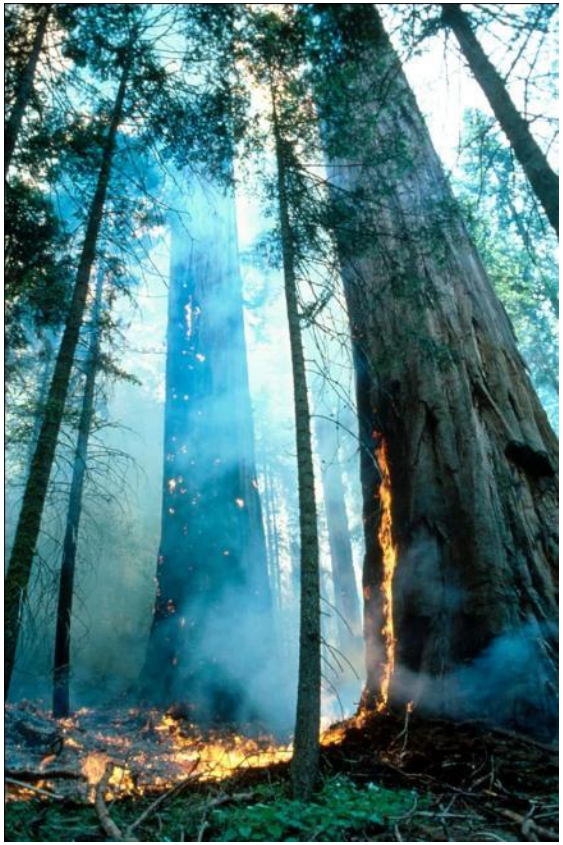
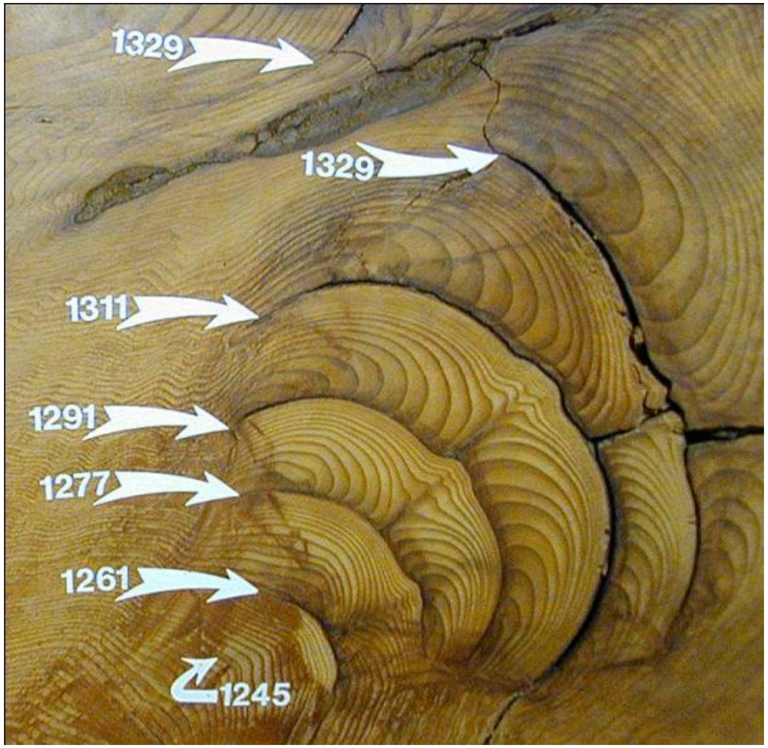
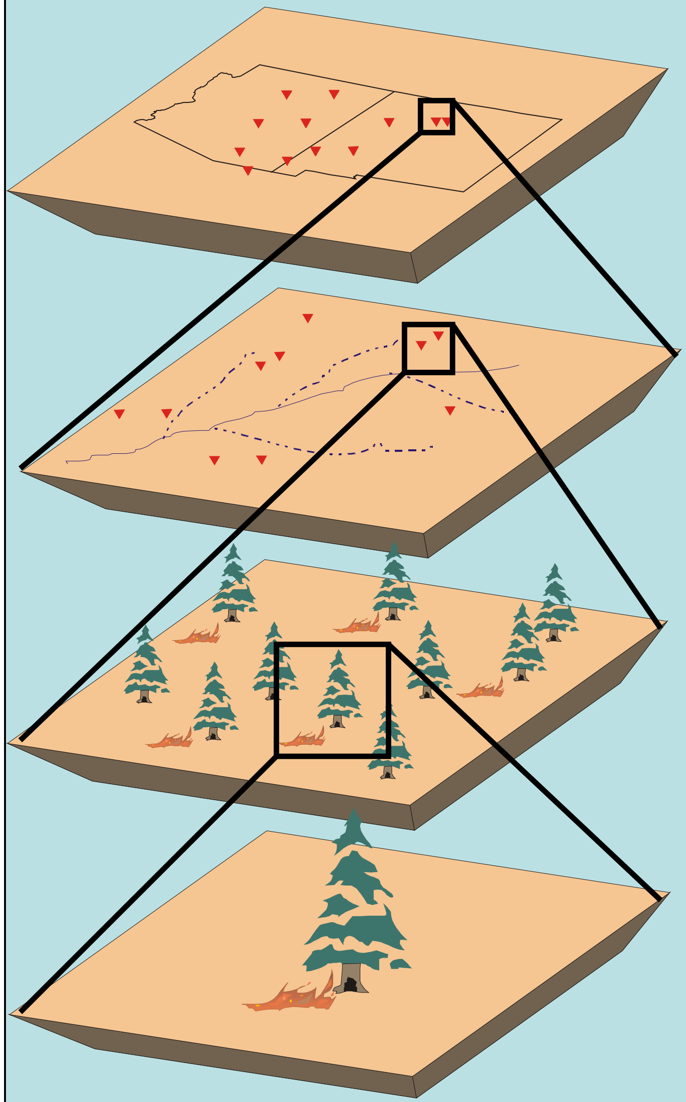
Fire History From Tree Rings





T.W. Swetnam, Laboratory of Tree-Ring Research

Scales of disturbance history analysis and types of factors involved in synchrony/asynchrony



Regional — Climate, broad-scale human land uses

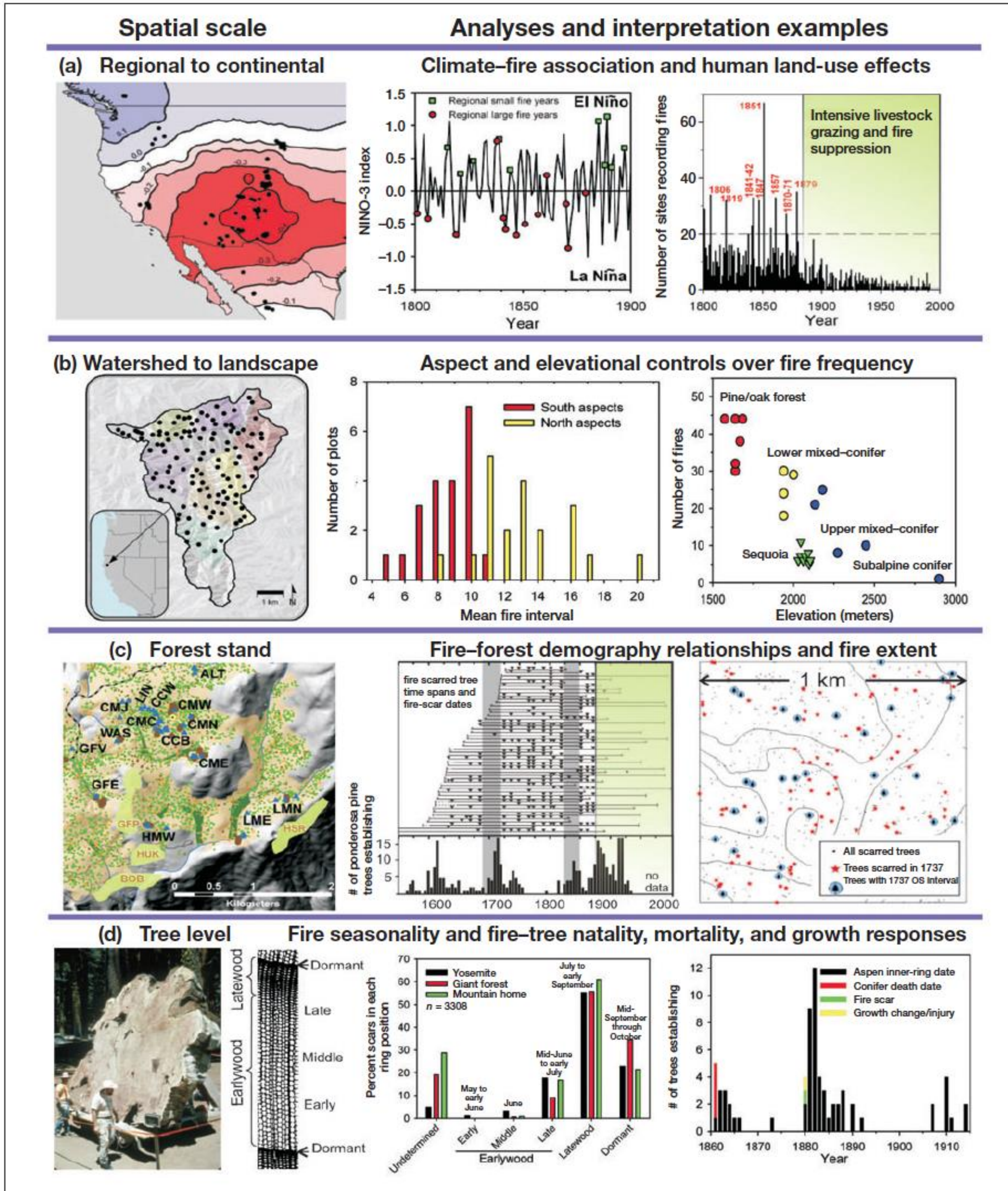
Watershed/ Landscape — Topographic and elevation effects on fire spread

Stand — Fine-scale vegetation, fuels, wind, micro-climate

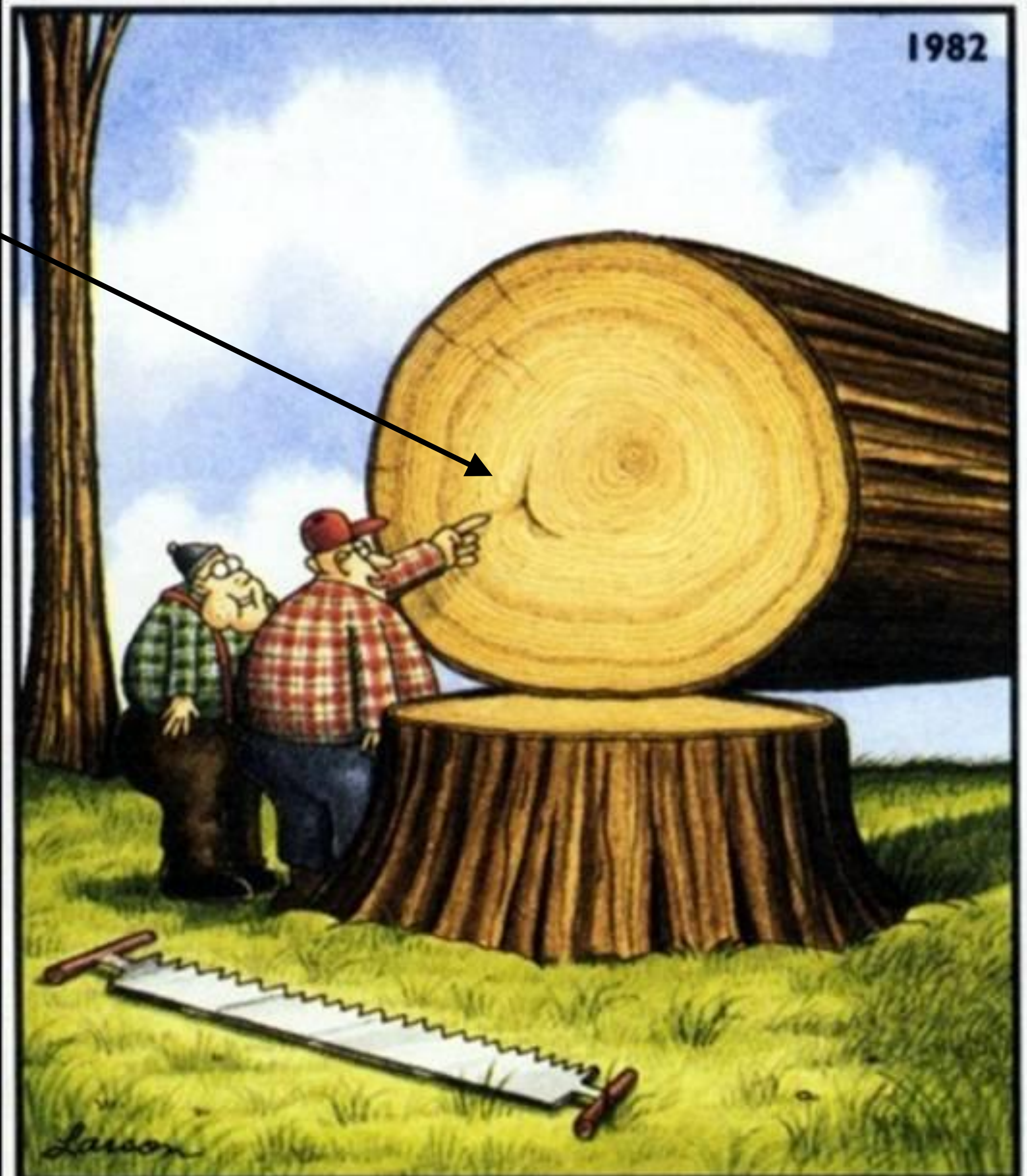
Tree — Very fine-scale, localized patterns determining first and subsequent scarring

Swetnam, T. W. and C. H. Baisan. 1996. USDA Forest Service General Technical Report RM-GTR-286.

Falk, D.A., E.K. Heyerdahl, P.M. Brown, C. Farris, PZ Fule, D. McKenzie, T.W. Swetnam, A.H. Taylor, and M.L. Van Horne. 2011. Multiscale controls of historical fire regimes: New insights from fire scar networks. *Frontiers in Ecology & Environment* 9(8): 446–54.



Fire Scar!



"And see this ring right here, Jimmy? … That's another time when the old fellow miraculously survived some big forest fire."

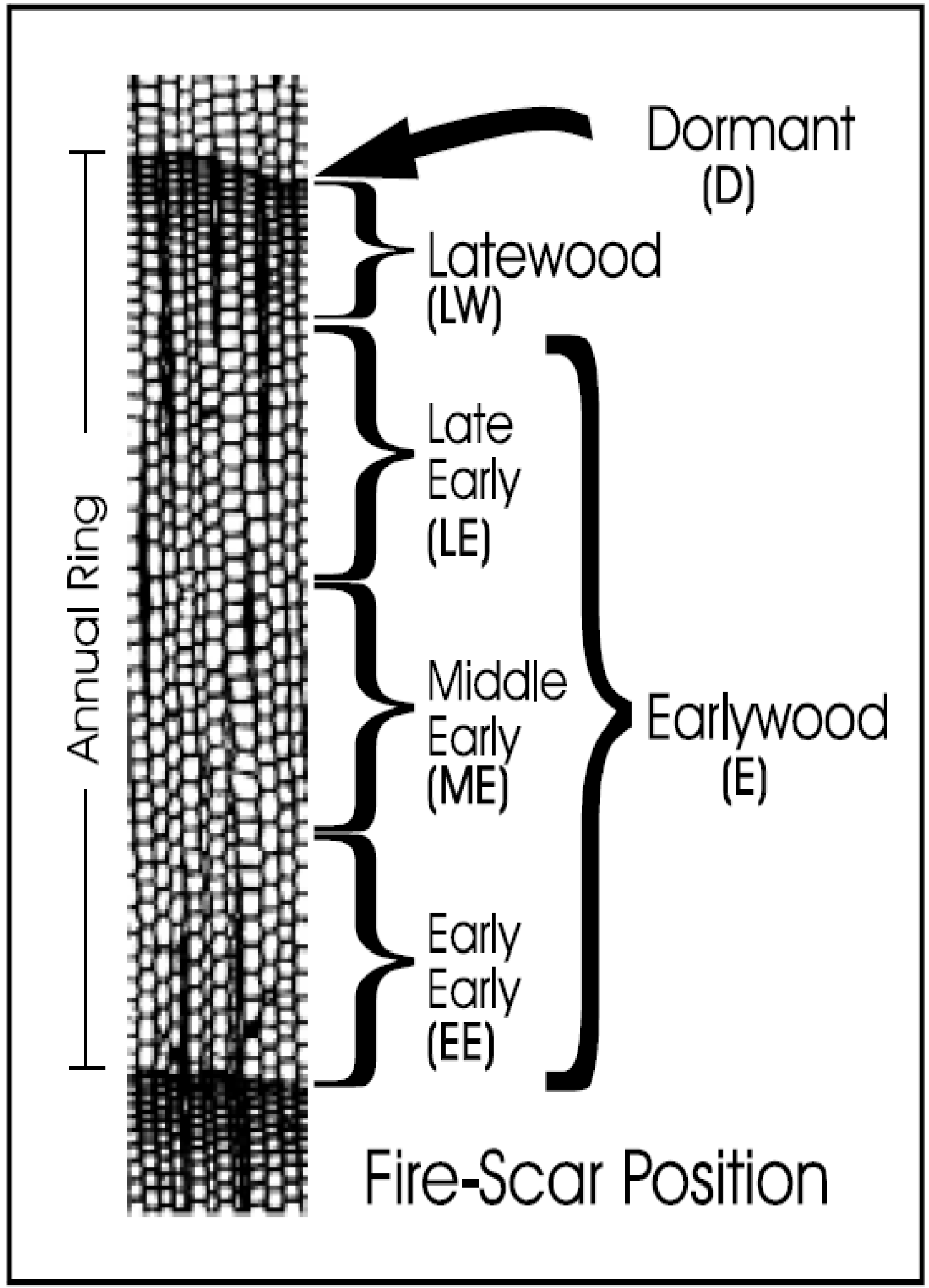
T.W. Swetnam, Laboratory of Tree-Ring Research

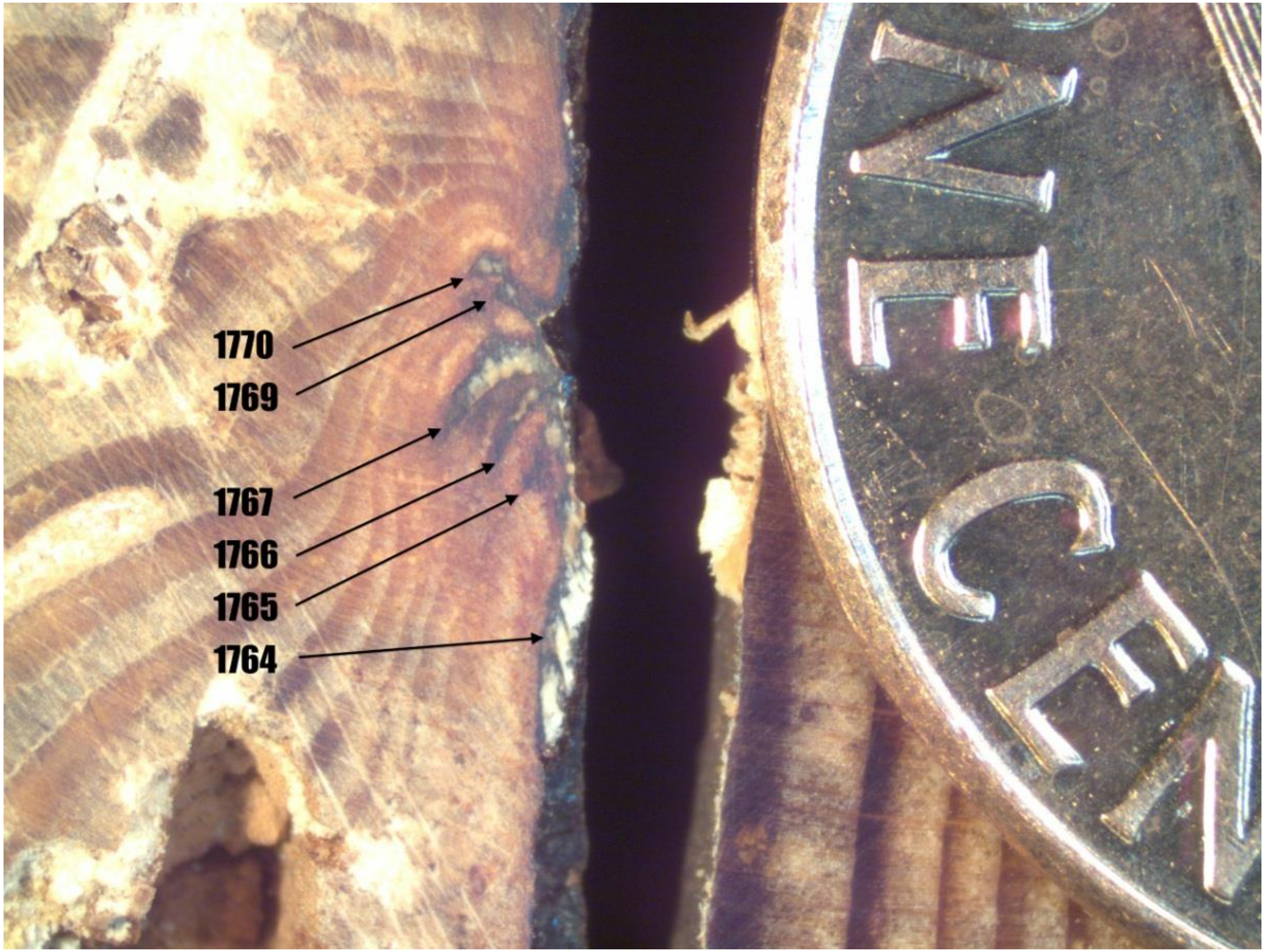
Fire-scarred trees can be reliable recorders of low to moderate intensity fires, and in some circumstances high intensity fires as well.

T.W. Swetnam, Laboratory of Tree-Ring Research

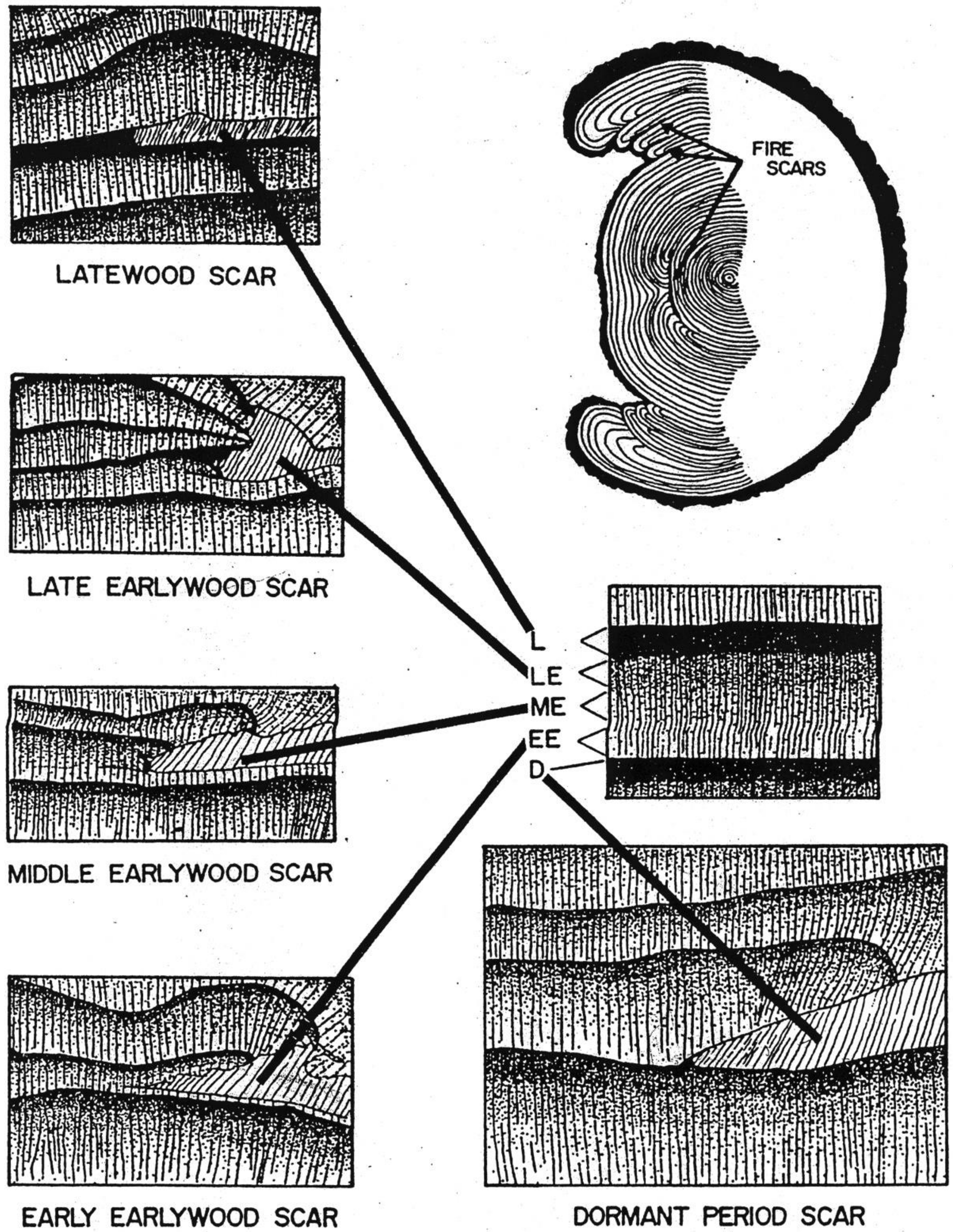
FIGURE 3. Careful inspection may occasionally reveal the season in which the fire occurred. Th upper scar (A) was produced in the earlywood while the tree was actively growing. The lower sca (B) was produced between the latewood cells of the previous year's growth and the earlywood cell of the next year's growth, indicating that the tree was dormant at the time of the fire.

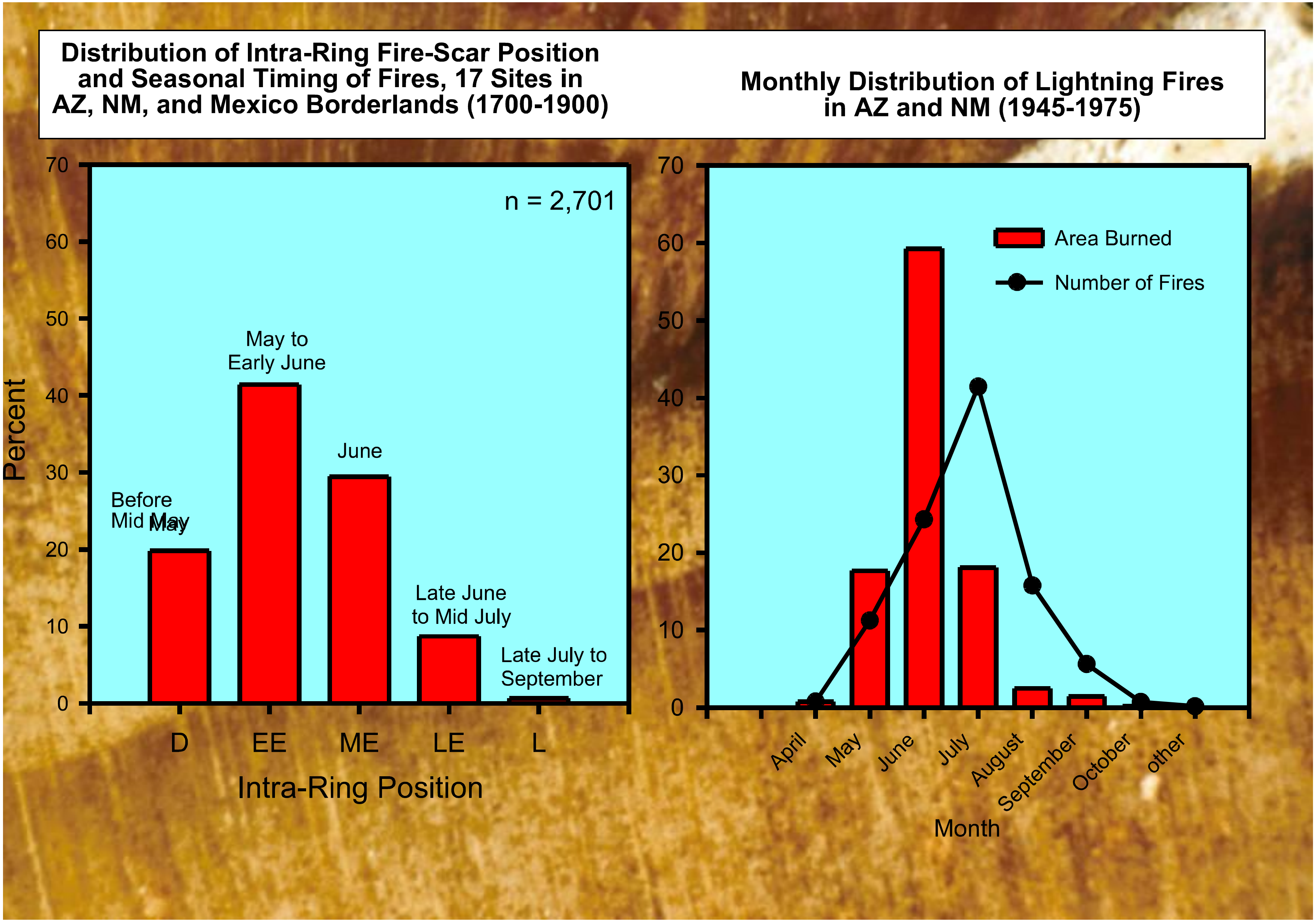
Caprio & Swetnam 1995





“scarlets” on red pine; photo by Kurt Kipfmueller


FIRE SCARS
LATEWOOD SCAR
LATE EARLYWOOD SCAR
MIDDLE EARLYWOOD SCAR
EARLY EARLYWOOD SCAR
DORMANT PERIOD SCAR
L
LE
ME
EE
D



Distribution of Intra-Ring Fire-Scar Position and Seasonal Timing of Fires, 17 Sites in AZ, NM, and Mexico Borderlands (1700-1900)
Monthly Distribution of Lightning Fires in AZ and NM (1945-1975)
n = 2,701
Percent
70
60
50
40
30
20
10
0
Before Mid May
May to Early June
June
Late June to Mid July
Late July to September
D
EE
ME
LE
L
Intra-Ring Position
Area Burned
Number of Fires
April
May
June
July
August
September
October
other
Month

Fire scars are unambiguous indicators of fire occurrence at that place and time

Lack of fire scars on trees, however, is ambiguous. Fire may or may not have occurred at that place over the lifetime of the tree.

