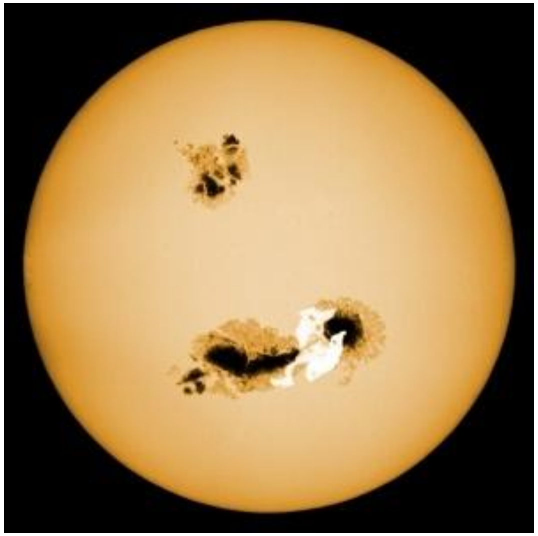
Vorlesungsfolien

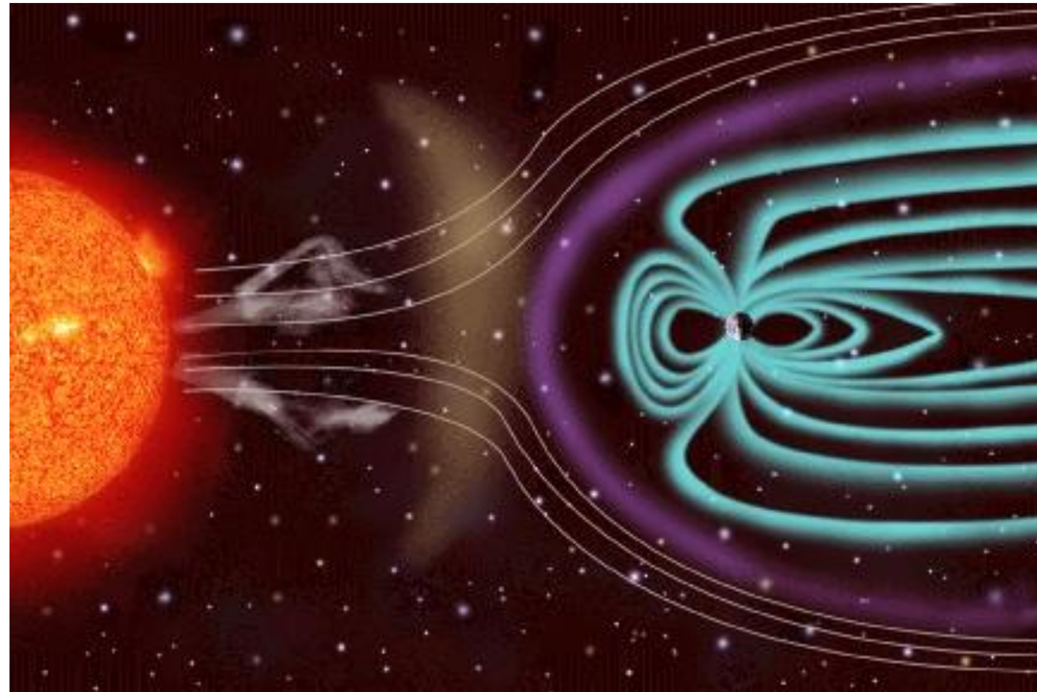
Radioisotope
8. Mai

Vorl. Terra-Astronomie
SoSe 2017

Ralph Neuhäuser

Mehr Sonnen-Aktivität (Flecke UND koronale Löcher) ➔ mehr Sonnen-Wind ➔ Geo-magnetische Aktivität und Aurorae

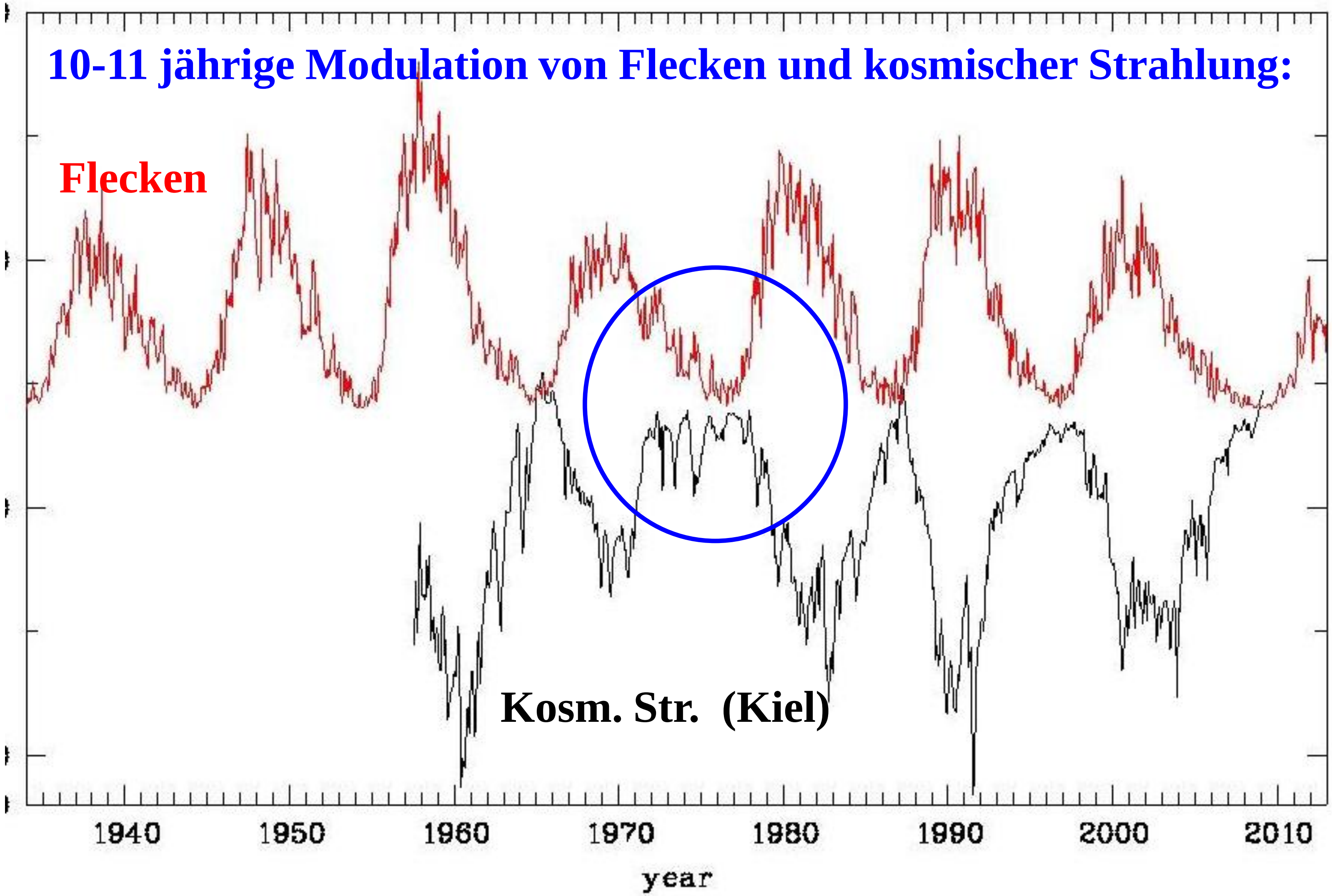




Je stärker der Sonnen-Wind,
desto weniger kosmische Strahlung
kommt ins Sonnensystem.

Weniger aktive Sonne, mehr kosm. Str.

➔ 10-11 jährige Modulation von
Flecken, Aurorae und kosm. Strahlung.
(Schwabe Zyklus)



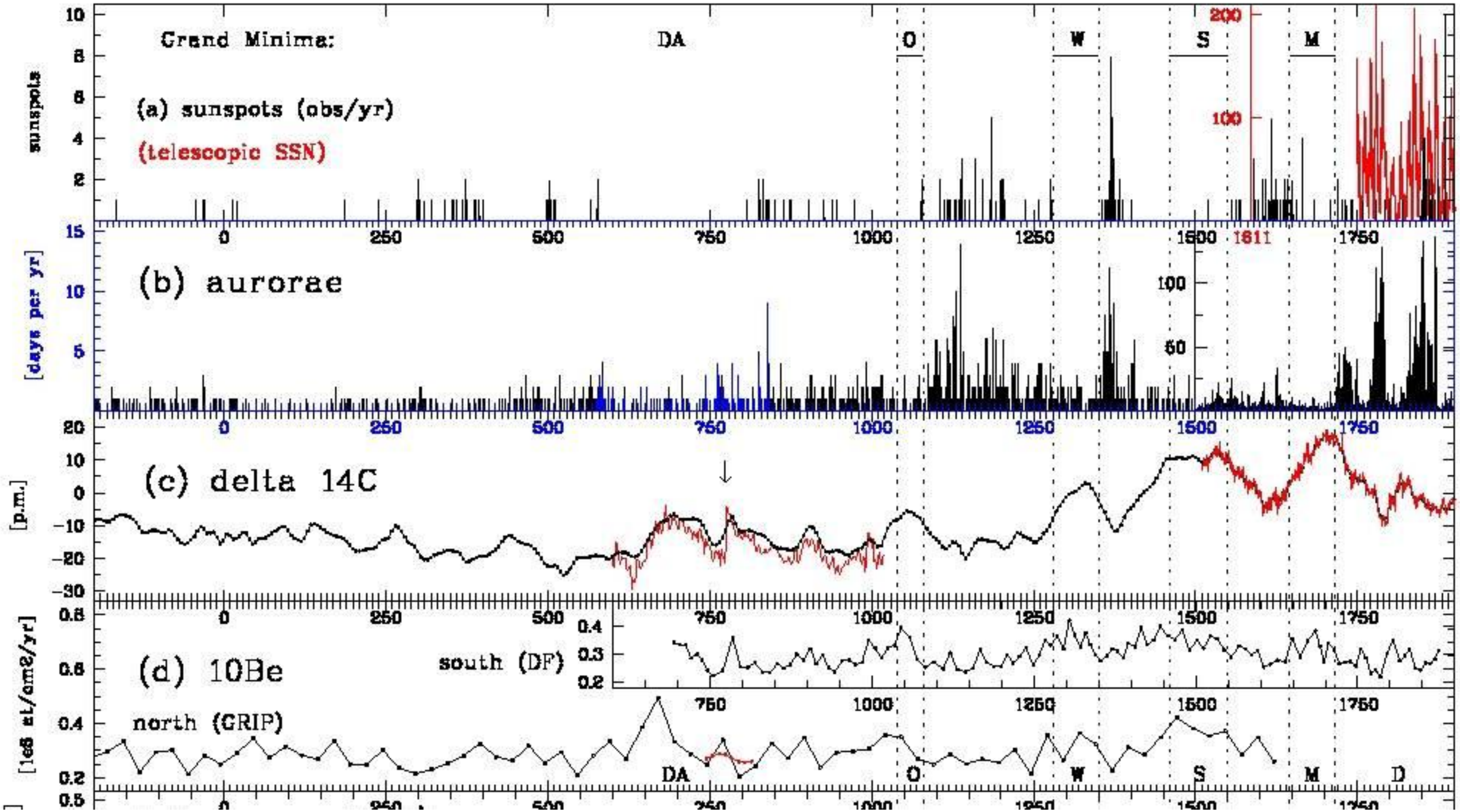
Je stärker der Sonnen-Wind, desto weniger kosmische Strahlung.

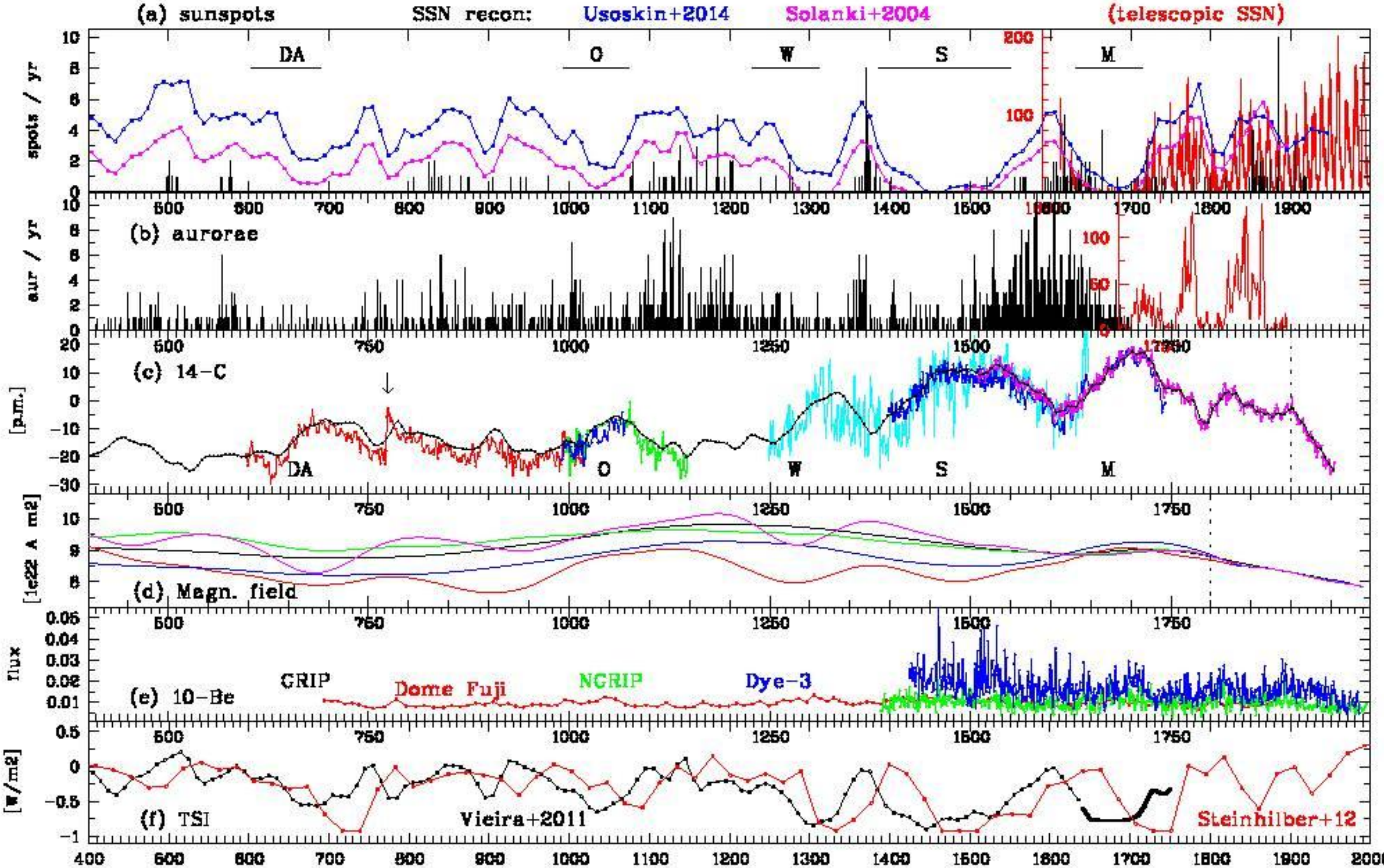
Weniger aktive Sonne, mehr kosm. Str.

➔ 10-11 jährige Modulation von Flecken, Aurorae und kosm. Strahlung.

Wenig Sonnen-Aktivität ➔ wenig Wind ➔ mehr kosm. Strahlung
➔ mehr ^{14}C und ^{10}Be

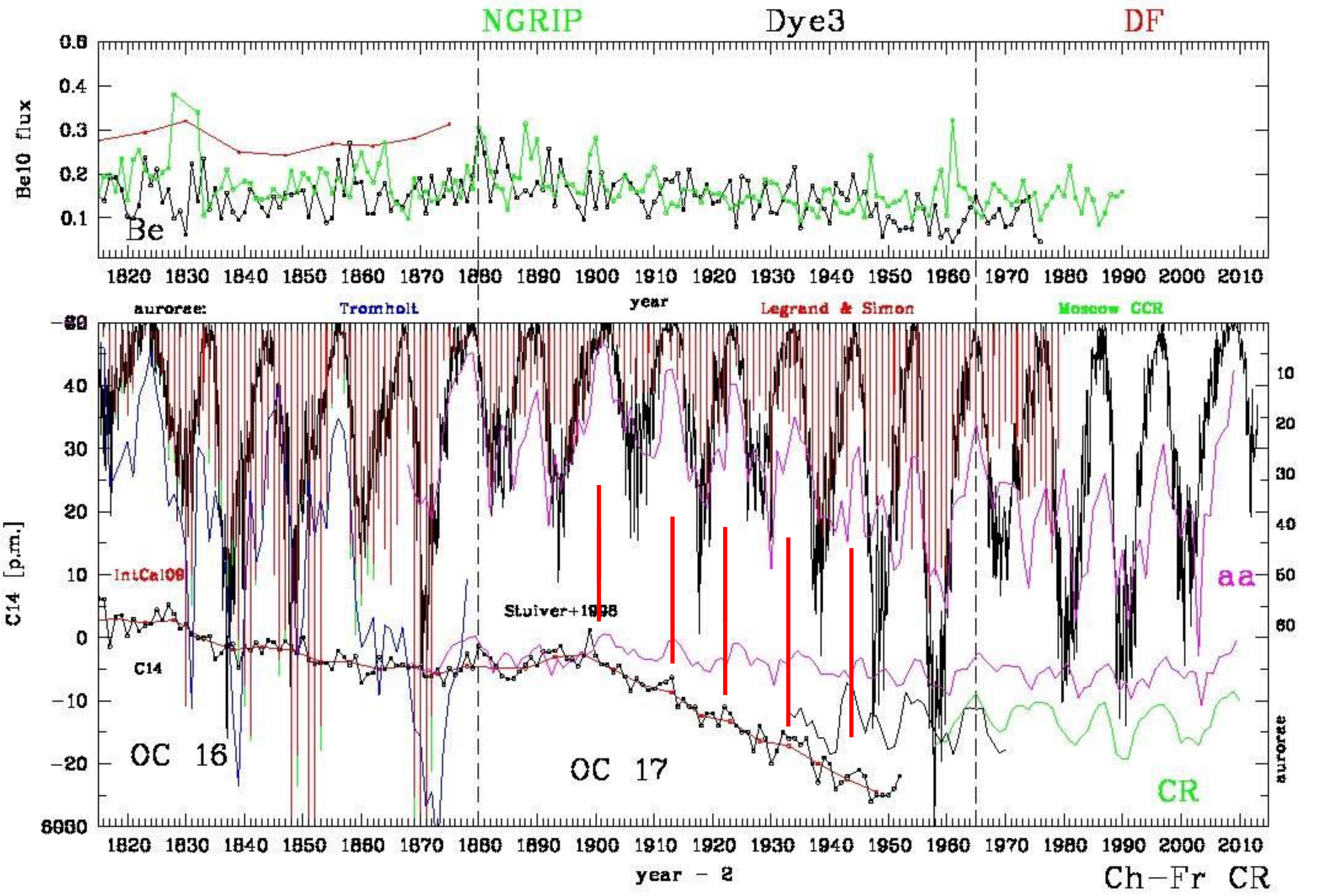
Grand Minima: **D**ark **A**ge **O**ort **W**olf **S**pörer **M**aunder



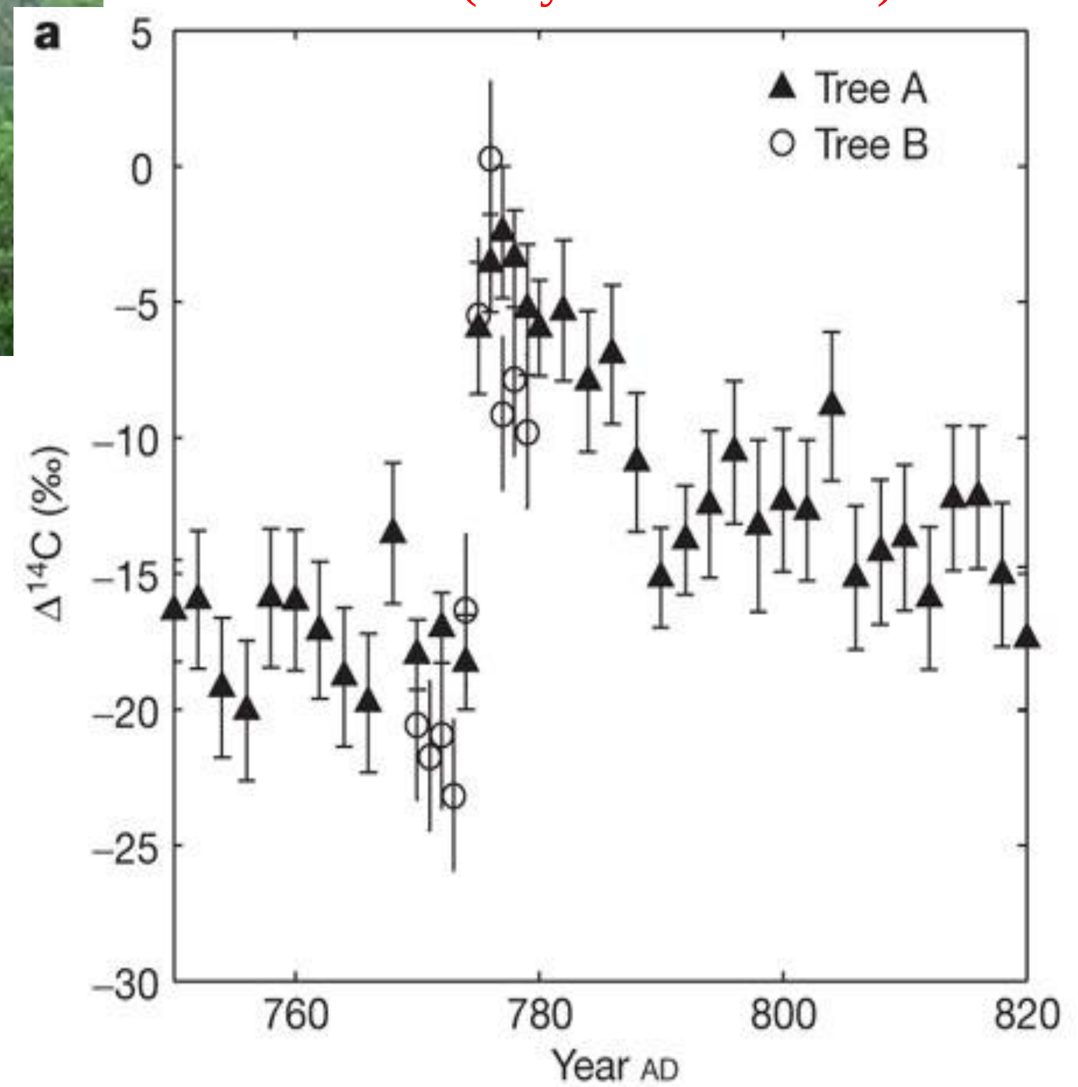


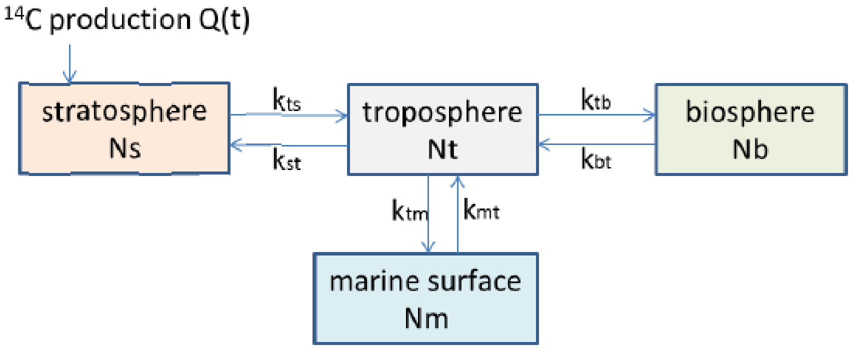
(a) sunspots
SSN recon:
Usoskin+2014
Solanki+2004
(telescopic SSN)
spots / yr
DA
O
W
S
M
(b) aurorae
aur / yr
(c) 14-C
[p.m.]
(d) Magn. field
[1e22 A m2]
(e) 10-Be
flux
GRIP
Dome Fuji
NGRIP
Dye-3
(f) TSI
[W/m2]
Vieira+2011
Steinhilber+12

Schwabe-Zyklus bei C-14, Be-10 und kosm. Str. (?)



