Nonparametric analysis of extreme precipitation with long return periods in Japan – using d4PDF

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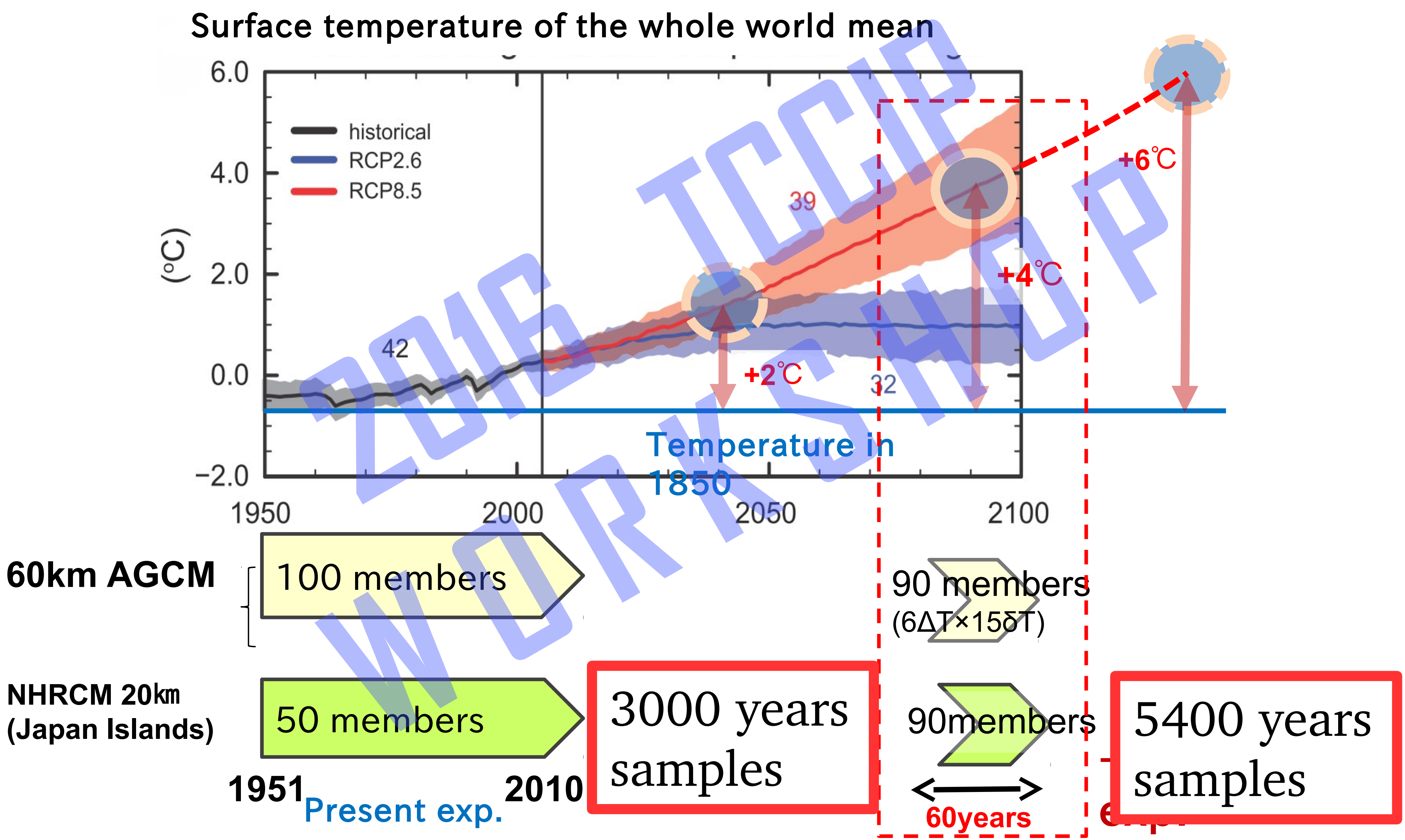
Introduction

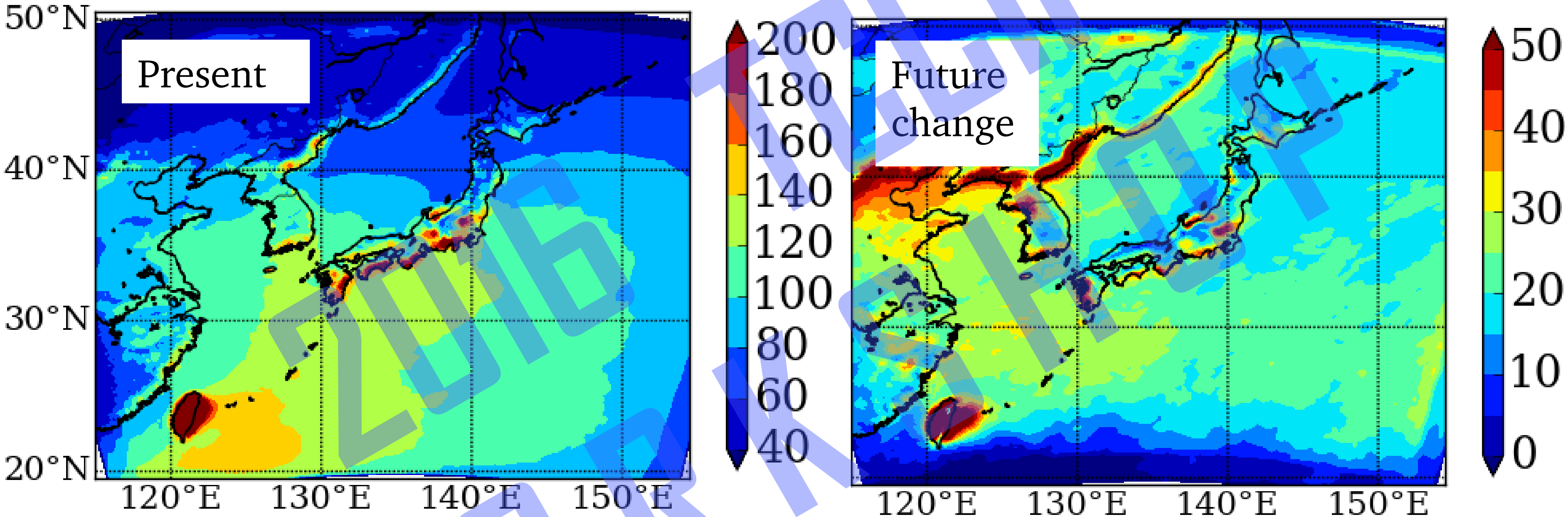
- Estimation of extreme precipitation is a important task to avoid disasters like floods, land-slide, and so on.
- This study focus on rare events such that they occur once, on average, in a given years (called return period)
- Analyses of extreme precipitation are usually based on annual maximum of daily precipitation (called R1d hereafter).
- However, observation or previous climate experiments yield a few samples of R1d (the order of tens or hundreds).
- Using d4PDF dataset, which has the data of the order of thousands, we improve the reliability of the estimate of extreme precipitation and reveal their statistical features.

Design of d4PDF experiments



Extreme precipitation (once a year - R1d) from regional model of d4PDf

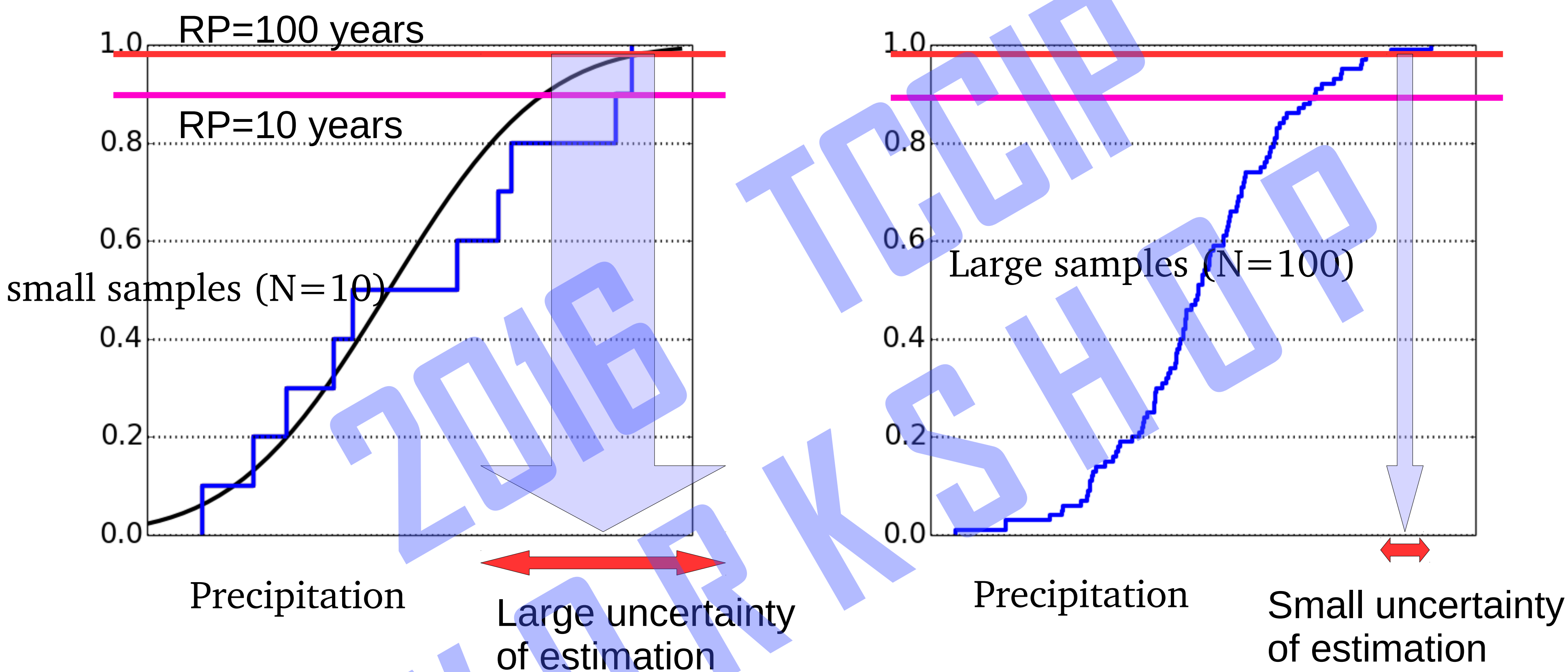
Ensemble mean of present R1d (mm) and future change (mm)



- Although R1d tends to decrease along the latitude in this domain, large values of R1d emerges on the land regions, particularly in Taiwan and on the coast of Pacific ocean of Japan islands.
- Geographic distribution is well reproduced thank to the downscaling to the regional model.

Return levels of extreme precipitation

Empirical cumulative distribution function (CDF) of R1d



- The estimation of extreme precipitation is difficult with small sample numbers.
- To solve this difficulty, we have two choices:
  (A) well-known functions (e.g., GEV) are fitted to empirical CDF (assumption about the characteristics of population of R1d data)
  (B) increase the number of samples.

Two method to calculate a return level when given a return period

(A) GEV (generalized extreme value) method

- Fit a GEV function to empirical CDF and read the precipitation value of the intersection point of the GEV function and the cumulative probability line which is determined by given return period.
- Fitting of the GEV distribution is performed using the maximum likelihood method.
- The uncertainty of the estimate of the return levels is derived from the uncertainty of the GEV fitting.

