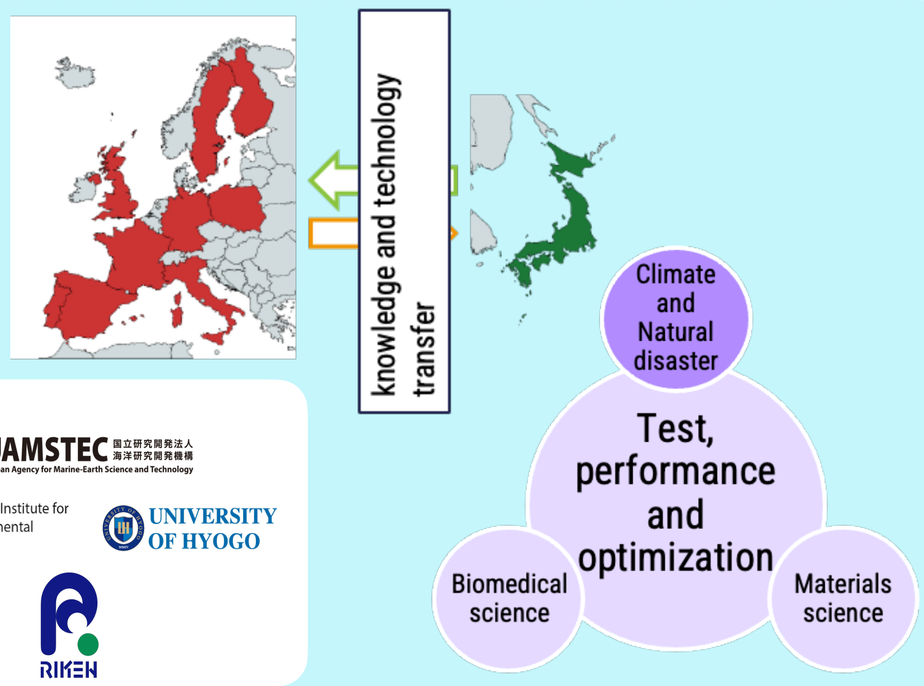
[jh250055] ReplicaEUJP: Research on the replicability of climate simulations across different computing environments

異なる計算機環境における気候シミュレーション再現性に関する研究

八代尚（国環研）、Mario Acosta（BSC）、Kai Keller（BSC）、Marta Alerany Sole（BSC）、Leo Arriola（BSC）
小玉知央（JAMSTEC）、Mohamed Wahib（理研R-CCS）、中島研吾（東大・情報基盤セ）、山崎一哉（東大・情報基盤セ）

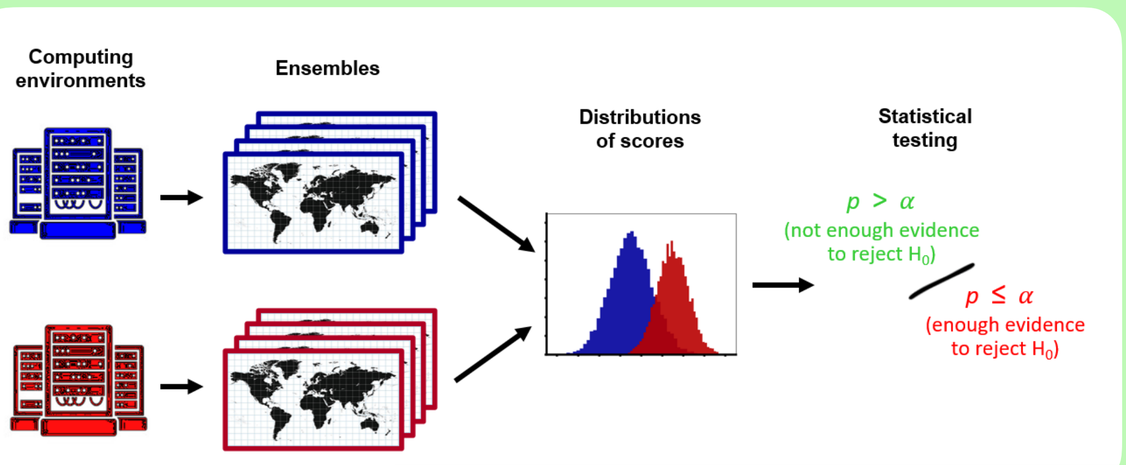
The HANAMI project

- **H**pc **A**llia**N**ce for **A**pplications and supercoM**M**puting **I**nnovation
  - EuroHPC-JU (2024-2027): Europe - Japan collaboration
  - Three Scientific Pillars:
    - **WP4 - Climate and natural disaster**
    - WP5 - Biomedical science
    - WP6 - Materials science
- WP4 has three projects:
  - **Earth-system-model performance assessment**
  - Earth-system-model benchmark suite (HPCW)
  - Large-eddy cloud simulation model (UWLCM)