T.W. Swetnam, Laboratory of Tree-Ring Research

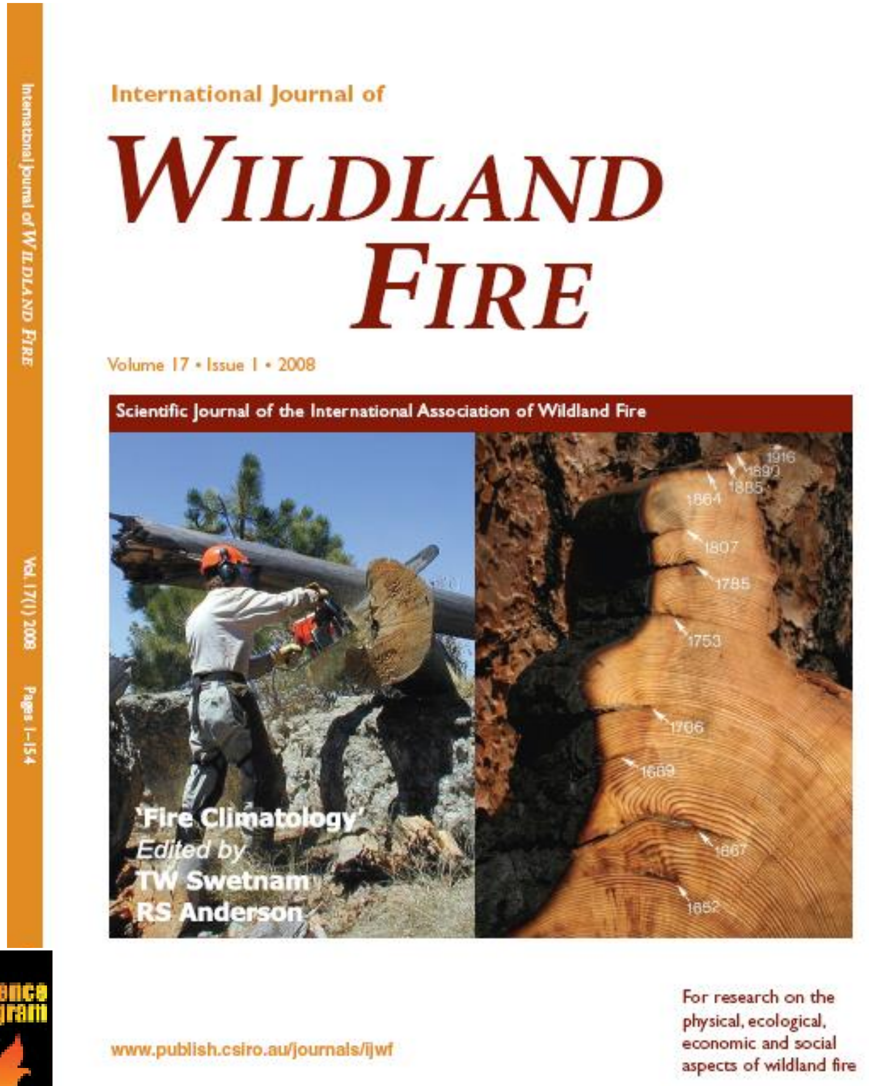
Fire History Networks

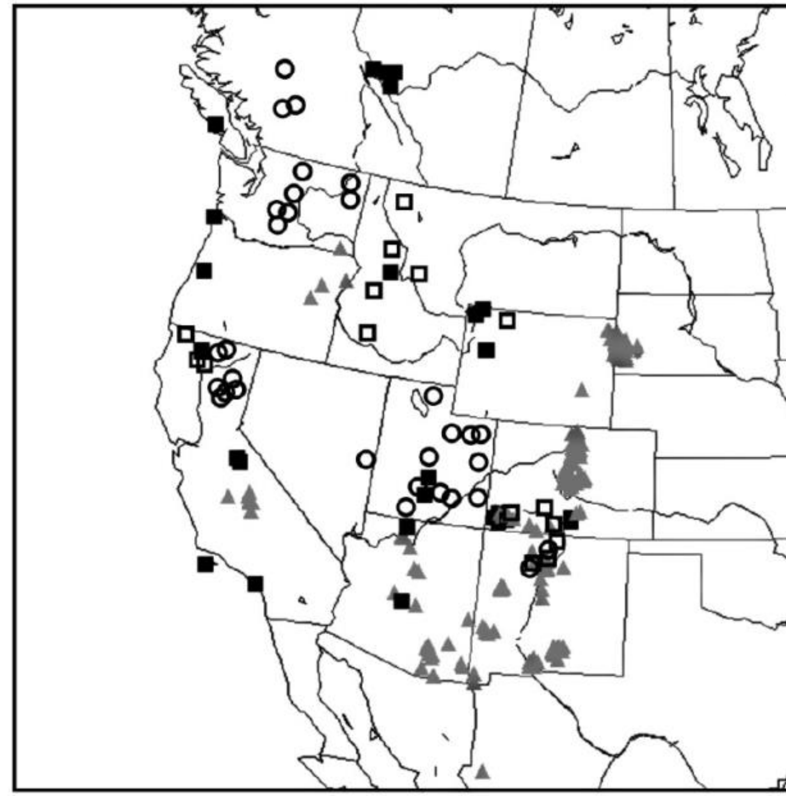
- Following strategies of dendroclimatology, fire-scar based fire history networks are now being compiled at regional to continental scales

- Fire scar networks enable us to evaluate broadscale, long-term fire-climate patterns and trends

- A general strategy is to use independent dendroclimatic reconstructions (e.g., precipitation, PDSI, ENSO, etc.) to compare/test against the fire history time series

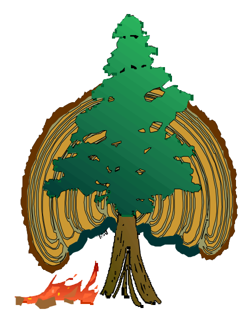
Special Issue on "Fire Climatology": 10 papers on modern and paleofire and climate research. Vol 17(1) 2008



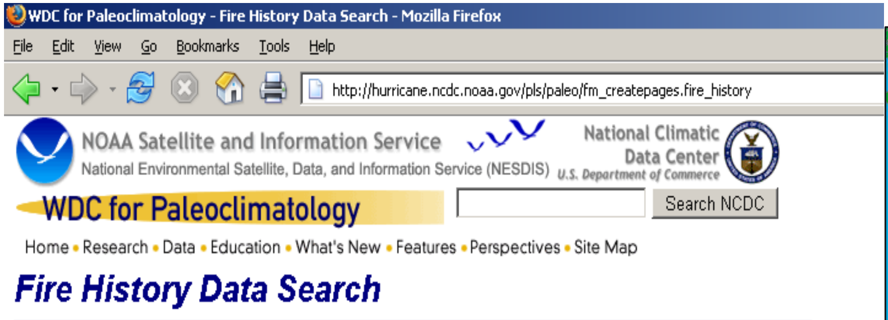


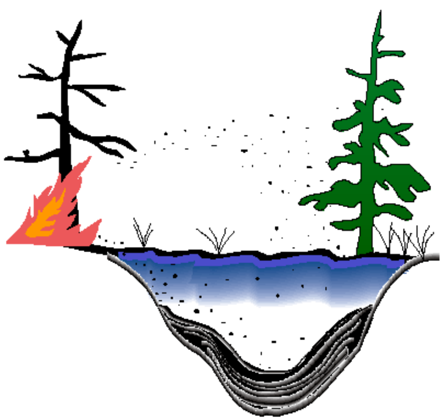
Joint Fire Science Program

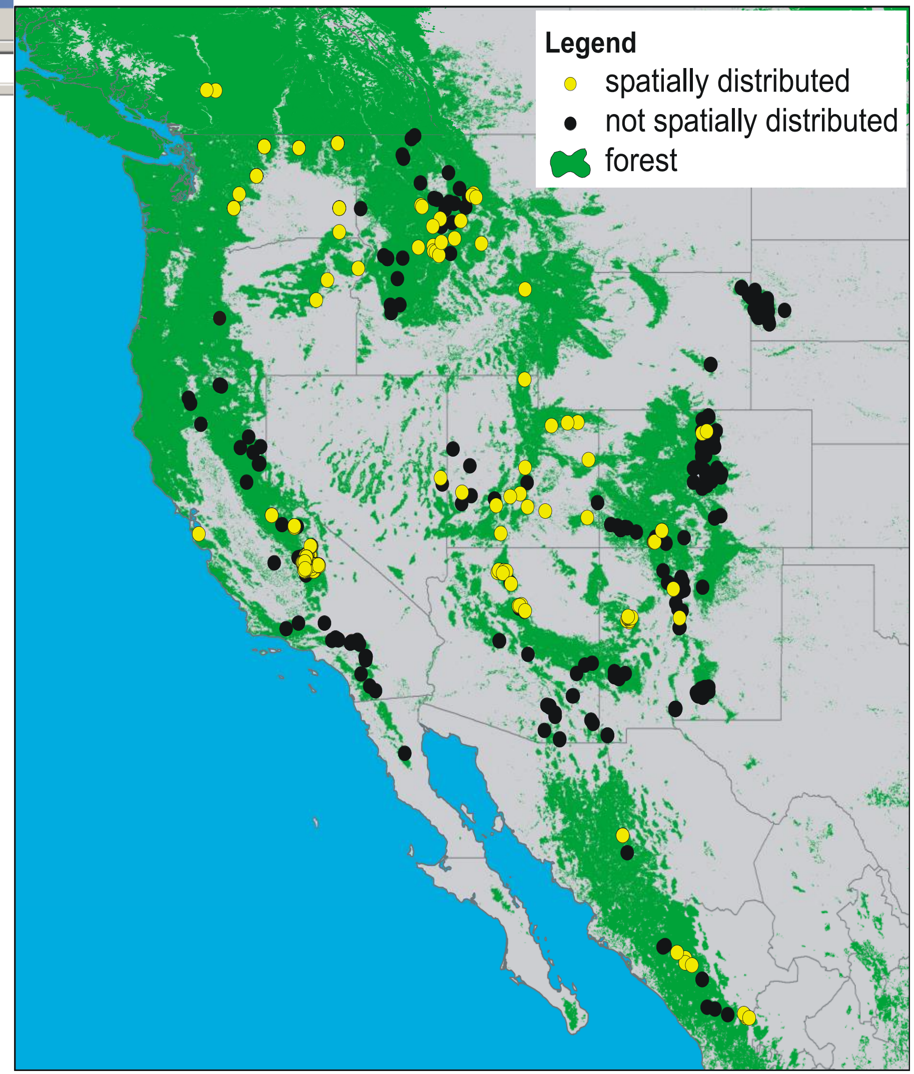
T.W. Swetnam, Laboratory of Tree-Ring Research



INTERNATIONAL MULTIPROXY PALEOFIRE DATABASE (IMPD)

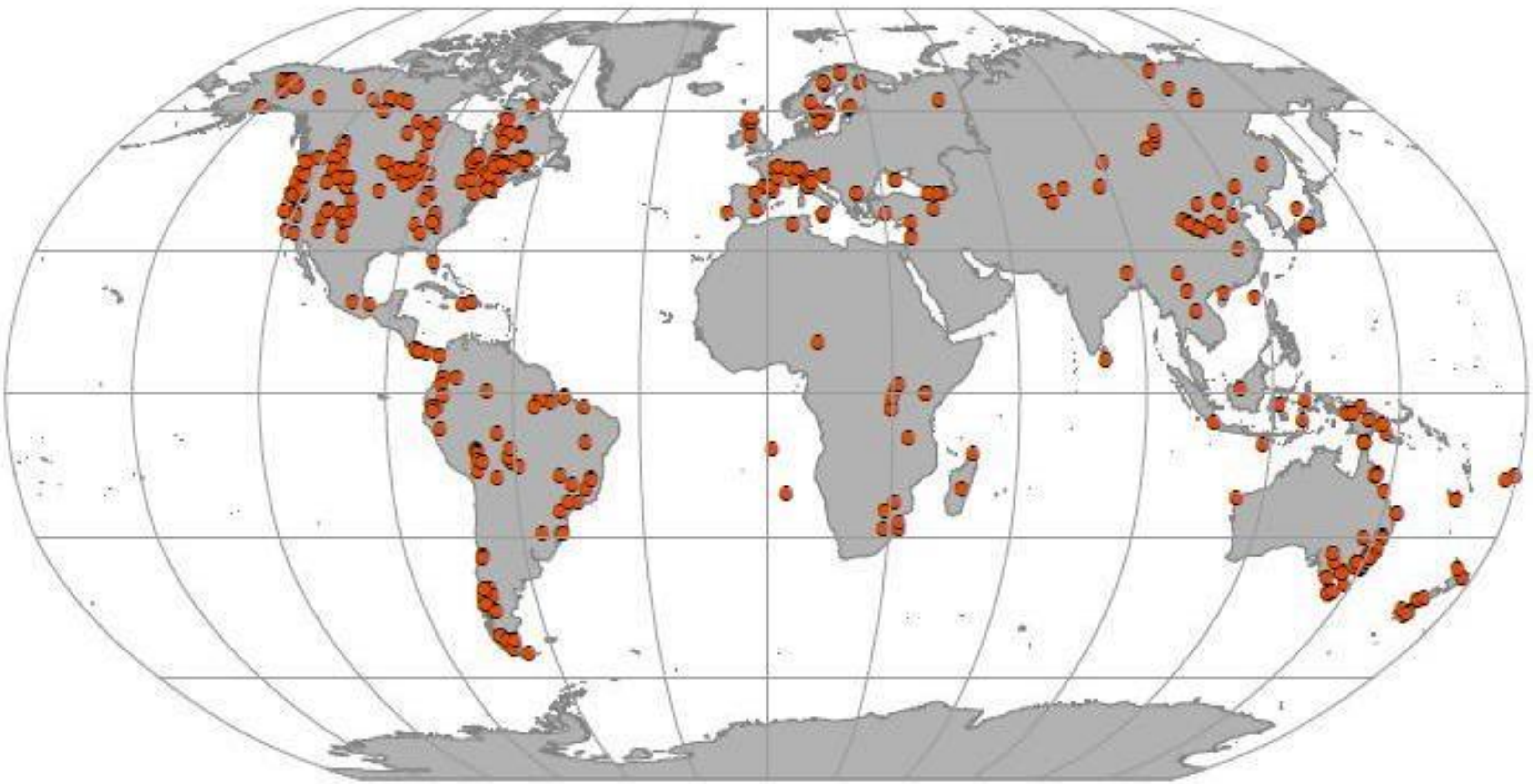






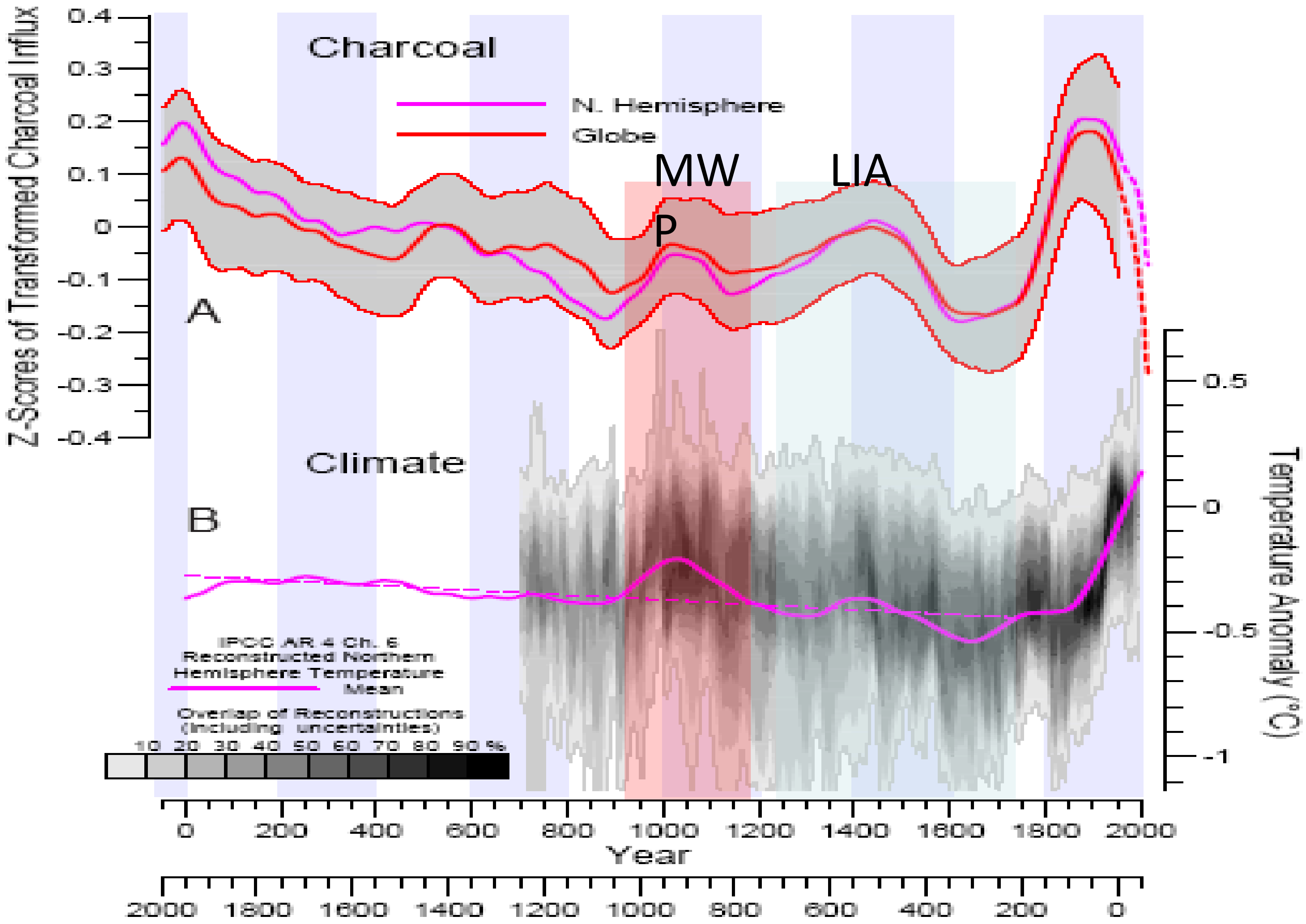
http://**www.ncdc.noaa.gov/paleo/impd/paleofire.html; map from Heyerdahl, Falk *et al.* in prep.**

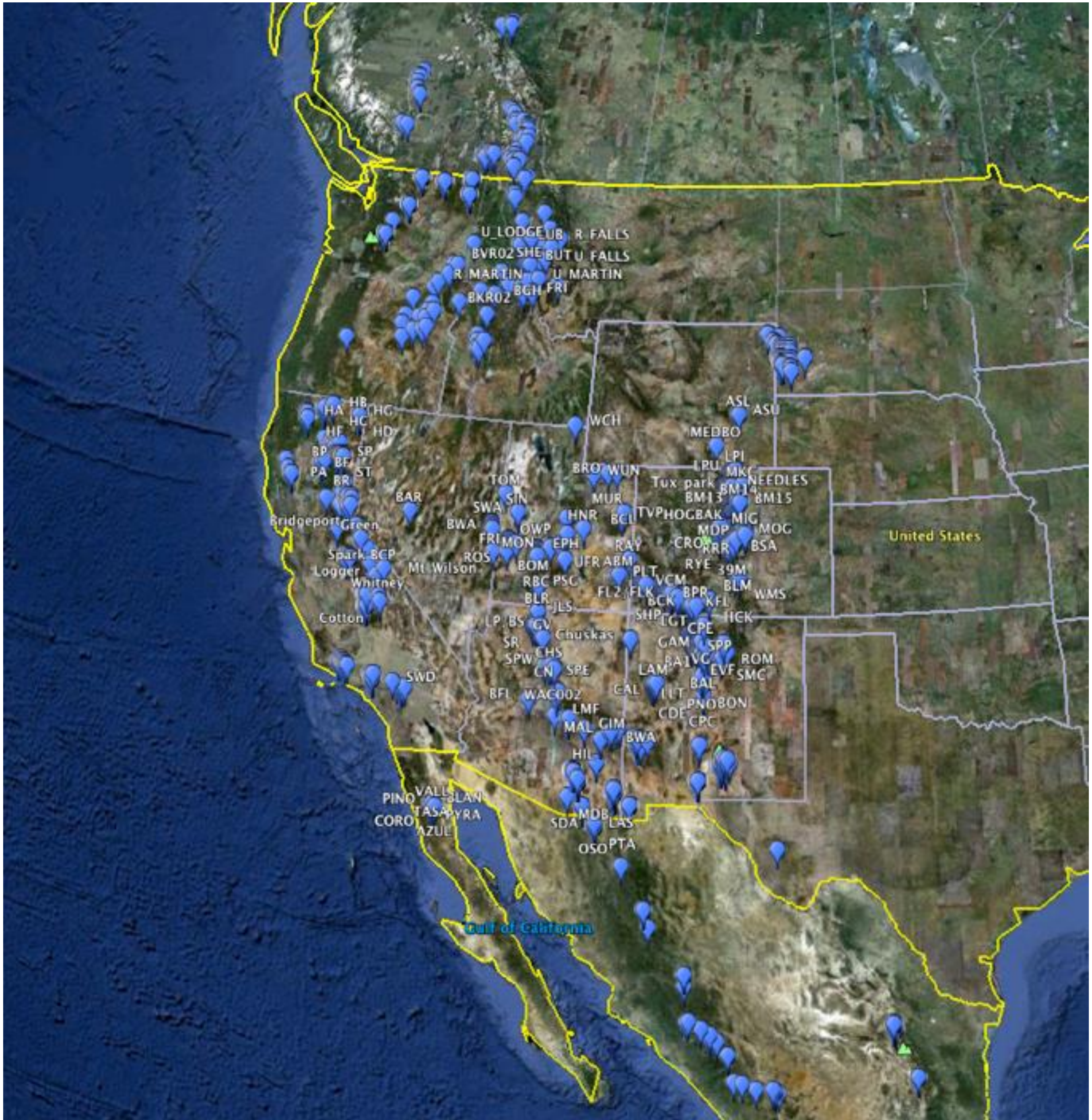
A global network of more than 400 sedimentary-charcoal records have been compiled and is now being used to evaluate regional, continental and global patterns of wildfire over the past 10,000+ years.



Charcoal inventory map (August 2008)
(http://www.bridge.bris.ac.uk/projects/QUEST_IGBP_Global_Palaeofire_WG/database.html)

Biomass burning based on charcoal data from 442 lake and wetland records, compared with reconstructions of climate over the last 2000 years (Marlon et al., Nature-Geosciences 2008).




U_LODGE
UB
R_FALLS
BVR02
SHE
BUT
U_FALLS
R_MARTIN
U_MARTIN
BGH
FRI
BKR02
HB
HA
HC
HC
HF
HD
BP
SP
BF
PA
ST
BR
BAR
Bridgeport
Green
Spark
BCP
Logger
Mt. Wilson
Whitney
Cotton
SWD
WCH
ASL
ASU
MEDBO
LPI
LPU
MKC
NEEDLES
Tux park
BM14
BM13
BM15
TOM
BRO
WUN
SIN
SWA
MUR
BWA
HNR
BCL
TVP
HOGBAK
MIG
OWP
MDP
MOG
FRI
MON
EPH
RAY
CRO
RRR
BSA
ROS
UFR
ABM
RYE
39M
BOM
RBC
PSC
PLT
VCM
BLM
FL2
FLK
BPR
WMS
BLR
BCK
KFL
JLS
SHP
LGT
HCK
LP
BS
GV
Chuskas
CPE
SR
GAM
SPP
SPW
CHS
BA1
VC
ROM
CN
SPE
LAM
EVF
SMC
BAL
BFI
WAC002
CAL
LLT
PNO
BON
LMF
CDE
CPC
MAL
GIM
BWA
HIL
United States
PINO
VALL
BLAN
TASA
PYRA
CORO
AZUL
MDB
SDA
LAS
OSO
PTA
Gulf of California

The fire-scar chronology network in southwestern North America currently includes about 120 sites.

Most sites 10-100 ha, some >1000 ha. Typical sample sizes ≈ 10-50 fire scarred trees, hundreds in a few cases.

The SW fire history network represents the collective effort of many people and institutions over more than 3 decades.

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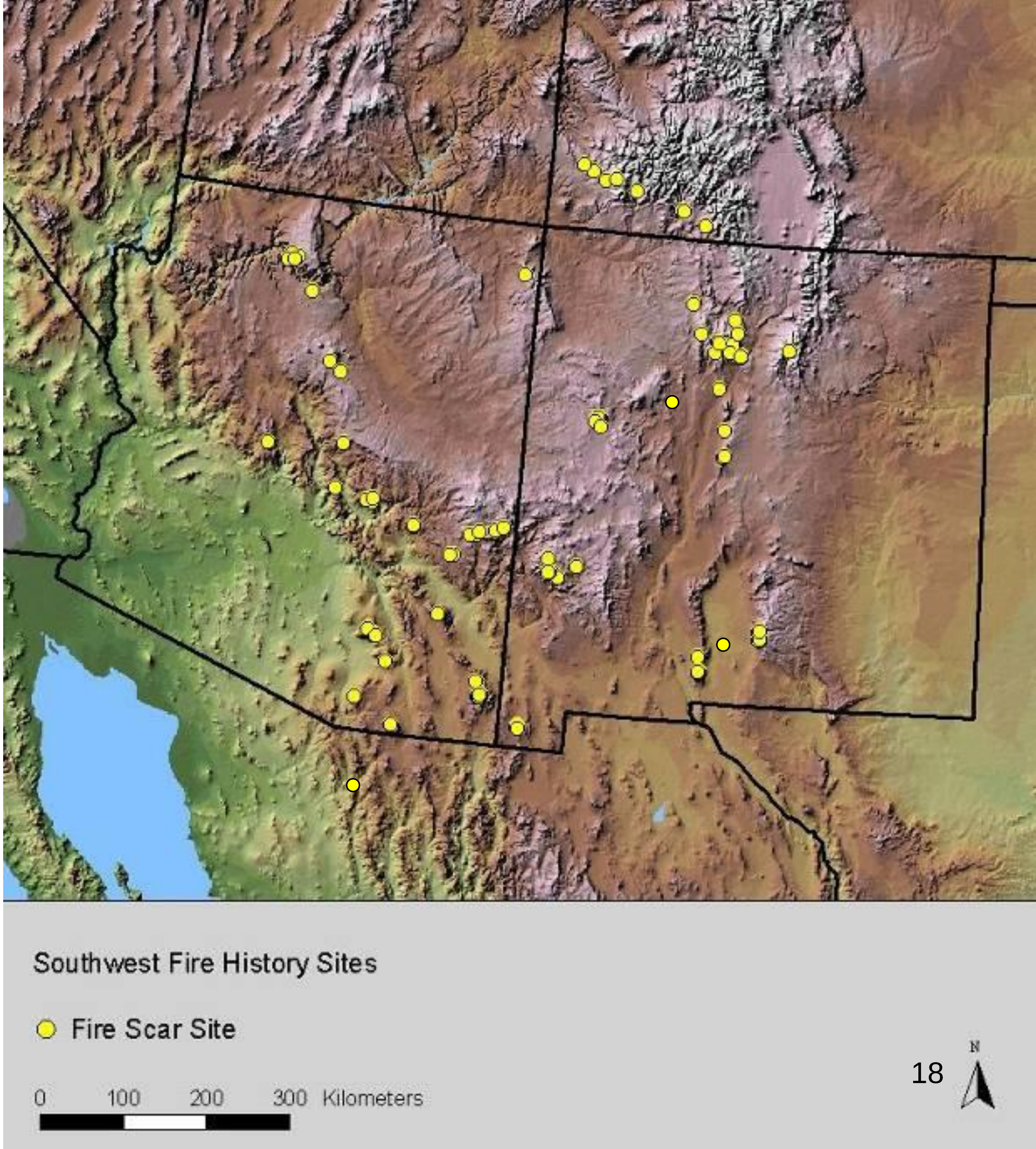
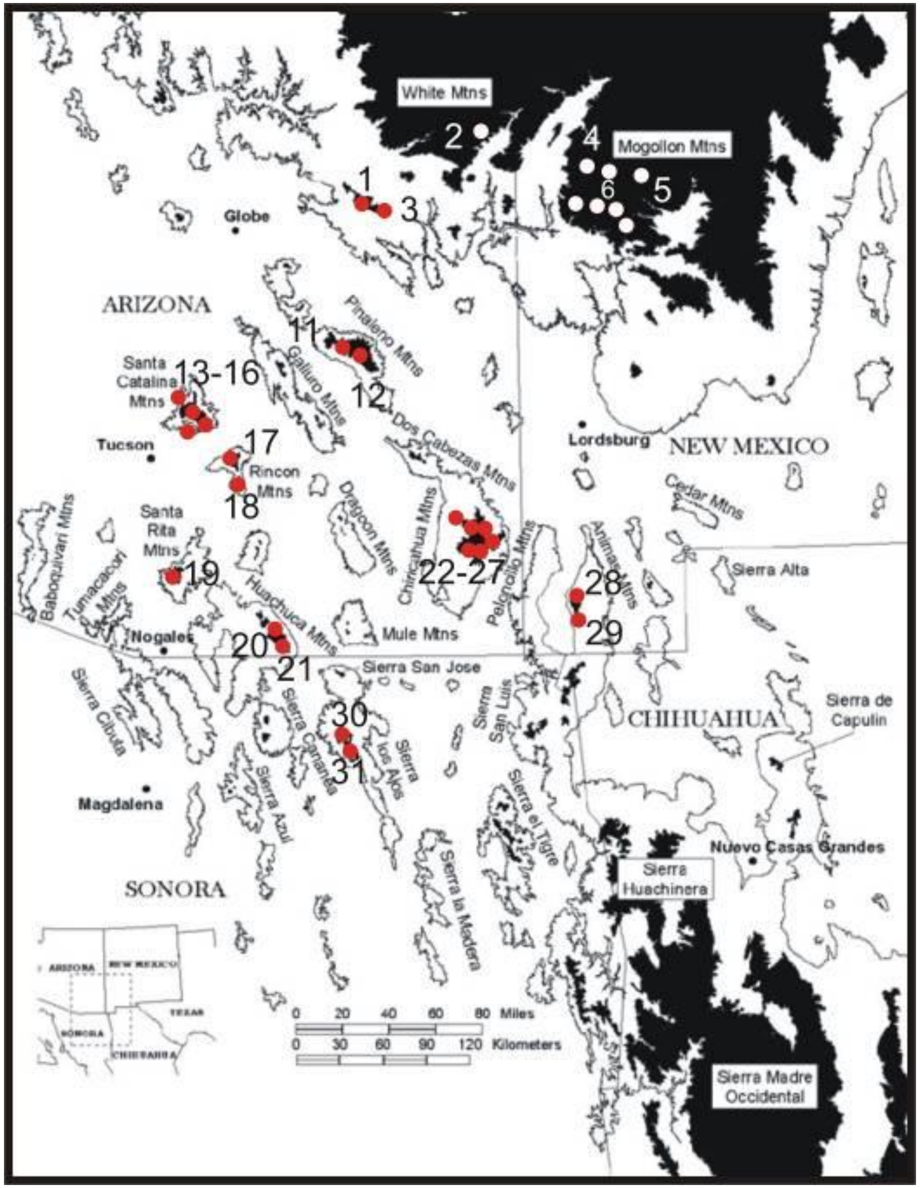


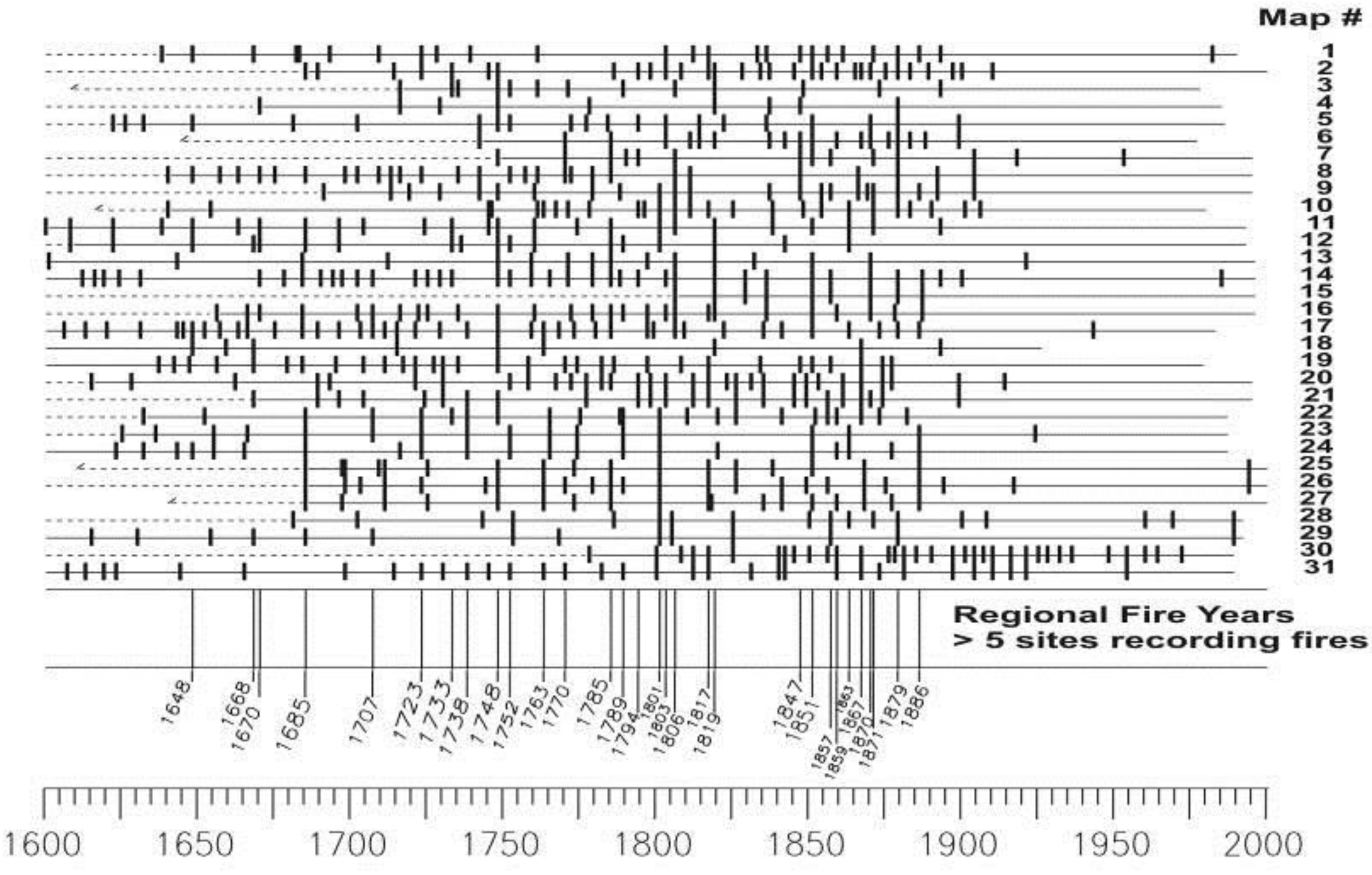
Mountain Ranges with Fire Scar Fire Histories:

- Santa Catalina
- Rincon
- Santa Rita
- Huachuca
- Pinaleno
- Chiricahua
- Sierra de los Ajos
- Animas
- Mogollon
- White



Swetnam, T.W. 2005. Fire histories from pine-dominant forests in the Madrean Archipelago. In: Connecting mountain islands and desert seas: biodiversity and management of the Madrean Archipelago II. Gottfried, Gerald J.; Gebow, Brooke S.; Eskew, Lane G.; and Edminster, Carleton B., compilers. 2004 May 11-15; Tucson, AZ. *USDA Forest Service, Proceedings RMRS-P* -36; pages 35-43.

