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The effect of the 1859 Solar Storm and What would happen if it were to Occur Today

On September 1, 1859, during solar maximum, astronomer Richard Carrington observed a series of large sunspots that developed into an immensely bright and powerful solar storm. The storm had far-reaching effects on the world at the time and would eventually bear his name. The Carrington Event is described as the most powerful solar event in the last 400-500 years and wreaked havoc on the relatively undeveloped industrial world of the mid-1800's. In this paper, I will investigate the timeline and effects of the storm and predict what would happen to our post-industrial society if such a storm were to occur in the present.

By the time Carrington had made his observation of the sunspots, the storm had already been going on for several days. The first reports of sunspots and flares were on August 28. Slightly before this time, the first of two Coronal Mass Ejections in the direction of Earth took place. Disturbances were first noted in the telegraphic system and bright aurorae were spotted. Aurorae were seen as far south as Cuba in the Caribbean. By August 30, much of the disturbances and aurora spotting had subsided. During his observations of the sunspots on September 1, Carrington saw a bright flare that would give rise to the second coronal mass ejection. This ejecta reached Earth in just over 17 hours, traveling through interplanetary space at 2300 kilometers per second. Coronal mass ejections usually do not reach the Earth this quickly. However, the first CME cleared the interim space of much of the pre-existing interplanetary particles. In essence, it cleared the path for the second CME. The second CME caused more aurorae spotting with recording sightings as far south as Venezuela. Aurora and other disturbances continued until around September 4 when they started to fade away.

The 1859 event is considered to be the most severe solar storm recorded and possibly even the most severe in 400-500 years. The aurora that the storm caused were so bright that people in midwestern America mistook aurora for dawn. People on the eastern coast claimed to be able to read by the light of the aurora alone. Many saw the red colors and believed neighboring locales must be on fire. Scientists think that the ozone layer took several years to recover after much was destroyed by the solar particles.

The storm wreaked massive havoc with the rudimentary telegraph systems of the time. The first coronal mass ejection caused many telegraph stations' electronics to melt. The storm caused such intense transient currents (geomagnetically induced currents from the distorted terrestrial magnetic field) that one operator in Washington DC was electrocuted as he leaned over some wires. On the morning of September 2, with the arrival of the second coronal mass ejection, telegraph operators across the country and world found it impossible to transmit messages. Amazingly, though, they found that they could intermittently transmit messages using the current generated by the geomagnetic storm in their lines once they disconnected their own power sources. Within a day, the worst effects began to subside.

The storm had the most severe impacts on human society of any storm recorded, however, to find a quantitative measure of the intensity, scientists turn to ice cores. The coronal mass ejection generates an increase in solar proton flux in the upper atmosphere at high latitudes. These fast moving protons interact with the atmosphere and create nitric oxide and other nitrogen oxygen compounds. These compounds eventually make their way to the surface and an increase in nitrate concentration in the air is recorded in ice core samples. Sharp spikes in nitrates from multiple sources have been connected to the 1859 event. Because the intensity of the event and the increase of nitrates is proportional, this is a way to quantify a storm's strength. Studying ice cores for the last several centuries, scientists found that storms of the intensity of the 1859 event occur roughly every 500 hundred years. Smaller storms, like the 1989 storms in Quebec occurring much more frequently, possibly several times every century.[1]

Although it is thought that events like the 1859 one are rare, they likely will happen again and may happen soon. It is important to know the possible risks of such

[1] Note: There has recently been some debate over the accuracy of ice core data to quantify solar storms. Many have shown that the 1859 event cannot be seen in sharp nitrate spikes in ice cores taken from other places in the world. They have suggested that an increase in solar protons does not explain a sharp spike as the nitrates produced in the upper atmosphere would take time to make it to the surface. They would also spread to lower latitudes before making it to ground level.

an event, in order to prepare for it. Much of the damage can be grouped into four broad categories: damage to people, damage to property, power transmission failure, and communications failure.

The sun outputs an enormous amount of radiation that would be very dangerous to humans if the atmosphere did not absorb much of it. Luckily, in the case of an intense solar storm, people on the surface would still have the atmosphere for protection. The only real physical risk to people in the case of a storm (excepting the occasional electric shock like the unfortunate telegraph operator in 1859) is to astronauts outside the atmosphere. While astronauts would not likely get an acutely fatal dose, they would get a significant amount. One estimate is that astronauts would get roughly 70 years of normal terrestrial background radiation within the few hours of intense flux. Other sources do say that astronauts would get a fatal dose.

A storm as powerful as the Carrington event would cause massive damage to electronics, both in satellites and on the Earth's surface. Some estimate that as many as 10% of the satellites currently in orbit could stop functioning completely. This breakdown would result from transient voltages and currents (and other radiation caused degradation) in on-board circuits due to incident charged particles and from increased drag from the atmosphere. The transient currents could overload many fragile integrated circuitry components, exceeding breakdown voltages and rendering them nonfunctional. The increased solar output that accompanies these events can heat the upper atmosphere, causing it rise and expand. This expansion can cause increased drag for many satellites, making their orbits decay and possibly making them plunge fully in the atmosphere where they will disintegrate. For example, a solar storm in the year 2000 caused the International Space Station to lose almost 300 times more altitude per day than it usually does. Fortunately, the International Space Station has emergency thrusters to keep it out of denser atmosphere. However, most satellites do no have these.

Some damage could also take place for electronics on the surface of the Earth. The transient voltages would also be present on the ground and could cause breakdown in electronic devices. Fortunately, things like phones and computers are less susceptible to damage than the satellites because of the shielding of the atmosphere. Even an event like the 1859 one would leave many small devices intact.

The power infrastructure would not be so lucky. The power transmission system in the U.S. is already fragile and close to maximum capacity. An intense solar storm could generate large potential differences over long power lines. These transient voltages could not be absorbed into the power system because it is already close to capacity. This could lead many things to malfunction, including transformers and power lines themselves. It could take many months to replace many transformers if there is widespread failures, especially because there is not many transformers kept in stock for emergencies like this. Replacing many of them would require manufacturing new ones which would take time. Much of the country and world would likely be out of power for a while. It would not matter if electronics continued to work because there would be no power.

Another area where a solar storm will cause damage is communications. The arriving solar particles will increase ionization in the upper atmosphere. This will make long distance radio communication difficult. The usual use of the ionosphere as a reflector for over-the-horizon communication is disrupted. As was mentioned before, satellites will likely malfunction and since much communication is relayed through them, many things will stop working.

In the end, the costs will be immense. The satellites that break alone could cost over $100 billion. Combined with the replacing of transformers and the fixing of other power equipment that will break, the total costs could easily be over $1 trillion. The costs would be more than just monetary too. The social shock of no power for months could cause significant social unrest.

Fortunately, we do have some amount of warning. Spacecraft that are between the Earth and the sun can warn of an incoming CME. Their warning would not be much in advance, but possibly enough to manually shut down sensitive power grids so the storm will not destroy them. It could also be enough to get any astronauts inside their craft to minimize their exposure.

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