Predictability of climate tipping : data assimilation approach

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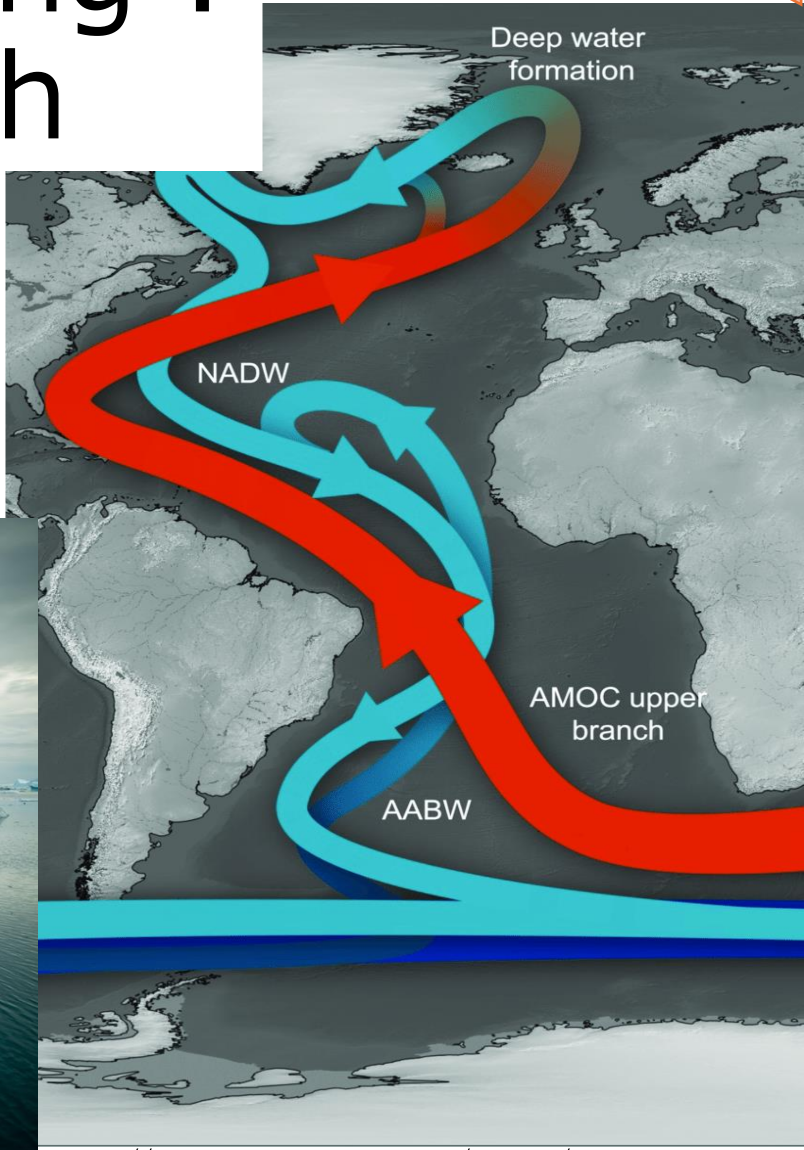
https://arxiv.org/pdf/2406.19639

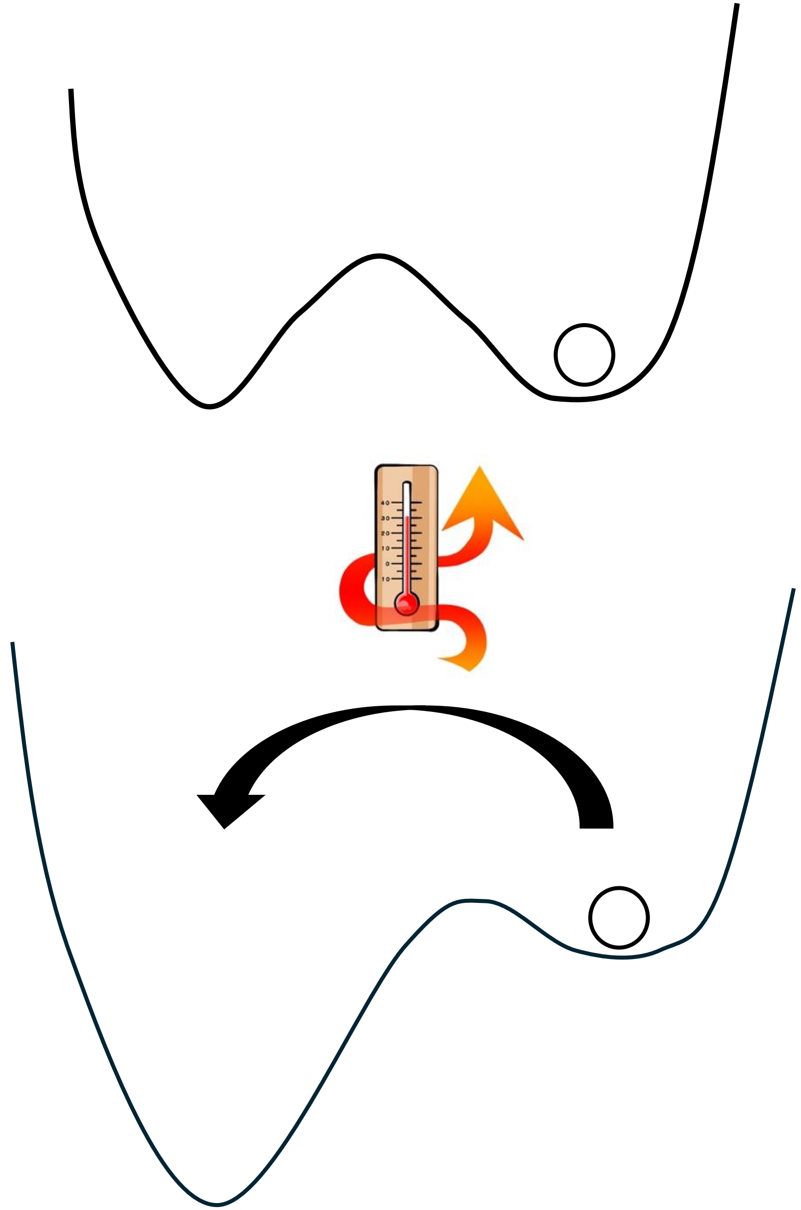
https://en.wikipedia.org/wiki/File:Amazon_rainforest_(orthographic_projection).svg

