National Aeronautics and Space Administration

TSIS-1

Tracking Sun's Power to Earth

FS-2017-11-136-GSFC

www.nasa.gov

TRACKING THE POWER SUPPLY TO **PLANET EARTH**

We live on a solar-powered planet. As we wake up in morning, the Sun peeks out over the horizon to shed light on us, blankets us with warmth, and provides cues to start our day. At the same time, the Sun's energy drives our planet's ocean currents, seasons, weather, and climate. Without the Sun, life on Earth would not exist.

NASA's Total and Spectral solar Irradiance Sensor, or TSIS-1, is a mission to measure the Sun's energy input to Earth. TSIS-1 will measure the total radiant energy that reaches Earth—known as the total solar irradiance (TSI). It will also monitor how that energy is distributed among ultraviolet, visible and infrared wavelengths, the solar spectral irradiance (SSI). Satellites have captured a continuous record of total solar irradiance since 1978 and have observed fluctuations in solar energy output on time scales ranging from minutes to several years.

One noticeable pattern occurs over a roughly eleven-year solar cycle that is associated with changes in the Sun's magnetic field. Over the course of this cycle, satellite observations show that total solar irradiance varies by about 0.1 percent.

The variation in irradiance over the last century is too small to explain the warming trend seen on Earth during this time, but it is possible that longer-term cycles or changes could have a more significant impact.

Trying to understand climate change without measuring the Sun is like trying to balance your checkbook without knowing your income.

The International Space Station carries TSIS-1. TSIS-1 operates like a sunflower: it follows the Sun, from the ISS sunrise to its sunset, which happens every 90 minutes. At sunset, it rewinds, recalibrates and waits for the next sunset.

Q&A

Who built TSIS-1?

NASA's Goddard Space Flight Center has overall responsibility for the development and operation of TSIS-1. Under contract with NASA, the Laboratory for Atmospheric and Space Physics at the University of Colorado Boulder, built TSIS-1 and gathers the science data. The Goddard Earth Science Data and Information Services Center distributes the data to the scientific community.

How long is the TSIS-1 mission?

The instrument is designed to last for 5 years.

What are the science goals of the mission?

Monitor the radiant energy from the Sun and how that energy is distributed over many wavelengths. TSIS-1 will provide the most accurate measurements of sunlight and continue the long-term climate data record.

How big is TSIS-1?

TSIS-1 fits within a 4-foot cube on launch but transforms to almost twice that size on orbit. The expanded dimensions are 4-feet tall by 4 feet wide by 8 feet long – about the size of a large refrigerator or full-grown buffalo.

When will scientists be able to use the data from TSIS-1?

Science data will be available approximately 6 months after TSIS-1 is turned on.

What is a solar cycle and how long does it last?

The Sun's activity rises and falls on a cycle lasting about 11 years – though cycles have been recorded as short as 9 years and as long as 14 years. Each 11-year activity cycle is one half of a 22-year solar magnetic cycle, throughout which the Sun's magnetic field gradually switches direction, then back again.

The solar cycle is primarily tracked through sunspots, which correspond roughly with the Sun's activity. When the Sun is most active within a cycle, this is called solar maximum, and the period of least solar activity is called solar minimum.

What are Sunspots?

A sunspot is a region on the Sun with a very concentrated, complicated magnetic field. Sunspots are slightly cooler than the surrounding areas, so they appear as dark patches in visible light. Sunspots form and dissipate over periods of days or weeks. Groups of sunspots are often linked to solar flares because of their complex magnetic field configurations, prone to huge releases of magnetic energy in the form of flares.

Scientists have measured total solar irradiance from space since 1978. What have they learned from the TSI data record?

The Sun's total solar energy output is not constant: it fluctuates with the 11-year sunspot cycle. Darkening from sunspots and brightening from the accompanying hot regions that surround them – called faculae – affect TSI. During the peak of an 11-year sunspot cycle, the faculae's brightening overwhelms the sunspots' dimming, and TSI increases.

Changes in the Sun's energy input to Earth are just one of the influences on Earth's climate. The space-based TSI record shows that it has not changed enough to account for the increase in global average surface temperatures recorded over the period of observations.

