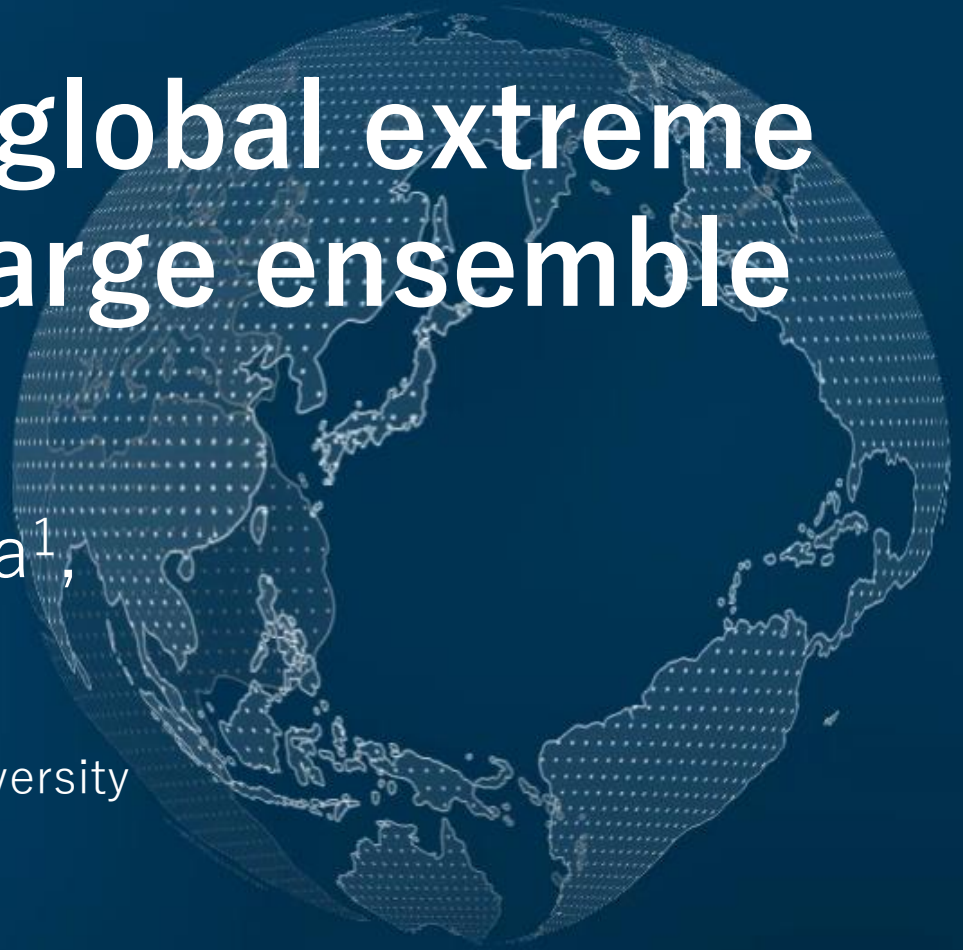
2025 WaveWorkshop, Santander
September 25, 2025

Future projection of global extreme storm surges using large ensemble projection d4PDF



Nobuhito Mori[1,2], Tomoya Shimura[1], Zuorui Lyu[1], William Pringle[3]
Collaboration with JMA-MRI

1 Disaster Prevention Research Institute, Kyoto University
2 Yokohama National University
3 Argonne National Laboratory, USA

Conclusion

- Large ensemble projection gives statistically stable values for global storm surge changes up to 100-300 yrs return values
- Future changes in storm surge heights are significant in the middle to higher latitudes.
- Systematic bias for extremes clearly exists (not shown)
- (Ongoing) Comparison with long-term historical run
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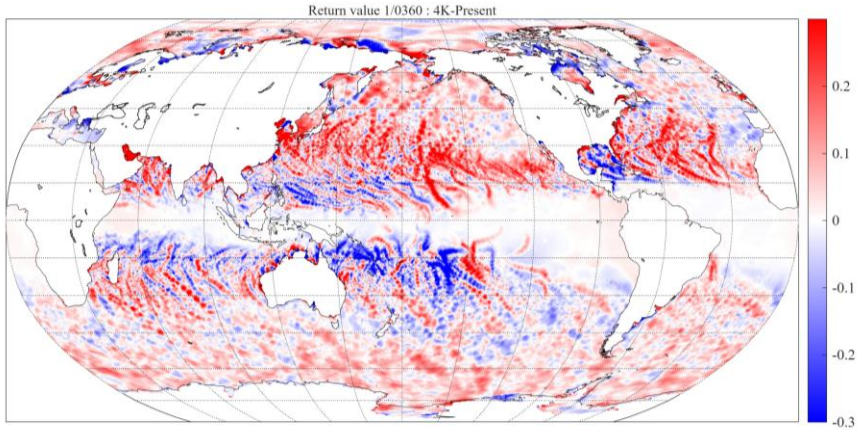
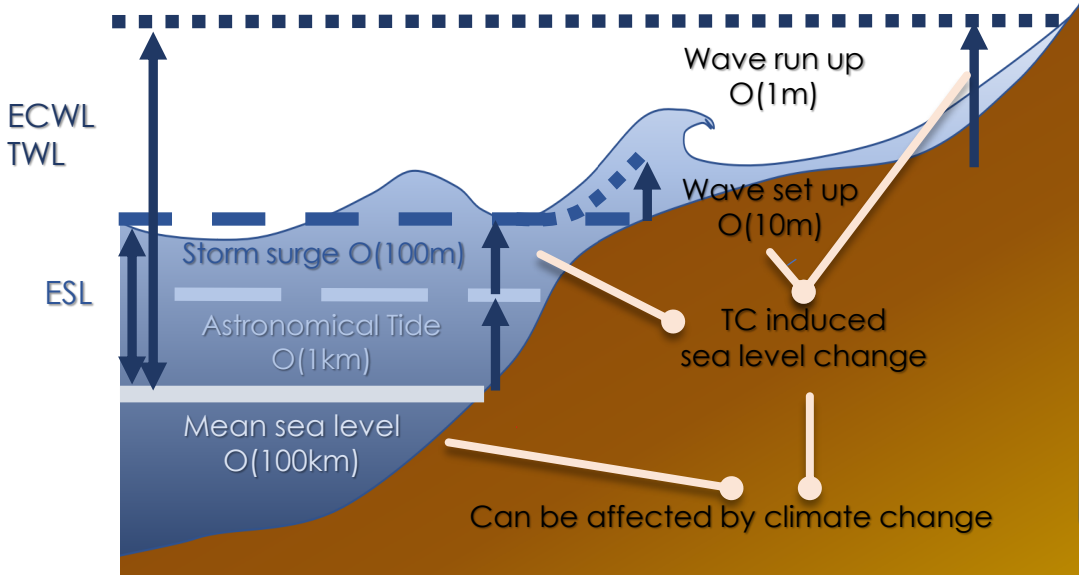




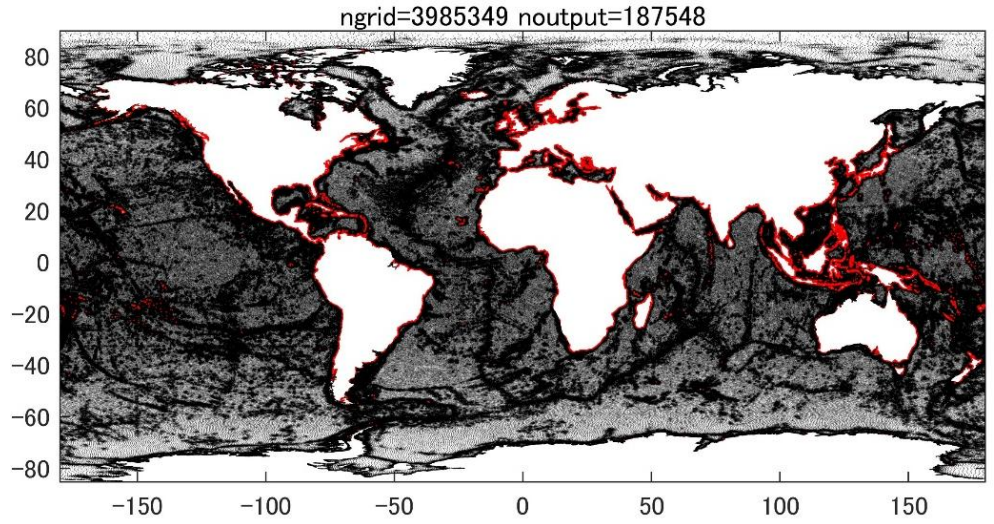
Mechanism
Historical and Projection
Information

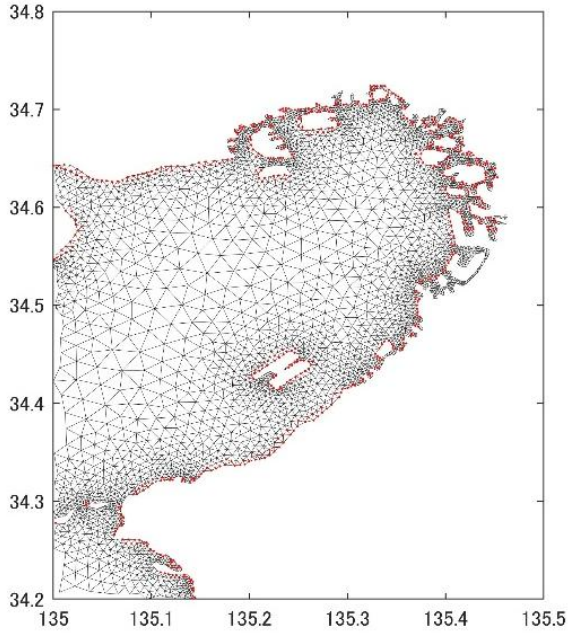
IPCC AR7 WGI Chapter outline

- 3. Changes in **regional climate and extremes**, and their causes
  - tropical cyclones, sea level rise
- 7. Projections of **regional climate and extremes**
  - tropical cyclones, extreme sea level
- **10. Climate information and services**
  - multi-hazards, early warning