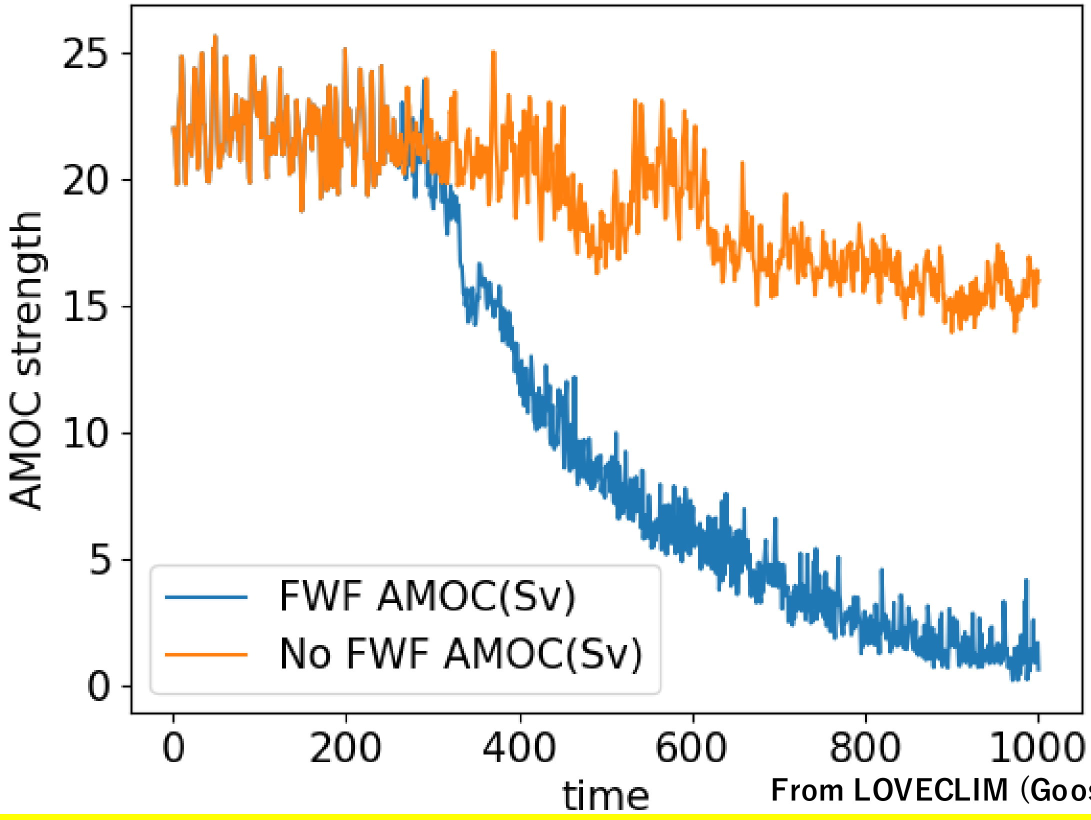
https://unsplash.com/ja/@mlenny



https://www.researchgate.net/profile/Stefano-Crivellari

Climate tipping





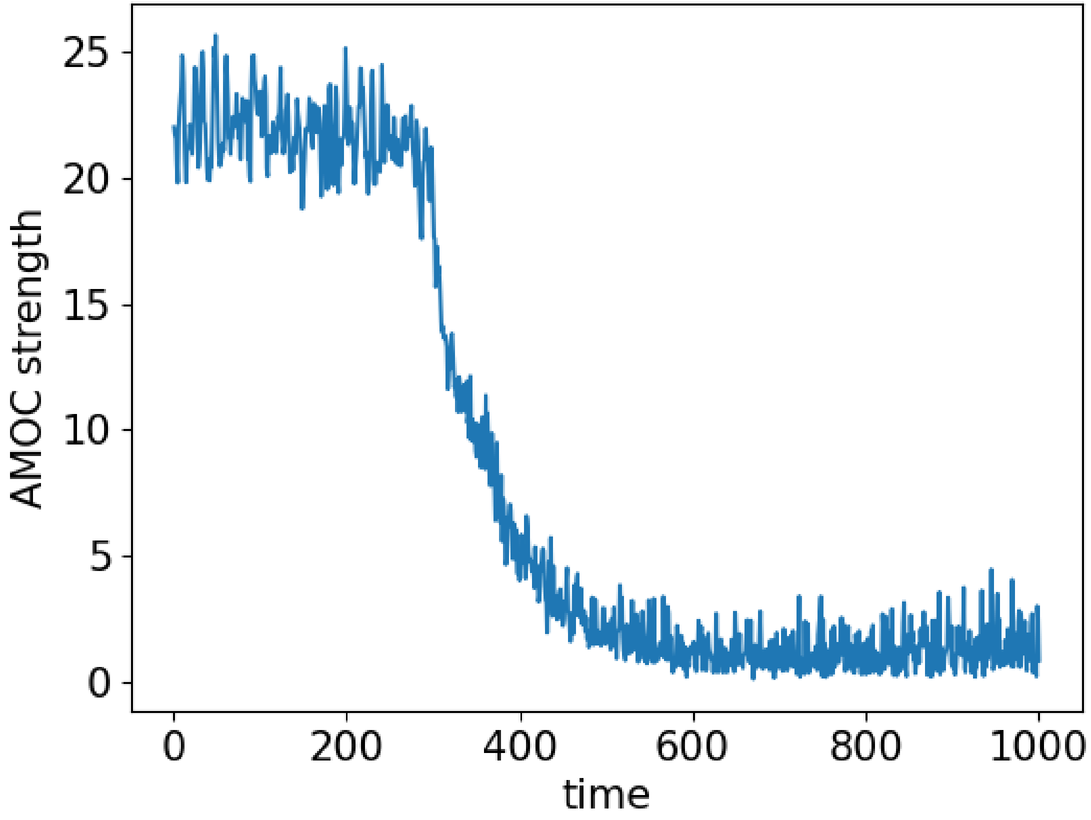
From LOVECLIM (Goose et al., 2010)

- ◻ Transition from one long-term stable state to another state
- ◻ Irreversible and have huge impact

→ Prediction of climate tipping is important

Climate tipping & data assimilation

Climate tipping includes lots of interesting topic related to data assimilation



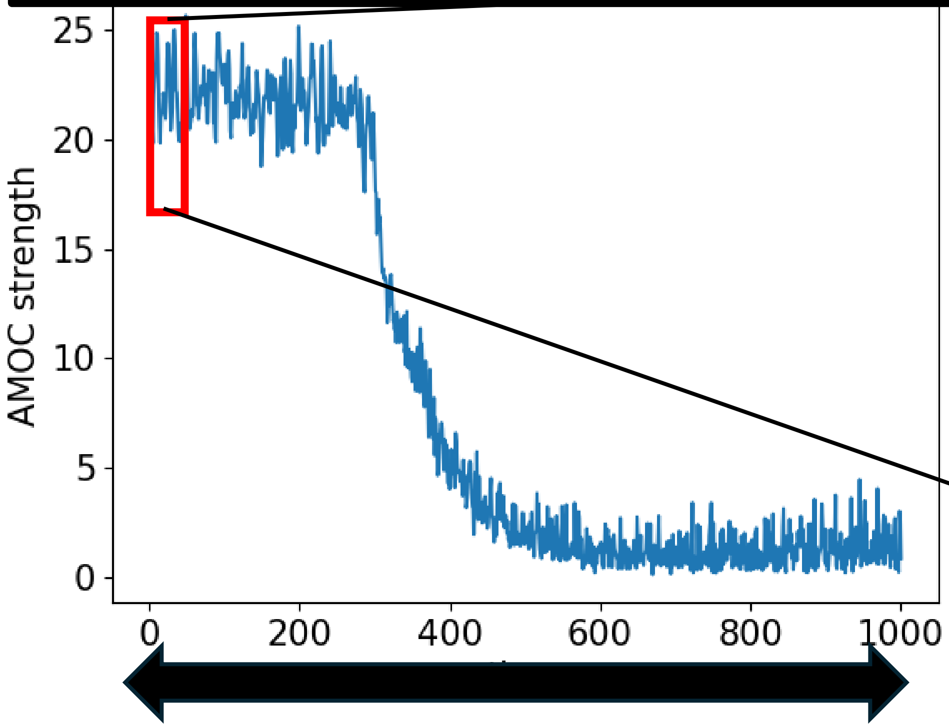
From LOVECLIM (Goose et al., 2010)

