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| Word | Definition | Source |
| Maunder Minimum | Period of very few sunspots between 1645 and 1715 | Britannica.com |
| Planetary wave | Rossby wave, meanders forming in the polar jet stream that are caused by an interaction between temperature and the earth’s rotation | Wikipedia |
| Radiative budget | Breakdown of how much light reaches the earth, how much is reflected, absorbed, trapped | Science.nasa.gov |
| Spectral density | Strength of a wave at different frequencies | Wikipedia |
| precession | Slow change in the angle of the earth’s axis | Dictionary.com |
| obliquity | The angle between the earth’s equator and the ecliptic plane | Merriam-webster.com |
| B.P. | Before Present | Wikipedia |
| paleoproxy | Data that indicates change in the earth’s climate from long ago | International environmental data rescue organization |
| Cosmogenic | Produced by cosmic rays | Merriam-webser.com |
| nuclide | Kind of atom, isotope | Britannica.com |
| Gleissberg and DeVries cycles | Cycles present in the sun’s magnetic activity | Wikipedia.com |
| Broad band |  |  |
| linearized | Make a dataset linear | Merriam-webster.com |
| prognostic | Helps to predict something | Merriam-webster.com |
| Perturbations | Disturbances` | Merriam-webster.com |
| speleothems | Cave formations such as stalactites | Merriam-webster.com |
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1. Introduction:

The influence of solar and orbital changes on climate have been thoroughly studied. The main way that changes in the sun influence the climate is through sunspots, dark patches caused by magnetic activity. The main dilemma in studying solar activity’s influence on climate is that changes in solar radiation are tiny, in comparison with total radiation. One major record of solar influence on past climate change is ice-rafted debris recorded in Iceland. The leading explanation for this influence is that changes in the sun’s UV output alter the latitudinal temperature gradient in the stratosphere, which impacts the behavior of the changes in the polar jet stream. Another explanation is that increased light amount (irradiance) caused higher sea temperatures and stronger convective winds, which alter the latitudinal temperature gradient, which alters the North Atlantic Oscillation. This paper focuses on supporting a completely new explanation for solar influence on climate: that changes in irradiance alter ENSO, or the longitudinal sea surface temperature gradient in the equatorial pacific, which then affects weather trends around the world.

1. Climate forcing over the Holocene

There are three main external factors that affected the earth’s climate over the Holocene (10,000BCE to the present). These factors are solar changes (sunspots), orbital changes, and volcanic eruptions. The study did not consider volcanic eruptions, because there was not adequate data available to study volcanic influence over the entire Holocene. The effects of orbital changes on insolation over the Holocene are easy to identify and analyze. They performed EOF (empirical orthogonal function) analysis to identify the changes in orbital forcing, precession (rotation of the earth’s axis) affected the difference in insolation between opposite seasons, and changes in obliquity (the angle of the earth’s axis) affected the mean insolation every year. The researchers observed the changes in solar (not orbital) forcing by recording the amount of certain isotopes affected by the sun’s magnetic field. They then compared these records with modern records of sunspot amounts to determine the amount of sunspots over the entire Holocene.

1. Experimental setting

The researchers ran a moderately complex model that included simulation of the air, the ocean, and the interactions between them, of only the equatorial Pacific. They inputted the solar forcing, orbital forcing, and a combination of the two in three separate runs. They measured changes in the sea surface temperature over the entire timespan. In order to provide an accurate simulation of climate during the Holocene, the researchers also needed to insert short-term weather noise into the model.

1. Results

The dependent variable that the researchers measured was the sea surface temperature difference between the eastern and western equatorial Pacific. The model simulation for only solar forcing revealed that their measure of ENSO is significantly connected to solar forcing. A visualization of the amplitude of the change in ENSO as related to the duration of the change and the time before present reveals that there is a large spike in ENSO activity with a duration of about 4 years. The researchers ran a control set of simulations to test whether this spike is statistically significant. It revealed that the spike was a result of internal variability within the model, not solar forcing. However, the temperature difference had statistically significant peaks with durations of about 500 and 1000 years. The researchers determined that the cause of this increase in activity on 500 and 1000-year timescales because upwelling causes the western Pacific to warm faster than the eastern Pacific. This warming change causes a positive feedback mechanism to create a statistically significant temperature gradient. Therefore, periods of increased irradiance due to an absence of sunspots induced La Nina-like conditions characterized by an increased east-west temperature gradient, while decreased irradiance caused Nino-like conditions.

