The Solar Cycle Turned Sideways

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Discovered more than 150 years ago and carefully studied ever since, the solar cycle is nevertheless, in one key way, widely misunderstood.

Many people and even some scientists embrace a simple, binary view of solar activity: Solar maximum is a time of action, marked by massive explosions and dangerous space weather that can affect engineered systems on Earth and in space, while solar minimum is a time of quiet, when almost nothing happens.

In fact, the situation is more complex ... and more interesting. Solar Min and Max are opposite extremes of a great stellar rhythm. Solar activity never stops; it just changes form as the pendulum swings. To visualize this, we turn the solar cycle sideways:

In the graphic, sunspot counts are plotted horizontally instead of vertically. Large sunspot numbers are on the right, small sunspot numbers are on the left. This rotated framework erases the concept of Solar Min and Solar Max, and replaces it with a terrestrial analog: La Niña and El Niño.

La Niña and El Niño are opposite extremes of a great Pacific oscillation. Every 2–7 years, surface waters across the equatorial Pacific Ocean warm up (El Niño) and then they cool down again (La Niña). Meteorologists struggle with a misunderstanding among some laypeople, who believe that El Niño brings wet, stormy weather, while La Niña brings a dry calm. In fact, each condition has its own distinct regional effects which are, like the extremes of the solar cycle, varied and complex. In southern California, for instance, El Niño years can bring heavy winter rainfall and floods; across the country, the very same El Niño pattern keeps New England warm and dry. In Ecuador and Peru, El Niño delivers good weather for farming. Fishermen hate it though, because their catch plummets at the same time that crop yields soar. On the other side of the Pacific, Australia experiences El Niño as a time of drought and wildfires—the exact opposite of the southern California imprint.

La Niña tends to reverse these trends, but not exactly. While the sea surface temperature anomalies of El Niño and La Niña are practically mirror images of one another, the consequences are not. Earth’s weather system is devilishly complex, and no 2 years react the same way to an El Niño or La Niña perturbation.

So it is with the solar cycle. Each extreme stirs up a unique mix of space weather that affects different parts of the Earth-Sun environment, and engineered systems, in varied and complex ways.

Consider the following:

During Solar La Niña (Solar Min), cosmic ray levels surge. Galactic cosmic rays coming from outside the solar system must propagate upstream against the solar wind and a thicket of solar magnetic fields. During the La Niña phase of the solar cycle, solar wind pressure decreases and Sun’s magnetic field weakens, making it easier for cosmic rays to reach Earth. Because cosmic rays are so potent—a single relativistic iron nucleus can easily shatter a strand of human DNA—Solar La Niña is a dangerous time for astronauts.

Sun’s El Niño phase (Solar Max) brings cosmic ray counts down, but solar flare activity surges. Solar explosions spray the solar system with X-rays, high energy protons, and billion-ton clouds of electrified plasma known as coronal mass ejections. This is scant relief for astronauts.

Solar El Niño affects many technologies. Ham radio operators grapple with radio blackouts. Airline traffic controllers are sometimes forced to divert international flights away from polar routes. A 2008 report by the National Research Council (NRC) warned that “extreme geomagnetic storms can cause worldwide power outages, water shortages, and disruptions to financial markets”, among other things.

Sun’s extreme ultraviolet (EUV) radiation is an excellent example of the solar cycle’s back-and-forth character. During sunspot peak years (Solar El Niño), EUV output is strong. EUV radiation heats Earth’s upper atmosphere, increasing aerodynamic drag on low-orbiting satellites. Satellites, including the International Space Station, tend to fall back to Earth during this time, which vexes satellite operators. On the other hand, space junk tends to fall back to Earth, too, which keeps the orbital environment clean.

During years of lower sunspot number (Solar La Niña), Sun’s EUV output drops, and the upper atmosphere begins to cool and contract. With sharply lower aerodynamic drag, satellites have less trouble staying in orbit—a good thing. On the other hand, space junk tends to accumulate, making the space around Earth a more dangerous place.
The solar cycle could be entering a phase with a stronger-than-usual “La Niña” character. Following a century-level solar minimum during 2008–2009, Solar Cycle 24 has risen up—but only enough to become the weakest cycle in more than 50 years. Total solar irradiance, which always experiences an uptick around Solar Max, has increased only half as much as in the three previous cycles, while UV/EUV irradiances (key drivers of space weather) are up only 50%–70%. These low numbers are not indicators of “quiet,” however. As the solar cycle turned sideways shows, solar variability always has the potential to have a major impact on Earth and humanity.

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Reference

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