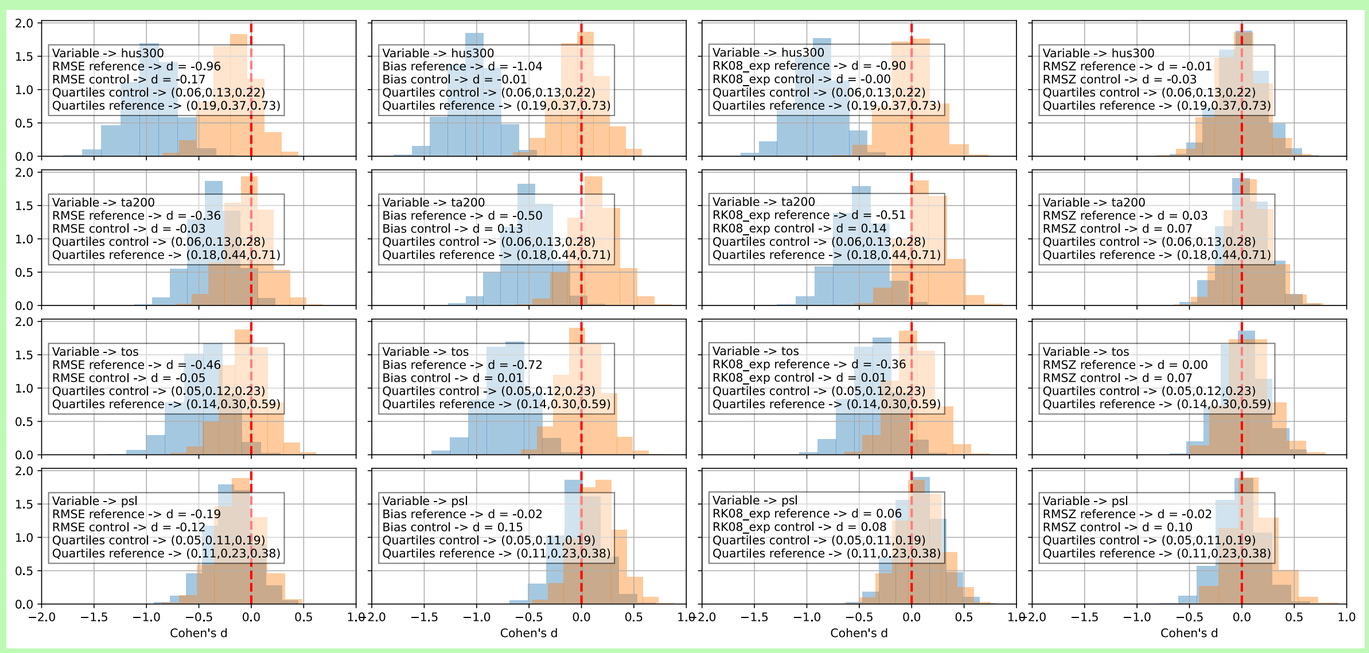


Purpose of this research

- **This study systematically evaluates the replicability of Earth System Model results across multiple supercomputers.**

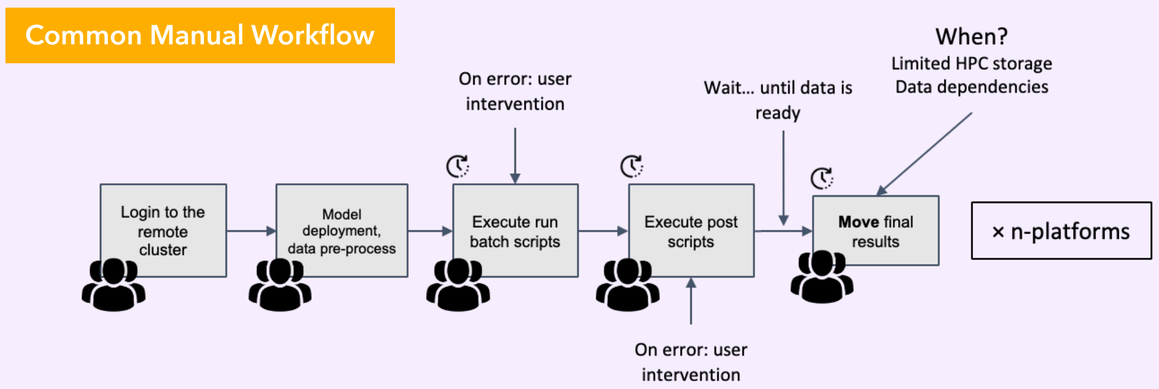


Keller, K. R., Alerany Solé, M., Acosta, M. (2025). Replicability in Earth System Models. EGUsphere [preprint]. https://doi.org/10.5194/egusphere-2025-1367



