Project Details

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Topic: Long Term Variability and Predictability of the Sun-Climate System

Project Title:
Internal decadal anomalies in atmospheric 14C quantified with tree-ring proxies and implications for long-term variability of the sun-climate system

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Summary:
We propose to quantify long-term dynamics of the sun-climate system with annual 14C series from tree rings over the Holocene, as part of FST #4: Long Term Variability and Predictability of the Sun-Climate System. We hypothesize that abrupt spikes in 14C production (internal decadal anomalies, IDA sometimes called Miyake events) precede the onset of longer solar minima and impact the solar forcing of global climate via shifting irradiance wavelets and ionization. Our objective is to develop IDA 14C records to improve the use of historical proxies for changes in solar forcing and validate climate models. The annual rate of 14C production in the low stratosphere-troposphere reflects the variance of electromagnetic radiation over time due to changes in galactic cosmic rays and solar energetic particles. This important feature of atmospheric chemistry can be used to identify changes in solar activity, particularly intensity of the Schwabe cycle during solar minima and solar maxima. 14C records will explore the interaction of the IDA signal with known and uncharacterized Grand Solar Minima (showing the irregular variability of solar activity), and the regular state of 14C behavior using wavelet analysis and dynamic time-warping methods. Changes in the Schwabe cycle at the beginning of the Spoerer and Maunder minima have been extensively studied (e.g. Eastoe et al. 2019, Moriya et al. 2019, and earlier references). However, the lack of highly-resolved 14C records obscures the impact of solar activity on climate during other solar minima. Our initial studies report different types of solar minima around 5480 BC and 835-778 BC that have no associations with specific climatic anomalies. Simulations of PMIP4-CMIP6 paleoclimate models have identified the broad range of solar irradiance variations, especially the transition from solar minima to regular solar activity (Jungclaus et al. 2017, Otto-Bliesner et al. 2017). Modeling of climate forcing across transitional climatic events (e.g. Little Ice Age) gives great insight into externally-forced variability and multidecadal climate dynamics (e.g. Fern ndez-Donado et al. 2013, Ortega et al. 2015, Zanchettin et al. 2015, Luterbacher et al. 2016). Yet, attribution of solar minima to cold-temperature regimes for many other Holocene abrupt events like 8.2ka, 6.3ka, 4.7ka, 2.7ka, 1550 BP, 550 BP is neither clear nor ambiguous (Wanner et al 2011). Temperature characteristics of other abrupt climate events recognized by regional climate proxies have not been well-defined. Our analysis will examine the relationship between irregular long-term solar variability, quantified with annual delta 14C (3-box model parameterization) and ranging multiproxy climate reconstructions. Recent simulations of Chemistry-Climate Models (CCM) show high-amplitude variations of total solar irradiance that are essential to reproduce the cooling events of global climate (Solanki et al. 2010, Calisto et al. 2011, Semeniuk et al. 2011, Shapiro et al. 2011, Rozanov et al. 2012, Anet et al. 2013). Regular changes of solar irradiance are well studied by climate forcing models. A typical increase over the 11-year solar cycle of ~0.1 % is well-documented by instrumental observations (ca. 1978) and sunspot number records (ca. 1610). Other changes (e.g. IDA) are irregular and manifest on a longer timescale. These changes are studied much less and their impact on the climatic system is debatable. These random solar events introduce additional volatility to the climate-forcing system that may last from several decades to centuries. For example, rapid solar-irradiance variations with larger amplitude during Grand Solar Minima or Grand Solar Maxima are superimposed on the 11 year cycle and offset the intensity and duration of the Schwabe solar cycle. The new 14C signal can be an indicator of climate forcing: new characteristics of solar activity and atmospheric chemistry: irradiance and atmospheric ionization.

Publication References:

no references