Starker Variation
des Radiokarbon (^{14}C)
um AD 775
in japanischen Zedern
(Miyake et al. 2012)





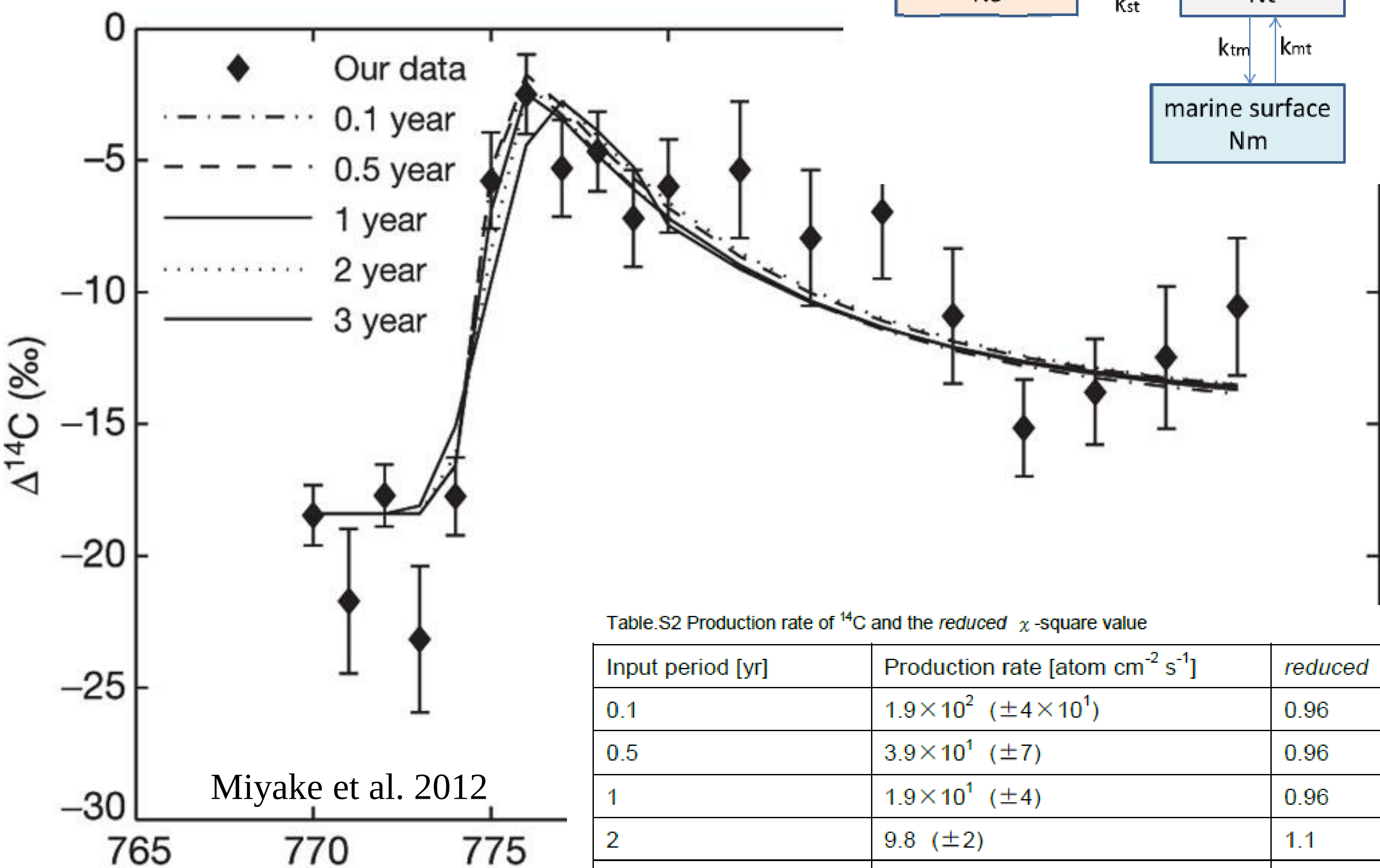


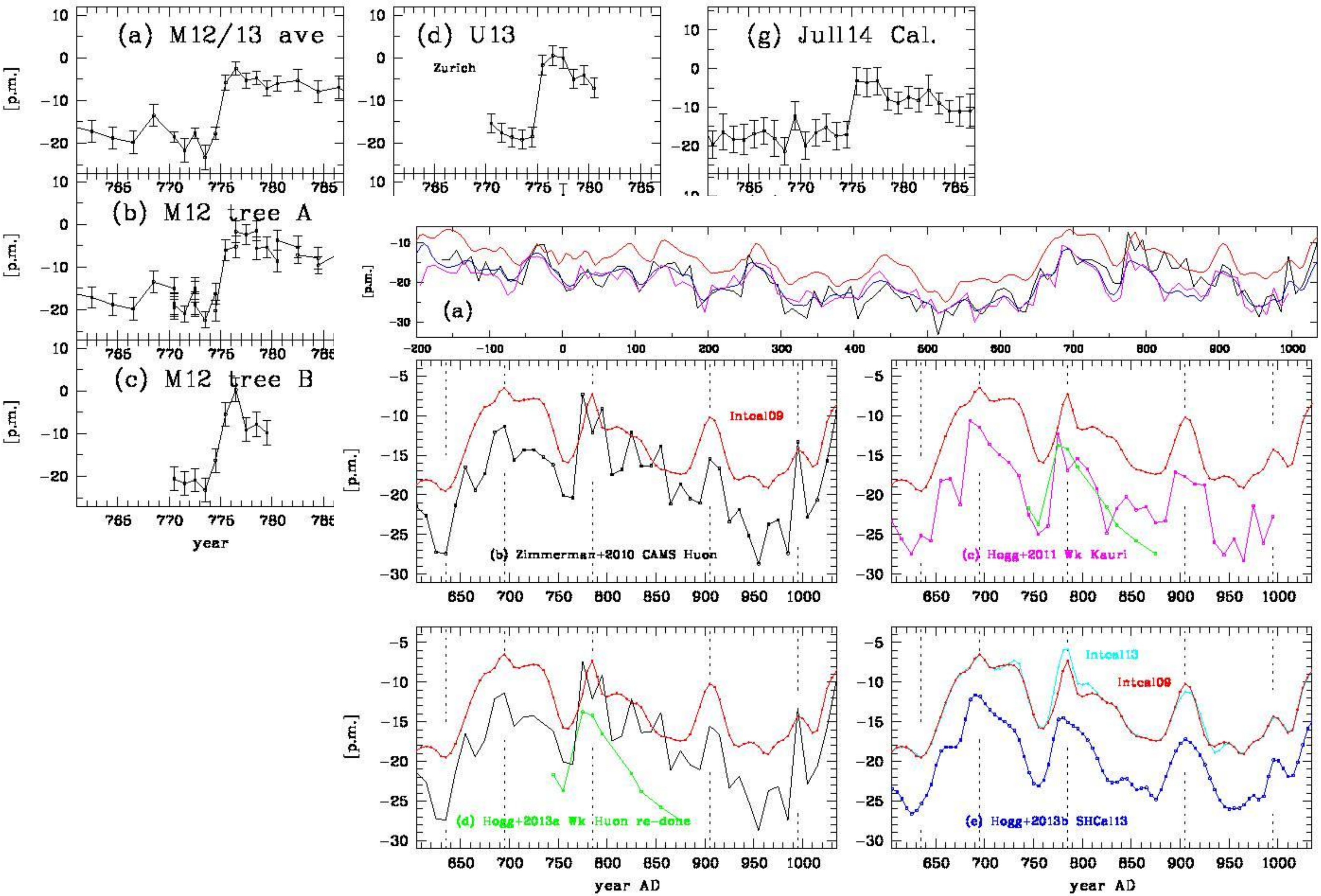
Table.S2 Production rate of ^{14}C and the *reduced* χ-square value

Input period [yr]	Production rate [atom cm^{-2} s^{-1}]	*reduced* χ-squared value
0.1	1.9×10^{2} ($\pm4\times10^{1}$)	0.96
0.5	3.9×10^{1} (±7)	0.96
1	1.9×10^{1} (±4)	0.96
2	9.8 (±2)	1.1
3	6.6 (±1)	1.6

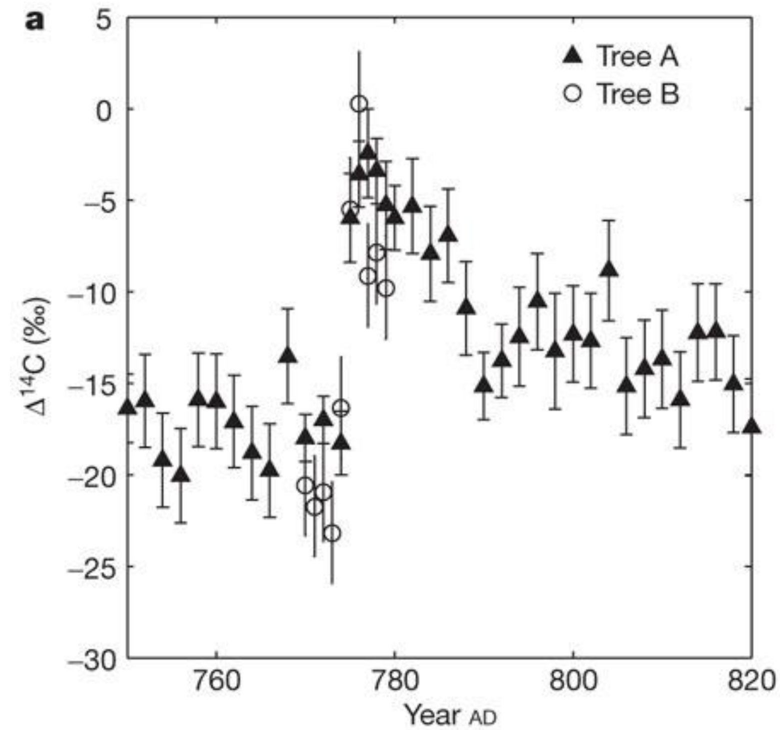
(7.0 +/- 1.5) x 10^{24} erg γ-Strahlen-Input auf die Erde (oberhalb 10 MeV)

oder

(8 +/- 2) x 10^{25} erg (Protonen-Input) als solare Protonen (2 x 10^{35} erg auf der Sonne)


(a) M12/13 ave
(d) U13
Zurich
(g) Jull14 Cal.
(b) M12 tree A
(c) M12 tree B
[p.m.]
year
(a)
Intcal09
(b) Zimmerman+2010 CAMS Huon
(c) Hogg+2011 Wk Kauri
(d) Hogg+2013a Wk Huon re-done
Intcal13
(e) Hogg+2013b SHCal13
year AD

Was war die Ursache ?



Miyake et al. 2012

Supernova ? Nein, zu schwach

Gamma-ray burst ? zu selten

Sonnen-Flare ?

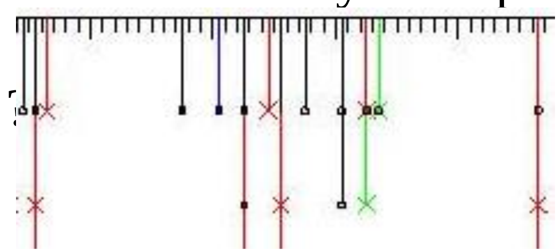
Sonstwas ?
(Komenteneinschlag, Magnetfeldschwankung, Vulkanausbruch, etc.)

Candidate Aurorae in the 770s:

770 Jun 20, Xian, China: “In the **NW**, a white vapour extended across the sky.” (Keimatsu) N=1, moon's last quarter Jun 20/21, possible aurora (?)

770 Jul 20, Xian, China: “A white vapour appeared in the **NW** direction. It extended accross the sky.” (Keimatsu), N=1, moon's last quarter Jul 2, possible aurora (?)

772 Sep 29, Ireland: “The assembly of the hand-clapping at which occurred lightning and thunder like the day of judgment. The hand-clapping on St Michael's Day 29 Sep which called **fire from heaven**.” (Usoskin)
N=2, new moon Oct 1, very possible aurora or thunderstrom ?



772 summer, Amida, Turkey: “Another sign appeared in the **northern** side …
a **red sceptre**, a **green** one, a black one, and a **yellow** one …
it would change into 70 shapes.” (Dall’Olmo)
N=3, probable aurora, between 771 Oct and 772 Sep at corn harvest: summer 772

773 June, Amida,Turkey: “The sign that was seen a year ago in the **northern** region was seen again in this year … **a red ray**, a **green** one …” (Dall’Olmo)
N=3, probable aurora, between 772 Oct and 773 Sep in Haziran: 773 June

(next 786)

Chronik von Zuqnin
aus Amida (= Diyabakır, Türkei),
beendet AD 775/6,
auf Alt-Syrisch (Palimpsest)

772: Ein anderes Zeichen erschien im Norden …
das war sein Anblick: Ein roter Strahl, ein grüner,
ein schwarzer und ein gelber. Es bewegte sich vom
Boden nach oben: Sobald ein Strahl niederging,
stieg ein anderer auf. Während es beobachtet wurde,
gab es 70 Veränderungen.

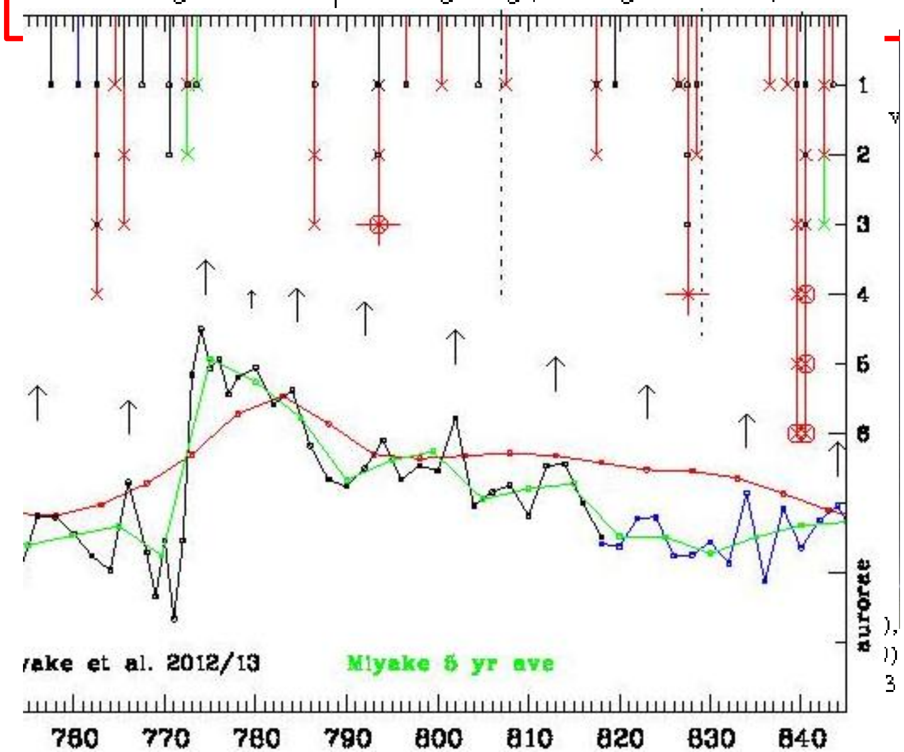
An einem Freitag im
Sommer AD 772

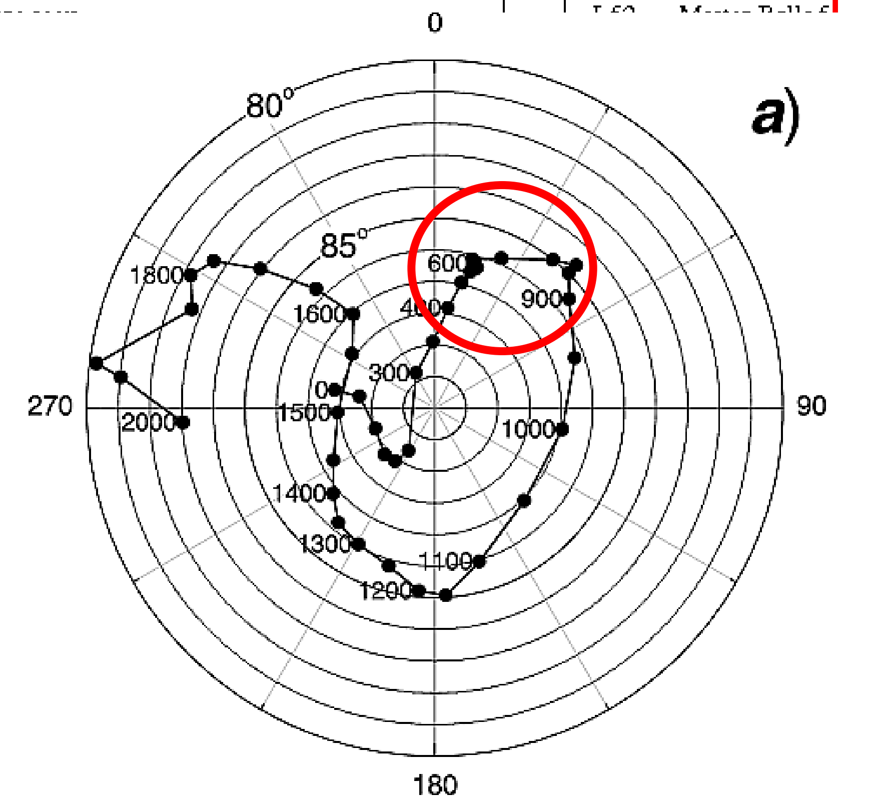
Und an einem Freitag
im Juni AD 773

Aurora sightings from AD 575 to 841

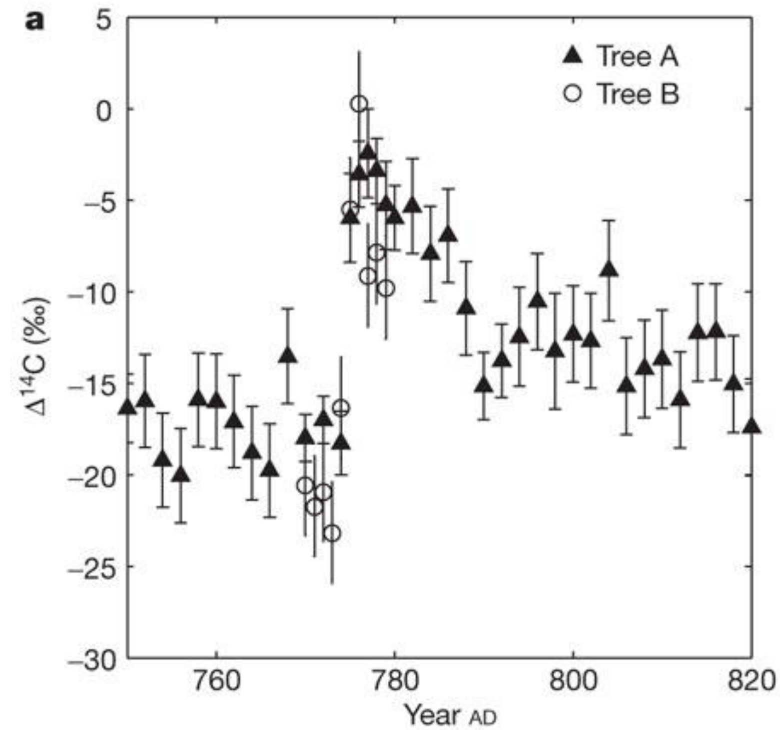
N: number of criteria for aurorae fullfilled. Fully independant events are separated by full horizontal lines. See text for details. References at bottom of table.

