



Institut de recherche pour le développement

Cosmogenic isotopes as proxies for the solar activity

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¹⁴C production and decay

cosmic

radiation





Geo- and helio-magnetic fields modulate the arrival of protons from galactic cosmic rays

> Cascade of particle reactions in the atmosphere (air shower)



Anti-correlation between the solar activity and the cosmic-ray flux measured by neutron monitors



Usoskin 2013 Liv. Rev. Solar Phys.

Geo- and heliomagnetic modulation

geomagnetic latitude



Production (¹⁰Be) as a function of altitude, the solar modulation potential ⊕ and the intensity of the geomagnetic dipole M/M_o



Studying the solar activity with cosmogenic nuclides from various "geological" archives"

¹⁴C & ¹⁰Be in marine sediments

¹⁴C in subfossil wood

¹⁴C in corals

¹⁰Be & ³⁶Cl in polar ice

¹⁴C in stalagmites

¹⁴C & ¹⁰Be by accelerator mass spectrometry in Aix-en-Provence





ASTERisques

The most recent ¹⁴C calibration curve prepared by the IntCal group: IntCal13 after 09, 04, 98, 93

Radiocarbon

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Volume in Open Access http://www.radiocarbon.org

RADIOCARBON, Vol 55, Nr 4, 2013, p 1869-1887

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INTCAL13 AND MARINE13 RADIOCARBON AGE CALIBRATION CURVES 0–50,000 YEARS CAL BP

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Atmospheric ¹⁴CO₂ molecules diffuse in the other reservoirs of the carbon cycle



Comparing ¹⁴C and ¹⁰Be records requires the use of numerical models of various complexity





Bomb tests in the early 60s provide us with the impulse response function



Hua & Barbetti 2004 Radiocarbon

The bomb ¹⁴C has diffused into other reservoirs of the carbon cycle, e.g. the ocean



Grottoli & Eakin 2007 Earth Sci. Rev.

Jenkins et al. 2010 Radiocarbon

Crightal tasks?

name brain probin

¹⁰Be measured in ice cores from Antarctica

> Barkne Island

Dome Yuj

Vosh

EPICA DC

TALDICE

South Pole

EPECA DAL

Ross Sea

¹⁰Be in ice cores from Antarctica and ¹⁴C in tree-rings (all converted in ¹⁴C units)



Bard et al. 1997 EPSL, 2000 Tellus, Horiuchi et al. 2008 QG, Delaygue & Bard 2011 Clim. Dyn.

¹⁰Be records from Greenland and Antarctica (GRIP and EDML)



Steinhilber et al. 2012 PNAS

Extracting the solar activity from the IntCal ¹⁴C curve



Stuiver et al. 1998 Radiocarbon as plotted by Solanki et al. 2004 Nature

Sunspot number reconstruction over the Holocene



Solanki et al. 2004 Nature

Sensitivity to the geomagnetic records

-6000

-8000



-4000

Years (-BC/AD)

-2000

2000

Usoskin et al. 2006 GRL, 2007 A&A

An unexpected and mysterious result in Δ^{14} C records with annual resolution

240 | NATURE | VOL 486 | 14 JUNE 2012

A signature of cosmic-ray increase in AD 774–775 from tree rings in Japan

Fusa Miyake¹, Kentaro Nagaya¹, Kimiaki Masuda¹ & Toshio Nakamura²

LETTER





doi:10.1038/nature11123

The spike has been replicated in trees from Germany, California, Siberia and New-Zealand



Carbon cycle box modeling shows it is compatible with an increase of 15-20 kg of ¹⁴C ≈ 2-3 times the average yearly production by GCR

Another spike (10 ‰) detected around 994 AD



Miyake et al. 2013 Nat. Comm.

Previously detected in a ¹⁰Be record from Antarctica but at low resolution



The spike is too rapid and too large for the solar modulation of galactic cosmic rays, hence: ➤ Supernova (but no other evidence), ➤ Strong solar energetic particle (SEP) event

Many thanks for listening

C Sigurður H. Stefnisson