Regional composite fire scar chronology from 31 sites in the Madrean Archipelago. The vertical tick marks are fire events recorded by 25% or more of sampled trees (in that year) within each site.



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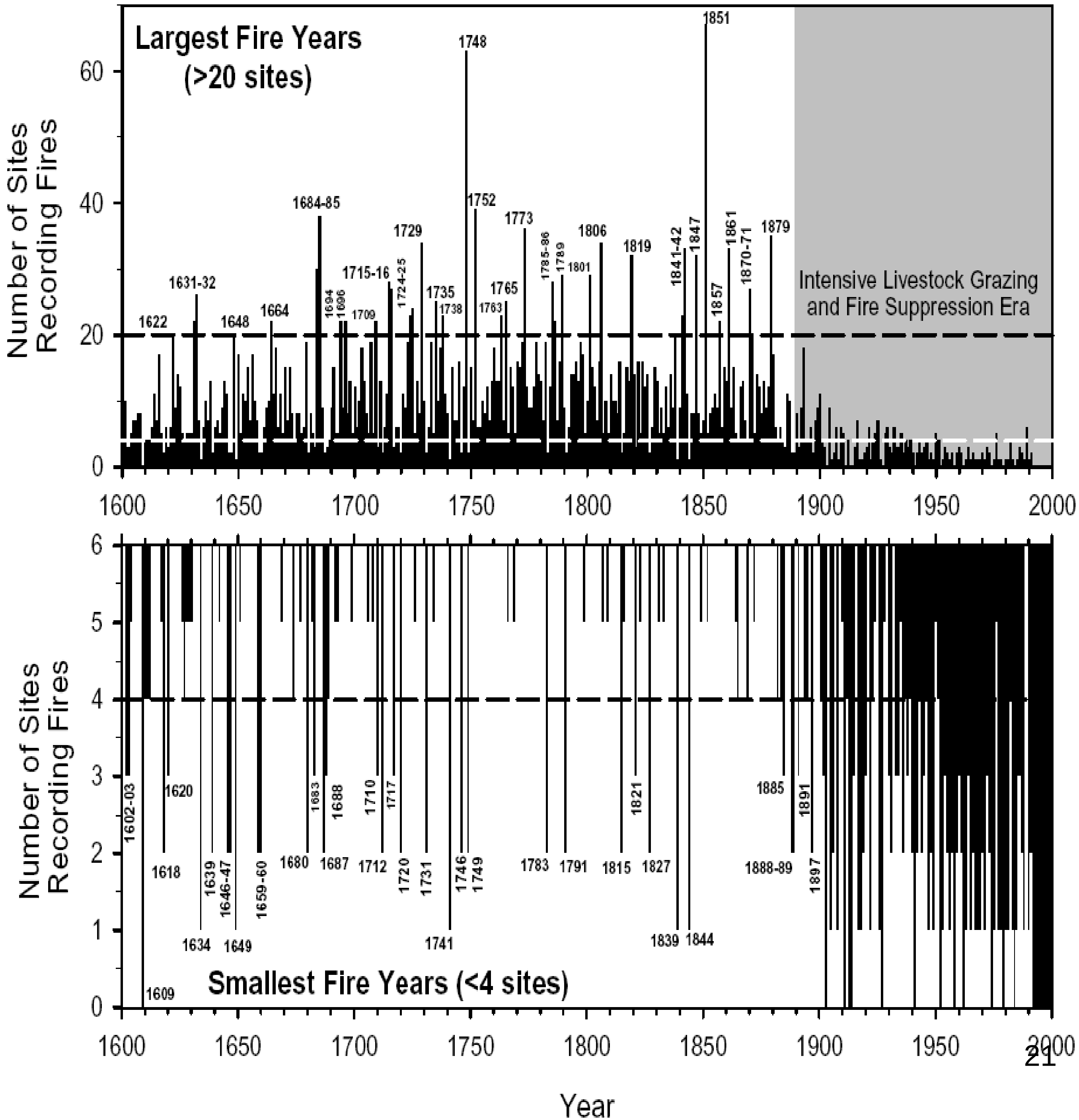
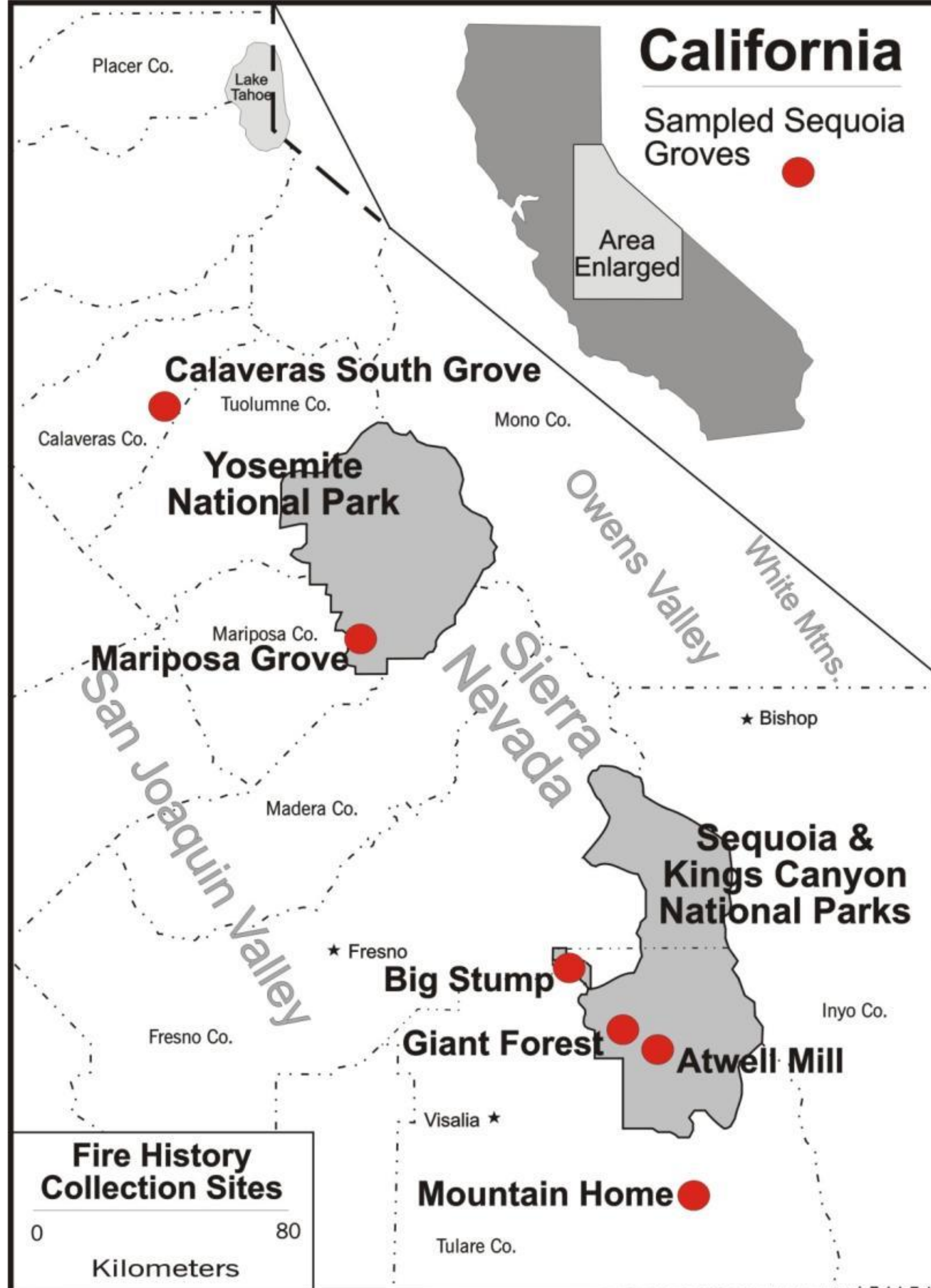
Synchrony is evident both in timing of fire events, and lack of events in multiple sites.



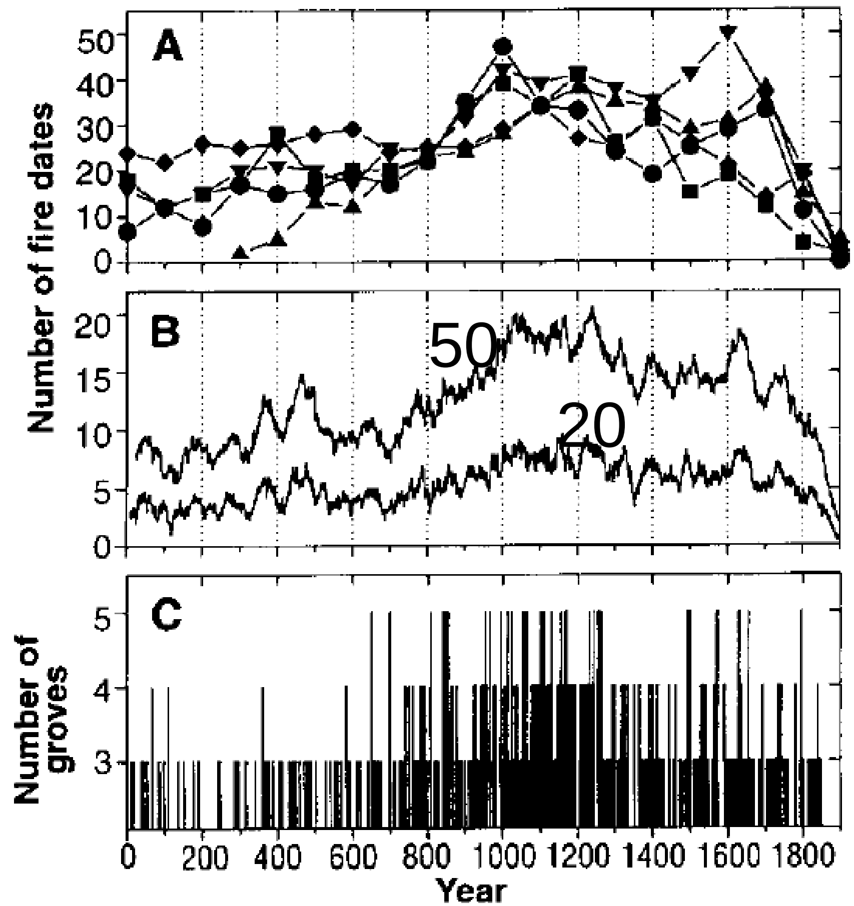
Swetnam, T.W. and P. M. Brown. 2011. Climatic inferences from dendroecological reconstructions. Chapter 9, In: Hughes, M.K., T.W. Swetnam, and H.F. Diaz, editors, Dendroclimatology: Progress and Prospects, Springer, New York.

Between 1988 and 1997 we collected fire scar specimens from more than 150 giant sequoia trees in six groves.

Projects funded by NPS and USGS Global Change Program, and CA State.



Fire History and Climate Change in Giant Sequoia Groves



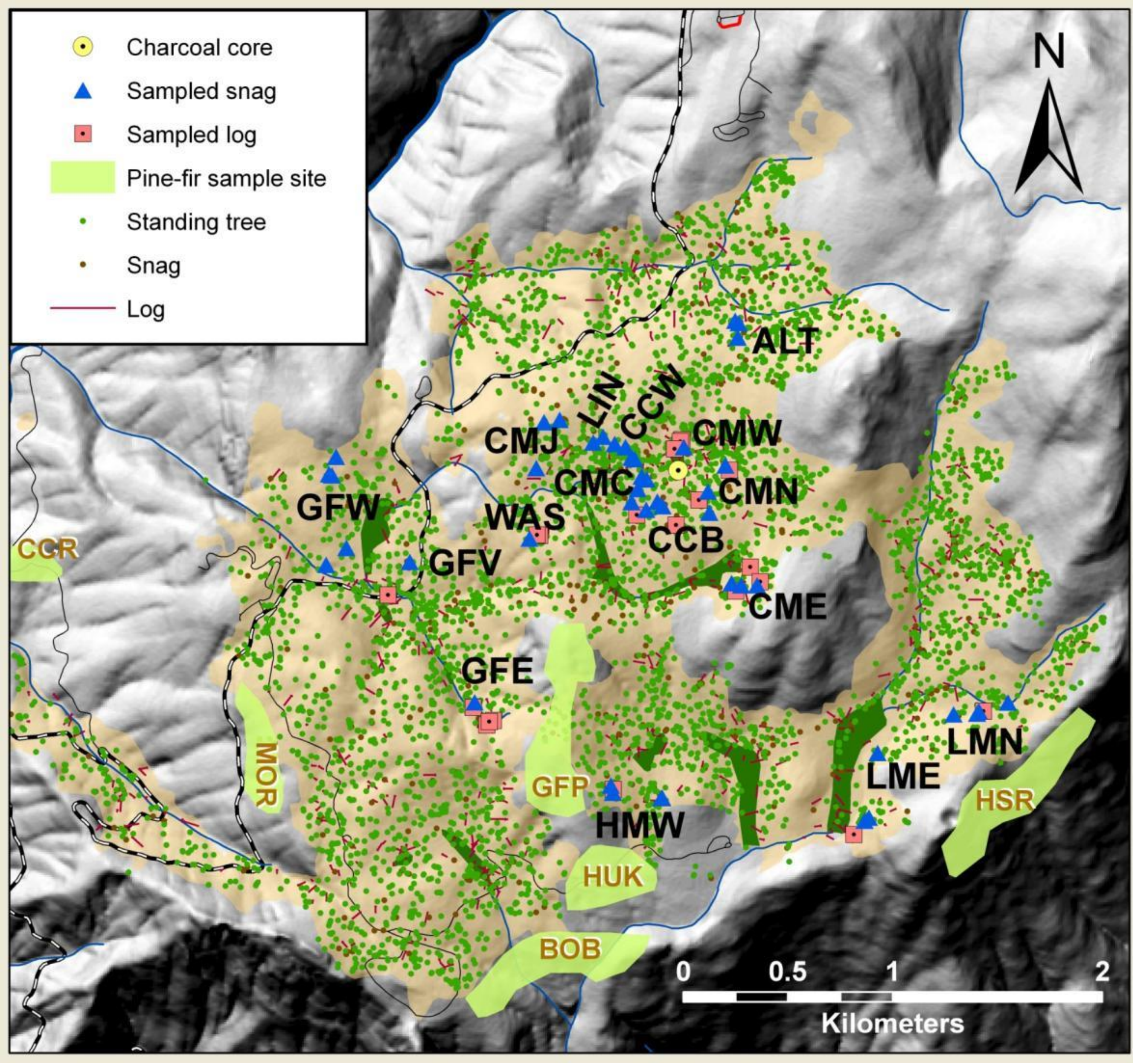
fires per century in 5 groves

50-yr and 20-yr running fire frequency

3,4 & 5 grove fire events

SCIENCE • VOL. 262 • 5 NOVEMBER 1993

Swetnam, T.W. 1993. Fire history and climate change in giant sequoia groves. *Science* 262:885-889.

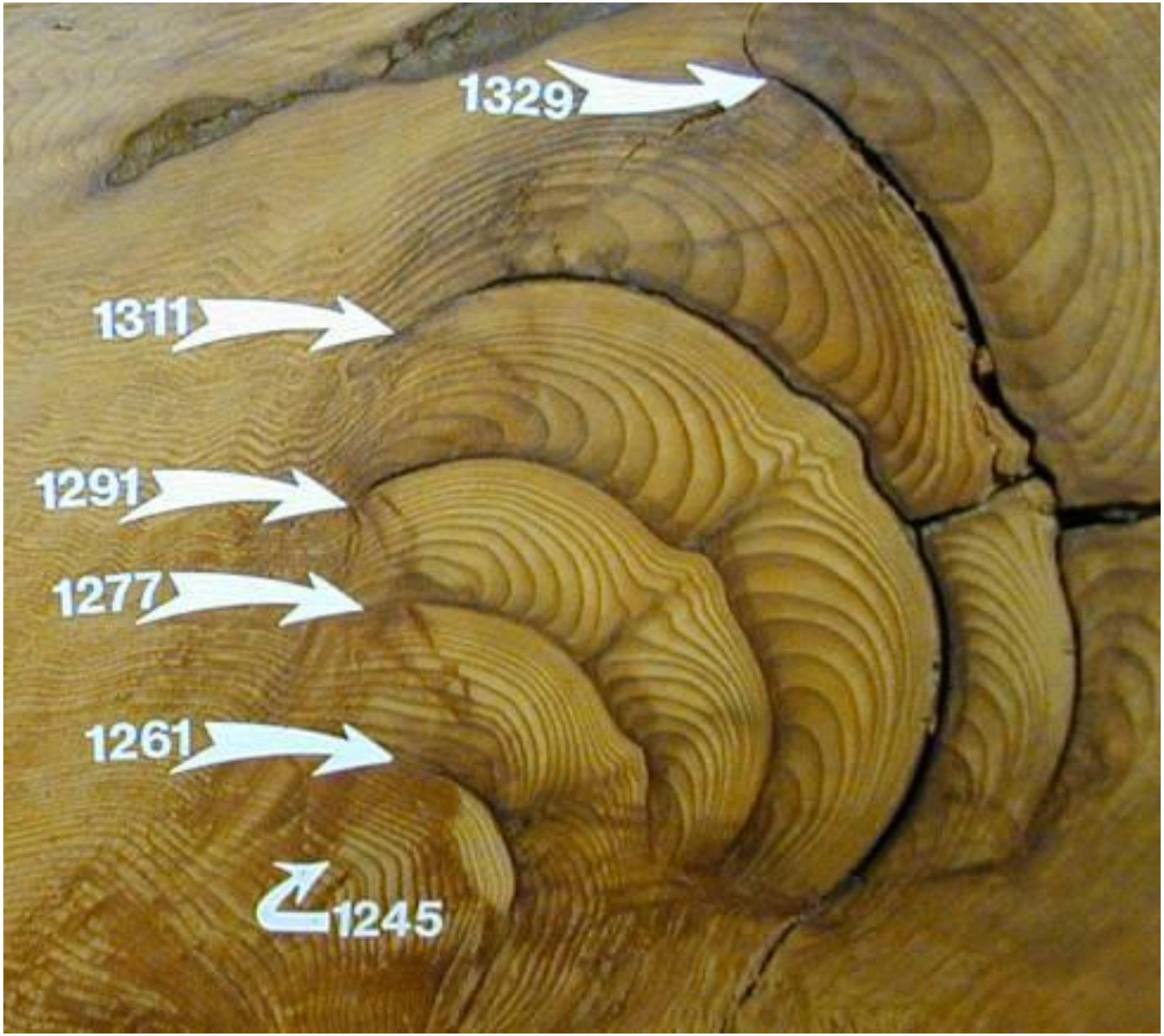


Swetnam et al. 2009, Fire Ecology

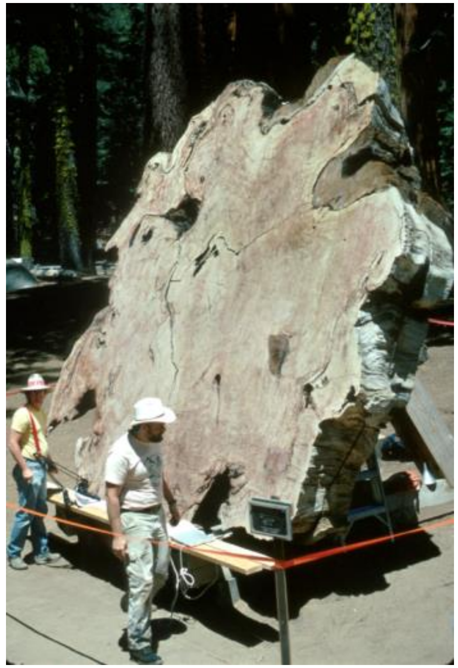
Fire-scar samples from five giant sequoia groves provide fire history evidence extending back 1500 to 3000 years.

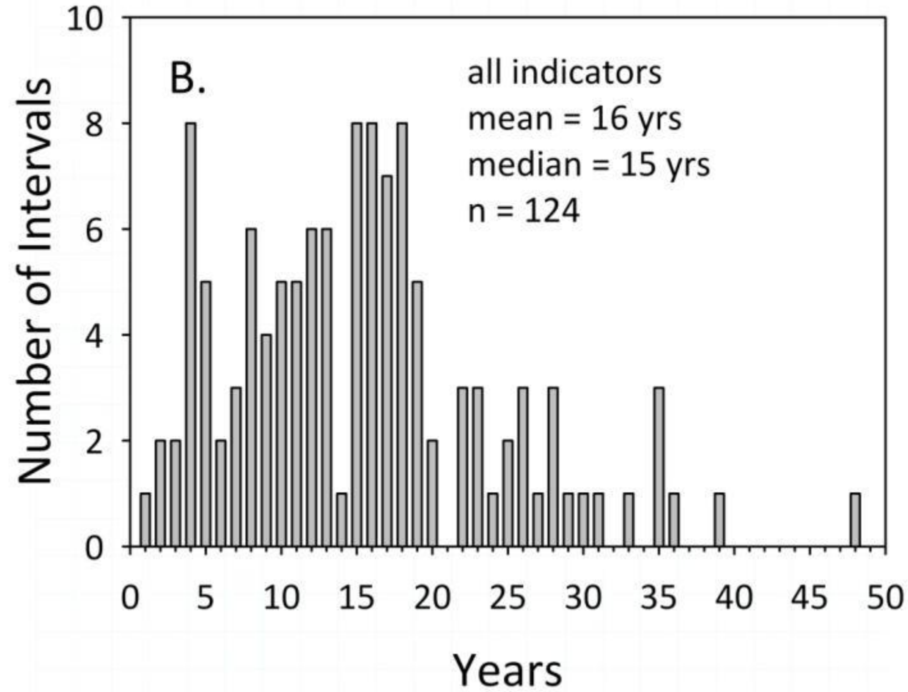
Photo by J. Dieterich

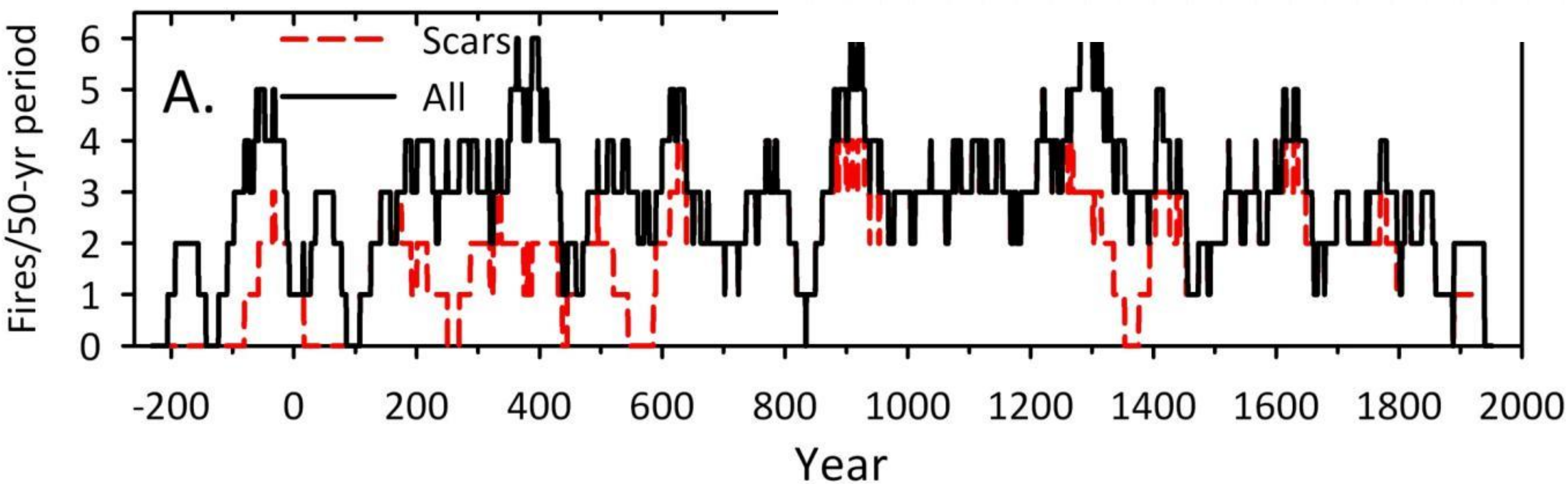
Photo by T. Caprio


1329
1311
1291
1277
1261
1245

The most complete fire history from a single tree (GVF1), resulted in 125 fire dates over the period 259 BCE to 1951 CE.

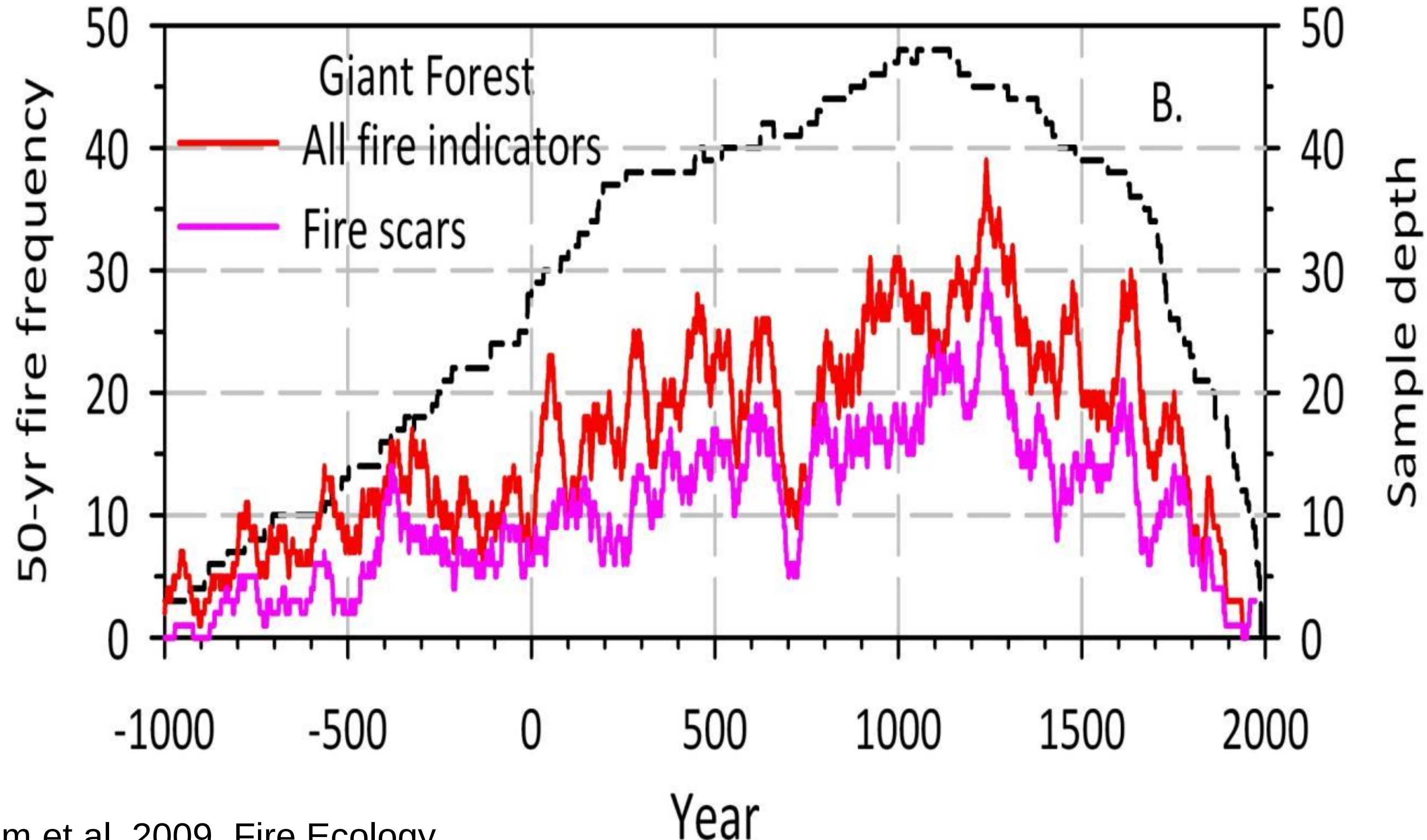






Swetnam, T.W., C. H. Baisan, A. C. Caprio, P. M. Brown, R. S. Anderson, and D. W. Hallett. 2009. Multi-millennia fire history of the Giant Forest, Sequoia National Park, USA. *Fire Ecology* 5(3):117-147.

