

Climate Change Impacts on Weather-Related Disaster Risks in Global Cities

気候変動による世界の都市の気象災害リスク

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Changes get larger with every increment of global warming

Change from 1850-1900

Current(2011-2020)

Future



Background & Objectives 背景と目的

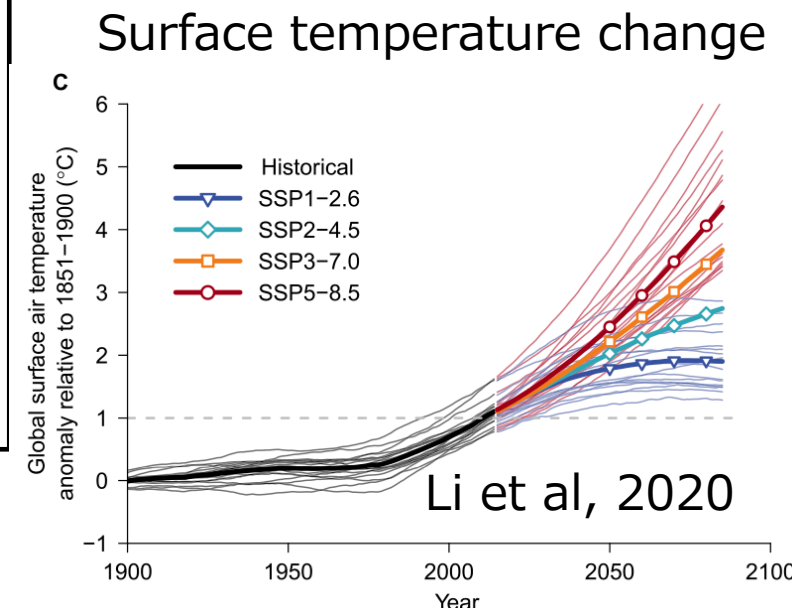
- Global warming is increasing extreme high temperature and precipitation events, including heavy rainfall and droughts.
- The global annual maximum daily precipitation has increased (Li et al., 2019).
- However, future projections of extreme precipitation remain highly uncertain.

Scientific Question 科学的な問い

1. How climate change affect weather hazards in major cities?
気候変動により、干ばつや大雨、異常高温のような世界の主要都市の気象災害は、どう変化するか？
2. What happens at a climate tipping point?
気候ティッピング現象が生じるとどうなるか？（氷床融解やアマゾン熱帯雨林の崩壊など不可逆的な変化）



- Investigate weather-related climate disaster risk in world major cities using large-ensemble climate simulations
- 大規模アンサンブル実験を用いて評価を行う



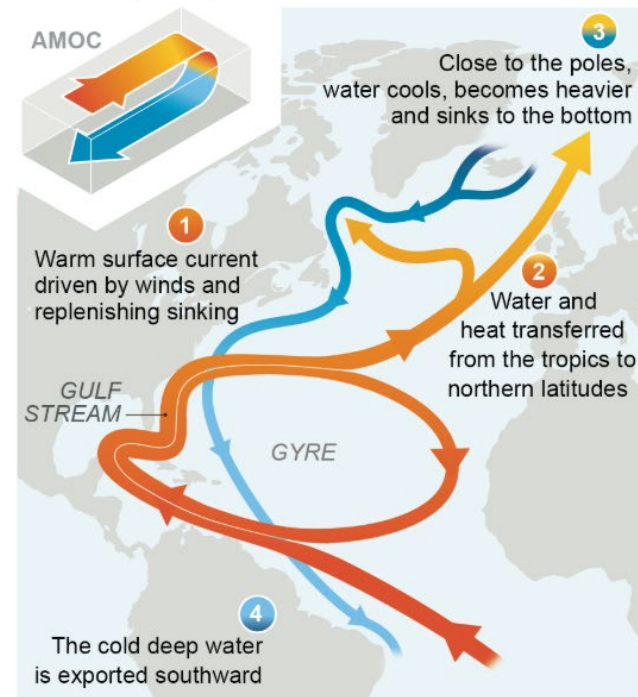
Thick lines are median of model ensembles
太線が各モデルの中央値

What Is Climate Tipping? 気候ティッピングとは

- Climate warming can trigger abrupt shifts in the Earth system by crossing critical thresholds (“climate tipping”).
- Climate tipping can cause large-scale, abrupt, and potentially irreversible changes.
- This study focuses on rapid sea-level rise caused by ice-sheet melting (氷床融解による海面上昇) and changes in weather-related disaster risks due to Atlantic Meridional Overturning Circulation (AMOC) slowdown (大西洋子午面循環の減速) .

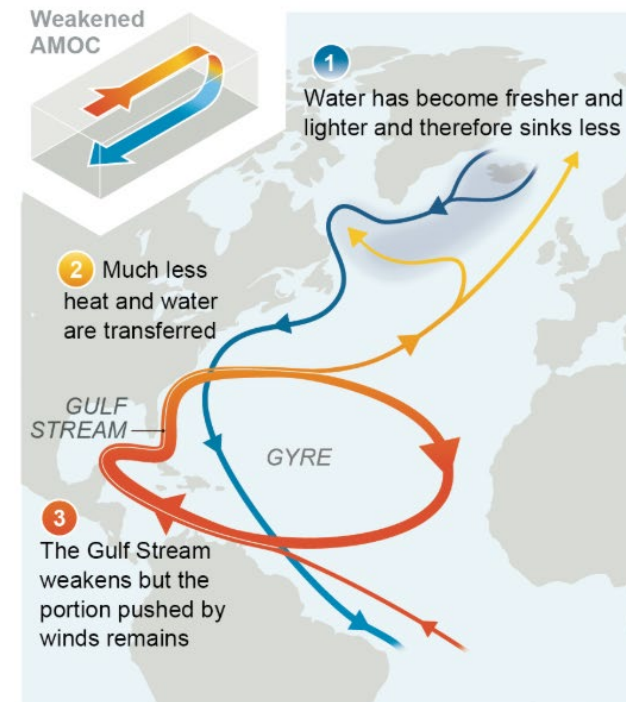
Today

The Gulf Stream is part of both the horizontal, subtropical gyre and the vertical, Atlantic Meridional Overturning Circulation (AMOC)

