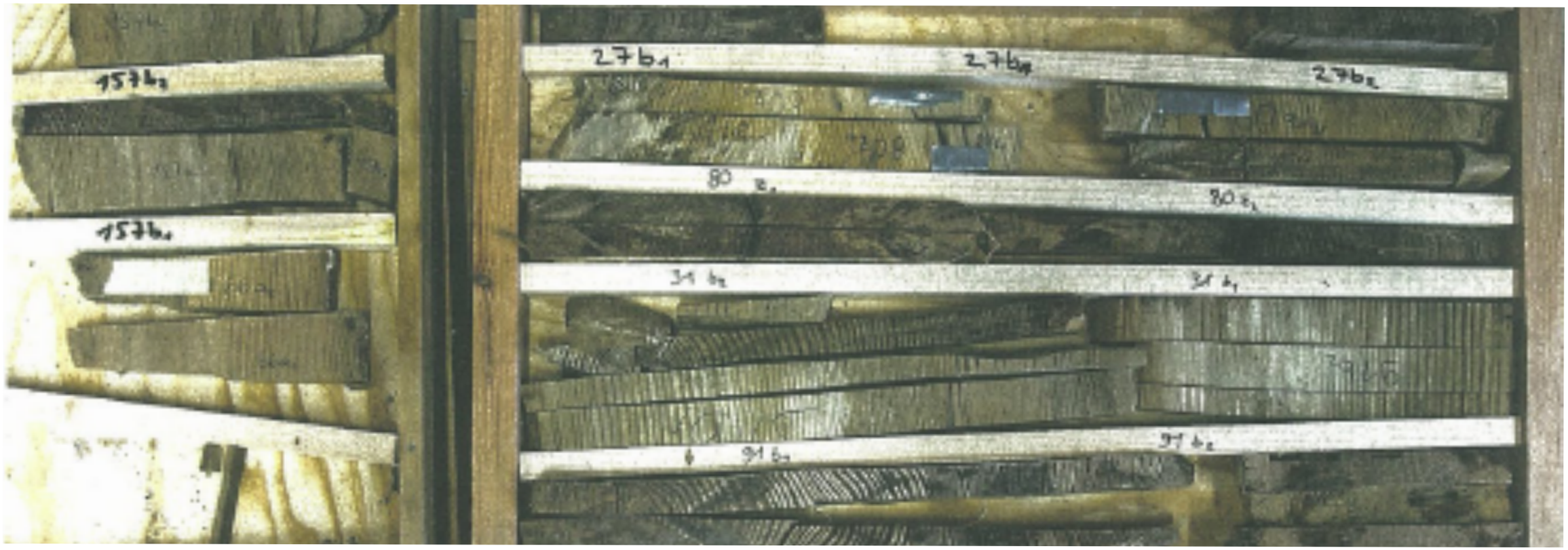

Tree-rings and Radiocarbon

Lukas Wacker

Requirements for accurate high-precision dating

Tree-rings as archive for atmospheric ^{14}C

- ★ *Annual structure*
- ★ *Long accurate annually resolved archives (back to 12 000 years)*
- ★ *Atmospheric radiocarbon signal (CO_2 uptake)*
- ★ *Growing season*
- ★ *CO_2 uptake and cellulose formation*

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What can we learn from ^{14}C in trees

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- ★ *Carbon cycle*
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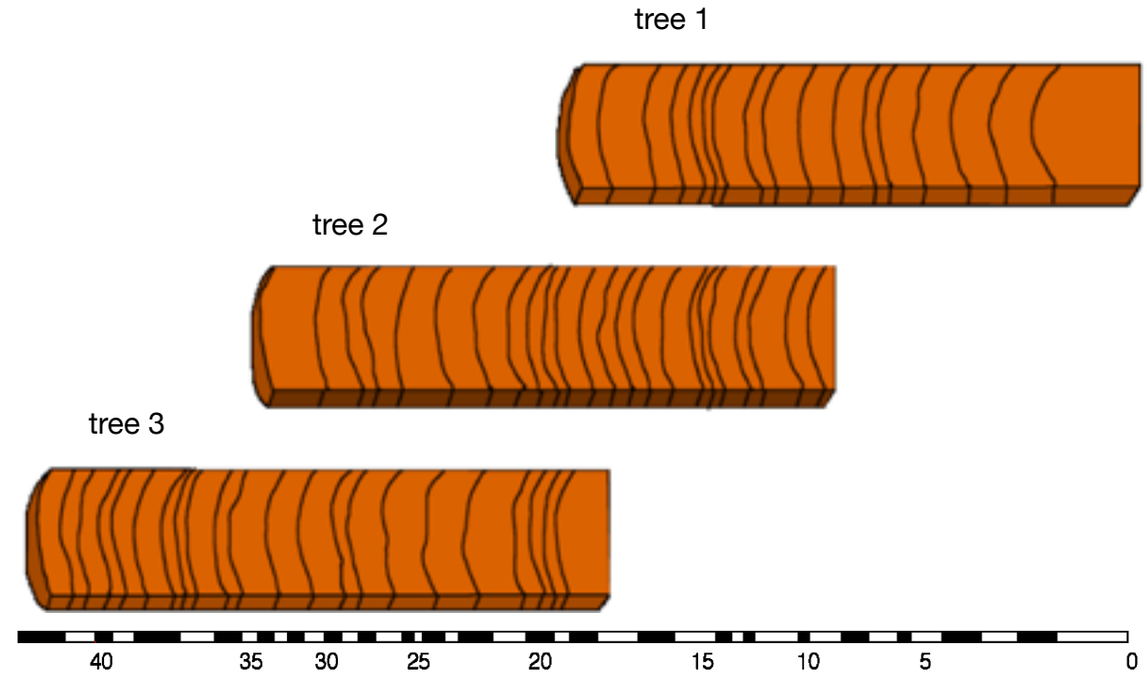
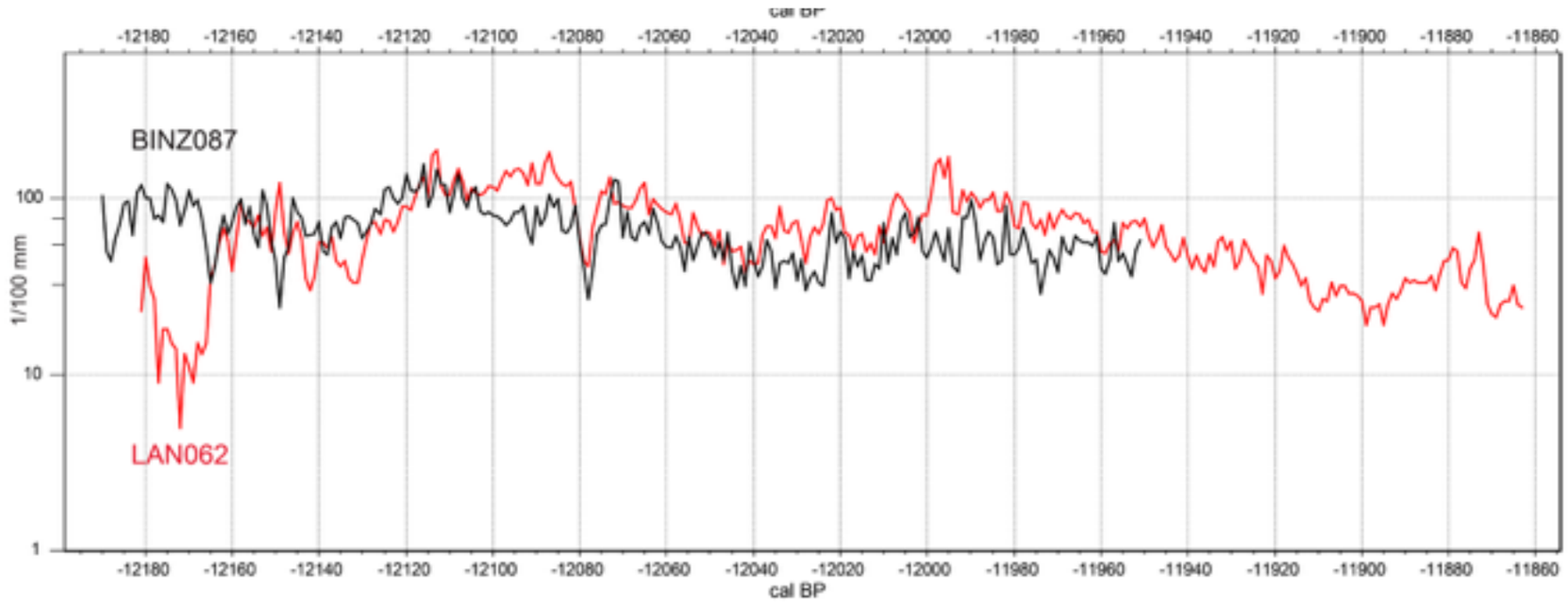
Radiocarbon calibration

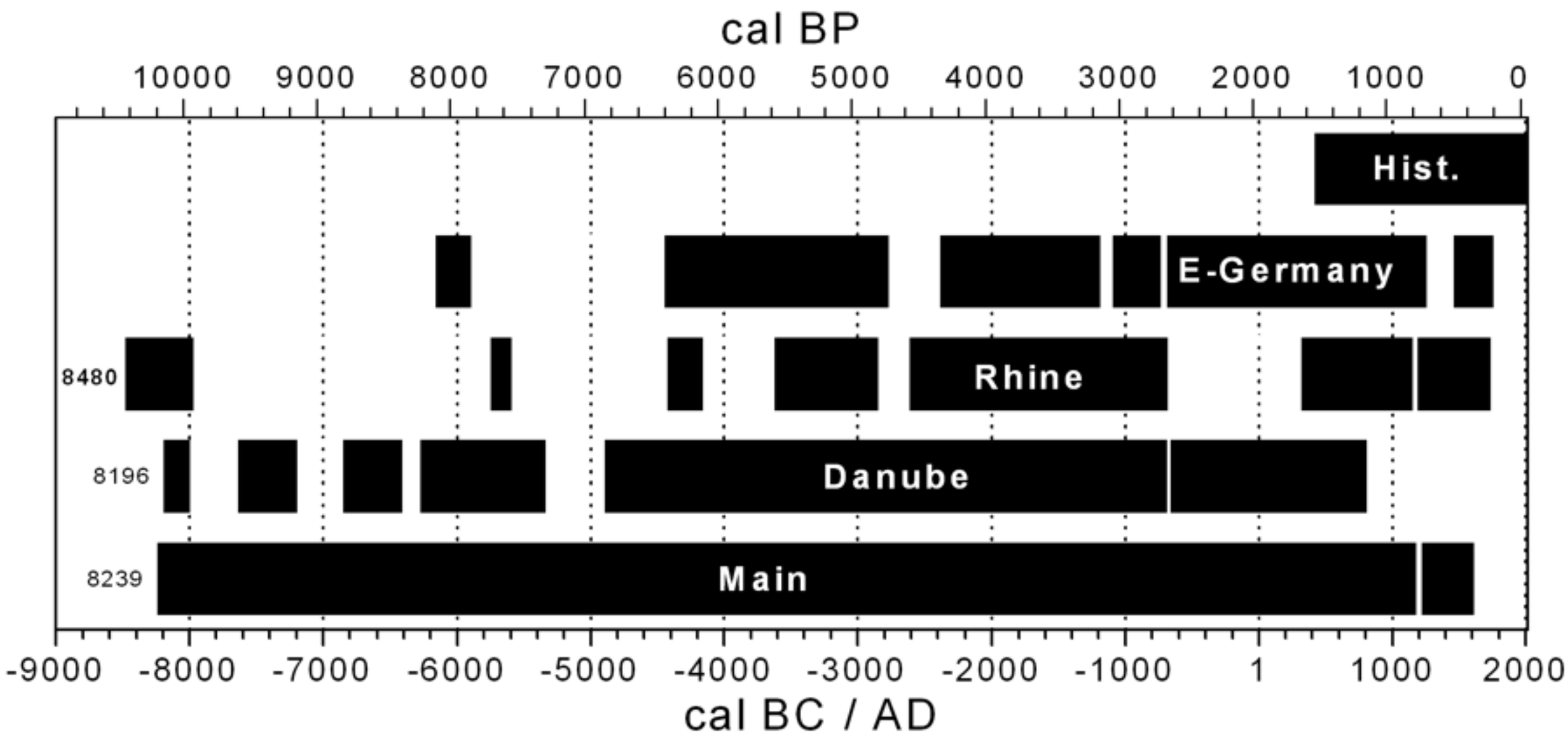
- ★ *Importance tree-ring signal for precise dating*
- ★ *Fine structure offers new opportunities…*

Dendrochronology



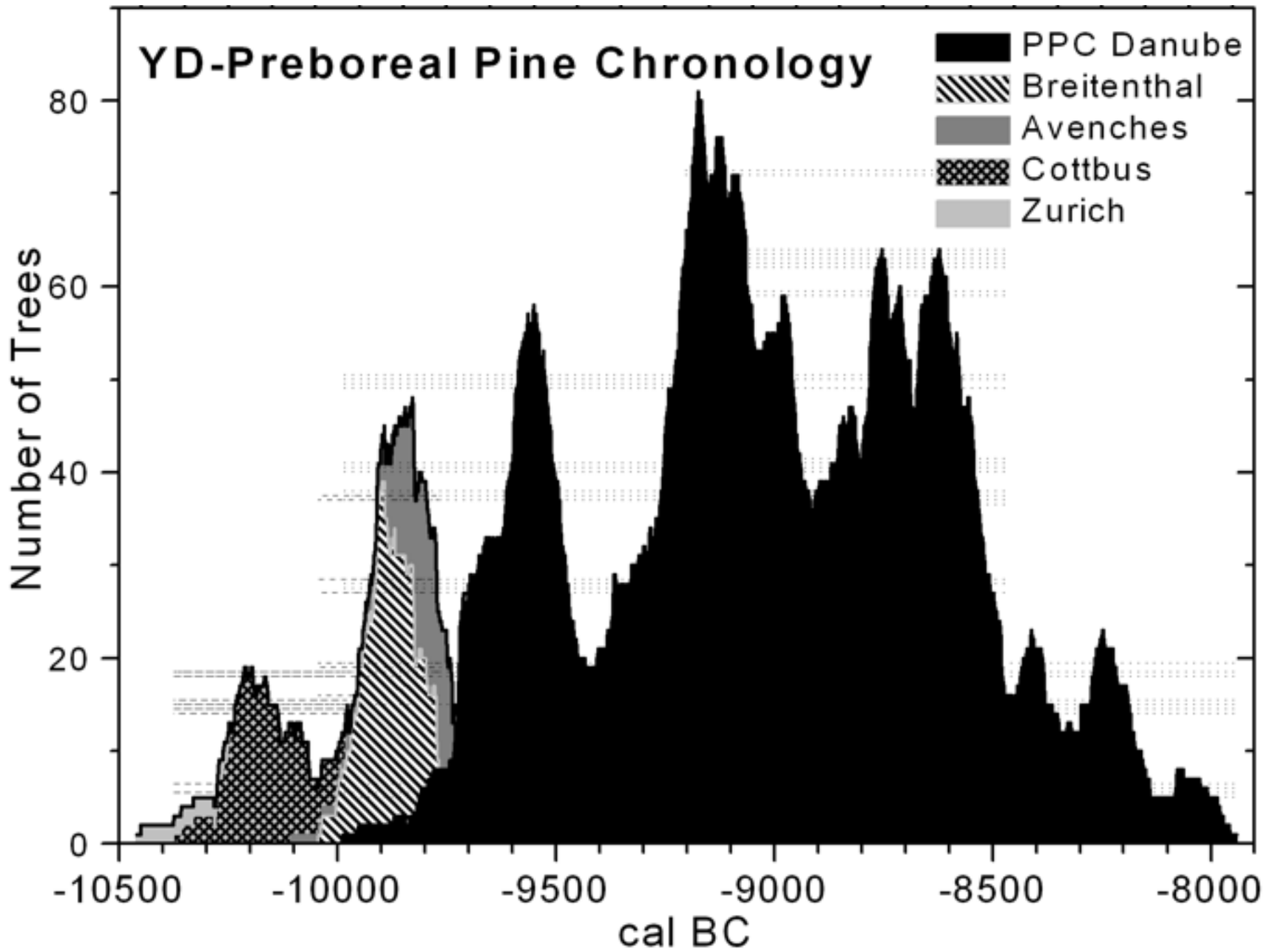


Hohenheim oak chronology



Friedrich et al. 2004

Pine tree extension



Friedrich et al. 2004

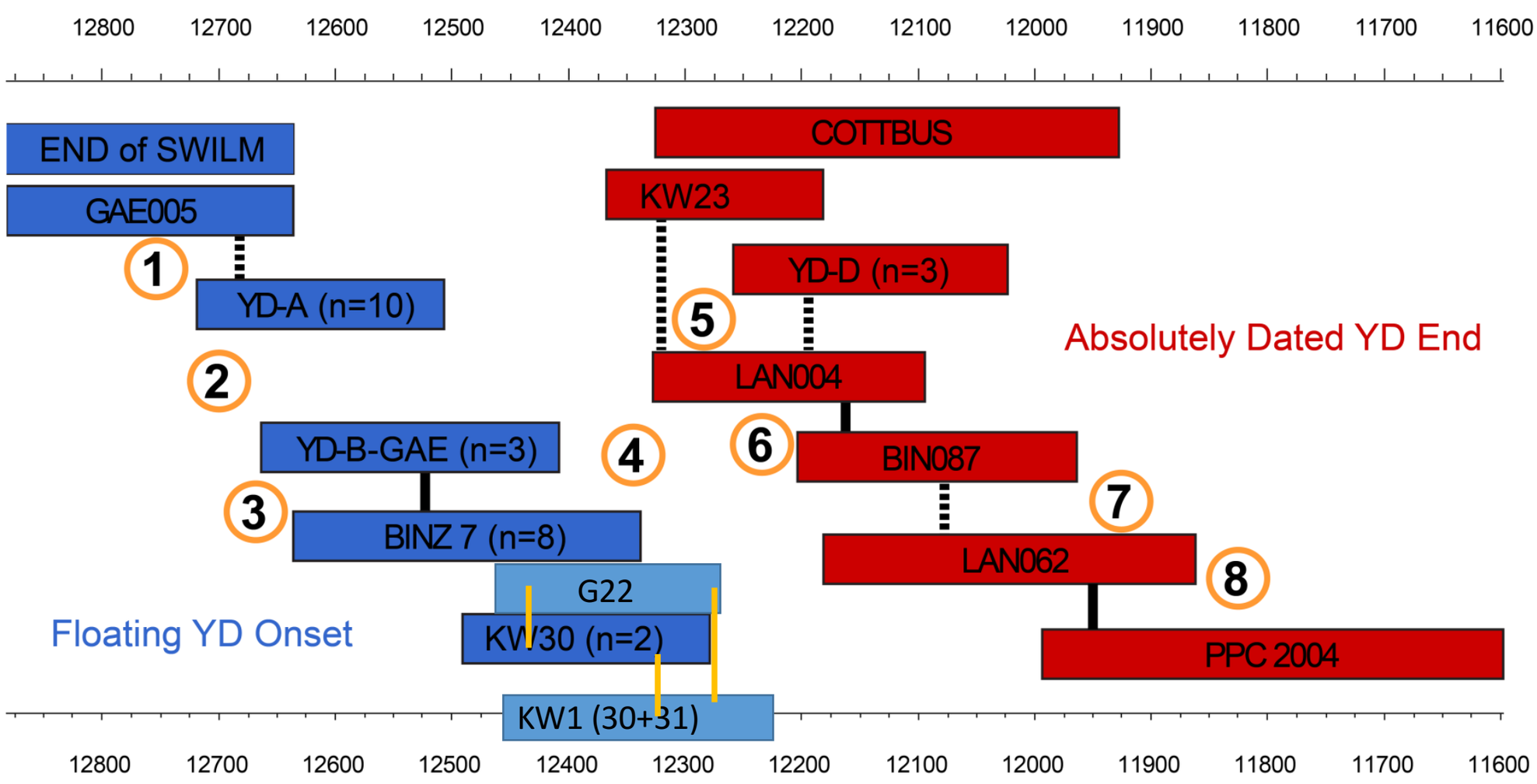
Late glacial extension of tree-ring based curve

New Late Glacial wood findings in Zurich

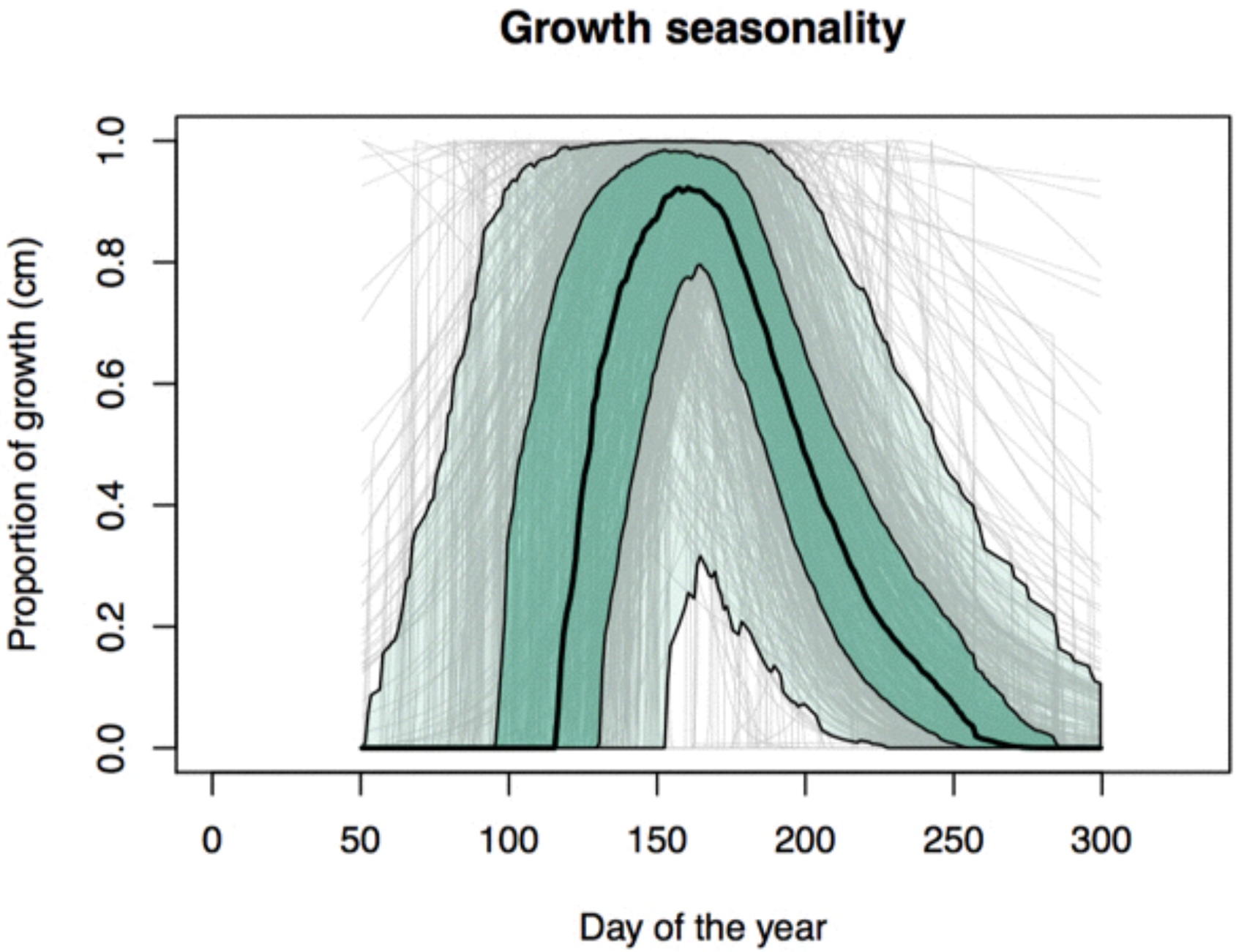
- 260 trees
- Well-preserved rootstocks
- Range: 11 500 - 13 000 BC