- **Predictability**
  - Application of the framework of weather predictability
- **Nonlinear Data assimilation**
  - DA robust to strong nonlinear system is necessary
- **Efficient Data assimilation**
  - Efficient enough to cope with high-dimension system

This study is the first step to assess the practical predictability of climate tipping

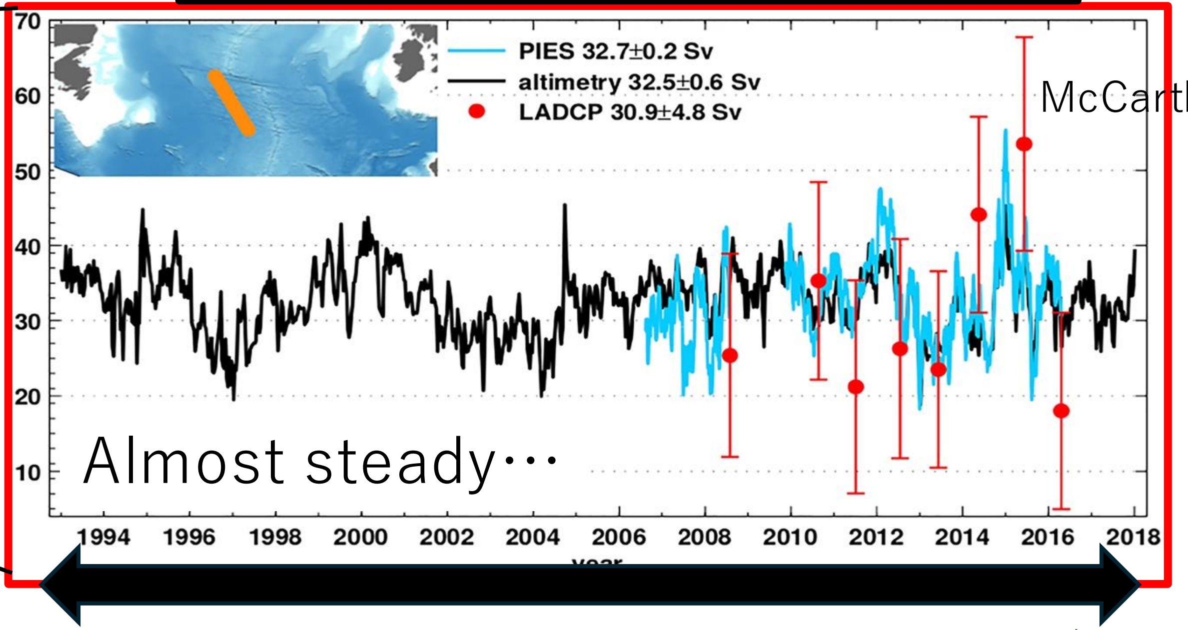
Feature of climate tipping observation

Model simulation of AMOC



1000 years

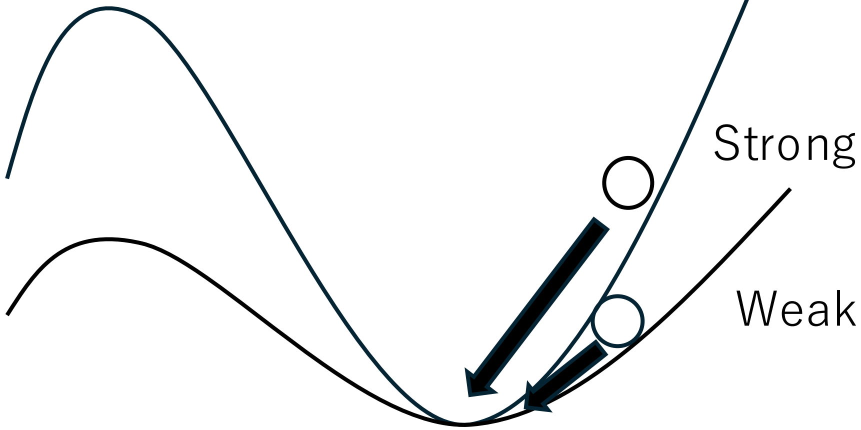
Observation of AMOC



24 years

McCarthy(2020)

Stability of the system can be inferred from internal variability. Scheffer(2009)

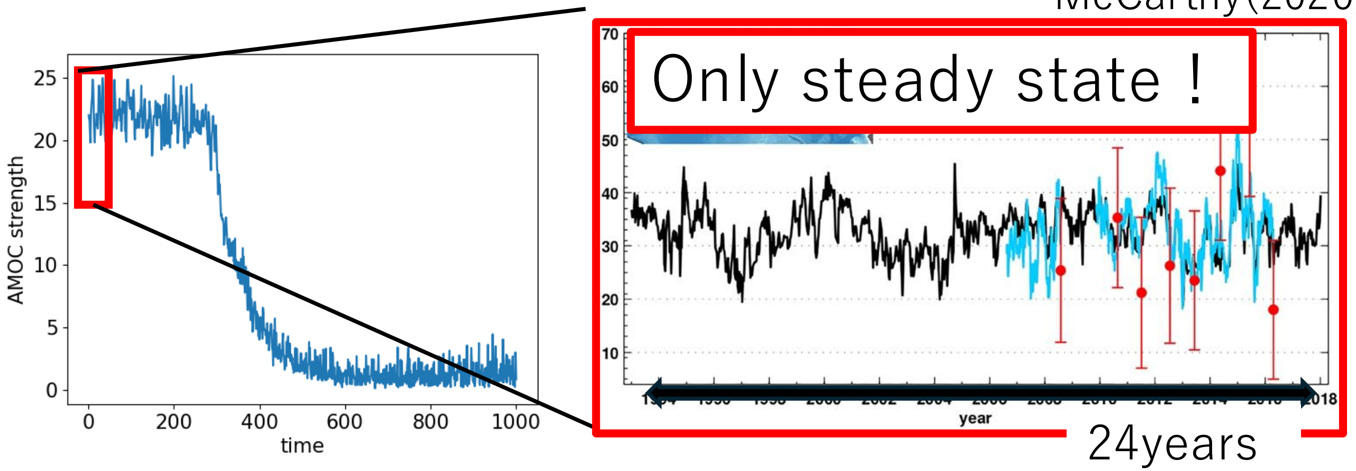


Research question

- Is the observation **without climate tipping** possible to improve model prediction of **whether or not and when climate tipping will happen?**

Observation deficit

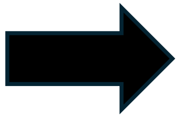
McCarthy(2020)



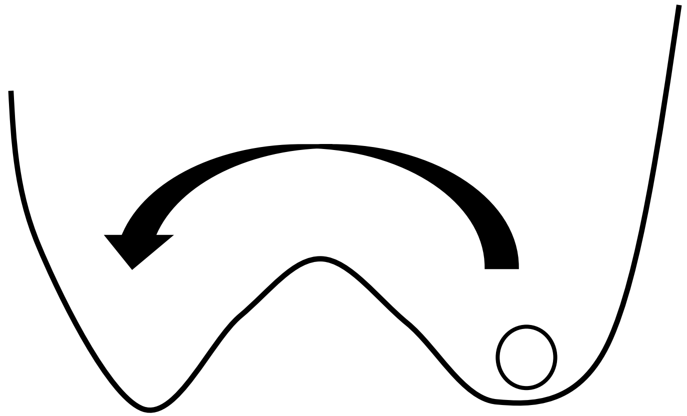
24years

Sam Sherriff-Tadano et al.(2021)

2500years



Can predict tipping?

