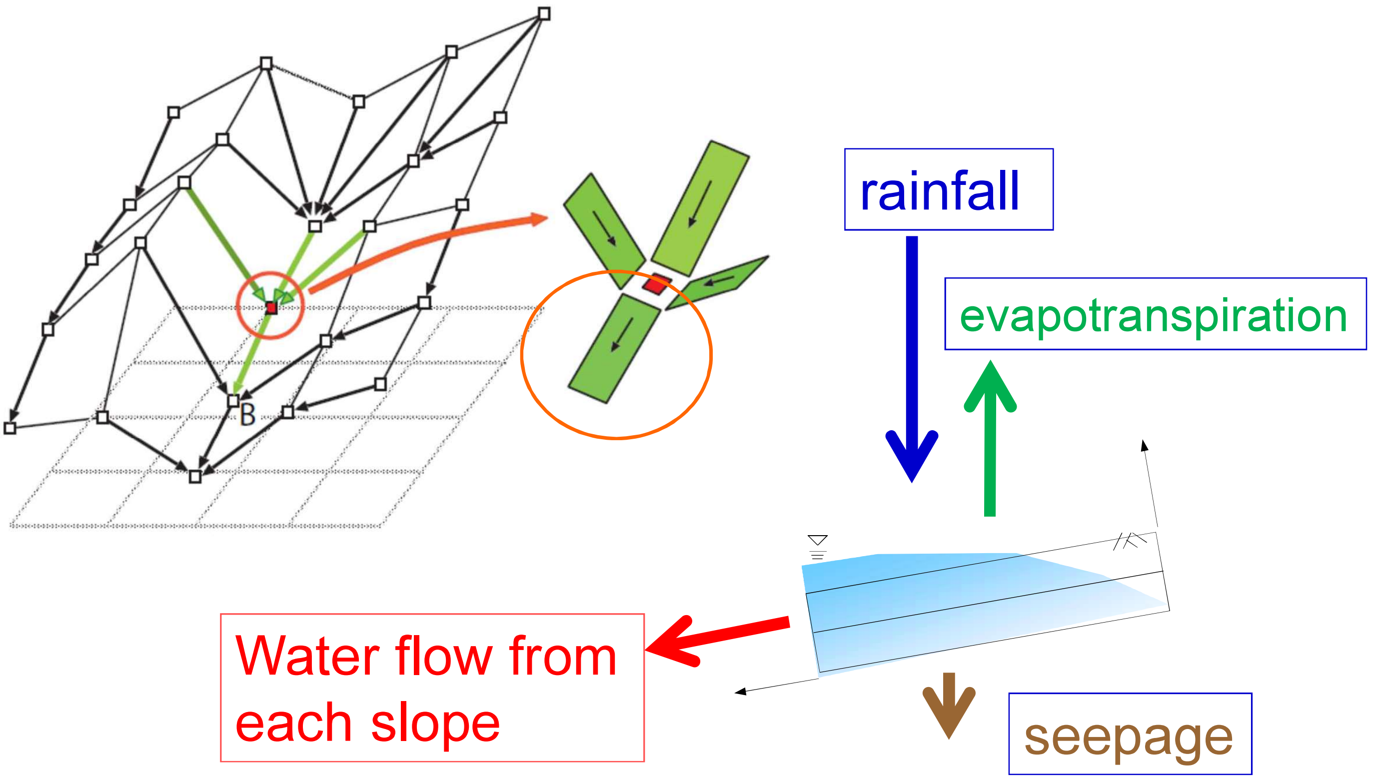
↓

Flood and inundation simulations

↓

The worst case impact assessment

Rainfall-Runoff Model



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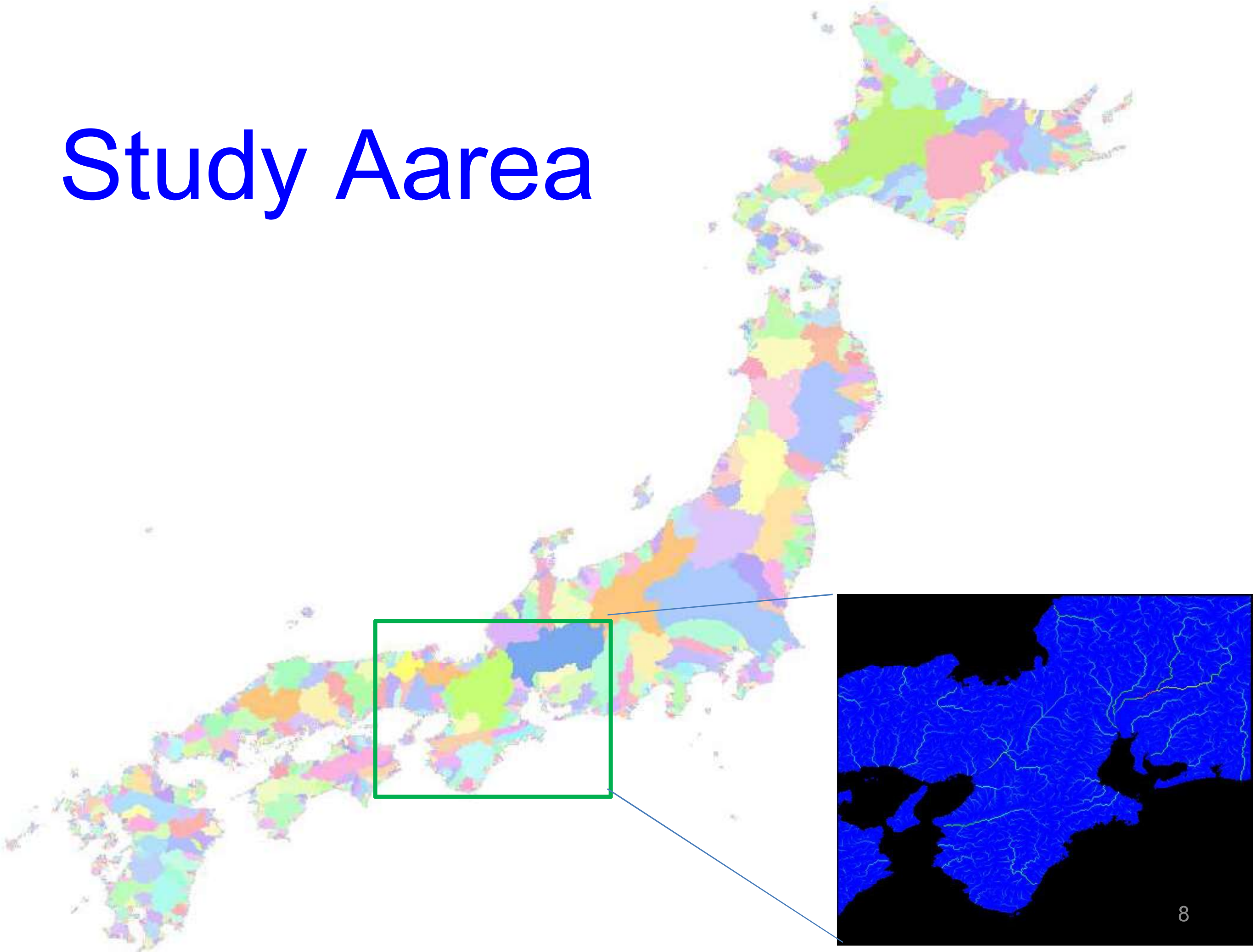
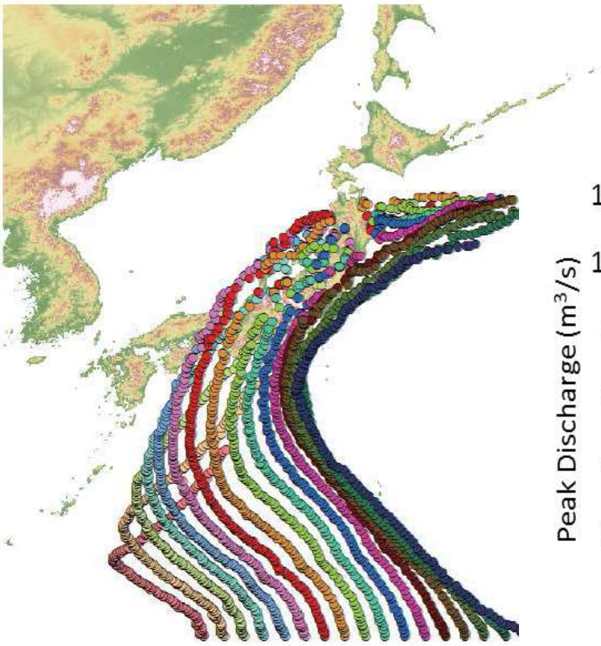
Study Aarea



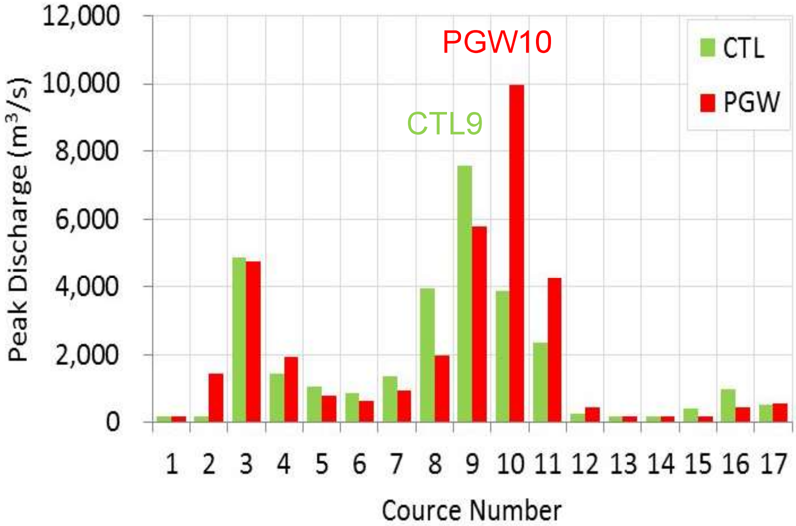
Typhoon Course Ensemble Simulations



1, 2, 3, …., 16, 17

Typhoon tracks

Peak discharge at Hirakata station for different typhoon tracks



CTL: Control experiments (present climate)

PGW: Pseudo Global Warming experiments