(B) Non-parametric method

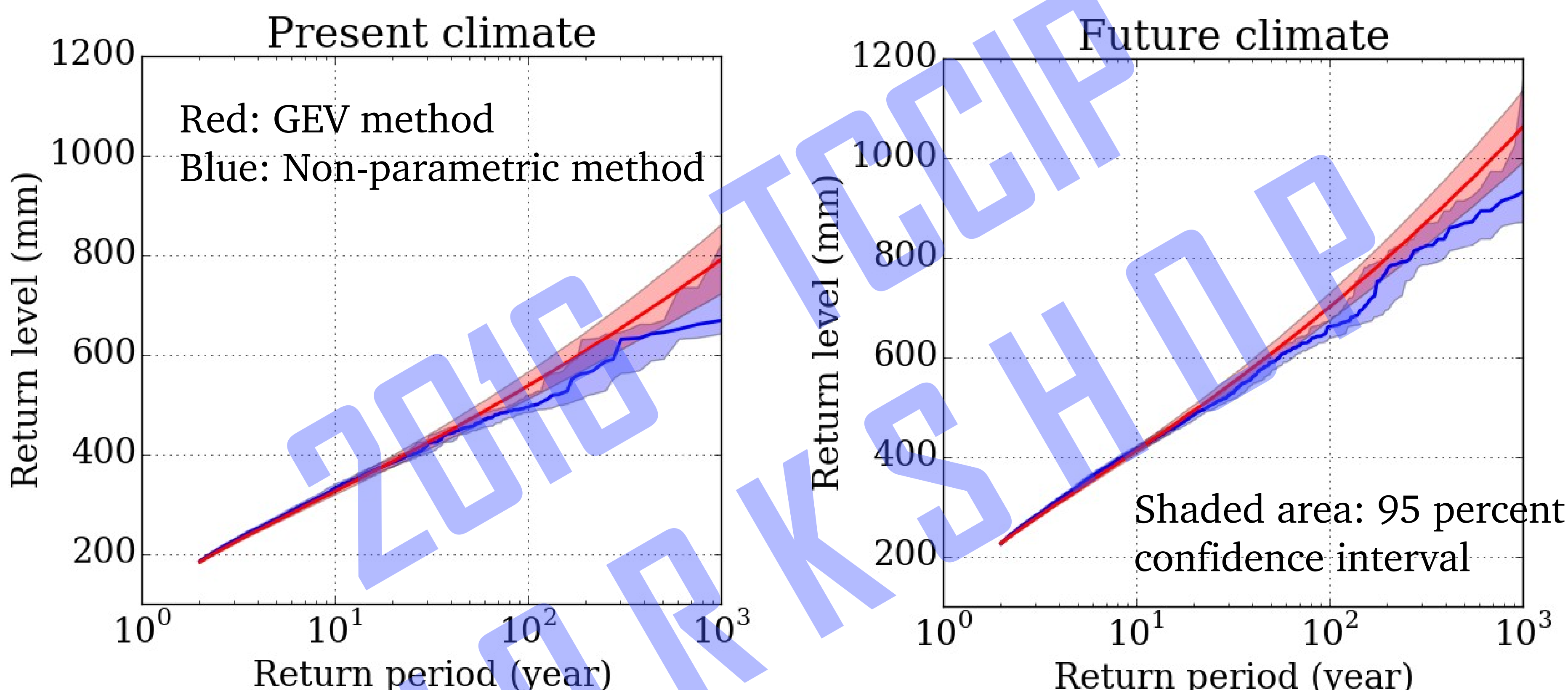
- Read the precipitation value of intersection point of the empirical CDF and the cumulative probability line directly.
- The uncertainty of the estimate is obtained with the bootstrap method (one of sub-sampling methods)

<u>Estimation from the non-parametric method is more reliable than that from the GEV method because no assumption about the statistical features of the R1d is made.</u>

Results

Results of return levels of precipitation

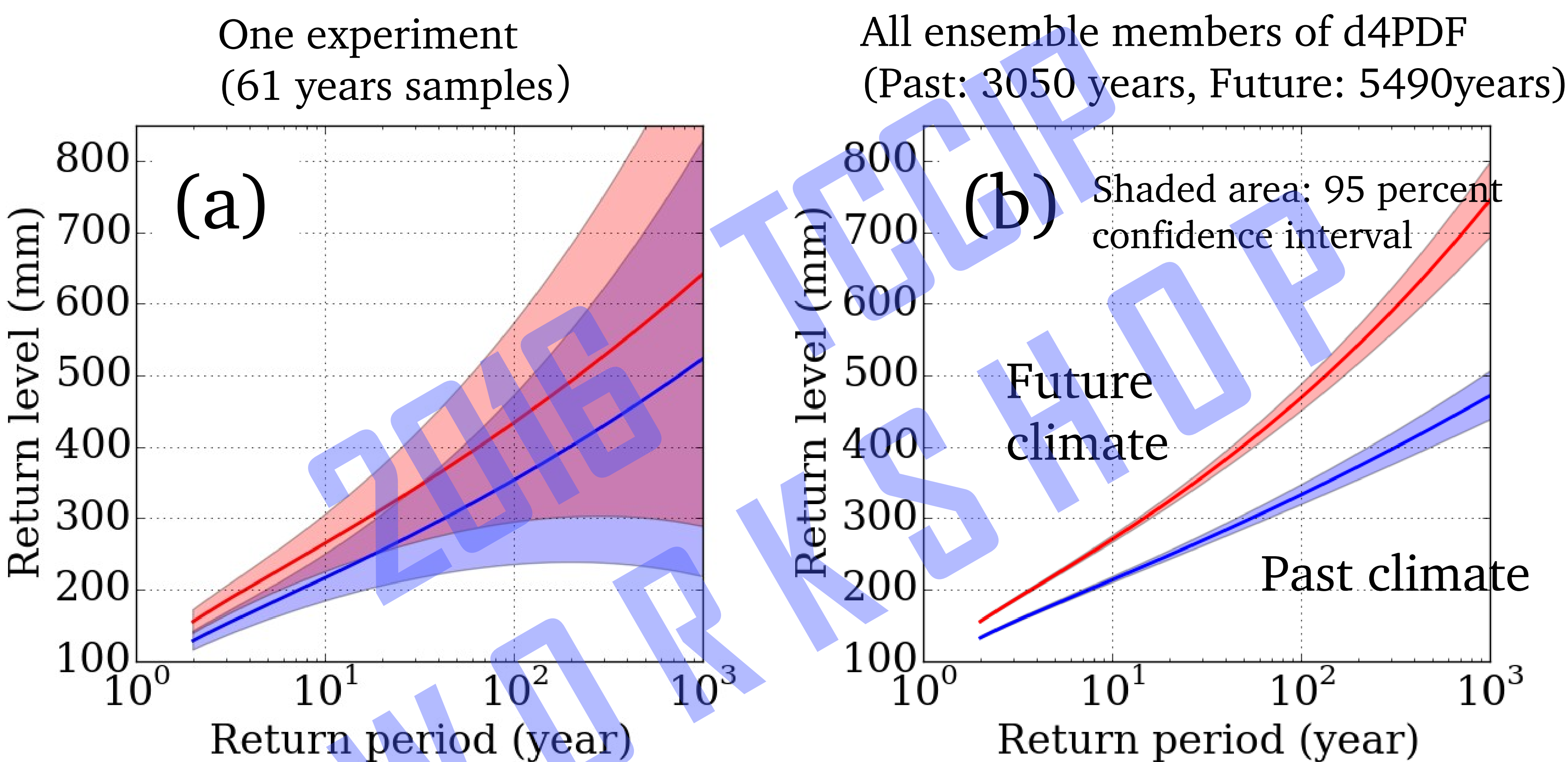
(at Taipei for example)



- GEV method and non-parametric methods yield approximately the same results about the return levels, which implies that the assumption of GEV fitting is reasonable for Taipei R1d data.
- Both methods project a increase of the extreme precipitation.

Benefits of large ensemble members from d4PDF

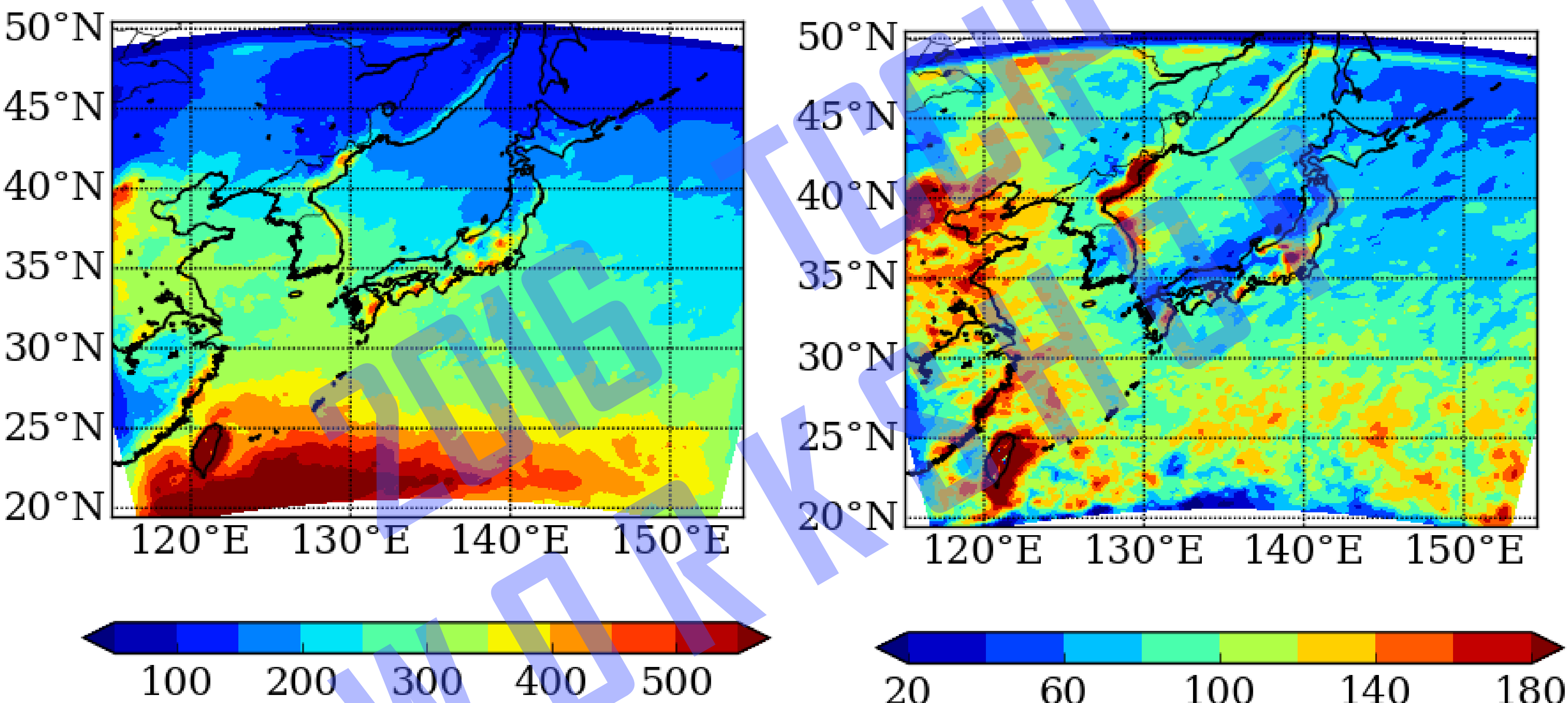
at Tokyo as an example



Confidence intervals of return levels shrink thanks to the large samples from d4PDF, leading to the reliability of estimation and enabling the detection of future changes of extreme precipitation in a statistical sense.

