# Verification of $^{14}C$ rapid excursions in the intervals 700-500 BCE and 1260-1286 CE preceding Grand Solar Minima

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Excursions in the radiocarbon ($^{14}C$) record are rapid changes above the regular fluctuations by a factor of 2-3, which occur on a scale of a few years. The $^{14}C$ excursions may be indicative to extreme space weather. These events are presumed to be caused by an extreme increase of incoming cosmic rays or gamma rays. Some these excursions have generated widespread interest, but few ones have been reproduced in many tree-ring records from many locations around the globe (see publications on 774-775CE and 993-994CE events). Only three such events (see 774-775CE, 993-994CE and ca. 660BCE events) were positively connected to the impact of strong Solar Energetic Particles (SEP) thru correlation with $^{10}Be$ and $^{36}Cl$ excursions in polar ice cores. Other proposed events are still under examination with ice core records to determine the cause of these rapid changes in $^{14}C$ production rate. Notable, other proposed events show different structures, coincide with Grand Solar Minima or of a lesser magnitude (see 815BCE, 5480BCE, 5410BCE, 1052/1054CE and 1279CE event). Understandably, other types of change in $^{14}C$ production also need to be replicated and confirmed with additional tree rings as well as variations of cosmic isotopes in ice cores. These excursions may be due to a mix of SEP and other astrophysical phenomena, such as gamma-ray bursts and geomagnetic excursions. We developed new annual and sub-annual $^{14}C$ datasets from tree rings in U.S. and Russia to confirm 1) whether the less-apparent spike around 1279CE and strong excursion with complex structure ca. 660 BC are reproducible and 2) whether new structural details for these events may appear at different latitudes and with finer time scale (1-year versa 2-3 month window). The new tree-ring locations are the Chuska Mountains (New Mexico, USA) and the Altai Mountains (Russia). We found a pronounced 660CE excursion in the new tree-ring record that confirms the original finding by Park et al. 2017. However, the results for 1279CE excursion reported by Brehm et al. 2021 is not confirmed. The annual $^{14}C$ series do not have a significant increase in $^{14}C$ production rate at this year, while early band and late band series of false rings register the spike (Fig.1). Another study examining the same interval with $^{14}C$ annual rings of asunaro (Japan) also do not did confirm the 1279CE excursion. We discuss the variance of carbon-14 signatures in time and space. The 1279CE signal is weak and befallen near the onset of the Wolf Grand Minima (ca. 1286CE). It seems that the intensity and structure of the $^{14}C$ signal is multifaced, which complicates understanding of the forcing and attribution to the underlying astrophysical events. Nevertheless, timing of these events is important to register the underlying recurrence intervals of these rapid events for identified and future $^{14}C$ excursions. More $^{14}C$ series from tree rings at various locations are needed to characterize such rapid but weak ‘events’ in the $^{14}C$ annual record. Can the cosmogenic isotope excursions recorded in terrestrial archives be considered extreme space weather events?
*Funding:* This research was supported in part by NASA grant 80NSSC21K1426 and the European Union and the State of Hungary, co-financed by the European Regional Development Fund in the project of GINOP-2.3.2-15-2016-00009 ‘ICER’. *Conflict of Interest*: A.J.T. Jull has disclosed an outside interest in Hungarian and Czech Academies of Sciences to the University of Arizona. Conflicts of interest resulting from this interest are being managed by the University of Arizona in accordance with its policies.

 

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Keywords: Radiocarbon , Tree Rings, Solar Energetic Particle event, Grand Solar Minima, Gamma Ray

**Figure 1.** Map with tree-ring locations of new and other $^{14}C$ records for the 1279CE excursion. A) New annual $^{14}C$ series from Ponderosa pine rings of the Chuska Mountains, U.S. New Mexico and Siberian larch of the Altai Mountains, Russia. B) Early band and late band series of Ponderosa pine "false" rings from the Chuska Mountains representing April-June and July-August growth. Vertical bars show the measurement error. Green vertical line marks the position of spike 1279CE proposed by Brehm et al. 2021.