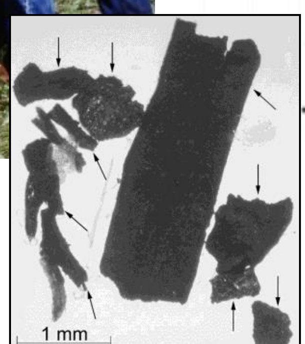
Fire frequencies were generally quite high throughout the past 3,000 years, with a maximum of about 3 to 5 fires per decade during the period circa 900 to 1300 CE.

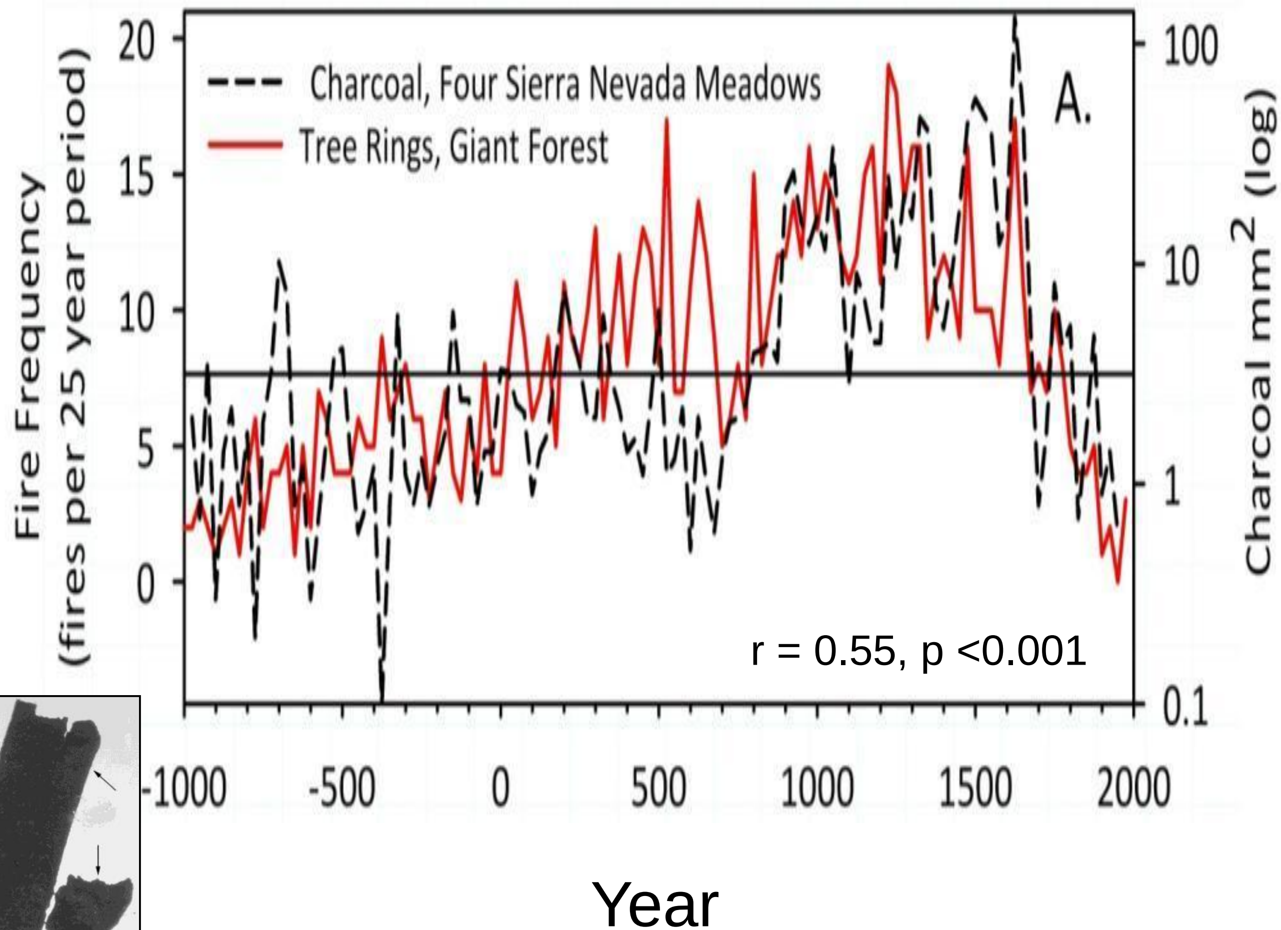


Swetnam et al. 2009, Fire Ecology

Comparison of giant sequoia fire scar history with regional sedimentary charcoal history from the same groves shows considerable correspondence.

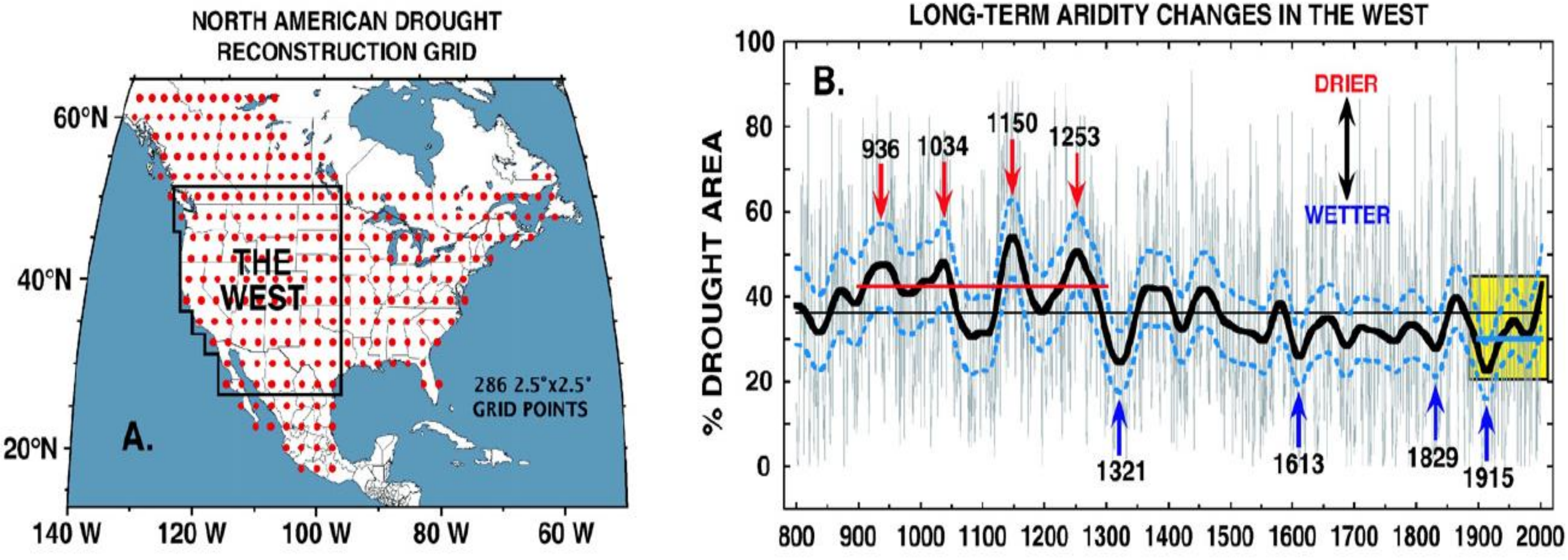
Scott Anderson & assistants.





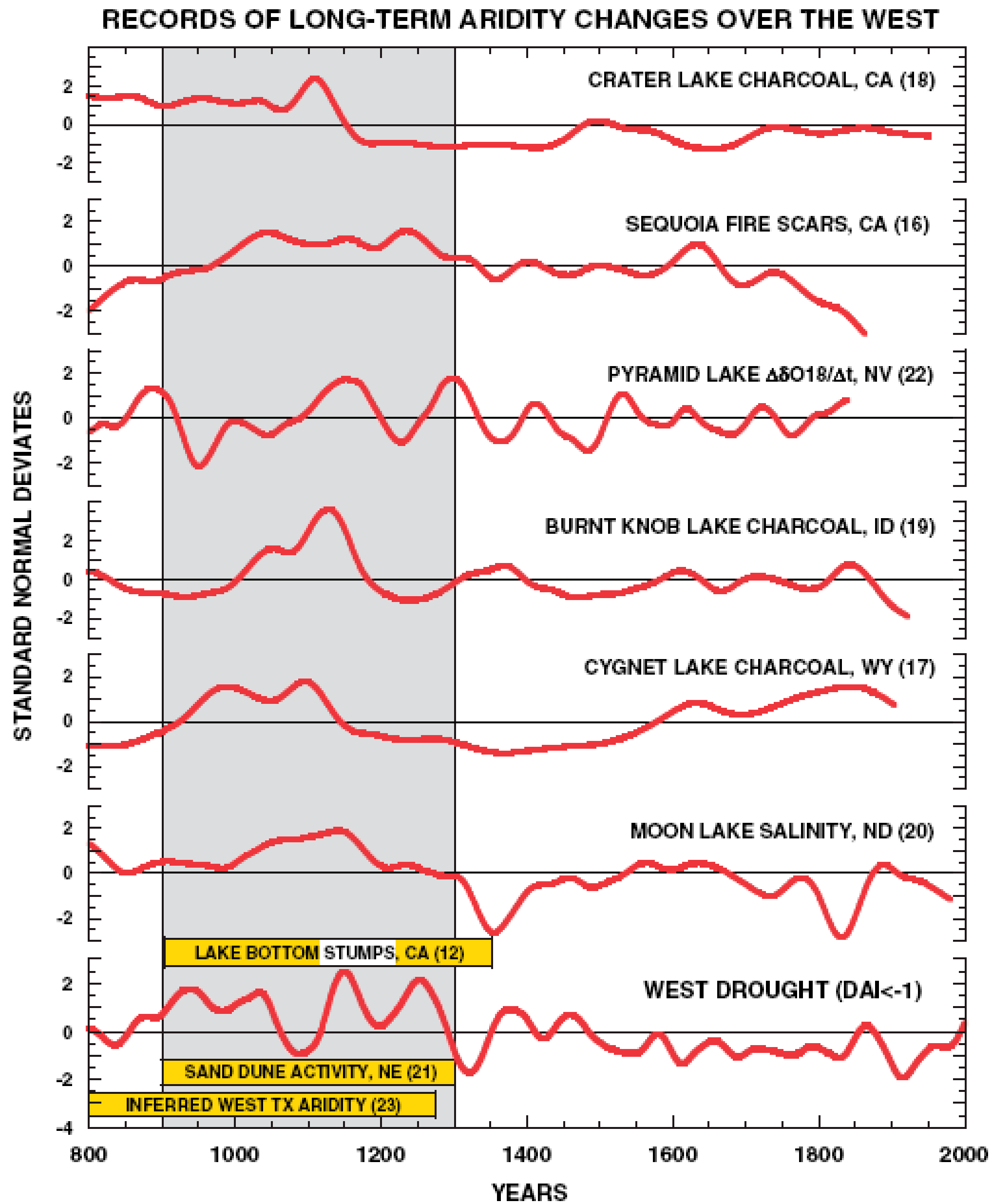
Swetnam et al. 2009, Fire Ecology

The North American Drought Atlas shows the period from circa 900 to 1300 was generally drier throughout the West, including droughts of magnitude and duration not yet experienced in modern period.



E.R. Cook Et al. Earth Sciences Review 81 (2007) 93-134

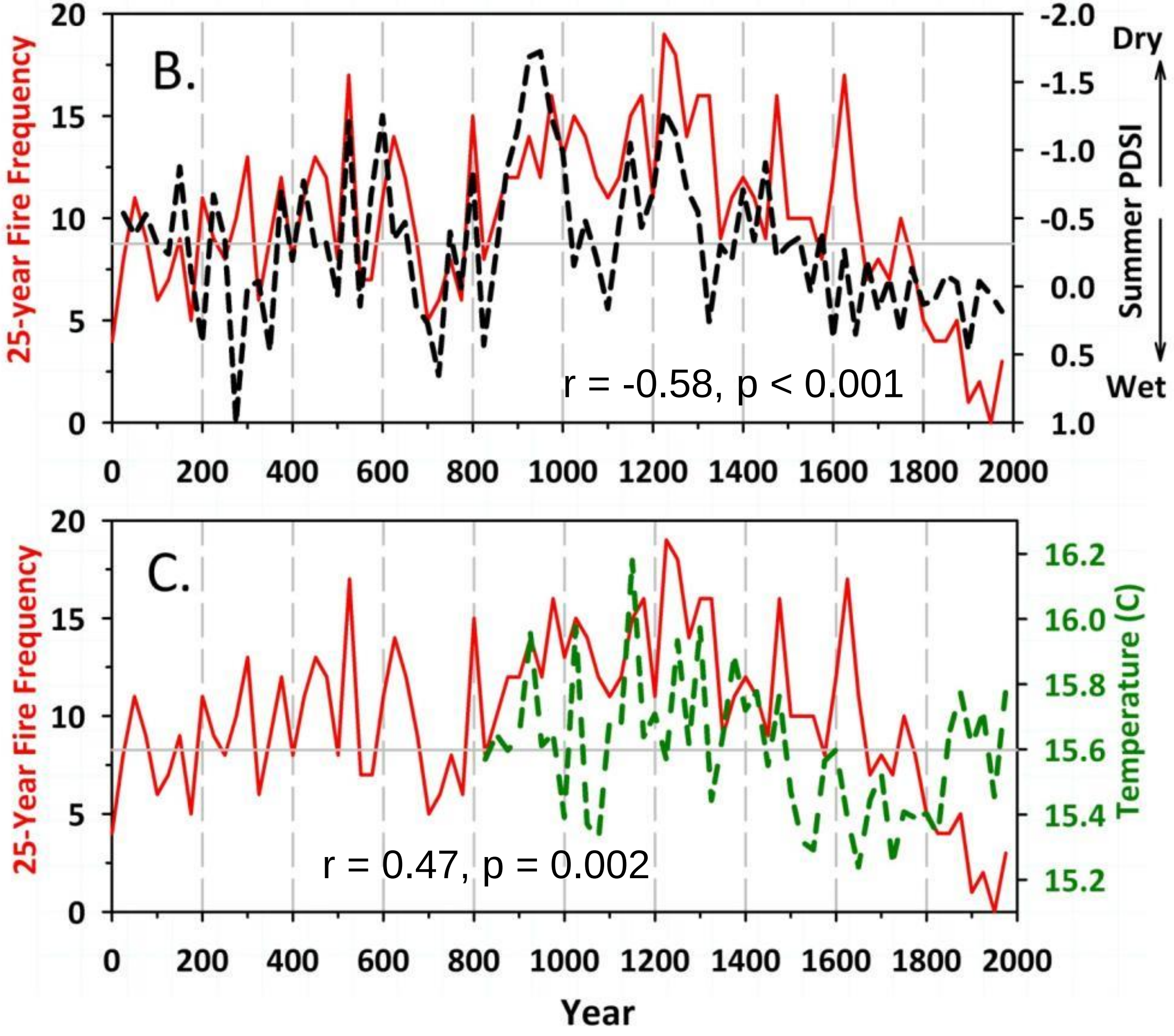
Cook et al. 2004 showed that the dry period ca. 900 to 1300 AD corresponded well with various fire and aridity indicators across the western US., including giant sequoia fire history.



Cook, E.R., C.A. Woodhouse, C.M. Eakin, D.M. Meko, D.W. Stahle. Science 306:1015-1018. Nov. 5 2004

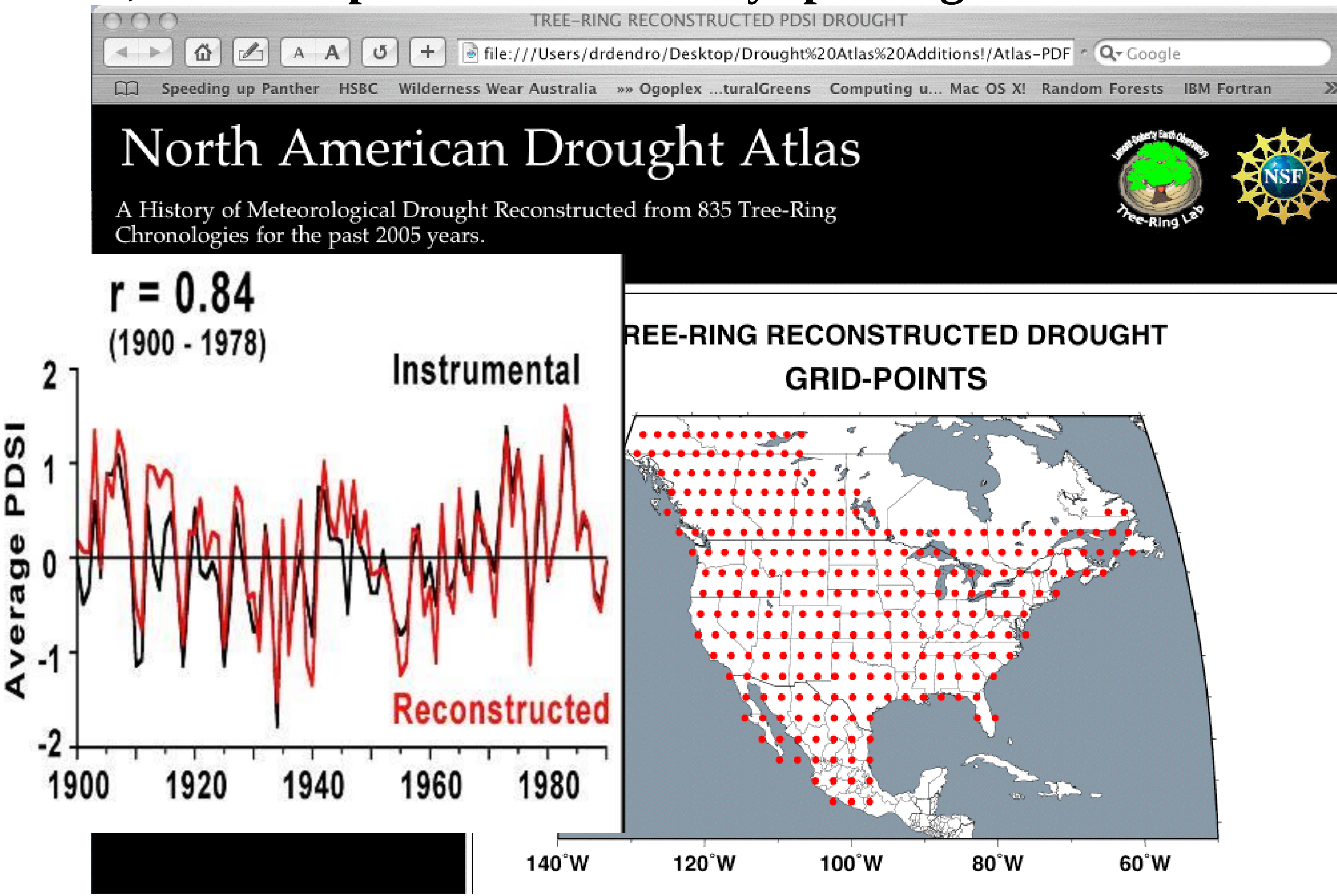
Decadal-scale drought and temperature variations are well-correlated with the fire frequency changes in the Giant Forest and four other sequoia groves over the past two millennia.

Photo courtesy Tony Caprio



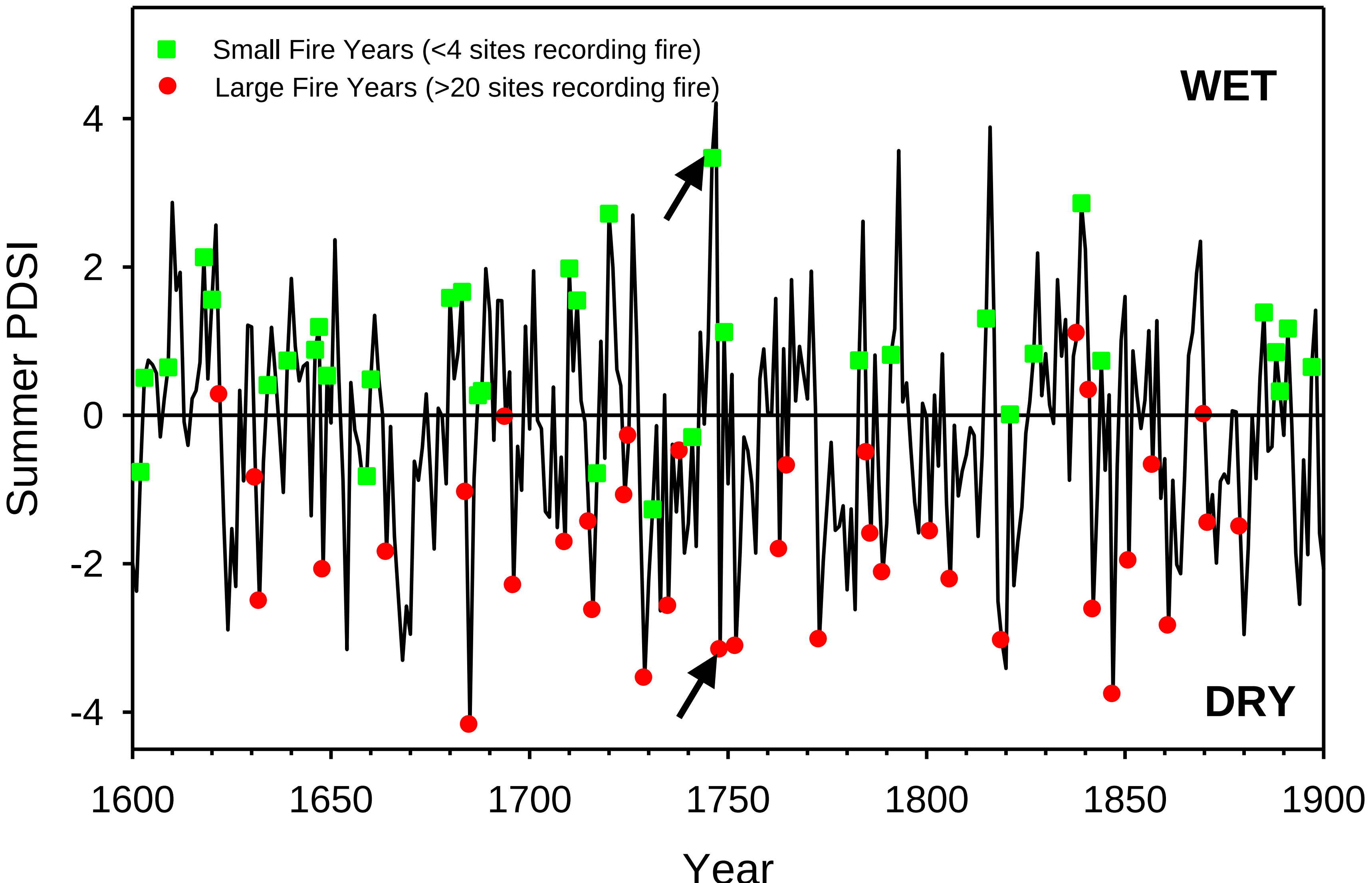
Swetnam et al. 2009, Fire Ecology

Drought sensitive tree-ring width chronologies are calibrated with instrumental-based records of Summer Palmer Drought Severity Index, and interpolated to an evenly spaced grid network.



Cook, E.R., C.A. Woodhouse, C.M. Eakin, D.M. Meko, D.W. Stahle. Science 306:1015-1018. Nov. 5 2004

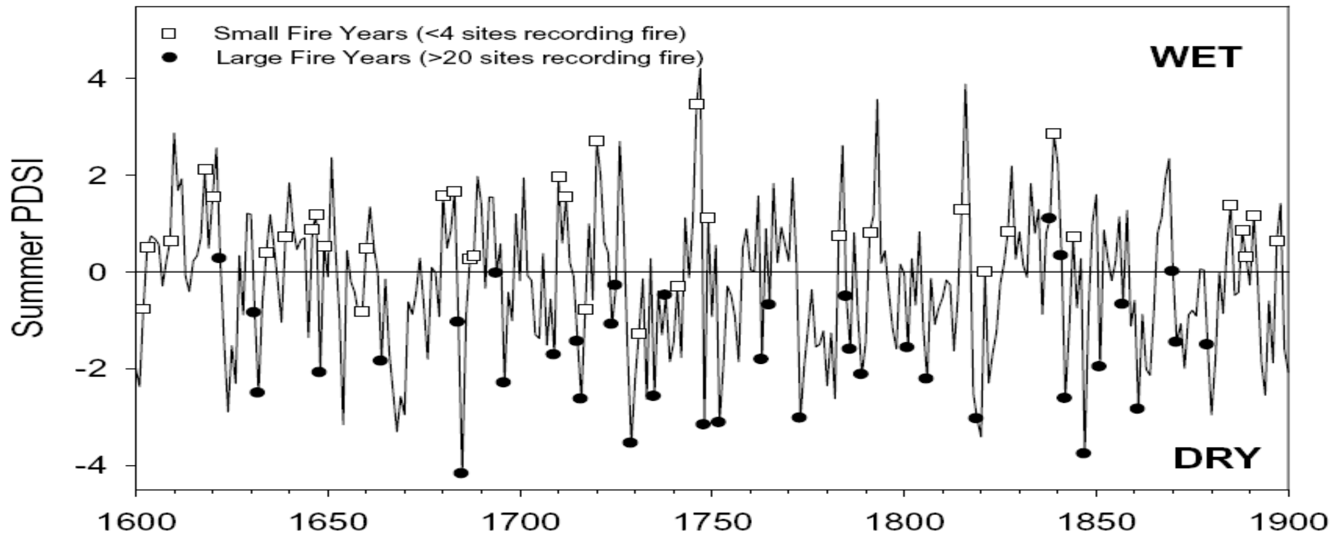
Regional large and small fire years in the Southwest are strongly linked to wet and dry conditions.



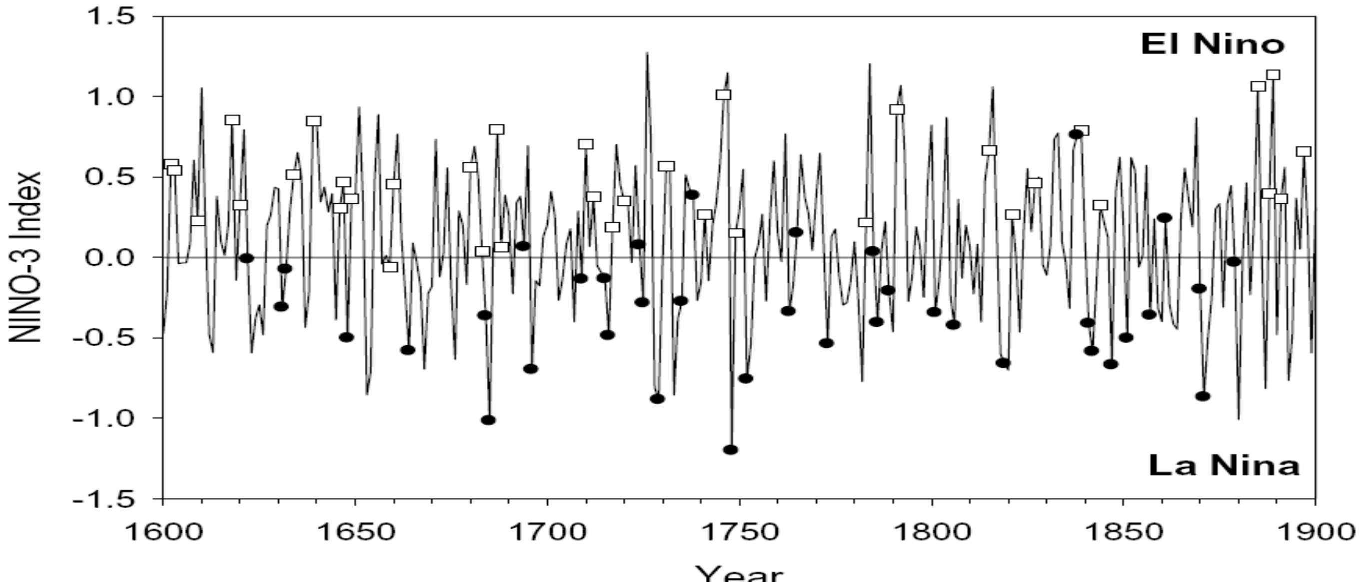
Swetnam, T.W., and J. L. Betancourt. 1998. Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. *Journal of Climate* 11:3128-3147.

Large regional fire years strongly coincide with drought and La Nina years, and small regional fire years coincide with wet and El Nino years.

Fire event years versus Cook et al PDSI reconstructions:



Fire event years versus Cook et al NINO 3 reconstructions:

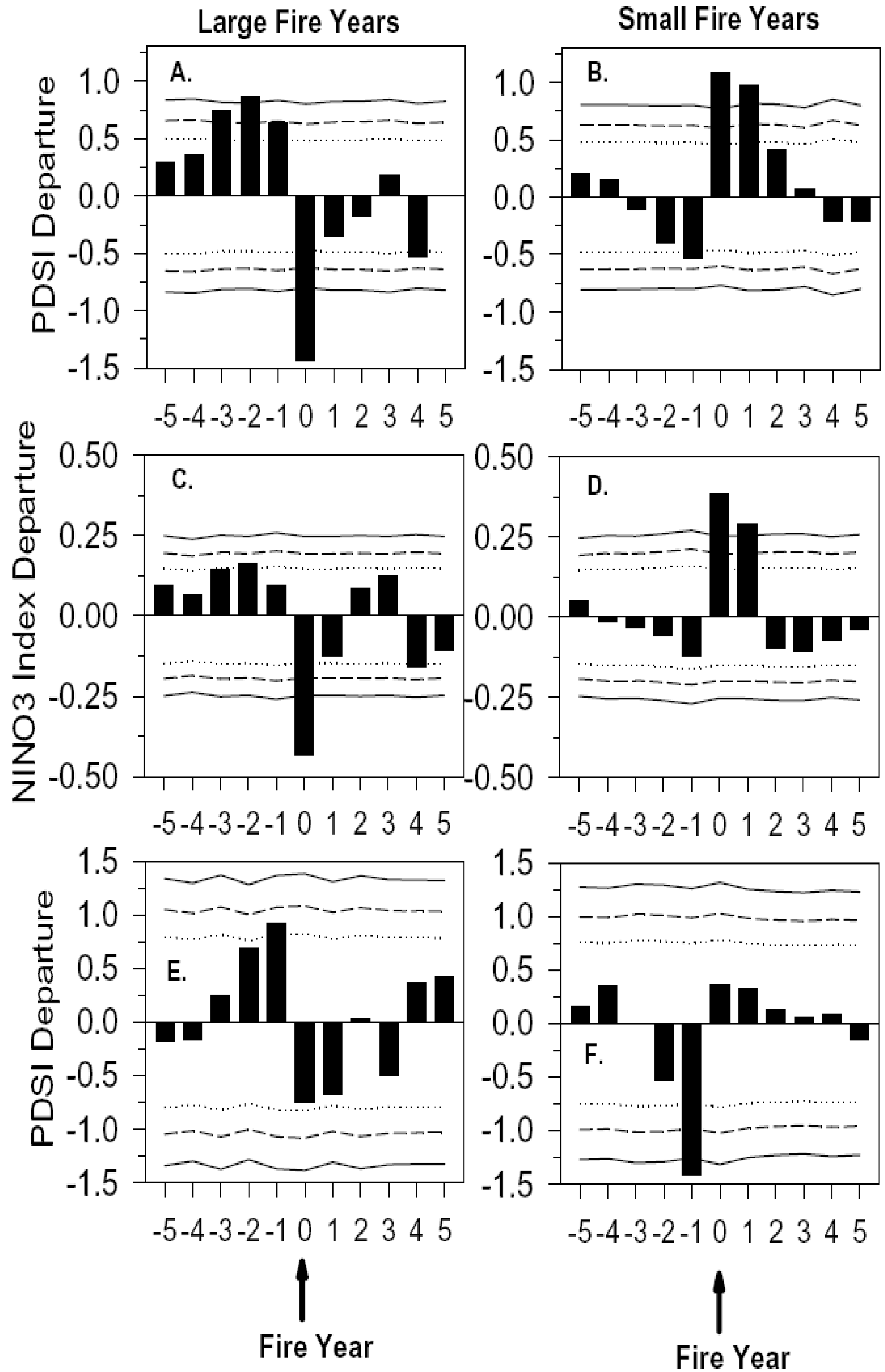


Swetnam & Brown, 2011

Superposed epoch analyses shows important lagging patterns in climate-fire relations in tree-ring and modern records.

