Supplemental Materials

Douglas-fir multiproxy tree-ring data glimpse MIS5 environment in U.S. Pacific Northwest

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We provide greater details on the analyzed tree rings and ^{14}C measurements of Douglas-fir from the ancient landslide with three tables related to tree-ring crossdating (Table S1), isotope sampling (Table S2) and initial ^{14}C measurements (Table S3). Comparisons of the ancient tree-ring parameters with those of modern trees are done in Table S4 (ring widths) and Table S5 (isotope composition). These additional data are intended for archiving the original site information that may be needed for re-analysis or further interpretation of the tree-ring results. We include one additional figure with individual isotopic measurements (Figure S1), which is used for quality control of the measurements. Figure S2 shows spectral properties of modern ring width chronologies from central Oregon.

Table S1. Summary of 13 wood specimens recovered from the U.S. Highway 20 project, the first 12 of which are Douglas-fir (*Pseudotsuga*).
OR-1 was not a large trunk but a subsampled 10-cm preliminary piece of wood initially conveyed to the University of Arizona before the large cross-sections, identified as western red cedar (*Thuja plicata*). "Outers" refer to the presence(Y)/
absence(N) of the most outer ring at the time of tree death. Each specimen was measured at two radii marked with "a" and "b" series.

Specimen ID	Number of rings	Radius (cm)	Pith	Outers	Correlation with master
351a	112	39	Y	N	
351b	111	39	Y	N	0.32
352a	264	66	Y	Y	0.37
352b	262	66	Y	Y	0.62
353a	296	78	Y	Y	0.59
352b	250	78	Y	Y	0.60
354a	250	46	Y	Y	0.63
354b	250	46	Y	Y	0.59
355a	260	62	Y	Y	0.55
355b	256	62	Y	N	0.58
356a	296	47	Y	N	0.59
256b	296	47	N	Y	0.68
357a	292	58	N	Y	0.63
357b	256	58	N	N	0.50
358a	209	55	N	N	0.49
358b	210	55	N	Y	056
359a	276	23	N	Y	0.49
359b	276	23	Y	Y	0.72
360a	292	62	N	N	0.67
360b	288	62	N	N	0.63
361a	214	20	N	Y	0.68

361b	215	20	N	Y	0.46
362a	296	38	N	Y	0.72
362b	258	38	N	Y	0.56
OR-1a	156	20	N	Y	0.67
OR-1b	156	21	Y	Y	048
					0.55

The $\delta^{13}C$ and $\delta^{18}O$ records were developed from four of the longest-lived trees by two methods: (1) pooling rings prior to analysis for most years, and (2) analyzing rings separately and then averaging values for ca. 10% of years. Trees #352, 353, 356, and 360 were used to develop the isotope records (Table S2).

Table S2. Summary of tree-ring width chronology and ring isotope chronologies. The isotope chronologies do not cover the full period of the dated rings. They begin at Year 22 to minimize any biasing from juvenile period of tree growth with 4 trees contributing to most years.

Tree-Ring Parameter	Chronology Span	Chronology interval >5 trees in TRW, =4 trees in isotopes	Missing years in measurements*	Adjusted Span of Chronology	Total Years
Width	1–297	3–297	—	1–297	297
^{13}C	22–297	33–238	229,238,269	22–295	273
^{18}O	22–260	33–238	146,216,229,231,234,236	22–258	236

*Inefficient cellulose or used up in analysis, so data for some rings are missing: six years for the O-isotope and three for the C-isotope analyses.

The $\delta^{18}O$ chronology has only a few values after year 251 because many samples had no cellulose remaining after $\delta^{13}C$ analysis. Those few post-251 values seem to fit well with values from the immediately earlier years. For the years when all four trees were analyzed separately, the greatest range was 3.58‰ and the smallest was 0.28‰ (average range= 1.65‰, SD= 0.80‰). The average standard deviation among the trees analyzed separately was 0.73‰. The O-isotope series did exhibit anomalously ^{18}O-depleted values at year 67 (24.21‰) and especially at year 87 (15.67‰). No cellulose remained to re-analyze, but the validity of the latter value is certainly suspect. The $\delta^{13}C$ series exhibited no such anomalous values.