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Future change analysis of extreme floods using large ensemble climate simulation data, d4PDF

Tachikawa, Y., Miyawaki, K., Tanaka, T., Yorozu, K., Kato, M., Ichikawa, Y., Kim, S., JSCE, 73(3), 2017

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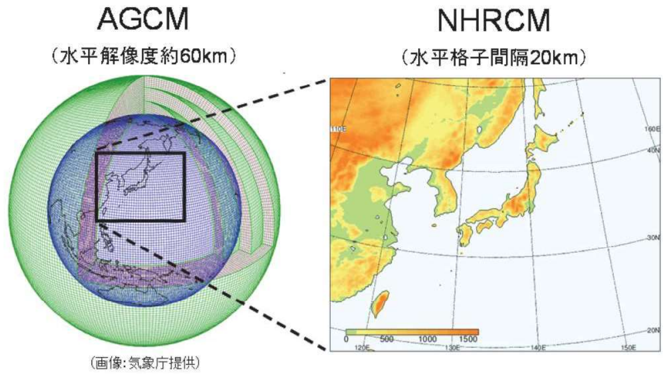
database for Policy Decision making for Future climate change (d4PDF)



The database consists of atmospheric simulations for the globe using MRI-AGCM 3.2H with 60km spatial resolution (Mizuta et al. 2012) and dynamically downscaled simulations using NHRCM with 20km resolution (Sasaki et al. 2011).

