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Editorial

Galactic energy and its role in a changing Earth

Proposed climate change mechanisms are many and various but generally attributable to our part of the solar system. They usually focus on temperature changes driven either by local processes such as variations in oceanic circulation, or, levels of atmospheric greenhouse gases such as carbon dioxide, or by global processes such as variations in received solar energy linked to changes in the parameters of the Earth's rotation and orbit or solar activity. However, two recent papers have suggested that we may need to look outside the Earth System and even outside our local planetary system for the possible origins of climate change, both on a decadal scale and over longer timescales of hundreds of millions of years. In each case, the galactic cosmic ray flux and its potential effects on cloud formation is considered to be the culprit.

Yu, writing in *Journal of Geophysical Research*, Volume 107 (DOI.10.1029/2001ja0000248), shows that the galactic cosmic ray flux correlates positively with low-level clouds and negatively with high-level clouds. He suggests that the production rate of cloud condensation nuclei by cosmic rays reduces with altitude, resulting in reduced high-level cloud cover and increased low-level cloud cover with increasing cosmic ray intensity. The flux of galactic cosmic rays reaching the Earth is a function of the intensity of the solar wind. This increases and decreases in strength with the sun's output, which is higher in years of sunspot peaks and when the sunspot cycle is shorter. Yu suggests that the relationship between cloudiness, solar output, and cosmic ray intensity may provide a mechanism to drive global temperature change. This exhibits a range 2.5 times greater than simple changes in solar irradiance can provide, although the detailed relationships are complex.

On a very much longer timescale, Shaviv, in *Physical Review Letters*, Volume 89 (DOI.10.1103/PhysRevLett.89.051102), has shown a good time correlation between emergence of the solar system after passage through galactic spiral-arms and large-scale glaciation, such as that seen during the Cenozoic or the Permo-Carboniferous (*c.* 300 million years ago). Again, galactic cosmic ray flux is implicated, but this time by long-term increases in its intensity associated with bursts of star formation and death as a spiral-arm density-wave passes through (galactic spiral-arms do not "orbit" per se, but are more like the spontaneous traffic jams that sometimes occur on major highways). Short-lived, high-mass stars are produced at a much higher rate within galactic spiral-arms than between them, and their supernova remnants are a source of increased cosmic ray flux as the solar system emerges from a passing arm (about every 140 million years). Increased low-level cloudiness, possibly explained by the mechanism proposed by Yu, would result, which, from satellite data, appears to be positively correlated with lower global average temperature. Ice ages are not guaranteed by increased cosmic ray flux, as there are many other factors involved, but this may be at least one of the major long-term triggers.

What these two studies serve to remind us is that the Earth System, although it may have its own metronomes and drivers on many timescales, is also at the mercy of completely extrinsic processes. It suggests that there is a connectedness that goes well beyond our planet, fitting it into an even larger whole. It also shows that high-energy physics has new and exciting things to contribute to studies of the Earth system.

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