

## **Galactic Cosmic Ray Intensity Variations During the Space Age and the Holocene**

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Most galactic cosmic rays are accelerated by shock waves from supernova, after acceleration they diffuse through the magnetic fields of our Galaxy. The inner heliosphere is to a large extent shielded from cosmic rays by the solar wind and its embedded interplanetary magnetic field (IMF). During solar maximum the IMF strength and turbulence level increases, and cosmic rays have more difficulty penetrating to the inner heliosphere. Thus, the near-Earth cosmic-ray intensity (integrated over all energies) varies by a factor of  $\sim 3$  to 4 over the solar cycle, in anti-correlation with the 11-year sunspot cycle.

Earth's atmosphere is partially shielded from cosmic rays by the geomagnetic field: in the polar regions cosmic rays of all energies reach the upper atmosphere, but near the equator lower-energy particles ( $\sim 90\%$  of all cosmic rays) are deflected. Nuclear and electromagnetic interactions of cosmic rays in the atmosphere produce secondary particles that penetrate to Earth's surface, contributing an important source of ionization in the stratosphere. There is a very controversial claim that cosmic rays can directly influence climate by facilitating cloud formation.

Ground-based and balloon-borne cosmic-ray measurements go back almost 100 years; measurements in space started in the late 1950's. Cosmic-ray intensities can also be traced back in time by measuring Be-10 and C-14 in polar ice cores, and C-14 in tree-rings. These cosmogenic radionuclides show that the cosmic-ray intensity over the past  $\sim 10,000$  years has typically been  $\sim 40\%$  to as much as  $\sim 80\%$  greater than the average over the space era. Over this period there is evidence for more than 20 "Grand Minima" (e. g., the Maunder Minimum) during which solar activity was low. For the last  $\sim 80$  years we have been in a "Grand Maximum" with high solar activity. However, it is interesting that the cosmic-ray intensity in late 2009 increased to a level  $\sim 14\%$  greater than it has been in more than 50 years.

This talk will review how the cosmic-ray intensity varies over the solar cycle and has varied during the space era, and it will describe how these variations are related to solar activity and solar-wind variations. It will then discuss efforts to relate the Be-10 and C-14 records over the last 10,000 years to other solar-activity records, including the interplanetary magnetic field strength and total solar irradiance.