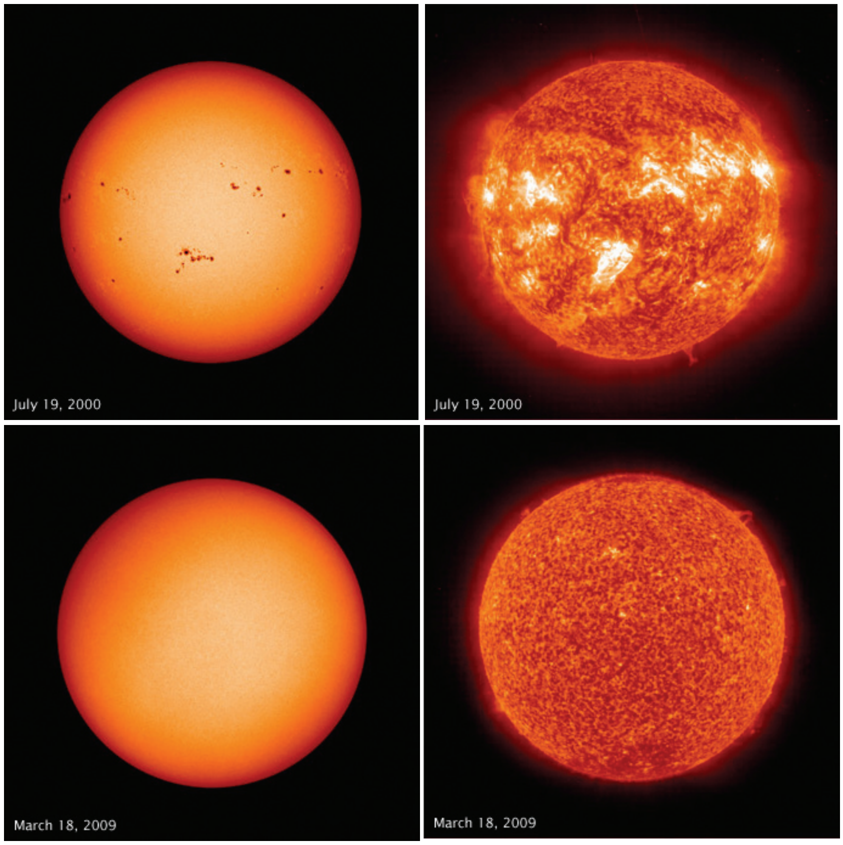
Calm before a storm of energy

—by Stuart Clark



Sunspots and activity [ultraviolet on the left] captured by NASA in July 2000 and March 2009. [http://earthobservatory.nasa.gov]

Sunspots come and go, but recently they have mostly gone. For centuries, astronomers have recorded when these dark blemishes on the solar surface emerge, only to fade away after a few days, weeks or months. Thanks to their efforts, we know that sunspot numbers ebb and flow in cycles lasting about 11 years.

For the past two years, though, the sunspots have mostly been missing. Their absence, the most prolonged in nearly 100 years, has taken even seasoned sun watchers by surprise. "This is solar behavior we haven't seen in living memory," says David Hathaway, a physicist at NASA's Marshall Space Flight Center in Huntsville, Ala.

The sun is under scrutiny as never before, thanks to an armada of space telescopes. The results they beam back are portraying our nearest star, and its influence on Earth, in a new light. Sunspots and other clues indicate that the sun's magnetic activity is diminishing and that the sun may even be shrinking. Together, the results hint that something profound is happening inside the sun. The big question is: What?

Groups of sunspots forewarn of gigantic solar storms that can unleash a billion times more energy than an atomic bomb. Fears that these giant eruptions could create havoc on Earth and disputes over the sun's role in climate change are adding urgency to these studies. When NASA and the European Space Agency launched the Solar and Heliospheric Observatory almost 15 years ago, "understanding the solar cycle was not one of its scientific objectives," says Bernhard Fleck, the mission's project scientist. "Now it is one of the key questions."

Sunspots are windows into the sun's magnetic soul. They form where giant loops of magnetism, generated deep inside the sun, well up and burst through the surface, leading to a localized drop in temperature that we see as a dark patch. Any changes in sunspot numbers reflect changes inside the sun. "During this transition, the sun is giving us a real glimpse into its interior," says Hathaway.

When sunspot numbers drop at the end of each 11-year cycle, solar storms die down and all becomes much calmer. This "solar minimum" doesn't last long. Within a year, the spots and storms begin to build toward a new crescendo, the next solar maximum.

What's special about this latest dip is that the sun is having trouble starting the next solar cycle. The sun began to calm down in late 2007, so no one expected many sunspots in 2008. But computer models predicted that when the spots did return, they would do so in force. Hathaway was reported as thinking the next solar cycle would be a doozy: more sunspots, more solar storms and more energy blasted into space. Others predicted that it would be the most active solar cycle on record.

The trouble was, no one told the sun.

The first sign that the prediction was wrong came when 2008 turned out to be even calmer than expected. That year, the sun was spot-free 73 percent of the time, an extreme dip even for a solar minimum. Only the minimum of 1913 was more pronounced, with 85 percent of that year clear.