Plots of isotopic measurements are shown in Figure S1. All four trees contributed to the $\delta^{13}C$ chronology from ca. chronology-year 40 to chronology-year 240, three trees contributed before year 40, two trees contributed after ca. year 240 to year 251, and after year 251 the isotopic values are from just one tree (#353). The large $\delta^{13}C$ isotopic shift after ca. year 251 seems to be an artifact of rings from only one tree (#353) being available after that year. Tree #353 is isotopically depleted by an average of 0.38‰ relative to the mean of the other three trees. On the other hand, the pattern/mean of rings at year 240 (when all four trees contributed to the isotope value) and year 251(when just two trees contributed) does not show any abrupt isotopic shift. One measure of inter-tree variability is the range of values, i.e., maximum − minimum $\delta^{13}C$.

During the period with all four trees analyzed separately, the greatest range was 2.49‰ and the smallest was 0.67‰ (average range of 1.50‰, standard deviation (SD)= 0.57‰). A second measure is standard deviation among the trees analyzed separately, which averages

0.66‰. The $\delta^{18}O$ chronology has only a few values after year 251 because many samples had no cellulose remaining after $\delta^{13}C$ analysis. Those few post-251 values seem to fit well with values from the immediately earlier years. For the years when all four trees were analyzed separately, the greatest range was 3.58‰ and the smallest was 0.28‰ (average range= 1.65‰, SD= 0.80‰). The average standard deviation among the trees analyzed separately was 0.73‰. The O-isotope series did exhibit anomalously ^{18}O-depleted values at year 67 (24.21‰) and especially at year 87 (15.67‰). No cellulose remained to re-analyze, but the validity of the latter value is certainly suspect. The $\delta^{13}C$ series exhibited no such anomalous values. Both isotope chronologies to year 251 (except for the two $\delta^{18}O$ outlier values), can be considered usable for exploring common environmental influences on $\delta^{13}C$ and $\delta^{18}O$. $\delta^{13}C$ was positively correlated with $\delta^{18}O$, r= 0.17 (p=0.01), although part of this relationship may be related to the upward trend exhibited by both isotopes. Correlation of first differences was used to eliminate the influence of trends, and the relationship between the two isotope series was not significant, r=0.01 (p=0.89).

Table S3. Results of original AMS radiocarbon dating of Douglas-fir tree trunks at the University of Arizona AMS facility.

Oregon wood sample ID	AA#*	$\delta^{13}C$	Fraction of Modern ^{14}C	Error (±1 SE)	^{14}C age BP
#351	87643	-26.7	-0.0023	0.0007	>52,700
#352	87644	-25.7	-0.0018	0.0007	>52,700
#353	87645	-27.0	-0.0021	0.0007	>52,700
#355 (outside)	87646	-25.6	-0.0020	0.0007	>52,700
#355 (inside)	87647	-25.5	-0.0008	0.0007	>52,700
#356	87648	-25.1	-0.0003	0.0008	>51,700
#357	87649	-26.2	-0.0003	0.0007	>52,700
#358	87650	-25.6	-0.0021	0.0007	>52,700
#359	87651	-25.3	-0.0013	0.0007	>52,700
#360	87652	-26.9	-0.0019	0.0017	>52,700
#361	87653	-24.2	-0.0021	0.0007	>52,700
*Arizona AMS radiocarbon sample number					

Table S4. Site statistics of modern Douglas fir ring width chronologies from central Oregon used in the study. Details on the climatic and ecological response of the ring-width chronologies are published in Dziak et al. (2015) and Black et al. (2021) [29,30].

Site name	Latitude deg N	Longitude deg W	Elevation, m a.s.l.	Span
Browder	44.359	122.114	1108	1318-1995
Marys Peak	44.504	123.56	900	1596-2013
Mike Miller	44.603	124.051	12	1713-2011
Cape Perpetua	44.273	124.073	244	1650-2006

Table S5. Statistics of tree-ring width measurements (TRW) and index chronologies (*) from the ancient and modern Douglas fir used in the study. Details of modern sites are shown in Table S4. SD indicates standard deviation. The data show comparable variance of the crossdated tree rings and chronologies from the ancient and modern samples.