Geographical distribution of extreme precipitation

(left) Present return levels (mm) with 100 years return periods and (right)their future changes

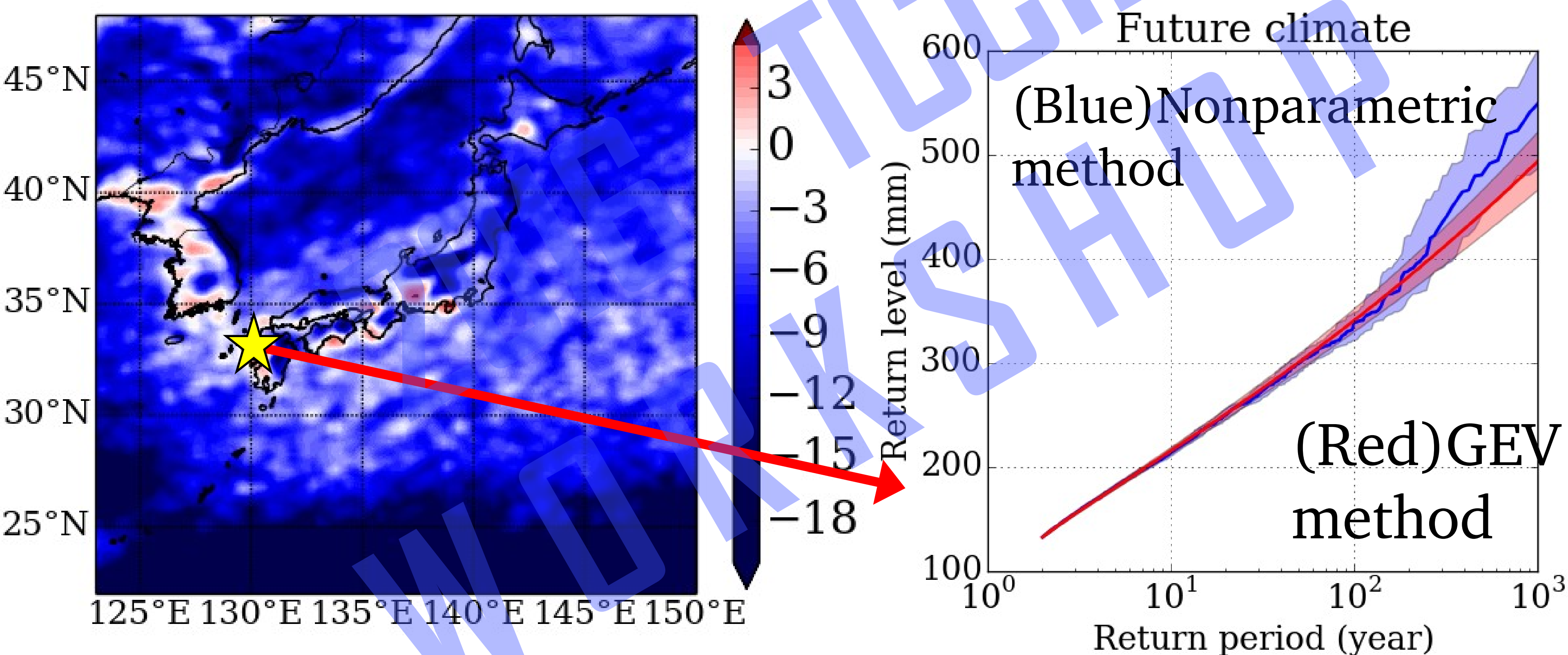


- The geographical pattern of the 100 years return levels is similar to that of R1d.
- However, the value of precipitation is much larger.
- The dynamical downscaling enables the analyses of extreme precipitation focusing on the detailed geographical distribution e.g., orographic precipitation.

Validity of the GEV assumtion

Comparison between the results of two methods: GEV method and nonparametric method

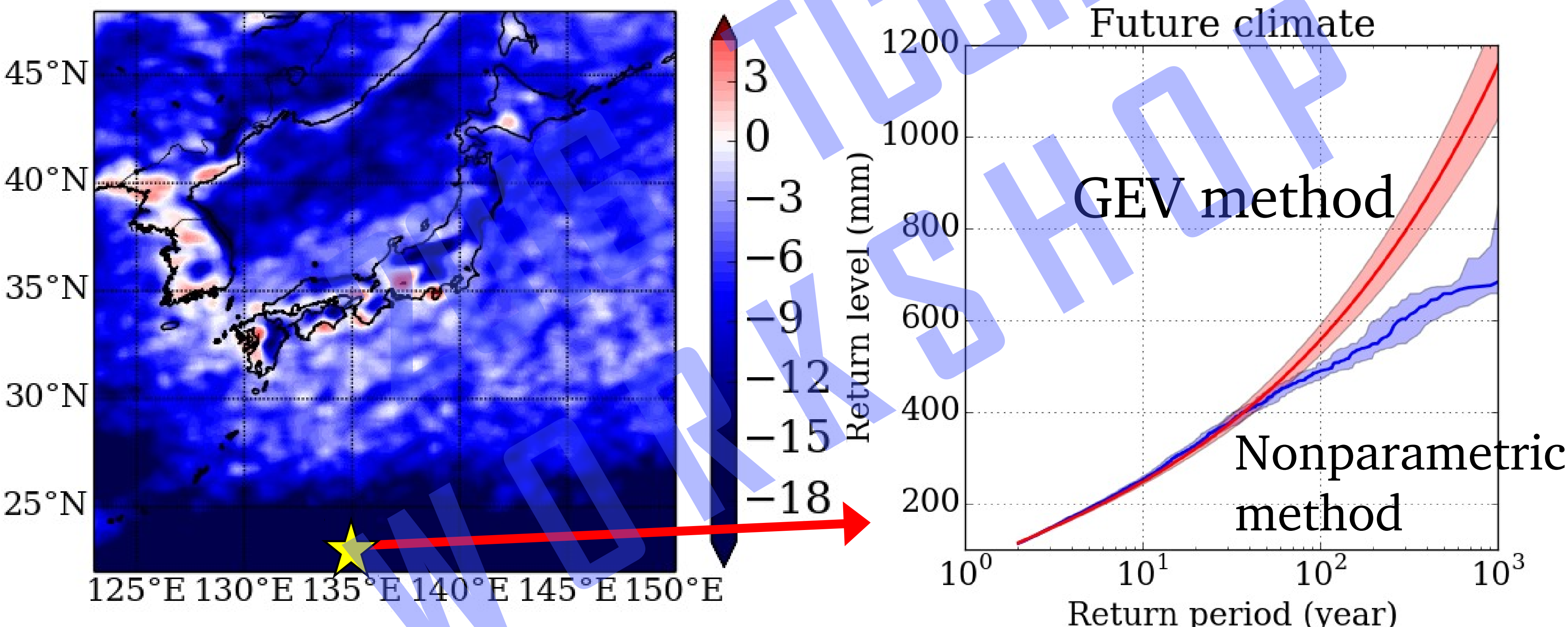
(Left) Relative difference (%) of 100 years return levels between the results by GEV method and nonparametric method.
Red area indicates under-estimate of GEV method and blue area is over-estimate.



- The reliability of GEV method is relatively good around Japan islands and Korean peninsula.
- The GEV method tends to yield overestimated return levels on the ocean.

Comparison between the results of two methods: GEV method and nonparametric method

(Left) Relative difference (%) of 100 years return levels between the results by GEV method and nonparametric method.
Red area indicates overestimation of GEV method and blue areas are underestimation.



- The reliability of GEV method is relatively good around Japan islands and Korean peninsula.
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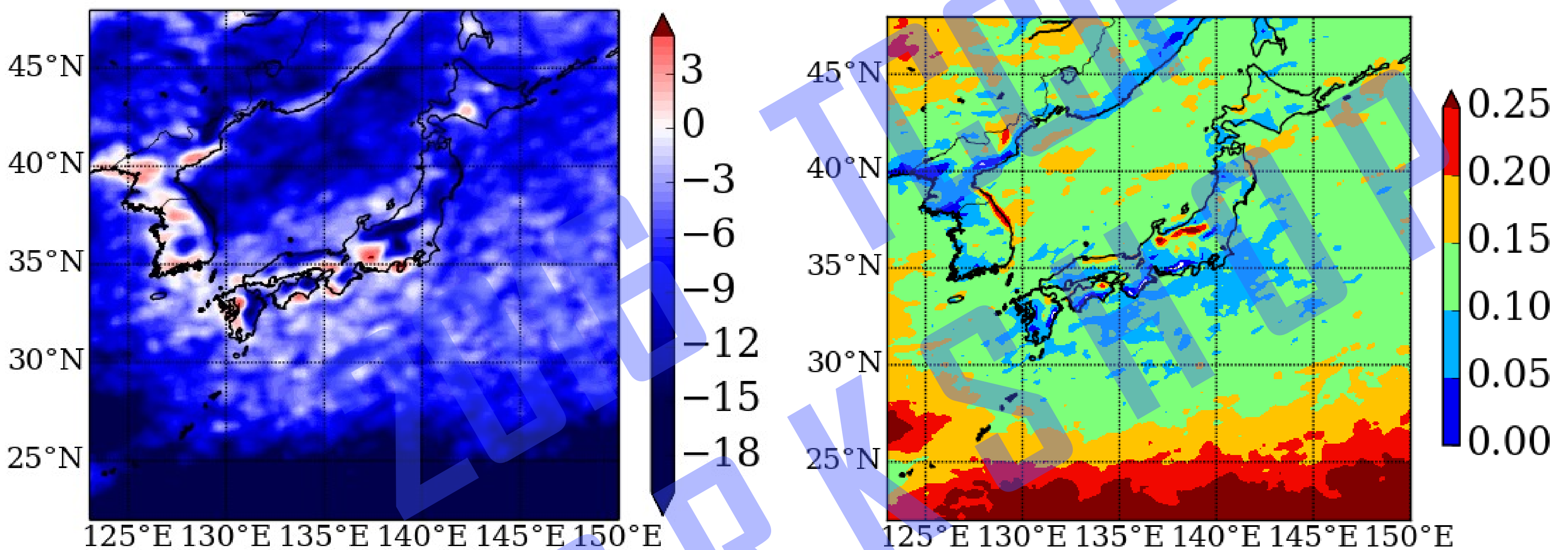
Why the fitness of GEV to R1d is low?

Shape parameter ξ of GEV (right figure); large ξ means heavy tailed GEV distribution.



The areas where overestimation of return levels are observed are overlapped with those of high shape parameters.

(i) Bad fitting of GEV to R1d distribution

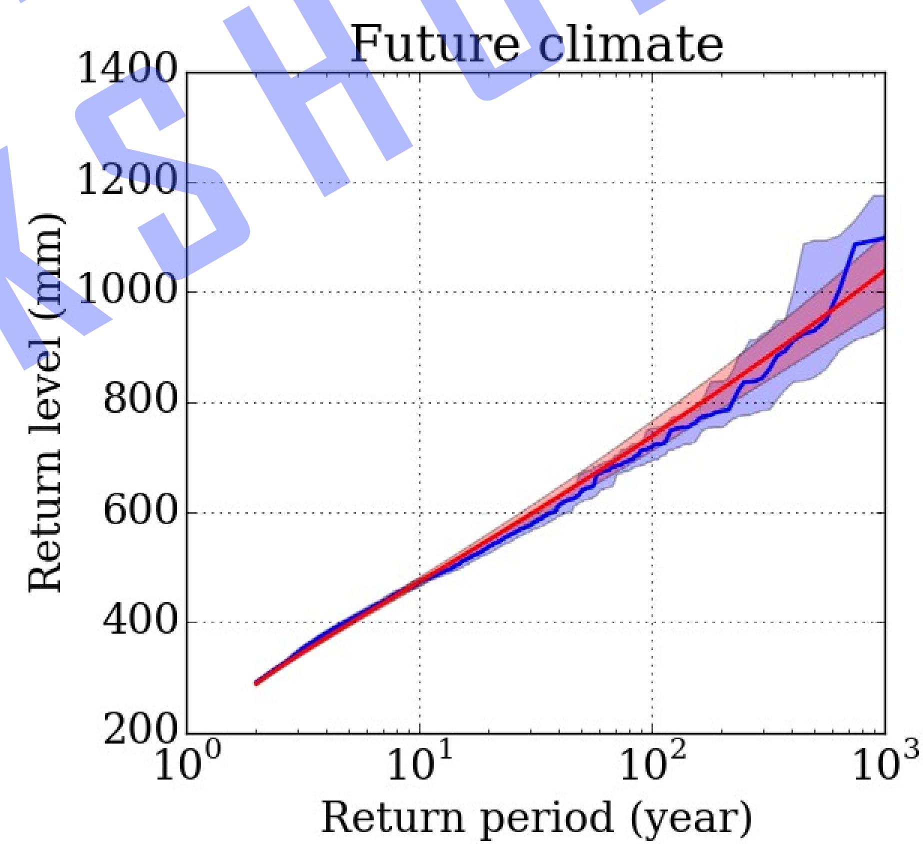
(ii) Artificial large shape parameter and heavier tail of GEV.

