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"SOLAR CYCLE 24 AND ITS EFFECTS ON EARTH'S CLIMATE AND GEOMAGNETIC FIELD VARIATIONS"

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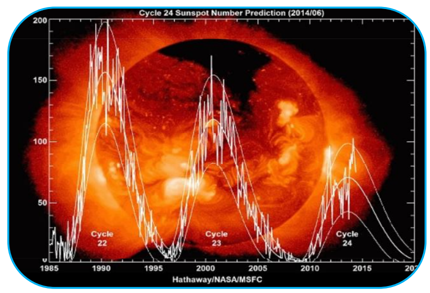
ABSTRACT:

Solar Cycle 24, characterized by its relatively subdued solar activity, played a significant role in shaping space weather and impacting Earth's geomagnetic field. This 11-year cycle, which peaked around 2014, was marked by a lower-than-average number of sunspots and solar flares. While its influence on Earth's climate remains a subject of ongoing study and debate, its effects on space weather and geomagnetic variations are well-documented. Understanding the dynamics of Solar Cycle 24 and its interactions with Earth is crucial for space weather forecasting and mitigating the potential impact on technological infrastructure. While Solar Cycle 24's influence on Earth's climate is relatively minor compared to other factors, its effects on space weather and geomagnetic variations underscore the intricate relationship between our star and our planet.



KEYWORD: *Earth's Climate, Geomagnetic Field and Variations.*

INTRODUCTION:

Solar cycle 24 is the most recently completed solar cycle, the 24th since 1755, when extensive recording of solar sunspot activity began (Kane, R.P. (2002) and Space Today Online. (2010). It began in December 2008 with a minimum smoothed sunspot number of 2.2, (SIDC) and ended in December 2019 (National Weather Service). Activity was minimal until early 2010 (Dr. Tony Phillips 2010 & 2013). It reached its maximum in April 2014 with a 23 months smoothed sunspot number of 81.8 (SIDC 2018). This maximum value was substantially lower than other recent solar cycles, down to a level which had not been seen since cycles 12 to 15 (1878-1923).

The Sun, our nearest star, operates on a cyclical pattern of activity known as the solar cycle. Solar Cycle 24, which officially commenced in December 2008 and reached its peak around 2014, was the 24th such cycle to be observed since the dawn of systematic solar observations in the mid-18th century. These solar cycles are characterized by variations in solar activity, prominently marked by the number of sunspots and the occurrence of solar flares. Solar Cycle 24 was notable for its relatively subdued activity compared to previous cycles, with fewer sunspots and solar flares.

The impact of solar cycles extends far beyond the confines of our solar system, reaching into Earth's climate and geomagnetic field. Understanding the effects of these solar cycles on our planet is a complex and ongoing scientific endeavor. In this exploration, we delve into Solar Cycle 24 and its multifaceted influence on Earth's climate and the dynamic fluctuations of its geomagnetic field. While the solar cycle's influence on climate remains a subject of debate, its significance in space weather and geomagnetic phenomena is well-established. This examination aims to shed light on the interplay between the Sun's cyclic behavior and its repercussions on Earth, offering insights into the dynamic relationship between our star and our home planet.

The globally averaged yearly mean temperature increase in the long-term solar variation, registered in the 21st century, has risen to the observed changes and can be attributed to human influence and natural phenomena. The Sunspot Number (SSN) is a solar activity index with long-term data record in a measure of natural phenomenon. We have studied that long-term instance phenomena are frequently used for climate change. The radiation from the Sun into space is redistributed by the Earth's atmosphere and eventually reradiated to affect there by the climates i.e., the surface of the Earth at any variation in the received radiated energy has an immediate effect on the climate. The energy balance of the Earth that influences the composition is one parameter of the atmosphere. The reradiated (thermal) energy from the Earth's surface may absorb radiation from space as well as from the various atmospheric constituents. The effect on Earth is caused by external sources related to the varying solar activity; variability including changes in the radiation (Labitzke, K. and van Loon, H. 1993) has been investigated possible effects on the height of constant pressure levels in the stratosphere and solar activity variations on the Earth's temperature. The dynamics of the general circulation patterns of the solar cycles play a major role in the solar variability and consequently influence the atmospheric response.