The entire globe experiment

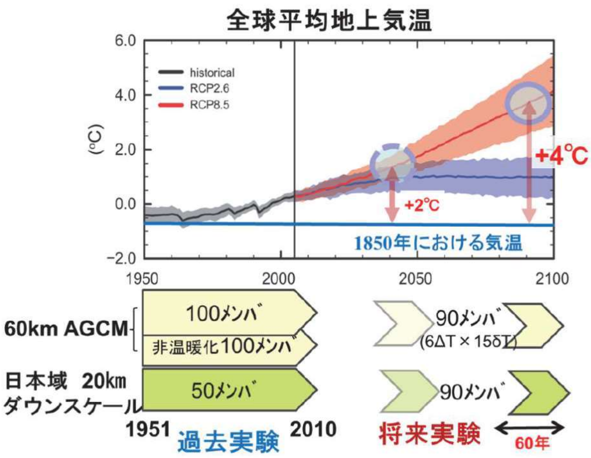
- Historical experiment 1951～2011×100 ensemble members
- 4°C increase experiment 2051～2111×90 ensemble members

Downscaled local experiment

- Historical experiment 1951～2011×50 ensemble members
- 4°C increase experiment 2051～2111×90 ensemble members

「地球温暖化対策に資するアンサンブル気候予測データベース」利用手引きより

database for Policy Decision making for Future climate change (d4PDF)

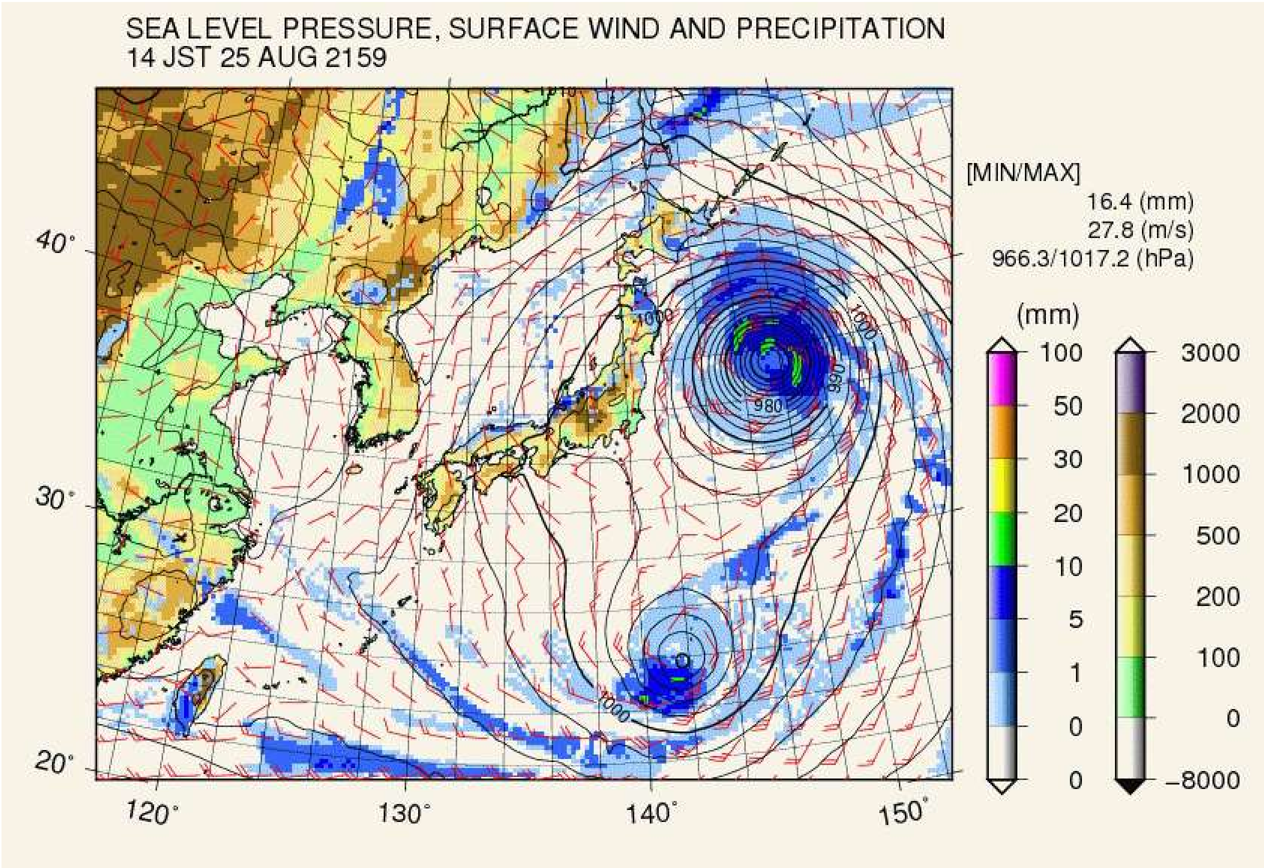


MRI-NHRCM, 20km spatial resolution

- Present Climate Experiments: 50 ensembles of 60 years climate simulation under different boundary conditions, which provides 3,000 years hydrologic time series data.
- The End of 21st Century Climate Experiments (4 degree increase): 15 ensembles of 60 years climate simulation under different initial and boundary conditions for 6 SST settings, which provides 5,400years (= 900years times 6 SSTs) hydrologic time series data.

「地球温暖化対策に資するアンサンブル気候予測データベース」利用手引きより

d4PDF data simulated by MRI-NHRCM (20km spatial resolution)

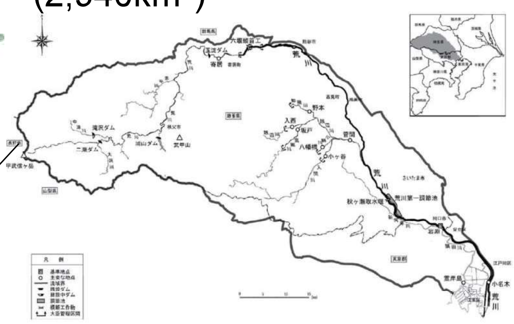


Developed by Mr. Kato at ISEE, Nagoya Univ.