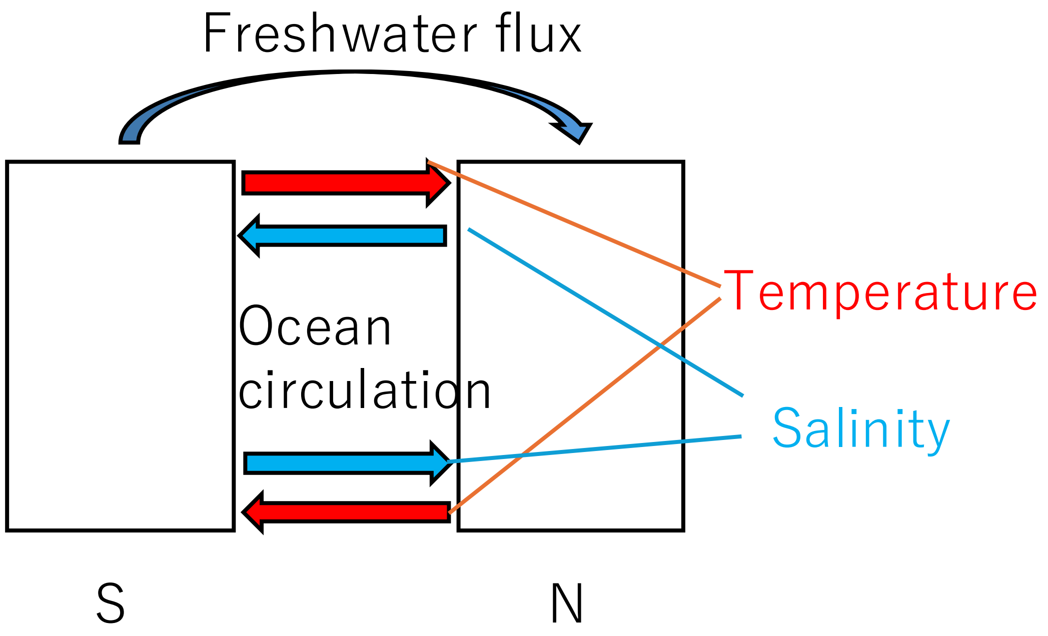


Climate tipping model and scenario

Method

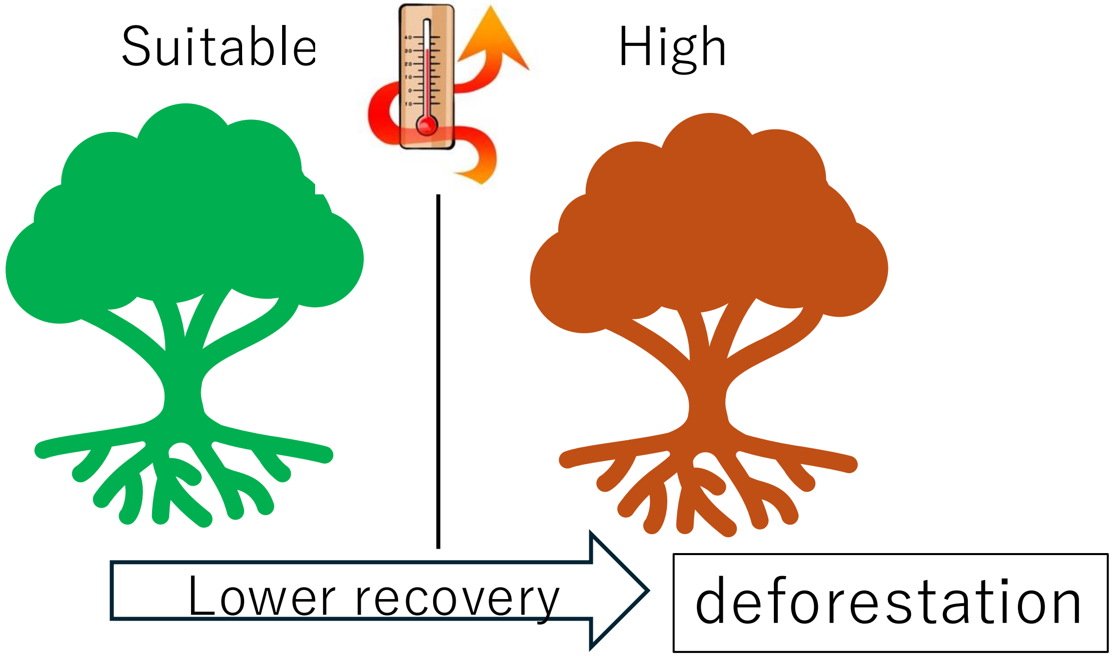
Temperature scenario

AMOC two-box model



AMOC strength

Amazon forest model

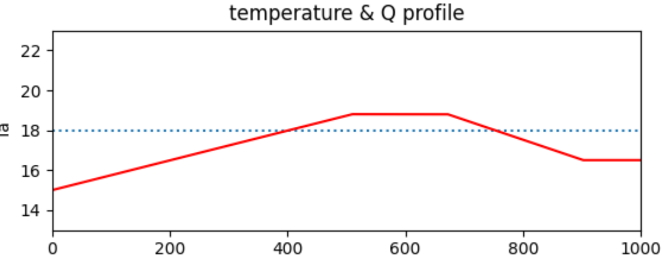


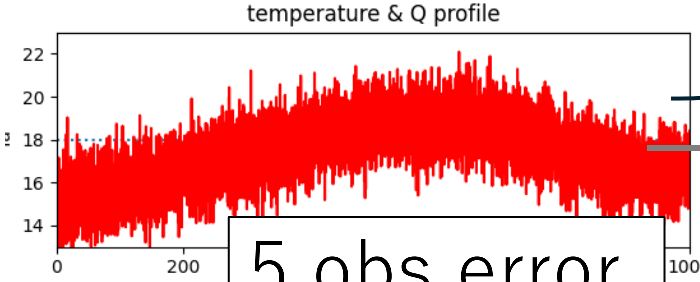
Tropical forest ratio

Detailed setting of OSSE

Forcing variability setting

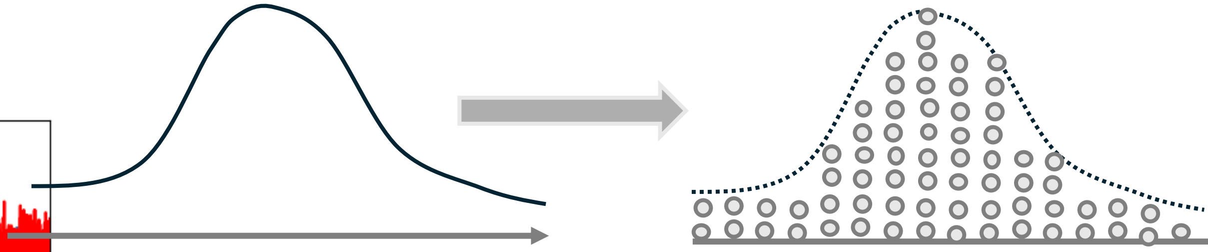
