New sunspot catalogue to improve space weather predictions

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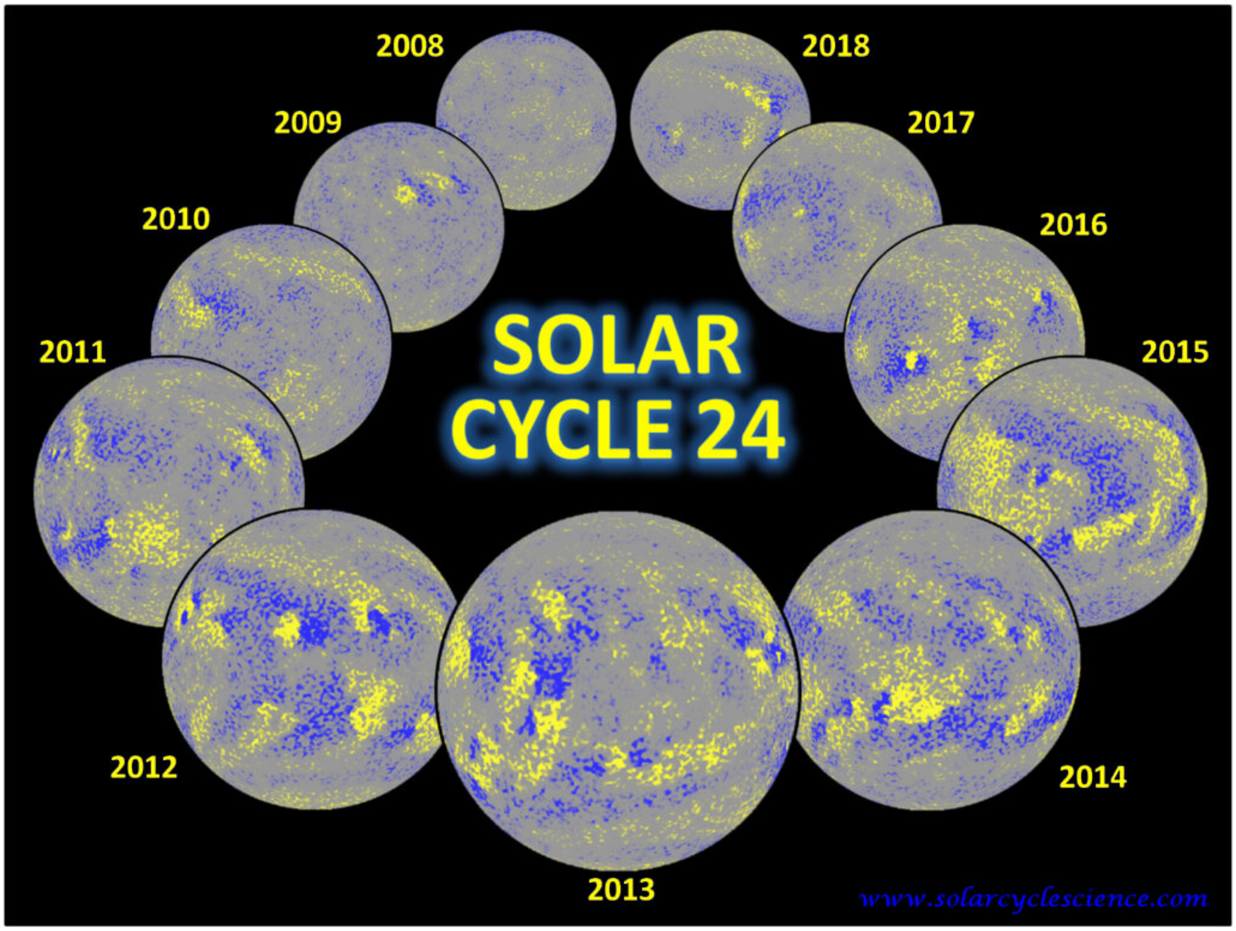

The image above shows the evolution of the Sun's magnetic field over the course of Solar Cycle 24. Blue and yellow represent the negative and the positive magnetic field, respectively. The field is weak and calm during the solar minimum, in 2008. It then grows increasingly active and strong, peaking during the solar maximum of 2014, before settling again into the next minimum. Credit: Solar Cycle Science/Lisa Upton

Scientists from the University of Graz, Kanzelhöhe Observatory, Skoltech, and the World Data Center SILSO at the Royal Observatory of Belgium, have presented the Catalog of Hemispheric sunspot Numbers. It will enable more accurate predictions of the solar cycle and space weather, which can affect human-made infrastructure both on Earth and in orbit. The study came out in the *Astronomy & Astrophysics* journal, and the catalog is available from SILSO—the World Data Center for the production, preservation, and dissemination of the international sunspot number.