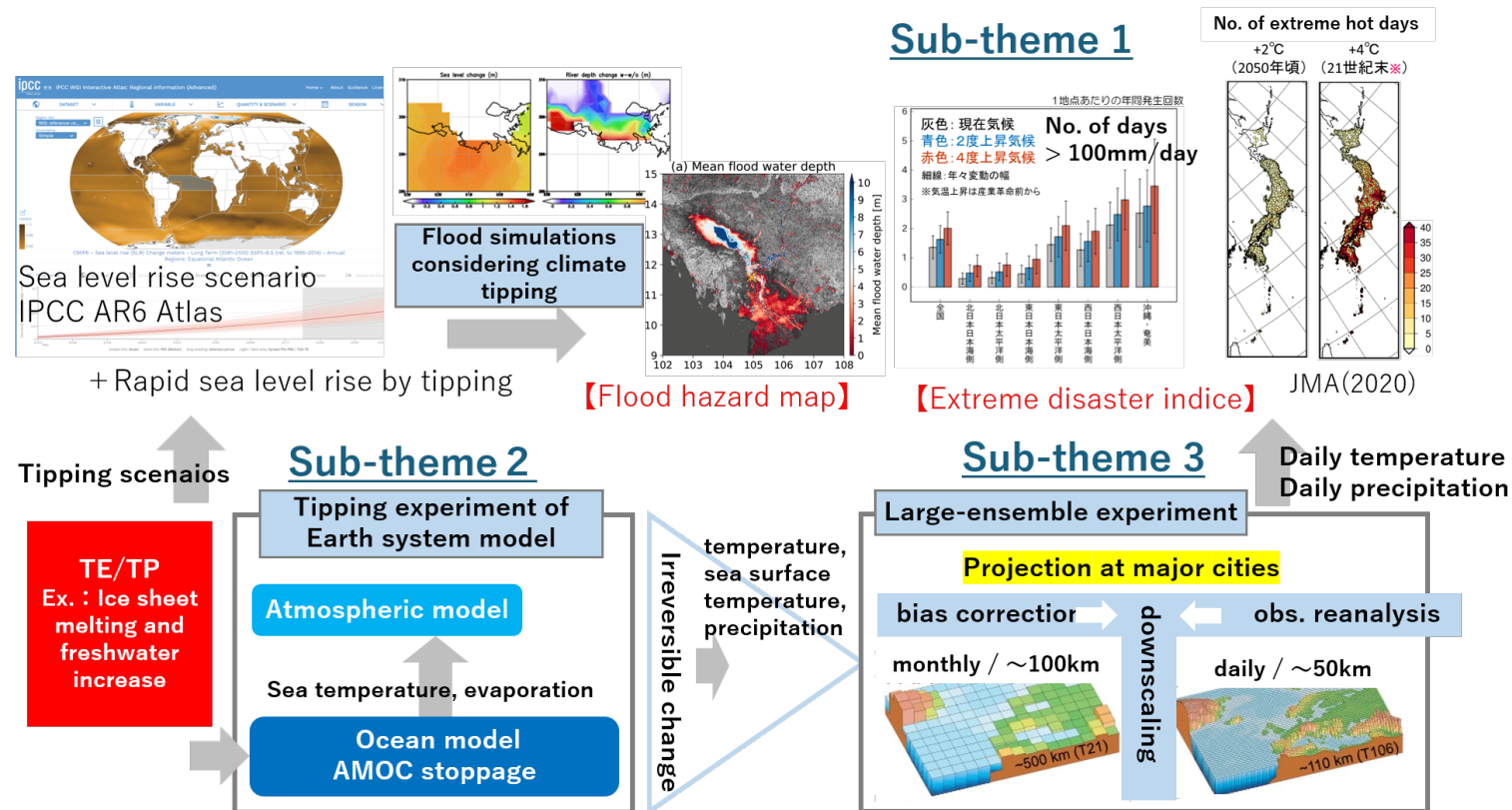


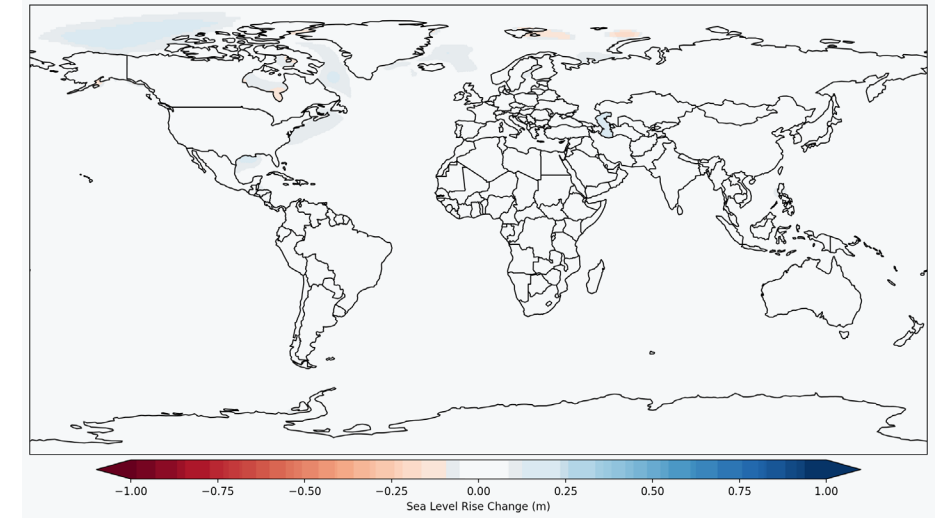
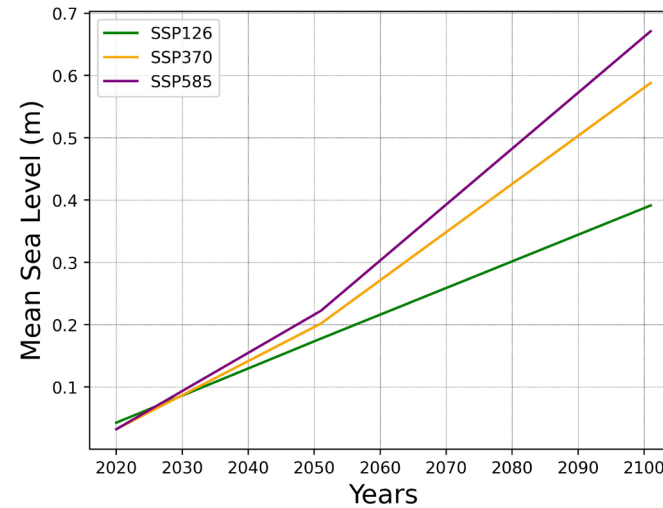
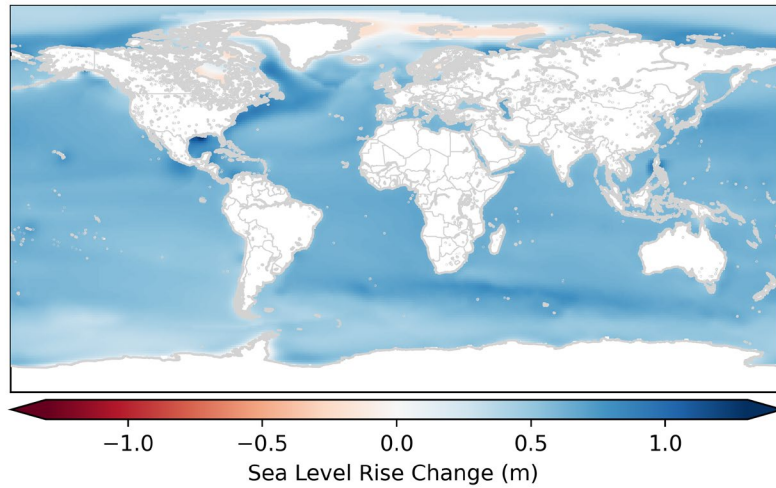
In a warmer world

Climate change weakens the AMOC, which slows the Gulf Stream down



- Conduct coupled atmosphere–ocean model experiments by adding 0.5 Sv of freshwater (1 Sv = $10^6 \text{ m}^3 \text{ s}^{-1}$) to the ocean to artificially reproduce a slowdown of the Atlantic Meridional Overturning Circulation (AMOC), one of the major climate tipping elements.
→Use the resulting climate conditions as boundary conditions for 50-member large-ensemble atmospheric model simulations, with bias correction and downscaling.