Preservation in clay

Extending the tree-ring IntCal curve



How do trees grow

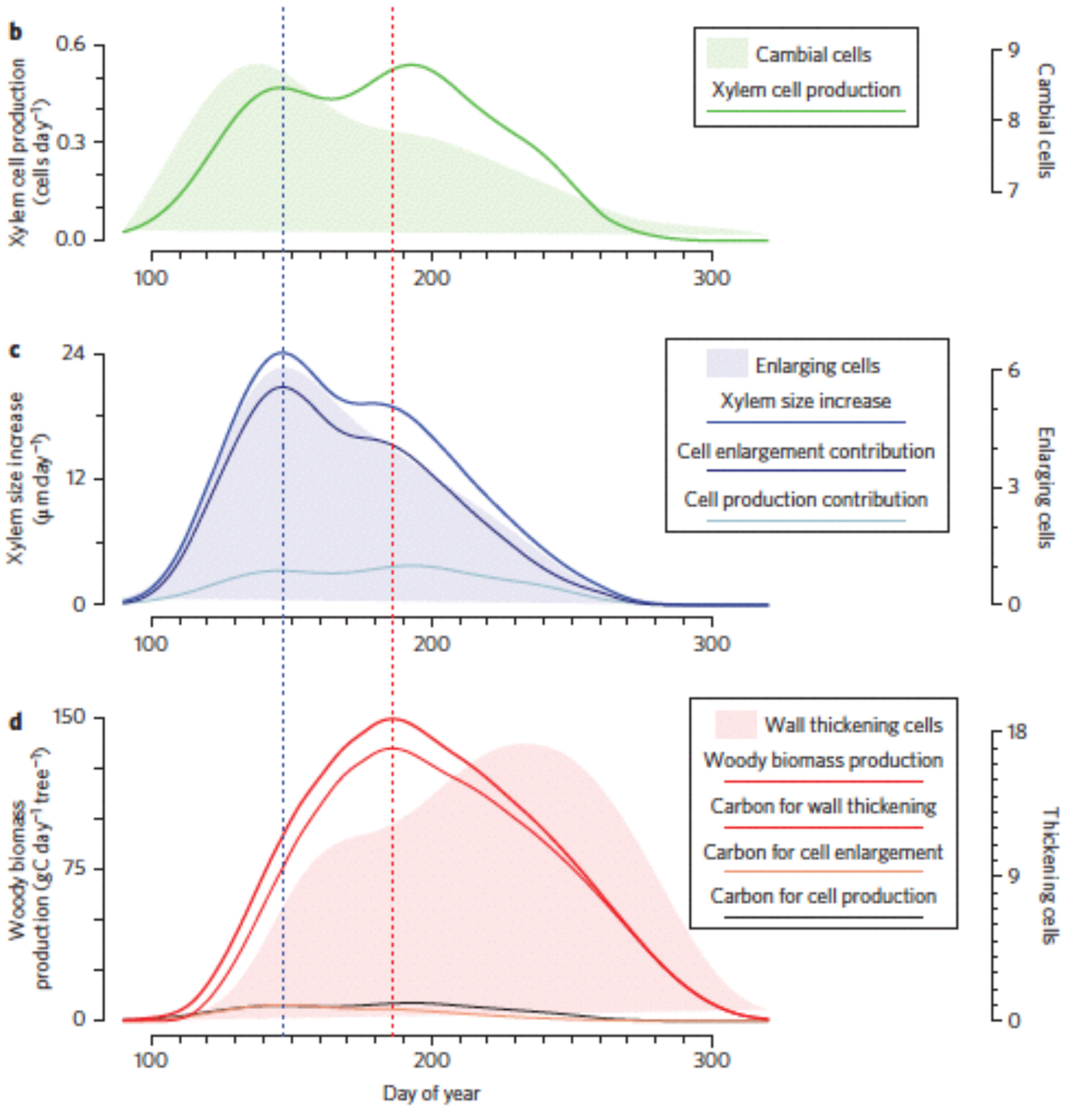


https://serc.si.edu/research/projects/tree-phenology

Seasonality of wood formation

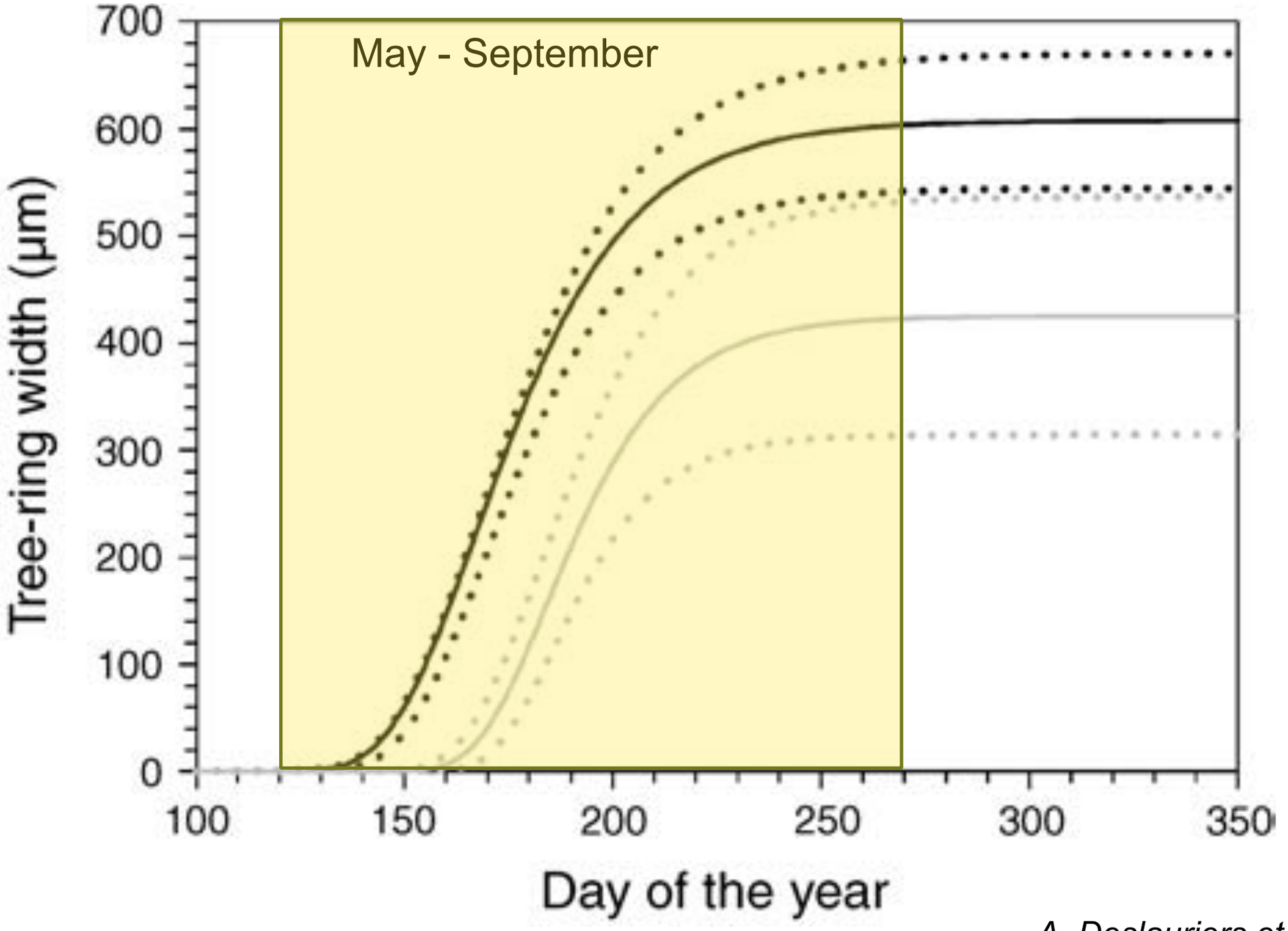
Growth: May - October

silver fir, Norway spruce and Scots pine



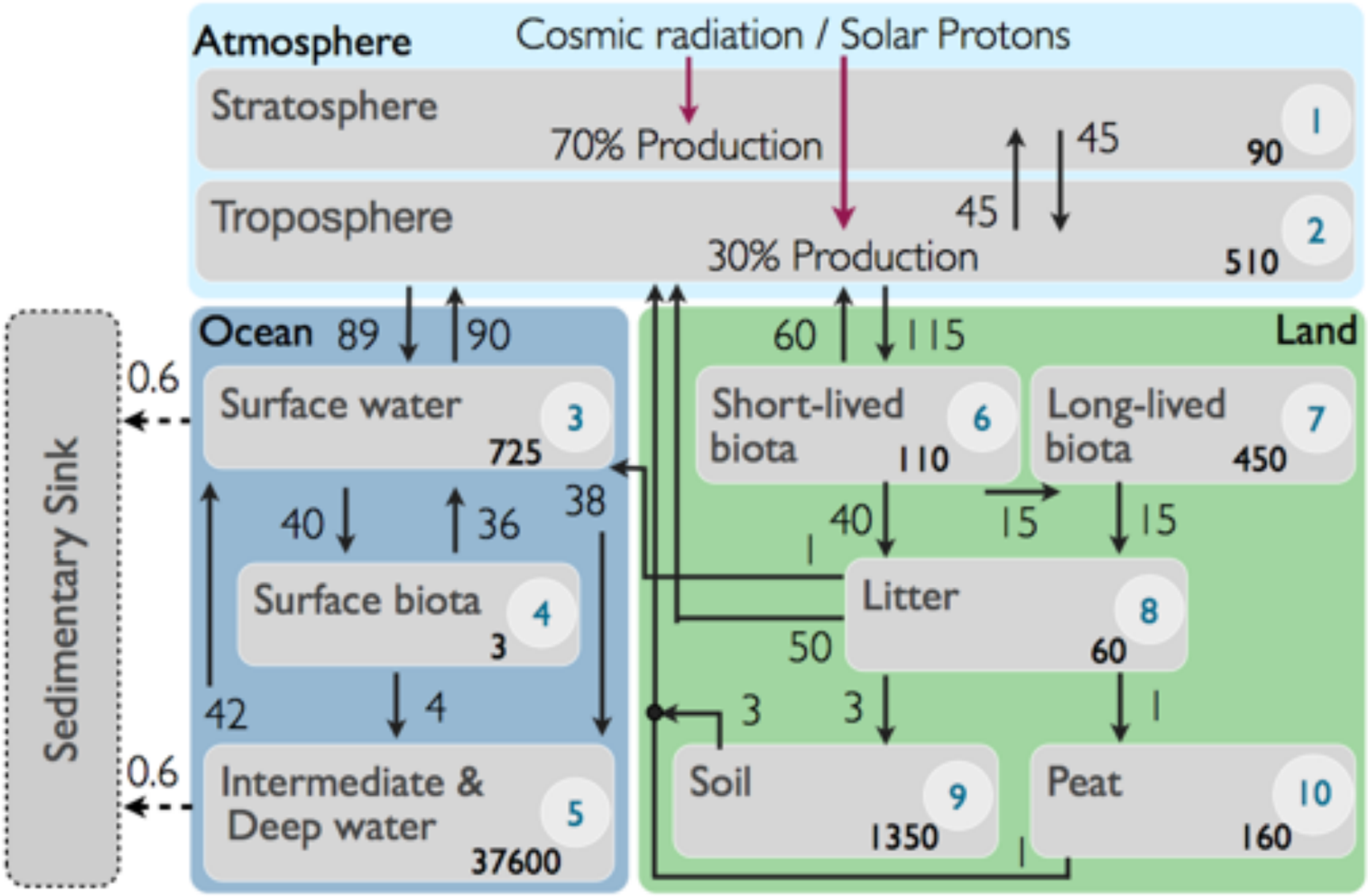
H.E. Cuny et al. 2015

Seasonal growth of tree



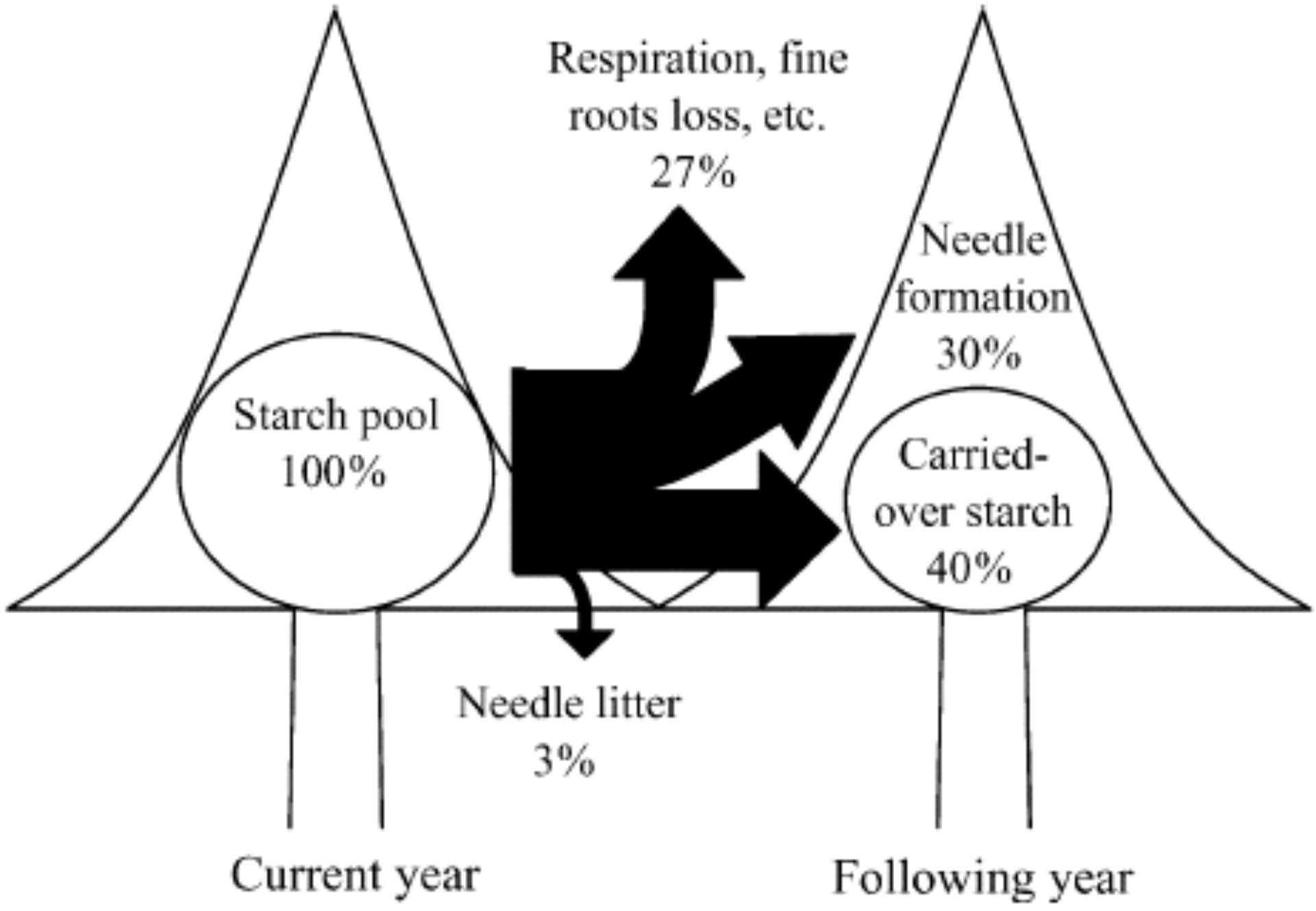
A. Deslauriers et al. 2008

Carbon cycle



D. Güttler et al. 2015

Non structural carbon



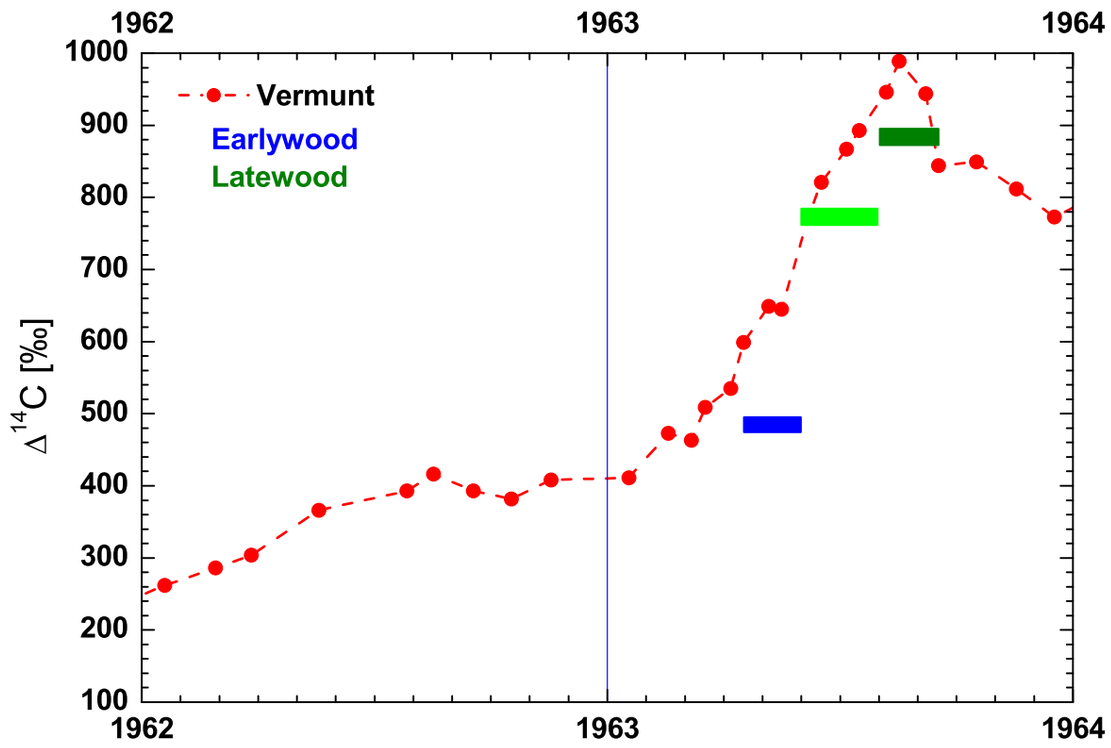
A. Kagawa et al. 2006

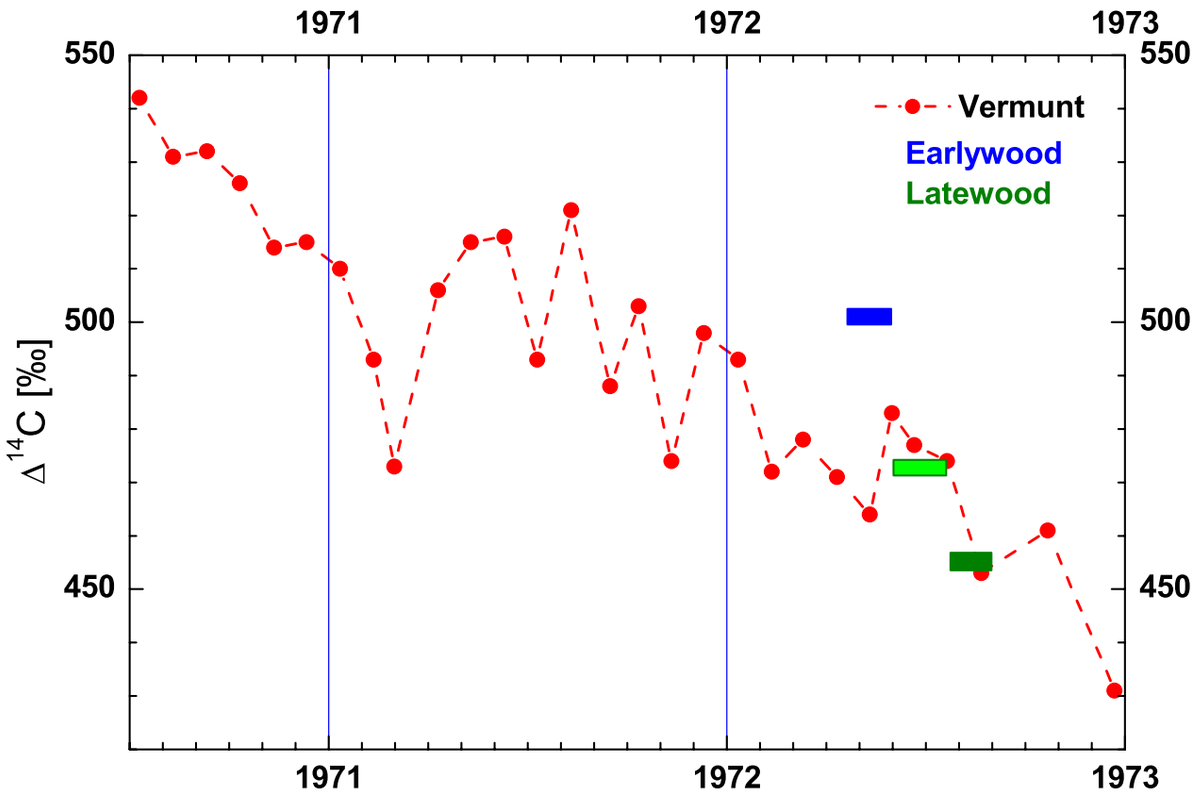
Age of non structural carbon in trees

		Sugar		Starch	
Site	Species	$F^{14}C$	Age	$F^{14}C$	Age
Howland Forest	Red maple	1.1087 ± 0.0466	12.4 ± 7.1	1.1236 ± 0.0856	12.9 ± 10.8
	Eastern hemlock	1.0900 ± 0.0326	9.4 ± 5.6	na	na
Bartlett Experimental Forest	Red maple	1.1119 ± 0.0326	13.0 ± 4.9	1.1347 ± 0.0663	15.5 ± 7.8
Harvard Forest	Red maple	1.0818 ± 0.0344	7.5 ± 5.8	1.0760 ± 0.0564	6.1 ± 8.8
	Eastern hemlock	1.0641 ± 0.0112	4.4 ± 2.7	na	na
All	Red maple	1.1015 ± 0.0393	11.1 ± 6.3	1.1119 ± 0.0728	11.6 ± 9.8
	Eastern hemlock	1.0763 ± 0.0266	6.8 ± 4.9	na	na

A.D. Richardson et al. 2013

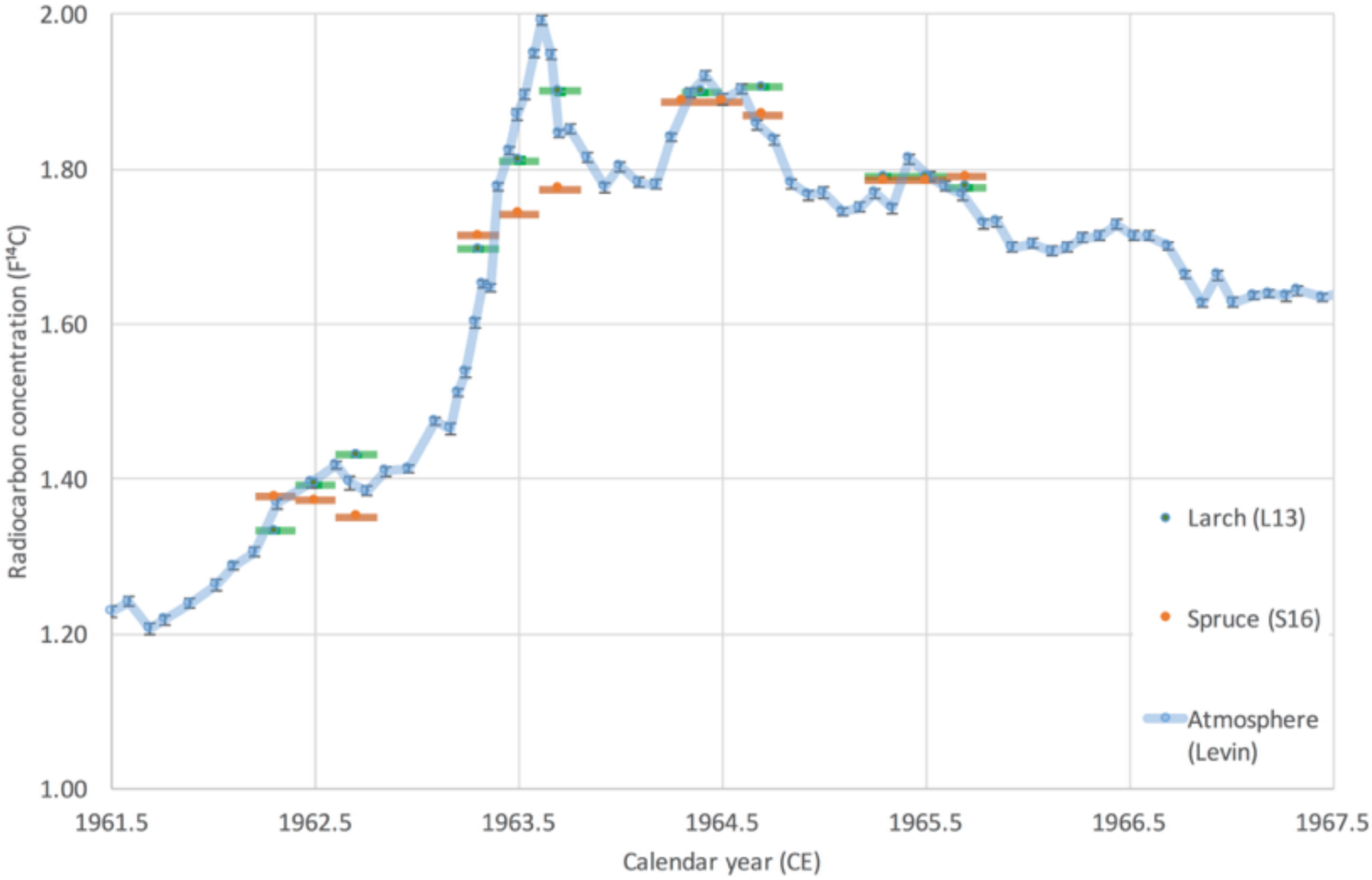
Earlywood / Latewood (oak)





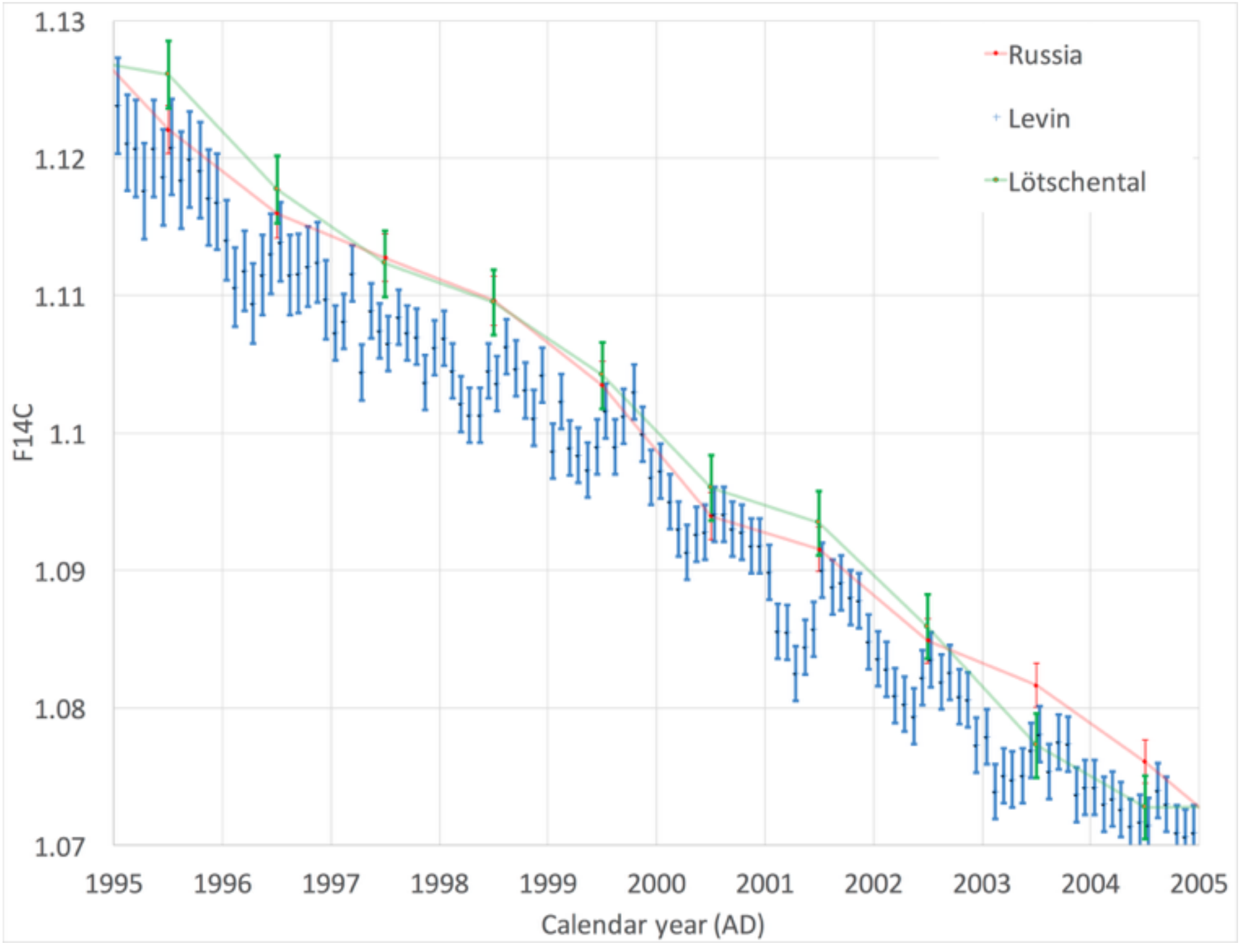
unpublished, ETHZ / Kromer

Earlywood / Latewood



unpublished, ETHZ / WSL

Annual variation



Trees as archives for atmospheric ^{14}C

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★ Long tree-ring chronologies can be built

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★ *Rings incorporate annual ^{14}C signal of atmosphere directly*

Trees as archives for atmospheric ^{14}C

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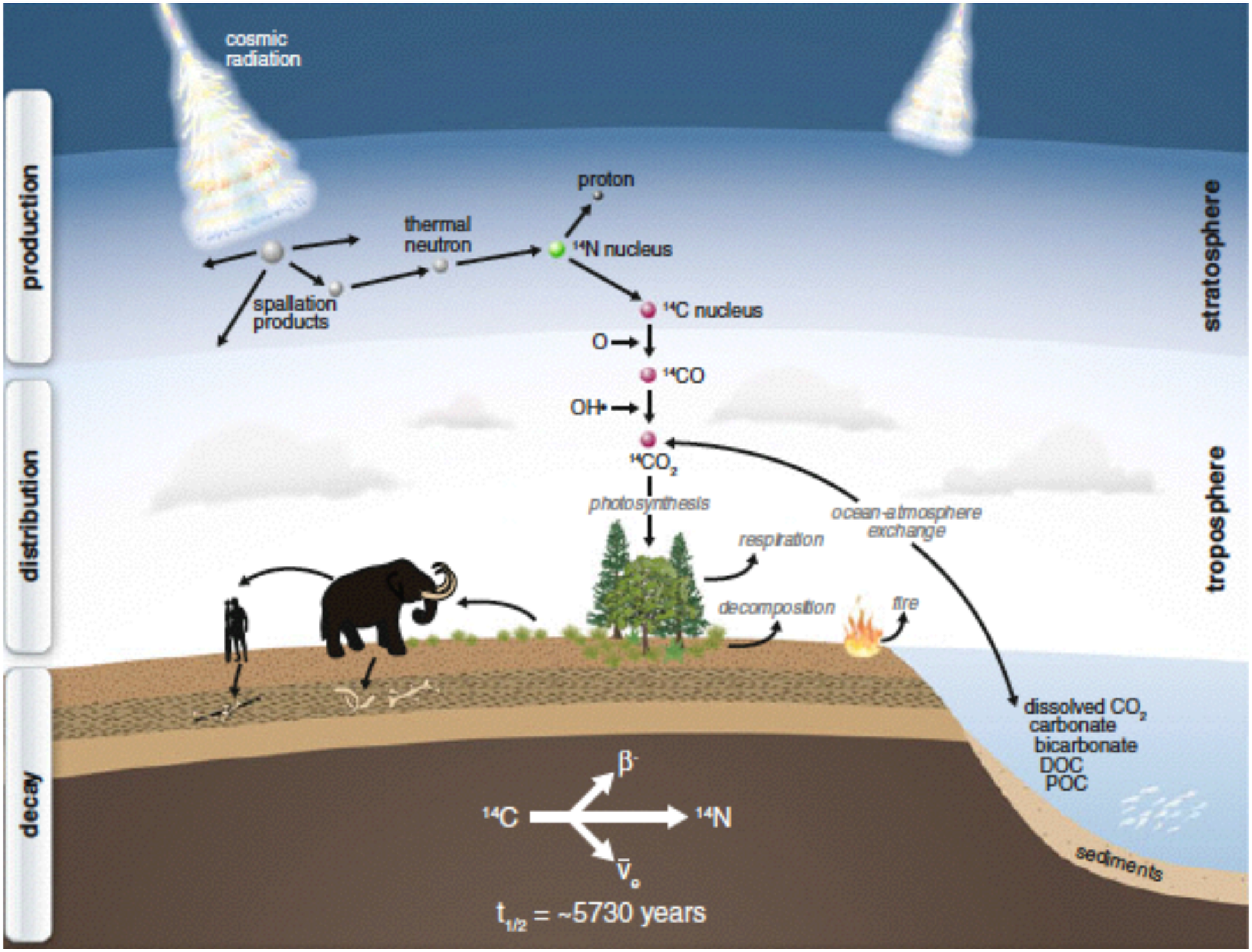
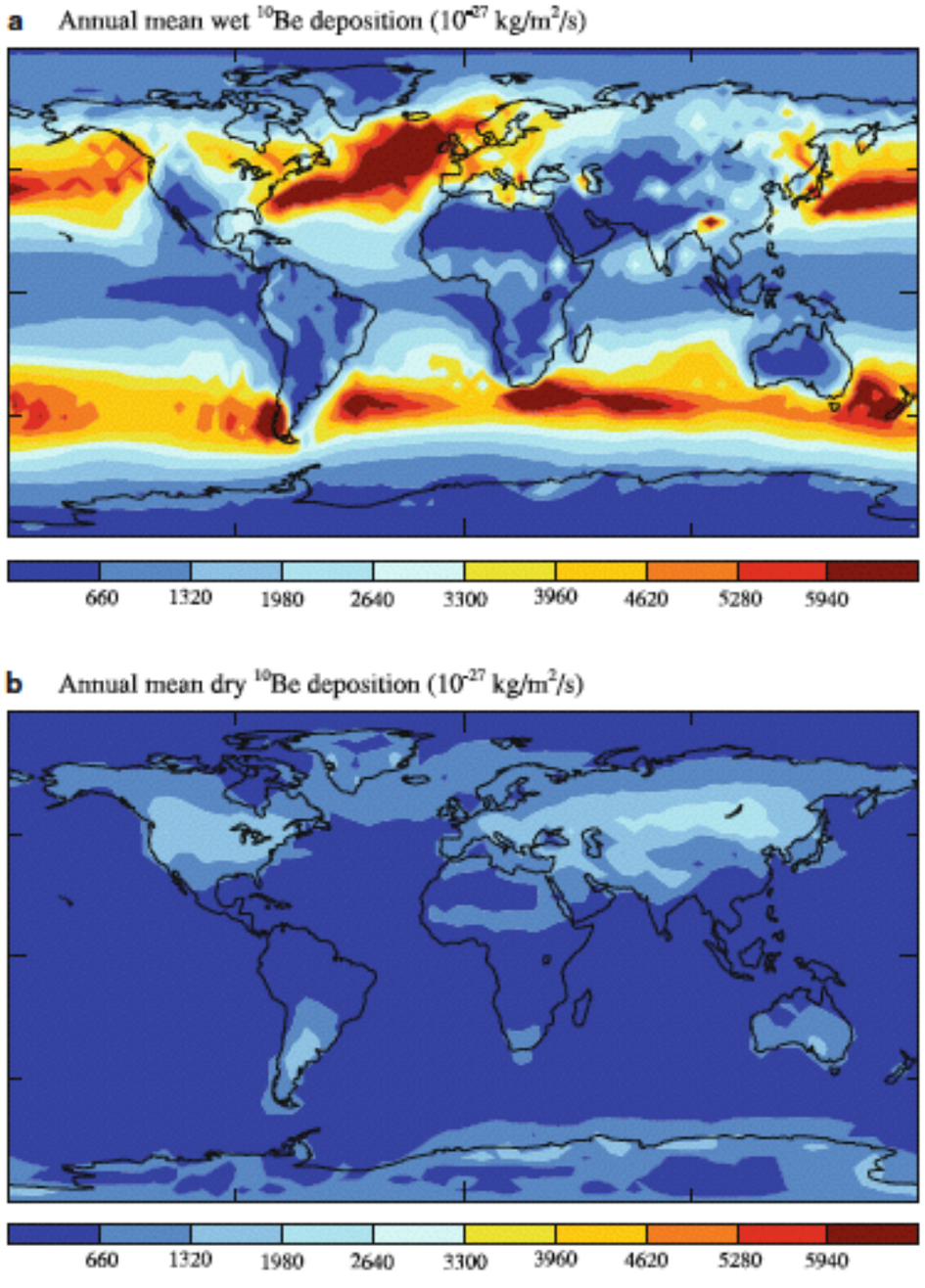
★ *Rings incorporate annual ^{14}C signal of atmosphere directly*