Year	location	reported text (original language or remark from lit. in brackets) [our comment]	N	Ref.	their sources
793	Arabia	In this year (177 hidschra, i.e. 793 Apr 18 - 794 Apr 6), according to what al-Waqidi has mentioned, there occurred a (violent) wind, and overshadowing (of the heavens) and a redness (in the sky), on the night of Sunday (i.e. the night of Saturday-Sunday, but actually Monday), the 26th of al-Muharram (793 May 13). Then there was a further overshadowing (of the heavens) on the night of Wednesday (i.e. the night of Tuesday-Wednesday), the 28th of al-Muharram (793 May 15), and then a violent wind and intense overshadowing of the heavens on Friday (actually Sunday), the 2nd of Safar (793 May 19). [very probable, new moon May 14/15, solar eclipse on May 14 in America, aurorae May 13-19]	4	NN	Bosworth 1989 f. al-Tabari
793	Europe	F73: large (Gross) [source not found, potential, maybe same as next]	0	F73	Schöning
793	Northumbria, England	In this year terrible portents appeared over Northumbria, and miserably frightened the inhabitants: these were exceptional high winds and flashes of lightning, and fiery dragons were seen flying in the air. A great famine soon followed these signs; and a little after that in the same year on 8 Jan, the harrying of the heathen miserably destroyed God's church in Lindisfarne by rapine and slaugther. [event with *heathen* men was first viking attac to England AD 793 Jun 8 according to Simeon of Durham; hence, the date given above in the Anglo-Saxon Chronicle text (Jan 8) is wrong, correct date is Jun 8] [very possible]	2	J70	Anglo-Saxon C.
793	England	S84: ca. AD 793 aurorae are seen in N Europe (fiery flying dragons and rain of blood)		S84	
793	England	terrific lightnings, and dragons in the air, and strokes [illegible]		[illegible]	[illegible]





Was war die Ursache ?



Miyake et al. 2012

Supernova ? Nein, zu schwach

Gamma-ray burst ? zu selten

Sonnen-Flare ? no

Sonstwas ?

(Komenteneinschlag, Magnetfeldschwankung, Vulkanausbruch, etc.)

In very cold spring and summer, some trees do not form a new tree ring (Mann et al. 2012 Nat. Geosc.)

Tree rings and volcanic cooling

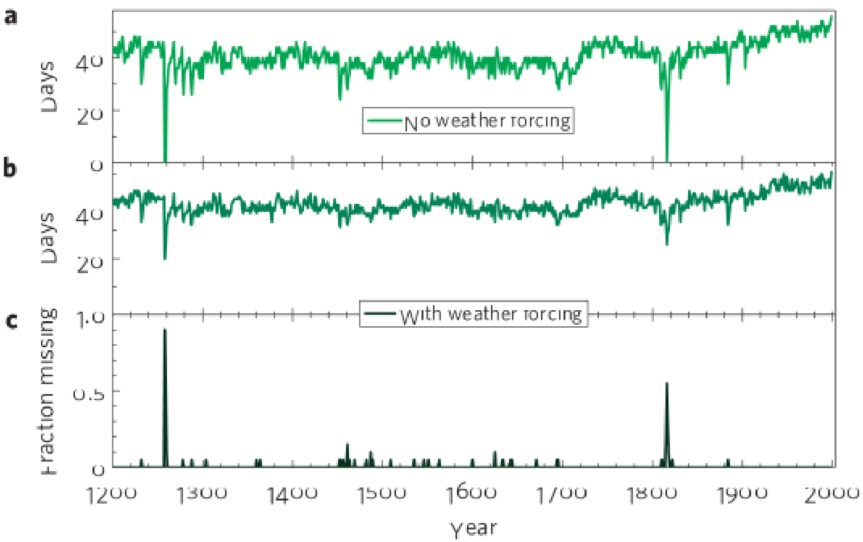
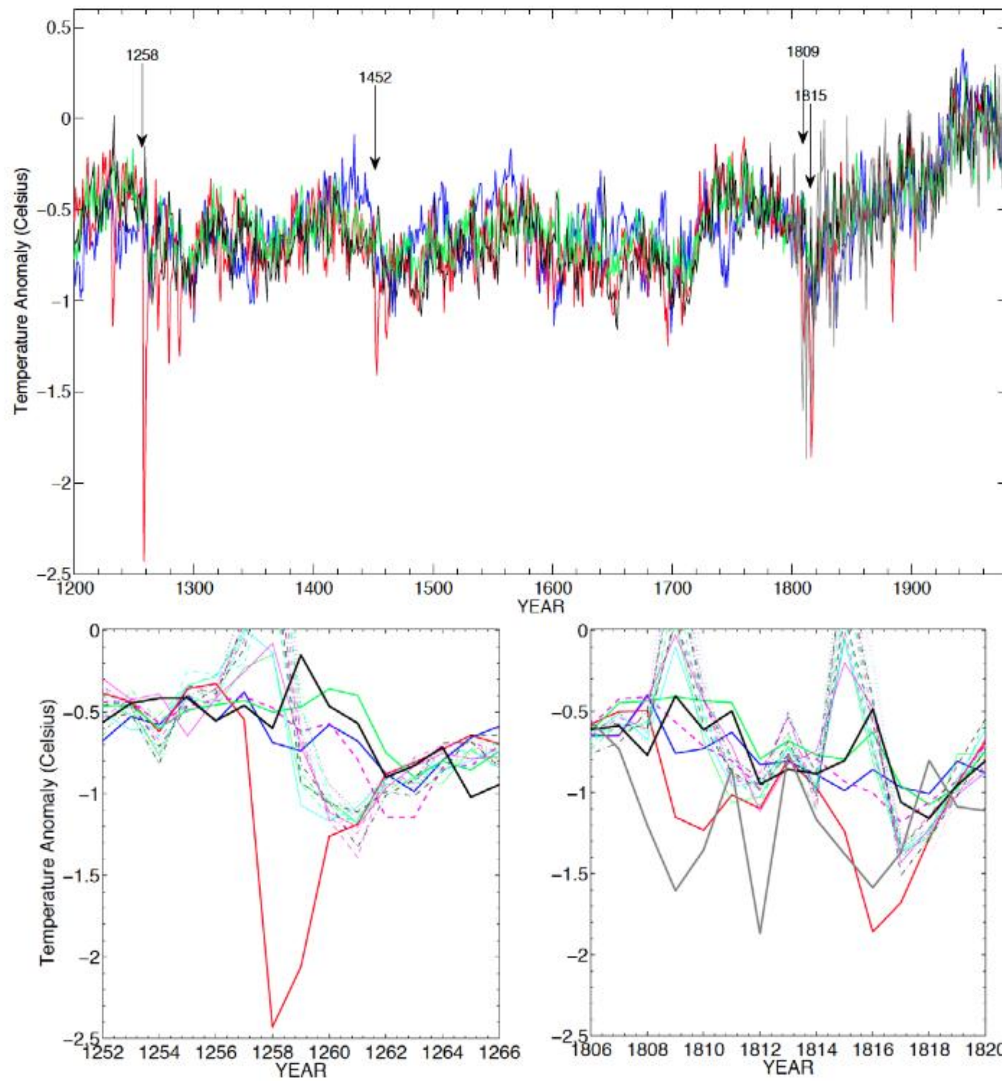


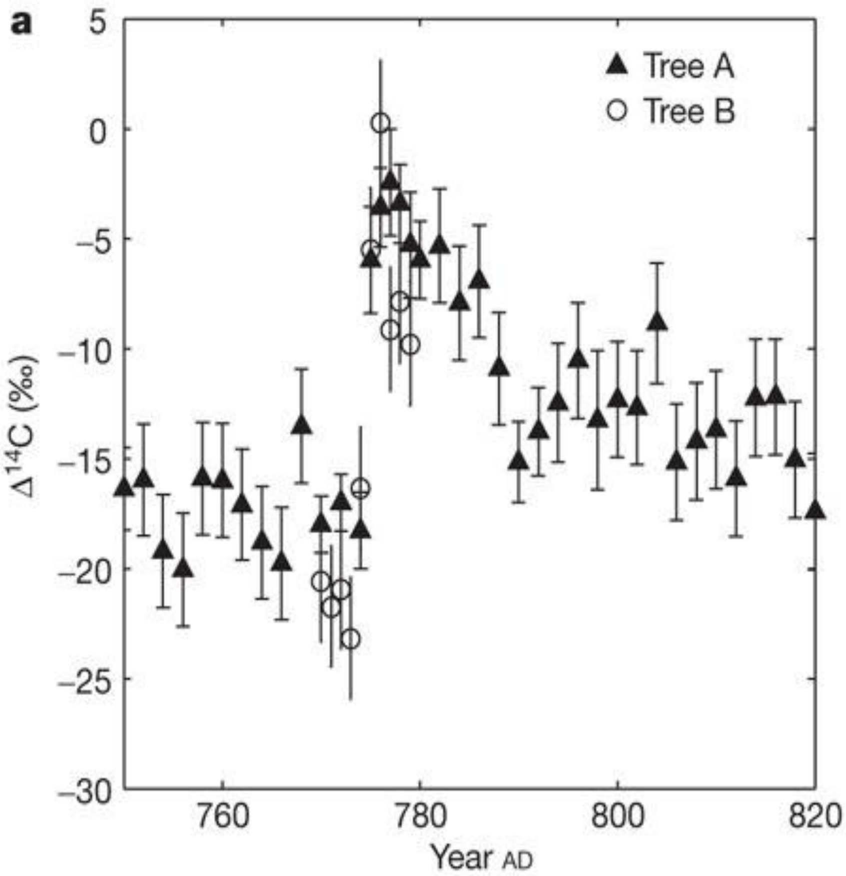
Figure 3 | Growing-season statistics. a,b, Estimated average length of the growing season (number of days of non-zero growth) based on the biological growth model driven by the GCM simulation without stochastic weather forcing (**a**) and with stochastic weather forcing (**b**). **c**, For the latter case, the fraction of the 20 regional series for which we infer a 'missing ring' for each year.



Short rise (7σ) within 1 yr

Difference in dating,
if no tree ring was formed
in 1 to few years ?!

Event was earlier (772 / 773)

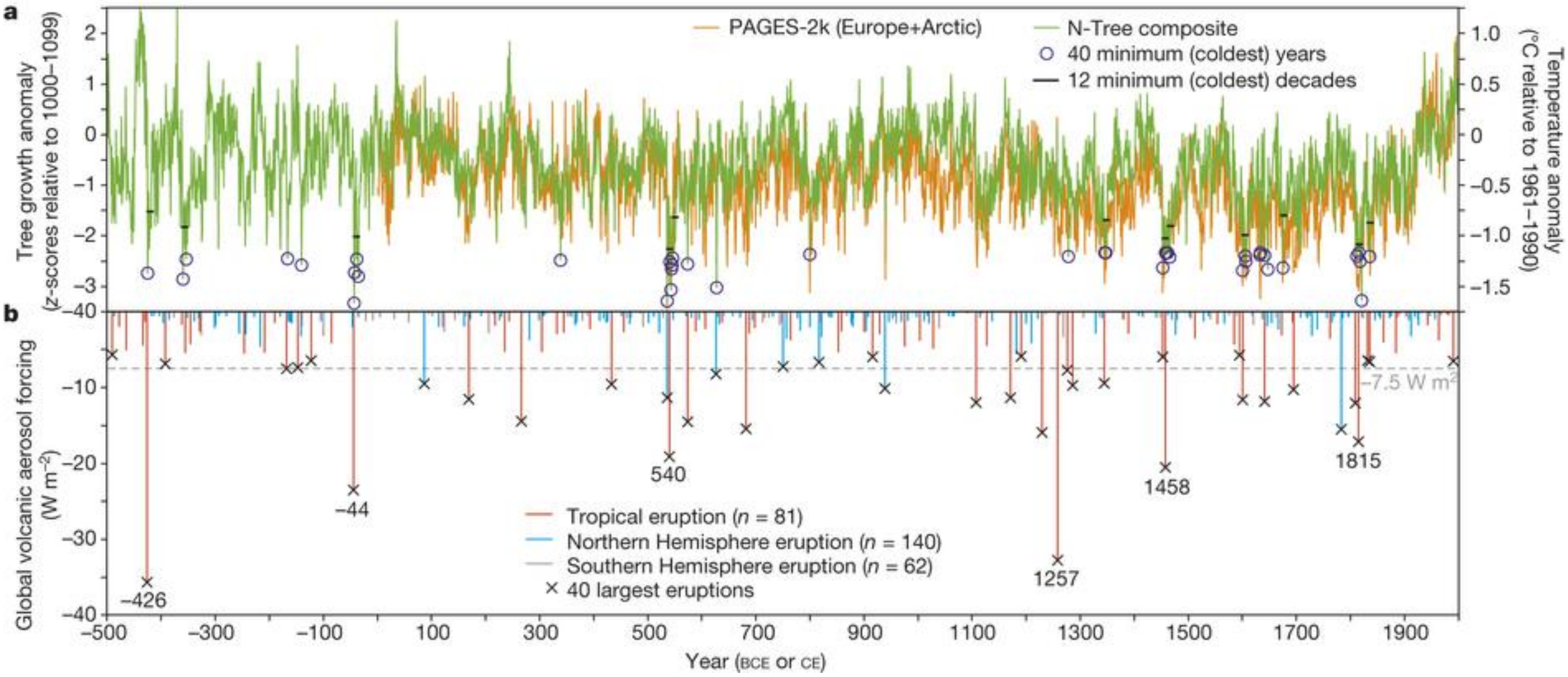


Difference in dating,
if 2 tree rings were formed
within one year ?!

Event was later (776 / 777 …)

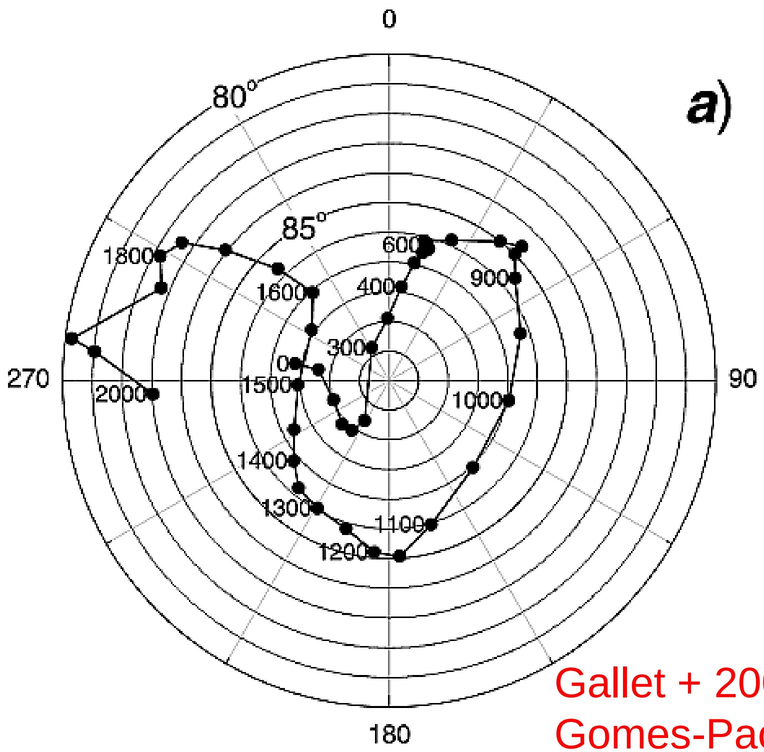
Or even no event at all (if no tree rings were
formed in the years before the apparent spike)

Volcanic eruptions during the Dark Ages

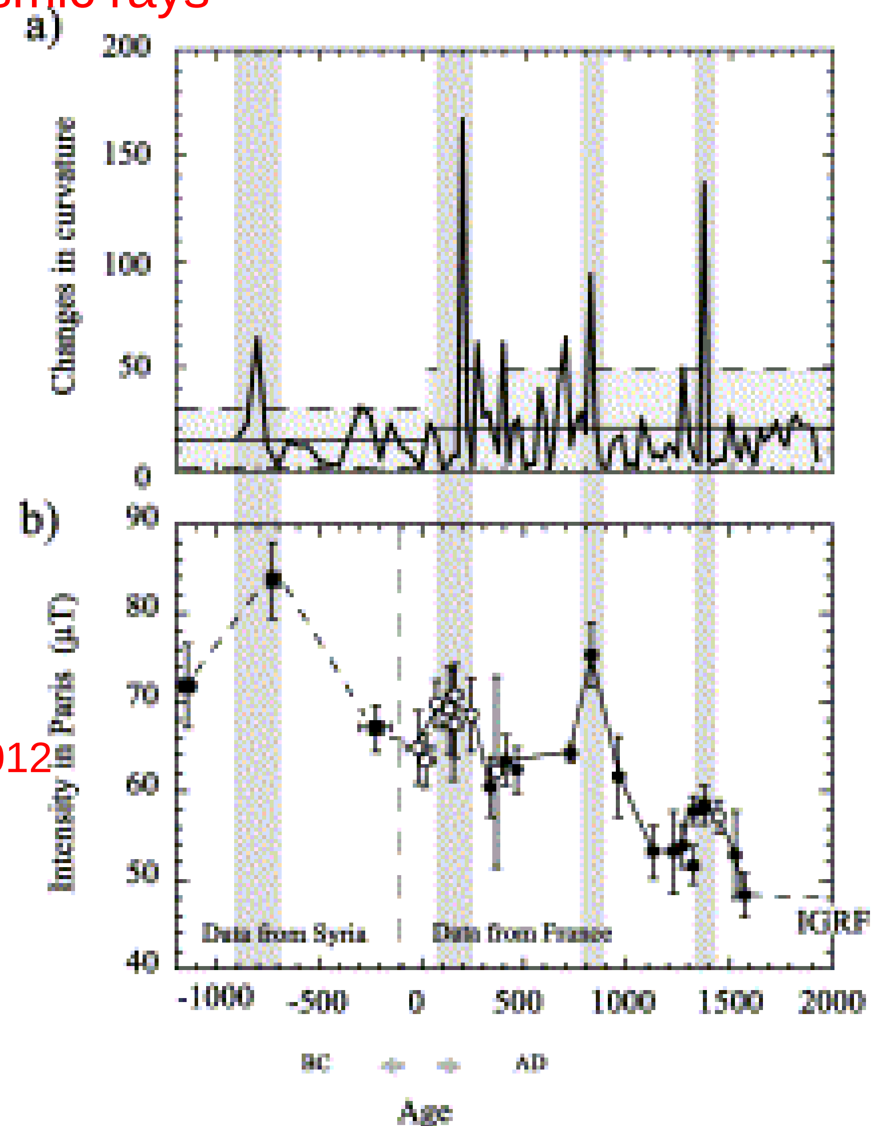


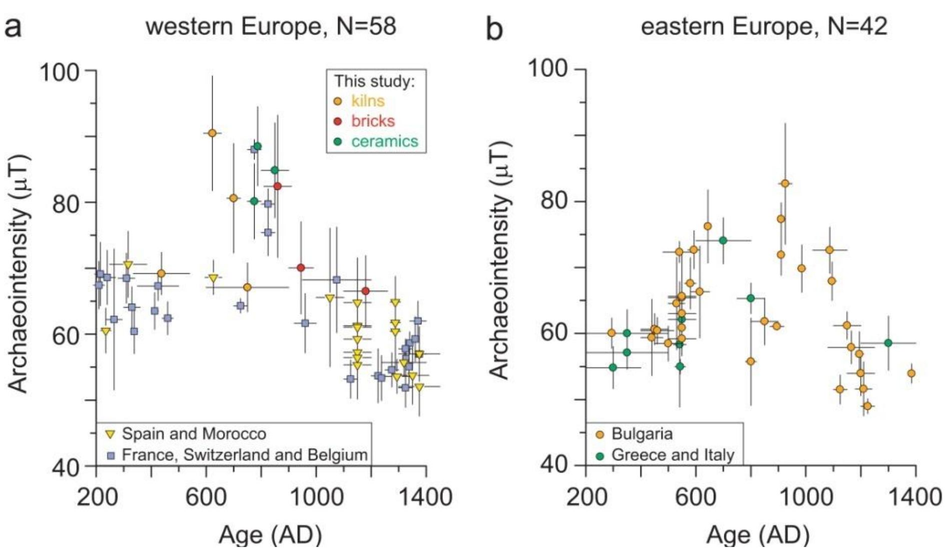
Sigl et al. 2015

Geomagnetic field: shields Earth from cosmic rays



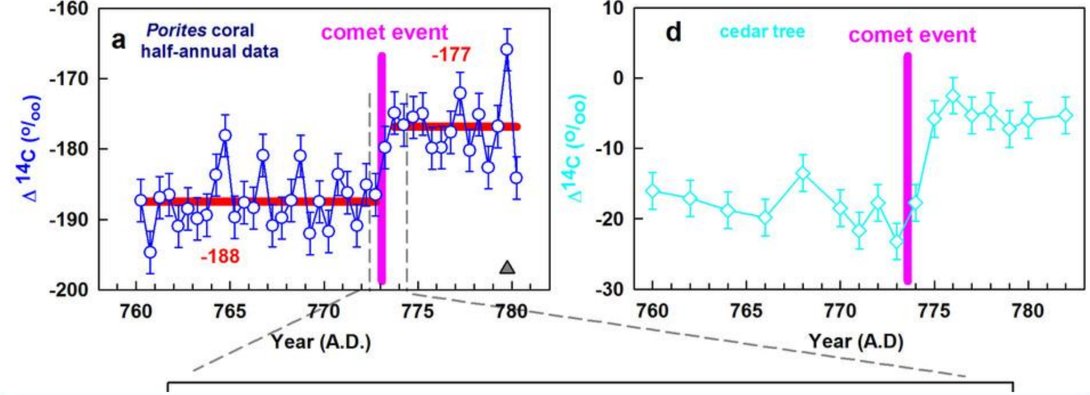
Gallet + 2006
Gomes-Paccard + 2012

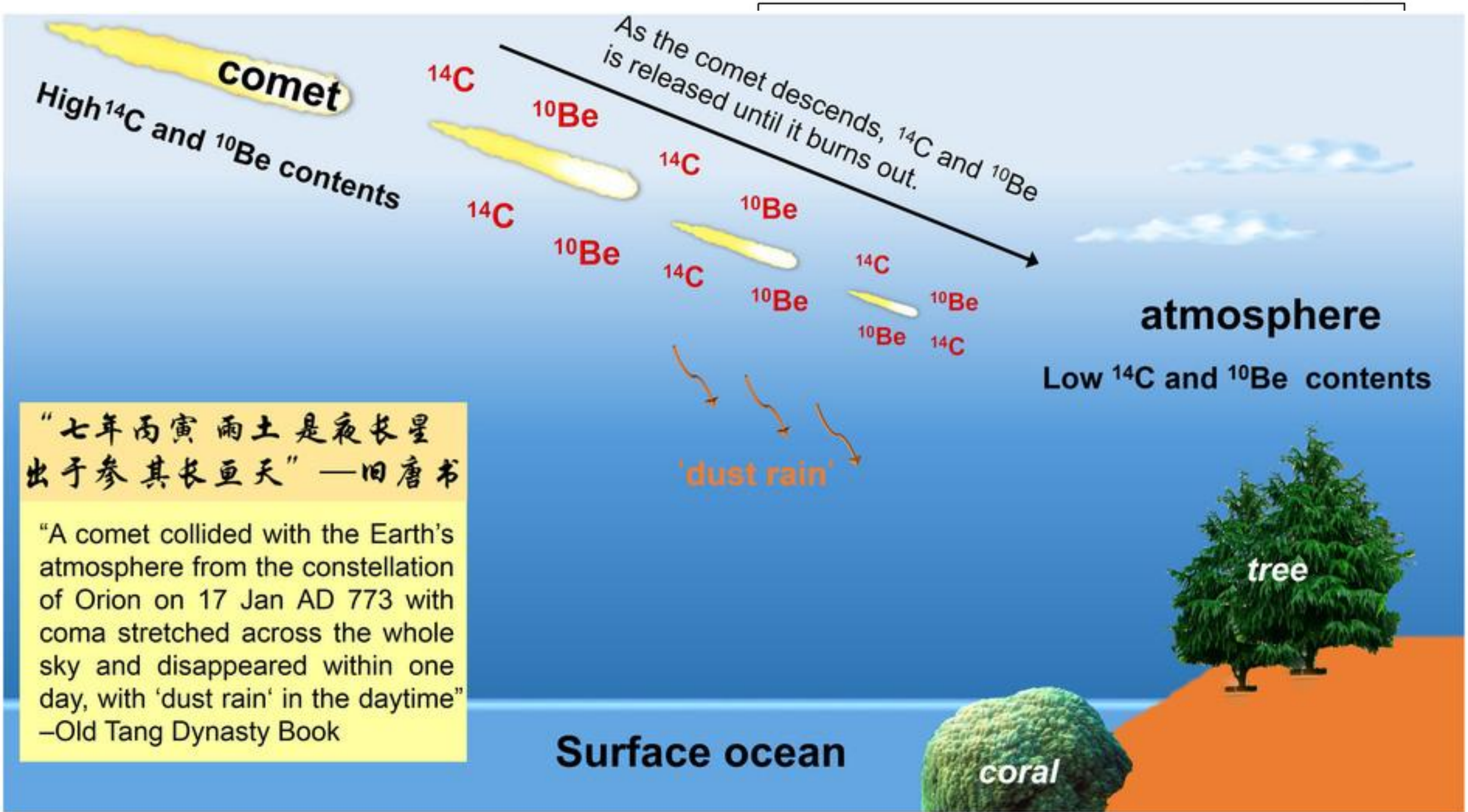




Around AD 800: Large directional change, broad peak, and deep short minimum ➔
Relation to cosmic-ray peak ?