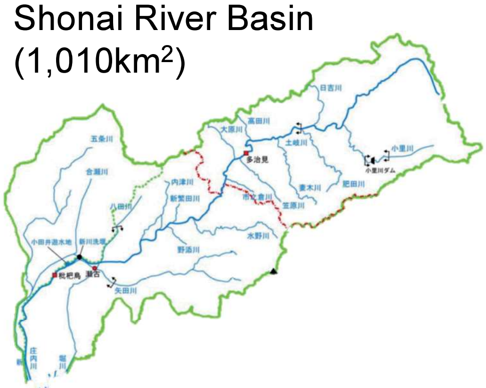
Study River Basins

Ara River Basin
(2,940km^2)

Yodo River Basin
(8,240km^2)

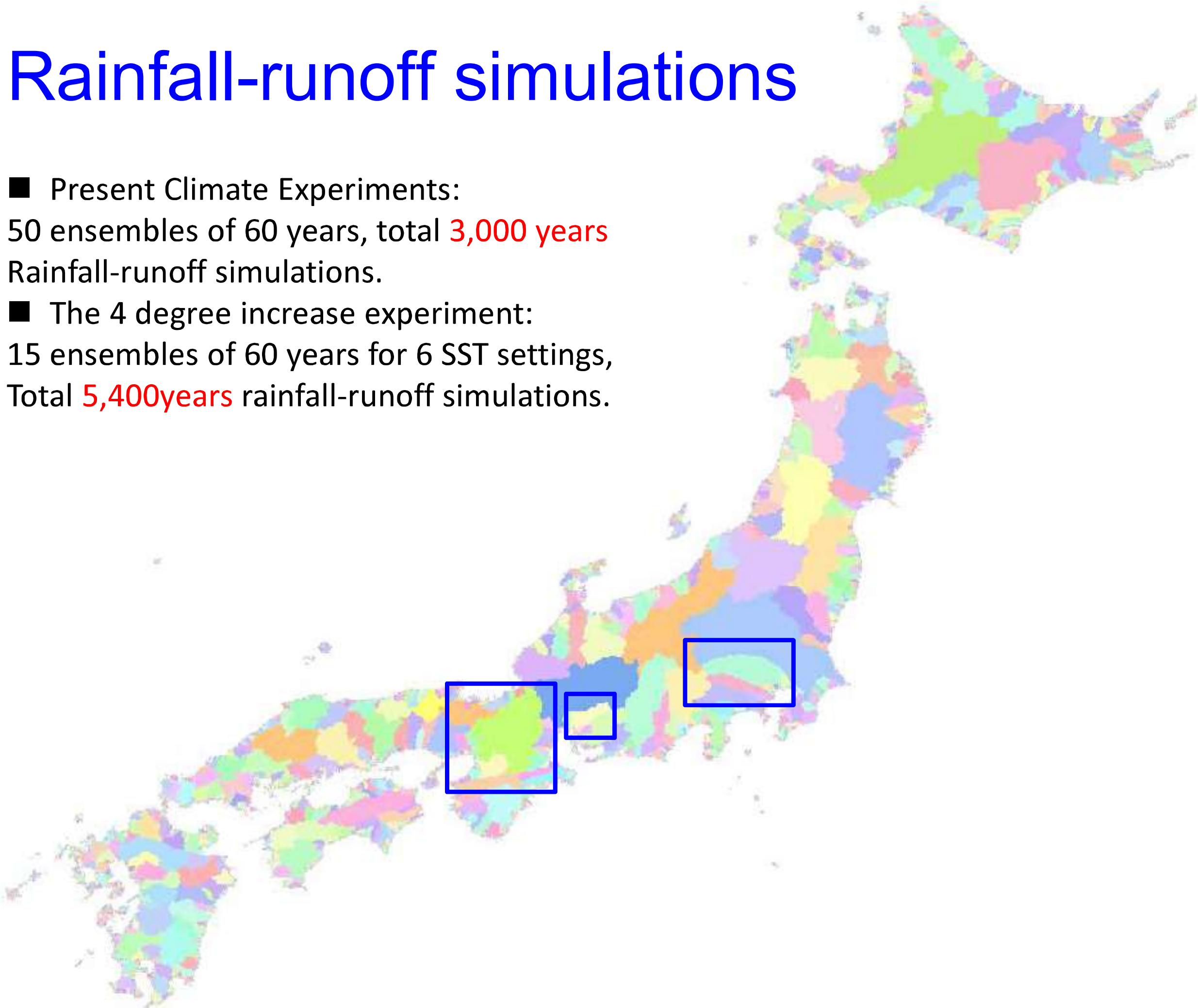


Shonai River Basin
(1,010km^2)



Rainfall-runoff simulations

■ Present Climate Experiments:
50 ensembles of 60 years, total 3,000 years
Rainfall-runoff simulations.
■ The 4 degree increase experiment:
15 ensembles of 60 years for 6 SST settings,
Total 5,400years rainfall-runoff simulations.