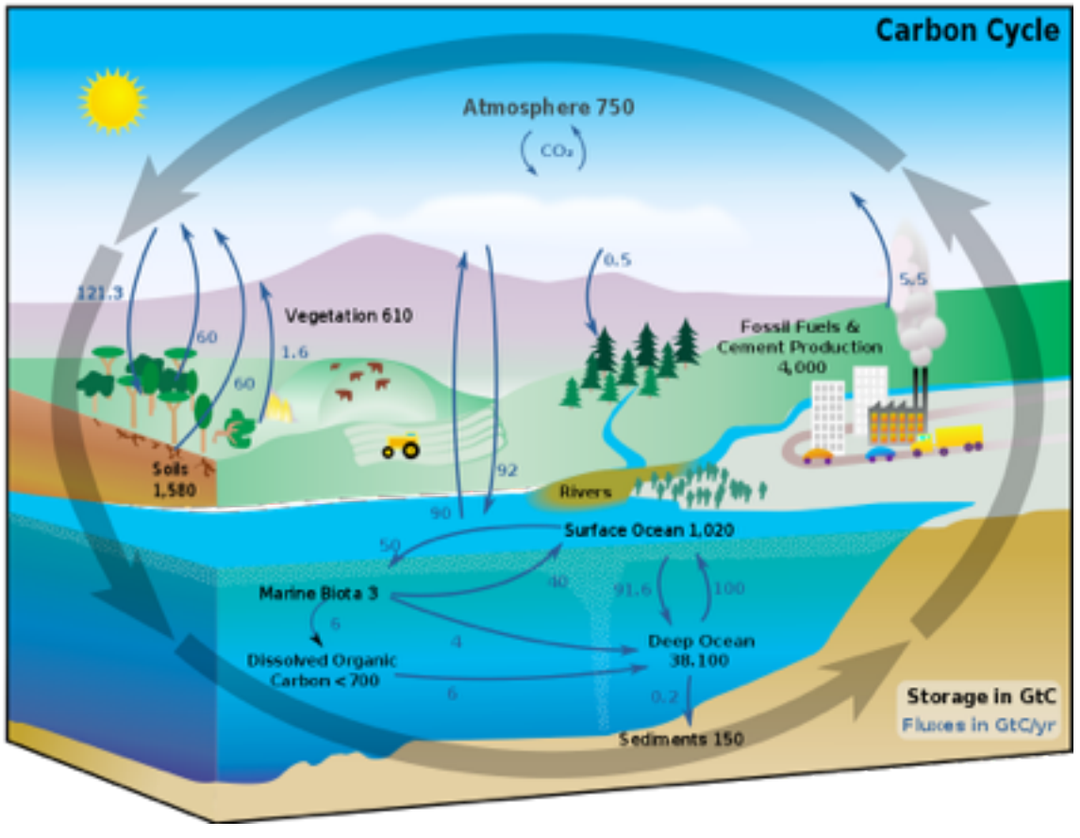
★ *Tree-rings sample atmospheric summer concentrations of ^{14}C*

Cosmic radionuclides



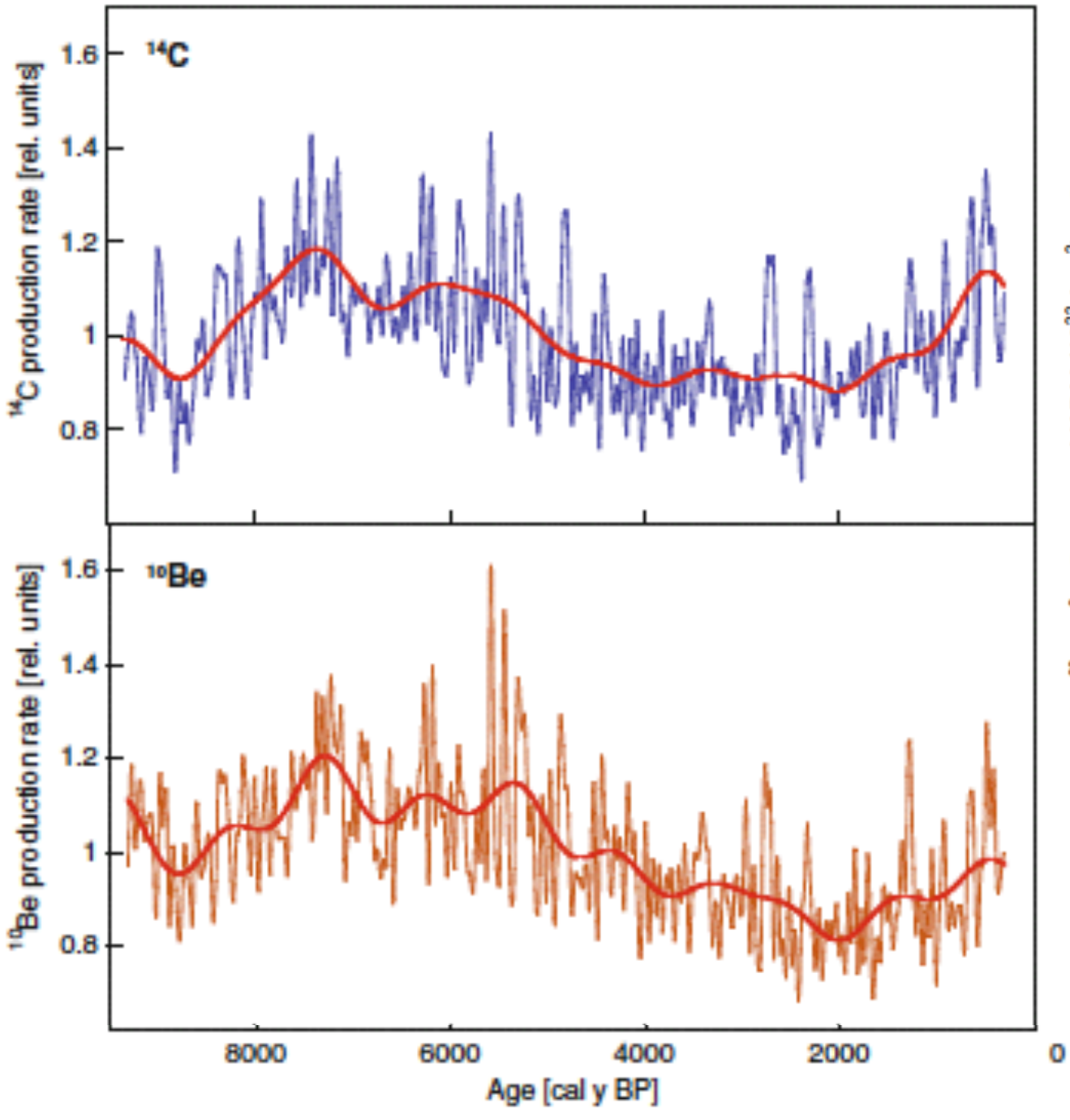
Cosmic radionuclides

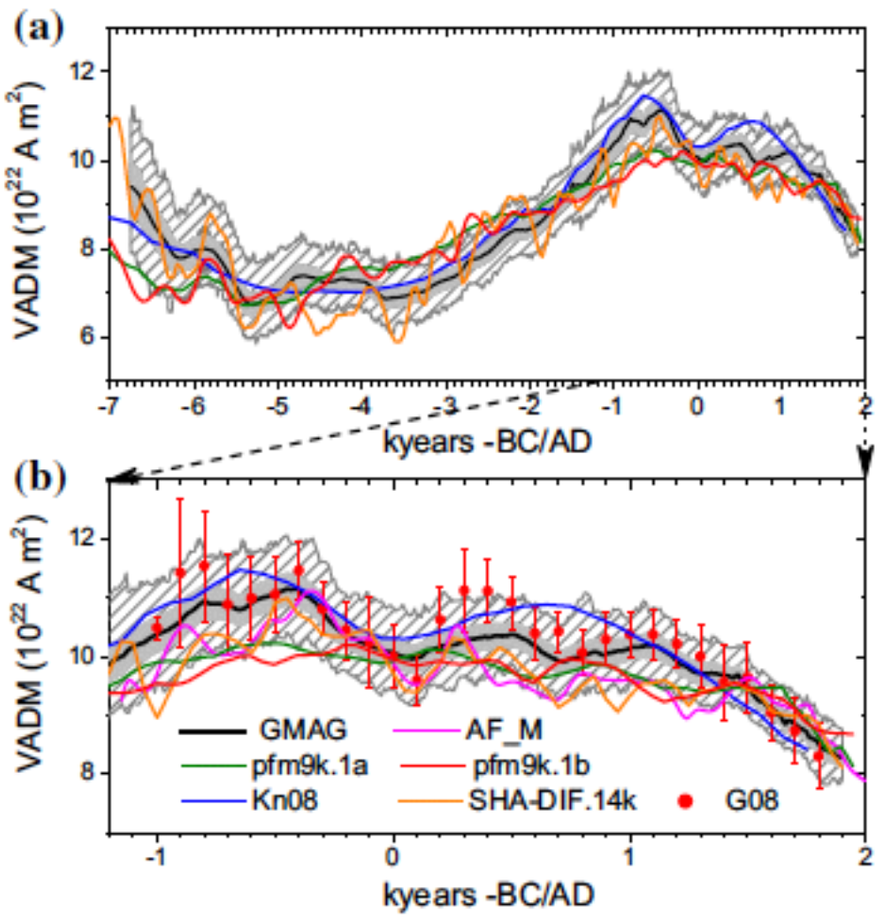




Beer et al. 2012 / Wikipedia

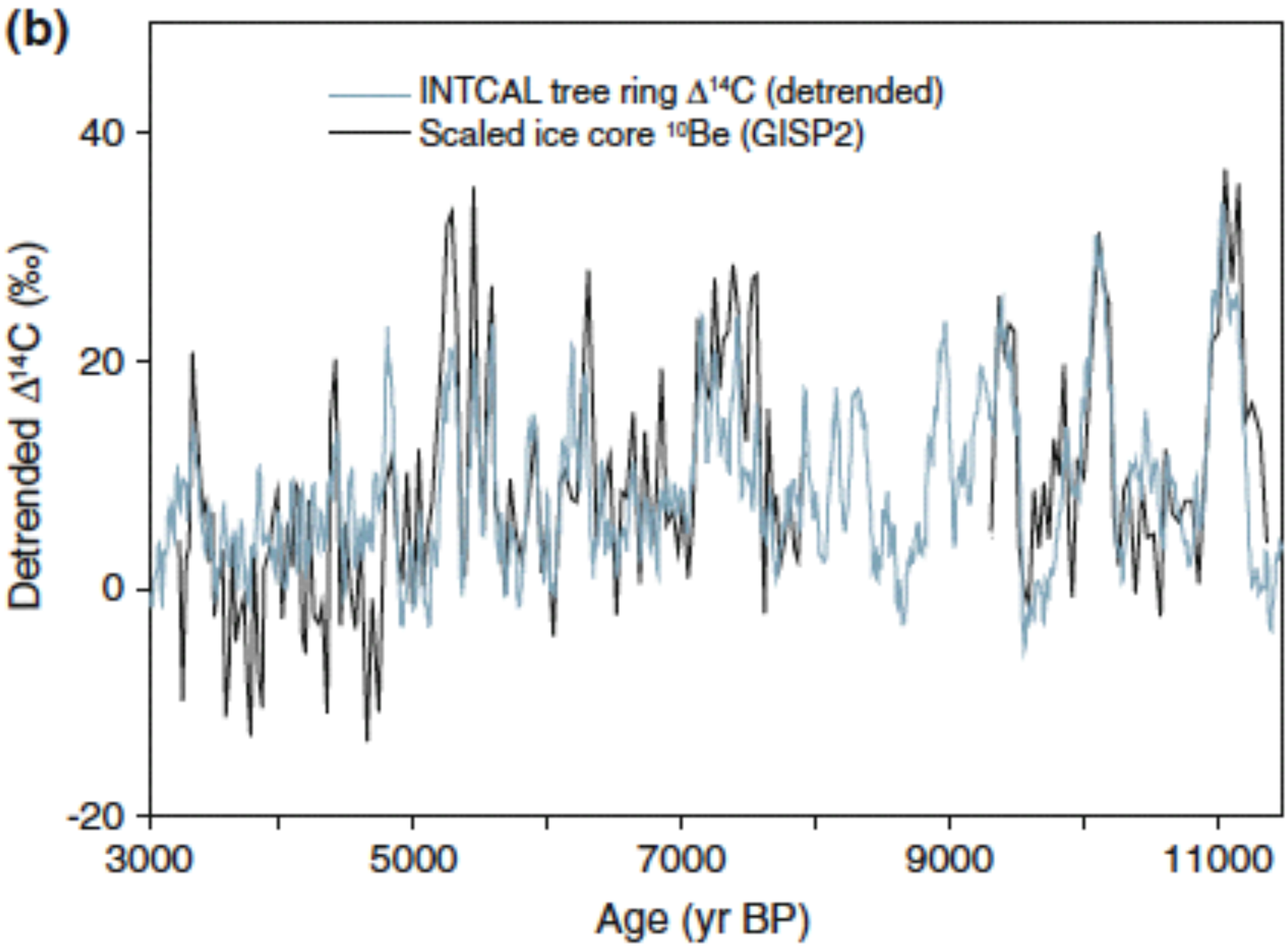
Production rates from ^{14}C and ^{10}Be



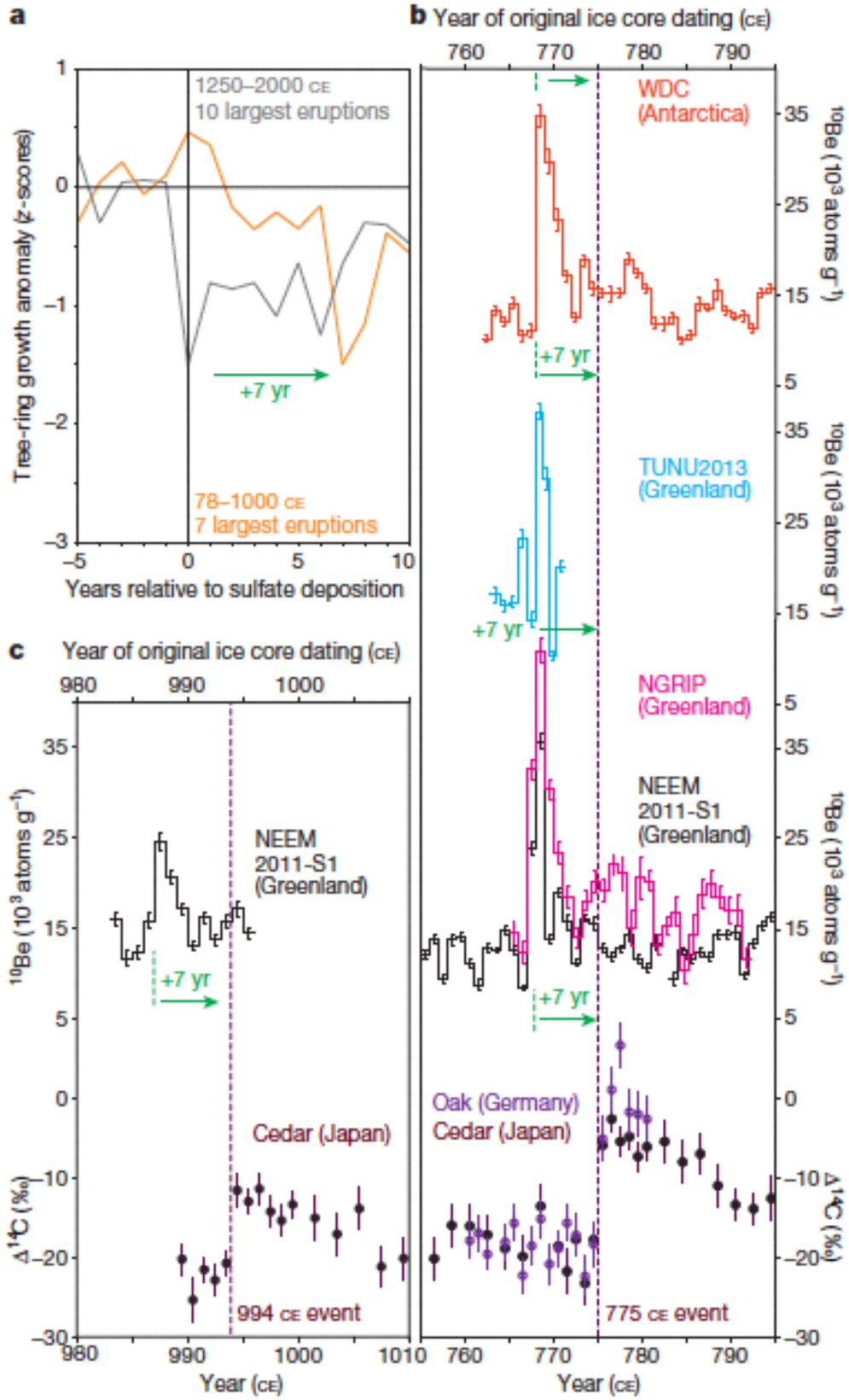


Cosmic radionuclides, Beer et al. 2012

Synchronizing tree-rings with ice cores



Time marker



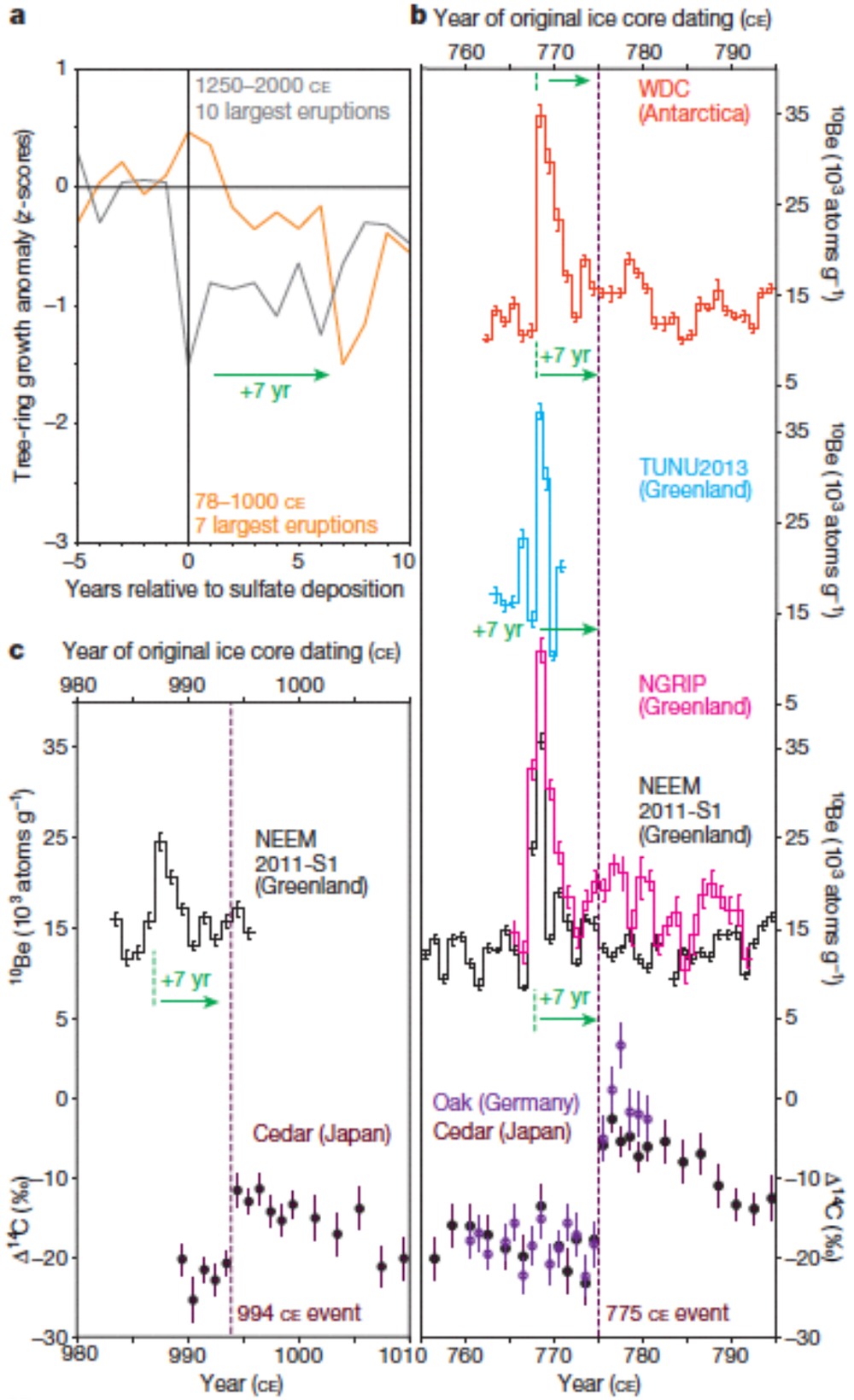
Sigl et al. 2015

Time marker

Fast changes in production

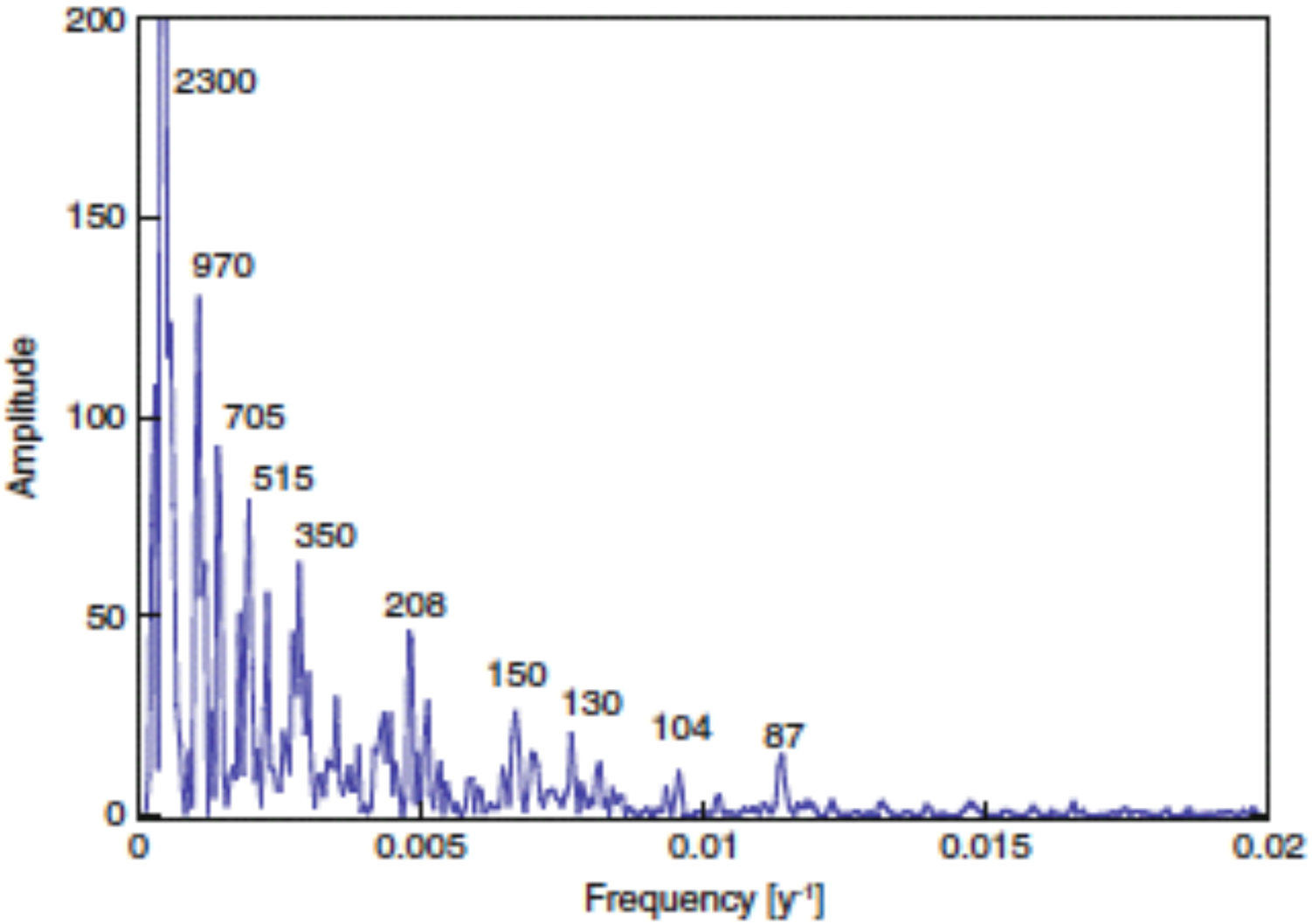
->

Synchronization of archives



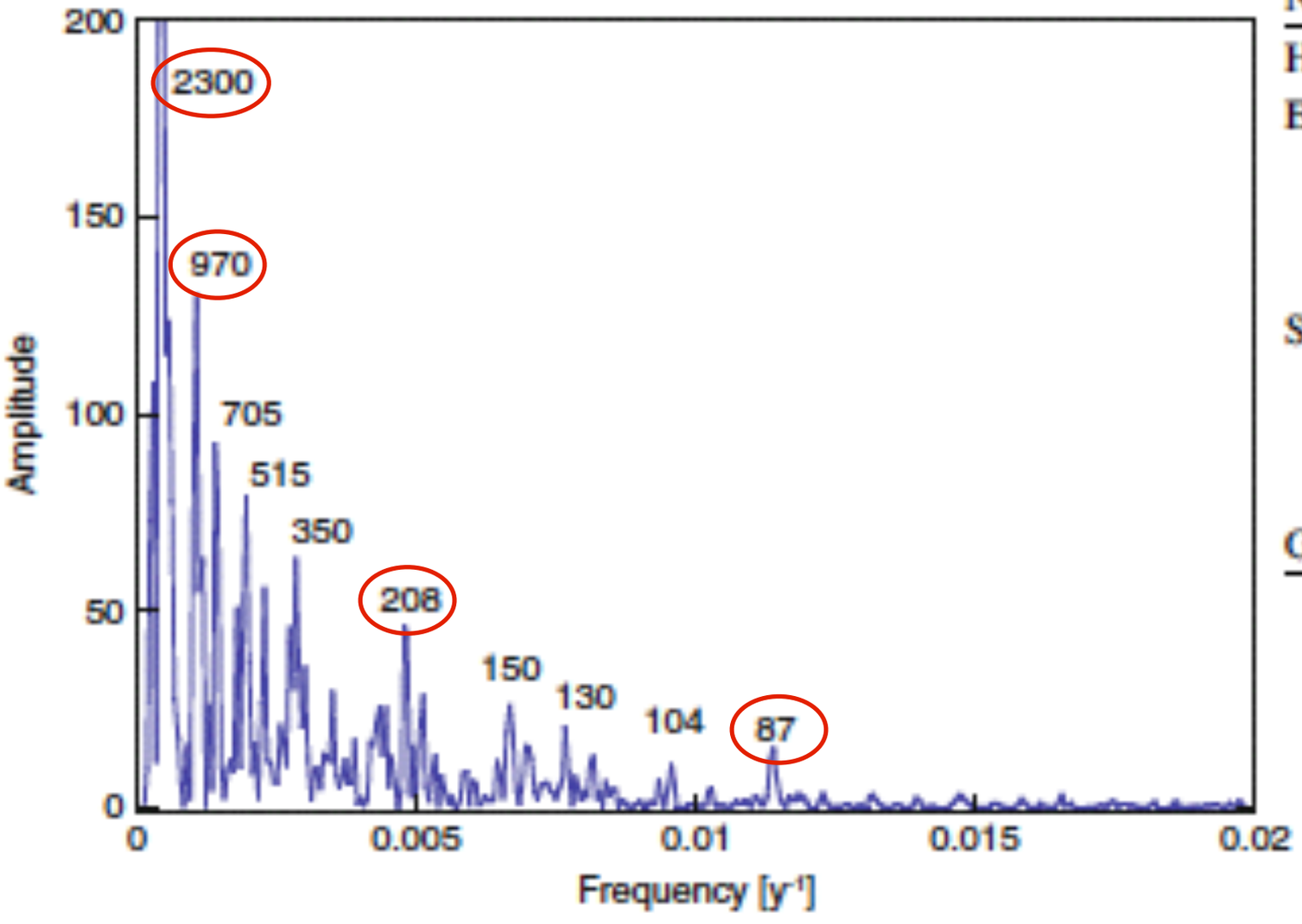
Sigl et al. 2015

Cosmic radionuclides



Cosmic radionuclides, Beer et al. 2012

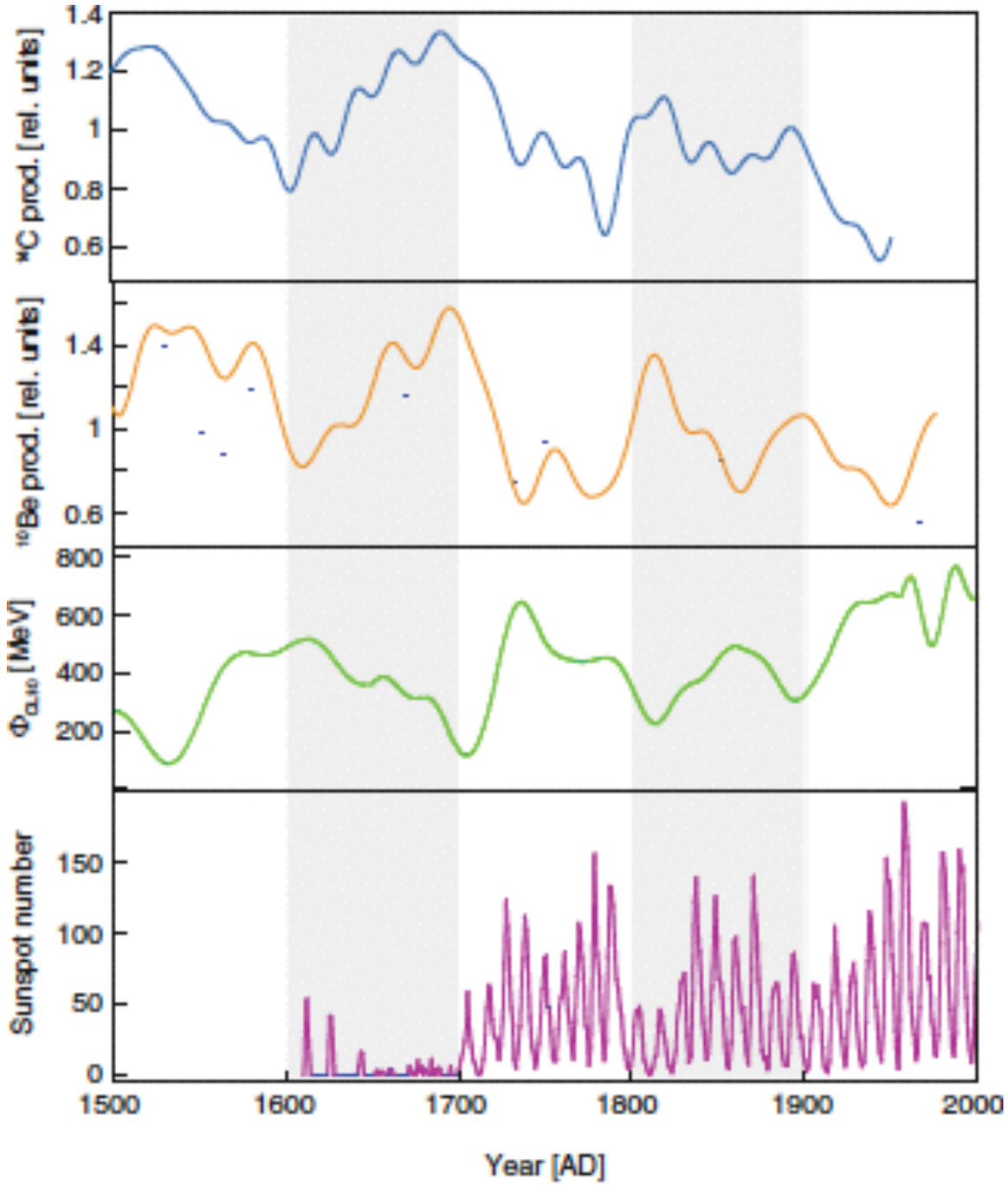
Cosmic radionuclides



Name	^{10}Be	Δ^{14}C
Hallstatt	2,300	2,275
Eddy	970	984
	705	714
	515	512
	350	350
Suess	208	208
	150	150*
	130	130*
	104	105
Gleissberg	87	88

