Nanjing University of Information Science and Technology

Changes in extreme temperature over China when global warming stabilized at 1.5 ℃ and 2.0℃

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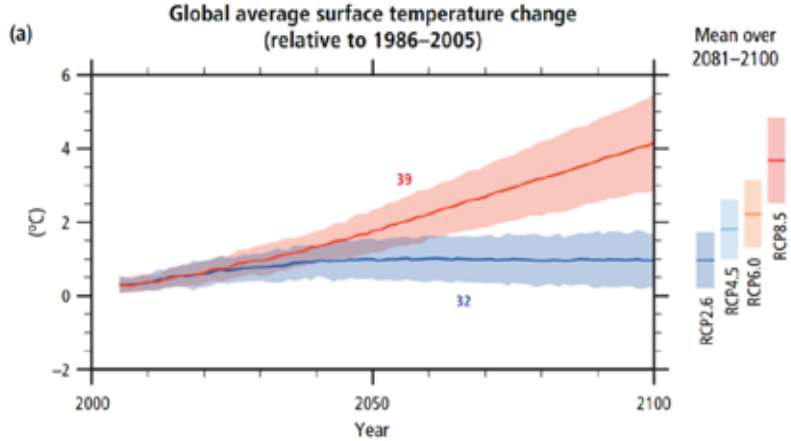
Outline

- **Introduction**
- Data & Methods
- Results
  - Changes in mean and extreme temperature
  - Changes in occurrence probabilities for hot extremes
  - Changes in occurrence probabilities for cold extremes
- Conclusions

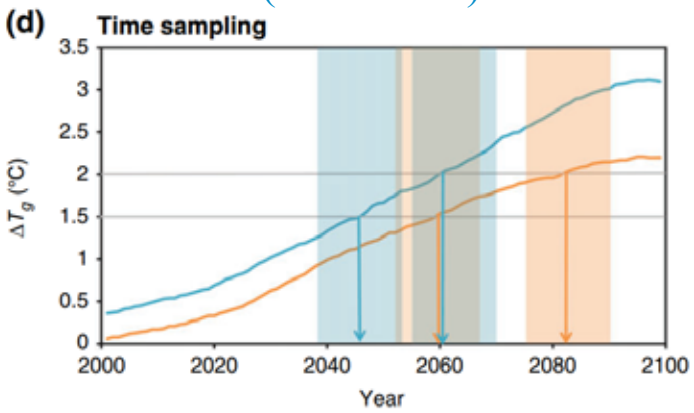
1. INTRODUCTION

- Paris Agreement: holding the increase in the global average temperature to well below 2.0℃ above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5℃ at the end of 21th century.

transient simulations (CMIP5)



(IPCC AR5)



(Rachel James et al, 2017)

stabilized simulations (HAPPI)