- We also generated large-ensemble simulation under conventional climate change scenarios.
- Analyze changes in weather-related disaster risks in major cities.





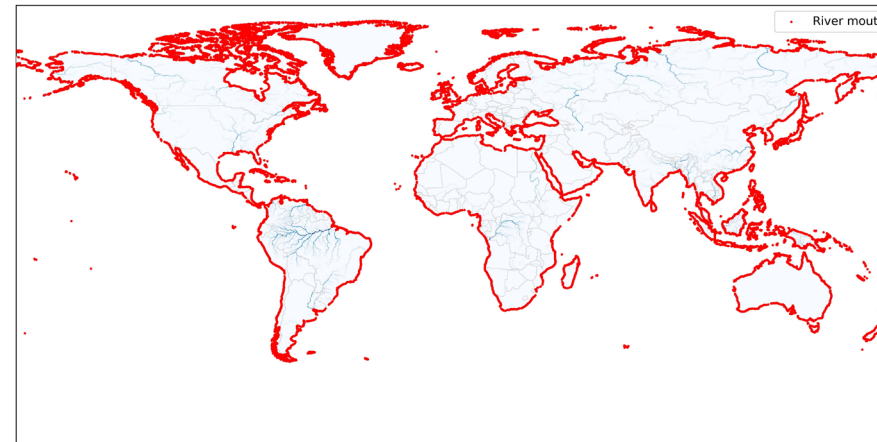
IPCC SLR data &
+3.5m for AMOC
shutdown

Linearly Inter- and
Extrapolation
(2020→2100)

Resampled ($1^\circ \rightarrow 0.25^\circ$)
Same as CaMa-Flood
Resolution

- SLR data used to updates the lower boundary conditions at the river mouth

(Modi et al., 2025 HRL)

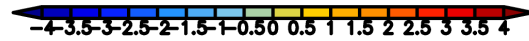
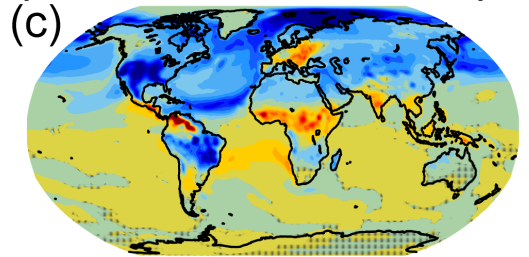