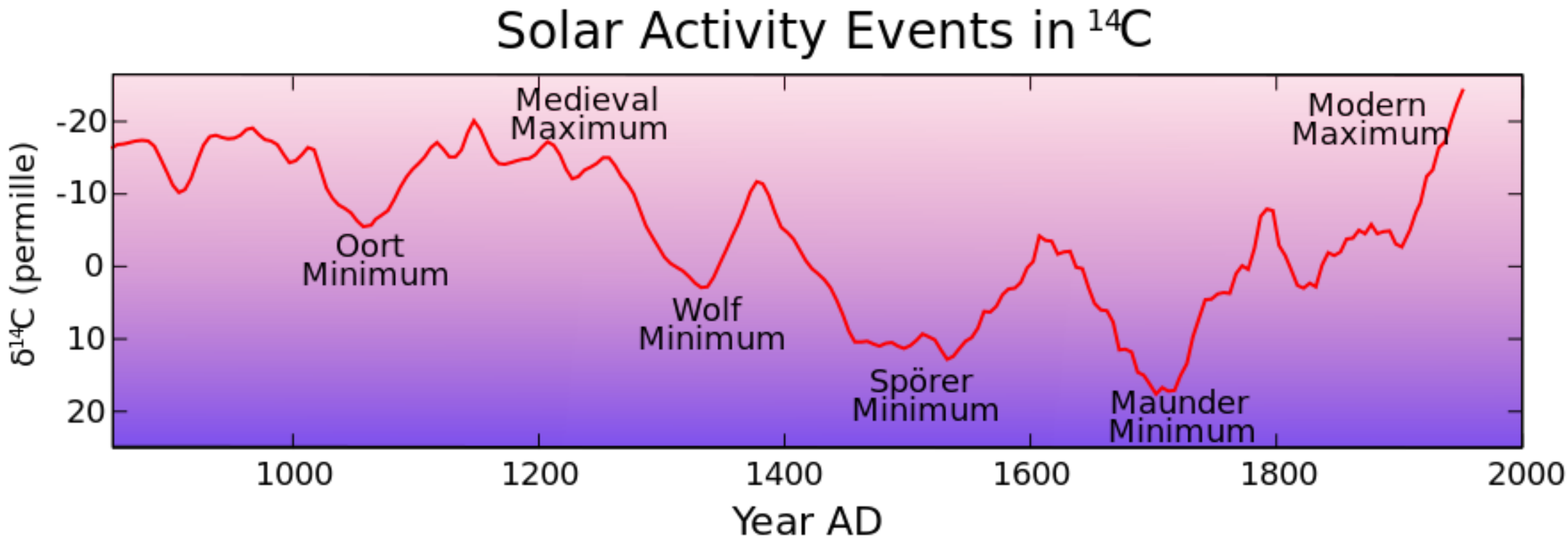
Cosmic radionuclides, Beer et al. 2012

Cosmic radionuclides



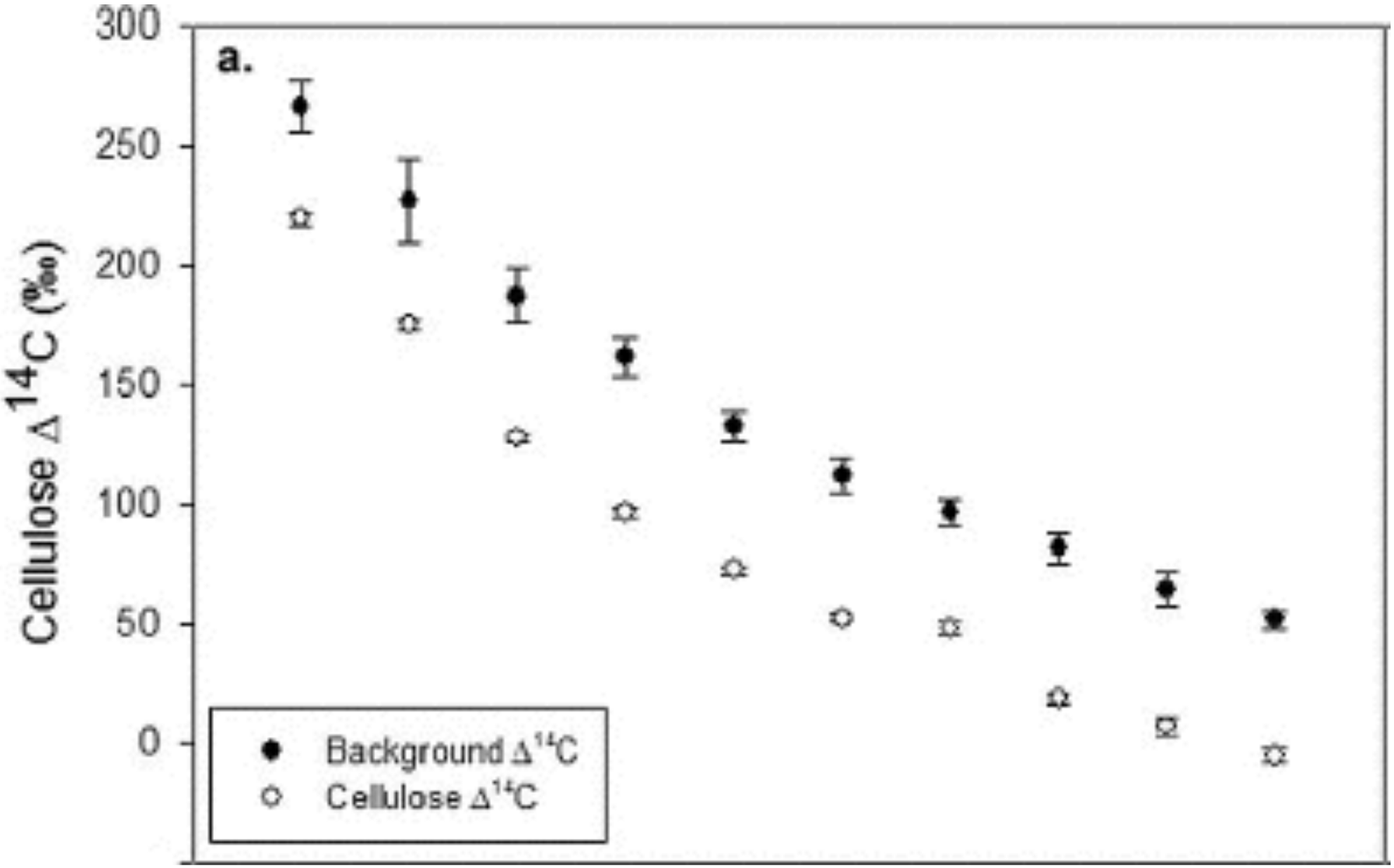
Cosmic radionuclides, Beer et al. 2012

Solar variations



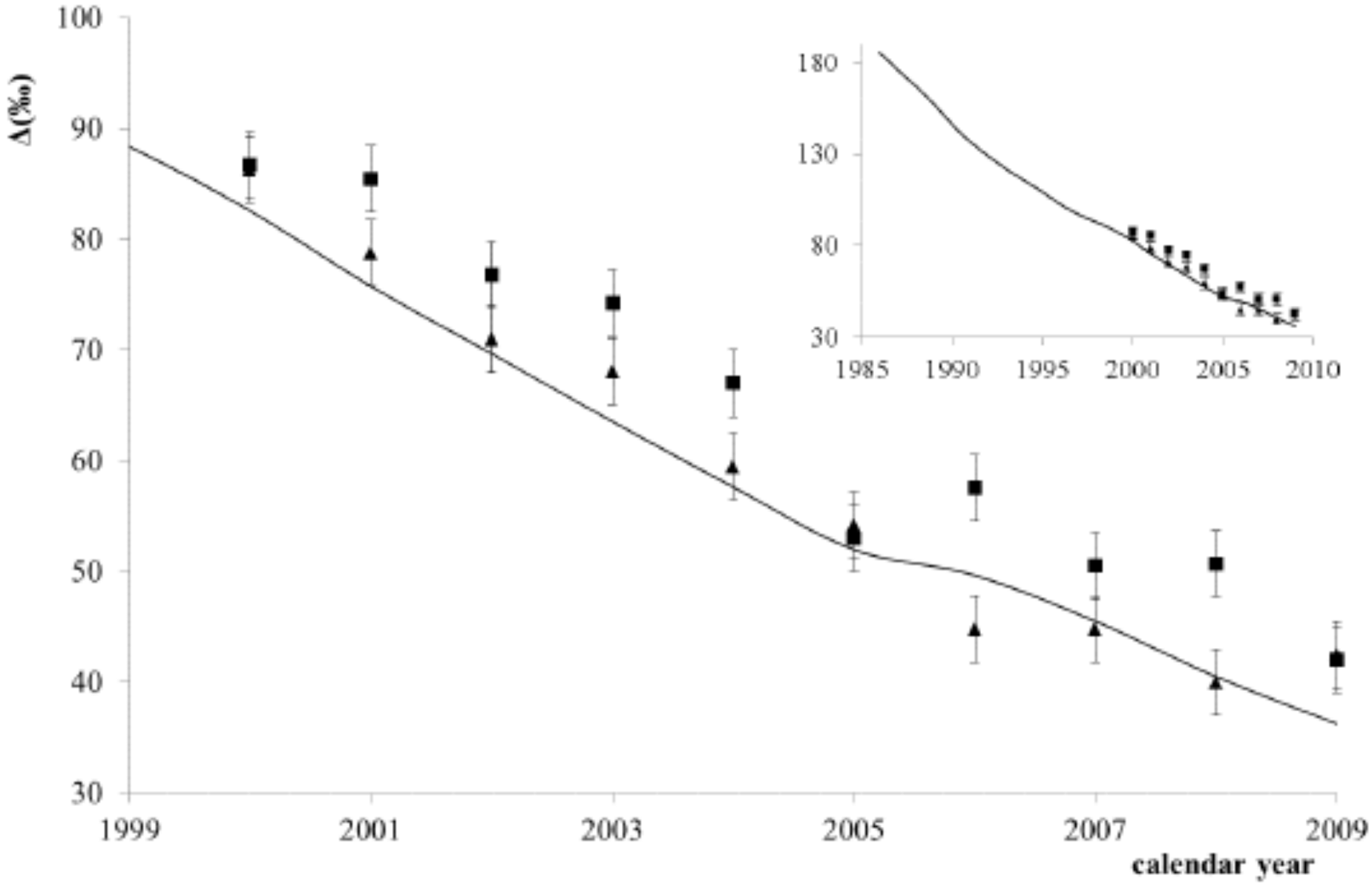
wikipedia

Fossile fuel emissions



S. Djuricin, X. Xu, and D. E. Pataki (2012)

Fossile fuel emissions



R. Janovics et al. 2013

What can we learn from ^{14}C in trees?

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★ Input signal for radiocarbon cycle

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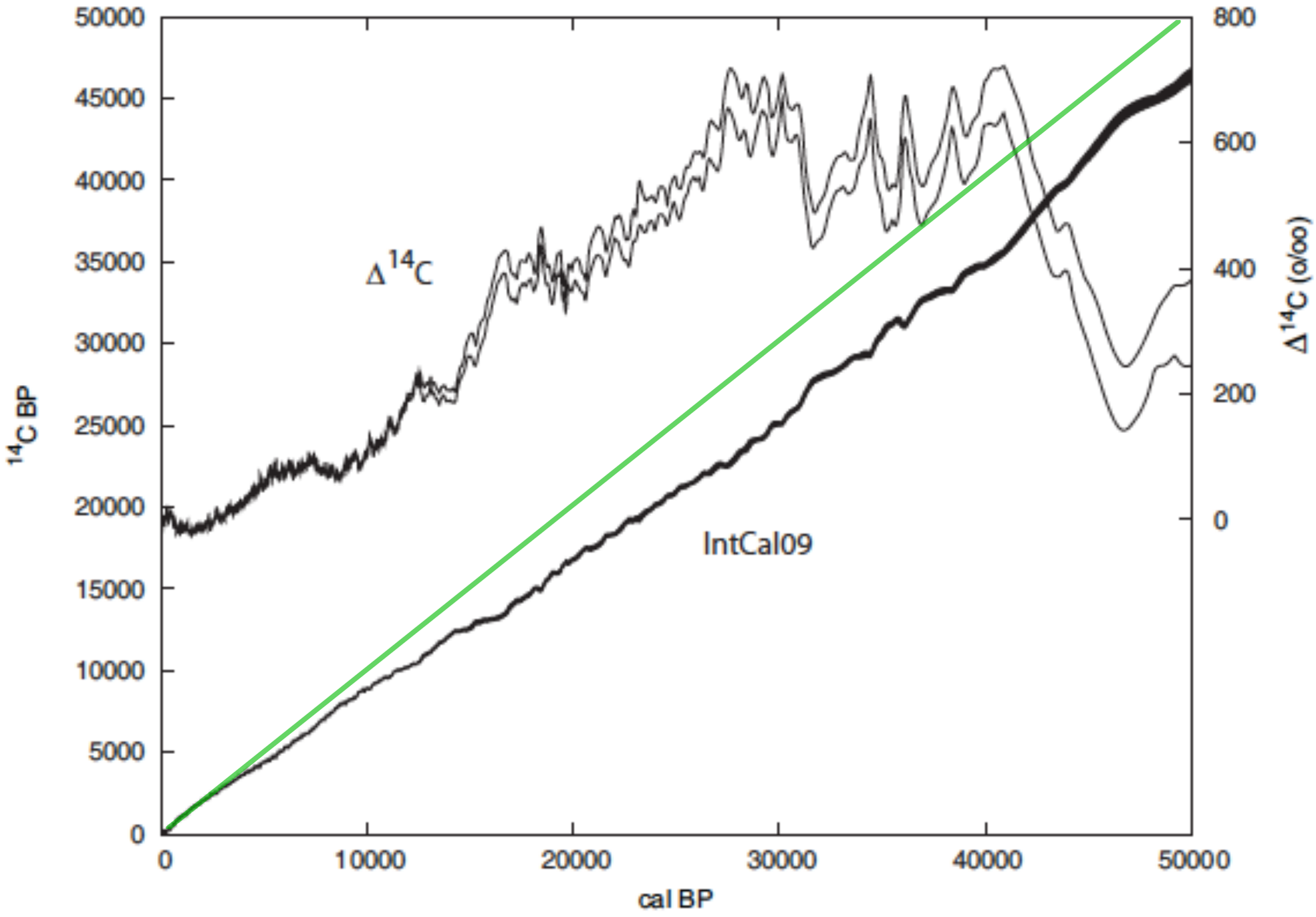
★ *Synchronization of archives*

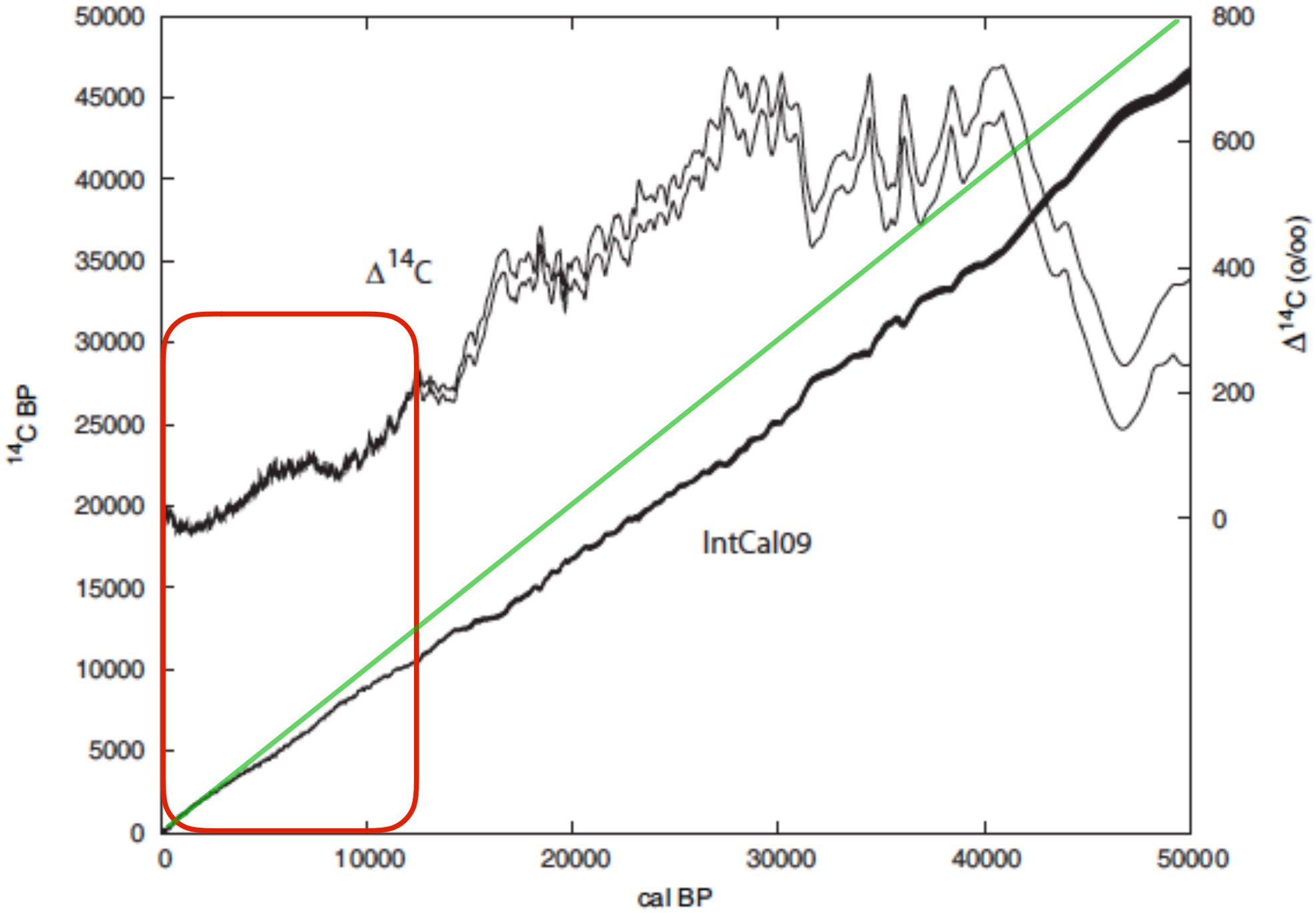
What can we learn from ^{14}C in trees?

- ★ Input signal for radiocarbon cycle
- ★ *Solar history / earth magnetic field*
- ★ *Synchronization of archives*
- ★ *Trace anthropogenic ^{14}C sources / fossile fuel emissions*

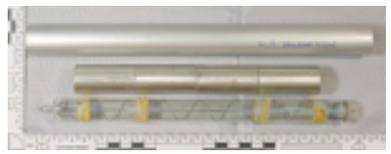
Radiocarbon calibration



Radiocarbon calibration

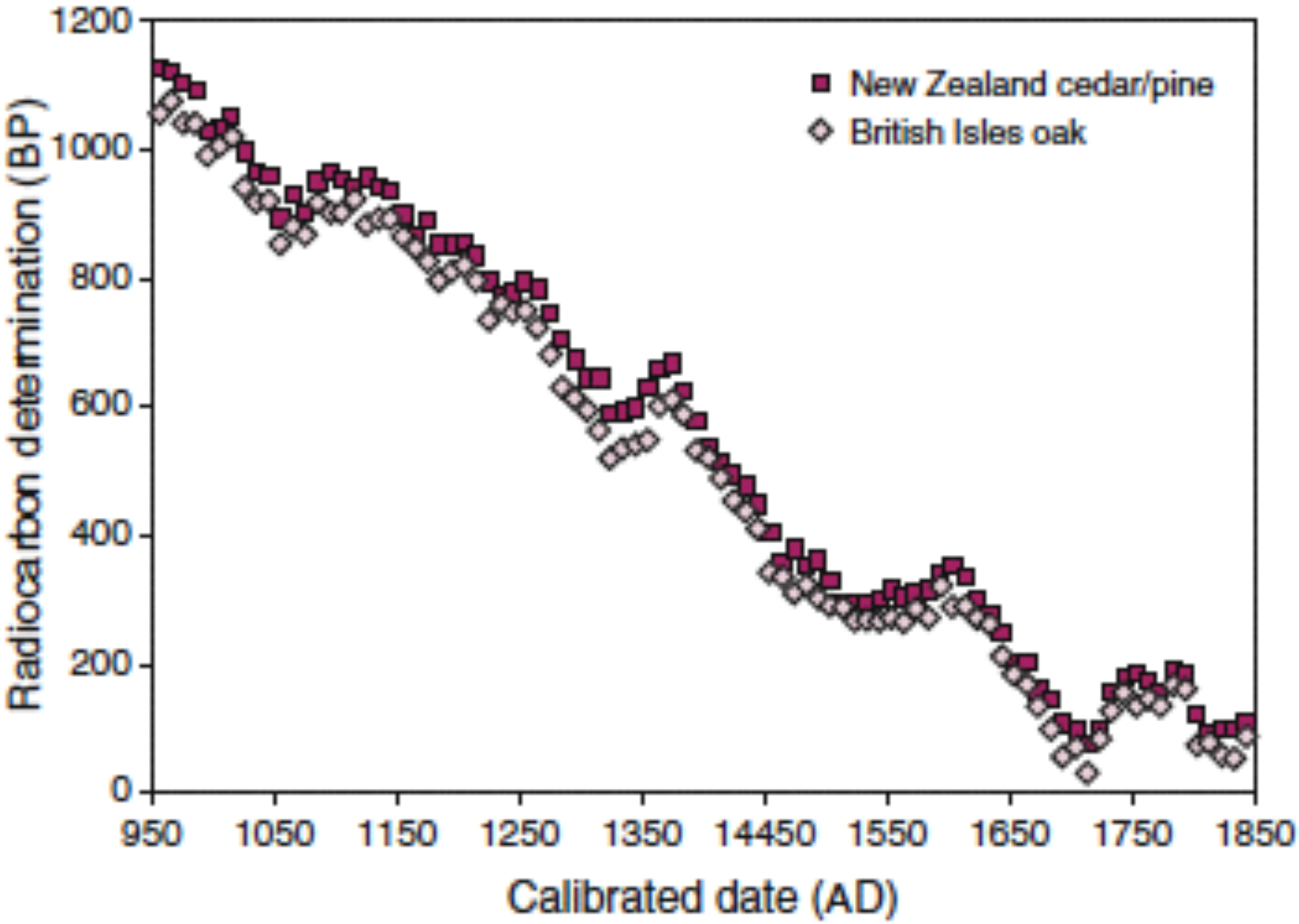


How was / is it measured?



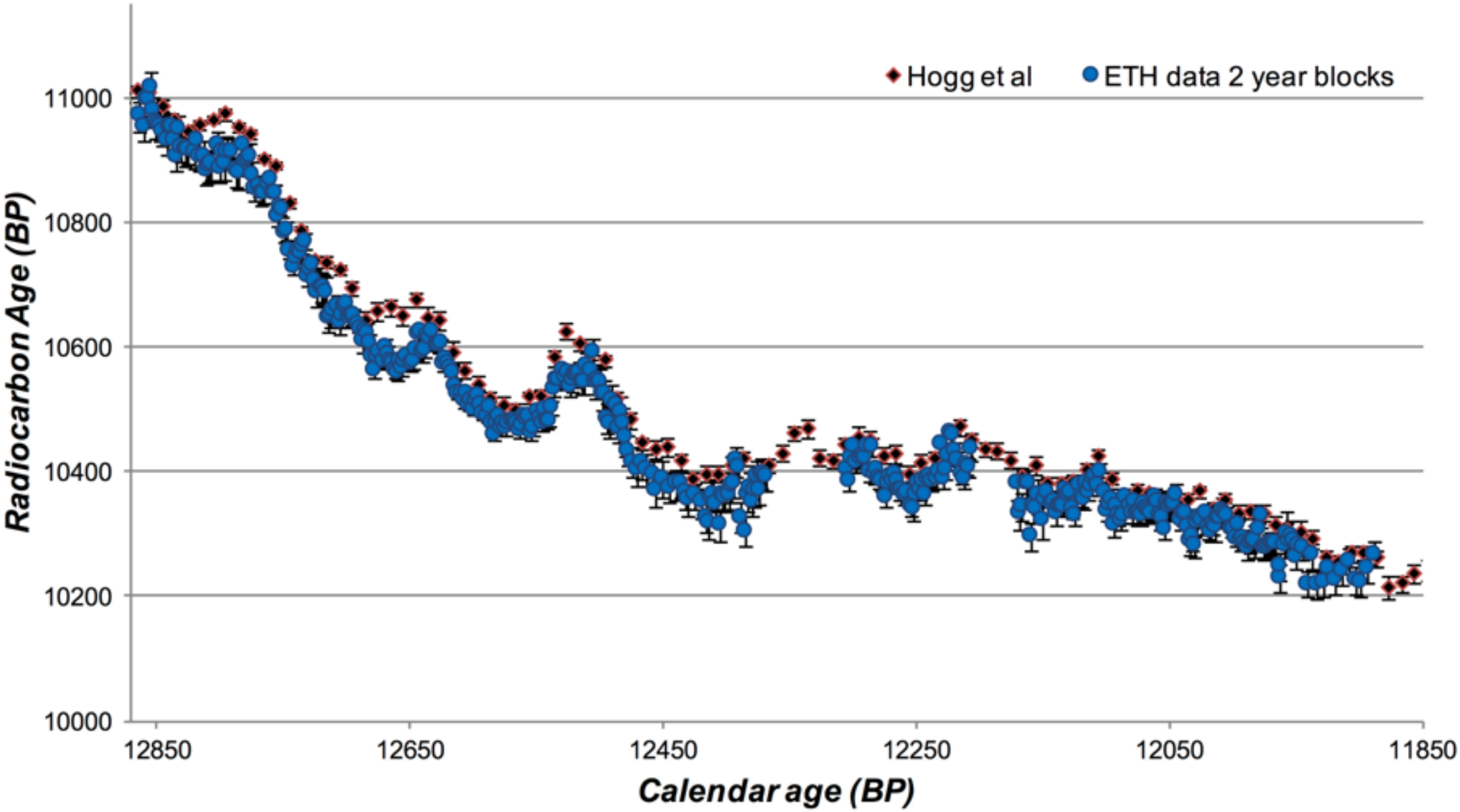
	AMS	Decay counting
required quantity	1 mg	1000 mg
Measurement time	1-2 h	4 weeks

Southern hemisphere offset

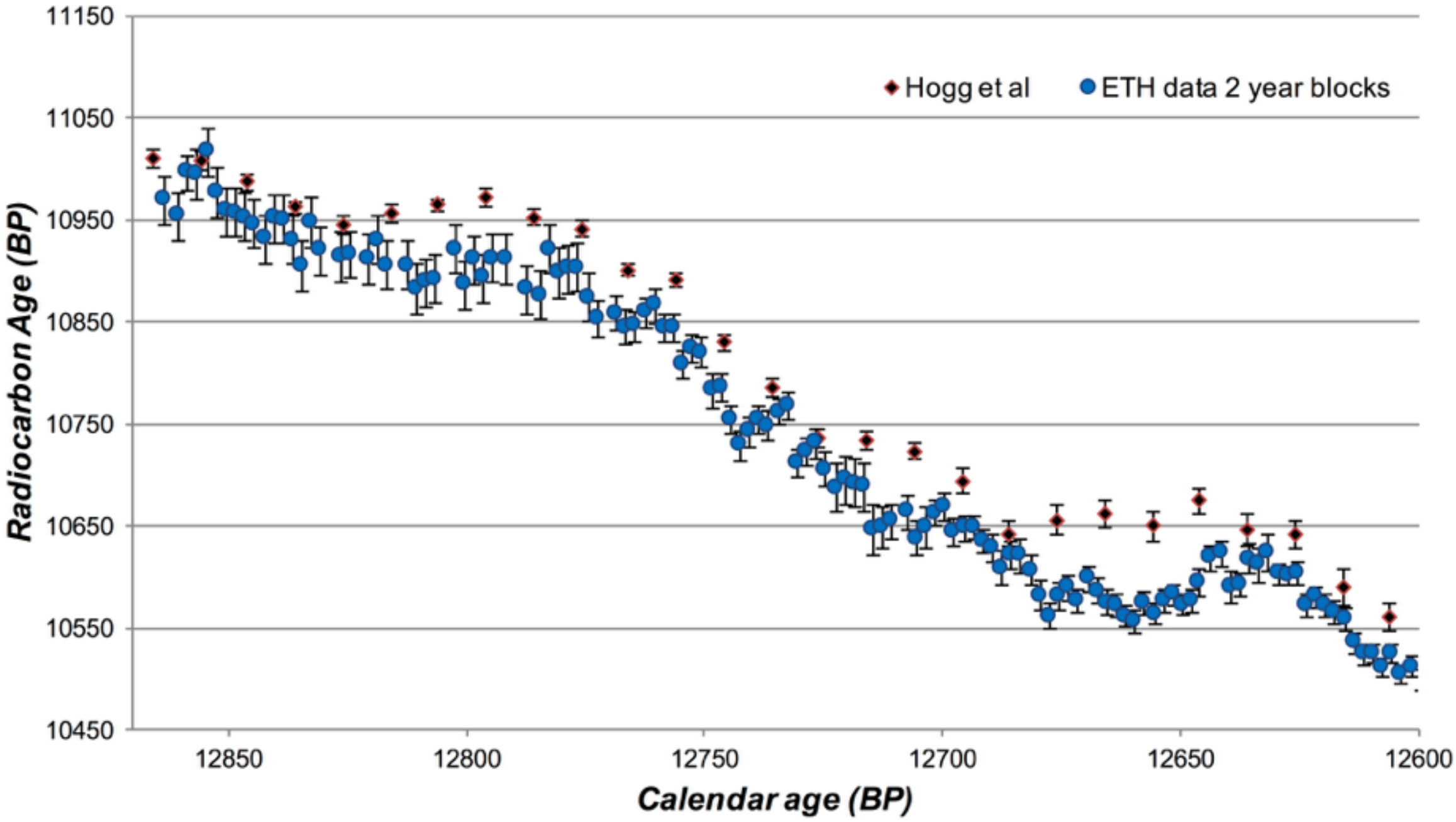


Hogg et al. 2002

Extension of tree-ring curve



Change in offset?