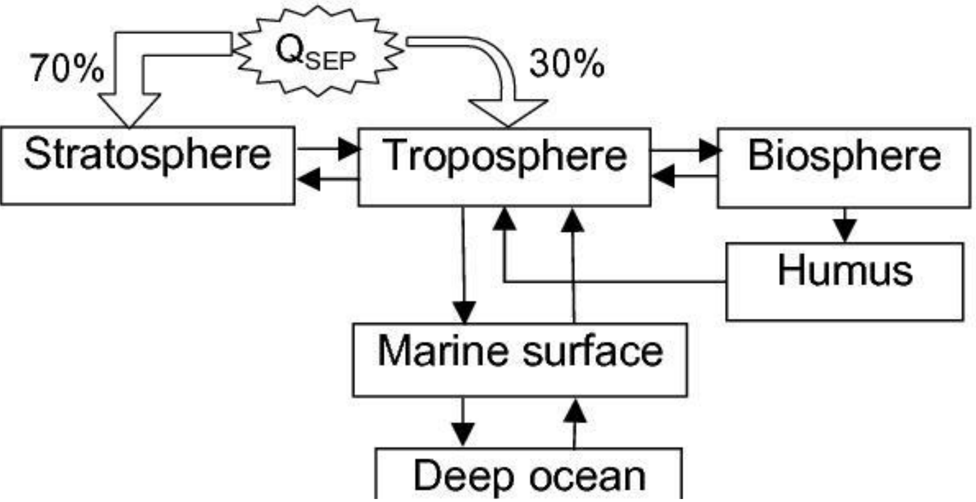
Liu et al. (2014 Nat SR):
Kometeneinschlag

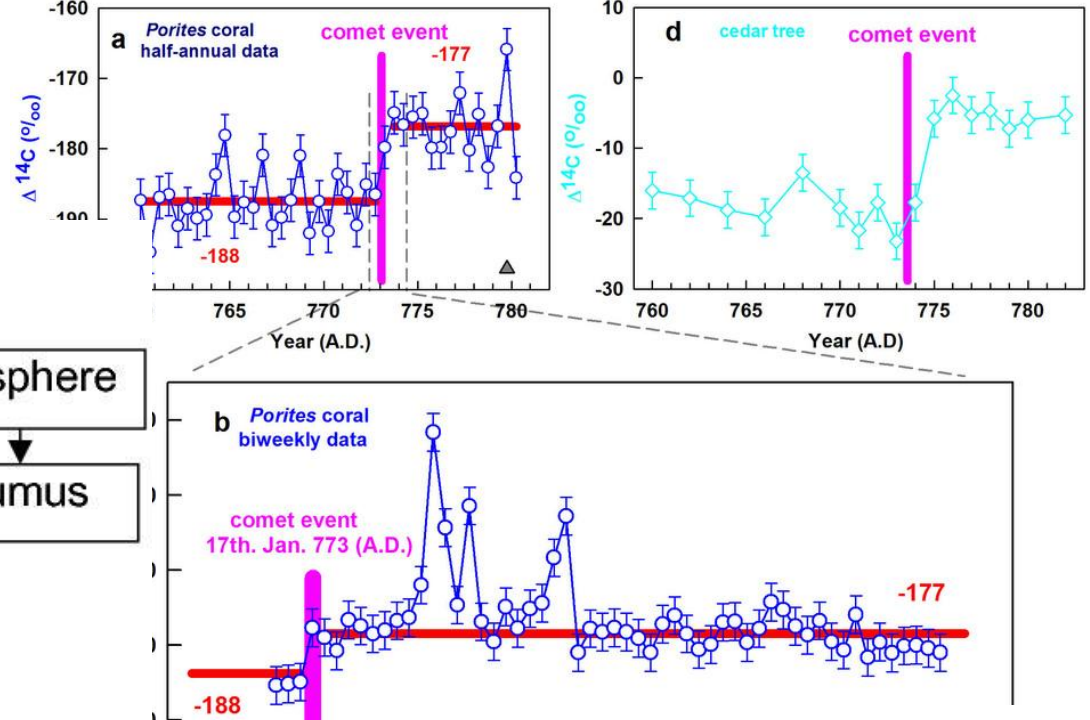


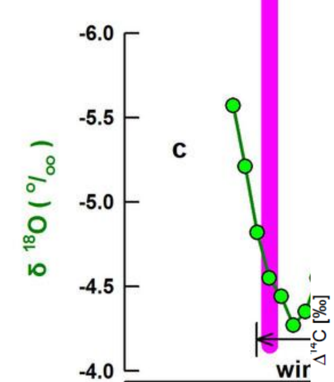


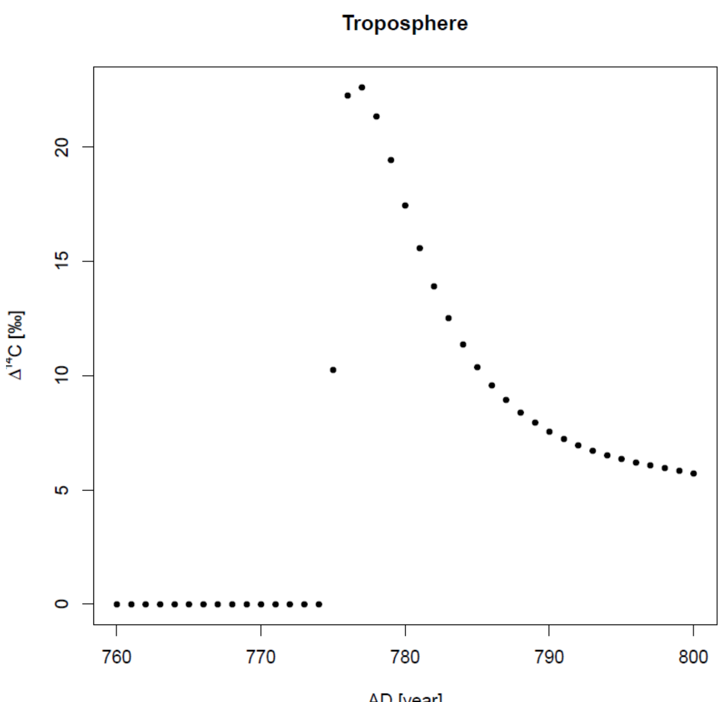
Liu et al. (2014 Nat SR)

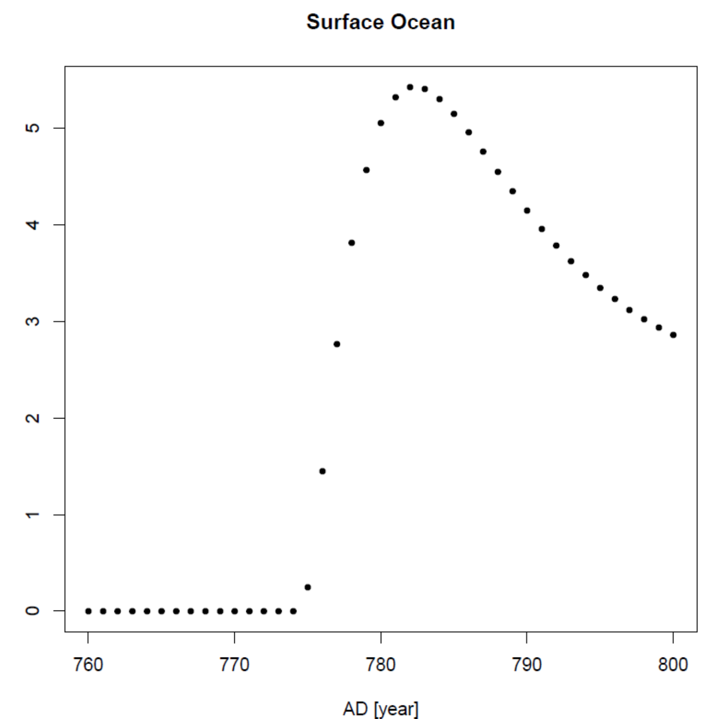
But:











Liu et al. (2014 Nat SR), **but:**

True Chinese text reads:

On 773 Jan 17 it rained down dust, and there was a long star that emerged beneath Orion. Its length traversed the sky. Long stars belong to the class of comets.

(observed later also in Japan)

Astron. Nachr. / AN **999**, No. 88, 789 – 792 (2014) / **DOI** ***please set DOI!***

The Chinese comet observation in AD 773 January

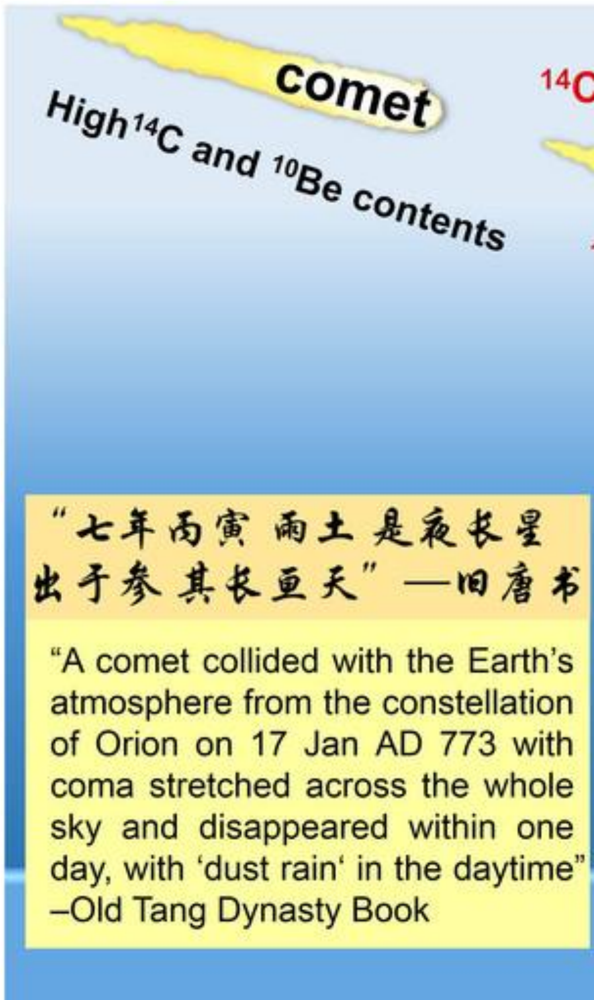
J. Chapman[1] *, M. Csikszentmihalyi[1], R. Neuhäuser[2]

[1] Department of East Asian Languages and Cultures, UC Berkeley, Berkeley CA, 94720, United States
[2] Astrophysikalisches Institut, Universität Jena, Schillergässchen 2-3, 07745 Jena, Germany

Received 2014, accepted
Published online

Key words comet AD 773, 14-C event AD 774/5

The strong ^{14}C increase in the year AD 774/5 detected in one German and two Japanese trees was recently suggested to have been caused by an impact of a comet onto Earth and a deposition of large amounts of ^{14}C into the atmosphere (Liu et al. 2014). The authors supported their claim using a report of a historic Chinese observation of a comet ostensibly colliding with Earth's atmosphere in AD 773 January. We show here that the Chinese text presented by those authors is not an original historic text, but that it is comprised of several different sources. Moreover, the translation presented in Liu et al. is misleading and inaccurate. We give the exact Chinese wordings and our English translations. According to the original sources, the Chinese observed a comet in mid January 773, but they report neither a collision nor a large coma, just a long tail. Also, there is no report in any of the source texts about *dust rain in the daytime* as claimed by Liu et al. (2014), but simply a normal dust storm. Ho (1962) reports sightings of this comet in China on AD 773 Jan 15 and/or 17 and in Japan on AD 773 Jan 20 (Ho 1962). At the relevant historic time, the Chinese held that comets were produced within the Earth's atmosphere, so that it would have been impossible for them to report a *collision* of a comet with Earth's atmosphere. The translation and conclusions made by Liu et al. (2014) are not supported by the historical record. Therefore, postulating a sudden increase in ^{14}C in corals off the Chinese coast precisely in mid January 773 (Liu et al. 2014) is not justified given just the ^{230}Th dating for AD 783 ± 14.



Liu Xu 劉昫, *The Old History of the Tang Dynasty* (*Jiu Tang shu* 舊唐書)

(1) 十二月丙寅，雨土。是夜，長星出於參。

(2) 十二月甲子，太白入羽林。丙寅，雨土，是夜，長星出于參。

Ouyang Xiu 歐陽修, *The New History of the Tang Dynasty* (*Xin Tang shu* 新唐書)

(3) 十二月丙寅，雨土，有長星出于參。

(4) 七年十二月丙寅，有長星于參下，其長亙天。長星，彗屬。參，唐星也。

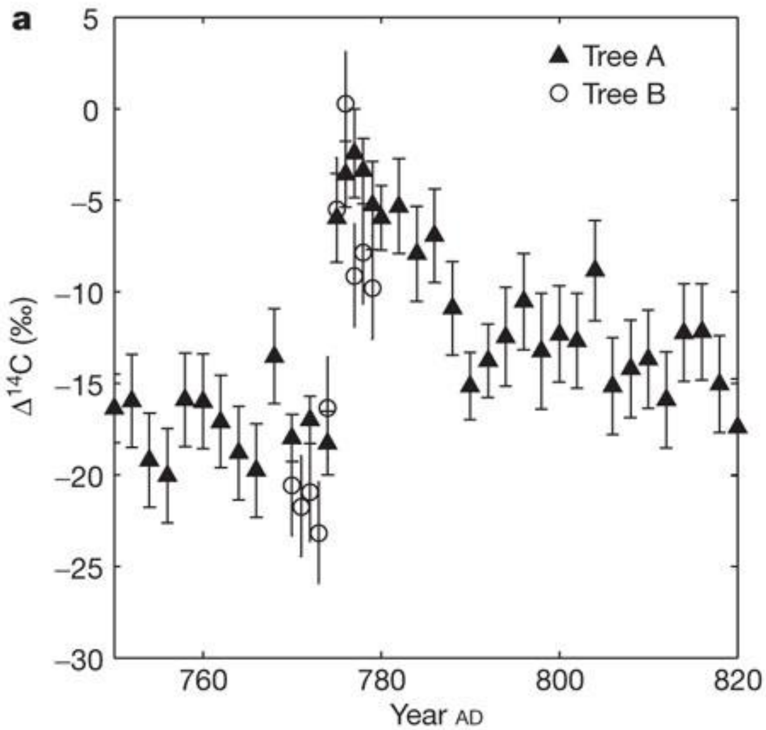
Wang Pu 王溥, *Essential Records of the Tang Dynasty* (*Tang Hui yao* 唐會要)

(5) 七年十二月二十日，長星見。

Ma Duanlin 馬端臨, *Comprehensive Investigation of Historical Documents* (*Wenxian tongkao* 文獻通考)

(6) 七年十二月丙寅，有長星於參下，其長亘天。長星，彗屬。參，唐星也。

Was war die Ursache ?



Miyake et al. 2012

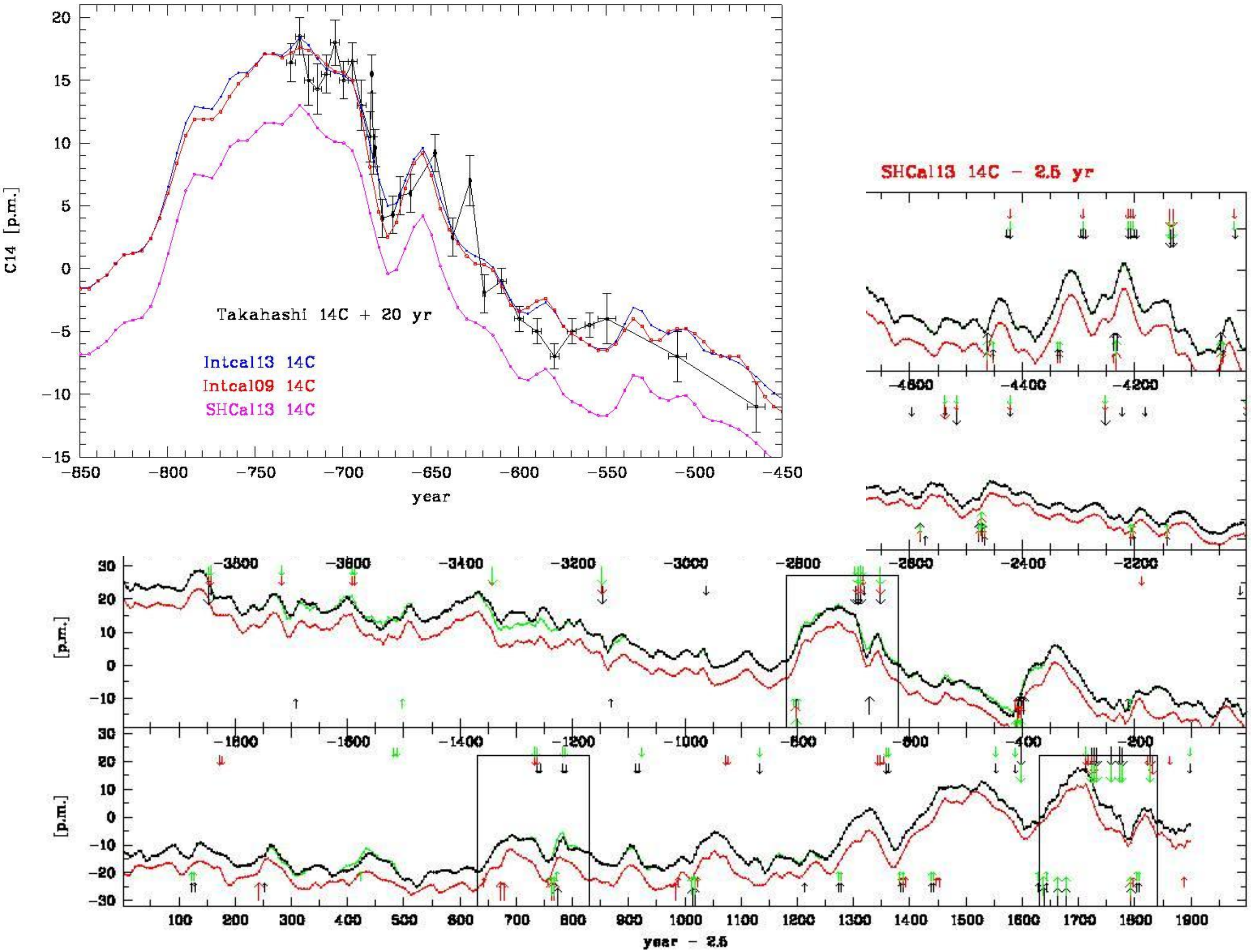
Supernova ? Nein, zu schwach

Gamma-ray burst ? zu selten

Sonnen-Flare ? no

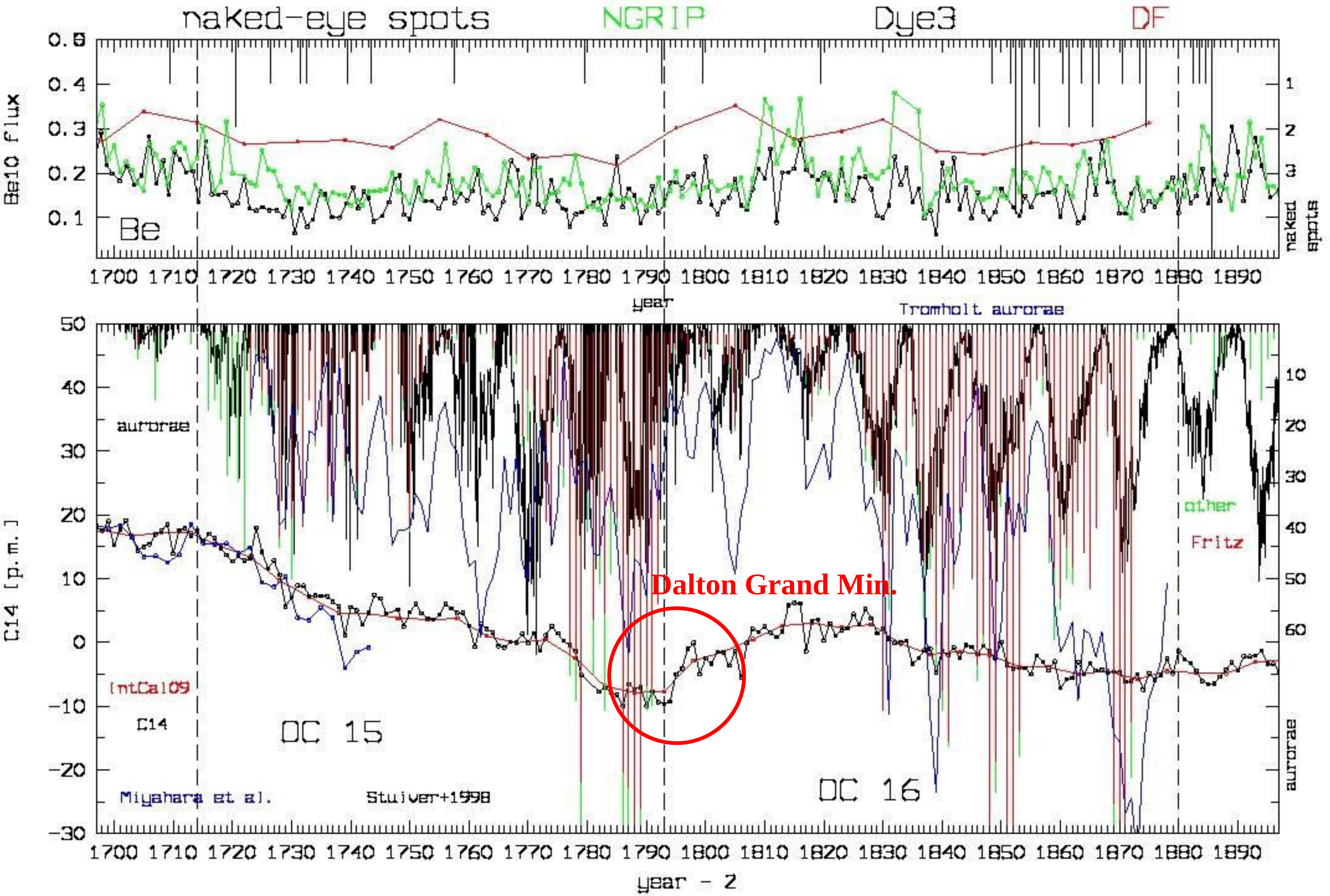
Sonstwas ?