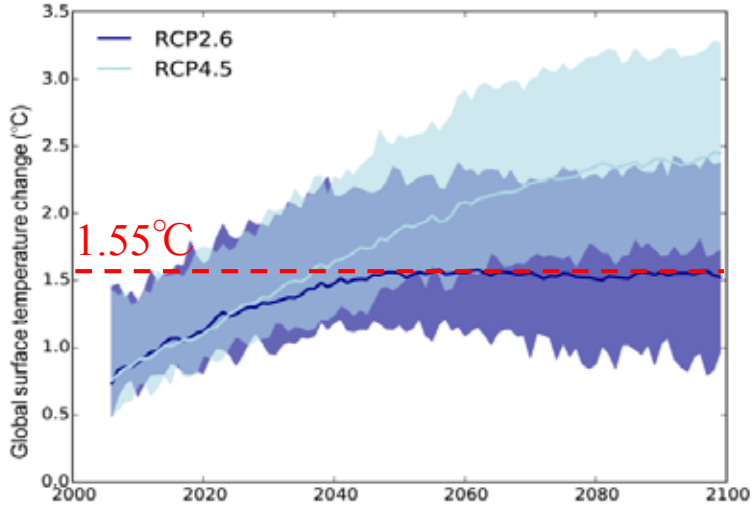


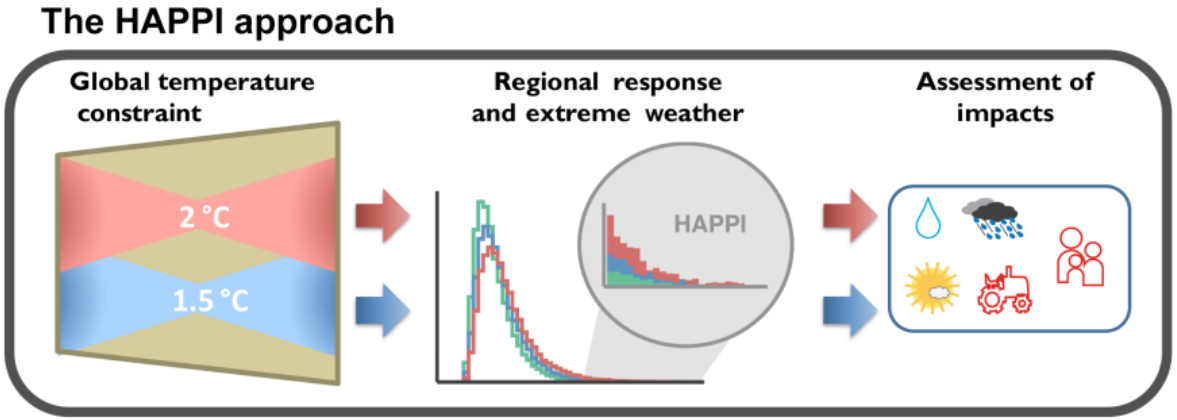
Figure 2. Time series of global annual mean surface-air temperature anomalies (relative to 1861–1880) from CMIP5 RCP2.6 and RCP4.5 experiments. Solid lines show the multi-model mean and shaded regions show the 5–95 % range across all 26 models. Only one simulation is used for each model. All models where the data were available for both scenarios were used, leading to 26 models in total.

(Mitchell D et al, 2017)

1. INTRODUCTION

- ‘Half a degree Additional warming, Prognosis and Projected Impacts’ (HAPPI) project——

  Using the SST patterns under present-day (2006-2015), 1.5℃ and 2.0℃ to drive AMIP models to obtain the stabilized global warming simulations.



(Mitchell D et al, 2017)

- The large ensemble size (≥100) of HAPPI reduces the uncertainty caused by internal variability, especially when dealing with extreme events.

1. INTRODUCTION

Questions:

- Is there any difference between results based on transient and stabilized simulations?

- The uncertainty of responses to global warming is caused by models' spreads and internal variability. If their contribution can be estimated quantitatively?

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2. DATA & METHODS

- **4 models of HAPPI**: 3 simulations of the Tier-1 experiment

(1) present-day climate (2006-2015), drived by observed SST patterns;

(2) 1.5°C warming level, drived by SST patterns from RCP2.6 scenario;

(3) 2.0°C warming level, drived by SST patterns from weighted RCP2.6 and RCP4.5 scenario

Basic information on 4 HAPPI models

Model	Resolution (#lat × #long)	Ensemble members
CanAM4	64×128	100
ECHAM6-3-LR	96×192	100
MIROC5	128×256	100
NorESM1	192×288	100

2. DATA & METHODS

- **15 models of CMIP5, under RCP4.5 scenario** (only for comparison under the additional 0.5℃ warming)

Basic information on CMIP5 models and the time of 1.5℃ and 2.0℃ global warming

Model	Resolution (#lat × #long)	Time of 1.5℃	Time of 2.0℃
BCC-CSM-1	64×128	2023	2045
BCC-CSM1-1-M	160×320	2014	2039
CCSM4	192×288	2017	2040
CNRM-CM5	128×256	2037	2059
CSIRO-MK3-6-0	96×192	2035	2048
GFDL-CM3	90×144	2023	2037
IPSL-CM5A-LR	96×96	2013	2030
IPSL-CM5A-MR	143×144	2017	2034
MIROC-ESM-CHEM	64×128	2022	2036
MPI-ESM-MR	96×192	2023	2045
MPI-ESM-LR	96×192	2021	2042
MRI-CGCM3	160×320	2054	2085
MIROC5	128×256	2040	2072
NorESM1-M	96×144	2041	2074
anESM2	64×128	2018	2031

2. DATA & METHODS

- **4 extreme temperature indices**: TXx, TNn, WSDI and FD

Definition of 4 extreme temperature indices

Abbrev-iation	Indicator name	Definitions（Units）
TXx	Hottest day	Annual maximum daily maximum temperature (°C)
TNn	Coldest day	Annual minimum daily minimum temperature (°C)
WSDI	Warm spell duration	Annual count of days with at least 6 consecutive days when daily maximum temperature >90th percentile (days)
FD	Frost days	Annual count of days when daily minimum temperature < 0°C (days)

2. DATA & METHODS

➢ Analysis of uncertainty

The HAPPI experimental design permits to explore variation of results attributable to inter-model differences and internal (inter-member) variation.

Internal (inter-member) variability: $$\sigma_N^2 = \frac{1}{M}\sum_{m=1}^{M}\{\frac{1}{N}\sum_{n=1}^{N}[x(m,n) - x_i(m)]^2\}$$

Models' spread (inter-model variability): $$\sigma_M^2 = \frac{1}{M}\sum_{m=1}^{M}[x_i(m) - x_e]^2$$

➢ Probability Ratio (PR) :

the ratio between the two occurrence probabilities of the event in future (p1) and in present day (p0):

$$PR=p1/p0$$

➢ Generalized Extreme Value (GEV) :

We used GEV approach to evaluate the probability of extreme indices.