How much does the brightness of the Sun change throughout the cycle?

It's a small amount. Total solar irradiance typically increases by about 0.1 percent during periods of high activity. However, certain wavelengths of sunlight—such as ultraviolet—vary more.

Is the Sun the cause of the global warming observed during the last century?

No. Scientists have studied the links between solar activity and climate and say the small variations in the Sun's irradiance over the last century – estimated to be about the same magnitude of a typical solar cycle variation – cannot explain the intensity and speed of warming trends seen on Earth over this time.

FOUR DECADES AND COUNTING
TSIS-1 MEASURES SUNSHINE ON EARTH

For the past 40 years, NASA has measured how much the Sun's energy reaches and powers Earth and found that the Sun's output energy is not constant. About every 11 years, our Sun goes through a period where scientists observed a peak in intense solar activity - including explosions of light and solar material – called solar maximum. During solar minimum, the Sun has fewer sunspots – dark areas that are often the source of increased solar activity – and stops producing as many explosions. Over the course of one solar cycle, the Sun's emitted energy varies by about 0.1 percent. That may not sound like a lot, but the Sun emits a large amount of energy – 1,361 watts per square meter. Even fluctuations at just a tenth of a percent can affect Earth.

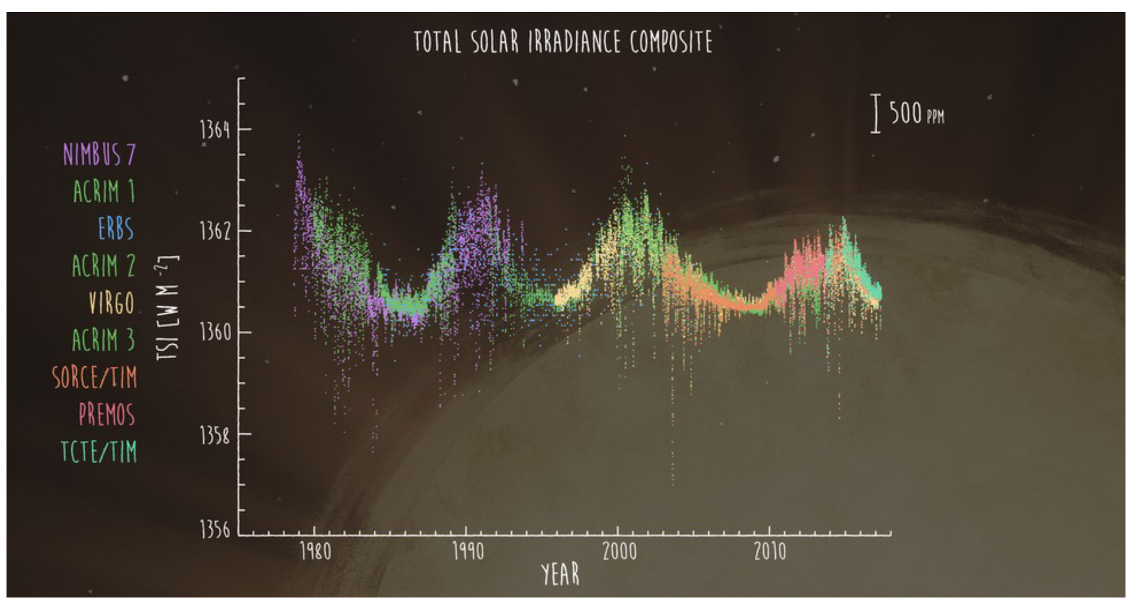
In addition to those 11-year changes, entire solar cycles can vary from decade to decade. Scientists have observed unusually quiet magnetic activity from the Sun for the past two decades with previous satellites. The latest solar maximum, during 2011-2014, was the weakest it has been in more than 100 years. During the last prolonged solar minimum in 2008-2009, our Sun was the calmest it has been since 1978. Scientists expect the Sun to enter a solar minimum within the next three years, and TSIS-1 will be primed to take measurements.

