

Solar cyclic activity reconstruction now covers the last millennium

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Solar cycle in sunspots and cosmic rays

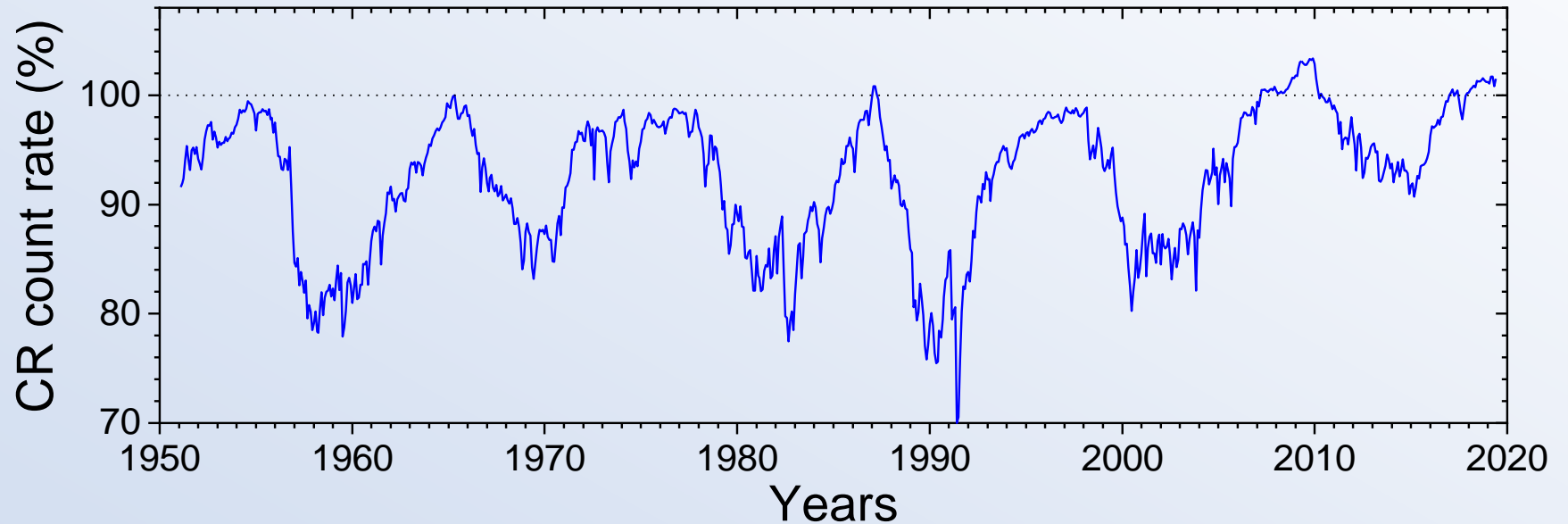
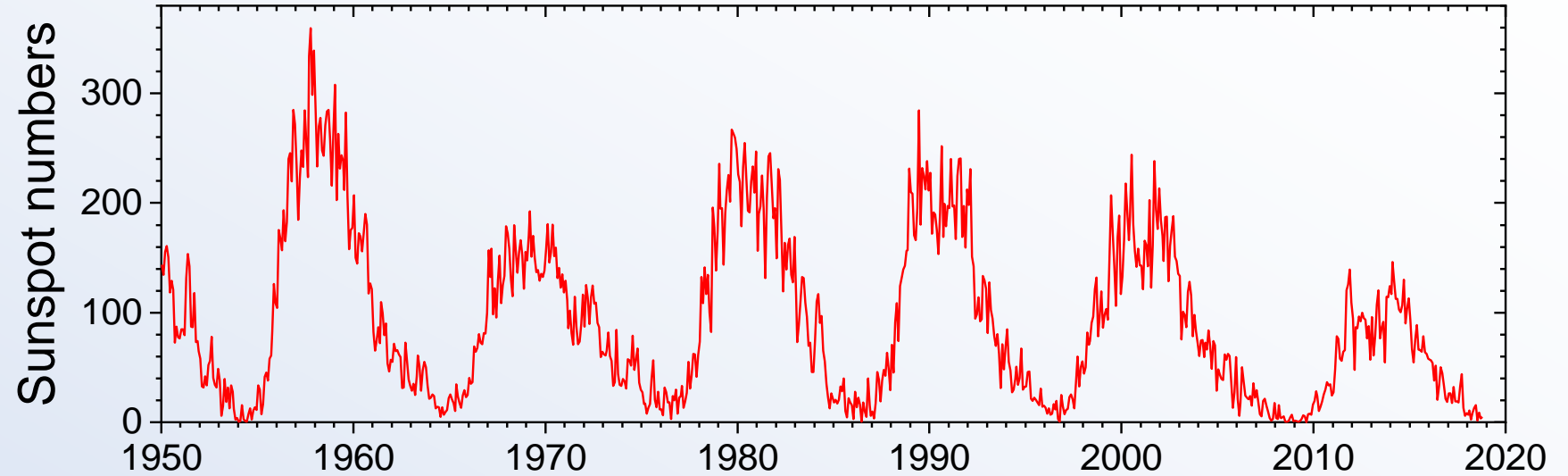


