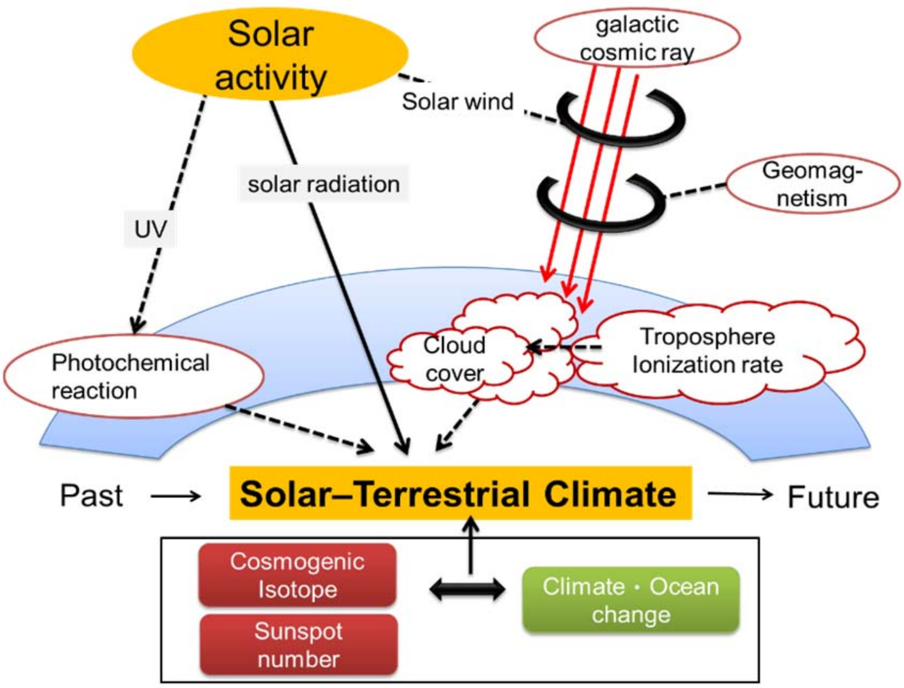
Project for Solar–Terrestrial Climate Research

Do variations in solar activity influence our weather and climate? Researchers specializing in fields such 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 exploring variations in solar activity. In 1801 the 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 as a result, influenced the price of wheat. This study is considered as 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 academics 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 (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 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 the quieting of solar activity leads to a period of cooling, 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 to 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 solar magnetic activity corresponding to the sunspot cycle was estimated at about 14 years during the Maunder Minimum. The sunspot cycle in Solar Cycle 24, which began in 2008, has grown to about 13 years, similar to that in the Maunder Minimum. This indicates that we are entering a period of low solar activity, where a cooling on a global scale can 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.

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 per ten 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, but a clear rise is not recognized in the observation of surface temperature. The topic “global warming hiatus” was taken up on the Internet news and blogs, went over the scientific community, and then had a huge impact on the



Project scheme for Solar–Terrestrial Climate Research.

general public. Based on a detailed analysis of the meteorological dataset from the land and ocean temperatures (e.g., HadCRUT3) and computer experiments with climate models such as MIRCO, it was indicated that the global warming hiatus was caused by natural characteristics. Although we still cannot provide sufficient explanation, it is evidenced that 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 that appear in the age of global warming will make the prediction of anthropogenic climate change more reliable. It is extremely important to draw up an environmental policy that stands on the influence on human society.

Radiocarbon (^{14}C) and Beryllium-10 (^{10}Be), known as cosmogenic isotopes, are produced at a rate that varies according to the intensity of the incoming cosmic rays 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 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 against paleoclimate data can improve the understanding of solar-driven climate change on a long time-scale.

We have accumulated evidences 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 cosmic ray physics with the aim of better understanding the variability in solar activity, fostering an understanding of solar-driven earth systems, and contributing to predictions of future global environments.

Main Activities in FY2018

ISEE International Collaborative Research Programs

In fiscal 2018, the international collaborative research on five issues related to the Interdisciplinary Research “Climate impact of solar activity” and general joint research on five subjects were conducted. In addition, 11 research meetings were held on various topics. New findings to understand the earth system driven by the sun were obtained by three and seven projects aiming at understanding the changes in climate and solar activity, respectively

Cosmic Ray Event in AD 993–994: Synchronicity in Northern and Southern Hemispheres

^{10}Be measurements at quasi-to-annual temporal resolution were conducted on the Dome Fuji ice core from Antarctica over the period in which the cosmic ray event in AD 994 would be expected. An approximately 50% increase in ^{10}Be concentration is consistent with that observed in the Greenland ice cores. Increases in ^{10}Be concentrations in both hemispheres support a solar origin of the AD 994 event.

Hydroclimatic changes in the Levant during the past 220000 years

The Dead Sea lake bottom sediments were collected by the Dead Sea Deep Drilling Program under the framework of the International Continental Scientific Drilling program. The sedimentary facies deposited during the past 220,000 years change synchronously with the solar radiation in the northern hemisphere’s midlatitude. It is new evidence that the hydroclimatic condition at the Dead Sea catchment area in the Levant can respond to specific circumstances in the North Atlantic and tropical zone which are partly affected by the solar radiation (Sun) changes.