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How do you determine the effects of a solar flare that took place 150 years ago?

We use a computer model of the Earth's atmosphere to compute the effects of an influx of charged particle (proton) radiation like that of the Carrington event. Since there is no data on this type of radiation from the time of the event, we have used an estimate of the energy input. This estimate was derived from data collected by Ken McCracken and collaborators from Greenland ice cores. Their procedure is to measure the enhancement of nitrate in the ice core and then correlate that with known radiation events to arrive at an estimate of the proton flux for the Carrington event.

Using this estimate, we then scale up atmospheric ionization data for a similar, but less powerful, event that occurred in 1989. This scaled data then goes into the atmospheric model as a source of nitrogen oxides.

What did it do to the Earth?

The results we focused on were changes to the atmosphere. When protons enter the atmosphere they interact with air molecules and produce nitrogen oxides. These compounds then go on to deplete ozone in catalytic cycles. We found that ozone is reduced by noticeable, but not dangerous amounts. The depletion is concentrated in the polar regions and reaches up to 80% reduction at high altitudes. From the perspective of someone on the ground, however, the reduction in the column density over a particular location is more like a few percent, at most about 14%. Averaged over latitudes, the maximum depletion is about 4%. This is similar in magnitude to the present day globally averaged depletion caused by manmade chemicals.

We find that the atmosphere recovers within about 2-3 years after the event. That recovery is mainly through rainout of the nitrogen oxides as nitric acid rain, which is where the enhancement of nitrate in the ice cores comes from.

How does it compare to more recent flares?

We use the October 1989 flare as one of the most energetic events in the era of satellite measurements. Compared to this event, we estimate that the Carrington event produced about 6.5 times the atmospheric ionization, and the depletion in column density of ozone over a given location is at maximum about 3.5 times larger.

What would happen if another Carrington flare went off today?

We would definitely have some spectacular auroral displays, and would likely have significant problems with power grids and such. In terms of the atmosphere, the event would perturb an atmosphere that is already affected by manmade compounds, depending on what season it occurred in. This could actually reduce its effectiveness, since if the Antarctic ozone "hole" is in place then there would be little ozone to be affected by the flare in that region. There could be more depletion at lower latitudes, though, which could extend the region affected by increased levels of UV.