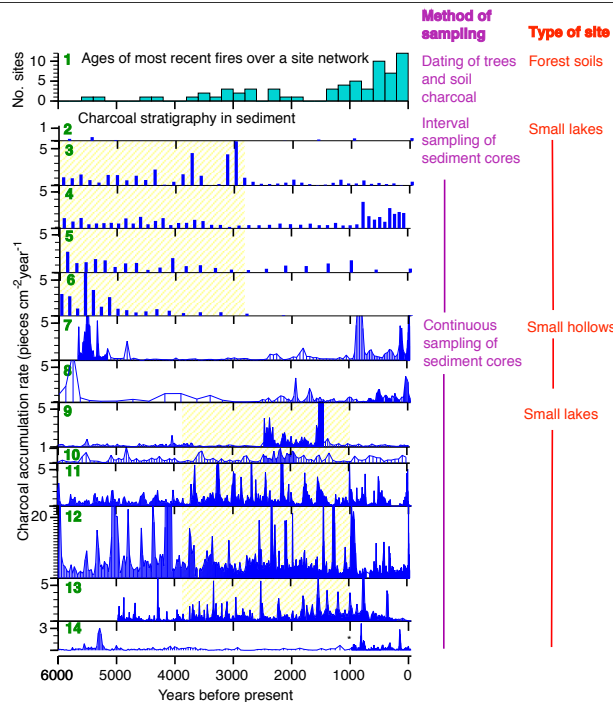
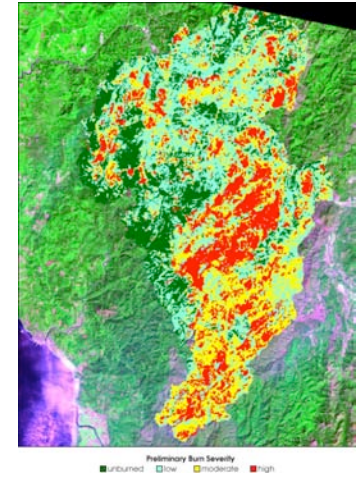
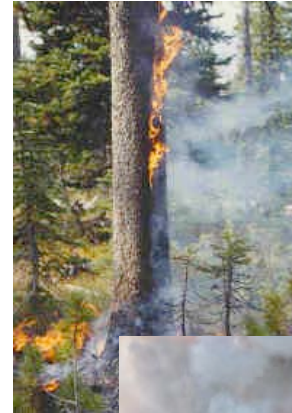


# Peak detection in sediment-charcoal records: impacts of alternative data analysis methods on fire-history interpretations