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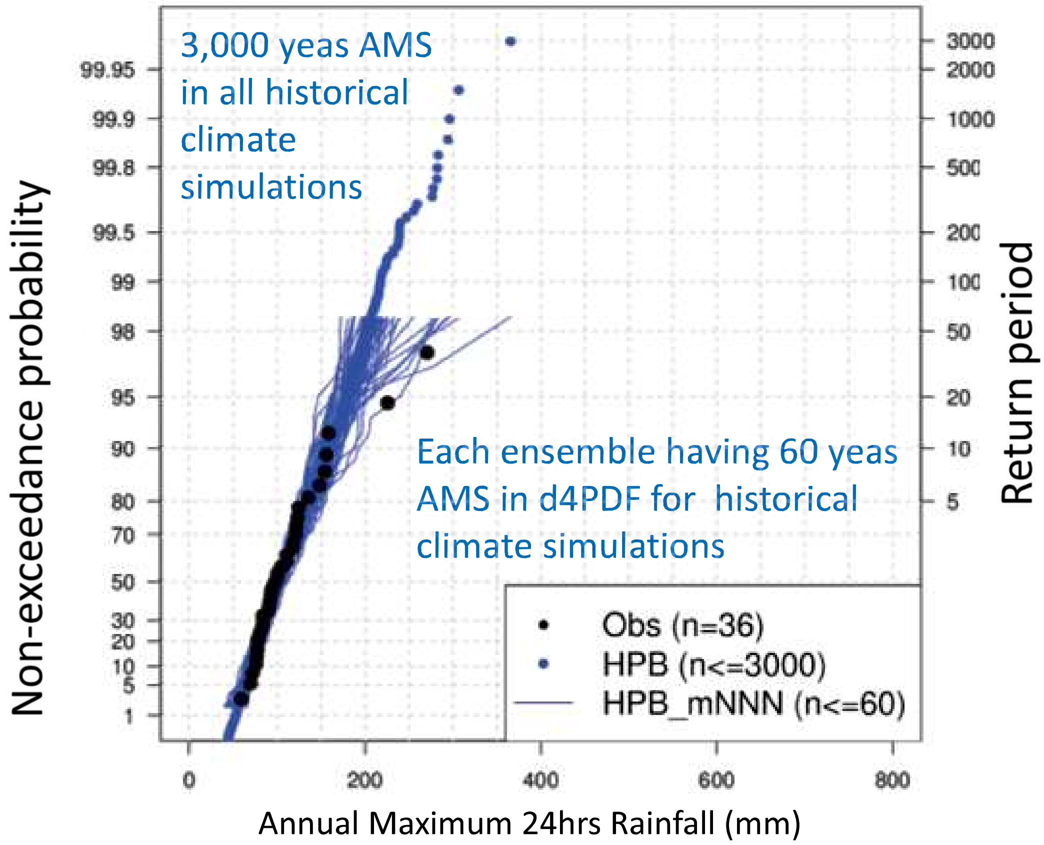
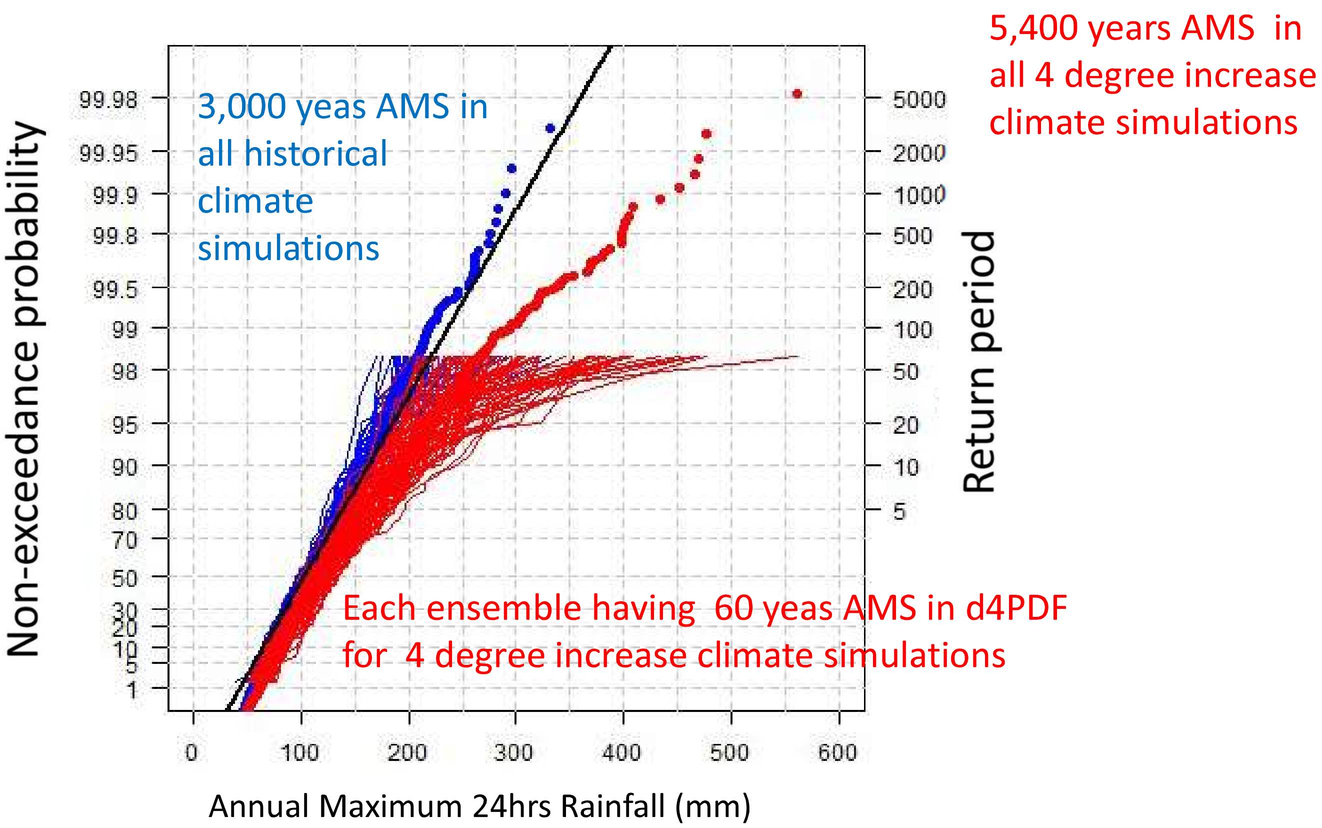
Probability Plot for Annual Maximum 24hrs Catchment Mean Rainfall at Yodo River Basin

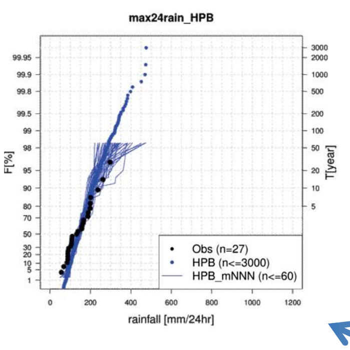


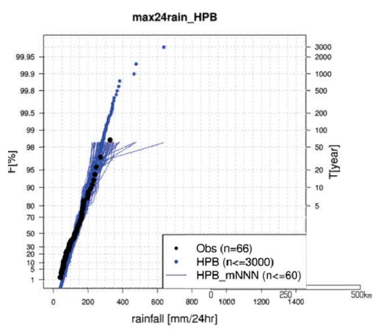
Probability Plot for Annual Maximum 24hrs Catchment Mean Rainfall at Yodo River Basin

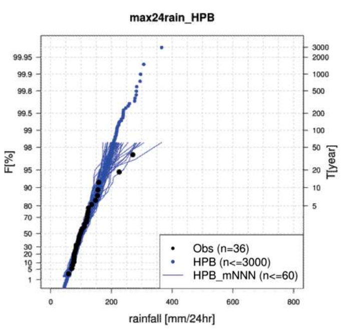


Observed(black) and Present(Blue) annual maximum 24-hour basin rainfall

- Increasing discharge at each return period was detected by using huge ensemble data
- Future 200 year discharge corresponds to present 900 year discharge