(iii) Overestimation of return levels with large return periods.

Why the fitness of GEV to R1d is low? (cont.)

- R1d is not a perfect extreme value.
  The assumption that a value is followed by GEV is that this value is the maximum value of large enough samples.
- This is considered as follows, on land, orographic extreme precipitation invariably happens at least once in a year, while on ocean, extreme precipitation does not occur without a direct hit of a tropical cyclone

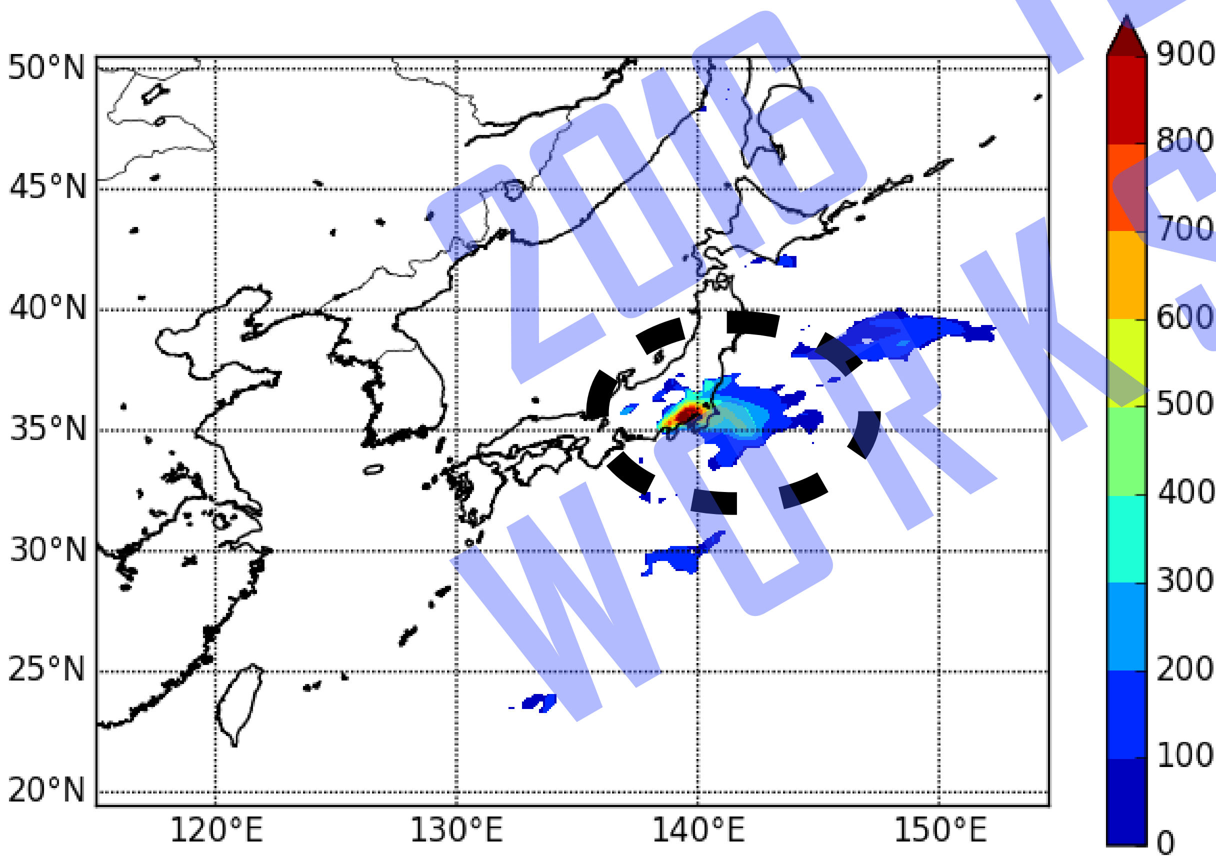
<u>GEV fitting test on the southern ocean</u>
<u>R10d : maximum daily precipitation over 10 years, not 1 year (R1d)</u>



- R10d is fully followed by GEV distribution and matches the results of nonparametric method.

Extreme precipitation with 1000 years return levels is a rare event?

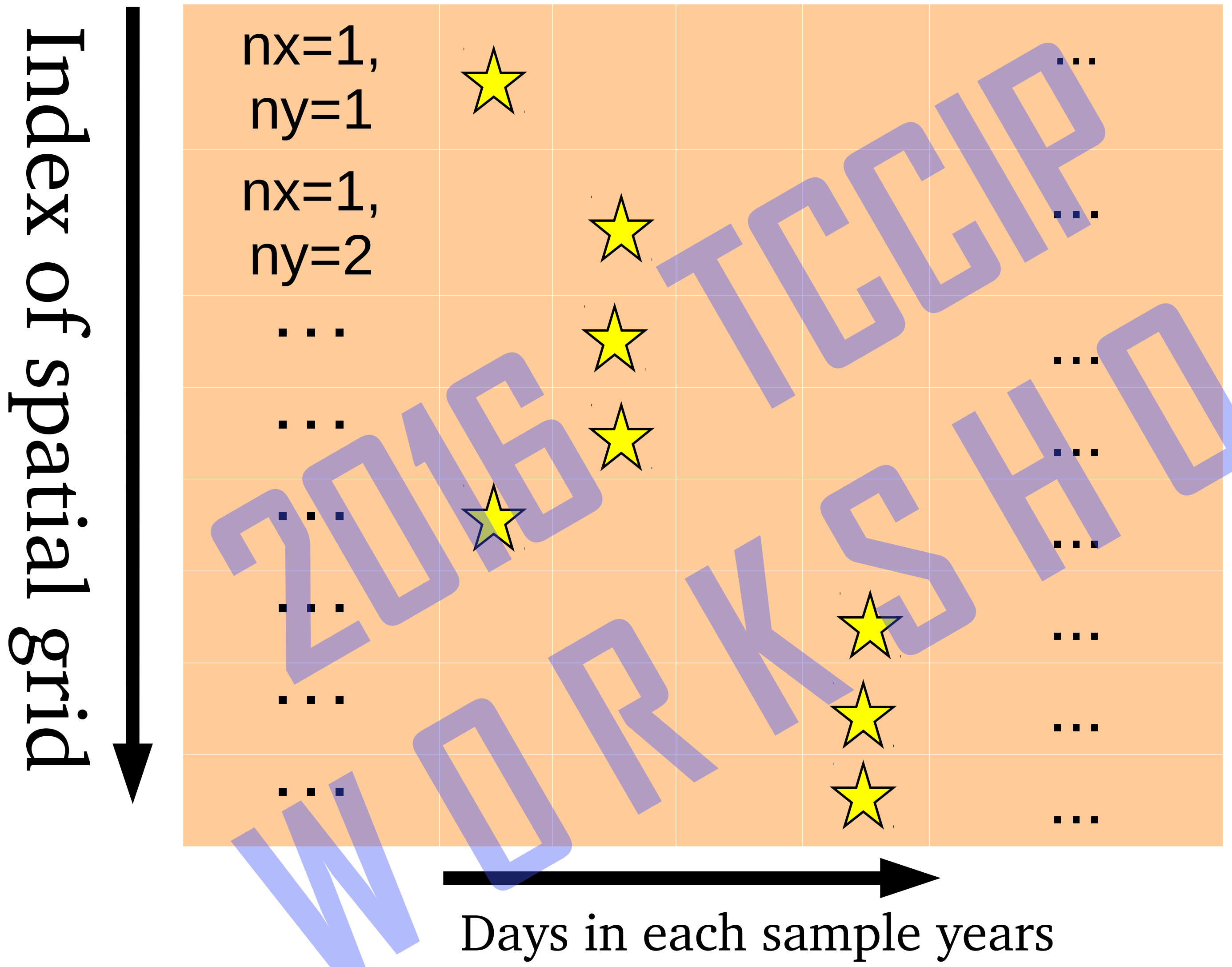
- Return levels are defined as a local estimation of extreme precipitation.
- The precipitation events usually do not extend to whole target areas (ex. Japan islands) and are limited in a small regions (e.g. bottom figure)
- Considering some areas, they happen more frequently somewhere in the areas than once for 1000 years.



Spatial distribution of precipitation (only locations of R1d precipitation) at the day when maximum precipitation over 5000 years data is obtained.

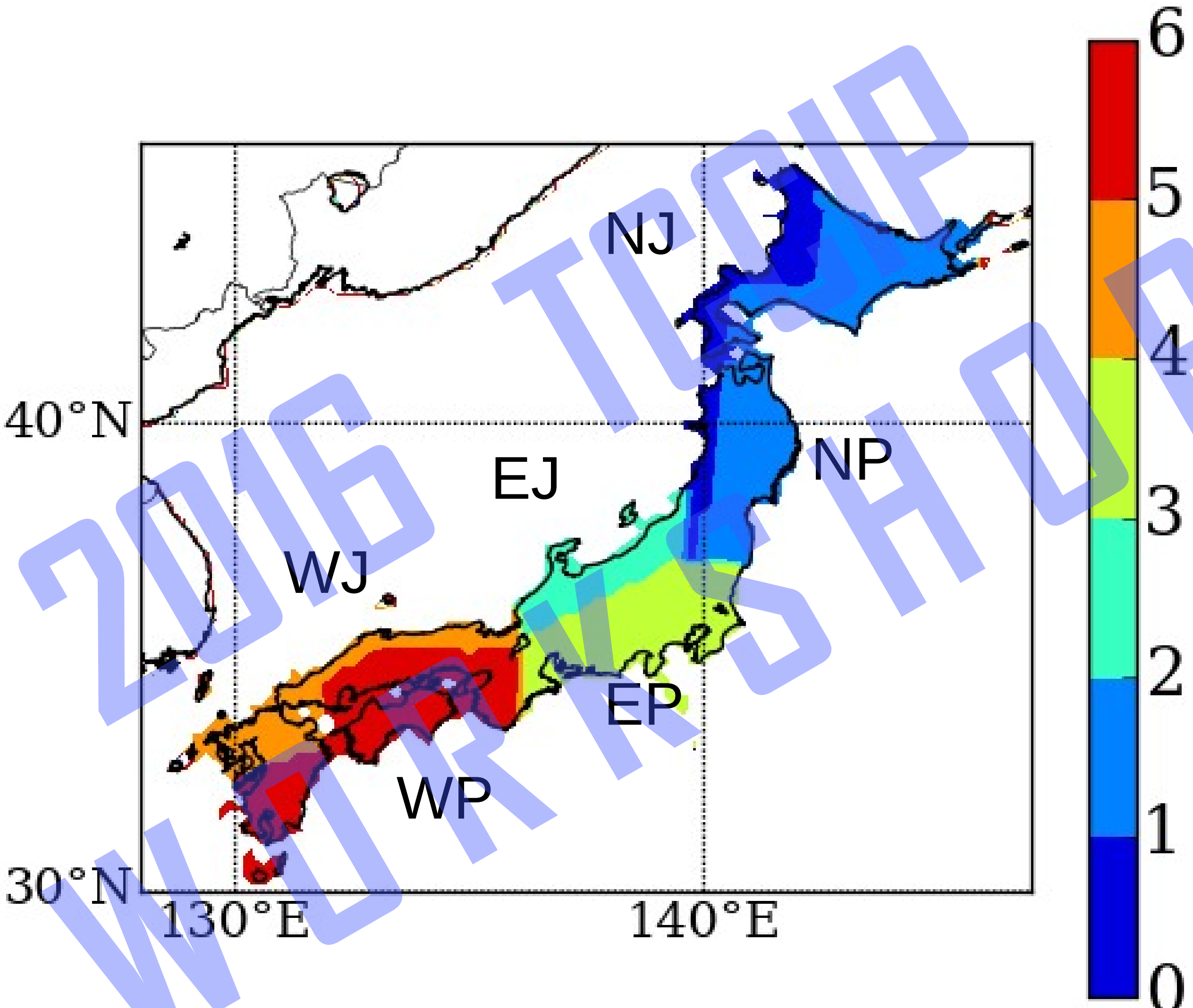
Regional return periods

(local return levels = 1000year in future experiment)