Temperature timeseries





Particle filter

1000 members



True model

5 Forcing variability

True state

5 obs error
6 obs freq

3 obs error
6 obs lead time

Compare

Observation

Model

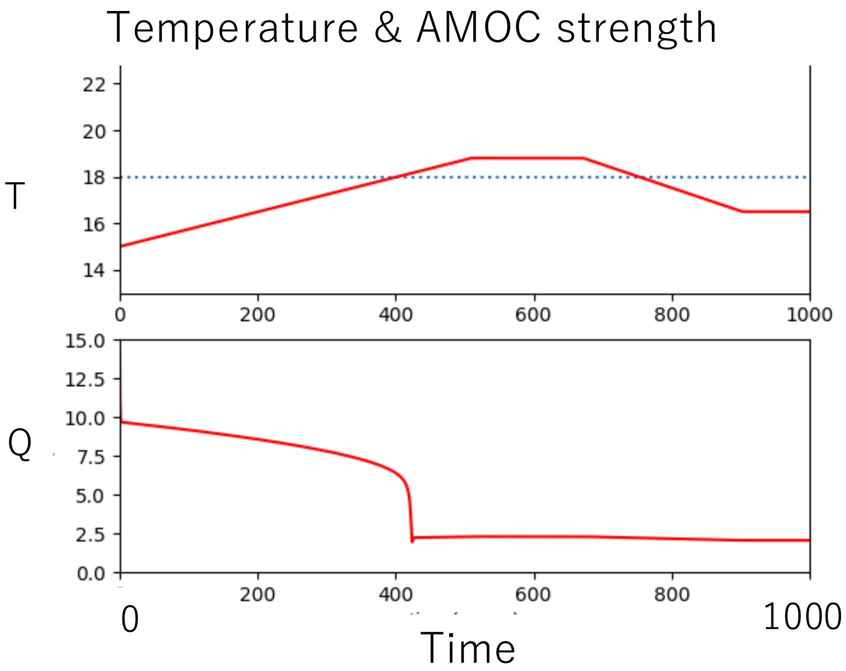
Only 2 parameter are unknown

Model output

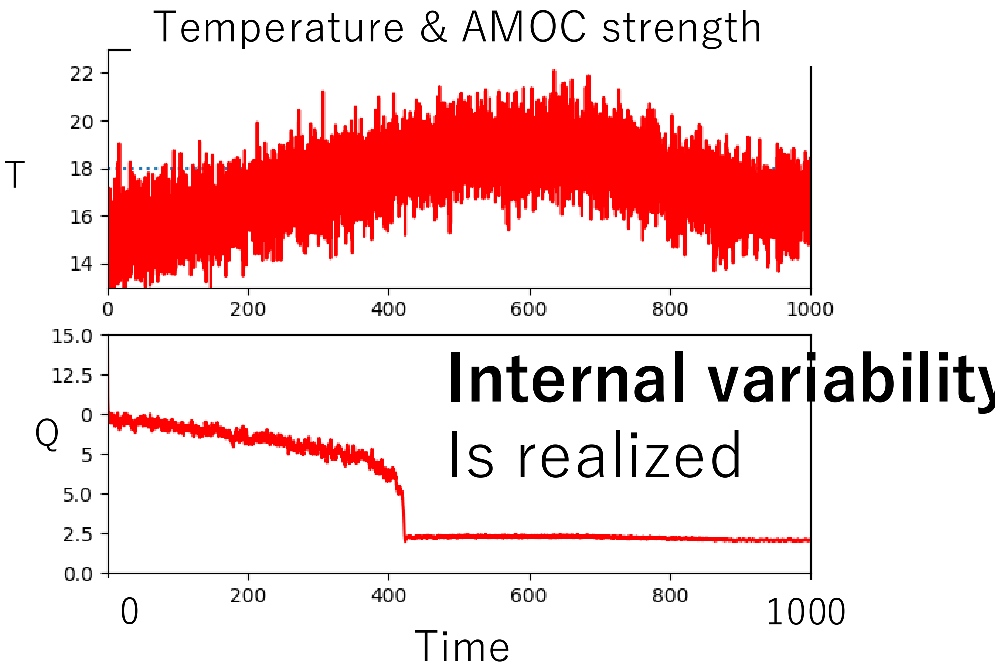
100 trials on each observation and model setting

What is the expected effect of the internal variability?