Setup: Global storm surge projection

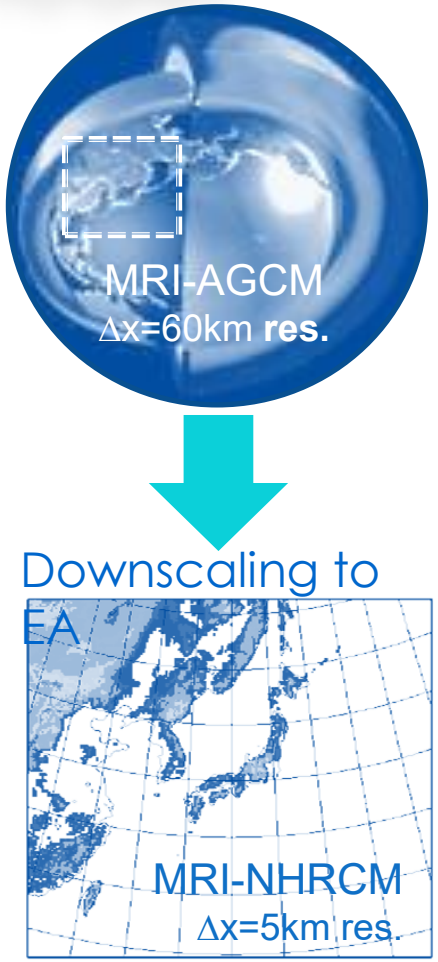
- Model (Surge)
  - ADCIRC
  - Global domain 2 – 25 km
  - Japanese domain 25 – 200 m
  - Node 3,985,349
  - Element 7,677,767
- Forcing Model (GCM)
  - d4PDF Global 60km
    - Historical: 12 ens = 720yr
    - 2K: 6 ens = 360yr
    - 4K: 6 ens = 360yr
  - with sea ice
  - 1 hourly U10 and SLP





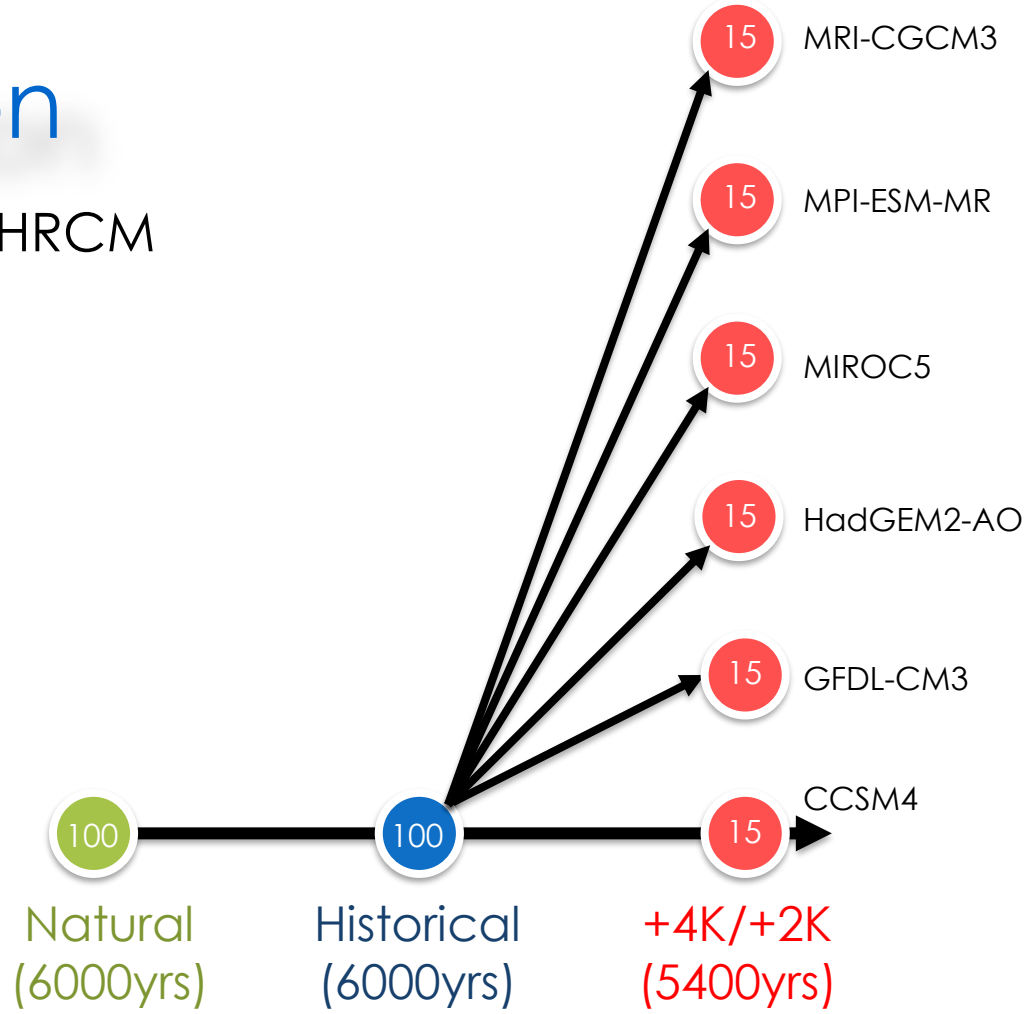
Large Ensemble Projection: d4PDF

Model



Exp. Configuration

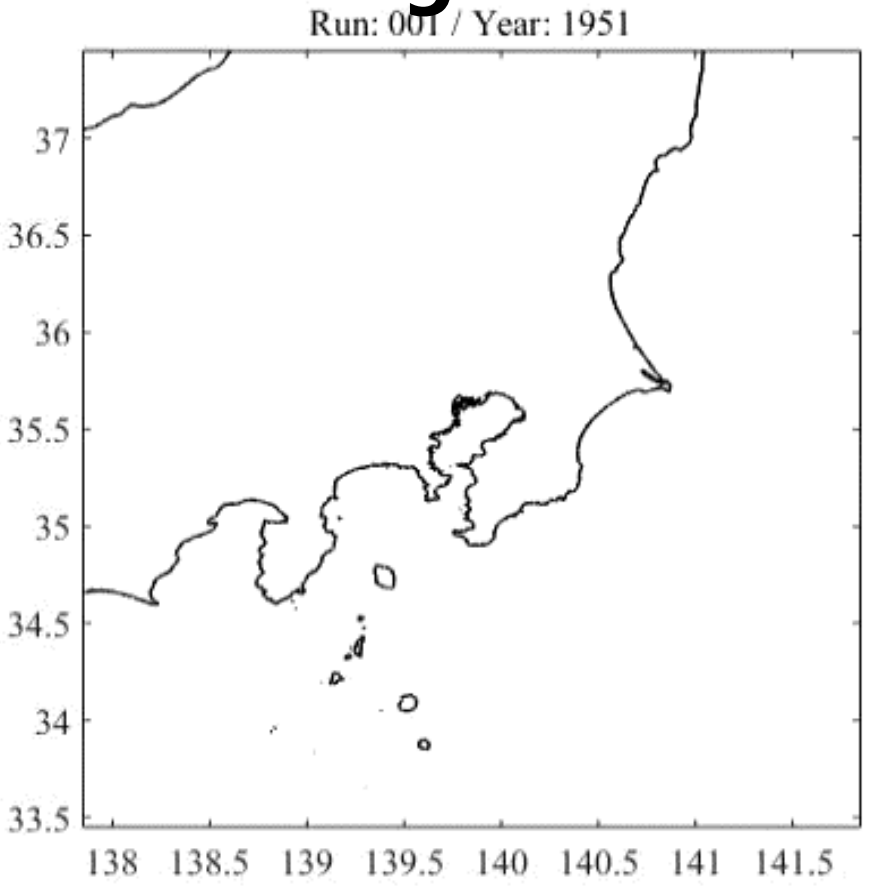
- Model: MRI-AGCM3.2H + NHRCM
- One ensemble
  - 60yrs
- Initial perturbation
  - 100 for historical/Nat.
  - 15 for future
- Climate conditions
  - Non-GW
  - Historical
  - +2K, +4K
- SST/Sea ice
  - Historical
    - COBE2-SST
  - Future
    - SSTs from CMIP5

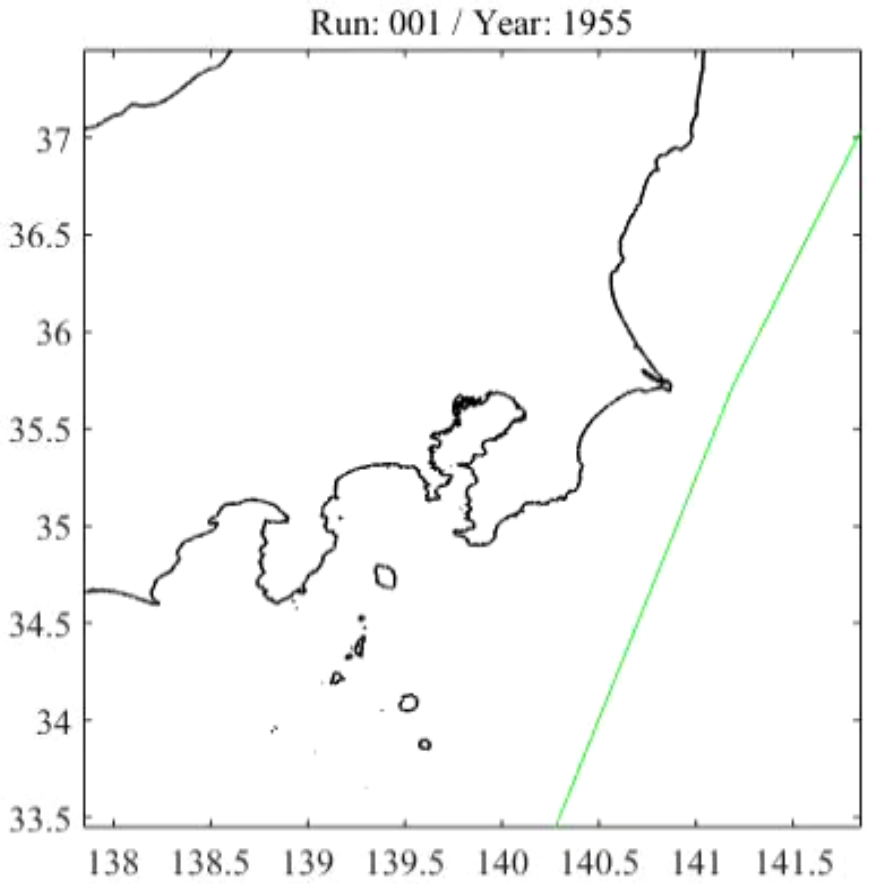


6 ensemble/climate conditions

Mizuta et al. (2017) BAMS / Ishii and Mori (2020) PEPS

How large ensemble d4PDF can increase TC?





