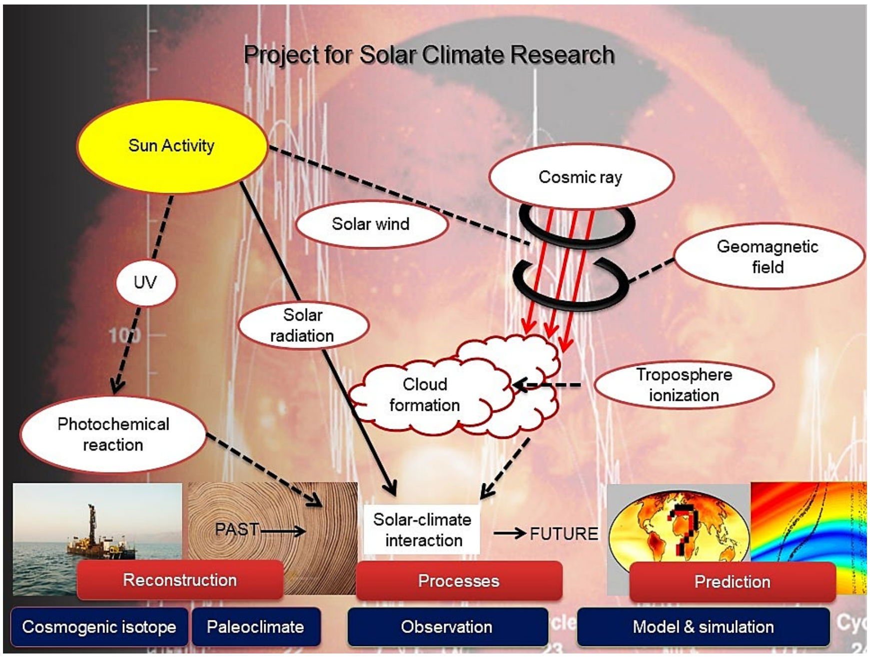
Project for Solar–Terrestrial Climate Research

Do variations in solar activity influence weather and climate? Researchers specializing in astronomy, solar physics, meteorology, climatology, paleoclimatology, and oceanography have addressed this question for the past 200 years or more. Two thousand years ago, astronomers of the Chinese Imperial Court chronicled sunspot activity to explore variations in solar activity. In 1801, British astronomer William Herschel discovered a significant correlation between the number of sunspots and the market value of wheat in London and reported his findings in a paper published by the Royal Society. He concluded that a reduction in the number of sunspots affected a change in climate that altered wheat yields, and influenced the price of wheat. This study is considered the first attempt to examine correlations among the Sun, climate, and society (human life). Even now, correctly identifying the characteristic variations of solar activity and investigating their effects on climate change and modern society remain important research topics in academia and society.

There is much evidence indicating that at least the Atlantic Ocean and surrounding areas, including Europe and North America, experienced significantly colder temperatures during the Maunder Minimum (70 years from 1645 to 1715) in which very few sunspots were observed, and solar activity appeared nearly stagnant. Historical records show that New York Harbor froze in the winter of 1780, enabling people to walk from Manhattan to Staten Island, and that sea ice surrounding Iceland extended for miles, closing the harbors and dealing a blow to the fishing industry and trade over a long period. While it is premature to conclude that the quietening of solar activity leads to a cooling period, many researchers believe that variations in solar activity influence medium- to long-term climate changes. However, to obtain conclusive evidence, it is necessary to reconstruct climate changes quantitatively and continue accumulating data on annual variations in solar activity.

Very few sunspots were observed from March 7 to March 20, 2017. The cycle length of the solar magnetic activity corresponding to the sunspot cycle was estimated to be approximately 14 years during the Maunder Minimum. The sunspot cycle in solar cycle 24, which began in 2008, has grown to approximately 13 years, similar to that during the Maunder Minimum. Therefore, we are entering a period of low solar activity, where cooling on a global scale could occur in the near future. To offer a qualified opinion on the likelihood of this prediction, we must examine diverse viewpoints on how solar activity affects climate.



A scheme of the ISEE project for Solar–Terrestrial Climate Research. The latest developments in solar physics, meteorology and climatology, environmental studies, paleoclimatology, geomagnetism, and cosmic ray physics are integrated.

The globally averaged surface temperature showed a clear upward trend after the latter half of the 20th century. However, it continued to increase in the temperature range of 0.03–0.05°C per10 years from 1998 to 2012, and the global warming pause or the global warming slowdown is called the “global warming hiatus.” Nonetheless, the atmospheric greenhouse gas concentration increases yearly; however, a clear rise is not recognized in the surface temperature observation. The topic “global warming hiatus” was taken up by the internet news and blogs, moved over the scientific community, and then had a considerable impact on the public. Based on a detailed analysis of the meteorological dataset from the land and ocean temperatures and computer experiments with climate models, the global warming hiatus was caused by natural characteristics. Although we still cannot provide sufficient explanation, the decadal-centurial-time scale climate change is indirectly driven by secular variation in solar activity. Encouraging the understanding of the characteristics and mechanisms of short-term natural fluctuations appearing in the age of global warming will predict anthropogenic climate change more reliable. It is extremely important to develop an environmental policy that influences human society.

Radiocarbon (^{14}C) and Beryllium-10 (^{10}Be), known as cosmogenic isotopes, are produced at a rate that varies based on the intensity of the incoming CRs to Earth, which in turn are influenced by solar activity. Analyzing ^{14}C in tree rings and ^{10}Be in ice cores are effective methods for studying the long-term variations in solar activity going back tens of thousands of years. Analyses of ^{14}C and ^{10}Be suggest that episodes of declining solar activity resembling the Maunder Minimum have occurred repeatedly 12 times throughout the Holocene, which spans the past ten thousand years. Comparing cosmogenic isotopes with paleoclimate data can improve the understanding of solar-driven climate change over a long-time scale.

We have accumulated evidence over the past quarter century that will be effective in studying the mechanisms by which variations in solar activity affect climate and human society. The interdisciplinary project for Solar–Terrestrial Climate Research at ISEE integrates the latest knowledge in solar physics, meteorology, climatology, environmental studies, paleoclimatology, space physics, and CR physics to better understand the variability in solar activity, foster an understanding of solar-driven Earth systems, and contribute to predicting future global environments.

Main Activities in FY2020

To reveal the details of the secular change of ^{14}C content that fluctuates with the CR intensity affected by solar activity, it is necessary to improve the accuracy (e.g., ± 0.2% level) and throughput of the accelerator mass spectrometry. The maintenance of the Tandetron ^{14}C measurement system of High Voltage Engineering of the Netherlands, which is operated by the ISEE, Nagoya University, has been performed. With the maximum performance of this system, it is possible to perform high-precision ^{14}C measurements of more than 3000 samples per year. In addition, the sample preparation efficiency was improved. We designed and developed an automatic sample preparation system for graphite preparation and improved the efficiency of separating cellulose from wood samples to undertake ^{14}C measurements of a huge number of samples.

Tandetron accelerator mass spectrometer (ISEE, Nagoya Univ.).

In 2020, the IntCal20 dataset was reported to contain annual resolution ^{14}C data for the last 5000 years (starting in 1950 AD). While improving the accuracy of these data, we plan to reveal the details of secular ^{14}C changes.