Expectation



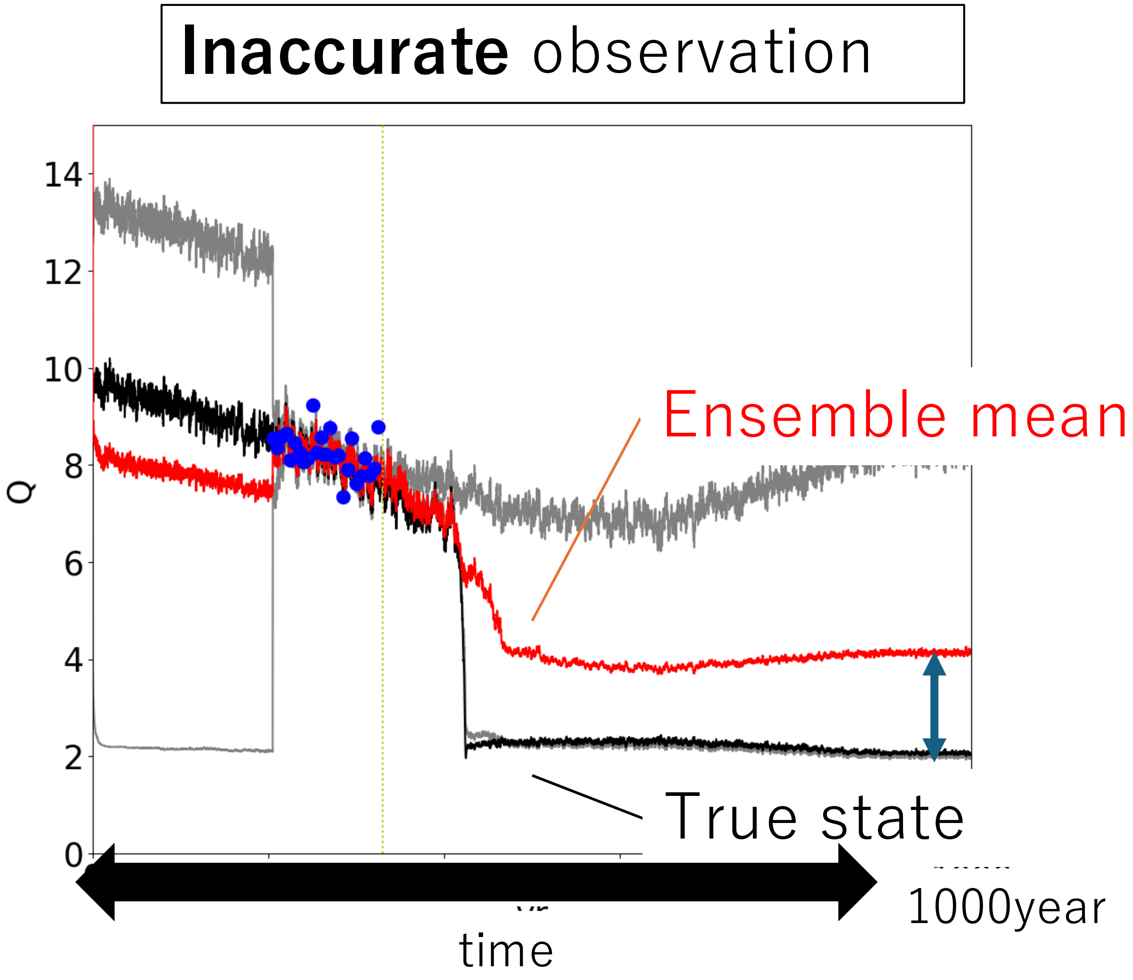
Adding
Forcing variability

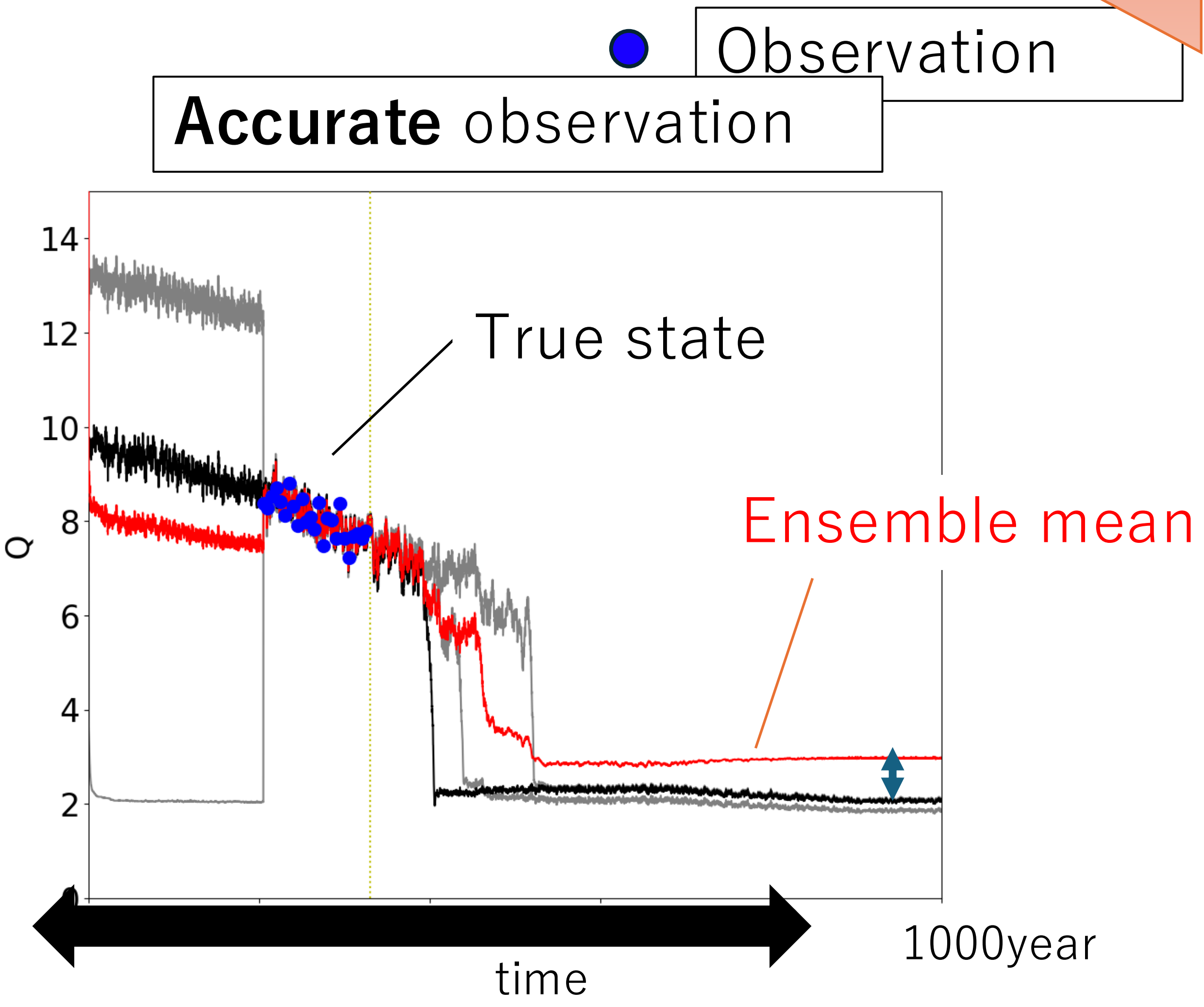


Forcing variability is noise and prediction of such random change is difficult

Potential to increase the predictability because we can see the response which is not observed w/o forcing variability.