CaMa-Flood
boundary
condition
modification at
river mouth

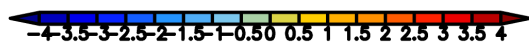
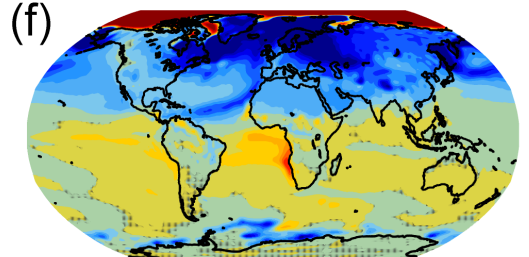
Three MIROC6-AGCM experiments: current climate, ssp370, ssp370+AMOC shutdown, each with 40 years x 50 ensemble members

Effects of AMOC shutdown

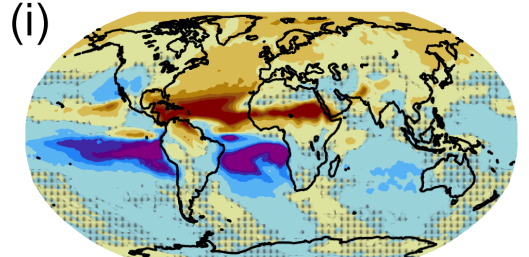
Annual daily maximum temperature (°C)



Annual daily minimum temperature (°C)

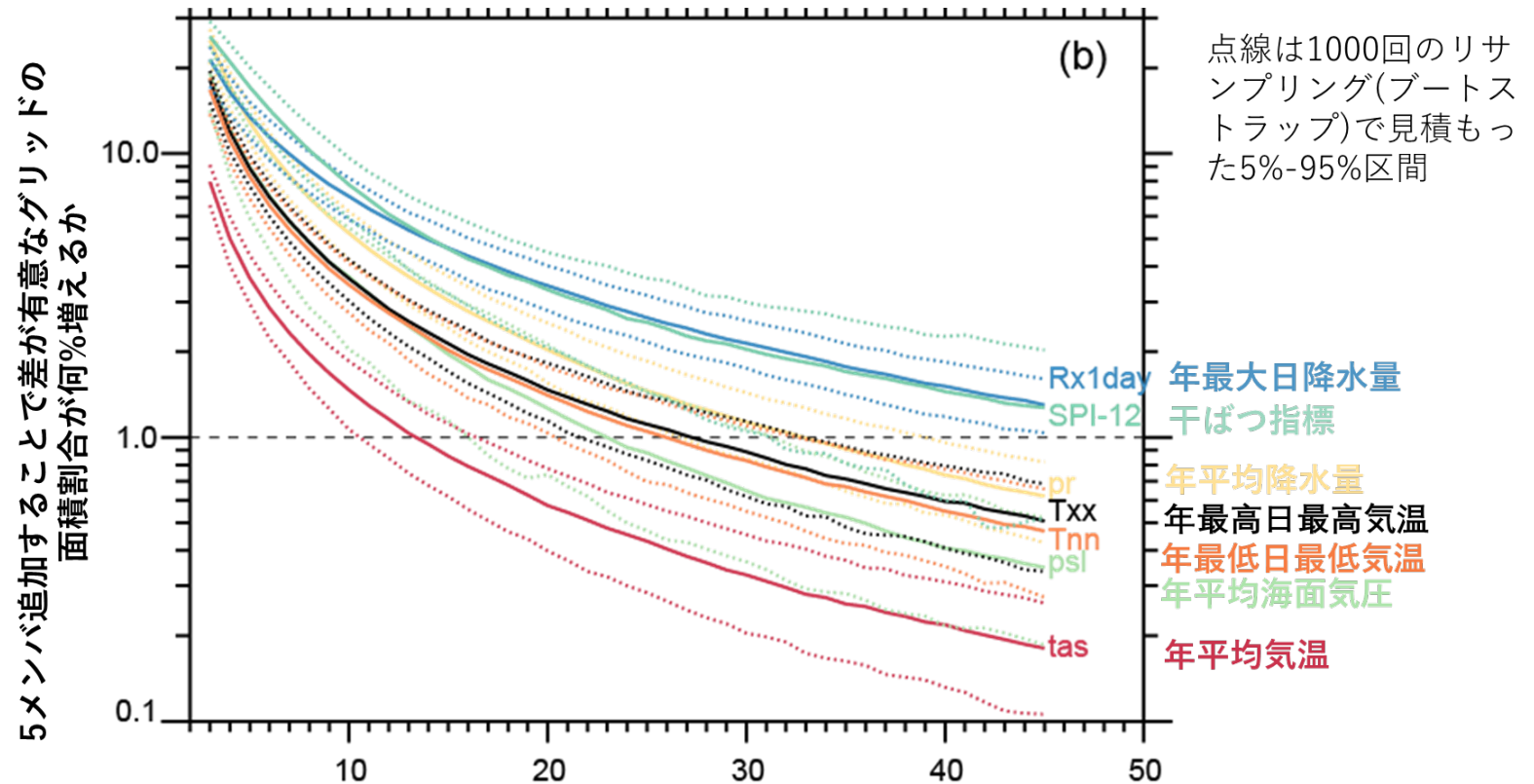


Annual maximum daily precipitation (%)