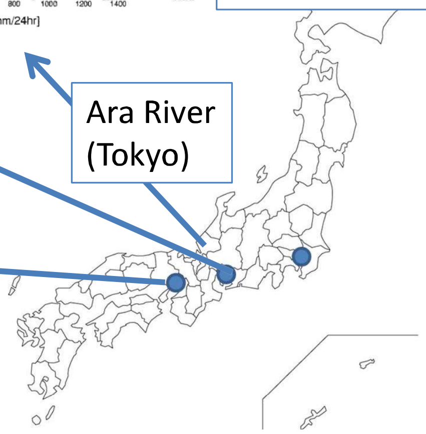




Shonai River (Nagoya)

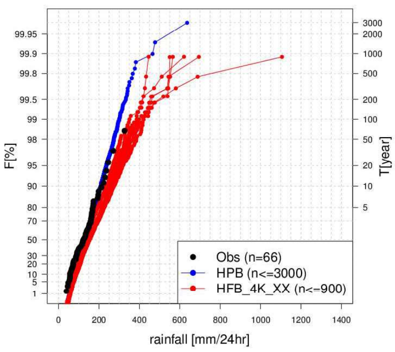
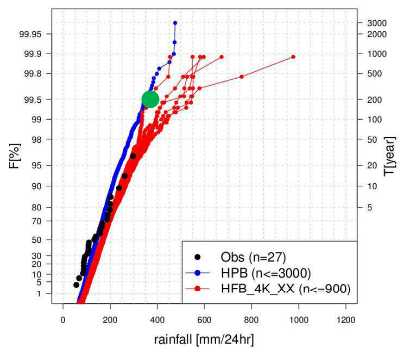
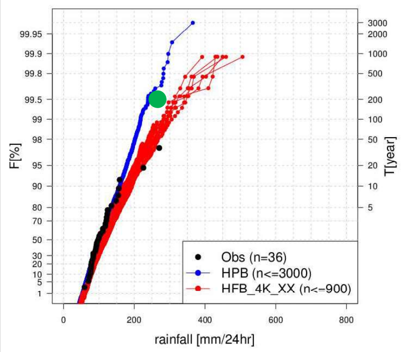
Ara River (Tokyo)

Yodo River (Osaka)



Tachikawa, Y., Miyawaki, K., Tanaka, T., Yorozu, K., Kato, M., Ichikawa, Y., Kim, S. (Kyoto University)

Annual Maximum 24hrs Catchment Average Rainfall

Ara River basin	Shonai River Basin	Yodo River Basin
		
200-years rainfall ● 548 mm/3day ● 330 mm/24hr ● 460 mm/24hr 1.3 times	200-years rainfall ● 376 mm/24hr ● 350 mm/24hr ● 470 mm/24hr 1.3 times	200-years rainfall ● 261 mm/24hr ● 240 mm/24hr ● 330 mm/24hr 1.4 times

- ● (green) 200-year annual maximum rainfall estimated by using observed data, which is used for the river improvement planning at Construction Ministry in Japan.
- ● (blue) 200-year annual maximum rainfall estimated by using d4PDF present simulation data
- ● (red) 200-year annual maximum rainfall estimated by using d4PDF future simulation data, which is mean of the ones of 6 SSTs.

Change of Annual Maximum Catchment Rainfall

Catchment	Duration time	Annual maximum Rainfall(mm)			
		Return period 200 years		Return period 900 years	
		Historical	4 deg. increase*1	Historical	4 deg. increase*2
Ara River	24 hours	333	459	466	664
	48 hours	415	555	552	816
	72 hours	480 (538)	610	623	856
	96 hours	513	646	645	891
Shounai	24 hours	350 (376)	474	470	638
River	48 hours	471	585	558	792
	72 hours	525	659	647	903
	96 hours	578	724	720	1010
Yodo	24 hours	239 (261)	329	296	455
River	48 hours	321	406	395	541
	72 hours	363	443	434	572
	96 hours	373	459	459	591

*1: mean of 4 degree increase experiments with setting different SSTs, *2: mean of the maximum values of 4 degree increase experiments with setting different SSTs, blue values is estimated by gauged data and adopted as a design rainfall by MLIT.

Change of Annual Maximum Catchment Rainfall

Catchment	Duration time	Annual maximum Rainfall(mm)					
		Return period 200 years			Return period 900 years		
		Historical	4 deg. increase*1		Historical		4 deg. increase*2
Ara River	24 hours	333	459	(1.34)	466		664
	48 hours	415	555	(1.34)	552		816
	72 hours	480	610	(1.27)	623		856
	96 hours	513	646	(1.26)	645		891
Shounai	24 hours	350	474	(1.35)	470		638
River	48 hours	471	585	(1.24)	558		792
	72 hours	525	659	(1.26)	647		903
	96 hours	578	724	(1.25)	720		1010
Yodo	24 hours	239	329	(1.38)	296		455
River	48 hours	321	406	(1.26)	395		541
	72 hours	363	443	(1.22)	434		572
	96 hours	373	459	(1.23)	459		591

1.3 times larger

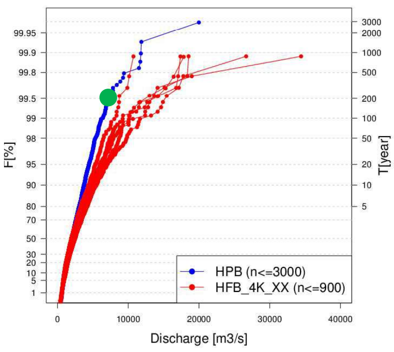
Change of Annual Maximum Catchment Rainfall