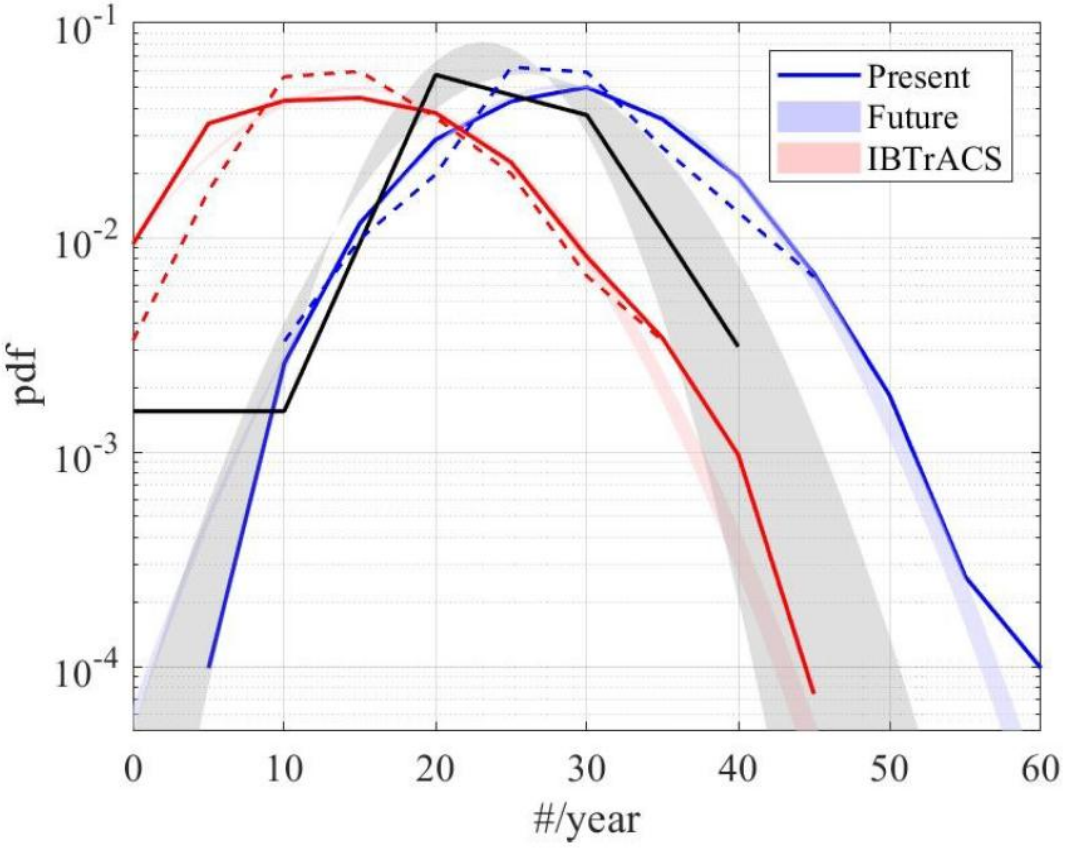
1 ensemble run
60 years

100 ensemble run
6000 years

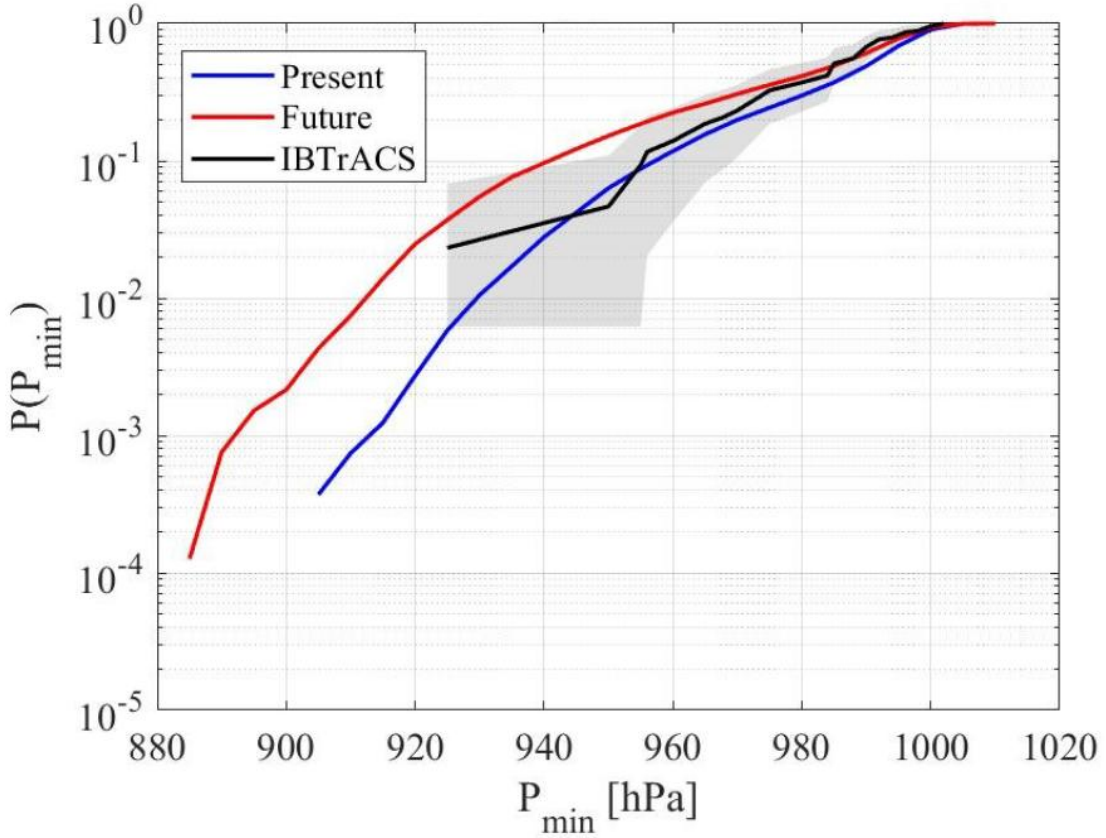
60 years climate run

d4PDF (6000 years)

Assessment for extremes
e.g. Tropical cyclones



PDF of cyclogenesis

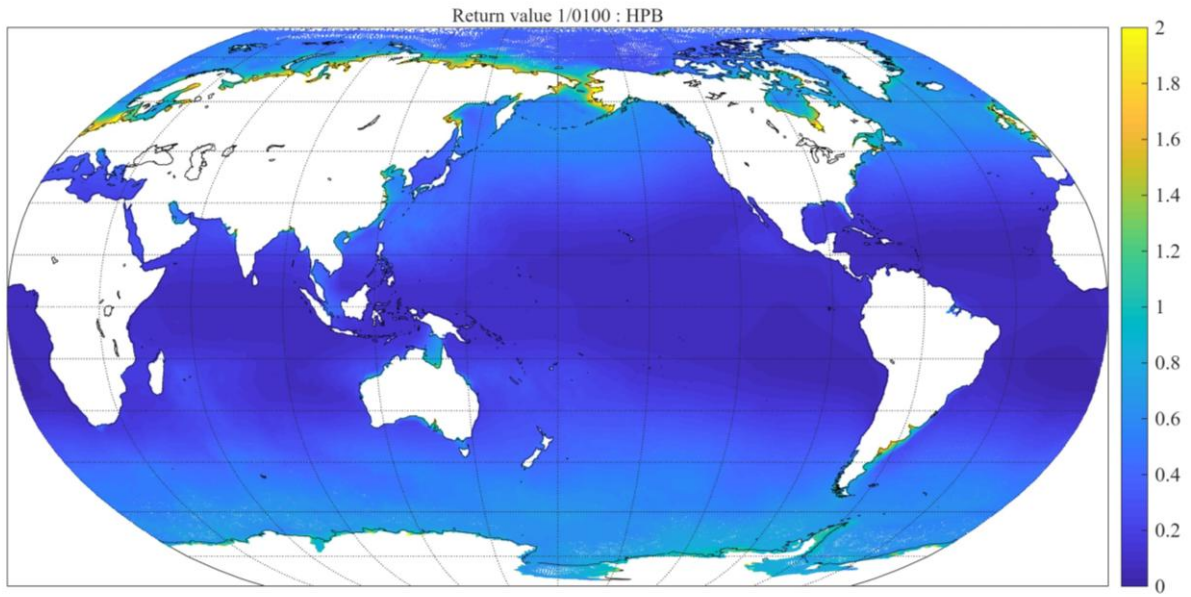


CDF of central pressure

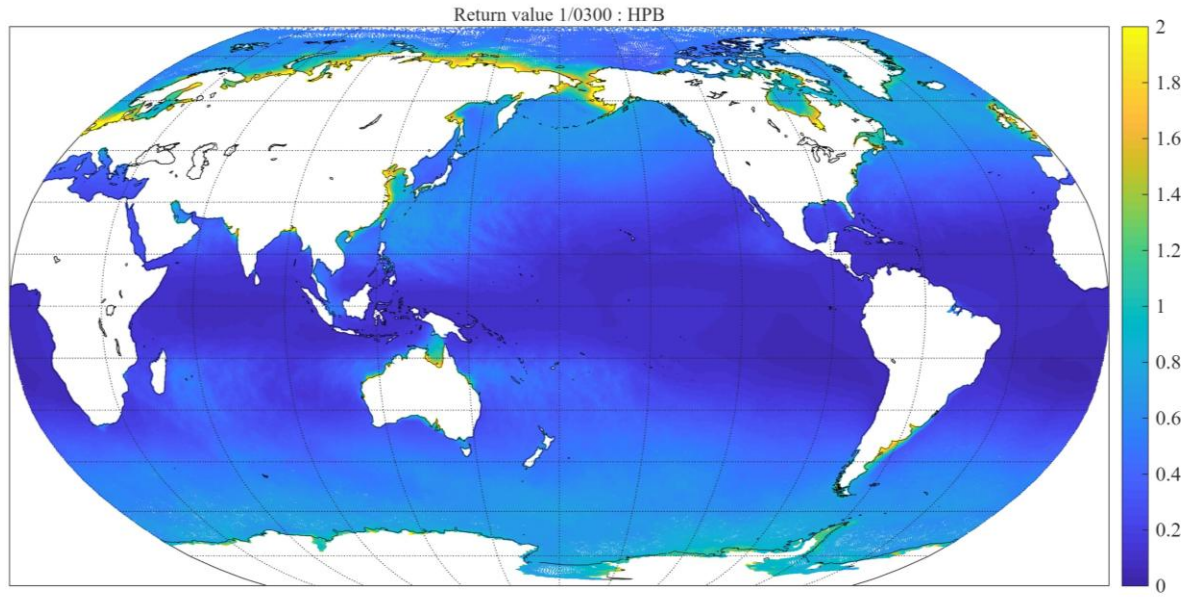
Present	#28.9/yr
+4K	#14.7/yr
Observation	#26.6/yr