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3.1 Changes in mean and extreme temperature

Mean temperature

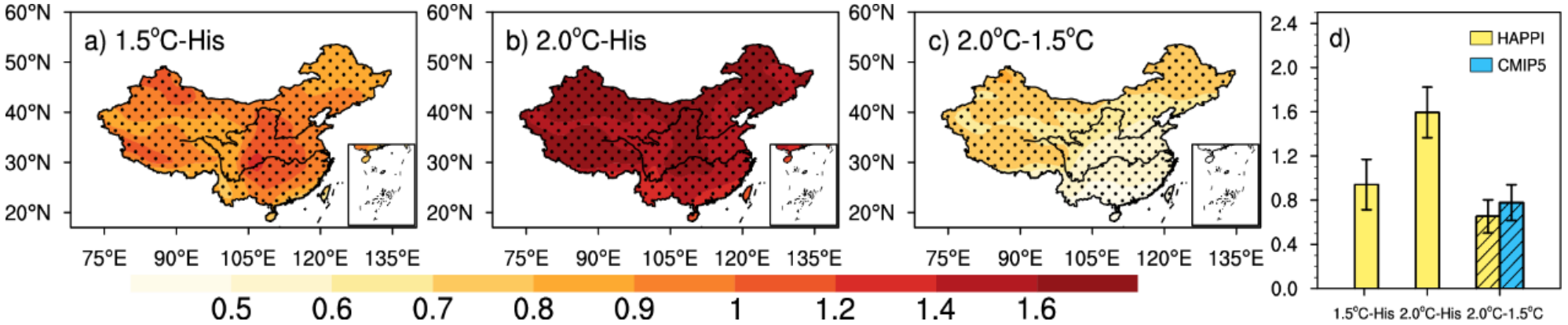

Figure 1. The changes of annual-mean temperature under stabilized 1.5℃ and 2℃ global warming relative to 2006-2015 (Units: ℃).

- The areal-mean over China increases by 0.94°C and 1.59°C, higher than the global mean.
- Large values are mainly located in Northwest and Northeast China.
- For 0.5°C warming, the national-mean result in transient simulation is significantly higher.

3.1 Changes in mean and extreme temperature

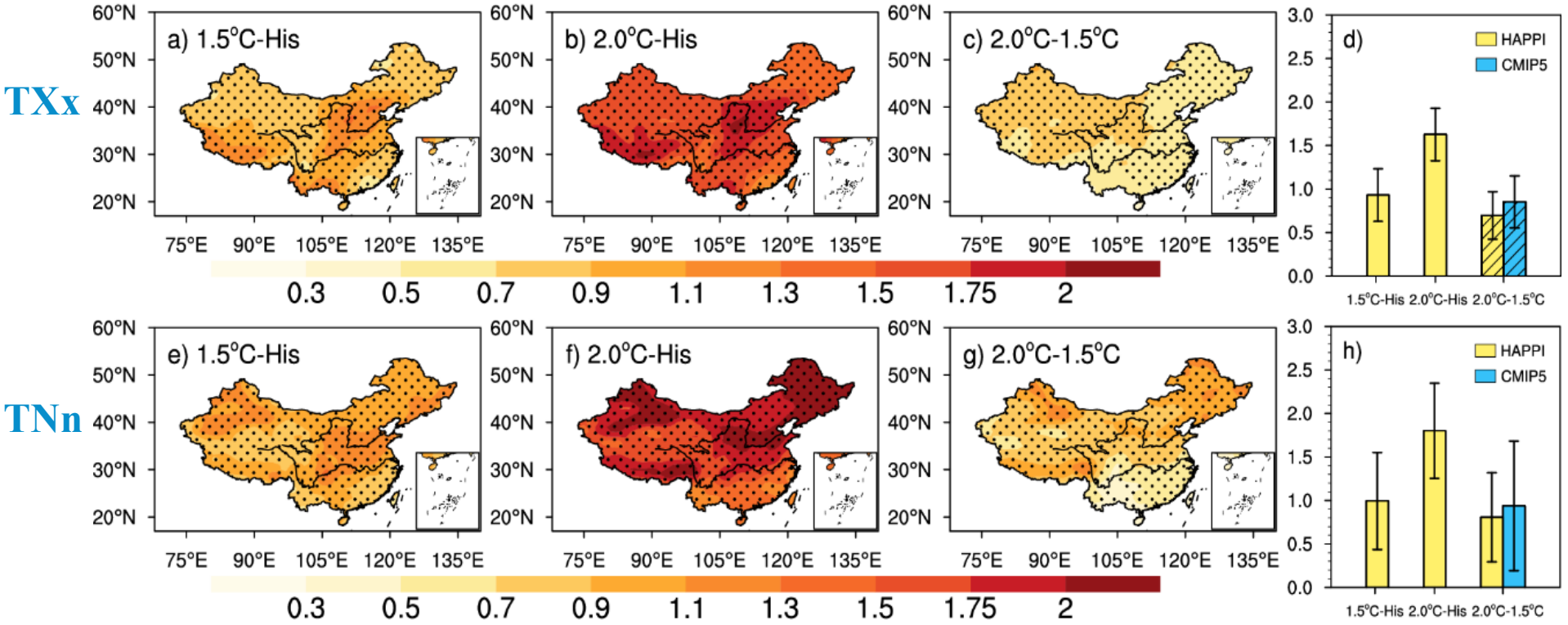

Figure 2. As in Fig.1, but for TXx (a-d) and TNn (e-h).

