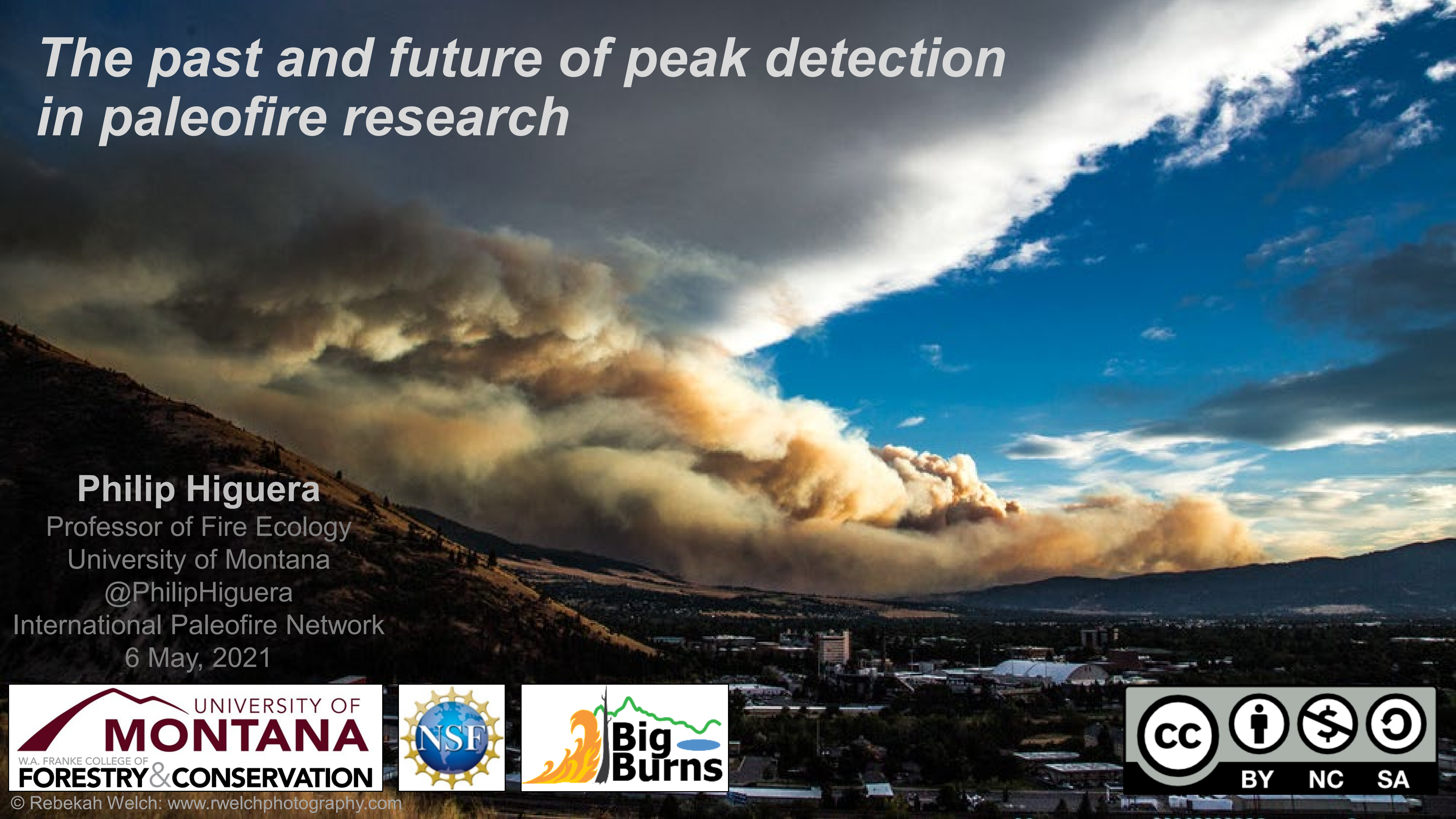
The past and future of peak detection in paleofire research



Philip Higuera
Professor of Fire Ecology
University of Montana
@PhilipHiguera

International Paleofire Network
6 May, 2021

UNIVERSITY OF MONTANA
W.A. FRANKE COLLEGE OF FORESTRY & CONSERVATION

NSF

Big Burns


Missoula

The past and future of peak detection

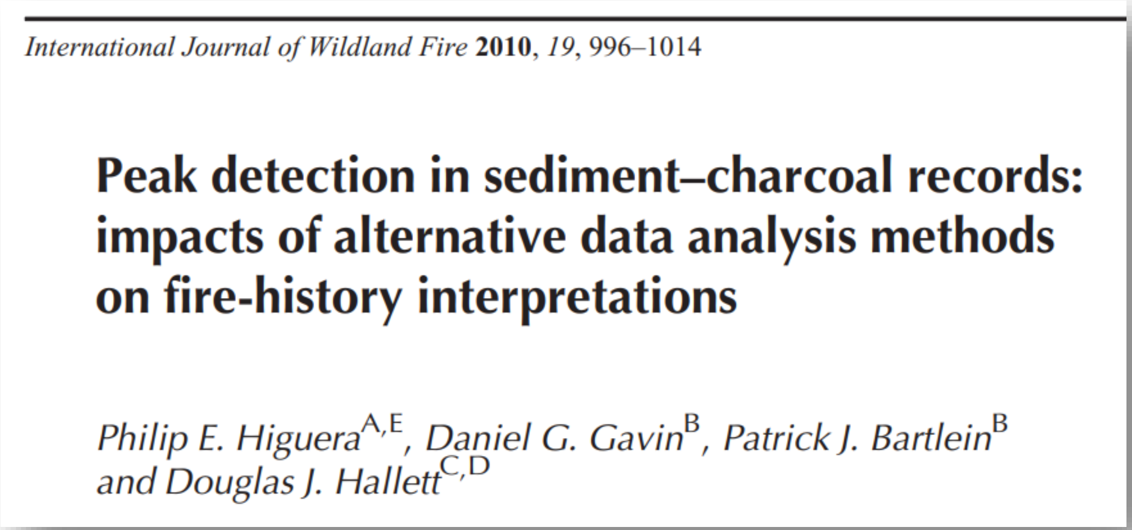
1. **Origin and development** of peak-detection methods

2. **Principles** of the decomposition approach and *CharAnalysis*

3. **Best practices and potential pitfalls** using peak detection to infer and interpret fire occurrence

4. **Future needs and opportunities**

*This will be fast…and I will skip things!


International Journal of Wildland Fire **2010**, *19*, 996–1014

Peak detection in sediment–charcoal records: impacts of alternative data analysis methods on fire-history interpretations

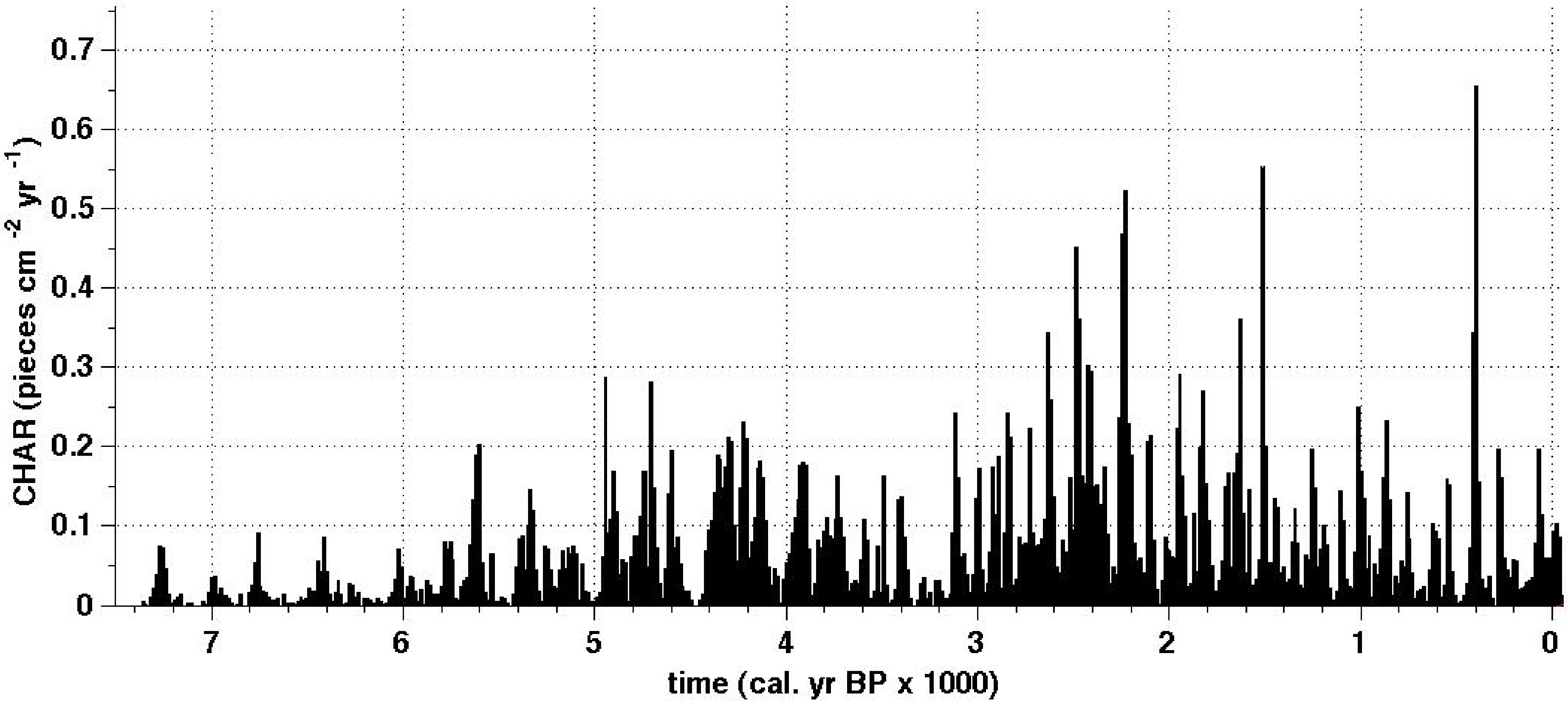
Philip E. Higuera[A,E], Daniel G. Gavin[B], Patrick J. Bartlein[B] and Douglas J. Hallett[C,D]

“Even when applying the most rigorous analytical techniques, there is no substitute for careful inspection of a record to assess whether it can provide an unbiased fire history in the first place.”

– Higuera et al. (2010)

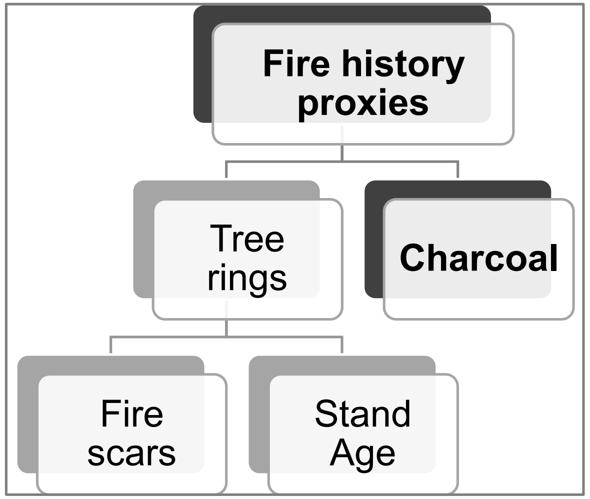
1. Origins and development

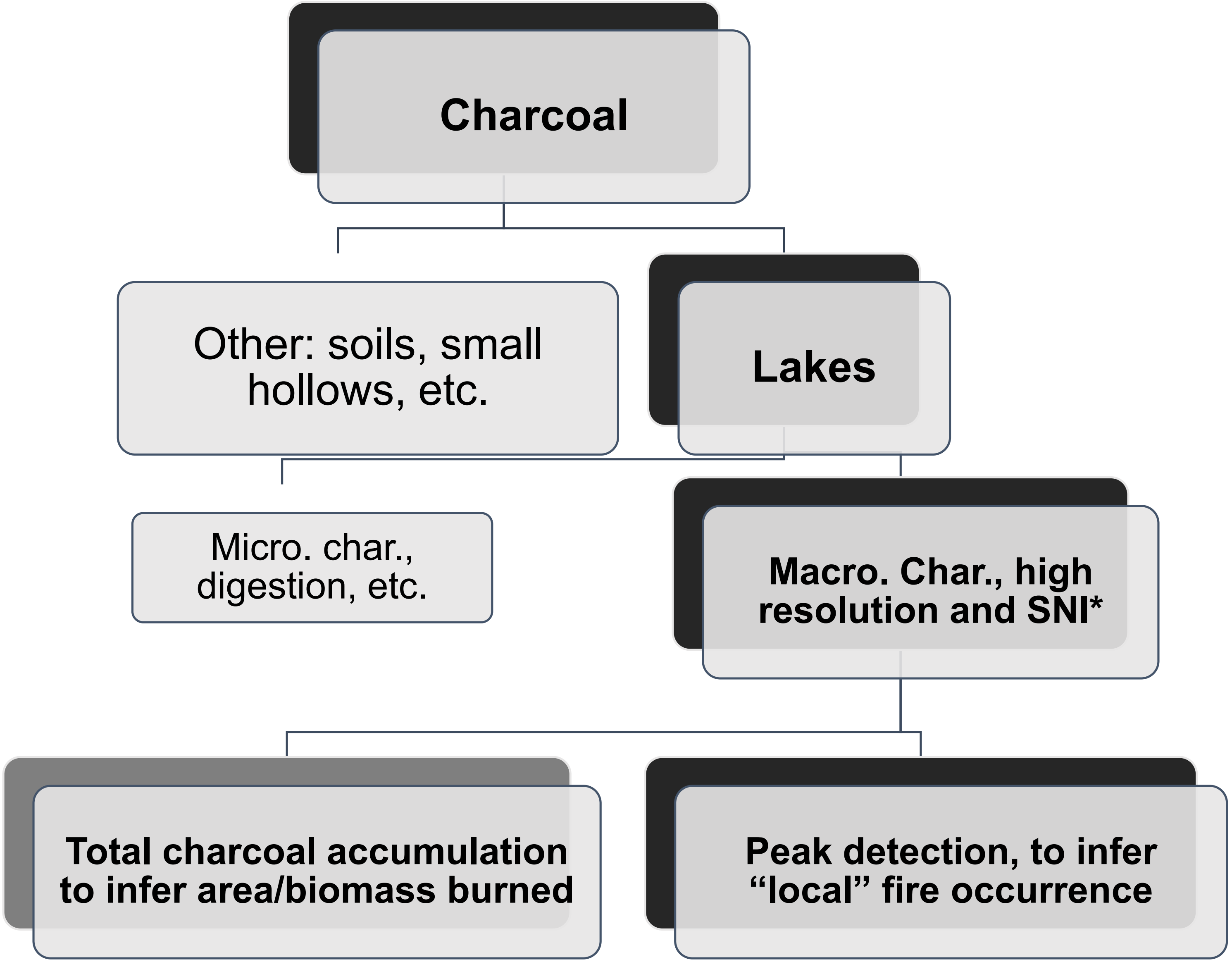
Peak detection: identifying charcoal "peaks" that are interpreted as individual fires or fire events; performed when the goal is to reconstruct "local" fire history.