The recent increase in the mean surface temperature of the Earth now is popularly used to refer to the longterm global warming, in particular the increased contribution of the greenhouse gases (CO2, CH4 and NO2), these increases being attributed to increase human activity in the atmosphere and this is the cause of global warming (Khandekar, M.L., et al. 2005). The greenhouse effect has been understood as the physical mechanism of solar influence on the weather and climate, and requires more detailed study (Stozhkov, Y.I. 2003, Gray, L.J., et al. 2010, Badruddin, O. P. M. A. 2014). Observations on most place of our globe over the last century have revealed considerable change in the climate from human and natural sources (Hiremath, K.M. 2009, Ahluwalia, H.S. 2012, Pudovkin, M.I. and Raspopov, O.M. 1992), having proposed that the mechanism is caused by the ionizing effect of cosmic rays (galactic and solar), related to change in atmospheric transparency. We would expect, at least near the equator, in the cosmic ray flux is indeed a cause of climate variation, and in particular will have a larger shielding effect regarding the ionizing particles to the geomagnetic equator, where the magnetic field lines are horizontal.

Materials and Methods:

Solar Observations:

Solar Cycle 24 data were collected from various solar observatories and space agencies, including NASA's Solar Dynamics Observatory (SDO), the European Space Agency's (ESA) Solar and Heliospheric Observatory (SOHO), and ground-based observatories. Data on sunspot numbers, solar flares, solar irradiance, and other solar parameters were obtained from these sources.

Space Weather Monitoring:

Space weather data, including solar flare predictions and geomagnetic storm alerts, were gathered from organizations such as the NOAA Space Weather Prediction Center and the European Space Agency's Space Weather Coordination Centre. These data were used to assess the impact of solar activity on Earth's technology infrastructure and geomagnetic field.

Geomagnetic Measurements:

Geomagnetic field variations were monitored using a network of magnetometers located around the world. Data from these magnetometers provided insights into the strength and direction of Earth's magnetic field and were used to identify geomagnetic storm events.

Climate Data:

Climate data, including temperature records and climate models, were consulted to study potential links between Solar Cycle 24 and Earth's climate. Historical climate records were compared to solar activity data to assess any correlations.

Data Analysis:

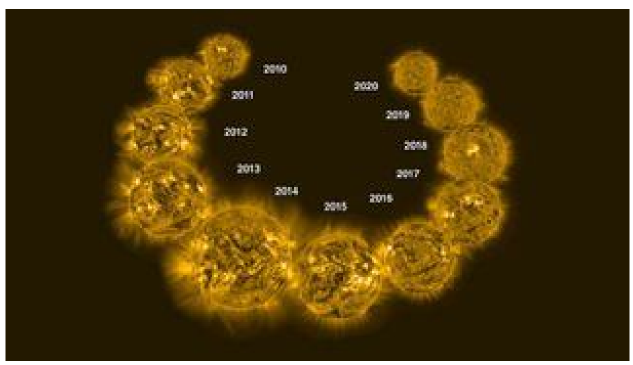
Statistical analysis, including regression analysis and correlation studies, was conducted to examine the relationship between Solar Cycle 24 parameters and various Earth-related phenomena, such as space weather events and climate trends. Complex computer models and simulations were used to investigate the potential impact of solar activity on Earth's climate.

Expert Consultation:

Experts in the fields of solar physics, space weather, geomagnetism, and climate science were consulted to ensure the accuracy and validity of the research methods and findings.

Publicly Available Data:

Publicly available datasets and research papers were utilized to access historical data, models, and simulations related to solar cycles and their effects on Earth. The combination of observational data, space weather monitoring, geomagnetic measurements, climate data analysis, statistical methods, literature review, and expert consultation provided a comprehensive approach to studying the impact of Solar Cycle 24 on Earth's climate and geomagnetic field variations. This multidisciplinary approach helped in gaining a deeper understanding of the complex interactions between the Sun and our planet during this particular solar cycle.