- Large values are mainly located in Northwest and Northeast-North China.

3.1 Changes in mean and extreme temperature

WSDI

FD

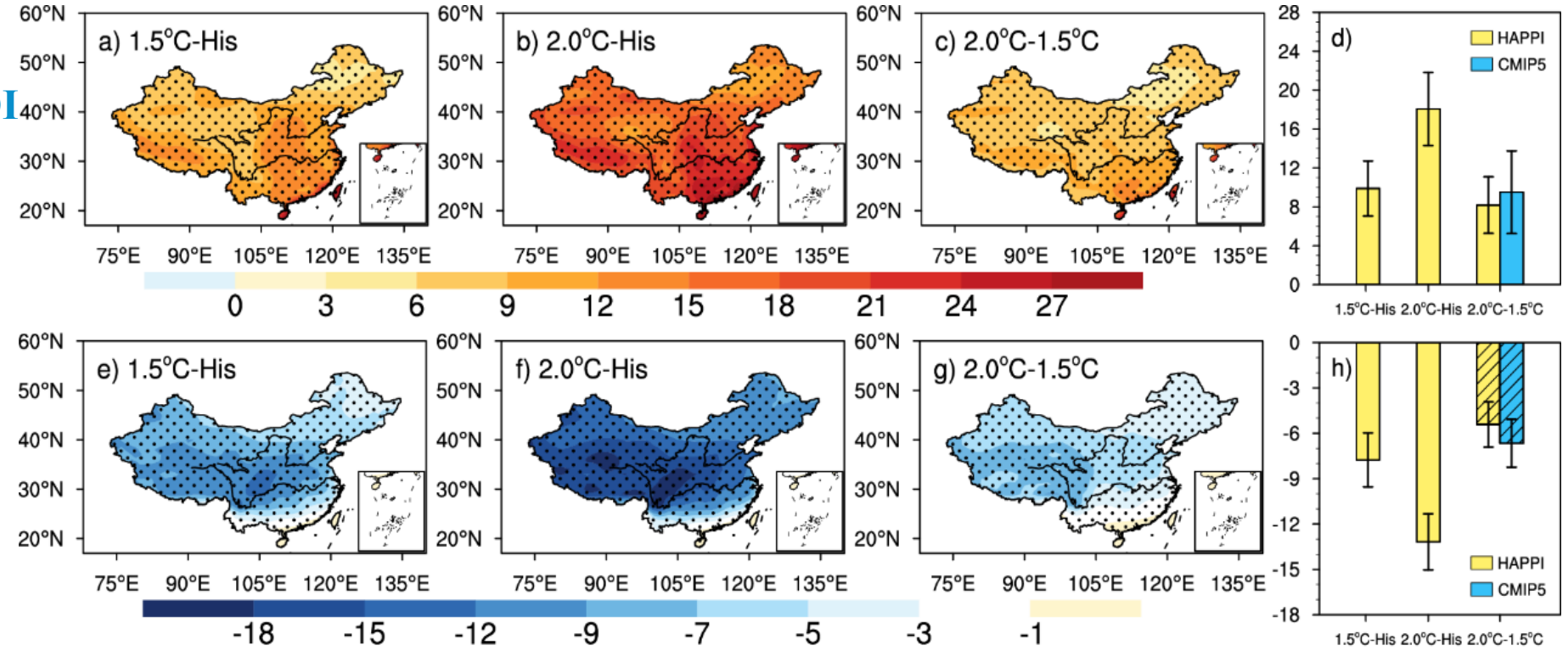

Figure 3. As in Fig.1, but for WSDI (a-d) and FD (e-h).

- WSDI mainly increases in the south of the Tibetan Plateau and in Southeast China, FD mainly decreases in the Tibetan Plateau, similar to transient results.