11-year cycle due to solar activity

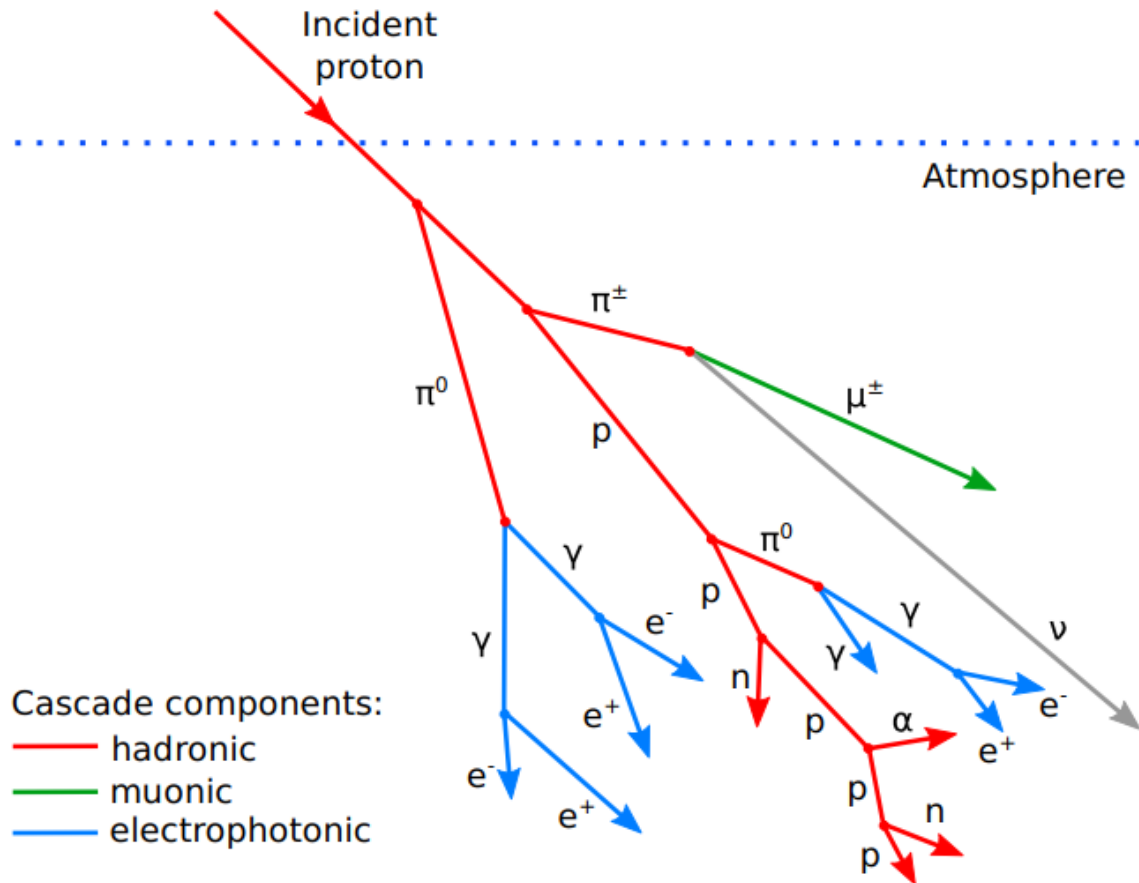
Weak 22-yr cycle (charge-dependent drift effects)

short-term fluctuations

Centennial variability?



Cosmogenic-isotope production

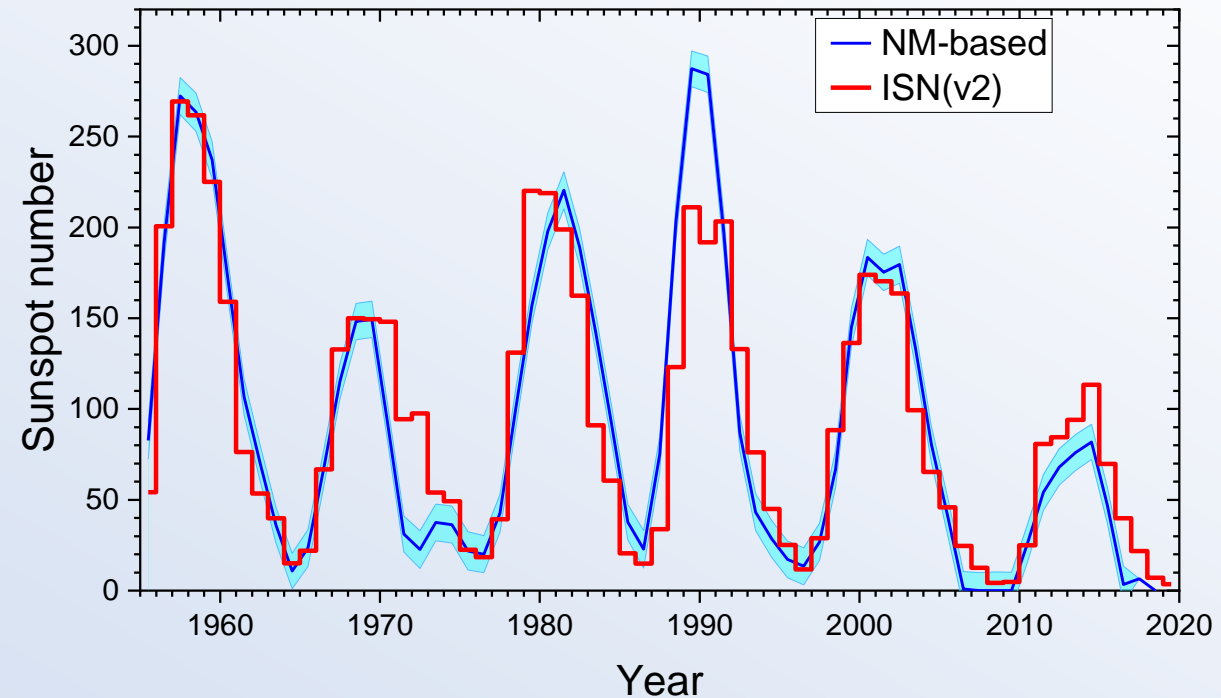


In the atmospheric cascade, nuclear reactions may take place, most important being:

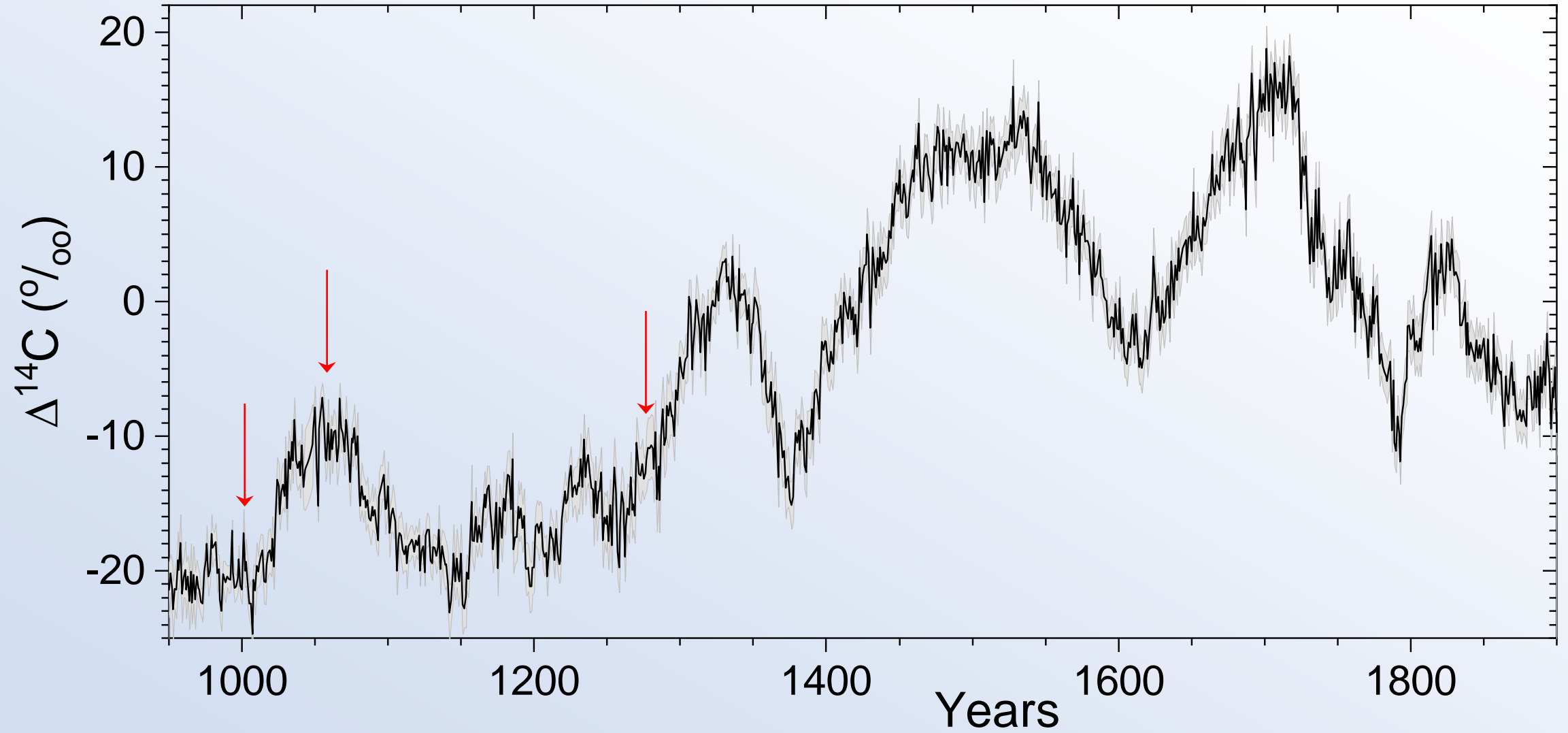
Spallation $O, N, Ar \rightarrow {}^7\text{Be}, {}^{10}\text{Be}, {}^{22}\text{Na}, {}^{36}\text{Cl}, \text{etc.}$