Philip E. Higuera\*, Daniel G. Gavin, Patrick J. Bartlein, Douglas J. Hallett

Photo: Grant Peregoodoff, Parks Canada

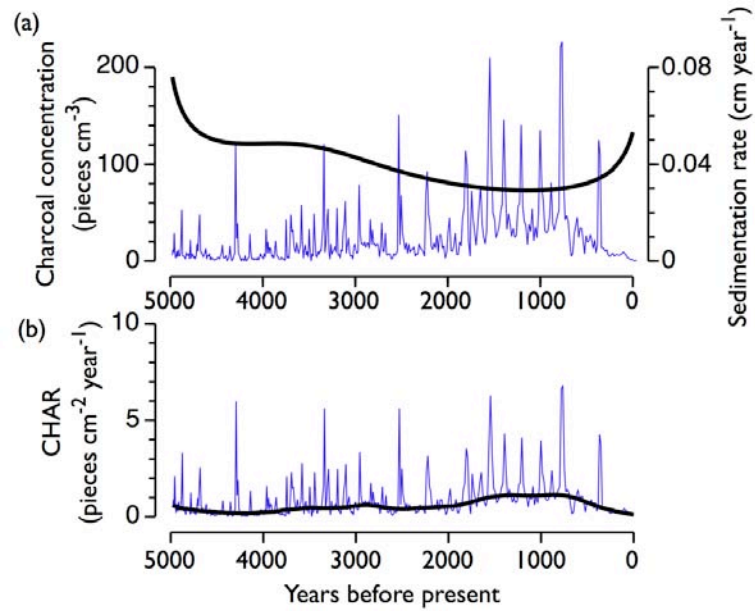


## Development of a charcoal stratigraphy

| Step  | Decisions  | Potential issues and sources of error   | Total effort=30 min. per sample  |
|---|--|---|--|
| 1. Sediment collection                        | Coring location  | Gaps in record  | 800 samples = 400 hours  |
| 2. Sediment subsampling                       | Sediment volume per sample   | Volume overestimate (core shrinkage).   | 3 min/sample   |
|   | Sampling interval  | Sample volume too small, resulting in low charcoal counts.<br><br>Interval too long to distinguish consecutive fire events. |  |
| 3. Sediment sieving                           | Sieve sizes  | Incomplete sieving  | 12 min/sample  |
|   |  | Sample spillage   |  |
| 4. Charcoal quantification                    | Count or area  | Misidentification   | 15 min/sample  |
| 5. Estimate charcoal accumulation rate (CHAR) | Age-depth model fitting to calculate sediment accumulation rates   | Breakage of charcoal results in inflated counts.<br>Poor chronological control  |  |
| 6. Interpolate CHAR to a constant interval    | Interval size (typical value is the median sample deposition time) | Loss of resolution in portions of the record  | <b>There exists a serious need for increased automation and quality control!</b> |