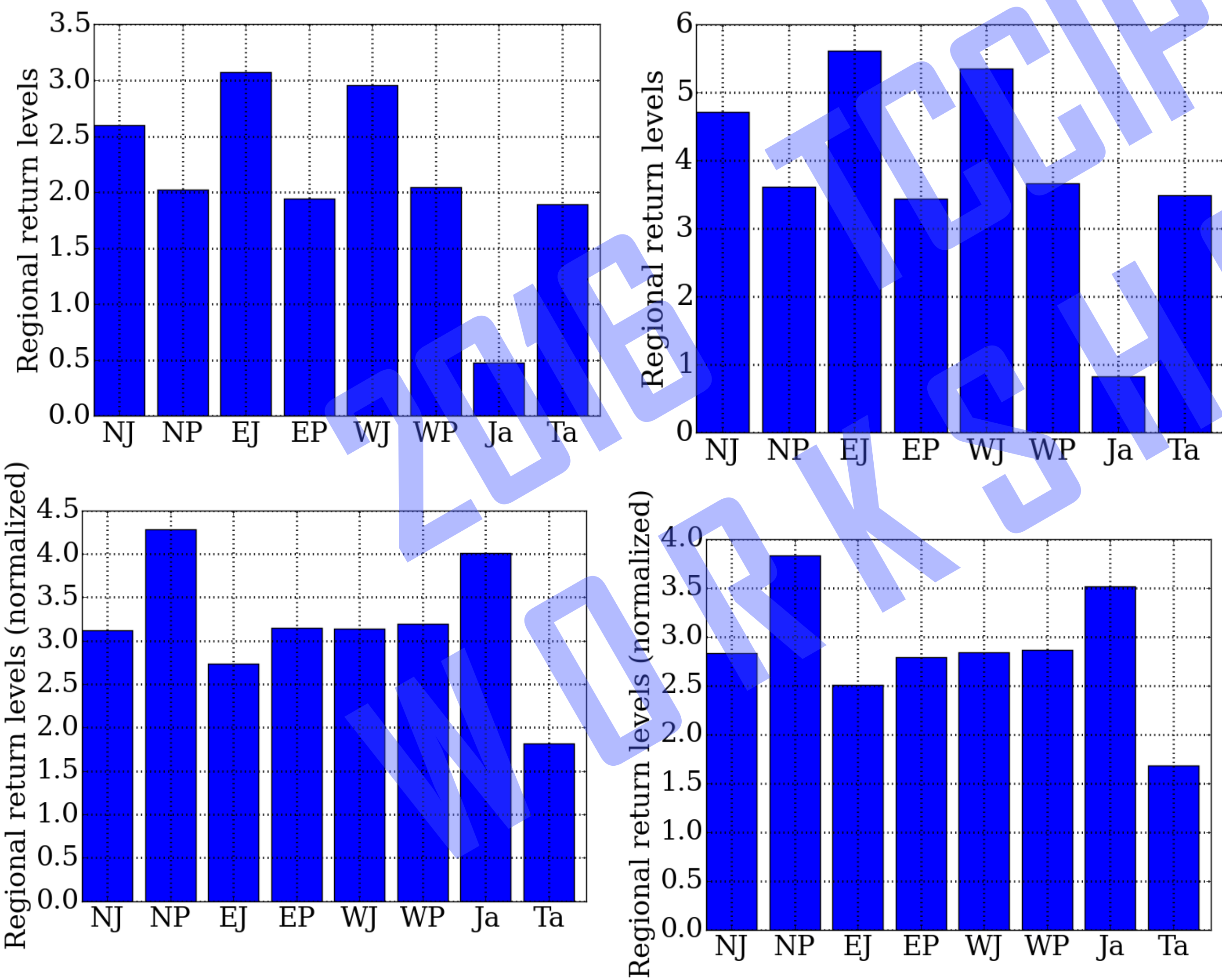
Only 5 events in each grid

Sample of years
Present: 3050 years, Future:5490 years



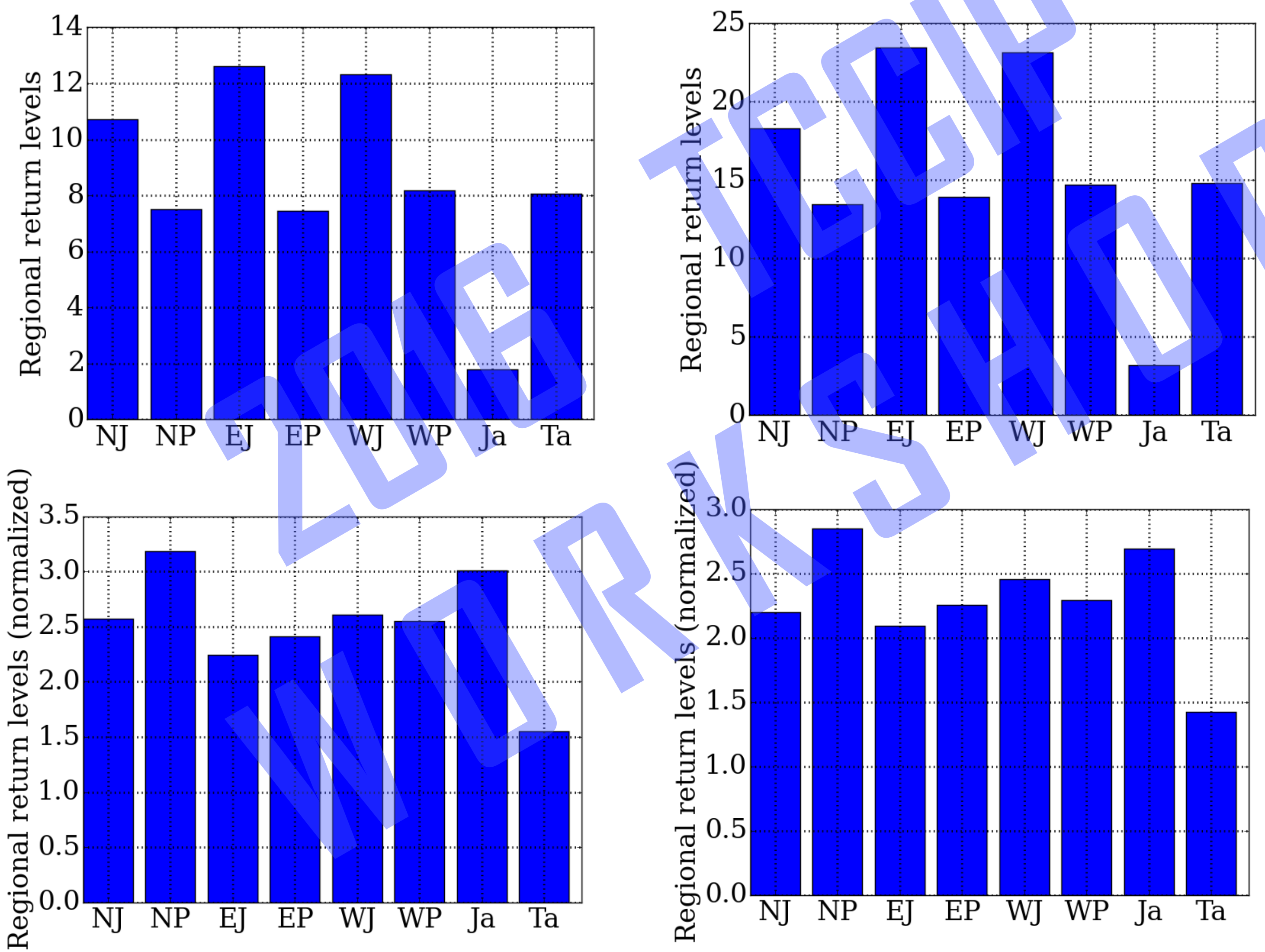
NJ
NP
EJ
WJ
EP
WP
40°N
30°N
130°E
140°E
6
5
4
3
2
1
0

How many days do we watch a news about extreme precipitaion with X return periods?



Local return period = 100 years (left) and 200 years (right)

Local return period = 500 years (left) and 1000 years (right)



