Modelling water isotopes using a global non-hydrostatic model with explicit convection scheme

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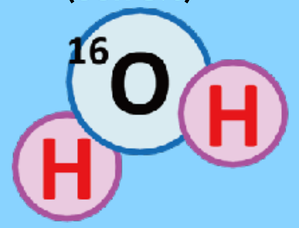
Introduction

- **Stable water isotopes**: useful tracer for understanding atmospheric hydrological cycle and modern- and paleo-climate.
- Many isotope-incorporated GCMs have been developed.
  (e.g., Joussaume et al., 1984; Risi et al., 2010; Yoshimura et al., 2008)
  - However, GCMs have uncertainty for tropical convective precipitation.
    (e.g., tropical cyclones and meso-scale convective system)
- **Global cloud-system-resolving models (GCRMs)** can be reduced these uncertainties by explicit convection scheme.
- We develop a new isotope-incorporated GCRM (**NICAM-WISO**). Then, we conduct simulations by the model and investigate usefulness of the model.

What is stable water isotopes(SWI)?

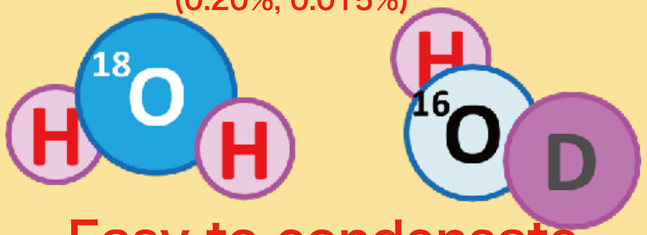
Normal Water molecular

(99.73%)



Stable water isotopes

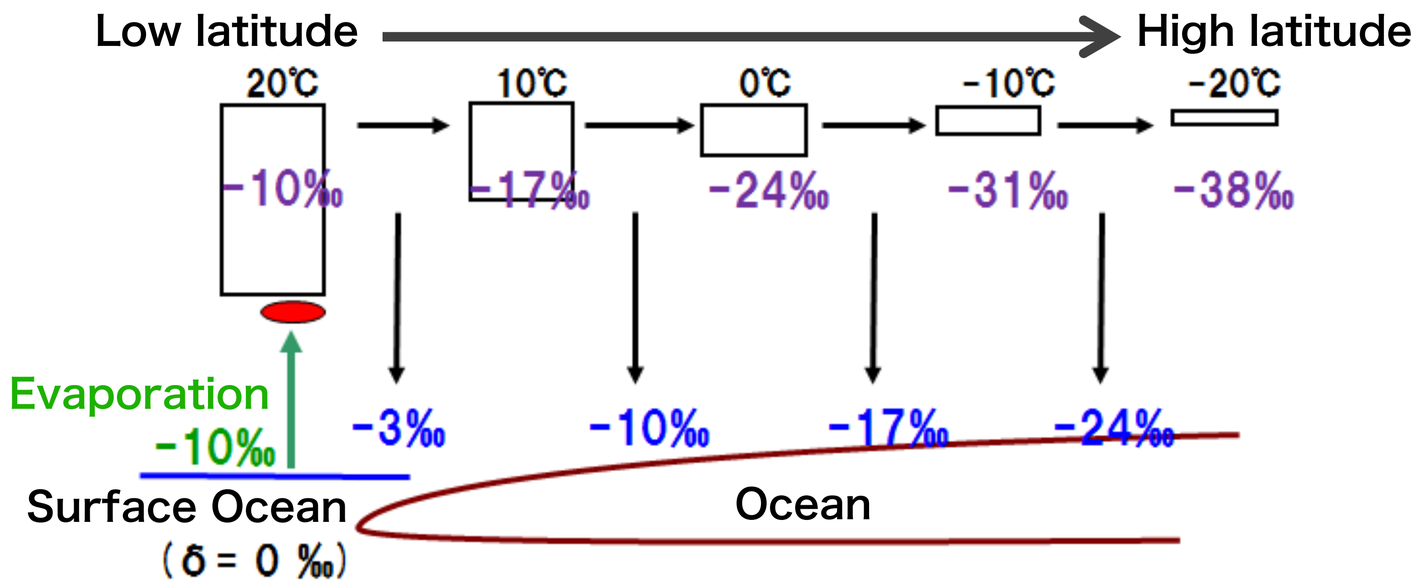
(0.20%, 0.015%)



Easy to condensate

$$R = \frac{{}^{1}H_2^{18}O}{{}^{1}H_2^{16}O} or \frac{{}^{1}H^{2}H^{16}O}{{}^{1}H_2^{16}O}$$

$$\delta = (\frac{R_{sample}}{R_{SNOW}} - 1) * 1000 \quad [‰]$$



An indicator of atmospheric hydrological cycle!