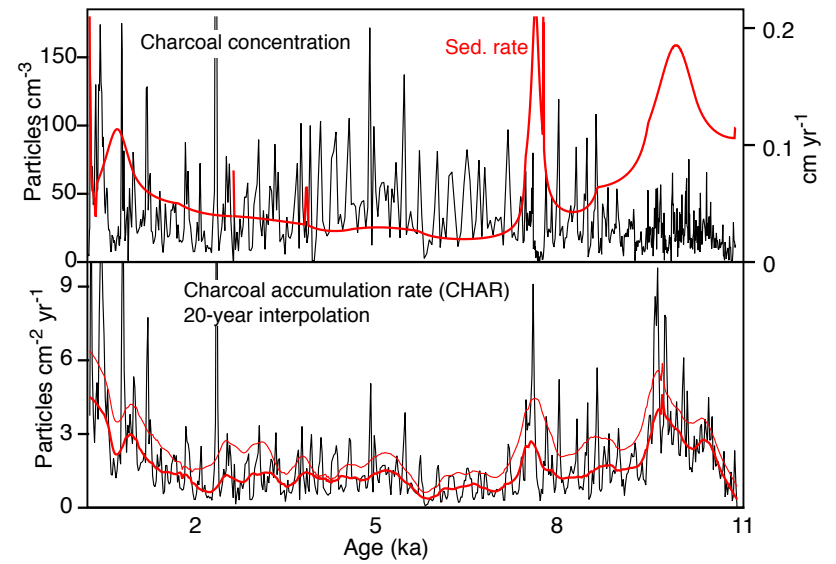
Higuera et al., IJWF, in press

## The ideal charcoal stratigraphy (Rockslide Lake, BC)



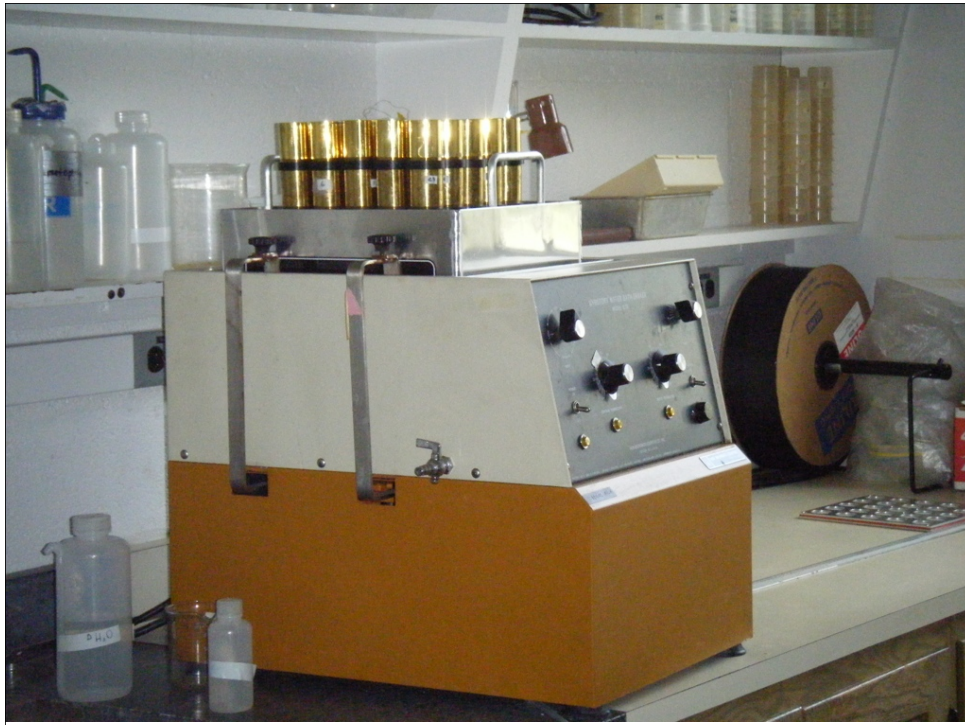
Gavin et al., Frontiers of Ecology and the Environment, 2007