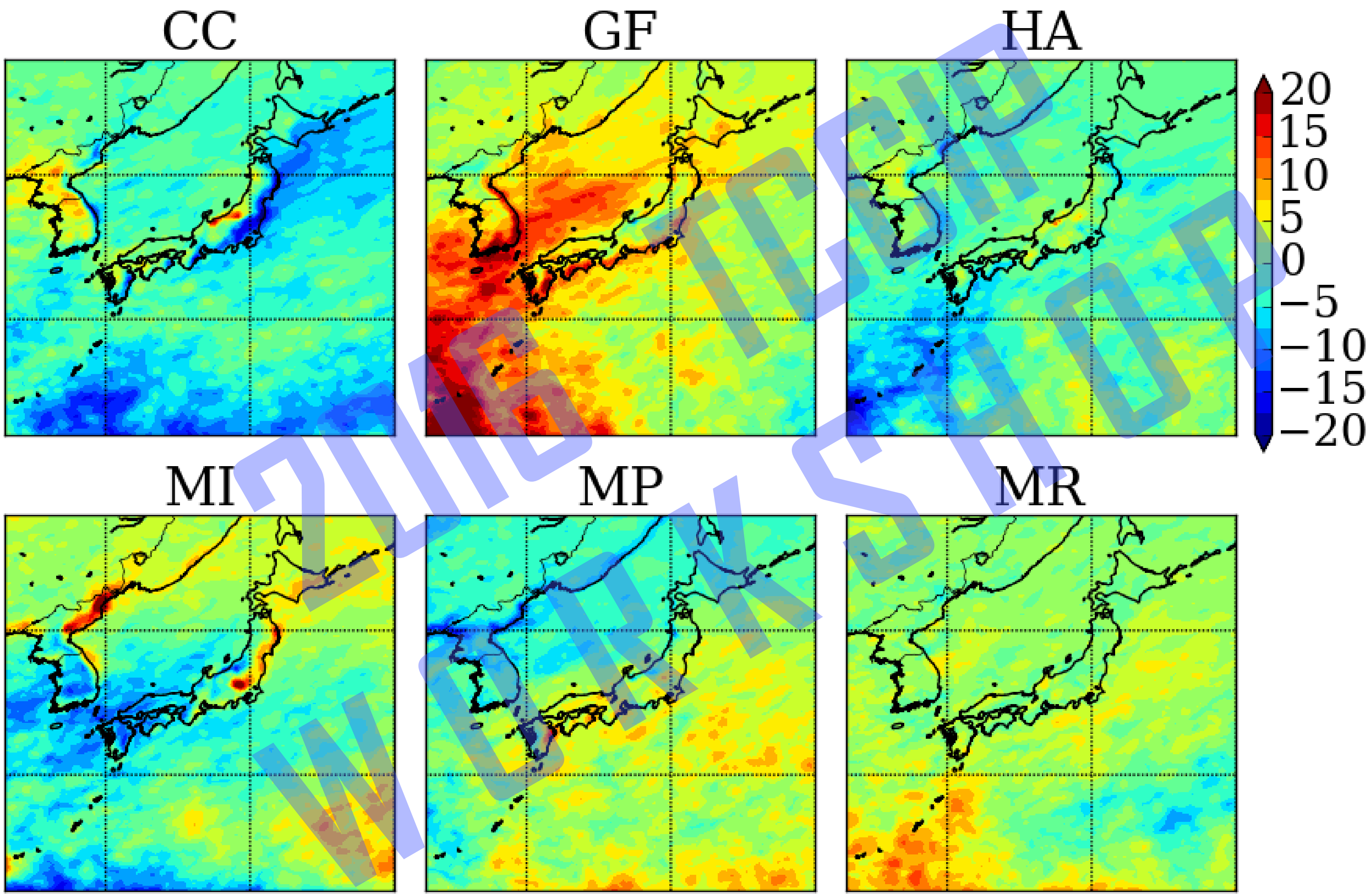
Summary and conclusion

- We estimate the present and future extreme precipitation using d4PDF regional data, which enables the calculation of the very extreme precipitation of the order of 1000 years and its spatial distribution.
- Non-parametric method yields reliable estimation of extreme percipitaion without any assumption about the statistical characteristics of extreme preciptaiont.
- The present study shows that the validity of the GEV method around Japanese islands areas is high. On the other hand, the GEV method yield overestimated values of large return levels on the ocean, which suggests the use of alternative functions to fit the R1d data (logarithimic normal, exponential etc.).
- The method using varisou fitting functions have technical problem about which function should be used; non-parametric method has an advantage over them.
- Non-parametric method enables the domain-accumulated frequency of extreme precipitation when given a return periods.

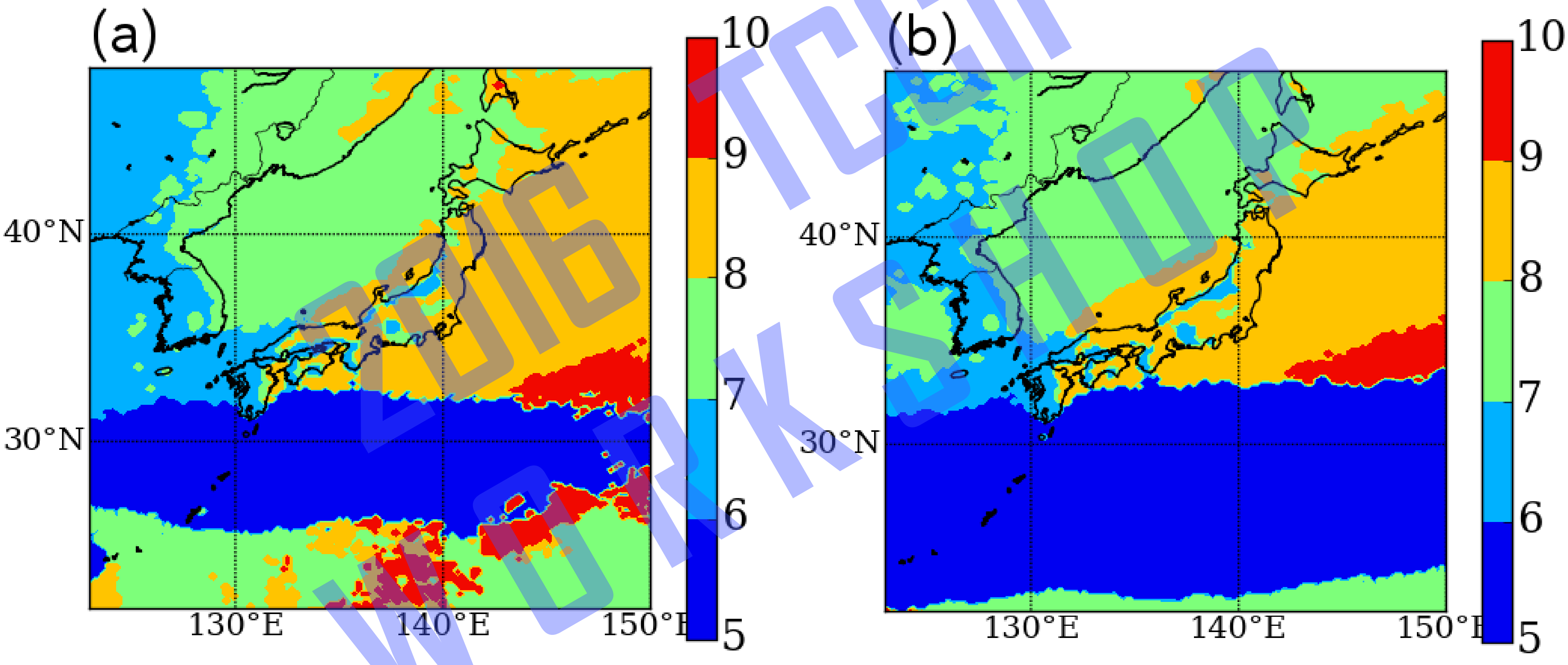
Thank you for your attention

This study was supported by Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) under the framework of the "SOUSEI" program.

アンサンブルグループ間の違い



R1dが最も多く取り出された月



Introduction of "Database for Probabilistic Description of Future Climate Change (d4PDF)"

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1: Meteorological Research Institute

2: Atmosphere and Ocean Research Institute, The University of Tokyo

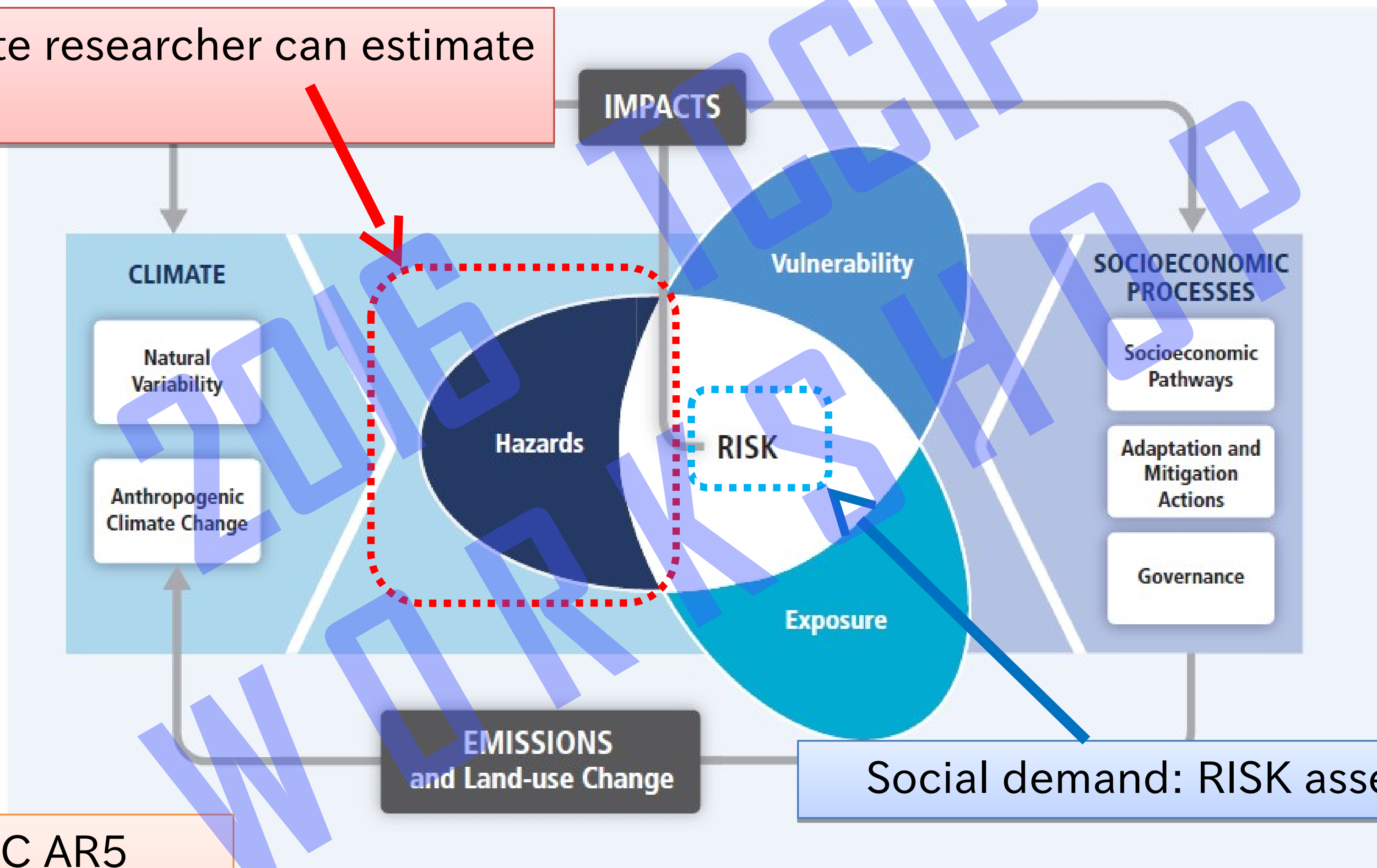
3: Disaster Prevention Research Institute, Kyoto University

V2.1

2015/11/25

Climatic Hazards and Risk Assessment

What climate researcher can estimate



Social demand: RISK assessment

Figure of IPPC AR5 WGII

...f the core concepts of the WGII AR5. Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous ...ulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability. [19.2, Figure 19-1]

Calculate many ensemble cases with a rather coarse resolution model

Calculate for specific case with a very high resolution model

Information needed for RISK assessment

①Disaster prevention

Probabilistic information

PEA (Probabilistic Event Attribution)