Code Lake, Alaska, the example datasets distributed with *CharAnalysis.*

1. Origins and development

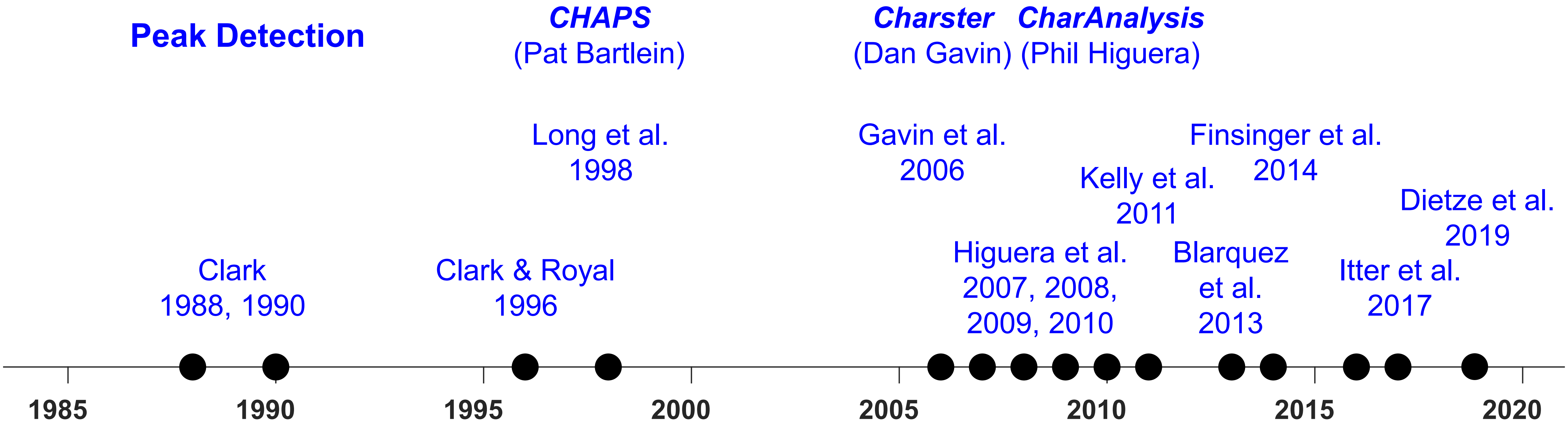




Peak detection is just one of many approaches used to infer fire history in paleo records

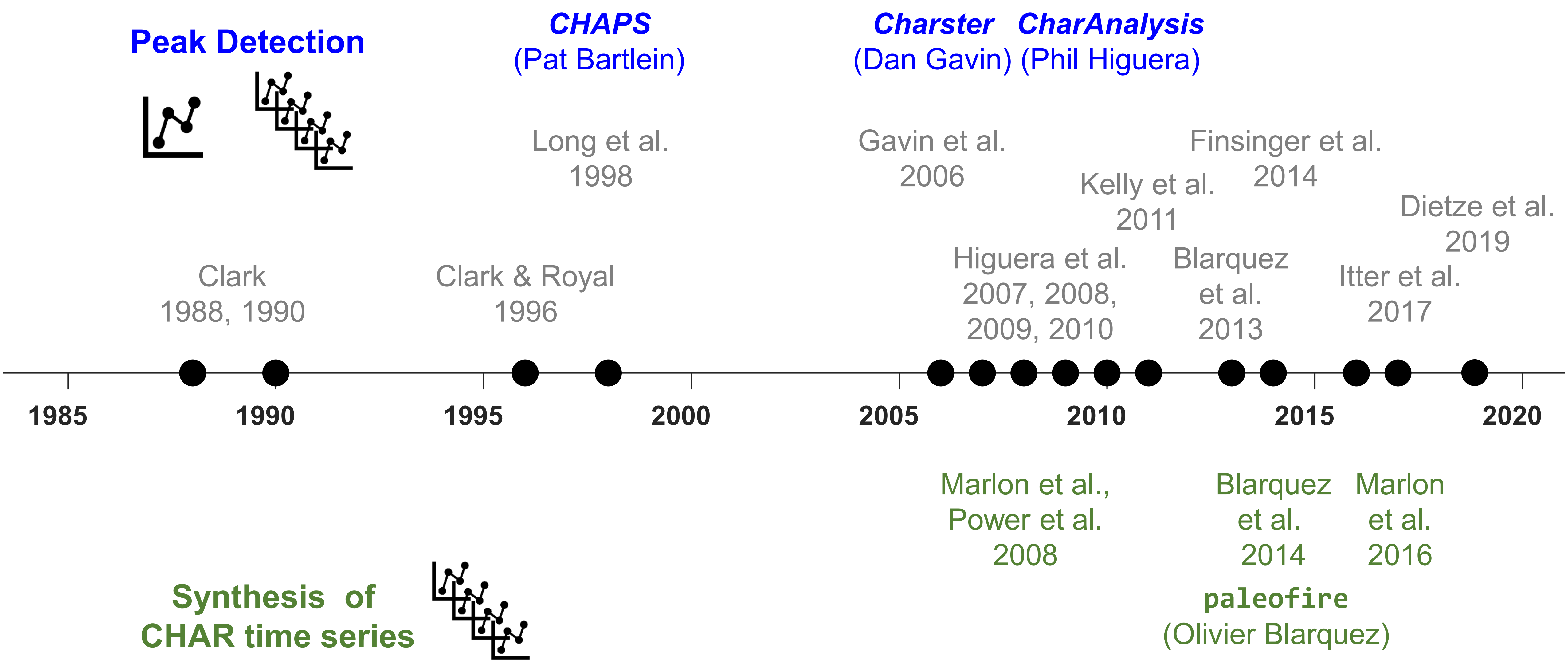
*SNI: signal-to-noise index, Kelly et al. (2011)

1. Origins and development



This is NOT a complete list; this highlights “first” papers introducing new peak-analysis methods, and/or significant advances.

1. Origins and development



1. Origins and development

QUATERNARY RESEARCH 30, 67–80 (1988)

Particle Motion and the Theory of Charcoal Analysis: Source Area, Transport, Deposition, and Sampling

JAMES S. CLARK[1]

Ecological Monographs, 60(2), 1990, pp. 135–159
© 1990 by the Ecological Society of America

FIRE AND CLIMATE CHANGE DURING THE LAST 750 YR IN NORTHWESTERN MINNESOTA[1]

JAMES S. CLARK[2]

NATURE VOL. 334 21 JULY 1988 LETTERS

Effect of climate change on fire regimes in northwestern Minnesota

James S. Clark*

Journal of Ecology 1996, 84, 365–382

Local and regional sediment charcoal evidence for fire regimes in presettlement north-eastern North America

JAMES S. CLARK and P. DANIEL ROYALL*

A 9000-year fire history from the Oregon Coast Range, based on a high-resolution charcoal study

Colin J. Long, Cathy Whitlock, Patrick J. Bartlein, and Sarah H. Millspaugh

ELSEVIER Quaternary Science Reviews 26 (2007) 1790–1809 QSR

Understanding the origin and analysis of sediment-charcoal records with a simulation model

Philip E. Higuera[a,b,*], Matthew E. Peters[c,d,1], Linda B. Brubaker[a], Daniel G. Gavin[e]

Ecological Monographs, 79(2), 2009, pp. 201–219
© 2009 by the Ecological Society of America

Vegetation mediated the impacts of postglacial climate change on fire regimes in the south-central Brooks Range, Alaska

PHILIP E. HIGUERA,[1,5] LINDA B. BRUBAKER,[1] PATRICIA M. ANDERSON,[2] FENG SHENG HU,[3] AND THOMAS A. BROWN[4]

Ecology, 87(7), 2006, pp. 1722–1732
© 2006 by the Ecological Society of America

WEAK CLIMATIC CONTROL OF STAND-SCALE FIRE HISTORY DURING THE LATE HOLOCENE

DANIEL G. GAVIN,[1,4] FENG SHENG HU,[1] KENNETH LERTZMAN,[2] AND PETER CORBETT[3]

International Journal of Wildland Fire 2010, 19, 996–1014

Peak detection in sediment–charcoal records: impacts of alternative data analysis methods on fire-history interpretations

Philip E. Higuera[A,E], Daniel G. Gavin[B], Patrick J. Bartlein[B] and Douglas J. Hallett[C,D]

RESEARCH ARTICLE WILEY

A model-based approach to wildland fire reconstruction using sediment charcoal records

Malcolm S. Itter[1] | Andrew O. Finley[1,2] | Mevin B. Hooten[3,4,5] | Philip E. Higuera[6] | Jennifer R. Marlon[7] | Ryan Kelly[8] | Jason S. McLachlan[9]

ELSEVIER Quaternary Research
journal homepage: www.elsevier.com/locate/yqres

Short Paper

A signal-to-noise index to quantify the potential for peak detection in sediment–charcoal records

Ryan F. Kelly[a,*], Philip E. Higuera[b], Carolyn M. Barrett[c], Feng Sheng Hu[a,c]

A guide to screening charcoal peaks in macrocharcoal-area records for fire-episode reconstructions

Walter Finsinger,[1] Ryan Kelly,[2] Jordan

The Holocene 2014, Vol. 24(8) 1002–1008

RESEARCH ARTICLE

Human-induced fire regime shifts during 19th century industrialization: A robust fire regime reconstruction using northern Polish lake sediments

Elisabeth Dietze[1,2,*], Dariusz Brykała[3], Laura T. Schreuder[4], Krzysztof Jażdżewski[5], Olivier Blarquez[6], Achim Brauer[2], Michael Dietze[7], Milena Obremska[8], Florian Ott[9], Anna Pieńczewska[10], Stefan Schouten[4,11], Ellen C. Hopmans[4], Michał Słowiński[12]

GEOPHYSICAL RESEARCH

Paleofire reconstruction based on an ensemble-member strategy applied to sedimentary charcoal

Olivier Blarquez,[1,2] Martin P. Girardin,[3] Bérangère Leys,[4] Adam A. Ali,[5] Julie C. Aleman,[4,5] Yves Bergeron,[2] and Christopher Carcaillet[4]

Clim Dyn (2008) 30:887–907
DOI 10.1007/s00382-007-0334-x

Changes in fire regimes since the Last Glacial Maximum: an assessment based on a global synthesis and analysis of charcoal data

M. J. Power · J. Marlon · N. Ortiz · P. J. Bartlein · S. P. Ha… · R. H. W. Bradshaw · C. Carcaillet · C. Cordova · S. Moone… · K. Thonicke · W. Tinner · C. Whitlock · Y. Zhang · Y. Zha… · H. Behling · C. Briles · K. J. Brown · A. Brunelle · M. Bush · D. Colombaroli · S. Connor · A.-L. Daniau · M. Daniels · J. … · W. Finsinger · D. Foster · J. Frechette · M.-J. Gaillard · D. … · D. J. Hallett · P. Higuera · G. Hope · S. Horn · J. Inoue · P. … · C. Larsen · C. J. Long · J. Lynch · E. A. Lynch · M. McGlo… · T. Minckley · J. Mohr · D. M. Nelson · J. New · R. Newnha… · P. J. H. Richard · C. Rowe · M. F. Sanchez Goñi · B. N. Sh… · C. Turney · D. H. Urrego-Sanchez · C. Umbanhowar · M. V… · M. Walsh · X. Wang · N. Williams · J. Wilmshurst · J. H. Zhang

ARTICLES

Climate and human influences on global biomass burning over the past two millennia

J. R. MARLON[1*], P. J. BARTLEIN[1], C. CARCAILLET[2], D. G. GAVIN[1], S. P. HARRISON[3], P. E. HIGUERA[4], F. JOOS[5], M. J. POWER[6] AND I. C. PRENTICE[7]

Computers & Geosciences 72 (2014) 255–261
Contents lists available at ScienceDirect
ELSEVIER Computers & Geosciences
journal homepage: www.elsevier.com/locate/cageo

paleofire: An R package to analyse sedimentary charcoal records from the Global Charcoal Database to reconstruct past biomass burning

Olivier Blarquez[a,b,*], Boris Vannière[c], Jennifer R. … Mitchell J. Power[f], Simon Brewer[g], Patrick J. Bart…

Biogeosciences, 13, 3225–3244, 2016
www.biogeosciences.net/13/3225/2016/
doi:10.5194/bg-13-3225-2016
© Author(s) 2016. CC Attribution 3.0 License.
Biogeosciences EGU

Reconstructions of biomass burning from sediment-charcoal records to improve data–model comparisons

Jennifer R. Marlon[1], Ryan Kelly[2], Anne-Laure Daniau[3], Boris Vannière[4], Mitchell J. Power[5], Patrick Bartlein[6], Philip Higuera[7], Olivier Blarquez[8], Simon Brewer[9], Tim Brücher[10], Angelica Feurdean[10,11], Graciela Gil Romera[12], Virginia Iglesias[6], S. Yoshi Maezumi[13], Brian Magi[14], Colin J. Courtney Mustaphi[15], and Tonishtan Zhihai[16]

This is NOT a complete list; this highlights "first" papers introducing new peak-analysis methods, and/or significant advances.

Any paper with Higuera as co-author is available here: https://www.cfc.umt.edu/research/paleoecologylab/publications/default.php

Blarquez, O., M. P. Girardin, B. Leys, A. A. Ali, J. C. Aleman, Y. Bergeron, and C. Carcaillet. 2013. Paleofire reconstruction based on an ensemble-member strategy applied to sedimentary charcoal. Geophysical Research Letters 40:2667-2672. https://doi.org/10.1002/grl.50504

Blarquez, O., B. Vannière, J. R. Marlon, A.-L. Daniau, M. J. Power, S. Brewer, and P. J. Bartlein. 2014. paleofire: An R package to analyze sedimentary charcoal records from the Global Charcoal Database to reconstruct past biomass burning. Computers & Geosciences 72:255-261. http://dx.doi.org/10.1016/j.cageo.2014.07.020

Clark, J. S. 1988. Effects of climate change on fire regimes in northwestern Minnesota. Nature 334:233-235. https://www.nature.com/articles/334233a0

Clark, J. S. 1988. Particle motion and the theory of charcoal analysis: source area, transport, deposition, and sampling. Quaternary Research 30:67-80. https://doi.org/10.1016/0033-5894(88)90088-9

Clark, J. S. 1990. Fire and climate change during the last 750 yr in northwestern Minnesota. Ecological Monographs 60:135-159. https://doi.org/10.2307/1943042

Clark, J. S., and P. D. Royall. 1996. Local and regional sediment charcoal evidence for fire regimes in presettlement north-eastern North America. Journal of Ecology 84:365-382. https://www.jstor.org/stable/pdf/2261199.pdf

Dietze, E., D. Brykala, L. T. Schreuder, K. Jazdzewski, O. Blarquez, A. Brauer, M. Dietze, M. Obremska, F. Ott, A. Pienczewska, et al. 2019. Human-induced fire regime shifts during 19th century industrialization: A robust fire regime reconstruction using northern Polish lake sediments. PLoS ONE 14:e0222011. https://doi.org/10.1371/journal.pone.0222011

Finsinger, W., R. Kelly, J. Fevre, and E. K. Magyari. 2014. A guide to screening charcoal peaks in macrocharcoal-area records for fire-episode reconstructions. The Holocene 24:1002-1008. https://doi.org/10.1177%2F0959683614534737

Gavin, D. G., F. S. Hu, K. Lertzman, and P. Corbett. 2006. Weak climatic control of stand-scale fire history during the late Holocene. Ecology 87:1722-1732. https://doi.org/10.1890/0012-9658(2006)87[1722:WCCOSF]2.0.CO;2

Higuera, P. E., L. B. Brubaker, P. M. Anderson, T. A. Brown, A. T. Kennedy, and F. S. Hu. 2008. Frequent Fires in Ancient Shrub Tundra: Implications of Paleorecords for Arctic Environmental Change. PLoS ONE 3:e0001744. https://doi.org/10.1371/journal.pone.0001744

Higuera, P. E., L. B. Brubaker, P. M. Anderson, F. S. Hu, and T. A. Brown. 2009. Vegetation mediated the impacts of postglacial climate change on fire regimes in the south-central Brooks Range, Alaska. Ecological Monographs 79:201-219. https://doi.org/10.1890/07-2019.1

Higuera, P. E., D. G. Gavin, P. J. Bartlein, and D. J. Hallett. 2010. Peak detection in sediment-charcoal records: impacts of alternative data analysis methods on fire-history interpretations. International Journal of Wildland Fire 19:996-1014. https://doi.org/10.1071/WF09134

Higuera, P. E., M. E. Peters, L. B. Brubaker, and D. G. Gavin. 2007. Understanding the origin and analysis of sediment-charcoal records with a simulation model. Quaternary Science Reviews 26:1790-1809. https://doi.org/10.1016/j.quascirev.2007.03.010

Itter, M. S., A. O. Finley, M. B. Hooten, P. E. Higuera, J. R. Marlon, R. Kelly, and J. S. McLachlan. 2017. A model-based approach to wildland fire reconstruction using sediment charcoal records. Environmetrics:e2450. https://doi.org/10.1002/env.2450

Kelly, R. F., P. E. Higuera, C. M. Barrett, and F. S. Hu. 2011. A signal-to-noise index to quantify the potential for peak detection in sediment-charcoal records. Quaternary Research 75:11-17. https://doi.org/10.1016/j.yqres.2010.07.011

Long, C. J., C. Whitlock, P. J. Bartlein, and S. H. Millspaugh. 1998. A 9000-year fire history from the Oregon Coast Range, based on a high-resolution charcoal study. Canadian Journal of Forest Research 28:774-787. https://doi.org/10.1139/x98-051

Marlon, J. R., P. J. Bartlein, C. Carcaillet, D. G. Gavin, S. P. Harrison, P. E. Higuera, F. Joos, M. J. Power, and I. C. Prentice. 2008. Climate and human influences on global biomass burning over the past two millennia. Nature Geoscience 1:697-702. https://www.nature.com/articles/ngeo313

Power, M. J., J. Marlon, N. Ortiz, P. J. Bartlein, S. P. Harrison, F. E. Mayle, A. Ballouche, R. H. W. Bradshaw, C. Carcaillet, C. Cordova, et al. 2008. Changes in fire regimes since the Last Glacial Maximum: an assessment based on a global synthesis and analysis of charcoal data. Climate Dynamics 30:887-907. https://link.springer.com/article/10.1007/s00382-007-0334-x

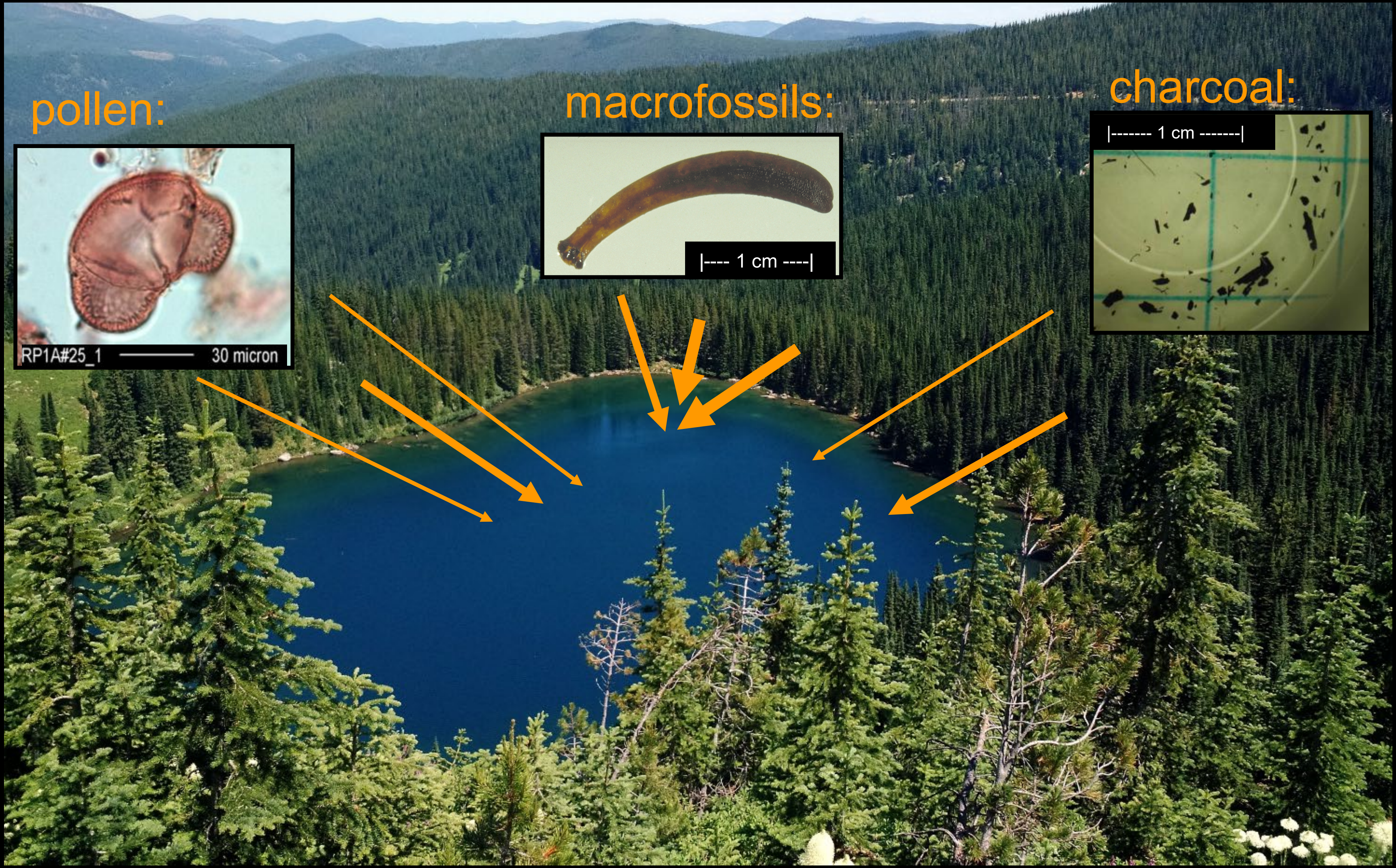
1. Origins and development

Peak detection is best suited for high-severity fire regimes

"Identifying fire episodes from charcoal records is most promising when fires:
(1) are large [relative to the charcoal source area];
(2) burn with high severity; and
(3) recur with average intervals at least five times the sampling resolution of the sediment record (Clark 1988b; Whitlock and Larsen 2001; Higuera et al. 2005, 2007).