SWIs are incorporated into hydrological cycle and cloud process in the model.

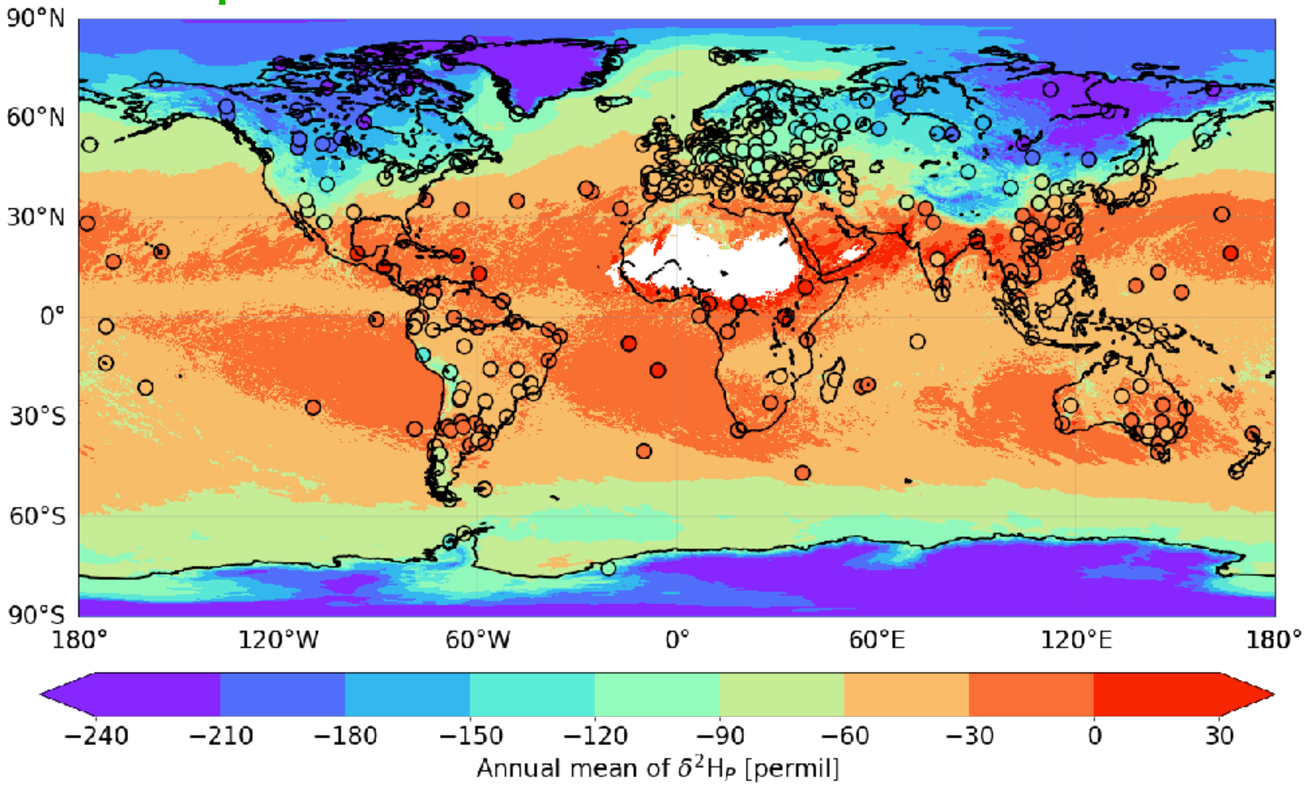
Experiment design

Name	Resolution	Period	Cloud process	Convective process	Calculation time per month
CTRL	GL07 (56 km), 78 layer	1979-1990	NSW6 Roh (Roh and Satoh, 2017)	--	55 min. (640 nodes)
HRES	GL09 (14 km), 78 layer	1979-1982	NSW6 Roh (Roh and Satoh, 2017)	--	250 min. (2560 nodes
LRES	GL05 (256 km), 78 layer	1979-1982	NSW6 Roh (Roh and Satoh, 2017)	--	107 min. (10 nodes)