Save infrastructure

②Disaster mitigation

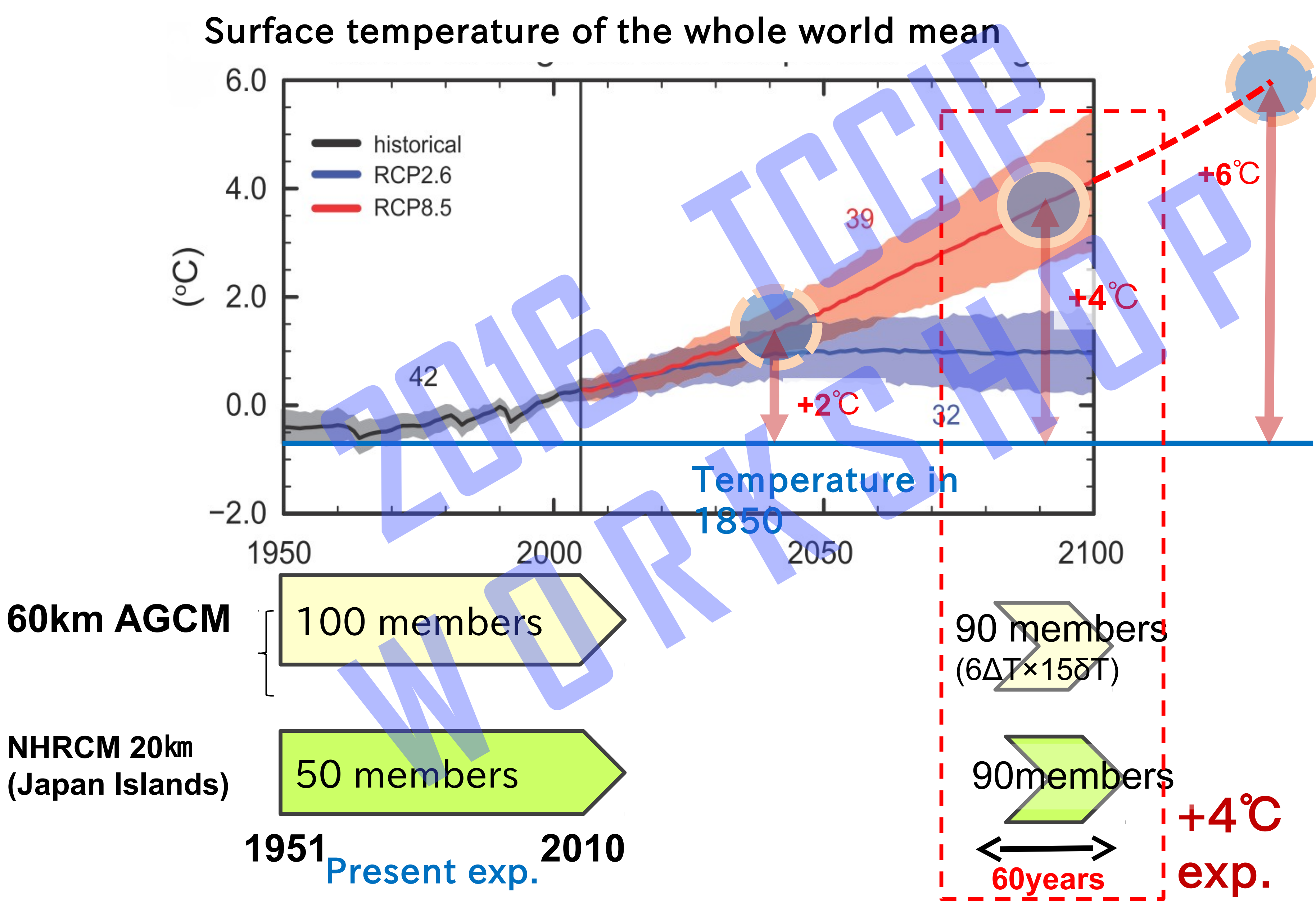
Worst case scenario

Event focusing

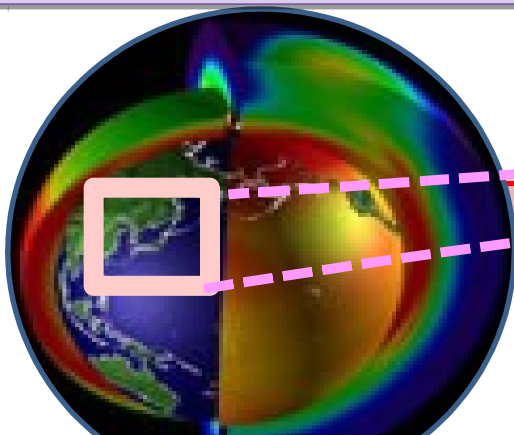
Prepare hazard-map and save life

d4PDF

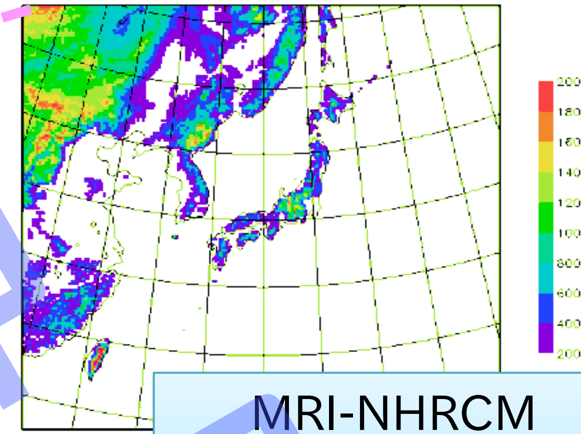
Design of d4PDF experiments



The database which express the 5,400 patterns in +4°C world



Dynamical downscaling

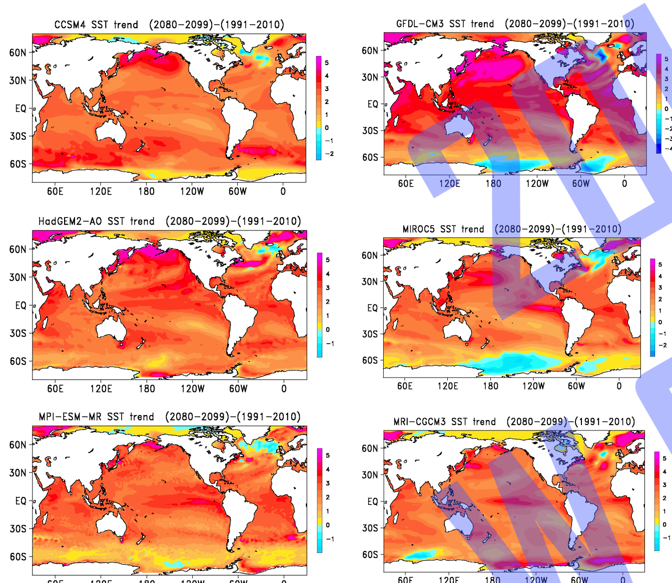


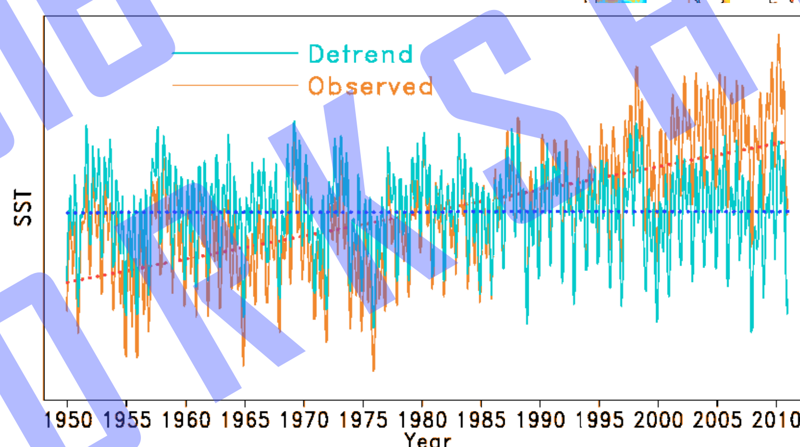
Data amount: 1.2 PB

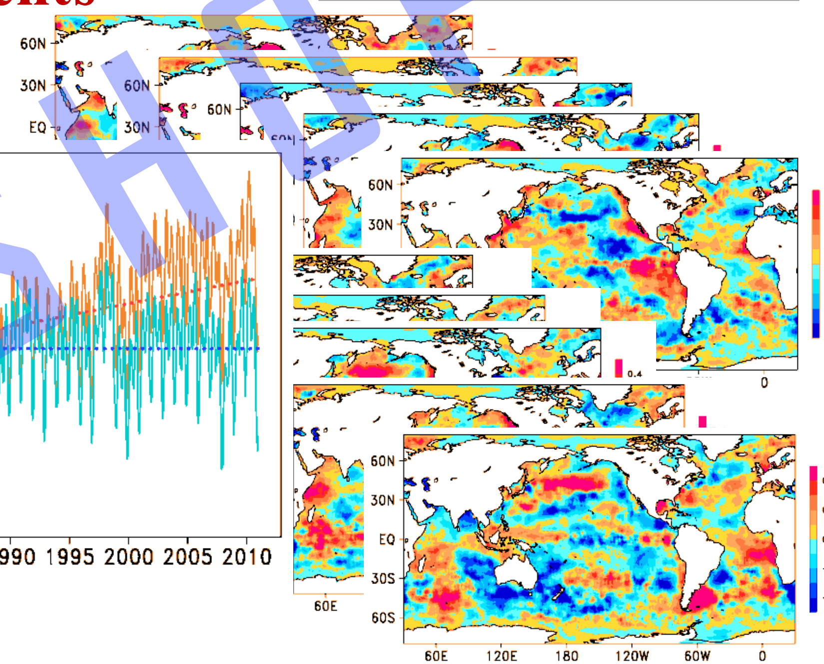
MRI-AGCM Grid size: 60km

MRI-NHRCM Grid size: 20km

SST for +4°C experiments







6 type C.C. trends in CMIP5 experiments
(ΔT; Shiogama et al. 2010)

×

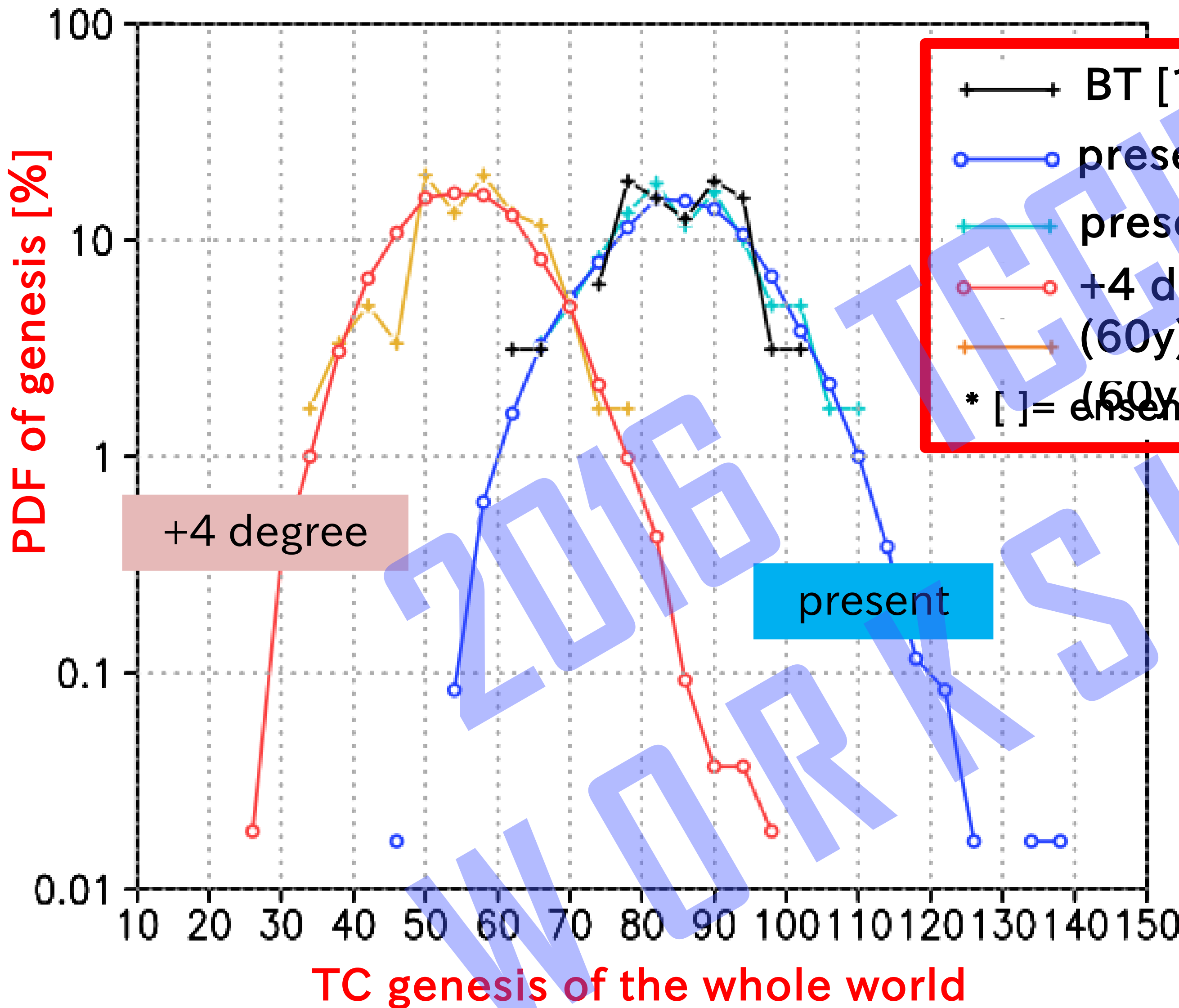
SST without trend
(blue line; COBE-SST2)