Sediment–charcoal records are thus particularly valuable for studying stand-replacing fire regimes in boreal and subalpine forests, where all three of these conditions are typically met." - Higuera et al. (2010)

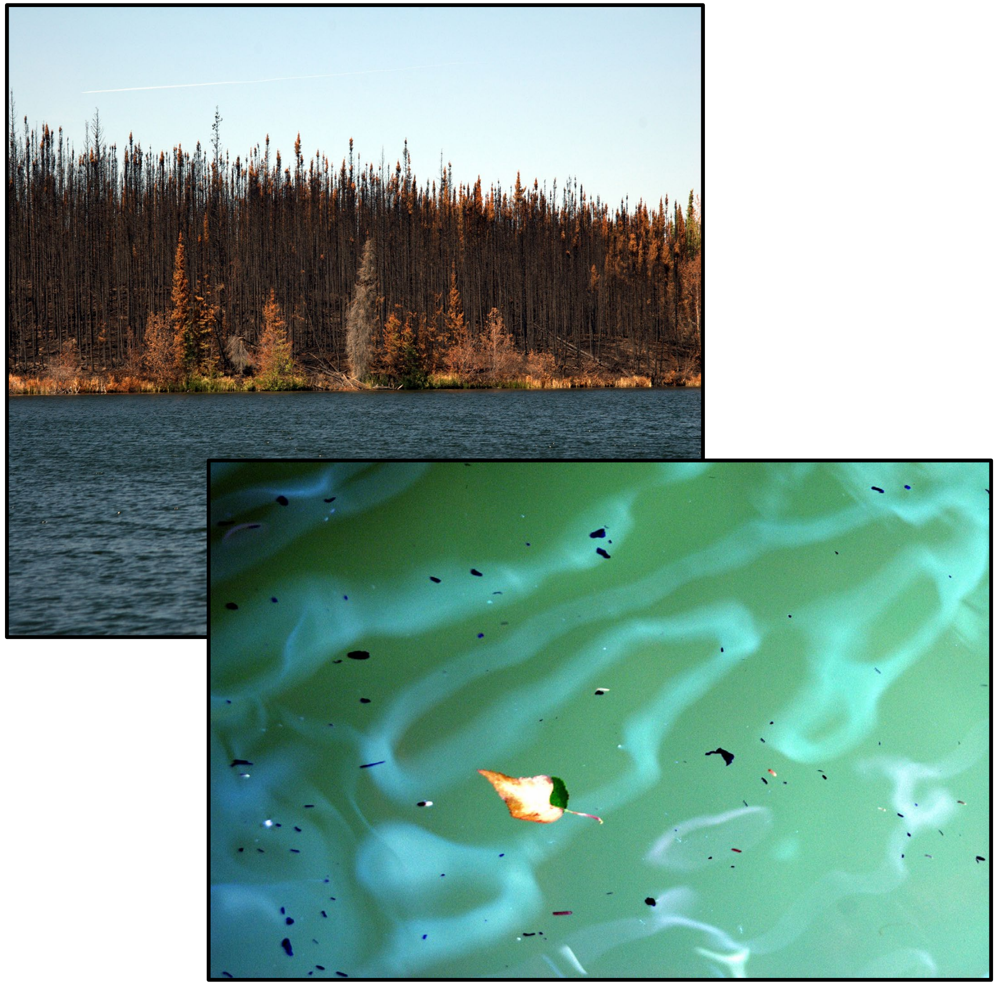
2. Principles of decomposition and *CharAnalysis*



Missoula Lake, Lolo National Forest, Montana (P. Higuera)

Charcoal comes from fire, primarily from airborne deposition

Charcoal production varies within and between fires



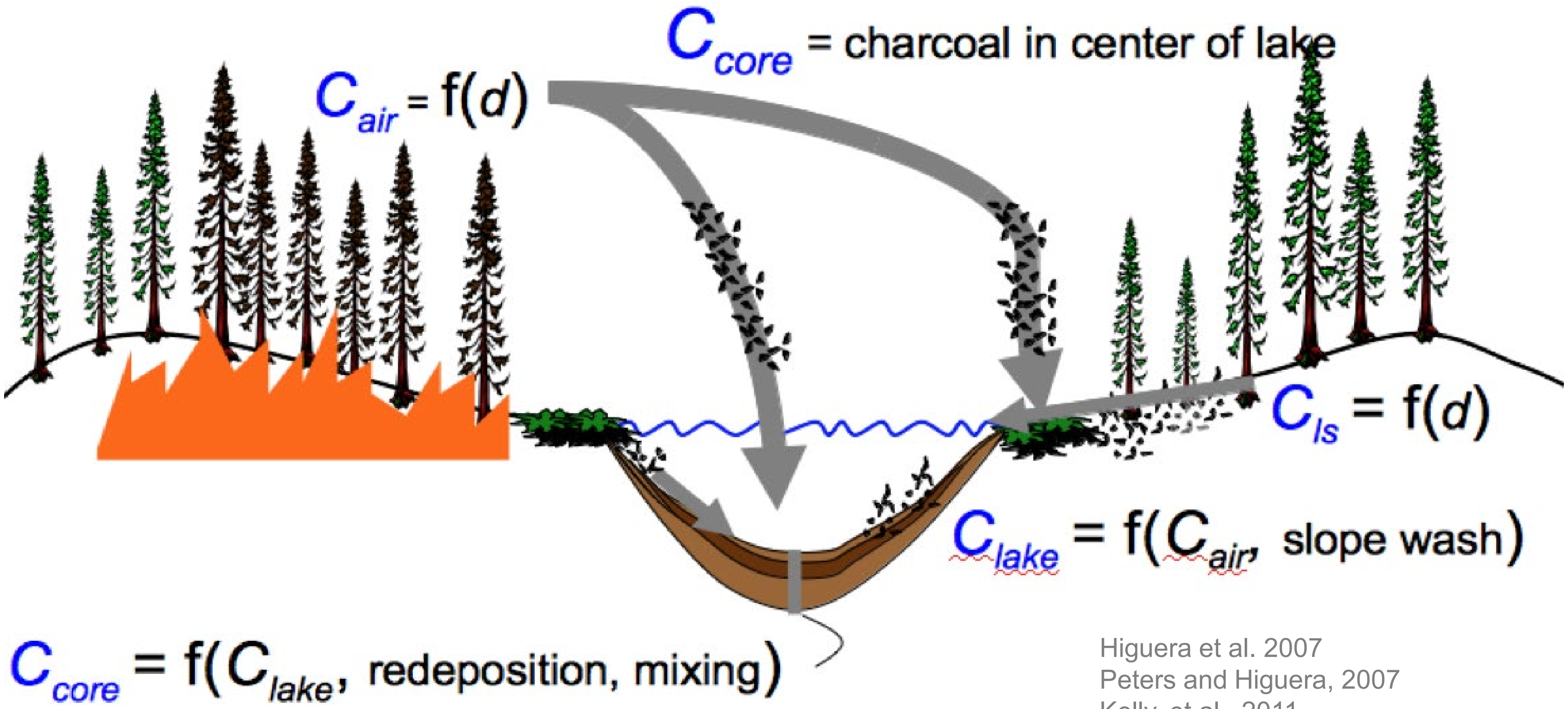
Charcoal floating on a lake surface days after a boreal forest fire in Alaska.

Crown-fire in a high-elevation (subalpine) forest in Yellowstone NP, characterized historically by a high-severity fire regimes (photo: NPS).

Surface-fire in a low-elevation (montane) forest in the N. Rockies, characterized historically by a low-severity fire regimes. .

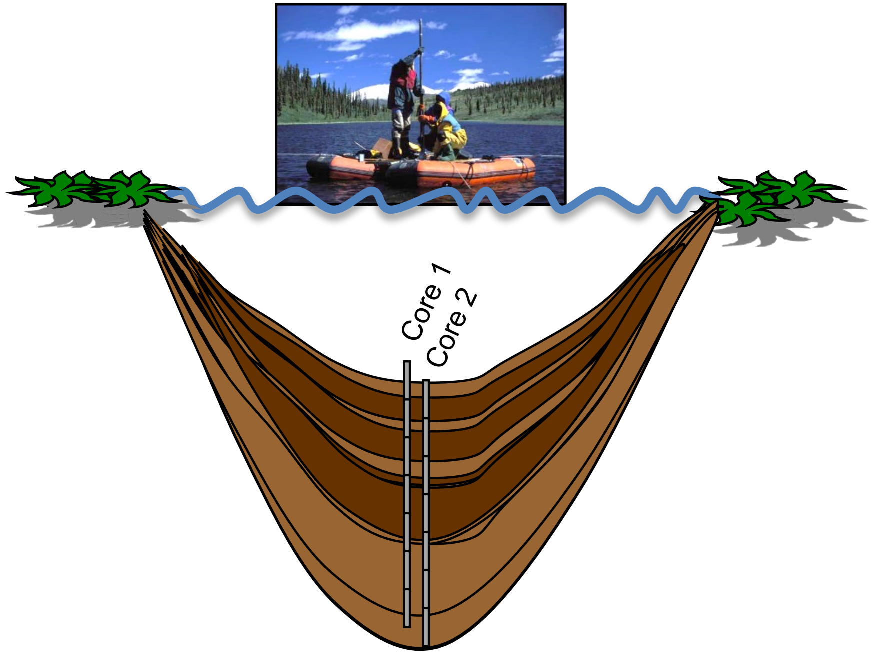
Amount of charcoal depends on charcoal production, distance, injection height, & wind

Slope wash, within-lake redeposition, and mixing "blur" record

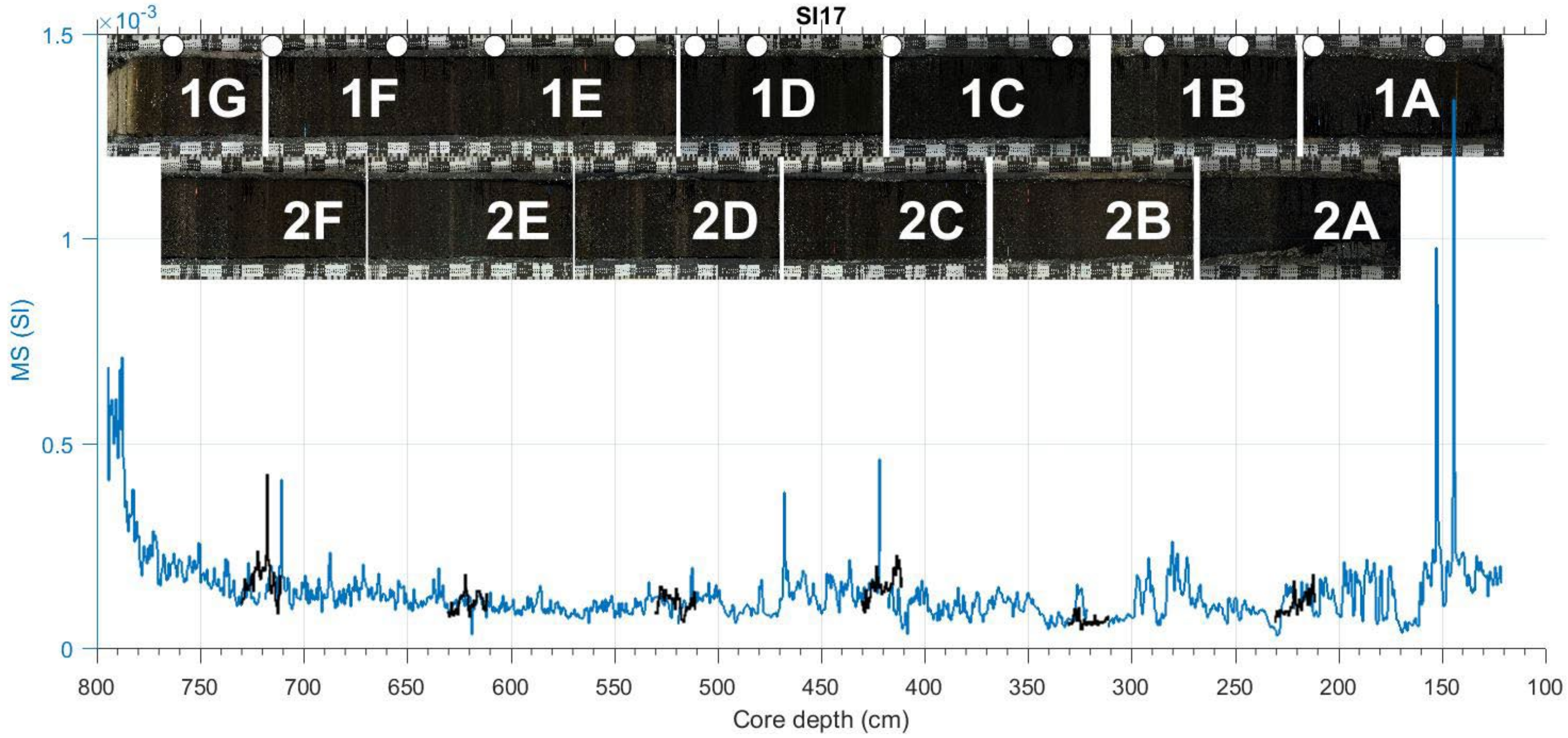


Higuera et al. 2007
Peters and Higuera, 2007
Kelly, et al., 2011

Small, deep lakes with small or no inlet maximize resolution, and minimize charcoal source area:

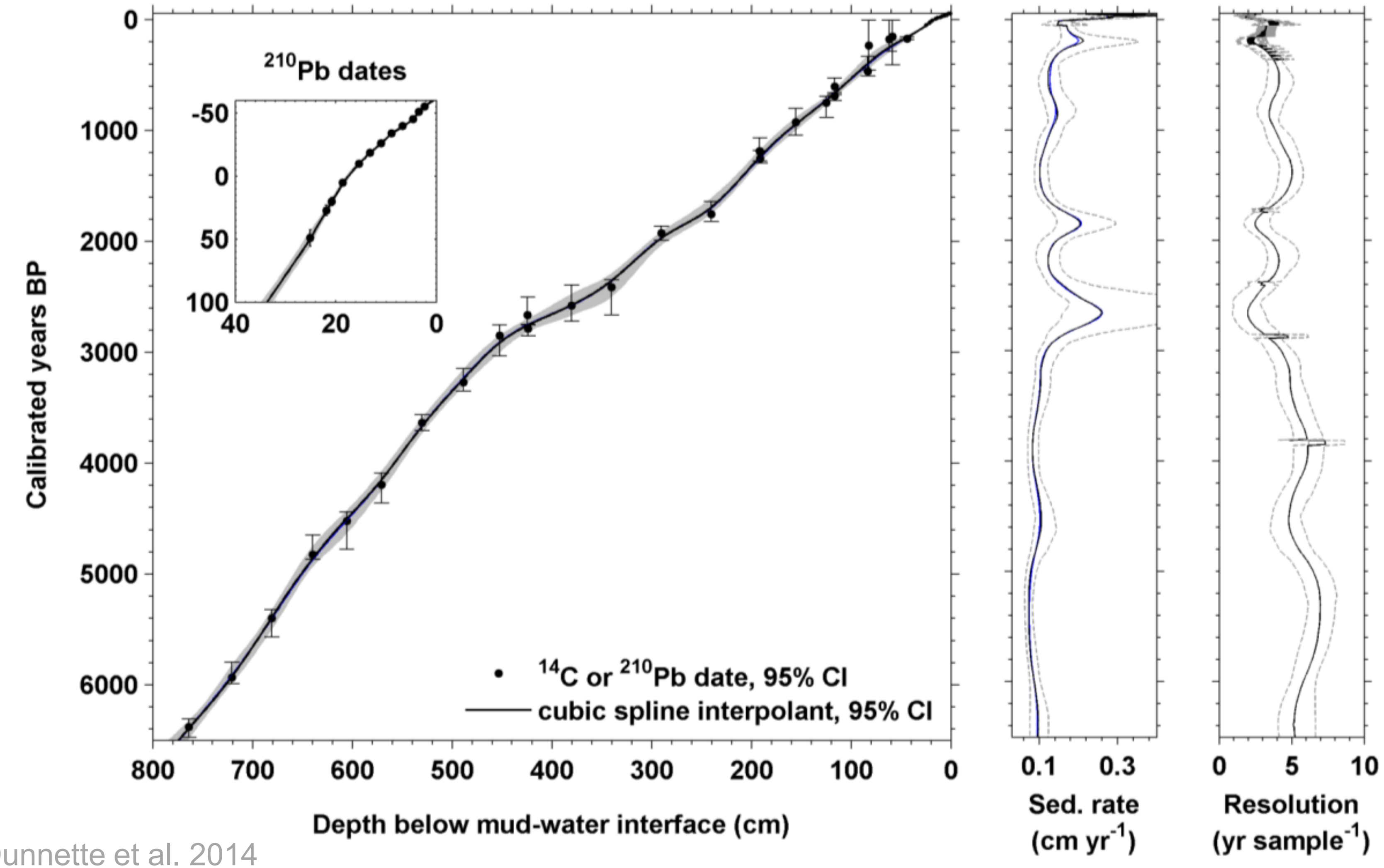


Because fire events are discrete, parallel cores and contiguous sampling needed to provide a continuous record:



Silver Lake, Montana (Wolf, Higuera et al., in prep.)