## A problematic charcoal stratigraphy (Eleanor Lake, BC)

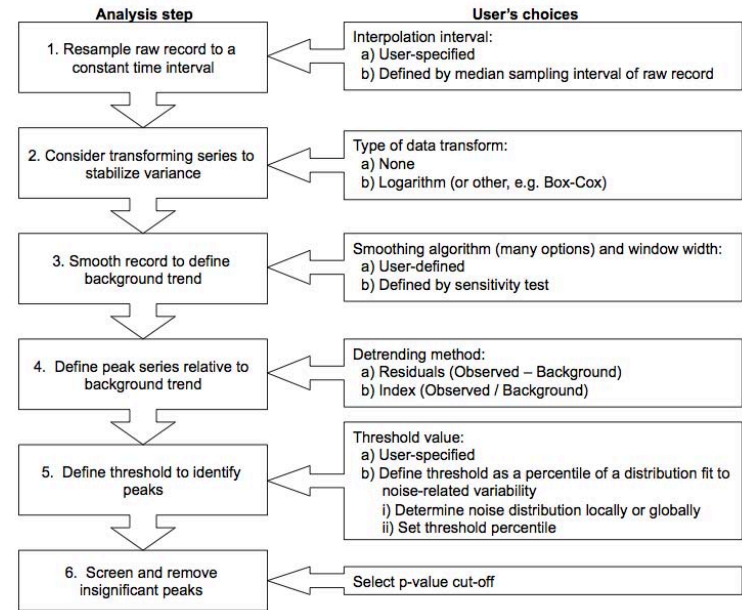


Gavin, unpublished data





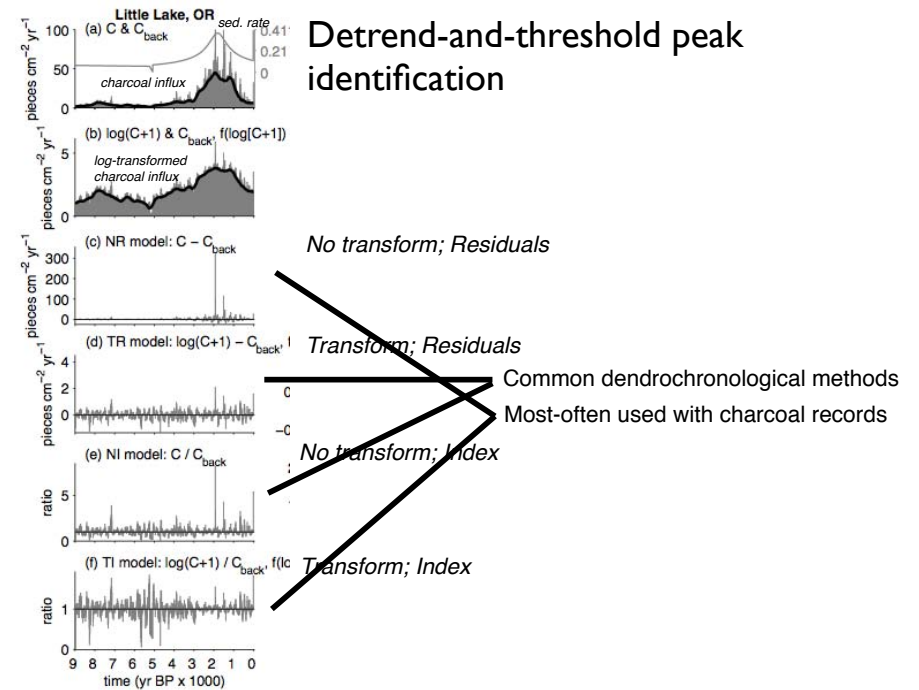
## Analytical steps for peak identification



Higuera et al., IJWF, in press

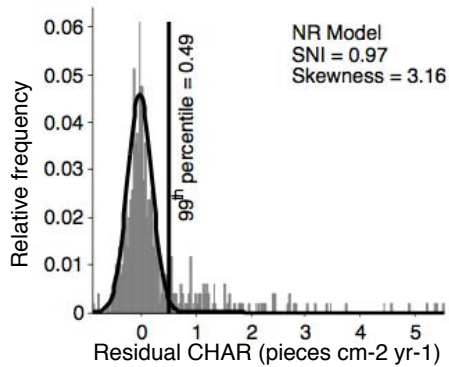
## Resampling to constant time interval

| Depth (cm)                             | Year               | Sed. rate   | Conc.   | CHAR |
|--|--------------------|---|---|------|
| 0                                      | 2010               |   |   |      |
| counts in 1 cm <sup>3</sup> subsamples | 10                 |   |   |      |
| CHAR per sample                        | $10^{(1/8)}=1.25$  |   |   |      |
| 1                                      | 2002               | $(1+(7/10)*1) / 15 = 0.113 \text{ cm yr}^{-1}$      | $10^{(8/15)}+32^{(7/15)} = 20.26 \text{ cm}^{-3}$ | 2.29 |
|  | 32                 |   |   |      |
|  | $32^{(1/10)}=3.2$  |   |   |      |
| 2                                      | 1995               |   |   |      |
|  | 1992               | $((3/10)^*1+(12/13)^*1) / 15 = 0.082 \text{ cm/yr}$ | $32^{(3/15)}+53^{(12/15)} = 48.8 \text{ cm}^{-3}$ | 4.00 |
|  | 53                 |   |   |      |
|  | $53^{(1/13)}=4.07$ |   |   |      |
| 3                                      | 1979               |   |   |      |
|  | 1980               |   |   |      |
|  | 108                |   |   |      |
| 4                                      | 1966               |   |   |      |



Higuera et al., IJWF, in press

## Peak threshold determination: Gaussian mixture models



Fit using CLUSTER by Charles Bouman, Perdue University.

Charcoal influx series represents a mixture of processes that should be apparent in the distributions of charcoal values.

- 1) Noise = unrelated to fires: sampling effects, analytical error.
- 2) Signal = following fires: episodic events.