C.C. trends is 1st mode of EOF

×

15 ensembles which count the uncertainty of observed value
(δT)

Change of TC genesis of the whole world



Standard deviation of annual variation

HPB(1951-2010): 10.35 (±0.90)

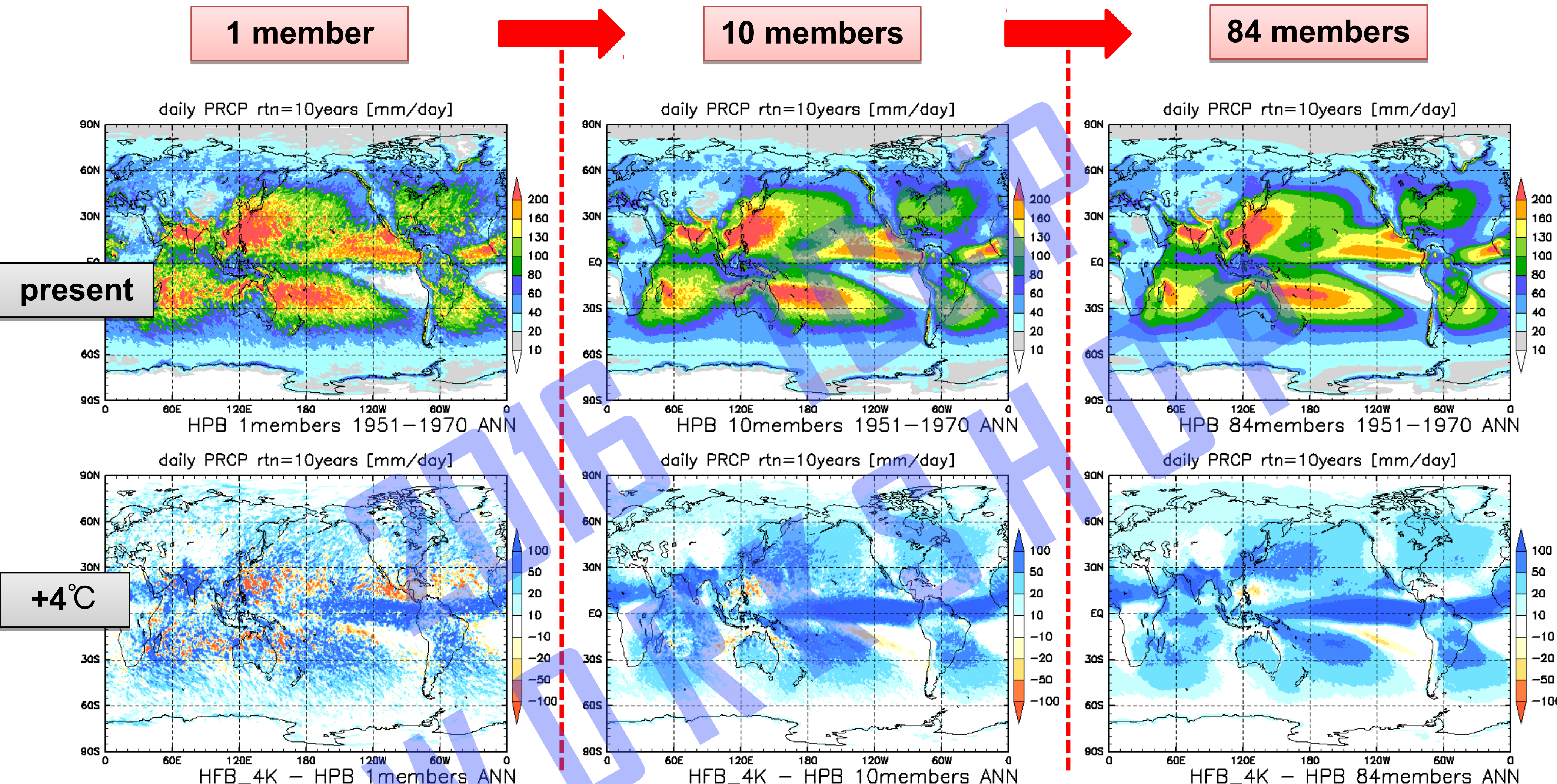
HPB(1979-2010): 9.74 (±1.24)

BT (1979-2010): 8.91

HFB(2051-2110): 8.76 (±0.88)

Yoshida（2015 MSJ fall meeting)

10 years return periods daily precipitation



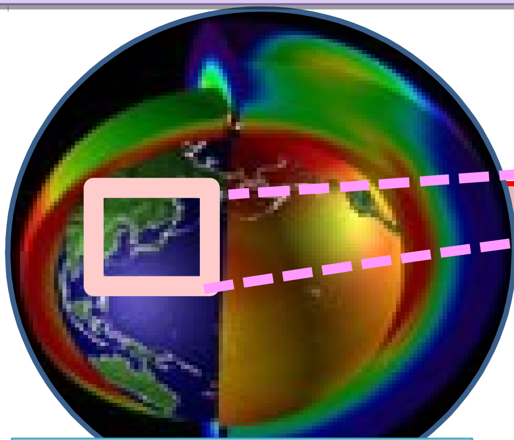
- Changes of such heavy precipitation become clear as the member increase
- Such heavy precipitation increase in the Eastern Pacific, India, and Western Africa

Mizuta（2015 MSJ fall meeting)

Summary

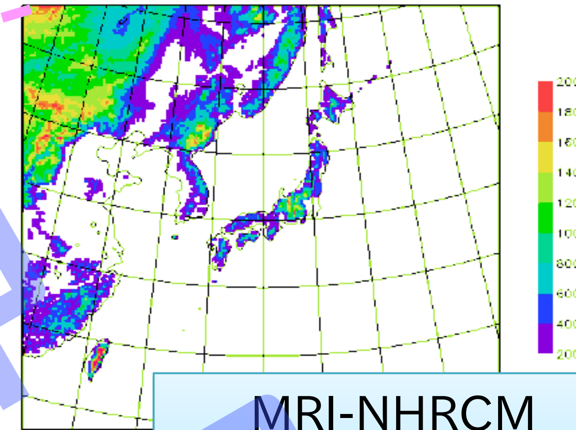
- For RISK assessment of C.C., we have to thin k how to calculate the C.C. by using our mod el.
- Here we have two schemes to get useful dat a for impact study researchers.
- One method is to calculate so many ensembl e number to get PDF of the phenomena.
- We introduce here d4PDF project.

The database which express the 5,400 patterns in +4°C world



MRI-AGCM Grid size: 60km

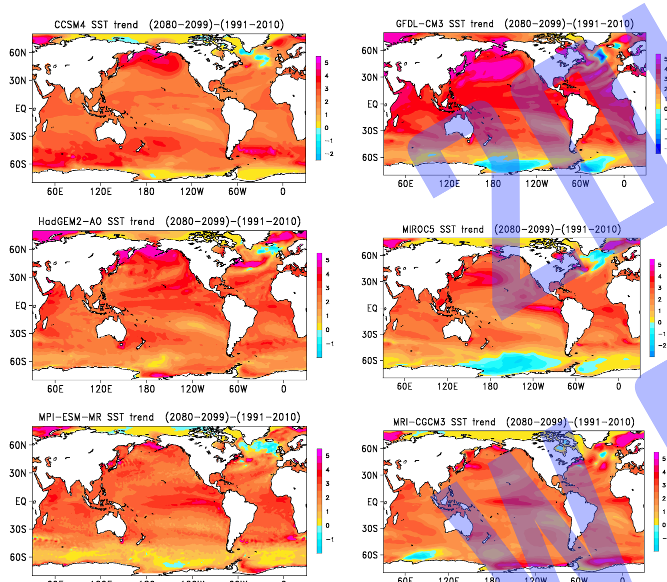
Dynamical downscaling

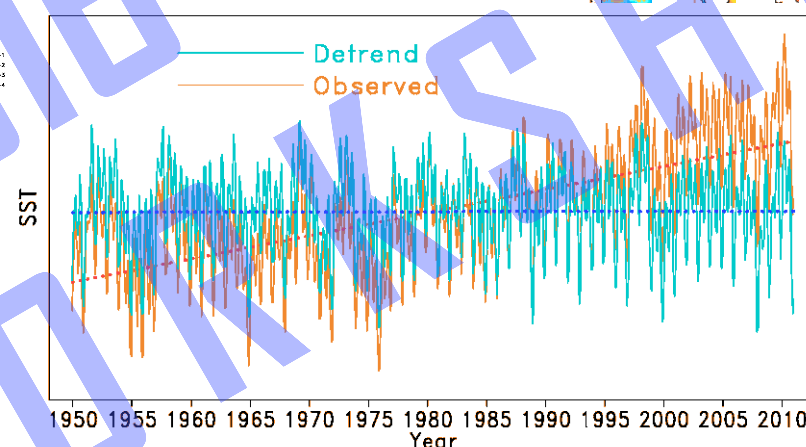


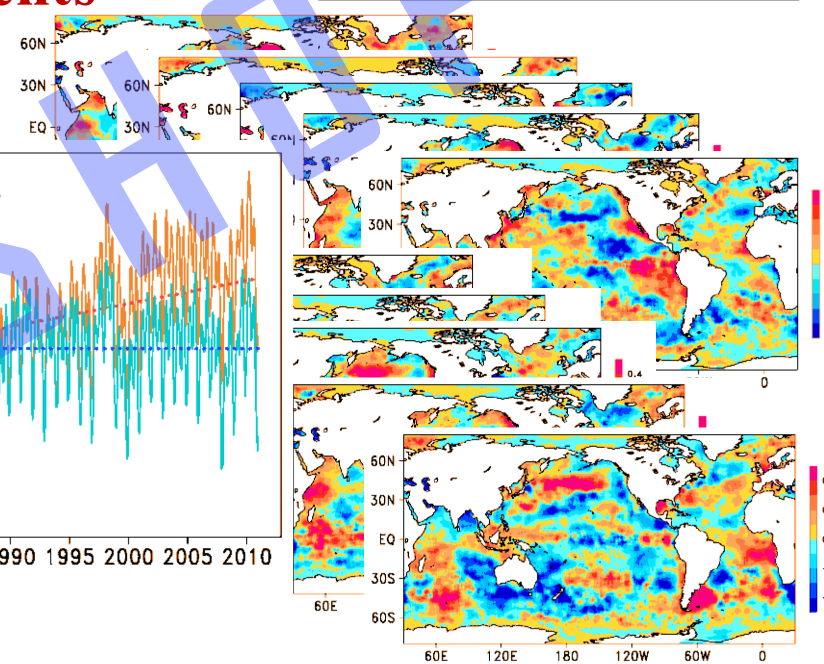
MRI-NHRCM Grid size: 20km

Data amount: 1.2 PB

SST for +4°C experiments







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