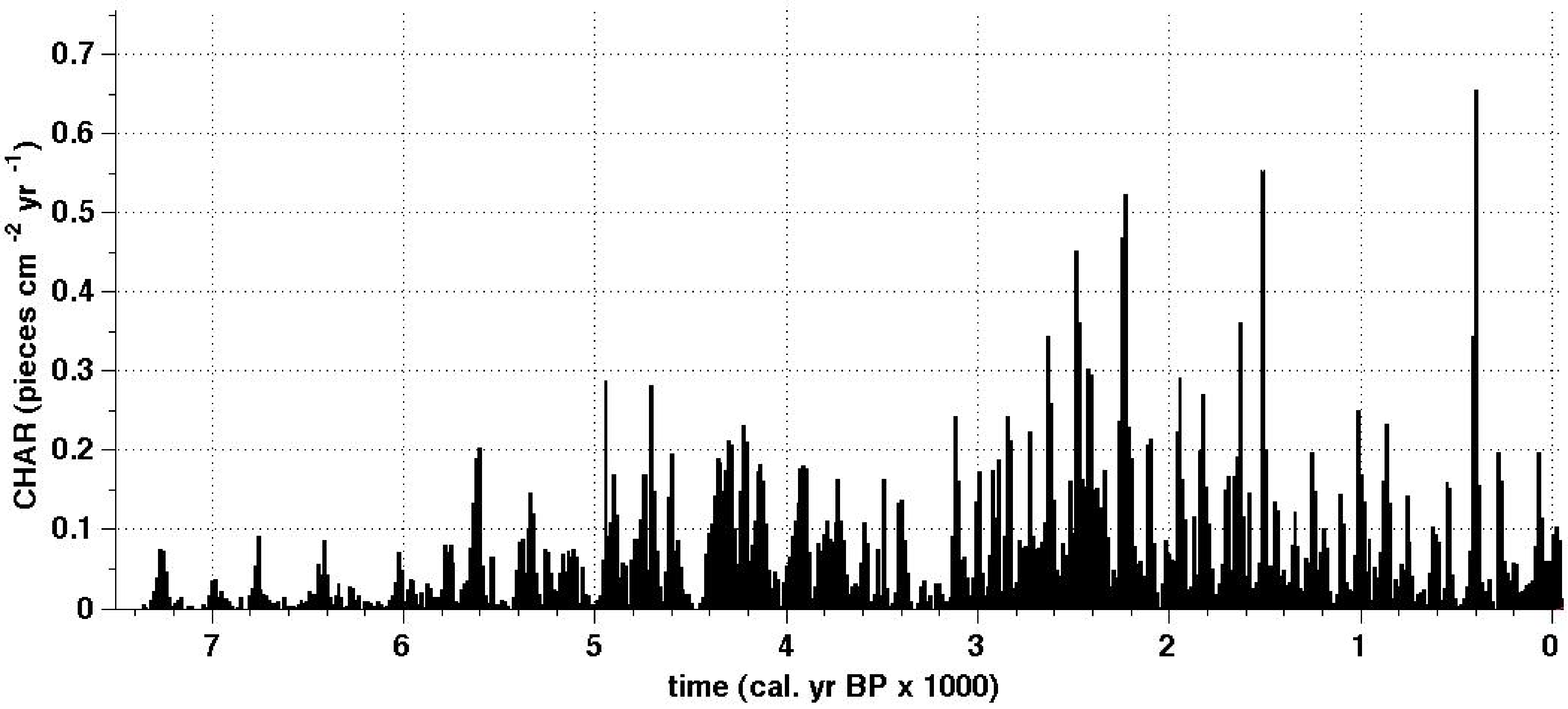
High-resolution, well-dated record necessary
(i.e., 1/5 expected mean fire return intervals)



Dunnette et al. 2014

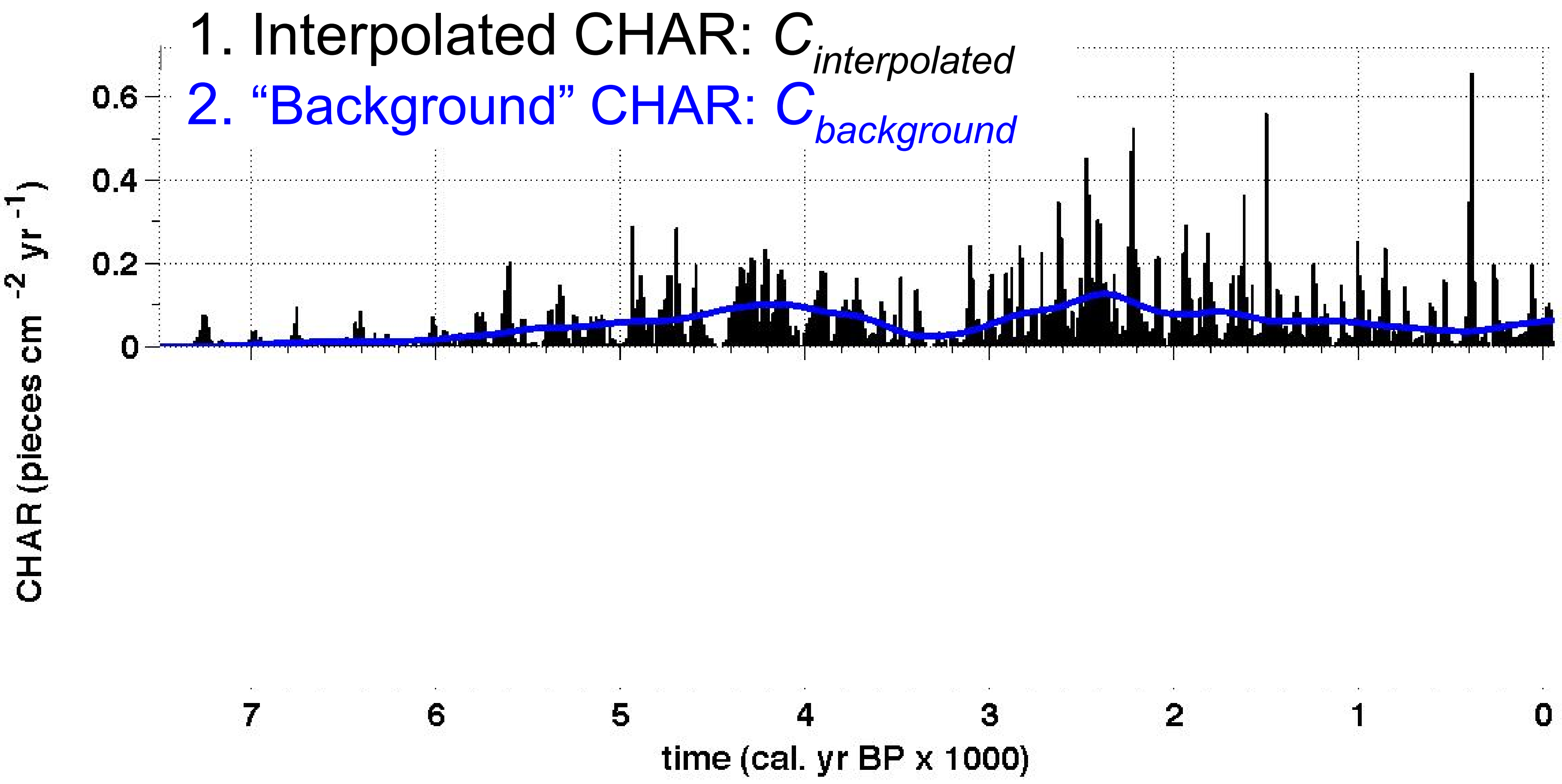
“Decomposition” approach

How many peaks are in this record?



Code Lake, Alaska, the example datasets distributed with *CharAnalysis.*

Charcoal records contain two sources of information: low- and high-frequency variability

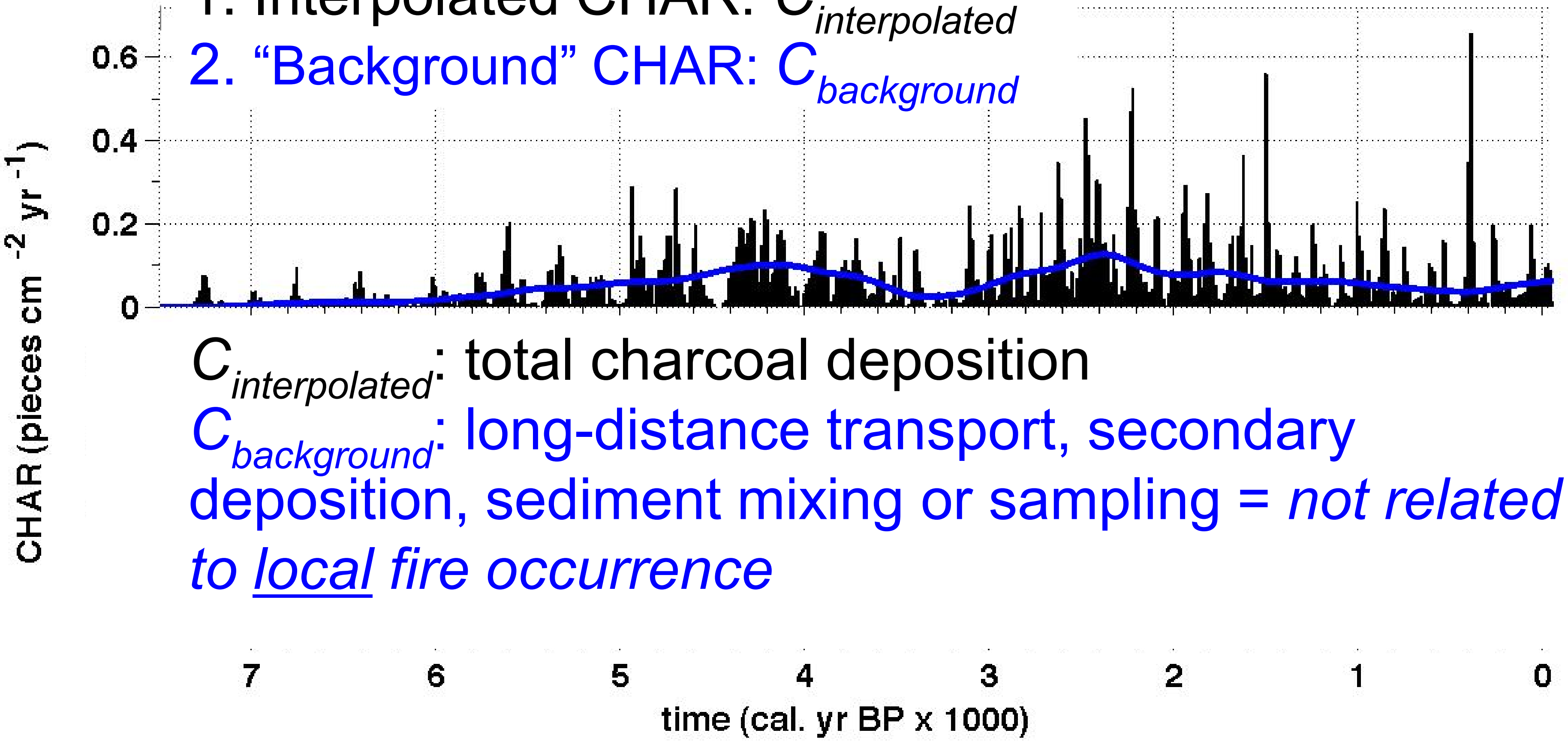


Code Lake, Alaska, the example datasets distributed with *CharAnalysis.*

Charcoal records contain two sources of information: low- and high-frequency variability

1. Interpolated CHAR: $C_{interpolated}$

2. “Background” CHAR: $C_{background}$

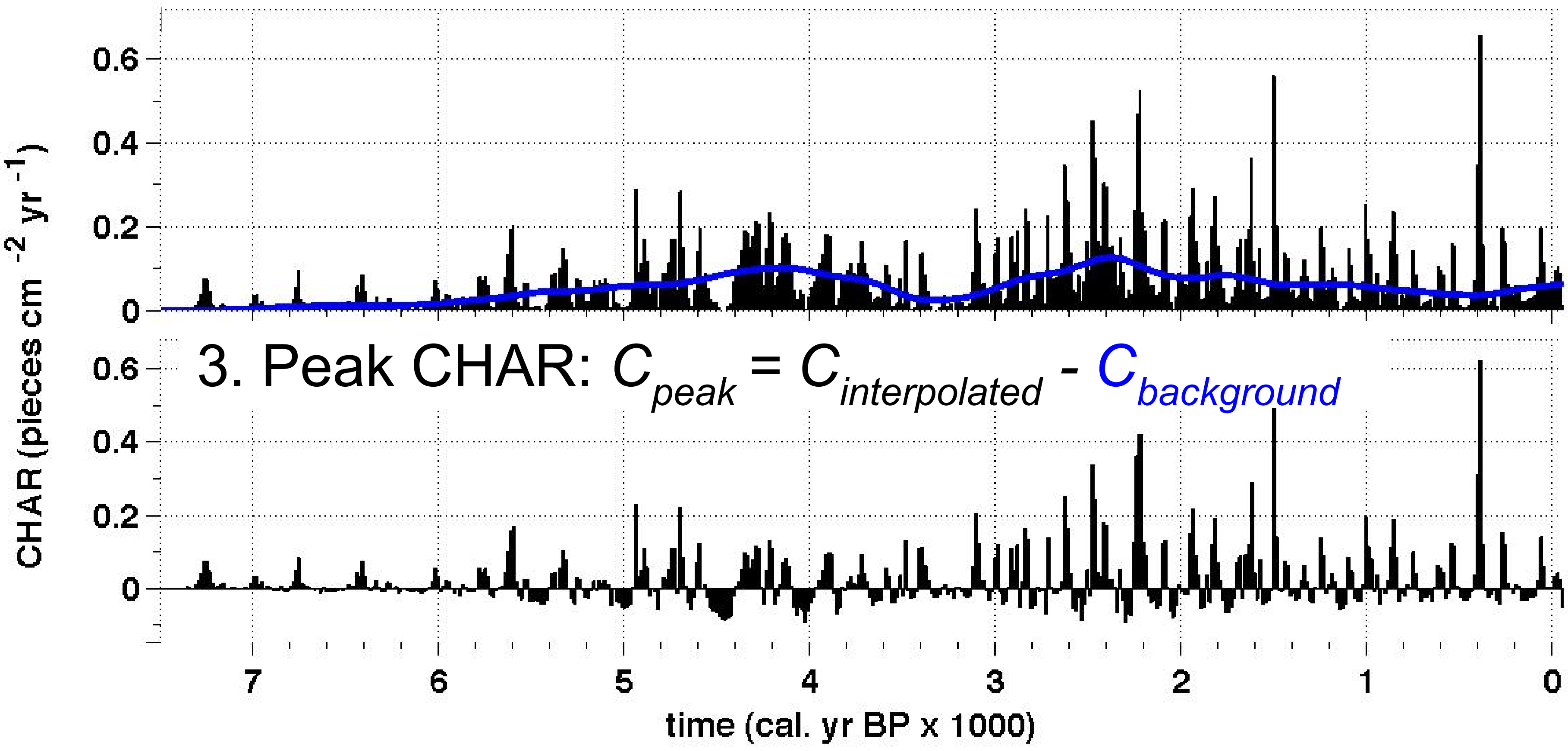


$C_{interpolated}$: total charcoal deposition

$C_{background}$: long-distance transport, secondary deposition, sediment mixing or sampling = *not related to local fire occurrence*