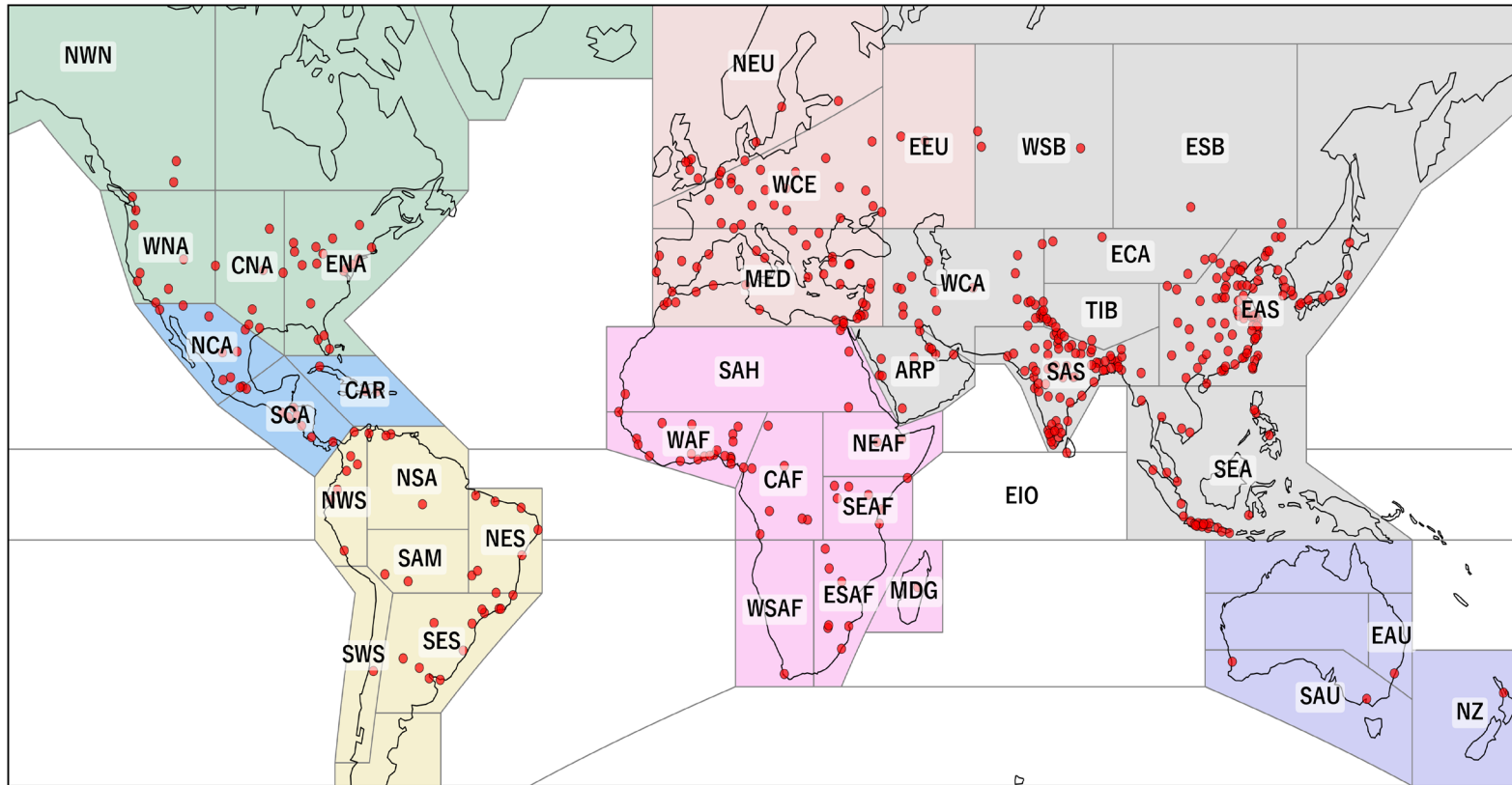


Hatching indicates areas where the difference is not statistically significant.

At what ensemble size does the benefit of increasing ensemble members saturate?



Cities Included in the Analysis 分析対象とした都市



Cities with populations of
1 million or more: 454 cities

Upscaled to ensure a consistent spatial
resolution:

454 cities → 450 cities

IPCC Climate Classification
(Iturbide et al., 2020)

Classified based on **climatic and regional**
characteristics:

38 regions

Population > 1 million, Meteorology – represented at 30min, Flooding – river model land mask >90% of city

