【Grant-in-Aid for Transformative Research Areas（B）】

Exploring the Predictive Limits of Climate Tipping Points through the Synergy of Earth and Mathematical Sciences

Principal Investigator	The University of Tokyo, Graduate School of Engineering, Associate Professor SAWADA Yohei　Researcher Number : 30784475
Project Information	Project Number : 26B201　Project Period (FY) : 2026-2028 Keywords : Climate tipping, Uncertainty Quantification, Predictability, Early warning signals

Purpose and Background of the Research

●Outline of the Research

As human-caused climate change progresses, sudden and irreversible changes in the Earth's climate are becoming a major concern. These changes are called climate tipping. Examples include the shutdown of the Atlantic Meridional Overturning Circulation, the large-scale collapse of the Antarctic ice sheet, and the large-scale dieback of the Amazon rainforest. Once such a tipping point is crossed, the climate system may not quickly return to its former state, even if the Earth is later cooled. Its effects on human civilization could therefore be very large and last for a very long time. Predicting climate tipping points is important, but many different simulation results currently exist, making quantitative discussion difficult. We aim to move this field beyond the question of whether tipping points exist, and toward the question of how well they can be predicted.

In this study, we will combine climate models that include current physical knowledge and its uncertainty with real-world observation data. Using Bayesian estimation, as shown in Figure 1, we will assess the predictability of climate tipping points. This will help identify when and where observations are most useful for prediction.

To address this challenge, our project brings together three fields: paleoclimatology, which studies past climate changes; weather prediction research, which develops forecasting methods; and applied mathematics, which analyzes complex systems using data. Through this new collaborative approach, we aim to tackle an unexplored problem that is important for the long-term sustainability of human society.

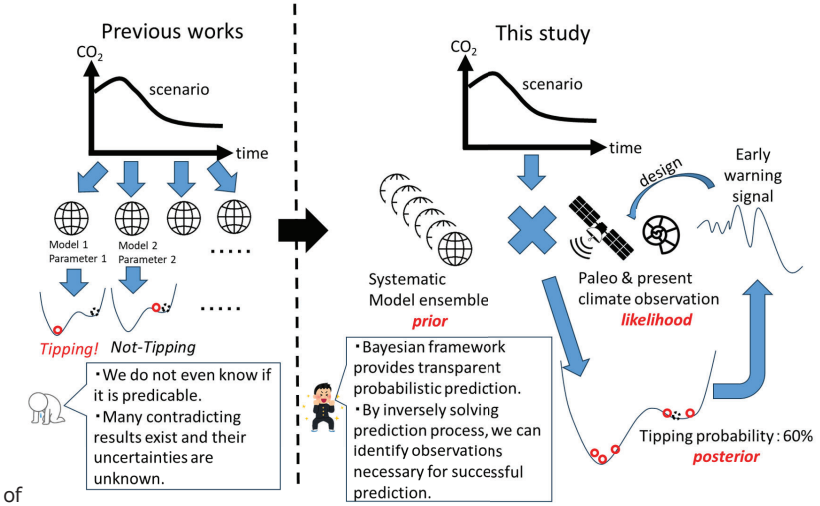

Figure 1. Overview of this study

Expected Research Achievements

●Goals of the Research Area

・Enabling to combine climate models, or Earth System Models (ESMs), that reflect physical knowledge and its uncertainty with observation data and to estimate the predictability of climate tipping within a Bayesian framework.

・Understanding early warning signals of climate tipping, and quantifying when, where, and with what level of accuracy observations are useful for predicting climate tipping.

●Goals of 3 research projects (Figure 2)

・Research A01-1 (Okazaki Group)

This group will use paleoclimate records of past climate tipping events, such as the weakening or shutdown of the Atlantic Meridional Overturning Circulation during the Younger Dryas and the 8.2 ka event. By using these records to constrain climate model parameters, the group will make it possible to quantify the predictability of climate tipping.

・Research A01-2 (Sawada Group)

This group will use dense and high-accuracy observations of year-to-year changes in the modern climate, or internal variability, over the past half century since the start of satellite observations. By using these data to constrain climate model parameters, the group will quantify the predictability of climate tipping.

・Research B01-3 (Hirata Group)

This group will use ensemble forecasts, which are sets of many forecast time series that reflect uncertainty in model predictions, to develop early warning signals for the possible emergence of climate tipping. These signals will be used for prediction. At the same time, by interpreting the signals, the group will provide a physical understanding of early signals of climate tipping and expand the limits of climate tipping point prediction by the Okazaki and Sawada Groups.

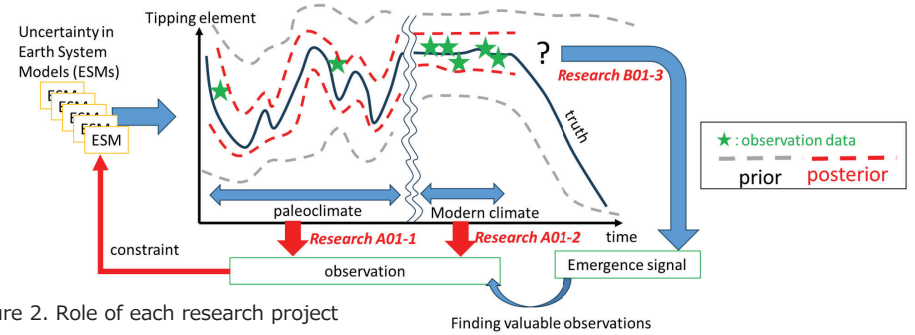

Figure 2. Role of each research project

●Wider Impact of the Research Area

The final goal of this research is to include risk assessments of climate tipping points, based on our findings, in international climate change risk assessments such as the assessment reports of the Intergovernmental Panel on Climate Change (IPCC). At present, the reliability of predictions about climate tipping points is still unclear. For this reason, they are not fully considered in international risk assessments used by policymakers. We aim to change this situation.

Once the method is established by this work, we will be exploring the international joint research to carry out integrated analyses using many different climate models developed around the world.

Website(s)	https://sites.google.com/g.ecc.u-tokyo.ac.jp/climate-tipping-prediction/home