Code Lake, Alaska, the example datasets distributed with *CharAnalysis.*

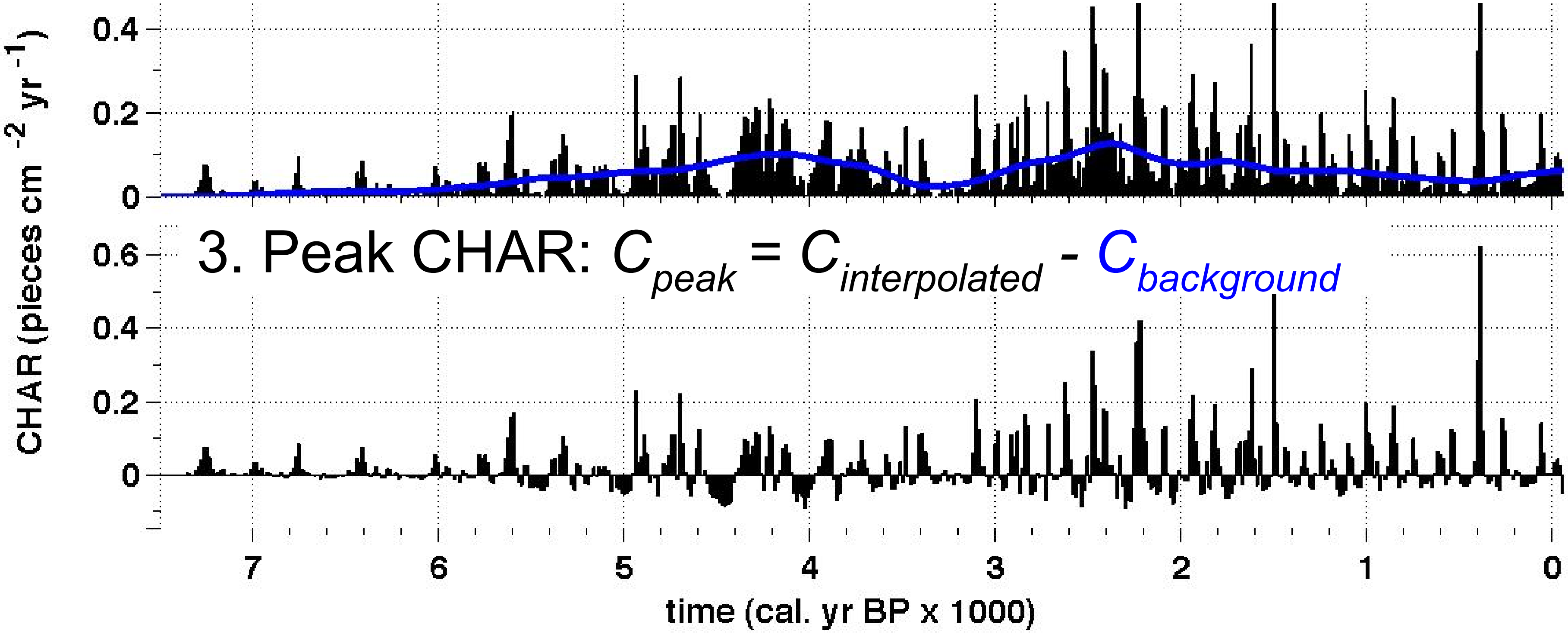
Charcoal records contain two sources of information: low- and high-frequency variability



Code Lake, Alaska, the example datasets distributed with *CharAnalysis.*

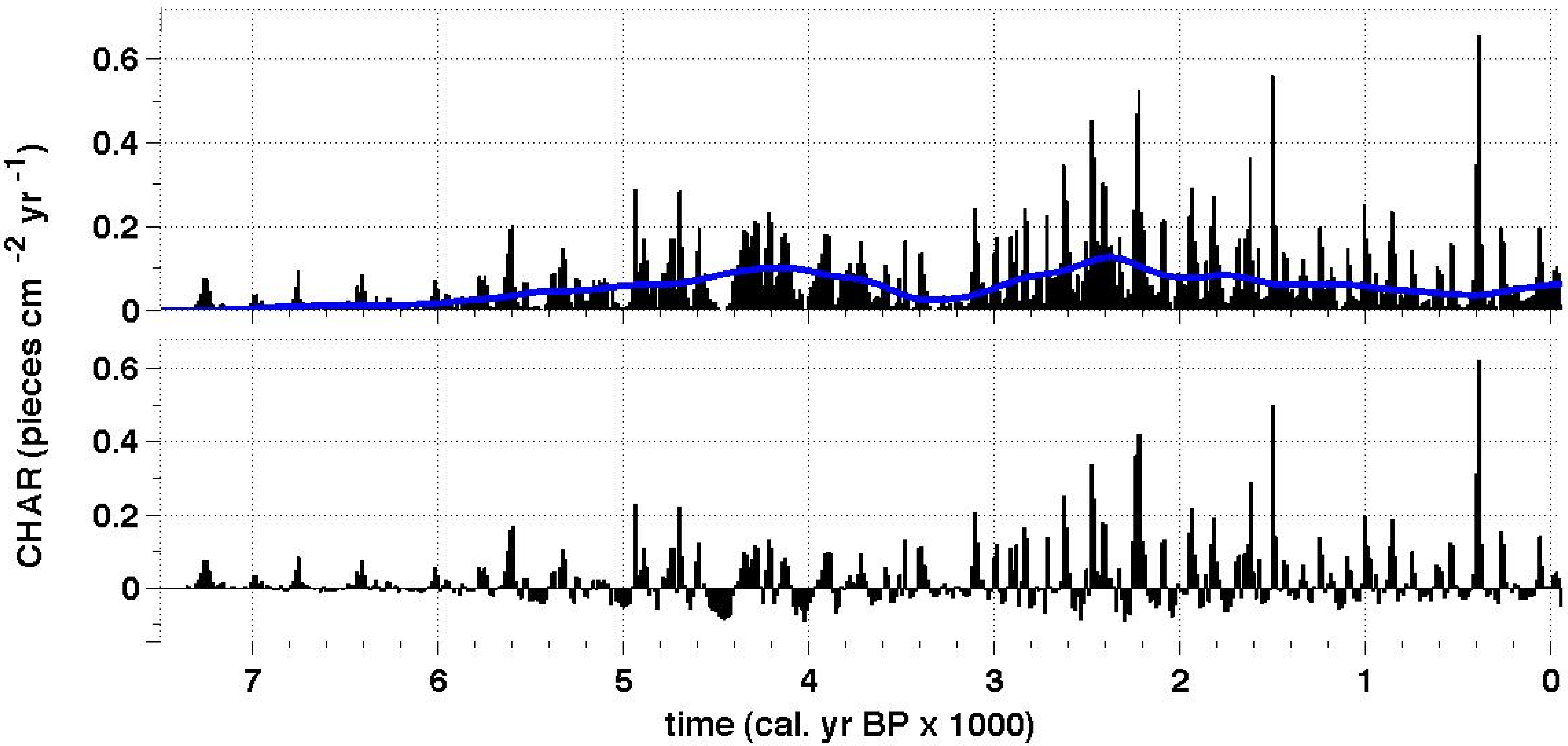
Charcoal records contain two sources of information: low- and high-frequency variability

C_{peak}: high-frequency variability; background removed. Includes signal from local fires, *plus noise*.



Code Lake, Alaska, the example datasets distributed with *CharAnalysis.*

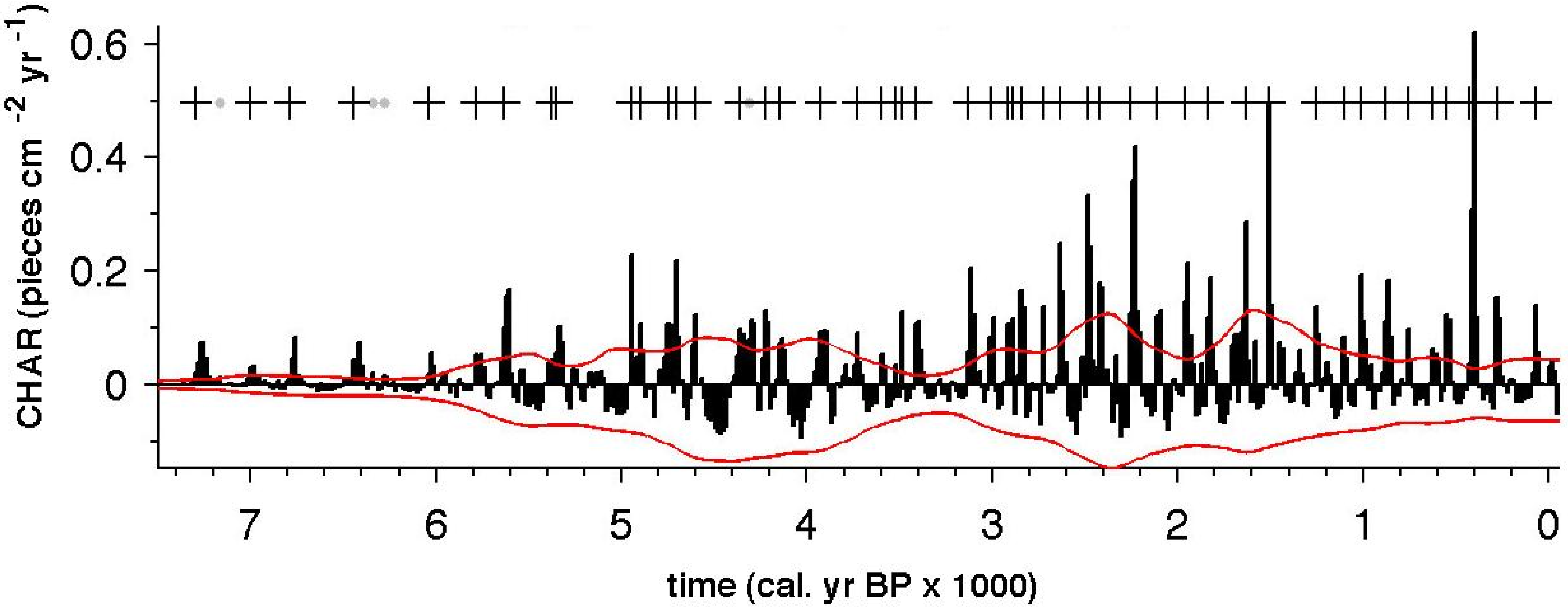
Goal of decomposition is to isolate signal of local fires from "noise" of distant fires, natural variability, and analytical variability



Code Lake, Alaska, the example datasets distributed with *CharAnalysis.*

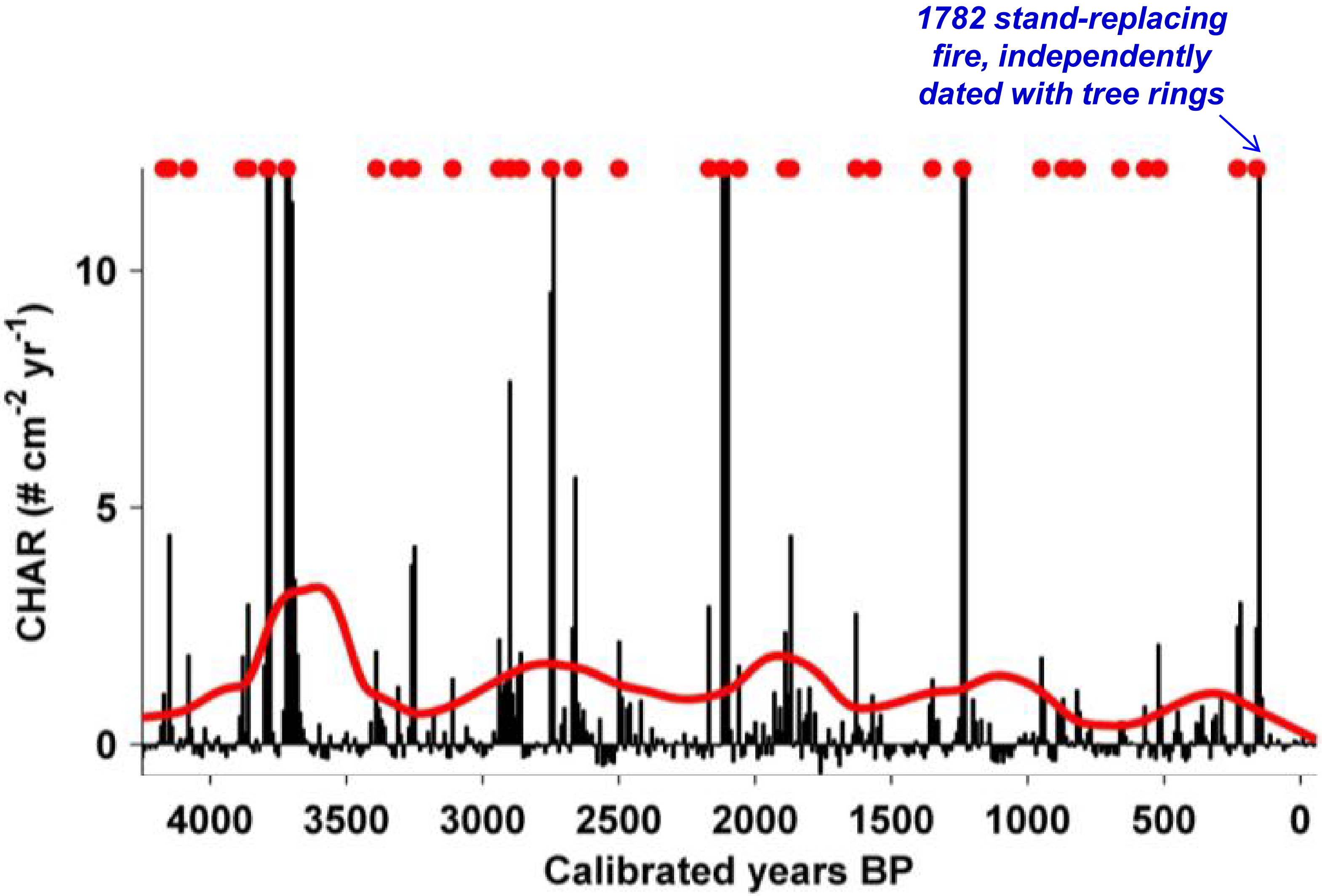
Varying threshold techniques are used to quantify the "noise" around background variability.

"Local" threshold methods respond to variability in background and peak size



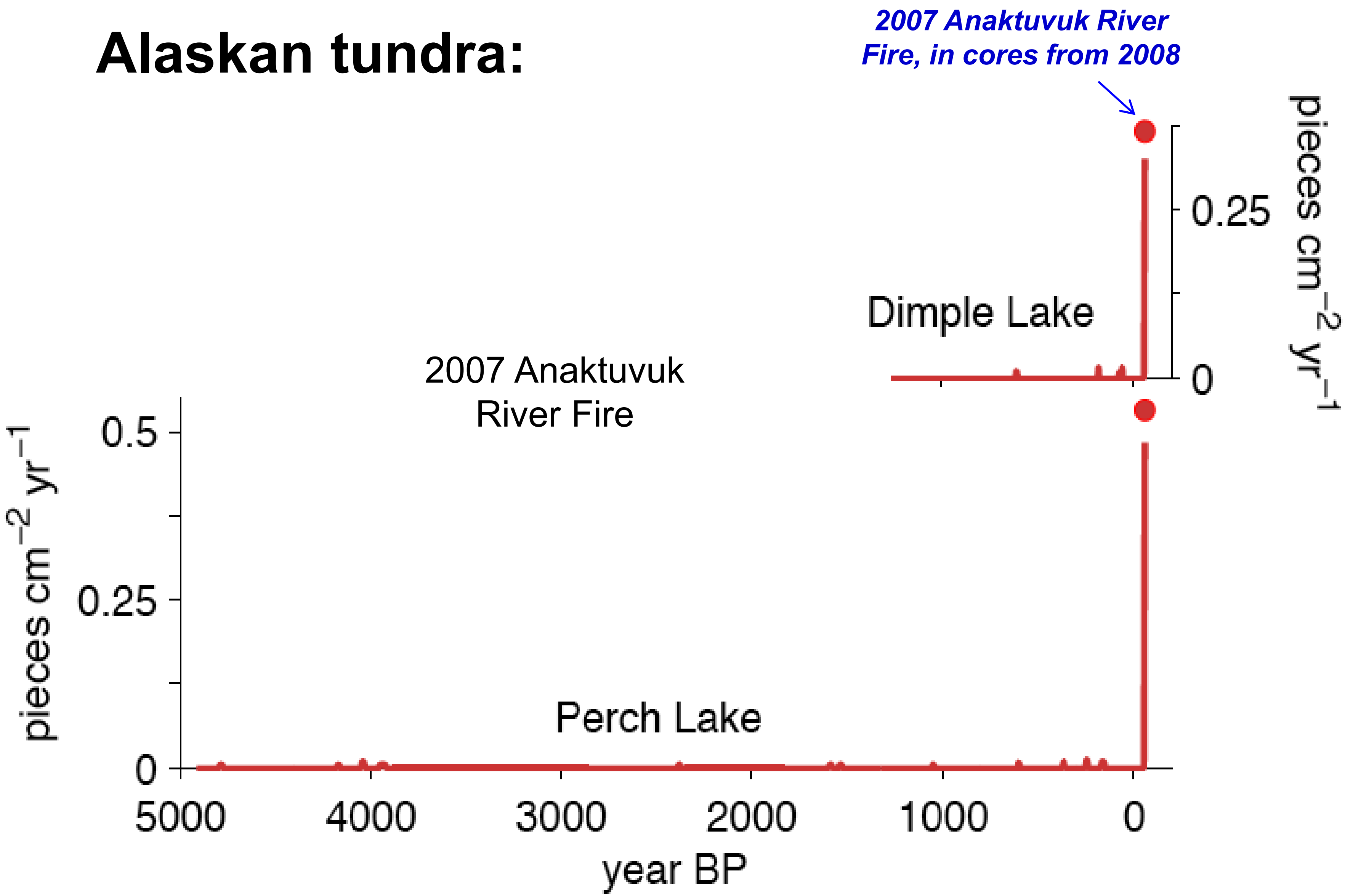
Higuera et al. (2009)