Site ID	Mean TRW mm	TRW Series intercorrelation	Mean Sensitivity	Span of Chronology Dates*	# Series*	SD*	Auto correlation Lag 1*
TRW Ancient							
This study, Oregon	2.10	0.58	0.22	297 years†	26	0.26	0.61
TRW Modern	1.95	0.52	0.21	1437-1921	79	0.24	0.50
Browder	1.36	0.67	0.21	1569-2013	38	0.22	0.61
Marys Peak	1.12	0.55	0.22	1632-2011	61	0.23	0.42
Mike Miller	2.12	0.55	0.21	1618-2006	30	0.28	0.64
Cape Perpetua							

†we do not know range of calendar dates, but the chronology is 297 years long

Table S6. Comparison of mean isotopic composition between modern coast Douglas-fir tree rings and the ancient one from this study. All isotopic measurements were done on ring cellulose.

Source	# Rings analyzed	$\delta^{13}C$	$\delta^{18}O$
This study	228	-22.6	28.1
[53] Barnard et al. (2012)	8	-25/-23.5*	28
[52] Roden et al. (2005)†	2	-25/-23.5*	29
[50] Panek and Waring (1997)	11-19	-23/-22*	n/a
[51] Levesque et al. (2013)‡	50	-22	25

†12-year-old trees

‡this study was done in Italy and Switzerland

*published $\delta^{13}C$ not corrected for shifting $\delta^{13}C_{air}$; 2nd value incorporates estimated correction.

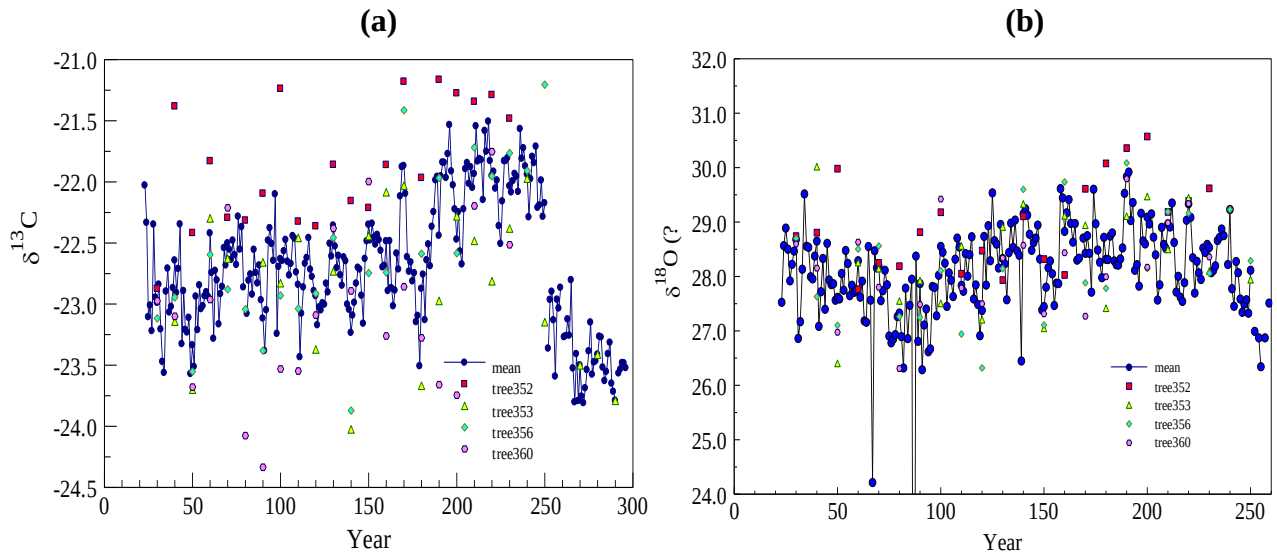

Figure S1. The $\delta^{13}C$ (a) and $\delta^{18}O$ (b) time series for the Oregon landslide Douglas-fir. The connected points represent isotopic composition of pooled samples from four trees for most

years and average isotopic composition of the trees analyzed separately every decade. The individual isotopic values for trees analyzed separately every decade are given with separate unconnected symbols.