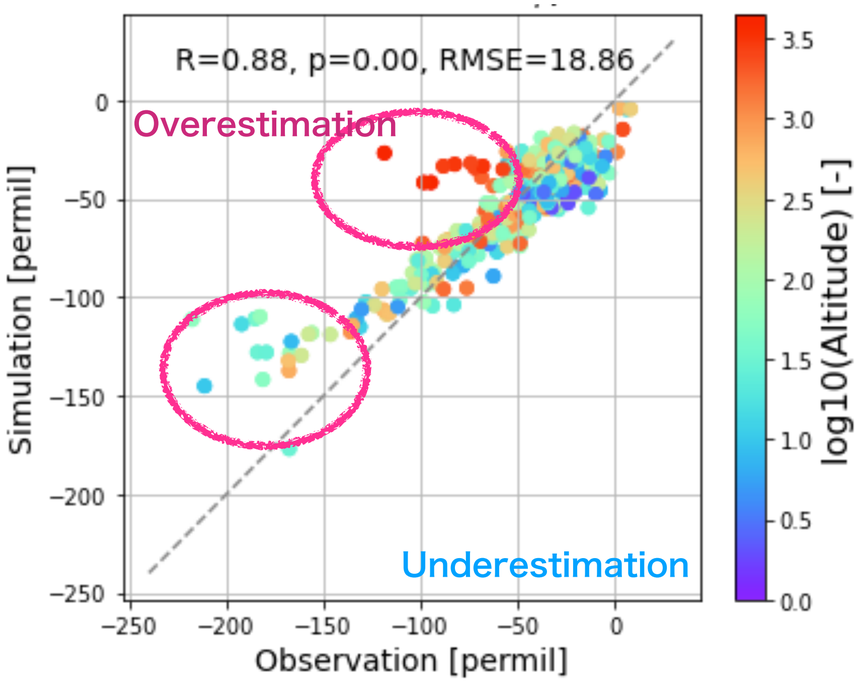
- **Used same setting between the simulations, except for horizontal resolution.**
  - Boundary condition: SST, ICE, Ozone (Kodama et al., 2015)
  - Initial condition：ERA5 2000/1/1
  - Mimic HighRerMIP experiment (Kodama et al., 2021).
- **We conducted these simulation on the Fugaku super-computer.**

Precipitation δ^2H

Precipitation δ^2H (Annual mean) (CTRL)