Chickaree Lake, Colorado subalpine forest:



Dunnette et al. (2014)

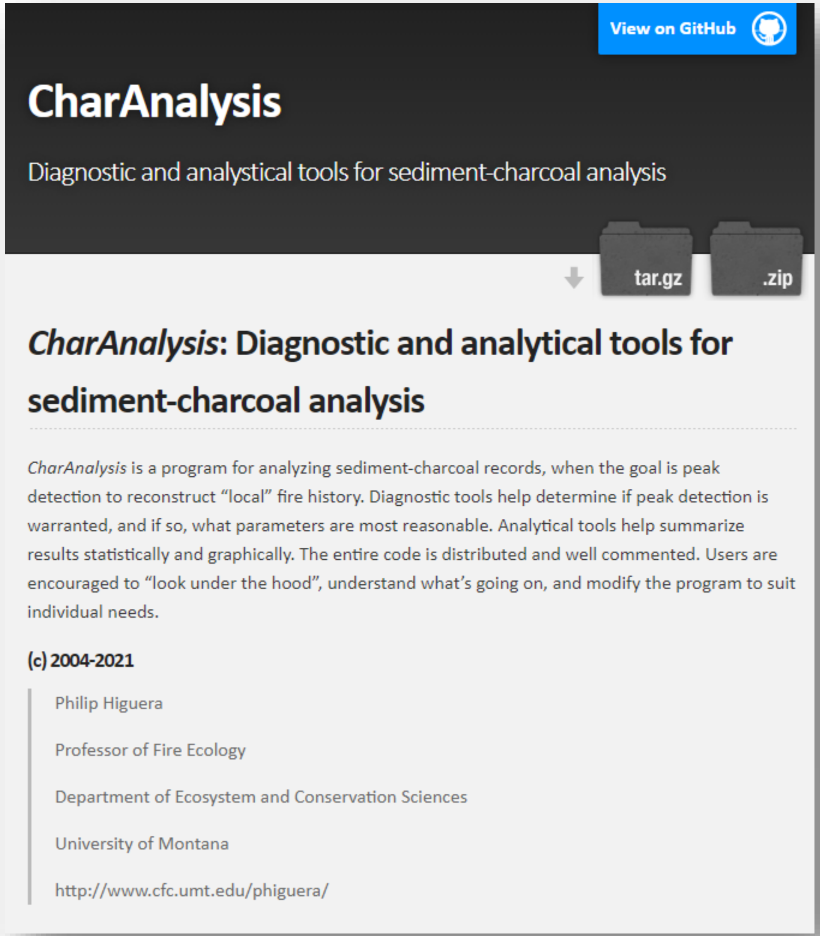
Alaskan tundra:



Hu et al. (2010); see also Chipman et al. (2015)

CharAnalysis - tools to implement peak detection

https://github.com/phiguera/CharAnalysis



View on GitHub

CharAnalysis

Diagnostic and analytical tools for sediment-charcoal analysis

tar.gz .zip

CharAnalysis: Diagnostic and analytical tools for sediment-charcoal analysis

CharAnalysis is a program for analyzing sediment-charcoal records, when the goal is peak detection to reconstruct "local" fire history. Diagnostic tools help determine if peak detection is warranted, and if so, what parameters are most reasonable. Analytical tools help summarize results statistically and graphically. The entire code is distributed and well commented. Users are encouraged to "look under the hood", understand what's going on, and modify the program to suit individual needs.

(c) 2004-2021

> Philip Higuera
>
> Professor of Fire Ecology
>
> Department of Ecosystem and Conservation Sciences
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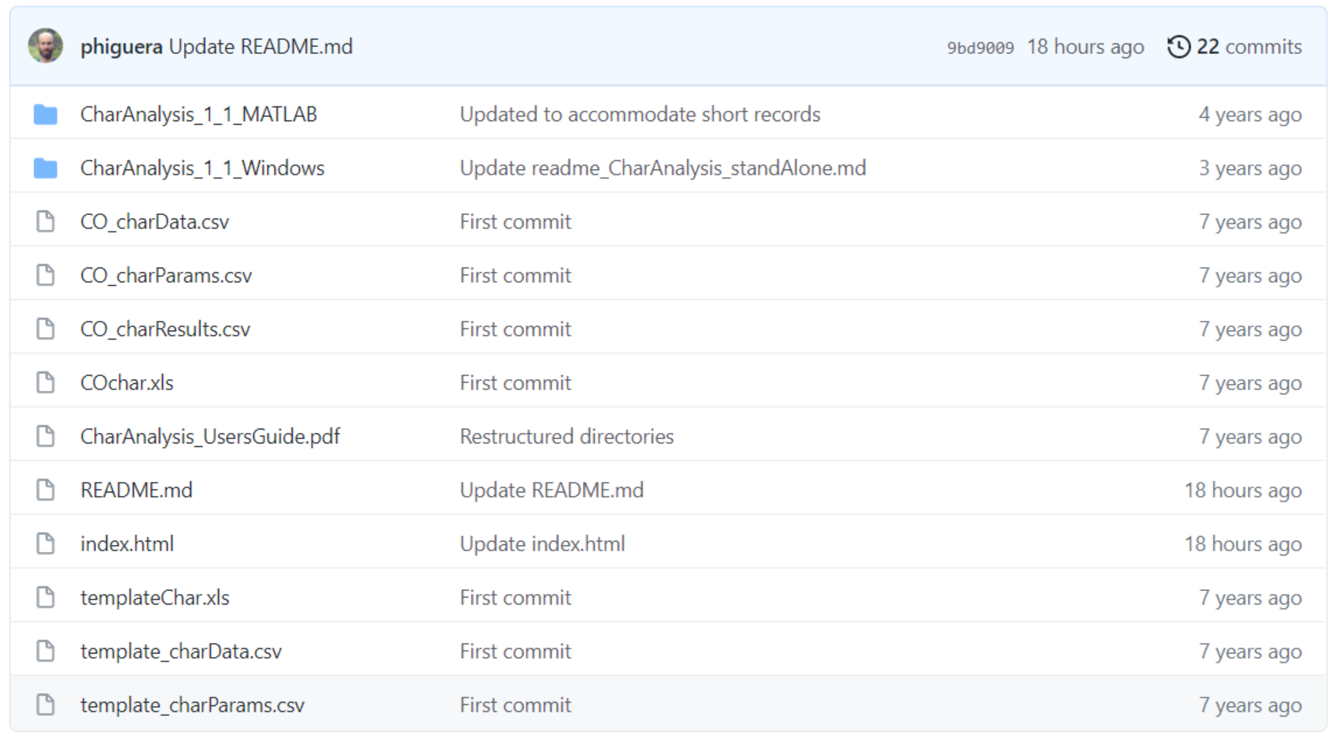
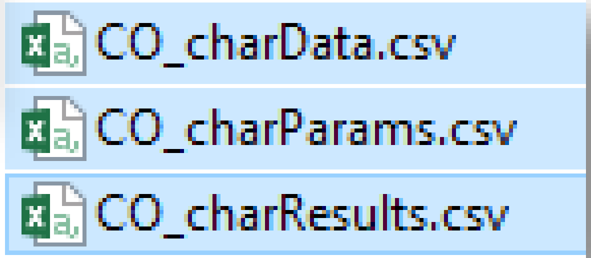
> University of Montana
>
> http://www.cfc.umt.edu/phiguera/



phiguera Update README.md 9bd9009 18 hours ago 22 commits

CharAnalysis_1_1_MATLAB	Updated to accommodate short records	4 years ago
CharAnalysis_1_1_Windows	Update readme_CharAnalysis_standAlone.md	3 years ago
CO_charData.csv	First commit	7 years ago
CO_charParams.csv	First commit	7 years ago
CO_charResults.csv	First commit	7 years ago
COchar.xls	First commit	7 years ago
CharAnalysis_UsersGuide.pdf	Restructured directories	7 years ago
README.md	Update README.md	18 hours ago
index.html	Update index.html	18 hours ago
templateChar.xls	First commit	7 years ago
template_charData.csv	First commit	7 years ago
template_charParams.csv	First commit	7 years ago



--- input charcoal data

--- parameters to use for analysis

--- output – results from *CharAnalysis*

User decisions in *CharAnalysis* directly map to the theory of peak analysis

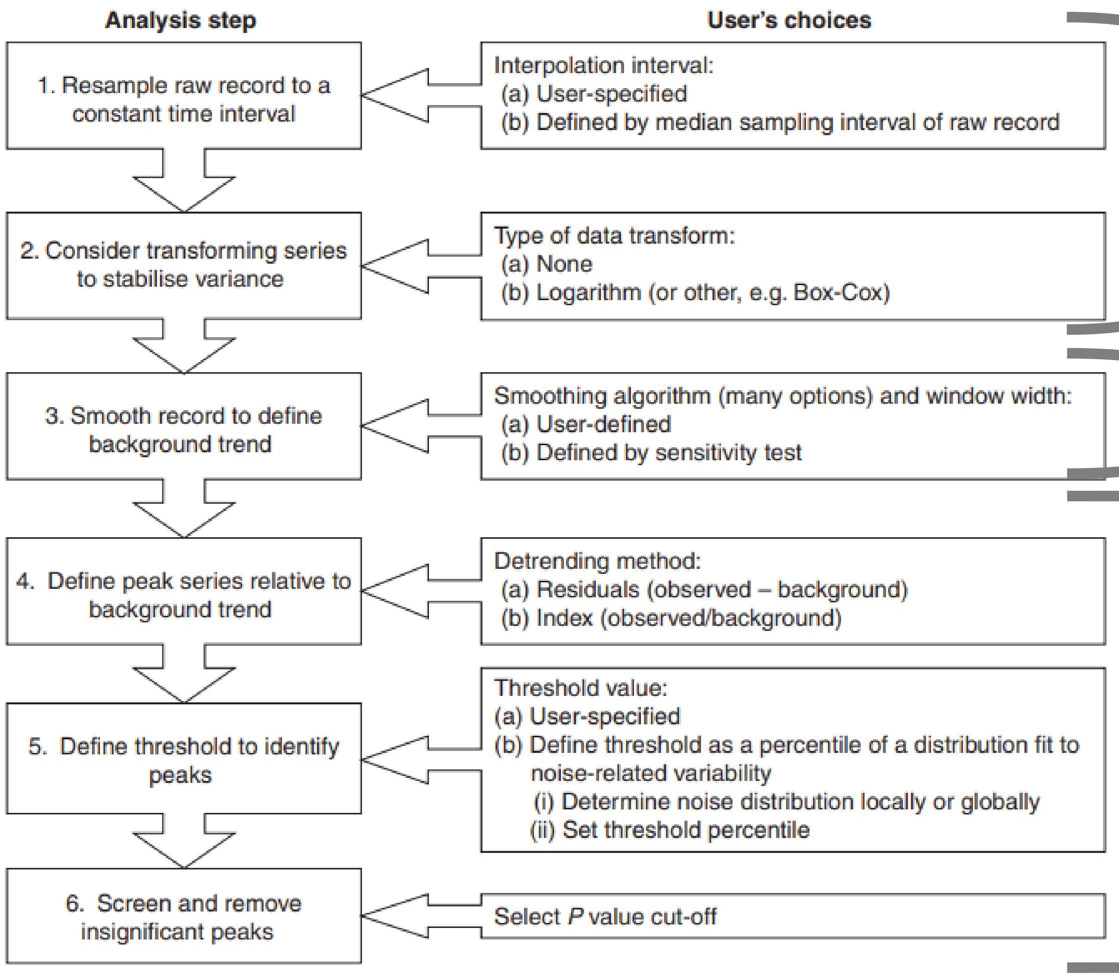


Fig. 1. The set of decisions required for analysing a charcoal time series with the goal of peak detection for interpretation of fire episodes. These steps are implemented in the *CharAnalysis* software (http://code.google.com/p/charanalysis/, accessed 30 November 2010).

Higuera et al. 2010

CO_charParams.csv

	A	B	C	D	E	F
1	Stage	Variable	Parameters	Units	Description and Options	
2	Pretreatment	zoneDiv	-51	cal. yr BP	Years defining beginning ar	
3			5500		*NOTE: YOU MUST INPUT	
4			7500		*NOTE: YOU MUST INPUT	
5			-9999		*NOTE: YOU MUST INPUT	
6			-9999		*NOTE: YOU MUST INPUT	
7			-9999		*NOTE: YOU MUST INPUT	
8			-9999		*NOTE: YOU MUST INPUT	
9			-9999		*NOTE: YOU MUST INPUT	
10		yrInterpolate	15	yr	Years to interpolate record	
11		transform	0	index	Do you want to transform th	
12	Smoothing	method	4	index	How do you want to estimat	
13		yr	500	yr	Years to smooth record ove	
14	Peak Analysis	cPeak	1	index	How do you want to calcula	
15		threshType	2	index	What type of threshold do y	
16		threshMethod	3	index	How do you want to determi	
17		threshValues	0.95	variable	What threshold values do y	
18			0.99			
19			0.999			
20			0.99			
21		minCountP	0.05	probability	Cut-off probability for minim	
22	Peak Analysis Results	peakFrequ	1000	yr	Years to smooth fire freque	
23		Cbackground sensitivity	1	index	Do you want to evaluate the	
24		saveFigures	1	index	Do you want to save the plo	
25		saveData	1	index	Do you want to save the out	
26		allFigures	1	index	Do you want to display all (	

All of this is done after the peak analysis – it's just different ways to plot the resulting peaks. All graphs and analyses could be repeated, modified, etc., using the resulting output data.

CO_charResults.csv

3. Best practices and pitfalls

Assess if record meets desired criteria for peak detection:

- Lake characteristics: inlet/outlet, size, topography….
- Sample resolution: years/sample, including impacts of mixing
- Expected fire regime: fire size, frequency, charcoal production

- ***Signal-to-noise index > 3 for majority of records where peak analysis is done***


Contents lists available at ScienceDirect
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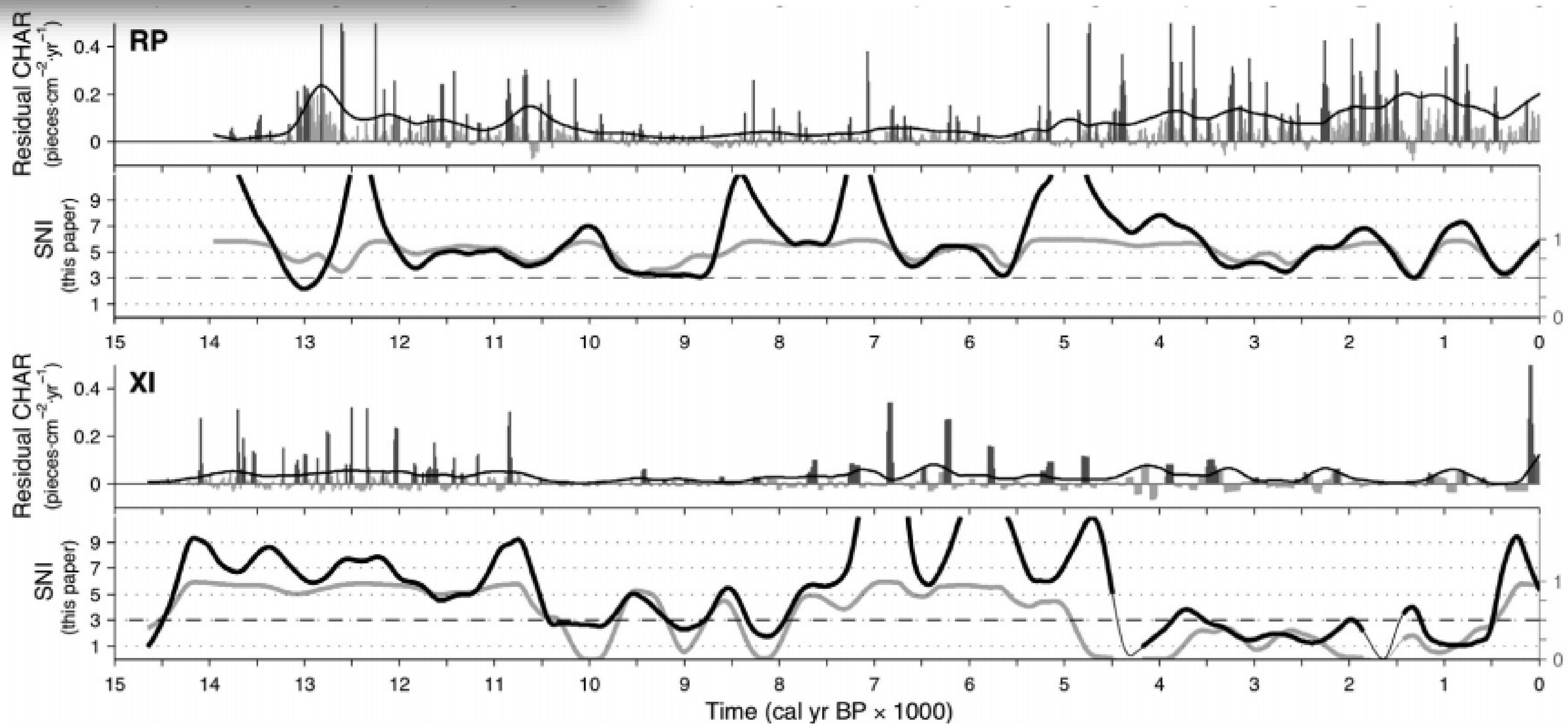
Short Paper

A signal-to-noise index to quantify the potential for peak detection in sediment–charcoal records

Ryan F. Kelly [a,*], Philip E. Higuera [b], Carolyn M. Barrett [c], Feng Sheng Hu [a,c]

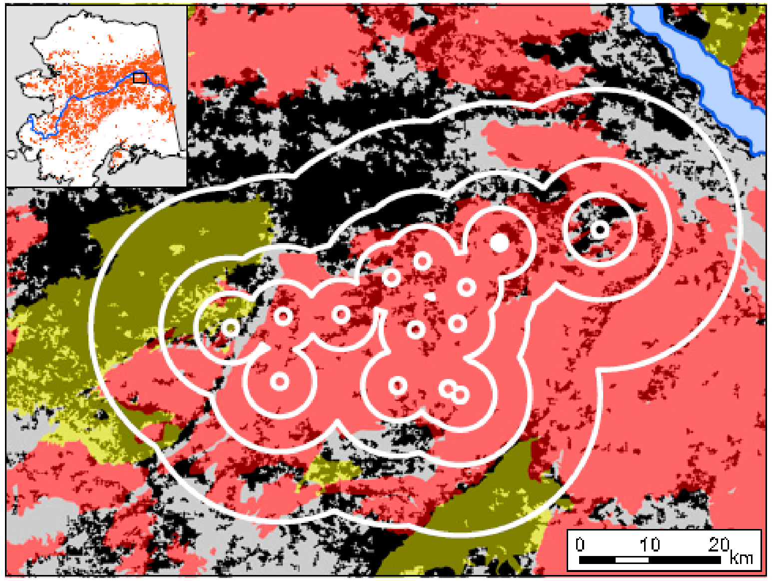
This signal-to-noise index (SNI) was explicitly designed to help answer the question "is this record appropriate for peak analysis?"