Neutron capture: ${}^{14}\text{N}+n \rightarrow {}^{14}\text{C}+p$

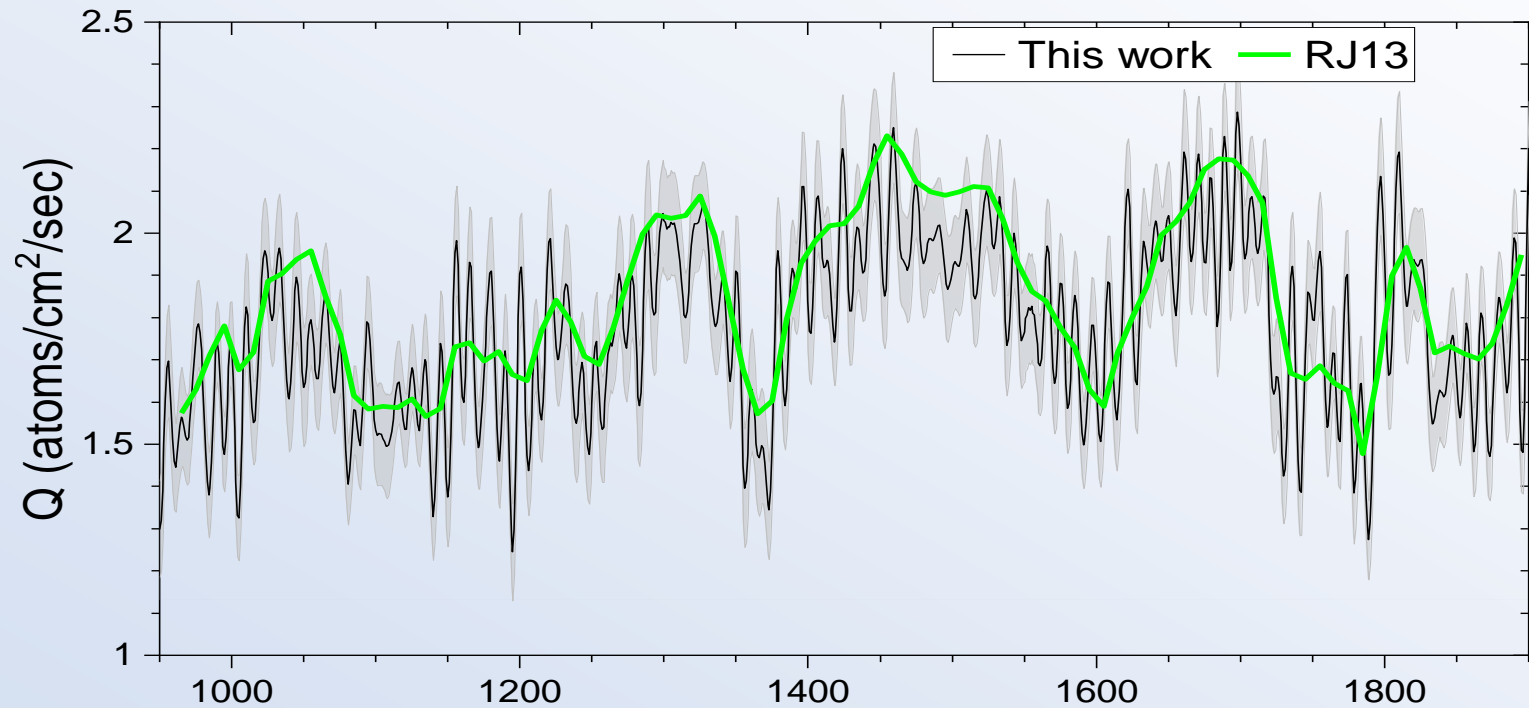
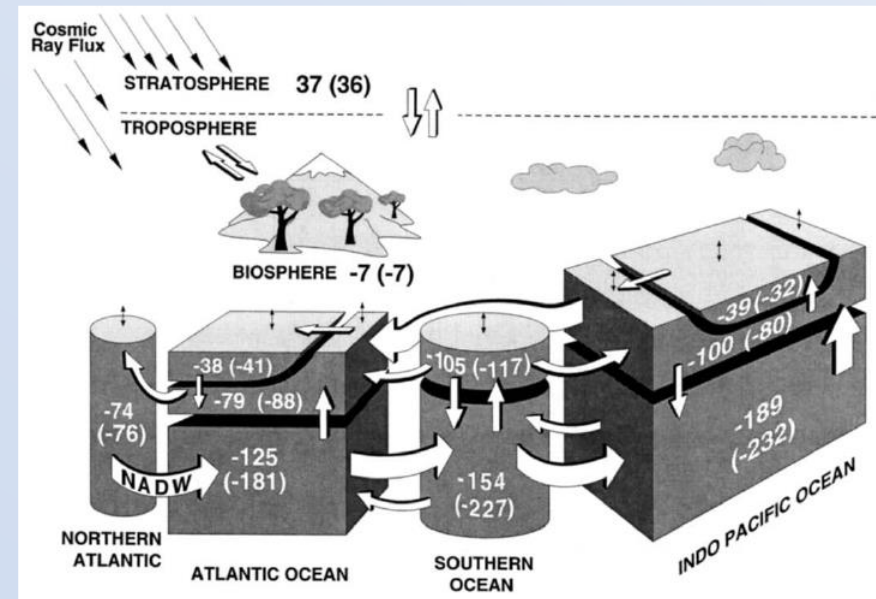
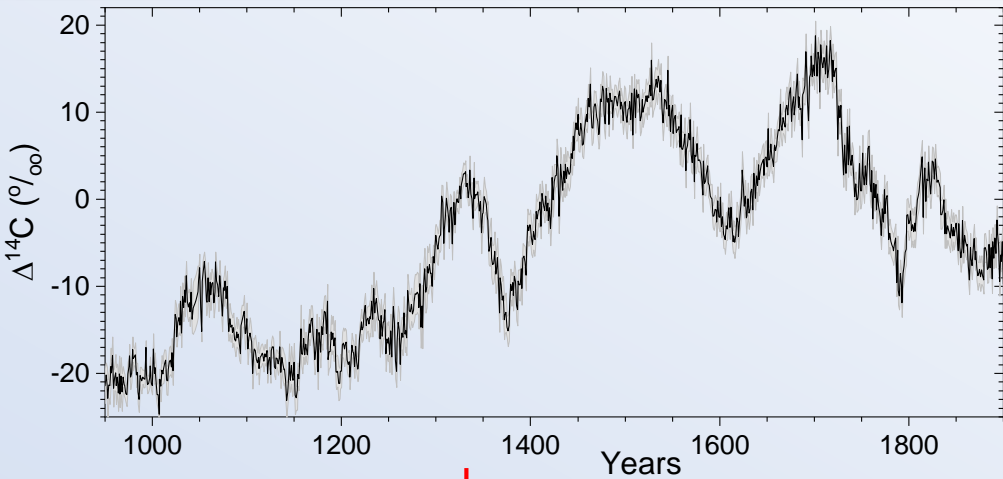
Storage in natural independently dated archives: ice cores, tree trunks, sediments, corals



