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A reconstruction of radiocarbon production and total solar irradiance from the Holocene ^{14}C and CO_2 records: implications of data and model uncertainties

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Past atmospheric CO_2 concentrations reconstructed from polar ice cores [Monnin et al, 2004] combined with its $\Delta^{14}C$ signature as conserved in tree-rings [Reimer et al, 2009] provide important information both on the cycling of carbon as well as the production of radiocarbon (Q) in the atmosphere. The latter is modulated by changes in the strength of the magnetic field enclosed in the solar wind and is a proxy for past changes in solar activity.

We perform transient carbon-cycle simulations spanning the past 21 kyr to reconstruct total solar irradiance (TSI). The radiocarbon production rate over the Holocene is diagnosed from the atmospheric ^{14}C and CO_2 records by solving the atmospheric ^{14}C budget within Bern3D-LPX, a fully featured Earth System Model of Intermediate Complexity (EMIC) with a 3D ocean, sediment and a dynamic vegetation model. We assess the sensitivity of Q to carbon-cycle changes by applying bounding assumptions for the processes governing the CO_2 increase over the last glacial termination. Deglacial processes slightly influence the Holocene ^{14}C evolution and diagnosed production. The error in the terrestrial ^{14}C data is translated into an uncertainty in Q using a Monte-Carlo approach. In addition, uncertainties in the global carbon inventory, GPP and air-sea gas-exchange are taken into account. The diagnosed modern production rate at of $\sim$1.7 atoms/cm^2/s is lower than the independent estimate by Masarik and Beer (2009) of 2 atoms/cm^2/s as obtained by applying their production model for cosmogenic isotopes.

Q is translated into the solar modulation potential (Φ) by applying the relationship between Φ, Q, and the geomagnetic field of Masarik and Beer, 1999 and geomagnetic data from Knudsen et al, 2008. The ^{14}C-based Φ record is extended from 1950 to 2005 with instrumental data [Usoskin et al., 2011]. Finally, past total solar irradiance is computed using a recently published Φ-TSI relationship (Steinhilber et al., 2009). Our Holocene TSI record shows, besides recent grand solar minima like the Maunder Minimum (MM), numerous centennial-scale variations with deviations from the long-term mean of only approx. 0.5 W/m^2, while the millennial-scale trend in TSI is even smaller. The frequency-spectrum of TSI reveals the well-known solar periodicities. Finally, our radiocarbon-based TSI record is fed back into Bern3D-LPX to model past changes in surfaces atmospheric temperature (SAT) caused by solar variations, leading to relatively low transient SAT excursions of less than 0.1 K.

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