Mori et al. (2019 CE)

Surge heights in present climate condition

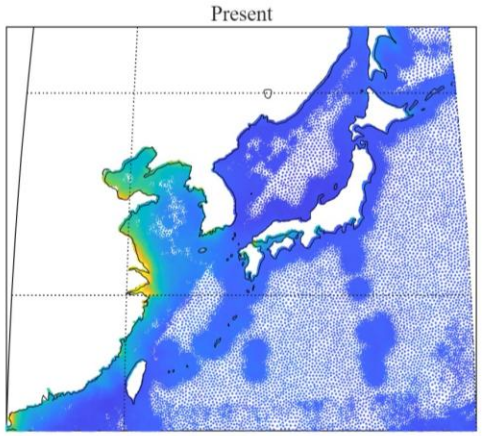


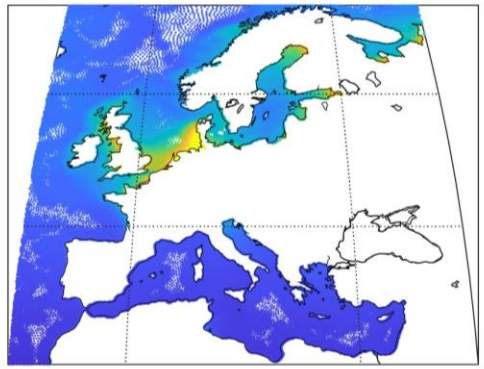
1/100 years

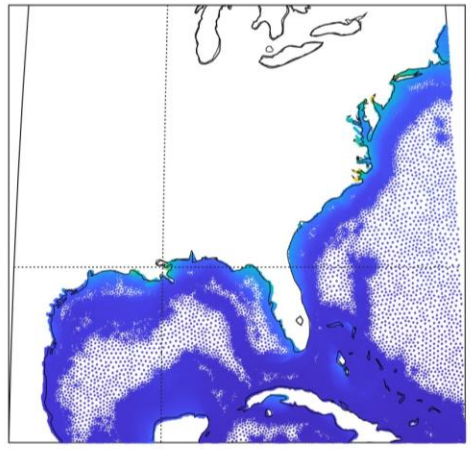


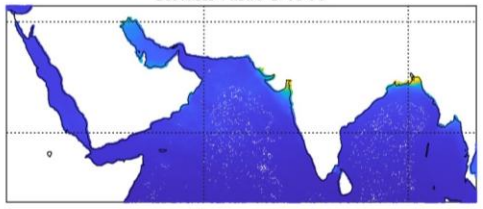
1/300 years

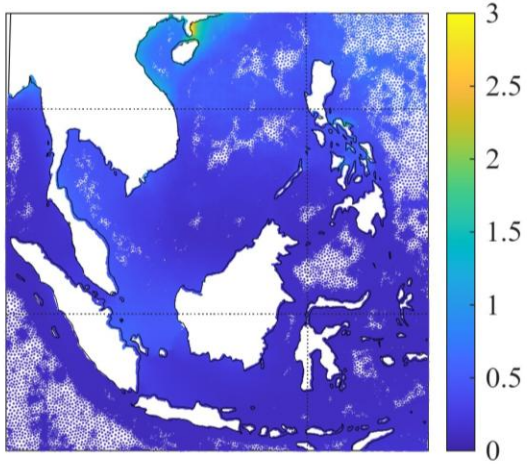
Surge height in present: 1/300 years



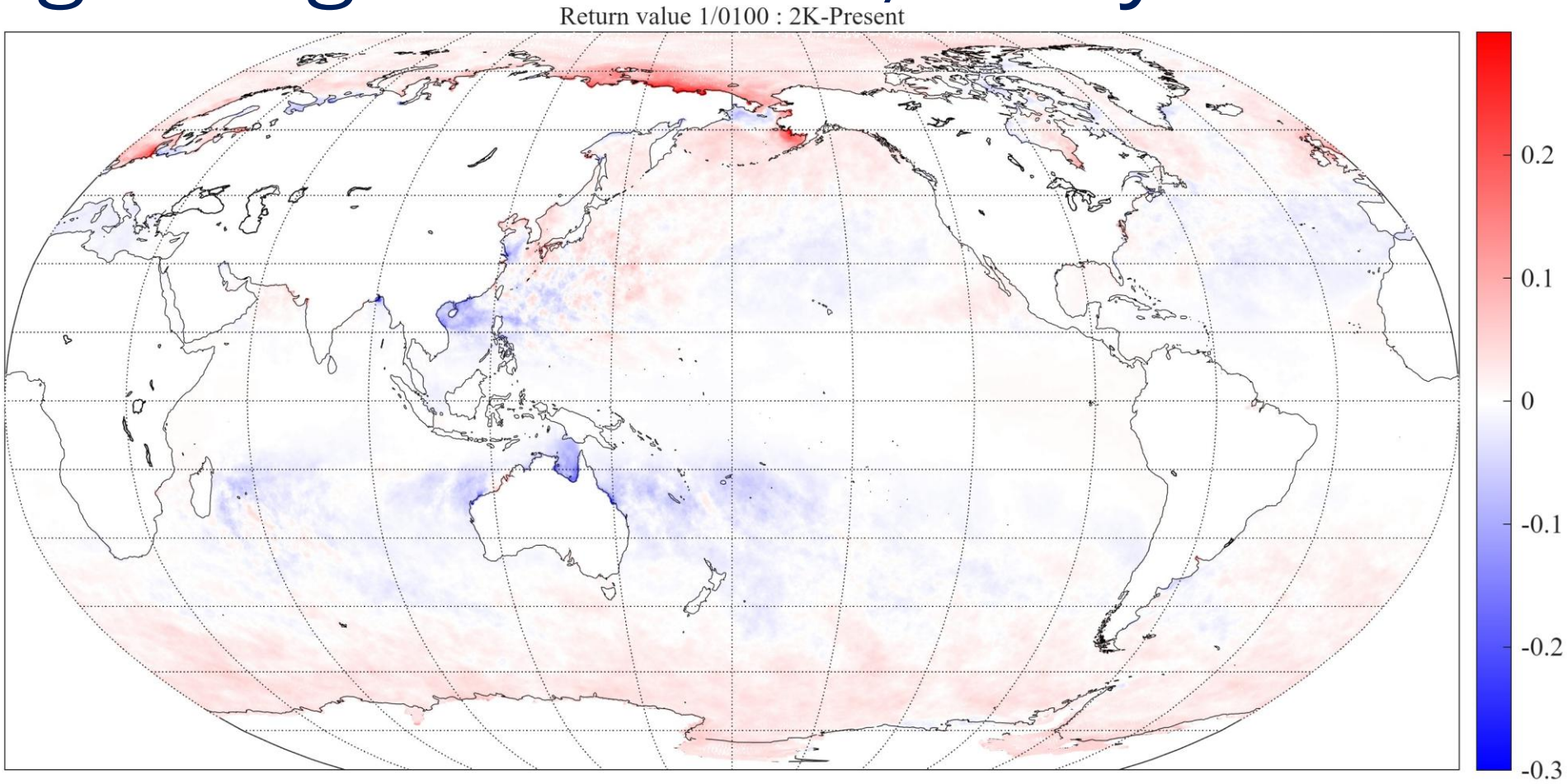




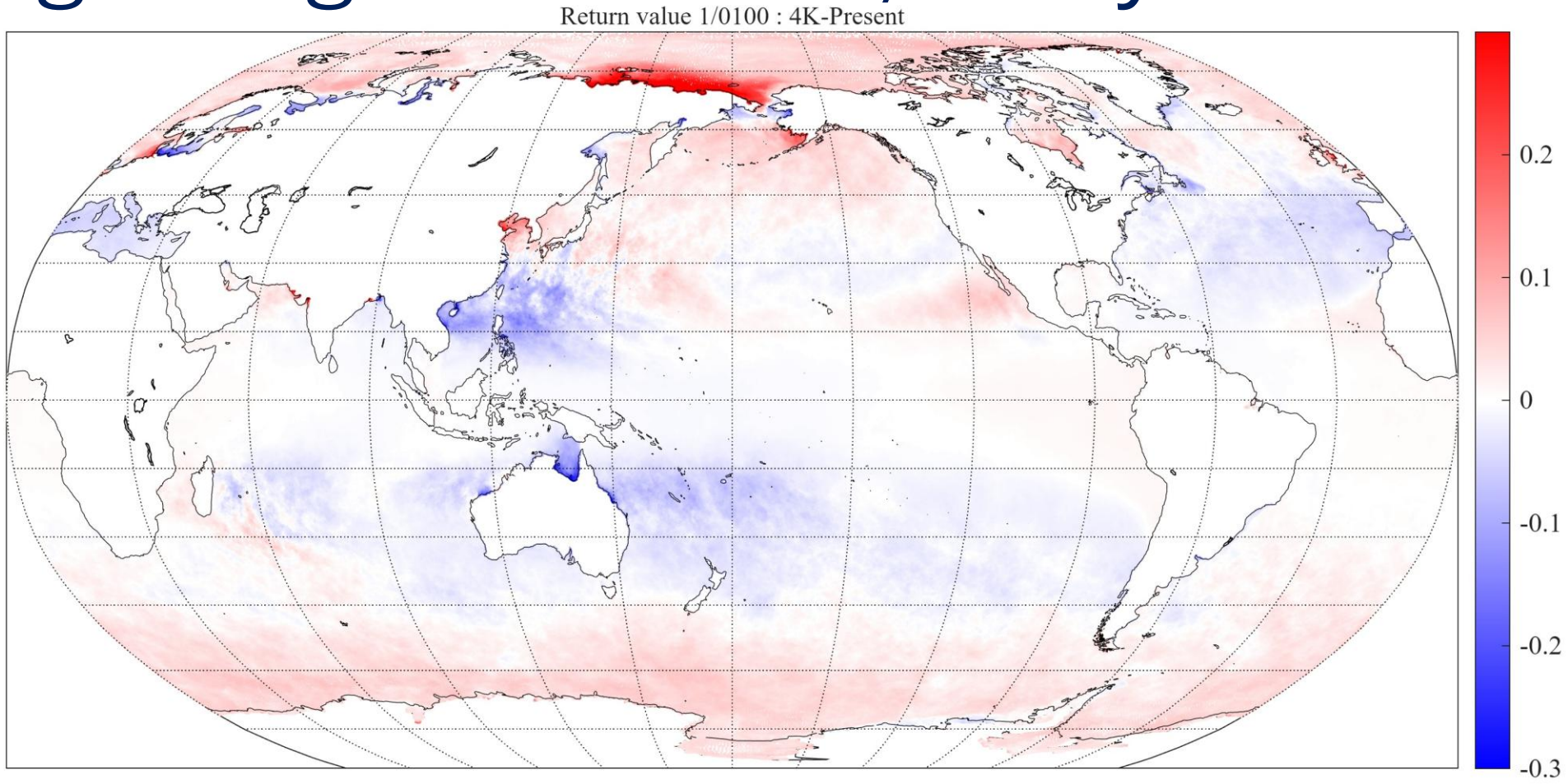




