【Grant-in-Aid for Scientific Research (S)】

Climate instability and tipping cascade: examining the climate risks posed by global warming

Principal Investigator	Hokkaido University, Institute of Low Temperature Science, Associate Professor SEKI Osamu　　Researcher Number : 30374648
Project Information	Project Number : 24H00074　　Project Period (FY) : 2024-2028 Keywords : climate instability, tipping cascade, global warming, past warm period

Purpose and Background of the Research

●Outline of the Research

Global warming is one of the serious issues faced by humans. Especially, climate instability is a significant climate risk, which threatens to have serious impacts on human society. Moreover, there is another concern of a global chain reaction of tipping elements known as a “tipping cascade”. However, it is uncertain whether these phenomena can really occur in the future due to global warming. This study addresses the crucial question regarding future climate risk "Will a +1.5 to +2°C warming (the Paris climate target range) in the future pose climate instability and even a tipping cascade?" based on a warm climate data-driven approach. We will generate high temporal resolution paleoclimate data sets in past warm periods, that are considered future climate analogues, in difference parts of the world to evaluate whether such climate events could occur by the global warming.

●Background of this study

In recent years, climate instability has emerged as a potential threat posed by global warming. Human civilization is highly vulnerable to climate instability, and climate stability depends on climate conditions. There has also been a growing concern about the occurrence of a "tipping cascade" due to global warming. This is a chain reaction in which when a climate subsystem crosses a tipping point, it triggers a chain of tipping points in other subsystems, causing serious risk on different parts of the world. However, it is not clear whether such climate crises could happen in warm climate condition.

●Aim of this study

To generate climate records around the world during past warm periods (MIS5e and MIS11c) to better understand the nature of climate variability under a warm climate condition.
To examine the possibility of climate instability and tipping cascades under a warmer climate (+1.5 or +2°C: the Paris climate target range).

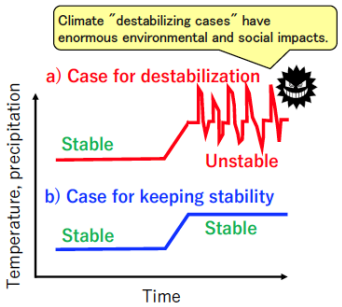


Figure 1. Cases of a) destabilizing climate and b) keeping climate stable, due to global warming. In the case of climate destabilization, its impact on human society is expected to be more severe.

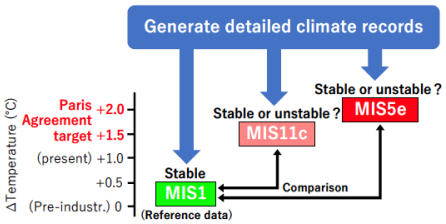


Figure 2. Strategy for the analysis of paleoclimate data in this study.

●Originality of this study

Earth’s climate is nonlinear dynamical system. Climate instability and tipping cascade are typical examples of nonlinear processes. In addition, the behavior of the climate system is dependent on climate state. Therefore, it is difficult to predict nonlinear climate change in a future warm climate condition based solely on the conventional approach. Past warm periods could be often considered as "natural warming experiment" that provide "observational constraints" on projections of future impacts. This study addresses the key questions based on a "warm climate data-driven" approach.

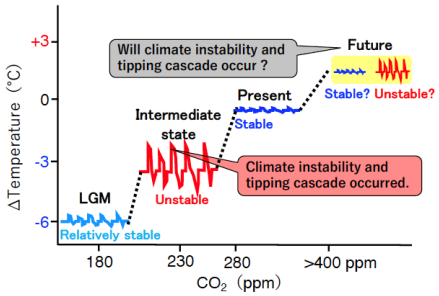


Figure 3. Relationship between climatic state and climate stability. Paleoclimate records have showed that climate stability depends on and varies with climate state.

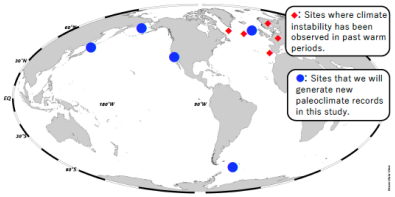
Expected Research Achievements

●Climate instability under the future warm climate

We apply three reliable temperature proxies to sediment cores collected in the mid and high latitudes of the Northern Hemisphere to generate time series records of surface ocean temperatures during the three interglacial periods (MIS1, MIS5e, and MIS11c). We then elucidate the nature of climate variability in each region during MIS1, MIS5e (+1°C) and MIS11c (+2°C). Then, we will examine the extent of the widespread occurrence of climate instability, which potentially threats to human society.

● Climate subsystem interaction under the future warm climate

The interaction between climate subsystems is examined by comparing the records of the Greenland ice sheet and Antarctic ice sheet with the AMOC record. Similarly, we will compare the AMOC variability with the pattern of variability in the North Pacific climate record to consider whether there is a linkage between the two and the extent to which linkages and interactions could have occurred under a warmer climate. Finally, all data will be synthesized to assess the likelihood, frequency, and magnitude of interactions between climate subsystems under +1°C and +2°C warmer than the present climates.



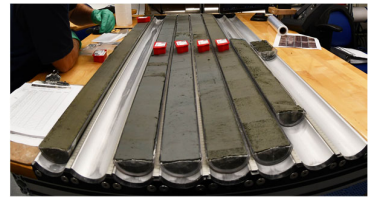


Figure 4. Locations and picture of sediment cores used in this study.

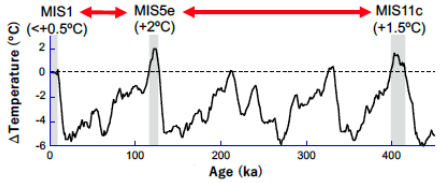


Figure 5. Global average Δtemperature over the past 450 kyrs (Friedrich et al., 2016).

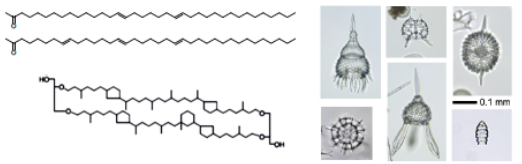


Figure 6. Paleotemperature proxies applied to this study.

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