TSIS-1 data are particularly important for helping scientists understand the causes of total solar irradiance fluctuations and how they are connected with the Sun's behavior over decades or centuries. Today, scientists have neither enough data nor the forecasting skill to predict whether total solar irradiance has any long-term trend. TSIS-1 will continue a data sequence that is vital to answering that question.

"We don't know what the next solar cycle is going to bring, but we've had a couple of solar cycles that have been weaker than we've had in quite a while so who knows. It's a pretty exciting time to be studying the Sun."

Dong Wu, TSIS-1 project scientist,
NASA Goddard Space Flight Center, Greenbelt, Maryland

These data are also important for understanding Earth's climate through models. Scientists use computer models to interpret changes in the Sun's energy input. If less solar energy is available, scientists can gauge how that will affect Earth's atmosphere, oceans, weather and seasons. The input from the Sun is just one of many factors scientists used to model Earth's climate. Knowing the Sun's energy input helps to quantify the impact of other climate influences, including those caused by humans or other natural influences like volcanoes.



NASA TSIS-1 instrument will be the tenth space-based mission to measure the total amount of energy reaching the top of Earth's atmosphere. This chart includes the TSI results from the prior nine missions.

TSIS-1 INSTRUMENTS

TSIS-1 includes:

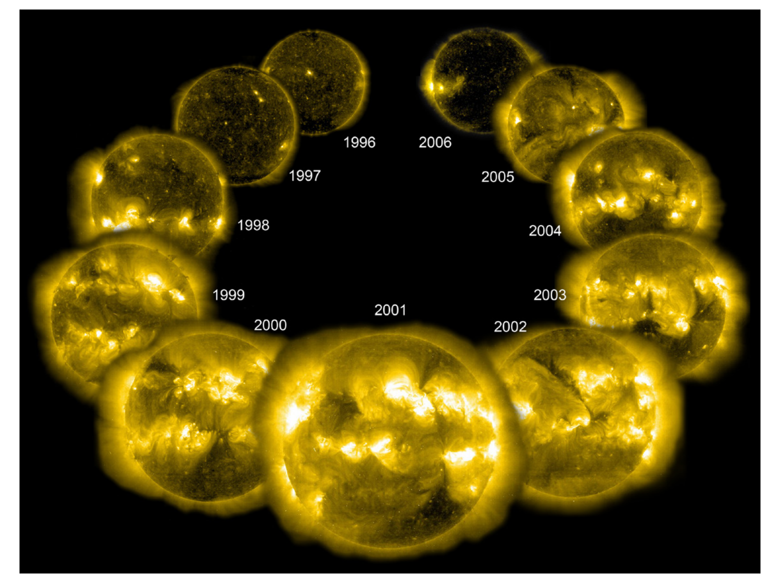
- **THE TOTAL IRRADIANCE MONITOR (TIM) INSTRUMENT:** Measures total solar irradiance (TSI) that is incident at the outer boundaries of the atmosphere.
- **THE SPECTRAL IRRADIANCE MONITOR (SIM) INSTRUMENT:** Measures solar spectral irradiance (SSI) from 200 nanometers to 2400 nanometers (96 percent of the TSI).
- Precision solar pointing of the TIM and SIM instruments.

Solar irradiance is one of the most fundamental climate data records acquired by space-based observatories. TSIS-1 is a dual-instrument package that will acquire solar irradiance measurements from the International Space Station for five years. It will provide critical data that will help determine the natural forcings of the climate system and will ensure the continuity of the solar irradiance Climate Data Record.

The TIM and SIM instruments have design heritage to those currently flying on the Solar Radiation and Climate Experiment (SORCE) satellite, which launched in 2003 and is now well beyond its six year prime-mission lifetime. TSIS-1 is required to continue the 38-year record of TSI, extend the newer 14-year record of SSI, and to provide highly accurate, stable, and continuous observations that are critical to understanding the present climate epoch and for predicting future climate.

HOW DOES SOLAR ACTIVITY INFLUENCE SOLAR IRRADIANCE?