Catchment	Duration time	Annual maximum Rainfall(mm)					
		Return period 200 years			Return period 900 years		
		Historical	4 deg. increase*1		Historical		4 deg. increase*2
Ara River	24 hours	333	459		466	(0.98)	664
	48 hours	415	555		552	(1.00)	816
	72 hours	480	610		623	(0.98)	856
	96 hours	513	646		645	(1.00)	891
Shounai	24 hours	350	474		470	(1.01)	638
River	48 hours	471	585		558	(1.05)	792
	72 hours	525	659		647	(1.02)	903
	96 hours	578	724		720	(1.25)	1010
Yodo	24 hours	239	329		296	(1.01)	455
River	48 hours	321	406		395	(1.03)	541
	72 hours	363	443		434	(1.02)	572
	96 hours	373	459		459	(1.00)	591

Almost similar

Change of Annual Maximum Hourly Discharge

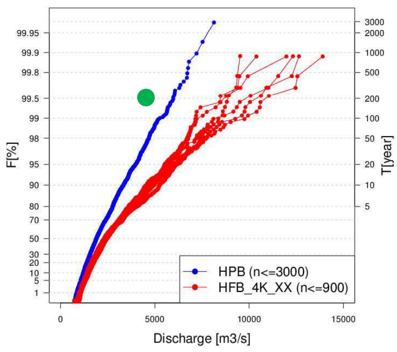
Ara River (Iwabuchi)



200-years discharge
- ● 7,000 m^3/s
- ● 7,600 m^3/s
- ● 12,800 m^3/s

1.7 times

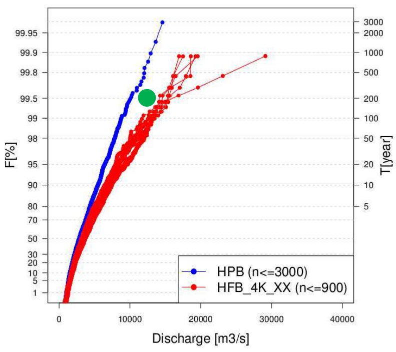
Shounai River (Biwajima)



200-years discharge
- ● 4,400 m^3/s
- ● 6,000 m^3/s
- ● 9,500 m^3/s

1.6 times

Yodo River (Hirakata)

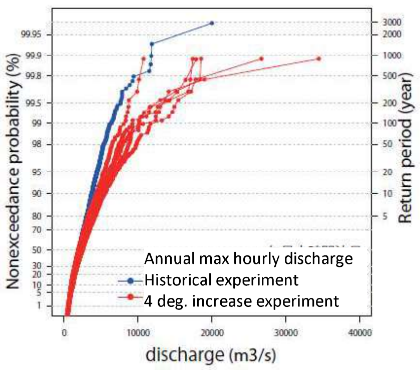


200-years discharge
- ● 12,000 m^3/s
- ● 10,100 m^3/s
- ● 15,200 m^3/s

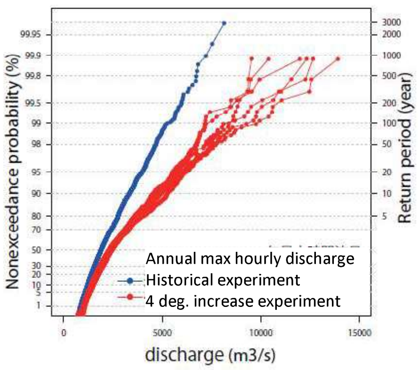
1.5 times

- ● (green) 200-year annual maximum discharge estimated by using observed data, which is used for the river improvement planning at Construction Ministry in Japan.
- ● (blue) 200-year annual maximum discharge estimated by using d4PDF present simulation data
- ● (red) 200-year annual maximum discharge estimated by using d4PDF future simulation data, which is mean of the ones of 6 SSTs.

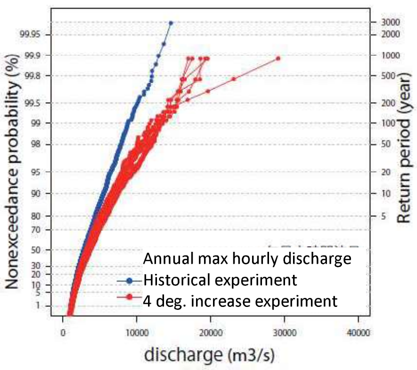
Change of Annual Maximum Hourly Discharge



Ara River basin



Shounai River basin

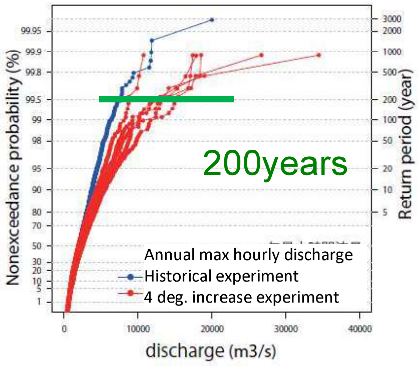


Yodo River basin

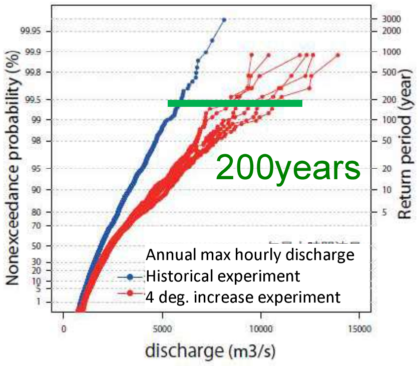
Catchment		Annual maximum hourly river discharge (m^3/sec)			
		Return period 200 years		Return period 900 years	
		Historical	4 deg. increase*1	Historical	4 deg. increase*2
Ara River (Iwabuchi)		7,611	12,801	11,780	20,934
Shounai River (Biwajima)		5,975	9,525	7,240	11,794
Yodo River (Hirakata)	With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

*1: mean of 4 degree increase experiments with setting different SSTs, *2: mean of the maximum values of 4 degree increase experiments with setting different SSTs.