Komenteneinschlag, Magnetfeldschwankung, Vulkanausbruch, etc.



Takahashi 14C + 20 yr
Intcal13 14C
Intcal09 14C
SHCal13 14C
C14 [p.m.]
year
SHCal13 14C − 2.5 yr
[p.m.]
year − 2.5

AD 1700 – 1900

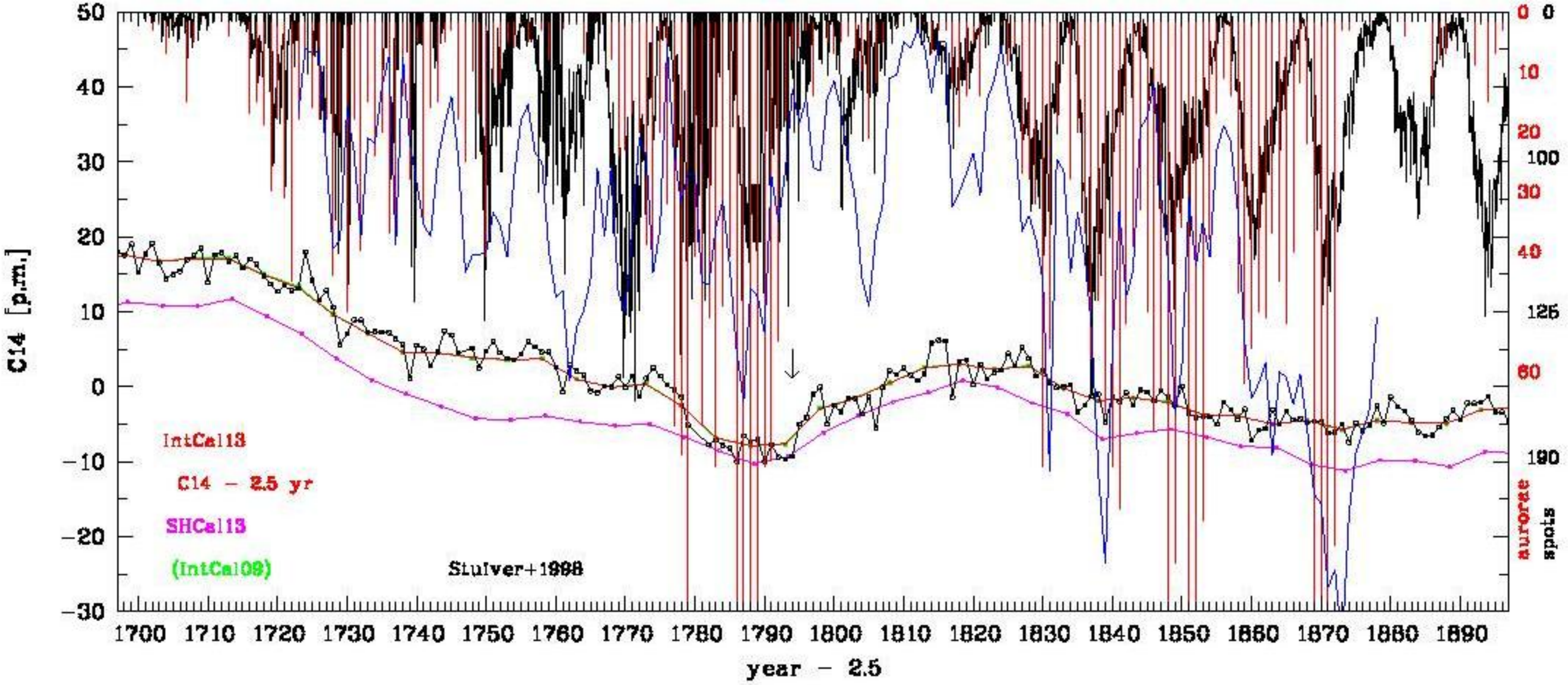


naked-eye spots
NGRIP
Dye3
DF
Be10 flux
Be
naked spots
year
Tromholt aurorae
aurorae
other
Fritz
Dalton Grand Min.
IntCal09
C14
DC 15
DC 16
C14 [p. m.]
Miyahara et al.
Stuiver+1998
aurorae
year - 2

Maunder Minimum ended AD 1712/15.

Aurora level increases from cycle minimum to minimum.

sunspots, aurorae (Tromholt, Fritz), ^{14}C



(1) At the end of the Grand Maximum (~1790) ➔ low ^{14}C level
(2) Decline of strong Schwabe cycle no. 4 (~ 1793) ➔ ^{14}C rises
(3) Weak activity in Dalton (~1800-1830) ➔ ^{14}C level high

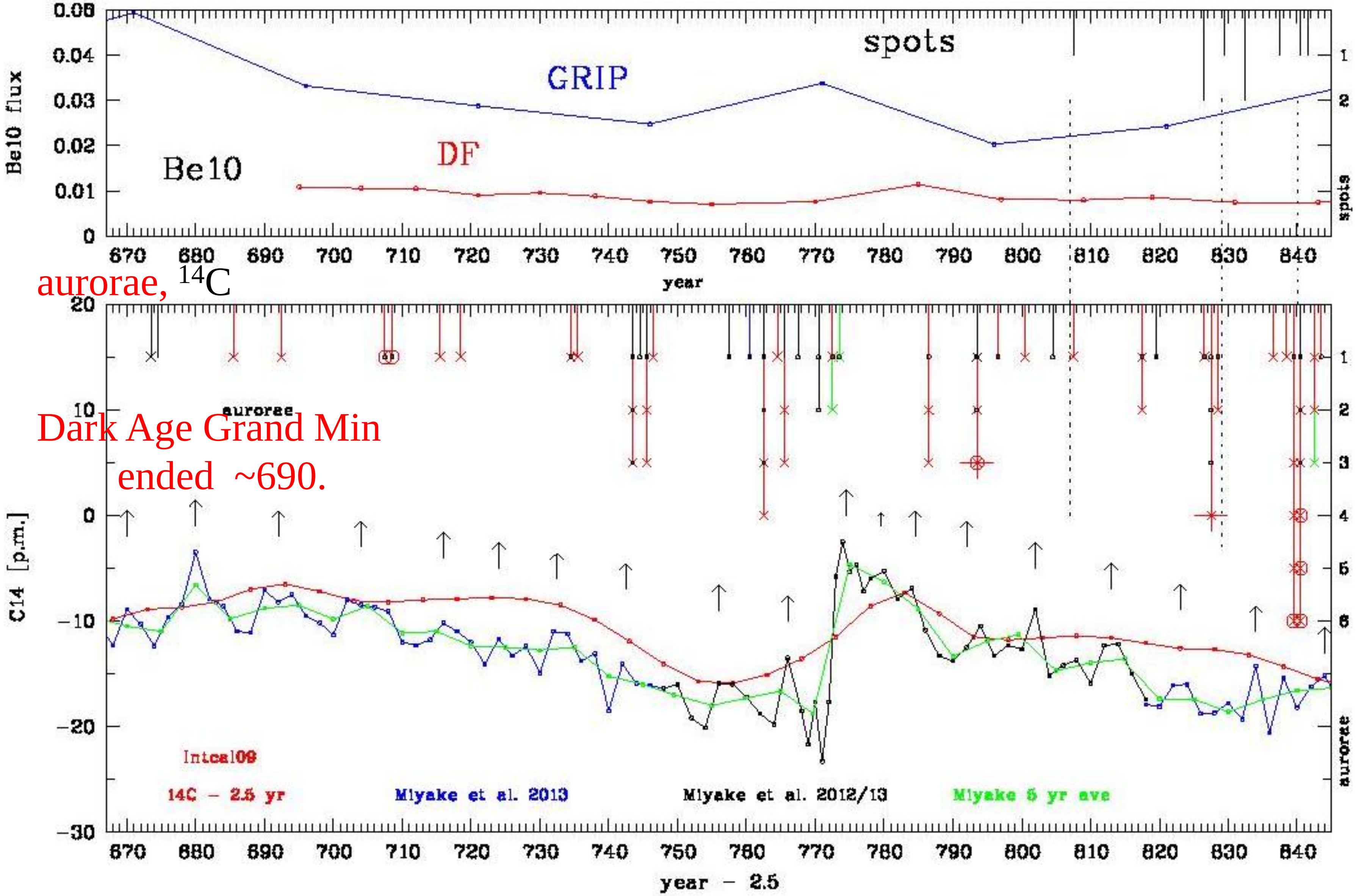
Maunder Minimum ended AD 1712/15.

Aurora level increases from cycle minimum to minimum.

sunspots, aurorae, ^{14}C

Same around AD 774/5 ?

(1) At the end of the Grand Maximum (~1790) ➔ low ^{14}C level
(2) Decline of strong Schwabe cycle no. 4 (~ 1793) ➔ ^{14}C rises
(3) Weak activity in Dalton (~1800-1830) ➔ ^{14}C level high



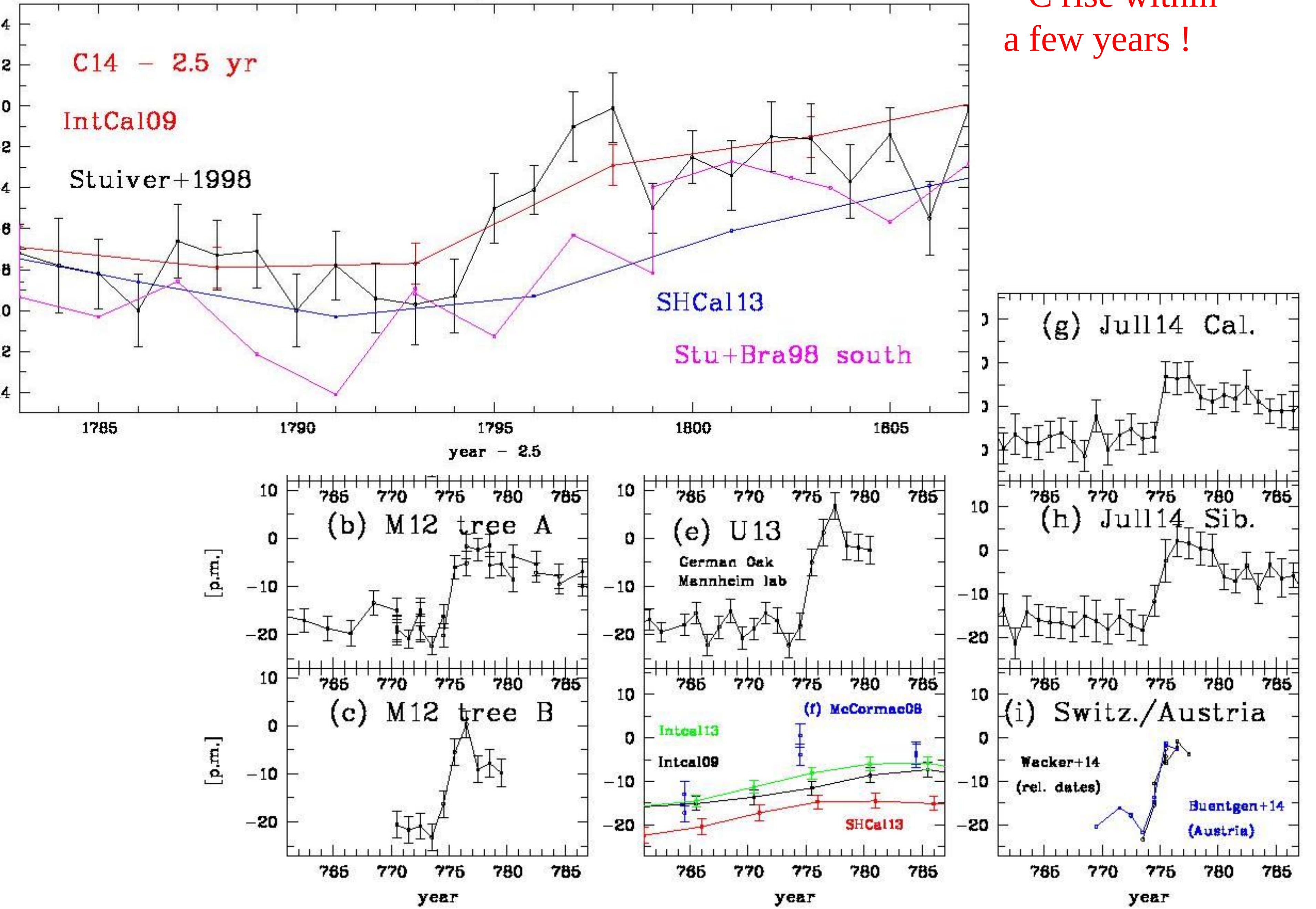
(1) At the end of the Grand Maximum (~770) ➔ low ^{14}C level

(2) Decline of strong Schwabe cycle no. 4 (~ 774) ➔ ^{14}C rises

(3) Weak activity ➔ ^{14}C level high

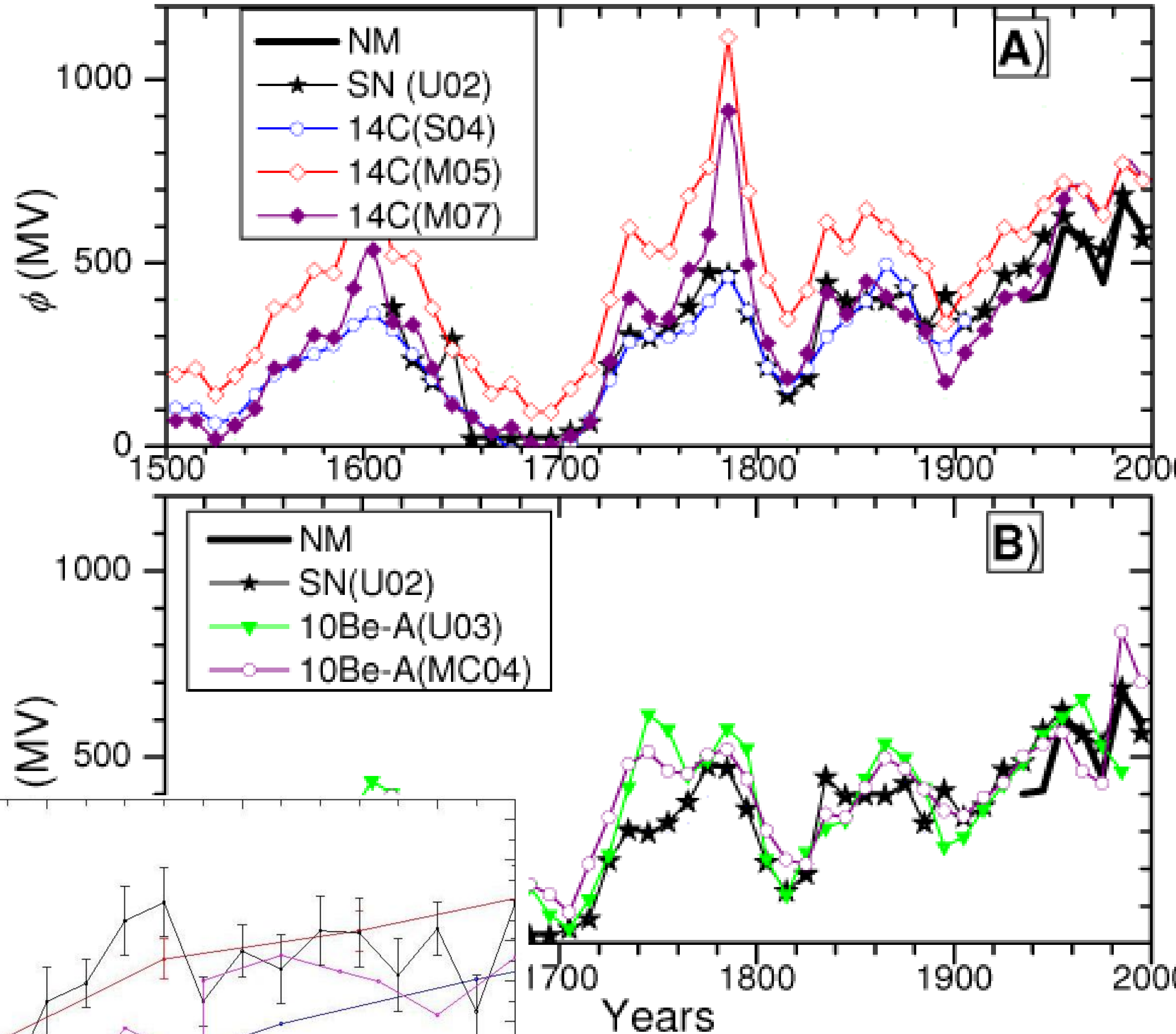
Neuh & Neuh 2015

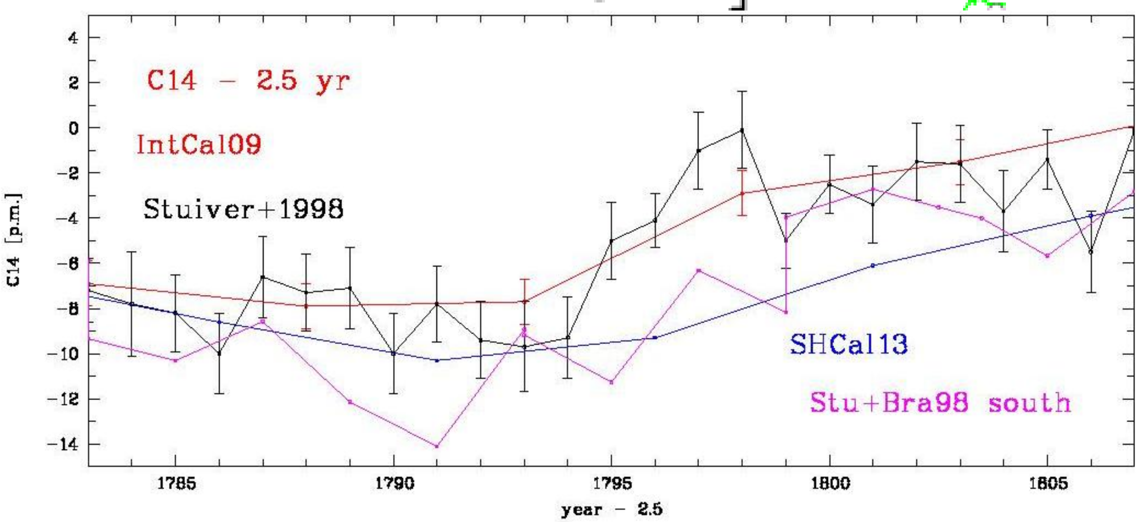
^{14}C rise within a few years !