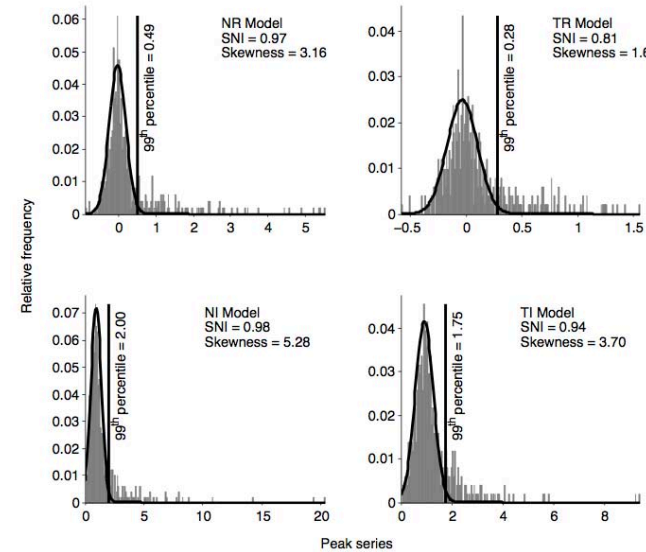
Signal to noise index (SNI) measures the distinction of the noise and signal distributions. SNI can determine suitability for peak ID.

$$SNI = \sigma^2_S / (\sigma^2_S + \sigma^2_N)$$

Contrast this method with: statistics-of-extremes methods

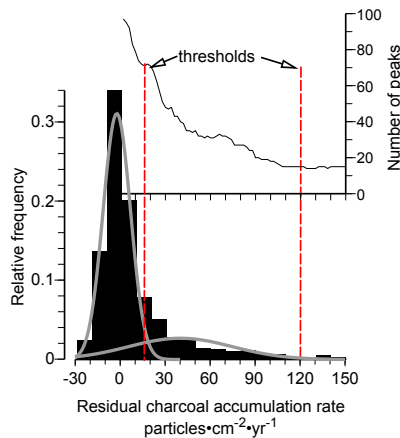
- 1) Generalized extreme value (GEV) distributions or Pareto distributions
- 2) Peak-over-threshold (POT) methods

## Peak threshold determination: Gaussian mixture models

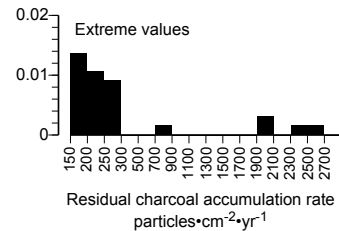


Skewness is a *good* property when using Gaussian mixture models.

## Peak threshold determination: Gaussian mixture models and a sensitivity test

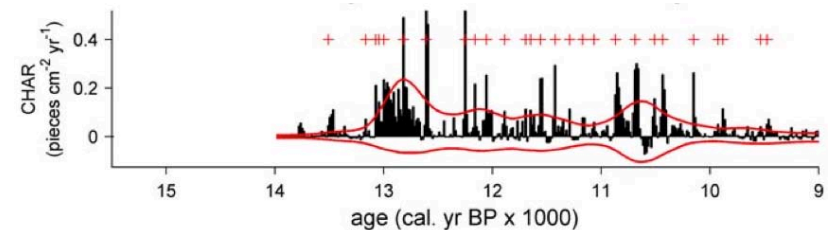


Upper Squaw Lake, Oregon. Three distributions fit (showing lower two only)....separating two classes of peaks.



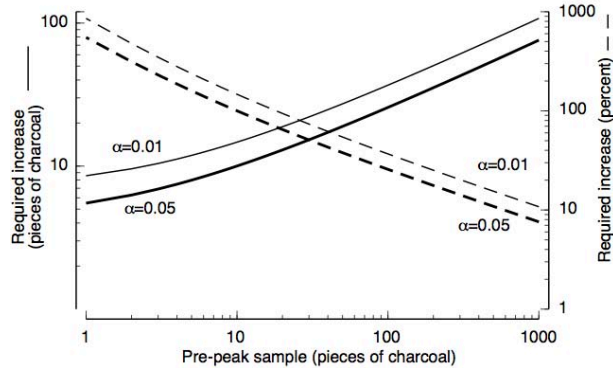
## Local Thresholding: GMM fit to moving windows: threshold is therefore fit to "local" variability.