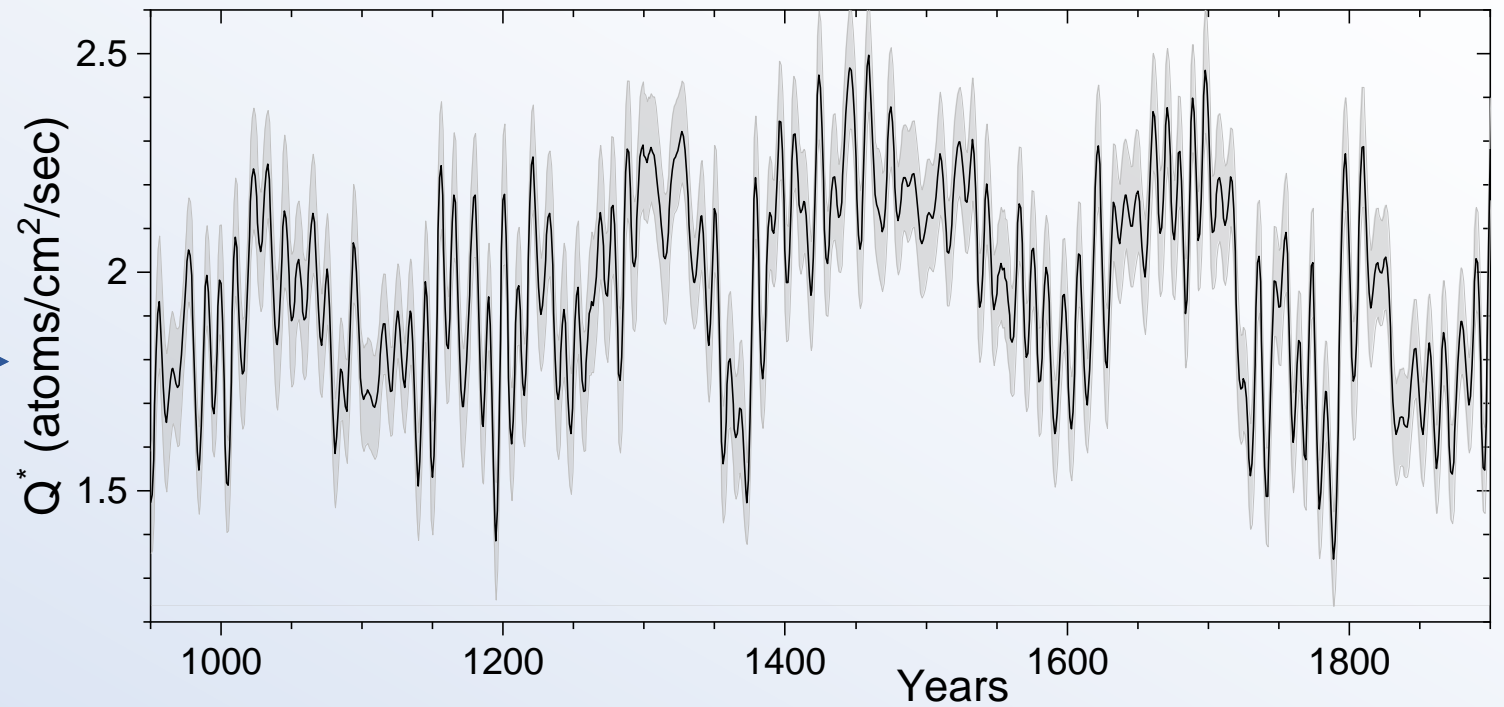
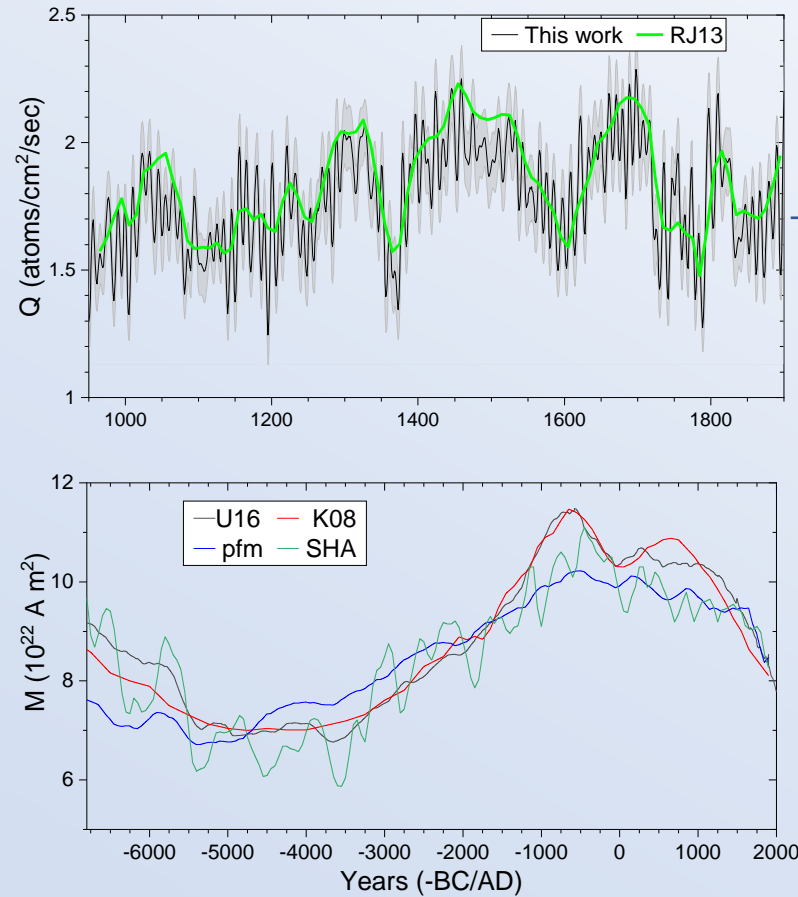
Data