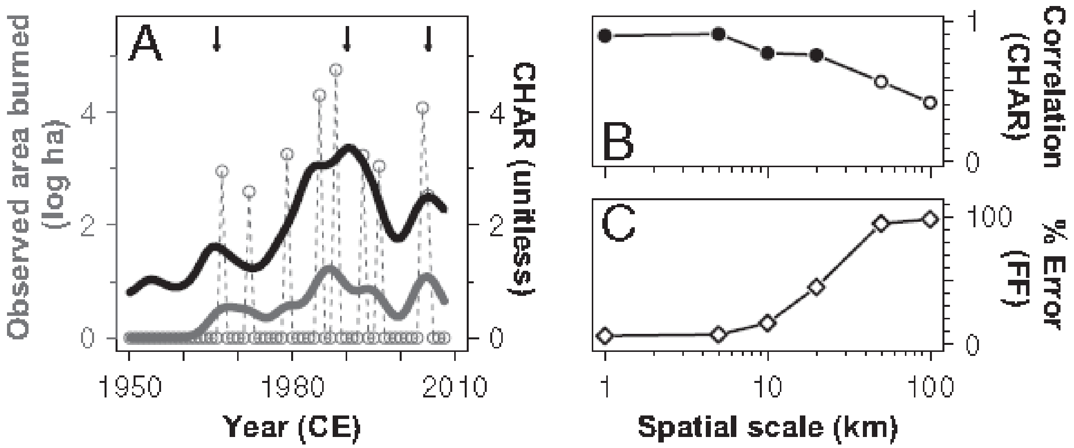


Kelly et al. (2011)

Pitfall: Inferring charcoal source area from limited fire history. e.g., if no fires occurred within X km, then it's impossible to have highest correspondence at those distances.

Solution: Reference studies with a complete sampling, or multiple studies, to obtain a range for charcoal source area.
Remember, peaks and background have different source areas

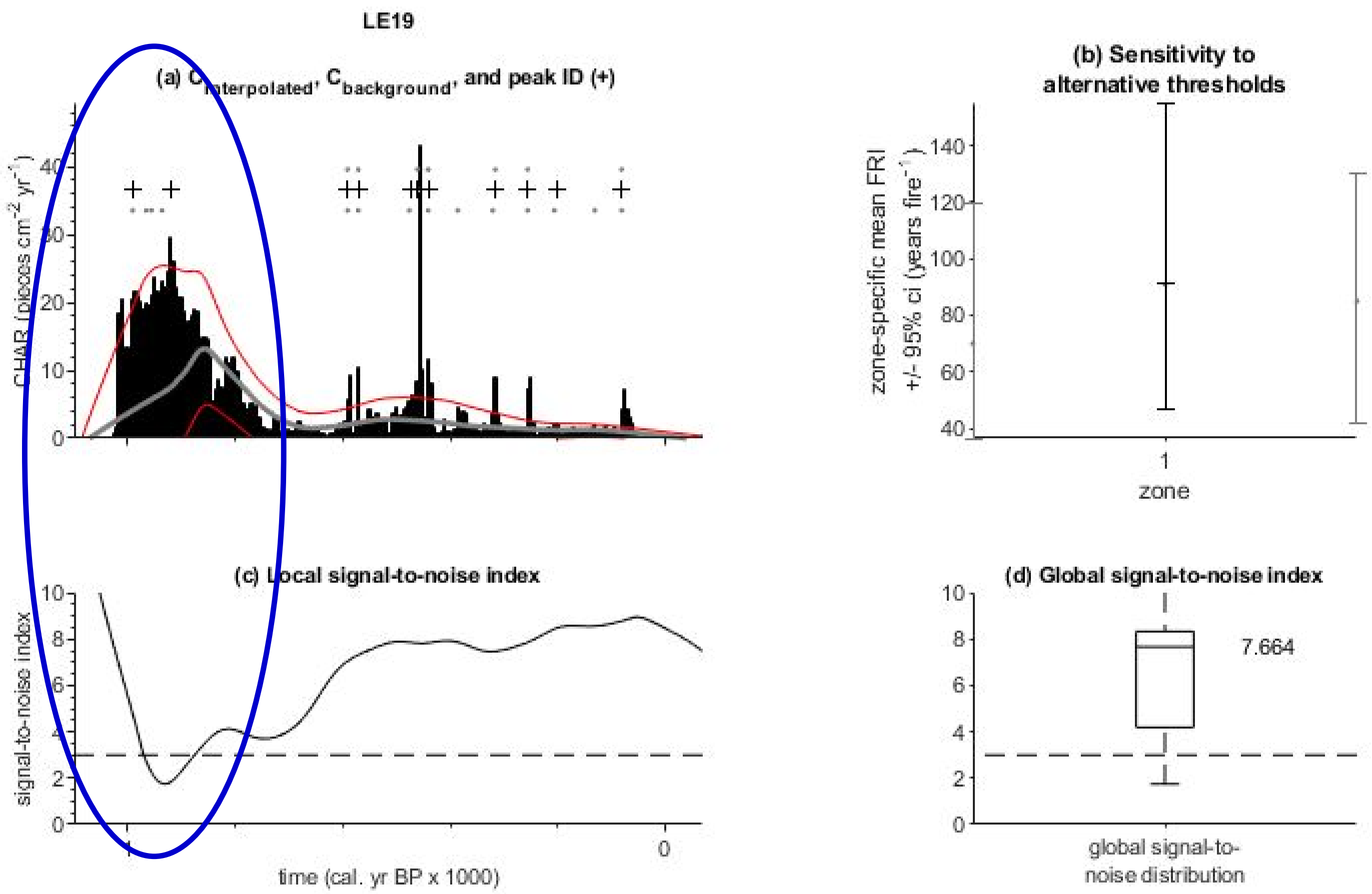




Kelly et al. 2013

Pitfall: Interpreting all peaks are fires, just because the program identified a peak. Not all peaks are fires – we don't know (!)

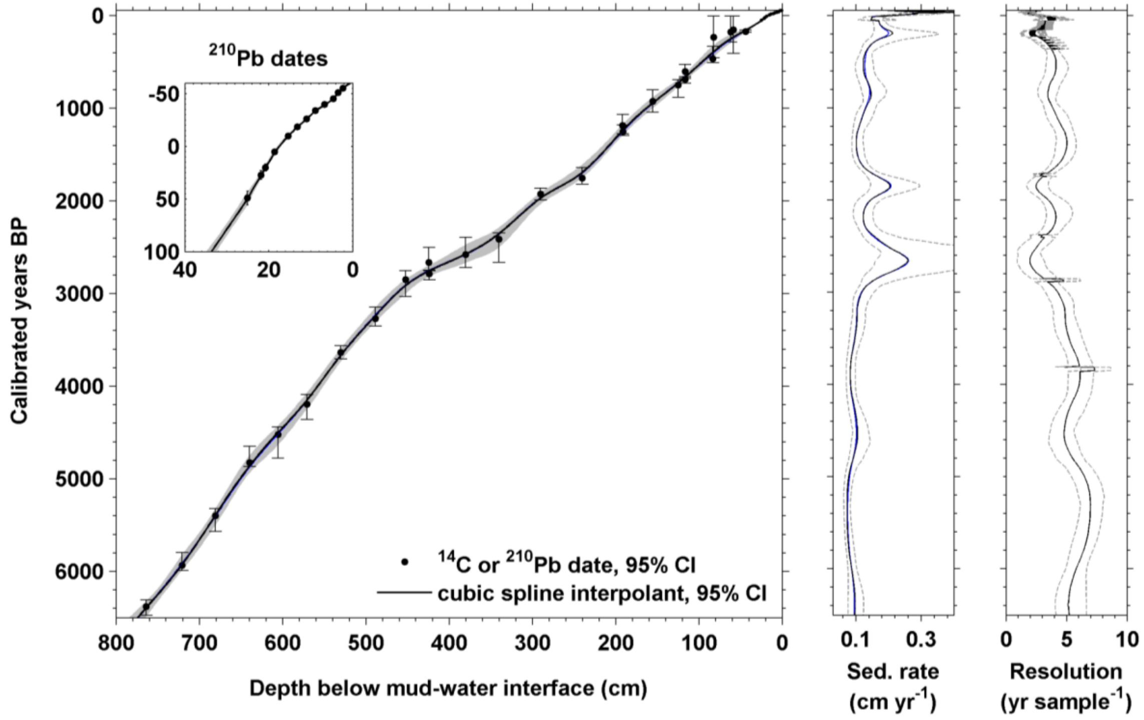
Solution: Use stratigraphy and dating to assess is "double peaks" or many peaks in section of a core may represent rapid sediment accumulation; and use the SNI.



Higuera et al. – in progress

Pitfall: Interpreting changes in fire frequency within or between records, which may ultimately reflect varying sample resolution.

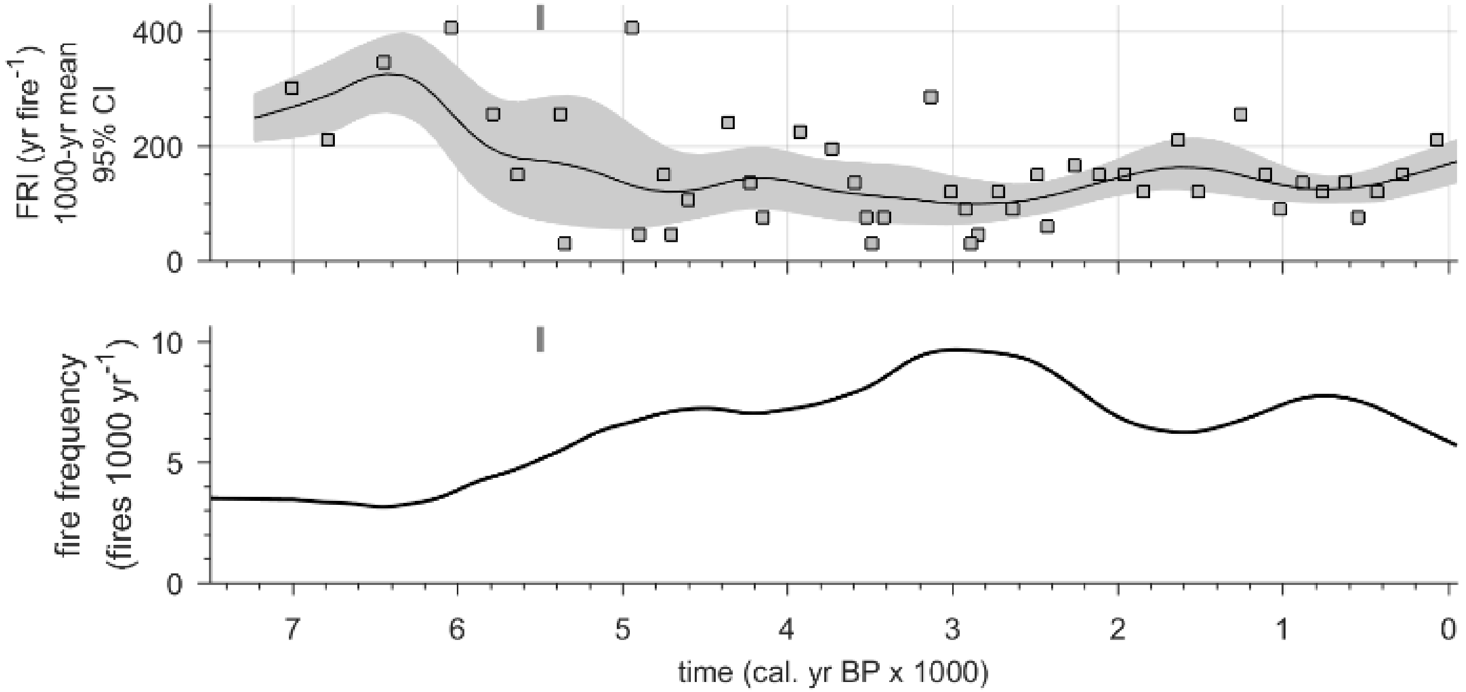
Solution: Interpolate samples to a common time interval helps, *IF* justified by overall range of sample resolution; interpret section(s) or records with lower resolution separately.



Dunnette et al. (2014)

Pitfall: Overinterpret variability in peak frequency as changes in fires regimes, forgetting that fire occurrence is highly stochastic, even in the absence of changing fire regimes.

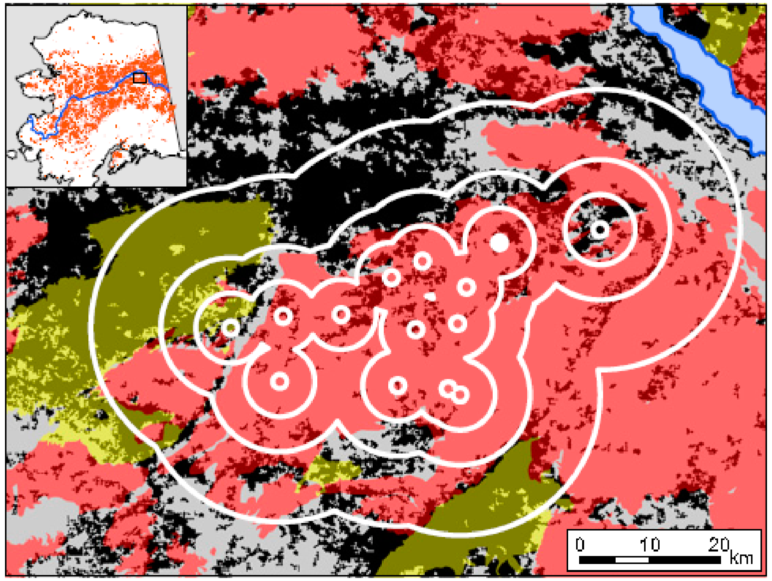
Solution: Use confidence or prediction intervals on fire frequency or fire-return intervals to assess statistically significant changes in fire occurrence; pool data from multiple sites to increase statistical power in detecting potentially changing fire activity.

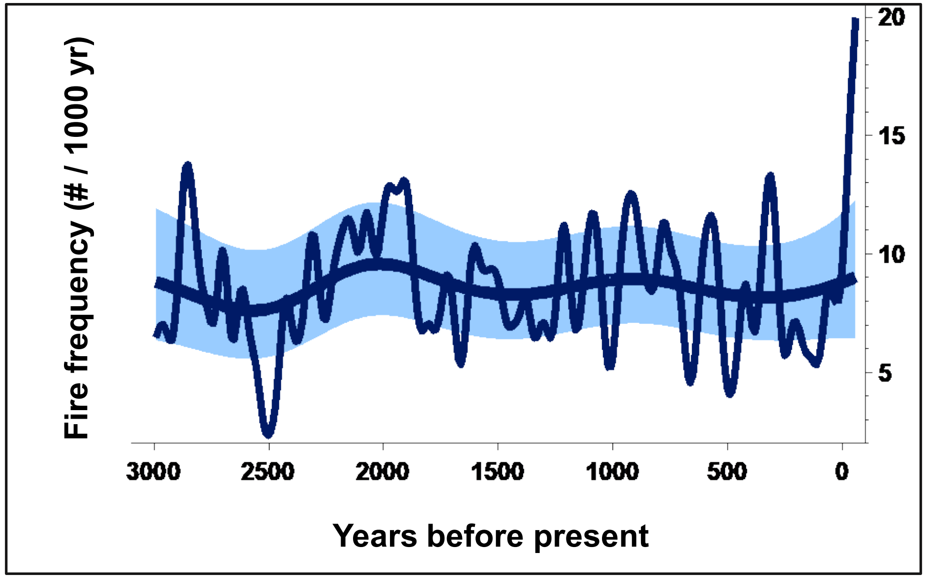


Example *CharAnalysis* output from Code Lake, Alaska (Higuera et al. 2009).