Ruppert Lake, Brooks Range, AK



1. Interpolation to 15-year intervals
2. Background detrending: Difference from 500-year loess regression
3. GMM fit in 500-year moving windows

## Minimum-count test for significant differences between two counts



$H_0$ :  $X_1$  and  $X_2$  are drawn from a single Poisson distribution.

$$d = \frac{X_1 - (X_1 + X_2) \left( \frac{V_1}{V_1 + V_2} \right) - 0.5}{\sqrt{(X_1 + X_2) \left( \frac{V_1}{V_1 + V_2} \right) \left( \frac{V_2}{V_1 + V_2} \right)}}$$

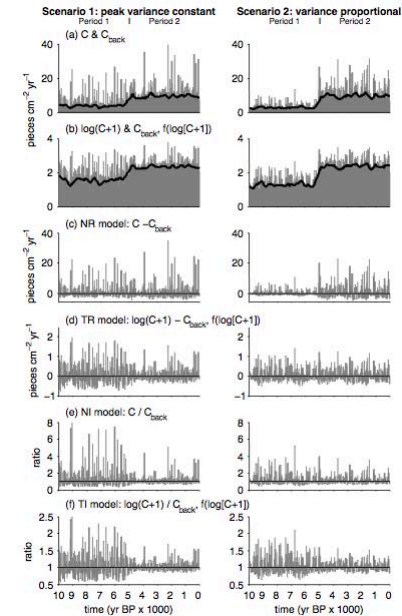
- $X_1$  and  $X_2$  are counts of samples 1 and 2
- $V_1$  and  $V_2$  are volumes of samples 1 and 2
- $d$  is normally distributed

- Detre, K, and C White (1970) Comparison of 2 Poisson-Distributed Observations. *Biometrics* 26, 851
- Shiu, WK, and LJ Bain (1982) Experiment size and power comparisons for two- sample Poisson tests. *Journal of Applied Statistics* 31, 130-134.

Higuera et al., IJWF, in press

## What is the effect of the detrending method?

Peak charcoal is independent of background (additive process)



Peak charcoal depends on background (multiplicative process)

$$C(i) = s_{acc} \left[ \frac{C_b(i)}{\max(C_b)} C_b(i) + C_p(i) \right]$$

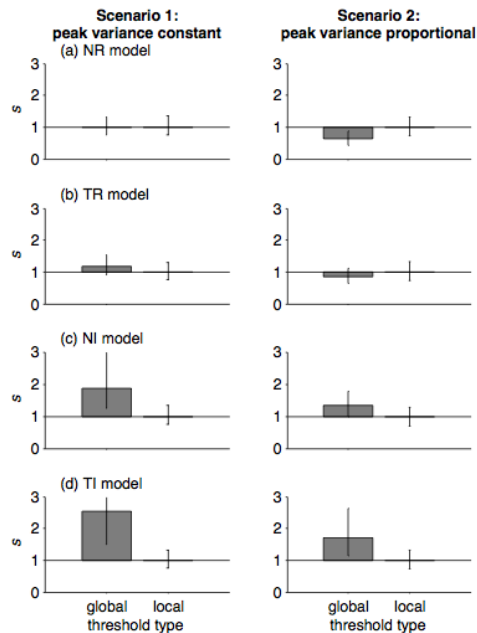
typo!