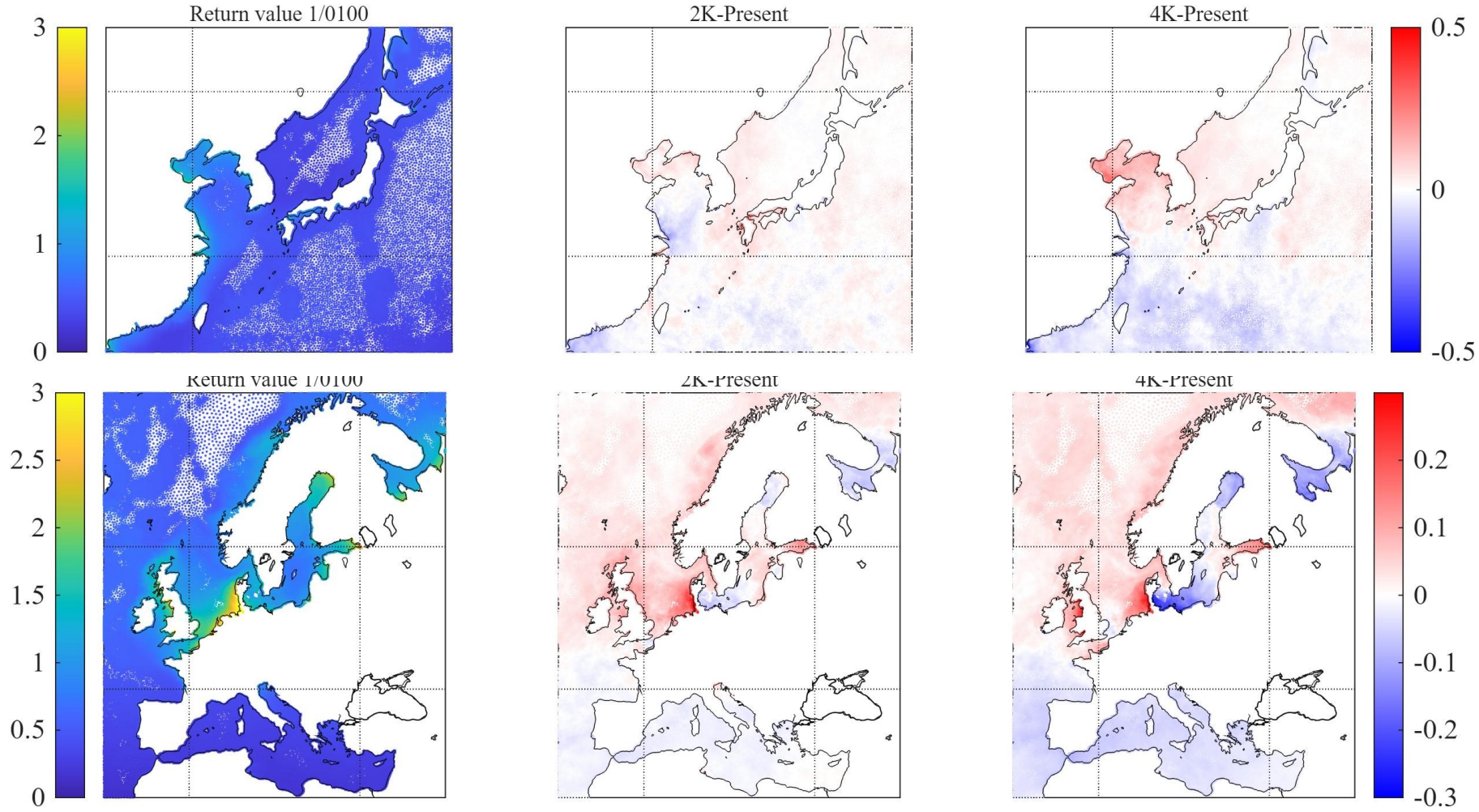
ΔSurge height in +2K: 1/100 years



ΔSurge height in +4K: 1/100 years



ΔSurge height in +2K/4K: 1/100 years

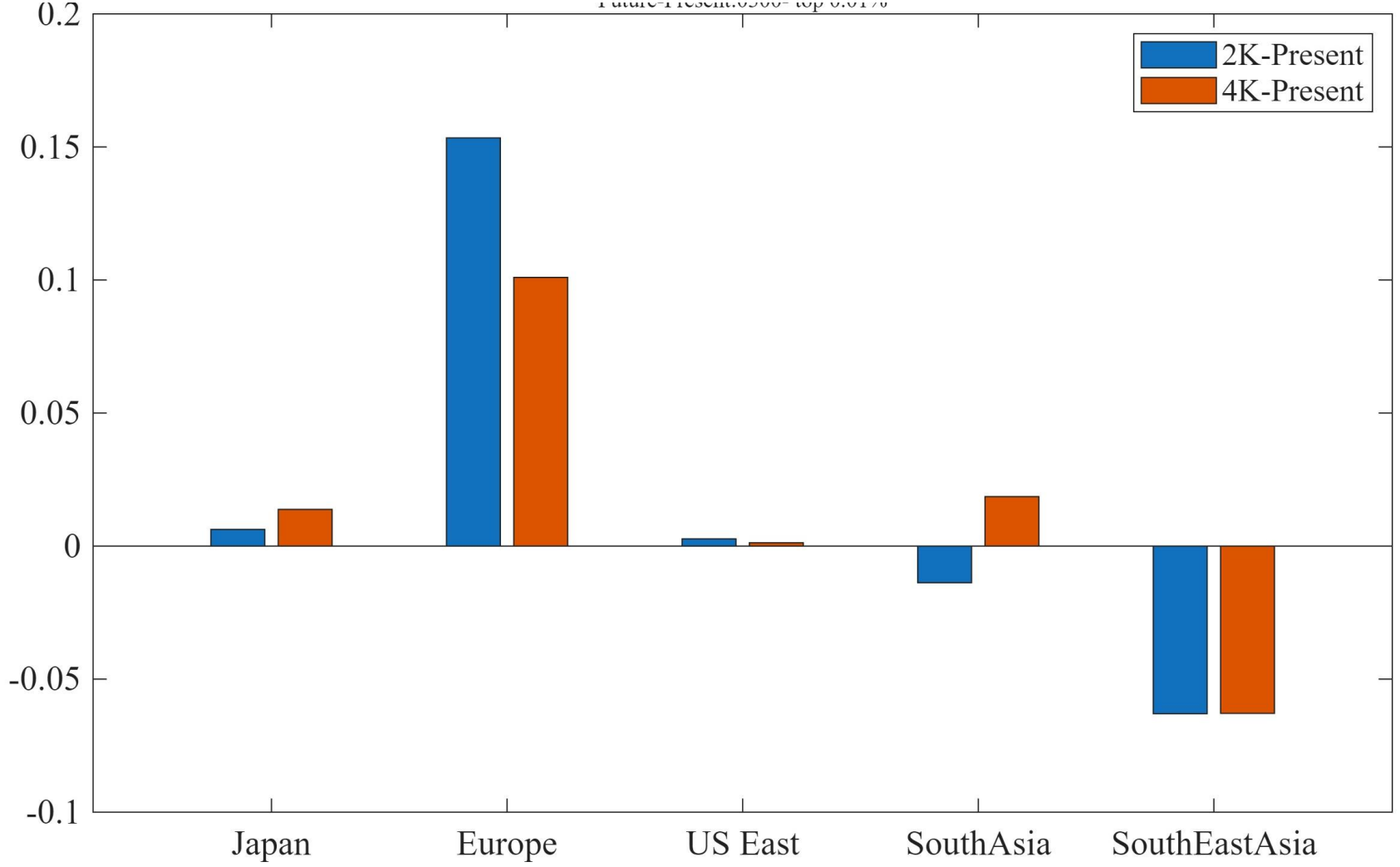


Present climate

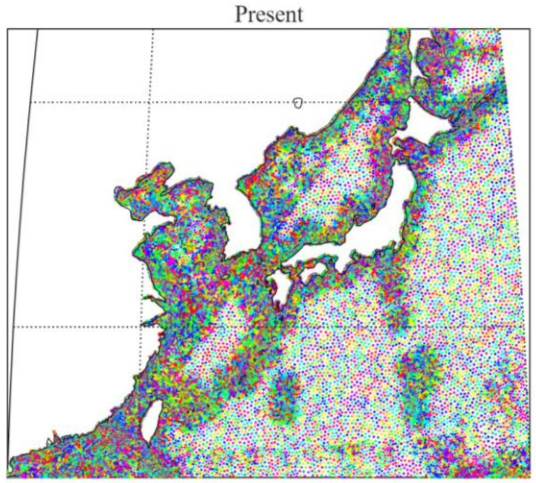
+2K-Present

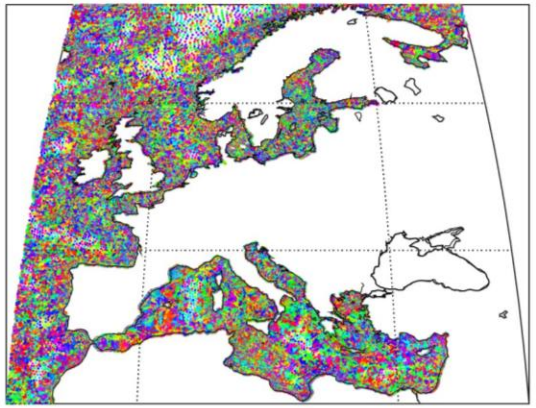
+4K-Present

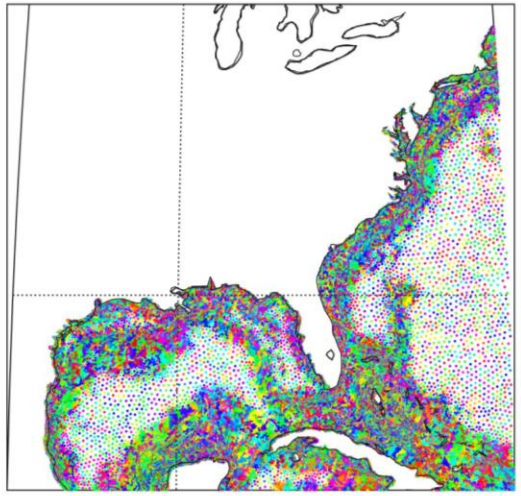
Future change summary: 1/100yr – Top 0.01%