The Sun normally varies in approximately 11-year cycles between more and less activity. In times of greater activity, more Sunspots can be seen on the Sun's surface. These darker areas represent cooler regions on the Sun, but they are surrounded by bright areas called faculae. The brightness of the faculae overwhelms the Sunspots, so the Sun is brighter and produces more energy during times when there are more Sunspots. TSIS-1's sensors detect these changes in energy caused by Sunspots and faculae as well as by other causes.



During periods of peak activity (front three images) Sunspots, solar flare, and coronal mass ejections are more common, and the Sun emits slightly more energy than during periods of low activity (back images).

KEEPING AN EYE ON THE SUN'S POWER OVER OZONE

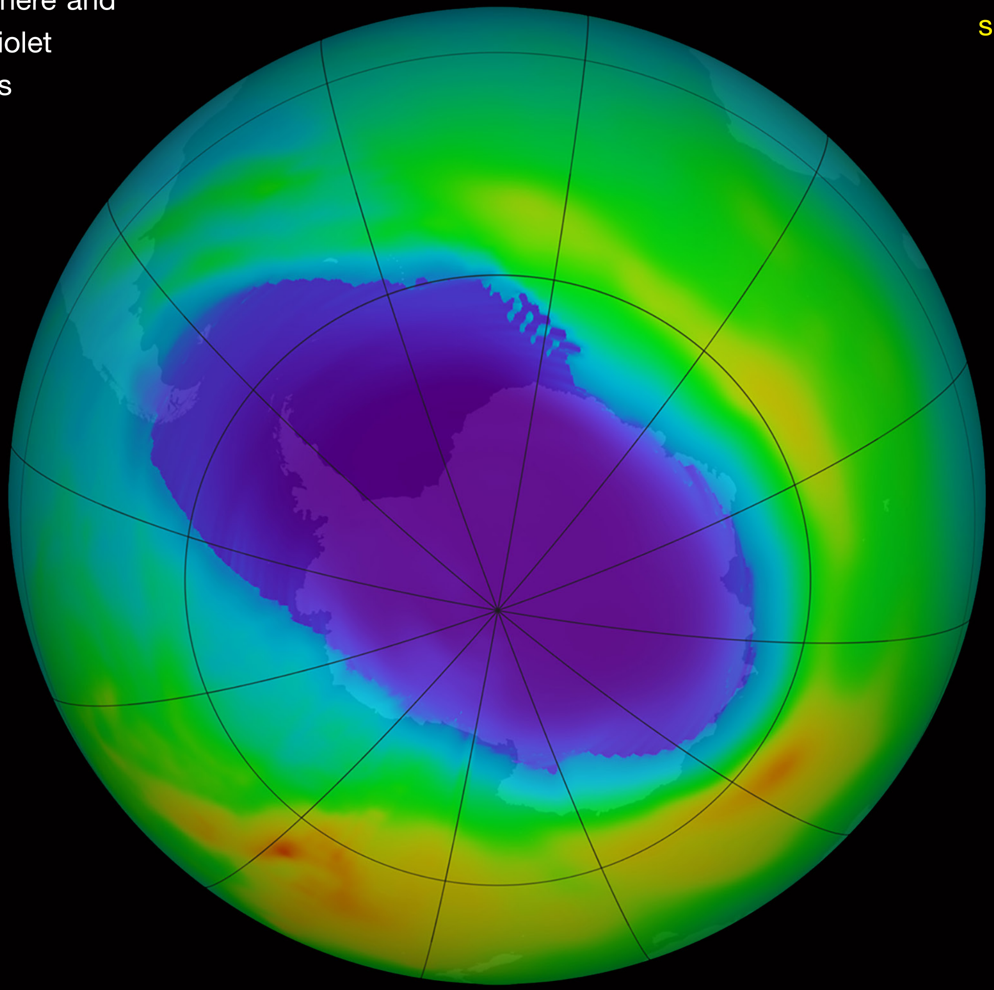
The ozone layer is Earth's natural sunscreen and protects life from harmful ultraviolet radiation. However, ozone is vulnerable to certain gases made by humans that reach the upper atmosphere. Once there, they react in the presence of sunlight and destroy ozone molecules. TSIS-1 measurements of the Sun's ultraviolet radiation help scientists understand the condition of this protective ozone layer.