$$C_p(i) = b[-\log \varepsilon(i)]^c$$

$$C(i) = s_{acc} [C_b(i) + C_p(i)]$$

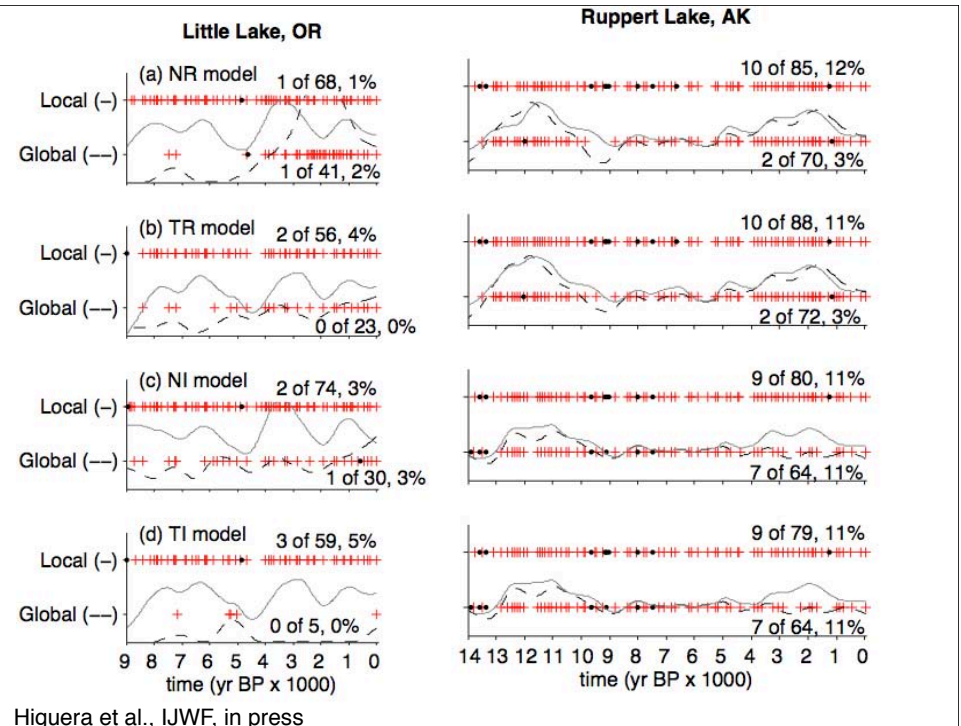
$s = \# \text{ peaks in period 1} / \# \text{ peaks in period 2}$

Higuera et al., IJWF, in press



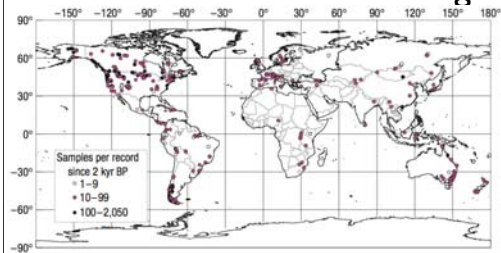
$s = \# \text{ peaks in period 1} / \# \text{ peaks in period 2}$

Higuera et al., IJWF, in press



Higuera et al., IJWF, in press

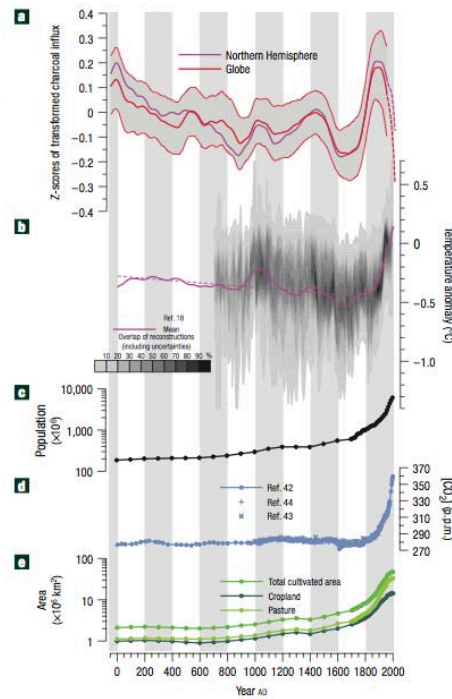
## Other uses of charcoal records: An index of “biomass burning”



Composite index = mean of z-scores of box-cox transformed charcoal accumulation rates

Maximum sampling resolution among sites = 20 year (reduces influence of high-resolution sites)

Marlon et al. Nature Geosciences, 2008



Full-day workshop at the 2010 Annual Meeting of the Ecological Society of America, Pittsburgh, PA.

July 31, 2010

Developing and interpreting fire histories from sediment charcoal records

Lead organizers: Daniel Gavin and Phil Higuera

Summary sentence: Recent developments in the reconstruction of fire histories from sediment charcoal data have opened the door to making landscape-scale interpretations of disturbance regimes over millennia. In this workshop we will discuss methods, analytical tools, and ecological interpretation of charcoal-based paleofire records.