Total – 454, Meteorology – 447, Flooding – 325

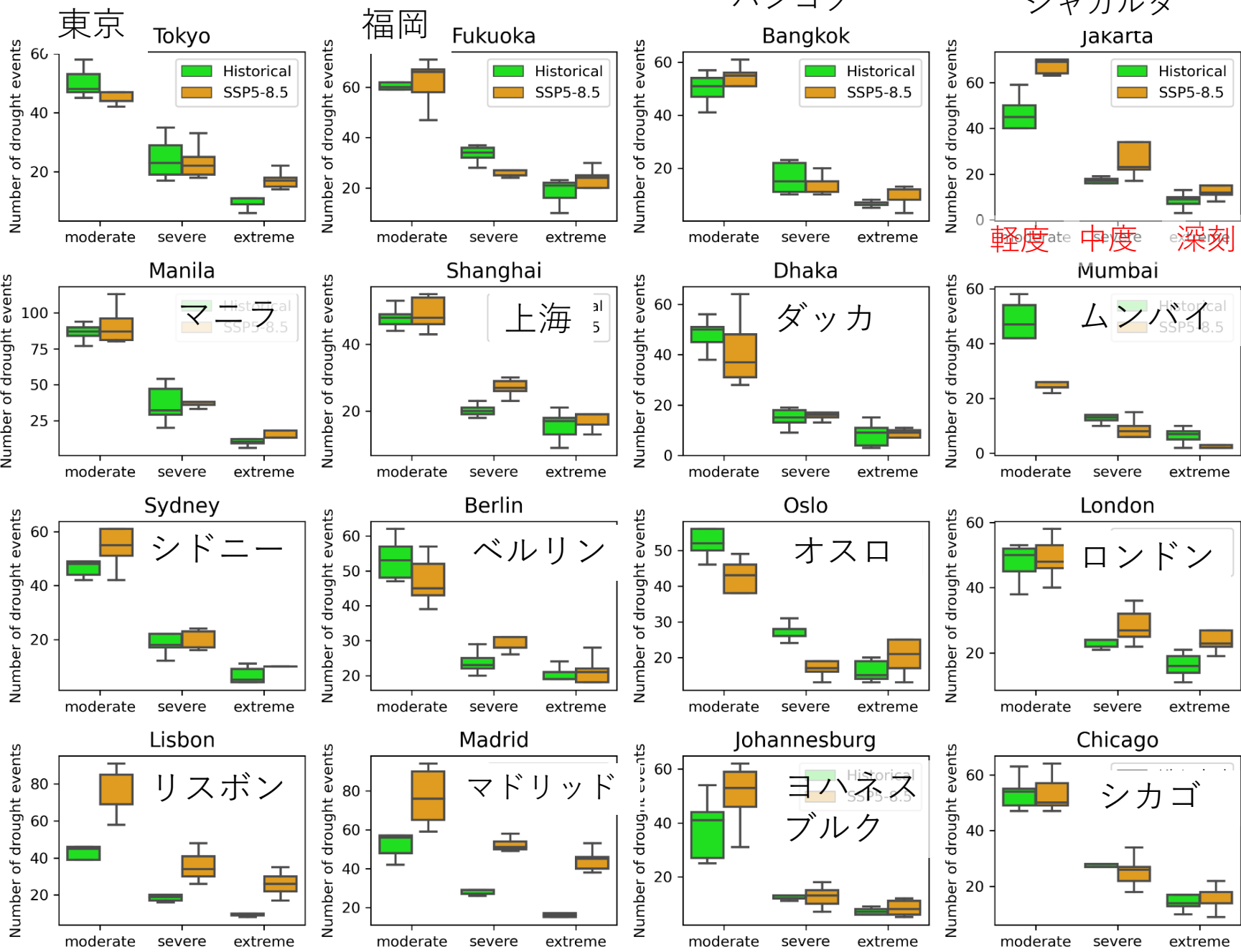
人口100万人以上の454都市のうち、30minで解像できる447都市を気象要素の分析対象、

河川モデルで陸地と定義できる325都市を河川洪水・沿岸浸水の分析対象とした

Climate Impacts on Drought in Cities 主要都市の干ばつの将来予測

SPI指標 (標準化干ばつ指数)
 Current climate 現在気候
 Future Climate ssp585 将来

- Drought is projected to increase in some countries and decrease in others.
- Drought is projected to increase in the Mediterranean region, including Lisbon and Madrid.
- Severe drought is projected to increase across many regions.