Golden Handfeste of Berne

Sample Number	Type	Radiocarbon age (BP)	+-	δ13C (‰)
ETH36716.1	parchment	888	20	-22.6
ETH36716.2	parchment	878	19	-20.7
ETH36716.3	parchment	882	19	-23.9
ETH36716.4	parchment	875	19	-22.3
ETH36716	**parchment**	**881**	**10**	**-22.4**

Sample Number	Type	Radiocarbon age (BP)	+-	δ13C (‰)
ETH36717.1	seal cord	800	20	-24
ETH36717.2	seal cord	808	19	-29.1
ETH36717.3	seal cord	833	18	-25.5
ETH36717.4	seal cord	808	18	-27.1
ETH36717.5	seal cord	800	17	-27.7
ETH36717	**seal cord**	**810**	**8**	**-26.7**

Golden Handfeste of Berne

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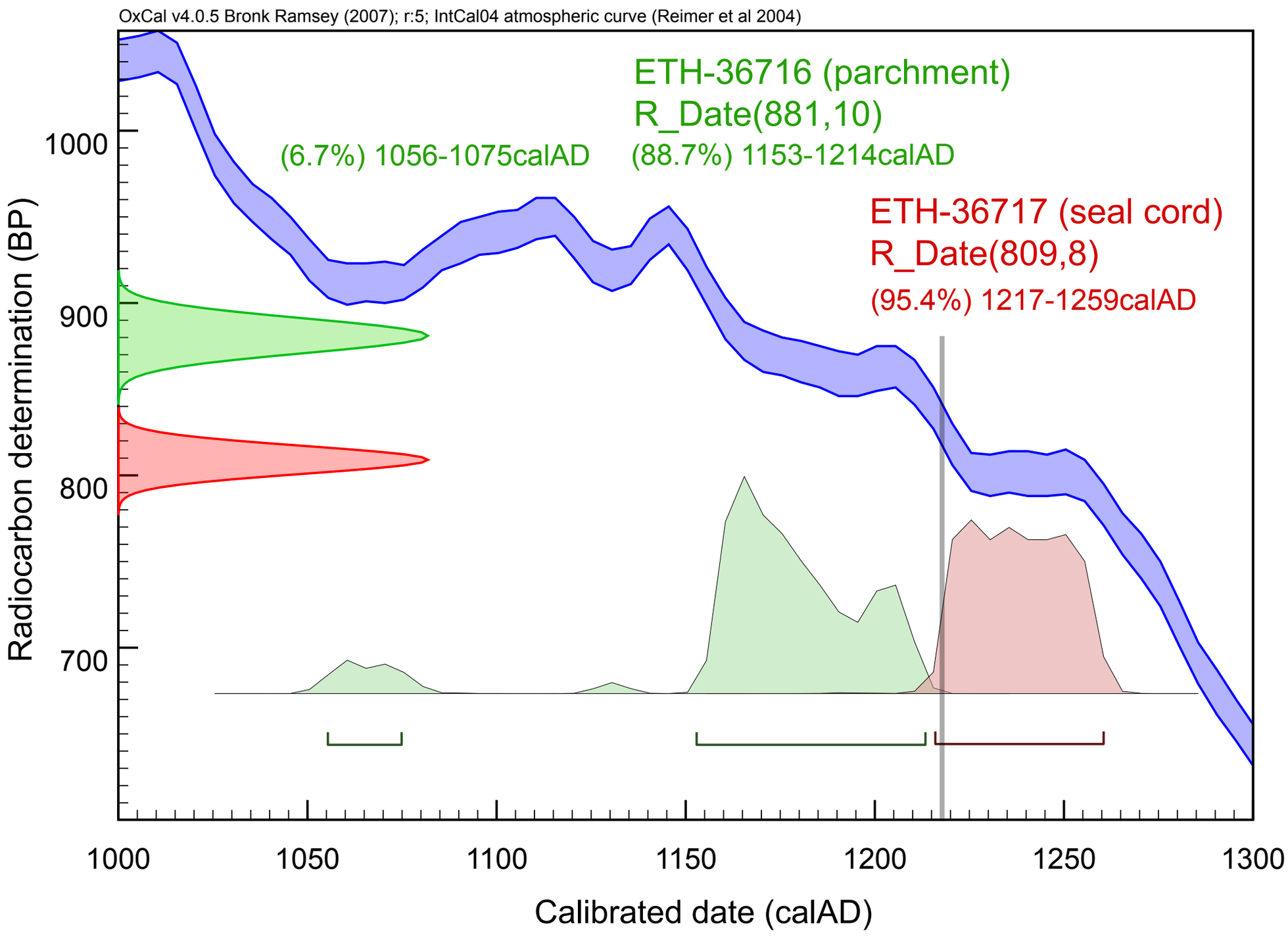
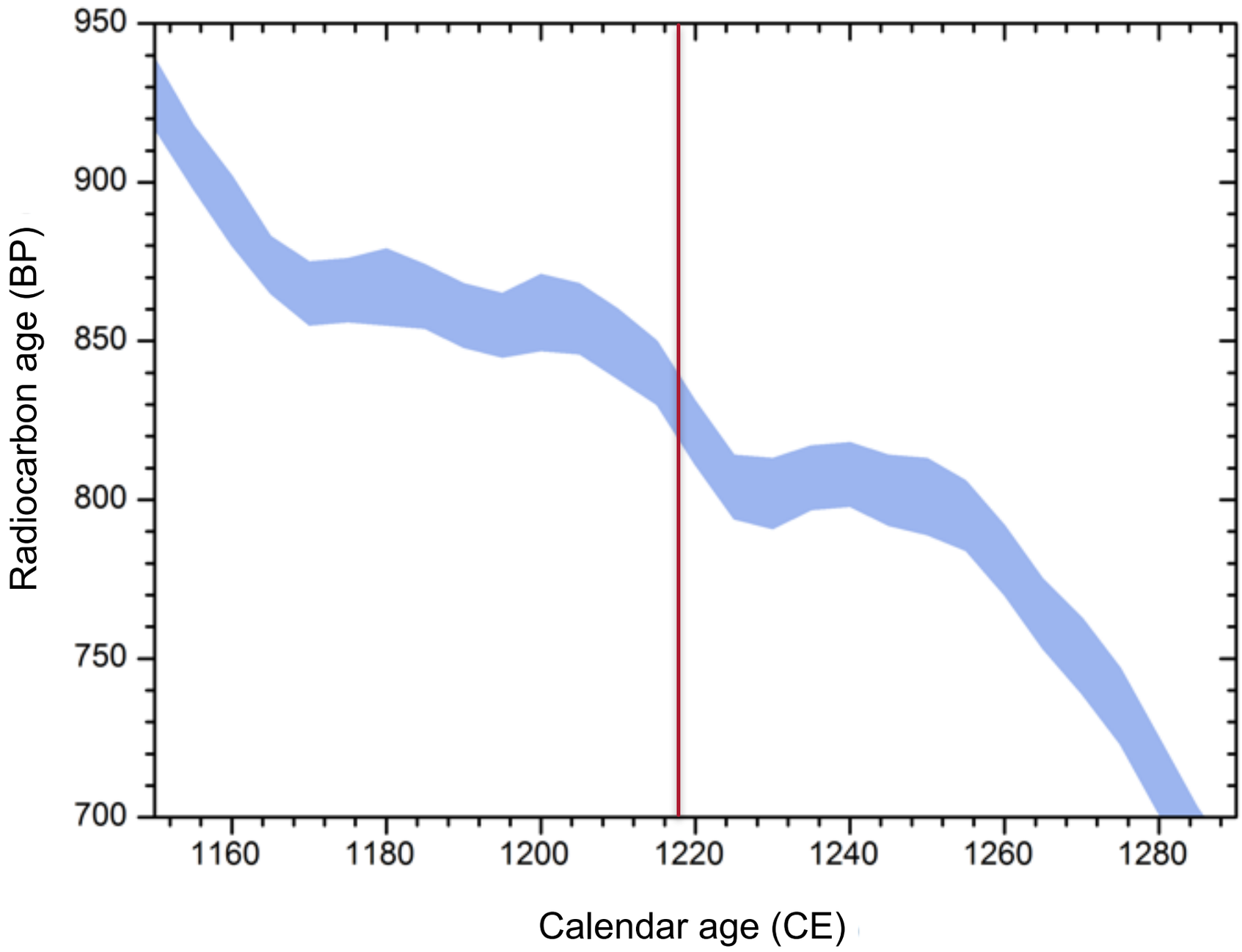
1 per mill!!!