3.1 Changes in mean and extreme temperature / analyses of uncertainty

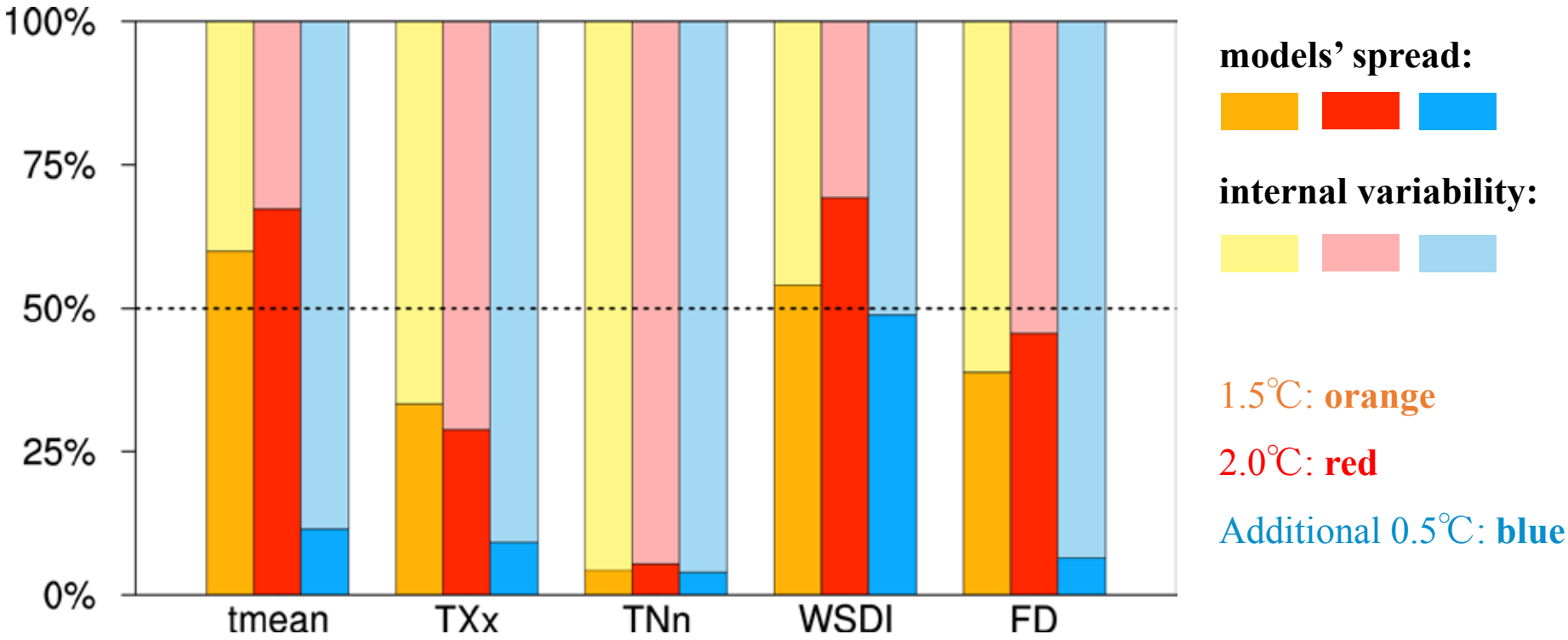

Figure 4. Percentages of variances for different areal-mean climate indices over China.

- For 1.5℃ and 2.0℃, the uncertainty of mean temperature is mainly derived from models' spread, while the extreme indices' uncertainty is mainly due to internal variability (except for WSDI)
- For 0.5℃, the uncertainty of all variables is mainly caused by internal variability (also except for WSDI).