1600-1900

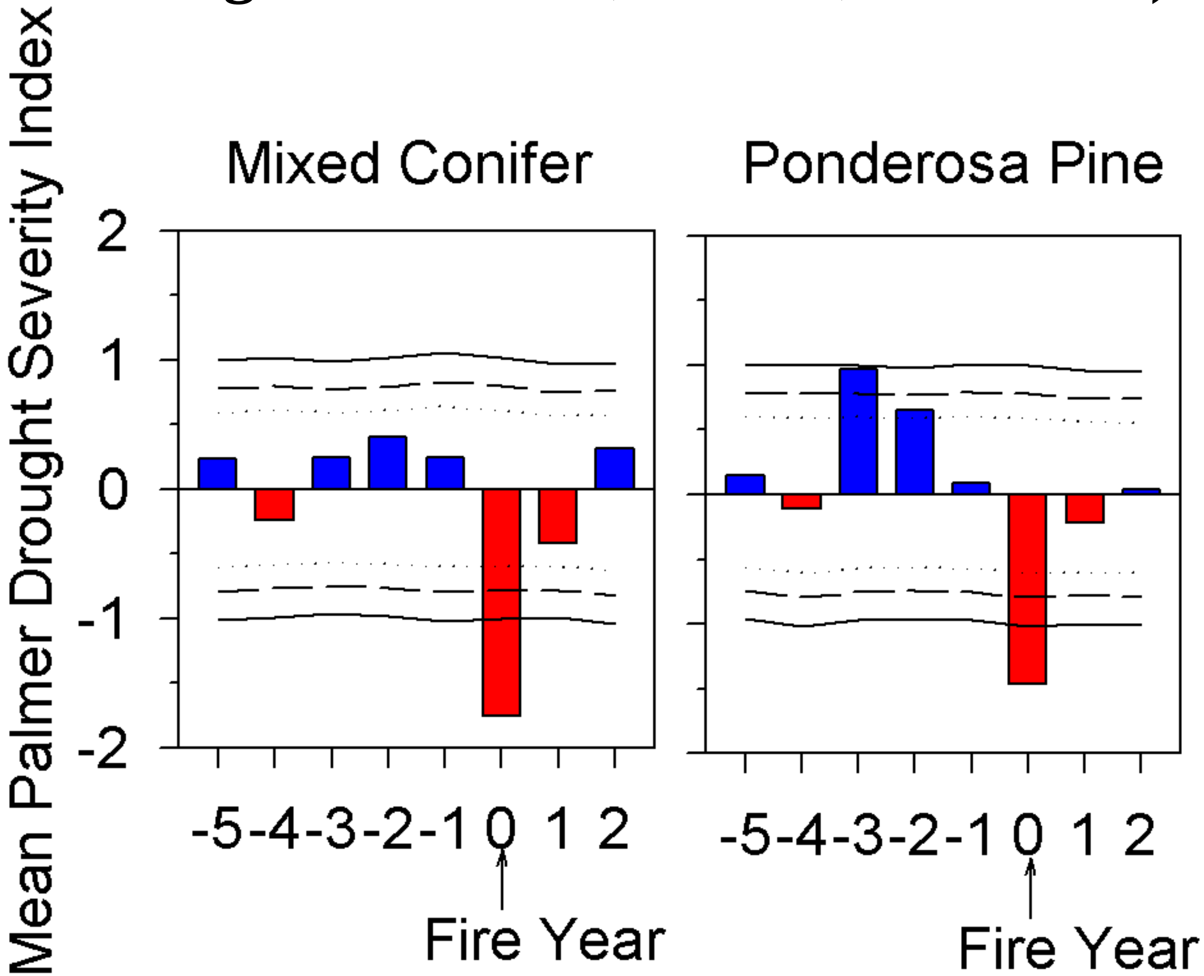
1905-2004



Swetnam, T.W. and P. M. Brown. 2011. Climatic inferences from dendroecological reconstructions. Chapter 9, In: Hughes, M.K., T.W. Swetnam, and H.F. Diaz, editors, Dendroclimatology: Progress and Prospects, Springer, New York.

Prior years wet conditions appears to be largely a factor in lower elevation pine-dominant forests where grass fuels are limiting to fire ignition and spread.

Large Fire Events, SW US, 1700-1900)

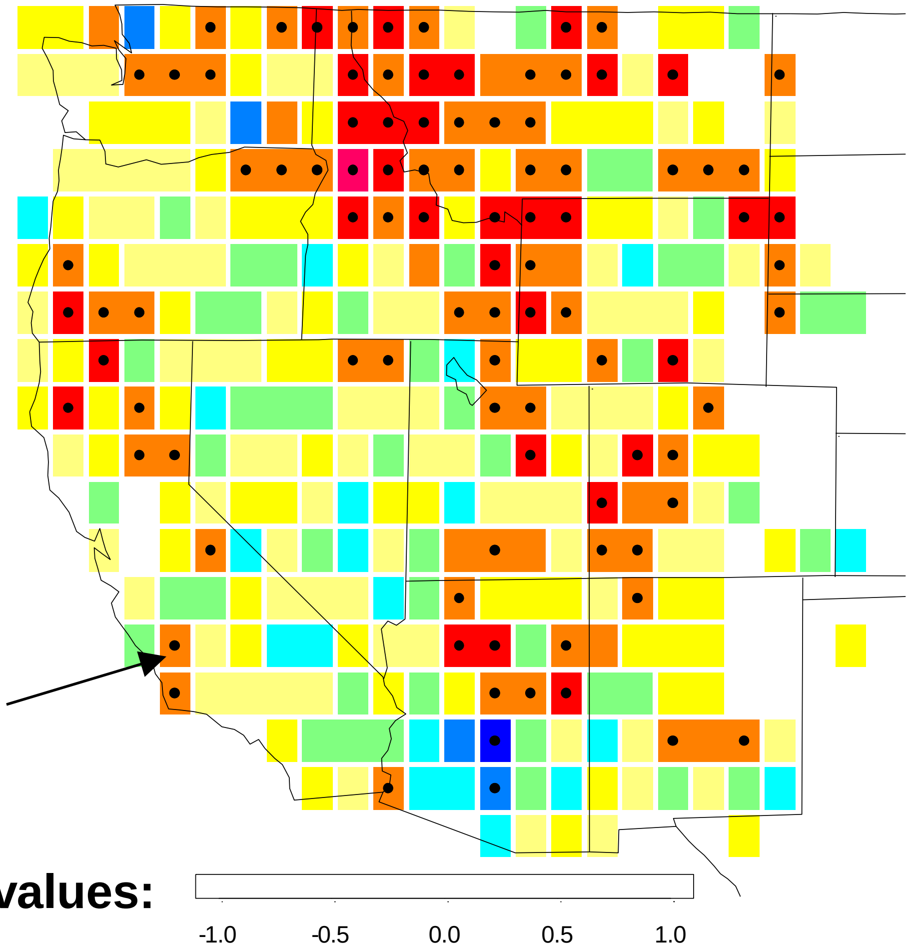


Swetnam and Betancourt. 1998. J. Climate.

Tony Westerling & his colleagues have assembled a gridded network of fire occurrence (1975-2005) for the western US from multiple data sources, and have conducted fire climatology analyses using a parallel gridded network of PDSI.

Current summer Palmer Drought Severity Index is inversely correlated with acres burned, especially in the inter-mountain west (1980-2000).

$p < 0.05$

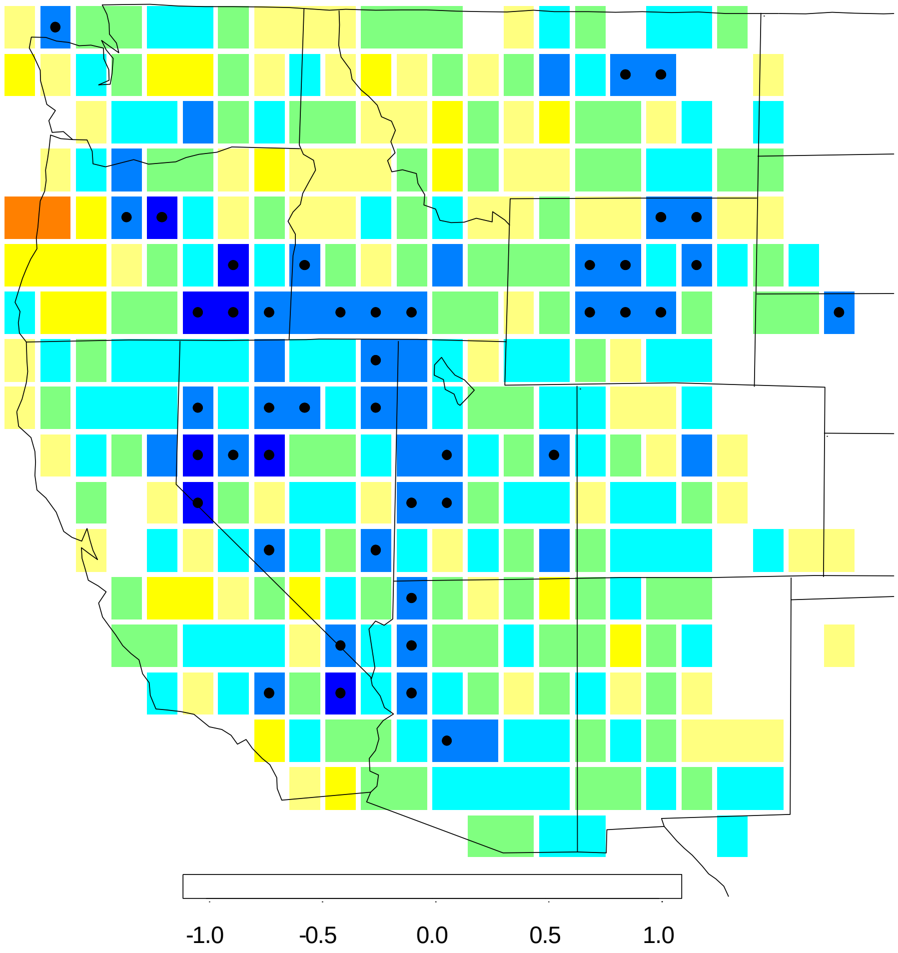


Pearson correlation, r values:

DRY August PDSI WET

Westerling AL, Gershunov A, Cayan DR, and Barnett, TP. 2002. Long lead statistical forecasts of area burned in western US wildfires by ecosystem province. INT J WILDLAND FIRE 11 (3-4): 257-266.

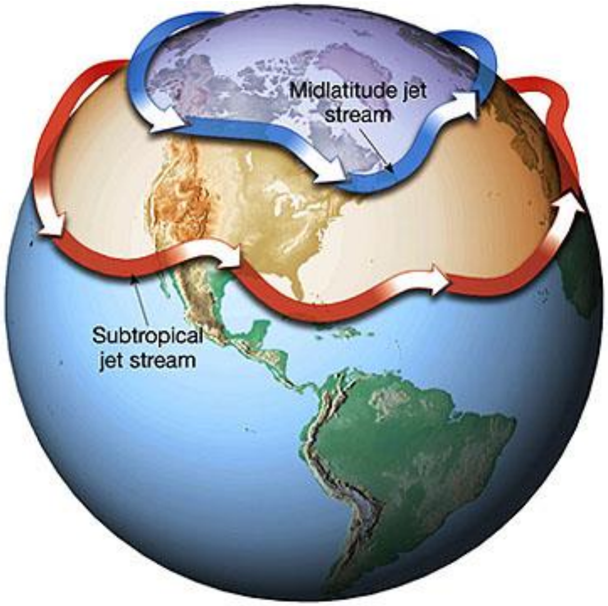
Previous year’s spring PDSI is positively correlated with acres burned, especially in the Great Basin and Southwest.



DRY May PDSI WET

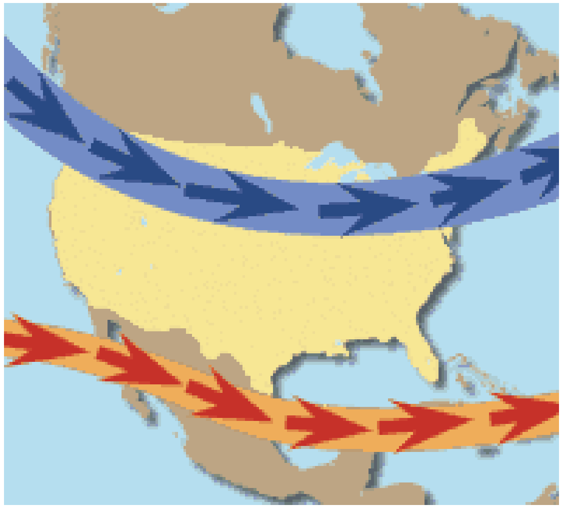
Westerling et al. 2002

Inter-annual to decadally persistent and repetitive features of the ocean-atmosphere explain substantial spatial and temporal variation in climate AND fire.

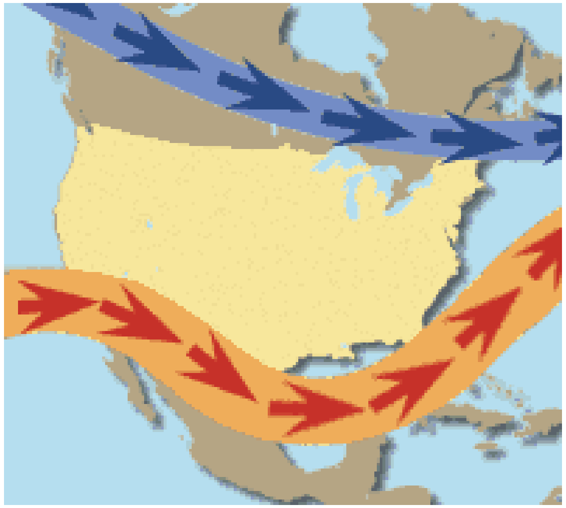


Typical Position of the Winter Jet Stream

Normal



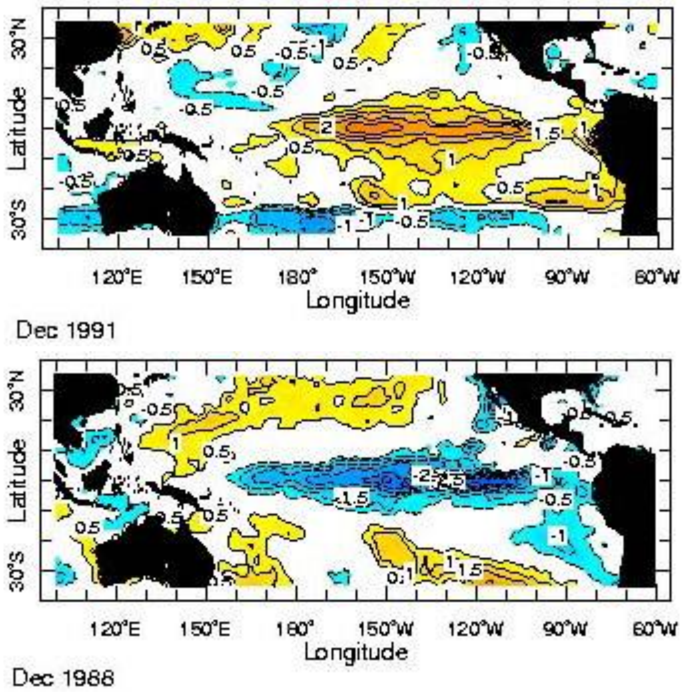
El Nino



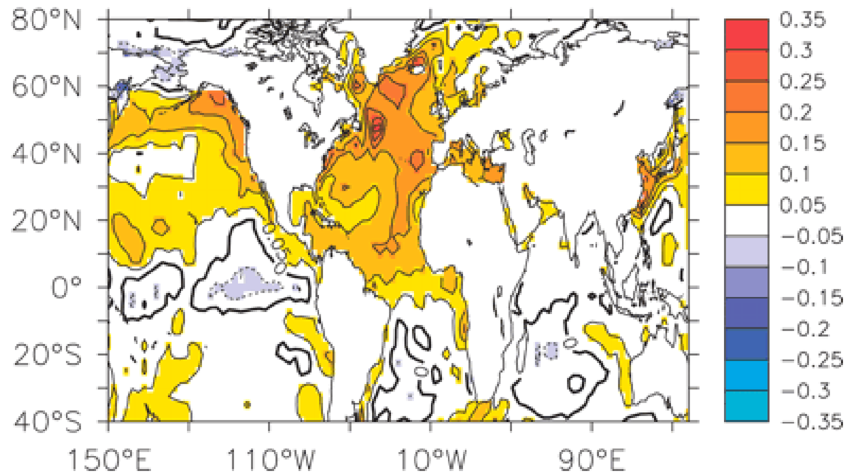
Ocean-Atmosphere Oscillations

El Niño

La Niña

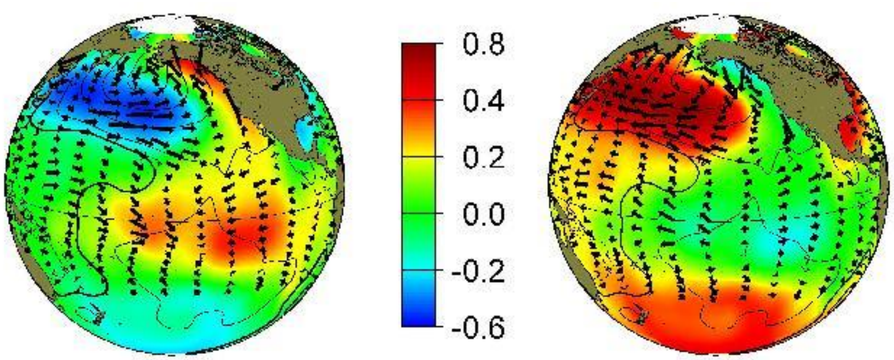


Atlantic Multidecadal Oscillation

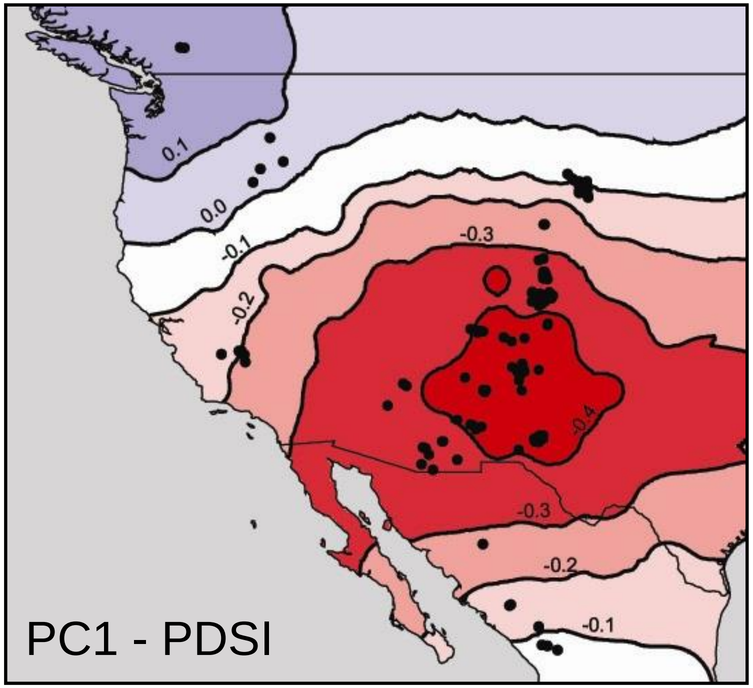


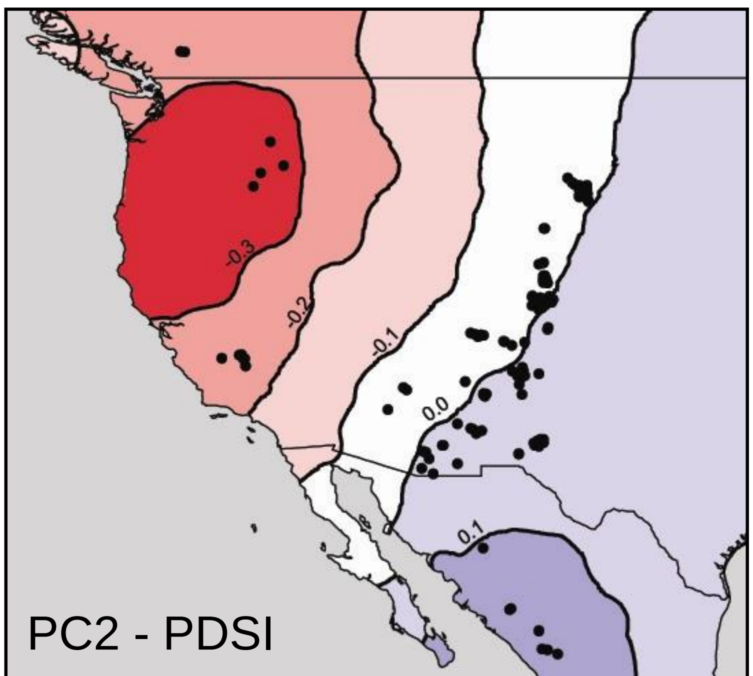
Pacific Decadal Oscillation

PDO + PDO -



T.W. Swetnam, Laboratory of Tree-Ring Research

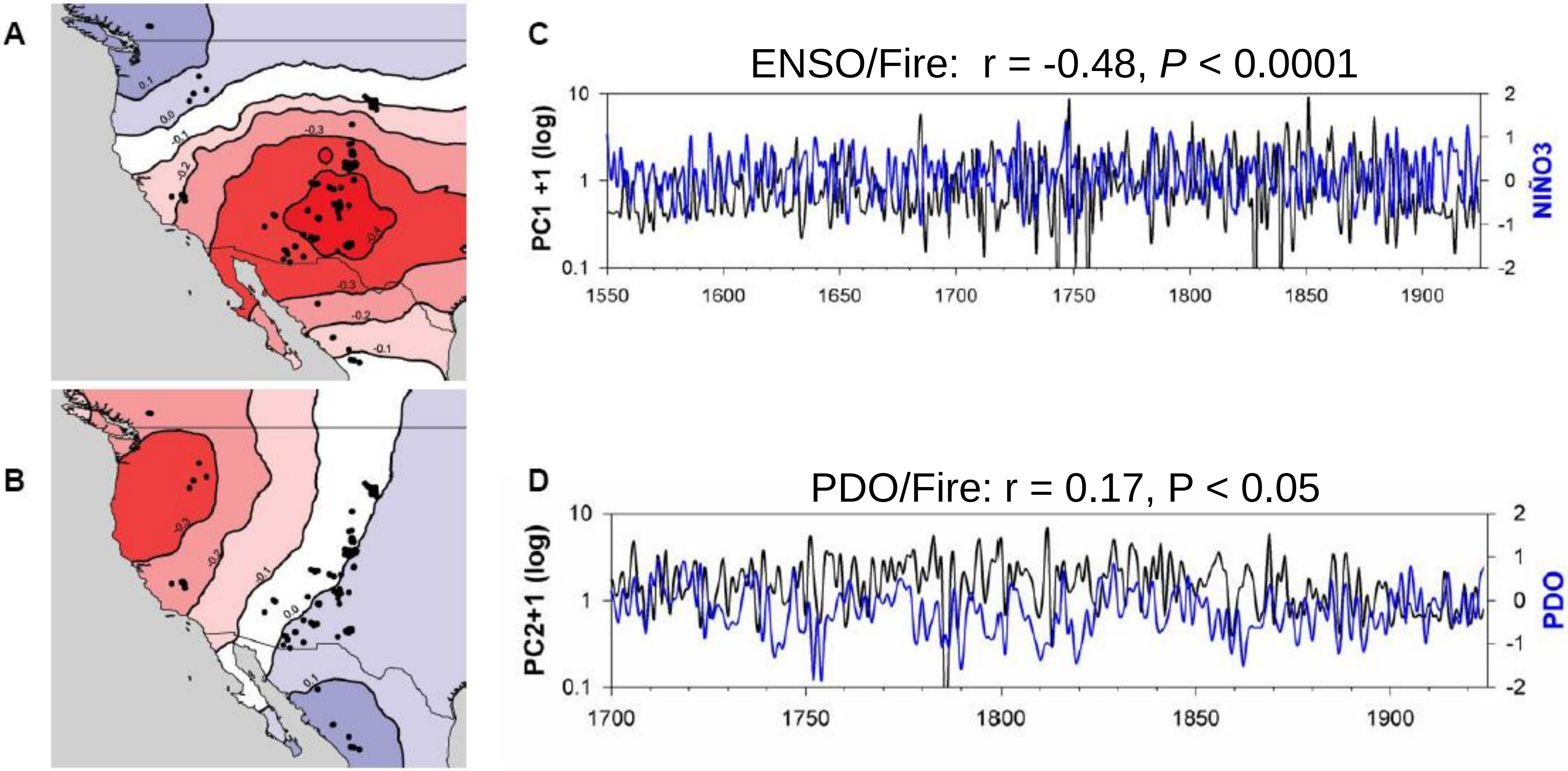




Correlations of the PC amplitude series with the gridded Cook et al. PDSI network in western North America shows a strong NW-SW dipole pattern. This is consistent with a known dipole pattern of precipitation and ENSO teleconnections across these regions (e.g., Dettinger et al. 1998, J. Climate).

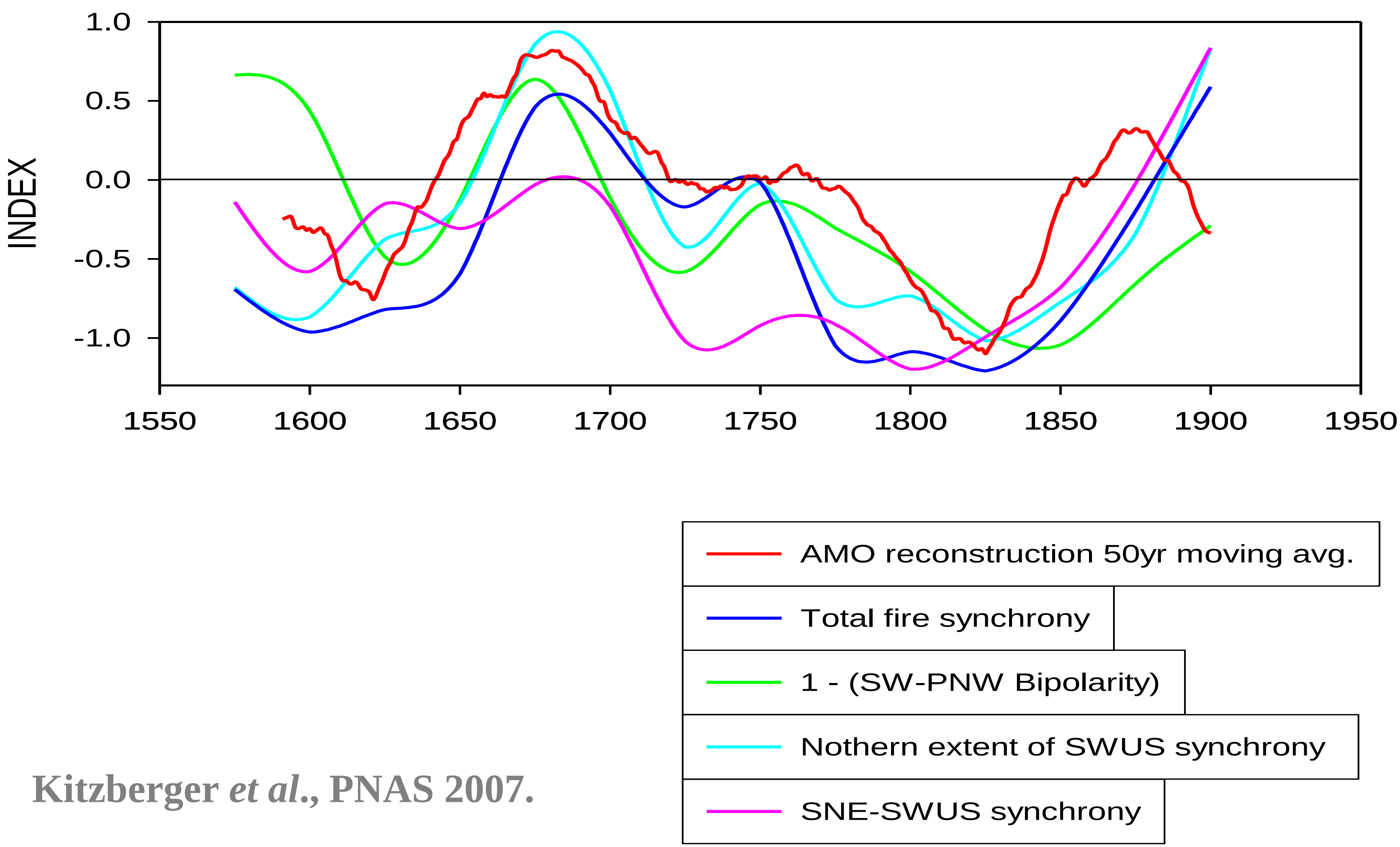
Kitzberger, T., P. M. Brown, E. K. Heyerdahl, T.W. Swetnam, and T. T. Veblen. 2007. Contingent Pacific-Atlantic ocean influence on multi-century wildfire synchrony over western North America. *Proceedings of the National Academy of Sciences* 104(2):543-548.

It appears that the first PC is moderately associated with ENSO, and the 2nd PC is weakly associated with PDO.