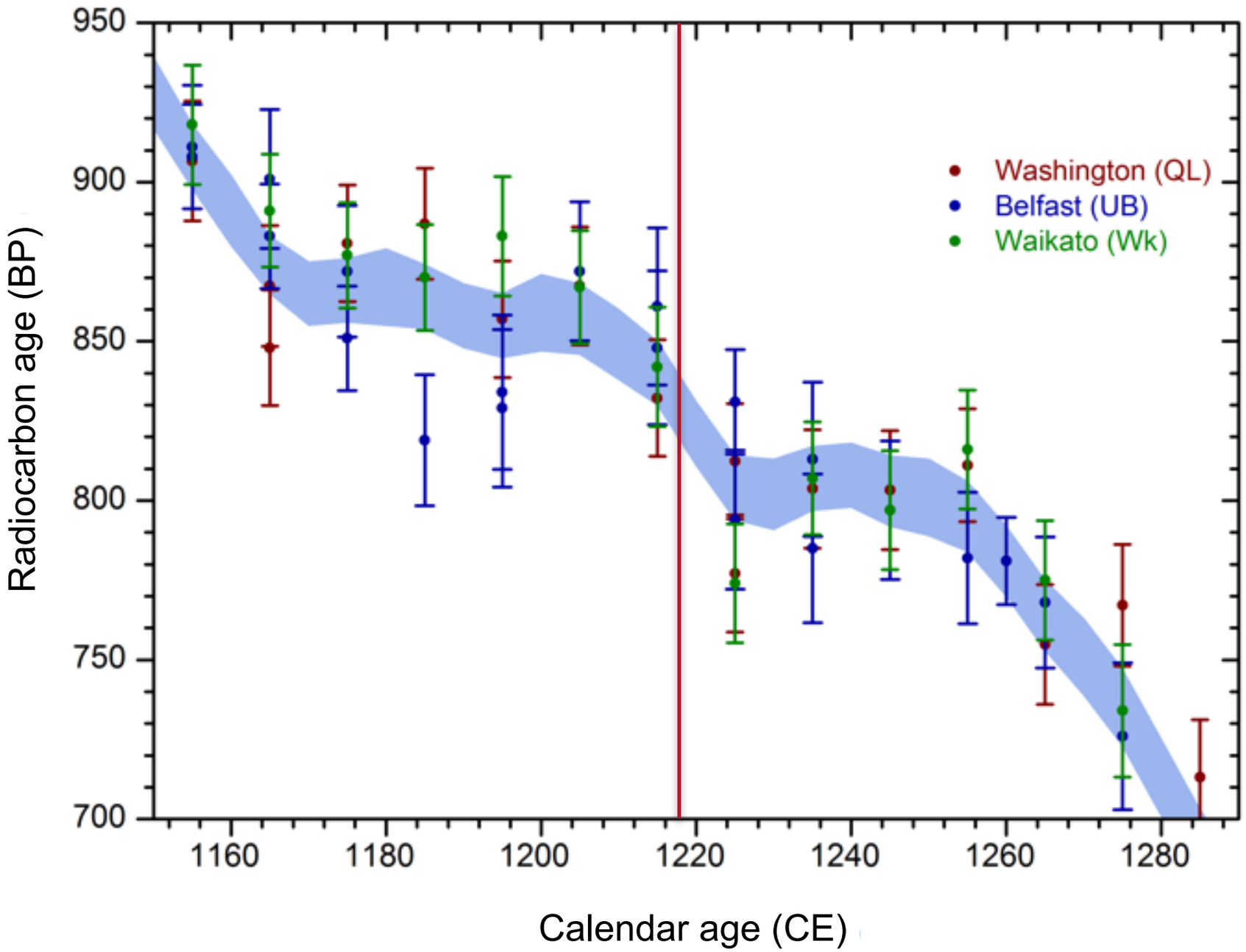
Calibration of the Handfeste



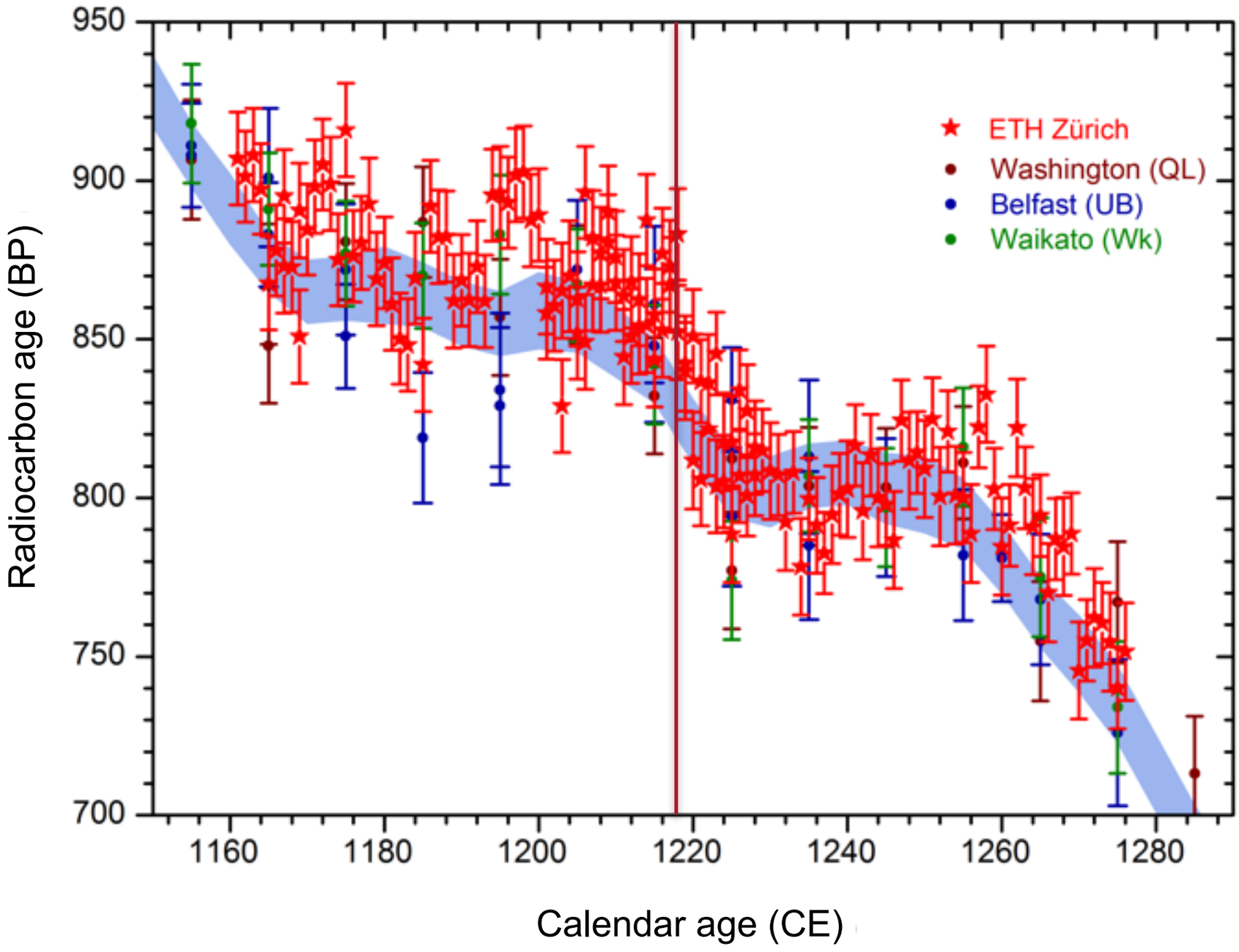
Calibration cure around 1220 AD



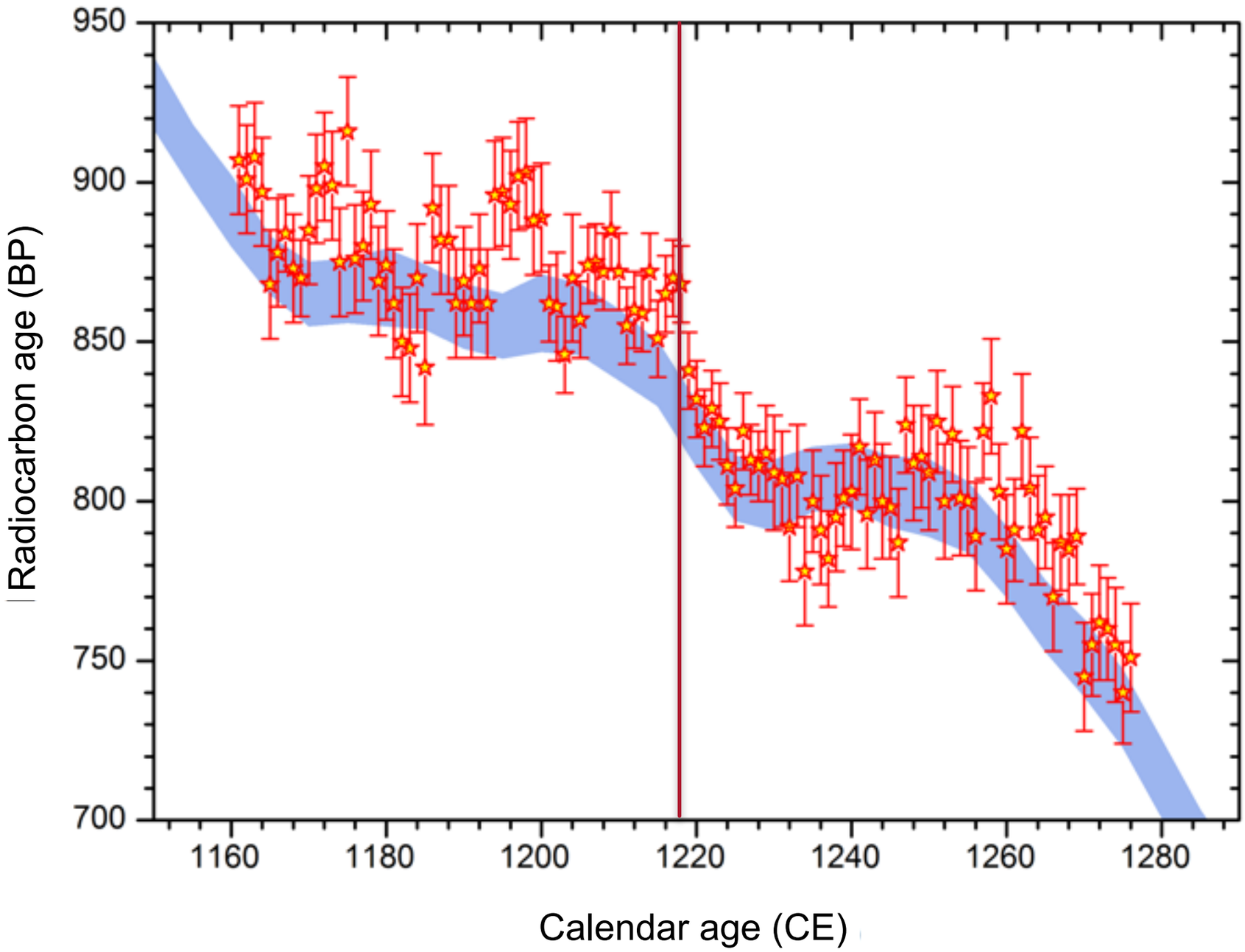
Calibration cure around 1220 AD



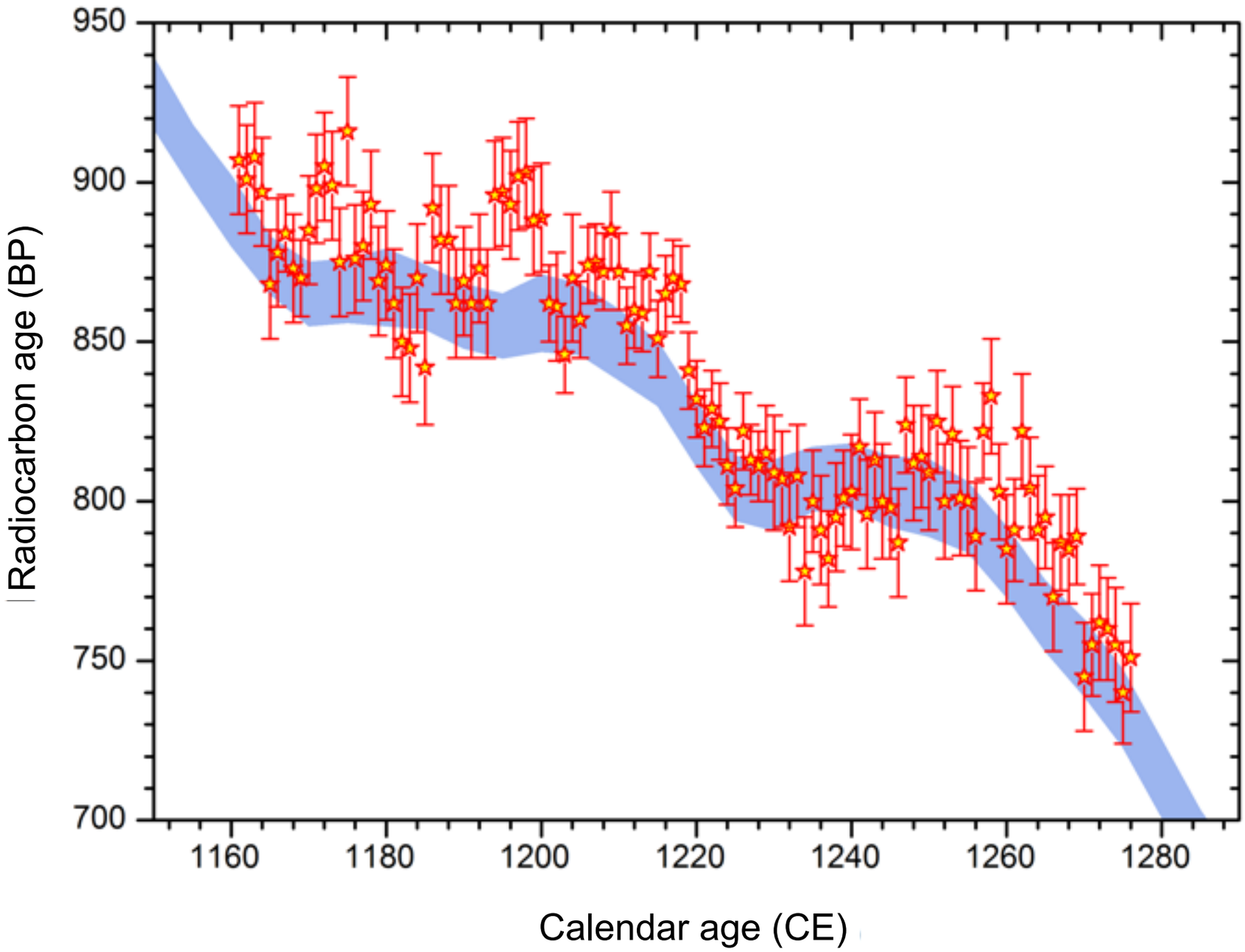
Calibration cure around 1220 AD



Calibration cure around 1220 AD



Calibration cure around 1220 AD



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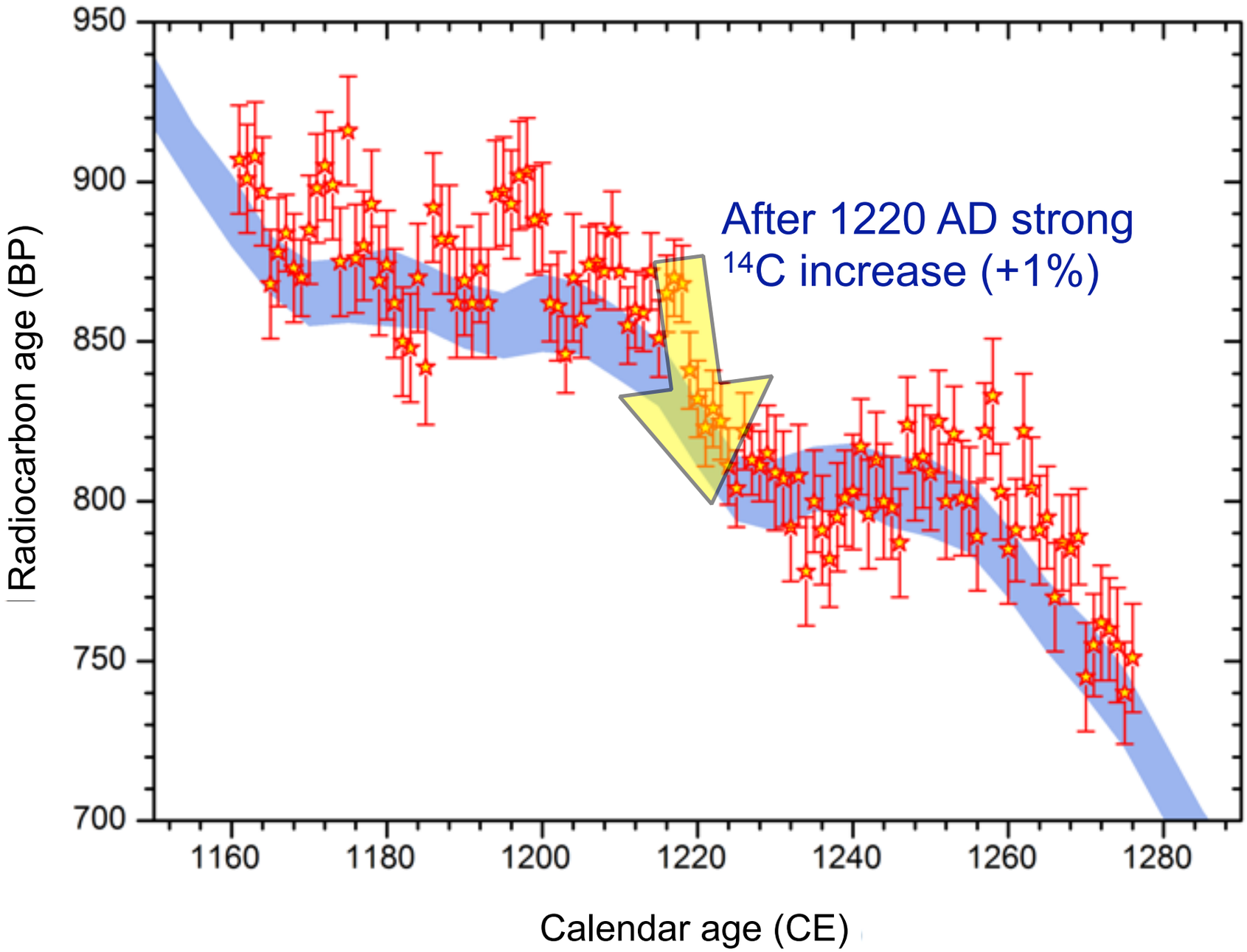
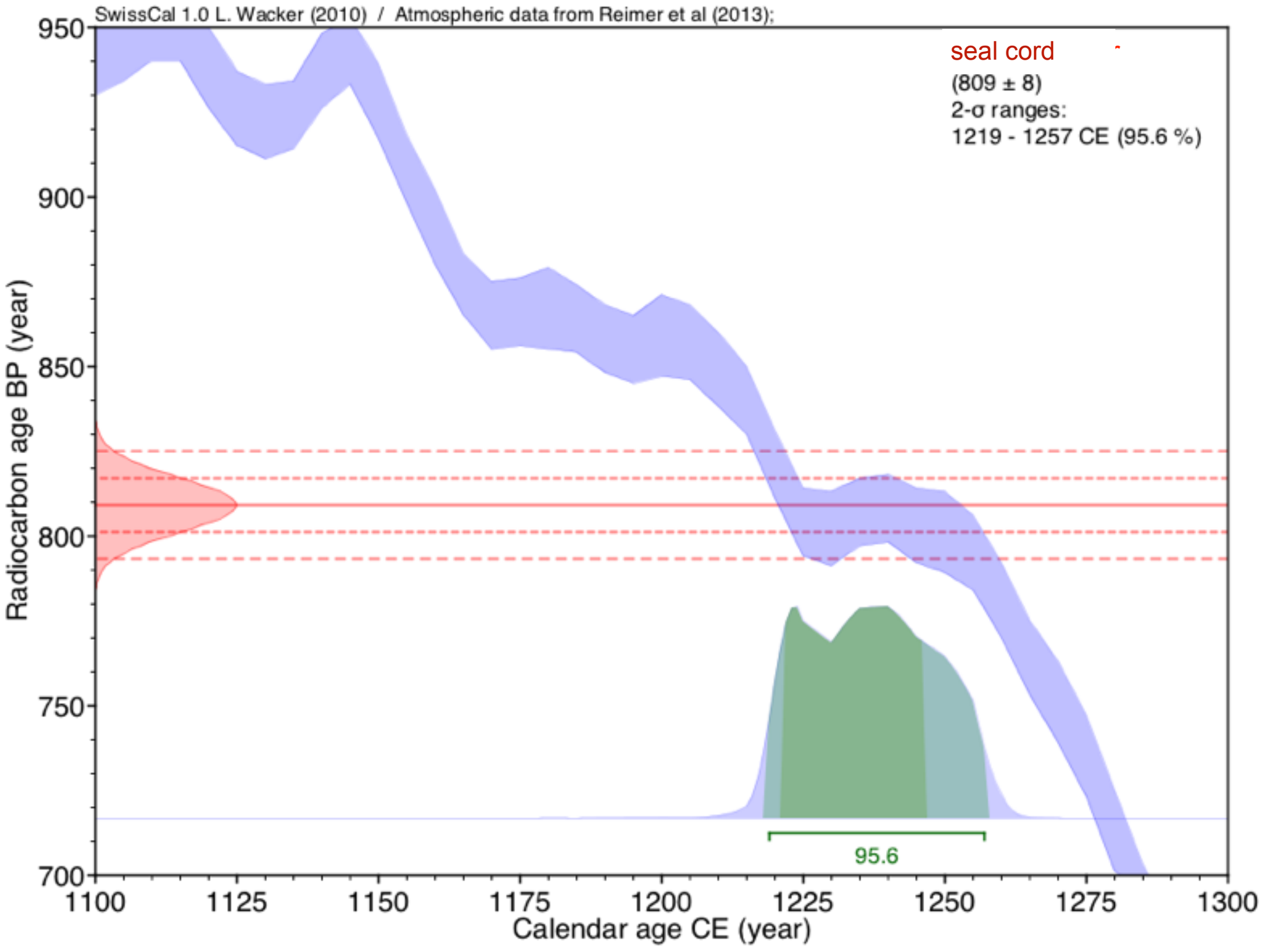
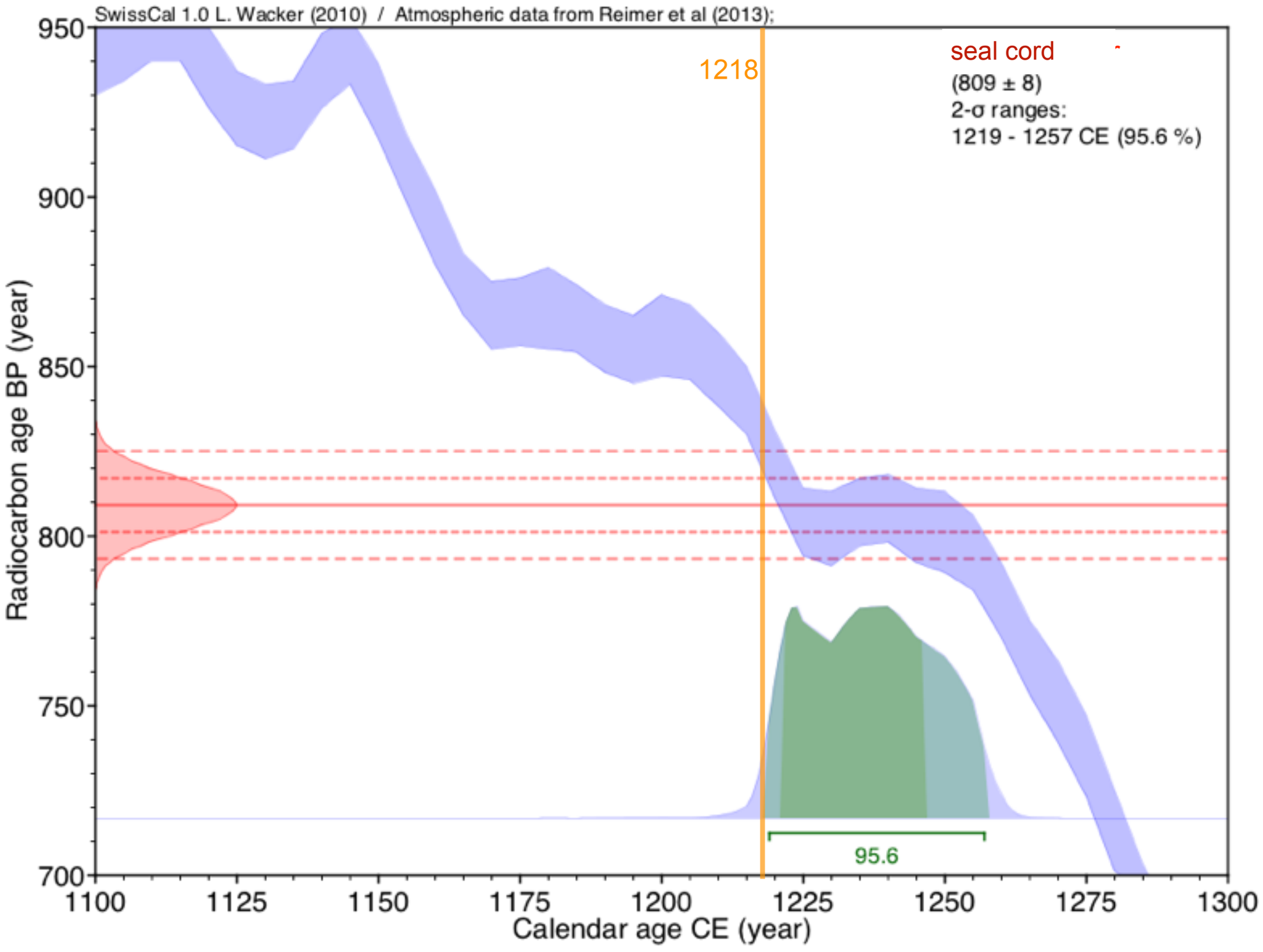


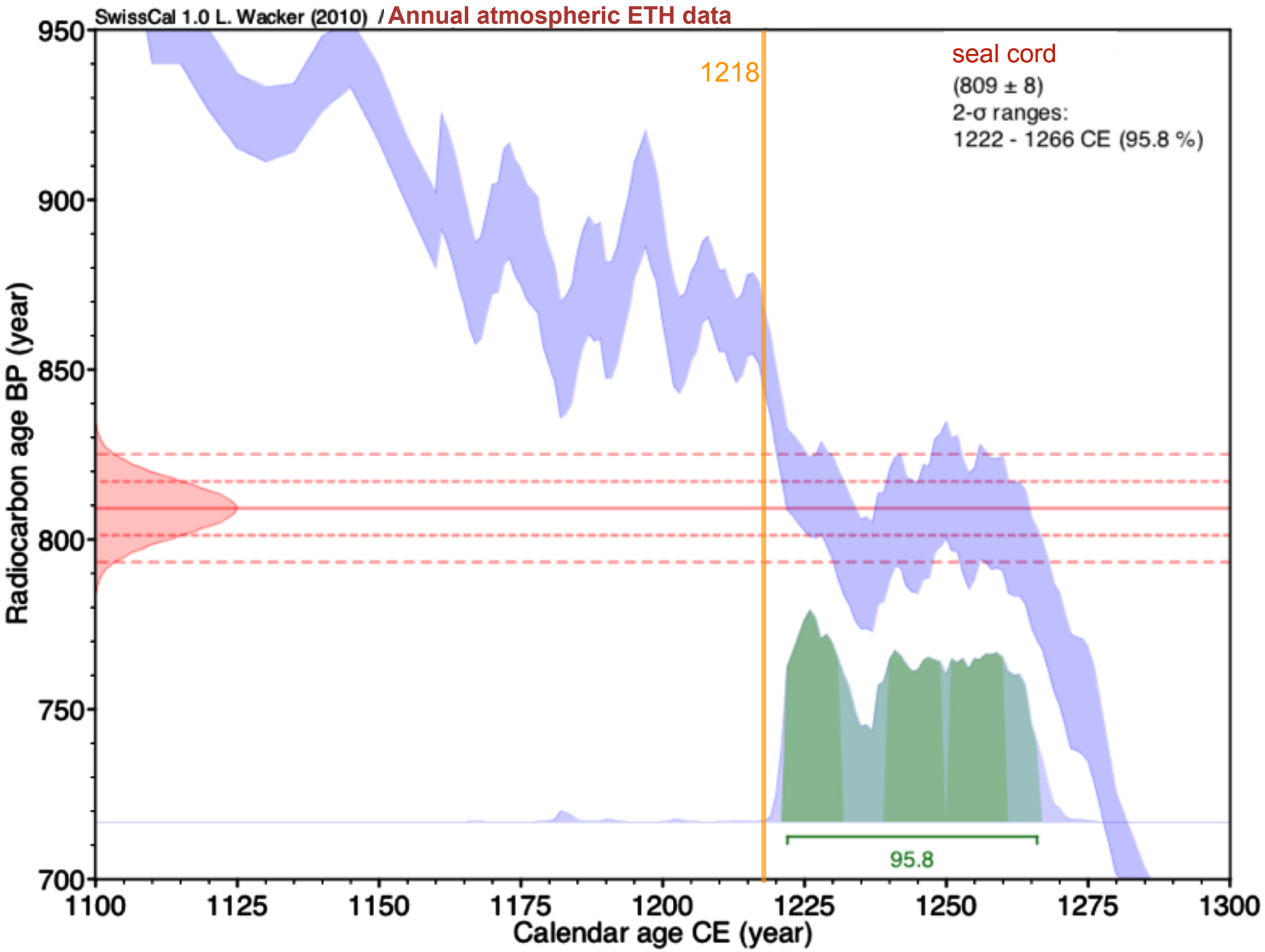
Calibration of the seal cord



Calibration of the seal cord



Calibration of the seal cord



Precise dating of the Goldene Handfeste

Parchment: old 1153 - 1214 AD
new 1156 - 1217 AD

Same, but more precise!

Precise dating of the Goldene Handfeste

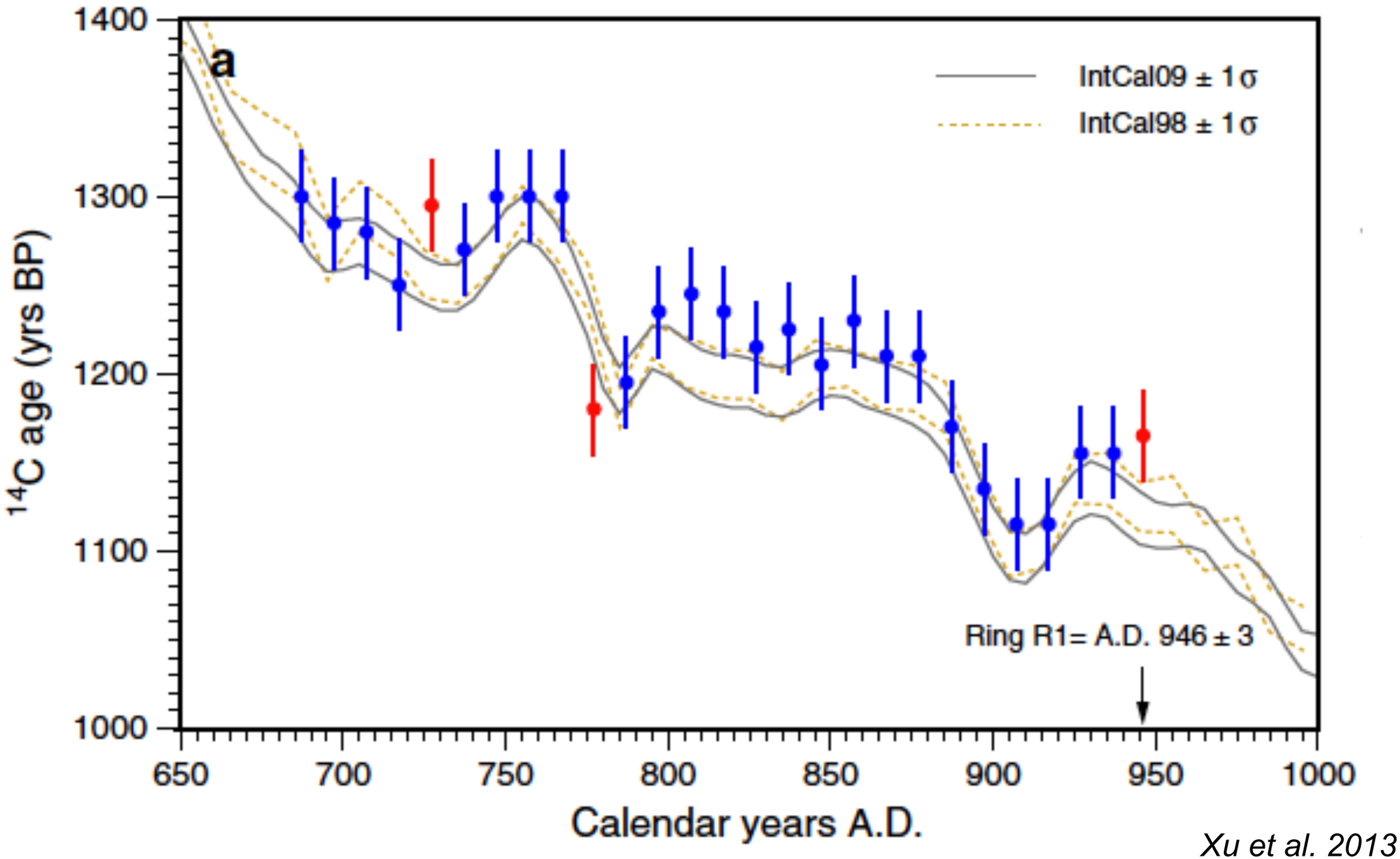
Parchment: old 1153 - 1214 AD
new 1156 - 1217 AD

Same, but more precise!

Seal cord: old 1217 - 1259 AD
new 1222 - 1266 AD

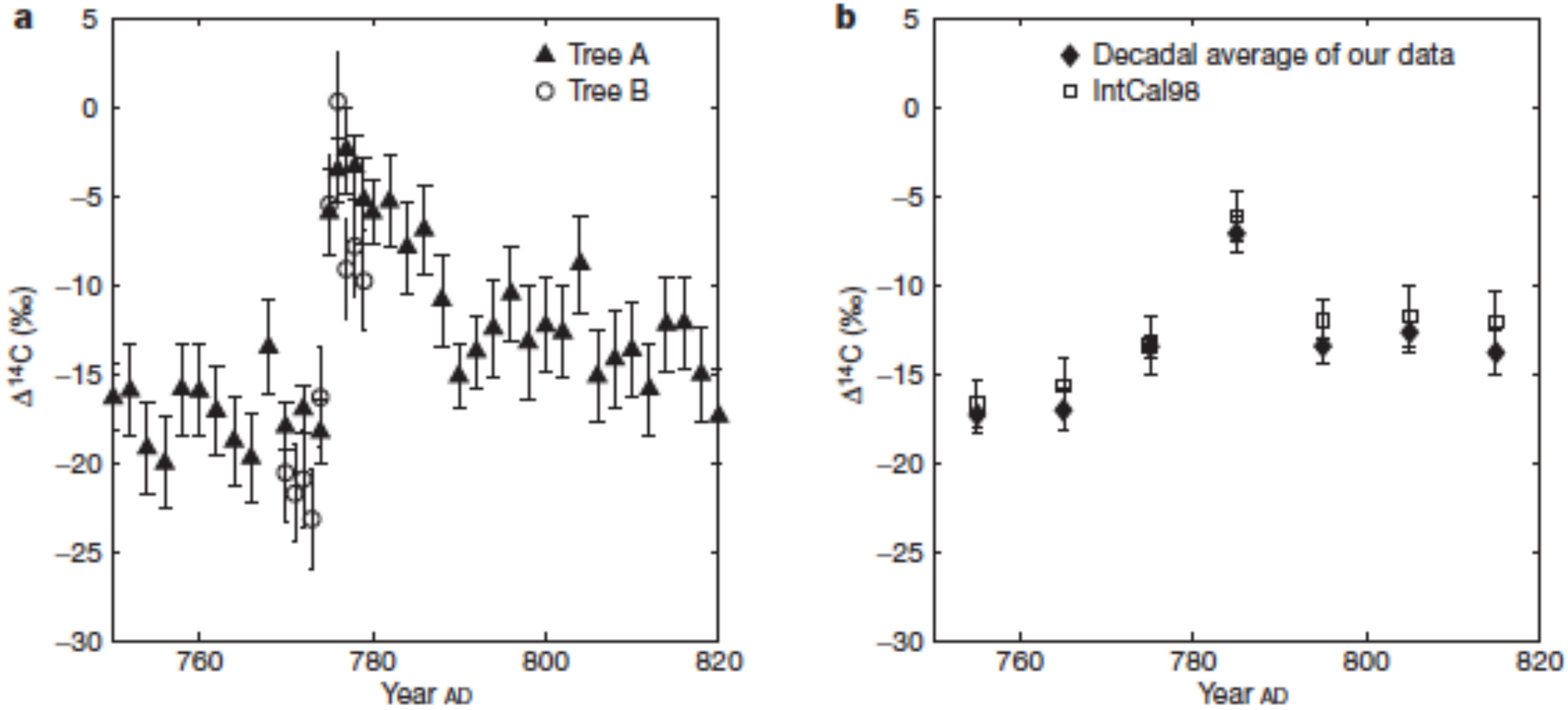
Same, but more precise!