3.2 Changes in occurrence probabilities for hot extremes

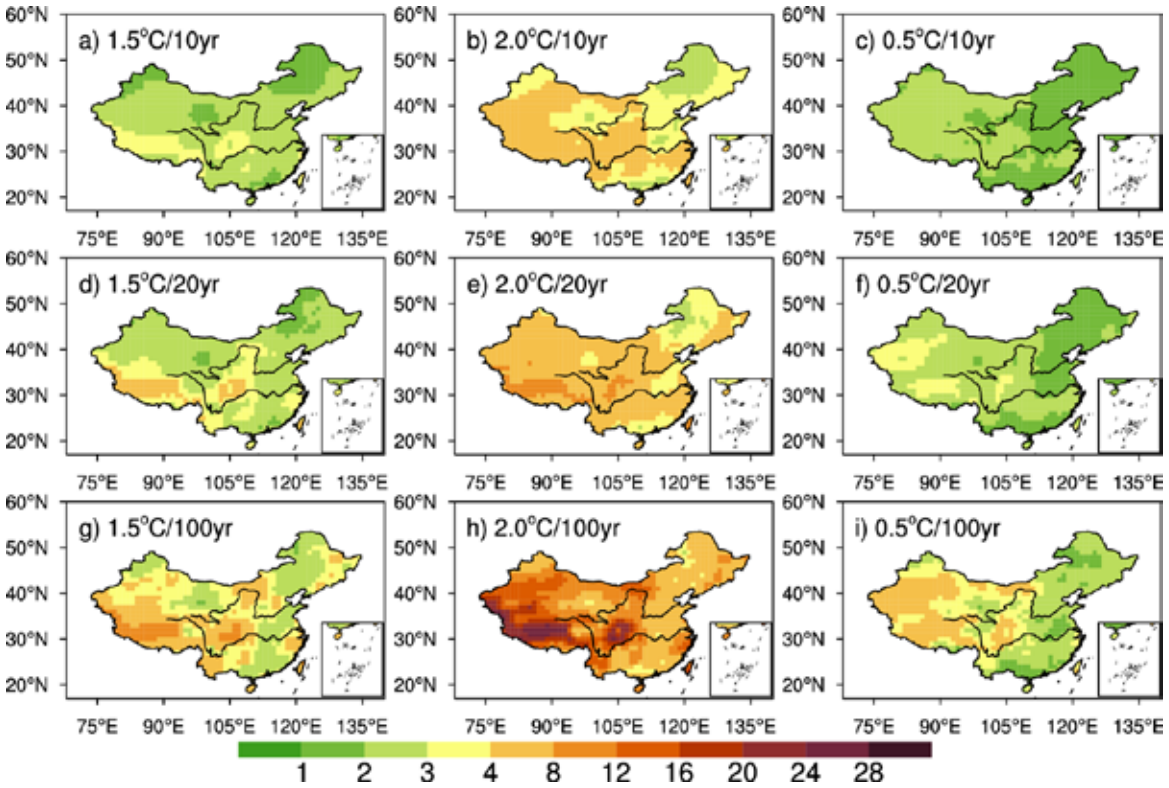

Figure 5. The spatial patterns of PR for 10-, 20- and 100-year TXx based on stabilized simulations.

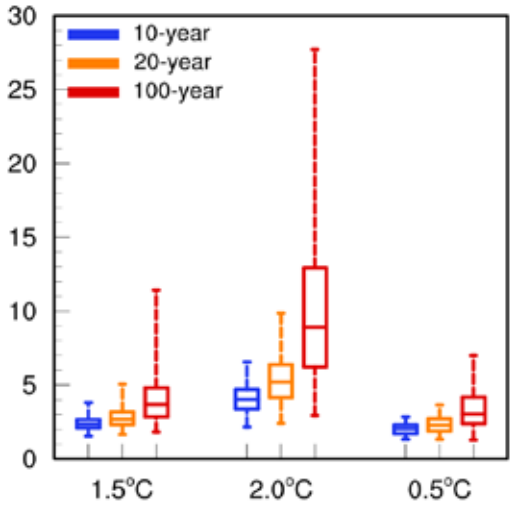

Figure S1. Boxplot of Figure 5.

- the spatial patterns of PR are similar between 1.5℃ and 2.0℃ global warming, the value is larger for a higher warming level and a rarer event.
- The PR is high in the south of the Tibetan Plateau and Northwest China.