Data assimilation improves the model prediction



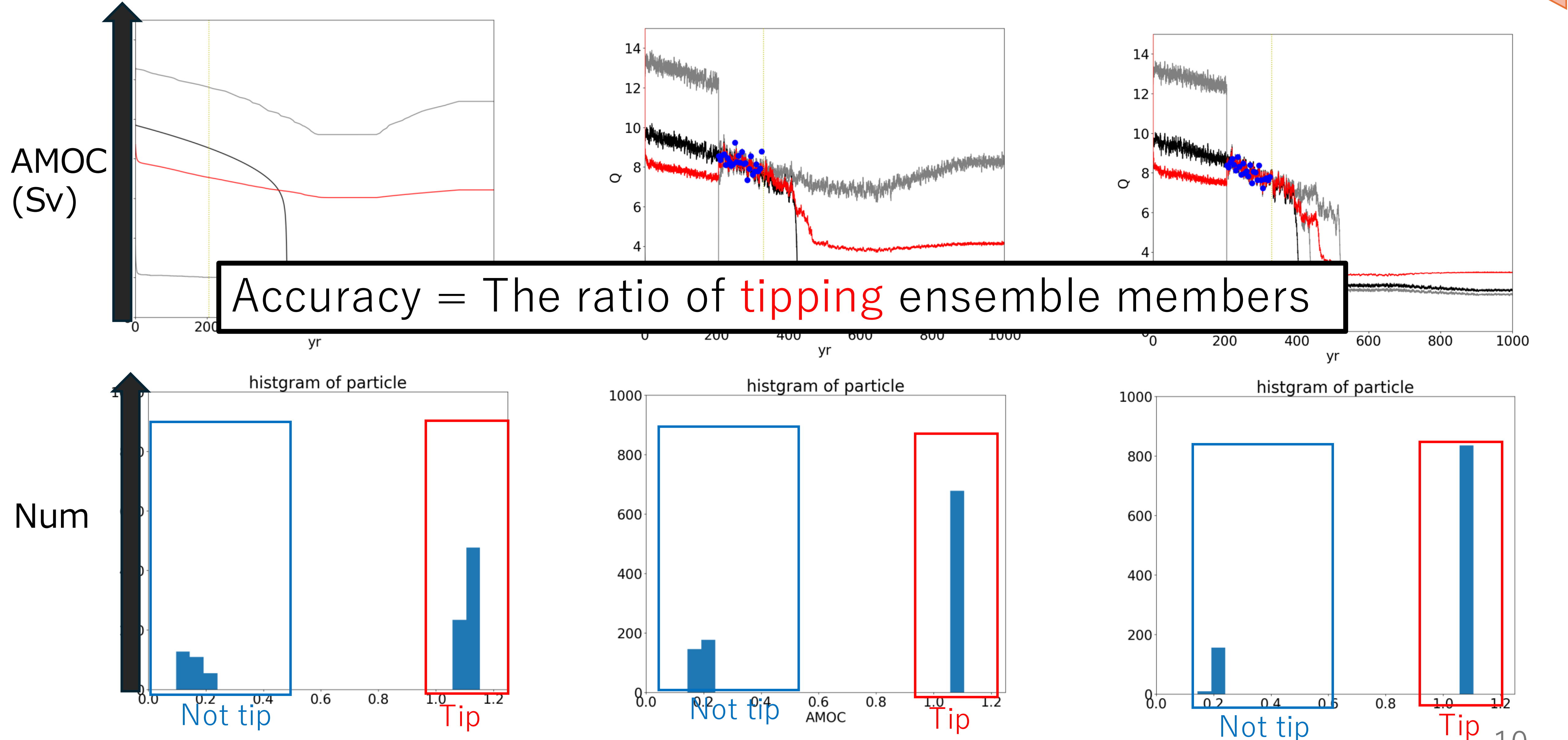


Not accurately predict tipping

Accurately predict tipping

Metric of prediction accuracy

Result



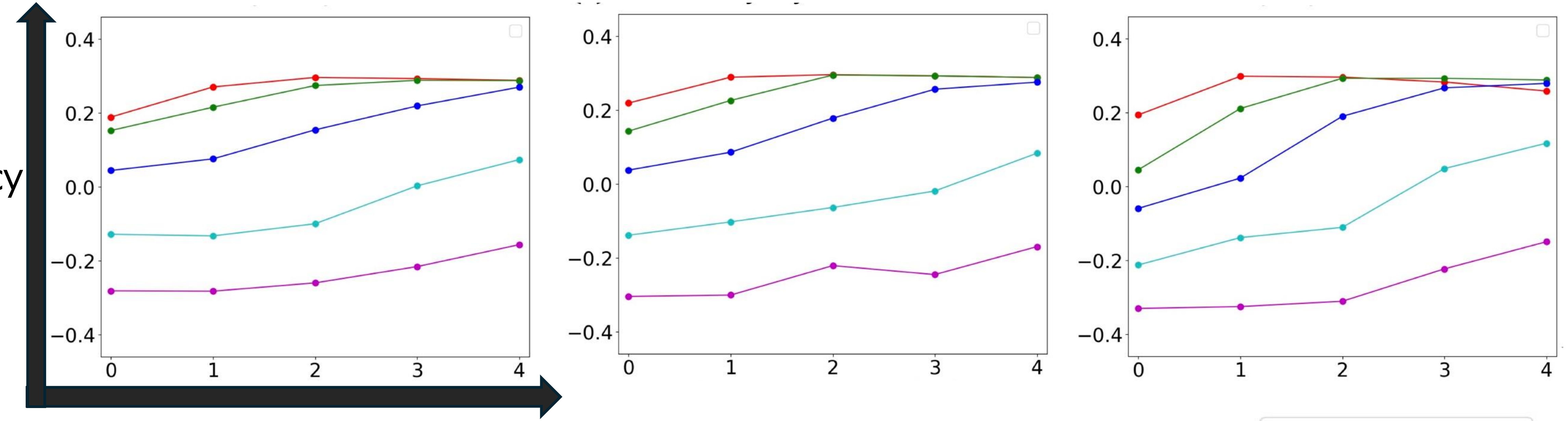
The last states of the tipping ensemble members are always similar.

Less accurate obs is effective with large forcing variability

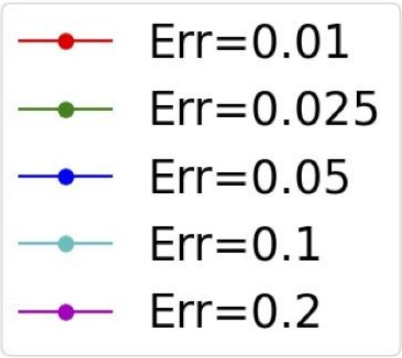
Frequency

1/ 2.5 (/years) 1/ 2 (/years) 1/ 1 (/years)

ΔAccuracy



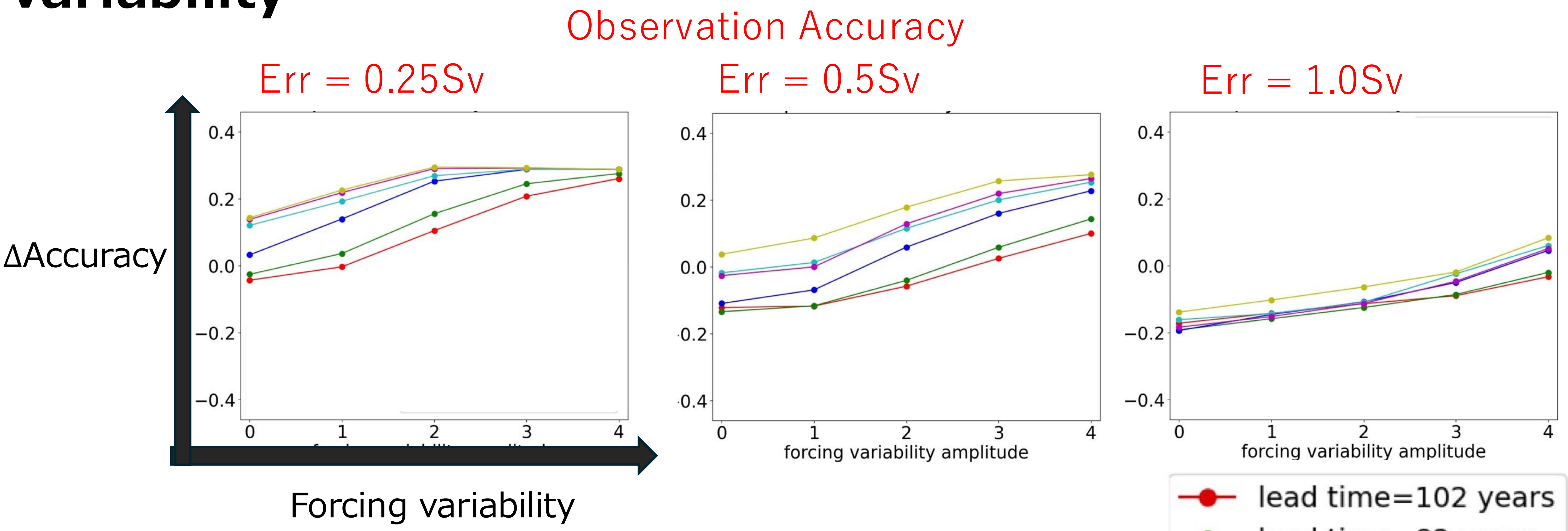
Forcing variability

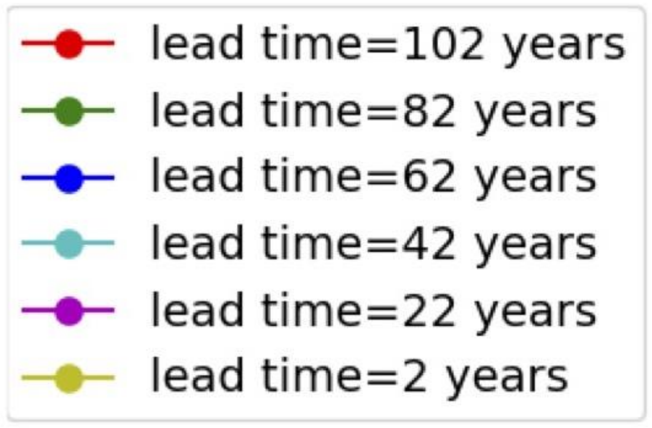


ΔAccuracy = Accueracy with obs – Accuracy without obs

Even with inaccurate observation, if **with large forcing variability**, possible to improve accuracy predict tipping.