Climate Impacts on heavy rainfall in cities

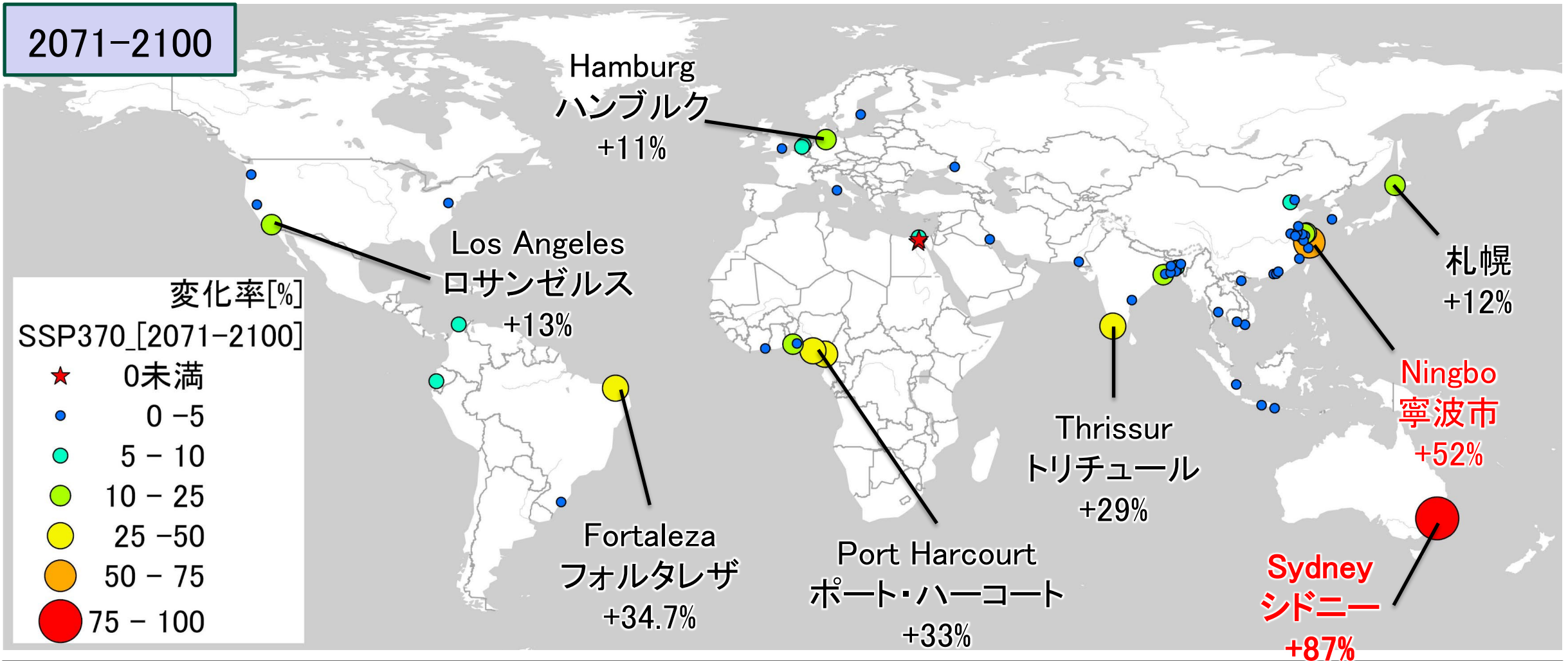
主要都市の大雨の将来予測

1/10 heavy precipitation 10年に1度の大雨
 1/50 heavy precipitation 50年に1度の大雨



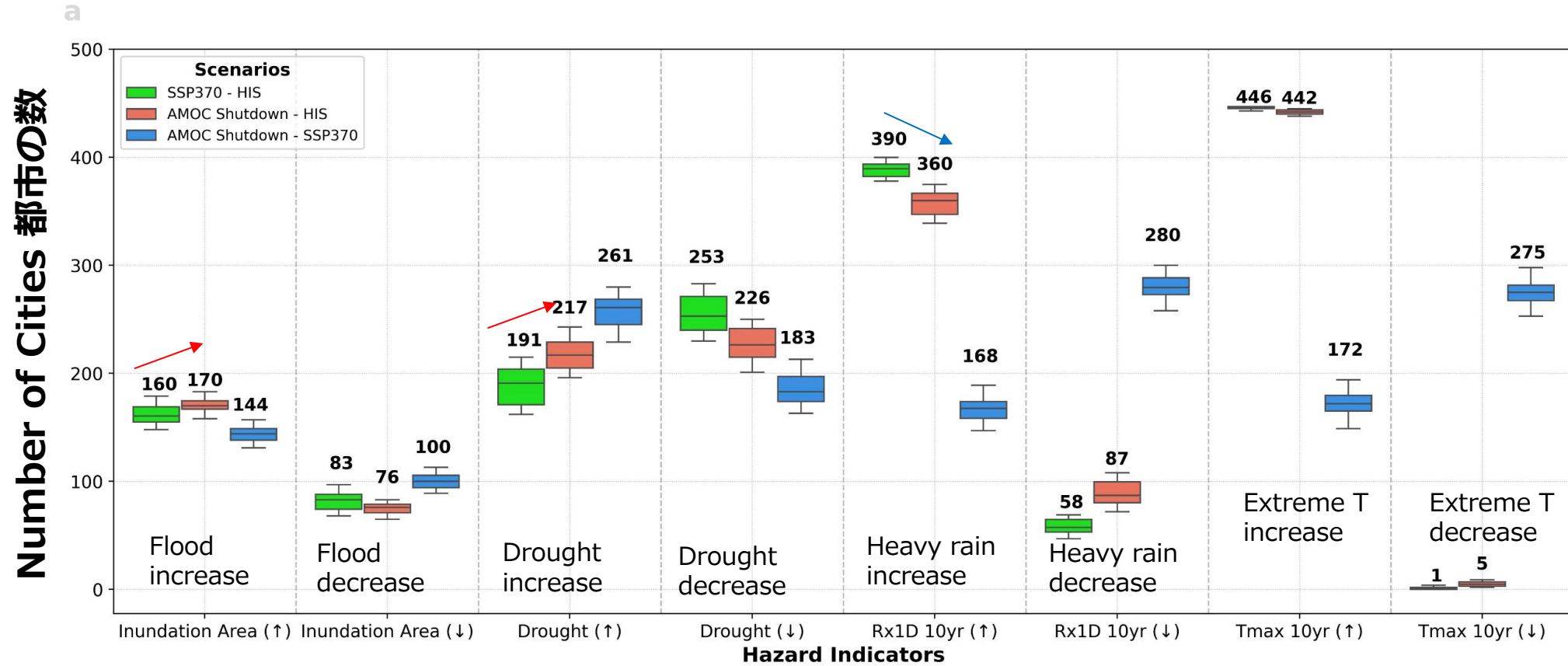
- Except for Lisbon, the risk of heavy rainfall increases with warming in all major cities.
- The increase becomes greater at higher warming levels, with more frequent extreme rainfall events that currently occur only once every 50 years.

Change in River Flood Losses with Sea-Level Rise



- 43 cities show changes of 0- $<5\%$, while 13 cities show changes of 10% or more.
- Some cities show particularly large changes, such as Sydney and Ningbo.