3.2 Changes in occurrence probabilities for hot extremes

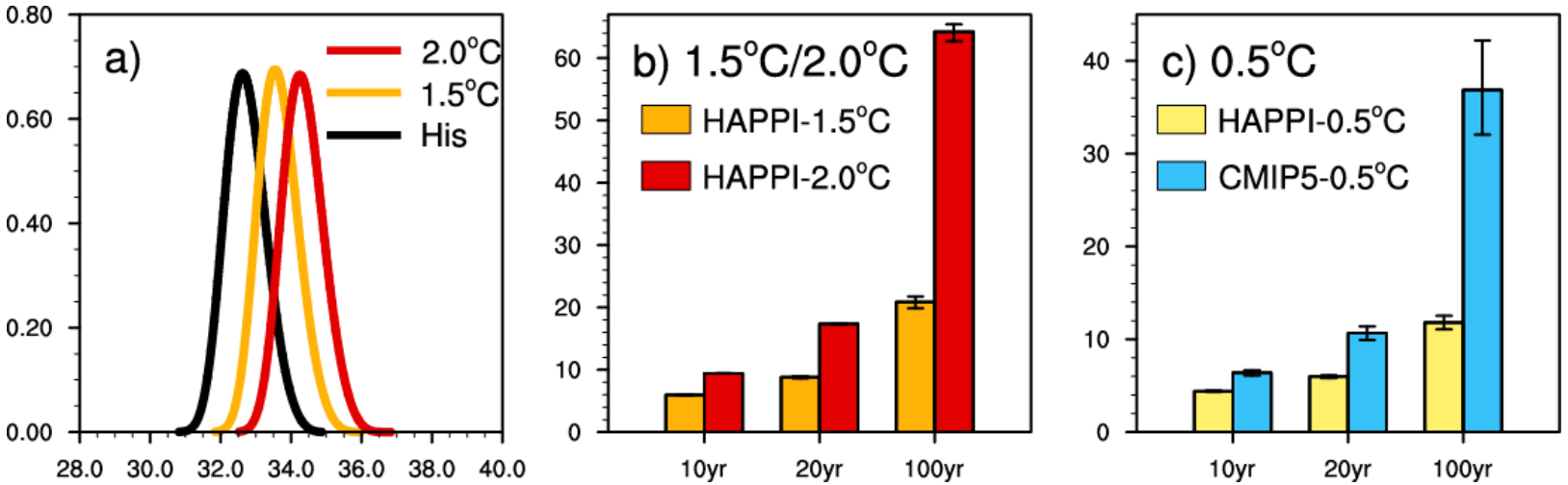

Figure 6. The PDF of areal-mean TXx series over China under stabilized 1.5℃ and 2.0℃ global warming (a) and the PR for 10-, 20- and 100-year areal-mean TXx in stabilized and transient simulations (b, c).

- The rarer extreme events, the higher warming levels, the largest value of PR.
- the additional 0.5°C: The PR in tranisent simulations are higher than that in stabilized simulations. The uncertainty ranges are wider.

3.3 Changes in occurrence probabilities for cold extremes

- Note that GEV distribution is only suitable for extreme large values, thus we take a negative sign for TNn when calculating PR.