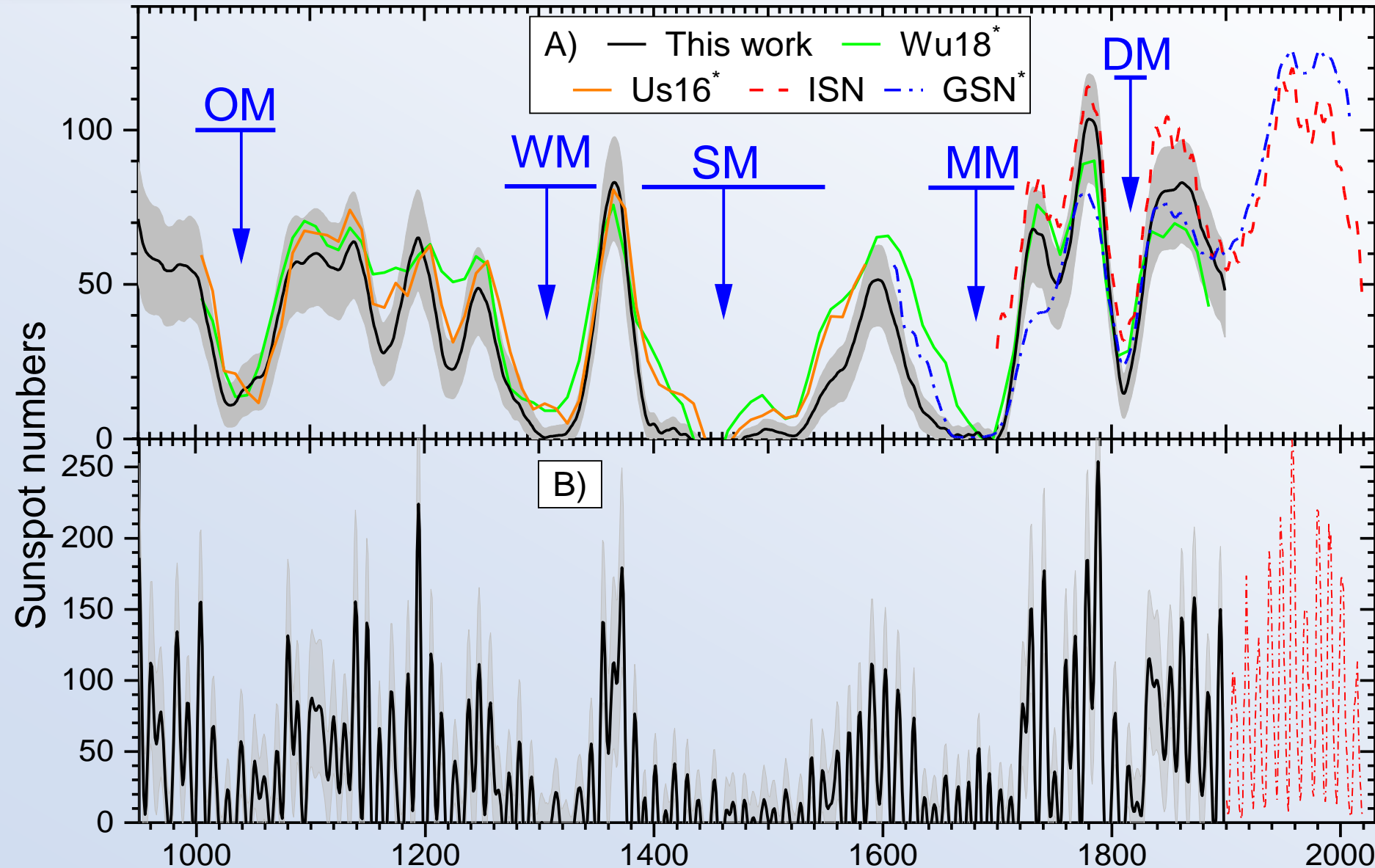
Q14C – production rate



Correction for the geomagnetic field



Solar activity reconstruction

