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Space or climate? Disentangling cosmogenic and climatic drivers of present-day tritium (^3H) in global precipitation

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The generation of cosmogenic tritium (^3H) through spallation of ^{14}N in the upper atmosphere and a its decay (half-life of 12.32 y) are the two main processes resulting in the global steady-state inventory of tritium in the hydrosphere of approximately 2.95 kg. Various mechanisms of scavenging of stratospheric ^3H into the troposphere, such as stratosphere-troposphere transports (STTs) during the so-called “spring leak”, or the tropospheric distribution by means of the Brewer-Dobson circulation, have been described to explain the observed spatial and seasonal distribution of present-day tritium levels in global precipitation. Following thermonuclear weapons testing prior to the Preliminary Test Ban Treaty in 1963, the natural ^3H input signal was overlaid by the so-called “bomb peak”. This characteristic tritium pulse has been used for decades in nuclear and hydrological sciences, with ^3H values in Vienna, the reference northern hemisphere station of the IAEA-WMO Global Network of Isotopes in Precipitation (GNIP), peaking in 1963 at approximately 400 Bq L^{-1}. Since the year 2000, this ^3H pulse has dissipated in the northern hemisphere, and ^3H levels at the Vienna monitoring site have reached their natural background value of ca. 1.2 Bq L^{-1}.

The present-day steady state of natural ^3H levels in precipitation allow to research their inter-annual variability as driven by cosmogenic input, with particular emphasis on neutron flux intensity governed by the 11-year sunspot cycles. With almost two full solar cycle’s worth of observed ^3H data in Vienna’s precipitation and other GNIP stations in the northern hemisphere, we discuss the impact of the neutron flux (as exemplified by the Oulu Neutron Monitor) in modulating the inter-annual variability. Our findings showed that while 52% of the interannual variability was explained by changes in the cosmogenic flux, an additional 31% of the variability resulted from the seasonal distribution of the amount of precipitation, a finding prominent in the previous solar cycle valley, particularly in the year 2015, that coincided with abnormally high winter precipitation.

While the regular oscillations of the neutron flux seem to constitute the main driver of the observed interannual changes of ^3H contents in precipitation, atmospheric circulation processes were of varying importance in 15 GNIP stations. In spite of the relative data paucity (i.e. absence of sufficiently long records at even spatial distribution), we hypothesize that changes in precipitation seasonality, due to climate change impacts on global or regional atmospheric circulation patterns, may drive fluctuations in the natural steady-stage ^3H levels in precipitation used to investigate atmospheric and hydrological processes. Hence, we stress the importance of spatially and temporally adequate observational baselines on a global level.