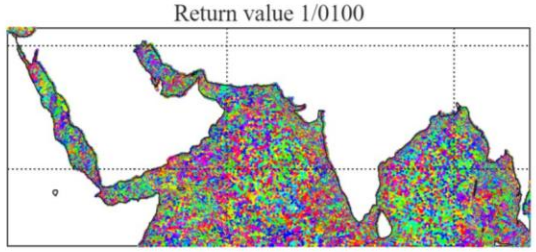


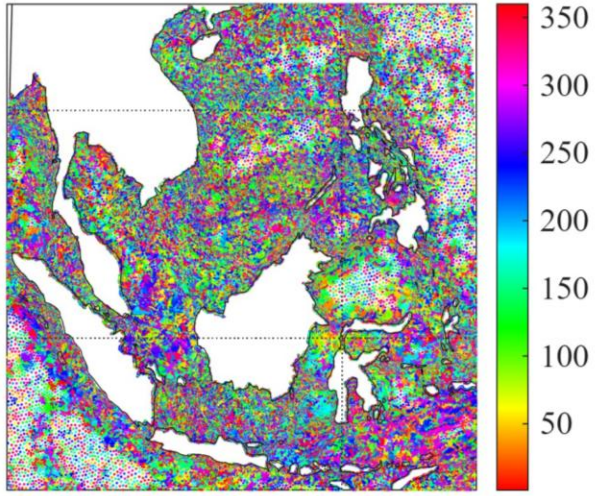
Statistical stability: 1/100 years



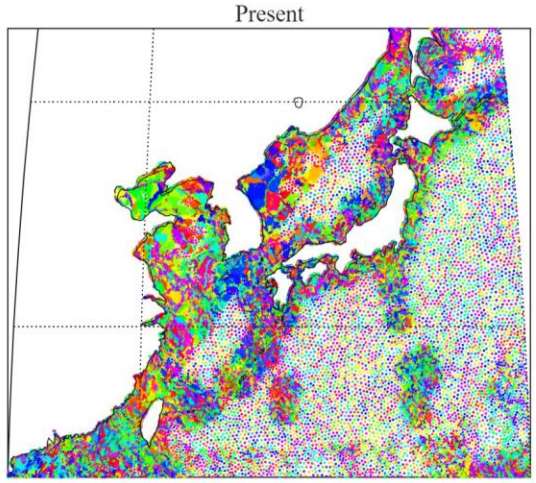


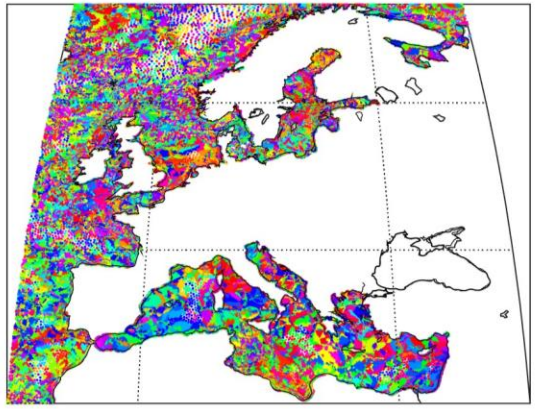


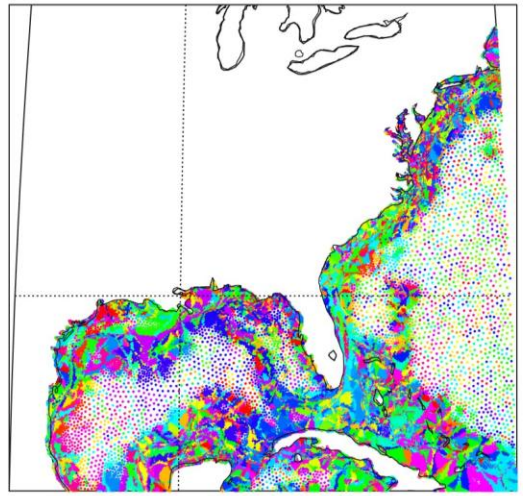


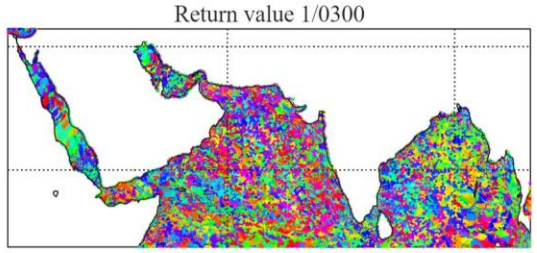


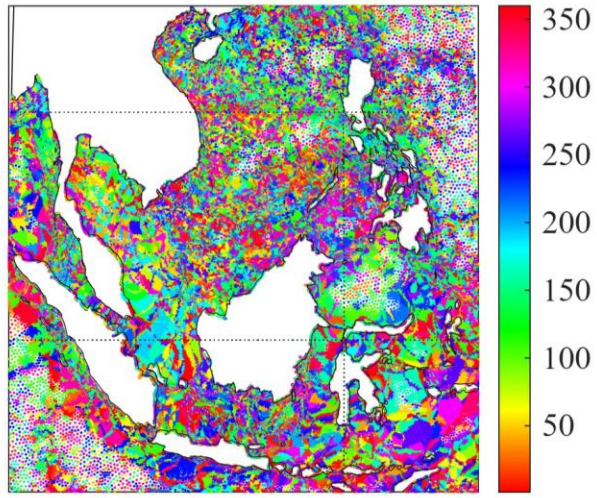
Statistical stability: 1/300 years











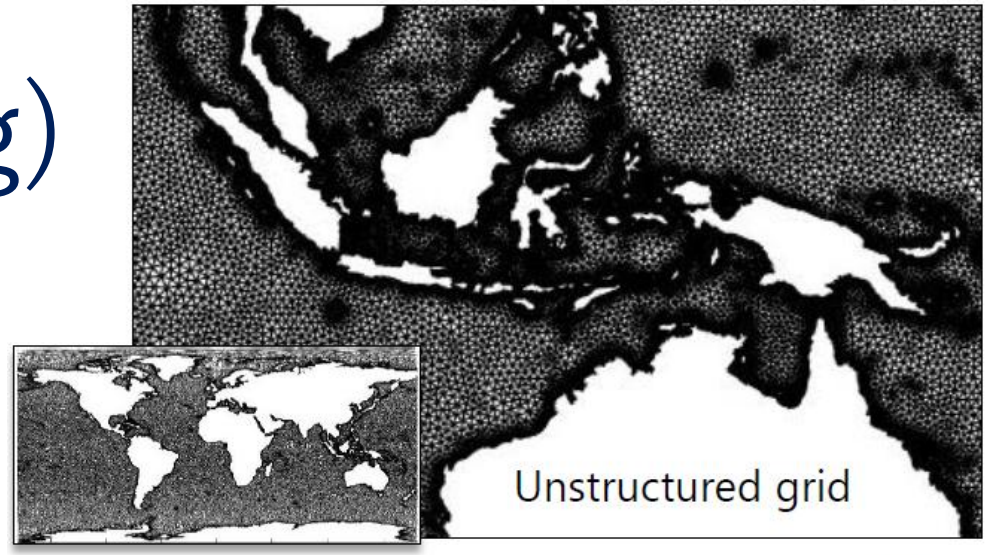
KYOTO

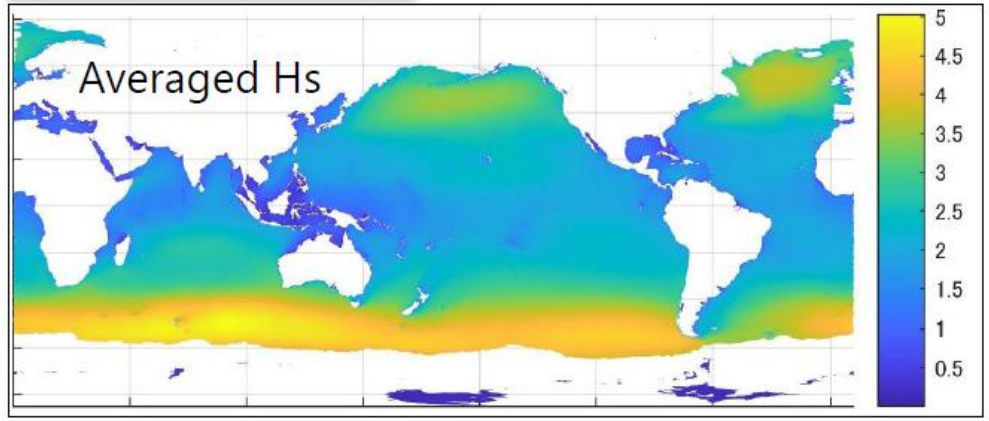
DPRI-KU

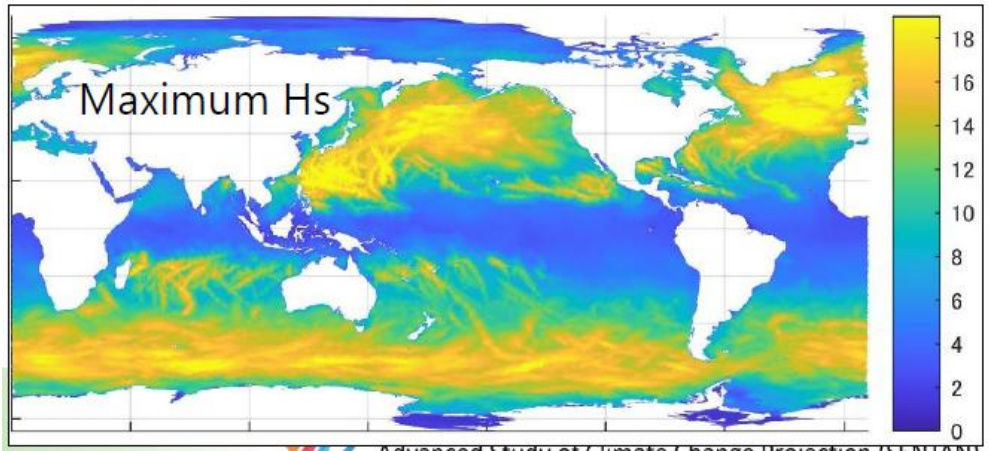
Wave Projection (ongong)