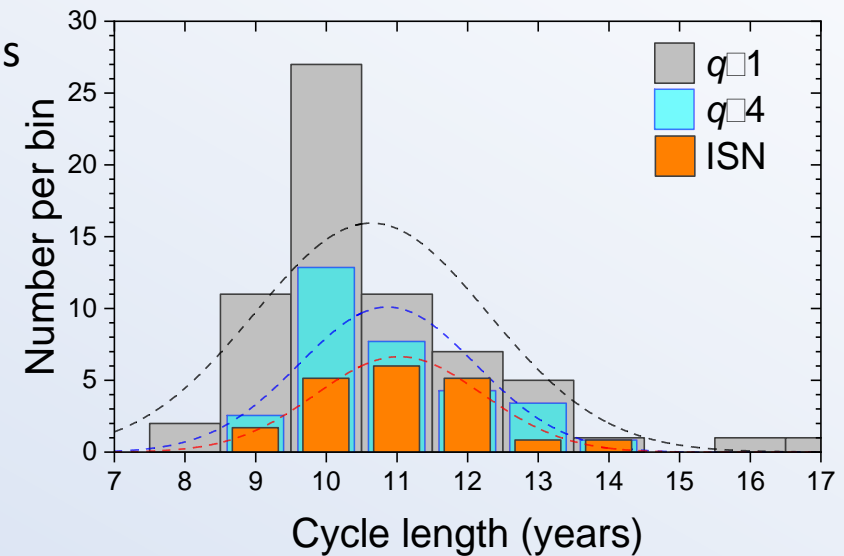
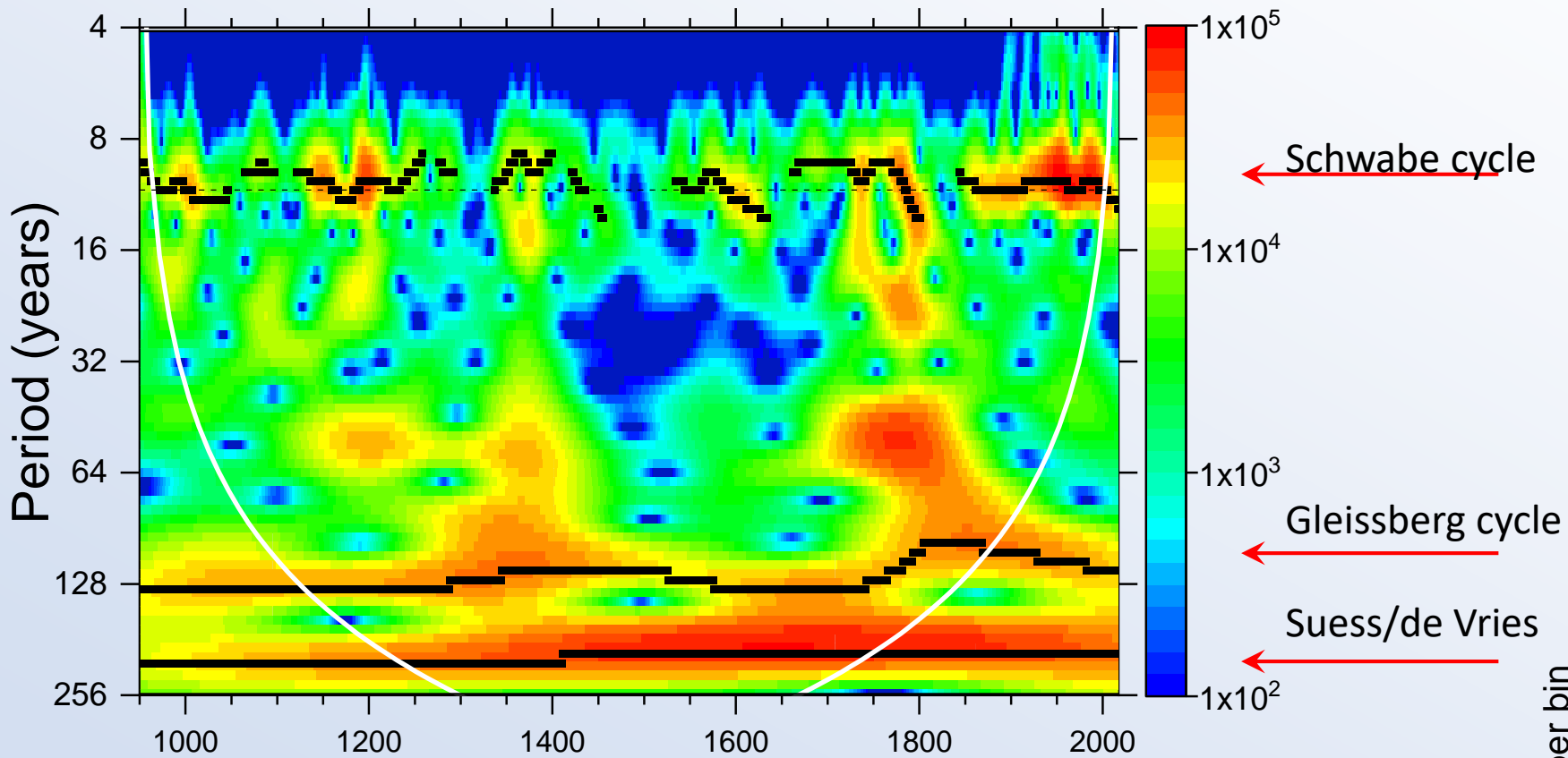


Direct sunspots → **36** solar cycles (**24** well, **8** poorly and **4** unresolved cycles)