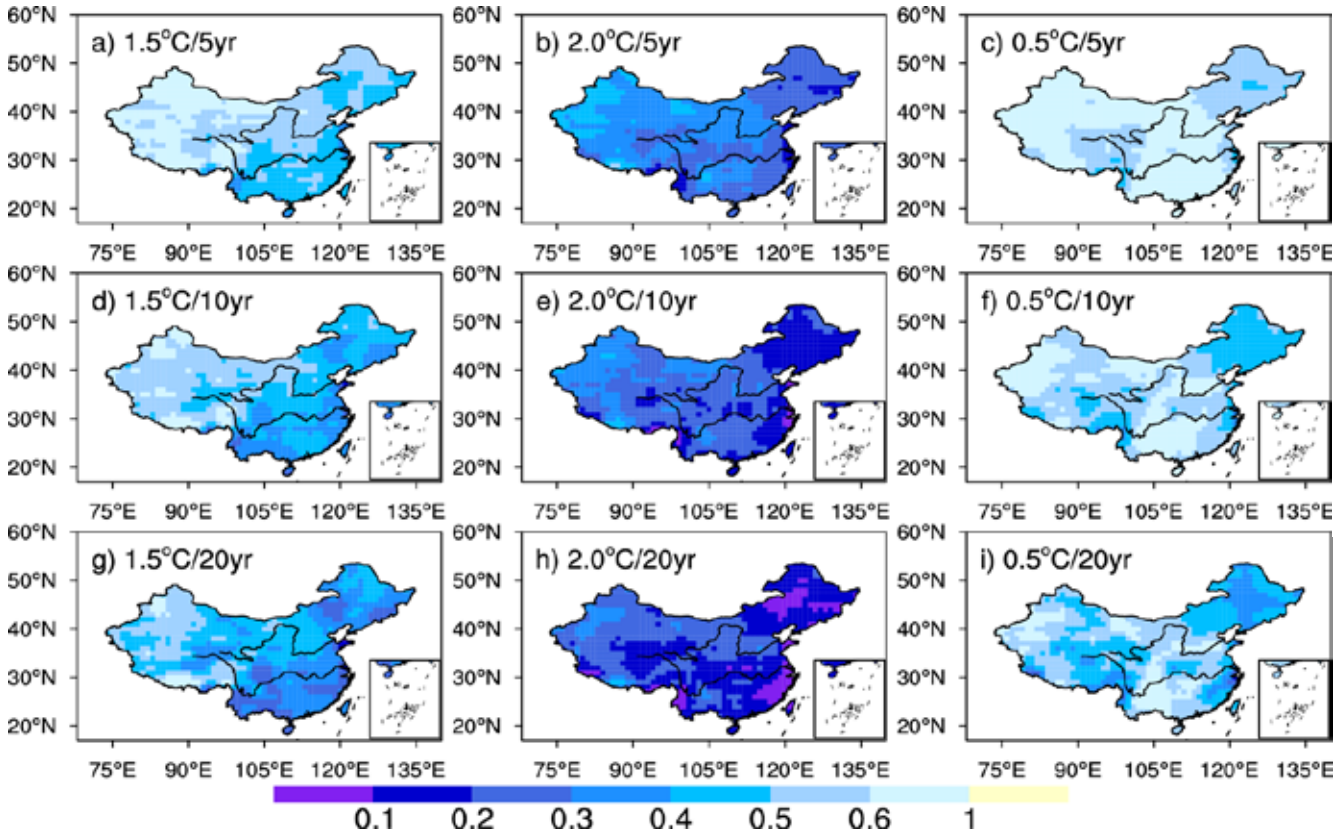

Figure 7. As in Fig.5, but for 5-, 10- and 20-year TNn

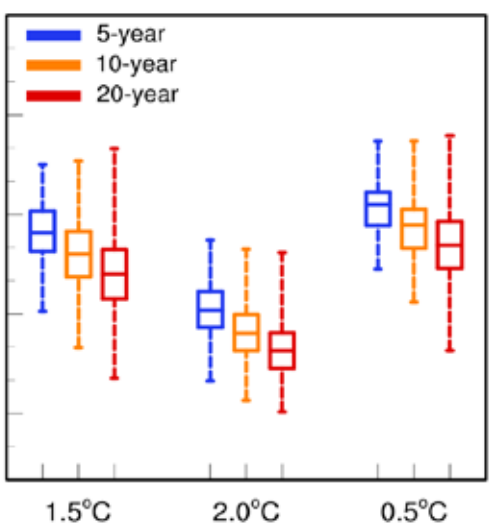

Figure S2. As in Fig.S1, but for TNn.

3.3 Changes in occurrence probabilities for cold extremes

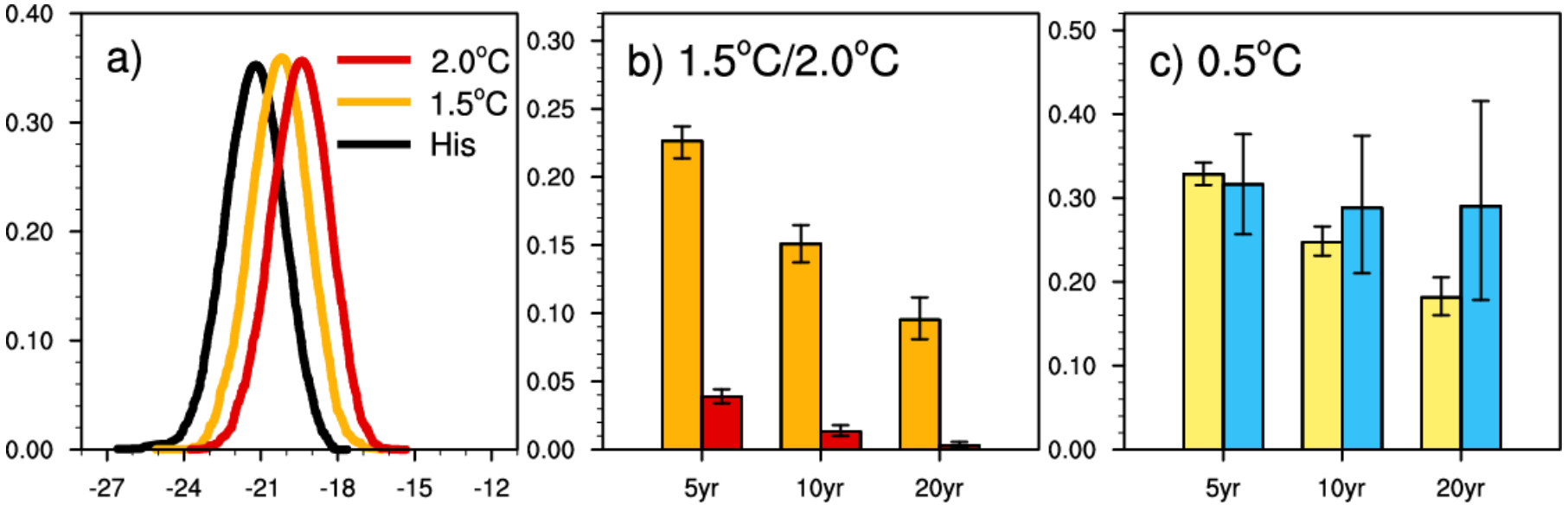

Figure S3. As in Fig.6, but for TNn

- The right shift of the PDF indicates an increase of TNn with global warming.
- PR for TNn will be smaller with higher global warming levels and rarer extreme cold events.
- under 2.0°C warming, 10-and 20-year extreme cold event is unlikely to happen.

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4. CONCLUSIONS

- When global warming stabilizes at 1.5°C/2.0°C, the areal-mean temperature for whole China increases by about 0.94°C/1.59°C (relative to 2006-2015). Notable increase regions are mainly found in Northwest and Northeast-North China, but warm spell duration increases mostly in Southeast China.

- For the additional 0.5°C, changes of mean and extreme temperature are larger in transient simulations than in stabilized simulations. The uncertainty range is also narrower in stabilized simulations.

- Under stabilized global warming scenario, 100-year extreme hot event becomes event occurring every 4.79 (1.5°C warming level) and 1.56 years (2.0°C warming level), 10-year extreme cold event becomes event occurring every 67 years under 1.5°C warming and is unlikely to occur under 2.0°C warming.

- The occurrence probabilities of extreme (hot and cold) events mainly change in the Tibetan Plateau, and the extreme cold events also change in Northeast and Southeast China.

Thanks for your attention.