Model and Data

- Model Spectral wave model
  - WaveWatchIII
- Domain
  - Unstructured-grid created by Oceanmesh2D (Robert et al., 2019): Matlab mesh generator
  - Global (50 km resolution) to coast (5 km resolution)
- The Unresolved Obstacles Source Term (Mentaschi et al., 2015)
- Sea ice concentration







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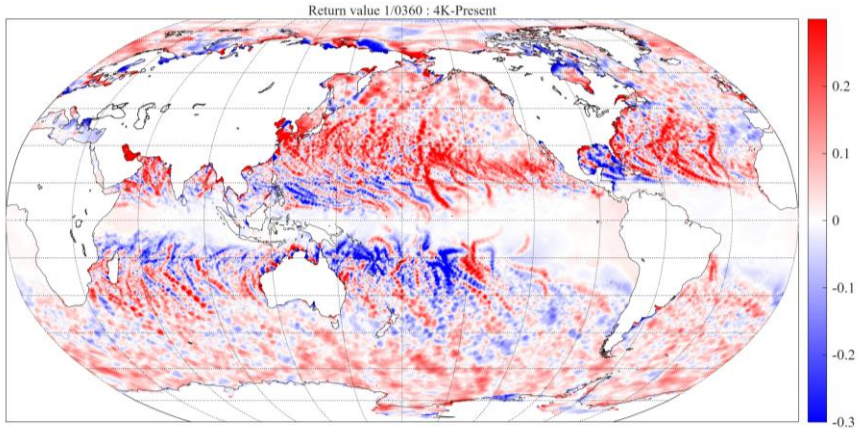
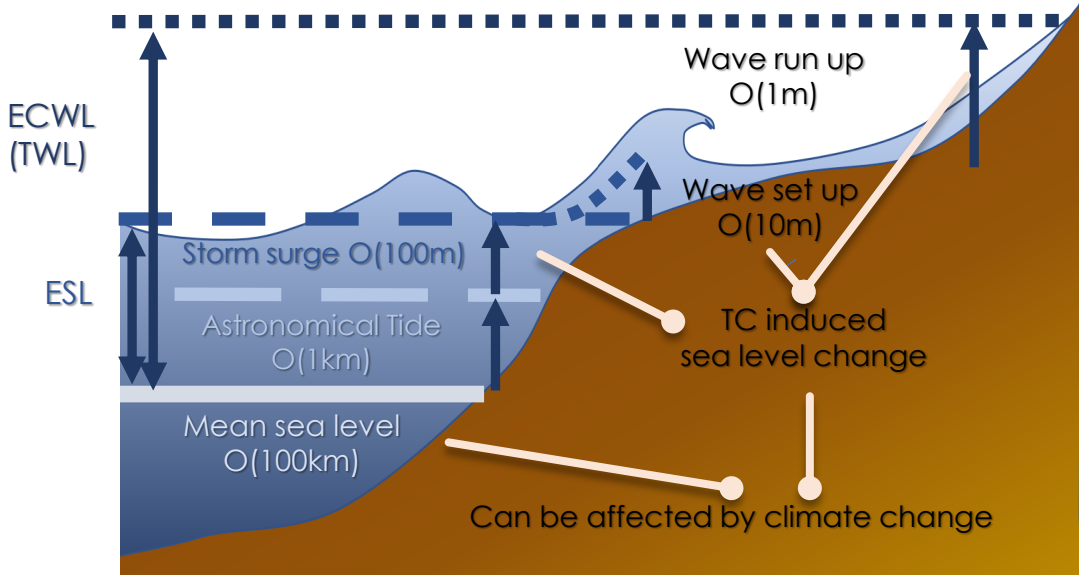


- Coordination of ensemble projection is important.
  - SurgeMIP (Friday afternoon)
  - COWCLiP3 (Hector; Thursday and Sat.)