Kitzberger et al. 2007, PNAS

Synchrony among regions is correlated with decadal variation in the Atlantic Multidecadal Oscillation (AMO)

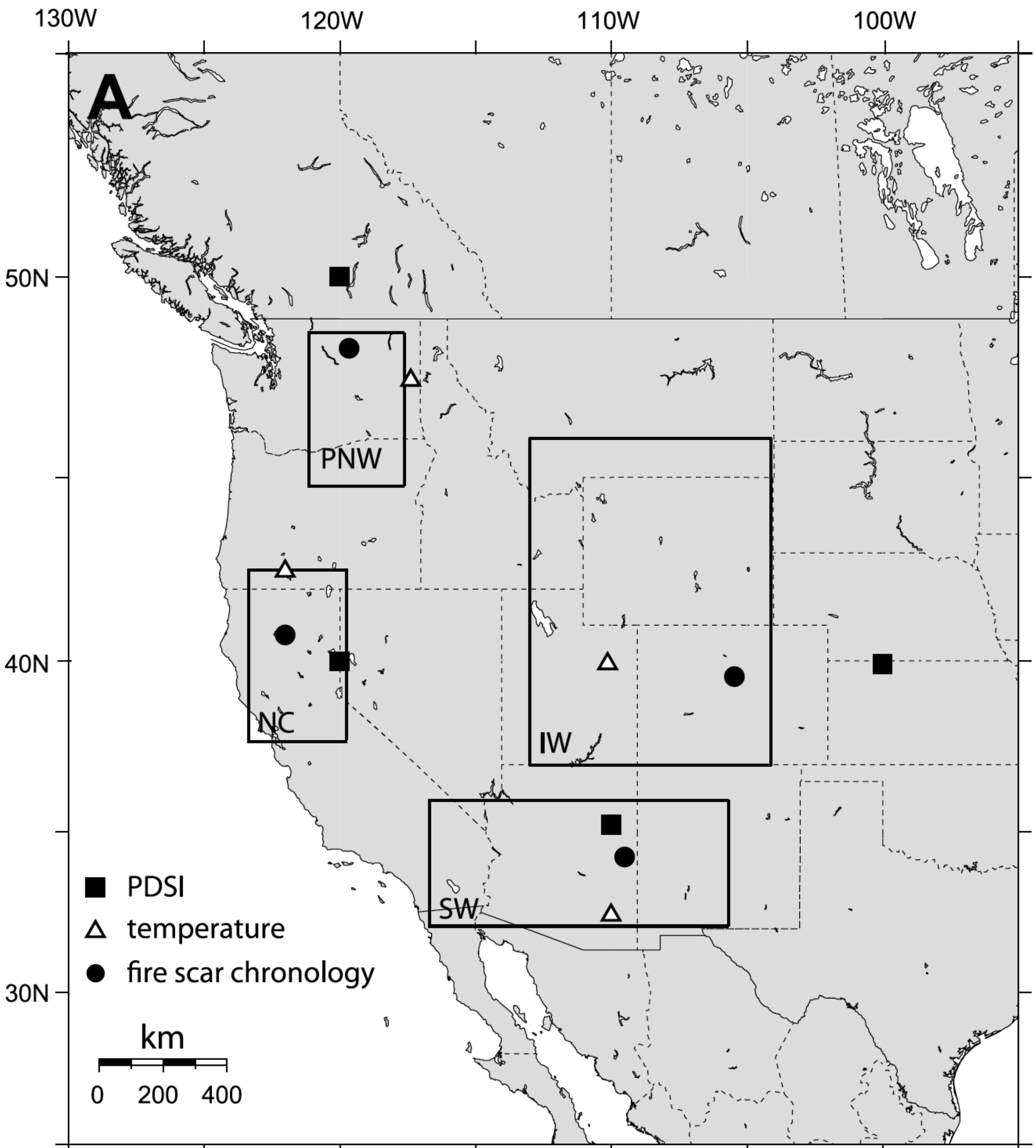


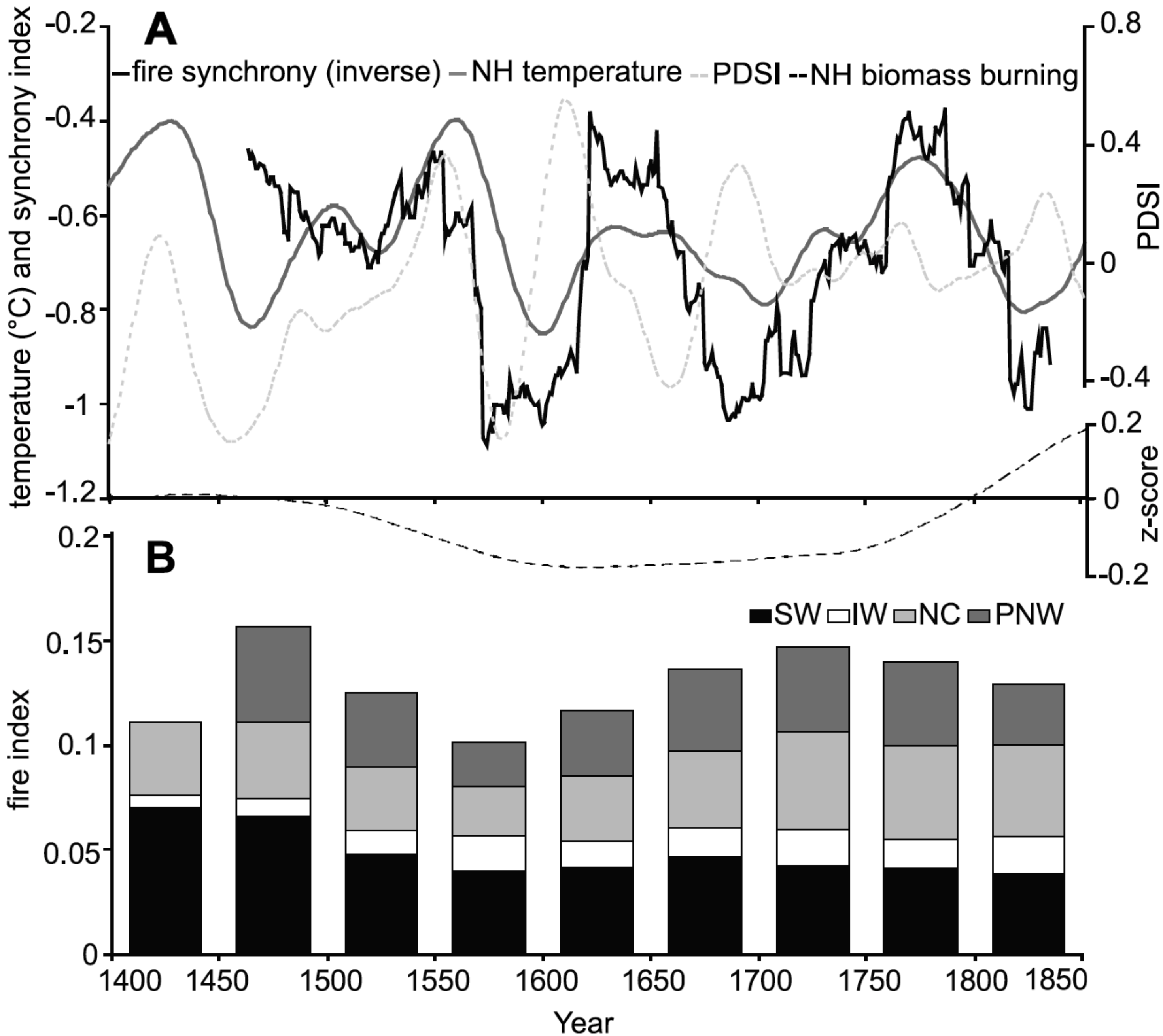
Kitzberger *et al*., PNAS 2007.

Fire-climate interactions in the American West since 1400 CE.

Valerie Trouet, Alan H. Taylor, Eugene R. Wahl, Carl N. Skinner, and Scott L. Stephens

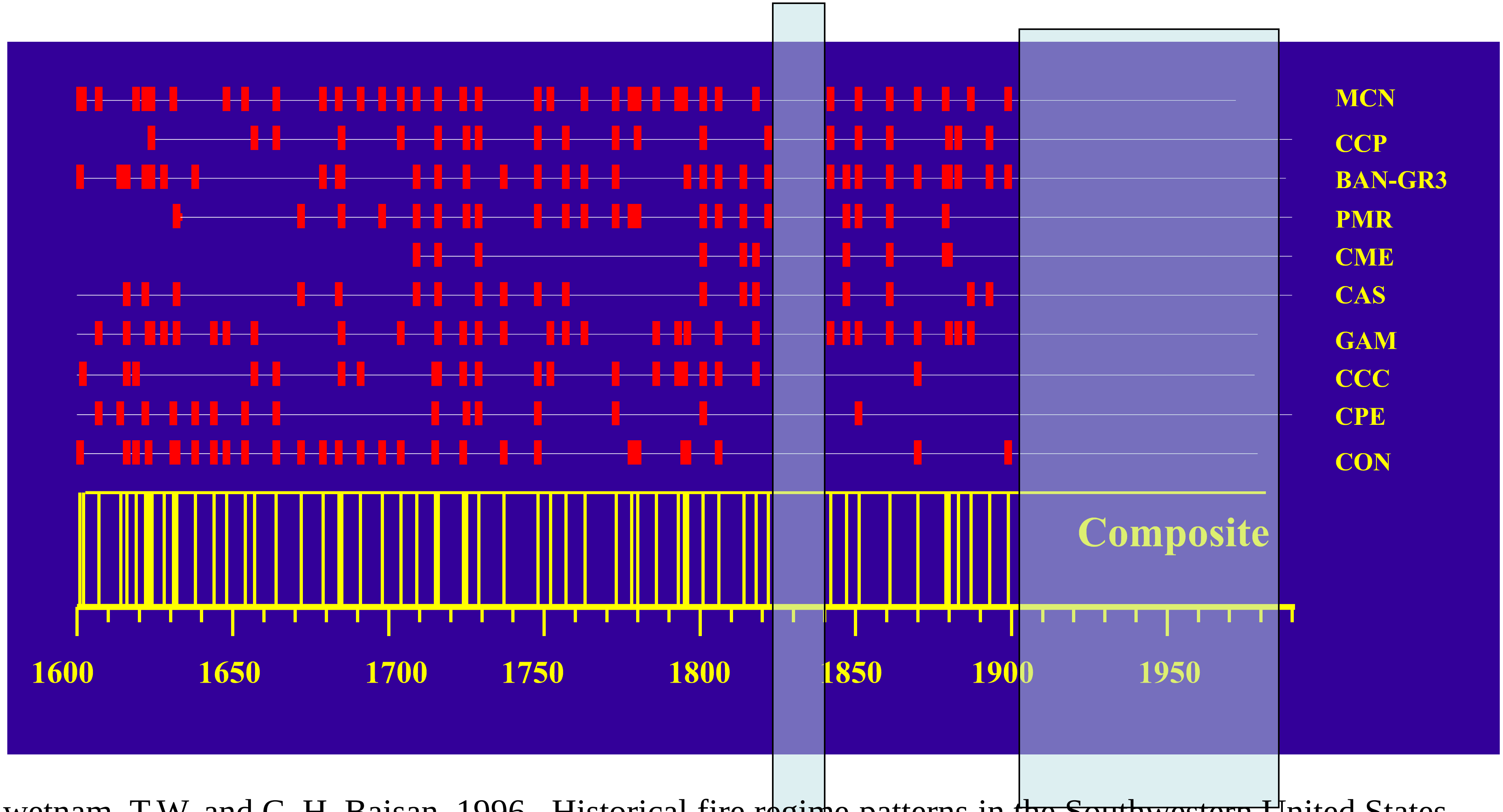
GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L04702, doi:10.1029/2009GL041695, 2010





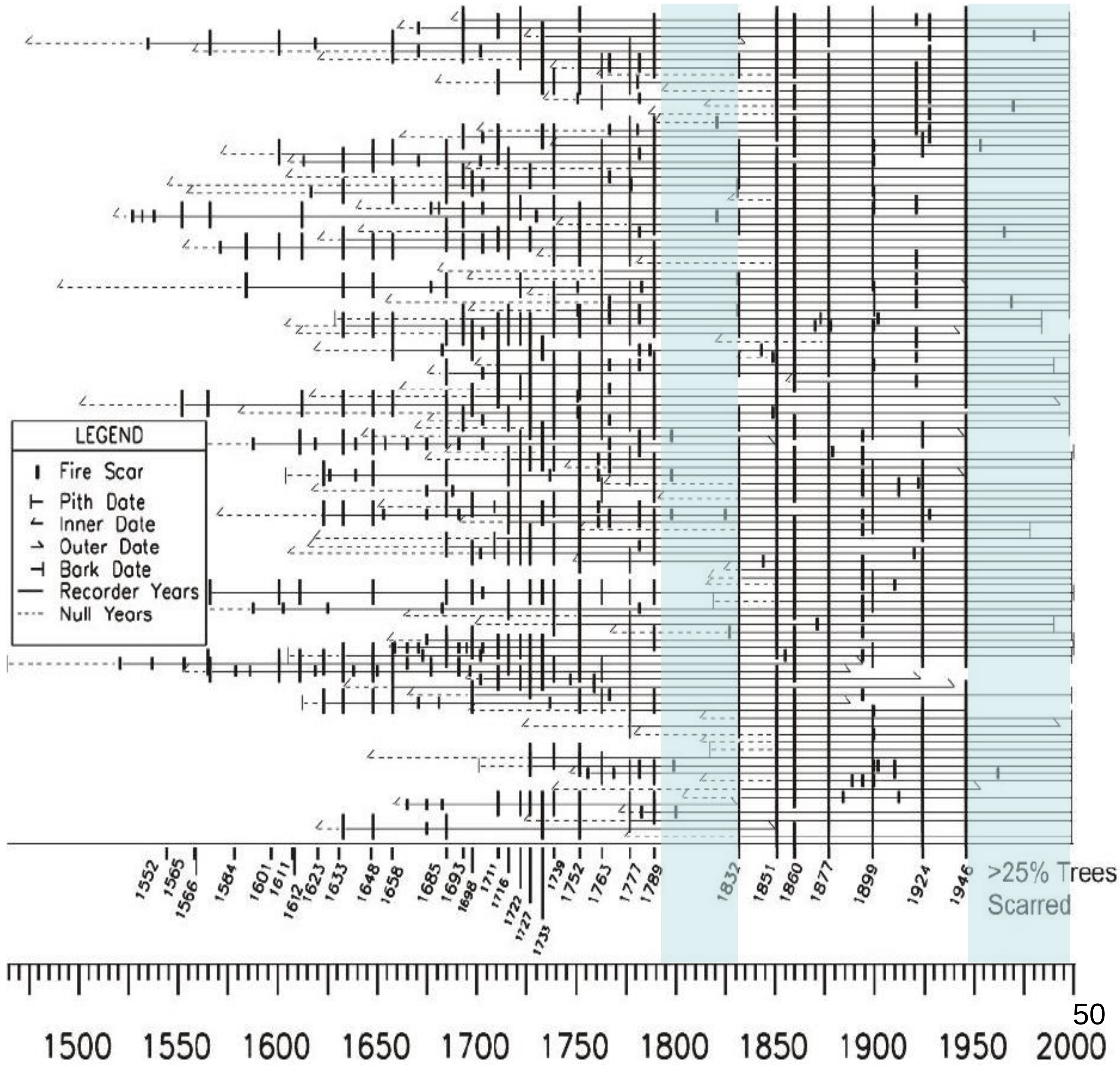
Trouet et al. GRL, 2010

Composite fire scar chronologies from 10 forest stands
In the Jemez Mountains, New Mexico



Swetnam, T.W. and C. H. Baisan. 1996. Historical fire regime patterns in the Southwestern United States since AD 1700. In C. Allen, editor, Fire effects in Southwestern Forests, Proceedings of the Second La Mesa Fire Symposium, Los Alamos, New Mexico, March 29-31, 1994. *USDA Forest Service General Technical Report RM-GTR*-286; pages 11-32.

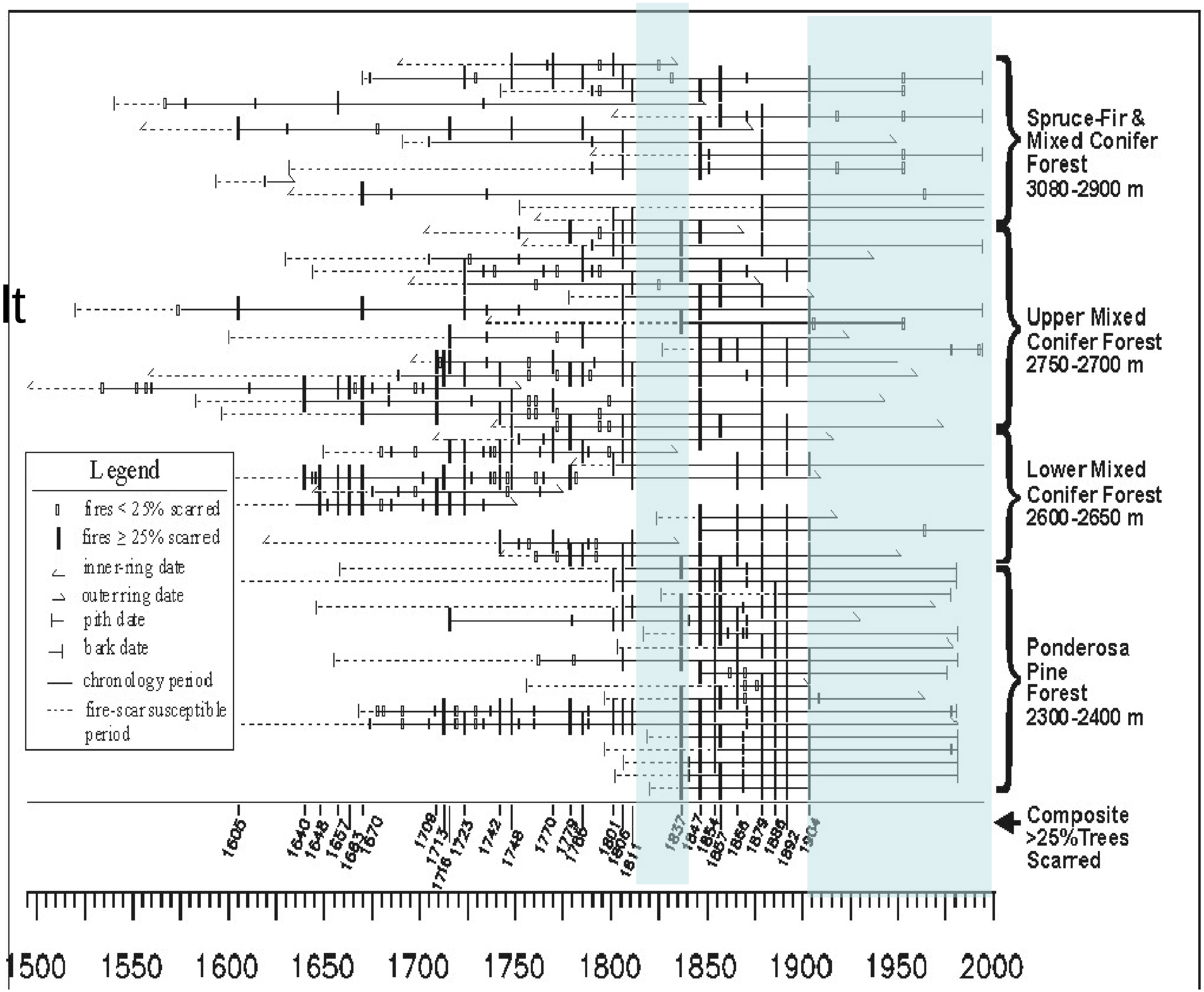
Fire-scar chronology, Sierra San Pedro Martir, Baja, MX.



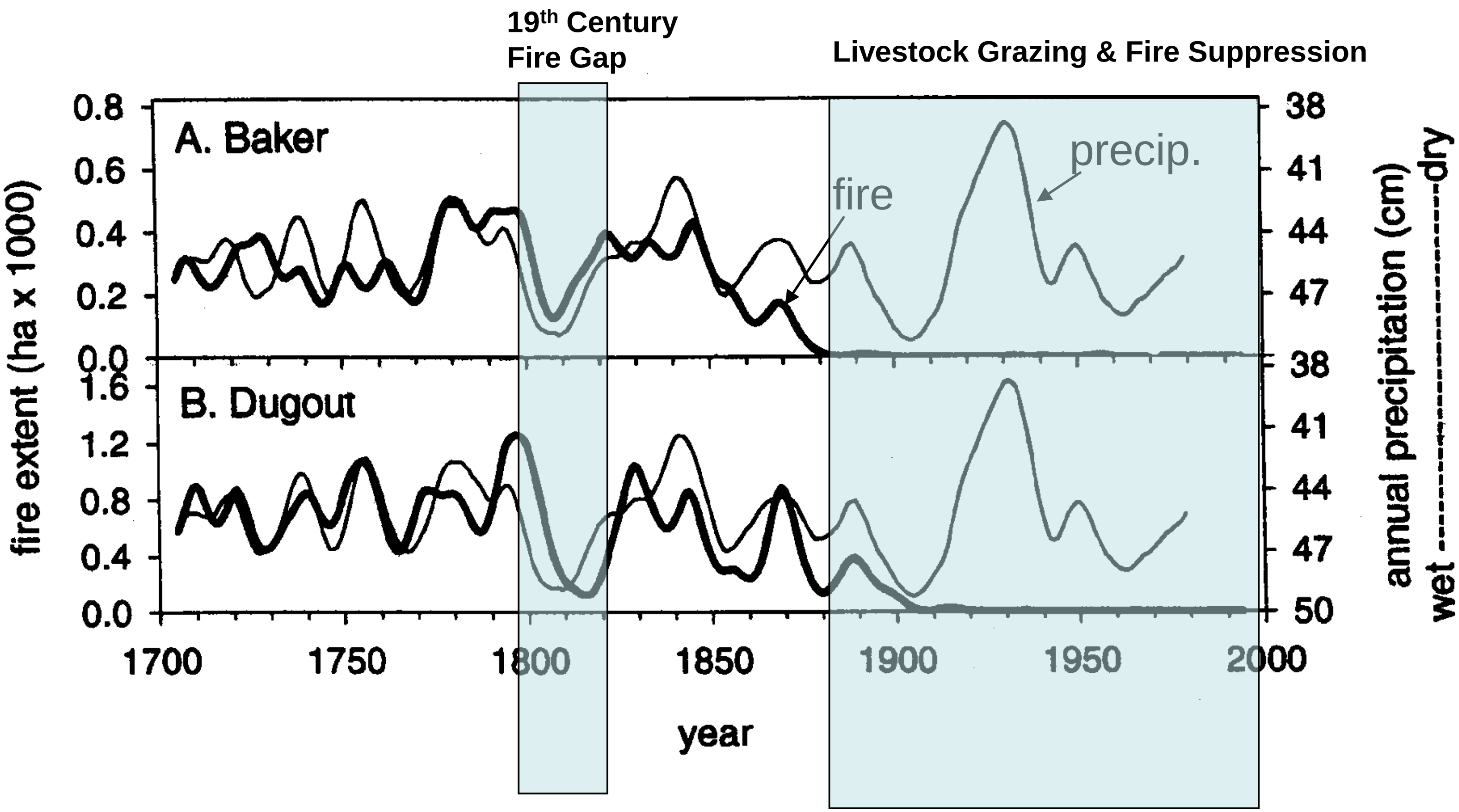
Stephens, Scott L, Carl N Skinner, and Samantha J Gill. 2003. “Dendrochronology-Based Fire History of Jeffrey Pine - Mixed Conifer Forests in the Sierra San Pedro Martir, Mexico.” Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 33 (6): 1090–1101.

Gila Wilderness fire history elevational transect.

Swetnam 1983, Abolt 1997

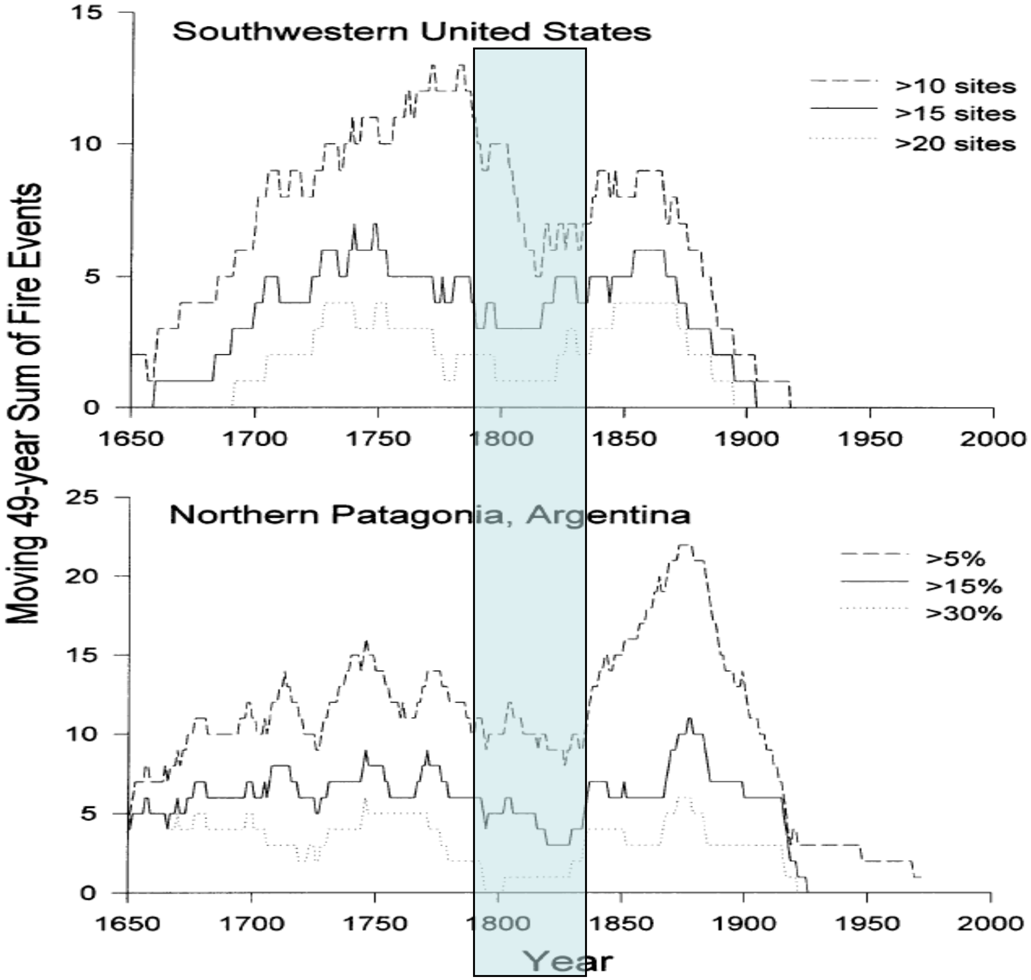


Fire extent in eastern Oregon is correlated with decadal-scale variations in annual precipitation.



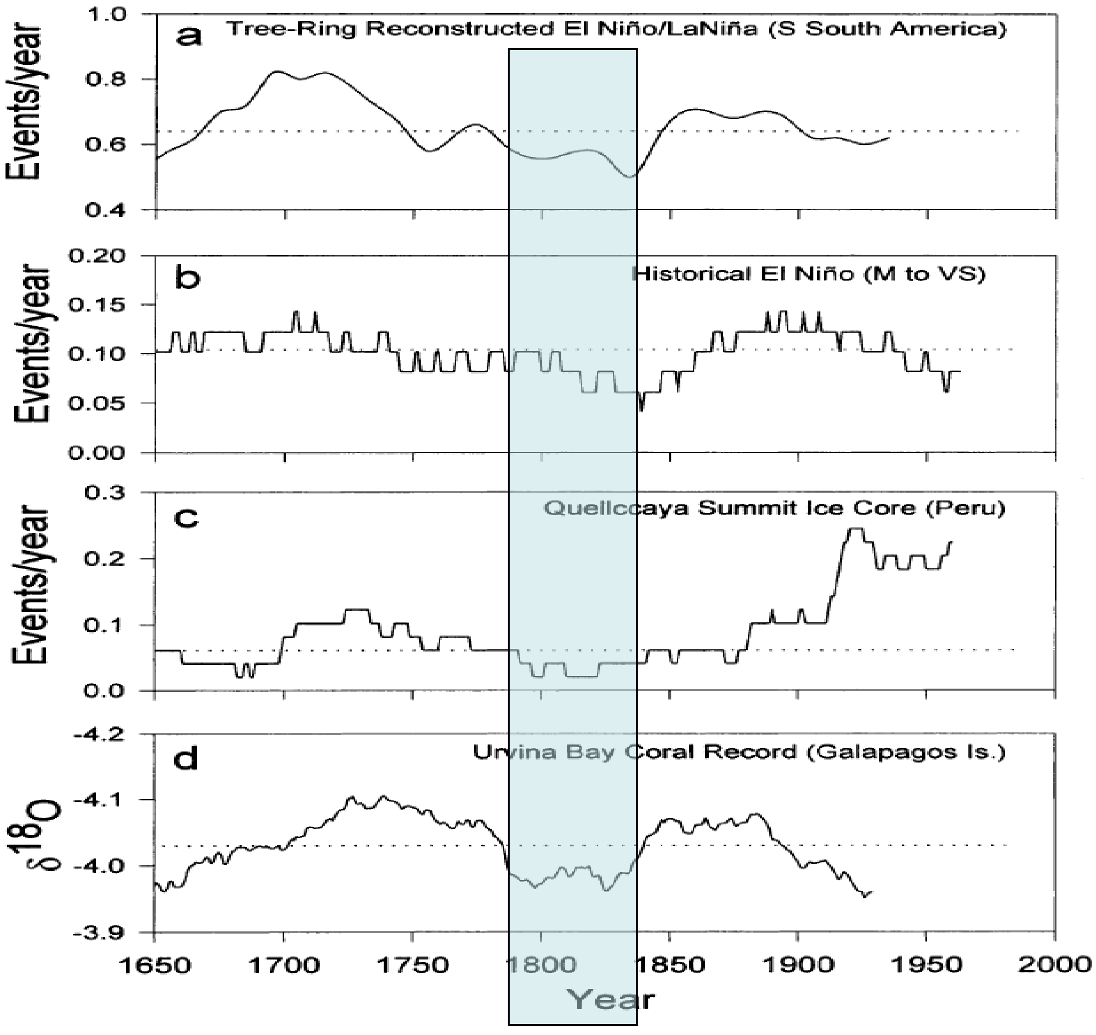
Heyerdahl, Emily K, Linda B Brubaker, and James K Agee. 2001. “Spatial Controls of Historical Fire Regimes: A Multiscale Example from the Interior West, USA.” The Holocene 82 (3): 31p. Heyerdahl et al. 2001.

Fire histories in both the SW US, and Patagonia show reduced fire frequency during the period circa 1780-1840.