Our sun is a big boiling ball of gas, most of which is so hot that electrons are ripped off from atoms, creating a circulating mix of charged particles, called plasma. These moving charges endow the sun with an enormous magnetic field, which bundles up as it rises from the solar interior and creates dark areas known as sunspots on the surface.

Sunspots are the primary sources of solar flares and coronal mass ejections, or CMEs. These are huge magnetic clouds of plasma released from the sun at great speeds. When directed toward the Earth, they cause powerful magnetic disturbances that can damage the equipment on satellites, incapacitate telecommunications, and even cause blackouts in a city—with devastating effects on the economy.

The appearance and disappearance of sunspots varies according to a roughly 11-year cycle. It begins with almost no sunspots. As it progresses, more and more spots emerge on the middle latitudes and migrate to the solar equator. Since the sun's equator rotates faster than the poles, its magnetic field becomes entangled and strengthened in bundles over the course of the cycle. Eventually, the field line bundles become strong enough to get pushed out through the photosphere as loops that trap and eject plasma as CMEs.

Monitoring sunspots is therefore crucial for predicting dangerous space weather events and their effects on air travelers, astronauts, and the equipment and infrastructure—both on Earth, in orbit, and on long-term space missions.

Initially observed by Galileo in the 17th century, sunspots are now monitored daily by about 80 observatories across the world. The World Data Center SILSO at the Royal Observatory of Belgium is the global hub for all sunspot data. Systematic data on the total count of sunspots is available starting from the 18th century. However, recent models suggest that solar activity is better understood as an interplay between the activities in the northern and the southern hemispheres considered separately. Such data is much more scarce, with the most important solar activity index—the International sunspot Number—only recording sunspot counts by hemisphere since 1992.

The authors of the recent study in *Astronomy & Astrophysics* came up with a method to greatly extend the available data by reconstructing historical hemispheric sunspot numbers. As a result, they released a continuous catalog of daily and monthly data of the northern and southern hemispheric sunspot numbers going back to 1874. The team showed its high correspondence to the existing hemispheric data and demonstrated that solar cycle predictions are indeed more accurate when the evolution of sunspot numbers is considered separately for the two hemispheres.

"Our sun is an intriguing star, and its physics is both simple and complicated. We have learned from our study that we can obtain a better understanding of the long-term evolution of the sun's activity by simply treating first the two hemispheres separately and only afterwards summing both contributions up to obtain the overall activity. The newly reconstructed data on hemispheric sunspot numbers will be available to the scientific community, and we believe they can provide an important basis to develop new, more accurate prediction schemes of solar activity," said Astrid Veronig, the lead author of the study, professor at the University of Graz, and head of the Kanzelhöhe Observatory for Solar and Environmental Research.

Skoltech graduate student and study co-author Shantanu Jain highlighted the practical utility of the new catalog: "We believe that this new catalog will be essential to accurately predict space weather since we now have continuous hemispheric data for a longer period to make meaningful solar cycle predictions. If we were to face extreme solar eruptions in today's age of technological dependency, it could easily knock out our power grids, satellite communications, the internet, and cause economic losses of up to trillions of dollars. An accurate prediction of space weather can help prepare ourselves and avoid such a scenario."

"For permanent technical infrastructures, for long-term issues like ozone depletion or climate, and in view of future long-duration manned space missions to the Moon or Mars, there is a growing need for mid- and long-term forecasts of the trend of solar activity over the next few months or years. As part of an emerging discipline called 'space climate," such long-term predictions of the strength of the solar cycle can only rest on a detailed knowledge of the actual evolution of many past solar cycles. Our new extended data series is one of the key steps in the growing efforts to revisit and fully exploit legacy data collections using the modern tools of the 21st century," study co-author and the head of the World Data Center SILSO Frédéric Clette commented.

"Currently, we still do not fully understand how the solar dynamo works and how the solar magnetic field is generated during the 11-year solar cycle. All the planets of our solar system orbit around the sun in a so-called ecliptic plane. It means that observatories on Earth or instruments on board any Earth-orbiting satellite which make images of the sun never really see what happens on the solar poles. However, in February

2020 a groundbreaking space mission—the Solar Orbiter—was launched to fly very close to the sun. It will perform gravitational maneuvers to reach out of the ecliptic and glimpse at the poles for the first time in history. The first polar pass is expected to take place in March 2025 with the spacecraft reaching an inclination of 17 degrees above the ecliptic plane and increasing to 33 degrees in July 2029. We think that the newly developed product of hemispheric sunspot numbers together with the unprecedented observations and fundamentally new knowledge from the Solar Orbiter will help us to advance solar cycle studies and space weather predictions. And whatever storms may rage, we wish everyone good weather in space," said Tatiana Podladchikova, a co-author of the paper and assistant professor at the Skoltech Space Center.

More information: A. M. Veronig et al, Hemispheric sunspot numbers 1874-2020, *Astronomy & Astrophysics* (2021). DOI: 10.1051/0004-6361/202141195

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