Radiocarbon wiggle-matching



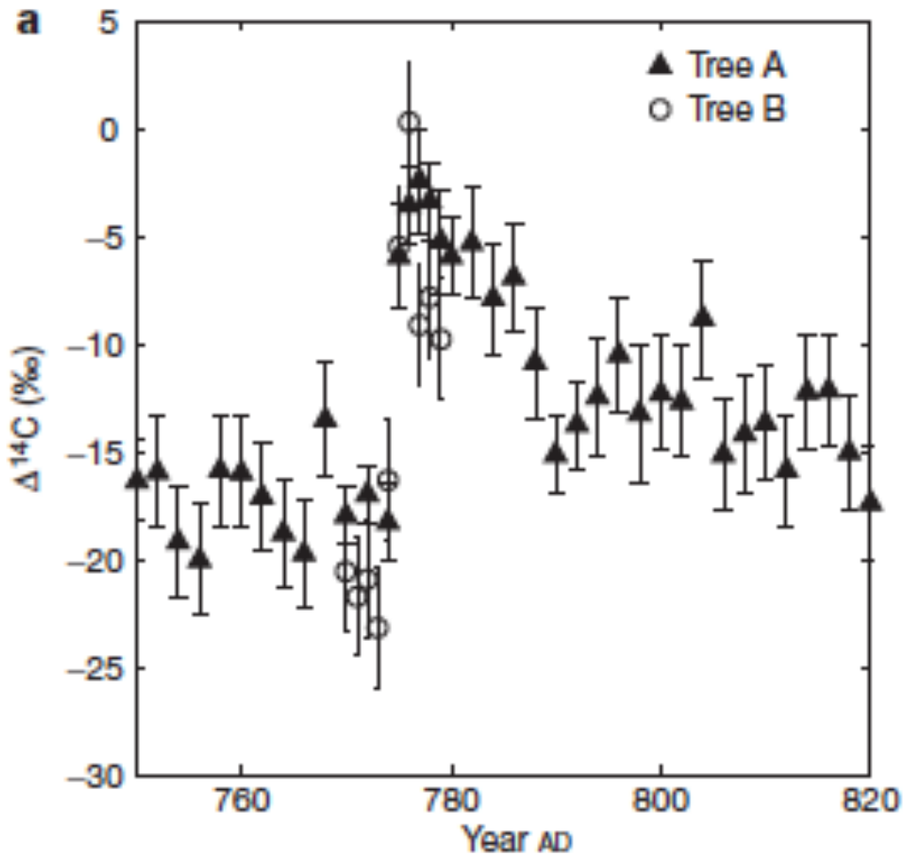
Xu et al. 2013

775 AD event

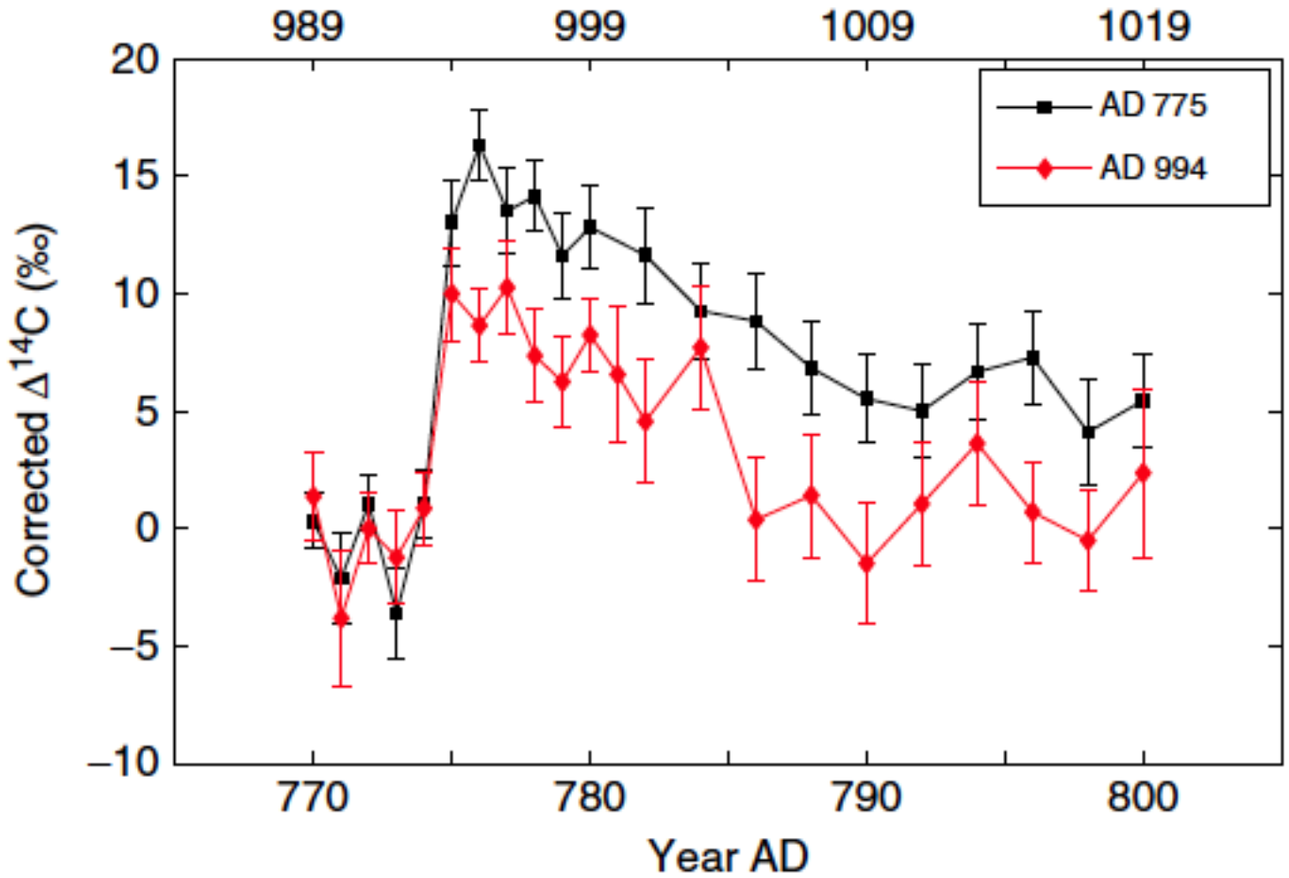


Miyake et al. 2012

775 AD event / 994 AD event

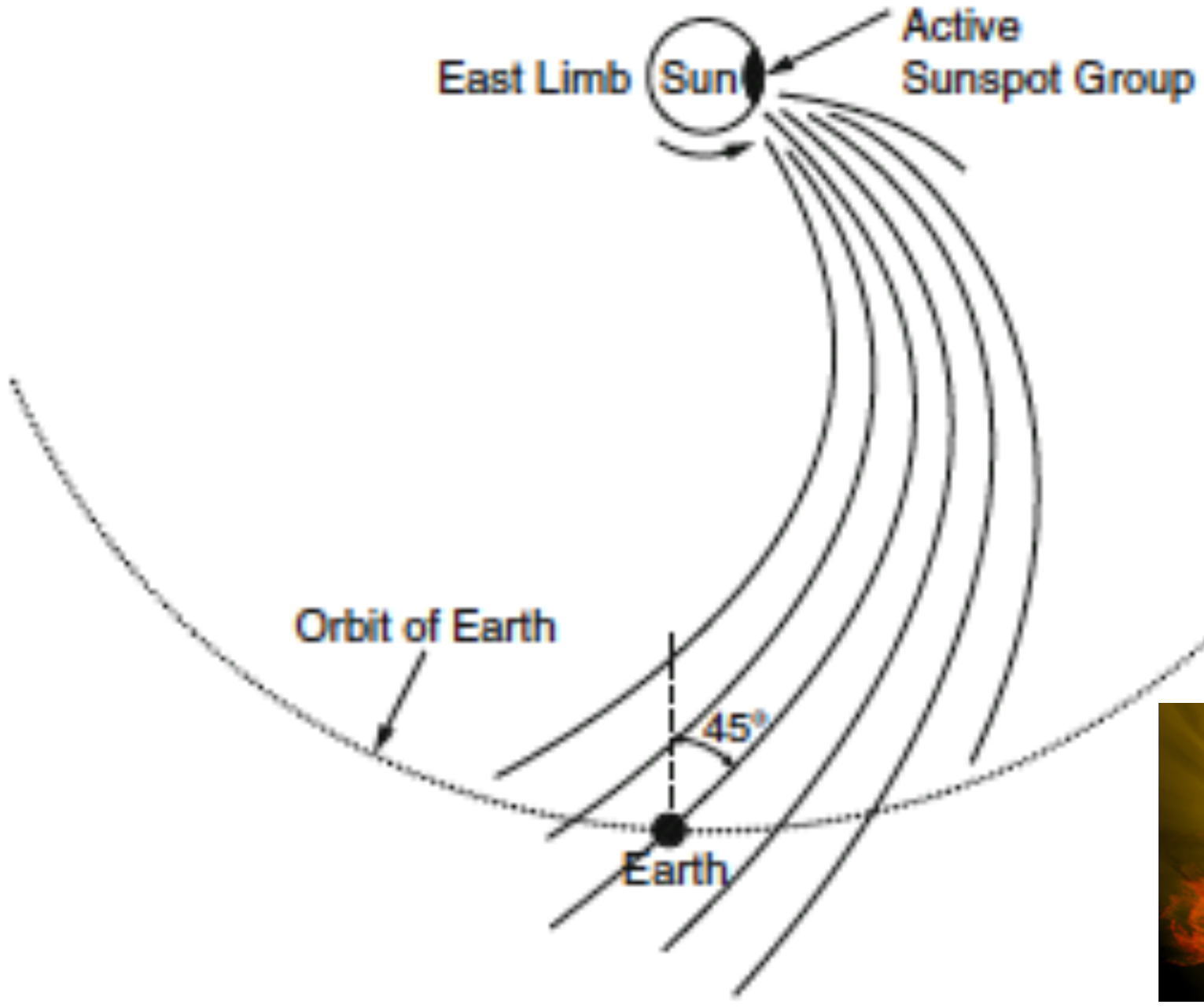


Miyake et al. 2012



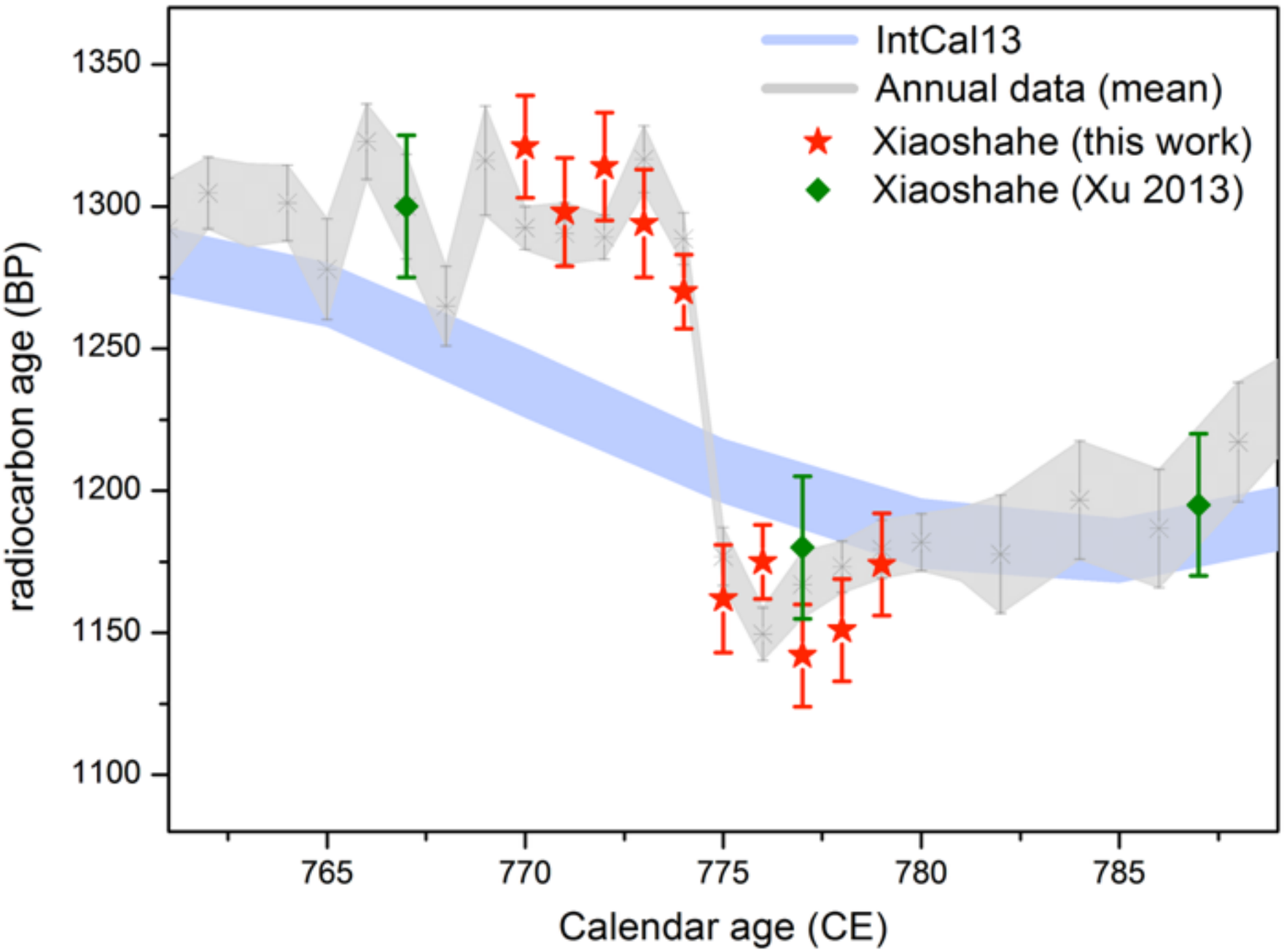
Miyake et al. 2013

Cosmic radionuclides



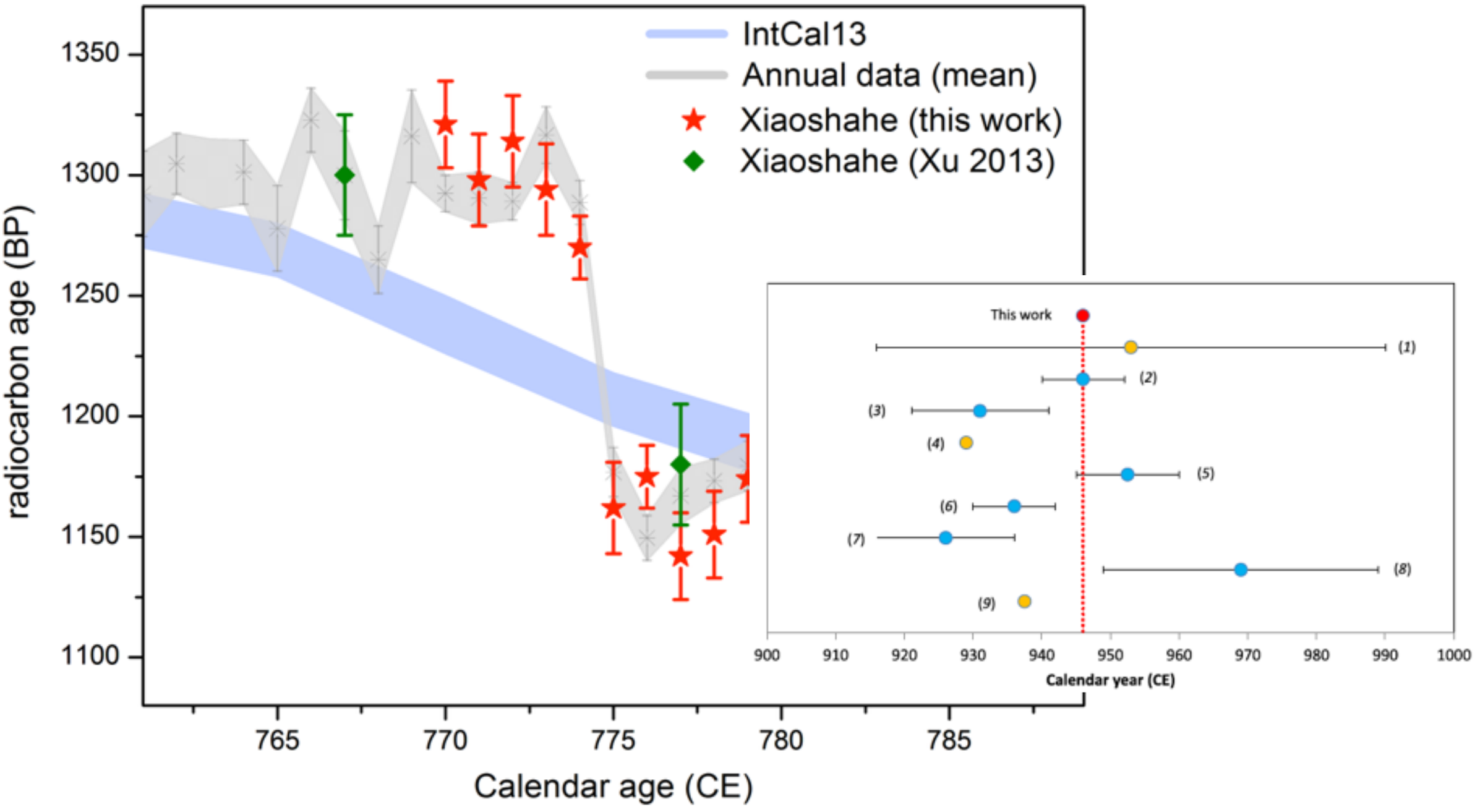
Cosmic radionuclides, Beer et al. 2012

Radiocarbon wiggle-matching



Oppenheimer et al. 2017

Radiocarbon wiggle-matching



Oppenheimer et al. 2017

Species

Mostly Conifers:

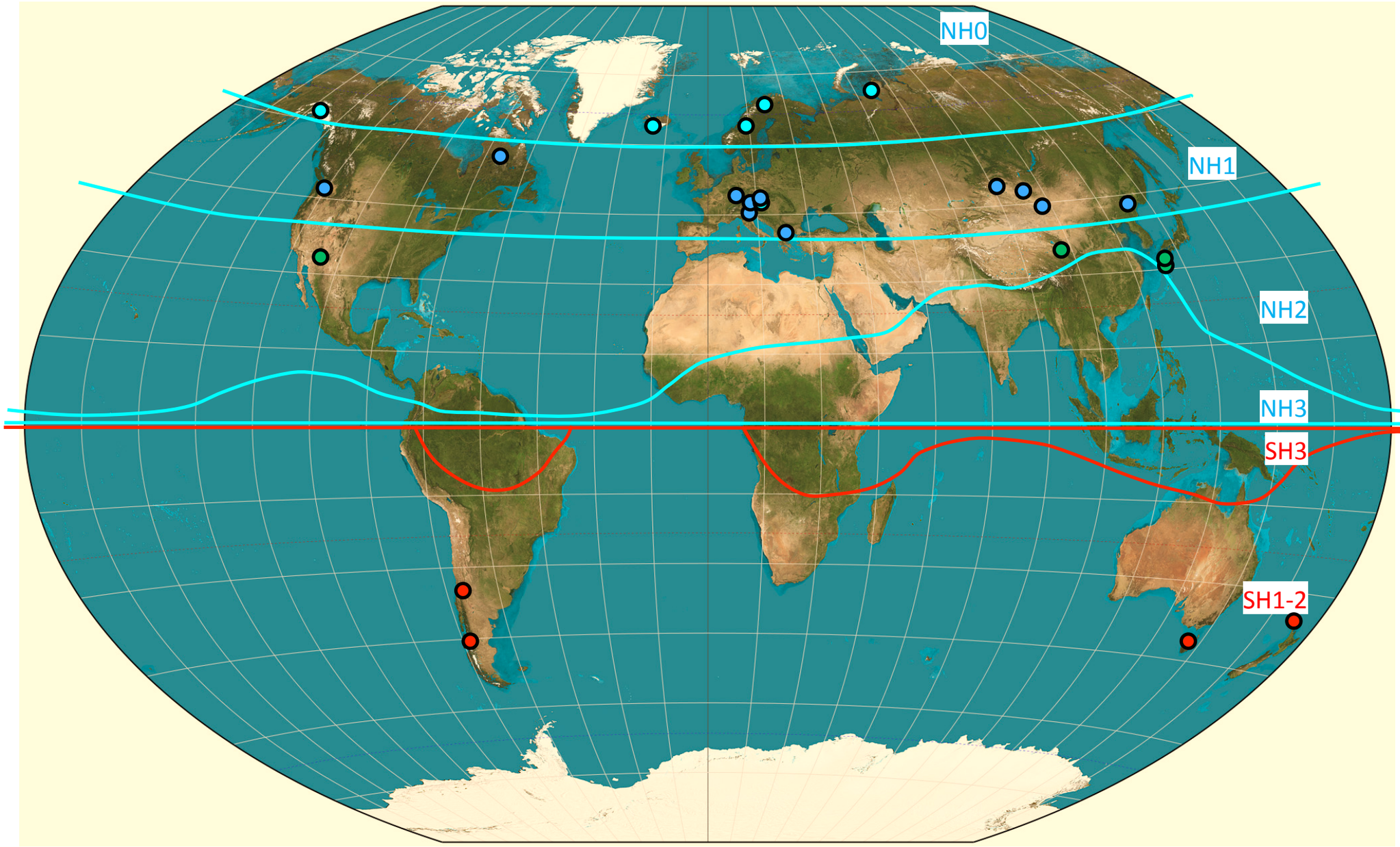
- ★ *Cryptomeria*
- ★ *Pinus*
- ★ *Juniperus*
- ★ *Larix*
- ★ *Picea*
- ★ *Tsuga*
- ★ *Agathis*

- ★ *Lagarostrobos*
- ★ *Austrocedrus*
- ★ *Fitzroya*

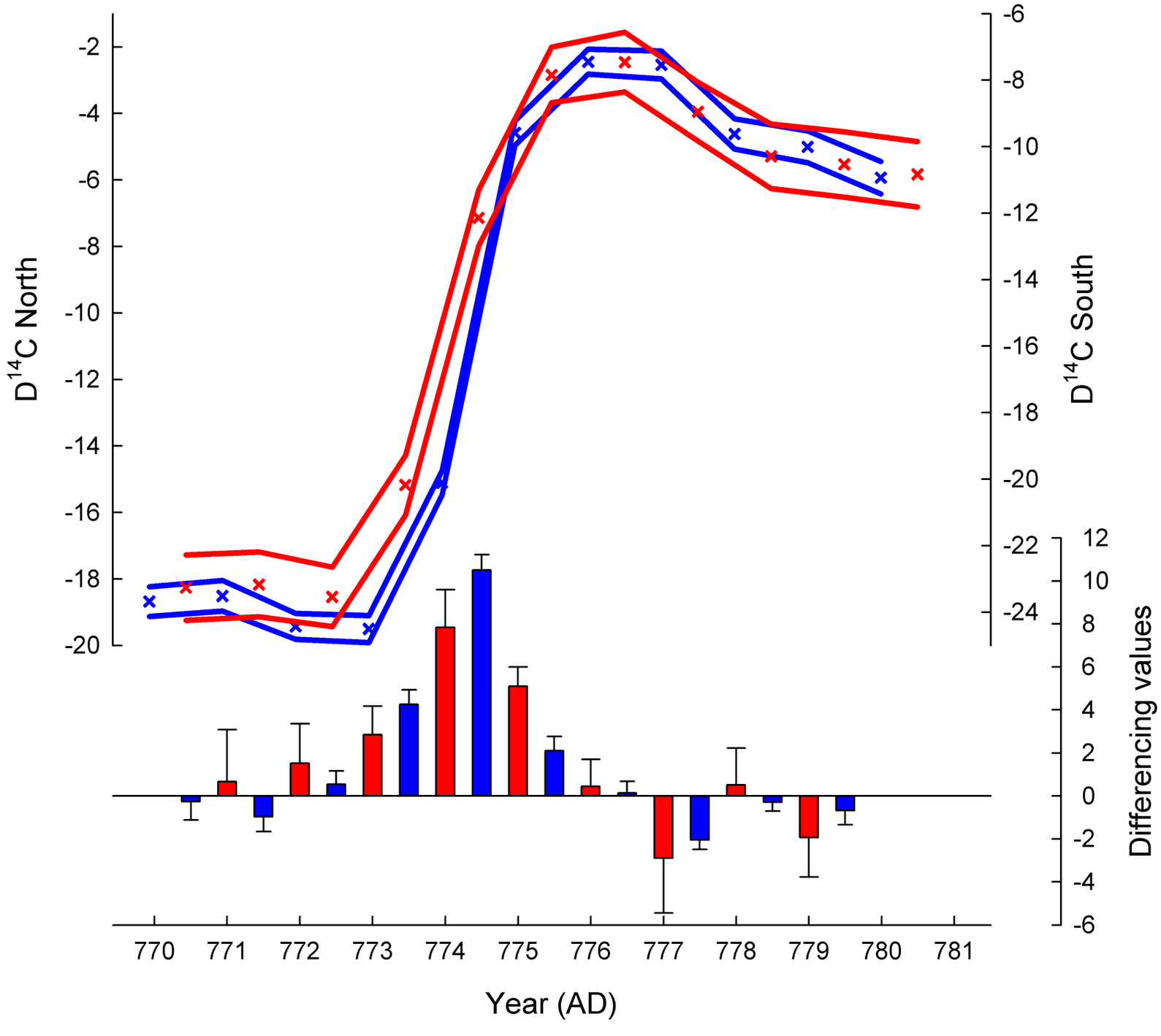
Broad leaved trees

- ★ *Betula*
- ★ *Quercus*

Comparison of chronologies



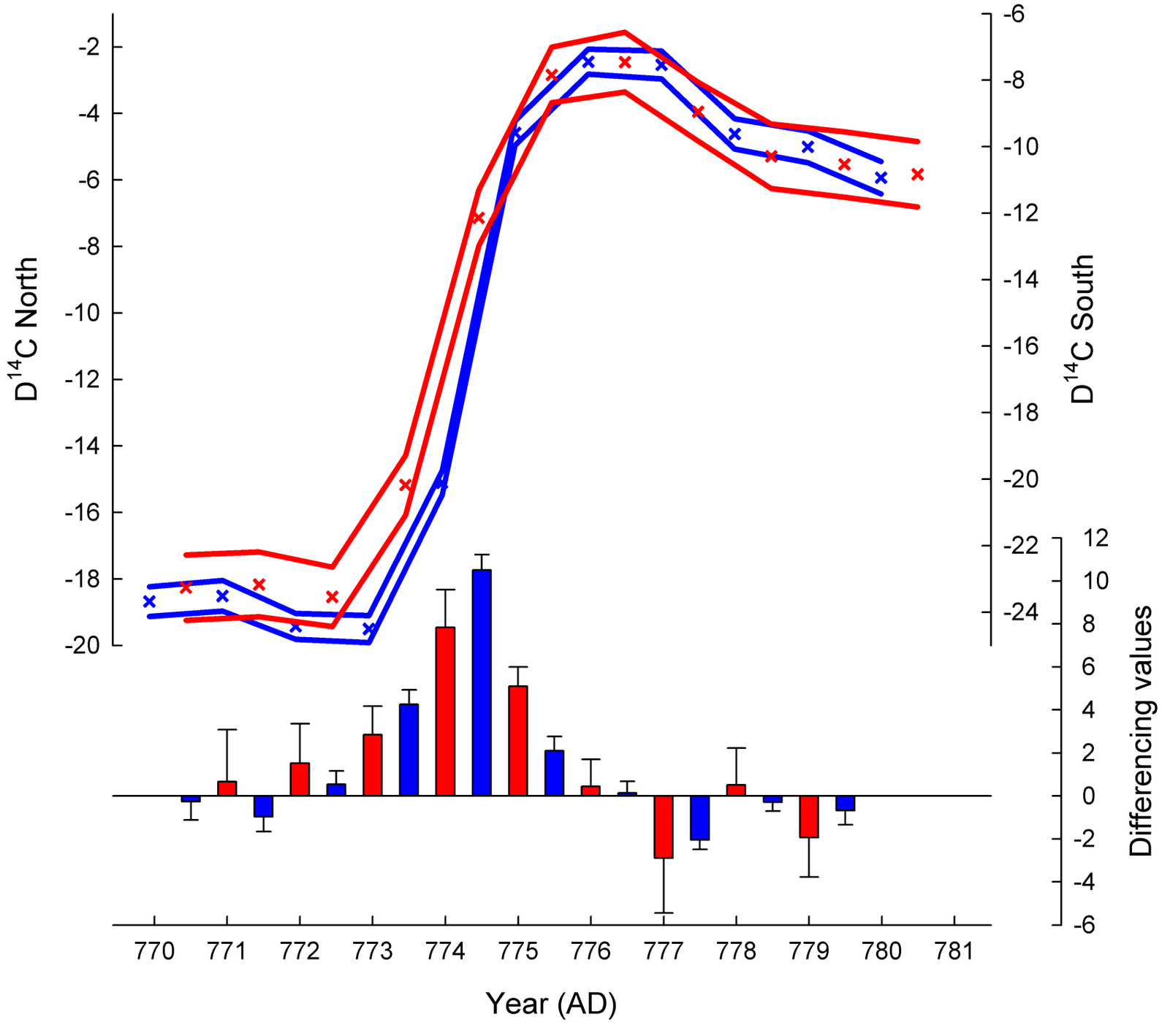
Worldwide signal



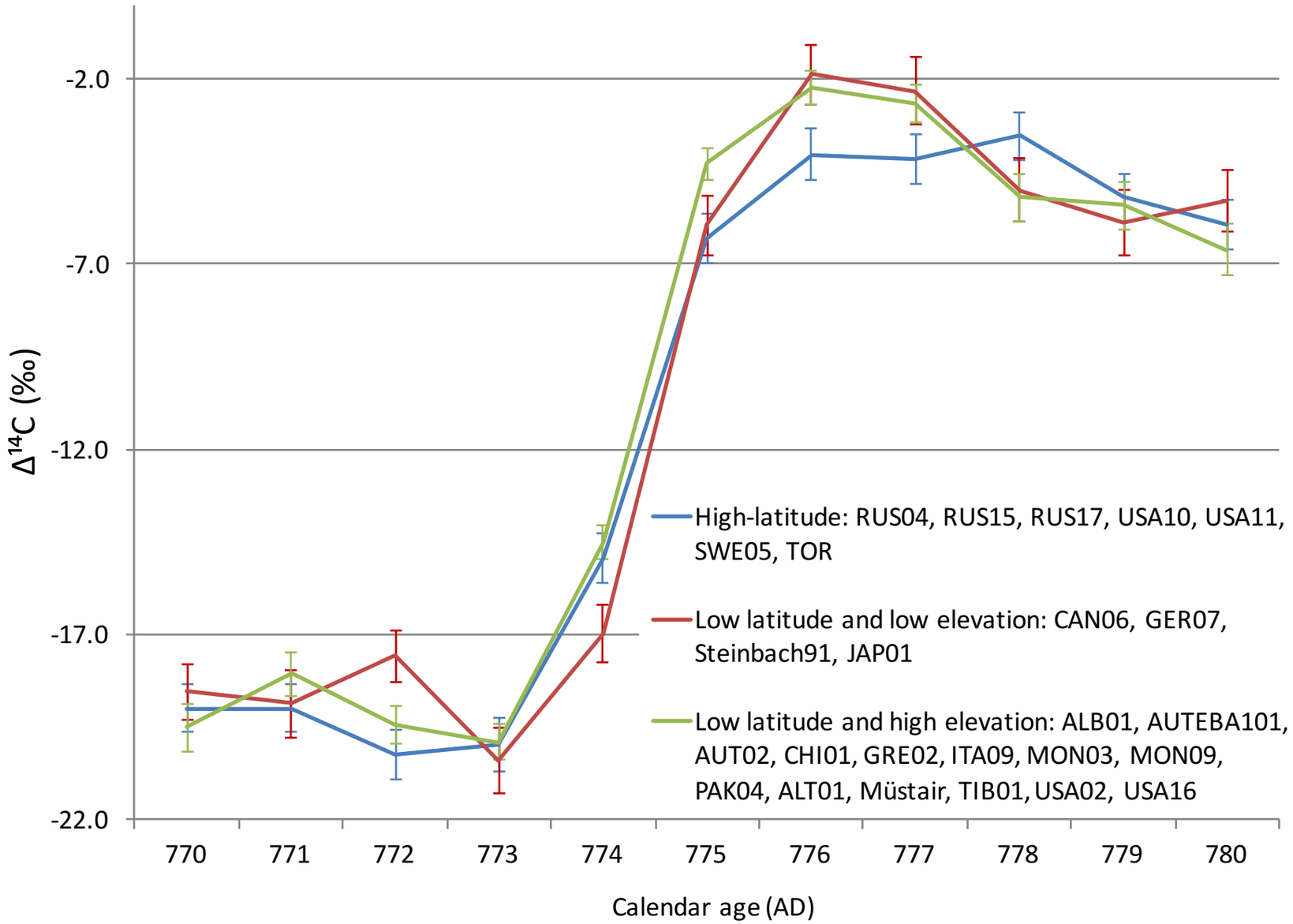
Worldwide signal

SH nearly 5‰ lower than NH

Dendro records agree in timing



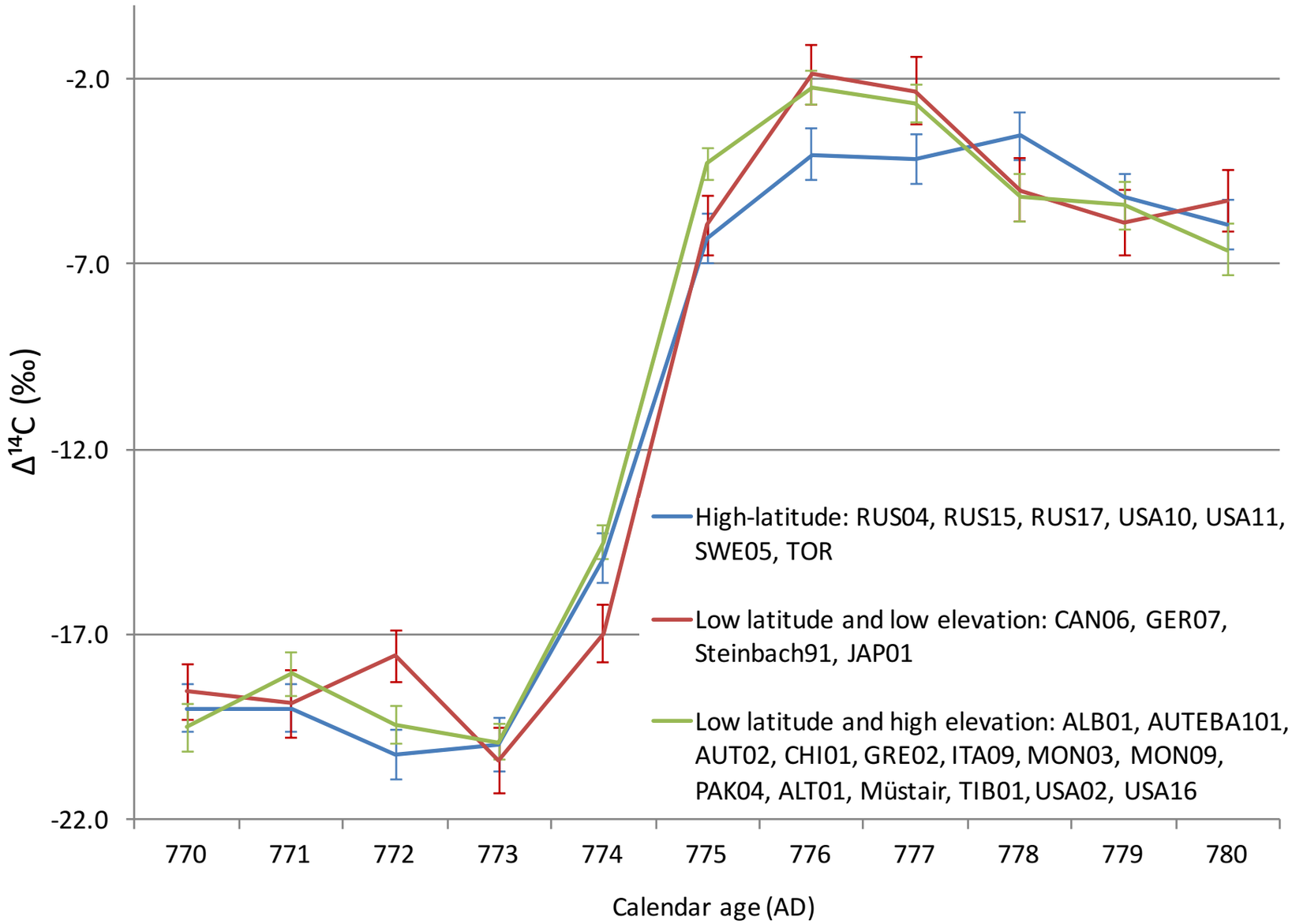
Worldwide signal



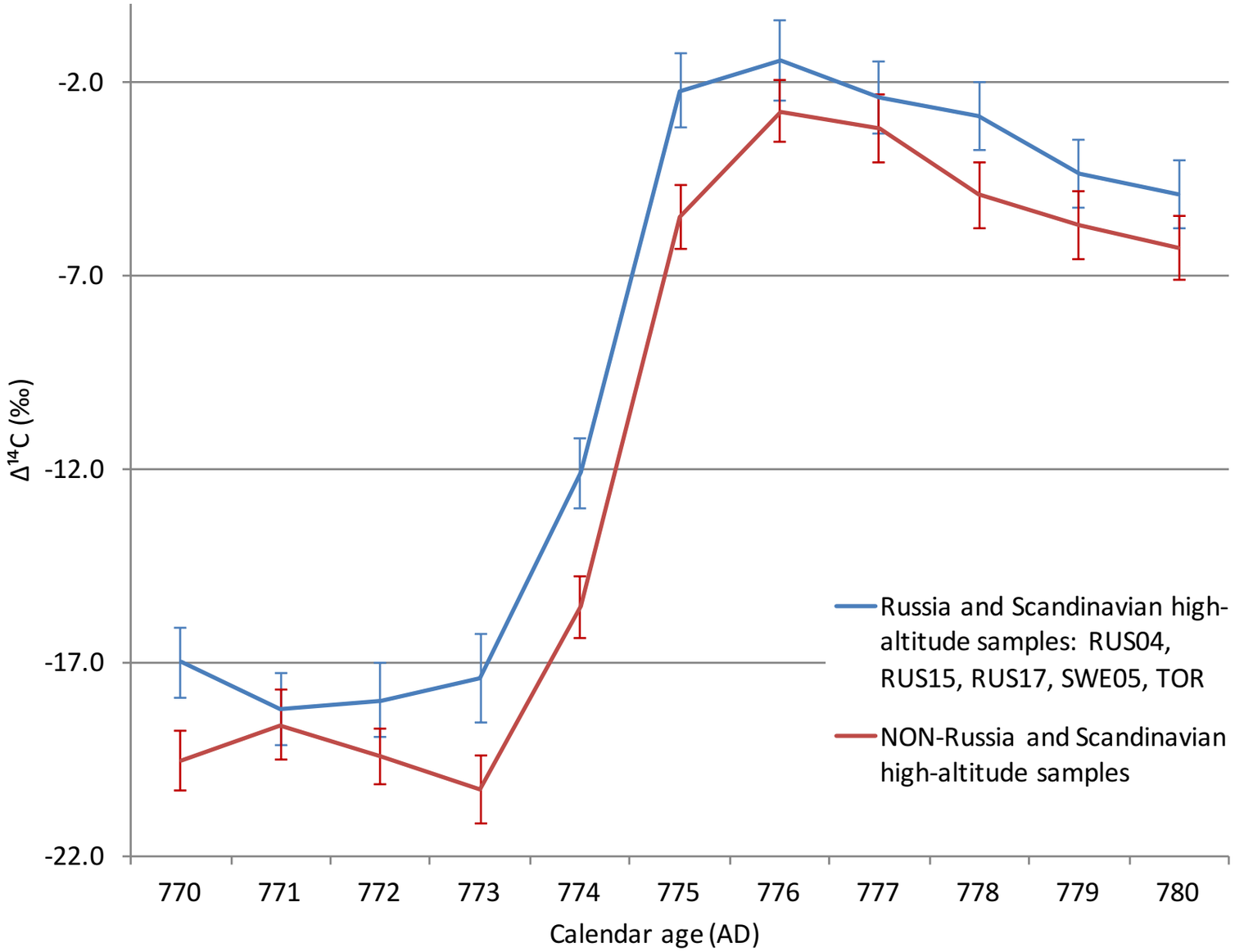
Worldwide signal

No offset between different species

No offset between different records from NH (except high latitude)