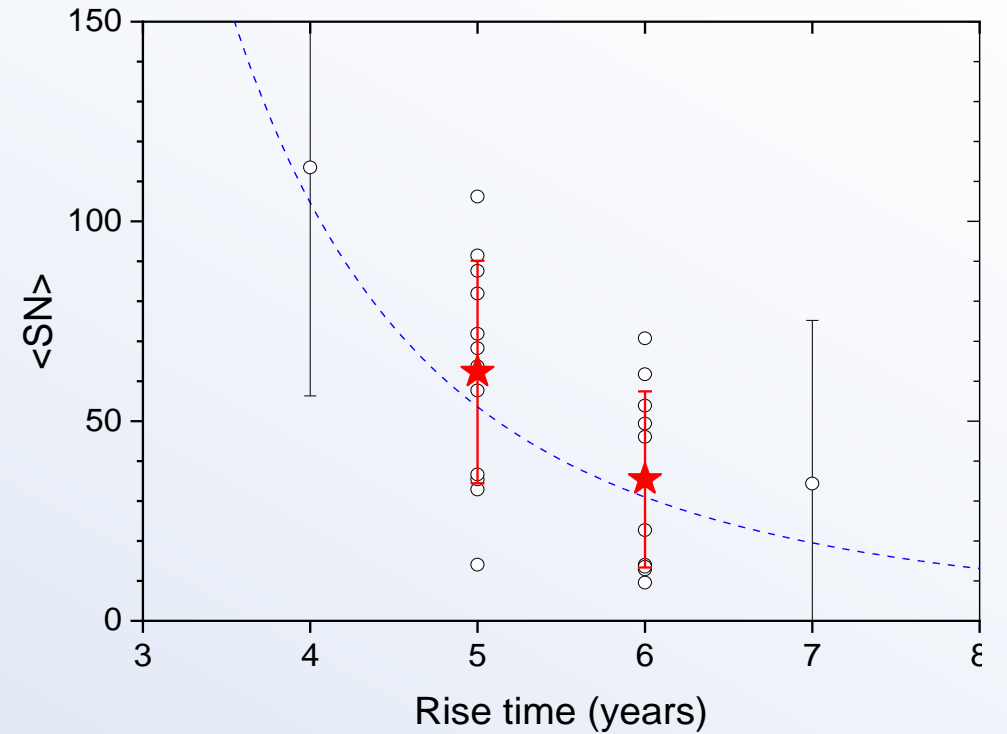
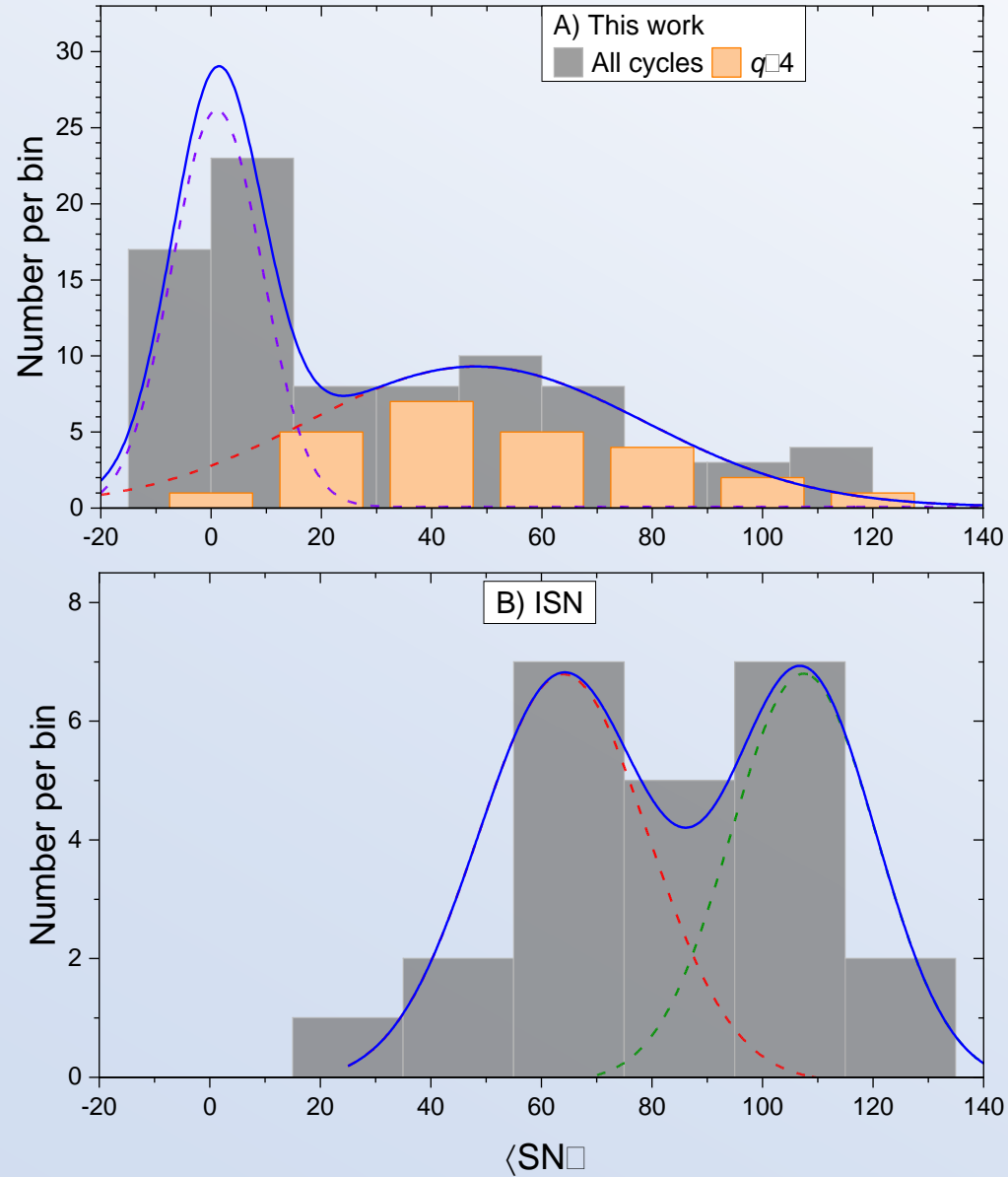
Proxy → **85** cycles (**35** well/reasonably, **21** poorly and **29** not reliably resolved)

Altogether: **96** (**50** well-, **17** poorly- and **29** not resolved cycles)

Periodicities and cycle lengths



Solar cycles and Waldmeier rule



Waldmeier's rule for good ($q > 3$) cycles:
 $R \sim 0.62$

Summary



- New the-highest-precision measurements of ^{14}C in tree rings have been made with annual resolution since 950 AD;
- About 90 individual solar cycles can be resolved for 950–1900, thus, the total number of solar cycles is about 96 now.
- Gleissberg and Suess/de Vries cycles are confirmed;
- 40% of time (~ 400 years) the Sun spent during the grand minimum mode (~ 200 years in the deep minimum state, with $\text{SN} \rightarrow 0$). This was a cluster of grand minima.
- The Waldmeier rule is statistically confirmed.
- A new door is open to study solar activity on a millennium time scale.

THANK YOU !