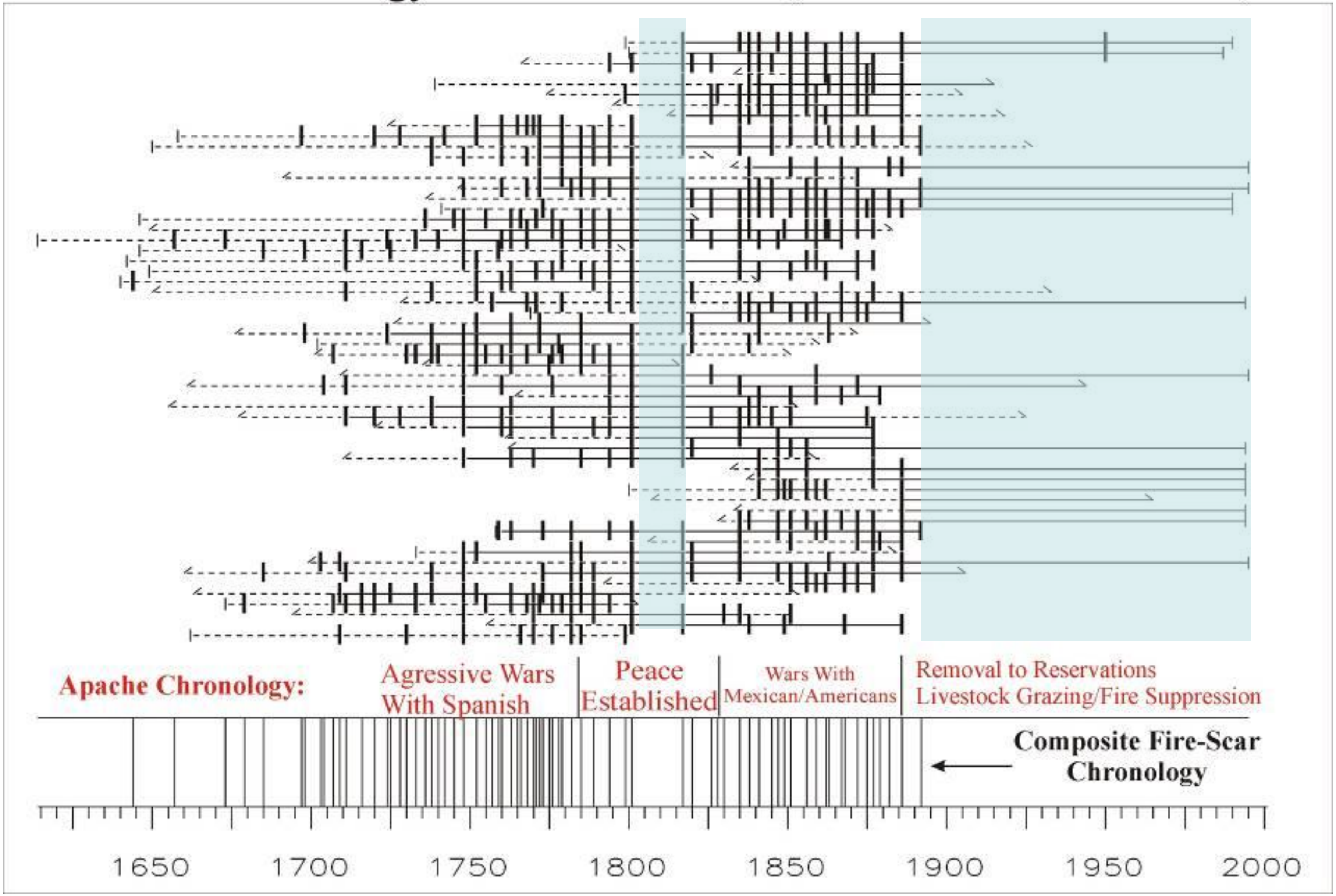
Kitzberger, T., T.W. Swetnam, and T. T. Veblen. 2001. Inter-hemispheric synchrony of forest fires and the El Nino-Southern Oscillation. *Global Ecology and Biogeography* 10 (3): 315-326.

Multi-proxy reconstructions of ENSO show reduced frequency (or amplitude) of ENSO events during the late 1700s to early 1800s.



Kitzberger et al. 2001, GEB

Fire-Scar Chronology from Rustler Park, Chiricahua Mountains, AZ



Kaib 1998, and Seklecki et al. 1996

A combined dendroclimatic-dendroecology approach

<u>Spearmans' R</u>

SR vs Observed:

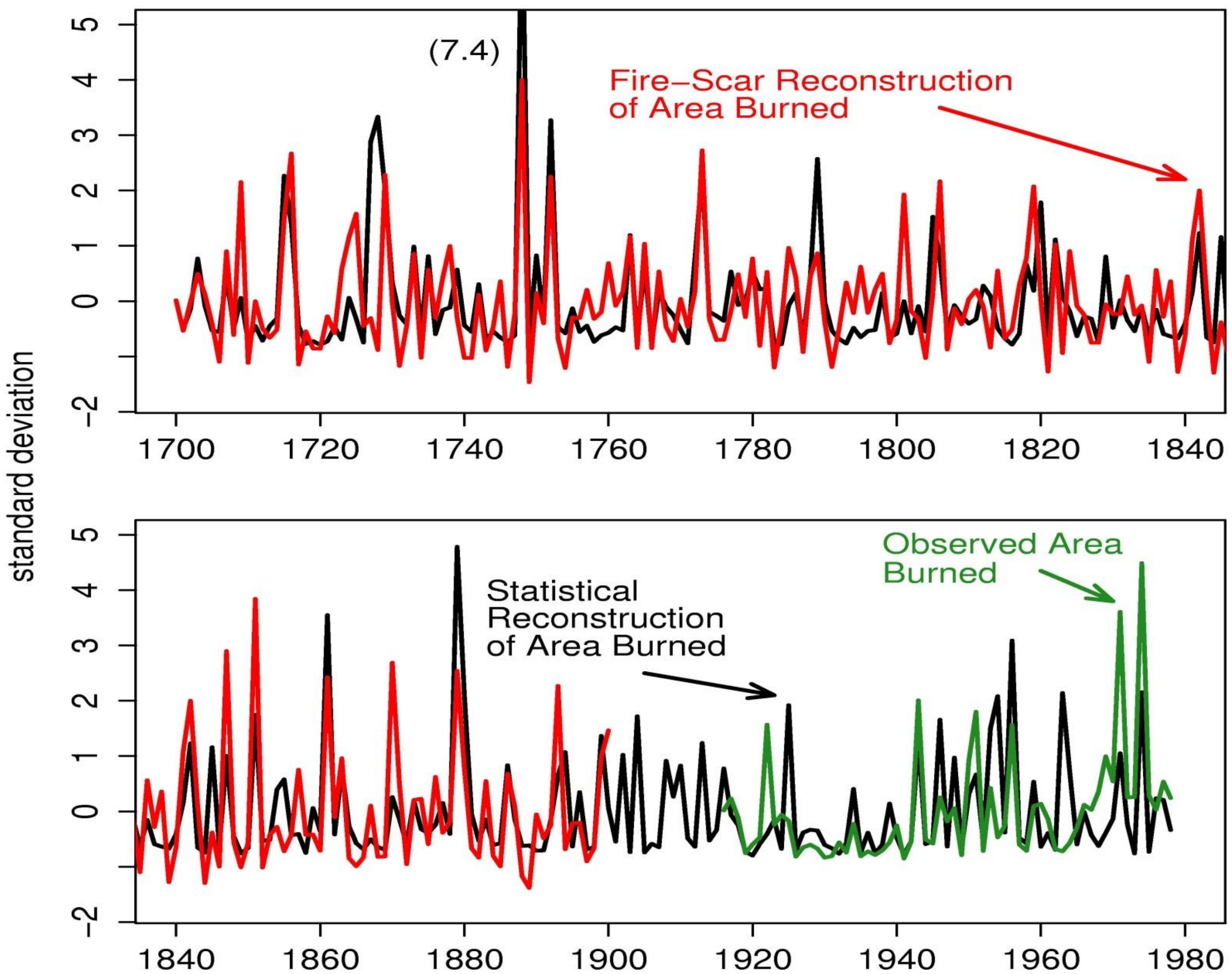
0.49, 1916-1978

0.71, 1916-1962

SR vs FSR

0.61, 1700-1900

(all p levels < 0.05)



Westerling, A. L., and T. W. Swetnam. 2003. Interannual to decadal drought and wildfire in the Western US. EOS Transactions American Geophysical Union 84(49):545-560.

Global Ecology and Biogeography, (*Global Ecol. Biogeogr.*) (2007) **16**, 557–566

RESEARCH PAPER

Interannual to decadal changes in area burned in Canada from 1781 to 1982 and the relationship to Northern Hemisphere land temperatures

Martin P. Girardin*

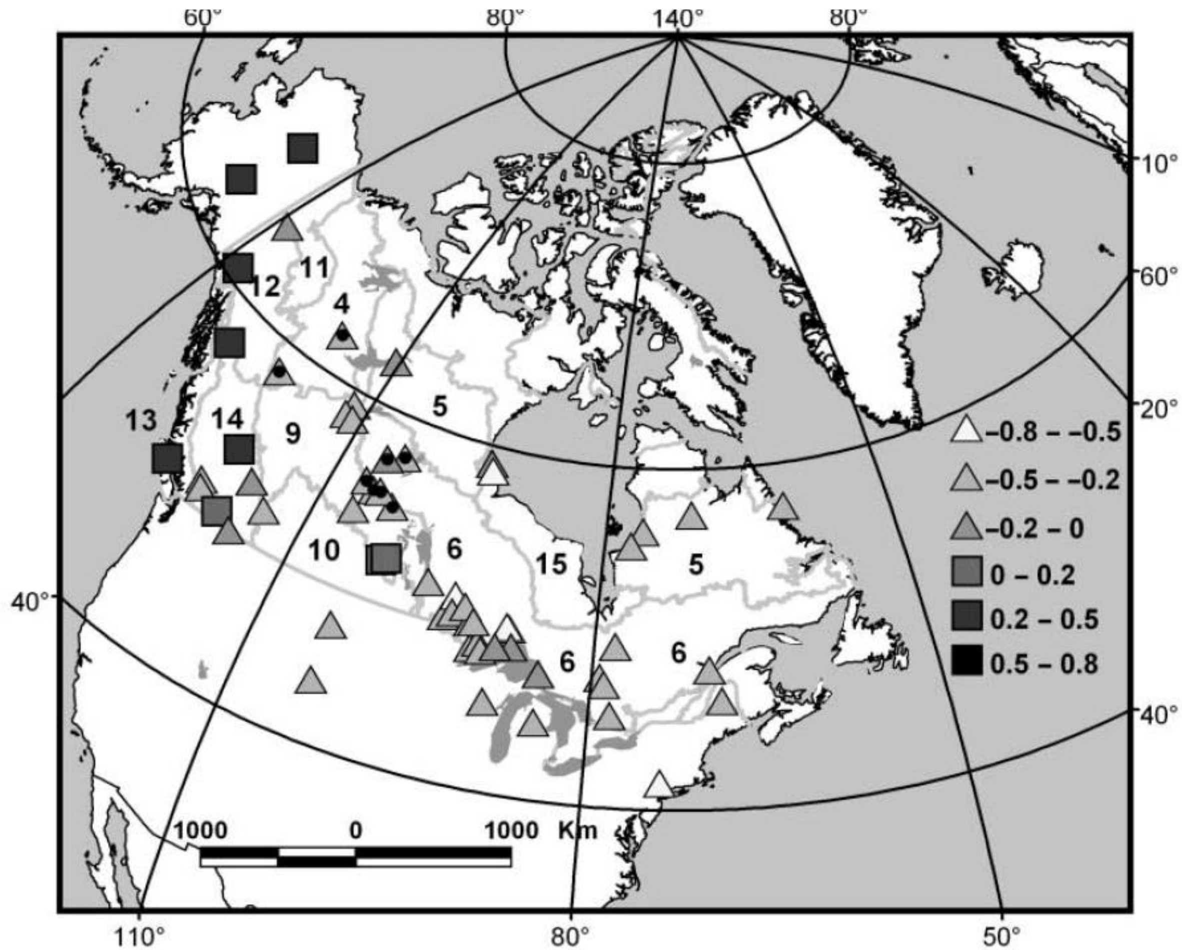
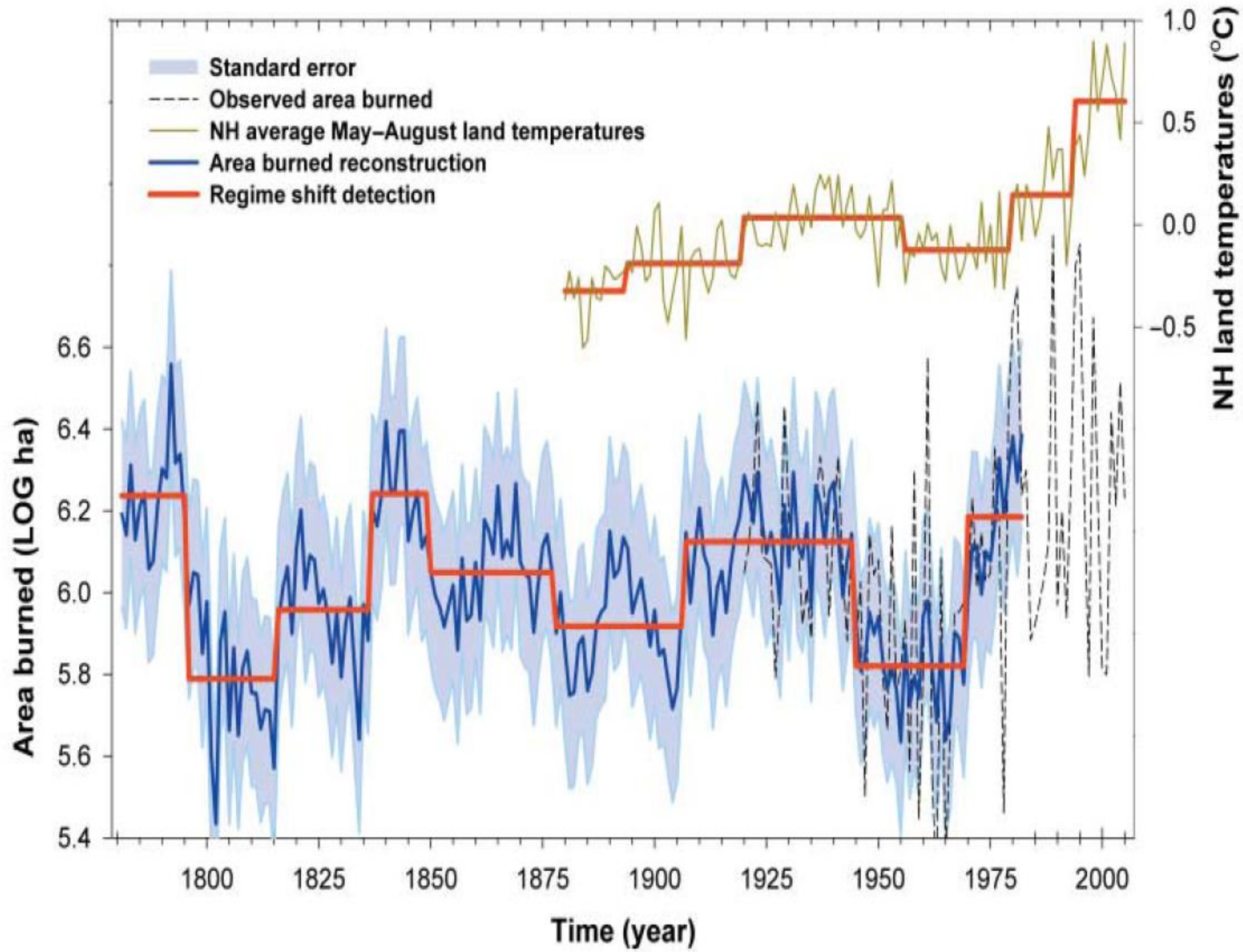


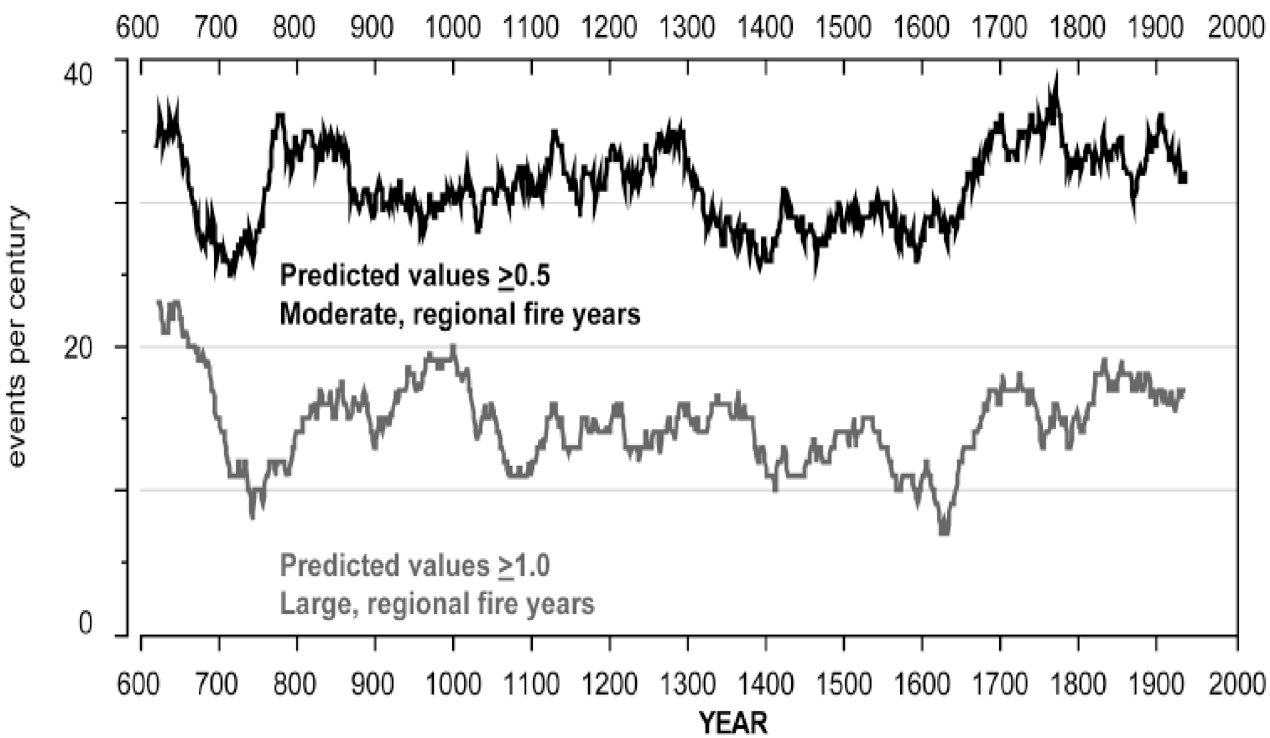
Figure 1 Distribution of the 61 tree-ring width chronologies used as annual area burned in Canada (AAB-Can) predictors. Symbols: correlation between predictors and estimated AAB-Can over 1781–1982; symbols marked with a dot denote the eight chronologies used in a sensitivity analysis (for these the correlation is over 1871–1982). Numbers refer to ecozones: 4, Taiga Plains; 5, Taiga Shield; 6, Boreal Shield; 9, Boreal Plains; 10, Prairies; 11, Taiga Cordillera; 12, Pacific Maritime; 13, Montane Cordillera; 14, Boreal Cordillera; 15, Hudson Plains.

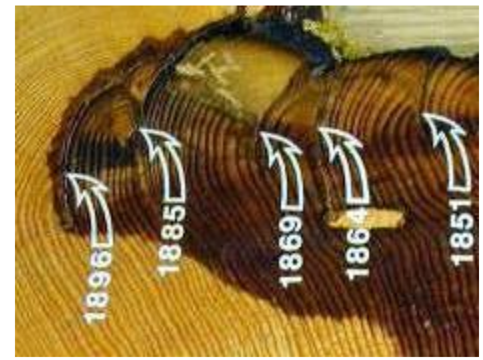
Girardin has used a Canadian network of ring-width chronologies to reconstruct Canadian area burned back to 18th century.

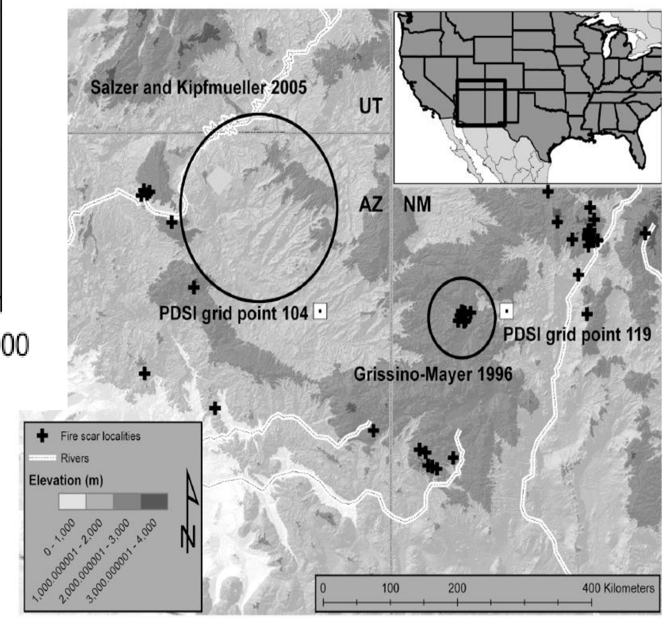


Martin P. Girardin. Interannual to decadal changes in area burned in Canada from 1781 to 1982 and the relationship to Northern Hemisphere land temperatures Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2007)16, 557–566

We used a 1,400 year PDSI and precipitation reconstructions from ring widths in the Southwest and a 200-year regional fire scar index from 44 sites to calibrate and validate a regression model, which we then used to retrodict fire history back through the "Little Ice Age" and the "Medieval Warm (Drought) Period".







Roos, C.I., and T.W. Swetnam. 2011. A 1,416-year reconstruction of annual, multi-decadal, and centennial variability in area burned for ponderosa pine forests of the southern Colorado Plateau region, Southwest USA. *The Holocene* 22(3):281-290.


THANKS, FOLKS
SMOKEY
ONLY YOU CAN PREVENT FOREST FIRES!

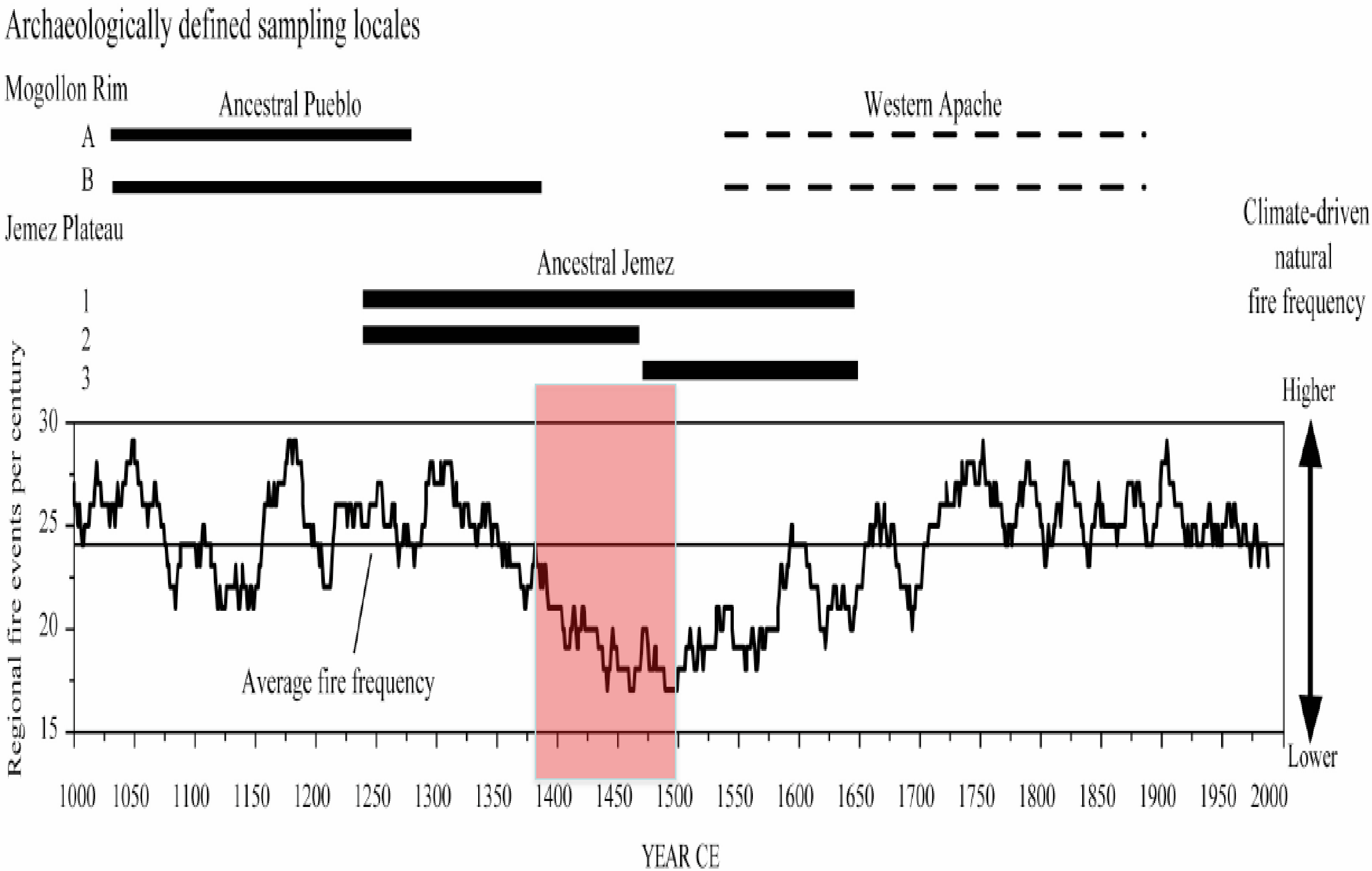
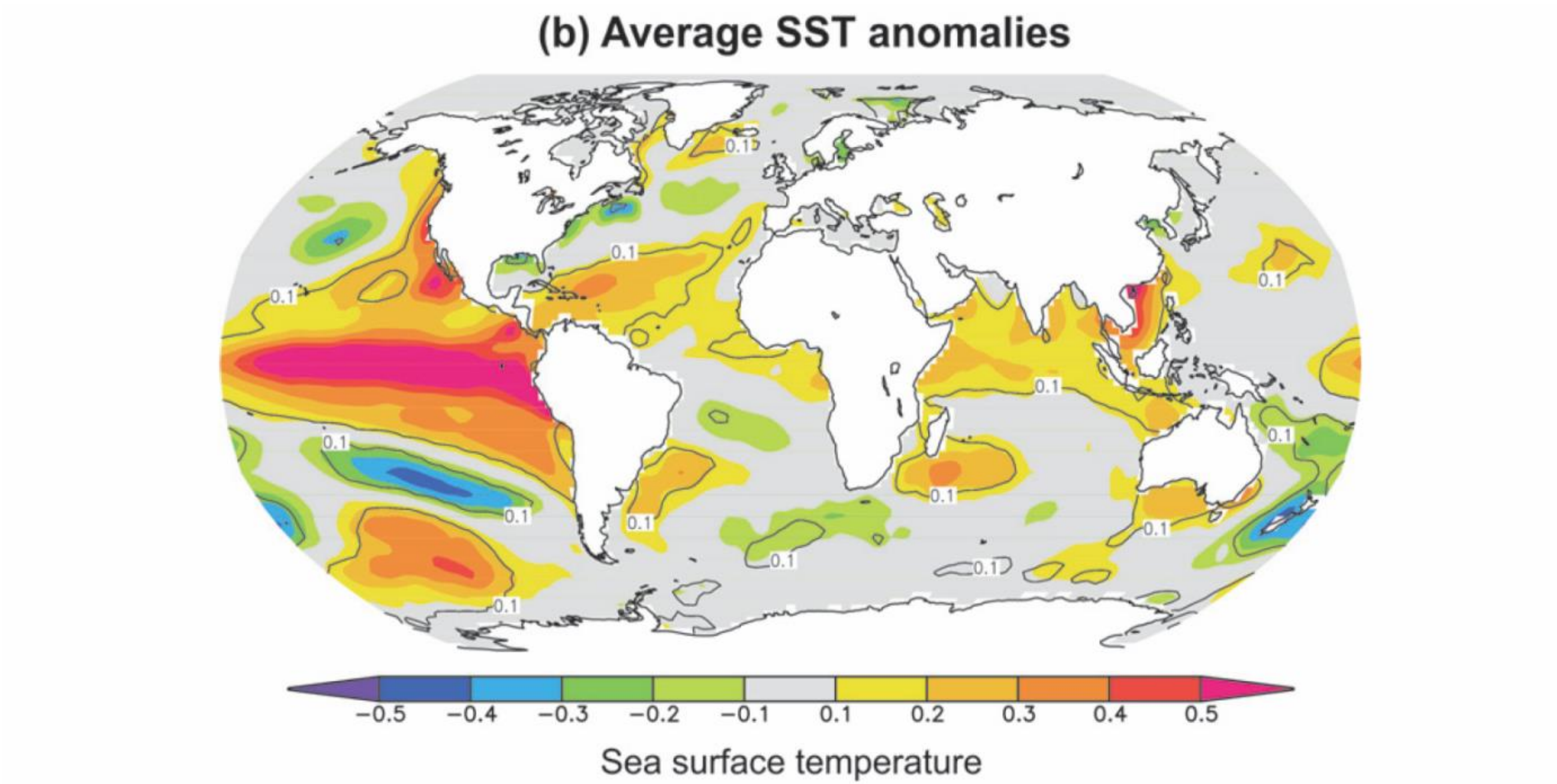
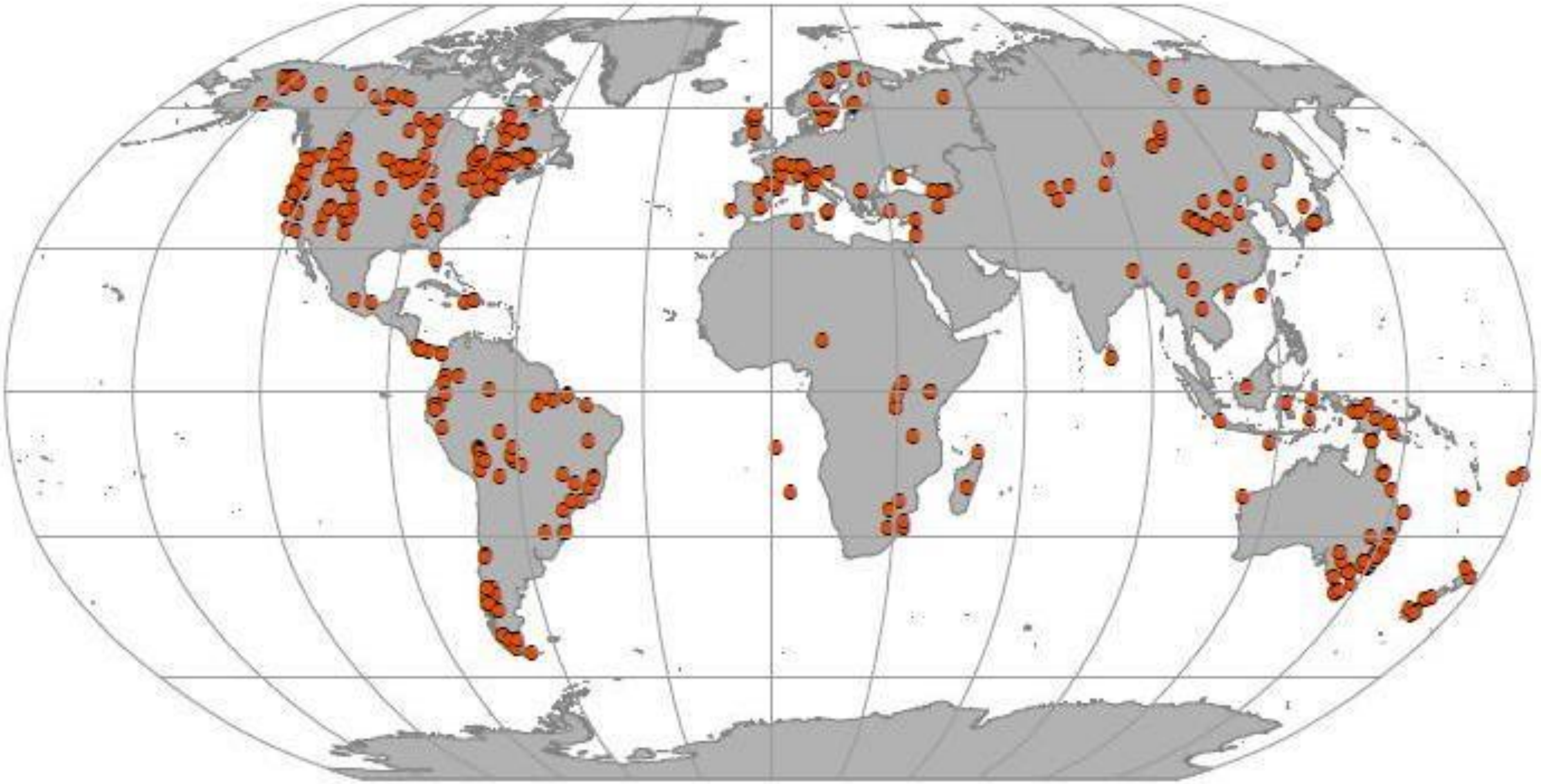


Figure 4. Reconstructed climate-driven regional fire frequencies (from Roos and Swetnam 2009) and occupational histories (horizontal lines A, B, 1 to 3) of the archaeologically defined study locales as defined in the text. Thicker lines denote larger populations. Dashed lines denote seasonal occupations.