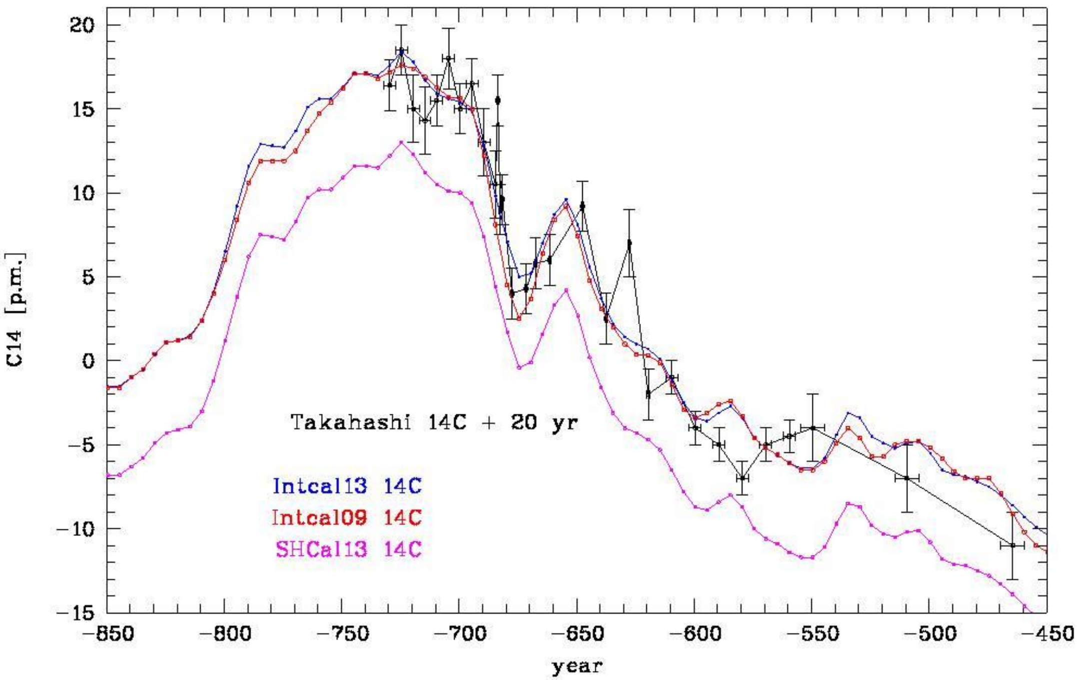


Living Review Usoskin:

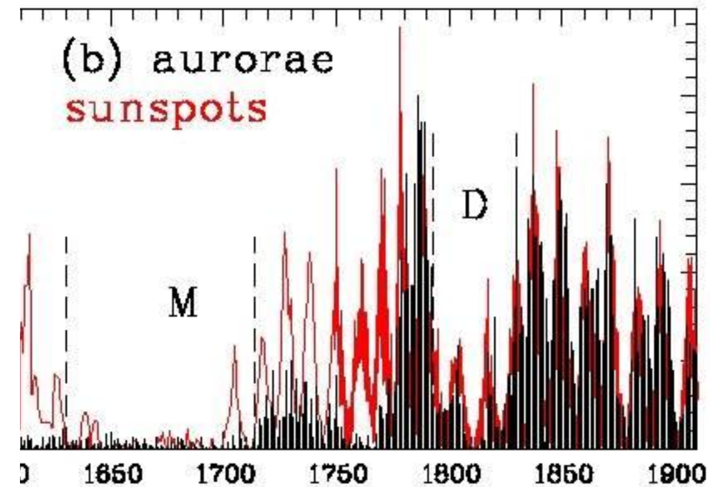
Fast strong drop in
solar modultion potential
is indeed possible,
e.g. around 1795



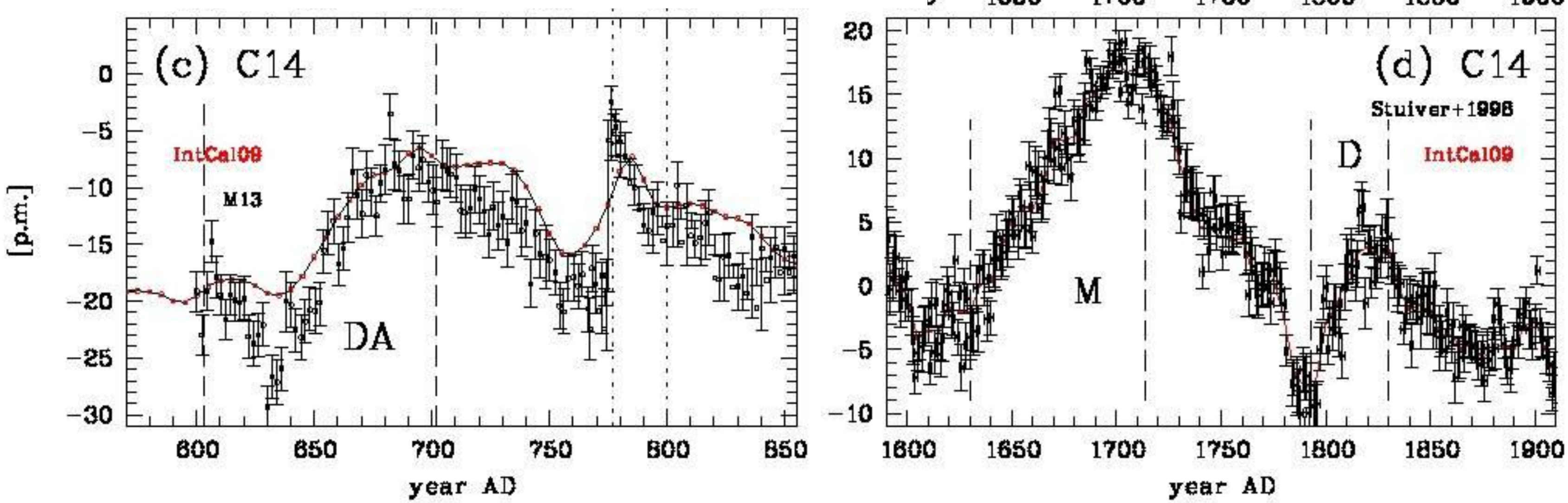




Takahashi 14C + 20 yr
Intcal13 14C
Intcal09 14C
SHCal13 14C
C14 [p.m.]
year

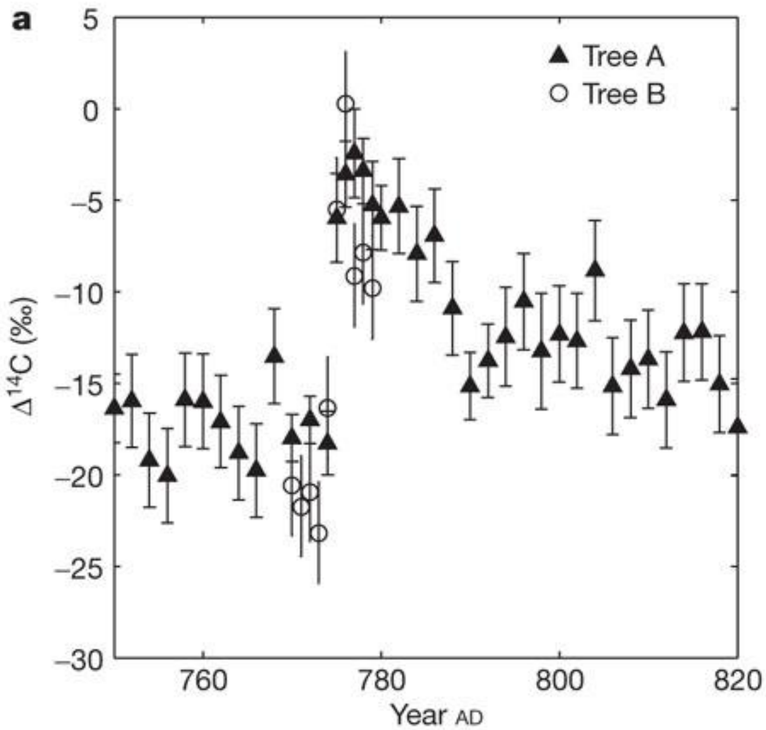


(b) aurorae
sunspots
M
D



(c) C14
IntCal09
M13
DA
[p.m.]
year AD
(d) C14
Stuiver+1998
IntCal09
M
D
year AD

Was war die Ursache ?



Miyake et al. 2012

Supernova ? Nein, zu schwach

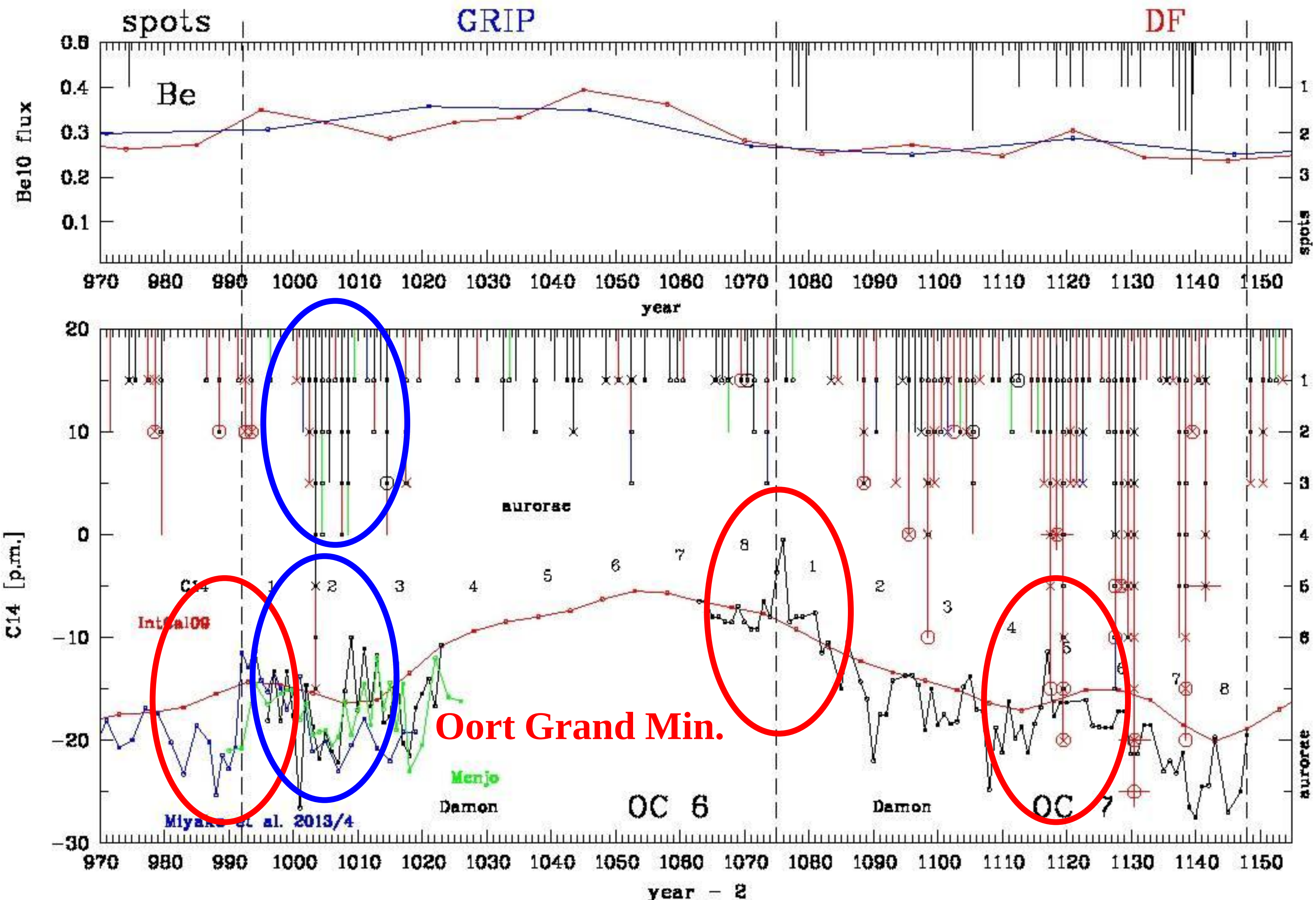
Gamma-ray burst ? zu selten

Sonnen-Flare ? no

Sonstwas ? Sonnenaktivitätsabfall
(um AD 775, 994, 1795, und BC 671)

AD 994 / 5

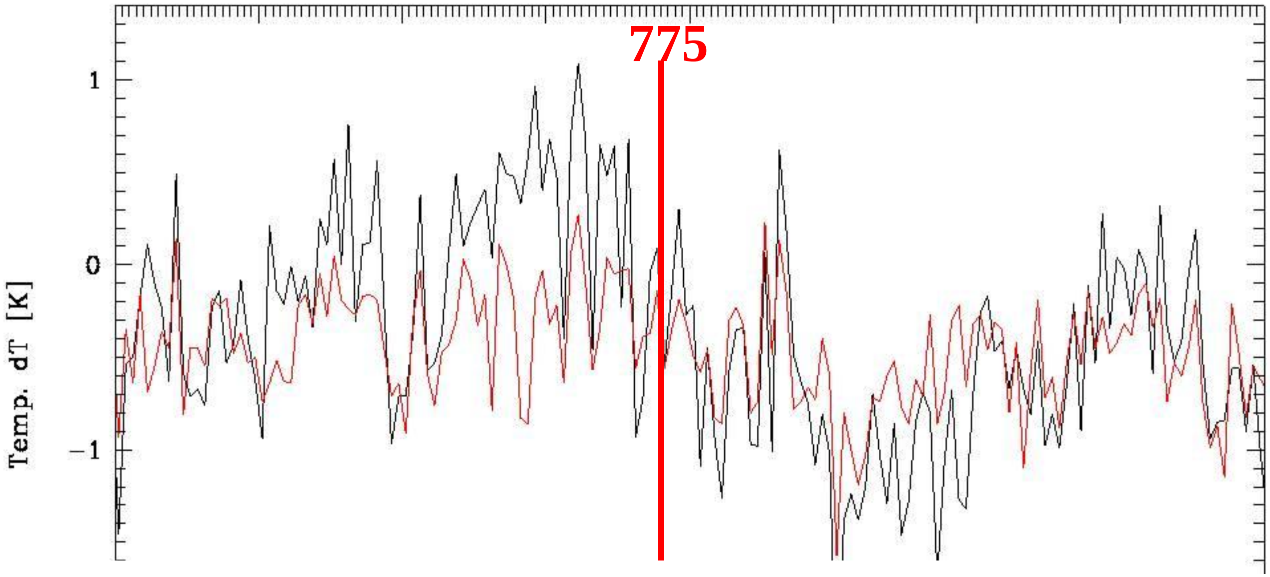
SN 1006 detected ? In 1009 ?

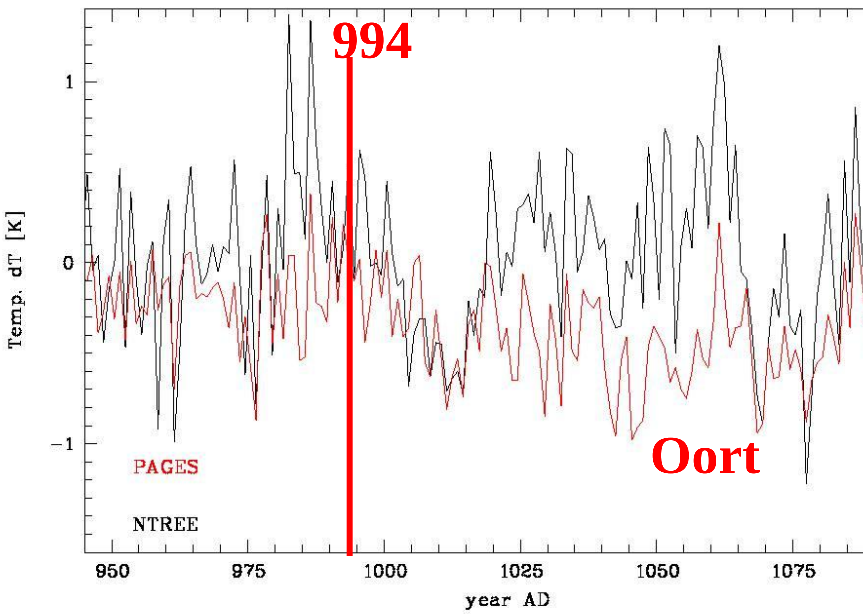


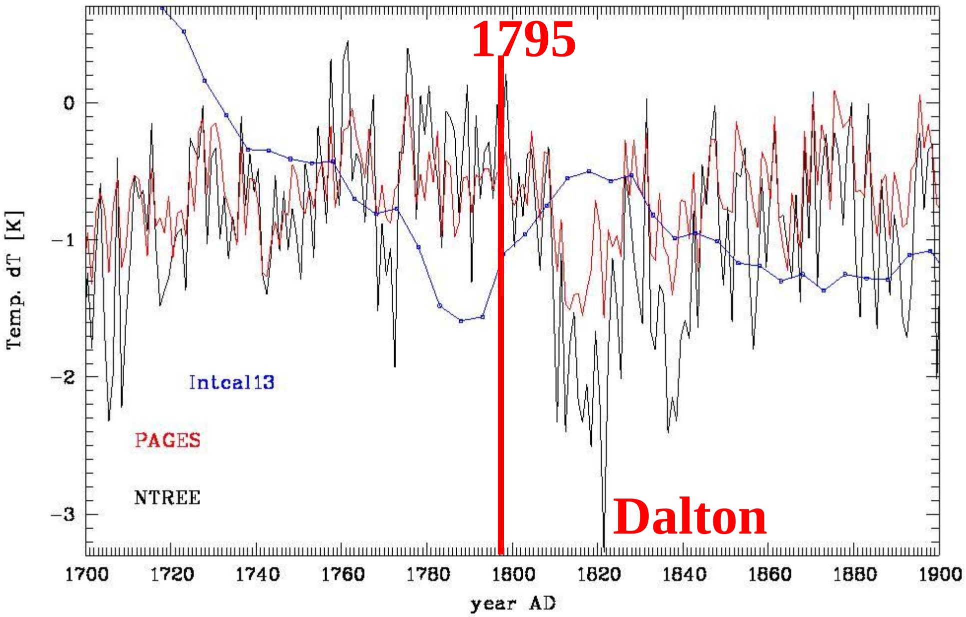
A fast strong drop in solar activity ➔ less solar wind ➔ more cosmic rays and ^{14}C

If 775 due to solar activity decline, then temperature decline on Earth expected …

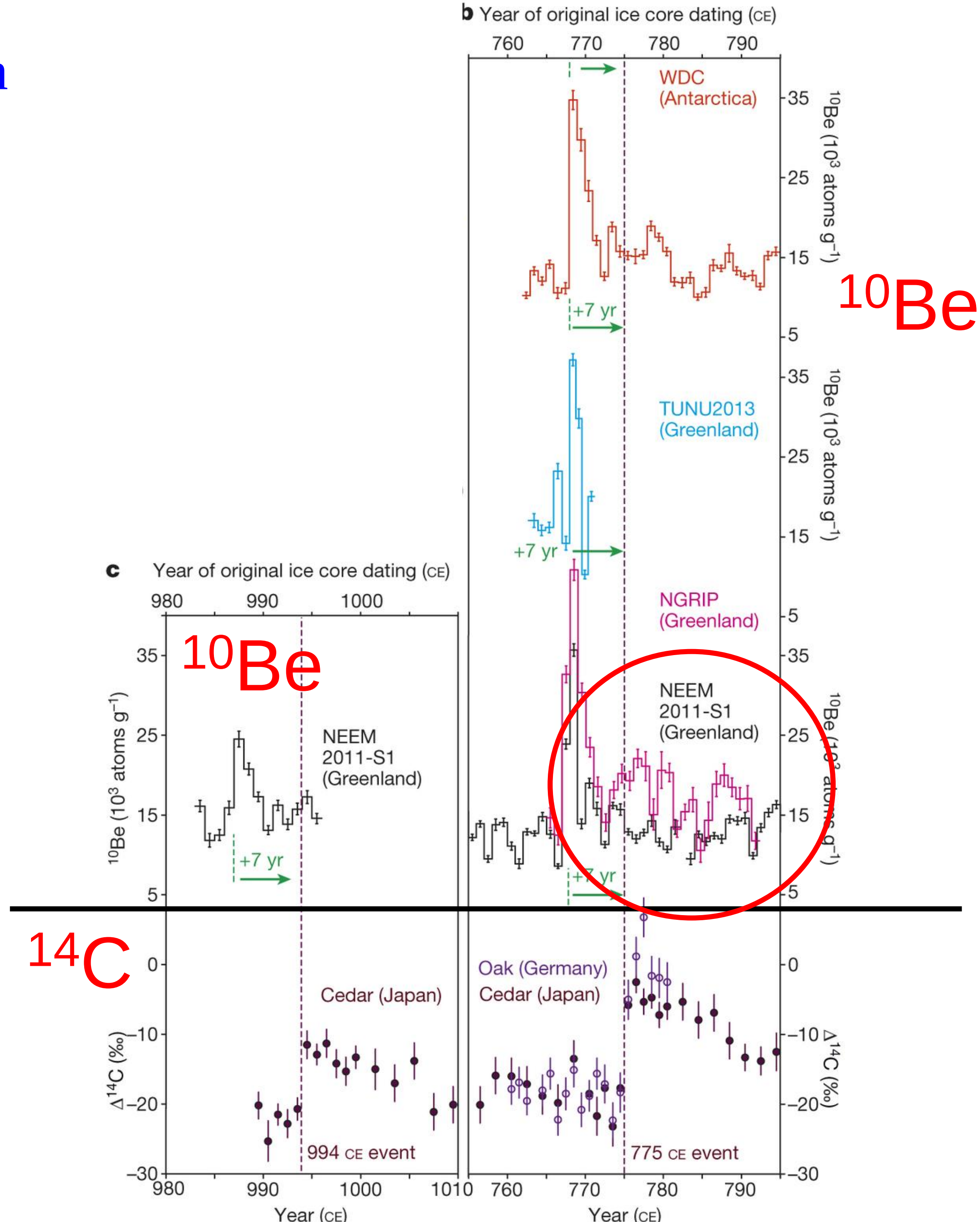
(which would not be expected after a solar super-flare)







quasi-annual resolution
^{10}Be
from north and south

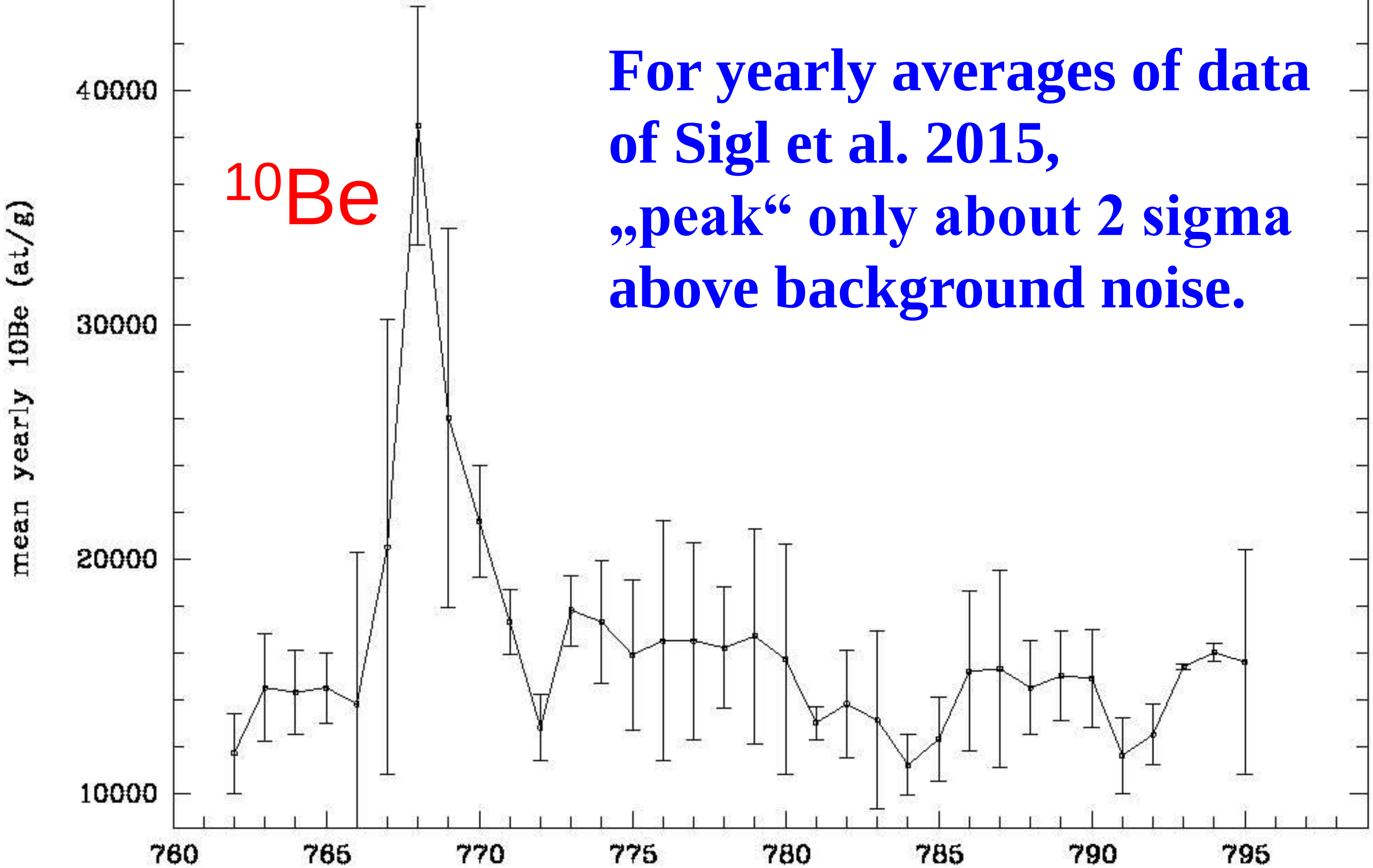


Significant differences between data sets, hence larger systematic errors in ^{10}Be data and / or dating.