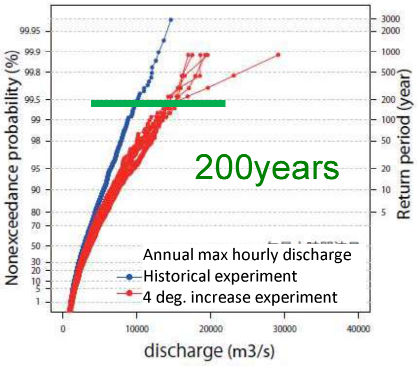
Change of Annual Maximum Hourly Discharge



Ara River basin



Shounai River basin

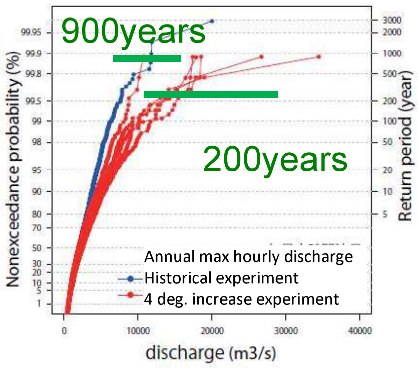


Yodo River basin

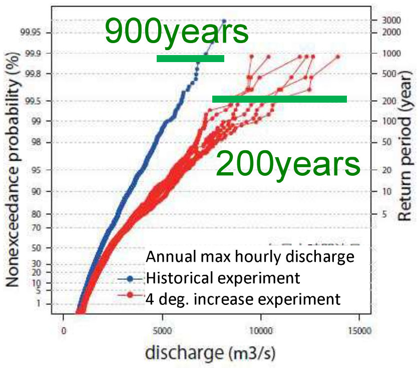
Catchment		Annual maximum hourly river discharge (m^3/sec)						
		Return period 200 years			Return period 900 years			
		Historical	4 deg. increase[*1]		Historical		4 deg. increase[*2]	
Ara River (Iwabuchi)		7,611	12,801	1.68	11,780		20,934	
Shounai River (Biwajima)		5,975	9,525	1.59	7,240		11,794	
Yodo River	With dam	10,100	15,165	1.50	12,987		20,168	
(Hirakata)	Without dam	12,307	18,328	1.49	15,723		23,191	

1.5 – 1.7 times larger

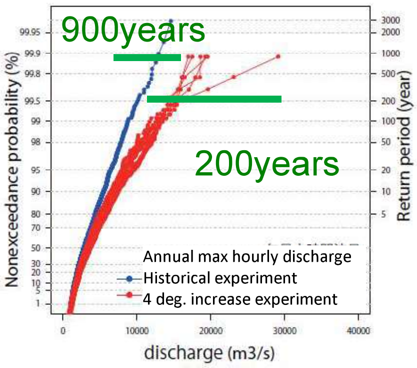
Change of Annual Maximum Hourly Discharge



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]	
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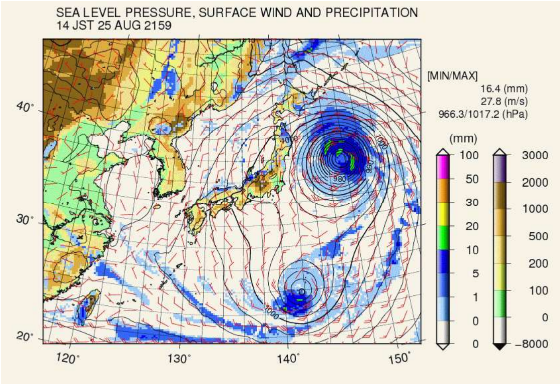
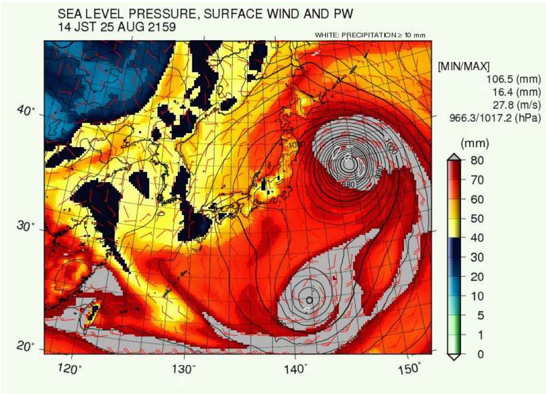
Yodo River	With dam	10,100	15,165		12,987	1.17	20,168	
(Hirakata)	Without dam	12,307	18,328		15,723	1.17	23,191	

1.1 – 1.3 times larger

Largest-class floods and rainfall simulated by d4PDF at Yodo River basin



(a) Rainfall and pressure



(b) Precipitable water

The largest-class rainfall and peak river discharge using d4PDF (over 1000-years return period)

Order	Qmax (m^3/s)	Rmax (mm/hr)	R24 (mm)	System	Time
Historical experiment (3000-yeas simulation, 60-years runs of 50 ensemble members)					
1	14,589	14	224	Typhoon	Aug. 22
2	13,642	38	239	Typhoon	Aug. 23
3	12,928	25	365	Typhoon	Aug. 22
4 degree increase experiment (5400-years run, 60-years runs of 90 ensemble members)					
1	29,135	63	442	typhoon	Aug. 25
2	23,115	37	330	typhoon	Aug. 18
3	19,604	28	195	typhoon	Sep. 3
4	19,570	21	403	low pressure	Jul. 27
5	19,263	25	505	front	Jul. 29

Historical floods after 1953 for in the Yodo River basin

Order	Qmax (m^3/s)	2 day rainfall (mm)	system	Time
1	9,500	295	typhoon	Sep. 2013
2	7,970	215	typhoon	Sep. 1959
3	7,800	249	typhoon	Sep. 1953
4	7,206	234	Front	Oct. 1961
5	6,868	203	typhoon	Sep. 1965

Conclusions

1. The frequency distributions of annual maximum 24-hours rainfall for d4PDF of the historical experiment match with the ones for observed data;
2. The 200-years annual maximum 24-hours rainfall for the d4PDF of the 4 degree increase experiment is 1.3 to 1.4 times larger than the one of the historical experiment and 1.5 to 1.7 times larger for the annual maximum river discharge;
3. The 200-years annual maximum 24 hours rainfall for the d4PDF of the 4 degree increase experiment is equivalent to the one of 900 years of the historical experiment; and
4. The rainfall patterns that cause largest-class floods simulated by d4PDF well match with the one of large historic floods for the three basins.

New opportunity for future hydrologic prediction and design

1) We can examine the change of hydrologic extremes using typhoon trach ensemble simulation data.

2) We can estimate over 1,000 year-annual maximum rainfall and flood events using the large ensemble climate simulation data.

Thank you very much for your attention