Average sea surface temperature anomalies during the 19 highest area burned years in the tree-ring reconstruction. Girardin and Sauchyn 2009.

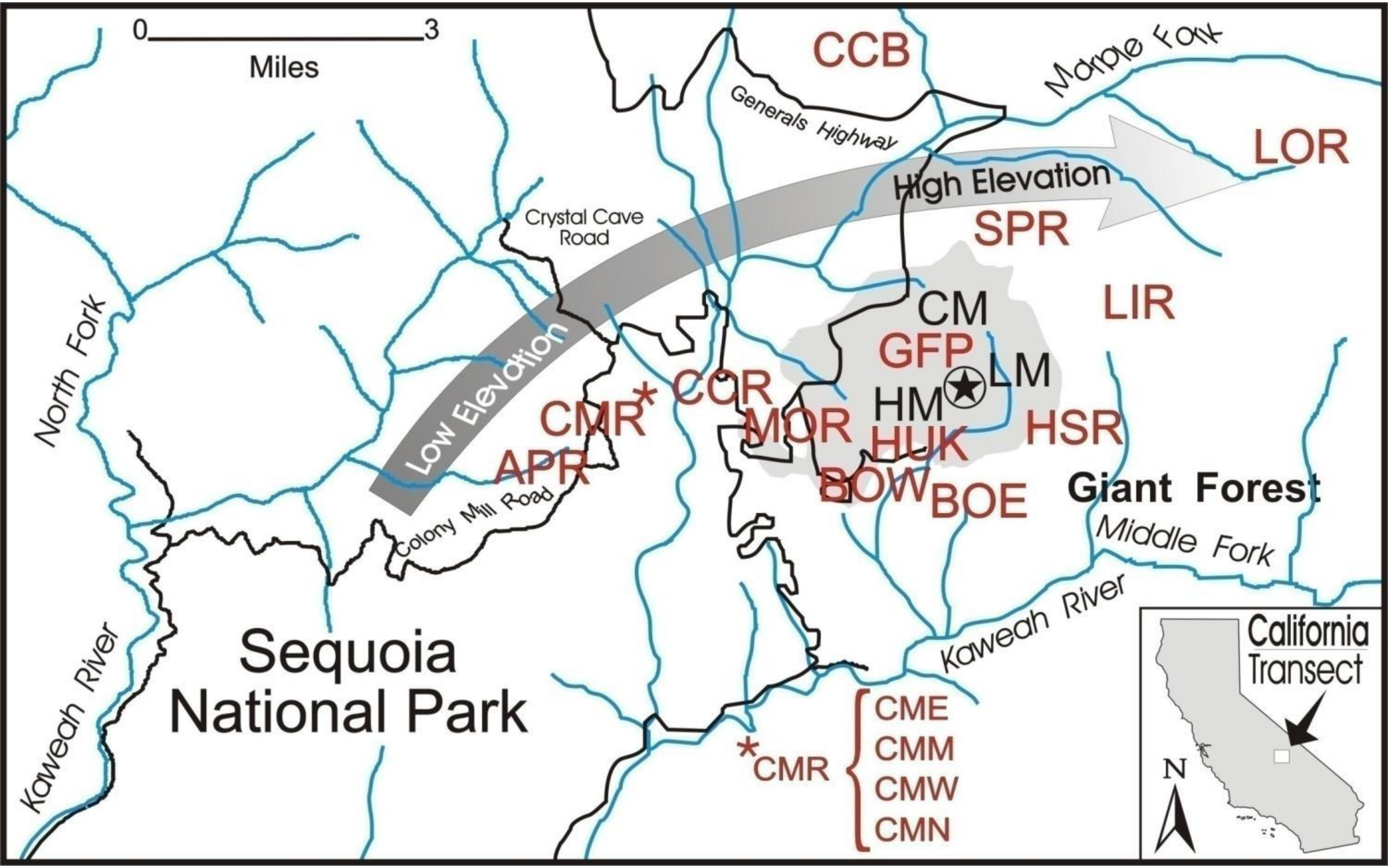


A global network of more than 400 sedimentary-charcoal records have been compiled and is now being used to evaluate regional, continental and global patterns of wildfire over the past 10,000+ years.

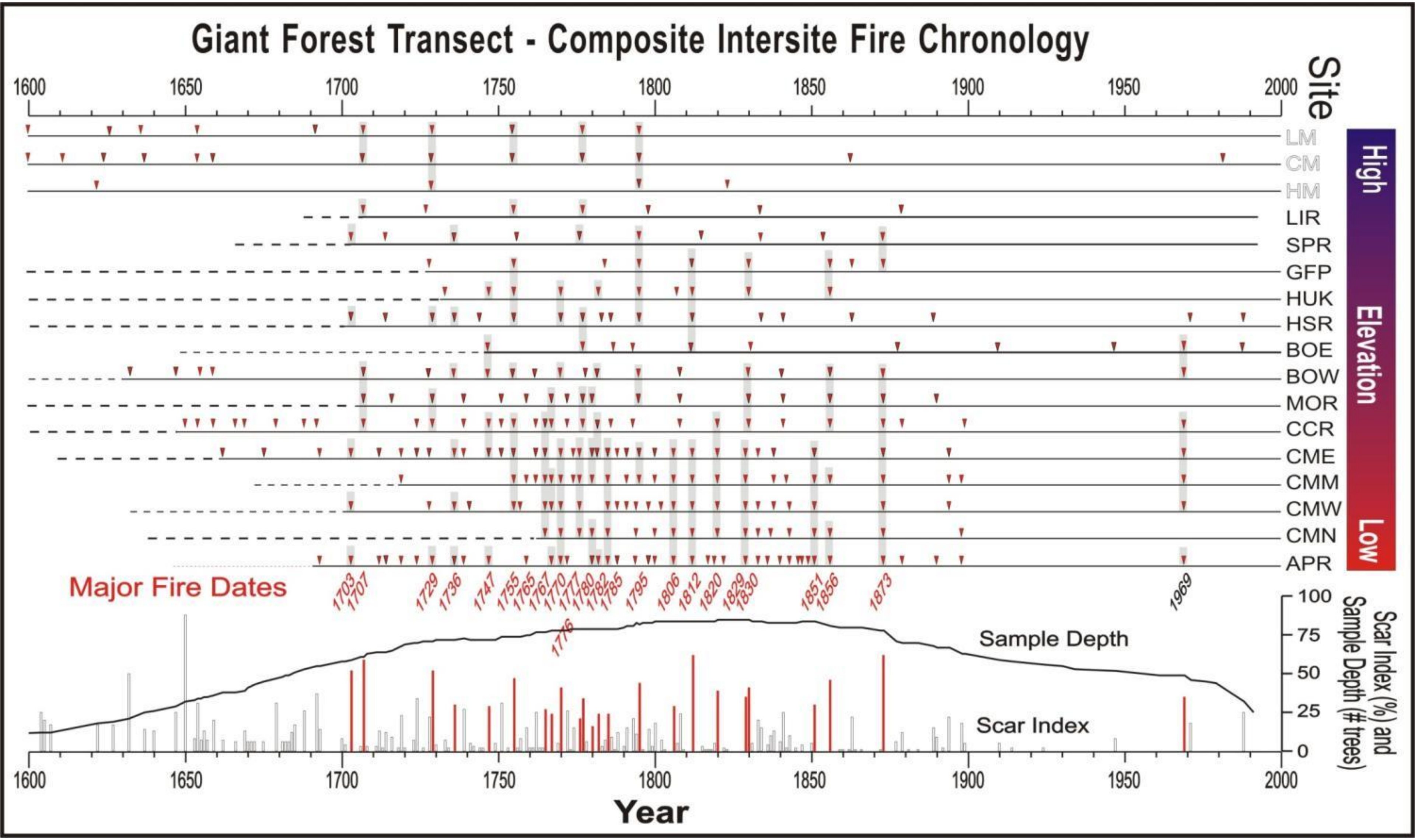


Charcoal inventory map (August 2008)
(http://www.bridge.bris.ac.uk/projects/QUEST_IGBP_Global_Palaeofire_WG/database.html)

Power et al. 2008. Climate Dynamics 30: 887-907.



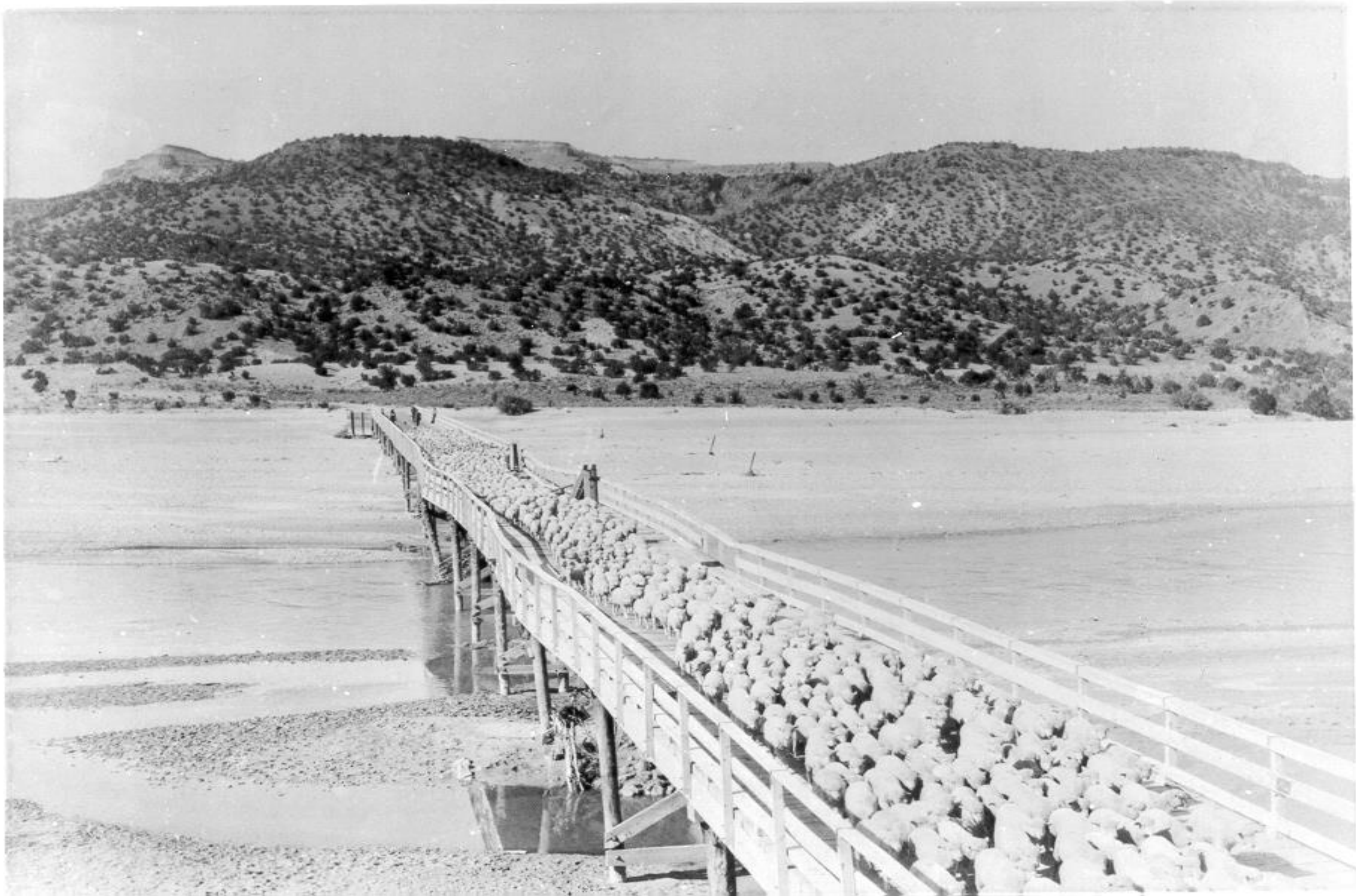
Caprio, A. C., and T. W. Swetnam.1995. Historic fire regimes along an elevational gradient on the west slope of the Sierra Nevada, California. In: J. K. Brown, R. W. Mutch, C. W. Spoon, and R. H. Wakimoto, tech. coords., Proceedings: Symposium on Fire in Wilderness and Park Management, Missoula, MT, March 30-April 1, 1993,. USDA Forest Service General Technical Report INT-320:173-179.



Caprio, A. C., and T. W. Swetnam.1995. Historic fire regimes along an elevational gradient on the west slope of the Sierra Nevada, California. In: J. K. Brown, R. W. Mutch, C. W. Spoon, and R. H. Wakimoto, tech. coords., Proceedings: Symposium on Fire in Wilderness and Park Management, Missoula, MT, March 30-April 1, 1993,. USDA Forest Service General Technical Report INT-320:173-179.

Legacy of Livestock Grazing

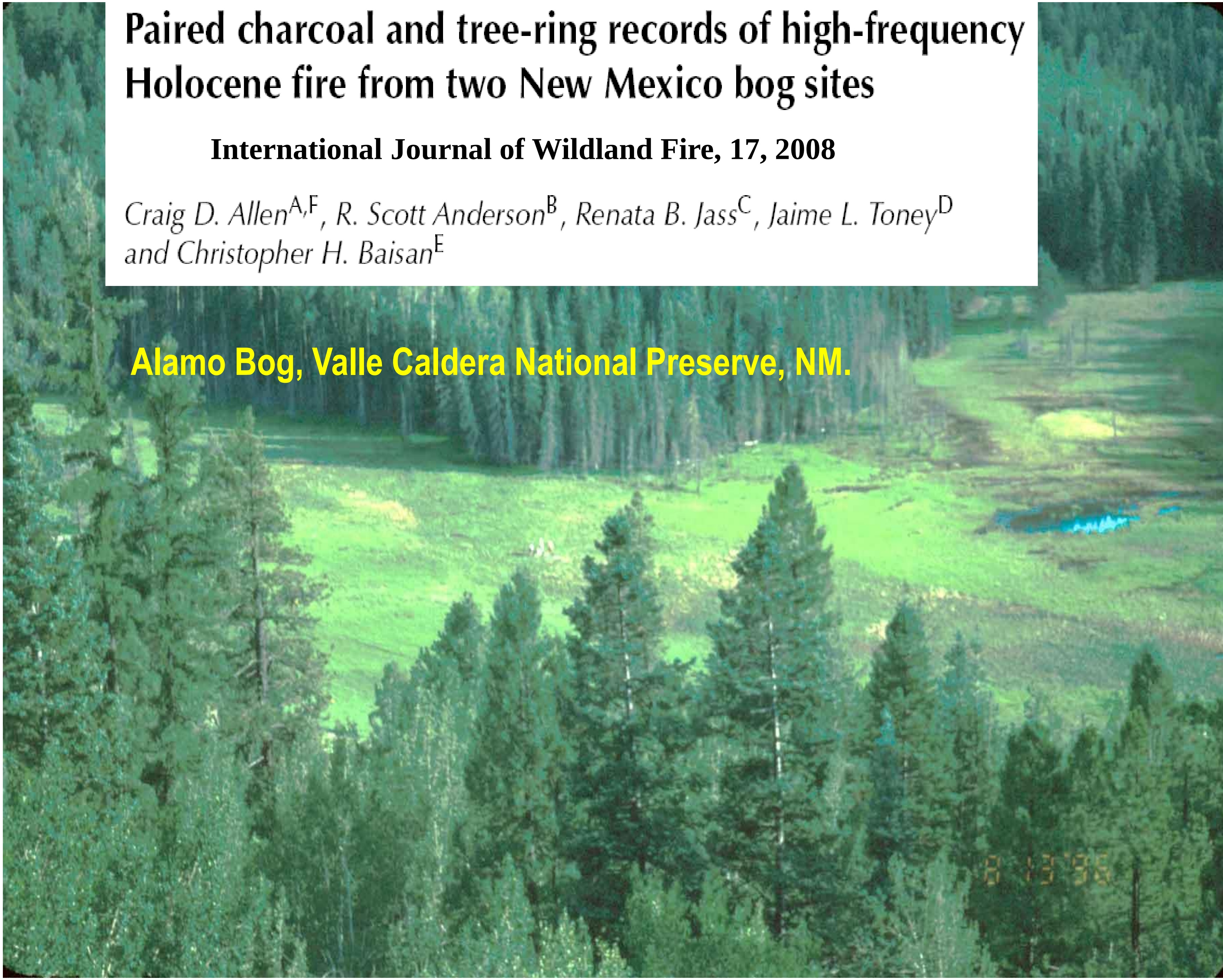
RAILROADS led to > 5 million sheep and 1.5 million cattle in New Mexico by 1890



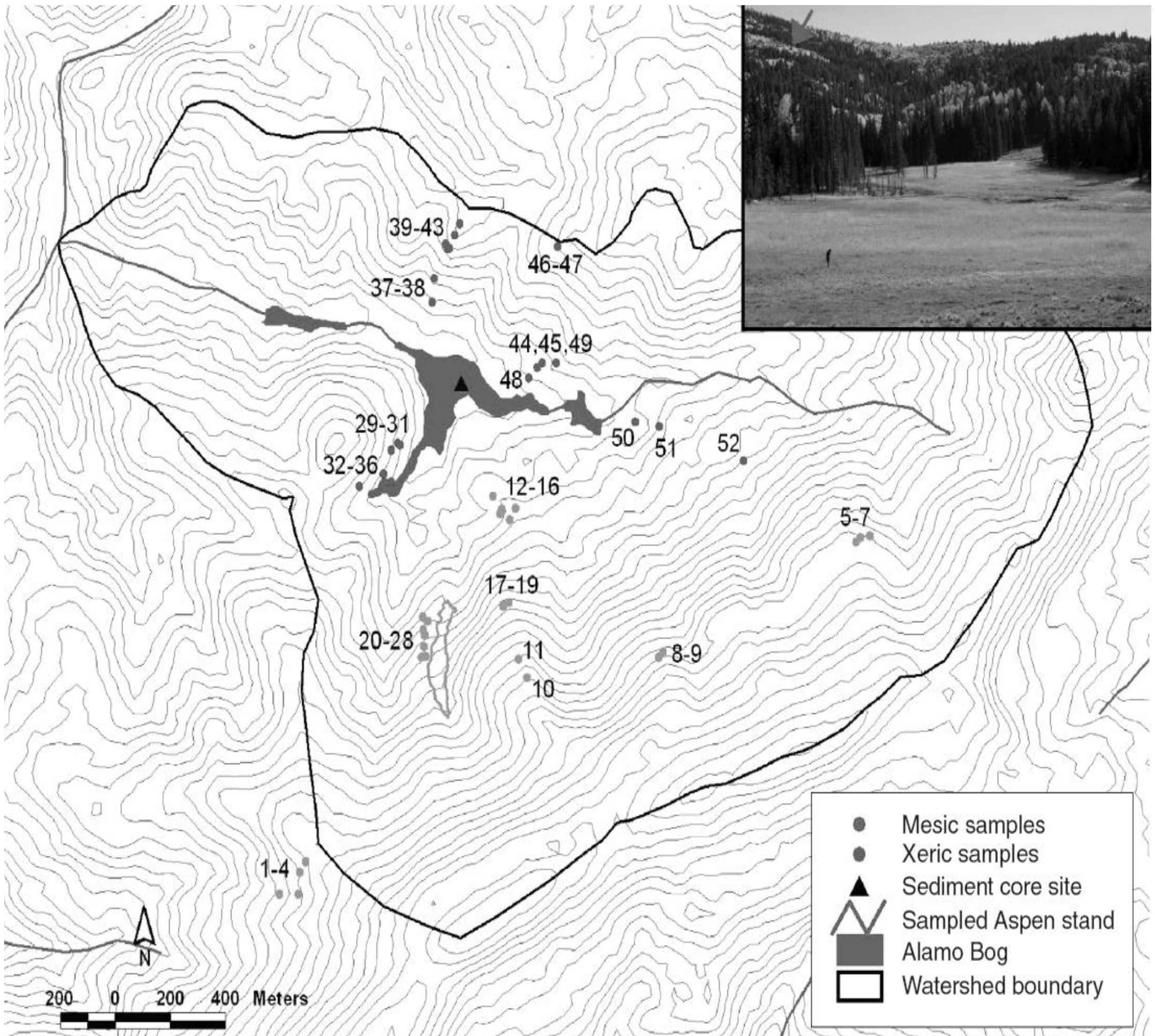
Paired charcoal and tree-ring records of high-frequency Holocene fire from two New Mexico bog sites

International Journal of Wildland Fire, 17, 2008

Craig D. Allen[A,F], R. Scott Anderson[B], Renata B. Jass[C], Jaime L. Toney[D] and Christopher H. Baisan[E]

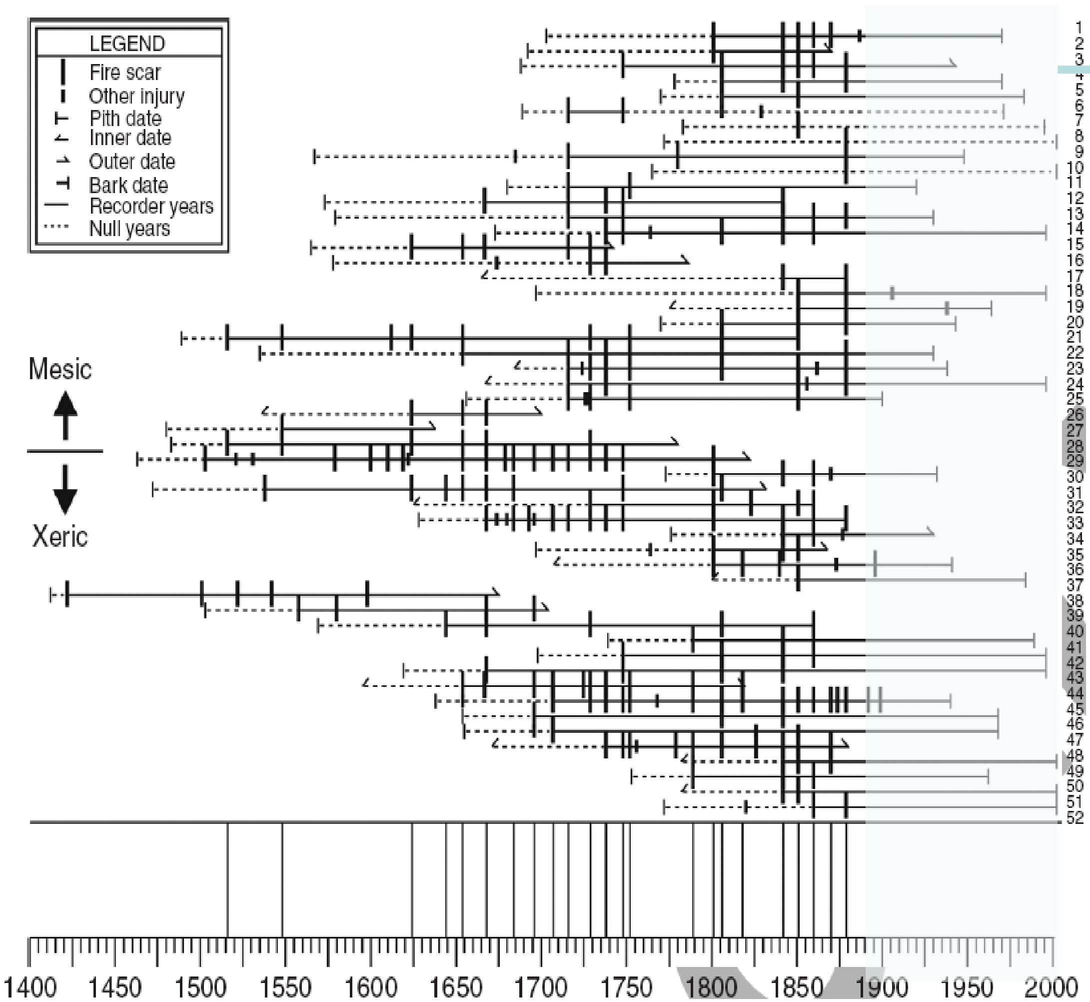


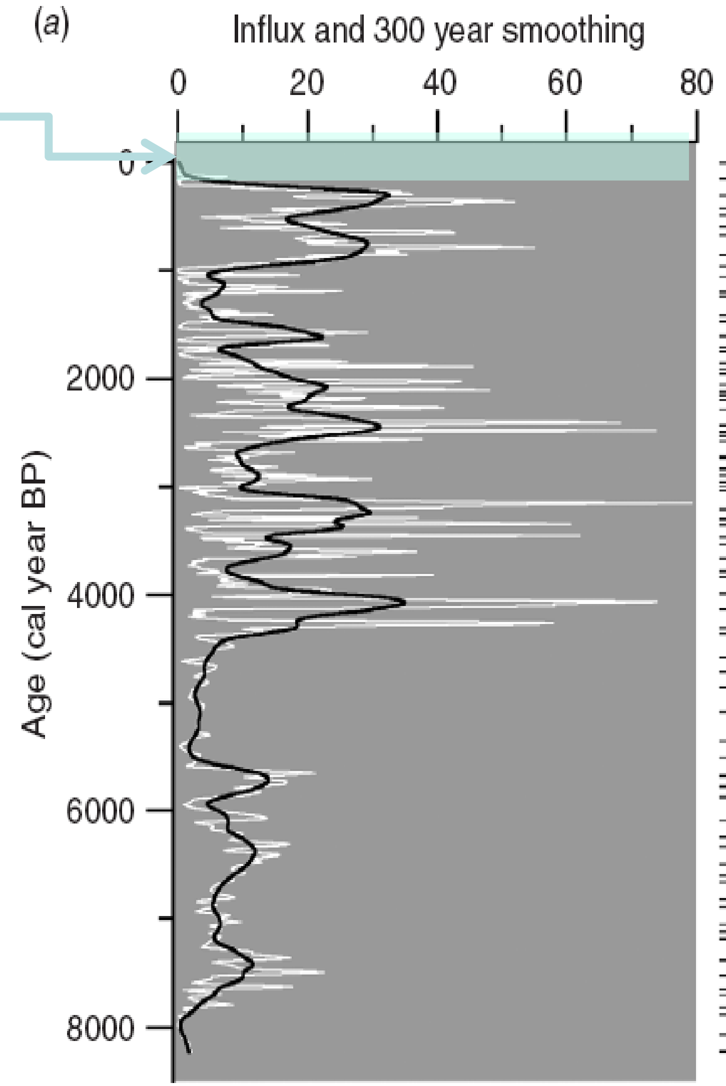
The fire-scar samples surround the bog, and so widespread fires indicated in the tree-ring record almost certainly fed charcoal into the bog, and/or burned the vegetation on the surface of the bog.



The fire scar records show the typical 20th century absence of surface fires, and the bog records show a corresponding charcoal hiatus at the top that is and unprecedented in at least 7,000 years.

Fire history at Alamo Bog





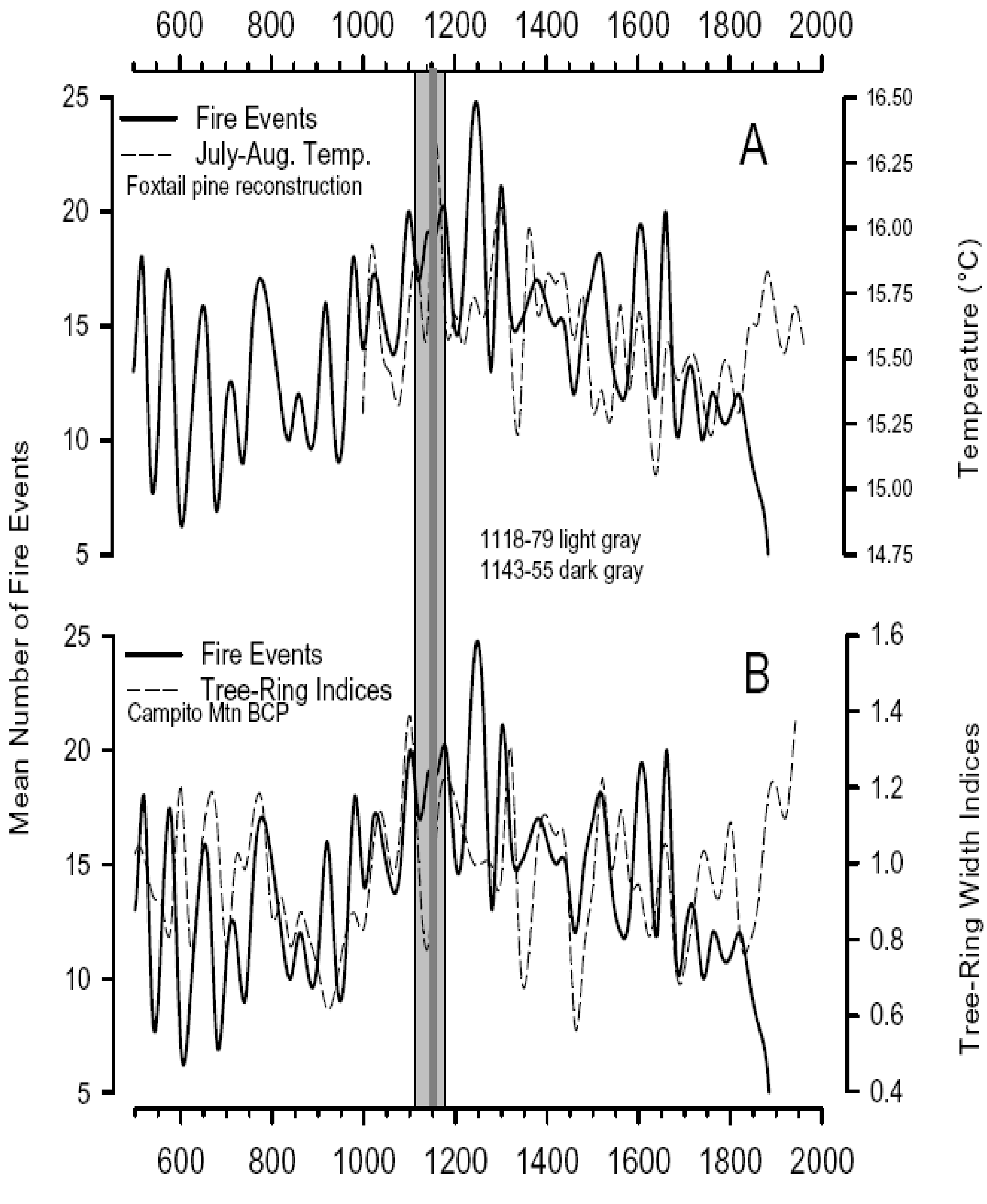
Fire-Climate-Human Interactions

- A long-standing debate and source of uncertainty in paleo-fire history is the relative role of human versus non-human controls and effects on fire regimes

- It is abundantly evident that humans have modified local-scale ecosystems and habitats for 10s of thousands of years. The uncertainty is their past effects at broader scales (landscapes to regions), and specific times and places where they were or were not controlling

- One aspect of this debate is the relative role of lightning versus human set fires

The longest duration drought in a recent Colorado River flow reconstruction (Meko et al. 2007, GRL) coincides with the longest duration high fire frequency period in giant sequoia groves.



Swetnam. 1993. Science 262: 885-889