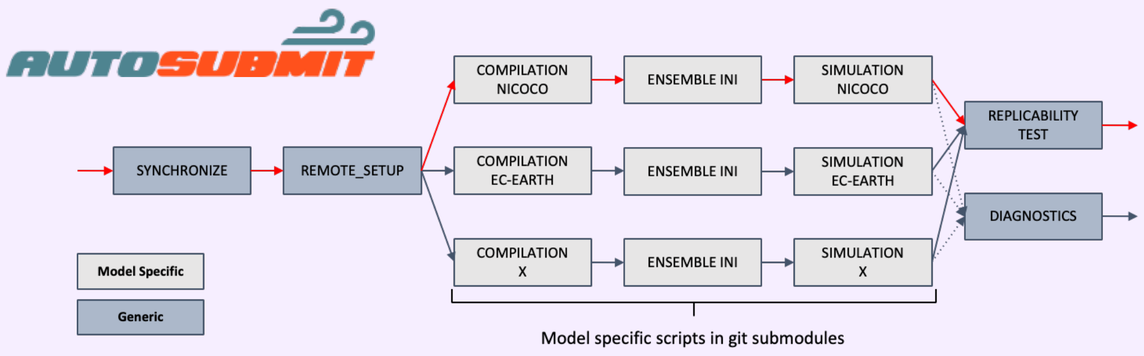
Statistical test results using the Large Ensemble Earth System Model Simulation Dataset (LENS2). Distributions were created using the bootstrap method, and show the control period (1960-1989) (red) and the reference period (1990-2014) (blue), respectively. The tiles from top to bottom show the results for specific humidity at 300 hPa (hus300), air temperature at 200 hPa (ta200), sea surface temperature (tos), and sea level pressure (psl). [From Keller et al. (2025) Figure 7]

Generic Workflow for Replicability Tests



Deployment of NICAM-COCO Atmosphere-Ocean coupling model (NICOCO) on Miyabi with Autosubmit

- **Autosubmit** (Manubens-Gil et al., 2016; Uruchi et al., 2021) is an open source Python experiment and workflow manager used to manage complex workflows on Cloud and HPC platforms.

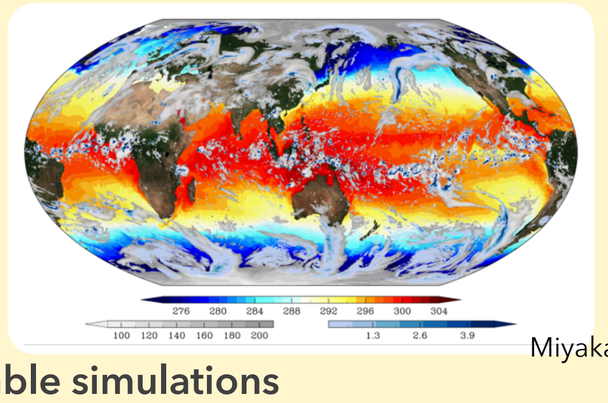


Experiments

Statistical Tests with Ensemble Simulations

We typically perform an ensemble of climate simulations to capture the natural internal variability of the climate represented by an Earth System Model (ESM). Our replicability test is based on the methodology presented by Massonnet et al. (2020), where the distribution among the ensemble members of the Reichler-Kim (2008) index, a scalar climate model performance score, is used to study statistical indistinguishability between two ensembles.

We aim to create ensembles generated using variations in the forcing (boundary conditions imposed throughout the simulations), the perturbations (introduced in the initial conditions), and the settings for the model parameterizations. Comparing ensembles with different modifications and studying the corresponding power will allow us to evaluate the test's sensitivity, as it will provide us with insights into the threshold effect sizes of climates to be detectable by our test.



Miyakawa et al. (2017)

NICOCO Ensemble simulations

We plan on running sets of experiments with the following characteristics:

- 150-years spin-up simulation with constant radiative forcing
  5 (members) x 150 (years) x 15 (configurations)
- 30-year historical simulation ensembles
  50 (members) x 30 (years) x 15 (configurations)

We will perform simulations at 1-degree resolution (~100 Km grid spacing) in varying model configurations. We will evaluate the simulations using the replicability test to assess the sensitivity of the differences in the model configuration and study the test's capability and limitations. The assessment involves estimating the False Positive Rate (FPR) by comparing sub-ensembles drawn from ensembles with the same configuration and the test's power and sensitivity by comparing sub-ensembles drawn from ensembles generated with different configurations.