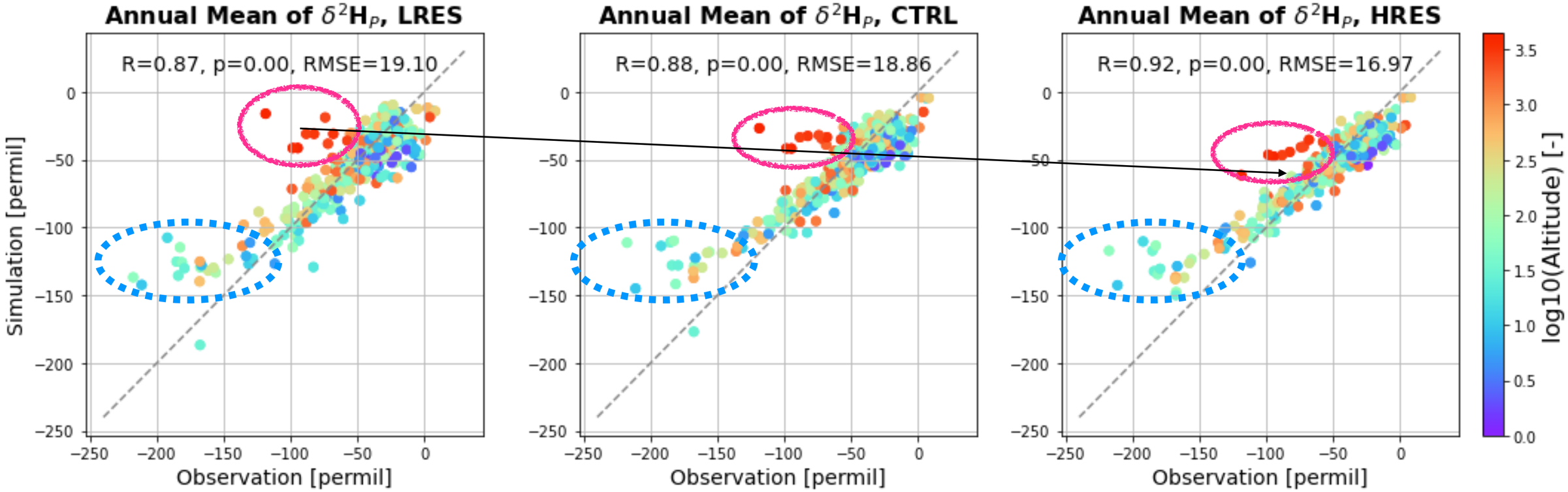


Simulation v.s. Observation



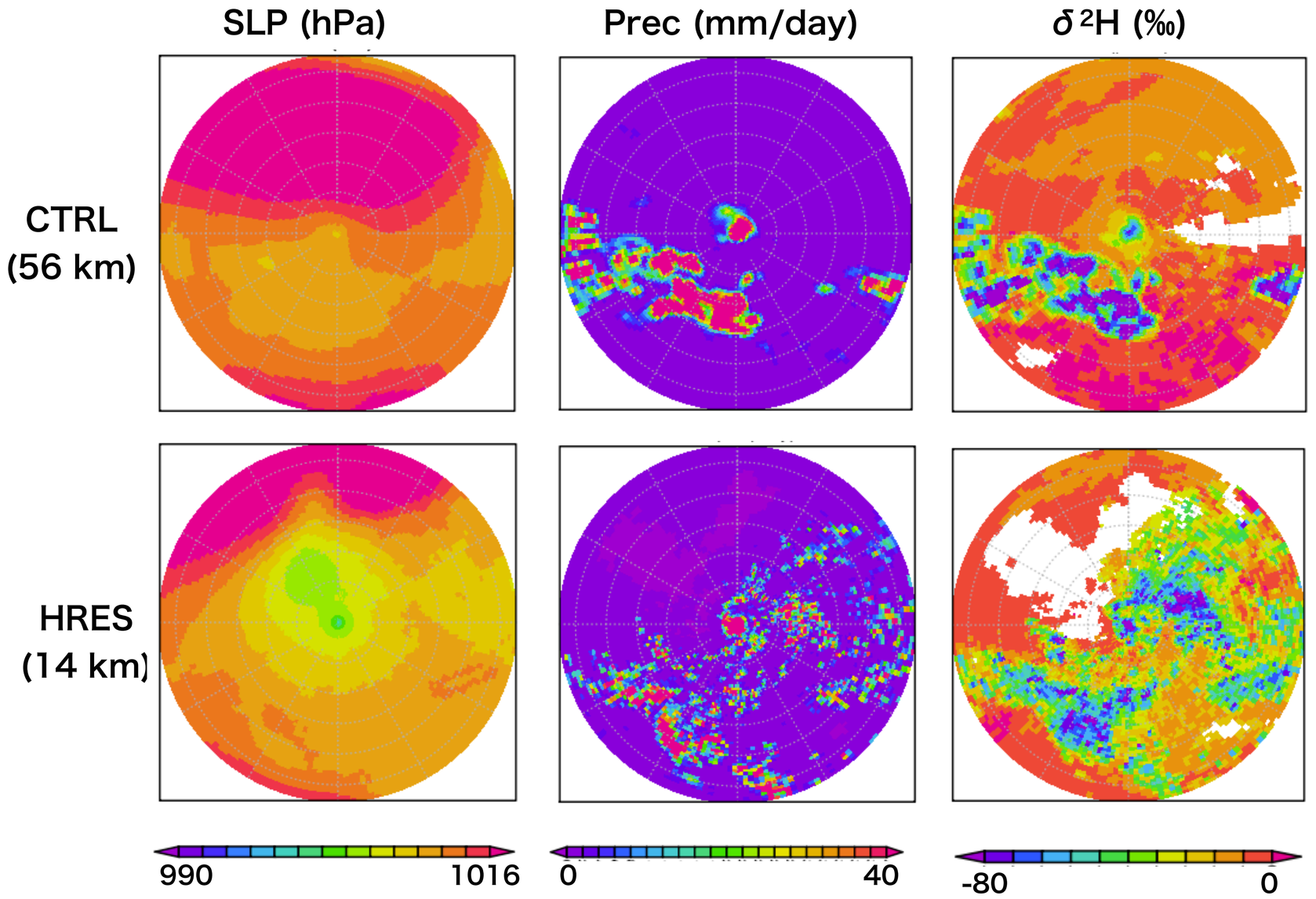
- CTRL could capture the observed distribution.
- However, the model overestimated in the regions with high-altitude (Andes) or high-latitudes (Canada, Siberia).

Bias of precipitation δ^2H



- Bias in high-altitude regions was Improved by increasing resolution.
- However, the bias in high-latitudes regions are remained.
  → Uncertainty of cloud microphysics affects the bias.
- SWIs are tracers that can uniquely identify model biases & uncertainties.

Tropical cyclone (TC)



- Investigated usefulness of NICAM-WISO.
- Detect TC centers and randomly selected one of TC.

- TC pressure pattern was clear for HRES, but unclear for CTRL.
- Some rain-bands were observed for HRES.
- δ^2H of precipitation was low corresponded to rain-bands.

- High resolution simulation using NICAM-WISO can be contributed to understand and investigate hydrological cycle of TCs.

Summary

- We developed a new isotope-incorporated global cloud-system-resolving model **NICAM-WISO**, and then conducted climatic experiment.
- The model shows better reproducibility of annual mean of precipitation isotopic ratios, however the model have a bias in the regions with high-altitude and high-latitudes.
- High resolution simulation using NICAM-WISO can be contributed to understand and investigate hydrological cycle of TCs.
- **Stable water isotopes are tracers that can uniquely identify model biases and uncertainties.**