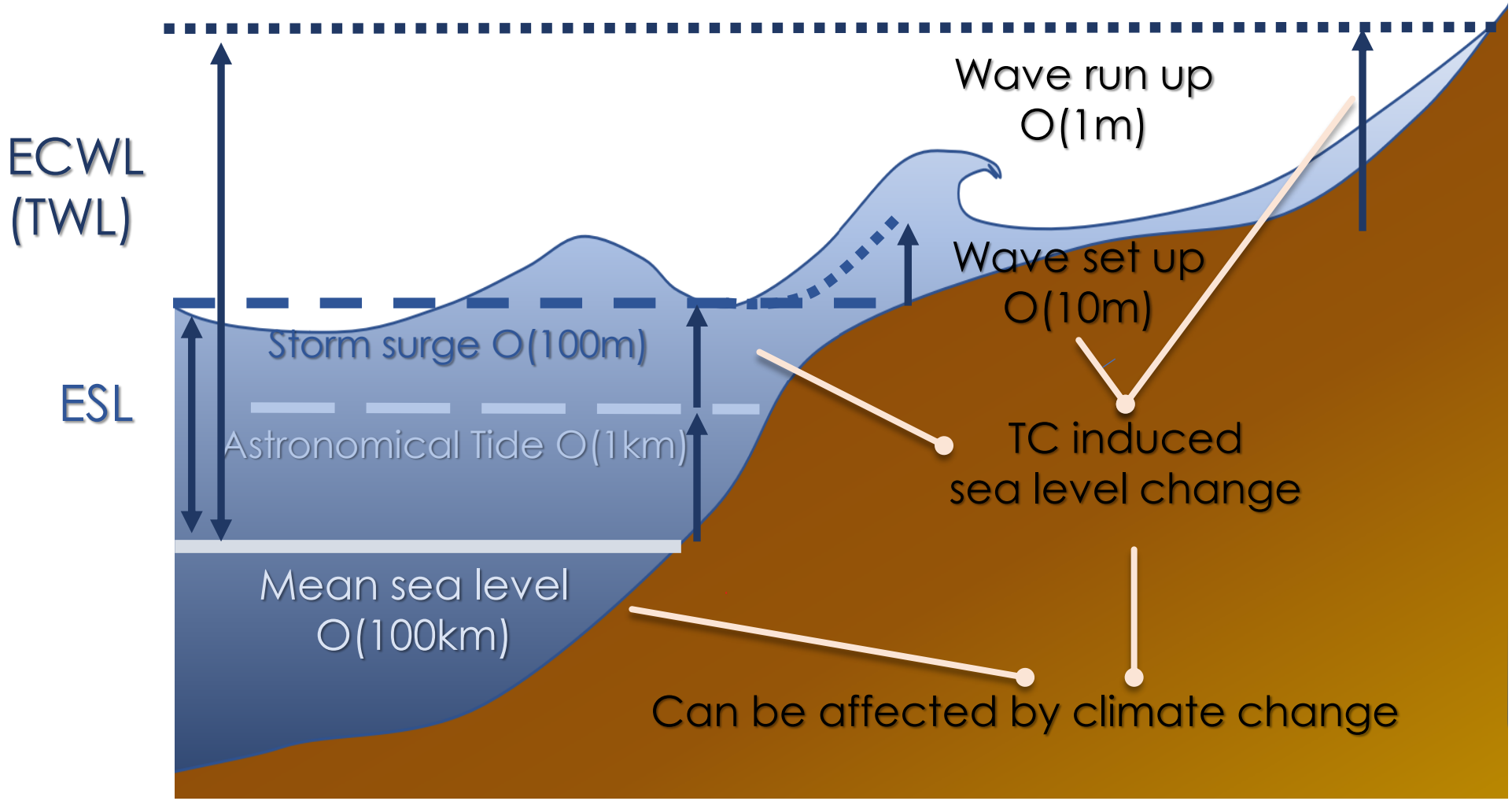
The End

mori@oceanwave.jp

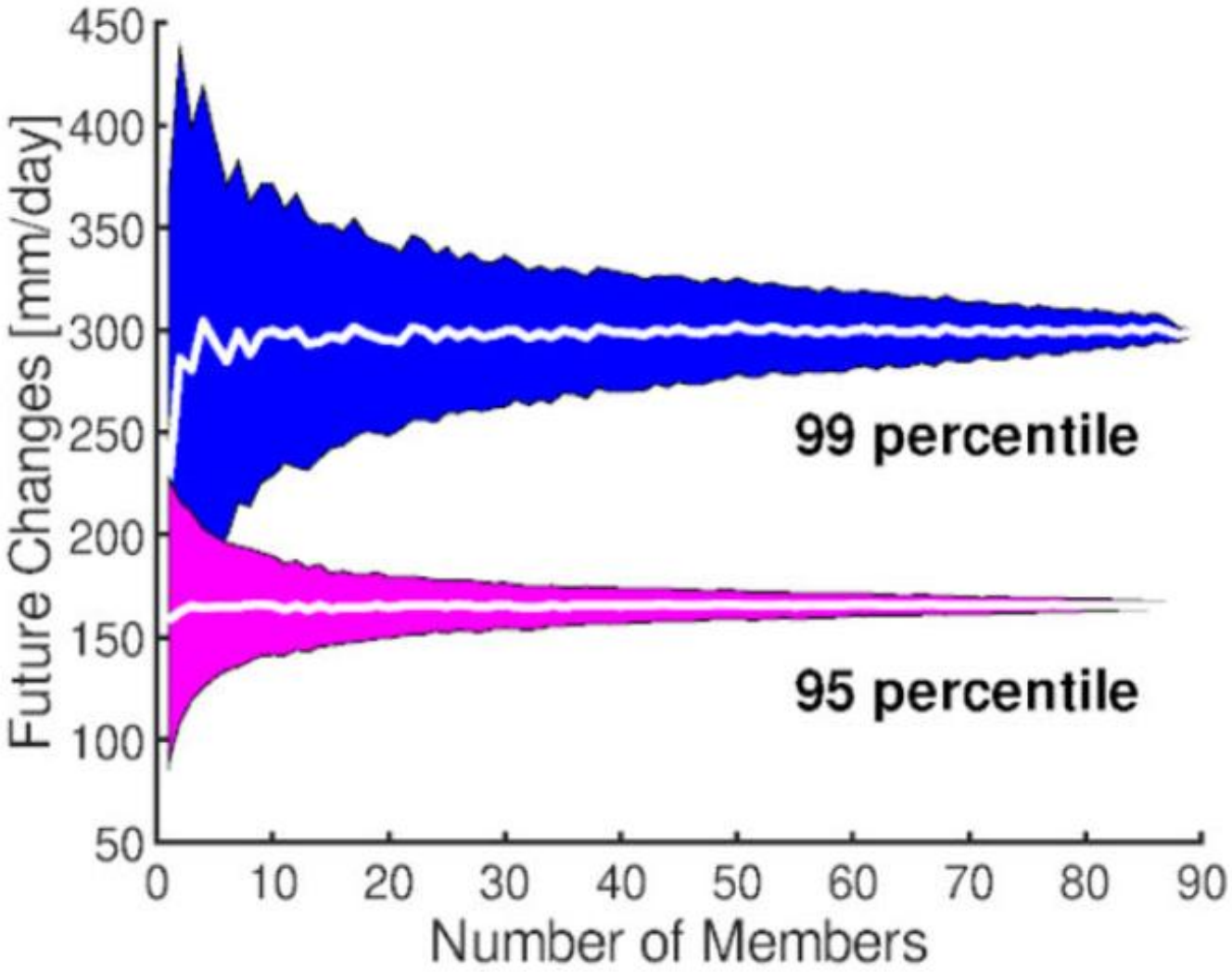
気候変動予測先端研究プログラム
Advanced Study of Climate Change Projection (SENTAN)

京都大学

Extreme Sea Level (ESL) / Extreme Coastal Water Level (ECWL)

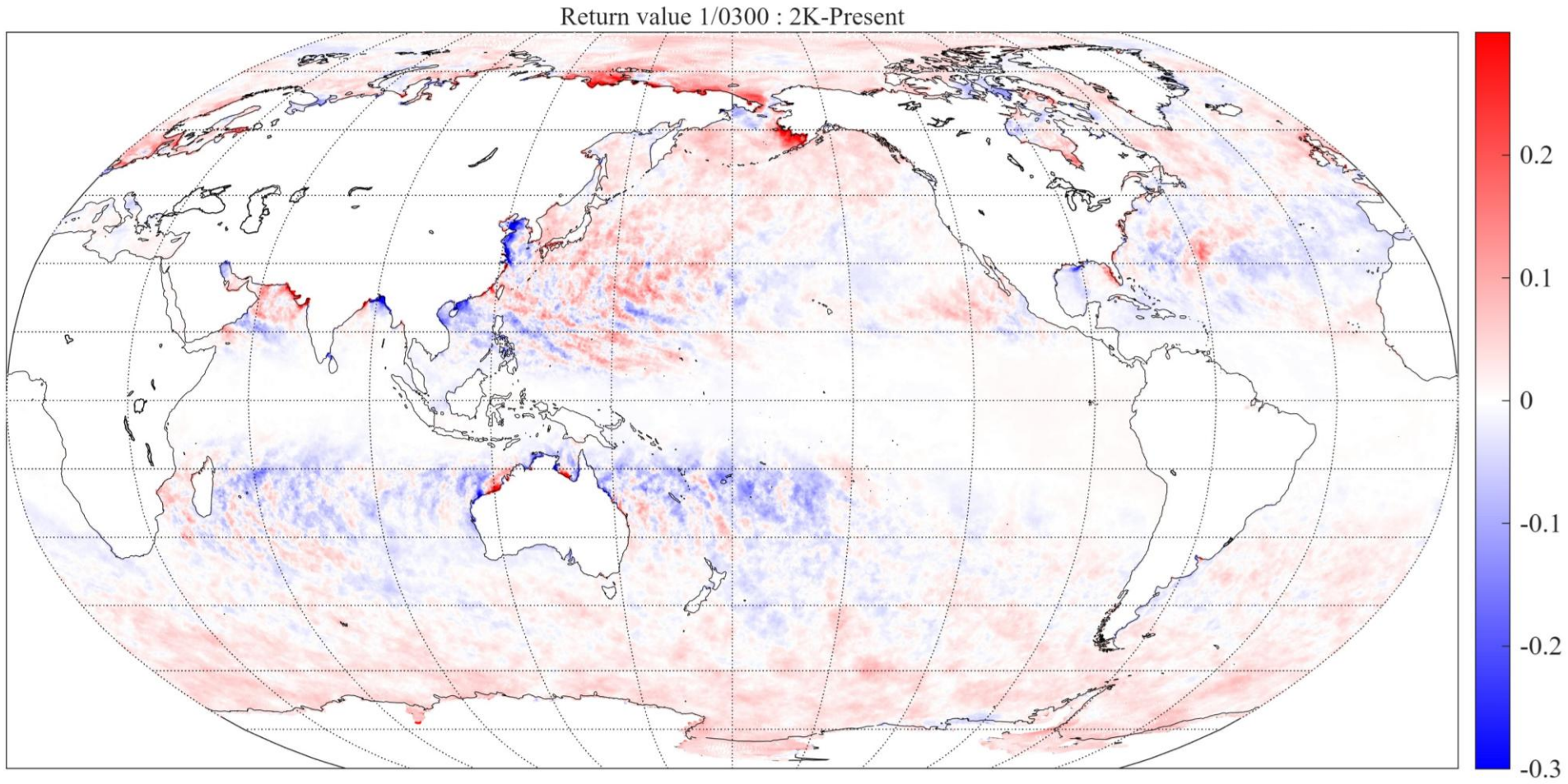


Large ensemble can reduce uncertainty



Ishii and Mori (2020) PEPS

ΔSurge height in +2K: 1/300 years



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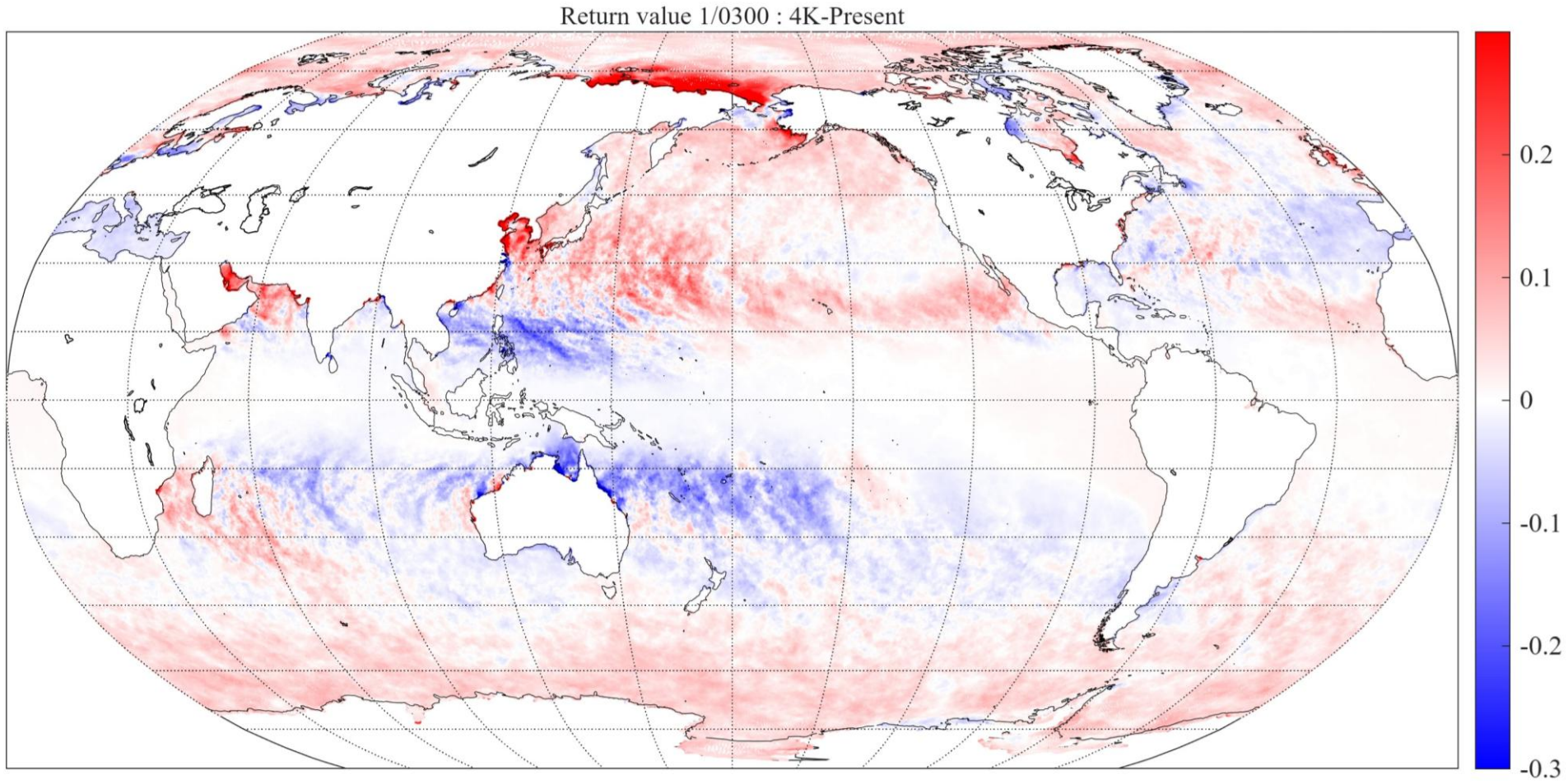

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