Longer lead time is realized with larger internal variability

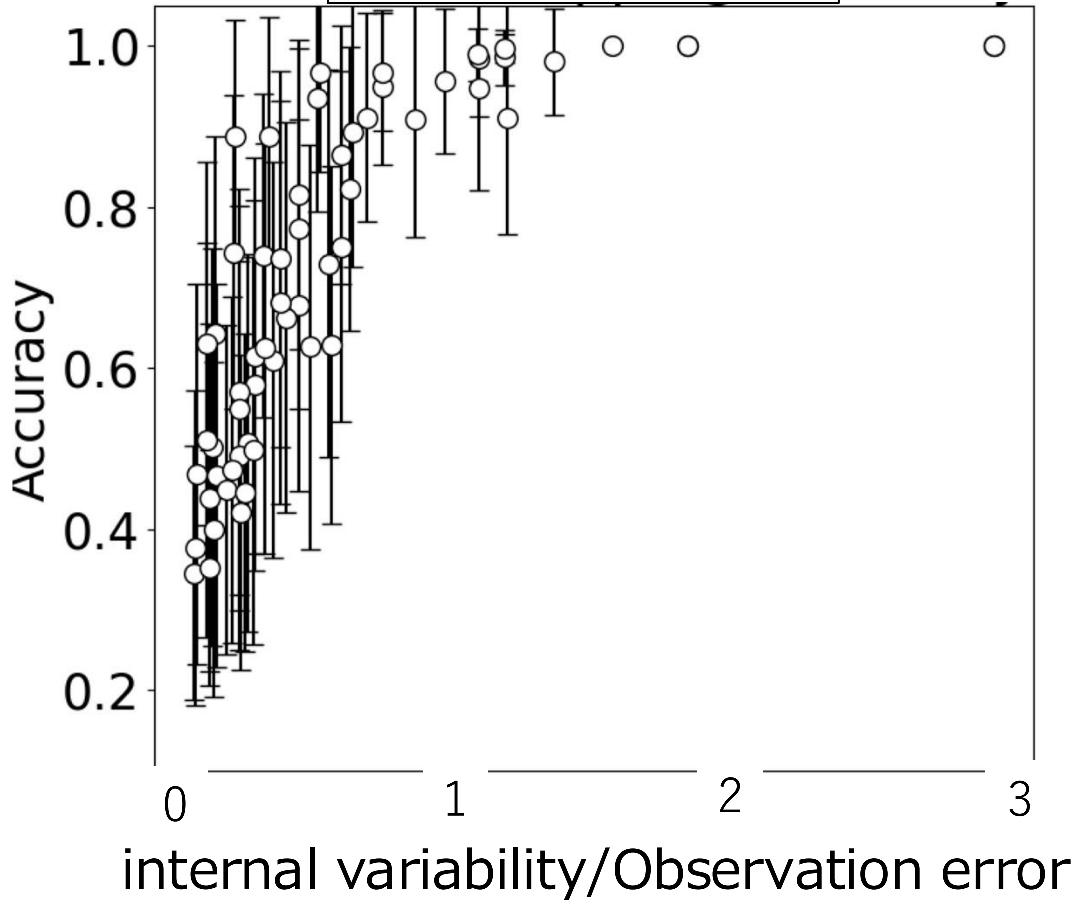




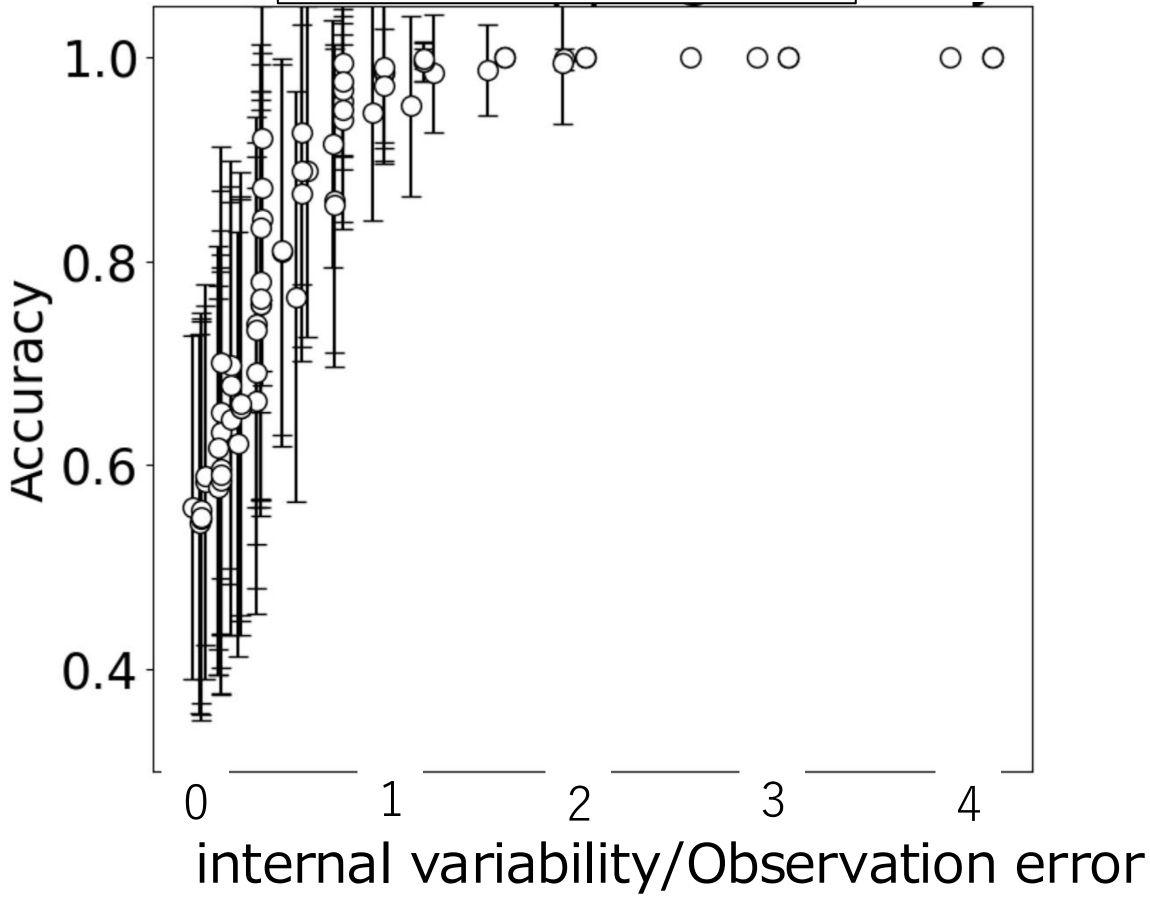
The larger forcing variability the system has,
the earlier it enables to accurately predict tipping

High internal variability/Observation error is important

Amazon



AMOC



The higher internal variability/Observation error is, the **more accurate** prediction of climate tipping is realized

Summary

- **We first discuss the predictability of Climate tipping**
- **Direct observation** of climate tipping is **not always necessary** if you have accurate model to describe climate tipping
- Observation which **resolves internal variability** is important
- Of course there is huge limitation of this study because we use just two simple conceptual models with finite settings.

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