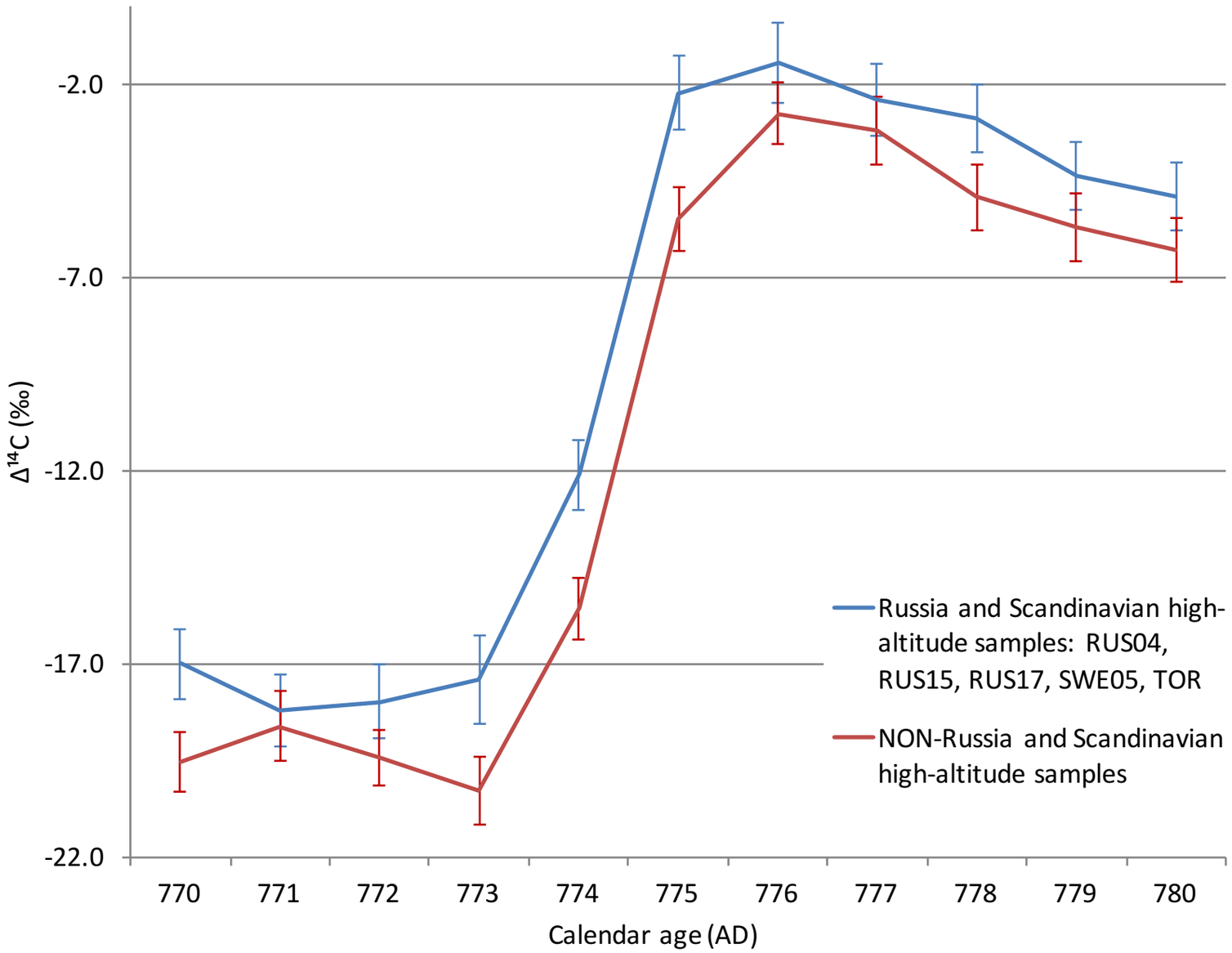


Worldwide signal

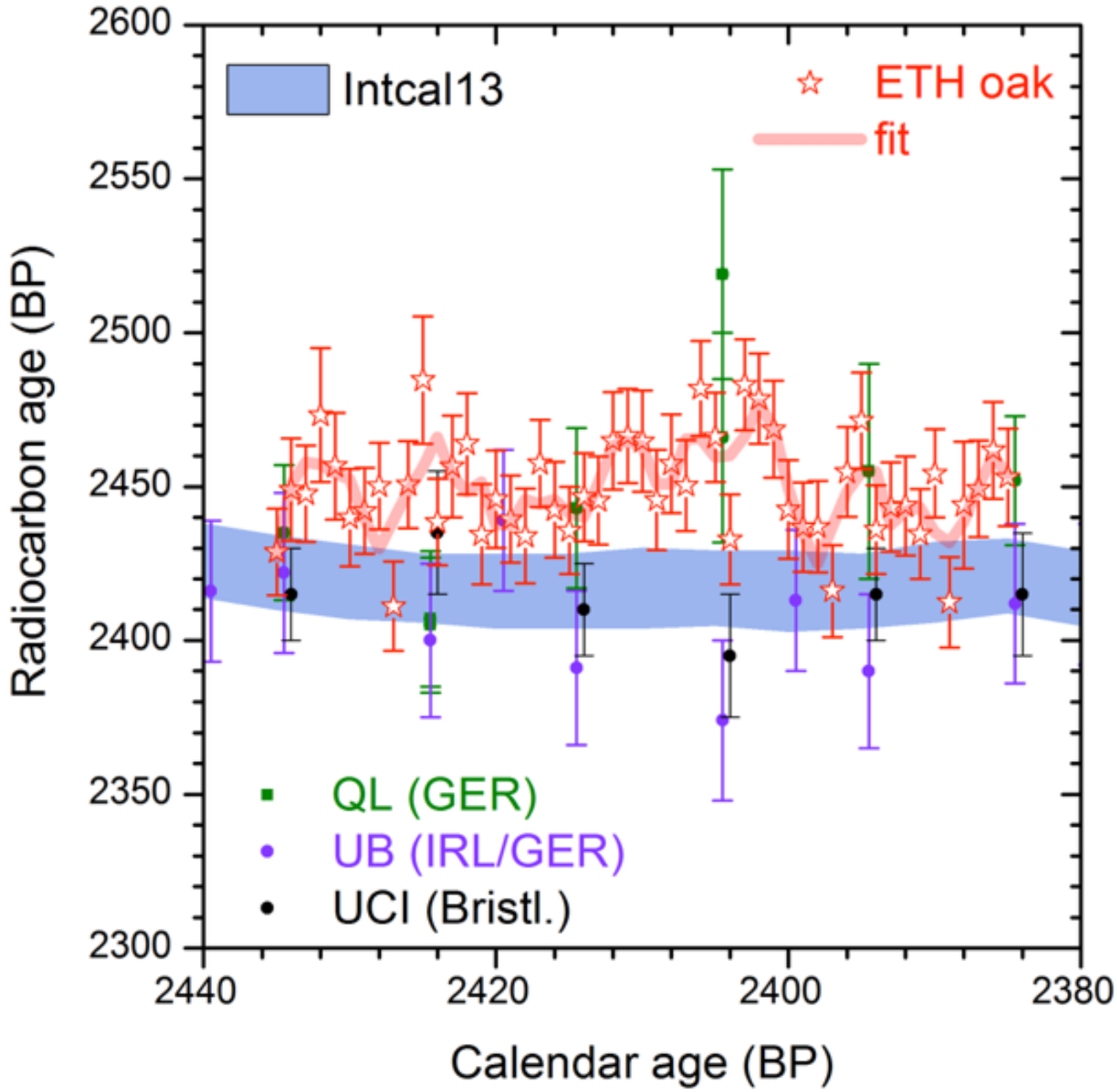


Worldwide signal

Exception???



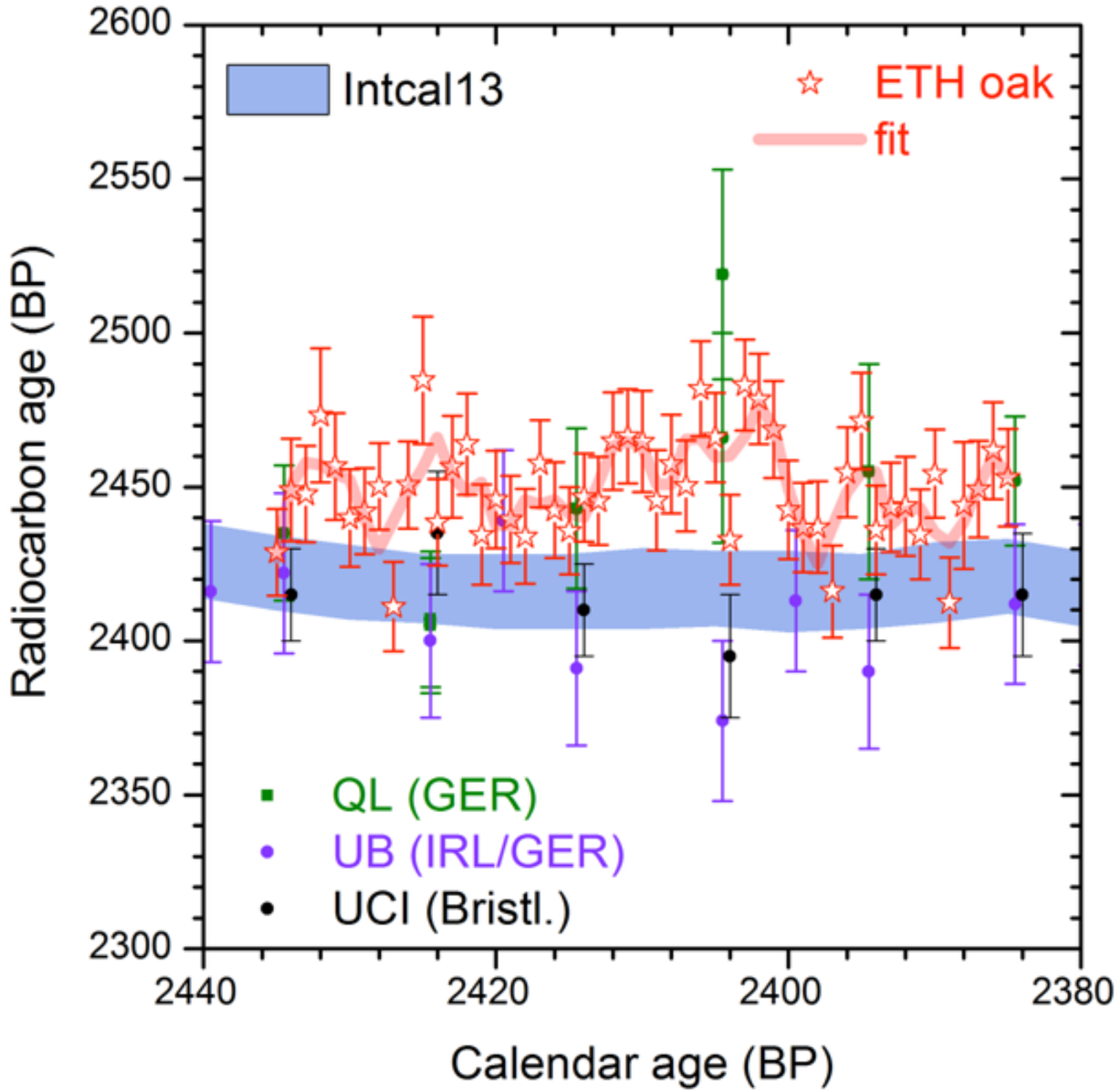
Hallstatt plateau: 2400 BP



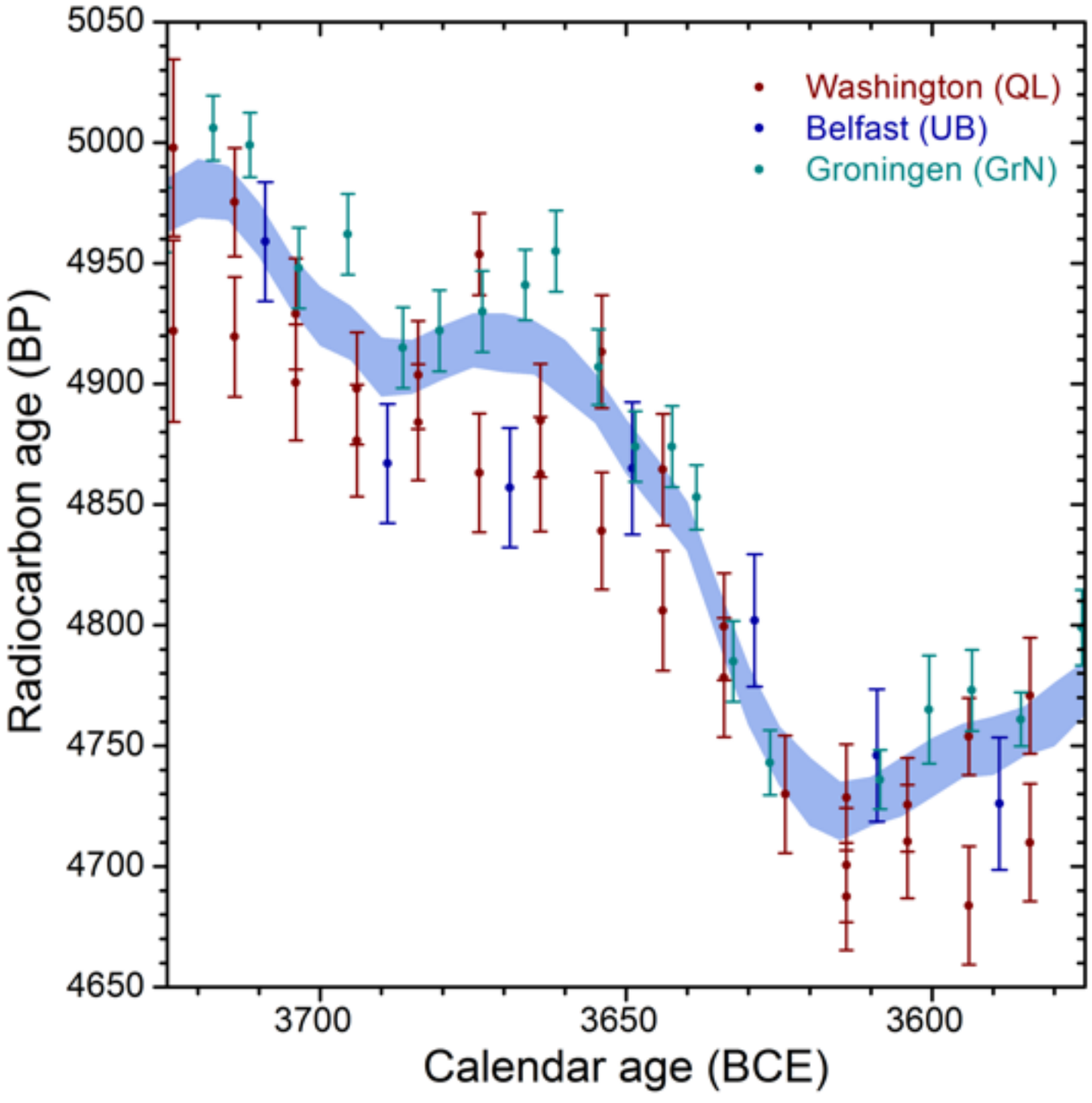
Hallstatt plateau: 2400 BP

Data is often offset

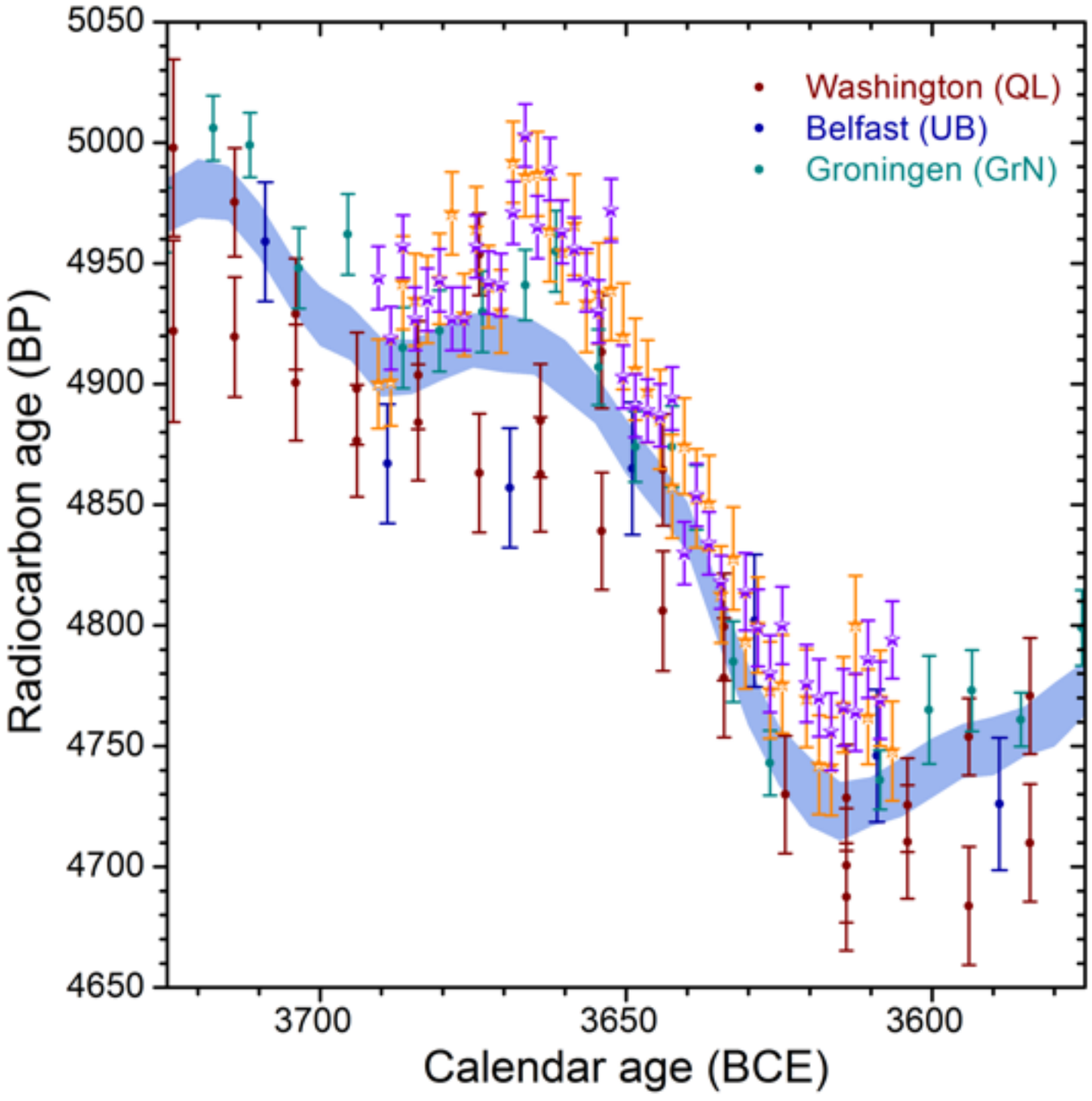
Curve has more structure!



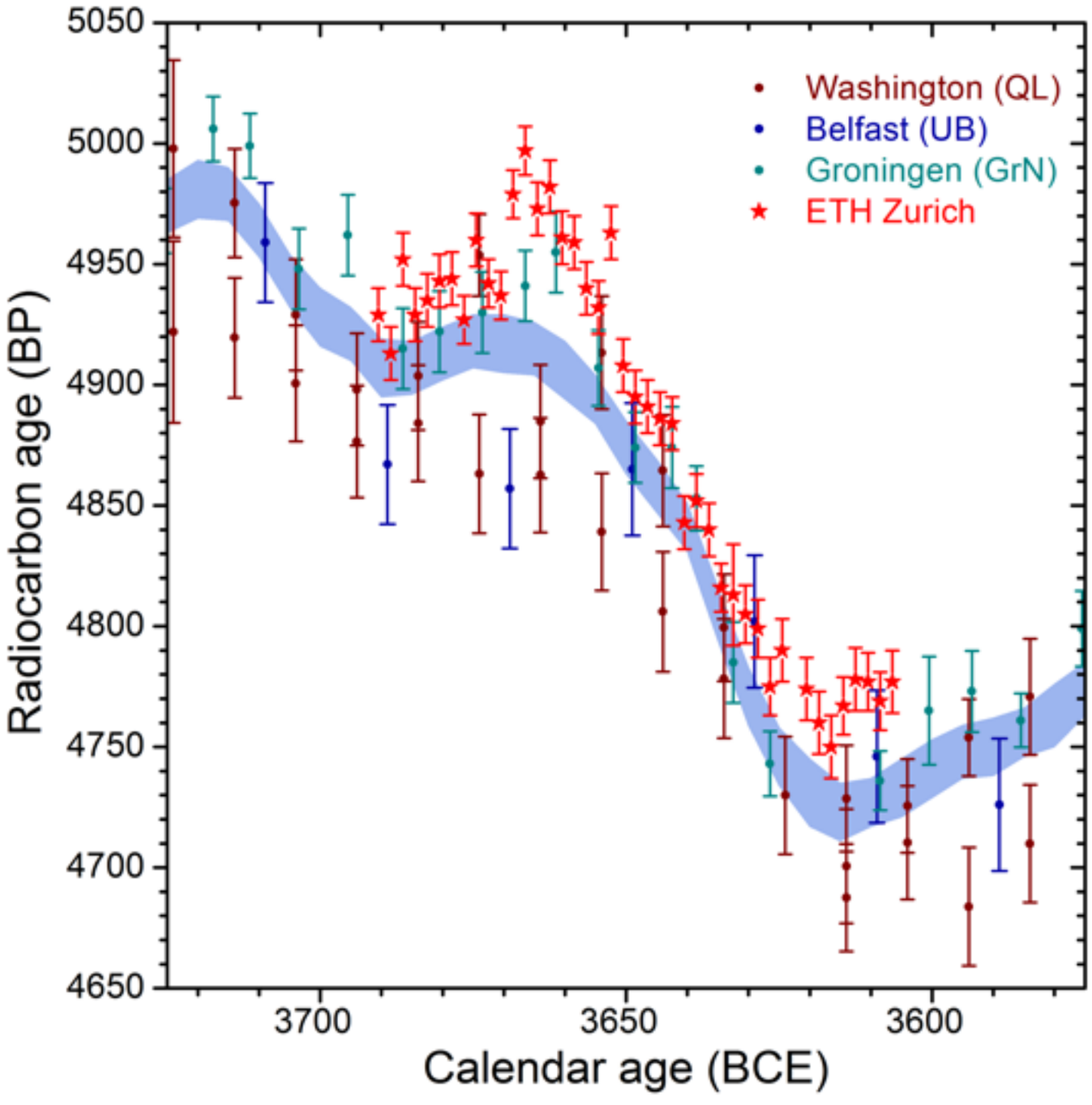
5600 BP


Washington (QL)
Belfast (UB)
Groningen (GrN)
Radiocarbon age (BP)
5050
5000
4950
4900
4850
4800
4750
4700
4650
3700
3650
3600
Calendar age (BCE)

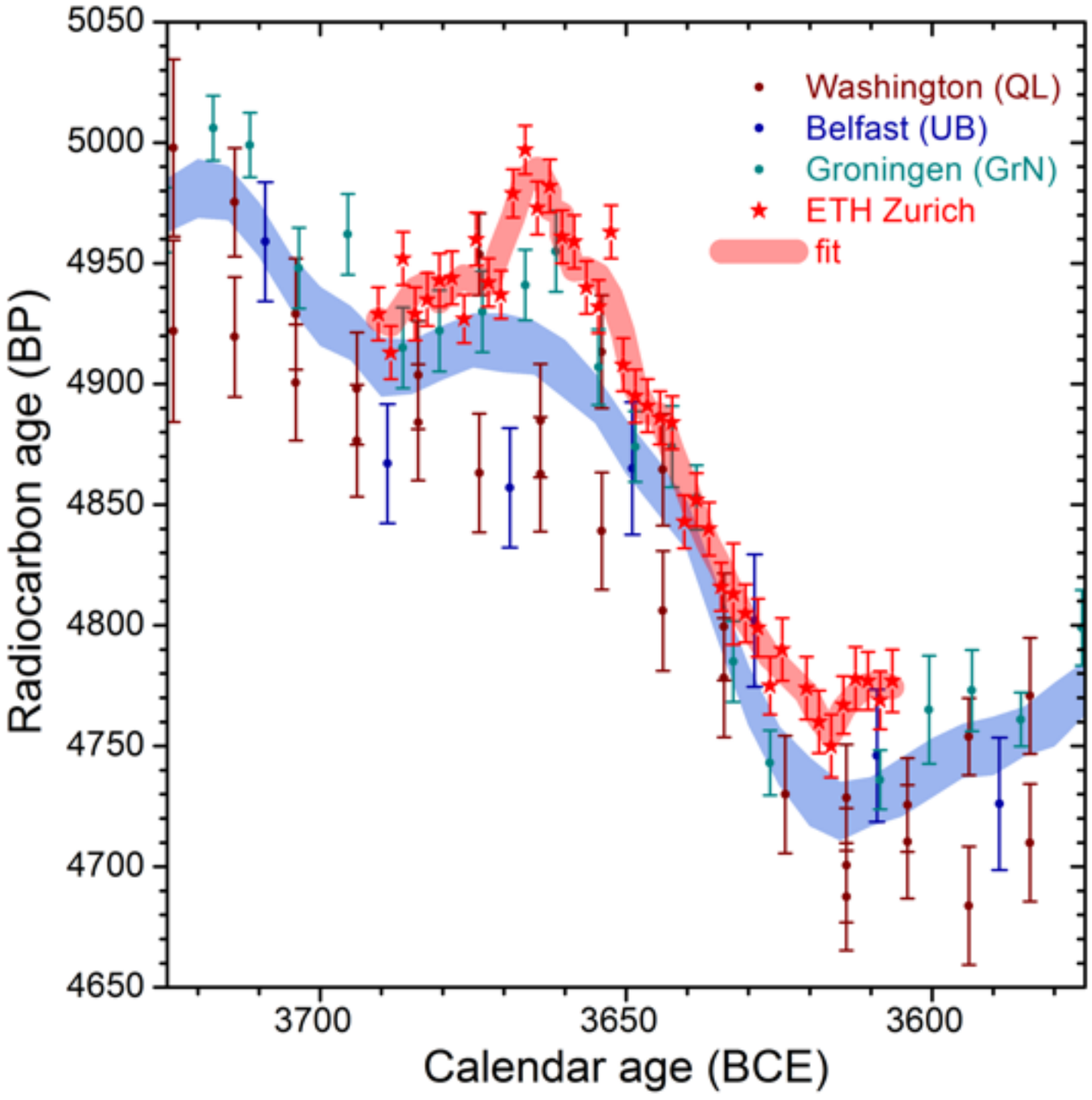
5600 BP


Washington (QL)
Belfast (UB)
Groningen (GrN)
Radiocarbon age (BP)
5050
5000
4950
4900
4850
4800
4750
4700
4650
3700
3650
3600
Calendar age (BCE)

5600 BP


Washington (QL)
Belfast (UB)
Groningen (GrN)
ETH Zurich
Radiocarbon age (BP)
5050
5000
4950
4900
4850
4800
4750
4700
4650
3700
3650
3600
Calendar age (BCE)

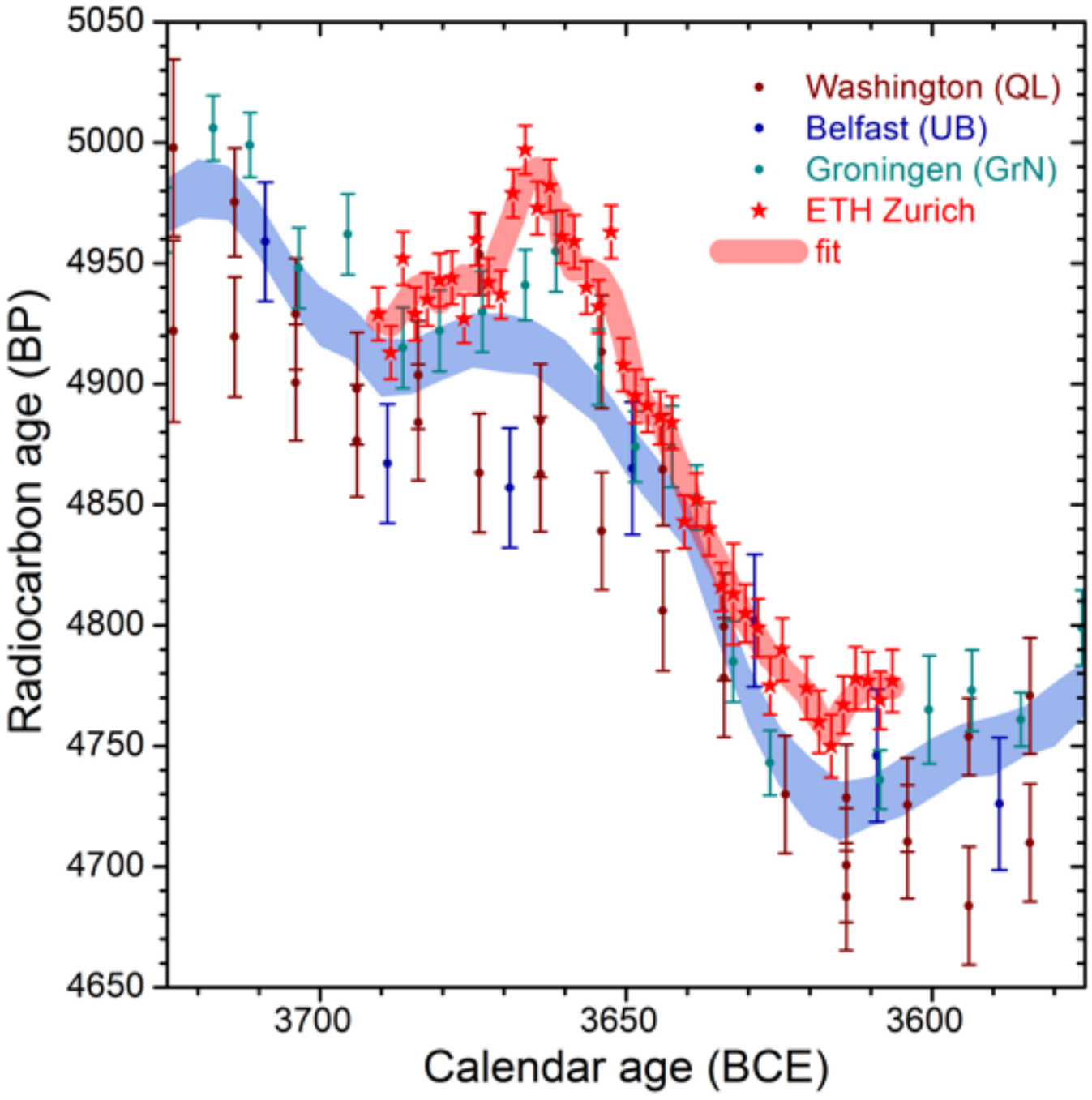
5600 BP


Washington (QL)
Belfast (UB)
Groningen (GrN)
ETH Zurich
fit
Radiocarbon age (BP)
5050
5000
4950
4900
4850
4800
4750
4700
4650
3700
3650
3600
Calendar age (BCE)

5600 BP

Well repeated!

Good agreement with Grongingen!



Tree-rings and radiocarbon dating

Tree-rings and radiocarbon dating

★ Tree-rings are the bases for precise radiocarbon dating

Tree-rings and radiocarbon dating

- ★ Tree-rings are the bases for precise radiocarbon dating
- ★ Radiocarbon calibration curve does not match up anymore

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- ★ Tree-rings are the bases for precise radiocarbon dating
- ★ Radiocarbon calibration curve does not match up anymore
- ★ It has more fine structure than expected that allows for more precise dating

Tree-rings and radiocarbon dating

★ Tree-rings are the bases for precise radiocarbon dating

★ Radiocarbon calibration curve does not match up anymore

★ It has more fine structure than expected that allows for more precise dating

★ *(AMS) data is often offset*


Thank
you
for your
attention!
Radiocarbon age BP (year)
1300
1200
1100
1000
900
800
700
700
775
850
925
1000
1075
1150
1225
1300
Calendar age CE (year)