Currently, NASA and several National Oceanic and Atmospheric Administration (NOAA) satellites track the amount of ozone in the upper atmosphere along with other partner organizations. TSIS-1 will measure how much sunlight reaches the top of Earth's atmosphere and how that light is distributed between different wavelengths, including ultraviolet wavelengths, as seen from above Earth's atmosphere. Ultraviolet radiation is particularly important component for evaluating the long-term effects of ozone-destroying chemistry.

TSIS-1 follows similar NASA missions that have also monitored solar irradiance, but it will do so with three times as much accuracy and lower interference from other sources of light. TSIS-1 will observe more than 1000 wavelength bands from 200 to 2400 nanometers. The part of the spectrum visible to human eyes goes from about 390 nanometers (blue) to 700 nanometers (red).

TSIS-1 will also see different types of ultraviolet (UV) light, including UV-B and UV-C. Each plays a different role in the ozone layer. UV-C rays are essential in creating ozone. UV-B, and some naturally occurring chemicals, regulate the abundance of ozone in the upper atmosphere. The amount of ozone is a balance between these natural production and loss processes. In the course of these processes, UV-C and UV-B rays are absorbed, preventing them from reaching Earth's surface and harming living organisms. Thinning of the ozone layer has allowed higher concentrations of UV-A and some UV-B rays to reach the ground.

As part of their work in monitoring the recovery of the ozone hole, scientists use computer models of the atmosphere that simulate the physical, chemical, and weather processes in the atmosphere. These atmospheric models can take input from ground and satellite observations of various atmospheric gases — both natural and human-produced — to help predict the pace of ozone layer recovery. Scientists test the models by simulating past changes and comparing the results with satellite measurements to see if the simulations match past outcomes. To run the best possible simulation, the models also need accurate measurements of sunlight across the spectrum. Scientists have learned that variations in UV radiance produce significant changes in the results of the computer simulations.



Antarctic Ozone Hole

Purple and blue represent areas of low ozone concentrations in the atmosphere; yellow and red are areas of higher concentrations. Carbon tetrachloride (CCl4), which was once used in applications such as dry cleaning and as a fire-extinguishing agent, was regulated in 1987 under the Montreal Protocol, along with other chlorofluorocarbons that destroy ozone and contribute to the ozone hole over Antarctica.

While UV light represents a tiny fraction of the total sunlight that reaches the top of Earth's atmosphere, it varies more, anywhere from 3 to 10 percent. That's enough to cause changes in the chemical composition and thermal structure of the upper atmosphere.

A HISTORY OF OZONE STUDY

In the 1970s, scientists theorized that certain human-made chemicals found in spray cans, air conditioners, and refrigerators could throw off the natural balance of ozone creation and depletion and cause an unnatural depletion of the protective ozone.

In the 1980s, they observed ozone loss consistent with the concentrations of these chemicals and confirmed this theory.

Ozone loss was far more severe than expected over the South Pole during the Antarctic spring (fall in the United States), a phenomenon that was named "the Antarctic ozone hole." The discovery that human-made chemicals could have such a large effect on Earth's atmosphere brought world leaders together. They created an international commitment to phase out ozone-depleting chemicals called the Montreal Protocol, which was universally ratified in 1987 by all countries that participate in the United Nations, and has been updated to tighten constraints and account for additional ozone depleting chemicals.

A decade after the ratification of the Montreal Protocol, the amount of human-made ozone-destroying chemicals in the atmosphere peaked and began a slow decline. However, it will take decades for these existing chemicals to completely cycle out of the upper atmosphere, and not all of the chemicals are decreasing as expected.

Over three decades after ratification, NASA satellites have verified that ozone losses have stabilized and, in some specific locations, have even begun to recover due to reductions in the ozone-destroying chemicals regulated under the Montreal Protocol.

That's where TSIS-1 comes in. Its high-quality measurements will allow scientists to fine tune their models and produce better simulations of the ozone layer's behavior – as well as other atmospheric processes influenced by sunlight, such as the movement of winds and weather.