The solar cycle viewed in ultraviolet light from 2010 to 2020 by the telescope aboard Europe's PROBA2 spacecraft. (Image credit: Dan Seaton/European Space Agency (Collage by NOAA/JPL-Caltech))

The solar cycle describes an approximately 11-year cycle of solar activity driven by the sun's magnetic field and indicated by the frequency and intensity of sunspots visible on the surface. Solar cycles are repetitive yet difficult to predict. A cycle can be as short as eight years or as long as 14 years and varies dramatically in intensity. The current cycle - solar cycle 25 - began in December 2019, according to a solar cycle 25 article from NASA. Solar activity is expected to ramp up until the predicted solar maximum as early as 2024. Heightened solar activity poses a risk to satellites, spacecraft and even spacewalking astronauts due to increased radiation exposure. On Earth, the large geomagnetic storms that solar activity triggers can interfere with high-frequency radio communications and Global Positioning Systems (GPS), according to NASA.

RESULTS AND DISCUSSION:

Solar Cycle 24 Activity:

Solar Cycle 24 was characterized by lower-than-average solar activity. The number of sunspots, a key indicator of solar activity, was notably reduced compared to previous cycles. This subdued activity was a departure from the more active solar cycles of the past, marking it as a relatively weak cycle.

Space Weather Impact:

Despite its lower activity, Solar Cycle 24 still posed significant space weather challenges. Solar flares, although less frequent, could be powerful and disruptive. These bursts of solar radiation and particles have the potential to interfere with communication and navigation systems, satellite operations, and even cause blackouts in power grids. Solar Cycle 24 highlighted the importance of space weather forecasting and preparedness.

Geomagnetic Field Variations:

The solar cycle had a tangible impact on Earth's geomagnetic field. Solar storms and coronal mass ejections during periods of heightened solar activity could trigger geomagnetic storms. These geomagnetic storms can lead to remarkable auroras at higher latitudes, visible as the Northern and Southern Lights, while also presenting challenges to technological infrastructure.

Climate Influence:

The connection between solar cycles and Earth's climate remains complex and not fully understood. Solar variations, including changes in solar irradiance and the solar magnetic field, are believed to have some influence on climate patterns. However, Solar Cycle 24's relatively weak activity had a limited direct impact on Earth's climate when compared to other factors such as greenhouse gas emissions.

Ongoing Research:

Solar Cycle 24 has fueled ongoing research into the interactions between the Sun and Earth. Scientists continue to study the dynamics of solar cycles to better predict space weather events, understand geomagnetic phenomena, and explore potential links between solar activity and long-term climate trends.

Future Implications:

As we look to future solar cycles, it is clear that the Sun's activity can have far-reaching consequences for our technology-dependent society. Understanding the timing and intensity of solar cycles will be crucial for space weather forecasting and mitigating potential disruptions. Additionally, continued research will help elucidate the role of solar cycles in Earth's climate and whether they play a more significant role in long-term climate patterns.

In conclusion, Solar Cycle 24, though relatively weak in solar activity, demonstrated that even subdued solar cycles can have substantial effects on space weather and Earth's geomagnetic field. While its direct influence on Earth's climate is limited, its impact on technology and geomagnetic phenomena underscores the need for ongoing research and preparedness in the face of future solar cycles.

CONCLUSION:

Solar Cycle 24, despite its relatively weak solar activity compared to previous cycles, had a notable impact on both space weather and Earth's geomagnetic field. While its influence on Earth's climate remains a subject of ongoing research and debate, its effects in other domains are more apparent. In terms of space weather, Solar Cycle 24 exhibited the potential for disruption. The lower-than-average number of sunspots and solar flares did not eliminate the risk. Solar flares, in particular, have the capacity to disrupt communication systems, satellite operations, and power grids, underlining the importance of space weather forecasting and preparedness. The interplay between Solar Cycle 24 and Earth's geomagnetic field was another significant aspect. The occurrence of geomagnetic storms, driven by solar storms and coronal mass ejections, could produce stunning auroras at higher latitudes while posing challenges to technological infrastructure.

Although Solar Cycle 24's influence on Earth's climate is relatively minor compared to other factors like greenhouse gas emissions, its impact on space weather and geomagnetic variations underscores the complex relationship between our Sun and our planet. Future solar cycles will continue to be subjects of intense scientific inquiry as we strive to better understand and predict their effects on Earth and the technologies that rely on our connection to the Sun. In doing so, we enhance our ability to mitigate and adapt to the challenges posed by the ever-changing solar activity.

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