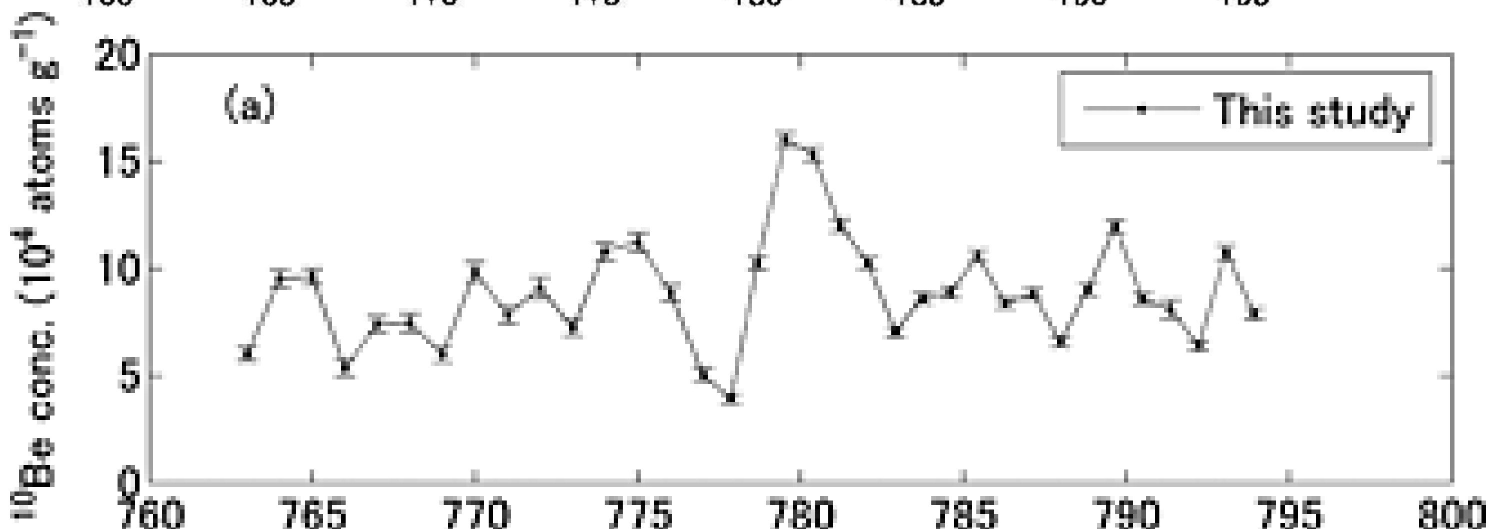
(Sigl et al. 2015)

For yearly averages of data of Sigl et al. 2015, „peak“ only about 2 sigma above background noise.

Average of Sigl et al. 2015

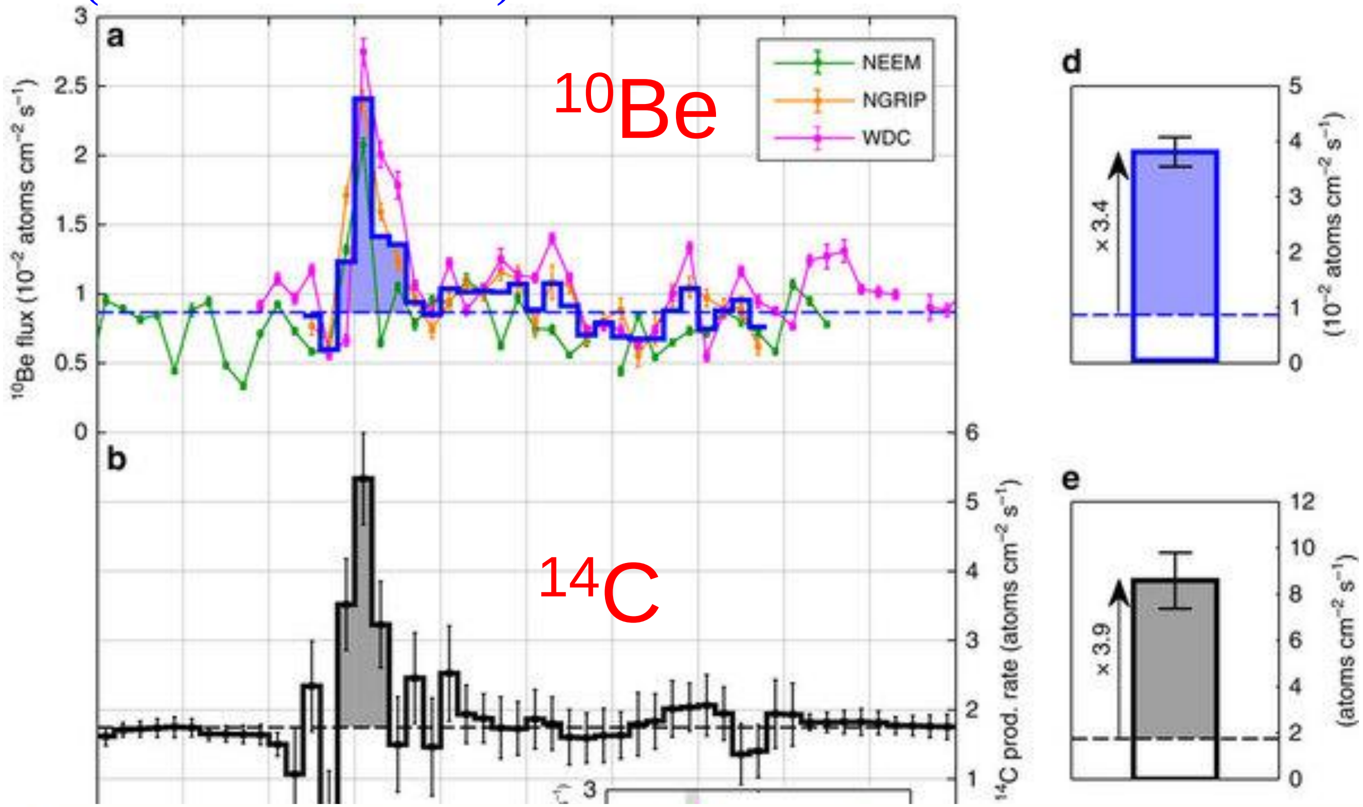


Miyake et al. 2015



AD 775

(Mekhaldi et al. 2015)



Ratio ^{14}C / ^{10}Be 775

$$\frac{8.64 - 1.8}{0.0394 - 0.01} = 233 \quad (\pm 20\%)$$

inconsistent with flare

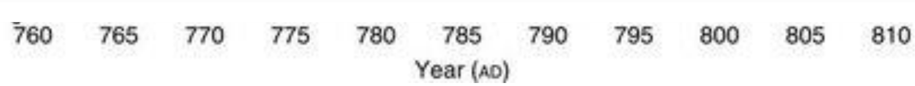
Similar for AD 994:

Ratio ^{14}C / ^{10}Be = 314

Differential production ratio of ^{14}C to ^{10}Be due to solar flare expected:

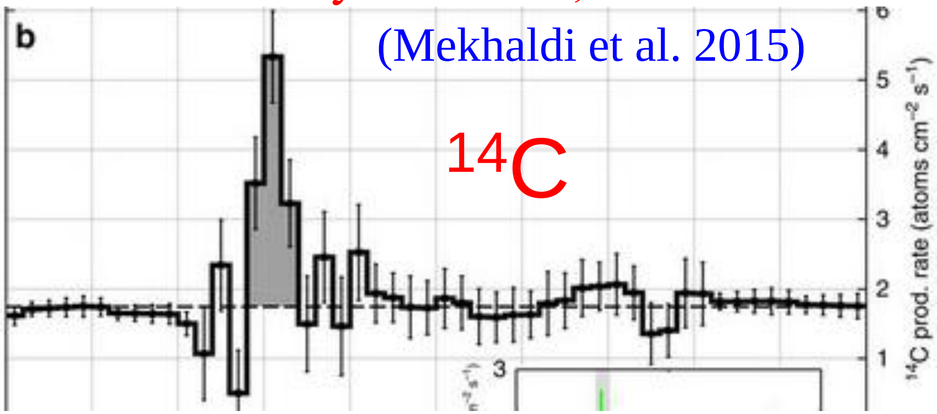
Usoskin & Kovaltsov (2012): <u>**~ 38 times more ^{14}C than ^{10}Be**</u>

Pavlov et al. (2014 MNRAS): <u>16-17 times more ^{14}C than ^{10}Be</u>



Is a ^{14}C production rate of ~5 atm/cm^2/s possible without flare ?

(modeled from Miyake's data, which show the largest amplitude)



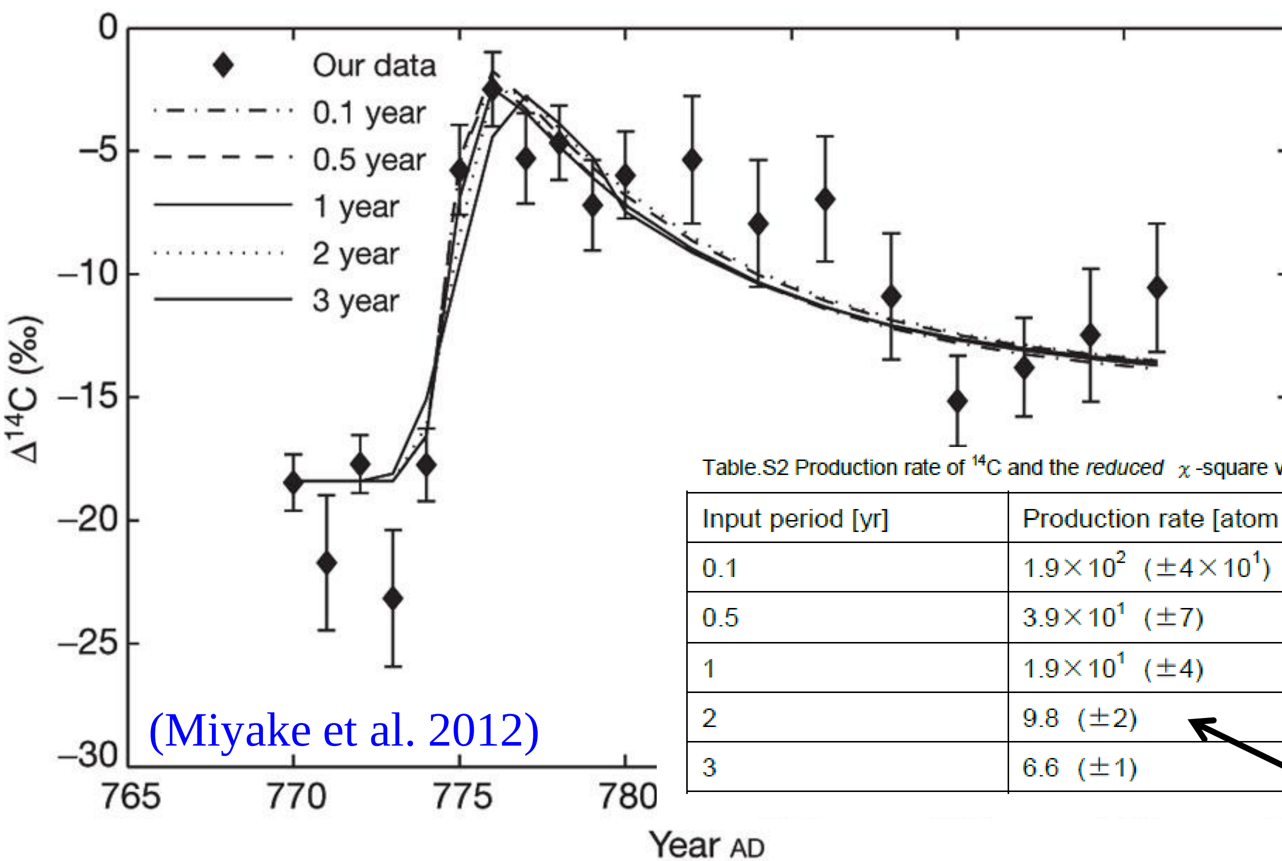
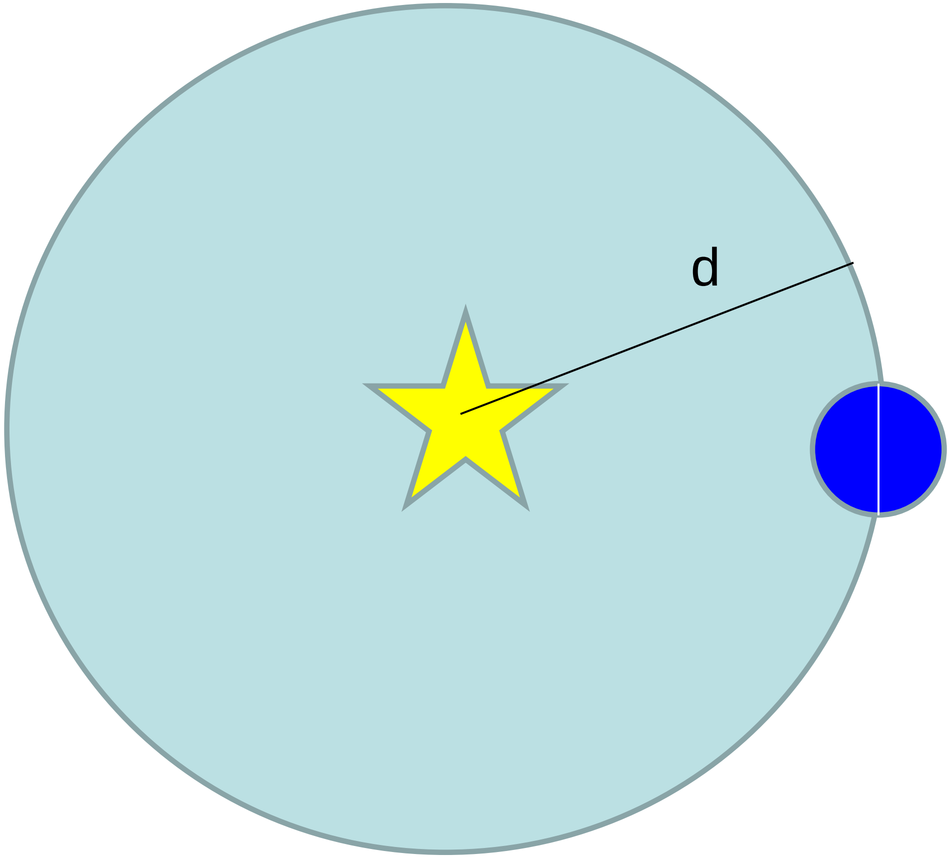


Table.S2 Production rate of ^{14}C and the *reduced* χ-square value

Input period [yr]	Production rate [atom cm^{-2} s^{-1}]	*reduced* χ-squared value
0.1	1.9×10^2 ($\pm4\times10^1$)	0.96
0.5	3.9×10^1 (±7)	0.96
1	1.9×10^1 (±4)	0.96
2	9.8 (±2)	1.1
3	6.6 (±1)	1.6

To be devided by 4.

Energetics



Flare at distance d between event and Earth

Energy E_{event} to spread homogeneous to whole sphere around event with area

$$4 \cdot \pi \cdot d^2$$

Energy E_{obs} to hit Earth under solid angle

$$\pi \cdot R^2$$

with Earth radius R.

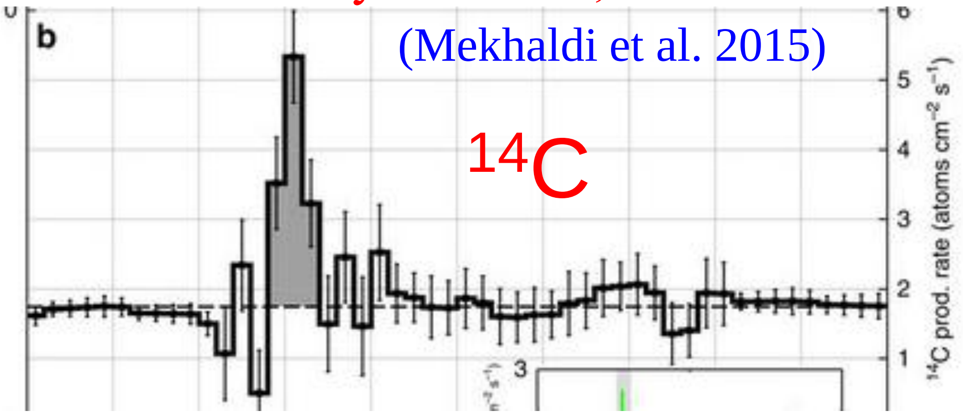
$$\frac{E_{\text{event}}}{E_{\text{obs}}} = \frac{4 \cdot \pi \cdot d^2}{\pi \cdot R^2}$$

$E_{obs} = 8 \times 10^{25}$ erg in protons

➔Need 2 x 10^{35} erg at Sun

Is a ^{14}C production rate of ~5 atm/cm^2/s possible without flare ?

(modeled from Miyake's data, which show the largest amplitude)



2 yr duration is as good a fit as 1 yr.

For 2 yr,
2.5 ± 0.5 atm/cm^2/s
in 773 and 774.

high background. Ok !

^{14}C & ^{10}Be do rise 2 to 4 yr since AD 773.

Schrijver et al. 2012:
^{14}C production models differ by > 2 orders of magnitude.