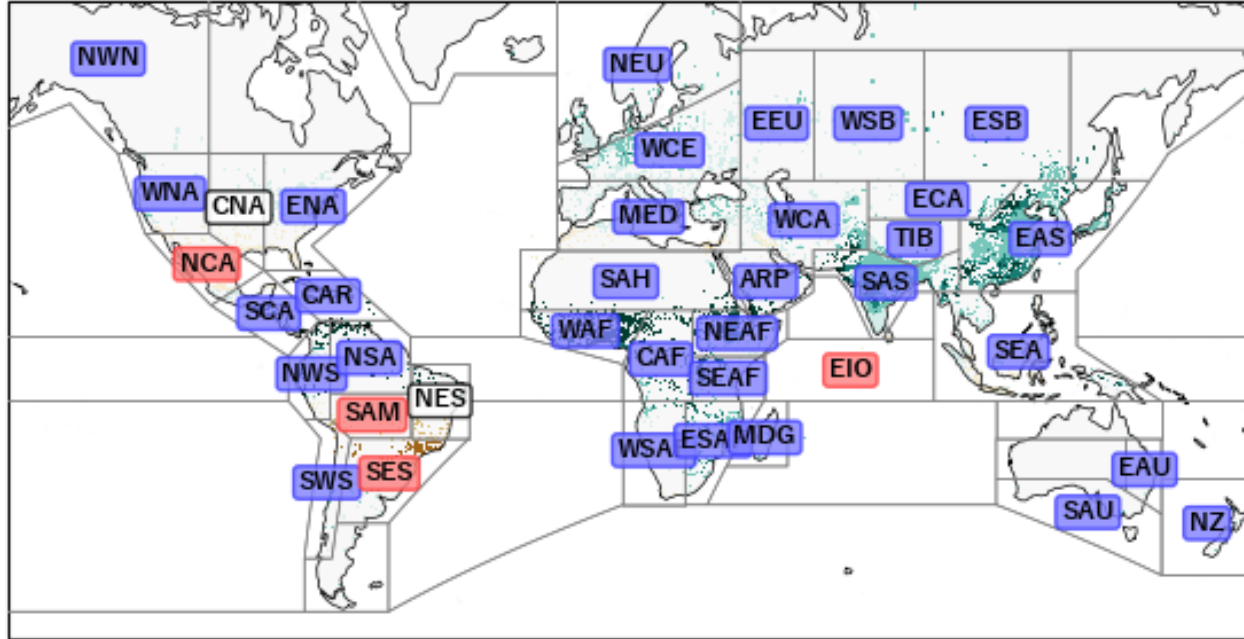
Impacts of AMOC Shutdown on Weather-Related Disasters



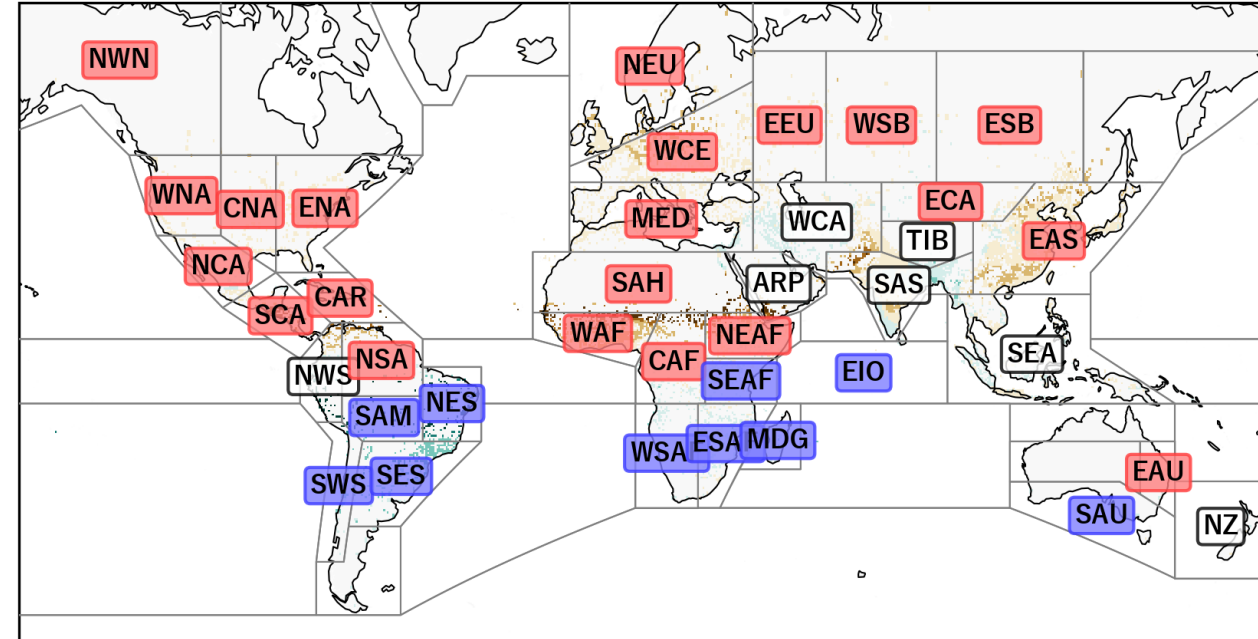
- **Extreme heat**– Most cities show an increase comparing to the past by climate change.
- **Heavy rainfall** – Most cities show an increase due to climate change, while AMOC shutdown reduces the number of cities showing an increase.
- **Flooding** – Flood risk increase at 160 cities, and AMOC shutdown increases in coastal regions.
- **Drought** - AMOC shutdown slightly increases the number of cities showing an increase.

Impacts of AMOC Shutdown on Weather-Related Disasters

Changes in heavy rainfall due to climate change
(ssp370-historical)



Changes in heavy rainfall due to AMOC shutdown
(ssp370+0.5Sv – ssp370)



- AMOC slowdown generally suppresses increases in heavy rainfall.
- However, heavy rainfall increases further in some regions, especially in the Southern Hemisphere.
- Responses vary across the Asian monsoon region, with further increases in some southern Indian cities.

Conclusion

- ◆ We conducted analyzing weather-related disaster change due to climate change and AMOC shutdown in about 400 major cities worldwide and mapping regional hotspots.
- ◆ Climate change increase extreme temperature and heavy precipitation in many global cities.
- ◆ If AMOC shutdown occurs:
 - ✓ Wetter conditions may weaken, increasing drought risk.
 - ✓ Extreme precipitation may slightly decrease.
 - ✓ In many regions, increases in extreme heat due to climate change are not fully offset.
 - ✓ Coastal flooding increases due to extreme sea-level rise.