9-3. Interdisciplinary Researches
Project for Solar–Terrestrial Climate Research

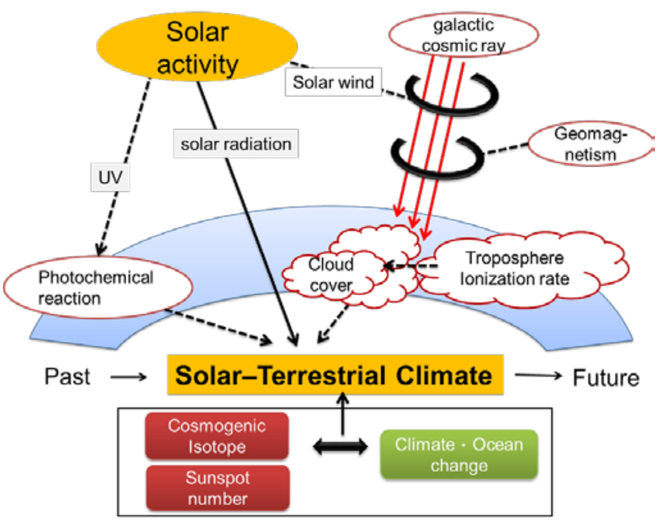
Introduction to Project for Solar–Terrestrial Climate Research

Do variations in solar activity influence our weather and climate? Researchers specializing in such fields as astronomy, solar physics, meteorology, climatology, paleoclimatology, and oceanography have grappled with this question for the past two hundred years or more. Two thousand years ago, astronomers of the Chinese imperial court chronicled sunspot activity for the purpose of studying variations in solar activity. In 1801 the British astronomer William Herschel discovered a significant correlation between the frequency of sunspot appearance and the market value of wheat in London and reported his findings in a paper published by the Royal Society. In the paper, he concluded that a reduction in the number of sunspots effected a change in climate that altered wheat yields and influenced the price of wheat as a result. This study is considered as the first attempt to examine correlations between 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 academics and society.

Solar activity varies over an 11-year cycle and is also known to exhibit variability in periods ranging from decades to thousands of years. Through observations using satellites, we know that solar irradiance varies about 0.1% over an approximate 11-year cycle of solar variability. Theoretical calculations indicate that a 0.1% increase in solar irradiance raises the global temperature only about 0.05°C on average. From the correlations between observed temperatures of seawater at the ocean surface and past solar activity indicators and climate change indicators, it is evident that, along with variations in solar activity over an approximate 11-year cycle, atmospheric temperature fluctuates at an amplitude about twice that estimated from theoretical values. More research will be needed to find a scientific explanation for this reality.

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 (a 70-year period 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 over 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 of time. While it is premature to conclude that a quieting of solar activity leads to a period of cooling, many researchers are of the opinion that variations in solar activity influence medium-to-long-term climate change. However, to obtain conclusive evidence it will be necessary to quantitatively reconstruct climate change and to continue accumulating data on annual variations in solar activity.

Radiocarbon (^{14}C) and Beryllium-10 (^{10}Be), known as cosmogenic isotopes, are produced at a rate that varies according to the intensity of incoming cosmic ray to Earth, which in turn are influenced by solar activity. Analyzing ^{14}C in tree rings and ^{10}Be in ice cores is an effective way to study long-term variations in solar activity going back tens of thousands of years. Such analyses of ^{14}C and ^{10}Be have suggested the possibility that episodes of declining solar activity resembling the Maunder Minimum may have occurred repeatedly a total of twelve times throughout the Holocene, which spans



Project scheme for Solar–Terrestrial Climate Research.

the past ten thousand years. Comparing cosmogenic isotopes against paleoclimate data could dramatically help us understand solar-driven climate change on a long-time scale.

Very few sunspots were observed in the period from March 7 to March 20, 2017. The cycle length of solar magnetic activity corresponding to the sunspot cycle is estimated at about 14 years during the Maunder Minimum. The projected sunspot cycle in Solar Cycle 24, which began in 2008, has grown to about 13 years, similar to the cycle length in the Maunder Minimum. This indicates that we may be entering a period of low solar activity, leading some to predict that cooling on a global scale could occur in the near future. In order to offer a qualified opinion on the likelihood of this prediction, we must examine diverse viewpoints on how solar activity affects climate.

We have accumulated evidence over the past quarter century that will be effective for 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 cosmic ray physics with the aim of better understanding variability in solar activity, fostering an understanding of solar-driven earth systems, and contributing to predictions of future global environments.

Main Achievements in FY2017

1. Solar activity around the Wolf minimum

We have advanced the scientific field of cosmic ray archeology to investigate the history of solar activity and cosmic ray intensity recorded in annual tree rings and an ice sheet core. We have obtained new insights into the cyclic nature of the Schwabe solar cycles, with approximately 11-year periodicity, and solar flare events in the past based on highly precise ^{14}C analyses of annual tree rings. In this academic year, we have worked intensively on the ^{14}C measurement of annual rings in the interval from the 2nd to the 14th century of the Japanese cedar from Yaku Island (*Yaku sugi*). The periodicity of the Schwabe solar cycles became longer during the Wolf sola minimum (AD 1280–1350) and an abrupt increase in ^{14}C was probably associated with a solar flare event in the 12th century.

2. New approach for improving sediment core chronology

We have developed a new approach to improve the chronology of sediment cores that record long climate change histories, to investigate climate change driven by medium and long-term solar changes. Through improved throughput in sediment analyses, we can decode high-resolution climate change records from long sediment cores; however, there is still no method for applying a reliable chronology to the records, which limits investigation of the influences of solar activity on climate change. A unique and effective method was developed to improve the ^{14}C based chronology of sediment records, with a particular focus on the optical characteristics of sediments. Application of the newly developed method will provide new insights into solar–terrestrial climate interactions on a variety of time scales.

3. Paleoclimate research network

To understand climate change in Asia in detail, the on-going research project “Changing climate and resident-environment in the migrations and expansions of Homo sapiens across the continent of Asia” (Scientific Research on Innovative Areas, Scientific Research on Innovative Areas, MEXT Grant-in-Aid Project FY2016–2020) has created the “*Paleoclimate research network*”, an international research network in cooperation with universities and research organizations in Israel, Oman, Pakistan, Vietnam and Mongolia. The network aims to enhance our understanding of climatic changes in the past, and human migration and adaptation to fluctuating climates in Asia.