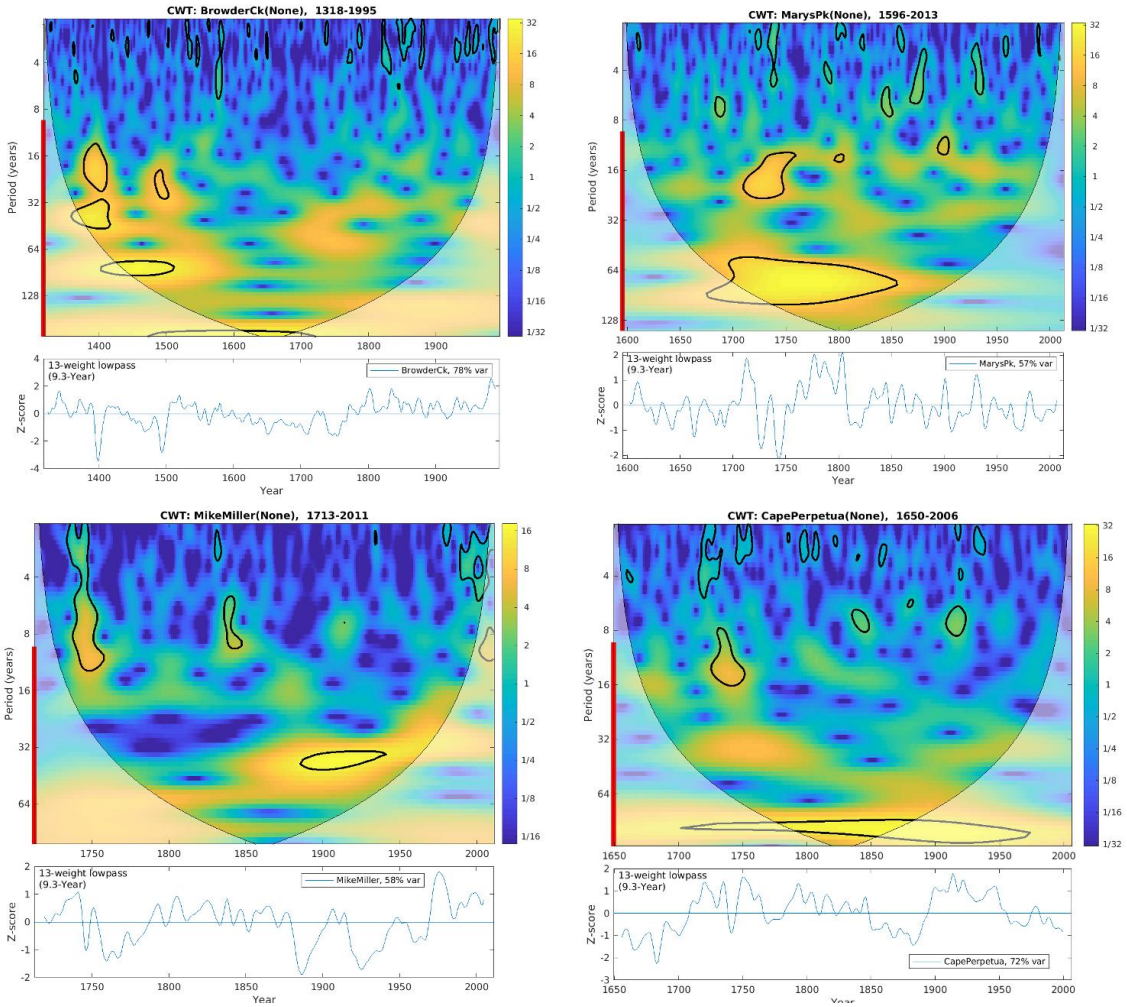

Figure S2. Continuous wavelet transforms (CWT) and smoothed time series plots of modern tree-ring width chronologies from central Oregon, see the sites listed in Table S4. CWT describes variance as function of time and frequency, with areas significant (95%) relative to red noise enclosed by solid black line. Color mapping, with key at right, is spectral power (high variance yellow, low variance blue). Title at top gives name of series, whether transformed (none were), and the year sequences (relative for floating, absolute for modern). Series smoothed by low-pass Hamming filter (number of weights and 50% response wavelength annotated) is plotted below CWT. Red vertical bar at left of CWT marks approximate range of wavelengths passed by filter; percentage of original variance retained in smoothed series is annotated in box at upper right of time plot.