The researchers performed the same analysis process on orbital forcing as solar forcing. The climate models indicated an increase in ENSO activity during the second half of the Holocene. The researchers’ explanation for this increase is that the observed orbital changes cause a more intense contrast between opposite seasons. Increase in seasonality causes the intertropical convergence zone to oscillate a greater distance, increasing the atmosphere’s response to increased insolation. Increased sunlight during the summer results in an overall cooler Pacific Ocean through the thermostat mechanism. Therefore, since during the early Holocene there was increased insolation, the Pacific Ocean was cooler, on average. This cooling led to a reduction in the intensity of ENSO activity.

Finally, the researchers determined the influence that a combination of solar and orbital forcing has on ENSO activity. The wavelet spectrum indicated that the effect of a combination of the orbital and solar forcing is approximately a sum of the two independent forcings. The researchers then analyzed the data to be able to predict the ENSO activity given the value of the solar and orbital forcing.

1. Global implications

The researchers identified some of the impacts that solar influence on ENSO had on global climate. They used records of 14C in tree rings and other isotopes in speleothems in North America to show that solar-induced ENSO led to significant droughts during the Holocene. Their analysis of this connection revealed a surprisingly high degree of correlation. Next, they explained the connection between solar-induced ENSO and records of ice-rafted debris in the North Atlantic. They used records of wind vector in the North Atlantic, records of sea surface temperature in the Pacific, and climate simulations to show that there is a statistically significant correlation between ENSO and wind vector in the North Atlantic. Their data lacked enough accuracy to support genuine causality, however. Finally, previous research shows that El Niño is able to weaken the Asian monsoon. The researchers used speleothem records from various locations in Asia to show that there is indeed a connection between solar-induced ENSO and the monsoon. There was a significant correlation between Icelandic ice-rafted debris and weakened monsoons that existed on a similar timescale as the variability of solar-induced El Nino, showing that solar-induced ENSO is likely affecting both processes.

1. Discussion

The researchers showed that solar and orbital forcing have an impact on ENSO that is not affected by internal processes, and that the strength of this impact is dependent on the strength of the forcing. One important limitation of this study was that they used a simplified climate model, which is not a perfect representation of actual past climate. It did not include many factors, including feedback loops that may have affected their entity. Additionally, their use of proxy data to record sunspot activity is incomplete and uncertain. Additionally, their research did not include any affects from volcanic eruptions. Finally, more data is needed to determine whether solar-induced ENSO affects the southern hemisphere as well as the northern.

1. Conclusion

The researchers provided evidence supporting the hypothesis that orbital and solar changes affected past climate by altering the equatorial Pacific temperature gradient. They found that increased irradiance brings about Nina-like periods, while reduced irradiance causes Nino-like conditions. They showed that solar-induced ENSO had significant effects on climate processes around the world. However, the data used is incomplete and they used a simplified atmospheric model.

Citation:

Emile-Geay, J., M. A. Cane, R. Seager, A. Kaplan, and P. Almasi (2007), El Niño as a mediator of the solar influence on climate, Paleoceanography, 22, PA3210, doi:10.1029/2006PA001304.

Questions:

1. This article does not consider the impact that changes in atmospheric composition have on the earth’s climate through long-term ENSO. How would factors such as greenhouse gasses factor into your hypothesis?
2. How would the principles of solar/orbital forcing affecting ENSO, which affects global climate change during even earlier time periods, such as the Cenozoic and Mesozoic eras?
3. What do these findings reveal about climate on shorter, more recent timescales? How do the effects of solar and orbital changes compare to those of human-caused greenhouse emission?