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The Sun, The Milky Way and Climate on Earth

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Accumulating evidence over the past two decades points to a clear link between cosmic rays and climate. The talk will review the empirical evidence, the theoretical understanding which is corroborated by laboratory experiments and how the link can be quantified. The empirical evidence includes a wealth of correlations between cosmic ray flux variations and climate on time scales ranging from the few day long Forbush decreases in the cosmic ray flux to billion year variations in the cosmic ray flux expected from our varying galactic environment. On the theoretical side, we have found three different microphysical mechanisms linking atmospheric ions to the formation and survival of cloud condensation nuclei. The three mechanisms which can be calculated ab initio, were all corroborated in specially designed lab experiments. The mechanisms where also implements in a global aerosol model initial results quantifying the global effect of the three mechanisms. In addition to the overview, the talk will concentrate on the geological evidence showing how spiral arm passages and oscillations perpendicular to the galactic plane have left a clear imprint in the paleoclimatic records. On shorter time scales, solar modulation of the cosmic ray flux also has clear effects on the climate. In particular, the 11-year solar cycle leaves a very clear imprint in the ocean heat content and the sea level. Namely, the oceans can be used as a calorimeter to quantify the size of the link. Thus, after two decades, we have a full picture which qualitatively and quantitatively explains the solar-climate and galactic-climate links.