Pitfall: Overinterpret variability in peak frequency as changes in fires regimes, forgetting that fire occurrence is highly stochastic, even in the absence of changing fire regimes.

Solution: Use confidence or prediction intervals on fire frequency or fire-return intervals to assess statistically significant changes in fire occurrence; **pool data from multiple sites to increase statistical power in detecting potentially changing fire activity.**





Kelly et al. 2013

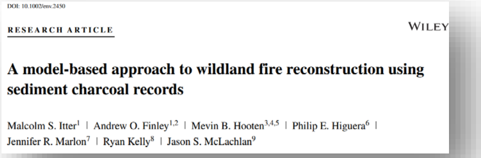
4. The future of peak detection

Technical needs:

- **Facilitate development and use** and by translating *CharAnalysis* from Matlab to R

- **Develop ways to propagate uncertainties**, in dating, peak detection, and sensitivity of parameter choices, e.g., by integrating existing tools and developing new approaches (e.g., Bayesian analyses, as in Itter et al. 2017)

- **Develop with backward compatibility and compatibility with databases in mind** (e.g., IPN, Neotoma, etc.)



DOI: 10.1002/env.2450

RESEARCH ARTICLE

WILEY

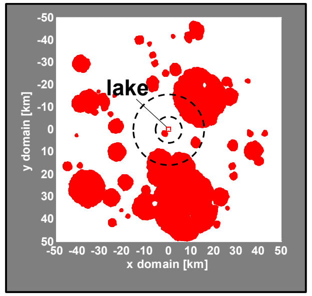
A model-based approach to wildland fire reconstruction using sediment charcoal records

Malcolm S. Itter[1] | Andrew O. Finley[1,2] | Mevin B. Hooten[3,4,5] | Philip E. Higuera[6] | Jennifer R. Marlon[7] | Ryan Kelly[8] | Jason S. McLachlan[9]

4. The future of peak detection

Conceptual or empirical needs:

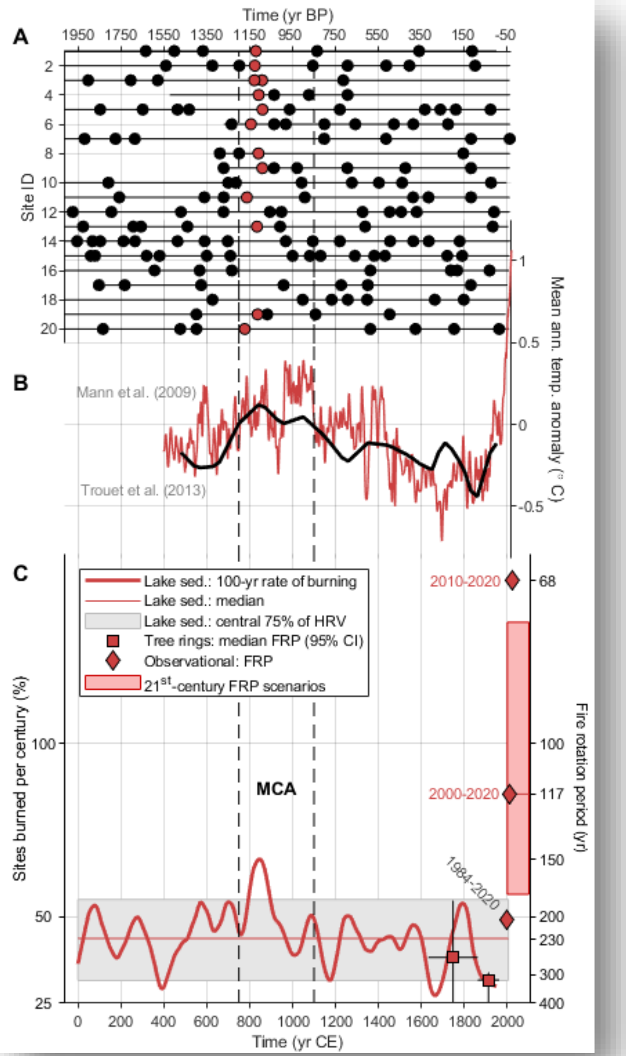
- Better understand **source area** reflected by peak, background, etc., under varying conditions, *and* implications for inference



4. The future of peak detection

Conceptual or empirical needs:

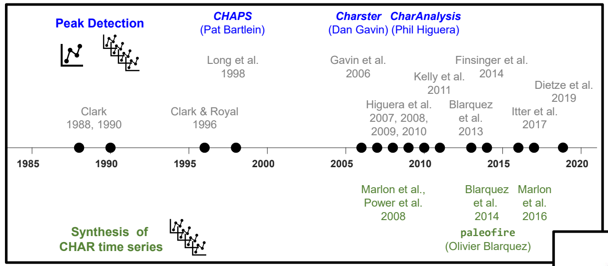
- Better understand **source area** reflected by peak, background, etc., under varying conditions, *and* implications for inference
- Improve ability to **link paleo-inferred and contemporary measures of fire activity and fire regimes**
- **Much more**: inferring fire severity, synchrony across regions, and lots of work beyond peak detection



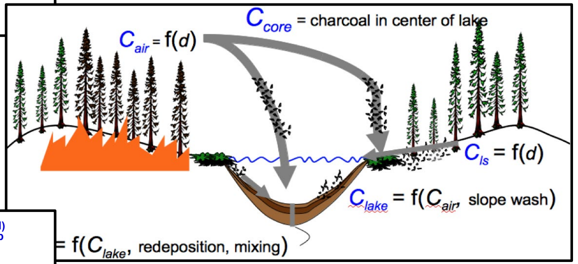
Higuera, Shuman, and Wolf. **"Rocky Mountain subalpine forests now burning more than any time in recent millennia."** *PNAS*. Accepted (4/2021)

The past and future of peak detection

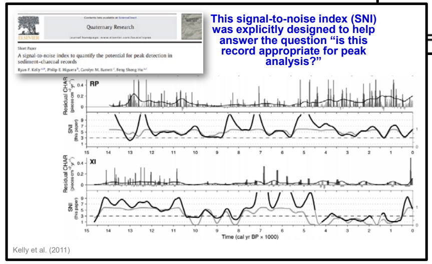
1. **Origin and development**



2. **Principles of the decomposition approach**



3. **Best practices and potential pitfalls**



4. **Future needs and opportunities**

MATLAB → R
Bchron
PALEOFIRE R-PACKAGE

Philip Higuera
Professor of Fire Ecology
@PhilipHiguera
https://github.com/phiguera/CharAnalysis

UNIVERSITY OF MONTANA
W.A. FRANKE COLLEGE OF FORESTRY & CONSERVATION
NSF
Big Burns

Your questions

1) How does one calculate charcoal accumulation rates from unconsolidated sediments where it's difficult to get bulk density estimates, **e.g. in Archeology?**

2) How does one **incorporate age dating and age-depth model uncertainties into the peak identification process?**

3) How does one **estimate the general reproducibility of charcoal records concerning variations within and between lakes and in counting** (best-practice advice?)?

4) **What does the background in the peak analysis represent and how could be interpreted in terms of fire history, fire factors, fire ecology or fire practice?**

5) How does one **deal with the background in multi-series comparisons (would we expect more regional heteorogeneity compared to peak-derived trends)?**

6) **How to analyze charcoal records from lake sediments in regions where we expect very frequent fire. Is peak detection always appropriate?**

1) May not be able to. Conceptually, account for varying time integrated into any sample of charcoal, and consider a null model for expectations.

2) See Calder et al. (2015, PNAS) for a good example. Qualitatively, interpret timing of peaks in context of age undercity – i.e., don't over interpret precision.

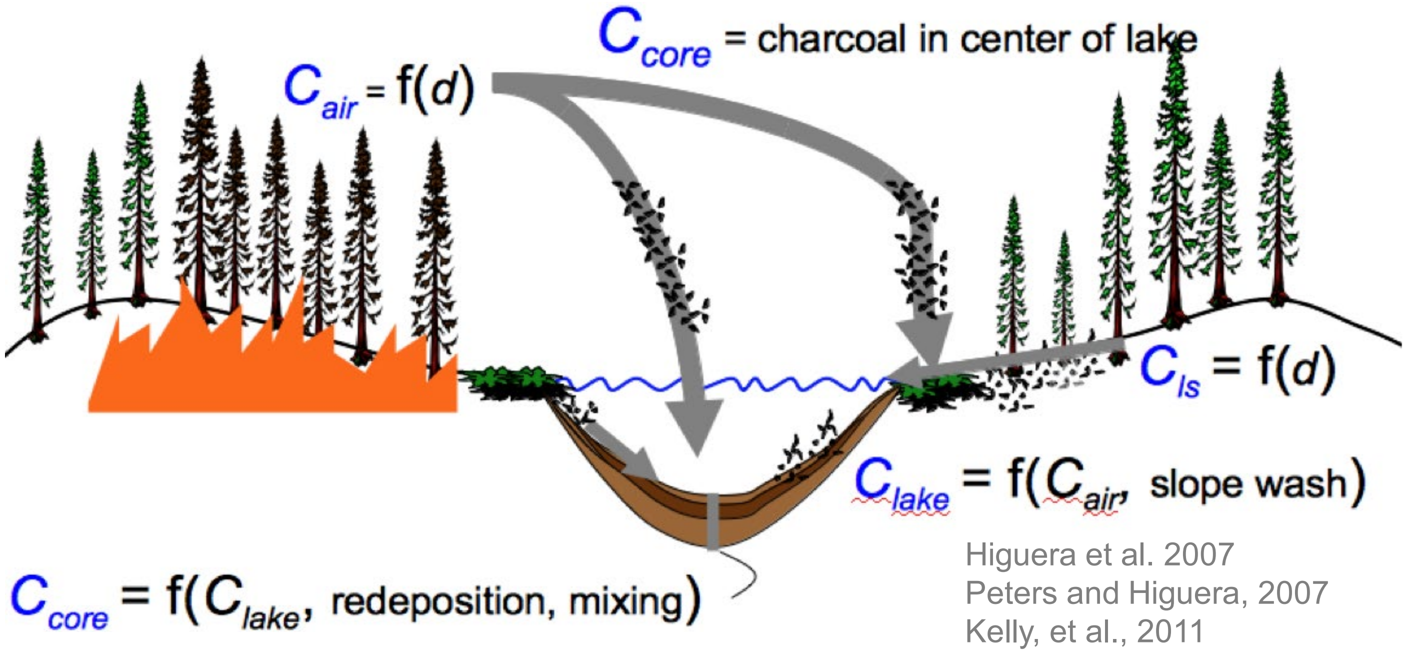
3) Increase sample size, and interpret based on sample size. Use multiple records to infer regional trends in fire activity, or only interpret changes over millennial time scales in an individual record. Even with perfect accuracy, peaks are highly stochastic.

4) Background reflects total charcoal production in a region; theoretically (Higuera et al. 2007) and empirically (Higuera et al. 2011, Kelly et al. 2013) it reflects total area burned. It could also reflect changes in taphonomy, so be careful….

5) We would expect more consistency among background trends (IF they reflect fire activity, vs. taphonomy), because it integrates more space and time. The *Paleofire* R package implements methods to composite background trends.

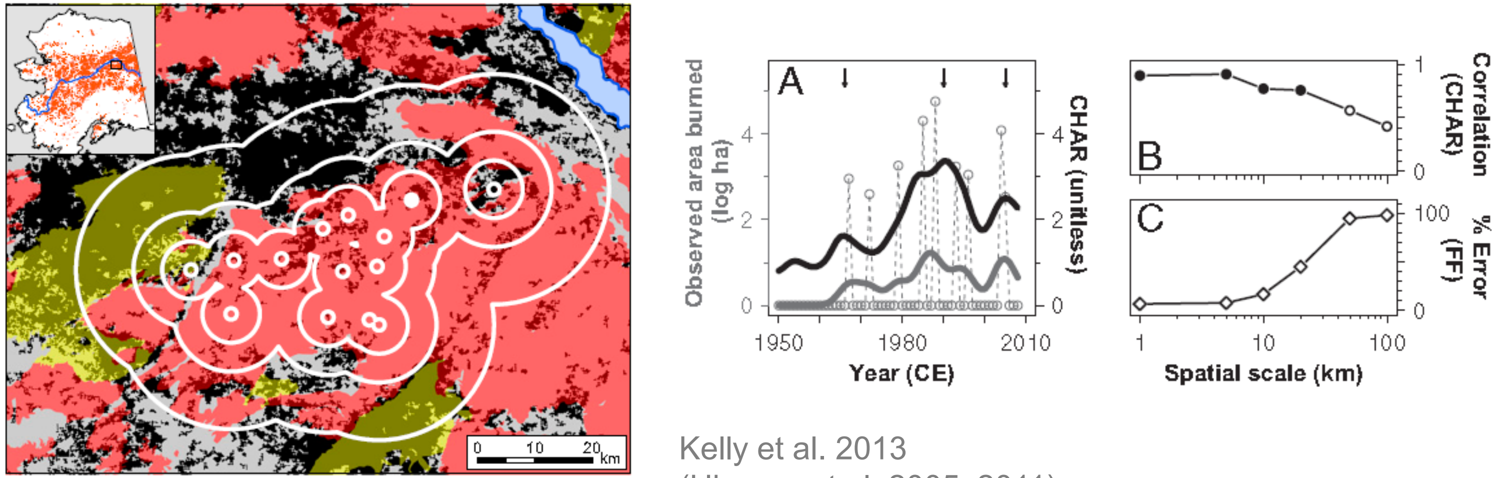
6) No, peak detection is not always appropriate. High-frequency, low-severity fire regimes typically result in low SNI.

Theoretical modeling:



Higuera et al. 2007
Peters and Higuera, 2007
Kelly, et al., 2011

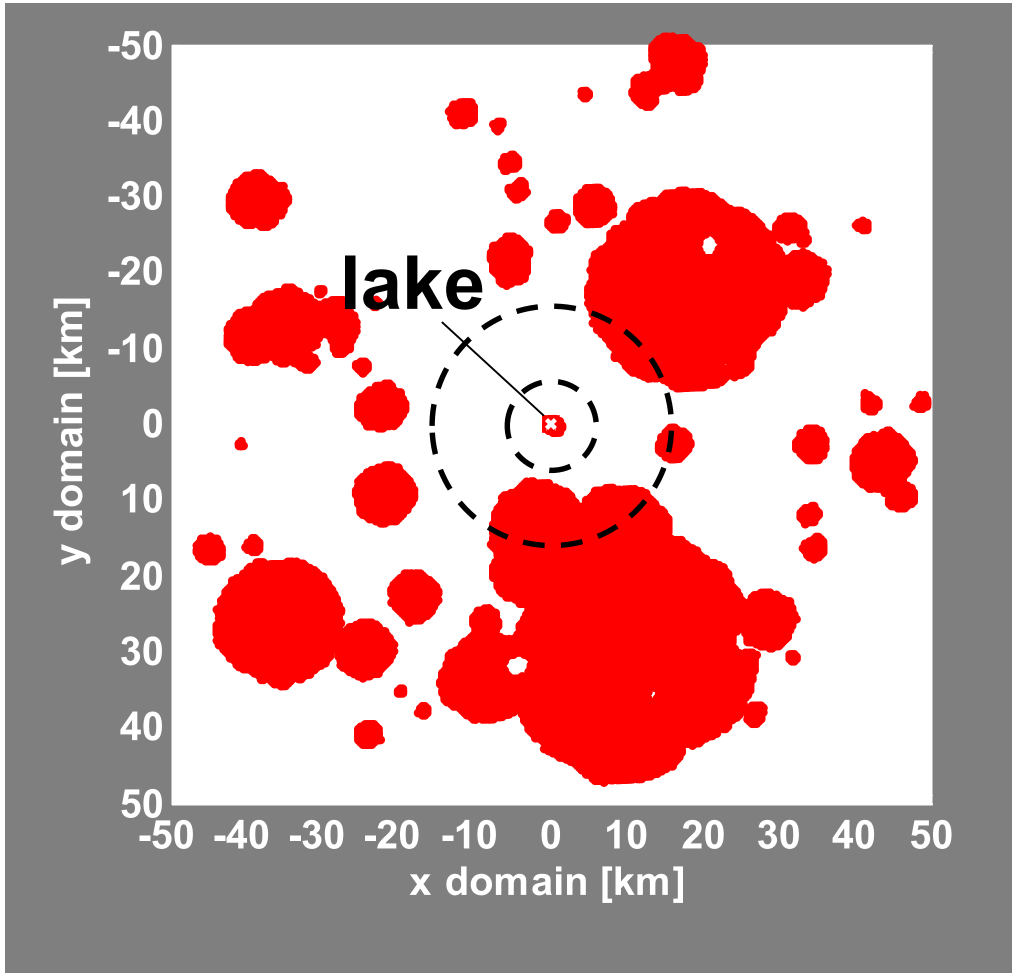
Empirical calibrations:



Kelly et al. 2013
(Higuera et al. 2005, 2011)

The "relevant charcoal source area" depends on dispersal distance of charcoal, *relative to* fire size.

Peak and total charcoal represent two different sources areas



Higuera et al. (2007)