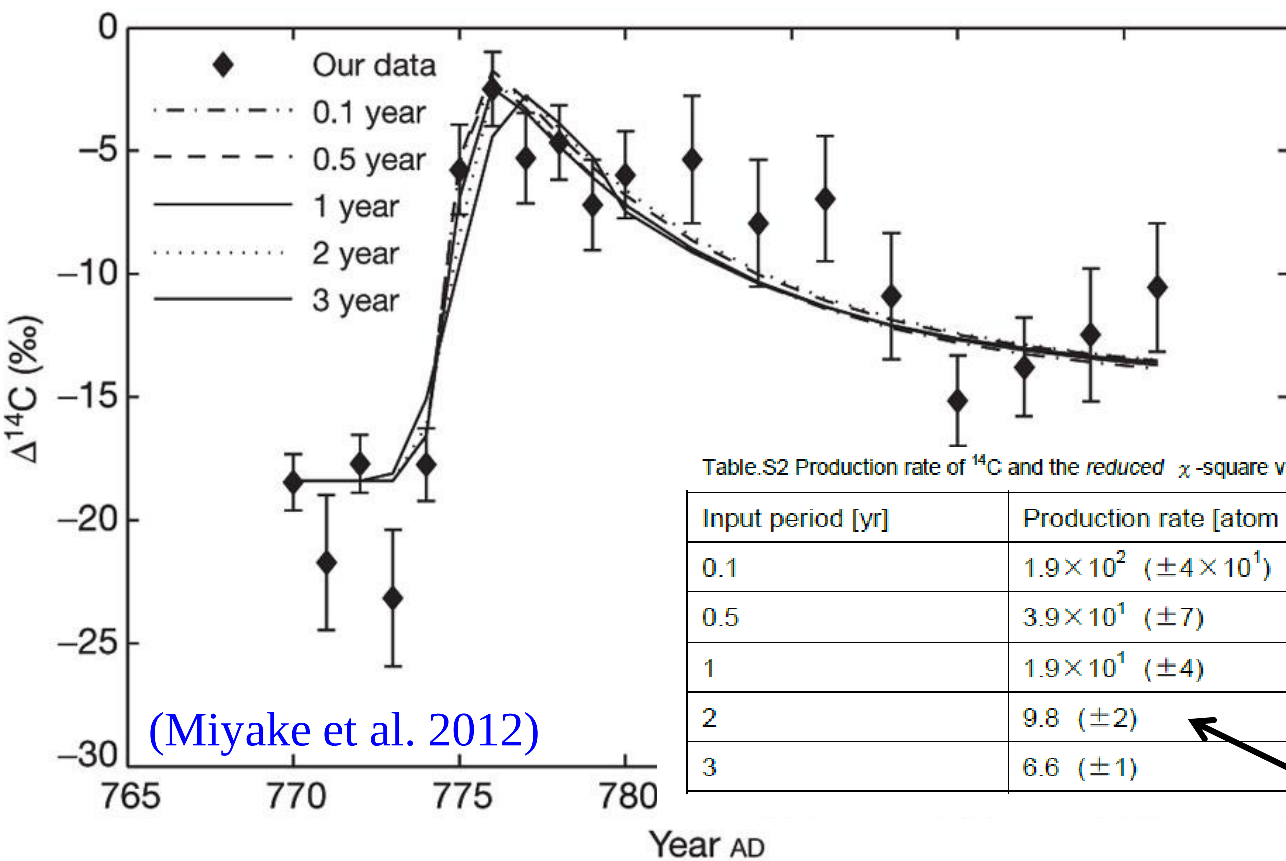
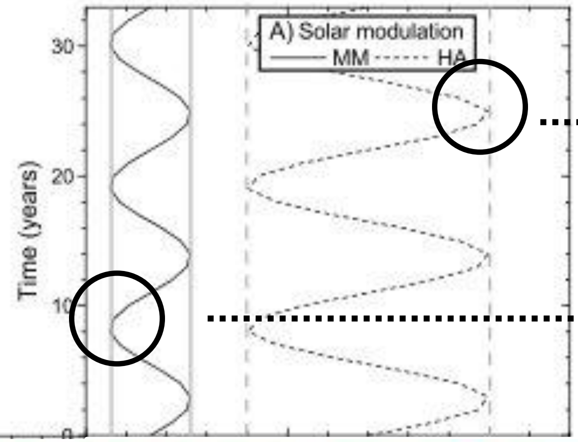


Table.S2 Production rate of ^{14}C and the *reduced* χ-square value

Input period [yr]	Production rate [atom cm^{-2} s^{-1}]	*reduced* χ-squared value
0.1	1.9×10^2 ($\pm4\times10^1$)	0.96
0.5	3.9×10^1 (±7)	0.96
1	1.9×10^1 (±4)	0.96
2	9.8 (±2)	1.1
3	6.6 (±1)	1.6

To be devided by 4.

figure from
Poluianov, Usoskin,
Kovaltsov 2014



Φ:
From ~1000 MV
in max of high activity
(Schwabe max in Grand max)
to ~60 MV
in min of low activity
(Schwabe min in Grand min)

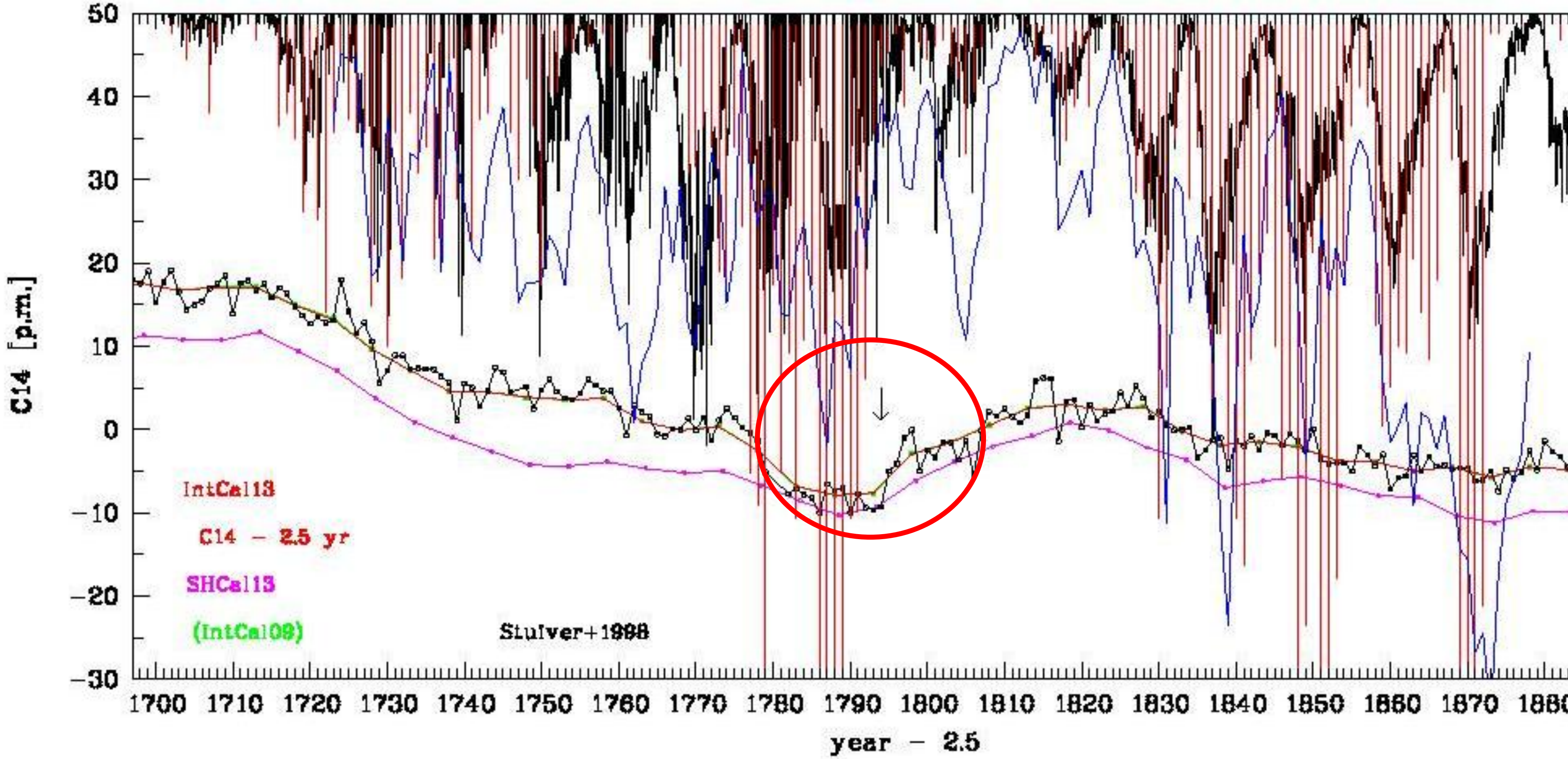
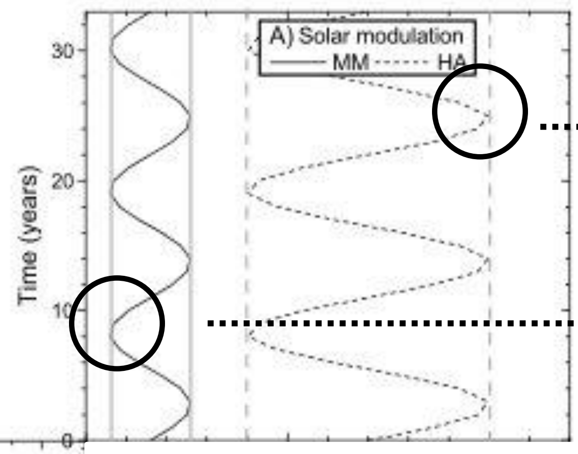
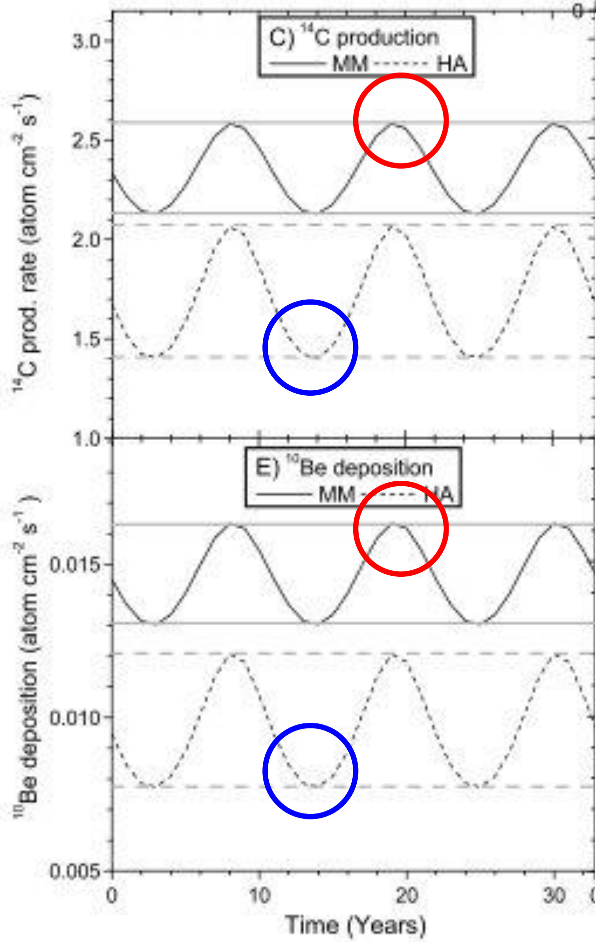


figure from Poluianov, Usoskin, Kovaltsov 2014



Φ:
From ~1000 MV
in max of high activity
(Schwabe max in Grand max)
to ~60 MV
in min of low activity
(Schwabe min in Grand min)



Ratio
^{14}C / ^{10}Be ≈ 172
in Schwabe max of high activity

^{14}C :
From ~1.3-1.4 atm/cm^2/s
in max of high activity
to ~2.6-2.8 atm/cm^2/s
in min of low activity

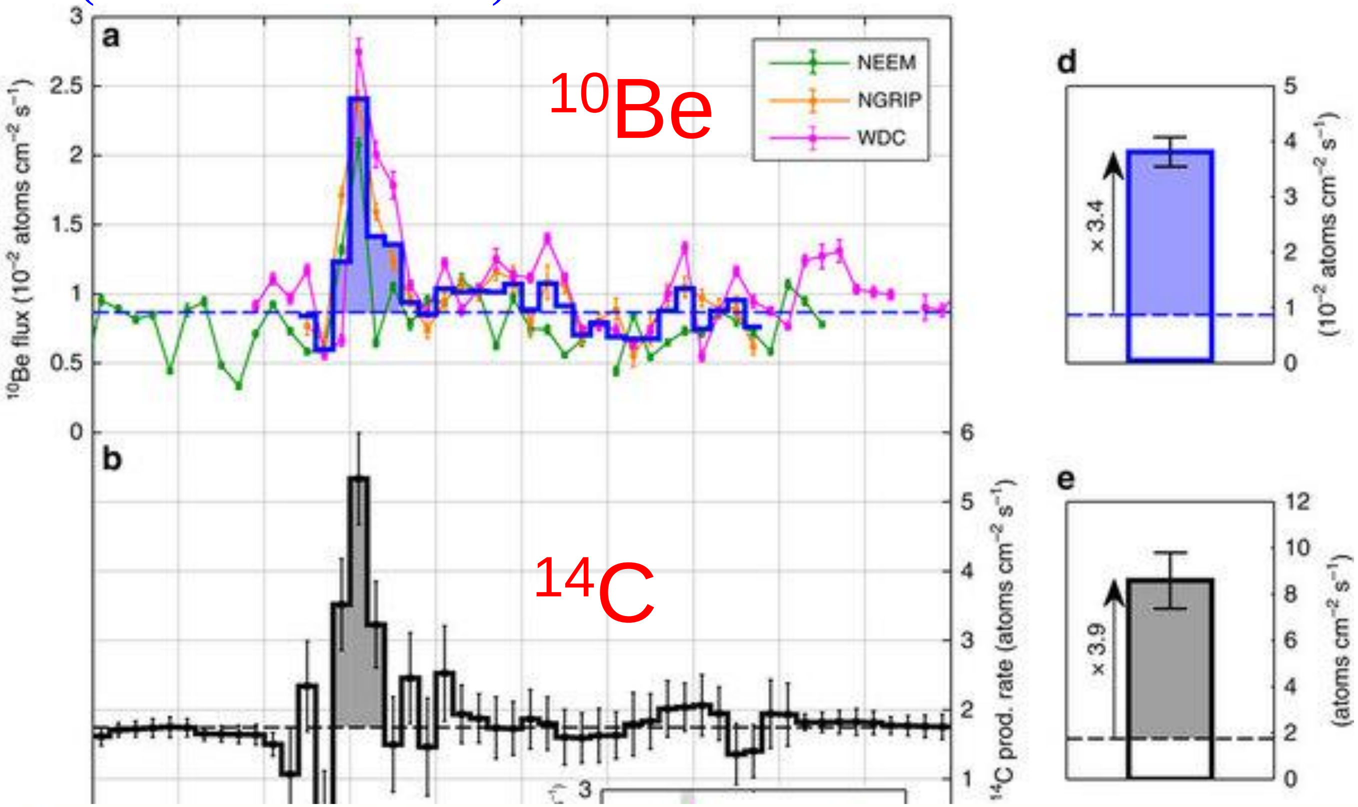
Ratio
^{14}C / ^{10}Be ≈ 166
in Schwabe min of low activity

^{10}Be:
From ~0.0078 atm/cm^2/s
in max of high activity
to ~0.0163 atm/cm^2/s
in min of low activity

(Mekhaldi for 775: Ratio ^{14}C / ^{10}Be ≈ 233 ± 20%)
Normal solar activity modes

(Mekhaldi et al. 2015)

AD 775



Ratio ^{14}C / ^{10}Be 775

$$\frac{8.64 - 1.8}{0.0394 - 0.01} = 233 \quad (\pm 20\%)$$

inconsistent with flare

Similar for AD 994:

Ratio ^{14}C / ^{10}Be = 314

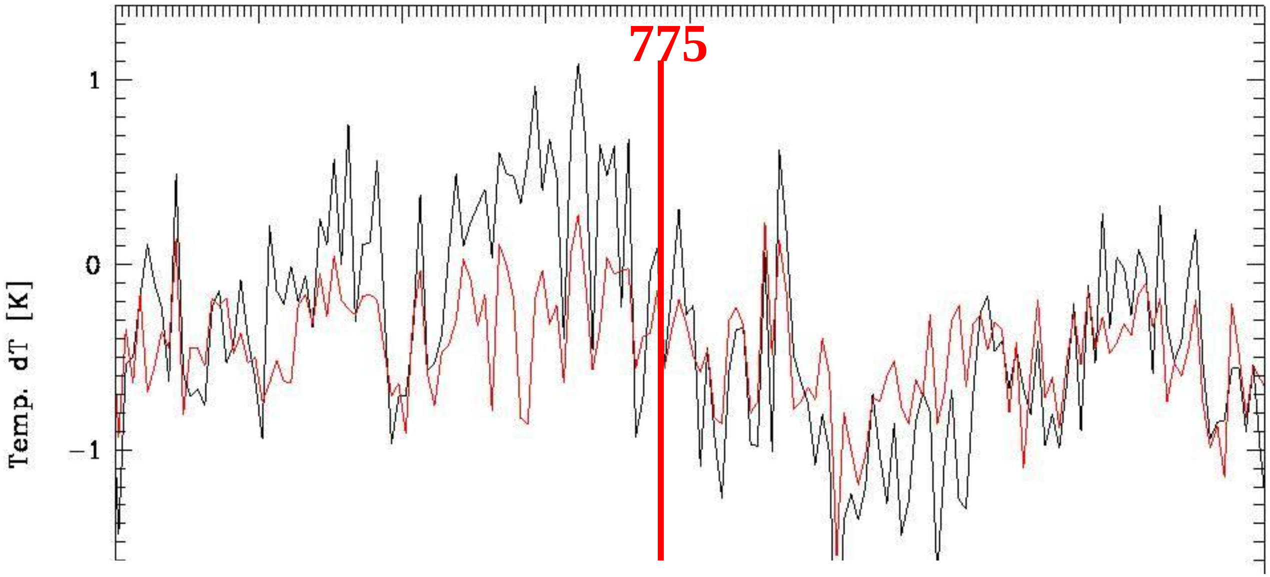
Differential production ratio of ^{14}C to ^{10}Be due to solar flare expected:

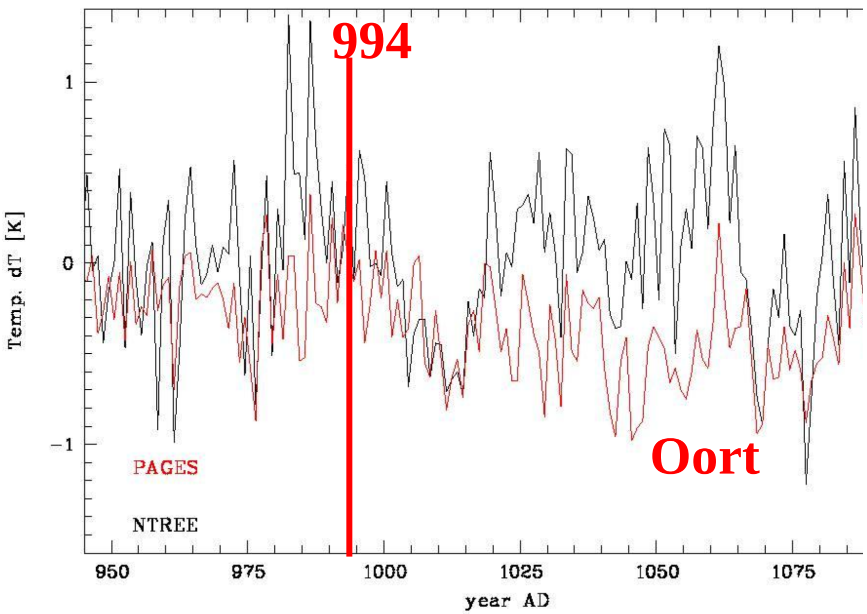
Usoskin & Kovaltsov (2012): **<u>~ 38 times more ^{14}C than ^{10}Be</u>**

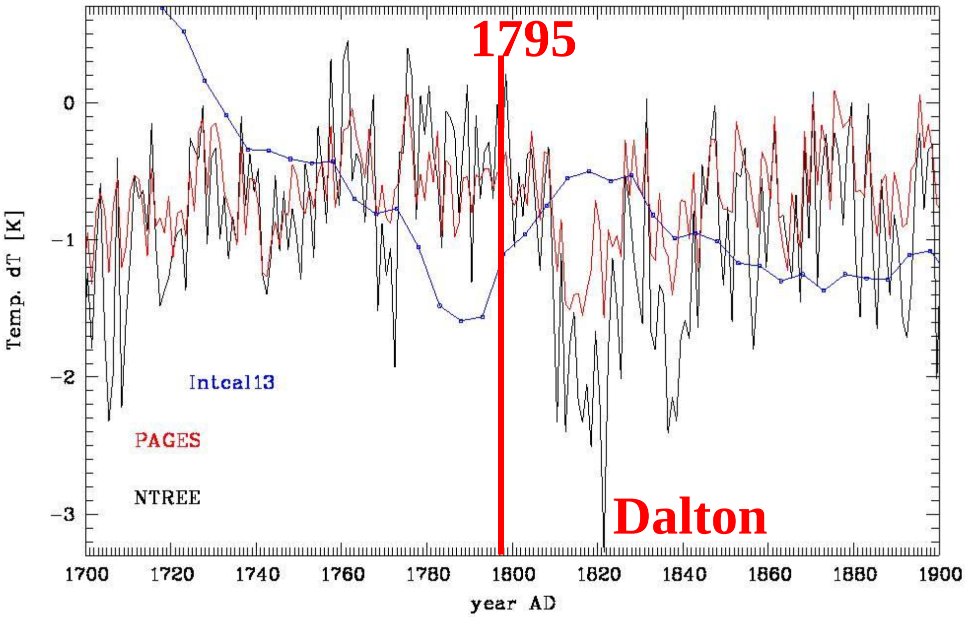
Pavlov et al. (2014 MNRAS): <u>16-17 times more ^{14}C than ^{10}Be</u>

If 775 due to solar activity decline, then temperature decline on Earth expected …

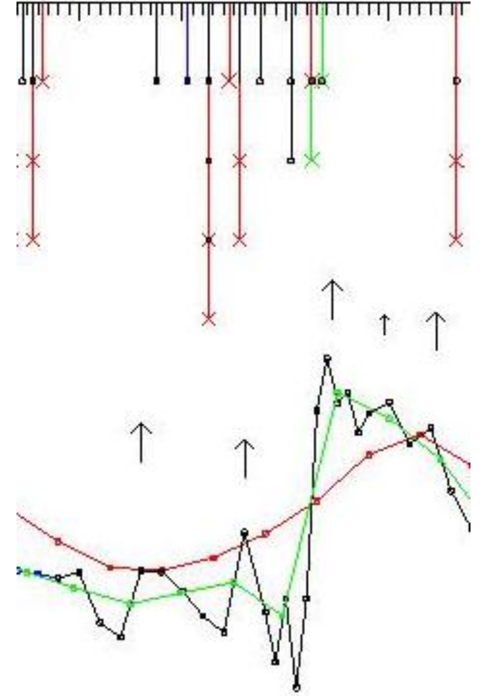
(which would not be expected after a solar super-flare)







What is the cause of the ^{14}C variation ?



A supernova ? Not observed, no remnant

A gamma-ray burst ? Possible, but very rare

A comet impact ? Did not happen

A solar super-flare ? Dubious, if possible at all (no spots, no aurorae)

What else ? **A fast strong drop in solar activity**

➔ less solar wind ➔ more cosmic rays and ^{14}C

(similar to the sudden start of the Dalton minimum
and maybe also BC 671, ~ once per millenium)

Neuh & Neuh 2015a
arXiv:1503.01581
+
Neuh & Neuh 2015b
arXiv:1508.06745

Timing ? When a weak short cycle happens after a strong cycle …