As 2009 arrived, solar physicists looked for some action. They didn't get it. The sun continued to languish until mid-December, when the largest group of sunspots to emerge in several years appeared. Even with the solar cycle finally underway again, the number of sunspots has so far been well below expectations. Something appears to have changed inside the sun, something the models did not predict. But what?

The flood of observations from space- and ground-based telescopes suggests that the answer lies in the behavior

NSPS ballot nominations, shown separately

of two vast conveyor belts of gas that endlessly cycle material and magnetism through the sun's interior and out across its surface. On average it takes 40 years for the conveyor belts to complete a circuit.

When Hathaway's NASA team looked over the observations to find out where their models had gone wrong, they noticed that the conveyor-belt flows of gas across the sun's surface have been speeding up since 2004.

But the circulation deep within the sun tells a different story. Rachel Howe and Frank Hill of the National Solar Observatory in Tucson have used observations of surface disturbances, caused by the solar equivalent of seismic waves, to infer what conditions are like within the sun. Analyzing data from 2009, they found that while the surface flows had sped up, the internal ones had slowed to a crawl. These contradictory findings have thrown the best computer models of the sun into disarray. "It is certainly challenging our theories," says Hathaway.

These changes are raising questions not just about the sun itself but also about the extent to which the sun's activity affects our climate. There are those who believe that the solar variability is the major cause of climate change, an idea that would let humans and their greenhouse gases off the hook. Others are equally convinced that the sun plays only a minuscule role in climate change.

The extended collapse in solar activity these past two years offers the possibility of an experiment to resolve this dispute, allowing scientists to examine what happens when you switch off one potential cause of climate change and leave the other alone. With so few sunspots, the amount of solar radiation bombarding our planet has significantly changed. "As a natural experiment, this is the very best thing to happen," says Joanna Haigh, a climatologist at Imperial College London. "Now we have to see how the Earth responds."

Frigid Europe

Michael Lockwood, a professor of space environment physics at the University of Reading in England, may already have identified one response: the unusually frigid

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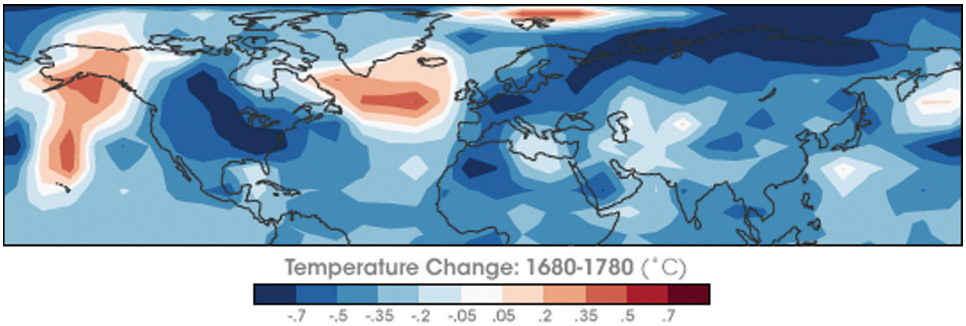

Chilly temperatures during the Maunder minimum 1680-1780. [http://earthobservatory.nasa.gov]

European winter of 2009-10. He has studied records back to 1650 and found that severe European winters are much more likely during periods of low solar activity. This fits an idea of solar activity's giving rise to small changes in the global climate overall but large regional effects.

Another example is the so-called Maunder minimum, the period from 1645 to 1715 during which sunspots virtually disappeared and solar activity plummeted. If a similar spell of solar inactivity were to begin now and continue until 2100, it would mitigate any temperature rise caused by global warming by no more than 0.3 degrees Celsius, according to calculations by Georg Feulner and Stefan Rahmstorf of the Potsdam Institute for Climate Impact Research in Germany.

However, something amplified the impact of the Maunder minimum on northern Europe, ushering in a period known as the Little Ice Age, when colder-than-average winters became more prevalent and the average temperature in Europe appeared to drop by between 1 and 2 degrees Celsius.

A corresponding increase in temperatures on Earth appears to be associated with peaks in solar output. In 2008, Judith Lean of the Naval Research Laboratory's space science division published a study showing that high solar activity has a disproportionate warming influence on northern Europe.

What the sun will do next is beyond our ability to predict. Most astronomers think that the solar cycle will proceed but at significantly depressed levels of activity, similar to those last seen in the 19th century. However, there is also evidence that the sun is inexorably losing its ability to produce sunspots. By 2015, they could be gone altogether, plunging us into a new Maunder minimum—and perhaps a new Little Ice Age.

Of course, solar activity is just one natural source of climate variability. Another is volcanic eruptions, spewing gas and dust into the atmosphere.

Nevertheless, it remains crucial to understand the precise changeability of the sun and the way it influences the various regional patterns of weather on Earth. Climate scientists will then be able to correct for these effects, not just in interpreting modern measurements but also when attempting to reconstruct the climate stretching back centuries. It is only by doing so that we can reach an unassailable consensus about the sun's true level of influence on the Earth and its climate.

Clark holds a PhD in astrophysics and writes regularly about astronomy. The author of "The Sun Kings" (Princeton), he blogs at http://:www.stuartclark.com. This article is adapted from one that appeared in the New Scientist; it can be viewd in full at http://www.newscientist.com.